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Tsuchiya

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(45) **Date of Patent: Feb. 18, 2025**

(54) **WIRELESS APPARATUS**

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(72) Inventor: **Masato Tsuchiya**, Kanagawa (JP)

(73) Assignee: **NEC Platforms, Ltd.**, Kanagawa (JP)

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(2) Date: **Jun. 22, 2022**

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Jul. 25, 2019 (JP) 2019-136946

(51) **Int. Cl.**
H01Q 1/22 (2006.01)
H01Q 1/24 (2006.01)
H01Q 1/48 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/24*** (2013.01); ***H01Q 1/48*** (2013.01)

(58) **Field of Classification Search**
CPC .. H01Q 1/24; H01Q 1/48; H01Q 9/30; H01Q 1/243; H01Q 1/22
See application file for complete search history.

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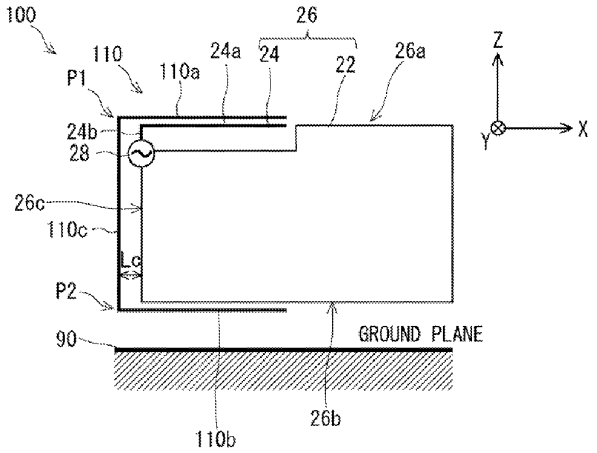
Primary Examiner — Hai V Tran
Assistant Examiner — Bamidele A Immanuel

(57) **ABSTRACT**

There is provided a wireless apparatus with which a communication range may be prevented from being reduced even in a case where the height of the apparatus is restricted. The wireless apparatus includes an antenna device configured by a substrate including a substrate ground and an antenna element provided on the substrate, and a conductor formed into a sideways U-shape. The conductor includes an upper section and a lower section that are disposed along a ground plane and vertically relative to each other, and a middle section that is disposed substantially perpendicular to the ground plane, between one end of the upper section and one end of the lower section. The conductor is disposed such that the upper section, the lower section, and the middle section thereof are near an upper side section, a lower side section, and a lateral side section of the antenna device, respectively. The upper section of the conductor is disposed near the antenna element, and the conductor functions as an antenna due to current being excited in the conductor when power is supplied to the antenna element.

4 Claims, 22 Drawing Sheets



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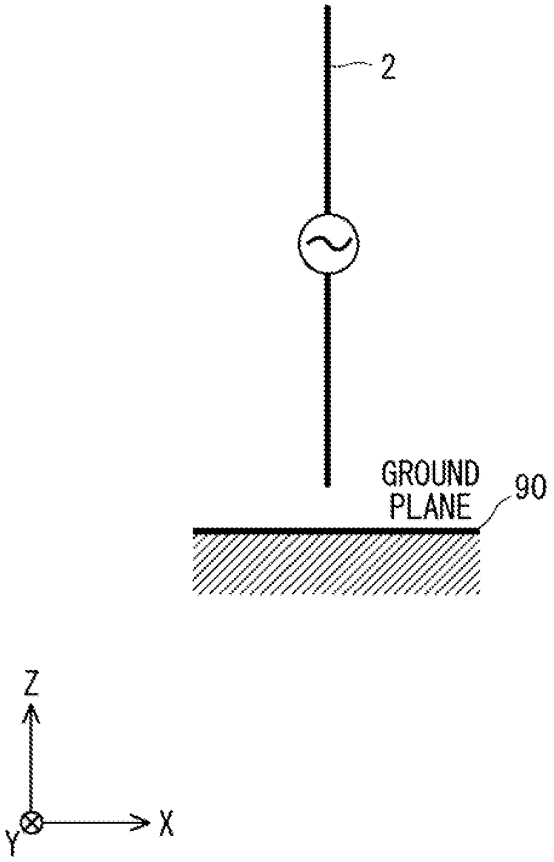


Fig. 1

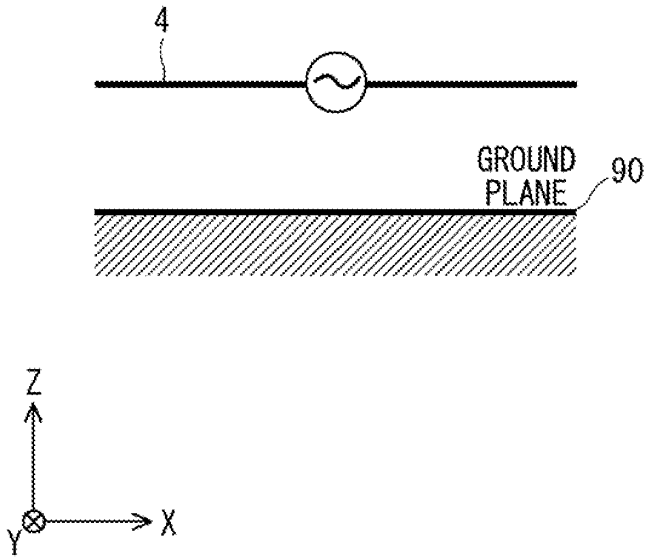
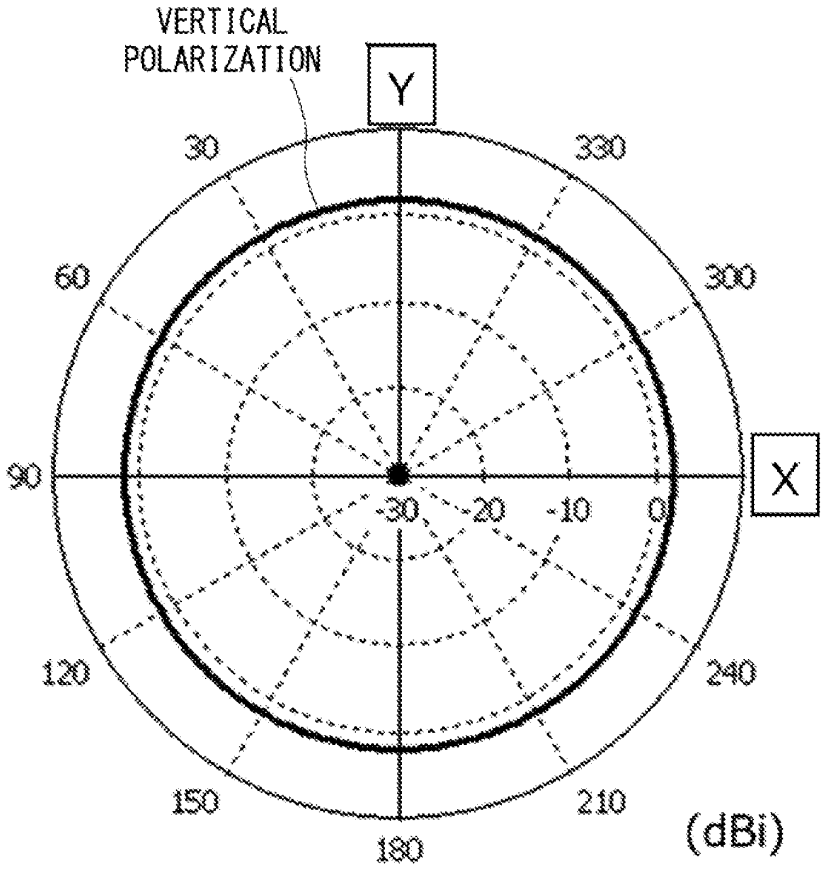


Fig. 2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(dBi)

Fig. 3

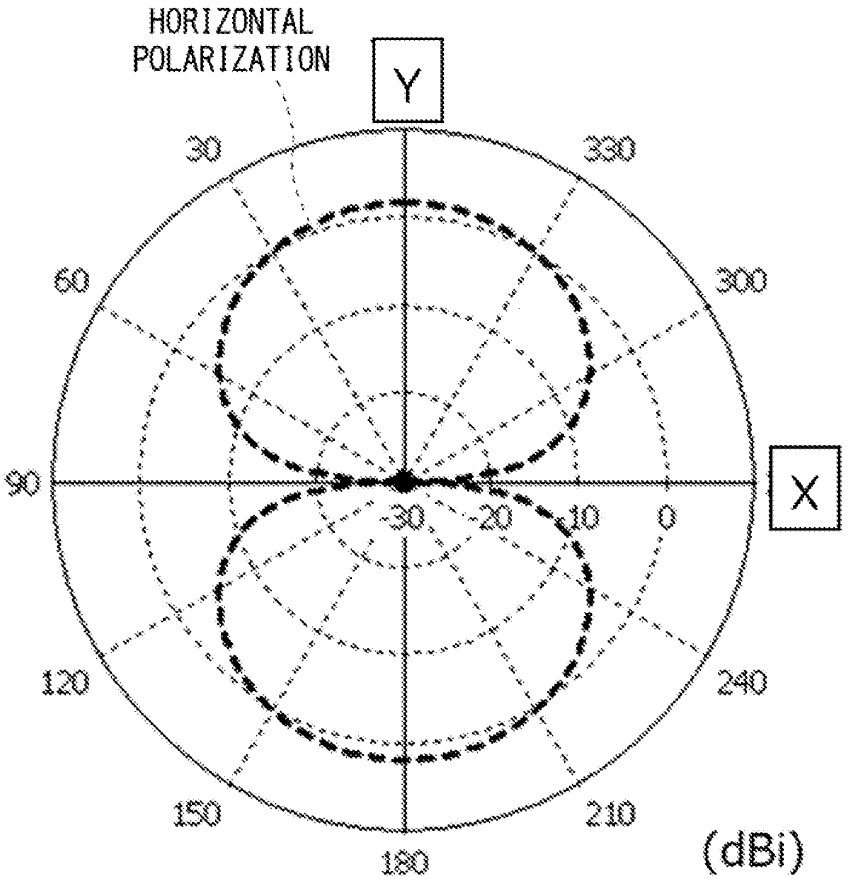
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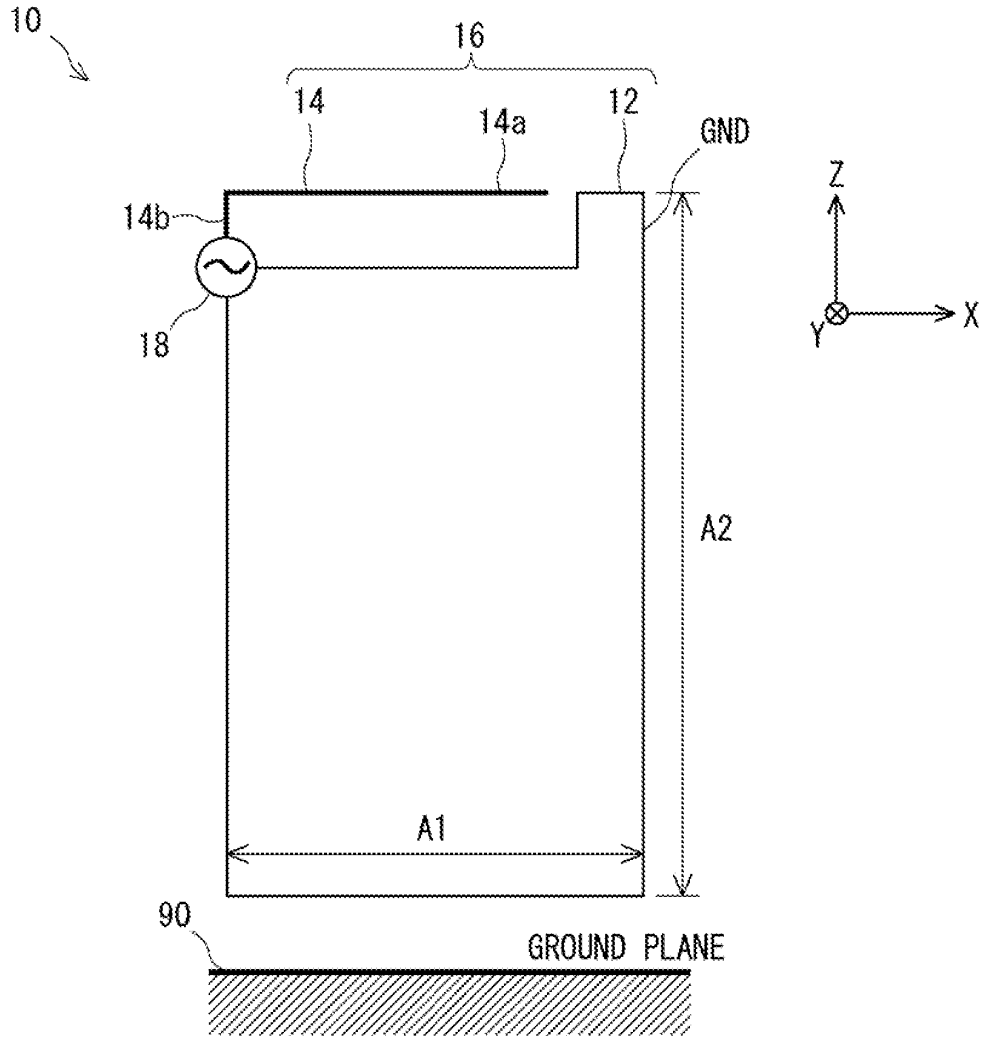
Fig. 4



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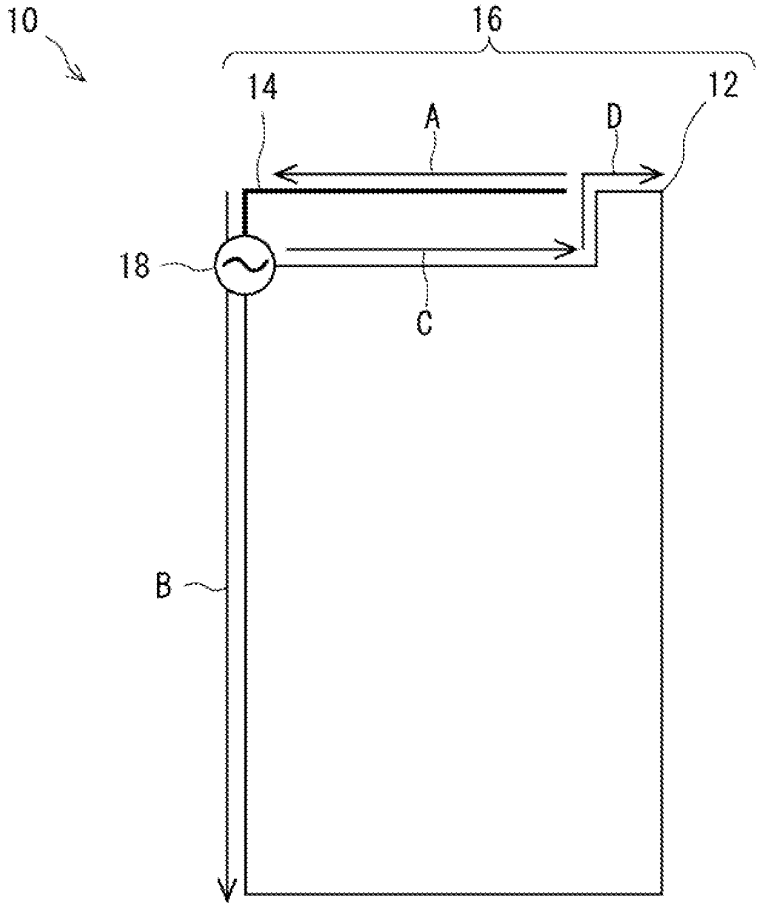

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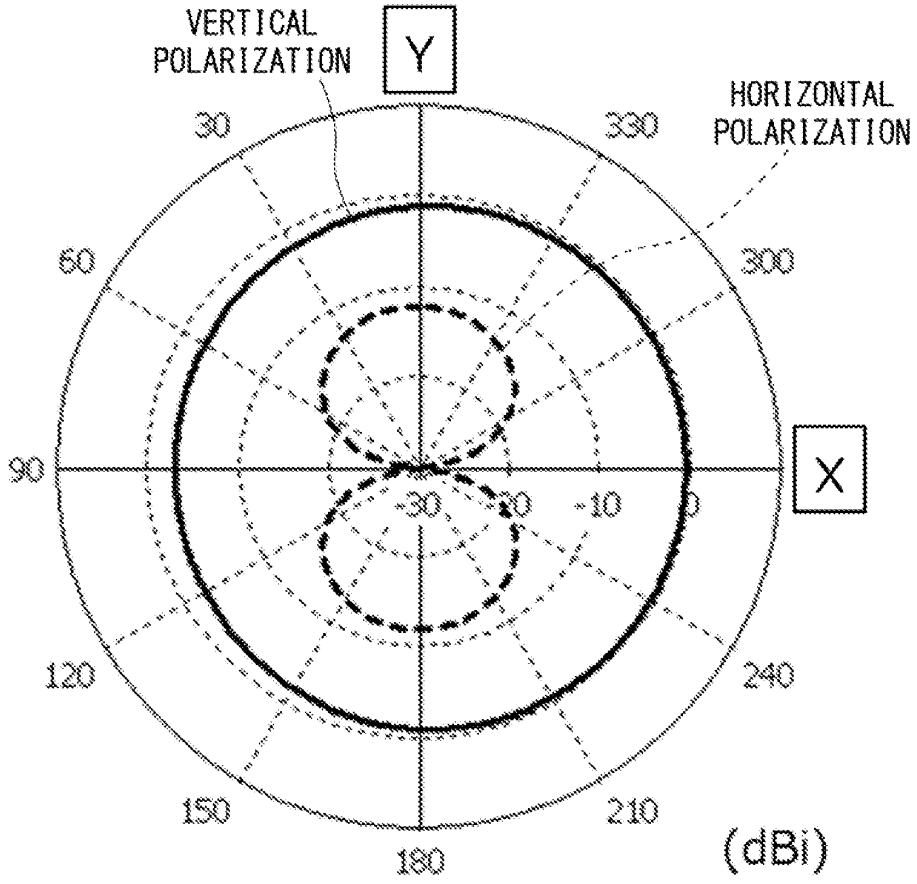
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Fig. 7

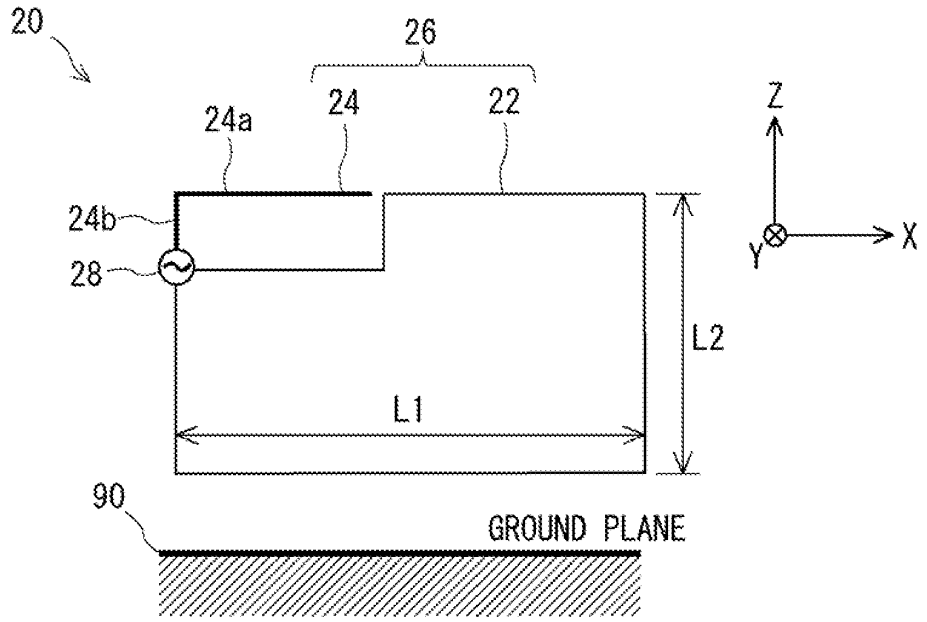


Fig. 8

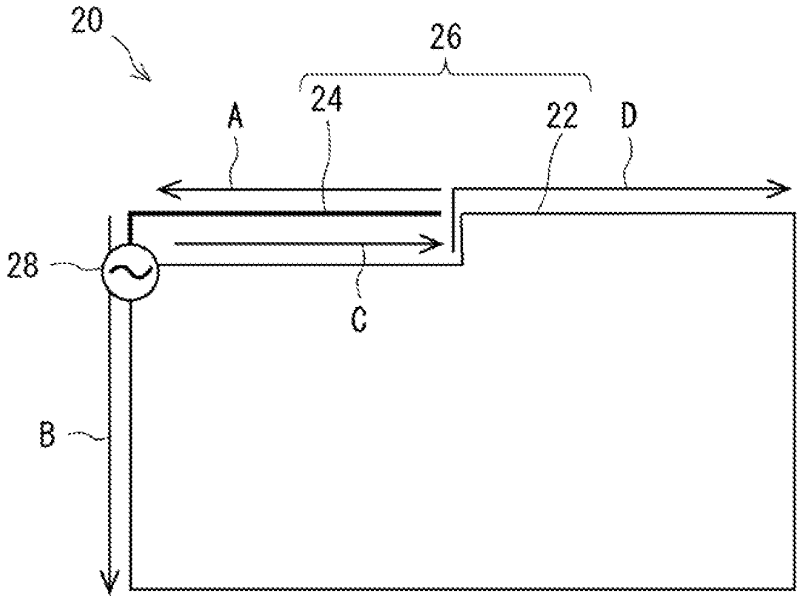
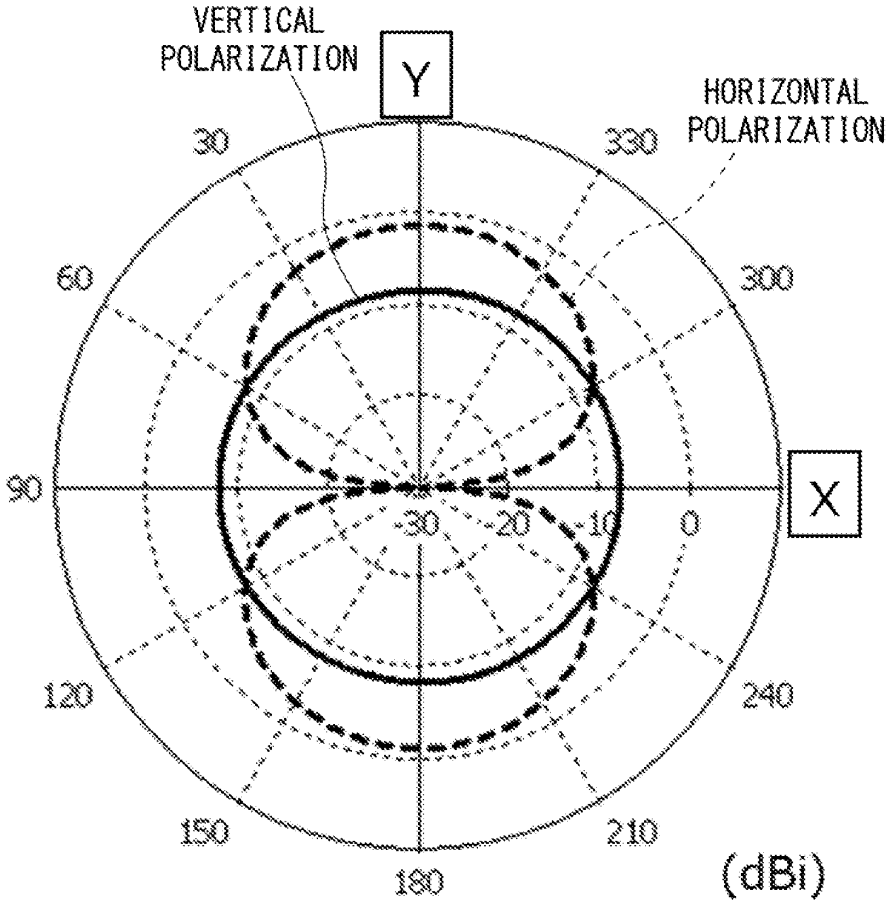


Fig. 9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HORIZONTAL
POLARIZATION
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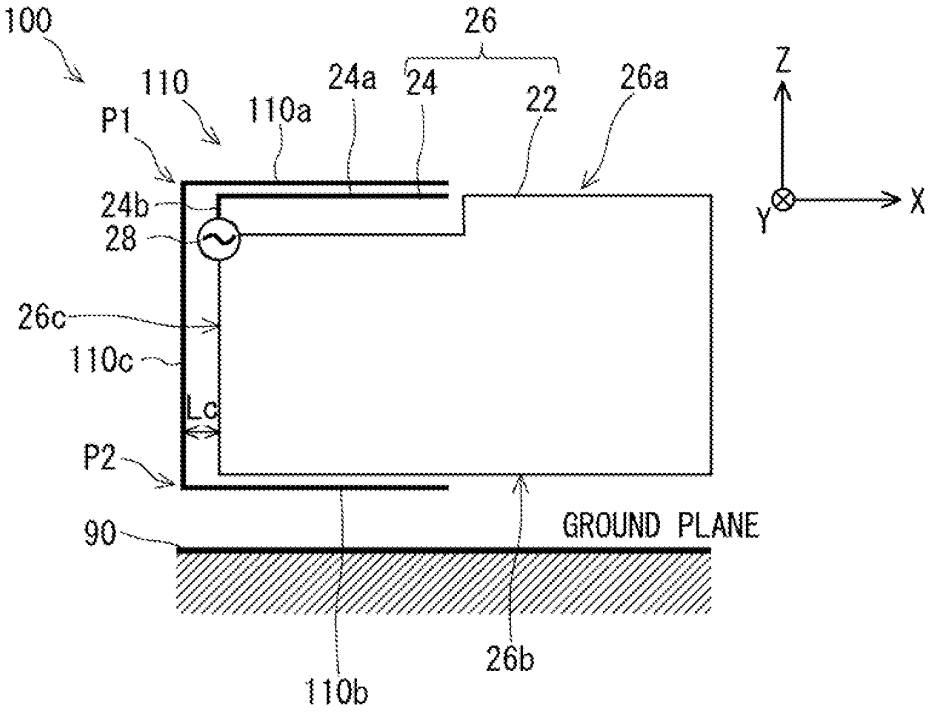
Fig. 10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26
110
24a
24
22
26a
Z
P1
110a
24b
28
Y
X
26c
110c
Lc
P2
90
GROUND PLANE
110b
26b

Fig. 11

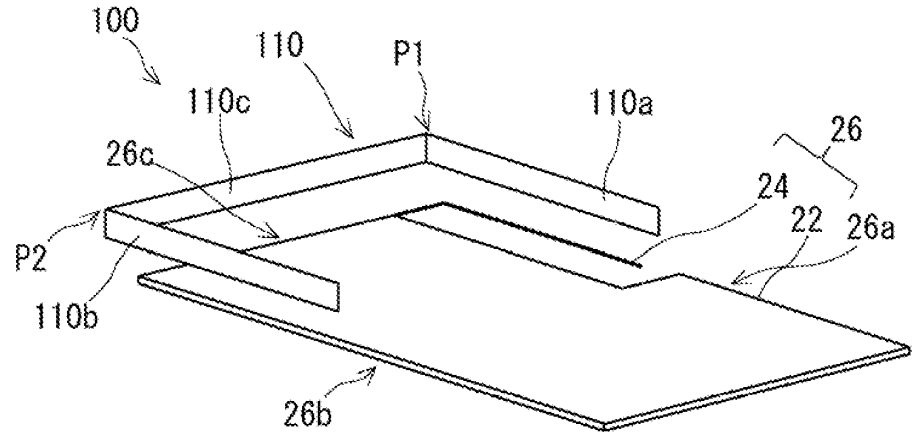


Fig. 12

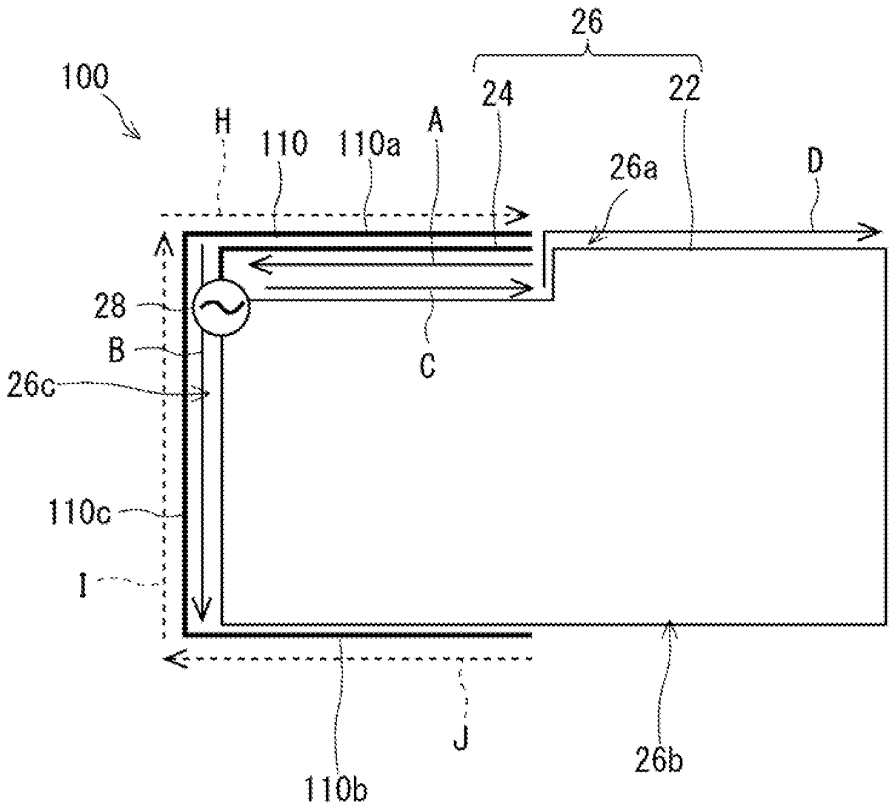
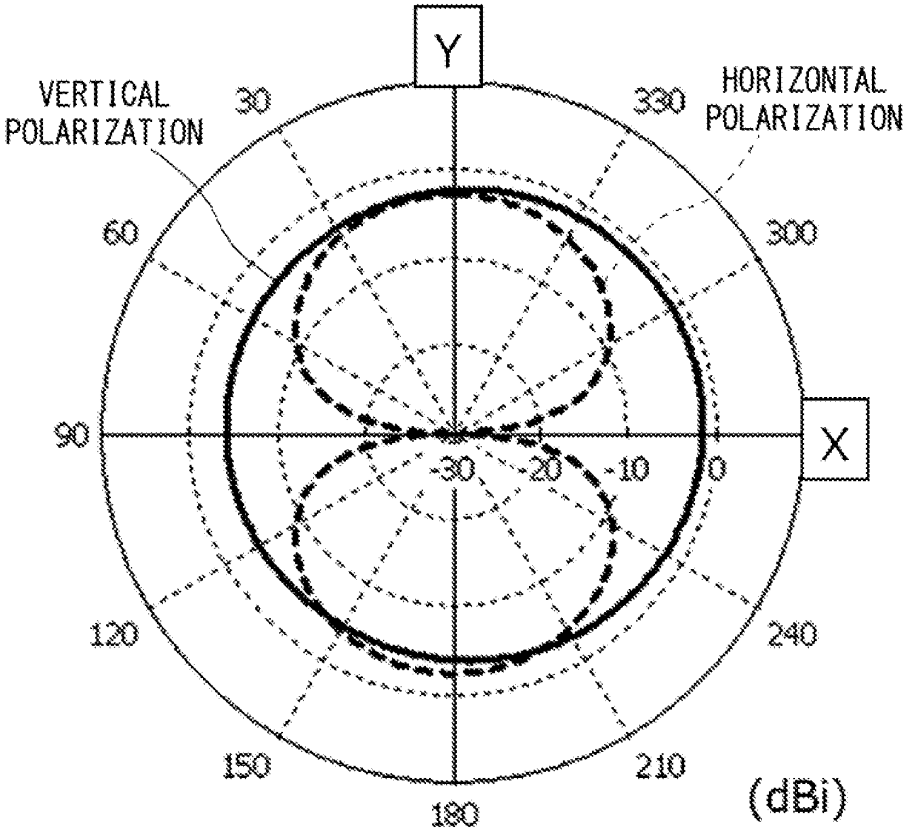


Fig. 13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X
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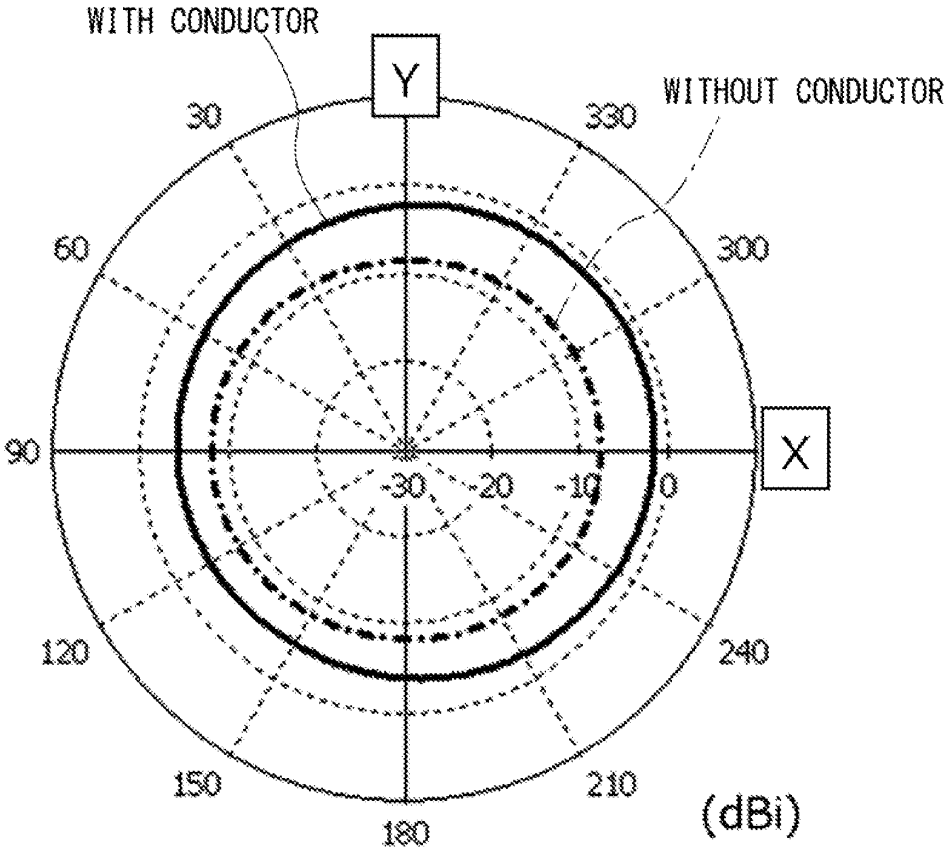
(dBi)

Fig. 14


WITH CONDUCTOR
WITHOUT CONDUCTOR
Y
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(dBi)

Fig. 15

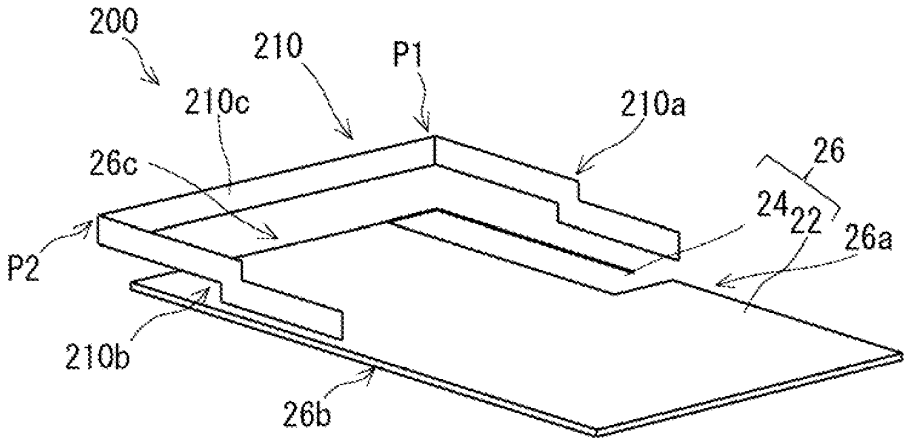
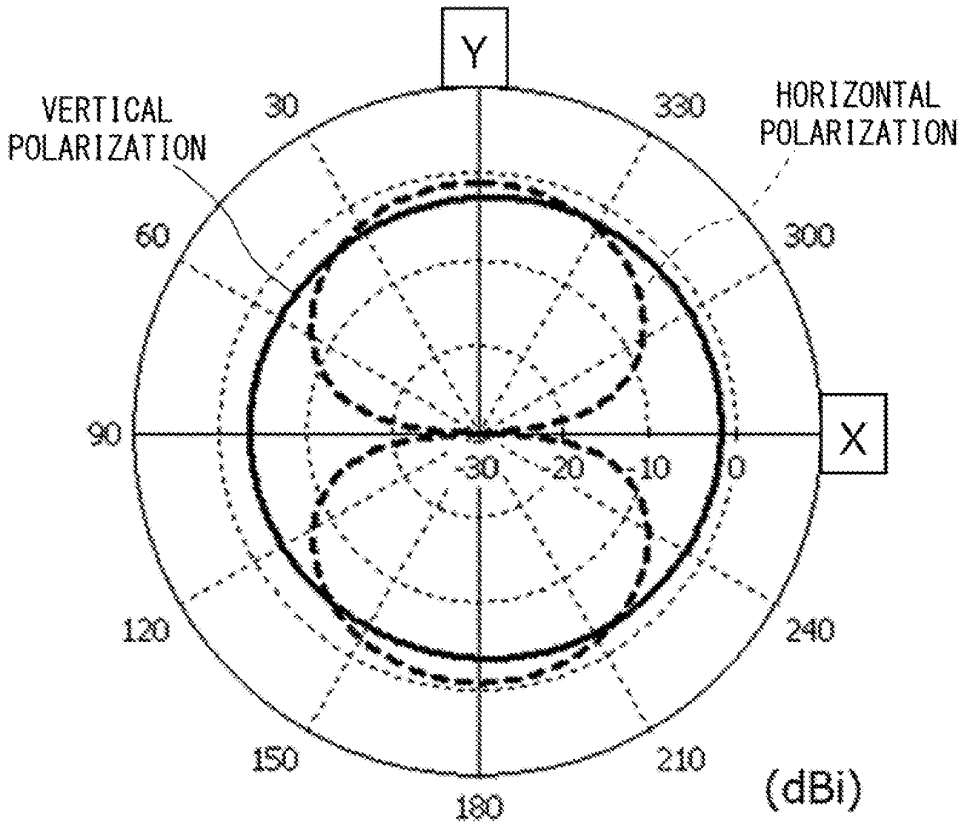


Fig. 16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HORIZONTAL POLARIZATION
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180
(dBi)

Fig. 17

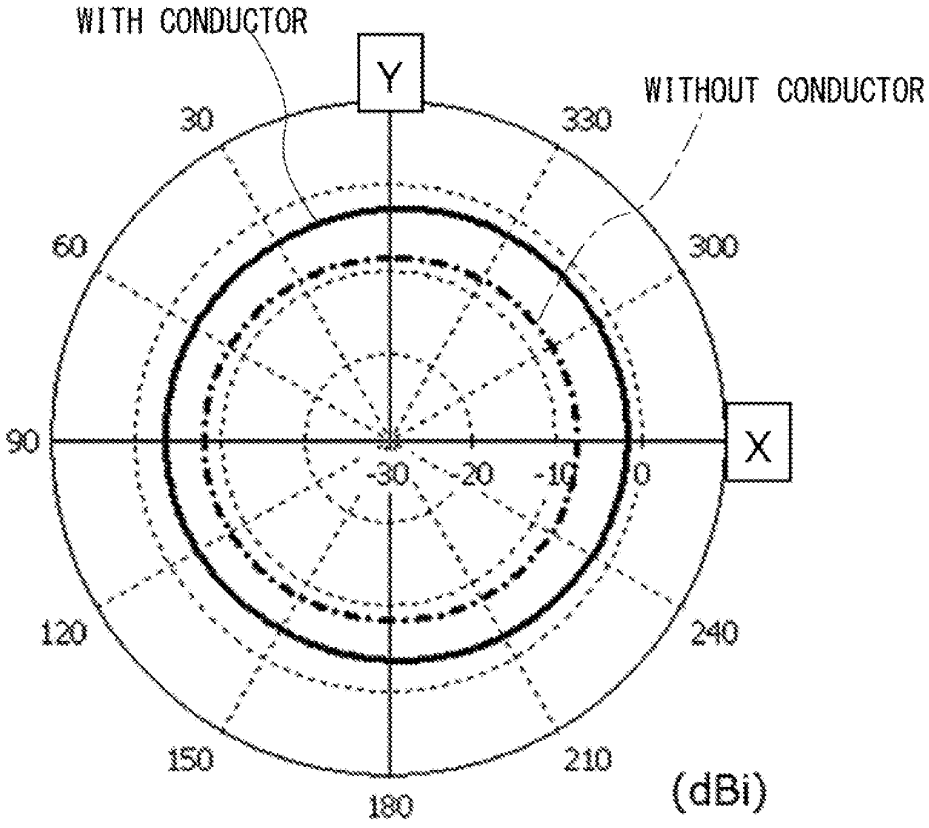
WITH CONDUCTOR
WITHOUT CONDUCTOR
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Fig. 18

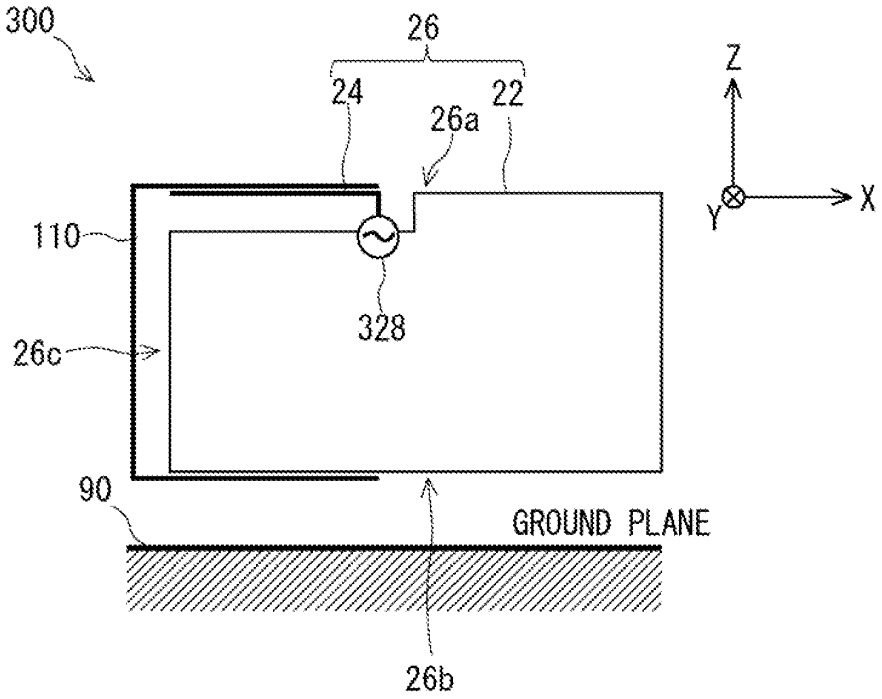

Fig. 19

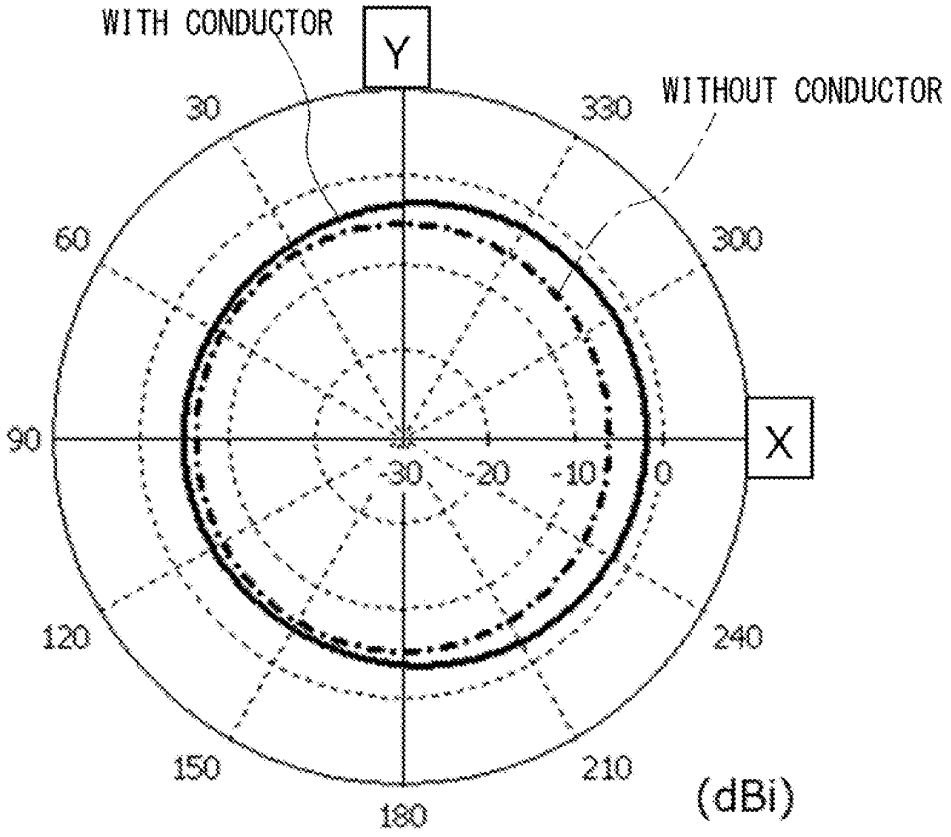
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Fig. 20

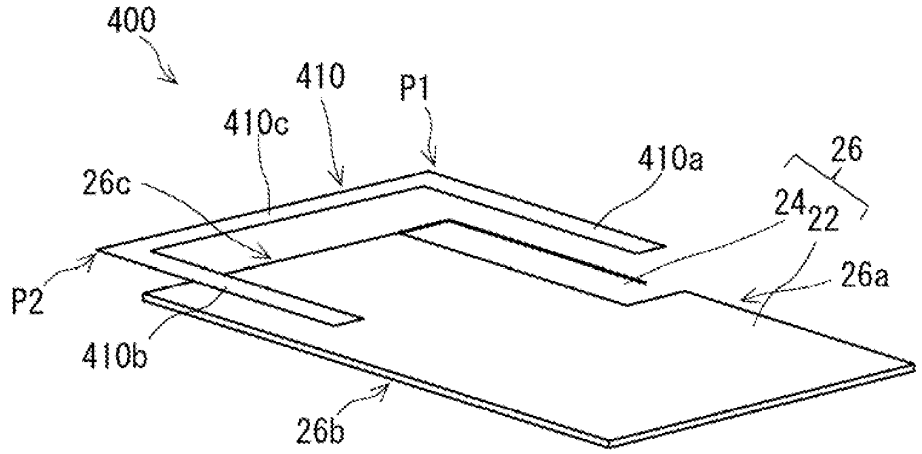

Fig. 21

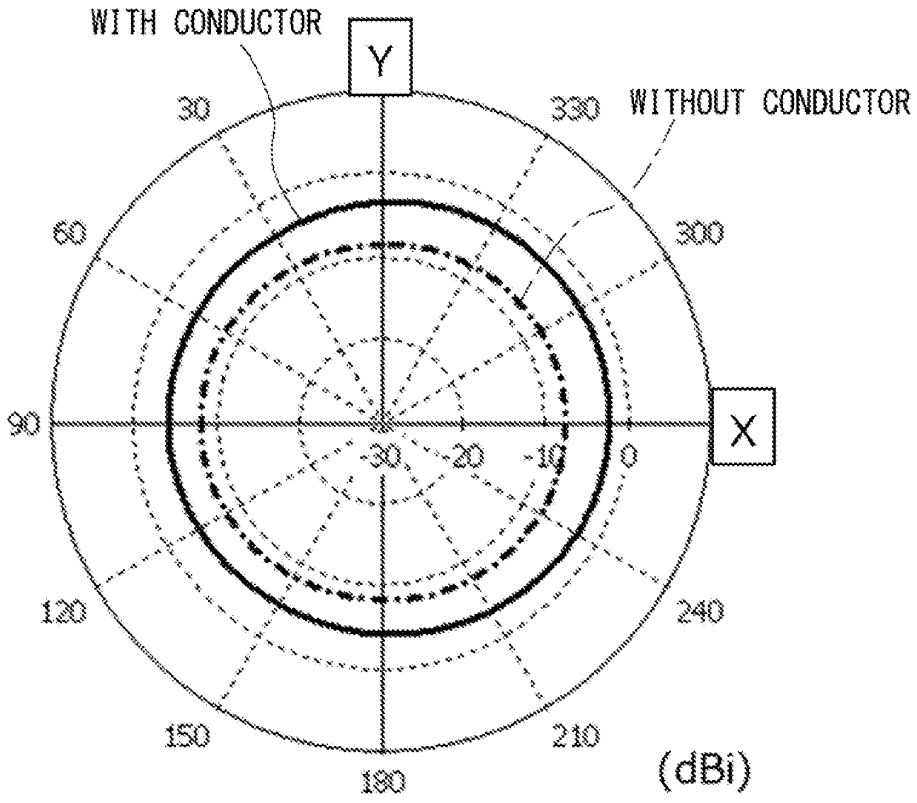
WITH CONDUCTOR
WITHOUT CONDUCTOR
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Fig. 22

WIRELESS APPARATUS

This application is a National Stage Entry of PCT/JP2020/023345 filed on Jun. 15, 2020, which claims priority from Japanese Patent Application 2019-136946 filed on Jul. 25, 2019, the contents of all of which are incorporated herein by reference, in their entirety.

TECHNICAL FIELD

The present invention relates to a wireless apparatus.

BACKGROUND ART

Patent Literature 1 discloses an installation body that is positioned near an antenna. The installation body according to Patent Literature 1 includes a conductor that is positioned near an antenna of a transmitter in a state where the transmitter is adjacent. An induced current is generated in the conductor by a drive current of the antenna, and the induced current has a current component in a direction different from the direction of the drive current.

Furthermore, Patent Literature 2 discloses a wireless apparatus including an antenna device for horizontal polarization. The antenna device for horizontal polarization includes a radiation conductor including two conductive plates obtained by bending, a ground conductor, and a feeding element, the two conductive plates being disposed facing each other across a predetermined gap, the radiation conductor being formed, as a whole, into a cylindrical shape extending in a vertical direction. The ground conductor is disposed in an inner space surrounded by the two conductive plates of the radiation conductor and is electrically grounded. The feeding element is disposed in the inner space, along inner walls of the conductive plates in a top view, and operates as a reverse L antenna when power is fed between one end portion thereof and the ground conductor, and feeds power to the radiation conductor by electromagnetic coupling.

CITATION LIST

Patent Literature

Patent Literature 1: International Patent Publication No. 2017/204132

Patent Literature 2: Japanese Unexamined Patent Application Publication No. 2013-131901

SUMMARY OF INVENTION

Technical Problem

To perform transmission/reception of radio waves between wireless apparatuses, polarizations of antennas have to be matched. Accordingly, in the case where the polarization of the antenna of a counterpart apparatus is only vertical polarization, the antenna of the subject apparatus needs to have vertical polarization. Here, generally, to achieve vertical polarization, a component, of the antenna device, perpendicular to a ground plane needs to have a certain length, and to increase the vertical polarization, the height of the apparatus has to be increased. However, the height of the apparatus is often restricted by installation conditions and the like of the apparatus, and in such a case, the vertical polarization possibly becomes small. This may result in a problem of a reduced communication range. The technologies according to Patent Literatures described above may not solve the problem described above.

An object of the present disclosure is to solve the problem as described above, and to provide a wireless apparatus with which a communication range may be prevented from being reduced even in a case where the height of the apparatus is restricted.

Solution to Problem

A wireless apparatus according to the present disclosure includes: an antenna device configured by a substrate including a substrate ground and an antenna element provided on the substrate; and a conductor formed into a sideways U-shape, in which the conductor includes an upper section and a lower section that are disposed along a ground plane and vertically relative to each other, and a middle section that is disposed substantially perpendicular to the ground plane, between one end of the upper section and one end of the lower section, the conductor is disposed such that the upper section, the lower section, and the middle section thereof are near an upper side section, a lower side section, and a lateral side section of the antenna device, respectively, and the upper section of the conductor is disposed near the antenna element, and the conductor functions as an antenna due to current being excited in the conductor when power is supplied to the antenna element.

Advantageous Effects of Invention

According to the present disclosure, there may be provided a wireless apparatus with which a communication range may be prevented from being reduced even in a case where the height of the apparatus is restricted.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram for describing a case where an antenna is a dipole antenna.

FIG. **2** is a diagram for describing a case where an antenna is a dipole antenna.

FIG. **3** is a diagram for describing a case where an antenna is a dipole antenna.

FIG. **4** is a diagram for describing a case where an antenna is a dipole antenna.

FIG. **5** is a diagram showing a wireless apparatus according to a first comparative example.

FIG. **6** is a diagram showing an example of a flow of a high-frequency current that flows through the wireless apparatus according to the first comparative example at a certain moment.

FIG. **7** is a diagram showing an example of a radiation pattern, in a ground plane direction, of the wireless apparatus according to the first comparative example shown in FIG. **5**.

FIG. **8** is a diagram showing a wireless apparatus according to a second comparative example.

FIG. **9** is a diagram showing an example of a flow of a high-frequency current that flows through the wireless apparatus according to the second comparative example at a certain moment.

FIG. **10** is a diagram showing an example of a radiation pattern, in a ground plane direction, of the wireless apparatus according to the second comparative example shown in FIG. **8**.

FIG. **11** is a diagram showing a wireless apparatus according to a first example embodiment.

FIG. **12** is a diagram showing the wireless apparatus according to the first example embodiment.

FIG. **13** is a diagram showing an example of a flow of a high-frequency current that flows through the wireless apparatus according to the first example embodiment at a certain moment.

FIG. **14** is a diagram showing an example of a radiation pattern, in a ground plane direction, of the wireless apparatus according to the first example embodiment shown in FIGS. **11** and **12**.

FIG. **15** is a diagram in which a radiation pattern for vertical polarization of the wireless apparatus according to the second comparative example and a radiation pattern for vertical polarization of the wireless apparatus according to the first example embodiment are superimposed on each other.

FIG. **16** is a diagram showing a wireless apparatus according to a second example embodiment.

FIG. **17** is a diagram showing an example of a radiation pattern, in a ground plane direction, of the wireless apparatus according to the second example embodiment shown in FIG. **16**.

FIG. **18** is a diagram in which a radiation pattern for vertical polarization of the wireless apparatus according to the second comparative example and a radiation pattern for vertical polarization of the wireless apparatus according to the second example embodiment are superimposed on each other.

FIG. **19** is a diagram showing a wireless apparatus according to a third example embodiment.

FIG. **20** is a diagram in which a radiation pattern for vertical polarization of the wireless apparatus according to the third example embodiment and a radiation pattern for vertical polarization in a case where a conductor is removed from the wireless apparatus according to the third example embodiment are superimposed on each other.

FIG. **21** is a diagram showing a wireless apparatus according to a fourth example embodiment.

FIG. **22** is a diagram in which a radiation pattern for vertical polarization of the wireless apparatus according to the fourth example embodiment and a radiation pattern for vertical polarization in a case where a conductor is removed from the wireless apparatus according to the fourth example embodiment are superimposed on each other.

DESCRIPTION OF EMBODIMENTS

(Outline of Example Embodiments of Present Disclosure)

Before describing example embodiments of the present disclosure, an outline of the example embodiments of the present disclosure will be given. First, polarization of an antenna will be described.

Polarization is one of antenna characteristics. A case where an electrical field is confined to one plane is referred to as linear polarization. Furthermore, of the linear polarization, a case where the electrical field is parallel to a ground plane is referred to as horizontal polarization, and a case where the electrical field is perpendicular to the ground plane is referred to as vertical polarization.

For example, polarization of an antenna is horizontal polarization when an antenna device is disposed parallel to the ground plane. When the antenna device is perpendicularly disposed relative to the ground plane, the polarization of the antenna is vertical polarization.

FIGS. **1** to **4** are diagrams for describing cases where an antenna is a dipole antenna. FIG. **1** shows a dipole antenna **2** that is disposed perpendicular to a ground plane **90**. FIG. **2** shows a dipole antenna **4** that is disposed parallel to the ground plane **90**. FIG. **3** is a diagram showing an example of a radiation pattern, in a ground plane direction (on an XY plane), of the dipole antenna **2** shown in FIG. **1**. FIG. **4** is a diagram showing an example of a radiation pattern, in the ground plane direction (on the XY plane), of the dipole antenna **4** shown in FIG. **2**. Additionally, the ground plane direction refers to a plane along the ground plane **90**.

In FIG. **3**, the radiation pattern for vertical polarization is indicated by a thick solid line (the same applies to the radiation patterns in other drawings). Furthermore, in FIG. **4**, the radiation pattern for horizontal polarization is indicated by a thick dashed line (the same applies to the radiation patterns in other drawings). As shown in FIG. **3**, in the case of a pure dipole antenna, polarization of the dipole antenna **2** disposed perpendicular to the ground plane **90** is only vertical polarization. Furthermore, as shown in FIG. **4**, polarization of the dipole antenna **2** disposed parallel to the ground plane **90** is only horizontal polarization. Additionally, a resonance frequency of the antenna according to the present disclosure is 900 MHz. Accordingly, the radiation patterns shown in FIGS. **3** and **4** each show a result for a case where the resonance frequency of the antenna is 900 MHz. Additionally, the resonance frequency of the antenna is not limited to 900 MHz.

Next, comparative examples against the example embodiments of the present disclosure will be described.

FIG. **5** is a diagram showing a wireless apparatus **10** according to a first comparative example. The wireless apparatus **10** according to the first comparative example includes a substrate **12**, an antenna element **14** provided on the substrate **12**, and a drive unit **18**. Furthermore, the substrate **12** and the antenna element **14** form an antenna device **16**. The drive unit **18** supplies power to the antenna element **14**. The substrate **12** includes a substrate ground (GND).

For example, the antenna element **14** may be an antenna pattern drawn (printed) on the substrate **12**. For example, the antenna element **14** is a reverse L-shaped antenna. Accordingly, the antenna element **14** includes a horizontal portion **14***a* that is a component parallel to the ground plane **90**, and a perpendicular portion **14***b* that is a component perpendicular to the ground plane **90**. The antenna element **14** (the antenna device **16**) thus has both horizontal polarization and vertical polarization.

Furthermore, the substrate **12** of the wireless apparatus **10** according to the first comparative example is formed such that a dimension A**1** in a direction parallel to the ground plane **90** is smaller than a dimension A**2** in a direction perpendicular to the ground plane **90**. That is, A**1**<A**2** is true. For example, A**1** is 60 mm and A**2** is 100 mm, but the dimensions of the substrate **12** are not limited thereto.

FIG. **6** is a diagram showing an example of a flow of a high-frequency current that flows through the wireless apparatus **10** according to the first comparative example at a certain moment. The antenna element **14** is provided on the substrate **12** including the substrate ground (GND), and thus, as indicated by arrows A to D in FIG. **6**, a high-frequency current flows through not only the antenna element **14** but also the substrate **12** (GND). Accordingly, the antenna device **16** formed by the substrate **12** and the antenna element **14** functions as an antenna.

FIG. **7** is a diagram showing an example of a radiation pattern, in the ground plane direction (on the XY plane), of the wireless apparatus **10** according to the first comparative example shown in FIG. **5**. Here, generation of horizontal polarization and vertical polarization is determined based on

distribution of the high-frequency current on the antenna device **16**, and is generally dependent on the length of a component, of the entire antenna device **16** functioning as the antenna, that is parallel to the ground plane **90** and the length of a component that is perpendicular to the ground plane **90**. With the wireless apparatus **10** according to the first comparative example, the length of the component that is perpendicular to the ground plane **90** is great and the length of the component that is parallel to the ground plane **90** is small, and thus, vertical polarization is great and horizontal polarization is small.

FIG. **8** is a diagram showing a wireless apparatus **20** according to a second comparative example. Like the wireless apparatus **10** according to the first comparative example, the wireless apparatus **20** according to the second comparative example includes a substrate **22**, an antenna element **24** provided on the substrate **22**, and a drive unit **28**. Furthermore, the substrate **22** and the antenna element **24** form an antenna device **26**. The drive unit **28** supplies power to the antenna element **24**. The substrate **22** includes a substrate ground (GND).

Like the antenna element **14**, the antenna element **24** may be an antenna pattern drawn (printed) on the substrate **22**, for example. The antenna element **24** is a reverse L-shaped antenna, for example. Accordingly, the antenna element **24** includes a horizontal portion **24***a* that is a component parallel to the ground plane **90**, and a perpendicular portion **24***b* that is a component perpendicular to the ground plane **90**. The antenna element **24** (and the antenna device **26**) thus has both horizontal polarization and vertical polarization.

The substrate **22** of the wireless apparatus **20** according to the second comparative example is formed such that the dimensions are switched, in a long direction and a short direction, of the substrate **12** of the wireless apparatus **10** according to the first comparative example. That is, the substrate **22** is formed such that a dimension L**1** in the direction parallel to the ground plane **90** is greater than a dimension L**2** in the direction perpendicular to the ground plane **90**. That is, L**1**>L**2** is true. For example, L**1** is 100 mm and L**2** is 60 mm, but the dimensions of the substrate **22** are not limited thereto.

FIG. **9** is a diagram showing an example of a flow of a high-frequency current that flows through the wireless apparatus **20** according to the second comparative example at a certain moment. Like the wireless apparatus **10** according to the first comparative example, the antenna element **24** is provided on the substrate **22** including the substrate ground (GND), and thus, as indicated by arrows A to D in FIG. **9**, a high-frequency current flows through not only the antenna element **24** but also the substrate **22** (GND). Accordingly, the antenna device **26** formed by the substrate **22** and the antenna element **24** functions as an antenna.

Here, the frequency of the high-frequency current is assumed to be 900 MHz. As indicated by the arrows A and B, the high-frequency current flows through the antenna element **24** and in the short direction (a perpendicular direction) of the substrate **22**. Furthermore, as indicated by the arrows C and D, the high-frequency current flows through a part facing the antenna element **24** (in the long direction (a horizontal direction) of the substrate **22**).

The direction of the high-frequency current flowing through the antenna element **24** (indicated by the arrow A) is opposite the direction of the high-frequency current flowing in the long direction of the substrate **22** (indicated by the arrows C and D). Accordingly, some horizontally polarized waves caused by the high-frequency current flowing in the horizontal direction cancel each other out, and remaining horizontally polarized waves that are not cancelled are radiated outside.

Furthermore, in a case where the dimension of the substrate **22** in the short direction (the perpendicular direction) is smaller than ¼ of a wavelength of the frequency 900 MHz, it becomes difficult for the high-frequency current to flow in the short direction. This reduces radiation, due to the high-frequency current in the perpendicular direction of the antenna device **26** (the current flowing in the direction indicated by the arrow B), in other words, the vertical polarization (see FIG. **10** described later). This is due to the following reason. That is, as described later, to obtain resonance in an antenna, the length of the antenna needs to be about ½ of the wavelength of the resonance frequency of the antenna (the antenna element **24**). In the case where about ¼ of the wavelength of the resonance frequency is secured by the antenna element **24**, the length of the remaining ¼ of the wavelength is required of the substrate **22**. Accordingly, if the dimension of the substrate **22** in the short direction (the perpendicular direction) is smaller than ¼ of the wavelength, the high-frequency current flows in the long direction where the length of ¼ of the wavelength is secured. Accordingly, it becomes difficult for the high-frequency current to flow in the short direction.

FIG. **10** is a diagram showing an example of a radiation pattern, in the ground plane direction (on the XY plane), of the wireless apparatus **20** according to the second comparative example shown in FIG. **8**. When compared with the wireless apparatus **10** according to the first comparative example, the wireless apparatus **20** according to the second comparative example has a shorter length in the direction perpendicular to the ground plane **90** (a vertical direction), and thus, the vertical polarization in FIG. **10** is smaller than the vertical polarization in FIG. **5**. In contrast, when compared with the wireless apparatus **10** according to the first comparative example, the wireless apparatus **20** according to the second comparative example has a longer length in the direction parallel to the ground plane **90** (the horizontal direction), and thus, the horizontal polarization in FIG. **10** is greater than the horizontal polarization in FIG. **5**. In this manner, to obtain great horizontal polarization, the length of the component of the antenna device that is parallel to the ground plane has to be increased, and to obtain great vertical polarization, the length of the component of the antenna device that is perpendicular to the ground plane has to be increased.

To perform transmission/reception of radio waves between wireless apparatuses, polarizations of antennas have to be matched between the wireless apparatuses. At this time, in the case where the antenna of the counterpart apparatus only has vertical polarization, the antenna of the subject wireless apparatus needs to have vertical polarization. As described above, to obtain vertical polarization, the component of the antenna device that is perpendicular to the ground plane has to be increased, and thus, to obtain great vertical polarization, the height of the wireless apparatus may have to be increased. However, the height of the wireless apparatus is often restricted by installation conditions and the like of the wireless apparatus. In such a case, the vertical polarization possibly becomes small, and this may result in a problem of a reduced communication range between the wireless apparatuses.

In contrast, a wireless apparatus according to the present disclosure includes an antenna device configured by a substrate including a substrate ground and an antenna element provided on the substrate, and a conductor formed into a

sideways U-shape. The conductor includes an upper section and a lower section that are disposed along a ground plane and vertically relative to each other (i.e., disposed above and below, respectively), and a middle section that is disposed substantially perpendicular to the ground plane, between one end of the upper section and one end of the lower section. The upper section, the lower section, and the middle section of the conductor are disposed near an upper side section, a lower side section, and a lateral side section of the antenna device, respectively. The upper section of the conductor is disposed near the antenna element, and the conductor functions as an antenna due to current being excited in the conductor when power is supplied to the antenna element.

In other words, the wireless apparatus according to the present disclosure includes an antenna device configured by a substrate including a substrate ground and an antenna element provided on the substrate, and a conductor that is formed into a sideways U-shape and that is disposed to partially surround the antenna device. One end portion of the conductor is disposed near the antenna element, and the conductor functions as an antenna due to current being excited in the conductor when power is supplied to the antenna element. Moreover, the conductor is disposed with a center portion of the conductor substantially perpendicular to ground.

According to such a configuration, the wireless apparatus according to the present disclosure may increase the vertical polarization without increasing the height of the apparatus, as described later. Therefore, with the wireless apparatus according to the present disclosure, the communication range may be prevented from being reduced even in a case where the height of the apparatus is restricted.

First Example Embodiment

In the following, an example embodiment will be described with reference to the drawings. The following description and drawings include omissions or are simplified as appropriate for the sake of clear description. Furthermore, same elements are denoted by a same reference sign in the drawings, and redundant description is omitted as necessary.

FIGS. **11** and **12** are diagrams showing a wireless apparatus **100** according to a first example embodiment. FIG. **11** is a plan view showing the wireless apparatus **100** from a Y direction, and FIG. **12** is a perspective view of the wireless apparatus **100**. Like the wireless apparatus **20** shown in FIG. **8**, the wireless apparatus **100** includes a substrate **22**, an antenna element **24** provided on the substrate **22**, and a drive unit **28**. The substrate **22** and the antenna element **24** form an antenna device **26**. The substrate **22** includes a substrate ground (GND). Furthermore, like the wireless apparatus **20** shown in FIG. **8**, the substrate **22** is formed in such a way that the dimension in the direction perpendicular to the ground plane **90** is smaller than the dimension in the direction parallel to the ground plane **90**.

The wireless apparatus **100** according to the first example embodiment further includes a conductor **110** that is formed into a sideways U-shape. The conductor **110** is disposed near the antenna device **26**, but is not physically connected to the antenna device **26**. Accordingly, the conductor **110** is a parasitic element to which power is not directly supplied by the drive unit **28**.

As shown in FIG. **11**, the conductor **110** includes an upper section **110***a*, a lower section **110***b*, and a middle section **110***c*. The upper section **110***a* and the lower section **110***b* are disposed along the ground plane **90** and vertically relative to each other. The middle section **110***c* is disposed substantially perpendicular to the ground plane **90**, between one end P**1** of the upper section **110***a* and one end P**2** of the lower section **110***b*. Here, "substantially perpendicular" means that an elevation angle is within a range of 90±45 degrees. Furthermore, in the present specification, the single term "perpendicular" does not mean that the elevation angle is exactly 90 degrees, but may mean that the elevation angle is within the range of 90±45 degrees. Additionally, the upper section **110***a*, the lower section **110***b*, and the middle section **110***c* are integrally formed, and the conductor **110** may be formed by bending a thin long conductor at P**1** and P**2**.

The conductor **110** is disposed such that the upper section **110***a* thereof is along the upper side section **26***a* of the antenna device **26**. Furthermore, the conductor **110** is disposed such that the lower section **110***b* thereof is along the lower side section **26***b* of the antenna device **26**. Furthermore, the conductor **110** is disposed such that the middle section **110***c* thereof is along the lateral side section **26***c* of the antenna device **26**. That is, the conductor **110** is disposed such that the upper section **110***a*, the lower section **110***b*, and the middle section **110***c* thereof are near the upper side section **26***a*, the lower side section **26***b*, and the lateral side section **26***c* of the antenna device **26**, respectively. Here, a gap between the middle section **110***c* and the lateral side section **26***c* is given as Lc. Furthermore, the length of the middle section **110***c* is desirably about the same or greater than the length of the lateral side section **26***c*.

The upper section **110***a* of the conductor **110** is disposed near the antenna element **24**. A total length of the conductor **110** (a combined length of the upper section **110***a*, the lower section **110***b*, and the middle section **110***c*) is desirably about the same as ½ of the wavelength of the resonance frequency. Resonance may thus be achieved in the conductor **110** at a desired frequency. Moreover, the conductor **110** is desirably disposed in such a way that a center portion of the conductor **110** is substantially perpendicular to the ground plane **90**.

The drive unit **28** is disposed near an outer edge (the lateral side section **26***c*) of the substrate **22**, and the drive unit **28** supplies power to the antenna element **24**. When power is supplied to the antenna element **24** by the drive unit **28**, a high-frequency current is excited in the conductor **110** disposed near the antenna element **24**. At this time, the conductor **110** resonates at such a frequency that the total length of the conductor **110** is about ½ of the wavelength, and thus functions as an antenna. That is, when a current is excited in the conductor **110** at a time of supply of power to the antenna element **24**, the conductor **110** functions as an antenna.

Additionally, in reality, the total length of the conductor **110** has to be shorter than ½ of the wavelength of the actual resonance frequency, when considering an influence of bending of the conductor **110** at P**1** and P**2**, an influence exerted due to the conductor **110** being adjacent to the substrate **22** (GND), and the like. The reason is as follows. In a case where the antenna is expressed as an RLC series equivalent circuit, when the antenna comes close to the ground (GND), the antenna is caused to have electrostatic capacitance, and C (capacitance) is increased. To offset the influence, L (inductance) has to be reduced, and L is adjusted to be small by making the total length shorter than ½ of the wavelength. Accordingly, the total length of the conductor **110** has to be made shorter than ½ of the wavelength of the actual resonance frequency.

Additionally, in the case where a dielectric body such as a housing of the wireless apparatus **100** is present near the conductor **110**, the total length of the conductor **110** has to be further reduced. Moreover, intensity of the high-fre-

quency current that is excited in the conductor **110** is dependent on the high-frequency current flowing through the antenna element **24** (the reverse L-shaped antenna). Accordingly, the resonance frequency of the antenna element **24** and the resonance frequency of the conductor **110** have to be matched.

FIG. **13** is a diagram showing an example of a flow of a high-frequency current that flows through the wireless apparatus **100** according to the first example embodiment at a certain moment. The frequency of the high-frequency current is assumed to be 900 MHz. Like the wireless apparatus **20** according to the second comparative example shown in FIG. **9**, the high-frequency current flows not only through the antenna element **24** but also the substrate **22**, as indicated by arrows A to D in FIG. **13**. Accordingly, the antenna device **26** formed by the substrate **22** and the antenna element **24** functions as an antenna.

Furthermore, as shown in FIG. **13**, a high-frequency current in an opposite direction from a high-frequency current flowing through the antenna element **24** and in the short direction (the perpendicular direction) of the substrate **22** is excited in the conductor **110**. Accordingly, a high-frequency current flows through the upper section **110***a* of the conductor **110** in a direction indicated by a dashed-line arrow H, and a high-frequency current flows through the middle section **110***c* of the conductor **110** in a direction indicated by a dashed-line arrow I, and a high-frequency current flows through the lower section **110***b* of the conductor **110** in a direction indicated by a dashed-line arrow J.

Here, with respect to the high-frequency current excited in the conductor **110**, the direction of the high-frequency current flowing through the upper section **110***a* (indicated by the arrow H) and the direction of the high-frequency current flowing through the lower section **110***b* (indicated by the arrow J) are opposite each other. Accordingly, polarizations of the high-frequency currents flowing through the two cancel each other. Accordingly, the upper section **110***a* and the lower section **110***b* hardly contribute to polarized (horizontally polarized) radiation.

A high-frequency current in a direction (indicated by the arrow I) opposite the direction (indicated by the arrow B) of the high-frequency current flowing in the short direction (the perpendicular direction) of the substrate **22** flows through the middle section **110***c*. As described above, the high-frequency current flowing through the short direction (the perpendicular direction) of the substrate **22** is weak. Accordingly, polarization of the high-frequency current flowing through the middle section **110***c* contributes to polarized (vertically polarized) radiation without being much canceled. Now, the high-frequency current that is excited in the conductor **110** whose total length is about ½ of the wavelength of the desired frequency is greatly distributed at the center portion of the conductor **110** and is not much distributed near tip ends. In the present example embodiment, the shape of the conductor **110** is a sideways U-shape, and thus, the center portion of the conductor **110** may be easily disposed to be substantially perpendicular to the ground plane **90**. The vertical polarization may thus be increased.

As described above, to increase the vertical polarization, it is important that the high-frequency current is strongly excited in the sideways U-shaped conductor **110**. For this purpose, electrical coupling to the antenna element **24** has to be strengthened, and thus, the upper section **110***a* of the conductor **110** has to be disposed near the antenna element **24**.

For its part, the middle section **110***c* of the conductor **110** is desirably disposed as far as possible from the lateral side section **26***c* of the substrate **22**. That is, the gap Lc between the middle section **110***c* and the lateral side section **26***c* is greater than a length that is determined in advance. That is, Lc>Lth is true. Here, Lth is the length that is determined in advance. For example, in the case where the frequency is 900 MHz, the dimension of the substrate **22** in the long direction is 100 mm and the dimension of the substrate **22** in the short direction is 60 mm, Lth is 5 mm. However, Lth is not limited to such a value. Furthermore, Lth may be set as appropriate according to the frequency and the dimensions of the substrate **22**.

Additionally, the reason why the middle section **110***c* of the conductor **110** is desirably disposed as far as possible from the lateral side section **26***c* of the substrate **22** is because the high-frequency current that is excited in the substrate **22** by the conductor **110** gets stronger the closer the middle section **110***c* gets to the substrate **22**. The direction of the high-frequency current that is excited in the substrate **22** by the conductor **110** is opposite the direction of the high-frequency current flowing through the conductor **110**. Accordingly, when the middle section **110***c* is close to the substrate **22** and the high-frequency current that is excited in the substrate **22** by the conductor **110** is strong, vertically polarized radiation is inhibited.

FIG. **14** is a diagram showing an example of a radiation pattern, in the ground plane direction (on the XY plane), of the wireless apparatus **100** according to the first example embodiment shown in FIGS. **11** and **12**. Furthermore, FIG. **15** is a diagram in which a radiation pattern for vertical polarization of the wireless apparatus **20** according to the second comparative example and a radiation pattern for vertical polarization of the wireless apparatus **100** according to the first example embodiment are superimposed on each other. In FIG. **15**, the radiation pattern for vertical polarization of the wireless apparatus **20** according to the second comparative example (that is, the radiation pattern for vertical polarization in FIG. **10**) is indicated by a thick dash-dotted line, and the radiation pattern for vertical polarization of the wireless apparatus **100** according to the first example embodiment is indicated by a thick solid line.

When comparing FIGS. **10** and **14**, the radiation patterns for horizontal polarization in the two are approximately the same. However, a circle of the radiation pattern for vertical polarization in FIG. **14** is larger than a circle of the radiation pattern for vertical polarization in FIG. **10**. This is also clear from FIG. **15**. That is, the vertical polarization of the wireless apparatus **100** according to the first example embodiment is greater than the vertical polarization of the wireless apparatus **20** according to the second comparative example. Accordingly, with the wireless apparatus **100** according to the first example embodiment, vertically polarized radiation may be increased while preventing the height of the apparatus from being increased.

Additionally, as described above, to increase the vertical polarization of the conductor **110** that is formed into a sideways U-shape, a magnitude of the high-frequency current flowing through the middle section **110***c* of the conductor **110** has to be greater than a magnitude of the high-frequency current flowing in the perpendicular direction of the substrate **22**. Furthermore, as described above, when the dimension of the substrate **22** in the perpendicular direction is reduced, distribution of components of the high-frequency current in the perpendicular direction becomes small. According to a result of a simulation, the effect of the wireless apparatus **100** according to the present disclosure is desirably obtained by making the dimension of the substrate **22** in the perpendicular direction equal to or smaller than ⅓

of the wavelength of the resonance frequency of the antenna (the antenna element **24**). That is, when the dimension of the substrate **22** in the perpendicular direction is made equal to or smaller than ⅓ of the wavelength of the resonance frequency, the high-frequency current flowing through the substrate **22** in the perpendicular direction may be reduced to an extent that polarization of the high-frequency current flowing through the middle section **110***c* is not greatly canceled.

Second Example Embodiment

Next, a description will be given of a second example embodiment. The following description and drawings include omissions or are simplified as appropriate for the sake of clear description. Furthermore, same elements are denoted by a same reference sign in the drawings, and redundant description is omitted as necessary.

FIG. **16** is a diagram showing a wireless apparatus **200** according to the second example embodiment. FIG. **16** is a perspective view of the wireless apparatus **200**. The wireless apparatus **200** includes the antenna device **26** (the antenna element **24** and the substrate **22**), and a conductor **210** that is formed into a sideways U-shape. Additionally, although not shown, as in the first example embodiment, the wireless apparatus **200** includes the drive unit **28** for supplying power to the antenna element **24**. The antenna device **26** shown in FIG. **16** is substantially the same as the antenna device **26** shown in FIG. **12**.

The conductor **210** includes an upper section **210***a*, a lower section **210***b*, and a middle section **210***c*. The middle section **210***c* is substantially the same as the middle section **110***c*. The upper section **210***a* is obtained by changing the shape of the upper section **110***a* such that a tip end portion comes closer to the substrate **22**. In the same manner, the lower section **210***b* is obtained by changing the shape of the lower section **110***b* such that a tip end portion comes closer to the substrate **22**.

The dimension of the conductor **210** and the positional relationship between the conductor **210** and the substrate **22** are substantially the same as those in the case of the conductor **110** according to the first example embodiment. That is, the length of the conductor **210** is about ½ of the wavelength of the resonance frequency. Furthermore, the upper section **210***a* and the lower section **210***b* are disposed along the ground plane **90** and vertically relative to each other. The middle section **210***c* is disposed substantially perpendicular to the ground plane **90**, between one end P**1** of the upper section **210***a* and one end P**2** of the lower section **210***b*. Furthermore, the conductor **210** is disposed such that the upper section **210***a* thereof is along the upper side section **26***a* of the antenna device **26**. The conductor **210** is disposed such that the lower section **210***b* thereof is along the lower side section **26***b* of the antenna device **26**. The conductor **210** is disposed such that the middle section **210***c* thereof is along the lateral side section **26***c* of the antenna device **26**.

FIG. **17** is a diagram showing an example of a radiation pattern, in the ground plane direction (on the XY plane), of the wireless apparatus **200** according to the second example embodiment shown in FIG. **16**. Furthermore, FIG. **18** is a diagram in which the radiation pattern for vertical polarization of the wireless apparatus **20** according to the second comparative example and a radiation pattern for vertical polarization of the wireless apparatus **200** according to the second example embodiment are superimposed on each other. In FIG. **18**, the radiation pattern for vertical polarization of the wireless apparatus **20** according to the second comparative example is indicated by a thick dash-dotted line, and the radiation pattern for vertical polarization of the wireless apparatus **200** according to the second example embodiment is indicated by a thick solid line.

When comparing FIGS. **10** and **17**, the radiation patterns for horizontal polarization in the two are approximately the same, as in the first example embodiment. However, a circle of the radiation pattern for vertical polarization in FIG. **17** is larger than the circle of the radiation pattern for vertical polarization in FIG. **10**. This is also clear from FIG. **18**. That is, the vertical polarization of the wireless apparatus **200** according to the second example embodiment is greater than the vertical polarization of the wireless apparatus **20** according to the second comparative example. Accordingly, also with the wireless apparatus **100** according to the second example embodiment, vertically polarized radiation may be increased while preventing the height of the apparatus from being increased. Accordingly, the conductor to be disposed near the antenna device **26** does not have to be perfectly sideways U-shaped as long as it has a sideways U-shape on the whole.

Third Example Embodiment

Next, a description will be given of a third example embodiment. The following description and drawings include omissions or are simplified as appropriate for the sake of clear description. Furthermore, same elements are denoted by a same reference sign in the drawings, and redundant description is omitted as necessary.

FIG. **19** is a diagram showing a wireless apparatus **300** according to the third example embodiment. FIG. **19** is a plan view showing the wireless apparatus **200** from the Y direction. As shown in FIG. **16**, the wireless apparatus **300** includes the antenna device **26** (the antenna element **24** and the substrate **22**), a drive unit **328**, and the conductor **110** that is formed into a sideways U-shape. Additionally, the conductor **110** may be replaced with the conductor **210**.

The drive unit **328** is disposed on an inner side of the substrate **22**. The drive unit **328** is disposed on the upper side section **26***a* of the substrate **22**. Furthermore, a tip end of the antenna element **24** faces outward of the antenna device **26**. That is, in the third example embodiment, a power supply position for the antenna element **24** is different from that in the first example embodiment.

FIG. **20** is a diagram in which a radiation pattern for vertical polarization of the wireless apparatus **300** according to the third example embodiment and a radiation pattern for vertical polarization in a case where the conductor **110** is removed from the wireless apparatus **300** according to the third example embodiment are superimposed on each other. In FIG. **20**, the radiation pattern for vertical polarization in the case where the conductor **110** is not included is indicated by a thick dash-dotted line, and the radiation pattern for vertical polarization of the wireless apparatus **300** according to the third example embodiment is indicated by a thick solid line.

As shown in FIG. **20**, a circle of the radiation pattern for vertical polarization of the wireless apparatus **300** according to the third example embodiment, or in other words, in the case where the conductor **110** is included, is larger than a circle of the radiation pattern for vertical polarization in the case where the conductor **110** is not included. That is, the vertical polarization of the wireless apparatus **300** according to the third example embodiment is greater than the vertical polarization in the case where the conductor **110** is not

included. Accordingly, also with the wireless apparatus **100** according to the third example embodiment, vertically polarized radiation may be increased while preventing the height of the apparatus from being increased. Accordingly, the antenna element **24** may take any form as long as a high-frequency current is excited in the conductor **110** that is formed into a sideways U-shape.

Fourth Example Embodiment

Next, a description will be given of a fourth example embodiment. The following description and drawings include omissions or are simplified as appropriate for the sake of clear description. Furthermore, same elements are denoted by a same reference sign in the drawings, and redundant description is omitted as necessary.

FIG. **21** is a diagram showing a wireless apparatus **400** according to the fourth example embodiment. FIG. **21** is a perspective view of the wireless apparatus **400**. As shown in FIG. **21**, the wireless apparatus **400** includes the antenna device **26** (the antenna element **24** and the substrate **22**), and a conductor **410** that is formed into a sideways U-shape. Additionally, although not shown, as in the first example embodiment, the wireless apparatus **400** includes the drive unit **28** for supplying power to the antenna element **24**. The antenna device **26** shown in FIG. **21** is substantially the same as the antenna device **26** shown in FIG. **12**.

The conductor **410** includes an upper section **410***a*, a lower section **410***b*, and a middle section **410***c*. When seen from the Y direction (an upward direction on the page), the conductor **410** is disposed overlapping the substrate **22** (the antenna device **26**).

The positional relationship between the conductor **410** and the substrate **22** in other respects, and the dimension of the conductor **410** are substantially the same as those in the case of the conductor **110** according to the first example embodiment. That is, the length of the conductor **410** is about ½ of the wavelength of the resonance frequency. Furthermore, the upper section **410***a* and the lower section **410***b* are disposed along the ground plane **90** and vertically relative to each other. The middle section **410***c* is disposed substantially perpendicular to the ground plane **90**, between one end P**1** of the upper section **410***a* and one end P**2** of the lower section **410***b*. Furthermore, the conductor **410** is disposed such that the upper section **410***a* thereof is along the upper side section **26***a* of the antenna device **26**. The conductor **410** is disposed such that the lower section **410***b* thereof is along the lower side section **26***b* of the antenna device **26**. The conductor **410** is disposed such that the middle section **410***c* thereof is along the lateral side section **26***c* of the antenna device **26**.

FIG. **22** is a diagram in which a radiation pattern for vertical polarization of the wireless apparatus **400** according to the fourth example embodiment and a radiation pattern for vertical polarization in a case where the conductor **410** is removed from the wireless apparatus **400** according to the fourth example embodiment are superimposed on each other. In FIG. **22**, the radiation pattern for vertical polarization in the case where the conductor **410** is not included is indicated by a thick dash-dotted line, and the radiation pattern for vertical polarization of the wireless apparatus **400** according to the fourth example embodiment is indicated by a thick solid line. Additionally, the radiation pattern for vertical polarization in the case where the conductor **410** is not included is substantially the same as the radiation pattern for vertical polarization of the wireless apparatus **20** according to the second comparative example.

As shown in FIG. **22**, a circle of the radiation pattern for vertical polarization of the wireless apparatus **400** according to the fourth example embodiment, or in other words, in the case where the conductor **410** is included, is larger than a circle of the radiation pattern for vertical polarization in the case where the conductor **410** is not included. That is, the vertical polarization of the wireless apparatus **400** according to the fourth example embodiment is greater than the vertical polarization in the case where the conductor **410** is not included. Accordingly, also with the wireless apparatus **400** according to the fourth example embodiment, vertically polarized radiation may be increased while preventing the height of the apparatus from being increased.

Modifications

Additionally, the present invention is not limited to the example embodiments described above, and may be changed as appropriate within the scope not departing from the spirit of the invention. For example, in the example embodiments described above, the antenna element **24** is a reverse L-shaped antenna, but the antenna element **24** is not limited to a reverse L-shaped antenna.

Furthermore, in the example embodiments described above, the total length of the conductor that is formed into a sideways U-shape is assumed to be about ½ of the wavelength of the resonance frequency, but such a configuration is not restrictive. Resonance may be generated in the conductor even when the total length of the conductor that is formed into a sideways U-shape is about (½)×N of the wavelength (where N is an integer of one or more). However, if N is two or more, the size of the conductor is increased.

Furthermore, in the example embodiments described above, the substrate **22** is formed such that the length in the horizontal direction is greater than the length in the perpendicular direction, but such a configuration is not restrictive. On the other hand, not only the vertical polarization but also the horizontal polarization may be increased by forming the substrate **22** in such a way that the length in the horizontal direction is greater than the length in the perpendicular direction.

Heretofore, the invention of the present application has been described with reference to the example embodiments, but the invention of the present application is not limited to the example embodiments described above. Various modifications that can be understood by those skilled in the art may be made within the scope of the invention in relation to configuration and details of the invention of the present application.

This application claims the benefit of priority to Japanese Patent Application No. 2019-136946 filed on Jul. 25, 2019, which is hereby incorporated by reference in its entirety.

REFERENCE SIGNS LIST

22 SUBSTRATE
24 ANTENNA ELEMENT
24*a* HORIZONTAL PORTION
24*b* PERPENDICULAR PORTION
26 ANTENNA DEVICE
26*a* UPPER SIDE SECTION
26*b* LOWER SIDE SECTION
26*c* LATERAL SIDE SECTION
28 DRIVE UNIT
90 GROUND PLANE
100 WIRELESS APPARATUS

110 CONDUCTOR
110*a* UPPER SECTION
110*b* LOWER SECTION
110*c* MIDDLE SECTION
200 WIRELESS APPARATUS
210 CONDUCTOR
210*a* UPPER SECTION
210*b* LOWER SECTION
210*c* MIDDLE SECTION
300 WIRELESS APPARATUS
328 DRIVE UNIT
400 WIRELESS APPARATUS
410 CONDUCTOR
410*a* UPPER SECTION
410*b* LOWER SECTION
410*c* MIDDLE SECTION

What is claimed is:

1. A wireless apparatus comprising:

an antenna device configured by a substrate including a substrate ground and an antenna element provided on the substrate; and

a conductor formed into a sideways U-shape, wherein

the conductor includes an upper section and a lower section that are disposed along a ground plane and vertically relative to each other, and a middle section that is disposed substantially perpendicular to the ground plane, between one end of the upper section and one end of the lower section, when the wireless apparatus is disposed above the ground plane which is a surface of earth,

the conductor is disposed such that the upper section, the lower section, and the middle section thereof are near an upper side section, a lower side section, and a lateral side section of the antenna device, respectively, and

the upper section of the conductor is disposed near the antenna element and a long direction of the upper section of the conductor is disposed along a long direction of the antenna element, and the conductor functions as an antenna due to current being excited in the conductor when power is supplied to the antenna element,

wherein the conductor is disposed in such a way that a gap between the middle section of the conductor and the lateral side section of the antenna device is greater than the shortest interval between the upper section of the conductor and the antenna element.

2. The wireless apparatus according to claim **1**, wherein the conductor is disposed with a center portion of the conductor substantially perpendicular to the ground plane.

3. The wireless apparatus according to claim **1**, wherein the substrate is formed in such a way that a dimension of the substrate in a direction perpendicular to the ground plane is smaller than a dimension of the substrate in a direction parallel to the ground plane.

4. The wireless apparatus according to claim **1**, wherein a dimension of the substrate in a direction perpendicular to the ground plane is equal to or smaller than ⅓ of a wavelength of a resonance frequency.

* * * * *

US012235225B2

(12) **United States Patent**
Chowdhury et al.

(10) **Patent No.: US 12,235,225 B2**
(45) **Date of Patent: Feb. 25, 2025**

(54) **SYSTEMS AND METHODS FOR NON-INTRUSIVE MATERIAL QUALITY INSPECTION USING THREE-DIMENSIONAL MONOSTATIC RADAR BASED IMAGING**

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(73) Assignee: **TATA CONSULTANCY SERVICES LIMITED**, Mumbai (IN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 231 days.

(21) Appl. No.: **18/185,476**

(22) Filed: **Mar. 17, 2023**

(65) **Prior Publication Data**

US 2023/0358691 A1 Nov. 9, 2023

(30) **Foreign Application Priority Data**

May 6, 2022 (IN) 202221026491

(51) **Int. Cl.**
G01N 22/02 (2006.01)
G01S 7/41 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G01N 22/02*** (2013.01); ***G01S 7/412*** (2013.01); ***G01S 13/532*** (2013.01); ***G01S 13/9064*** (2019.05)

(58) **Field of Classification Search**
CPC G01N 22/02; G01S 13/9064; G01S 7/412; G01S 13/532
See application file for complete search history.

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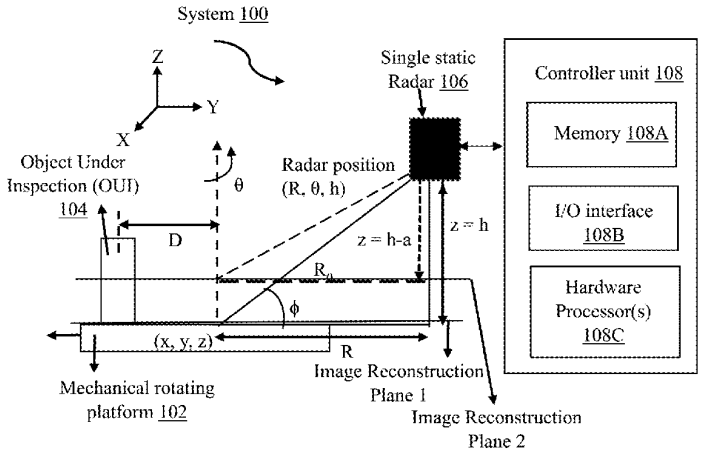
Primary Examiner — Ladimir Magloire
Assistant Examiner — Bongani Jabulani Mashele
(74) *Attorney, Agent, or Firm* — FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER LLP

(57) **ABSTRACT**

This disclosure relates generally to material quality inspection. Conventional approaches available for material quality inspection are unable to address concerns of complexity and cost involved. The technical problem of occluded object detection and material quality inspection for intrinsic defects identification is addressed in the present disclosure. The present disclosure provides a system and method for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging, where the object under inspection undergoes a circular translation motion on a rotating platform. A modified delay-and-sum (m-DAS)
(Continued)



algorithm is built by incorporating virtual antenna array to obtain a 3D image reconstruction of the object. From 3D reconstructed images, radial displacement as well as the angular locations of the object is identified which are further used for quality inspection of the material comprised in the object.

15 Claims, 16 Drawing Sheets

(51) **Int. Cl.**
G01S 13/532 (2006.01)
G01S 13/90 (2006.01)

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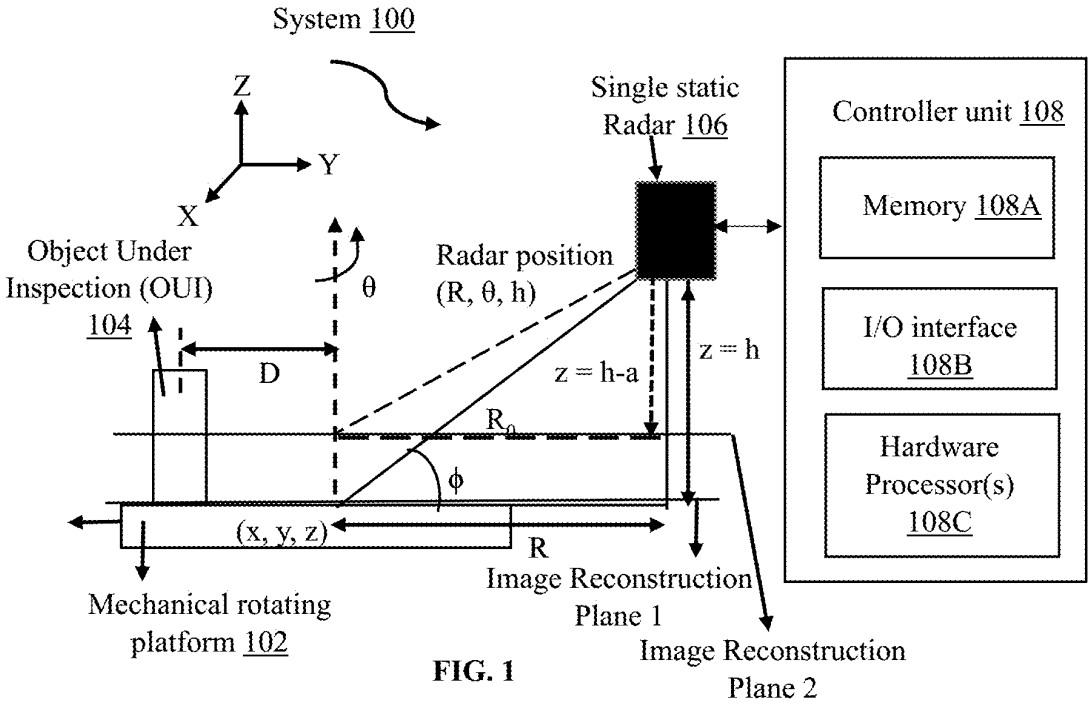
System 100
Z
Y
X
Object Under Inspection (OUI) 104
θ
D
Radar position (R, θ, h)
Single static Radar 106
Controller unit 108
Memory 108A
I/O interface 108B
Hardware Processor(s) 108C
z = h-a
z = h
R_0
ϕ
(x, y, z)
R
Mechanical rotating platform 102
Image Reconstruction Plane 1
Image Reconstruction Plane 2

FIG. 1

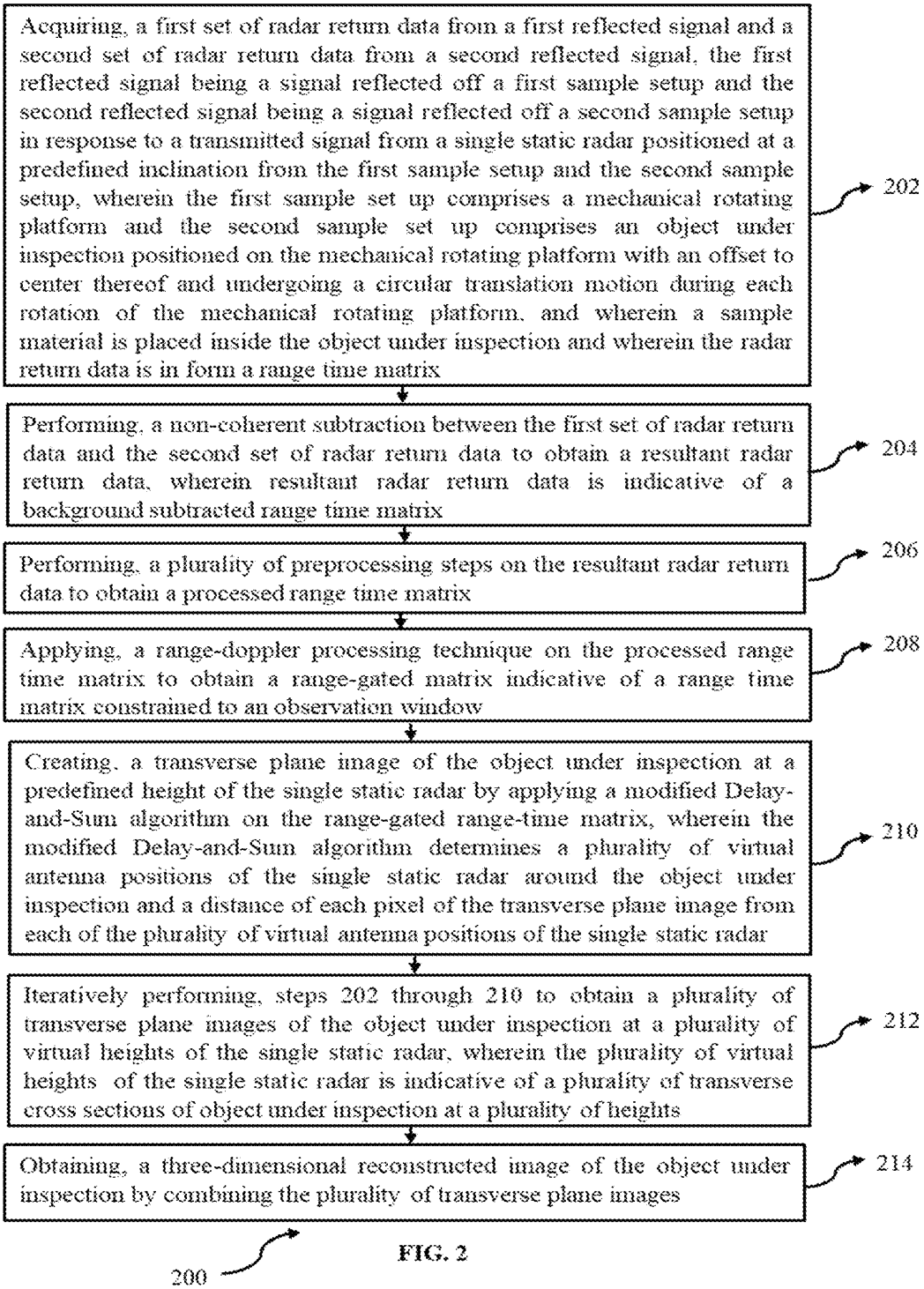
Acquiring, a first set of radar return data from a first reflected signal and a second set of radar return data from a second reflected signal, the first reflected signal being a signal reflected off a first sample setup and the second reflected signal being a signal reflected off a second sample setup in response to a transmitted signal from a single static radar positioned at a predefined inclination from the first sample setup and the second sample setup, wherein the first sample set up comprises a mechanical rotating platform and the second sample set up comprises an object under inspection positioned on the mechanical rotating platform with an offset to center thereof and undergoing a circular translation motion during each rotation of the mechanical rotating platform, and wherein a sample material is placed inside the object under inspection and wherein the radar return data is in form a range time matrix
202
Performing, a non-coherent subtraction between the first set of radar return data and the second set of radar return data to obtain a resultant radar return data, wherein resultant radar return data is indicative of a background subtracted range time matrix
204
Performing, a plurality of preprocessing steps on the resultant radar return data to obtain a processed range time matrix
206
Applying, a range-doppler processing technique on the processed range time matrix to obtain a range-gated matrix indicative of a range time matrix constrained to an observation window
208
Creating, a transverse plane image of the object under inspection at a predefined height of the single static radar by applying a modified Delay-and-Sum algorithm on the range-gated range-time matrix, wherein the modified Delay-and-Sum algorithm determines a plurality of virtual antenna positions of the single static radar around the object under inspection and a distance of each pixel of the transverse plane image from each of the plurality of virtual antenna positions of the single static radar
210
Iteratively performing, steps 202 through 210 to obtain a plurality of transverse plane images of the object under inspection at a plurality of virtual heights of the single static radar, wherein the plurality of virtual heights of the single static radar is indicative of a plurality of transverse cross sections of object under inspection at a plurality of heights
212
Obtaining, a three-dimensional reconstructed image of the object under inspection by combining the plurality of transverse plane images
214
200

FIG. 2

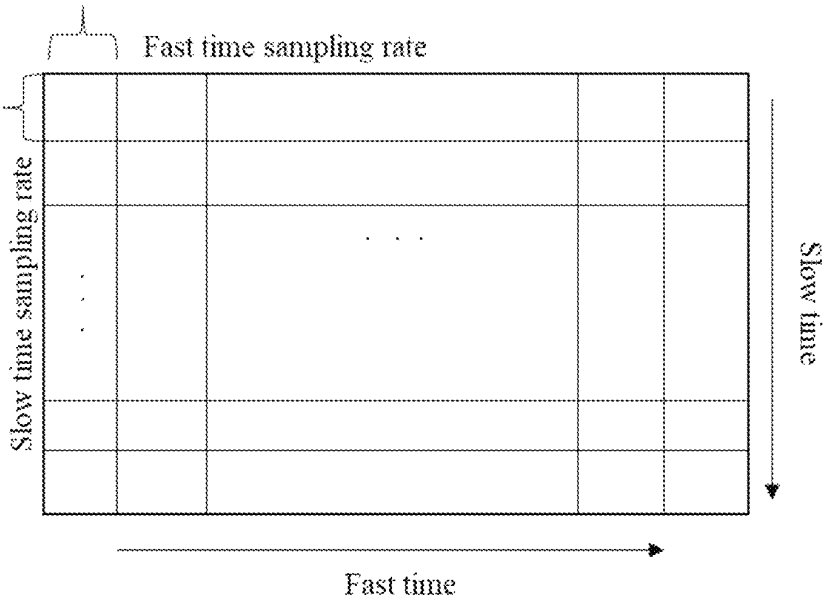
Fast time sampling rate
Slow time sampling rate
Slow time
Fast time

FIG. 3

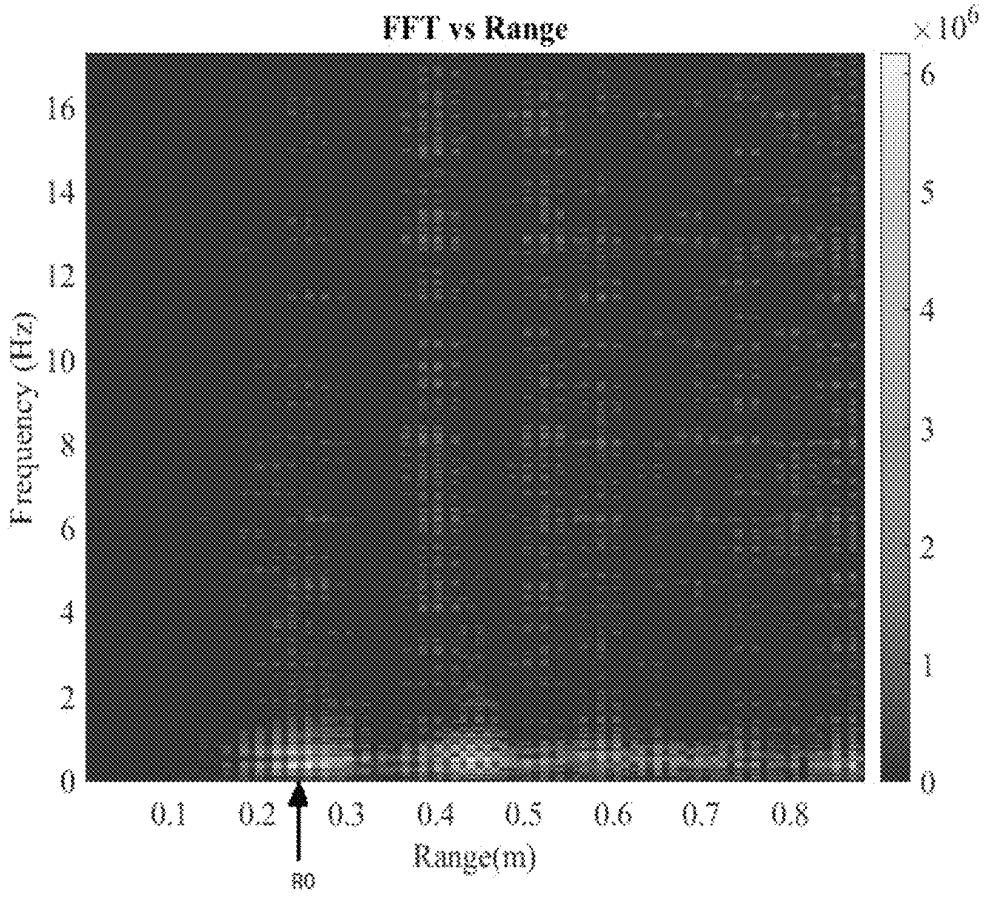
FFT vs Range
×10^6
6
5
4
3
2
1
0
16
14
12
10
8
6
4
2
0
Frequency (Hz)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Range(m)
R0

FIG. 4A

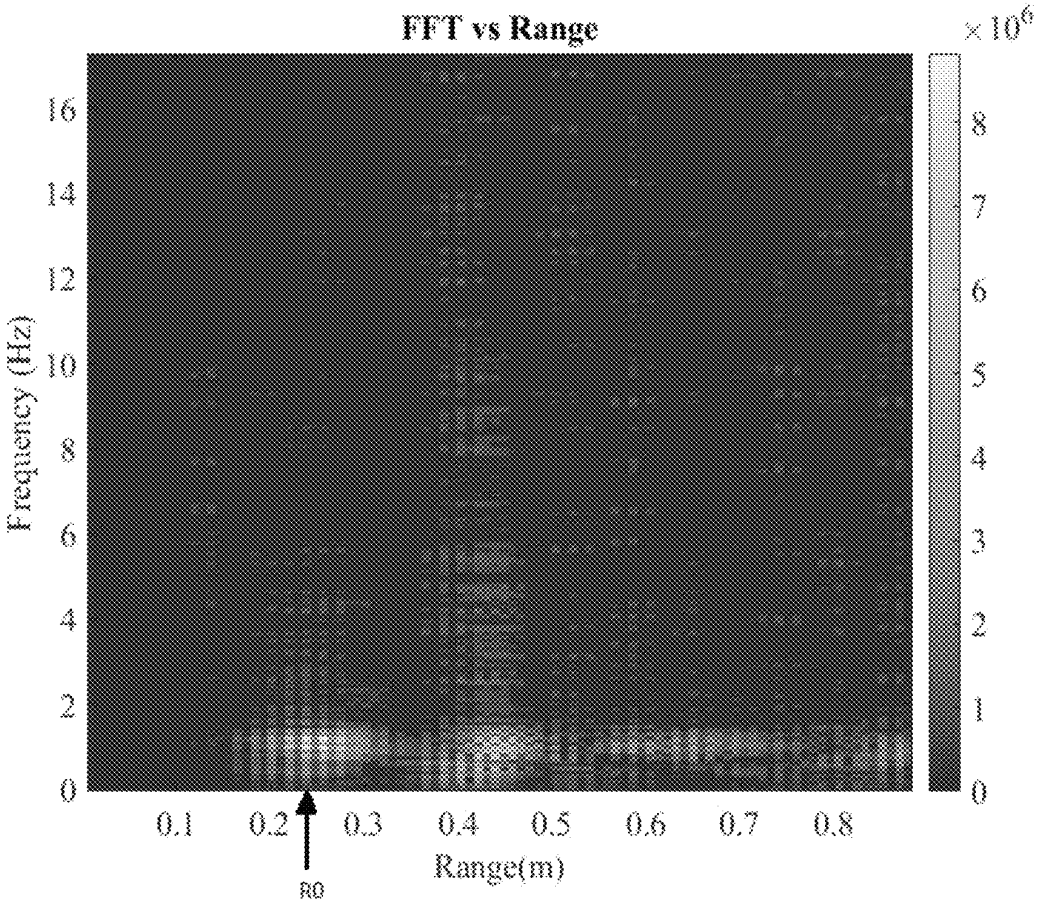
FFT vs Range
$\times 10^6$
Frequency (Hz)
16
14
12
10
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Range(m)
RO
8
7
6
5
4
3
2
1
0

FIG. 4B

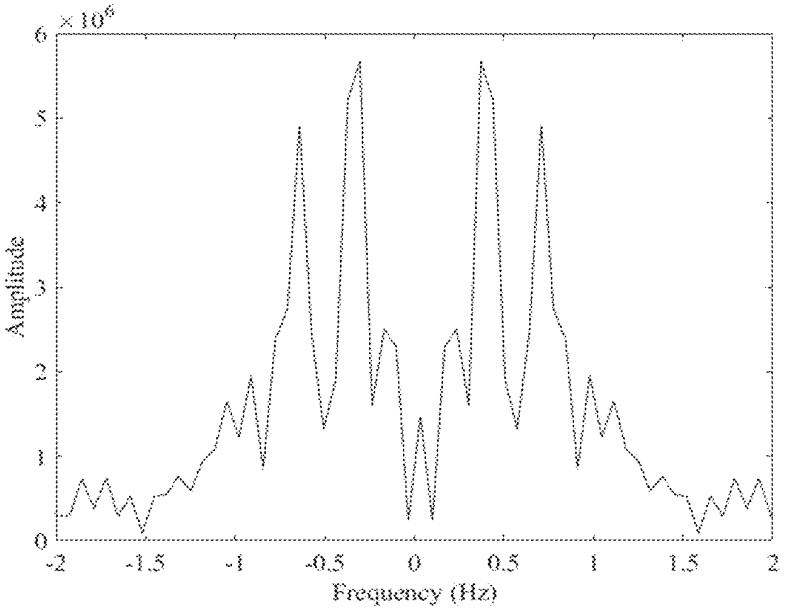
×10^6
6
5
4
3
2
1
0
Amplitude
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Frequency (Hz)

FIG. 5A

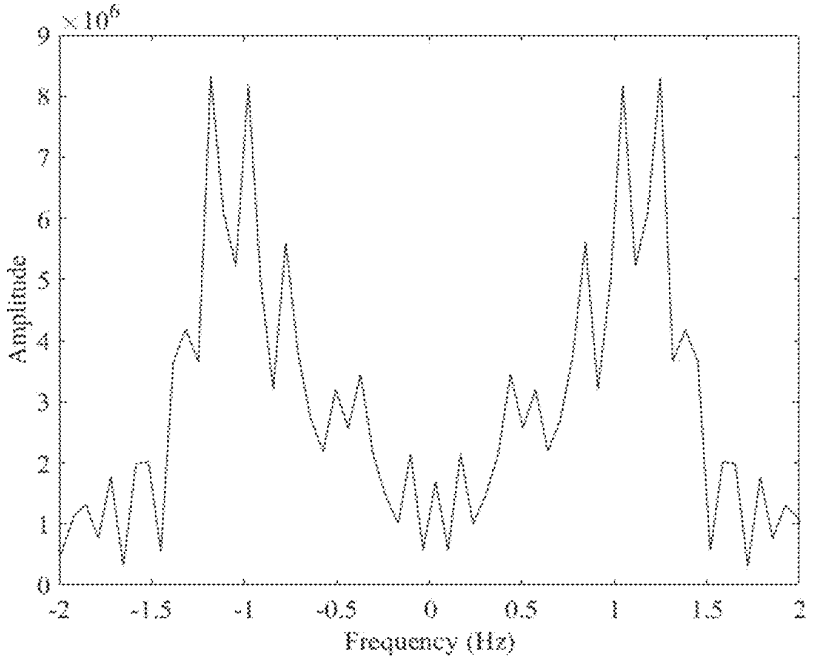
×10^6
9
8
7
6
5
4
3
2
1
0
Amplitude
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Frequency (Hz)

FIG. 5B

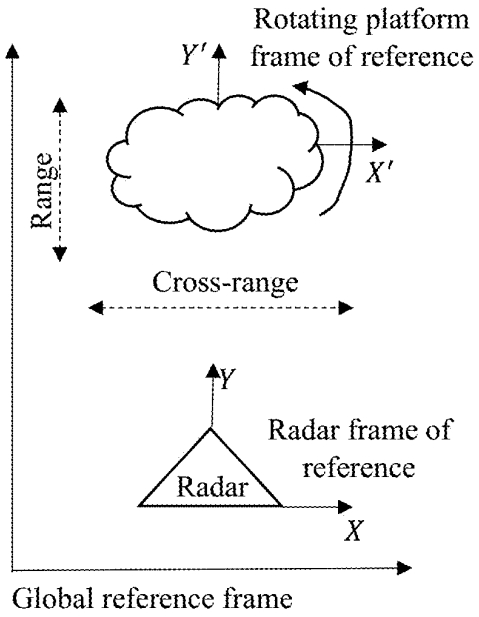
Rotating platform
frame of reference
Y′
X′
Range
Cross-range
Y
Radar frame of
reference
Radar
X
Global reference frame

FIG. 6A

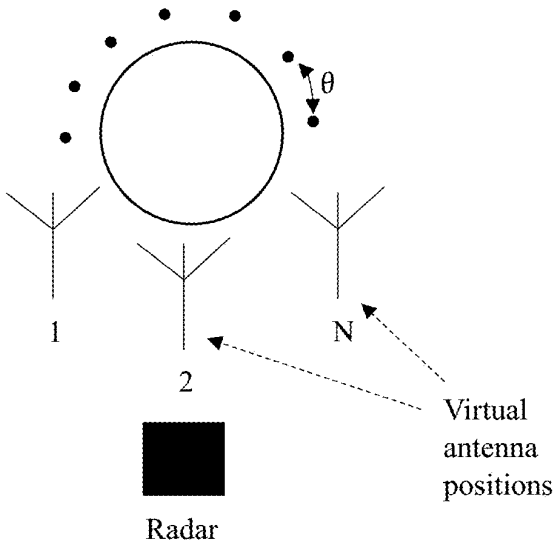
θ
1
2
N
Virtual
antenna
positions
Radar

FIG. 6B

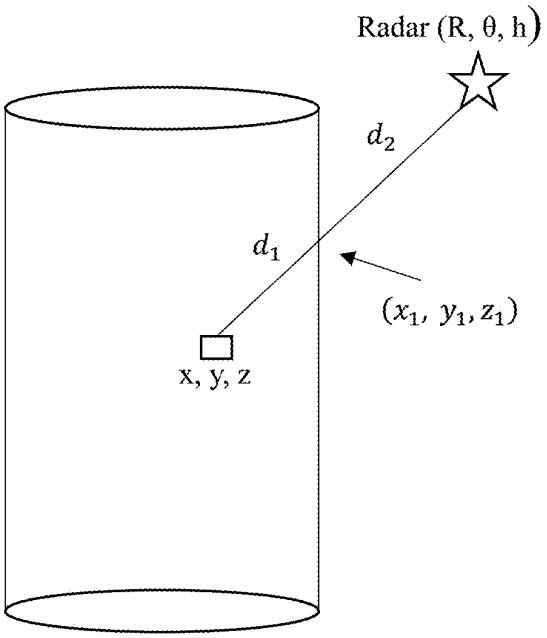

FIG. 7

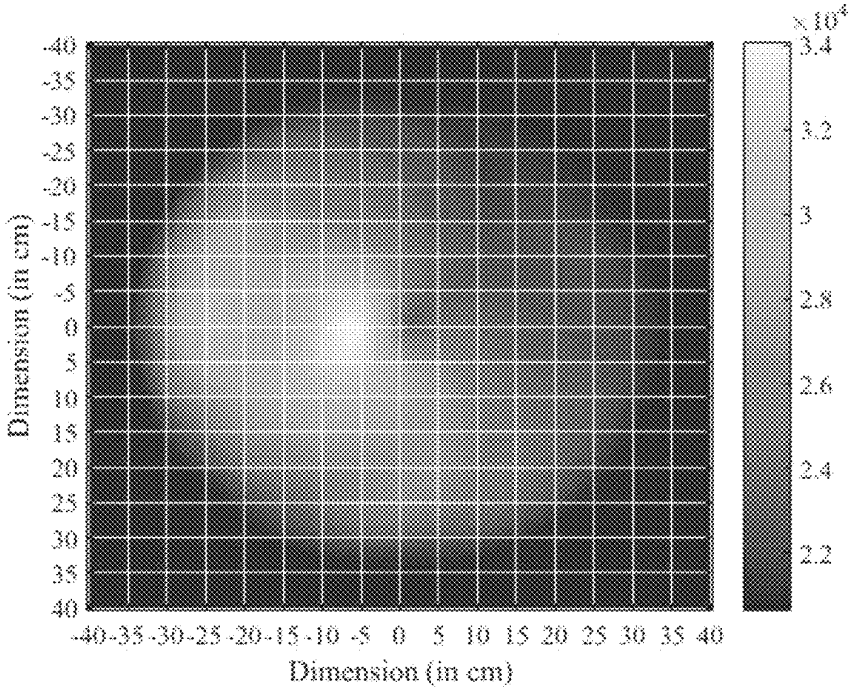
x 10^4
3.4
3.2
3
2.8
2.6
2.4
2.2
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
Dimension (in cm)
-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40
Dimension (in cm)

FIG. 8

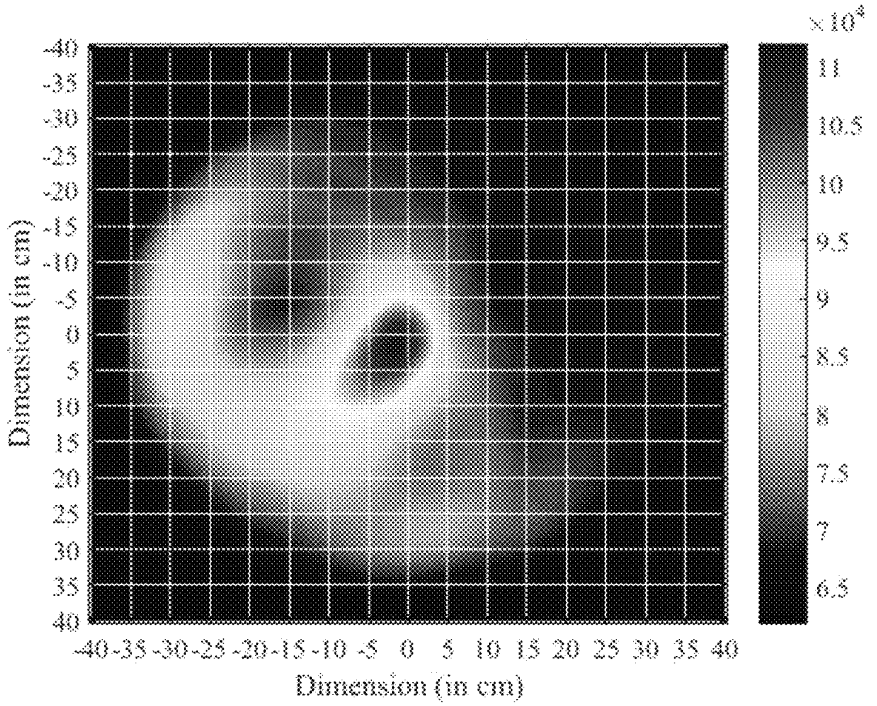
×10^4
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
Dimension (in cm)
-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40
Dimension (in cm)

FIG. 9

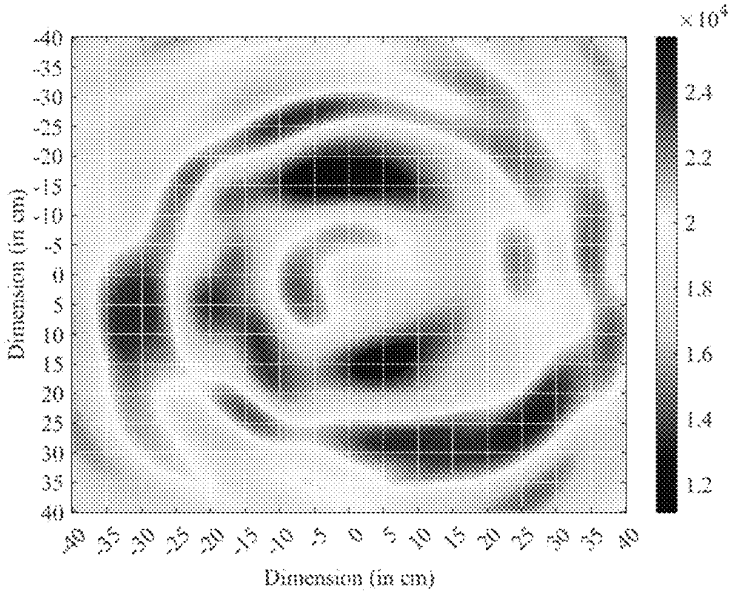

FIG. 10A

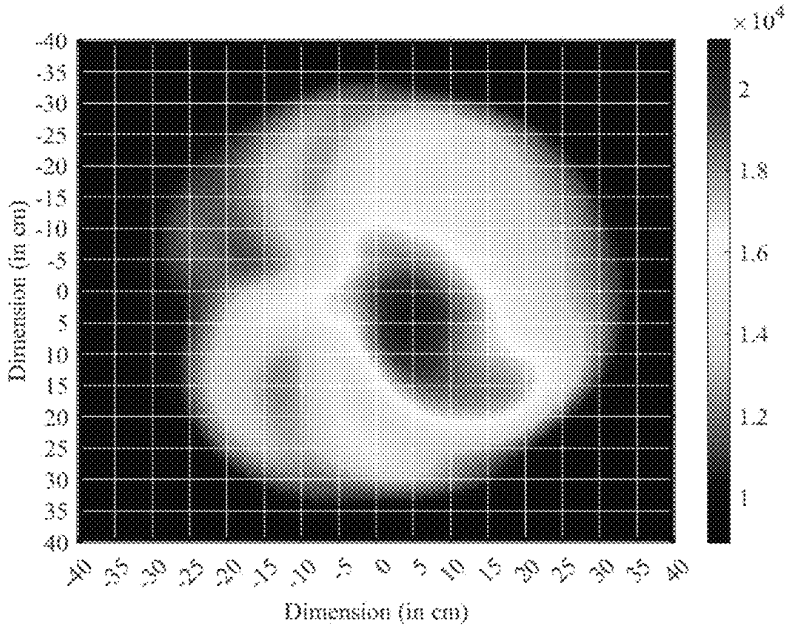

FIG. 10B

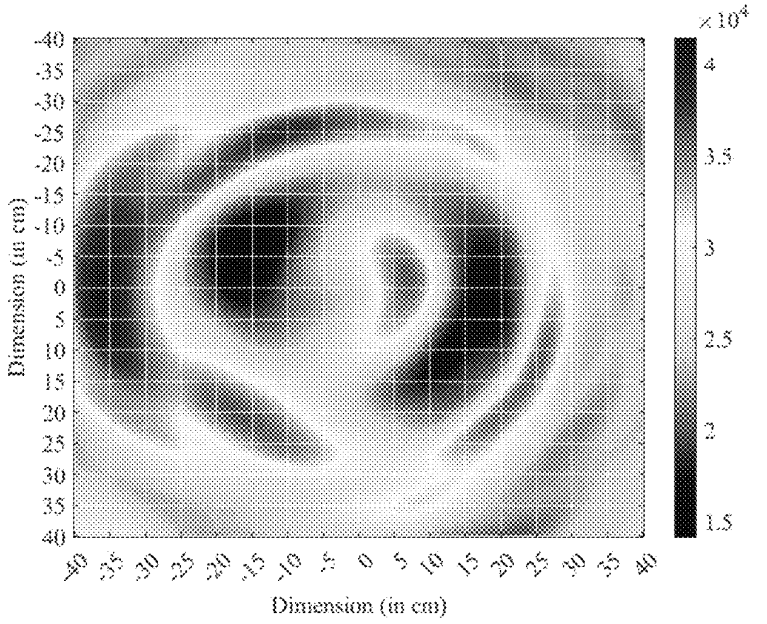

FIG. 10C

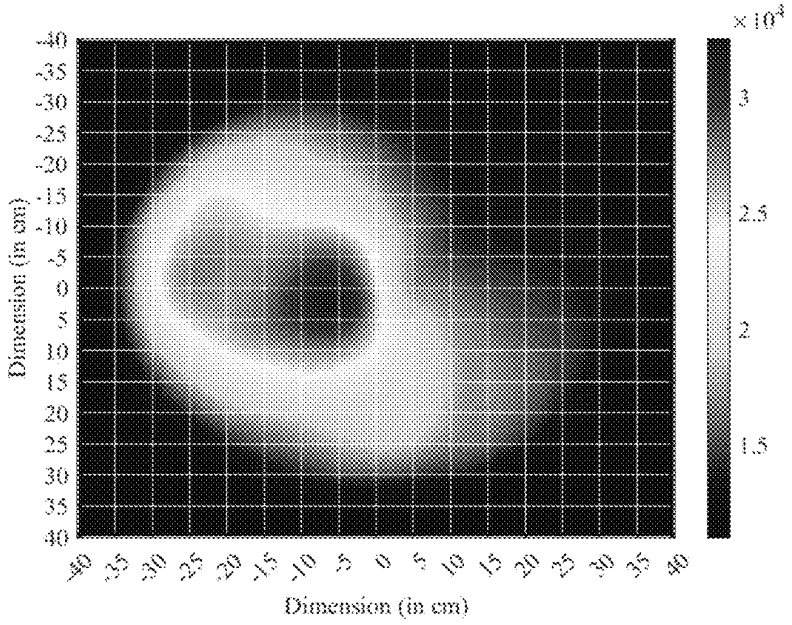

FIG. 10D

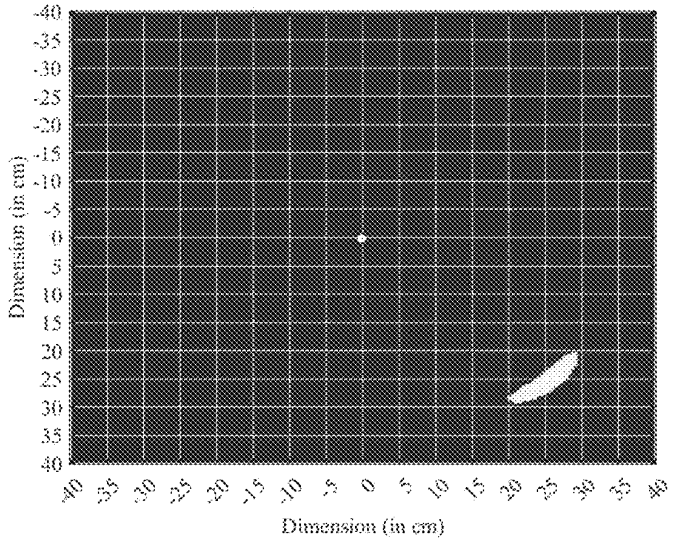

FIG. 11A

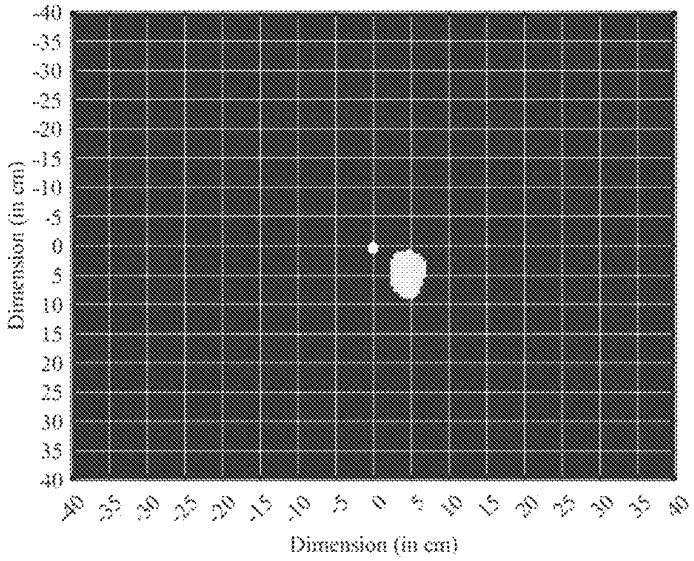

FIG. 11B

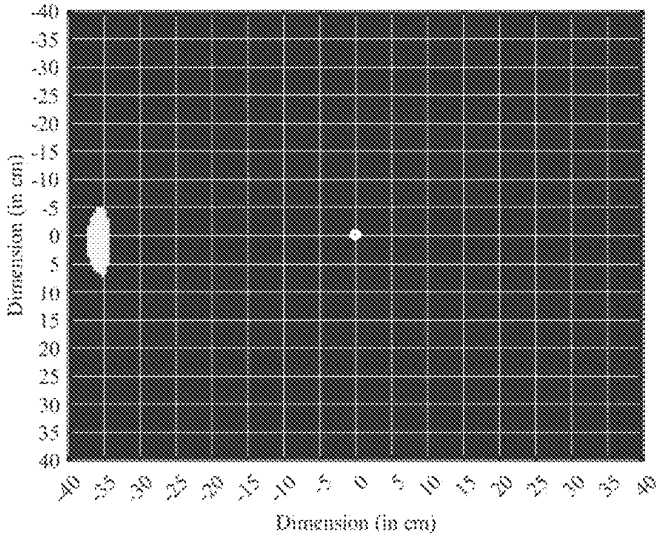

FIG. 11C

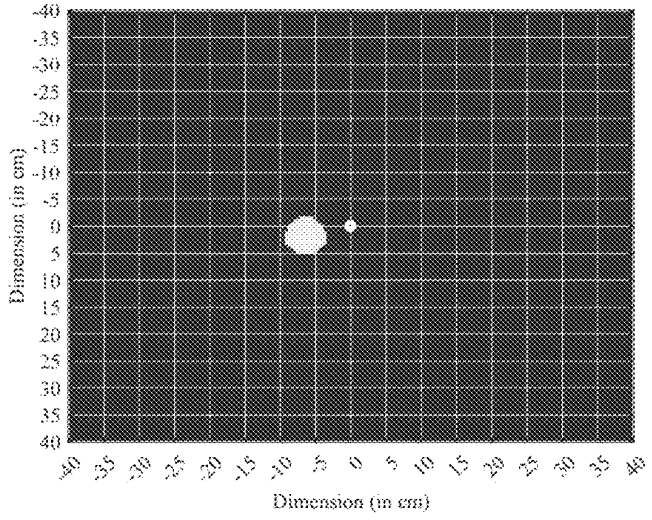

FIG. 11D

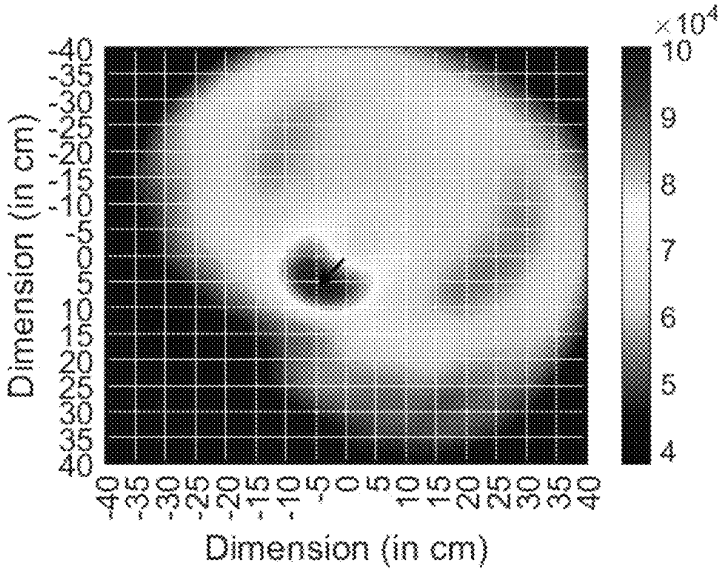

FIG. 12A

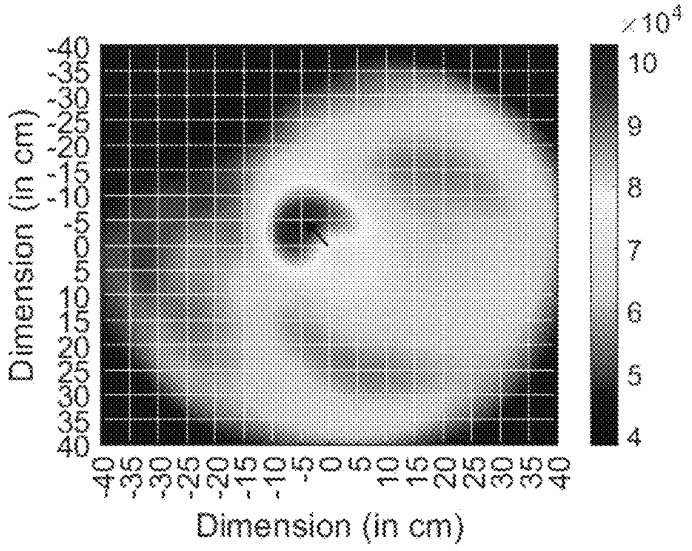

FIG. 12B

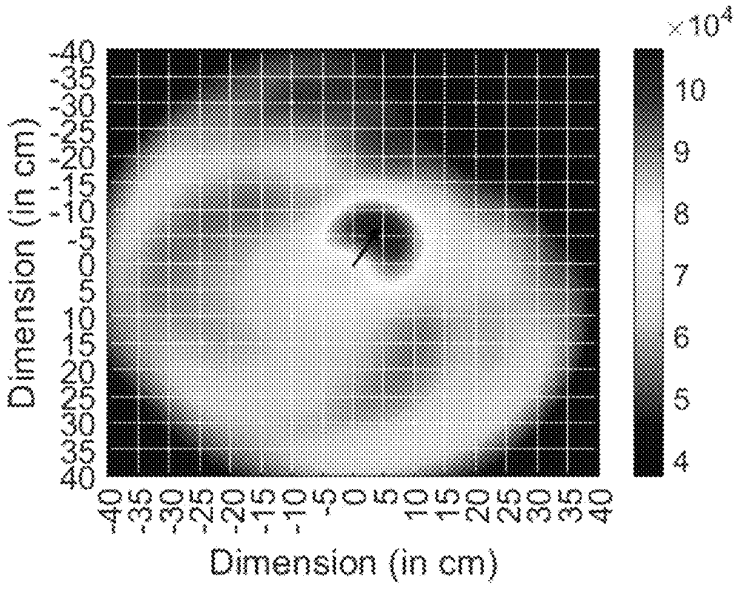

FIG. 12C

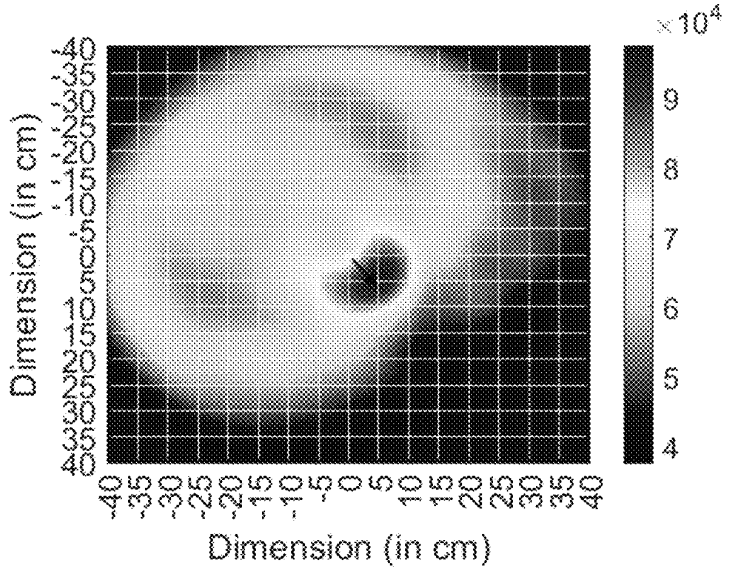

FIG. 12D

SYSTEMS AND METHODS FOR NON-INTRUSIVE MATERIAL QUALITY INSPECTION USING THREE-DIMENSIONAL MONOSTATIC RADAR BASED IMAGING

PRIORITY CLAIM

This U.S. patent application claims priority under 35 U.S.C. § 119 to: India Application No. 202221026491, filed on May 6, 2022. The entire contents of the aforementioned application are incorporated herein by reference.

TECHNICAL FIELD

The disclosure herein generally relates to the field of material quality inspection, and, more particularly, systems and methods for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging.

BACKGROUND

Identification of concealed objects is considered as an imperative challenge in industrial scenarios where an object is ought to be recognized without even opening its enclosure. Further, a prerequisite for occluded object, metallic or non-metallic, inside boxes/casings, is an ability to penetrate through layers of occlusion. A standard alternative is to implement imaging based identification such as radar microwave imaging in occluded spaces owing to its unobtrusive sensing potency. Radar based microwave imaging is broadly categorized as radar based imaging and microwave tomography. Further, millimeter wave (MMW) radar based occluded object detection is also used. For detecting presence of a given object in a sealed package, a conventional concept of using a large array of antennas may be employed. However, high complexity and use of costly switches are a problem with this conventional concept rendering it practically undesirable.

SUMMARY

Embodiments of the present disclosure present technological improvements as solutions to one or more of the above-mentioned technical problems recognized by the inventors in conventional systems. For example, In an aspect, there is provided a system comprising: a mechanical rotating platform; an object under inspection positioned on the mechanical rotating platform; a single static radar positioned at a positioned at a predefined inclination from the object under inspection and the mechanical rotating platform; and a controller unit in communication with the single static radar, wherein the controller unit comprises: one or more data storage devices configured to store instructions; one or more communication interfaces; and one or more hardware processors operatively coupled to the one or more data storage devices via the one or more communication interfaces, wherein the one or more hardware processors are configured by the instructions to: (i) acquire, a first set of radar return data from a first reflected signal and a second set of radar return data from a second reflected signal, the first reflected signal being a signal reflected off a first sample setup and the second reflected signal being a signal reflected off a second sample setup in response to a transmitted signal from the single static radar positioned at a predefined inclination from the first sample setup and the second sample setup, wherein the first sample set up comprises the mechanical rotating platform and the second sample set up comprises the object under inspection positioned on the mechanical rotating platform with an offset to center thereof and undergoing a circular translation motion during each rotation of the mechanical rotating platform, and wherein a sample material is placed inside the object under inspection and wherein the radar return data is in form a range time matrix; (ii) perform, a non-coherent subtraction between the first set of radar return data and the second set of radar return data to obtain a resultant radar return data, wherein resultant radar return data is indicative of a background subtracted range time matrix; (iii) perform, a plurality of preprocessing steps on the resultant radar return data to obtain a processed range time matrix; (iv) apply, a range-doppler processing technique on the processed range time matrix to obtain a range-gated matrix indicative of a range time matrix constrained to an observation window; (v) create a transverse plane image of the object under inspection at a predefined height of the single static radar by applying a modified Delay-and-Sum algorithm on the range-gated range-time matrix, wherein the modified Delay-and-Sum algorithm determines a plurality of virtual antenna positions of the single static radar around the object under inspection and a distance of each pixel of the transverse plane image from each of the plurality of virtual antenna positions of the single static radar; (vi) iteratively perform steps (i) through (v) to obtain a plurality of transverse plane images of the object under inspection at a plurality of virtual heights of the single static radar, wherein the plurality of virtual heights of the single static radar is indicative of a plurality of transverse cross sections of object under inspection at a plurality of heights; and (vii) obtain, a three-dimensional reconstructed image of the object under inspection by combining the plurality of transverse plane images.

In another aspect, there is provided a processor implemented method comprising: acquiring, via one or more hardware processors, a first set of radar return data from a first reflected signal and a second set of radar return data from a second reflected signal, the first reflected signal being a signal reflected off a first sample setup and the second reflected signal being a signal reflected off a second sample setup in response to a transmitted signal from a single static radar positioned at a predefined inclination from the first sample setup and the second sample setup, wherein the first sample set up comprises a mechanical rotating platform and the second sample set up comprises an object under inspection positioned on the mechanical rotating platform with an offset to center thereof and undergoing a circular translation motion during each rotation of the mechanical rotating platform, and wherein a sample material is placed inside the object under inspection and wherein the radar return data is in form a range time matrix; performing, via the one or more hardware processors, a non-coherent subtraction between the first set of radar return data and the second set of radar return data to obtain a resultant radar return data, wherein resultant radar return data is indicative of a background subtracted range time matrix; performing, via the one or more hardware processors, a plurality of preprocessing steps on the resultant radar return data to obtain a processed range time matrix; applying, via the one or more hardware processors, a range-doppler processing technique on the processed range time matrix to obtain a range-gated matrix indicative of a range time matrix constrained to an observation window; creating, via the one or more hardware processors, a transverse plane image of the object under inspection at a predefined height of the single static radar by applying a modified Delay-and-Sum algorithm on the range-

gated range-time matrix, wherein the modified Delay-and-Sum algorithm determines a plurality of virtual antenna positions of the single static radar around the object under inspection and a distance of each pixel of the transverse plane image from each of the plurality of virtual antenna positions of the single static radar; iteratively performing, via the one or more hardware processors, steps of acquiring the first set of radar return data and the second set of radar return data to creating the transverse plane image of the object under inspection to obtain a plurality of transverse plane images of the object under inspection at a plurality of virtual heights of the single static radar, wherein the plurality of virtual heights of the single static radar is indicative of a plurality of transverse cross sections of object under inspection at a plurality of heights; and obtaining, via the one or more hardware processors, a three-dimensional reconstructed image of the object under inspection by combining the plurality of transverse plane images.

In yet another aspect, there are provided one or more non-transitory machine-readable information storage mediums comprising one or more instructions, which when executed by one or more hardware processors cause a processor implemented method for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging. The method includes acquiring, a first set of radar return data from a first reflected signal and a second set of radar return data from a second reflected signal, the first reflected signal being a signal reflected off a first sample setup and the second reflected signal being a signal reflected off a second sample setup in response to a transmitted signal from a single static radar positioned at a predefined inclination from the first sample setup and the second sample setup, wherein the first sample set up comprises a mechanical rotating platform and the second sample set up comprises an object under inspection positioned on the mechanical rotating platform with an offset to center thereof and undergoing a circular translation motion during each rotation of the mechanical rotating platform, and wherein a sample material is placed inside the object under inspection and wherein the radar return data is in form a range time matrix; performing, a non-coherent subtraction between the first set of radar return data and the second set of radar return data to obtain a resultant radar return data, wherein resultant radar return data is indicative of a background subtracted range time matrix; performing, a plurality of preprocessing steps on the resultant radar return data to obtain a processed range time matrix; applying, a range-doppler processing technique on the processed range time matrix to obtain a range-gated matrix indicative of a range time matrix constrained to an observation window; creating, a transverse plane image of the object under inspection at a predefined height of the single static radar by applying a modified Delay-and-Sum algorithm on the range-gated range-time matrix, wherein the modified Delay-and-Sum algorithm determines a plurality of virtual antenna positions of the single static radar around the object under inspection and a distance of each pixel of the transverse plane image from each of the plurality of virtual antenna positions of the single static radar; iteratively performing, steps of acquiring the first set of radar return data and the second set of radar return data to creating the transverse plane image of the object under inspection to obtain a plurality of transverse plane images of the object under inspection at a plurality of virtual heights of the single static radar, wherein the plurality of virtual heights of the single static radar is indicative of a plurality of transverse cross sections of object under inspection at a plurality of heights; and obtaining, a three-dimensional reconstructed image of the object under inspection by combining the plurality of transverse plane images.

In accordance with an embodiment of the present disclosure, the one or more hardware processors are further configured to obtain, a 3D reflection intensity map of the object under inspection by using (i) a boundary detection technique and (ii) a thresholding technique; create, a 3D heatmap view model using the 3D reflection intensity map of the object under inspection for visualization of the sample material placed inside the object under inspection; and identify, at least one of (i) a high intensity location and (ii) a location with change detection in the 3D heatmap view model to identify one or more anomalies in the sample material placed inside the object under inspection.

In accordance with an embodiment of the present disclosure, the one or more hardware processors are further configured to use the resultant set of radar return data is used to determine an initial three-dimensional reconstructed image of the object under inspection.

In accordance with an embodiment of the present disclosure, the plurality of preprocessing steps includes performing motion filtering, mean subtraction, and envelope detection on the resultant radar return data.

In accordance with an embodiment of the present disclosure, the plurality of virtual antenna positions of the single static radar is indicative of virtual motion of the single static radar around the object under investigation in a virtual circular trajectory.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles.

FIG. **1** illustrates an exemplary block diagram of a system for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging, according to some embodiments of the present disclosure.

FIG. **2** is an exemplary flow diagram illustrating a method for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging, according to some embodiments of the present disclosure.

FIG. **3** provides a pictorial representation of the radar return data in the form of the range time matrix according to some embodiments of the present disclosure.

FIGS. **4**A and **4**B show graphical representation of experimental results of the range doppler processing technique when the OUI is radially displaced from center of the mechanical rotating platform by 4 cm and 7.8 cm, respectively, according to some embodiments of the present disclosure.

FIGS. **5**A and **5**B show a graphical representation of doppler frequency components corresponding to two radial displacements in a relevant frequency range for a given R_0 according to some embodiments of the present disclosure.

FIGS. **6**A and **6**B provides a pictorial representation illustrating two reference frames according to some embodiments of the present disclosure.

FIG. **7** illustrates an example for determining a modified value of the round-trip distance of each pixel of the transverse plane image of the OUI, according to some embodiments of the present disclosure.

FIG. **8** provides a plot of the 3D reflection intensity map of the object under inspection, according to some embodiments of the present disclosure.

FIG. **9** provides a plot of the 3D heatmap view model of the object under inspection, according to some embodiments of the present disclosure.

FIGS. **10**A, **10**B, **10**C, and **10**D illustrate simulation results of m-DAS algorithm with and without range gating when OUI is radially displaced from the center of the mechanical rotating platform, according to some embodiments of the present disclosure.

FIGS. **11**A, **11**B, **11**C, and **11**D illustrate simulation results of m-DAS algorithm with and without respective thresholded images when OUI is radially displaced from the center of the mechanical rotating platform, according to some embodiments of the present disclosure.

FIGS. **12**A, **12**B, **12**C, and **12**D show simulation results for the case where the starting angular locations of the object under inspection are kept at 0°, 90°, 180° and 270°, respectively, according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

Exemplary embodiments are described with reference to the accompanying drawings. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. Wherever convenient, the same reference numbers are used throughout the drawings to refer to the same or like parts. While examples and features of disclosed principles are described herein, modifications, adaptations, and other implementations are possible without departing from the scope of the disclosed embodiments.

Identification of concealed objects and inspection of material quality inside the concealed objects for identification of intrinsic defects is considered as an imperative challenge in industrial scenarios where an object is ought to be recognized without even opening its enclosure. Material quality inspection requires identification of intrinsic defects which are not observable from outside an object/structure's boundary. The intrinsic defects can be lumps in semi-liquid or voids in solid structures. The material quality inspection method should identify the presence and nature of the intrinsic defect. A prerequisite for occluded object detection including metallic or non-metallic and inside boxes/casings, is an ability to penetrate through layers of occlusion. In a classical consideration for detecting presence of a given object in a sealed package and material quality inspection, radar based technique utilize a large array of antennas and more than one radars. Radar based techniques mainly apply synthetic aperture radar (SAR) or inverse synthetic aperture radar (ISAR) for image formation. It is envisaged that in an ideal industrial deployment scenario, a target object will be in motion with respect to a static radar. This is akin to the Inverse Synthetic Aperture Radar (ISAR) imaging. The large array of antennas is controlled by highly complex and costly switches, rendering it practically undesirable. Thus, complexity and cost of a quality inspection system is a very important consideration.

The technical problem of focusing on industrial use case of occluded object detection, material quality inspection to identify intrinsic defects and simultaneously considering practical problems in realizing microwave imaging, is addressed in the present disclosure. The present disclosure provides an image guided object detection solution using a monostatic radar and moving object. Even though, angular (cross-range) resolution of the monostatic radar is lower compared to the MMW radars owing to their longer wavelengths, but penetrability and ability to confer geometric information about the object is better in case of the monostatic radar. The present disclosure provides a system and method for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging. In other words, a motion-induced radar imaging method and system is incorporated in the present disclosure where an object under inspection (OUI) undergoes a circular translation motion on a rotating platform. Traditional, a delay and sum (DAS) algorithm is used for object detection and material quality inspection which assumes an array of antennas necessary to be formed as digital beamforming However, in the present disclosure, a single antenna (monostatic mode) is utilized to create virtual radar aperture from the motion of the OUI. Therefore, to generate an accurate image, the DAS algorithm is modified to include an array of virtual antenna positions, generated by exploiting the motion of the OUI. This modified DAS algorithm is built to estimate shape of the object and its radial and angular displacement with respect to center of the rotating platform and monostatic radar position, respectively. The radial displacement as well as the angular locations of the OUI are identified from three-dimensional reconstructed images.

In the context of the subject disclosure, definitions of certain expressions and their usage are as explained herein below.

- Object under inspection refers to an object containing a sample material that is kept on the mechanical rotating platform and then investigated using the radar.
- Transverse plane refers to a plane orthogonal to direction of propagation of a radar transmitted pulse on which an image is generated inside a predefined area. In the context of present disclosure, the transverse plane is a plane that is parallel to ground.
- Transverse plane image refers to an image generated on the transverse plane, that shows horizontal cross-section of the object under inspection and its surroundings inside a predefined area and at a given height.
- The expressions 'Transverse plane image' and 'image' may be interchangeably used.
- The expressions 'single static radar' and 'radar' may be interchangeably used.
- The expressions x-axis, y-axis and z-axis may be interchangeably represented as X-axis, Y-axis and Z-axis respectively.
- φ and phi may be interchangeably used.
- θ and theta may be interchangeably used.

Referring now to the drawings, and more particularly to FIG. **1** through FIG. **12**D, where similar reference characters denote corresponding features consistently throughout the figures, there are shown preferred embodiments and these embodiments are described in the context of the following exemplary system and/or method.

FIG. **1** illustrates an exemplary block diagram of a system **100** for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging, according to some embodiments of the present disclosure. In an embodiment, the system **100** comprises a mechanical rotating platform **102**, an object under inspection **104** positioned on the mechanical rotating platform **102**, and a single static radar **106** positioned at a predefined inclination from the object under inspection **104** and the mechanical rotating platform **102**. Top portion of the mechanical rotating platform has high reflectivity. The single static radar (hereafter referred as radar throughout the description) could be but not

limited an ultra-wideband frequency (UWB) radar or an impulse radar. In an embodiment, the radar could be mounted with one of (i) a single transmitter and single receiver and (ii) a single transmitter with an array of receivers. In the present disclosure, for experimentation, a PulsON™ 440 (P440) radar module is used which is an UWB radio transceiver operating between 3.1 GHz (λ=9.67 cm) and 4.8 GHz (λ=6.25 cm) in monostatic mode, with center frequency at 4.3 GHz (λ=6.97 cm). The radar module utilizes BroadSpec™ antennas having a beam pattern which is omnidirectional in azimuth. Range resolution for the radar is 9.1 mm and transmit gain is set to −31.6 dBm. The radar is positioned at a direct line-of-sight distance (R_0) of 24 cm between phase center of the BroadSpec™ antennas and the center of the mechanical rotating platform **102**, with an inclination angle ϕ=45°. In other words, as shown in FIG. **1**, the radar looks towards the mechanical rotating platform **102** from a fixed height h. Horizontal distance of the radar from the mechanical rotating platform **102** is given by $R=R_0\cdot\cos(\phi)$ and the height of the radar is given by $h=R_0\cdot\sin(\phi)$. Further, angular direction of rotation of the mechanical rotating platform is denoted by θ. These parameters are used to reconstruct an image of the object under inspection which is a horizontal cross-section of an observation window. The mechanical rotating platform rotates at a speed of 7.5 rpm and radius of the mechanical rotating platform is 10 cm. The OUI is placed on the mechanical rotating platform with an offset (D) to the center and thus, it undergoes a circular translation motion on the mechanical rotating platform, unlike a typical ISAR scenario where an object rotates on its own axis. Here, the OUI consists of 73 solid, metallic ball bearings of 1 cm diameter densely packed in a cylindrical plastic container of diameter 3.5 cm and height 11.3 cm. In an embodiment, the radar module can integrate multiple scans coherently to improve Signal-to-Noise Ratio (SNR), which increases by 3 dB every time the integration is doubled. A Pulse Integration Index (PII), which indicates number of times the integration is doubled, is set to a maximum allowable value of 15 which gives us a SNR improvement of 45 dB. Further, data collection is restricted to a smallest permissible observation range of 0.88 m. For the above PII and observation range, minimum lossless scan interval is 29 milliseconds (i.e., 34.4 Hz sampling rate). As the mechanical rotating platform **102** has a rotation per minute (rpm) of 7.5, it completes 1 rotation in 8 seconds. Thus, number of scans required to cover 1 full rotation is provided by 8/0.029 which is equal to 276. Correspondingly, angular sampling is provided as 360°/276 which is equal to 1.3°.

The system **100** further comprises a controller unit **108** that is in communication with the single static radar **106**. In an embodiment, the controller unit **108** comprises one or more data storage devices or memory **108**A configured to store instructions; one or more communication interfaces **108**B; and one or more hardware processors **108**C operatively coupled to the one or more data storage devices **108**A via the one or more communication interfaces **108**B.

The one or more hardware processors **108**C can be implemented as one or more microprocessors, microcomputers, microcontrollers, digital signal processors, central processing units, state machines, graphics controllers, logic circuitries, and/or any devices that manipulate signals based on operational instructions. Among other capabilities, the processor(s) are configured to fetch and execute computer-readable instructions stored in the memory. In the context of the present disclosure, the expressions 'processors' and 'hardware processors' may be used interchangeably. In an embodiment, the one or more hardware processors **108**C can be implemented in a variety of computing systems, such as laptop computers, notebooks, hand-held devices, workstations, mainframe computers, servers, a network cloud and the like.

In an embodiment, the communication interface(s) or input/output (I/O) interface(s) **108**B may include a variety of software and hardware interfaces, for example, a web interface, a graphical user interface, and the like and can facilitate multiple communications within a wide variety of networks N/W and protocol types, including wired networks, for example, LAN, cable, etc., and wireless networks, such as WLAN, cellular, or satellite. In an embodiment, the I/O interface(s) can include one or more ports for connecting a number of devices to one another or to another server.

The one or more data storage devices or memory **108**A may include any computer-readable medium known in the art including, for example, volatile memory, such as static random access memory (SRAM) and dynamic random access memory (DRAM), and/or non-volatile memory, such as read only memory (ROM), erasable programmable ROM, flash memories, hard disks, optical disks, and magnetic tapes.

FIG. **2** is an exemplary flow diagram illustrating a method **200** for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging, according to some embodiments of the present disclosure. The steps of the method **200** will now be explained in detail with reference to the components of the system **100** of FIG. **1**. Although process steps, method steps, techniques or the like may be described in a sequential order, such processes, methods and techniques may be configured to work in alternate orders. In other words, any sequence or order of steps that may be described does not necessarily indicate a requirement that the steps be performed in that order. The steps of processes described herein may be performed in any order practical. Further, some steps may be performed simultaneously.

In accordance with an embodiment of the present disclosure, at step **202** of FIG. **2**, the one or more hardware processors **108**C are configured to acquire, a first set of radar return data from a first reflected signal and a second set of radar return data from a second reflected signal. The first reflected signal is a signal reflected off a first sample setup and the second reflected signal is a signal reflected off a second sample setup in response to a transmitted signal from the single static radar. The single static radar is positioned at a predefined inclination from the first sample setup and the second sample setup. In an embodiment, the first sample set up comprises the mechanical rotating platform and the second sample set up comprises the object under inspection positioned on the mechanical rotating platform with an offset to center thereof and undergoing a circular translation motion during each rotation of the mechanical rotating platform. In accordance with the present disclosure, a sample material is placed inside the object under inspection. In an embodiment, the sample material could be a solid material, a semisolid material and a liquid material. In an embodiment, the acquired radar return data is in form a range time matrix. The range time matrix of dimensions m×n, represents m scans of length n. FIG. **3** provides a pictorial representation of the radar return data in the form of the range time matrix according to some embodiments of the present disclosure. As can be seen in FIG. **3**, every single row vector of the range time matrix forms a fast time axis, while column vectors form a slow-time axis. It is depicted

from FIG. **3** that a fast time sampling occurs at 61 picoseconds (i.e., 16.39 GHz sampling rate denoted by F_s).

In accordance with an embodiment of the present disclosure, at step **204** of FIG. **2**, the one or more hardware processors **108**C are configured to perform a non-coherent subtraction between the first set of radar return data and the second set of radar return data to obtain a resultant radar return data. In an embodiment, the non-coherent subtraction refers to subtract square of amplitude of first set of radar return data (indicative of background data) from the square of amplitude of the second set of radar return data (indicative of target object data) and then taking a square root. In an embodiment, prior to performing non-coherent subtraction, the first set of radar return data and the second set of radar return data are filtered using a 3rd order Infinite Impulse Response (IIR) bandpass filter covering a frequency range of 3.1-4.8 GHz. In an embodiment, the resultant radar return data is indicative of a background subtracted range time matrix which is used to determine an initial three-dimensional reconstructed image of the object under inspection.

Further, at step **206** of FIG. **2**, the one or more hardware processors **108**C are configured to perform a plurality of preprocessing steps on the resultant radar return data to obtain a processed range time matrix. In an embodiment, the plurality of preprocessing steps includes performing motion filtering, mean subtraction, and envelope detection on the resultant radar return data. The resultant radar return data is first motion-filtered using a 4-Tap difference filter to obtain a motion filtered data M, provided by equation (1) below:

$$y(n)=x(n)-0.6\times x(n-1)-0.3\times x(n-2)-0.1\times x(n-3) \quad (1)$$

Equation (1) governs functioning of a motion filter. Each row of resultant radar return data matrix is given by x which are provided as input to the motion filter. Each row of the motion filtered data matrix M is indicated by y, which indicates output of the motion filter equation. So, n^{th} row of M gets its values form the n^{th}, $n-1^{th}$, $n-2^{th}$ and $n-3^{th}$ row of the resultant radar return data matrix where each of the input rows are multiplied by their corresponding coefficients as given in the equation (1). The motion-filtered data M is first averaged for each range bin to obtain an array M_{avg}, of size 1×n. Then, the average signal is subtracted from each scan of M to obtain a signal matrix P. Lastly a low-pass filter (6^{th} order IIR) is applied on P to obtain its envelop. Final dataset obtained after low pass filtering is the processed range time matrix denoted as M_1 which is a m×n matrix where m denotes total number of scans and n denotes total number of range bins from where the reflected signals are captured. The low pass filters used in the present disclosure are known in the art standard filters where filter coefficients are configured for PulsON 440 (P440) UWB radar module

In accordance with an embodiment of the present disclosure, at step **208** of FIG. **2**, the one or more hardware processors **108**C are configured to apply a range-doppler processing technique on the processed range time matrix to obtain a range-gated matrix indicative of a range time matrix constrained to an observation window.

In an embodiment, the step **208** is better understood by way of the following exemplary explanation.

In an embodiment, a range-doppler data is determined from the processed range time matrix M_1 by computing N-point FFT of the slow-time scans for each range bin where N is nearest power of 2 greater than m, and then plotting a resulting range-frequency 2D matrix. This is used as a data quality check. For a given R_0, the observation window of interest becomes fixed since diameter of the mechanical rotating platform is known. As R_0 is reference distance from the center of the mechanical rotating platform **102**, the observation window size (in range) becomes symmetric with respect to R_0. Suppose the observation window is of size n_1. Then an operating data matrix of size m×n known as the range-gated matrix and denoted by M_2 is obtained where any cell outside the observation window is set to 0. This range-gated matrix is used to generate intensity values to form an image. In an embodiment, two test scenarios are considered wherein in the first scenario considers center of OUI placed at 4 cm and 7.8 cm radial distance, respectively, from the center of the mechanical rotating platform, and in the second scenario the starting angular locations of OUI on the mechanical rotating platform are considered to be fixed at angles of 0°, 90°, 180° and 270° with respect to the radar line-of-sight. Here, position closest to the radar location is marked as 0°. In an embodiment, for a given R_0 and ϕ, the observation window gets fixed. For instance, when R_0 is 24 cm and ϕ is 45°, the maximum range requirement gets limited to 32 cm which is the furthest edge of the mechanical rotating platform. Therefore, an accurate image is formed if the observation window is considered only.

FIGS. **4**A and **4**B show graphical representation of experimental results of the range doppler processing technique when the OUI is radially displaced from center of the mechanical rotating platform **102** by 4 cm and 7.8 cm, respectively according to some embodiments of the present disclosure. Here, extent of observation range around R_0 is determined by observing dominant Doppler frequency components. FIGS. **4**A and **4**B display a symmetry around R_0. In an embodiment, a repeating doppler pattern at higher ranges is observed due to a multipath effect. The multipath effect is observed where secondary paths lead to similar frequency signatures getting repeated at higher range bins. In an embodiment, multipath segregation is possible because of high range resolution of an UWB impulse radar corresponding to 9.1 mm. Dimensions of the OUI is comparable to wavelength and it shows a specific doppler signature while in motion. FIGS. **5**A and **5**B show a graphical representation of doppler frequency components corresponding to two radial displacements in a relevant frequency range for the given R_0 according to some embodiments of the present disclosure. Radial displacement is 4 cm in FIG. **5**A and 7.8 cm in FIG. **5**B.

In accordance with an embodiment of the present disclosure, at step **210** of FIG. **2**, the one or more hardware processors **108**C are configured to create a transverse plane image of the object under inspection at a predefined height of the single static radar by applying a modified Delay-and-Sum (m-DAS) algorithm on the range-gated range-time matrix. Traditionally, DAS algorithm is employed for cases where the object is kept stationary and the radar is placed on a moving platform. In the present disclosure, the object is kept on a rotating platform and radar is kept stationary. Thus, the modified Delay-and-Sum algorithm determines a plurality of virtual antenna positions of the single static radar around the object under inspection and a distance of each pixel of the transverse plane image from each of the plurality of virtual antenna positions of the single static radar. The plurality of virtual antenna positions of the single static radar is indicative of virtual motion of the single static radar around the object under investigation in a virtual circular trajectory. In accordance with an embodiment of the present disclosure, at step **210** of FIG. **2**, the one or more hardware processors **108**C are configured to iteratively perform steps of acquiring the first set of radar return data and the second set of radar return data to creating the transverse plane image of the object under inspection to obtain a plurality of

transverse plane images of the object under inspection at a plurality of virtual heights of the single static radar. In an embodiment, the plurality of virtual heights of the single static radar is indicative of a plurality of transverse cross sections of object under inspection at a plurality of heights. Further, at step **214** of FIG. **2**, the one or more hardware processors **108**C are configured to obtain a three-dimensional reconstructed image of the object under inspection by combining the plurality of transverse plane images.

The steps **210** through **214** are better understood by way of following exemplary explanation.

In an embodiment, two reference frames are considered. FIGS. **6**A and **6**B provides a pictorial representation illustrating the two reference frames according to some embodiments of the present disclosure.

Case 1: Radar frame of reference (radar as origin).

Case 2: Rotating platform frame of reference (Centre of rotating platform as origin)

Origin translation from case 1 to case 2 effectively means that the radar is rotating around the OUI in the virtual circular trajectory. Hence, the plurality of virtual antenna positions is created by rotating the mechanical rotating platform with the OUI. This is valid under that assumption that, for small rotational angles of the OUI, the reflected signals from the same reflector for different echoes are centered at the same range bin. Conventional DAS techniques involve time-shifting and summing up the reflected signals from different antenna angles to construct a transverse plane view of the object. After shifting coordinate system to target frame of reference (body fixed frame), the modified delay and sum algorithm is applied for image creation in the transverse plane of the target. The transverse plane is divided into a grid of needed resolution in a cross-range and range directions, with each grid point being called a pixel. Reflections from boundaries are added coherently at the pixels for cross range and range directions. By repetitive summation, noise clutter from the environment is removed and actual reflections get robustly summed up.

For applying the m-DAS algorithm, an arbitrary area of 80 cm×80 cm is considered. The area is divided into a grid of 201×201 pixels in the transverse plane. Further, different cross-sectional views in the transverse plane of the OUI are considered that arises from considering the height of the OUI. As shown in FIG. **1**, the virtual height of the radar is given by z, where 0<z<h. From the target frame of reference, the transmitter-receiver (T_x-R_x) antenna pair of the radar seems virtually rotating around the object under inspection with each angular position denoted as θ, where θ varies from 0° to 360°, with angular resolution 1.3°. Each scan in M_2 corresponds to a respective virtual antenna position, for a total of m values of θ, forming an Θ array of length m. Each projection of the virtual antenna position on the transverse plane is denoted by (X, Y). The k^{th} position of virtual antenna for different values of k (k=1, 2, . . . m) is described by equation 2 below:

$$\begin{cases} X(k) = R\cos(\Theta(k)) \\ Y(k) = R\sin(\Theta(k)) \end{cases}, \text{ for } k = 1, 2, \ldots m. \tag{2}$$

For each pixel point denoted by (x_i, y_j, z), where i, j=1, 2, . . . 201, and 0<z<h, total intensity is computed using m-DAS algorithm to obtain a final intensity matrix denoted by I (x_i, y_j, z), at coordinates x_i, y_j and z. Round-trip distance of each pixel (x_i, y_j, z) from the k^{th} virtual antenna position is stored in an array d(k), where d(k) is provided in equation (3) below:

$$d(k)=2\sqrt{(X(k)-x_i)^2+(Y(k)-y_j)^2+z^2} \tag{3}$$

In the m-DAS algorithm described in the present disclosure, d(k) is modified considering different permittivities of medium of the sample material placed inside the OUI and outside the OUI. FIG. **7** illustrates an example for determining a modified value of the round-trip distance of each pixel of the transverse plane image of the OUI, according to some embodiments of the present disclosure. As shown in FIG. **7**, coordinate of intersection point of line denoted by joining the pixel (x_i, y_j, z) and radar position (R, θ, h) is computed. The coordinate of intersection point is denoted by (x_1, y_1, z_1). Further, due to different permittivities of the mediums inside and outside the OUI, the round trip distance is determined as sum of distance of each pixel from the intersection point and distance of radar position (R, θ, h) from the intersection point. As shown in FIG. **7**, d_1 denotes distance of (x_i, y_j, z) from (x_1, y_1, z_1) and d_2 denotes distance of (x_1, y_1, z_1) from (R, θ, h) and $d(k)=d_1(k)+d_2(k)$. For each scan (i.e. different virtual antenna position), the split of d(k) is done in accordance with permittivity of the medium which is denoted by eps. The entire process of modifying d(k) can be further better understood by way of following pseudo code provided as example:

```
for (k = 1, k ≤ m, k = k + 1)

  elevationangle = tan^-1( |z − h| / sqrt((x_i − Rcos(θ))^2 + (y_j − Rsin(θ))^2) ) %

  in degrees
    if (elevationangle ≤ 10) {
      if (d1(k)/d(k)) < 0.1) {
        d'(k) = d1(k) + d2(k);}
      else if (d1(k)/d(k)) ≥ 0.1 && (d1(k)/d(k)) < 0.25) {
        d'(k) = 0.5.d1(k).sqrt(eps) + 0.5.d1(k) + d2(k);}
      else (d1(k)/d(k)) ≥ 0.25 && (d1(k)/d(k)) < 0.5) {
        d'(k) = d1(k).sqrt(eps);}
    }
}
```

Here, final distance is provided by d(k).

In an embodiment, since the OUI is rotating, maximum reflection from different range bins for different scans is obtained. So, location of a peak intensity in any scan is an indication of location of the OUI and hence distance from the radar. This forms a key step in imaging the OUI in the transverse plane. Relative distance of (x_i, y_j) from the radar changes from scan to scan. This leads to a change in reflection intensity for the same reflector in successive scans. In an embodiment, the range bin is defined by location of peak intensity for each scan as the "scan priority" (SP), which forms an array of length m, obtained using equation (4) provided below:

$$SP(k)=L(k)-\text{offset} \tag{4}$$

where, L(k) represents location of the peak intensity in k^{th} scan and offset represents first few range bins (in all scans) which is neglected from the m-DAS algorithm processing due to excess noise (here, offset=10). SP is used for synthetic focusing of scans. Each scan is subsequently multiplied by its corresponding SP to get a matrix M_3. This leads to synthetic focusing and adaptive intensity change of the scans where the object under inspection is at higher distances,

since they get multiplied by a higher value of SP. In order to obtain relevant intensity values from the k^{th} scan, index of range bin is computed. This index of range bin denoted by b(k), is computed using equation (5) provided below:

$$b(k) = \frac{d(k) \cdot F_s}{c} \tag{5}$$

where F_s represents fast-time sampling frequency=16.39 GHz and c represents speed of light=3×10^8 m/s. Further, for non-integer b(k), contribution for a pixel (x_i, y_j) from the k^{th} scan is computed by interpolating linearly from the intensities of two nearest range bins. Towards that, w(k) and ind(k) for each scan are computed using equations (6) and (7) provided below:

$$w(k)=(b(k))-\lfloor b(k) \rfloor \tag{6}$$

where $0 \leq w(k) < 1$.

$$ind(k)=\min\{\lfloor b(k) \rfloor, n\} \tag{7}$$

This is done to get the position of the range bin which is nearest to a pixel at distance d. According to exact distance and elevation of the pixel in consideration, w(k) is further modified.

The process of further modifying w(k) can be further better understood by way of following pseudo code provided as example:

START

```
a(k) = 1 for all k;
for (k = 1, k ≤ m, k = k + 1) {
```

$$elevationangle = \tan^{-1}\left(\frac{|z-h|}{\sqrt{(x_i - R\cos(\theta))^2 + (y_j - R\sin(\theta))^2}}\right)\%$$

```
  in degrees
  if (elevationangle ≤ 10) {
    a(k) = 0;
  }
  else {
    a(k) = 1/max(d',TH); % TH = 0.2 to 0.3 m, threshold obtained
  heuristically
    ang = θ(k) − tan⁻¹(y/x);
    if (langl < 45) {
      view = 1;}
    else if (langl > 45) {
      view = 0.5;}
    else (langl > 100) {
      view = 0.1;}
    a(k) = a(k).view;
    }
}
```

The values of w(k) and a(k) are used as final weights in calculating a resultant intensity at the pixel (x_i, y_j, z). Contribution to the resultant intensity of the pixel (x_i, y_j, z) from the k^{th} scan is calculated as provided in equation (8) below:

$$pc(k)=M_3(k,ind(k))\cdot(1-w(k))+M_3(k,\ \min(ind(k)+1,n))\cdot w(k) \tag{8}$$

Then, the total intensity at this particular pixel is provided in equation (9) below:

$$I(x_i,y_j)=\Sigma_{k=1}{}^{m} pc(k)\cdot a(k) \tag{9}$$

The entire algorithm, from Eqns. 2 to 9, is calculated for all the other pixels to obtain a three-dimensional (3D) reconstructed image of the object under inspection.

In another embodiment, as shown in FIG. **1**, downwards vertical distance from the radar **106** is 'z', where value of z lies between minimum 0 at the radar position and maximum 'h' at the surface of the rotating platform. Now, a transverse image is initially created at the height of z=h from the radar, (i.e., the image reconstruction plane 1) located on surface of the mechanical rotating platform **102** which forms a horizontal cross-section of the radar's area of investigation at that height, and this is imaged through the modified delay-and-sum algorithm where the value of z=h is put in the equation 3 (pixel distance calculation) and subsequent steps are performed. Further, the horizontal cross-section at the image reconstruction plane 2, given at any other value of z, (say z=h−a (0<a<h)) as in shown in FIG. **1** is considered, and this transverse plane is subsequently imaged. This height change occurs computationally in the modified delay-and-sum algorithm only, and not by changing the actual height of the radar. Finally, after several iterations, a plurality of transverse plane images is formed, which are subsequently combined to form the 3D reconstructed image.

In an embodiment, the one or more hardware processors **108**C are further configured to a 3D reflection intensity map of the object under inspection by using (i) a boundary detection technique and (ii) a thresholding technique. It must be appreciated that the boundary detection technique and the thresholding technique are known in the art. FIG. **8** provides a plot of the 3D reflection intensity map of the object under inspection, according to some embodiments of the present disclosure. In an embodiment, the 3D reconstructed image contains contributions from all scans and is cluttered with noise components. So, a thresholding technique is applied on the 3D reconstructed image to sharpen image quality, whereby any pixel intensity values that are equal to or below a predefined threshold is set equal to 0. The values above the predefined threshold are left as they are. In an embodiment, the predefined threshold value is configurable and depends on number and position(s) of the reflectors or scatterers. In the context of present disclosure, the value of the predefined threshold is assumed to be 99.5th quantile value of intensity distribution. Upon applying thresholding technique, a final thresholded image I is obtained. In other words, once an initial estimate of reflection intensity is obtained (i.e., an initial 3D view), using the thresholding technique and the boundary detection technique, a shape of the OUI is formed. For example, in the present discourse, a cylindrical shape is formed which indicates a container shape. Further, the 3D reflection intensity map, which consists of a positive real number for each coordinate point is obtained. Furthermore, the one or more hardware processors **108**C are configured to create a 3D heatmap view model using the 3D reflection intensity map of the object under inspection for visualization of the sample material placed inside the object under inspection. FIG. **9** provides a plot of the 3D heatmap view model of the object under inspection, according to some embodiments of the present disclosure. Once the 3D heatmap view model is created, the one or more hardware processors **108**C are configured to identify at least one of (i) a high intensity location and (ii) a location with change detection in the 3D heatmap view model to identify one or more anomalies in the sample material placed inside the object under inspection. In other words, a location where high intensity is observed or a change is detected for the sample material placed inside the object under inspection (compared to a known homogeneous sample), is scanned specifically by adjusting R. Further, a detailed image is formed for the identified location part of the sample material and change is tracked. If such consecutive changes are detected for than

three times, an alert is raised for further investigation in a cloud-based system. All of the processed data is stored in cloud, where scan is tagged to the position of radar with respect to the sample material placed inside object under inspection. Also, since there are many samples on which the tests are performed, average deviation study is conducted to detect anomaly (alternatively referred as intrinsic defects) in the 3D reconstructed images.

Experimental Results

The reflected signals from various positions of the object under test which is a ball bearing cylinder in the present disclosure are depicted on transverse range-cross range plane. FIGS. **10**A through **10**D illustrate simulation results of m-DAS algorithm without and without range gating when OUI is radially displaced from the center of the mechanical rotating platform, according to some embodiments of the present disclosure. FIGS. **10**A and **10**B illustrate simulation results of m-DAS algorithm without and without range gating when OUI is radially displaced from the center of the mechanical rotating platform at a distance of 4 cm. FIGS. **8**C and **8**D illustrate simulation results of m-DAS algorithm without and without range gating when OUI is radially displaced from the center of the mechanical rotating platform at a distance of 7.8 cm.

FIGS. **11**A through **11**D illustrate simulation results of m-DAS algorithm with and without respective thresholded images when OUI is radially displaced from the center of the mechanical rotating platform, according to some embodiments of the present disclosure. From the reconstructed images, it is seen that the reflections from the object under inspection form a high intensity core region with a diffraction halo around it. By applying a threshold, a desired image is obtained as seen in FIGS. **11**C and **11**D for two displacements of 4 cm and 7.8 cm, respectively. In other words, from FIGS. **11**C and **11**D, displacement of the OUI from the center of the mechanical rotating platform is estimated. It is observed from FIGS. **11**C and **11**D, that the reconstructed 3D images form an ellipse (unlike an expected circle of diameter of 3.5 cm). However, from FIGS. **11**A and **11**B, it is observed that process of thresholding could not extract the desired image.

Table 1 below provides a comparison of an actual and an estimated displacement of the object under inspection. The displacements shown in the Table 1 are with respect to the center of the OUI's high-intensity region in horizontal cross-section.

TABLE 1

Case	Actual Displacement (cm)	Estimated Displacement (cm)	Estimated Dimension (cm × cm)
1	4	5.4	3.6 × 5.6
2	7.8	6.6	4.4 × 5.2

An estimated dimension for each case is also presented. However, the dimension estimation is critically dependent on threshold level. Therefore, the method of the present disclosure is used for only an approximate estimation of the shape and size of the object under inspection. While the estimated displacements shown in Table 1 deviate from their actual values, separation of two displacement centers are clearly seen from estimated figures. The displacement and size estimations in this case have been affected by poor horizontal resolution due to omnidirectional nature of the antennas (leading to wide field of view), large wavelengths (6.25 cm to 9.67 cm) and the OUI's radar cross-section (RCS) (in terms of circumference and height) being comparable to wavelength, leading to Mie-scattering region, where the RCS is oscillatory with frequency. In conventional systems where similar radar is used, it is shown that the minimum object size that is identifiable is 12 mm×30 mm×70 mm, though a higher gain directional antipodal Vivaldi antenna is used. Further, conventionally an improved DAS algorithm is used to detect tumor of the RCS given by circumference/λ=2.4. However, the modified DAS of the present disclosure demonstrates the detection of objects with smaller RCS≈1.5 in comparison to the conventional systems.

FIGS. **12**A through **12**D show simulation results for the case where the starting angular locations of the object under inspection are kept at 0°, 90°, 180° and 270°, respectively, according to some embodiments of the present disclosure.

The written description describes the subject matter herein to enable any person skilled in the art to make and use the embodiments. The scope of the subject matter embodiments is defined by the claims and may include other modifications that occur to those skilled in the art. Such other modifications are intended to be within the scope of the claims if they have similar elements that do not differ from the literal language of the claims or if they include equivalent elements with insubstantial differences from the literal language of the claims.

The embodiment of present disclosure provides a systems and methods for non-intrusive material quality inspection using three-dimensional monostatic radar based imaging. The method of the present disclosure utilizes ISAR microwave imaging using a single monostatic UWB impulse radar, where the object under inspection (OUI) (a cylindrical plastic container densely packed with metallic ball bearings in the present disclosure) undergoes the circular motion on the mechanical rotating platform. To image an observation plane, a modified DAS algorithm is used in the resent disclosure that is built upon a concept of virtual antenna positions forming an array surrounding a target OUI. Thus, the present disclosure provides a method for estimating a target object's shape, size and its radial and angular displacement with respect to a fixed reference point. The method of the present disclosure is able to detect an object with smaller RCS in comparison to conventional methods. Moreover, despite near-field effects and phase errors, a method of microwave imaging by virtual radar aperture creation is described in the present disclosure. The method of the present disclosure could be used in chemical, food, paint and many manufacturing units for material inspection, quality check and control.

It is to be understood that the scope of the protection is extended to such a program and in addition to a computer-readable means having a message therein; such computer-readable storage means contain program-code means for implementation of one or more steps of the method, when the program runs on a server or mobile device or any suitable programmable device. The hardware device can be any kind of device which can be programmed including e.g., any kind of computer like a server or a personal computer, or the like, or any combination thereof. The device may also include means which could be e.g., hardware means like e.g., an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a combination of hardware and software means, e.g., an ASIC and an FPGA, or at least one microprocessor and at least one memory with software processing components located therein. Thus, the

means can include both hardware means and software means. The method embodiments described herein could be implemented in hardware and software. The device may also include software means. Alternatively, the embodiments may be implemented on different hardware devices, e.g., using a plurality of CPUs.

The embodiments herein can comprise hardware and software elements. The embodiments that are implemented in software include but are not limited to, firmware, resident software, microcode, etc. The functions performed by various components described herein may be implemented in other components or combinations of other components. For the purposes of this description, a computer-usable or computer readable medium can be any apparatus that can comprise, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device.

The illustrated steps are set out to explain the exemplary embodiments shown, and it should be anticipated that ongoing technological development will change the manner in which particular functions are performed. These examples are presented herein for purposes of illustration, and not limitation. Further, the boundaries of the functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternative boundaries can be defined so long as the specified functions and relationships thereof are appropriately performed. Alternatives (including equivalents, extensions, variations, deviations, etc., of those described herein) will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein. Such alternatives fall within the scope of the disclosed embodiments. Also, the words "comprising," "having," "containing," and "including," and other similar forms are intended to be equivalent in meaning and be open ended in that an item or items following any one of these words is not meant to be an exhaustive listing of such item or items, or meant to be limited to only the listed item or items. It must also be noted that as used herein and in the appended claims, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise.

Furthermore, one or more computer-readable storage media may be utilized in implementing embodiments consistent with the present disclosure. A computer-readable storage medium refers to any type of physical memory on which information or data readable by a processor may be stored. Thus, a computer-readable storage medium may store instructions for execution by one or more processors, including instructions for causing the processor(s) to perform steps or stages consistent with the embodiments described herein. The term "computer-readable medium" should be understood to include tangible items and exclude carrier waves and transient signals, i.e., be non-transitory. Examples include random access memory (RAM), read-only memory (ROM), volatile memory, nonvolatile memory, hard drives, CD ROMs, DVDs, flash drives, disks, and any other known physical storage media.

It is intended that the disclosure and examples be considered as exemplary only, with a true scope of disclosed embodiments being indicated by the following claims.

What is claimed is:

1. A system comprising:

a mechanical rotating platform;

an object under inspection positioned on the mechanical rotating platform;

a single static radar positioned at a positioned at a predefined inclination from the object under inspection and the mechanical rotating platform; and

a controller unit in communication with the single static radar, wherein the controller unit comprises:

one or more data storage devices configured to store instructions;

one or more communication interfaces; and

one or more hardware processors operatively coupled to the one or more data storage devices via the one or more communication interfaces, wherein the one or more hardware processors are configured by the instructions to:

(i) acquire, a first set of radar return data from a first reflected signal and a second set of radar return data from a second reflected signal, the first reflected signal being a signal reflected off a first sample setup and the second reflected signal being a signal reflected off a second sample setup in response to a transmitted signal from the single static radar positioned at a predefined inclination from the first sample setup and the second sample setup, wherein the first sample set up comprises the mechanical rotating platform and the second sample set up comprises the object under inspection positioned on the mechanical rotating platform with an offset to center thereof and undergoing a circular translation motion during each rotation of the mechanical rotating platform, and wherein a sample material is placed inside the object under inspection and wherein the radar return data is in form a range time matrix;

(ii) perform, a non-coherent subtraction between the first set of radar return data and the second set of radar return data to obtain a resultant radar return data, wherein resultant radar return data is indicative of a background subtracted range time matrix;

(iii) perform, a plurality of preprocessing steps on the resultant radar return data to obtain a processed range time matrix;

(iv) apply, a range-doppler processing technique on the processed range time matrix to obtain a range-gated matrix indicative of a range time matrix constrained to an observation window;

(v) create a transverse plane image of the object under inspection at a predefined height of the single static radar by applying a modified Delay-and-Sum algorithm on the range-gated range-time matrix, wherein the modified Delay-and-Sum algorithm determines a plurality of virtual antenna positions of the single static radar around the object under inspection and a distance of each pixel of the transverse plane image from each of the plurality of virtual antenna positions of the single static radar;

(vi) iteratively perform steps (i) through (v) to obtain a plurality of transverse plane images of the object under inspection at a plurality of virtual heights of the single static radar, wherein the plurality of virtual heights of the single static radar is indicative of a plurality of transverse cross sections of object under inspection at a plurality of heights; and

(vii) obtain, a three-dimensional reconstructed image of the object under inspection by combining the plurality of transverse plane images.

2. The system of claim 1, wherein the one or more hardware processors are further configured to

obtain, a 3D reflection intensity map of the object under inspection by using (i) a boundary detection technique and (ii) a thresholding technique;

create, a 3D heatmap view model using the 3D reflection intensity map of the object under inspection for visualization of the sample material placed inside the object under inspection; and

identify, at least one of (i) a high intensity location and (ii) a location with change detection in the 3D heatmap view model to identify one or more anomalies in the sample material placed inside the object under inspection.

3. The system of claim 1, wherein the one or more hardware processors are further configured to use the resultant set of radar return data to determine an initial three-dimensional reconstructed image of the object under inspection.

4. The system of claim 1, wherein the plurality of preprocessing steps comprise performing motion filtering, mean subtraction, and envelope detection on the resultant radar return data.

5. The system of claim 1, wherein the plurality of virtual antenna positions of the single static radar is indicative of virtual motion of the single static radar around the object under investigation in a virtual circular trajectory.

6. A processor implemented method, comprising:

acquiring, via one or more hardware processors, a first set of radar return data from a first reflected signal and a second set of radar return data from a second reflected signal, the first reflected signal being a signal reflected off a first sample setup and the second reflected signal being a signal reflected off a second sample setup in response to a transmitted signal from a single static radar positioned at a predefined inclination from the first sample setup and the second sample setup, wherein the first sample set up comprises a mechanical rotating platform and the second sample set up comprises an object under inspection positioned on the mechanical rotating platform with an offset to center thereof and undergoing a circular translation motion during each rotation of the mechanical rotating platform, and wherein a sample material is placed inside the object under inspection and wherein the radar return data is in form a range time matrix;

performing, via the one or more hardware processors, a non-coherent subtraction between the first set of radar return data and the second set of radar return data to obtain a resultant radar return data, wherein resultant radar return data is indicative of a background subtracted range time matrix;

performing, via the one or more hardware processors, a plurality of preprocessing steps on the resultant radar return data to obtain a processed range time matrix;

applying, via the one or more hardware processors, a range-doppler processing technique on the processed range time matrix to obtain a range-gated matrix indicative of a range time matrix constrained to an observation window;

creating, via the one or more hardware processors, a transverse plane image of the object under inspection at a predefined height of the single static radar by applying a modified Delay-and-Sum algorithm on the range-gated range-time matrix, wherein the modified Delay-and-Sum algorithm determines a plurality of virtual antenna positions of the single static radar around the object under inspection and a distance of each pixel of the transverse plane image from each of the plurality of virtual antenna positions of the single static radar;

iteratively performing, via the one or more hardware processors, steps of acquiring the first set of radar return data and the second set of radar return data to creating the transverse plane image of the object under inspection to obtain a plurality of transverse plane images of the object under inspection at a plurality of virtual heights of the single static radar, wherein the plurality of virtual heights of the single static radar is indicative of a plurality of transverse cross sections of object under inspection at a plurality of heights; and

obtaining, via the one or more hardware processors, a three-dimensional reconstructed image of the object under inspection by combining the plurality of transverse plane images.

7. The method of claim 6, further comprising:

obtaining, a 3D reflection intensity map of the object under inspection by using (i) a boundary detection technique and (ii) a thresholding technique;

creating, a 3D heatmap view model using the 3D reflection intensity map of the object under inspection for visualization of the sample material placed inside the object under inspection; and

identifying, at least one of (i) a high intensity location and (ii) a location with change detection in the 3D heatmap view model to identify one or more anomalies in the sample material placed inside the object under inspection.

8. The method of claim 6, wherein the resultant set of radar return data is used to determine an initial three-dimensional reconstructed image of the object under inspection.

9. The method of claim 6, wherein the plurality of preprocessing steps comprise performing motion filtering, mean subtraction, and envelope detection on the resultant radar return data.

10. The method of claim 6, wherein the plurality of virtual antenna positions of the single static radar is indicative of virtual motion of the single static radar around the object under investigation in a virtual circular trajectory.

11. One or more non-transitory computer readable mediums comprising one or more instructions which when executed by one or more hardware processors cause:

acquiring, a first set of radar return data from a first reflected signal and a second set of radar return data from a second reflected signal, the first reflected signal being a signal reflected off a first sample setup and the second reflected signal being a signal reflected off a second sample setup in response to a transmitted signal from a single static radar positioned at a predefined inclination from the first sample setup and the second sample setup, wherein the first sample set up comprises a mechanical rotating platform and the second sample set up comprises an object under inspection positioned on the mechanical rotating platform with an offset to center thereof and undergoing a circular translation motion during each rotation of the mechanical rotating platform, and wherein a sample material is placed inside the object under inspection and wherein the radar return data is in form a range time matrix;

performing, a non-coherent subtraction between the first set of radar return data and the second set of radar return data to obtain a resultant radar return data, wherein resultant radar return data is indicative of a background subtracted range time matrix;

performing, a plurality of preprocessing steps on the resultant radar return data to obtain a processed range time matrix;

applying, a range-doppler processing technique on the processed range time matrix to obtain a range-gated matrix indicative of a range time matrix constrained to an observation window;

creating, a transverse plane image of the object under inspection at a predefined height of the single static radar by applying a modified Delay-and-Sum algorithm on the range-gated range-time matrix, wherein the modified Delay-and-Sum algorithm determines a plurality of virtual antenna positions of the single static radar around the object under inspection and a distance of each pixel of the transverse plane image from each of the plurality of virtual antenna positions of the single static radar;

iteratively performing, steps of acquiring the first set of radar return data and the second set of radar return data to creating the transverse plane image of the object under inspection to obtain a plurality of transverse plane images of the object under inspection at a plurality of virtual heights of the single static radar, wherein the plurality of virtual heights of the single static radar is indicative of a plurality of transverse cross sections of object under inspection at a plurality of heights; and

obtaining, a three-dimensional reconstructed image of the object under inspection by combining the plurality of transverse plane images.

12. The non-transitory computer readable mediums of claim **11**, further comprising:

obtaining, a 3D reflection intensity map of the object under inspection by using (i) a boundary detection technique and (ii) a thresholding technique;

creating, a 3D heatmap view model using the 3D reflection intensity map of the object under inspection for visualization of the sample material placed inside the object under inspection; and

identifying, at least one of (i) a high intensity location and (ii) a location with change detection in the 3D heatmap view model to identify one or more anomalies in the sample material placed inside the object under inspection.

13. The non-transitory computer readable mediums of claim **11**, wherein the resultant set of radar return data is used to determine an initial three-dimensional reconstructed image of the object under inspection.

14. The non-transitory computer readable mediums of claim **11**, wherein the plurality of preprocessing steps comprise performing motion filtering, mean subtraction, and envelope detection on the resultant radar return data.

15. The non-transitory computer readable mediums of claim **11**, wherein the plurality of virtual antenna positions of the single static radar is indicative of virtual motion of the single static radar around the object under investigation in a virtual circular trajectory.

* * * * *

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(54) **ELECTRONIC DEVICE AND METHOD FOR DETECTING EXTERNAL OBJECT BY USING ANTENNA ARRAY**

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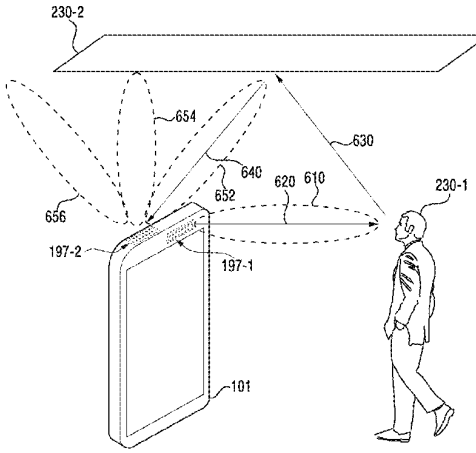
(57) **ABSTRACT**

An electronic device according to various embodiments of the present disclosure may include a plurality of antenna arrays and at least one processor operatively connected to the plurality of antenna arrays. The at least one processor may transmit a first radio signal including a specific polarization, generated through a first antenna array of the plurality of antenna arrays. The at least one processor may receive a second radio signal which is a reflected signal of the first radio signal and includes the specific polarization, generated through a second antenna array different from the first antenna array of the plurality of antenna arrays. The at least one processor may identify external objects around the
(Continued)



electronic device on the basis of the second radio signal. Other various embodiments may be possible.

20 Claims, 21 Drawing Sheets

(51) **Int. Cl.**

G01S 7/41	(2006.01)
G01S 13/86	(2006.01)
H04B 7/0404	(2017.01)
H01Q 3/24	(2006.01)

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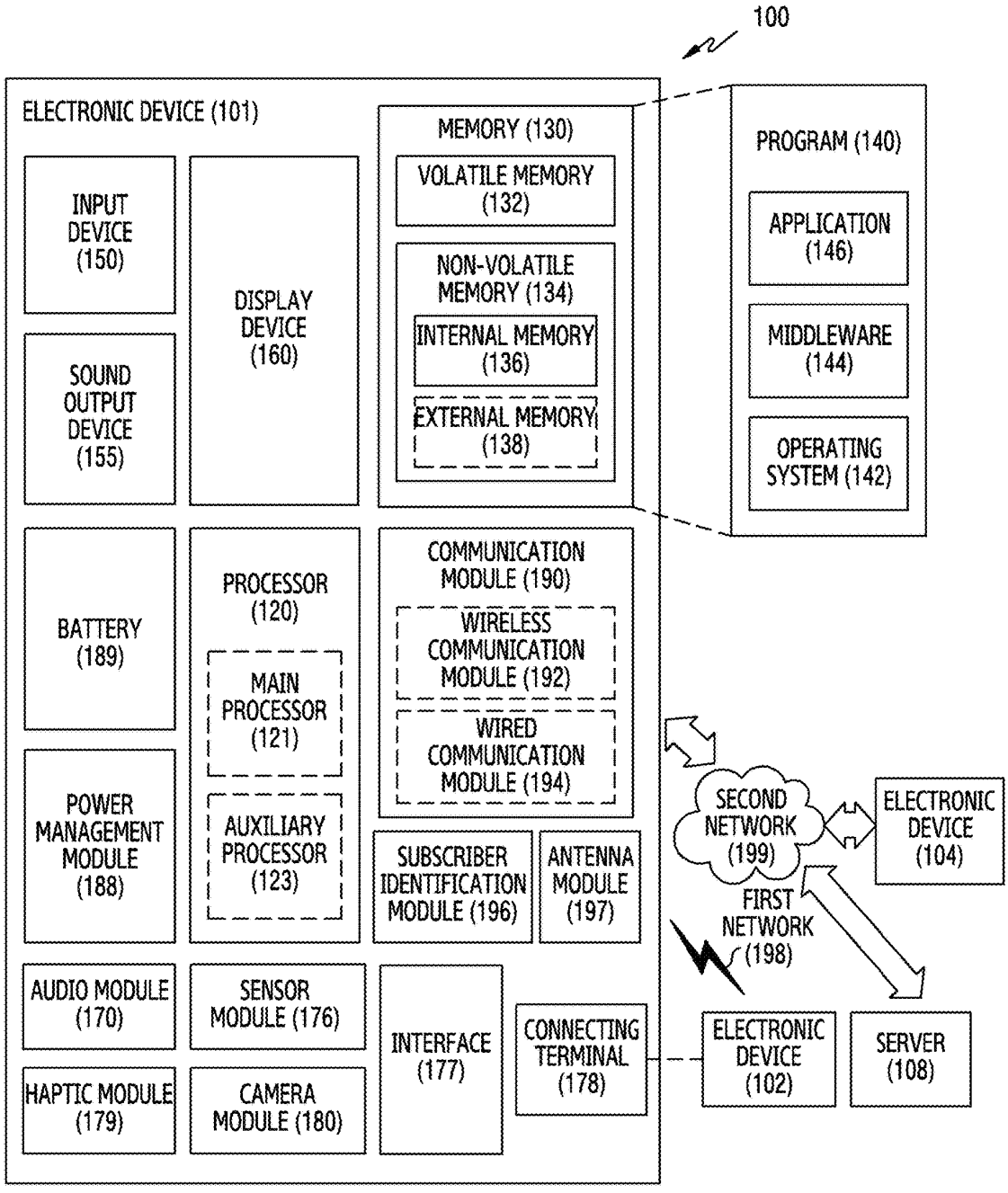
100
ELECTRONIC DEVICE (101)
INPUT DEVICE (150)
SOUND OUTPUT DEVICE (155)
DISPLAY DEVICE (160)
MEMORY (130)
VOLATILE MEMORY (132)
NON-VOLATILE MEMORY (134)
INTERNAL MEMORY (136)
EXTERNAL MEMORY (138)
PROGRAM (140)
APPLICATION (146)
MIDDLEWARE (144)
OPERATING SYSTEM (142)
BATTERY (189)
PROCESSOR (120)
MAIN PROCESSOR (121)
AUXILIARY PROCESSOR (123)
COMMUNICATION MODULE (190)
WIRELESS COMMUNICATION MODULE (192)
WIRED COMMUNICATION MODULE (194)
POWER MANAGEMENT MODULE (188)
SUBSCRIBER IDENTIFICATION MODULE (196)
ANTENNA MODULE (197)
SECOND NETWORK (199)
ELECTRONIC DEVICE (104)
FIRST NETWORK (198)
AUDIO MODULE (170)
SENSOR MODULE (176)
INTERFACE (177)
CONNECTING TERMINAL (178)
HAPTIC MODULE (179)
CAMERA MODULE (180)
ELECTRONIC DEVICE (102)
SERVER (108)

FIG. 1

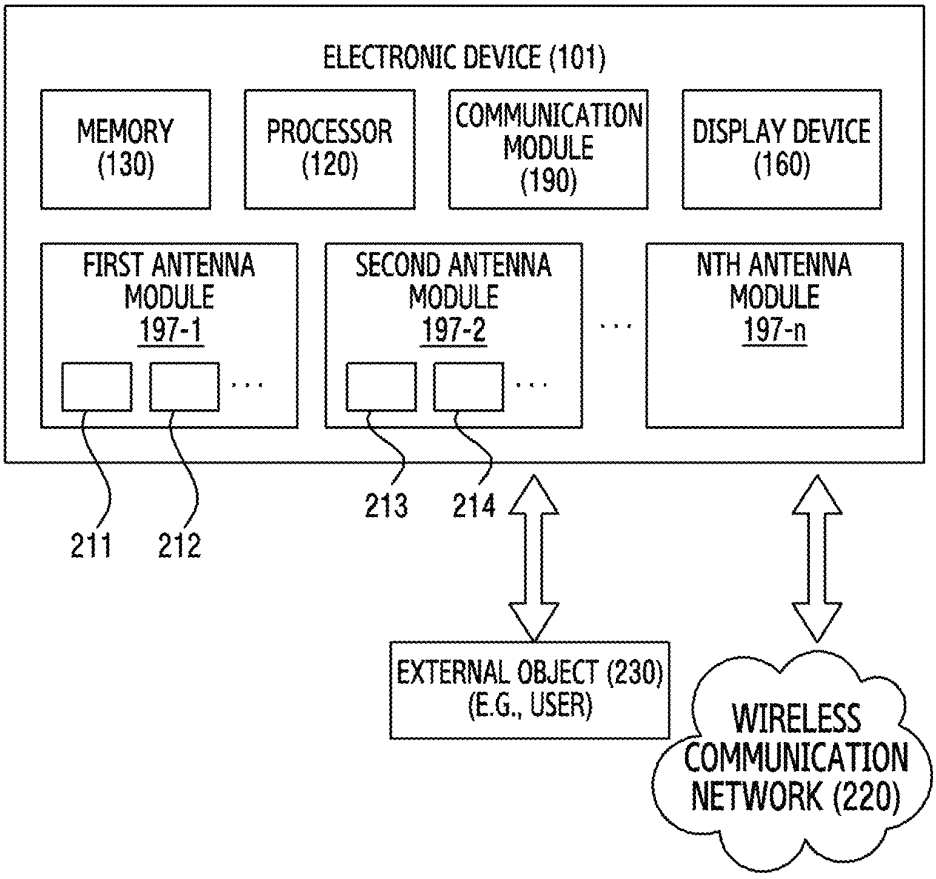
ELECTRONIC DEVICE (101)
MEMORY (130)
PROCESSOR (120)
COMMUNICATION MODULE (190)
DISPLAY DEVICE (160)
FIRST ANTENNA MODULE 197-1
SECOND ANTENNA MODULE 197-2
NTH ANTENNA MODULE 197-n
211
212
213
214
EXTERNAL OBJECT (230) (E.G., USER)
WIRELESS COMMUNICATION NETWORK (220)

FIG.2

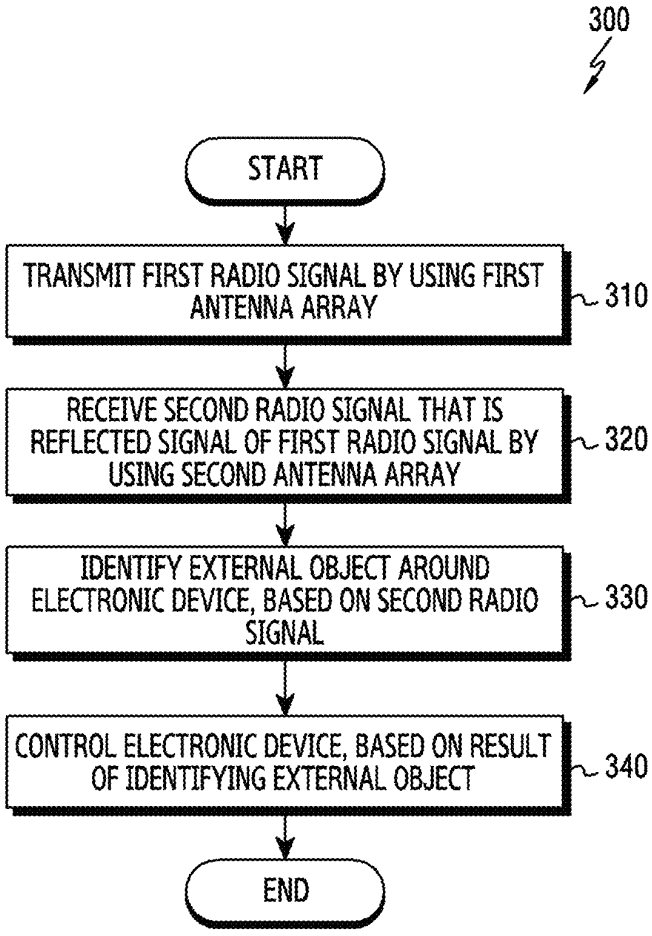
300
START
TRANSMIT FIRST RADIO SIGNAL BY USING FIRST ANTENNA ARRAY
310
RECEIVE SECOND RADIO SIGNAL THAT IS REFLECTED SIGNAL OF FIRST RADIO SIGNAL BY USING SECOND ANTENNA ARRAY
320
IDENTIFY EXTERNAL OBJECT AROUND ELECTRONIC DEVICE, BASED ON SECOND RADIO SIGNAL
330
CONTROL ELECTRONIC DEVICE, BASED ON RESULT OF IDENTIFYING EXTERNAL OBJECT
340
END

FIG.3

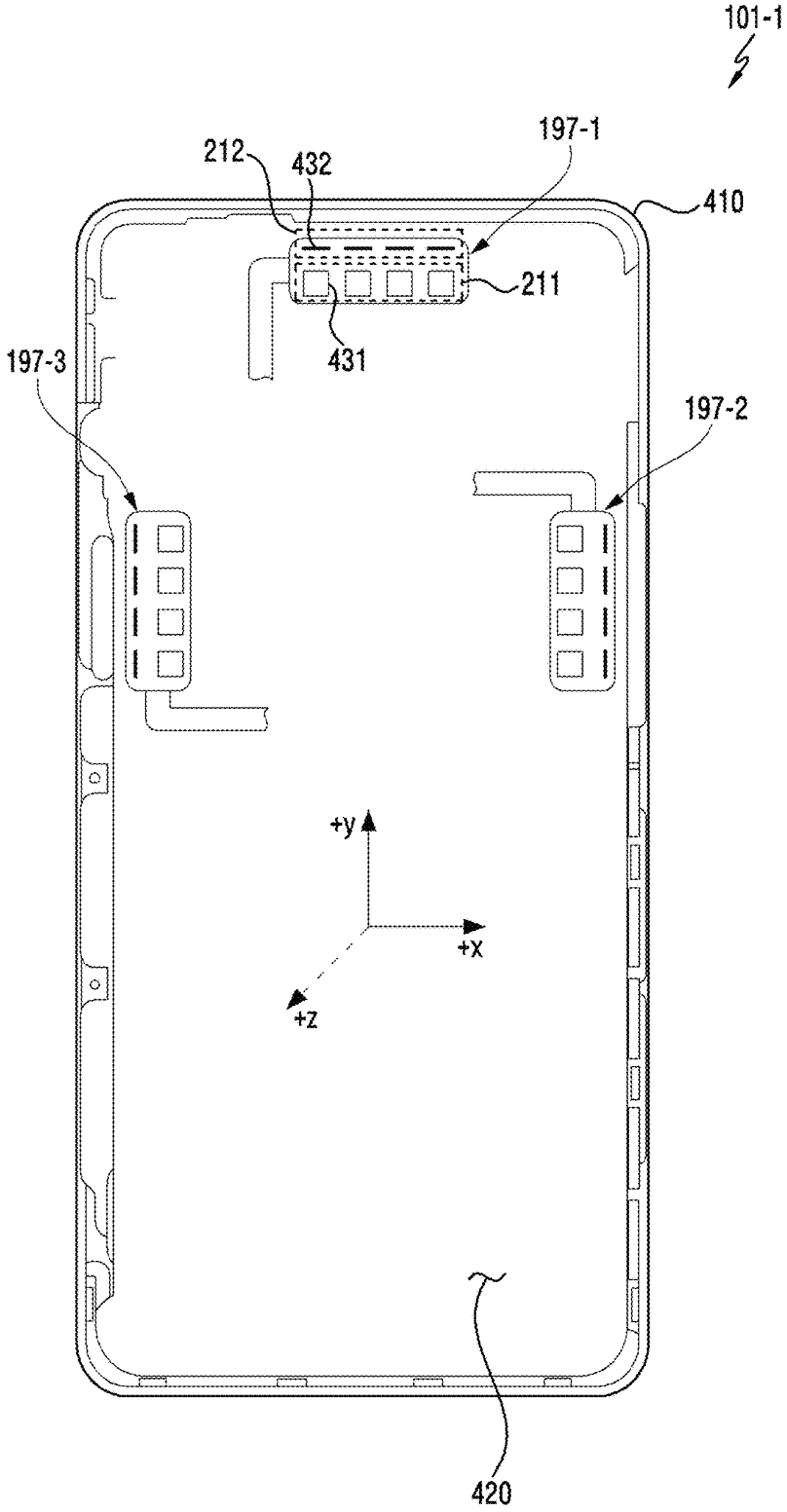

FIG.4A

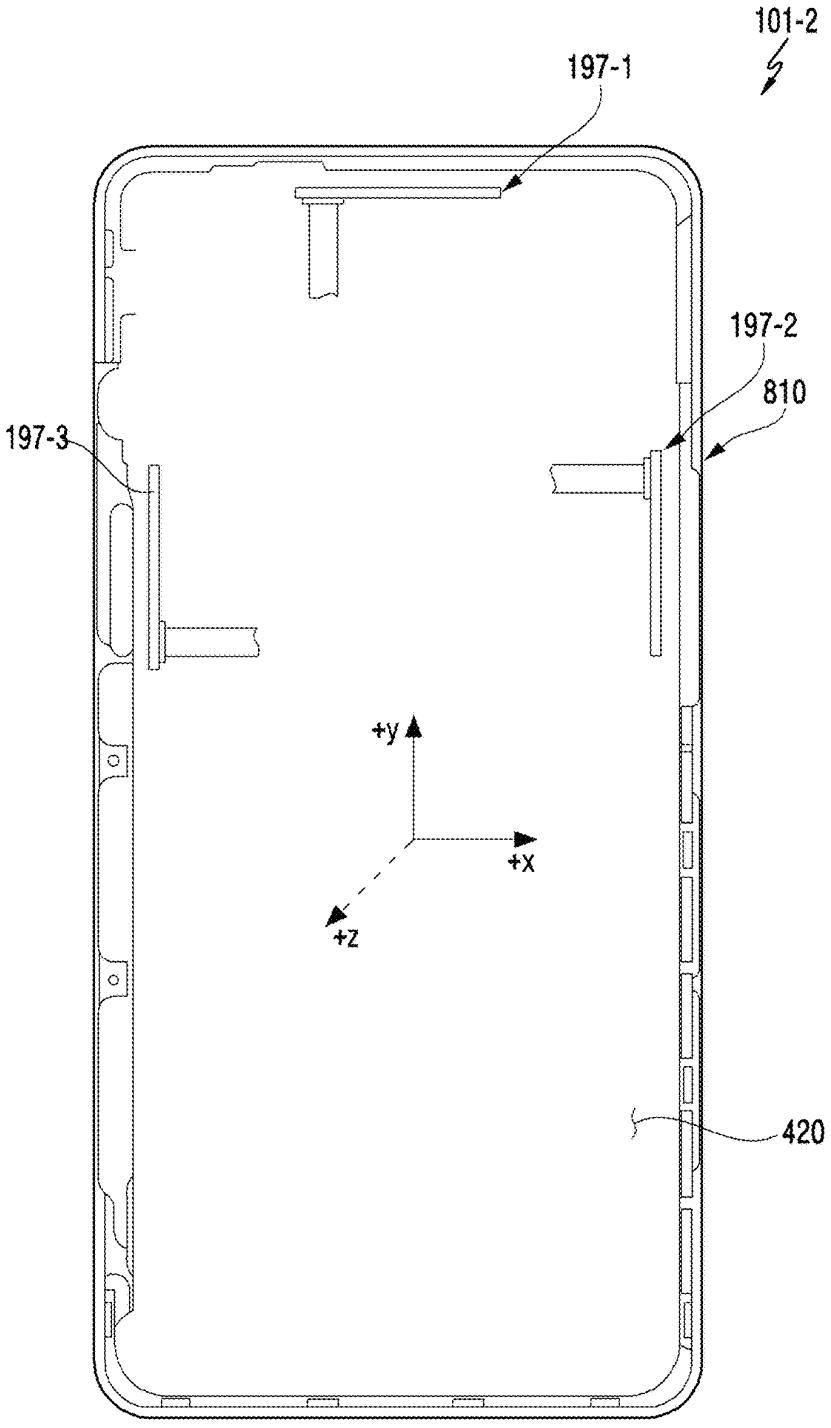

FIG.4B

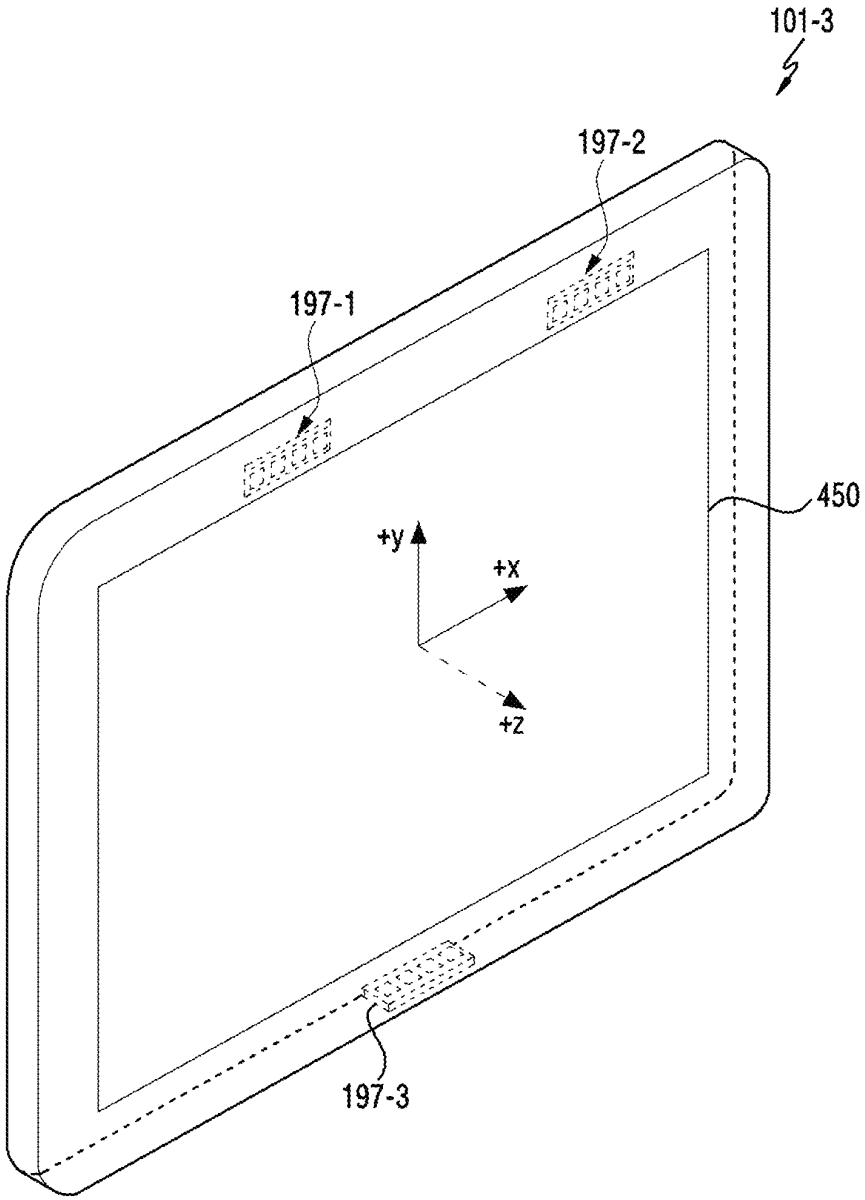

FIG.4C

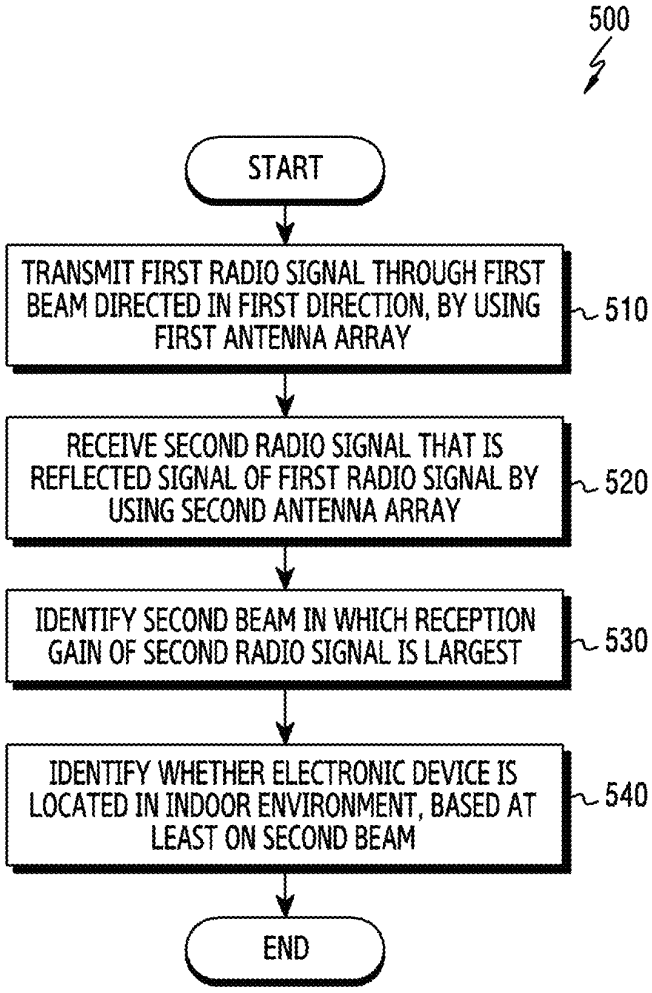
500
START
TRANSMIT FIRST RADIO SIGNAL THROUGH FIRST BEAM DIRECTED IN FIRST DIRECTION, BY USING FIRST ANTENNA ARRAY
510
RECEIVE SECOND RADIO SIGNAL THAT IS REFLECTED SIGNAL OF FIRST RADIO SIGNAL BY USING SECOND ANTENNA ARRAY
520
IDENTIFY SECOND BEAM IN WHICH RECEPTION GAIN OF SECOND RADIO SIGNAL IS LARGEST
530
IDENTIFY WHETHER ELECTRONIC DEVICE IS LOCATED IN INDOOR ENVIRONMENT, BASED AT LEAST ON SECOND BEAM
540
END

FIG.5

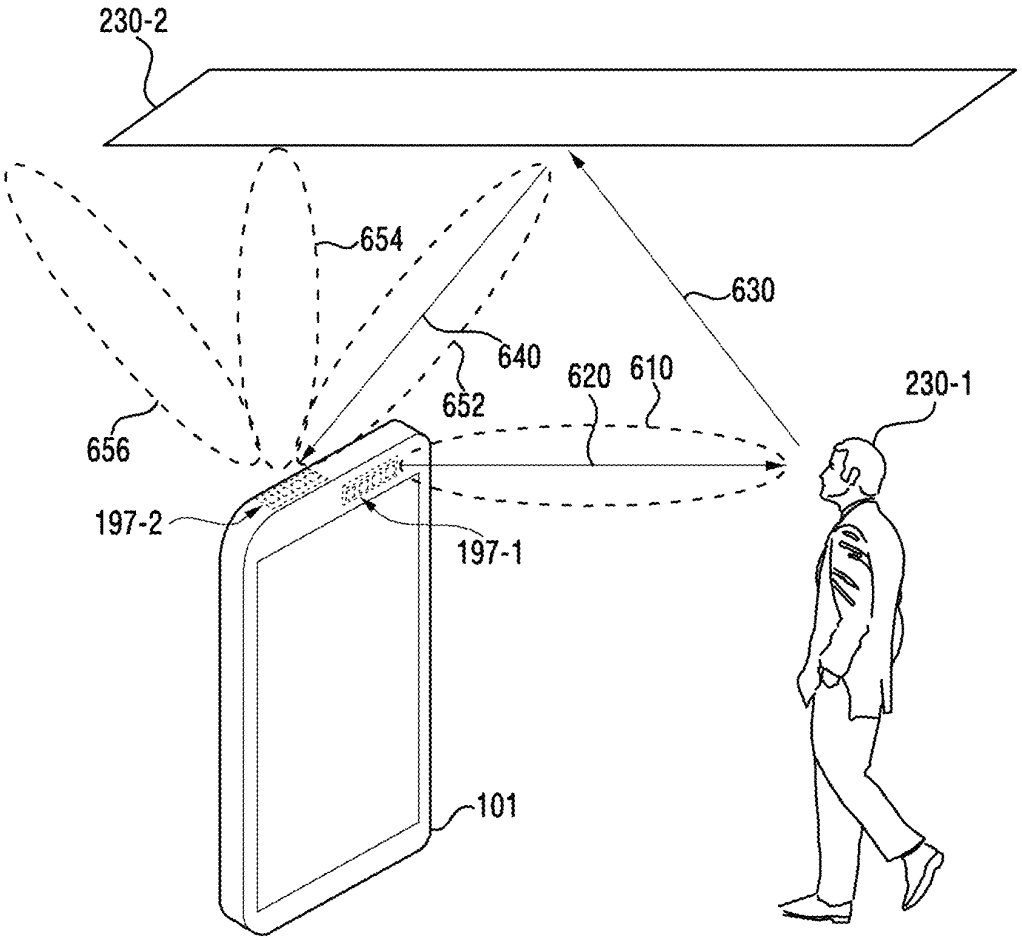

FIG.6

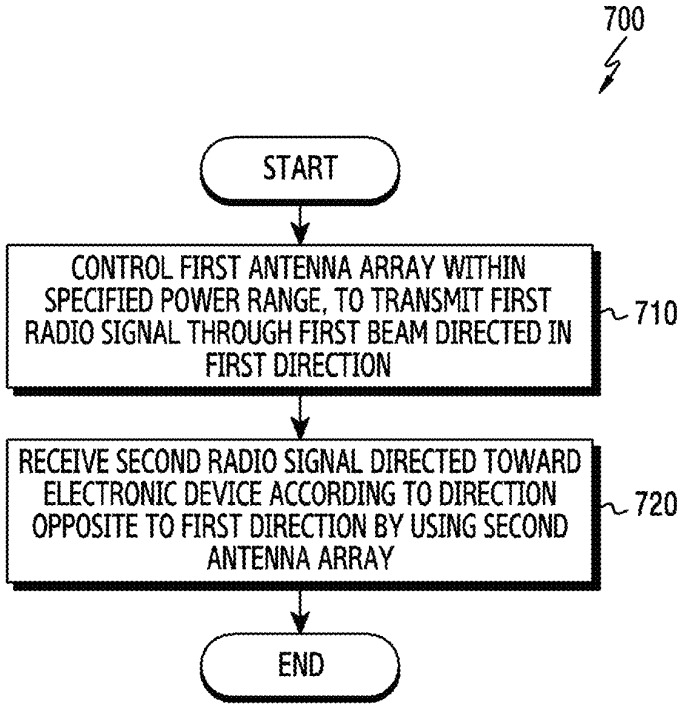
700
START
CONTROL FIRST ANTENNA ARRAY WITHIN SPECIFIED POWER RANGE, TO TRANSMIT FIRST RADIO SIGNAL THROUGH FIRST BEAM DIRECTED IN FIRST DIRECTION
710
RECEIVE SECOND RADIO SIGNAL DIRECTED TOWARD ELECTRONIC DEVICE ACCORDING TO DIRECTION OPPOSITE TO FIRST DIRECTION BY USING SECOND ANTENNA ARRAY
720
END

FIG.7

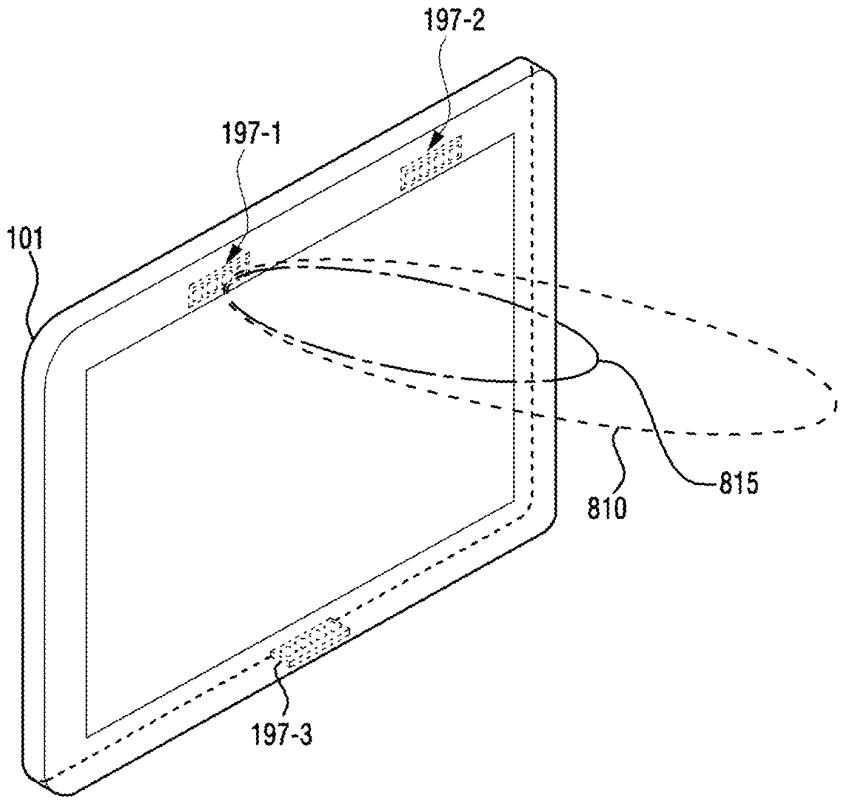

FIG.8

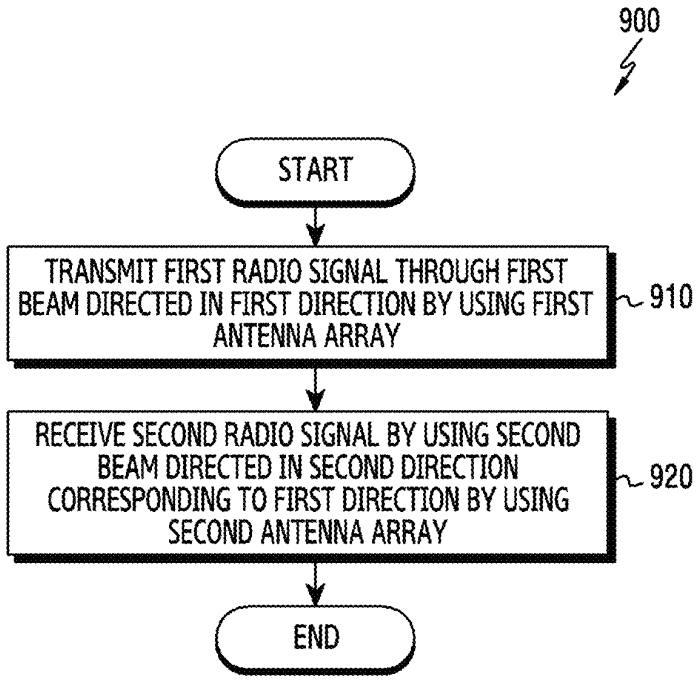
900
START
TRANSMIT FIRST RADIO SIGNAL THROUGH FIRST BEAM DIRECTED IN FIRST DIRECTION BY USING FIRST ANTENNA ARRAY
910
RECEIVE SECOND RADIO SIGNAL BY USING SECOND BEAM DIRECTED IN SECOND DIRECTION CORRESPONDING TO FIRST DIRECTION BY USING SECOND ANTENNA ARRAY
920
END

FIG.9

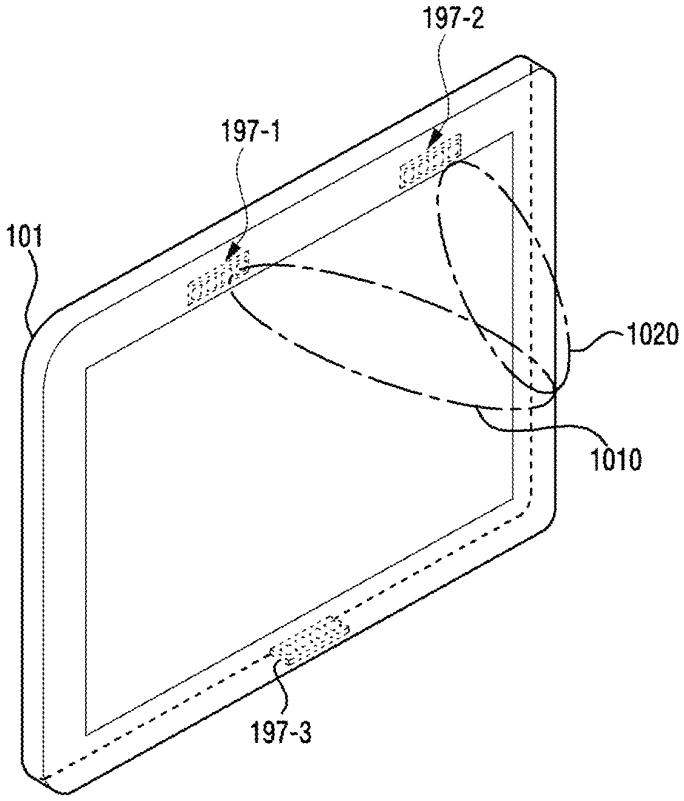

FIG.10A

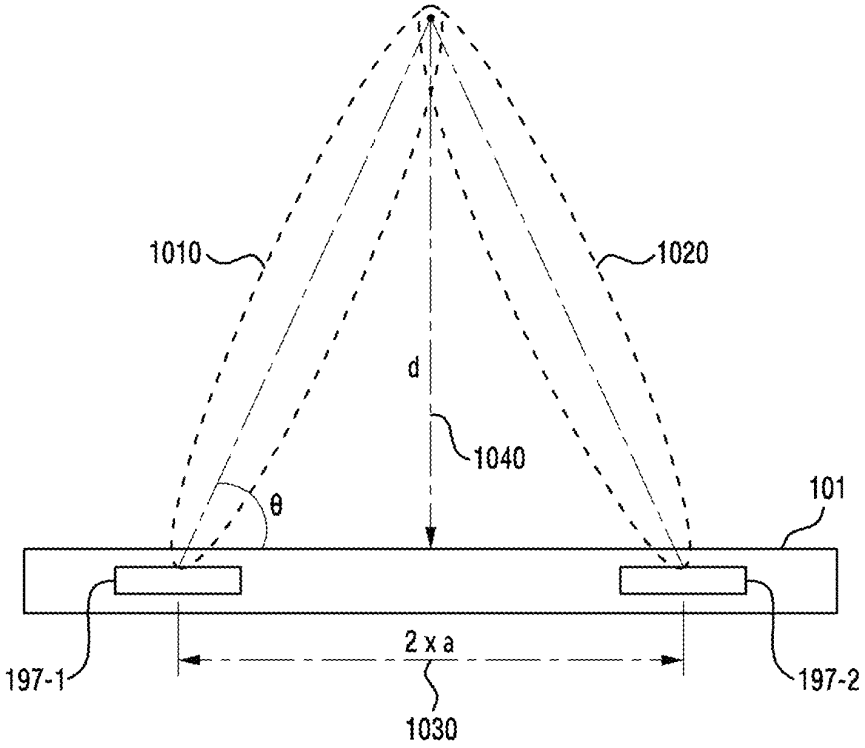

FIG.10B

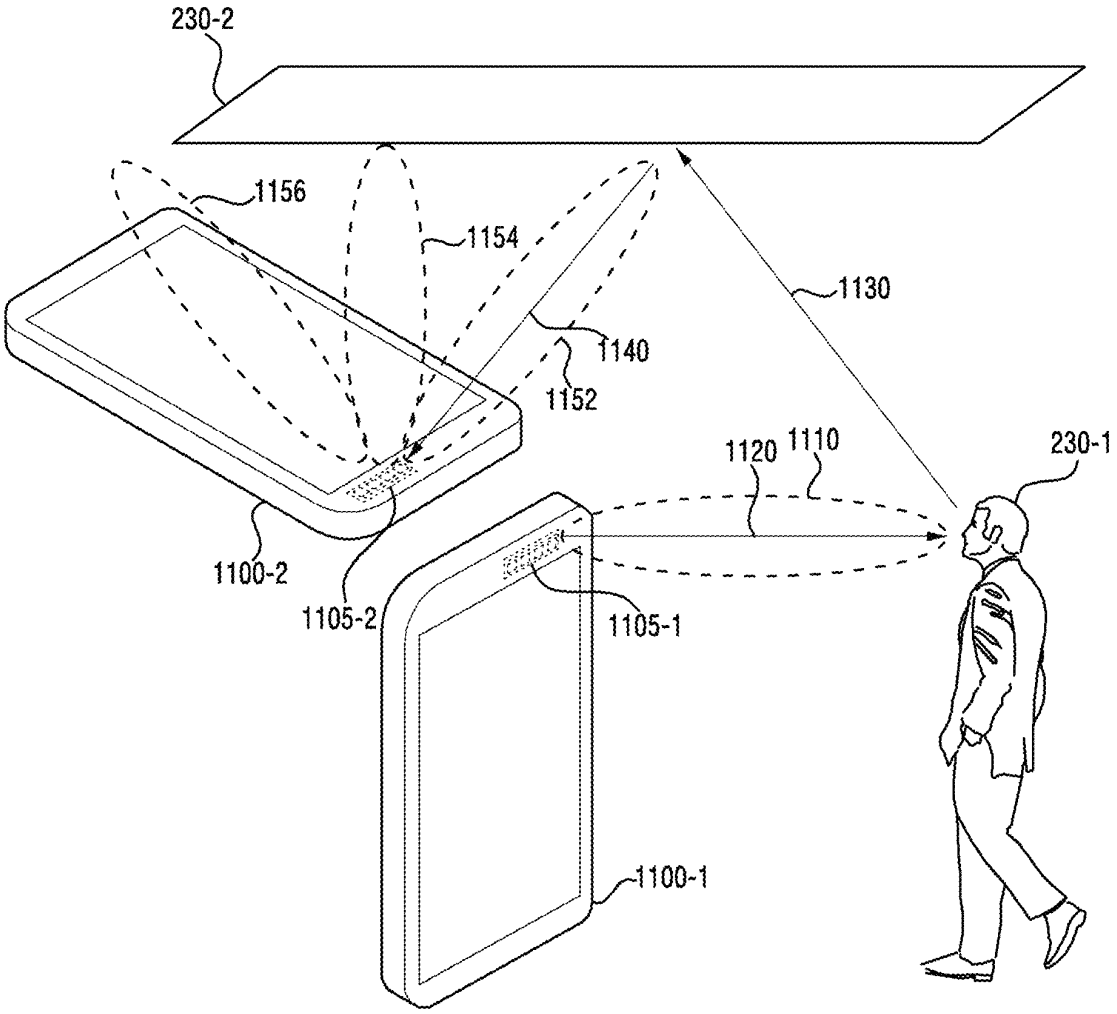
230-2
1156
1154
1130
1140
1152
1120
1110
230-1
1100-2
1105-2
1105-1
1100-1

FIG.11

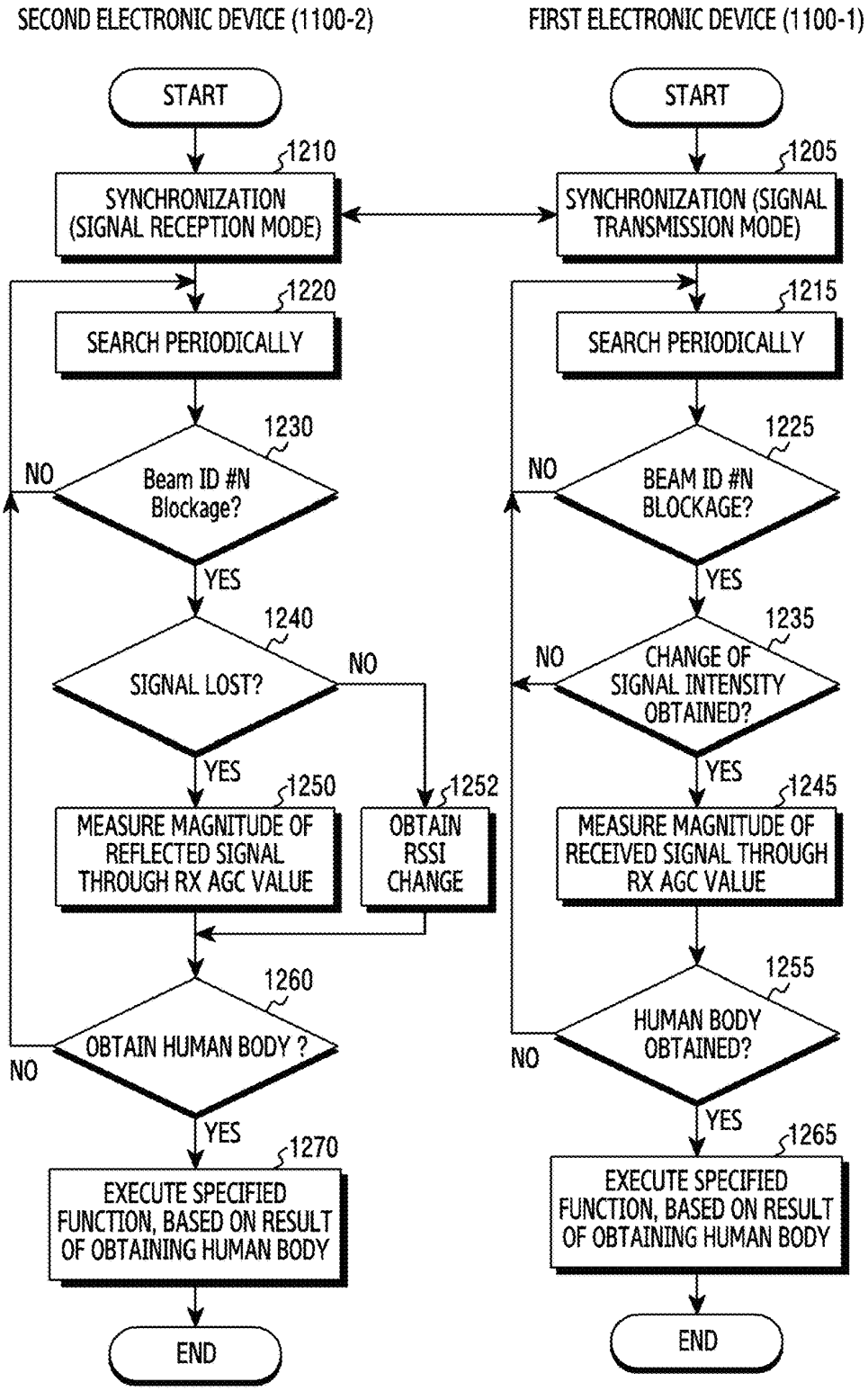
SECOND ELECTRONIC DEVICE (1100-2)
FIRST ELECTRONIC DEVICE (1100-1)
START
START
1210
SYNCHRONIZATION (SIGNAL RECEPTION MODE)
1205
SYNCHRONIZATION (SIGNAL TRANSMISSION MODE)
1220
SEARCH PERIODICALLY
1215
SEARCH PERIODICALLY
1230
Beam ID #N Blockage?
NO
1225
BEAM ID #N BLOCKAGE?
NO
YES
YES
1240
SIGNAL LOST?
NO
1235
CHANGE OF SIGNAL INTENSITY OBTAINED?
NO
YES
YES
1250
MEASURE MAGNITUDE OF REFLECTED SIGNAL THROUGH RX AGC VALUE
1252
OBTAIN RSSI CHANGE
1245
MEASURE MAGNITUDE OF RECEIVED SIGNAL THROUGH RX AGC VALUE
1260
OBTAIN HUMAN BODY ?
NO
1255
HUMAN BODY OBTAINED?
NO
YES
YES
1270
EXECUTE SPECIFIED FUNCTION, BASED ON RESULT OF OBTAINING HUMAN BODY
1265
EXECUTE SPECIFIED FUNCTION, BASED ON RESULT OF OBTAINING HUMAN BODY
END
END

FIG.12

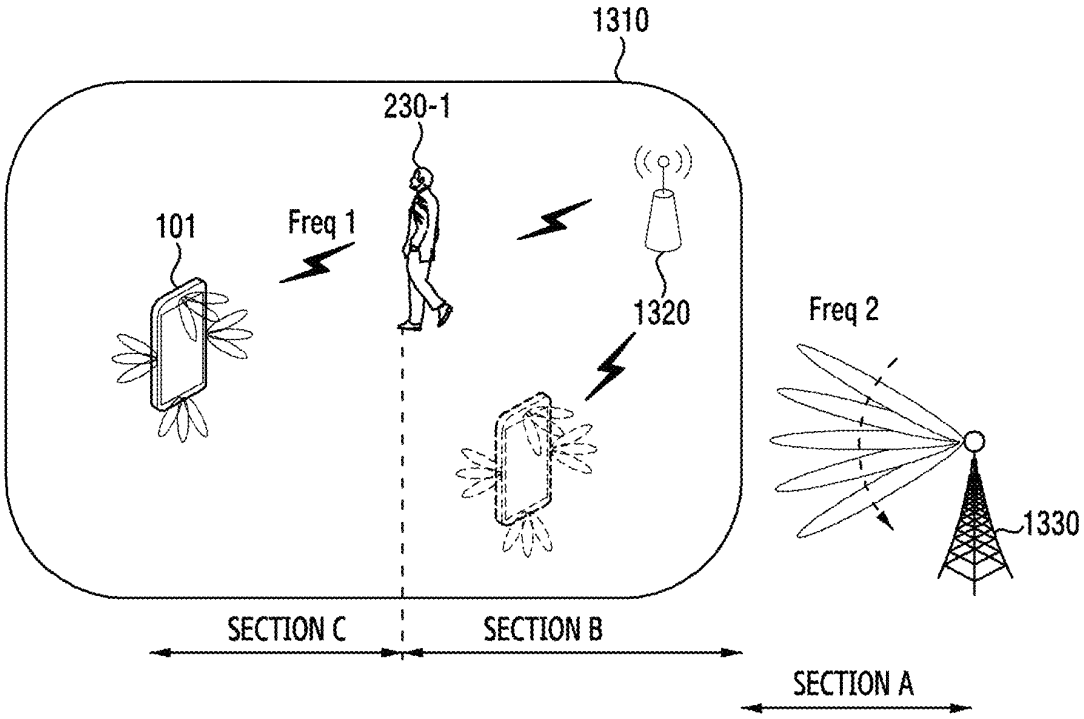
1310
230-1
101
Freq 1
1320
Freq 2
1330
SECTION C
SECTION B
SECTION A

FIG.13

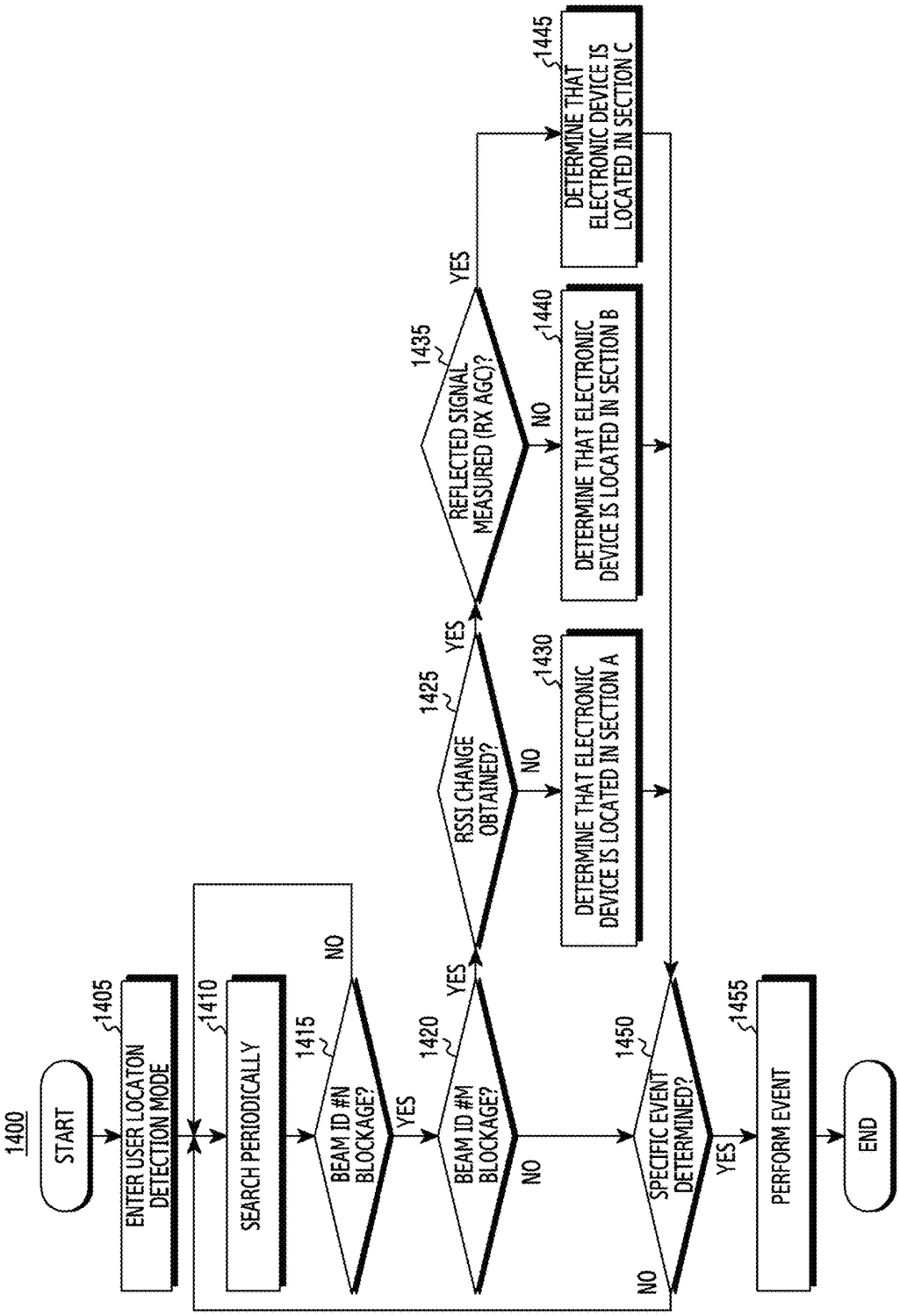
1400
START
1405
ENTER USER LOCATON DETECTION MODE
1410
SEARCH PERIODICALLY
1415
BEAM ID #N BLOCKAGE?
NO
YES
1420
BEAM ID #M BLOCKAGE?
YES
NO
1425
RSSI CHANGE OBTAINED?
YES
NO
1430
DETERMINE THAT ELECTRONIC DEVICE IS LOCATED IN SECTION A
1435
REFLECTED SIGNAL MEASURED (RX AGC)?
YES
NO
1440
DETERMINE THAT ELECTRONIC DEVICE IS LOCATED IN SECTION B
1445
DETERMINE THAT ELECTRONIC DEVICE IS LOCATED IN SECTION C
1450
SPECIFIC EVENT DETERMINED?
YES
NO
1455
PERFORM EVENT
END

FIG. 14

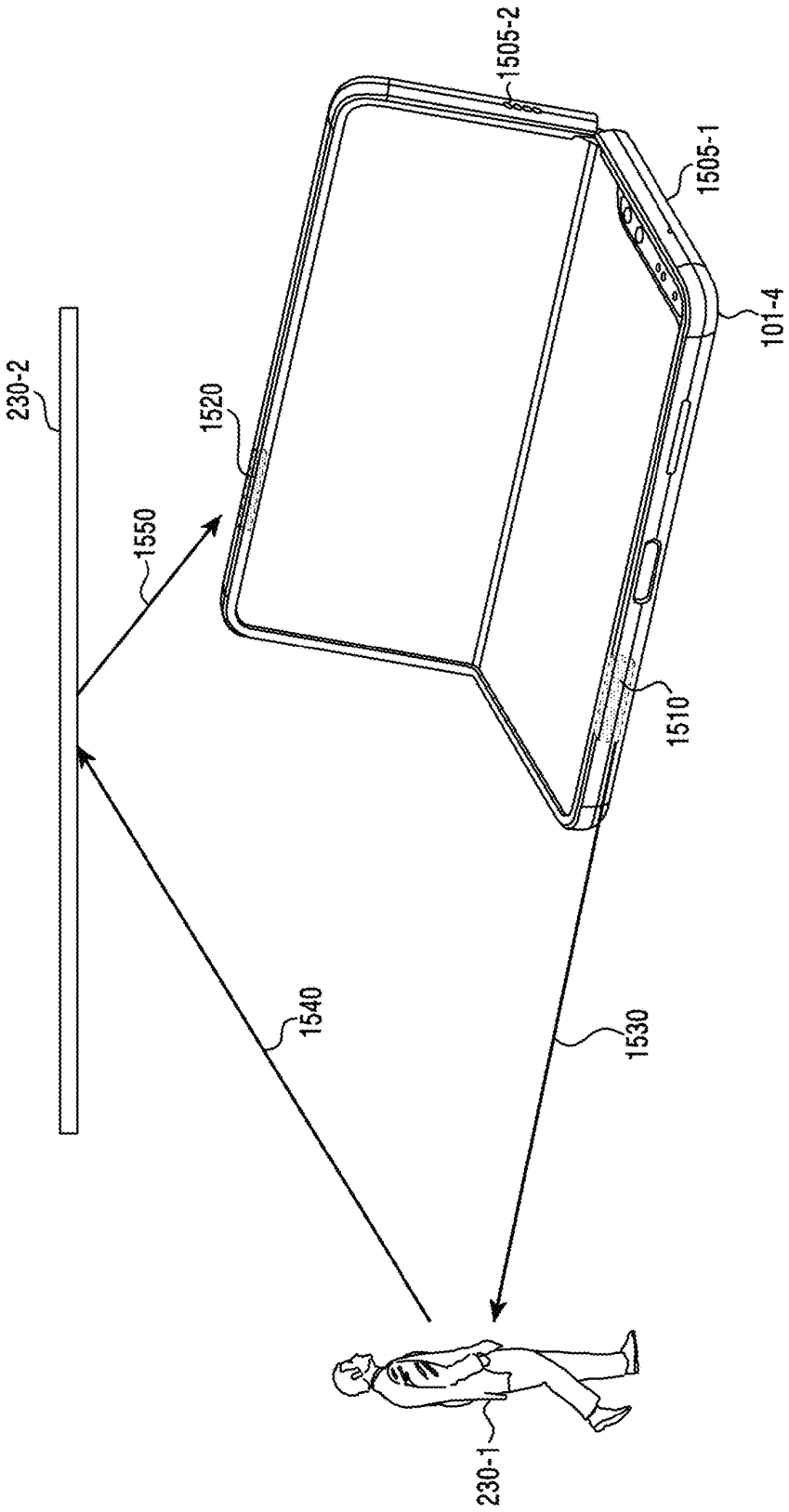

FIG.15

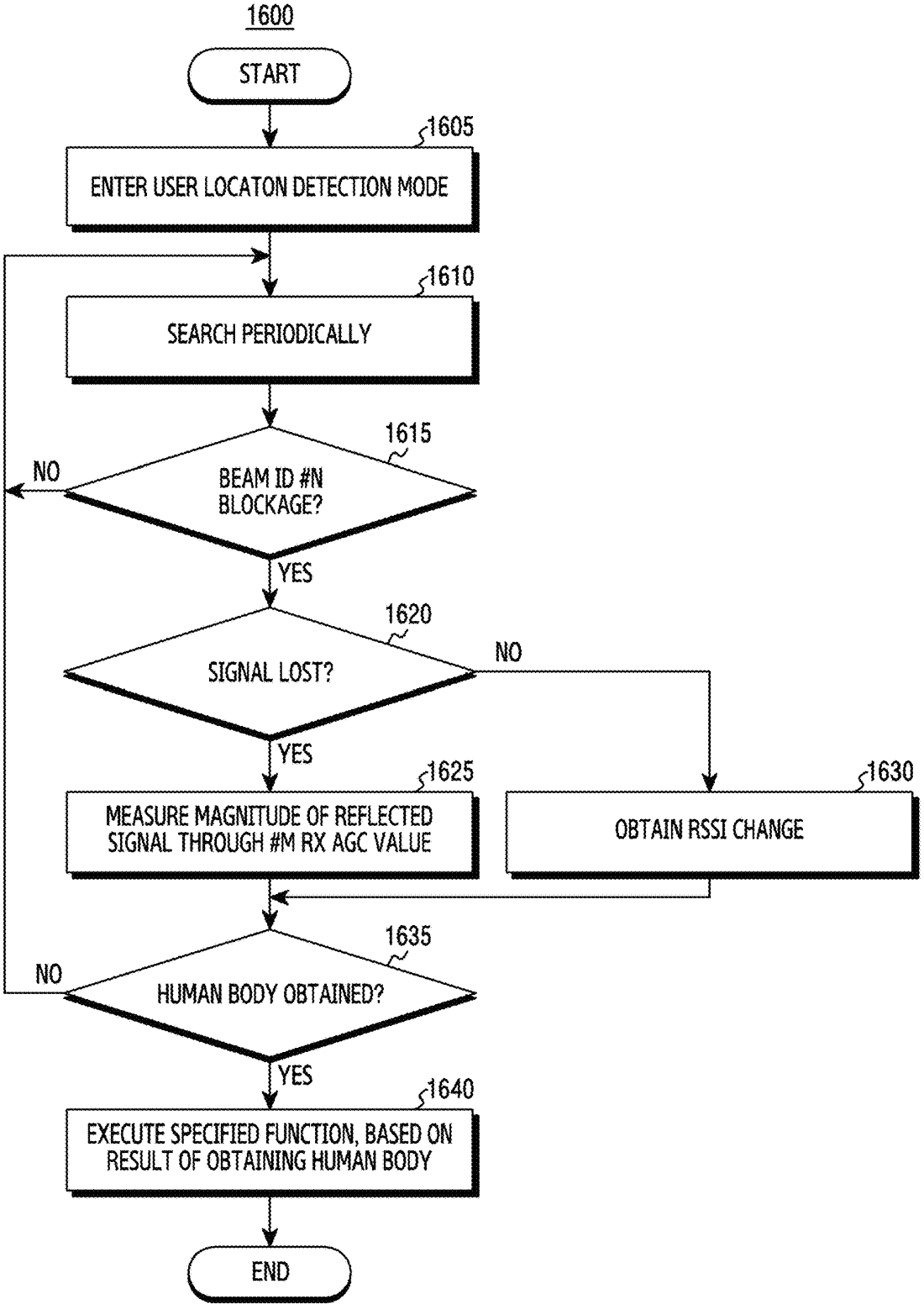
1600
START
1605
ENTER USER LOCATON DETECTION MODE
1610
SEARCH PERIODICALLY
1615
BEAM ID #N BLOCKAGE?
NO
YES
1620
SIGNAL LOST?
NO
YES
1625
MEASURE MAGNITUDE OF REFLECTED SIGNAL THROUGH #M RX AGC VALUE
1630
OBTAIN RSSI CHANGE
1635
HUMAN BODY OBTAINED?
NO
YES
1640
EXECUTE SPECIFIED FUNCTION, BASED ON RESULT OF OBTAINING HUMAN BODY
END

FIG.16

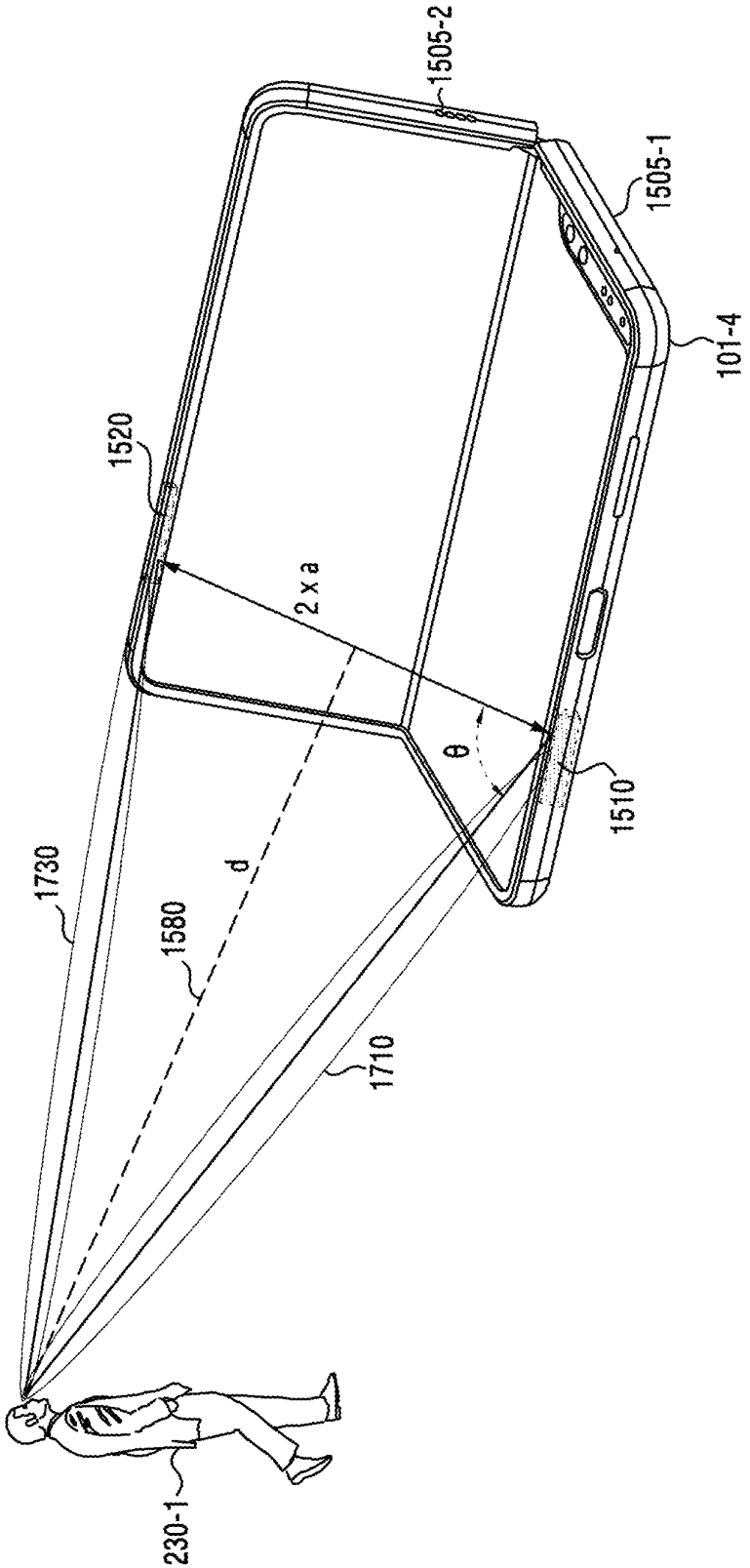

FIG. 17

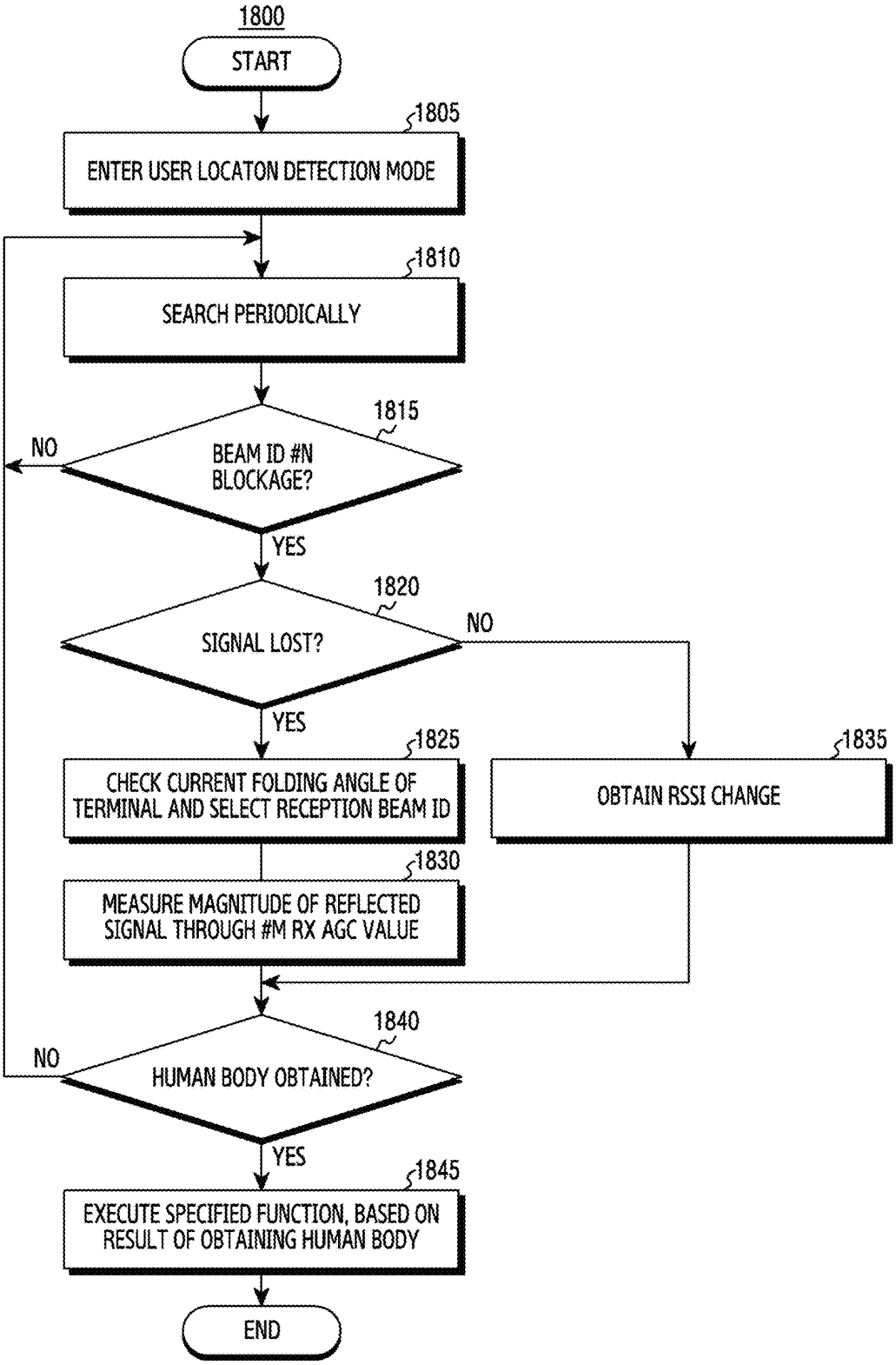
1800
START
1805
ENTER USER LOCATON DETECTION MODE
1810
SEARCH PERIODICALLY
1815
BEAM ID #N BLOCKAGE?
NO
YES
1820
SIGNAL LOST?
NO
YES
1825
CHECK CURRENT FOLDING ANGLE OF TERMINAL AND SELECT RECEPTION BEAM ID
1835
OBTAIN RSSI CHANGE
1830
MEASURE MAGNITUDE OF REFLECTED SIGNAL THROUGH #M RX AGC VALUE
1840
HUMAN BODY OBTAINED?
NO
YES
1845
EXECUTE SPECIFIED FUNCTION, BASED ON RESULT OF OBTAINING HUMAN BODY
END

FIG.18

ELECTRONIC DEVICE AND METHOD FOR DETECTING EXTERNAL OBJECT BY USING ANTENNA ARRAY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of International Application No. PCT/KR2020/009131 filed on Jul. 10, 2020, which claims priority to Korean Patent Application No. 10-2019-0084243 filed on Jul. 12, 2019, the disclosures of which are herein incorporated by reference in their entirety.

BACKGROUND

1. Field

Various embodiments relate to an electronic device for detecting an external object by using one or more antenna arrays, and a method thereof.

2. Description of Related Art

With the recent development of digital technology, various types of electronic devices such as mobile communication terminals, smart phones, tablet personal computers (PC), electronic notebooks, personal digital assistants, or wearable devices are being widely used.

To meet a demand for wireless data traffic that is increasing after the commercialization of a 4th-generation (4G) communication system, efforts are being made to develop a 5th-generation (5G) communication system or a pre-5G communication system. For this reason, the 5G communication system or the pre-5G communication system is called a beyond 4G Network communication system or a post long term evolution (LTE) system.

To achieve a high data rate, the implementation of the 5G communication system in a high frequency (mmWave) band (e.g., such as a 60 GHz band) is being considered. To alleviate a path loss of radio waves in a high frequency band and increase a propagation distance of radio waves, beamforming, massive MIMO, Full Dimensional MIMO (FD-MIMO), array antenna, analog beam-forming, and large scale antenna technologies are under discussion in the 5G communication system.

It may be difficult to detect an external object in a range larger than a range in which an illuminance sensor and/or a grip sensor may detect the external object, in order to make an electromagnetic wave emitted in a specified direction and/or angle based on beamforming reach another electronic device (e.g., a base station) without being blocked and/or reflected by the external object.

When it is intended to sense an external object by using a mmWave band signal, in case that the external object is in a close position, if a signal is transmitted in the same direction and a reflected signal is received in the same direction, a reception quality may be deteriorated, because many signals are received by a reception module due to a leakage of the transmitted signal compared to a signal reflected and returned.

Even when transmitting or receiving a sensor signal by the same beam by using two transmission and reception modules disposed in the same direction, a reception quality may be deteriorated due to a leakage of a transmitted signal.

Various embodiments may provide a method and device for preventing or decreasing the degradation of reception performance caused by a leakage which occurs when a mmWave band signal is used for a proximity sensor function.

The technical problems to be achieved in the present document are not limited to the above-mentioned technical problems, and other technical problems not mentioned will be able to be clearly understood by those having an ordinary skill in the art to which the present disclosure belongs from the description below.

SUMMARY

An electronic device of various embodiments may include a plurality of antenna arrays, and at least one processor operatively connected to the plurality of antenna arrays. The at least one processor may transmit a first radio signal having a specified polarized wave through a first antenna array among the plurality of antenna arrays, receive a second radio signal that is a reflected signal of the first radio signal and has the specified polarized wave, through a second antenna array different from the first antenna array among the plurality of antenna arrays, and identify an external object around the electronic device, based on the second radio signal.

A method of an electronic device of various embodiments may include transmitting a first radio signal having a specified polarized wave through a first antenna array among a plurality of antenna arrays of the electronic device, receiving a second radio signal which is a reflected signal of the first radio signal and has the specified polarized wave, through a second antenna array different from the first antenna array among the plurality of antenna arrays, and identifying an external object around the electronic device based on the second radio signal.

An electronic device of various embodiments and a method thereof may detect an external object in a range larger than a range in which an illuminance sensor and/or a grip sensor may detect the external object, using an electromagnetic wave propagated in a specified direction and/or angle.

Effects obtainable in the present disclosure are not limited to the above-mentioned effects, and other effects not mentioned will be able to be clearly understood by those having an ordinary skill in the art to which the present disclosure belongs from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a block diagram of an electronic device in a network environment according to various embodiments of the present disclosure.

FIG. **2** illustrates a block diagram of an electronic device according to various embodiments of the present disclosure.

FIG. **3** illustrates a flowchart for explaining an operation of an electronic device according to various embodiments of the present disclosure.

FIG. **4**A illustrates an exemplary diagram for explaining the arrangement of at least one antenna module in electronic devices according to various embodiments of the disclosure.

FIG. **4**B illustrates an exemplary diagram for explaining the arrangement of at least one antenna module in electronic devices according to various embodiments of the disclosure.

FIG. **4**C illustrates an exemplary diagram for explaining the arrangement of at least one antenna module in electronic devices according to various embodiments of the present disclosure.

FIG. **5** illustrates a flowchart for explaining an operation of an electronic device according to various embodiments of the present disclosure.

FIG. **6** illustrates a diagram for explaining an operation in which an electronic device identifies external objects according to various embodiments of the present disclosure.

FIG. **7** illustrates a flowchart for explaining an operation of an electronic device according to various embodiments of the present disclosure.

FIG. **8** illustrates a diagram for explaining an operation in which an electronic device identifies an external object by using a beam of a specific direction according to various embodiments of the present disclosure.

FIG. **9** illustrates a flowchart for explaining an operation of an electronic device according to various embodiments of the present disclosure.

FIG. **10**A illustrates a diagram for explaining an operation in which an electronic device identifies an external object based on beams of different directions according to various embodiments of the present disclosure.

FIG. **10**B illustrates a diagram for explaining an operation in which an electronic device identifies an external object, based on beams of different directions according to various embodiments of the present disclosure.

FIG. **11** illustrates an exemplary diagram for explaining an operation in which a plurality of electronic devices identify external objects according to various embodiments of the present disclosure.

FIG. **12** illustrates a flowchart for explaining an operation performed by a plurality of electronic devices according to various embodiments of the present disclosure.

FIG. **13** illustrates an exemplary diagram for explaining an operation in which an electronic device communicates with at least one of a plurality of base stations according to various embodiments of the present disclosure.

FIG. **14** illustrates a flowchart for explaining an operation performed by an electronic device according to various embodiments of the present disclosure.

FIG. **15** illustrates an exemplary diagram for explaining an operation in which an electronic device detects an external object according to an embodiment of the present disclosure.

FIG. **16** illustrates a flowchart for explaining an operation performed by an electronic device according to various embodiments of the present disclosure.

FIG. **17** illustrates an exemplary diagram for explaining an operation in which an electronic device detects an external object according to an embodiment of the present disclosure.

FIG. **18** illustrates a flowchart for explaining an operation performed by an electronic device according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

Hereinafter, various embodiments of the present document will be described with reference to the accompanying drawings. However, this do not intend to limit the technology mentioned in the present document to a specific embodiment form, and it should be understood to include various modifications, equivalents and/or alternatives of an embodiment of the present document. In relation to a description of the drawing, like reference symbols may be used for like components.

In the present document, the expressions "have," "may have," "comprise," "may comprise," etc. indicate the existence of a corresponding feature (e.g., a constituent element such as a numerical value, a function, an operation, a part or the like), and do not exclude the existence of an additional feature.

In the present document, the expression "A or B," "at least one of A or/and B," "one or more of A or/and B" or the like may include all available combinations of items enumerated together. For example, "A or B," "at least one of A and B" or "at least one of A or B" may denote all (1) including at least one A, (2) including at least one B, or (3) including all of at least one A and at least one B.

The expression "first," "second," "firstly," "secondly" or the like may modify various constituent elements irrespective of order and/or importance, and are nothing but used to distinguish a constituent element from another constituent element and do not limit the corresponding constituent elements. For example, a first user device and a second user device may represent mutually different user devices, regardless of order or importance. For example, a first constituent element may be named a second constituent element without departing from the scope of right mentioned in the present document. Likely, even a second constituent element may be named interchangeably with a first constituent element.

When it is mentioned that some constituent element (e.g., a first constituent element) is "(operatively or communicatively) coupled with/to" or is "connected to" another constituent element (e.g., a second constituent element), it should be understood that some constituent element may be directly coupled to another constituent element, or be coupled to the another constituent element through a further constituent element (e.g., a third constituent element). On the other hand, when it is mentioned that some constituent element (e.g., a first constituent element) is "directly coupled to" or is "directly connected to" another constituent element (e.g., a second constituent element), it may be understood that a further constituent element (e.g., a third constituent element) does not exist between some constituent element and another constituent element.

The expression "configured (or set) to~" used in the present document may be used interchangeably with, for example, "suitable for~," "having the capacity to~," "designed to~," "adapted to~," "made to~," or "capable of~" according to context. The term "configured (or set) to~" may not necessarily mean only "specifically designed to" in hardware. Instead, in some context, the expression "device configured to~" may mean that the device is "capable of ~" together with other devices or parts. For example, the phrase "processor configured (or set) to perform A, B, and C" may mean an exclusive processor (e.g., an embedded processor) for performing a corresponding operation, or a generic-purpose processor (e.g., a central processing unit (CPU) or an application processor (AP)) capable of performing corresponding operations by executing one or more software programs stored in a memory device.

The terms used in the present document are terms used to just explain a specific embodiment, and may not intend to limit the scope of another embodiment. The expression of a singular form may include the expression of a plural form unless otherwise dictating clearly in context. The terms used herein inclusive of technological or scientific terms may have the same meaning as those commonly understood by a person having ordinary skill in the art mentioned in the present document. Among the terms used in the present document, the terms defined in a general dictionary may be interpreted as having the same or similar meanings to the contextual meanings of a related technology, and are not interpreted as having ideal or excessively formal meanings

unless defined clearly in the present document. According to cases, even the terms defined in the present document may not be interpreted to exclude embodiments of the present document.

An electronic device of various embodiments of the present document may, for example, include at least one of a smart phone, a tablet personal computer (PC), a mobile phone, a video phone, an electronic book (e-book) reader, a desktop PC, a laptop PC, a netbook computer, a workstation, a server, a personal digital assistant (PDA), a portable multimedia player (PMP), a moving picture experts group (MPEG-1 or MPEG-2) audio layer **3** (MP3) player, a mobile medical device, a camera or a wearable device. According to various embodiments of the present disclosure, the wearable device may include at least one of an accessory type (e.g., a watch, a ring, a wristlet, an anklet, a necklace, glasses, a contact lens, a head-mounted-device (HMD) or the like), a fabric or clothing integrated type (e.g., electronic clothes), a body mount type (e.g., a skin pad or tattoo) or a bio-implant type (e.g., an implantable circuit).

In some embodiments, the electronic device may be a home appliance. The home appliance may, for example, include at least one of a television, a digital video disk (DVD) player, an audio system, a refrigerator, an air conditioner, a cleaner, an oven, a microwave, a washing machine, an air cleaner, a set-top box, a home automation control panel, a security control panel, a TV box (e.g., Samsung HomeSync™, Apple TV™ or Google TV™), a game console (e.g., Xbox™, PlayStation™), an electronic dictionary, an electronic locking system, a camcorder, or an electronic frame.

In another embodiment, the electronic device may include at least one of various medical devices (e.g., various portable medical measuring devices (i.e., a blood sugar measuring device, a heart rate measuring device, a blood pressure measuring device, a body temperature measuring device or the like), magnetic resonance angiography (MRA), magnetic resonance imaging (MRI), computerized tomography (CT), a photographing machine, an ultrasonic machine or the like), a navigation device, a global navigation satellite system (GNSS), an event data recorder (EDR), a flight data recorder (FDR), a car infotainment device, an electronic equipment for ship (e.g., a navigation device for ship, a gyrocompass, etc.), avionics, a security device, a head unit for car, an industrial or home robot, an automatic teller's machine (ATM) of a financial institution, a point of sales (POS) of a shop or an Internet of things (IoT) device (e.g., an electric bulb, various sensors, an electricity or gas meter, a sprinkler device, a fire alarm, a thermostat, a streetlight, a toaster, an exerciser, a hot water tank, a heater, a boiler, etc.).

According to some embodiment, the electronic device may include at least one of a part of furniture or building/structure, an electronic board, an electronic signature receiving device, a projector or various metering devices (e.g., a tap water, electricity, gas or radio wave metering device, etc.). In various embodiments, the electronic device may be a combination of one or more of the aforementioned various devices. The electronic device of some embodiment may be a flexible electronic device or a foldable electronic device. Also, the electronic device of an embodiment of the present document is not limited to the aforementioned devices, and may include a new electronic device following the development of technology.

In the present document, the term 'user' may denote a person who uses the electronic device or a device (e.g., an artificial-intelligence electronic device) which uses the electronic device.

Various embodiments are described below with reference to the accompanying drawings. However, the sizes of constituent elements in the drawings may be exaggerated or reduced for description convenience's sake. For instance, a size and thickness of each constituent element shown in the drawings are arbitrarily shown for description convenience's sake and therefore, the present disclosure is not necessarily limited to the illustrated drawings.

FIG. **1** is a block diagram illustrating an electronic device **101** in a network environment **100** according to various embodiments of the present disclosure. Referring to FIG. **1**, the electronic device **101** in the network environment **100** may communicate with an electronic device **102** via a first network **198** (e.g., a short-range wireless communication network), or an electronic device **104** or a server **108** via a second network **199** (e.g., a long-range wireless communication network). According to an embodiment, the electronic device **101** may communicate with the electronic device **104** via the server **108**. According to an embodiment, the electronic device **101** may include a processor **120**, memory **130**, an input device **150**, a sound output device **155**, a display device **160**, an audio module **170**, a sensor module **176**, an interface **177**, a haptic module **179**, a camera module **180**, a power management module **188**, a battery **189**, a communication module **190**, a subscriber identification module (SIM) **196**, or an antenna module **197**. In some embodiments, at least one (e.g., the display device **160** or the camera module **180**) of the components may be omitted from the electronic device **101**, or one or more other components may be added in the electronic device **101**. In some embodiments, some of the components may be implemented as single integrated circuitry. For example, the sensor module **176** (e.g., a fingerprint sensor, an iris sensor, or an illuminance sensor) may be implemented as embedded in the display device **160** (e.g., a display).

The processor **120** may execute, for example, software (e.g., a program **140**) to control at least one other component (e.g., a hardware or software component) of the electronic device **101** coupled with the processor **120**, and may perform various data processing or computation. According to one embodiment, as at least part of the data processing or computation, the processor **120** may load a command or data received from another component (e.g., the sensor module **176** or the communication module **190**) in volatile memory **132**, process the command or the data stored in the volatile memory **132**, and store resulting data in non-volatile memory **134**. According to an embodiment, the processor **120** may include a main processor **121** (e.g., a central processing unit (CPU) or an application processor (AP)), and an auxiliary processor **123** (e.g., a graphics processing unit (GPU), an image signal processor (ISP), a sensor hub processor, or a communication processor (CP)) that is operable independently from, or in conjunction with, the main processor **121**. Additionally or alternatively, the auxiliary processor **123** may be adapted to consume less power than the main processor **121**, or to be specific to a specified function. The auxiliary processor **123** may be implemented as separate from, or as part of the main processor **121**.

The auxiliary processor **123** may control at least some of functions or states related to at least one component (e.g., the display device **160**, the sensor module **176**, or the communication module **190**) among the components of the electronic device **101**, instead of the main processor **121** while the main processor **121** is in an inactive (e.g., sleep) state, or together with the main processor **121** while the main processor **121** is in an active state (e.g., executing an application). According to an embodiment, the auxiliary processor

123 (e.g., an image signal processor or a communication processor) may be implemented as part of another component (e.g., the camera module 180 or the communication module 190) functionally related to the auxiliary processor 123.

The memory 130 may store various data used by at least one component (e.g., the processor 120 or the sensor module 176) of the electronic device 101. The various data may include, for example, software (e.g., the program 140) and input data or output data for a command related thereto. The memory 130 may include the volatile memory 132 or the non-volatile memory 134.

The program 140 may be stored in the memory 130 as software, and may include, for example, an operating system (OS) 142, middleware 144, or an application 146.

The input device 150 may receive a command or data to be used by another component (e.g., the processor 120) of the electronic device 101, from the outside (e.g., a user) of the electronic device 101. The input device 150 may include, for example, a microphone, a mouse, a keyboard, or a digital pen (e.g., a stylus pen).

The sound output device 155 may output sound signals to the outside of the electronic device 101. The sound output device 155 may include, for example, a speaker or a receiver. The speaker may be used for general purposes, such as playing multimedia or playing record, and the receiver may be used for an incoming calls. According to an embodiment, the receiver may be implemented as separate from, or as part of the speaker.

The display device 160 may visually provide information to the outside (e.g., a user) of the electronic device 101. The display device 160 may include, for example, a display, a hologram device, or a projector and control circuitry to control a corresponding one of the display, hologram device, and projector. According to an embodiment, the display device 160 may include touch circuitry adapted to detect a touch, or sensor circuitry (e.g., a pressure sensor) adapted to measure the intensity of force incurred by the touch.

The audio module 170 may convert a sound into an electrical signal and vice versa. According to an embodiment, the audio module 170 may obtain the sound via the input device 150, or output the sound via the sound output device 155 or a headphone of an external electronic device (e.g., an electronic device 102) directly (e.g., wiredly) or wirelessly coupled with the electronic device 101.

The sensor module 176 may detect an operational state (e.g., power or temperature) of the electronic device 101 or an environmental state (e.g., a state of a user) external to the electronic device 101, and then generate an electrical signal or data value corresponding to the detected state. According to an embodiment, the sensor module 176 may include, for example, a gesture sensor, a gyro sensor, an atmospheric pressure sensor, a magnetic sensor, an acceleration sensor, a grip sensor, a proximity sensor, a color sensor, an infrared (IR) sensor, a biometric sensor, a temperature sensor, a humidity sensor, or an illuminance sensor.

The interface 177 may support one or more specified protocols to be used for the electronic device 101 to be coupled with the external electronic device (e.g., the electronic device 102) directly (e.g., wiredly) or wirelessly. According to an embodiment, the interface 177 may include, for example, a high definition multimedia interface (HDMI), a universal serial bus (USB) interface, a secure digital (SD) card interface, or an audio interface.

A connecting terminal 178 may include a connector via which the electronic device 101 may be physically connected with the external electronic device (e.g., the electronic device 102). According to an embodiment, the connecting terminal 178 may include, for example, a HDMI connector, a USB connector, a SD card connector, or an audio connector (e.g., a headphone connector).

The haptic module 179 may convert an electrical signal into a mechanical stimulus (e.g., a vibration or a movement) or electrical stimulus which may be recognized by a user via his tactile sensation or kinesthetic sensation. According to an embodiment, the haptic module 179 may include, for example, a motor, a piezoelectric element, or an electric stimulator.

The camera module 180 may capture a still image or moving images. According to an embodiment, the camera module 180 may include one or more lenses, image sensors, image signal processors, or flashes.

The power management module 188 may manage power supplied to the electronic device 101. According to one embodiment, the power management module 188 may be implemented as at least part of, for example, a power management integrated circuit (PMIC).

The battery 189 may supply power to at least one component of the electronic device 101. According to an embodiment, the battery 189 may include, for example, a primary cell which is not rechargeable, a secondary cell which is rechargeable, or a fuel cell.

The communication module 190 may support establishing a direct (e.g., wired) communication channel or a wireless communication channel between the electronic device 101 and the external electronic device (e.g., the electronic device 102, the electronic device 104, or the server 108) and performing communication via the established communication channel. The communication module 190 may include one or more communication processors that are operable independently from the processor 120 (e.g., the application processor (AP)) and supports a direct (e.g., wired) communication or a wireless communication.

According to an embodiment, the communication module 190 may include a wireless communication module 192 (e.g., a cellular communication module, a short-range wireless communication module, or a global navigation satellite system (GNSS) communication module) or a wired communication module 194 (e.g., a local area network (LAN) communication module or a power line communication (PLC) module). A corresponding one of these communication modules may communicate with the external electronic device via the first network 198 (e.g., a short-range communication network, such as Bluetooth™, wireless-fidelity (Wi-Fi) direct, or infrared data association (IrDA)) or the second network 199 (e.g., a long-range communication network, such as a cellular network, the Internet, or a computer network (e.g., LAN or wide area network (WAN)). These various types of communication modules may be implemented as a single component (e.g., a single chip), or may be implemented as multi components (e.g., multi chips) separate from each other. The wireless communication module 192 may identify and authenticate the electronic device 101 in a communication network, such as the first network 198 or the second network 199, using subscriber information (e.g., international mobile subscriber identity (IMSI)) stored in the subscriber identification module 196.

The antenna module 197 may transmit or receive a signal or power to or from the outside (e.g., the external electronic device) of the electronic device 101. According to an embodiment, the antenna module 197 may include an antenna including a radiating element composed of a conductive material or a conductive pattern formed in or on a substrate (e.g., PCB). According to an embodiment, the

antenna module **197** may include a plurality of antennas. In such a case, at least one antenna appropriate for a communication scheme used in the communication network, such as the first network **198** or the second network **199**, may be selected, for example, by the communication module **190** (e.g., the wireless communication module **192**) from the plurality of antennas. The signal or the power may then be transmitted or received between the communication module **190** and the external electronic device via the selected at least one antenna. According to an embodiment, another component (e.g., a radio frequency integrated circuit (RFIC)) other than the radiating element may be additionally formed as part of the antenna module **197**.

At least some of the above-described components may be coupled mutually and communicate signals (e.g., commands or data) therebetween via an inter-peripheral communication scheme (e.g., a bus, general purpose input and output (GPIO), serial peripheral interface (SPI), or mobile industry processor interface (MIPI)).

According to an embodiment, commands or data may be transmitted or received between the electronic device **101** and the external electronic device **104** via the server **108** coupled with the second network **199**. Each of the electronic devices **102** and **104** may be a device of a same type as, or a different type, from the electronic device **101**. According to an embodiment, all or some of operations to be executed at the electronic device **101** may be executed at one or more of the external electronic devices **102**, **104**, or **108**. For example, if the electronic device **101** may perform a function or a service automatically, or in response to a request from a user or another device, the electronic device **101**, instead of, or in addition to, executing the function or the service, may request the one or more external electronic devices to perform at least part of the function or the service. The one or more external electronic devices receiving the request may perform the at least part of the function or the service requested, or an additional function or an additional service related to the request, and transfer an outcome of the performing to the electronic device **101**. The electronic device **101** may provide the outcome, with or without further processing of the outcome, as at least part of a reply to the request. To that end, a cloud computing, distributed computing, or client-server computing technology may be used, for example.

The electronic device according to various embodiments of the present disclosure may be one of various types of electronic devices. The electronic devices may include, for example, a portable communication device (e.g., a smartphone), a computer device, a portable multimedia device, a portable medical device, a camera, a wearable device, or a home appliance. According to an embodiment of the disclosure, the electronic devices are not limited to those described above.

It should be appreciated that various embodiments of the present disclosure and the terms used therein are not intended to limit the technological features set forth herein to particular embodiments and include various changes, equivalents, or replacements for a corresponding embodiment. With regard to the description of the drawings, similar reference numerals may be used to refer to similar or related elements. It is to be understood that a singular form of a noun corresponding to an item may include one or more of the things unless the relevant context clearly indicates otherwise. As used herein, each of such phrases as "A or B," "at least one of A and B," "at least one of A or B," "A, B, or C," "at least one of A, B, and C," and "at least one of A, B, or C," may include any one of, or all possible combinations of the items enumerated together in a corresponding one of the phrases. As used herein, such terms as "1st" and "2nd," or "first" and "second" may be used to simply distinguish a corresponding component from another, and does not limit the components in other aspect (e.g., importance or order). It is to be understood that if an element (e.g., a first element) is referred to, with or without the term "operatively" or "communicatively," as "coupled with," "coupled to," "connected with," or "connected to" another element (e.g., a second element), it means that the element may be coupled with the other element directly (e.g., wiredly), wirelessly, or via a third element.

As used herein, the term "module" may include a unit implemented in hardware, software, or firmware, and may interchangeably be used with other terms, for example, "logic," "logic block," "part," or "circuitry." A module may be a single integral component, or a minimum unit or part thereof, adapted to perform one or more functions. For example, according to an embodiment, the module may be implemented in a form of an application-specific integrated circuit (ASIC).

Various embodiments as set forth herein may be implemented as software (e.g., the program **140**) including one or more instructions that are stored in a storage medium (e.g., internal memory **136** or external memory **138**) that is readable by a machine (e.g., the electronic device **101**). For example, a processor (e.g., the processor **120**) of the machine (e.g., the electronic device **101**) may invoke at least one of the one or more instructions stored in the storage medium, and execute it, with or without using one or more other components under the control of the processor. This allows the machine to be operated to perform at least one function according to the at least one instruction invoked. The one or more instructions may include a code generated by a complier or a code executable by an interpreter. The machine-readable storage medium may be provided in the form of a non-transitory storage medium. Wherein, the term "non-transitory" simply means that the storage medium is a tangible device, and does not include a signal (e.g., an electromagnetic wave), but this term does not differentiate between where data is semi-permanently stored in the storage medium and where the data is temporarily stored in the storage medium.

According to an embodiment, a method according to various embodiments of the disclosure may be included and provided in a computer program product. The computer program product may be traded as a product between a seller and a buyer. The computer program product may be distributed in the form of a machine-readable storage medium (e.g., compact disc read only memory (CD-ROM)), or be distributed (e.g., downloaded or uploaded) online via an application store (e.g., PlayStore™), or between two user devices (e.g., smart phones) directly. If distributed online, at least part of the computer program product may be temporarily generated or at least temporarily stored in the machine-readable storage medium, such as memory of the manufacturer's server, a server of the application store, or a relay server.

According to various embodiments of the present disclosure, each component (e.g., a module or a program) of the above-described components may include a single entity or multiple entities. According to various embodiments of the present disclosure, one or more of the above-described components may be omitted, or one or more other components may be added. Alternatively or additionally, a plurality of components (e.g., modules or programs) may be integrated into a single component. In such a case, according to

various embodiments of the present disclosure, the integrated component may still perform one or more functions of each of the plurality of components in the same or similar manner as they are performed by a corresponding one of the plurality of components before the integration. According to various embodiments of the present disclosure, operations performed by the module, the program, or another component may be carried out sequentially, in parallel, repeatedly, or heuristically, or one or more of the operations may be executed in a different order or omitted, or one or more other operations may be added.

FIG. **2** illustrates a block diagram of an electronic device **101** according to various embodiments of the present disclosure. The electronic device **101** of FIG. **2** may correspond to the electronic device **101** of FIG. **1**. The electronic device **101** may correspond to at least one of a smart phone, a smart pad, a tablet PC, a personal digital assistant (PDA), a laptop PC or a desktop PC. The electronic device **101** may correspond to a wearable device which includes at least one of an accessory type (e.g., a watch, a ring, a wristlet, an anklet, a necklace, glasses, a contact lens, or a head-mounted-device (HMD)), a fabric or clothing integrated type (e.g., electronic clothes), a human-body mount type (e.g., a skin pad or tattoo), or a bio implantation type (e.g., an implantable circuit). The electronic device **101** may be home appliances such as a refrigerator, a television (TV), a cleaner, an air conditioner, a washing machine and a lighting device.

Referring to FIG. **2**, the electronic device **101** of various embodiments may include at least one of a processor **120**, a memory **130**, a communication module **190**, and a display device **160**. The electronic device **101** of various embodiments may include at least one antenna module related to radio frequency (RF) and/or microwave. In various embodiments, the number of antenna modules included in the electronic device **101** may be different. Referring to FIG. **2**, the electronic device **101** of an embodiment may include antenna modules (a first antenna module **197-1**, a second antenna module **197-2**, . . . , an n-th antenna module **197-*n***). In the electronic device **101** of an embodiment, the processor **120**, the memory **130**, the communication module **190**, the display device **160**, and/or the at least one antenna module may be operably and/or electrically connected through a communication bus (not shown).

The processor **120** may execute one or more instructions stored in the memory **130**. The processor **120** may include at least one of a circuit for processing data, for example, an integrated circuit (IC), an arithmetic logic unit (ALU), a field programmable gate array (FPGA), and a large scale integration (LSI). The memory **130** may store data related to the electronic device **101**. The memory **130** may include a volatile memory such as a random access memory (RAM) including a static random access memory (SRAM) or a dynamic RAM (DRAM), or may include a non-volatile memory such as not only a read only memory (ROM), a magneto resistive RAM (MRAM), a spin-transfer torque MRAM (STT-MRAM), a phase-change RAM (PRAM), a resistive RAM (RRAM), and a ferroelectric RAM (FeRAM), but also a flash memory, an embedded multi media card (eMMC), and a solid state drive (SSD). Although one processor **120** and one memory **130** are illustrated, in various embodiments, the number of the processors **120** and the memories **130** included in the electronic device **101** may be one or more.

The memory **130** may store instructions related to an application and instructions related to an operating system (OS). The operating system is system software executed by the processor **120**. By executing the operating system, the processor **120** may manage hardware components included in the electronic device **101**. The operating system may present an application programming interface (API) as an application that is software other than the system software.

One or more applications which are a set of a plurality of instructions may be installed in the memory **130**. That the application is installed in the memory **130** may mean that the application is stored in a format which is executable by the processor **120** connected to the memory **130**.

The display device **160** may visually output information to a user by using at least one of organic light emitting diodes (OLEDs), liquid crystal displays (LCDs), and light emitting diodes (LEDs). In order to more intuitively control a user interface (UI) outputted through the display device **160**, the electronic device **101** may include a touch screen panel (TSP) (not shown) disposed on the display device **160**. The touch sensor panel may touch the display device **160** or detect a location of an object (e.g., a user's finger, a stylus) hovering over the display device **160**, by using at least one of a resistive film, a capacitive component, a surface acoustic wave, and an infrared ray.

The communication module **190** may connect the electronic device **101** to a wireless communication network **220** such as Bluetooth, wireless fidelity (WiFi), near field communication (NFC), long term evolution (LTE), and 5G new radio (NR), and a wired communication network such as a local area network (LAN) and Ethernet. The communication module **190** may include at least one of a communication circuit, a communication processor (CP), and a communication interface supporting at least one wireless communication standard and/or at least one wired communication standard.

According to various embodiments of the present disclosure, at least one antenna module (e.g., the first antenna module **197-1**, the second antenna module **197-2**, . . . , the nth antenna module **197-*n***) included in the electronic device **101** may include an antenna array which is formed in a patch type (or a pattern type) on a substrate (e.g., a printed circuit board (PCB)). The antenna array may include a conductive member which is disposed in a specified direction with respect to an axis of an antenna module and/or an antenna (e.g., in a direction transverse to the axis), or a plurality of conductors (e.g., an antenna element) of a dipole form.

In an embodiment of FIG. **2**, the antenna module (e.g., the first antenna module **197-1** or the second antenna module **197-2**) may include a plurality of antenna arrays (e.g., antenna arrays **211** and **212** or antenna arrays **213** and **214**). The plurality of antenna arrays may include antenna elements for providing beams directed in different directions. For example, the antenna arrays **211**, **212**, **213**, or **214** of FIG. **2** may be a 1×4 antenna array. The antenna array may output a directive and/or radioactive electromagnetic wave, based on the arrangement of the antenna elements. At least one antenna module included in the electronic device **101** may use, for example, a millimeter wave (e.g., a band of 25 GHz or higher) as an operating frequency band. The arrangement of the at least one antenna module and the at least one antenna array in the electronic device **101** will be described with reference to FIG. **4**A to FIG. **4**C.

The electronic device **101** of various embodiments may control at least one antenna module and/or at least one antenna array, to form an antenna beam in a space adjacent to the electronic device **101**. The antenna beam may be referred to a space, direction, location in which the antenna module and/or the antenna array radiate an electromagnetic wave, and/or a form of the electromagnetic wave. When the antenna module and/or antenna array detect an external

electromagnetic wave, the antenna beam may mean the space, direction, location in which the antenna module and/or antenna array may detect the external electromagnetic wave, and/or a form of the external electromagnetic wave. Hereinafter, the antenna beam may be referred to as a beam.

In various embodiments, a direction of a beam formed by the antenna array may vary according to the control of the electronic device **101**. The electronic device **101** of various embodiments may distinguish directions of mutually different beams formable by the antenna array, based on a specified parameter such as a beam identifier. In an embodiment, the beam identifier may indicate a direction of a beam.

The electronic device **101** of various embodiments may store information for controlling the antenna array in the memory **130**. In an embodiment, the information is information for controlling the antenna array, based on the beam identifier, and may include, for example, codebook information. The codebook information may be defined as information about a set of defined quantized channel vectors. The codebook information may be referred by various terms including a beam book or a precoding matrix. The codebook information may store data for providing beams of different directions, based on beam identifiers corresponding to the directions.

The electronic device **101** of various embodiments may control at least one antenna module and/or at least one antenna array, to connect to the wireless communication network **220**. The wireless communication network **220** is a 5G network, and may be operated independently (e.g., stand-alone (SA)) of, or be operated in connection (e.g., non-stand alone (NSA)) to, other networks (e.g., legacy networks such as LTE) different from the 5G network. For example, the 5G network may include only an access network (e.g., a 5G radio access network (RAN) or a next generation RAN (NG RAN)), and not include a core network (e.g., a next generation core (NGC)). In this case, after the electronic device **101** accesses an access network of the wireless communication network **220** which is the 5G network, the electronic device **101** may access an external network (e.g., the Internet) under the control of a core network (e.g., an evolved packed core (EPC)) of a legacy network. Protocol information (e.g., LTE protocol information) for communication with the legacy network and/or protocol information (e.g., new radio (NR) protocol information) for communication with the 5G network may be stored in the memory **130**, and may be accessed by the processor **120** and/or the communication module **190**.

In an embodiment, in order for the electronic device **101** to connect to the wireless communication network **220**, the electronic device **101** may control at least one antenna module and/or at least one antenna array to form a beam. By using the formed beam, the electronic device **101** may transmit and/or receive a radio signal. In an embodiment, when the electronic device **101** transmits the radio signal, based on a millimeter wave, the radio signal may be propagated in a specific direction, based on the straightness of the millimeter wave. The electronic device **101** of an embodiment may control the at least one antenna module and/or the at least one antenna array, based on beamforming, to propagate the radio signal toward an external electronic device (e.g., an access point (AP)) related to the wireless communication network **220**.

When the radio signal being based on the millimeter wave propagates between the electronic device **101** and an external electronic device, the radio signal may be attenuated by an obstacle between the electronic device **101** and the external electronic device. For example, when an external object **230** is located between the electronic device **101** and the external electronic device, the radio signal may be blocked or attenuated by the external object **230**. For example, the external object **230** may include a user of the electronic device **101**.

By using the at least one antenna module and/or the at least one antenna array, the electronic device **101** of various embodiments may detect the external object **230** adjacent to the electronic device **101**. In an embodiment, by adjusting a direction of a millimeter wave beam, based on beamforming, the electronic device **101** may detect the external object **230** adjacent to the electronic device **101**. In an embodiment, the electronic device **101** may detect a distance between the external object **230** and the electronic device **101**. As the electronic device **101** of various embodiments detects the external object **230** by using the at least one antenna module and/or the at least one antenna array, the electronic device **101** may detect the external object **230** located in a range of exceeding a range (e.g., a distance of less than 10 mm from the electronic device **101**) detectable by a proximity sensor, a grip sensor and/or an illuminance sensor.

The electronic device **101** of various embodiments may transmit a first radio signal through any one (e.g., the first antenna array **211** or the third antenna array **213**) of a plurality of antenna arrays, and may receive a second radio signal that corresponds to the first radio signal and is reflected from the external object **230**, through the other one (e.g., the second antenna array **212** or the fourth antenna array **214**) of the plurality of antenna arrays. In a state in which at least a part of the first radio signal transmitted through the first antenna array **211** or the third antenna array **213** is not reflected from the external object **230**, it may be directly received by the second antenna array **212** or the fourth antenna array **214** receiving the second radio signal. The electronic device **101** of various embodiments may control a plurality of antenna arrays, to minimize the influence of the first radio signal propagated directly to the second antenna array **212** or the fourth antenna array **214** receiving the second radio signal. Below, a description will be made for an operation performed by the electronic device **101** of various embodiments so as to minimize the influence of the first radio signal directly propagated to the second antenna array **212** or the fourth antenna array **214** receiving the second radio signal.

FIG. **3** illustrates a flowchart **300** for explaining an operation of an electronic device of various embodiments of the present disclosure. The electronic device of FIG. **3** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. The operation of FIG. **3** may be performed by at least one of the electronic device **101**, the processor **120**, and/or the communication module **190** of FIG. **1** to FIG. **2**.

Referring to FIG. **3**, in operation **310**, the electronic device of various embodiments may transmit a first radio signal by using a first antenna array (e.g., the first antenna array **211** of FIG. **2**). The first radio signal may be radiated to a space adjacent to the electronic device **101** based on an electromagnetic wave having directivity.

In an embodiment, the electronic device may transmit a first radio signal having a specified polarized wave by using the first antenna array. The polarized wave may mean an electromagnetic wave in which a vibration direction of an electric field is constant. In an embodiment, the first radio signal may be outputted through an electromagnetic wave having a specified polarized wave among a vertically-polarized wave, a horizontally-polarized wave, or a dual-polarized wave. The electronic device of various embodi-

ments may form a beam directed in a specified direction by using the first antenna array, and transmit the first radio signal through the beam. In an embodiment, the electronic device may control the first antenna array, based on information (e.g., codebook information) corresponding to a beam identifier corresponding to the specified direction, to transmit the first radio signal. When an external object (e.g., the external object **230** of FIG. **2**) is located in a space adjacent to the electronic device, the first radio signal may be reflected by the external object.

Referring to FIG. **3**, in operation **320**, the electronic device of various embodiments may receive a second radio signal that is a reflected signal of the first radio signal, by using a second antenna array (e.g., the second antenna array **212**, the third antenna array **213** or the fourth antenna array **214** of FIG. **2**). The second antenna array may be different from the first antenna array for transmitting the first radio signal of operation **310**. The second antenna array may be included in an antenna module (e.g., the first antenna module **197-1** of FIG. **2**) including the first antenna array, or may be included in another antenna module (e.g., the second antenna module **197-2**) different from the antenna module including the first antenna array.

The electronic device of an embodiment may receive the second radio signal that is the reflected signal of the first radio signal and has a specified polarized wave, by using the second antenna array different from the first antenna array. For example, when the first radio signal is transmitted through an electromagnetic wave having a horizontally-polarized wave, the electronic device may control the second antenna array to receive the electromagnetic wave having the horizontally-polarized wave, to receive the second radio signal. The electronic device may control the second antenna array, based on a direction of a beam used for transmission of the first radio signal, to receive the second radio signal. The direction of the beam of the second antenna array controlled by the electronic device may be different according to an embodiment. For example, the direction of the beam of the first antenna array and the direction of the beam of the second antenna array may coincide with each other or may be different from each other. An operation in which the electronic device of various embodiments adjusts the direction of the beam of the second antenna array will be described with reference to the following drawings (e.g., FIG. **5**, FIG. **7** and/or FIG. **9**).

Referring to FIG. **3**, in operation **330**, the electronic device of various embodiments may identify an external object around the electronic device, based on the second radio signal received in operation **330**. In an embodiment, the electronic device may identify the external object, based on an antenna gain of the second antenna array receiving the second radio signal. The antenna gain may mean a ratio between a power density in a radiation direction (e.g., boresight) of an antenna array and a power density of a reference antenna (e.g., an omni-directional antenna). The electronic device of various embodiments may determine whether an external object is located adjacent to the electronic device, based on the antenna gain of the second antenna array and/or a strength of the second radio signal.

Referring to FIG. **3**, in operation **340**, the electronic device of various embodiments may control the electronic device, based on a result of identifying the external object in operation **330**. In response to identifying the external object (e.g., the external object **230** of FIG. **2**), the electronic device of various embodiments may perform an operation corresponding to the identified external object. In an embodiment, in response to identifying the external object, the electronic device may display a user interface (UI) being based on the external object in a display. In an embodiment, in response to identifying the external object, the electronic device may adjust a beam used to communicate with a wireless communication network (e.g., the wireless communication network **220** of FIG. **2**). In an embodiment, in response to identifying the external object, the electronic device connected to any one of a plurality of APs included in the wireless communication network may connect (hand-over) to another AP different from the connected AP. In an embodiment, in response to identifying the external object, the electronic device may switch an access method used to connect to the wireless communication network (e.g., the wireless communication network **220** of FIG. **2**) (e.g., may switch from an access method based on a 5G wireless communication network to an access method based on an LTE communication network).

In an embodiment, an operation corresponding to the external object may include a wake-up operation of converting a state of the electronic device from a sleep state to an active state. In an embodiment, the active state may mean a state in which a processor (e.g., the processor **120** of FIG. **1** to FIG. **2**) of the electronic device receives a power greater than or equal to a normal power, a reference power, and/or a specified power. In an embodiment, the active state may mean a state in which the electronic device may display a UI through a display device, or execute one or more instructions in order to receive a user input through an input device. In an embodiment, the sleep state is a state different from the active state, and may mean a state in which the electronic device does not require booting so as to enter the active state. In an embodiment, the sleep state may mean a state in which the processor of the electronic device receives a power less than the normal power, the reference power, and/or the specified power. In an embodiment, the sleep state may include one or more of an inactive state, an idle state, a standby state, or a low power state.

In an embodiment, an operation corresponding to the external object may include an operation of controlling or adjusting a connection between an electronic device and a wireless network. For example, in a state of transmitting or receiving a third radio signal for communicating with a wireless network by using at least one of a plurality of antenna arrays (e.g., the first antenna array **211** or the second antenna array **212** of FIG. **2**), the electronic device may identify the external object, based on at least one of operations of FIG. **3**. In response to identifying the external object, the electronic device may adjust the third radio signal for communicating with the wireless network. For example, the electronic device may change a beam corresponding to the third radio signal or change a strength of the third radio signal.

FIG. **4**A illustrates a diagram for explaining the arrangement of antenna modules **197-1**, **197-2** and **197-3** in electronic devices **101-1**, **101-2**, and **101-3** according to various embodiments of the present disclosure. FIG. **4**B illustrates a diagram for explaining the arrangement of antenna modules **197-1**, **197-2** and **197-3** in electronic devices **101-1**, **101-2**, and **101-3** according to various embodiments of the present disclosure. FIG. **4**C illustrates a diagram for explaining the arrangement of antenna modules **197-1**, **197-2** and **197-3** in electronic devices **101-1**, **101-2**, and **101-3** according to various embodiments of the present disclosure. The electronic devices **101-1**, **101-2**, and **101-3** of FIG. **4**A to FIG. **4**C may be related to the electronic device **101** of FIG. **1** to FIG. **2**.

Referring to FIG. **4**A, the electronic device **101-1** of various embodiments may include a housing **410**. In an embodiment, the antenna modules **197-1**, **197-2** and **197-3** may be disposed in an internal space **420** of the electronic device **101-1** that is separated by the housing **410**. For example, the antenna modules **197-1**, **197-2**, and **197-3** may be disposed adjacent to a side surface of the housing **410** within the rectangular parallelepiped housing **410**.

In each of the antenna modules **197-1**, **197-2**, and **197-3**, one or more antenna arrays may be disposed. Referring to FIG. **4**A, a plurality of antenna arrays (the first antenna array **211** and the second antenna array **212**) disposed in the first antenna module **197-1** are illustrated. The first antenna array **211** may include a plurality of antenna elements (e.g., an antenna element **431**) formed in an array form. The second antenna array **212** may also include a plurality of antenna elements (e.g., an antenna element **432**) formed in an array form. The plurality of antenna elements may be disposed to be spaced a specified interval apart on a substrate of the first antenna module **197-1**. The specified interval may be related to a frequency and/or wavelength of a radio signal transmitted or received through the first antenna module **197-1**. For example, the specified interval may correspond to a half of the wavelength. The wavelength may be included in a millimeter wave wavelength band.

In an embodiment, the electronic device **101-1** may form a beam directed to an upper-side surface (e.g., +y direction) of the housing **410**, by using the second antenna array **212** of the first antenna module **197-1**. The electronic device **101-1** may form a beam directed to a front surface (e.g., +z direction) and/or rear surface (e.g., −z direction) of the housing **410**, by using the first antenna array **211** of the first antenna module **197-1**. In an embodiment, the electronic device **101-1** may form a beam directed to a right-side surface (e.g., +x direction) of the housing **410** and/or the beam directed to the front surface and/or rear surface of the housing **410**, by using at least one of antenna arrays of the second antenna module **197-2**. In an embodiment, the electronic device **101-1** may form a beam directed to a left-side surface (e.g., −x direction) of the housing **410** and/or the beam directed to the front surface and/or rear surface of the housing **410**, by using at least one of antenna arrays of the third antenna module **197-3**.

According to various embodiments of the present disclosure, a portion of the housing **410** adjacent to a portion of the internal space **420** in which the plurality of antenna modules **197-1**, **197-2** and **197-3** are disposed may be formed of other materials (e.g., a dielectric material) not a conductive material in order to prevent a deterioration of the radiation performance of the antenna module. The material of the portion of the housing **410** may be varied according to various embodiments of the present disclosure, and for example, in the portion of the housing **410**, a hole related to a beamforming direction may be formed, or a metal period structure (e.g., a metal grid) through which a beam is possible to pass may be formed.

In an embodiment, the antenna module may include a phase shifter (not shown). For example, the first antenna module **197-1** may include a plurality of phase shifters which correspond to the antenna arrays (e.g., the first antenna array **211** and the second antenna array **212**) and/or the plurality of antenna elements. Each of the plurality of phase shifters may adjust a beam direction, by delaying an output time of a radio signal of the corresponding antenna element.

For example, when a first beam directed in a +y direction is formed using the second antenna array **212**, the electronic device **101-1** may control the plurality of phase shifters corresponding to the plurality of antenna elements of the second antenna array **212** to have a phase delay. For example, the electronic device **101-1** may control each of the plurality of phase shifters to have a phase delay of 0 degree and/or 180 degrees.

For example, when a second beam rotated by 30 degrees from the +y direction to a left direction is formed using the second antenna array **212**, the electronic device **101-1** may control the plurality of phase shifters wherein a phase delay of the plurality of phase shifters increases by 30 degrees in the left direction. For example, the phase shifter corresponding to the antenna element **432** may have a phase delay of 90 degrees, and be controlled to have a phase delay of 60 degrees, 30 degrees, and 0 degree from a phase shifter of an antenna element close to the antenna element **432**, respectively.

For example, when a third beam rotated by 30 degrees from the +y direction to a right direction is formed using the second antenna array **212**, the electronic device **101-1** may control the plurality of phase shifters wherein a phase delay of the plurality of phase shifters increases by 30 degrees in the right direction. For example, the phase shifter corresponding to the antenna element **432** may have a phase delay of 0 degree, and be controlled to have a phase delay of 30 degrees, 60 degrees, and 90 degrees from a phase shifter of an antenna element close to the antenna element **432**, respectively.

The above-described first to third beams each may correspond to different beam identifiers. That the electronic device **101-1** controls the first antenna module **197-1** and/or the second antenna array **212**, based on any one of the first beam to the third beam, for example, may be performed for the transmission of the first radio signal of operation **310** of FIG. **3** or the reception of the second radio signal of operation **320** of FIG. **3**. Similarly to the above-described operation of controlling the first antenna module **197-1** and/or the second antenna array **212**, the electronic device **101-1** may control the second antenna module **197-2**, the third antenna module **197-3**, or the antenna arrays of the second antenna module **197-2** and third antenna module **197-3**.

Referring to FIG. **4**A, the first antenna module **197-1** to the third antenna module **197-3** may be disposed wherein the first antenna arrays **211** of the first antenna module **197-1** to the third antenna module **197-3** face the front surface or rear surface of the housing **410** in the internal space **420**. The arrangement of the first antenna module **197-1** to the third antenna module **197-3** in the internal space **420** may be different according to an embodiment. Referring to an embodiment of the electronic device **101-2** illustrated in FIG. **4**B, the first antenna module **197-1** to the third antenna module **197-3** may be disposed wherein the first antenna arrays **211** of the first antenna module **197-1** to the third antenna module **197-3** face the side surface of the housing **410** in the internal space **420**.

The first antenna module **197-1** to the third antenna module **197-3** may be disposed similarly in the electronic device **101-3** of a form of FIG. **4**C as well as a form such as the electronic device **101-1** of FIG. **4**A and the electronic device **101-2** of FIG. **4**B. Referring to FIG. **4**C, the first antenna arrays **211** of the first antenna module **197-1** and the second antenna module **197-2** may be disposed in the internal space of the electronic device **101-3** to face the +z direction of the electronic device **101-3** in which the display **450** is disposed. The first antenna array **211** of the third

antenna module **197-3** may be disposed in the internal space of the electronic device **101-3** to face the −y direction of the electronic device **101-3**.

When the electronic device **101-3** includes antenna modules disposed in the same direction (e.g., the +z direction of the electronic device **101-3**) such as the first antenna module **197-1** and the second antenna module **197-2** of FIG. **4**C, the electronic device **101-3** of an embodiment may decrease interference and/or performance degradation between the antenna modules while detecting an external object, in a state of controlling, based on the same beam, the antenna modules. An operation performed by the electronic device **101-3** by using the antenna modules disposed in the same direction will be described with reference to FIG. **7** to FIG. **8**.

FIG. **5** illustrates a flowchart **500** for explaining an operation of the electronic device **101** according to various embodiments of the present disclosure. The electronic device **101** of FIG. **5** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. The operation of FIG. **5** may be performed by at least one of the electronic device **101**, the processor **120**, and/or the communication module **190** of FIG. **1** to FIG. **2**. At least one of operations of FIG. **5** may be performed in relation to, or similar to, at least one of operations of FIG. **3**.

Referring to FIG. **5**, in operation **510**, the electronic device (e.g., the electronic device **101** of FIG. **2**) of various embodiments may transmit a first radio signal through a first beam directed in a first direction, by using a first antenna array (e.g., the first antenna array **211** of FIG. **2**). The electronic device of an embodiment may perform operation **510** similarly to operation **310** of FIG. **3**. When the electronic device of an embodiment includes a plurality of antenna modules (e.g., the first antenna module **197-1** to the second antenna module **197-2** of FIG. **2**), the electronic device may control a first antenna module among the plurality of antenna modules, and radiate an electromagnetic wave having a specified polarized wave (e.g., a horizontally-polarized wave), based on the first beam. The electromagnetic wave may be radiated in the first direction corresponding to the first beam. The electromagnetic wave may include the first radio signal.

Referring to FIG. **5**, in operation **520**, the electronic device of various embodiments may receive a second radio signal that is a reflected signal of the first radio signal, by using a second antenna array (e.g., the second antenna array **212**, the third antenna array **213**, or the fourth antenna array **214** of FIG. **2**). For example, the second radio signal may mean the first radio signal reflected from an external object adjacent to the electronic device. For example, the second radio signal may correspond to the first radio signal sequentially reflected from at least two external objects (e.g., a user and a wall) adjacent to the electronic device. The second radio signal may have the same polarized wave and/or the same wavelength as the first radio signal. The electronic device of an embodiment may perform operation **520** similarly to operation **320** of FIG. **3**. When the electronic device of an embodiment includes the plurality of antenna modules (e.g., the first antenna module **197-1** to the second antenna module **197-2** of FIG. **2**), the electronic device may control a second antenna module different from the first antenna module for transmitting the first radio signal, to receive the second radio signal.

In an embodiment, the electronic device may receive the second radio signal by using at least one beam formable within the second antenna array. The second antenna array may be included in the second antenna module for receiving the second radio signal. For example, the electronic device may transmit the first radio signal by using the first antenna array disposed toward a first surface of the housing. In this case, the electronic device may receive the second radio signal by using the second antenna array disposed toward a second surface of the electronic device that is different from the first surface. In an embodiment, the first antenna array and the second antenna array each may be included in the first antenna module and the second antenna module.

Referring to FIG. **5**, in operation **530**, the electronic device of various embodiments may identify a second beam in which a reception gain of the second radio signal is largest. The electronic device of an embodiment may identify the second beam by sequentially forming a plurality of beams formable in the second antenna array, based on, for example, beam sweeping. For example, the electronic device may identify the second beam in which a reception gain of the second radio signal is largest among a plurality of beams. The reception gain may be related to an antenna gain of the second antenna array.

Referring to FIG. **5**, in operation **540**, the electronic device of various embodiments may identify whether the electronic device is located in an indoor environment, based at least on the second beam. The electronic device of an embodiment may identify whether the electronic device is located in the indoor environment, based on a second direction corresponding to the second beam identified in operation **530**. For example, a direction (e.g., a first beam and/or a first direction) in which the electronic device transmits a first radio signal and a direction (e.g., a second beam and/or a second direction) in which the electronic device receives a second radio signal may be different from each other. The electronic device of an embodiment may determine that the electronic device is located in the indoor environment, in response to identifying the second beam directed in the second direction different from the first direction. In response to identifying the second beam, the electronic device of an embodiment may determine at least one of whether the electronic device is located in the indoor environment or whether the external object is adjacent to the electronic device. Hereinafter, an operation in which the electronic device of an embodiment detects a location of the electronic device and the external object by using a directional radio signal will be described with reference to FIG. **6**.

FIG. **6** illustrates a diagram for explaining an operation in which the electronic device **101** of various embodiments identifies external objects **230-1** and **230-2**. The electronic device **101** of FIG. **6** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. The electronic device **101** of FIG. **6** may perform at least one of operations of FIG. **3** and/or FIG. **5**.

Referring to FIG. **6**, the electronic device **101** of an embodiment may control the first antenna module **197-1** to transmit a first radio signal **620** through a first beam **610** propagated toward a front surface of the electronic device **101**. That the electronic device **101** transmits the first radio signal **620** may be performed, for example, based on operation **510** of FIG. **5**. As the first radio signal **620** is propagated toward the front surface of the electronic device **101**, based on the first beam **610**, the first radio signal **620** may reach the external object **230-1** adjacent to the front surface of the electronic device **101**. The external object **230-1** may correspond to, for example, a user.

The first radio signal **620** reaching the user may be reflected in one or more directions different from an incidence direction. Referring to FIG. **6**, a part of the first radio

signal **620** may be reflected in a direction **630** different from the incidence direction. The first radio signal **620** reflected along the direction **630** may reach the external object **230-2** different from the external object **230-1**. The external object **230-2** may mean, for example, a wall surface of a building, such as a ceiling.

Referring to FIG. **6**, the electronic device **101** of an embodiment may control the second antenna module **197-2** disposed in a different direction from the first antenna module **197-1**, to receive a second radio signal **640** corresponding to a reflected signal of the first radio signal **620**. That the electronic device **101** receives the second radio signal **640** may be performed, for example, based on operation **520** of FIG. **5**.

The electronic device **101** of an embodiment may receive the second radio signal **640**, by using at least one of a plurality of beams **652**, **654**, and **656** formable by the second antenna module **197-2**. The electronic device **101** of an embodiment may identify the beam **652** in which a gain of the second radio signal **640** is largest, based on, for example, operation **530** of FIG. **5**. The direction of the beam **652** may correspond to a direction of the second radio signal **640** reaching the second antenna module **197-2**.

In response to identifying the beam **652** and/or the second radio signal **640**, the electronic device **101** of an embodiment, for example, may determine whether the electronic device **101** is located indoors and/or whether the external object **230-1** is adjacent to the electronic device **101**, based on operation **540** of FIG. **5**. When the electronic device **101** receives a reflected signal of the first radio signal **620** by using only the first antenna module **197-1** for transmitting the first radio signal **620**, the first antenna module **197-1** may suffer from an error caused by a radio signal (e.g., a radio signal directly radiated from a transmission antenna array of the first antenna module **197-1** to a reception antenna array) other than the reflected signal. The electronic device **101** of an embodiment may prevent the error by using the first antenna module **197-1** and the second antenna module **197-2** directing in mutually different directions, while determining whether the electronic device **101** is located indoors and/or whether the external object **230-1** is adjacent to the electronic device **101**.

In an embodiment, when the electronic device **101** performs all of the transmission and reception of the radio signal by using the plurality of antenna modules, the electronic device **101** may adjust a strength of the radio signal in order to prevent the error. Hereinafter, an embodiment in which the electronic device **101** adjusts the strength of the radio signal will be described with reference to FIG. **7** to FIG. **8**.

FIG. **7** illustrates a flowchart **700** for explaining an operation of an electronic device according to various embodiments of the present disclosure. The electronic device of FIG. **7** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. The operation of FIG. **7** may be performed by at least one of the electronic device **101**, the processor **120** and/or the communication module **190** of FIG. **1** to FIG. **2**.

Referring to FIG. **7**, in operation **710**, the electronic device of various embodiments may control a first antenna array (e.g., the first antenna array **211** of FIG. **2**) within a specified power range, to transmit a first radio signal through a first beam directed in a first direction. The electronic device of an embodiment may control the first antenna array within a specified power range less than a specified first power of the first antenna array, to transmit the first radio signal through the first beam directed in the first direction. For example, the electronic device may control the first antenna array by power of less than 20 dB to 30 dB compared to the first power of the first antenna array, to transmit the first radio signal. In an embodiment, that the electronic device transmits the first radio signal based on operation **710** may be performed similarly to operation **310** of FIG. **3**.

Referring to FIG. **7**, in operation **720**, the electronic device of various embodiments may receive a second radio signal by using a second antenna array (e.g., the second antenna array **212** of FIG. **2**). When the electronic device of an embodiment transmits the first radio signal of operation **710** by using a first antenna array included in a specific antenna module, the electronic device may receive the second radio signal of operation **720** by using a second antenna array included in the specific antenna module. The second radio signal may mean a reflected signal of the first radio signal reflected by an external object. For example, the second radio signal may have the same polarized wave and/or the same wavelength as the first radio signal. In an embodiment, receiving the second radio signal by the electronic device based on operation **720** may be performed similarly to operation **320** of FIG. **3**.

An operation performed by the electronic device of an embodiment after the reception of the second radio signal based on operation **720** may be similar to at least one of operations **330** and **340** of FIG. **3**. For example, in response to the reception of the second radio signal, the electronic device may identify an external object or display a UI corresponding to the identified external object. As the electronic device of an embodiment transmits the first radio signal, based on the specified power range, the reception of a radio signal (e.g., a radio signal radiated directly from the first antenna array to the second antenna array) affecting the identification of the external object in addition to the second radio signal may be minimized. The specified power range may be determined heuristically in consideration of a gain of the radio signal directly radiated from the first antenna array to the second antenna array.

FIG. **8** illustrates a diagram for explaining an operation in which the electronic device **101** identifies an external object by using a beam of a specific direction according to various embodiments of the present disclosure. The electronic device **101** of FIG. **8** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. The electronic device **101** of FIG. **8** may correspond to any one (e.g., the electronic device **101-3**) of the electronic devices **101-1**, **101-2**, and **101-3** of FIG. **4A** to FIG. **4C**. The electronic device **101** of FIG. **8** may perform at least one of operations of FIG. **3** and/or FIG. **7**.

Referring to FIG. **8**, the first antenna array **211** and the second antenna array **212** included in one (e.g., a first antenna module **197-1** or a second antenna module **197-2**) of a plurality of antenna modules included in the electronic device **101** of an embodiment may be disposed toward the same direction (e.g., the front surface of the electronic device **101**). When detecting the external object by using the plurality of antenna arrays **211** and **212** disposed in the same direction, the electronic device **101** may fail to accurately detect the external object because of the reception of a radio signal other than a radio signal reflected from the external object.

For example, when the first antenna array **211** and the second antenna array **212** installed in the first antenna module **197-1** or the second antenna module **197-2** are disposed in the same direction, or an external object is detected using all of the first antenna module **197-1** and the second antenna module **197-2** disposed close to each other,

the electronic device **101** may receive a radio signal directed to the first antenna array **211** and/or the second antenna array **212** without being reflected from the external object. The radio signal may disturb that the electronic device **101** detects the external object.

Referring to FIG. **8**, in a state in which the electronic device **101** controls the first antenna array **211** and/or the second antenna array **212** of the first antenna module **197-1** based on the first power, a beam **810** formed by each of the first antenna array **211** and the second antenna array **212** may be the same. The electronic device **101** of an embodiment, for example, may control the first antenna array **211** and/or the second antenna array **212**, based on a specified second power range less than the first power (e.g., power less than 20 dB to 30 dB compared to the first power), based on operation **710** of FIG. **7**.

Referring to FIG. **8**, in a state in which the electronic device **101** controls the first antenna array **211** and/or the second antenna array **212** based on the specified second power range, a beam **815** formed by each of the first antenna array **211** and/or the second antenna arrays **212** may be the same. As each of the first antenna array **211** and/or the second antenna array **212** is controlled to be less than the first power, a size of the beam **815** may be less than a size of the beam **810** corresponding to the first power.

The electronic device **101** of an embodiment may transmit the first radio signal of operation **710** of FIG. **7** by using the beam **815**. In response to the transmission of the first radio signal, the electronic device **101** may receive the second radio signal of operation **720** of FIG. **7** by using the beam **815**. The electronic device **101** of an embodiment may independently control the first antenna array **211** and the second antenna array **212**. By controlling the first antenna array **211** and the second antenna array **212** by less than the first power, the electronic device **101** may decrease a radio signal directed to the first antenna array **211** and/or the second antenna array **212** without being reflected from the external object.

The above-mentioned description of FIG. **8** has been made for controlling the first antenna array **211** and the second antenna array **212** installed in one antenna module, but may be identically applied to when using the first antenna array **211** installed in the first antenna module **197-1** and the second antenna array **212** installed in the second antenna module **197-2** adjacent to each other. In this case, beams provided by the respective antenna array **211** and **212** may be slightly different.

In an embodiment, the electronic device **101** may detect the external object by using a plurality of antenna modules (e.g., the first antenna module **197-1** and the second antenna module **197-2**) disposed in the same direction. Hereinafter, an embodiment in which the electronic device **101** detects the external object by using the plurality of antenna modules will be described with reference to FIG. **9** and FIG. **10**A to FIG. **10**B.

FIG. **9** illustrates a flowchart **900** for explaining an operation of an electronic device according to various embodiments of the present disclosure. The electronic device of FIG. **9** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. The operation of FIG. **9** may be performed by at least one of the electronic device **101**, the processor **120**, and/or the communication module **190** of FIG. **1** to FIG. **2**. At least one of operations of FIG. **9** may be performed in relation to, or similar to, at least one of operations of FIG. **3**.

Referring to FIG. **9**, in operation **910**, the electronic device of various embodiments may transmit a first radio signal through a first beam directed in a first direction, by using a first antenna array (e.g., the first antenna array **211** of FIG. **2**). When the electronic device of an embodiment includes a plurality of antenna modules (e.g., the first antenna module **197-1** to the second antenna module **197-2** of FIG. **2**), a first antenna array may be included in a first antenna module among the plurality of antenna modules. The electronic device of an embodiment may perform operation **910** similarly to operation **310** of FIG. **3**.

Referring to FIG. **9**, in operation **920**, the electronic device of various embodiments may receive a second radio signal through a second beam directed in a second direction corresponding to the first direction, by using a second antenna array (e.g., the second antenna array **212**, the third antenna array **213**, or the fourth antenna array **214** of FIG. **2**). For example, the second radio signal may mean the first radio signal reflected from an external object adjacent to the electronic device. The second radio signal may have the same polarized wave and/or the same wavelength as the first radio signal of operation **910**. The electronic device of an embodiment may perform operation **920** similarly to operation **320** of FIG. **3**.

When the electronic device of an embodiment includes the plurality of antenna modules (e.g., the first antenna module **197-1** to the second antenna module **197-2** of FIG. **2**), a second antenna array may be included in a second antenna module different from the first antenna module including the first antenna array. The first antenna array (or the first antenna module) and the second antenna array (or the second antenna module) may be disposed to be spaced a specified distance apart in the electronic device. In an embodiment, the first antenna array (or the first antenna module) and the second antenna array (or the second antenna module) may be disposed in the same direction.

In an embodiment, the first direction of the first beam of the first antenna array of operation **910** and the second direction of the second beam of the second antenna array of operation **920** may not be parallel to each other. For example, the first beam directed in the first direction and the second beam directed in the second direction may be converged at one point in a space adjacent to the electronic device. Forms of the first beam and the second beam will be described with reference to FIG. **10**A to FIG. **10**B.

An operation performed by the electronic device of an embodiment after the receiving of the second radio signal based on operation **920** may be similar to at least one of operations **330** and **340** of FIG. **3**. For example, in response to the reception of the second radio signal, the electronic device may identify an external object or display a UI corresponding to the identified external object. In response to identifying the external object based on the second radio signal of operation **920**, the electronic device of an embodiment may acquire a distance between the electronic device and the external object, based on at least one of a distance between the first antenna array and the second antenna array, a first direction corresponding to a first radio signal, and a second direction corresponding to a second radio signal. Hereinafter, an operation in which the electronic device identifies the external object based on operation of FIG. **9** will be described with reference to FIG. **10**A to FIG. **10**B.

FIG. **10**A illustrates a diagram for explaining an operation in which the electronic device **101** of various embodiments identifies an external object based on beams of different directions. FIG. **10**B is a diagram for explaining an operation in which the electronic device **101** of various embodiments identifies an external object based on beams of different directions.

The electronic device **101** of FIG. **10**A to FIG. **10**B may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. The electronic device **101** of FIG. **10**A to FIG. **10**B may respond to any one (e.g., the electronic device **101-3**) of the electronic devices **101-1**, **101-2**, and **101-3** of FIG. **4**A to FIG. **4**C. The electronic device **101** of FIG. **10**A to FIG. **10**B may perform at least one of operations of FIG. **3** and/or FIG. **9**.

Referring to FIG. **10**A, two (e.g., the first antenna module **197-1** and the second antenna module **197-2**) of at least one of a plurality of antenna modules included in the electronic device **101** of an embodiment may be arranged in the same direction (e.g., the front surface of the electronic device **101**). The electronic device **101** of an embodiment, for example, may control each of the first antenna module **197-1** and the second antenna module **197-2**, based on operations of FIG. **9**.

As in FIG. **10**A, the electronic device **101** may control each of the first antenna module **197-1** and the second antenna module **197-2**, to form a pair of beams **1010** and **1020** converged at any one point in an adjacent space in the electronic device **101**. In an embodiment, in a state in which the electronic device **101** transmits the first radio signal of operation **910** of FIG. **9** by using the beam **1010** of the first antenna module **197-1**, the electronic device **101** may receive the second radio signal of operation **920** of FIG. **9** by using the beam **1020** of the second antenna module **197-2**.

According to an embodiment, the electronic device **101** may determine whether the external object is located in adjacent to the electronic device **101**, based on a reception gain of the second radio signal received using the beam **1020** and/or an antenna gain of the second antenna module **197-2**. The electronic device **101** of an embodiment may acquire a distance between the electronic device **101** and the external object, based on the reception gain of the second radio signal received using the beam **1020** and/or the antenna gain of the second antenna module **197-2**.

Referring to FIG. **10**B, the first antenna module **197-1** and the second antenna module **197-2** may be disposed to be separated as much as a specified distance (e.g., 2×a). When an angle (e.g., a beam angle) formed between each of the paired beams **1010** and **1020** and the housing of the electronic device **101** is 0, the shortest distance **1040** (*d*) between a point at which the beams **1010** and **1020** are converged and the electronic device **101** may be (a×tan θ). In a state of performing operations **910** and **920** of FIG. **9** by using the beams **1010** and **1020**, the electronic device **101** may determine a distance between the electronic device **101** and the external object, as "d," based on the reception of the second radio signal and/or a strength of the received second radio signal.

The electronic device **101** of an embodiment may control the first antenna module **197-1** and the second antenna module **197-2**, based on a beam identifier. The mutually different beam identifiers may correspond to mutually different directions (e.g., the beam angle (0)). The beam identifier, the beam angle, and the distance **1040** of the electronic device **101** may correspond to each other as shown in Table 1.

TABLE 1

Object recognition range/ distance (d)	Beam identifier (beam identifier of first antenna module 197-1 & beam identifier of second antenna module 197-2)	beam angle (θ)	Note
10 mm	#42 & #24	50°	Co-polarized wave (H pole)
	#156 & #152	50°	Co-polarized wave (V pole)
15 mm	#41 & #25	62°	Co-polarized wave (H pole)
	#167 & 170	65°	Co-polarized wave (V pole)
20 mm	#25 & #40	70°	Co-polarized wave (H pole)
	#168 & #169	72°	Co-polarized wave (V pole)

The electronic device **101** of an embodiment may control the first antenna module **197-1** and the second antenna module **197-2**, based on the above-described pair of beam identifiers. For example, the electronic device **101** may sequentially control the first antenna module **197-1** and the second antenna module **197-2**, from a pair of beam identifiers corresponding to a near distance (e.g., #42 & #24 corresponding to 10 mm) to a pair of beam identifiers corresponding to a far distance (e.g., #25 & #40 corresponding to 20 mm). When the reception gain of the received second radio signal and/or the antenna gain of the second antenna module **197-2** satisfy a specified condition or exceed a specified threshold in a specific pair of beam identifiers, the electronic device **101** may determine the distance between the external object and the electronic device **101**, as a distance corresponding to a specific beam identifier.

According to an embodiment, the distance between the identified external object and the electronic device **101**, for example, may be used to perform various operations related to the electronic device such as operation **340** of FIG. **3**. For example, the electronic device **101** may display a UI corresponding to the distance or may change the UI according to the distance. For example, the electronic device **101** may adjust a beam used to communicate with a wireless communication network, based on the distance, or perform switching between a plurality of APs of the wireless communication network. The switching may include hand-over between a plurality of APs (e.g., a plurality of APs of a 5G network, a first AP of a 5G network, and a second AP of an LTE network). As the electronic device **101** of various embodiments detects the external object by using one or more antenna modules such as the first antenna module **197-1** and the second antenna module **197-2**, the electronic device **101** may detect the external object in a greater range than that of when using a proximity sensor, a grip sensor, and/or an illuminance sensor.

FIG. **11** illustrates an exemplary diagram for explaining an operation in which a plurality of electronic devices **1100-1** and **1100-2** identify external objects **230-1** and **230-2** according to various embodiments of the present disclosure. The plurality of electronic devices **1100-1** and **1100-2** of FIG. **11** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. For example, the plurality of electronic devices **1100-1** and **1100-2** may be terminals carried by a user, or may include an access point installed in an indoor environment. The plurality of electronic devices **1100-1** and **1100-2** may support wireless communication that is based on a millimeter wave.

In an embodiment, the plurality of electronic devices **1100-1** and **1100-2** may communicate with each other, based on short-range communication. For example, the plurality of electronic devices **1100-1** and **1100-2** may be synchronized, based on short-range communication. The synchronization may include operating in operation modes (e.g., a transmission mode for a radio signal and/or a reception mode for the radio signal) that are different from each other in a specific time section and/or a specific moment. For example, while the first electronic device **1100-1** operates based on a transmission mode of transmitting a first radio signal **1120** for detecting the external object **230-1**, the second electronic device **1100-2** may operate based on a reception mode of receiving a second radio signal **1140** corresponding to a reflected signal of the first radio signal **1120**. The synchronization may include sharing a result in which the plurality of electronic devices **1100-1** and **1100-2** operate in operation modes different from each other.

In an embodiment, the plurality of electronic devices **1100-1** and **1100-2** may communicate with each other, based on a directional electromagnetic wave, such as a millimeter wave. Referring to FIG. **11**, an antenna module **1105-1** included in the first electronic device **1100-1** and an antenna module **1105-2** included in the second electronic device **1100-2** are illustrated. The antenna modules **1105-1** and **1105-2** may correspond to the first antenna module **197-1** of FIG. **2** and/or FIG. **4**A.

Referring to FIG. **11**, the first electronic device **1100-1** may control the antenna module **1105-1**, to transmit the first radio signal **1120** through a first beam **1110**. For example, the first radio signal **1120** may have a frequency included in a millimeter wave band. The first radio signal **1120** may reach the first external object **230-1** adjacent to the first electronic device **1100-1**. The first external object **230-1** may correspond to, for example, a user.

The first radio signal **1120** reaching the user may be reflected in one or more directions different from an incidence direction. Referring to FIG. **11**, for example, a part of the first radio signal **1120** may be reflected in a direction **1130** different from the incidence direction. The first radio signal **1120** reflected along the direction **1130** may reach the second external object **230-2** that is different from the first external object **230-1**. The second external object **230-2**, for example, may mean a wall surface of a building, such as a ceiling.

According to an embodiment, while the first electronic device **1100-1** transmits the first radio signal **1120** toward the first external object **230-1**, the second electronic device **1100-2** may control the antenna module **1105-2**, to receive the second radio signal **1140** corresponding to the reflected signal of the first radio signal **1120**. For example, the second electronic device **1100-2** may receive the second radio signal **1140** by using at least one of a plurality of beams **1152**, **1154**, and **1156** formed using the antenna module **1105-2**. The second electronic device **1100-2** may identify the beam **1152** in which a gain of the second radio signal **1140** is largest. A direction of the beam **1152** may correspond to a direction of the second radio signal **1140** reaching the second antenna module **1105-2**.

In an embodiment, an operation in which the first electronic device **1100-1** transmits the first radio signal **1120** through the antenna module **1105-1** may be carried out similarly to an operation in which the electronic device **101** of FIG. **6** transmits the first radio signal **620** through the first antenna module **197-1**. In an embodiment, an operation in which the second electronic device **1100-2** receives the second radio signal **1140** through the antenna module **1105-2** may be performed similarly to an operation in which the electronic device **101** of FIG. **6** receives the second radio signal **640** through the second antenna module **197-2**. According to an embodiment, in response to the identification of the beam **1152** and/or the second radio signal **1140**, the second electronic device **1100-2** may determine whether the plurality of electronic devices **1100-1** and **1100-2** are located indoors and/or whether the first external object **230-1** is adjacent to the first electronic device **1100-1**. Hereinafter, an operation in which the plurality of electronic devices **1100-1** and **1100-2** communicate with each other and identify the first external object **230-1** will be described with reference to FIG. **12**.

FIG. **12** illustrates a flowchart for explaining an operation performed by a plurality of electronic devices **1100-1** and **1100-2** according to various embodiments of the present disclosure. The plurality of electronic devices **1100-1** and **1100-2** of FIG. **12** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**. The plurality of electronic devices **1100-1** and **1100-2** of FIG. **12** may correspond to the plurality of electronic devices **1100-1** and **1100-2** of FIG. **11**, respectively.

Referring to FIG. **12**, in operations **1205** and **1210**, the plurality of electronic devices **1100-1** and **1100-2** may be synchronized with each other. The synchronization of the plurality of electronic devices **1100-1** and **1100-2** may include, for example, an operation in which the plurality of electronic devices **1100-1** and **1100-2** each enter operation modes different from each other. For example, the first electronic device **1100-1** may enter a signal transmission mode of transmitting a radio signal for detecting an external object (e.g., the first external object **230-1** of FIG. **11**). For example, the second electronic device **1100-2** may enter a signal reception mode of receiving a reflected signal of the radio signal for detecting the external object. A time section and/or a time period during which the first electronic device **1100-1** operates in the signal transmission mode may coincide with a time section and/or a time period during which the second electronic device **1100-2** operates in the signal reception mode.

According to various embodiments of the present disclosure, the synchronization operation may be possible any time in course of performing mmWave communication, and the synchronization operation may also be performed using another communication method having a less possibility of causing the blockage of a signal due to an object, in addition to the mmWave communication. For example, the synchronization operation between the plurality of electronic devices **1100-1** and **1100-2** may be performed using a communication scheme such as Bluetooth, WiFi, or LTE. As another example, ID information of a beam used for an operation for detecting an object during the synchronization operation may be exchanged between the plurality of electronic devices **1100-1** and **1100-2**.

According to various embodiments of the present disclosure, when the first electronic device **1100-1** is an AP or a small base station, and the second electronic device **1100-2** is a terminal, the first electronic device **1100-1** and the second electronic device **1100-2** may detect, without the synchronization operation, the external object, based on a signal transmitted from the counterpart in a partial section of the communication. In this case, the synchronization operations **1205** and **1210** may be omitted.

Referring to FIG. **12**, in operations **1215** and **1220**, the plurality of electronic devices **1100-1** and **1100-2** may perform an operation of searching for the external object, based on a specified period. In operations **1225** and **1230**, the

plurality of electronic devices **1100-1** and **1100-2** may identify an identifier of a blocked beam. For example, when there are one or more external objects adjacent to the plurality of electronic devices **1100-1** and **1100-2** such as the external objects **230-1** and **230-2** of FIG. **11**, a radio signal being based on a specific beam (e.g., a beam whose beam identifier is N) may be blocked by the external object. When the blocked beam does not exist (**1225**—No, **1230**—No), the plurality of electronic devices **1100-1** and **1100-2** may perform an operation of searching for the external object, based on operations **1215** and **1220**.

When the blocked beam exists (**1225**—Yes), in operation **1235**, the first electronic device **1100-1** may obtain a change of a strength of a radio signal, based on the blocked beam. When the strength of the radio signal does not change (**1235**—No), the first electronic device **1100-1** may perform the operation of searching for an external object, based on operation **1215**. When the strength of the radio signal changes (**1235**—Yes), in operation **1245**, the first electronic device **1100-1** may measure a magnitude of the radio signal, based on an antenna gain (e.g., Rx AGC) corresponding to the changed radio signal. In operation **1255**, the first electronic device **1100-1** may determine whether a human body (e.g., the first external object **230-1** of FIG. **11**) has been obtained, based on the measured size of the radio signal. When the human body has not been obtained (**1255**—No), the first electronic device **1100-1** may perform the operation of searching for an external object, based on operation **1215**.

When the blocked beam exists (**1230**—Yes), in operation **1240**, the second electronic device **1100-2** may determine whether a radio signal being based on the blocked beam has been lost. When the radio signal based on the blocked beam has been lost (**1240**—Yes), in operation **1250**, the second electronic device **1100-2** may measure a magnitude of the radio signal (e.g., the reflected signal reflected from the external object), based on an antenna gain corresponding to the lost radio signal. When the radio signal based on the blocked beam has not been lost (**1240**—NO), in operation **1252**, the second electronic device **1100-2** may obtain a change of a received signal strength indicator (RSSI) of the radio signal.

In operation **1260**, the second electronic device **1100-2** may determine whether a human body (e.g., the external object **230-1** of FIG. **11**) has been obtained, based on at least one of the magnitude of the radio signal measured in operation **1250** and the change of the RSSI obtained in operation **1252**. When the human body has not been obtained (**1260**—No), the second electronic device **1100-2** may perform an operation of searching for an external object, based on operation **1220**.

When the human body has been obtained (**1255**—Yes, **1260**—Yes), in operations **1265** and **1270**, the plurality of electronic devices **1100-1** and **1100-2** may execute a specified function, based on the result of obtaining the human body. In an embodiment, the plurality of electronic devices **1100-1** and **1100-2** may perform operations **1265** and **1270** similarly to operation **340** of FIG. **3**. For example, at least one of the plurality of electronic devices **1100-1** and **1100-2** may display a UI that is based on the obtained human body. In an embodiment, in response to the identification of the human body, at least one of the plurality of electronic devices **1100-1** and **1100-2** may adjust a beam used to communicate with a wireless communication network.

FIG. **13** illustrates an exemplary diagram for explaining an operation in which the electronic device **101** communicates with at least one of a plurality of base stations **1320** and **1330** according to various embodiments of the present disclosure. The electronic device **101** of FIG. **13** may correspond to the electronic device **101** of FIG. **1** to FIG. **2**.

Referring to FIG. **13**, the electronic device **101** of various embodiments may communicate with one or more nearby base stations (e.g., the first base station **1320** and/or the second base station **1330**). For example, the first base station **1320** may be installed in an indoor environment **1310**. For example, the second base station **1330** may be installed in an outdoor environment different from an indoor environment **1310**. That the electronic device **101** communicates with one or more base stations may be performed, for example, based on a radio signal having a frequency (e.g., Freq**1** and/or Freq**2**) included in a directional millimeter wave band. When the first external object **230-1** such as a user exists between the electronic device **101** and the base station (e.g., the first base station **1320** or the second base station **1330**), the radio signal of the directional millimeter wave band may be blocked and/or attenuated.

According to an embodiment, the electronic device **101** may identify the first external object **230-1** existing between the electronic device **101** and the base station (e.g., the first base station **1320** or the second base station **1330**), based on the blocking and/or attenuation of the radio signal. When the electronic device **101** simultaneously communicates with the plurality of base stations such as the first base station **1320** and the second base station **1330**, the electronic device **101** of an embodiment may identify the first external object **230-1**, based on the strengths of a plurality of radio signals each corresponding to the plurality of base stations.

In an embodiment, the electronic device **101** may determine whether the electronic device **101** is included in the indoor environment **1310**, based on the attenuation of a first radio signal corresponding to the first base station **1320** and/or the attenuation of a second radio signal corresponding to the second base station **1330**. For example, as the electronic device **101** is moved to the indoor environment **1310** by the user, the second radio signal corresponding to the second base station **1330** received by the electronic device **101** may be attenuated. In response to the identification of the attenuation of the second radio signal, the electronic device **101** may determine that the electronic device **101** has entered the indoor environment **1310**.

In an embodiment, the electronic device **101** may compare the degree of attenuation of the first radio signal and the degree of attenuation of the second radio signal, and determine whether the electronic device **101** has entered the indoor environment **1310**. For example, as the electronic device **101** is moved to the indoor environment **1310** by the user, a magnitude of the second radio signal corresponding to the second base station **1330** received by the electronic device **101** may decrease, and a magnitude of the first radio signal corresponding to the first base station **1320** received by the electronic device **101** may increase. In response to the identification of the attenuated second radio signal and the increased first radio signal, the electronic device **101** may determine that the electronic device **101** has entered the indoor environment **1310**.

In an embodiment, when the electronic device **101** exists in the indoor environment **1310**, the electronic device **101** may identify a location of the electronic device **101** in the indoor environment **1310**, based on the strength of the signal reflected by the external object **230-1**. For example, the electronic device **101** may identify whether the electronic device **101** exists in any one of Section B or Section C.

For example, when the electronic device **101** is located in Section B and communicates with the first base station **1320** without an obstacle (e.g., the first external object **230-1**), the

electronic device **101** may simultaneously receive the first radio signal corresponding to the first base station **1320** and a reflected signal of the first radio signal reflected from the first external object **230-1**. In this case, the electronic device **101** may distinguish the first radio signal directly received from the first base station **1320** and the reflected signal, thereby determining that the electronic device **101** is located in Section B of the indoor environment **1310**.

For example, when the electronic device **101** is located in Section C and an obstacle (e.g., the first external object **230-1**) exists between the electronic device **101** and the first base station **1320**, the electronic device **101** may receive a reflected signal of the first radio signal reflected from the first external object **230-1**. In this case, the electronic device **101** may determine that the electronic device **101** is located in Section C of the indoor environment **1310**, based on the received reflected signal.

FIG. **14** illustrates a flowchart **1400** for explaining an operation performed by the electronic device **101** according to various embodiments of the present disclosure. The electronic device **101** of FIG. **14** may correspond to the electronic device **101** of FIG. **1** to FIG. **2** to the electronic device **101** of FIG. **13**.

Referring to FIG. **14**, in operation **1405**, the electronic device **101** of various embodiments may enter a specified operation mode (e.g., a user location detection mode) for detecting a user's location. For example, the electronic device **101** may enter an operation mode for detecting an external object (e.g., the external object **230-1** of FIG. **12**) similarly to operations **1205** and **1210** of FIG. **12**.

Referring to FIG. **14**, in operation **1410**, the electronic device **101** of various embodiments may perform an operation of searching for an external object, based on a specified period. In operation **1415**, the electronic device **101** of various embodiments may identify an identifier of a blocked beam. The electronic device **101** may perform operations **1410** and **1415** similarly to operations **1215**, **1220**, **1225**, and **1230** of FIG. **12**. When the blocked beam does not exist (**1415**—No), the electronic device **101** of an embodiment may perform the operation of periodically searching for an external object according to operation **1410**.

When the blocked beam (e.g., beam ID #N) exists (**1415**—Yes), in operation **1420**, the electronic device **101** of various embodiments may additionally determine whether another beam is blocked in order to increase the reliability of blocking. In an embodiment, the electronic device **101** may check whether even another beam ID (e.g., beam ID #M) within the same or similar range is blocked, or may again verify whether beam ID #N or beam ID #M is blocked even in another antenna array or another antenna module, to increase the reliability of blocking.

When even another beam ID has been blocked (**1420**—Yes), in operation **1425**, the electronic device **101** of various embodiments may obtain an RSSI change of a radio signal. For example, the electronic device **101** may obtain an RSSI change of a radio signal received from the second base station **1330** that is located outdoors and is different from the indoor environment **1310** of FIG. **13**.

When the RSSI change has not been obtained (**1425**—NO), in operation **1430**, the electronic device **101** of various embodiments may determine that the electronic device **101** is located outdoors as in Section A of FIG. **13**.

When the RSSI change has been obtained (**1425**—Yes), in operation **1435**, the electronic device **101** of various embodiments may measure a reflected signal. The reflected signal is based on a radio signal radiated from the first base station **1330** and/or the electronic device **101** of FIG. **13**, and may mean a reflected signal reflected by the first external object **230-1**. For example, the measuring of the reflected signal may include measuring a reception antenna gain (RX AGC).

When the reflected signal has not been measured (**1435**—NO), in operation **1440**, the electronic device **101** of various embodiments may determine that the electronic device **101** is located in Section B of FIG. **13** in which no obstacle (e.g., the first external object **230-1** of FIG. **13**) exists between the electronic device **101** and the base station (e.g., the first base station **1320** of FIG. **13**).

When the reflected signal has been measured (**1435**—Yes), in operation **1445**, the electronic device **101** of various embodiments may determine that the electronic device **101** is located in Section C of FIG. **13** in which an obstacle (e.g., the first external object **230-1** of FIG. **13**) exists between the electronic device **101** and the base station.

Referring to FIG. **14**, in operation **1450**, the electronic device **101** of various embodiments may determine an event related to the location of the electronic device **101**, based on the result of determining the identified location (e.g., Section A, Section B, or Section C of FIG. **13**) of the electronic device **101**. When the determined event does not exist (**1450**—No), the electronic device **101** of an embodiment may perform the operation of searching for an external object as in operation **1410**.

When the determined event exists (**1450**—Yes), in operation **1455**, the electronic device **101** of various embodiments may perform the determined event. The electronic device **101** of an embodiment may perform operation **1455** similarly to operation **340** of FIG. **3**. For example, the electronic device **101** may display a UI being based on the obtained external object. For example, in response to obtaining the external object, the electronic device **101** may adjust a beam used to communicate with a wireless communication network.

Hereinafter, an operation of identifying the first external object **230-1** in further consideration of a form of the electronic device **101** when the electronic device **101** is a foldable electronic device including a housing deformable by an external force will be described with reference to FIG. **15** to FIG. **18**.

FIG. **15** illustrates an exemplary diagram for explaining an operation in which the electronic device **101-4** detects the first external object **230-1** according to an embodiment. The electronic device **101-4** of FIG. **15** may be related to the electronic device **101** of FIG. **1** to FIG. **2**. The electronic device **101-4** of an embodiment may include a flexible display. The electronic device **101-4** may include a plurality of housings connected by one or more hinges making possible the bending, folding, and/or rolling of the flexible display. FIG. **15** illustrates an embodiment of the electronic device **101-4** having the plurality of housings (e.g., a first housing **1505-1** and a second housing **1505-2**) connected by the hinge disposed along a center axis of the flexible display.

Referring to FIG. **15**, the electronic device **101-4** of an embodiment may include antenna modules (e.g., a first antenna module **1510** and a second antenna module **1520**). The antenna modules **1510** and **1520** may correspond to at least one of the antenna modules **197-1**, **197-2** and **197-3** of FIG. **2**. The antenna modules **1510** and **1520** may be disposed in an internal space of the electronic device **101-4** distinguished by the housing. For example, the first antenna module **1510** may be disposed in the first housing **1505-1** of the electronic device **101-4**, and the second antenna module **1520** may be disposed in the second housing **1505-2** of the electronic device **101-4**.

The electronic device **101-4** of an embodiment may form a beam directed in a specific direction by using the first antenna module **1505-1**. The electronic device **101-4** may radiate a first radio signal **1530** through the first antenna module **1510**, based on the formed beam. While radiating the first radio signal **1530**, the electronic device **101-4** may control the second antenna module **1520** to search for a reflected signal of the first radio signal **1530**. For example, when the first external object **230-1** such as a user exists adjacent to the electronic device **101-4**, the first radio signal **1530** may be reflected by the first external object **230-1**. For example, the reflected signal of the first radio signal **1530** reflected from the first external object **230-1** may be radiated in a direction **1540** and then be reflected by the second external object **230-2** and radiated toward the antenna module **1520**. For example, a second radio signal **1550** may mean the reflected signal of the first radio signal **1530** reflected by the second external object **230-2** and radiated toward the second antenna module **1520**.

The electronic device **101-4** of an embodiment may control the second antenna module **1520** to receive the second radio signal **1550** corresponding to the reflected signal of the first radio signal **1530**. The second radio signal **1550** may be received based on any one of a plurality of beams formable by the second antenna module **1520**. The electronic device **101-4** may identify a beam in which a gain of the second radio signal **1550** is largest, from among the plurality of beams formable by the second antenna module **1520**. A direction of the identified beam may correspond to a direction of the second radio signal **1550** reaching the second antenna module **1520**.

In response to the second radio signal **1550** and the identification of the beam, the electronic device **101-4** of an embodiment may determine whether the electronic device **101-4** is located indoors and/or whether the first external object **230-1** is adjacent to the electronic device **101-4**. Hereinafter, an operation of determining whether the electronic device **101-4** is located indoors based on the first antenna module **1510** and the second antenna module **1520** and/or whether the first external object **230-1** is adjacent to the electronic device **101-4** will be described with reference to FIG. **16**.

FIG. **16** illustrates a flowchart **1600** illustrating an operation performed by the electronic device **101-4** according to various embodiments of the present disclosure. The electronic device **101-4** of FIG. **16** may correspond to the electronic device **101-4** of FIG. **15**. For example, at least one of the operations of FIG. **16** may be performed by the electronic device **101-4** of FIG. **15**.

Referring to FIG. **16**, in operation **1605**, the electronic device **101-4** of an embodiment may enter a specified operation mode (e.g., a user location detection mode) for detecting a user's location. For example, the electronic device **101-4** may perform operation **1605** similarly to operation **1405** of FIG. **14**. Upon entering the specified operation mode, the electronic device **101-4** may perform at least one operation for detecting an external object (e.g., the external objects **230-1** and **230-2** of FIG. **15**).

Referring to FIG. **16**, in operation **1610**, the electronic device **101-4** of an embodiment may perform an operation of searching for an external object, based on a specified period. In operation **1615**, the electronic device **101-4** of an embodiment may identify an identifier of a blocked beam. The electronic device **101-4** may perform operations **1610** and **1615** similarly to operations **1410** and **1415** of FIG. **14**. When the blocked beam does not exist (**1615**—No), the electronic device **101-4** of an embodiment may perform the operation of detecting an external object, based on operation **1610**.

When the blocked beam exists (**1615**—Yes), in operation **1620**, the electronic device **101-4** of an embodiment may determine whether a radio signal being based on the blocked beam has been lost. The electronic device **101-4** of an embodiment may perform operation **1620** similarly to operation **1240** of FIG. **12**. When the radio signal being based on the blocked beam has been lost (**1620**—Yes), in operation **1625**, the electronic device **101-4** of an embodiment may measure a magnitude of a reflected signal (e.g., the second radio signal **1550** of FIG. **15**) corresponding to the lost radio signal. For example, the electronic device **101-4** may measure the magnitude of the reflected signal, based on a reception antenna gain (e.g., #M RX AGC) in the beam identifier corresponding to the reflected signal. When the radio signal being based on the blocked beam has not been lost (**1620**—NO), in operation **1630**, the electronic device **101-4** of an embodiment may detect a change of an RSSI of the radio signal. The electronic device **101-4** of an embodiment may perform operation **1630** similarly to operation **1252** of FIG. **12**.

Referring to FIG. **16**, in operation **1635**, the electronic device **101-4** of an embodiment may determine whether a human body (e.g., the first external object **230-1** of FIG. **15**) is detected, based on at least one of the magnitude of the reflected signal measured according to operation **1625** or the change of the RSSI of the radio signal obtained according to operation **1630**. When the human body has not been obtained (**1635**—NO), the electronic device **101-4** may perform an operation of detecting an external object, based on operation **1610**.

When the human body has been obtained (**1635**—Yes), in operation **1640**, the electronic device **101-4** of an embodiment may execute a specified function, based on the result of obtaining the human body. The electronic device **101-4** of an embodiment may perform operation **1640** similarly to operation **340** of FIG. **3**. For example, the electronic device **101-4** may display a UI being based on the obtained human body. For example, the electronic device **101-4** may form a beam in a direction not blocked by the human body, and communicate with another electronic device and/or a base station.

FIG. **17** illustrates an exemplary diagram for explaining an operation in which the electronic device **101-4** detects an external object **230-1** according to an embodiment. The electronic device **101-4** of FIG. **17** may be related to the electronic device **101** of FIG. **1** to FIG. **2**. The electronic device **101-4** of FIG. **17** may correspond to the electronic device **101-4** of FIG. **15**. For example, one or more constituent elements (e.g., a first antenna module **1510**, a second antenna module **1520**, a first housing **1505-1** and a second housing **1505-2**) included in the electronic device **101-4** of FIG. **17** may coincide with the constituent elements included in the electronic device **101-4** of FIG. **15**.

According to an embodiment, the electronic device **101-4** may identify the external object **230-1** in further consideration of even a form of the electronic device **101-4** deformed by an external force. Referring to FIG. **17**, as the first housing **1505-1** and the second housing **1505-2** are folded centering on a hinge, a distance between the first antenna module **1510** and the second antenna module **1520** may be changed to (2×a). The electronic device **101-4** of an embodiment may include a hardware component capable of detecting the form of the electronic device **101-4**, such as a bending sensor. For example, the electronic device **101-4**

may identify the distance (2×a) between the first antenna module **1510** and the second antenna module **1520**, based on the bending sensor.

The electronic device **101-4** of an embodiment may form a beam **1710** in a specified direction by using the first antenna module **1510**, and transmit a first radio signal, based on the formed beam **1710**. When the first radio signal is reflected by the first external object **230-1**, the electronic device **101-4** may receive a second radio signal that is a reflected signal of the first radio signal, by using the second antenna module **1520**. For example, the electronic device **101-4** may receive the second radio signal, based on a beam **1730** formed in a direction different from the beam **1710** corresponding to the first radio signal.

The electronic device **101-4** of an embodiment may identify an angle (θ) formed between the beam and an axis connecting the first antenna module **1510** and the second antenna module **1520**, based on the beam **1710** related to the transmission of the first radio signal and the beam **1730** related to the reception of the second radio signal. The electronic device **101-4** of an embodiment may acquire a distance (d) between the axis and the first external object **230-1**, based on the identified angle (θ) and the distance (2×a) between the first antenna module **1510** and the second antenna module **1520**. For example, the (d) may be (a×tan θ). The electronic device **101-4** may determine a distance between the first external object **230-1** and the electronic device **101-4** and/or whether the external object **230-1** exists, based on the acquired (d). Hereinafter, operations performed by the electronic device **101-4** of FIG. **17** will be described with reference to FIG. **18**.

FIG. **18** illustrates a flowchart **1800** for explaining an operation performed by the electronic device **101-4** according to an embodiment of the present disclosure. The electronic device **101-4** of FIG. **18** may correspond to the electronic device **101-4** of FIG. **17**. For example, at least one of operations of FIG. **18** may be performed by the electronic device **101-4** of FIG. **17**.

Referring to FIG. **18**, in operation **1805**, the electronic device **101-4** of an embodiment may enter a specified operation mode (e.g., a user location detection mode) for detecting a user's location. For example, the electronic device **101-4** may perform operation **1805** similarly to operation **1405** of FIG. **14** and/or operation **1605** of FIG. **16**. As entering the specified operation mode, the electronic device **101-4** may perform at least one operation for detecting an external object (e.g., the first external object **230-1** of FIG. **17**).

Referring to FIG. **18**, in operation **1810**, the electronic device **101-4** of an embodiment may perform an operation of searching for an external object, based on a specified period. In operation **1815**, the electronic device **101-4** of an embodiment may identify an identifier of a blocked beam. The electronic device **101-4** may perform operations **1805** and **1810** similarly to operations **1410** and **1415** of FIG. **14** and/or operations **1610** and **1615** of FIG. **16**. When the blocked beam does not exist (**1815**—No), the electronic device **101-4** of an embodiment may perform the operation of searching for an external object, based on operation **1810**.

If the blocked beam exists (**1815**—Yes), in operation **1820**, the electronic device **101-4** of an embodiment may determine whether a radio signal being based on the blocked beam has been lost. The electronic device **101-4** of an embodiment may perform operation **1820** similarly to operation **1240** of FIG. **12** and/or operation **1620** of FIG. **16**. When the radio signal being based on the blocked beam has not been lost (**1820**—No), in operation **1835**, the electronic device **101-4** of an embodiment may obtain a change of an RSSI of the radio signal. The electronic device **101-4** of an embodiment may perform operation **1835** similarly to operation **1252** of FIG. **12** and/or operation **1630** of FIG. **16**.

When the radio signal being based on the blocked beam has been lost (**1820**—Yes), in operation **1825**, the electronic device **101-4** of an embodiment may identify a folding angle (e.g., an angle formed by the first housing **1505-1** and the second housing **1505-2** of FIG. **17**) of the electronic device **101-4**. The electronic device **101-4** of an embodiment may identify a beam identifier of a reflected signal (e.g., the beam identifier of the reflected signal received by the second antenna module **1520** of FIG. **17**). In operation **1830**, the electronic device **101-4** of an embodiment may measure a magnitude of the reflected signal (e.g., the radio signal received by the second antenna module **1520** of FIG. **17**) corresponding to the lost radio signal. For example, the electronic device **101-4** may measure the magnitude of the reflected signal, based on a reception antenna gain (e.g., #M RX AGC) in a beam identifier corresponding to the reflected signal.

Referring to FIG. **18**, in operation **1840**, the electronic device **101-4** of an embodiment may determine whether a human body (e.g., the external object **230-1** of FIG. **17**) has been obtained, based on at least one of the magnitude of the reflected signal measured in operation **1830**, the folding angle of the electronic device **101-4**, and/or the change of the RSSI of the radio signal obtained according to operation **1835**. When the human body has not been obtained (**1840**—NO), the electronic device **101-4** of an embodiment may perform an operation of searching for an external object, based on operation **1810**.

When the human body has been obtained (**1840**—Yes), in operation **1845**, the electronic device **101-4** of an embodiment may execute a specified function, based on the result of obtaining the human body. The electronic device **101-4** of an embodiment may perform operation **1845** similarly to operation **340** of FIG. **3**. For example, the electronic device **101-4** may display a UI that is based on the obtained human body. For example, the electronic device **101-4** may form a beam in a direction not blocked by the human body, and communicate with another electronic device and/or a base station.

As described above, an electronic device (e.g., the electronic device **101** of FIG. **1** to FIG. **2**) of various embodiments may include a plurality of antenna arrays (e.g., the first antenna array **211** or the second antenna array **212** of FIG. **2**), and at least one processor (e.g., the processor **120** of FIG. **1** or FIG. **2**) operatively connected to the plurality of antenna arrays. The at least one processor may transmit a first radio signal (e.g., the first radio signal **620** of FIG. **6**) having a specified polarized wave by using a first antenna array (e.g., the first antenna array **211** of FIG. **2**) among the plurality of antenna arrays, receive a second radio signal (e.g., the second radio signal **640** of FIG. **6**) that is a reflected signal of the first radio signal and has the specified polarized wave, by using a second antenna array (e.g., the second antenna array **212** of FIG. **2**) different from the first antenna array among the plurality of antenna arrays, and identify an external object (e.g., the external object **230** of FIG. **2** and/or the external objects **230-1** and **230-2** of FIG. **6**) around the electronic device, based on the second radio signal.

According to an embodiment, the at least one processor may transmit the first radio signal through a first beam directed in a first direction by using the first antenna array, receive the second radio signal by using at least one beam formable within the second antenna array, identify a second

beam in which a reception gain of the second radio signal is largest from among the at least one beam, and identify whether the electronic device is located in an indoor environment, based on a second direction corresponding to the second beam.

According to an embodiment, the at least one processor may transmit the first radio signal by using the first antenna array disposed toward a first surface of the electronic device, and receive the second radio signal by using the second antenna array disposed toward a second surface of the electronic device different from the first surface.

According to an embodiment, the at least one processor may, in response to identifying the second beam directed in the second direction different from the first direction, determine that the electronic device is located in the indoor environment.

According to an embodiment, the at least one processor may control the first antenna array within a specified power range less than a specified first power of the first antenna array, to transmit the first radio signal through the first beam directed in the first direction, and receive the second radio signal through the first beam directed in the first direction by using the second antenna array.

According to an embodiment, the at least one processor may transmit the first radio signal by using the first antenna array included in an antenna module included in the electronic device, and receive the second radio signal by using the second antenna array included in the antenna module.

According to an embodiment, the at least one processor may transmit the first radio signal through the first beam directed in the first direction by using the first antenna array, and receive the second radio signal through the second beam directed in the second direction corresponding to the first direction by using the second antenna array.

According to an embodiment, the first antenna array and the second antenna array may be disposed to be spaced a specified distance apart from each other in the electronic device, and in response to identifying the external object, the at least one processor may acquire a distance between the electronic device and the external object, based on at least one of the specified distance, the first direction and the second direction.

According to an embodiment, the electronic device may further include a display, and in response to identifying the external object, the at least one processor may display a user interface being based on the external object in the display.

According to an embodiment, the at least one processor may transmit a third radio signal for communicating with a wireless network by using at least one of the plurality of antenna arrays, and in response to identifying the external object, adjust the third radio signal for communicating with the wireless network.

According to an embodiment, a method of an electronic device may include transmitting a first radio signal having a specified polarized wave by using a first antenna array among a plurality of antenna arrays of the electronic device, receiving a second radio signal which is a reflected signal of the first radio signal and has the specified polarized wave, by using a second antenna array different from the first antenna array among the plurality of antenna arrays, and identifying an external object around the electronic device, based on the second radio signal.

According to an embodiment, the transmitting may include transmitting the first radio signal through a first beam directed in a first direction by using the first antenna array, and the receiving may include receiving the second radio signal by using at least one beam formable within the second antenna array, and identifying a second beam in which a reception gain of the second radio signal is largest from among the at least one beam, and identifying the external object may include identifying whether the electronic device is located in an indoor environment, based on a second direction corresponding to the second beam.

According to an embodiment, the transmitting may include transmitting the first radio signal by using the first antenna array disposed toward a first surface of the electronic device, and the receiving may include receiving the second radio signal by using the second antenna array disposed toward a second surface of the electronic device different from the first surface.

According to an embodiment, identifying whether the electronic device is located in an indoor environment may include, in response identifying the second beam directed in the second direction different from the first direction, determining that the electronic device is located in the indoor environment.

According to an embodiment, the transmitting may include controlling the first antenna array within a specified power range less than a specified first power of the first antenna array, to transmit the first radio signal through a first beam directed in a first direction, and the receiving may include receiving the second radio signal through the first beam directed in the first direction by using the second antenna array.

According to an embodiment, the transmitting may include transmitting the first radio signal by using the first antenna array included an antenna module included in the electronic device, and the receiving may include receiving the second radio signal by using the second antenna array included in the antenna module.

According to an embodiment, the transmitting may include transmitting the first radio signal through the first beam directed in the first direction by using the first antenna array, and the receiving may include receiving the second radio signal through the second beam directed in the second direction corresponding to the first direction by using the second antenna array.

According to an embodiment, the first antenna array and the second antenna array may be disposed to be spaced a specified distance apart from each other in the electronic device, and in response to identifying the external object, the at least one processor may acquire a distance between the electronic device and the external object, based on at least one of the specified distance, the first direction and the second direction.

According to an embodiment, a method further including, in response to identifying the external object, displaying a user interface being based on the external object in a display may be presented.

According to an embodiment, a method further including transmitting a third radio signal for communicating with a wireless network by using at least one of the plurality of antenna arrays, and in response to identifying the external object, adjusting the third radio signal for communicating with the wireless network may be presented.

Methods of embodiments mentioned in the claims or specification of the present disclosure may be implemented in the form of hardware, software, or a combination of hardware and software.

In response to being implemented by software, a computer-readable storage media storing one or more programs (software modules) may be presented. The one or more programs stored in the computer-readable storage media are configured to be executable by one or more processors

within an electronic device. The one or more programs include instructions for enabling the electronic device to execute the methods of the embodiments stated in the claims or specification of the present disclosure.

These programs (i.e., software modules and/or software) may be stored in a random access memory (RAM), a non-volatile memory including a flash memory, a read only memory (ROM), an electrically erasable programmable ROM (EEPROM), a magnetic disc storage device, a compact disc-ROM (CD-ROM), digital versatile discs (DVDs), an optical storage device of another form, and/or a magnetic cassette. Or, the programs may be stored in a memory that is constructed in combination of some of them or all. Also, each constructed memory may be included in the plural as well.

Also, the program may be stored in an attachable storage device that may access via a communication network such as Internet, an intranet, a local area network (LAN), a wireless LAN (WLAN) or a storage area network (SAN), or a communication network constructed in combination of them. This storage device may be connected to a device performing an embodiment of the present disclosure via an external port. Also, a separate storage device on the communication network may be connected to the device performing the embodiment of the present disclosure as well.

In the aforementioned concrete embodiments of the present disclosure, a constituent element included in the disclosure has been expressed in a singular form or a plural form according to a provided concrete embodiment. But, the expression of the singular form or plural form is selected suitable to a given situation for description convenience's sake, and the present disclosure is not limited to singular or plural constituent elements. Even if a constituent element is expressed in the plural form, the constituent element may be constructed in the singular form, or even if a constituent element is expressed in the singular form, the constituent element may be constructed in the plural form.

On the other hand, in a detailed description of the present disclosure, a concrete embodiment has been described, but it is undoubted that various modifications are available without departing from the scope of the present disclosure. Therefore, the scope of the present disclosure should not be limited to and defined by the described embodiment and should be defined by not only claims stated later but also equivalents to these claims.

What is claimed is:

1. An electronic device comprising:

a plurality of antenna arrays for communicating with a first base station installed in an indoor space and a second base station installed in an outdoor space; and

at least one processor electrically connected to the plurality of antenna arrays; and

memory storing instructions that, when executed by the at least one processor, cause the electronic device to:

identify that the electronic device enters the indoor space based on increase of a strength of a first signal received from the first base station, and decrease of a strength of a second signal received from the second base station,

transmit a first radio signal including a specified polarized wave through a first antenna array among the plurality of antenna arrays,

in case that a second radio signal that is a reflected signal of the first radio signal and includes the specified polarized wave is received through a second antenna array different from the first antenna array among the plurality of antenna arrays, identify that an external object exists between the electronic device and the first base station, and

in case that the second radio signal is not received, identify that the external object does not exist between the electronic device and the first base station.

2. The electronic device of claim **1**, wherein the instructions, when executed by the at least one processor, cause the electronic device to:

transmit the first radio signal through a first beam directed in a first direction through the first antenna array;

receive the second radio signal using at least one beam formable through the second antenna array;

identify a second beam comprising a largest reception gain of the second radio signal than other radio signals among the at least one beam; and

determine whether the electronic device is located in the indoor space based on a second direction corresponding to the second beam.

3. The electronic device of claim **1**, wherein the instructions, when executed by the at least one processor, cause the electronic device to:

transmit the first radio signal through the first antenna array disposed toward a first face of the electronic device; and

receive the second radio signal through the second antenna array disposed toward a second face of the electronic device different from the first face.

4. The electronic device of claim **2**, wherein the instructions, when executed by the at least one processor, cause the electronic device to:

in response to identifying the second beam directed in the second direction different from the first direction, determine that the electronic device is located in the indoor space.

5. The electronic device of claim **1**, wherein the instructions, when executed by the at least one processor, cause the electronic device to:

adjust transmission power of the first radio signal within a specified power range less than a specified first power;

transmit, through the first antenna array, the first radio signal with the adjusted transmission power through a first beam directed in a first direction; and

receive the second radio signal through the first beam directed in the first direction using the second antenna array.

6. The electronic device of claim **5**, wherein the instructions, when executed by the at least one processor, cause the electronic device to:

transmit the first radio signal through the first antenna array included in an antenna module of the electronic device; and

receive the second radio signal through the second antenna array included in the antenna module.

7. The electronic device of claim **1**, wherein the instructions, when executed by the at least one processor, cause the electronic device to:

transmit, through the first antenna array, the first radio signal through a first beam directed in a first direction; and

receive, through the second antenna array, the second radio signal through a second beam directed in a second direction corresponding to the first direction.

8. The electronic device of claim 7,

wherein the first antenna array and the second antenna array are disposed in a specified distance apart from each other in the electronic device; and

wherein, in response to identifying that the external object exists between the electronic device and the first base station, the at least one processor is further configured to acquire a distance between the electronic device and the external object based on at least one of the specified distance, the first direction, or the second direction.

9. The electronic device of claim 1, further comprising:

a display,

wherein, in response to identifying the external object exists between the electronic device and the first base station, the at least one processor is further configured to display, on the display a user interface based on the external object.

10. The electronic device of claim 1, wherein the instructions, when executed by the at least one processor, cause the electronic device to:

transmit a third radio signal for communicating with a wireless network through at least one of the plurality of antenna arrays; and

in response to identifying that the external object exists between the electronic device and the first base station, adjust at least one of a strength or a beam corresponding to a fourth radio signal for communicating with the wireless network.

11. A method of an electronic device, the method comprising:

identifying that the electronic device enters an indoor space based on increase of a strength of a first signal received from a first base station installed in the indoor space, and decrease of a strength of a second signal received from a second base station installed in an outdoor space;

transmitting a first radio signal including a specified polarized wave through a first antenna array among a plurality of antenna arrays of the electronic device;

in case that a second radio signal that is a reflected signal of the first radio signal and includes the specified polarized wave is received through a second antenna array different from the first antenna array among the plurality of antenna arrays, identifying that an external object exists between the electronic device and the first base station; and

in case that the second radio signal is not received, identifying that the external object does not exist between the electronic device and the first base station.

12. The method of claim 11, further comprising:

transmitting the first radio signal through a first beam directed in a first direction through the first antenna array;

receiving the second radio signal using at least one beam formable through the second antenna array;

identifying a second beam comprising a largest reception gain of the second radio signal that other radio signals among the at least one beam; and

determining whether the electronic device is located in the indoor space based on a second direction corresponding to the second beam.

13. The method of claim 11, further comprising:

transmitting the first radio signal through the first antenna array disposed toward a first face of the electronic device; and

receiving the second radio signal through the second antenna array disposed toward a second face of the electronic device different from the first face.

14. The method of claim 12, further comprising:

in response to identifying the second beam directed in the second direction different from the first direction, determining that the electronic device is located in the indoor space.

15. The method of claim 11, further comprising:

adjusting transmission power of the first radio signal within a specified power range less than a specified first power;

transmitting, through the first antenna array, the first radio signal with the adjusted transmission power through a first beam directed in a first direction; and

receiving the second radio signal through the first beam directed in the first direction using the second antenna array.

16. The method of claim 15, further comprising:

transmitting the first radio signal through the first antenna array included in an antenna module of the electronic device; and

receiving the second radio signal through the second antenna array included in the antenna module.

17. The method of claim 11, further comprising:

transmitting, through the first antenna array, the first radio signal through a first beam directed in a first direction; and

receiving, through the second antenna array, the second radio signal through a second beam directed in a second direction corresponding to the first direction.

18. The method of claim 17, further comprising:

in response to identifying that the external object exists between the electronic device and the first base station, acquiring a distance between the electronic device and the external object based on at least one of a specified distance, the first direction, or the second direction,

wherein the first antenna array and the second antenna array are disposed in the specified distance apart from each other in the electronic device.

19. The method of claim 11, further comprising:

in response to identifying that the external object exists between the electronic device and the first base station, displaying, on a display, a user interface based on the external object.

20. The method of claim 11, further comprising:

transmitting a third radio signal for communicating with a wireless network through at least one of the plurality of antenna arrays; and

in response to identifying that the external object exists between the electronic device and the first base station, adjusting at least one of a strength or a beam corresponding to a fourth radio signal for communicating with the wireless network.

* * * * *

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(12) **United States Patent**
Nishi et al.

(10) **Patent No.: US 12,237,555 B2**
(45) **Date of Patent: Feb. 25, 2025**

(54) **WAVEGUIDE, METHOD OF MANUFACTURING WAVEGUIDE AND ANTENNA**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 198 days.

(21) Appl. No.: **18/169,211**

(22) Filed: **Feb. 15, 2023**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
H01P 3/02 (2006.01)
H01P 1/02 (2006.01)

(52) **U.S. Cl.**
CPC . ***H01P 3/02*** (2013.01); ***H01P 1/02*** (2013.01)

(58) **Field of Classification Search**
CPC H01P 1/2056; H01P 1/02; H01P 1/025; H01P 1/042; H01P 1/205; H01P 3/02; H01P 7/10
See application file for complete search history.

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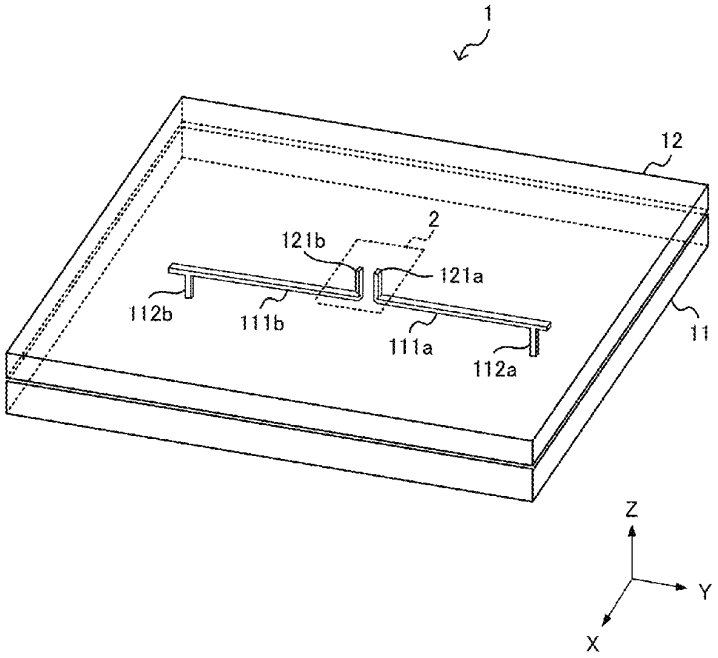
(74) *Attorney, Agent, or Firm* — HAUPTMAN HAM, LLP

(57) **ABSTRACT**

The first conductor plate has a groove portion that has a rectangular cross section and is formed in parallel with a first main surface such that the longitudinal direction becomes a first direction, and a first vertical tube portion formed in a direction away from the second conductor plate in a second direction orthogonal to the first direction and the first main surface, with a branch position in the groove as a starting point. The second conductor plate includes a reflection portion that is inserted into the groove portion in a manner protruding from a second main surface, which is a flat surface of the second conductor plate in contact with the first main surface, and has a reflection surface that reflects the radio wave, propagated along the groove portion, toward the first vertical tube portion.

7 Claims, 10 Drawing Sheets



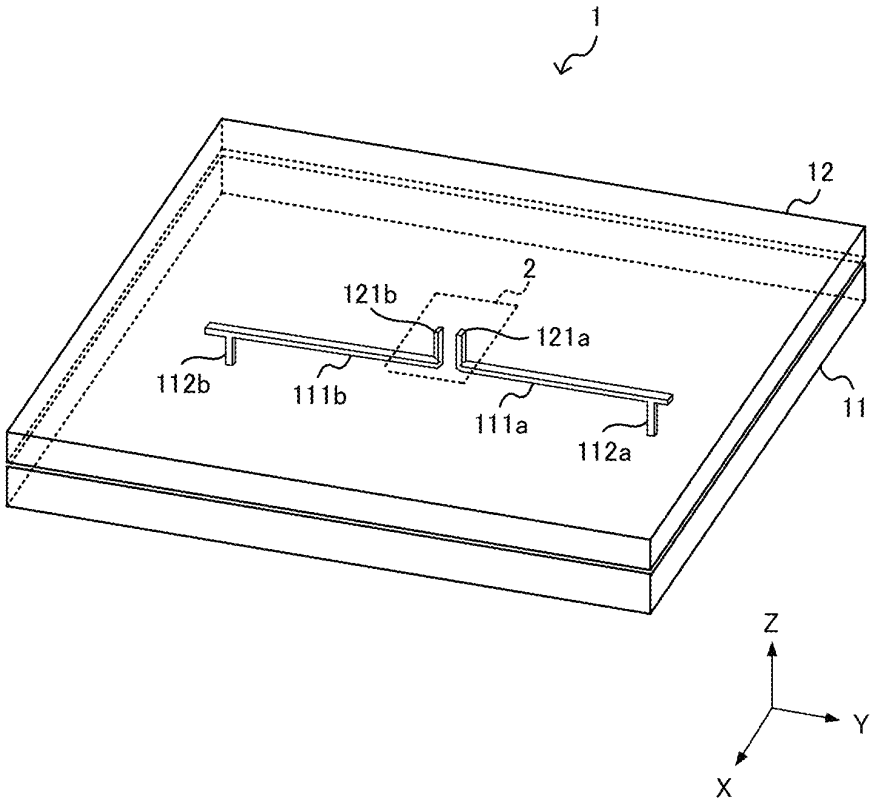


FIG. 1

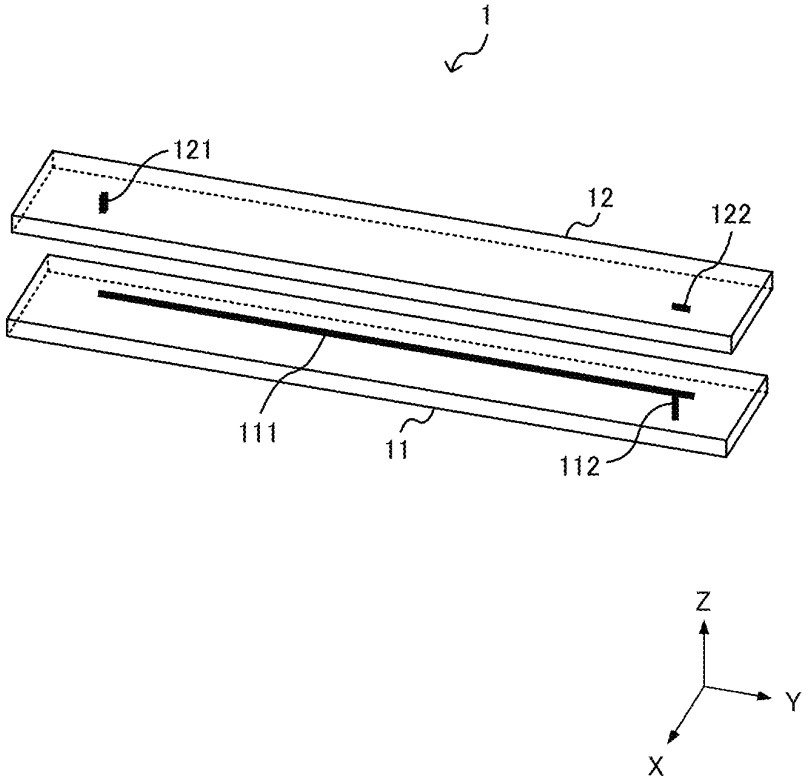


FIG. 2

FIG. 3A

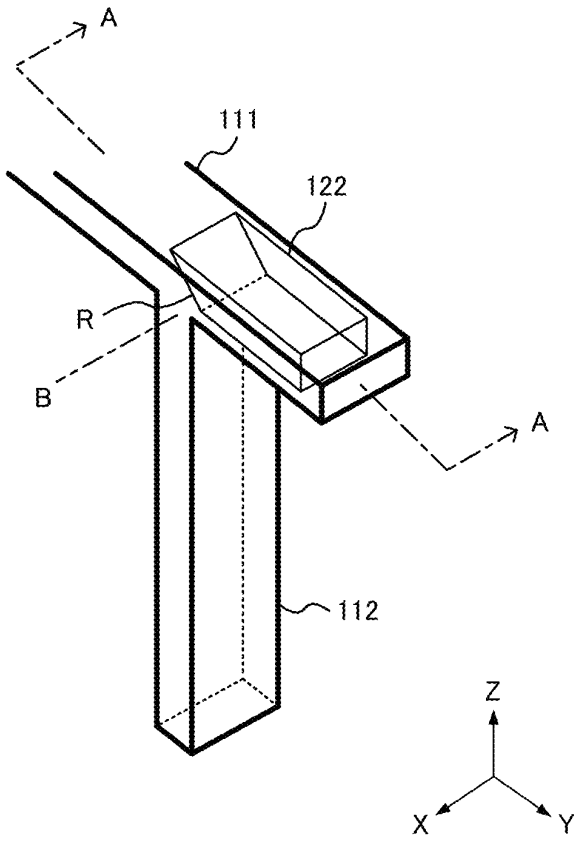


FIG. 3B

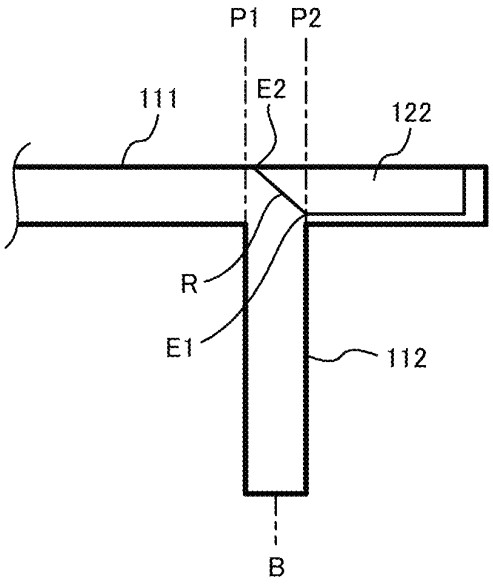


FIG. 4A

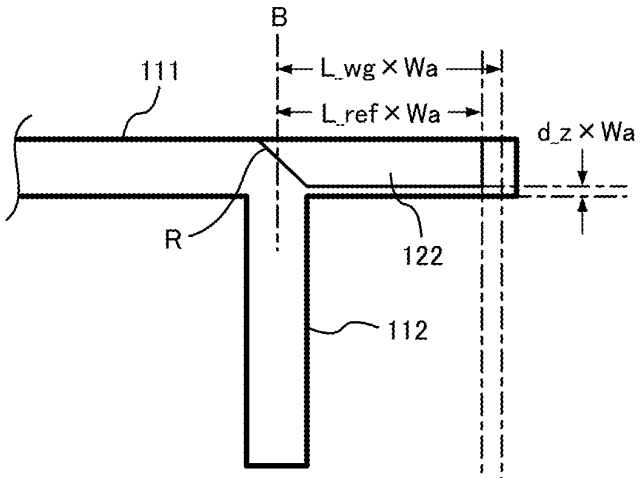


FIG. 4B

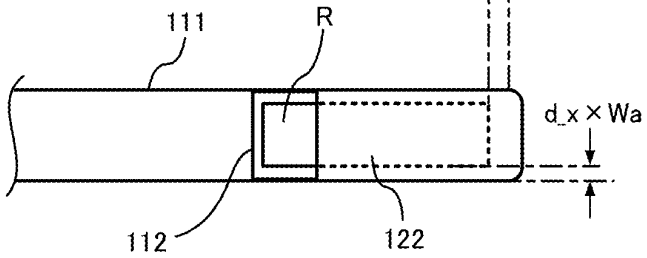


FIG. 5A

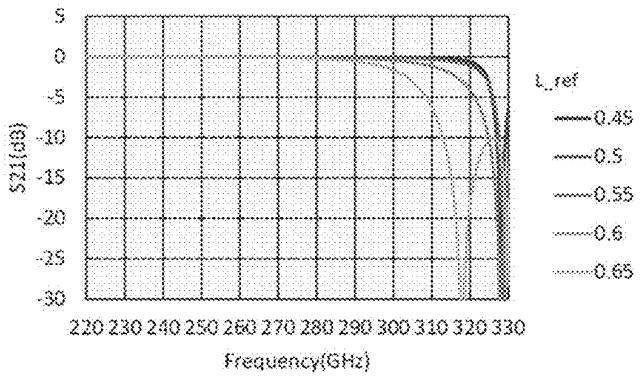


FIG. 5B

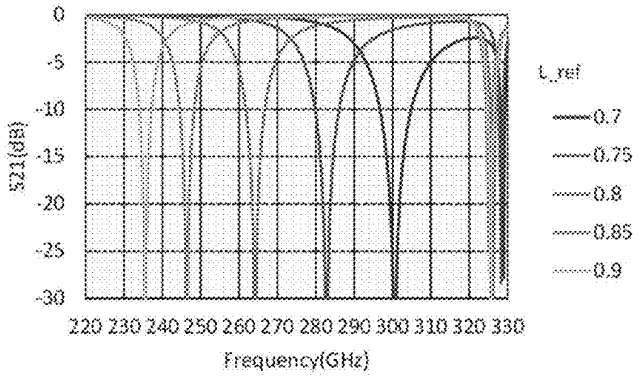


FIG. 5C

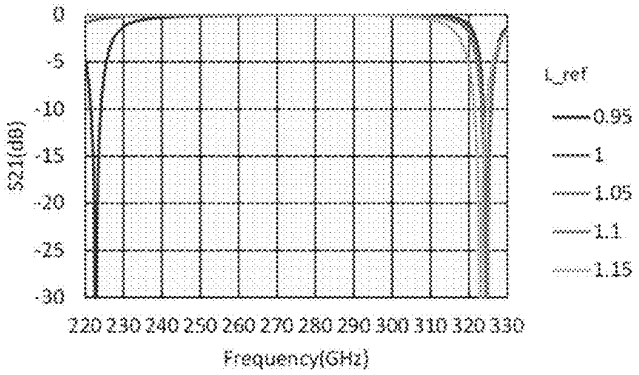


FIG. 6D

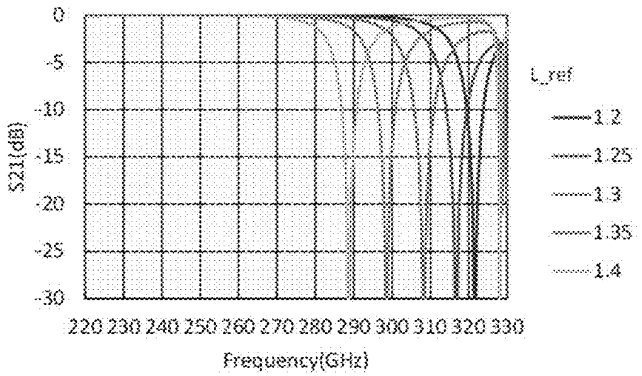


FIG. 6E

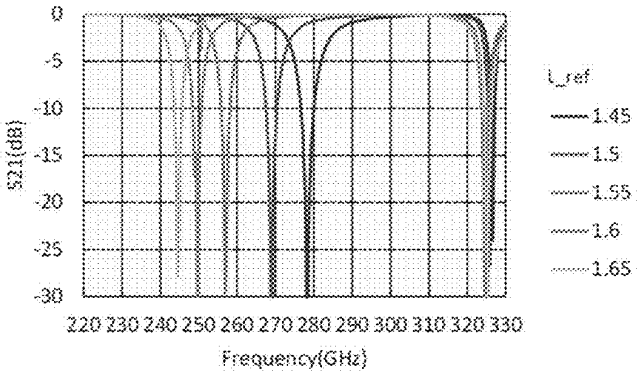


FIG. 6F

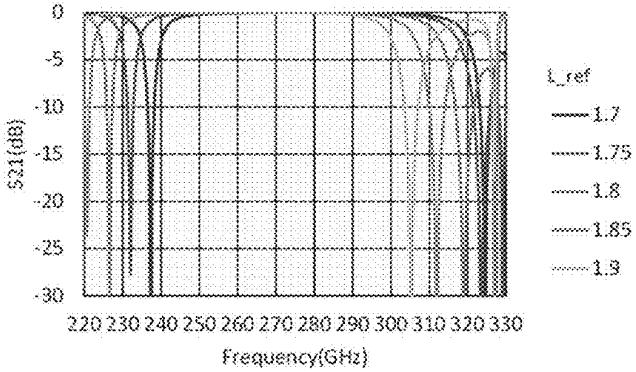


FIG. 7A

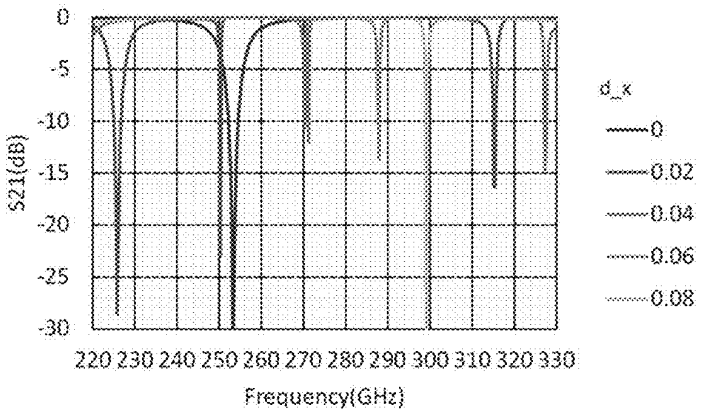


FIG. 7B

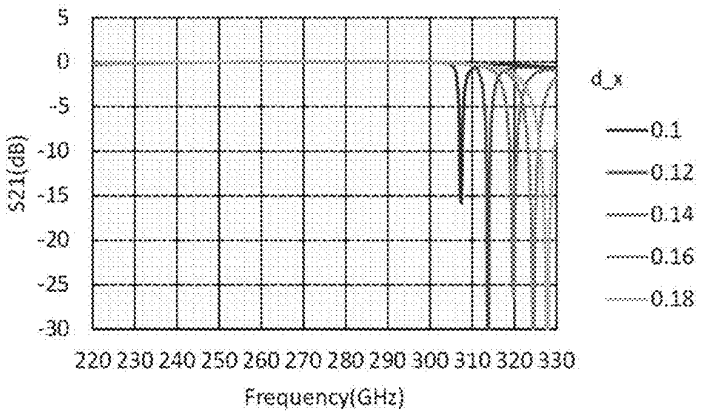


FIG. 7C

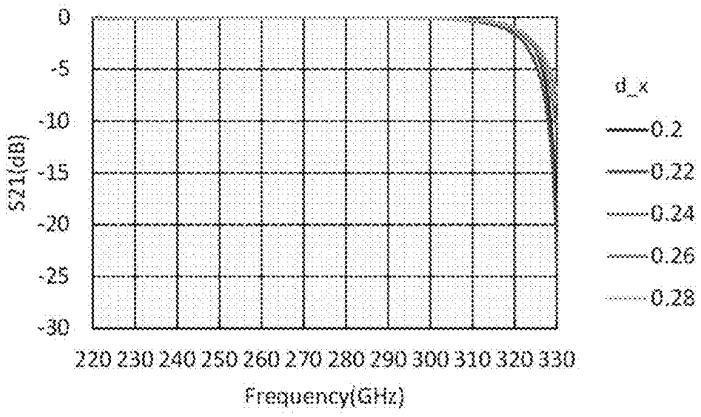


FIG. 8D

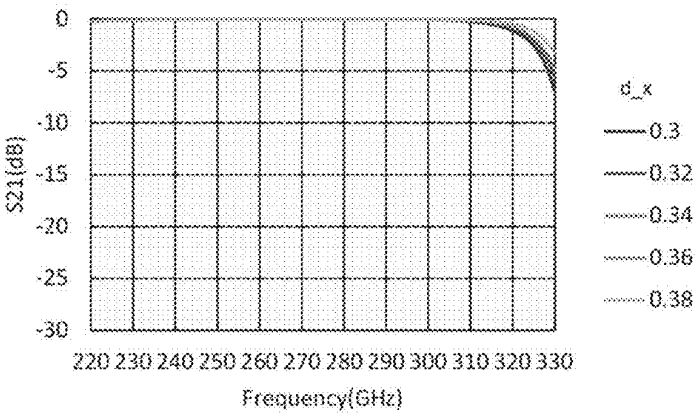

0
-5
-10
-15
-20
-25
-30
S21(dB)
220 230 240 250 260 270 280 290 300 310 320 330
Frequency(GHz)
d_x
0.3
0.32
0.34
0.36
0.38

FIG. 8E

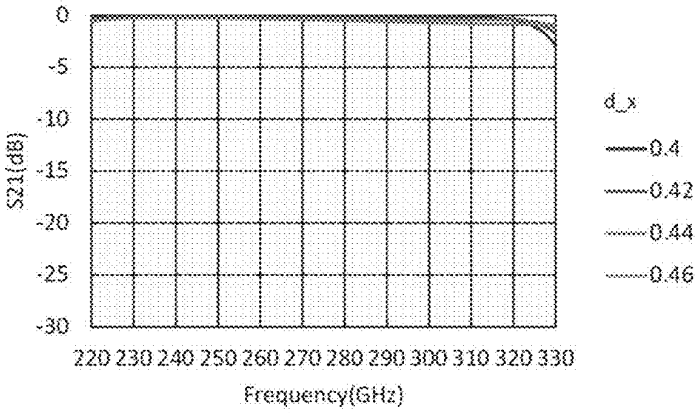

0
-5
-10
-15
-20
-25
-30
S21(dB)
220 230 240 250 260 270 280 290 300 310 320 330
Frequency(GHz)
d_x
0.4
0.42
0.44
0.46

FIG. 9A

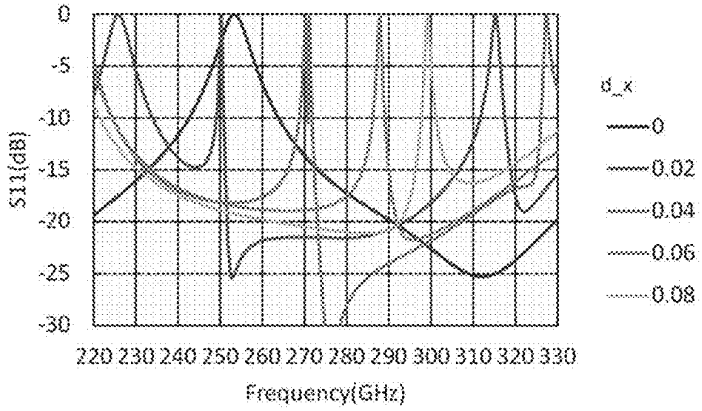


FIG. 9B

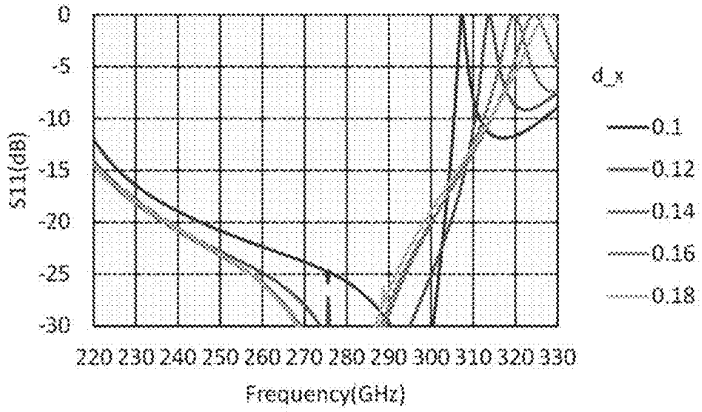


FIG. 9C

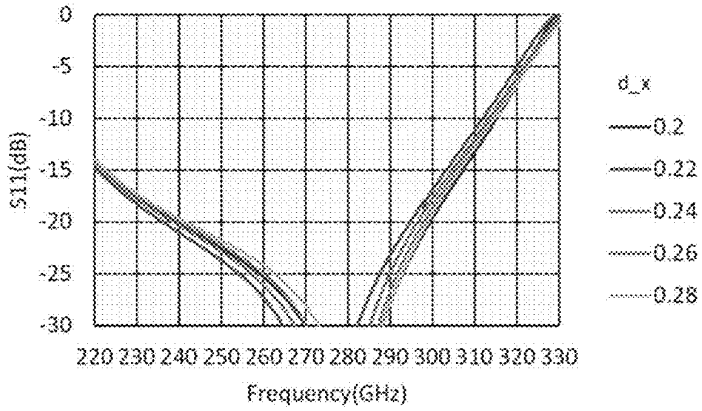


FIG. 10D

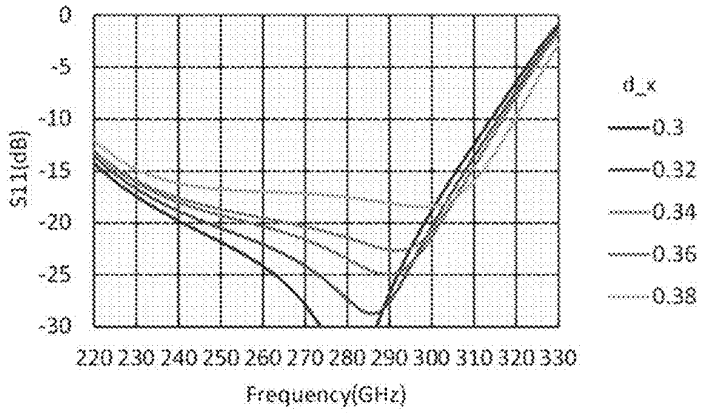
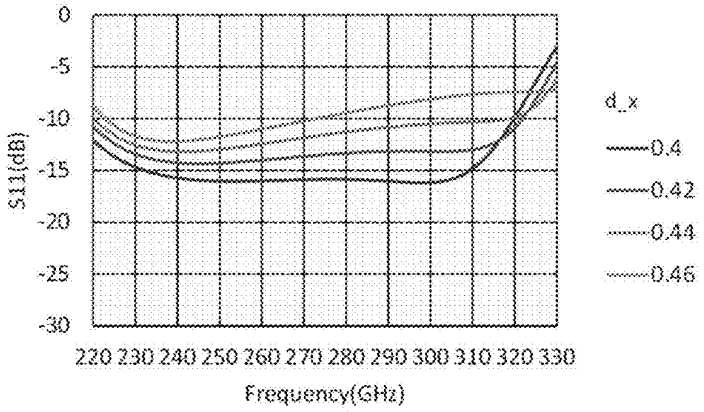


FIG. 10E



WAVEGUIDE, METHOD OF MANUFACTURING WAVEGUIDE AND ANTENNA

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to Japanese Patent Application number 2022-208578, filed on Dec. 26, 2022, contents of which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

The present invention relates to a waveguide, a method of manufacturing a waveguide, and an antenna.

Conventionally, as described in Japanese Unexamined Patent Application Publication No. 2005-20077, there has been known a bent waveguide in which a plurality of waveguides having different directions are connected.

A conventional waveguide is formed by covering the waveguide and a metal member with a metal plate, in a state in which the metal member having a tapered surface of 45 degrees on one side is fitted to an intersection of two orthogonal waveguides. When the frequency of the signal transmitted by the waveguide is increased, it is necessary to reduce the diameters of the waveguide and the metal member. If the diameters of the waveguide and the metal member are reduced, the influence of positional displacement of the metal member on the frequency characteristic of the waveguide is increased.

BRIEF SUMMARY OF THE INVENTION

The present invention has been made in view of the above circumstances, and an object of the present invention is to realize miniaturization of a waveguide while maintaining favorable frequency characteristics of the waveguide.

A waveguide according to a first aspect of the present invention is a waveguide having a first conductor plate and a second conductor plate in contact with the first conductor plate, wherein the first conductor plate includes: a groove portion that has a rectangular cross section and is formed parallel to a first main surface, which is a flat surface of the first conductor plate on the second conductor plate side, such that a longitudinal direction of the groove portion is a first direction; and a first vertical tube portion formed in a direction away from the second conductor plate in a second direction, which is orthogonal to the first direction and the first main surface, starting from a branch position in the groove portion; and the second conductor plate includes a reflective portion that is inserted into the groove portion and protrudes from a second main surface, which is a flat surface of the second conductor plate in contact with the first main surface, and has a reflective surface which reflects a radio wave, propagated along the groove portion, toward the first vertical tube portion.

A method of manufacturing a waveguide according to a second aspect of the present invention a method of manufacturing a waveguide, comprising: forming, in a first conductor plate material, a groove portion that has a rectangular cross section such that a longitudinal direction of the groove portion becomes a first direction and the groove portion is parallel to a first main surface of the first conductor plate material; manufacturing a first conductor plate by forming, in the first conductor plate material, a vertical pipe portion extending in a second direction, which is orthogonal to the first direction and the first main surface, starting from a branch position in the groove portion; a step of manufacturing a second conductor plate by forming, in a second conductor plate material different from the first conductor plate material, a reflective portion having a reflective surface for reflecting a radio wave, propagated along the groove portion, toward the vertical tube portion, such that the reflective portion protrudes from a second main surface of the second conductor plate material in contact with the first main surface; and coupling the first conductor plate and the second conductor plate such that the first main surface and the second main surface are in contact with each other in a state where the reflective portion is inserted into the groove portion, after forming the first conductor plate and the second conductor plate.

An antenna according to a third aspect of the present invention is an antenna comprising: an antenna element having an antenna port; and a waveguide connected to the antenna port, wherein the waveguide is a waveguide having a first conductor plate and a second conductor plate in contact with the first conductor plate, the first conductor plate includes: a groove portion that has a rectangular cross section and is formed parallel to a first main surface, which is a flat surface of the first conductor plate on the second conductor plate side, such that the longitudinal direction of the groove portion is a first direction; and a first vertical tube portion formed in a direction away from the second conductor plate in a second direction, which is orthogonal to the first direction and the first main surface, starting from a branch position in the groove portion; and the second conductor plate includes: a second vertical tube portion formed in the second direction between the antenna port and the groove portion; a reflective portion which is inserted into the groove portion in a manner to project from a second main surface, which is a flat surface of the second conductor plate in contact with the first main surface, and has a reflective surface which reflects a radio wave, propagated along the groove portion, toward the first vertical tube portion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing an outline of a configuration of a waveguide **1**.

FIG. **2** is an exploded view of a portion of the waveguide **1**.

FIGS. **3**A and **3**B are enlarged views of a partial region of the waveguide **1**.

FIGS. **4**A and **4**B are diagrams illustrating parameters used in a simulation.

FIGS. **5**A to **5**C are diagrams showing simulation results of an L_ref dependency of transmission characteristics of the waveguide **1**.

FIGS. **6**D to **6**F are diagrams showing simulation results of the L_ref dependency of transmission characteristics of the waveguide **1**.

FIGS. **7**A to **7**C are diagrams showing simulation results of a d_x dependency of transmission characteristics of the waveguide **1**.

FIGS. **8**D and **8**E are diagrams showing simulation results of the d_x dependency of transmission characteristics of the waveguide **1**.

FIGS. **9**A to **9**C are diagrams showing simulation results of the d_x dependency of reflection characteristics of the waveguide **1**.

FIGS. **10**D and **10**E are diagrams showing simulation results of the d_x dependency of reflection characteristics of the waveguide **1**.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, the present invention will be described through embodiments of the invention, but the following embodiments do not limit the invention as in the claims, and all combinations of features described in the embodiments are not necessarily essential to means for solving the invention.

[Configuration of Waveguide **1**]

FIG. **1** is a perspective view showing an outline of a configuration of a waveguide **1**. FIG. **2** is an exploded view of a portion of the waveguide **1**. FIGS. **3**A and **3**B are enlarged views of a partial region of the waveguide **1**.

As shown in FIG. **1**, the waveguide **1** is configured to be connected to an antenna element **2**. An antenna is formed by connecting the antenna element **2** to the waveguide **1**. The waveguide **1** has a waveguide that propagates a radio wave input from an output port of the antenna element **2**. The waveguide **1** propagates a radio wave input from the antenna element **2** to a position different from the output port of the antenna element **2**, and outputs the radio wave. In the example shown in FIG. **1**, the waveguide **1** has two waveguides, but the waveguide **1** may have one waveguide or three or more waveguides.

The waveguide **1** includes a first conductor plate **11** and a second conductor plate **12** in contact with the first conductor plate **11**. The first conductor plate **11** and the second conductor plate **12** are each made of, for example, a rectangular plate-shaped metal (for example, copper), but the shapes of the first conductor plate **11** and the second conductor plate **12** are arbitrary. In order to facilitate alignment between the first conductor plate **11** and the second conductor plate **12** at the time of manufacturing the waveguide **1**, the shapes of the first conductor plate **11** and the second conductor plate **12** are desirably shapes in which a plurality of side surfaces of the first conductor plate **11** and a plurality of corresponding side surfaces of the second conductor plate **12** are positioned in the same plane, in a state where the first conductor plate **11** and the second conductor plate **12** are brought into contact with each other.

The first conductor plate **11** includes a groove **111** and a first vertical tube portion **112**. The second conductor plate **12** includes a second vertical tube portion **121** and a reflection portion **122**. In FIG. **1**, a first waveguide reaching a first vertical tube portion **112***a* from a second vertical tube portion **121***a* via a groove portion **111***a* and a second waveguide reaching a first vertical tube portion **112***b* from a second vertical tube portion **121***b* via a groove portion **111***b* are shown at positions symmetrical with respect to the antenna element **2**. In the following description, the first waveguide that reaches the first vertical tube portion **112***a* from the second vertical tube portion **121***a* via the groove portion **111***a* will be described as an example.

The groove portion **111** is formed parallel to a first main surface, which is a flat surface of the first conductor plate **11** on the second conductor plate **12** side, such that the longitudinal direction thereof becomes a first direction. The cross section of the groove **111** is rectangular. The first direction in the example shown in FIG. **1** is, for example, the longitudinal direction of the first conductor plate **11** and the second conductor plate **12**, and is the Y direction in FIGS. **1** to **3**.

A reflection surface for changing the direction of a radio wave, incident from the antenna element **2** in the Z direction through the second vertical tube portion **121**, to the Y direction is formed at an end portion of the groove portion **111** corresponding to a position where the groove portion **111** is coupled to the second vertical tube portion **121**. Since the propagation direction of the radio wave changes by 90° at the reflection surface, the second vertical tube portion **121** and the groove portion **111** function as a first corner waveguide.

The first vertical tube portion **112** is formed in a direction away from the second conductor plate **12** in a second direction, which is orthogonal to the first direction and the first main surface, starting from a branch position in the groove portion **111**. The second direction is the thickness direction of the first conductor plate **11**, and is the Z direction in FIGS. **1** to **3**. The branch position is a center position of the first vertical tube portion **112** in the first direction, as indicated by the symbol B in FIGS. **3**A and **3**B. The first vertical tube portion **112** is formed to penetrate the waveguide **1**, for example. The cross section of the first vertical tube portion **112** is rectangular, for example.

One end of the second vertical tube portion **121** is coupled to the antenna element **2**, and the other end of the second vertical tube portion **121** is coupled to the groove portion **111**. As shown in FIGS. **1** and **2**, the second vertical tube portion **121** extends in the second direction from the end portion of the groove portion **111** opposite to the side where the first vertical tube portion **112** is formed, and penetrates through the second conductor plate **12**. The cross section of the second vertical tube portion **121** is rectangular, for example.

As shown in the perspective view of FIG. **3**A, the reflective portion **122** is inserted into the groove portion **111** in a manner protruding from a second main surface, which is a flat surface of the second conductor plate **12** in contact with the first main surface. The reflection portion **122** has a reflection surface R that reflects a radio wave, propagated along the groove portion **111** in the Y direction, toward the first vertical tube portion **112** in the Z direction. Since the propagation direction of the radio wave changes by 90° at the reflection surface R, the groove **111**, the reflection portion **122**, and the first vertical tube portion **112** function as a second corner waveguide.

The reflective portion **122** may be formed by cutting the conductor plate with a drill, or may be connected to the conductor plate in a pre-formed state. In a case where the reflective portion **122** is cut by a drill, since it is difficult to form a reflective surface R that is completely flat, the reflective surface R may be formed with a stepped shape.

The reflection portion **122** is inserted in a region of the groove portion **111** farther away from the branch position B than the second vertical tube portion **121** (right-hand side in FIG. **3**A). The width of the reflection portion **122** in a third direction (the X direction in FIGS. **1** to **3**), which is orthogonal to the first direction and the second direction, is smaller than the width of the groove portion **111** in the third direction, so as to be accommodated in the groove portion **111**. As shown in FIG. **3**A, the end surface of the reflective portion **122** opposite the side where the reflective surface R is formed need not be in contact with the inner surface of the groove portion **111**, but may be in contact with the inner surface of the groove portion **111**.

FIG. **3**B is a cross-sectional view taken along the line A-A of the region shown in FIG. **3**A. As shown in FIG. **3**B, the reflective portion **122** need not be in contact with the lower

surface of the groove portion **111**, but may be in contact with the lower surface of the groove portion **111**.

As shown in FIG. **3**B, the reflection surface R has a reflection region located between a position P**1** in the first direction on the surface of the first vertical tube portion **112** closest to the side where the radio wave is incident and a position P**2** in the first direction on the surface of the first vertical tube portion **112** farthest from the side where the radio wave is incident.

As an example, the position in the first direction of a first end portion E**1** of the reflection surface R on the side of the first conductor plate **11** is the same as a position P**2** in the first direction of the surface of the first vertical tube portion **112** that is farthest from the incident side where the radio wave is incident. The position in the first direction of a second end portion E**2** of the reflection surface R opposite to the first end portion E**1** is between a position P**1** in the first direction of the surface of the first vertical tube portion **112** closest to the incident side and a position P**2** in the first direction of the surface of the first vertical tube portion **112** farthest from the incident side. By providing the reflection surface R at such a position, the radio wave reflected by the reflection surface R is likely to propagate along the first vertical tube portion **112** without hitting the lower surface of the groove portion **111**. As a result, a decrease in the intensity of the radio wave output from the waveguide **1** can be prevented.

[Method of Manufacturing the Waveguide **1**]

An example of a method of manufacturing the waveguide **1** will be described.

First, an unprocessed first conductor plate material and an unprocessed second conductor plate material are prepared. Then, a groove **111** having a rectangular cross section is formed in the prepared first conductor plate material, such that the longitudinal direction thereof becomes the first direction and the groove **111** is parallel to the first main surface of the first conductor plate material. A reflection surface inclined by 45° with respect to the first main surface and the first direction is formed at one end of the groove **111**. At the other end of the groove **111**, an end surface orthogonal to the first main surface and the first direction is formed.

Subsequently, the first vertical pipe portion **112** extending in the second direction, which is orthogonal to the first direction and the first main surface, is formed in the first conductor plate material starting from the branch position in the groove portion **111**, whereby the first conductor plate **11** is completed. The method of forming the groove portion **111** and the first vertical tube portion **112** is arbitrary, but the groove portion **111** and the first vertical tube portion **112** can be formed by a milling machine, for example.

Before or after the processing of the first conductor plate material, or in parallel with the processing of the first conductor plate material, the second vertical tube portion **121** and the reflection portion **122** are formed in the unprocessed second conductor plate material. Specifically, the second conductor plate material is processed such that a region other than the reflective portion **122** is cut off from the unprocessed second conductor plate material, thereby leaving the reflective portion **122** in a protruding state. After this, the second vertical tube portion **121** is formed to complete the second conductor plate **12**. Although the method of forming the second vertical tube portion **121** and the reflection portion **122** is arbitrary, a milling machine can be used, for example.

After the groove portion **111**, the first vertical tube portion **112**, the second vertical tube portion **121**, and the reflection portion **122** are formed, the first conductor plate **11** and the second conductor plate **12** are coupled such that the first main surface (the surface on which the groove portion **111** is formed) of the first conductor plate **11** and the second main surface (the surface on which the reflection portion **122** is formed) of the second conductor plate **12** come into contact with each other in a state where the reflection portion **122** is inserted into the groove portion **111**. In a case where the flat surface shapes of the first conductor plate and the second conductor plate are the same, by coupling the first conductor plate **11** and the second conductor plate **12** such that the four sides of the first conductor plate and the four sides of the second conductor plate coincide with each other, the reflection portion **122** can be inserted at a desired position with high accuracy.

[Simulation Results]

Hereinafter, results of a simulation of characteristics of the waveguide **1** will be described with reference to FIGS. **4** to **9**. FIGS. **4**A and **4**B are diagrams illustrating parameters used in the simulation.

FIG. **4**A is a cross-sectional view taken along the line A-A, which is equivalent to the view in FIG. **3**B. FIG. **4**B is a view showing a state in which the waveguide **1** is viewed from the end portion side of the first vertical tube portion **112**, in the direction of the second conductor plate **12**. When the groove portion **111** is cut by a drill, it is difficult to make the angle of the groove portion **111** a right angle, and therefore, in FIG. **4**B, the angle of the right end portion of the groove portion **111** is arc-shaped.

As shown in FIG. **4**A, the distance between the lower surface of the reflective portion **122** and the inner surface on the lower side of the groove portion **111** is d_z×Wa. The distance between the branch position B and an end surface of the reflective portion **122** on the side opposite the reflective surface R is L_ref×Wa. The distance between the branch position B and the end surface of the groove **111** is L_wg×Wa. As shown in FIG. **4**B, the distance between the side surface of the reflective portion **122** and the inner side surface of the groove portion **111** is d_x×Wa. Here, Wa is an internal width as defined by the rectangular waveguide standard. As an example, in the case of a waveguide that is WR-3, Wa=0.864 mm. A position where the longitudinal side surface of the groove **111** begins to bend inward is defined as an end surface of the groove **111**.

FIGS. **5** and **6** show simulation results of the L_ref dependency of the transmission characteristic of the waveguide **1**. Specifically, FIGS. **5** and **6** show frequency characteristics of the transmission coefficient S**21** when (L_wg-L_ref)×Wa=0.1 mm, d_z×Wa=0.05 mm, and d_x×Wa=0.138 mm. It was confirmed that, if L_ref is in a range of 0.45 or more and 0.60 or less, 0.90 or more and 1.20 or less, or 1.60 or more and 1.90 or less, no resonance point is generated in the transmission coefficient S**21** in a range where the frequency of the radio wave propagating through the waveguide **1** is 240 GHz or more and 300 GHz or less.

This frequency range varies depending on the size of the waveguide. Specifically, with the inner width of the waveguide as defined by the rectangular waveguide standard being Wa [mm] and the light speed being C0 [10^6 m/s], it was confirmed that the frequency of the radio wave is 1.4×C0/(2×Wa) [GHz] or more and 1.7×C0/(2×Wa) [GHz] or less.

FIGS. **7** and **8** show simulation results of the d_x dependency of transmission characteristics of the waveguide **1**. Specifically, FIGS. **7** and **8** show frequency characteristics of the transmission coefficient S**21** when (L_wg-L_ref)×Wa=0.1 mm, d_z×Wa=0.05 mm, and L_ref=0.105. It was confirmed that, when d_x is equal to or greater than 0.12, no

resonance point is generated in the transmission coefficient S21 in a range in which the frequency of the radio wave propagating through the waveguide **1** is equal to or greater than 240 GHz and equal to or less than 300 GHz.

FIGS. **9** and **10** show simulation results of the d_x dependency of the reflection characteristic of the waveguide **1**. Specifically, FIGS. **9** and **10** show the frequency characteristic of the input reflection coefficient S11 when (L_wg-L_ref)×Wa=0.1 mm, d_z×Wa=0.05 mm, and L_ref=0.105. It was confirmed that, when d_x is 0.38 or more, the input reflection coefficient S11 deteriorated in a range in which the frequency of the radio wave propagating through the waveguide **1** is 240 GHz or more and 300 GHz or less.

From the results shown with reference to FIGS. **7** and **8** and the results shown with reference to FIGS. **9** and **10**, it was confirmed that d_x is desirably equal to or greater than 0.12 and less than 0.38. That is, it was confirmed that the distance d_x×Wa between the outer surface of the reflective portion **122** parallel to the first direction and the inner surface of the groove portion **111** parallel to the first direction is preferably equal to or greater than 12% and less than 38% of the distance between the two inner surfaces of the groove portion **111**.

[Effect of the Waveguide **1**]

As described above, the waveguide **1** includes the first conductor plate **11** and the second conductor plate **12**. The first conductor plate **11** includes the groove portion **111**, which has a rectangular cross section and is formed parallel to the first main surface of the first conductor plate **11** such that the longitudinal direction of the groove portion **111** becomes the first direction, and a first vertical tube portion **112** formed in a direction away from the second conductor plate **12** starting from the branch position B in the groove portion **111**. The second conductor plate **12** includes the reflection portion **122** having a reflection surface R that reflects a radio wave, propagated along the groove portion **111**, toward the first vertical tube portion **112**, with the reflection surface **122** being inserted into the groove portion **111** in a manner protruding from the second main surface which is a flat surface in contact with the first main surface in the second conductor plate.

Since the waveguide **1** is configured in this manner, by aligning the positions of the first conductor plate **11** and the second conductor plate **12**, the reflection portion **122** is fixed at a desired position with high accuracy. As a result, the waveguide can be downsized while maintaining favorable frequency characteristics of the waveguide.

Although the embodiments of the present invention have been described above, the technical scope of the present invention is not limited to the embodiments described above, and various modifications and changes can be made without departing from the scope of the present invention. For example, all or a portion of the device may be functionally or physically distributed and integrated in arbitrary units. Further, new embodiments resulting from arbitrary combinations of a plurality of embodiments are also included in the embodiments of the present invention. The effect of the new embodiment caused by the combination has the effect of the original embodiment.

What is claimed is:

1. A waveguide having a first conductor plate and a second conductor plate in contact with the first conductor plate, wherein

the first conductor plate includes:

a groove portion that has a rectangular cross section and is formed parallel to a first main surface, which is a flat surface of the first conductor plate on the second conductor plate side, such that a longitudinal direction of the groove portion is a first direction; and

a first vertical tube portion formed in a direction away from the second conductor plate in a second direction, which is orthogonal to the first direction and the first main surface, starting from a branch position in the groove portion; and

the second conductor plate includes a reflective portion that is inserted into the groove portion and protrudes from a second main surface, which is a flat surface of the second conductor plate in contact with the first main surface, and has a reflective surface which reflects a radio wave, propagated along the groove portion, toward the first vertical tube portion.

2. The waveguide according to claim **1**, wherein

the reflective surface has a reflective region positioned between i) a position in the first direction of a surface of the first vertical tube portion closest to a side where the radio wave is incident and ii) a position in the first direction of a surface of the first vertical tube portion farthest from the side where the radio wave is incident.

3. The waveguide according to claim **1**, wherein

a position in the first direction of a first end portion of the reflective surface on the first conductor plate side is the same as a position in the first direction of a surface of the first vertical tube portion farthest from an incident side where the radio wave is incident;

a position in the first direction of a second end portion of the reflective surface, which is opposite to the first end portion, is between a position in the first direction of a surface of the first vertical tube portion closest to the incident side and a position in the first direction of a surface of the first vertical tube portion farthest from the incident side.

4. The waveguide according to claim **1**, wherein

the second conductor plate further includes a second vertical tube portion that extends in the second direction, from an end portion of the groove portion opposite to a side where the first vertical tube portion is formed, and penetrates through the second conductor plate.

5. The waveguide according to claim **1**, wherein

in a case where an inner width of the waveguide as defined by a rectangular waveguide standard is Wa [mm] and a light speed is C0 [10^6 m/s]:

a frequency of the radio wave is 1.4×C0/(2×Wa) [GHz] or more and 1.7×C0/(2×Wa) [GHz] or less; and

a distance between an outer surface of the reflective portion parallel to the first direction and an inner surface of the groove portion parallel to the first direction is equal to or greater than 12% and less than 38% of a distance between two inner surfaces of the groove portion.

6. A method of manufacturing a waveguide, comprising:

forming, in a first conductor plate material, a groove portion that has a rectangular cross section such that a longitudinal direction of the groove portion becomes a first direction and the groove portion is parallel to a first main surface of the first conductor plate material;

manufacturing a first conductor plate by forming, in the first conductor plate material, a vertical pipe portion extending in a second direction, which is orthogonal to the first direction and the first main surface, starting from a branch position in the groove portion;

a step of manufacturing a second conductor plate by forming, in a second conductor plate material different from the first conductor plate material, a reflective

portion having a reflective surface for reflecting a radio wave, propagated along the groove portion, toward the vertical tube portion, such that the reflective portion protrudes from a second main surface of the second conductor plate material in contact with the first main surface; and

coupling the first conductor plate and the second conductor plate such that the first main surface and the second main surface are in contact with each other in a state where the reflective portion is inserted into the groove portion, after forming the first conductor plate and the second conductor plate.

7. An antenna comprising:

an antenna element having an antenna port; and

a waveguide connected to the antenna port, wherein

the waveguide is a waveguide having a first conductor plate and a second conductor plate in contact with the first conductor plate,

the first conductor plate includes:

a groove portion that has a rectangular cross section and is formed parallel to a first main surface, which is a flat surface of the first conductor plate on the second conductor plate side, such that the longitudinal direction of the groove portion is a first direction; and

a first vertical tube portion formed in a direction away from the second conductor plate in a second direction, which is orthogonal to the first direction and the first main surface, starting from a branch position in the groove portion; and

the second conductor plate includes:

a second vertical tube portion formed in the second direction between the antenna port and the groove portion;

a reflective portion which is inserted into the groove portion in a manner to project from a second main surface, which is a flat surface of the second conductor plate in contact with the first main surface, and has a reflective surface which reflects a radio wave, propagated along the groove portion, toward the first vertical tube portion.

* * * * *

US012237564B2

(12) **United States Patent**
Yoo et al.

(10) **Patent No.: US 12,237,564 B2**
(45) **Date of Patent: Feb. 25, 2025**

(54) **ANTENNA AND ELECTRONIC DEVICE INCLUDING SAME**

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(73) Assignee: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 189 days.

(21) Appl. No.: **18/119,126**

(22) Filed: **Mar. 8, 2023**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Sep. 9, 2020 (KR) 10-2020-0115249

(51) **Int. Cl.**
H01Q 1/12 (2006.01)
H01Q 1/24 (2006.01)
H01Q 9/04 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/1207*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 9/045*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/1207; H01Q 1/243; H01Q 9/045
See application file for complete search history.

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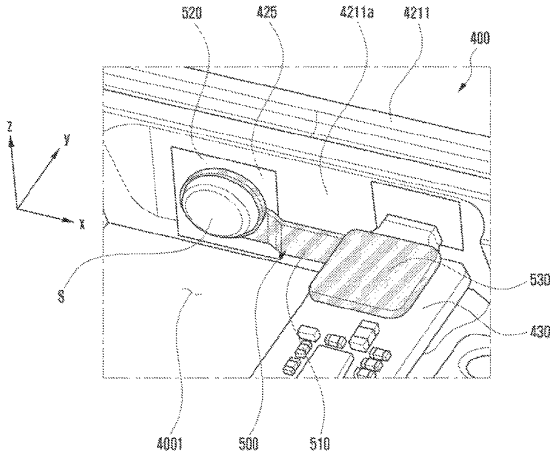
Primary Examiner — Graham P Smith
Assistant Examiner — Amal Patel
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

An electronic device includes: a housing; a substrate disposed in the housing; an antenna radiator; and an electrical connection member electrically interconnecting the antenna radiator and the substrate, wherein the electrical connection member includes: a plate portion including a first surface facing the antenna radiator and a second surface facing away from the first surface; a first fixing portion provided at a first end of the plate portion, the first fixing portion including a through hole and a tension structure; and a second fixing portion provided at a second end of the plate portion and electrically connecting the electrical connection member to the substrate, wherein the first fixing portion is fixed to the antenna radiator via a locking device that passes through the through hole, and wherein the tension structure is configured to contact the antenna radiator and maintain tension between the electrical connection member and the antenna radiator during fastening of the locking device.

20 Claims, 25 Drawing Sheets



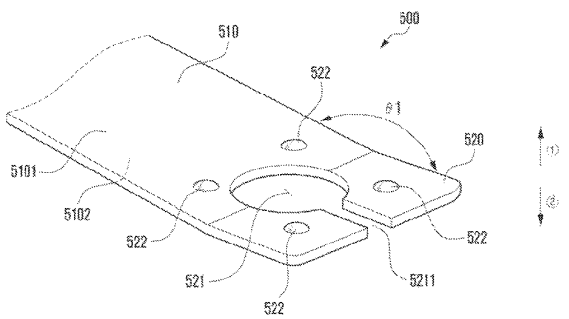


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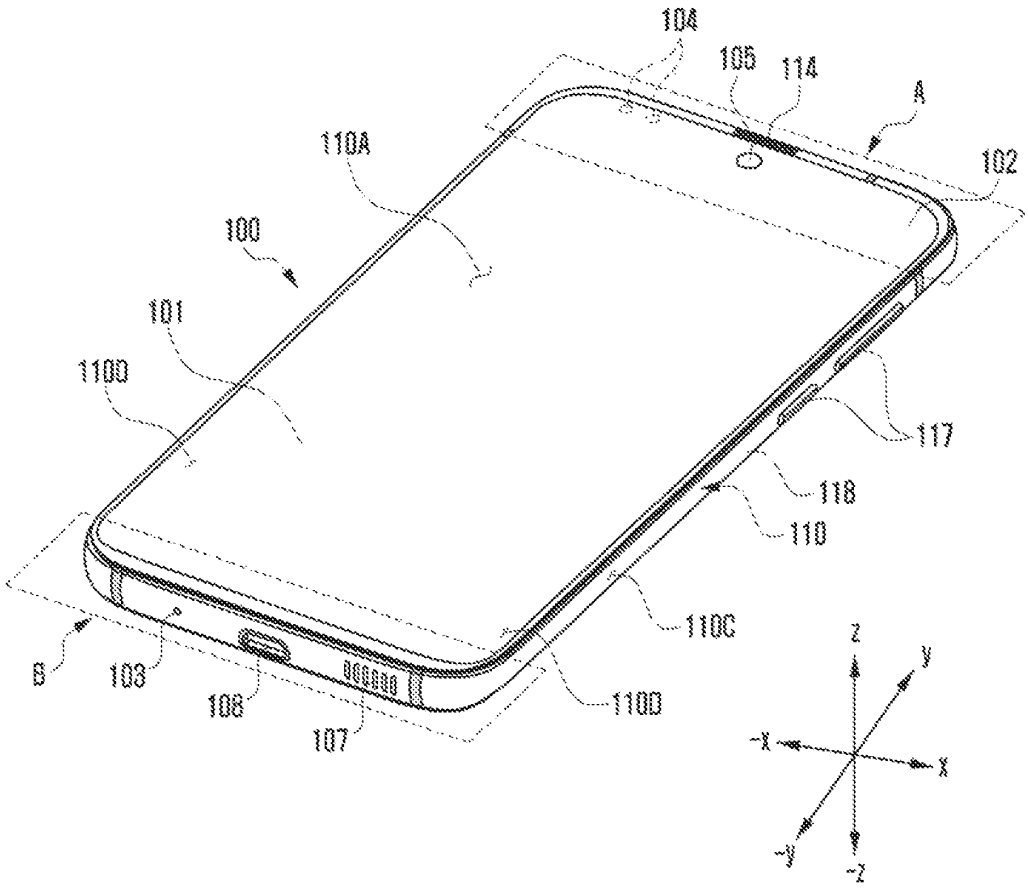
FIG. 1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114
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110A
102
100
101
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110C
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103
108
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-y
-z

FIG. 2

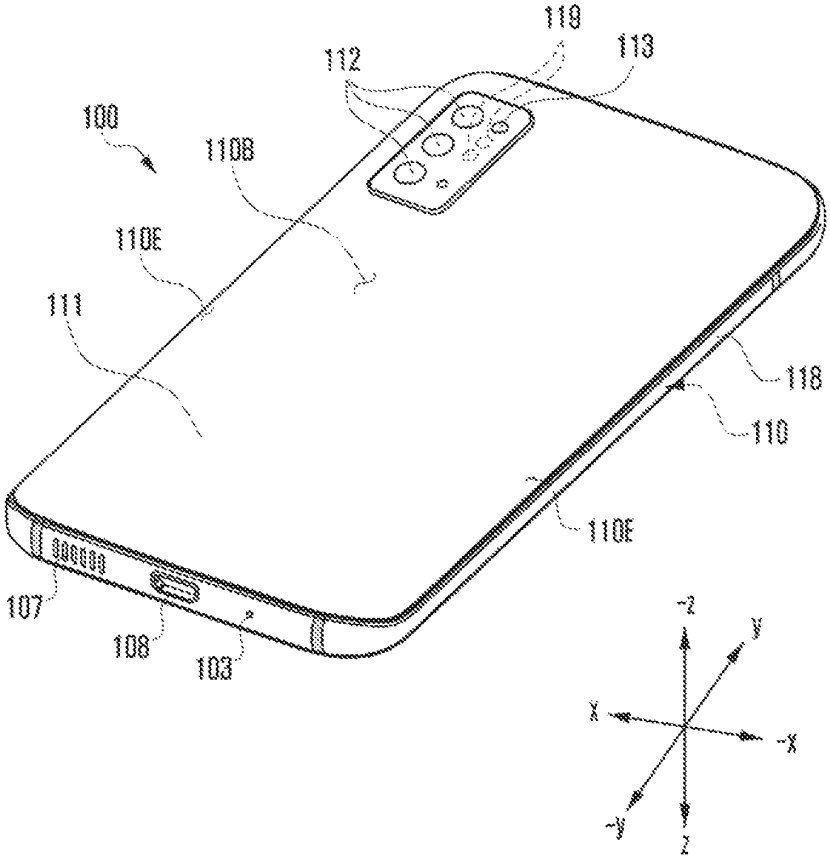


FIG. 3

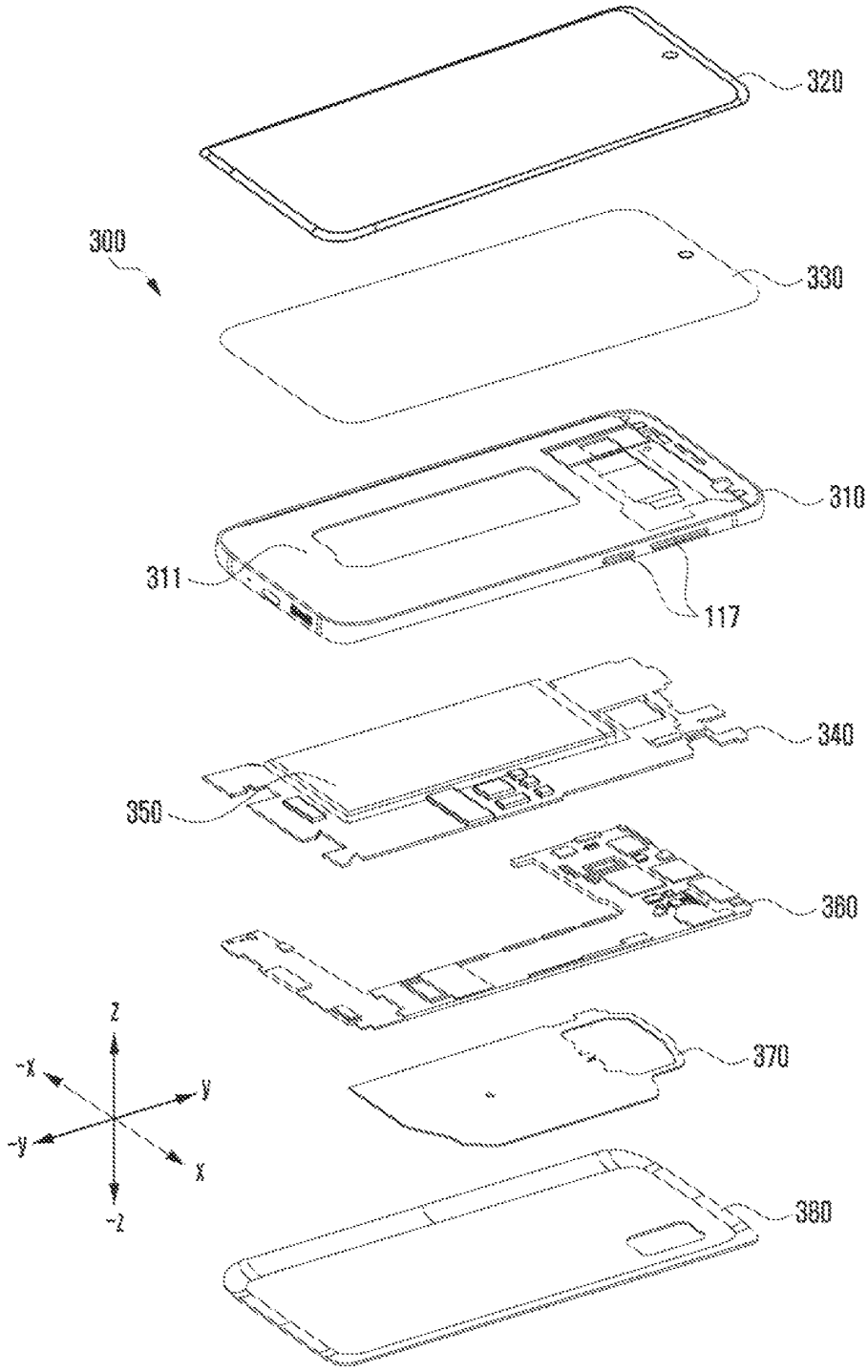
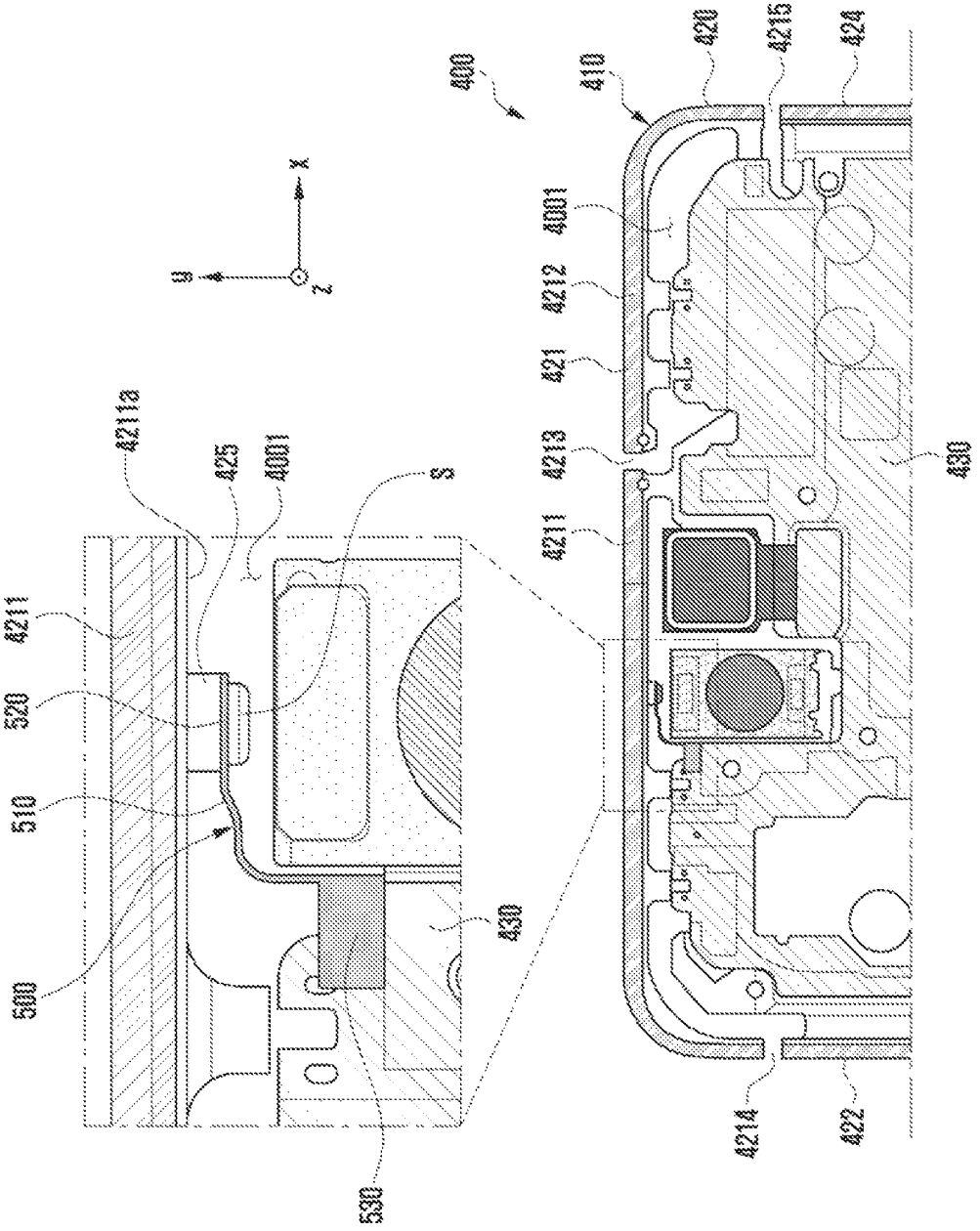


FIG. 4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4211
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FIG. 5A

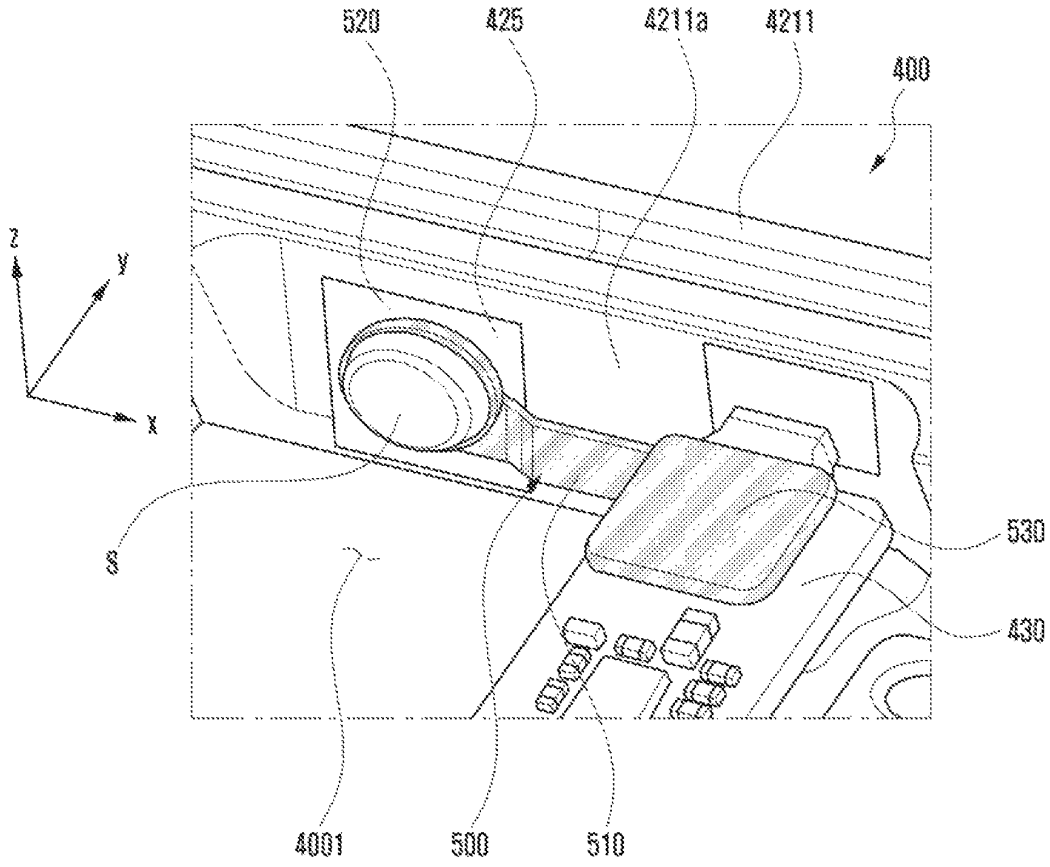


FIG. 5B

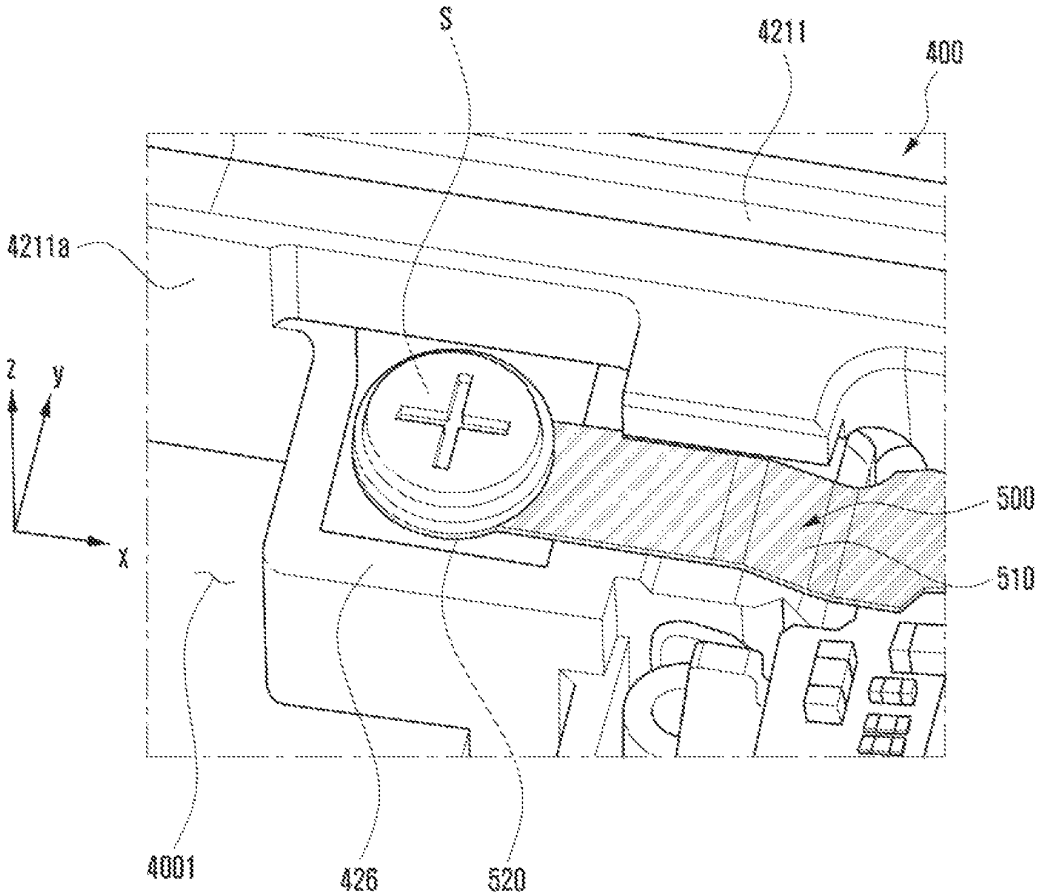


FIG. 6A

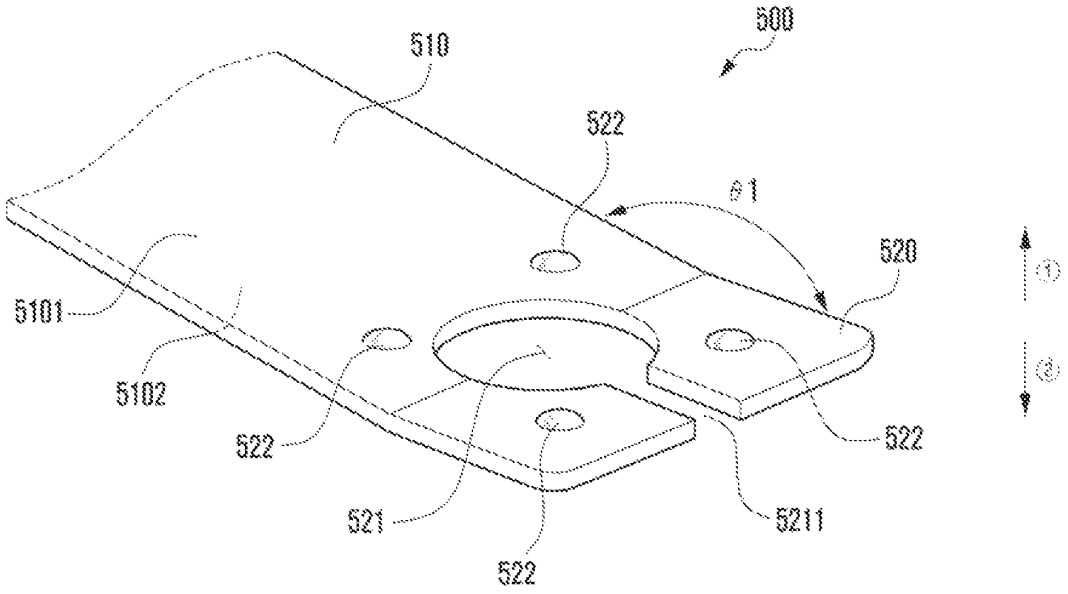
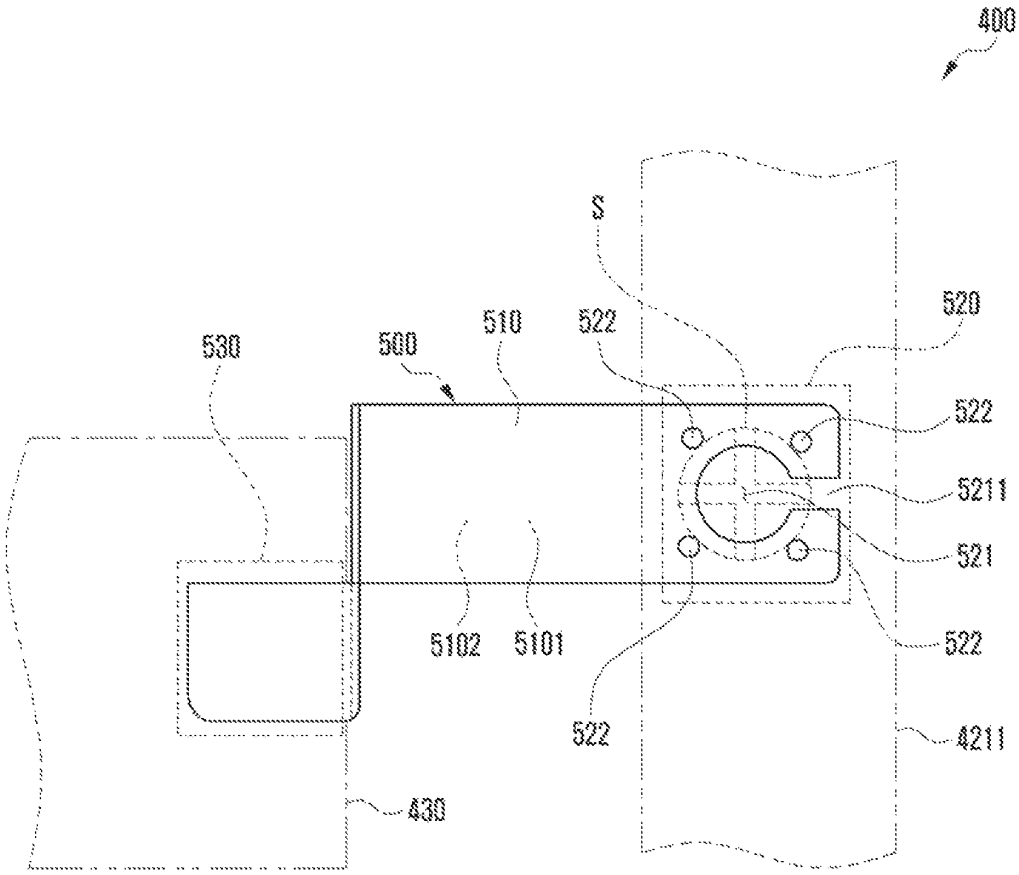


FIG. 6B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5101
522
4211
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FIG. 7A

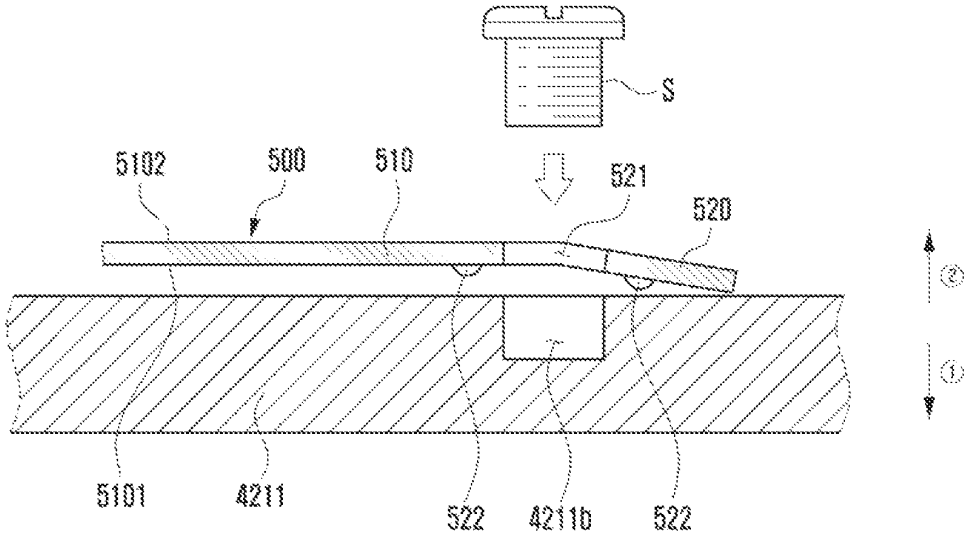


FIG. 7B

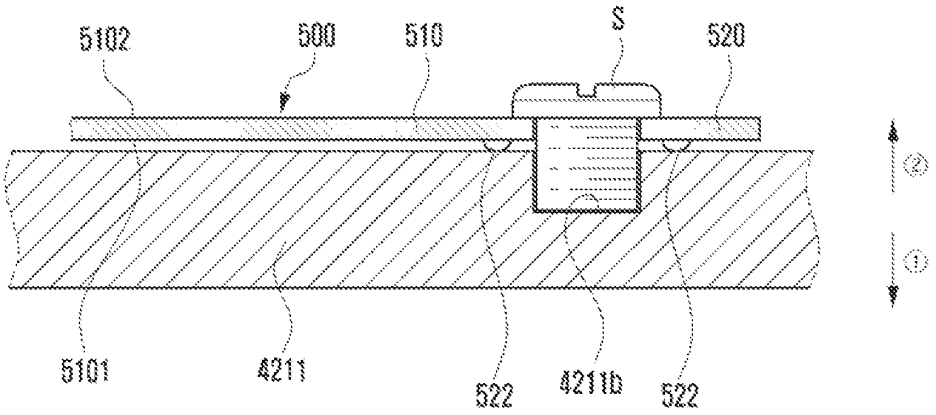


FIG. 7C

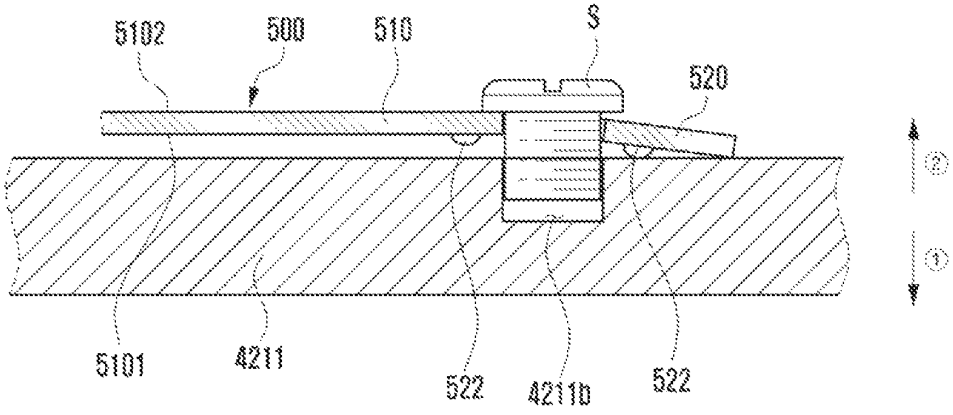


FIG. 8A

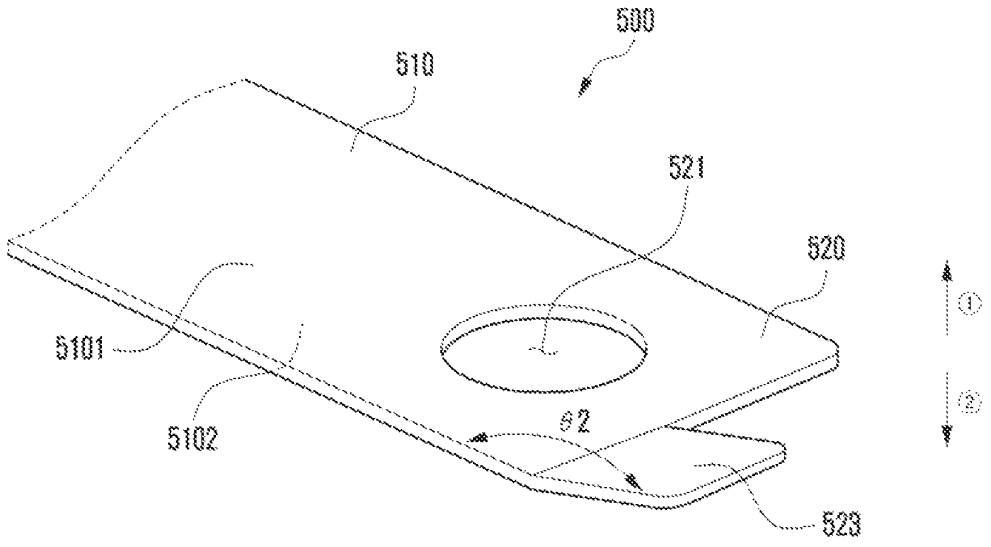


FIG. 8B

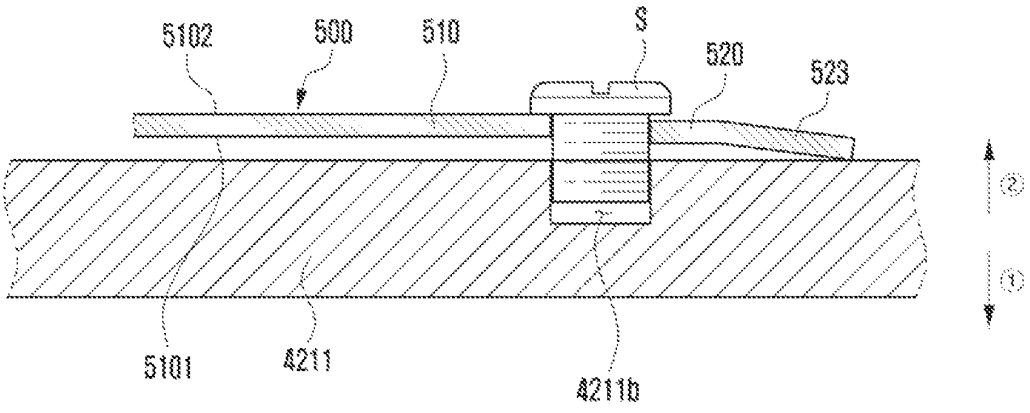


FIG. 9A

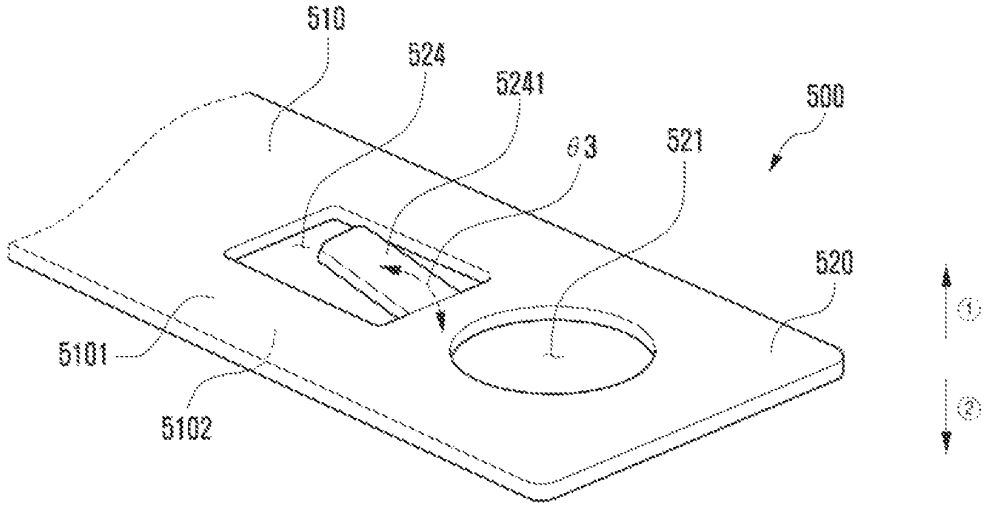


FIG. 9B

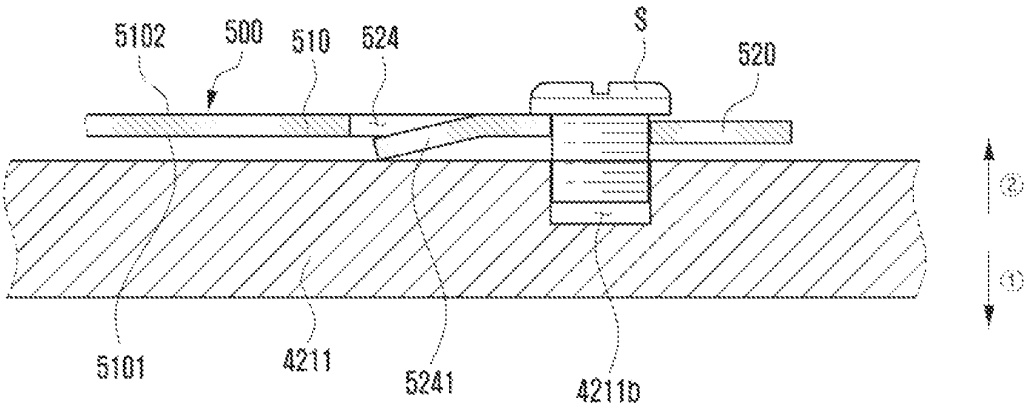


FIG. 10A

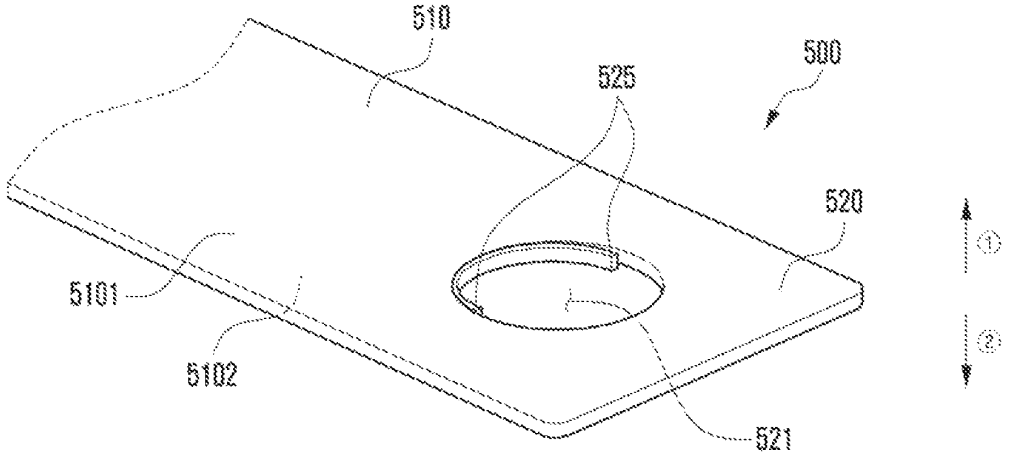


FIG. 10B

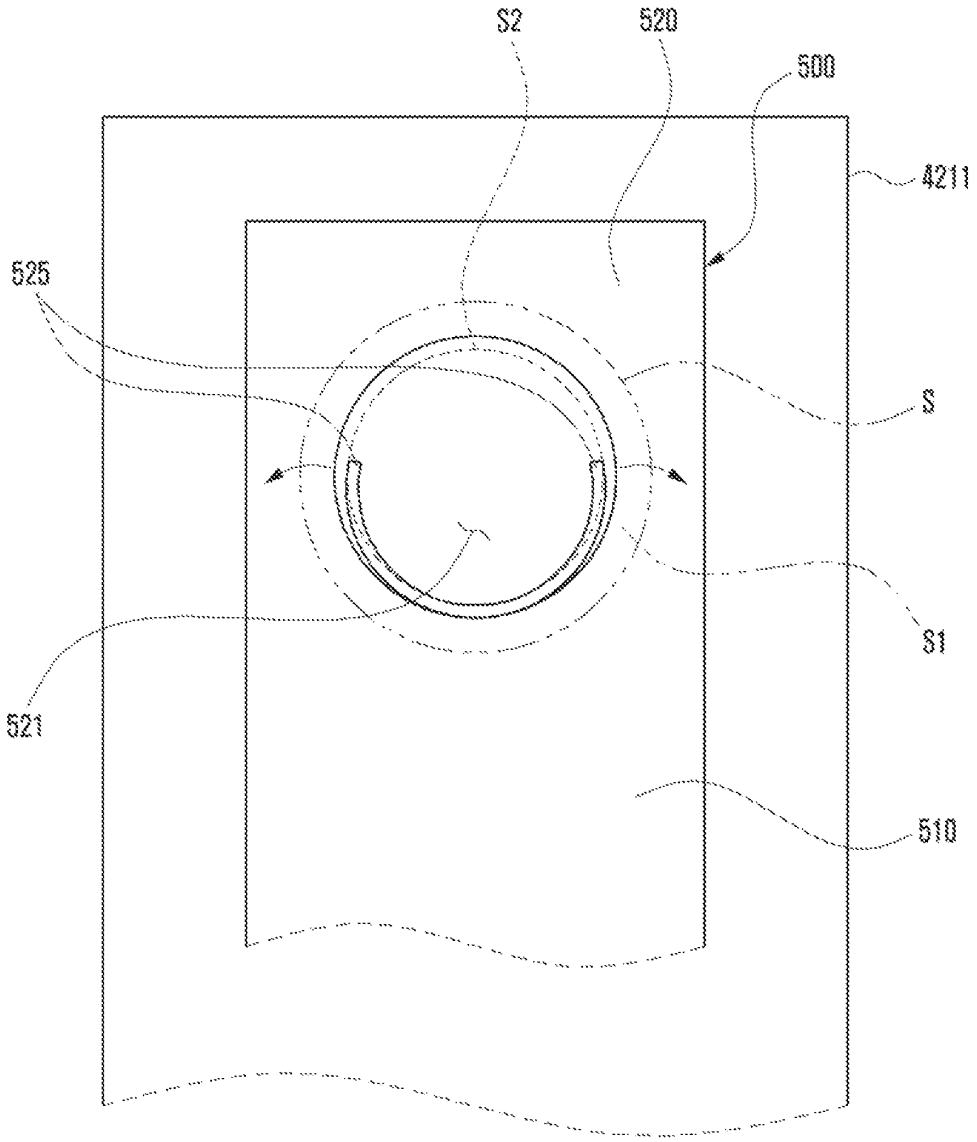
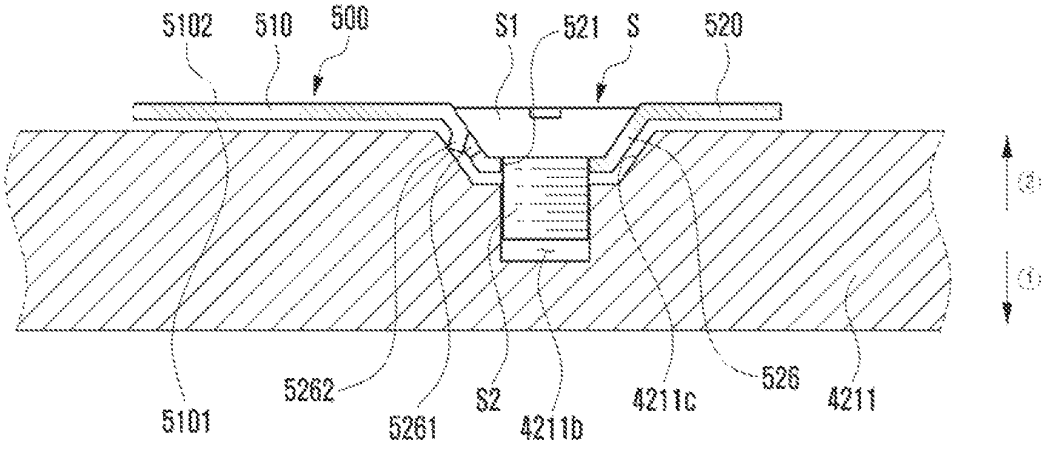


FIG. 11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500
S1
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5262
5261
S2
4211b
4211c
526
4211
③
①

FIG. 12A

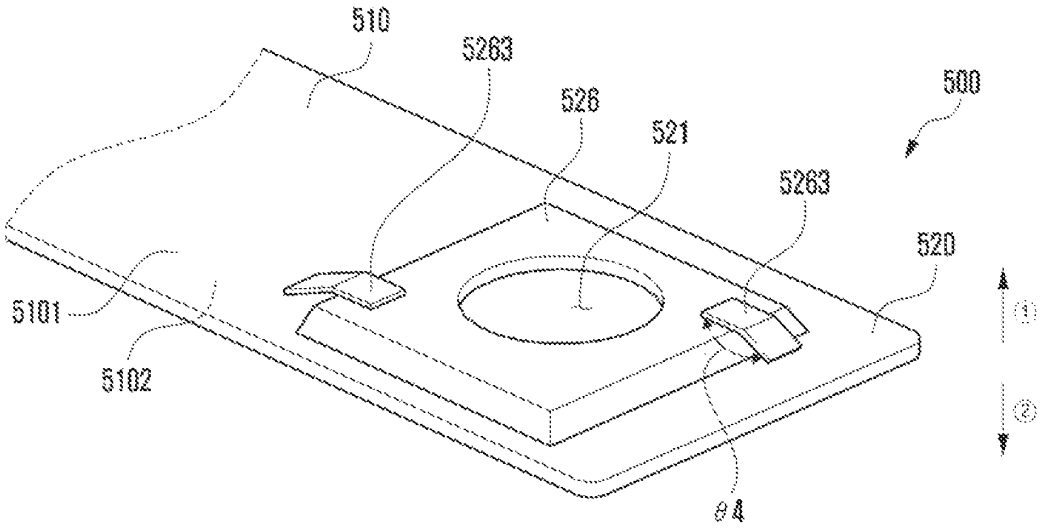


FIG. 12B

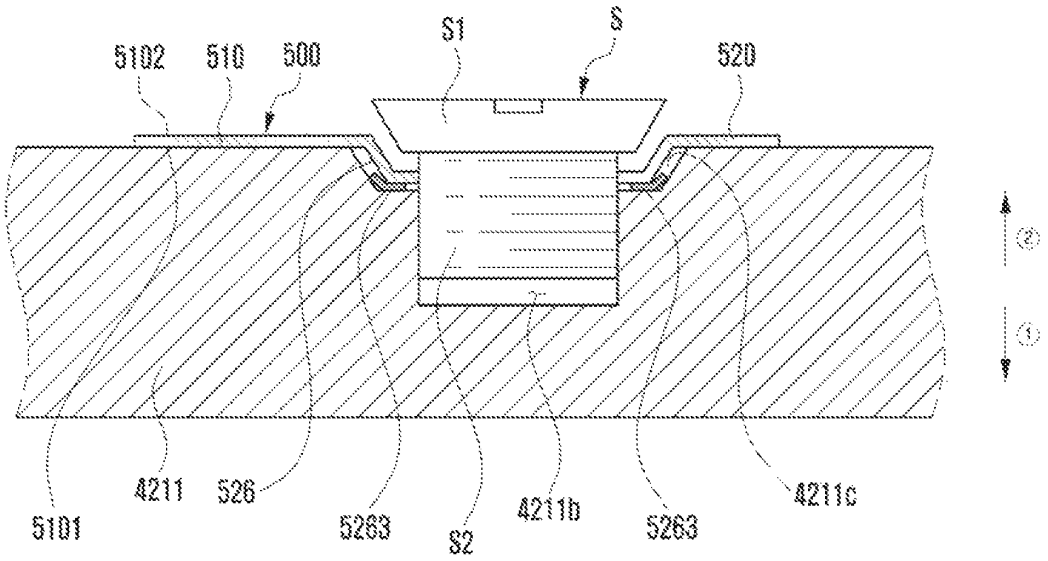


FIG. 13A

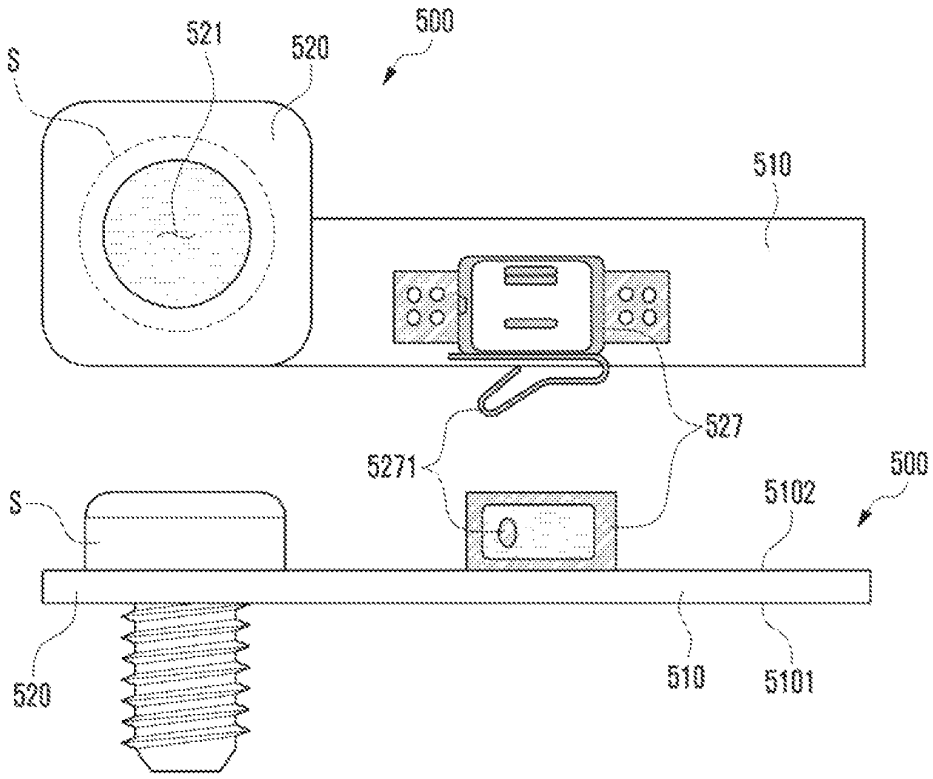


FIG. 13B

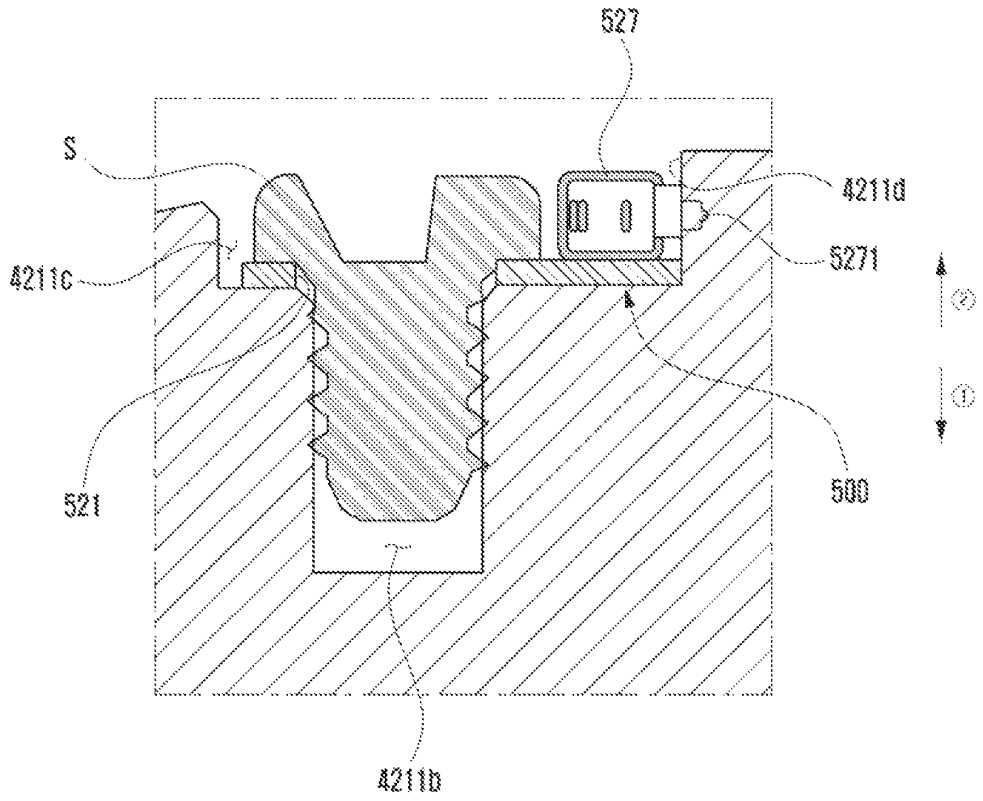


FIG. 14

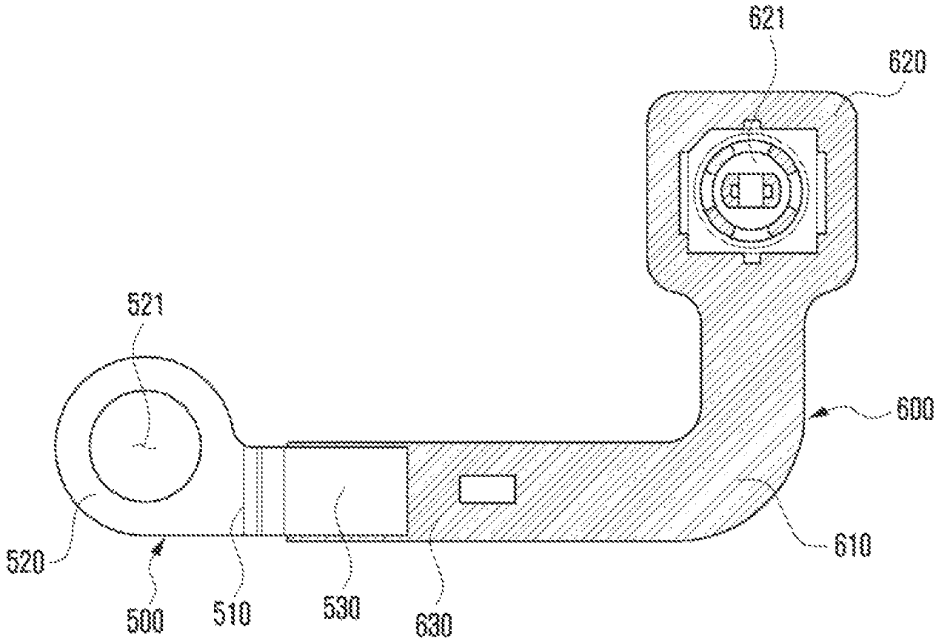


FIG. 15A

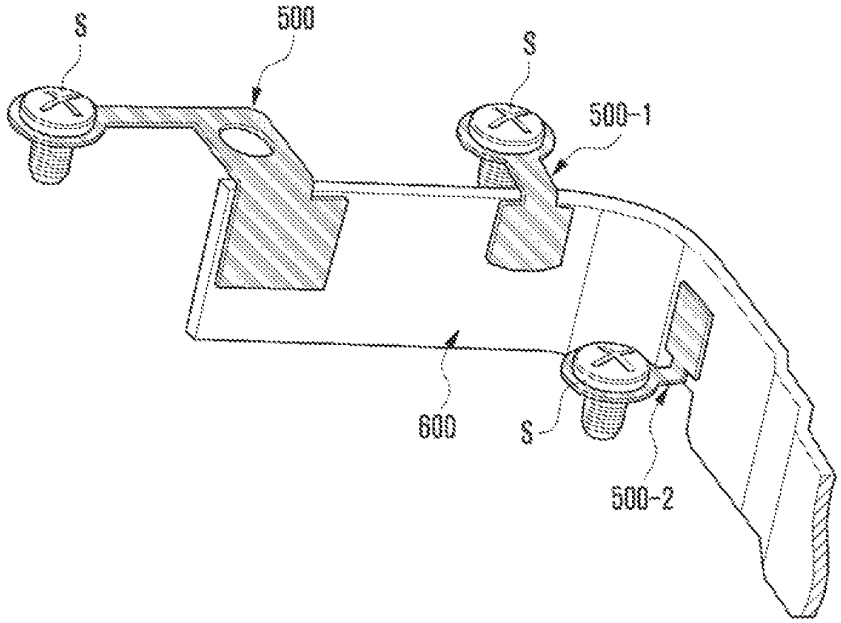
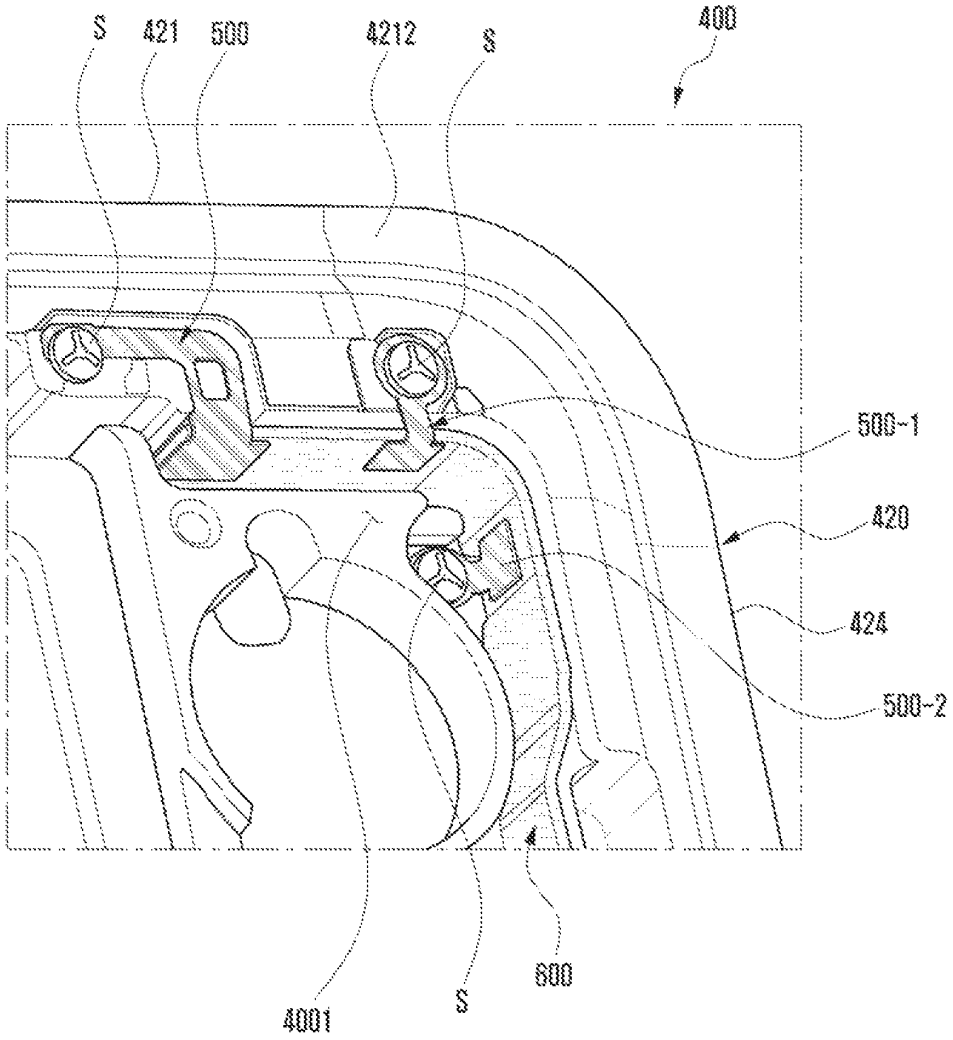


FIG. 15B



ANTENNA AND ELECTRONIC DEVICE INCLUDING SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a by-pass continuation of International Application No. PCT/KR2021/011929, filed on Sep. 3, 2021, which is based on and claims priority to Korean Patent Application No. 10-2020-0115249, filed on Sep. 9, 2020, in the Korean Intellectual Property Office, the disclosures of which are incorporated by reference herein in their entireties.

BACKGROUND

1. Field

The disclosure relates to an antenna and an electronic device including the same.

2. Description of Related Art

An electronic device may include a plurality of electronic function groups and/or electrical structures. Electronic components and/or electrical structures included in an electronic device may be arranged in a state of being spaced apart from each other by a predetermined interval in an inner space of the electronic device and electrically connected to each other via an electrical connection member. Through this spaced arrangement, the electronic components and/or electric structures may be free from mutual interference and may be efficiently designed.

At least some conductive structures arranged in an electronic device may be electrically connected to a substrate disposed nearby via an electrical connection member. For example, at least some conductive structures electrically connected to a substrate may be used as an antenna radiator for communication via at least one wireless communication circuit disposed on the substrate. A conductive structure used as an antenna radiator may maintain physical contact with a peripheral substrate via an electrical connection member. For example, the electrical connection member may include a metal plate having a predetermined shape, and may be connected to a conductive structure via an electrical connection structure such as a C-clip, a different metal, or soldering.

However, when a conductive contact such as a C-clip is used, an impedance value required for an antenna may not be maintained, and the conductive contact may be difficult to apply when the conductive structure is disposed relatively far from the substrate. In addition, when connected via a different metal, desensing due to galvanic corrosion may occur, which may cause deterioration in radiation performance of an antenna. In addition, when an electrical connection member is fixed to a conductive structure through soldering, maintenance may be difficult.

An electrical connection member may be used when it is relatively far away from a substrate in the inner space of the electronic device, and may be fixed via a locking device such as a screw to secure physical contact reliability with a conductive structure used as an antenna radiator.

However, when the electronic device is used for a long period of time or is subjected to an external impact, the locking device fastened to the conductive structure may be loosened and released, a defect may occur in the electrical connection between the conductive structure and the electrical connection member, and as a result, the radiation performance of the antenna may be deteriorated.

SUMMARY

Provided are an antenna having an electrical connection structure capable of being resistant to an external impact or being used for a long period of time, and an electronic device including the same.

According to an aspect of the disclosure, an electronic device includes: a housing; a substrate disposed in the housing; an antenna radiator; and an electrical connection member electrically interconnecting the antenna radiator and the substrate, wherein the electrical connection member includes: a plate portion including a first surface facing the antenna radiator and a second surface facing away from the first surface; a first fixing portion provided at a first end of the plate portion, the first fixing portion including a through hole and a tension structure; and a second fixing portion provided at a second end of the plate portion and electrically connecting the electrical connection member to the substrate, wherein the first fixing portion is fixed to the antenna radiator via a locking device that passes through the through hole, and wherein the tension structure is configured to contact the antenna radiator and maintain tension between the electrical connection member and the antenna radiator during fastening of the locking device.

The tension structure may include at least one tension rib extending from the first surface of the plate portion or the first fixing portion at a first angle.

The at least one tension rib may extend from an end of the first fixing portion.

The first fixing portion may include an opening spaced apart from the through hole, and wherein the at least one tension rib extends into the opening.

The tension structure may include at least one tension rib extending in a direction parallel to the first surface from the through hole.

The at least one tension rib may have a curved shape.

The at least one tension rib may have a curvature that is smaller than a curvature of an inner diameter of the through hole.

The at least one tension rib may protrude beyond a plane defined by the first surface in a direction toward the antenna radiator.

The tension structure may include a bend in the plate portion, and the through hole is disposed between an end of the first fixing portion and the bend.

The antenna radiator may have a fastening hole in which the locking device is inserted to fix the first fixing portion to the antenna radiator, a recess may be provided in an outer surface of the antenna radiator around the fastening hole, and the first fixing portion may include a protrusion seated in the recess.

The tension structure may include at least one tension rib disposed on the protrusion and extending outward from the protrusion to elastically contact an inner wall of the recess.

The at least one tension rib may be disposed on the first surface and is at least partially bent in a direction in which the second surface is oriented.

The at least one tension rib may extend outward from the protrusion through an opening in the protrusion.

The tension structure may include a conductive contact disposed on the plate portion or the first fixing portion, and configured to continuously provide a contact force to an inner wall of the recess.

The antenna radiator may include a unit conductive portion provided via at least one non-conductive portion in a portion of the housing.

The unit conductive portion may form a portion of an exterior of the electronic device.

The electronic device may further include a flexible substrate disposed between the electrical connection member and the substrate and electrically connected to the substrate, and the second fixing portion of the electrical connection member may be electrically connected to the flexible substrate.

The first fixing portion may be fastened to the antenna radiator in a direction parallel to the substrate.

The first fixing portion may be fastened to the antenna radiator in a direction perpendicular to the substrate.

The antenna radiator may be disposed in the housing.

According to one or more embodiments, an electrical connection member may be capable of always providing a reliable electrical connection structure through its own tension structure, thereby preventing degradation of the radiation performance of an antenna, even when the electronic device is used for a long period of time or the locking device is loosened as an external impact is applied thereto.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of certain embodiments of the present disclosure will be more apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a front perspective view of an electronic device (e.g., a mobile electronic device) according to various embodiments of the disclosure;

FIG. **2** is a rear perspective view of the electronic device of FIG. **1** according to various embodiments of the disclosure;

FIG. **3** is an exploded perspective view of the electronic device of FIG. **1** according to various embodiments of the disclosure;

FIG. **4** is a partial configuration view of an electronic device according to various embodiments of the disclosure;

FIGS. **5**A and **5**B are partial perspective views illustrating a state in which a conductive portion is electrically connected to a substrate via an electrical connection member according to various embodiments of the disclosure;

FIG. **6**A is a partial perspective view of an electrical connection member according to various embodiments of the disclosure;

FIG. **6**B is a plan view illustrating a state in which an electrical connection member according to various embodiments of the disclosure is fixed to a substrate and a conductive portion;

FIG. **7**A is a cross-sectional view illustrating a state before the electrical connection member of FIG. **6**B according to various embodiments of the disclosure is fastened to the conductive portion;

FIG. **7**B is a cross-sectional view illustrating a state in which the electrical connection member of FIG. **6**B according to various embodiments of the disclosure is fastened to the conductive portion;

FIG. **7**C is a cross-sectional view illustrating a contact relationship between an electrical connection member and a conductive portion according to releasing of a locking device according to various embodiments of the disclosure;

FIG. **8**A is a partial perspective view of the electrical connection member of FIG. **6**B according to various embodiments of the disclosure;

FIG. **8**B is a cross-sectional view illustrating a contact relationship between an electrical connection member and a conductive portion according to releasing of a locking device according to various embodiments of the disclosure;

FIG. **9**A is a partial perspective view of an electrical connection member according to various embodiments of the disclosure;

FIG. **9**B is a cross-sectional view illustrating a contact relationship between an electrical connection member and a conductive portion according to releasing of a locking device according to various embodiments of the disclosure;

FIG. **10**A is a partial perspective view of an electrical connection member according to various embodiments of the disclosure;

FIG. **10**B is a partial plan view illustrating a state in which a locking device is fastened to an electrical connection member according to various embodiments of the disclosure;

FIG. **11** is a cross-sectional view illustrating a contact relationship between an electrical connection member and a conductive portion according to releasing of a locking device according to various embodiments of the disclosure;

FIG. **12**A is a partial perspective view of an electrical connection member according to various embodiments of the disclosure;

FIG. **12**B is a cross-sectional view illustrating a contact relationship between an electrical connection member and a conductive portion according to releasing of a locking device according to various embodiments of the disclosure;

FIG. **13**A is a configuration view of an electrical connection member including a conductive contact according to various embodiments of the disclosure;

FIG. **13**B is a cross-sectional view illustrating a state in which an electrical connection member including a conductive contact according to various embodiments of the disclosure is fixed to a conductive portion by a locking device.

FIG. **14** is a plan view illustrating a state in which an electrical connection member and a flexible substrate (a flexible printed circuit board (FPCB)-type RF cable) according to various embodiments of the disclosure are connected to each other;

FIG. **15**A is a perspective view illustrating a flexible substrate to which a plurality of electrical connection members are fixed according to various embodiments of the disclosure; and

FIG. **15**B is a perspective view illustrating a state in which a flexible substrate including a plurality of electrical connection members according to various embodiments of the disclosure is disposed in an electronic device.

DETAILED DESCRIPTION

FIG. **1** illustrates a perspective view showing a front surface of a mobile electronic device according to an embodiment of the disclosure, and FIG. **2** illustrates a perspective view showing a rear surface of the mobile electronic device shown in FIG. **1** according to an embodiment of the disclosure.

Referring to FIGS. **1** and **2**, a mobile electronic device **100** may include a housing **110** that includes a first surface (or front surface) **110**A, a second surface (or rear surface) **110**B, and a lateral surface **110**C that surrounds a space between the first surface **110**A and the second surface **110**B. The housing **110** may refer to a structure that forms a part of the first surface **110**A, the second surface **110**B, and the lateral surface **110**C. The first surface **110**A may be formed of a front plate **102** (e.g., a glass plate or polymer plate coated

with a variety of coating layers) at least a part of which is substantially transparent. The second surface **110**B may be formed of a rear plate **111** which is substantially opaque. The rear plate **111** may be formed of, for example, coated or colored glass, ceramic, polymer, metal (e.g., aluminum, stainless steel (STS), or magnesium), or any combination thereof. The lateral surface **110**C may be formed of a lateral bezel structure (or "lateral member") **118** which is combined with the front plate **102** and the rear plate **111** and includes a metal and/or polymer. The rear plate **111** and the lateral bezel structure **118** may be integrally formed and may be of the same material (e.g., a metallic material such as aluminum).

The front plate **102** may include two first regions **110**D disposed at long edges thereof, respectively, and bent and extended seamlessly from the first surface **110**A toward the rear plate **111**. Similarly, the rear plate **111** may include two second regions **110**E disposed at long edges thereof, respectively, and bent and extended seamlessly from the second surface **110**B toward the front plate **102**. The front plate **102** (or the rear plate **111**) may include only one of the first regions **110**D (or of the second regions **110**E). The first regions **110**D or the second regions **110**E may be omitted in part. When viewed from a lateral side of the mobile electronic device **100**, the lateral bezel structure **118** may have a first thickness (or width) on a lateral side where the first region **110**D or the second region **110**E is not included, and may have a second thickness, being less than the first thickness, on another lateral side where the first region **110**D or the second region **110**E is included.

The mobile electronic device **100** may include at least one of a display **101**, audio modules **103**, **107** and **114**, sensor modules **104** and **119**, camera modules **105**, **112** and **113**, a key input device **117**, a light emitting device, and connector hole **108**. The mobile electronic device **100** may omit at least one (e.g., the key input device **117** or the light emitting device) of the above components, or may further include other components.

The display **101** may be exposed through a substantial portion of the front plate **102**, for example. At least a part of the display **101** may be exposed through the front plate **102** that forms the first surface **110**A and the first region **110**D of the lateral surface **110**C. The display **101** may be combined with, or adjacent to, a touch sensing circuit, a pressure sensor capable of measuring the touch strength (pressure), and/or a digitizer for detecting a stylus pen. At least a part of the sensor modules **104** and **119** and/or at least a part of the key input device **117** may be disposed in the first region **110**D and/or the second region **110**E.

The audio modules **103**, **107** and **114** may correspond to a microphone hole **103** and speaker holes **107** and **114**, respectively. The microphone hole **103** may contain a microphone disposed therein for acquiring external sounds and, in a case, contain a plurality of microphones to sense a sound direction. The speaker holes **107** and **114** may be classified into an external speaker hole **107** and a call receiver hole **114**. The microphone hole **103** and the speaker holes **107** and **114** may be implemented as a single hole, or a speaker (e.g., a piezo speaker) may be provided without the speaker holes **107** and **114**.

The sensor modules **104** and **119** may generate electrical signals or data corresponding to an internal operating state of the mobile electronic device **100** or to an external environmental condition. The sensor modules **104** and **119** may include a first sensor module **104** (e.g., a proximity sensor) and/or a second sensor module (e.g., a fingerprint sensor) disposed on the first surface **110**A of the housing **110**, and/or a third sensor module **119** (e.g., a heart rate monitor (HRM) sensor) and/or a fourth sensor module (e.g., a fingerprint sensor) disposed on the second surface **110**B of the housing **110**. The fingerprint sensor may be disposed on the second surface **110**B as well as the first surface **110**A (e.g., the display **101**) of the housing **110**. The electronic device **100** may further include at least one of a gesture sensor, a gyro sensor, an air pressure sensor, a magnetic sensor, an acceleration sensor, a grip sensor, a color sensor, an infrared (IR) sensor, a biometric sensor, a temperature sensor, a humidity sensor, or an illuminance sensor.

The camera modules **105**, **112** and **113** may include a first camera device **105** disposed on the first surface **110**A of the electronic device **100**, and a second camera device **112** and/or a flash **113** disposed on the second surface **110**B. The camera module **105** or the camera module **112** may include one or more lenses, an image sensor, and/or an image signal processor. The flash **113** may include, for example, a light emitting diode or a xenon lamp. Two or more lenses (infrared cameras, wide angle and telephoto lenses) and image sensors may be disposed on one side of the electronic device **100**.

The key input device **117** may be disposed on the lateral surface **110**C of the housing **110**. The mobile electronic device **100** may not include some or all of the key input device **117** described above, and the key input device **117** which is not included may be implemented in another form such as a soft key on the display **101**. The key input device **117** may include the sensor module disposed on the second surface **110**B of the housing **110**.

The light emitting device may be disposed on the first surface **110**A of the housing **110**. For example, the light emitting device may provide status information of the electronic device **100** in an optical form. The light emitting device may provide a light source associated with the operation of the camera module **105**. The light emitting device may include, for example, a light emitting diode (LED), an IR LED, or a xenon lamp.

The connector hole **108** may include a first connector hole **108** adapted for a connector (e.g., a universal serial bus (USB) connector) for transmitting and receiving power and/or data to and from an external electronic device. The connector hole **108** may include a second connector hole (not shown) adapted for a connector (e.g., an earphone jack) for transmitting and receiving an audio signal to and from an external electronic device.

Some sensor modules **105** of camera modules **105** and **212**, some sensor modules **104** of sensor modules **104** and **119**, or an indicator may be arranged to be exposed through a display **101**. For example, the camera module **105**, the sensor module **104**, or the indicator may be arranged in the internal space of an electronic device **100** so as to be brought into contact with an external environment through an opening of the display **101**, which is perforated up to a front plate **102**. In another embodiment, some sensor modules **104** may be arranged to perform their functions without being visually exposed through the front plate **102** in the internal space of the electronic device. For example, in this case, an area of the display **101** facing the sensor module may not require a perforated opening.

According to various embodiments, the electronic device **100** may include at least one antenna radiator (e.g., the first conductive portion **4211** of FIG. **4**) configured via at least a portion of the conductive side surface member **118**. According to an embodiment, at least one antenna radiator (e.g., the first conductive portion **4211** of FIG. **4**) may be disposed on an upper area (e.g., area A) and/or a lower area (e.g., area B)

of the electronic device **100**. At least one antenna radiator (e.g., the first conductive portion **4211** of FIG. **4**) according to exemplary embodiments of the disclosure may be configured to operate in at least one frequency band via at least one electrical connection member (e.g., the electrical connection member **500** of FIG. **6**A) disposed inside the electronic device **100**.

FIG. **3** illustrates an exploded perspective view showing a mobile electronic device shown in FIG. **1** according to an embodiment of the disclosure.

The electronic device **300** in FIG. **3** may be at least partially similar to the electronic device **100** in FIG. **1** and FIG. **2** or may further include other embodiments.

Referring to FIG. **3**, a mobile electronic device **300** may include a lateral bezel structure **310**, a first support member **311** (e.g., a bracket), a front plate **320**, a display **330**, an electromagnetic induction panel, a printed circuit board (PCB) **340**, a battery **350**, a second support member **360** (e.g., a rear case), an antenna **370**, and a rear plate **380**. The mobile electronic device **300** may omit at least one (e.g., the first support member **311** or the second support member **360**) of the above components or may further include another component. Some components of the electronic device **300** may be the same as or similar to those of the mobile electronic device **100** shown in FIG. **1** or FIG. **2**, thus, descriptions thereof are omitted below.

The first support member **311** is disposed inside the mobile electronic device **300** and may be connected to, or integrated with, the lateral bezel structure **310**. The first support member **311** may be formed of, for example, a metallic material and/or a non-metal (e.g., polymer) material. The first support member **311** may be combined with the display **330** at one side thereof and also combined with the printed circuit board (PCB) **340** at the other side thereof. On the PCB **340**, a processor, a memory, and/or an interface may be mounted. The processor may include, for example, one or more of a central processing unit (CPU), an application processor (AP), a graphics processing unit (GPU), an image signal processor (ISP), a sensor hub processor, or a communications processor (CP).

The memory may include, for example, one or more of a volatile memory and a non-volatile memory.

The interface may include, for example, a high definition multimedia interface (HDMI), a USB interface, a secure digital (SD) card interface, and/or an audio interface. The interface may electrically or physically connect the mobile electronic device **300** with an external electronic device and may include a USB connector, an SD card/multimedia card (MMC) connector, or an audio connector.

The battery **350** is a device for supplying power to at least one component of the mobile electronic device **300**, and may include, for example, a non-rechargeable primary battery, a rechargeable secondary battery, or a fuel cell. At least a part of the battery **350** may be disposed on substantially the same plane as the PCB **340**. The battery **350** may be integrally disposed within the mobile electronic device **300**, and may be detachably disposed from the mobile electronic device **300**.

The antenna **370** may be disposed between the rear plate **380** and the battery **350**. The antenna **370** may include, for example, a near field communication (NFC) antenna, a wireless charging antenna, and/or a magnetic secure transmission (MST) antenna. The antenna **370** may perform short-range communication with an external device, or transmit and receive power required for charging wirelessly. An antenna structure may be formed by a part or combination of the lateral bezel structure **310** and/or the first support member **311**.

FIG. **4** is a partial configuration view of an electronic device **400** according to various embodiments of the disclosure.

The electronic device **400** of FIG. **4** may be at least partially similar to the electronic device **100** of FIGS. **1** and/or the electronic device **300** of FIG. **3**, or may include other embodiments of the same.

Referring to FIG. **4**, the electronic device **400** (e.g., the electronic device **100** of FIG. **1** and/or the electronic device **300** of FIG. **3**) may include a housing **410** (e.g., the housing **110** of FIG. **1**) (e.g., a housing structure) that includes a front surface cover (e.g., the front surface plate **102** of FIG. **1**) (e.g., the first cover or first plate), a rear surface cover facing away from the front surface cover (e.g., the rear surface plate **111** of FIG. **2**) (e.g., the second cover or second plate), and a side surface member **420** (e.g., the side surface member **118** of FIG. **1**) surrounding the inner space **4001** between the front surface cover and the rear surface cover. According to an embodiment, the side surface member **420** may be at least partially made of a conductive member.

According to various embodiments, the side surface member **420** may include a first side surface **421** having a first length, a second side surface **422** extending in a vertical direction from the first side surface **421** and having a second length longer than the first length, a third side surface extending in a direction parallel to the first side surface **421** from the second side surface **422** and having the first length, and a fourth side surface **424** extending from the third side surface in a direction parallel to the second side surface **422** and having the second length.

According to various embodiments, the side surface member **420** made of a conductive material (e.g., metal) may include one or more conductive portions **4211** and **4212** electrically disconnected by one or more non-conductive portions **4213**, **4214**, and **4215**. According to an embodiment, the electronic device **400** may include two unit conductive portions **4211** and **4212** disposed via three non-conductive portions **4213**, **4214**, and **4215** in an upper area (e.g., area A of FIG. **1**). For example, the electronic device **400** may include a first conductive portion **4211** disposed through a first non-conductive portion **4213** provided in at least a portion of the first side surface **421** and a second non-conductive portion **4214** provided in at least a portion of the second side surface **422**. According to an embodiment, the electronic device **400** may include a second conductive portion **4212** disposed adjacent to the first conductive portion **4211** via the first non-conductive portion **4213** and a third non-conductive portion **4215** provided in at least a portion of the fourth side surface **424**. In some embodiments, the electronic device **400** may include one or more conductive portions disposed in a substantially similar manner in a lower area (e.g., area B of FIG. **1**) of the side surface member **420** as well.

According to various embodiments, the electronic device **400** may include a substrate **430** (e.g., a printed circuit board, a device board, or a main board) disposed in the inner space **4001**. According to an embodiment, the substrate **430** may include at least one wireless communication circuit (e.g., a feeder). According to an embodiment, the substrate **430** may be electrically connected to the first conductive portion **4211** via an electrical connection member **500** according to exemplary embodiments of the disclosure. For example, the wireless communication circuit disposed on the substrate **430** may be configured to transmit and/or

receive a wireless signal in at least one predetermined frequency band by using the first conductive portion **4211** electromagnetically connected thereto via the electrical connection member **500** as an antenna radiator. In some embodiments, the substrate **430** may be electrically connected to at least a portion of the second conductive portion **4212** via another electrical connection member. In this case, the wireless communication circuit may be configured to transmit and/or receive a wireless signal by using the second conductive portion **4212** as another antenna radiator.

According to various embodiments, the electrical connection member **500** may electrically interconnect the first conductive portion **4211** and the substrate **430** spaced apart from the same by a predetermined distance in the inner space **4001** of the electronic device **400**. For example, the predetermined distance may include a distance in which the substrate **430** and the first conductive portion **4211** are not electrically connectable via a conductive contact (e.g., a C-clip or conductive tape). According to an embodiment, the electrical connection member **500** is a metal plate and may be configured in various shapes to easily interconnect the first conductive portion **4211** and the substrate **430**. According to an embodiment, the electrical connection member **500** may include a plate portion **510** having a length, a first fixing portion **520** provided at one end of the plate portion **510** and including a through hole (e.g., the through hole **521** of FIG. **6**A) through which at least a portion of a locking device S (e.g., a screw or fastening member) passes, and a second fixing portion **530** provided at the other end of the plate portion **510** and fixed to the substrate **430**. According to an embodiment, the first fixing portion **520** may pass through the through hole **521** and may be fixed to the first conductive portion **4211** via the locking device S fastened to the inner surface **4211***a* of the first conductive portion **4211**. According to an embodiment, the second fixing portion **530** may be fixed to a corresponding conductive pad of the substrate **430** via a fixing structure such as soldering. In some embodiments, the second fixing portion **530** may be electrically connected to the substrate **430** through conductive bonding or structural coupling. In some embodiments, the second fixing portion **530** may be electrically connected to the substrate **430** via a conductive contact (e.g., a C-clip or conductive tape).

According to an exemplary embodiment of the disclosure, the electrical connection member **500** may include a tension structure. For example, even when the electronic device **400** is used for a long period of time or the locking device S is loosened or partially released due to an external impact, the electrical connection member **500** is able to maintain a reliable electrical connection (e.g., physical contact) between the first fixing portion **520** and the first conductive portion **4211** via the tension structure, thereby preventing deterioration in radiation performance of the first conductive portion **4211** due to the loosening of the locking device.

In some embodiments, the first conductive portion **4211** may be replaced with another antenna structure (e.g., an antenna carrier or an antenna structure disposed on another substrate) spaced apart from the substrate in the inner space of the electronic device.

FIGS. **5**A and **5**B are partial perspective views illustrating a state in which a conductive portion is electrically connected to a substrate via an electrical connection member according to various embodiments of the disclosure.

Referring to FIG. **5**A, the electronic device **400** may include an electrical connection member **500** disposed in an inner space **4001** of the electronic device **400** and electrically interconnecting a first conductive portion **4211** used as an antenna radiator and a substrate **430**. According to an embodiment, the second fixing portion **520** of the electrical connection member **500** may be assembled to come into surface contact with the inner surface **4211***a* of the first conductive portion **4211** in a locking device fastening part **425**. In this case, the locking device S may be fastened in a direction perpendicular to the inner surface of the first conductive portion **4211** (e.g., the y-axis direction).

Referring to FIG. **5**B, in the inner space **4001** of the electronic device **400**, the second fixing portion **520** of the electrical connection member **500** may be fixed to a locking device fastening portion **426** extending from a portion of the first conductive portion **4211** to the inner space. For example, the second fixing portion **520** may be assembled in a direction perpendicular to the inner surface **4211***a* of the first conductive portion **4211** (e.g., the z-axis direction). In this case, the locking device S may be fastened to the locking device fastening portion **426** in a direction parallel to the inner surface **4211***a* of the first conductive portion **4211**.

Hereinafter, various embodiments of the electrical connection member **500** and the tension structure applied thereto will be described in detail, and the first conductive portion **4211** may be referred to as a "conductive portion."

FIG. **6**A is a partial perspective view of the electrical connection member **500** according to various embodiments of the disclosure. FIG. **6**B is a view illustrating a state in which the electrical connection member **500** is fixed to a substrate **430** and the conductive portion **4211** according to various embodiments of the disclosure.

Referring to FIGS. **6**A and **6**B, an electronic device **400** may include a substrate **430** disposed in the inner space of the electronic device, a conductive portion **4211** spaced apart from the substrate **430**, and an electrical connection member **500** that electrically interconnects the conductive portion **4211** and the substrate **430**. According to an embodiment, the electrical connection member **500** may include a plate portion **510**, a first fixing portion **520** provided at one end of the plate portion **510** and fixed to the conductive portion **4211** by a locking device S, and a second fixing portion **530** provided at the other end of the plate portion **510** and fixed to the substrate **430**. According to an embodiment, the first fixing portion **520** may include a through hole **521** through which the locking device S passes. According to an embodiment, the electrical connection member **500** may include a first surface **5101** oriented in a first direction (direction ①) (e.g., the direction toward the conductive portion) and a second surface **5102** oriented in a second direction (direction ②) opposite to the first direction (direction ①). According to an embodiment, in the first fixing portion **520**, an end portion including at least a portion of the through hole **521** may be bent with respect to the plate portion **510** in the first direction (direction ①) by a predetermined angle θ1. According to an embodiment, the electrical connection member **500** may include at least one tension protrusion **522** protruding from the first surface **5101** in the periphery of the through hole **521** of the first fixing portion **520**. According to an embodiment, the electrical connection member **500** may include at least one tension slit **5211** provided to be connected to the through hole **521** from at least a portion of an end of the first fixing portion **520**. According to an embodiment, when the first fixing portion **520** is fastened to the conductive portion by the locking device S via an end of the first fixing portion **520** bent in the first direction (direction ①) and at least one tension protrusion **522**, the first fixing portion **520** has its own tension and may come into contact with the conductive portion **4211** by the fastening force of the locking device S. According to

an embodiment, the at least one tension slit **5211** may assist elastic deformation through at least one divided portion of the first fixing portion **520**.

FIG. **7**A is a view illustrating a state before the electrical connection member **500** of FIG. **6**B according to various embodiments of the disclosure is coupled to the conductive portion **4211**. FIG. **7**B is a view illustrating a state in which the electrical connection member **500** of FIG. **6**B according to various embodiments of the disclosure is fastened to the conductive portion **4211**. FIG. **7**C is a view illustrating a contact relationship between the electrical connection member **500** of FIG. **6**B and the conductive portion **4211** according to the releasing of the locking device S according to various embodiments of the disclosure.

Referring to FIG. **7**A, when the electrical connection member **500** is placed on the conductive portion **4211**, only the end portion of the partially bent first fixing portion **520** including the through hole **521** may come into contact with the conductive portion **4211**. In this case, the through hole **521** of the first fixing portion **520** may remain aligned with the fastening hole **4211***b* of the conductive portion **4211** for fastening the locking device.

Referring to FIG. **7**B, the electrical connection member **500** may be fixed to the conductive portion **4211** by the locking device S, which passes through the through hole **521** of the first fixing portion **520** and is then fastened to the fastening hole **4211***b* of the conductive portion **4211**. In this case, the first fixing portion **520** may be elastically deformed to be parallel to the plate portion **510** by the fastening force of the locking device S, so that at least one tension protrusion **522** may remain in contact with the conductive portion **4211**. In some embodiments, when the tension protrusion **522** is not present, the plate portion **510** and the first fixing portion **520** may brought into contact with the conductive portion **4211** as a whole by the fastening force of the locking device.

Referring to FIG. **7**C, when an electronic device (e.g., the electronic device **400** of FIG. **4**) is subjected to an external impact, and the locking device S is partially released thereby, the electrical connection member **500** may be spaced apart from the conductive portion **4211** in the second direction (direction ②). In this case, the elastically deformed first fixing portion **520** of the electrical connection member **500** may be continuously maintained in contact with the conductive portion **4211** by a force applied by the end portion in the first direction (direction ②). Therefore, even if the locking device S is partially released, since the continuous physical contact between the electrical connection member **500** and the conductive portion **4211** is maintained, it is possible to prevent degradation of the radiation performance of the conductive portion **4211** used as an antenna radiator.

FIG. **8**A is a partial perspective view of an electrical connection member **500** according to various embodiments of the disclosure. FIG. **8**B is a view illustrating a contact relationship between the electrical connection member **500** and the conductive portion **4211** according to the releasing of the locking device S according to various embodiments of the disclosure.

Referring to FIG. **8**A, the electrical connection member **500** may include at least one tension rib **523** extending outward from the first fixing portion **520**. According to an embodiment, the tension rib **523** may be bent from the end of the first fixing portion **520** in the first direction (direction ①) by a predetermined angle θ2. According to an embodiment, two or more tension ribs **523**, which are spaced apart from each other at the end of the first fixing portion **520** by a predetermined distance, may be provided.

Referring to FIG. **8**B, when an electronic device (e.g., the electronic device **400** of FIG. **4**) is subjected to an external impact, and the locking device S is partially released thereby, the electrical connection member **500** may be spaced apart from the conductive portion **4211** in the second direction (direction ②). In this case, even if the plate portion **510** and the first fixing portion **520** are spaced apart from the conductive portion **4211**, the elastically deformed tension rib **523** of the electrical connection member **500** may be continuously maintained in contact with the conductive portion **4211** by the force applied by the tension rib **523** in the first direction (direction ①). Therefore, even if the locking device S is partially released, since the continuous physical contact between the electrical connection member **500** and the conductive portion **4211** is maintained by the tension rib **523**, it is possible to prevent degradation of the radiation performance of the conductive portion **4211** used as an antenna radiator.

FIG. **9**A is a partial perspective view of an electrical connection member **500** according to various embodiments of the disclosure. FIG. **9**B is a view illustrating a contact relationship between the electrical connection member **500** and the conductive portion **4211** according to the releasing of the locking device S according to various embodiments of the disclosure.

Referring to FIG. **9**A, the electrical connection member **500** may include an opening **524** provided in at least a partial area of the plate portion **510** and/or the first fixing portion **520** in the periphery of the through hole **521**, and at least one tension rib **5241** extending into the opening **524**. According to an embodiment, the tension rib **5241** may be bent from a portion at which the opening **524** of the first fixing portion **520** is initiated in the first direction (direction ①) by a predetermined angle θ3. According to an embodiment, two or more tension ribs **5241**, which extend into the opening **524** and are spaced apart from each other by a predetermined distance, may be provided.

Referring to FIG. **9**B, when an electronic device (e.g., the electronic device **400** of FIG. **4**) is subjected to an external impact, and the locking device S is partially released thereby, the electrical connection member **500** may be spaced apart from the conductive portion **4211** in the second direction (direction ②). In this case, even if the plate portion **510** and the first fixing portion **520** are spaced apart from the conductive portion **4211**, the elastically deformed tension rib **5241** of the electrical connection member **500** may be continuously maintained in contact with the conductive portion **4211** by the force applied by the tension rib **523** in the first direction (direction ①). Therefore, even if the locking device S is partially released, since the continuous physical contact between the electrical connection member **500** and the conductive portion **4211** is maintained by the tension rib **5241**, it is possible to prevent degradation of the radiation performance of the conductive portion **4211** used as an antenna radiator.

FIG. **10**A is a partial perspective view of an electrical connection member **500** according to various embodiments of the disclosure. FIG. **10**B is a view illustrating a state in which a locking device S is fastened to the electrical connection member **500** according to various embodiments of the disclosure.

Referring to FIG. **10**A, the electrical connection member **500** may include at least one tension rib **525** extending into at least a partial space of a through hole **521**. According to an embodiment, the at least one tension rib **525** may be

provided in a curved shape extending from the through hole **521** in a direction parallel to a first surface **5101** and having a curvature smaller than that of the inner diameter of the through hole **521**. According to an embodiment, the tension rib **525** may be configured integrally with the first fixing portion **520** or fixed inside the through hole **521**. In some embodiments, the tension rib **525** may protrude in a direction in which the first surface **5101** is oriented (e.g., direction ①).

Referring to FIG. **10**B, when a threaded portion S**2** of a locking device S passes through the through hole **521**, the curved tension rib **525** may be elastically deformed while being spread in the left and right directions (in the directions indicated by the arrows), and may maintain physical contact with the outer circumferential surface of the threaded portion S**2** while retaining an elastic restoring force. In this case, even if the electronic device (e.g., the electronic device **400** of FIG. **4**) is subjected to an external impact, and the locking device S is partially released thereby, the tension rib **525** is continuously in contact with the threaded portion S**2** of the locking device S, and the threaded portion S**2** may maintain the electrically connected state with the conductive portion **4211** via the fastening hole **4211***b*. Thus, it is possible to prevent degradation in the radiation performance of the conductive portion **4211** used as an antenna radiator. The configuration of the tension rib **525** may be advantageous for use of a locking device in which the diameter of the threaded portion S**2** gradually increases toward the head S**1**.

FIG. **11** is a view illustrating a contact relationship between the electrical connection member **500** and the conductive portion **4211** according to the releasing of the locking device S according to various embodiments of the disclosure.

Referring to FIG. **11**, at least a portion of the first fixing portion **520** of the electrical connection member **500** and the conductive portion **4211** corresponding thereto may include a seating structure. According to an embodiment, in the conductive portion **4211**, the seating structure may include a fastening hole **4211***b* and a recess **4211***c* lower than the outer surface of the conductive portion **4211**. According to an embodiment, the seating structure may include a protrusion **526** which protrudes in a first direction (direction ①) in which the first surface **5101** is oriented in the first fixing portion **520** and is seated in the recess **4211***c* of the conductive portion **4211**. According to an embodiment, the protrusion **526** may include a through hole **521** through which a locking device S passes. According to an embodiment, with the configuration of the protrusion **526**, the first fixing portion **520** may accommodate the locking device S having a countersunk head S**1** and a threaded portion S**2** extending from the same. Therefore, when the locking device S passes through the electrical connection member **500** and is fastened to the fastening hole **4211***b* of the conductive portion **4211**, the head S**1** may be disposed not to be higher than the second surface **5102**.

According to various embodiments, the electrical connection member **500** may include at least one tension rib **5262** protruding from the protrusion **526** in the first direction. According to an embodiment, the tension rib **5262** may protrude from the opening **5261** provided in at least a portion of the protrusion **526** in the first direction in which the first surface is oriented (direction ①). According to an embodiment, when the protrusion **526** is seated in the recess **4211***c* of the conductive portion **4211** and is then fastened by the locking device S, the tension rib **5262** may retain a restoring force through elastic deformation and may maintain the state of being in physical contact with the inner surface of the recess **4211***c*.

According to various embodiments, as illustrated, when an electronic device (e.g., the electronic device **400** of FIG. **4**) is subjected to an external impact, and the locking device S is partially released thereby, the electrical connection member **500** may be spaced apart from the conductive portion **4211** in the second direction (direction ②). In this case, even if the plate portion **510** and the first fixing portion **520** are spaced apart from the conductive portion **4211**, the tension rib **5262** elastically deformed from the protrusion **526** of the electrical connection member **500** may be continuously maintained in contact with the conductive portion **4211** by the force applied by the tension rib **523** in the first direction (direction ①). Therefore, even if the locking device S is partially released, since the continuous physical contact between the electrical connection member **500** and the conductive portion **4211** is maintained by the tension rib **5262**, it is possible to prevent degradation of the radiation performance of the conductive portion **4211** used as an antenna radiator.

FIG. **12**A is a partial perspective view of an electrical connection member **500** according to various embodiments of the disclosure. FIG. **12**B is a view illustrating a contact relationship between the electrical connection member **500** and the conductive portion **4211** according to the releasing of the locking device S according to various embodiments of the disclosure.

Referring to FIG. **12**A, the electrical connection member **500** may include at least one tension rib **5263** disposed to protrude outward from the outer surface of a protrusion **526**. According to an embodiment, the at least one tension rib **5263** may be at least partially bent by a predetermined angle θ4 in a second direction in which a second surface **5102** is oriented (direction ②) (e.g., the same direction as the direction in which the locking device is released). According to an embodiment, the at least one tension rib **5263** may be attached to the outer surface of the protrusion **526** through a soldering, bonding, or welding process.

According to various embodiments, the electrical connection member **500** may be fixed to the conductive portion **4211** by a locking device S, which, after the protrusion **526** is seated in the recess **4211***c* of the conductive portion **4211**, passes through the through hole **521** of the protrusion **526** and is fastened to the fastening hole **4211***b* of the conductive portion **4211**. In this case, the at least one tension rib **5263** protruding from the outer surface of the protrusion **526** and bent in the second direction (direction ②) may be engaged with the inner surface of the recess **4211***c* to be fixed, thereby maintaining the physical contact between the electrical connection member **500** and the conductive portion **4211**.

According to various embodiments, as illustrated, when an electronic device (e.g., the electronic device **400** of FIG. **4**) is subjected to an external impact and the locking device S is partially released thereby, in the electrical connection member **500**, only the locking device S is released and the contact structure provided by the coupling between the protrusion **526** (and/or the tension rib **5263**) and the recess **4211***c* may be continuously maintained by the at least one tension rib **5263**, which is bent in the second direction (direction ②) and comes into contact with the inner surface of the recess **4211***c* to be engaged with the inner surface of the recess **4211***c*. Therefore, even if the locking device S is partially released, since the continuous physical contact between the electrical connection member **500** and the conductive portion **4211** is maintained by the tension rib

5263, it is possible to prevent degradation of the radiation performance of the conductive portion **4211** used as an antenna radiator.

FIG. **13**A is a configuration view of an electrical connection member **500** including a conductive contact **527** according to various embodiments of the disclosure. FIG. **13**B is a view illustrating a state in which the electrical connection member **500** including the conductive contact **527** according to various embodiments of the disclosure is fixed to a conductive portion **4211** by a locking device S.

Referring to FIG. **13**A, the electrical connection member **500** may include a plate portion **510** and a first fixing portion **520** disposed at an end of the plate portion **510**. According to an embodiment, the first fixing portion **520** may include a through hole **521** through which the locking device S passes. According to an embodiment, the electrical connection member **500** may include a conductive contact **527** disposed in the periphery of the through hole **521** and including an elastic contact portion **5271**. According to an embodiment, the conductive contact **527** may be disposed on a second surface **5102** of the electrical connection member **500**. According to an embodiment, the conductive contact **527** may include a C-clip, a pogo pin, or an elastic spring. According to an embodiment, the conductive contact **527** may be disposed on the second surface **5102** and protrude in a direction perpendicular to the second surface **5102**.

Referring to FIG. **13**B, the conductive portion **4211** may include a recess **4211***c* including a fastening hole **4211***b* and provided to be lower than the outer surface of the conductive portion **4211**. According to an embodiment, when the electrical connection member **500** is fastened to the conductive portion **4211** by the locking device S, the elastic contact portion **5271** of the conductive contact **527** may come into contact with an inner wall of the recess **4211***c* with elasticity. According to an embodiment, even if an electronic device (e.g., the electronic device **400** of FIG. **4**) is subjected to an external impact and the locking device S is partially released, the continuous contact structure between the electrical connection member **500** and the conductive portion **4211** may be maintained by the elastic contact portion **5271** of the conductive contact **527** that is in contact with the inner wall **4211***d* of the recess **4211***c* with elasticity. Therefore, even if the locking device S is partially released, since the continuous physical contact between the electrical connection member **500** and the conductive portion **4211** is maintained by the conductive contact **527**, it is possible to prevent degradation of the radiation performance of the conductive portion **4211** used as an antenna radiator.

FIG. **14** is a view illustrating a state in which an electrical connection member **500** and a flexible substrate **600** according to various embodiments of the disclosure are connected to each other.

Referring to FIG. **14**, the electrical connection member **500** may be fixed to the flexible substrate **600** (e.g., a flexible printed circuit board (FPCB)-type RF cable) connected to a substrate (e.g., the printed circuit board **340** of FIG. **3**) of an electronic device (e.g., the electronic device **300** of FIG. **3**). According to an embodiment, the flexible substrate **600** may include a connection portion **610** having a specified length and shape. According to an embodiment, the flexible substrate **600** may include a connector **621** disposed at one end **620** of a connection portion **610** and connected to a receptacle of a substrate (e.g., the printed circuit board **340** of FIG. **3**). According to an embodiment, the other end **630** of the flexible substrate **600** may be fixed to the electrical connection member **500**.

According to various embodiments, the electrical connection member **500** may include a plate portion **510**, a first fixing portion **520** electrically connected to a conductive portion (e.g., the first conductive portion **4211** of FIG. **4**) used as an antenna radiator of the electronic device (e.g., the electronic device **400** of FIG. **4**) via a locking device passing through a through hole **521** at one end of the plate portion **510**, and a second fixing portion **530** electrically connected to the other end **630** of the flexible substrate **600** at the other end of the plate portion **510**. According to an embodiment, the second fixing portion **530** may be electrically connected and fixed to the other end **630** of the flexible substrate **600** through a soldering process.

FIG. **15**A is a view illustrating a flexible substrate to which a plurality of electrical connection members are fixed according to various embodiments of the disclosure. FIG. **15**B is a view illustrating a state in which a flexible substrate **600** including a plurality of electrical connection members **500**, **500-1**, and **500-2** according to various embodiments of the disclosure is disposed in an electronic device.

Referring to FIG. **15**A, the flexible substrate **600** may include a plurality of electrical connection members **500**, **500-1**, and **500-2** spaced apart from each other by a predetermined interval and fixed to the flexible substrate **600** in the same manner as that illustrated in FIG. **14**. According to an embodiment, the flexible substrate **600** may be used when a substrate (e.g., the printed circuit board **340** of FIG. **3**) is electrically connected to a conductive portion **4212** disposed relatively far from the substrate in the inner space **4001** of the electronic device **400**. In this case, a plurality of electrical connection members **500**, **500-1**, and **500-2** may be fixed in such a way that the members are branched from at least a portion of the flexible substrate **600**, and may be fixed to the corresponding conductive side surfaces **421** and **424** of the conductive side surface member **420** by locking devices S. For example, the flexible substrate **600** may be disposed to be bent in a corner portion where a first side surface **421** and a fourth side surface **424** of the conductive side surface member **420** meet in the inner space **4001** of the electronic device **400**. In this case, a first electrical connection member **500** and a second electrical connection member **500-1** branched from the flexible substrate **600** may be fixed to a portion corresponding to the first side surface **421** by a locking device S, and the third electrical connection member **500-2** may be fixed to a portion corresponding to the fourth side surface **424** by a locking device S.

The embodiments of the disclosure disclosed in the specification and drawings are provided merely to propose specific examples in order to easily describe the technical features according to the embodiments of the disclosure and to help understanding of the embodiments of the disclosure, and are not intended to limit the scope of the embodiments of the disclosure. Accordingly, the scope of the various embodiments of the disclosure should be construed in such a manner that, in addition to the embodiments disclosed herein, all changes or modifications derived from the technical idea of the various embodiments of the disclosure are included in the scope of the various embodiments of the disclosure.

What is claimed is:

1. An electronic device comprising:

a housing;

a substrate disposed in the housing;

an antenna radiator; and

an electrical connection member electrically interconnecting the antenna radiator and the substrate,

wherein the electrical connection member comprises:

a plate portion comprising a first surface facing the antenna radiator and a second surface facing away from the first surface;

a first fixing portion provided at a first end of the plate portion, the first fixing portion comprising a through hole and a tension structure; and

a second fixing portion provided at a second end of the plate portion and electrically connecting the electrical connection member to the substrate,

wherein the first fixing portion is fixed to the antenna radiator via a locking device that passes through the through hole, and

wherein the tension structure is configured to contact the antenna radiator and maintain tension between the electrical connection member and the antenna radiator during fastening of the locking device.

2. The electronic device of claim **1**, wherein the tension structure comprises at least one tension rib extending from the first surface of the plate portion or the first fixing portion at a first angle.

3. The electronic device of claim **2**, wherein the at least one tension rib extends from an end of the first fixing portion.

4. The electronic device of claim **2**, wherein the first fixing portion comprises an opening spaced apart from the through hole, and wherein the at least one tension rib extends into the opening.

5. The electronic device of claim **1**, wherein the tension structure comprises at least one tension rib extending in a direction parallel to the first surface from the through hole.

6. The electronic device of claim **5**, wherein the at least one tension rib has a curved shape.

7. The electronic device of claim **6**, wherein the at least one tension rib has a curvature that is smaller than a curvature of an inner diameter of the through hole.

8. The electronic device of claim **5**, wherein the at least one tension rib protrudes beyond a plane defined by the first surface in a direction toward the antenna radiator.

9. The electronic device of claim **1**, wherein the tension structure comprises a bend in the plate portion, and the through hole is disposed between an end of the first fixing portion and the bend.

10. The electronic device of claim **1**, wherein the antenna radiator has a fastening hole in which the locking device is inserted to fix the first fixing portion to the antenna radiator,

wherein a recess is provided in an outer surface of the antenna radiator around the fastening hole, and

wherein the first fixing portion comprises a protrusion seated in the recess.

11. The electronic device of claim **10**, wherein the tension structure comprises at least one tension rib disposed on the protrusion and extending outward from the protrusion to elastically contact an inner wall of the recess.

12. The electronic device of claim **11**, wherein the at least one tension rib is disposed on the first surface and is at least partially bent in a direction in which the second surface is oriented.

13. The electronic device of claim **11**, wherein the at least one tension rib extends outward from the protrusion through an opening in the protrusion.

14. The electronic device of claim **10**, wherein the tension structure comprises a conductive contact disposed on the plate portion or the first fixing portion, and configured to continuously provide a contact force to an inner wall of the recess.

15. The electronic device of claim **1**, wherein the antenna radiator comprises a unit conductive portion provided via at least one non-conductive portion in a portion of the housing.

16. The electronic device of claim **15**, wherein the unit conductive portion forms a portion of an exterior of the electronic device.

17. The electronic device of claim **1**, further comprising a flexible substrate disposed between the electrical connection member and the substrate and electrically connected to the substrate,

wherein the second fixing portion of the electrical connection member is electrically connected to the flexible substrate.

18. The electronic device of claim **1**, wherein the first fixing portion is fastened to the antenna radiator in a direction parallel to the substrate.

19. The electronic device of claim **1**, wherein the first fixing portion is fastened to the antenna radiator in a direction perpendicular to the substrate.

20. The electronic device of claim **15**, wherein the antenna radiator is disposed in the housing.

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Guo et al.

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(54) **ANTENNA APPARATUS AND ELECTRONIC DEVICE**

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CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/50*** (2013.01); ***H04M 1/0266*** (2013.01); ***H04M 1/0277*** (2013.01)

(58) **Field of Classification Search**
CPC H05K 2201/10128; H05K 1/189; H05K 1/028; H05K 3/361; H05K 1/0281;
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(57) **ABSTRACT**

The electronic device includes a frame, a screen, and a circuit board assembly. A part of the frame forms a radiator of an antenna, or the radiator of the antenna is fixed on an inner side of the frame. The circuit board assembly is located on the inner side of the frame. The circuit board assembly includes a first conductive member, and a first board, an elevating board, and a second board sequentially stacked. The first board is located on one side of the second board away from the screen. The first board includes a first main body portion and a first extension portion connected to the
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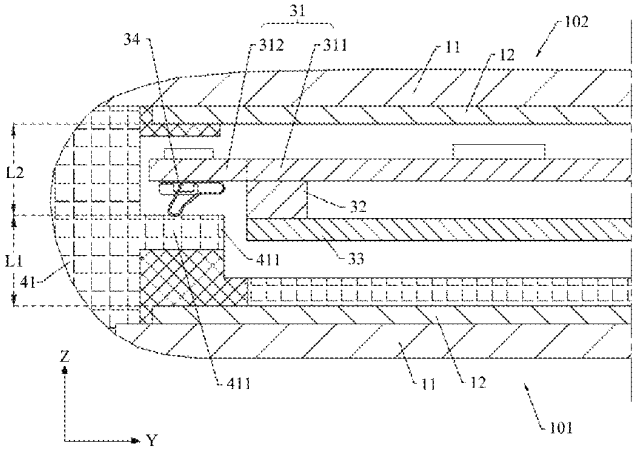

first main body portion. The first main body portion is fixedly connected to the elevating board. The first extension portion protrudes relative to the elevating board and the second board, and is disposed close to the radiator.

18 Claims, 26 Drawing Sheets

(58) **Field of Classification Search**
CPC H05K 2201/055; H05K 2201/056; G02F 1/13452; G06F 1/1652
See application file for complete search history.

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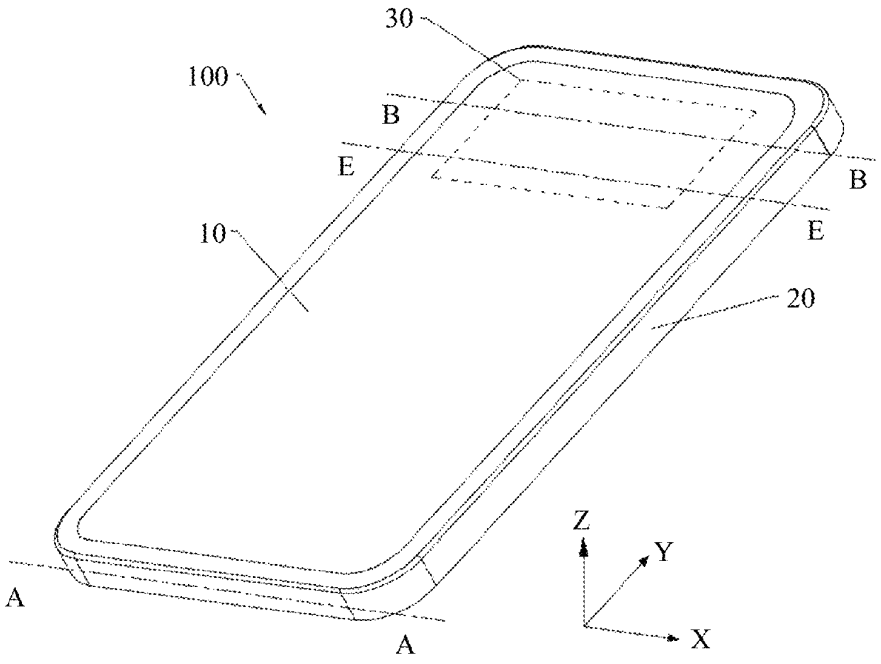


FIG. 1

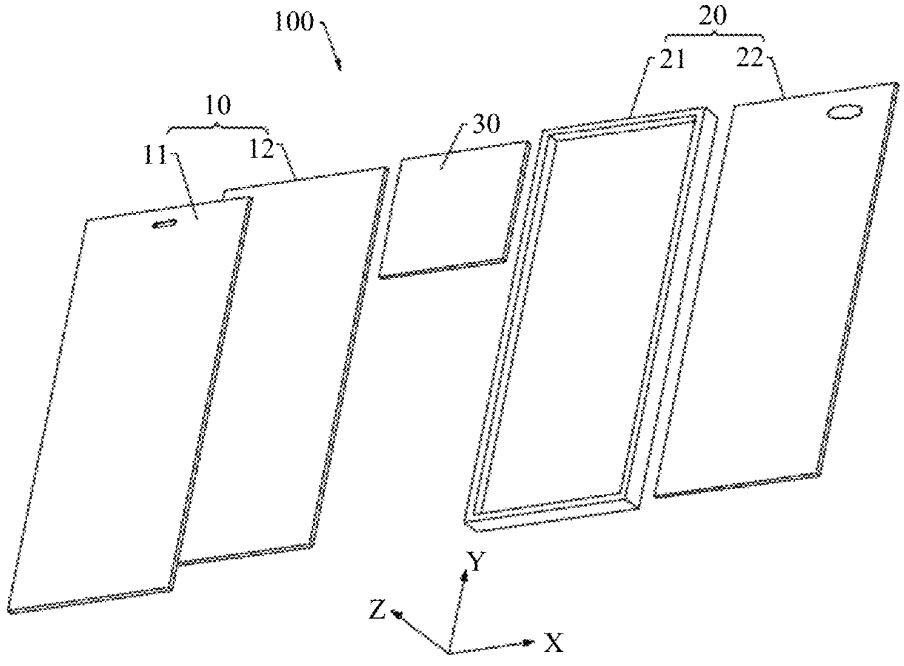
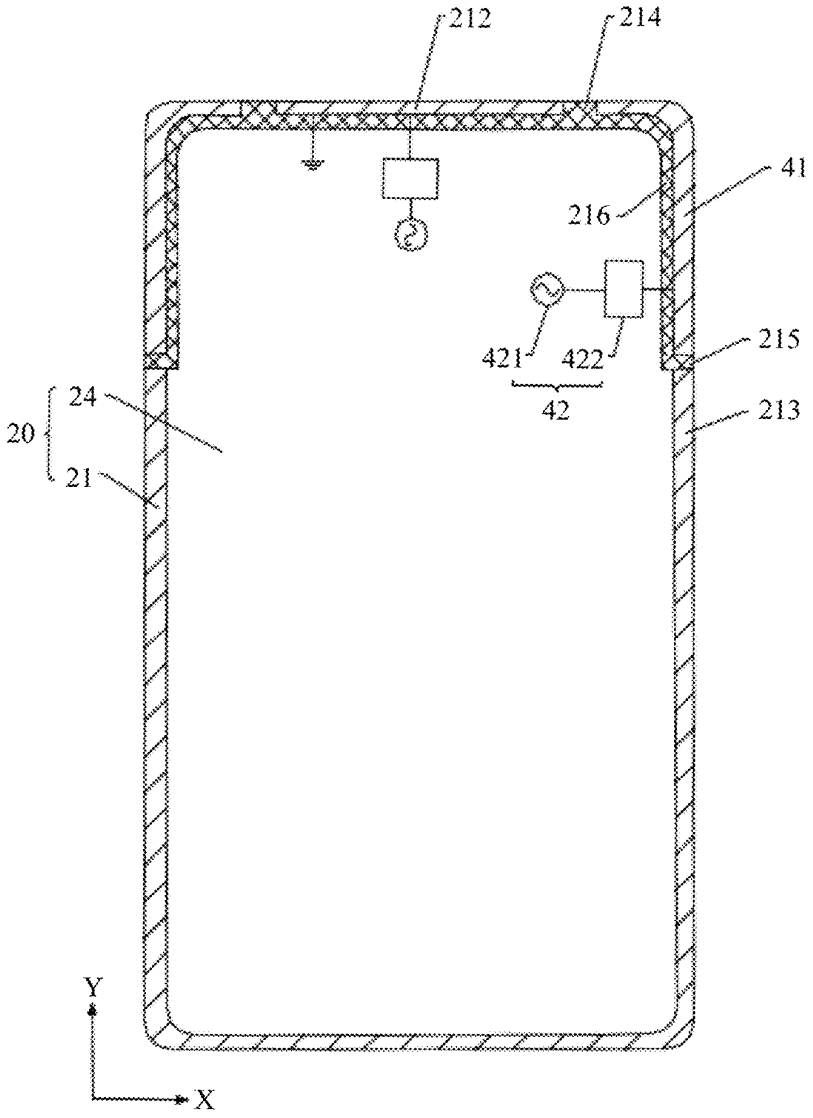


FIG. 2



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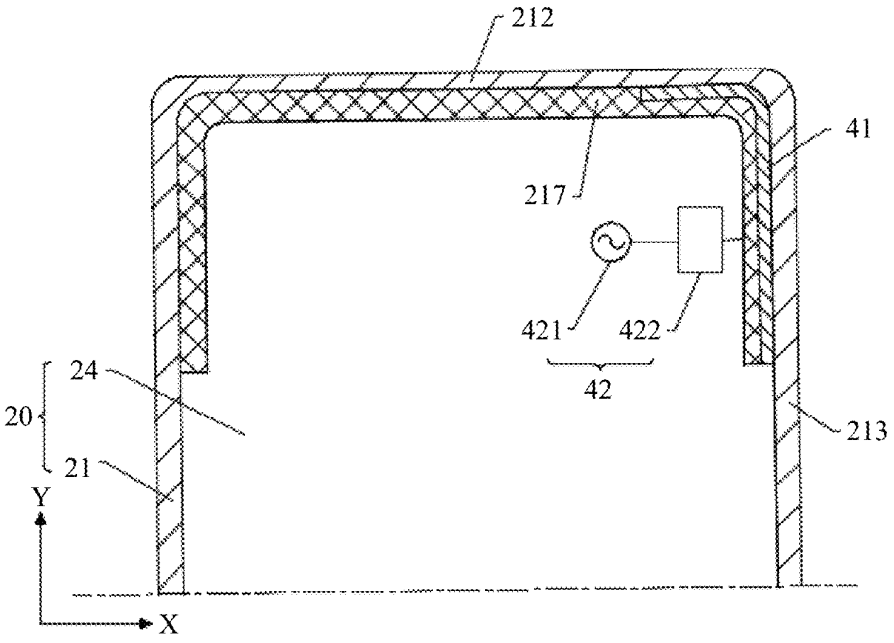

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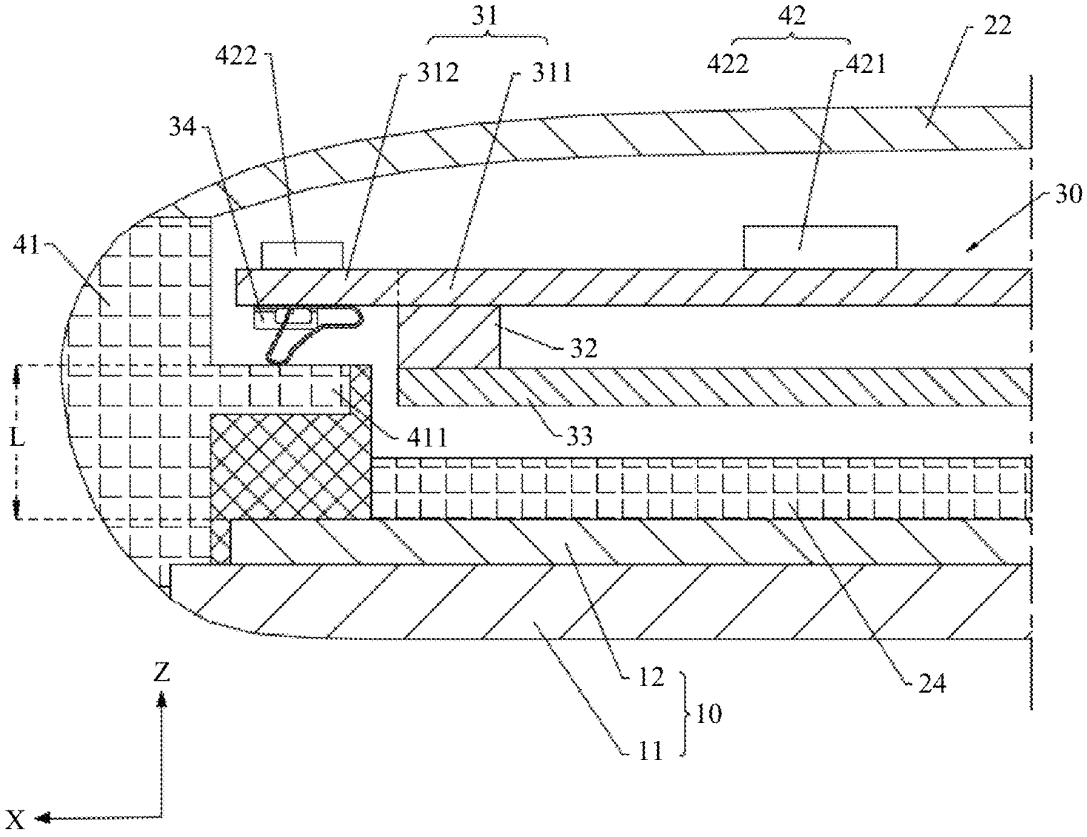

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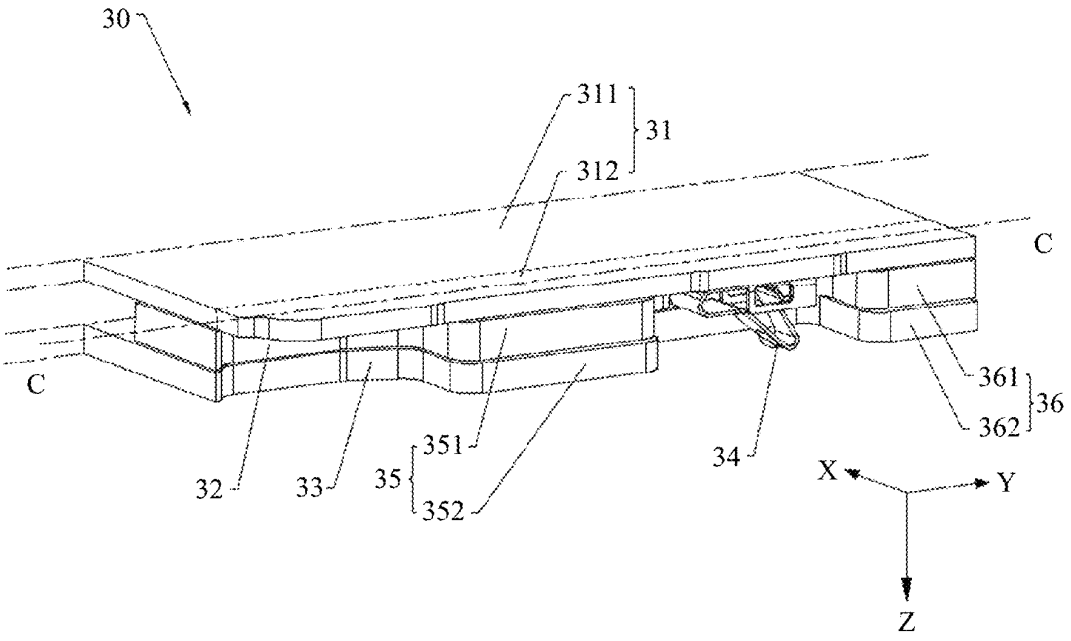

FIG. 6

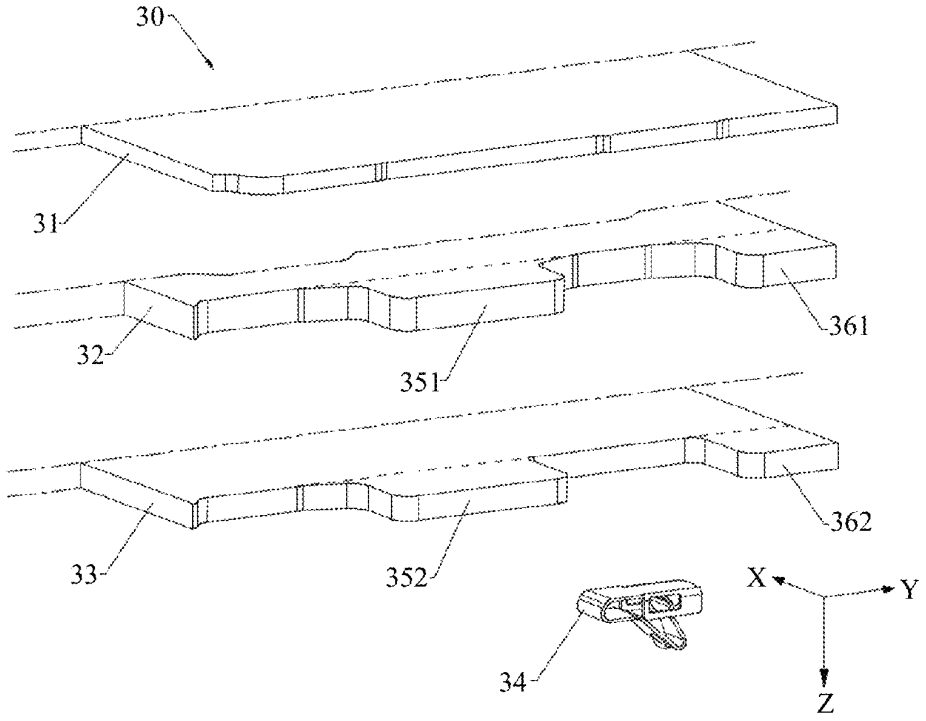

FIG. 7

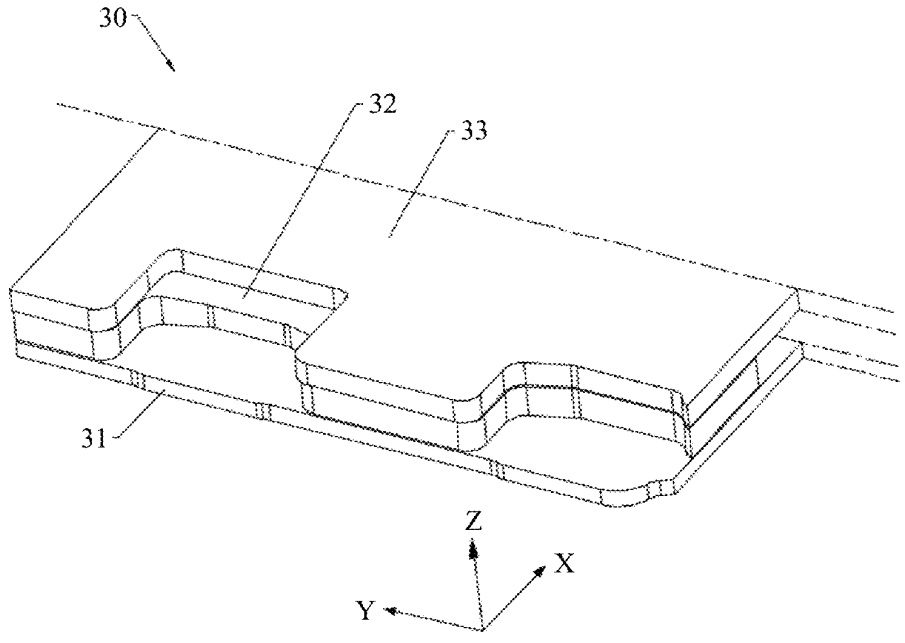

FIG. 8a

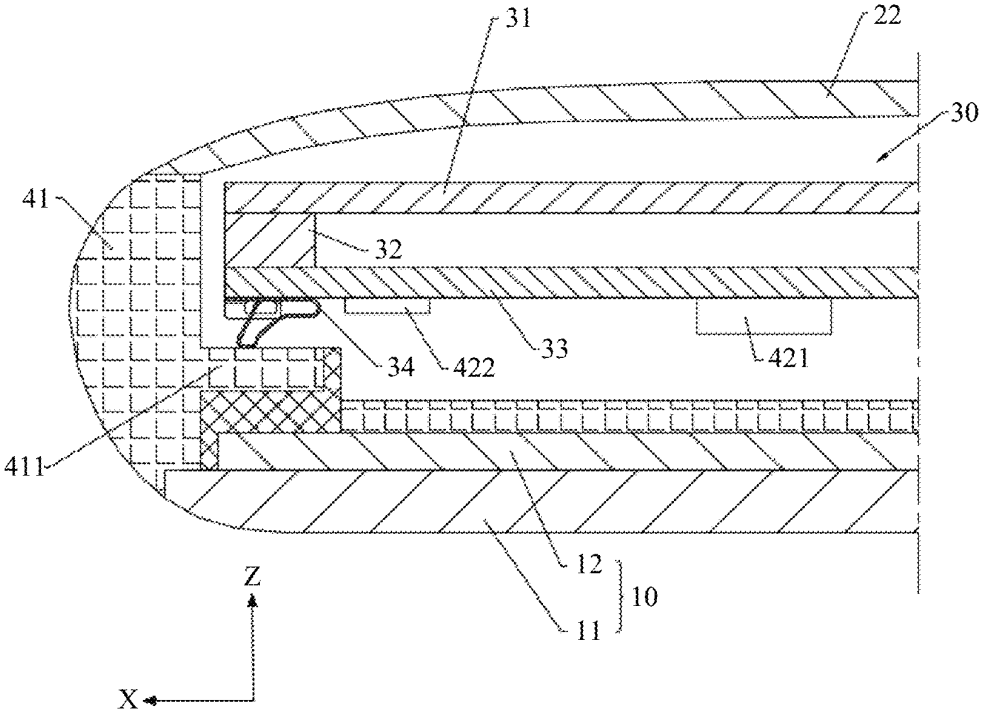
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FIG. 8b

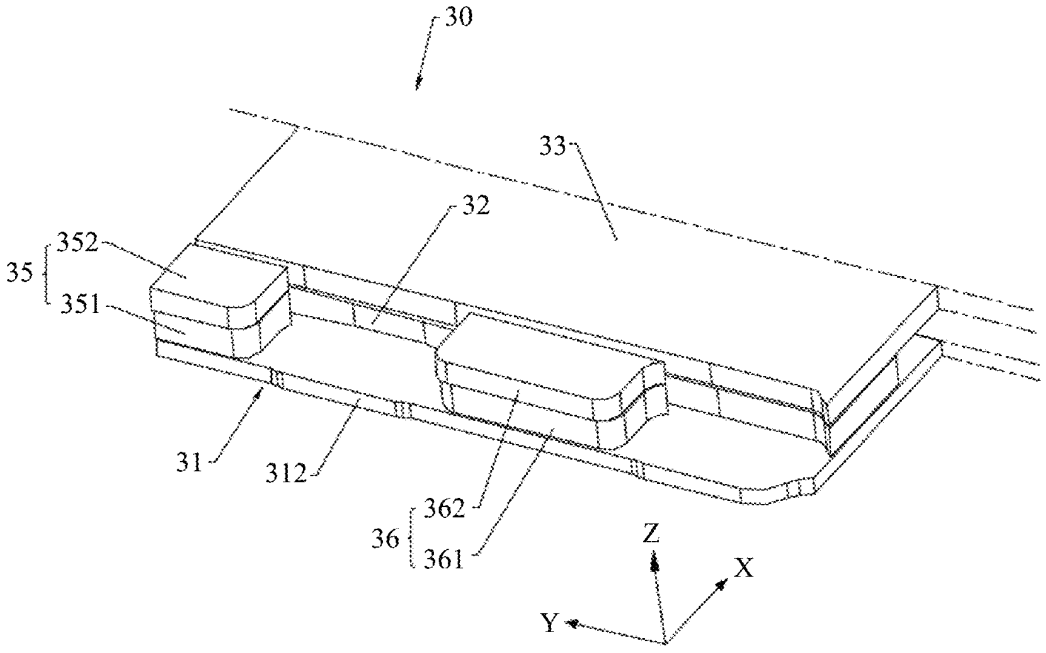
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FIG. 9

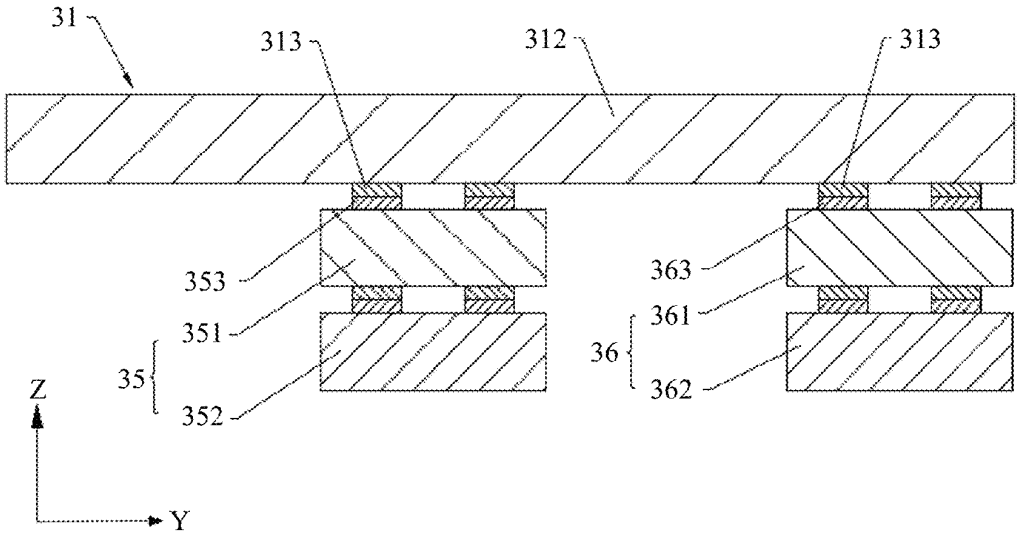
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FIG. 10

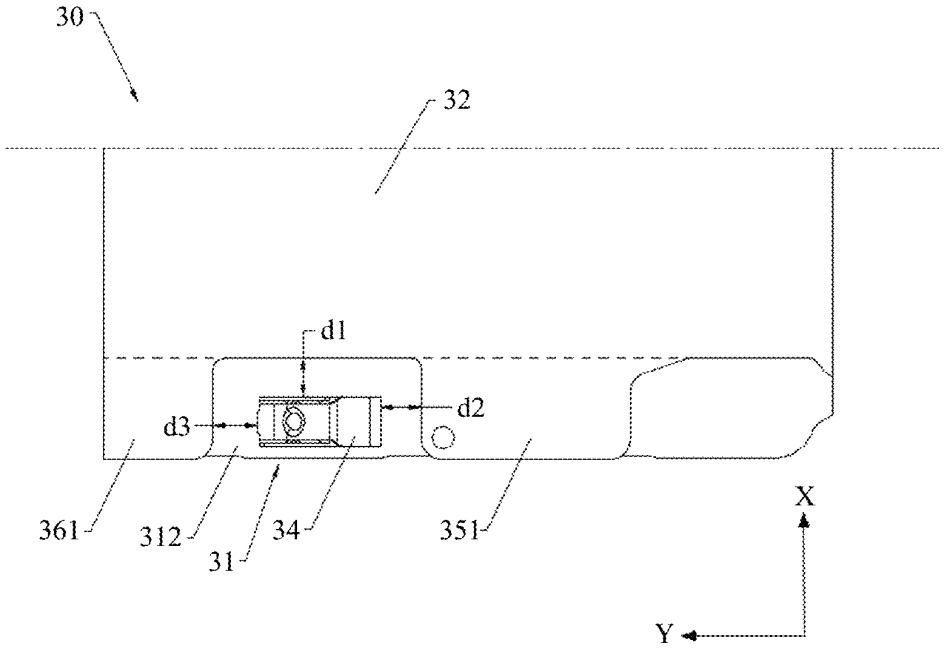
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FIG. 11

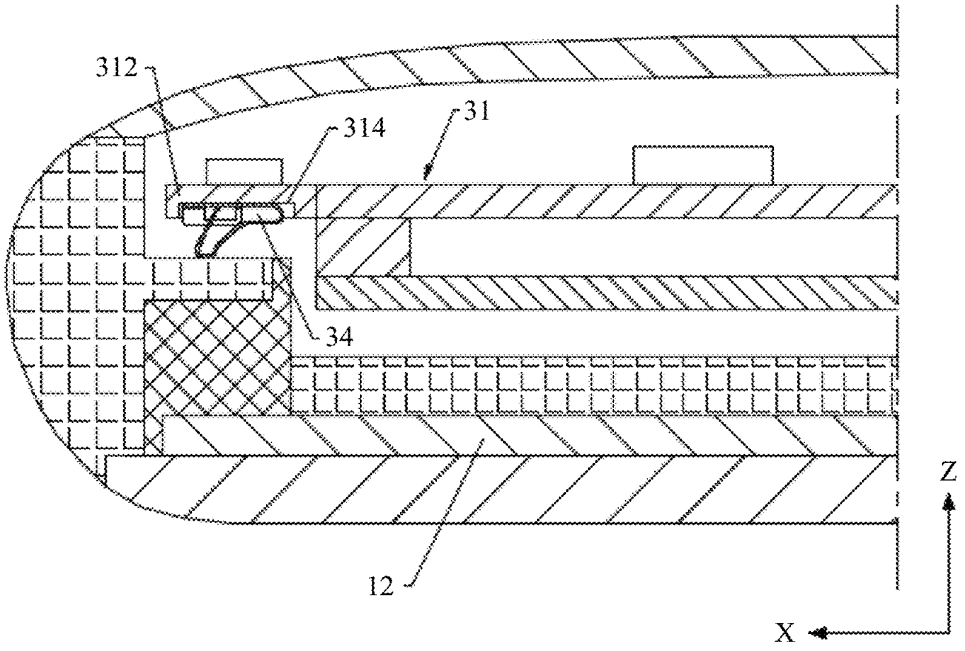


FIG. 12

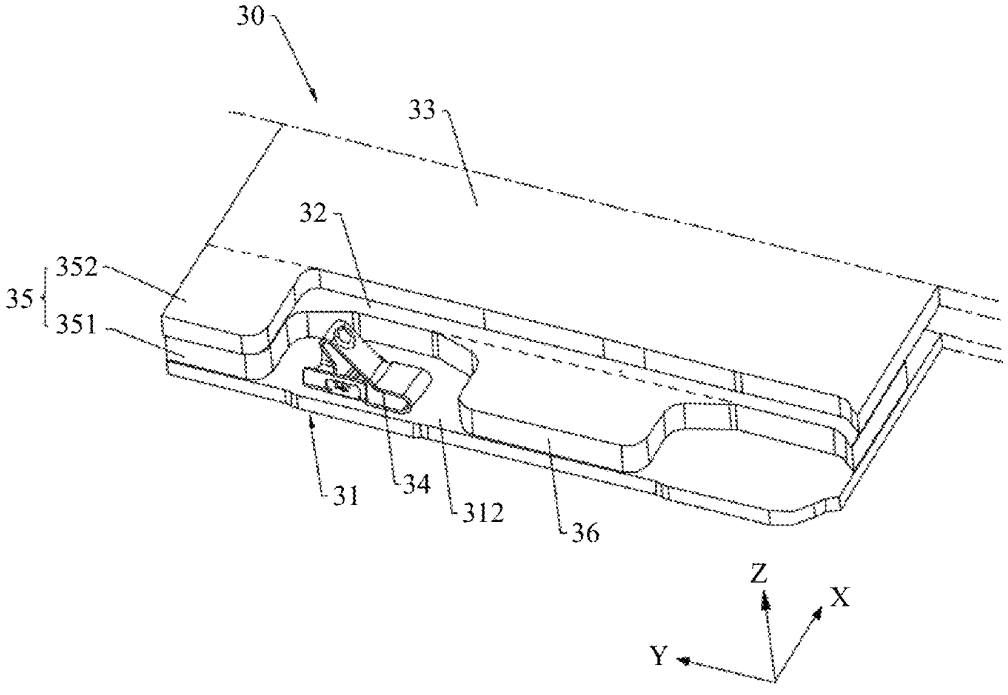


FIG. 13a

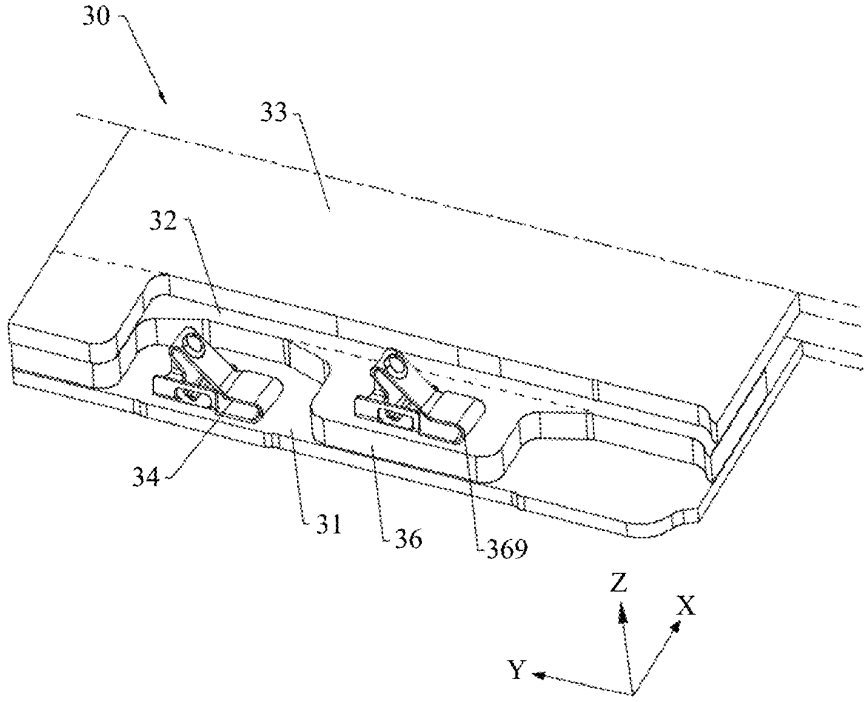


FIG. 13b

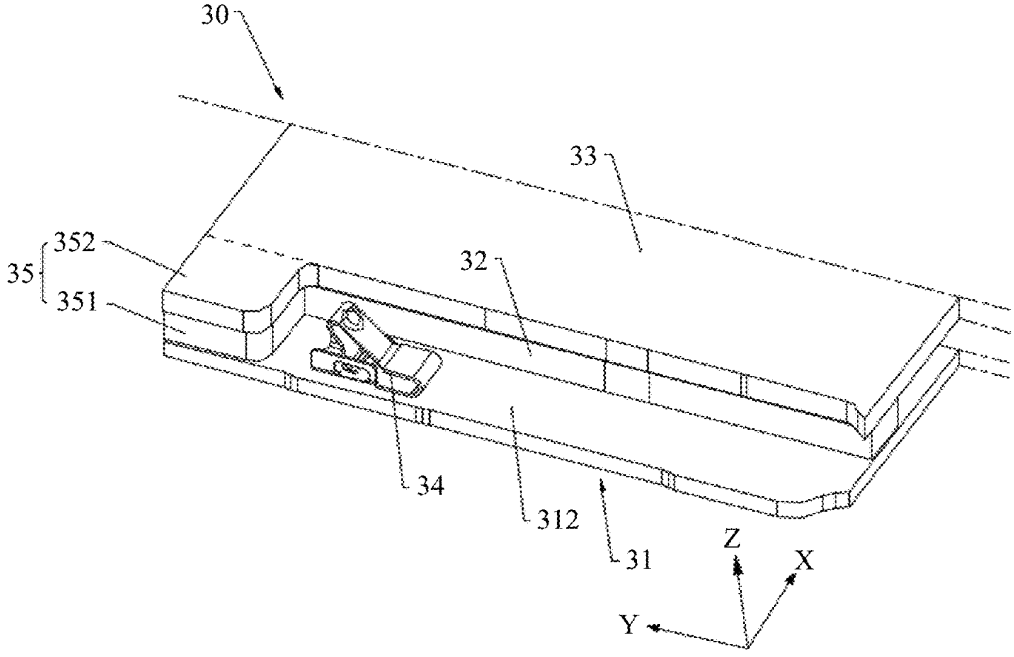


FIG. 14

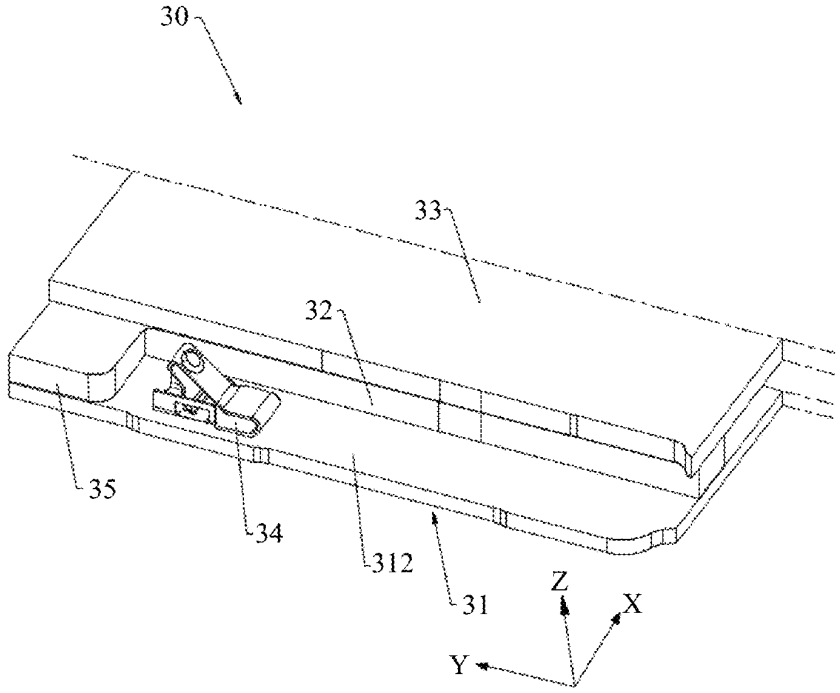


FIG. 15

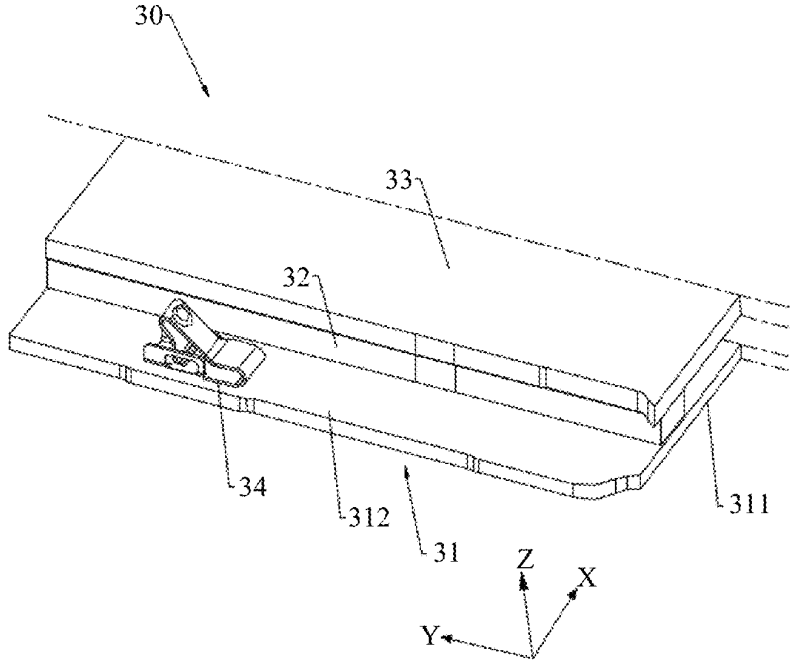
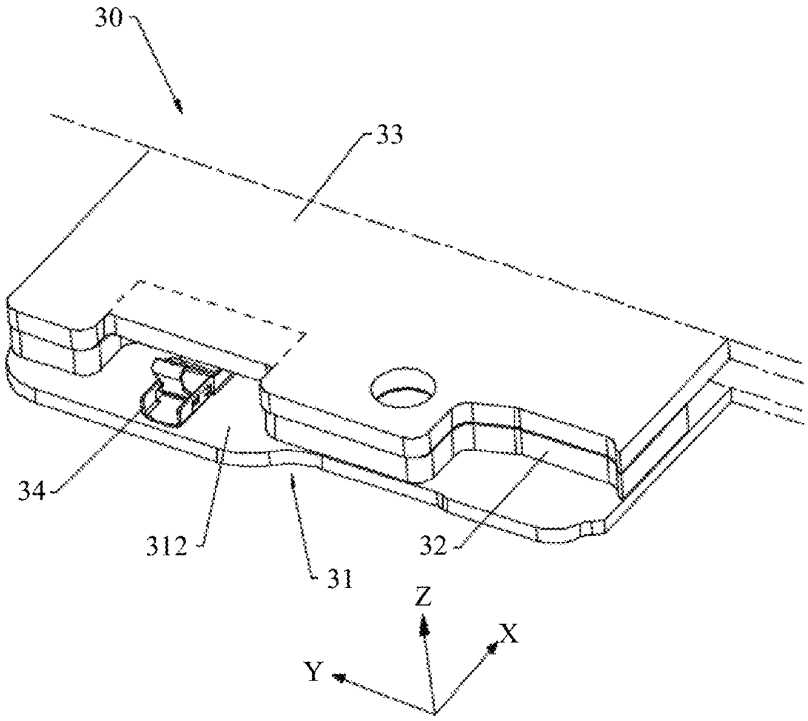


FIG. 16



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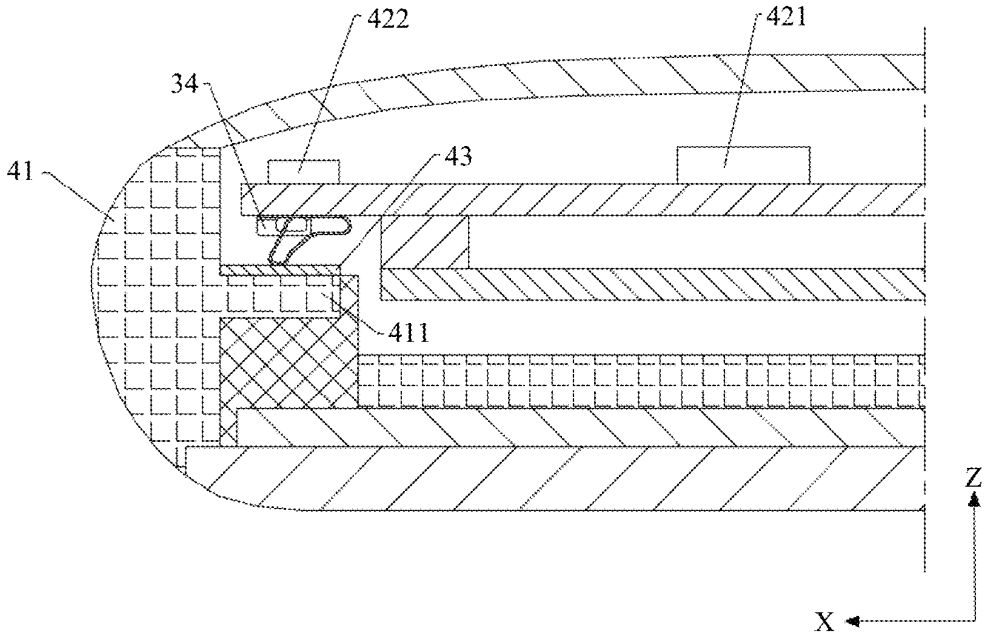

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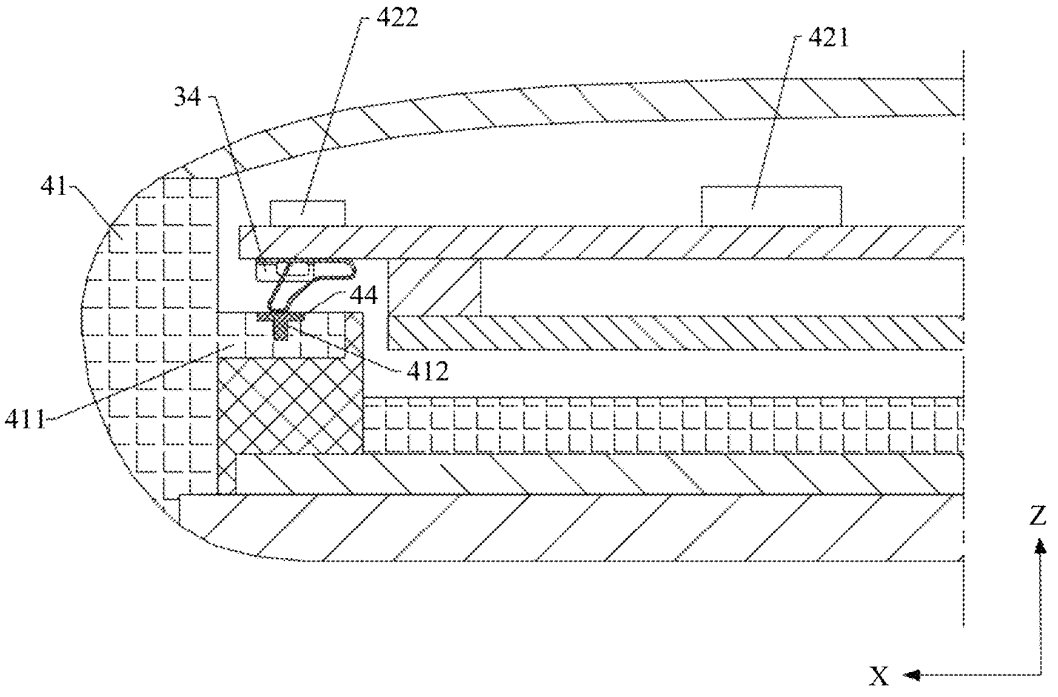


FIG. 19

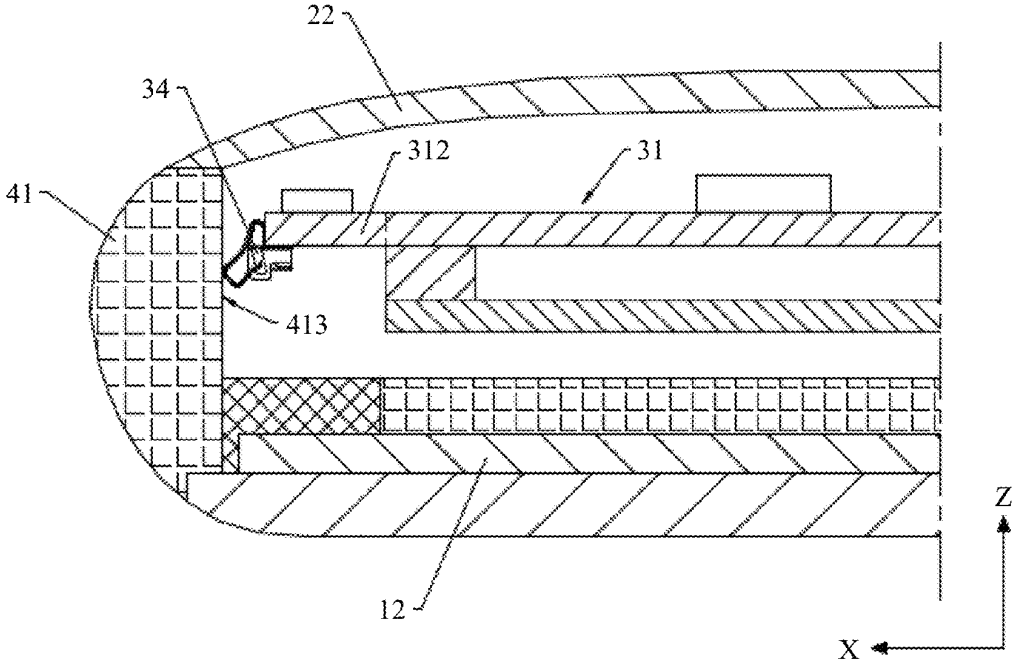


FIG. 20a

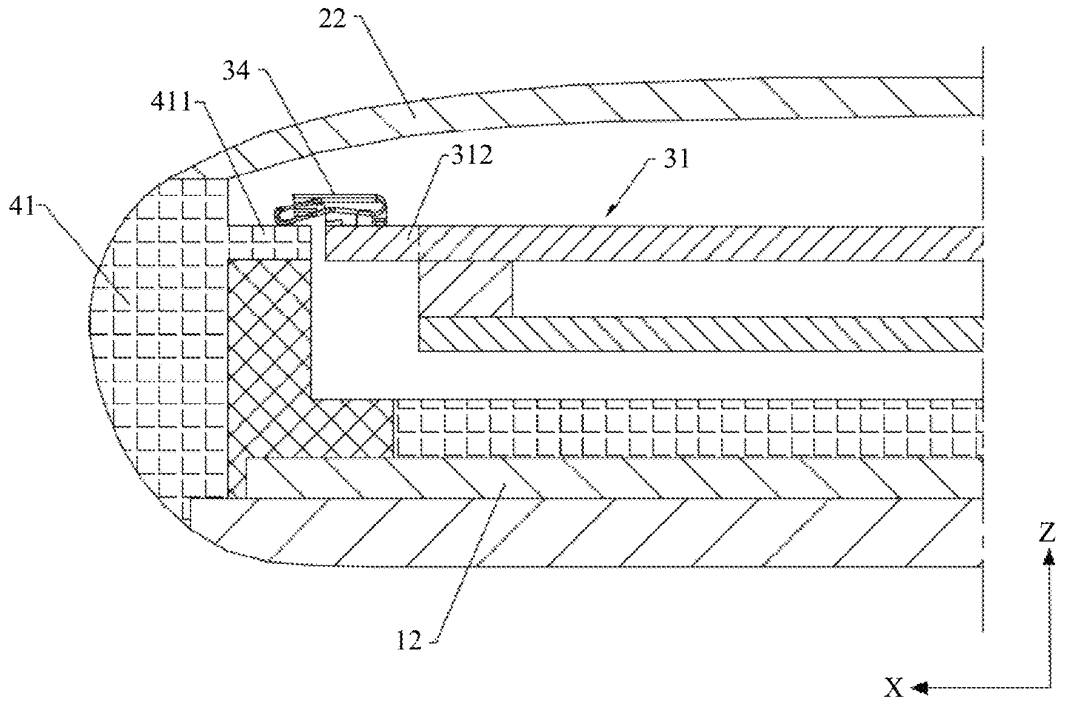


FIG. 20b

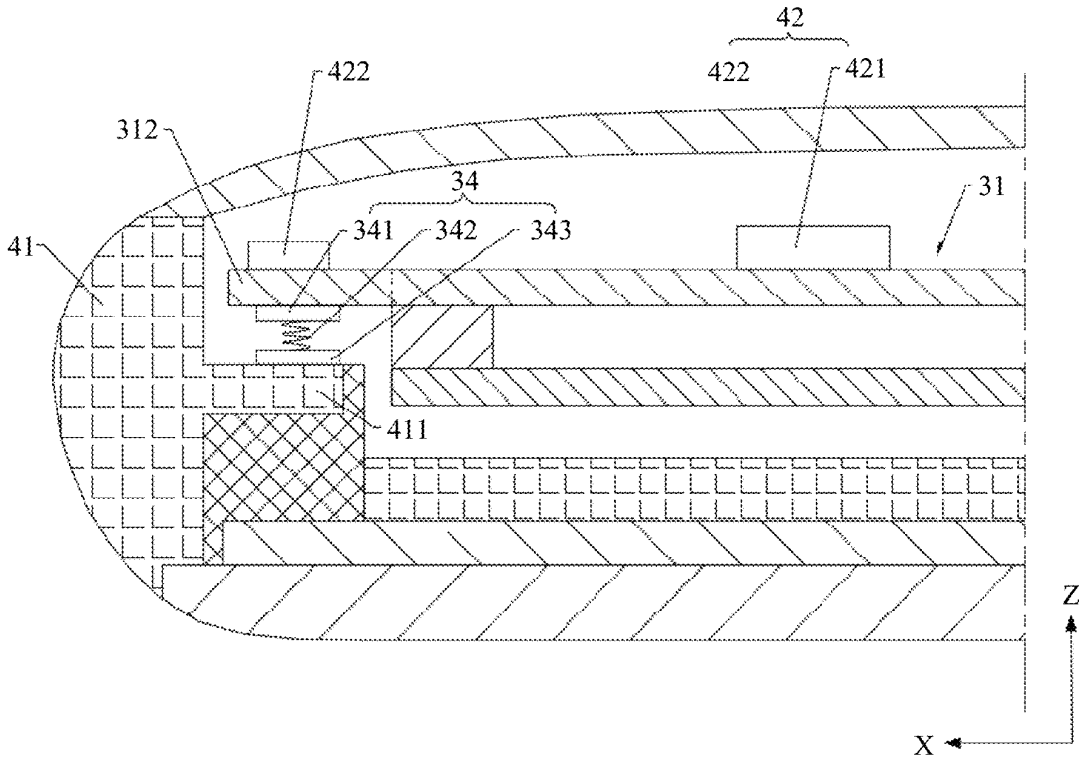


FIG. 21

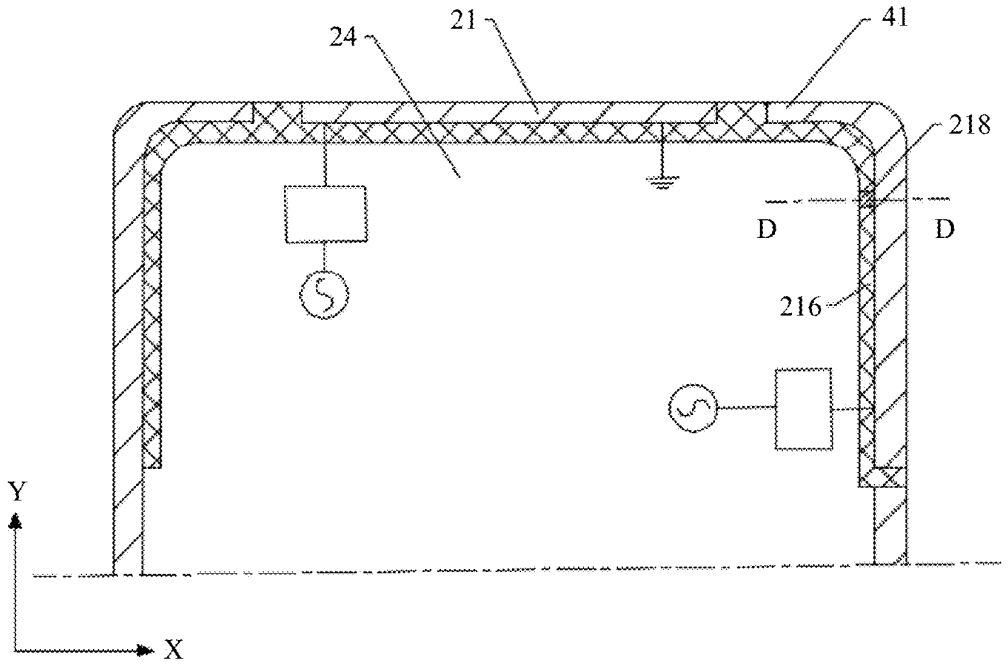
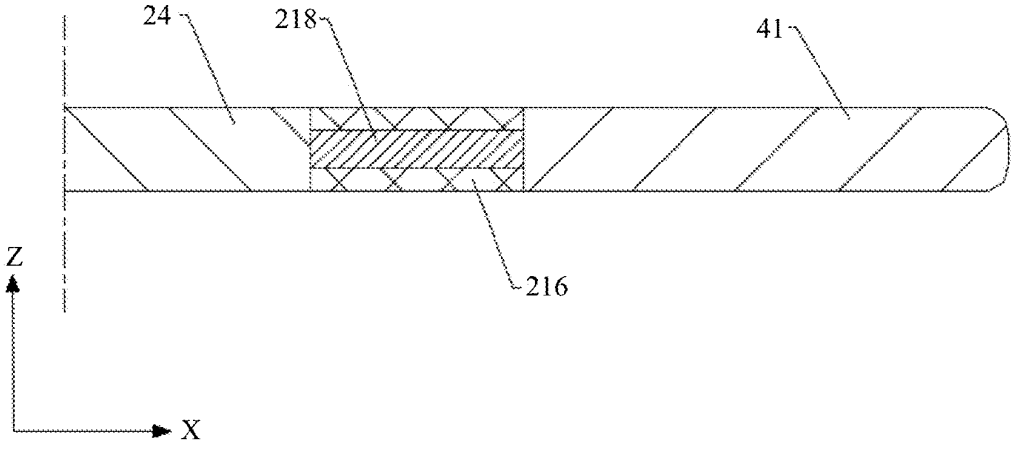


FIG. 22



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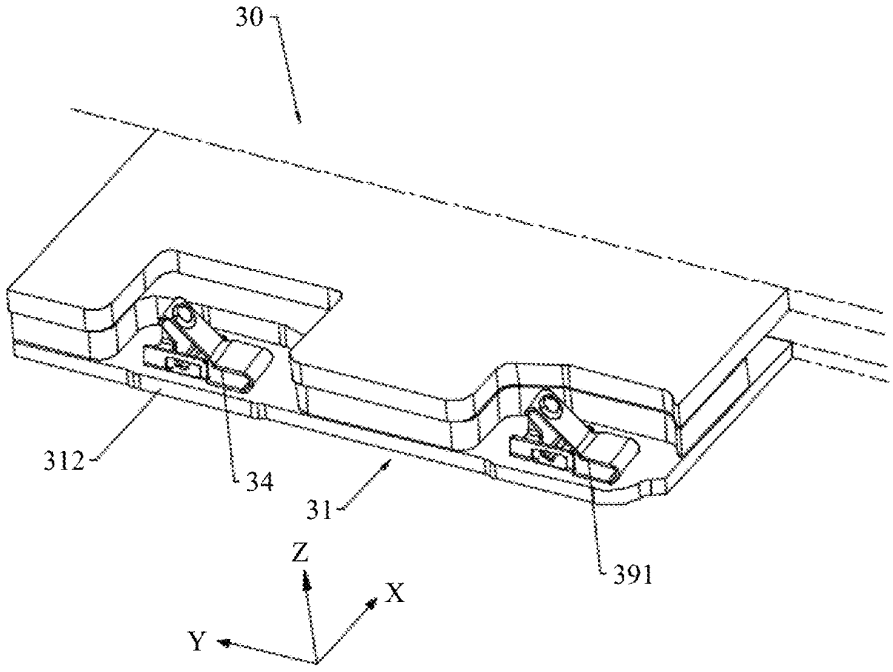

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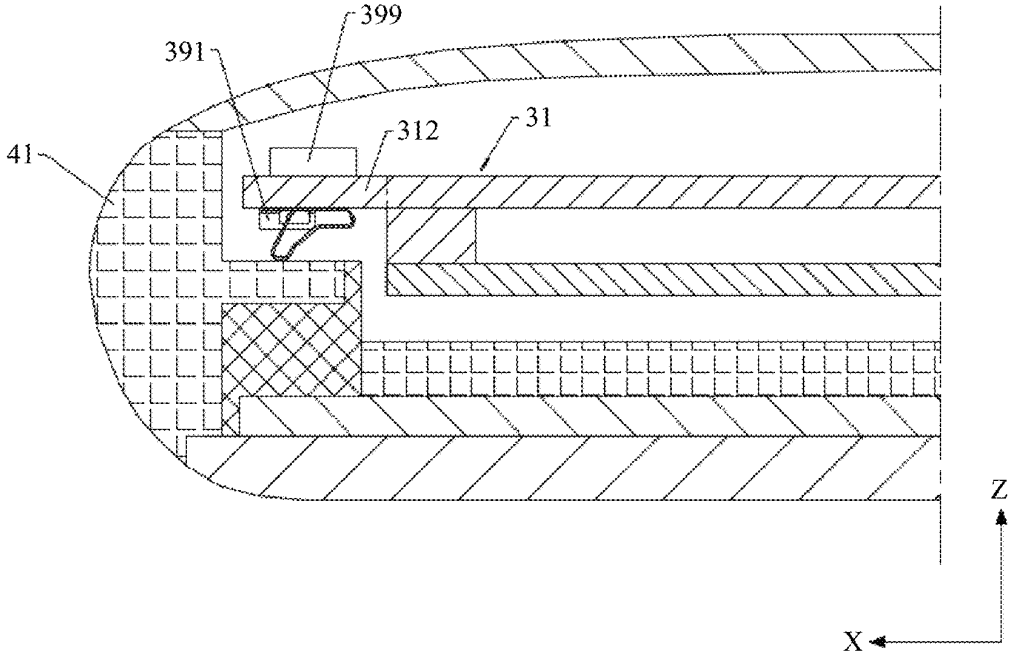

FIG. 25

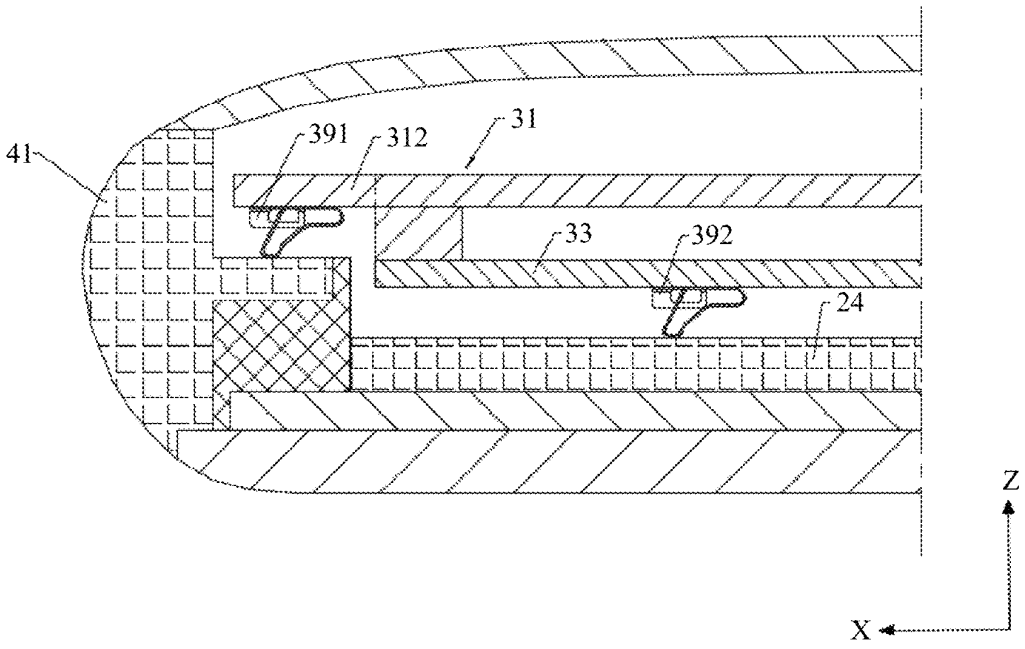

FIG. 26

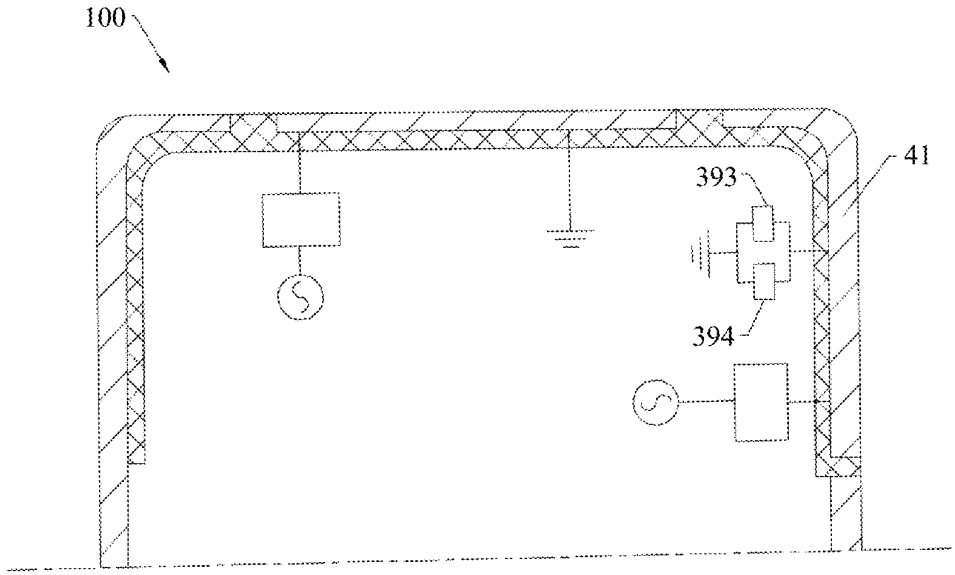

FIG. 27

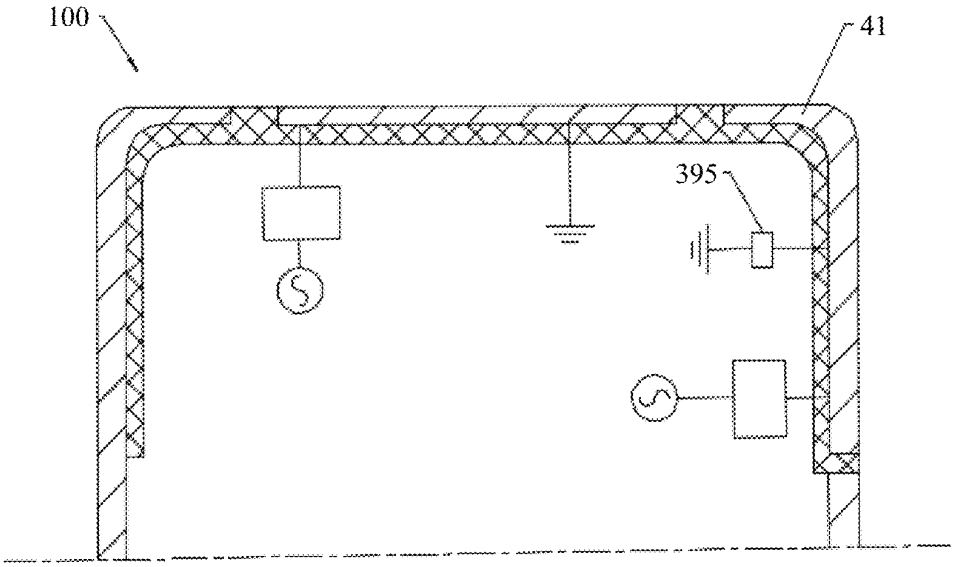

FIG. 28

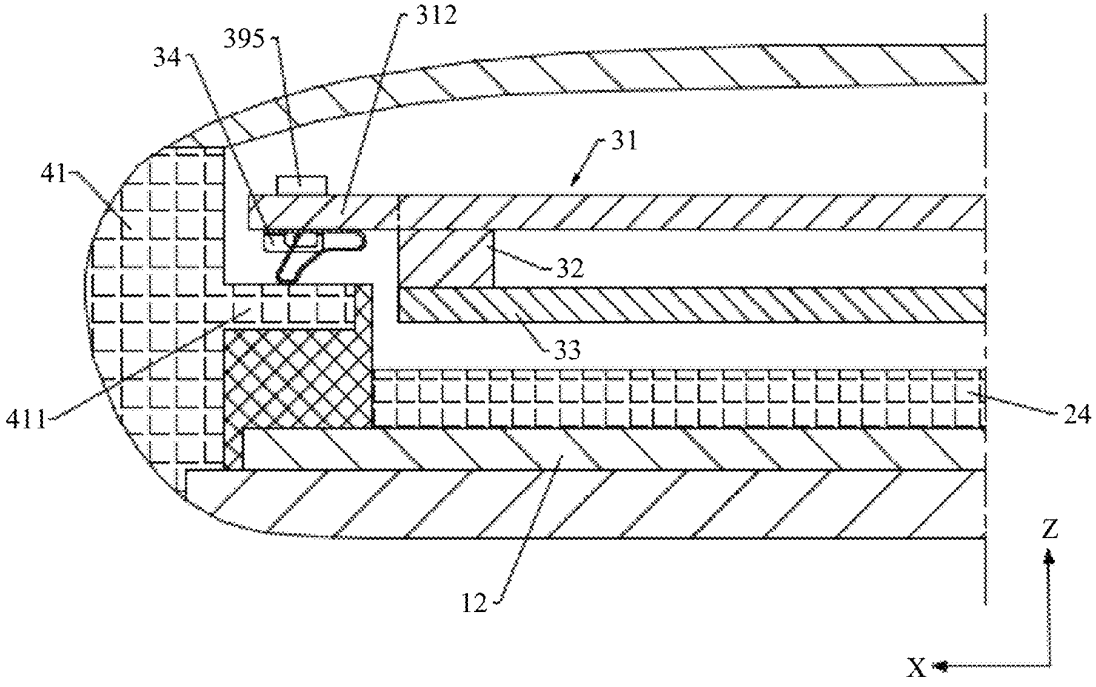

FIG. 29

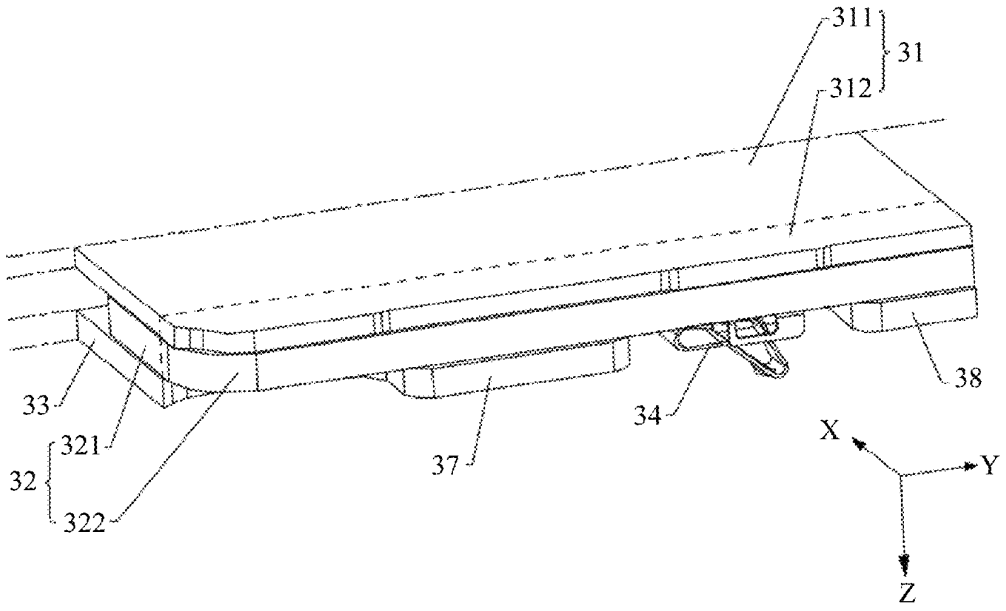

FIG. 30

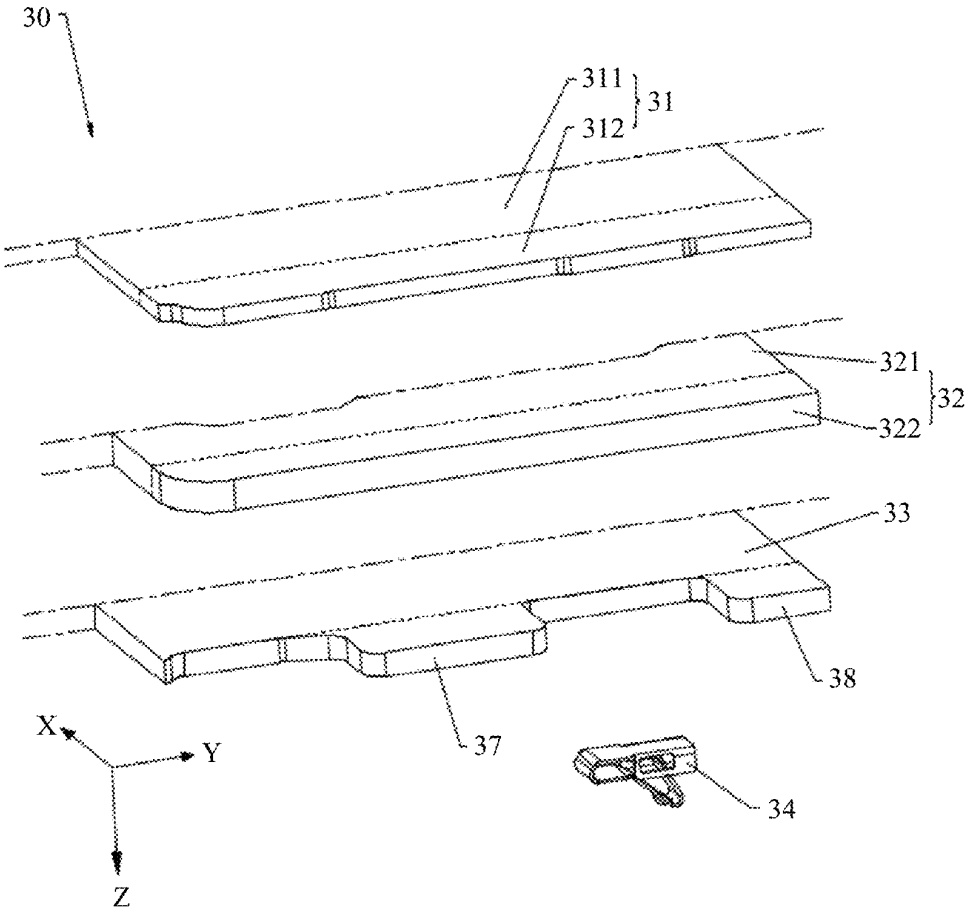

FIG. 31

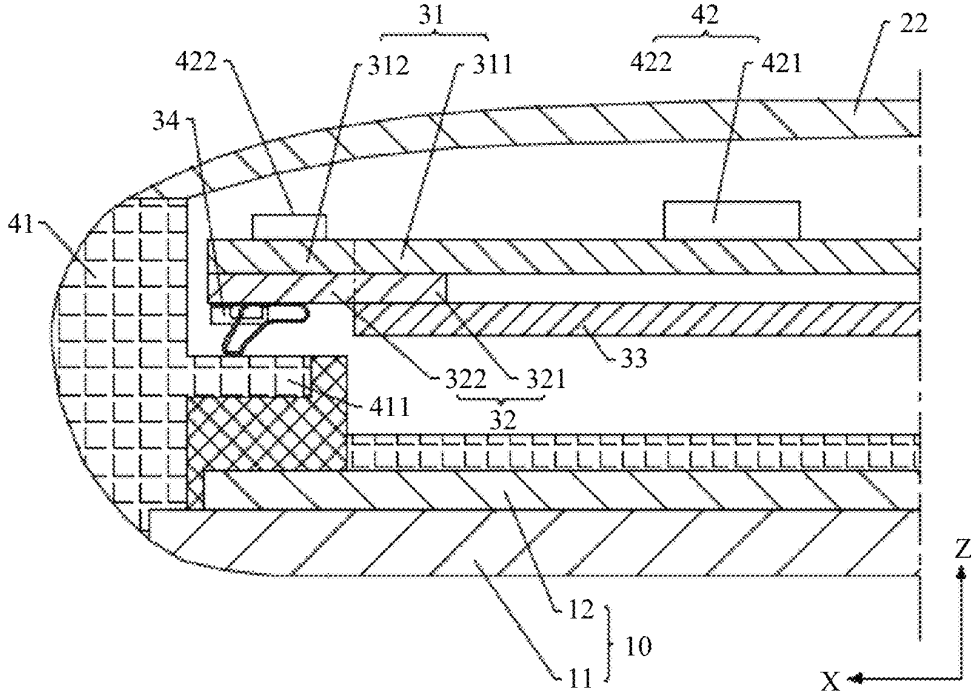
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FIG. 32

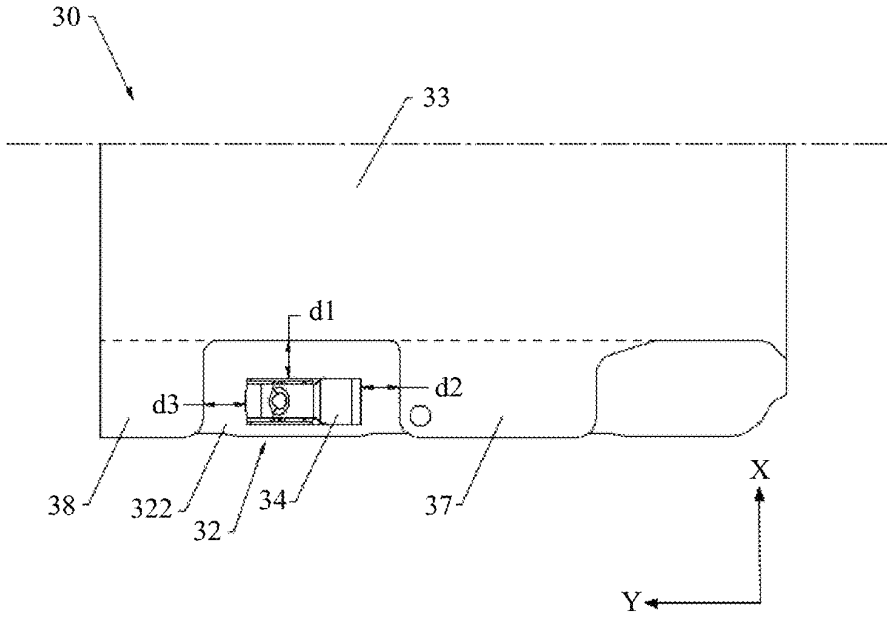
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FIG. 33

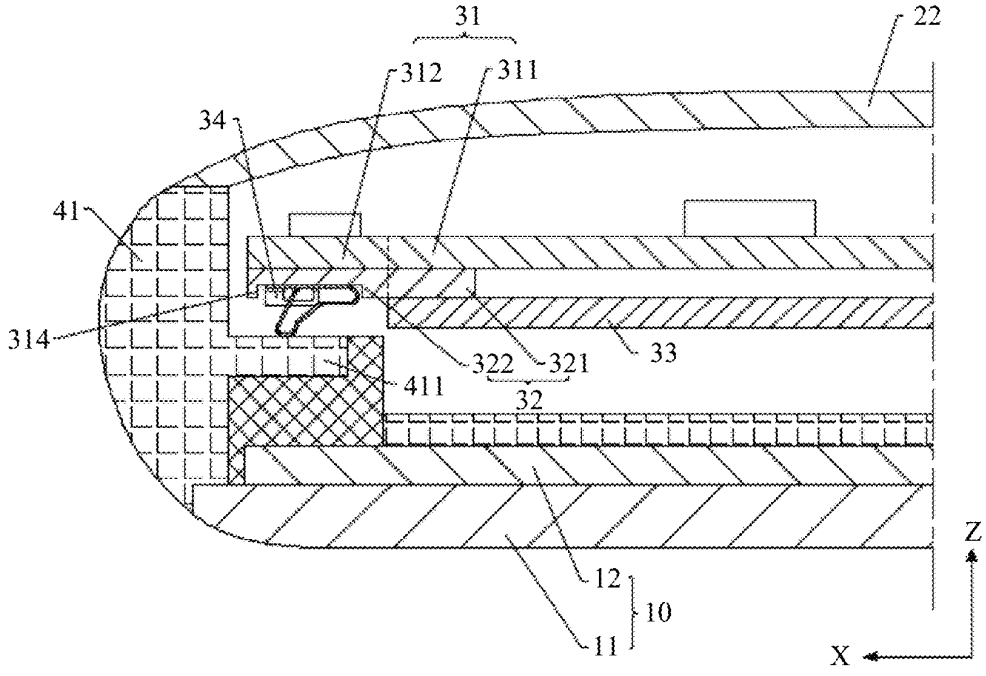
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FIG. 34

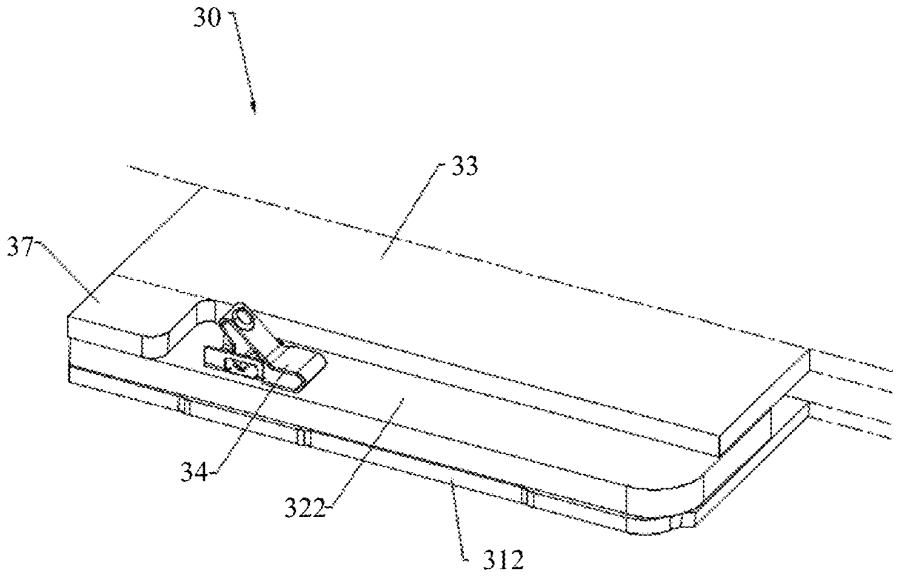
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FIG. 35

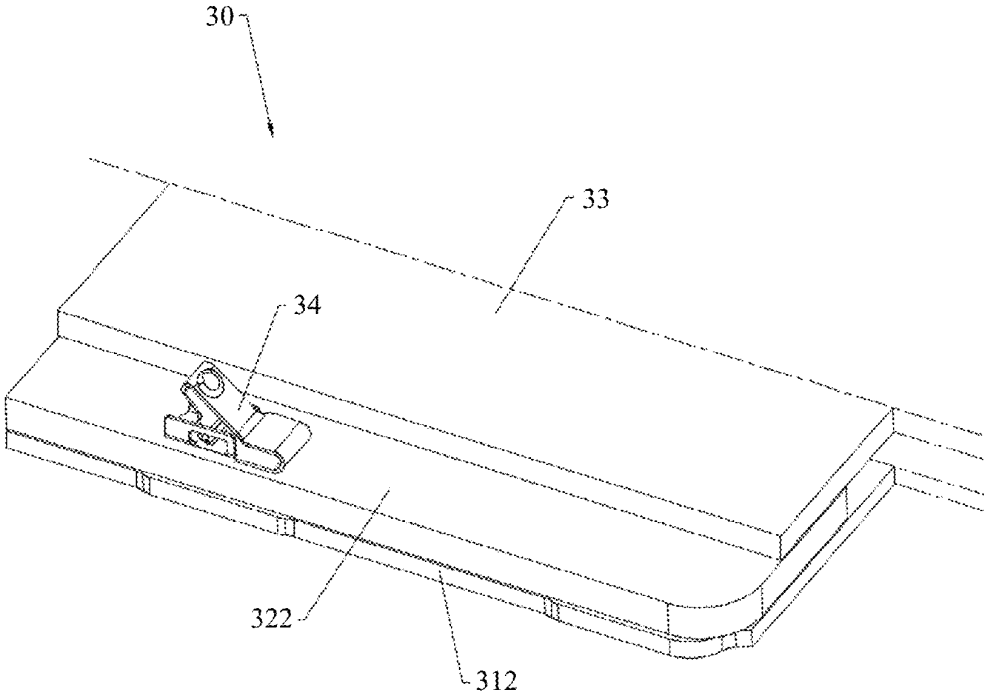

FIG. 36

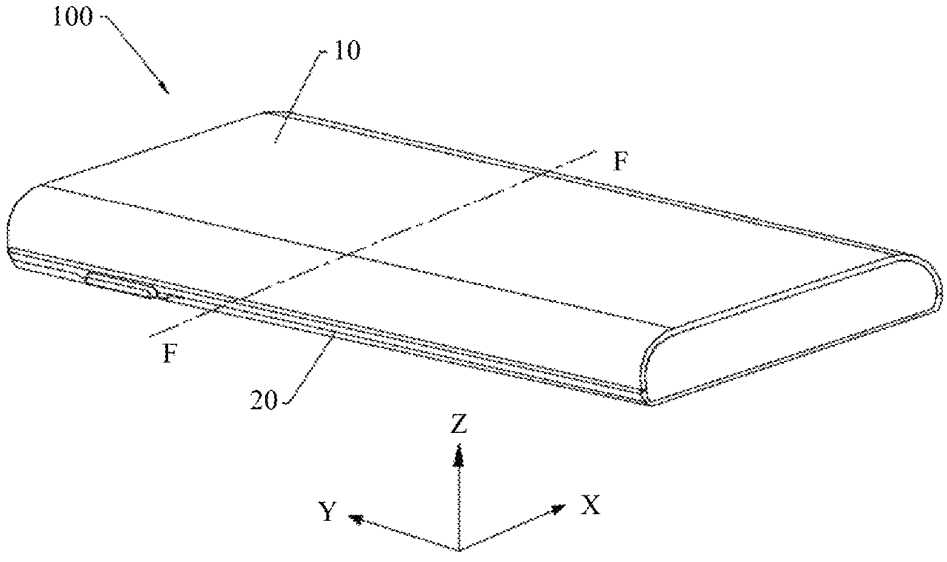

FIG. 37

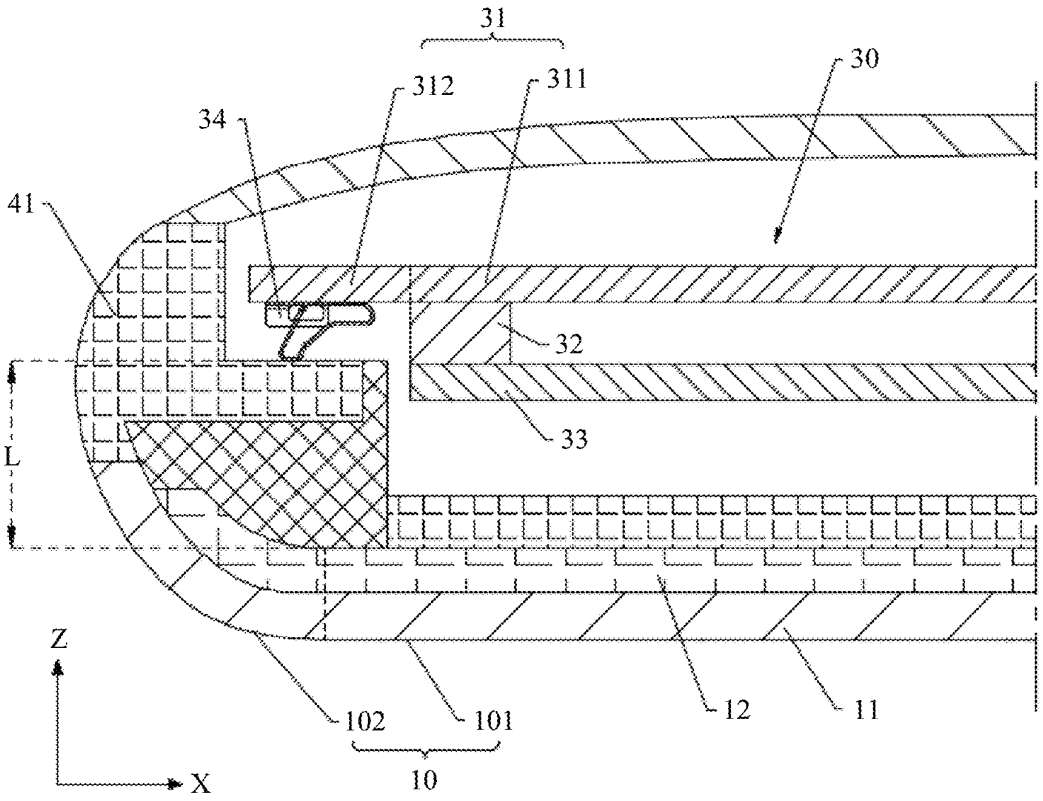

FIG. 38

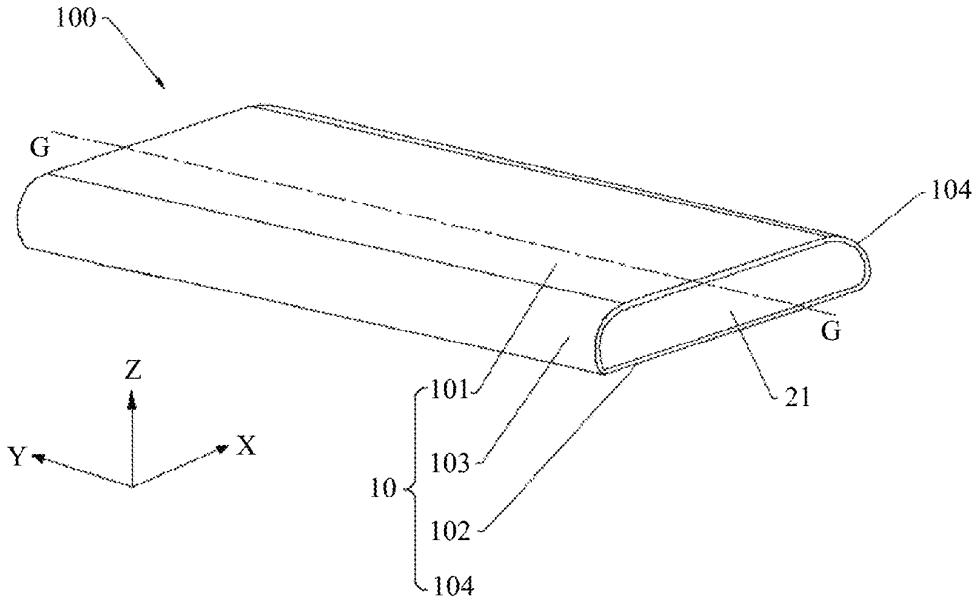
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FIG. 39

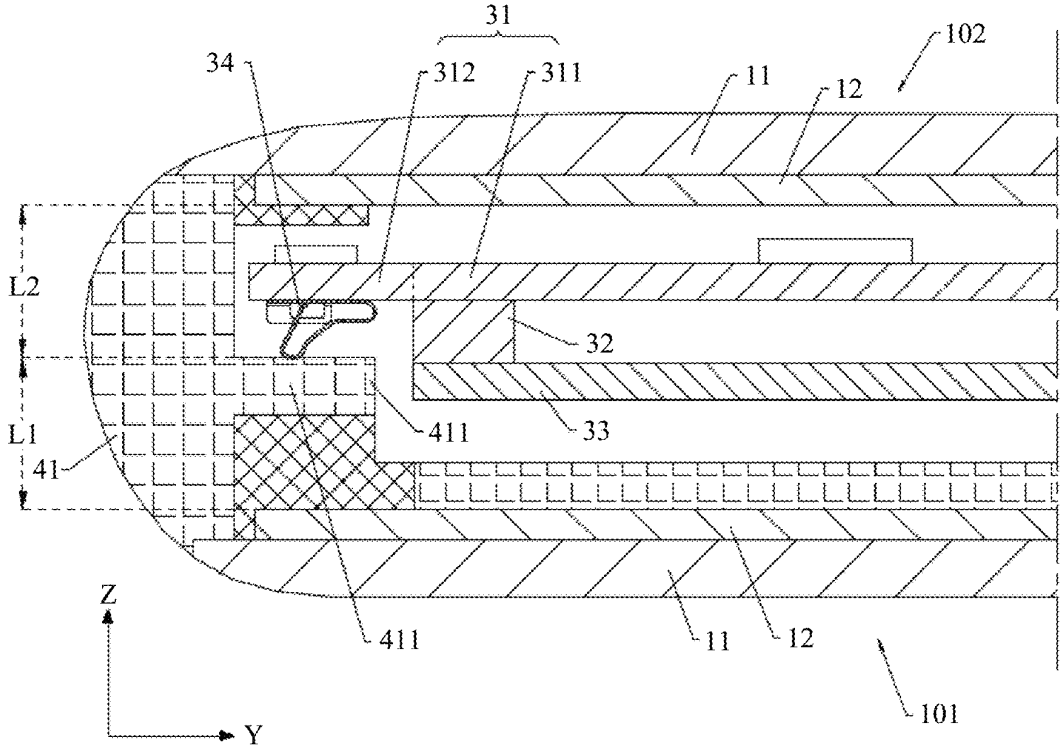
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FIG. 40

ANTENNA APPARATUS AND ELECTRONIC DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national stage of International Application No. PCT/CN2021/086876, filed on Apr. 13, 2021, which claims priority of Chinese Patent Application No. 202010292512.5, filed on Apr. 14, 2020. Both of the aforementioned applications are hereby incorporated by reference in its entirety.

This application claims priority to Chinese Patent Application No. 202010292512.5, filed with the China National Intellectual Property Administration on Apr. 14, 2020, and entitled "ANTENNA APPARATUS AND ELECTRONIC DEVICE", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present invention relates to the technical field of antennas, and in particular, to an antenna apparatus and an electronic device.

BACKGROUND

As electronic device technologies evolve, users hope that more electronic components (for example, cameras and various types of sensors) can be integrated into a mobile phone to realize more diverse functions of the mobile phone. However, as more and more electronic components are arranged inside the mobile phone, there is less space for arranging antennas. In addition, with the rapid development of 5G mobile phones, there are more and more 5G frequency bands and more and more antennas. In this way, in a tense environment in which there is little space for arranging antennas and the number of antennas is large, the clearance area of the antenna of a conventional mobile phone is small, and the antenna has poor ability to transmit and receive electromagnetic waves.

SUMMARY

The clearance area of an electronic device provided by the technical solutions of this application is larger, and the performance of an antenna of the electronic device is better.

According to a first aspect, an electronic device is provided. The electronic device may be a mobile phone, a watch, or other forms of a device capable of transmitting and receiving electromagnetic wave signals. The electronic device includes a frame, a screen, and a circuit board assembly.

The screen is mounted on one side of the frame. In an implementation, the screen includes a protective cover plate and a display screen. The protective cover plate is stacked on the display screen. The display screen is disposed close to the circuit board assembly relative to the protective cover plate. The protective cover plate may be mainly configured to protect the display screen and prevent dust.

A part of the frame forms a radiator of an antenna, or the radiator of the antenna is fixed on an inner side of the frame.

The circuit board assembly is located on the inner side of the frame. The circuit board assembly includes a first conductive member, and a first board, an elevating board, and a second board sequentially stacked. In other words, the elevating board is located between the first board and the second board. The first board is located on one side of the second board away from the screen. In other words, the first board is disposed away from the screen relative to the second board. The first board includes a first main body portion and a first extension portion connected to the first main body portion. The first main body portion is fixedly connected to the elevating board. The first extension portion protrudes relative to the elevating board and the second board, and is disposed close to the radiator. The first conductive member is fixed to the first extension portion. The first conductive member is in elastic contact with the radiator.

It should be noted that, the first conductive member may be an elastic piece having electrical conductivity or may alternatively be a spring having electrical conductivity, which is not limited in this application. In each of the solutions that can be implemented below, the first conductive member is described by taking a first elastic piece as an example.

In this implementation, by disposing the first extension portion that protrudes relative to the elevating board and the second board, and fixedly connecting the first elastic piece to the first extension portion, the first elastic piece is disposed away from the display screen of the screen, that is, in a thickness direction of the electronic device, a distance between the first elastic piece and the display screen becomes greater. In this way, the antenna clearance area between the first elastic piece and the display screen can be increased to a greater extent, and the performance of the antenna is better.

In addition, when the first elastic piece is disposed away from the display screen, a contact point at which the first elastic piece is in contact with the radiator can also be arranged away from the display screen. In this way, the contact point (feed point) between the first elastic piece and the radiator is less affected by the display screen.

In addition, compared with a solution of fixing the first elastic piece on the second board, in this implementation, by fixing the first elastic piece on the first extension portion, there are no longer any antenna-related components or wiring (for example, antenna switches, inductances, capacitors, or resistors) disposed on the elevating board and the second board. In this way, on the one hand, the structure of the circuit board assembly is simpler, that is, the assembly difficulty of the circuit board assembly is reduced, and the cost investment of the circuit board assembly is lower; and on the other hand, more space can be freed up on the second board to arrange more electronic components.

In addition, by bringing the first elastic piece into elastic contact with the radiator, the transmission of radio frequency signals between the first elastic piece and the radiator is ensured to be more stable. Specifically, because the first elastic piece has an elastic force, the first elastic piece can always be in contact with the radiator when the first elastic piece is in elastic contact with the radiator, so that the connection stability between the first elastic piece and the radiator is better.

In addition, by sequentially stacking the first board, the elevating board, and the second board, the board area of the circuit board assembly can be significantly increased, thereby increasing the number of electronic components arranged on the circuit board assembly. Specifically, when the first board and the second board are elevated by the elevating board, on the circuit board assembly, electronic components (for example, a CPU, a battery management chip, or the like) not only can be arranged on a surface of the first board facing a rear cover and a surface of the second

board facing the display screen, but also can be arranged in a space between the first board and the second board (on a surface of the first board facing the second board and a surface of the second board facing the first board). In other words, on the circuit board assembly of this implementation, more electronic components can be arranged. In this way, on the one hand, the electronic device has more and more functions and better user experience; and on the other hand, in a case that the internal environment of the electronic device is tense, by arranging a large number of electronic components of the electronic device on the circuit board assembly, more space can be freed up inside the electronic device. When this part of space is applied to the clearance area of the antenna, the clearance area of the antenna can be significantly increased, thereby significantly improving the performance of the antenna.

In a possible implementation according to the first aspect, the electronic device further includes a radio frequency path. The radio frequency path can be configured to transmit radio frequency signals to the radiator of the antenna, so that the radiator of the antenna transmits electromagnetic wave signals according to the radio frequency signals. In addition, when the radiator of the antenna converts the received electromagnetic wave signals into radio frequency signals, the radio frequency path can further be configured to receive the radio frequency signals transmitted by the radiator of the antenna. In this case, the first elastic piece is electrically connected between the radio frequency path and the radiator.

In another possible implementation, the first elastic piece is electrically connected between the radiator and a ground layer of the first extension portion.

In another possible implementation, the first elastic piece is electrically connected to the ground layer of the first extension portion through a matching circuit.

According to the first aspect, or any one of the implementations of the first aspect described above, the first elastic piece is fixed to one side of the first extension portion facing the screen. In this case, the first elastic piece, the elevating board, and the second board are located on the same side of the first board. In the thickness direction of the electronic device, there is an overlapping region between the first elastic piece and the elevating board. The first elastic piece utilizes a space of the elevating board facing the side of the radiator. In this way, in the thickness direction of the electronic device, the circuit board assembly does not thicken due to the configuration of the first elastic piece.

In addition, the space between a surface of the first extension portion facing the screen and the radiator is generally small. General chips or electronic components are not easy to be disposed in this region. In this case, the space is unused, which easily results in a waste of space. In this implementation, by fixing the first elastic piece with a small size to one side of the first extension portion facing the display screen, on the one hand, the space of this part can be effectively utilized to improve the internal space utilization of the electronic device; and on the other hand, compared with a case in which the first elastic piece is disposed on one side of the first board facing the rear cover, in this implementation, a space occupied by at least one first elastic piece can be saved by a space between the first board and the rear cover, and in this case, the space saved can be used for arranging more electronic components, thereby improving the space utilization of the circuit board assembly to a greater extent.

According to the first aspect, or any one of the implementations of the first aspect described above,

In addition, a distance L from the contact point between the first elastic piece and the radiator to the display screen is greater than or equal to 2 mm. For example, L equals 2 mm, 2.5 mm, 3 mm, 3.5 mm or 4 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece and the radiator to the display screen is greater than or equal to 2 mm, the first elastic piece can be disposed away from the display screen to a greater extent. In this way, the antenna clearance area between the first elastic piece and the display screen can be increased to a greater extent, and the performance of the antenna is better.

According to the first aspect, or any one of the implementations of the first aspect described above, the distance L from the contact point between the first elastic piece and the radiator to the display screen is less than or equal to 4.7 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece and the radiator to the display screen is less than or equal to 4.7 mm, on the one hand, it can be ensured that the first elastic piece is disposed away from the display screen; and on the other hand, it can be ensured that a thickness of the electronic device in a Z direction is not great, which is conducive to thinning configuration.

According to the first aspect, or any one of the implementations of the first aspect described above, a distance between the first elastic piece and the elevating board is between 0.15 mm and 30 mm.

It may be understood that, when the distance between the first elastic piece and the elevating board ranges from 0.15 mm to 30 mm, the size of the first extension portion located between the first elastic piece and the elevating board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the elevating board is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the elevating board, thereby counteracting the reaction force with an internal stress of the elevating board.

According to the first aspect, or any one of the implementations of the first aspect described above, the circuit board assembly further includes a first strengthening board. The first strengthening board is located on one side of the first elastic piece and fixedly connected to a board surface of the first extension portion facing the screen.

It may be understood that, by stacking the first strengthening board on one side of the first elastic piece and on the first extension portion, a thickness of a part of the first extension portion is significantly increased, which further significantly improves the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the first aspect, or any one of the implementations of the first aspect described above, the first strengthening board includes a first portion and a second

portion connected to the first portion. The first portion is fixedly connected to the board surface of the first extension portion facing the screen, and the first portion is fixedly connected to the elevating board. The second portion is fixedly connected to the second board. In the thickness direction of the electronic device, a thickness of the first strengthening board is greater than a thickness of the elevating board.

It may be understood that, the first portion and the second portion are sequentially stacked on the first extension portion, the first portion is fixedly connected to the elevating board, and the second portion is fixedly connected to the second board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the elevating board, and the second board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In another possible implementation, the first strengthening board is fixedly connected to the elevating board. In a thickness direction of the electronic device, a thickness of the first strengthening board is less than or equal to a thickness of the elevating board.

It may be understood that, the first strengthening board is stacked on the first extension portion, and the first strengthening board is fixedly connected to the elevating board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board and the elevating board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force.

According to the first aspect, or any one of the implementations of the first aspect described above, the first portion and the elevating board are of an integrally formed structure, and the second portion and the second board are of an integrally formed structure. In other words, the first portion and the elevating board are an integral board. In this case, the connection between the first portion and the elevating board is firmer. In this way, the first portion and the elevating board are not easy to fracture or crack when receiving an external force. In addition, the second portion and the second board are an integral board. In this case, the connection between the second portion and the second board is firmer. In this way, the second portion and the second board are not easy to fracture or crack when subjected to an external force.

In another possible implementation, the first portion can alternatively be fixedly connected to the elevating board by a soldering process. the second portion can alternatively be fixedly connected to the second board by a soldering process.

According to the first aspect, or any one of the implementations of the first aspect described above, the first portion is provided with a first strengthening solder pad. The first extension portion is provided with a second strengthening solder pad. The first strengthening solder pad is soldered to the second strengthening solder pad.

It may be understood that, when the first portion and the first extension portion are soldered together through the first strengthening solder pad and the second strengthening solder pad, the connection between the first portion and the first extension portion is firmer, and the integral strength of the circuit board assembly is better. In addition, after the first strengthening solder pad and the second strengthening solder pad are soldered together, the first strengthening solder pad and the second strengthening solder pad can effectively protect a solder pad (the solder pad of this part is mainly configured for electrical connection between wiring of the first board and wiring of the elevating board) between the first main body portion of the first board and the elevating board. That is, the solder pad between the first body portion and the elevating board is avoided from easily breaking due to an external force.

According to the first aspect, or any one of the implementations of the first aspect described above, a distance between the first elastic piece and the first portion ranges from 0.15 mm to 30 mm. In this case, the size of the first extension portion located between the first elastic piece and the first portion is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the first portion is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the first portion, thereby counteracting the reaction force by an internal stress of the first portion.

According to the first aspect, or any one of the implementations of the first aspect described above, the circuit board assembly further includes a second strengthening board. The second strengthening board is located on one side of the first elastic piece away from the first strengthening board, and is fixedly connected to the board surface of the first extension portion facing the screen.

It may be understood that, by stacking the first strengthening board on one side of the first elastic piece and on the first extension portion, and stacking the second strengthening board on the other side of the first elastic piece and on the first extension portion, a thickness of a part of the first extension portion is significantly increased, which further significantly improves the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board and the second strengthening board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the first aspect, or any one of the implementations of the first aspect described above, the second strengthening board includes a third portion and a fourth portion connected to the third portion. The third portion is fixedly connected to the board surface of the first extension portion facing the screen, and the third portion is fixedly connected to the elevating board. The fourth portion is fixedly connected to the second board. In the thickness

direction of the electronic device, a thickness of the second strengthening board is greater than a thickness of the elevating board.

It may be understood that, the third portion and the fourth portion connected to the third portion are sequentially stacked on the first extension portion, the third portion is fixedly connected to the elevating board, and the fourth portion is fixedly connected to the second board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the second strengthening board, the elevating board, and the second board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In another possible implementation, the second strengthening board is fixedly connected to the elevating board. In a thickness direction of the electronic device, a thickness of the second strengthening board is less than or equal to a thickness of the elevating board.

According to the first aspect, or any one of the implementations of the first aspect described above, the third portion and the elevating board are of an integrally formed structure. The fourth portion and the second board are of an integrally formed structure. In other words, the third portion and the elevating board are an integral board. In this case, the connection between the third portion and the elevating board is firmer. In this way, the third portion and the elevating board are not easy to fracture or crack when receiving an external force. In addition, the fourth portion and the second board are an integral board. In this case, the connection between the fourth portion and the second board is firmer. In this way, the fourth portion and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the third portion can alternatively be fixedly connected to the elevating board by a soldering process. The fourth portion can alternatively be fixedly connected to the second board by a soldering process.

According to the first aspect, or any one of the implementations of the first aspect described above, a distance d3 between the first elastic piece and the third portion ranges from 0.15 mm to 30 mm.

In this case, the size of the first extension portion located between the first elastic piece and the third portion is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the third portion is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the third portion, thereby counteracting the reaction force by an internal stress of the third portion.

According to the first aspect, or any one of the implementations of the first aspect described above, the first extension portion is provided with a groove. The groove is located between the first strengthening board and the second strengthening board, and an opening of the groove is located on a surface of the first extension portion facing the screen. A part of the first elastic piece is mounted in the groove.

It may be understood that, when a part of the first elastic piece is mounted in the groove, in the thickness direction of the electronic device, there is an overlapping region between the first elastic piece and the first extension portion. In this case, the first elastic piece can be disposed further away from the display screen, that is, in the thickness direction of the electronic device, a distance between the first elastic piece and the display screen can be significantly increased. In this case, a distance from the contact point between the first elastic piece and the radiator to the display screen is significantly increased. In this way, in the thickness direction of the electronic device, the antenna clearance area between the first elastic piece and the display screen can be made larger, and the performance of the antenna is better.

In addition, when the first extension portion is provided with the first strengthening board and the second strengthening board, the first strengthening board and the second strengthening board are located at the periphery of the groove. In this case, the first strengthening board and the second strengthening board can improve the strength of the first extension portion, thereby avoiding the first extension portion from being reduced in strength due to the opening of the groove.

According to the first aspect, or any one of the implementations of the first aspect described above, a conductive piece is disposed on a surface of the radiator facing the first elastic piece. The first elastic piece is in elastic contact with the conductive piece.

It may be understood that, when the conductive piece is disposed on the radiator, the conductive piece can improve the surface flatness of the radiator. In this way, when the first elastic piece is in elastic contact with the radiator through the conductive piece, the elastic contact between the first elastic piece and the radiator is more stable. In this way, the radio frequency signals are also more stable in the process of transmission between the radiator and the first elastic piece, thereby ensuring better antenna performance of the electronic device.

According to the first aspect, or any one of the implementations of the first aspect described above, the oxidation resistance of the conductive piece is better than that of the radiator. It may be understood that, under an environment with the same temperature and humidity, the conductive piece is not easy to be oxidized compared with the radiator. In this way, compared with a solution in which the first elastic piece directly comes into elastic contact with the radiator, a contact resistance between the first elastic piece and the conductive piece is smaller, that is, the contact resistance between the first elastic piece and the conductive piece is more stable, and the transmission loss of the radio frequency signals is smaller. In this case, the performance of the antenna of the electronic device is better.

According to the first aspect, or any one of the implementations of the first aspect described above, the electronic device includes a fastener. The radiator is provided with a blind hole. The fastener is fixed into the blind hole. The first elastic piece is in elastic contact with the fastener.

It may be understood that, compared with a solution of soldering the conductive piece on the radiator, this implementation saves the process of soldering the conductive piece on the radiator by disposing the fastener in the blind hole of the radiator, and electrically connecting the first elastic piece to the radiator of the antenna through the fastener. Therefore, on the one hand, the cost investment of the electronic device is reduced, and there is no need to

further increase the input cost of the soldering process; and on the other hand, the case that the performance of the radiator in transmitting and receiving electromagnetic waves is affected by the generation of gas holes, slag inclusions, solder joints, or cracks in the soldering process in the radiator is avoided.

According to the first aspect, or any one of the implementations of the first aspect described above, the radiator has an inner side surface facing the circuit board assembly. The first elastic piece is in elastic contact with the inner side surface. In this way, the first elastic piece can be disposed away from the display screen to a greater extent. In the thickness direction of the electronic device, a distance between the first elastic piece and the display screen can be significantly increased. In this way, in the thickness direction of the electronic device, the antenna clearance area between the first elastic piece and the display screen can be made larger, and the performance of the antenna is better.

In addition, a distance from the contact point between the first elastic piece and the radiator to the display screen is significantly increased, and in this case, the signal interference of the display screen to the contact point between the first elastic piece and the radiator is less.

In addition, the radiator may not need to be provided with a protrusion to come into contact with the first elastic piece, and in this case, in the thickness direction of the electronic device, the space omitting the protrusion may also be used for the clearance area of the antenna. In this way, the clearance area of the antenna is larger, and the performance of the antenna is better.

According to the first aspect, or any one of the implementations of the first aspect described above, the first elastic piece is fixed to one side of the first extension portion of the first board facing the rear cover. In addition, the first elastic piece is in elastic contact with the protrusion of the radiator.

It may be understood that, by fixing the first elastic piece to one side of the first extension portion facing the rear cover, and bringing the first elastic piece into elastic contact with the protrusion of the radiator, the first elastic piece can be disposed close to the rear cover to a greater extent, that is, the first elastic piece can be disposed away from the display screen to a greater extent, that is, in the thickness direction of the electronic device, a distance between the first elastic piece and the display screen can be significantly increased. In this way, in the thickness direction of the electronic device, the protrusion configured to be in contact with the first elastic piece can be disposed away from the display screen to a greater extent. The antenna clearance area between the bottom of the protrusion and the display screen can be made larger, and the performance of the antenna is better.

In addition, a distance from the contact point between the first elastic piece and the radiator to the display screen is significantly increased, and in this case, the signal interference of the display screen to the contact point between the first elastic piece and the radiator is less.

According to the first aspect, or any one of the implementations of the first aspect described above, the first elastic piece includes a first fixed piece, an elastic member, and a second fixed piece. The elastic member is connected between the first fixed piece and the second fixed piece. It may be understood that, the elastic member may be, but is not limited to, an elastic piece or a spring. In addition, the first fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece. The second fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece.

In addition, the first fixed piece is fixedly connected to the radiator. The second fixed piece is fixedly connected to the first extension portion of the first board.

It may be understood that, the first elastic piece has a simple structure and is easy to assemble, which can reduce the assembly difficulty of the electronic device.

According to the first aspect, or any one of the implementations of the first aspect described above, the electronic device further includes a middle plate. The middle plate is located on the inner side of the frame. The middle plate is grounded. The frame further includes a connection segment. One end of the connection segment is connected to the radiator and the other end is connected to the middle plate.

It may be understood that, the radiator is grounded in a relatively simple manner and has a simple structure and relatively low cost investment.

According to the first aspect, or any one of the implementations of the first aspect described above, the circuit board assembly further includes a second conductive member. The second conductive member may be, but is not limited to, an elastic piece or a spring. The second conductive member is disposed on the first extension portion of the first board. The second conductive member is electrically connected between the ground layer of the first board and the radiator. In other words, the second conductive member is configured to ground the radiator.

It may be understood that, the radiator is grounded in a relatively simple manner and has a simple structure and relatively low cost investment.

According to the first aspect, or any one of the implementations of the first aspect described above, the first board is provided with a second matching circuit. The second matching circuit includes an inductor, a capacitor, a resistor, or an antenna switch. A second elastic piece is electrically connected to the second matching circuit and is electrically connected to the ground layer of the first board through the second matching circuit. The second matching circuit is configured to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves and the impedance matching for the antenna. In this way, the antenna is more widely applied to transmit and receive electromagnetic waves and has better performance.

According to the first aspect, or any one of the implementations of the first aspect described above, the electronic device further includes a middle plate. The middle plate is grounded. The middle plate is located on the inner side of the frame. The circuit board assembly further includes a second conductive member and a third conductive member. The second conductive member is fixed to the first extension portion of the first board. The second conductive member is in elastic contact with the radiator. The third conductive member is fixed to the second board. The third conductive member is in elastic contact with the middle plate, and is electrically connected to the second conductive member.

It may be understood that, by disposing the second conductive member on the first extension portion, disposing the third conductive member on the second conductive member, and utilizing the third conductive member for grounding, a ground path of the radiator is increased. In this case, in the ground path of the radiator, a matching circuit may be disposed on the circuit board assembly to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves, so that the frequency bands of the antenna for receiving and transmitting are wider.

According to the first aspect, or any one of the implementations of the first aspect described above, the radiator includes a protrusion facing an interior of the electronic device. The first conductive member is fixed to one side of the first extension portion facing the screen. The first conductive member is in elastic contact with the protrusion, and the first conductive member is electrically connected between the radiator and a radio frequency path of the antenna. The radio frequency path is mounted on the circuit board assembly;

The circuit board assembly further includes a first strengthening board and a second strengthening board. The first strengthening board and the second strengthening board are respectively located on two sides of the first conductive member. In the thickness direction of the electronic device, a thickness of the first strengthening board and a thickness of the second strengthening board are both greater than a thickness of the elevating board.

The first strengthening board includes a first portion and a second portion connected to the first portion. The first portion is fixedly connected to the board surface of the first extension portion facing the screen. The first portion is fixedly connected to the elevating board. The second portion is fixedly connected to the second board.

The second strengthening board includes a third portion and a fourth portion connected to the third portion. The third portion is fixedly connected to the board surface of the first extension portion facing the screen. The third portion is fixedly connected to the elevating board, and the fourth portion is fixedly connected to the second board.

The first portion, the third portion, and the elevating board are of an integrally formed structure. The second portion, the fourth portion, and the second board are of an integrally formed structure.

It may be understood that, by sequentially stacking the first portion and the second portion on one side of the first elastic piece and on the first extension portion, and sequentially stacking the third portion and the fourth portion on the other side of the first elastic piece and on the first extension portion, a thickness of a part of the first extension portion is significantly increased, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first portion, the second portion, the third portion, and the fourth portion, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In addition, the first elastic piece is fixed to one side of the first extension portion facing the display screen. In this case, the first elastic piece, the elevating board, and the second board are located on the same side of the first board. In the thickness direction of the electronic device, there is an overlapping region between the first elastic piece and the elevating board. The first elastic piece utilizes a space of the elevating board facing the side of the radiator. In this way, in the thickness direction of the electronic device, the circuit board assembly does not thicken due to the configuration of the first elastic piece.

In addition, the space between a surface of the first extension portion facing the screen and the radiator is generally small. General chips or electronic components are not easy to be disposed in this region. In this case, the space is unused, which easily results in a waste of space. In this implementation, by fixing the first elastic piece with a relatively small size on the side of the first extension portion facing the display screen, on the one hand, the space of this part can be effectively utilized, to improve the internal space utilization of the electronic device, and on the other hand, compared with a case in which the first elastic piece is disposed on one side of the first board facing a rear cover, in this implementation, a space between the first board and the rear cover can save the space occupied by at least one first elastic piece. In this case, the saved space can be used for arranging more electronic components, thereby greatly improving the space utilization of the circuit board assembly.

In addition, the first portion and the elevating board are an integral board. In this case, the connection between the first portion and the elevating board is firmer. In this way, the first portion and the elevating board are not easy to fracture or crack when receiving an external force. In addition, the second portion and the second board are an integral board. In this case, the connection between the second portion and the second board is firmer. In this way, the second portion and the second board are not easy to fracture or crack when subjected to an external force.

According to a second aspect, an electronic device is provided. The electronic device may be a mobile phone, a watch, or other forms of a device capable of transmitting and receiving electromagnetic wave signals. The electronic device includes a frame, a screen, and a circuit board assembly.

The screen is mounted on one side of the frame. In an implementation, the screen includes a protective cover plate and a display screen. The protective cover plate is stacked on the display screen. The display screen is disposed close to the circuit board assembly relative to the protective cover plate. The protective cover plate may be mainly configured to protect the display screen and prevent dust.

A part of the frame forms a radiator of an antenna, or the radiator of the antenna is fixed on an inner side of the frame.

The circuit board assembly is located on the inner side of the frame. The circuit board assembly includes a first board, an elevating board, a second board, and a first conductive member. The first board and the elevating board are both located on one side of the second board away from the screen. In other words, the first board and the elevating board are disposed away from the screen relative to the second board. The first board includes a first main body portion and a first extension portion connected to the first main body portion. The elevating board includes a second main body portion and a second extension portion connected to the second main body portion. The first main body portion, the second main body portion, and the second board are sequentially stacked. In other words, the second main body portion is located between the first main body portion and the second board. The first extension portion and the second extension portion are stacked, and both the first extension portion and the second extension portion protrude relative to the second board and are disposed close to the radiator. The first conductive member is fixed to the second extension portion, and is in elastic contact with the radiator.

It should be noted that, the first conductive member may be an elastic piece having electrical conductivity or may alternatively be a spring having electrical conductivity, which is not limited in this application. In each of the solutions that can be implemented below, the first conductive member is described by taking a first elastic piece as an example.

In this implementation, by disposing the second extension portion that protrudes relative to the second board, and fixedly connecting the first elastic piece to the second extension portion, the first elastic piece is disposed away from the display screen, that is, in a thickness direction of the electronic device, a distance between the first elastic piece and the display screen becomes greater. In this way, the antenna clearance area between the first elastic piece and the display screen can be increased to a greater extent, and the performance of the antenna is better.

In addition, when the first elastic piece is disposed away from the display screen, a contact point between the first elastic piece and the radiator can also be arranged away from the display screen. In this way, the contact point (feed point) at which the first elastic piece is in contact with the radiator is less affected by the display screen.

In addition, by stacking the second extension portion on the first extension portion, and in this case, by the cooperation of the second extension portion and the first extension portion, the integral strength of this part can be improved. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, with the cooperation of the first extension portion, the second extension portion can effectively counteract the force, thereby avoiding the second extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In addition, by bringing the first elastic piece into elastic contact with the radiator, the transmission of radio frequency signals between the first elastic piece and the radiator is ensured to be more stable. Specifically, because the first elastic piece has an elastic force, the first elastic piece can always be in contact with the radiator when the first elastic piece is in elastic contact with the radiator, so that the connection stability between the first elastic piece and the radiator is better.

In a possible implementation according to the second aspect, the electronic device further includes a radio frequency path. The radio frequency path can be configured to transmit radio frequency signals to the radiator of the antenna, so that the radiator of the antenna transmits electromagnetic wave signals according to the radio frequency signals. In addition, when the radiator of the antenna converts the received electromagnetic wave signals into radio frequency signals, the radio frequency path can further be configured to receive the radio frequency signals transmitted by the radiator of the antenna. In this case, the first elastic piece is electrically connected between the radio frequency path and the radiator.

In another possible implementation, the first elastic piece is electrically connected between the radiator and a ground layer of the second extension portion.

In another possible implementation, the first elastic piece is electrically connected to the ground layer of the second extension portion through a matching circuit.

According to the second aspect, or any one of the implementations of the second aspect described above, the first elastic piece is fixed to one side of the second extension portion facing the display screen. In this case, the first elastic piece and the second board are on the same side of the elevating board. In the thickness direction of the electronic device, there is an overlapping region between the first elastic piece and the second board. The first elastic piece utilizes a space of the second board facing one side of the radiator. In this way, in the thickness direction of the electronic device, the circuit board assembly does not thicken due to the configuration of the first elastic piece.

In addition, the space between a surface of the second extension portion facing the screen and the radiator is generally small. General chips or electronic components are not easy to be disposed in this region. In this case, the space is unused, which easily results in a waste of space. In this implementation, by fixing the first elastic piece with a small size to one side of the second extension portion facing the display screen, on the one hand, the space of this part can be effectively utilized to improve the internal space utilization of the electronic device; and on the other hand, compared with a case in which the first elastic piece is disposed on one side of the first board facing the rear cover, in this implementation, a space occupied by at least one first elastic piece can be saved by a space between the first board and the rear cover, and in this case, the space saved can be used for arranging more electronic components, thereby improving the space utilization of the circuit board assembly to a greater extent.

According to the second aspect, or any one of the implementations of the second aspect described above, a distance L from the contact point between the first elastic piece and the radiator to the display screen is greater than or equal to 2 mm. For example, L equals 2 mm, 2.5 mm, 3 mm, 3.5 mm or 4 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece and the radiator to the display screen is greater than or equal to 2 mm, the first elastic piece can be disposed away from the display screen to a greater extent. In this way, the antenna clearance area between the first elastic piece and the display screen can be increased to a greater extent, and the performance of the antenna is better.

According to the second aspect, or any one of the implementations of the second aspect described above, the distance L from the contact point between the first elastic piece and the radiator to the display screen is less than or equal to 4.7 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece and the radiator to the display screen is less than or equal to 4.7 mm, on the one hand, it can be ensured that the first elastic piece is disposed away from the display screen; and on the other hand, it can be ensured that a thickness of the electronic device in a Z direction is not great, which is conducive to thinning configuration.

According to the second aspect, or any one of the implementations of the second aspect described above, a distance between the first elastic piece and the second board is between 0.15 mm and 30 mm.

It may be understood that, when the distance between the first elastic piece and the second board ranges from 0.15 mm to 30 mm, the size of the second extension portion located between the first elastic piece and the second board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the second board is not easy to fracture or crack. In other words, the reaction force received by the second extension portion can be rapidly transmitted to the second board, thereby counteracting the reaction force by an internal stress of the second board.

According to the second aspect, or any one of the implementations of the second aspect described above, the circuit

board assembly further includes a third strengthening board. The third strengthening board is located on one side of the first elastic piece and fixedly connected to a board surface of the second extension portion facing the screen.

It may be understood that, by stacking the third strengthening board on one side of the first elastic piece and on the second extension portion, a thickness of a part of the second extension portion is significantly increased, which further significantly improves the structural strength of the elevating board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the second extension portion of the elevating board. In this case, with the cooperation of the third strengthening board, the second extension portion can effectively counteract the force, thereby avoiding the second extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the second aspect, or any one of the implementations of the second aspect described above, the third strengthening board and the second board are of an integrally formed structure. In other words, the third strengthening board and the second board are an integral board. In this case, the integral structural strength of the third strengthening board and the second board is better. In this way, the third strengthening board and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the third strengthening board may be connected to the second board by a soldering process, or the third strengthening board may be disposed separately from the second board.

According to the second aspect, or any one of the implementations of the second aspect described above, a distance between the first elastic piece and the third strengthening board ranges from 0.15 mm to 30 mm. In this case, the size of the second extension portion located between the first elastic piece and the third strengthening board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the third strengthening board is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the third strengthening board, thereby counteracting the reaction force by an internal stress of the third strengthening board.

According to the second aspect, or any one of the implementations of the second aspect described above, the circuit board assembly further includes a fourth strengthening board. The fourth strengthening board is located on one side of the first elastic piece away from the third strengthening board, and is fixedly connected to the board surface of the second extension portion facing the screen.

It may be understood that, by stacking the fourth strengthening board on one side of the first elastic piece and on the second extension portion, a thickness of a part of the second extension portion is significantly increased, which further significantly improves the structural strength of the elevating board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the second extension portion of the elevating board. In this case, with the cooperation of the fourth strengthening board, the second extension portion can effectively counteract the force, thereby avoiding the second extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the second aspect, or any one of the implementations of the second aspect described above, the fourth strengthening board and the second board are of an integrally formed structure. In other words, the fourth strengthening board and the second board are an integral board. In this case, the integral structural strength of the fourth strengthening board and the second board is better. In this way, the fourth strengthening board and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the fourth strengthening board may be connected to the second board by a soldering process, or the fourth strengthening board may be disposed separately from the second board.

According to the second aspect, or any one of the implementations of the second aspect described above, a distance between the first elastic piece and the fourth strengthening board ranges from 0.15 mm to 30 mm. In this case, the size of the second extension portion located between the first elastic piece and the fourth strengthening board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the fourth strengthening board is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the fourth strengthening board, thereby counteracting the reaction force by an internal stress of the fourth strengthening board.

According to the second aspect, or any one of the implementations of the second aspect described above, the second extension portion is provided with a groove, the groove is located between the third strengthening board and the fourth strengthening board, an opening of the groove is located on a surface of the second extension portion facing the screen, and a part of the first elastic piece is mounted in the groove.

It may be understood that, when a part of the first elastic piece is mounted in the groove, in the thickness direction of the electronic device, there is an overlapping region between the first elastic piece and the second extension portion. In this case, the first elastic piece can be disposed further away from the display screen, that is, in the thickness direction of the electronic device, a distance between the first elastic piece and the display screen can be significantly increased. In this case, a distance from the contact point between the first elastic piece and the radiator to the display screen is significantly increased. In this way, in the thickness direction of the electronic device, the antenna clearance area between the first elastic piece and the display screen can be made larger, and the performance of the antenna is better.

In addition, when the second extension portion is provided with the first strengthening board and the second strengthening board, the first strengthening board and the second strengthening board can improve the strength of the second extension portion, thereby avoiding the second extension portion from being reduced in strength due to the opening of the groove.

According to the second aspect, or any one of the implementations of the second aspect described above, a conduc-

tive piece is disposed on a surface of the radiator facing the first elastic piece. The first elastic piece is in elastic contact with the conductive piece.

It may be understood that, when the conductive piece is disposed on the radiator, the conductive piece can improve the surface flatness of the radiator. In this way, when the first elastic piece is in elastic contact with the radiator through the conductive piece, the elastic contact between the first elastic piece and the radiator is more stable. In this way, the radio frequency signals are also more stable in the process of transmission between the radiator and the first elastic piece, thereby ensuring better antenna performance of the electronic device.

According to the second aspect, or any one of the implementations of the second aspect described above, the oxidation resistance of the conductive piece is better than that of the radiator. It may be understood that, under an environment with the same temperature and humidity, the conductive piece is not easy to be oxidized compared with the radiator. In this way, compared with a solution in which the first elastic piece directly comes into elastic contact with the radiator, a contact resistance between the first elastic piece and the conductive piece is smaller, that is, the contact resistance between the first elastic piece and the conductive piece is more stable, and the transmission loss of the radio frequency signals is smaller. In this case, the performance of the antenna of the electronic device is better.

According to the second aspect, or any one of the implementations of the second aspect described above, the electronic device includes a fastener. The radiator is provided with a blind hole. The fastener is fixed into the blind hole. The first elastic piece is in elastic contact with the fastener.

It may be understood that, compared with a solution of soldering the conductive piece on the radiator, this implementation saves the process of soldering the conductive piece on the radiator by disposing the fastener in the blind hole of the radiator, and electrically connecting the first elastic piece to the radiator of the antenna through the fastener. Therefore, on the one hand, the cost investment of the electronic device is reduced, and there is no need to further increase the input cost of the soldering process; and on the other hand, the case that the performance of the radiator in transmitting and receiving electromagnetic waves is affected by the generation of gas holes, slag inclusions, solder joints, or cracks in the soldering process in the radiator is avoided.

According to the second aspect, or any one of the implementations of the second aspect described above, the radiator has an inner side surface facing the circuit board assembly. The first elastic piece is in elastic contact with the inner side surface. In this way, the first elastic piece can be disposed away from the display screen to a greater extent. In the thickness direction of the electronic device, a distance between the first elastic piece and the display screen can be significantly increased. In this way, in the thickness direction of the electronic device, the antenna clearance area between the first elastic piece and the display screen can be made larger, and the performance of the antenna is better.

In addition, a distance from the contact point between the first elastic piece and the radiator to the display screen is significantly increased, and in this case, the signal interference of the display screen to the contact point between the first elastic piece and the radiator is less.

In addition, the radiator may not need to be provided with a protrusion to come into contact with the first elastic piece, and in this case, in the thickness direction of the electronic device, the space omitting the protrusion may also be used for the clearance area of the antenna. In this way, the clearance area of the antenna is larger, and the performance of the antenna is better.

According to the second aspect, or any one of the implementations of the second aspect described above, the first elastic piece includes a first fixed piece, an elastic member, and a second fixed piece. The elastic member is connected between the first fixed piece and the second fixed piece. It may be understood that, the elastic member may be, but is not limited to, an elastic piece or a spring. In addition, the first fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece. The second fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece.

In addition, the first fixed piece is fixedly connected to the radiator. The second fixed piece is fixedly connected to the second extension portion of the elevating board.

It may be understood that, the first elastic piece has a simple structure and is easy to assemble, which can reduce the assembly difficulty of the electronic device.

According to the second aspect, or any one of the implementations of the second aspect described above, the electronic device further includes a middle plate. The middle plate is located on the inner side of the frame. The middle plate is grounded. The frame further includes a connection segment. One end of the connection segment is connected to the radiator and the other end is connected to the middle plate.

It may be understood that, the radiator is grounded in a relatively simple manner and has a simple structure and relatively low cost investment.

According to the second aspect, or any one of the implementations of the second aspect described above, the circuit board assembly further includes a second conductive member. The second conductive member may be, but is not limited to, an elastic piece or a spring. The second conductive member is disposed on the second extension portion of the elevating board. The second conductive member is electrically connected between the ground layer of the elevating board and the radiator. In other words, the second conductive member is configured to ground the radiator.

It may be understood that, the radiator is grounded in a relatively simple manner and has a simple structure and relatively low cost investment.

According to the second aspect, or any one of the implementations of the second aspect described above, the first board is provided with a second matching circuit. The second matching circuit includes an inductor, a capacitor, a resistor, or an antenna switch. A second elastic piece is electrically connected to the second matching circuit, and is electrically connected to the ground layer of the elevating board through the second matching circuit. The second matching circuit is configured to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves and the impedance matching for the antenna. In this way, the antenna is more widely applied to transmit and receive electromagnetic waves and has better performance.

According to the second aspect, or any one of the implementations of the second aspect described above, the electronic device further includes a middle plate. The middle plate is grounded. The middle plate is located on the inner side of the frame. The circuit board assembly further includes a second conductive member and a third conductive member. The second conductive member is fixed to the second extension portion of the elevating board. The second conductive member is in elastic contact with the radiator. The third conductive member is fixed to the second board.

The third conductive member is in elastic contact with the middle plate, and is electrically connected to the second conductive member.

It may be understood that, by disposing the second conductive member on the second extension portion, disposing the third conductive member on the second conductive member, and utilizing the third conductive member for grounding, a ground path of the radiator is increased. In this case, in the ground path of the radiator, a matching circuit may be disposed on the circuit board assembly to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves, so that the frequency bands of the antenna for receiving and transmitting are wider.

According to a third aspect, an electronic device is provided. The electronic device may be a mobile phone, a watch, or other forms of a device capable of transmitting and receiving electromagnetic wave signals. The electronic device includes a frame, a screen, and a circuit board assembly.

The screen is mounted on the frame and is disposed around the frame. In an implementation, the screen includes a protective cover plate and a display screen. The protective cover plate is stacked on the display screen. The display screen is disposed close to the circuit board assembly relative to the protective cover plate. The protective cover plate may be mainly configured to protect the display screen and prevent dust.

In addition, the screen includes a first screen region and a second screen region disposed opposite to each other.

A part of the frame forms a radiator of an antenna, or the radiator of the antenna is fixed on an inner side of the frame.

The circuit board assembly is located on the inner side of the frame. The circuit board assembly includes a first conductive member, and a first board, an elevating board, and a second board sequentially stacked. In other words, the elevating board is located between the first board and the second board. The first board is disposed away from the first screen region relative to the second board. In other words, the first board is disposed away from the first screen region relative to the second board. The first board includes a first main body portion and a first extension portion connected to the first main body portion. The first main body portion is fixedly connected to the elevating board. The first extension portion protrudes relative to the elevating board and the second board, and is disposed close to the radiator. The first conductive member is fixed to the first extension portion, and is in elastic contact with the radiator.

A distance from the contact point between the first conductive member and the radiator to the first screen region is a first distance. A distance from the contact point between the first conductive member and the radiator to the second screen region is a second distance. A ratio of the first distance to the second distance ranges from 0.5 to 2.

It should be noted that, the first conductive member may be an elastic piece having electrical conductivity or may alternatively be a spring having electrical conductivity, which is not limited in this application. In each of the solutions that can be implemented below, the first conductive member is described by taking a first elastic piece as an example.

It may be understood that, when the first elastic piece is fixed to the second board, in the thickness direction of the electronic device, a distance between the first elastic piece and the first screen region is relatively small, that is, the first elastic piece is disposed close to the first screen region. In this implementation, by fixedly connecting the first elastic piece to the first extension portion, and when the ratio of the first distance to the second distance ranges from 0.5 to 2, in the thickness direction of the electronic device, the distance between the first elastic piece and the first screen region is increased to a greater extent. In this way, in the thickness direction of the electronic device, the antenna clearance area between the first elastic piece and the first screen region can be increased to a greater extent, and the performance of the antenna is also improved to a greater extent. In addition, when the ratio of the first distance to the second distance ranges from 0.5 to 2, the distance from the contact point between the first conductive member and the radiator to the second screen region is relatively moderate, and in this case, the second screen region has less influence on the performance of the antenna receiving and transmitting electromagnetic waves.

In addition, by bringing the first elastic piece into elastic contact with the radiator, the transmission of radio frequency signals between the first elastic piece and the radiator is ensured to be more stable. Specifically, because the first elastic piece has an elastic force, the first elastic piece can always be in contact with the radiator when the first elastic piece is in elastic contact with the radiator, so that the connection stability between the first elastic piece and the radiator is better.

In a possible implementation according to the third aspect, the electronic device further includes a radio frequency path. The radio frequency path can be configured to transmit radio frequency signals to the radiator of the antenna, so that the radiator of the antenna transmits electromagnetic wave signals according to the radio frequency signals. In addition, when the radiator of the antenna converts the received electromagnetic wave signals into radio frequency signals, the radio frequency path can further be configured to receive the radio frequency signals transmitted by the radiator of the antenna. In this case, the first elastic piece is electrically connected between the radio frequency path and the radiator.

In another possible implementation, the first elastic piece is electrically connected between the radiator and a ground layer of the first extension portion.

In another possible implementation, the first elastic piece is electrically connected to the ground layer of the first extension portion through a matching circuit.

According to a third aspect, or any one of the implementations of the third aspect described above, the first elastic piece is fixed to one side of the first extension portion facing the first screen region. In this case, the first elastic piece, the elevating board, and the second board are located on the same side of the first board. In the thickness direction of the electronic device, there is an overlapping region between the first elastic piece and the elevating board. The first elastic piece utilizes a space of the elevating board facing the side of the radiator. In this way, in the thickness direction of the electronic device, the circuit board assembly does not thicken due to the configuration of the first elastic piece.

In addition, the space between a surface of the first extension portion facing the first screen region and the radiator is generally small. General chips or electronic components are not easy to be disposed in this region. In this case, the space is unused, which easily results in a waste of space. In this implementation, by fixing the first elastic piece with a small size to one side of the first extension portion facing the first screen region, on the one hand, the space of this part can be effectively utilized to improve the internal space utilization of the electronic device; and on the other hand, compared with a case in which the first elastic piece is disposed on one side of the first board facing the rear

cover, in this implementation, a space occupied by at least one first elastic piece can be saved by a space between the first board and the rear cover, and in this case, the space saved can be used for arranging more electronic components, thereby improving the space utilization of the circuit board assembly to a greater extent.

According to a third aspect, or any one of the implementations of the third aspect described above, a first distance from the contact point between the first elastic piece and the radiator to the first screen region is greater than or equal to 2 mm. For example, L1 equals 2 mm, 2.5 mm, 3 mm, 3.5 mm or 4 mm.

It may be understood that, when the first distance L1 from the contact point between the first elastic piece and the radiator to the first screen region is greater than or equal to 2 mm, the first elastic piece can be disposed away from the first screen region to a greater extent. In this case, in the thickness direction of the electronic device, the antenna clearance area between the first elastic piece and the first screen region can be increased to a greater extent, and the performance of the antenna is also better.

In addition, the first distance L1 from the contact point between the first elastic piece and the radiator to the first screen region is less than or equal to 4.7 mm.

It may be understood that, when the first distance L1 from the contact point between the first elastic piece and the radiator to the first screen region is less than or equal to 4.7 mm, on the one hand, it can be ensured that the first elastic piece is disposed away from the first screen region; and on the other hand, it can be ensured that a thickness of the electronic device is not great, which is conducive to the thinning configuration of the electronic device.

According to a third aspect, or any one of the implementations of the third aspect described above, a distance between the first elastic piece and the elevating board is between 0.15 mm and 30 mm.

It may be understood that, when the distance between the first elastic piece and the elevating board ranges from 0.15 mm to 30 mm, the size of the first extension portion located between the first elastic piece and the elevating board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the elevating board is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the elevating board, thereby counteracting the reaction force with an internal stress of the elevating board.

According to a third aspect, or any one of the implementations of the third aspect described above, the circuit board assembly further includes a first strengthening board. The first strengthening board is located on one side of the first elastic piece and fixedly connected to a board surface of the first extension portion facing the first screen region.

It may be understood that, by stacking the first strengthening board on one side of the first elastic piece and on the first extension portion, a thickness of a part of the first extension portion is significantly increased, which further significantly improves the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to a third aspect, or any one of the implementations of the third aspect described above, the first strengthening board includes a first portion and a second portion connected to the first portion. The first portion is fixedly connected to the board surface of the first extension portion facing the first screen region, and the first portion is fixedly connected to the elevating board. The second portion is fixedly connected to the second board. In the thickness direction of the electronic device, a thickness of the first strengthening board is greater than a thickness of the elevating board.

It may be understood that, the first portion and the second portion are sequentially stacked on the first extension portion, the first portion is fixedly connected to the elevating board, and the second portion is fixedly connected to the second board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the elevating board, and the second board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In another possible implementation, the first strengthening board is fixedly connected to the elevating board. In a thickness direction of the electronic device, a thickness of the first strengthening board is less than or equal to a thickness of the elevating board.

It may be understood that, the first strengthening board is stacked on the first extension portion, and the first strengthening board is fixedly connected to the elevating board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board and the elevating board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force.

According to a third aspect, or any one of the implementations of the third aspect described above, the first portion and the elevating board are of an integrally formed structure, and the second portion and the second board are of an integrally formed structure. In other words, the first portion and the elevating board are an integral board. In this case, the connection between the first portion and the elevating board is firmer. In this way, the first portion and the elevating board are not easy to fracture or crack when receiving an external force. In addition, the second portion and the second board are an integral board. In this case, the connection between the second portion and the second board is firmer. In this way, the second portion and the second board are not easy to fracture or crack when subjected to an external force.

In another possible implementation, the first portion can alternatively be fixedly connected to the elevating board by

a soldering process. the second portion can alternatively be fixedly connected to the second board by a soldering process.

According to a third aspect, or any one of the implementations of the third aspect described above, the first portion is provided with a first strengthening solder pad. The first extension portion is provided with a second strengthening solder pad. The first strengthening solder pad is soldered to the second strengthening solder pad.

It may be understood that, when the first portion and the first extension portion are soldered together through the first strengthening solder pad and the second strengthening solder pad, the connection between the first portion and the first extension portion is firmer, and the integral strength of the circuit board assembly is better. In addition, after the first strengthening solder pad and the second strengthening solder pad are soldered together, the first strengthening solder pad and the second strengthening solder pad can effectively protect a solder pad (the solder pad of this part is mainly configured for the electrical connection between wiring of the first board and wiring of the elevating board) between the first main body portion of the first board and the elevating board. That is, the solder pad between the first main body portion and the elevating board is avoided from easily breaking due to an external force.

According to a third aspect, or any one of the implementations of the third aspect described above, a distance between the first elastic piece and the first portion ranges from 0.15 mm to 30 mm. In this case, the size of the first extension portion located between the first elastic piece and the first portion is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the first portion is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the first portion, thereby counteracting the reaction force by an internal stress of the first portion.

According to a third aspect, or any one of the implementations of the third aspect described above, the circuit board assembly further includes a second strengthening board. The second strengthening board is located on one side of the first elastic piece away from the first strengthening board, and is fixedly connected to the board surface of the first extension portion facing the first screen region.

It may be understood that, by stacking the first strengthening board on one side of the first elastic piece and on the first extension portion, and stacking the second strengthening board on the other side of the first elastic piece and on the first extension portion, a thickness of a part of the first extension portion is significantly increased, which further significantly improves the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board and the second strengthening board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to a third aspect, or any one of the implementations of the third aspect described above, the second strengthening board includes a third portion and a fourth portion connected to the third portion. The third portion is fixedly connected to the board surface of the first extension portion facing the first screen region, and the third portion is fixedly connected to the elevating board. The fourth portion is fixedly connected to the second board. In the thickness direction of the electronic device, a thickness of the second strengthening board is greater than a thickness of the elevating board.

It may be understood that, the third portion and the fourth portion connected to the third portion are sequentially stacked on the first extension portion, the third portion is fixedly connected to the elevating board, and the fourth portion is fixedly connected to the second board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the second strengthening board, the elevating board, and the second board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In another possible implementation, the second strengthening board is fixedly connected to the elevating board. In a thickness direction of the electronic device, a thickness of the second strengthening board is less than or equal to a thickness of the elevating board.

According to a third aspect, or any one of the implementations of the third aspect described above, the third portion and the elevating board are of an integrally formed structure. The fourth portion and the second board are of an integrally formed structure. In other words, the third portion and the elevating board are an integral board. In this case, the connection between the third portion and the elevating board is firmer. In this way, the third portion and the elevating board are not easy to fracture or crack when receiving an external force. In addition, the fourth portion and the second board are an integral board. In this case, the connection between the fourth portion and the second board is firmer. In this way, the fourth portion and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the third portion can alternatively be fixedly connected to the elevating board by a soldering process. The fourth portion can alternatively be fixedly connected to the second board by a soldering process.

According to a third aspect, or any one of the implementations of the third aspect described above, a distance d3 between the first elastic piece and the third portion ranges from 0.15 mm to 30 mm.

In this case, the size of the first extension portion located between the first elastic piece and the third portion is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the third portion is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the third portion, thereby counteracting the reaction force by an internal stress of the third portion.

According to a third aspect, or any one of the implementations of the third aspect described above, a conductive

piece is disposed on a surface of the radiator facing the first elastic piece. The first elastic piece is in elastic contact with the conductive piece.

It may be understood that, when the conductive piece is disposed on the radiator, the conductive piece can improve the surface flatness of the radiator. In this way, when the first elastic piece is in elastic contact with the radiator through the conductive piece, the elastic contact between the first elastic piece and the radiator is more stable. In this way, the radio frequency signals are also more stable in the process of transmission between the radiator and the first elastic piece, thereby ensuring better antenna performance of the electronic device.

According to a third aspect, or any one of the implementations of the third aspect described above, the oxidation resistance of the conductive piece is better than that of the radiator. It may be understood that, under an environment with the same temperature and humidity, the conductive piece is not easy to be oxidized compared with the radiator. In this way, compared with a solution in which the first elastic piece directly comes into elastic contact with the radiator, a contact resistance between the first elastic piece and the conductive piece is smaller, that is, the contact resistance between the first elastic piece and the conductive piece is more stable, and the transmission loss of the radio frequency signals is smaller. In this case, the performance of the antenna of the electronic device is better.

According to a third aspect, or any one of the implementations of the third aspect described above, the electronic device includes a fastener. The radiator is provided with a blind hole. The fastener is fixed into the blind hole. The first elastic piece is in elastic contact with the fastener.

It may be understood that, compared with a solution of soldering the conductive piece on the radiator, this implementation saves the process of soldering the conductive piece on the radiator by disposing the fastener in the blind hole of the radiator, and electrically connecting the first elastic piece to the radiator of the antenna through the fastener. Therefore, on the one hand, the cost investment of the electronic device is reduced, and there is no need to further increase the input cost of the soldering process; and on the other hand, the case that the performance of the radiator in transmitting and receiving electromagnetic waves is affected by the generation of gas holes, slag inclusions, solder joints, or cracks in the soldering process in the radiator is avoided.

According to a third aspect, or any one of the implementations of the third aspect described above, the radiator has an inner side surface facing the circuit board assembly. The first elastic piece is in elastic contact with the inner side surface. In this way, the radiator may not need to be provided with a protrusion to come into contact with the first elastic piece, and in this case, in the thickness direction of the electronic device, the space omitting the protrusion may also be used for the clearance area of the antenna. In this way, the clearance area of the antenna is larger, and the performance of the antenna is better.

According to a third aspect, or any one of the implementations of the third aspect described above, the first elastic piece includes a first fixed piece, an elastic member, and a second fixed piece. The elastic member is connected between the first fixed piece and the second fixed piece. It may be understood that, the elastic member may be, but is not limited to, an elastic piece or a spring. In addition, the first fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece. The second fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece.

In addition, the first fixed piece is fixedly connected to the radiator. The second fixed piece is fixedly connected to the first extension portion of the first board.

It may be understood that, the first elastic piece has a simple structure and is easy to assemble, which can reduce the assembly difficulty of the electronic device.

According to a third aspect, or any one of the implementations of the third aspect described above, the electronic device further includes a middle plate. The middle plate is located on the inner side of the frame. The middle plate is grounded. The frame further includes a connection segment. One end of the connection segment is connected to the radiator and the other end is connected to the middle plate.

It may be understood that, the radiator is grounded in a relatively simple manner and has a simple structure and relatively low cost investment.

According to a third aspect, or any one of the implementations of the third aspect described above, the circuit board assembly further includes a second conductive member. The second conductive member may be, but is not limited to, an elastic piece or a spring. The second conductive member is disposed on the first extension portion of the first board. The second conductive member is electrically connected between the ground layer of the first board and the radiator. In other words, the second conductive member is configured to ground the radiator.

It may be understood that, the radiator is grounded in a relatively simple manner and has a simple structure and relatively low cost investment.

According to a third aspect, or any one of the implementations of the third aspect described above, the first board is provided with a second matching circuit. The second matching circuit includes an inductor, a capacitor, a resistor, or an antenna switch. A second elastic piece is electrically connected to the second matching circuit and is electrically connected to the ground layer of the first board through the second matching circuit. The second matching circuit is configured to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves and the impedance matching for the antenna. In this way, the antenna is more widely applied to transmit and receive electromagnetic waves and has better performance.

According to a third aspect, or any one of the implementations of the third aspect described above, the electronic device further includes a middle plate. The middle plate is grounded. The middle plate is located on the inner side of the frame. The circuit board assembly further includes a second conductive member and a third conductive member. The second conductive member is fixed to the first extension portion of the first board. The second conductive member is in elastic contact with the radiator. The third conductive member is fixed to the second board. The third conductive member is in elastic contact with the middle plate, and is electrically connected to the second conductive member.

It may be understood that, by disposing the second conductive member on the first extension portion, disposing the third conductive member on the second conductive member, and utilizing the third conductive member for grounding, a ground path of the radiator is increased. In this case, in the ground path of the radiator, a matching circuit may be disposed on the circuit board assembly to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves, so that the frequency bands of the antenna for receiving and transmitting are wider.

According to a fourth aspect, an electronic device is provided. The electronic device may be a mobile phone, a watch, or other forms of a device capable of transmitting and receiving electromagnetic wave signals. The electronic device includes a frame, a screen, and a circuit board assembly.

The screen is mounted on the frame and is disposed around the frame. In an implementation, the screen includes a protective cover plate and a display screen. The protective cover plate is stacked on the display screen. The display screen is disposed close to the circuit board assembly relative to the protective cover plate. The protective cover plate may be mainly configured to protect the display screen and prevent dust.

In addition, the screen includes a first screen region and a second screen region disposed opposite to each other.

A part of the frame forms a radiator of an antenna, or the radiator of the antenna is fixed on an inner side of the frame.

The circuit board assembly is located on the inner side of the frame. The circuit board assembly includes a first board, an elevating board, a second board, and a first conductive member. The first board and the elevating board are both located on one side of the second board away from the first screen region. In other words, the first board and the elevating board are disposed away from the first screen region relative to the second board. The first board includes a first main body portion and a first extension portion connected to the first main body portion. The elevating board includes a second main body portion and a second extension portion connected to the second main body portion. The first main body portion, the second main body portion, and the second board are sequentially stacked. In other words, the second main body portion is located between the first main body portion and the second board. The first extension portion and the second extension portion are stacked, and both the first extension portion and the second extension portion protrude relative to the second board and are disposed close to the radiator. The first conductive member is fixed to the second extension portion, and is in elastic contact with the radiator.

A distance from the contact point between the first conductive member and the radiator to the first screen region is a first distance. A distance from the contact point between the first conductive member and the radiator to the second screen region is a second distance. A ratio of the first distance to the second distance ranges from 0.5 to 2.

It should be noted that, the first conductive member may be an elastic piece having electrical conductivity or may alternatively be a spring having electrical conductivity, which is not limited in this application. In each of the solutions that can be implemented below, the first conductive member is described by taking a first elastic piece as an example.

It may be understood that, when the first elastic piece is fixed to the second board, in the thickness direction of the electronic device, a distance between the first elastic piece and the first screen region is relatively small, that is, the first elastic piece is disposed close to the first screen region. In this implementation, by fixedly connecting the first elastic piece to the second extension portion, and when the ratio of the first distance to the second distance ranges from 0.5 to 2, in the thickness direction of the electronic device, the distance between the first elastic piece and the first screen region is increased to a greater extent. In this way, in the thickness direction of the electronic device, the antenna clearance area between the first elastic piece and the first screen region can be increased to a greater extent, and the performance of the antenna is also improved to a greater extent. In addition, when the ratio of the first distance to the second distance ranges from 0.5 to 2, the distance from the contact point between the first conductive member and the radiator to the second screen region is relatively moderate, and in this case, the second screen region has less influence on the performance of the antenna receiving and transmitting electromagnetic waves.

In addition, by bringing the first elastic piece into elastic contact with the radiator, the transmission of radio frequency signals between the first elastic piece and the radiator is ensured to be more stable. Specifically, because the first elastic piece has an elastic force, the first elastic piece can always be in contact with the radiator when the first elastic piece is in elastic contact with the radiator, so that the connection stability between the first elastic piece and the radiator is better.

In a possible implementation according to the fourth aspect, the electronic device further includes a radio frequency path. The radio frequency path can be configured to transmit radio frequency signals to the radiator of the antenna, so that the radiator of the antenna transmits electromagnetic wave signals according to the radio frequency signals. In addition, when the radiator of the antenna converts the received electromagnetic wave signals into radio frequency signals, the radio frequency path can further be configured to receive the radio frequency signals transmitted by the radiator of the antenna. In this case, the first elastic piece is electrically connected between the radio frequency path and the radiator.

In another possible implementation, the first elastic piece is electrically connected between the radiator and a ground layer of the second extension portion.

In another possible implementation, the first elastic piece is electrically connected to the ground layer of the second extension portion through a matching circuit.

According to the fourth aspect, or any implementation of the fourth aspect described above, the first elastic piece is fixed to one side of the second extension portion facing the first screen region. In this case, the first elastic piece and the second board are on the same side of the elevating board. In the thickness direction of the electronic device, there is an overlapping region between the first elastic piece and the second board. The first elastic piece utilizes a space of the second board facing one side of the radiator. In this way, in the thickness direction of the electronic device, the circuit board assembly does not thicken due to the configuration of the first elastic piece.

In addition, a space between a surface of the second extension portion facing the first screen region and the radiator is generally small. General chips or electronic components are not easy to be disposed in this region. In this case, the space is unused, which easily results in a waste of space. In this implementation, the first elastic piece with a relatively small size is fixed on the side of the second extension portion facing the first screen region. On the one hand, the space of this part can be effectively utilized, to improve the internal space utilization of the electronic device. On the other hand, compared with a case in which the first elastic piece is disposed on one side of the first board facing a rear cover, in this implementation, a space between the first board and the rear cover can save the space occupied by at least one first elastic piece. In this case, the saved space can be used for arranging more electronic components, thereby greatly improving the space utilization of the circuit board assembly.

According to the fourth aspect, or any implementation of the fourth aspect described above, a distance L from a contact point between the first elastic piece and the radiator to the first screen region is greater than or equal to 2 mm. For example, L equals 2 mm, 2.5 mm, 3 mm, 3.5 mm or 4 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece and the radiator to the first screen region is greater than or equal to 2 mm, the first elastic piece can be disposed away from the first screen region to a greater extent. In this way, an antenna clearance area between the first elastic piece and the first screen region can be greatly increased, and the performance of the antenna is also better.

According to the fourth aspect, or any implementation of the fourth aspect described above, the distance L from the contact point between the first elastic piece and the radiator to the first screen region is less than or equal to 4.7 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece and the radiator to the first screen region is less than or equal to 4.7 mm, on the one hand, it can be ensured that the first elastic piece is disposed away from the first screen region; and on the other hand, it can be ensured that a thickness of the electronic device in a Z direction is not great, which is conducive to thinning configuration.

According to the fourth aspect, or any implementation of the fourth aspect described above, a distance between the first elastic piece and the second board is between 0.15 mm and 30 mm.

It may be understood that, when the distance between the first elastic piece and the second board ranges from 0.15 mm to 30 mm, the size of the second extension portion located between the first elastic piece and the second board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the second board is not easy to fracture or crack. In other words, the reaction force received by the second extension portion can be rapidly transmitted to the second board, thereby counteracting the reaction force by an internal stress of the second board.

According to the fourth aspect, or any implementation of the fourth aspect described above, the circuit board assembly further includes a third strengthening board. The third strengthening board is located on one side of the first elastic piece, and is fixedly connected to a board surface of the second extension portion facing the first screen region.

It may be understood that, by stacking the third strengthening board on one side of the first elastic piece and on the second extension portion, a thickness of a part of the second extension portion is significantly increased, which further significantly improves the structural strength of the elevating board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the second extension portion of the elevating board. In this case, with the cooperation of the third strengthening board, the second extension portion can effectively counteract the force, thereby avoiding the second extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the fourth aspect, or any implementation of the fourth aspect described above, the third strengthening board and the second board are of an integrally formed structure. In other words, the third strengthening board and the second board are an integral board. In this case, the integral structural strength of the third strengthening board and the second board is better. In this way, the third strengthening board and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the third strengthening board may be connected to the second board by a soldering process, or the third strengthening board may be disposed separately from the second board.

According to the fourth aspect, or any implementation of the fourth aspect described above, a distance between the first elastic piece and the third strengthening board ranges from 0.15 mm to 30 mm. In this case, the size of the second extension portion located between the first elastic piece and the third strengthening board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the third strengthening board is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the third strengthening board, thereby counteracting the reaction force by an internal stress of the third strengthening board.

According to the fourth aspect, or any implementation of the fourth aspect described above, the circuit board assembly further includes a fourth strengthening board. The fourth strengthening board is located on one side of the first elastic piece away from the third strengthening board, and is fixedly connected to the board surface of the second extension portion facing the first flat screen region.

It may be understood that, by stacking the fourth strengthening board on one side of the first elastic piece and on the second extension portion, a thickness of a part of the second extension portion is significantly increased, which further significantly improves the structural strength of the elevating board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the second extension portion of the elevating board. In this case, with the cooperation of the fourth strengthening board, the second extension portion can effectively counteract the force, thereby avoiding the second extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the fourth aspect, or any implementation of the fourth aspect described above, the fourth strengthening board and the second board are of an integrally formed structure. In other words, the fourth strengthening board and the second board are an integral board. In this case, the integral structural strength of the fourth strengthening board and the second board is better. In this way, the fourth strengthening board and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the fourth strengthening board may be connected to the second board by a soldering process, or the fourth strengthening board may be disposed separately from the second board.

According to the fourth aspect, or any implementation of the fourth aspect described above, a distance between the first elastic piece and the fourth strengthening board ranges from 0.15 mm to 30 mm. In this case, the size of the second extension portion located between the first elastic piece and

the fourth strengthening board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the fourth strengthening board is not easy to fracture or crack. In other words, a reaction force received by the second extension portion can be quickly transmitted to the fourth strengthening board. Therefore, the reaction force is counteracted by an internal stress of the fourth strengthening board.

According to the fourth aspect, or any implementation of the fourth aspect described above, a surface of the radiator facing the first elastic piece is provided with a conductive piece. The first elastic piece is in elastic contact with the conductive piece.

It may be understood that, when the conductive piece is disposed on the radiator, the conductive piece can improve the surface flatness of the radiator. In this way, when the first elastic piece is in elastic contact with the radiator through the conductive piece, the elastic contact between the first elastic piece and the radiator is more stable. In this way, the radio frequency signals are also more stable in the process of transmission between the radiator and the first elastic piece, thereby ensuring better antenna performance of the electronic device.

According to the fourth aspect, or any implementation of the fourth aspect described above, the oxidation resistance of the conductive piece is higher than that of the radiator. It may be understood that, under an environment with the same temperature and humidity, the conductive piece is not easy to be oxidized compared with the radiator. In this way, compared with a solution in which the first elastic piece directly comes into elastic contact with the radiator, a contact resistance between the first elastic piece and the conductive piece is smaller, that is, the contact resistance between the first elastic piece and the conductive piece is more stable, and the transmission loss of the radio frequency signals is smaller. In this case, the performance of the antenna of the electronic device is better.

According to the fourth aspect, or any implementation of the fourth aspect described above, the electronic device includes a fastener. The radiator is provided with a blind hole. The fastener is fixed into the blind hole. The first elastic piece is in elastic contact with the fastener.

It may be understood that, compared with a solution of soldering the conductive piece on the radiator, this implementation saves the process of soldering the conductive piece on the radiator by disposing the fastener in the blind hole of the radiator, and electrically connecting the first elastic piece to the radiator of the antenna through the fastener. Therefore, on the one hand, the cost investment of the electronic device is reduced, and there is no need to further increase the input cost of the soldering process; and on the other hand, the case that the performance of the radiator in transmitting and receiving electromagnetic waves is affected by the generation of gas holes, slag inclusions, solder joints, or cracks in the soldering process in the radiator is avoided.

According to the fourth aspect, or any implementation of the fourth aspect described above, the radiator includes an inner side surface facing the circuit board assembly. The first elastic piece is in elastic contact with the inner side surface. In this way, the radiator may not need to be provided with a protrusion to come into contact with the first elastic piece, and in this case, in the thickness direction of the electronic device, the space omitting the protrusion may also be used for the clearance area of the antenna. In this way, the clearance area of the antenna is larger, and the performance of the antenna is better.

According to the fourth aspect, or any implementation of the fourth aspect described above, the first elastic piece includes a first fixed piece, an elastic member, and a second fixed piece. The elastic member is connected between the first fixed piece and the second fixed piece. It may be understood that, the elastic member may be, but is not limited to, an elastic piece or a spring. In addition, the first fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece. The second fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece.

In addition, the first fixed piece is fixedly connected to the radiator. The second fixed piece is fixedly connected to the second extension portion of the elevating board.

It may be understood that, the first elastic piece has a simple structure and is easy to assemble, which can reduce the assembly difficulty of the electronic device.

According to the fourth aspect, or any implementation of the fourth aspect described above, the electronic device further includes a middle plate. The middle plate is located on the inner side of the frame. The middle plate is grounded. The frame further includes a connection segment. One end of the connection segment is connected to the radiator and the other end is connected to the middle plate.

It may be understood that, the radiator is grounded in a relatively simple manner and has a simple structure and relatively low cost investment.

According to the fourth aspect, or any implementation of the fourth aspect described above, the circuit board assembly further includes a second conductive member. The second conductive member may be, but is not limited to, an elastic piece or a spring. The second conductive member is disposed on the second extension portion of the elevating board. The second conductive member is electrically connected between the ground layer of the elevating board and the radiator. In other words, the second conductive member is configured to ground the radiator.

It may be understood that, the radiator is grounded in a relatively simple manner and has a simple structure and relatively low cost investment.

According to the fourth aspect, or any implementation of the fourth aspect described above, the first board is provided with a second matching circuit. The second matching circuit includes an inductor, a capacitor, a resistor, or an antenna switch. A second elastic piece is electrically connected to the second matching circuit, and is electrically connected to the ground layer of the elevating board through the second matching circuit. The second matching circuit is configured to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves and the impedance matching for the antenna. In this way, the antenna is more widely applied to transmit and receive electromagnetic waves and has better performance.

According to the fourth aspect, or any implementation of the fourth aspect described above, the electronic device further includes a middle plate. The middle plate is grounded. The middle plate is located on the inner side of the frame. The circuit board assembly further includes a second conductive member and a third conductive member. The second conductive member is fixed to the second extension portion of the elevating board. The second conductive member is in elastic contact with the radiator. The third conductive member is fixed to the second board. The third

conductive member is in elastic contact with the middle plate, and is electrically connected to the second conductive member.

It may be understood that, by disposing the second conductive member on the second extension portion, disposing the third conductive member on the second conductive member, and utilizing the third conductive member for grounding, a ground path of the radiator is increased. In this case, in the ground path of the radiator, a matching circuit may be disposed on the circuit board assembly to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves, so that the frequency bands of the antenna for receiving and transmitting are wider.

In a fifth aspect, an antenna apparatus is provided. The antenna apparatus can transmit and receive electromagnetic wave signals. The antenna apparatus includes a radiator and a circuit board assembly.

The circuit board assembly is located on the inner side of the frame. The circuit board assembly includes a first conductive member, and a first board, an elevating board, and a second board sequentially stacked. In other words, the elevating board is located between the first board and the second board. The first board includes a first main body portion and a first extension portion connected to the first main body portion. The first main body portion is fixedly connected to the elevating board. The first extension portion protrudes relative to the elevating board and the second board, and is disposed close to the radiator. The first conductive member is fixed to the first extension portion, and the first conductive member, the elevating board, and the second board are located on the same side of the first board. The first conductive member is in elastic contact with the radiator.

It should be noted that, the first conductive member may be an elastic piece having electrical conductivity or may alternatively be a spring having electrical conductivity, which is not limited in this application. In each of the solutions that can be implemented below, the first conductive member is described by taking a first elastic piece as an example.

In this implementation, by disposing the first extension portion that protrudes relative to the elevating board and the second board, and fixedly connecting the first elastic piece to the first extension portion, and the first elastic piece, the elevating board, and the second board are located on the same side of the first board, in a thickness direction of the circuit board assembly, there is an overlapping region between the first elastic piece and the elevating board. The first elastic piece utilizes a space of the elevating board facing the side of the radiator. In this way, in a thickness direction of the antenna apparatus, the circuit board assembly is not thickened due to the configuration of the first elastic piece.

In addition, compared with a solution of fixing the first elastic piece on the second board, in this implementation, by fixing the first elastic piece on the first extension portion, there are no longer any antenna-related components or wiring (for example, antenna switches, inductances, capacitors, or resistors) disposed on the elevating board and the second board. In this way, on the one hand, the structure of the circuit board assembly is simpler, that is, the assembly difficulty of the circuit board assembly is reduced, and the cost investment of the circuit board assembly is lower; and on the other hand, more space can be freed up on the second board to arrange more electronic components.

In addition, by bringing the first elastic piece into elastic contact with the radiator, the transmission of radio frequency signals between the first elastic piece and the radiator is ensured to be more stable. Specifically, because the first elastic piece has an elastic force, the first elastic piece can always be in contact with the radiator when the first elastic piece is in elastic contact with the radiator, so that the connection stability between the first elastic piece and the radiator is better.

In addition, a space between the radiator and a surface of the first extension portion facing the radiator is generally small. General chips or electronic components are not easy to be disposed in this region. In this case, the space is unused, which easily results in a waste of space. In this implementation, by fixing the first elastic piece with a relatively small size on one side of the first extension portion facing the radiator, the space of this part can be effectively utilized, to improve the internal space utilization of the antenna apparatus.

In addition, by sequentially stacking the first board, the elevating board, and the second board, the board area of the circuit board assembly can be significantly increased, thereby increasing the number of electronic components arranged on the circuit board assembly. Specifically, when the first board and the second board are elevated by the elevating board, on the circuit board assembly, electronic components (for example, a CPU, a battery management chip, or the like) not only can be arranged on a surface of the first board facing away from the second board and a surface of the second board facing away from the first board, but also can be arranged in a space between the first board and the second board (on a surface of the first board facing the second board and a surface of the second board facing the first board). In other words, on the circuit board assembly of this implementation, more electronic components can be arranged.

In a possible implementation according to the fifth aspect, the antenna apparatus further includes a radio frequency path. The radio frequency path can be configured to transmit radio frequency signals to the radiator of the antenna, so that the radiator of the antenna transmits electromagnetic wave signals according to the radio frequency signals. In addition, when the radiator of the antenna converts the received electromagnetic wave signals into radio frequency signals, the radio frequency path can further be configured to receive the radio frequency signals transmitted by the radiator of the antenna. In this case, the first elastic piece is electrically connected between the radio frequency path and the radiator.

In another possible implementation, the first elastic piece is electrically connected between the radiator and a ground layer of the first extension portion.

In another possible implementation, the first elastic piece is electrically connected to the ground layer of the first extension portion through a matching circuit.

According to the fifth aspect, or any implementation of the fifth aspect described above, a distance between the first elastic piece and the elevating board is between 0.15 mm and 30 mm.

It may be understood that, when the distance between the first elastic piece and the elevating board ranges from 0.15 mm to 30 mm, the size of the first extension portion located between the first elastic piece and the elevating board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the elevating board is not easy to fracture or crack. In other words, the reaction force

received by the first extension portion can be rapidly transmitted to the elevating board, thereby counteracting the reaction force with an internal stress of the elevating board.

According to the fifth aspect, or any implementation of the fifth aspect described above, the circuit board assembly further includes a first strengthening board. The first strengthening board is located on one side of the first elastic piece, and is fixedly connected to a board surface of the first extension portion facing the second board.

It may be understood that, by stacking the first strengthening board on one side of the first elastic piece and on the first extension portion, a thickness of a part of the first extension portion is significantly increased, which further significantly improves the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the fifth aspect, or any implementation of the fifth aspect described above, the first strengthening board includes a first portion and a second portion connected to the first portion. The first portion is fixedly connected to the board surface of the first extension portion facing the second board, and the first portion is fixedly connected to the elevating board. The second portion is fixedly connected to the second board. In a thickness direction of the antenna apparatus, a thickness of the first strengthening board is greater than a thickness of the elevating board.

It may be understood that, the first portion and the second portion are sequentially stacked on the first extension portion, the first portion is fixedly connected to the elevating board, and the second portion is fixedly connected to the second board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the elevating board, and the second board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In another possible implementation, the first strengthening board is fixedly connected to the elevating board. In the thickness direction of the antenna apparatus, the thickness of the first strengthening board is less than or equal to the thickness of the elevating board.

It may be understood that, the first strengthening board is stacked on the first extension portion, and the first strengthening board is fixedly connected to the elevating board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board and the elevating board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force.

According to the fifth aspect, or any implementation of the fifth aspect described above, the first portion and the elevating board are of an integrally formed structure, and the second portion and the second board are of an integrally formed structure. In other words, the first portion and the elevating board are an integral board. In this case, the connection between the first portion and the elevating board is firmer. In this way, the first portion and the elevating board are not easy to fracture or crack when receiving an external force. In addition, the second portion and the second board are an integral board. In this case, the connection between the second portion and the second board is firmer. In this way, the second portion and the second board are not easy to fracture or crack when subjected to an external force.

In another possible implementation, the first portion can alternatively be fixedly connected to the elevating board by a soldering process. the second portion can alternatively be fixedly connected to the second board by a soldering process.

According to the fifth aspect, or any implementation of the fifth aspect described above, the first portion is provided with a first strengthening solder pad. The first extension portion is provided with a second strengthening solder pad. The first strengthening solder pad is soldered to the second strengthening solder pad.

It may be understood that, when the first portion and the first extension portion are soldered together through the first strengthening solder pad and the second strengthening solder pad, the connection between the first portion and the first extension portion is firmer, and the integral strength of the circuit board assembly is better. In addition, after the first strengthening solder pad and the second strengthening solder pad are soldered together, the first strengthening solder pad and the second strengthening solder pad can effectively protect a solder pad (the solder pad of this part is mainly configured for the electrical connection between wiring of the first board and wiring of the elevating board) between the first main body portion of the first board and the elevating board. That is, the solder pad between the first main body portion and the elevating board is avoided from easily breaking due to an external force.

According to the fifth aspect, or any implementation of the fifth aspect described above, a distance between the first elastic piece and the first portion ranges from 0.15 mm to 30 mm. In this case, the size of the first extension portion located between the first elastic piece and the first portion is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the first portion is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the first portion, thereby counteracting the reaction force by an internal stress of the first portion.

According to the fifth aspect, or any implementation of the fifth aspect described above, the circuit board assembly further includes a second strengthening board. The second strengthening board is located on one side of the first elastic piece away from the first strengthening board, and is fixedly connected to a board surface of the first extension portion facing the second board.

It may be understood that, by stacking the first strengthening board on one side of the first elastic piece and on the first extension portion, and stacking the second strengthening board on the other side of the first elastic piece and on the first extension portion, a thickness of a part of the first extension portion is significantly increased, which further significantly improves the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board and the second strengthening board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the fifth aspect, or any implementation of the fifth aspect described above, the second strengthening board includes a third portion and a fourth portion connected to the third portion. The third portion is fixedly connected to the board surface of the first extension portion facing the second board, and the third portion is fixedly connected to the elevating board. The fourth portion is fixedly connected to the second board. In the thickness direction of the antenna apparatus, a thickness of the second strengthening board is greater than the thickness of the elevating board.

It may be understood that, the third portion and the fourth portion connected to the third portion are sequentially stacked on the first extension portion, the third portion is fixedly connected to the elevating board, and the fourth portion is fixedly connected to the second board, thereby significantly improving the structural strength of the first board. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the first extension portion of the first board. In this case, with the cooperation of the first strengthening board, the second strengthening board, the elevating board, and the second board, the first extension portion can effectively counteract the force, thereby avoiding the first extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In another possible implementation, the second strengthening board is fixedly connected to the elevating board. In the thickness direction of the antenna apparatus, the thickness of the second strengthening board is less than or equal to the thickness of the elevating board.

According to the fifth aspect, or any implementation of the fifth aspect described above, the third portion and the elevating board are of an integrally formed structure. The fourth portion and the second board are of an integrally formed structure. In other words, the third portion and the elevating board are an integral board. In this case, the connection between the third portion and the elevating board is firmer. In this way, the third portion and the elevating board are not easy to fracture or crack when receiving an external force. In addition, the fourth portion and the second board are an integral board. In this case, the connection between the fourth portion and the second board is firmer. In this way, the fourth portion and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the third portion can alternatively be fixedly connected to the elevating board by a soldering process. The fourth portion can alternatively be fixedly connected to the second board by a soldering process.

According to the fifth aspect, or any implementation of the fifth aspect described above, a distance d**3** between the first elastic piece and the third portion ranges from 0.15 mm to 30 mm.

In this case, the size of the first extension portion located between the first elastic piece and the third portion is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the first extension portion. In this case, the first extension portion located between the first elastic piece and the third portion is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the third portion, thereby counteracting the reaction force by an internal stress of the third portion.

According to the fifth aspect, or any implementation of the fifth aspect described above, the first extension portion is provided with a groove. The groove is located between the first strengthening board and the second strengthening board, and an opening of the groove is located on a surface of the first extension portion facing the radiator. A part of the first elastic piece is mounted in the groove.

It may be understood that, when a part of the first elastic piece is mounted in the groove, in a thickness direction of the circuit board assembly, there is an overlapping region between the first elastic piece and the first extension portion. In this case, there is an overlapping region between the first elastic piece and the first board as well. In this way, in a thickness direction of the antenna apparatus, the circuit board assembly is not thickened due to the configuration of the first elastic piece.

In addition, when the first extension portion is provided with the first strengthening board and the second strengthening board, the first strengthening board and the second strengthening board can improve the strength of the first extension portion, thereby avoiding the first extension portion from being reduced in strength due to the opening of the groove.

According to the fifth aspect, or any implementation of the fifth aspect described above, a surface of the radiator facing the first elastic piece is provided with a conductive piece. The first elastic piece is in elastic contact with the conductive piece.

It may be understood that, when the conductive piece is disposed on the radiator, the conductive piece can improve the surface flatness of the radiator. In this way, when the first elastic piece is in elastic contact with the radiator through the conductive piece, the elastic contact between the first elastic piece and the radiator is more stable. In this way, radio frequency signals are also relatively stably transmitted between the radiator and the first elastic piece, thereby ensuring that the antenna apparatus has better antenna performance.

According to the fifth aspect, or any implementation of the fifth aspect described above, the oxidation resistance of the conductive piece is higher than that of the radiator. It may be understood that, under an environment with the same temperature and humidity, the conductive piece is not easy to be oxidized compared with the radiator. In this way, compared with a solution in which the first elastic piece directly comes into elastic contact with the radiator, a contact resistance between the first elastic piece and the conductive piece is smaller, that is, the contact resistance

between the first elastic piece and the conductive piece is more stable, and the transmission loss of the radio frequency signals is smaller. In this case, the antenna performance of the antenna apparatus is better.

According to the fifth aspect, or any implementation of the fifth aspect described above, the antenna apparatus includes a fastener. The radiator is provided with a blind hole. The fastener is fixed into the blind hole. The first elastic piece is in elastic contact with the fastener.

It may be understood that, compared with a solution of soldering the conductive piece on the radiator, this implementation saves the process of soldering the conductive piece on the radiator by disposing the fastener in the blind hole of the radiator, and electrically connecting the first elastic piece to the radiator of the antenna through the fastener. Therefore, on the one hand, the cost investment of the antenna apparatus is reduced, and there is no need to increase the input cost of a soldering process. and on the other hand, the case that the performance of the radiator in transmitting and receiving electromagnetic waves is affected by the generation of gas holes, slag inclusions, solder joints, or cracks in the soldering process in the radiator is avoided.

According to the fifth aspect, or any implementation of the fifth aspect described above, the radiator includes an inner side surface facing the circuit board assembly. The first elastic piece is in elastic contact with the inner side surface. In this way, the radiator can be in contact with the first elastic piece without disposing a protrusion. In this case, in the thickness direction of the antenna apparatus, the space omitting the protrusion can be used for an antenna clearance area. In this way, the clearance area of the antenna is larger, and the performance of the antenna is better. In addition, the radiator of the antenna also has a relatively simple structure, and is easy to mass-produce.

According to the fifth aspect, or any implementation of the fifth aspect described above, the first elastic piece includes a first fixed piece, an elastic member, and a second fixed piece. The elastic member is connected between the first fixed piece and the second fixed piece. It may be understood that, the elastic member may be, but is not limited to, an elastic piece or a spring. In addition, the first fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece. The second fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece.

In addition, the first fixed piece is fixedly connected to the radiator. The second fixed piece is fixedly connected to the first extension portion of the first board.

It may be understood that, the first elastic piece has a simple structure and is easy to assemble, which can reduce the assembly difficulty of the antenna apparatus.

According to the fifth aspect, or any implementation of the fifth aspect described above, the circuit board assembly further includes a second conductive member. The second conductive member may be, but is not limited to, an elastic piece or a spring. The second conductive member is disposed on the first extension portion of the first board. The second conductive member is electrically connected between the ground layer of the first board and the radiator. In other words, the second conductive member is configured to ground the radiator.

It may be understood that, the radiator of this implementation is grounded in a relatively simple manner and has a simple structure and low cost investment.

According to the fifth aspect, or any implementation of the fifth aspect described above, the first board is provided with a second matching circuit. The second matching circuit includes an inductor, a capacitor, a resistor, or an antenna switch. A second elastic piece is electrically connected to the second matching circuit and is electrically connected to the ground layer of the first board through the second matching circuit. The second matching circuit is configured to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves and the impedance matching for the antenna. In this way, the antenna is more widely applied to transmit and receive electromagnetic waves and has better performance.

In a sixth aspect, an antenna apparatus is provided. The antenna apparatus can transmit and receive electromagnetic wave signals. The antenna apparatus includes a radiator and a circuit board assembly.

The circuit board assembly is located on the inner side of the frame. The circuit board assembly includes a first board, an elevating board, a second board, and a first conductive member. The first board includes a first main body portion and a first extension portion connected to the first main body portion. The elevating board includes a second main body portion and a second extension portion connected to the second main body portion. The first main body portion, the second main body portion, and the second board are sequentially stacked. In other words, the second main body portion is located between the first main body portion and the second board. The first extension portion and the second extension portion are stacked, and both the first extension portion and the second extension portion protrude relative to the second board and are disposed close to the radiator. The first conductive member is fixed to the second extension portion, and the first conductive member and the second board are located on the same side of the elevating board. The second conductive member is in elastic contact with the radiator.

It should be noted that, the first conductive member may be an elastic piece having electrical conductivity or may alternatively be a spring having electrical conductivity, which is not limited in this application. In each of the solutions that can be implemented below, the first conductive member is described by taking a first elastic piece as an example.

In this implementation, by disposing the second extension portion that protrudes relative to the second board, and fixedly connecting the first elastic piece to the second extension portion, and the first conductive member and the second board are located on the same side of the elevating board in a thickness direction of the circuit board assembly, there is an overlapping region between the first elastic piece and the second board. The first elastic piece utilizes a space of the second board facing one side of the radiator. In this way, in a thickness direction of the antenna apparatus, the circuit board assembly is not thickened due to the configuration of the first elastic piece.

In addition, by stacking the second extension portion on the first extension portion, and in this case, by the cooperation of the second extension portion and the first extension portion, the integral strength of this part can be improved. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, with the cooperation of the first extension portion, the second extension portion can effectively counteract the force, thereby avoiding the second extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In addition, by bringing the first elastic piece into elastic contact with the radiator, the transmission of radio frequency

signals between the first elastic piece and the radiator is ensured to be more stable. Specifically, because the first elastic piece has an elastic force, the first elastic piece can always be in contact with the radiator when the first elastic piece is in elastic contact with the radiator, so that the connection stability between the first elastic piece and the radiator is better.

In addition, a space between a surface of the second extension portion facing the radiator and the radiator is generally small. General chips or electronic components are not easy to be disposed in this region. In this case, the space is unused, which easily results in a waste of space. In this implementation, by fixing the first elastic piece with a relatively small size fixed on one side of the second extension portion facing the radiator, the space of this part can be effectively utilized, to improve the internal space utilization of the antenna apparatus.

In a possible implementation according to the sixth aspect, the antenna apparatus further includes a radio frequency path. The radio frequency path can be configured to transmit radio frequency signals to the radiator of the antenna, so that the radiator of the antenna transmits electromagnetic wave signals according to the radio frequency signals. In addition, when the radiator of the antenna converts the received electromagnetic wave signals into radio frequency signals, the radio frequency path can further be configured to receive the radio frequency signals transmitted by the radiator of the antenna. In this case, the first elastic piece is electrically connected between the radio frequency path and the radiator.

In another possible implementation, the first elastic piece is electrically connected between the radiator and a ground layer of the second extension portion.

In another possible implementation, the first elastic piece is electrically connected to the ground layer of the second extension portion through a matching circuit.

According to the sixth aspect, or any implementation of the sixth aspect described above, a distance between the first elastic piece and the second board is between 0.15 mm and 30 mm.

It may be understood that, when the distance between the first elastic piece and the second board ranges from 0.15 mm to 30 mm, the size of the second extension portion located between the first elastic piece and the second board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the second board is not easy to fracture or crack. In other words, the reaction force received by the second extension portion can be rapidly transmitted to the second board, thereby counteracting the reaction force by an internal stress of the second board.

According to the sixth aspect, or any implementation of the sixth aspect described above, the circuit board assembly further includes a third strengthening board. The third strengthening board is located on one side of the first elastic piece, and is fixedly connected to a board surface of the second extension portion facing the second board.

It may be understood that, by stacking the third strengthening board on one side of the first elastic piece and on the second extension portion, a thickness of a part of the second extension portion is significantly increased, which further significantly improves the structural strength of the elevating board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the second extension portion of the elevating board. In this case, with the cooperation of the third strengthening board, the second extension portion can effectively counteract the force, thereby avoiding the second extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the sixth aspect, or any implementation of the sixth aspect described above, the third strengthening board and the second board are of an integrally formed structure. In other words, the third strengthening board and the second board are an integral board. In this case, the integral structural strength of the third strengthening board and the second board is better. In this way, the third strengthening board and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the third strengthening board may be connected to the second board by a soldering process, or the third strengthening board may be disposed separately from the second board.

According to the sixth aspect, or any implementation of the sixth aspect described above, a distance between the first elastic piece and the third strengthening board ranges from 0.15 mm to 30 mm. In this case, the size of the second extension portion located between the first elastic piece and the third strengthening board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the third strengthening board is not easy to fracture or crack. In other words, the reaction force received by the first extension portion can be rapidly transmitted to the third strengthening board, thereby counteracting the reaction force by an internal stress of the third strengthening board.

According to the sixth aspect, or any implementation of the sixth aspect described above, the circuit board assembly further includes a fourth strengthening board. The fourth strengthening board is located on one side of the first elastic piece away from the third strengthening board, and is fixedly connected to the board surface of the second extension portion facing the second board.

It may be understood that, by stacking the fourth strengthening board on one side of the first elastic piece and on the second extension portion, a thickness of a part of the second extension portion is significantly increased, which further significantly improves the structural strength of the elevating board. In this way, when the first elastic piece is in elastic contact with the radiator, the first elastic piece receives a reaction force of the radiator of the antenna. The first elastic piece transmits the reaction force to the second extension portion of the elevating board. In this case, with the cooperation of the fourth strengthening board, the second extension portion can effectively counteract the force, thereby avoiding the second extension portion from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

According to the sixth aspect, or any implementation of the sixth aspect described above, the fourth strengthening board and the second board are of an integrally formed structure. In other words, the fourth strengthening board and the second board are an integral board. In this case, the integral structural strength of the fourth strengthening board and the second board is better. In this way, the fourth

strengthening board and the second board are not easy to fracture or crack when receiving an external force.

In another possible implementation, the fourth strengthening board may be connected to the second board by a soldering process, or the fourth strengthening board may be disposed separately from the second board.

According to the sixth aspect, or any implementation of the sixth aspect described above, a distance between the first elastic piece and the fourth strengthening board ranges from 0.15 mm to 30 mm. In this case, the size of the second extension portion located between the first elastic piece and the fourth strengthening board is relatively moderate. In this way, when the first elastic piece is in elastic contact with the radiator of the antenna, the first elastic piece receives a reaction force of the radiator. The first elastic piece transmits the reaction force to the second extension portion. In this case, the second extension portion located between the first elastic piece and the fourth strengthening board is not easy to fracture or crack. In other words, a reaction force received by the second extension portion can be quickly transmitted to the fourth strengthening board. Therefore, the reaction force is counteracted by an internal stress of the fourth strengthening board.

According to the sixth aspect, or any implementation of the sixth aspect described above, the second extension portion is provided with a groove, the groove is located between the third strengthening board and the fourth strengthening board, an opening of the groove is located on a surface of the second extension portion facing the radiator, and a part of the first elastic piece is mounted in the groove.

It may be understood that, when a part of the first elastic piece is mounted in the groove, in a thickness direction of the circuit board assembly, there is an overlapping region between the first elastic piece and the second extension portion. In this case, there is an overlapping region between the first elastic piece and the first board as well. In this way, in a thickness direction of the antenna apparatus, the circuit board assembly is not thickened due to the configuration of the first elastic piece.

In addition, when the second extension portion is provided with the first strengthening board and the second strengthening board, the first strengthening board and the second strengthening board can improve the strength of the second extension portion, thereby avoiding the second extension portion from being reduced in strength due to the opening of the groove.

According to the sixth aspect, or any implementation of the sixth aspect described above, a surface of the radiator facing the first elastic piece is provided with a conductive piece. The first elastic piece is in elastic contact with the conductive piece.

It may be understood that, when the conductive piece is disposed on the radiator, the conductive piece can improve the surface flatness of the radiator. In this way, when the first elastic piece is in elastic contact with the radiator through the conductive piece, the elastic contact between the first elastic piece and the radiator is more stable. In this way, radio frequency signals are also relatively stably transmitted between the radiator and the first elastic piece, thereby ensuring that the antenna apparatus has better antenna performance.

According to the sixth aspect, or any implementation of the sixth aspect described above, the oxidation resistance of the conductive piece is higher than that of the radiator. It may be understood that, under an environment with the same temperature and humidity, the conductive piece is not easy to be oxidized compared with the radiator. In this way, compared with a solution in which the first elastic piece directly comes into elastic contact with the radiator, a contact resistance between the first elastic piece and the conductive piece is smaller, that is, the contact resistance between the first elastic piece and the conductive piece is more stable, and the transmission loss of the radio frequency signals is smaller. In this case, the antenna performance of the antenna apparatus is better.

According to the sixth aspect, or any implementation of the sixth aspect described above, the antenna apparatus includes a fastener. The radiator is provided with a blind hole. The fastener is fixed into the blind hole. The first elastic piece is in elastic contact with the fastener.

It may be understood that, compared with a solution of soldering the conductive piece on the radiator, this implementation saves the process of soldering the conductive piece on the radiator by disposing the fastener in the blind hole of the radiator, and electrically connecting the first elastic piece to the radiator of the antenna through the fastener. Therefore, on the one hand, the cost investment of the antenna apparatus is reduced, and there is no need to increase the input cost of a soldering process. and on the other hand, the case that the performance of the radiator in transmitting and receiving electromagnetic waves is affected by the generation of gas holes, slag inclusions, solder joints, or cracks in the soldering process in the radiator is avoided.

According to the sixth aspect, or any implementation of the sixth aspect described above, the radiator includes an inner side surface facing the circuit board assembly. The first elastic piece is in elastic contact with the inner side surface. In this way, the radiator can be in contact with the first elastic piece without disposing a protrusion. In this case, in the thickness direction of the circuit board assembly, the space omitting the protrusion can also be used for an antenna clearance area. In this way, the clearance area of the antenna is larger, and the performance of the antenna is better.

According to the sixth aspect, or any implementation of the sixth aspect described above, the first elastic piece includes a first fixed piece, an elastic member, and a second fixed piece. The elastic member is connected between the first fixed piece and the second fixed piece. It may be understood that, the elastic member may be, but is not limited to, an elastic piece or a spring. In addition, the first fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece. The second fixed piece may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece.

In addition, the first fixed piece is fixedly connected to the radiator. The second fixed piece is fixedly connected to the second extension portion of the elevating board.

It may be understood that, the first elastic piece has a simple structure and is easy to assemble, which can reduce the assembly difficulty of the antenna apparatus.

According to the sixth aspect, or any implementation of the sixth aspect described above, the circuit board assembly further includes a second conductive member. The second conductive member may be, but is not limited to, an elastic piece or a spring. The second conductive member is disposed on the second extension portion of the elevating board. The second conductive member is electrically connected between the ground layer of the elevating board and the radiator. In other words, the second conductive member is configured to ground the radiator.

It may be understood that, the radiator of this implementation is grounded in a relatively simple manner and has a simple structure and low cost investment.

According to the sixth aspect, or any implementation of the sixth aspect described above, the first board is provided with a second matching circuit. The second matching circuit includes an inductor, a capacitor, a resistor, or an antenna switch. A second elastic piece is electrically connected to the second matching circuit, and is electrically connected to the ground layer of the elevating board through the second matching circuit. The second matching circuit is configured to tune the frequency bands of the antenna for receiving and transmitting electromagnetic waves and the impedance matching for the antenna. In this way, the antenna is more widely applied to transmit and receive electromagnetic waves and has better performance.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic structural view of an electronic device in an optional manner provided by an embodiment of this application;

FIG. **2** is a schematic exploded view of an electronic device shown in FIG. **1**,

FIG. **3** is a partial cross-sectional view of an electronic device shown in FIG. **1** in an optional manner taken along a line A-A;

FIG. **4** is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line A-A;

FIG. **5** is a partial cross-sectional view of an electronic device shown in FIG. **1** in an optional manner taken along a line B-B;

FIG. **6** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in an optional manner;

FIG. **7** is a schematic exploded view of a circuit board assembly shown in FIG. **6**;

FIG. **8***a* is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in another optional manner;

FIG. **8***b* is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line B-B;

FIG. **9** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **10** is a schematic cross-sectional view of a circuit board assembly shown in FIG. **6** taken along a line C-C;

FIG. **11** is a partial schematic structural view of a circuit board assembly shown in FIG. **6** from another angle;

FIG. **12** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B;

FIG. **13***a* is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **13***b* is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **14** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **15** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **16** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **17** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **18** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B;

FIG. **19** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B;

FIG. **20***a* is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B;

FIG. **20***b* is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B;

FIG. **21** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B;

FIG. **22** is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line A-A;

FIG. **23** is a partial cross-sectional view of an electronic device shown in FIG. **22** taken along a line D-D;

FIG. **24** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **25** is a partial cross-sectional view of an electronic device shown in FIG. **1** in an optional manner taken along a line E-E;

FIG. **26** is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line E-E;

FIG. **27** is a partial cross-sectional view of an electronic device shown in FIG. **1** in yet another optional manner taken along a line A-A;

FIG. **28** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still yet another optional manner taken along a line A-A;

FIG. **29** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B;

FIG. **30** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **31** is a schematic exploded view of a circuit board assembly shown in FIG. **30**;

FIG. **32** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B;

FIG. **33** is a partial schematic structural view of a circuit board assembly shown in FIG. **30** from another angle;

FIG. **34** is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line B-B;

FIG. **35** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **36** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner;

FIG. **37** is a schematic structural view of an electronic device in another optional manner provided by an embodiment of this application;

FIG. **38** is a partial cross-sectional view of an electronic device shown in FIG. **37** in an optional manner taken along a line F-F;

FIG. **39** is a schematic structural view of an electronic device in another optional manner provided by an embodiment of this application; and

FIG. **40** is a partial cross-sectional view of an electronic device shown in FIG. **39** in an optional manner taken along a line G-G;

DESCRIPTION OF EMBODIMENTS

FIG. **1** is a schematic structural view of an electronic device in an optional manner provided by an embodiment of this application. An electronic device **100** may be a mobile phone, a watch, a tablet personal computer (tablet personal computer), a laptop computer (laptop computer), a personal digital assistant (personal digital assistant, PDA), a personal computer, a notebook computer, an in-vehicle device, a wearable device, augmented reality (augmented reality, AR) glasses, an AR helmet, virtual reality (virtual reality, VR) glasses, a VR helmet, or another device capable of transmitting and receiving electromagnetic wave signals in other forms. The electronic device **100** of an embodiment shown in FIG. **1** is described by taking a mobile phone as an example. For the convenience of description, a width direction of the electronic device **100** is defined as the X axis. A length direction of the electronic device **100** is the Y axis. A thickness direction of the electronic device **100** is the Z axis.

In this application, structures of three electronic devices **100** are mainly described below. One is an electronic device **100** in which a screen is a flat screen. The other is an electronic device **100** in which a screen is a curved screen. Another is an electronic device in which a screen is a 360° curved screen. First, the electronic device **100** in which a screen is a flat screen according to a first embodiment is described in detail below with reference to the related accompanying drawings.

First embodiment: With reference to FIG. **1**, FIG. **2** is a schematic exploded view of an electronic device shown in FIG. **1**. The electronic device **100** includes a screen **10**, a housing **20**, and a circuit board assembly **30**. It may be understood that, FIG. **1** and FIG. **2** merely schematically show some components included in the electronic device **100**, and the actual shapes, actual sizes, and actual structures of these components are not limited by FIG. **1** and FIG. **2**.

The screen **10** may be configured to display images, texts, or the like. The screen **10** is a flat screen. In addition, the screen **10** includes a protective cover plate **11** and a display screen **12**. The protective cover plate **11** is stacked on the display screen **12**. The protective cover plate **11** may be disposed close to the display screen **12**, and may be mainly configured to protect the display screen **12** and prevent dust. The material of the protective cover plate **11** may be, but not limited to, glass. The display screen **12** may be an organic light-emitting diode (organic light-emitting diode, OLED) display screen, an active-matrix organic light-emitting diode (active-matrix organic light-emitting diode, AMOLED) display screen, a quantum dot light emitting diodes (quantum dot light emitting diodes, QLED) display screen, or the like.

The housing **20** may be configured to support the screen **10**. The housing **20** includes a frame **21** and a rear cover **22**. The rear cover **22** is disposed opposite to the screen **10**. The rear cover **22** and the screen **10** are mounted on opposite sides of the frame **21** respectively. In this case, the rear cover **22**, the frame **21**, and the screen **10** together enclose an interior of the electronic device **100**. The interior of the electronic device **100** may be used for accommodating components of the electronic device **100**, such as a battery, a receiver, a microphone, or the like.

In an optional manner, the rear cover **22** is fixedly connected to the frame **21** by adhesive. In another optional manner, the rear cover **22** and the frame **21** form an integral structure, that is, the rear cover **22** and the frame **21** is of an integral structure.

In addition, the housing **20** may further be used as a part of the radiator of the antenna, or an inner side of the housing **20** may be used for fixing the radiator of the antenna.

It may be understood that, the electronic device **100** may utilize the antenna and communicate with a network or another device through one or more of the following communication technologies. The communication technologies include the bluetooth (bluetooth, BT) communication technology, global positioning system (global positioning system, GPS) communication technology, wireless fidelity (wireless fidelity, Wi-Fi) communication technology, global system for mobile communications (global system for mobile communications, GSM) communication technology, wideband code division multiple access (wideband code division multiple access, WCDMA) communication technology, long term evolution (long term evolution, LTE) communication technology, 5G communication technology, SUB-6G communication technology, another future communication technology, or the like.

In addition, the electronic device **100** may share mobile data traffic or wireless network sharing with other devices (for example, mobile phones, watches, tablet computers, or other devices capable of transmitting and receiving electromagnetic wave signals) through the antenna. For example, when other devices enable the data traffic sharing network, the electronic device **100** may access the data traffic sharing network of other devices by receiving the antenna signals of the other devices. In this way, the electronic device **100** does not affect the user experience of the electronic device **100** because the traffic thereof is insufficient or has stopped being used.

The radiator of the antenna is configured to transmit and receive electromagnetic wave signals. There are a plurality of configuration manners for the radiator of the antenna. Two optional manners are described in detail below with reference to the relevant accompanying drawings.

First optional manner: FIG. **3** is a partial cross-sectional view of an electronic device shown in FIG. **1** in an optional manner taken along a line A-A. It may be understood that, the cross-sectional view illustrated in FIG. **3** is a cross-sectional view of the electronic device of FIG. **1** taken along the line A-A and viewed along the negative direction of the Z axis. The frame **21** of the housing **20** is made of a metal material, for example, steel. In this case, a metal segment is isolated on the frame **21**, and the metal segment forms the radiator **41** of the antenna. Specifically, the frame **21** includes a first short frame **212** and a first long frame **213** connecting the first short frame **212**. The first short frame **212** includes a first gap **214**. The first long frame **213** includes a second gap **215**. In this way, an independent metal segment is isolated on the frame **21** by the first gap **214** and the second gap **215**, to form the radiator **41** of the antenna.

In this implementation, the housing **20** further includes a middle plate **24**. The middle plate **24** is made of a metal material, for example, steel. The middle plate **24** is connected to an inner surface of the frame **21**. There is a third gap **216** among a part of the middle plate **24**, the first short frame **212**, and the first long frame **213**. The third gap **216** is in communication with the first gap **214** and the second gap **215**. In this way, the first gap **214**, the second gap **215**, and the third gap **216** can form an antenna clearance area. In

another optional manner, the housing **20** may alternatively not include the middle plate **24**.

In addition, the first gap **214**, the second gap **215**, and the third gap **216** may alternatively be filled with insulating materials. For example, the insulating materials may be polymers, glass, ceramics, or the like, or a combination of these materials. In another optional manner, the first gap **214**, the second gap **215**, and the third gap **216** may be in a hollow state, that is, the first gap **214**, the second gap **215**, and the third gap **216** are not filled with other substances.

It may be understood that, the position of the radiator **41** of the antenna is not limited to the position illustrated in FIG. **3**. For example, an independent metal segment is isolated on the first short frame **212**, to form the radiator **41** of the antenna. Alternatively, an independent metal segment is isolated on the first long frame **213**, to form the radiator **41** of the antenna. Certainly, the radiator **41** of the antenna may alternatively be formed in another part of the frame **21**. Details are not limited in this embodiment.

Second optional manner: FIG. **4** is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line A-A. It may be understood that, the cross-sectional view illustrated in FIG. **4** is a cross-sectional view of the electronic device of FIG. **1** taken along the line A-A and viewed along the negative direction of the Z axis. The frame **21** of the housing **20** is made of an insulating material. For example, the insulating material may be polymer, glass, or a combination of these materials. In this case, a conductive conductor is formed on an inner surface of the frame **21** by a laser direct structuring (laser direct structuring, LDS) or a printing direct structuring technique. A conductive conductor may be made of, but is not limited to, a copper, gold, or graphene material. The conductive conductor forms the radiator **41** of the antenna. It may be understood that, the position of the radiator **41** is not limited to inner surfaces of the first short frame **212** and the first long frame **213** illustrated in FIG. **4**. For example, the radiator **41** may be located on the inner surface of the first short frame **212**. The radiator **41** may alternatively be located on the inner surface of the first long frame **213**, or on an inner surface of another part of the frame **21**.

In addition, the housing **20** further includes a middle plate **24**. The middle plate **24** is made of a metal material, for example, steel. The middle plate **24** is connected to an inner surface of the frame **21**. There is a fourth gap **217** among a part of the middle plate **24**, the first short frame **212**, and the first long frame **213**. In this way, the fourth gap **217** can form an antenna clearance area. In another optional manner, the housing **20** may alternatively not include the middle plate **24**.

It may be understood that, the radiator **41** of the antenna may alternatively be implemented in another manner. For example, a flexible circuit board is fixedly connected to the inner surface of the frame **21**. The flexible circuit board forms the radiator **41** of the antenna. The configuration manner of the radiator **41** of the antenna is not described herein again. In the following embodiments, the structure of the radiator **41** of the antenna is described by taking the first optional manner as an example.

FIG. **5** is a partial cross-sectional view of an electronic device shown in FIG. **1** in an optional manner taken along a line B-B; It may be understood that, the cross-sectional view illustrated in FIG. **5** is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. The circuit board assembly **30** is located in an interior of the electronic device **100**. The circuit board assembly **30** may be fixed on the middle plate **24** by screws, pins, or rivets to ensure stability. The circuit board assembly **30** may be configured to mount a radio frequency path **42** of the antenna. The radio frequency path **42** may be configured to transmit radio frequency signals to the radiator **41** of the antenna, so that the radiator **41** of the antenna transmits electromagnetic wave signals according to the radio frequency signals. In addition, when the radiator **41** of the antenna converts the received electromagnetic wave signals into radio frequency signals, the radio frequency path **42** may further be configured to receive the radio frequency signals transmitted by the radiator **41** of the antenna.

The radio frequency path **42** includes a radio frequency transceiver chip **421** and a first matching circuit **422**. It may be understood that, FIG. **3** to FIG. **5** only schematically show the radio frequency transceiver chip **421** and the first matching circuit **422**. However, the actual shapes, actual sizes, and actual structures of the radio frequency transceiver chip **421** and the first matching circuit **422** are not limited by FIG. **3** to FIG. **5**.

The radio frequency transceiver chip **421** is configured to transmit the radio frequency signals to the radiator **41** of the antenna, and is further configured to receive the radio frequency signals transmitted by the radiator **41** of the antenna. It may be understood that, when functions of transmitting and receiving radio frequency signals are integrated on an independent module (the radio frequency transceiver chip **421**), the radio frequency transceiver chip **421** can operate independently to transmit and receive radio frequency signals. In this case, the transmission efficiency and processing efficiency of the radio frequency signals are significantly improved.

In another optional manner, the functions of transmitting and receiving radio frequency signals may alternatively be integrated on a central processing unit (central processing unit, CPU) of the electronic device **100**, or on another chip of the electronic device **100**, such as a battery management chip. In this case, because the CPU or the another chip of the electronic device **100** also have the functions of transmitting and receiving radio frequency signals, the space occupied by one chip (the radio frequency transceiver chip **421**) can be saved inside the electronic device **100**, thereby improving the utilization of the internal space of the electronic device **100**.

The first matching circuit **422** is electrically connected between the radio frequency transceiver chip **421** and the radiator **41**. In other words, the radio frequency signals transmitted by the radio frequency transceiver chip **421** can be transmitted to the radiator **41** via the first matching circuit **422**. In addition, after the radiator **41** converts the received electromagnetic wave signals into radio frequency signals, the radio frequency signals can further be transmitted to the radio frequency transceiver chip **421** via the first matching circuit **422**. The first matching circuit **422** may be electrically connected to the radio frequency transceiver chip **421** through wiring in the circuit board assembly **30**. The first matching circuit **422** may be configured to perform signal processing, such as signal amplification, filtering, or the like, on the radio frequency signals. The first matching circuit **422** may include electronic components such as antenna switches, capacitors, inductors, or resistors.

It may be understood that, the general structure of the electronic device **100** and the general structure of the antenna in the electronic device **100** are described above in detail with reference to the related accompanying drawings.

In order to bring a more comfortable visual experience to the user, the electronic device **100** may adopt a full-screen industry design (industry design, ID). A full screen means a huge screen-to-body ratio (usually above 90%). In this case, a width of the frame **21** of the electronic device **100** is greatly reduced, and internal components, such as a battery, receiver, microphone, antenna, or the like, of the electronic device **100** need to be rearranged. In particular, for the design of the antenna, when the width of the frame **21** of the electronic device **100** is greatly reduced, the antenna clearance area is also greatly reduced. The size, bandwidth, and efficiency of the antenna are interrelated and affect each other. In addition, if the size (space) of the antenna is reduced, the efficiency-bandwidth product of the antenna is bound to decrease. However, in this embodiment, under the circumstance in which the arrangement of the antenna is tight, a circuit board assembly **30** structure is arranged and the related components of the antenna are rearranged, so that the antenna has a wider clearance area, thereby significantly improving the antenna performance of the electronic device **100**.

FIG. **6** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in an optional manner. FIG. **7** is a schematic exploded view of a circuit board assembly shown in FIG. **6**. The circuit board assembly **30** includes a first board **31**, an elevating board **32**, a second board **33**, and a first conductive member **34**. It may be understood that, in order to be able to clearly see a part of the detailed structure of the circuit board assembly **30**, FIG. **6** and FIG. **7** merely schematically illustrate the part of the structure of the circuit board assembly **30**. In optional manners below, the accompanying drawings of the optional manners also schematically illustrate a partial structural view of the circuit board assembly **30**. Details are not described below. In addition, the first conductive member **34** may be an elastic piece with electrical conductivity or a spring with electrical conductivity. which is not limited in this application. In the following embodiments, the first conductive member **34** is described by taking the first elastic piece **34** as an example.

The first board **31**, the elevating board **32**, and the second board **33** are sequentially stacked. In other words, the elevating board **32** is fixed between the first board **31** and the second board **33**. FIG. **6** illustrates that the first board **31**, the elevating board **32**, and the second board **33** are sequentially stacked along the Z-axis direction. In another optional manner, when the electronic device **100** is in other forms, the first board **31**, the elevating board **32**, and the second board **33** may alternatively be sequentially stacked and disposed along the X axis, the Y axis or another direction.

In an optional manner, the first board **31** and the elevating board **32** may be fixed to each other by a soldering process. In another optional manner, the first board **31** and the elevating board **32** may be bonded and fixed to each other by conductive glue.

In an optional manner, the second board **33** and the elevating board **32** may be fixed to each other by a soldering process. In another optional manner, the second board **33** and the elevating board **32** may be bonded and fixed to each other by conductive glue.

In this embodiment, with reference to FIG. **5**, by sequentially stacking the first board **31**, the elevating board **32**, and the second board **33** along the Z-axis direction, the board surface area of the circuit board assembly **30** can be significantly increased, thereby increasing the number of electronic components arranged on the circuit board assembly **30**. Specifically, when the first board **31** and the second board **33** are elevated in the Z-axis direction by the elevating board **32**, on the circuit board assembly **30**, electronic components (for example, a CPU, a battery management chip, or the like) can not only be arranged on a surface of the first board **31** facing the rear cover **22** and a surface of the second board **33** facing the display screen **12**, but also can be arranged in a space between the first board **31** and the second board **33** (on a surface of the first board **31** facing the second board **33** and a surface of the second board **33** facing the first board **31**). In other words, more electronic components can be arranged on the circuit board assembly **30** of this embodiment. In this way, on the one hand, the electronic device **100** has more and more functions, and the user experience is also better. On the other hand, when the internal environment of the electronic device **100** is tense, by arranging a large number of electronic components of the electronic device **100** on the circuit board assembly **30**, more space can be freed up inside the electronic device **10**. When this part of space is applied to the clearance area of the antenna, the clearance area of the antenna can be significantly increased, thereby significantly improving the performance of the antenna.

It may be understood that, FIG. **5** and FIG. **6** illustrate that the elevating board **32** and the second board **33** are disposed flush with each other. In another optional manner, the elevating board **32** and second board **33** may alternatively be staggered. Specifically, FIG. **8***a* is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in another optional manner. A part of the elevating board **32** is staggered with the second board **33**, that is, the part of the elevating board **32** protrudes relative to the second board **33**. In this case, the elevating board **32** and the second board **33** form a stepped shape. It may be understood that, FIG. **8***a* illustrates that a part of the elevating board **32** protrudes along the X-axis direction relative to the second board **33**. In another optional manner, a part of the elevating board **32** may alternatively protrude along the Y-axis direction relative to the second board **33**.

Further referring to FIG. **5**, the first board **31** is disposed away from the display screen **12** relative to the second board **33**, that is, the first board **31** is located on one side of the second board **33** away from the display screen **12**. In this case, the first board **31** is disposed close to the rear cover **22**. The second board **33** is disposed close to the display screen **12**.

The first board **31**, the elevating board **32**, and the second board **33** may all be rigid boards, flexible boards, or boards combining soft and hard characteristics. In addition, the first board **31**, the elevating board **32**, and the second board **33** may be FR-4 dielectric boards, Rogers (Rogers) dielectric boards, Rogers and FR-4 mixed media boards, or the like. FR-4 is the code name for a flame-resistant material grade, and the Rogers dielectric board is a high-frequency board.

In addition, the radio frequency transceiver chip **421** and the first matching circuit **422** are both located on the first board **31**. It may be understood that, the first board **31** is disposed away from the display screen **12** relative to the second board **33**. Therefore, compared with the solution of disposing the radio frequency transceiver chip **421** and the first matching circuit **422** on the second board **33**, in this embodiment, both the radio frequency transceiver chip **421** and the first matching circuit **422** are disposed on the first board **31**, so that distances from the radio frequency transceiver chip **421** and the first matching circuit **422** to the display screen **12** are longer. In this way, the internal circuit of the display screen **12** has less influence on the radio

frequency transceiver chip **421** and the first matching circuit **422**, that is, the performance of the antenna is better.

In addition, it should be noted that the positions of the radio frequency transceiver chip **421** and the first matching circuit **422** are not limited to the surface of the first board **31** facing the rear cover **22** illustrated in FIG. **5**. For example, the radio frequency transceiver chip **421** and the first matching circuit **422** may alternatively be disposed inside the first board **31**.

In another optional manner, the radio frequency transceiver chip **421** and the first matching circuit **422** may alternatively both be located on the elevating board **32** or the second board **33**.

FIG. **8***b* is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line B-B. It may be understood that, the schematic cross-sectional view illustrated in FIG. **8***b* is a cross-sectional view taken along a line B-B in the electronic device of FIG. **1** and viewed along the positive direction of the Y axis, and the cross-sectional view is rotated by 180° with the Y axis as the rotation axis to form a cross-sectional view illustrated in FIG. **8***b*. The first elastic piece **34** is fixed on the surface of the second board **33** facing the screen **10**. The first elastic piece **34** is in elastic contact with the radiator **41** of the antenna. In this implementation, the radiator **41** includes a protrusion **411** facing the inside of the electronic device **100**. In this case, the first elastic piece **34** is in elastic contact with the protrusion **411**. In addition, the first elastic piece **34** is electrically connected between the first matching circuit **422** and the radiator **41**. In this case, a contact point between the first elastic piece **34** and the radiator **41** is a feed point. In this way, the radio frequency signals transmitted by the radio frequency transceiver chip **421** can be transmitted to the radiator **41** via the first matching circuit **422** and the first elastic piece **34**. In addition, after the radiator **41** converts the received electromagnetic wave signals into radio frequency signals, the radio frequency signals can further be transmitted to the radio frequency transceiver chip **421** via the first elastic piece **34** and the first matching circuit **422**.

The drawbacks of the solution shown in FIG. **8***b* are as follows:

1. The first elastic piece **34** is disposed close to the display screen **12**, that is, in the Z-axis direction, the distance between the first elastic piece **34** and the display screen **12** is relatively close. In this case, in the Z-axis direction, the protrusion **411** configured to be in contact with the first elastic piece **34** may alternatively be disposed close to the display screen **12** to a greater extent. In this way, the antenna clearance area between the bottom of the protrusion **411** and the display screen **12** is largely compressed. In this way, the display screen **12** may extremely easily affect the radiator **41** to transmit and receive electromagnetic wave signals, and the antenna performance is poor.
2. When both the first elastic piece **34** and the protrusion **411** are disposed close to the display screen **12**, the contact point of the first elastic piece **34** in contact with the protrusion **411** is also arranged close to the display screen **12**. In this way, the contact point (feed point) of the first elastic piece **34** in contact with the protrusion **411** is extremely easily affected by the display screen **12**.
3. When the first elastic piece **34** is fixed on the surface of the second board **33** facing the screen **10**, in the Z-axis direction, the thickness of the circuit board assembly **30** includes a thickness of the first elastic piece **34**. In this case, the thickness of the circuit board assembly **30** is relatively large. When the circuit board assembly **30** is applied to the electronic device **100**, the thickness of the electronic device **100** is also extremely easy to increase, which is not conducive to thinning design.
4. The radio frequency transceiver chip **421** and the first matching circuit **422** are disposed on the third board **33**. The radio frequency transceiver chip **421** and the first matching circuit **422** are disposed close to the display screen **12**, and are easily affected by the display screen **12**.

In this embodiment, by arranging a structure of the circuit board assembly **30** and rearranging the related components of the antenna, the antenna has a wider clearance area, thereby significantly improving the antenna performance of the electronic device **100**. Details are described as follows:

Further referring to FIG. **5** and FIG. **6**, the first board **31** includes a first main body portion **311** and a first extension portion **312**. The first main body portion **311**, the elevating board **32**, and the second board **33** are sequentially stacked along the Z-axis direction. The first extension portion **312** protrudes relative to the elevating board **32** and the second board **33**. FIG. **5** illustrates that the first extension portion **312** protrudes along the X-axis direction relative to the elevating board **32** and the second board **33**. The first extension portion **312** is disposed close to the radiator **41** relative to the first main body portion **311**. In another optional manner, the first extension portion **312** may alternatively protrude along another direction, such as the Y-axis direction, relative to the elevating board **32** and the second board **33**. which is not limited in this application.

In addition, the first elastic piece **34** is fixed to the first extension portion **312**. Specifically, the first elastic piece **34** is fixed to one side of the first extension portion **312** facing the display screen **12**. In this case, the first elastic piece **34**, the elevating board **32**, and the second board **33** are located on the same side of the first board **31**. In addition, the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna. In this implementation, the radiator **41** includes a protrusion **411** facing the inside of the electronic device **100**. In this case, the first elastic piece **34** is in elastic contact with the protrusion **411**. It may be understood that, a thickness of the protrusion **411** in the Z-axis direction in this optional manner may be correspondingly reduced according to actual needs, thereby avoiding the reduction of a clearance area between the protrusion **411** and the display screen **12** due to a relatively large size of the protrusion **411**. In another optional manner, the radiator **41** may alternatively not be provided with a protrusion **411**. Specifically, details are described below according to the corresponding accompanying drawing (FIG. **20***a*), which are not described herein again. In addition, in another embodiment, the first elastic piece **34** may alternatively be disposed on one side of the first board **31** facing the rear cover **22**.

In addition, in an optional manner, by deoxidizing a surface of the protrusion **411** in contact with the first elastic piece **34** by the laser forming technology, it can be ensured that a position at which the protrusion **411** is in contact with the first elastic piece **34** has better electrical connection stability.

In addition, the first elastic piece **34** is electrically connected between the first matching circuit **422** of the radio frequency path **42** and the radiator **41**. In this case, a contact point between the first elastic piece **34** and the radiator **41** is a feed point. In this way, the radio frequency signals transmitted by the radio frequency transceiver chip **421** can be transmitted to the radiator **41** via the first matching circuit **422** and the first elastic piece **34**. In addition, after the

radiator **41** converts the received electromagnetic wave signals into radio frequency signals, the radio frequency signals can further be transmitted to the radio frequency transceiver chip **421** via the first elastic piece **34** and the first matching circuit **422**. In another optional manner, the position at which the first elastic piece **34** is in contact with the radiator **41** may alternatively be an antenna ground tuning point. Details are described below, which are not described herein again.

In this embodiment, by disposing the first extension portion **312** that protrudes relative to the elevating board **32** and the second board **33**, and fixedly connecting the first elastic piece **34** to the first extension portion **312**, the first elastic piece **34** is disposed away from the display screen **12**, that is, in the Z-axis direction, the distance between the first elastic piece **34** and the display screen **12** becomes larger. In this case, in the Z-axis direction, the protrusion **411** configured to be in contact with the first elastic piece **34** may also be disposed away from the display screen **12** to a greater extent. In this way, the antenna clearance area between the bottom of the protrusion **411** and the display screen **12** is greatly increased, and the performance of the antenna is also better.

In addition, when both the first elastic piece **34** and the protrusion **411** are disposed away from the display screen **12**, the contact point of the first elastic piece **34** in contact with the protrusion **411** may also be arranged away from the display screen **12**. In this way, the contact point (feed point) of the first elastic piece **34** in contact with the protrusion **411** is less affected by the display screen **12**.

In addition, the first elastic piece **34** is fixed to the first extension portion **312**, so that the circuit between the first elastic piece **34** and the radio frequency transceiver chip **421** disposed on the first board **31** is made shorter. In this way, the transmission path of the radio frequency signals is shorter, and the transmission loss of the radio frequency signals is smaller, that is, the performance of the antenna is better.

In addition, compared with the solution of fixing the first elastic piece **34** on the second board **33**, in this embodiment, the first elastic piece **34** is fixed on the first extension portion **312**. Therefore, components and wiring (for example, antenna switches, inductors, capacitors or resistors) related to the antenna are no longer disposed on the elevating board **32** and the second board **33**. In this way, on the one hand, the structure of the circuit board assembly **30** is more concise, that is, the assembly difficulty of the circuit board assembly **30** is reduced, and the cost investment of the circuit board assembly **30** is lower. On the other hand, more space can be freed up on the second board **33** to arrange more electronic components.

In addition, the radio frequency path **42** is electrically connected to the radiator **41** by the first elastic piece **34**, which can ensure that the connection between the radio frequency path **42** and the radiator **41** is more stable. Specifically, because the first elastic piece **34** has an elastic force, when the first elastic piece **34** is in elastic contact with the radiator **41**, the first elastic piece **34** can always be in contact with the radiator **41**, thereby ensuring better connection stability between the radio frequency path **42** and the radiator **41**.

In addition, it may be understood that, a space between a surface of the first extension portion **312** facing the display screen **12** and the radiator **41** is generally small. General chips or electronic components are not easy to be disposed in this region. In this case, the space is unused, which easily results in a waste of space. However, in this embodiment, the first elastic piece **34** with a relatively small size is fixed on the side of the first extension portion **312** facing the display screen **12**. On the one hand, the space of this part can be effectively utilized, to improve the internal space utilization of the electronic device **100**. On the other hand, compared with a case in which the first elastic piece **34** is disposed on the surface of the first board **31** facing the rear cover **22**, in this embodiment, the space between the first board **31** and the rear cover **22** can save the space occupied by at least one first elastic piece **34**. In this way, the saved space can be used for arranging more electronic components, thereby greatly improving the space utilization of the circuit board assembly **30**.

Further referring to FIG. **5**, a distance L from the contact point between the first elastic piece **34** and the radiator **41** to the display screen **12** is greater than or equal to 2 mm. For example, L equals 2 mm, 2.5 mm, 3 mm, 3.5 mm or 4 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece **34** and the radiator **41** to the display screen **12** is greater than or equal to 2 mm, the first elastic piece **34** may be disposed away from the display screen **12** to a greater extent. In this case, in the Z-axis direction, the protrusion **411** may also be disposed away from the display screen **12** to a greater extent. In this way, the antenna clearance area between the bottom of the protrusion **411** and the display screen **12** is greatly increased, and the performance of the antenna is also better.

In addition, the distance L from the contact point between the first elastic piece **34** and the radiator **41** to the display screen **12** is less than or equal to 4.7 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece **34** and the radiator **41** to the display screen **12** is less than or equal to 4.7 mm, on the one hand, it can be ensured that the first elastic piece **34** is disposed away from the display screen **12**; and on the other hand, it can be ensured that the thickness of the electronic device **100** in the Z-axis direction is not too large, which is conducive for thinning configuration.

In this embodiment, there are a plurality of configuration manners for the circuit board assembly **30**. Several configuration manners for the circuit board assembly **30** are described in detail below with reference to the related accompanying drawings.

First optional manner: Further referring to FIG. **6** and FIG. **7**, the circuit board assembly **30** further includes a first strengthening board **35** and a second strengthening board **36**. The first strengthening board **35** and the second strengthening board **36** are located on two sides of the first elastic piece **34** respectively. In the Z-axis direction, thicknesses of the first strengthening board **35** and the second strengthening board **36** are both larger than the thickness of the elevating board **32**.

The first strengthening board **35** includes a first portion **351** and a second portion **352** connected to the first portion **351**. The first portion **351** is fixedly connected to the board surface of the first extension portion **312** facing the screen **10**. In this case, the first extension portion **312**, the first portion **351**, and the second portion **352** of the first board **31** are sequentially stacked along the Z-axis direction. The second strengthening board **36** includes a third portion **361** and a fourth portion **362** connected to the third portion **361**. The third portion **361** is fixedly connected to the board surface of the first extension portion **312** facing the screen **10**. In this case, the first extension portion **312**, the third portion **361**, and the fourth portion **362** of the first board **31** are sequentially stacked along the Z-axis direction. In addition, in FIG. **7**, the first portion **351**, the third portion **361**,

and the elevating board **32** are schematically distinguished by dashed lines, and the second portion **352**, the fourth portion **362**, and the second board **33** are schematically distinguished by dashed lines.

It may be understood that, by sequentially stacking the first portion **351** and the second portion **352** on one side of the first elastic piece **34** and on the first extension portion **312**, and sequentially stacking the third portion **361** and the fourth portion **362** on the other side of the first elastic piece **34** and on the first extension portion **312**, a thickness of a part of the first extension portion **312** in the Z-axis direction is increased, thereby significantly improving the structural strength of the first board **31**. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41**, the first elastic piece **34** receives a reaction force of the radiator **41** of the antenna. The first elastic piece **34** transmits the reaction force to the first extension portion **312** of the first board **31**. In this case, the first extension portion **312** may effectively counteract the force under the cooperation of the first portion **351**, the second portion **352**, the third portion **361**, and the fourth portion **362**, thereby avoiding the first extension portion **312** from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

Further referring to FIG. **7**, the first portion **351** and the third portion **361** are fixedly connected to the elevating board **32**.

In an optional manner, the first portion **351**, the third portion **361**, and the elevating board **32** are of an integrally formed structure. In other words, the first portion **351**, the third portion **361**, and the elevating board **32** are an integral board. In this case, the overall structural strength of the first portion **351**, the third portion **361**, and the elevating board **32** is better. In this way, the first portion **351**, the third portion **361**, and the elevating board **32** are not easy to fracture or crack when receiving an external force. In another optional manner, the first portion **351** and the third portion **361** may alternatively be fixedly connected to the elevating board **32** by a soldering process.

Further referring to FIG. **7**, the second portion **352** and the fourth portion **362** are fixedly connected to the second board **33**.

In an optional manner, the second portion **352**, the fourth portion **362**, and the second board **33** are of an integrally formed structure. In other words, the second portion **352**, the fourth portion **362**, and the second board **33** are an integral board. In this case, the connection of the second portion **352**, the fourth portion **362**, and the second board **33** is firmer. In this way, the second portion **352**, the fourth portion **362**, and the second board **33** are not easy to fracture or crack when receiving an external force. In another optional manner, the second portion **352** and the fourth portion **362** may alternatively be connected to the second board **33** by a soldering process.

FIG. **9** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. The first portion **351** of the first strengthening board **35** and the third portion **361** of the second strengthening board **36** may be disposed separately from the elevating board **32**. That is, the first portion **351** and the third portion **361** are directly fixed to the first extension portion **312** of the first board **31**, and do not need to be fixedly connected to the elevating board **32**.

In addition, the second portion **352** of the first strengthening board **35** and the fourth portion **362** of the second strengthening board **36** may be disposed separately from the second board **33**. That is, the second portion **352** and the fourth portion **362** are directly fixed to the first extension portion **312** of the first board **31**, and do not need to be fixedly connected to the second board **33**.

In this implementation, by sequentially stacking the first portion **351** and the second portion **352** on the first extension portion **312**, and sequentially stacking the third portion **361** and the fourth portion **362** on the first extension portion **312**, the structural strength of the first board **31** is significantly improved.

In addition, the first portion **351**, the third portion **361**, and the elevating board **32** are disposed separately. Therefore, the selection of materials of the first portion **351** and the third portion **361** are not limited to the same material as the elevating board **32**. For example, the first portion **351** and the third portion **361** may be made of low-cost rigid plastic plates.

In addition, the second portion **352**, the fourth portion **362**, and the second board **33** are disposed separately. Therefore, the selection of materials of the second portion **352** and the fourth portion **362** are not limited to the same material as the second board **33**. For example, the second portion **352** and the fourth portion **362** may be made of lower cost rigid plastic plates.

With reference to FIG. **6**, FIG. **10** is a schematic cross-sectional view of a circuit board assembly shown in FIG. **6** taken along a line C-C. It may be understood that, the cross-sectional view illustrated in FIG. **10** is a cross-sectional view taken along a line C-C in the circuit board assembly of FIG. **6** and viewed along the negative direction of the X axis. The first portion **351** of the first strengthening board **35** is provided with a first strengthening solder pad **353**. The first extension portion **312** of the first board **31** is provided with a second strengthening solder pad **313**. The first strengthening solder pad **353** is soldered to the second strengthening solder pad **313**. It may be understood that, when the first portion **351** and the first extension portion **312** are soldered together by the first strengthening solder pad **353** and the second strengthening solder pad **313**, the connection between the first portion **351** and the first extension portion **312** is firmer, and the overall strength of the circuit board assembly **30** is better. In addition, after the first strengthening solder pad **353** and the second strengthening solder pad **313** are soldered together, the first strengthening solder pad **353** and the second strengthening solder pad **313** can effectively protect a solder pad (the solder pad of this part is mainly configured for the electrical connection between wiring of the first board **31** and wiring of the elevating board **32**) between the first main body portion **311** of the first board **31** and the elevating board **32**. That is, the solder pad between the first main body portion **311** and the elevating board **32** is avoided from easily breaking due to an external force.

In addition, the third portion **361** of the second strengthening board **36** is further provided with a third strengthening solder pad **363**. The third strengthening solder pad **363** is soldered to the second strengthening solder pad **313**. It may be understood that, when the third portion **361** and the first extension portion **312** are soldered together by the third strengthening solder pad **363** and the second strengthening solder pad **313**, the connection between the third portion **361** and the first extension portion **312** is firmer, and the overall strength of the circuit board assembly **30** is better. In addition, after the third strengthening solder pad **363** and the second strengthening solder pad **313** are soldered together, the third strengthening solder pad **363** and the second strengthening solder pad **313** can effectively protect a solder pad (the solder pad of this part is mainly configured for the

electrical connection between wiring of the first board **31** and wiring of the elevating board **32**) between the first main body portion **311** of the first board **31** and the elevating board **32**. That is, the solder pad between the first main body portion **311** and the elevating board **32** is avoided from easily breaking due to an external force.

In another optional manner, the first portion **351** and the second portion **352** of the first strengthening board **35** may alternatively be soldered together by a solder pad. In this case, the connection between the first portion **351** and the second portion **352** is firmer, and the overall strength of the circuit board assembly **30** is better. In addition, after the first portion **351** and the second portion **352** are soldered together by a solder pad, a solder pad (the solder pad of this part is mainly configured for the electrical connection between the wiring of the elevating board **32** and the wiring of the second board **33**) located between the elevating board **32** and the second board **33** is not easily broken due to an external force.

In addition, the third portion **361** and the fourth portion **362** of the second strengthening board **36** may alternatively be soldered together by a solder pad. In this case, the connection between the third portion **361** and the fourth portion **362** is firmer, and the overall strength of the circuit board assembly **30** is better. In addition, after the third portion **361** and the fourth portion **362** are soldered together by a solder pad, a solder pad (the solder pad of this part is mainly configured for the electrical connection between the wiring of the elevating board **32** and the wiring of the second board **33**) located between the elevating board **32** and the second board **33** is not easily broken due to an external force.

FIG. **11** is a partial schematic structural view of a circuit board assembly shown in FIG. **6** from another angle. A distance d**1** between the first elastic piece **34** and the elevating board **32** ranges from 0.15 mm to 30 mm. It may be understood that, in FIG. **6**, the elevating board **32** and the second board **33** are disposed flush with each other. In this case, the elevating board **32** is just blocked by the second board **33** at an angle of FIG. **11**. In this case, in order to be able to clearly see the elevating board **32**, the second board **33** is no longer illustrated in FIG. **11**.

In this implementation, when the distance d**1** between the first elastic piece **34** and the elevating board **32** ranges from 0.15 mm to 30 mm, the size of the first extension portion **312** located between the first elastic piece **34** and the elevating board **32** is relatively moderate. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41**, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the first extension portion **312**. In this case, the first extension portion **312** located between the first elastic piece **34** and the elevating board **32** is not easy to fracture or crack. In other words, the reaction force received by the first extension portion **312** can be rapidly transmitted to the elevating board **32**, so that the reaction force is counteracted by an internal stress of the elevating board **32**.

Referring to FIG. **11** again, a distance d**2** between the first elastic piece **34** and the first portion **351** ranges from 0.15 mm to 30 mm. It may be understood that, the second portion **352** is also not illustrated in FIG. **11**. In this case, the size of the first extension portion **312** located between the first elastic piece **34** and the first portion **351** is relatively moderate. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the first extension portion **312**. In this case, the first extension portion **312** located between the first elastic piece **34** and the first portion **351** is not easy to fracture or crack. In other words, the reaction force received by the first extension portion **312** can be rapidly transmitted to the first portion **351**, so that the reaction force is counteracted by an internal stress of the first portion **351**.

Referring to FIG. **11** again, a distance d**3** between the first elastic piece **34** and the third portion **361** ranges from 0.15 mm to 30 mm. It may be understood that, the fourth portion **362** is also not illustrated in FIG. **11**. In this case, the size of the first extension portion **312** located between the first elastic piece **34** and the third portion **361** is relatively moderate. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the first extension portion **312**. In this case, the first extension portion **312** located between the first elastic piece **34** and the third portion **361** is not easy to fracture or crack. In other words, the reaction force received by the first extension portion **312** can be rapidly transmitted to the third portion **361**, so that the reaction force is counteracted by an internal stress of the third portion **361**.

FIG. **12** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B. It may be understood that, the cross-sectional view illustrated in FIG. **12** is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. The first extension portion **312** of the first board **31** is provided with a groove **314**. An opening of the groove **314** is located on a surface of the first extension portion **312** facing the display screen **12**. A part of the first elastic piece **34** is mounted in the groove **314**.

It may be understood that, when a part of the first elastic piece **34** is mounted in the groove **314**, in the Z-axis direction, there is an overlapping region between the first elastic piece **34** and the first extension portion **312**. In this case, the first elastic piece **34** can be disposed further away from the display screen **12**, that is, in the Z-axis direction, the distance between the first elastic piece **34** and the display screen **12** can be significantly increased. In this case, the distance from the contact point between the first elastic piece **34** and the radiator **41** to the display screen **12** is significantly increased. In this way, in the Z-axis direction, the protrusion **411** of the radiator **41** can also be disposed in a direction away from the display screen **12**, that is, the antenna clearance area between the bottom of the protrusion **411** and the display screen **12** can be made larger, and the performance of the antenna is also better.

In an optional manner, when the first extension portion **312** is provided with the first strengthening board **35** and the second strengthening board **36**, the groove **314** is located between the first strengthening board **35** and the second strengthening board **36**. In this case, the first strengthening board **35** and the second strengthening board **36** may improve the strength of the first extension portion **312**, thereby avoiding the strength of the first extension portion **312** from being reduced due to the groove **314** being opened.

Second optional manner: The same technical contents of the second optional manner as in the first optional manner are not repeated again. FIG. **13***a* is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in yet another optional manner. The circuit board assembly **30** further includes a first strengthening board **35** and a second strengthening board **36**. The

first strengthening board **35** and the second strengthening board **36** are located on two sides of the first elastic piece **34** respectively. The thickness of the first strengthening board **35** is greater than that of the elevating board **32** in the Z-axis direction. The thickness of the second strengthening board **36** is less than or equal to the thickness of the elevating board **32**.

The first strengthening board **35** includes a first portion **351** and a second portion **352** connected to the first portion **351**. The first portion **351** is fixedly connected to the board surface of the first extension portion **312** facing the screen **10**. In this case, the first extension portion **312**, the first portion **351**, and the second portion **352** of the first board **31** are sequentially stacked along the Z-axis direction. In this way, the thickness of a part of the first extension portion **312** in the Z-axis direction is increased.

In addition, different from the first optional manner, the second strengthening board **36** no longer includes the fourth portion **362**, that is, the second strengthening board **36** includes only the third portion **361** in the first optional manner. The second strengthening board **36** is fixedly connected to a board surface of the first extension portion **312** facing the screen **10**. In this case, the first extension portion **312** of the first board **31** and the second strengthening board **36** are stacked in the Z-axis direction.

It may be understood that, by sequentially stacking the first portion **351** and the second portion **352** on one side of the first elastic piece **34** and on the first extension portion **312**, and stacking the second strengthening board **36** on the other side of the first elastic piece **34** and on the first extension portion **312**, the structural strength of the first board **31** is significantly improved. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the first extension portion **312**. In this case, with the cooperation of the first strengthening board **35** and the second strengthening board **36**, the first extension portion **312** can effectively counteract the force, thereby avoiding the first extension portion **312** from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In this implementation, FIG. **13***a* shows that the elevating board **32** and the second board **33** are disposed staggered in the X-axis direction, that is, a part of the elevating board **32** protrudes in the X-axis direction relative to the second board **33**. In another optional manner, the elevating board **32** may alternatively be disposed flush with the second board **33**.

In another optional manner, the configuration manner for the circuit board assembly **30** may refer to the configuration manner for the circuit board assembly **30** in the first optional manner. In an example, the connection relationships of the first strengthening board **35** with the second strengthening board **36** and the first strengthening board **35** with the elevating board **32** may refer to the connection relationships of the first strengthening board **35** with the second strengthening board **36** and with the elevated board **32** in the first optional manner. In another example, the position relationships of the first elastic piece **34** respectively with the elevating board **32**, the first strengthening board **35**, and the second strengthening board **36** may also refer to the position relationships of the first elastic piece **34** respectively with the elevated board **32**, the first strengthening board **35**, and the second strengthening board **36** in the first optional manner. Details are not described herein again.

FIG. **13***b* is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still yet another optional manner. In this implementation, the circuit board assembly **30** further includes a ground conductive member **369**. The configuration manner for the ground conductive member **369** may refer to the configuration manner for the first elastic piece **34**. The ground conductive member **369** is disposed on a surface of the second strengthening board **36** facing away from the first board **31**. The ground conductive member **369** is electrically connected to a ground point, that is, the ground conductive member **369** is grounded. Certainly, in another optional manner, the ground conductive member **369** may also be used in other antennas.

In this implementation, the ground conductive member **369** is disposed on the second strengthening board **36**, so that the ground conductive member **369** is used for grounding the radiator **41**, or used in other antennas. In this way, the functions of the circuit board assembly **30** can be further increased. In addition, the space on the second strengthening board **36** can also be effectively used, that is, the space utilization of the circuit board assembly **30** is improved.

In an optional manner, when the second strengthening board **36** and the elevating board **32** are of an integrally formed structure, wiring is arranged in the second strengthening board **36**, and thereby the wiring in the second strengthening board **36** is electrically connected to the wiring in the elevating board **32**, or the wiring in the second strengthening board **36** is electrically connected to the wiring of the first board **31**.

In another optional manner, when the second strengthening board **36** and the elevating board **32** are disposed separately, wiring is arranged in the second strengthening board **36**, and thereby the wiring in the second strengthening board **36** is electrically connected to the wiring of the first board **31**.

Third optional manner: The same technical contents of the third optional manner as in the first optional manner and the second optional manner are not repeated again. FIG. **14** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. The circuit board assembly **30** includes a first strengthening board **35**. The first strengthening board **35** is located on one side of the first elastic piece **34**. In the Z-axis direction, the thickness of the first strengthening board **35** is greater than that of the elevating board **32**.

The first strengthening board **35** includes a first portion **351** and a second portion **352** connected to the first portion **351**. The first portion **351** is fixedly connected to the board surface of the first extension portion **312** facing the screen **10**. In this case, the first extension portion **312**, the first portion **351**, and the second portion **352** of the first board **31** are sequentially stacked along the Z-axis direction.

It may be understood that, the first strengthening board **35** is stacked on one side of the first elastic piece **34** and on the first extension portion **312**, so that the structural strength of the first board **31** is significantly improved. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41** of the antenna. The first elastic piece **34** transmits the reaction force to the first extension portion **312** of the first board **31**. In this case, with the cooperation of the first strengthening board **35**, the first extension portion **312** can effectively counteract the force, thereby avoiding the first extension portion **312** from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In this implementation, FIG. **0.14** shows that the elevating board **32** and the second board **33** are disposed flush with

each other. In another optional manner, alternatively, a part of the elevating board **32** may be staggered from the second board **33** in the X-axis direction, that is, a part of the elevating board **32** protrudes in the X-axis direction relative to the second board **33**.

In another optional manner, for the configuration manner for the circuit board assembly **30**, reference may be made to the configuration manner for the circuit board assembly **30** in the first optional manner. In an example, the connection relationship of the first strengthening board **35** with the elevating board **32** may refer to the connection relationship of the first strengthening board **35** with the elevating board **32** in the first optional manner. In another example, the position relationships of the first elastic piece **34** respectively with the elevating board **32** and the first strengthening board **35** may also refer to the position relationships of the first elastic piece **34** respectively with the elevating board **32** and the first strengthening board **35** in the first optional manner. Details are not described herein again.

Fourth optional manner: The same technical contents of the fourth optional manner as in the first optional manner are not repeated again. FIG. **15** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. The circuit board assembly **30** includes a first strengthening board **35**. The first strengthening board **35** is located on one side of the first elastic piece **34**. In addition, the first extension portion **312** of the first board **31** and the first strengthening board **35** are stacked in the Z-axis direction. In the Z-axis direction, the thickness of the first strengthening board **35** is less than or equal to the thickness of the elevating board **32**. It may be understood that, different from the foregoing optional manners, the first strengthening board **35** no longer includes the second portion **352**, that is, the first strengthening board **35** includes only the first portion **351** in the first optional manner.

It may be understood that, by stacking the first strengthening board **35** on one side of the first elastic piece **34** and on the first extension portion **312**, the structural strength of the first board **31** is significantly improved. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41** of the antenna. The first elastic piece **34** transmits the reaction force to the first extension portion **312** of the first board **31**. In this case, with the cooperation of the first strengthening board **35**, the first extension portion **312** can effectively counteract the force, thereby avoiding the first extension portion **312** from being damaged or cracked due to an external force.

In this implementation, FIG. **0.15** shows that the elevating board **32** and the second board **33** are disposed flush with each other. In another optional manner, a part of the elevating board **32** and the second board **33** may alternatively be disposed staggered in the X-axis direction, that is, a part of the elevating board **32** protrudes in the X-axis direction relative to the second board **33**.

In another optional manner, for the configuration manner for the circuit board assembly **30**, reference may be made to the configuration manner for the circuit board assembly **30** in the first optional manner. In an example, the connection relationship of the first strengthening board **35** with the elevating board **32** may refer to the connection relationship of the first strengthening board **35** with the elevating board **32** in the first optional manner. In another example, the position relationships of the first elastic piece **34** respectively with the elevating board **32** and the first strengthening board **35** may also refer to the position relationships of the first elastic piece **34** respectively with the elevating board **32** and the first strengthening board **35** in the first optional manner. Details are not described herein again.

Fifth optional manner: The same technical contents of the fifth optional manner as in the first optional manner are not repeated again. FIG. **16** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. The circuit board assembly **30** no longer includes the first strengthening board **35** and the second strengthening board **36**. In this way, the space of the first extension portion **312** is wider. In this case, a part of the first matching circuit **422** may be arranged on the first extension portion **312**, so that the first main body portion **311** of the first board **31** can arrange more electronic components, thereby significantly improving the space utilization of the circuit board assembly **30**.

In this implementation, FIG. **0.16** shows that the elevating board **32** and the second board **33** are disposed flush with each other. In another optional manner, alternatively, a part of the elevating board **32** may be staggered from the second board **33** in the X-axis direction, that is, a part of the elevating board **32** protrudes in the X-axis direction relative to the second board **33**.

In another optional manner, for the configuration manner for the circuit board assembly **30**, reference may be made to the configuration manner for the circuit board assembly **30** in the first optional manner. For example, the position relationship of the first elastic piece **34** with the elevating board **32** may also refer to the position relationship of the first elastic piece **34** with the elevating board **32** in the first optional manner. Details are not described herein again.

Sixth optional manner: The same technical contents of the sixth optional manner as in the first optional manner are not repeated again. FIG. **17** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. In this implementation, a part of the second board **33** protrudes relative to the elevating board **32**. In this case, the protruding part of the second board **33** relative to the elevating board **32** (the region indicated by a dashed line in FIG. **17**) is disposed opposite the first extension portion **312** of the first board **31**.

In addition, a part of the first elastic piece **34** extends between the first board **31** and the second board **33**, that is, a part of the first elastic piece **34** is located between the second board **33** and the first board **31**. A part of the first elastic piece **34** protrudes relative to the second board **33**. It may be understood that, a part of the first elastic piece **34** with a lower height in the Z-axis direction may extend between the first board **31** and the second board **33**. A part of the first elastic piece **34** with a higher height in the Z-axis direction protrudes relative to the second board **33**.

In this implementation, a part of the first elastic piece **34** extends between the first board **31** and the second board **33**, so that the first elastic piece **34** is protected by using the second board **33**, thereby avoiding the first elastic piece **34** from being collided with other components in the electronic device **100**. In addition, when the second board **33** protrudes relative to the elevating board **32**, the board surface area of the second board **33** is increased significantly. In this case, more electronic components can be arranged in the second board **33**, that is, more electronic components can be arranged in the circuit board assembly **30**, thereby facilitating the implementation of the multifunctional needs of the electronic device **100**.

Several configuration manners for the circuit board assembly **30** are described above in detail with reference to the associated drawings, and in the following, several con-

figuration manners for electrically connecting the first elastic piece **34** to the radiator **41** are described in detail with reference to the associated drawings.

FIG. **18** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B. It may be understood that, the cross-sectional view illustrated in FIG. **18** is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. A conductive piece **43** is disposed on a surface of the radiator **41** facing the first elastic piece **34**. The conductive piece **43** may be, but is not limited to, a gold piece, a silver piece, or a copper piece. Specifically, the conductive piece **43** is disposed in the protrusion **411**. In an optional manner, the conductive piece **43** may be connected to the radiator **41** by a soldering process. In this case, the connection between the conductive piece **43** and the radiator **41** is firmer. Certainly, in other optional manners, the conductive piece **43** may alternatively be fixedly connected to the radiator **41** by a conductive glue.

In addition, the first elastic piece **34** is in elastic contact with the conductive piece **43**. In other words, the first elastic piece **34** is electrically connected to the radiator **41** through the conductive piece **43**. In this way, when the radio frequency transceiver chip **421** transmits a radio frequency signal, the radio frequency signal is transmitted to the radiator **41** via the first matching circuit **422**, the first elastic piece **34**, and the conductive piece **43**. In addition, when the radiator **41** receives an electromagnetic wave signal and converts the electromagnetic wave signal into a radio frequency signal, the radio frequency signal is transmitted to the radio frequency transceiver chip **421** via the conductive piece **43**, the first elastic piece **34**, and the first matching circuit **422**.

It may be understood that, when the radiator **41** is provided with the conductive piece **43**, the conductive piece **43** can increase the surface flatness of the radiator **41**. In this case, when the first elastic piece **34** is in elastic contact with the radiator **41** through the conductive piece **43**, the elastic contact of the first elastic piece **34** with the radiator **41** is stable. In this way, the radio frequency signal is also stable in the process of being transmitted between the radiator **41** and the first elastic piece **34**, thereby ensuring better antenna performance of the electronic device **100**.

In an optional manner, the oxidation resistance of the conductive piece **43** is higher than that of the radiator **41**. It may be understood that, in an environment with the same temperature and humidity, the conductive piece **43** is not easy to be oxidized compared to the radiator **41**. In this way, compared with the solution in which the first elastic piece **34** is in direct elastic contact with the radiator **41**, the contact resistance of the first elastic piece **34** with the conductive piece **43** is less, that is, the contact resistance of the first elastic piece **34** with the conductive piece **43** is stable, and the transmission loss of the radio frequency signal is less. In this case, the antenna performance of the electronic device **100** is better.

In other optional manners, alternatively, the oxidation resistance of the conductive piece **43** may be equal to or lower than that of the radiator **41** of the antenna.

FIG. **19** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B. It may be understood that, the cross-sectional view illustrated in FIG. **19** is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. The electronic device **100** includes a fastener **44**. The fastener **44** may be, but is not limited to, a screw, a rivet, or a pin. The fastener **44** is made of a conductive material. In addition, the radiator **41** is provided with a blind hole **412**. Specifically, the blind hole **412** is located on the protrusion **411**. The fastener **44** is fixed into the blind hole **412**. The first elastic piece **34** is in elastic contact with the fastener **44**. In this way, when the radio frequency transceiver chip **421** emits the radio frequency signal, the radio frequency signal is transmitted to the radiator **41** via the first matching circuit **422**, the first elastic piece **34**, and the fastener **44**. In addition, when the radiator **41** receives an electromagnetic wave signal and converts the electromagnetic wave signal into a radio frequency signal, the radio frequency signal is transmitted to the radio frequency transceiver chip **421** via the fastener **44**, the first elastic piece **34**, and the first matching circuit **422**.

It may be understood that, compared with the solution in which the conductive piece **43** is soldered on the radiator **41**, in this embodiment, the fastener **44** is disposed in the blind hole **412** of the radiator **41**, and the first elastic piece **34** is electrically connected to the radiator **41** of the antenna through the fastener **44**, thereby omitting the process of soldering the conductive piece **43** on the radiator **41**. Therefore, on the one hand, the cost investment of the electronic device **100** is reduced, and there is no need to increase the investment cost of the soldering process; and on the other hand, the case that the performance of the radiator **41** in transmitting and receiving the electromagnetic wave is affected due to the generation of gas holes, slag inclusions, solder joints or cracks during the soldering process in the radiator **41** is avoided.

In an optional manner, the oxidation resistance of the fastener **44** is higher than that of the radiator **41**. In this way, compared with the solution in which the first elastic piece **34** is in direct elastic contact with the radiator **41**, the contact resistance of the first elastic piece **34** with the fastener **44** is less, that is, the contact resistance of the first elastic piece **34** with the fastener **44** is stable. In this case, the transmission loss of the radio frequency signal is less, and the antenna performance of the electronic device **100** is better. In other optional manners, the oxidation resistance of the fastener **44** may alternatively be equal to or lower than that of the radiator **41** of the antenna.

In an optional manner, the resistivity of the fastener **44** is less than that of the radiator **41**. In this case, the conductive performance of the fastener **44** is better than that of the radiator **41**, so that when the first elastic piece **34** is in elastic contact with the fastener **44**, the transmission rate of the radio frequency signal between the fastener **44** and the first elastic piece **34** is faster and the loss is smaller, that is, the antenna performance of the electronic device **100** is better.

FIG. **20***a* is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B. It may be understood that, the cross-sectional view illustrated in FIG. **20***a* is a cross-sectional view formed by taking a cross section from the electronic device in FIG. **1** along a line B-B, viewing along a positive direction of the Y-axis, and then rotating the obtained cross-sectional view by 180° with the Y-axis as a rotational axis. In this implementation, the first elastic piece **34** is fixed to a side of the first extension portion **312** of the first board **31** facing the display screen **12**. The first elastic piece **34** is in elastic contact with an inner side surface **413**

of the radiator **41**. In this case, the protrusion **411** may no longer be disposed in the radiator **41**, that is, the first elastic piece **34** may not be in elastic contact with the protrusion **411** of the radiator **41**. In this way, the first elastic piece **34** can be disposed relatively close to the rear cover **22**, that is, the first elastic piece **34** can be disposed relatively far away from the display screen **12**. In this way, in the Z-axis direction, the distance between the first elastic piece **34** and the display screen **12** can be significantly increased. In this way, in the Z-axis direction, the antenna clearance area between the first elastic piece **34** and the display screen **12** can be larger, and the performance of the antenna is also better.

In addition, the distance from the contact point between the first elastic piece **34** and the radiator **41** to the display screen **12** is significantly increased. In this case, the display screen **12** has less signal interference to the contact point of the first elastic piece **34** and the radiator **41**.

In addition, in the Z-axis direction, the space omitting the protrusion **411** in this optional manner may also be used for the clearance area of the antenna. In this way, the clearance area of the antenna is larger, and the performance of the antenna is better.

In an optional manner, a part of the first elastic piece **34** is fixedly connected to a side surface of the first extension portion **312**. In this case, the first board **31** may apply pressure onto the first elastic piece **34** in the negative direction of the X-axis, and thereby the first elastic piece **34** is in contact with the radiator **41** more stably.

In another optional manner, the inner side surface **413** of the radiator **41** may also be disposed with reference to the configuration manner of the protrusion **411** of the radiator **41** described above. For example, a conductive piece is disposed on the inner side surface **413** of the radiator **41**, or the opening of the radiator **41** for opening the blind hole is located on the inner side surface **413** of the radiator **41**. Details are not described herein again.

FIG. **20***b* is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B. It may be understood that, the schematic cross-sectional view illustrated in FIG. **20***b* is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. In this implementation, the first elastic piece **34** is fixed to a side of the first extension portion **312** of the first board **31** facing the rear cover **22**. In addition, the first elastic piece **34** is in elastic contact with the protrusion **411** of the radiator **41**.

In this implementation, the first elastic piece **34** is fixed to the side of the first extension portion **312** facing the rear cover **22**, and is in elastic contact with the protrusion **411** of the radiator **41** by using the first elastic piece **34**, so that the first elastic piece **34** can be disposed relatively close to the rear cover **22**, that is, the first elastic piece **34** can be disposed relatively far from the display screen **12**, that is, in the Z-axis direction, the distance between the first elastic piece **34** and the display screen **12** can be significantly increased. In this way, in the Z-axis direction, the protrusion **411** for contact with the first elastic piece **34** can also be disposed substantially away from the display screen **12**. The antenna clearance area between the bottom of the protrusion **411** and the display screen **12** can be larger in the Z-axis direction, and the performance of the antenna is also better.

In addition, the distance from the contact point between the first elastic piece **34** and the radiator **41** to the display screen **12** is significantly increased. In this case, the display screen **12** has less signal interference to the contact point of the first elastic piece **34** and the radiator **41**.

In another optional manner, the first elastic piece **34** may be a broken elastic piece. Specifically, by opening a through hole or groove in the first extension portion **312** of the first board **31**, a part of the first elastic piece **34** is mounted in the through hole or groove, and a part of the first elastic piece **34** is exposed relative to the first extension portion **312**. In this way, the contact position between the first elastic piece **34** and the protrusion **411** is not limited to the contact position illustrated in FIG. **20***b*, which is arranged flush with the surface of the first extension portion **312** facing the rear cover **22**. The contact position between the first elastic piece **34** and the protrusion **411** may be flexibly arranged according to the position of the first elastic piece **34**. For example, the contact position between the first elastic piece **34** and the protrusion **411** may be flush with the surface of the first extension portion **312** facing the display screen **12**.

FIG. **21** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B. It may be understood that, the cross-sectional view illustrated in FIG. **21** is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. In this implementation, another structure of the first conductive member **34** is described in detail with reference to FIG. **21**. Specifically, the first conductive member **34** includes a first fixation piece **341**, an elastic member **342**, and a second fixation piece **343**. The elastic member **342** is connected between the first fixation piece **341** and the second fixation piece **343**. It may be understood that, the elastic member **342** may be, but is not limited to, an elastic piece or a spring. In addition, the first fixation piece **341** may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece. The second fixation piece **343** may be, but is not limited to, a copper piece, an aluminum piece, or a gold piece.

In addition, the first fixation piece **341** is fixedly connected to the radiator **41**. Specifically, the first fixation piece **341** is fixed to the protrusion **411** of the radiator **41**. The second fixation piece **343** is fixedly connected to the first extension portion **312** of the first board **31**. In this case, when the radio frequency transceiver chip **421** emits a radio frequency signal, the radio frequency signal is transmitted to the radiator **41** via the first matching circuit **422**, the second fixation piece **343**, the elastic member **342**, and the first fixation piece **341**. In addition, when the radiator **41** receives an electromagnetic wave signal and converts the electromagnetic wave signal into a radio frequency signal, the radio frequency signal is transmitted to the radio frequency transceiver chip **421** via the first fixation piece **341**, the elastic member **342**, the second fixation piece **343**, and the first matching circuit **422**.

In this implementation, the first conductive member **34** has a simple structure, and is easy to assemble, which may reduce the difficulty of assembling the electronic device **100**.

Several manners of elastic contact of the first elastic piece **34** with the radiator **41** are described above in detail with reference to the associated drawings. In addition, the foregoing radiator **41** adopts an ungrounded solution. Several configuration manners in which the radiator **41** is grounded are described in detail below with reference to the associated drawings.

First optional manner: FIG. **22** is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line A-A. FIG. **23** is a partial cross-sectional view of an electronic device shown in FIG. **22** taken along a line D-D. The frame **21** further includes a connection segment **218**. It may be understood that, the cross-sectional view illustrated in FIG. **22** is a cross-sectional view of the electronic device of FIG. **1** taken along the line A-A and viewed along the negative direction of the Z axis. In addition, the cross-sectional view illustrated in FIG. **23** is a schematic diagram obtained by taking a cross section from the electronic device in FIG. **22** along a line D-D and viewing along a positive direction of the Y-axis. The connection segment **218** is connected between the radiator **41** and the middle plate **24**. It may be understood that, In the electronic device **100**, the middle plate **24** is generally in a grounded state. In this way, the radiator **41** is grounded by being connected to the middle plate **24** through the connection segment **218**. In addition, as can be seen from FIG. **23**, the thickness of the connection segment **218** in the Z-axis direction is less than that of the radiator **41** in the Z-axis direction. In this case, the third gap **216** between the radiator **41** and the middle plate **24** is not partitioned by the connection segment **218**.

It may be understood that, the radiator **41** of the optional manner is grounded in a simpler manner, and has a simpler structure and a low investment cost.

In an optional manner, the connection segment **218** and the radiator **41** are of an integrally formed structure. In this case, compared with the manner of connecting the connection segment **218** to the radiator **41** by the soldering process, the soldering process is omitted in this optional manner, thereby saving the cost investment of the soldering process. Certainly, in other optional manners, the connection segment **218** may alternatively be connected to the radiator **41** by soldering or the like.

Second optional manner: FIG. **24** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. FIG. **25** is a partial cross-sectional view of an electronic device shown in FIG. **1** in an optional manner taken along a line E-E. It may be understood that, the cross-sectional view illustrated in FIG. **25** is a cross-sectional view formed by taking a cross section from the electronic device in FIG. **1** along a line B-B, viewing along a positive direction of the Y-axis, and then rotating the obtained cross-sectional view by 180° with the Y-axis as a rotational axis. The circuit board assembly **30** further includes a second conductive member **391**. It may be understood that, the structure and the configuration manner for the second conductive member **391** may refer to the structure and configuration manner for the first conductive member **34**. For example, the second conductive member **391** is disposed in the first extension portion **312** of the first board **31**. Details are not described herein again. In addition, in this implementation, the second conductive member **391** is described using a second elastic piece **391** as an example. Different from the first elastic piece **34**, the second elastic piece **391** is electrically connected between a ground layer of the first board **31** and the radiator **41**. In other words, the second elastic piece **391** is configured to ground the radiator **41**.

It may be understood that, the radiator **41** of the optional manner is grounded in a simpler manner, and has a simpler structure and a low investment cost.

Referring to FIG. **25** again, the first board **31** is provided with a second matching circuit **399**. The second matching circuit **399** includes an inductor, capacitor, resistor, or antenna switch. The second elastic piece **391** is electrically connected to the second matching circuit **399**, and is electrically connected to the ground layer of the first board **31** through the second matching circuit **399**. The second matching circuit **399** is configured to tune the frequency band of the antenna for transmitting and receiving the electromagnetic waves, and is used for the impedance matching of the antenna. In this way, the performance of the antenna for transmitting and receiving the electromagnetic waves is better. In another optional manner, the first board **31** may alternatively not be provided with a second matching circuit **399**.

Third optional manner: FIG. **26** is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line E-E. It may be understood that, the cross-sectional view illustrated in FIG. **26** is a cross-sectional view formed by taking a cross section from the electronic device in FIG. **1** along a line B-B, viewing along a positive direction of the Y-axis, and then rotating the obtained cross-sectional view by 180° with the Y-axis as a rotational axis. The circuit board assembly **30** further includes a second conductive member **391** and a third conductive member **392**. It may be understood that, the structure and the configuration manner for the second conductive member **391** may refer to the structure and configuration manner for the first conductive member **34**. which are not described herein again. In addition, in this implementation, the second conductive member **391** is described using a second elastic piece **391** as an example. In addition, the third conductive member **392** may be an elastic piece with electrical conductivity or a spring with electrical conductivity. which is not limited in this application. In this implementation, the third conductive member **392** is described using a third elastic piece **392** as an example.

In addition, different from the first elastic piece **34**, the second elastic piece **391** is electrically connected between the radiator **41** and the third elastic piece **392** fixed onto the second board **33**.

In an optional manner, the third elastic piece **392** is electrically connected to the second elastic piece **391** through the wiring in the circuit board assembly **30**. In other optional manners, a wire is disposed on the circuit board assembly **30**, and in this case, the third elastic piece **392** is electrically connected to the second elastic piece **391** by the wire.

In addition, the third elastic piece **392** is in elastic contact with the middle plate **24**. In this case, the radiator **41** is electrically connected to the middle plate **24** through the second elastic piece **391** and the third elastic piece **392**. In other words, the radiator **41** is grounded through the second elastic piece **391** and the third elastic piece **392**.

It may be understood that, the second elastic piece **391** is disposed on the first extension portion **312**, and the third elastic piece **392** is disposed on the second board **33** and is used for grounding, and thereby the ground path of the radiator **41** is increased. In this case, in the ground path of the radiator **41**, a matching circuit may be disposed on the circuit board assembly **30** to tune the frequency band of the antenna for transmitting and receiving the electromagnetic waves, so that the transmitting and receiving frequency band of the antenna is wider. For example, with reference to FIG. **26**, FIG. **27** is a partial cross-sectional view of an electronic device shown in FIG. **1** in yet another optional manner taken along a line A-A. It may be understood that, the cross-sectional view illustrated in FIG. **27** is a cross-sectional view of the electronic device of FIG. **1** taken along the line A-A and viewed along the negative direction of the Z axis. The

electronic device **100** includes a first branch **393** and a second branch **394** disposed in parallel, and the first branch **393** and the second branch **394** are located between the second elastic piece **391** and the third elastic piece **392**. The first branch **393** includes a capacitor. The second branch **394** includes an inductor. When switched to the first branch **393**, the electronic device **100** transmits and receives an antenna signal with a first frequency band, for example, the first frequency band is an intermediate frequency band for LTE. When switched to the second branch **394**, the electronic device **100** transmits and receives an antenna signal with a second frequency band, for example, the second frequency band is a high frequency band for LTE.

In an optional manner, antenna switches for antenna are disposed in the first branch **393** and the second branch **394**. The second branch **394** is disconnected by the antenna switch for antenna when the electronic device **100** needs to be switched to the first branch **393**. The first branch **393** is disconnected by the antenna switch for antenna when the electronic device **100** needs to be switched to the second branch **394**.

Several grounding manners of the radiator **41** of the antenna are described above in detail with reference to the associated drawings. The several grounding manners may alternatively be applied in combination with each other. In addition, in each of the foregoing optional manners, the first elastic piece **34** is mainly configured to feed the radio frequency signal emitted by the radio frequency path **42** to the radiator **41**, or to transmit the radio frequency signal converted by the radiator **41** to the radio frequency path **42**. In other words, the position at which the first elastic piece **34** is in elastic contact with the radiator **41** is a feed point. Another application environment of the first elastic piece **34** is described in detail below with reference to the associated drawings. The first elastic piece **34** may alternatively be configured to ground the radiator **41**, or to electrically connect to the matching circuit of the antenna to be grounded through the matching circuit. In this case, the contact position between the first elastic piece **34** and the radiator **41** is an antenna ground tuning point.

In this implementation, the same technical contents as in each of the foregoing optional manners are not repeated. FIG. **28** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still yet another optional manner taken along a line A-A. FIG. **29** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B. It may be understood that, the cross-sectional view illustrated in FIG. **28** is a cross-sectional view of the electronic device of FIG. **1** taken along the line A-A and viewed along the negative direction of the Z axis. the cross-sectional view illustrated in FIG. **29** is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. The circuit board assembly **30** includes a first board **31**, an elevating board **32**, a second board **33**, and a first conductive member **34**. The configuration manners for the first board **31**, the elevating board **32**, the second board **33**, and the first conductive member **34** may refer to the configuration manners for the first board **31**, the elevating board **32**, the second board **33**, and the first conductive member **34** in each of the foregoing optional manners. which are not described herein again.

In this implementation, the electronic device **100** includes a second matching circuit **395**. The second matching circuit **395** is configured to tune the frequency band of the antenna for transmitting and receiving the electromagnetic waves. Certainly, the second matching circuit **395** may also be used for the impedance matching of the antenna. The second matching circuit **395** is disposed on the first board **31**. In addition, the second matching circuit **395** is electrically connected between the first elastic piece **34** and the ground layer of the first board **31**. In other words, the radiator **41** is grounded through the first elastic piece **34** and the second matching circuit **395**. In addition, the second matching circuit **395** may include an antenna switch, capacitor, or inductance.

It may be understood that, by disposing the first extension portion **312** that protrudes relative to the elevating board **32** and the second board **33**, and fixedly connecting the first elastic piece **34** to the first extension portion **312**, the first elastic piece **34** is disposed away from the display screen **12**, that is, in the Z-axis direction, the distance between the first elastic piece **34** and the display screen **12** can be significantly increased. In this way, in the Z-axis direction, the protrusion **411** of the radiator **41** can also be disposed in a direction away from the display screen **12**, that is, the antenna clearance area between the bottom of the protrusion **411** and the display screen **12** can be made larger, and the performance of the antenna is also better.

In addition, when the first elastic piece **34** and the protrusion **411** are both disposed away from the display screen **12**, the contact point (the antenna ground tuning point) at which the first elastic piece **34** is in contact with the protrusion **411** can also be arranged away from the display screen **12**. In this way, the contact point (the antenna ground tuning point) at which the first elastic piece **34** is in contact with the protrusion **411** is less affected by the display screen **12**.

In addition, by disposing the second matching circuit **395** on the first board **31**, the tuning circuit **395** is disposed away from the display screen **12**, that is, the distance between the second matching circuit **395** and the display screen **12** in the Z-axis direction can be significantly increased. In this way, in the Z-axis direction, the antenna clearance area between the display screen **12** and the second matching circuit **395** can be larger, and the performance of the antenna is better.

In addition, when the antenna clearance area is greatly increased, by disposing the first extension portion **312** protruding relative to the elevating board **32** and the second board **33**, and fixedly connecting the first elastic piece **34** to the first extension portion **312**, and making the first elastic piece **34** be in elastic contact with the radiator **41**, the ground path of the radiator **41** is greatly reduced, thereby improving the antenna performance.

In addition, the grounding manner of the radiator **41** in the optional manner through the first elastic piece **34** and the second matching circuit **395** is simple and is easy to operate.

In another optional manner, the electronic device **100** may alternatively not include the second matching circuit **395**. In this case, the radiator **41** is directly electrically connected to the ground layer of the first board **31**, that is, the radiator **41** is directly grounded.

Several structures of the circuit board assembly **30** and several application scenarios of the first elastic piece **34** are described above in detail with reference to the associated drawings. In each of the foregoing optional manners, the first elastic piece **34** is disposed on the first extension portion **312** of the first board **31**. Several configuration manners for the circuit board assembly **30** are described in detail below with reference to the associated drawings. It may be understood that, several first elastic pieces **34** of the circuit board assembly **30** described below are disposed on an extension

portion of the elevating board **32**. Details may refer to the following description. In addition, in each of the following optional manners, the same technical contents as in the foregoing optional manners are not repeated.

FIG. **30** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. FIG. **31** is a schematic exploded view of a circuit board assembly shown in FIG. **30**. The circuit board assembly **30** includes a first elastic piece **34**, and a first board **31**, an elevating board **32**, and a second board **33** sequentially stacked.

The first board **31** includes a first main body portion **311** and a first extension portion **312**. The first extension portion **312** protrudes relative to the second board **33**. FIG. **30** and FIG. **31** both show that the first extension portion **312** protrudes in an X-axis direction relative to the second board **33**. In another optional manner, the first extension portion **312** may alternatively protrude in another direction relative to the second board **33**, for example in a Y-axis direction. which is not limited in this application.

In addition, the elevating board **32** includes a second main body portion **321** and a second extension portion **322**. The first main body portion **311**, the second main body portion **321**, and the second board **33** are sequentially stacked. The second extension portion **322** is stacked on the first extension portion **312**, and the second extension portion **322** protrudes relative to the second board **33**. In this implementation, FIG. **30** and FIG. **31** both show that the second extension portion **322** and the first extension portion **312** are disposed flush with each other. In another optional manner, the second extension portion **322** may alternatively be staggered from the first extension portion **312**.

FIG. **32** is a partial cross-sectional view of an electronic device shown in FIG. **1** in still another optional manner taken along a line B-B. It may be understood that, the cross-sectional view illustrated in FIG. **32** is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. The first extension portion **312** is disposed close to the radiator **41** relative to the first main body portion **311**. The second extension portion **322** is also disposed close to the radiator **41** relative to the second main body portion **321**.

In addition, the first elastic piece **34** is fixed to the second extension portion **322**, and the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna. In this case, the first elastic piece **34** and the second board **33** are located on a same side of the elevating board **32**. In this implementation, the first elastic piece **34** is in elastic contact with the protrusion **411**. In another optional manner, the radiator **41** may alternatively not be provided with a protrusion **411**. In this case, the first elastic piece **34** may adopt the manner of being in elastic contact with the inner side surface of the radiator **41**, and details may refer to the optional manner in FIG. **20***a* described above. which are not described herein again.

In addition, the first elastic piece **34** is electrically connected between the radio frequency path **42** and the radiator **41**. In this way, the radio frequency signals transmitted by the radio frequency transceiver chip **421** can be transmitted to the radiator **41** via the first matching circuit **422** and the first elastic piece **34**. In addition, after the radiator **41** converts the received electromagnetic wave signals into radio frequency signals, the radio frequency signals can further be transmitted to the radio frequency transceiver chip **421** via the first elastic piece **34** and the first matching circuit **422**.

In this embodiment, by disposing the second extension portion **322** that protrudes relative to the second board **33**, and fixedly connecting the first elastic piece **34** to the second extension portion **322**, the first elastic piece **34** is disposed away from the display screen **12**, that is, in the Z-axis direction, the distance between the first elastic piece **34** and the display screen **12** can be significantly increased. In this case, the distance from the contact point between the first elastic piece **34** and the radiator **41** to the display screen **12** is significantly increased. In this way, in the Z-axis direction, the protrusion **411** of the radiator **41** can also be disposed in a direction away from the display screen **12**, that is, the antenna clearance area between the bottom of the protrusion **411** and the display screen **12** can be made larger, and the performance of the antenna is also better.

In addition, when both the first elastic piece **34** and the protrusion **411** are disposed away from the display screen **12**, the contact point of the first elastic piece **34** in contact with the protrusion **411** may also be arranged away from the display screen **12**. In this way, the contact point (feed point) of the first elastic piece **34** in contact with the protrusion **411** is less affected by the display screen **12**.

In addition, the second extension portion **322** is stacked on the first extension portion **312**. In this case, the overall strength of this part may be improved with the cooperation of the second extension portion **322** and the first extension portion **312**. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the second extension portion **322**. In this case, with the cooperation of the first extension portion **312**, the second extension portion **322** can effectively counteract the force, thereby avoiding the second extension portion **322** from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

Referring to FIG. **30** and FIG. **31** again, the circuit board assembly **30** further includes a third strengthening board **37** and a fourth strengthening board **38**. The third strengthening board **37** and the fourth strengthening board **38** are also respectively located on both sides of the first elastic piece **34**. In FIG. **31**, the third strengthening board **37**, the fourth strengthening board **38**, and the second board **33** are schematically distinguished by a dashed line. In addition, the third strengthening board **37** and the fourth strengthening board **38** are stacked on a board surface of the second extension portion **322** of the elevating board **32** facing the screen **10**. In this way, the overall strength of the second extension portion **322** is further improved. In this case, when the first elastic piece **34** is in elastic contact with the radiator **41**, the first elastic piece **34** receives a reaction force of the radiator **41** of the antenna. The first elastic piece **34** transmits the reaction force to the second extension portion **322** of the first board **31**. In this case, with the cooperation of the third strengthening board **37** and the fourth strengthening board **38**, the second extension portion **322** can effectively counteract the force, thereby avoiding the second extension portion **322** from being damaged or cracked due to an external force.

In an optional manner, the third strengthening board **37**, the fourth strengthening board **38**, and the second board **33** are of an integrally formed structure. In other words, the third strengthening board **37**, the fourth strengthening board **38**, and the second board **33** are an integral board. In this

case, the overall structural strength of the third strengthening board **37**, the fourth strengthening board **38**, and the second board **33** is better. In this way, the third strengthening board **37**, the fourth strengthening board **38**, and the second board **33** is not easy to fracture or crack when subjected to an external force.

In another optional manner, the third strengthening board **37** and the fourth strengthening board **38** may also be connected to the second board **33** by the soldering process.

In another optional manner, the third strengthening board **37**, the fourth strengthening board **38**, and the second board **33** may also be separately disposed, that is, the third strengthening board **37** and the fourth strengthening board **38** are directly fixed to the second extension portion **322** of the elevating board **32** without being fixedly connected to the second board **33**.

FIG. **33** is a partial schematic structural view of a circuit board assembly shown in FIG. **30** from another angle. A distance d**1** between the first elastic piece **34** and the second board **33** ranges from 0.15 mm to 30 mm.

In this implementation, when the distance d**1** between the first elastic piece **34** and the second board **33** ranges from 0.15 mm to 30 mm, the size of the second extension portion **322** located between the first elastic piece **34** and the second board **33** is relatively moderate. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41**, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the second extension portion **322**. In this case, the second extension portion **322** located between the first elastic piece **34** and the second board **33** is not easy to fracture or crack. In other words, the reaction force received by the second extension portion **322** can be rapidly transmitted to the second board **33**, so that the reaction force is counteracted by an internal stress of the second board **33**.

Referring to FIG. **33** again, a distance d**2** between the first elastic piece **34** and the third strengthening board **37** ranges from 0.15 mm to 30 mm. In this case, the size of the second extension portion **322** located between the first elastic piece **34** and the third strengthening board **37** is relatively moderate. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the second extension portion **322**. In this case, the second extension portion **322** located between the first elastic piece **34** and the third strengthening board **37** is not easy to fracture or crack. In other words, the reaction force received by the second extension portion **322** can be rapidly transmitted to the third strengthening board **37**, so that the reaction force is counteracted by an internal stress of the third strengthening board **37**.

Referring to FIG. **33** again, a distance d**3** between the first elastic piece **34** and the fourth strengthening board **38** ranges from 0.15 mm to 30 mm. In this case, the size of the second extension portion **322** located between the first elastic piece **34** and the fourth strengthening board **38** is relatively moderate. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the second extension portion **322**. In this case, the second extension portion **322** located between the first elastic piece **34** and the fourth strengthening board **38** is not easy to fracture or crack. In other words, the reaction force received by the second extension portion **322** can be rapidly transmitted to the fourth strengthening board **38**, so that the reaction force is counteracted by an internal stress of the fourth strengthening board **38**.

FIG. **34** is a partial cross-sectional view of an electronic device shown in FIG. **1** in another optional manner taken along a line B-B. It may be understood that, the cross-sectional view illustrated in FIG. **34** is a cross-sectional view formed by taking a cross section from the electronic device of FIG. **1** along a line B-B and viewing along the positive direction of the Y axis, and then rotating the obtained cross-sectional view by 180° with the Y axis as the rotation axis. The second extension portion **322** of the elevating board **32** is provided with a groove **314**. An opening of the groove **314** is located on a surface of the elevating board **32** facing the display screen **12**. A part of the first elastic piece **34** is mounted in the groove **314**.

It may be understood that, when a part of the first elastic piece **34** is mounted in the groove **314**, in the Z-axis direction, there is an overlapping region between the first elastic piece **34** and the second extension portion **322**. In this case, the first elastic piece **34** can be disposed further away from the display screen **12**, that is, in the Z-axis direction, the distance between the first elastic piece **34** and the display screen **12** can be significantly increased. In this way, in the Z-axis direction, the protrusion **411** of the radiator **41** can also be disposed in a direction away from the display screen **12**, that is, the antenna clearance area between the bottom of the protrusion **411** and the display screen **12** can be made larger, and the performance of the antenna is also better.

In addition, when both the first elastic piece **34** and the protrusion **411** are disposed away from the display screen **12**, the contact point of the first elastic piece **34** in contact with the protrusion **411** may also be arranged away from the display screen **12**. In this way, the contact point at which the first elastic piece **34** is in contact with the protrusion **411** is less affected by the display screen **12**.

In an optional manner, when the third strengthening board **37** and the fourth strengthening board **38** are disposed in the second extension portion **322**, the groove **314** is located between the first strengthening board **35** and the second strengthening board **36**. In this case, the third strengthening board **37**, the fourth strengthening board **38**, and the first extension portion **312** may improve the strength of the second extension portion **322**, thereby avoiding the strength of the second extension portion **322** from being reduced due to the groove **314** being opened.

FIG. **35** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. The circuit board assembly **30** includes a third strengthening board **37**. The third strengthening board **37** is located on one side of a first elastic piece **34**.

In addition, the third strengthening board **37** is stacked on the second extension portion **322**. In this way, the second extension portion **322**, the second board **33**, and the third strengthening board **37** enclose the first elastic piece **34**.

It may be understood that, by stacking the third strengthening board **37** on one side of the first elastic piece **34** and on the second extension portion **322**, the structural strength of the second extension portion **322** is significantly improved. In this way, when the first elastic piece **34** is in elastic contact with the radiator **41** of the antenna, the first elastic piece **34** receives a reaction force of the radiator **41**. The first elastic piece **34** transmits the reaction force to the second extension portion **322**. In this case, with the cooperation of the third strengthening board **37** and the first extension portion **312**, the second extension portion **322** can effectively counteract the force, thereby avoiding the second

extension portion **322** from being damaged or cracked due to an external force, and thus avoiding the disconnection of the circuit of the antenna.

In this implementation, FIG. **35** shows that the second extension portion **322** and the first extension portion **312** are disposed flush with each other. In another optional manner, the second extension portion **322** may alternatively be staggered from the first extension portion **312**.

In another optional manner, a plurality of first elastic pieces **34** may be disposed on the second extension portion **322**. Different first elastic pieces **34** may be applied in different antennas. In this way, the circuit board assembly **30** has lots of functions and is widely used.

FIG. **36** is a partial schematic structural view of a circuit board assembly of an electronic device shown in FIG. **1** in still another optional manner. The circuit board assembly **30** no longer includes the third strengthening board **37** and the fourth strengthening board **38**. In this way, the space of the second extension portion **322** is wider. In addition, because the second extension portion **322** of the elevating board **32** is stacked on the first extension portion **312** of the first board **31**, the structural strength of the second extension portion **322** is better. In this case, the plurality of first elastic pieces **34** may be disposed on the second extension portion **322**. Different first elastic pieces **34** may be applied in different antennas. In this way, the circuit board assembly **30** has lots of functions and is widely used.

In this implementation, FIG. **36** shows that the second extension portion **322** and the first extension portion **312** are disposed flush with each other. In another optional manner, the second extension portion **322** may alternatively be staggered from the first extension portion **312**.

The first embodiment of the electronic device **100** in which the screen **10** is flat is described above in detail with reference to the associated drawings. A second embodiment of an electronic device **100** in which a screen **10** is curved is described in detail below with reference to the associated drawings.

In the second embodiment, the same technical contents as in the first embodiment are not described again. FIG. **37** is a schematic structural view of an electronic device in another optional manner provided by an embodiment of this application. The screen **10** of the electronic device **100** is a curved screen. The screen **10** may be a 2.5-dimensions (Dimensions, D) curved screen or a 3D curved screen. Details are not limited in this embodiment. FIG. **37** shows that the screen **10** covers the majority of a housing **20**.

FIG. **38** is a partial cross-sectional view of an electronic device shown in FIG. **37** taken along a line F-F. It may be understood that, the cross-sectional view illustrated in FIG. **38** is a partial cross-sectional view formed by taking a cross section from the electronic device in FIG. **37** along a line F-F, viewing along a positive direction of the Y-axis, and then rotating the obtained cross-sectional view by 180° with the Y-axis as a rotational axis. The screen **10** includes a flat portion **101** and a bending portion **102** connected to the flat portion **101**. It may be understood that, the flat portion **101** is a flat part in the screen **10**, and the bending portion **102** is a bent part in the screen **10**. In addition, the flat portion **101** includes a part of a protective cover plate **11** and a part of a display screen **12**. the bending portion **102** includes a part of the protective cover plate **11** and a part of the display screen **12**.

In this embodiment, a circuit board assembly **30** of the electronic device **100** includes a first board **31**, an elevating board **32**, a second board **33**, and a first conductive member **34**. The configuration manners for the first board **31**, the elevating board **32**, the second board **33**, and the first conductive member **34** may refer to the configuration manners for the first board **31**, the elevating board **32**, the second board **33**, and the first conductive member **34** in the first embodiment. which are not described herein again.

It may be understood that, when the screen **10** is a curved screen, the bending portion **102** of the screen **10** form a side of the electronic device **100**. In this case, when the first elastic piece **34** is disposed on the second board **33**, the first elastic piece **34** is likely to be surrounded by the bending portion **102** of the screen **10** in the X-axis direction. In this case, the radio frequency signal of the antenna is more affected by the bending portion **102** of the screen **10**. In addition, in the Z-axis direction, the distance between the first elastic piece **34** and the flat portion **101** of the screen **10** is short, so that in the Z-axis direction, the clearance area of the antenna is extremely compressed, and the performance of the antenna is poor. However, in this embodiment, by disposing the first extension portion **312** protruding relative to the elevating board **32** and the second board **33** on the first board **31**, and fixedly connecting the first elastic piece **34** to the first extension portion **312**, in the X-axis direction, the first elastic piece **34** is no longer surrounded by the bending portion **102** of the screen **10**. In this way, the first elastic piece **34** is less affected by the bending portion **102**, and the performance of the antenna is better. In addition, when the first elastic piece **34** is fixedly connected to the first extension portion **312**, in the Z-axis direction, the distance between the first elastic piece **34** and the flat portion **101** of the screen **10** is further. In this way, in the Z-axis direction, the antenna clearance area between the first elastic piece **34** and the flat portion **101** of the screen **10** is larger, and the performance of the antenna is better.

In addition, when both the first elastic piece **34** and the protrusion **411** are disposed away from the display screen **12**, the contact point of the first elastic piece **34** in contact with the protrusion **411** may also be arranged away from the display screen **12**. In this way, the contact point at which the first elastic piece **34** is in contact with the protrusion **411** is less affected by the display screen **12**.

Referring to FIG. **38** again, a distance L from the contact point between the first elastic piece **34** and the radiator **41** to the flat portion **101** is greater than or equal to 2 mm. For example, L equals 2 mm, 2.5 mm, 3 mm, 3.5 mm or 4 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece **34** and the radiator **41** to the flat portion **101** is greater than or equal to 2 mm, the first elastic piece **34** can be disposed away from the flat portion **101** to a greater extent. In this case, in the Z-axis direction, the protrusion **411** may also be disposed away from the display screen **12** to a greater extent. In this way, the antenna clearance area between the bottom of the protrusion **411** and the display screen **12** is greatly increased, and the performance of the antenna is also better.

In addition, a distance L from the contact point between the first elastic piece **34** and the radiator **41** to the flat portion **101** is less than or equal to 4.7 mm.

It may be understood that, when the distance L from the contact point between the first elastic piece **34** and the radiator **41** to the flat portion **101** is less than or equal to 4.7 mm, on the one hand, it can be ensured that the first elastic piece **34** is disposed away from the flat portion **101**; on the other hand, it can be ensured that the thickness of the electronic device **100** in the Z-axis direction is not too large, which is conducive for thinning configuration.

It may be understood that, FIG. **38** shows only one structure of the circuit board assembly **30**. In another

optional manner, the electronic device **100** with a curved screen may also include various structures of the circuit board assembly **30** in the first embodiment.

The embodiment of the electronic device **100** in which the screen **10** is curved is described above in detail with reference to the associated drawings. An embodiment of another electronic device **100** in which a screen **10** is curved is described in detail below with reference to the associated drawings.

In the third embodiment, the same technical contents as in the first embodiment and the second embodiment are not described again. FIG. **39** is a schematic structural view of an electronic device in still another optional manner provided by an embodiment of this application. The screen **10** of the electronic device **100** includes a first screen region **101** and a second screen region **102** disposed relative to each other, and a third screen region **103** and a fourth screen region **104** disposed relative to each other. The third screen region **103** and the fourth screen region **104** are connected between the first screen region **101** and the second screen region **102**. In this case, the screen **10** of the electronic device **100** is a 360° curved screen.

In this implementation, a housing **20** no longer includes a rear cover **22**, that is, the housing **20** includes a frame **21**. The first screen region **101**, the third screen region **103**, the second screen region **102**, and the fourth screen region **104** are disposed around the frame **21**. FIG. **39** shows that the first screen region **101** and the second screen region **102** are located on a top side and bottom side of the frame **21**, and the third screen region **103** and the fourth screen region **104** are located on a left side and right side of the frame **21**.

FIG. **40** is a partial cross-sectional view of an electronic device shown in FIG. **39** taken along a line G-G. It may be understood that, the cross-sectional view illustrated in FIG. **40** is a cross-sectional view formed by taking a cross section from the electronic device in FIG. **39** along a line G-G, viewing along a positive direction of the Y-axis, and then rotating the obtained cross-sectional view by 180° with the Y-axis as a rotational axis. The first screen region **101** and the second screen region **102** both include a part of a protective cover plate **11** and a part of a display screen **12**. In addition, a circuit board assembly **30** of the electronic device **100** includes a first board **31**, an elevating board **32**, a second board **33**, and a first conductive member **34**. The configuration manners for the first board **31**, the elevating board **32**, the second board **33**, and the first conductive member **34** may refer to the configuration manners for the first board **31**, the elevating board **32**, the second board **33**, and the first conductive member **34** in the first embodiment. which are not described herein again. In this embodiment, the first conductive member **34** is described using a first elastic piece **34** as an example.

In addition, the distance from the contact point between the first conductive member **34** and the radiator **41** to the first screen region **101** is a first distance L**1**. The distance from the contact point between the first conductive member **34** and the radiator **41** to the second screen region **102** is a second distance L**2**, and the ratio of the first distance L**1** to the second distance L**2** ranges from 0.5 to 2. For example, the ratio of the first distance L**1** to the second distance L**2** is 0.5, 0.8, 1, 1.4, 1.5, 1.8, or 2.

It may be understood that, when the first elastic piece **34** is fixed to the second board **33**, in the Z-axis direction, the distance between the first elastic piece **34** and the first screen region **101** is small, that is, the first elastic piece **34** is disposed close to the first screen region **101**. In this implementation, when the first elastic piece **34** is fixedly connected to the first extension portion **312**, and the ratio of the first distance L**1** to the second distance L**2** ranges from 0.5 to 2, in the Z-axis direction, the distance between the first elastic piece **34** and the first screen region **101** is greatly increased. In this way, in the Z-axis direction, the antenna clearance area between the first elastic piece **34** and the first screen region **101** is greatly increased, and the performance of the antenna is also greatly improved. In addition, when the ratio of the first distance L**1** to the second distance L**2** ranges from 0.5 to 2, the distance from the contact point between the first conductive member **34** and the radiator **41** to the second screen region **102** is relatively moderate. In this case, the second screen region **102** has less influence on the performance of the antenna for transmitting and receiving the electromagnetic waves.

In an optional manner, the first distance L**1** from the contact point between the first conductive member **34** and the radiator **41** to the first screen region **101** is greater than or equal to 2 mm. For example, L**1** equals 2 mm, 2.5 mm, 3 mm, 3.5 mm or 4 mm.

It may be understood that, when the first distance L**1** from the contact point between the first conductive member **34** and the radiator **41** to the first screen region **101** is greater than or equal to 2 mm, the first elastic piece **34** can be disposed away from the first screen region **101** to a greater extent. In this case, in the Z-axis direction, the protrusion **411** can also be disposed away from the first screen region **101** to a greater extent, so that the antenna clearance area between the bottom of the protrusion **411** and the first screen region **101** is greatly increased, and the performance of the antenna is also better.

In addition, the first distance L**1** from the contact point between the first conductive member **34** and the radiator **41** to the first screen region **101** is less than or equal to 4.7 mm.

It may be understood that, when the first distance L**1** from the contact point between the first conductive member **34** and the radiator **41** to the first screen region **101** is less than or equal to 4.7 mm, on the one hand, it can be ensured that the first elastic piece **34** is disposed away from the first screen region **101**; and on the other hand, it can be ensured that the thickness of the electronic device **100** in the Z-axis direction is not great, which facilitates thinning of the electronic device **100**.

It may be understood that, FIG. **40** shows only one structure of the circuit board assembly **30**. In another optional manner, the electronic device **100** with a curved screen may also include various structures of the circuit board assembly **30** in the first embodiment.

Embodiments of three electronic devices **100** are described above in detail. Among the three electronic devices **100**, each of the electronic devices **100** is provided with the circuit board assembly **30** of each of the foregoing optional manners. In this way, in an environment where the antenna arrangement is tight, the antenna of the electronic device **100** has a wide clearance area, thereby significantly improving the antenna performance of the electronic device **100**. In another embodiment, the circuit board assembly **30** of each of the foregoing optional manners may also be disposed in an electronic device with a folding screen. In this way, in the electronic device with a folding screen, the electronic device can also have a wide clearance area for antenna in an environment where the antenna arrangement is tight, thereby significantly improving the antenna performance of the electronic device **100**.

The foregoing descriptions are merely specific implementations of this application, but are not intended to limit the protection scope of this application. Any variation or

replacement readily figured out by a person skilled in the art within the technical scope disclosed in this application shall fall within the protection scope of this application. Therefore, the protection scope of this application shall be subject to the protection scope of the claims.

What is claimed is:

1. An electronic device, comprising a frame, a screen, and a circuit board assembly; wherein

the screen is mounted on one side of the frame, and a part of the frame forms a radiator of an antenna or the radiator of the antenna is fixed on an inner side of the frame; and

the circuit board assembly is located on the inner side of the frame, the circuit board assembly comprises a first conductive member, a first board, an elevating board, and a second board, with the first board, the elevating board, and the second board being sequentially stacked, the first board is located on one side of the second board away from the screen, the first board comprises a first main body portion and a first extension portion connected to the first main body portion, the first main body portion is fixedly connected to the elevating board, the first extension portion protrudes relative to the elevating board and the second board, and is disposed close to the radiator, and the first conductive member is fixed to the first extension portion and is in elastic contact with the radiator;

the circuit board assembly further comprises a first strengthening board, and the first strengthening board is located on one side of the first conductive member, and is fixedly connected to a board surface of the first extension portion facing the screen.

2. The electronic device according to claim **1**, wherein the first strengthening board comprises a first portion and a second portion connected to the first portion, the first portion is fixedly connected to the board surface of the first extension portion facing the screen, the first portion is fixedly connected to the elevating board, the second portion is fixedly connected to the second board, and in a thickness direction of the electronic device, a thickness of the first strengthening board is greater than a thickness of the elevating board.

3. The electronic device according to claim **2**, wherein the first portion is provided with a first strengthening solder pad, the first extension portion is provided with a second strengthening solder pad, and the first strengthening solder pad is soldered to the second strengthening solder pad.

4. The electronic device according to claim **1**, wherein the circuit board assembly further comprises a second strengthening board, and the second strengthening board is located on one side of the first conductive member away from the first strengthening board, and is fixedly connected to the board surface of the first extension portion facing the screen.

5. The electronic device according to claim **4**, wherein the first extension portion is provided with a groove, the groove is located between the first strengthening board and the second strengthening board, an opening of the groove is located on a surface of the first extension portion facing the screen, and a part of the first conductive member is mounted in the groove.

6. The electronic device according to claim **1**, wherein the electronic device comprises a fastener, the radiator is provided with a blind hole, the fastener is fixed into the blind hole, and the first conductive member is in elastic contact with the fastener.

7. The electronic device according to claim **1**, wherein the radiator comprises an inner side surface facing the circuit board assembly, and the first conductive member is in elastic contact with the inner side surface.

8. The electronic device according to claim **1**, wherein the electronic device further comprises a middle plate, the middle plate is located on the inner side of the frame, the middle plate is grounded, the frame further comprises a connection segment, one end of the connection segment is connected to the radiator, and the other end is connected to the middle plate.

9. The electronic device according to claim **1**, wherein the electronic device further comprises a middle plate, the middle plate is grounded, the middle plate is located on the inner side of the frame, the circuit board assembly further comprises a second conductive member and a third conductive member, the second conductive member is fixed to the first extension portion of the first board, the second conductive member is in elastic contact with the radiator, the third conductive member is fixed to the second board, and the third conductive member is in elastic contact with the middle plate, and is electrically connected to the second conductive member.

10. The electronic device according to claim **1**, wherein the radiator comprises a protrusion facing an interior of the electronic device, the first conductive member is fixed to one side of the first extension portion facing the screen, the first conductive member is in elastic contact with the protrusion, the first conductive member is electrically connected between the radiator and a radio frequency path of the antenna, and the radio frequency path is mounted on the circuit board assembly;

the circuit board assembly further comprises a first strengthening board and a second strengthening board, the first strengthening board and the second strengthening board are respectively located on two sides of the first conductive member, and in a thickness direction of the electronic device, a thickness of the first strengthening board and a thickness of the second strengthening board are both greater than a thickness of the elevating board;

the first strengthening board comprises a first portion and a second portion connected to the first portion, the first portion is fixedly connected to a board surface of the first extension portion facing the screen, the first portion is fixedly connected to the elevating board, and the second portion is fixedly connected to the second board;

the second strengthening board comprises a third portion and a fourth portion connected to the third portion, the third portion is fixedly connected to the board surface of the first extension portion facing the screen, the third portion is fixedly connected to the elevating board, and the fourth portion is fixedly connected to the second board; and

the first portion, the third portion, and the elevating board are of an integrally formed structure, and the second portion, the fourth portion, and the second board are of an integrally formed structure.

11. An electronic device, comprising a frame, a screen, and a circuit board assembly; wherein

the screen is mounted on the frame and is disposed around the frame, and the screen comprises a first screen region and a second screen region disposed opposite to each other;

a part of the frame forms a radiator of an antenna, or the radiator of the antenna is fixed on an inner side of the frame;

the circuit board assembly is located on the inner side of the frame, the circuit board assembly comprises a first conductive member, a first board, an elevating board, and a second board with the first board, the elevating board, and the second board being sequentially stacked, the first board is disposed away from the first screen region relative to the second board, the first board comprises a first main body portion and a first extension portion connected to the first main body portion, the first main body portion is fixedly connected to the elevating board, the first extension portion protrudes relative to the elevating board and the second board, and is disposed close to the radiator, and the first conductive member is fixed to the first extension portion and is in elastic contact with the radiator; and

a distance from a contact point between the first conductive member and the radiator to the first screen region is a first distance, a distance from the contact point between the first conductive member and the radiator to the second screen region is a second distance, and a ratio of the first distance to the second distance ranges from 0.5 to 2.

12. The electronic device according to claim **11**, wherein the circuit board assembly further comprises a first strengthening board, the first strengthening board is located on one side of the first conductive member, and is fixedly connected to a board surface of the first extension portion facing the first screen region.

13. The electronic device according to claim **12**, wherein the circuit board assembly further comprises a second strengthening board, and the second strengthening board is located on one side of the first conductive member away from the first strengthening board, and is fixedly connected to the board surface of the first extension portion facing the first screen region.

14. The electronic device according to claim **11**, wherein the radiator comprises an inner side surface facing the circuit board assembly, and the first conductive member is in elastic contact with the inner side surface.

15. The electronic device according to claim **1**, wherein the first portion and the elevating board are of an integrally formed structure, and the second portion and the second board are of an integrally formed structure.

16. The electronic device according to claim **4**, wherein the second strengthening board comprises a third portion and a fourth portion connected to the third portion, the third portion is fixedly connected to the board surface of the first extension portion facing the screen, the third portion is fixedly connected to the elevating board, the fourth portion is fixedly connected to the second board, and in a thickness direction of the electronic device, a thickness of the second strengthening board is greater than a thickness of the elevating board.

17. The electronic device according to claim **16**, wherein the third portion and the elevating board are of an integrally formed structure, and the fourth portion and the second board are of an integrally formed structure.

18. The electronic device according to claim **1**, wherein a conductive piece is disposed on a surface of the radiator facing the first conductive member, and the first conductive member is in elastic contact with the conductive piece.

* * * * *

US012237567B2

(12) **United States Patent**
Jung et al.

(10) **Patent No.: US 12,237,567 B2**
(45) **Date of Patent: Feb. 25, 2025**

(54) **ELECTRONIC DEVICE COMPRISING ANTENNA**

(71) Applicant: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

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(73) Assignee: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 259 days.

(21) Appl. No.: **18/067,119**

(22) Filed: **Dec. 16, 2022**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. PCT/KR2022/004311, filed on Mar. 28, 2022.

(30) **Foreign Application Priority Data**

Mar. 30, 2021 (KR) 10-2021-0041144

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 3/12 (2006.01)
H01Q 5/314 (2015.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 3/12*** (2013.01); ***H01Q 5/314*** (2015.01)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 5/314; H01Q 3/12
See application file for complete search history.

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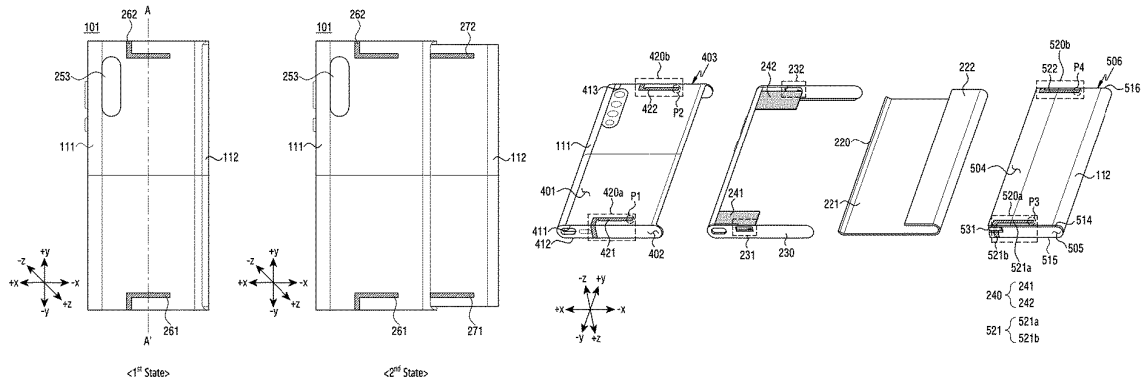
Primary Examiner — Henry Luong
(74) *Attorney, Agent, or Firm* — Nixon & Vanderhye, P.C.

(57) **ABSTRACT**

According to various embodiments of the disclosure, an electronic device may include: a first housing, a second housing, a printed circuit board (PCB), and a wireless communication circuit, wherein the first housing may include a first surface and a second surface perpendicular to the first surface at a first edge, and a first conductive area, and the first conductive area may include a first portion of a first slit extending from a point on the first surface to the first edge, a third surface of the second housing may include a second conductive area, and the second conductive area may include a second slit, wherein, in a first state, at least a portion of the first portion of the first slit may overlap the second slit when viewed in a second direction perpendicular to the first surface of the first housing, and wherein the wireless communication circuit may be configured to trans-
(Continued)



mit and/or receive a signal of a first frequency band based on an electrical path including the first portion.

20 Claims, 24 Drawing Sheets

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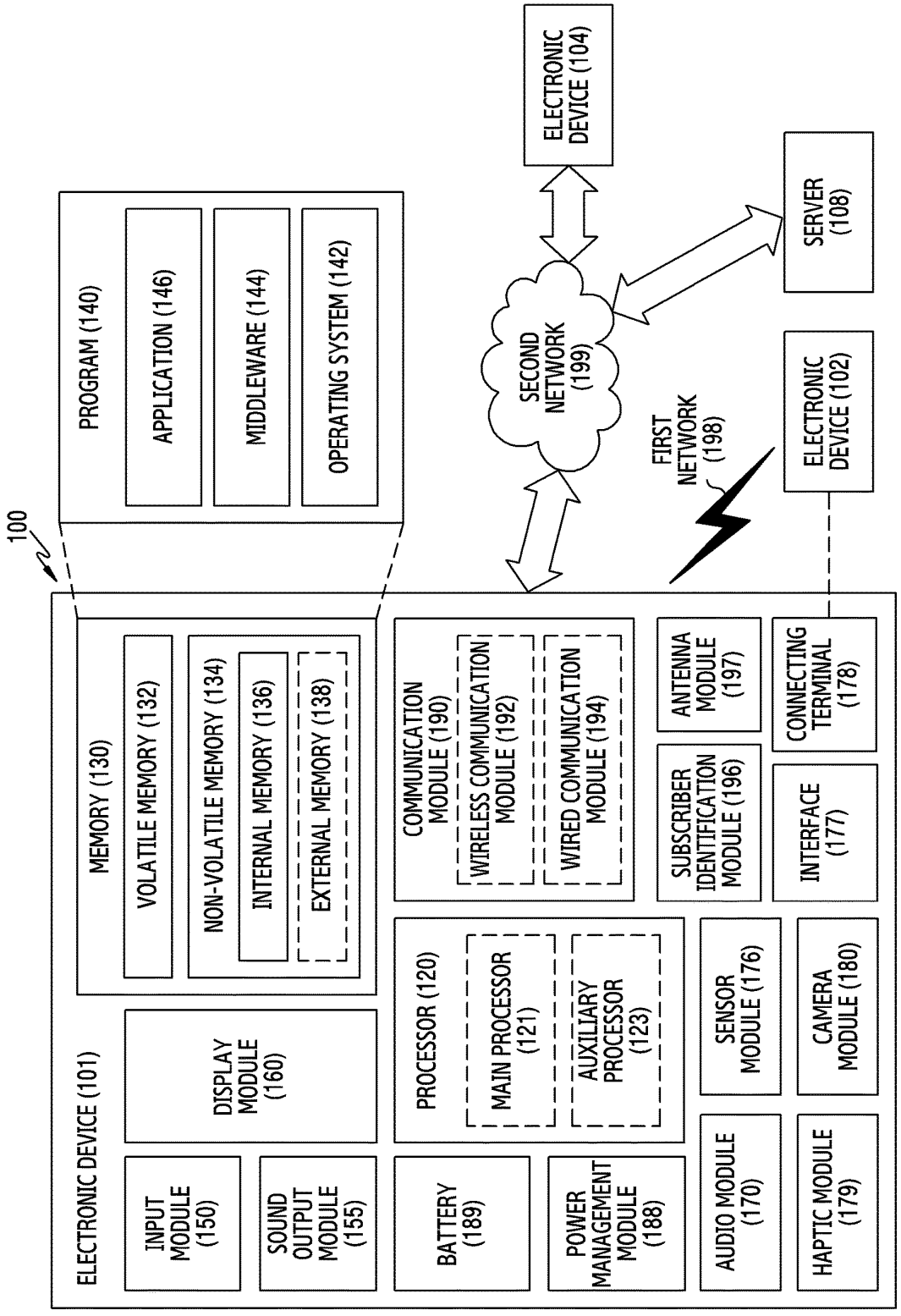
100
ELECTRONIC DEVICE (101)
INPUT MODULE (150)
SOUND OUTPUT MODULE (155)
DISPLAY MODULE (160)
MEMORY (130)
VOLATILE MEMORY (132)
NON-VOLATILE MEMORY (134)
INTERNAL MEMORY (136)
EXTERNAL MEMORY (138)
PROGRAM (140)
APPLICATION (146)
MIDDLEWARE (144)
OPERATING SYSTEM (142)
BATTERY (189)
POWER MANAGEMENT MODULE (188)
PROCESSOR (120)
MAIN PROCESSOR (121)
AUXILIARY PROCESSOR (123)
AUDIO MODULE (170)
SENSOR MODULE (176)
HAPTIC MODULE (179)
CAMERA MODULE (180)
COMMUNICATION MODULE (190)
WIRELESS COMMUNICATION MODULE (192)
WIRED COMMUNICATION MODULE (194)
SUBSCRIBER IDENTIFICATION MODULE (196)
ANTENNA MODULE (197)
INTERFACE (177)
CONNECTING TERMINAL (178)
FIRST NETWORK (198)
SECOND NETWORK (199)
ELECTRONIC DEVICE (104)
SERVER (108)
ELECTRONIC DEVICE (102)

FIG. 1

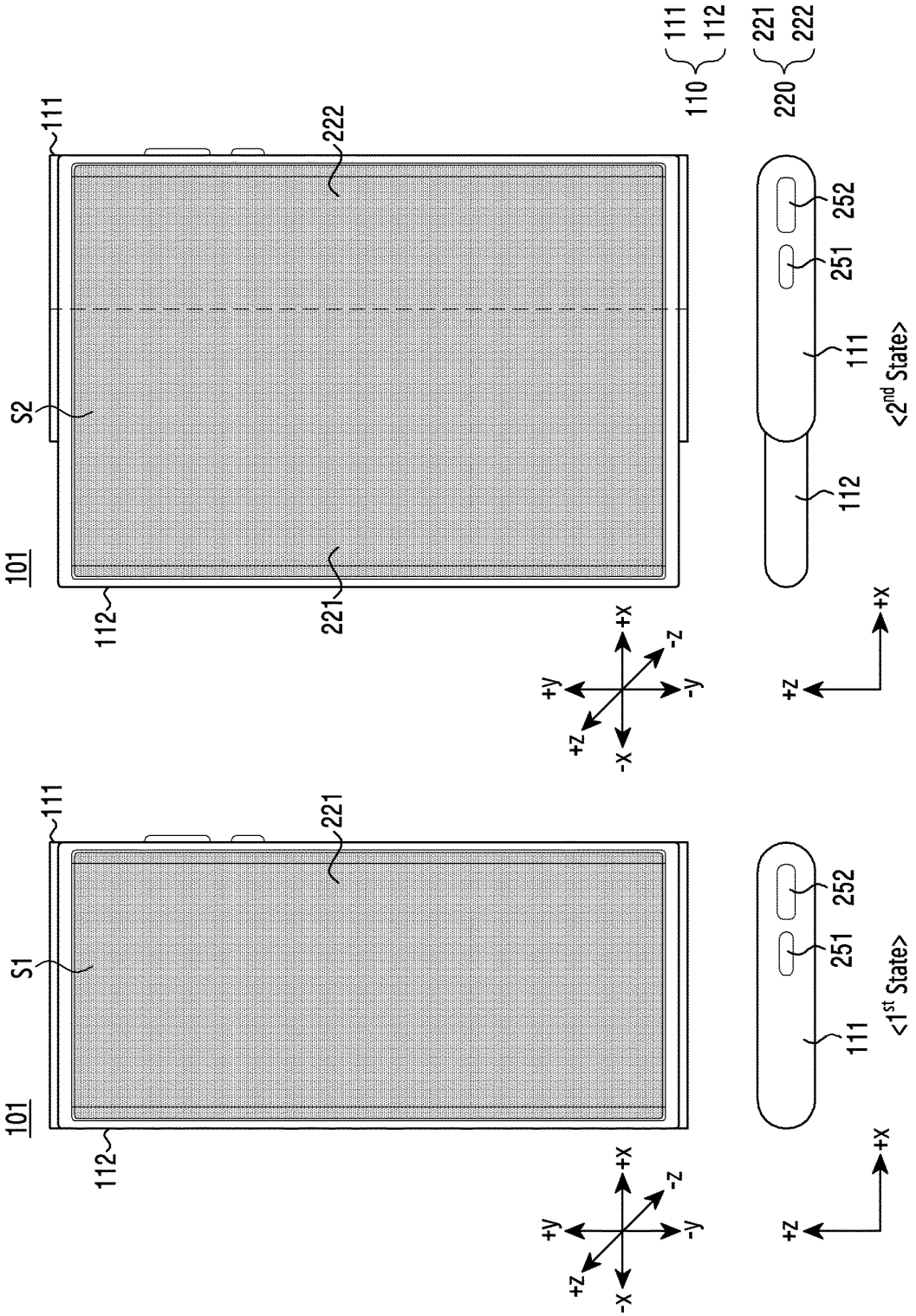
111
222
S2
101
112
221
110
111
112
220
221
222
252
251
111
<2nd State>
112
+x
+z
+y
-z
-y
-x
111
221
S1
101
112
252
251
111
<1st State>

FIG.2A

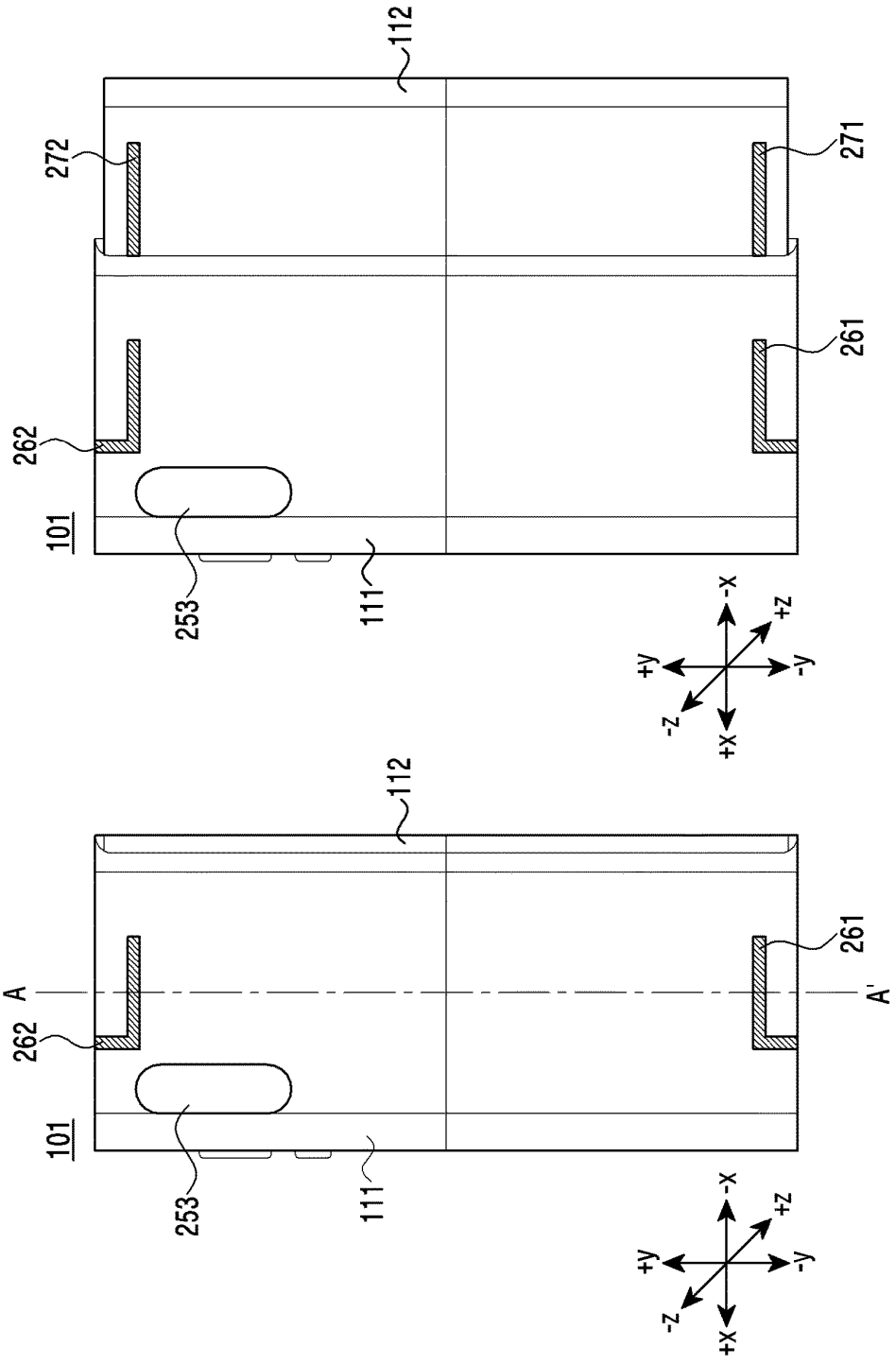
112
272
271
261
262
101
253
111
-x
+z
+y
-y
-z
+x
<2nd State>
112
261
A
A'
262
101
253
111
-x
+z
+y
-y
-z
+x
<1st State>

FIG.2B

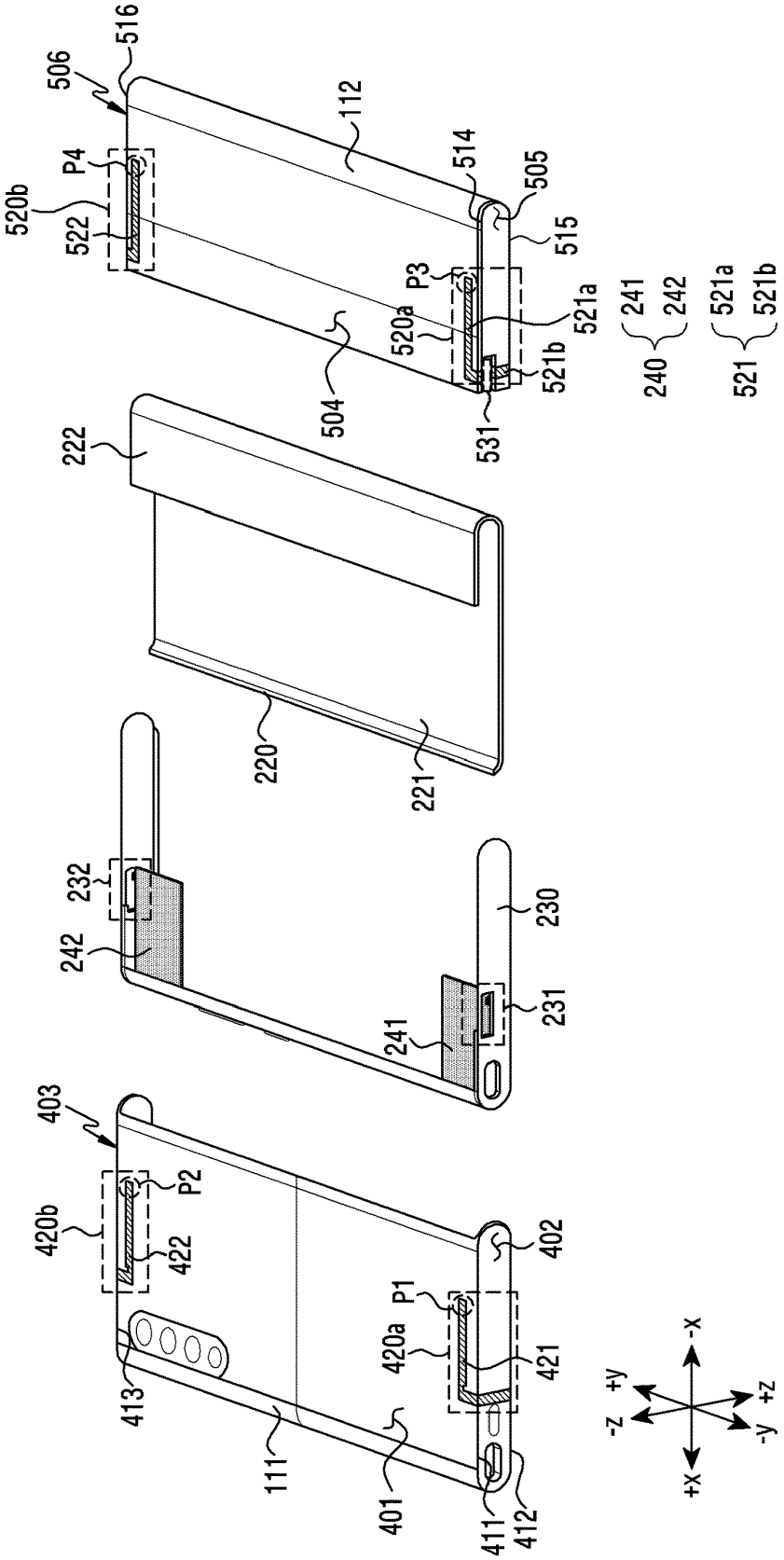
516
506
112
P4
520b
522
514
505
515
P3
520a
521a
521b
504
531
241
242
240
521a
521b
521
222
220
221
232
242
230
231
241
403
P2
420b
422
402
P1
420a
421
413
111
401
411
412
-z +y
-x
+x
-y +z

FIG.3

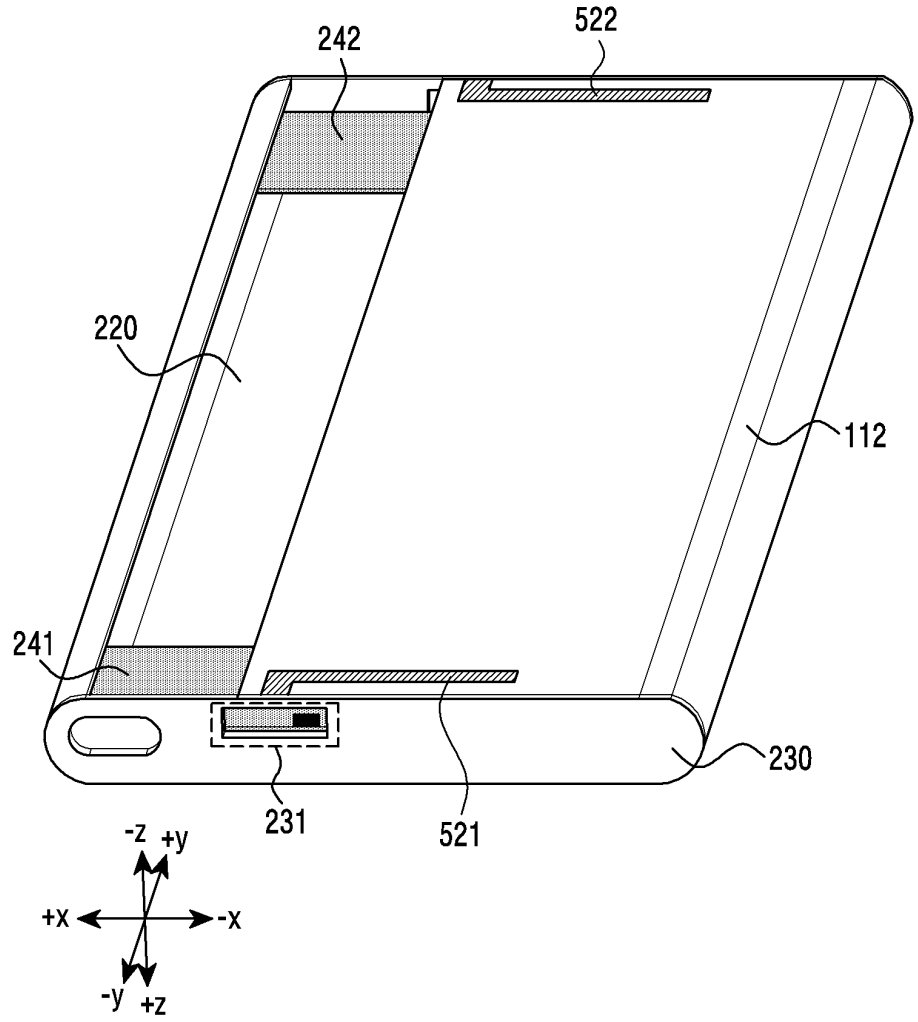

FIG.4

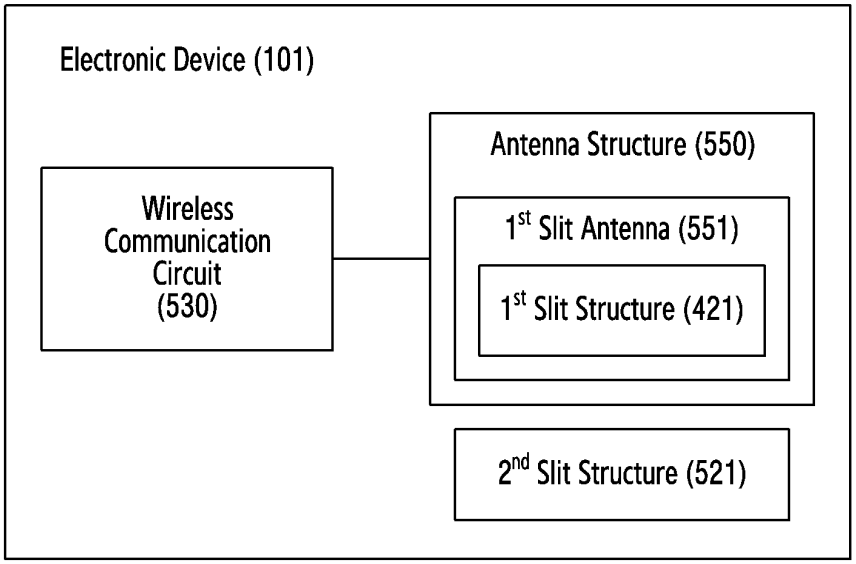
Electronic Device (101)
Antenna Structure (550)
Wireless Communication Circuit (530)
1st Slit Antenna (551)
1st Slit Structure (421)
2nd Slit Structure (521)

FIG.5

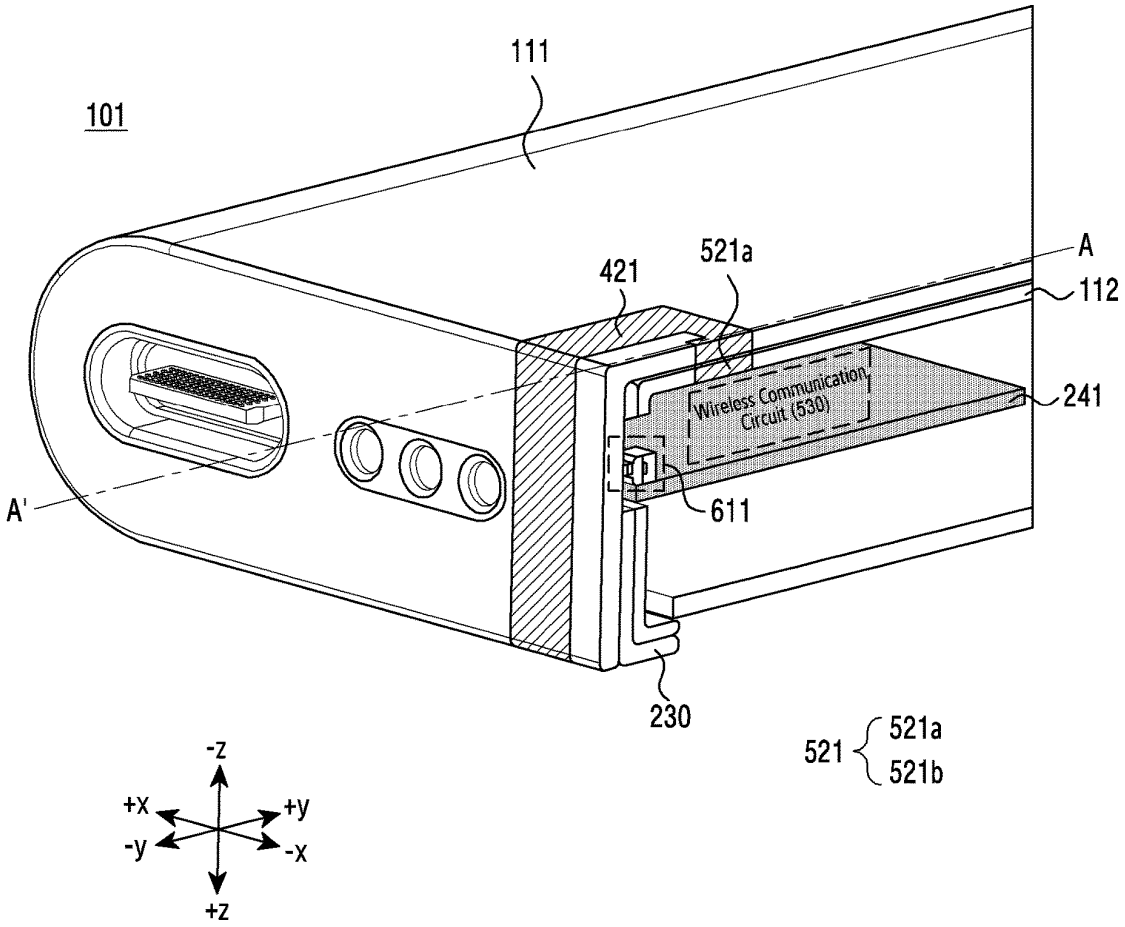
101
111
421
521a
A
112
241
Wireless Communication Circuit (530)
611
A'
230
521
521a
521b
-z
+x
+y
-y
-x
+z

FIG.6

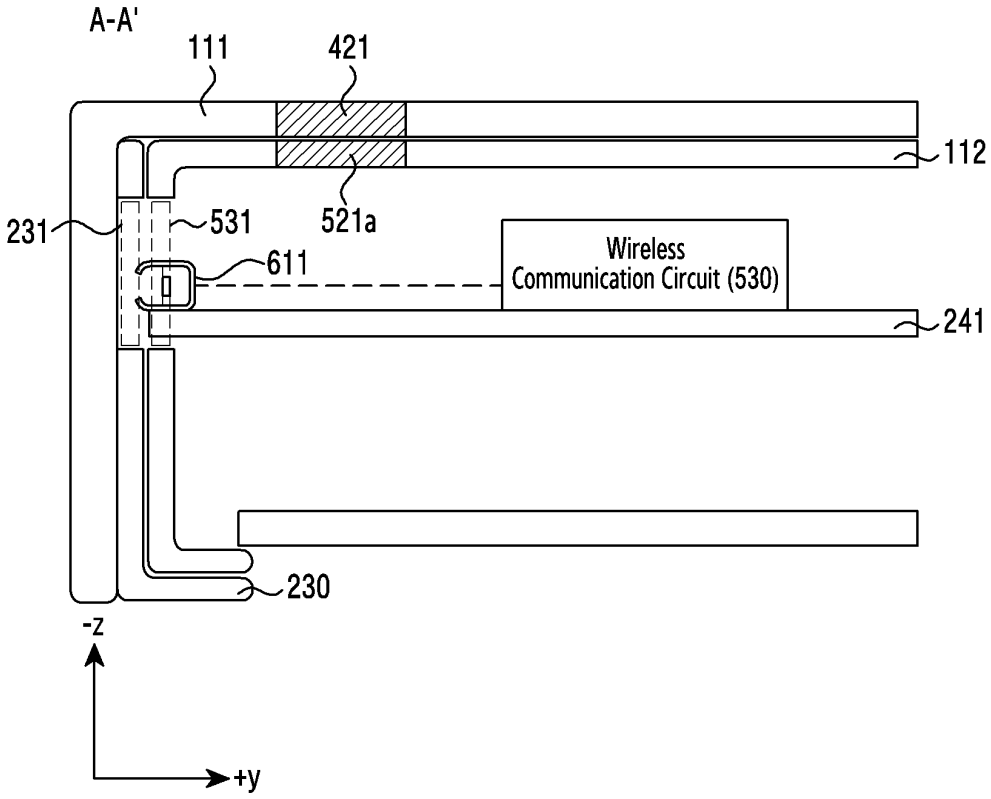
A-A'
111
421
112
231
531
521a
611
Wireless
Communication Circuit (530)
241
230
-z
+y

FIG.7

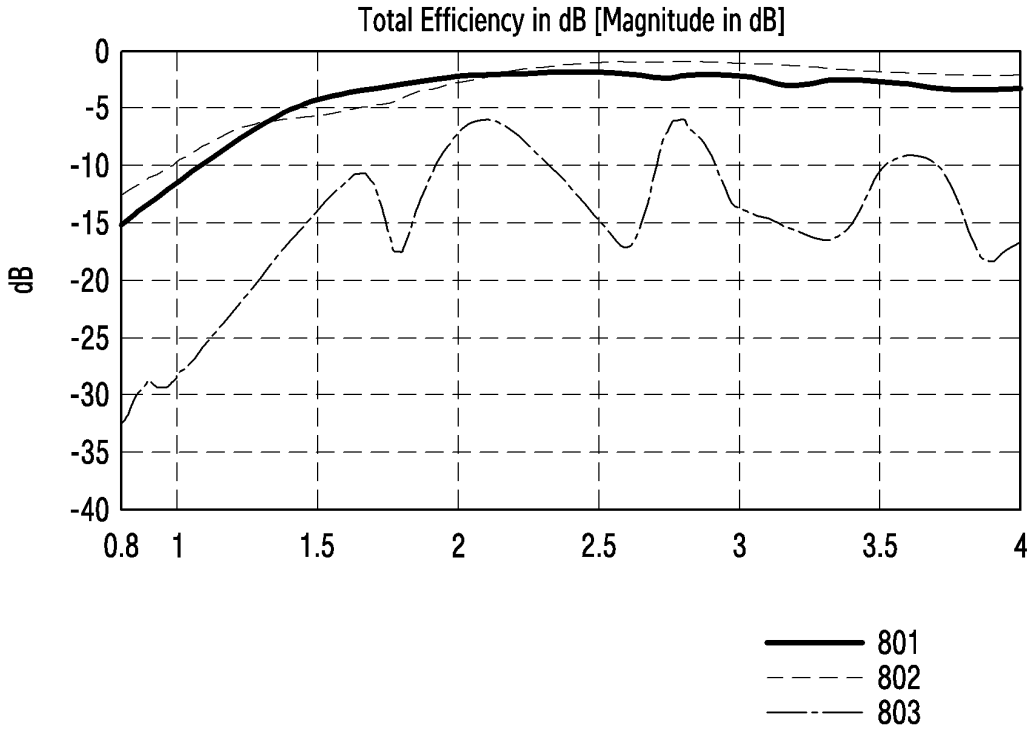
Total Efficiency in dB [Magnitude in dB]
dB
0
-5
-10
-15
-20
-25
-30
-35
-40
0.8
1
1.5
2
2.5
3
3.5
4
801
802
803

FIG.8

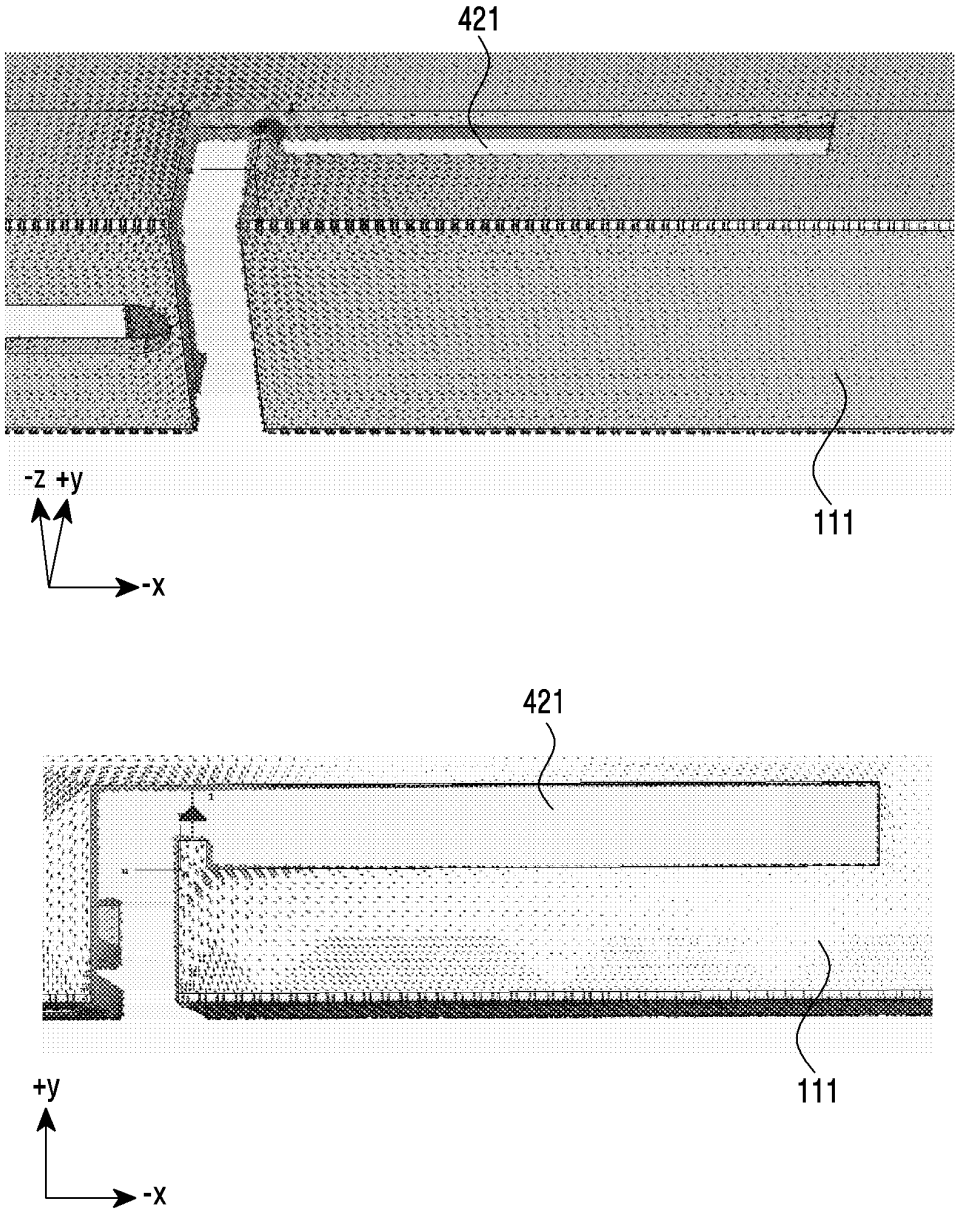

FIG.9

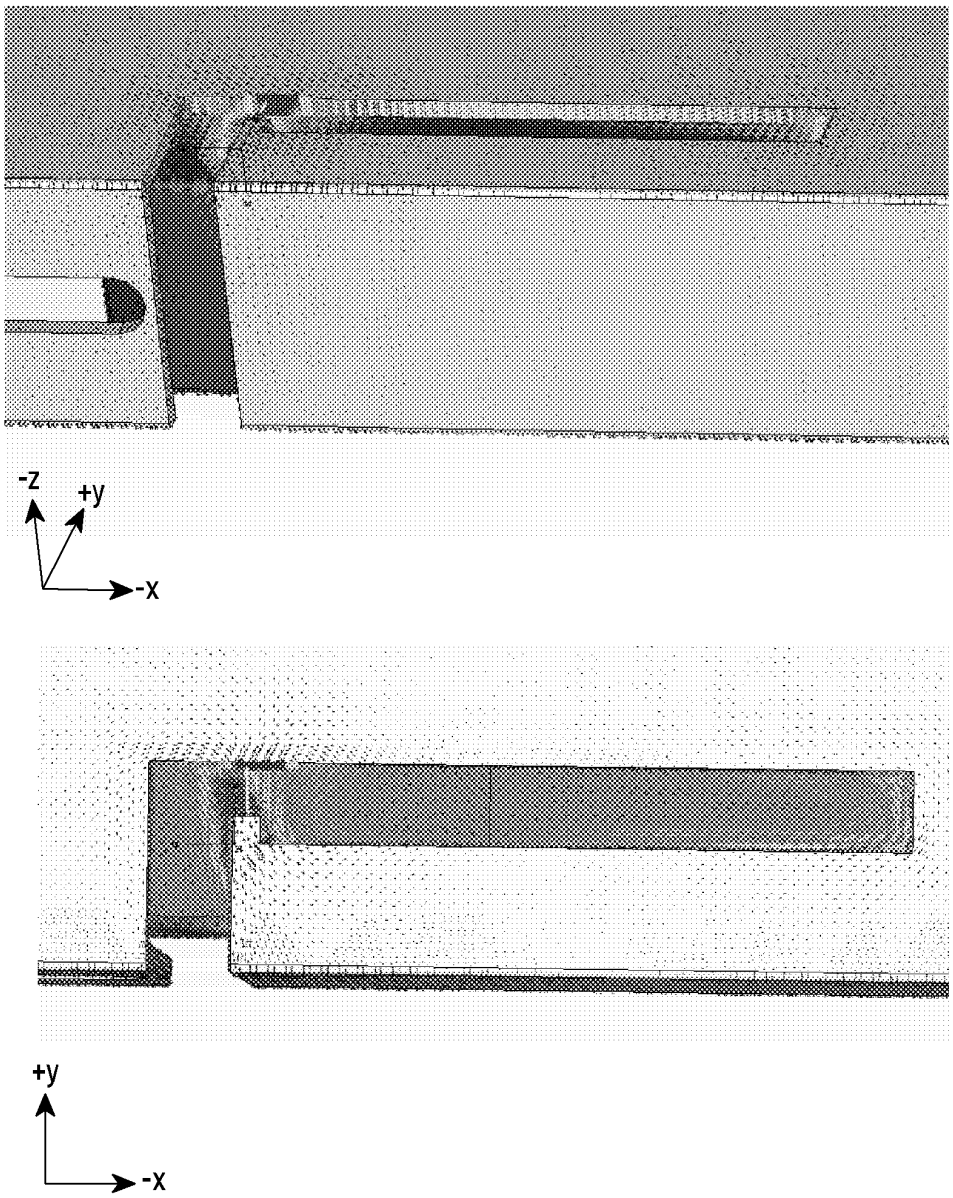

FIG.10

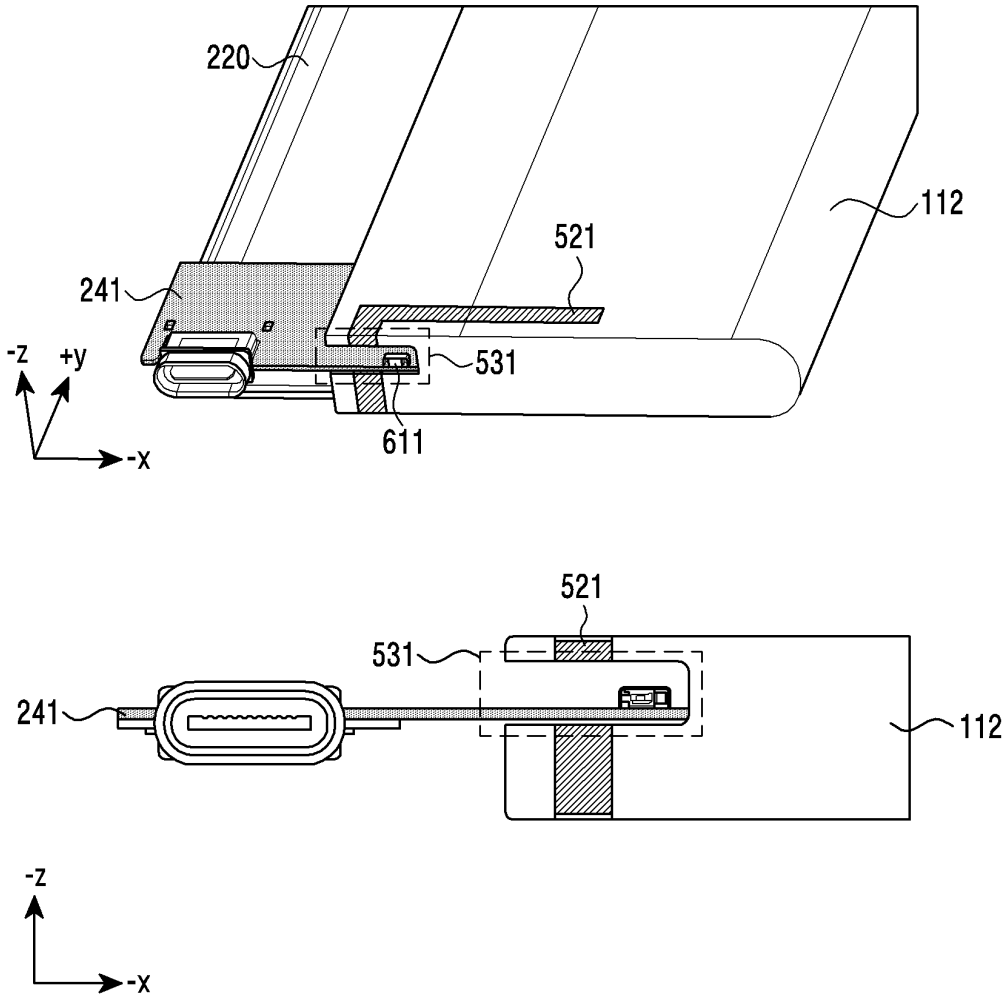

FIG.11

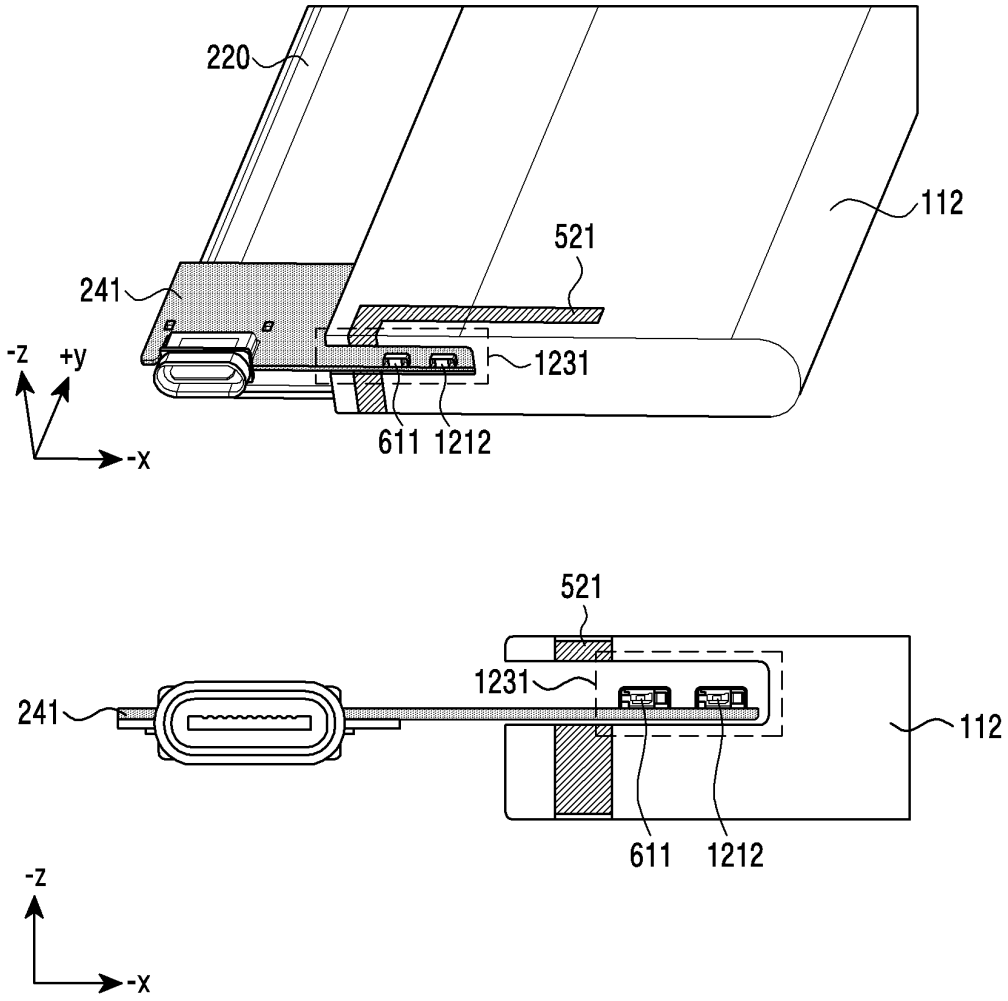

FIG.12

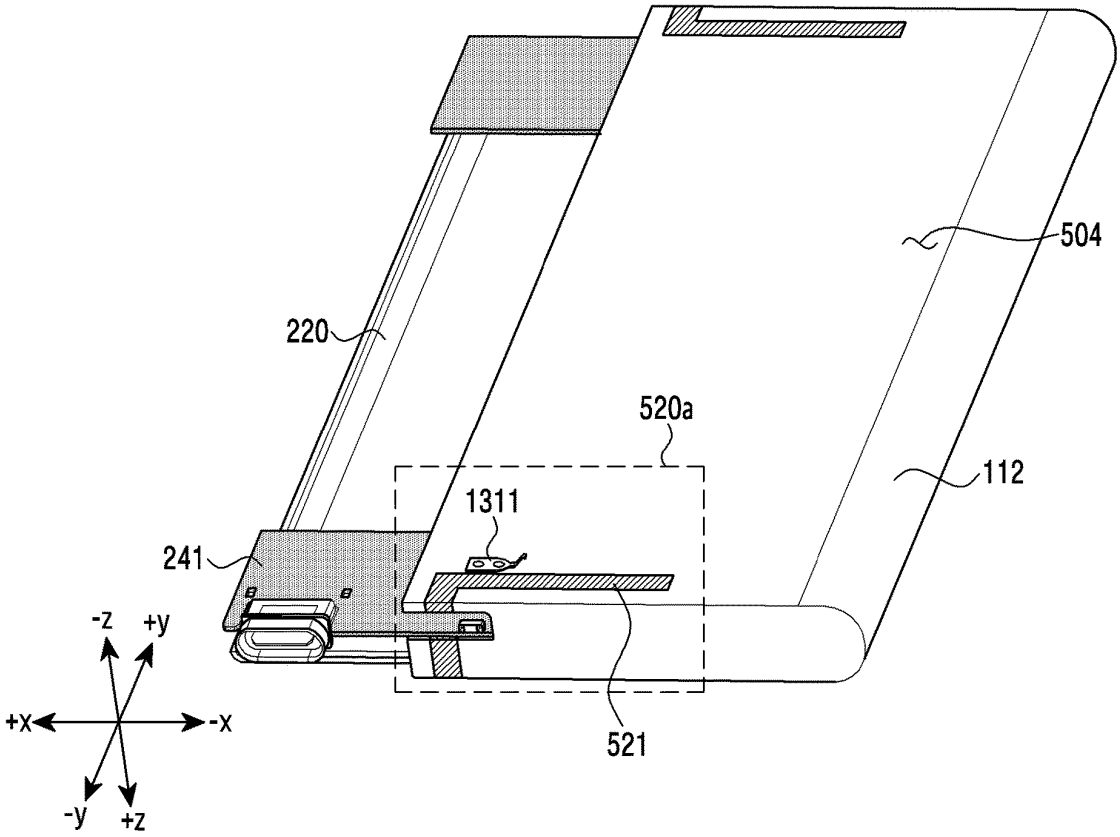

FIG.13

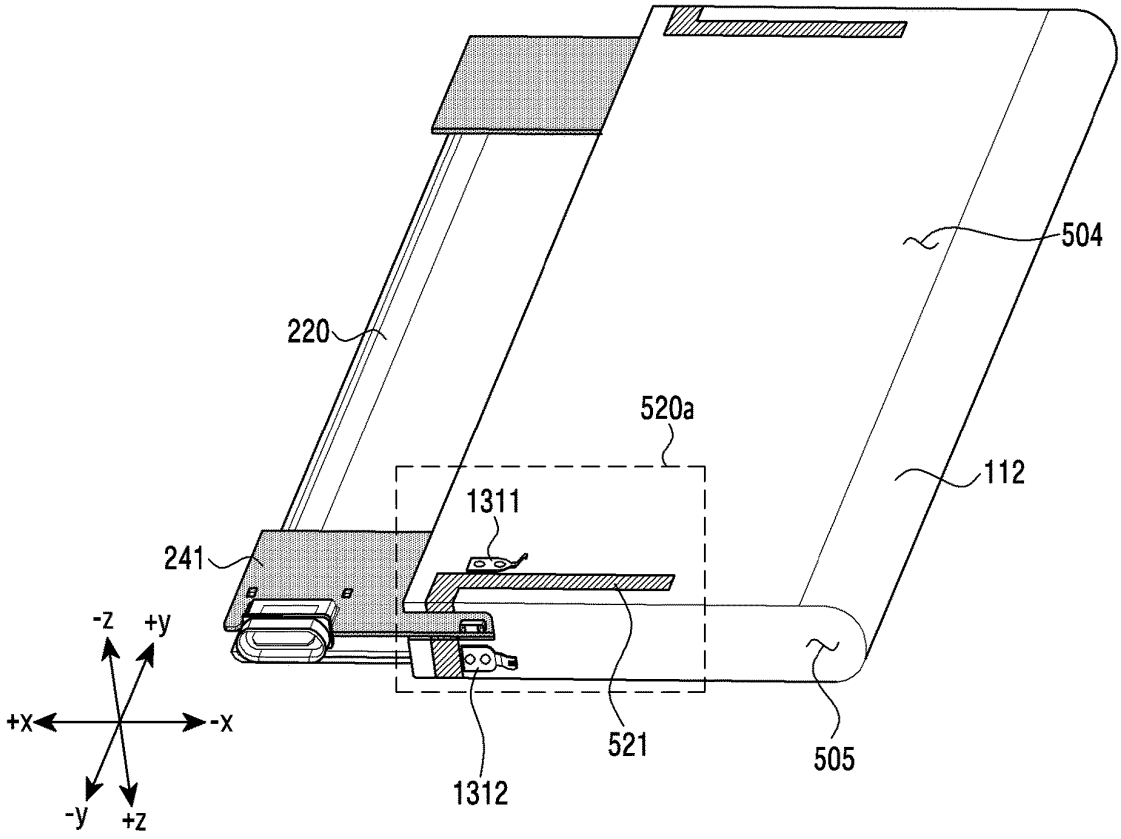

FIG.14

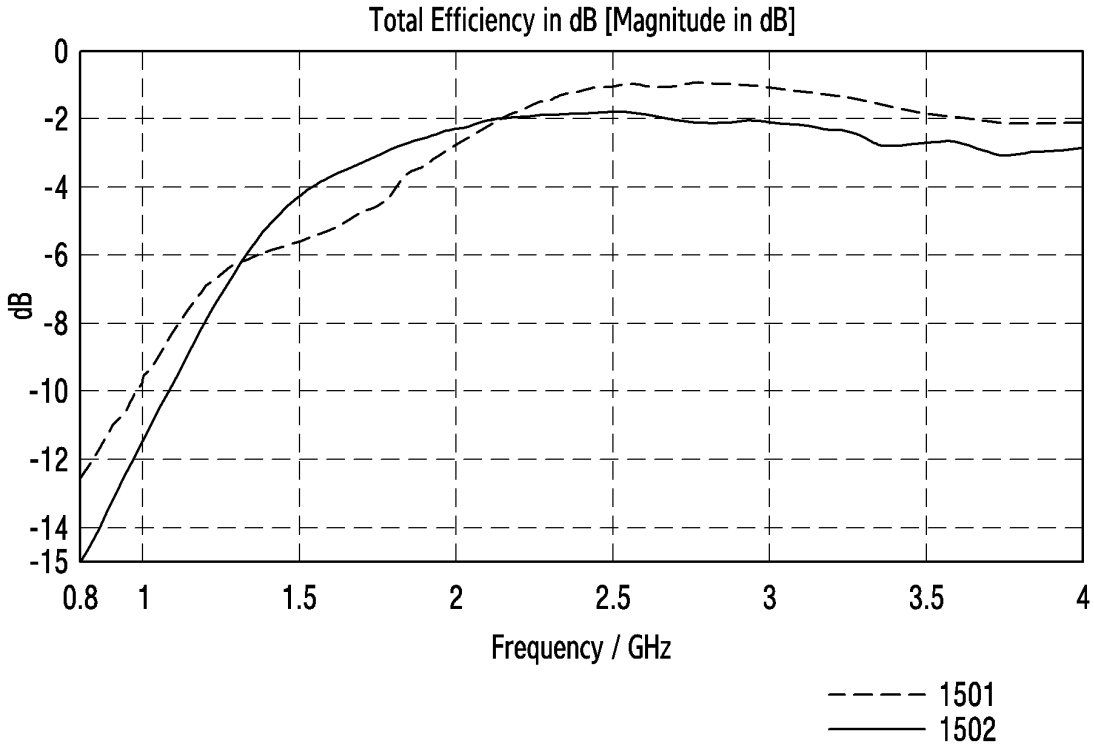
Total Efficiency in dB [Magnitude in dB]
0
-2
-4
-6
-8
-10
-12
-14
-15
dB
0.8
1
1.5
2
2.5
3
3.5
4
Frequency / GHz
1501
1502

FIG.15

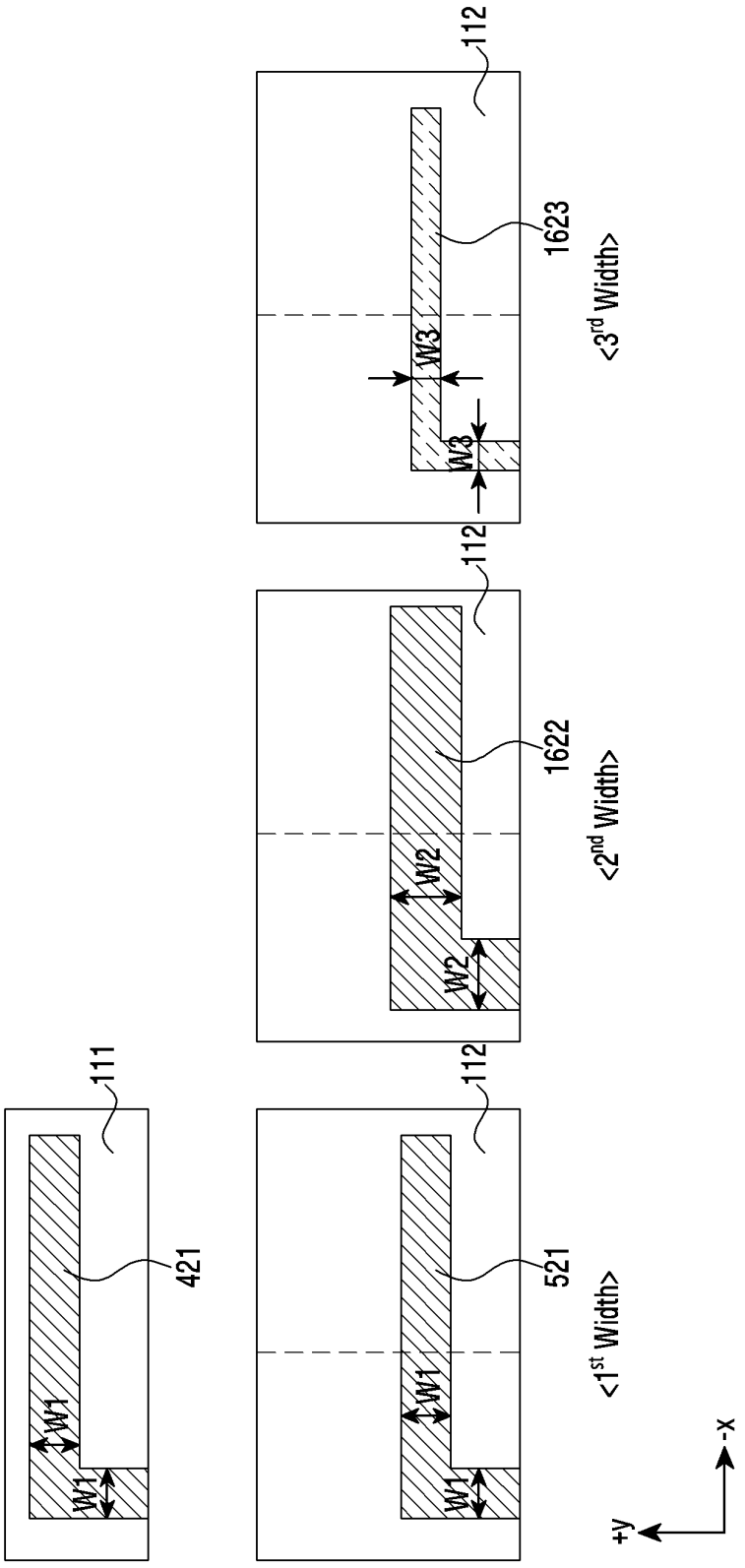
111
421
W1
W1
112
521
W1
W1
<1st Width>
112
1622
W2
W2
<2nd Width>
112
1623
W3
W3
<3rd Width>
+y
-x

FIG. 16

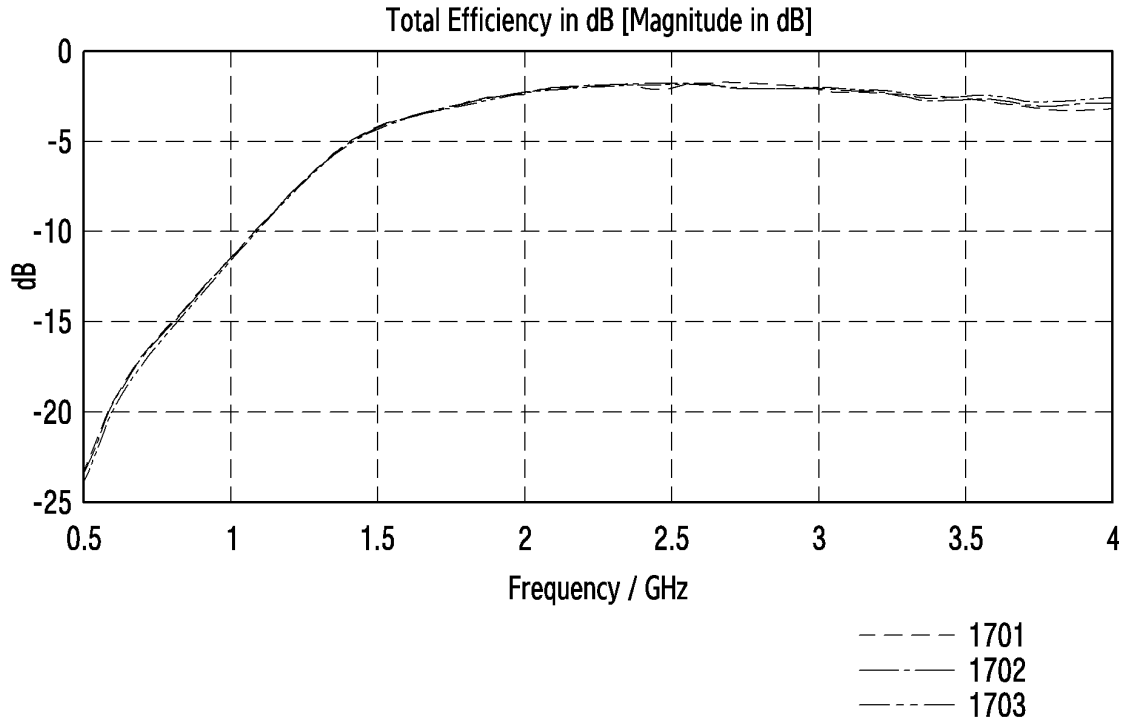
Total Efficiency in dB [Magnitude in dB]
0
-5
-10
-15
-20
-25
dB
0.5
1
1.5
2
2.5
3
3.5
4
Frequency / GHz
1701
1702
1703

FIG.17

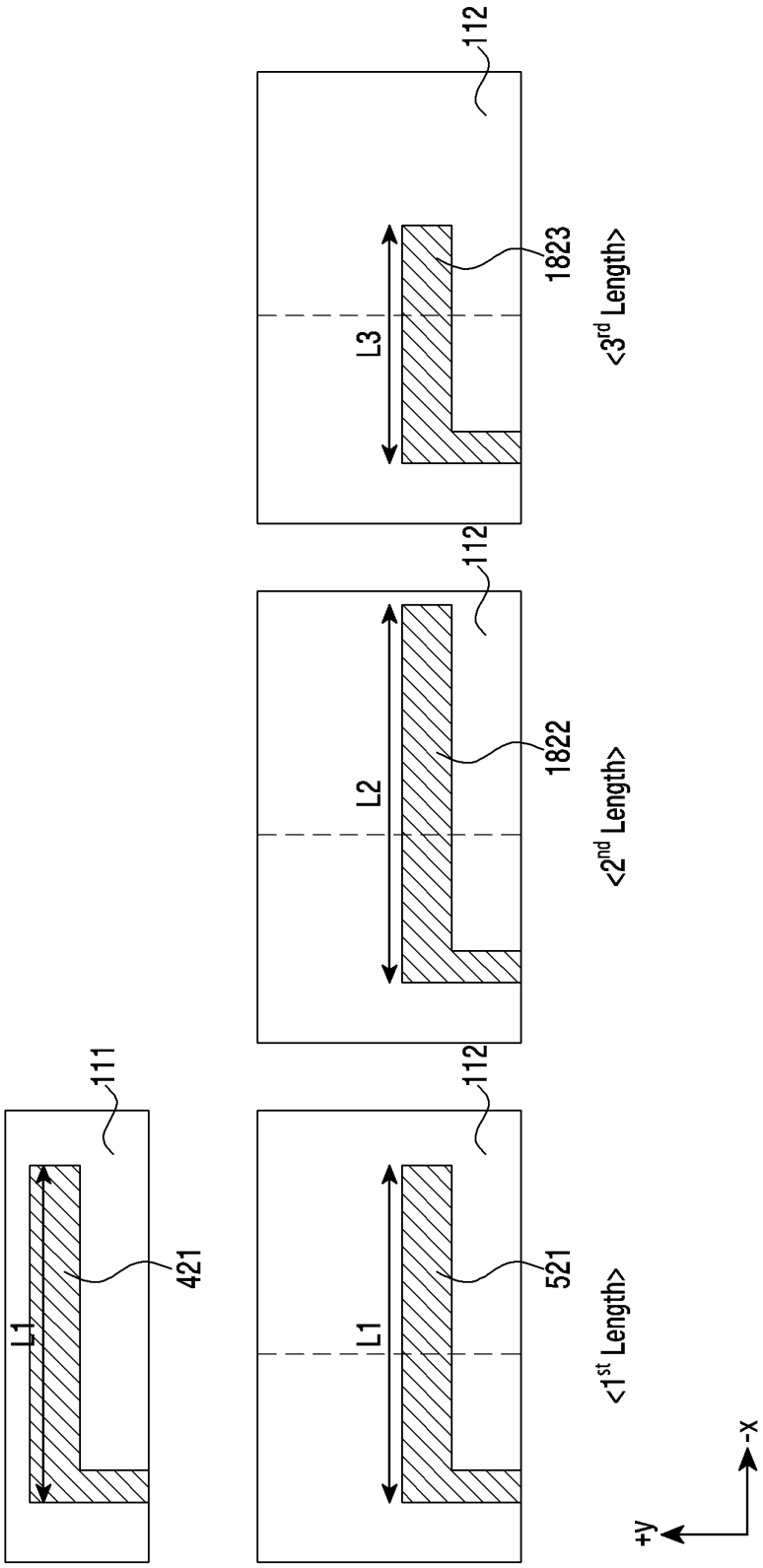
111
421
L1
112
521
L1
<1st Length>
112
1822
L2
<2nd Length>
112
1823
L3
<3rd Length>
+y
-x

FIG.18

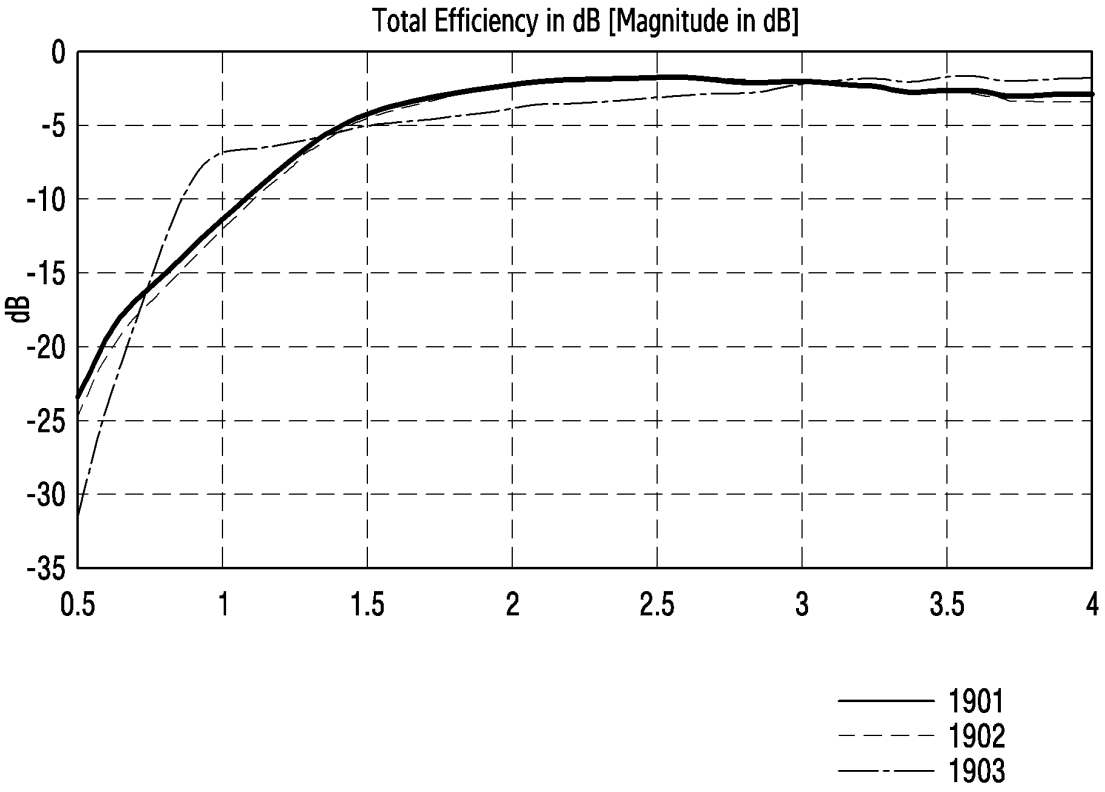
Total Efficiency in dB [Magnitude in dB]
0
-5
-10
-15
-20
-25
-30
-35
dB
0.5
1
1.5
2
2.5
3
3.5
4
1901
1902
1903

FIG.19

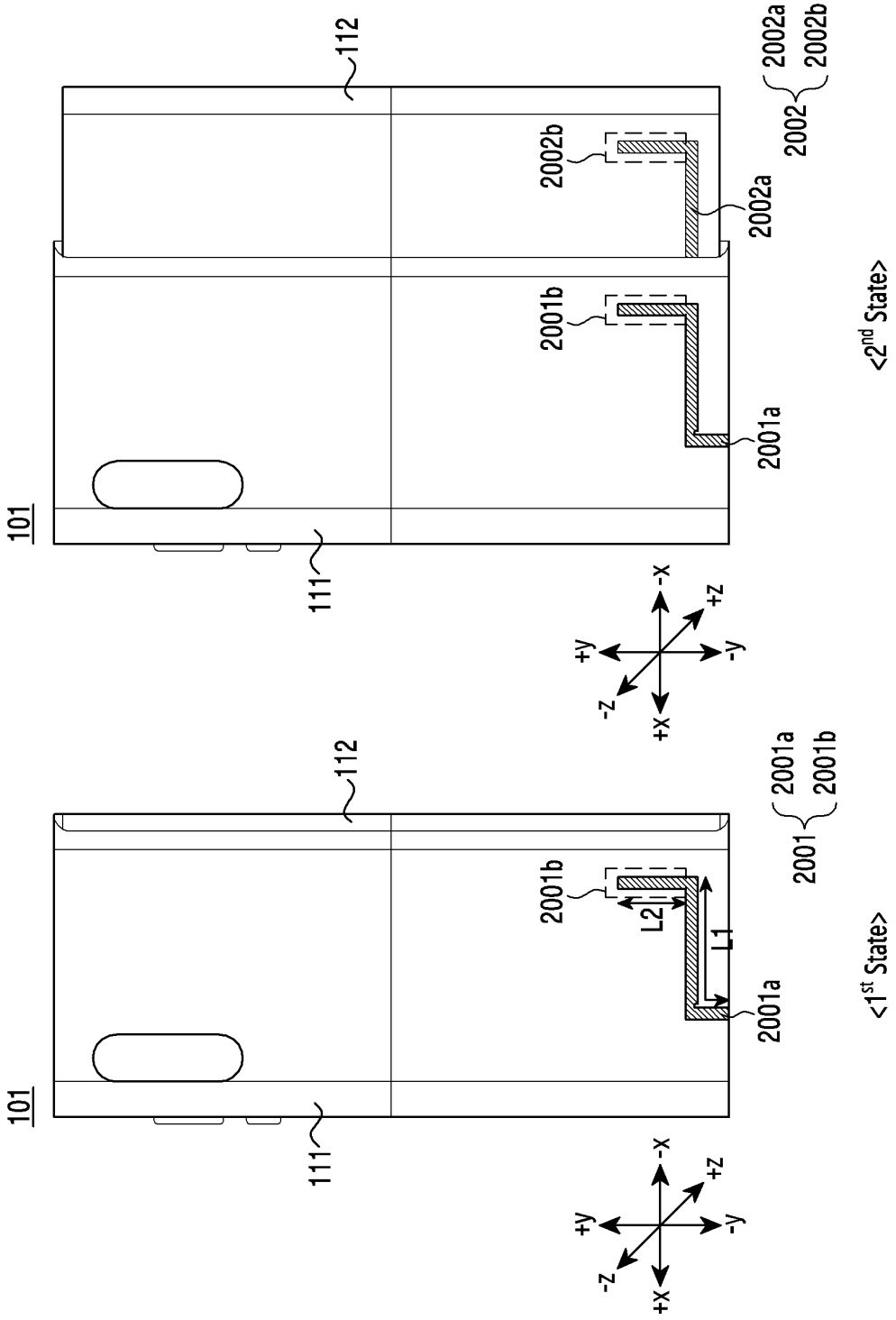
112
2002a
2002b
2002
2002b
2002a
2001b
2001a
101
111
-x
+z
+y
-y
-z
+x
<2nd State>
112
2001a
2001b
2001
2001b
L2
L1
2001a
101
111
-x
+z
+y
-y
-z
+x
<1st State>

FIG.20

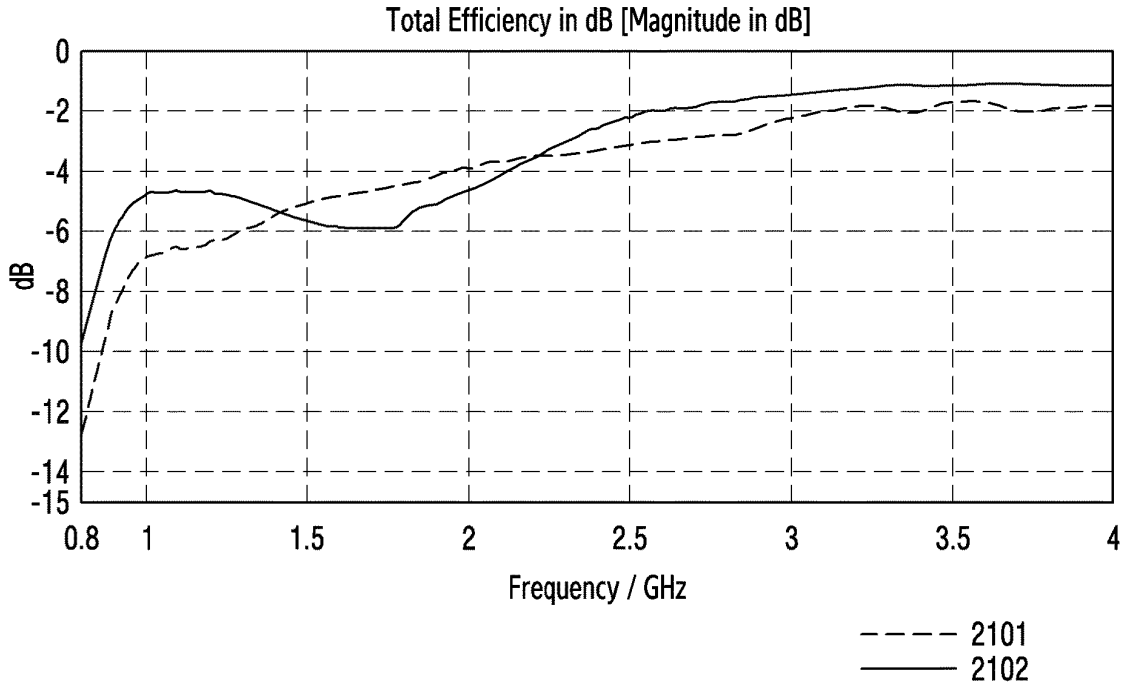
Total Efficiency in dB [Magnitude in dB]
0
-2
-4
-6
-8
-10
-12
-14
-15
dB
0.8
1
1.5
2
2.5
3
3.5
4
Frequency / GHz
2101
2102

FIG.21

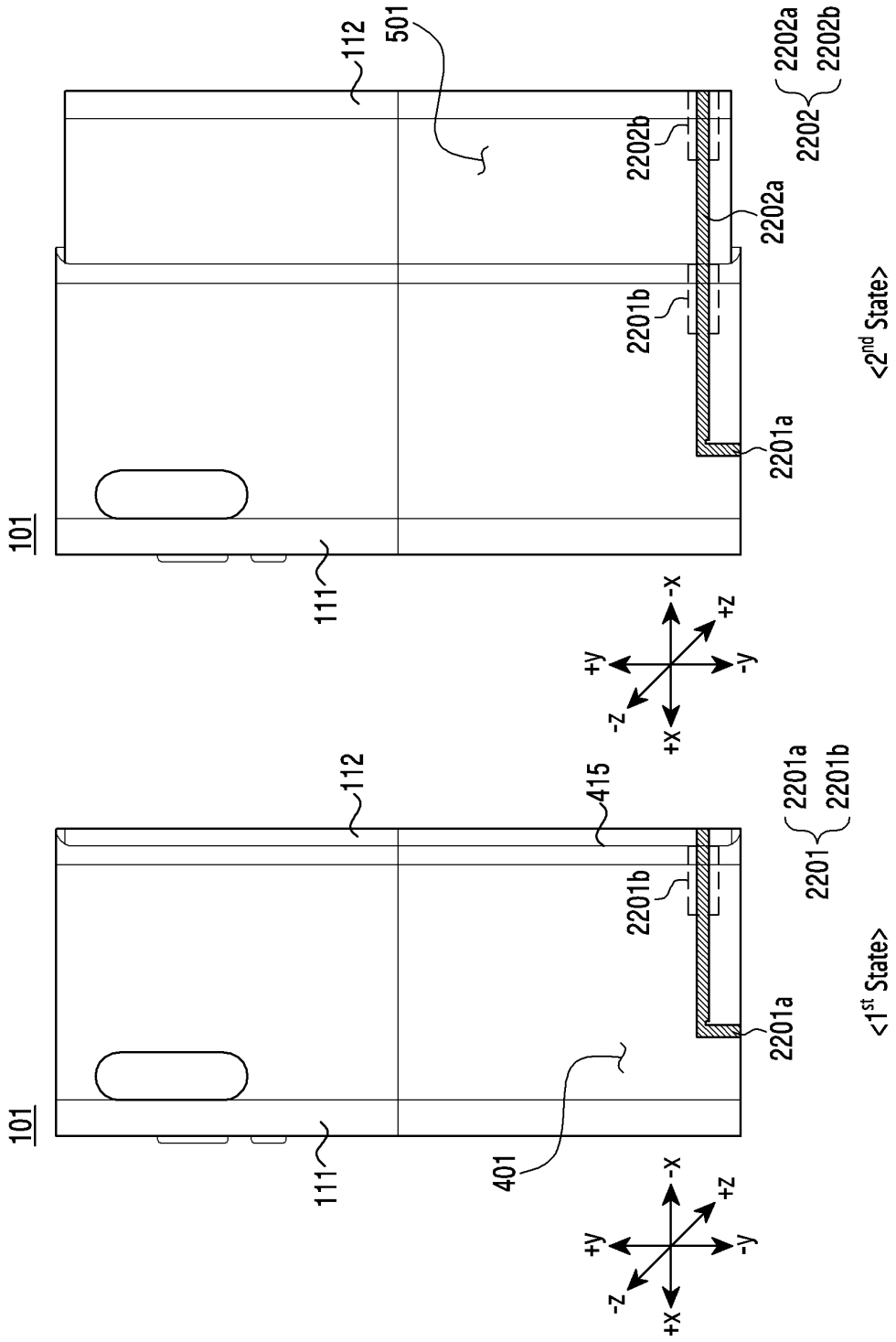
112
501
2202a
2202b
2202
2202b
2202a
2201b
2201a
101
111
<2nd State>
112
415
2201a
2201b
2201
2201b
2201a
101
111
401
<1st State>
-x
+z
+y
-y
-z
+x

FIG.22

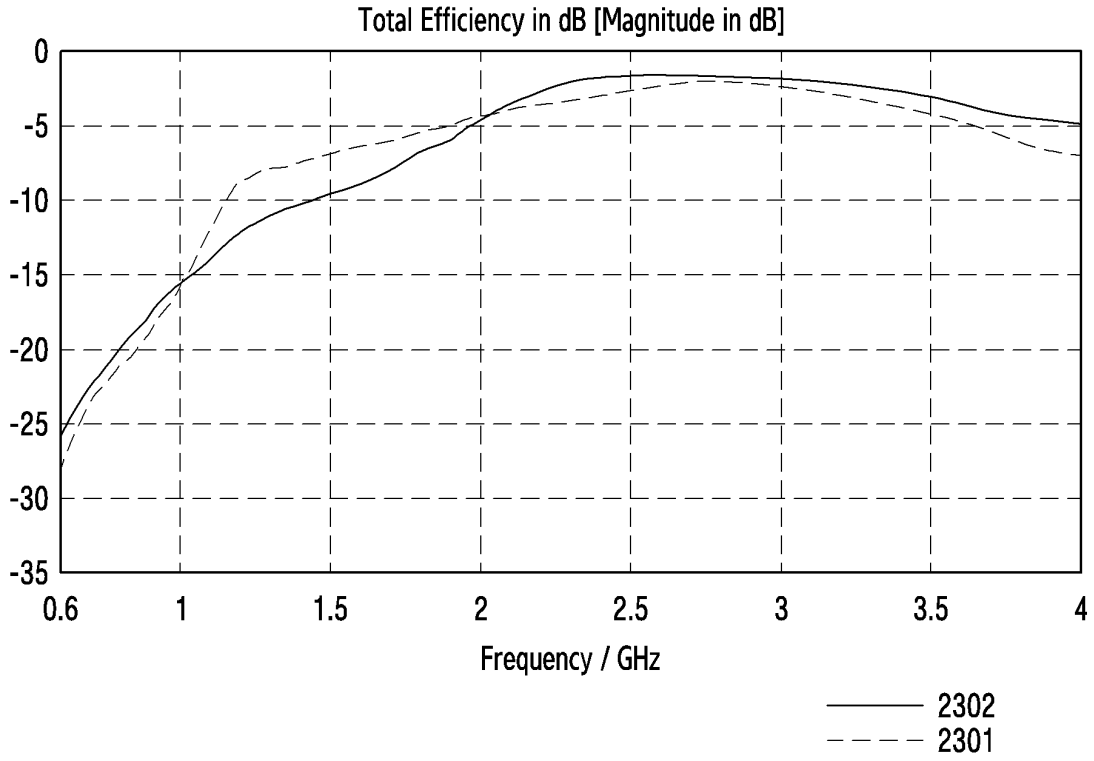
Total Efficiency in dB [Magnitude in dB]
0
-5
-10
-15
-20
-25
-30
-35
0.6
1
1.5
2
2.5
3
3.5
4
Frequency / GHz
2302
2301

FIG.23

ELECTRONIC DEVICE COMPRISING ANTENNA

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of International Application No. PCT/KR2022/004311 designating the United States, filed on Mar. 28, 2022, in the Korean Intellectual Property Receiving Office and claiming priority to Korean Patent Application No. 10-2021-0041144, filed on Mar. 30, 2021, in the Korean Intellectual Property Office, the disclosures of which are incorporated by reference herein in their entireties.

BACKGROUND

Field

Embodiments of the disclosure relate to an electronic device including an antenna.

Description of Related Art

An electronic device may include a display having a larger area to provide a wide screen. However, since the size of the electronic device also increases as the size of the display increases, there may be a limit to the size of the display. In order to overcome this limitation, a rollable electronic device as a next-generation display device may include a flexible display. The flexible display may be selectively slid into the housing, whereby the flexible display may have a large area for providing a large screen while maintaining the size of the electronic device.

An electronic device having a communication function may include a plurality of antennas in order to provide mobile communication services of different frequency bands using a single electronic device while being reduced in size and weight. For example, a multi-input multi-output (MIMO) technique is defined in IEEE 802.11n, IEEE 802.11ac, and IEEE 802.11ax standards, and MIMO antennas related to 2G, 3G, 4G, and 5G may be included in an electronic device.

A rollable electronic device may include a first housing and a second housing slidably connected to the first housing. In a first state, the second housing may overlap the first housing, and at least a portion of the second housing may be slid into 5 the first housing. The first housing may include a first conductive area, and at least a portion of the first conductive area may operate as a radiator of an antenna. The second housing may include a second conductive area. The antenna may have to secure a separation distance greater than or equal to a specific distance from the second conductive area in order to secure the performance thereof. However, in the first state, as the second housing is slid into the first housing, the antenna including at least a portion of the first conductive area may be located adjacent to the second conductive area. Accordingly, in the first state, it may be difficult for the antenna to secure the separation distance greater than or equal to the specific distance from the second conductive area, and the radiation performance of the antenna may be degraded.

SUMMARY

Embodiments of the disclosure provide an electronic device having a second housing that may include a slit structure provided in a second conductive area thereof and in a first state, the slit structure may overlap an antenna provided in a first conductive area of a first housing when viewed in a specific direction, making it possible to secure a separation distance between the antenna and the second conductive area in the first state.

An electronic device according to various example embodiments of the disclosure may include: a first housing, a second housing slidably connected to the first housing, a printed circuit board (PCB) disposed in the electronic device, and a wireless communication circuit disposed on the PCB, wherein the first housing may include a first surface and a second surface perpendicular to the first surface at a first edge, and the first housing may include a first conductive area, the first conductive area may include a first portion of a first slit extending from a point on the first surface to the first edge, wherein the second housing may include a third surface including a second conductive area, and the second conductive area may include a second slit extending to an edge of the second housing corresponding to the first edge of the first housing, wherein, in a first state in which the second housing is slid in a first direction to be adjacent to the first housing, at least a portion of the first portion of the first slit may overlap the second slit when viewed in a second direction perpendicular to the first surface of the first housing, and the wireless communication circuit may be configured to transmit and/or receive a signal of a first frequency band based on an electrical path including the first portion of the first slit.

An electronic device according to various example embodiments of the disclosure may include: a first metal housing, a second metal housing slidably connected to the first metal housing, and a wireless communication circuit disposed in the electronic device, wherein the first metal housing may include a first surface and a second surface perpendicular to the first surface at a first edge, and the first surface may include a first slit extending to the first edge from a point on the first surface, wherein the second metal housing may include a third surface including a second slit extending to an edge of the second metal housing corresponding to the first edge of the first metal housing, wherein in a first state in which the second metal housing is slid in a direction approaching the first metal housing, at least a portion of the first slit may overlap the second slit when viewed in a first direction perpendicular to the first surface of the first metal housing, and the wireless communication circuit may be configured to transmit and/or receive a signal of a first frequency band based on an electrical path including the first slit structure.

According to various example embodiments disclosed herein, since the separation distance between an antenna and a conductive area is secured in an electronic device, it is possible to reduce degradation of the radiation performance of the antenna.

In addition, various effects directly or indirectly identified through the disclosure may be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features and advantages of certain embodiments of the present disclosure will be more apparent from the following detailed description, taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a block diagram illustrating an example electronic device in a network environment according to various embodiments;

FIG. **2**A is a diagram illustrating the front side of an electronic device when the electronic device is in a first state or a second state according to various embodiments;

FIG. **2**B is a diagram illustrating the rear side of the electronic device when the electronic device is in the first state or the second state according to various embodiments;

FIG. **3** is an exploded perspective view of an electronic device according to various embodiments;

FIG. **4** is a perspective view illustrating an internal structure in which a support member, a flexible display, and a second housing are coupled when the electronic device is in the first state according to various embodiments;

FIG. **5** is a block diagram illustrating an example operation of a slit antenna according to a state of an electronic device according to various embodiments;

FIG. **6** is a partial sectional perspective view illustrating a cross section A-A' of the electronic device of FIG. **2**B, according to various embodiments;

FIG. **7** is a diagram illustrating a cross-section A-A' of an electronic device when viewed in the +x direction according to various embodiments;

FIG. **8** is a radiation efficiency graph of a first slit antenna including a first slit structure in the case in which a second slit structure is included in the second housing and a radiation efficiency graph a first slit antenna including the first slit structure in the case in which the second slit structure is not included in the second housing according to various embodiments;

FIG. **9** is a diagram illustrating a current distribution of the first slit structure in the case in which the second slit structure is present in the second housing according to various embodiments;

FIG. **10** is a diagram illustrating a current distribution of the first slit structure in the case in which the second slit structure is not present in the second housing according to various embodiments;

FIG. **11** is a perspective and partial sectional view illustrating a power feeding structure using a first conductive connection member according to various embodiments;

FIG. **12** is a perspective and partial sectional view illustrating a power feeding structure using a first conductive connection member and a second conductive connection member according to various embodiments;

FIG. **13** is a perspective view illustrating a third conductive connection member coupled to a second conductive area of the second housing according to various embodiments;

FIG. **14** is a perspective view illustrating a fourth conductive connection member coupled to the second conductive area of the second housing is added according to various embodiments;

FIG. **15** is an antenna radiation efficiency graph in a case in which the first conductive area is electrically connected to the second conductive area of the second housing via the third conductive connection member, and an antenna radiation efficiency graph in a case in which the first conductive area is not connected to the second conductive area according to various embodiments;

FIG. **16** is a diagram illustrating a second slit structure of a second housing having various widths according to various embodiments;

FIG. **17** is a radiation efficiency graph of the first slit antenna including the first slit structure in respective cases in which the second slit structure has various widths of FIG. **16** according to various embodiments;

FIG. **18** is a diagram illustrating a second slit structure of a second housing having various slit lengths according to various embodiments;

FIG. **19** is a radiation efficiency graph of the first slit antenna including the first slit structure in respective cases in which the second slit structure has various slit lengths of FIG. **18** according to various embodiments;

FIG. **20** is a diagram illustrating a first slit structure according to various embodiments;

FIG. **21** is an antenna radiation efficiency graph of FIG. **20** according to various embodiments;

FIG. **22** is a diagram illustrating a first slit structure according to various embodiments; and

FIG. **23** is an antenna radiation efficiency graph of FIG. **22** according to various embodiments.

DETAILED DESCRIPTION

Hereinafter, various example embodiments of the disclosure will be described with reference to the accompanying drawings. However, it shall be understood that it is not intended to limit the disclosure to specific embodiments, and that the disclosure includes various modifications, equivalents, or alternatives of the embodiments of the disclosure.

FIG. **1** is a block diagram illustrating an example electronic device **101** in a network environment **100** according to various embodiments. Referring to FIG. **1**, the electronic device **101** in the network environment **100** may communicate with an electronic device **102** via a first network **198** (e.g., a short-range wireless communication network), or at least one of an electronic device **104** or a server **108** via a second network **199** (e.g., a long-range wireless communication network). According to an embodiment, the electronic device **101** may communicate with the electronic device **104** via the server **108**. According to an embodiment, the electronic device **101** may include a processor **120**, memory **130**, an input module **150**, a sound output module **155**, a display module **160**, an audio module **170**, a sensor module **176**, an interface **177**, a connecting terminal **178**, a haptic module **179**, a camera module **180**, a power management module **188**, a battery **189**, a communication module **190**, a subscriber identification module (SIM) **196**, or an antenna module **197**. In some embodiments, at least one of the components (e.g., the connecting terminal **178**) may be omitted from the electronic device **101**, or one or more other components may be added in the electronic device **101**. In some embodiments, some of the components (e.g., the sensor module **176**, the camera module **180**, or the antenna module **197**) may be implemented as a single component (e.g., the display module **160**).

The processor **120** may execute, for example, software (e.g., a program **140**) to control at least one other component (e.g., a hardware or software component) of the electronic device **101** coupled with the processor **120**, and may perform various data processing or computation. According to an embodiment, as at least part of the data processing or computation, the processor **120** may store a command or data received from another component (e.g., the sensor module **176** or the communication module **190**) in volatile memory **132**, process the command or the data stored in the volatile memory **132**, and store resulting data in non-volatile memory **134**. According to an embodiment, the processor **120** may include a main processor **121** (e.g., a central processing unit (CPU) or an application processor (AP)), or an auxiliary processor **123** (e.g., a graphics processing unit (GPU), a neural processing unit (NPU), an image signal processor (ISP), a sensor hub processor, or a communication processor (CP)) that is operable independently from, or in conjunction with, the main processor **121**. For example, when the electronic device **101** includes the main processor

121 and the auxiliary processor 123, the auxiliary processor 123 may be adapted to consume less power than the main processor 121, or to be specific to a specified function. The auxiliary processor 123 may be implemented as separate from, or as part of the main processor 121.

The auxiliary processor 123 may control at least some of functions or states related to at least one component (e.g., the display module 160, the sensor module 176, or the communication module 190) among the components of the electronic device 101, instead of the main processor 121 while the main processor 121 is in an inactive (e.g., sleep) state, or together with the main processor 121 while the main processor 121 is in an active state (e.g., executing an application). According to an embodiment, the auxiliary processor 123 (e.g., an image signal processor or a communication processor) may be implemented as part of another component (e.g., the camera module 180 or the communication module 190) functionally related to the auxiliary processor 123. According to an embodiment, the auxiliary processor 123 (e.g., the neural processing unit) may include a hardware structure specified for artificial intelligence model processing. An artificial intelligence model may be generated by machine learning. Such learning may be performed, e.g., by the electronic device 101 where the artificial intelligence is performed or via a separate server (e.g., the server 108). Learning algorithms may include, but are not limited to, e.g., supervised learning, unsupervised learning, semi-supervised learning, or reinforcement learning. The artificial intelligence model may include a plurality of artificial neural network layers. The artificial neural network may be a deep neural network (DNN), a convolutional neural network (CNN), a recurrent neural network (RNN), a restricted boltzmann machine (RBM), a deep belief network (DBN), a bidirectional recurrent deep neural network (BRDNN), deep Q-network or a combination of two or more thereof but is not limited thereto. The artificial intelligence model may, additionally or alternatively, include a software structure other than the hardware structure.

The memory 130 may store various data used by at least one component (e.g., the processor 120 or the sensor module 176) of the electronic device 101. The various data may include, for example, software (e.g., the program 140) and input data or output data for a command related thereto. The memory 130 may include the volatile memory 132 or the non-volatile memory 134.

The program 140 may be stored in the memory 130 as software, and may include, for example, an operating system (OS) 142, middleware 144, or an application 146.

The input module 150 may receive a command or data to be used by another component (e.g., the processor 120) of the electronic device 101, from the outside (e.g., a user) of the electronic device 101. The input module 150 may include, for example, a microphone, a mouse, a keyboard, a key (e.g., a button), or a digital pen (e.g., a stylus pen).

The sound output module 155 may output sound signals to the outside of the electronic device 101. The sound output module 155 may include, for example, a speaker or a receiver. The speaker may be used for general purposes, such as playing multimedia or playing record. The receiver may be used for receiving incoming calls. According to an embodiment, the receiver may be implemented as separate from, or as part of the speaker.

The display module 160 may visually provide information to the outside (e.g., a user) of the electronic device 101. The display module 160 may include, for example, a display, a hologram device, or a projector and control circuitry to control a corresponding one of the display, hologram device, and projector. According to an embodiment, the display module 160 may include a touch sensor adapted to detect a touch, or a pressure sensor adapted to measure the intensity of force incurred by the touch.

The audio module 170 may convert a sound into an electrical signal and vice versa. According to an embodiment, the audio module 170 may obtain the sound via the input module 150, or output the sound via the sound output module 155 or a headphone of an external electronic device (e.g., an electronic device 102) directly (e.g., wiredly) or wirelessly coupled with the electronic device 101.

The sensor module 176 may detect an operational state (e.g., power or temperature) of the electronic device 101 or an environmental state (e.g., a state of a user) external to the electronic device 101, and then generate an electrical signal or data value corresponding to the detected state. According to an embodiment, the sensor module 176 may include, for example, a gesture sensor, a gyro sensor, an atmospheric pressure sensor, a magnetic sensor, an acceleration sensor, a grip sensor, a proximity sensor, a color sensor, an infrared (IR) sensor, a biometric sensor, a temperature sensor, a humidity sensor, or an illuminance sensor.

The interface 177 may support one or more specified protocols to be used for the electronic device 101 to be coupled with the external electronic device (e.g., the electronic device 102) directly (e.g., wiredly) or wirelessly. According to an embodiment, the interface 177 may include, for example, a high definition multimedia interface (HDMI), a universal serial bus (USB) interface, a secure digital (SD) card interface, or an audio interface.

A connecting terminal 178 may include a connector via which the electronic device 101 may be physically connected with the external electronic device (e.g., the electronic device 102). According to an embodiment, the connecting terminal 178 may include, for example, a HDMI connector, a USB connector, a SD card connector, or an audio connector (e.g., a headphone connector).

The haptic module 179 may convert an electrical signal into a mechanical stimulus (e.g., a vibration or a movement) or electrical stimulus which may be recognized by a user via his tactile sensation or kinesthetic sensation. According to an embodiment, the haptic module 179 may include, for example, a motor, a piezoelectric element, or an electric stimulator.

The camera module 180 may capture a still image or moving images. According to an embodiment, the camera module 180 may include one or more lenses, image sensors, image signal processors, or flashes.

The power management module 188 may manage power supplied to the electronic device 101. According to an embodiment, the power management module 188 may be implemented as at least part of, for example, a power management integrated circuit (PMIC).

The battery 189 may supply power to at least one component of the electronic device 101. According to an embodiment, the battery 189 may include, for example, a primary cell which is not rechargeable, a secondary cell which is rechargeable, or a fuel cell.

The communication module 190 may support establishing a direct (e.g., wired) communication channel or a wireless communication channel between the electronic device 101 and the external electronic device (e.g., the electronic device 102, the electronic device 104, or the server 108) and performing communication via the established communication channel. The communication module 190 may include one or more communication processors that are operable independently from the processor 120 (e.g., the application

processor (AP)) and supports a direct (e.g., wired) communication or a wireless communication. According to an embodiment, the communication module **190** may include a wireless communication module **192** (e.g., a cellular communication module, a short-range wireless communication module, or a global navigation satellite system (GNSS) communication module) or a wired communication module **194** (e.g., a local area network (LAN) communication module or a power line communication (PLC) module). A corresponding one of these communication modules may communicate with the external electronic device via the first network **198** (e.g., a short-range communication network, such as Bluetooth™ wireless-fidelity (Wi-Fi) direct, or infrared data association (IrDA)) or the second network **199** (e.g., a long-range communication network, such as a legacy cellular network, a 5G network, a next-generation communication network, the Internet, or a computer network (e.g., LAN or wide area network (WAN)). These various types of communication modules may be implemented as a single component (e.g., a single chip), or may be implemented as multi components (e.g., multi chips) separate from each other. The wireless communication module **192** may identify and authenticate the electronic device **101** in a communication network, such as the first network **198** or the second network **199**, using subscriber information (e.g., international mobile subscriber identity (IMSI)) stored in the subscriber identification module **196**.

The wireless communication module **192** may support a 5G network, after a 4G network, and next-generation communication technology, e.g., new radio (NR) access technology. The NR access technology may support enhanced mobile broadband (eMBB), massive machine type communications (mMTC), or ultra-reliable and low-latency communications (URLLC). The wireless communication module **192** may support a high-frequency band (e.g., the mmWave band) to achieve, e.g., a high data transmission rate. The wireless communication module **192** may support various technologies for securing performance on a high-frequency band, such as, e.g., beamforming, massive multiple-input and multiple-output (massive MIMO), full dimensional MIMO (FD-MIMO), array antenna, analog beam-forming, or large scale antenna. The wireless communication module **192** may support various requirements specified in the electronic device **101**, an external electronic device (e.g., the electronic device **104**), or a network system (e.g., the second network **199**). According to an embodiment, the wireless communication module **192** may support a peak data rate (e.g., 20 Gbps or more) for implementing eMBB, loss coverage (e.g., 164 dB or less) for implementing mMTC, or U-plane latency (e.g., 0.5 ms or less for each of downlink (DL) and uplink (UL), or a round trip of 1 ms or less) for implementing URLLC.

The antenna module **197** may transmit or receive a signal or power to or from the outside (e.g., the external electronic device) of the electronic device **101**. According to an embodiment, the antenna module **197** may include an antenna including a radiating element including a conductive material or a conductive pattern formed in or on a substrate (e.g., a printed circuit board (PCB)). According to an embodiment, the antenna module **197** may include a plurality of antennas (e.g., array antennas). In such a case, at least one antenna appropriate for a communication scheme used in the communication network, such as the first network **198** or the second network **199**, may be selected, for example, by the communication module **190** (e.g., the wireless communication module **192**) from the plurality of antennas. The signal or the power may then be transmitted or received between the communication module **190** and the external electronic device via the selected at least one antenna. According to an embodiment, another component (e.g., a radio frequency integrated circuit (RFIC)) other than the radiating element may be additionally formed as part of the antenna module **197**.

According to various embodiments, the antenna module **197** may form a mmWave antenna module. According to an embodiment, the mmWave antenna module may include a printed circuit board, a RFIC disposed on a first surface (e.g., the bottom surface) of the printed circuit board, or adjacent to the first surface and capable of supporting a designated high-frequency band (e.g., the mmWave band), and a plurality of antennas (e.g., array antennas) disposed on a second surface (e.g., the top or a side surface) of the printed circuit board, or adjacent to the second surface and capable of transmitting or receiving signals of the designated high-frequency band.

At least some of the above-described components may be coupled mutually and communicate signals (e.g., commands or data) therebetween via an inter-peripheral communication scheme (e.g., a bus, general purpose input and output (GPIO), serial peripheral interface (SPI), or mobile industry processor interface (MIPI)).

According to an embodiment, commands or data may be transmitted or received between the electronic device **101** and the external electronic device **104** via the server **108** coupled with the second network **199**. Each of the electronic devices **102** or **104** may be a device of a same type as, or a different type, from the electronic device **101**. According to an embodiment, all or some of operations to be executed at the electronic device **101** may be executed at one or more of the external electronic devices **102**, **104**, or **108**. For example, if the electronic device **101** should perform a function or a service automatically, or in response to a request from a user or another device, the electronic device **101**, instead of, or in addition to, executing the function or the service, may request the one or more external electronic devices to perform at least part of the function or the service. The one or more external electronic devices receiving the request may perform the at least part of the function or the service requested, or an additional function or an additional service related to the request, and transfer an outcome of the performing to the electronic device **101**. The electronic device **101** may provide the outcome, with or without further processing of the outcome, as at least part of a reply to the request. To that end, a cloud computing, distributed computing, mobile edge computing (MEC), or client-server computing technology may be used, for example. The electronic device **101** may provide ultra low-latency services using, e.g., distributed computing or mobile edge computing. In another embodiment, the external electronic device **104** may include an internet-of-things (IoT) device. The server **108** may be an intelligent server using machine learning and/or a neural network. According to an embodiment, the external electronic device **104** or the server **108** may be included in the second network **199**. The electronic device **101** may be applied to intelligent services (e.g., smart home, smart city, smart car, or healthcare) based on 5G communication technology or IoT-related technology.

FIG. **2**A is a diagram illustrating the front side of an electronic device when the electronic device is in a first state or a second state according to various embodiments.

FIG. **2**B is a diagram illustrating the rear side of the electronic device when the electronic device is in the first state or the second state according to various embodiments.

Referring to FIGS. **2**A and **2**B, the electronic device **101** according to an embodiment may include a housing **110** that forms an exterior.

According to an embodiment, the housing **110** may form a partial area of the front surface, a partial area of the rear surface, and/or a side surface of the electronic device **101**. According to an embodiment, the housing **110** may form a partial area of the side surface and/or the rear surface of the electronic device **101**. In an embodiment, the housing **110** may include a conductive material (e.g., metal).

According to an embodiment, the housing **110** may include a first housing **110** and a second housing **112** connected to the first housing **111** to be slidable (e.g., slide-in or slide-out) relative to the first housing **111** and the first housing **111** in a specific range.

According to an embodiment, the first housing **111** may include a speaker hole **251**, a connector hole **252**, and/or a camera hole **253**. In an embodiment, a sound output module **155** (refer to FIG. **1**) disposed in the electronic device **101** may output sound to the outside of the electronic device **101** through the speaker hole **251**. In an embodiment, the connector hole **252** may accommodate, for example, a connector (e.g., a USB connector) for transmitting and/or receiving power and/or data to and/or from an external electronic device. In an embodiment, the camera hole **253** may correspond to a hole through which at least one lens of the camera module **180** is exposed. Light outside the electronic device **101** may be incident to the camera module **180** disposed inside the electronic device **101** through the camera hole **253**.

According to an embodiment, the first housing **111** may include a first slit structure **261** and a first additional slit structure **262** on the rear surface. In an embodiment, as will be described with reference to FIG. **6**, the electronic device **101** may transmit and/or receive a radio frequency (RF) signal of a specific frequency band using the first slit structure **261** and the first additional slit structure **262**. In an embodiment, the second housing **112** may include a second slit structure **271** and/or a second additional slit structure **272** on the rear surface. In an embodiment, as will be described later with reference to FIG. **6**, in the electronic device **101**, the first slit structure **261** and the first additional slit structure **262** of the first housing **111** may be spaced apart from a conductive area provided in the second housing **112** by a specific distance or more in a specific direction (e.g., the −z direction) using the second slit structure **271** and the second additional slit structure **272**, respectively.

According to an embodiment, the electronic device **101** may have a first state and/or a second state. In an embodiment, the electronic device **101** may have a first state, a second state, and/or an intermediate state between the first state and the second state.

In an embodiment, the first state and/or the second state of the electronic device **101** may be determined depending on a relative position of the second housing **112** with respect to the first housing **111**. For example, the state in which the second housing **112** is slid in a direction approaching the first housing **111** (e.g., the +x direction) and the first housing **111** and the second housing **112** are adjacent to or in contact with each other may be referred to as the first state. As another example, the state in which the second housing **112** is slid in a direction away from the first housing **111** (e.g., the −x direction) may be referred to as the second state. In an embodiment, the first state and the second state of the electronic device **101** may be determined depending on the size of the flexible display **220** exposed to the outside. For example, only a first portion **221** of the flexible display **220** may be exposed (e.g., visible—as used herein when referring to the amount of a flexible display visible to the outside, the terms "exposed" and "visible" may be used interchangeably) to the outside of the electronic device **101**, and the state in which the flexible display **220** exposed to the outside has the first size S**1** may be the first state. As another example, the first portion **221** and the second portion of the flexible display **220** may be exposed to the outside of the electronic device **101**, and the state in which the exposed flexible display **220** exposed to the outside has a second size S**2** may be the second state. As another example, the state in which the size of the flexible display **220** exposed to the outside has a third size between the first size S**1** and the second size S**2** may be an intermediate state.

In an embodiment, the electronic device **101** may be switched between the first state and the second state through a user's manipulation or a mechanical operation. According to an embodiment, the housing **110** may include a button in a portion, and the electronic device **101** may be switched between the first state and the second state through the user's manipulation (e.g., an input of pushing or touching the button).

According to an embodiment, the flexible display **220** may occupy most of the front surface of the electronic device **101**. For example, the front surface of the electronic device **101** may include a flexible display **220** and a bezel region partially surrounding the periphery of the flexible display **220**. According to an embodiment, the flexible display **220** may be disposed to include at least a portion of a flat shape or at least a portion of a curved shape.

According to an embodiment, the flexible display **220** may include a first portion **221** and/or a second portion **222** extending from the first portion **221**. In an embodiment, the second portion **222** of the flexible display **220** may be slid into the housing **110** or slid out of the housing **110** depending on the state of the electronic device **101**. For example, when the electronic device **101** is in the first state, the second portion **222** of the flexible display **220** may be slid into and disposed in the housing **110** and may not be viewed from the outside. As another example, when the electronic device **101** is in the second state, the second portion **222** of the flexible display **220** may be slid and disposed out of the housing **110**, and may be viewed from the outside.

The shape of the electronic device **101** illustrated in FIGS. **2**A and **2**B is provided for describing an example of the electronic device **101** capable of expanding the display area, and the shape of the electronic device **101** is not limited that illustrated in FIGS. **2**A and **2**B.

FIG. **3** is an exploded perspective view of an electronic device according to various embodiments.

Referring to FIG. **3**, the electronic device **101** according to an embodiment may include a first housing **111**, a second housing **112**, a flexible display **220**, a printed circuit board (PCB) **240**, and/or a support member (e.g., support) **230**.

According to an embodiment, the first housing **111** may include a first surface **401** that provides at least a portion of the rear surface of the electronic device **101** and a second surface **402** that is perpendicular to the first surface **401** at a first edge **411**. In an embodiment, the first housing **111** may include a first slit structure **421** provided on the first surface **401** and the second surface **402**. In an embodiment, the first slit structure **421** may extend from a first point P**1** of the first surface **401** to the first edge **411**. In addition, the first slit structure **421** may further extend from the first edge **411** to the second edge **412** along the second surface **402** in a first direction (e.g., the +z direction). In an embodiment, the first slit structure **421** may be provided in a first conductive area

420*a* of the first housing **111**. In FIG. **3**, the first conductive area **420***a* of the first housing **111** is indicated as a partial area of the first housing **111**. However, this is for convenience of description, and the range of the first conductive area **420***a* is limited thereto. In an embodiment, the first slit structure **421** may be substantially the same as or similar to the first slit structure **261** of FIG. **2**B.

According to an embodiment, the first housing **111** may include a third surface **403** perpendicular to the first surface **401** at a third edge **413**. In an embodiment, the first housing **111** may include a first additional slit structure **422** provided on the first surface **401** and the third surface **403**. In an embodiment, the first additional slit structure **422** may extend from a second point P**2** of the first surface **401** to the third edge **413**. In addition, although not illustrated in FIG. **3**, the first additional slit structure **422** may further extend from the third edge **413** in the first direction (e.g., the +z direction). In an embodiment, the first additional slit structure **422** may be provided in a first additional conductive area **420***b* of the first housing **111**. In FIG. **3**, the first additional conductive area **420***b* of the first housing **111** is indicated as a partial area of the first housing **111**. However, this is for convenience of description, and the range of the first additional conductive area **420***b* is limited thereto. In an embodiment, the first additional slit structure **422** may be substantially the same as or similar to the first additional slit structure **262** of FIG. **2**B.

According to an embodiment, the first slit structure **421** may have various shapes (e.g., an L shape, a V shape, or an inverted L shape) and various lengths depending on a frequency band in which a slit antenna including the first slit structure **421** is desired to operate. As another example, the first additional slit structure **422** may have various shapes (e.g., an L shape, a V shape, or an inverted L shape) and various lengths depending on a frequency band in which a slit antenna including the first additional slit structure **422** is desired to operate. According to an embodiment, the first slit structure **421** may have an open slit structure in which one end extends to the second edge **412**. As another example, the first additional slit structure **422** may have an open slit structure.

According to an embodiment, the first slit structure **421** and/or the first additional slit structure **422** may have a closed slit structure. In an embodiment, the first housing **111** may include an additional slit structure provided in the conductive area of the first housing **111** in addition to the first slit structure **421** and the second slit structure **521**. According to an embodiment, the first housing **111** may include only the first slit structure **421** or only the first additional slit structure **422**.

According to an embodiment, the PCB **240** may include a first PCB **241** and/or a second PCB **242**. According to an embodiment, a plurality of electronic components may be disposed on the PCB **240**. For example, a processor **120**, a wireless communication circuit, a memory **130**, a control circuit, and/or an interface **177** (refer to FIG. **1**) may be disposed on the PCB **240**. In an embodiment, the PCB **240** may be formed of a material (e.g., FR4) having a non-bendable property. According to an embodiment, the PCB **240** may be a flexible printed circuit board (FPCB) having a bendable property (or "flexible property"). In an embodiment, the first PCB **241** and the second PCB **242** may be configured integrally. In an embodiment, the first PCB **241** and the second PCB **242** may be electrically connected to each other.

According to an embodiment, the support member **230** may include a first opening **231** and/or a second opening **232**. A conductive connection member, which will be described in greater detail below with reference to FIG. **11**, may be electrically connected to the first slit structure **421** provided in the first conductive area **420***a* of the first housing **111** through the first opening **231** and/or the second opening **232**. In an embodiment, at least a portion of the flexible display **220** may be fixedly seated on the support member **230**. In an embodiment, the support member **230** may include an insulating material (e.g., plastic or resin).

According to an embodiment, the second housing **112** may include a fourth surface **504** that provides at least a portion of the rear surface of the electronic device **101** and a fifth surface **505** that is perpendicular to the fourth surface **504** at a fourth edge **514**. In an embodiment, the second housing **112** may include a second slit structure **521** provided on the fourth surface **504** and the fifth surface **505**. In an embodiment, the second slit structure **521** may include a first portion **521***a* and a second portion **521***b*. A portion of the first portion **521***a* of the second slit structure **521** extends from a third point P**3** of the fourth surface **504** to the fourth edge **514**, and another portion may be provided on the fifth surface **505** in the first direction (e.g., the +z direction). The second portion **521***b* of the second slit structure **521** may be a portion that is provided on a portion of the fifth surface **505** in the second direction (e.g., the −z direction) from the fifth edge **515** of the second housing **112**. In an embodiment, the second slit structure **521** may be provided in a second conductive area **520***a* of the second housing **112**. In FIG. **3**, the second conductive area **520***a* of the second housing **112** is indicated as a partial area of the second housing **112**. However, this is for convenience of description, and the range of the second conductive area **520***a* is limited thereto. In an embodiment, the second slit structure **521** may be substantially the same as the second slit structure **271** of FIG. **2**B. According to an embodiment, the second housing **112** may include only the first portion **521***a* of the second slit structure **521** without including the second portion **521***b* of the second slit structure **521**.

According to an embodiment, the second housing **112** may include a sixth surface **506** perpendicular to the fourth surface **504** at a sixth edge **516**. In an embodiment, the second housing **112** may include a second additional slit structure **522** provided on the fourth surface **504** and the sixth surface **506**. A portion of the second additional slit structure **522** may extend on the fourth surface **504** from the fourth point P**4** to the sixth edge **516** of the second housing **112**, and another portion may be provided on the sixth surface **506** in the first direction (e.g., the +z direction). In FIG. **3**, the portion of the second additional slit structure **522** provided along the sixth surface **506** is not illustrated since the sixth surface **506** is not illustrated, but in practice, the second housing **112** may include the portion of the second additional slit structure **522** provided on the sixth surface **506**. In an embodiment, the second additional slit structure **522** may be provided in a second additional conductive area **520***b* of the second housing **112**. In FIG. **3**, the second additional conductive area **520***b* of the second housing **112** is indicated as a partial area of the second housing **112**. However, this is for convenience of description, and the range of the second additional conductive area **520***b* is limited thereto. In an embodiment, the second additional slit structure **522** may be substantially the same as the second additional slit structure **272** of FIG. **2**B.

According to an embodiment, the second slit structure **521** may have a shape corresponding to the shape of the first slit structure **421** of the first housing **111**. For example, when the first slit structure **421** has an L shape, the second slit

structure **521** may have an L shape corresponding to the first slit structure **421**. In an embodiment, the second additional slit structure **522** may have a shape corresponding to the shape of the first additional slit structure **422** of the first housing **111**. For example, when the first additional slit structure **422** has a V shape, the second additional slit structure **522** may have a V shape to correspond to the first additional slit structure **422**.

According to an embodiment, the second housing **112** may include only the second slit structure **521** or only the second additional slit structure **522**.

According to an embodiment, the second housing **112** may include a first groove **531** extending from one edge portion of the fifth surface **505** in the second direction (e.g., −x direction). Although not illustrated in FIG. **3**, the second housing **112** may include a second groove extending from one edge portion of the sixth surface **506** in the second direction (e.g., the −x direction).

FIG. **4** is a perspective view illustrating an internal structure in which a support member, a flexible display, and a second housing are coupled when the electronic device is in the first state according to various embodiments.

Referring to FIG. **4**, when the electronic device **101** according to an embodiment is in the first state, at least a portion of the second housing **112** may be slid into the support member **230**. In FIG. **4**, the first housing **111** is omitted in order to describe the internal structure, but, in the first state, in practice, the support member **230** may be disposed inside the first housing **111**, and the second housing **112** may be slid into the support member **230**. Accordingly, the support member **230** may be disposed between the first housing **111** and the second housing **112**. In an embodiment, the support member **230** may include an insulating material, and may be disposed between the first housing **111** and the second housing **112** to prevent or reduce coupling between a conductive portion (e.g., the first conductive area **420***a* in FIG. **3**) of the first housing **111** and the conductive portion (e.g., the second conductive area **520***a* in FIG. **3**) of the second housing **112**.

In an embodiment, in the first state, when viewed in the −y-axis direction, the first opening **231** formed in the first support member **230** may overlap at least a portion of the first groove **531** formed in the second housing **112**.

FIG. **5** is a block diagram for describing an example operation of a slit antenna according to a state of an electronic device according to various embodiments.

Referring to FIG. **5**, an electronic device **101** according to an embodiment may include a wireless communication circuit **530** and an antenna structure **550**.

According to an embodiment, when the electronic device **101** is in the first state, the wireless communication circuit **530** may transmit and/or receive an RF signal of a first frequency band by feeding power to a point of the first slit structure **421**. Hereinafter, an antenna including the first slit structure **421** may be referred to as a first slit antenna **551**. In an embodiment, when the electronic device **101** is in the first state, as will be described in greater detail below with reference to FIG. **6**, at least a portion of the second slit structure **521** may be disposed to overlap the first slit structure **421** when viewed in a specific direction. In an embodiment, when the electronic device **101** is in the first state, as will be described in greater detail below with reference to FIG. **16** and/or FIG. **18**, the frequency band in which the first slit antenna **551** operates may vary depending on the length and/or width of the second slit structure **521**.

According to an embodiment, when the electronic device **101** is in the second state, the wireless communication circuit **530** may transmit and/or receive an RF signal of the first frequency band by feeding power to a point of the first slit structure **421**.

In an embodiment, the antenna structure **550** may additionally include various types of antenna structures. For example, the antenna structure **550** may include, without limitation, a patch antenna, a dipole antenna, a monopole antenna, a slit antenna, a loop antenna, an inverted-F antenna, a planar inverted-F antenna, and/or an antenna structure in which two or more of these antennas are combined, in addition to the first slit antenna **551**.

FIG. **6** is a partial sectional perspective view illustrating a cross section A-A' of the electronic device of FIG. **2**B, according to various embodiments.

Referring to FIG. **6**, when the electronic device **101** according to an embodiment is in the first state, at least a portion of the second housing **112** may be slid into the first housing **111**. In an embodiment, since the second housing **112** is slid into the first housing **111** when the electronic device **101** is in the first state, at least a portion of the second slit structure **521** of the second housing **112** may overlap the first slit structure **421** of the first housing **111** when viewed in a specific direction. For example, in the first state, at least a portion of the first portion **521***a* of the second slit structure **521** may overlap the first slit structure **421** when viewed in the first direction (e.g., the +z direction). As another example, although covered by the first housing **111** in FIG. **6**, at least a portion of the second portion **521***b* of the second slit structure **521** may overlap the first slit structure **421** when viewed in the second direction (e.g., the +y direction).

According to an embodiment, a wireless communication circuit **530** may be disposed on the first PCB **241**. The wireless communication circuit **530** may feed power to a point of the first slit structure **421** via a first conductive connection member **611** (e.g., a C-clip) to transmit and/or receive an RF signal of a first frequency band.

According to an embodiment, the electronic device **101** may include a lumped element (not illustrated) electrically connected to the first slit structure **421**. The wireless communication circuit **530** may transmit and/or receive an RF signal of a second frequency band based on an electrical path including the first slit structure **421** and the lumped element. For example, the electronic device **101** may implement multiple bands using the lumped element. As another example, the electronic device **101** may implement a specific frequency matching using the lumped element.

According to an embodiment, since the second slit structure **521** overlaps the first slit structure **421** when viewed in a specific direction (e.g., the +z direction), the first slit antenna **551** including the first slit structure **421** may be spaced apart from the second conductive area **520***a* of the second housing **112** by a specific distance or more. Accordingly, the electronic device **101** may reduce an induced current from the first slit structure **421** generated when the wireless communication circuit **530** feeds power to the first slit structure **421**. In addition, the electronic device **101** may suppress degradation in radiation efficiency of the first slit antenna **551** including the first slit structure **421**. In an embodiment, the specific distance may refer, for example, to a distance having, for example, a length of about ¼ of a wavelength corresponding to a frequency band in which the first slit antenna **551** including the first slit structure **421** transmits and receives.

FIG. **7** is a diagram illustrating a cross-section A-A' of an electronic device when viewed in the +x direction according to various embodiments.

Referring to FIG. **7**, according to an embodiment, when the electronic device **101** is in the first state, at least a portion of the first groove **531** of the second housing **112** may be disposed to overlap with the first opening **231** of the support member **230** when viewed in a specific direction (e.g., the +y direction). The first conductive connection member **611** according to an embodiment may be electrically connected to a point of the first slit structure **421** of the first housing **111** through the first groove **531** of the second housing **112** and the first opening **231** of the support member **230**. As another example, when the first opening **231** and the second housing **112** do not overlap when the electronic device **101** is in the first state, in the first state, the first groove **531** may be omitted.

FIG. **8** is a radiation efficiency graph of a first slit antenna including a first slit structure in the case in which a second slit structure is included in the second housing according to an embodiment and a radiation efficiency graph a first slit antenna including the first slit structure in the case in which the second slit structure is not included in the second housing according to various embodiments.

Referring to FIG. **8**, the first graph **801** is a radiation efficiency graph according to an embodiment of the first slit antenna **551** when the second housing **112** includes the second slit structure **521** and the electronic device **101** is in the first state. In an embodiment, the second graph **802** is a radiation efficiency graph of the first slit antenna **551** when the second housing **112** includes the second slit structure **521** and the electronic device **101** is in the second state. In an embodiment, when comparing the first graph **801** and the second graph **802**, when the electronic device **101** is in the first state and when the electronic device **101** is in the second state, the first slit antenna **551** has an antenna radiation efficiency of about −15 to −2 dB in the frequency band of about 0.8 to 4 GHz. Accordingly, it can be seen that when the second housing **112** includes the second slit structure **521**, the first slit antenna **551** maintains the antenna performance either when the electronic device **101** is in the first state or when the electronic device **101** is in the second state.

A third graph **803** according to an embodiment is a radiation efficiency graph of the first slit antenna **551** when the second housing **112** does not include the second slit structure **521** and the electronic device **101** is in the first state. In an embodiment, when comparing the first graph **801** and the third graph **803**, it can be seen that the third graph **803** shows a relatively low radiation efficiency compared to the first graph **801** in the frequency band of about 0.8 to 4 GHz. When the second housing **112** does not include the second slit structure **521**, due to an induced current due to coupling between the first housing **111** and the second housing **112** when the electronic device is in the first state, the radiation efficiency of the first slit antenna **551** is degraded. Accordingly, when the second housing **112** includes the second slit structure **521**, it is possible for the first slit antenna **551** to secure the separation distance from the ground of the second housing **112**, and when the electronic device **101** is in the first state, it is possible to suppress the degradation of radiation performance of the first slit antenna **551**.

FIG. **9** is a diagram illustrating a current distribution of the first slit structure in the case in which the second slit structure is present in the second housing according to various embodiments.

Referring to FIG. **9**, a current distribution is illustrated when the wireless communication circuit **530** according to an embodiment feeds power to a point of the first slit structure **421**. In an embodiment, it can be seen that a current is distributed along the periphery of the first slit structure **421** since no induced current is generated due to coupling with the second housing **112**.

FIG. **10** is a diagram illustrating a current distribution of the first slit structure in the case in which the second slit structure is not present in the second housing according to various embodiments.

Referring to FIG. **10**, it can be seen that when power is fed to the first slit structure of the first housing, an induced current is generated due to coupling with the second housing, and thus the current distribution is concentrated between the feeding point for the first slit structure of the first housing and the second housing. Accordingly, when the second housing does not include the second slit structure, the radiation performance of the first slit antenna including the first slit structure may be degraded due to the generation of an induced current.

FIG. **11** is a perspective and partial sectional view illustrating a power feeding structure using a first conductive connection member according to various embodiments.

Referring to FIG. **11**, the first conductive connection member **611** according to an embodiment may be coupled to a point of the first PCB **241**, and may be electrically connected to a point of the first slit structure **421** of the first housing **111** via the first groove **531** of the second housing **112**. In an embodiment, the first conductive connection member **611** may include, for example, a C-clip, a metal wire, a flexible printed circuit board (FPCB), or a pogo pin.

FIG. **12** is a perspective and partial sectional view illustrating a structure of an electronic device including a first conductive connection member and a second conductive connection member according to various embodiments.

Referring to FIG. **12**, the electronic device **101** according to an embodiment may include a second conductive connection member **1212**, and the second conductive connection member **1212** may be electrically connected to the wireless communication circuit **530**.

According to an embodiment, the electronic device **101** may transmit and/or receive an RF signal of a first frequency band by feeing power to a point of the first slit structure **421** of the first housing **111** via a first conductive connection member (e.g., C-clip). In addition, the wireless communication circuit **530** may feed power to a point different from the point on the conductive portion of the second surface **402** of the first housing **111** via the second conductive connection member **1212**, and may transmit and/or receive an RF signal in a second frequency band using the first conductive area **420***a* of the second surface **402** of the first housing **111**. For example, the electronic device **101** may secure a plurality of power feeding paths for implementing multiple bands of the electronic device **101** via a plurality of conductive connection members.

According to an embodiment, the electronic device **101** may, for example, form a planar inverted-F antenna (PIFA) via the first conductive connection member **611** and the second conductive connection member **1212**. For example, the first PCB **241** may include a ground, and the second conductive connection member **1212** may be electrically connected to the ground of the first PCB **241**. In an example, the wireless communication circuit **530** may feed power to a point of the first conductive area **420***a* of the second surface **402** of the first housing **111** via the first conductive connection member **611**, and may transmit and/or receive an RF signal of a specific frequency band based on an electrical path grounded to a ground of the first PCB **241** via the second conductive connection member **1212**.

According to an embodiment, when the electronic device **101** includes a plurality of conductive connection members in the first PCB **241**, an additional groove **1231** that is greater than the first groove **531** of the second housing **112** illustrated in FIG. **11** may be included. In an embodiment, the first conductive connection member **611** and/or the second conductive connection member **612** may come into contact with the second surface **402** of the first housing **111** through the additional groove **1231**.

FIG. **13** is a perspective view illustrating a third conductive connection member coupled to a second conductive area of the second housing according to various embodiments.

Referring to FIG. **13**, the second housing **112** according to an embodiment may include a second conductive area **520***a*. An electronic device **101** according to an embodiment may include a third conductive connection member **1311** (e.g., a C-clip), and the third conductive connection member **1311** may be disposed at a point in the second conductive area **520***a* of the fourth surface **504**.

According to an embodiment, when the electronic device is in the first state, the third conductive connection member **1311** may be positioned in a specific direction (e.g., the +z direction) of the first conductive area **420***a* of the first housing **111** to be electrically connected to a point in the first conductive area **420***a*. Accordingly, the point of the first conductive area **420***a* may be electrically connected to the second conductive area **520***a* of the second housing **112** via the third conductive connection member **1311**.

FIG. **14** is a perspective view in which a fourth conductive connection member coupled to the second conductive area **520***a* of the second housing is added according to various embodiments.

Referring to FIG. **14**, the second housing **112** according to an embodiment may include the second conductive area **520***a*. In an embodiment, an electronic device **101** may include a fourth conductive connection member **1312** (e.g., a C-clip), and the fourth conductive connection member **1312** may be disposed at a point in the second conductive area **520***a* of the fifth surface **505**. When the electronic device is in the first state, the fourth conductive connection member **1312** may be positioned in a specific direction (e.g., the +y direction) of the first conductive area **420***a*. However, in the case of the support member **230** of FIG. **3**, the electrical connection between the first slit structure **421** of the first housing **111** and the fourth conductive connection member **1312** may be blocked. Thus, in an embodiment, a portion of the support member **230** may be removed or an additional opening may be formed in the support member **230** to correspond to the position of the fourth conductive connection member **1312**. Accordingly, when an additional opening is formed in the support member **230** to correspond to the position of the fourth conductive connection member **1312**, the fourth conductive connection member **1312** may be positioned in a specific direction (e.g., the +y direction) of the first conductive area **420***a* to be electrically connected to a point of the first conductive area **420***a*. Accordingly, via the fourth conductive connection member **1312**, the electronic device **101** may electrically connect the first conductive area **420***a* and the second conductive area **520***a* of the second housing **112** to each other.

FIG. **15** is an antenna radiation efficiency graph in a case in which the first conductive area is electrically connected to the second conductive area of the second housing via the third conductive connection member, and an antenna radiation efficiency graph in a case in which the first conductive area is not connected to the second conductive area according to an embodiment.

Referring to FIG. **15**, the first graph **1501** according to an embodiment may be referred to as a radiation efficiency graph of the first slit antenna **551** when the first conductive area **420***a* and the second conductive area **520***a* are electrically connected to each other via the third conductive connection member **1311**. In an embodiment, the second graph **1502** may be referred to as a radiation efficiency graph of the first slit antenna **551** when the third conductive connection member **1311** is not used.

Comparing the first graph **1501** and the second graph **1502** according to an embodiment, the first graph **1501** has a higher antenna efficiency value that that of the second graph **1502** in the frequency band of about 0.8 to 1.3 GHz and the frequency band of about 2.2 to 4 GHz.

In an embodiment, the first conductive area **420***a* and the second conductive area **520***a* of the second housing **112** may be electrically connected to each other using the third conductive connection member **1311**. In this case, the electronic device **101** may further secure a ground electrically connected to the first slit antenna **551**. Through the increase of grounds, it is possible to prevent or reduce the degradation of antenna radiation performance in the electronic device **10** due to an induced current. Accordingly, the radiation efficiency of the first slit antenna **551** can be improved in specific frequency bands (e.g., 0.8 to 1.3 GHz and 2.2 to 4 GHz).

FIG. **16** is a diagram illustrating a second slit structure of a second housing having various widths according to various embodiments.

Referring to FIG. **16**, the first slit structure **421** of the first housing **111** according to an embodiment may have a first width W**1**. In an embodiment, the second slit structure of the second housing **112** may have various widths to correspond to the first slit structure **421**. For example, the second slit structure **521** of the second housing **112** may have a first width W**1** that is substantially the same as that of the first slit structure **421**. As another example, the second slit structure **1622** of the second housing **112** may have a second width W**2** greater than the first width W**1**. As another example, the second slit structure **1623** of the second housing **112** may have a third width W**3** smaller than the first width W**1**.

FIG. **17** is a radiation efficiency graph of the first slit antenna including the first slit structure in respective cases in which the second slit structure have various widths of FIG. **16**, according to various embodiments.

Referring to FIG. **17**, the first graph **1701** according to an embodiment is a radiation efficiency graph of the first slit antenna **551** when the second slit structure has the first width W**1**. The second graph **1702** is a radiation efficiency graph of the first slit antenna **551** when the second slit structure has the second width W**2**. The third graph **1703** is a radiation efficiency graph of the first slit antenna **551** when the second slit structure has the third width W**3**. Comparing the first graph **1701**, the second graph **1702**, and the third graph **1703** according to an embodiment, the first graph **1701**, the second graph **1702**, and the third graph **1703** have substantially the same antenna radiation efficiency value in the frequency band of about 0.5 to 4 GHz. Accordingly, even when the width of the second slit structure **521** of the second housing **112** is changed, in the electronic device **101**, it is possible to secure substantially the same radiation performance of the first slit antenna **551**.

FIG. **18** is a diagram illustrating a second slit structure of a second housing having various slit lengths according to various embodiments.

Referring to FIG. **18**, the first slit structure **421** of the first housing **111** according to an embodiment may have a first

length L1. In an embodiment, the second slit structure of the second housing **112** may have various slit lengths to correspond to the first slit structure **421**. For example, the second slit structure **521** of the second housing **112** may have a first length L1 that is substantially the same as that of the first slit structure **421**. As another example, the second slit structure **1822** of the second housing **112** may have a second length L2 greater than the first length L1. As another example, the second slit structure **1823** of the second housing **112** may have a third length L3 less than the first length L1.

FIG. **19** is a radiation efficiency graph of the first slit antenna including the first slit structure in respective cases in which the second slit structure has various slit lengths of FIG. **18**, according to various embodiments.

Referring to FIG. **19**, the first graph **1901** according to an embodiment is a radiation efficiency graph of the first slit antenna **551** when the second slit structure has the first length L1. The second graph **1902** is a radiation efficiency graph of the first slit antenna **551** when the second slit structure has the second length L2. The third graph **1903** is a radiation efficiency graph of the first slit antenna **551** when the second slit structure has the third length L3.

Comparing the first graph **1901** and the second graph **1902** according to an embodiment, the first graph **1701** and the second graph **1702** have substantially the same antenna radiation efficiency value in the frequency band of about 0.5 to 4 GHz. Accordingly, even when the slit length of the second slit structure **521** of the second housing **112** is increased, in the electronic device **101**, it is possible to secure substantially the same radiation performance of the first slit antenna **551**.

Comparing the third graph **1903** with the first graph **1901** and the second graph **1902** according to an embodiment, the third graph **1903** has a relatively high antenna radiation efficiency value compared to the first graph **1901** and the second graph **1902** in the frequency band of about 0.7 to 1.4 GHz. Therefore, in the case in which the slit length of the second slit structure **521** of the second housing **112** is reduced, the wireless communication circuit **530** may transmit and/or receive an RF signal of a relatively low frequency band via the first slit antenna **551** compared to that in the case in which the slit length of the second slit structure **521** is not reduced. In the electronic device **101**, the resonance frequency of the antenna may be changed by changing the slit length of the second slit structure **521**.

FIG. **20** is a diagram illustrating a first slit structure according to an embodiment.

Referring to FIG. **20**, the first housing **111** according to an embodiment may include a first slit structure **2001**. In an embodiment, the first slit structure **2001** may include a first portion **2001***a* and a second portion **2001***b*, and the first portion **2001***a* of the first slit structure **2001** may correspond to the first slit structure **421** illustrated in FIG. **3**. In an embodiment, the first portion **2001***a* of the first slit structure **2001** may have a first length L1 (e.g., 34 mm). In an embodiment, the second portion **2001***b* of the first slit structure **2001** may correspond to a portion extending from one end of the first portion **2001***a* and having a specific length L2 (e.g., 16 mm) in a specific direction (e.g., the +y direction). In an embodiment, the second portion **2001***b* of the first slit structure **2001** may be provided in a conductive area of the first housing **111**.

In an embodiment, the length and/or shape of the second portion of the first slit structure **2001** may vary depending on the frequency band in which the slit antenna including the first slit structure **2001** is desired to operate.

The second housing **112** according to an embodiment may include a second slit structure **2002**. In an embodiment, the second slit structure **2002** may include a third portion **2002***a* and/or a fourth portion **2002***b*, and the third portion **2002***a* of the second slit structure **2002** may correspond to the second slit structure **521** illustrated in FIG. **3**. In an embodiment, the fourth portion **2002***b* of the second slit structure **2002** may correspond to a portion extending from one end of the third portion **2002***a* and having a specific length in a specific direction (e.g., the +y direction).

In an embodiment, the length and/or shape of the fourth portion of the second slit structure **2002** may vary depending on the frequency band in which the slit antenna including the second slit structure **2002** is desired to operate.

FIG. **21** is an antenna radiation efficiency graph of the example illustrated in FIG. **20** according to various embodiments.

Referring to FIG. **21**, the first graph **2101** according to an embodiment is a radiation efficiency graph of a slit antenna including a first slit structure **2001** when the electronic device **101** is in the first state. The second graph **2102** is a radiation efficiency graph of a slit antenna including a first slit structure **2001** when the electronic device **101** is in the second state.

According to an embodiment, comparing the first graph **2101** and the second graph **2102**, the antenna radiation efficiency values of the first graph **2101** and the second graph **2102** have a different within about 2 dB in the frequency band of about 0.8 to 4 GHz. Therefore, it can be seen that, even in the second state in which at least a portion of the second housing **112** is slid into the first housing **111**, the radiation efficiency of the slit antenna including the first slit structure **2001** is maintained as in the first state.

According to an embodiment, the first graph **2101** has an antenna radiation efficiency of about −6 to −5 dB in the frequency band of about 0.9 to 1.5 GHz. In an embodiment, the wireless communication circuit **530** may transmit and/or receive an RF signal in the frequency band of about 0.9 to 1.5 GHz based on the electrical path including the second portion **2001***b* of the first slit structure **2001**.

FIG. **22** is a diagram illustrating a first slit structure according to various embodiments.

Referring to FIG. **22**, the first housing **111** according to an embodiment may include a first slit structure **2201**. In an embodiment, the first slit structure **2201** may include a first portion **2201***a* and a second portion **2201***b*, and the first portion **2201***a* of the first slit structure **2201** may correspond to the first slit structure **421** illustrated in FIG. **3**. In an embodiment, the second portion **2201***b* of the first slit structure **2201** may correspond to a portion extending from one end of the first portion **2001***a* and having a specific length in a specific direction (e.g., the −x direction). In an embodiment, the second portion **2201***b* of the first slit structure **2201** may be provided in a conductive area of the first housing **111**.

In an embodiment, the length and/or shape of the second portion of the first slit structure **2201** may vary depending on the frequency band in which the slit antenna including the first slit structure **2201** is desired to operate.

The second housing **112** according to an embodiment may include a second slit structure **2202**. In an embodiment, the second slit structure **2202** may include a third portion **2202***a* and/or a fourth portion **2202***b*, and the third portion **2202***a* of the second slit structure **2202** may correspond to the second slit structure **521** illustrated in FIG. **3**. In an embodiment, the fourth portion **2202***b* of the second slit structure **2202** may correspond to a portion extending from one end

of the third portion **2202***a* and having a specific length in a specific direction (e.g., the −x direction).

In an embodiment, the length and/or shape of the fourth portion **2202***b* of the second slit structure **2202** may vary depending on the frequency band in which the slit antenna including the first slit structure **2201** is desired to operate.

FIG. **23** is an antenna radiation efficiency graph of the example illustrated in FIG. **22** according to various embodiments.

Referring to FIG. **23**, the first graph **2301** according to an embodiment is a radiation efficiency graph of a slit antenna including a first slit structure **2201** when the electronic device is in the first state. The second graph **2302** is a radiation efficiency graph of a slit antenna including a first slit structure **2201** when the electronic device is in the second state.

According to an embodiment, comparing the first graph **2301** and the second graph **2302**, the antenna radiation efficiency values of the first graph **2301** and the second graph **2302** have a different within about 1 dB in the frequency band of about 0.8 to 4 GHz. Therefore, it can be seen that, even in the second state in which at least a portion of the second housing **112** is slid into the first housing **111**, the radiation efficiency of the slit antenna including the first slit structure **2201** is maintained as in the first state.

An electronic device according to an example embodiment may include: a first housing, a second housing slidably connected to the first housing, a printed circuit board (PCB) disposed in the electronic device, and a wireless communication circuit disposed on the PCB, wherein the first housing may include a first surface and a second surface perpendicular to the first surface at a first edge, and the first housing may include a first conductive area, the first conductive area may include a first portion of a first slit extending from a point on the first surface to the first edge, wherein the second housing may include a third surface including a second conductive area, and the second conductive area may include a second slit extending to an edge of the second housing corresponding to the first edge of the first housing, wherein, in a first state in which the first housing is slid in a first direction to be adjacent to the first housing, at least a portion of the first portion of the first slit may overlap the second slit when viewed in a second direction perpendicular to the first surface of the first housing, and the wireless communication circuit may be configured to transmit and/or receive a signal of a first frequency band based on an electrical path including the first portion of the first slit.

According to an example embodiment, the first portion of the first slit may further extend from the first edge of the first housing in the second direction along the second surface of the first housing.

The electronic device according to an example embodiment may further include a conductive connection member comprising a conductor coupled to a point of the PCB, wherein the conductive connection member may be configured come into contact with the first portion of the first slit provided on the second surface of the first housing, and the wireless communication circuit may be electrically connected to the conductive connection member, and may be configured to feed power to the point of the first portion of the first slit structure via the conductive connection member.

According to an example embodiment, the second housing may include a fourth surface perpendicular to a third surface of the second housing, and the fourth surface of the second housing may include a groove extending in a direction opposite to the first direction from one end thereof. In the first state, the fourth surface of the second housing may overlap the second surface when viewed in a third direction perpendicular to the second surface of the first housing, and the conductive connection member may be configured to pass through the groove of the fourth surface to come into contact with the first portion of the first slit provided on the second surface.

According to an example embodiment, in a second state in which the second housing is slid in a direction opposite to the first direction, the wireless communication **5** circuit may be configured to transmit and/or receive a signal of the first frequency band based on an electrical path including the first portion of the first slit.

According to an example embodiment, the first frequency band may include a range of 2 to 3.5 GHz.

According to an example embodiment, the first portion of the first slit may be L-shaped.

According to an example embodiment, the first portion of the first slit structure may extend from the point on the first surface of the first housing by a specific length in the first direction and extend to the first edge of the first housing, and the second portion of the first slit may extend from one end of the first portion of the first slit in a third direction perpendicular to the second surface of the first housing along the first surface of the first housing.

According to an example embodiment, the wireless communication circuit may be configured to transmit and/or receive a signal of a second frequency band based on an electrical path including the second portion of the first slit.

According to an example embodiment, the second frequency band may include a range of 0.8 to 1.5 GHz.

The electronic device according to an example embodiment may further include a flexible display, wherein the flexible display may include a first portion and a second portion extending from the first portion thereof, and wherein the second portion of the flexible display may be configured to be slid into the first housing in the first state and slid out of the first housing in a second state in which the second housing is slid in the direction opposite to the first direction.

According to an example embodiment, at least a portion of the second conductive area may include a ground.

The electronic device according to an example embodiment may further include a conductive connection member comprising a conductor, wherein the conductive connection member may be coupled to a point of a ground of the second conductive area, and in the first state, the conductive connection member may be positioned in the second direction of the first portion to be electrically connected to the first portion of the first slit.

According to an example embodiment, in the first state, at least a portion of the second housing may be configured to be slid into the first housing.

The electronic device according to an example embodiment may further include a lumped element electrically connected to the first portion of the first slit, wherein the wireless communication circuit may be configured to transmit and/or receive a signal of the second frequency band based on an electrical path including the first portion of the first slit and the lumped element.

An electronic device according to an example embodiment may include: a first metal housing, a second metal housing slidably connected to the first metal housing, and a wireless communication circuit disposed in the electronic device, wherein the first metal housing may include a first surface and a second surface perpendicular to the first surface at a first edge, and the first surface may include a first slit extending to the first edge from a point on the first surface, wherein the second metal housing may include a

third surface including a second slit extending to an edge of the second metal housing corresponding to the first edge of the first metal housing, wherein in a first state in which the second metal housing is slid in a direction approaching the first metal housing, at least a portion of the first slit may overlap the second slit when viewed in a first direction perpendicular to the first surface of the first metal housing, and the wireless communication circuit may be configured to transmit and/or receive a signal of a first frequency band based on an electrical path including the first slit structure.

According to an example embodiment, the first slit may further extend from the first edge of the first metal housing in the first direction along the second surface of the first metal housing.

According to an example embodiment, the first slit may be L-shaped.

The electronic device according to an example embodiment may further include a flexible display, wherein the flexible display may include a first portion and a second portion extending from the first portion thereof, wherein the second portion of the flexible display may be configured to be slid into the first metal housing in the first state, and slid out of the first metal housing in a second state in which the second metal housing is slid away from the first metal housing.

According to an example embodiment, in the first state, at least a portion of the second metal housing may be configured to be slid into the first metal housing.

The electronic device according to various embodiments may be one of various types of electronic devices. The electronic devices may include, for example, a portable communication device (e.g., a smartphone), a computer device, a portable multimedia device, a portable medical device, a camera, a wearable device, or a home appliance. According to an embodiment of the disclosure, the electronic devices are not limited to those described above.

It should be appreciated that various embodiments of the present disclosure and the terms used therein are not intended to limit the technological features set forth herein to particular embodiments and include various changes, equivalents, or replacements for a corresponding embodiment. With regard to the description of the drawings, similar reference numerals may be used to refer to similar or related elements. It is to be understood that a singular form of a noun corresponding to an item may include one or more of the things, unless the relevant context clearly indicates otherwise. As used herein, each of such phrases as "A or B," "at least one of A and B," "at least one of A or B," "A, B, or C," "at least one of A, B, and C," and "at least one of A, B, or C," may include any one of, or all possible combinations of the items enumerated together in a corresponding one of the phrases. As used herein, such terms as "1st" and "2nd," or "first" and "second" may be used to simply distinguish a corresponding component from another, and does not limit the components in other aspect (e.g., importance or order). It is to be understood that if an element (e.g., a first element) is referred to, with or without the term "operatively" or "communicatively", as "coupled with," "coupled to," "connected with," or "connected to" another element (e.g., a second element), it means that the element may be coupled with the other element directly (e.g., wiredly), wirelessly, or via a third element.

As used in connection with various embodiments of the disclosure, the term "module" may include a unit implemented in hardware, software, or firmware, and may interchangeably be used with other terms, for example, "logic," "logic block," "part," or "circuitry". A module may be a single integral component, or a minimum unit or part thereof, adapted to perform one or more functions. For example, according to an embodiment, the module may be implemented in a form of an application-specific integrated circuit (ASIC).

Various embodiments as set forth herein may be implemented as software (e.g., the program **140**) including one or more instructions that are stored in a storage medium (e.g., internal memory **136** or external memory **138**) that is readable by a machine (e.g., the electronic device **101**). For example, a processor (e.g., the processor **120**) of the machine (e.g., the electronic device **101**) may invoke at least one of the one or more instructions stored in the storage medium, and execute it, with or without using one or more other components under the control of the processor. This allows the machine to be operated to perform at least one function according to the at least one instruction invoked. The one or more instructions may include a code generated by a complier or a code executable by an interpreter. The machine-readable storage medium may be provided in the form of a non-transitory storage medium. Wherein, the term "non-transitory" simply means that the storage medium is a tangible device, and does not include a signal (e.g., an electromagnetic wave), but this term does not differentiate between where data is semi-permanently stored in the storage medium and where the data is temporarily stored in the storage medium.

According to an embodiment, a method according to various embodiments of the disclosure may be included and provided in a computer program product. The computer program product may be traded as a product between a seller and a buyer. The computer program product may be distributed in the form of a machine-readable storage medium (e.g., compact disc read only memory (CD-ROM)), or be distributed (e.g., downloaded or uploaded) online via an application store (e.g., PlayStore™), or between two user devices (e.g., smart phones) directly. If distributed online, at least part of the computer program product may be temporarily generated or at least temporarily stored in the machine-readable storage medium, such as memory of the manufacturer's server, a server of the application store, or a relay server.

According to various embodiments, each component (e.g., a module or a program) of the above-described components may include a single entity or multiple entities, and some of the multiple entities may be separately disposed in different components. According to various embodiments, one or more of the above-described components may be omitted, or one or more other components may be added. Alternatively or additionally, a plurality of components (e.g., modules or programs) may be integrated into a single component. In such a case, according to various embodiments, the integrated component may still perform one or more functions of each of the plurality of components in the same or similar manner as they are performed by a corresponding one of the plurality of components before the integration. According to various embodiments, operations performed by the module, the program, or another component may be carried out sequentially, in parallel, repeatedly, or heuristically, or one or more of the operations may be executed in a different order or omitted, or one or more other operations may be added.

While the disclosure has been illustrated and described with reference to various example embodiments, it will be understood that the various example embodiments are intended to be illustrative, not limiting. It will be further understood by those skilled in the art that various changes in

form and detail may be made without departing from the true spirit and full scope of the disclosure, including the appended claims and their equivalents. It will also be understood that any of the embodiment(s) described herein may be used in conjunction with any other embodiment(s) described herein.

What is claimed is:

1. An electronic device comprising:

a first housing including a first surface and a second surface perpendicular to the first surface at a first edge, and a first conductive area, the first conductive area including a first portion of a first slit extending from a point on the first surface to the first edge;

a second housing slidably connected to the first housing and including a third surface including a second conductive area, the second conductive area including a second slit extending to an edge of the second housing corresponding to the first edge of the first housing;

a printed circuit board (PCB) disposed in the electronic device; and

a wireless communication circuit disposed on the PCB,

wherein, in a first state in which the second housing is slid in a first direction to be adjacent to the first housing, at least a portion of the first portion of the first slit overlaps the second slit when viewed in a second direction perpendicular to the first surface of the first housing, and

wherein the wireless communication circuit is configured to transmit and/or receive a signal of a first frequency band based on an electrical path including the first portion of the first slit.

2. The electronic device of claim **1**, wherein the first portion of the first slit further extends from the first edge of the first housing in the second direction along the second surface of the first housing.

3. The electronic device of claim **2**, further comprising:

a conductive connection member comprising a conductor coupled to a point of the PCB,

wherein the conductive connection member is configured to come into contact with the first portion of the first slit provided on the second surface of the first housing, and

wherein the wireless communication circuit is electrically connected to the conductive connection member, and is configured to feed power to a point of the first portion of the first slit via the conductive connection member.

4. The electronic device of claim **3**, wherein the second housing includes a fourth surface perpendicular to a third surface of the second housing, and

wherein the fourth surface of the second housing includes a groove extending in a direction opposite to the first direction from one end, and

wherein, in the first state, the fourth surface of the second housing overlaps the second surface when viewed in a third direction perpendicular to the second surface of the first housing, and the conductive connection member passes through the groove of the fourth surface to come into contact with the first portion of the first slit formed on the second surface.

5. The electronic device of claim **1**, wherein, in a second state in which the second housing is slid in a direction opposite to the first direction, the wireless communication circuit is configured to transmit and/or receive a signal of the first frequency band based on an electrical path including the first portion of the first slit.

6. The electronic device of claim **1**, wherein the first frequency band is in a range of 2 to 3.5 GHz.

7. The electronic device of claim **1**, wherein the first portion of the first slit is L-shaped.

8. The electronic device of claim **1**, wherein the first portion of the first slit extends from the point on the first surface of the first housing by a specific length in the first direction and extends to the first edge of the first housing, and

wherein the second portion of the first slit extends from one end of the first portion of the first slit in a third direction perpendicular to the second surface of the first housing along the first surface of the first housing.

9. The electronic device of claim **8**, wherein the wireless communication circuit is configured to transmit and/or receive a signal of a second frequency band based on an electrical path including the second portion of the first slit.

10. The electronic device of claim **9**, wherein the second frequency band is in a range of 0.8 to 1.5 GHz.

11. The electronic device of claim **1**, further comprising:

a flexible display,

wherein the flexible display includes a first portion and a second portion extending from the first portion, and

wherein the second portion of the flexible display is configured to be slid into the first housing in the first state and slid out of the first housing in a second state in which the second housing is slid in the direction opposite to the first direction.

12. The electronic device of claim **1**, wherein at least a portion of the second conductive area includes a ground.

13. The electronic device of claim **12**, further comprising:

a conductive connection member comprising a conductor,

wherein the conductive connection member is coupled to a point of a ground of the second conductive area, and

wherein the conductive connection member is positioned in the second direction of the first portion of the first slit in the first state to be electrically connected to the first portion of the first slit.

14. The electronic device of claim **1**, wherein, in the first state, at least a portion of the second housing is slid into the first housing.

15. The electronic device of claim **1**, further comprising:

a lumped element electrically connected to the first portion of the first slit,

wherein the wireless communication circuit is configured to transmit and/or receive a signal of the second frequency band based on an electrical path including the first portion of the first slit and the lumped element.

16. An electronic device comprising:

a first metal housing including a first surface and a second surface perpendicular to the first surface at a first edge, the first surface including a first slit extending from a point on the first surface to the first edge;

a second metal housing slidably connected to the first metal housing and including a third surface including a second slit extending to an edge of the second metal housing corresponding to the first edge of the first metal housing; and

a wireless communication circuit disposed in the electronic device,

wherein, in a first state in which the second metal housing is slid in a direction approaching the first metal housing, at least a portion of the first slit overlaps the second slit when viewed in a first direction perpendicular to the first surface of the first metal housing, and

wherein the wireless communication circuit is configured to transmit and/or receive a signal of a first frequency band based on an electrical path including the first slit.

17. The electronic device of claim **16**, wherein the first slit further extends from the first edge of the first metal housing in the first direction along the second surface of the first metal housing.

18. The electronic device of claim **16**, wherein the first slit is L-shaped.

19. The electronic device of claim **16**, further comprising:

a flexible display,

wherein the flexible display includes a first portion and a second portion extending from the first portion thereof, and

wherein the second portion of the flexible display is configured to be slid into the first metal housing in the first state, and slid out of the first metal housing in a second state in which the second metal housing is slid away from the first metal housing.

20. The electronic device of claim **16**, wherein in the first state, at least a portion of the second metal housing is slid into the first metal housing.

* * * * *

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(12) **United States Patent**
Chang et al.

(10) **Patent No.: US 12,237,577 B2**
(45) **Date of Patent: Feb. 25, 2025**

(54) **CAVITY-BACKED SLOT ANTENNA SYSTEM**

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(73) Assignee: **ASUSTEK COMPUTER INC.**, Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 253 days.

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(22) Filed: **Sep. 21, 2022**

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(30) **Foreign Application Priority Data**

Oct. 20, 2021 (TW) 110212376

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H01Q 1/22 (2006.01)
H01Q 5/378 (2015.01)

(52) **U.S. Cl.**
CPC ***H01Q 13/18*** (2013.01); ***H01Q 1/2266*** (2013.01); ***H01Q 5/378*** (2015.01)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/2266; H01Q 5/378–392; H01Q 7/00; H01Q 13/18
See application file for complete search history.

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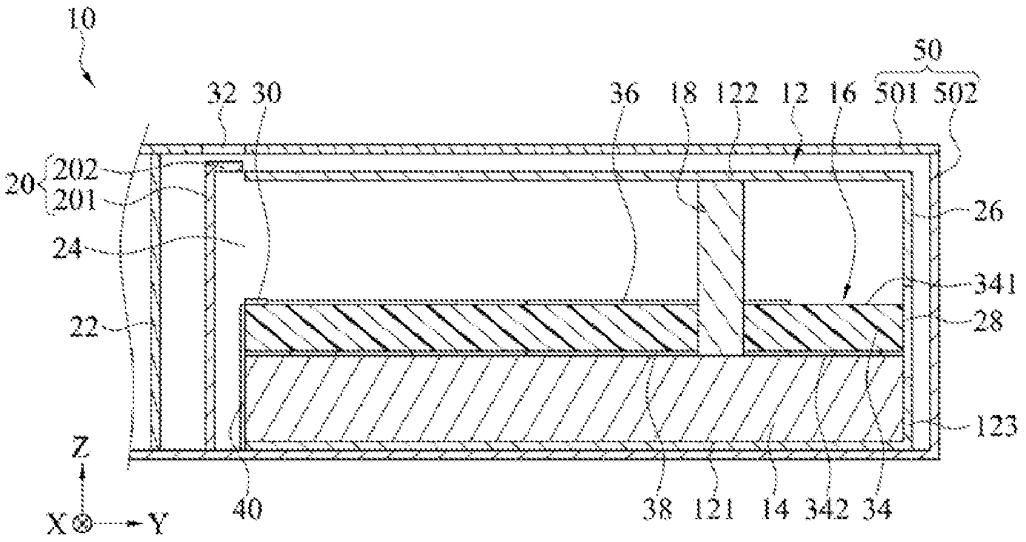
Primary Examiner — Dameon E Levi
Assistant Examiner — Leah Rosenberg
(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(57) **ABSTRACT**

A cavity-backed slot antenna system provided in this disclosure is installed in a housing of an electronic device and includes a metal cavity, a supporting element, an antenna device, a conductive post, and a coupling metal part. The metal cavity is in the housing and includes an opening and a closed surface opposite to each other. A slot is on the closed surface. The supporting element is in the metal cavity. The antenna device is in the metal cavity and on the supporting element, to expose one side surface of the antenna device. The antenna device includes a feed source. The conductive post penetrates the antenna device and connects to the metal cavity. The coupling metal part is in the housing and close to the opening of the metal cavity, so that the coupling metal part is close to and corresponds to the feed source of the antenna device.

14 Claims, 7 Drawing Sheets



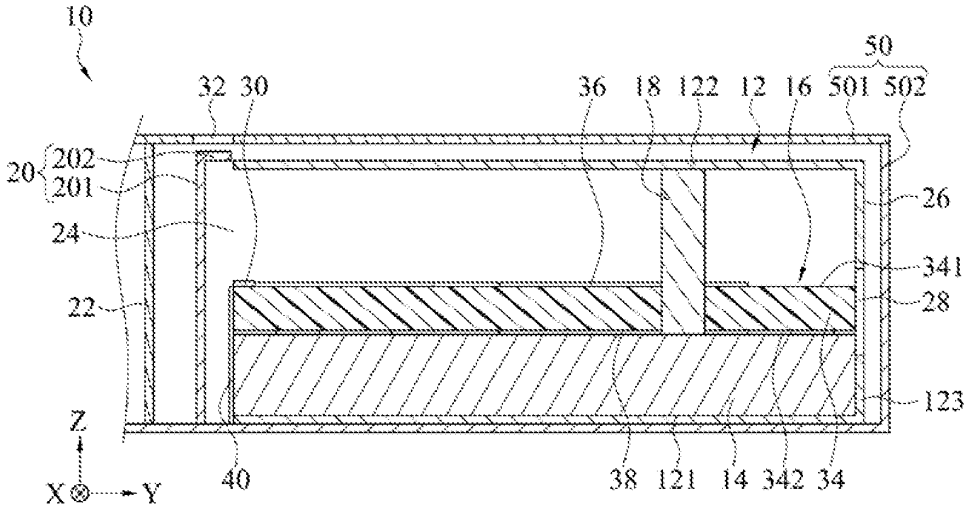

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FIG. 1

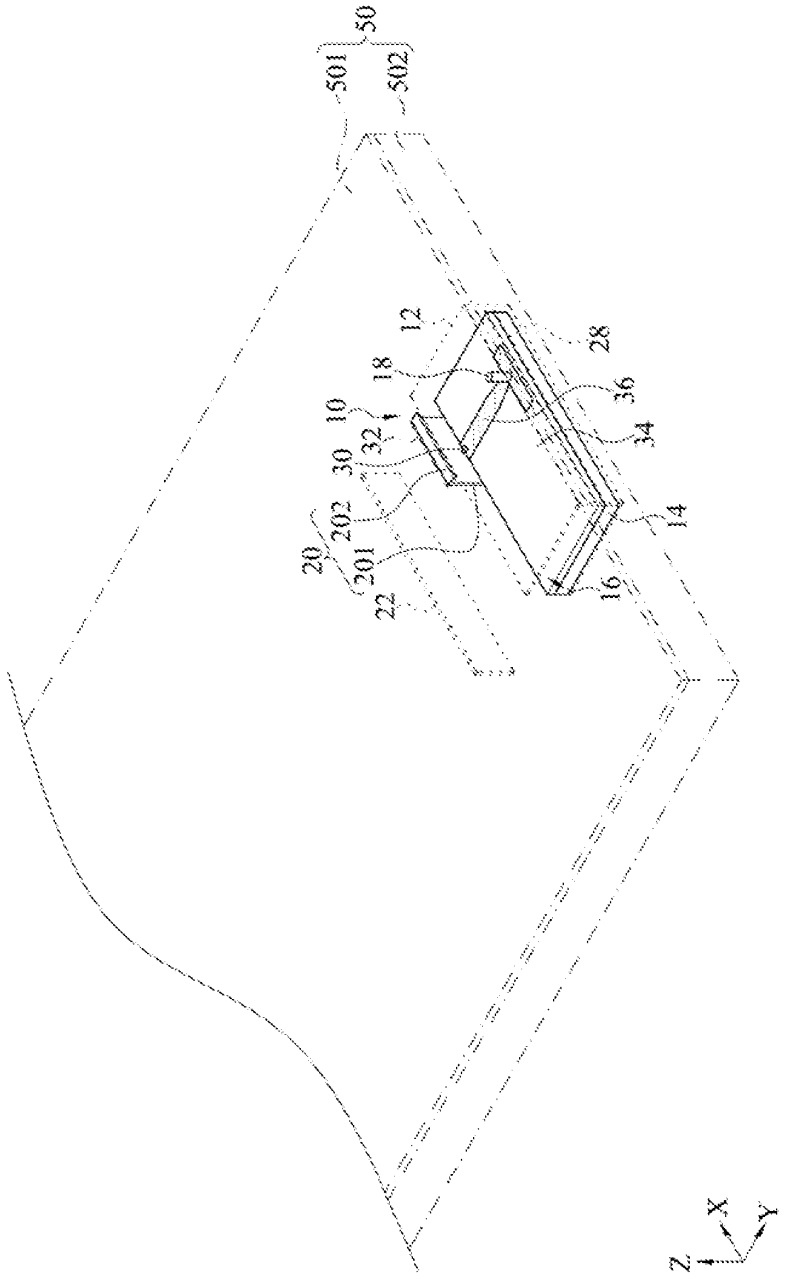

FIG. 2

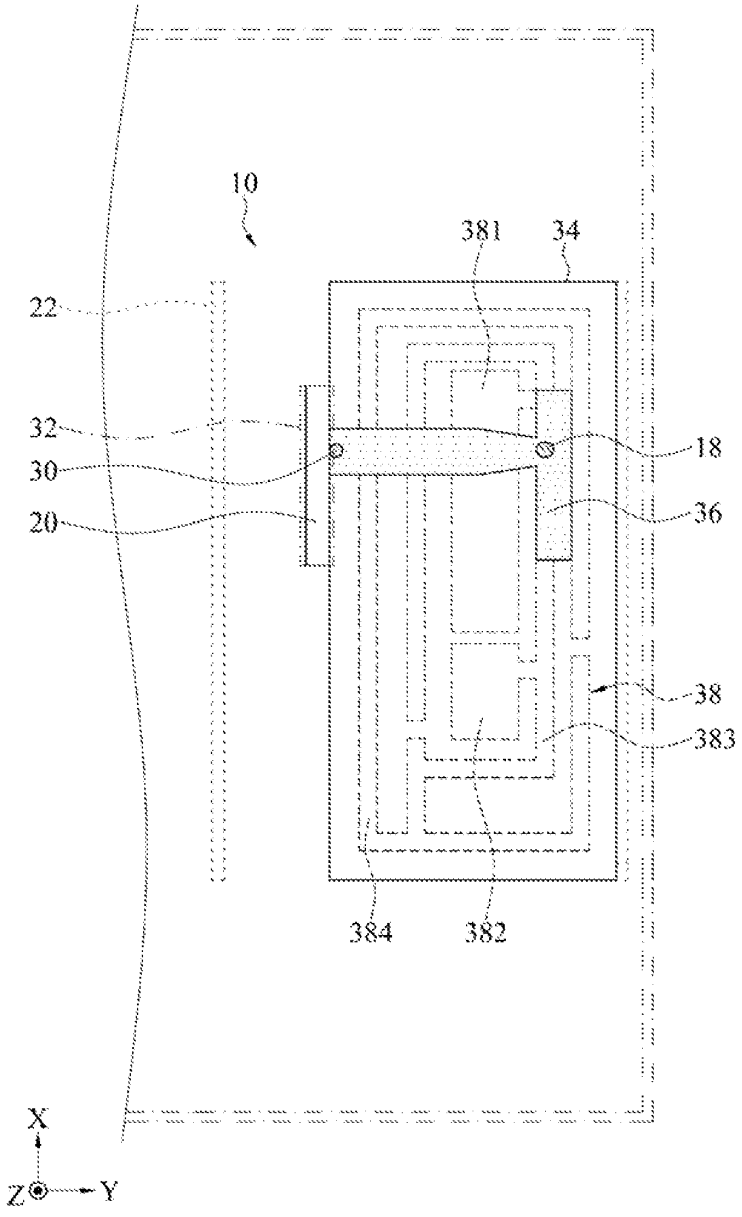

FIG. 3

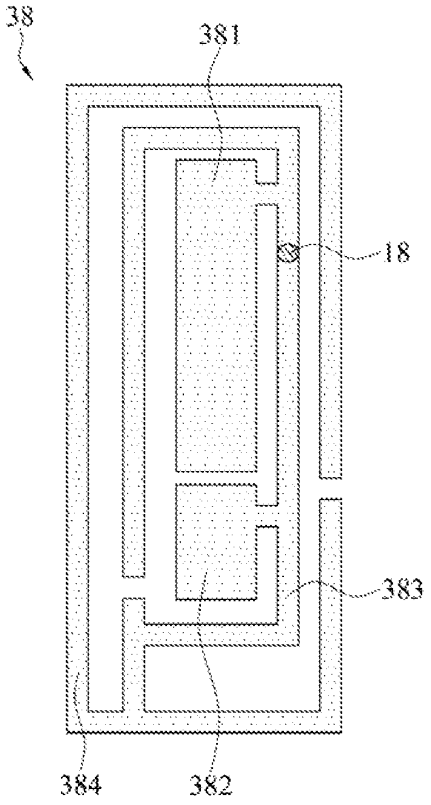
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FIG. 4

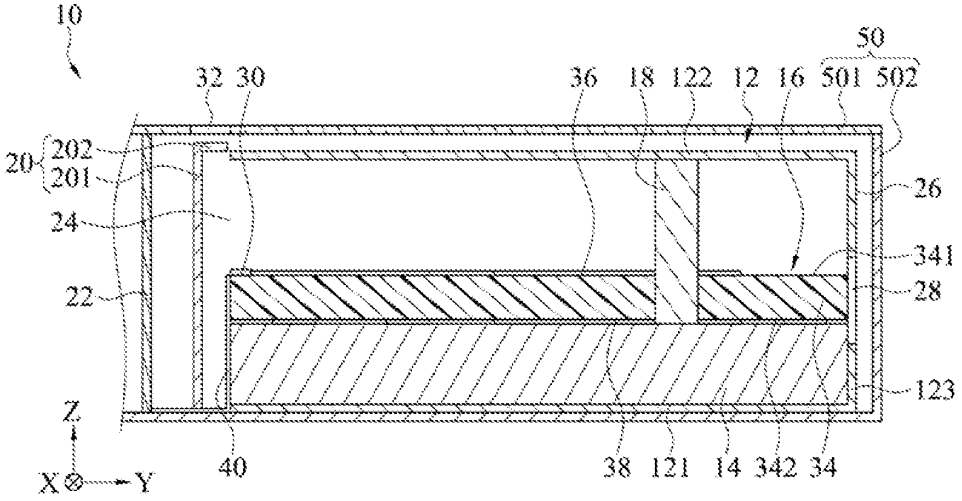
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FIG. 5

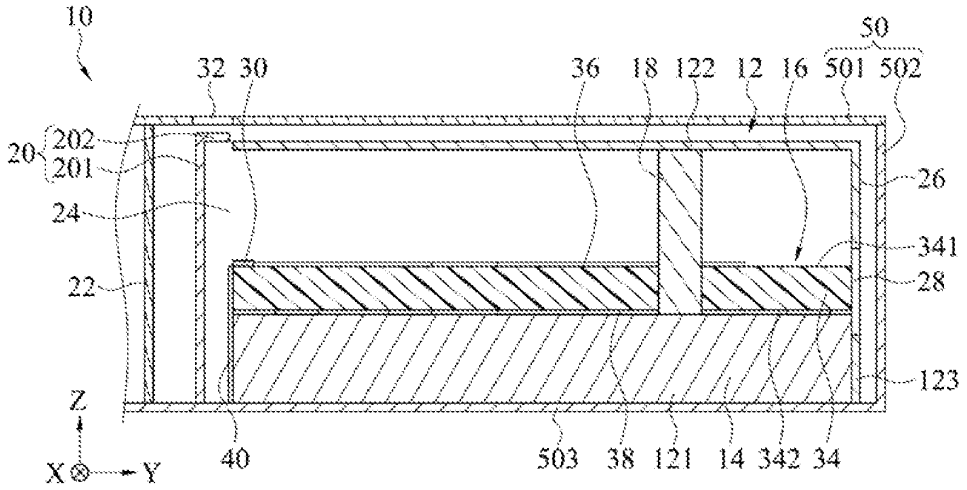
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FIG. 6

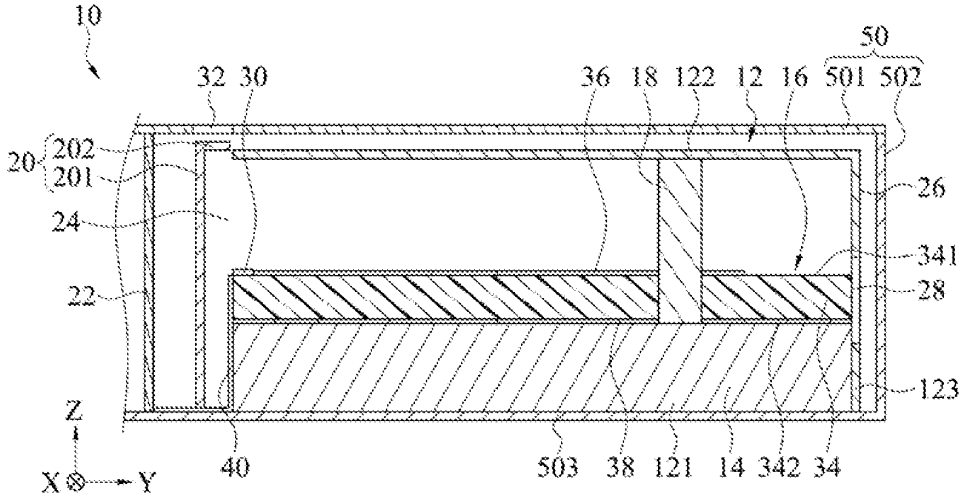
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FIG. 7

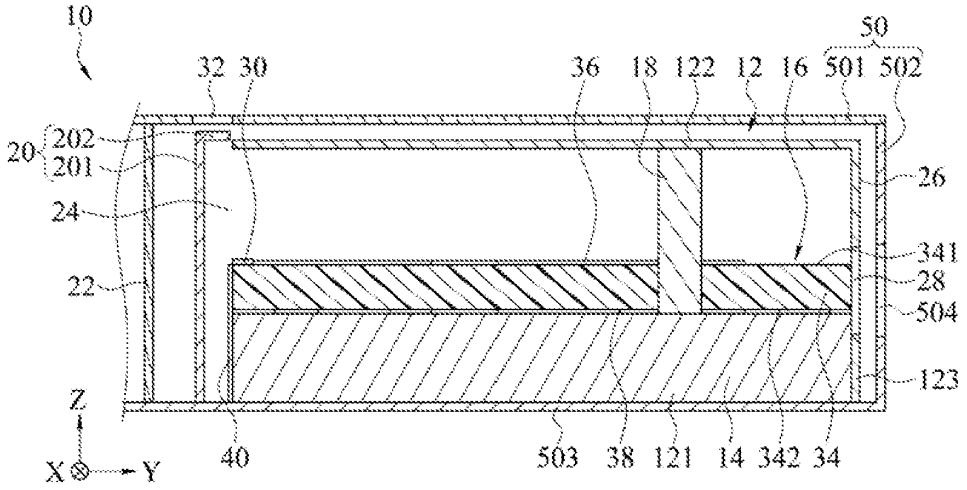
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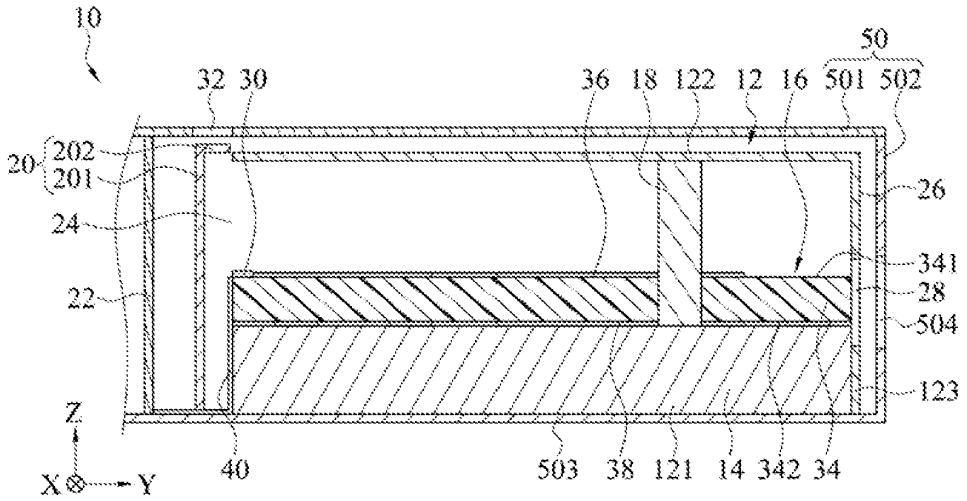
FIG. 8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503 38 121 14 342 34

FIG. 9

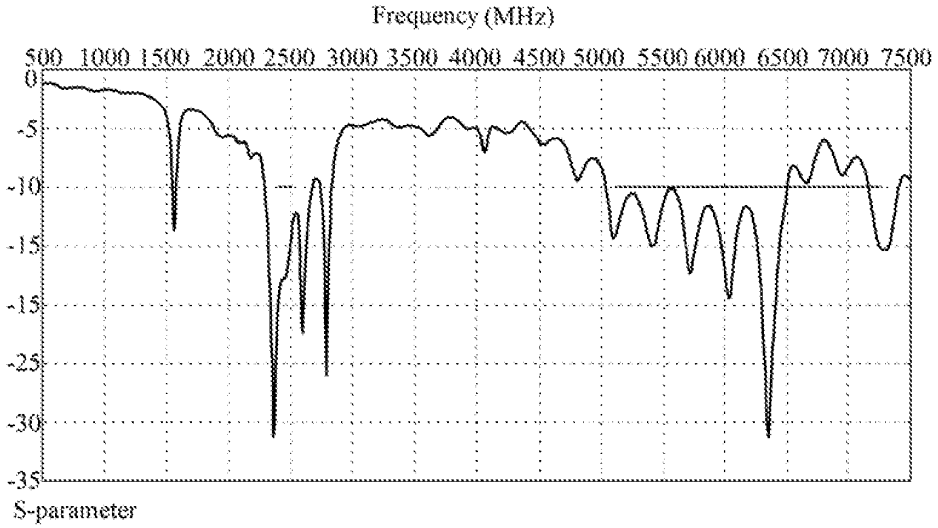
Frequency (MHz)
500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500
0
-5
-10
-15
-15
-25
-30
-35
S-parameter

FIG. 10

CAVITY-BACKED SLOT ANTENNA SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial No. 110212376, filed on Oct. 20, 2021. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of the specification.

BACKGROUND OF THE INVENTION

Field of the Invention

The disclosure relates to a built-in miniaturized cavity-backed slot antenna system.

Description of the Related Art

Nowadays, consumers have increasingly high requirements on the appearance of products, and the metal case has a great advantage in terms of mechanical strength, heat dissipation and appearance. Therefore, more manufacturers are designing wireless mobile devices with metal cases in response to the market demand. However, the metal case tends to shield the internal antenna radiation signal and is not easy to achieve broadband operation. Therefore, many manufacturers arrange a slot or metal frame breakpoint on the metal case, which further affects the aesthetic appearance of the product.

On the other hand, for the cavity-backed slot antenna, the slot is arranged on the side edge and covered by the design process, so as to prevent consumers from directly viewing the slot from the outside, which greatly increases the aesthetics of the product. Moreover, because the cavity-backed slot antenna is easily attached or co-constructed with metal mechanical components, this antenna design is commonly found on metal platform vehicles such as automotive, aerospace, marine and military vehicles. However, compared with other types of antennas, the biggest disadvantage of the conventional cavity-backed slot antenna is that the cavity is excessive in the overall size and is difficult to be embedded. Therefore, the design of the cavity-backed slot antenna is rarely applied to wireless mobile devices that need to be light and thin.

In order to reduce the size of the conventional cavity-backed slot antenna, the simplest and most common means of miniaturization is to fill the metal cavity with a medium such as a high dielectric or high permeability material to reduce the overall volume of the metal cavity and the size of the slot. However, the design method sharply reduces the antenna bandwidth and the antenna efficiency decreases. Moreover, the use of the high conductivity or high permeability material sharply increases the overall design costs of the antenna, which is detrimental to the antenna development.

BRIEF SUMMARY OF THE DISCLOSURE

According to an aspect of the disclosure, a cavity-backed slot antenna system installed in a housing of an electronic device is provided. The cavity-backed slot antenna system includes a metal cavity, a supporting element, an antenna device, a conductive post, and a coupling metal part. The metal cavity is located in the housing, and the metal cavity includes an opening and a closed surface opposite to each other, and a slot is arranged on the closed surface. The supporting element is located in the metal cavity. The antenna device is located in the metal cavity and on the supporting element, to expose one side surface of the antenna device from the slot, and the antenna device includes a feed source. The conductive post penetrates the antenna device and extends and connects to the metal cavity. The coupling metal part is located in the housing and close to the opening of the metal cavity so that the coupling metal part corresponds to the feed source of the antenna device.

To sum up, the disclosure relates to a design of a built-in miniaturized cavity-backed slot antenna system applicable to a metal case. In addition to effectively reducing an overall size of the whole cavity-backed slot antenna system, the antenna design in the disclosure is easy to resist the coupling of metal elements in the surrounding environment, and achieves the operating bandwidth of both a low-frequency band (2400 to 2480 MHz) and a high-frequency band (5150 to 7150 MHz) of a wireless local area network (WLAN), so as to achieve the purpose of miniaturization and broadband.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a structural cross-sectional view of a cavity-backed slot antenna system according to an embodiment of the disclosure.

FIG. **2** is a schematic 3D structural view of a cavity-backed slot antenna system according to an embodiment of the disclosure.

FIG. **3** is a schematic structural view of an antenna device of a cavity-backed slot antenna system according to an embodiment of the disclosure.

FIG. **4** is a schematic structural view of a parasitic loop circuit of an antenna device according to an embodiment of the disclosure.

FIG. **5** is a structural cross-sectional view of a cavity-backed slot antenna system according to another embodiment of the disclosure.

FIG. **6** is a structural cross-sectional view of a cavity-backed slot antenna system according to still another embodiment of the disclosure.

FIG. **7** is a structural cross-sectional view of a cavity-backed slot antenna system according to yet another embodiment of the disclosure.

FIG. **8** is a structural cross-sectional view of a cavity-backed slot antenna system according to yet another embodiment of the disclosure.

FIG. **9** is a structural cross-sectional view of a cavity-backed slot antenna system according to yet another embodiment of the disclosure.

FIG. **10** is a schematic simulation diagram of S-parameter generated by the cavity-backed slot antenna system according to the disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring to FIG. **1** and FIG. **2** together, a built-in miniaturized cavity-backed slot antenna system **10** of the disclosure is installed in a housing **50** of an electronic device, the housing **50** includes an upper housing **501** and a lower housing **502**, and the upper housing **501** and the lower housing **502** are assembled together. The cavity-backed slot antenna system **10** includes a metal cavity **12**, a supporting element **14**, an antenna device **16**, a conductive post **18**, a coupling metal part **20**, and a metal wall **22**.

In an embodiment, the electronic device is a notebook computer. In this case, the housing **50** is composed of a keyboard top cover (commonly known as C part) and a keyboard base (commonly known as D part), that is, the upper housing **501** is the keyboard top cover and the lower housing **502** is the keyboard base, so that the cavity-backed slot antenna system **10** is installed on the lower housing **502** of the housing **50**. In another embodiment, the cavity-backed slot antenna system **10** is installed upside down on the upper housing **501** of the housing **50**.

As shown in FIG. **1** and FIG. **2**, in the cavity-backed slot antenna system **10**, the metal cavity **12** is arranged in the housing **50** and on an inner surface of the lower housing **502**, and the metal cavity **12** includes an opening **24** and a closed surface **26** opposite to each other. The opening **24** faces an interior of the housing **50**, while the closed surface **26** is close to and faces a side wall of the housing **50** (the lower housing **502**), and a slot **28** is arranged on the closed surface **26**. In an embodiment, a size of the slot **28** is a length of half a wavelength of a working band of the antenna. The supporting element **14** is located in the metal cavity **12** and is made of a non-conductive material. The antenna device **16** is also located in the metal cavity **12** and on the supporting element **14**, to expose one side surface of the antenna device **16** from the slot **28**, and the antenna device **16** includes a feed source **30**. The conductive post **18** is located in the metal cavity **12**. The conductive post **18** penetrates the antenna device **16** and extends and connects to an inner wall of the metal cavity **12**, so that the conductive post **18** electrically connects the antenna device **16** and the metal cavity **12**. The coupling metal part **20** is located in the housing **50** and on an inner surface of the lower housing **502**. The coupling metal part **20** is close to the opening **24** of the metal cavity **12** to correspond to the feed source **30** of the antenna device **16**. An antenna window **32** is further arranged on the upper housing **501** of the housing **50** and at a position on a projection plane of the coupling metal part **20** on the upper housing **501**, so that the coupling metal part **20** transmits wireless signals through the antenna window **32**. The metal wall **22** is located in the housing **50** and on an outer side of the coupling metal part **20**. A height of the metal wall **22** is greater than a height of the coupling metal part **20** to block signal interference from a system end of the electronic device.

In an embodiment, the coupling metal part **20** further includes a vertical metal portion **201** and a horizontal metal portion **202**, one side edge of the vertical metal portion **201** is connected to the lower housing **502** of the housing **50**, and the other side edge is vertically connected to the horizontal metal portion **202**, so that the horizontal metal portion **202** corresponds to the antenna window **32**, and a size of the antenna window **32** is greater than or equal to a size of the horizontal metal portion **202** of the coupling metal part **20**.

In an embodiment, referring to FIG. **1** to FIG. **4** together, the antenna device **16** includes a substrate **34**, a feed strip line **36**, the feed source **30**, and a parasitic loop circuit **38**. The substrate **34** is a printed circuit board (PCB) and includes a first surface **341** and a second surface **342** which are up and down opposite. The feed strip line **36** is located on the first surface **341** of the substrate **34**. The feed source **30** is also located on the first surface **341** of the substrate **34** and is close to the coupling metal part **20**, and the feed source **30** is electrically connected to the feed strip line **36**. The parasitic loop circuit **38** is located on the second surface **342** of the substrate **34**. The conductive post **18** penetrates the substrate **34**, the feed strip line **36**, and the parasitic loop circuit **38**, and extends upward to the metal cavity **12**, so that the conductive post **18** electrically connects the feed strip line **36**, the parasitic loop circuit **38**, and the metal cavity **12**. In an embodiment, the structure design of the feed strip line **36** and the parasitic loop circuit **38** is not limited in the disclosure, and the feed strip line **36** is T-shaped as shown in FIG. **3**. The parasitic loop circuit **38** is designed as the circuit shown in FIG. **4**. The parasitic loop circuit **38** includes a first metal portion **381**, a second metal portion **382**, a first metal loop **383**, and a second metal loop **384**. The first metal loop **383** surrounds a periphery of the first metal portion **381** and the second metal portion **382** and connects the first metal portion **381** and the second metal portion **382**. The second metal loop **384** surrounds a periphery of the first metal loop **383** and connects to the first metal loop **383** to form the parasitic loop circuit **38**. However, the structure design is not limited in the disclosure, and other circuit patterns care also available. In this embodiment, the conductive post **18** penetrates the first metal loop **383** of the parasitic loop circuit **38**.

In an embodiment, referring to FIG. **1** to FIG. **2** together, in the cavity-backed slot antenna system **10**, the metal cavity **12** further includes a metal bottom plate **121**, a metal cover plate **122**, and a metal side plate **123**. The metal bottom plate **121** is located below the supporting element **14**, the metal cover plate **122** is located above the antenna device **16**, and the metal side plate **123** is located at a periphery between the metal bottom plate **121** and the metal cover plate **122**, so that the metal bottom plate **121**, the metal cover plate **122**, and the metal side plate **123** are connected to each other to form the metal cavity **12**, and the opening **24** and the closed surface **26** opposite to each other are formed, so that the slot **28** on the closed surface **26** (the metal side plate **123**) corresponds to and exposes the antenna device **16**, and the opening **24** corresponds to the coupling metal part **20**.

To enhance a grounding effect, the cavity-backed slot antenna system **10** further includes a metal layer **40** located on a side wall of the antenna device **16** and extending downward from the feed source **30** to connect to the metal bottom plate **121** of the metal cavity **12**, so as to electrically connect the feed source **30** to the metal bottom plate **121** for grounding.

In another embodiment, referring to FIG. **5**, the cavity-backed slot antenna system **10** further includes a metal layer **40** located on a side wall of the antenna device **16**, and after extending downward from the feed source **30** to connect to the metal bottom plate **121** of the metal cavity **12**, the metal layer **40** further extends below the coupling metal part **20**, so that a side edge of the vertical metal portion **201** of the coupling metal part **20** is connected to the metal layer **40** to electrically connect both the feed source **30** and the coupling metal part **20** to the metal bottom plate **121** for grounding.

In an embodiment, referring to FIG. **6**, in the cavity-backed slot antenna system **10**, the metal bottom plate used for the metal cavity **12** is a metal bottom surface **503** at the bottom of the housing **50**, that is, the metal bottom surface **503** of the lower housing **501** is used as a part of the metal cavity **12**. As shown in FIG. **6**, the metal cavity **12** further includes a metal bottom plate **121**, a metal cover plate **122**, and a metal bottom surface **503**, the supporting element **14** is directly located on a surface of the metal bottom surface **503**, the metal cover plate **122** is located above the antenna device **16**, and the metal side plate **123** is located at a periphery between the metal bottom surface **503** and the metal cover plate **122**, so that the metal bottom surface **503**, the metal cover plate **122**, and the metal side plate **123** are connected to each other to form the metal cavity **12** for accommodating the supporting element **14**, the antenna

device **16**, and the conductive post **18**, and the opening **24** and the closed surface **26** are formed, so that the slot **28** on the closed surface **26** (the metal side plate **123**) corresponds to and exposes the antenna device **16**, and the opening **24** corresponds to the coupling metal part **20**. In this embodiment, the metal layer **40** is located on a side wall of the antenna device **16** and extends downward from the feed source **30** to connect to the metal bottom surface **503** of the metal cavity **12**, so as to electrically connect the feed source **30** to the metal bottom surface **503** for grounding. The rest of the structure is the same as that in the cavity-backed slot antenna system **10** shown in FIG. **1**, and no repeated description is provided.

In another embodiment, referring to FIG. **7**, the metal layer **40** in the cavity-backed slot antenna system **10** is located on a side wall of the antenna device **16**, and after extending downward from the feed source **30** to connect to the metal bottom surface **503** of the metal cavity **12**, the metal layer **40** further extends below the coupling metal part **20** along the metal bottom surface **503**, so that a lower side edge of the vertical metal portion **201** of the coupling metal part **20** is connected to the metal layer **40**, to electrically connect both the feed source **30** and the coupling metal part **20** to the metal bottom surface **503** for grounding.

In an embodiment, as shown in FIG. **8** and FIG. **9**, in the cavity-backed slot antenna system **10**, if a side wall of the lower housing **502** in the housing **50** is a metal part or metal material, an antenna window **504** is arranged on a metal side wall of the lower housing **502** and at a position corresponding to the slot **28** to expose the slot **28** from the antenna window **504**, so that the coupling metal part **20** transmits wireless signals through the slot **28** and the antenna window **504**, thereby providing an energy radiation outlet in a high-frequency operating band to optimize a coverage ratio of a radiation field pattern. A size of the antenna window **504** is greater than or equal to the size of the slot **28**. The rest of the structure is the same as that in the foregoing embodiment, and no repeated description is provided.

In an embodiment, as shown in FIG. **1** to FIG. **9**, elements such as the metal cavity **12** (the metal bottom plate **121**, the metal cover plate **122**, and the metal side plate **123**), the feed strip line **36** and the parasitic loop circuit **38** of the antenna device **16**, the conductive post **18**, the coupling metal part **20** (the vertical metal portion **201** and the horizontal metal portion **202**), and the metal wall **22** are made of conductive metal materials, such as silver, copper, aluminum, iron or alloy thereof.

Referring to FIG. **1** to FIG. **9** together, using an example in which the antenna is applied to a WLAN, a low-frequency operating band (2400 to 2480 MHz) is operated in the low-frequency band by a **214** resonant mode formed by the feed source **30** and the coupling metal part **20** located near the feed source **30**, and the antenna window **32** is arranged at the position on the projection plane above the coupling metal part **20** to provide an energy radiation outlet in the low-frequency operating band. A high-frequency operating band (5150 to 7150 MHz) is determined by a geometry size associated with the metal cavity **12** (including a length and a width of the slot **28** and a depth of the metal cavity **12**), and is related to relative positions of the conductive post **18** and the feed source **30** with respect to the metal cavity **12** to operate in the high-frequency band. The high-frequency band in this embodiment is a $\lambda/2$ resonant mode.

The cavity-backed slot antenna system **10** provided in the disclosure does have a good return loss. Referring to FIG. **1** to FIG. **10**, the cavity-backed slot antenna system **10** is used to perform simulation analysis of S-parameter when a radio frequency signal is transmitted. An S-parameter simulation result of the cavity-backed slot antenna system **10** in the low-frequency operating band (2400 to 2480 MHz) and the high-frequency operating band (5150 to 7150 MHz) are shown in FIG. **10**. It is seen from the curve shown in the figure that, in the disclosure, most of the return loss (S-parameter) of an antenna resonance band shown in the low-frequency operating band and the high-frequency operating band is greater than 10 dB (S-parameter is less than −10 dB). The performance that the return loss is still greater than 6 dB (S-parameter is less than −6 dB) even in the high-frequency operating band from 6500 to 7150 MHz proves that the cavity-backed slot antenna system **10** has a good return loss in both the low-frequency operating band and the high-frequency operating band, so that the cavity-backed slot antenna system **10** is effectively applicable to both the low-frequency operating band (2400 to 2480 MHz) and the high-frequency operating band (5150 to 7150 MHz).

Miniaturized antennas are usually accompanied by extremely small input resistances and extremely high dummy sections, which leads to excessively narrow bandwidths. Compared with a metal planar slotted design, the cavity-backed slot antenna is usually accompanied by a narrower operating bandwidth. Therefore, a multistage impedance matching network is required to extend the multimode resonance to extend the bandwidth, but this method increases the design costs and results in poor antenna efficiency due to an additional loss introduced by the multistage matching network. In the disclosure, by adjusting the geometry size and structure of the feed strip line and the surrounding parasitic loop circuit in the antenna device in the metal cavity, the antenna structure generates additional capacitance and inductance value loads, and eliminates the characteristic of drastic reactance change accompanied by the miniaturized cavity-backed antenna, so as to obtain better impedance matching to further expand the antenna operation. Based on this, the cavity-backed slot antenna system provided in the disclosure covers the high-frequency working bandwidth of the WLAN while reducing the size of the metal cavity. Furthermore, the size of the slot on the metal cavity in the foregoing embodiment is the length of half the wavelength, which is reduced by about half compared with the length of the conventional cavity-backed slot which is slightly longer than one wavelength, and the depth of the metal cavity is reduced by less than a quarter of the wavelength. The overall size of the metal cavity is significantly reduced for a built-in antenna design.

To sum up, the disclosure relates to a design of a built-in miniaturized cavity-backed slot antenna system applicable to a metal case. In addition to effectively reducing an overall size of the whole cavity-backed slot antenna system, the antenna design in the disclosure is easy to resist the coupling of metal elements in the surrounding environment, and achieves the operating bandwidth of both a low-frequency band (2400 to 2480 MHz) and a high-frequency band (5150 to 7150 MHz) of a WLAN, so as to achieve the purpose of miniaturization and broadband.

The foregoing embodiments are only intended to illustrate the technical ideas and features of the disclosure, the purpose of which is to enable those familiar with this technology to understand the content of the disclosure and implement them accordingly but are not to limit the patent scope of the disclosure, that is, any equivalent change or modification made in accordance with the spirit disclosed in the disclosure shall also be encompassed in the patent scope of the disclosure.

What is claimed is:

1. A cavity-backed slot antenna system comprising:

a housing of an electronic device;

a metal cavity, located in the housing, wherein the metal cavity comprises an opening and a closed surface opposite to each other, and a slot is arranged on the closed surface;

a supporting element, located in the metal cavity;

an antenna device, located in the metal cavity and on the supporting element, to expose one side surface of the antenna device from the slot, wherein the antenna device comprises a feed source;

a conductive post, penetrating the antenna device and connecting to the metal cavity; and

a coupling metal part, located in the housing and adjacent to the opening of the metal cavity, wherein the coupling metal part and the feed source of the antenna device form a resonant mode.

2. The cavity-backed slot antenna system according to claim 1, wherein the antenna device comprises:

a substrate, comprising a first surface and a second surface which are up and down opposite;

a feed strip line, located on the first surface of the substrate;

the feed source, located on the first surface of the substrate and electrically connected to the feed strip line; and

a parasitic loop circuit, located on the second surface of the substrate, wherein the conductive post penetrates the substrate, the feed strip line, and the parasitic loop circuit, so that the conductive post electrically connects the substrate, the feed strip line, the parasitic loop circuit, and the metal cavity.

3. The cavity-backed slot antenna system according to claim 1, further comprising a metal wall located in the housing and on an outer side of the coupling metal part.

4. The cavity-backed slot antenna system according to claim 3, wherein a height of the metal wall is greater than a height of the coupling metal part.

5. The cavity-backed slot antenna system according to claim 1, wherein an antenna window is further arranged at a position on a projection plane of the coupling metal part on the housing.

6. The cavity-backed slot antenna system according to claim 5, wherein the coupling metal part further comprises a vertical metal portion and a horizontal metal portion, one side edge of the vertical metal portion is connected to the housing, and the other side edge is connected to the horizontal metal portion, so that the horizontal metal portion corresponds to the antenna window.

7. The cavity-backed slot antenna system according to claim 6, wherein a size of the antenna window is greater than or equal to a size of the horizontal metal portion of the coupling metal part.

8. The cavity-backed slot antenna system according to claim 1, wherein the metal cavity further comprises a metal bottom plate, a metal cover plate, and a metal side plate, the metal bottom plate is located below the supporting element, the metal cover plate is located above the antenna device, and the metal side plate is located at a periphery between the metal bottom plate and the metal cover plate to form the opening and the closed surface.

9. The cavity-backed slot antenna system according to claim 8, wherein the metal bottom plate is a metal bottom surface of the housing.

10. The cavity-backed slot antenna system according to claim 8, further comprising a metal layer located on a side wall of the antenna device and extending and connecting to the metal bottom plate of the metal cavity, to electrically connect the feed source to the metal bottom plate for grounding.

11. The cavity-backed slot antenna system according to claim 10, wherein the metal layer further extends below the coupling metal part, to electrically connect the coupling metal part to the metal bottom plate for grounding.

12. The cavity-backed slot antenna system according to claim 1, wherein a size of the slot is a length of half a wavelength of a working band.

13. The cavity-backed slot antenna system according to claim 1, wherein a side wall of the housing is a metal part and an antenna window is arranged on the side wall of the housing and at a position corresponding to the slot.

14. The cavity-backed slot antenna system according to claim 13, wherein a size of the antenna window is greater than or equal to a size of the slot.

* * * * *

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(12) **United States Patent**
Baek et al.

(10) **Patent No.: US 12,238,878 B2**
(45) **Date of Patent: Feb. 25, 2025**

(54) **ELECTRONIC DEVICE INCLUDING CONDUCTIVE CONNECTION MEMBER**

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(72) Inventors: **Seungchang Baek**, Suwon-si (KR); **Hyeongsam Son**, Suwon-si (KR); **Changhyeok Shin**, Suwon-si (KR); **Yoonhee Lee**, Suwon-si (KR); **Junghyun Im**, Suwon-si (KR); **Sungho Cho**, Suwon-si (KR); **Jungwoo Choi**, Suwon-si (KR); **Hangyu Hwang**, Suwon-si (KR); **Minwoo Yoo**, Suwon-si (KR)

(73) Assignee: **Samsung Electronics Co., Ltd.**, Suwon-si (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 379 days.

(21) Appl. No.: **17/894,543**

(22) Filed: **Aug. 24, 2022**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(30) **Foreign Application Priority Data**

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H01Q 1/24 (2006.01)
H05K 5/02 (2006.01)

(52) **U.S. Cl.**
CPC ***H05K 5/0217*** (2013.01); ***H01Q 1/243*** (2013.01)

(58) **Field of Classification Search**
CPC H05K 5/0217; H01Q 1/243
See application file for complete search history.

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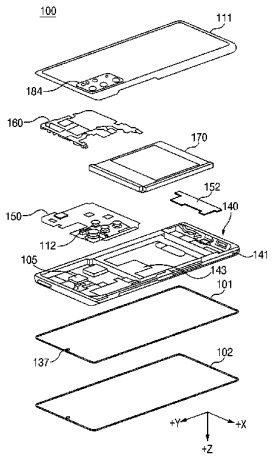
Primary Examiner — Graham P Smith
(74) *Attorney, Agent, or Firm* — Jefferson IP Law, LLP

(57) **ABSTRACT**

An electronic device is provided. The electronic device includes a display, a frame structure including a first conductive member defining an external appearance of the electronic device and operated as an antenna element of the electronic device, a second conductive member coupled and electrically connected to the first conductive member, and a nonconductive member that supports the display together with the second conductive member, a bonding layer including a first layer at least partially disposed between the first conductive member and the nonconductive member, and a second layer at least partially disposed between the second conductive member and the nonconductive member, and at least one conductive connection member disposed at a portion, at which the first conductive member and the second conductive member are coupled to each other, and contacting the first conductive member and the second conductive member.

20 Claims, 23 Drawing Sheets



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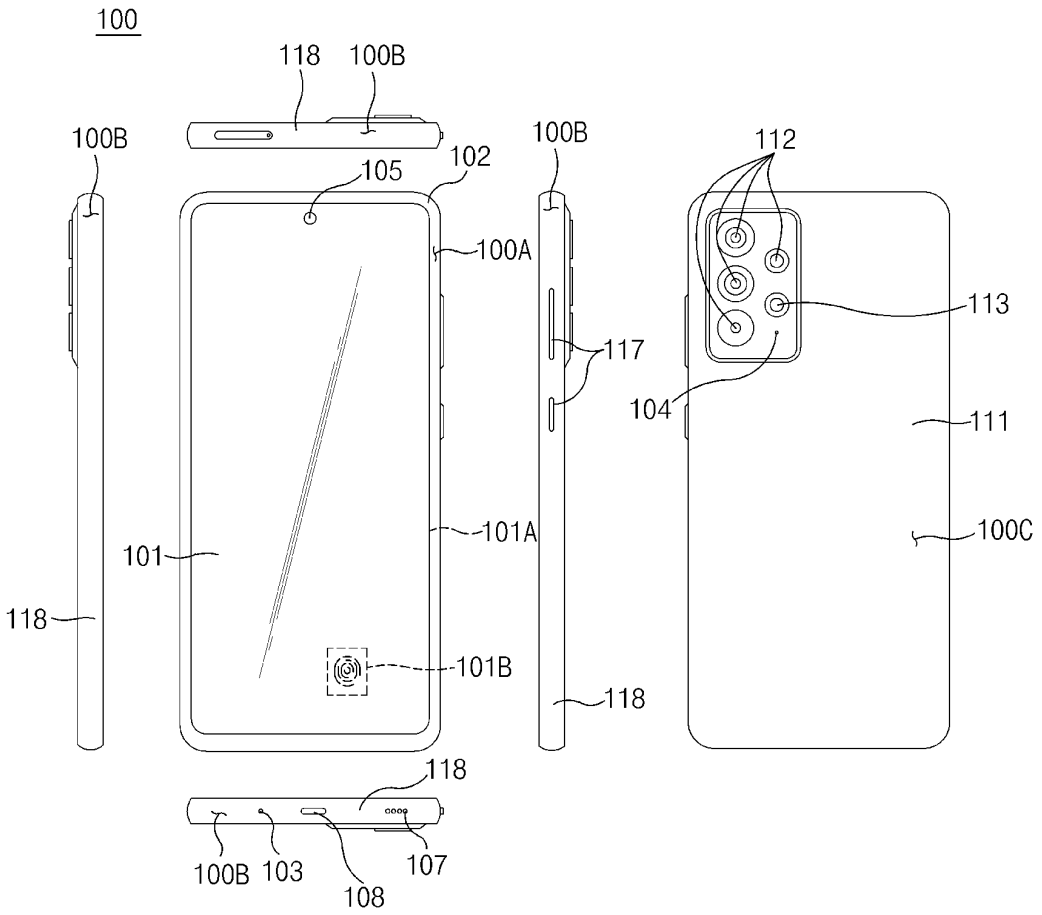
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107
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FIG.1

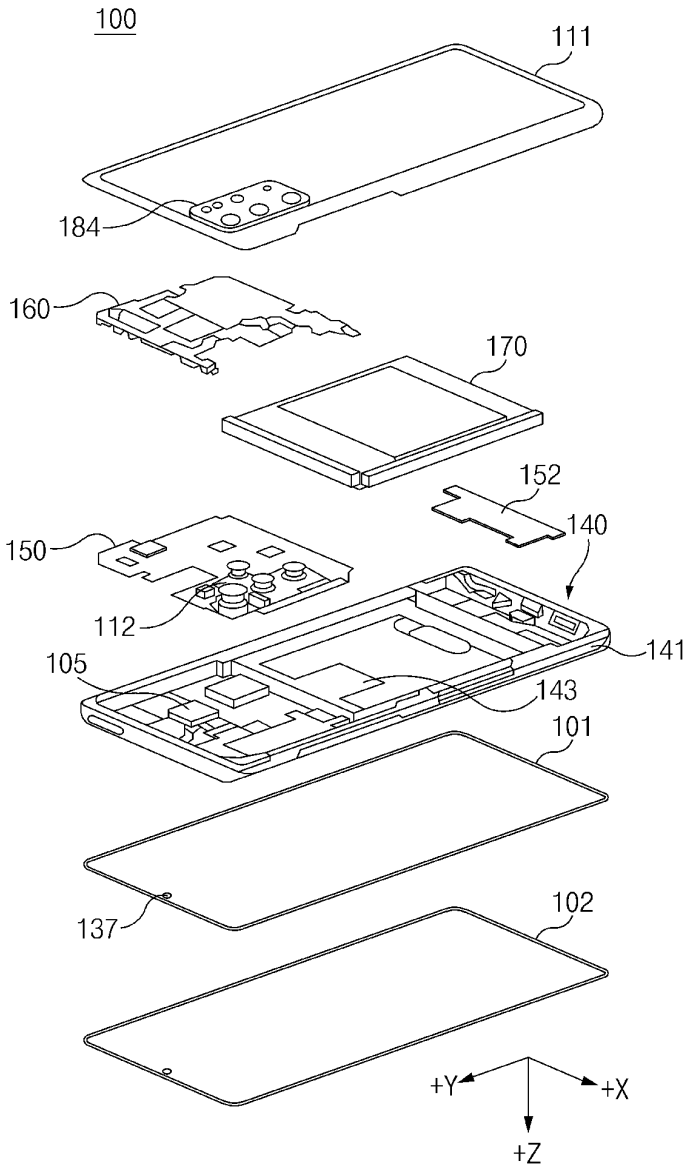


FIG.2

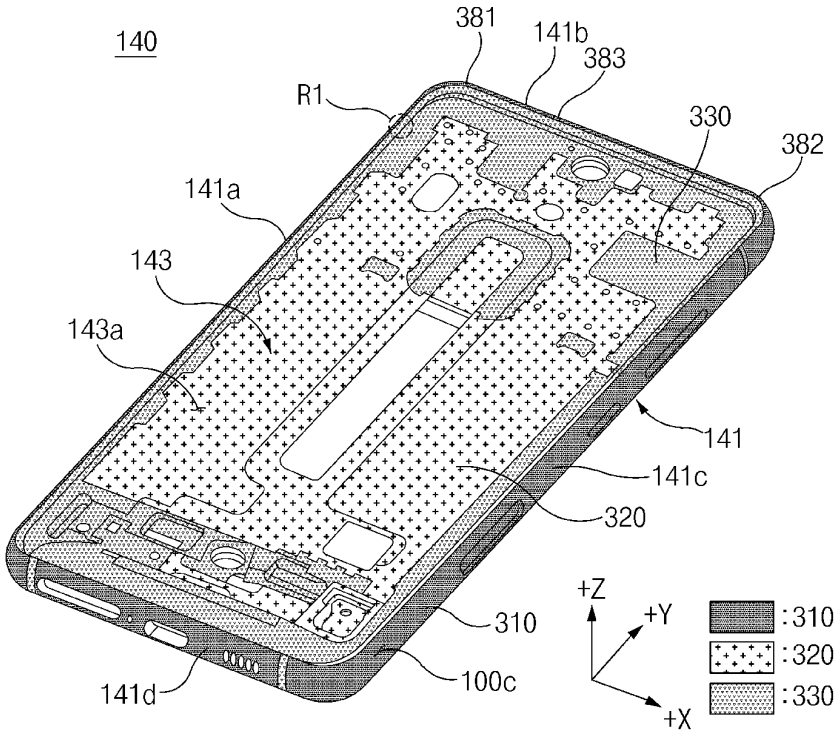

140
381
141b
383
R1
330
382
141a
143
143a
141
141c
320
310
100c
141d
+Z
+Y
+X
:310
:320
:330

FIG.3A

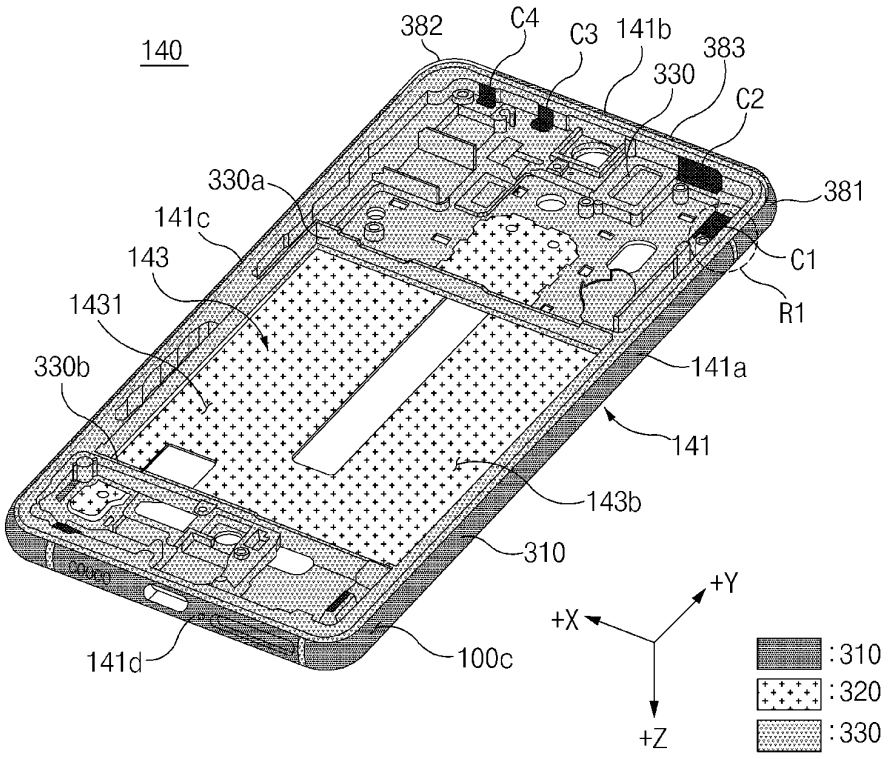

140
382
C4
C3
141b
383
330
C2
381
330a
141c
143
C1
1431
R1
330b
141a
141
143b
310
+Y
+X
+Z
141d
100c
:310
:320
:330

FIG.3B

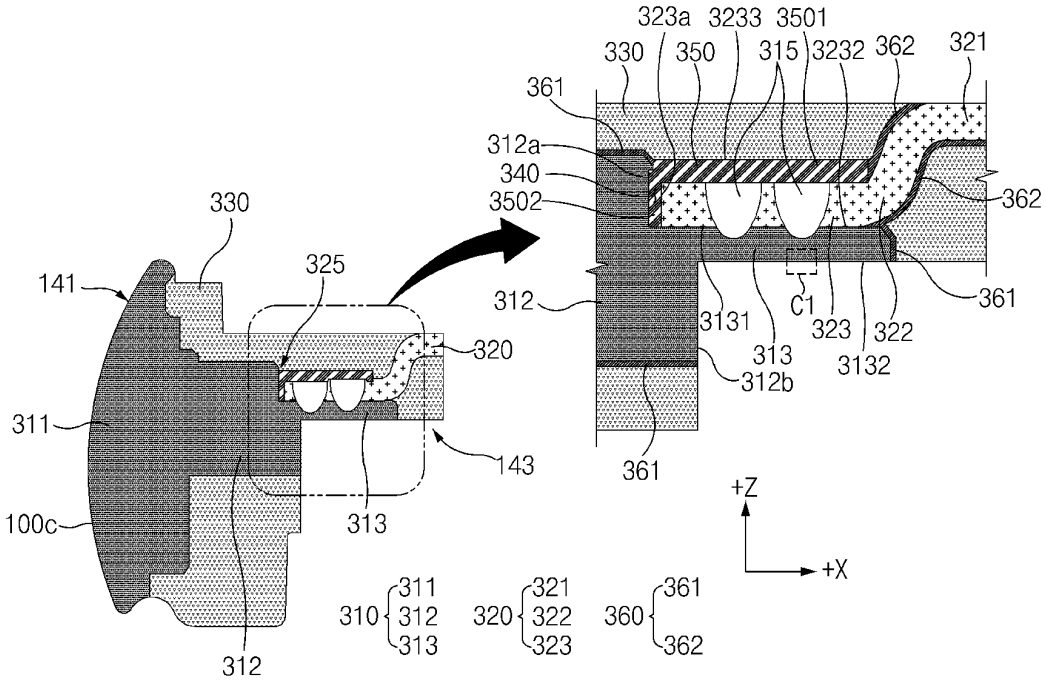

323a
3233
3501
330
350
315
3232
362
321
361
312a
340
3502
362
330
325
141
320
312
3131
C1
323
322
361
313
3132
312b
311
143
361
100c
313
+Z
+X
310 311 312 313
320 321 322 323
360 361 362
312

FIG.3C

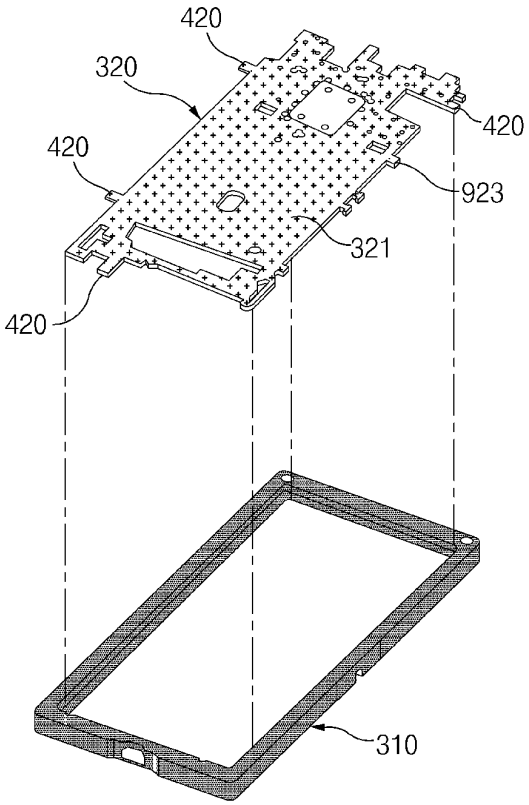


FIG.4

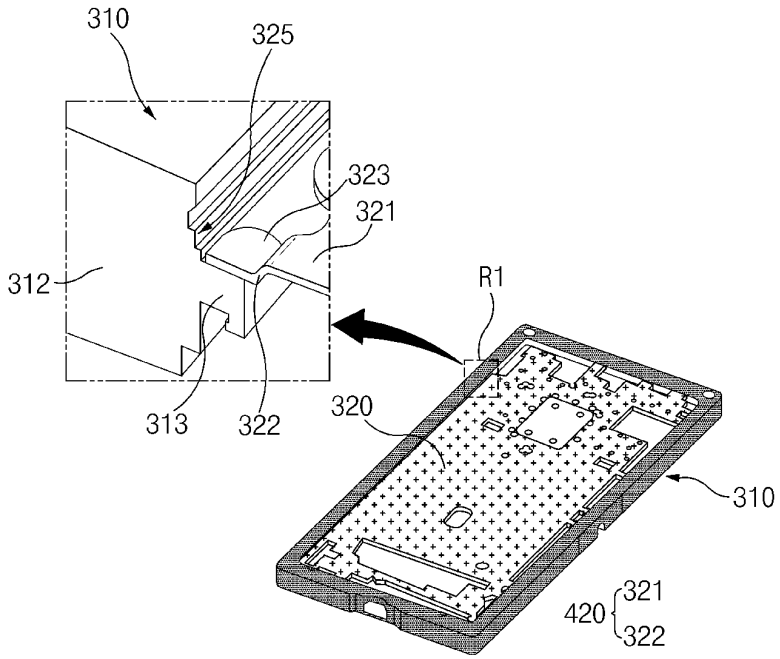


FIG.5A

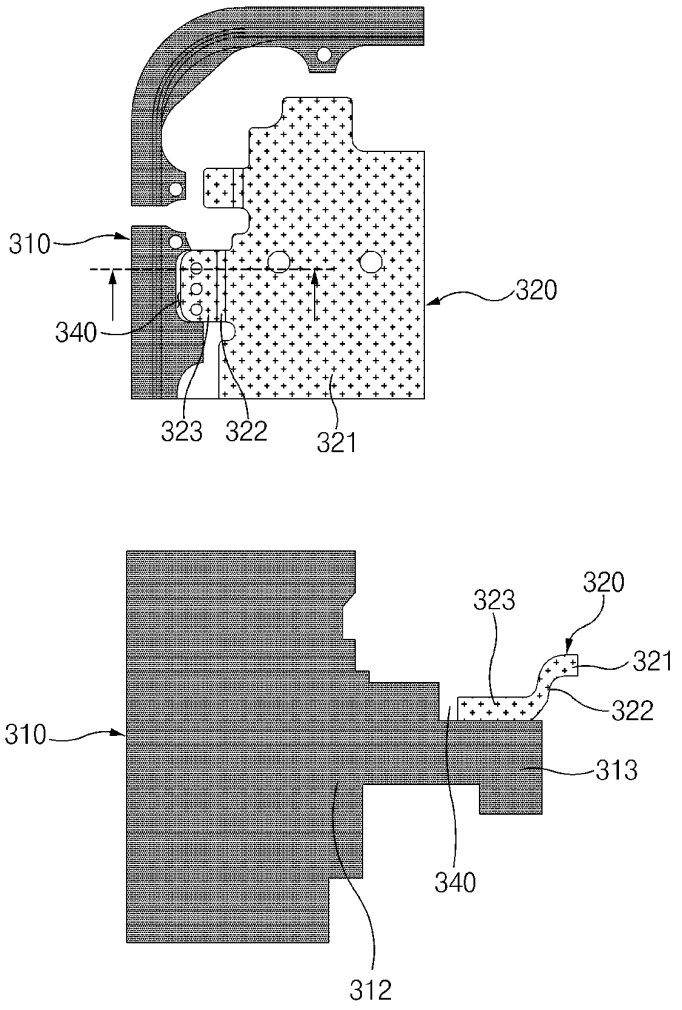


FIG.5B

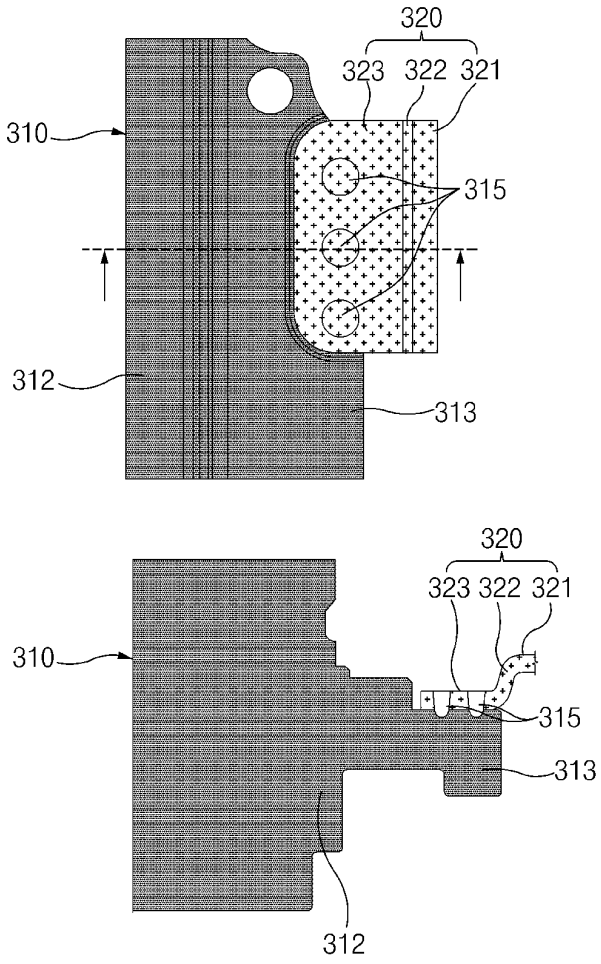


FIG.5C

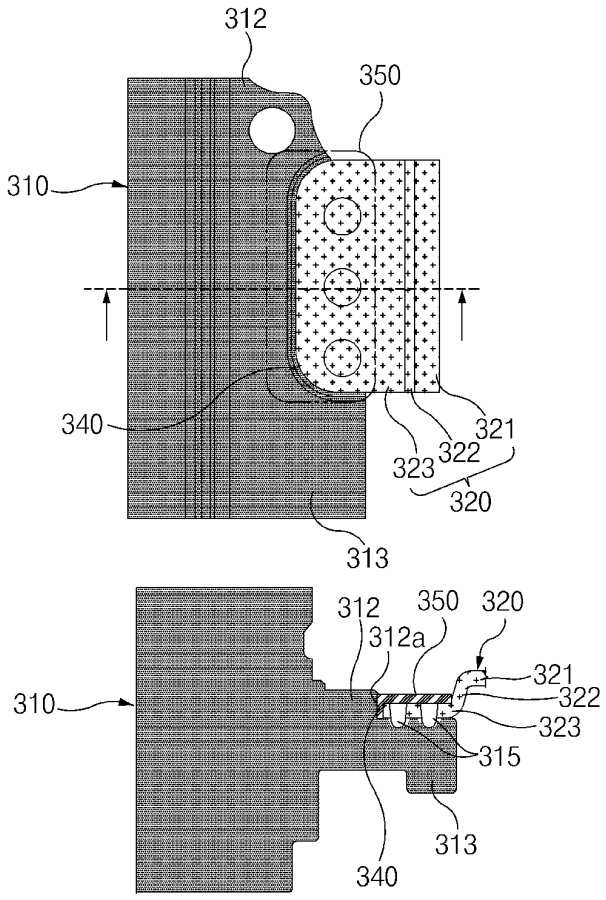

312
350
310
340
321
322
323
320
313
312
350
320
312a
321
322
310
323
315
313
340

FIG.6

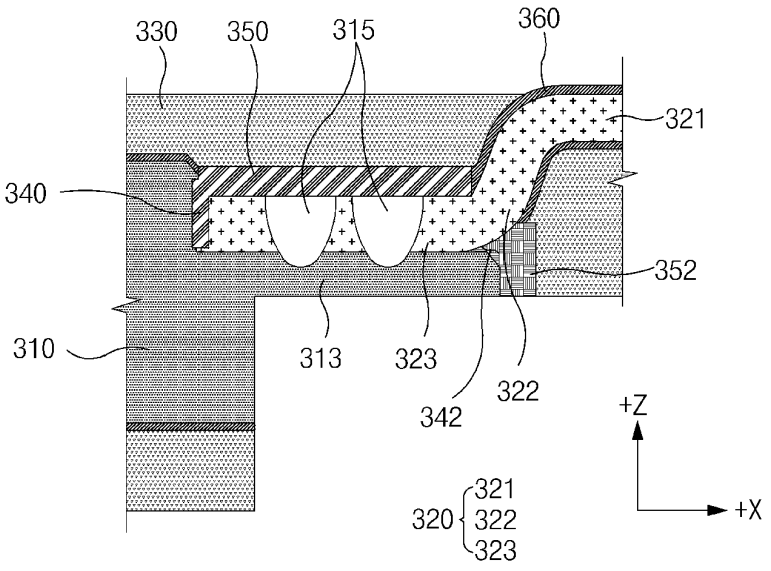

330
350
315
360
321
340
352
310
313
323
342
322
+Z
+X
320
321
322
323

FIG.7

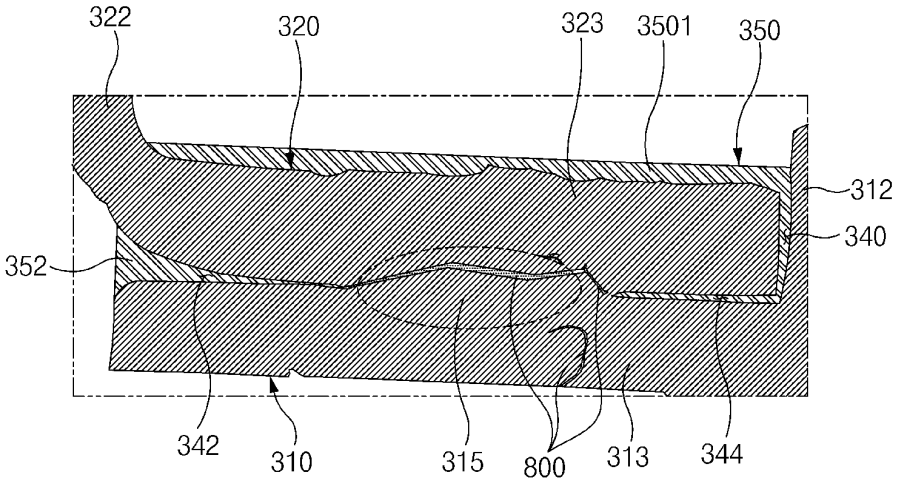


FIG.8

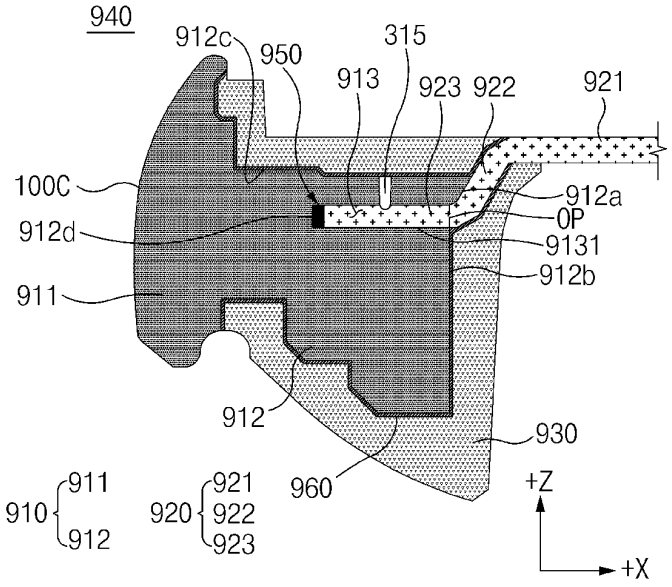

940
912c
950
315
913
923
922
921
100C
912a
OP
912d
9131
912b
911
912
930
960
910
911
912
920
921
922
923
+Z
+X

FIG.9A

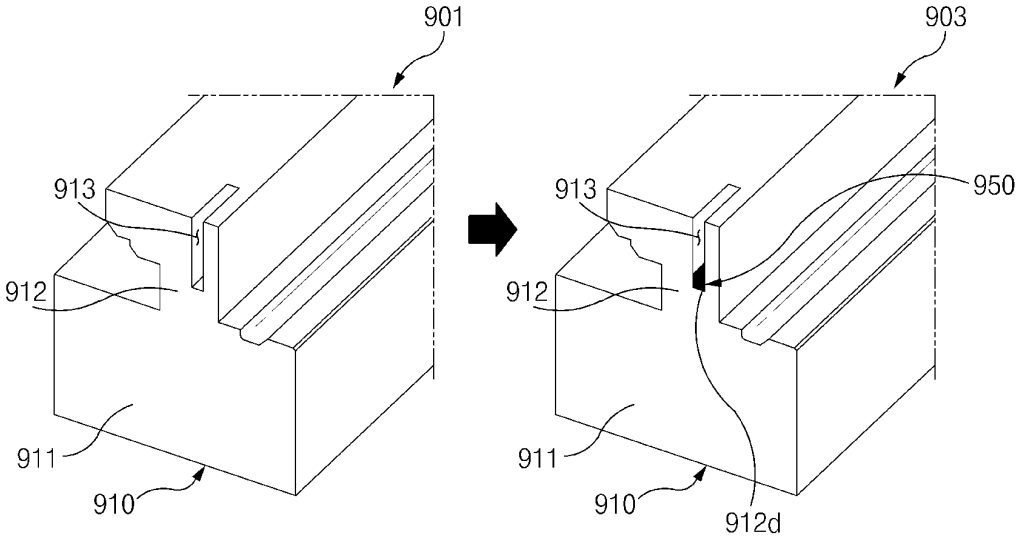


FIG.9B

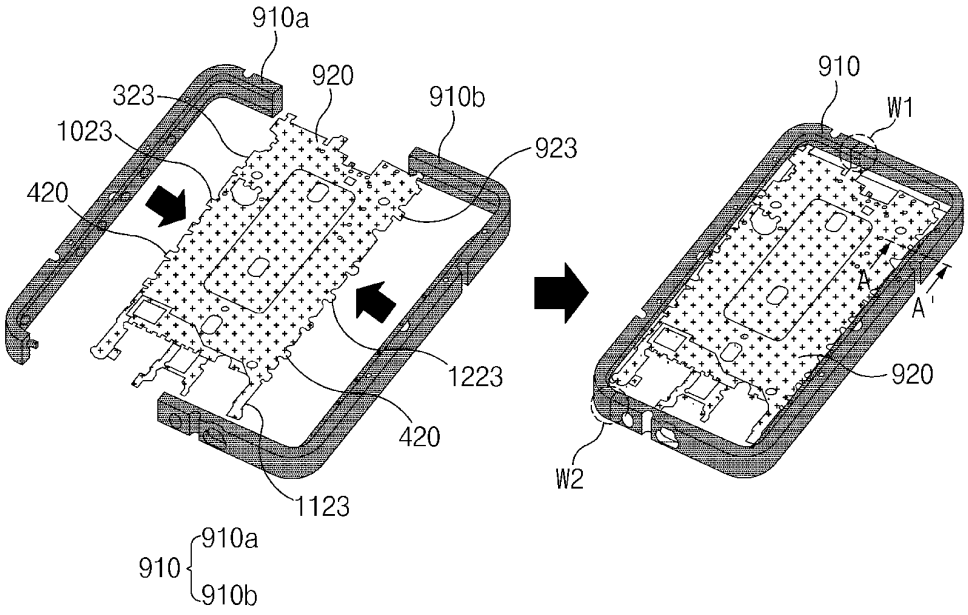

910a
920
910b
323
1023
923
420
1223
420
1123
910a
910
910b
910
W1
A
A'
920
W2

FIG.9C

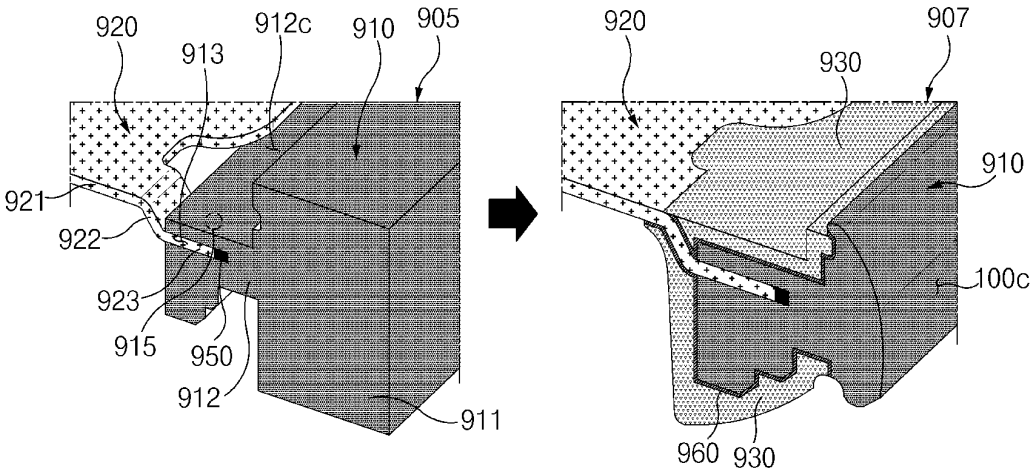

920
913
912c
910
905
921
922
923
915
950
912
911
920
907
930
910
100c
960
930

FIG.9D

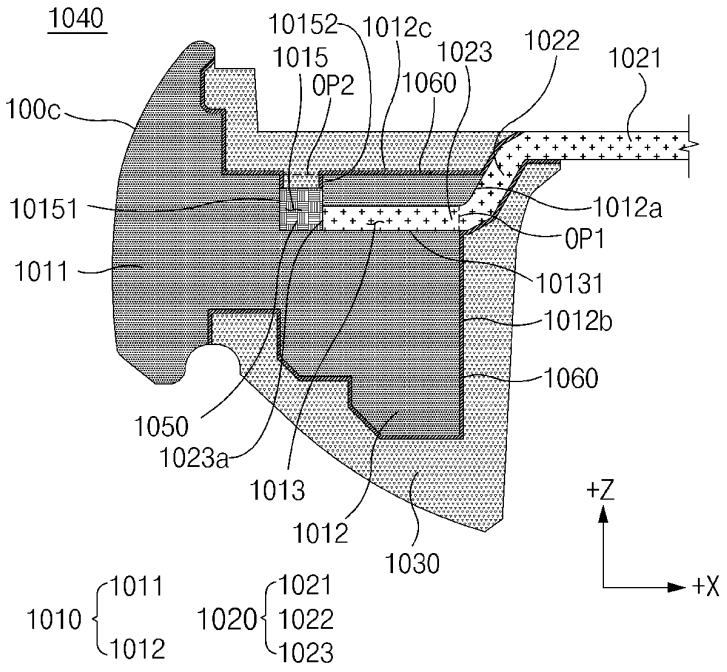

1040
10152
1012c
1015
1023
1022
1021
0P2
1060
100c
10151
1012a
0P1
1011
10131
1012b
1060
1050
1023a
1013
1012
1030
+Z
+X
1010
1011
1012
1020
1021
1022
1023

FIG.10A

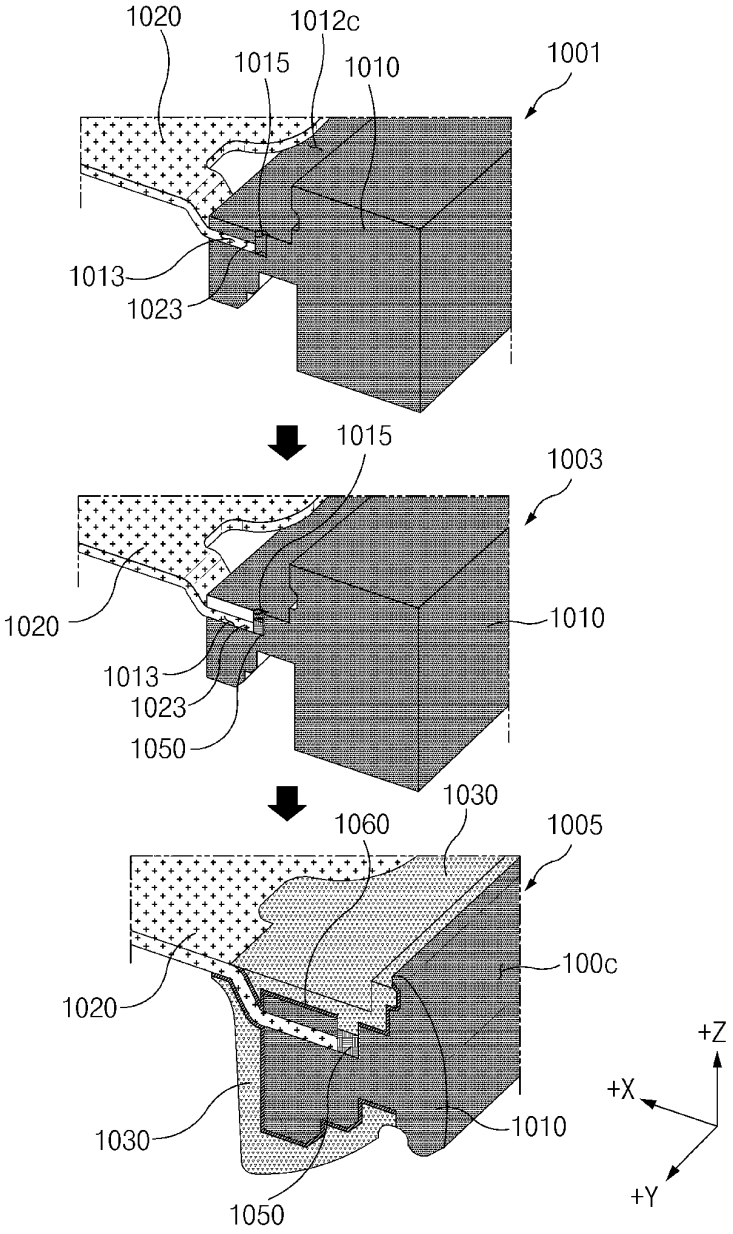

1020
1012c
1015
1010
1001
1013
1023
1015
1003
1020
1010
1013
1023
1050
1030
1060
1005
100c
1020
1030
1010
1050
+Z
+X
+Y

FIG.10B

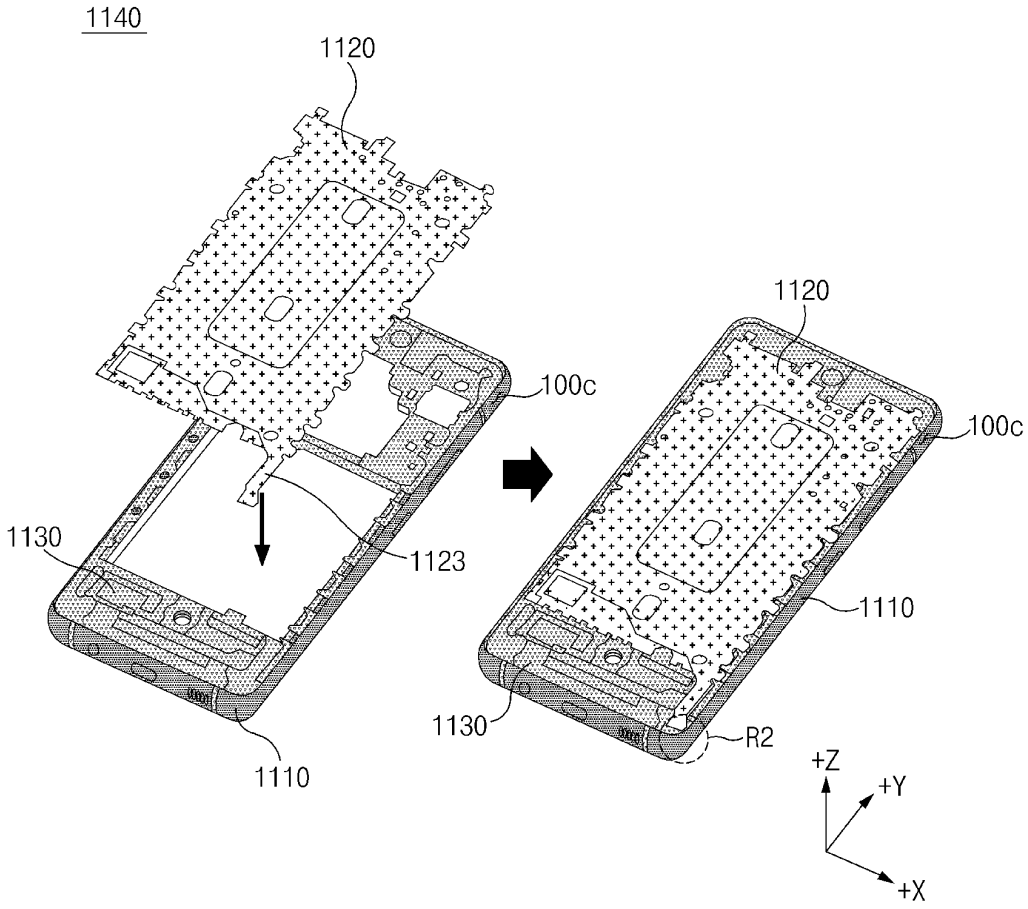


FIG.11A

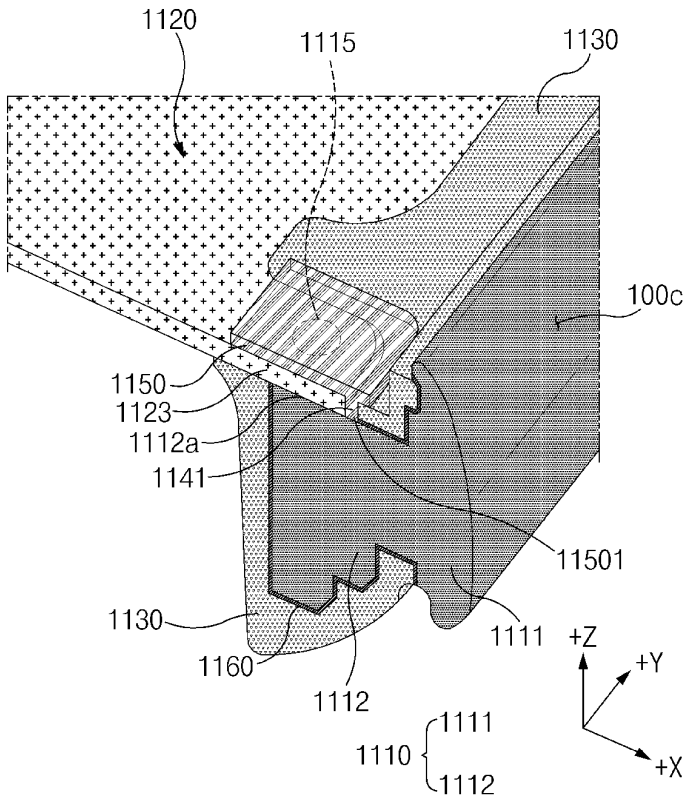

1120
1115
1130
100c
1150
1123
1112a
1141
11501
1130
1160
1112
1111
+Z
+Y
+X
1111
1110
1112

FIG.11B

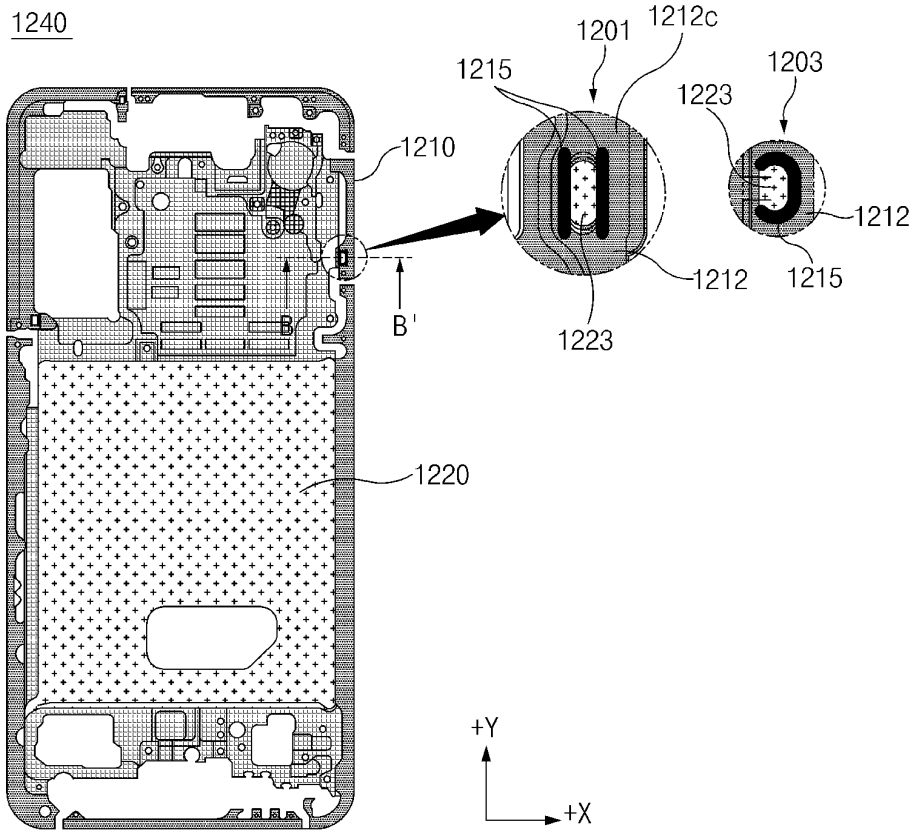
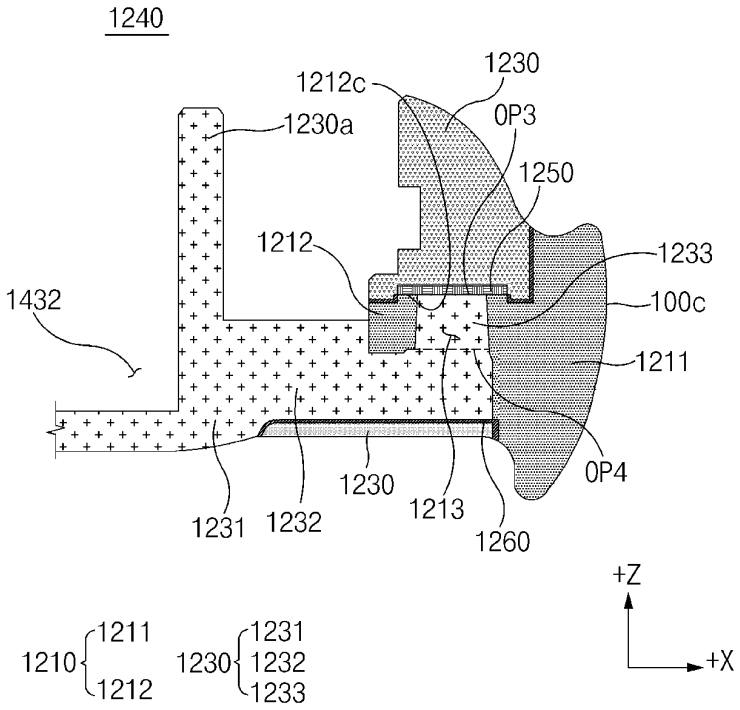

1240
1201
1212c
1215
1203
1223
1210
1212
1212
1215
B'
1223
B
1220
+Y
+X

FIG.12A


1240
1212c
1230
0P3
1230a
1250
1212
1233
1432
100c
1211
0P4
1230
1231
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1213
1260
+Z
+X
1210
1211
1212
1230
1231
1232
1233

FIG.12B

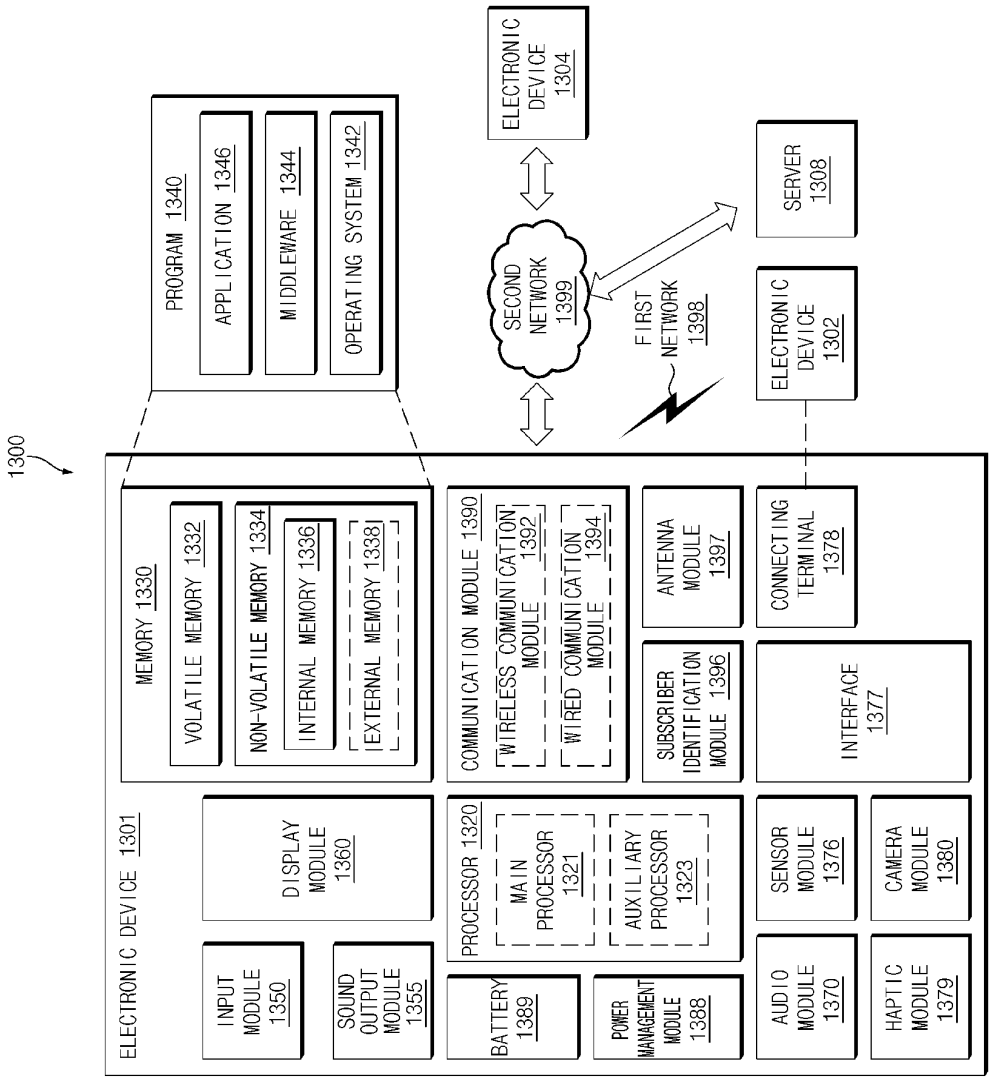
1300
ELECTRONIC DEVICE 1301
PROGRAM 1340
APPLICATION 1346
MIDDLEWARE 1344
OPERATING SYSTEM 1342
MEMORY 1330
VOLATILE MEMORY 1332
NON-VOLATILE MEMORY 1334
INTERNAL MEMORY 1336
EXTERNAL MEMORY 1338
INPUT MODULE 1350
SOUND OUTPUT MODULE 1355
DISPLAY MODULE 1360
PROCESSOR 1320
MAIN PROCESSOR 1321
AUXILIARY PROCESSOR 1323
BATTERY 1389
POWER MANAGEMENT MODULE 1388
COMMUNICATION MODULE 1390
WIRELESS COMMUNICATION MODULE 1392
WIRED COMMUNICATION MODULE 1394
SUBSCRIBER IDENTIFICATION MODULE 1396
ANTENNA MODULE 1397
INTERFACE 1377
CONNECTING TERMINAL 1378
AUDIO MODULE 1370
SENSOR MODULE 1376
CAMERA MODULE 1380
HAPTIC MODULE 1379
ELECTRONIC DEVICE 1304
SECOND NETWORK 1399
FIRST NETWORK 1398
ELECTRONIC DEVICE 1302
SERVER 1308

FIG. 13

ELECTRONIC DEVICE INCLUDING CONDUCTIVE CONNECTION MEMBER

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation application, claiming priority under § 365(c), of an International application No. PCT/KR2022/012305, filed on Aug. 18, 2022, which is based on and claims the benefit of a Korean patent application number 10-2021-0154237, filed on Nov. 10, 2021, in the Korean Intellectual Property Office, the disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The disclosure relates to an electronic device including a conductive connection member.

BACKGROUND ART

An electronic device may include a housing that defines an external appearance. The housing may include a metal part. The metal part may constitute an antenna structure of the electronic device. For example, the electronic device may perform wireless communication by using the metal part as an antenna radiator.

Meanwhile, the metal part of the housing, which constitutes the antenna structure, may have two members. For example, the metal part of the housing may include a first member that constitutes an outer periphery of the electronic device, and a second member that is located inside the first member. In this case, it is required to electrically connect the first member and the second member to use the metal part as the antenna. Accordingly, the first member and the second member may be welded to be physically and chemically bonded to each other, or contact each other through a physical connection structure to electrically connect each other.

The above information is presented as background information only to assist with an understanding of the disclosure. No determination has been made, and no assertion is made, as to whether any of the above might be applicable as prior art with regard to the disclosure.

DISCLOSURE

Technical Problem

An electrical connection may vary according to a coupling quality of the first member and the second member that constitute the housing. For example, when the two members are welded and bonded to each other, the electrical connection between the first member and the second member may be degraded due to a crack of a welded part or fine coming-over of a periphery of the welded part. As the electrical connection is degraded, performances of antennas using the first member and the second member may be degraded.

A housing may have one member to prevent and/or decrease degradation of antenna performance, but manufacturing costs may be increased.

A pressed piece of sheet metal may be applied to the second member located inside the first member. In this case, a contact point between the first member and the second member may become vulnerable according to a condition and an environment of a process. For example, a welding deformation may occur or a fine gap may be caused due to a small thickness of a pressed sheet.

Unlike the pressed piece of sheet metal, a second member manufactured through die casting may be applied to an inside of the first member. In this case, the contact point between the first member and the second member may be short-circuited according to a pore defect of a die casting process and a welding state.

An electrical contact vulnerable part between the first member and the second member may cause an antenna performance defect, and thus manufacturing costs may be increased.

Aspects of the disclosure are to address at least the above-mentioned problems and/or disadvantages and to provide at least the advantages described below. Accordingly, an aspect of the disclosure is to provide an electronic device that includes a conductive connection member disposed in a coupling part of a first conductive member and a second conductive member, which constitute a housing, to enhance an electrical connection between the first conductive member and the second conductive member and prevent and/or decrease an antenna performance defect.

Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

Technical Solution

In accordance with an aspect of the disclosure, an electronic device is provided. The electronic device includes a display, a frame structure including a first conductive member defining an external appearance of the electronic device and operated as an antenna element of the electronic device, a second conductive member coupled and electrically connected to the first conductive member, and a nonconductive member that supports the display together with the second conductive member, a bonding layer including a first layer at least partially disposed between the first conductive member and the nonconductive member, and a second layer at least partially disposed between the second conductive member and the nonconductive member, and at least one conductive connection member disposed at a portion, at which the first conductive member and the second conductive member are coupled to each other, and contacting the first conductive member and the second conductive member.

In accordance with another aspect of the disclosure, an electronic device is provided. The electronic device includes a display, a frame structure, the frame structure includes a first conductive member operated as an antenna element of the electronic device, the first conductive member includes an outer part defining a side surface of the electronic device, and a coupling part extending from the outer part to an inside of the electronic device, a second conductive member electrically connected to the first conductive member, the second conductive member includes an inner part that supports the display, and at least one end part extending from the inner part and coupled to the coupling part of the first conductive member, and a nonconductive member at least partially surrounding the first conductive member and the second conductive member, and that supports the display together with the second conductive member, a bonding layer at least partially disposed between the first conductive member and the nonconductive member, and at least partially between the second conductive member and the nonconductive member, and at least one conductive connection member disposed at a portion, at which the coupling part of the first

conductive member and the at least one end part of the second conductive member are coupled to each other, and contacting the first conductive member and the second conductive member.

Advantageous Effects

According to the disclosure, a deviation of antenna performances due to a deviation of coupling qualities of the first conductive member and the second conductive member used as antennas may be reduced.

According to the disclosure, degradation of antenna performances due to a coupling defect of the first conductive member and the second conductive member may be prevented and/or alleviated.

According to the disclosure, costs may be reduced through simplification of a manufacturing process for the frame structure and reduction of manufacturing costs.

According to the disclosure, because the support part of the frame structure may be formed through the second conductive member including the pressed piece of sheet metal and the nonconductive member, the manufacturing process for the frame structure may be simplified and costs of the frame structure may be reduced.

According to the disclosure, the electronic device may be light-weighted.

According to the disclosure, because the support part of the frame structure is formed through the second conductive member including the pressed piece of sheet metal, and the nonconductive member, the electronic device may be light-weighted.

According to the disclosure, a yield rate of the frame structure may be enhanced, and losses due to degradation of the yield rate may be reduced.

According to the disclosure, a yield rate of the frame structure may be enhanced through the conductive connection member that electrically connects the first conductive member and the second conductive member of the frame structure, and losses due to degradation of the yield rate may be reduced.

According to the disclosure, an efficiency of a manufacturing process for the frame structure may be increased.

According to the disclosure, a process and a quality may be easily managed through the conductive connection member, in which a color is implemented, and an efficiency of the manufacturing process for the frame structure may be increased.

According to the disclosure, a durability of a bonding part of the first conductive member and the second conductive member used as antennas may be enhanced.

According to the disclosure, the bonding part may be protected from an external environment through the conductive connection member that covers the bonding part of the first conductive member and the second conductive member used as antennas, and the durability of the bonding part may be enhanced.

In addition, the disclosure may provide various effects that are directly or indirectly recognized.

Other aspects, advantages, and salient features of the disclosure will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, discloses various embodiments of the disclosure.

DESCRIPTION OF DRAWINGS

The above and other aspects, features, and advantages of certain embodiments of the disclosure will be more apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a view illustrating an electronic device according to an embodiment of the disclosure;

FIG. **2** is an exploded perspective view of an electronic device according to an embodiment of the disclosure;

FIG. **3**A is a first perspective view of a frame structure according to an embodiment of the disclosure;

FIG. **3**B is a second perspective view of a frame structure according to an embodiment of the disclosure;

FIG. **3**C is a cross-sectional view corresponding to area R**1** of FIGS. **3**A and **3**B according to an embodiment of the disclosure;

FIG. **4** is a view illustrating a process of assembling a first conductive member and a second conductive member according to an embodiment of the disclosure;

FIG. **5**A is a view illustrating a state, in which a first conductive member and a second conductive member are assembled, according to an embodiment of the disclosure;

FIG. **5**B is a view illustrating a plan view and a cross-sectional view of a frame structure corresponding to area R**1** of FIG. **3**A or FIG. **5**A according to an embodiment of the disclosure;

FIG. **5**C is a view illustrating a process of coupling a first conductive member and a second conductive member according to an embodiment of the disclosure;

FIG. **6** is a view illustrating a process of forming a first conductive connection member of a frame structure according to an embodiment of the disclosure;

FIG. **7** is a cross-sectional view illustrating a frame structure according to an embodiment of the disclosure;

FIG. **8** is a view illustrating a coupling part of a first conductive member and a second conductive member according to an embodiment of the disclosure;

FIG. **9**A is a cross-sectional view illustrating a frame structure according to an embodiment of the disclosure;

FIG. **9**B is a view illustrating a process of forming a first hole and a process of disposing a first conductive connection member in the first hole according to an embodiment of the disclosure;

FIG. **9**C is a view illustrating a process of coupling a first conductive member and a second conductive member according to an embodiment of the disclosure;

FIG. **9**D is a cross-sectional perspective view, taken along line A-A' of FIG. **9**C according to an embodiment of the disclosure;

FIG. **10**A is a cross-sectional view illustrating a frame structure according to an embodiment of the disclosure;

FIG. **10**B is a view illustrating a process of manufacturing a frame structure according to an embodiment of the disclosure;

FIG. **11**A is a view illustrating a process of manufacturing a frame structure according to an embodiment of the disclosure;

FIG. **11**B is a cross-sectional perspective view corresponding to an area R**2** of FIG. **11**A according to an embodiment of the disclosure;

FIG. **12**A is a view illustrating a frame structure according to an embodiment of the disclosure;

FIG. **12**B is a cross-sectional view taken along line B-B' of FIG. **12**A according to an embodiment of the disclosure; and

FIG. **13** illustrates an electronic device in a network environment according to an embodiment of the disclosure.

Throughout the drawings, it should be noted that like reference numbers are used to depict the same or similar elements, features, and structures.

MODE FOR INVENTION

The following description with reference to the accompanying drawings is provided to assist in a comprehensive understanding of various embodiments of the disclosure as defined by the claims and their equivalents. It includes various specific details to assist in that understanding but these are to be regarded as merely exemplary. Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the various embodiments described herein can be made without departing from the scope and spirit of the disclosure. In addition, descriptions of well-known functions and constructions may be omitted for clarity and conciseness.

The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used by the inventor to enable a clear and consistent understanding of the disclosure. Accordingly, it should be apparent to those skilled in the art that the following description of various embodiments of the disclosure is provided for illustration purpose only and not for the purpose of limiting the disclosure as defined by the appended claims and their equivalents.

It is to be understood that the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a component surface" includes reference to one or more of such surfaces.

FIG. **1** is a view illustrating an electronic device according to an embodiment of the disclosure.

Referring to FIG. **1**, an electronic device **100** according to an embodiment may include a housing that defines an external appearance of the electronic device **100**. For example, the housing may include a first surface (or a front surface) **100**A, a second surface (or a rear surface) **100**B, and a third surface (or a side surface) **100**C surrounding a space between the first surface **100**A and the second surface **100**B. In an embodiment, the housing may refer to a structure (e.g., a frame structure **140** of FIG. **3**A) that defines at least some of the first surface **100**A, the second surface **100**B, and/or the third surface **100**C.

The electronic device **100** according to an embodiment may include a front plate **102** that is substantially transparent. According to an embodiment, the front plate **102** may define at least a portion of the first surface **100**A. In an embodiment, the front plate **102**, for example, may include a glass plate or a polymer plate including various coating layers, but the disclosure is not limited thereto.

The electronic device **100** according to an embodiment may include a rear plate **111** that is substantially opaque. According to an embodiment, the rear plate **111** may define at least a portion of the second surface **100**B. In an embodiment, the rear plate **111**, for example, may be formed of coated or colored glass, ceramics, a polymer, a metal (e.g., aluminum, stainless steel (STS), or magnesium), or a combination of at least two thereof.

The electronic device **100** according to an embodiment may include a side bezel structure (or a side member) **118** (e.g., a side wall **141** of the frame structure **140** of FIG. **3**A). In an embodiment, the side bezel structure **118** may be coupled to the front plate **102** and/or the rear plate **111** to define at least a portion of the third surface **100**C of the electronic device **100**. For example, the side bezel structure **118** may define the entire third surface **100**C of the electronic device **100**, and as another example, the side bezel structure **118** may define the third surface **100**C of the electronic device **100** together with the front plate **102** and/or the rear plate **111**.

Unlike the illustrated embodiment, when the third surface **100**C of the electronic device **100** is partially defined by the front plate **102** and/or the rear plate **111**, the front plate **102** and/or the rear plate **111** may include an area that is deflected from a periphery thereof toward the rear plate **111** and/or the front plate **102** and extends seamlessly. The extending area of the front plate **102** and/or the rear plate **111**, for example, may be located at opposite ends of a long edge of the electronic device **100**, but is not limited to the above-described example.

In an embodiment, the side bezel structure **118** may include a metal and/or a polymer. In an embodiment, the rear plate **111** and the side bezel structure **118** may be integrally formed and may include the same material (e.g., a metallic material such as aluminum), but is not limited thereto. For example, the rear plate **111** and the side bezel structure **118** may be formed as separate configurations, and/or may include different materials.

In an embodiment, the electronic device **100** may include at least one of a display **101**, audio modules **103**, **104**, and **107**, a sensor module (not illustrated), camera modules **105**, **112**, and **113**, a key input device **117**, a light emitting element (not illustrated), and/or a connector hole **108**. In another embodiment, at least one (e.g., the key input device **117** or the light emitting element (not illustrated)) of the elements may be omitted from the electronic device **100** or another component may be additionally included in the electronic device **100**.

In an embodiment, the display **101** (e.g., a display module **1360** of FIG. **13**) may be visually exposed through a considerably large portion of the front plate **102**. For example, at least a portion of the display **101** may be viewed through the front plate **102** that defines the first surface **100**A. In an embodiment, the display **101** may be disposed on a rear surface of the front plate **102**.

In an embodiment, the display **101** may have an outskirt shape that is substantially the same as an outskirt shape of the front plate **102** that is adjacent to the display **101**. In an embodiment, in order to expand the area, by which the display **101** is visually exposed, the intervals between the outskirts of the display **101** and the outskirts of the front plate **102** may be substantially the same.

In an embodiment, the display **101** (e.g., the first surface **100**A of the electronic device **100**) may include a screen display area **101**A. In an embodiment, the display **101** may provide visual information to a user through the screen display area **101**A. In the illustrated embodiment, it is illustrated that the screen display area **101**A is spaced apart from an outskirt of the first surface **100**A to be located inside the first surface **100**A when the first surface **100**A is viewed from a front side, but the disclosure is not limited thereto. In another embodiment, when the first surface **100**A is viewed from the front side, at least a portion of a periphery of the screen display area **101**A may substantially coincide with a periphery of the first surface **100**A (or the front plate **102**).

In an embodiment, the screen display area **101**A may include a sensing area **101**B that is configured to acquire biometric information of a user. Here, the expression that "the screen display area **101**A includes the sensing area **101**B" may be understood that at least a portion of the sensing area **101**B may overlap the screen display area **101**A. For example, the sensing area **101**B may display visual information on the display **101** like other areas of the screen display area **101**A, and additionally, may mean an

area that may acquire biometric information (e.g., a fingerprint) of the user. In another embodiment, the sensing area **101**B also may be formed in the key input device **117**.

In an embodiment, the display **101** may include an area, in which the first camera module **105** (e.g., a camera module **1380** of FIG. **13**). In an embodiment, an opening part may be formed in the area of the display **101**, and the first camera module **105** (e.g., a punch hole camera) may be at least partially disposed in the opening part to face the first surface **100**A. In this case, the screen display area **101**A may surround at least a portion of a periphery of the opening part. In another embodiment, the first camera module **105** (e.g., an under display camera (UCD)) may be disposed under the display **101** to overlap the area of the display **101**. In this case, the display **101** may provide visual information to the user through the area, and additionally, the first camera module **105** may acquire an image corresponding to a direction that faces the first surface **100**A through the area of the display **101**.

In an embodiment, the display **101** may be coupled to or be disposed to be adjacent to a touch detection circuit, a pressure sensor that may measure the strength (the pressure) of a touch, and/or a digitizer that detects a stylus pen of a magnetic field type.

According to an embodiment, the audio modules **103**, **104**, and **107** (e.g., an audio module **1370** of FIG. **13**) may include microphone holes **103** and **104** and a speaker hole **107**.

In an embodiment, the microphone holes **103** and **104** may include the first microphone hole **103** formed in a partial area of the third surface **100**C, and the second microphone hole **104** formed in a partial area of the second surface **100**B. Microphones (not illustrated) for acquiring external sounds may be disposed in interiors of the microphone holes **103** and **104**. The microphones may include a plurality of microphones to sense a direction of sound.

In an embodiment, the second microphone hole **104** formed in a partial area of the second surface **100**B may be disposed to be adjacent to the camera modules **105**, **112**, and **113**. For example, the second microphone hole **104** may acquire sounds according to operations of the camera modules **105**, **112**, and **113**. However, the disclosure is not limited thereto.

In an embodiment, the speaker hole **107** may include the external speaker hole **107** and a communication receiver hole (not illustrated). The external speaker hole **107** may be formed at a portion of the third surface **100**C of the electronic device **100**. In another embodiment, the external speaker hole **107** and the microphone hole **103** may be implemented with one hole. Although not illustrated, the communication receiver hole (not illustrated) may be formed at another portion of the third surface **100**C. For example, a receiver hole for communication may be formed on the third surface **100**C on an opposite side to the external speaker hole **107**. For example, with respect to the illustration of FIG. **1**, the external speaker hole **107** may be formed on the third surface **100**C corresponding to a lower end of the electronic device **100**, and the receiver hole for communication may be formed on the third surface **100**C corresponding to an upper end of the electronic device **100**. However, the disclosure is not limited thereto, and in another embodiment, the receiver hole for communication may be formed at a location other than the third surface **100**C. For example, the receiver hole for communication may be defined by a spacing space between the front plate **102** (or the display **101**) and the side bezel structure **118**.

In an embodiment, the electronic device **100** may include at least one speaker (not illustrated) that outputs sounds to an outside of the housing through the external speaker hole **107** and/or the receiver hole for communication (not illustrated).

In an embodiment, the sensor module (not illustrated) (e.g., a sensor module **1376** of FIG. **13**) may generate an electrical signal or a data value corresponding to an operation state of the interior of the electronic device **100** or an environmental state of the outside. For example, the sensor module may include at least one of a proximity sensor, a heart rate monitor (HRM) sensor, a fingerprint sensor, a gesture sensor, a gyro sensor, an atmospheric pressure sensor, a magnetic sensor, an acceleration sensor, a grip sensor, a color sensor, an infrared (IR) sensor, a biometric sensor, a temperature sensor, a humidity sensor, and an illumination sensor.

In an embodiment, the camera modules **105**, **112**, and **113** (e.g., the camera module **1380** of FIG. **13**) may include the first camera module **105** disposed to face the first surface **100**A of the electronic device **100**, the second camera module **112** and the flash **113** disposed to face the second surface **100**B.

In an embodiment, the second camera module **112** may include a plurality of cameras (e.g., a dual camera, a triple camera, or a quad camera). However, the second camera module **112** is not limited to necessarily include a plurality of cameras, and may include one camera.

In an embodiment, the first camera modules **105** and the second camera module **112** may include one or a plurality of lenses, an image sensor, and/or an image signal processor.

In an embodiment, the flash **113**, for example, may include a light emitting diode or a xenon lamp. In another embodiment, two or more lenses (an infrared ray camera, and a wide angle/telephoto lens), and image sensors may be disposed on one surface of the electronic device **100**.

In an embodiment, the key input device **117** (e.g., an input module **1350** of FIG. **13**) may be disposed on the third surface **100**C of the electronic device **100**. In another embodiment, the electronic device **100** may not include some or all of the above-mentioned key input devices **117** and the key input devices **117**, which are not included, may be realized in different forms, such as a soft key, on the display **101**.

In an embodiment, the connector hole **108** may be formed on the third surface **100**C of the electronic device **100** to accommodate a connector of an external device. A connection terminal (e.g., a connection terminal **1378** of FIG. **13**) electrically connected to the connector of the external device may be disposed in the connector hole **108**. The electronic device **100** according to an embodiment may include an interface module (e.g., an interface **1377** of FIG. **13**) for processing an electrical signal transmitted and received through the connection terminal.

In an embodiment, the electronic device **100** may include a light emitting element (not illustrated). For example, the light emitting element (not illustrated) may be disposed on the first surface **100**A of the housing. The light emitting element (not illustrated) may provide state information on the electronic device **100** in the form of light. In another embodiment, the light emitting element (not illustrated) may provide a light source that interworks with an operation of the camera module **105**. For example, the light emitting element (not illustrated) may include a light emitting diode (LED), an IR LED, and/or a xenon lamp.

FIG. **2** is an exploded perspective view of an electronic device according to an embodiment of the disclosure.

Hereinafter, a repeated description of configurations having the same reference numerals as the above-described configurations will be omitted.

Referring to FIG. **2**, the electronic device **100** according to an embodiment may include the frame structure **140**, a first printed circuit board **150**, a second printed circuit board **152**, a cover plate **160**, and a battery **170**.

In an embodiment, the frame structure **140** may include the side wall **141** that defines an external appearance (e.g., the third surface **100**C of FIG. **1**) of the electronic device **100**, and a support part **143** that extends inwards from the side wall **141**. In an embodiment, the frame structure **140** may be disposed between the display **101** and the rear plate **111**. In an embodiment, the side wall **141** of the frame structure **140** may surround a space between the rear plate **111** and the front plate **102** (and/or the display **101**), and the support part **143** of the frame structure **140** may extend from the side wall **141** in the space.

In an embodiment, the frame structure **140** may support or accommodate other elements included in the electronic device **100**. For example, the display **101** may be disposed on one surface (e.g., an one surface **143***a* of FIG. **3**A) of the frame structure **140**, which faces one direction (e.g., the +z axis direction), and the display **101** may be supported by the support part **143** of the frame structure **140**. As another example, the first printed circuit board **150**, the second printed circuit board **152**, the battery **170**, and the second camera module **112** may be disposed on an opposite surface (e.g., an opposite surface **143***b* of FIG. **3**B) that faces an opposite direction (e.g., the −z axis direction) to the one surface. The first printed circuit board **150**, the second printed circuit board **152**, the battery **170**, and the second camera module **112** may be seated in a recess defined by the side wall **141** and/or the support part **143** of the frame structure **140**.

In an embodiment, the first printed circuit board **150**, the second printed circuit board **152**, and the battery **170** may be coupled to the frame structure **140**. For example, the first printed circuit board **150** and the second printed circuit board **152** may be fixedly disposed in the frame structure **140**, through a coupling member, such as a screw. For example, the battery **170** may be fixedly disposed in the frame structure **140**, through an adhesion member (e.g., a double-sided tape). However, the disclosure is not limited by the above-described example.

In an embodiment, the cover plate **160** may be disposed between the first printed circuit board **150** and the rear plate **111**. In an embodiment, the cover plate **160** may be disposed on the first printed circuit board **150**. For example, the cover plate **160** may be disposed on a surface of the first printed circuit board **150**, which faces the −z axis direction.

In an embodiment, the cover plate **160** may at least partially overlap the first printed circuit board **150** with respect to the z axis. In an embodiment, the cover plate **160** may cover at least a partial area of the first printed circuit board **150**. Through this, the cover plate **160** may protect the first printed circuit board **150** from a physical impact, or may prevent or alleviate deviation of the connector coupled to the first printed circuit board **150**.

In an embodiment, the cover plate **160** may be fixedly disposed in the first printed circuit board **150** through a coupling member (e.g., a screw), or may be coupled to the frame structure **140** together with the first printed circuit board **150** through the coupling member.

In an embodiment, the display **101** may be disposed between the frame structure **140** and the front plate **102**. For example, the front plate **102** may be disposed on one side (e.g., the +z axis direction) of the display **101**, and the frame structure **140** may be disposed on an opposite side (e.g., the −z axis direction).

In an embodiment, the front plate **102** may be coupled to the display **101**. For example, the front plate **102** and the display **101** may be bonded to each other through an adhesion member for optics (e.g., an optically clear adhesive (OCA) or an optically clear resin (OCR)) interposed therebetween.

In an embodiment, the front plate **102** may be coupled to the frame structure **140**. For example, the front plate **102** may include an outskirt part that extends to an outside of the display **101** when viewed in the z axis direction, and may be bonded to the frame structure **140** through an adhesion member (e.g., a double-sided tape) disposed between the outskirt part of the front plate **102** and the frame structure **140** (e.g., the side wall **141**). However, the disclosure is not limited by the above-described example.

In an embodiment, a processor (e.g., a processor **1320** of FIG. **13**), a memory (e.g., a memory **1330** of FIG. **13**), and/or an interface (e.g., an interface **1377** of FIG. **13**) may be mounted in the first printed circuit board **150** and/or the second printed circuit board **152**. The processor, for example, may include one or more central processing units, an application processor, a graphic processing unit, an image signal processor, a sensor hub processor, or a communication processor. The memory, for example, may include a volatile and/or nonvolatile memory. The interface, for example, may include a high definition multimedia interface (HDMI), a universal serial bus (USB), a secure digital (SD) card interface, and/or an audio interface. The interface, for example, may electrically or physically connect the electronic device **100** to an external electronic device, and may include a USB connector, an SD card/multimedia card (MMC) connector, and an audio connector. In an embodiment, the first printed circuit board **150** and the second printed circuit board **152** may be operatively or electrically connected to each other through a connection member (e.g., a flexible printed circuit board).

In an embodiment, the battery (e.g., a battery **1389** of FIG. **13**) may supply electric power to at least one element of the electronic device **100**. For example, the battery **170** may include a rechargeable secondary battery or a fuel cell. At least a portion of the battery **170** may be disposed on substantially the same plane as the first printed circuit board **150** and/or the second printed circuit board **152**.

The electronic device **100** according to an embodiment may include an antenna module (not illustrated) (e.g., an antenna module **1397** of FIG. **13**). According to an embodiment, the antenna module may be disposed between the rear plate **111** and the battery **170**. The antenna module, for example, may include a near field communication (NFC) antenna, a wireless charging antenna, and/or a magnetic secure transmission (MST) antenna. The antenna module, for example, may perform short-range communication with an external device, or may wirelessly transmit and receive electric power to and from the external device.

In an embodiment, the first camera module **105** (e.g., the front camera) may be disposed at least a portion (e.g., the support part **143**) of the frame structure **140** such that the lens receives external light through a partial area (e.g., a camera area **137**) of the front plate **102** (e.g., the first surface **100**A of FIG. **1**).

In an embodiment, the second camera module **112** (e.g., the rear camera) may be disposed between the frame structure **140** and the rear plate **111**. In an embodiment, the second camera module **112** may be electrically connected to

the first printed circuit board **150** through a connection member (e.g., a connector). In an embodiment, the second camera module **112** may be disposed such that the lens receives external light through a camera area **184** of the rear plate **111** of the electronic device **100**.

In an embodiment, the camera area **184** may be formed on a surface (e.g., the second surface **100**B of FIG. **1**) of the rear plate **111**. In an embodiment, the camera area **184** may be formed to be at least transparent such that external light is input to the lens of the second camera module **112**. In an embodiment, at least a portion of the camera area **184** may protrude from the surface of the rear plate **111** by a specific height. However, this is not limited thereto, and in another embodiment, the camera area **184** may define a plane that is substantially the same as the surface of the rear plate **111**.

In an embodiment, the housing of the electronic device **100** may refer to a configuration or a structure that defines at least a portion of an external appearance of the electronic device **100**. In this regard, at least some of the front plate **102**, the frame structure **140**, and/or the rear plate **111** that define the external appearance of the electronic device **100** may be referenced as the housing of the electronic device **100**.

FIG. **3**A is a first perspective view of a frame structure according to an embodiment of the disclosure.

FIG. **3**B is a second perspective view of a frame structure according to an embodiment of the disclosure.

FIG. **3**C is a cross-sectional view corresponding to an area R**1** of FIGS. **3**A and **3**B according to an embodiment of the disclosure. FIG. **3**C may be a cross-sectional view obtained by cutting the area R**1** of the frame structure by an x-z plane according to an embodiment of the disclosure.

Referring to FIGS. **3**A and **3**B, the frame structure **140** according to an embodiment may include a first conductive member (or a first conductive part) **310**, a second conductive member (or a second conductive part) **320**, and a nonconductive member (or a nonconductive part) **330**. In an embodiment, the first conductive member **310** and the second conductive member **320** may include an electrically conductive material, for example, a conductive metal or alloy. For example, the first conductive member **310** and/or the second conductive member **320** may include aluminum, an aluminum alloy, stainless steel, titanium, a titanium alloy, magnesium, a magnesium alloy, copper, a copper alloy, or a combination thereof, but the disclosure is not limited by the above-described example. In an embodiment, the first conductive member **310** and the second conductive member **320** may include the same or different materials. In an embodiment, the nonconductive member **330** may include an electrically nonconductive material, for example, a resin.

In an embodiment, the side wall **141** of the frame structure **140** may include a first side wall **141***a* that extends in a lengthwise direction (e.g., the y axis direction) of the electronic device **100**, a second side wall **141***b* that extends from the first side wall **141***a* in a widthwise direction, a third side all **141***c* that extends from the second side wall **141***b* to face the first side wall **141***a*, and a fourth side wall **141***d* that extends from the third side wall **141***c* to the first side wall **141***a* to face the second side wall **141***b*. In an embodiment, the first side wall **141***a* and the third side wall **141***c* may extend substantially in parallel to each other, but the disclosure is not limited thereto. In an embodiment, the second side wall **141***b* and the fourth side wall **141***d* may extend substantially in parallel to each other, but the disclosure is not limited thereto. In an embodiment, the first side wall **141***a* and the third side wall **141***c* may have lengths that are larger than those of the second side wall **141***b* and the fourth side wall **141***d*, but the disclosure is not limited thereto. In an embodiment, it is illustrated that a shape of the electronic device **100** has a rectangular bar-type shape, a length of which is larger than a width thereof, but the disclosure is not limited by the illustrated example.

In an embodiment, the side wall **141** of the frame structure **140** may be defined by the first conductive member **310** and the nonconductive member **330**. In an embodiment, the nonconductive member **330** corresponding to the side wall **141** may define the third surface **100**C of the electronic device **100** together with the first conductive member **310**. In an embodiment, it may be understood that the side wall **141** of the frame structure **140** is defined by the first conductive member **310**, the second conductive member **320**, and the nonconductive member **330**, but the second conductive member **320** may not be exposed through the third surface **100**C of the electronic device **100**.

In an embodiment, the first conductive member **310** may include a plurality of segments. The plurality of segments may be at least partially separated from adjacent segments. In an embodiment, a spacing space may be formed as the plurality of segments are at least partially separated. In an embodiment, the nonconductive member **330** may be at least partially disposed in the spacing spaces defined between the adjacent segments. For example, the first conductive member **310** may include a first segment **381**, and a second segment **382** that is adjacent to the first segment **381**. The first segment **381** and the second segment **382** may be at least partially spaced apart from each other, and a spacing space **383** may be formed between the first segment **381** and the second segment **382**. The nonconductive member **330** corresponding to the side wall **141** (or the second side wall **141***b*) may be at least partially filled in the spacing space **383**.

In an embodiment, it may be understood that the second conductive member **320** is connected to some of the plurality of segments of the first conductive member **310** to form the plurality of segments together with the first conductive member **310**. For example, the second conductive member **320** may be electrically connected to at least some of the plurality of segments of the first conductive member **310**.

In an embodiment, contact parts (or contact points) may be provided in at least some of the plurality of segments. For example, a first contact part C**1** and a second contact part C**2** may be formed in the first segment **381**. A third contact part C**3** and a fourth contact part C**4** may be formed in the second segment **382**.

In an embodiment, through the contact parts, at least some of the plurality of segments may be electrically connected to a wireless communication circuit (e.g., a wireless communication module **1392** of FIG. **13**) disposed in a printed circuit board (e.g., the first printed circuit board **150** of FIG. **2**), and/or a ground part (e.g., a ground plane provided in the printed circuit board) of the electronic device **100**. At least some of the plurality of segments may be operated as antenna radiators (or antenna elements) for receiving electric power from the wireless communication circuit and transmitting and receiving a wireless signal of a specific band. For example, the first segment **381** may be electrically connected to a ground plane provided in the printed circuit board through the first contact part C**1**, and may be electrically connected to the wireless communication circuit through the second contact part C**2**. For example, the second segment **382** may be electrically to the wireless communication circuit through the third contact part C**3**, and may be electrically connected to the ground plane of the printed circuit board through the fourth contact part C**4**. In an

embodiment, the first segment **381** and the second segment **382** may be operated as antenna radiators for transmitting and receiving a wireless signal of a specific band. However, electrical connection relationships through the contact parts of the first segment **381** and/or the second segment **382** are not limited to the above-described example. For example, antenna structures of various types may be applied to the first segment **381** and/or the second segment **382** of the first conductive member **310**, and thus at least one or more of the first to fourth contact parts C1 to C4 may be omitted or a contact part that is not illustrated may be further included.

In an embodiment, the first conductive member **310** may be electrically connected to the second conductive member **320**. For example, the first segment **381** and/or the second segment **382** of the first conductive member **310** may be electrically connected to the second conductive member **320**. In this case, the first conductive member **310** may at least partially form the antenna structure of the electronic device **100** together with the second conductive member **320**. For example, the first conductive member **310** may at least partially form the antenna radiator of the electronic device **100** together with the second conductive member **320**.

In an embodiment, various connection members, for example, a C-clip or a coaxial cable may be used to electrically connect the first segment **381** and the second segment **382** to the contact parts, but the disclosure is not limited to the above-described example.

In an embodiment, the first segment **381** may include a portion of the first side wall **141***a*, and a first part of the second side wall **141***b*, which extends from the portion of the first side wall **141***a*. The nonconductive members **330** may be disposed at opposite ends of the first segment **381**. The second segment **382** may include a second part of the second side wall **141***b*, which is at least partially separated from the first segment **381** while the nonconductive member **330** disposed in the spacing space **383** being interposed therebetween, and a portion of the third side wall **141***c* that extends from the second part. The nonconductive members **330** may be at least partially disposed at opposite ends of the second segment **382**. Physical features (e.g., a length, a thickness, and a shape) of the first segment **381** and/or the second segment **382** that forms the antenna structure are not limited to the illustrated embodiment. For example, various design changes that may be applied by an ordinary person in the art may be made to the first segment **381** and/or the second segment **382** according to characteristics (e.g., a frequency, a bandwidth, and the like) of a wireless signal that is to be transmitted or received by using them.

In an embodiment, the support part **143** of the frame structure **140** may extend from the side wall **141** to an inside of the electronic device **100**. In an embodiment, the support part **143** may be defined by the second conductive member **320** and the nonconductive member **330**. In another embodiment, the support part **143** may be defined by the first conductive member **310**, the second conductive member **320**, and the nonconductive member **330**.

In an embodiment, the support part **143** may be configured to support various elements of the electronic device **100**. For example, referring to FIG. **3**A, the one surface **143***a* of the support part **143** may be at least partially formed to be substantially flat, and may support the display (e.g., the display **101** of FIG. **1**) disposed thereon. The one surface **143***a* of the support part **143** may be defined by the second conductive member **320** and the nonconductive member **330**.

In an embodiment, the support part **143** may be configured to accommodate various elements of the electronic device **100**. For example, referring to FIG. **3**B, the support part **143** may include a plurality of partition walls that define a recess for accommodating various elements of the electronic device **100**. For example, the support part **143** of the frame structure **140** may further include the opposite surface **143***b* that is formed to be substantially flat. The opposite surface **143***b* may be an opposite surface to the one surface **143***a* of the support part **143**. The support part **143** of the frame structure **140** may include a first partition wall **330***a* and a second partition wall **330***b* that extend from the opposite surface **143***b* in a height direction (e.g., the –z axis direction). In an embodiment, a partial area of the opposite surface **143***b* of the support part **143**, the first partition wall **330***a*, and the second partition wall **330***b* may define a recess **1431**, together with the first side wall **141***a* and the third side wall **141***c*. A battery (e.g., the battery **170** of FIG. **2**), for example, may be accommodated in the recess **1431**. In an embodiment, the first partition wall **330***a* and the second partition wall **330***b* may be defined by the nonconductive member **330**. In an embodiment, the opposite surface **143***b* may be defined by the second conductive member **320**.

Referring to FIG. **3**C, the first conductive member **310** of the frame structure **140** may include an outer part **311**, and a coupling part **312** that extends from the outer part **311**.

In an embodiment, the outer part **311** of the first conductive member **310** may define the third surface **100**C of the electronic device **100**. In an embodiment, the coupling part **312** of the first conductive member **310** may extend from the outer part **311** in an inward direction of the electronic device **100**. As another example, the coupling part **312** may extend from the outer part **311** toward the second conductive member **320**. As another example, the coupling part **312** may extend from the outer part **311** toward a side wall located on an opposite side. For example, the coupling part **312** may extend from the outer part **311** corresponding to the first side wall **141***a* toward the third side wall **141***c* located on an opposite side.

In an embodiment, the coupling part **312** may include a protruding part **313** that extends to at least partially face the second conductive member **320**. In an embodiment, the protruding part **313** may extend between a first side surface **312***a* and a second side surface **312***b* of the coupling part **312**, in a direction (e.g., the x axis direction) that becomes farther away from the outer part **311**. In an embodiment, the protruding part **313** may at least partially overlap the second conductive member **320**.

In an embodiment, the protruding part **313** may have a first thickness. In an embodiment, the coupling part **312** may have a second thickness. In an embodiment, the outer part **311** may have a third thickness. For example, the second thickness of the coupling part **312** may be larger than the first thickness of the protruding part **313**. For example, the third thickness of the outer part **311** may be larger than the first thickness of the protruding part **313**. However, the disclosure is not limited by the above-described example. The first thickness, the second thickness, and the third thickness may mean lengths of the protruding part **313**, the coupling part **312**, and the outer part **311** with respect to the z axis of FIG. **3**C.

In an embodiment, the second conductive member **320** may include an inner part **321**, a connecting part **322**, and an end part **323**. In an embodiment, the inner part **321** may be formed to be substantially flat. For example, as in the description made with reference to FIG. **3**A, the inner part **321** may at least partially define the one surface of the

second conductive member **320** that is formed to be substantially flat to support the display. For example, the inner part **321** may have an at least partially plate-like shape. In an embodiment, the connecting part **322** may extend from a periphery of the inner part **321** to the end part **323** toward the first conductive member **310**. In an embodiment, the connecting part **322** may include a curved portion. For example, the connecting part **322** may extend from the inner part **321** to a height that is different from that of the inner part **321**. The height may mean a location with respect to the z axis of FIG. **3**C. In another embodiment, the second conductive member **320** may not include the connecting part **322**, or the connecting part **322** may not include a curved portion (or a portion that extends at an inclination that is different from that of the inner part **321**). In this case, the inner part **321** and the end part **323** of the second conductive member **320** may be located at substantially the same height.

In an embodiment, the end part **323** of the second conductive member **320** may extend from the connecting part **322** toward the coupling part **312** (or the outer part **311**) of the first conductive member **310**. In an embodiment, the end part **323** of the second conductive member **320** may be located at a height that is different from the inner part **321**. For example, the end part **323** of the second conductive member **320** may be located on a lower side (e.g., the −z axis direction) of the inner part **321**, with respect to the illustration of FIG. **3**C. However, the disclosure is not limited thereto, and the end part **323** of the second conductive member **320** may be located at substantially the same height as that of the inner part **321**.

In an embodiment, the end part **323** of the second conductive member **320** may be seated on a stepped part **325** (or a seating part) defined by the first side surface **312***a* of the coupling part **312** and a first surface **3131** (or a first surface **3131** of the protruding part **313**).

In an embodiment, the end part **323** of the second conductive member **320** may at least partially overlap the protruding part **313** of the first conductive member **310**. In an embodiment, the end part **323** of the second conductive member **320** may extend substantially in parallel to the protruding part **313** of the first conductive member **310**, but the disclosure is not limited thereto.

In an embodiment, the end part **323** of the second conductive member **320** may at least partially contact the protruding part **313** of the first conductive member **310**. In an embodiment, the protruding part **313** may include the first surface **3131** that extends from a periphery of the first side surface **312***a* of the coupling part **312**. In an embodiment, the end part **323** of the second conductive member **320** may include a second surface **3232** that faces the protruding part **313**. In an embodiment, the first surface **3131** of the protruding part **313** and the second surface **3232** of the end part **323** may at least partially contact each other.

In an embodiment, the end part **323** of the second conductive member **320** may be partially spaced apart from the first conductive member **310**. For example, the end part **323** of the second conductive member **320** may be spaced apart from the coupling part **312** of the first conductive member **310**. For example, the end part **323** of the second conductive member **320** may be spaced apart from the first side surface **312***a* of the coupling part **312** while being seated on the stepped part **325** of the coupling part **312**. In an embodiment, the end part **323** of the second conductive member **320** may be spaced apart from the coupling part **312** of the first conductive member **310** to form a first gap **340**. The first gap **340** may a space, in which a tolerance of a process of coupling (or assembling) the first conductive member **310** and the second conductive member **320** is considered.

In an embodiment, the first gap **340** may be defined by a partial area of the first surface **3131** of the protruding part **313**, which does not contact the second conductive member **320**, the first side surface **312***a* of the coupling part **312**, and a surface **323***a* of the end part **323**. The surface **323***a* of the end part **323** may extend from a periphery of the second surface **3232** to a periphery of a third surface **3233**. In an embodiment, the first side surface **312***a* of the coupling part **312** and the first surface **3131** of the protruding part **313** may extend at different inclinations to define the stepped part **325**. For example, the first surface **3131** of the protruding part **313** may extend in a first direction (e.g., the x axis direction), and the first side surface **312***a* of the coupling part **312** may extend from a periphery (e.g., a periphery in the −x axis direction) of the first surface **3131** in a second direction (e.g., the +z axis direction) that is different from the first direction. In an embodiment, the surface **323***a* of the end part **323** may extend from the second surface **3232** of the end part **323** at an inclination that is different from that of the second surface **3232**. For example, the second surface **3232** of the end part **323** may extend in a third direction (e.g., the x axis direction), and the surface **323***a* of the end part **323** may extend from a periphery (e.g., a periphery in the −x axis direction) of the second surface **3232** in a fourth direction (e.g., the +z axis direction) that is different from the third direction. In an embodiment, the first direction, in which the first surface **3131** of the protruding part **313** extends, and the third direction, in which the second surface **3232** of the end part **323** extends, may be substantially the same direction, but the disclosure is not limited thereto. In an embodiment, the second direction, in which the first surface **3131** of the coupling part **312** extends, and the fourth direction, in which the second surface **3232** of the end part **323** extends, may be substantially the same direction, but the disclosure is not limited thereto. In an embodiment, the surface **323***a* of the end part **323** and the first side surface **312***a* of the coupling part **312** may at least partially face each other, and may be spaced apart from each other.

In an embodiment, the coupling part **312** of the first conductive member **310** and the end part **323** of the second conductive member **320** may be bonded to each other through a bonding part **315**. For example, the bonding part **315** may be formed through a laser welding process (however, the disclosure is not limited thereto as will be described below).

In an embodiment, the first conductive member **310** and the second conductive member **320** may be coupled to each other, through the above-described coupling structure, and may be electrically connected to each other.

In an embodiment, the first conductive member **310** and/or the second conductive member **320** may be provided with an antenna contact part. For example, the first contact part C**1** may be provided in the protruding part **313** of the first conductive member **310**. For example, the first contact part C**1** may be located on an opposite surface **3132** of the first surface **3131** of the protruding part **313**, but the disclosure is not limited thereto. In another embodiment, the first contact part C**1** may be located on the second side surface **312***b* of the coupling part **312**, which is adjacent to the opposite surface **3132** of the protruding part **313**. In an embodiment, the first conductive member **310** and the second conductive member **320** may be supplied with electric power in the first contact part C**1** and may be operated as antenna radiators.

The electronic device **100** according to an embodiment may include a first conductive connection member **350** and a bonding layer **360**.

In an embodiment, the first conductive connection member **350** may be configured to have an electrical conductivity. The first conductive connection member **350**, for example, may include a conductive solution, a conductive deposition layer (or a metal deposition layer), or a conductive film.

In an embodiment, the first conductive connection member **350** may be disposed at a portion, at which the first conductive member **310** and the second conductive member **320** are coupled (or bonded) to each other. For example, the first conductive connection member **350** may be at least partially disposed in the stepped part **325** of the first conductive member **310**, in which the end part **323** of the second conductive member **320** is seated. In an embodiment, the first conductive connection member **350** may electrically connect the first conductive member **310** and the second conductive member **320**.

In an embodiment, the first conductive connection member **350** may be disposed to at least partially contact the first conductive member **310** and the second conductive member **320**. For example, the first conductive connection member **350** may be disposed to at least partially contact the coupling part **312** and the protruding part **313** of the first conductive member **310**, and the end part **323** of the second conductive member **320**.

In an embodiment, the first conductive connection member **350** may include a first part **3501** and a second part **3502**. In an embodiment, the first part **3501** of the first conductive connection member **350** may be at least partially disposed on the third surface **3233** that is an opposite surface to the second surface **3232** of the end part **323**. The third surface **3233** of the end part **323** may extend from a periphery of the surface **323***a* of the end part **323** to the connecting part **322**.

In an embodiment, the first part **3501** of the first conductive connection member **350** may extend to the first side surface **312***a* of the first conductive member **310**. In an embodiment, the first part **3501** of the first conductive connection member **350** may contact the first conductive member **310** and the second conductive member **320**, and may electrically connect them.

In an embodiment, the second part **3502** of the first conductive connection member **350** may extend from the first part **3501** to the protruding part **313** of the first conductive member **310**. For example, the second part **3502** of the first conductive connection member **350** may be disposed along the surface **323***a* of the end part **323** to be at least partially disposed in the first gap **340**. In an embodiment, the second part **3502** of the first conductive connection member **350** may contact the first side surface **312***a* of the coupling part **312** and the surface **323***a* of the end part **323** to electrically connect the first conductive member **310** and the second conductive member **320**. In another embodiment, the first conductive connection member **350** may not include at least a portion of the second part **3502**.

In an embodiment, a thickness of the first conductive connection member **350**, for example, may be 1 mm or less, but the disclosure is not limited thereto.

In an embodiment, the bonding layer (or a technologies rise from iwate (TRI)) **360** may include a first layer **361** at least partially interposed between the first conductive member **310** and the nonconductive member **330**, and a second layer **362** at least partially interposed between the second conductive member **320** and the nonconductive member **330**. The first layer **361** and the second layer **362** of the bonding layer **360** is for the purpose of classifying only a location of the bonding layer **360**, and not for the purpose of limiting other technical features.

In an embodiment, the bonding layer **360** is for the purpose of enhancing a bonding force between the first and second conductive members **310** and **320**, and the nonconductive member **330**, and may include an organic compound such as triazine thiol or a triazine thiol based derivative. The bonding layer **360**, for example, may be formed through a technologies rise from iwate (TRI) system or method. For example, the technologies rise from iwate (TRI) system or method may be described as a system or a method for sticking a metal and a resin.

In an embodiment, the bonding layer **360** may not be disposed between the first conductive connection member **350** and the nonconductive member **330**. Because the bonding layer **360** is disposed between the nonconductive member **330** and the first and second conductive members **310** and **320**, a bonding quality with the nonconductive member **330** may not become problematic even though the bonding layer **360** is not disposed between the first conductive connection member **350** and the nonconductive member **330**. However, the disclosure is not limited thereto, and in another embodiment, the bonding layer **360** may be disposed between the first conductive connection member **350** and the nonconductive member **330**.

The coupling structure of the first conductive member **310** and the second conductive member **320**, which has been described with reference to FIG. **3**C may be referenced as "a first coupling structure". In an embodiment, in an aspect, in which the first conductive connection member **350** is at least partially disposed in the first coupling structure and enhances an electrical connection between the first conductive member **310** and the second conductive member **320**, it may be understood that the first conductive connection member **350** is included in the first coupling structure or forms the first coupling structure together.

In an embodiment, the first coupling structure may be applied to a frame structure **940** illustrated in FIG. **9**A. For example, the end part **323** of the first coupling structure may be applied to any one or more (e.g., the end part **323** of FIG. **9**C) of a plurality of protrusions **420** illustrated in FIG. **9**C. In this case, a first conductive member **910** may include the coupling part **312** and the protruding part **313**, which correspond to the protrusion **420**, to which the first coupling structure is applied. The stepped part **325** may be formed in the coupling part **312** and the protruding part **313**. Similarly to the above-described one, the first coupling structure may be applied to a frame structure **1040** illustrated in FIG. **10**A.

Hereinafter, a process of manufacturing the frame structure **140** will be described with reference to FIGS. **4**, **5**A, **5**B, **5**C, and **6**, together with FIG. **3**C.

FIG. **4** is a view illustrating a process of assembling a first conductive member and a second conductive member according to an embodiment of the disclosure.

Referring to FIG. **4**, in an embodiment, the first conductive member **310** and the second conductive member **320** may be provided.

In an embodiment, the first conductive member **310** may be manufactured through an extrusion process. Although FIG. **4** illustrates that the first conductive member **310** is integrally formed, but the disclosure is not limited thereto. For example, the first conductive member **310** may be formed in a scheme of coupling the plurality of separated configurations (e.g., a first member **910***a* and a second member **910***b* of FIG. **9**C).

In an embodiment, the second conductive member **320** may be manufactured through rolling and pressing pro-

cesses. In an embodiment, the second conductive member **320** may be pressed sheets formed through the rolling and pressing processes. In an embodiment, the second conductive member **320** may be thin plates manufactured through the rolling and pressing processes. For example, a thickness of the second conductive member **320** may be about 0.4 mm, but the disclosure is not limited thereto.

Referring to FIG. **4**, the second conductive member **320** may include the plurality of protrusions **420** formed at a periphery of the inner part **321**.

In an embodiment, at least some of the plurality of protrusions **420** may correspond to the connecting part **322** and the end part **323** of the second conductive member **320** of FIG. **3**C. For example, the description of the connecting part **322** and the end part **323** provided with reference to FIG. **3**C may be applied to the plurality of protrusions **420** in substantially the same, similar, or corresponding manner.

In an embodiment, the first conductive member **310** and the second conductive member **320** may be assembled with each other.

FIG. **5**A is a view illustrating a state, in which a first conductive member and a second conductive member are assembled, according to an embodiment of the disclosure.

FIG. **5**B is a view illustrating a plan view and a cross-sectional view of a frame structure corresponding to the area R**1** of FIG. **3**A or FIG. **5**A according to an embodiment of the disclosure.

Referring to FIG. **5**A, in an embodiment, the second conductive member **320** may be assembled with the first conductive member **310** in a form, in which the end part **323** thereof is seated on the stepped part **325** of the coupling part **312**.

Referring to FIG. **5**B, in an embodiment, the second conductive member **320** may be seated on the stepped part **325** in a form, in which the end part **323** thereof is spaced apart from the first conductive member **310** (e.g., the first side surface **312***a* of the first conductive member **310**) while the first gap **340** being interposed therebetween.

FIG. **5**C is a view illustrating a process of coupling the first conductive member **310** and the second conductive member **320** according to an embodiment of the disclosure.

Referring to FIG. **5**C, in an embodiment, the end part **323** of the second conductive member **320** and the protruding part **313** of the first conductive member **310** may be coupled to each other. For example, the end part **323** of the second conductive member **320** and the protruding part **313** of the first conductive member **310** may be bonded to each other through the bonding part **315**. The bonding part **315**, for example, may be formed through welding (e.g., laser welding). However, a method for mechanically and/or electrically connecting the end part **323** of the second conductive member **320** and the protruding part **313** of the first conductive member **310** is not limited to bonding through the above-described welding, and various methods that may be easily used by an ordinary person in the art may be applied. For example, the protruding part **313** of the first conductive member **310** and the end part **323** of the second conductive member **320** may be bonded to each other through a pressure welding or soldering process. As another example, unlike the illustration, the protruding part **313** of the first conductive member **310** and the end part **323** of the second conductive member **320** may be formed to be press-fitted with each other to be mechanically coupled to each other, and the first conductive member **310** and the second conductive member **320** that physically contact each other may be electrically connected to each other. In this case, to enhance an electrical conductivity between the first conductive member **310** and the second conductive member **320**, a separate intermediate member (e.g., a conductive adhesive or conductive foam) may be disposed between the protruding part **313** and the end part **323**, but the disclosure is not limited thereto. As another example, unlike the illustration, the protruding part **313** of the first conductive member **310** and the end part **323** of the second conductive member **320** may be formed to be mechanically coupled to each other through a separate coupling member (e.g., a screw), and the first conductive member **310** and the second conductive member **320** that physically contact each other may be electrically connected to each other. In this case, as described above, the intermediate member may be disposed between the first conductive member **310** and the second conductive member **320**, but the disclosure is not limited thereto.

FIG. **6** is a view illustrating a process of forming a first conductive connection member of a frame structure according to an embodiment of the disclosure. FIG. **6** may be a plan view and a cross-sectional view corresponding to the area R**1** of FIG. **3**A or FIG. **5**A.

Referring to FIG. **6**, in an embodiment, the first conductive connection member **350** according to an embodiment may be disposed at a coupling part (or a bonding part) of the first conductive member **310** and the second conductive member **320**. In an embodiment, the first conductive connection member **350** may be disposed to cover at least the end part **323** of the second conductive member **320**. For example, as in the plan view illustrated in FIG. **6**, the first conductive connection member **350** may be disposed on the coupling part **312** of the first conductive member **310** over the end part **323** of the second conductive member **320**. As another example, as in the cross-sectional view illustrated in FIG. **6**, the first conductive connection member **350** may be disposed on the end part **323** of the second conductive member **320** to the first side surface **312***a* of the coupling part **312**. Additionally, the first conductive connection member **350** may be at least partially filled in the first gap **340**.

In an embodiment, the first conductive connection member **350**, for example, may include a conductive solution, a conductive deposition layer, or a conductive film.

The conductive solution, for example, may include a resin including conductive particles. For example, the conductive particles may include conductive metal particles formed of silver, copper, gold, aluminum, zinc, nickel, iron, or tin, but the disclosure is not limited by the above-described examples. The resin, for example, may include a thermosetting resin including epoxy or silicon or a thermosetting bonding resin, but the disclosure is not limited to the above-described example. In an embodiment, the first conductive connection member **350** may be formed by applying and curing the conductive solution. In an embodiment, when an injection-molding process is performed after the first conductive connection member **350** is applied, the conductive solution of the first conductive connection member **350** may include the thermosetting resin such that the first conductive connection member **350** is not damaged by heat applied in the injection-molding process. Additionally, an organic/inorganic pigment is applied to the conductive solution and thus a color of the first conductive connection member **350** may be implemented. Through this, it may be easily identified whether the application of the first conductive connection member **350** is omitted or an application quality satisfies a reference value.

The conductive deposition layer (or the conductive thin film), for example, may include one or a plurality of conductive layers formed through a deposition process using

various conductive metals as a source. In this case, the first conductive connection member **350** may be formed through the above-described deposition process. Through a color of the source metal of the conductive deposition layer, a color of the first conductive connection member **350** may be implemented. Through this, it may be easily identified whether the application of the first conductive connection member **350** is omitted or a deposition quality satisfies a reference value.

In an embodiment, when the first conductive connection member **350** includes a conductive film, the first conductive connection member **350** may be formed by attaching the conductive film onto the first conductive member **310** and the second conductive member **320**. In an embodiment, when the injection-molding process is performed after the conductive film is attached, the conductive film of the first conductive connection member **350** may include a thermosetting resin such that the conductive film is prevented from being damaged by the heat applied during the injection-molding process. Additionally, the conductive film may include a color printing layer. Through the color printing layer, a color may be implemented in the first conductive connection member **350**. Through this, it may be easily identified whether the attachment of the first conductive connection member **350** is omitted or an attachment quality satisfies a reference value.

Referring to FIG. **3**C, in an embodiment, the bonding layer **360** may be formed on surfaces of the first conductive member **310** and the second conductive member **320** which are coupled to each other. As described above, the bonding layer **360**, for example, may be formed by applying an organic compound such as triazine thiol or a triazine thiol based derivative. An area, to which the bonding layer **360** is applied, may correspond to an area, in which the nonconductive member **330**. As described above, in an embodiment, the bonding layer **360** may not be applied onto the first conductive connection member **350**. In another embodiment, the bonding layer **360** may be applied onto the first conductive connection member **350**, together with the first conductive member **310** and the second conductive member **320**.

Thereafter, the nonconductive member **330** may be formed through an injection-molding process. The resin applied to the injection-molding process may include a thermoplastic material. For example, resins of various materials, such as polycarbonate, polybutylene terephthalate, polyethylene terephthalate, polyether aryl ketone, polyphenyline sulfone, polyphenyline sulfide, polyamide, and polyphthalamide. Additionally, various inorganic materials, such that glass fiber, carbon fiber, talc, whisker, wollastonite, glass powder, and zirconia-based ceramic material, may be added to the resin applied to the injection-molding process. However, the disclosure is not limited by the above-described example.

The nonconductive member **330** may surround at least the coupling part of the first conductive member **310** and the second conductive member **320** such that they are not exposed to an outside. Through this, a coupling force of the first conductive member **310**, the second conductive member **320**, and the first conductive connection member **350** may be enhanced, and the coupling part of the first conductive member **310** and the second conductive member **320**, and the first conductive connection member **350** disposed herein may be protected from an external environment.

After the injection-molding process, a shape of the third surface **100**C of the electronic device **100** may be formed through mechanical machining (e.g., computer numerical control (CNC) machining). For example, as illustrated in FIG. **3**C, the third surface **100**C of the electronic device **100** may be machined to have a curved surface. However, the shape of the third surface **100**C formed through the mechanical machining is not limited to the illustrated example. In another embodiment, the third surface **100**C of the electronic device **100** may at least partially include a substantially flat area.

After the shape of the third surface **100**C of the electronic device **100** is formed, a surface-treating process (e.g., anodizing) of the first conductive member **310** and the second conductive member **320** may be performed.

A frame structure according to a comparative example may include a metal member. The metal member may form a structure for accommodating or supporting various elements of the electronic device through a die casting process or a mechanical machining process, such as cutting. The second conductive member **320** according to an embodiment may be manufactured in a form of a thin plate through a pressing process, and the nonconductive member **330** may be formed by injection-molding the second conductive member **320** in the form of a thin plate. The nonconductive member **330** formed through the above-described injection-molding process may define a structure (e.g., the one surface **143***a* of FIG. **3**A) for supporting various elements of the electronic device **100** or a recess (e.g., the recess **1431** of FIG. **3**B) that may accommodate various elements, together with the second conductive member **320**. Accordingly, the frame structure **140** according to an embodiment may be manufactured easily and efficiently and reduce a process time and manufacturing costs as compared with the comparative example. A ratio of a resin to a metal of the frame structure **140** according to an embodiment may be larger than that of the frame structure of the comparative example. In general, because the metal has a specific gravity that is higher than that of a resin, the frame structure **140** according to an embodiment may be lighter than the frame structure according to the comparative embodiment, and may be advantageous in the light weight of the electronic device **100**.

FIG. **7** is a cross-sectional view illustrating a frame structure according to an embodiment of the disclosure. FIG. **7** may be a cross-sectional view obtaining by cutting the area R**1** of FIG. **3**A along the X-Z plane.

Referring to FIG. **7**, the frame structure **140** of the electronic device **100** according to an embodiment may further include a second conductive connection member **352**.

The description of the first conductive connection member **350** may be applied to the description of the second conductive connection member **352** according to an embodiment in substantially the same, similar, or corresponding manner, and a repeated description thereof will be omitted.

In an embodiment, the protruding part **313** of the first conductive member **310** and the second conductive member **320** may be partially spaced apart from each other to define a second gap **342**. For example, the protruding part **313** of the first conductive member **310** and the connecting part **322** of the second conductive member **320** may be spaced apart from each other to define the second gap **342**. In an embodiment, the second conductive connection member **352** may be at least partially disposed in the second gap **342**. In this case, unlike the illustration of FIG. **3**C, the bonding layer **360** may not be disposed in an area, in which the second conductive connection member **352** is disposed.

In another embodiment, the second gap **342** may not be formed. For example, unlike the illustration, an end of the

protruding part **313** may not include a chamfered part, and the protruding part **313** may be formed to be shorter than the illustration such that an end thereof overlaps the end part **323** of the second conductive member **320**. As another example, unlike the illustration, the end of the protruding part **313** may not include a chamfered part, and the connecting part **322** of the second conductive member **320** may extend substantially in parallel to the end part **323**. In another embodiment, the second conductive connection member **352** may be disposed to contact both of the protruding part **313** of the first conductive member **310** and the end part **323** (or the connecting part **322**) of the second conductive member **320**, even when the second gap **342** is not formed.

In an embodiment, the second conductive connection member **352** may enhance an electrical connection between the first conductive member **310** and the second conductive member **320**. In an embodiment, in an aspect, in which the second conductive connection member **352** is at least partially disposed in the first coupling structure of the first conductive member **310** and the second conductive member **320** and enhances an electrical connection between the first conductive member **310** and the second conductive member **320**, it may be understood that the second conductive connection member **352** is included in the first coupling structure together with the first conductive connection member **350** or forms the first coupling structure together.

In an embodiment, the bonding layer **360** may not be disposed between the second conductive connection member **352** and the nonconductive member **330**. In another embodiment, the bonding layer **360** may be interposed between the second conductive connection member **352** and the nonconductive member **330**.

In an embodiment, the second conductive connection member **352** may be formed through the substantially the same process as the process of forming the first conductive connection member **350** described with reference FIG. **6**. In an embodiment, the process of forming the second conductive connection member **352** may be performed before or after the process of forming the first conductive connection member **350** is performed. In another embodiment, the process of forming the second conductive connection member **352** may be performed together with the process of forming the first conductive connection member **350**.

FIG. **8** is a view illustrating the coupling part of a first conductive member and a second conductive member according to an embodiment of the disclosure.

Referring to FIG. **8**, in an embodiment, the first conductive member **310** and the second conductive member **320** may be bonded to each other through the bonding part **315**.

The first gap **340** may be formed by an assembly tolerance of the first conductive member **310** and the second conductive member **320**.

Because the second gap **342** includes a part obtained by bending the connecting part **322** of the second conductive member **320**, the second conductive member **320** and the protruding part **313** of the first conductive member **310** may be spaced apart from each other. Furthermore, due to a defect of the bonding process, the second conductive member **320** may come over from the first conductive member **310**, and thus the second gap **342** may become wide or deep as compared with a designed size.

Even when the second conductive member **320** according to another embodiment does not include the connecting part **322** or the connecting part **322** does not include a bent part (that is, the end part **323** of the second conductive member **320** extends to be substantially flat over the protruding part **313** of the first conductive member **310**), the second gap **342** may be formed due to a defect of the above-described bonding process.

A third gap **344** may be formed as the end part **323** of the second conductive member **320** comes over due to the defect of the bonding process. Because the second conductive member **320** has a thin plate shape manufactured through a pressing process, it has a small thickness so that a vulnerable part such as the second gap **342** and the third gap **344** may be caused due to an environmental factor that is different from a condition of the bonding process. For example, when the first conductive member **310** and the second conductive member **320** are bonded to each other through welding, the second conductive member **320** may be deformed while being melted, and a crack **800** may be generated or destructed due to the fragility thereof. In this case, an electrical connection of the first conductive member **310** and the second conductive member **320** may be degraded. When the first conductive member **310** and the second conductive member **320** are used as antenna radiators, the above-described degradation of the electrical connection may degrade antenna performances (e.g., voltage standing wave ratios (VSWRs) thereof.

In an embodiment, the first conductive connection member **350** may be disposed on the end part **323** of the second conductive member **320**. In an embodiment, the first conductive connection member **350** may be at least partially disposed in the first gap **340** and the third gap **344**. In an embodiment, the first conductive connection member **350** may electrically connect the first conductive member **310** and the second conductive member **320**.

In an embodiment, the second conductive connection member **352** may be at least partially disposed in the second gap **342**, and may electrically connect the first conductive member **310** and the second conductive member **320**.

In an embodiment, even when the electrical connection is degraded due to the bonding defect of the first conductive member **310** and the second conductive member **320**, the electrical connection may be enhanced by the first conductive connection member **350** and the second conductive connection member **352**, and a required antenna performance may be satisfied. Through this, an antenna performance deviation due to a deviation of a bonding quality may be reduced, and a loss due to a defective product that fails to satisfy the bonding quality and the antenna performance may be reduced.

In an embodiment, even when the first conductive connection member **350** fails to be filled in the third gap **344** (for example, when a defect is caused after the product is released), the first conductive connection member **350** may enhance the electrical connection between the first conductive member **310** and the second conductive member **320**, through at least the first part **3501**.

In another embodiment, the first conductive member **310** and the second conductive member **320** may be coupled to each other through a physical connection structure (e.g., coupling through a press-fitting scheme or coupling through a screw). In this case, the electrical connection between the first conductive member **310** and the second conductive member **320** may become lower as compared with the case, in which the first conductive member **310** and the second conductive member **320** are physically and chemically bonded to each other through welding. In an embodiment, even when the first conductive member **310** and the second conductive member **320** are coupled to each other through a physical connection structure, the first conductive connection member **350** and the second conductive connection

member **352** may satisfy a required antenna performance by enhancing the electrical connection between the first conductive member **310** and the second conductive member **320**.

FIG. **9**A is a cross-sectional view illustrating a frame structure according to an embodiment of the disclosure.

Referring to FIG. **9**A, the frame structure **940** according to an embodiment may include the first conductive member **910**, a second conductive member **920**, a nonconductive member **930**, a bonding layer **960**, and a first conductive connection member **950**.

The description made with reference to the frame structure **140**, the first conductive member **310**, the second conductive member **320**, the nonconductive member **330**, the bonding layer **360**, and the first conductive connection member **350** may be applied to a description of the first conductive member **910**, the second conductive member **920**, the nonconductive member **930**, the bonding layer **960**, and the first conductive connection member **950** of the frame structure **940** in substantially the same, similar, or corresponding manner, and thus a repeated description thereof will be omitted.

In an embodiment, the first conductive member **910** may include an outer part **911** (e.g., the outer part **311** of FIG. **3**C) and a coupling part **912**.

In an embodiment, the coupling part **912** may extend from the outer part **911** in an inward direction of the electronic device **100**. For example, the coupling part **912** may extend from the outer part **911** in a direction that faces the center of the electronic device **100**. As another example, the coupling part **912** may extend from the outer part **911** toward a side wall located on an opposite side. For example, when the outer part **911** corresponds to a first side wall (e.g., the first side wall **141***a* of FIG. **3**A), the coupling part **912** may extend from the outer part **911** toward a third side wall (e.g., the third side wall **141***c* of FIG. **3**A) that faces the first side wall.

In an embodiment, the coupling part **912** may include a first side surface **912***a*, a second side surface **912***b*, and an upper surface **912***c* that extends from a periphery of the first side surface **912***a* to the outer part **911**. In an embodiment, the coupling part **912** may include a first hole **913** formed between the first side surface **912***a* and the second side surface **912***b*. In an embodiment, the first hole **913** may extend in a direction that is different from those of the first side surface **912***a* and the second side surface **912***b*. For example, the first side surface **912***a* may extend in a first direction (e.g., a direction that is inclined in the +x axis direction with respect to the z axis), and the second side surface **912***b* may extend in a second direction (e.g., the −z axis direction). The first hole **913** may extend in a third direction that is different from the first direction and the second direction. For example, the first hole **913** may extend in a direction (e.g., the −x axis direction) that faces the outer part **911**, between the first side surface **912***a* and the second side surface **912***b*. In an embodiment, one side of the first hole **913** that faces the outer part **911** may be closed, and the first hole **913** may include a surface **912***d* that closes the one side. In an embodiment, the first hole **913** may include an inner peripheral surface **9131** that extends from a periphery of the surface **912***d*. In an embodiment, the inner peripheral surface **9131** of the first hole **913** may extend to an opening part OP formed on the first side surface **912***a* and the second side surface **912***b* of the coupling part **912**. In an embodiment, the inner peripheral surface **9131** of the first hole **913** may be communicated with the opening part OP, and an opposite side (e.g., an opposite side to the one side) of the first hole **913** may be opened. In an embodiment, the first hole **913** may extend from the opening part OP to an interior of the coupling part **912**.

In an embodiment, the second conductive member **920** may include an inner part **921** (e.g., the inner part **321** of FIG. **3**C), a connecting part **922** (e.g., the connecting part **322** of FIG. **3**C), and an end part **323** (e.g., the end part **323** of FIG. **3**C).

In an embodiment, the connecting part **922** may contact the first side surface **912***a* of the first conductive member **910**. However, the disclosure is not limited thereto. For example, when the connecting part **922** of the first conductive member **910** extends substantially in parallel to the end part **923** and/or the first side surface **912***a* of the first conductive member **910** extends at substantially the same inclination as that of the second side surface **912***b*, the connecting part **922** may not contact the first side surface **912***a* of the first conductive member **910**.

In an embodiment, the second conductive member **920** may be coupled to the first conductive member **910**. In an embodiment, the end part **323** of the second conductive member **920** may be coupled to the coupling part **912** of the first conductive member **910**. For example, the second conductive member **920** may be coupled to the first conductive member **910** in a form, in which the end part **323** thereof is inserted into the first hole **913** formed in the coupling part **912**. In an embodiment, the end part **323** of the second conductive member **920** may be at least partially accommodated in the first hole **913** of the first conductive member **910**. In an embodiment, the end part **323** of the second conductive member **920** may be at least partially disposed in the first hole of the first conductive member **910**. In an embodiment, the end part **323** of the second conductive member **920** accommodated in the first hole **913** may at least partially contact the inner peripheral surface **9131** of the first hole **913**. In an embodiment, the bonding part **315** may be formed through laser welding performed on the upper surface **912***c* of the coupling part **912** such that the first conductive member **910** and the second conductive member **920** are bonded to each other. In this case, a distance (or a thickness of the coupling part **912** corresponding to the first side surface **912***a*) between the upper surface **912***c* of the coupling part **912** and the end part **323** of the second conductive member **920**, which is inserted into the first hole **913**, may be determined such that laser welding is possible through the upper surface **912***c*. However, as described above, a method for physically and electrically connecting the first conductive member **910** and the second conductive member **920** is not limited to welding. In an embodiment, the first conductive member **910** and the second conductive member **920** may be electrically connected to each other, through the above-described coupling structure.

In an embodiment, the first conductive member **910** and/or the second conductive member **920** may be provided with an antenna contact part (not illustrated). In an embodiment, the first conductive member **910** and the second conductive member **920** may be electrically connected to the wireless communication module (e.g., the wireless communication module **1392** of FIG. **13**) through the antenna contact part to be operated as antenna radiators.

In an embodiment, the first conductive connection member **950** may be disposed in a coupling part (or a bonding part) of the first conductive member **910** and the second conductive member **920**. In an embodiment, the end part **323** of the second conductive member **920** may be spaced apart from the surface **912***d* of the first hole **913**, and the first conductive connection member **950** may be disposed

between the end part **323** of the second conductive member **920** and the surface **912***d* of the first hole **913**. In an embodiment, the first conductive connection member **950** may contact the first conductive member **910** and the second conductive member **920**. In an embodiment, the first conductive connection member **950** may electrically connect the first conductive member **910** and the second conductive member **920**.

An electrical connection of the first conductive member **910** and the second conductive member **920** may be degraded according to an assembly tolerance of the end part **323** of the second conductive member **920** and the first hole **913**. As another example, due to a defect of the bonding part **315**, the electrical connection of the first conductive member **910** and the second conductive member **920** may be degraded. The first conductive connection member **950** according to an embodiment may enhance the electrical connection of the first conductive member **910** and the second conductive member **920**. Through this, degradation of antenna performances of the first conductive member **910** and the second conductive member **920** may be prevented and/or alleviated, and the antenna performances may be enhanced.

The coupling structure of the first conductive member **910** and the second conductive member **920**, which has been described with reference to FIG. **9**A may be referenced as "a second coupling structure". In an embodiment, in an aspect, in which the first conductive connection member **950** is disposed in the second coupling structure and enhances an electrical connection between the first conductive member **910** and the second conductive member **920**, it may be understood that the first conductive connection member **950** is included in the second coupling structure or forms the second coupling structure together.

In an embodiment, the second coupling structure may be applied to the frame structure **140** illustrated in FIG. **3**A. For example, the end part **923** of the second coupling structure may be applied to any one or more (e.g., the end part **923** of FIG. **4**) of the plurality of protrusions **420** illustrated in FIG. **4**. In this case, the first conductive member **310** may include the coupling part **912** having the first hole **913**, which corresponds to the protrusion **420**, to which the second coupling structure is applied. Similarly to the above-described one, the second coupling structure may be applied to the frame structure **1040** illustrated in FIG. **10**A.

Hereinafter, referring to FIGS. **9**B, **9**C, and **9**C, together with FIG. **9**A, a process of manufacturing the frame structure **940** according to another embodiment will be described.

FIG. **9**B is a view illustrating a process of forming a first hole and a process of disposing a first conductive connection member in the first hole according to an embodiment of the disclosure.

Referring to FIG. **9**B, with respect to reference numeral **901**, the first hole **913** may be formed in the first conductive member **910**. For example, the first hole **913** may be formed through a mechanical process such as CNC machining. In an embodiment, a cross-sectional shape of the first hole **913** may be a rectangular shape, but the disclosure is not limited thereto. For example, the first hole **913** may have a shape that is the same as or similar to the end part **323** to accommodate the end part **323** of the second conductive member **920**.

Referring to reference numeral **903**, the first conductive connection member **950** may be disposed (or formed) in the first hole **913**. In an embodiment, the first conductive connection member **950** may include a conductive solution, a conductive deposition layer, or a conductive film. For example, the first conductive connection member **950** may be formed in a scheme, in which the conductive solution is applied in the first hole **913**. In an embodiment, because the first conductive member **910** is arranged such that the surface **912***d* of the first hole **913** faces a gravitational direction as in the illustration of FIG. **9**B, flows of the conductive solution to the first hole **913** may be prevented and/or alleviated when the conductive solution is applied. As another example, the first conductive connection member **950** may be formed in a scheme, in which the conductive deposition layer is formed on the surface **912***d* of the first hole **913** through a deposition process. As another example, the first conductive connection member **950** may be formed in a scheme, in which the conductive film is attached to the surface **912***d* of the first hole **913**.

FIG. **9**C is a view illustrating a process of coupling the first conductive member **910** and the second conductive member **920** according to an embodiment of the disclosure.

Referring to FIG. **9**C, illustration of a spacing space (e.g., the spacing space **383**, in which the nonconductive member **330** of FIG. **3**A is disposed) defined by the first conductive member **910** and in which the nonconductive member corresponding to the side wall (the side wall **141** of FIG. **3**A) is disposed will be omitted for convenience of description.

FIG. **9**D is a cross-sectional perspective view, taken along line A-A' of FIG. **9**C according to an embodiment of the disclosure.

Referring to FIG. **9**C, the first conductive member **910** may include the first member **910***a* and the second member **910***b*. In an embodiment, the first member **910***a* and the second member **910***b* of the first conductive member **910** and the second conductive member **920** may be assembled.

Referring to FIG. **9**D together with FIG. **9**C, with respect to reference numeral **905**, opposite ends of the first member **910***a* and opposite ends of the second member **910***b* may contact and/or be connected to each other while the first member **910***a* and the second member **910***b* of the first conductive member **910** and the second conductive member **920** are assembled with each other, and the end part **323** of the second conductive member **920** may be inserted into the first hole **913** formed in the second conductive member **920**.

In an embodiment, a bonding process, such as laser welding, may be performed on parts W**1** and W**2**, in which the first member **910***a* and the second member **910***b* contact and/or be connected to each other. Through the bonding process, the first member **910***a* and the second member **910***b* of the first conductive member **910** may be coupled to each other. However, a method for coupling the first member **910***a* and the second member **910***b* is not limited to the above-described bonding process, such as welding, but various methods that may be easily used by an ordinary person in the art may be applied.

In an embodiment, the first conductive member **910** and the second conductive member **920** may be coupled (or bonded) to each other. For example, laser welding may be performed on the upper surface **912***c* of the coupling part **912**, which overlaps the second conductive member **920**. For example, because the laser welding is performed on a specific portion (or an area) **915**, at which the second conductive member **920** and the coupling part **912** overlap each other, the first conductive member **910** and the second conductive member **920** may be coupled to each other.

Referring to reference numeral **907**, the bonding layer **960** may be applied onto the first conductive member **910** and the second conductive member **920** to correspond to a location, at which the nonconductive member **930** is formed, and the nonconductive member **930** may be formed through an

injection-molding process after the bonding layer **960** is applied. After the injection-molding process, a process of machining and surface-treating the third surface **100**C may be performed. The above description made with reference to FIG. **3**C may be applied to the process of applying the bonding layer **960**, the process of injection-molding the nonconductive member **930**, and the process for the third surface **100**C in substantially the same, similar, or corresponding manner.

FIG. **10**A is a cross-sectional view illustrating a frame structure according to an embodiment of the disclosure.

Referring to FIG. **10**A, the frame structure **1040** according to an embodiment may include a first conductive member **1010**, a second conductive member **1020**, a nonconductive member **1030**, a bonding layer **1060**, and a first conductive connection member **1050**.

The description of the first conductive member **910** made with reference to FIG. **9**A may be applied to a description of the first conductive member **1010** according to an embodiment in substantially the same, similar, or corresponding manner. For example, the description of the first conductive member **310** made with reference to FIG. **3**C may be applied to a description of the first conductive member **1010** in substantially the same, similar, or corresponding manner. For example, the first conductive member **1010** may include an outer part **1011** and a coupling part **1012**. The outer part **1011** may define the third surface **100**C of the electronic device **100**, together with the nonconductive member **1030** corresponding to the side wall. For example, the coupling part **1012** of the first conductive member **1010** may extend from the outer part **1011** in an inward direction of the electronic device **100**. For example, the coupling part **1012** may include a first side surface **1012***a*, a second side surface **1012***b*, and an upper surface **1012***c*.

In an embodiment, the upper surface **1012***c* of the coupling part **1012** may extend from a periphery of the first side surface **1012***a* to the outer part **1011**.

In an embodiment, the coupling part **1012** may include a first hole **1013**, and a second hole **1015** communicated with the first hole **1013**. In an embodiment, the first hole **1013** may extend in a first direction (e.g., the x axis direction), and the second hole **1015** may extend in a second direction (e.g., the y axis direction) that is different from the first direction. In an embodiment, the first hole **1013** may include a first inner peripheral surface **10131**, and the second hole **1015** may include a second inner peripheral surface **10151**. In an embodiment, the first inner peripheral surface **10131** may extend from the second inner peripheral surface **10151** to the first side surface **1012***a* and the second side surface **1012***b* of the coupling part **1012**. In an embodiment, the first inner peripheral surface **10131** of the first hole **1013** may be communicated with a first opening part OP**1** formed on the first side surface **1012***a* and the second side surface **1012***b*, and one side (one side in the +x axis direction) of the first hole **1013** may be opened through the first opening part OP**1**. In an embodiment, an opposite side of the first hole **1013**, in an opposite direction (e.g., the −x axis direction) to the one side may be communicated with the second hole **1015**. In an embodiment, the second hole **1015** may extend from the first hole **1013** to the upper surface **1012***c* of the coupling part **1012**. In an embodiment, the second inner peripheral surface **10151** of the second hole **1015** may extend from the first inner peripheral surface **10131** to the upper surface **1012***c*. In an embodiment, the second inner peripheral surface **10151** of the second hole **1015** may be communicated with a second opening part OP**2** formed on the upper surface **1012***c*, and one side (one side in the +z axis direction) of the second hole **1015** may be opened through the second opening part OP**2**.

The description of the second conductive member **920** made with reference to FIG. **9**A may be applied to a description of the second conductive member **1020** according to an embodiment in substantially the same, similar, or corresponding manner. For example, the description of the second conductive member **320** made with reference to FIG. **3**C may be applied to a description of the second conductive member **1020** in substantially the same, similar, or corresponding manner. For example, the second conductive member **1020** may include an inner part **1021**, a connecting part **1022**, and an end part **1023**.

In an embodiment, the end part **1023** of the second conductive member **1020** may be at least partially accommodated in the first hole **1013** and the second hole **1015** of the first conductive member **1010**. In an embodiment, the end part **1023** of the second conductive member **1020** may at least partially contact the first inner peripheral surface **10131** of the first hole **1013**. In an embodiment, the first conductive member **1010** and the second conductive member **1020** may be bonded to each other through welding through the upper surface **1012***c* of the coupling part **1012** (however, the disclosure is not limited thereto). Through the above-described coupling structure, the first conductive member **1010** and the second conductive member **1020** may be electrically connected to each other.

According to an embodiment, the end part **1023** of the second conductive member **1020** may include a surface **1023***a* that defines an end thereof. As illustrated, the surface **1023***a* of the end part **1023** may be arranged on a surface **10152** of the second inner peripheral surface **10151** of the second hole **1015**, which faces the first side surface **1012***a*. For example, the surface **1023***a* of the end part **1023** may be arranged with the surface **10152** of the second hole **1015**, with respect to the z axis. In another embodiment, the end part **1023** of the second conductive member **1020** may extend further than in the illustrated example such that the surface **1023***a* thereof is located on the second inner peripheral surface **10151** of the second hole **1015**. In another embodiment, the end part **1023** of the second conductive member **1020** may extend less than in the illustrated example such that the surface **1023***a* thereof is spaced apart from the second inner peripheral surface **10151** of the second hole **1015**.

In an embodiment, the first conductive member **1010** and/or the second conductive member **1020** may be provided with an antenna contact part (not illustrated). The first conductive member **1010** and the second conductive member **1020** may be electrically connected to the wireless communication module through the antenna contact part to be operated as antenna radiators.

In an embodiment, the first conductive connection member **1050** may be disposed in a coupling part (or a bonding part) of the first conductive member **1010** and the second conductive member **1020**. In an embodiment, the first conductive connection member **1050** may be at least partially disposed in the first hole **1013** and/or the second hole **1015**. In an embodiment, the first conductive connection member **1050** may be disposed in the first hole **1013** and/or the second hole **1015** to at least partially contact the first conductive member **1010** and the second conductive member **1020**. For example, the first conductive connection member **1050** may be disposed in the second hole **1015** to contact the end part **1023** of the second conductive member **1020**. The first conductive connection member **1050** dis-

posed in the second hole **1015** may contact the second inner peripheral surface **10151** of the second hole **1015** to contact the first conductive member **1010**. For example, the first conductive connection member **1050** may be disposed between the end part **1023** of the second conductive member **1020** and the second opening part OP**2** communicated with the second hole **1015**. As another example, the first conductive connection member **1050** may be disposed in the second hole **1015** to define the upper surface **1012***c* together with the coupling part **1012**. When the first conductive connection member **1050** is partially formed in the first hole **1013** and/or the second hole **1015**, the nonconductive member **1030** may be disposed in the remaining portions of the first hole **1013** and/or the second hole **1015** to cover the first conductive connection member **1050**.

In an embodiment, the first conductive connection member **1050** may contact the first conductive member **1010** and the second conductive member **1020**. In an embodiment, the first conductive connection member **1050** may electrically connect the first conductive member **1010** and the second conductive member **1020**. The description made with reference to the first conductive connection member **350** and/or the first conductive connection member **950** may be applied to a description of the first conductive connection member **1050** according to an embodiment in substantially the same as, similar, or corresponding manner. For example, an electrical connection of the first conductive member **1010** and the second conductive member **1020** may be degraded according to an assembly tolerance of the end part **1023** of the second conductive member **1020** and the first hole **1013** and/or a defect of the bonding part (not illustrated). The first conductive connection member **1050** according to an embodiment may enhance an electrical connection of the first conductive member **1010** and the second conductive member **1020**, may prevent and/or alleviate a defect of performance of the antennas including the first conductive member **1010** and the second conductive member **1020**, and may enhance the performance of the antennas.

In an embodiment, the bonding layer **1060** (e.g., the bonding layer **360** of FIG. **3**C or the bonding layer **960** of FIG. **9**A) may include a first layer (e.g., the first layer **361** of FIG. **3**C) disposed between the first conductive member **1010** and the nonconductive member **1030**, and a second layer (e.g., the second layer **362** of FIG. **3**C) interposed between the second conductive member **1020** and the nonconductive member **1030**. As described above, in an embodiment, the bonding layer **1060** may not be formed on the first conductive connection member **1050**. The bonding layer **1060** may not be disposed in the second hole **1015**. However, the disclosure is not limited thereto, and unlike the illustration of FIG. **10**A, in another embodiment, the bonding layer **1060** may be formed on the first conductive connection member **1050** to be at least partially disposed in the second hole **1015**. In this case, the bonding layer **1060** may be interposed between the nonconductive member **1030** and the first conductive connection member **1050**.

The coupling structure of the first conductive member **1010** and the second conductive member **1020**, which has been described with reference to FIG. **10**A, may be referenced as "a third coupling structure". In an embodiment, in an aspect, in which the first conductive connection member **1050** is at least partially disposed in the third coupling structure and enhances an electrical connection between the first conductive member **1010** and the second conductive member **1020**, it may be understood that the first conductive connection member **1050** is included in the third coupling structure or forms the third coupling structure together.

In an embodiment, the third coupling structure may be applied to the frame structure **140** illustrated in FIG. **3**A or the frame structure **940** illustrated in FIG. **9**A. For example, the end part **1023** of the third coupling structure may be applied to any one or more (e.g., the end part **1023** of FIG. **9**C) of the plurality of protrusions **420** illustrated in FIG. **4** or FIG. **9**C. In this case, the first conductive member may include the coupling part **1012**, the first hole **1013**, and the second hole **1015**, which correspond to the protrusion **420**, to which the third coupling structure is applied.

FIG. **10**B is a view illustrating a process of manufacturing a frame structure according to an embodiment of the disclosure.

Referring to FIG. **10**B, a process of manufacturing a frame structure **1040** according to an embodiment will be described.

Referring to reference numeral **1001** of FIG. **10**B, the first conductive member **1010** and the second conductive member **1020** may be provided. The first hole **1013** and the second hole **1015** may be formed in the first conductive member **1010** through mechanical machining. Thereafter, as in the description made with reference to FIG. **9**C, the first conductive member **1010** and the second conductive member **1020** may be assembled. For example, the first conductive member **1010** may include a first member (e.g., the first member **910***a* of FIG. **9**C) and a second member (e.g., the second member **910***b* of FIG. **9**C). Opposite ends of the first member and the second member may be connected to each other while the first member and the second member of the first conductive member **1010**, and the second conductive member **1020** are assembled, and the end part **1023** of the second conductive member **1020** may be inserted into the first hole **1013** of the first conductive member **1010**. After the second conductive member **1020** is inserted into the first hole **1013**, the end part **1023** of the second conductive member **1020** and the first conductive member **1010** may be bonded to each other. For example, the first conductive member **1010** and the second conductive member **1020** may be bonded to each other by performing laser welding on the upper surface **1012***c* of the first conductive member **1010**, which overlaps the end part **1023** of the first conductive member **1010**, but the disclosure is not limited to the above-described example.

Referring to reference numeral **1003** of FIG. **10**B, the first conductive connection member **1050** may be disposed in the second hole **1015**. The descriptions of the first conductive connection member **350** and the first conductive connection member **950** made with reference to FIGS. **6** and **9**B may be applied to a description of a process for disposing the first conductive connection member **1050** in substantially the same, similar, or corresponding manner.

In another embodiment, the first conductive connection member **1050** may be disposed in the first hole **1013** and/or the second hole **1015** before the first conductive member **1010** and the second conductive member **1020** are assembled with each other.

Referring to reference numeral **1005** of FIG. **10**B, the bonding layer **1060** may be applied onto the first conductive member **1010** and the second conductive member **1020** to correspond to a location, at which the nonconductive member **1030** is formed. The bonding layer **1060** may be applied onto the first conductive member **1010**, and unlike the illustration, may not be applied onto the first conductive member **1010**. After the bonding layer **1060** is applied, the nonconductive member **1030** may be formed through an injection-molding process. After the injection-molding process, a process of machining and surface-treating the third

surface **100**C may be performed. The description of the process of applying the bonding layer **360**, the process of injection-molding the nonconductive member **330**, and the process of treating the third surface **100**C of the frame structure **140**, which have been made with reference to FIG. **3**C, may be applied to the process of applying the bonding layer **1060**, the process of injection-molding the nonconductive member **1030**, and the process of treating the third surface **100**C, which have been made above, in substantially the same, similar, or corresponding manner.

FIG. **11**A is a view illustrating a process of manufacturing a frame structure according to an embodiment of the disclosure.

FIG. **11**B is a cross-sectional perspective view corresponding to an area R**2** of FIG. **11**A according to an embodiment of the disclosure. FIG. **11**B may be a sectional perspective view obtained by cutting the area R2 of FIG. **11**A by the X-Z plane according to an embodiment of the disclosure.

Referring to FIGS. **11**A and **11**B, a frame structure **1140** according to an embodiment may include a first conductive member **1110**, a second conductive member **1120**, a nonconductive member **1130**, a bonding layer **1160**, and a first conductive connection member **1150**.

The description made with reference to the frame structures **340**, **940**, and **1040**, the first conductive members **310**, **910**, and **1010**, the second conductive members **320**, **920**, and **1030**, the nonconductive members **330**, **930**, and **1030**, the bonding layers **360**, **960**, and **1060**, and the first conductive connection members **350**, **950**, and **1050** may be applied to a description of the frame structure **1140**, the first conductive member **1110**, the second conductive member **1120**, the nonconductive member **1130**, the bonding layer **1160**, and the first conductive connection member **1150** according to an embodiment in substantially the same, similar, or corresponding manner, and thus a repeated description thereof will be omitted.

In an embodiment, the first conductive member **1110** and the second conductive member **1120** may be formed of different materials. For example, the first conductive member **1110** may be formed of aluminum or an aluminum-based alloy and the second conductive member **1120** may be formed of magnesium or a magnesium-based alloy, but the disclosure is not limited thereto. In another embodiment, the first conductive member **1110** and the second conductive member **1120** may be formed of substantially the same material.

In an embodiment, the first conductive member **1110** may be coupled to the nonconductive member **1130** through an application process and an injection-molding process of the bonding layer **1160** before being coupled to the second conductive member **1120**. For the first conductive member **1110** coupled to the nonconductive member **1130**, the third surface **100**C of the electronic device **100** may be machined and an external surface treating process, such as anodizing, may be performed. In an embodiment, because an injection-molding process is performed before the first conductive member **1110** is coupled to the second conductive member **1120**, the bonding layer **1160** may be interposed only between the first conductive member **1110** and the nonconductive member **1130**.

The second conductive member **1120** may be manufactured in a form of a thin plate through rolling and pressing processes. Thereafter, a surface treating process may be performed on the second conductive member **1120**.

In an embodiment, after the surface treating process on the first conductive member **1110** and the second conductive member **1120** is finished, the second conductive member **1120** may be coupled to the first conductive member **1110**, to which the nonconductive member **1130** is coupled. For example, referring to FIG. **11**B, a coupling part **1112** of the first conductive member **1110** according to an embodiment may include an upper surface **1112***a* that extends substantially in parallel to an end part **1123** of the second conductive member **1120**. In an embodiment, the upper surface **1112***a* of the first conductive member **1110** may define a stepped part (e.g., the stepped part **325** of FIG. **3**C) together with the nonconductive member **1130**. In an embodiment, the second conductive member **1120** may be assembled with the first conductive member in a form, in which the end part **1123** is disposed in the stepped part including the upper surface **1112***a* of the coupling part **1112**. In an embodiment, the second conductive member **1120** may be spaced apart from the first conductive member **1110** coupled to the nonconductive member **1130**, while a first gap **1141** being interposed therebetween.

The first conductive member **1110** and the second conductive member **1120** may be bonded to each other through a bonding part **1115**, by performing welding after being assembled. However, as described above, a method for mechanically and electrically connecting the first conductive member **1110** and the second conductive member **1120** is not limited to a welding process.

Through the above-described coupling structure of the first conductive member **1110** and the second conductive member **1120**, the first conductive member **1110** and the second conductive member **1120** may be electrically connected to each other.

In an embodiment, after the first conductive member **1110** and the second conductive member **1120** are bonded to each other, the first conductive connection member **1150** may be disposed. In an embodiment, the first conductive connection member **1150** may be disposed in a coupling part (or a bonding part) of the first conductive member **1110** and the second conductive member **1120**. In an embodiment, the first conductive connection member **1150** may be disposed on the end part **1123** of the second conductive member **1120**. In an embodiment, the first conductive connection member **1150** may be disposed on the end part **1123** of the second conductive member **1120** to cover the bonding part **1115**. In an embodiment, the first conductive connection member **1150** may be at least partially disposed in the first gap **1141**. For example, the first conductive connection member **1150** may include a part **11501** (e.g., the second part **3502** of FIG. **3**C) disposed in the first gap **1141**. In an embodiment, because the first conductive connection member **1150** is disposed after the injection-molding process, the first conductive connection member **1150** may not be covered by the nonconductive member **1130**. Furthermore, the first conductive connection member **1150** may include a part that is disposed on the nonconductive member **1130** over the first gap **1141**.

In an embodiment, the first conductive connection member **1150** may electrically connect the first conductive member **1110** and the second conductive member **1120**. In an embodiment, the first conductive connection member **1150** may enhance an electrical connection between the first conductive member **1110** and the second conductive member **1120**.

It is illustrated that the first conductive connection member **1150** is disposed in the first gap **1141**, but the disclosure is not limited to the illustrated embodiment. For example, the first conductive connection member **1150** according to another embodiment may not be disposed in the first gap

1141. Accordingly, even when areas of the first conductive connection member **1150**, which contact the first conductive member **1110** and the second conductive member **1120**, vary, an electrical connection that is required between the first conductive member **1110** and the second conductive member **1120** may be secured by changing characteristics (e.g., an electric conductivity) of the first conductive connection member **1150**.

The coupling structure of the first conductive member **1110** and the second conductive member **1120**, which has been described with reference to FIGS. **11**A and **11**B, may be referenced as "a fourth coupling structure". In an embodiment, in an aspect, in which the first conductive connection member **1150** is at least partially disposed in the fourth coupling structure and enhances an electrical connection between the first conductive member **1110** and the second conductive member **1120**, it may be understood that the first conductive connection member **1150** is included in the fourth coupling structure or forms the fourth coupling structure together.

It has been described that for the embodiment including the fourth coupling structure, which has been described with reference to FIGS. **11**A and **11**B, an injection-molding process for the first conductive member **1110** may be performed first before the process of coupling the first conductive member **1110** and the second conductive member **1120**. However, in spite of the description, it is not limited to the fourth coupling structure that may be applied only when the injection-molding process for the first conductive member **1110** is performed first before the coupling process of the first conductive member **1110** and the second conductive member **1120**. For example, the fourth coupling structure may be applied even though the injection-molding process is performed to manufacture the frame structure after the first conductive member and the second conductive member are coupled to each other. For example, the end part **1123** of the fourth coupling structure may be applied to any one or more (e.g., the end part **1123** of FIG. **9**C) of the plurality of protrusions **420** illustrated in FIG. **4** or FIG. **9**C. In an embodiment, the first conductive connection member **1150** may be disposed in a coupling part of the first conductive member **1110** and the second conductive member **1120**, before the injection-molding process. During the injection-molding process, the bonding layer **1160** and the nonconductive member **1130** may not be formed on the first conductive connection member **1150** of the fourth coupling structure.

FIG. **12**A is a view illustrating a frame structure according to an embodiment of the disclosure.

In FIG. **12**A, illustration of a nonconductive part (e.g., the nonconductive member **330** of FIG. **12**B) is omitted.

FIG. **12**B is a cross-sectional view taken along line B-B' of FIG. **12**A according to an embodiment of the disclosure.

Referring to FIGS. **12**A and **12**B, a frame structure **1240** may include a first conductive member **1210**, a second conductive member **1220**, and a first conductive connection member **1250**.

The description made with reference to the first conductive members **310**, **910**, **1010**, and **1110**, which have been described above, may be at least partially applied to the first conductive member **1210** according to an embodiment in substantially the same, similar, or corresponding manner, and a repeated description thereof will be omitted.

In an embodiment, the first conductive member **1210** may include an outer part **1211** and a coupling part **1212** that extends from the outer part **1211** in an inward direction of the electronic device **100**. In an example, the coupling part **1212** may extend from the outer part **1211** toward a side wall located on an opposite side. In an embodiment, the coupling part **1212** may extend in a direction (e.g., the −x axis direction) that is substantially perpendicular to the third surface **100**C.

In an embodiment, a through-hole **1213** may be formed in the coupling part **1212**. In an embodiment, the through-hole **1213** may communicate a third opening part OP**3** formed on an upper surface **1212***c* of the coupling part **1212**, and a fourth opening part OP**4** formed on a surface of the coupling part **1212**, which faces the opposite direction to the upper surface **1212***c*.

In an embodiment, the second conductive member **1220** may include an inner part **1221**, a connecting part **1222**, and an end part **1223**. In an embodiment, the second conductive member **1220** may be manufactured through casting or mechanical machining. Because the second conductive member **1220** is formed through the casting or the mechanical machining, the inner part **1221** of the second conductive member **1220** may include a partition wall **1230***a*. The inner part **1221** of the second conductive member **1220** may define a recess **1432** for accommodating various elements of the electronic device **100**, together with the partition wall **1230***a*.

In an embodiment, the connecting part **1222** of the second conductive member **1220** may extend from the inner part **1221** toward the outer part **1211** of the first conductive member **1210**. For example, the connecting part **1222** may extend from the inner part **1221** in the +x axis direction. In an embodiment, the connecting part **1222** of the second conductive member **1220** may at least partially overlap the coupling part **1212** of the first conductive member **1210**. For example, with reference to the illustration of FIG. **12**B, the connecting part **1222** of the second conductive member **1220** may be located on a lower side (e.g., in the −z axis direction) of the coupling part **1212** of the first conductive member **1210**.

In an embodiment, the end part **1223** of the second conductive member **1220** may extend in a direction that is different from a direction, in which the connecting part **1222** extends. In an embodiment, the end part **1223** of the second conductive member **1220** may extend from the connecting part **1222** toward the through-hole **1213** of the first conductive member **1210**. In an embodiment, the end part **1223** of the second conductive member **1220** may pass through the fourth opening part OP**4** of the through-hole **1213**, and may extend to the third opening part OP**3** of the through-hole **1213**. In an embodiment, the end part **1223** of the second conductive member **1220** may be at least partially accommodated in the through-hole **1213** of the first conductive member **1210**.

In an embodiment, the end part **1223** and the through-hole **1213** of the second conductive member **1220** may be formed such that a diameter thereof decreases as it goes to the upper surface **1212***c* of the coupling part **1212** whereby the second conductive member **1220** is easily assembled in the through-hole **1213** of the first conductive member **1210**. However, the disclosure is not limited thereto.

In an embodiment, the end part **1223** of the second conductive member **1220** may be coupled to the through-hole **1213** to define substantially the same plane as the upper surface **1212***c* of the coupling part **1212**. In an embodiment, the end part **1223** of the second conductive member **1220** may be exposed through the upper surface **1212***c* of the coupling part **1212** while being coupled to the through-hole **1213**. In an embodiment, the end part **1223** of the second conductive member **1220** may be bonded to the coupling

part **1212** of the first conductive member **1210** while being inserted into the through-hole **1213**. For example, referring to FIG. **12**A, the end part **1223** of the second conductive member **1220**, which is exposed through the upper surface **1212***c* of the coupling part **1212**, may be bonded to the first conductive member **1210** in at least one section along a border between the first conductive member **1210** and the coupling part **1212**. For example, referring to reference numeral **1201** of FIG. **12**A, the first conductive member **1210** and the second conductive member **1220** may be bonded to each other as a bonding part **1215** is formed through welding in two sections that are separated from each other and extend along the border. As another example, referring to reference numeral **1203** of FIG. **12**A, the first conductive member **1210** and the second conductive member **1220** may be bonded to each other as the bonding part **1215** is formed through welding in one section that extends along the border.

Through the above-described coupling structure of the first conductive member **1210** and the second conductive member **1220**, the first conductive member **1210** and the second conductive member **1220** may be electrically connected to each other.

Referring to FIGS. **12**A and **12**B, in an embodiment, after the first conductive member **1210** and the second conductive member **1220** are bonded to each other, the first conductive connection member **1250** may be disposed. In an embodiment, the first conductive connection member **1250** may be disposed on the upper surface **1212***c* of the coupling part **1212** and the end part **1223** of the first conductive member **1210**, which forms the same plane as the upper surface **1212***c*, to cover the bonding part **1215**. In an embodiment, the first conductive connection member **1250** may protect the bonding part **1215** from an external environment.

In an embodiment, a bonding layer **1260** may be at least partially applied onto the first conductive member **1210** and the second conductive member **1220** to correspond to a location, at which a nonconductive member **1230** is formed. For example, the bonding layer **1260** may be at least partially disposed between the first conductive member **1210** and the nonconductive member **1230**, and may be at least partially disposed between the second conductive member **1220** and the nonconductive member **1230**. In an embodiment, the bonding layer **1260** may not be formed on the first conductive connection member **1250**, but the disclosure is not limited thereto. For example, unlike the illustration, the bonding layer **1260** also may be applied onto the first conductive connection member **1250**.

In an embodiment, after the bonding layer **1260** is applied, the nonconductive member **1230** may be formed through an injection-molding process. In an embodiment, the nonconductive member **1230** may be formed on the bonding layer **1260**. Furthermore, the nonconductive member **1230** may be formed on the first conductive connection member **1250**. In another embodiment, when the bonding layer **1260** is also applied onto the first conductive connection member **1250**, the nonconductive member **1230** may be formed on the bonding layer **1260** applied to the first conductive connection member **1250**.

In an embodiment, the nonconductive member **1230** may be formed to at least partially surround the coupling part of the first conductive member **1210** and the second conductive member **1220**.

In an embodiment, an antenna contact part that is not illustrated may be formed in the first conductive member **1210** and/or the second conductive member **1220**. Through the antenna contact part, the first conductive member **1210** and/or the second conductive member **1220** may be operatively connected to the wireless communication circuit.

In an embodiment, the first conductive connection member **1250** may electrically connect the first conductive member **1210** and the second conductive member **1220**, may compensate for degradation of an electrical connection due to an assembly tolerance and/or a bonding defect between the first conductive member **1210** and the second conductive member **1220**. For example, even when the electrical connection is degraded due to the assembly tolerance and/or the bonding defect between the first conductive member **1210** and the second conductive member **1220**, the first conductive connection member **1250** may enhance the electrical connection between the first conductive member **1210** and the second conductive member **1220**. Through this, degradation of performances of the antennas including the first conductive member **1210** and the second conductive member **1220** may be prevented and/or alleviated.

The coupling structure of the first conductive member **1210** and the second conductive member **1220**, which has been described with reference to FIGS. **12**A and **12**B, may be referenced as "a fifth coupling structure". In an embodiment, in an aspect, in which the first conductive connection member **1250** is at least partially disposed in the fifth coupling structure and enhances an electrical connection between the first conductive member **1210** and the second conductive member **1220**, it may be understood that the first conductive connection member **1250** is included in the fifth coupling structure or forms the fifth coupling structure together.

It has been described in the embodiment including the fifth coupling structure, which has been described with reference to FIGS. **12**A and **12**B that the second conductive member **1220** is formed through a die casting process, instead of in a form of a thin plate. However, it is not limited to that the fifth coupling structure cannot applied to the frame structure (e.g., the frame structures **140**, **940**, **1040**, and **1140**) including the second conductive member having a this plate shape, due to the description. Even when the second conductive member has the thin plate shape, the fifth coupling structure may be applied. For example, the end part **1223** of the fifth coupling structure may be applied to any one or more (e.g., the end part **1223** of FIG. **9**C) of the plurality of protrusions **420** illustrated in FIG. **4** or FIG. **9**C. In this case, the first conductive member may include the coupling part **1212** and the through-hole **1213**, which correspond to the protrusion **420**, to which the fifth coupling structure is applied.

According to the above-described various embodiments, the electronic device **100** may include at least one of the first coupling structure, the second coupling structure, the third coupling structure, the fourth coupling structure, and/or the fifth coupling structure.

The electronic device **100** according to an embodiment may include a plurality of coupling structures. For example, the electronic device **100** according to an embodiment may include a first coupling structure and a second coupling structure. In this case, the coupling parts **312** and **912** of the first conductive members **310** and **910** may include the stepped part **325** that are integrally formed and are spaced apart from each other, and the first hole **913**, or may be separated from each other to be referenced as the first coupling part and the second coupling part. However, even when the coupling parts **312** and **912** are referenced as the first coupling part and the second coupling part, the coupling parts **312** and **912** necessarily have to be separated from each other, and even when the coupling parts **312** and **912** are

integrally formed, they may be referenced as the first coupling part and the second coupling part for convenience of classification. Furthermore, the inner parts **321** and **921** of the second conductive members **320** and **920** may be integrally formed and be referenced as one inner part, and the end parts **323** and **923** may be referenced as the first end part and the second end part that extend from the one inner part. Furthermore, the connecting parts **322** and **922** that connect the end parts **323** and **923** and the one inner part may be referenced as the first connecting part and the second connecting part. In this regard, it may be understood that the electronic device **100** according to an embodiment may include at least one coupling structure and the at least one coupling structure includes at least one coupling part and at least one end part. Furthermore, it may be understood that the electronic device **100** according to an embodiment includes the one inner part of the second conductive member, and at least one connecting part that connects the at least one end part. Furthermore, it may be understood that the electronic device **100** according to an embodiment includes at least one conductive connection member that is disposed at a portion, at which the first conductive member and the second conductive member are coupled to each other to electrically connect them.

An electronic device (e.g., the electronic device **100** of FIG. **1**) according to an embodiment of the disclosure includes a display (e.g., the display **101** of FIG. **2**), a frame structure (e.g., the frame structure **140** of FIG. **3**A) including a first conductive member (e.g., the first conductive member **310** of FIG. **3**A) defining an external appearance of the electronic device and operated as an antenna element of the electronic device, a second conductive member (e.g., the second conductive member **320** of FIG. **3**A) coupled and electrically connected to the first conductive member, and a nonconductive member (e.g., the nonconductive member **330** of FIG. **3**A) that supports the display together with the second conductive member, a bonding layer (e.g., the bonding layer **360** of FIG. **3**C) including a first layer (e.g., the first layer **361** of FIG. **3**C) at least partially disposed between the first conductive member and the nonconductive member, and a second layer (e.g., the second layer **362** of FIG. **3**C) at least partially disposed between the second conductive member and the nonconductive member, and at least one conductive connection member (e.g., the first conductive connection member **350** of FIG. **3**C) disposed at a portion, at which the first conductive member and the second conductive member are coupled to each other, and contacting the first conductive member and the second conductive member.

In an embodiment, the first conductive member may include an outer part (e.g., the outer part **311** of FIG. **3**C) defining a side surface of the electronic device, and a coupling part (e.g., the coupling part **312** of FIG. **3**C) extending inwards from the outer part, the second conductive member may include an inner part (e.g., the inner part **321** of FIG. **3**C) that supports the display, and at least one end part (e.g., the end part **323** of FIG. **3**C) extending from the inner part toward the outer part of the first conductive member, and the coupling part of the first conductive member may be coupled to the at least one end part of the second conductive member.

In an embodiment, the at least one conductive connection member may include a first conductive connection member, the at least one end part of the second conductive member may include a first end part (e.g., the end part **323** of FIG. **3**C), a stepped part (e.g., the stepped part **325** of FIG. **3**C) may formed in the coupling part of the first conductive member, the first end part of the second conductive member may be seated on the stepped part, and the first conductive connection member may be disposed on the first end part of the second conductive member.

In an embodiment, the stepped part may be defined by a first surface (e.g., the first surface **3131** of FIG. **3**C) of the coupling part, which contacts the first end part of the second conductive member, and a first side surface (e.g., the first side surface **312***a* of FIG. **3**C) extending from a periphery of the first surface in a direction that is different from that of the first surface, and the first end part of the second conductive member may contacts the first surface, and is spaced apart from the first side surface.

In an embodiment, the first conductive member may include a first part (e.g., the first part **3501** of FIG. **3**C) disposed on the first end part of the second conductive member, and a second part (e.g., the second part **3502** of FIG. **3**C) extending from the first part, and the second part of the first conductive connection member may be at least partially disposed in a first gap (e.g., the first gap **340** of FIG. **3**C), by which the first end part of the second conductive member is spaced apart from the first side surface.

In an embodiment, the nonconductive member may surround the entire first conductive member.

In an embodiment, the at least one conductive connection member may include a second conductive connection member (e.g., the second conductive connection member **352** of FIG. **7**), the second conductive member includes a connecting part (e.g., the connecting part **322** of FIG. **7**) connecting the first end part and the inner part, and the second conductive connection member may contact the coupling part of the first conductive member and the connecting part of the second conductive member.

In an embodiment, the coupling part of the first conductive member may be spaced apart from the connecting part of the second conductive member, and the second conductive connection member may be at least partially disposed in a second gap (e.g., the second gap **342** of FIG. **7**), by which the coupling part and the connecting part are spaced apart from each other.

In an embodiment, the at least one conductive connection member includes a second conductive connection member (e.g., the first conductive connection member **950** of FIG. **9**A), the at least one end part of the second conductive member includes a second end part (e.g., the end part **923** of FIG. **9**A), a first opening (e.g., the opening OP of FIG. **9**A) and a first hole (e.g., the first hole **913** of FIG. **9**A) communicated with the first opening and extending into an interior of the coupling part are formed in the coupling part of the first conductive member, the second conductive connection member may be disposed in the first hole, and the second end part of the second conductive member may be at least partially inserted into the first hole to contact the second conductive connection member.

In an embodiment, a second opening (e.g., the second opening OP**2** of FIG. **10**A) and a second hole (e.g., the second hole **1015** of FIG. **10**A) may be formed in the coupling part of the first conductive member, the second hole may extend from the first hole (e.g., the first hole **1013** of FIG. **10**A) in a direction that is different from that of the first hole and may be communicated with the second opening, and the second conductive connection member may be at least partially disposed in the first hole and the second hole.

In an embodiment, the at least one end part of the second conductive member includes a second end part (e.g., the end part **1123** of FIG. **11**B), the at least one conductive connec-

tion member includes a second conductive connection member (e.g., the first conductive connection member **1150** of FIG. **11**B), the second conductive connection member may be disposed on the second end part, and the nonconductive member may not be formed on the second conductive connection member.

In an embodiment, the at least one conductive connection member includes a second conductive connection member (e.g., the first conductive connection member **1250** of FIG. **12**B), a first opening (e.g., the third opening OP**3** of FIG. **12**B), a second opening (e.g., the fourth opening OP**4** of FIG. **12**B), and a through-hole (e.g., the through-hole **1213** of FIG. **12**B) that communicates the first opening and the second opening are formed in the coupling part (e.g., the coupling part **1212** of FIG. **12**) of the first conductive member, the at least one end part of the second conductive member includes a second end part (e.g., the end part **1233** of FIG. **12**) extending in a direction that is different from that of the inner part and inserted into the through-hole, the second end part may pass through the second opening and extends to the first opening, and the second conductive connection member may be at least partially disposed on a surface (e.g., the upper surface **1212***c* of FIG. **12**B) of the coupling part, in which the first opening is formed, and the second end part to contact the coupling part of the first conductive member and the second end part of the second conductive member.

In an embodiment, the entire second conductive connection member may be surrounded by the nonconductive member.

In an embodiment, the at least one conductive connection member may include a solution containing conductive particles, a metal deposition layer, or a conductive film.

In an embodiment, the electronic device may include a bonding part (e.g., the bonding part **315** of FIG. **3**C) formed between the first conductive member and the second conductive member, and the bonding part may be formed through welding.

An electronic device (e.g., the electronic device **100** of FIG. **1**) according to an embodiment of the disclosure includes a display (e.g., the display **101** of FIG. **2**), a frame structure, the frame structure includes a first conductive member (e.g., the first conductive member **310** of FIG. **3**C) operated as an antenna element of the electronic device, the first conductive member includes an outer part (e.g., the outer part **311** of FIG. **3**C) defining a side surface (e.g., the third surface **100**C of FIG. **3**C) of the electronic device, and a coupling part (e.g., the coupling part **312** of FIG. **3**C) extending from the outer part to an inside of the electronic device, a second conductive member (e.g., the second conductive member **320** of FIG. **3**C) electrically connected to the first conductive member, the second conductive member includes an inner part (e.g., the inner part **321** of FIG. **3**C) that supports the display, and at least one end part (e.g., the end part **323** of FIG. **3**C) extending from the inner part and coupled to the coupling part of the first conductive member, and a nonconductive member (e.g., the nonconductive member **330** of FIG. **3**C) at least partially surrounding the first conductive member and the second conductive member, and that supports the display together with the second conductive member, a bonding layer (e.g., the bonding layer **360** of FIG. **3**C) at least partially disposed between the first conductive member and the nonconductive member, and at least partially between the second conductive member and the nonconductive member, and at least one conductive connection member (e.g., the first conductive connection member **350** of FIG. **3**C) disposed at a portion, at which the coupling part of the first conductive member and the at least one end part of the second conductive member are coupled to each other, and contacting the first conductive member and the second conductive member.

In an embodiment, the at least one conductive connection member may include a first conductive connection member, the at least one end part of the second conductive member may include a first end part (e.g., the end part **323** of FIG. **3**C), a stepped part (e.g., the stepped part **325** of FIG. **3**C), in which the first end part is seated, is formed in the coupling part of the first conductive member, wherein the stepped part is defined by a first surface (e.g., the first surface **3131** of FIG. **3**C) partially contacting the first end part, and a first side surface (e.g., the first side surface **312***a* of FIG. **3**C) extending from a periphery of the first surface in a direction that is different from that of the first surface, and spaced apart from the first end part, and the first conductive connection member may include a first part (e.g., the first part **3501** of FIG. **3**C) disposed on the first end part of the second conductive member, and extending to the first side surface, and a second part (e.g., the second part **3502** of FIG. **3**C) extending from the first part between the first side surface and the first end part.

In an embodiment, the at least one conductive connection member may include a second conductive connection member (e.g., the first conductive connection member **950** of FIG. **9**A), the at least one end part of the second conductive member may include a second end part (e.g., the end part **923** of FIG. **9**A), a hole (e.g., the first hole **913** of FIG. **9**C) may formed in the coupling part of the first conductive member, one side of the hole is opened through an opening part (e.g., the opening OP of FIG. **9**A) formed on a surface of the coupling part, and an opposite side of the hole is closed, the second end part of the second conductive member may be partially disposed in the hole, and the second conductive connection member may be disposed between the opposite side of the hole and the second end part, in the hole.

In an embodiment, the at least one conductive connection member may include a third conductive connection member, the at least one end part of the second conductive member may include a third end part (e.g., the end part **1023** of FIG. **10**A), a first hole (e.g., the first hole **1013** of FIG. **10**A) and a second hole (e.g., the second hole **1015** of FIG. **10**A) communicated with one side of the first hole are formed in the coupling part of the first conductive member, the first hole may extend from a first opening part (e.g., the first opening OP**1** of FIG. **10**A) formed on a surface of the coupling part to the one side in a first direction that faces an interior of the coupling part, the second hole may extend from the one side of the first hole to a second opening part (e.g., the second opening OP**2** of FIG. **10**A) formed on a surface of the coupling part in a second direction that is different from the first direction, the third end part of the second conductive member may be at least partially disposed in the first hole, and the third conductive connection member may be at least partially formed in the first hole and/or the second hole to contact the third end part disposed in the first hole and the coupling part.

In an embodiment, the at least one conductive connection member includes a fourth conductive connection member (e.g., the first conductive connection member **1250** of FIG. **12**B), the at least one end part of the second conductive member includes a fourth end part (e.g., the end part **1223** of FIG. **12**B), the coupling part of the first conductive member may include a third opening (e.g., the third opening OP**3** of FIG. **12**B) formed on a first surface (e.g., the upper

surface **1212***c* of FIG. **12**B) of the coupling part, a fourth opening (e.g., the fourth opening OP**4** of FIG. **12**B) formed on a second surface that is different from the first surface of the coupling part, and a through-hole (e.g., the through-hole **1213** of FIG. **12**B) that communicates the third opening and the fourth opening, the fourth end part may extend in a direction that is different from that of the inner part and is inserted into the through-hole, and passes through the fourth opening of the through-hole and extends to the third opening, and the fourth conductive connection member may be at least partially disposed on the first surface of the coupling part, in which the third opening is formed, to cover the fourth end part that extends to the third opening.

In an embodiment, the coupling part may include a second side surface and an upper surface that extends from a periphery of the first side surface to the outer part.

In an embodiment, the first hole may be formed between the first side surface and the second side surface.

In an embodiment, the first side surface may extend on a first axis and the second side surface may extend on a second axis. The first hole may extend on a third axis that is different from the first axis and the second axis.

FIG. **13** is a block diagram illustrating an electronic device in a network environment according to an embodiment of the disclosure.

Referring to FIG. **13**, an electronic device **1301** in a network environment **1300** may communicate with an electronic device **1302** via a first network **1398** (e.g., a short-range wireless communication network), or at least one of an electronic device **1304** or a server **1308** via a second network **1399** (e.g., a long-range wireless communication network). According to an embodiment, the electronic device **1301** may communicate with the electronic device **1304** via the server **1308**. According to an embodiment, the electronic device **1301** may include a processor **1320**, memory **1330**, an input module **1350**, a sound output module **1355**, a display module **1360**, an audio module **1370**, a sensor module **1376**, an interface **1377**, a connecting terminal **1378**, a haptic module **1379**, a camera module **1380**, a power management module **1388**, a battery **1389**, a communication module **1390**, a subscriber identification module (SIM) **1396**, or an antenna module **1397**. In some embodiments, at least one of the components (e.g., the connecting terminal **1378**) may be omitted from the electronic device **1301**, or one or more other components may be added in the electronic device **1301**. In some embodiments, some of the components (e.g., the sensor module **1376**, the camera module **1380**, or the antenna module **1397**) may be implemented as a single component (e.g., the display module **1360**).

The processor **1320** may execute, for example, software (e.g., a program **1340**) to control at least one other component (e.g., a hardware or software component) of the electronic device **1301** coupled with the processor **1320**, and may perform various data processing or computation. According to one embodiment, as at least part of the data processing or computation, the processor **1320** may store a command or data received from another component (e.g., the sensor module **1376** or the communication module **1390**) in volatile memory **1332**, process the command or the data stored in the volatile memory **1332**, and store resulting data in non-volatile memory **1334**. According to an embodiment, the processor **1320** may include a main processor **1321** (e.g., a central processing unit (CPU) or an application processor (AP)), or an auxiliary processor **1323** (e.g., a graphics processing unit (GPU), a neural processing unit (NPU), an image signal processor (ISP), a sensor hub processor, or a communication processor (CP)) that is operable independently from, or in conjunction with, the main processor **1321**. For example, when the electronic device **1301** includes the main processor **1321** and the auxiliary processor **1323**, the auxiliary processor **1323** may be adapted to consume less power than the main processor **1321**, or to be specific to a specified function. The auxiliary processor **1323** may be implemented as separate from, or as part of the main processor **1321**.

The auxiliary processor **1323** may control at least some of functions or states related to at least one component (e.g., the display module **1360**, the sensor module **1376**, or the communication module **1390**) among the components of the electronic device **1301**, instead of the main processor **1321** while the main processor **1321** is in an inactive (e.g., sleep) state, or together with the main processor **1321** while the main processor **1321** is in an active state (e.g., executing an application). According to an embodiment, the auxiliary processor **1323** (e.g., an image signal processor or a communication processor) may be implemented as part of another component (e.g., the camera module **1380** or the communication module **1390**) functionally related to the auxiliary processor **1323**. According to an embodiment, the auxiliary processor **1323** (e.g., the neural processing unit) may include a hardware structure specified for artificial intelligence model processing. An artificial intelligence model may be generated by machine learning. Such learning may be performed, e.g., by the electronic device **1301** where the artificial intelligence is performed or via a separate server (e.g., the server **1308**). Learning algorithms may include, but are not limited to, e.g., supervised learning, unsupervised learning, semi-supervised learning, or reinforcement learning. The artificial intelligence model may include a plurality of artificial neural network layers. The artificial neural network may be a deep neural network (DNN), a convolutional neural network (CNN), a recurrent neural network (RNN), a restricted boltzmann machine (RBM), a deep belief network (DBN), a bidirectional recurrent deep neural network (BRDNN), deep Q-network or a combination of two or more thereof but is not limited thereto. The artificial intelligence model may, additionally or alternatively, include a software structure other than the hardware structure.

The memory **1330** may store various data used by at least one component (e.g., the processor **1320** or the sensor module **1376**) of the electronic device **1301**. The various data may include, for example, software (e.g., the program **1340**) and input data or output data for a command related thereto. The memory **1330** may include the volatile memory **1332** or the non-volatile memory **1334**.

The program **1340** may be stored in the memory **1330** as software, and may include, for example, an operating system (OS) **1342**, middleware **1344**, or an application **1346**.

The input module **1350** may receive a command or data to be used by another component (e.g., the processor **1320**) of the electronic device **1301**, from the outside (e.g., a user) of the electronic device **1301**. The input module **1350** may include, for example, a microphone, a mouse, a keyboard, a key (e.g., a button), or a digital pen (e.g., a stylus pen).

The sound output module **1355** may output sound signals to the outside of the electronic device **1301**. The sound output module **1355** may include, for example, a speaker or a receiver. The speaker may be used for general purposes, such as playing multimedia or playing record. The receiver may be used for receiving incoming calls. According to an embodiment, the receiver may be implemented as separate from, or as part of the speaker.

The display module **1360** may visually provide information to the outside (e.g., a user) of the electronic device **1301**. The display module **1360** may include, for example, a display, a hologram device, or a projector and control circuitry to control a corresponding one of the display, hologram device, and projector. According to an embodiment, the display module **1360** may include a touch sensor adapted to detect a touch, or a pressure sensor adapted to measure the intensity of force incurred by the touch.

The audio module **1370** may convert a sound into an electrical signal and vice versa. According to an embodiment, the audio module **1370** may obtain the sound via the input module **1350**, or output the sound via the sound output module **1355** or a headphone of an external electronic device (e.g., an electronic device **1302**) directly (e.g., wiredly) or wirelessly coupled with the electronic device **1301**.

The sensor module **1376** may detect an operational state (e.g., power or temperature) of the electronic device **1301** or an environmental state (e.g., a state of a user) external to the electronic device **1301**, and then generate an electrical signal or data value corresponding to the detected state. According to an embodiment, the sensor module **1376** may include, for example, a gesture sensor, a gyro sensor, an atmospheric pressure sensor, a magnetic sensor, an acceleration sensor, a grip sensor, a proximity sensor, a color sensor, an infrared (IR) sensor, a biometric sensor, a temperature sensor, a humidity sensor, or an illuminance sensor.

The interface **1377** may support one or more specified protocols to be used for the electronic device **1301** to be coupled with the external electronic device (e.g., the electronic device **1302**) directly (e.g., wiredly) or wirelessly. According to an embodiment, the interface **1377** may include, for example, a high definition multimedia interface (HDMI), a universal serial bus (USB) interface, a secure digital (SD) card interface, or an audio interface.

A connecting terminal **1378** may include a connector via which the electronic device **1301** may be physically connected with the external electronic device (e.g., the electronic device **1302**). According to an embodiment, the connecting terminal **1378** may include, for example, a HDMI connector, a USB connector, a SD card connector, or an audio connector (e.g., a headphone connector).

The haptic module **1379** may convert an electrical signal into a mechanical stimulus (e.g., a vibration or a movement) or electrical stimulus which may be recognized by a user via his tactile sensation or kinesthetic sensation. According to an embodiment, the haptic module **1379** may include, for example, a motor, a piezoelectric element, or an electric stimulator.

The camera module **1380** may capture a still image or moving images. According to an embodiment, the camera module **1380** may include one or more lenses, image sensors, image signal processors, or flashes.

The power management module **1388** may manage power supplied to the electronic device **1301**. According to one embodiment, the power management module **1388** may be implemented as at least part of, for example, a power management integrated circuit (PMIC).

The battery **1389** may supply power to at least one component of the electronic device **1301**. According to an embodiment, the battery **1389** may include, for example, a primary cell which is not rechargeable, a secondary cell which is rechargeable, or a fuel cell.

The communication module **1390** may support establishing a direct (e.g., wired) communication channel or a wireless communication channel between the electronic device **1301** and the external electronic device (e.g., the electronic device **1302**, the electronic device **1304**, or the server **1308**) and performing communication via the established communication channel. The communication module **1390** may include one or more communication processors that are operable independently from the processor **1320** (e.g., the application processor (AP)) and supports a direct (e.g., wired) communication or a wireless communication. According to an embodiment, the communication module **1390** may include a wireless communication module **1392** (e.g., a cellular communication module, a short-range wireless communication module, or a global navigation satellite system (GNSS) communication module) or a wired communication module **1394** (e.g., a local area network (LAN) communication module or a power line communication (PLC) module). A corresponding one of these communication modules may communicate with the external electronic device via the first network **1398** (e.g., a short-range communication network, such as Bluetooth™ wireless-fidelity (Wi-Fi) direct, or infrared data association (IrDA)) or the second network **1399** (e.g., a long-range communication network, such as a legacy cellular network, a fifth generation (5G) network, a next-generation communication network, the Internet, or a computer network (e.g., LAN or wide area network (WAN)). These various types of communication modules may be implemented as a single component (e.g., a single chip), or may be implemented as multi components (e.g., multi chips) separate from each other. The wireless communication module **1392** may identify and authenticate the electronic device **1301** in a communication network, such as the first network **1398** or the second network **1399**, using subscriber information (e.g., international mobile subscriber identity (IMSI)) stored in the subscriber identification module **1396**.

The wireless communication module **1392** may support a 5G network, after a fourth generation (4G) network, and next-generation communication technology, e.g., new radio (NR) access technology. The NR access technology may support enhanced mobile broadband (eMBB), massive machine type communications (mMTC), or ultra-reliable and low-latency communications (URLLC). The wireless communication module **1392** may support a high-frequency band (e.g., the millimeter wave (mmWave) band) to achieve, e.g., a high data transmission rate. The wireless communication module **1392** may support various technologies for securing performance on a high-frequency band, such as, e.g., beamforming, massive multiple-input and multiple-output (massive MIMO), full dimensional MIMO (FD-MIMO), array antenna, analog beam-forming, or large scale antenna. The wireless communication module **1392** may support various requirements specified in the electronic device **1301**, an external electronic device (e.g., the electronic device **1304**), or a network system (e.g., the second network **1399**). According to an embodiment, the wireless communication module **1392** may support a peak data rate (e.g., 20 Gbps or more) for implementing eMBB, loss coverage (e.g., 1364 dB or less) for implementing mMTC, or U-plane latency (e.g., 0.5 ms or less for each of downlink (DL) and uplink (UL), or a round trip of 13 ms or less) for implementing URLLC.

The antenna module **1397** may transmit or receive a signal or power to or from the outside (e.g., the external electronic device) of the electronic device **1301**. According to an embodiment, the antenna module **1397** may include an antenna including a radiating element composed of a conductive material or a conductive pattern formed in or on a substrate (e.g., a printed circuit board (PCB)). According to an embodiment, the antenna module **1397** may include a

plurality of antennas (e.g., array antennas). In such a case, at least one antenna appropriate for a communication scheme used in the communication network, such as the first network **1398** or the second network **1399**, may be selected, for example, by the communication module **1390** (e.g., the wireless communication module **1392**) from the plurality of antennas. The signal or the power may then be transmitted or received between the communication module **1390** and the external electronic device via the selected at least one antenna. According to an embodiment, another component (e.g., a radio frequency integrated circuit (RFIC)) other than the radiating element may be additionally formed as part of the antenna module **1397**.

According to various embodiments, the antenna module **1397** may form a mmWave antenna module. According to an embodiment, the mmWave antenna module may include a printed circuit board, a RFIC disposed on a first surface (e.g., the bottom surface) of the printed circuit board, or adjacent to the first surface and capable of supporting a designated high-frequency band (e.g., the mmWave band), and a plurality of antennas (e.g., array antennas) disposed on a second surface (e.g., the top or a side surface) of the printed circuit board, or adjacent to the second surface and capable of transmitting or receiving signals of the designated high-frequency band.

At least some of the above-described components may be coupled mutually and communicate signals (e.g., commands or data) therebetween via an inter-peripheral communication scheme (e.g., a bus, general purpose input and output (GPIO), serial peripheral interface (SPI), or mobile industry processor interface (MIPI)).

According to an embodiment, commands or data may be transmitted or received between the electronic device **1301** and the external electronic device **1304** via the server **1308** coupled with the second network **1399**. Each of the electronic devices **1302** or **1304** may be a device of a same type as, or a different type, from the electronic device **1301**. According to an embodiment, all or some of operations to be executed at the electronic device **1301** may be executed at one or more of the external electronic devices **1302** or **1304**, or the server **1308**. For example, if the electronic device **1301** should perform a function or a service automatically, or in response to a request from a user or another device, the electronic device **1301**, instead of, or in addition to, executing the function or the service, may request the one or more external electronic devices to perform at least part of the function or the service. The one or more external electronic devices receiving the request may perform the at least part of the function or the service requested, or an additional function or an additional service related to the request, and transfer an outcome of the performing to the electronic device **1301**. The electronic device **1301** may provide the outcome, with or without further processing of the outcome, as at least part of a reply to the request. To that end, a cloud computing, distributed computing, mobile edge computing (MEC), or client-server computing technology may be used, for example. The electronic device **1301** may provide ultra low-latency services using, e.g., distributed computing or mobile edge computing. In another embodiment, the external electronic device **1304** may include an internet-of-things (IoT) device. The server **1308** may be an intelligent server using machine learning and/or a neural network. According to an embodiment, the external electronic device **1304** or the server **1308** may be included in the second network **1399**. The electronic device **1301** may be applied to intelligent services (e.g., smart home, smart city, smart car, or healthcare) based on 5G communication technology or IoT-related technology.

The electronic device according to various embodiments may be one of various types of electronic devices. The electronic devices may include, for example, a portable communication device (e.g., a smartphone), a computer device, a portable multimedia device, a portable medical device, a camera, a wearable device, or a home appliance. According to an embodiment of the disclosure, the electronic devices are not limited to those described above.

It should be appreciated that various embodiments of the disclosure and the terms used therein are not intended to limit the technological features set forth herein to particular embodiments and include various changes, equivalents, or replacements for a corresponding embodiment. With regard to the description of the drawings, similar reference numerals may be used to refer to similar or related elements. It is to be understood that a singular form of a noun corresponding to an item may include one or more of the things, unless the relevant context clearly indicates otherwise. As used herein, each of such phrases as "A or B," "at least one of A and B," "at least one of A or B," "A, B, or C," "at least one of A, B, and C," and "at least one of A, B, or C," may include any one of, or all possible combinations of the items enumerated together in a corresponding one of the phrases. As used herein, such terms as "1st" and "2nd," or "first" and "second" may be used to simply distinguish a corresponding component from another, and does not limit the components in another aspect (e.g., importance or order). It is to be understood that if an element (e.g., a first element) is referred to, with or without the term "operatively" or "communicatively", as "coupled with," "coupled to," "connected with," or "connected to" another element (e.g., a second element), it means that the element may be coupled with the other element directly (e.g., wiredly), wirelessly, or via a third element.

As used in connection with various embodiments of the disclosure, the term "module" may include a unit implemented in hardware, software, or firmware, and may interchangeably be used with other terms, for example, "logic," "logic block," "part," or "circuitry". A module may be a single integral component, or a minimum unit or part thereof, adapted to perform one or more functions. For example, according to an embodiment, the module may be implemented in a form of an application-specific integrated circuit (ASIC).

Various embodiments as set forth herein may be implemented as software (e.g., the program **1340**) including one or more instructions that are stored in a storage medium (e.g., internal memory **1336** or external memory **1338**) that is readable by a machine (e.g., the electronic device **1301**). For example, a processor (e.g., the processor **1320**) of the machine (e.g., the electronic device **1301**) may invoke at least one of the one or more instructions stored in the storage medium, and execute it, with or without using one or more other components under the control of the processor. This allows the machine to be operated to perform at least one function according to the at least one instruction invoked. The one or more instructions may include a code generated by a complier or a code executable by an interpreter. The machine-readable storage medium may be provided in the form of a non-transitory storage medium. Wherein, the term "non-transitory" simply means that the storage medium is a tangible device, and does not include a signal (e.g., an electromagnetic wave), but this term does not differentiate

between where data is semi-permanently stored in the storage medium and where the data is temporarily stored in the storage medium.

According to an embodiment, a method according to various embodiments of the disclosure may be included and provided in a computer program product. The computer program product may be traded as a product between a seller and a buyer. The computer program product may be distributed in the form of a machine-readable storage medium (e.g., compact disc read only memory (CD-ROM)), or be distributed (e.g., downloaded or uploaded) online via an application store (e.g., PlayStore™), or between two user devices (e.g., smart phones) directly. If distributed online, at least part of the computer program product may be temporarily generated or at least temporarily stored in the machine-readable storage medium, such as memory of the manufacturer's server, a server of the application store, or a relay server.

According to various embodiments, each component (e.g., a module or a program) of the above-described components may include a single entity or multiple entities, and some of the multiple entities may be separately disposed in different components. According to various embodiments, one or more of the above-described components may be omitted, or one or more other components may be added. Alternatively or additionally, a plurality of components (e.g., modules or programs) may be integrated into a single component. In such a case, according to various embodiments, the integrated component may still perform one or more functions of each of the plurality of components in the same or similar manner as they are performed by a corresponding one of the plurality of components before the integration. According to various embodiments, operations performed by the module, the program, or another component may be carried out sequentially, in parallel, repeatedly, or heuristically, or one or more of the operations may be executed in a different order or omitted, or one or more other operations may be added.

While the disclosure has been shown and described with reference to various embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the disclosure as defined by the appended claims and their equivalents.

What is claimed is:

1. An electronic device comprising:

a display;

a frame structure including a first conductive member defining an external appearance of the electronic device and operated as an antenna element of the electronic device, a second conductive member coupled and electrically connected to the first conductive member, and a nonconductive member configured to support the display together with the second conductive member;

a bonding layer including a first layer at least partially disposed between the first conductive member and the nonconductive member, and a second layer at least partially disposed between the second conductive member and the nonconductive member; and

at least one conductive connection member disposed at a portion at which the first conductive member and the second conductive member are coupled to each other, the at least one conductive connection member contacting the first conductive member and the second conductive member.

2. The electronic device of claim **1**,

wherein the first conductive member includes an outer part defining a side surface of the electronic device, and a coupling part extending inwards from the outer part,

wherein the second conductive member includes an inner part configured to support the display, and at least one end part extending from the inner part toward the outer part of the first conductive member, and

wherein the coupling part of the first conductive member is coupled to the at least one end part of the second conductive member.

3. The electronic device of claim **2**,

wherein the at least one conductive connection member includes a first conductive connection member,

wherein the at least one end part of the second conductive member includes a first end part,

wherein a stepped part is formed in the coupling part of the first conductive member,

wherein the first end part of the second conductive member is seated on the stepped part, and

wherein the first conductive connection member is disposed on the first end part of the second conductive member.

4. The electronic device of claim **3**,

wherein the stepped part is defined by:

a first surface of the coupling part, which contacts the first end part of the second conductive member, and

a first side surface extending from a periphery of the first surface in a direction that is different from that of the first surface, and

wherein the first end part of the second conductive member contacts the first surface, and is spaced apart from the first side surface.

5. The electronic device of claim **4**,

wherein the first conductive connection member includes:

a first part disposed on the first end part of the second conductive member, and

a second part extending from the first part, and

wherein the second part of the first conductive connection member is at least partially disposed in a first gap, by which the first end part of the second conductive member is spaced apart from the first side surface.

6. The electronic device of claim **5**, wherein the nonconductive member surrounds an entirety of the first conductive member.

7. The electronic device of claim **3**,

wherein the at least one conductive connection member includes a second conductive connection member,

wherein the second conductive member includes a connecting part connecting the first end part and the inner part, and

wherein the second conductive connection member contacts the coupling part of the first conductive member and the connecting part of the second conductive member.

8. The electronic device of claim **7**,

wherein the coupling part of the first conductive member is spaced apart from the connecting part of the second conductive member, and

wherein the second conductive connection member is at least partially disposed in a second gap, by which the coupling part and the connecting part are spaced apart from each other.

9. The electronic device of claim **2**,

wherein the at least one conductive connection member includes a second conductive connection member,

wherein the at least one end part of the second conductive member includes a second end part,

wherein a first opening and a first hole communicated with the first opening and extending into an interior of the coupling part are formed in the coupling part of the first conductive member,

wherein the second conductive connection member is disposed in the first hole, and

wherein the second end part of the second conductive member is at least partially inserted into the first hole to contact the second conductive connection member.

10. The electronic device of claim **9**,

wherein a second opening and a second hole are formed in the coupling part of the first conductive member,

wherein the second hole extends from the first hole in a direction that is different from that of the first hole and is communicated with the second opening, and

wherein the second conductive connection member is at least partially disposed in the first hole and the second hole.

11. The electronic device of claim **2**,

wherein the at least one end part of the second conductive member includes a second end part,

wherein the at least one conductive connection member includes a second conductive connection member,

wherein the second conductive connection member is disposed on the second end part, and

wherein the nonconductive member is not formed on the second conductive connection member.

12. The electronic device of claim **2**,

wherein the at least one conductive connection member includes a second conductive connection member,

wherein a first opening, a second opening, and a through-hole that communicates the first opening and the second opening are formed in the coupling part of the first conductive member,

wherein the at least one end part of the second conductive member includes a second end part extending in a direction that is different from that of the inner part and inserted into the through-hole,

wherein the second end part passes through the second opening and extends to the first opening, and

wherein the second conductive connection member is at least partially disposed on a surface of the coupling part, in which the first opening is formed, and the second end part to contact the coupling part of the first conductive member and the second end part of the second conductive member.

13. The electronic device of claim **12**, wherein an entirety of the second conductive connection member is surrounded by the nonconductive member.

14. The electronic device of claim **1**, wherein the at least one conductive connection member includes:

a solution containing conductive particles;

a metal deposition layer; or

a conductive film.

15. The electronic device of claim **1**, comprising:

a bonding part formed between the first conductive member and the second conductive member, wherein the bonding part is formed through welding.

16. An electronic device comprising:

a display;

a frame structure including:

a first conductive member operated as an antenna element of the electronic device, the first conductive member including an outer part defining a side surface of the electronic device, and a coupling part extending from the outer part to an inside of the electronic device,

a second conductive member electrically connected to the first conductive member, the second conductive member including an inner part configured to support the display, and at least one end part extending from the inner part and coupled to the coupling part of the first conductive member, and

a nonconductive member at least partially surrounding the first conductive member and the second conductive member, and configured to support the display together with the second conductive member;

a bonding layer at least partially disposed between the first conductive member and the nonconductive member, and at least partially between the second conductive member and the nonconductive member; and

at least one conductive connection member disposed at a portion at which the coupling part of the first conductive member and the at least one end part of the second conductive member are coupled to each other, the at least one conductive connection member contacting the first conductive member and the second conductive member.

17. The electronic device of claim **16**,

wherein the at least one conductive connection member includes a first conductive connection member,

wherein the at least one end part of the second conductive member includes a first end part,

wherein a stepped part, in which the first end part is seated, is formed in the coupling part of the first conductive member,

wherein the stepped part is defined by:

a first surface partially contacting the first end part, and

a first side surface extending from a periphery of the first surface in a direction that is different from that of the first surface, and spaced apart from the first end part, and

wherein the first conductive connection member includes:

a first part disposed on the first end part of the second conductive member, and extending to the first side surface, and

a second part extending from the first part between the first side surface and the first end part.

18. The electronic device of claim **17**,

wherein the at least one conductive connection member includes a second conductive connection member,

wherein the at least one end part of the second conductive member includes a second end part,

wherein a hole is formed in the coupling part of the first conductive member,

wherein one side of the hole is opened through an opening part formed on a surface of the coupling part, and an opposite side of the hole is closed,

wherein the second end part of the second conductive member is partially disposed in the hole, and

wherein the second conductive connection member is disposed between the opposite side of the hole and the second end part, in the hole.

19. The electronic device of claim **18**,

wherein the at least one conductive connection member includes a third conductive connection member,

wherein the at least one end part of the second conductive member includes a third end part,

a first hole and a second hole communicated with one side of the first hole are formed in the coupling part of the first conductive member,

wherein the first hole extends from a first opening part formed on a surface of the coupling part to the one side in a first direction that faces an interior of the coupling part,

wherein the second hole extends from the one side of the first hole to a second opening part formed on a surface of the coupling part in a second direction that is different from the first direction,

wherein the third end part of the second conductive member is at least partially disposed in the first hole, and

wherein the third conductive connection member is at least partially formed in at least one of the first hole or the second hole to contact the third end part disposed in the first hole and the coupling part.

20. The electronic device of claim **19**,

wherein the at least one conductive connection member includes a fourth conductive connection member,

wherein the at least one end part of the second conductive member includes a fourth end part,

wherein the coupling part of the first conductive member includes a third opening formed on a first surface of the coupling part, a fourth opening formed on a second surface that is different from the first surface of the coupling part, and a through-hole that communicates the third opening and the fourth opening,

wherein the fourth end part extends in a direction that is different from that of the inner part and is inserted into the through-hole, and passes through the fourth opening of the through-hole and extends to the third opening, and

wherein the fourth conductive connection member is at least partially disposed on the first surface of the coupling part, in which the third opening is formed, to cover the fourth end part that extends to the third opening.

* * * * *

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Pais et al.

(10) **Patent No.: US 12,244,052 B2**
(45) **Date of Patent: Mar. 4, 2025**

(54) **COMMUNICATION DEVICE HAVING A HEAT SINK ANTENNA**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 908 days.

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H01Q 5/30	(2015.01)
H01Q 7/00	(2006.01)
H01Q 9/04	(2006.01)

(Continued)

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CPC ***H01Q 1/002*** (2013.01); ***H01Q 5/30*** (2015.01); ***H01Q 7/00*** (2013.01); ***H01Q 9/0421*** (2013.01); ***H01Q 9/30*** (2013.01); *H04W 88/06* (2013.01)

(58) **Field of Classification Search**

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See application file for complete search history.

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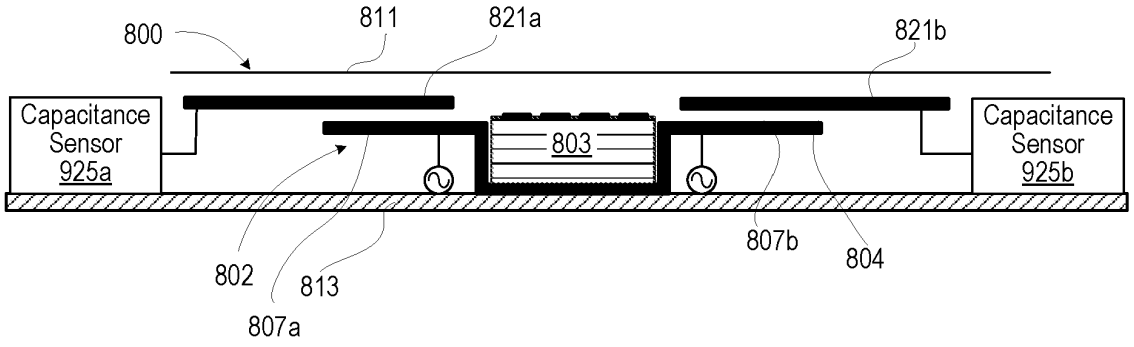
Primary Examiner — Hai V Tran
Assistant Examiner — Bamidele A Immanuel
(74) *Attorney, Agent, or Firm* — Isidore PLLC

(57) **ABSTRACT**

A communication device, computer program product, and method provide a heat sink antenna that performs dual functions of thermal energy transferring and radio frequency (RF) communication. The communication device includes a millimeter wave (mmWave) antenna module. The communication device includes a heat sink antenna having a first portion in thermal conductive contact with at least a portion of a surface of the mmWave antenna module. The heat sink antenna has a second portion extending away from the first mmWave antenna module to transfer thermal energy away from the first mmWave antenna module. An RF front end of the communication device includes mmWave transmitter that radiates a mmWave signal via the mmWave antenna module, resulting in generation of the thermal energy.

19 Claims, 8 Drawing Sheets



(51) **Int. Cl.**
H01Q 9/30 (2006.01)
H04W 88/06 (2009.01)

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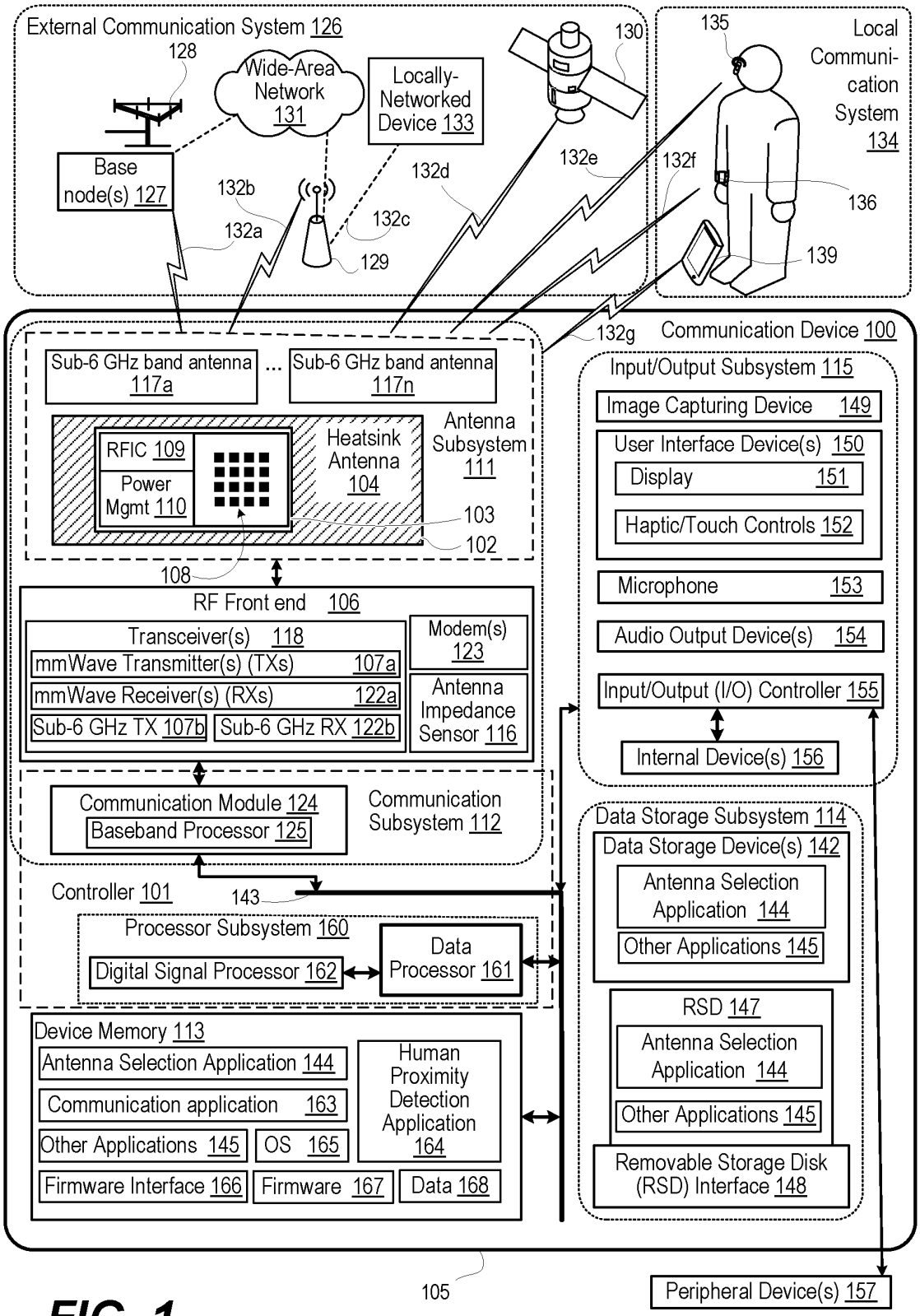
External Communication System 126
128
Wide-Area Network 131
Locally-Networked Device 133
130
135
Local Communi-cation System 134
Base node(s) 127
132b
132a
132c
129
132d
132e
132f
136
139
132g
Communication Device 100
Sub-6 GHz band antenna 117a
...
Sub-6 GHz band antenna 117n
Antenna Subsystem 111
RFIC 109
Power Mgmt 110
Heatsink Antenna 104
103
102
108
RF Front end 106
Transceiver(s) 118
mmWave Transmitter(s) (TXs) 107a
mmWave Receiver(s) (RXs) 122a
Sub-6 GHz TX 107b
Sub-6 GHz RX 122b
Modem(s) 123
Antenna Impedance Sensor 116
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Baseband Processor 125
Communication Subsystem 112
Controller 101
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Processor Subsystem 160
Digital Signal Processor 162
Data Processor 161
Device Memory 113
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Communication application 163
Other Applications 145
OS 165
Firmware Interface 166
Firmware 167
Data 168
Human Proximity Detection Application 164
Input/Output Subsystem 115
Image Capturing Device 149
User Interface Device(s) 150
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Haptic/Touch Controls 152
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Audio Output Device(s) 154
Input/Output (I/O) Controller 155
Internal Device(s) 156
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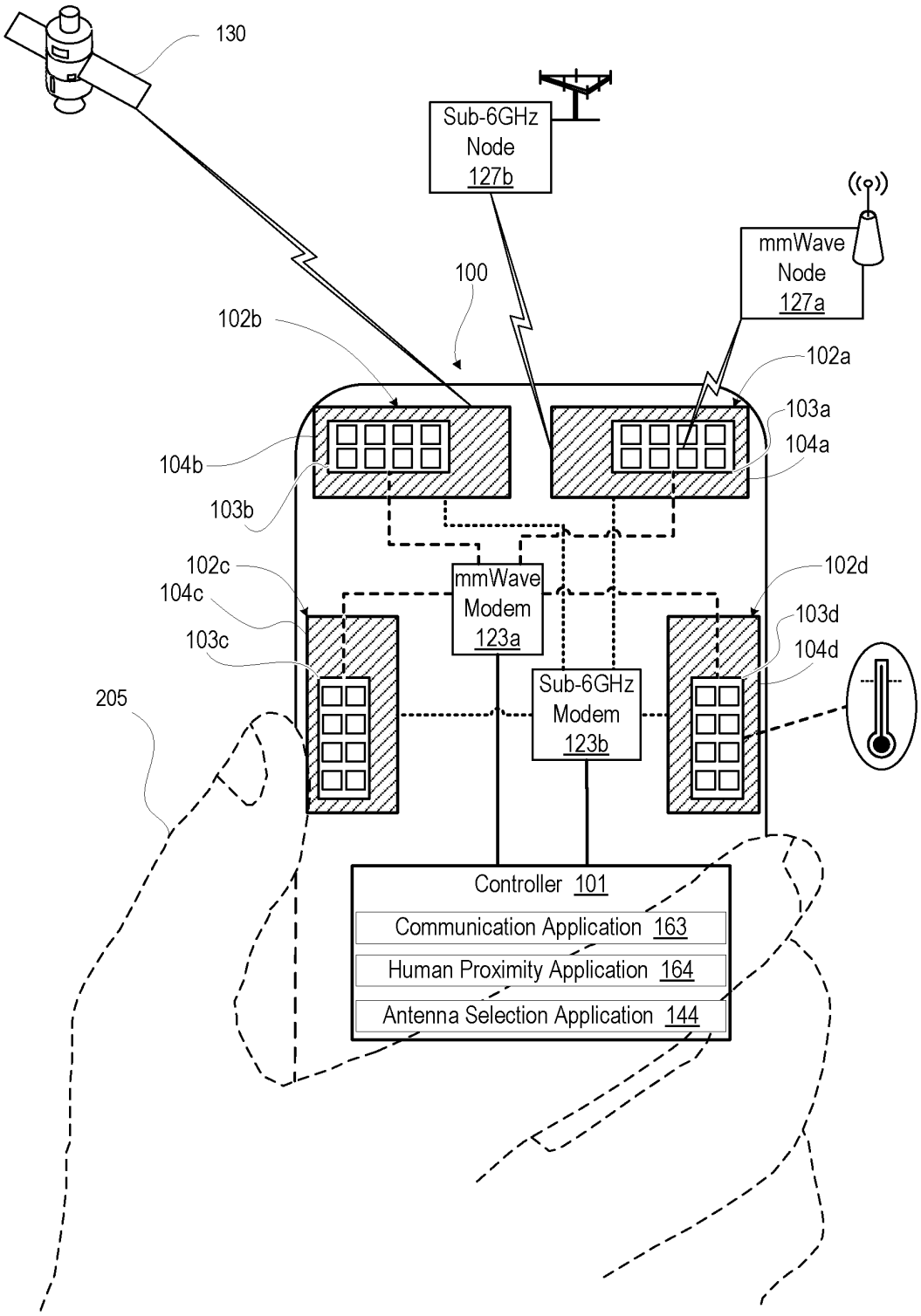
Peripheral Device(s) 157

FIG. 1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Sub-6GHz Node 127b
mmWave Node 127a
100
102b
102a
103a
104a
104b
103b
102c
102d
104c
mmWave Modem 123a
103d
103c
104d
205
Sub-6GHz Modem 123b
Controller 101
Communication Application 163
Human Proximity Application 164
Antenna Selection Application 144

FIG. 2

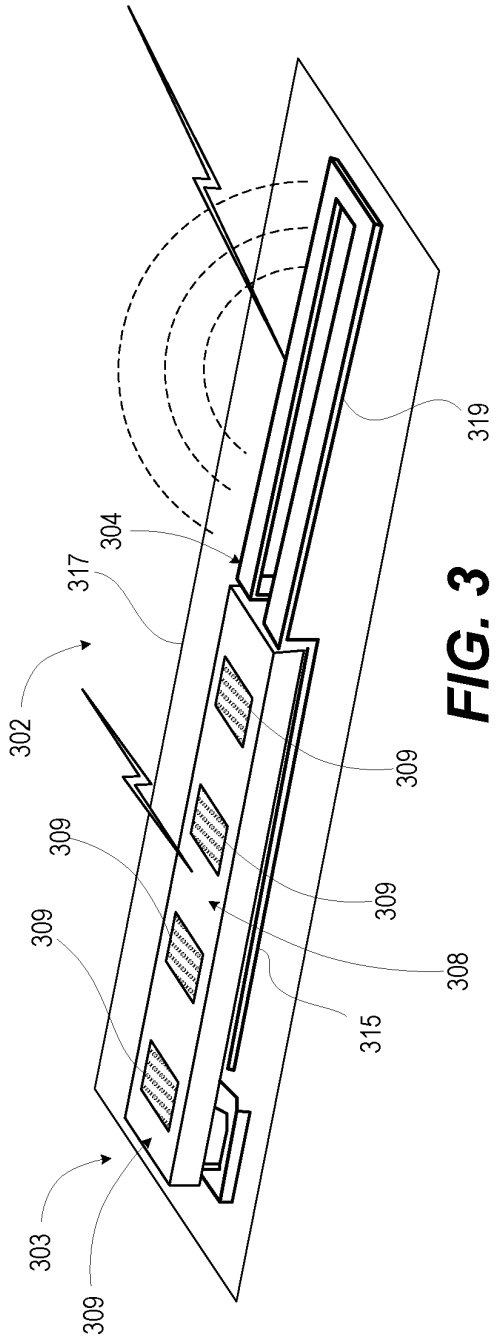

FIG. 3

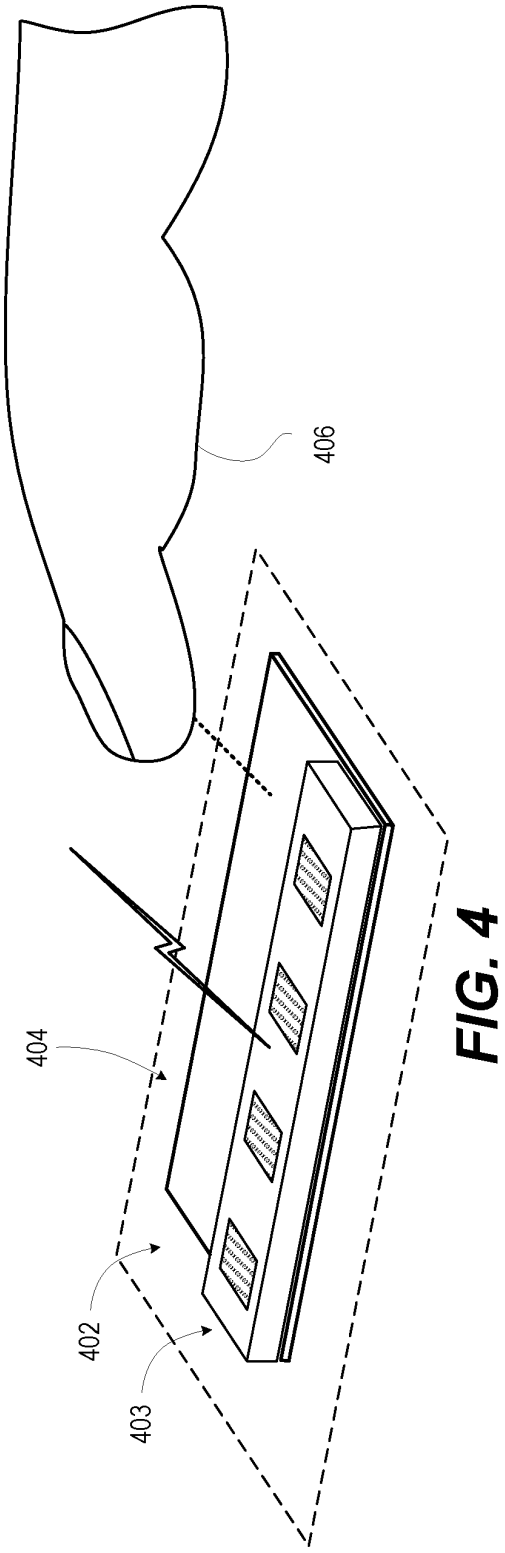

FIG. 4

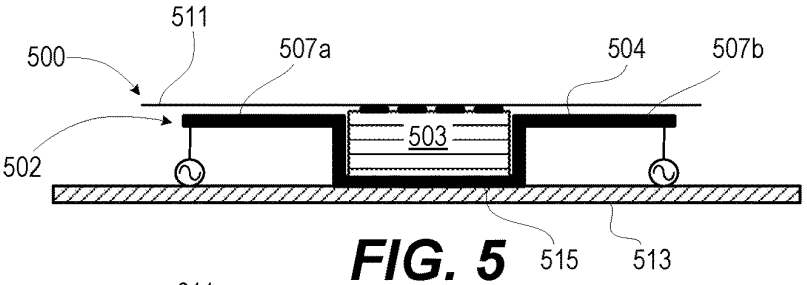

FIG. 5

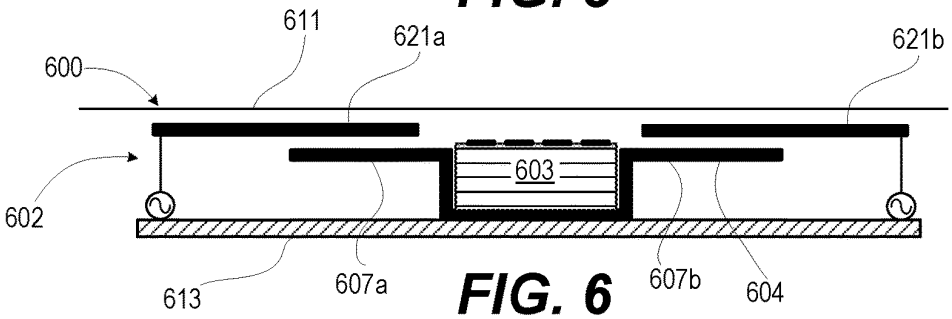

FIG. 6

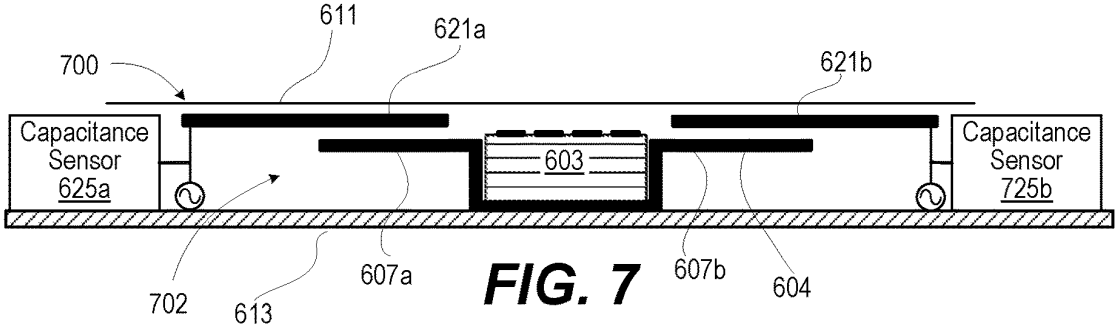

FIG. 7

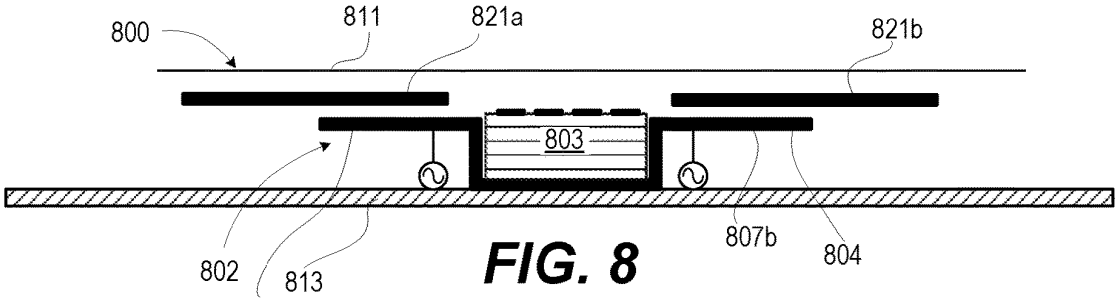

FIG. 8

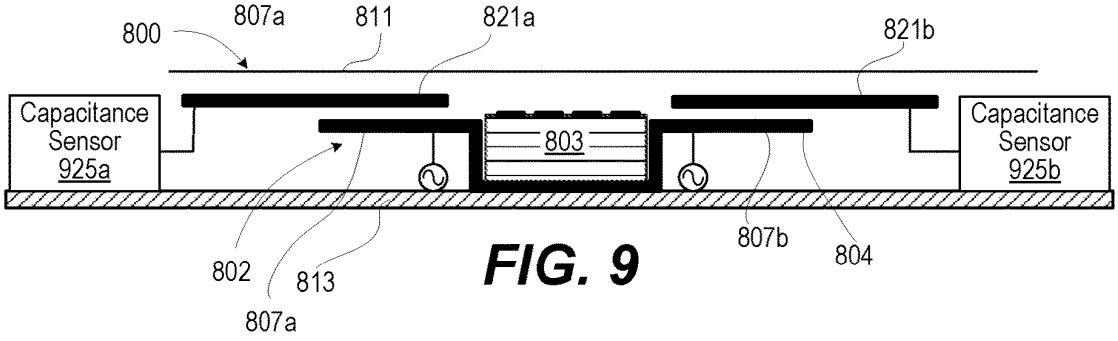

FIG. 9

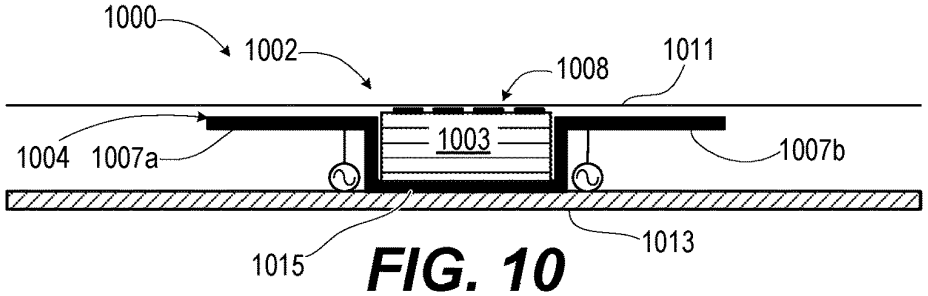

FIG. 10

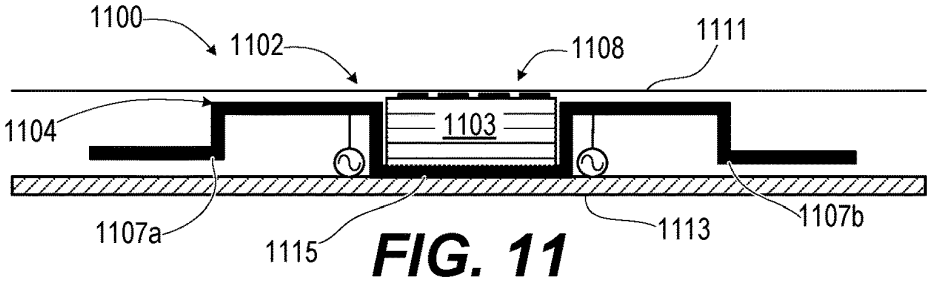

FIG. 11

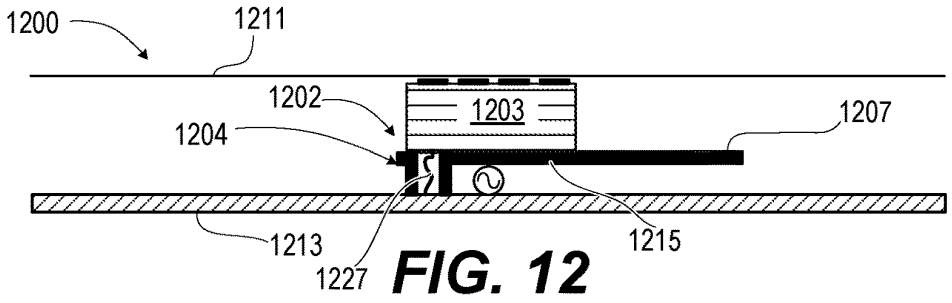

FIG. 12

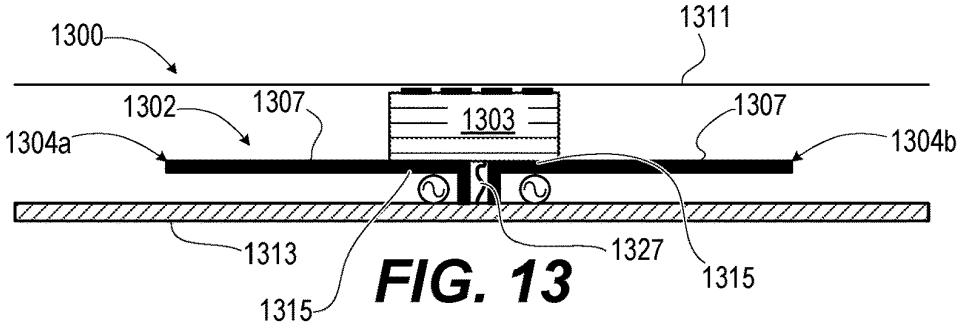

FIG. 13

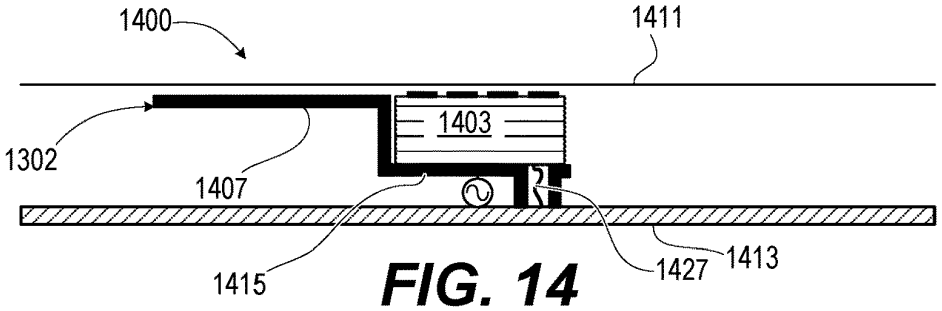

FIG. 14

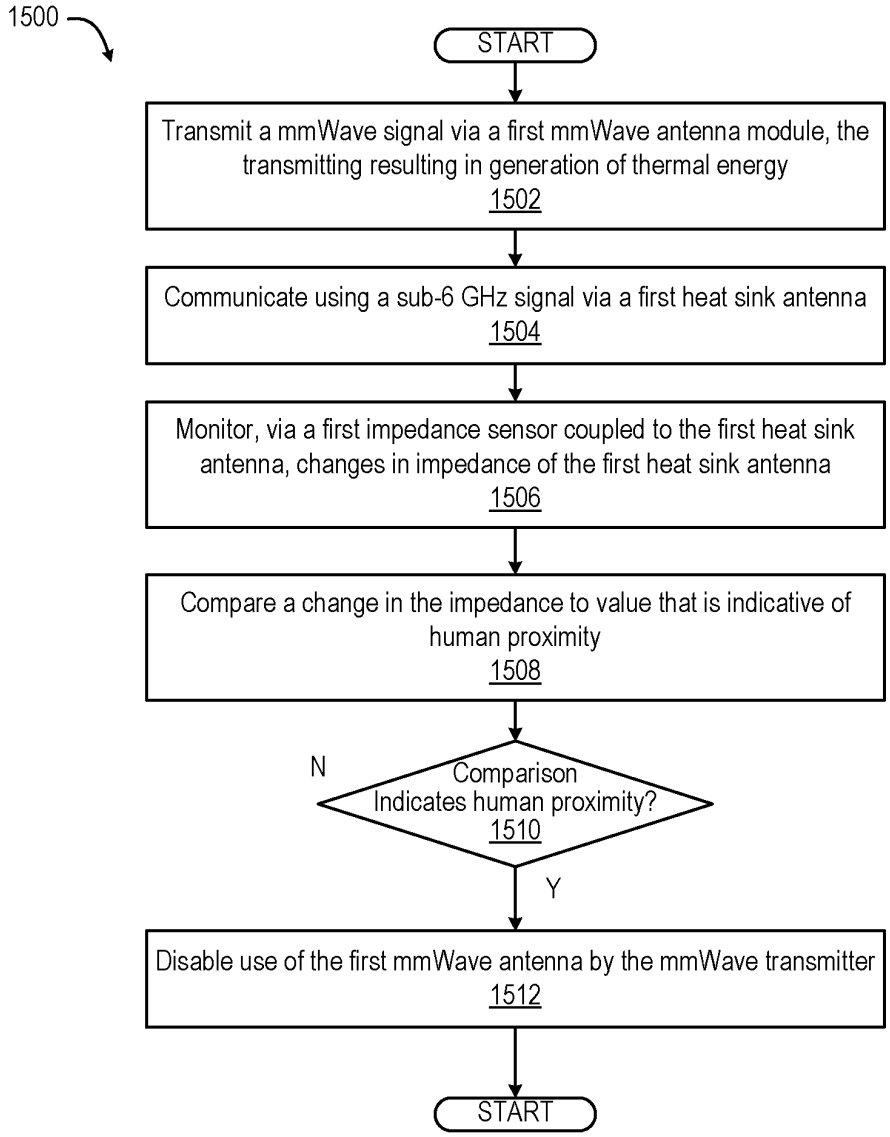
1500
START
Transmit a mmWave signal via a first mmWave antenna module, the transmitting resulting in generation of thermal energy
1502
Communicate using a sub-6 GHz signal via a first heat sink antenna
1504
Monitor, via a first impedance sensor coupled to the first heat sink antenna, changes in impedance of the first heat sink antenna
1506
Compare a change in the impedance to value that is indicative of human proximity
1508
N
Comparison Indicates human proximity?
1510
Y
Disable use of the first mmWave antenna by the mmWave transmitter
1512
START

FIG. 15

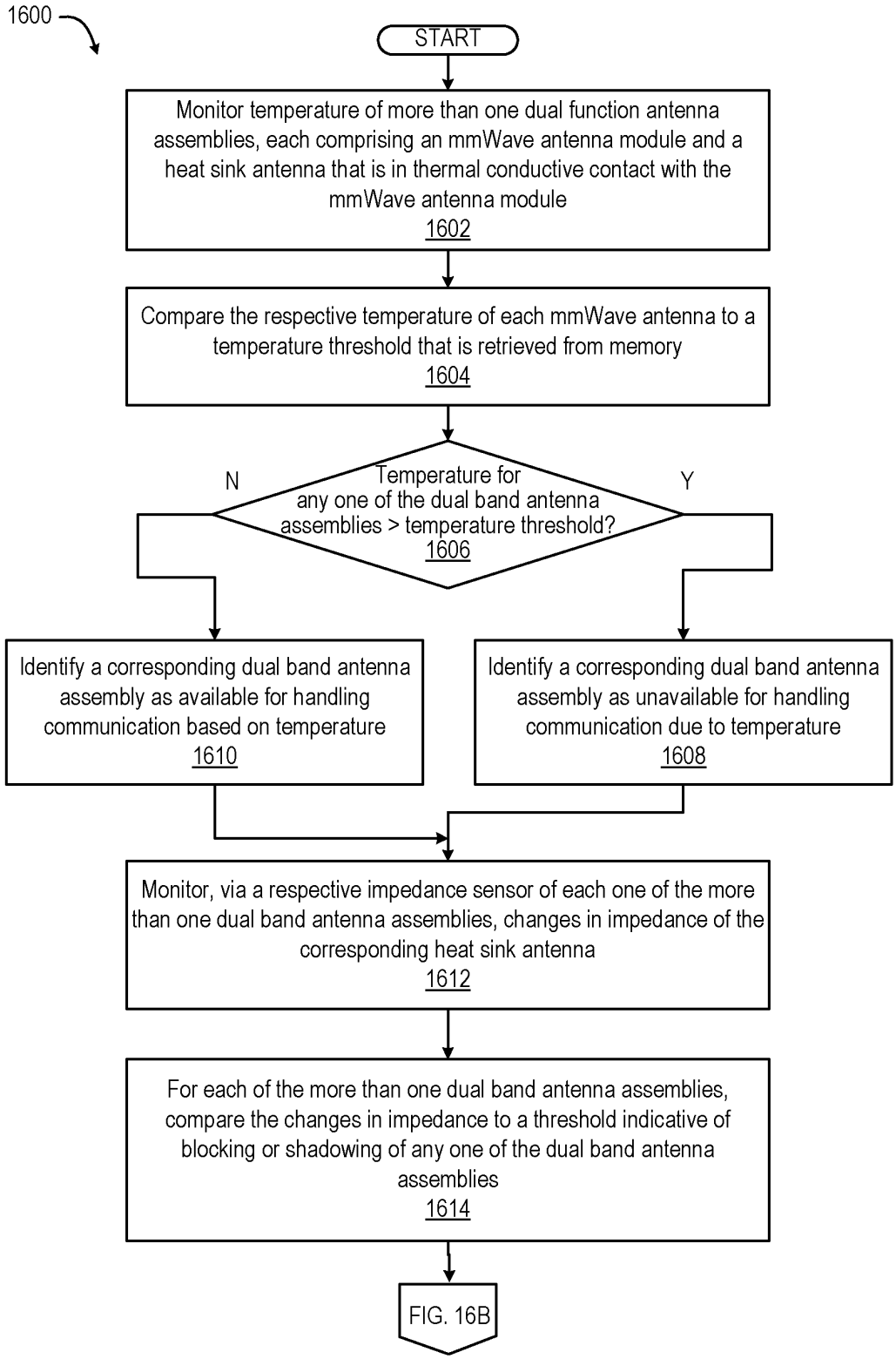
1600
START
Monitor temperature of more than one dual function antenna assemblies, each comprising an mmWave antenna module and a heat sink antenna that is in thermal conductive contact with the mmWave antenna module
1602
Compare the respective temperature of each mmWave antenna to a temperature threshold that is retrieved from memory
1604
Temperature for any one of the dual band antenna assemblies > temperature threshold?
1606
N
Y
Identify a corresponding dual band antenna assembly as available for handling communication based on temperature
1610
Identify a corresponding dual band antenna assembly as unavailable for handling communication due to temperature
1608
Monitor, via a respective impedance sensor of each one of the more than one dual band antenna assemblies, changes in impedance of the corresponding heat sink antenna
1612
For each of the more than one dual band antenna assemblies, compare the changes in impedance to a threshold indicative of blocking or shadowing of any one of the dual band antenna assemblies
1614
FIG. 16B

FIG. 16A

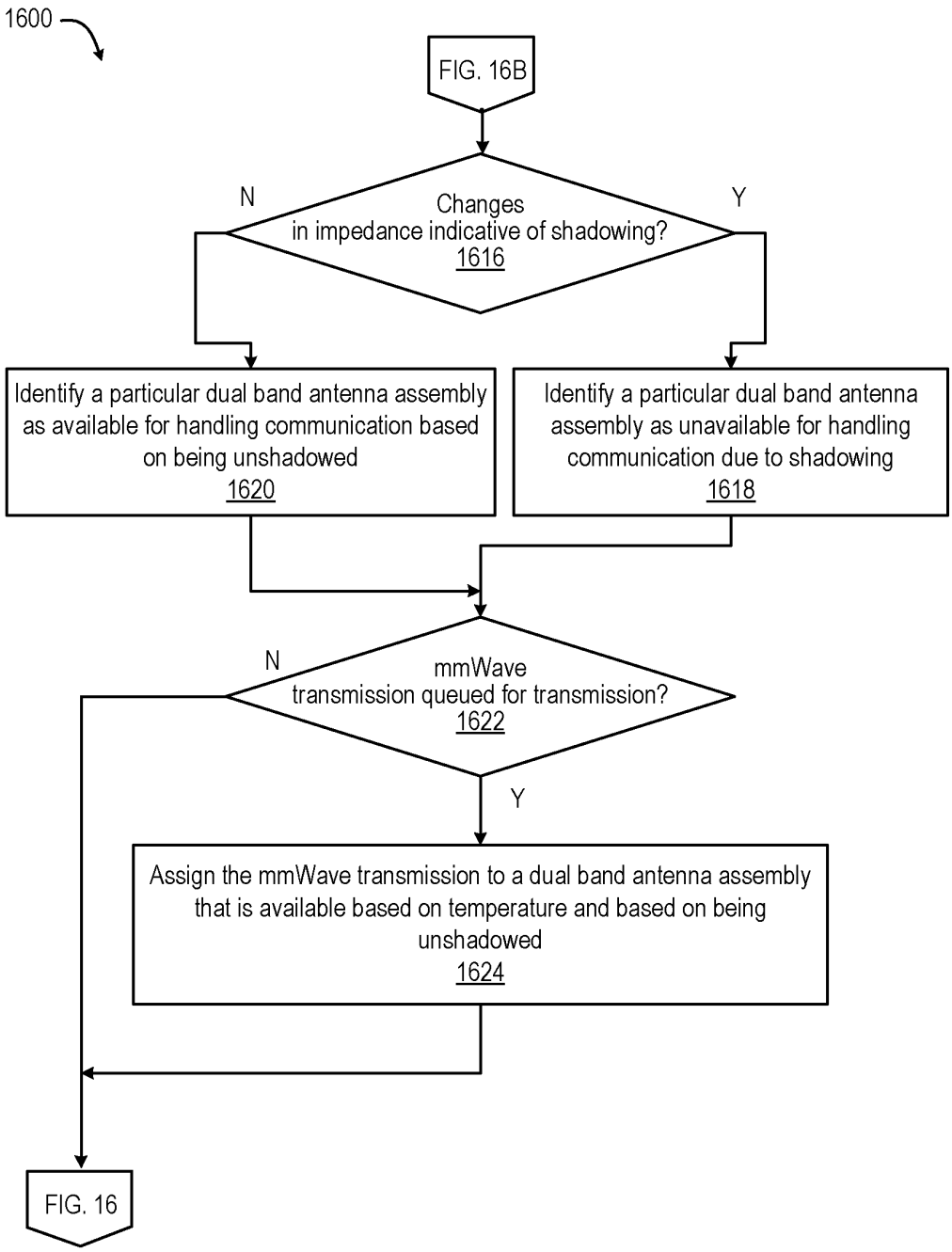
1600
FIG. 16B
Changes in impedance indicative of shadowing? 1616
N
Y
Identify a particular dual band antenna assembly as available for handling communication based on being unshadowed 1620
Identify a particular dual band antenna assembly as unavailable for handling communication due to shadowing 1618
mmWave transmission queued for transmission? 1622
N
Y
Assign the mmWave transmission to a dual band antenna assembly that is available based on temperature and based on being unshadowed 1624
FIG. 16

FIG. 16B

COMMUNICATION DEVICE HAVING A HEAT SINK ANTENNA

1. TECHNICAL FIELD

The present disclosure relates generally to communication devices having antenna arrays, and more particularly to communication devices having heat mitigation for antenna arrays.

2. DESCRIPTION OF THE RELATED ART

Recent developments and standards for communication devices include use of higher communication bands that can support higher data rates. For example, the latest cellular service standard referred to as fifth generation new radio (5G NR) uses spectrum in the existing fourth generation long term evolved (4G LTE) standard in sub-6 GHz frequency range (600 MHz to 6 GHz). For higher data rates, 5G NR also uses spectrum in millimeter wave (mmWave) bands (24-86 GHz). The mmWave band assigned to 5G NR has short wavelengths of 1-10 mm that require placement of the antenna at or near the surface of the communication device for satisfactory antenna performance. At these frequencies, the individual antennas can be small and directional.

Antenna configurations in these communication devices are designed to accommodate multiple transmit and receive antennas to exploit multipath propagation, particularly in the mmWave bands for 5G NR. Generally, these 5G devices are implemented for higher data rates and faster communication performance and thus generate a heat load that is extensive. Being small and close to the surface, the 5G NR antenna configuration concentrates the heat load in a small area that can exceed user comfort levels for holding and using the communication device. If allowed to continue generating the heat load, the antenna modules can reach their thermal specification limits in a short amount of time, causing a need for some form of thermal mitigation or device shutdown.

BRIEF DESCRIPTION OF THE DRAWINGS

The description of the illustrative embodiments can be read in conjunction with the accompanying figures. It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements are exaggerated relative to other elements. Embodiments incorporating teachings of the present disclosure are shown and described with respect to the figures presented herein, in which:

FIG. **1** is a functional block diagram of an electronic device that operates as a communication device in a communication environment and within which the features of the present disclosure are advantageously implemented, according to one or more embodiments;

FIG. **2** is an antenna configuration diagram of four dual band antenna assemblies managed by a controller based on temperature and antenna blocking, according to one or more embodiments;

FIG. **3** is a three-dimensional view of an example dual band antenna assembly having a millimeter wave (mmWave) antenna module that is thermally cooled by an example heat sink antenna configured as a loop antenna that is utilized for sub-6 GHz communication, according to one or more embodiments;

FIG. **4** is a three-dimensional view of an example dual band antenna assembly having a mmWave antenna module that is thermally cooled by an example heat sink antenna configured as a planar inverted F antenna (PIFA), which is used for human proximity detection, according to one or more embodiments;

FIG. **5** is a side view of an example dual band antenna assembly having an example heat sink antenna that is configured as a sub-6 GHz loop antenna, according to one or more embodiments;

FIG. **6** is a side view of an example dual band antenna assembly having an example heat sink antenna that is configured as a capacitively coupled sub-6 GHz loop antenna, according to one or more embodiments;

FIG. **7** is a side view of an example dual band antenna assembly having an example heat sink antenna that is configured as a capacitively coupled sub-6 GHz loop antenna with a capacitance sensor for human proximity detection, according to one or more embodiments;

FIG. **8** is a side view of an example dual band antenna assembly having an example heat sink antenna that is configured as a capacitively coupled sub-6 GHz monopole antenna, according to one or more embodiments;

FIG. **9** is a side view of an example dual band antenna assembly having an example heat sink antenna that is configured as a capacitively coupled sub-6 GHz monopole antenna with a capacitance sensor for human proximity detection, according to one or more embodiments;

FIG. **10** is a side view of an example dual band antenna assembly having an example heat sink antenna configured as a sub-6 GHz PIFA antenna having a portion positioned close to an exterior surface of the communication device for thermal convective thermal transfer, according to one or more embodiments;

FIG. **11** is a side view of an example dual band antenna assembly having an example heat sink antenna configured as sub-6 GHz PIFA antenna with an outer portion for thermal conductive heat transfer, according to one or more embodiments;

FIG. **12** is a side view of an example dual band antenna assembly with radio frequency integrated circuit (RFID) connection to a printed circuit board (PCB) and having an example heat sink antenna configured as a one-sided, low profile sub-6 GHz PIFA antenna, according to one or more embodiments;

FIG. **13** is a side view of an example dual band antenna assembly with RFID connection to a PCB and having an example heat sink antenna configured as a dual low-profile sub-6 GHz PIFA antenna, according to one or more embodiments;

FIG. **14** is a side view of an example dual band antenna assembly with RFID connection to a PCB and having an example heat sink antenna configured as a one-sided sub-6 GHz PIFA antenna having a portion positioned close to an exterior surface of the communication device for thermal convective thermal transfer, according to one or more embodiments;

FIG. **15** presents a flow diagram of a method for dual function use of a sub-6 GHz heat sink antenna for communication and thermal energy transfer from a mmWave antenna module, according to one or more embodiments; and

FIGS. **16**A-**16**B (FIG. **16**) present a flow diagram of a method for reliably radiating a mmWave transmit signal from a communication device using multiple dual band antenna assemblies that mitigate thermal loads and detect shadowing that blocks transmission, according to one or more embodiments.

DETAILED DESCRIPTION

According to aspects of the present disclosure, a communication device, computer program product, and method provide a heat sink antenna that performs dual functions of thermal energy transferring and radio frequency (RF) communication. The communication device includes a millimeter wave (mmWave) antenna module. The communication device includes a heat sink antenna having a first portion in thermal conductive contact with at least a portion of a surface of the mmWave antenna module. The heat sink antenna has a second portion extending away from the first mmWave antenna module to transfer thermal energy away from the first mmWave antenna module. An RF front end of the communication device includes a mmWave transmitter that radiates a mmWave signal via the mmWave antenna module, resulting in generation of the thermal energy. In one or more embodiments, the RF front end further includes a sub-6 GHz transmitter that radiates a sub-6 GHz signal via the heat sink antenna. In one or more particular embodiments, the communication device includes an impedance sensor communicatively coupled to a controller and that senses changes in impedance of the heat sink antenna. The controller disables transmission via the mmWave antenna module in response to detecting a proximity of a human, based on the change in impedance.

In the following detailed description of exemplary embodiments of the disclosure, specific exemplary embodiments in which the various aspects of the disclosure may be practiced are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, architectural, programmatic, mechanical, electrical and other changes may be made without departing from the spirit or scope of the present disclosure. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims and equivalents thereof. Within the descriptions of the different views of the figures, similar elements are provided similar names and reference numerals as those of the previous figure(s). The specific numerals assigned to the elements are provided solely to aid in the description and are not meant to imply any limitations (structural or functional or otherwise) on the described embodiment. It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements are exaggerated relative to other elements.

It is understood that the use of specific component, device and/or parameter names, such as those of the executing utility, logic, and/or firmware described herein, are for example only and not meant to imply any limitations on the described embodiments. The embodiments may thus be described with different nomenclature and/or terminology utilized to describe the components, devices, parameters, methods and/or functions herein, without limitation. References to any specific protocol or proprietary name in describing one or more elements, features or concepts of the embodiments are provided solely as examples of one implementation, and such references do not limit the extension of the claimed embodiments to embodiments in which different element, feature, protocol, or concept names are utilized. Thus, each term utilized herein is to be given its broadest interpretation given the context in which that term is utilized.

As further described below, implementation of the functional features of the disclosure described herein is provided within processing devices and/or structures and can involve use of a combination of hardware, firmware, as well as several software-level constructs (e.g., program code and/or program instructions and/or pseudo-code) that execute to provide a specific utility for the device or a specific functional logic. The presented figures illustrate both hardware components and software and/or logic components.

Those of ordinary skill in the art will appreciate that the hardware components and basic configurations depicted in the figures may vary. The illustrative components are not intended to be exhaustive, but rather are representative to highlight essential components that are utilized to implement aspects of the described embodiments. For example, other devices/components may be used in addition to or in place of the hardware and/or firmware depicted. The depicted example is not meant to imply architectural or other limitations with respect to the presently described embodiments and/or the general invention. The description of the illustrative embodiments can be read in conjunction with the accompanying figures. Embodiments incorporating teachings of the present disclosure are shown and described with respect to the figures presented herein.

FIG. **1** is a functional block diagram of an electronic device in an operating environment within which the features of the present disclosure are advantageously implemented. In particular, the electronic device is presented as communication device **100**, which is managed by controller **101**.

While presented as communication device **100**, it is appreciated that the features describe herein are fully applicable to other types of electronic devices, and that the presentation of communication device **100** is solely as an example and not meant to be limiting on the disclosure. Communication device **100** can be one of a host of different types of devices, including but not limited to, a mobile cellular phone, satellite phone, or smart-phone, a laptop, a net-book, an ultra-book, a networked smart watch or networked sports/exercise watch, and/or a tablet computing device or similar device that can include wireless communication functionality. As a device supporting wireless communication, communication device **100** can be utilized as, and also be referred to as, a system, device, subscriber unit, subscriber station, mobile station (MS), mobile, mobile device, remote station, remote terminal, user terminal, terminal, user agent, user device, a Session Initiation Protocol (SIP) phone, a wireless local loop (WLL) station, a personal digital assistant (PDA), computer workstation, a handheld device having wireless connection capability, a computing device, or other processing devices connected to a wireless modem.

Referring now to the specific component makeup and the associated functionality of the presented components. Communication device **100** incudes dual antenna assembly **102**. Dual antenna assembly **102** includes mmWave antenna module **103** and heat sink antenna **104**, which is in thermal conductive contact with at least a portion of a surface of mmWave antenna module **103** and extends away from mmWave antenna module **103** to transfer thermal energy away from mmWave antenna module **103**. In one or more embodiments, the thermal energy transfer is at least in part conductive transfer within housing **105** of communication device **100**. The thermal conduction spreads the thermal energy to a larger area within communication device **100** to avoid uncomfortable or damaging temperatures immediately around mmWave antenna module **103**. In one or more

embodiments, the thermal energy transfer is at least in part convective transfer away from housing **105**. Heat sink antenna **104** has a portion close to the exterior surface of housing **105**. Heat sink antenna **104** is convectively cooled, transferring the thermal load to the air external to housing **105**. A radio frequency (RF) front end **106** includes mmWave transmitter **107***a* that radiates a mmWave signal via mmWave antenna module **103**, resulting in generation of the thermal energy. The mmWave antenna module **103** of dual band antenna assembly **102** integrally includes patch antenna array **108**, radio frequency integrated circuit (RFIC) **109**, and power management system **110**. Dual band antenna assembly **102** is part of antenna subsystem **111**.

In one or more embodiments, communication device **100** includes communication subsystem **112**, device memory **113**, data storage subsystem **114**, and input/output (I/O) subsystem **115**. Each subsystem (**112**-**115**) is managed by controller **101**. Communication subsystem **112** includes antenna subsystem **111**. Antenna subsystem **111** includes one or more impedance sensors, such as antenna impedance sensor(s) **116**, for detecting human proximity to a portion of antenna subsystem **111**. Antenna impedance sensor (s) **116** can detect a change in one or more of capacitance and impedance that is indicative of the presence of a human body. In addition to dual band antenna assembly **102**, antenna subsystem **111** includes sub-6 GHz antennas **117***a*-**117***n* for communication in high frequency band (HB), IEEE 802.11 wireless bands, and 4G cellular bands.

Communication subsystem **112** also includes RF front end **106** having transceiver(s) **118** that includes mmWave transmitter(s) **107***a*, sub-6 GHz transmitter(s) **107***b*, mmWave receiver(s) **122***a*, and sub-6 GHz receiver(s) **122***b*. Sub-6 GHz transmitter(s) **107***b* and mmWave transmitter(s) **107***a* are collectively referred to herein as transmitter(s) **107**. Sub-6 GHz receiver(s) **122***b* and mmWave receiver(s) **122***a* are collectively referred to herein as receiver(s) **122**. RF front end **106** further includes modem(s) **123**. Communication subsystem **112** includes communication module **124** having baseband processor **125**. Baseband processor **125** communicates with controller **101** and RF front end **106**. Baseband processor **125** operates in baseband frequency range to encode data for transmission and decode received data, according to a communication protocol. Modem(s) **123** modulate baseband encoded data from communication module **124** onto a carrier signal to provide a transmit signal that is amplified by transmitter(s) **107**. Modem(s) **123** demodulates each signal received from external communication system **126** detected by antenna subsystem **111**. The received signal is amplified and filtered by receiver(s) **122**, which demodulate received encoded data from a received carrier signal.

In one or more embodiments, controller **101**, via communication subsystem **112**, performs multiple types of over-the-air (OTA) or wireless communication with external communication system **126**. External communication system **126** can include devices such as base node(s) **127** elevated on respective radio tower(s) **128**, access node(s) **129**, and global positioning system (GPS) satellites **130**. Some of these devices can be communicatively coupled to at least one wide area network **131**. Communication subsystem **112** communicates via OTA communication channel(s) **132***a* with base node **127**. Communication subsystem **112** communicates via wireless communication channel(s) **132***b* with access node **129**. In one or more particular embodiments, access node **129** supports communication using one or more IEEE 802.11 wireless local area network (WLAN) protocols. Access node **129** is connected to wide area network **131**, such as the Internet. In one or more particular embodiments, communication subsystem **112** communicates with one or more locally networked devices **133** via wired or wireless link **132***c* provided by access node **129**. Communication subsystem **112** receives downlink broadcast channel(s) **132***d* from GPS satellites **130** to obtain geospatial location information.

In one or more embodiments, local communication system **134** includes wireless headset **135** and smart watch **136** that are coupled to communication device **100** to form a personal access network (PAN). Communication subsystem **112** communicates via low power wireless communication channel(s) **132***e* with headset **135**. Communication subsystem **112** communicates via second low power wireless communication channel(s) **132***f*, such as Bluetooth, with smart watch **136**. In one or more particular embodiments, communication subsystem **112** communicates with other communication device(s) **139** via wireless link **132***g* to form an ad hoc network.

Data storage subsystem **114** of communication device **100** includes data storage device(s) **142**. Controller **101** is communicatively connected, via system interlink **143**, to data storage device(s) **142**. Data storage subsystem **114** provides nonvolatile storage that is accessible by controller **101**. For example, data storage subsystem **114** can provide a selection of applications, such as antenna selection application **144** and other application(s) **145** that can be loaded into device memory **113**. In one or more embodiments, data storage device(s) **142** can include hard disk drives (HDDs), optical disk drives, and/or solid-state drives (SSDs), etc. Data storage subsystem **114** of communication device **100** can include removable storage device(s) (RSD(s)) **147**, which is received in RSD interface **148**. Controller **101** is communicatively connected to RSD **147**, via system interlink **143** and RSD interface **148**. In one or more embodiments, RSD **147** is a non-transitory computer program product or computer readable storage device. Controller **101** can access RSD **147** or data storage device(s) **142** to provision communication device **100** with program code, such as antenna mode application **144** and other applications **145**. When executed by controller **101**, the program code causes or configures communication device **100** to provide the functionality described herein.

I/O subsystem **115** includes image capturing device **149**, user interface device(s) **150** having one or more of displays **151**, touch/haptic controls **152**, microphone **153**, and audio output device(s) **154**. I/O subsystem **115** also includes I/O controller **155**, which connects to internal devices **156** and peripheral devices **157** external to housing **105** of communication device **100**.

Controller **101** includes processor subsystem **160**, which includes one or more central processing units (CPUs), depicted as data processor **161**. Processor subsystem **160** can include one or more digital signal processors **162** that are integrated with data processor **161** or are communicatively coupled to data processor **161**, such as baseband processor **125**. In one or embodiments that are not depicted, controller **101** can further include distributed processing and control components that are peripheral or remote to housing **105** or grouped with other components, such as I/O subsystem **115**. Data processor **161** is communicatively coupled, via system interlink **143**, to device memory **113**. In one or more embodiments, controller **101** of communication device **100** is communicatively coupled via system interlink **143** to communication subsystem **112**, data storage subsystem **114**, and I/O subsystem **115**. System interlink **143** represents internal components that facilitate internal communication

by way of one or more shared or dedicated internal communication links, such as internal serial or parallel buses. As utilized herein, the term "communicatively coupled" means that information signals are transmissible through various interconnections, including wired and/or wireless links, between the components. The interconnections between the components can be direct interconnections that include conductive transmission media or may be indirect interconnections that include one or more intermediate electrical components. Although certain direct interconnections (system interlink **143**) are illustrated in FIG. **1**, it is to be understood that more, fewer, or different interconnections may be present in other embodiments.

Controller **101** manages, and in some instances directly controls, the various functions and/or operations of communication device **100**. These functions and/or operations include, but are not limited to including, application data processing, communication with other electronic devices, navigation tasks, and signal processing. In one or more alternate embodiments, communication device **100** may use hardware component equivalents for application data processing and signal processing. For example, communication device **100** may use special purpose hardware, dedicated processors, general purpose computers, microprocessor-based computers, micro-controllers, optical computers, analog computers, dedicated processors and/or dedicated hard-wired logic.

Device memory **113** includes applications such as antenna selection application **144**, communication application **163**, human proximity detection application **164**, and other application(s) **145**. Device memory **113** further includes operating system (OS) **165**, firmware interface **166**, such as basic input/output system (BIOS) or Uniform Extensible Firmware Interface (UEFI), and firmware **167**. Device memory **113** includes data **168** used by antenna mode application **144**, communication application **163**, and other application(s) **145**. Processor subsystem **160** of controller **101** executes program code to provide operating functionality of communication device **100**. These software and/or firmware modules have varying functionality when their corresponding program code is executed by processor subsystem **160** or secondary processing devices within communication device **100**. Processor subsystem **160** of controller **101** can execute program code of antenna mode application **144** to configure antenna subsystem **111** based on execution of human proximity detection application **164**. The mmWave antenna module **104** is small and shadowed only when a human is less than 1 cm away, Close proximity of heat sink antenna **104** to mmWave antenna module **103** enables accurate detection of human proximity.

FIG. **2** depicts an antenna configuration diagram of communication device **100** having four dual band antenna assemblies **102***a*-**102***d* that are selected for operation by controller **101** based on temperature and detection of antenna blocking. Controller **101** is communicatively coupled to mmWave modem **123***a*, which switches to one or more available mmWave antenna modules **103***a*-**103***d*, respectively, of dual band antenna assemblies **102***a*-**102***d* to support mmWave communication. Controller **101** is communicatively coupled to sub-6 GHz modem **123***b*, which switches to one or more available sub-6 GHz antenna modules **104***a*-**104***d*, respectively, of dual band antenna assemblies **102***a*-**102***d* to support sub-6 GHz communication. Controller **101** executes communication application **163**, which enables communication device **100** to generate or consume communication data via mmWave and sub-6 GHz modems **123***a*-**123***b*. For example, mmWave antenna module **103***a* transmits uplink **201** to mmWave node **127***a*.

In the presented embodiment, in addition to transferring thermal energy away from mmWave antenna module **103***a*, sub-6 GHz heat sink antenna **104***b* communicates with sub-6 GHz node **127***b*. Sub-6 GHz heat sink antenna **104***b* is being used to receive broadcasts **203** from GPS satellites **130**. Corresponding mmWave antenna module **103***b* of dual band antenna assembly **102***b* is not active. Controller **101** executes human proximity application **164**, which configures communication device **100** to avoid ineffective attempts to communicate via a blocked or shadowed mmWave antenna module **103***c*. Controller **101** utilizes sub-6 GHz heat sink antenna **104***c* of dual band antenna assembly **102***c* to detect proximity of person **205**. Controller **101** executes antenna selection application **144**, which tracks available and unavailable dual band antenna assemblies **102***a*-**102***d*. Availability of a particular dual band antenna assemblies **102***a*-**102***d* includes in part being appropriate for the communication band and direction to the communication target. A particular dual band antenna assemblies **102***a*-**102***d* can be unavailable due to over-temperature or shadowing/blocking. Each mmWave antenna module **103***a*-**103***d* performs thermal management, which involves reporting their temperature to controller **101** and shutting themselves off if the temperature poses a risk of damaging the respective mmWave antenna module **103***a*-**103***d*. Controller **101** and mmWave modem **172***a* either anticipate an impending over-temperature condition or react to shutdown of particular mmWave antenna module **103***d* by switching active communication to another mmWave antenna module **103***a*-**103***b*. In one or more embodiments, controller **101** implements a lower temperature threshold than the threshold utilized by mmWave antenna modules **103***a*-**103***d* in order to maintain a comfortable touch temperature.

FIG. **3** depicts a three-dimensional view of example dual band antenna assembly **302** having mmWave antenna module **303** that is thermally cooled by example heat sink antenna **304**. Patch antenna array **308** of mmWave antenna module **303** has a 1×4 pattern of patch antenna elements **309**. Example heat sink antenna **304** has a first portion **315** that is in thermal contact with a surface of mmWave antenna module **303**, in particular the surface proximate to printed circuit board (PCB) **317**. Example heat sink antenna **304** has a second portion **319** extending away from mmWave antenna module **303**. Second portion **319** is configured as a loop antenna for sub-6 GHz communication. In one or more embodiments, example heat sink antenna **304** has a planar metallic structure that serves as a good heat sink for transferring thermal energy (heat) away from the mmWave antenna module **303** as a heat sink fin. In one or more embodiments, example heat sink antenna **304** is fabricated from materials having both high electrical conductivity and high thermal conductivity to support the dual functions of antenna and heat sink. For example, example heat sink antenna **304** can be fabricated from aluminum. In one or more embodiments, antenna elements are constructed of copper with thickness of approximately 200 μm for sufficient thermal conductivity. In one or more embodiments, heat sink antenna **304** is constructed of a copper-graphite laminate with the copper providing low loss antenna functionality and the graphite providing high heat spreading. The mmWave antenna module **303** is placed close to an outer shell of communication device **100** (FIG. **1**). In one or more embodiments, the outer shell is plastic or glass. A minimum separation distance from mmWave module **303** to the plastic/glass surface is implemented to avoid frequency detun-

ing/efficiency degradation. The mmWave antenna module **303** is connected to PCB **317** by flexible PCBs.

FIG. **4** depicts a three-dimensional view of example dual band antenna assembly **402** having mmWave antenna module **403** that is thermally cooled by example heat sink antenna **404**. Heat sink antenna **404** is configured as a planar inverted F antenna (PIFA) that is used for proximity detection of humans, e.g., human **406**. Resonant frequencies of example heat sink antenna **404** have a longer wavelength than mmWave antenna module **403**. Changes in impedance due to proximity of human **406** is detectable by heat sink antenna **404** at a correspondingly longer distance than mmWave antenna module **406**. Switching of transmissions from mmWave antenna module **406** can be started in expectation of mmWave antenna module **406** being blocked or shadowed by human **406**. At mmWave frequencies, transmission do not penetrate significantly into tissue. Disabling transmission does reduce a surface temperature of dual band antenna assembly **402** and provides an opportunity to gracefully transition communication to another antenna that is not blocked or shadowed.

FIG. **5** is a side view of example dual band antenna assembly **502** having mmWave antenna module **503** that is in thermal conductive contact with first portion **515** of example heat sink antenna **504**. Heat sink antenna **504** is in contact on the lateral sides and underside of mmWave antenna module **503**. Heat sink antenna **504** is configured as a sub-6 GHz loop antenna. Second portion **507***a*-**507***b* of heat sink antenna **504** extends left and right approximately co-planar with patch antenna array **508** of mmWave antenna module **503**. Being close to exterior surface **511** of communication device **500** facilitates convective cooling of heat sink antenna **504**. Some thermal transfer can also pass conductively to internal structure **513** of communication device **500**. Internal structure **513** structurally and electrically supports dual band antenna assembly **502**.

FIG. **6** is a side view of example dual band antenna assembly **602** having mmWave antenna module **603** that is in thermal conductive contact with first portion **615** of example heat sink antenna **604**. Heat sink antenna **604** is in contact on the lateral sides and underside of mmWave antenna module **603**. Heat sink antenna **604** is configured as a capacitively coupled sub-6 GHz loop antenna that is energized via capacitive plates **621***a*-**621***b*. Second portion **607***a*-**607***b* of heat sink antenna **604** extends left and right approximately co-planar with patch antenna array **608** of mmWave antenna module **603**. Being close to exterior surface **611** of communication device **600** facilitates convective cooling of heat sink antenna **604**. Some thermal transfer can also pass conductively to internal structure **613** of communication device **600**. Internal structure **613** structurally and electrically supports dual band antenna assembly **602**. Some transfer of thermal energy can pass across the gap between capacitive plates **621***a*-**621***b* and second portion **607***a*-**607***b* respectively of heat sink antenna **604**.

FIG. **7** is a side view of example dual band antenna assembly **702** that is identical to dual band antenna assembly **602** (FIG. **6**). Communication device **700** additionally has human proximity detection. In particular each of capacitive plates **621***a*-**621***b* is respectively coupled to capacitance sensor **725***a*-**725***b*. Capacitance sensors **725***a*-**725***b* detect changes in capacitance of capacitive plates **621***a*-**621***b* that occur when communication device **700** is brought close to a person.

FIG. **8** is a side view of example dual band antenna assembly **802** having mmWave antenna module **803** that is in thermal conductive contact with first portion **815** of example heat sink antenna **804**. Heat sink antenna **804** is in thermal contact with lateral sides and an underside of mmWave antenna module **803**. Heat sink antenna **804** is configured as a capacitively coupled sub-6 GHz monopole antenna. Second portions **807***a*-**807***b* of heat sink antenna **804** are energized and couple to capacitive plates **821***a*-**821***b*. Second portions **807***a*-**807***b* extend left and right, approximately co-planar with patch antenna array **808** of mmWave antenna module **803**. Second portions **807***a*-**807***b* and capacitive plates **821***a*-**821***b* of heat sink antenna **804** are close to exterior surface **811** of communication device **800**. Being close to exterior surface **811** of communication device **800** facilitates convective cooling of heat sink antenna **804**. Some thermal transfer can also pass conductively to internal structure **813** of communication device **800**. Internal structure **813** structurally and electrically supports dual band antenna assembly **802**. Some transfer of thermal energy can pass across the gap between capacitive plates **821***a*-**821***b* and second portion **807***a*-**807***b* respectively of heat sink antenna **804**.

FIG. **9** is a side view of example dual band antenna assembly **902** that is identical to dual band antenna assembly **802** (FIG. **8**). Communication device **900** additionally has human proximity detection. In particular, each of capacitive plates **821***a*-**821***b* is respectively coupled to capacitance sensor **925***a*-**925***b*. Capacitance sensors **925***a*-**925***b* detect changes in capacitance of capacitive plates **821***a*-**821***b* that occur when communication device **900** is brought close to a person.

FIG. **10** is a side view of example dual band antenna assembly **1002** having mmWave antenna module **1003** that is in thermal conductive contact with first portion **1015** of example heat sink antenna **1004**. Heat sink antenna **1004** is in thermal contact with lateral sides and an underside of mmWave antenna module **1003**. Heat sink antenna **1004** is configured as a sub-6 GHz PIFA, which can perform satisfactorily when carried against a person, unlike other antenna configurations that do better in free space. Second portions **1007***a*-**1007***b* extends left and right of as depicted mmWave antenna module **1003**. Second portion **1007***a*-**1007***b* are approximately co-planar with patch antenna array **1008** of mmWave antenna module **1003**. Second portions **1007***a*-**1007***b* of heat sink antenna **1004** are close to exterior surface **1011** of communication device **1000**. Being close to exterior surface **1011** of communication device **1000** facilitates convective cooling of heat sink antenna **1004**. Some thermal transfer can also pass conductively to internal structure **1013** of communication device **1000**. Internal structure **1013** structurally and electrically supports dual band antenna assembly **1002**.

FIG. **11** is a side view of example dual band antenna assembly **1102** having mmWave antenna module **1103** that is in thermal conductive contact with first portion **1115** of example heat sink antenna **1104**. Heat sink antenna **1104** is in thermal contact with lateral sides and an underside of mmWave antenna module **1103**. Heat sink antenna **1104** is configured as a sub-6 GHz PIFA. Second portion **1107***a*-**1107***b* extends left and right of mmWave antenna module **1103** as depicted. Second portions **1107***a*-**1107***b* are approximately co-planar with patch antenna array **1108** of mmWave antenna module **1103**. Second portions **1107***a*-**1107***b* of heat sink antenna **1104** are close to exterior surface **1111** of communication device **1100**. Being close to exterior surface **1111** of communication device **1100** facilitates convective cooling of heat sink antenna **1104**. Outward portions of second portion **1107***a*-**1107***b* turn inwardly and then extend proximate to internal structure **1113**. Some thermal transfer

can also pass conductively to internal structure **1113** of communication device **1100**. Internal structure **1113** structurally and electrically supports dual band antenna assembly **1102**.

FIG. **12** is a side view of example dual band antenna assembly **1202** having mmWave antenna module **1203** that is in thermal conductive contact with first portion **1215** of example heat sink antenna **1204**. Heat sink antenna **1204** is in contact with an underside of mmWave antenna module **1203**. RFIC connection **1227** electrically connects mmWave antenna module **1203** to internal structure **1213**, such as a PCB. In one or more embodiments, mmWave antenna module **1203** is elevated 2-4 mm from internal structure **1213** to be close to exterior surface **1211** of communication device **1200** to achieve a desired field of view. Heat sink antenna **1204** is configured as a sub-6 GHz PIFA. Second portion **1207** extends to one side (to the right as depicted). Second portion **1207** is not close to exterior surface **1211** of communication device **1200**. Thermal transfer by heat sink antenna **1204** largely passes conductively to internal structure **1213** of communication device **1200**. Heatsink antenna **1204** is an example of adding an additional antenna to communication device **1200** that has limited areas of external surface **1211** that are available. First portion **1215** of heat sink antenna **1204** utilizes the space between internal structure **1213** and mmWave antenna module **1203**. Second portion **1207** of heat sink antenna **1204** also extends close to internal structure **1213**. In one or more embodiments, heat sink antenna **1204** can support ultra-high band (UHB) communication in n78 or n79 bands for 4G LTE communication.

FIG. **13** is a side view of example dual band antenna assembly **1302** having mmWave antenna module **1303** that is in thermal conductive contact with first portion **1215** respectively of two heat sink antennas **1304***a*-**1304***b*. Each heat sink antenna **1304***a*-**1304***b* is in contact with a respective portion of the underside of mmWave antenna module **1303** that is spaced above internal structure **1313**, such as a PCB, of communication device **1300**. RFIC connection **1327** electrically connects mmWave antenna module **1303** to internal structure **1313**. Each heat sink antenna **1304***a*-**1304***b* is configured as a sub-6 GHz PIFA. Second portion **1307** of each heat sink antenna **1304***a*-**1304***b*, respectively, extends to respective sides (to the left and right as depicted). In one or more embodiments, heat sink antenna **1304***a*-**1304***b* are configured for different communication bands. In one or more embodiments, heat sink antenna **1304***a*-**1304***b* are configured for the same communication band and can be transmitted with respective power amplitude and phases for antenna beam shaping.

FIG. **14** is a side view of example dual band antenna assembly **1402** having mmWave antenna module **1403** that is in thermal conductive contact with first portion **1415** of example heat sink antenna **1404**. Heat sink antenna **1404** is in thermal contact to an underside and one lateral side of mmWave antenna module **1403**. RFIC connection **1427** electrically connects mmWave antenna module **1403** to internal structure **1413**. Heat sink antenna **1404** is configured as a sub-6 GHz PIFA. Second portion **1407** extends to one side (to the left as depicted) close to exterior surface **1411** of communication device **1400**, enabling thermal transfer to pass convectively from exterior surface of communication device **1400**.

FIG. **15** presents a flow diagram of a method for reliably radiating a mmWave transmit signal from a communication device. In particular, the reliable transmission is enabled by use of a sub-6 GHz heat sink antenna for dual functions of communication and thermal energy transfer from a mmWave antenna module. The description of method **1500** is provided with general reference to the specific components illustrated within the preceding FIGS. **1-14**. In at least one embodiment, method **1500** can be performed using antenna subsystem **111** of communication device **100**, managed by controller **101** (FIG. **1**). Specific component described in method **1500** can be identical or similar to specific components of the same name used to describe preceding FIGS. **1-14**.

With reference to FIG. **15**, method **1500** includes transmitting a mmWave signal via a first mmWave antenna module, the transmitting resulting in generation of thermal energy (block **1502**). Method **1500** includes communicating using a sub-6 GHz signal via a first heat sink antenna (FIG. **1504**). The first heat sink antenna has a first portion in thermal conductive contact with at least a portion of a surface of the first mmWave antenna module. The first heat sink antenna has a second portion extending away from the first mmWave antenna module to transfer the thermal energy away from the first mmWave antenna module. Method **1500** includes monitoring, via a first impedance sensor coupled to the first heat sink antenna, changes in impedance of the first heat sink antenna (block **1506**). Method **1500** includes comparing a change in the impedance to a value that is indicative of human proximity (block **1508**). A determination is made, in decision block **1510**, whether the comparison indicates human proximity. In response to determining that the comparison does not indicate human proximity, then method **1500** returns to block **1502**. In response to determining that the comparison does indicate human proximity, then method **1500** includes disabling use of the first mmWave antenna by the mmWave transmitter (block **1512**). Then method **1500** ends.

FIGS. **16**A-**16**B (FIG. **16**) present a flow diagram of a method for reliably radiating a mmWave transmit signal from a communication device having multiple dual band antenna assemblies. In particular, the reliable transmission is enabled by use of a sub-6 GHz heat sink antenna for the dual functions of communication and thermal energy transfer from a mmWave antenna module. The description of method **1600** is provided with general reference to the specific components illustrated within the preceding FIGS. **1-14**. In at least one embodiment, method **1600** can be performed using antenna subsystem **111** of communication device **100**, managed by controller **101** (FIG. **1**). Specific components described in method **1600** can be identical or similar to specific components of the same name used to describe preceding FIGS. **1-16**.

With reference to FIG. **16**A, method **1600** includes monitoring temperature of more than one dual function antenna assemblies, each antenna assembly comprising an mmWave antenna module and a heat sink antenna that is in thermal conductive contact with the mmWave antenna module (block **1602**). Method **1600** includes comparing the respective temperature of each mmWave antenna to a temperature threshold that is retrieved from memory (block **1604**). A determination is made, in decision block **1606**, whether the respective temperature is greater than the temperature threshold for any one of the dual band antenna assemblies. In response to determining that the respective temperature is greater than the temperature threshold for any one of the dual band antenna assemblies, method **1600** includes identifying a corresponding dual band antenna assembly as unavailable due to temperature (block **1608**). In response to determining that the respective temperature is less than or equal to the temperature threshold for any one of the dual

band antenna assemblies, method **1600** includes identifying a corresponding dual band antenna assembly as available for handling communication based on temperature (block **1610**).

After either block **1608** or block **1610**, method **1600** includes monitoring, via a respective impedance sensor of each one of the more than one dual band antenna assemblies, changes in impedance of the corresponding heat sink antenna (block **1612**). For each of the more than one dual band antenna assemblies, method **1600** includes comparing the changes in impedance to a threshold indicative of blocking or shadowing of any one of the dual band antenna assemblies (block **1614**).

With reference to FIG. **16**B, a determination is made, in decision block **1616**, whether the changes in impedance is indicative of shadowing. In response to determining that the change in impedance is indicative of blocking or shadowing of any one of the dual band antenna assemblies, method **1600** includes identifying a particular dual band antenna assembly as unavailable due to shadowing (block **1618**). In response to determining that the change in impedance is not indicative of blocking or shadowing of any one of the dual band antenna assemblies, method **1600** includes identifying a particular dual band antenna assembly as available based on being unshadowed (block **1620**). After either block **1618** or block **1620**, a determination is made, in decision block **1622**, whether a mmWave transmission is queued for transmission. In response to determining that a mmWave transmission is not queued for transmission, method **1600** returns to block **1602** (FIG. **16**A). In response to determining that a mmWave transmission is queued for transmission, method **1600** includes assigning the mmWave transmission to a dual band antenna assembly that is available based on temperature and based on being unshadowed (block **1620**). Then method **1600** returns to block **1602** (FIG. **16**A).

In the above described flow charts presented herein, certain steps of the methods can be combined, performed simultaneously or in a different order, or perhaps omitted, without deviating from the spirit and scope of the described innovation. While the method steps are described and illustrated in a particular sequence, use of a specific sequence of steps is not meant to imply any limitations on the innovation. Changes may be made with regards to the sequence of steps without departing from the spirit or scope of the present innovation. Use of a particular sequence is therefore, not to be taken in a limiting sense, and the scope of the present innovation is defined only by the appended claims.

Aspects of the present innovation are described above with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the innovation. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

As will be appreciated by one skilled in the art, embodiments of the present innovation may be embodied as a system, device, and/or method. Accordingly, embodiments of the present innovation may take the form of an entirely hardware embodiment or an embodiment combining software and hardware embodiments that may all generally be referred to herein as a "circuit," "module" or "system."

While the innovation has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made, and equivalents may be substituted for elements thereof without departing from the scope of the innovation. In addition, many modifications may be made to adapt a particular system, device, or component thereof to the teachings of the innovation without departing from the essential scope thereof. Therefore, it is intended that the innovation not be limited to the particular embodiments disclosed for carrying out this innovation, but that the innovation will include all embodiments falling within the scope of the appended claims. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the innovation. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprise" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present innovation has been presented for purposes of illustration and description but is not intended to be exhaustive or limited to the innovation in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the innovation. The embodiments were chosen and described in order to best explain the principles of the innovation and the practical application, and to enable others of ordinary skill in the art to understand the innovation for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A communication device comprising:

a first millimeter wave (mmWave) antenna module;

a first heat sink antenna having a first portion in thermal conductive contact with at least a portion of a surface of the first mmWave antenna module and having a second portion extending away from the first mmWave antenna module to transfer thermal energy away from the first mmWave antenna module, the first heat sink antenna configured as a capacitively coupled sub-6 GHz antenna for communication, with a capacitance sensor for human proximity detection; and

a radio frequency (RF) front end comprising a mmWave transmitter that radiates a mmWave signal via the first mmWave antenna module, resulting in generation of the thermal energy, the RF front end further comprising a sub-6 GHz transmitter that radiates a sub-6 GHz signal via the first heat sink antenna.

2. The communication device of claim **1**, wherein the first heat sink antenna operates as a heat sink for the first mmWave antenna module and is configured as one of: (i) a

loop antenna; (ii) a capacitively coupled loop antenna; (iii) a planar inverted-F antenna (PIFA); and (iv) a capacitively coupled monopole antenna.

3. The communication device of claim **1**, wherein the first heat sink antenna comprises a copper structure having a thickness of at least 200 μm for thermal and electrical conduction.

4. The communication device of claim **1**, wherein the first heat sink antenna comprises a copper-graphite laminate structure.

5. The communication device of claim **1**, further comprising:

a first impedance sensor that is communicatively coupled to the first heat sink antenna; and

a controller that is communicatively coupled to the first impedance sensor and which:

monitors, via the first impedance sensor, changes in impedance of the first heat sink antenna;

determines, based on the changes in impedance, whether a human is blocking the first mmWave antenna module; and

disables use of the first mmWave antenna module by the mmWave transmitter in response to determining that the human is blocking the first mmWave antenna module.

6. The communication device of claim **1**, further comprising:

a controller; and

more than one dual band assemblies that are each communicatively coupled to the controller and each comprise a corresponding combination of a mmWave antenna, a heat sink antenna, and an impedance sensor;

wherein:

the first mmWave antenna, the first heat sink antenna, and the first impedance sensor comprise a first dual band antenna assembly;

each mmWave antenna respectively of the more than one dual band antenna assemblies comprises a temperature management component, wherein; and

the controller:

monitors a respective temperature of each mmWave antenna of the more than one dual band antenna assemblies;

compares the respective temperature of each mmWave antenna to a temperature threshold; and

in response to the respective temperature being greater than the temperature threshold for any one of the dual band antenna assemblies, identifies a corresponding dual band antenna assembly as unavailable.

7. The communication device of claim **6**, further comprising:

a first impedance sensor that is communicatively coupled to the first heat sink antenna; and

wherein the controller:

monitors, via a respective impedance sensor of each one of the more than one dual band antenna assemblies, changes in impedance of the corresponding heat sink antenna;

for each of the more than one dual band antenna assemblies, identifies a particular dual band antenna assembly as unavailable in response to determining, based on the changes in impedance via the corresponding impedance sensor, that a human is blocking the corresponding mmWave antenna; and

in response to determining that the human is blocking the mmWave antenna of the first dual band antenna assembly, switches the mmWave transmitter to an available mmWave antenna having a temperature that is less than or equal to the temperature threshold and is not blocked by a human.

8. The communication device of claim **1**, wherein the first heat sink antenna has a planar metallic structure.

9. The communication device of claim **1**, wherein the first heat sink antenna is fabricated from materials having both high electrical conductivity and high thermal conductivity to support dual functions of an antenna and a heat sink.

10. A method for reliably radiating a millimeter wave (mmWave) transmit signal from a communication device, the method comprising:

transmitting a mmWave signal via a first mmWave antenna module that is in thermal conductive contact with a first heat sink antenna, the transmitting resulting in generation of thermal energy, wherein the first heat sink antenna is configured as a sub-6 GHz antenna for communication, with a capacitance sensor for human proximity detection; and

communicating using a sub-6 GHz signal via the first heat sink antenna that has a first portion in thermal conductive contact with at least a portion of a surface of the first mmWave antenna module and a second portion extending away from the first mmWave antenna module to transfer the thermal energy away from the first mmWave antenna module.

11. The method of claim **10**, further comprising:

monitoring, via a first impedance sensor coupled to the first heat sink antenna, changes in impedance of the first heat sink antenna;

determining, based on the changes in impedance, whether a human is blocking the first mmWave antenna module; and

disabling use of the first mmWave antenna by the mmWave transmitter, in response to determining that the human is blocking the first mmWave antenna.

12. The method of claim **10**, further comprising transmitting the sub-6 GHz signal via the first heat sink antenna, the first heat sink antenna providing thermal energy transfer away from the first mmWave antenna module and being configured as one of: (i) a loop antenna; (ii) a capacitively coupled loop antenna; (iii) a planar inverted-F antenna (PIFA); and (iv) a capacitively coupled monopole antenna.

13. The method of claim **10**, wherein the first mmWave antenna module, the first heat sink antenna, and the first impedance sensor comprise a first dual band antenna assembly of more than one dual band antenna assemblies within the communication device, the method further comprising:

monitoring a respective temperature of each mmWave antenna of the more than one dual band antenna assemblies;

comparing the respective temperature of each mmWave antenna to a temperature threshold; and

in response to the respective temperature being greater than the temperature threshold for any one of the dual band antenna assemblies, identifying a corresponding dual band antenna assembly as unavailable.

14. The method of claim **13**, further comprising:

monitoring, via a respective impedance sensor of each one of the more than one dual band antenna assemblies, changes in impedance of the corresponding heat sink antenna;

for each of the more than one dual band antenna assemblies, identifying a particular dual band antenna assembly as unavailable in response to determining, based on

the changes in impedance via the corresponding impedance sensor, that a human is blocking the corresponding mmWave antenna; and

switching the mmWave transmitter to a mmWave antenna that is available based on both having a temperature that is less than or equal to the temperature threshold and is not blocked by a human in response to determining that the human is blocking the mmWave antenna of the first dual band antenna assembly.

15. A computer program product comprising:

a computer readable storage device; and

program code on the computer readable storage device that when executed by a processor associated with a communication device, the program code enables the communication device to provide the functionality of:

transmitting a mmWave signal via a first mmWave antenna module that is in thermal conductive contact with a first heat sink antenna, the transmitting resulting in generation of thermal energy, wherein the first heat sink antenna is configured as an antenna for sub-6 GHz communication, with a capacitance sensor for human proximity detection; and

communicating using a sub-6 GHz signal via the first heat sink antenna that has a first portion in thermal conductive contact with at least a portion of a surface of the first mmWave antenna module and a second portion extending away from the first mmWave antenna module to transfer the thermal energy away from the first mmWave antenna module, the first heat sink antenna configured to support sub-6 GHz communication.

16. The computer program product of claim **15**, wherein the program code enables the communication device to provide the functionality of:

monitoring, via a first impedance sensor coupled to the first heat sink antenna, changes in impedance of the first heat sink antenna;

determining, based on the changes in impedance, whether a human is blocking the first mmWave antenna module; and—

disabling use of the first mmWave antenna by the mmWave transmitter, in response to determining that the human is blocking the first mmWave antenna module.

17. The computer program product of claim **15**, wherein the program code enables the communication device to provide the functionality of transmitting the sub-6 GHZ signal via the first heat sink antenna, the first heat sink antenna providing thermal energy transfer away from the first mmWave antenna and being configured as one of: (i) a loop antenna; (ii) a capacitively coupled loop antenna; (iii) a planar inverted-F antenna (PIFA); and (iv) a capacitively coupled monopole antenna.

18. The computer program product of claim **15**, wherein the first mmWave antenna module, the first heat sink antenna, and the first impedance sensor comprise a first dual band antenna assembly of more than one dual band antenna assemblies of the communication device, the program code enables the communication device to provide the functionality of:

monitoring a respective temperature of each mmWave antenna of the more than one dual band antenna assemblies;

comparing the respective temperature of each mmWave antenna to a temperature threshold; and

in response to the respective temperature being greater than the temperature threshold for any one of the dual band antenna assemblies, identifying a corresponding dual band antenna assembly as unavailable.

19. The computer program product of claim **18**, wherein the program code enables the communication device to provide the functionality of:

monitoring, via a respective impedance sensor of each one of the more than one dual band antenna assemblies, changes in impedance of the corresponding heat sink antenna;

for each of the more than one dual band antenna assemblies, identifying a particular dual band antenna assembly as unavailable in response to determining, based on the changes in impedance via the corresponding impedance sensor, that a human is blocking the corresponding mmWave antenna; and

switching the mmWave transmitter to a mmWave antenna that is available based on both having a temperature that is less than or equal to the temperature threshold and is not blocked by a human in response to determining that the human is blocking the mmWave antenna of the first dual band antenna assembly.

* * * * *

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(12) **United States Patent**
Zhao et al.

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(45) **Date of Patent: Mar. 4, 2025**

(54) **COMMUNICATION DEVICE HAVING A CONFIGURABLE HOUSING ASSEMBLY WITH MULTIPLE ANTENNAS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 451 days.

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H01Q 1/24 (2006.01)
H01Q 21/28 (2006.01)

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CPC ***H01Q 3/06*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 21/28*** (2013.01)

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CPC H01Q 3/06; H01Q 1/243; H01Q 21/28
See application file for complete search history.

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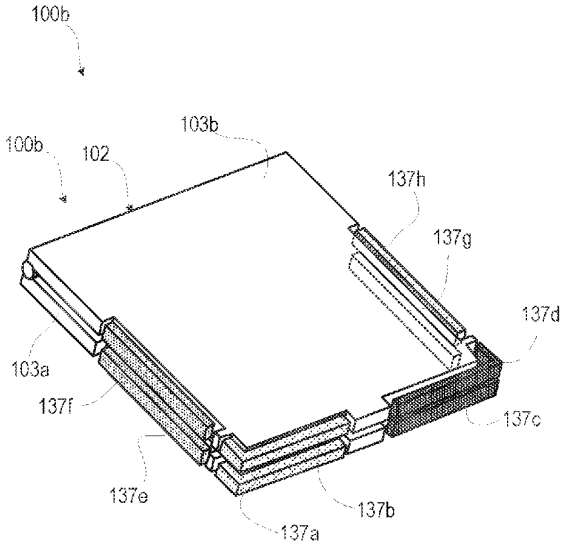
(57) **ABSTRACT**

A communication device, method and computer program product enable transceivers to communicate via antennas supported by a configurable housing assembly. First and second housing portions are connected at respective proximal sides for relative movement between an open position and a closed position about a lateral axis. First and second antenna elements of a first antenna array each have an elongated shape and are configured to communicate in radio frequency (RF) communication band(s). The first and the second antenna elements are supported respectively by the first and the second housing portions. The first antenna element is proximate to and substantially aligned in parallel with the second antenna element when the housing assembly is in the closed position and separated when the housing assembly is in the open position. A first antenna feed/source network eliminates array cancellations between the first and the second antenna elements when the housing assembly is in the closed position.

20 Claims, 17 Drawing Sheets



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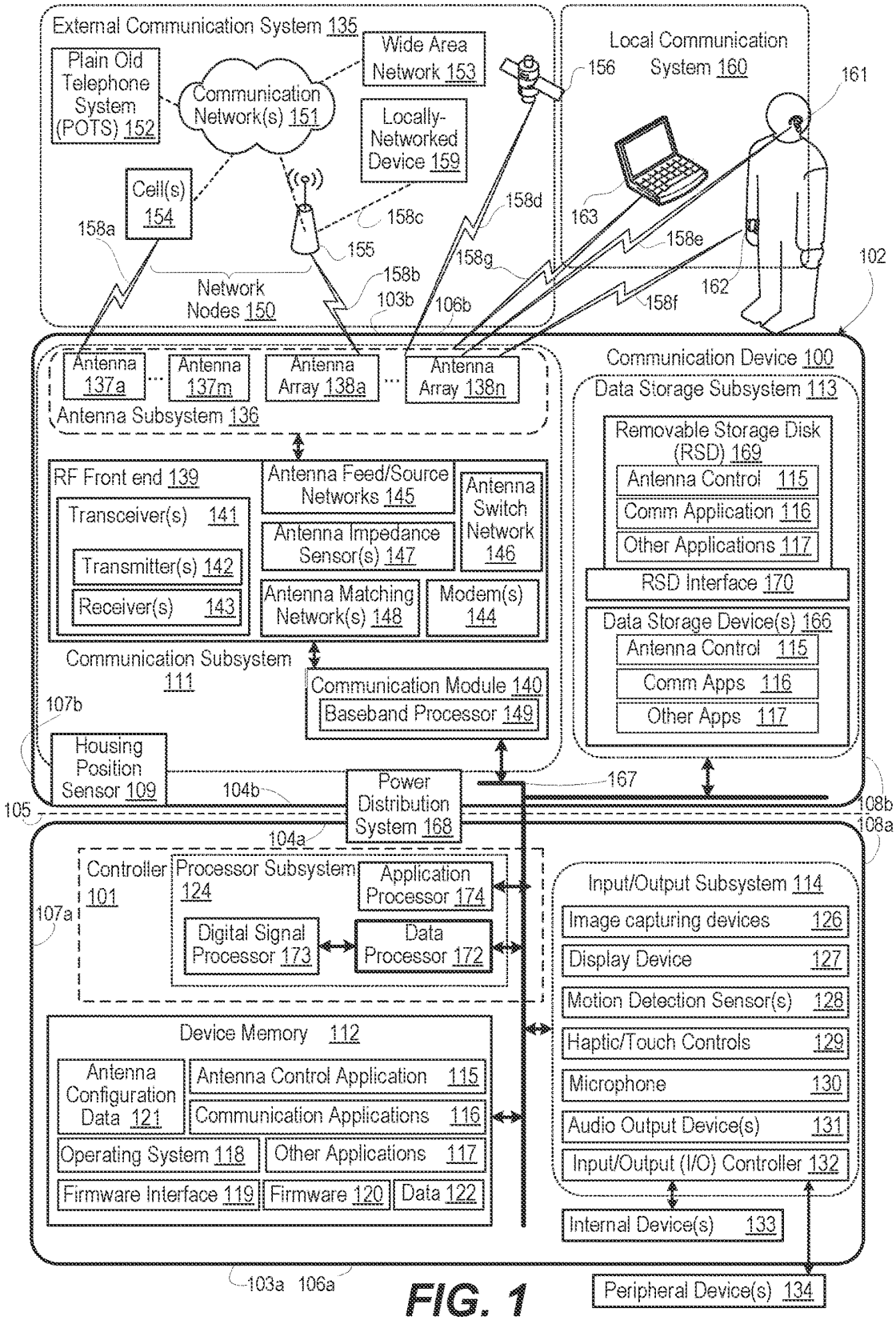
External Communication System 135
Plain Old Telephone System (POTS) 152
Communication Network(s) 151
Wide Area Network 153
Locally-Networked Device 159
Cell(s) 154
Network Nodes 150
Local Communication System 160
156
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158g
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106b
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Antenna 137m
Antenna Array 138a
Antenna Array 138n
Antenna Subsystem 136
Communication Device 100
Data Storage Subsystem 113
Removable Storage Disk (RSD) 169
Antenna Control 115
Comm Application 116
Other Applications 117
RSD Interface 170
Data Storage Device(s) 166
Antenna Control 115
Comm Apps 116
Other Apps 117
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Transceiver(s) 141
Transmitter(s) 142
Receiver(s) 143
Antenna Feed/Source Networks 145
Antenna Impedance Sensor(s) 147
Antenna Matching Network(s) 148
Antenna Switch Network 146
Modem(s) 144
Communication Subsystem 111
Communication Module 140
Baseband Processor 149
107b
Housing Position Sensor 109
104b
Power Distribution System 168
167
105
108b
108a
104a
Controller 101
Processor Subsystem 124
Application Processor 174
Digital Signal Processor 173
Data Processor 172
107a
Input/Output Subsystem 114
Image capturing devices 126
Display Device 127
Motion Detection Sensor(s) 128
Haptic/Touch Controls 129
Microphone 130
Audio Output Device(s) 131
Input/Output (I/O) Controller 132
Internal Device(s) 133
Device Memory 112
Antenna Configuration Data 121
Antenna Control Application 115
Communication Applications 116
Operating System 118
Other Applications 117
Firmware Interface 119
Firmware 120
Data 122
103a
106a
Peripheral Device(s) 134

FIG. 1

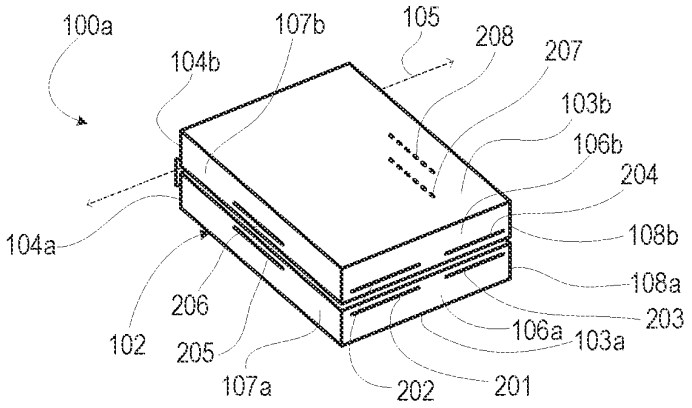

FIG. 2A

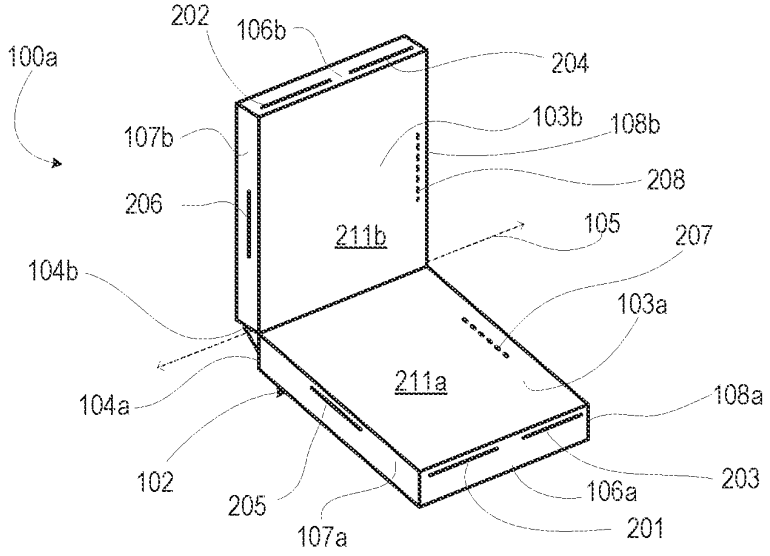

FIG. 2B

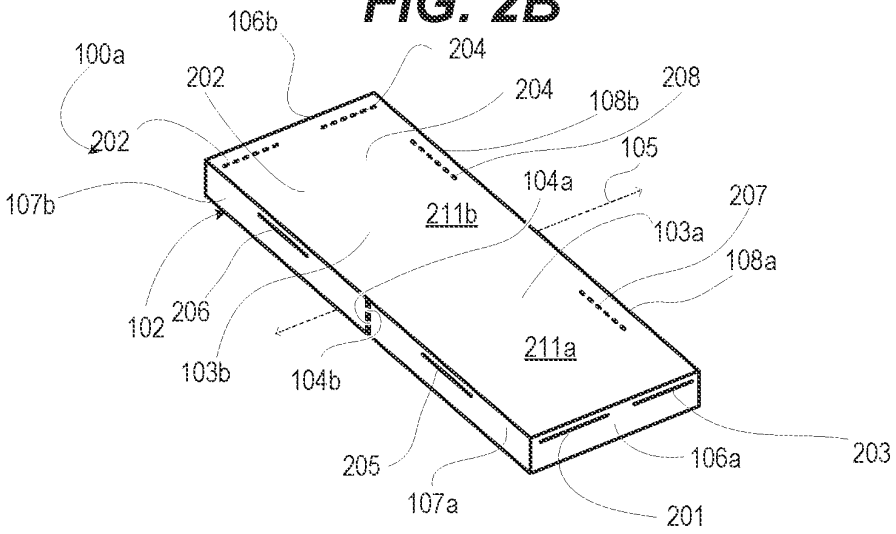

FIG. 2C

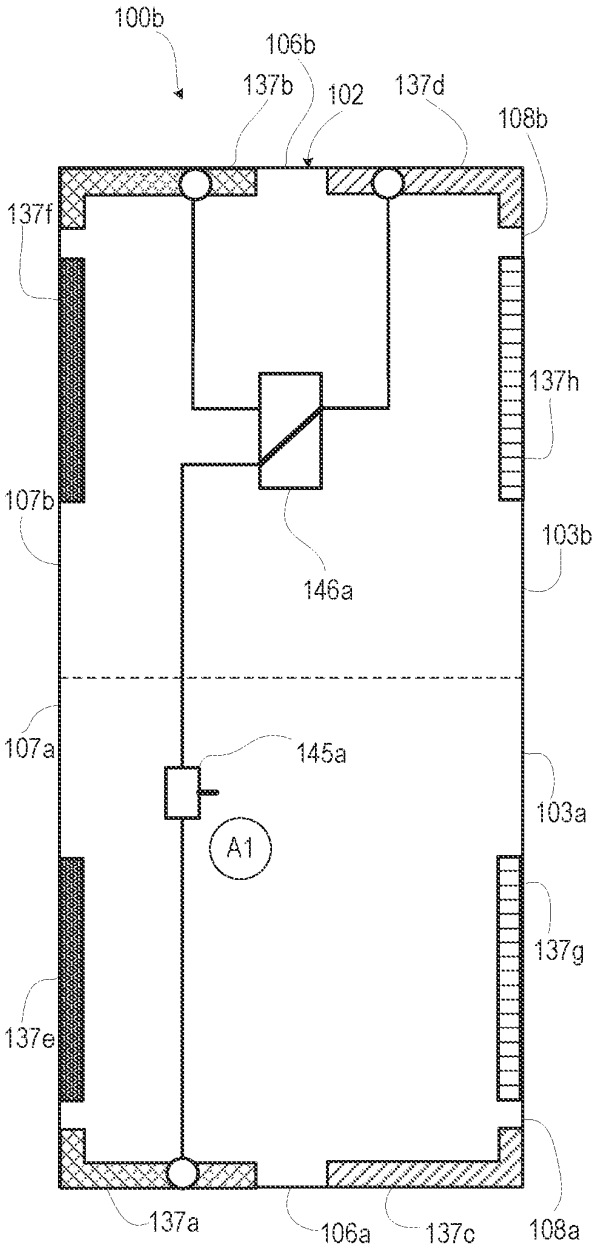
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FIG. 3A

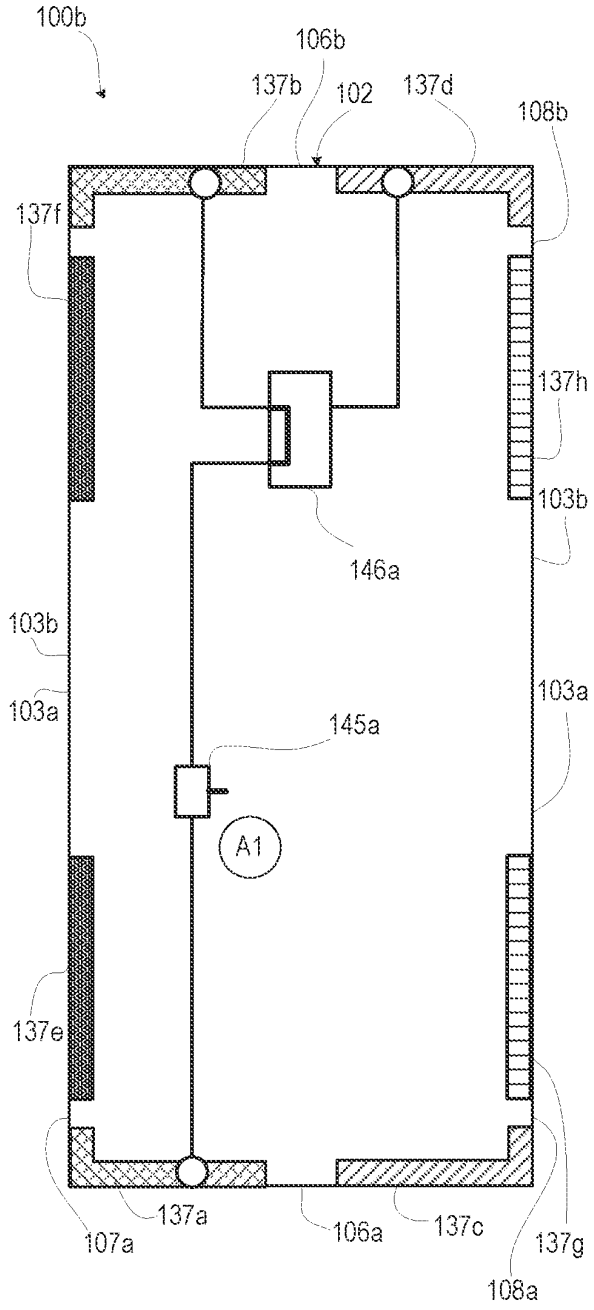
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FIG. 3B

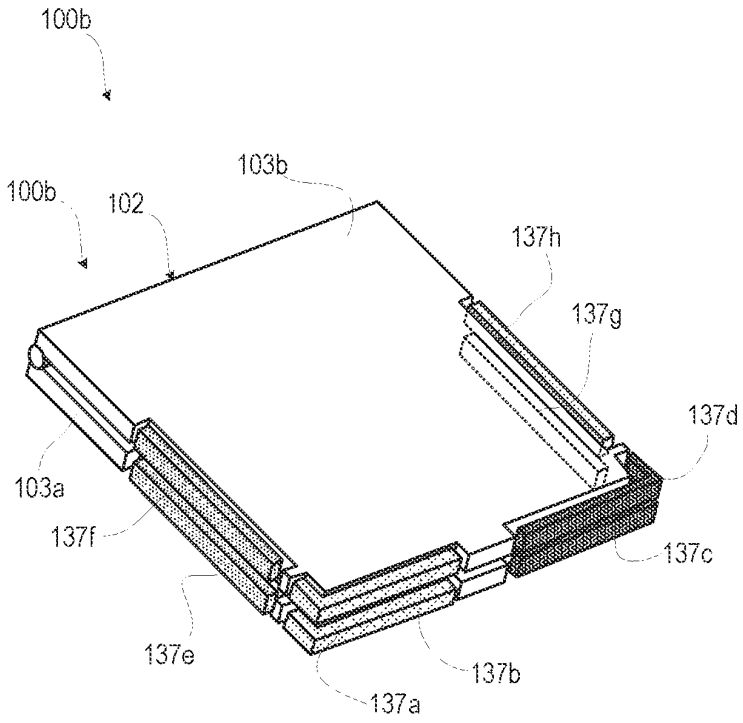
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FIG. 3C

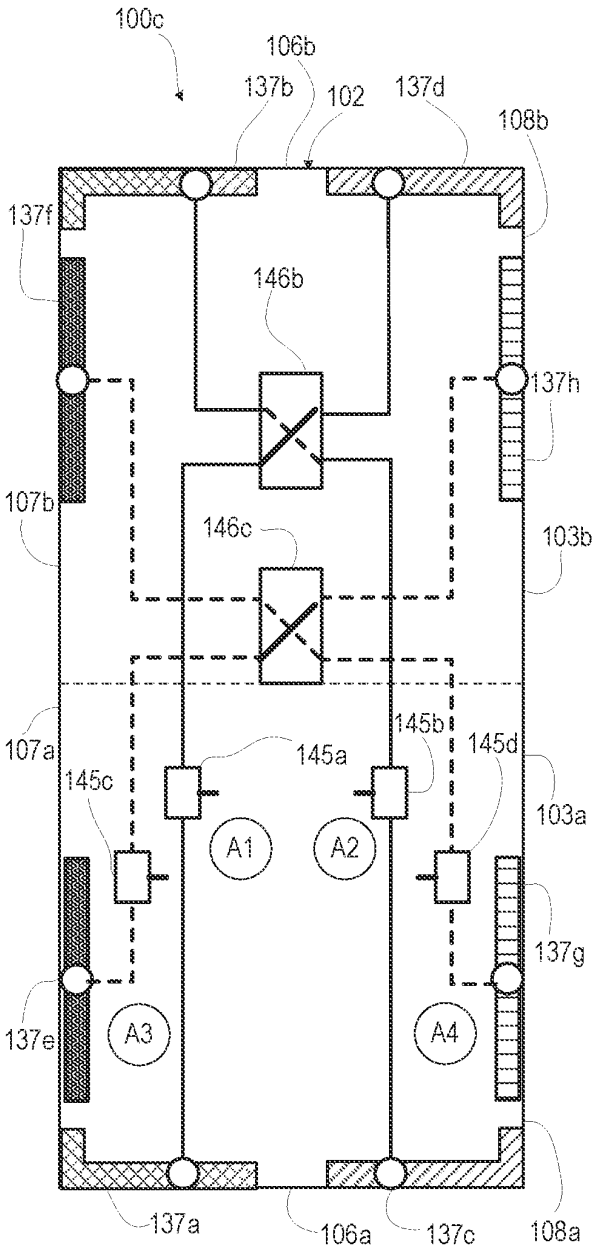
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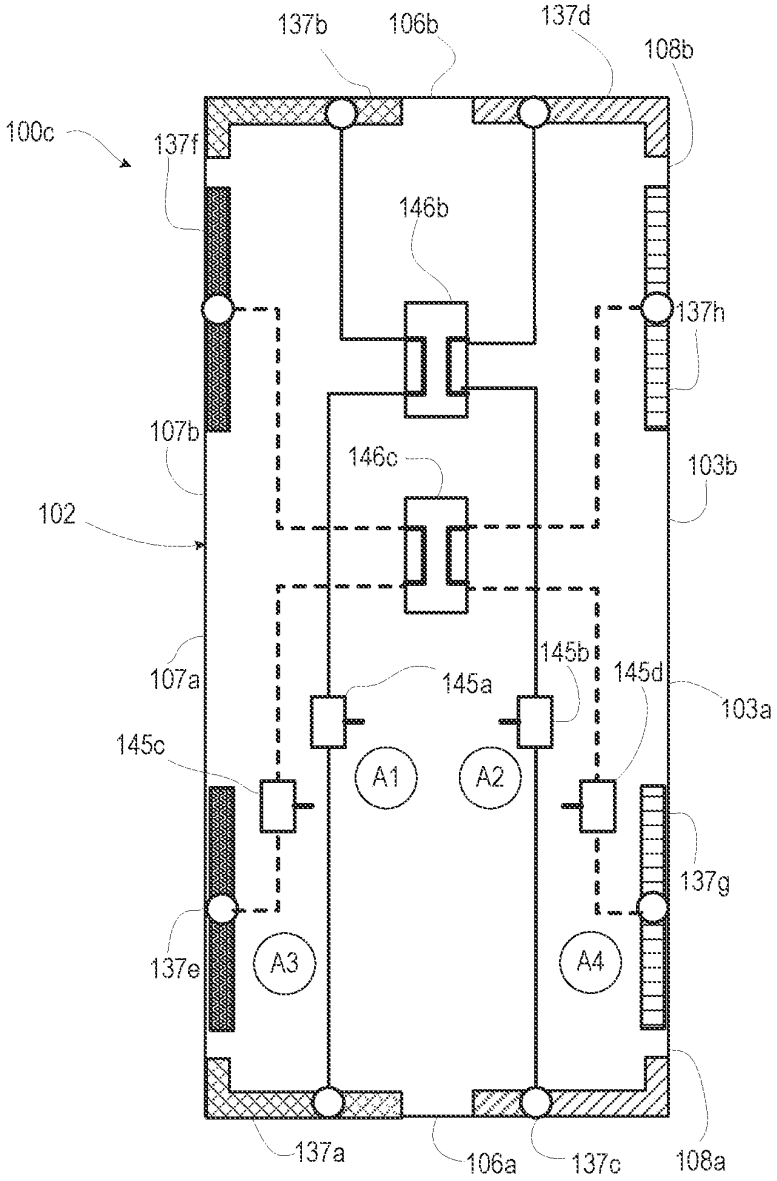
FIG. 4A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146c
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102
107a
145b
145d
145a
103a
145c
A1
A2
137g
137e
A3
A4
137a
106a
137c
108a

FIG.4B

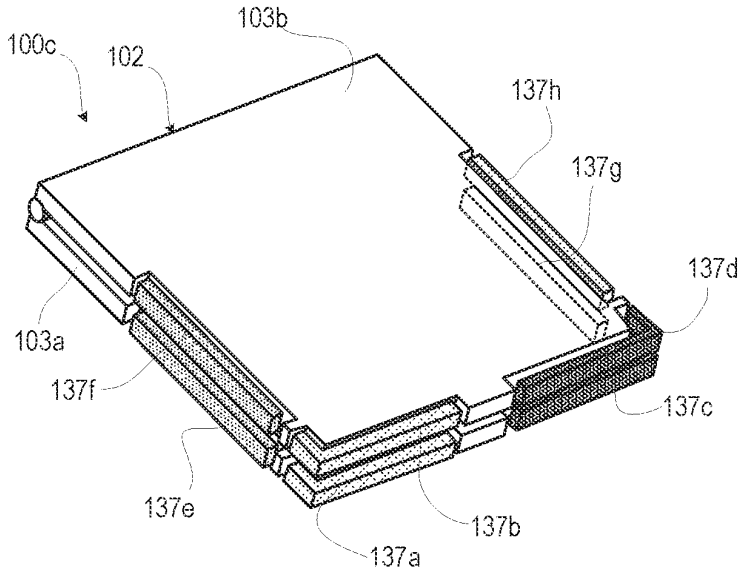

FIG. 4C

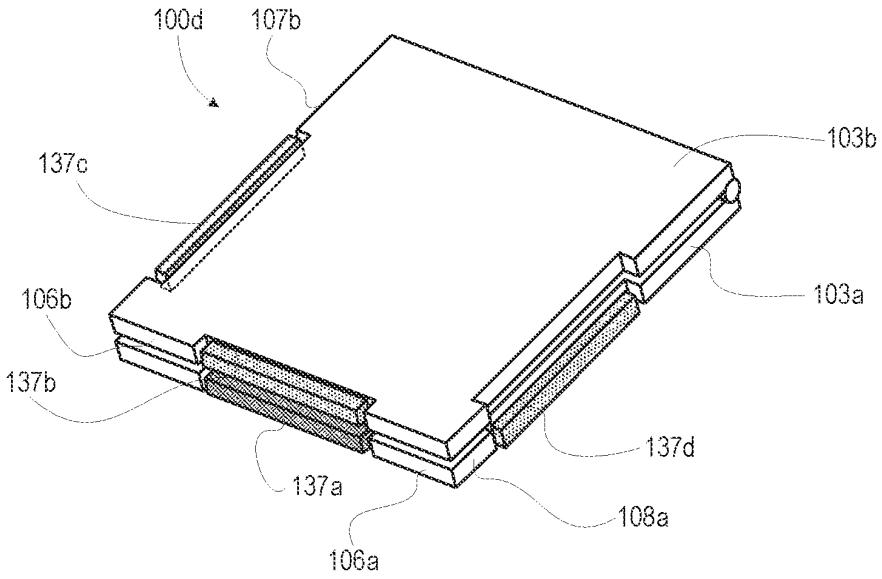
100d
107b
137c
103b
106b
103a
137b
137d
137a
108a
106a

FIG. 5

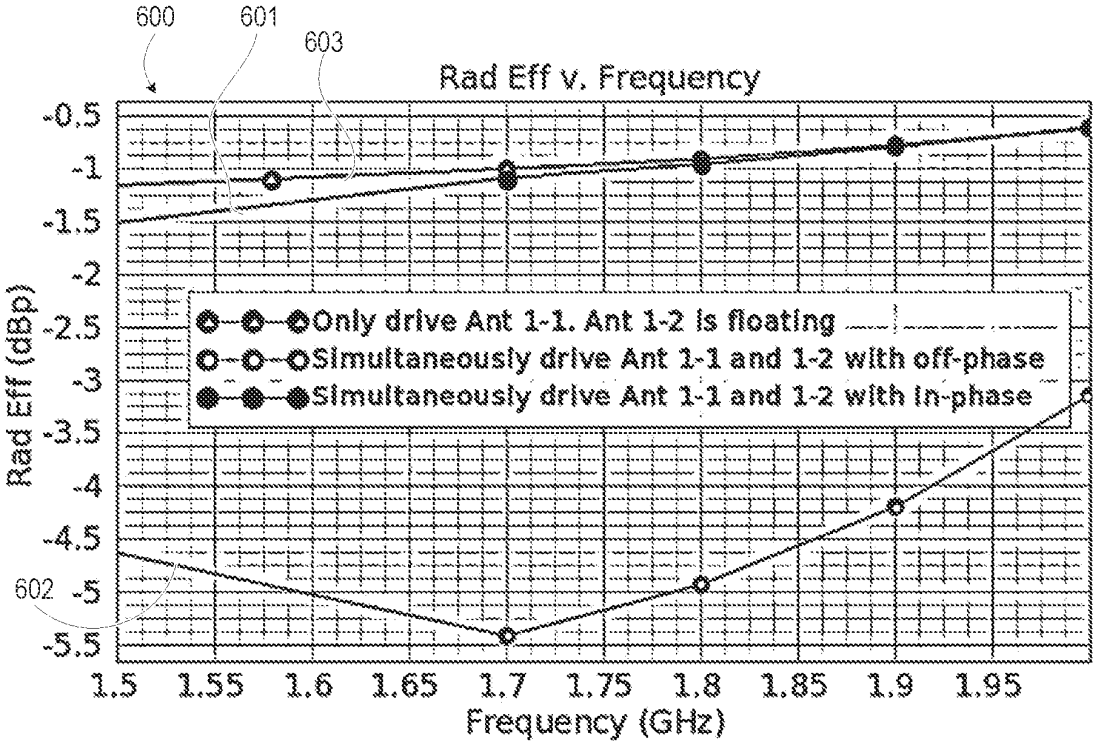
600
601
603
Rad Eff v. Frequency
Rad Eff (dBp)
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
602
Only drive Ant 1-1. Ant 1-2 is floating
Simultaneously drive Ant 1-1 and 1-2 with off-phase
Simultaneously drive Ant 1-1 and 1-2 with in-phase
1.5
1.55
1.6
1.65
1.7
1.75
1.8
1.85
1.9
1.95
Frequency (GHz)

FIG. 6

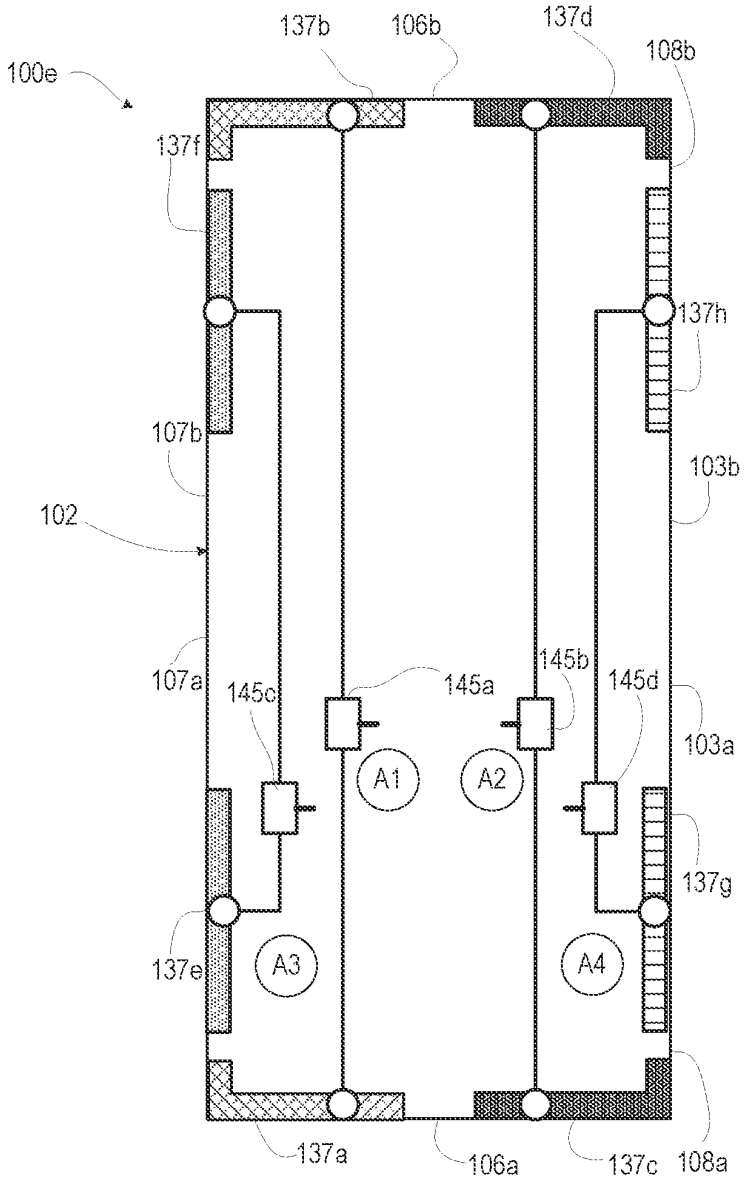
100e
137b
106b
137d
108b
137f
137h
107b
103b
102
107a
145c
145a
145b
145d
103a
A1
A2
137g
137e
A3
A4
137a
106a
137c
108a

FIG. 7A

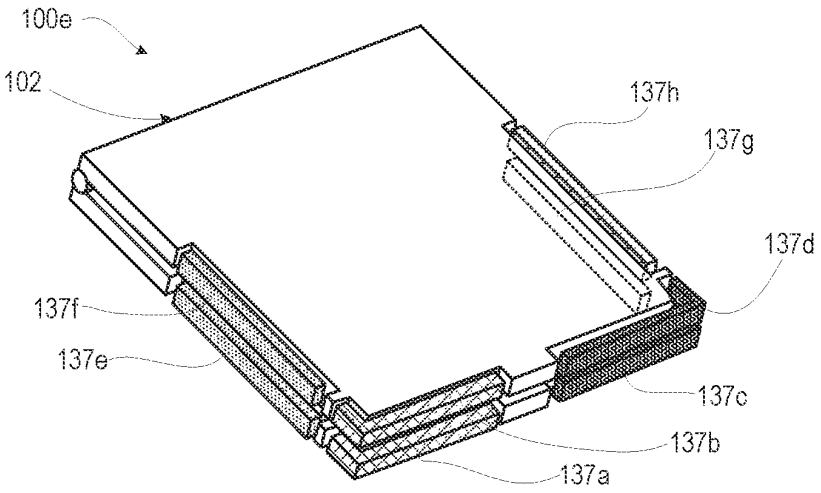

FIG. 7B

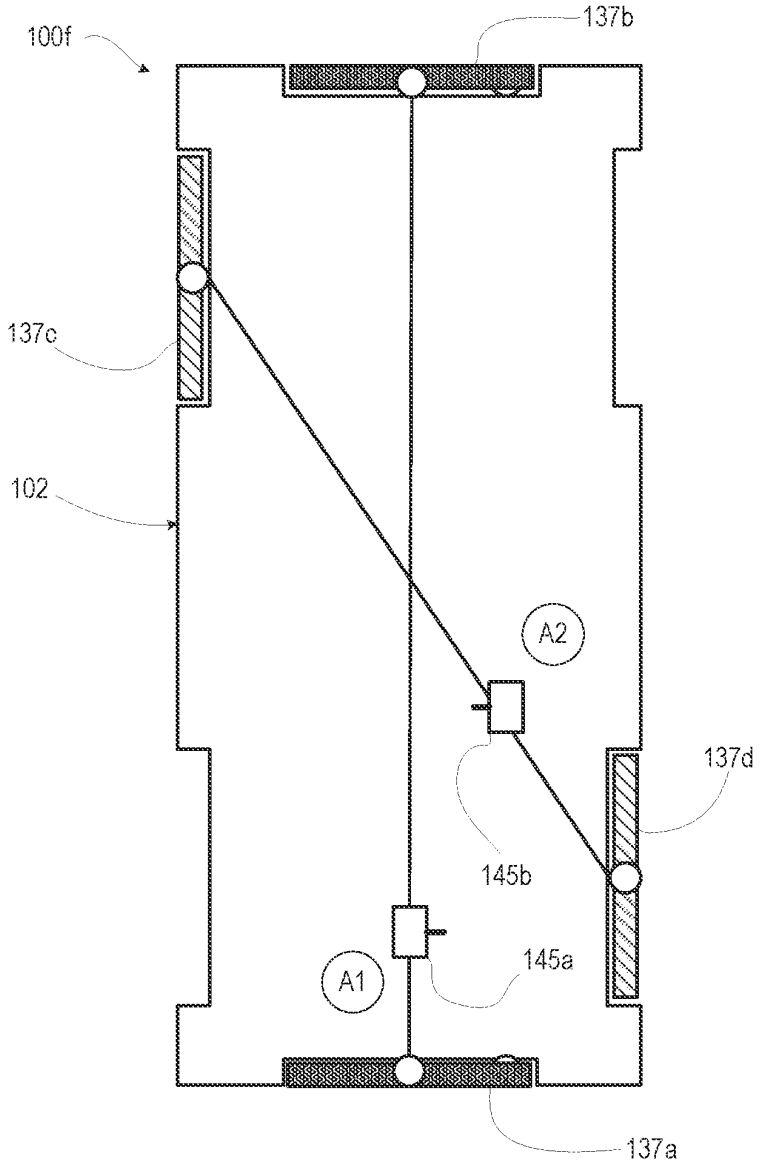

FIG. 8

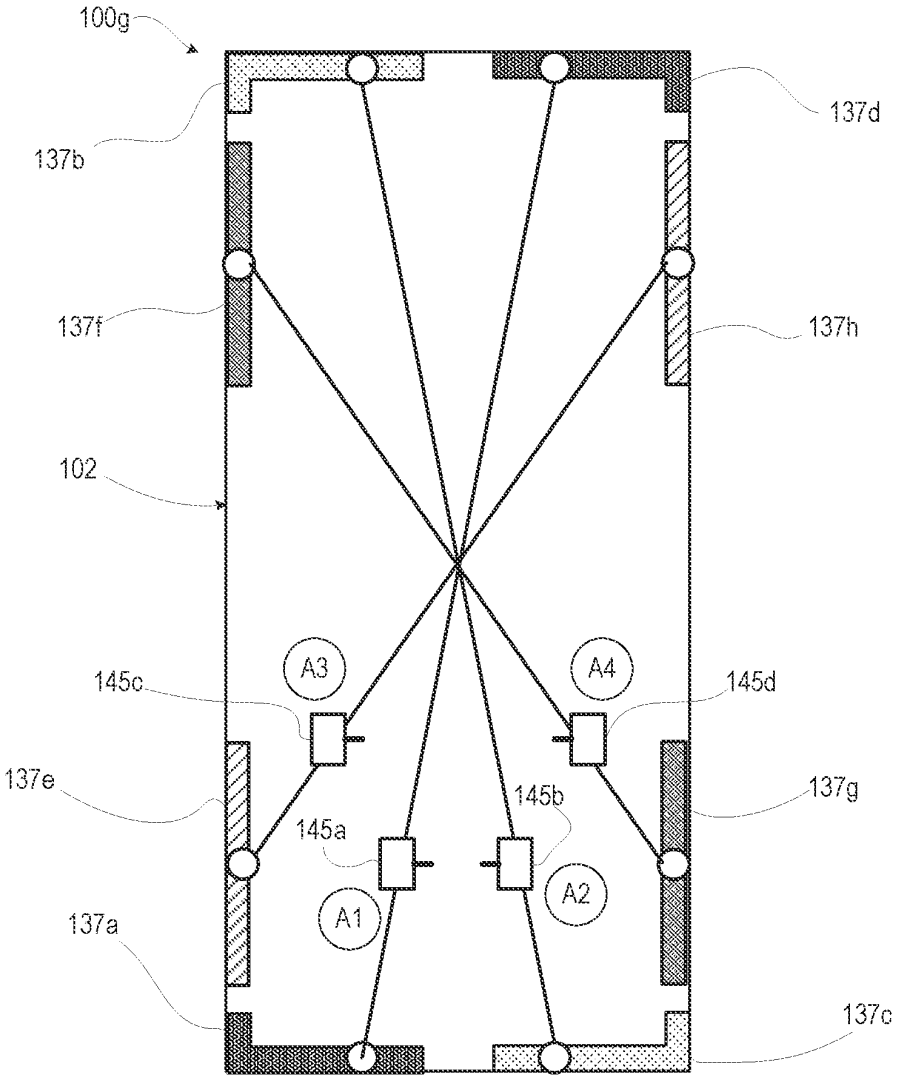
100g
137b
137d
137f
137h
102
A3
A4
145c
145d
137e
145b
137g
145a
A2
A1
137a
137c

FIG. 9A

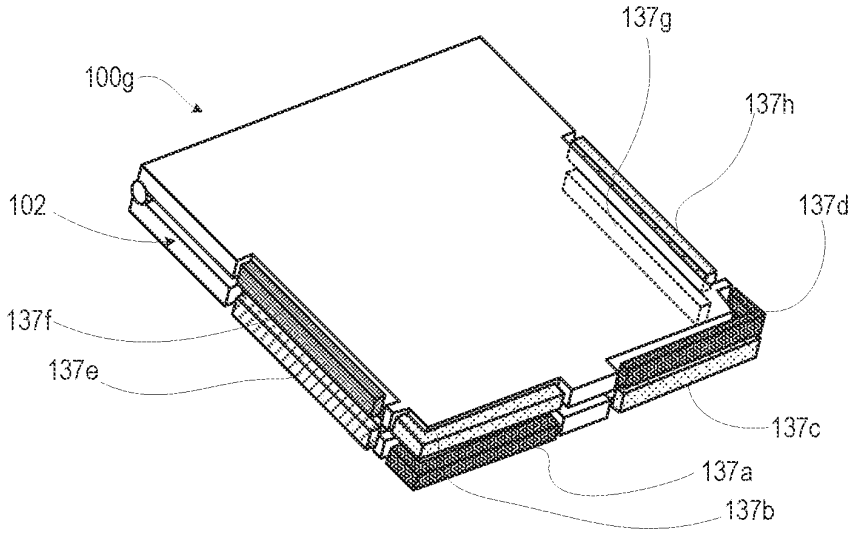

FIG. 9B

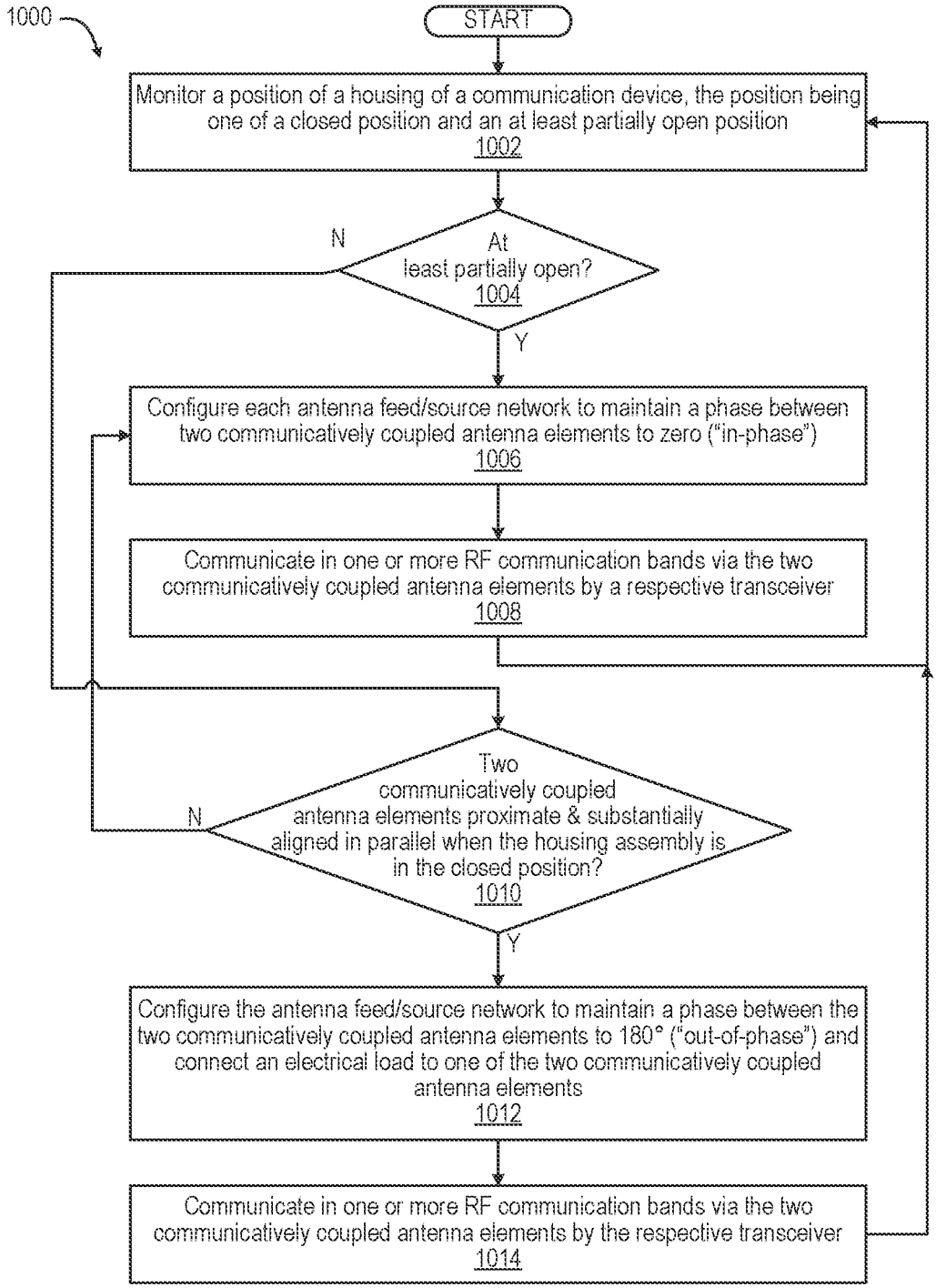
1000
START
Monitor a position of a housing of a communication device, the position being one of a closed position and an at least partially open position
1002
At least partially open?
1004
N
Y
Configure each antenna feed/source network to maintain a phase between two communicatively coupled antenna elements to zero ("in-phase")
1006
Communicate in one or more RF communication bands via the two communicatively coupled antenna elements by a respective transceiver
1008
Two communicatively coupled antenna elements proximate & substantially aligned in parallel when the housing assembly is in the closed position?
1010
N
Y
Configure the antenna feed/source network to maintain a phase between the two communicatively coupled antenna elements to 180° ("out-of-phase") and connect an electrical load to one of the two communicatively coupled antenna elements
1012
Communicate in one or more RF communication bands via the two communicatively coupled antenna elements by the respective transceiver
1014

FIG. 10

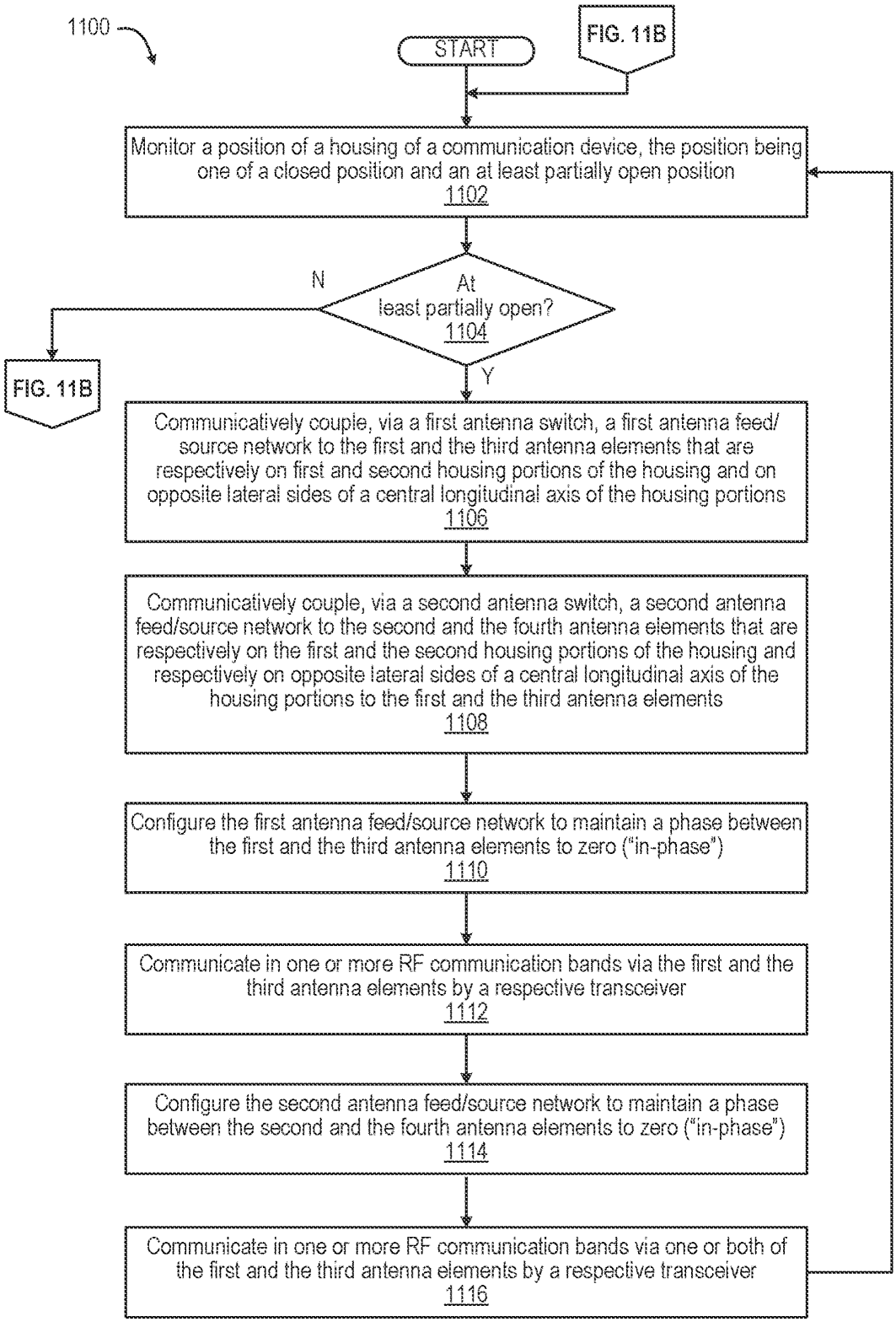
1100
START
FIG. 11B
Monitor a position of a housing of a communication device, the position being one of a closed position and an at least partially open position
1102
At least partially open?
1104
N
Y
FIG. 11B
Communicatively couple, via a first antenna switch, a first antenna feed/source network to the first and the third antenna elements that are respectively on first and second housing portions of the housing and on opposite lateral sides of a central longitudinal axis of the housing portions
1106
Communicatively couple, via a second antenna switch, a second antenna feed/source network to the second and the fourth antenna elements that are respectively on the first and the second housing portions of the housing and respectively on opposite lateral sides of a central longitudinal axis of the housing portions to the first and the third antenna elements
1108
Configure the first antenna feed/source network to maintain a phase between the first and the third antenna elements to zero ("in-phase")
1110
Communicate in one or more RF communication bands via the first and the third antenna elements by a respective transceiver
1112
Configure the second antenna feed/source network to maintain a phase between the second and the fourth antenna elements to zero ("in-phase")
1114
Communicate in one or more RF communication bands via one or both of the first and the third antenna elements by a respective transceiver
1116

FIG. 11A

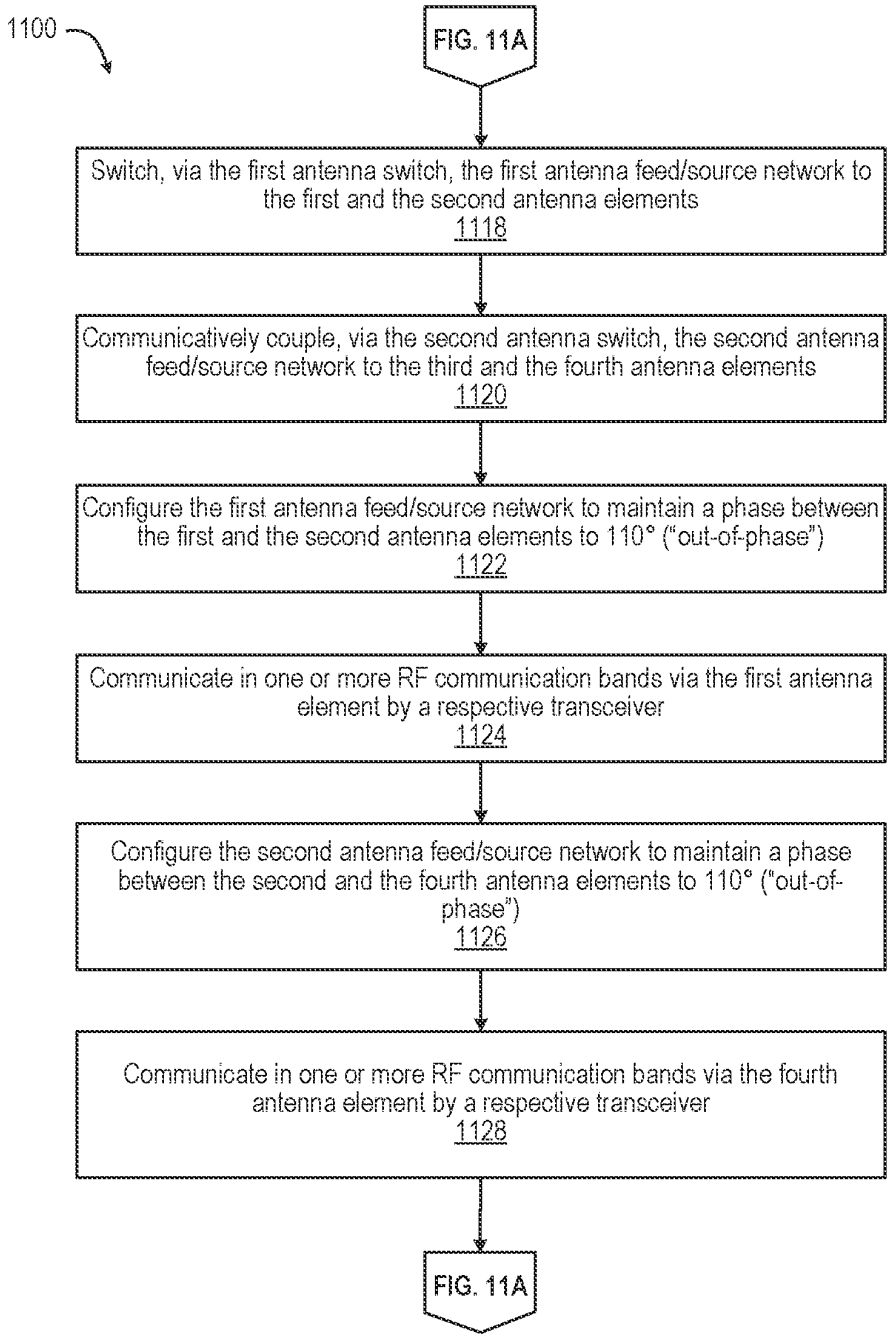
1100
FIG. 11A
Switch, via the first antenna switch, the first antenna feed/source network to the first and the second antenna elements
1118
Communicatively couple, via the second antenna switch, the second antenna feed/source network to the third and the fourth antenna elements
1120
Configure the first antenna feed/source network to maintain a phase between the first and the second antenna elements to 110° ("out-of-phase")
1122
Communicate in one or more RF communication bands via the first antenna element by a respective transceiver
1124
Configure the second antenna feed/source network to maintain a phase between the second and the fourth antenna elements to 110° ("out-of-phase")
1126
Communicate in one or more RF communication bands via the fourth antenna element by a respective transceiver
1128
FIG. 11A

FIG. 11B

COMMUNICATION DEVICE HAVING A CONFIGURABLE HOUSING ASSEMBLY WITH MULTIPLE ANTENNAS

TECHNICAL FIELD

The present disclosure relates generally to communication devices having multiple antennas that support simultaneous communication channels, and more particularly to communication devices having multiple antennas that support simultaneous communication channels within a configurable housing assembly adjustable between an open and a closed position.

DESCRIPTION OF THE RELATED ART

Communication devices, such as smartphones, incorporate a number of antennas to support multiple frequency bands assigned to various types of communication networks. Generally-known communication devices having a flip form factor can have degraded antenna performance in certain RF bands when a configurable housing assembly of the communication device is folded or closed. During folding or closing, components in one movable portion of the communication device are brought close to components in the other portion of the communication device, changing antenna performance for certain antennas or antenna arrays. Conventionally, communication devices having a "candy bar" form factor that do not fold or close have an antenna architecture that spaces antennas around a periphery of a unitary housing. Communication device having a flip form factor ("flip phone") are generally smaller with insufficient places to put antennas for antenna isolation when the device is closed. The flip phones thus lose functionality for simultaneous communication by multiple transceivers.

BRIEF DESCRIPTION OF THE DRAWINGS

The description of the illustrative embodiments can be read in conjunction with the accompanying figures. It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. As an example, the dimensions of some of the elements are exaggerated relative to other elements. Embodiments incorporating teachings of the present disclosure are shown and described with respect to the figures presented herein, in which:

FIG. **1** depicts a functional block diagram of a communication device having multiple antennas operating in a communication environment and within which the features of the present disclosure are advantageously implemented, according to one or more embodiments;

FIG. **2**A depicts a three-dimensional view of an example communication device having a configurable housing assembly, presented in a closed position, according to one or more embodiments;

FIG. **2**B depicts a three-dimensional view of the example communication device of FIG. **2**A with the configurable housing assembly in a partially open position, according to one or more embodiments;

FIG. **2**C depicts a three-dimensional view of the example communication device of FIG. **2**A with the configurable housing assembly in a fully open position, according to one or more embodiments;

FIG. **3**A depicts a front view of an example communication device with one antenna feed/source network switched in response to the housing assembly being in the open position, according to one or more embodiments;

FIG. **3**B depicts a different front view of the example communication device of FIG. **3**A with the antenna feed/source network switched, according to one or more embodiments;

FIG. **3**C depicts a three-dimensional view of the example communication device of FIG. **3**B with the housing assembly in the closed position, according to one or more embodiments;

FIG. **4**A depicts a front view of an example communication device configured with four antenna feed/source networks that are switched in response to the housing assembly being in the open position, according to one or more embodiments;

FIG. **4**B depicts a different front view of the example communication device of FIG. **4**A having the four antenna feed/source networks switched, according to one or more embodiments;

FIG. **4**C depicts a three-dimensional view of the example communication device of FIG. **4**A with the housing assembly is in the closed position, according to one or more embodiments;

FIG. **5** depicts a three-dimensional view of an example communication device having four antennas supported by a housing assembly that is in a closed position, according to one or more embodiments;

FIG. **6** is a graphical plot of radiation efficiency versus frequency for three antenna feed/source network configurations between two proximate antennas that are in a substantially parallel alignment, according to one or more embodiments;

FIG. **7**A depicts a front view of an example communication device having a housing assembly that is in the open position and with four antenna feed/source networks that change a phase between a respective pair of antennas in response to the housing assembly being in the open position, according to one or more embodiments;

FIG. **7**B depicts a three-dimensional view of the example communication device of FIG. **7**A with the housing assembly in the closed position, according to one or more embodiments;

FIG. **8** depicts a front diagram of an example communication device having a housing assembly that is in the open position and with one of two antenna feed/source networks that change a phase between a respective pair of antennas in response to the housing assembly being in the open position, according to one or more embodiments;

FIG. **9**A depicts a front diagram of an example communication device with four antenna feed/source networks that change an active/inactive status of a respective pair of antenna elements in response to the housing assembly being in the open position, according to one or more embodiments;

FIG. **9**B depicts a three-dimensional view of the example communication device of FIG. **9**A with the housing assembly in the closed position, according to one or more embodiments;

FIG. **10** presents a flow diagram of a method for enabling multiple transceiver communication in a communication device having multiple antennas arranged within a configurable housing assembly, according to one or more embodiments; and

FIGS. **11**A-**11**B (FIG. **11**) present a flow diagram of a method for enabling multiple transceiver communication with increased spatial diversity in a communication device while a configurable housing assembly is in an open position, according to one or more embodiments.

DETAILED DESCRIPTION

According to aspects of the present disclosure, a communication device, a computer program product, and a method enable multiple transceivers to communicate via multiple antennas supported by a configurable housing assembly. The communication device includes first and second housing portions, connected at respective proximal sides for relative movement between an open position and a closed position about a lateral axis. First and second antenna elements of a first antenna array are supported respectively by the first and the second housing portions. Each of the first and the second antenna elements has an elongated shape and is configured to communicate in at least a radio frequency (RF) low band. The first antenna element is proximate to and substantially aligned in parallel with the second antenna element when the housing assembly is in the closed position. The first antenna element is separated from the second antenna element when the housing assembly is in the open position. A first antenna feed/source network that is communicatively coupled to the first and the second antenna elements eliminates array cancellations between the first and the second antenna elements when the housing assembly is in the closed position.

In the following detailed description of exemplary embodiments of the disclosure, specific exemplary embodiments in which the various aspects of the disclosure may be practiced are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, architectural, programmatic, mechanical, electrical, and other changes may be made without departing from the spirit or scope of the present disclosure. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims and equivalents thereof. Within the descriptions of the different views of the figures, similar elements are provided similar names and reference numerals as those of the previous figure(s). The specific numerals assigned to the elements are provided solely to aid in the description and are not meant to imply any limitations (structural or functional or otherwise) on the described embodiment. It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. As an example, the dimensions of some of the elements are exaggerated relative to other elements.

It is understood that the use of specific component, device and/or parameter names, such as those of the executing utility, logic, and/or firmware described herein, are for example only and not meant to imply any limitations on the described embodiments. The embodiments may thus be described with different nomenclature and/or terminology utilized to describe the components, devices, parameters, methods and/or functions herein, without limitation. References to any specific protocol or proprietary name in describing one or more elements, features or concepts of the embodiments are provided solely as examples of one implementation, and such references do not limit the extension of the claimed embodiments to embodiments in which different element, feature, protocol, or concept names are utilized. Thus, each term utilized herein is to be given its broadest interpretation given the context in which that term is utilized.

As further described below, implementation of the functional features of the disclosure described herein is provided within processing devices and/or structures and can involve use of a combination of hardware, firmware, as well as several software-level constructs (e.g., program code and/or program instructions and/or pseudo-code) that execute to provide a specific utility for the device or a specific functional logic. The presented figures illustrate both hardware components and software and/or logic components.

Those of ordinary skill in the art will appreciate that the hardware components and basic configurations depicted in the figures may vary. The illustrative components are not intended to be exhaustive, but rather are representative to highlight essential components that are utilized to implement aspects of the described embodiments. As an example, other devices/components may be used in addition to or in place of the hardware and/or firmware depicted. The depicted example is not meant to imply architectural or other limitations with respect to the presently described embodiments and/or the general invention. The description of the illustrative embodiments can be read in conjunction with the accompanying figures. Embodiments incorporating teachings of the present disclosure are shown and described with respect to the figures presented herein.

FIG. **1** is a functional block diagram of an electronic device, and more particularly communication device **100**, which is managed by controller **101**, in an operating environment and within which the features of the present disclosure are advantageously implemented. According to one aspect, communication device **100** includes configurable housing assembly **102** having first and second housing portions **103***a*-**103***b* that are connected at respective first and second proximal sides **104***a*-**104***b* enabling relative movement of the housing portions about lateral axis **105** between an open position and a closed position. Each of first and the second housing portions **103***a*-**103***b* have respective distal side **106***a*-**106***b* opposite to respective proximal side **104***a*-**104***b*. First lateral side **107***a* and second lateral side **108***a* extend between proximal side **104***a* and distal side **106***a* of first housing portion **103***a*. First lateral side **107***b* and second lateral side **108***b* extend between proximal side **104***b* and distal side **106***b* of second housing portion **103***b*. Controller **101** is communicatively coupled to housing position sensor **109** that detects when housing assembly **102** is in: (i) a closed position; and (ii) a partially open position or fully open position. Controller **101** configures communication subsystem **111** based at least in part on the position of housing assembly **102**. Housing position sensor **109** can be one of: (i) a two-position binary switch which detects the closed position and any other position considered a partially open position (i.e., not a closed position); (ii) a multiple position switch or discrete values; or (iii) a continuous range sensor. With each implementation, housing position sensor **109** detects the partially open position based on the two housing portions being a predetermined distance or number of degrees apart from each other (e.g., at 30° or 45°). The distance or number of degrees can be empirically determined to correspond with when the antennas are sufficiently apart from each other to not cause antenna-to-antenna transmission interference.

Communication device **100** can be one of a host of different types of devices, including but not limited to, a mobile cellular phone, satellite phone, or smart-phone, a laptop, a net-book, an ultra-book, a networked smart watch or networked sports/exercise watch, and/or a tablet computing device or similar device that can include wireless and/or wired communication functionality. As an electronic device supporting wireless communication, communication device **100** can be utilized as, and also be referred to as, a system, device, subscriber unit, subscriber station, mobile station

(MS), mobile, mobile device, remote station, remote terminal, user terminal, terminal, user agent, user device, a Session Initiation Protocol (SIP) phone, a wireless local loop (WLL) station, a personal digital assistant (PDA), computer workstation, a handheld device having wireless connection capability, a computing device, or other processing devices connected to a wireless modem.

Referring again to the specific component makeup and the associated functionality of communication device **100**. In one or more embodiments, communication device **100** includes device memory **112**, communication subsystem **111**, data storage subsystem **113**, and input/output (I/O) subsystem **114**. Device memory **112** and each subsystem (**111**, **113**, and **114**) are managed by controller **101**. Device memory **112** includes program code and applications such as antenna control application **115**, communication applications **116**, and other application(s) **117** that use communication services. Device memory **112** further includes operating system (OS) **118**, firmware interface **119**, such as basic input/output system (BIOS) or Uniform Extensible Firmware Interface (UEFI), and firmware **120**. Device memory **112** includes antenna configuration data **121** or other computer data **122** used by antenna control application **115**. As an example, antenna configuration data **121** can include antenna assignments to a particular transceiver communication channel based on operating contexts. As an example, context can be MIMO antenna control for increased antenna gain. As another example, the context can be supporting execution of one or more applications. Particular applications can have particular rates of transmitting and receiving data with specific data latency requirements that dictate particular prioritization of communication connections. As an additional example, context can be based at least in part on power consumption and device thermal management that limit communication channels.

Processor subsystem **124** of controller **101** executes program code to provide operating functionality of communication device **100**. The software and/or firmware modules have varying functionality when their corresponding program code is executed by processor subsystem **124** or secondary processing devices within communication device **100**. Processor subsystem **124** of controller **101** can execute program code of antenna control application **115** to configure communication subsystem **111**.

I/O subsystem **114** includes image capturing device(s) **126**. I/O subsystem **114** includes user interface devices such as display device **127**, motion detection sensors **128**, touch/haptic controls **129**, microphone **130**, and audio output device(s) **131**. I/O subsystem **114** also includes I/O controller **132**. In one or more embodiments, motion detection sensors **128** can detect an orientation and movement of the communication device **100** that indicates that the communication device **100** should activate display device **127** or should vertically reorient visual content presented on display device **127**. In one or more embodiments, motion detection sensors **128** are used for functions other than user inputs, such as detecting an impending ground impact. I/O controller **132** connects to internal devices **133**, which are internal to housing assembly **102** and to peripheral devices **134**, such as external speakers, which are external to housing assembly **102** of communication device **100**. Examples of internal devices **133** are computing, storage, communication, or sensing components depicted within housing assembly **102**. I/O controller **132** supports the necessary configuration of connectors, electrical power, communication protocols, and data buffering to act as an interface to internal devices **133** and peripheral devices **134** to other components of communication device **100** that use a different configuration for inputs and outputs.

Communication subsystem **111** of communication device **100** enables wireless communication with external communication system **135**. Communication subsystem **111** includes antenna subsystem **136** having lower band antennas **137***a*-**137***m* and higher band antenna array modules **138***a*-**138***n* that can be attached in/at different portions of housing assembly **102**. Communication subsystem **111** includes radio frequency (RF) front end **139** and communication module **140**. RF front end **139** includes transceiver(s) **141**, which includes transmitter(s) **142** and receiver(s) **143**. RF front end **139** further includes modem(s) **144**. RF front end **139** includes antenna feed/source networks **145**, antenna switch network **146**, antenna impedance sensor(s) **147**, and antenna matching network(s) **148**. Communication module **140** of communication subsystem **111** includes baseband processor **149** that communicates with controller **101** and RF front end **139**. Baseband processor **149** operates in a baseband frequency range to encode data for transmission and decode received data, according to a communication protocol. Modem(s) **144** modulate baseband encoded data from communication module **140** onto a carrier signal to provide a transmit signal that is amplified by transmitter(s) **142**. Modem(s) **144** demodulates each signal received from external communication system **135** detected by antenna subsystem **136**. The received signal is amplified and filtered by receiver(s) **143**, which demodulate received encoded data from a received carrier signal. Antenna feed/source networks **145** transmits or receives from particular portions of antenna subsystem **136** and can adjust a phase between particular portions of antenna subsystem **136**. Antenna switch network **146** can connect particular combinations of antennas (**137***a*-**137***m*, **138***a*-**138***n*) to transceiver(s) **141**. Controller **101** can monitor changes in antenna impedance detected by antenna impedance sensor(s) **147** for determining portions of antenna subsystem **136** that are blocked. Antenna matching network(s) **148** are connected to particular lower band antennas **137***a*-**137***m* to tune impedances respectively of lower band antennas **137***a*-**137***m* to match impedances of transceivers **141**. Antenna matching network(s) **148** can also be used to detune the impedance of lower band antennas **137***a*-**137***m* to not match the impedance of transceivers **141** to electromagnetically isolate a particular antenna.

In one or more embodiments, controller **101**, via communication subsystem **111**, performs multiple types of over-the-air (OTA) communication with network nodes **150** of external communication system **135**. Particular network nodes **150** can be part of communication networks **151** of public land mobile networks (PLMNs) that provide connections to plain old telephone systems (POTS) **152** for voice calls and wide area networks (WANs) **153** for data sessions. WANs **153** can include Internet and other data networks. The particular network nodes **150** can be cells **154** such as provided by base stations or base nodes that support cellular OTA communication using RAT as part of a radio access network (RAN). Unlike earlier generations of cellular services, where voice and data were handled using different RATs, both are now integrated with voice being considered one kind of data communication. Conventionally, broadband, packet-based transmission of text, digitized voice, video, and multimedia communication are provided using Fourth generation (4G) RAT of evolved UTMS radio access (E-UTRA), referred to a Long Term Evolved (LTE), although some cellular data service is still being provided by

third generation (3G) Universal Mobile Telecommunications Service (UMTS). A fifth generation (5G) RAT, referred to as fifth generation new radio (5G NR), is being deployed to at least augment capabilities of 4G LTE with a yet higher capability of data transfer. Development continues for what will be six generation (6G) RATs and more advanced RATs.

In one or more embodiments, network nodes **150** can be access node(s) **155** that support wireless OTA communication. Communication subsystem **111** can receive OTA communication from location services such as provided by global positioning system (GPS) satellites **156**. Communication subsystem **111** communicates via OTA communication channel(s) **158***a* with cells **154**. Communication subsystem **111** communicates via wireless communication channel(s) **158***b* with access node **155**. In one or more particular embodiments, access node **155** supports communication using one or more IEEE 802.11 wireless local area network (WLAN) protocols. In one or more particular embodiments, communication subsystem **111** communicates with one or more locally networked devices **159** via wired or wireless link **158***c* provided by access node **155**. Communication subsystem **111** receives downlink broadcast channel(s) **158***d* from GPS satellites **156** to obtain geospatial location information.

In one or more embodiments, controller **101**, via communication subsystem **111**, performs multiple types of OTA communication with local communication system **160**. In one or more embodiments, local communication system **160** includes wireless headset **161** and smart watch **162** that are coupled to communication device **100** to form a personal access network (PAN). Communication subsystem **111** communicates via low power wireless communication channel(s) **158***e* with headset **161**. Communication subsystem **111** communicates via second low power wireless communication channel(s) **158***f*, such as Bluetooth, with smart watch **162**. In one or more particular embodiments, communication subsystem **111** communicates with other communication device(s) **163** via wireless link **158***g* to form an ad hoc network.

Data storage subsystem **113** of communication device **100** includes data storage device(s) **166**. Controller **101** is communicatively connected, via system interlink **167**, to data storage device(s) **166**. Data storage subsystem **113** provides applications, program code, and stored data on nonvolatile storage that is accessible by controller **101**. As an example, data storage subsystem **113** can provide a selection of program code and applications such as antenna control application **115**, location service applications **116**, and other application(s) **117** that use communication services. These applications can be loaded into device memory **112** for execution by controller **101**. In one or more embodiments, data storage device(s) **166** can include hard disk drives (HDDs), optical disk drives, and/or solid-state drives (SSDs), etc. Data storage subsystem **113** of communication device **100** can include removable storage device(s) (RSD(s)) **169**, which is received in RSD interface **170**. Controller **101** is communicatively connected to RSD **169**, via system interlink **167** and RSD interface **170**. In one or more embodiments, RSD **169** is a non-transitory computer program product or computer readable storage device. Controller **101** can access RSD **169** or data storage device(s) **166** to provision communication device **100** with program code, such as antenna control application **115** and other applications **117**. When executed by controller **101**, the program code causes or configures communication device **100** to provide the multi-transceiver operational functionality using a configurable housing assembly described herein.

Controller **101** includes processor subsystem **124**, which includes one or more central processing units (CPUs), depicted as data processor **172**. Processor subsystem **124** can include one or more digital signal processors **173** that are integrated with data processor **172** or are communicatively coupled to data processor **172**, such as baseband processor **149** of communication module **140**. Controller **101** can include one or more application processor(s) **174** to monitor sensors or controls such as housing position sensor **109** and antenna switch network **146**. In one or embodiments that are not depicted, controller **101** can further include distributed processing and control components that are peripheral or remote to housing assembly **102** or grouped with other components, such as I/O subsystem **114**. Data processor **172** is communicatively coupled, via system interlink **167**, to device memory **112**. In one or more embodiments, controller **101** of communication device **100** is communicatively coupled via system interlink **167** to communication subsystem **111**, data storage subsystem **113**, and input/output subsystem **114**. System interlink **167** represents internal components that facilitate internal communication by way of one or more shared or dedicated internal communication links, such as internal serial or parallel buses. As utilized herein, the term "communicatively coupled" means that information signals are transmissible through various interconnections, including wired and/or wireless links, between the components. The interconnections between the components can be direct interconnections that include conductive transmission media or may be indirect interconnections that include one or more intermediate electrical components. Although certain direct interconnections (interlink **167**) are illustrated in FIG. **1**, it is to be understood that more, fewer, or different interconnections may be present in other embodiments. Interlink **167** communicatively connects components in first housing portion **103***a* to components in second housing portion **103***b*. Power distribution subsystem **168** provides electrical power to components in first housing portion **103***a* and components in second housing portion **103***b*.

Controller **101** manages, and in some instances directly controls, the various functions and/or operations of communication device **100**. These functions and/or operations include, but are not limited to including, application data processing, communication with other communication devices, navigation tasks, image processing, and signal processing. In one or more alternate embodiments, communication device **100** may use hardware component equivalents for application data processing and signal processing. As an example, communication device **100** may use special purpose hardware, dedicated processors, general purpose computers, microprocessor-based computers, micro-controllers, optical computers, analog computers, dedicated processors and/or dedicated hard-wired logic.

Within the description of the remaining figures, references to similar components presented in a previous figure are provided the same reference numbers across the different figures. Where the named component is presented with different features or functionality, a different reference numeral or a subscripted reference numeral is provided (e.g., **100***a* in place of **100**). FIG. **2**A depicts a three-dimensional view of an example communication device **100***a* having housing assembly **102** configured in a closed position. Communication device **100***a* can have similar or identical components and functionality of communication device **100** (FIG. **1**). FIG. **2**B depicts a three-dimensional view of example communication device **100***a* having housing assembly **102** configured in a partially open position. Hous-

ing position sensor **109** (FIG. **1**) can detect a particular amount of pivoting from the closed position to the partially open position that is sufficient for a change in an operational characteristic of communication device **100***a*. As an example, the partially open position can be sufficient for viewing display device **127** (FIG. **1**), prompting controller **101** (FIG. **1**) to activate display device **127** (FIG. **1**). For another example, the partially open position can be sufficient for two or more antennas that are respectively on first and second housing portions **103***a*-**103***b* to sufficiently separated for independent operation without impairing antenna efficiency. The partially open position can be substantially the same as the fully open position with regard to antenna operation. FIG. **2**C depicts a three-dimensional view of example communication device **100***a* having housing assembly **102** configured in a fully open position. In FIGS. **2**A-**2**C, housing assembly **102** of communication device **100***a* is configurable by having first and second housing portions **103***a*-**103***b* that are connected at respective first and second proximal sides **104***a*-**104***b* for relative movement about lateral axis **105** between an open position and a closed position. In one embodiment, first housing portion **103***a* is a base housing, second housing portion **103***b* is a flip housing, first lateral sides **107***a*-**107***b* are on the left, and second lateral sides **108***a*-**108***b* are on the right.

According to one aspect, housing assembly **102** includes a plurality of possible antenna mounting locations, illustrated as antenna mounting locations **201**-**208**. First antenna mounting location **201** is a left section of distal side **106***a* of first housing portion **103***a*. Second antenna mounting location **202** is a left section of distal side **106***b* of second housing portion **103***b*. Third antenna mounting location **203** is a right section of distal side **106***a* of first housing portion **103***a*. Fourth antenna mounting location **204** is a right section of distal side **106***b* of second housing portion **103***b*. Fifth antenna mounting location **205** is on left lateral side **107***a* of first housing portion **103***a*. Sixth antenna mounting location **206** is on left lateral side **107***b* of second housing portion **103***b*. Seventh antenna mounting location **207** is on right lateral side **108***a* of first housing portion **103***a*. Eighth antenna mounting location **208** on right lateral side **108***b* of second housing portion **103***b*. While housing assembly **102** is in the closed position of FIG. **2**A, specific pairs of antenna mounting locations **201**-**208** are aligned proximate to each other across the base and flip housing. These aligned pairs include: (i) first and second antenna mounting locations **201**-**202**; (ii) third and fourth antenna mounting locations **203**-**204**; (iii) fifth and sixth antenna mounting locations **205**-**206**; and (iv) seventh and eight antenna mounting locations **207**-**208**. The close proximity impairs antenna efficiency.

At a partially open position of housing assembly **102** in FIG. **2**B, separation between first and second housing portions **103***a*-**103***b* is sufficient for viewing front surfaces **211***a*-**211***b* respectively of first and second housing portions **103***a*-**103***b*. At a partially open position of housing assembly **102** in FIG. **2**B, separation between paired antenna mounting locations **201**-**208** is sufficient for antenna performance in low bands that is substantially the same as housing assembly **102** being in the fully open position of FIG. **2**C. The at least partially open position of housing assembly **102** can be one or more positions greater than 0° and less than 180° defined as pivot angles between first and second housing portions **103***a*-**103***b*. As an example, the defined pivot angles can be based on one or more considerations such as: (i) capabilities of housing position sensor **109** (FIG. **1**); (ii) mechanically available positions of housing position **102**; (iii) usability of user interface components; and (iv) spatial coverage of antennas **137***a*-**137***d* as a function of pivot angle. As one example, housing assembly **102** can have a pivot mechanism that is stable in three positions: (i) fully closed; (ii) open 90°; and (iii) fully open. At least partially open position can be based on a pivot position of at least 45° that corresponds to activating a front display device in preparation for viewing at 90° or fully open. As another example, certain pivot positions affect an ability to communicate in certain spatial directions. Detecting one or more positions of housing **102** can be used to select antennas **137***a*-**137***d* for spatial diversity. Two or more at least partially open positions of housing assembly **102** can be detected for triggering changes in an operational mode of communication device **100***a*, such as changing a use of display devices **127** (FIG. **1**). For clarity, eight (8) positions **201**-**208** for receiving eight (8) antennas **137***a*-**137***h* (FIG. **1**) are provided. In one or more embodiments, fewer or more antenna positions can be provided for use with fewer or more antennas. In FIG. **2**C, housing assembly **102** is in a fully open position with substantially 180° rotation between first and second housing portions **103***a*-**103***b*.

FIG. **3**A depicts a front diagram of example communication device **100***b* having one antenna feed/source network that is in a switch state that corresponds to the housing assembly being in one of the closed position and the open position. Communication device **100***b* can have similar or identical components and functionality of communication device **100** (FIG. **1**). In one or more embodiments, communication device **100***b* includes antennas **137***a*-**137***d* within first housing portion **100***a* and antennas **137***e*-**137***h* within second housing portion **100**. When housing assembly **102** is in the close position, first lateral sides **170***a*-**107***b*, distal sides **106***a*-**106***b*, and second lateral sides **108***a*-**108***b* of first and second housing portions **103***a*-**103***b* respectively align. Antennas **137***a*, **137***c*, **137***e*, and **137***g* substantially align in parallel respectively with antenna **137***b*, **137***d*, **137***f*, and **137***h*. First antenna **137***a* is positioned at a first lateral section of distal side **106***a* of first housing portion **103***a*. Second antenna **137***b* is positioned at a first lateral section of distal side **106***b* of second housing portion **103***b*. Third antenna **137***c* is positioned at a second lateral section of distal side **106***a* of first housing portion **103***a*. Fourth antenna **137***d* is positioned at a second lateral section of distal side **106***b* of second housing portion **103***b*. Fifth antenna **137***e* is positioned at first lateral side **107***a* of first housing portion **103***a*. Sixth antenna **137***f* is positioned at first lateral side **107***b* of second housing portion **103***b*. Seventh antenna **137***g* is positioned at second lateral side **108***a* of first housing portion **103***a*. Eighth antenna **137***h* is positioned at second lateral side **108***b* of second housing portion **103***b*. First antenna feed/source network(s) **145***a* is communicatively connected to first antenna **137***a*. First antenna switch **146***a* communicatively connects first antenna feed/source network(s) **145***a* to one of second and fourth antennas **137***b*-**137***d*. In one or more embodiments, first antenna switch **146***a* is a one pole two throw switch that is configured to connect first antenna feed/source network **145***a* to third antenna **137***c* while housing assembly **102** is in the open position. First and fourth antennas **137***a*, **137***d* provide increased physical separation for spatial diversity over first and second antennas **137***a*-**137***b*. Second antenna **137***b* is available for being used separately.

FIG. **3**B depicts a front diagram of example communication device **100***b* with first antenna feed/source network **145***a* that is switched by first antenna switch **146***a* to second antenna **137***b*. FIG. **3**C depicts a three-dimensional view of

example communication device **100***b* while housing assembly **102** is in the closed position. The two antennas in each of the different pairs of antennas **137***a*-**137***h* are too close to each other for independent communication. Also, while housing assembly **102** is in the closed position, first and second antennas **137***a*-**137***b* are proximate to and substantially aligned with each other. Fourth antenna **137***d* is available for being used separately. In response to housing assembly **102** is in the closed position, first antenna feed/source network **145***a* is switched by first antenna switch **146***a* to second antenna **137***b* as depicted in FIG. **3**B.

FIG. **4**A depicts a front diagram of example communication device **100***c* with four antenna feed/source networks switched by first antenna switch **146***b* in response to the housing assembly **102** being in the open position. Communication device **100***c* can have similar or identical components and functionality of communication device **100** (FIG. **1**). Antennas **137***a*-**137***h* are positioned identically or similarly as described above for communication device **100***b* (FIGS. **3**A-**3**B). In addition to first antenna feed/source network **145***a*, communication device **100***c* includes second, third, and fourth antenna feed/source networks **145***b*-**145***d*. First and second antenna switches **146***b*-**146***c* are two pole two throw switches. Second antenna feed/source network **145***b* is communicatively connected to third antenna **137***c*. First antenna switch **146***b* further communicatively connects second antenna feed/source network **145***b* to one of second and fourth antennas **137***b*, **137***d*. First antenna feed/source network(s) **145***a* is communicatively connected to first antenna **137***a*. First antenna switch **146***b* communicatively connects first antenna feed/source network(s) **145***a* to one of second and fourth antennas **137***b*, **137***d*. First antenna switch **146***b* is further configured to connect second antenna feed/source network(s) **145***b* to second antenna **137***b* while housing assembly **102** is in the open position. While housing assembly **102** is in the open position, first and fourth antennas **137***a*, **137***d* are on opposite corners of communication device **100***c*. Similarly, second and third antennas **137***b*-**137***c* are on the other opposite corners of communication device **100***c*. The greatest possible physical separation of each combination (1^{st} and 4^{th}; and 2^{nd} and 3^{rd}) provides the highest possible spatial diversity.

Third antenna feed/source network **145***c* is communicatively connected to fifth antenna **137***e*. Fourth antenna feed/source network **145***d* is communicatively connected to seventh antenna **137***g*. To increase spatial diversity while housing assembly **102** is in the open position, second antenna switch **146***c* communicatively connects third antenna feed/source network **145***c* to eighth antenna **137***h*. To increase spatial diversity while housing assembly **102** is in the open position, second antenna switch **146***c* is further configured to connect fourth antenna feed/source network(s) **145***d* to sixth antenna **137***f*. While the housing assembly **102** is in the open position, antenna feed/source networks **145***a*-**145***d* create relative feed phases at the communicatively-connected pair of antennas **137***a*-**137***h* at specific values for best performance. As an example, first, second, third, and fourth antenna feed/source networks **145***a*-**145***d* create an off-phase (180°) difference at ULB/LB RF communication bands and in-phase (0°) difference connection for MB/HB RF communication bands at respective reference points of two of antennas **137***a*-**137***h*.

FIG. **4**B depicts a front diagram of example communication device **100***c* with first, second, third, and fourth antenna feed/source networks **145***a*-**145***d* switched Each of first, second, third, and fourth antenna feed/source networks **145***a*-**145***d* (FIG. **4**A) configures the respective pair of antennas **137***a*-**137***h* to operate as one antenna, providing four RF transceiver chain capability for communication device **100***c*. As an example, each antenna feed/source network **145***a*-**145***d* provides a zero phase difference ("in-phase") to transceived signals at affected RF communication bands of ultra-low band (ULB) and low band (LB) between communicatively connected antennas **137***a*-**137***h* to mitigate cancellations between the proximate antennas **137***a*-**137***h*. RF communication bands, such mid-band (MB) and high band (HB), that are not significantly affected by proximity can be maintained in-phase with zero degree phase difference. In one or more embodiments, the potential negative effects of antenna proximity are mitigated by open circuiting, short circuiting to ground, and/or connecting a reactive load to one of the antennas **137***a*-**137***h* that has a paired antenna in close proximity when the housing assembly is in the closed position.

FIG. **4**C depicts a three-dimensional view of example communication device **100***c* while housing assembly **102** is in the closed position. The two antennas in each of the different pairs of antennas **137***a*-**137***h* are too close to each other for independent communication. Also, while housing assembly **102** is in the closed position, first and second antennas **137***a*-**137***b* are proximate to and substantially aligned with each other. Fourth antenna **137***d* is available for being used separately. In response to housing assembly **102** is in the closed position, first antenna feed/source network **145***a* is switched by first antenna switches **146***b*-**146***c* as depicted in FIG. **4**B.

FIG. **5** depicts a three-dimensional view of example communication device **100***d* having antenna **137***a*-**137***d* supported by housing assembly **102** that is in a closed position. Communication device **100***d* can have similar or identical components and functionality of communication device **100** (FIG. **1**). First antenna **137***a* is positioned on distal side **106***a* of first housing portion **103***a*. Second antenna **137***b* is positioned on distal side **106***b* of second housing portion **103***b*. Third antenna **137***c* is positioned at a first lateral side **107***b* of second housing portion **103***b*. Fourth antenna **137***d* is positioned at second lateral side **108***a* of first housing portion **103***a*. While housing assembly **102** is in the closed position, first and second antennas **137***a*-**137***b* are proximate and substantially aligned in parallel ("co-located"). Combined radiation efficiency is additive for co-located antennas **137***a*-**137***b* that are driven with in-phase signals. Combined radiation efficiency is subtractive (canceled) for co-located antennas **137***a*-**137***b* that are driven with off-phase signals.

FIG. **6** is a graphical plot **600** of radiation efficiency versus frequency for three antenna feed/source network configurations between two antennas that are proximate to and substantially aligned in parallel with each other, such as depicted by communication device **100***d* of FIG. **5**. First trace **601** is plot of radiation efficiency versus frequency for driving only one of antennas **137***a*-**137***b* (FIG. **5**) with the other one of antennas **137***a*-**137***b* floating (i.e., electrically disconnected). Second trace **602** is a plot of radiation efficiency versus frequency for simultaneously driving antenna **137***a* (FIG. **5**) in-phase and driving antenna **137***b* off-phase with about 4 dB in cancellation resulting, as compared to first trace **601**. Third trace **603** is a plot of radiation efficiency versus frequency for driving both antennas **137***a*-**137***b* (FIG. **5**) in-phase, resulting in about 0.4 dB higher efficiency at 1.5 GHz and about the same efficiency about 1.7 GHz, as compared to first trace **601**.

FIG. **7**A depicts a front diagram of example communication device **100***e* with four antenna feed/source networks that change phase between a respective pair of antennas in

response to housing assembly **102** being in the open position. Communication device **100***e* can have similar or identical components and functionality of communication device **100** (FIG. **1**). Antennas **137***a*-**137***h* are positioned identically or similarly as described above for communication device **100***b* (FIGS. **3**A-**3**B). First antenna feed/source network **145***a* is communicatively connected to first and second antennas **137***a*-**137***b*. Second antenna feed/source network **145***b* is communicatively connected to third and fourth antennas **137***c*-**137***d*. Third antenna feed/source network **145***c* is communicatively connected to fifth and sixth antennas **137***e*-**137***f*. Fourth antenna feed/source network **145***d* is communicatively connected to seventh and eighth antennas **137***g*-**137***h*. First, second, third, and fourth antenna feed/source networks **145***a*-**145***d* create an off-phase (180°) difference at ULB/LB RF communication bands and in-phase (0°) difference connection for MB/HB RF communication bands at respective reference points of two of the antennas **137***a*-**137***h*.

FIG. **7**B depicts a three-dimensional view of example communication device **100***e* while housing assembly **102** is in the closed position. First and second antennas **137***a*-**137***b* are co-located. Third and fourth antennas **137***c*-**137***d* are co-located. Fifth and sixth antennas **137***e*-**137***f* are co-located. Seventh and eighth antennas **137***g*-**137***h* are co-located. In one or more embodiments, phases at reference points of each pair of co-located antennas **137***a*-**137***h* are maintained in-phase for all RF communication bands. In one or more embodiments, one of co-located antennas **137***a*-**137***h* are open circuited, short circuited to ground, or electrically connected to a reactive load. The respective antenna feed/source network **145***a*-**145***d* (FIG. **7**A) redistributes all of the power to the active antenna of the two co-located antennas **137***a*-**137***h*.

FIG. **8** depicts a front diagram of example communication device **100***f* with one of two antenna feed/source networks that change a phase between a respective pair of antennas in response to the housing assembly **102** being in the open position. Communication device **100***f* can have similar or identical components and functionality of communication device **100** (FIG. **1**). First, second, third, and fourth antennas **137***a*-**137***d* are positioned identically or similarly to communication device **100***d* (FIG. **5**). First antenna feed/source network **145***a* is communicatively connected to first and second antennas **137***a*-**137***b* ("inline antenna array architecture"). First antenna feed/source network **145***a* operates as described above for communication device **100***e* (FIG. **7**A), which was also configured with an in-line antenna array architecture. Second antenna feed/source network **145***b* is communicatively connected to third and fourth antennas **137***c*-**137***d* (providing a "diagonal antenna array architecture"). In the closed position, third and fourth antennas **137***c*-**137***d* are not co-located. While housing assembly **102** is both in the open position and the closed position, second antenna feed/source network **145***b* creates an off-phase (180°) difference at ULB/LB RF communication bands and in-phase (0°) difference connection for MB/RB RF communication bands at respective reference points of antennas **137***c*-**137***d*.

FIG. **9**A depicts a front diagram of example communication device **100***g* with four antenna feed/source networks that change phase between a respective pair of antennas in response to the housing assembly **102** being in the open position. Communication device **100***g* can have similar or identical components and functionality of communication device **100** (FIG. **1**). Antennas **137***a*-**137***h* are positioned identically or similarly as described above for communication device **100***b* (FIGS. **3**A-**3**B). First antenna feed/source network **145***a* is communicatively connected to first and fourth antennas **137***a*, **137***d*. Second antenna feed/source network **145***b* is communicatively connected to second and third antennas **137***b*, **137***c*. Third antenna feed/source network **145***c* is communicatively connected to fifth and eighth antennas **137***e*, **137***h*. Fourth antenna feed/source network **145***d* is communicatively connected to sixth and seventh antennas **137***f*, **137***g*. While the housing assembly **102** is in the open position, antenna feed/source networks **145***a*-**145***d* create relative feed phases at the communicatively-connected pair of antennas **137***a*-**137***h* at specific values for best performance. As an example, first, second, third, and fourth antenna feed/source networks **145***a*-**145***d* create an off-phase (180°) difference at ULB/LB RF communication bands and in-phase (0°) difference connection for MB/HB RF communication bands at respective reference points of two of the antennas **137***a*-**137***h*.

FIG. **9**B depicts a three-dimensional view of example communication device **100***g* while housing assembly **102** is in the closed position. First, second, third, and fourth antenna feed/source networks **145***a*-**145***d* deactivate one antenna **137***a*-**137***h* of each pair of co-located antennas **137***a*-**137***h*. As an example, deactivation can include open circuiting, short circuiting to ground, or electrically connecting a reactive load. First, second, third, and fourth antenna feed/source networks **145***a*-**145***d* (FIG. **9**A) distribute all of the power to the one of co-located antennas **137***a*-**137***h* that is active.

FIG. **10** presents a flow diagram of a method for enabling multiple transceiver communication in a communication device having a plurality of antennas arrange in a configurable housing assembly. The description of method **1000** is provided with general reference to the specific components illustrated within the preceding FIGS. **1**, **2**A-**2**C, **3**A-**3**B, **4**A-**4**C, **5**, **6**, **7**A-**7**B, **8**, and **9**A-**9**B. In at least one embodiment, communication device **100**, managed by controller **101**, performs method **1000** by dynamically configuring RF front end **124** using antenna feed/source networks in response to a housing assembly position detected by housing position sensor **109** (FIG. **1**). Controller **101** executes antenna control application **115** (FIG. **1**) to provide the multiple transceiver communication functionality of method **1000**. Specific components described in method **1000** can be identical or similar to components of the same name used to describe preceding FIGS. **1**, **2**A-**2**C, **3**A-**3**B, **4**A-**4**C, **5**, **6**, **7**A-**7**B, **8**, and **9**A-**9**B. Following the start block, method **1000** includes monitoring, via the housing position sensor a position of a housing assembly of a communication device, the position being one of a closed position and an at least partially open position (block **1002**). Method **1000** includes determining whether the housing assembly is in the at least partially open position (decision block **1004**). In response to determining that the housing assembly is in the at least partially open position, method **1000** includes configuring each antenna feed/source network to adjust a phase between two communicatively coupled antenna elements to zero ("in-phase") (block **1006**). Method **1000** includes communicating in one or more RF communication bands via the two communicatively coupled antenna elements by a respective transceiver (block **1008**). Then method **1000** returns to block **1002**.

In response to determining that the housing assembly is not in the at least partially open position, method **1000** includes determining, in decision block **1010**, whether the two communicatively coupled antenna elements are identified as being proximate to each other and substantially

aligned in parallel when the housing assembly is in the closed position. In response to determining that the two communicatively coupled antenna elements are not identified as being proximate to each other and substantially aligned in parallel when the housing assembly is in the closed position, method **1000** returns to block **1006**. In response to determining that the two communicatively coupled antenna elements are identified as being proximate to each other and substantially aligned in parallel when the housing assembly is in the closed position, method **1000** includes configuring the antenna feed/source network to adjust a phase between the two communicatively coupled antenna elements to 180° ("out-of-phase") and connecting an electrical load to one of the two communicatively coupled antenna elements (block **1012**). Method **1000** includes communicating in one or more RF communication bands via the other one of the two communicatively coupled antenna elements by the respective transceiver (block **1014**). Then method **1000** returns to block **1002**.

FIGS. **11**A-**11**B (FIG. **11**) present a flow diagram of a method for enabling multiple transceiver communication with increased spatial diversity in a communication device while a configurable housing assembly is in an open position. The description of method **1100** is provided with general reference to the specific components illustrated within the preceding FIGS. **1**, **2**A-**2**C, **3**A-**3**B, **4**A-**4**C, **5**, **6**, **7**A-**7**B, **8**, **9**A-**9**B, and **10**. In at least one embodiment, communication device **100**, managed by controller **101**, performs method **1000** by dynamically configuring RF front end **124** using antenna feed/source networks in response to housing position sensor **109** (FIG. **1**). Controller **101** executes antenna control application **115** (FIG. **1**) to provide the multiple transceiver communication functionality of method **1000**. Specific components described in method **1000** can be identical or similar to components of the same name used to describe preceding FIGS. **1**, **2**A-**2**C, **3**A-**3**B, **4**A-**4**C, **5**, **6**, **7**A-**7**B, **8**, **9**A-**9**B, and **10**.

With reference to FIG. **11**A, method **1100** includes monitoring a position of a housing assembly of a communication device, the position being one of a closed position and an at least partially open position (block **1102**). First, second, third, and fourth antenna elements are supported by the housing assembly. Method **1100** includes determining whether the housing assembly is in the at least partially open position (decision block **1104**). In response to determining that the housing assembly is in the at least partially open position, method **1100** includes communicatively coupling, via a first antenna switch, a first antenna feed/source network to the first and the third antenna elements that are respectively on first and second housing portions of the housing assembly and on opposite lateral sides of a central longitudinal axis of the housing portions (block **1106**). Method **1100** includes communicatively coupling, via a second antenna switch, a second antenna feed/source network to the second and the fourth antenna elements that are respectively on the first and the second housing portions of the housing assembly and respectively on opposite lateral sides of a central longitudinal axis of the housing portions to the first and the third antenna elements (block **1108**). Method **1100** includes configuring the first antenna feed/source network to adjust a phase between the first and the third antenna elements to zero ("in-phase") (block **1110**). Method **1100** includes communicating in one or more RF communication bands via one or both of the first and the third antenna elements by a respective transceiver (block **1112**). Method **1100** includes configuring the second antenna feed/source network to adjust a phase between the second and the fourth antenna elements to zero ("in-phase") (block **1114**). Method **1100** includes communicating in one or more RF communication bands via the first and the third antenna elements by a respective transceiver (block **1116**). Then method **1100** returns to block **1102**.

In response to determining that the housing assembly is not in the at least partially open position (i.e., closed position), method **1100** includes communicatively coupling, via the first antenna switch, the first antenna feed/source network to the first and the second antenna elements (block **1118**). Method **1100** includes communicatively coupling, via the second antenna switch, the second antenna feed/source network to the third and the fourth antenna elements (block **1120**). Method **1100** includes configuring the first antenna feed/source network to adjust a phase between the first and the second antenna elements to 180° ("out-of-phase") (block **1122**). Method **1100** includes communicating in one or more RF communication bands via the first antenna element by a respective transceiver (block **1124**). Method **1100** includes configuring the second antenna feed/source network to adjust a phase between the second and the fourth antenna elements to 180° ("out-of-phase") (block **1126**). Method **1100** includes communicating in one or more RF communication bands via the fourth antenna element by a respective transceiver (block **1128**). Then method **1100** returns to block **1102**.

For clarity, method **1100** (FIGS. **11**A-**11**B) includes adjusting phase by a particular antenna feed/source network that remains coupled to at least two antenna elements while the housing assembly is in the closed position and in the at least partially open position. Certain pairs of antenna elements can remain separate while the housing assembly is in both the closed position and in the at least partially open position. Certain pairs of antenna elements can become proximate and substantially aligned in parallel while the housing assembly is in the at least partially open position. Method **1100** (FIGS. **11**A-**11**B) includes switching antennas for antenna diversity between four antenna elements. Communication devices **100** can include various combinations of two or more antenna elements that have phases adjusted, phases not adjusted, and/or are switched pairings based on position of a configurable housing assembly.

Aspects of the present innovation are described above with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the innovation. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

As will be appreciated by one skilled in the art, embodiments of the present innovation may be embodied as a system, device, and/or method. Accordingly, embodiments of the present innovation may take the form of an entirely hardware embodiment or an embodiment combining software and hardware embodiments that may all generally be referred to herein as a "circuit," "module" or "system."

While the innovation has been described with reference to exemplary embodiments, it will be understood by those

skilled in the art that various changes may be made, and equivalents may be substituted for elements thereof without departing from the scope of the innovation. In addition, many modifications may be made to adapt a particular system, device, or component thereof to the teachings of the innovation without departing from the essential scope thereof. Therefore, it is intended that the innovation not be limited to the particular embodiments disclosed for carrying out this innovation, but that the innovation will include all embodiments falling within the scope of the appended claims. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the innovation. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprise" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present innovation has been presented for purposes of illustration and description but is not intended to be exhaustive or limited to the innovation in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the innovation. The embodiments were chosen and described in order to best explain the principles of the innovation and the practical application, and to enable others of ordinary skill in the art to understand the innovation for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A communication device comprising:

a housing assembly having first and second housing portions connected at respective proximal sides for relative movement between an open position and a closed position about a lateral axis;

a housing position sensor that detects when housing assembly is in the closed position and the open position;

a first antenna array comprised of first and second antenna elements each having an elongated shape and configured to communicate in one or more radio frequency (RF) communication bands, the first and the second antenna elements supported respectively by the first and the second housing portions, the first antenna element proximate to and substantially aligned in parallel with the second antenna element when the housing assembly is in the closed position and separated from the second antenna element when the housing assembly is in the open position;

a first antenna feed/source network communicatively coupled to the first and the second antenna elements and configured to eliminate array cancellations between the first and the second antenna elements when the housing assembly is in the closed position, the first antenna feed/source network transmitting and receiving via one or a combination of the first antenna element and the second antenna element, the first antenna feed/source network capable of adjusting a phase between the first and second antenna elements, and the first antenna feed/source network eliminates array cancellations while the housing assembly is in the closed position by adjusting a phase difference of the first antenna array between 0 and 180 degrees; and

a controller communicatively coupled to the housing position sensor and to a radio frequency (RF) front end comprising the first antenna feed/source network, wherein the controller:

determines, from housing position signal received from the housing position sensor, whether the housing assembly is in the closed position or in the at least partially open position; and

in response to housing assembly being in the closed position, where the first and second antenna elements are proximate to each other and substantially aligned in parallel, configuring the antenna feed/source network to adjust a phase between the first antenna element and the second antenna element to an 180° "out-of-phase" relationship.

2. The communication device of claim **1**, wherein further the first antenna feed/source network eliminates array cancellations in the closed position by connecting a reactive load to one of the first and the second antenna elements.

3. The communication device of claim **1**, further comprising:

a third antenna element supported by the second housing portion; and

a first antenna switch having an input communicatively coupled to the first antenna feed/source network and having an output that is communicatively coupled to the third antenna element when the housing assembly is in the open position for transmission and spatial diversity and which is communicatively coupled to the second antenna element when the housing assembly is in the closed position, enabling the third antenna element to communicate separately from the first and the second antenna elements while the housing assembly is in both the open and the closed position.

4. The communication device of claim **3**, further comprising:

a second antenna array comprised of the third antenna element and a fourth antenna element each having an elongated shape and configured to communicate in one or more RF communication bands, the third and the fourth antenna elements supported respectively by the second and the first housing portions, the third antenna element proximate to and substantially aligned in parallel with the second antenna element when the housing assembly is in the closed position and separated from the second antenna element when the housing assembly is in the open position, the third and the fourth antenna elements of the second antenna array being longitudinally positioned respectively at distal sides of the first and the second housing portions, opposite to the proximal side, and laterally positioned in a second lateral direction from a central longitudinal axis of the housing assembly; and

a second antenna feed/source network communicatively coupled to the fourth antenna element.

5. The communication device of claim **4**, further comprising:

a third antenna array having fifth and sixth antenna elements each having an elongated shape and supported

respectively by a first lateral side of the first and the second housing portions, the fifth antenna element proximate to and substantially aligned in parallel with the sixth antenna element when the housing assembly is in the closed position and not proximately with the sixth antenna element when the housing assembly is in the open position;

a fourth antenna array having seventh and eighth antenna elements, each having an elongated shape and supported respectively by a second lateral side of the first and the second housing portions, the seventh antenna element proximate to and substantially aligned with the eighth antenna element when the housing assembly is in the closed position and not proximately with the eighth antenna element when the housing assembly is in the open position;

a third, and a fourth antenna feed/source network, the third antenna feed/source network communicatively coupled to the fifth antenna element, the fourth antenna feed/source network communicatively coupled to the seventh antenna element;

a second antenna switch having a dual pole, dual throw configuration, a first pole of the second antenna switch communicatively coupled to the fourth antenna feed/source network, a second pole of the second antenna switch communicatively coupled to the third antenna feed/source network, a first throw of the second antenna switch communicatively coupled to the sixth antenna element, and a second throw of the second antenna switch communicatively coupled to the eighth antenna element.

6. The communication device of claim **5**, wherein:

the first and the second antenna elements of the first antenna array are longitudinally positioned respectively at distal sides, opposite to the proximal side, of the first and the second housing portions and laterally positioned in a first lateral direction from a central longitudinal axis of the housing assembly; and

the first antenna switch has a dual pole, dual throw configuration, a first pole of the first antenna switch communicatively coupled to the first antenna feed/source network, a second pole of the first antenna switch communicatively coupled to the second antenna feed/source network, a first throw of the first antenna switch communicatively coupled to the third antenna element, and a second throw of the first antenna switch communicatively coupled to the second antenna element.

7. The communication device of claim **1**, wherein:

the first and the second antenna elements are longitudinally positioned with respective elongated shapes in orientations mirrored about the lateral axis respectively on the first and the second housing portions when the housing assembly is in the open position; and

the first antenna feed/source network extends longitudinally between the first and the second antenna elements.

8. The communication device of claim **7**, wherein:

the first and the second antenna elements of the first antenna array are longitudinally positioned respectively at distal sides of the first and the second housing portions opposite to the proximal side, and laterally positioned in a first lateral direction from a central longitudinal axis of the housing assembly; and

the communication device further comprises:

a second antenna array having third and fourth antenna elements each having an elongated shape, supported respectively at the distal sides of the first and the second housing portions and laterally positioned in a second lateral direction from the central longitudinal axis of the housing assembly, the third antenna element proximate to and substantially aligned in parallel with the fourth antenna element when the housing assembly is in the closed position and separated from the fourth antenna element when the housing assembly is in the open position; and

a second antenna feed/source network extending longitudinally between the third and the fourth antenna elements and configured to eliminate array cancellations when the housing assembly is in the closed position.

9. The communication device of claim **8**, further comprising:

a third antenna array having fifth and sixth antenna elements each having an elongated shape and supported respectively by a first lateral side of the first and the second housing portions, the fifth antenna element proximate to and substantially aligned in parallel with the sixth antenna element when the housing assembly is in the closed position and not proximate with the sixth antenna element when the housing assembly is in the open position;

a third antenna feed/source network extending longitudinally between the fifth and the sixth antenna elements and configured to eliminate array cancellations between the fifth and the sixth antenna elements in the closed position;

a fourth antenna array having seventh and eighth antenna elements, each having an elongated shape and supported respectively at a second lateral side of the first and the second housing portions, the seventh antenna element proximate to and substantially aligned with the eighth antenna element when the housing assembly is in the closed position and not proximate with the eighth antenna element when the housing assembly is in the open position;

a fourth antenna feed/source network extending longitudinally between the seventh and the eighth antenna elements and configured to eliminate array cancellations in the closed position.

10. The communication device of claim **1**, wherein:

the first and the second antenna elements of the first antenna array are supported respectively by distal sides, opposite to the proximal side, of the first and the second housing portions; and

the communication device further comprises:

a second antenna array having third and fourth antenna elements, each having an elongated shape and supported respectively by a first lateral side of the first housing portion and a second lateral side of the second housing portion; and

a second antenna feed/source network extending between the third and the fourth antenna elements and configured to maintain a respective phase of the third and the fourth antenna elements to be substantially in-phase.

11. The communication device of claim **1**, wherein:

the first and the second antenna elements of the first antenna array are supported by the distal side, opposite to the proximal side, respectively of the first and the second housing portions and laterally positioned respectively in a first and a second lateral direction from a central longitudinal axis of the housing assembly; and

the communication device further comprising:

a second antenna array having third and fourth antenna elements, each having an elongated shape and supported respectively by the distal side, opposite to the proximal side, respectively of the first and the second housing portions and laterally positioned respectively in the second and the first lateral direction from the central longitudinal axis of the housing assembly, the first antenna element proximate to and substantially aligned with the fourth antenna element when the housing assembly is in the closed position and the second antenna element proximate to and substantially aligned with the third antenna element when the housing assembly is in the closed position; and

a second antenna feed/source network extending between the third and the fourth antenna elements.

12. The communication device of claim **11**, further comprising:

a third antenna array having fifth and sixth antenna elements supported respectively by a first lateral side of the first housing portion and a second lateral side of the second housing portion;

a third antenna feed/source network extending between the fifth and the sixth antenna elements;

a fourth antenna array having seventh and eighth antenna elements supported respectively by a second lateral side of the first housing portion and a first lateral side of the second housing portion, the fifth antenna element proximate to and substantially aligned with the eighth antenna element when the housing assembly is in the closed position and the sixth antenna element proximate to and substantially aligned with the seventh antenna element when the housing assembly is in the closed position; and

a fourth antenna feed/source network extending between the seventh and the eighth antenna elements.

13. The communication device of claim **12**, wherein each of the first, the second, the third, and the fourth antenna feed/source networks are configured: (i) when the housing assembly is in the open position to adjust phases of respective antenna elements to off-phase in ultra-low band and low band and to in-phase in medium band and high bands; and (ii) when the housing assembly is in the closed position to activate a selected one of: (i) the first and the second antenna elements of the first antenna array; (ii) the third and the fourth antenna elements of the second antenna array; (iii) the fifth and the sixth antenna elements of the third antenna array; and (iv) the seventh and the eight antenna elements of the fourth antenna array.

14. A method comprising:

determining, by a controller, a position of a housing assembly of a communication device, the housing assembly having first and second housing portions connected at proximal ends for relative movement between an open position and a closed position, the first and the second housing portions supporting respectively a first and a second antenna element of a first antenna array, each of the first and the second antenna elements each having an elongated shape, the first antenna element proximate to and substantially aligned in parallel with the second antenna element when the housing assembly is in the closed position and separated from the second antenna element when the housing assembly is in the open position, the first and second antenna elements communicatively coupled to a first antenna feed/source network, the first antenna feed/source network transmitting and receiving via one or a combination of the first antenna element and the second antenna element, the first antenna feed/source network capable of adjusting a phase between the first and second antenna elements, and the first antenna feed/source network eliminating array cancellations while the housing assembly is in the closed position by adjusting a phase difference of the first antenna array between 0 and 180 degrees; and

in response to determining that the housing assembly is in an at least partially open position, communicating in one or more radio frequency (RF) communication bands via the at least one of a first and the second antenna element; and

in response to determining that the housing assembly is in the closed position:

configuring the first antenna feed/source network to eliminate array cancellations across/between the first and second antenna elements by adjusting, by the first antenna feed/source network, a phase difference of the first antenna array between 0 and 180 degrees; and

communicating in the one or more RF communication bands via a selected one of the first and the second antenna elements of the first antenna array.

15. The method of claim **14**, wherein:

the communication device further comprises a second antenna array comprised of a third and a fourth antenna element each having an elongated shape, respectively supported by the first and the second housing portions, and which are proximate to each other and aligned in parallel while the housing assembly is in the closed position, the first and the second antenna elements on an opposite lateral side of the housing assembly to the third and fourth antenna elements; and

the method further comprising:

in response to determining that the housing assembly is in the closed position:

configuring a second antenna feed/source network to eliminate array cancellations across/between the third and the fourth antenna elements; and

communicating in one or more RF communication bands via one antenna element of the second antenna array; and

in response to determining that the housing assembly is in the at least partially open position:

configuring the first antenna feed/source network to communicate via the first and the third antenna elements;

configuring the second antenna feed/source network to communicate via the second and the fourth antenna elements; and

communicating in one or more RF communication bands respectively via each of the first and the second antenna feed/source networks.

16. The method of claim **14**, wherein:

in response to determining that the housing assembly is in the at least partially open position, communicating in one or more RF communication bands via at least one second antenna array of a third and a fourth antenna element, each of the third and the fourth antenna elements having an elongated shape, supported respectively by the first and the second housing portions, and the third antenna element separated from the fourth antenna element when the housing assembly is in the at least partially open position, the third antenna element proximate to and substantially aligned in parallel with

the fourth antenna element while the housing assembly is in the closed position; and

in response to determining that the housing assembly is in the closed position:

configuring a respective second antenna feed/source network communicatively coupled to the third and the fourth antenna elements to eliminate array cancellations across/between the third and the fourth antenna elements; and

communicating in one or more RF communication bands via one of the third and the fourth antenna elements of the second antenna array.

17. The method of claim **14**, further comprising:

communicating via the first and the second antenna elements of the first antenna array that are supported by the distal side, respectively opposite to the proximal side, of the first and the second housing portions;

communicating in one or more RF bands via a second antenna array having third and fourth antenna elements, each having an elongated shape and supported respectively by a first lateral side of the first housing portion and a second lateral side of the second housing portion; and

maintaining, by a second antenna feed/source network extending between the third and the fourth antenna elements, a respective phase of the third and the fourth antenna elements to be substantially in-phase.

18. The method of claim **14**, further comprising:

in response to determining that the housing assembly is in the at least partially open position:

communicating via the first and the second antenna elements of the first antenna array that are supported respectively by the distal side, opposite to the proximal side, respectively of the first and the second housing portions and laterally positioned respectively in a first and a second lateral direction from a central longitudinal axis of the housing assembly; and

communicating in one or more RF bands via a second antenna array that has a third and a fourth antenna element supported by the distal side respectively of the first and the second housing portions and laterally positioned respectively in the second and the first lateral direction from the central longitudinal axis of the housing assembly;

communicating in one or more RF bands via a third antenna array that has a fifth and a sixth antenna element supported by the second and the first distal side respectively of the first and the second housing portions; and

communicating in one or more RF bands via a fourth antenna array that has a seventh and an eighth antenna element respectively supported by the first and the second distal side respectively of the first and the second housing portions; and

in response to determining that the housing assembly is in the closed position, configuring respective antenna feed/source networks to eliminate array cancellations caused respectively by the second, the fourth, the sixth, and the eighth antenna elements.

19. A computer program product comprising:

a computer readable storage device; and

program code on the computer readable storage device that when executed by a processor associated with a device, the program code enables the communication device to provide the functionality of:

determining a position of a housing assembly of a communication device, the housing assembly having first and second housing portions connected at proximal ends for relative movement between an open position and a closed position, the first and the second housing portions supporting respectively a first and a second antenna element of a first antenna array, each of the first and the second antenna elements each having an elongated shape, the first antenna element proximate to and substantially aligned in parallel with the second antenna element when the housing assembly is in the closed position and separated from the second antenna element when the housing assembly is in the open position, the first and second antenna elements communicatively coupled to a first antenna feed/source network, the first antenna feed/source network transmitting and receiving via one or a combination of the first antenna element and the second antenna element, the first antenna feed/source network capable of adjusting a phase between the first and second antenna elements, and the first antenna feed/source network eliminating array cancellations while the housing assembly is in the closed position by adjusting a phase difference of the first antenna array between 0 and 180 degrees;

in response to determining that the housing assembly is in an at least partially open position, communicating in one or more radio frequency (RF) communication bands via the at least one of a first and the second antenna element; and

in response to determining that the housing assembly is in the closed position:

configuring the first antenna feed/source network to eliminate array cancellations across/between the first and second antenna elements; and

communicating in the one or more RF communication bands via a selected one of the first and the second antenna elements of the first antenna array.

20. The computer program product of claim **19**, wherein the program code enables the communication device to provide the functionality of:

configuring the first antenna feed/source network to eliminate array cancellations in the closed position by adjusting, by the first antenna feed/source network, a phase different of the first antenna array between 0 and 180 degrees.

* * * * *

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(12) **United States Patent**
Tipul

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(45) **Date of Patent: Mar. 11, 2025**

(54) **ULTRA-WIDE BAND ANTENNA AND RELATED SYSTEM**

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(73) Assignee: **2J ANTENNAS USA, CORPORATION**, Gilbert, AZ (US)

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H01Q 9/04 (2006.01)
H01Q 21/30 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 9/0414*** (2013.01); ***H01Q 21/30*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 9/0414; H01Q 21/30
See application file for complete search history.

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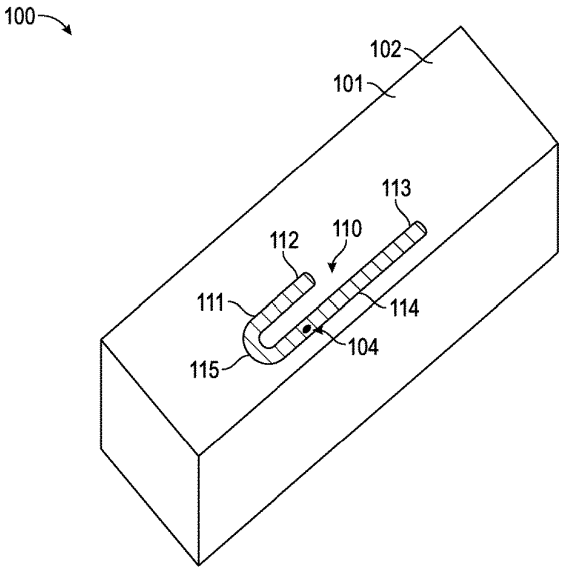
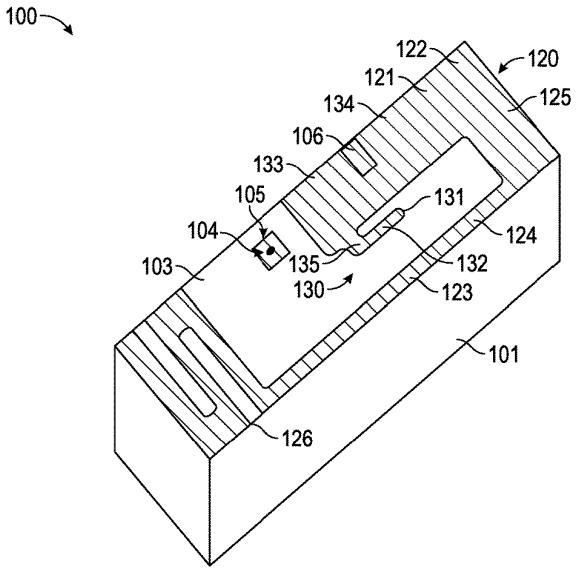
(57) **ABSTRACT**

An ultra-wide band antenna is disclosed. The antenna generally includes a substrate having a top surface and a bottom surface. A first radiator having a positive polarization is disposed at the top surface, and a second radiator and a third radiator, each having a negative polarization, are disposed at the bottom surface. The first, second, and third radiators each have a minor portion and a major portion which are parallel with respect to each other. Size of each radiator in descending order from largest to smallest radiator is the second radiator, the first radiator, and the third radiator.

20 Claims, 5 Drawing Sheets





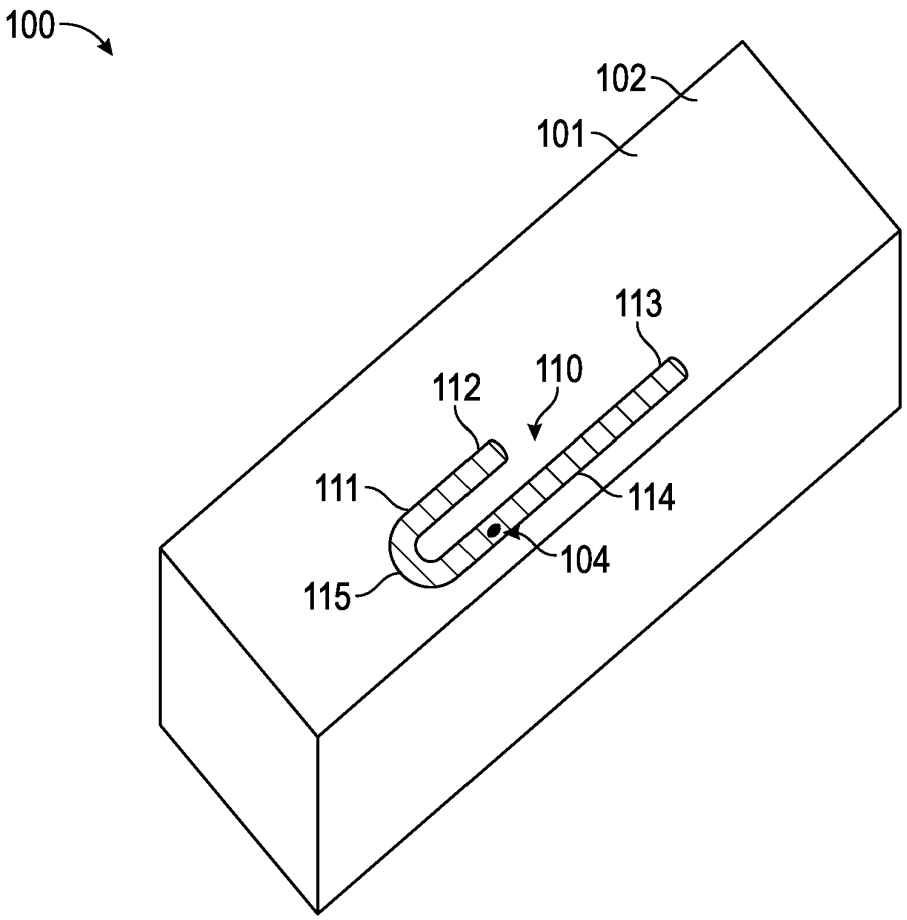


FIG. 1

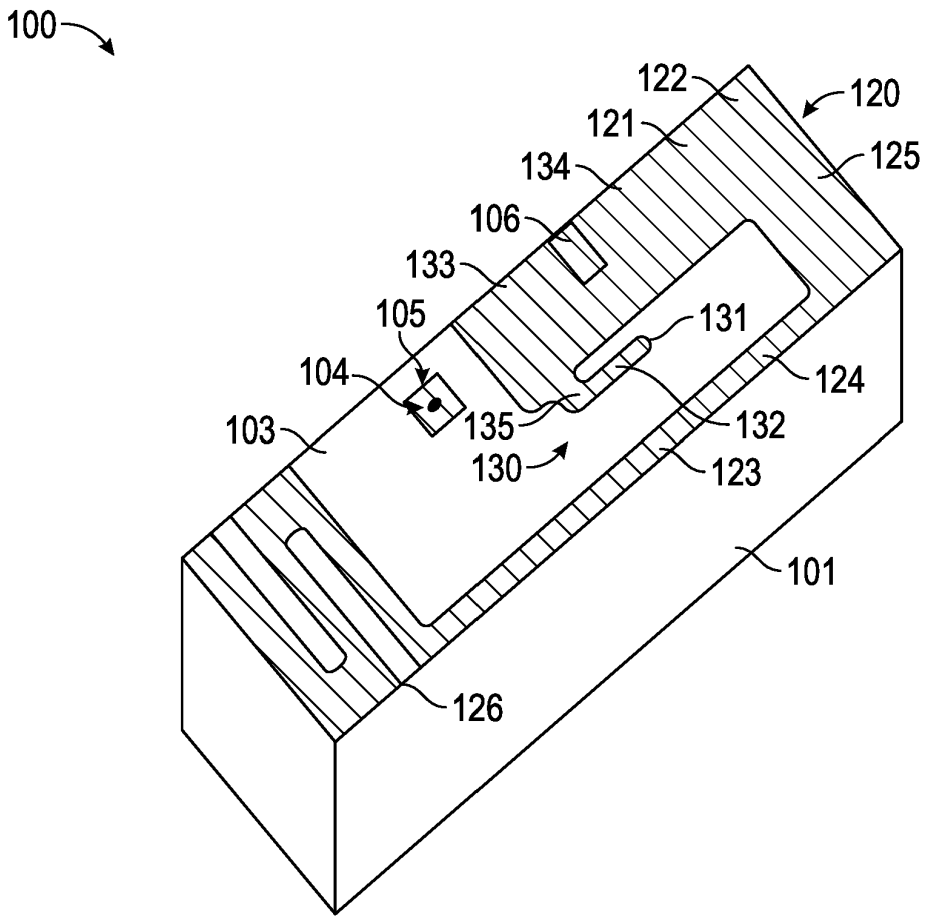

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FIG. 2

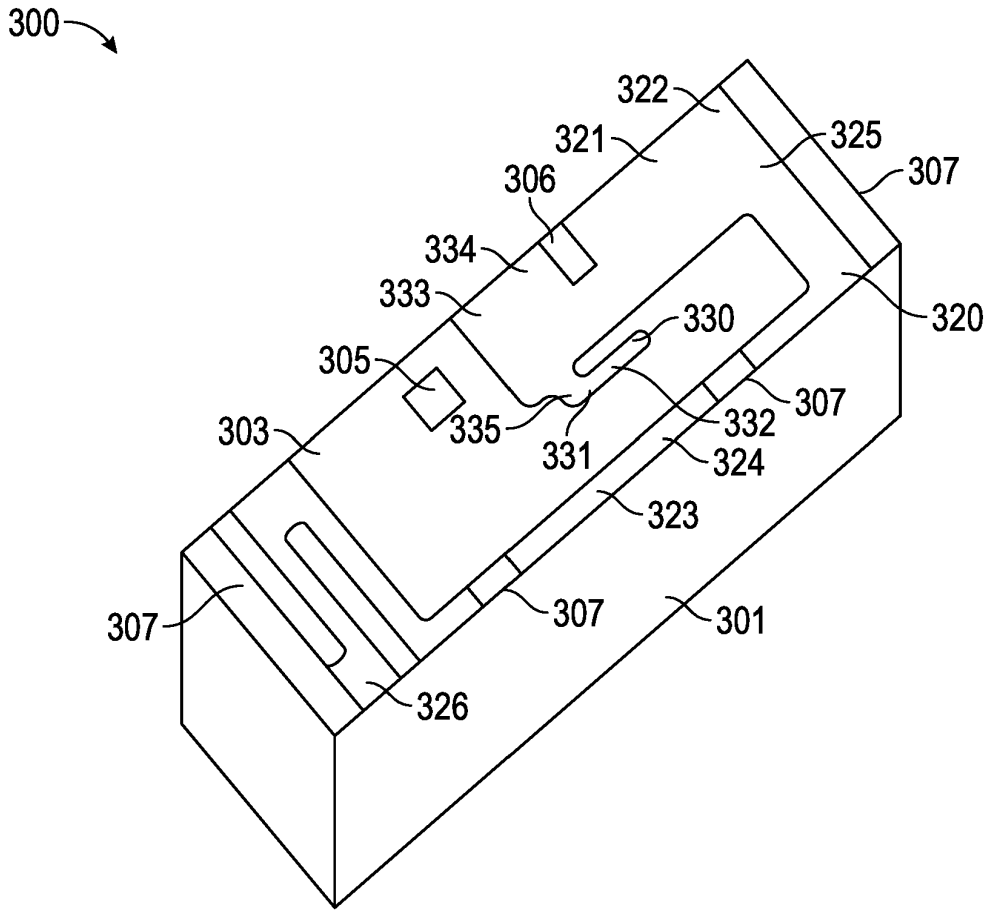
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FIG. 3

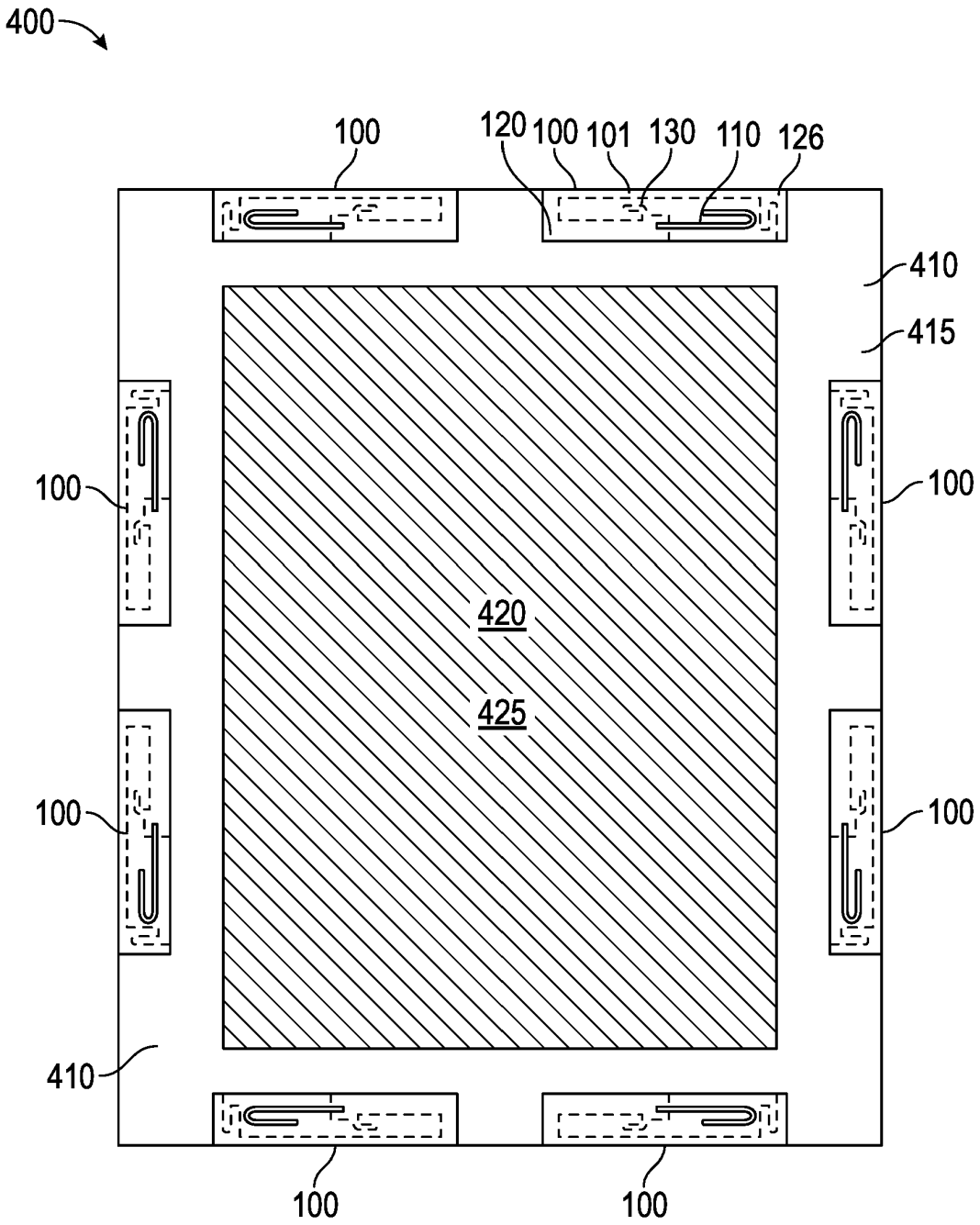
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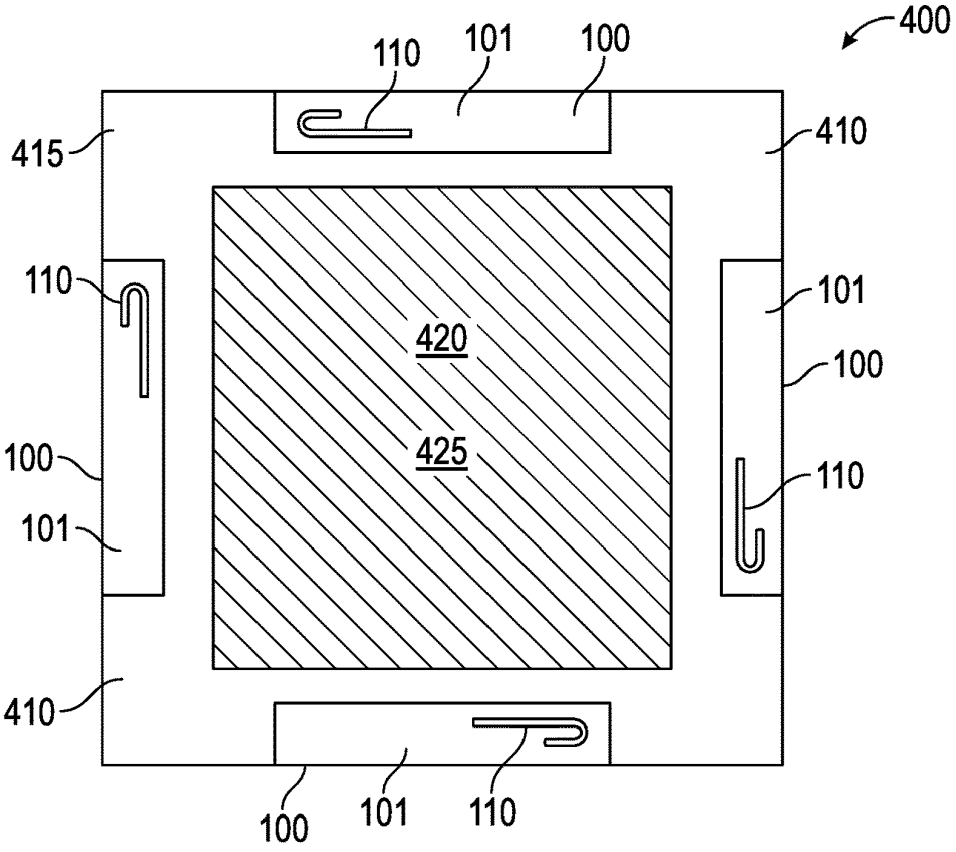
FIG. 4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110

FIG. 5A

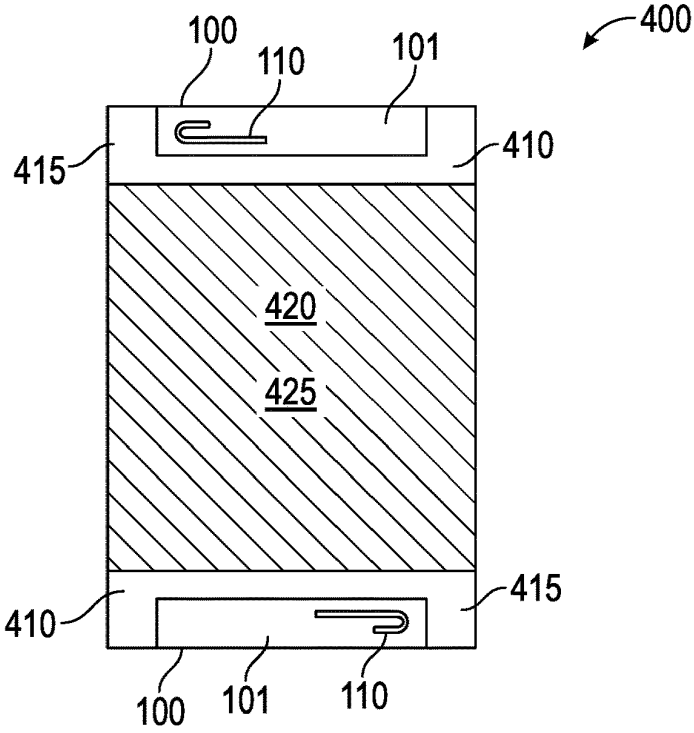
400
100
110
101
415
410
420
425
410
415
100
101
110

FIG. 5B

ULTRA-WIDE BAND ANTENNA AND RELATED SYSTEM

TECHNICAL FIELD

This invention relates to antennas; more particularly, surface mount antennas for operation in 4GLTE and 5GNR.

BACKGROUND ART

Previously, antenna designs have predominantly been focused on topologies in the higher frequencies. However, lower frequencies at the 600 and 700 MHz bands that were previously used by old analog television are now part of cellular applications due to increase market demands. Antennas now need to cover bands in both the high and low frequencies.

SUMMARY OF INVENTION

Technical Problem

Bandwidths for cellular applications have widened with the inclusion of lower bands like 617-960 MHz. A single antenna radiator that efficiently covers the entire bandwidth is not realistic given the different requirements optimal antennas possess for lower frequencies compared to higher frequencies. Additional challenges are present when designing antenna topologies that cover a wide spectrum of 617-960 MHz, 1427-2690 MHz, 3300-5000 MHz, and 5150-7125 MHz to operate 4GLTE and 5GNR around the world.

New antenna topologies are needed to efficiently cover both high frequencies and low frequencies while maintaining a small form factor, which is desirable in the electronic industry to simplify manufacturing, especially in high volume applications.

Solution to Problem

Disclosed is an antenna that comprises a substrate having a top surface and a bottom surface. A first radiator having a positive polarization is disposed at the top surface, and a second radiator and a third radiator, each having a negative polarization, are disposed at the bottom surface. The first, second, and third radiators each have a minor portion and a major portion which are parallel with respect to each other. Size of each radiator in descending order from largest to smallest radiator is the second radiator, the first radiator, and the third radiator.

Advantageous Effects of Invention

An antenna comprising a large, medium, and small resonators described herein is capable of efficiently cover both high and low frequencies while maintaining a small form factor.

The large, medium, and small resonators having alternating polarizations of negative, positive, negative, respectively maximizes conservation of energy.

The two negative resonators each being disposed on the substrate at the bottom surface lowers the resonance necessary to cover the newly added 600 MHz frequencies. A serpentine termination additionally helps to improve resonance at lower frequencies.

Mounting pads make adhesion of the antenna to a circuit strong and secure.

A single antenna which has a small form factor and can cover a wide frequency band is highly desirable in the electronic industry. It lowers costs, simplifies manufacturing processes, and allows products to be smaller overall.

Other features and benefits will be appreciated by one having skill in the art upon a thorough review of the instant disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features, combinations, and embodiments will be appreciated by one having the ordinary level of skill in the art of antennas and accessories upon a thorough review of the following details and descriptions, particularly when reviewed in conjunction with the drawings, wherein:

FIG. **1** shows a top perspective view of an antenna in accordance with a first illustrated embodiment;

FIG. **2** shows a bottom perspective view of the antenna according to the first illustrated embodiment;

FIG. **3** shows a bottom perspective view of the antenna in accordance with a second illustrated embodiment;

FIG. **4** shows a top view of a MIMO antenna system in accordance with a third illustrated embodiment;

FIG. **5**A shows a top view of a MIMO antenna system in accordance with a fourth illustrated embodiment; and

FIG. **5**B shows a top view of a MIMO antenna system in accordance with a fifth illustrated embodiment.

DETAILED DESCRIPTION

For purposes of explanation and not limitation, details and descriptions of certain preferred embodiments are hereinafter provided such that one having ordinary skill in the art may be enabled to make and use the invention. These details and descriptions are representative only of certain preferred embodiments, however, a myriad of other embodiments which will not be expressly described will be readily understood by one having skill in the art upon a thorough review of the instant disclosure. Accordingly, any reviewer of the instant disclosure should interpret the scope of the invention only by the claims, as such scope is not intended to be limited by the embodiments described and illustrated herein.

For purposes herein, the term "MIMO" means Multiple Input Multiple Output.

The term "substrate" means a flat or nearly flat surface that contains a conducting portion and can be used a holder of surface mount antennas.

The term "perimeter" means one or more portions that defines an outer region of a geometric shape.

The term "radiator" means a conducting element of an antenna that is electrically connected to a radio receiver and/or a radio transmitter and which transmits and/or receives radio waves.

The term "embedded antenna" means a metallic conductor embedded in a dielectric material.

The term "mirrored" means an object that is identical in form to another, but with the structure reversed.

Unless explicitly defined herein, terms are to be construed in accordance with the plain and ordinary meaning as would be appreciated by one having skill in the art.

General Description of Embodiments

In one general embodiment, an ultra-wide band antenna is disclosed. The antenna comprises a substrate having a top surface and a bottom surface opposite the top surface, a first resonator disposed on the top surface, a second resonator

disposed on the bottom surface, and a third resonator disposed on the bottom surface. The first resonator comprises a first major portion, a first minor portion in parallel alignment with the first major portion, and a first connecting portion coupled to each of the first major portion and the first minor portion. The first resonator comprises a positive polarization. The second resonator comprises a second major portion having a second major length, a second minor portion having a second minor length, the second minor portion being in parallel alignment with the second major portion, and a second connecting portion coupled to each of the second major portion and the second minor portion. The second resonator comprises a negative polarization. The third resonator comprises a third major portion having a third major length, a third minor portion having a third minor length, the third minor portion being in parallel alignment with the third major portion, and a third connecting portion coupled to each of the third major portion and the third minor portion. The third resonator comprises a negative polarization. Additionally, the second minor portion comprises the third major portion.

In some embodiments, the second major portion may further comprise a meandering portion coupled to a terminal end thereof.

Generally, the second major length is greater than second minor length, and the third major length is greater than third minor length. Generally, the second major length is greater than the first major length, and the third major length is less than the first major length.

In some embodiments, the second minor length is greater than the first minor length, and the third minor length is less than the first minor length.

In some embodiments, the second major portion may comprise a thickness less than the second minor portion.

In some embodiments, the antenna may further comprise a negative mount pad disposed on the second minor portion. In some embodiments, the antenna may further comprise a via extending between the top and bottom surfaces, and a positive mounting pad coupled to the via on the bottom surface.

In some embodiments, the antenna comprises a monopole-PFA structure.

In a second general embodiment, an ultra-wide band antenna is disclosed. The antenna comprises a substrate having a top surface and a bottom surface opposite the top surface, a first resonator disposed on the top surface, a second resonator disposed on the bottom surface, and a third resonator disposed on the bottom surface. The first resonator comprises a first major portion, a first minor portion, and a first connecting portion coupled to each of the first major portion and the first minor portion. The second resonator comprises a second major portion having a second major length, a second minor portion having a second minor length, and a second connecting portion coupled to each of the second major portion and the second minor portion. The third resonator comprises a third major portion having a third major length, a third minor portion having a third minor length, and a third connecting portion coupled to each of the third major portion and the third minor portion. Additionally, the first radiator is in positive polarization and the second and third radiators are each in negative polarization.

Generally, the first major and minor portions are in parallel alignment, the second major and minor portions are in parallel alignment, and the third major and minor portions are in parallel alignment.

In some embodiments, the second minor portion comprises the third major portion.

In some embodiments, the second major portion may further comprise a meandering portion coupled to a terminal end thereof.

Generally, the second major length is greater than second minor length, and the third major length is greater than third minor length. In some embodiments, the second major length is greater than the first major length, and the third major length is less than the first major length.

Generally, the second minor length is greater than the first minor length, and the third minor length is less than the first minor length.

In some embodiments, the second minor portion may comprise a thickness less than the second major portion.

In some embodiments, the antenna comprises a monopole-PFA structure.

In a third general embodiment, a MIMO antenna system is disclosed. The system comprises a system substrate comprising a perimeter and a center portion. The perimeter comprises a clearance zone and the center portion comprises a ground plane. The system further comprises a plurality of embedded antennas disposed along the perimeter, wherein each of the plurality of embedded antennas comprises a substrate having a top surface and a bottom surface opposite the top surface, a first resonator disposed on the top surface, a second resonator disposed on the bottom surface, and a third resonator disposed on the bottom surface. The first resonator comprises a first major portion, a first minor portion, and a first connecting portion coupled to each of the first major portion and the first minor portion, wherein the first resonator comprises a positive polarization. The second resonator comprises a second major portion having a second major length, a second minor portion having a second minor length, and a second connecting portion coupled to each of the second major portion and the second minor portion, wherein the second resonator comprises a negative polarization. The third resonator comprises a third major portion having a third major length, a third minor portion having a third minor length, and a third connecting portion coupled to each of the third major portion and the third minor portion, wherein the third resonator comprises a negative polarization.

Generally, the first major and minor portions are in parallel alignment, the second major and minor portions are in parallel alignment, and the third major and minor portions are in parallel alignment.

In some embodiments, the second minor portion comprises the third major portion.

In some embodiments, the second major portion may further comprise a meandering portion coupled to a terminal end thereof.

Generally, the second major length is greater than second minor length, and the third major length is greater than third minor length. In some embodiments, the second major length is greater than the first major length, and the third major length is less than the first major length.

Generally, the second minor length is greater than the first minor length, and the third minor length is less than the first minor length.

In some embodiments, the second minor portion may comprise a thickness less than the second major portion.

In some embodiments, each antenna comprises a monopole-PFA structure.

Manufacturing

Generally, the substrate is made of industry standard material such as ceramic, plastic polymer, or low-cost fiber-

glass. Examples may include FR4, Kapton or Pyralux with printed circuit design affixed thereto. Otherwise, the substrate can be fabricated in accordance with the level and knowledge of one having skill in the art.

The antenna radiators may be fabricated by etching the antenna element pattern in a metal trace bonded to an insulating dielectric substrate, such as a printed circuit board.

Each of the components of the antenna and related system described herein may be manufactured and/or assembled in accordance with the conventional knowledge and level of a person having skill in the art.

While various details, features, combinations are described in the illustrated embodiments, one having skill in the art will appreciate a myriad of possible alternative combinations and arrangements of the features disclosed herein. As such, the descriptions are intended to be enabling only, and non-limiting. Instead, the spirit and scope of the invention is set forth in the appended claims.

Illustrated Description of Embodiments

FIG. **1** shows a top perspective view of an antenna (**100**) in accordance with a first illustrated embodiment. The antenna comprises a substrate (**101**) having a top surface (**102**) and a bottom surface (not shown) opposite the top surface. Disposed on the top surface is a first resonator (**110**). The first resonator comprises a first major portion (**113**) having a first major length (**114**) and a first minor portion (**111**) having a first minor length (**112**). The first major portion and the first minor portion are electrically coupled together by a first connecting portion (**115**). The connecting portion can be curved as shown, or alternatively angled or linear in shape. The first radiator is in positive polarization and is configured to operate efficiently with relatively mid frequencies.

Disposed on the first radiator (**110**) is a via (**104**) which extends from the top surface (**102**) through the substrate (**101**) to the bottom surface. The via is shown located on the first major portion (**113**). In alternative embodiments, the via may be disposed on the first minor portion (**111**), the first connecting portion (**115**), or elsewhere on the top surface which is electrically coupled to the first radiator.

The first major portion (**113**) and the first minor portion (**111**) are shown each comprising linear, elongated portions of the first radiator (**110**). The first major and minor portions are in a parallel alignment with each other. As shown, the first major length (**114**) is greater than the first minor length (**112**). In alternative embodiments the first minor length can be equal to or greater than the first major length. Thickness of the first major and minor portions are illustrated as being generally equal in size. In alternative embodiment, thicknesses of the first major and minor portions can differ such that the first major portion comprises a greater thickness or a smaller thickness.

FIG. **2** shows a bottom perspective view of a bottom surface (**103**) of the antenna (**100**) according to the first illustrated embodiment. Disposed on the bottom surface of a substrate (**101**) is a second radiator (**120**) and a third radiator (**130**). The second radiator comprises a second minor portion (**121**) parallel to a second major portion (**123**). A second connecting portion (**125**) is coupled to both the second major and minor portions. Generally, the second major portion comprises a second major length (**124**) and the second minor portion comprises a second minor length (**122**) such that the second major length is greater than the second minor length.

The third radiator (**130**) comprises a third minor portion (**131**) having a third minor length (**132**) and a third major portion (**133**) having a third major length (**134**). Preferably, the second minor portion (**121**) comprises the third major portion such that the third major portion and the second minor portion are one of the same. The third minor portion is coupled to the third major portion, and additionally the second minor portion, by a third connecting portion (**135**). Like the first radiator (FIG. **1**, **110**) and the second radiator (**120**), the major and minor portions of the third radiator are in a parallel formation with respect to each other.

Both the second resonator (**120**) and the third radiator (**130**) are in negative polarization which assists with covering particular frequency bands like the 600 MHz band. The antenna comprises three radiators, namely the first radiator (FIG. **1**, **110**), the second radiator, and the third radiator. The second radiator can be characterized as the largest of the three radiators and the third radiator can be characterized as the smallest of the three resonators. The polarization of the first, second, and third radiators can be described as alternating (negative, positive, negative) based on descending size (second radiator, first radiator, third radiator) which maximizes conservation of energy. The second radiator is configured to operate efficiently with lower frequencies whereas the third radiator is configured to operate efficiently with higher frequencies.

The second radiator (**120**) further comprises an optional meandering portion (**126**) coupled to a terminal end of the second major portion (**123**). More specifically, the meandering portion is coupled to the second major portion at an opposite end to where the second major portion couples with the second connecting portion (**125**). The meandering portion is configured to improve resonance at lower frequencies. As shown, the meandering portion comprises three parallel portions coupled together to form an angled S-shape. Other shapes of the meandering portion, including additional portions beyond three may also be utilized by one having skill in the art for improving resonance at lower frequencies.

The bottom surface (**103**) further comprises a via (**104**) which extends from the bottom surface to the top surface (FIG. **1**, **102**). The via is electrically coupled to a positive terminal pad (**105**) on the bottom surface. Signals passing through the positive terminal pad are configured to travel through the substrate (**101**) to the first radiator (FIG. **1**, **110**) disposed on the top surface, or alternatively the positive terminal pad is configured to receive signals from the first radiator. In some embodiments, the positive terminal pad is configured to couple to a port of a cellular module. A negative terminal pad (**106**) is disposed on the second radiator (**120**) and is configured to couple to a ground of an electronic circuit board where the antenna (**100**) is being affixed therewith.

FIG. **3** shows a bottom perspective view of the antenna (**300**) in accordance with a second illustrated embodiment. The antenna comprises a substrate (**301**) having a bottom surface (**303**) and a top surface (not shown), opposite the bottom surface. The bottom surface comprises a second radiator (**320**) and a third radiator (**330**). The second radiator comprises a second connecting portion (**325**) coupled to both a second major portion (**323**) and a second minor portion (**321**). The third radiator comprises a third minor portion (**331**) coupled to the second minor portion by a third connecting portion (**335**) such that the second minor portion is also a third major portion (**333**) for the third radiator. A negative terminal pad (**306**) is electrically coupled to the

second and third radiators, and a positive terminal pad (**305**) is electrically coupled to a first radiator (not shown) disposed on the top surface.

The second minor portion (**321**) comprises a second minor length (**322**) and the second major portion (**323**) comprises a second major length (**324**) wherein the second major length is greater than the second minor length. Additionally, the third minor portion (**331**) comprises a third minor length (**332**) and the third major portion (**333**) comprises a third major length (**334**) wherein the third major length is greater than the third minor length.

In an exemplary embodiment, the second major length (**324**) is longer to both the third major length (**334**) and a first major length (FIG. **1**, **114**). Additionally, the third major length may be shorter to both the first major length and second major length.

In an exemplary embodiment, the second minor length (**322**) is longer to both the third minor length (**332**) and a first minor length (FIG. **1**, **112**). Additionally, the third minor length may be shorter to both the first minor length and the second minor length.

As shown, the second major portion (**323**) comprises a thickness which is less than a thickness associated with the second minor portion (**321**). In other embodiments, a thickness associated with the second minor portion may be equal to or greater than a thickness of the second major portion. To maximize space, the second connecting portion (**325**) comprises a linear shape such that corners formed by the second connecting portion and the second major and minor portions are right angles which conform to corners of the substrate (**301**). The second minor portion is disposed on one end of the substrate and the second major portion is disposed on an opposite end. A meandering portion (**326**) is coupled to the second major portion wherein the meandering portion is disposed on the substrate opposite the second connecting portion.

The antenna (**300**) further comprises mounting pads (**307**) disposed on the bottom surface (**303**) for the purpose of strongly securing the antenna to an electronic circuit board. The mounting pads are compatible with surface mount technology known to one having skill in the art. As shown, the mounting pads are disposed on the second connecting portion (**325**), the meandering portion (**326**), and the second major portion (**323**). Other configurations can similarly be implemented for securely coupling the bottom surface to an electronic circuit board.

Between the second minor portion (**321**) and the meandering portion (**326**) is unoccupied surface which is free from negatively polarized resonators. Preferably, the first radiator (FIG. **1**, **110**) overlaps with a substantial portion of the unoccupied surface.

FIG. **4** shows a top view of a MIMO antenna system (**400**) in accordance with a third illustrated embodiment. The MIMO antenna system comprises a system substrate having a center portion (**420**) and a perimeter (**410**) surrounding the center portion. The center portion comprises a ground plane (**425**). The perimeter comprises a clearance zone (**415**) disposed between the ground plane and a plurality of antennas (**100**) disposed on the perimeter. As shown, two antennas are disposed on each side for a total of eight antennas. The antenna comprises a substrate (**101**) having a first radiator (**110**) disposed on a top surface, and a second radiator (**120**) and third radiator (**130**) disposed on a bottom surface, the bottom surface being coupled to the perimeter. Coupled to the second radiator is a meandering portion (**126**). Each pair of antennas on each side are in a mirrored position with respect to each other. Antennas on opposite ends of the MIMO antenna system are also in a mirrored position with respect to each other.

FIG. **5**A shows a top view of a MIMO antenna system (**400**) in accordance with a fourth illustrated embodiment. The MIMO antenna system comprises a system substrate having a center portion (**420**) and a perimeter (**410**) surrounding the center portion. The center portion comprises a ground plane (**425**). The perimeter comprises a clearance zone (**415**) disposed between the ground plane and a plurality of antennas (**100**) disposed on the perimeter. As shown, an antenna is disposed on each side for a total of four antennas. The antenna comprises a substrate (**101**) having a first radiator (**110**) disposed on a top surface. A second radiator (not shown) and a third radiator (not shown) are disposed on a bottom surface of each of the plurality of antennas. Antennas on opposite ends of the ground plane are in a mirror configuration with respect to each other.

FIG. **5**B shows a top view of a MIMO antenna system (**400**) in accordance with a fifth illustrated embodiment. The MIMO antenna system comprises a system substrate having a center portion (**420**) and a perimeter (**410**) disposed on opposite ends of the center portion. The center portion comprises a ground plane (**425**). Each perimeter comprises a clearance zone (**415**) disposed between the ground plane and a plurality of antennas (**100**) disposed on the perimeter. As shown, an antenna is disposed on each perimeter. The antenna comprises a substrate (**101**) having a first radiator (**110**) disposed on a top surface. A second radiator (not shown) and a third radiator (not shown) are disposed on a bottom surface of each of the plurality of antennas. Both antennas are positioned such that the respective first radiator of each antenna is in an opposite direction from the first radiator of the other antenna.

FEATURE LIST

antenna (**100**, **300**)
substrate (**101**, **310**)
top surface (**102**)
bottom surface (**103**, **303**)
via connection (**104**)
positive terminal pad (**105**, **305**)
negative terminal pad (**106**, **306**)
mounting pads (**307**)
first resonator (**110**)
first minor portion (**111**)
first minor length (**112**)
first major portion (**113**)
first major length (**114**)
first connecting portion (**115**)
second resonator (**120**, **320**)
second minor portion (**121**, **321**)
second minor length (**122**, **322**)
second major portion (**123**, **323**)
second major length (**124**, **324**)
second connecting portion (**125**, **325**)
meandering portion (**126**, **326**)
third resonator (**130**, **330**)
third minor portion (**131**, **331**)
third minor n length (**132**, **332**)
third major portion (**133**, **333**)
third major length (**134**, **334**)
third connecting portion (**135**, **335**)
MIMO antenna system (**400**)
perimeter (**410**)
clearance zone (**415**)

center portion (**420**)
ground plane (**425**)

What is claimed is:

1. An ultra-wide band antenna configured to operate in a frequency band, comprising:

a substrate having a top surface and a bottom surface opposite the top surface;

a first resonator disposed on the top surface,

the first resonator comprising a first major portion, a first minor portion in parallel alignment with the first major portion, and a first connecting portion coupled to each of the first major portion and the first minor portion, wherein the first resonator comprises a positive polarization;

a second resonator disposed on the bottom surface,

the second resonator comprising a second major portion having a second major length, a second minor portion having a second minor length, the second minor portion being in parallel alignment with the second major portion, and a second connecting portion coupled to each of the second major portion and the second minor portion, wherein the second resonator comprises a negative polarization; and

a third resonator disposed on the bottom surface,

the third resonator comprising a third major portion having a third major length, a third minor portion having a third minor length, the third minor portion being in parallel alignment with the third major portion, and a third connecting portion coupled to each of the third major portion and the third minor portion, wherein the third resonator comprises a negative polarization, and further wherein the second minor portion comprises the third major portion;

wherein the second resonator and the third resonator are configured to operate efficiently at different ranges of the frequency band.

2. The antenna of claim **1**, the second major portion further comprising a meandering portion coupled to a terminal end thereof, wherein the meandering portion comprises three parallel portions.

3. The antenna of claim **1**, wherein the first resonator, second resonator, and the third resonator are each configured to operate efficiently at different ranges of the frequency band such that the first resonator is configured to operate efficiently at the mid frequencies of the frequency band, the second resonator is configured to operate efficiently at the lower frequencies of the frequency band, and the third resonator is configured to operate efficiently at the higher frequencies of the frequency band.

4. The antenna of claim **1**, wherein the second resonator is larger than the first resonator.

5. The antenna of claim **1**, the bottom surface further comprising a plurality of corners wherein the second connecting portion conforms to at least two of the plurality of corners.

6. The antenna of claim **1**, the bottom surface further comprising a plurality of edges, wherein the second minor portion is disposed along one of the plurality of edges, and the second minor portion is disposed along one of the plurality of edges opposite the second minor portion, such that the second minor portion and the second major portion are each characterizes as being a linear structure.

7. The antenna of claim **1**, wherein each section of the bottom surface disposed between the third minor portion and the second major portion is free of negatively polarized resonators.

8. The antenna of claim **1**, wherein the first major portion and the first minor portion are each characterized as being a linear structure, wherein the first major portion and the first minor portion each comprise a terminal end of the first resonator such that each terminal end of the first resonator is not coupled to another positively polarized resonator.

9. The antenna of claim **1**, wherein the second minor portion is characterized as being a linear structure such that one end of the second minor portion is coupled to the second connecting portion and another end of the second minor portion is not coupled to another negatively polarized resonator.

10. The antenna of claim **1**, wherein the third minor portion comprises a terminal end of the third resonator such that the terminal end of the third resonator is not coupled to another negatively polarized resonator.

11. An ultra-wide band antenna configured to operate in a frequency band, comprising:

a substrate having a top surface and a bottom surface opposite the top surface;

a first resonator disposed on the top surface,

the first resonator comprising a first major portion, a first minor portion, and a first connecting portion coupled to each of the first major portion and the first minor portion, wherein the first resonator comprises a positive polarization;

a second resonator disposed on the bottom surface,

the second resonator comprising a second major portion having a second major length, a second minor portion having a second minor length, and a second connecting portion coupled to each of the second major portion and the second minor portion, wherein the second resonator comprises a negative polarization; and

a third resonator disposed on the bottom surface,

the third resonator comprising a third major portion having a third major length, a third minor portion having a third minor length, and a third connecting portion coupled to each of the third major portion and the third minor portion, wherein the third resonator comprises a negative polarization;

wherein the second resonator and the third resonator are configured to operate efficiently at different ranges of the frequency band.

12. The antenna of claim **11**, wherein the second minor portion comprises the third major portion.

13. The antenna of claim **11**, wherein the first resonator, second resonator, and the third resonator are each configured to operate efficiently at different ranges of the frequency band such that the first resonator is configured to operate efficiently at the mid frequencies of the frequency band, the second resonator is configured to operate efficiently at the lower frequencies of the frequency band, and the third resonator is configured to operate efficiently at the higher frequencies of the frequency band.

14. The antenna of claim **11**, wherein the second resonator is larger than the first resonator.

15. The antenna of claim **11**, the bottom surface further comprising a plurality of corners wherein the second connecting portion conforms to at least two of the plurality of corners.

16. The antenna of claim **11**, the bottom surface further comprising a plurality of edges, wherein the second minor portion is disposed along one of the plurality of edges, and the second minor portion is disposed along one of the plurality of edges opposite the second minor portion, such

that the second minor portion and the second major portion are each characterizes as being a linear structure.

17. The antenna of claim **11**, wherein each section of the bottom surface disposed between the third minor portion and the second major portion is free of negatively polarized resonators.

18. The antenna of claim **11**, wherein the first major portion and the first minor portion are each characterized as being a linear structure, wherein the first major portion and the first minor portion each comprise a terminal end of the first resonator such that each terminal end of the first resonator is not coupled to another positively polarized resonator.

19. The antenna of claim **11**, wherein the second minor portion is characterized as being a linear structure such that one end of the second minor portion is coupled to the second connecting portion and another end of the second minor portion is not coupled to another negatively polarized resonator.

20. The antenna of claim **11**, wherein the third minor portion comprises a terminal end of the third resonator such that the terminal end of the third resonator is not coupled to another negatively polarized resonator.

* * * * *

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(12) **United States Patent**
Liu et al.

(10) **Patent No.: US 12,249,776 B2**
(45) **Date of Patent: Mar. 11, 2025**

(54) **COMPOSITE ANTENNA AND ELECTRONIC DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 245 days.

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CPC ***H01Q 9/0414*** (2013.01); ***H01Q 3/22*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/12; H01Q 1/20; H01Q 1/2266; H01Q 1/243; H01Q 1/36; H01Q 1/38; H01Q 1/48; H01Q 1/50; H01Q 3/22; H01Q 7/00; H01Q 9/0414; H01Q 9/265; H01Q 9/285; H01Q 1/46; H01Q 5/00
See application file for complete search history.

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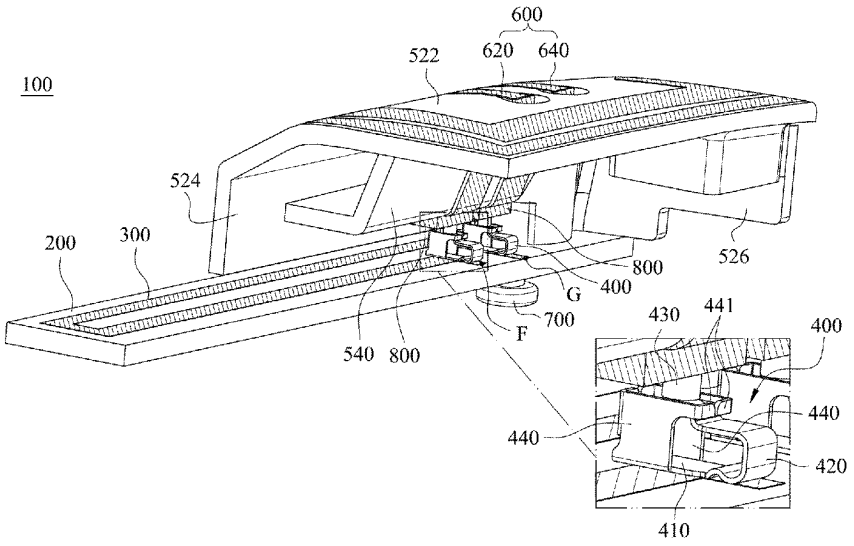
(57) **ABSTRACT**

A composite antenna and an electronic device are proposed. The electronic device includes the composite antenna, and the composite antenna includes a substrate, a first antenna structure, two contact springs, an antenna holder and a second antenna structure. The first antenna structure is disposed on the substrate, and two ends of the first antenna structure are coupled to a feeding point and a grounding point, respectively. The two contact springs are disposed on the first antenna structure, and electrically connected to the feeding point and the grounding point, respectively. The antenna holder is removably disposed on the substrate. The second antenna structure is disposed on the antenna holder and electrically connected to the two contact springs.

18 Claims, 9 Drawing Sheets



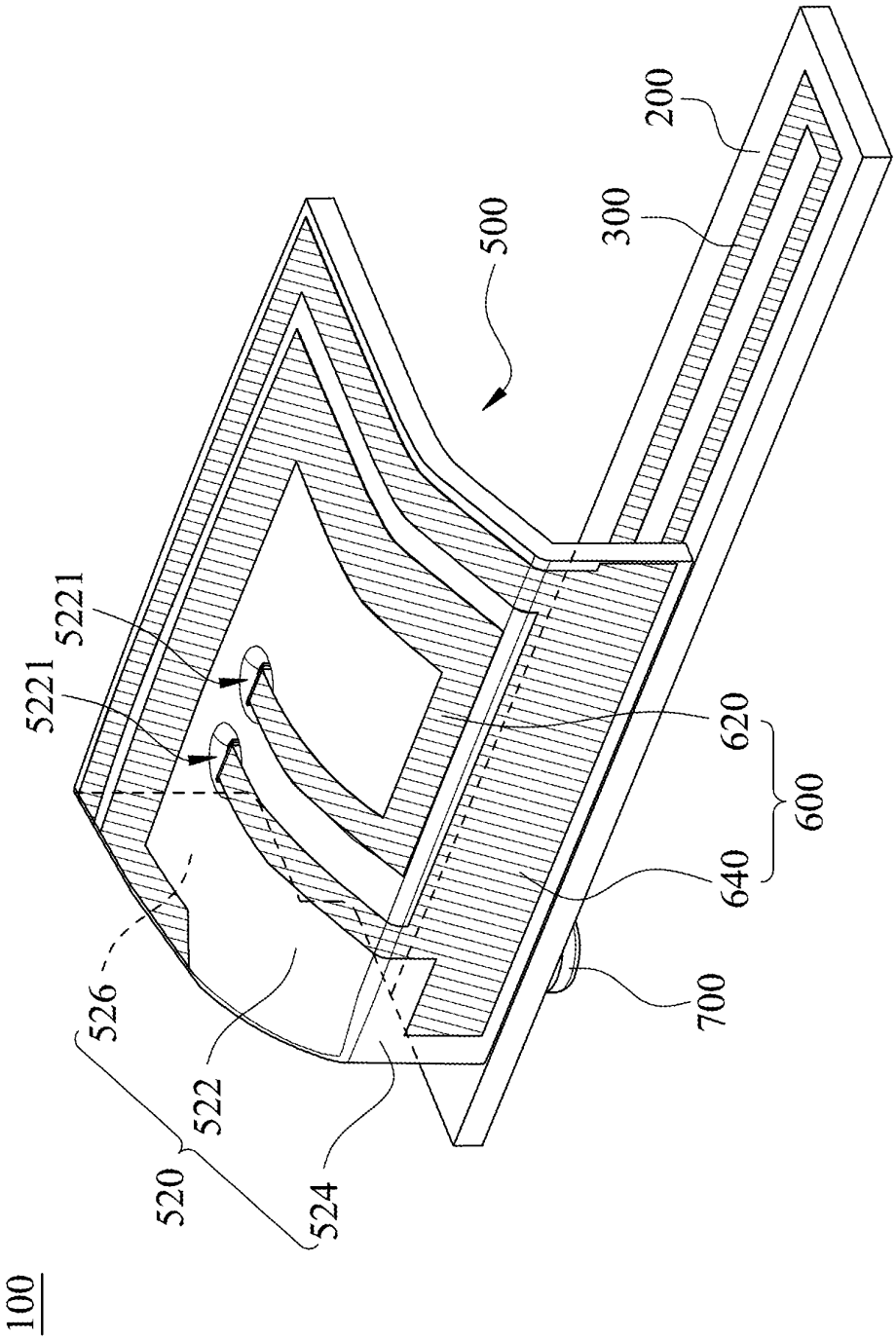
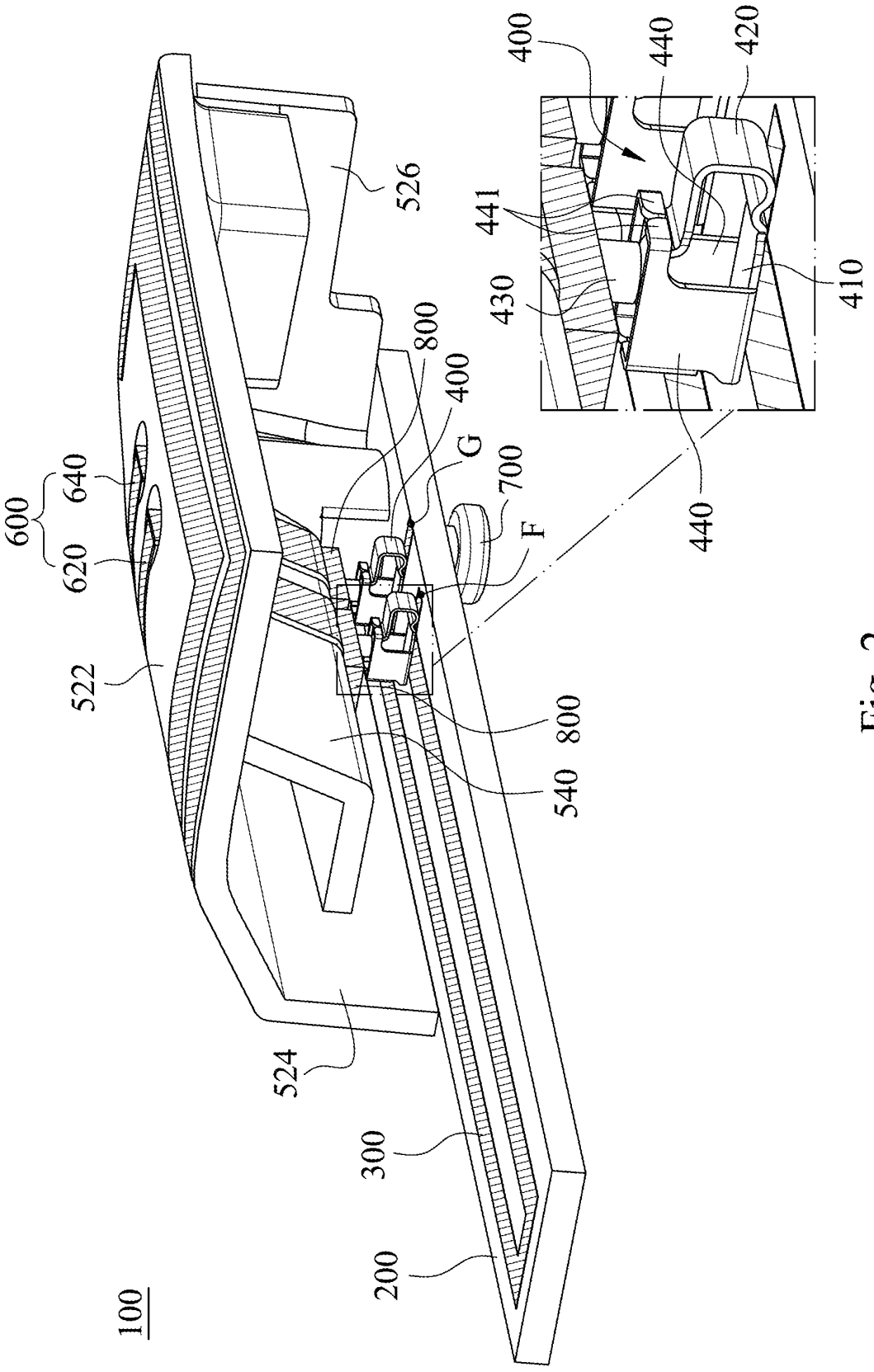


Fig. 1


100
200
300
524
526
522
600
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620
800
400
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700
F
540
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440
420
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430
410
440

Fig. 2

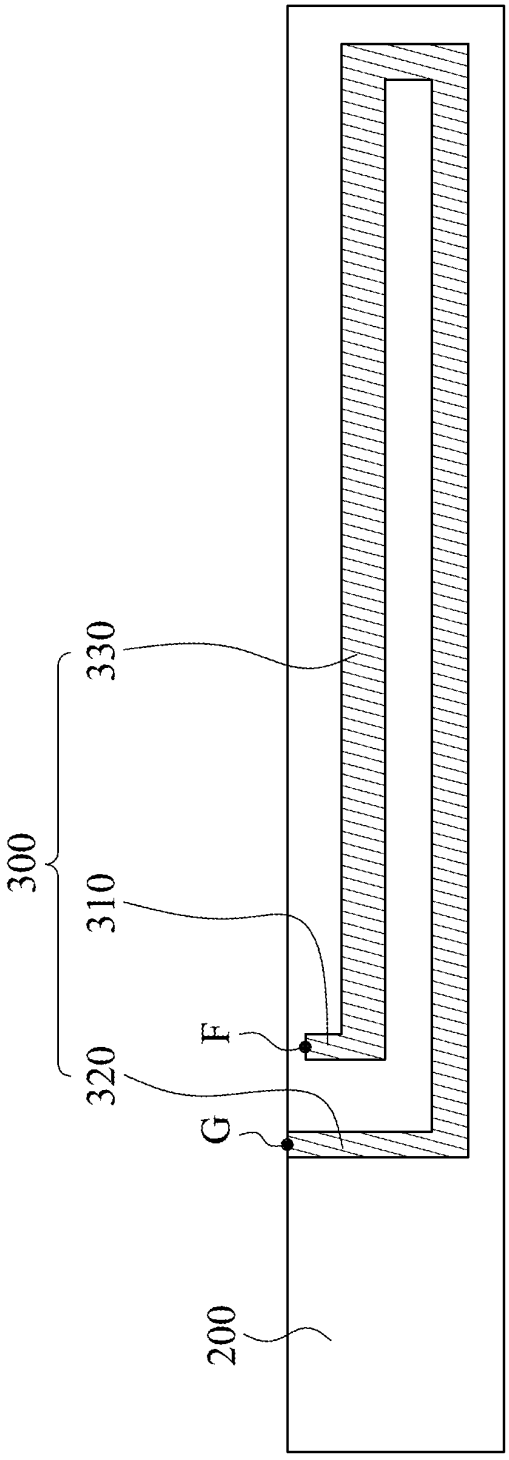

Fig. 3

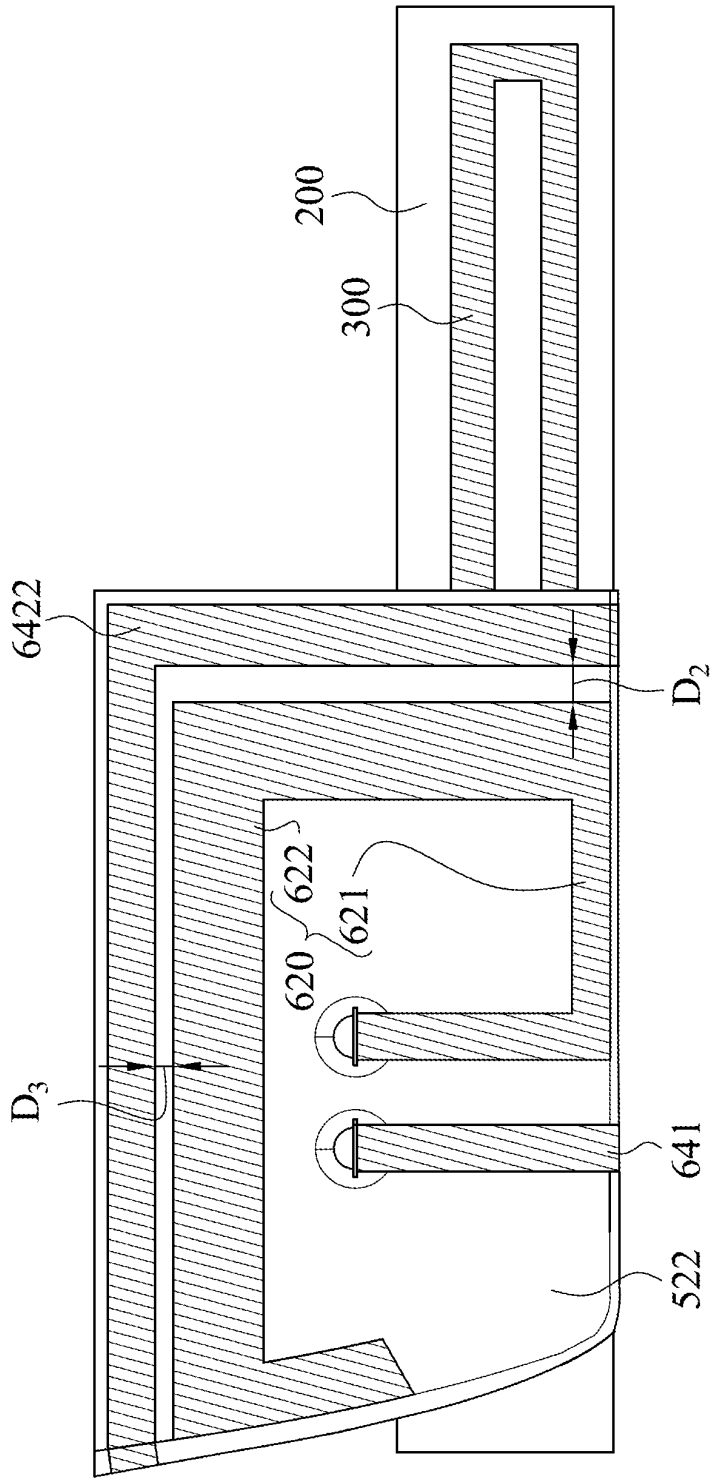

Fig. 4

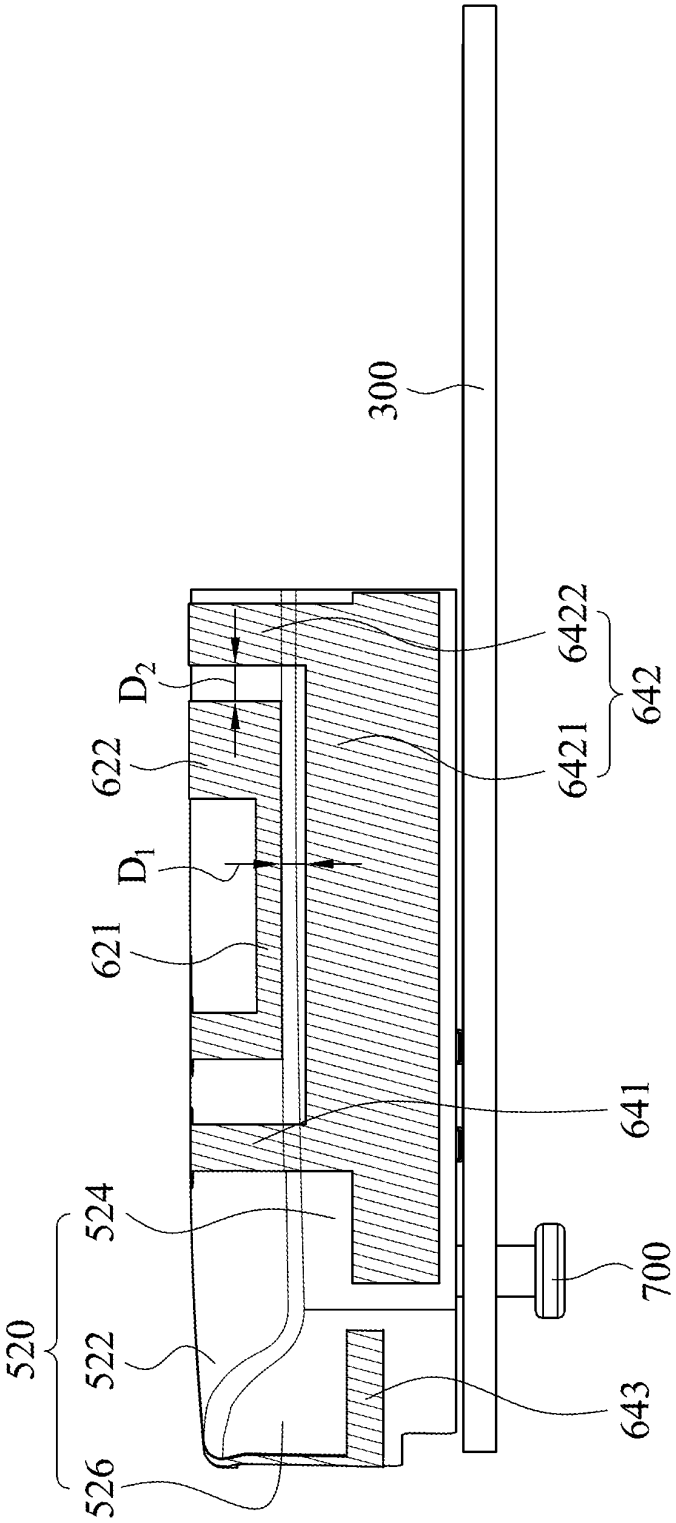

Fig. 5

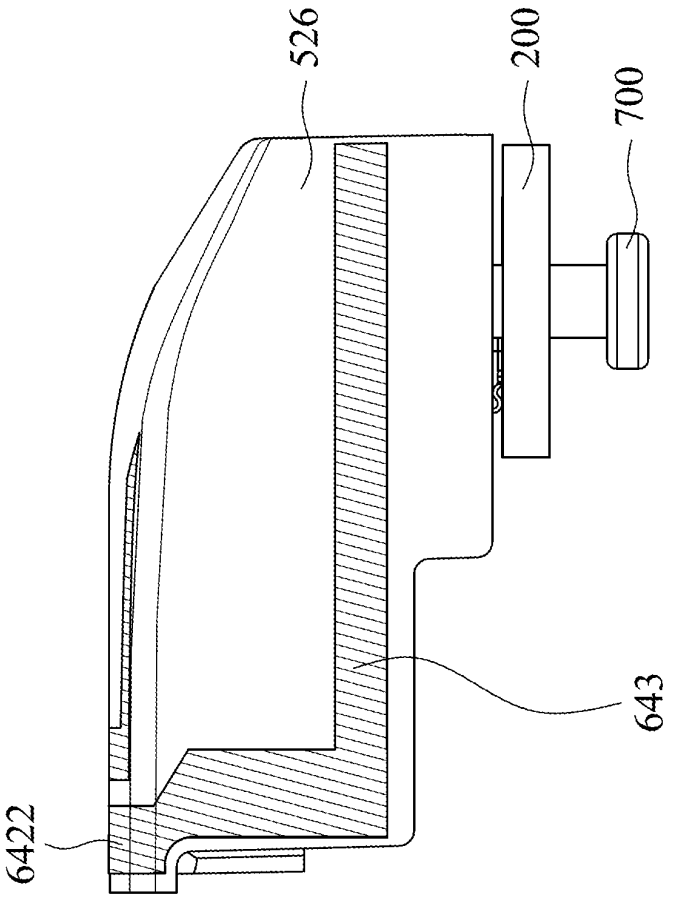

Fig. 6

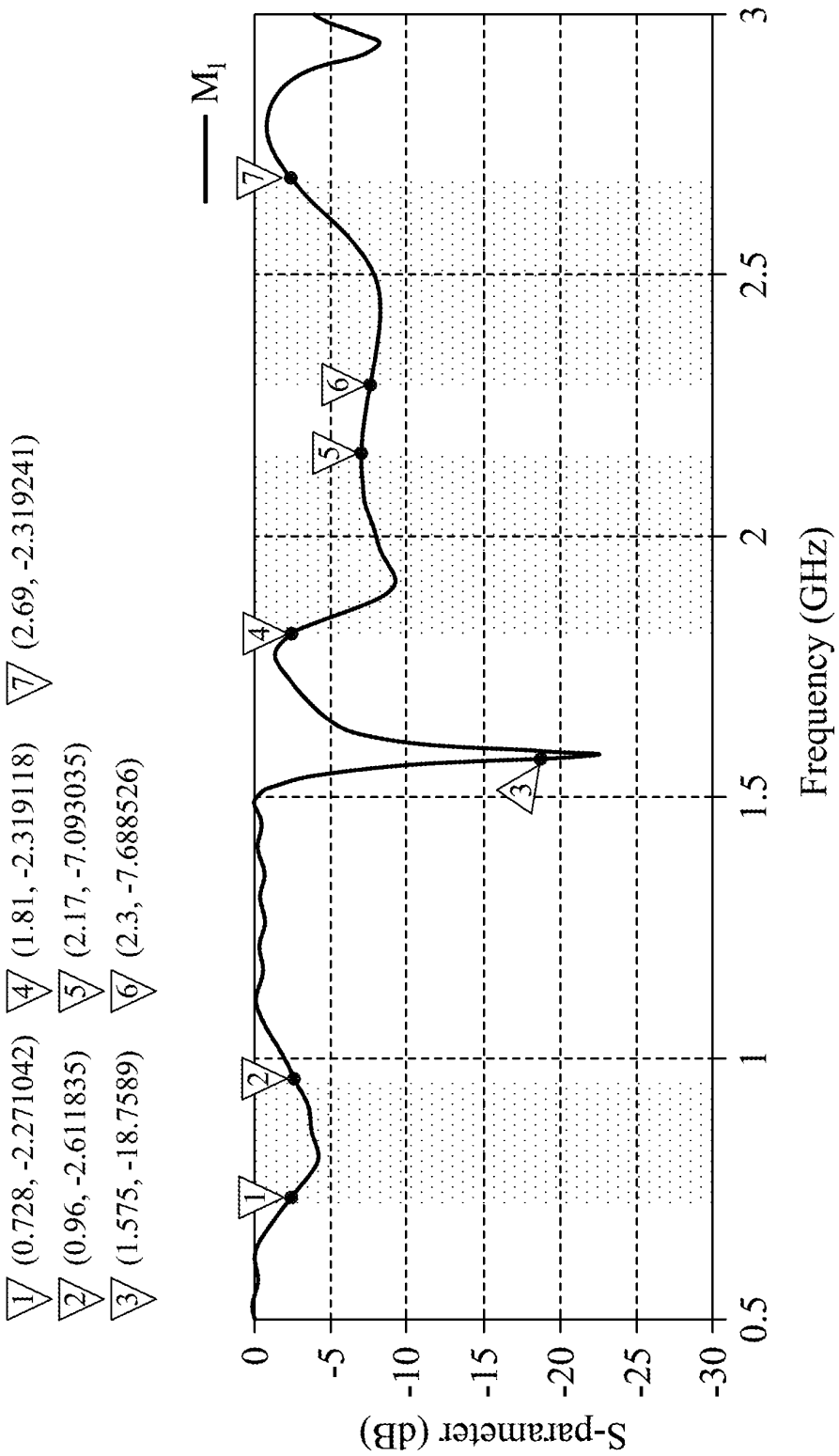
M1
1 (0.728, -2.271042)
2 (0.96, -2.611835)
3 (1.575, -18.7589)
4 (1.81, -2.319118)
5 (2.17, -7.093035)
6 (2.3, -7.688526)
7 (2.69, -2.319241)
S-parameter (dB)
0
-5
-10
-15
-20
-25
-30
0.5
1
1.5
2
2.5
3
Frequency (GHz)

Fig. 7

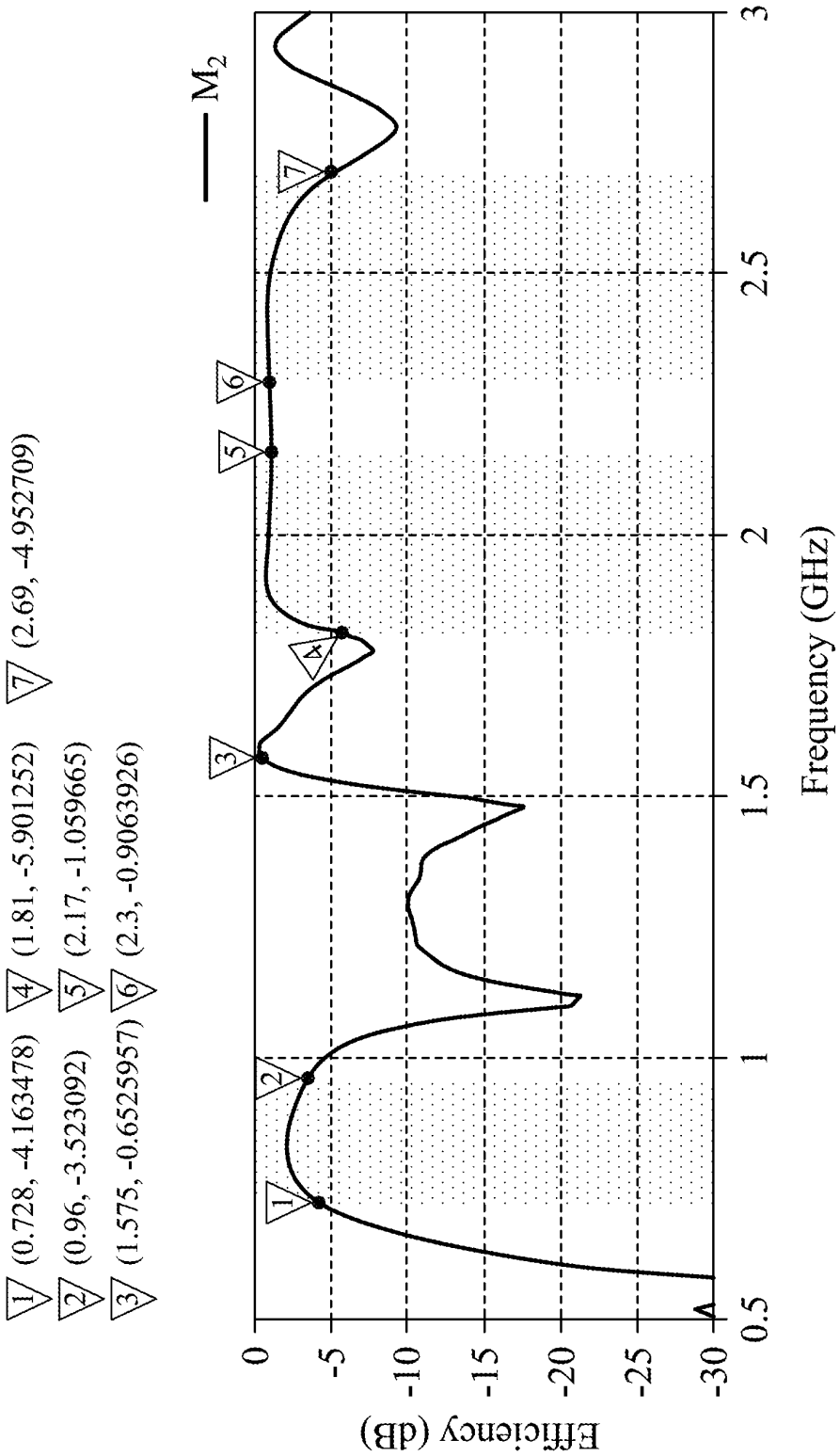
M2
1 (0.728, -4.163478)
2 (0.96, -3.523092)
3 (1.575, -0.6525957)
4 (1.81, -5.901252)
5 (2.17, -1.059665)
6 (2.3, -0.9063926)
7 (2.69, -4.952709)
Efficiency (dB)
0
-5
-10
-15
-20
-25
-30
0.5
1
1.5
2
2.5
3
Frequency (GHz)

Fig. 8

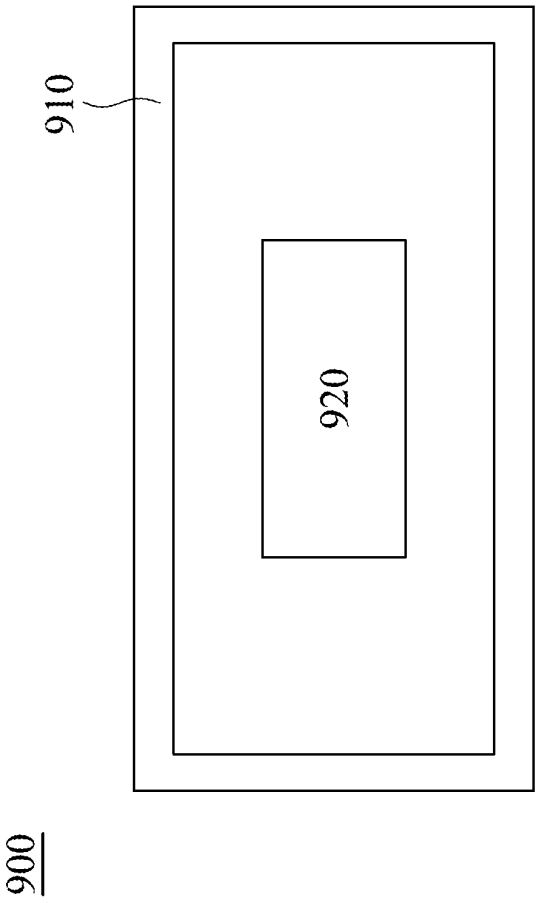

Fig. 9

COMPOSITE ANTENNA AND ELECTRONIC DEVICE

RELATED APPLICATIONS

This application claims priority to China Patent Application Serial Number 202211726830.3, filed Dec. 29, 2022, which is herein incorporated by reference.

BACKGROUND

Technical Field

The present disclosure relates to a composite antenna and an electronic device. More particularly, the present disclosure relates to a composite antenna and an electronic device combining two antenna structures by disposing an antenna bracket on a substrate.

Description of Related Art

With the rapid development of wireless communication technology, the number of antennas required in mobile communication devices (such as notebook, tablet and mobile phone) is increasing. In addition, most of the current mobile communication devices use screens with narrow borders, and are developing toward the trend of miniaturization. However, under the trend of miniaturization, the hardware space of the mobile communication device is severely compressed. Correspondingly, the clearance area for disposing the antenna in the mobile communication device is becoming more and more limited.

Thus, it can be seen that there is a lack of a composite antenna and electronic device in the current market, which can expand multiple antennas in a limited antenna clearance area and still maintain high antenna efficiency, so relevant industries are looking for solutions.

SUMMARY

According to one aspect of the present disclosure, a composite antenna includes a substrate, a first antenna structure, two contact springs, an antenna holder and a second antenna structure. The first antenna structure is disposed on the substrate, and two ends of the first antenna structure are coupled to a feeding point and a grounding point, respectively. The two contact springs are disposed on the first antenna structure, and electrically connected to the feeding point and the grounding point, respectively. The antenna holder is removably disposed on the substrate. The second antenna structure is disposed on the antenna holder and electrically connected to the two contact springs.

According to another aspect of the present disclosure, an electronic device includes at least one of the composite antenna of any one of the aforementioned aspects.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure can be more fully understood by reading the following detailed description of the embodiment, with reference made to the accompanying drawings as follows:

FIG. **1** shows a three-dimensional schematic view of a composite antenna according to a first embodiment of the present disclosure.

FIG. **2** shows another three-dimensional schematic view of the composite antenna of FIG. **1**.

FIG. **3** shows a top view of a substrate and a first antenna structure of the composite antenna of FIG. **1**.

FIG. **4** shows a top view of the composite antenna of FIG. **1**.

FIG. **5** shows a lateral view of the composite antenna of FIG. **1**.

FIG. **6** shows another lateral view of the composite antenna of FIG. **1**.

FIG. **7** shows a schematic graph illustrating S-parameter of the composite antenna of FIG. **1**.

FIG. **8** shows a schematic graph illustrating the performance of the composite antenna of FIG. **1**.

FIG. **9** shows a schematic view of an electronic device according to a second embodiment of the present disclosure.

DETAILED DESCRIPTION

Please refer to FIGS. **1** and **2**. FIG. **1** shows a three-dimensional schematic view of a composite antenna **100** according to a first embodiment of the present disclosure. FIG. **2** shows another three-dimensional schematic view of the composite antenna **100** of FIG. **1**. As shown in FIGS. **1** and **2**, the composite antenna **100** includes a substrate **200**, a first antenna structure **300**, two contact springs **400**, an antenna holder **500** and a second antenna structure **600**.

The substrate **200** can be a planar substrate, for example, a system mainboard, a printed circuit board (PCB), a Flame Retardant 4 (FR4) substrate or a flexible printed circuit board (FPCB) in communication equipment or electronic devices. The thickness of the substrate **200** can be 0.9 mm, and the area of the substrate **200** (i.e., the area of the antenna clearance area) can be 6 mm*40 mm. The first antenna structure **300** is disposed on the substrate **200**, and made of metal material, such as copper, silver, aluminum, iron, or alloy of the aforementioned metals. In addition, the first antenna structure **300** can be electroplated and/or 3D printed on the surface of the substrate **200**. Two ends of the first antenna structure **300** are coupled to a feeding point F and a grounding point G, respectively. The feeding point F can be coupled to a signal source like a radio frequency (RF) module, and the signal source can be used to excite the first antenna structure **300**, so that the first antenna structure **300** operates in a first frequency band. The grounding point G can extend to the outside of the substrate **200** and be coupled to a ground voltage, and the ground voltage can be provided by a system ground plane of the composite antenna **100**.

The contact springs **400** are disposed on the first antenna structure **300**, and electrically connected to the feeding point F and the grounding point G, respectively. The antenna holder **500** is removably disposed on the substrate **200**. The second antenna structure **600** is disposed on the antenna holder **500** and can include a first radiator **620** and a second radiator **640**, which are electrically connected to the contact springs **400**, respectively. In particular, the antenna holder **500** can have a groove (not shown), which is configured to accommodate a nut (not shown). The composite antenna **100** can further include a positioning element **700** passing through the substrate **200** and locking the aforementioned nut so as to position the antenna holder **500** to the substrate **200**. The first radiator **620** and the second radiator **640** of the second antenna structure **600** can be made of metal material, such as copper, silver, aluminum, iron, or alloy of the aforementioned metals, and manufactured in the antenna holder **500** by using laser direct structuring (LDS). It should be noted that in the second antenna structure **600**, the first radiator **620** can be electrically connected to the feeding point F through one of the contact springs **400**, and the

second radiator **640** can be electrically connected to the grounding point G through the other one of the contact springs **400**. The first radiator **620** is excited by the feeding point F to operate in a second frequency band, and the second radiator **640** is coupled to the first radiator **620** to operate in a third frequency band and a fourth frequency band. It has to be noted that the composite antenna **100** of the present disclosure is not limited to sizes, materials, manufacturing methods of the abovementioned elements and the connection relationship with environmental elements.

Thus, the composite antenna **100** of the present disclosure arranges the contact springs **400** and the antenna holder **500** on the substrate **200**, and uses the contact springs **400** to electrically connect the second antenna structure **600** disposed on the antenna holder **500** to the feeding point F and the grounding point G, so that the second antenna structure **600** and the first antenna structure **300** disposed on the substrate **200** can share the same antenna clearance area; in other words, the second antenna structure **600** is not located on a horizontal plane of the substrate **200**, and located on one side of the substrate **200** instead. Therefore, it can effectively save space and expand the antenna frequency band.

In detail, the antenna holder **500** can include a main frame body **520** and a sub-frame body **540**. The main frame body **520** includes an outward convex arc portion **522**, an extending portion **524** and a side portion **526**. The outward convex arc portion **522** includes two through holes **5221**. The extending portion **524** is connected to the outward convex arc portion **522** and formed in a planar shape, and the extending portion **524** is perpendicular to the substrate **200**. The side portion **526** is connected to the outward convex arc portion **522** and the extending portion **524**, and perpendicular to the substrate **200**. The sub-frame body **540** is connected between the outward convex arc portion **522** and the extending portion **524**, and located between the substrate **200** and the outward convex arc portion **522**.

Further, the composite antenna **100** can further include two conductive elements **800**. The conductive elements **800** are disposed on the sub-frame body **540**. Two ends of the conductive elements **800** respectively pass through the through holes **5221** to be connected to the first radiator **620** and the second radiator **640** of the second antenna structure **600**, and another two ends of the conductive elements **800** are abutted by two contact portions **430** of the contact springs **400**, respectively. Furthermore, each of the contact springs **400** can be a connector with electrical conductivity, and is welded to the first antenna structure **300**. Each of the contact springs **400** can include a bottom plate **410**, an elastic supporting portion **420**, the contact portion **430** and two side plates **440**. The bottom plate **410** is disposed on the first antenna structure **300**. The elastic supporting portion **420** is reversely bent from one end of the bottom plate **410** toward the other end of the bottom plate **410**. The contact portion **430** is connected to the elastic supporting portion **420** and perpendicular to the bottom plate **410**. The side plates **440** are disposed opposite to the bottom plate **410** and perpendicular to the bottom plate **410**, and each of the side plates **440** can include a limiting portion **441**. The limiting portions **441** of the side plates **440** are located above the elastic supporting portion **420** and configured to limit the elastic supporting portion **420** so as to prevent the antenna holder **500** from detaching from the substrate **200** or the sub-frame body **540** deformed due to excessive elastic force of the elastic supporting portion **420**. In other embodiments, the contact springs can be soldered to the substrate and directly connected to the feeding point and the grounding point, respectively. Therefore, the contact springs of the present disclosure do not need to be completely disposed on the first antenna structure, and only need to be electrically connected to the feeding point and the grounding point.

Please refer to FIG. **3**. FIG. **3** shows a top view of the substrate **200** and the first antenna structure **300** of the composite antenna **100** of FIG. **1**. As shown in FIG. **3**, the first antenna structure **300** can include a feeding portion **310**, a grounding portion **320** and a radiating portion **330**. The feeding portion **310** is electrically connected to the feeding point F. The grounding portion **320** is electrically connected to the grounding point G and parallel to the feeding portion **310**, and the grounding portion **320** is spaced apart from the feeding portion **310**. The radiating portion **330** is formed in a ring shape, and two ends of the radiating portion **330** are connected to the feeding portion **310** and the grounding portion **320**, respectively. Further, the first antenna structure **300** can be a loop antenna, such as a GPS antenna, and the radiating portion **330** can cover the first frequency band, and a center frequency of the first frequency band is 1.575 GHz.

Please refer to FIGS. **1**, **2**, **4**, **5** and **6**. FIG. **4** shows a top view of the composite antenna **100** of FIG. **1**. FIG. **5** shows a lateral view of the composite antenna **100** of FIG. **1**. FIG. **6** shows another lateral view of the composite antenna **100** of FIG. **1**. In particular, the second antenna structure **600** can be a dipole antenna, such as a WWAN Aux antenna. As shown in FIG. **4**, the first radiator **620** of the second antenna structure **600** is disposed on the outward convex arc portion **522** of the main frame body **520**, and can include an extended feeding portion **621** and a high-frequency resonance portion **622**. One end of the extended feeding portion **621** is electrically connected to the feeding point F through the one of the contact springs **400** and one of the conductive elements **800**. The high-frequency resonance portion **622** is connected to the other end of the extended feeding portion **621** and excited by the feeding point F to operate in the second frequency band. Viewing the first radiator **620** from the top view, the extended feeding portion **621** is formed in a L-shape, and the high-frequency resonance portion **622** is formed in a U-shape, but the present disclosure is not limited thereto.

In FIGS. **4** and **5**, the second radiator **640** can include an extended grounding portion **641**, an intermediate-frequency resonance portion **642** and a low-frequency resonance portion **643**. The extended grounding portion **641** is disposed on the outward convex arc portion **522** of the main frame body **520**, and one end of the extended grounding portion **641** is electrically connected to the grounding point G via the other one of the contact springs **400** and another one of the conductive elements **800**. The intermediate-frequency resonance portion **642** includes a first segment **6421** and a second segment **6422**. The first segment **6421** is disposed on the extending portion **524** of the main frame body **520** and connected to the other end of the extended grounding portion **641**, and the first segment **6421** operates in the third frequency band by coupling with the first radiator **620**. The second segment **6422** is disposed on the outward convex arc portion **522** of the main frame body **520**, and one end of the second segment **6422** is connected to the first segment **6421**. The first segment **6421** can be formed in a long rectangle, and the second segment **6422** can be formed in a L-shape from the top view, but the present disclosure is not limited thereto. As shown in FIG. **6**, the low-frequency resonance portion **643** is disposed on the side portion **526** of the main frame body **520** and connected to the other end of the second segment **6422**, and the low-frequency resonance portion **643** is coupled to the first radiator **620** to operate in the fourth

frequency band. The second frequency band is between 2300 MHz and 2690 MHz, the third frequency band is between 1810 MHz and 2170 MHz, and the fourth frequency band is between 728 MHz and 960 MHz.

Further, a coupling interval D_1 is formed between the extended feeding portion **621** of the first radiator **620** and the first segment **6421** of the intermediate-frequency resonance portion **642** of the second radiator **640**. A coupling interval D_2 and a coupling interval D_3 are formed between the high-frequency resonance portion **622** of the first radiator **620** and the second segment **6422** of the intermediate-frequency resonance portion **642** of the second radiator **640**. The coupling interval D_2 is equal to the coupling interval D_1 and can be between 0.7 mm and 1.3 mm, and the coupling interval D_3 is smaller than the coupling interval D_2 and can be between 0.3 mm and 0.7 mm. Therefore, the composite antenna **100** of the present disclosure uses an inner branch (i.e., the first radiator **620**) arranged on the antenna holder **500** to provide the high-frequency resonance and can fine-tune the second frequency band by adjusting the width of the high-frequency resonance portion **622**; uses a branch located on a side of the antenna holder **500** close to the substrate **200** (i.e., the first segment **6421** of the intermediate-frequency resonance portion **642**) to couple out the intermediate frequency and can fine-tune the resonant frequency point and the bandwidth by adjusting the size of the first segment **6421**; and uses an outer branch located on another side of the antenna holder **500** near the substrate **200** (i.e., the low-frequency resonance portion **643**) to provide the low-frequency resonance to achieve the function of transmitting multi-band wireless signals.

Please refer to FIGS. **7** and **8**. FIG. **7** shows a schematic graph illustrating S-parameter of the composite antenna **100** of FIG. **1**. FIG. **8** shows a schematic graph illustrating the performance of the composite antenna **100** of FIG. **1**. In FIG. **7**, the horizontal axis represents frequency (GHz), and the vertical axis represents S-parameters (dB). A curve M_1 is a reflection coefficient (S**11**) of the composite antenna **100** as a function of the operating frequency, the reflection coefficient of the center frequency (1.575 GHZ) of the first frequency band is less than −20 dB, the reflection coefficient of the second frequency band (2.3 GHZ to 2.69 GHz) is less than −3 dB, the reflection coefficient of the third frequency band (1.81 GHz to 2.17 GHz) is less than −3 dB, and the reflection coefficient of the fourth frequency band (0.728 GHz to 0.96 GHz) is less than −3 dB. Therefore, the composite antenna **100** of the present disclosure has the good reflection coefficient in both of the low-frequency operating frequency band and the high-frequency operating frequency band. In FIG. **8**, the horizontal axis represents frequency (GHz), and the vertical axis represents efficiency (dB). A curve M_2 is the antenna efficiency of the composite antenna **100** as a function of the operating frequency. In the first to fourth frequency bands, the antenna efficiency of the composite antenna **100** can be maintained within −6 dB, which can meet the practical application requirements of the general multi-input and multi-output antenna systems. Thus, the composite antenna **100** of the present disclosure can be divided into two different antenna forms, one is the first antenna structure **300** (e.g., the GPS antenna) disposed on the substrate **200**, and the other is the second antenna structure **600** disposed on the antenna holder **500** (e.g., the WWAN Aux antenna). Both of the first antenna structure **300** and the second antenna structure **600** share the feeding point F and the grounding point G, so there is no isolation problem.

Please refer to FIG. **9**. FIG. **9** shows a schematic view of an electronic device **900** according to a second embodiment of the present disclosure. As shown in FIG. **9**, the electronic device **900** at least includes a housing **910** and a composite antenna **920**. The composite antenna **920** is disposed on the housing **910**. Specifically, the electronic device **900** can be a mobile electronic device, such as a smart phone, a tablet computer, or a notebook computer. The housing **910** can be at least partially made of a non-conductive material so as to transmit the electromagnetic waves of the composite antenna **920**. For example, the composite antenna **920** can be the composite antenna **100** of the first embodiment in FIG. **1**, and its structure and function will not be described here again. Although not shown in FIG. **9**, the electronic device **900** can further include a system mainboard and other environmental components, such as a processor, a storage device, a speaker, a battery module or/and a touch control panel, and the substrate of the composite antenna **920** is a part of the system motherboard of the electronic device **900**.

In summary, the present disclosure has the following advantages. First, the composite antenna of the present disclosure has a simple structure and is easy to assemble. Since the antenna holder can be combined with the printed circuit board (i.e., the substrate), the overall operating frequency band is highly variable, and the configuration of the antenna structure can be changed on the antenna holder according to different products or client requirements. Second, by arranging the first antenna structure and the second antenna structure in the same antenna clearance area, it can effectively save space and expand the antenna frequency band. Third, if the product or client does not need to use multiple frequency bands, the radiator can be simply printed on the substrate of the composite antenna, so it has a zero-cost advantage.

Although the present disclosure has been described in considerable detail with reference to certain embodiments thereof, other embodiments are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the embodiments contained herein.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present disclosure without departing from the scope or spirit of the disclosure. In view of the foregoing, it is intended that the present disclosure cover modifications and variations of this disclosure provided they fall within the scope of the following claims.

What is claimed is:

1. A composite antenna, comprising:

a substrate;

a first antenna structure disposed on the substrate, wherein two ends of the first antenna structure are coupled to a feeding point and a grounding point, respectively;

two contact springs disposed on the first antenna structure and electrically connected to the feeding point and the grounding point, respectively;

an antenna holder removably disposed on the substrate; and

a second antenna structure disposed on the antenna holder and electrically connected to the two contact springs.

2. The composite antenna of claim **1**, wherein the first antenna structure comprises:

a feeding portion electrically connected to the feeding point;

a grounding portion electrically connected to the grounding point and parallel to the feeding portion, wherein the grounding portion is spaced apart from the feeding portion; and

a radiating portion formed in a ring shape, wherein two ends of the radiating portion are connected to the feeding portion and the grounding portion, respectively.

3. The composite antenna of claim **2**, wherein the radiating portion operates in a first frequency band, and a center frequency of the first frequency band is 1.575 GHz.

4. The composite antenna of claim **1**, wherein the antenna holder comprises:

a main frame body, comprising:

an outward convex arc portion;

an extending portion connected to the outward convex arc portion and formed in a planar shape, wherein the extending portion is perpendicular to the substrate; and

a side portion connected to the outward convex arc portion and the extending portion and perpendicular to the substrate; and

a sub-frame body connected between the outward convex arc portion and the extending portion, and located between the substrate and the outward convex arc portion.

5. The composite antenna of claim **4**, wherein the outward convex arc portion comprises two through holes, and the composite antenna further comprises:

two conductive elements disposed on the sub-frame body, wherein two ends of the two conductive elements respectively pass through the two through holes to be connected to the second antenna structure, and another two ends of the two conductive elements are abutted by the two contact springs, respectively.

6. The composite antenna of claim **4**, wherein the second antenna structure comprises:

a first radiator disposed on the outward convex arc portion of the main frame body, and comprising:

an extended feeding portion electrically connected to the feeding point through one of the two contact springs; and

a high-frequency resonance portion connected to the extended feeding portion and operating in a second frequency band.

7. The composite antenna of claim **4**, wherein the second antenna structure comprises:

a second radiator, comprising:

an extended grounding portion disposed on the outward convex arc portion of the main frame body and electrically connected to the grounding point through one of the two contact springs;

an intermediate-frequency resonance portion comprising:

a first segment disposed on the extending portion of the main frame body and connected to the extended grounding portion, wherein the first segment operates in a third frequency band; and

a second segment disposed on the outward convex arc portion of the main frame body and connected to the first segment; and

a low-frequency resonance portion disposed on the side portion of the main frame body and connected to the second segment, wherein the low-frequency resonance portion operates in a fourth frequency band.

8. The composite antenna of claim **1**, wherein the second antenna structure operates in a second frequency band, a third frequency band and a fourth frequency band, the second frequency band is between 2300 MHz and 2690 MHz, the third frequency band is between 1810 MHz and 2170 MHz, and the fourth frequency band is between 728 MHz and 960 MHz.

9. The composite antenna of claim **1**, wherein the first antenna structure is a loop antenna, and the second antenna structure is a dipole antenna.

10. An electronic device, comprising:
at least one of the composite antenna of claim **1**.

11. An electronic device, comprising:
at least one of the composite antenna of claim **2**.

12. An electronic device, comprising:
at least one of the composite antenna of claim **3**.

13. An electronic device, comprising:
at least one of the composite antenna of claim **4**.

14. An electronic device, comprising:
at least one of the composite antenna of claim **5**.

15. An electronic device, comprising:
at least one of the composite antenna of claim **6**.

16. An electronic device, comprising:
at least one of the composite antenna of claim **7**.

17. An electronic device, comprising:
at least one of the composite antenna of claim **8**.

18. An electronic device, comprising:
at least one of the composite antenna of claim **9**.

* * * * *

US012249777B2

(12) **United States Patent**
Wu

(10) **Patent No.: US 12,249,777 B2**
(45) **Date of Patent: Mar. 11, 2025**

(54) **ULTRA-WIDEBAND ANTENNA DEVICE**

(71) Applicant: **ASUSTeK COMPUTER INC.**, Taipei (TW)

(72) Inventor: **Yu-Ching Wu**, Taipei (TW)

(73) Assignee: **ASUSTEK COMPUTER INC.**, Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 201 days.

(21) Appl. No.: **18/181,839**

(22) Filed: **Mar. 10, 2023**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
H01Q 5/25 (2015.01)
H01Q 5/364 (2015.01)
H01Q 9/04 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 9/0421*** (2013.01); ***H01Q 5/25*** (2015.01); ***H01Q 5/364*** (2015.01)

(58) **Field of Classification Search**
CPC H01Q 1/38; H01Q 9/0407; H01Q 9/0421; H01Q 5/25
See application file for complete search history.

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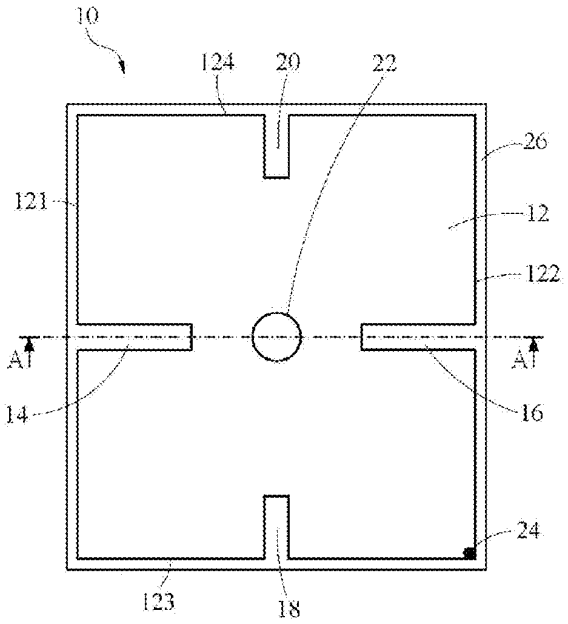
(57) **ABSTRACT**

An ultra-wideband antenna device includes a radiation metal body, a first slotted hole, a second slotted hole, a third slotted hole, a fourth slotted hole, a ground point, and a feeding source. The radiation metal body includes a first side edge and a second side edge opposite to each other and a third side edge and a fourth side edge opposite to each other, the first slotted hole extends inward from the first side edge, the second slotted hole extends inward from the second side edge, the third slotted hole extends inward from the third side edge, and the fourth slotted hole extends inward from the fourth side edge. The ground point is located at a middle position of the radiation metal body, and the feeding source is located on the radiation metal body and away from the middle position.

14 Claims, 7 Drawing Sheets



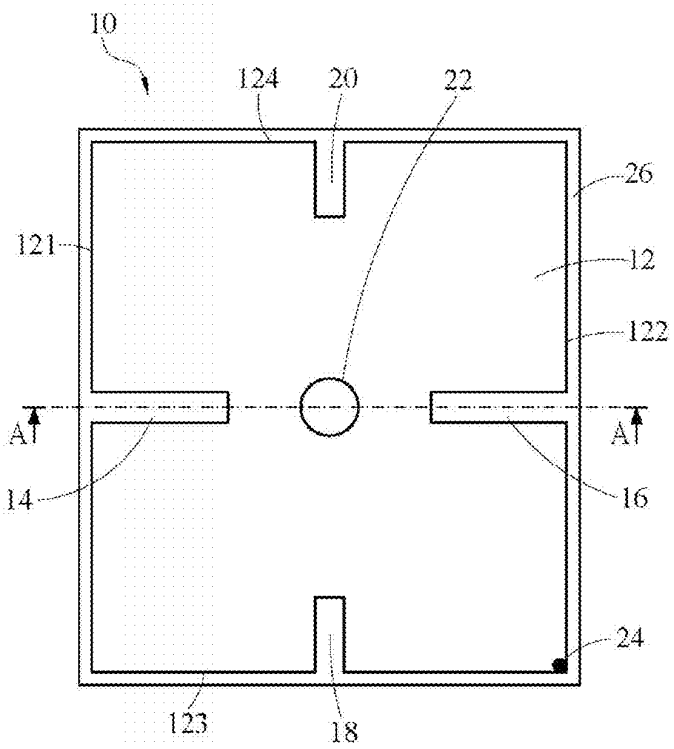


FIG. 1

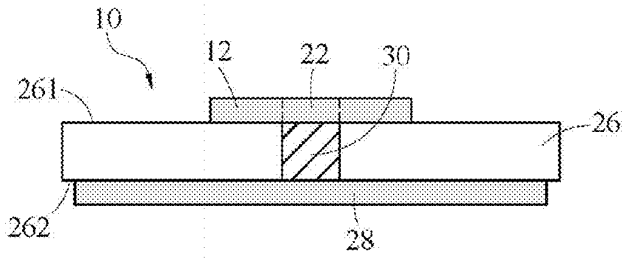


FIG. 2

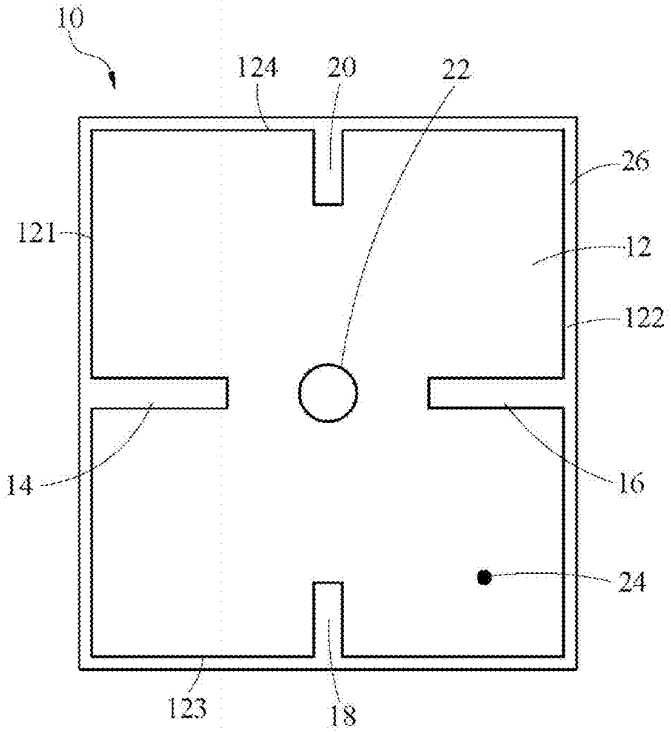


FIG. 3

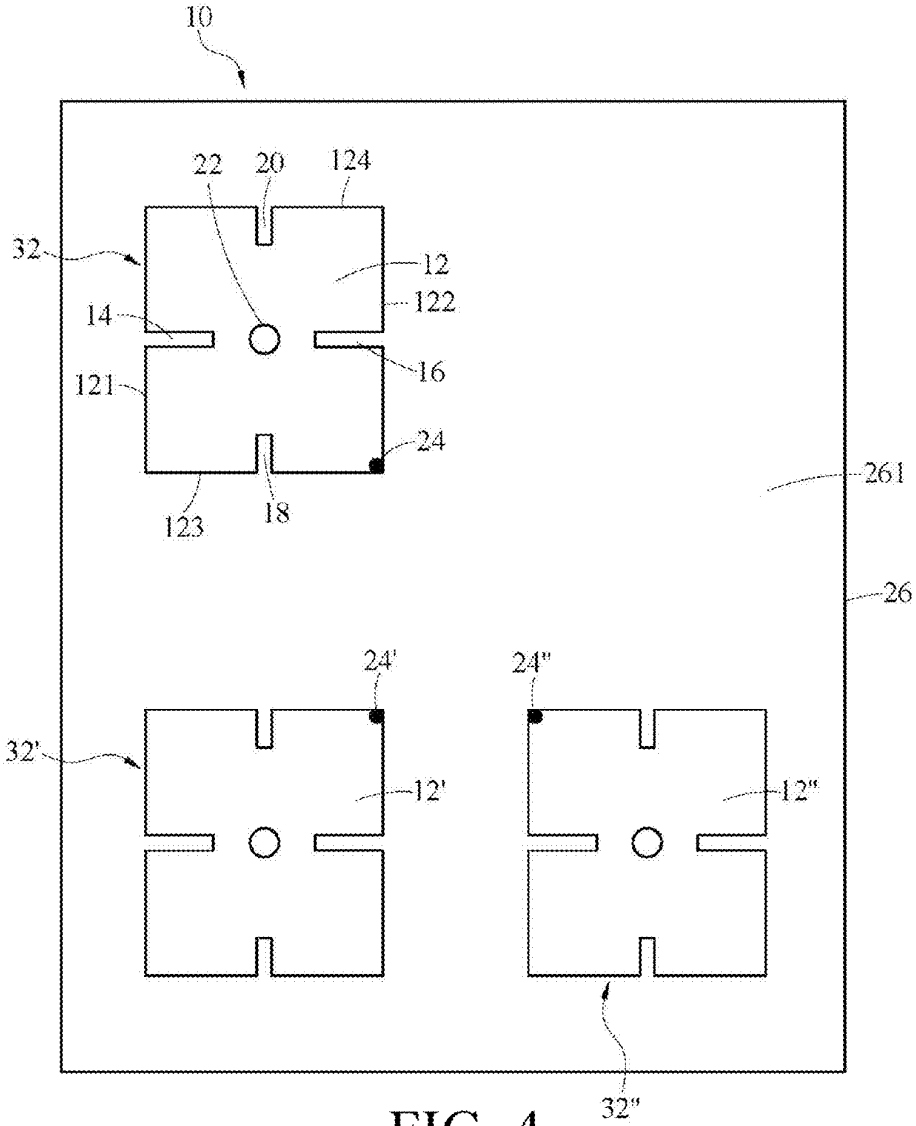


FIG. 4

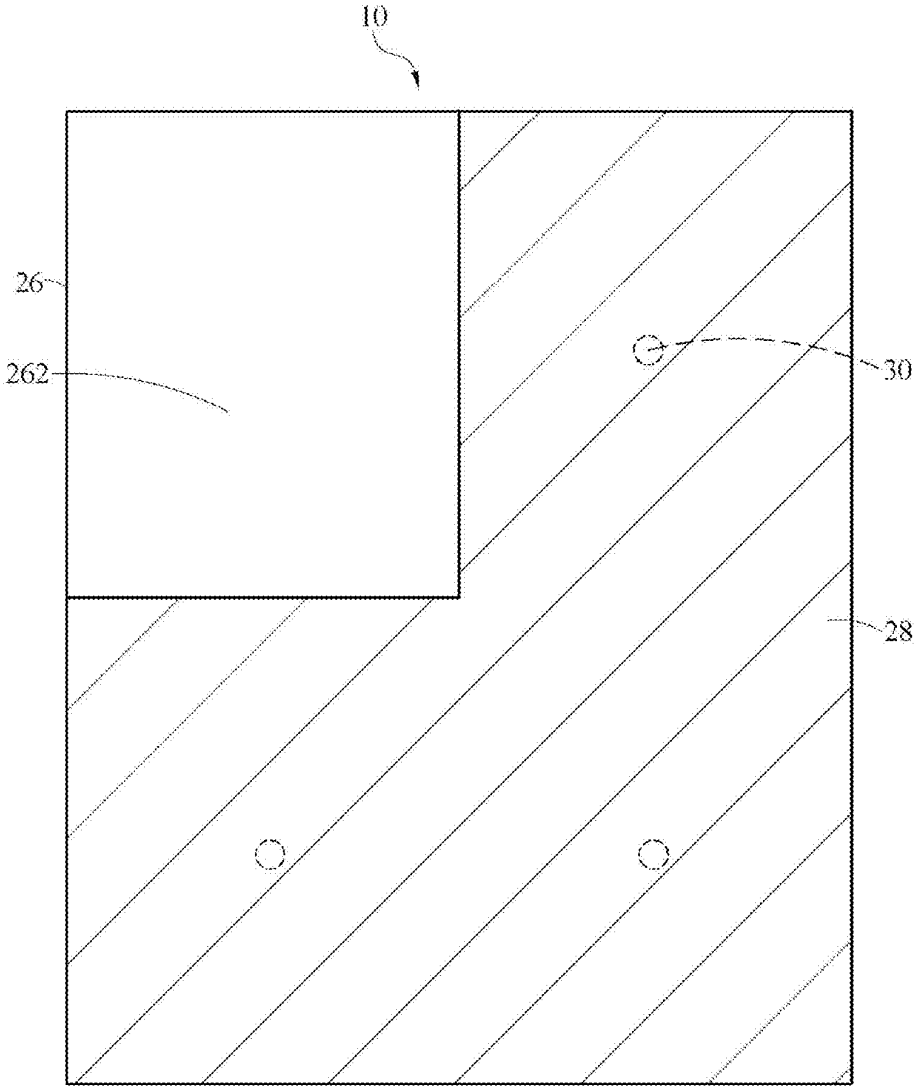


FIG. 5

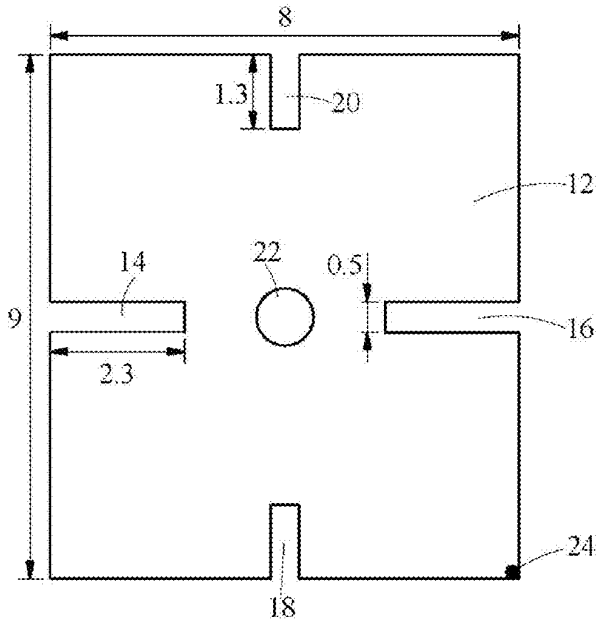

8
1.3
20
12
14
22
0.5
9
16
2.3
24
18

FIG. 6

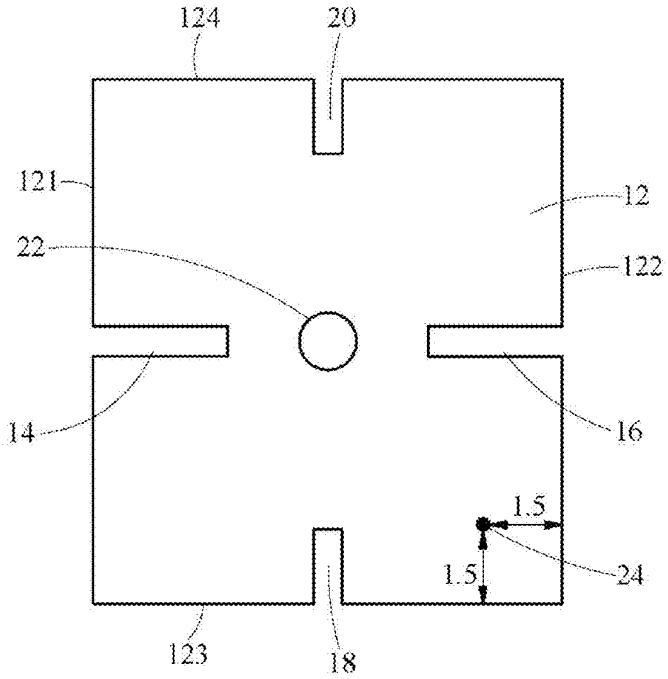

124
20
121
12
22
122
14
16
1.5
1.5
24
123
18

FIG. 7

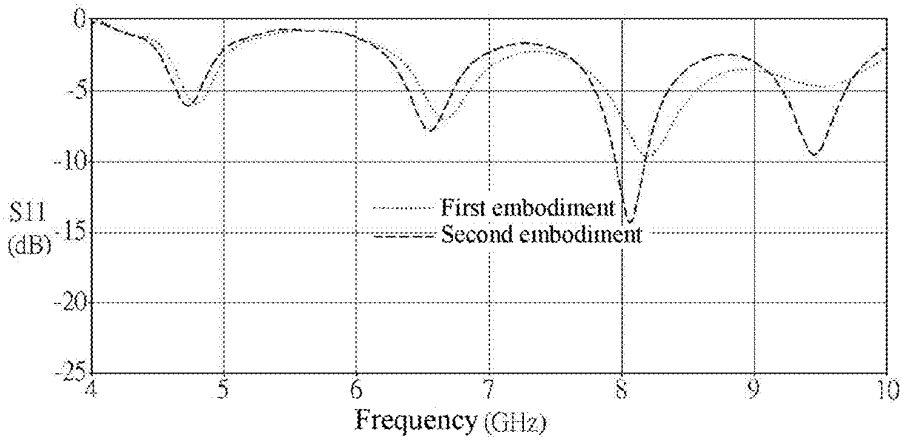

0
-5
-10
-15
-20
-25
S11
(dB)
First embodiment
Second embodiment
4
5
6
7
8
9
10
Frequency (GHz)

FIG. 8

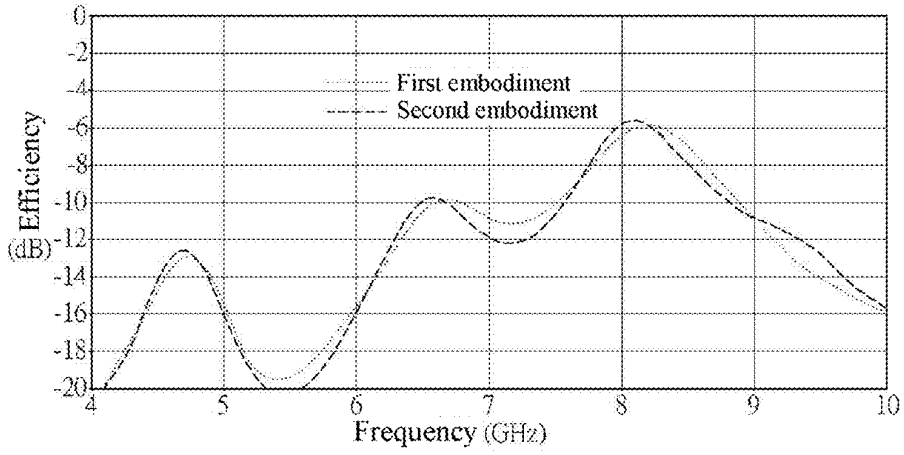

0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
Efficiency
(dB)
First embodiment
Second embodiment
4
5
6
7
8
9
10
Frequency (GHz)

FIG. 9

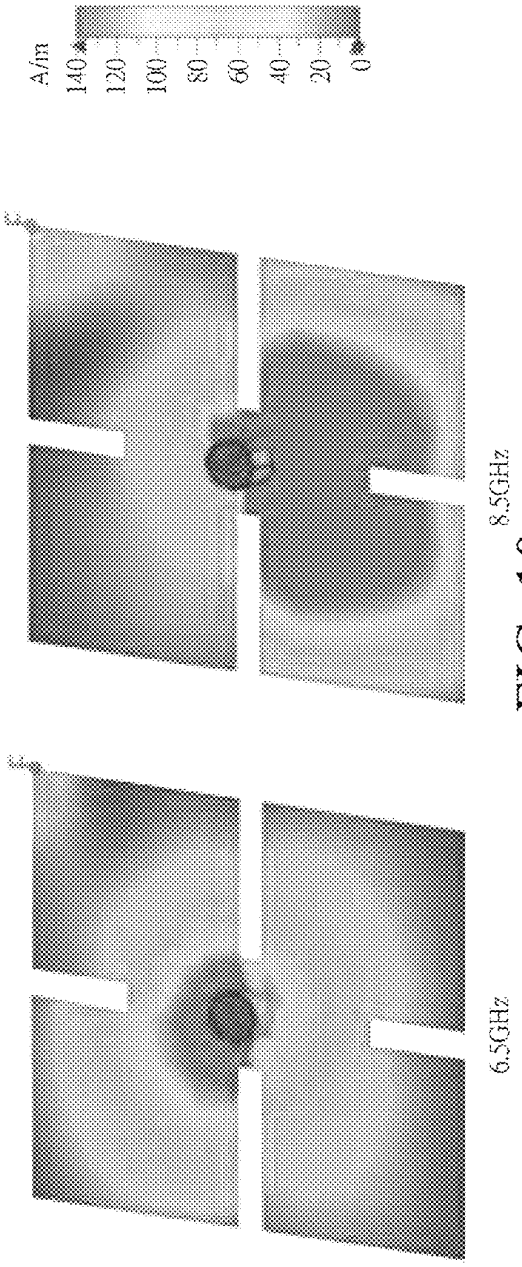


FIG. 10

ULTRA-WIDEBAND ANTENNA DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the priority benefit of Taiwan application serial No. 111128216, filed on Jul. 27, 2022. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of the specification.

BACKGROUND OF THE DISCLOSURE

Field of the Invention

The disclosure relates to an ultra-wideband antenna device with a ground design.

Description of the Related Art

Electronic devices need to use antennas when transmitting or receiving radio frequency signals. The antennas can not only be used to transmit the radio frequency signals, but also be used to implement positioning functions. In the related art, the electronic devices use ultra-wideband (UWB) positioning technologies to realize indoor positioning. For an ultra-wideband antenna, a transmission distance of the ultra-wideband antenna is usually within 10 meters, and a bandwidth is above 1 GHz. An ultra-wideband is a carrier-free communication technology, which uses nanosecond (ns) to picosecond (ps) non-sinusoidal narrow pulses to transmit data, and these pulses occupy a wide bandwidth range.

However, with the development of communication technologies, there are increasing types of radio frequency signals that the electronic devices need to support, such as 4G, 5G, WiFi and other radio frequency signals. Therefore, more antennas need to be arranged inside the electronic devices, resulting in smaller space inside the electronic devices, which is insufficient for arrangement of the ultra-wideband antenna to realize positioning. Therefore, when the size of the ultra-wideband antenna is compressed in a small electronic device, transmission performance of the ultra-wideband antenna is severely affected, causing a negative impact on signal transmitting and receiving of the antenna.

BRIEF SUMMARY OF THE INVENTION

According to the first aspect of this disclosure, an ultra-wideband antenna device is provided. The ultra-wideband antenna device includes a radiation metal body, a first slotted hole, a second slotted hole, a third slotted hole, a fourth slotted hole, a ground point, and a feeding source. The radiation metal body includes a first side edge and a second side edge opposite to each other and a third side edge and a fourth side edge opposite to each other, the first slotted hole is located on the radiation metal body and extends inward from the first side edge, the second slotted hole is located on the radiation metal body and extends inward from the second side edge, the third slotted hole is located on the radiation metal body and extends inward from the third side edge, and the fourth slotted hole is located on the radiation metal body and extends inward from the fourth side edge. The ground point is located at a middle position of the radiation metal body, and the feeding source is located on the radiation metal body and away from the middle position.

According to the second aspect of this disclosure, an ultra-wideband antenna device is provided. The ultra-wideband antenna device includes: a dielectric substrate, three ultra-wideband antennas, and a ground plane. The dielectric substrate includes a first surface and a second surface. The three ultra-wideband antennas are arranged on the first surface of the dielectric substrate, and each ultra-wideband antenna includes a radiation metal body, a first slotted hole, a second slotted hole, a third slotted hole, a fourth slotted hole, a ground point, a feeding source, and a via. The radiation metal body includes a first side edge and a second side edge opposite to each other and a third side edge and a fourth side edge opposite to each other, the first slotted hole is located on the radiation metal body and extends inward from the first side edge, the second slotted hole is located on the radiation metal body and extends inward from the second side edge, the third slotted hole is located on the radiation metal body and extends inward from the third side edge, and the fourth slotted hole is located on the radiation metal body and extends inward from the fourth side edge. The ground point is located at the middle position of the radiation metal body, the feeding source is located on the radiation metal body and away from the middle position, and the via penetrates the dielectric substrate and is connected to the ground point. The ground plane is located on the second surface of the dielectric substrate, and the ground plane is electrically connected to the ground point by using the via.

In summary, the disclosure relates to an ultra-wideband antenna device, which implements the receiving and transmitting of radio frequency signals in two frequency bands by using a design of a smaller antenna size without increasing the antenna size and space, so that the ultra-wideband antenna device in the disclosure effectively improves antenna efficiency in limited space to maintain good wireless communication quality. Based on this, the disclosure still maintains good antenna performance while reducing the size of the ultra-wideband antenna device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic structural diagram of an ultra-wideband antenna device according to a first embodiment of the disclosure.

FIG. **2** is a structural cross-sectional view of the ultra-wideband antenna device taken along line segment AA according to FIG. **1**.

FIG. **3** is a schematic structural diagram of an ultra-wideband antenna device according to a second embodiment of the disclosure.

FIG. **4** is a schematic structural diagram of an ultra-wideband antenna device according to another embodiment of the disclosure.

FIG. **5** is a schematic structural diagram of a bottom surface of an ultra-wideband antenna device according to FIG. **4**.

FIG. **6** is a schematic structural diagram of a size of a radiation metal body used in an ultra-wideband antenna device according to a first embodiment of the disclosure.

FIG. **7** is a schematic structural diagram of a size of a radiation metal body used in an ultra-wideband antenna device according to a second embodiment of the disclosure.

FIG. **8** is a schematic simulation diagram of parameter S generated by an ultra-wideband antenna device in different frequencies according to the disclosure.

FIG. **9** is a schematic simulation diagram of radiation efficiency of an ultra-wideband antenna device under different frequencies according to the disclosure.

FIG. **10** is a diagram of current distribution of an ultra-wideband antenna device operating in frequency bands of 6.5 GHz and 8.5 GHz according to the disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Embodiments of the disclosure are described below with reference to relevant drawings. The same reference numbers in the drawings represent the same or similar components or circuits. It should be understood that although terms such as "first", "second" in this specification may be used for describing various elements, components, areas, or functions, the elements, components, areas, or functions are not limited by such terms. The terms are only used to distinguish one element, component, area, or function from another element, component, area, or function.

FIG. **1** is a schematic structural diagram of an ultra-wideband antenna device according to a first embodiment of the disclosure. Referring to FIG. **1**, in the first embodiment, an ultra-wideband antenna device **10** basically includes a radiation metal body **12**, a first slotted hole **14**, a second slotted hole **16**, a third slotted hole **18**, a fourth slotted hole **20**, a ground point **22**, and a feeding source **24**.

In the ultra-wideband antenna device **10**, the radiation metal body **12** includes a first side edge **121** and a second side edge **122** opposite to each other, and a third side edge **123** and a fourth side edge **124** opposite to each other. The third side edge **123** is adjacent to a same end of the first side edge **121** and the second side edge **122**, and the fourth side edge **124** is adjacent to the other end of the first side edge **121** and the second side edge **122**. The first slotted hole **14** is located on the radiation metal body **12** and extends vertically inward from the first side edge **121**, so that the first slotted hole **14** formed on the radiation metal body **12** is closed at one end and open at the other end. The second slotted hole **16** is located on the radiation metal body **12** and extends vertically inward from the second side edge **122**, so that the second slotted hole **16** formed on the radiation metal body **12** is closed at one end and open at the other end. The third slotted hole **18** is located on the radiation metal body **12** and extends vertically inward from the third side edge **123**, so that the third slotted hole **18** formed on the radiation metal body **12** is closed at one end and open at the other end. The fourth slotted hole **20** is located on the radiation metal body **12** and extends vertically inward from the fourth side **124**, so that the fourth slotted hole **20** formed on the radiation metal body **12** is closed at one end and open at the other end. The ground point **22** is located at a middle position of the radiation metal body **12**. In an embodiment, the middle position of the ground point **22** is a geometric center of the radiation metal body **12** to connect a position with a strongest current to ground. The feeding source **24** is located on the radiation metal body **12** and away from the middle position, so that the feeding source **24** is arranged at an edge corner of the radiation metal body **12** to receive or transmit a radio frequency signal by using the feeding source **24**. In this embodiment, the feeding source **24** is at a lower right corner, but the disclosure is not limited thereto.

In an embodiment, the first slotted hole **14** and the second slotted hole **16** have a same first length, and the first slotted hole **14** and the second slotted hole **16** are located on a same horizontal line. The third slotted hole **18** and the fourth slotted hole **20** have a same second length, and the third slotted hole **18** and the fourth slotted hole **20** are located on a same vertical line. The first length is different from the second length. The first slotted hole **14** and the second slotted hole **16** having the first length are used to implement resonance of a first frequency band, so that the ultra-wideband antenna device **10** supports reception and transmission of a radio frequency signal in the first frequency band. The third slotted hole **18** and the fourth slotted hole **20** having the second length are used to implement resonance of a second frequency band, so that the ultra-wideband antenna device **10** supports reception and transmission of a radio frequency signal in the second frequency band. In this embodiment, the first length is greater than the second length, so the first slotted hole **14** and the second slotted hole **16** having the first length are used to implement the resonance of the lower first frequency band, while the third slotted hole **18** and the fourth slotted hole **20** having the second length are used to implement the resonance of the higher second frequency band.

Referring to FIG. **1** and FIG. **2** together, the ultra-wideband antenna device **10** further includes a dielectric substrate **26**, a ground plane **28**, and a via **30**. The dielectric substrate **26** includes a first surface **261** and a second surface **262** opposite to each other. The radiation metal body **12** is arranged on the first surface **261** of the dielectric substrate **26**. The ground plane **28** is located on the second surface **262** of the dielectric substrate **26**. The via **30** penetrates the dielectric substrate **26** to electrically connect the ground point **22** and the ground plane **28**, so that the ground point **22** of the radiation metal body **12** is electrically connected and grounded to the ground plane **28** through the via **30**.

FIG. **3** is a schematic structural diagram of an ultra-wideband antenna device according to a second embodiment of the disclosure. Referring to FIG. **2** and FIG. **3** together, in the second embodiment, the ultra-wideband antenna device **10** further includes a radiation metal body **12**, a first slotted hole **14**, a second slotted hole **16**, a third slotted hole **18**, a fourth slotted hole **20**, a ground point **22**, a feeding source **24**, a dielectric substrate **26**, a ground plane **28**, and a via **30**. The feeding source **24** is arranged on the radiation metal body **12** and away from a middle position, so that the feeding source **24** is arranged at a position of the radiation metal body **12** surrounded by the second slotted hole **16** and the third slotted hole **18**, so as to receive or transmit a radio frequency signal through the feeding source **24**. Based on this, the position of the feeding source **24** is changed to improve antenna performance in the disclosure. In this embodiment, the feeding source **24** is at a position of the radiation metal body **12** surrounded by the second slotted hole **16** and the third slotted hole **18**, but the disclosure is not limited thereto. In the second embodiment, other components are the same as in the first embodiment except the position of the feeding source **24**. Therefore, reference is made to the foregoing description, and the disclosure is not described herein again.

In an embodiment, the ultra-wideband antenna device **10** further includes a plurality of ultra-wideband antennas **32**, **32'**, **32"**. Referring to FIG. **4** and FIG. **5** together, an ultra-wideband antenna device **10** includes a dielectric substrate **26**, three ultra-wideband antennas **32**, **32'**, **32"**, and a ground plane **28**. The dielectric substrate **26** includes a first surface **261** and a second surface **262**. The three ultra-wideband antennas **32**, **32'**, **32"** are arranged on the first surface **261** of the dielectric substrate **26** and arranged in an L-shape. Each ultra-wideband antenna **32**, **32'**, **32"** has a same structural design. In an embodiment, the ultra-wideband antenna **32** includes a radiation metal body **12**, a first slotted hole **14**, a second slotted hole **16**, a third slotted hole **18**, a fourth slotted hole **20**, a ground point **22**, a feeding source **24**, and a via **30**. The radiation metal body **12**

includes a first side edge **121** and a second side edge **122** opposite to each other and a third side edge **123** and a fourth side edge **124** opposite to each other. The first slotted hole **14** is located on the radiation metal body **12** and extends inward from the first side edge **121**, the second slotted hole **16** is located on the radiation metal body **12** and extends inward from the second side edge **122**, the third slotted hole **18** is located on the radiation metal body **12** and extends inward from the third side edge **123**, and the fourth slotted hole **20** is located on the radiation metal body **12** and extends inward from the fourth side edge **124**. The ground point **22** is located in a middle position of the radiation metal body **12**, and the feeding source **24** is located on the radiation metal body **12** and away from the middle position. The via **30** penetrates the dielectric substrate **26** and is connected to the ground point **22**. The ground plane **28** is located on the second surface **262** of the dielectric substrate **26**, and the ground plane **28** is connected to the ground point **22** through the via **30**, so that the ground point **22** is electrically connected and grounded to the ground plane **28** through the via **30**. The feeding source **24**, **24'**, **24"** of each ultra-wideband antenna **32**, **32'**, **32"** is located at a different position. The feeding source **24**, **24'**, **24"** of each ultra-wideband antenna **32**, **32'**, **32"** is located at an edge corner close of the radiation metal bodies **12**, **12'**, **12"** close the other ultra-wideband antennas **32**, **32'**, **32"**. More specifically, the feeding source **24** of the ultra-wideband antenna **32** is located at an edge corner of the radiation metal bodies **12** close to the other ultra-wideband antennas **32'**, **32"**, that is, the feeding source **24** of the ultra-wideband antenna **32** is arranged at an edge corner of the lower right corner of the radiation metal body **12**. The feeding source **24'** of the ultra-wideband antenna **32'** is located at an edge corner of the radiation metal body **12'** close to the other ultra-wideband antennas **32**, **32'**, that is, the feeding source **24'** of the ultra-wideband antenna **32'** is arranged at an edge corner of an upper right corner of the radiation metal body **12'**. The feeding source **24"** of the ultra-wideband antenna **32"** is located at an edge corner position of the radiation metal body **12"** close the other ultra-wideband antennas **32**, **32'**, that is, the feeding source **24"** of the ultra-wideband antenna **32"** is located at an edge corner of an upper left corner of the radiation metal body **12"**.

In an embodiment, as shown in FIG. **1** to FIG. **5**, the dielectric substrate **26** is a printed circuit board or a plastic substrate, but the disclosure is not limited thereto. It is feasible to use any carrier on which the radiation metal body **12**, the via **30**, and the ground plane **28** as the dielectric substrate **26** of the disclosure.

In an embodiment, as shown in FIG. **1** to FIG. **5**, the radiation metal body **12** and the ground plane **28** are respectively formed on the first surface **261** and the second surface **262** of the dielectric substrate **26** by printing. In an embodiment, the dielectric substrate **26**, and the radiation metal body **12** and the ground plane **28** on the dielectric substrate **26** are printed circuit boards (PCB) having antenna patterns printed thereon.

In an embodiment, as shown in FIG. **1** to FIG. **5**, the radiation metal body **12** and the ground plane **28** are made of conductive materials, such as silver, copper, iron, aluminum, or alloys thereof, but the disclosure is not limited thereto.

In an embodiment, the ground plane **28** is an independent metal sheet or metal layer, or located on a metal plane of an electronic device. In an embodiment, the ground plane **28** is a metal frame of an electronic device or a metal sheet or a sputtered metal portion inside a housing of an electronic device, but the disclosure is not limited thereto. In an embodiment, when the electronic device is a notebook computer, the ground plane **28** is a system ground plane of a screen of the notebook computer or a metal portion such as an EMI aluminum foil or a sputtered metal region inside a housing of the screen of the notebook computer.

In an embodiment, as shown in FIG. **6**, in the radiation metal body **12** used in the ultra-wideband antenna device **10** in the first embodiment, the radiation metal body **12** has a length of 9 mm and a width of 8 mm. The first slotted hole **14** and the second slotted hole **16** have a width of 0.5 mm, and a length of 2.3 mm. The third slotted hole **18** and the fourth slotted hole **20** have a width of 0.5 mm and a length of 1.3 mm. The first length of the first slotted hole **14** and the second slotted hole **16** is greater than the second length of the third slotted hole **18** and the fourth slotted hole **20**. As shown in FIG. **7**, a size of the radiation metal body **12** used in the ultra-wideband antenna device **10** in the second embodiment is the same as that in the first embodiment shown in FIG. **4**, except that the feeding source **24** is located at a distance of 1.5 mm from the second side edge **122** and at a distance of 1.5 mm from the third side edge **123**. In the disclosure, simulation experiments are performed on the ultra-wideband antenna device **10** including the radiation metal body **12** in the first embodiment of FIG. **6** and the ultra-wideband antenna device **10** including the radiation metal body **12** in the second embodiment of FIG. **7**.

Referring to FIG. **1**, FIG. **3**, FIG. **8** and FIG. **9** together, simulation of parameter S (S**11**) and antenna efficiency is carried out by using the ultra-wideband antenna device **10** including the radiation metal body **12** in the first embodiment of FIG. **6** and the ultra-wideband antenna device **10** including the radiation metal body **12** in the second embodiment of FIG. **7**. When the antenna device **10** is in a 6.5 GHz operating band and an 8 GHz operating band, a simulation result of parameter S of the antenna device **10** is shown in FIG. **8**. From the curves shown in the diagram, it can be seen that reflection coefficients (S**11**) of low frequency band (6.5 GHz, a first frequency band) and high frequency band (8 GHz, a second frequency band) resonance modes shown in the diagram are both less than −5 dB (S**11**<−5 dB), indicating that the ultra-wideband antenna device **10** in the first embodiment and the ultra-wideband antenna device **10** in the second embodiment have good reflection coefficients in both the first frequency band and the second frequency band. On the other hand, as shown in FIG. **9**, under different operating frequency bands, antenna efficiency of the ultra-wideband antenna device **10** in the first embodiment is equivalent to antenna efficiency of the ultra-wideband antenna device **10** in the second embodiment, indicating that the ultra-wideband antenna device **10** also has good antenna radiation efficiency.

Referring to FIG. **1** and FIG. **6** together, in an embodiment, current distribution of the ultra-wideband antenna device **10** including the radiation metal body **12** in the first embodiment of FIG. **6** is simulated. FIG. **10** is a diagram of current distribution of an ultra-wideband antenna device operating in frequency bands of 6.5 GHz and 8.5 GHz according to the disclosure. As shown in FIG. **10**, a current under 6.5 GHz is mainly distributed in the first slotted hole **14** and the second slotted hole **16**, and a current under 8.5 GHz is mainly distributed in the third slotted hole **18** and the fourth slotted hole **20**. Therefore, the disclosure maintains good antenna performance while maintaining the size of the ultra-wideband antenna device **10**.

In summary, the disclosure relates to an ultra-wideband antenna device, which implements the receiving and trans-

mitting of radio frequency signals in two frequency bands by using a design of a smaller antenna size without increasing the antenna size and space, so that the ultra-wideband antenna device in the disclosure effectively improves the antenna efficiency in limited space to maintain good wireless communication quality. Based on this, the disclosure still maintains good antenna performance in a case that a size of the ultra-wideband antenna device is reduced.

The foregoing embodiments are merely for describing the technical ideas and the characteristics of the disclosure, and are intended to enable those skilled in the art to understand and hereby implement the content of the disclosure. However, the scope of claims of the disclosure is not limited thereto. In other words, equivalent changes or modifications made according to the spirit disclosed in the disclosure shall still fall into scope of the claims of the disclosure.

What is claimed is:

1. An ultra-wideband antenna device, comprising:

a radiation metal body, comprising a first side edge and a second side edge opposite to each other and a third side edge and a fourth side edge opposite to each other;

a first slotted hole, located on the radiation metal body and extending inward from the first side edge;

a second slotted hole, located on the radiation metal body and extending inward from the second side edge;

a third slotted hole, located on the radiation metal body and extending inward from the third side edge;

a fourth slotted hole, located on the radiation metal body and extending inward from the fourth side edge;

a ground point, located at a middle position of the radiation metal body; and

a feeding source, located on the radiation metal body and away from the middle position.

2. The ultra-wideband antenna device according to claim **1**, wherein the first slotted hole and the second slotted hole have a same first length, the third slotted hole and the fourth slotted hole have a same second length, and the first length is different from the second length.

3. The ultra-wideband antenna device according to claim **2**, wherein the first slotted hole and the second slotted hole are located on a same horizontal line, and the third slotted hole and the fourth slotted hole are located on a same vertical line.

4. The ultra-wideband antenna device according to claim **3**, wherein the first length is greater than the second length.

5. The ultra-wideband antenna device according to claim **1**, wherein the middle position of the ground point is a geometric center of the radiation metal body.

6. The ultra-wideband antenna device according to claim **1**, further comprising a dielectric substrate, wherein the dielectric substrate comprises a first surface and a second surface, and the radiation metal body is arranged on the first surface of the dielectric substrate.

7. The ultra-wideband antenna device according to claim **6**, further comprising:

a ground plane, located on the second surface of the dielectric substrate; and

a via, penetrating the dielectric substrate to electrically connect the ground point and the ground plane.

8. The ultra-wideband antenna device according to claim **1**, wherein the feeding source is located at an edge corner of the radiation metal body.

9. An ultra-wideband antenna device, comprising:

a dielectric substrate, comprising a first surface and a second surface;

three ultra-wideband antennas, arranged on the first surface of the dielectric substrate, and each of the ultra-wideband antennas comprises:

a radiation metal body, comprising a first side edge and a second side edge opposite to each other and a third side edge and a fourth side edge opposite to each other;

a first slotted hole, located on the radiation metal body and extending inward from the first side edge;

a second slotted hole, located on the radiation metal body and extending inward from the second side edge;

a third slotted hole, located on the radiation metal body and extending inward from the third side edge;

a fourth slotted hole, located on the radiation metal body and extending inward from the fourth side edge;

a ground point, located at a middle position of the radiation metal body;

a feeding source, located on the radiation metal body and away from the middle position; and

a via, wherein the via penetrates the dielectric substrate and is connected to the ground point; and

a ground plane, located on the second surface, wherein the ground plane is electrically connected to the ground point through the via.

10. The ultra-wideband antenna device according to claim **9**, wherein the feeding source of each ultra-wideband antenna is located at an edge corner of the radiation metal body close to the other ultra-wideband antennas.

11. The ultra-wideband antenna device according to claim **9**, wherein the first slotted hole and the second slotted hole have a same first length, the third slotted hole and the fourth slotted hole have a same second length, and the first length is different from the second length.

12. The ultra-wideband antenna device according to claim **11**, wherein the first slotted hole and the second slotted hole are located on a same horizontal line, and the third slotted hole and the fourth slotted hole are located on a same vertical line.

13. The ultra-wideband antenna device according to claim **12**, wherein the first length is greater than the second length.

14. The ultra-wideband antenna device according to claim **9**, wherein the middle position of the ground point is a geometric center of the radiation metal body.

* * * * *

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(45) **Date of Patent: Mar. 18, 2025**

(54) **EMBEDDED ANTENNAS IN MOBILE ELECTRONIC DEVICES**

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(22) Filed: **Mar. 13, 2023**

(51) **Int. Cl.**
H01Q 1/27 (2006.01)
H01Q 7/00 (2006.01)
H01Q 9/04 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/276*** (2013.01); ***H01Q 7/00*** (2013.01); ***H01Q 9/0414*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/27; H01Q 1/273; H01Q 1/276; H01Q 7/00; H01Q 9/0414
See application file for complete search history.

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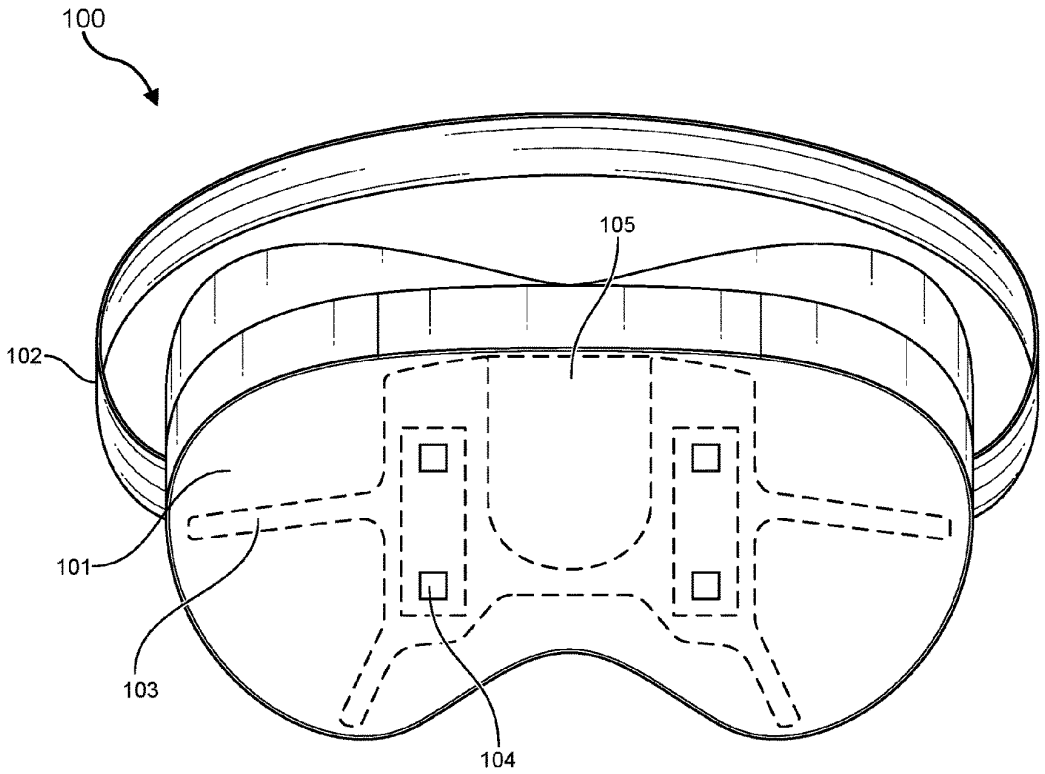
Primary Examiner — Hoang V Nguyen
(74) *Attorney, Agent, or Firm* — Greenberg Traurig, LLP

(57) **ABSTRACT**

The disclosed system may include a sensor mounting bracket that has various mounting points for different sensors. The sensor mounting bracket may include a center portion and multiple different branches extending from the center portion. The system may also include a printed circuit board that includes antenna feed components. At least one of the branches of the sensor mounting bracket may be modified to form a specific type of antenna. The antenna feed components may be electrically connected to the antenna. Various other mobile electronic devices, apparatuses, and virtual reality headsets are also disclosed.

20 Claims, 9 Drawing Sheets



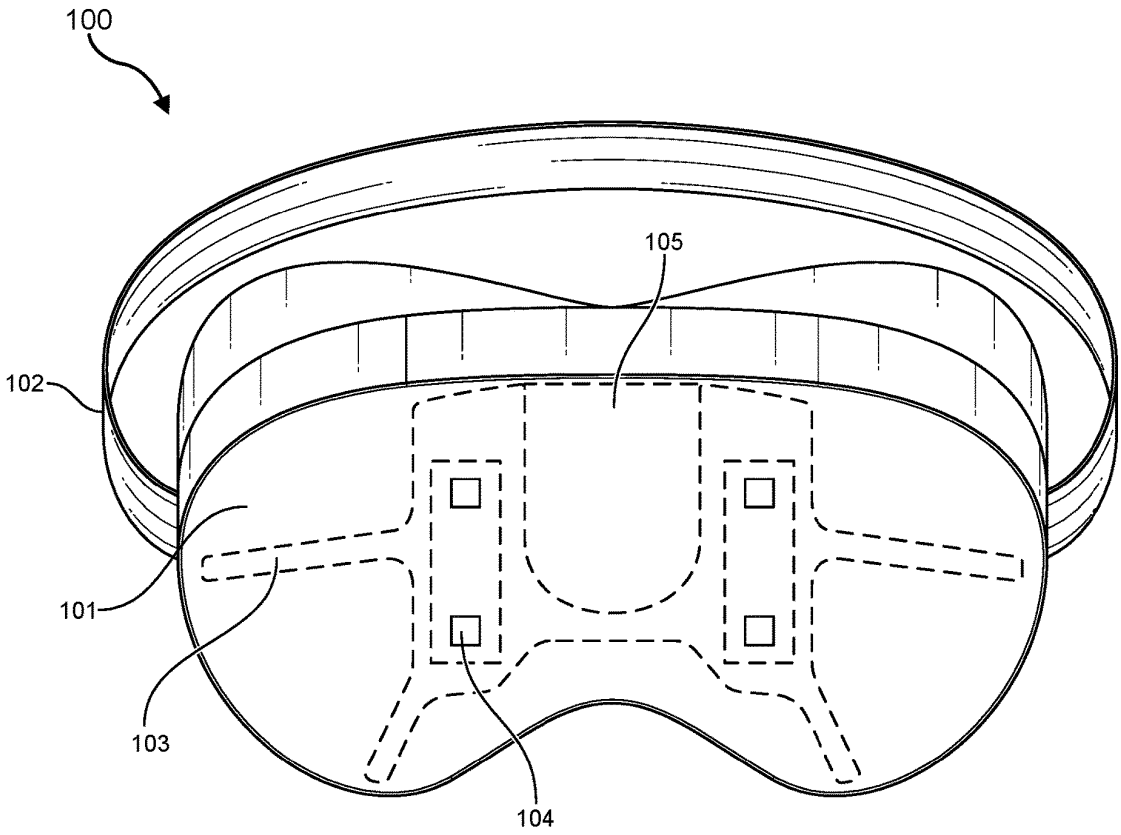


FIG. 1

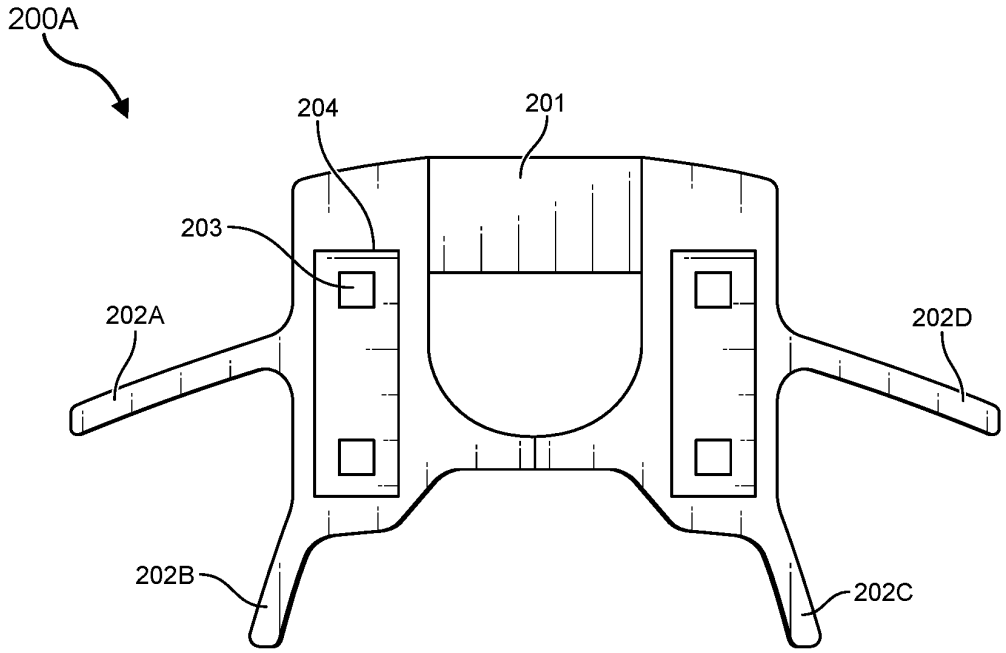

200A
204
201
203
202A
202D
202B
202C

FIG. 2A

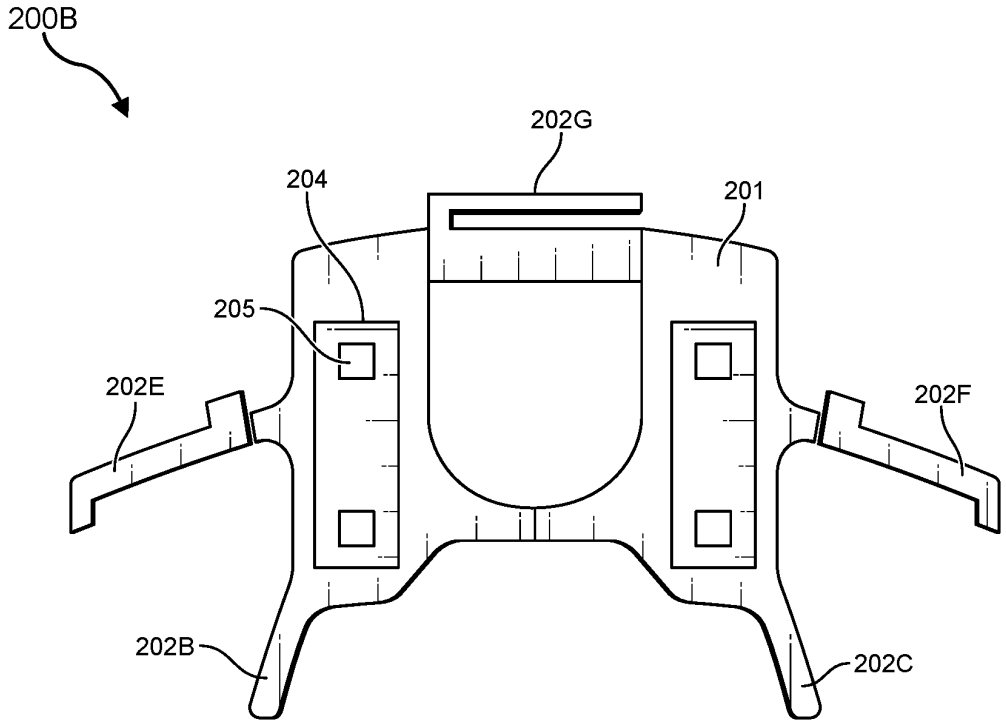

200B
202G
204
201
205
202E
202F
202B
202C

FIG. 2B

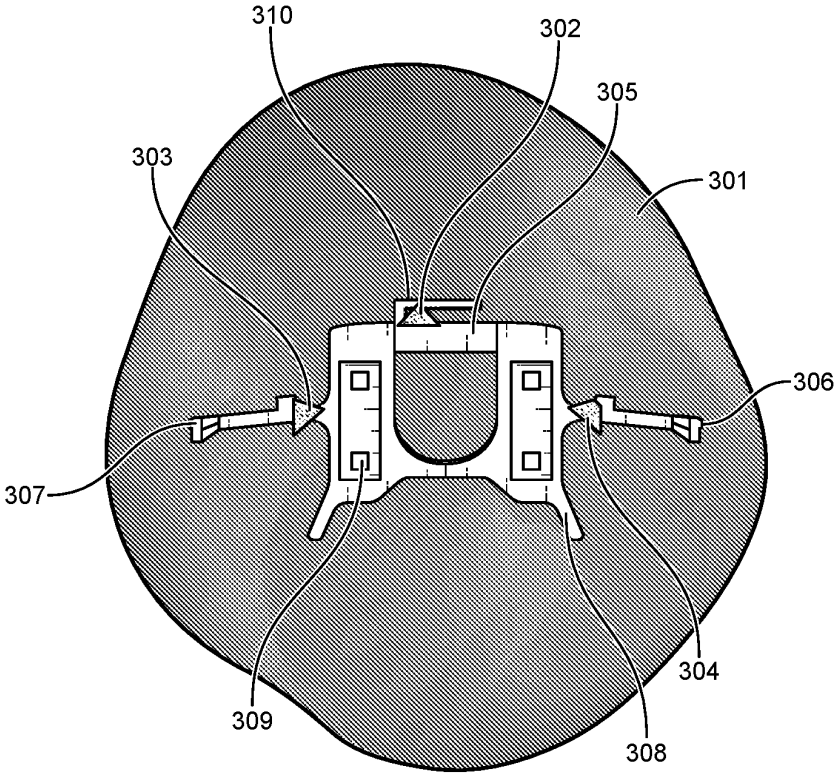

310
302
305
303
301
306
307
304
309
308

FIG. 3A

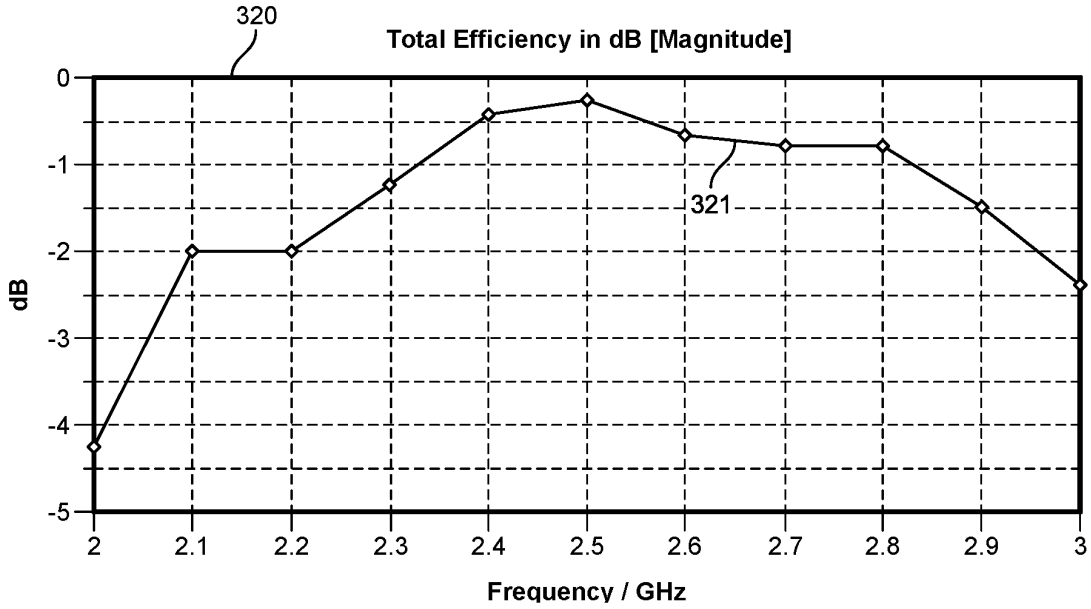

320
Total Efficiency in dB [Magnitude]
0
-1
-2
-3
-4
-5
dB
321
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
Frequency / GHz

FIG. 3B

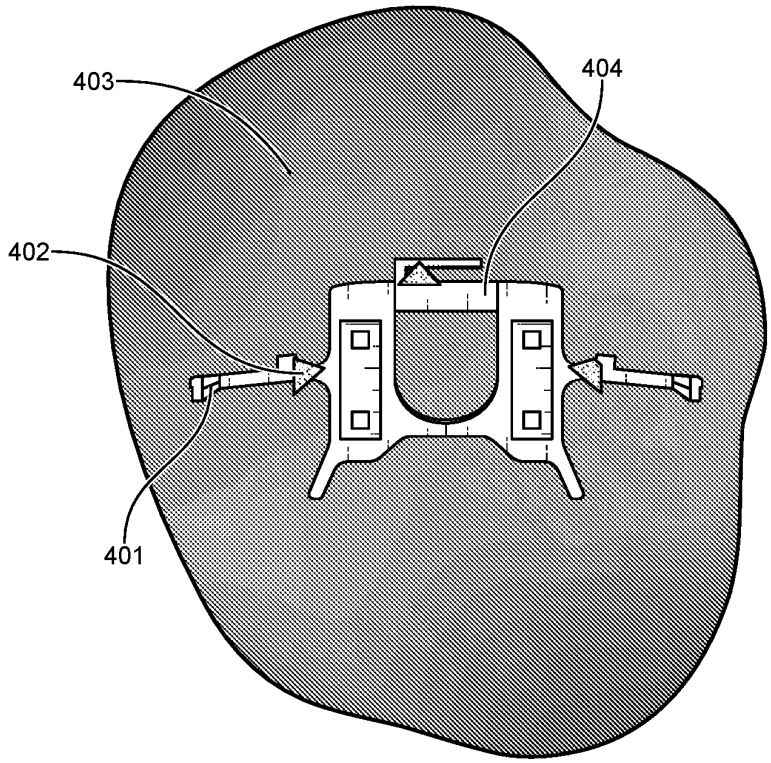

403
404
402
401

FIG. 4A

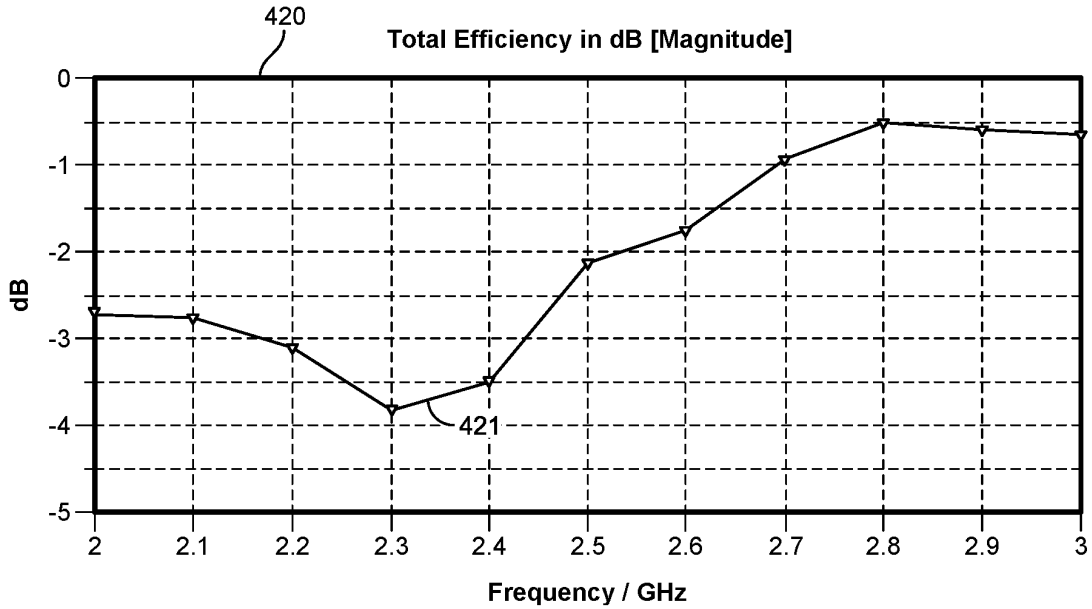

420
Total Efficiency in dB [Magnitude]
0
-1
-2
-3
-4
-5
dB
421
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
Frequency / GHz

FIG. 4B

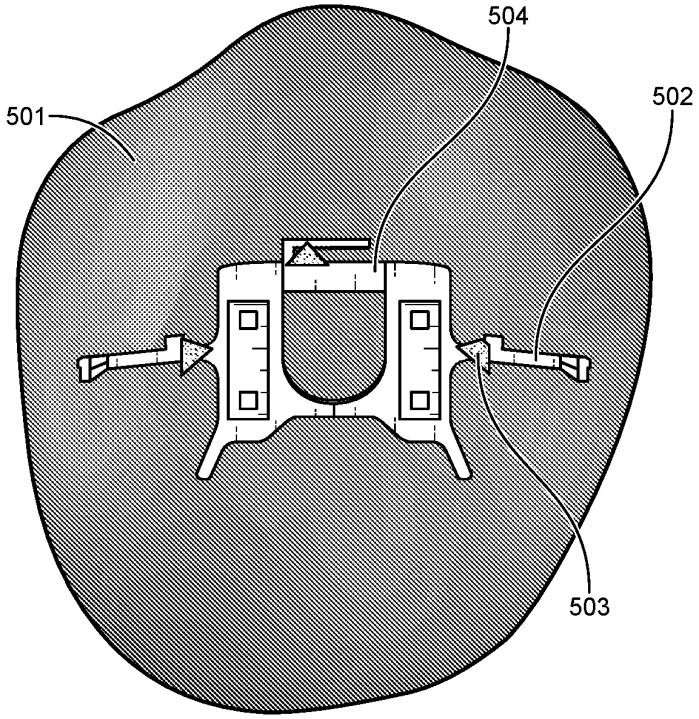

504
501
502
503

FIG. 5A

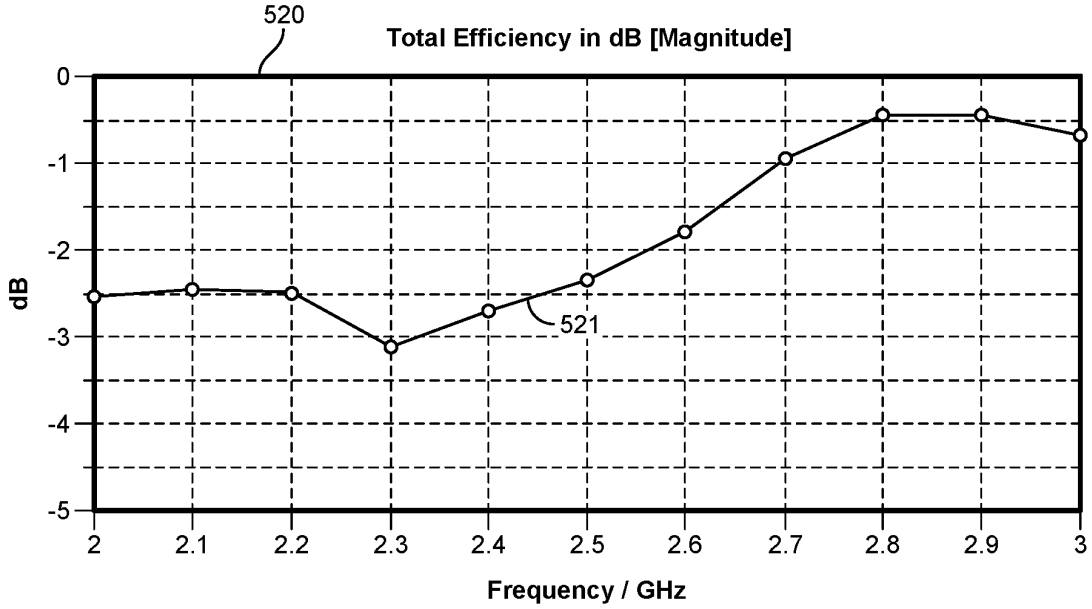

520
Total Efficiency in dB [Magnitude]
0
-1
-2
-3
-4
-5
dB
521
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
Frequency / GHz

FIG. 5B

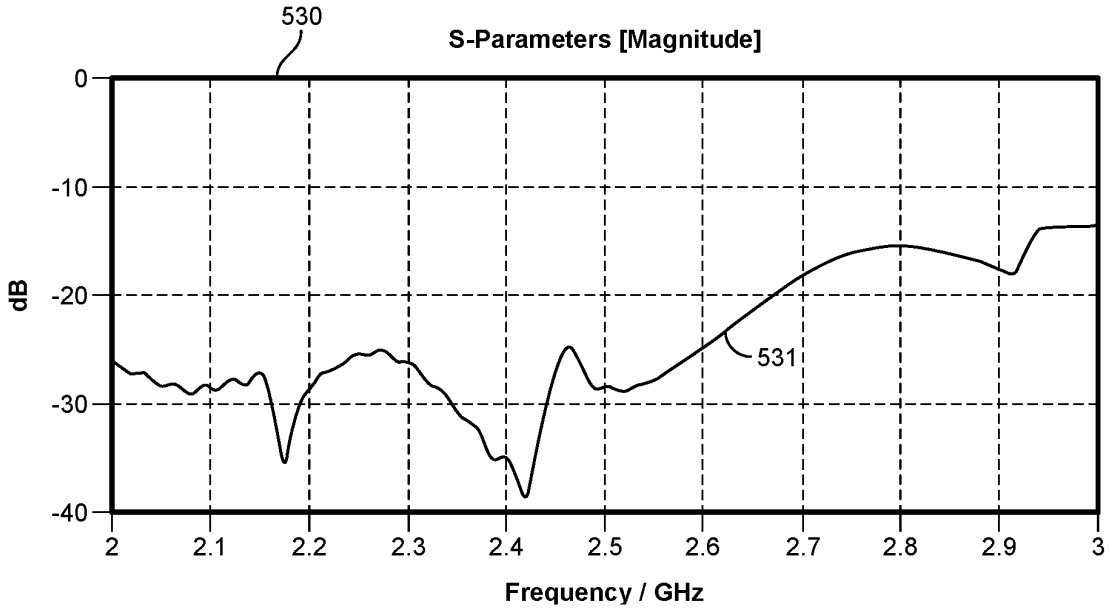

530
S-Parameters [Magnitude]
0
-10
-20
-30
-40
dB
531
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
Frequency / GHz

FIG. 5C

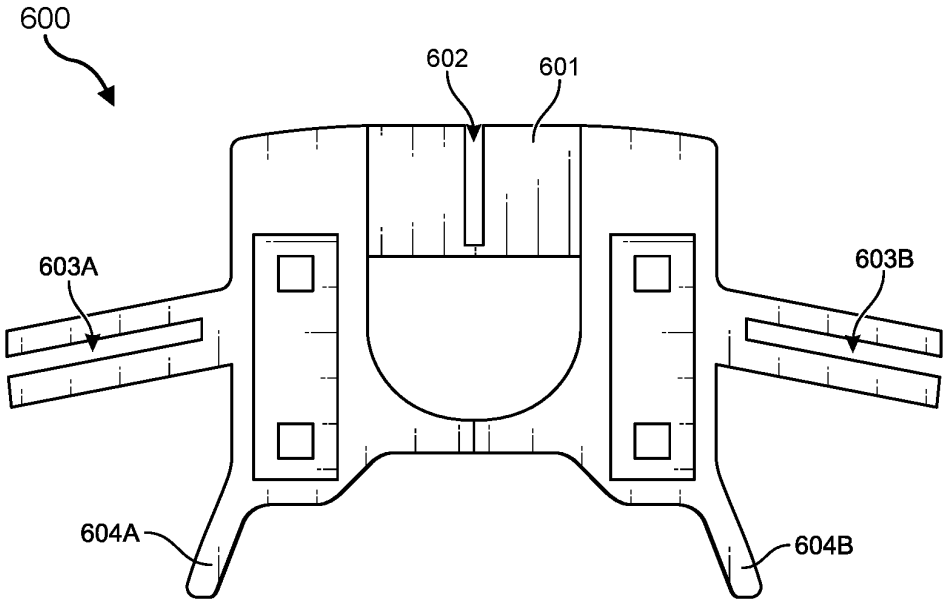


FIG. 6

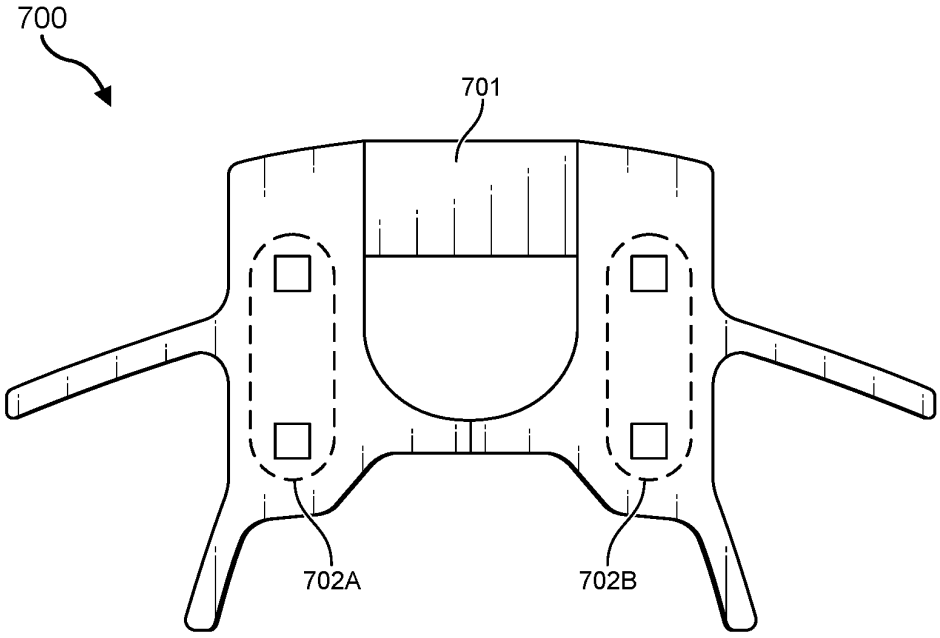


FIG. 7

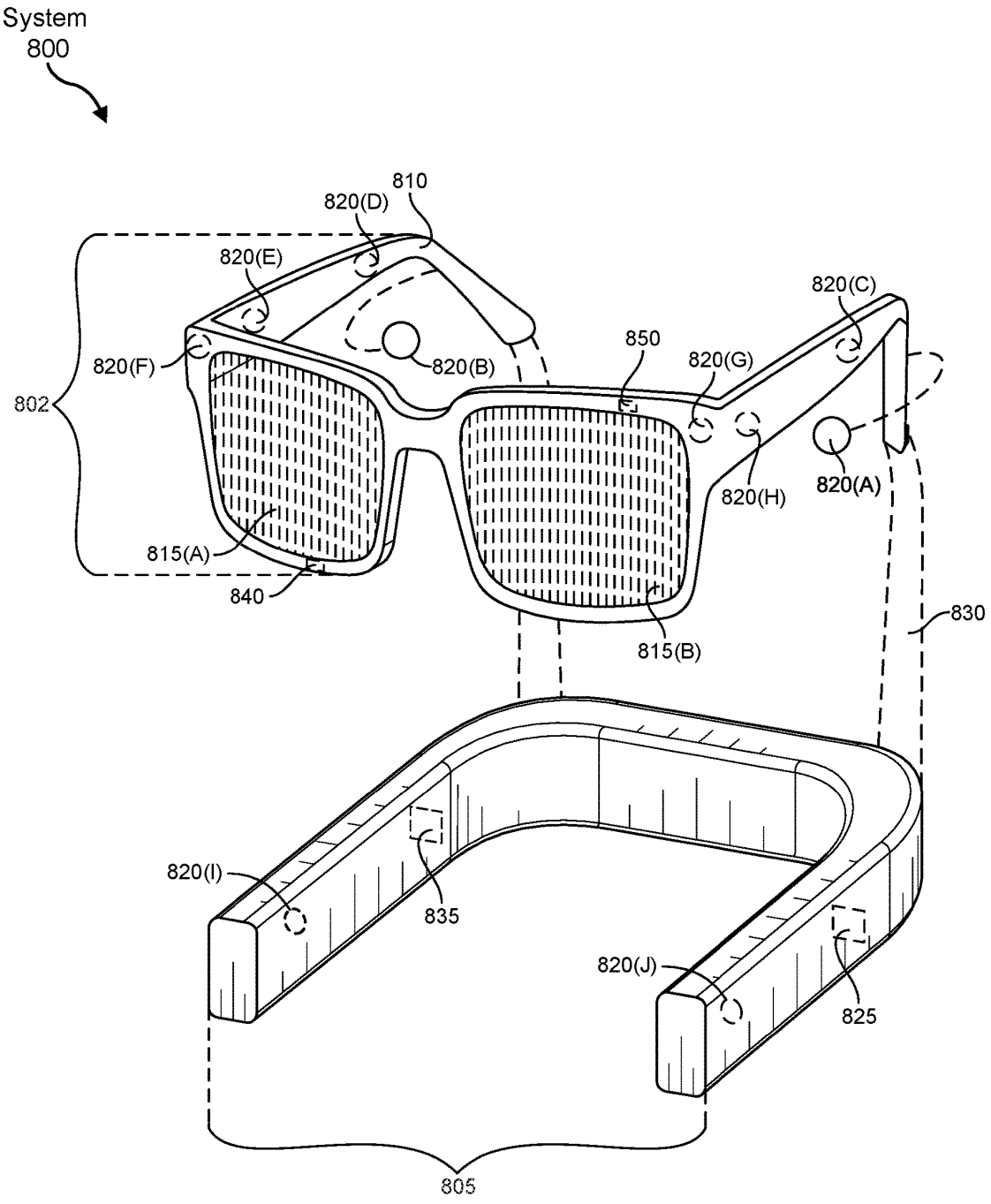

System
800
810
820(D)
820(E)
820(C)
820(F)
820(B)
850
820(G)
802
820(H)
820(A)
815(A)
840
830
815(B)
820(I)
835
820(J)
825
805

FIG. 8

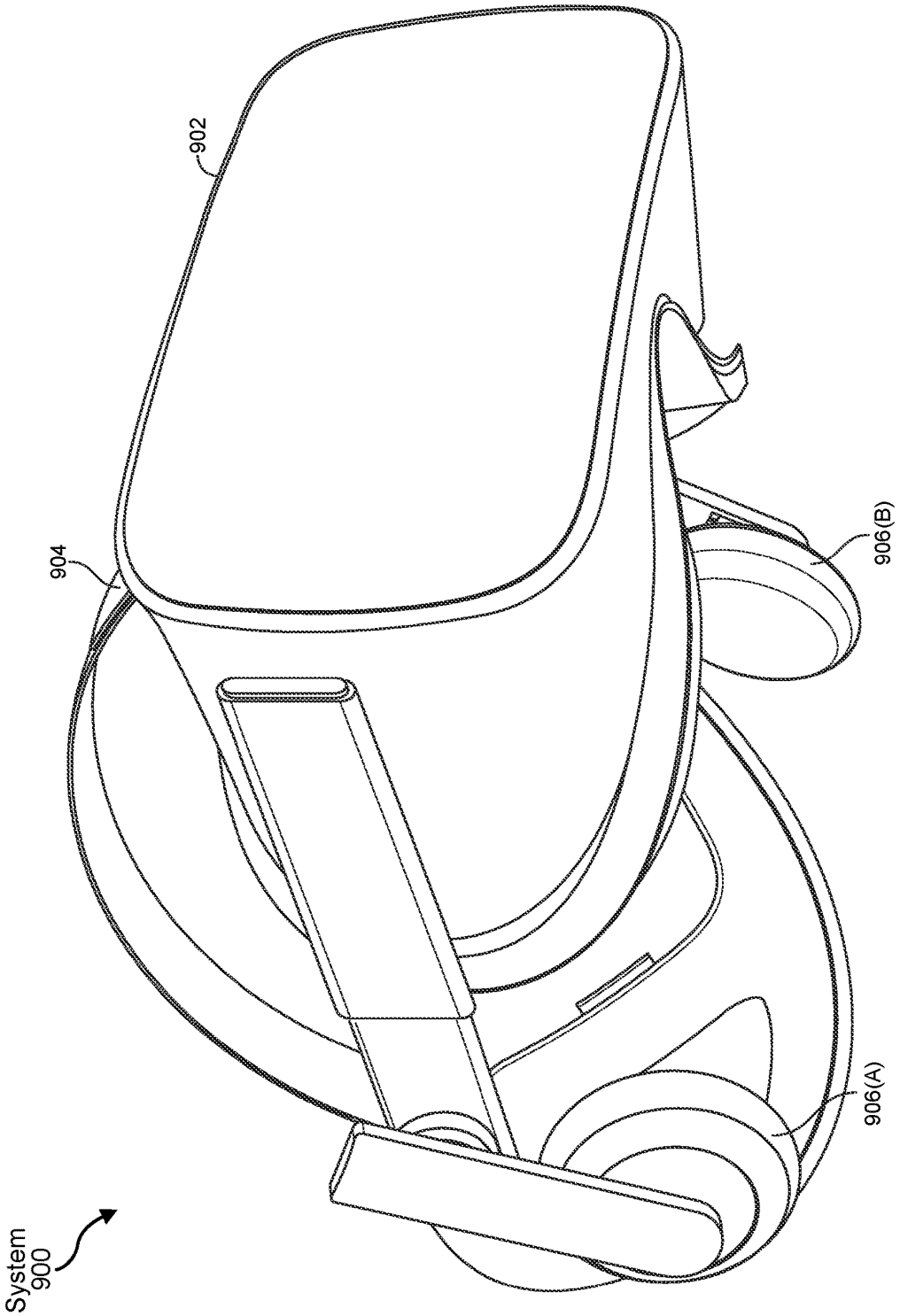


FIG. 9

EMBEDDED ANTENNAS IN MOBILE ELECTRONIC DEVICES

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate a number of exemplary embodiments and are a part of the specification. Together with the following description, these drawings demonstrate and explain various principles of the present disclosure.

FIG. **1** illustrates a sensor mounting bracket within a virtual reality (VR) head mounted display (HMD).

FIGS. **2**A and **2**B illustrate embodiments in which a sensor mounting bracket may be modified to form one or more antennas.

FIGS. **3**A and **3**B illustrate radiation patterns and antenna efficiency measurements for an example embodiment of a sensor mounting bracket.

FIGS. **4**A and **4**B illustrate radiation patterns and antenna efficiency measurements for an alternative example embodiment of a sensor mounting bracket.

FIGS. **5**A-**5**C illustrate radiation patterns, antenna efficiency measurements, and S-parameter measurements for an alternative example embodiment of a sensor mounting bracket.

FIG. **6** illustrates an embodiment in which a sensor mounting bracket may be modified to form one or more alternative antennas.

FIG. **7** illustrates an embodiment in which a sensor mounting bracket may be modified to form one or more alternative antennas.

FIG. **8** is an illustration of exemplary augmented-reality glasses that may be used in connection with embodiments of this disclosure.

FIG. **9** is an illustration of an exemplary virtual-reality headset that may be used in connection with embodiments of this disclosure.

Throughout the drawings, identical reference characters and descriptions indicate similar, but not necessarily identical, elements. While the exemplary embodiments described herein are susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, the exemplary embodiments described herein are not intended to be limited to the particular forms disclosed. Rather, the present disclosure covers all modifications, equivalents, and alternatives falling within the scope of the appended claims.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Virtual reality, augmented reality, and other electronic devices typically employ multiple different antennas to communicate with the outside world. These antennas may include cellular, Wifi, Bluetooth, global positioning system (GPS), near field communication (NFC), or other antennas. Over time, the mobile electronic devices housing these antennas have gotten increasingly smaller. These smaller form factors leave less room to house the various antennas needed for outside communication. Moreover, many inner electronic components of the mobile devices may interfere with the different antennas. As such, viable positions or placements for each of the antennas within the mobile devices may be limited.

In at least some of the embodiments herein, antennas may be embedded into various portions of a mobile electronic device's frame. In some embodiments, a mobile device such as a virtual reality (VR) head mounted device (HMD) or augmented reality (AR) device, smartwatch, or other similar device may include a sensor mounting bracket. While many of the embodiments described herein are presented in reference to a VR HMD, it will be recognized that these embodiments may be implemented with substantially any type of mobile electronic device. The sensor mounting bracket may be made of a rigid or semi-rigid material that is configured to hold multiple different sensors in place. The sensor mounting bracket may be made of metal, plastic, glass, ceramic, or other rigid or semi-rigid material (or combination of materials). The sensor mounting bracket may include apertures that are designed to hold different sensors or different types of sensors in place. The sensors may include visible light (i.e., image) sensors, infrared light sensors, motion sensors, heat sensors, touch sensors, or other types of sensors.

In one embodiment, a VR HMD may have a sensor mounting bracket with a central portion and multiple structural arms that extend from the center out to the sides of the device. The center portion and/or the metallic arms may provide structural support and housings for different sensors such as cameras. The embodiments described herein may use these structural support arms as antennas. These antennas may include different types of antenna designs, including slot antennas, loop antennas, inverted-F or planar inverted-F antennas (PIFAs), or other types of antennas. By using existing components of the VR HMD or other mobile device, space may be freed up for other electronic or mechanical components. This, in turn, may allow for even smaller form factors to be used with these devices.

The present disclosure provides antenna designs that integrate multiple different antennas into a structural plate. Moreover, the present disclosure describes antenna designs that provide sufficient separation to the various radiating elements of the antennas to provide at least a minimum threshold amount of operational efficiency. Such efficiency may be achieved while still preserving the structural integrity of the supporting plate. Still further, the present disclosure provides antenna designs that encompass VR HMD/controller scenarios that implement two WiFi antennas at opposite sides (for multiple in multiple out (MIMO) operation), as well as a centered Bluetooth antenna for controller communication. These Bluetooth and WiFi antennas may be positioned orthogonally to each other to provide both spatial separation and different polarization. These and other embodiments will be described in further detail below with regard to FIGS. **1-9**.

Features from any of the embodiments described herein may be used in combination with one another in accordance with the general principles described herein. These and other embodiments, features, and advantages will be more fully understood upon reading the following detailed description in conjunction with the accompanying drawings and claims.

FIG. **1** illustrates an embodiment of a VR HMD **100**. As noted above, the VR HMD **100** could be substantially any type of electronic device. For simplicity's sake, however, most of the embodiments herein will be described with reference to a virtual reality HMD. The VR HMD **100** may include a display portion **101** and a head strap **102** that may be wrapped around a user's head to secure the VR HMD **100** to the user's face. The display portion **101** may have multiple mechanical and/or electrical elements and may have multiple layers of such elements.

For example, the display portion **101** may have an interior portion with a display panel. The display panel may be

visible to the user of the HMD and may display images as directed by a controller. The display panel may be one of many different types of display, include a liquid crystal display (LCD), a light emitting diode (LED) display, an organic LED (OLED) display, a holographic display, or other type of display component or device that generates images visible to a user. The display portion **101** may also have an exterior layer that acts as a protective cover. This exterior portion may have apertures for sensors such as cameras. Still further, the display portion may have an intermediary layer between the display panel and the exterior layer. This intermediary layer may include a sensor mounting bracket **105**.

The sensor mounting bracket **105** may include different portions or areas including a center portion and various branches that extend from the center portion. The branches **103** may extend from the center portion in substantially any direction and in substantially any number. The branches **103** may be formed at the same length or at different lengths, or at the same width or at different widths. In the embodiment shown in FIG. **1**, the sensor bracket **105** may include four branches, although different embodiments may include different numbers or placements of branches. The sensor bracket **105** may include apertures **104** for different sensors. The apertures **104** may be formed in different shapes and sizes to accommodate different sensors. In some embodiments, the sensors may be cameras, infrared sensors, motion sensors, heat sensors, or other types of sensors. The sensor bracket **105** may include substantially any number of apertures, each of which may be variably placed in different locations based on the needs and purposes of each electronic device.

FIG. **2**A illustrates an embodiment of a sensor mounting bracket **200**A that includes one or more mounting points **204** for various sensors **203**. As noted above, the sensor mounting bracket **200**A may include substantially any number of mounting points **204** for substantially any number, size, or shape of sensors **203**. The sensor mounting bracket **200**A may include a center portion **201** and multiple different branches (e.g., **202**A-**202**D) extending from the center portion. The center portion **201** may be formed in substantially any size or shape, and may be solid, or may include apertures in various locations. In some cases, the center portion **201** may be shaped to conform to the outlines of a VR HMD or other electronic device. The branches **202**A-**202**D may likewise be formed in different shapes and sizes and may similarly conform to the outlines of the associated electronic device.

As will be explained further below, the branches may be modified to form different types of antennas. Each of these antennas may have an associated antenna feed. The antenna feed may include tuners, amplifiers, signal processors, impedance matching circuits, or other antenna feed components. Each of these components may be housed on a printed circuit board mounted within the mobile electronic device (e.g., a VR HMD). The antenna feed components on the printed circuit board may be electrically connected to the different types of antennas formed in the various branches **202**A, **202**B, **202**C, and/or **202**D.

FIG. **2**B illustrates an embodiment of a sensor mounting bracket **200**B that includes different types of antennas. For example, the sensor mounting bracket **200**B may include a planar inverted-F antenna (PIFA) in the top part of the center portion **201**. If the sensor mounting bracket **200**B is mounted upright as shown in FIG. **2**B, the top part of the center portion **201** may be formed as a planar inverted-F antenna **202**G with an L-shaped prong and a slot. The PIFA **202**G may operate in various frequency bands and may be tuned using a tuner in the associated antenna feed.

At least in some cases, the PIFA **202**G may be shaped and formed in a manner that functions as a radiating element. This radiating element may receive and transmit signals while, itself, being embedded in and part of the sensor mounting bracket **200**B. The planar inverted-F antenna **202**G may be grounded to one of the bottom branches (e.g., **202**B and/or **202**C) that protrude from the bottom part of the center portion **201** of the sensor mounting bracket. In some cases, for example, the PIFA **202**G may be a Bluetooth antenna. The Bluetooth antenna may be configured to communicate with VR controllers or other mobile electronic devices. The Bluetooth antenna may be placed orthogonal to the left- and right-side antennas (e.g., Wi-Fi 2.4 GHz antennas) to achieve relatively high isolation via polarization diversity. Indeed, the placement of PIFA antenna **202**G above and orthogonal to the left- and right-side antennas **202**E/**202**F may allow the PIFA antenna **202**G to operate at a different polarization than the antennas **202**E/**202**F. This, in turn, may provide greater isolation and higher efficiency for each of the antennas **202**E, **202**F, and **202**G.

The sensor mounting bracket **200**A of FIG. **2**A may also include left-side branches and right-side branches (e.g., **202**A and **202**D). These branches may be modified, as shown in FIG. **2**B, to form planar inverted-F antennas **202**E and **202**F, respectively. As with the PIFA **202**G, each of the PIFAs **202**E and **202**F may be grounded to either or both of the bottom branches **202**B and **202**C or to another part of the center portion **201** of the sensor mounting bracket **200**B. In some cases, the PIFAs **202**E and **202**F may be WiFi antennas configured to communicate with surrounding mobile electronic devices. These two WiFi antennas may operate in multiple in multiple out (MIMO) fashion. The WiFi antennas may be spatially separated by at least a minimum distance. This minimum distance may ensure that the WiFi antennas can operate with little to no interference with each other and may operate at high efficiency in the MIMO fashion.

In some cases, at least some amount of separation may exist between the antennas (e.g., **202**E or **202**F) and the center portion of the sensor mounting bracket **200**A. In such cases, carbon fiber or other non-conductive materials may be used to fill this gap and thereby link the main body of the sensor bracket (including one or more of the sensors **205**) to the branches. This may allow for some amount of separation between the branches and the sensor mounting plate while still providing sufficient structural support for the sensors.

Here, it will be recognized that, while PIFA antennas are described and shown in FIGS. **2**A and **2**B, the branches **202**A-**202**D and/or the center portion **201** of the sensor bracket may be modified to form substantially any type of antenna, including monopole, dipole, slot, loop, or other type of antenna. Moreover, while Bluetooth and WiFi antennas are specifically identified in the examples herein, it will be recognized that these antennas may operate in cellular bands, GPS bands, NFC bands, or in other frequency bands, and may be tuned for operation within a desired frequency range.

FIG. **3**A illustrates a simulated radiation pattern for the top antenna **310** of the antennas generally shown in FIG. **2**B. The radiation pattern **301** illustrates radiation from the topmost antenna of the sensor mounting bracket **305**. The sensor mounting bracket **305** may include apertures for various sensors **309**. The sensor mounting bracket **305** may also include antenna feeds **302**, **303**, and **304**, each of which may be electrically connected to a corresponding antenna.

These antennas (e.g., **306**, **307**, **310**, or other antennas) may each be tuned to operate at a specific frequency or tuned to operate within a specific frequency band. At least in some cases, the antennas may be grounded to one of the other branches (e.g., **308**).

As can be seen in FIG. **3**A, the antennas **307** and/or **308** may be formed in three dimensions, each having an end portion that extends upward from the surface of the sensor mounting bracket **305**. Each of these antennas may provide omnidirectional radiation patterns that provide even coverage for communicating with surrounding devices. The radiation pattern **301** may correspond specifically to the planar inverted-F antenna **310** that is embedded within and is part of the top portion of the sensor mounting bracket **305**. The radiation patterns of the other two antennas of FIG. **3**A are shown further below with regard to FIGS. **4**A and **5**A. The efficiency of the antenna **310** may be shown in chart **320** of FIG. **3**B, in which the total efficiency (in dB) is illustrated over a span of frequencies from 2-3 GHz in plot line **321**. As can be seen, relatively high efficiency transmission and reception may advantageously occur at or near 2.4 GHz.

Similarly, in FIG. **4**A, the radiation pattern **403** of the left-most antenna **401** is shown. This radiation pattern **403** is similarly omnidirectional relative to the location of the antenna **401**. The antenna **401** may be fed by antenna feed **402**, which itself may be electrically connected to a printed circuit board of the underlying mobile electronic device. The printed circuit board may be affixed to the sensor mounting bracket **404** or to another structural component. The total efficiency of this antenna **401** may be reflected in graph **420** of FIG. **4**B. As can be seen in plot line **421**, this antenna **401** may be most efficient between approximately 2.7-3 GHz.

Still further, as shown in FIG. **5**A, the radiation pattern **501** for the right-most antenna **502** may be relatively omnidirectional in relation to the location of antenna **502**. The antenna **502** may be fed by antenna feed **503**. The antenna feed **503** may be electrically connected to a printed circuit board, control board, or other controller. The antenna **502** may be embedded within and may be formed from existing portions of the sensor bracket **504**. In some cases, portions of the sensor bracket **504** may be removed to create a certain type of antenna (e.g., a slot or PIFA antenna). In other cases, material may be added to the sensor bracket **504** to create monopole, dipole, or other types of antennas. The cutouts or additions may be placed anywhere on the sensor mounting bracket **504** of the mobile device. The total efficiency of the antenna **502** may be shown in chart **520** of FIG. **5**B. Plot line **521** illustrates a higher overall antenna efficiency between 2.7-3 GHz, while plot line **531** of chart **530** in FIG. **5**C illustrates advantageous S-parameter measurements at approximately 2.2 GHz and 2.4 GHz.

FIG. **6** illustrates an alternative embodiment **600** in which a sensor mounting bracket **601** may be modified to include a slot antenna **602**. The top portion of the sensor mounting bracket **601** may have various portions removed to include a slot that allows the top portion of the sensor mounting bracket **601** to function as a slot antenna. The slot antenna **602** may be driven by an antenna feed that is connected to a PCB of the mobile device. Additionally or alternatively, the left-side branch may be modified to form a slot antenna **603**A, and the right-side branch may be modified to form a slot antenna **603**B. Any or all of these antennas may be tuned for operation within a specific frequency range, and may be used as Bluetooth, WiFi, GPS, cellular, or other types of antennas. Other branches, including **604**A and/or **604**B may also be used as antennas, and may be formed into slot, PIFA, loop, or other antennas.

FIG. **7** illustrates an alternative embodiment **700** in which a sensor mounting bracket **701** may be modified to include one or more loop antennas (e.g., **702**A and **702**B). In this embodiment, the top portion of the sensor mounting bracket **701** may have various portions removed to include a PIFA or slot antenna, as generally described above. The PIFA antenna may be driven by an antenna feed that is connected to a PCB of the mobile device. The left-side and/or right-side branches may be modified to include loop antennas **702**A/**702**B. The loops may extend around an array of sensors as generally shown in FIG. **7** or may encompass different portions of the sensor mounting bracket **701**. Each of these loop antennas **702**A/**702**B may be tuned for operation within a specific frequency range and, as above, may be used as Bluetooth, WiFi, GPS, cellular, or other types of antennas.

At least in some embodiments, one or more of the various branches may function as ground for the loop antennas **702**A/**702**B. In this manner, existing sensor mounting bracket components or elements may be modified or changed to function as radiating elements and may be tuned to operate in specific frequency ranges or as specific types of antennas. By placing the antennas relatively far apart on the sensor mounting bracket, the systems herein may provide sufficient spatial diversity for the antennas to operate with little to no interference. As such, the antennas may operate more efficiently, using less power while still transmitting and receiving at expected or higher transmission rates.

In addition to the system described above, a mobile electronic device may be provided which includes a sensor mounting bracket that includes one or more mounting points for various sensors. The sensor mounting bracket may include a center portion and multiple different branches extending from that center portion. The sensor mounting bracket may also include a printed circuit board that has one or more antenna feed components. At least one of the branches of the sensor mounting bracket may be modified to form a specific type of antenna, where the antenna feed components are electrically connected to the antenna.

Still further, a virtual reality headset may be provided that includes a sensor mounting bracket that includes a sensor mounting bracket that includes one or more mounting points for various sensors. The sensor mounting bracket may include a center portion and multiple different branches extending from that center portion. The sensor mounting bracket may also include a printed circuit board that has one or more antenna feed components. At least one of the branches of the sensor mounting bracket may be modified to form a specific type of antenna, where the antenna feed components are electrically connected to the antenna.

EXAMPLE EMBODIMENTS

Example 1: A system comprising: a sensor mounting bracket that includes one or more mounting points for a plurality of sensors, the sensor mounting bracket including a center portion and a plurality of different branches extending from the center portion, and a printed circuit board that includes one or more antenna feed components, wherein at least one of the branches of the sensor mounting bracket is modified to form a specific type of antenna, and wherein the antenna feed components are electrically connected to the antenna.

Example 2: The system of Example 1, wherein a top branch that comprises a top portion of the center portion of the sensor mounting bracket comprises a planar inverted-F antenna.

Example 3: The system of Example 1 or Example 2, wherein the planar inverted-F antenna is grounded to a bottom branch that comprises a bottom portion of the center portion of the sensor mounting bracket.

Example 4: The system of any of Examples 1-3, wherein the planar inverted-F antenna comprises a Bluetooth antenna.

Example 5: The system of any of Examples 1-4, wherein a left-side branch of the plurality of branches is modified to form a planar inverted-F antenna.

Example 6: The system of any of Examples 1-5, wherein a right-side branch of the plurality of branches is modified to form a planar inverted-F antenna.

Example 7: The system of any of Examples 1-6, wherein the left-side and right-side branches are grounded to a bottom branch that comprises a bottom portion of the center portion of the sensor mounting bracket.

Example 8: The system of any of Examples 1-7, wherein the left-side branch and the right-side branch comprise WiFi antennas.

Example 9: The system of any of Examples 1-8, wherein the left-side and right-side branches are tuned for operation within a specific frequency range.

Example 10: The system of any of Examples 1-9, wherein a top branch that comprises a top portion of the center portion of the sensor mounting bracket includes a slot antenna.

Example 11: The system of any of Examples 1-10, wherein a left-side branch of the plurality of branches is modified to form a slot antenna.

Example 12: The system of any of Examples 1-11, wherein a right-side branch of the plurality of branches is modified to form a slot antenna.

Example 13: The system of any of Examples 1-12, wherein the left-side and right-side branches are tuned for operation within a specific frequency range.

Example 14: A mobile electronic device comprising: a sensor mounting bracket that includes one or more mounting points for a plurality of sensors, the sensor mounting bracket including a center portion and a plurality of different branches extending from the center portion, and a printed circuit board that includes one or more antenna feed components, wherein at least one of the branches of the sensor mounting bracket is modified to form a specific type of antenna, and wherein the antenna feed components are electrically connected to the antenna.

Example 15: The mobile electronic device of Example 14, wherein a top branch that comprises a top portion of the center portion of the sensor mounting bracket comprises a planar inverted-F antenna.

Example 16: The mobile electronic device of Example 14 or Example 15, wherein a left-side portion of the center portion of the sensor mounting bracket is modified to form a loop antenna.

Example 17: The mobile electronic device of any of Examples 14-16, wherein a right-side portion of the center portion of the sensor mounting bracket is modified to form a loop antenna.

Example 18: The mobile electronic device of any of Examples 14-17, wherein the left-side and right-side loop antennas comprise WiFi antennas.

Example 19: The mobile electronic device of any of Examples 14-18, wherein the left-side and right-side loop antennas are tuned for operation within a specific frequency range.

Example 20: A virtual reality headset comprising: a sensor mounting bracket that includes one or more mounting points for a plurality of sensors, the sensor mounting bracket including a center portion and a plurality of different branches protruding from the center portion, and a printed circuit board that includes one or more antenna feed components, wherein at least one of the branches of the sensor mounting bracket is modified to form a specific type of antenna, and wherein the antenna feed components are electrically connected to the antenna.

Embodiments of the present disclosure may include or be implemented in conjunction with various types of artificial-reality systems. Artificial reality is a form of reality that has been adjusted in some manner before presentation to a user, which may include, for example, a virtual reality, an augmented reality, a mixed reality, a hybrid reality, or some combination and/or derivative thereof. Artificial-reality content may include completely computer-generated content or computer-generated content combined with captured (e.g., real-world) content. The artificial-reality content may include video, audio, haptic feedback, or some combination thereof, any of which may be presented in a single channel or in multiple channels (such as stereo video that produces a three-dimensional (3D) effect to the viewer). Additionally, in some embodiments, artificial reality may also be associated with applications, products, accessories, services, or some combination thereof, that are used to, for example, create content in an artificial reality and/or are otherwise used in (e.g., to perform activities in) an artificial reality.

Artificial-reality systems may be implemented in a variety of different form factors and configurations. Some artificial-reality systems may be designed to work without near-eye displays (NEDs). Other artificial-reality systems may include an NED that also provides visibility into the real world (such as, e.g., augmented-reality system **800** in FIG. **8**) or that visually immerses a user in an artificial reality (such as, e.g., virtual-reality system **900** in FIG. **9**). While some artificial-reality devices may be self-contained systems, other artificial-reality devices may communicate and/or coordinate with external devices to provide an artificial-reality experience to a user. Examples of such external devices include handheld controllers, mobile devices, desktop computers, devices worn by a user, devices worn by one or more other users, and/or any other suitable external system.

Turning to FIG. **8**, augmented-reality system **800** may include an eyewear device **802** with a frame **810** configured to hold a left display device **815**(A) and a right display device **815**(B) in front of a user's eyes. Display devices **815**(A) and **815**(B) may act together or independently to present an image or series of images to a user. While augmented-reality system **800** includes two displays, embodiments of this disclosure may be implemented in augmented-reality systems with a single NED or more than two NEDs.

In some embodiments, augmented-reality system **800** may include one or more sensors, such as sensor **840**. Sensor **840** may generate measurement signals in response to motion of augmented-reality system **800** and may be located on substantially any portion of frame **810**. Sensor **840** may represent one or more of a variety of different sensing mechanisms, such as a position sensor, an inertial measurement unit (IMU), a depth camera assembly, a structured light emitter and/or detector, or any combination thereof. In some embodiments, augmented-reality system **800** may or may not include sensor **840** or may include more than one sensor. In embodiments in which sensor **840** includes an IMU, the IMU may generate calibration data based on measurement signals from sensor **840**. Examples of sensor **840** may

include, without limitation, accelerometers, gyroscopes, magnetometers, other suitable types of sensors that detect motion, sensors used for error correction of the IMU, or some combination thereof.

In some examples, augmented-reality system **800** may also include a microphone array with a plurality of acoustic transducers **820**(A)-**820**(J), referred to collectively as acoustic transducers **820**. Acoustic transducers **820** may represent transducers that detect air pressure variations induced by sound waves. Each acoustic transducer **820** may be configured to detect sound and convert the detected sound into an electronic format (e.g., an analog or digital format). The microphone array in FIG. **8** may include, for example, ten acoustic transducers: **820**(A) and **820**(B), which may be designed to be placed inside a corresponding ear of the user, acoustic transducers **820**(C), **820**(D), **820**(E), **820**(F), **820**(G), and **820**(H), which may be positioned at various locations on frame **810**, and/or acoustic transducers **820**(I) and **820**(J), which may be positioned on a corresponding neckband **805**.

In some embodiments, one or more of acoustic transducers **820**(A)-(J) may be used as output transducers (e.g., speakers). For example, acoustic transducers **820**(A) and/or **820**(B) may be earbuds or any other suitable type of headphone or speaker.

The configuration of acoustic transducers **820** of the microphone array may vary. While augmented-reality system **800** is shown in FIG. **8** as having ten acoustic transducers **820**, the number of acoustic transducers **820** may be greater or less than ten. In some embodiments, using higher numbers of acoustic transducers **820** may increase the amount of audio information collected and/or the sensitivity and accuracy of the audio information. In contrast, using a lower number of acoustic transducers **820** may decrease the computing power required by an associated controller **850** to process the collected audio information. In addition, the position of each acoustic transducer **820** of the microphone array may vary. For example, the position of an acoustic transducer **820** may include a defined position on the user, a defined coordinate on frame **810**, an orientation associated with each acoustic transducer **820**, or some combination thereof.

Acoustic transducers **820**(A) and **820**(B) may be positioned on different parts of the user's ear, such as behind the pinna, behind the tragus, and/or within the auricle or fossa. Or, there may be additional acoustic transducers **820** on or surrounding the ear in addition to acoustic transducers **820** inside the ear canal. Having an acoustic transducer **820** positioned next to an ear canal of a user may enable the microphone array to collect information on how sounds arrive at the ear canal. By positioning at least two of acoustic transducers **820** on either side of a user's head (e.g., as binaural microphones), augmented-reality system **800** may simulate binaural hearing and capture a 3D stereo sound field around about a user's head. In some embodiments, acoustic transducers **820**(A) and **820**(B) may be connected to augmented-reality system **800** via a wired connection **830**, and in other embodiments acoustic transducers **820**(A) and **820**(B) may be connected to augmented-reality system **800** via a wireless connection (e.g., a BLUETOOTH connection). In still other embodiments, acoustic transducers **820**(A) and **820**(B) may not be used at all in conjunction with augmented reality system **800**.

Acoustic transducers **820** on frame **810** may be positioned in a variety of different ways, including along the length of the temples, across the bridge, above or below display devices **815**(A) and **815**(B), or some combination thereof. Acoustic transducers **820** may also be oriented such that the microphone array is able to detect sounds in a wide range of directions surrounding the user wearing the augmented-reality system **800**. In some embodiments, an optimization process may be performed during manufacturing of augmented-reality system **800** to determine relative positioning of each acoustic transducer **820** in the microphone array.

In some examples, augmented-reality system **800** may include or be connected to an external device (e.g., a paired device), such as neckband **805**. Neckband **805** generally represents any type or form of paired device. Thus, the following discussion of neckband **805** may also apply to various other paired devices, such as charging cases, smart watches, smart phones, wrist bands, other wearable devices, hand-held controllers, tablet computers, laptop computers, other external compute devices, etc.

As shown, neckband **805** may be coupled to eyewear device **802** via one or more connectors. The connectors may be wired or wireless and may include electrical and/or non-electrical (e.g., structural) components. In some cases, eyewear device **802** and neckband **805** may operate independently without any wired or wireless connection between them. While FIG. **8** illustrates the components of eyewear device **802** and neckband **805** in example locations on eyewear device **802** and neckband **805**, the components may be located elsewhere and/or distributed differently on eyewear device **802** and/or neckband **805**. In some embodiments, the components of eyewear device **802** and neckband **805** may be located on one or more additional peripheral devices paired with eyewear device **802**, neckband **805**, or some combination thereof.

Pairing external devices, such as neckband **805**, with augmented-reality eyewear devices may enable the eyewear devices to achieve the form factor of a pair of glasses while still providing sufficient battery and computation power for expanded capabilities. Some or all of the battery power, computational resources, and/or additional features of augmented-reality system **800** may be provided by a paired device or shared between a paired device and an eyewear device, thus reducing the weight, heat profile, and form factor of the eyewear device overall while still retaining desired functionality. For example, neckband **805** may allow components that would otherwise be included on an eyewear device to be included in neckband **805** since users may tolerate a heavier weight load on their shoulders than they would tolerate on their heads. Neckband **805** may also have a larger surface area over which to diffuse and disperse heat to the ambient environment. Thus, neckband **805** may allow for greater battery and computation capacity than might otherwise have been possible on a stand-alone eyewear device. Since weight carried in neckband **805** may be less invasive to a user than weight carried in eyewear device **802**, a user may tolerate wearing a lighter eyewear device and carrying or wearing the paired device for greater lengths of time than a user would tolerate wearing a heavy standalone eyewear device, thereby enabling users to more fully incorporate artificial-reality environments into their day-to-day activities.

Neckband **805** may be communicatively coupled with eyewear device **802** and/or to other devices. These other devices may provide certain functions (e.g., tracking, localizing, depth mapping, processing, storage, etc.) to augmented-reality system **800**. In the embodiment of FIG. **8**, neckband **805** may include two acoustic transducers (e.g., **820**(I) and **820**(J)) that are part of the microphone array (or

potentially form their own microphone subarray). Neckband **805** may also include a controller **825** and a power source **835**.

Acoustic transducers **820**(I) and **820**(J) of neckband **805** may be configured to detect sound and convert the detected sound into an electronic format (analog or digital). In the embodiment of FIG. **8**, acoustic transducers **820**(I) and **820**(J) may be positioned on neckband **805**, thereby increasing the distance between the neckband acoustic transducers **820**(I) and **820**(J) and other acoustic transducers **820** positioned on eyewear device **802**. In some cases, increasing the distance between acoustic transducers **820** of the microphone array may improve the accuracy of beamforming performed via the microphone array. For example, if a sound is detected by acoustic transducers **820**(C) and **820**(D) and the distance between acoustic transducers **820**(C) and **820**(D) is greater than, e.g., the distance between acoustic transducers **820**(D) and **820**(E), the determined source location of the detected sound may be more accurate than if the sound had been detected by acoustic transducers **820**(D) and **820**(E).

Controller **825** of neckband **805** may process information generated by the sensors on neckband **805** and/or augmented-reality system **800**. For example, controller **825** may process information from the microphone array that describes sounds detected by the microphone array. For each detected sound, controller **825** may perform a direction-of-arrival (DOA) estimation to estimate a direction from which the detected sound arrived at the microphone array. As the microphone array detects sounds, controller **825** may populate an audio data set with the information. In embodiments in which augmented-reality system **800** includes an inertial measurement unit, controller **825** may compute all inertial and spatial calculations from the IMU located on eyewear device **802**. A connector may convey information between augmented-reality system **800** and neckband **805** and between augmented-reality system **800** and controller **825**. The information may be in the form of optical data, electrical data, wireless data, or any other transmittable data form. Moving the processing of information generated by augmented-reality system **800** to neckband **805** may reduce weight and heat in eyewear device **802**, making it more comfortable to the user.

Power source **835** in neckband **805** may provide power to eyewear device **802** and/or to neckband **805**. Power source **835** may include, without limitation, lithium-ion batteries, lithium-polymer batteries, primary lithium batteries, alkaline batteries, or any other form of power storage. In some cases, power source **835** may be a wired power source. Including power source **835** on neckband **805** instead of on eyewear device **802** may help better distribute the weight and heat generated by power source **835**.

As noted, some artificial-reality systems may, instead of blending an artificial reality with actual reality, substantially replace one or more of a user's sensory perceptions of the real world with a virtual experience. One example of this type of system is a head-worn display system, such as virtual-reality system **900** in FIG. **9**, that mostly or completely covers a user's field of view. Virtual-reality system **900** may include a front rigid body **902** and a band **904** shaped to fit around a user's head. Virtual-reality system **900** may also include output audio transducers **906**(A) and **906**(B). Furthermore, while not shown in FIG. **9**, front rigid body **902** may include one or more electronic elements, including one or more electronic displays, one or more inertial measurement units (IMUs), one or more tracking emitters or detectors, and/or any other suitable device or system for creating an artificial-reality experience.

Artificial-reality systems may include a variety of types of visual feedback mechanisms. For example, display devices in augmented-reality system **800** and/or virtual-reality system **900** may include one or more liquid crystal displays (LCDs), light emitting diode (LED) displays, microLED displays, organic LED (OLED) displays, digital light projector (DLP) micro-displays, liquid crystal on silicon (LCoS) micro-displays, and/or any other suitable type of display screen. These artificial-reality systems may include a single display screen for both eyes or may provide a display screen for each eye, which may allow for additional flexibility for varifocal adjustments or for correcting a user's refractive error. Some of these artificial-reality systems may also include optical subsystems having one or more lenses (e.g., concave or convex lenses, Fresnel lenses, adjustable liquid lenses, etc.) through which a user may view a display screen. These optical subsystems may serve a variety of purposes, including to collimate (e.g., make an object appear at a greater distance than its physical distance), to magnify (e.g., make an object appear larger than its actual size), and/or to relay (to, e.g., the viewer's eyes) light. These optical subsystems may be used in a non-pupil-forming architecture (such as a single lens configuration that directly collimates light but results in so-called pincushion distortion) and/or a pupil-forming architecture (such as a multi-lens configuration that produces so-called barrel distortion to nullify pincushion distortion).

In addition to or instead of using display screens, some of the artificial-reality systems described herein may include one or more projection systems. For example, display devices in augmented-reality system **800** and/or virtual-reality system **900** may include micro-LED projectors that project light (using, e.g., a waveguide) into display devices, such as clear combiner lenses that allow ambient light to pass through. The display devices may refract the projected light toward a user's pupil and may enable a user to simultaneously view both artificial-reality content and the real world. The display devices may accomplish this using any of a variety of different optical components, including waveguide components (e.g., holographic, planar, diffractive, polarized, and/or reflective waveguide elements), light-manipulation surfaces and elements (such as diffractive, reflective, and refractive elements and gratings), coupling elements, etc. Artificial-reality systems may also be configured with any other suitable type or form of image projection system, such as retinal projectors used in virtual retina displays.

The artificial-reality systems described herein may also include various types of computer vision components and subsystems. For example, augmented-reality system **800** and/or virtual-reality system **900** may include one or more optical sensors, such as two-dimensional (2D) or 3D cameras, structured light transmitters and detectors, time-of-flight depth sensors, single-beam or sweeping laser rangefinders, 3D LiDAR sensors, and/or any other suitable type or form of optical sensor. An artificial-reality system may process data from one or more of these sensors to identify a location of a user, to map the real world, to provide a user with context about real-world surroundings, and/or to perform a variety of other functions.

The artificial-reality systems described herein may also include one or more input and/or output audio transducers. Output audio transducers may include voice coil speakers, ribbon speakers, electrostatic speakers, piezoelectric speakers, bone conduction transducers, cartilage conduction trans-

ducers, tragus-vibration transducers, and/or any other suitable type or form of audio transducer. Similarly, input audio transducers may include condenser microphones, dynamic microphones, ribbon microphones, and/or any other type or form of input transducer. In some embodiments, a single transducer may be used for both audio input and audio output.

In some embodiments, the artificial-reality systems described herein may also include tactile (i.e., haptic) feedback systems, which may be incorporated into headwear, gloves, bodysuits, handheld controllers, environmental devices (e.g., chairs, floor mats, etc.), and/or any other type of device or system. Haptic feedback systems may provide various types of cutaneous feedback, including vibration, force, traction, texture, and/or temperature. Haptic feedback systems may also provide various types of kinesthetic feedback, such as motion and compliance. Haptic feedback may be implemented using motors, piezoelectric actuators, fluidic systems, and/or a variety of other types of feedback mechanisms. Haptic feedback systems may be implemented independent of other artificial-reality devices, within other artificial-reality devices, and/or in conjunction with other artificial-reality devices.

By providing haptic sensations, audible content, and/or visual content, artificial-reality systems may create an entire virtual experience or enhance a user's real-world experience in a variety of contexts and environments. For instance, artificial-reality systems may assist or extend a user's perception, memory, or cognition within a particular environment. Some systems may enhance a user's interactions with other people in the real world or may enable more immersive interactions with other people in a virtual world. Artificial-reality systems may also be used for educational purposes (e.g., for teaching or training in schools, hospitals, government organizations, military organizations, business enterprises, etc.), entertainment purposes (e.g., for playing video games, listening to music, watching video content, etc.), and/or for accessibility purposes (e.g., as hearing aids, visual aids, etc.). The embodiments disclosed herein may enable or enhance a user's artificial-reality experience in one or more of these contexts and environments and/or in other contexts and environments.

As detailed above, the computing devices and systems described and/or illustrated herein broadly represent any type or form of computing device or system capable of executing computer-readable instructions, such as those contained within the modules described herein. In their most basic configuration, these computing device(s) may each include at least one memory device and at least one physical processor.

In some examples, the term "memory device" generally refers to any type or form of volatile or non-volatile storage device or medium capable of storing data and/or computer-readable instructions. In one example, a memory device may store, load, and/or maintain one or more of the modules described herein. Examples of memory devices include, without limitation, Random Access Memory (RAM), Read Only Memory (ROM), flash memory, Hard Disk Drives (HDDs), Solid-State Drives (SSDs), optical disk drives, caches, variations or combinations of one or more of the same, or any other suitable storage memory.

In some examples, the term "physical processor" generally refers to any type or form of hardware-implemented processing unit capable of interpreting and/or executing computer-readable instructions. In one example, a physical processor may access and/or modify one or more modules stored in the above-described memory device. Examples of physical processors include, without limitation, microprocessors, microcontrollers, Central Processing Units (CPUs), Field-Programmable Gate Arrays (FPGAs) that implement softcore processors, Application-Specific Integrated Circuits (ASICs), portions of one or more of the same, variations or combinations of one or more of the same, or any other suitable physical processor.

Although illustrated as separate elements, the modules described and/or illustrated herein may represent portions of a single module or application. In addition, in certain embodiments one or more of these modules may represent one or more software applications or programs that, when executed by a computing device, may cause the computing device to perform one or more tasks. For example, one or more of the modules described and/or illustrated herein may represent modules stored and configured to run on one or more of the computing devices or systems described and/or illustrated herein. One or more of these modules may also represent all or portions of one or more special-purpose computers configured to perform one or more tasks.

In addition, one or more of the modules described herein may transform data, physical devices, and/or representations of physical devices from one form to another. Additionally or alternatively, one or more of the modules recited herein may transform a processor, volatile memory, non-volatile memory, and/or any other portion of a physical computing device from one form to another by executing on the computing device, storing data on the computing device, and/or otherwise interacting with the computing device.

In some embodiments, the term "computer-readable medium" generally refers to any form of device, carrier, or medium capable of storing or carrying computer-readable instructions. Examples of computer-readable media include, without limitation, transmission-type media, such as carrier waves, and non-transitory-type media, such as magnetic-storage media (e.g., hard disk drives, tape drives, and floppy disks), optical-storage media (e.g., Compact Disks (CDs), Digital Video Disks (DVDs), and BLU-RAY disks), electronic-storage media (e.g., solid-state drives and flash media), and other distribution systems.

The process parameters and sequence of the steps described and/or illustrated herein are given by way of example only and can be varied as desired. For example, while the steps illustrated and/or described herein may be shown or discussed in a particular order, these steps do not necessarily need to be performed in the order illustrated or discussed. The various exemplary methods described and/or illustrated herein may also omit one or more of the steps described or illustrated herein or include additional steps in addition to those disclosed.

The preceding description has been provided to enable others skilled in the art to best utilize various aspects of the exemplary embodiments disclosed herein. This exemplary description is not intended to be exhaustive or to be limited to any precise form disclosed. Many modifications and variations are possible without departing from the spirit and scope of the present disclosure. The embodiments disclosed herein should be considered in all respects illustrative and not restrictive. Reference should be made to the appended claims and their equivalents in determining the scope of the present disclosure.

Unless otherwise noted, the terms "connected to" and "coupled to" (and their derivatives), as used in the specification and claims, are to be construed as permitting both direct and indirect (i.e., via other elements or components) connection. In addition, the terms "a" or "an," as used in the specification and claims, are to be construed as meaning "at

least one of." Finally, for ease of use, the terms "including" and "having" (and their derivatives), as used in the specification and claims, are interchangeable with and have the same meaning as the word "comprising."

What is claimed is:

1. A system comprising:

a sensor mounting bracket that includes one or more mounting points for a plurality of sensors, the sensor mounting bracket including a center portion and a plurality of different branches extending from the center portion; and

a printed circuit board that includes one or more antenna feed components,

wherein at least one of the branches of the sensor mounting bracket is modified to form a specific type of antenna, and

wherein the antenna feed components are electrically connected to the antenna.

2. The system of claim **1**, wherein a top branch that comprises a top portion of the center portion of the sensor mounting bracket comprises a planar inverted-F antenna.

3. The system of claim **2**, wherein the planar inverted-F antenna is grounded to a bottom branch that comprises a bottom portion of the center portion of the sensor mounting bracket.

4. The system of claim **2**, wherein the planar inverted-F antenna comprises a Bluetooth antenna.

5. The system of claim **2**, wherein a left-side branch of the plurality of branches is modified to form a planar inverted-F antenna.

6. The system of claim **5**, wherein a right-side branch of the plurality of branches is modified to form a planar inverted-F antenna.

7. The system of claim **6**, wherein the left-side and right-side branches are grounded to a bottom branch that comprises a bottom portion of the center portion of the sensor mounting bracket.

8. The system of claim **6**, wherein the left-side branch and the right-side branch comprise WiFi antennas.

9. The system of claim **6**, wherein the left-side and right-side branches are tuned for operation within a specific frequency range.

10. The system of claim **1**, wherein a top branch that comprises a top portion of the center portion of the sensor mounting bracket includes a slot antenna.

11. The system of claim **10**, wherein a left-side branch of the plurality of branches is modified to form a slot antenna.

12. The system of claim **11**, wherein a right-side branch of the plurality of branches is modified to form a slot antenna.

13. The system of claim **12**, wherein the left-side and right-side branches are tuned for operation within a specific frequency range.

14. A mobile electronic device comprising:

a sensor mounting bracket that includes one or more mounting points for a plurality of sensors, the sensor mounting bracket including a center portion and a plurality of different branches extending from the center portion; and

a printed circuit board that includes one or more antenna feed components,

wherein at least one of the branches of the sensor mounting bracket is modified to form a specific type of antenna, and

wherein the antenna feed components are electrically connected to the antenna.

15. The mobile electronic device of claim **14**, wherein a top branch that comprises a top portion of the center portion of the sensor mounting bracket comprises a planar inverted-F antenna.

16. The mobile electronic device of claim **15**, wherein a left-side portion of the center portion of the sensor mounting bracket is modified to form a loop antenna.

17. The mobile electronic device of claim **16**, wherein a right-side portion of the center portion of the sensor mounting bracket is modified to form a loop antenna.

18. The mobile electronic device of claim **17**, wherein the left-side and right-side loop antennas comprise WiFi antennas.

19. The mobile electronic device of claim **17**, wherein the left-side and right-side loop antennas are tuned for operation within a specific frequency range.

20. A virtual reality headset comprising:

a sensor mounting bracket that includes one or more mounting points for a plurality of sensors, the sensor mounting bracket including a center portion and a plurality of different branches extending from the center portion; and

a printed circuit board that includes one or more antenna feed components,

wherein at least one of the branches of the sensor mounting bracket is modified to form a specific type of antenna, and

wherein the antenna feed components are electrically connected to the antenna.

* * * * *

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(54) **TRANSPARENT ANTENNA AND DEVICE**

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See application file for complete search history.

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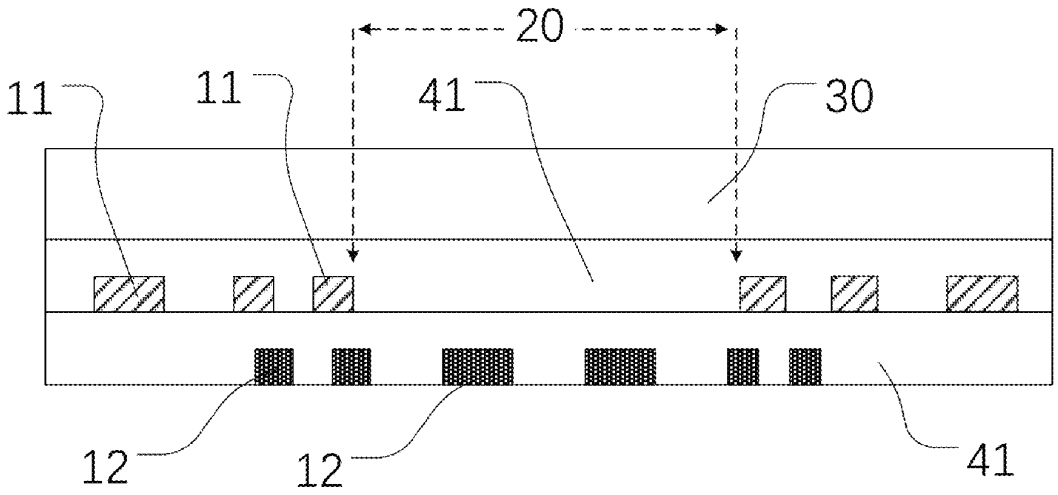
(57) **ABSTRACT**

Disclosed are a transparent antenna and a device. The transparent antenna includes: a first polymer layer; a first transparent antenna, wherein the first transparent antenna includes an antenna body and a partition region, and one side of the first polymer layer is provided with a grid-like conductive wire to form the antenna body; a second polymer layer, wherein the second polymer layer is provided at one side, where the first transparent antenna is provided, of the first polymer layer; and a second transparent antenna, wherein the second transparent antenna is provided at one side of the second polymer layer away from the first transparent antenna, the second transparent antenna includes an antenna body, and one side of the second polymer layer away from the first transparent antenna is provided with a grid-like conductive wire to form the antenna body.

15 Claims, 7 Drawing Sheets



(51) **Int. Cl.**

H01Q 1/36	(2006.01)
H01Q 1/38	(2006.01)
H01Q 19/12	(2006.01)
H01Q 21/28	(2006.01)

(52) **U.S. Cl.**

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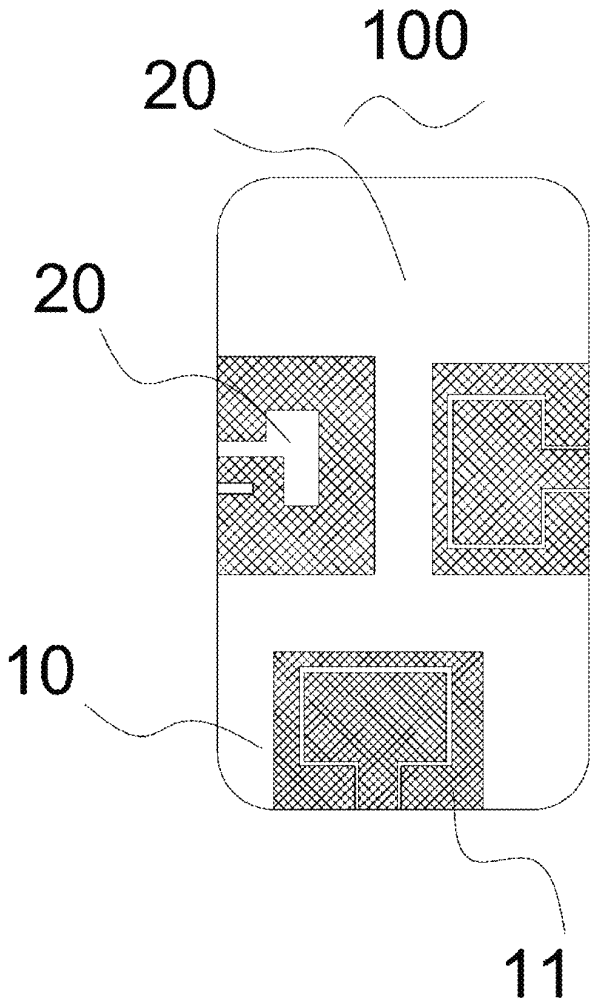

FIG. 1

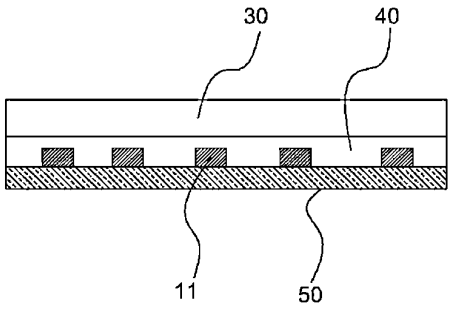

FIG. 2

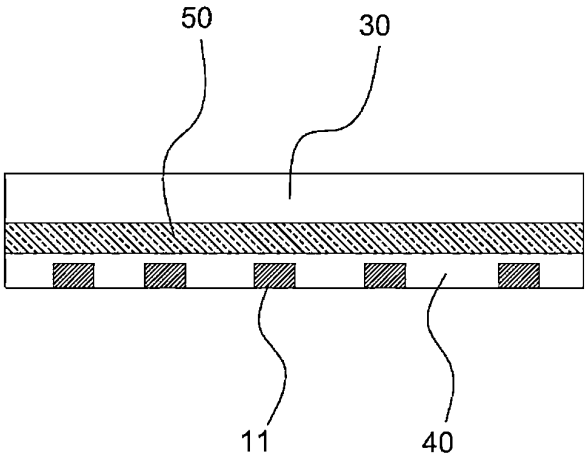

FIG. 3

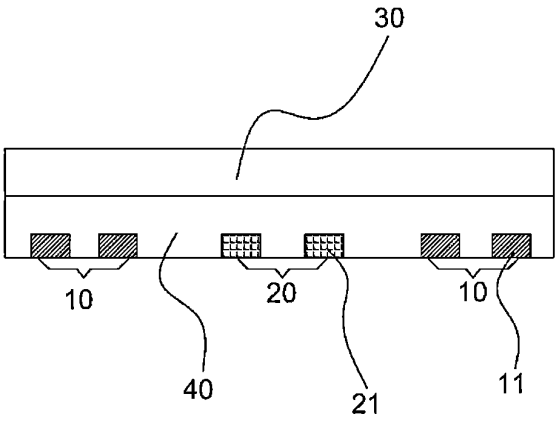

FIG. 4

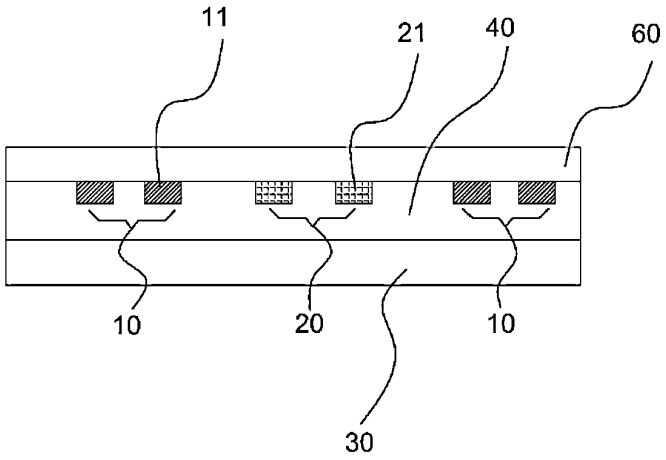

FIG. 5

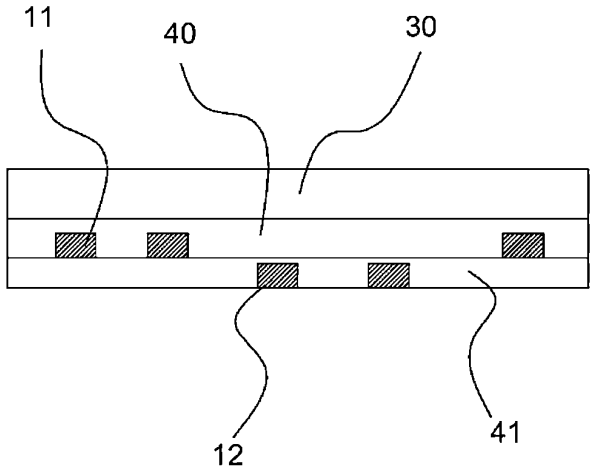

FIG. 6

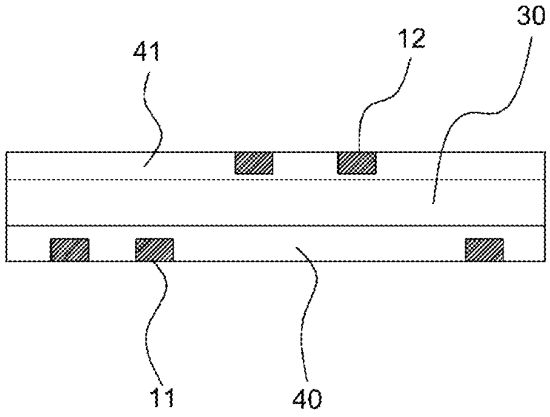

FIG. 7

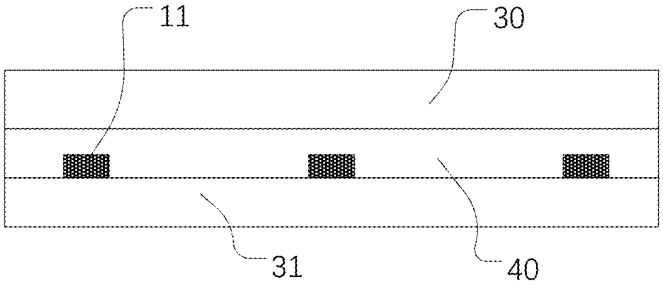

FIG. 8

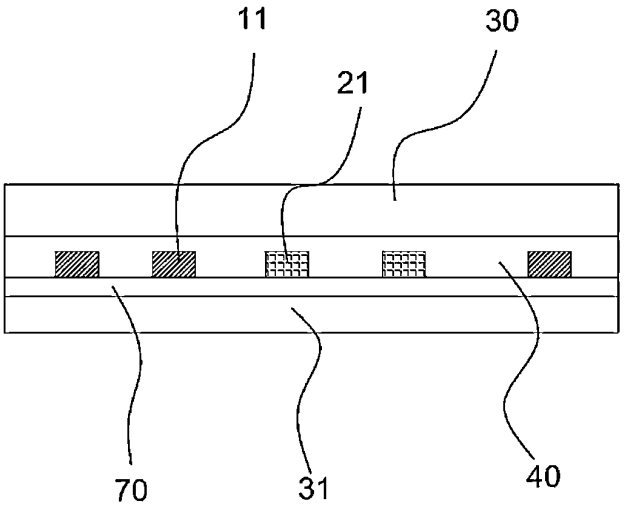

FIG. 9

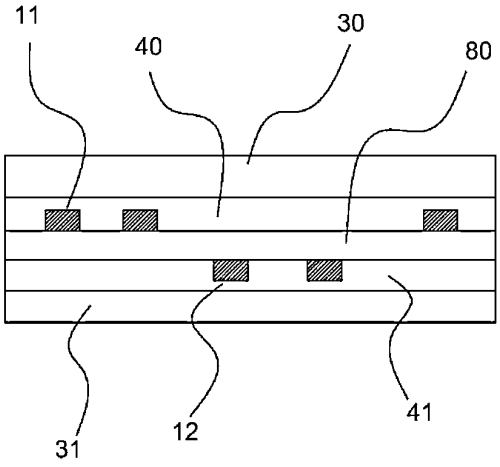

FIG. 10

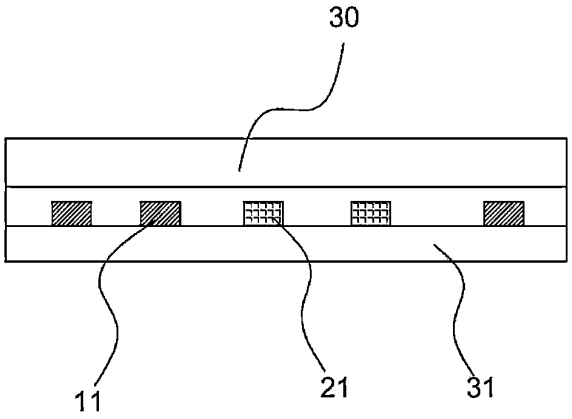

FIG. 11

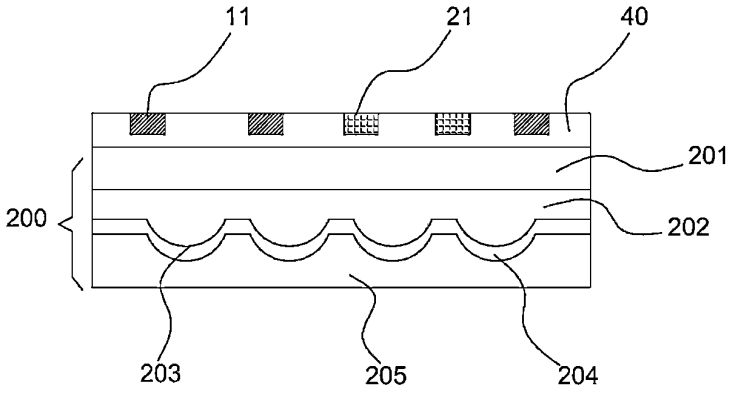

FIG. 12

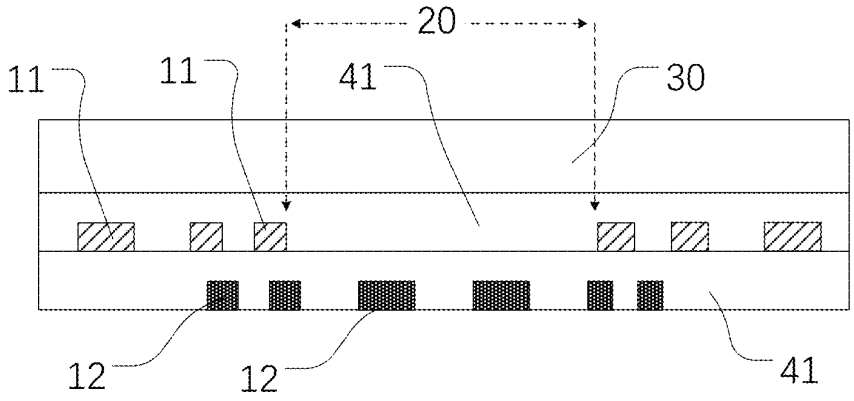

FIG. 13

TRANSPARENT ANTENNA AND DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of International Application No. PCT/CN2020/121937, filed on Oct. 19, 2020, which claims priority to Chinese Patent Application 201911240344.9, filed on Dec. 6, 2019, and Chinese Patent Application 201911270707.3, filed on Dec. 12, 2019. All applications are incorporated herein by reference in their entireties.

TECHNICAL FIELD

The present disclosure relates to the technical field of photoelectric products, in particular to a transparent antenna and a device.

BACKGROUND

With the arrival of the age of commercialized 5G, more and more 5G base stations are being built to provide wireless coverage and realize wireless signal transmission between wired communication networks and wireless terminals. The architecture and form of the base stations directly affect how 5G network is deployed. In the current technical standards, the frequency band of 5G is much higher than that of 2G, 3G and 4G networks. At present stage, the 5G network mainly works in the frequency band of 3000-5000 MHz. Because the higher the frequency, the greater the attenuation during the propagation of signals, the density of the base stations of the 5G network should be higher.

Because the attenuation of 5G signal is particularly serious, the requirements for the structure of the antenna and the reception and transmission of the antenna are becoming higher and higher. For example, there may be great impact on the traditional mobile phone antenna with disuse of a metal back cover. The antenna has to be moved outward to enhance the reception and transmission of the signal. Moreover, because the signal is very easy to attenuate, the glass of buildings may need to be used as the base station of the signal, but it cannot affect the light transmission, which requires a new antenna structure to be used on a device and the base station.

SUMMARY

Based on this, it is necessary to provide a transparent antenna and a device to solve the above technical problems.

A technical solution of the present disclosure is disclosed as below.

A transparent antenna includes:

a first polymer layer;

a first transparent antenna, including an antenna body and a partition region, wherein a side of the first polymer layer is provided with a grid-like conductive wire to form the antenna body;

a second polymer layer, provided on a side of the first polymer layer where the first transparent antenna is provided;

a second transparent antenna, provided on a side of the second polymer layer away from the first transparent antenna, wherein the second transparent antenna includes an antenna body and the side of the second polymer layer away from the first transparent antenna is provided with a grid-like conductive wire to form the antenna body.

In an embodiment of the present disclosure, a supporting body is further included, and the supporting body is provided on another side of the first polymer layer.

In an embodiment of the present disclosure, a side of the first polymer layer away from the supporting body is provided with a concave structure, and the concave structure is provided with conductive material to form the first transparent antenna.

In an embodiment of the present disclosure, a side of the second polymer layer away from the supporting body is provided with a concave structure, and the concave structure is provided with conductive material to form the second transparent antenna.

In an embodiment of the present disclosure, a height of the conductive material is less than a depth of the concave structure; or a height of the conductive material is equal to a depth of the concave structure; or a height of the conductive material is greater than a depth of the concave structure.

In an embodiment of the present disclosure, the concave structure includes a bottom surface, two side surfaces and an opening, and black material is provided close to the bottom surface and/or the opening.

In an embodiment of the present disclosure, an included angle between each of the two side surfaces and the bottom surface is not equal to 90 degrees.

In an embodiment of the present disclosure, a projection of the second transparent antenna covers at least 60% of an area of the partition region of the first transparent antenna.

In an embodiment of the present disclosure, in the case where there is an overlapping region between the first transparent antenna and the second transparent antenna, a grid linewidth at the overlapping region is less than a grid linewidth at a non-overlapping region.

A transparent antenna includes:

a supporting body, including a first surface and a second surface provided opposite to the first surface;

a first polymer layer, provided on the first surface of the supporting body;

a first transparent antenna, including an antenna body and a partition region, wherein a side of the first polymer layer away from the supporting body is provided with a concave structure, and the concave structure is provided with conductive material to form the first transparent antenna;

a second polymer layer, provided on the second surface of the supporting body;

a second transparent antenna, including an antenna body, wherein a side of the second polymer layer away from the supporting body is provided with a concave structure, and the concave structure is provided with conductive material to form the second transparent antenna.

In an embodiment of the present disclosure, a projection of the second transparent antenna covers at least 60% of an area of the partition region of the first transparent antenna.

In an embodiment of the present disclosure, in a case where there is an overlapping region between the first transparent antenna and the second transparent antenna, a grid linewidth at the overlapping region is less than a grid linewidth at a non-overlapping region.

A device includes any one of the transparent antennas described above.

In an embodiment of the present disclosure, the device is one of mobile phones, PADs, vehicles, buildings, household appliances, signal base stations and cards requiring signal reception and transmission.

Beneficial effects of the present disclosure: the present disclosure provides a transparent antenna, which can realize the reception and transmission of signals on a transparent material. The positions of two layers of transparent antennas form a mutual "filling" positional relationship, so that the transparent antennas are visually unified and there is no obvious difference in transmittance when people use objects with transparent antennas. Moreover, in order to eliminate obvious visual difference, the antennas can also be provided on different supporting bodies and correspond to the partition regions of different layers respectively.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a layout diagram of a transparent antenna in the present disclosure.

FIG. **2** is a cross-sectional structural diagram of a transparent antenna in the present disclosure.

FIG. **3** is a structural diagram of a transparent antenna in the present disclosure.

FIG. **4** is another cross-sectional structural diagram of a transparent antenna in the present disclosure.

FIG. **5** is another structural diagram of a transparent antenna in the present disclosure.

FIG. **6** is yet another cross-sectional structural diagram of a transparent antenna in the present disclosure.

FIG. **7** is yet another structural diagram of a transparent antenna in the present disclosure.

FIG. **8** is still another cross-sectional structural diagram of a transparent antenna in the present disclosure.

FIG. **9** is still another structural diagram of a transparent antenna in the present disclosure.

FIG. **10** is still another structural diagram of a transparent antenna in the present disclosure.

FIG. **11** is still another structural diagram of a transparent antenna in the present disclosure.

FIG. **12** is a cross-sectional diagram of a transparent antenna in the present disclosure.

FIG. **13** is a cross-sectional diagram of a transparent antenna in the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In order to make objects, technical details and advantages of the present disclosure more apparent, the present disclosure will be further described specifically with reference to the accompanying drawings and embodiments. It should be understood that, the specified embodiments described herein are only used to explain the present disclosure, but not to limit the present disclosure.

In the description of the present disclosure, unless otherwise clearly specified and limited, the terms "first" and "second" are only used for the purpose of description and should not be understood as indicating or implying relative importance; unless otherwise specified or stated, the term "multiple" refers to two or more; and the terms "connection" and "fixed" should be understood in a broad sense. For example, "connection" is a fixed connection, a detachable connection, an integrated connection, or an electrical connection, and is connected directly or indirectly through intermediate media. For those skilled in the art, the specific meanings of the above terms in the present disclosure are understood according to specific situations.

The present disclosure provides a transparent antenna, including: a supporting body or a supporting layer, which is made of polymer material or glass and is mainly used as a support of an antenna; a transparent antenna including an antenna body and a partition region, in which a side of the supporting layer is provided with a grid-like conductive wire to form the antenna body, and the transparent antenna is visually transparent and is actually made of a conductive material, but lines are thin enough for human eyes to distinguish; and a dummy electrode. The partition region is provided with a grid to form the dummy electrode, and the dummy electrode is electrically insulated from the antenna body. Of course, the dummy electrode may also be random line segments. Because the transparent antenna is made of a conductive material, which will affect the transmittance to some extent, in other words, there is a difference in the transmittance between a region with the transparent antenna and a region without the transparent antenna resulting in visual difference of human eyes. Therefore, the dummy electrode is provided in the partition region of the transparent antenna, and the dummy electrode cannot function as an antenna. The material of the dummy electrode may be the same as the material of the transparent antenna, and the material of the dummy electrode may be a conductive material or a non-conductive material. Moreover, in the case where the dummy electrode includes random or regular line segments, the line segments may be overlapped, or all line segments may be independent and not intersect with each other. And of course, the extension lines of the line segments may intersect with each other.

For example, the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 20%. Furthermore, the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 10%, or the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 5% in order to achieve a smaller difference in visual effect.

In an embodiment of the present disclosure, the conductive wire of the transparent antenna is protruded on the supporting layer. Of course, the conductive wire may also be embedded on a side of the supporting layer. In the case where the transparent antenna is an embedded structure, it is equivalent to that a side of the supporting layer is provided with a concave structure, the concave structure forms a grid, and the concave structure is provided with a conductive material to form the conductive wire embedded on the side of the supporting layer. The height of the conductive material is less than the depth of the concave structure; or the height of the conductive material is equal to the depth of the concave structure; or the height of the conductive material is greater than the depth of the concave structure.

For example, the concave structure includes a bottom surface, two side surfaces and an opening, and a black material is provided close to the bottom surface and/or the opening. That is, the bottom of the conductive material in the concave structure is provided with the black material, or the top of the conductive material in the concave structure is provided with the black material, or both the bottom and the top of the conductive material in the concave structure are provided with the black material. Of course, the black material itself may also be conductive. An included angle between each of the two side surfaces and the bottom surface

is not equal to 90 degrees. Of course, the included angle between each of the two side surfaces and the bottom surface may also be equal to 90 degrees or less than 90 degrees.

In an embodiment, the grid which forms the dummy electrode includes multiple grid lines, and at least one of the grid lines is disconnected, so that the grid line is disconnected to prevent the dummy electrode from being connected with the antenna body. In this way, the grid of the dummy electrode is disconnected, which further ensures the safety of the antenna body. The grid lines are made of a conductive material and/or a non-conductive material, and the grid lines are embedded in the partition region. Therefore, the grid of the dummy electrode is a convex structure or an embedded structure, and is formed synchronously with the antenna body or is formed by separate processes. The difference between the dummy electrode and the antenna body is that the antenna body plays a role of an antenna, such as receiving and transmitting signals, while the dummy electrode does not play the role of the antenna itself.

Referring to FIG. **1**, a transparent antenna array **100** includes a transparent antenna **10**, and the transparent antenna **10** includes an antenna body **11** and a partition region **20**. It is illustrated in FIG. **1** that a single transparent antenna **10** itself includes an antenna body **11** and a partition region **20**, and there is also a partition region **20** between multiple transparent antennas **10**. In this way, the single transparent antenna **10** includes the antenna body **11** and the partition region **20**, and the partition region **20** is provided with a dummy electrode. The dummy electrode includes a grid or line segments, and the dummy electrode is electrically insulated from the antenna body. There may also be a partition region **20** between multiple transparent antennas **10**, the partition region **20** may also be provided with a dummy electrode, and the dummy electrode includes a grid or line segments. Moreover, the grid or line segments composing the dummy electrode may be connected, or the grid lines composing the grid are disconnected. In the case where the line segments are used to compose the dummy electrode, the line segments are intersect or not intersect with each other.

Referring to FIG. **2**, a transparent antenna is disclosed, and the transparent antenna includes a supporting body **30**, a polymer layer **40**, an antenna body **11** and a shielding layer **50**. The supporting body **30** is made of glass or PMMC, or is made of PET, PC, PE or composite board. A side of the supporting body **30** is provided with the polymer layer **40**. The side of the polymer layer **40** away from the supporting body **30** is provided with a concave structure, and the concave structure is provided with a conductive material to form the antenna body **11**. Of course, the antenna body **11** may also be a convex structure (not shown in the figure). The side of the polymer layer **40** provided with the antenna body **11** is further provided with the shielding layer **50**. The shielding layer **50** is made of colored ink or other colored shielding materials for shielding. Of course, the transparent antenna applying the structure shown in FIG. **2** may also be provided with a dummy electrode (not shown in the figure). The structure in FIG. **2** may be used as cover plates of some electronic devices or as cover plates of some household appliances in practical applications, for example, the structure is used in mobile phones, PADs, watches, televisions and other devices that need antennas.

Referring to FIG. **3**, another product structure of a transparent antenna is disclosed, and the transparent antenna includes a supporting body **30**, a polymer layer **40**, an antenna body **11** and a shielding layer **50**. The supporting body **30** is made of glass, PMMC, PET, PC, PE or composite board. A side of the supporting body **30** is provided with the shielding layer **50**, which is made of colored ink or other colored shielding materials for shielding. The side of the shielding layer **50** away from the supporting body **30** is provided with the polymer layer **40**, and the side of the polymer layer **40** away from the shielding layer **50** is provided with a concave structure. The concave structure is provided with a conductive material to form the antenna body **11**. Of course, the antenna body **11** may also be a convex structure (not shown in the figure). Of course, the transparent antenna applying the structure in FIG. **3** may also be provided with a dummy electrode (not shown in the figure). Moreover, if the supporting body **30** is an using surface (or called as a user surface), because the antenna body **11** is shielded by the shielding layer **50** and the antenna body **11** cannot be seen in user vision, the antenna body **11** may also be non-transparent, or the transmittance of the transparent antenna does not need to be particularly high, for example, the transmittance is 20%, 40%, or 70%. Of course, the transmittance of the transparent antenna may be similar or the same as the transmittance of the transparent antenna towards the user surface, for example, greater than 85%, or greater than 90%, or even higher, greater than 92%. The product structure in FIG. **3** may also be applied to cover plates of some electronic devices, as well as cover plates of some household appliances, or used in vehicles and buildings, for example, the structure is used in mobile phones, PADs, watches, televisions and other devices that need antennas.

Referring to FIG. **4**, another embodiment of a transparent antenna is disclosed. The transparent antenna includes a supporting body **30**, a polymer layer **40**, a transparent antenna **10** and a dummy electrode **20**. The polymer layer **40** is provided on a side of the supporting body **30**, the side of the polymer layer **40** away from the supporting body **30** is provided with a concave structure, and the concave structure is provided with a conductive material to form the transparent antenna **10** and the dummy electrode **20**. The transparent antenna **10** includes an antenna body **11** and a partition region, and the antenna body **11** includes a grid-like conductive wire. The dummy electrode is provided in the partition region and includes a gird or line segments, and the grid includes multiple grid lines **21**. The absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 20%. For better visual effect, the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 10%, or is not greater than 5%.

The transparent antenna **10** and the dummy electrode **20** shown in FIG. **4** are both concave structures. The antenna body **11** of the transparent antenna **10** may be embedded in the polymer layer **40**, in which the embedding refers to that the conductive material is provided in the concave structure with the thickness of the conductive material being less than the depth of the concave structure, or being equal to the depth of the concave structure or being higher than the depth of the concave structure. The antenna body **11** of the transparent antenna **10** may also be a convex structure. Of course, the grid lines **21** of the dummy electrode **20** may also be a convex structure. And the dummy electrode may also include line segments, and the line segments may be independent and not intersect with each other, or may be overlapped with each other. In the case where the dummy electrode includes a grid, the grid lines composing the dummy electrode **20** are electrically disconnected, so that the grid lines of the dummy electrode are not conductive.

The transparent antenna disclosed in FIG. **4** can be used on electrical devices, including electronic devices with display function, such as mobile phones, PADs, etc. The transparent antenna may be directly formed in a display region in front of a mobile phone, in this case, the supporting body **30** is made of glass, and the transparent antenna **10** is provided below the glass, so that the display region of the mobile phone can also be used to provide the receiving and transmitting terminals of the antenna, without affecting the normal use and viewing of the mobile phone. Of course, the structure may also be applied on a back cover of the mobile phone, and is provided under the glass or composite plate of the back cover of the mobile phone, which does not affect the appearance of the back cover of the mobile phone. In addition, the transparent antenna may also be applied on windows of vehicles. With the commercialization of 5G, the number of signal base stations increases sharply, and 5G signal is easy to be shielded. Therefore, the transparent antenna can be formed on the windows (such as glass, PMMA or other transparent materials) of vehicles, such as the glass of the car window, the glass of the high-speed rail, etc., which can well ensure the reception and transmission of the signal. The transparent antenna may also be used on glass of buildings or components with transmittance. Moreover, the transparent antenna may be directly formed on glass, or may be bonded to the glass or transparent medium through bonding.

Referring to FIG. **5**, another structure of a transparent antenna is disclosed. The transparent antenna includes a supporting body **30**, a polymer layer **40**, a protective layer **60**, a transparent antenna **10** and a dummy electrode **20**. The polymer layer **40** is provided on a side of the supporting body **30**, the side of the polymer layer **40** away from the supporting body **30** is provided with a concave structure, and the concave structure is provided with a conductive material to form the transparent antenna **10** and the dummy electrode **20**. The transparent antenna **10** includes an antenna body **11** and a partition region. The antenna body **11** includes a grid-like conductive wire, and the dummy electrode **20** is provided in the partition region. The dummy electrode includes a grid or line segments, and the grid includes grid lines **21**. And the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 20%. For better visual effect, the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 10%, or not greater than 5%. The side of the transparent antenna **10** and the dummy electrode **20** away from the supporting body **30** is provided with the protective layer **60**. The protective layer **60** may be made of a material with a hardness not less than 2H. Of course, the protective layer **60** may also be made of a material like transparent leather, so the protective layer **60** may be made of a UV material, a PU material, a TPU material, etc.

Referring to FIG. **5**, in the transparent antenna structure of FIG. **5**, the transparent antenna **10** and the dummy electrode **20** are both directly provided on the user surface, and the protective layer needs to be provided on the surface of the transparent antenna to protect the transparent antenna structure from being damaged. Moreover, the structure has no location limitation. Taking a mobile phone as an example, the transparent antenna of this structure is provided under a screen cover, and is also provided above the screen cover, or is provided under glass of the back cover of the mobile phone, or is provided directly outside the back cover of the mobile phone. The transparent antenna structure shown in FIG. **5** is very advantageous for use in car windows, buildings, etc., and can be well used as an antenna of a base station or as an antenna for communication.

Referring to FIG. **6** and FIG. **13**, another embodiment of a transparent antenna is disclosed. The transparent antenna includes a supporting body **30**, a first polymer layer **40** (the "first" here is only for convenience of description, and can also be referred to as the polymer layer **40**), a second polymer layer **41**, a first transparent antenna and a second transparent antenna. The first polymer layer **40** is provided on a side of the supporting body **30**, and the side of the first polymer layer **40** away from the supporting body **30** is provided with a concave structure. The concave structure is provided with a conductive material to form the first transparent antenna, the first transparent antenna includes an antenna body **11** (can also be referred to as a "first antenna body") and a partition region, and the antenna body **11** includes a grid-like conductive wire. The second polymer layer **41** is provided on a side of the first polymer layer **41**, and the side of the second polymer layer **41** away from the first polymer layer **40** is provided with a concave structure. The concave structure is provided with a conductive material to form the second transparent antenna, the second transparent antenna includes an antenna body **12** (can also be referred to as a "second antenna body"), and the antenna body **12** includes a grid conductive wire. And the projection of the second transparent antenna covers at least 60% of the area of the partition region of the first transparent antenna, or covers 80% of the area of the partition region of the first transparent antenna, or covers more than 95% of the area of the partition region of the first transparent antenna in order to achieve better visual effect. The partition region described here is a partition region of a single transparent antenna, or a partition region between two transparent antennas. In the present embodiment, the first transparent antenna and the second transparent antenna cooperate with each other to "fill" their respective partition regions, in which the partition regions may be completely "filled" or partially "filled", in order to reduce visual difference caused by difference in transmittance. Of course, as shown in FIG. **13**, in the case where there is an overlapping region between the first transparent antenna and the second transparent antenna, in order to ensure a similar transmittance, the grid linewidth at the overlapping region is less than the grid linewidth at a non-overlapping region, so as to ensure that the transmittance at the overlapping region is similar to the transmittance at the non-overlapping region. For example, the grid linewidth at the overlapping region of the antenna body **11** of the first transparent antenna is 3 microns, while the grid linewidth at the non-overlapping region of the antenna body **11** is 5 microns, so that the absolute value of the difference between the grid linewidth at the overlapping region and the grid linewidth at the non-overlapping region is not less than 0.5 microns. Of course, the same is true for the second transparent antenna.

Referring to FIG. **7**, another structure of a transparent antenna is disclosed, the structure is obtained from a change of the structure shown in FIG. **6**, in which the first polymer layer **40** and the second polymer layer **41** are respectively provided on both sides of the supporting body **30**. Therefore, the first transparent antenna and the second transparent antenna are located on both sides of the supporting body **30**, and the other structures are similar to the structure shown in FIG. **6**.

The structures of the transparent antennas shown in FIG. **6** and FIG. **7** are both applicable for mobile phones, PADs, household appliances, buildings and vehicles.

Referring to FIG. **8**, another embodiment discloses a transparent antenna. The transparent antenna includes a supporting body **30**, a polymer layer **40** and a covering layer **31**. The polymer layer **40** is provided on a side of the supporting body **30**, a concave structure is provided on the side of the polymer layer **40** away from the supporting body **30**, and the concave structure is provided with a conductive material to form the transparent antenna. The transparent antenna includes an antenna body **11**, and the antenna body **11** includes a grid-like conductive wire. The covering layer **31** is provided on the side of the polymer layer **40** away from the supporting body **30**. Both the covering layer **31** and the supporting body **30** are made of glass, or the material of the covering layer is different from the material of the supporting body, so that the transparent antenna is located between the covering layer and the supporting body. For example, there are many double-layer glass in architectural glass allowing the transparent glass structure to be provided between two layers of glass, and there are many structures with an interlayer in window glass of vehicles.

Referring to FIG. **9**, another structure of a transparent antenna is disclosed. The transparent antenna includes a supporting body **30**, a polymer layer **40**, an optical interlayer **70** and a covering layer **31**. The polymer layer **40** is provided on a side of the supporting body **30**. The side of the polymer layer **40** away from the supporting body **30** is provided with a concave structure, and the concave structure is provided with a conductive material to form a transparent antenna and a dummy electrode. The transparent antenna includes an antenna body **11** and a partition region, and the antenna body **11** includes a grid-like conductive wire. The dummy electrode is provided in the partition region and includes a grid or line segments, and the grid includes grid lines **21**. The absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 20%. For better visual effect, the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 10%, or not greater than 5%. Both the covering layer **31** and the supporting body **30** are made of glass, or the material of the covering layer is different from the material of the supporting body, so that the transparent antenna is located between the covering layer and the supporting body. The structures of the dummy electrode and the transparent antenna here are the same as that described above. The optical interlayer **70** is located between the polymer layer **40** and the covering layer **31**. The optical interlayer **70** may be a vacuum layer. Of course, the optical interlayer **70** may also be made of an optical glue, so that the covering layer **31** can be bonded with the polymer layer **40**, which is well applied to transparent materials with an interlayer or transparent materials with a vacuum interlayer.

Referring to FIG. **10**, a structure of another transparent antenna is disclosed. The transparent antenna includes a supporting body **30**, a first polymer layer **40**, an adhesive layer **80**, a second polymer layer **41** and a covering layer **31**. The first polymer layer **40** is provided on a side of the supporting body **30**, and the side of the first polymer layer **40** away from the supporting body **30** is provided with a concave structure, and the concave structure is provided with a conductive material to form a first transparent antenna. The first transparent antenna includes a first antenna body **11** and a partition region, and the first antenna body **11** includes a grid-like conductive wire. The second polymer layer **41** is provided on a side of the covering layer **31**, the side of the second polymer layer **41** away from the covering layer **31** is provided with a concave structure, and the concave structure is provided with a conductive material to form a second transparent antenna. The second transparent antenna includes a second antenna body **12** and a partition region, and the second antenna body **12** includes a grid-like conductive wire. And the covering layer **31** here plays a role of a supporting body, only names being with different. The projection of the second transparent antenna covers at least 60% of the area of the partition region of the first transparent antenna, of course, or covers 80% of the area of the partition region of the first transparent antenna, or in order to achieve better visual effect, covers more than 95% of the area of the partition region of the first transparent antenna. The partition region described here is a partition region of a single transparent antenna, or a partition region between two transparent antennas. In the present embodiment, the first transparent antenna and the second transparent antenna cooperate with each other to "fill" their respective partition regions, in which the partition regions may be completely "filled" or partially "filled", in order to reduce visual difference caused by difference in transmittance. Of course, in the case where there is an overlapping region between the first transparent antenna and the second transparent antenna, in order to ensure a similar transmittance, the grid linewidth at the overlapping region is less than the grid linewidth at a non-overlapping region, so as to ensure that the transmittance at the overlapping region is similar to the transmittance at the non-overlapping region. For example, the grid linewidth at the overlapping region of the antenna body **11** of the first transparent antenna is 3 microns, while the grid linewidth at the non-overlapping region of the antenna body **11** is 5 microns, so that the absolute value of the difference between the grid linewidth at the overlapping region and the grid linewidth at the non-overlapping region is not less than 0.5 microns. Of course, the same is true for the second transparent antenna. The first transparent antenna and the second transparent antenna are connected with each other through the adhesive layer **80**, for example, the first transparent antenna and the second transparent antenna are bonded to each other "face to face" (as shown in FIG. **10**). Of course, the first transparent antenna is bonded to the side of the covering layer **31** away from the second transparent antenna through the adhesive layer **80** (not shown in the figure), so this structure can also be used in electronic devices, household appliances, buildings and vehicles.

Referring to FIG. **11**, another transparent antenna structure is disclosed, and the transparent antenna structure is similar to the transparent antenna structure in FIG. **8**. The difference is that the transparent antenna structure here includes a transparent antenna and a dummy electrode, and the transparent antenna includes an antenna body **11** and a partition region. The antenna body **11** includes a grid-like conductive wire, and the dummy electrode is provided in the partition region. The dummy electrode includes a grid or line segments, and the grid includes grid lines **21**. Furthermore, the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 20%. Furthermore, for better visual effect, the absolute value of the difference between the transmittance of the antenna body and the transmittance of the dummy electrode is not greater than 10%, or not greater than 5%.

The transparent antenna described above is applied to fields including mobile phones, PADs, household appliances, cards requiring signal reception and transmission, windows or transparent regions of buildings, vehicles, and other electronic devices, such as watches. With the increas-

ing number of 5G base stations, the transparent antenna can also be used as an antenna of the 5G base station. Although the present disclosure discloses a transparent antenna, the transparent antenna does not necessarily need to be used in devices that need to be transparent and may also be used in devices that do not need to be transparent.

Referring to FIG. **12**, another embodiment discloses a cover plate module. The cover plate module includes: a supporting layer **201** including a first surface and a second surface provided opposite to the first surface, in which the supporting layer **201** may be made of PET, glass, PU, TPU, PE, PMMA and other materials that play a supporting role; a transparent antenna including an antenna body **11** and a partition region, in which the first surface of the supporting layer **201** is provided with a grid-like conductive wire to form the antenna body **11**; a dummy electrode, including a grid or line segments, in which the grid includes grid lines **21** and the absolute value of the difference between the transmittance of the antenna body **11** and the transmittance of the dummy electrode is not greater than 20%, for better visual effect, the absolute value of the difference between the transmittance of antenna body **11** and the transmittance of the dummy electrode is not greater than 10%, or not greater than 5%, and the dummy electrode is electrically insulated from the antenna body **11**; and a decorative layer **200**, provided on the second surface of the supporting layer **201**, in which the decorative layer **200** can reflect an effect of gradual light and shadow, or an effect of light and shadow with a normal straight line or a curve, or an effect of light and shadow forming an image. The decorative layer **200** includes: a micro-nano structural layer **202**, provided on the second surface of the supporting layer **201**, in which the side of the micro-nano structural layer **202** away from the supporting layer **201** is provided with a micro-nano structure **203** which may be a linear cylindrical mirror, a curved cylindrical mirror, a line segment structure (in shape of a small short line), a microlens, a concave structure, a CD pattern, a trihedral cone, a tetrahedral cone and other structures, and the material of the micro-nano structural layer **202** may be a colored polymer, such as a colored UV-curable resin, of course or a heat-curable colored glue; a reflective layer **204**, provided on the side of the micro-nano structural layer **202** away from the supporting layer **201**, in which the reflective layer **204** plays a role of reflection or color displaying, and in fact, a reflective layer with a certain transmittance is also provided on the first surface of the supporting layer **201**, that is, between the polymer layer **40** and the supporting layer **201**, and/or, a reflective layer with a certain transmittance is also provided between the micro-nano structural layer **202** and the supporting layer **201**; and a coloring layer **205**, provided on the side of the reflecting layer **204** away from the micro-nano structural layer **202**, in which the coloring layer **205** is mainly used to shield light, and can also play a role of color displaying together with the reflecting layer **204**.

In an embodiment, the decorative layer **200** includes at least two layers of the micro-nano structural layer **202**, which may achieve a richer visual effect, so that the cover plate module can have both decorative effects and functions of signal transmission and reception.

In order to make the above purpose, features and advantages of the present disclosure more obvious and easier to understand, the specific embodiments of the present disclosure are described in detail above with reference to the accompanying drawings. Many specific details are illustrated in the above description to facilitate a full understanding of the present disclosure. However, the present disclosure may be implemented in many other ways different from those described above. Those skilled in the art can make similar improvements without violating the connotation of the disclosure. Therefore, the present disclosure is not limited by the specific embodiments disclosed above. Moreover, the technical features of the above embodiments can be combined arbitrarily. In order to make the description concise, all possible combinations of the technical features in the above embodiments are not described. However, as long as there is no contradiction in the combination of these technical features, they should fall in the scope recorded in this specification.

The above embodiments only disclose several embodiments of the present disclosure, and the description is more specific and detailed, but it cannot be understood as a limit of the scope of the patent of the present disclosure. It should be noted that for those skilled in the art, several modifications and improvements can be made without departing from the concept of the present disclosure, which belong to the protection scope of the disclosure. Therefore, the protection scope of the patent of this disclosure should be subject to the appended claims.

What is claimed is:

1. A transparent antenna, comprising: a first polymer layer; a first transparent antenna, comprising an antenna body and a partition region, wherein a side of the first polymer layer is provided with a grid-like conductive wire to form the antenna body; a second polymer layer, provided on a side of the first polymer layer where the first transparent antenna is provided; a second transparent antenna, provided on a side of the second polymer layer away from the first transparent antenna, wherein the second transparent antenna comprises an antenna body, the antenna body of the second transparent antenna covers at least a part of the partition region of the first transparent antenna, and the side of the second polymer layer away from the first transparent antenna is provided with a grid-like conductive wire to form the antenna body; and an adhesive layer, located between the first polymer layer and the second polymer layer; wherein a grid linewidth at an overlapping region is less than a grid linewidth at a non-overlapping region between the first transparent antenna and the second transparent antenna.

2. The transparent antenna of claim **1**, further comprising a supporting body, wherein the supporting body is provided on another side of the first polymer layer.

3. The transparent antenna of claim **2**, wherein a side of the first polymer layer away from the supporting body is provided with a concave structure, and the concave structure is provided with conductive material to form the first transparent antenna.

4. The transparent antenna of claim **3**, wherein a height of the conductive material is less than a depth of the concave structure; or a height of the conductive material is equal to a depth of the concave structure; or a height of the conductive material is greater than a depth of the concave structure.

5. The transparent antenna of claim **2**, wherein a side of the second polymer layer away from the supporting body is provided with a concave structure, and the concave structure is provided with conductive material to form the second transparent antenna.

6. The transparent antenna of claim **5**, wherein a height of the conductive material is less than a depth of the concave structure; or a height of the conductive material is equal to a depth of the concave structure; or a height of the conductive material is greater than a depth of the concave structure.

7. The transparent antenna of claim **3**, wherein the concave structure comprises a bottom surface, two side surfaces

and an opening, and a black material is provided close to the bottom surface and/or the opening.

8. The transparent antenna of claim **7**, wherein an included angle between each of the two side surfaces and the bottom surface is not equal to 90 degrees.

9. The transparent antenna of claim **5**, wherein the concave structure comprises a bottom surface, two side surfaces and an opening, and a black material is provided close to the bottom surface and/or the opening.

10. The transparent antenna of claim **9**, wherein an included angle between each of the two side surfaces and the bottom surface is not equal to 90 degrees.

11. The transparent antenna of claim **1**, wherein a projection of the second transparent antenna covers at least 60% of an area of the partition region of the first transparent antenna.

12. A device, comprising the transparent antenna according to claim **1**.

13. The device of claim **12**, wherein the device is one of mobile phones, PADs, vehicles, buildings, household appliances, signal base stations and cards requiring signal reception and transmission.

14. A transparent antenna, comprising: a supporting body, comprising a first surface and a second surface provided opposite to the first surface; a first polymer layer, provided on the first surface of the supporting body; a first transparent antenna, comprising an antenna body and a partition region, wherein a side of the first polymer layer away from the supporting body is provided with a concave structure, and the concave structure is provided with conductive material to form the first transparent antenna; a second polymer layer, provided on the second surface of the supporting body; a second transparent antenna, comprising an antenna body, wherein the antenna body of the second transparent antenna covers at least a part of the partition region of the first transparent antenna, a side of the second polymer layer away from the supporting body is provided with a concave structure, and the concave structure is provided with conductive material to form the second transparent antenna; and an adhesive layer, located between the first polymer layer and the second polymer layer; wherein a grid linewidth at an overlapping region is less than a grid linewidth at a non-overlapping region between the first transparent antenna and the second transparent antenna.

15. The transparent antenna of claim **14**, wherein a projection of the second transparent antenna covers at least 60% of an area of the partition region of the first transparent antenna.

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(12) **United States Patent**
Su et al.

(10) **Patent No.: US 12,255,392 B2**
(45) **Date of Patent: Mar. 18, 2025**

(54) **WIDEBAND ANTENNA SYSTEM**

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(72) Inventors: **Chun-Chieh Su**, Taipei (TW); **Wei-Cheng Lo**, Taipei (TW); **Chien-Ming Hsu**, Taipei (TW); **Che-Yen Lin**, Taipei (TW); **Chuan-Chien Huang**, Taipei (TW)

(73) Assignee: **ASUSTEK COMPUTER INC.**, Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 207 days.

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H01Q 1/48 (2006.01)
(Continued)

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CPC ***H01Q 1/50*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 5/328*** (2015.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 5/328; H01Q 5/335; H01Q 5/50; H01Q 9/42
See application file for complete search history.

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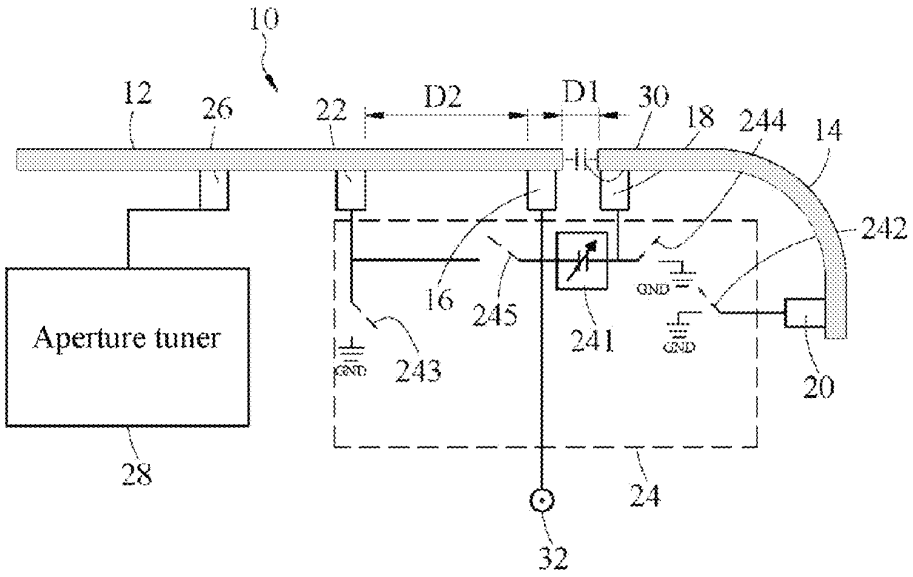
Primary Examiner — Daniel Munoz
(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(57) **ABSTRACT**

A wideband antenna system includes a first metal radiation portion, having a coupling distance with a second metal radiation portion; a first feeding contact and a second feeding contact, electrically connected to the first metal radiation portion and the second metal radiation portion respectively, and close to the coupling distance; a first ground contact, electrically connected to the second metal radiation portion; a second ground contact, electrically connected to the first metal radiation portion; an impedance tuner, electrically connected to the first feeding contact, the second feeding contact, the first ground contact, the second ground contact, and a radio frequency signal source, to switch the first metal radiation portion and the second metal radiation portion; an aperture contact, electrically connected to the first metal radiation portion; and an aperture tuner, electrically connected to the aperture contact.

11 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

H01Q 1/50	(2006.01)
H01Q 5/328	(2015.01)
H01Q 5/335	(2015.01)
H01Q 5/50	(2015.01)
H01Q 9/42	(2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 5/335*** (2015.01); ***H01Q 5/50*** (2015.01); ***H01Q 9/42*** (2013.01)

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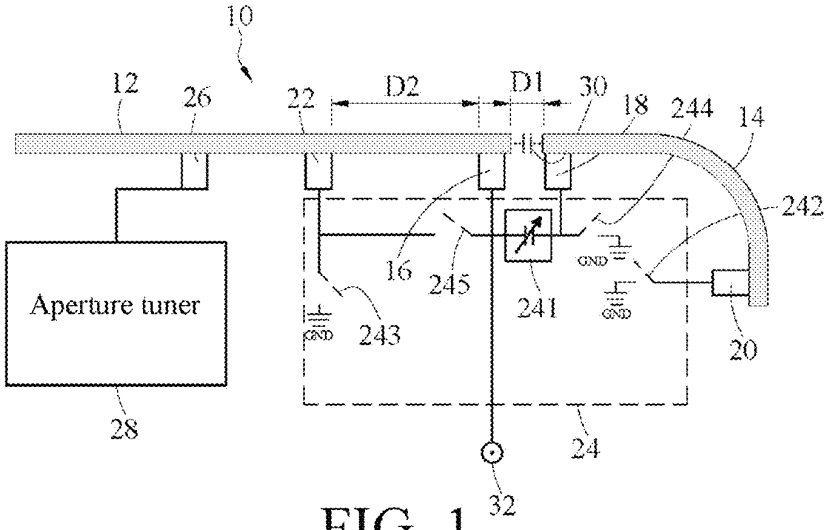

10
12
26
22
D2
D1
30
18
244
14
242
16
245
241
243
20
24
32
28
Aperture tuner
GND

FIG. 1

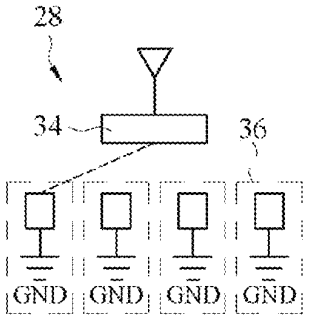


FIG. 2A

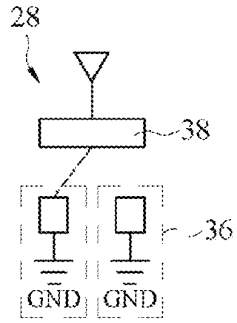


FIG. 2B

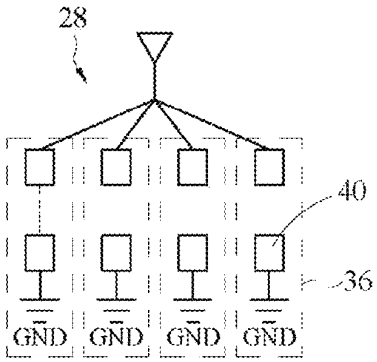


FIG. 2C

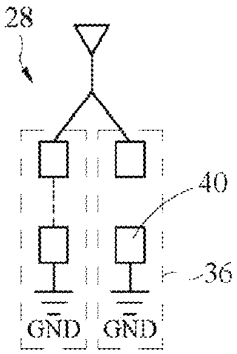


FIG. 2D

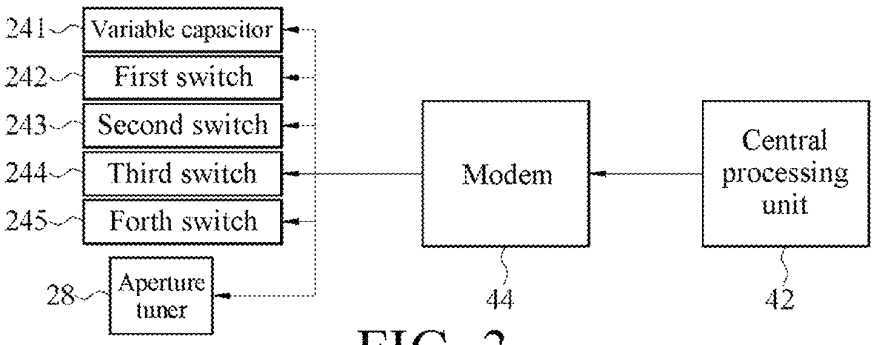
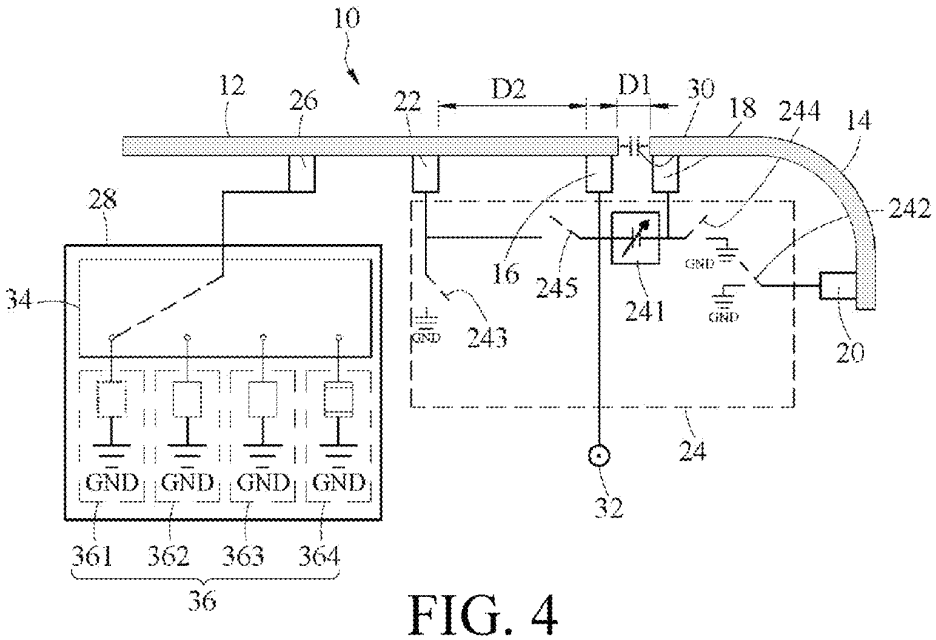

241
Variable capacitor
242
First switch
243
Second switch
244
Third switch
245
Forth switch
28
Aperture tuner
Modem
44
Central processing unit
42

FIG. 3


10
12
26
22
D2
D1
30
18
244
14
242
28
34
16
245
241
GND
GND
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20
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32
GND
GND
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GND
361
362
363
364
36

FIG. 4

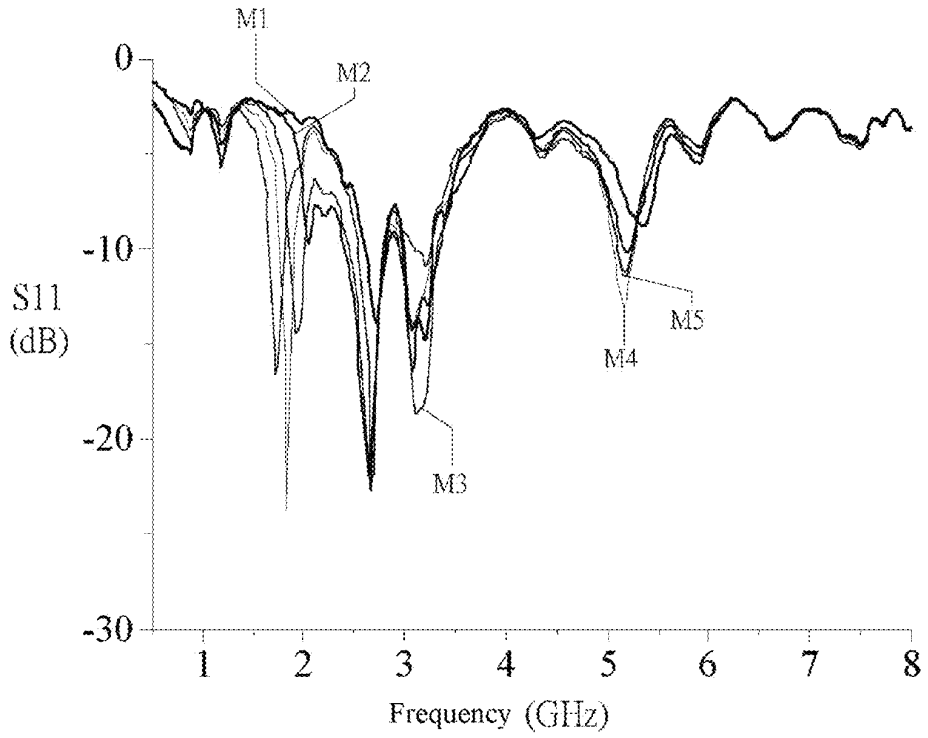

FIG. 5

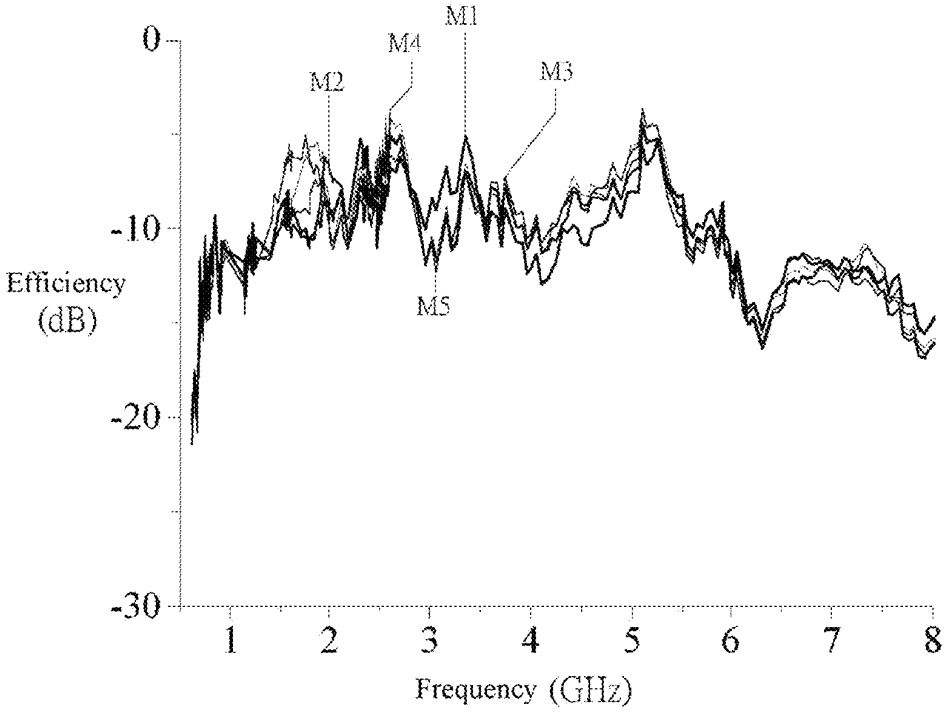

FIG. 6

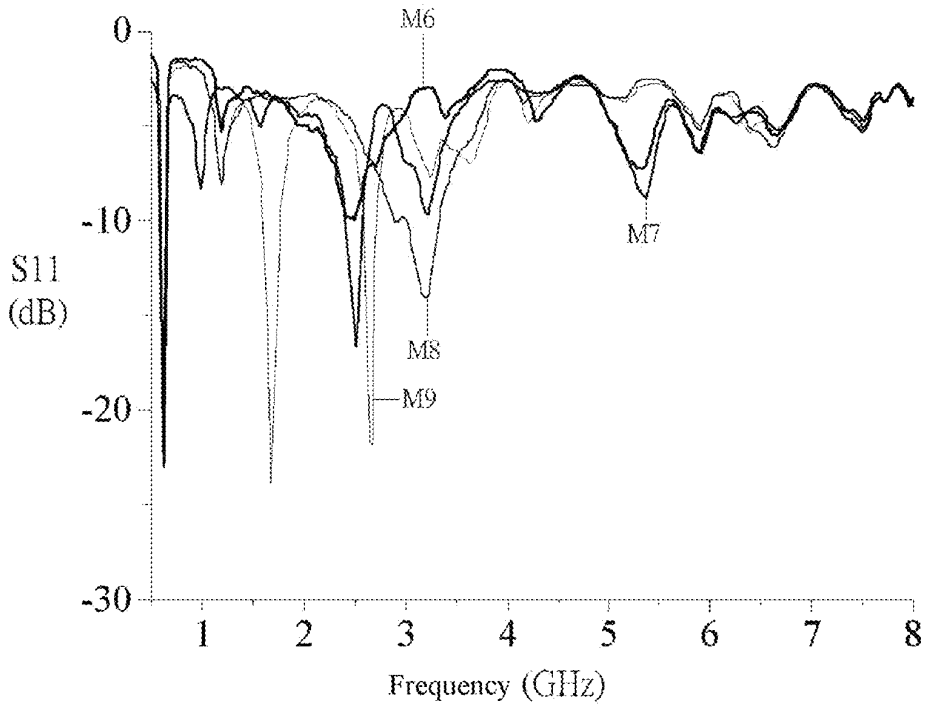

FIG. 7

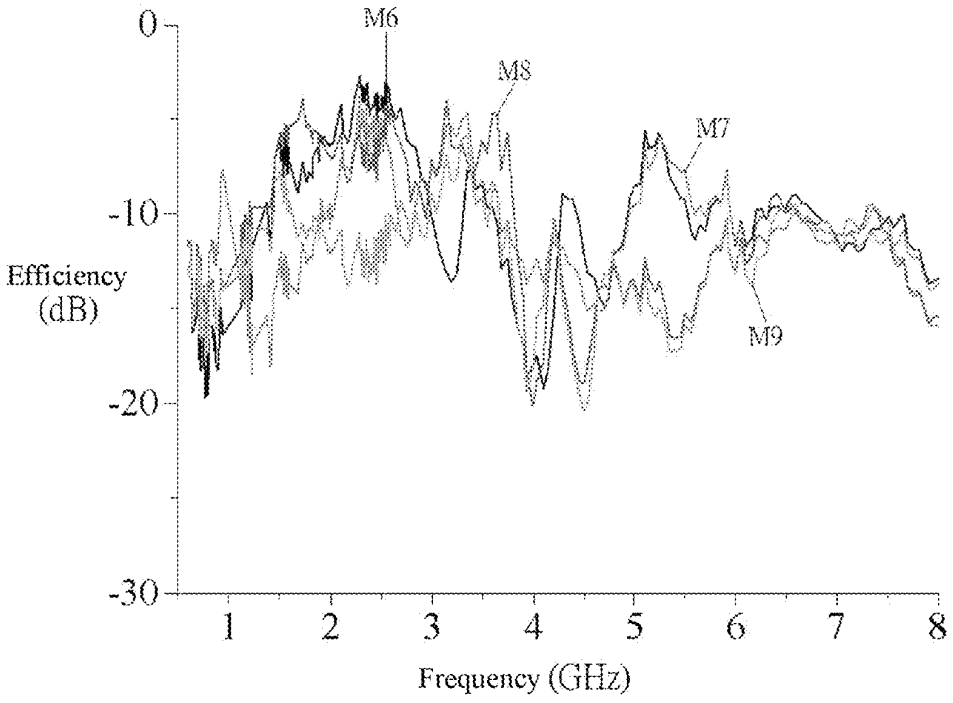

FIG. 8

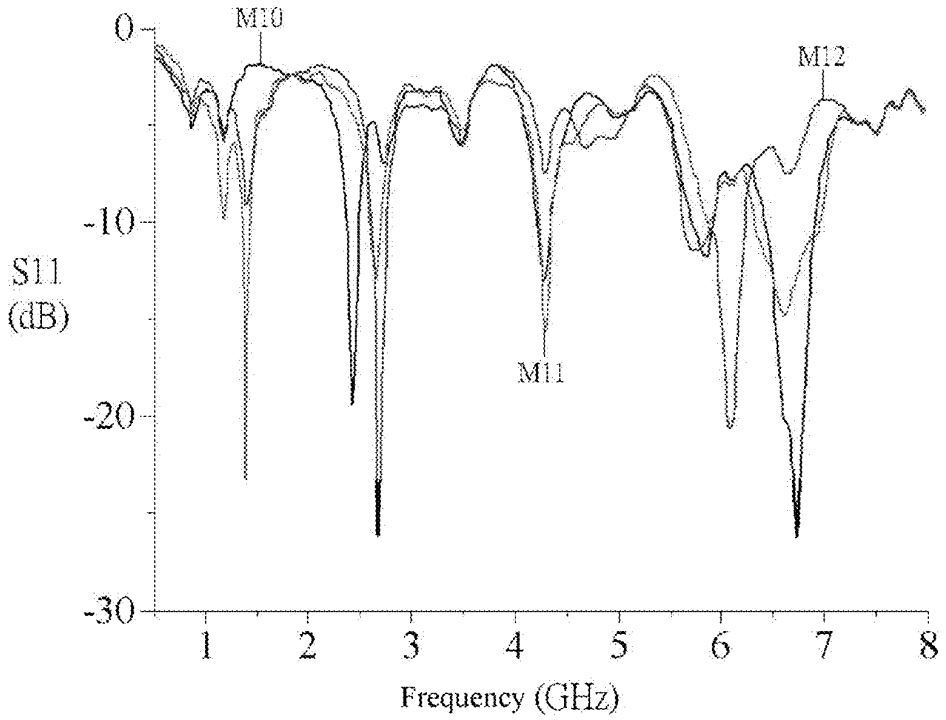

FIG. 9

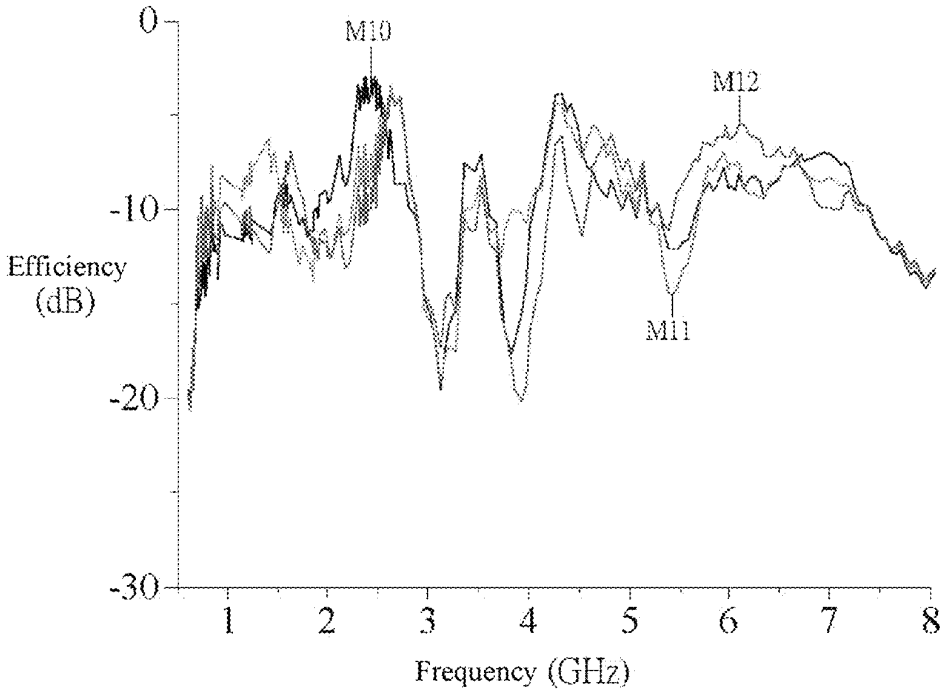

FIG. 10

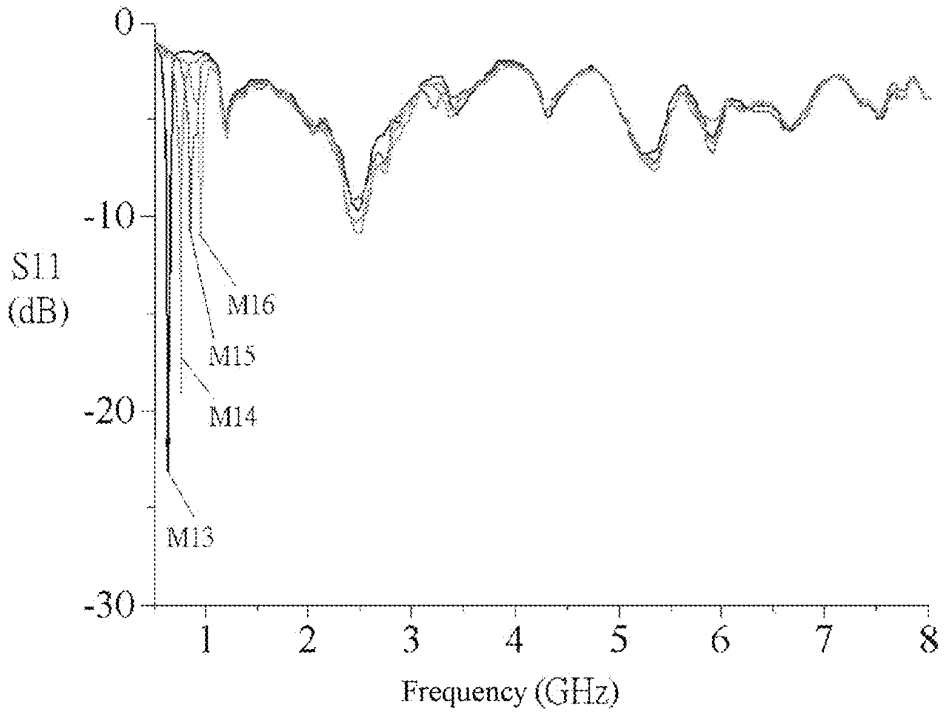

FIG. 11

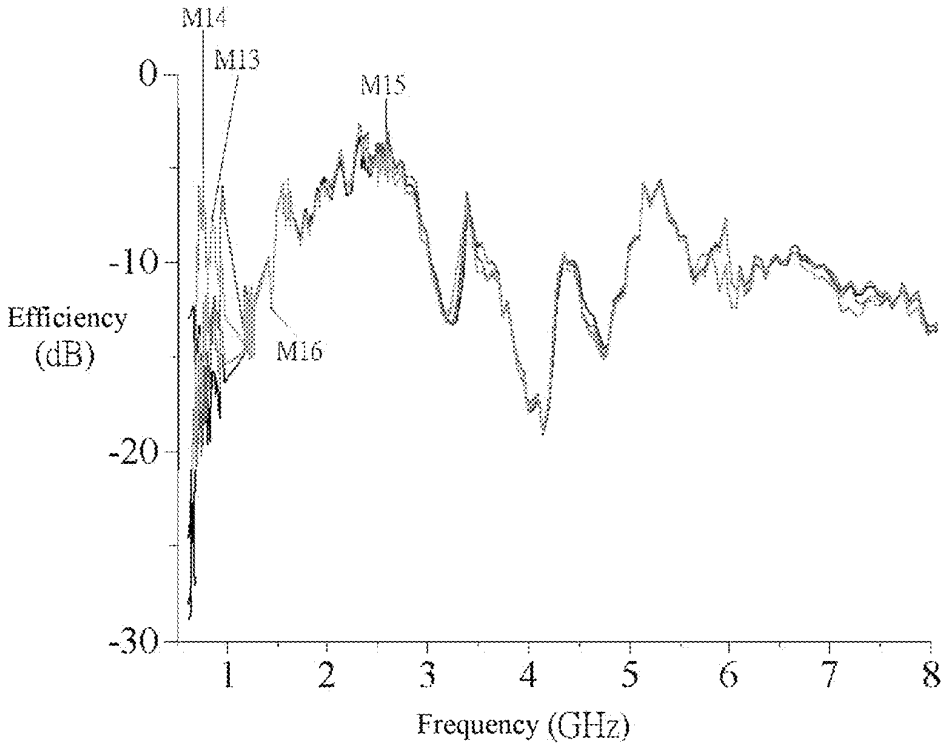
M14
M13
M15
M16
0
-10
-20
-30
Efficiency
(dB)
1
2
3
4
5
6
7
8
Frequency (GHz)

FIG. 12

WIDEBAND ANTENNA SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application program claims the priority benefit of Taiwan application serial NO. 111131574, filed on Aug. 22, 2022. The entirety of the above-mentioned patent applications is hereby incorporated by reference herein and made a part of the specification.

BACKGROUND OF THE DISCLOSURE

Field of the Invention

The disclosure relates to a wideband antenna system that effectively uses a coupled radiator.

Description of the Related Art

In the existing consumer electronic products, the frequency band of an antenna design has evolved from the previous 2G/3G/4G to 5G, and the frequency band of 6G has also been developed from supporting 2.4G/5G in WIFI communication. The above operating frequencies are roughly divided into a low frequency band (617 MHz-960 MHz), an intermediate frequency band (1475 MHz-2170 MHz), a high frequency band (2300 MHz-2700 MHz), an ultrahigh frequency band (3300 MHz-5000 MHz), a WIFI 5G frequency band (5150 MHz-5850 MHz), and a WIFI 6E frequency band (5925 MHz-7125 MHz). In the previous antenna design, it is relatively difficult to cover all the above frequency bands to one antenna, and therefore the antenna is usually split to support different frequency bands. However, with the support of communication technologies such as a multi-input multi-output (MIMO) technology, a carrier aggregation (CA) technology, and an E-UTRA-NR dual connectivity (EN-DC) technology, the quantity of antennas is greatly increased, which is difficult to achieve in a limited space. Therefore, it is often necessary to sacrifice the performance of some antennas to meet the requirements, especially for handheld electronic products that have the relatively smallest space but need to support the most functions among electronic products. Therefore, a wideband antenna design is required.

In order to achieve the wideband antenna design, an antenna impedance tuner or an antenna aperture tuner are usually introduced, so that a plurality of frequency bands is covered on the same antenna. However, most of the existing antenna designs only provide support at a fixed frequency, and even if there is a way to support the wideband, the radiation efficiency of some frequency bands is sacrificed, and not all frequency bands are taken into consideration.

BRIEF SUMMARY OF THE INVENTION

According to an aspect of this disclosure, a wideband antenna system is provided. The wideband antenna system includes a first metal radiation portion, a second metal radiation portion, a first feeding contact, a second feeding contact, a first ground contact, a second ground contact, an impedance tuner, an aperture contact, and an aperture tuner. The second metal radiation portion has a coupling distance with the first metal radiation portion, so that there is a coupling capacitor between the first metal radiation portion and the second metal radiation portion. The first feeding contact is electrically connected to the first metal radiation portion and close to the coupling distance, and the first feeding contact is electrically connected to a radio frequency signal source. The second feeding contact is electrically connected to the second metal radiation portion and close to the coupling distance. The first ground contact is electrically connected to the second metal radiation portion, and the second ground contact is electrically connected to the first metal radiation portion. The impedance tuner is electrically connected to the first feeding contact, the second feeding contact, the first ground contact, the second ground contact, and the radio frequency signal source, to switch the first metal radiation portion and the second metal radiation portion. The aperture contact is electrically connected to the first metal radiation portion, so that the second ground contact is located between the first feeding contact and the aperture contact, and the aperture tuner is electrically connected to the aperture contact.

In summary, the disclosure is a wideband antenna system, which effectively uses an adjacent metal radiation portion as a wideband design, to make different use of the metal radiation portion according to requirements of different frequency bands, so that a good antenna radiation efficiency is provided in the supported frequency bands. Therefore, the wideband antenna system of the disclosure obtains a wideband effect by circuit switching, which effectively supports a bandwidth of 617-7125 MHz and provides good radiation efficiency, thereby reducing the quantity of antennas in electronic products.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic architectural diagram of a wideband antenna system according to an embodiment of the disclosure.

FIG. **2**A to FIG. **2**D are schematic circuit diagrams of an aperture tuner according to an embodiment of the disclosure.

FIG. **3** is a schematic block diagram of action controlled by a central processing unit according to an embodiment of the disclosure.

FIG. **4** is a schematic circuit diagram of a wideband antenna system in an operating state according to an embodiment of the disclosure.

FIG. **5** is a schematic simulation diagram of an S-parameter of a wideband antenna system from a first operating state to a fifth operating state according to an embodiment of the disclosure.

FIG. **6** is a schematic simulation diagram of radiation efficiency of a wideband antenna system from a first operating state to a fifth operating state according to an embodiment of the disclosure.

FIG. **7** is a schematic simulation diagram of an S-parameter of a wideband antenna system from a sixth operating state to a ninth operating state according to an embodiment of the disclosure.

FIG. **8** is a schematic simulation diagram of radiation efficiency of a wideband antenna system from a sixth operating state to a ninth operating state according to an embodiment of the disclosure.

FIG. **9** is a schematic simulation diagram of an S-parameter of a wideband antenna system from a tenth operating state to a twelfth operating state according to an embodiment of the disclosure.

FIG. **10** is a schematic simulation diagram of radiation efficiency of a wideband antenna system from a tenth operating state to a twelfth operating state according to an embodiment of the disclosure.

FIG. **11** is a schematic simulation diagram of an S-parameter of a wideband antenna system from a thirteenth operating state to a sixteenth operating state according to an embodiment of the disclosure.

FIG. **12** is a schematic simulation diagram of radiation efficiency of a wideband antenna system from a thirteenth operating state to a sixteenth operating state according to an embodiment of the disclosure.

DESCRIPTION OF EMBODIMENTS

Embodiments of the disclosure are described with reference to relevant drawings. In addition, some components or structures are omitted from the drawings in the embodiments, to clearly show the technical features of the disclosure. The same reference numbers in the drawings represent the same or similar components or circuits. It should be understood that although terms such as "first" and "second" in this specification are used for describing various elements, components, regions, or functions, the elements, components, regions, or functions are not limited by the terms. The terms are only used to distinguish one element, component, region, or function from another element, component, region, or function.

Referring to FIG. **1**, a wideband antenna system **10** includes a first metal radiation portion **12**, a second metal radiation portion **14**, a first feeding contact **16**, a second feeding contact **18**, a first ground contact **20**, a second ground contact **22**, an impedance tuner **24**, an aperture contact **26**, and an aperture tuner **28**. In the wideband antenna system **10**, the first metal radiation portion **12** is located on one side of the second metal radiation portion **14**, and there is a coupling distance D**1** between the first metal radiation portion **12** and the second metal radiation portion **14**, so that there is a coupling capacitor **30** between the first metal radiation portion **12** and the second metal radiation portion **14**, to use the first metal radiation portion **12** as a main radiator and use the second metal radiation portion **14** as a coupled radiator. The first feeding contact **16** is electrically connected to one end of the first metal radiation portion **12** and close to the coupling distance D**1**. The first feeding contact **16** is electrically connected to a radio frequency signal source **32**. The second feeding contact **18** is electrically connected to one end of the second metal radiation portion **14** and close to the coupling distance D**1**. The first ground contact **20** is electrically connected to an other end of the second metal radiation portion **14**, and the second ground contact **22** is electrically connected to the first metal radiation portion **12**. The impedance tuner **24** is electrically connected to the first feeding contact **16**, the second feeding contact **18**, the first ground contact **20**, the second ground contact **22**, and the radio frequency signal source **32**, to switch the first metal radiation portion **12** and the second metal radiation portion **14** using a circuit inside the impedance tuner **24**, to achieve a wideband effect. The aperture contact **26** is also electrically connected to the first metal radiation portion **12**, so that the second ground contact **22** is located between the first feeding contact **16** and the aperture contact **26**. The aperture tuner **28** is electrically connected to the aperture contact **26** to switch a ground path.

As shown in FIG. **1**, the impedance tuner **24** used in the wideband antenna system **10** further includes a variable capacitor **241**, a first switch **242**, a second switch **243**, a third switch **244**, and a fourth switch **245**. In the impedance tuner **24**, the variable capacitor **241** is electrically connected to the first feeding contact **16** and the second feeding contact **18**, to connect the coupling capacitor **30** between the first metal radiation portion **12** and the second metal radiation portion **14** in parallel using the variable capacitor **241**. The first switch **242** is electrically connected between the first ground contact **20** and a ground terminal GND to selectively connect the first ground contact **20** to the ground terminal GND. The second switch **243** is electrically connected between the second ground contact **22** and the ground terminal GND to selectively connect the second ground contact **22** to the ground terminal GND. The third switch **244** is electrically connected between the second feeding contact **18** and the ground terminal GND to selectively connect the second feeding contact **18** to the ground terminal GND. The fourth switch **245** is electrically connected between the second ground contact **22** and the radio frequency signal source **32** to selectively connect the second ground contact **22** to the radio frequency signal source **32**. When the fourth switch **245** is turned on and the second ground contact **22** is connected to the radio frequency signal source **32**, the second ground contact **22** is used as a feeding contact, so that the wideband antenna system **10** achieves a form of double-feeding using functions of the first feeding contact **16** and the second ground contact **22**.

In an embodiment, a distance D**2** between the first feeding contact **16** and the second ground contact **22** is a distance of 0.05 to 0.025 times a wavelength of a lowest operating frequency.

In an embodiment, referring to FIG. **1**, the first metal radiation portion **12** and the second metal radiation portion **14** are a metal frame of an electronic device, or a metal plane attached to an electronic device. In an embodiment, the first metal radiation portion **12** and the second metal radiation portion **14** are metal portions or metal strips inside a metal case of the electronic device or a plastic case of the electronic device. The first metal radiation portion **12** and the second metal radiation portion **14** are vary as an application of the wideband antenna system **10**. As shown in FIG. **1**, the second metal radiation portion **14** is bent in cooperation with a frame bending portion of the electronic device. In another embodiment, the second metal radiation portion **14** is also designed as a straight segment.

In an embodiment, the electronic device is a mobile phone, a personal digital assistant, a tablet computer, or a notebook computer, and any portable electronic device with a mobile communication function is covered in the disclosure.

In an embodiment, the aperture tuner **28** further includes a switch module and a plurality of ground paths, to be switched by the switch module to select one of the ground paths, and the ground path includes at least one of an open circuit ground path and at least one passive component ground path, and a zero-ohm resistor ground path. Referring to FIG. **2**A, the switch module in the aperture tuner **28** is a single pole four throw (SP4T) switch **34**, and the SP4T switch **34** is connected to four ground paths **36**. Each ground path **36** includes a passive component, an open circuit, or a zero-ohm resistor connected to the ground terminal, to form a passive component ground path, an open circuit ground path, or a zero-ohm resistor ground path respectively. In this embodiment, the four ground paths **36** include one open circuit ground path, two passive component ground paths, and one zero-ohm resistor ground path. Referring to FIG. **2**B, the switch module in the aperture tuner **28** is at least one single pole double throw (SPDT) switch **38**, and the SPDT switch **38** is connected to two ground paths **36**. Each ground path **36** includes a passive component, an open circuit, or a zero-ohm resistor connected to the ground terminal GND, to form a passive component ground path, an open circuit

ground path, or a zero-ohm resistor ground path respectively. In this embodiment, the two ground paths include one open circuit ground path or one passive component ground path, and one zero-ohm resistor ground path.

In an embodiment, the aperture tuner **28** further uses a plurality of single pole single throw (SPST) switches **40** to switch the ground path **36**. Referring to FIG. **2**C, the switch module in the aperture tuner **28** is four single pole single throw (SPST) switches **40**, and each SPST switch **40** is connected to one ground path **36**. Each ground path **36** includes a passive component, an open circuit, or a zero-ohm resistor connected to the ground terminal GND through the SPST switch **40**, to form a passive component ground path, an open circuit ground path, or a zero-ohm resistor ground path respectively. In this embodiment, the four ground paths include one open circuit ground path, two passive component ground paths, and one zero-ohm resistor ground path. Referring to FIG. **2**D, the switch module in the aperture tuner **28** is two single pole single throw (SPST) switches **40**, and each SPST switch **40** is connected to one ground path **36**. Each ground path **36** includes a passive component, an open circuit, or a zero-ohm resistor connected to the ground terminal GND through the SPST switch **40**, to form a passive component ground path, an open circuit ground path, or a zero-ohm resistor ground path respectively. In this embodiment, the two ground paths **36** include one open circuit ground path or one passive component ground path, and one zero-ohm resistor ground path.

In an embodiment, the passive component ground path is a capacitor ground path, an inductor ground path, or a resistor ground path.

In an embodiment, referring to FIG. **1** and FIG. **3** together, the variable capacitor **241**, the first switch **242**, the second switch **243**, the third switch **244**, and the fourth switch **245** in the aperture tuner **28** and the impedance tuner **24** are controlled by a central processing unit (CPU) **42**. The CPU **42** generates a corresponding mobile industry processor interface (MIPI) control signal according to a requirement of an antenna frequency band. The MIPI control signal is transmitted to the aperture tuner **28**, the first switch **242**, the second switch **243**, the third switch **244**, and the fourth switch **245** through a modem **44** to control on and off of all the switches, and the MIPI control signal is also transmitted to the variable capacitor **241** through the modem **44** to control a capacitance value of the variable capacitor **241**.

The following further describes details of the wideband antenna system **10**. Referring to FIG. **1** and FIG. **4** together, in this embodiment, the aperture tuner **28** in the wideband antenna system **10** uses a single pole four throw (SP4T) switch **34**, and the SP4T switch **34** is connected to four ground paths **36**: one open circuit ground path **361**, two passive component ground paths **362** and **363**, and one zero-ohm resistor ground path **364**.

Referring to FIG. **4**, FIG. **5**, and FIG. **6** together, the wideband antenna system **10** of the disclosure overlaps the first metal radiation portion **12** and the second metal radiation portion **14** using the variable capacitor **241** in the impedance tuner **24**, so that the variable capacitor **241** is equivalently connected in parallel to the coupling capacitor **30** to adjust coupling performance between the first metal radiation portion **12** and the second metal radiation portion **14**. In an embodiment, the capacitance value of the variable capacitor **241** is 0.75 pF to 8.996 pF. In a first operating state M**1**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242**, the second switch **243**, the third switch **244**, and the fourth switch **245** are in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In a second operating state M**2**, the capacitance value of the variable capacitor **241** is 3 pF, the first switch **242**, the second switch **243**, the third switch **244**, and the fourth switch **245** are in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In a third operating state M**3**, the capacitance value of the variable capacitor **241** is 5.1 pF, the first switch **242**, the second switch **243**, the third switch **244**, and the fourth switch **245** are in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In a fourth operating state M**4**, the capacitance value of the variable capacitor **241** is 9.1 pF, the first switch **242**, the second switch **243**, the third switch **244**, and the fourth switch **245** are in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In a fifth operating state M**5**, the capacitance value of the variable capacitor **241** is an infinite pF (a short circuit), the first switch **242**, the second switch **243**, the third switch **244**, and the fourth switch **245** are in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. Simulation results are shown in FIG. **5** and FIG. **6**. From the first operation state M**1** to the fifth operation state M**5**, it is to be learned that a frequency band and an efficiency of an intermediate frequency band are controllable. Therefore, the wideband antenna system **10** supports the intermediate frequency band and the capacitance value of the variable capacitor **241** in the disclosure is adjusted to control the intermediate frequency band of the wideband antenna system **10**.

Referring to FIG. **4**, FIG. **7**, and FIG. **8** together, the wideband antenna system **10** switches the first metal radiation portion (main radiator) **12** and the second metal radiation portion (coupled radiator) **14** using the first switch **242**, the second switch **243**, the third switch **244**, and the fourth switch **245** inside the impedance tuner **24**. In a sixth operating state M**6**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the off state, the second switch **243** is in the on state, the third switch **244** is in the off state, the fourth switch **245** is in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In a seventh operating state M**7**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the on state, the second switch **243** is in the on state, the third switch **244** is in the off state, the fourth switch **245** is in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In an eighth operating state M**8**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the on state, the second switch **243** is in the on state, the third switch **244** is in the on state, the fourth switch **245** is in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In a ninth operating state M**9**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the off state, the second switch **243** is in the on state, the third switch **244** is in the on state, the fourth switch **245** is in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. Simulation results are shown in FIG. **7** and FIG. **8**. From the sixth operating state M**6** to the ninth operating state M**9**, the efficiency of a high frequency band, an ultrahigh frequency band, and a WIFI 6E frequency band is improved. Therefore, the wideband antenna system **10** effectively supports the high frequency band, the ultrahigh frequency band, and the WIFI 6E frequency band.

Referring to FIG. **4**, FIG. **9** and FIG. **10** together, the wideband antenna system **10** of the disclosure overlaps the second ground contact **22** and the first feeding contact **16** using the function of the fourth switch **245** in the impedance tuner **24**, so that both the second ground contact **22** and the

first feeding contact **16** are connected to the radio frequency signal source **32** to achieve a double-feeding antenna design. In a tenth operating state M**10**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the off state, the second switch **243** is in the off state, the third switch **244** is in the off state, the fourth switch **245** is in the on state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In an eleventh operating state M**11**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the on state, the second switch **243** is in the off state, the third switch **244** is in the off state, the fourth switch **245** is in the on state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In a twelfth operating state M**12**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the off state, the second switch **243** is in the off state, the third switch **244** is in the on state, the fourth switch **245** is in the on state, and the aperture tuner **28** is switched to the open circuit ground path **361**. Simulation results are shown in FIG. **9** and FIG. **10**. From the tenth operating state M**10** to the twelfth operating state M**12**, the second ground contact **22** is used as a feeding contact and cooperates with the first feeding contact **16**, and the efficiency of the intermediate frequency band, the WIFI 5G frequency band, and the WIFI 6E frequency band is improved. Therefore, the wideband antenna system **10** effectively supports the intermediate frequency band, the WIFI 5G frequency band, and the WIFI 6E frequency band.

Referring to FIG. **4**, FIG. **11** and FIG. **12** together, the wideband antenna system **10** switches a low frequency using the aperture tuner **28**. In a thirteenth operating state M**13**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the off state, the second switch **243** is in the on state, the third switch **244** is in the off state, the fourth switch **245** is in the off state, and the aperture tuner **28** is switched to the open circuit ground path **361**. In a fourteenth operating state M**14**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the off state, the second switch **243** is in the on state, the third switch **244** is in the off state, the fourth switch **245** is in the off state, and the aperture tuner **28** is switched to the passive component ground path **362**, which uses a 22 nH inductor component. In a fifteenth operating state M**15**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the off state, the second switch **243** is in the on state, the third switch **244** is in the off state, the fourth switch **245** is in the off state, and the aperture tuner **28** is switched to the passive component ground path **362**, which uses a 7.5 nH inductor component. In a sixteenth operating state M**16**, the capacitance value of the variable capacitor **241** is 0.8 pF, the first switch **242** is in the off state, the second switch **243** is in the on state, the third switch **244** is in the off state, the fourth switch **245** is in the off state, and the aperture tuner **28** is switched to the passive component ground path **362**, which uses a 3.9 nH inductor component. Simulation results are shown in FIG. **11** and FIG. **12**. From the thirteenth operating state M**13** to the sixteenth operating state M**16**, a radiation efficiency of the low frequency band is above a certain level and has a good performance. Therefore, the wideband antenna system **10** effectively supports the low frequency band and controls the low frequency band by adjusting the aperture tuner **28**.

As shown in FIG. **1**, in the disclosure, the impedance tuner **24** is connected in parallel to a breakpoint (coupling distance D**1**) between the first metal radiation portion **12** and the second metal radiation portion **14**, to improve a bandwidth efficiency and an antenna efficiency using the first metal radiation portion **12** and the second metal radiation portion **14**, and obtain a wideband effect in cooperation with the switching of the impedance tuner **24**. The wideband antenna system **10** of the disclosure effectively supports all frequency bands such as the low frequency band, the intermediate frequency band, the high frequency band, the ultra-high frequency band, the WIFI 5G frequency band, and the WIFI 6E frequency band in cooperation with the function of the aperture tuner **28**.

In summary, the disclosure is a wideband antenna system, which effectively uses an adjacent metal radiation portion as a wideband design, to make different use of the metal radiation portion according to requirements of different frequency bands, so that a good antenna radiation efficiency is provided in the supported frequency bands. Therefore, the wideband antenna system of the disclosure obtains a wideband effect by circuit switching, which effectively supports a bandwidth of 617-7125 Mhz and provides good radiation efficiency, thereby reducing the quantity of antennas in electronic products.

The foregoing embodiments are merely for describing the technical ideas and the characteristics of the disclosure, and are intended to enable those skilled in the art to understand and hereby implement the content of the disclosure. However, the scope of claims of the disclosure is not limited thereto. In other words, equivalent changes or modifications made according to the spirit disclosed in the disclosure shall still fall into scope of the claims of the disclosure.

What is claimed is:

1. A wideband antenna system, comprising:

a first metal radiation portion;

a second metal radiation portion, wherein the second metal radiation portion has a coupling distance with the first metal radiation portion, so that there is a coupling capacitor between the first metal radiation portion and the second metal radiation portion;

a first feeding contact, electrically connected to the first metal radiation portion and close to the coupling distance, wherein the first feeding contact is electrically connected to a radio frequency signal source;

a second feeding contact, electrically connected to the second metal radiation portion and close to the coupling distance;

a first ground contact, electrically connected to the second metal radiation portion;

a second ground contact, electrically connected to the first metal radiation portion;

an impedance tuner, electrically connected to the first feeding contact, the second feeding contact, the first ground contact, the second ground contact, and the radio frequency signal source, to switch the first metal radiation portion and the second metal radiation portion;

an aperture contact, electrically connected to the first metal radiation portion, so that the second ground contact is located between the first feeding contact and the aperture contact; and

an aperture tuner, electrically connected to the aperture contact.

2. The wideband antenna system according to claim **1**, wherein the impedance tuner further comprises:

a variable capacitor, electrically connected to the first feeding contact and the second feeding contact;

a first switch, electrically connected between the first ground contact and a ground terminal to selectively connect the first ground contact to the ground terminal;

a second switch, electrically connected between the second ground contact and the ground terminal to selectively connect the second ground contact to the ground terminal;

a third switch, electrically connected between the second feeding contact and the ground terminal to selectively connect the second feeding contact to the ground terminal; and

a fourth switch, electrically connected to the second ground contact and the radio frequency signal source to selectively connect the second ground contact to the radio frequency signal source, so that the second ground contact is used as a feeding contact.

3. The wideband antenna system according to claim **2**, wherein the aperture tuner further comprises a plurality of ground paths to select one of the ground paths, wherein the ground path comprises at least one of an open circuit ground path and at least one passive component ground path, and a zero-ohm resistor ground path.

4. The wideband antenna system according to claim **3**, wherein the first switch, the second switch, the third switch, and the fourth switch are in an off state; and when the aperture tuner is switched to the open circuit ground path, a capacitance value of the variable capacitor is adjusted to control an intermediate frequency band of the wideband antenna system.

5. The wideband antenna system according to claim **3**, wherein the first switch and the third switch are in an on state or off state, the second switch is in the on state, and the fourth switch is in the off state; and when the aperture tuner is switched to the open circuit ground path, the wideband antenna system supports a high frequency band, an ultrahigh frequency band, and a WIFI 6E frequency band.

6. The wideband antenna system according to claim **3**, wherein the first switch and the third switch are in an on state or off state, the second switch is in the off state, and the fourth switch is in the on state, so that the second ground contact is used as the feeding contact, and when the aperture tuner is switched to the open circuit ground path, the wideband antenna system supports an intermediate frequency band, a WIFI 5G frequency band, and a WIFI 6E frequency band.

7. The wideband antenna system according to claim **3**, wherein the first switch, the third switch, and the fourth switch are in an off state, and the second switch is in an on state; and when the aperture tuner is switched to the open circuit ground path or the passive component ground path, the wideband antenna system supports a low frequency band, and the aperture tuner is adjusted to control the low frequency band.

8. The wideband antenna system according to claim **3**, wherein the passive component ground path is a capacitor ground path, an inductor ground path, or a resistor ground path.

9. The wideband antenna system according to claim **3**, wherein the aperture tuner further comprises a switch module, configured to selectively electrically connect to one of the ground paths.

10. The wideband antenna system according to claim **9**, wherein the switch module is a single pole four throw (SP4T) switch, at least one single pole double throw (SPDT) switch, or a plurality of single pole single throw (SPST) switches.

11. The wideband antenna system according to claim **1**, wherein a distance between the first feeding contact and the second ground contact is a distance of 0.05 to 0.025 times a wavelength of a lowest operating frequency.

* * * * *

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(12) **United States Patent**
Sezai

(10) **Patent No.: US 12,255,397 B2**
(45) **Date of Patent: Mar. 18, 2025**

(54) **ANTENNA, ELECTRONIC APPARATUS, AND METHOD OF MANUFACTURING AN ANTENNA**

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(72) Inventor: **Toshihiro Sezai**, Tokyo (JP)

(73) Assignee: **Japan Aerospace Exploration Agency**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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§ 371 (c)(1),
(2) Date: **Sep. 28, 2022**

(87) PCT Pub. No.: **WO2022/249644**
PCT Pub. Date: **Dec. 1, 2022**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

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H01Q 15/16 (2006.01)
H01Q 1/28 (2006.01)
H01Q 15/14 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 15/16*** (2013.01); ***H01Q 1/28*** (2013.01); ***H01Q 15/141*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 15/16; H01Q 15/141
See application file for complete search history.

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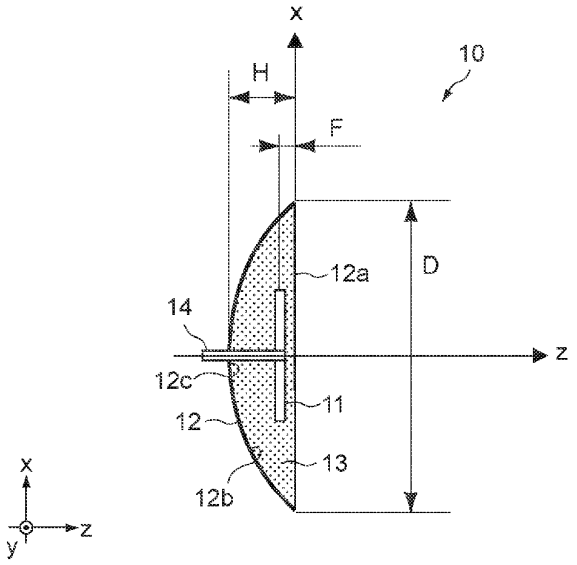
Primary Examiner — Hoang V Nguyen
Assistant Examiner — Alladin Abdulbaki
(74) *Attorney, Agent, or Firm* — Saliwanchik, Lloyd & Eisenschenk

(57) **ABSTRACT**

An antenna according to an embodiment of the present invention includes a primary radiator and a reflector mirror. The primary radiator radiates radio waves. The reflector mirror reflects radio waves radiated from the primary radiator, has same aperture diameter and height as a parabolic reflector mirror whose aperture diameter is equal to or less than 1.7 times a wavelength of the radio waves, and has a non-parabolic surface as a mirror surface shape.

7 Claims, 9 Drawing Sheets



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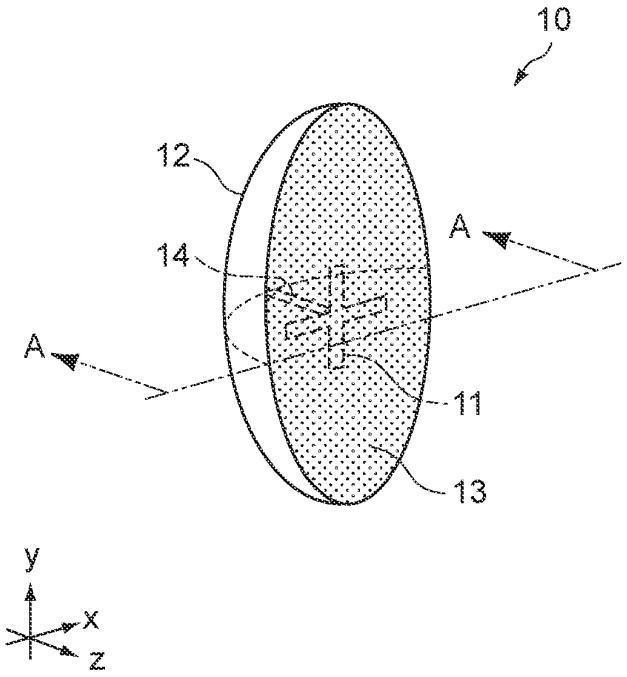


FIG.1

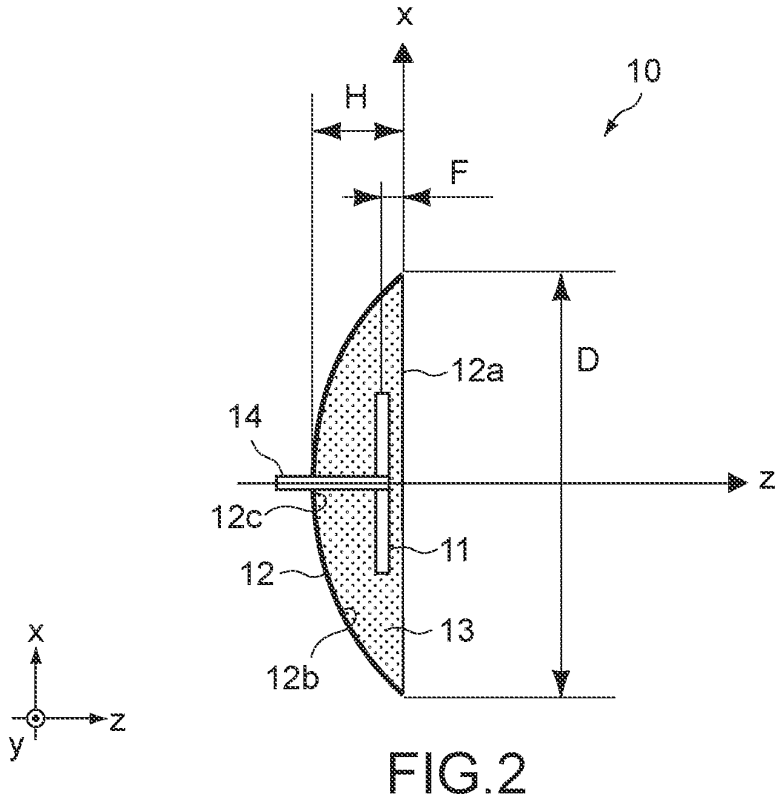
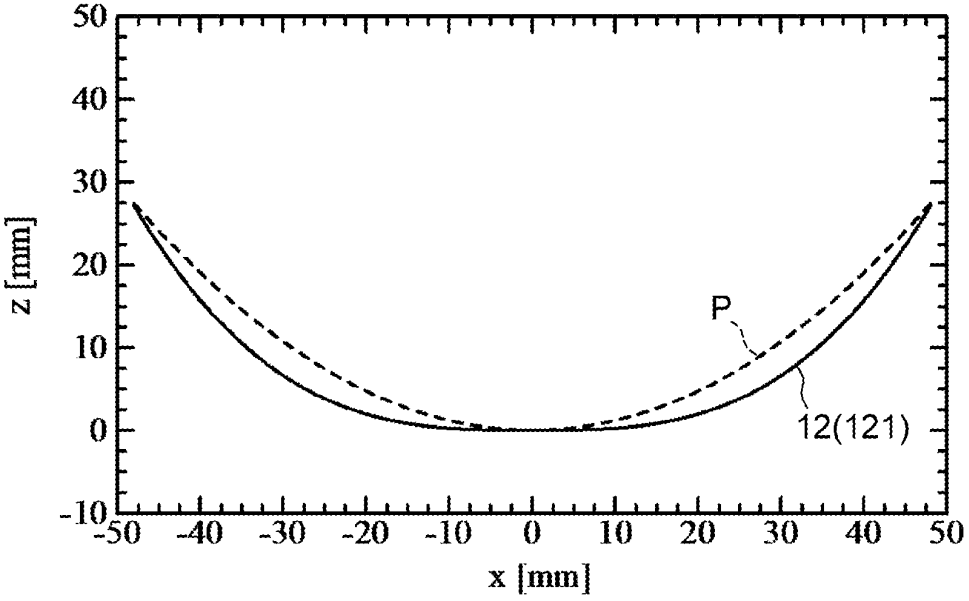


FIG.2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20
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0
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z [mm]
-50 -40 -30 -20 -10 0 10 20 30 40 50
x [mm]
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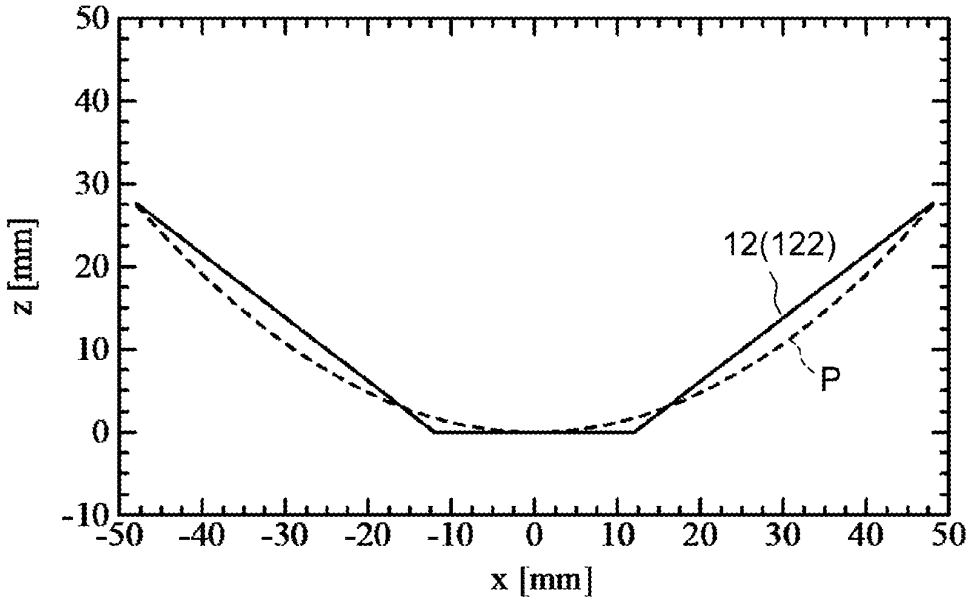
FIG.3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-10
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x [mm]
12(122)
P

FIG.4

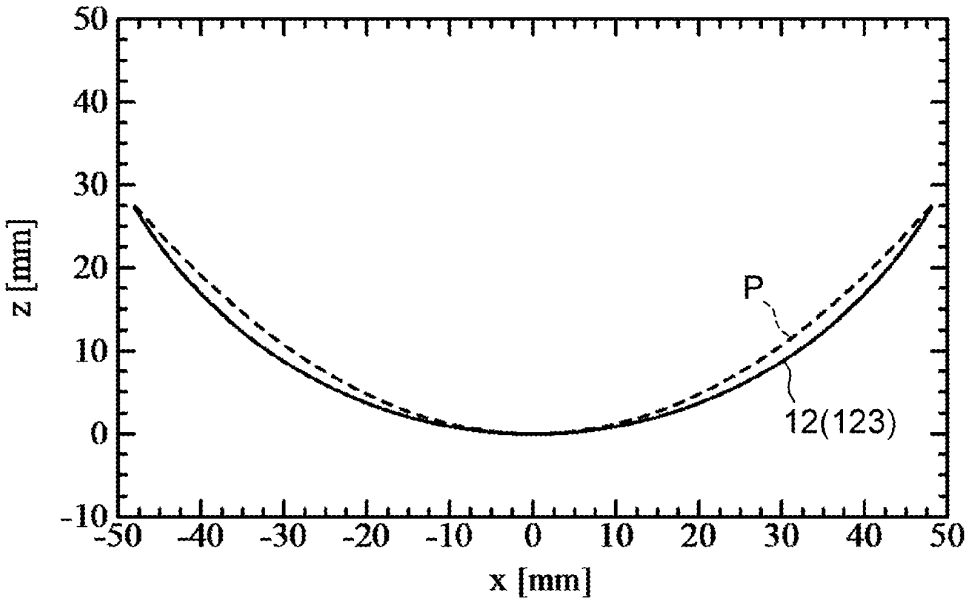
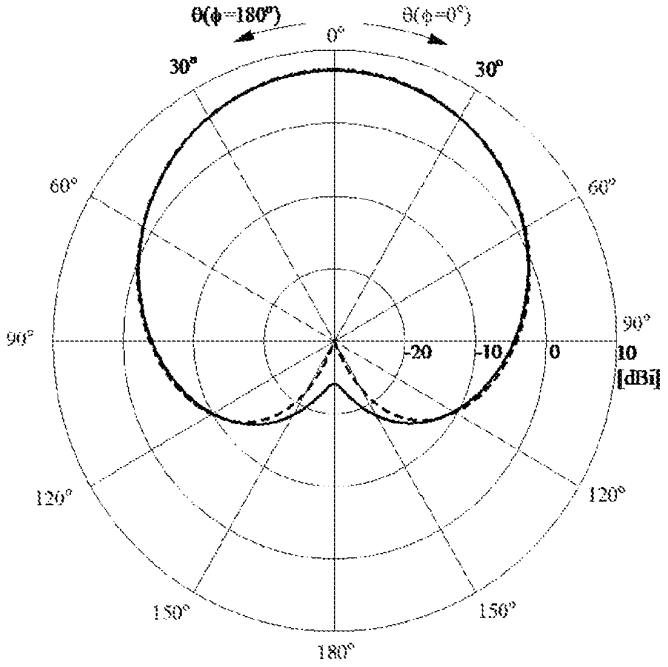


FIG.5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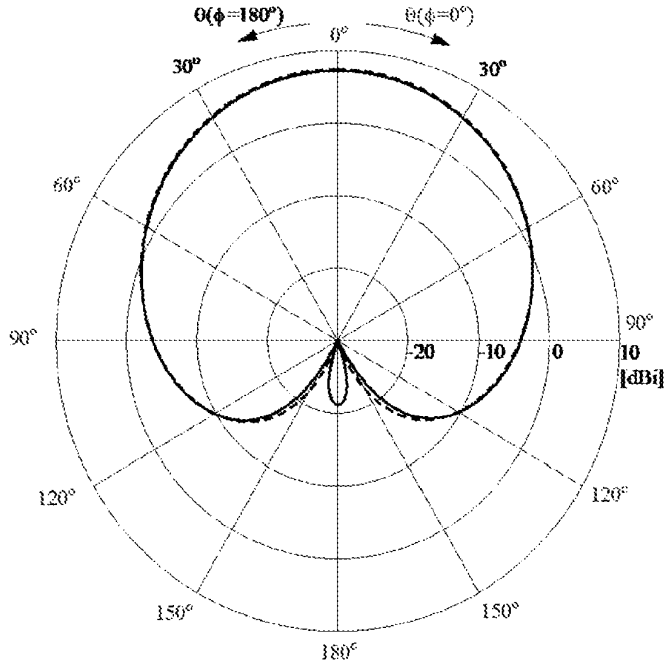
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-10
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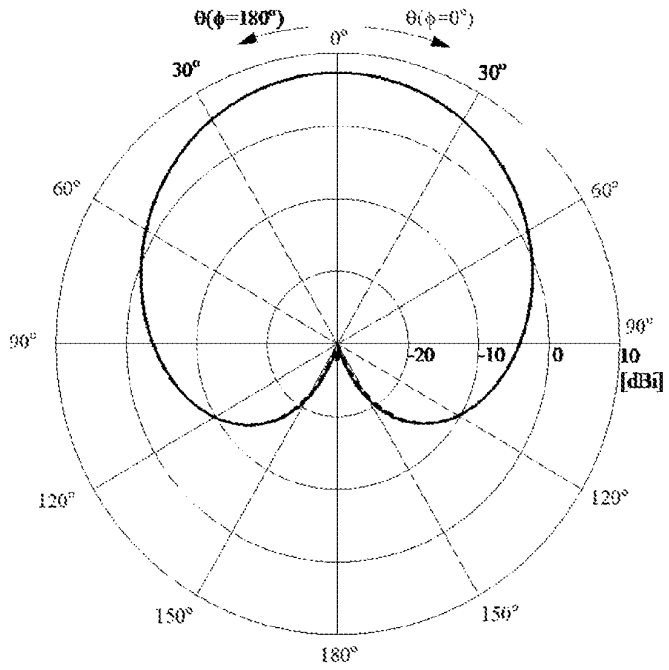
[dBi]

(2)

FIG.6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[dBi]

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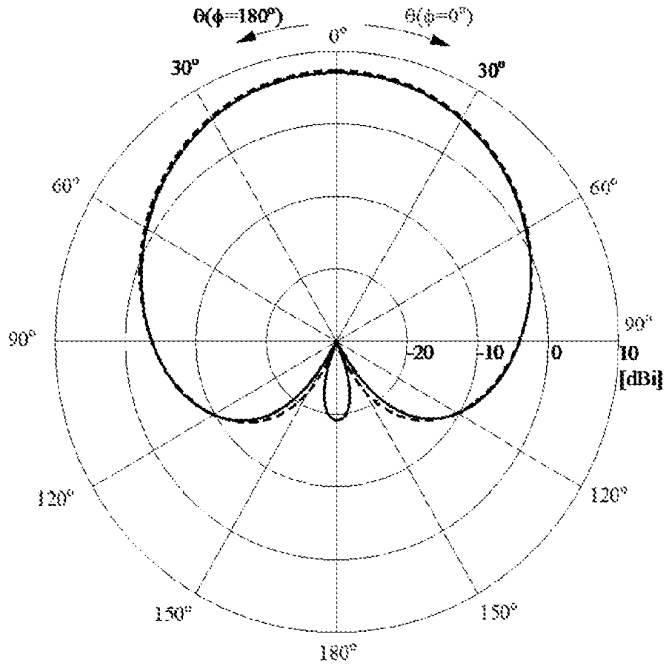
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10
[dBi]

(2)

FIG.7

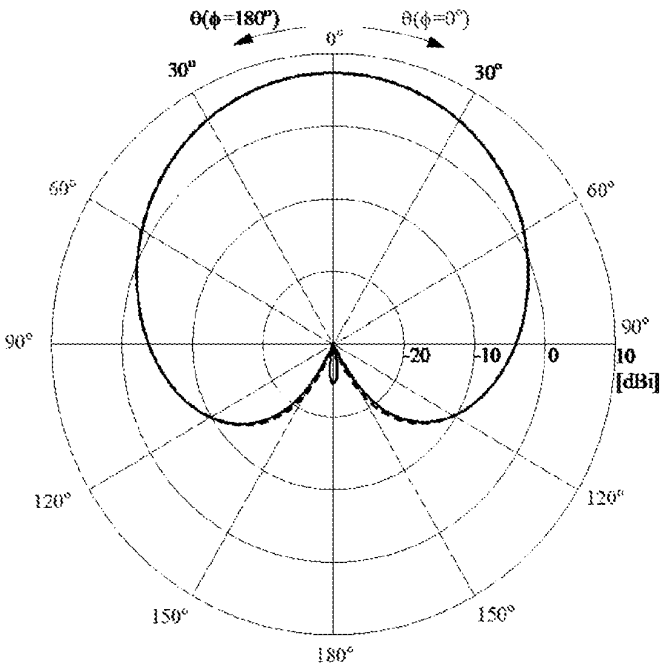
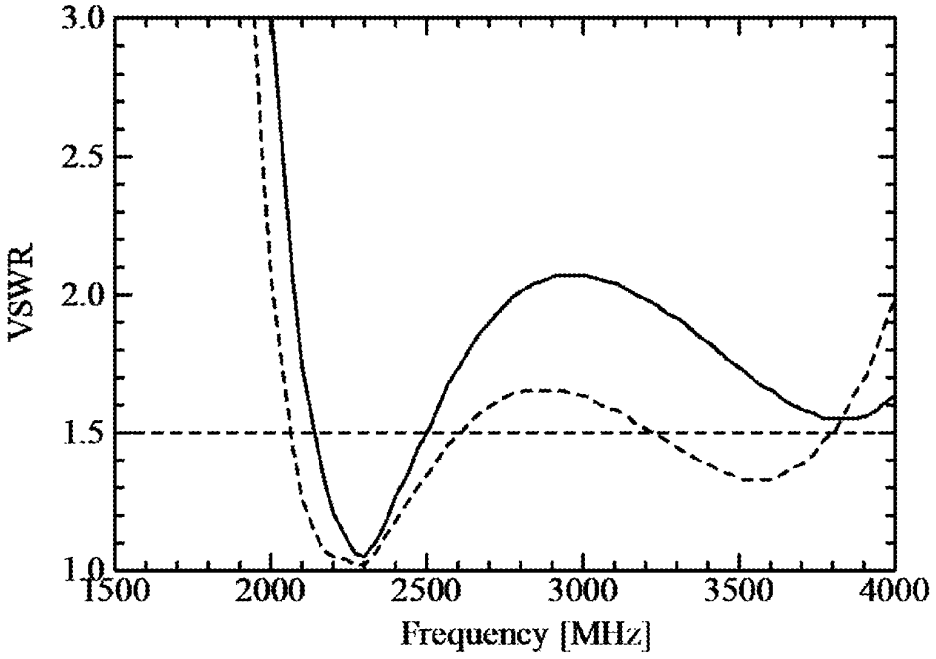


FIG.8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1.5
1.0
VSWR
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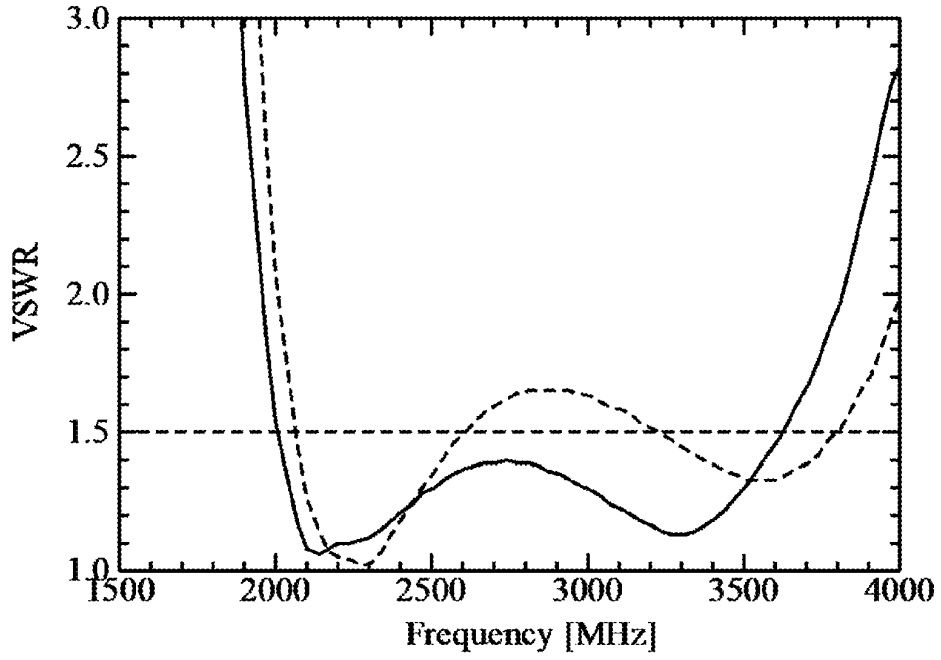
2000
2500
3000
3500
4000
Frequency [MHz]

(1)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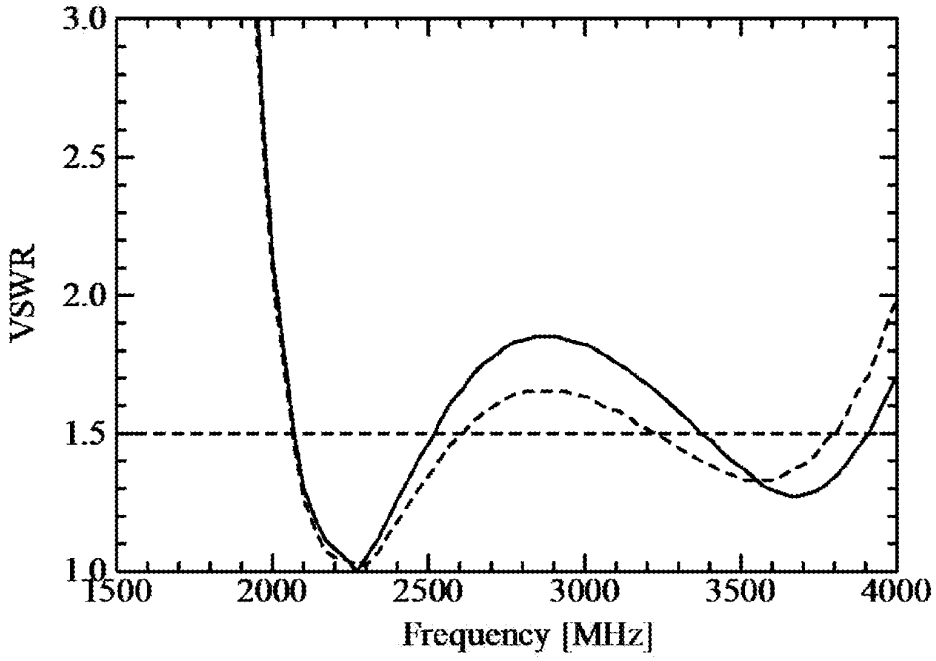
1.5
1.0
VSWR
1500
2000
2500
3000
3500
4000
Frequency [MHz]

(2)

FIG.9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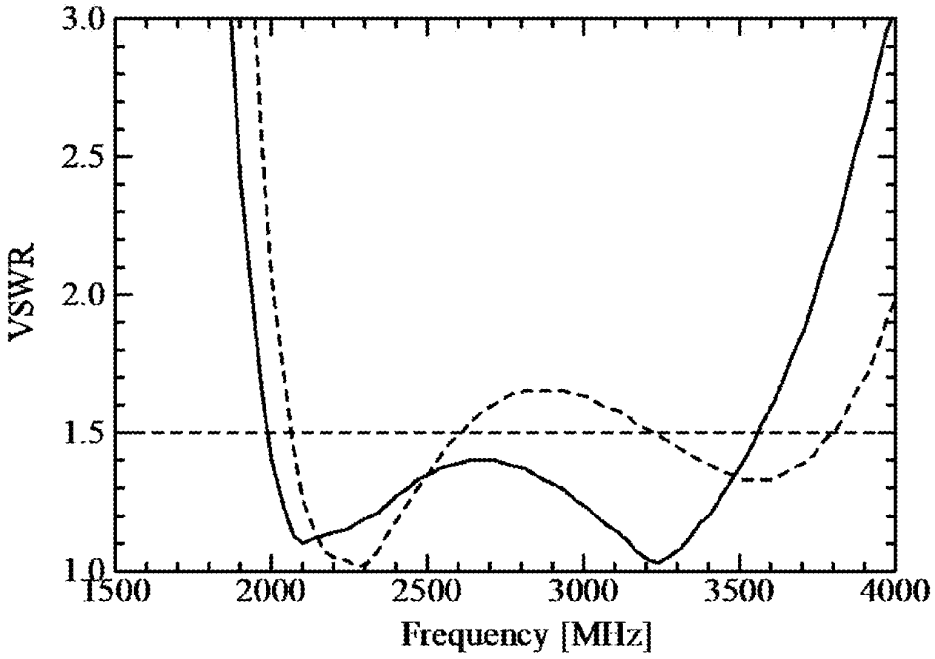
2.0
1.5
1.0
VSWR
1500
2000
2500
3000
3500
4000
Frequency [MHz]

(1)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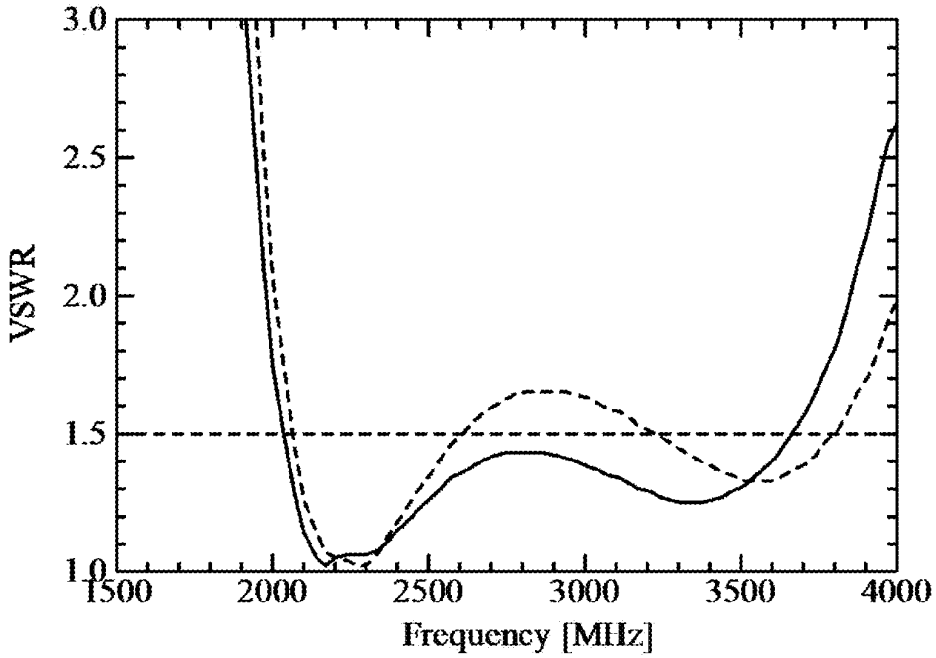
2.0
1.5
1.0
VSWR
1500
2000
2500
3000
3500
4000
Frequency [MHz]

(2)

FIG.10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2.5
2.0
1.5
1.0
VSWR
1500
2000
2500
3000
3500
4000
Frequency [MHz]

FIG.11

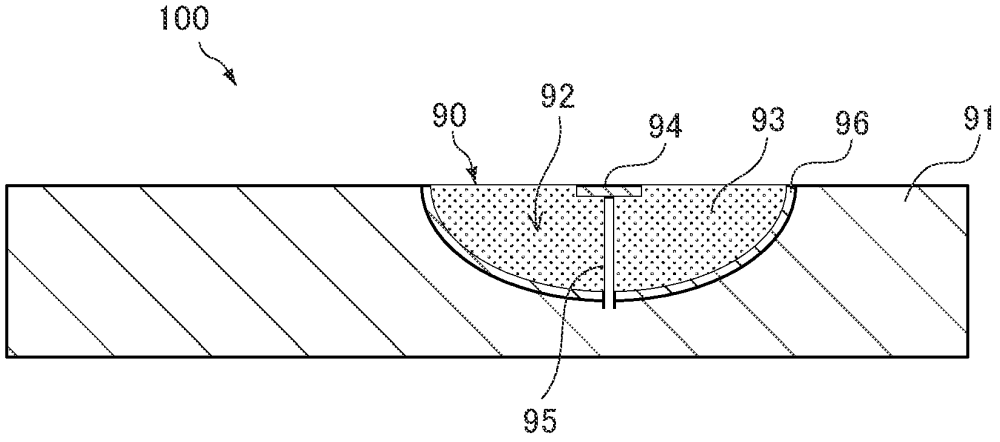
100
90
92
94
93
96
91
95

FIG.12

ANTENNA, ELECTRONIC APPARATUS, AND METHOD OF MANUFACTURING AN ANTENNA

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is the U.S. national stage application of International Patent Application No. PCT/JP2022/010606, filed Mar. 10, 2022, which claims the benefit under 35 U.S.C. § 119 of Japanese Application No. 2021-089062, filed May 27, 2021, the disclosures of each of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

The present invention relates to a technology of an antenna mounted on a flying object such as a rocket and an aircraft.

BACKGROUND ART

An antenna to be mounted on a flying object such as a rocket and an aircraft is required to uniformly radiate radio waves in a wide area and to withstand aerodynamic load and aerodynamic heat generated during a flight. The inventor of the present invention has proposed an antenna in Patent Literature 1 as an antenna that meets such requirements.

The antenna according to Patent Literature 1 includes a primary radiator and a parabolic reflector mirror. The antenna according to Patent Literature 1 can provide uniformly stable pattern characteristics in a wide area without generating null points in an antenna pattern on a hemisphere where radio waves are radiated by setting an aperture diameter of the parabolic reflector mirror to be equal to or less than 1.7 times a wavelength.

CITATION LIST

Patent Literature

Patent Literature 1: Japanese Patent Application Laid-open No. 2020-120153

DISCLOSURE OF INVENTION

Technical Problem

However, in the antenna according to Patent Literature 1, the primary radiator is placed very close to the parabolic reflector mirror as compared to a generally-used parabolic antenna because the aperture diameter of parabolic reflector mirror is small as equal to or less than 1.7 times the wavelength. Therefore, impedance characteristics of the primary radiator are strongly affected by the reflector mirror, and it is difficult to arbitrarily change the impedance characteristics of the primary radiator.

In view of the above-mentioned circumstances, it is an objective of the present invention to provide an antenna, an electronic apparatus, and a method of manufacturing an antenna, by which it is possible to arbitrarily change impedance characteristics of a primary radiator while maintaining uniformly stable pattern characteristics in a wide area.

Solution to Problem

An antenna according to an embodiment of the present invention includes a primary radiator and a reflector mirror.

The primary radiator radiates radio waves.

The reflector mirror reflects radio waves radiated from the primary radiator, has same aperture diameter and height as a parabolic reflector mirror whose aperture diameter is equal to or less than 1.7 times a wavelength of the radio waves, and has a non-parabolic surface as a mirror surface shape.

In the antenna according to the embodiment of the present invention, since the reflector mirror has the aperture whose diameter is equal to or less than 1.7 times the wavelength of radio waves, uniformly stable pattern characteristics in a wide area can be provided without generating null points in an antenna pattern on a hemisphere where radio waves are radiated.

Moreover, since the reflector mirror of the antenna according to Patent Literature 1 is a parabolic reflector mirror, i.e., a reflector mirror in a shape of a paraboloid of revolution, the shape of the reflector mirror is determined from the aperture diameter and height. On the other hand, the antenna according to the embodiment of the present invention adopts the reflector mirror of the non-parabolic surface whose shape is different from the paraboloid of revolution. That is, although the aperture diameter and height of the reflector mirror are set to be identical to those of the parabolic reflector mirror, the mirror surface shape is modified from the paraboloid of revolution. With such a configuration, the primary radiator can have impedance characteristics different from those obtained in a case where the reflector mirror has a parabolic shape. In the concrete, for the impedance of the antenna according to the embodiment of the present invention, a frequency band that matches a feed system can set to be narrower or wider than that of the antenna according to Patent Literature 1.

The non-parabolic surface may have a shape whose height from a mirror surface bottom portion of the reflector mirror is proportional to a distance from a center axis of the reflector mirror raised to an exponent excluding 2.

Alternatively, the non-parabolic surface may have a truncated conical surface, a partially spherical surface, a conical surface, a cylindrical surface, or the like.

Alternatively, the non-parabolic surface may have a shape combining two or more different non-parabolic surfaces.

The primary radiator may be disposed on an aperture plane of the reflector mirror or in a region of its inside.

The reflector mirror may have a dielectric material layer with which a region inside an aperture plane of the reflector mirror is filled.

An electronic apparatus according to an embodiment of the present invention has a configuration that the above-mentioned antenna is embedded in a cavity in a surface of or inside a mounting object on which the antenna is mounted.

A hole having the same shape and dimension as the reflector mirror is formed in a surface of or inside the mounting object. With this hole, the antenna can be mounted without projecting from the surface of the mounting object. In a case of a flying object such as a rocket and an aircraft, for example, this configuration greatly reduces aerodynamic load and aerodynamic heat. Since the antenna according to the embodiment of the present invention has a small aperture diameter, influence of forming the hole on the flying object is ignorably small. Moreover, in a case where the antenna according to the embodiment of the present invention is mounted inside or outside an electronic apparatus with a wireless communication function, such as a personal computer (PC), or a building, the antenna can be mounted without projecting from the surface by forming a hole with the same shape and dimension as the reflector mirror, for

example, in a substrate of electronic components and the like are mounted, in an outer wall, interior wall, or ceiling surface of the building, or inside the mounting object. In addition, the footprint can also be reduced due to the reduced aperture diameter. The thickness and weight can be thus reduced in comparison with stick antennas and the like in the related art. Higher antenna gain can be obtained because the parabolic antenna is used as a basic configuration. The antenna can be made unremarkable by using the same color and patterns for a front surface of the antenna as the wall or ceiling of the building.

A method of manufacturing an antenna according to an embodiment of the present invention includes:

designing a reflector mirror of a parabolic mirror surface that reflects radio waves radiated from a primary radiator, and has an aperture diameter equal to or less than 1.7 times a wavelength of the radio waves; and

modifying the mirror surface to be a non-parabolic surface that has same aperture diameter and height as the parabolic surface.

Advantageous Effects of Invention

According to the present invention, it is possible to arbitrarily change impedance characteristics of a primary radiator while maintaining uniformly stable pattern characteristics in a wide area.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** A perspective view showing a configuration of an antenna according to an embodiment of the present invention.

FIG. **2** A cross-sectional view taken along the line A-A of FIG. **1**.

FIG. **3** A view for describing an embodiment of the antenna, which is a cross-sectional view of a shape whose height from a mirror surface bottom portion of a reflector mirror surface is proportional to a distance from a center axis raised to an exponent excluding 2.

FIG. **4** A view for describing an embodiment of the antenna, which is a cross-sectional view in a case where a reflector mirror has a truncated conical shape.

FIG. **5** A view for describing an embodiment of the antenna, which is a cross-sectional view in a case where a reflector mirror has a partially spherical surface shape.

FIG. **6** A view for describing an embodiment of the antenna, which depicts analytic values of an antenna pattern (right-handed polarization) in the xz-plane in a case where the reflector mirror has a shape whose height from the mirror surface bottom portion of the reflector mirror surface is proportional to the distance from the center axis raised to an exponent excluding 2.

FIG. **7** A view for describing an embodiment of the antenna, which depicts analytic values of an antenna pattern (right-handed polarization) in the xz-plane in a case where the shape of the reflector mirror is a truncated cone.

FIG. **8** A view for describing an embodiment of the antenna, which depicts analytic values of an antenna pattern (right-handed polarization) in the xz-plane in a case where the shape of the reflector mirror is a partially spherical surface.

FIG. **9** A view for describing an embodiment of the antenna, which depicts analytic values of a voltage standing wave ratio (VSWR), with respect to 50Ω, which shows impedance characteristics of the primary radiator as frequency characteristics in a case of a shape whose height from the mirror surface bottom portion of the reflector mirror surface is proportional to the distance from the center axis raised to an exponent excluding 2.

FIG. **10** A view for describing an embodiment of the antenna, which depicts analytic values of the VSWR with respect to 50Ω, which shows impedance characteristics of the primary radiator as frequency characteristics in a case where the shape of the reflector mirror is the truncated conical shape.

FIG. **11** A view for describing an embodiment of the antenna, which depicts analytic values of the VSWR, with respect to 50Ω, which shows impedance characteristics of the primary radiator as frequency characteristics in a case where the shape of the reflector mirror is the partially spherical shape.

FIG. **12** A cross-sectional view of main parts of an electronic apparatus on which an antenna according to an embodiment of the present invention is mounted.

MODE(S) FOR CARRYING OUT THE INVENTION

Hereinafter, embodiments of the present invention will be described with reference to the drawings.

First Embodiment

FIG. **1** is a perspective view showing a configuration of an antenna **10** according to an embodiment of the present invention. FIG. **2** is a cross-sectional view taken along the line A-A of FIG. **1**. In each figure, the x-axis, the y-axis, and the z-axis denote three axis directions orthogonal to one another and the z-axis corresponds to a center axis of a reflector mirror **12** of the antenna **10**.

[Overall Configuration of Antenna]

As shown in FIGS. **1** and **2**, the antenna **10** includes a primary radiator **11** and the reflector mirror **12**. The antenna **10** further includes a dielectric material layer **13** and a feed cable **14**. A region inside an aperture plane **12***a* of the reflector mirror **12** is filled with the dielectric material layer **13**. The feed cable **14** is connected to the primary radiator **11**. The antenna **10** according to the present embodiment is mounted on a flying object such as a rocket and an aircraft.

The primary radiator **11** is an antenna element that radiates radio waves. Any antenna element can be used as the primary radiator **11** as long as the antenna element has a predetermined impedance. An example using a cross-dipole antenna is shown in the present embodiment. Alternatively, a dipole antenna, a horn antenna, or the like may be used.

The reflector mirror **12** has a diameter (aperture diameter) D of the aperture plane **12***a*, has a height H from a mirror surface bottom portion **12***c* to the aperture plane **12***a*, and is a reflector mirror, made of an electrically conductive material, which has a different shape (non-parabolic surface) from a paraboloid of revolution (parabolic surface). The primary radiator **11** is positioned at a depth F from the aperture plane **12***a* of the reflector mirror **12**.

Moreover, the reflector mirror **12** reflects radio waves radiated from the primary radiator **11** and its aperture diameter D is reduced to be equal to or smaller than an aperture diameter which does not generate any null points in an antenna pattern on a hemisphere where the reflected radio waves are radiated. In the present embodiment, the reflector mirror **12** has the aperture diameter D equal to or less than 1.7 times the wavelength of radio waves. The aperture diameter D and the dimension of the primary radiator **11** can be reduced within a range enabling the antenna to function.

The range enabling the antenna to function means a range enabling the primary radiator **11** to provide a predetermined impedance. In other words, it means a range where a voltage standing wave ratio (VSWR) of the primary radiator **11** is equal to or smaller than a value required by a system using the antenna. Since no null points are generated in the antenna **10** according to the present embodiment, side lobes are also not generated as a matter of course. That is, the antenna **10** according to the present embodiment can radiate uniform radio waves in a wide area on the hemisphere where radio waves are radiated.

The dielectric material **13** is filled up in a region from the aperture plane **12***a* of the reflector mirror **12** to a mirror surface **12***b* that is an inner surface of the reflector mirror **12**. The dielectric material that constitutes the dielectric material layer **13** is not particularly limited, and for example, a synthetic resin material such as high-density polyethylene, polytetrafluoroethylene or the like is used. The dielectric constant of the dielectric material is also not particularly limited, and can be arbitrarily set depending on kind, properties, and the like of a mounting object on which the antenna **10** is mounted.

The primary radiator **11** is disposed in the dielectric material layer **13**. For example, the primary radiator **11** is disposed at a position on the aperture plane **12***a* or inside such a position. Moreover, the feed cable **14** is a coaxial cable for feeding power to the primary radiator **11**. In FIGS. **1** and **2**, an example that the feed cable **14** is provided to the primary radiator **11** through the mirror surface bottom portion **12***c* is shown. However, the path of the feed cable **14** is not limited as long as the feed cable **14** is located in the reflector mirror **12**.

The dielectric material layer **13** functions to retain the primary radiator **11** and the feed cable **14** at predetermined positions. The dielectric material layer **13** also functions to protect the primary radiator **11** and the feed cable **14** from aerodynamic load and aerodynamic heat generated during a flight of a rocket or the like, and can further downsize the antenna **10** due to the wavelength reduction effect of the dielectric material. It should be noted that the dielectric material layer **13** may have a cavity (not shown). With this configuration, the antenna **10** can be reduced in weight.

Here, as for the antenna **10**, the frequency of radio waves is 2.28 GHZ, the primary radiator **11** and the reflector mirror **12** are made of copper, high-density polyethylene is filled up as the dielectric material layer **13**, the aperture diameter D is 96 mm, the height H of the reflector mirror **12** is 28 mm, and the depth F from the aperture plane **12***a* to the primary radiator **11** is 7 mm. It should be noted that the aperture diameter D is about 0.73 wavelength because the wavelength is about 132 mm.

[Details of Reflector Mirror]

As for the reflector mirror **12**, the aperture diameter and height are the same as a parabolic reflector mirror, and the shape of the mirror surface **12***b* is a non-parabolic surface. The aperture diameter and height of the parabolic reflector mirror are correspond to the aperture diameter D and the height H of the reflector mirror **12**, respectively. The aperture diameter D is equal to or less than 1.7 times the wavelength of radio waves radiated from the primary radiator **11** as described above.

As described above, the aperture diameter and height of the reflector mirror **12** in the antenna **10** according to the present embodiment are the same as the parabolic reflector mirror, but it is different in that the shape of the mirror surface **12***b* is the non-parabolic surface. The non-parabolic surface refers to, for example, (1) a shape whose height from the mirror surface bottom portion **12***c* of the mirror surface **12***b* is proportional to a distance from a center axis (z-axis) of the reflector mirror **12** raised to an exponent excluding 2, (2) a truncated conical surface, (3) a partially spherical surface, (4) a conical surface, (5) a cylindrical surface. The non-parabolic surface may be a shape arbitrarily combining two or more of (1) to (5) above. Moreover, for example, any value of 1 to 3 (excluding 2) can be adopted as the exponent of the exponentiation in (1) above.

For example, FIG. **3** is a cross-sectional view taken along the xz-plane, which shows a mirror surface shape of a reflector mirror **12** in an antenna **10** according to an embodiment of the present invention (solid line in the figure) as compared to a mirror surface shape of a parabolic reflector mirror P (dotted line in the figure) with the same aperture diameter D and the same height H. Here, a reflector mirror **121** adopting the mirror surface shape corresponding to (1) above is shown as the reflector mirror **12**. The reflector mirror **121** has a mirror surface shape, with D=96 mm and H=28 mm, whose height from the mirror surface bottom portion **12***c* of the mirror surface **12***b* is proportional to the distance from the center axis (z-axis) cubed.

FIG. **4** is a cross-sectional view taken along the xz-plane, which shows a mirror surface shape of a reflector mirror **12** in an antenna **10** according to another embodiment of the present invention (solid line in the figure) as compared to a mirror surface shape of the parabolic reflector mirror P (dotted line in the figure) with the same aperture diameter D and the same height H. Here, a reflector mirror **122** adopting the mirror surface shape corresponding to (2) above is shown as the reflector mirror **12**. The reflector mirror **122** has a mirror surface shape whose bottom surface of the mirror surface **12***b* has an aperture diameter of 24 mm.

FIG. **5** is a cross-sectional view taken along the xz-plane, which shows a mirror surface shape of a reflector mirror **12** in an antenna **10** according to still another embodiment of the present invention (solid line in the figure) as compared to a mirror surface shape of the parabolic reflector mirror P (dotted line in the figure) with the same aperture diameter D and the same height H. Here, a reflector mirror **123** adopting the mirror surface shape corresponding to (3) above is shown as the reflector mirror **12**. The reflector mirror **123** has a mirror surface shape that is a partially spherical surface shape with D=96 mm and H=28 mm.

FIG. **6** depicts analytic values of an antenna pattern (right-handed polarization) of the antenna **10** according to the present embodiment in the xz-plane in a case where D=96 mm, H=28 mm, and F=7 mm and a shape whose height from the mirror surface bottom portion **12***c* of the mirror surface **12***b* is proportional to the distance from the center axis raised to an exponent excluding 2 is adopted. The FIG. **1**), (2) shows a case of adopting a shape whose height from the mirror surface bottom portion **12***c* of the mirror surface **12***b* is proportional to the distance from the center axis to the power 1.5, 3.0, respectively. It should be noted that the dotted line in the figure denotes analytic values of the antenna pattern (right-handed polarization) of the antenna according to Patent Literature 1 in a case where D=96 mm, H=28 mm, and F=7 mm and the reflector mirror surface has a parabolic shape.

As it can be seen from FIG. **6**, the antenna pattern of the antenna **10** according to the present embodiment is substantially identical to the antenna pattern of the antenna according to Patent Literature 1 in the area above the antenna aperture plane.

FIG. **7** depicts analytic values of an antenna pattern (right-handed polarization) of the antenna **10** according to

the present embodiment in the xz-plane in a case where D=96 mm, H=28 mm, and F=7 mm and the shape of the mirror surface **12***b* is a truncated cone. The FIG. **1**), (2) shows a case where the bottom surface of the mirror surface **12***b* has an aperture diameter of 24 mm, 48 mm, respectively. It should be noted that the dotted line in the figure denotes analytic values of the antenna pattern (right-handed polarization) of the antenna according to Patent Literature 1 in a case where D=96 mm, H=28 mm, and F=7 mm and the reflector mirror surface has a parabolic shape.

As it can be seen from FIG. **7**, the antenna pattern of the antenna **10** according to the present embodiment is substantially identical to the antenna pattern of the antenna according to Patent Literature 1 in the area above the antenna aperture plane.

FIG. **8** depicts analytic values of an antenna pattern (right-handed polarization) of the antenna **10** according to the present embodiment in the xz-plane in a case where D=96 mm, H=28 mm, and F=7 mm and the shape of the mirror surface **12***b* is a partially spherical surface. It should be noted that the dotted line in the figure denotes analytic values of the antenna pattern (right-handed polarization) of the antenna according to Patent Literature 1 in a case where D=96 mm, H=28 mm, and F=7 mm and the reflector mirror surface has a parabolic shape.

As it can be seen from FIG. **8**, the antenna pattern of the antenna **10** according to the present embodiment is substantially identical to the antenna pattern of the antenna according to Patent Literature 1 in the area above the antenna aperture plane.

FIG. **9** depicts analytic values of the VSWR with respect to 50Ω as frequency characteristics, which shows impedance characteristics of the primary radiator **11** of the antenna **10** according to the present embodiment in a case where D=96 mm, H=28 mm, and F=7 mm and a shape whose height from the mirror surface bottom portion **12***c* of the mirror surface **12***b* is proportional to the distance from the center axis raised to an exponent excluding 2 is adopted. The FIG. **1**), (2) shows a case of adopting a shape whose height from the mirror surface bottom portion **12***c* of the mirror surface **12***b* is proportional to the distance from the center axis to the power 1.5, 3.0, respectively. It should be noted that the dotted line in the figure denotes analytic values of the VSWR indicating impedance characteristics as frequency characteristics in a case where D=96 mm, H=28 mm, and F=7 mm and the reflector mirror surface has a parabolic shape, i.e., a primary radiator of the antenna according to Patent Literature 1.

Comparing the range where the VSWR is equal to or smaller than 1.5 in FIG. **9**, it can be seen that the range in the FIG. **1**) is narrower than that of the antenna according to Patent Literature 1 and the range in the FIG. **2**) is wider than that of the antenna according to Patent Literature 1. It can be thus seen that the impedance characteristics of the primary radiator of the antenna can be changed by changing the shape of the reflector mirror.

FIG. **10** depicts analytic values of the VSWR with respect to 50Ω as frequency characteristics, which shows impedance characteristics of the primary radiator **11** of the antenna **10** according to the present embodiment in a case where D=96 mm, H=28 mm, and F=7 mm and the shape of the mirror surface **12***b* is a truncated cone. The FIG. **1**), (2) shows a case where the bottom surface of the mirror surface **12***b* has an aperture diameter of 24 mm, 48 mm, respectively. It should be noted that the dotted line in the figure denotes analytic values of the VSWR indicating impedance characteristics as frequency characteristics in a case where D=96 mm, H=28 mm, and F=7 mm and the reflector mirror surface has a parabolic shape, i.e., a primary radiator of the antenna according to Patent Literature 1.

Comparing the range where the VSWR is equal to or smaller than 1.5 in FIG. **10**, it can be seen that the range in the FIG. **1**) is narrower than that of the antenna according to Patent Literature 1 and the range in the FIG. **2**) is wider than that of the antenna according to Patent Literature 1. It can be thus seen that the impedance characteristics of the primary radiator of the antenna can be changed by changing the shape of the reflector mirror.

FIG. **11** depicts analytic values of the VSWR with respect to 50Ω as frequency characteristics, which shows impedance characteristics of the primary radiator **11** of the antenna **10** according to the present embodiment in a case where D=96 mm, H=28 mm, and F=7 mm and the shape of the mirror surface **12***b* is a partially spherical surface. It should be noted that the dotted line in the figure denotes analytic values of the VSWR indicating impedance characteristics as frequency characteristics in a case where D=96 mm, H=28 mm, and F=7 mm and the reflector mirror surface has a parabolic shape, i.e., a primary radiator of the antenna according to Patent Literature 1.

Comparing the range where the VSWR is equal to or smaller than 1.5 in FIG. **11**, it can be seen that the range of the antenna **10** is wider than that of the antenna according to Patent Literature 1 according to the present embodiment. It can be thus seen that the impedance characteristics of the primary radiator of the antenna can be changed by changing the shape of the reflector mirror.

[Method of Manufacturing Antenna]

The antenna **10** according to the present embodiment configured in the above-mentioned manner is manufactured by designing a reflector mirror of a parabolic mirror surface with an aperture diameter equal to or less than 1.7 times the wavelength of radio waves and modifying the mirror surface to be a non-parabolic surface with the same aperture diameter and height as the parabolic surface.

Other than the shape whose height from the mirror surface bottom portion of the reflector mirror is proportional to the distance from the center axis of the reflector mirror raised to an exponent excluding 2 as described above, any shape such as a truncated conical surface, a partially spherical surface, a conical surface, and a cylindrical surface can be adopted as the non-parabolic surface depending on impedance characteristics and the like of a feed system of the primary radiator **11**.

For modifying the mirror surface to be a non-parabolic surface, any method can be adopted so as to narrow or widen the frequency band that matches the feed system. As an example, the shape of a mirror surface formed as a parabolic surface is modified to be a non-parabolic surface by machine working or the like. As another example, a parabolic surface is modified to be a non-parabolic surface during a design process.

Actions of Present Embodiment

As described above, with the antenna **10** according to the present embodiment, since the reflector mirror **12** has the aperture diameter D equal to or less than 1.7 times the wavelength of radio waves, uniformly stable pattern characteristics in a wide area can be provided without generating null points in an antenna pattern on a hemisphere where radio waves are radiated (sec FIG. 4 in Patent Literature 1). More specifically, the following actions can be obtained.

The antenna beam is widened, and radio waves are radiated to wide area. Radio waves can also be radiated to an area below the antenna aperture plane.

There are no null points and hollows in the hemisphere above the antenna aperture plane.

Owing to the reflector mirror antenna, the antenna pattern is not substantially affected by a shape and an antenna mounting portion of a mounting object on which the antenna is mounted.

Therefore, with the antenna **10** according to the present embodiment, the following actions are provided.

Uniformly stable pattern characteristics in a wide area are provided, and the gain is higher as compared to an antenna mounted on a flying object in the current state.

In a case where the antenna **10** is mounted on a flying object, a mounting object that is the flying object is not affected by operational limitations due to pattern characteristics.

In a case where the antenna **10** is mounted on a flying object, aerodynamic load and aerodynamic heat generated in the antenna **10** are greatly reduced.

The thickness and weight are reduced as compared to antennas in the related art, and the antenna can be made more unremarkable.

Moreover, in accordance with the present embodiment, the antenna can be mounted without projecting from the surface of the mounting object by forming a hole with the same shape and dimension as the reflector mirror in a surface of or inside the mounting object. With this configuration, for example, in a case of a flying object such as a rocket and an aircraft, aerodynamic load and aerodynamic heat are greatly reduced. Since the antenna according to the present embodiment has a small aperture diameter, influence of forming the hole on the flying object is ignorably small. Moreover, in a case where the antenna according to the embodiment of the present invention is mounted inside or outside an electronic apparatus with a wireless communication function, such as a personal computer (PC), or a building, the antenna can be mounted without projecting from the surface by forming a hole having the same shape and dimension as the reflector mirror, for example, in a substrate on which electronic components and the like are mounted, in an outer wall, interior wall, or ceiling surface of the building, or inside the mounting object. In addition, the footprint can also be reduced due to the reduced aperture diameter. The thickness and weight can be thus reduced in comparison with stick antennas and the like in the related art. Higher antenna gain can be obtained because the parabolic antenna is used as a basic configuration. The antenna can be made unremarkable by using the same color and patterns as the wall or ceiling for the aperture plane.

Furthermore, with the antenna **10** according to the present embodiment, since the antenna **10** has the same aperture diameter and height as the parabolic reflector mirror and the mirror surface shape is the non-parabolic surface, it is possible to change the impedance characteristics of the primary radiator of the antenna while maintaining the pattern characteristics of the antenna according to Patent Literature 1. More specifically, it is possible to set the frequency band that achieves impedance matching with the feed system of the primary radiator **11** to be narrower or wider than that of the antenna according to Patent Literature 1.

For example, in a case where the frequency band that achieves impedance matching with the feed system of the primary radiator **11** is set to be narrower, it is unnecessary to prepare a filter that cuts radio waves at a frequency wished to be removed.

On the other hand, in a case where the frequency band that achieves impedance matching with the feed system of the primary radiator **11** is set to be wider, it is unnecessary to prepare a plurality of antennas because a plurality of frequency ranges can be used only by the antenna **10** according to the present embodiment. Moreover, in a case where the antenna **10** according to the present embodiment is used for communication, the communication capacity can be increased.

Second Embodiment

FIG. **12** is a cross-sectional view of main parts of an electronic apparatus **100** according to another embodiment of the present invention. The electronic apparatus **100** includes a substrate **91** and an antenna **90** embedded in a surface of the substrate **91**.

As shown in FIG. **12**, the substrate **91** is provided with a hole **92** matching the shape of the reflector mirror, and an electrically conductive thin film **96** is formed on a surface of the hole **92**. The electrically conductive thin film **96** functions as a reflector mirror of the antenna **90**. A dielectric material layer **93** constituted by a dielectric material such as high-density polyethylene is filled up in a region inside an aperture plane of the hole **92**. A primary radiator **94** of the antenna **90** is disposed on the aperture plane of the hole **92** and is held by the dielectric material layer **93**.

The hole **92** corresponds to a cavity provided in a surface of or inside a mounting object, on which the antenna **90** is mounted, and the antenna **90** is embedded in this cavity. The hole **92** is formed to have the same aperture diameter and height as the parabolic reflector mirror and have a shape of a non-parabolic surface. Therefore, the electrically conductive thin film **96** formed on a surface of the hole **92** forms a mirror surface that is the non-parabolic surface.

The hole **92** (electrically conductive thin film **96**) is formed to have such an aperture diameter (equal to or less than 1.7 times the wavelength) that does not generate any null points in an antenna pattern on a hemisphere where the reflector mirror reflects radio waves radiated from the primary radiator **94**. A feed cable **95** is retained by the dielectric material layer **93** and connected to the primary radiator **94**.

In the present embodiment, the antenna **90** is constituted by the hole **92** with the electrically conductive thin film **96**, the dielectric material layer **93**, and the primary radiator **94**. With the electronic apparatus **100** on which such an antenna **90** is mounted, the antenna **90** can be mounted without projecting from the surface of the substrate **91**. In addition, the footprint can also be reduced due to the reduced aperture diameter of the antenna **90**. The thickness and weight can be thus reduced in comparison with stick antennas and the like in the related art. Higher antenna gain can be obtained because the reflector mirror antenna is used as a basic configuration.

Moreover, since the electrically conductive thin film **96** that forms the mirror surface of the antenna **90** has the non-parabolic shape, it is possible to arbitrarily make adjustment, e.g., setting the frequency band that matches the feed system to be narrower or wider as compared to that of the antenna of the parabolic reflector mirror disclosed in Patent Literature 1.

Although the embodiments of the present invention have been described above, the present technology is not limited

to the above-mentioned embodiments and various modifications can be made as a matter of course.

Although the present invention is applied to the antenna mounted on the flying object such as the rocket and the aircraft as an example in the above embodiments, the present invention can also be applied to a movable object such as a train, an automobile, and an underwater craft, an electronic apparatus such as a portable terminal and a personal computer (PC), and a building. In a case where the antenna according to the present invention is mounted outside or inside a building, the antenna can be made unremarkable by using the same color and patterns for a front surface of the antenna as the wall or ceiling of the building.

REFERENCE SIGNS LIST

10, **90** antenna
11, **94** primary radiator
12, **121**, **122**, **123** reflector mirror
12*a* aperture plane
12*b* mirror surface
12*c* mirror surface bottom portion
13, **93** dielectric material layer
92 hole (cavity)
100 electronic apparatus

The invention claimed is:

1. An antenna, comprising:
a primary radiator that radiates radio waves; and
a reflector mirror that reflects radio waves radiated from the primary radiator, has a same aperture diameter and height as a parabolic reflector mirror whose aperture diameter is equal to or less than 1.7 times a wavelength of the radio waves, and has a non-parabolic surface as a mirror surface shape,
wherein the primary radiator is disposed in a region inside an aperture plane of the reflector mirror,
wherein the reflector mirror has such pattern characteristics that no null points are generated in an antenna pattern on a hemisphere on which the radio waves are reflected and radiated, and
wherein the antenna is configured such that impedance characteristics of the primary radiator are changeable without changing a radiation pattern of the primary radiator.

2. The antenna according to claim **1**, wherein the non-parabolic surface has a shape combining non-parabolic surfaces having two or more different shapes.

3. The antenna according to claim **1**, wherein the non-parabolic surface has a shape whose height from a mirror surface bottom portion of the reflector mirror is proportional to a distance from a center axis of the reflector mirror raised to an exponent excluding 2, a truncated conical surface, a partially spherical surface, a conical surface, a cylindrical surface, or a shape combining two or more thereof.

4. The antenna according to claim **1**, wherein the reflector mirror has a dielectric material layer with which a region inside an aperture plane of the reflector mirror is filled.

5. An electronic apparatus comprising the antenna according to claim **1** that is embedded in a cavity in a surface of a mounting object, on which the antenna is mounted, or inside the mounting object.

6. A method of manufacturing an antenna, comprising:
designing a reflector mirror that reflects radio waves radiated from a primary radiator, has a mirror surface whose aperture diameter is equal to or less than 1.7 times a wavelength of the radio waves, and has a parabolic surface as the mirror surface; and
modifying the mirror surface to be a non-parabolic surface that has a same aperture diameter and height as the parabolic surface and has a shape whose height from a mirror surface bottom portion of the reflector mirror is proportional to a distance from a center axis of the reflector mirror raised to an exponent excluding 2,
wherein the primary radiator is disposed in a region inside an aperture plane of the reflector mirror,
wherein a frequency band that achieves impedance matching with a feed system of the primary radiator is set to be narrower or wider than that of the reflector mirror with the parabolic surface by changing a value of the exponentiation, and
wherein the antenna is configured such that impedance characteristics of the primary radiator are changeable without changing a radiation pattern of the primary radiator.

7. A method of manufacturing an antenna, comprising:
designing a reflector mirror that reflects radio waves radiated from a primary radiator, has a mirror surface whose aperture diameter is equal to or less than 1.7 times a wavelength of the radio waves, and has a parabolic surface as the mirror surface; and
modifying the mirror surface to be a non-parabolic surface that has a same aperture diameter and height as the parabolic surface and has a truncated conical surface shape,
wherein the primary radiator is disposed in a region inside an aperture plane of the reflector mirror,
wherein a frequency band that achieves impedance matching with a feed system of the primary radiator is set to be narrower or wider than that of the reflector mirror with the parabolic surface by changing an aperture diameter of a bottom surface of the mirror surface, and
wherein the antenna is configured such that impedance characteristics of the primary radiator are changeable without changing a radiation pattern of the primary radiator.

* * * * *

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(12) **United States Patent**
Mori et al.

(10) **Patent No.: US 12,255,399 B2**
(45) **Date of Patent: Mar. 18, 2025**

(54) **ANTENNA MODULE, COMMUNICATION APPARATUS INCLUDING THE SAME, AND CIRCUIT SUBSTRATE**

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(73) Assignee: **MURATA MANUFACTURING CO., LTD.**, Nagaokakyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 495 days.

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H01Q 1/22 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 21/065*** (2013.01); ***H01Q 1/2283*** (2013.01); ***H01Q 5/385*** (2015.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 21/065; H01Q 21/0006; H01Q 1/48; H01Q 1/2283; H01Q 5/385; H01Q 21/24; H04B 1/0057; H04B 1/006
See application file for complete search history.

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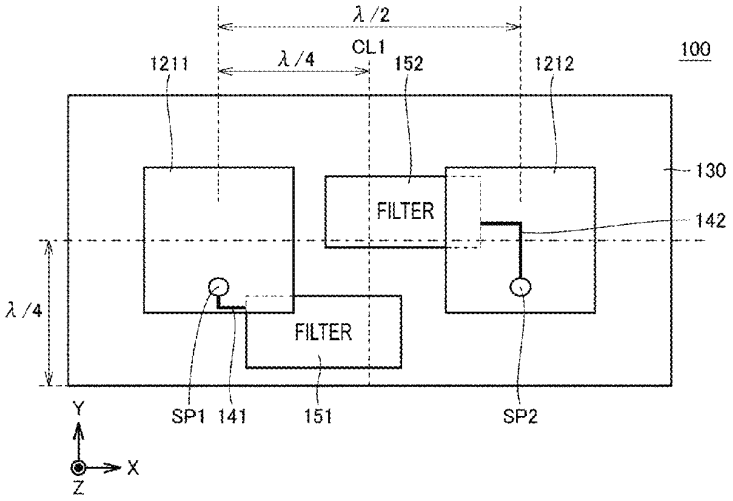
Primary Examiner — Hoang V Nguyen
Assistant Examiner — Yonchan J Kim
(74) *Attorney, Agent, or Firm* — XSENSUS LLP

(57) **ABSTRACT**

An antenna module includes feeding elements arranged adjacent to each other and filters connected to the respective feeding elements. Each of the filters includes a plurality of resonant lines that is not connected to each other. The filters are arranged between the feeding elements so as to cross a virtual line equidistant from the feeding elements when the antenna module is viewed in plan from the normal direction.

20 Claims, 16 Drawing Sheets



(51) **Int. Cl.**

H01Q 1/48	(2006.01)
H01Q 5/385	(2015.01)
H01Q 21/00	(2006.01)
H01Q 21/24	(2006.01)
H04B 1/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 21/0006*** (2013.01); ***H01Q 21/24*** (2013.01); ***H04B 1/0057*** (2013.01); *H01Q 1/48* (2013.01)

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FIG. 1

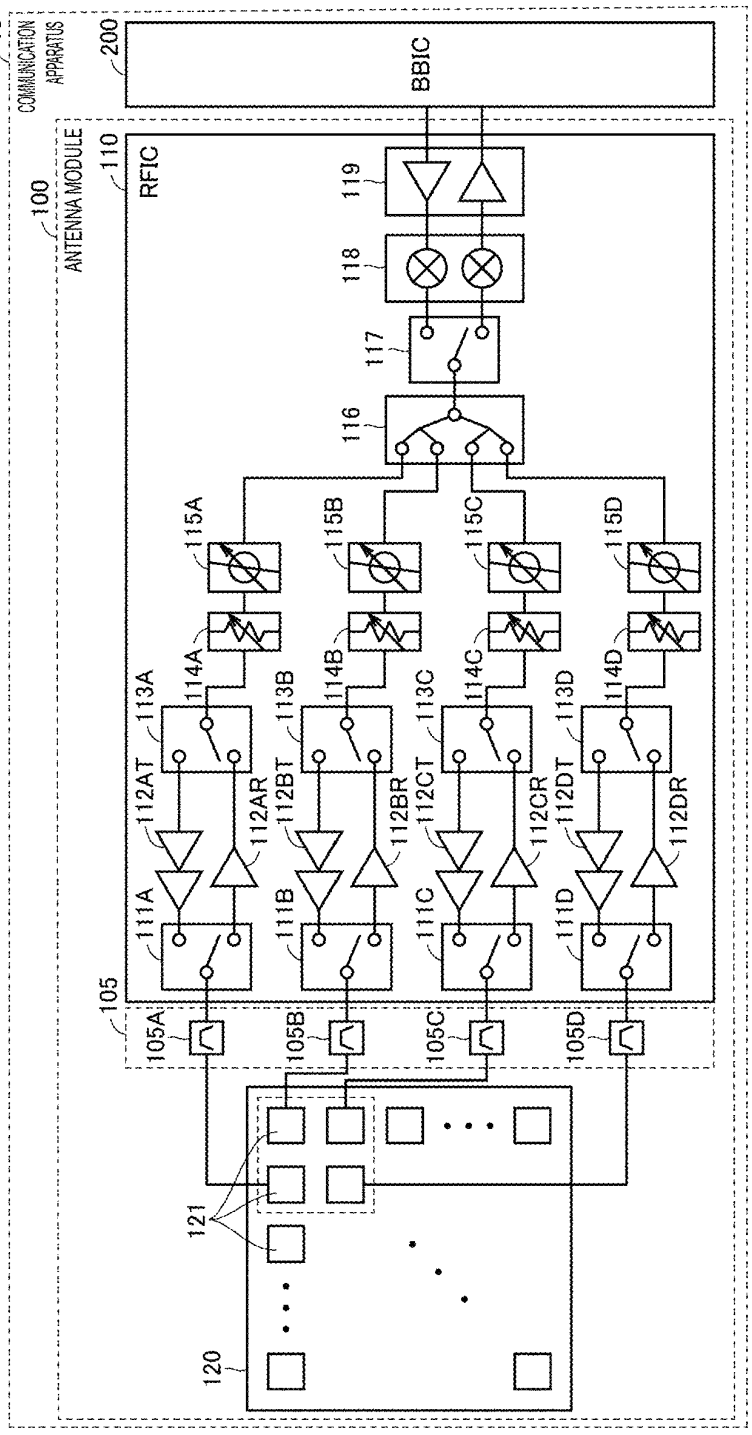
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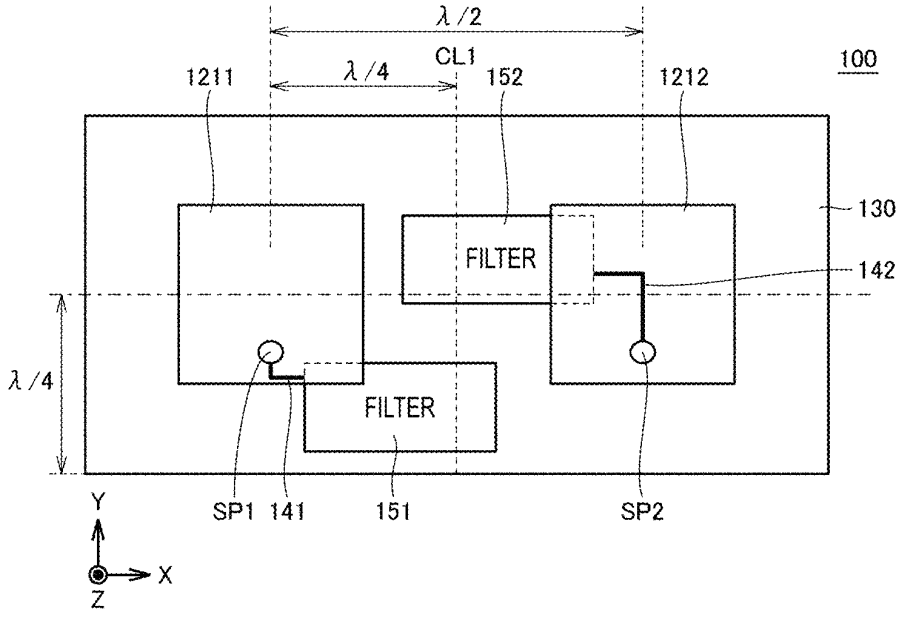
FIG. 2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Z

FIG. 3

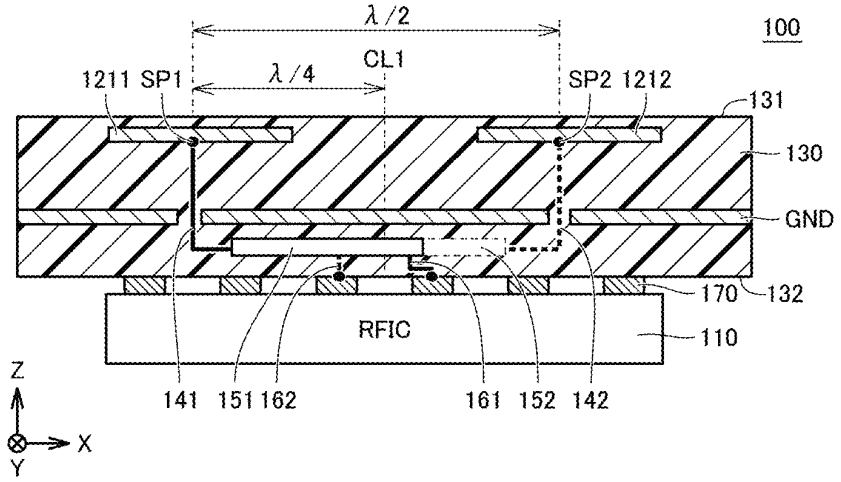
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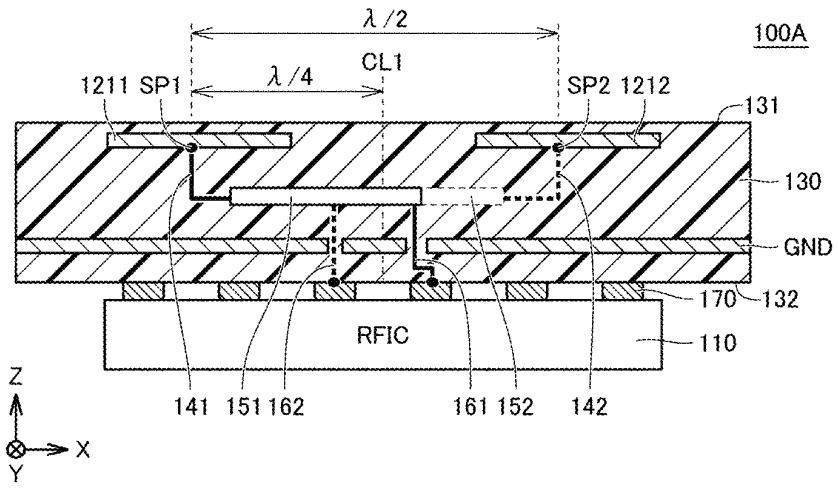
FIG. 4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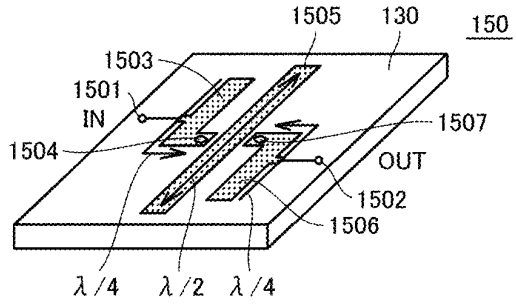
142
Z
X
Y

FIG. 5

(a)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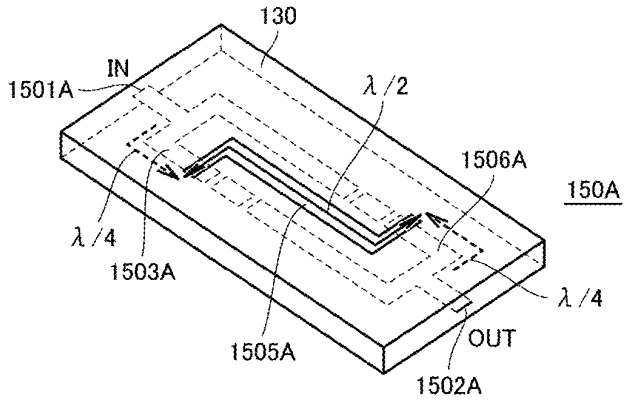
1501
IN
1507
1504
OUT
1502
1506
λ/4
λ/2
λ/4

(b)


130
IN
1501A
λ/2
1506A
150A
λ/4
1503A
λ/4
OUT
1505A
1502A

(c)

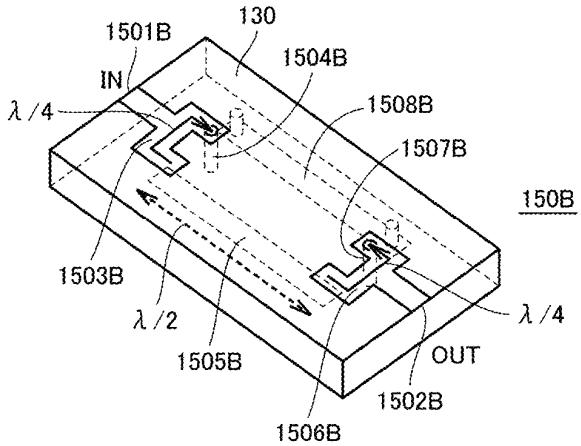

1501B
130
IN
1504B
λ/4
1508B
1507B
150B
1503B
λ/4
λ/2
OUT
1505B
1502B
1506B

FIG. 6

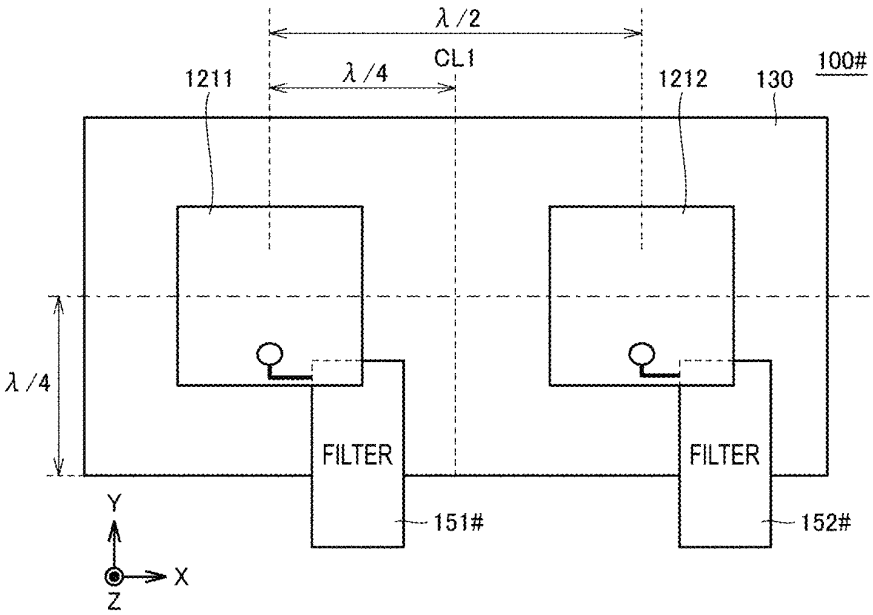

λ/2
CL1
λ/4
1211
1212
130
100#
λ/4
FILTER
FILTER
151#
152#
Y
X
Z

FIG. 7

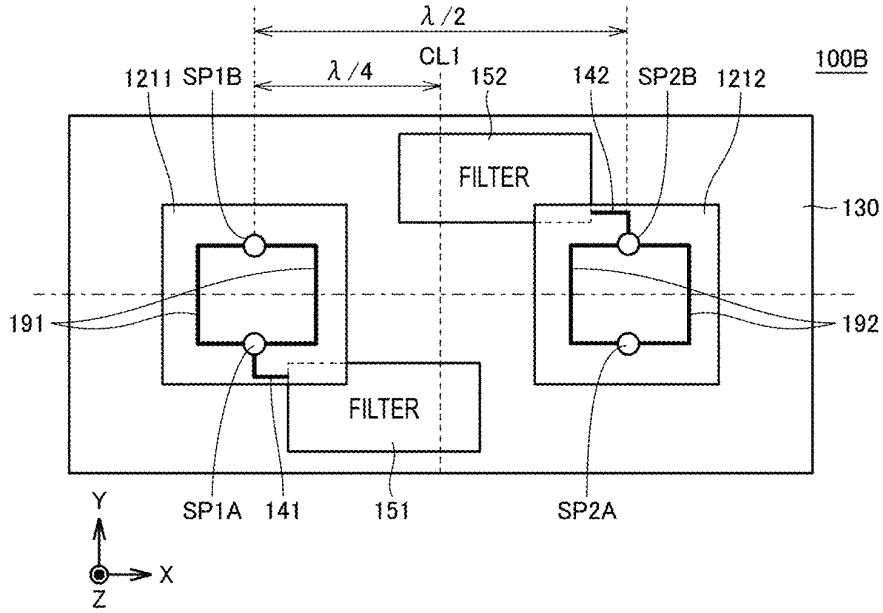

λ/2
CL1
λ/4
1211
SP1B
152
142
SP2B
1212
100B
FILTER
130
191
192
FILTER
SP1A
141
151
SP2A
Y
X
Z

FIG. 8

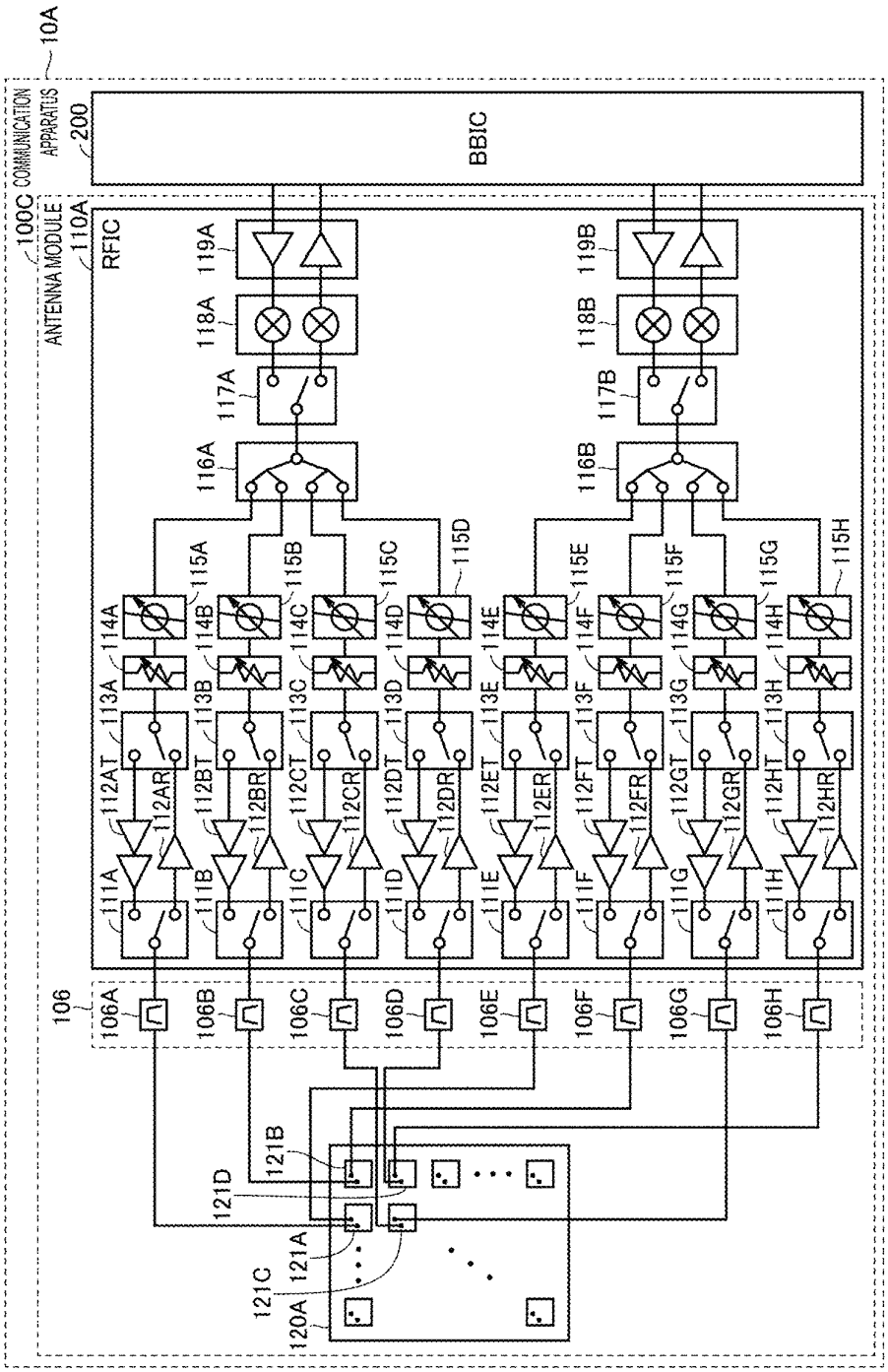

10A
COMMUNICATION APPARATUS
200
BBIC
100C
ANTENNA MODULE
110A
RFIC
119A
119B
118A
118B
117A
117B
116A
116B
115A
115B
115C
115D
115E
115F
115G
115H
114A
114B
114C
114D
114E
114F
114G
114H
113A
113B
113C
113D
113E
113F
113G
113H
112AT
112AR
112BT
112BR
112CT
112CR
112DT
112DR
112ET
112ER
112FT
112FR
112GT
112GR
112HT
112HR
111A
111B
111C
111D
111E
111F
111G
111H
106
106A
106B
106C
106D
106E
106F
106G
106H
121B
121D
121A
121C
120A

FIG. 9

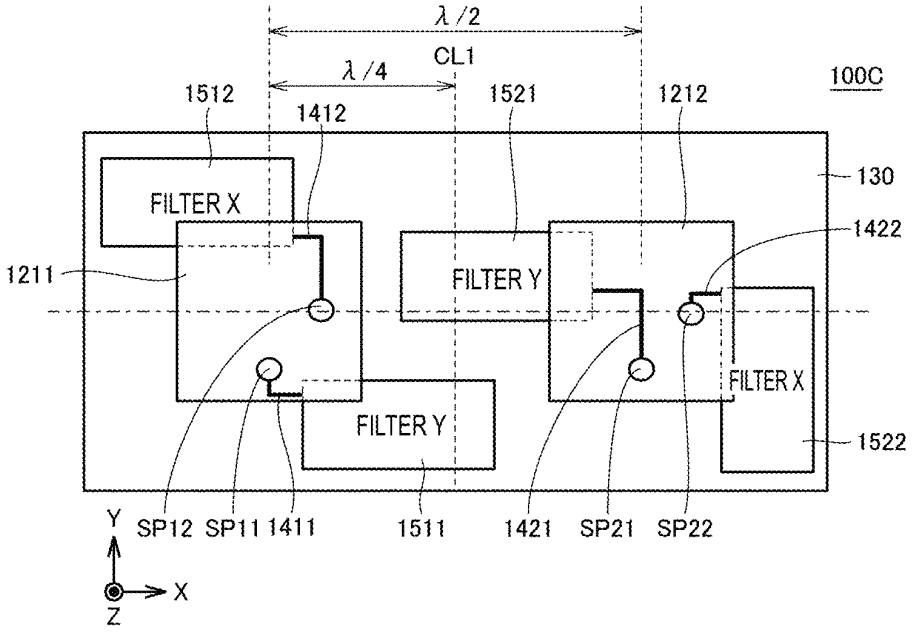

λ/2
CL1
λ/4
100C
1512
1412
1521
1212
130
FILTER X
1422
1211
FILTER Y
FILTER X
FILTER Y
1522
Y
SP12
SP11
1411
1511
1421
SP21
SP22
X
Z

FIG. 10

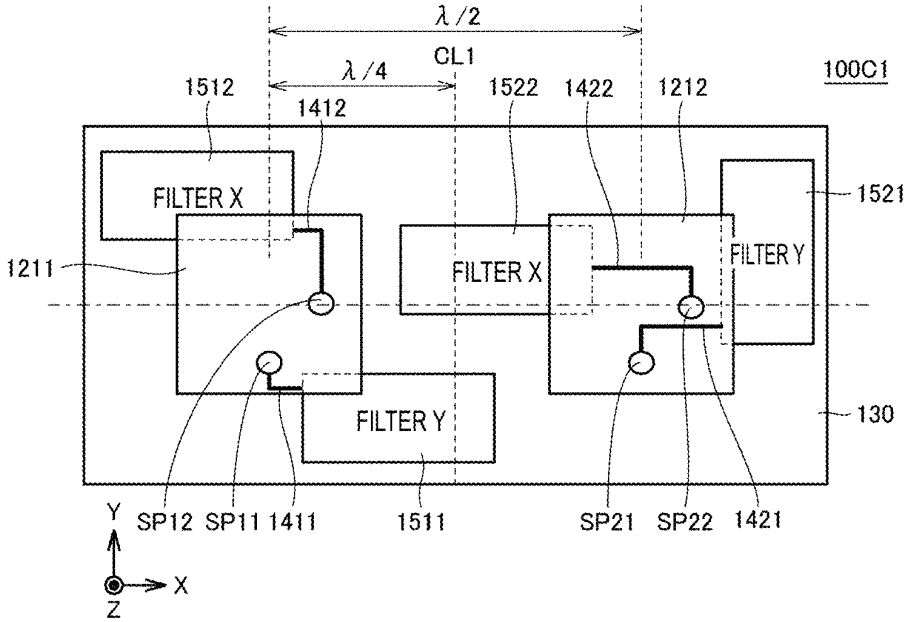

λ/2
CL1
λ/4
100C1
1512
1412
1522
1422
1212
FILTER X
1521
1211
FILTER X
FILTER Y
FILTER Y
130
Y
SP12
SP11
1411
1511
SP21
SP22
1421
X
Z

FIG. 11

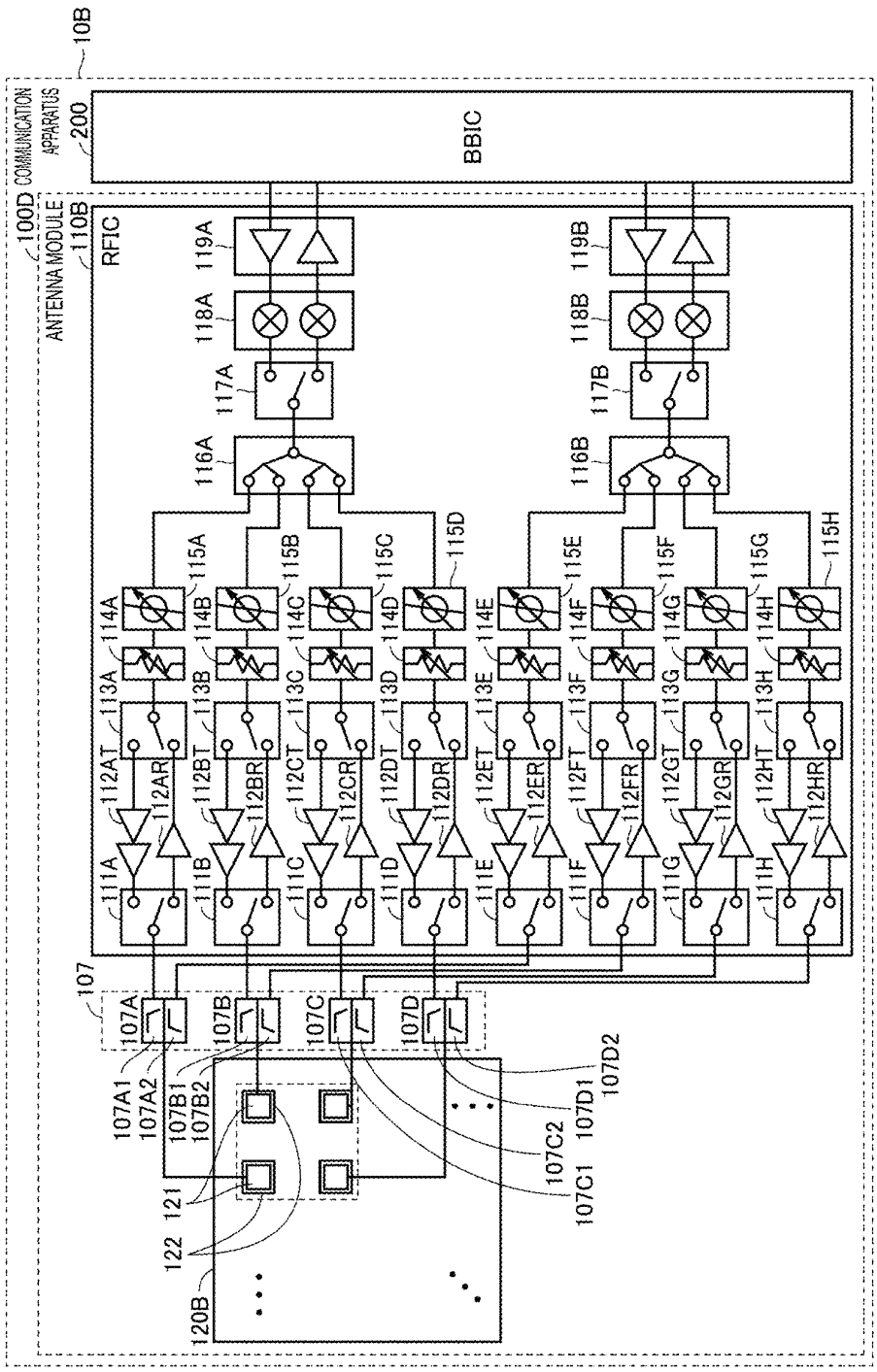

10B
COMMUNICATION APPARATUS
200
BBIC
100D
ANTENNA MODULE
110B
RFIC
119A
119B
118A
118B
117A
117B
116A
116B
115A
115B
115C
115D
115E
115F
115G
115H
114A
114B
114C
114D
114E
114F
114G
114H
113A
113B
113C
113D
113E
113F
113G
113H
112AT
112AR
112BT
112BR
112CT
112CR
112DT
112DR
112ET
112ER
112FT
112FR
112GT
112GR
112HT
112HR
111A
111B
111C
111D
111E
111F
111G
111H
107
107A
107B
107C
107D
107A1
107A2
107B1
107B2
107C2
107C1
107D1
107D2
121
122
120B

FIG. 12

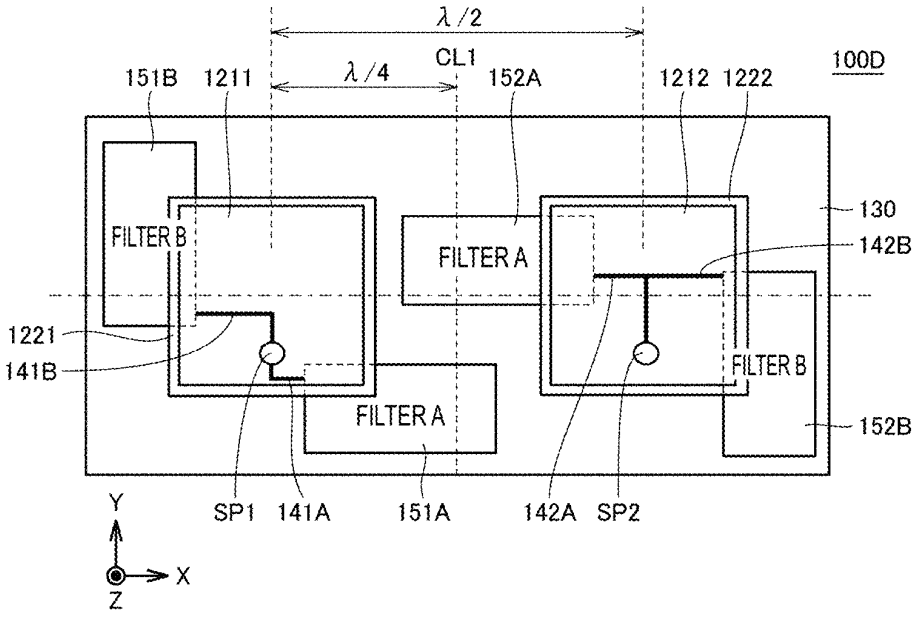

λ/2
CL1
λ/4
100D
151B
1211
152A
1212
1222
130
142B
FILTER B
FILTER A
1221
141B
FILTER B
FILTER A
152B
SP1
141A
151A
142A
SP2
Y
X
Z

FIG. 13

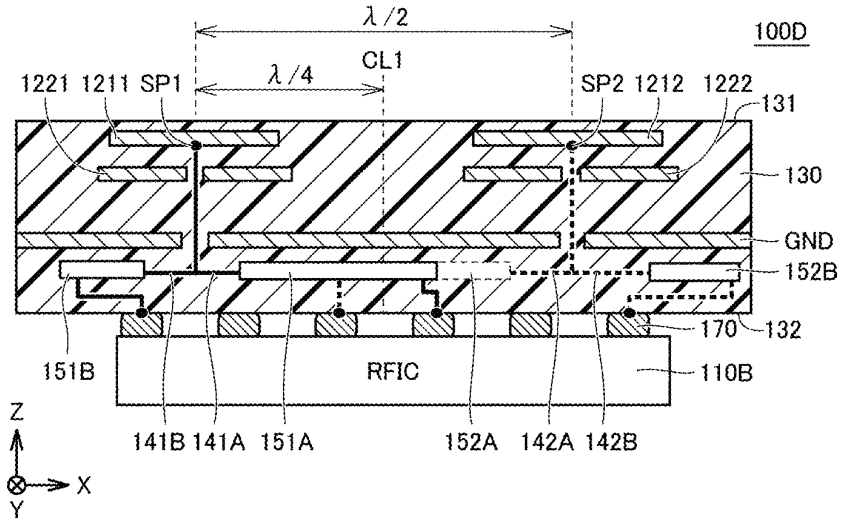

λ/2
CL1
λ/4
100D
1221
1211
SP1
SP2
1212
1222
131
130
GND
152B
170
132
151B
RFIC
110B
Z
X
Y
141B
141A
151A
152A
142A
142B

FIG. 14

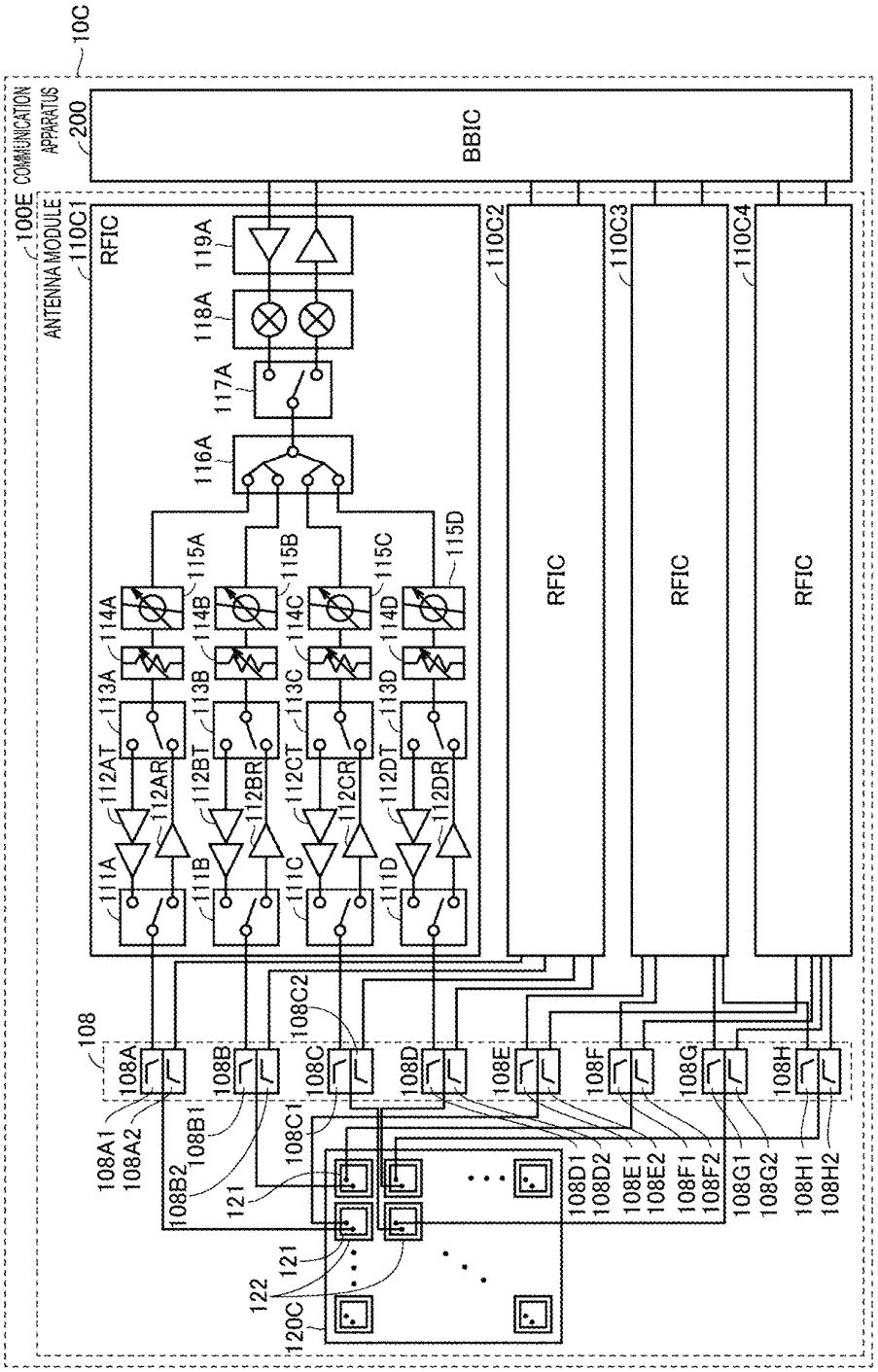

10C
COMMUNICATION APPARATUS
200
BBIC
100E
ANTENNA MODULE
110C1
RFIC
110C2
110C3
110C4
RFIC
RFIC
RFIC
119A
118A
117A
116A
115A
115B
115C
115D
114A
114B
114C
114D
113A
113B
113C
113D
112AT
112AR
112BT
112BR
112CT
112CR
112DT
112DR
111A
111B
111C
111D
108
108A
108B
108C
108C2
108D
108E
108F
108G
108H
108A1
108A2
108B1
108B2
108C1
121
122
120C
108D1
108D2
108E1
108E2
108F1
108F2
108G1
108G2
108H1
108H2

FIG. 15

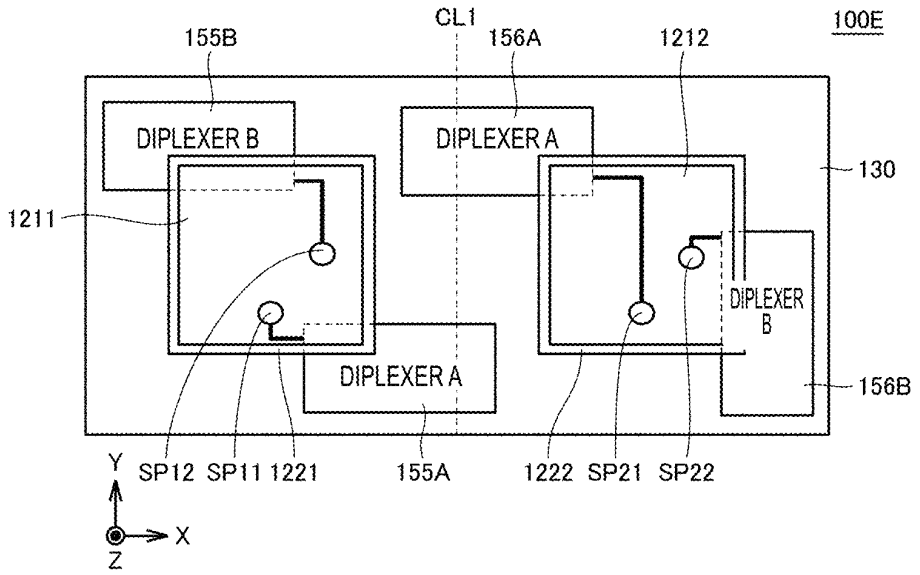

CL1
155B
156A
1212
100E
DIPLEXER B
DIPLEXER A
130
1211
DIPLEXER B
DIPLEXER A
156B
Y
SP12
SP11
1221
155A
1222
SP21
SP22
X
Z

FIG. 16

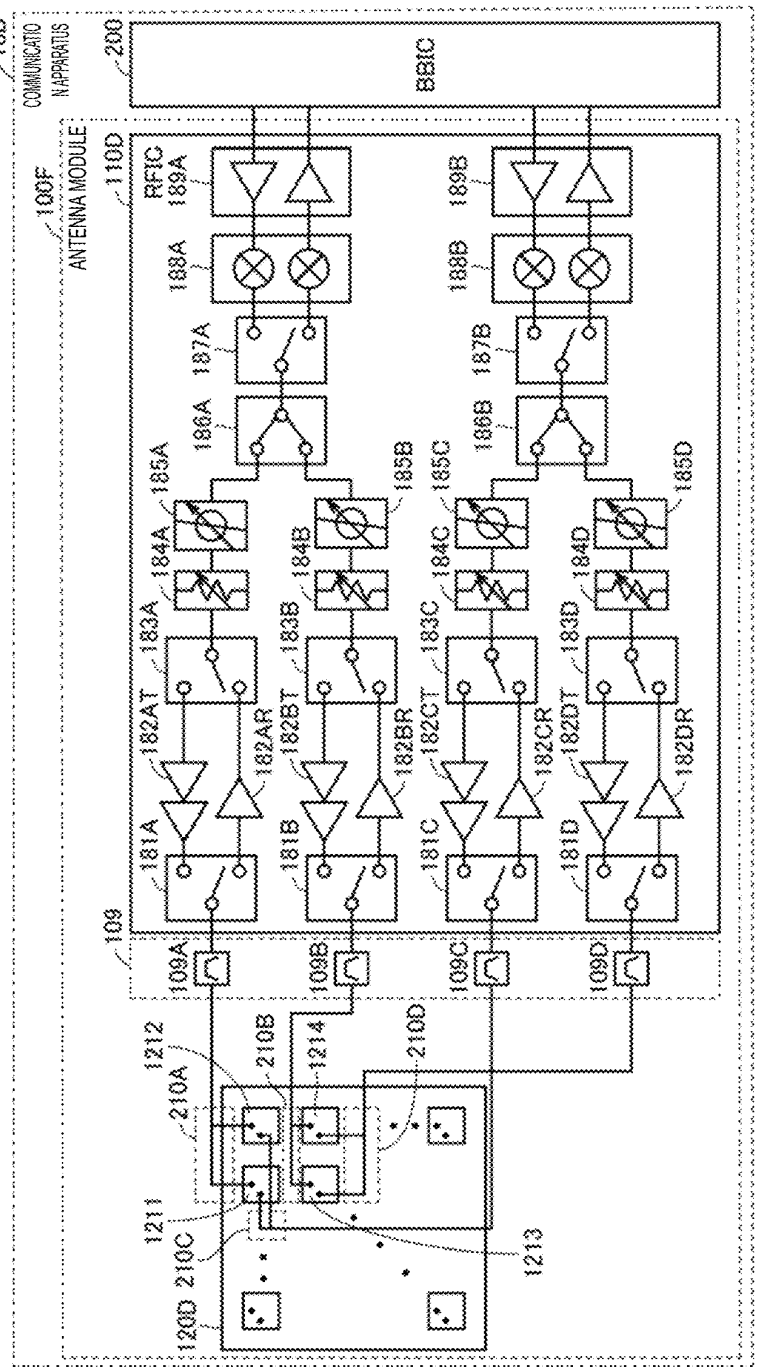

10D
COMMUNICATIO N APPARATUS
100F
ANTENNA MODULE
200
BBIC
110D
RFIC
189A
189B
188A
188B
187A
187B
186A
186B
185A
185B
185C
185D
184A
184B
184C
184D
183A
183B
183C
183D
182AT
182AR
182BT
182BR
182CT
182CR
182DT
182DR
181A
181B
181C
181D
109
109A
109B
109C
109D
1212
210A
210B
1214
210D
1211
210C
1213
120D

FIG. 17

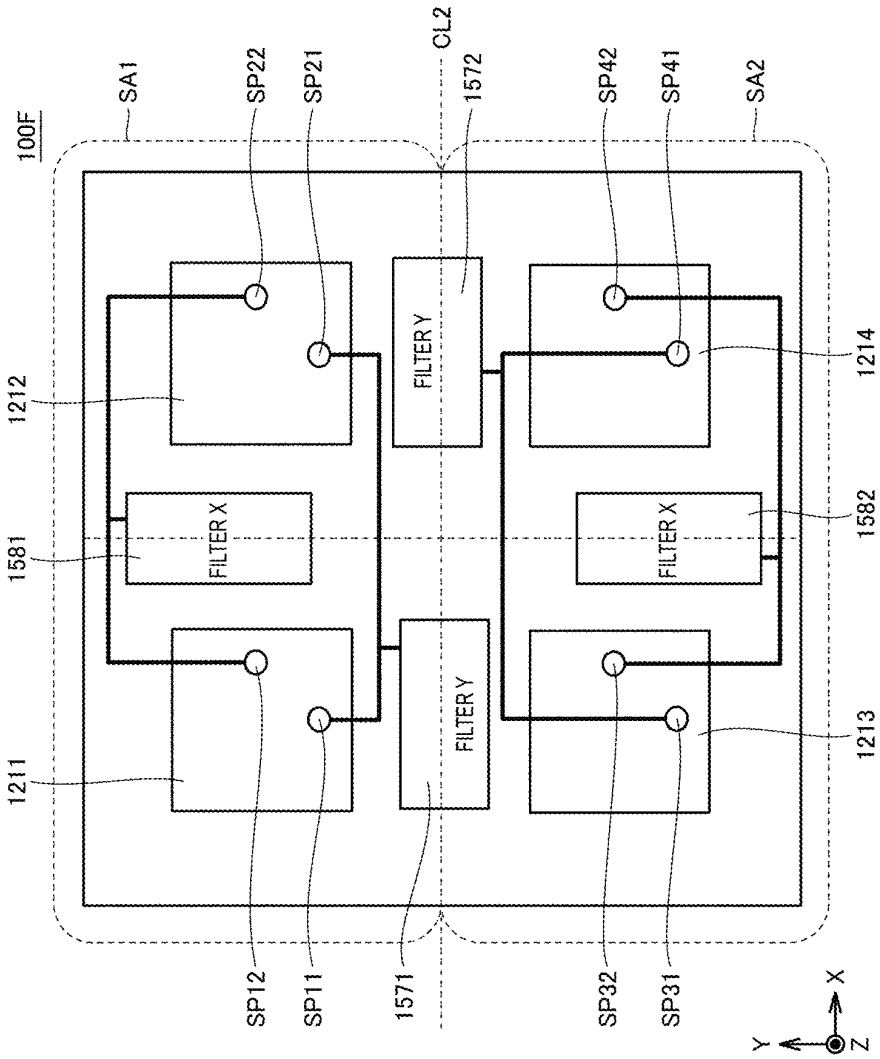

100F
SA1
SP22
SP21
CL2
1572
SP42
SP41
SA2
1212
FILTER Y
1214
1581
FILTER X
FILTER X
1582
1211
FILTER Y
1213
SP12
SP11
1571
SP32
SP31
X
Y
Z

FIG. 18

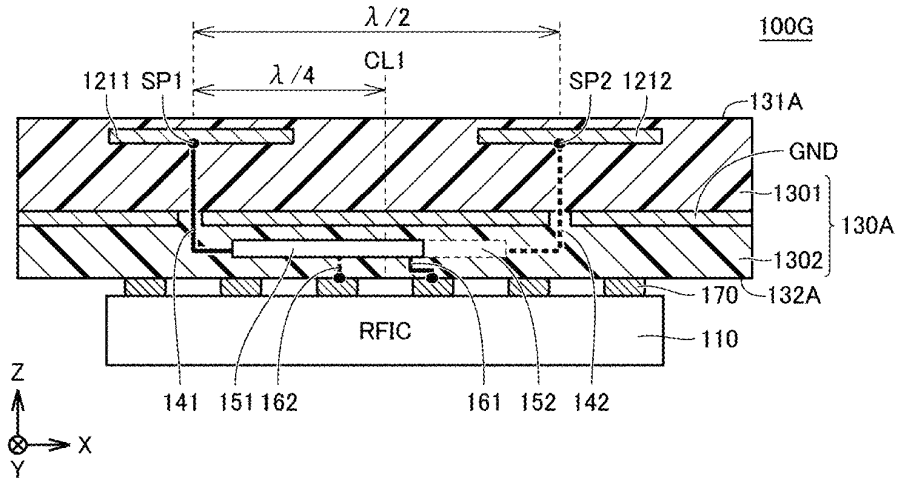

λ/2
λ/4
CL1
100G
1211 SP1
SP2 1212
131A
GND
1301
130A
1302
170
132A
RFIC
110
141 151 162
161 152 142
Z
X
Y

FIG. 19

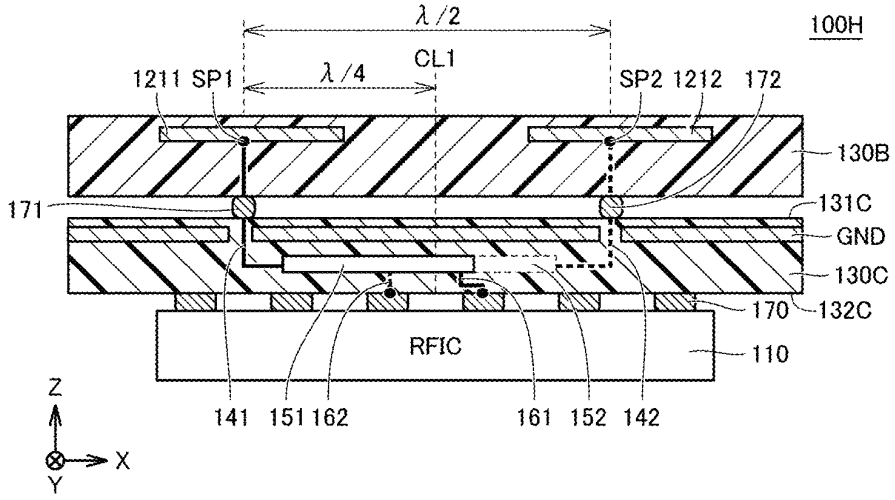

λ/2
λ/4
CL1
100H
1211 SP1
SP2 1212 172
130B
171
131C
GND
130C
170
132C
RFIC
110
141 151 162
161 152 142
Z
X
Y

FIG. 20

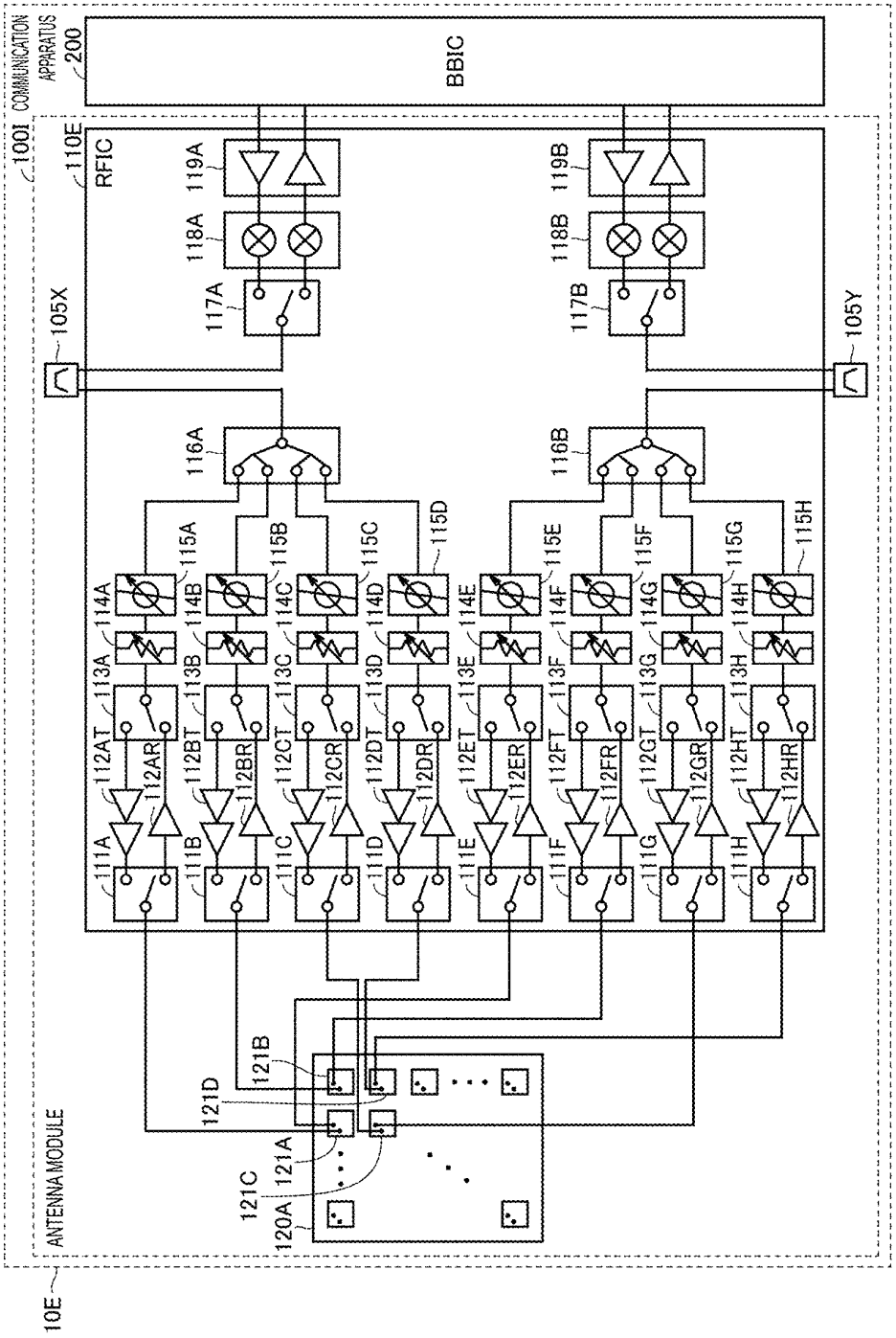

COMMUNICATION APPARATUS
200
BBIC
100I
110E
RFIC
119A
118A
117A
105X
119B
118B
117B
105Y
116A
116B
115A
115B
115C
115D
115E
115F
115G
115H
114A
114B
114C
114D
114E
114F
114G
114H
113A
113B
113C
113D
113E
113F
113G
113H
112AT
112AR
112BT
112BR
112CT
112CR
112DT
112DR
112ET
112ER
112FT
112FR
112GT
112GR
112HT
112HR
111A
111B
111C
111D
111E
111F
111G
111H
121B
121D
121A
121C
120A
ANTENNA MODULE
10E

FIG. 21

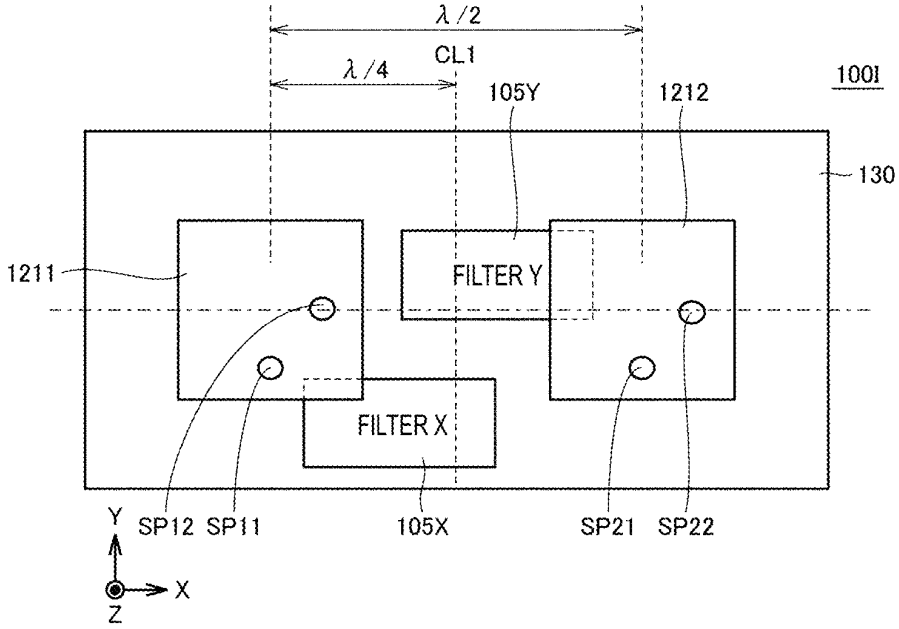
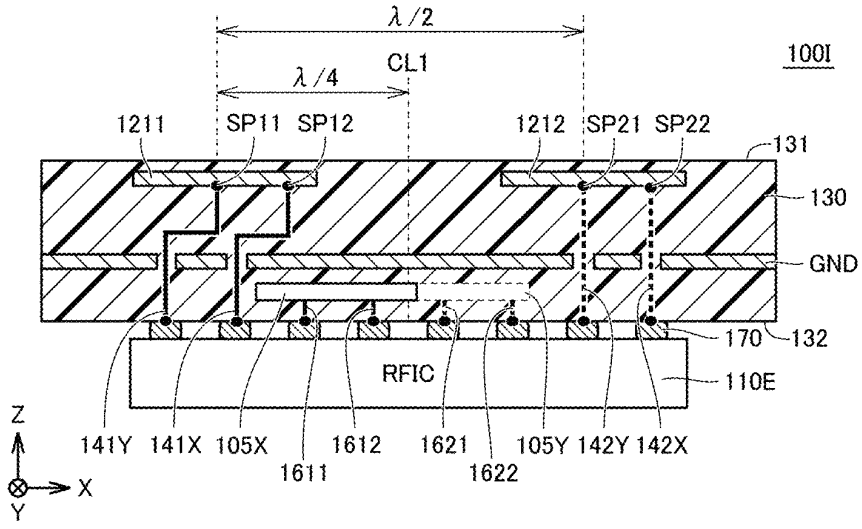

λ/2
CL1
λ/4
105Y
1212
100I
130
1211
FILTER Y
FILTER X
Y
SP12
SP11
105X
SP21
SP22
X
Z

FIG. 22


λ/2
CL1
λ/4
100I
1211
SP11
SP12
1212
SP21
SP22
131
130
GND
170
132
RFIC
110E
Z
141Y
141X
105X
1612
1621
105Y
142Y
142X
1611
1622
X
Y

ANTENNA MODULE, COMMUNICATION APPARATUS INCLUDING THE SAME, AND CIRCUIT SUBSTRATE

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to Japanese patent application JP2019-106776, filed Jun. 7, 2019, and PCT/JP2020/017024, filed Apr. 20, 2020, the entire contents of each of which being incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to an antenna module, a communication apparatus including the antenna module, and a circuit substrate. More specifically, the present disclosure relates to arrangement of filters in an array antenna in which the filters are formed in the same substrate.

BACKGROUND ART

Japanese Unexamined Patent Application Publication No. 2000-114847 (Patent Document 1) discloses an array antenna in which a plurality of antenna elements is two-dimensionally arrayed. In the array antenna disclosed in Japanese Unexamined Patent Application Publication No. 2000-114847 (Patent Document 1), the antenna elements are divided into a plurality of array groups, and a common feeding point is set for each of the groups. A radio frequency signal distributed from the corresponding feeding point is supplied to the antenna elements of each array group. With such a configuration, directional characteristics of radio waves to be radiated can be adjusted by individually controlling the array groups.

CITATION LIST

Patent Document

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2000-114847

SUMMARY

Technical Problems

In the array antenna as described above, the radio frequency signal is supplied from the common feeding point to the respective antenna elements (radiation elements) using individual feeder lines. In general, in the array antenna, when a wavelength of the radio waves that are radiated is λ, the radiation elements may be arranged at an interval of substantially λ/2. In this case, as recognized by the present inventors, in order to prevent interference of the feeder lines between the adjacent radiation elements each other, it is necessary to arrange the corresponding feeder lines in regions of a distance of λ/4 from the respective antenna elements.

Further, in the case where circuits such as filters are arranged for the respective radiation elements in the substrate of the array antenna, when a single circuit cannot be arranged in the region of the distance of λ/4 from the corresponding antenna element, the circuits are not possibly accommodated in a region of the whole array antenna unless the circuits are appropriately laid out.

The present disclosure has been made in order to solve such problems, and an aspect thereof is to appropriately arrange a plurality of filters in a region of an antenna module in which the filters are formed in the same substrate while suppressing increase in the size of the antenna module in an array antenna formed by including the antenna module.

Solutions

An antenna module according to an aspect of the present disclosure includes a first radiation element and a second radiation element arranged adjacent to each other and having planar shapes, a first filter connected to the first radiation element, and a second filter connected to the second radiation element. Each of the first filter and the second filter includes a plurality of resonant lines that is not connected to each other. Each of the first filter and the second filter is arranged between the first radiation element and the second radiation element so as to cross a virtual line equidistant from the first radiation element and the second radiation element when the antenna module is viewed in plan from a normal direction.

An antenna module according to another aspect of the present disclosure includes a first sub antenna and a second sub antenna arranged adjacent to each other. Each of the first sub antenna and the second sub antenna includes a plurality of radiation elements having planar shapes and arrayed in a second direction different from a first direction toward the second sub antenna from the first sub antenna. The antenna module further includes a first filter connected to the radiation element included in the first sub antenna and a second filter connected to the radiation element included in the second sub antenna. Each of the first filter and the second filter includes a plurality of resonant lines that is not connected to each other. Each of the first filter and the second filter is arranged between the first sub antenna and the second sub antenna so as to cross a virtual line equidistant from the first sub antenna and the second sub antenna when the antenna module is viewed in plan from a normal direction. The first filter and the second filter are arranged side by side in the second direction.

A circuit substrate according to still another aspect of the present disclosure relates to a circuit substrate including a first terminal and a second terminal connected to a first radiation element and a second radiation element arranged adjacent to each other and having planar shapes, respectively. The circuit substrate includes a first filter connected to the first terminal and a second filter connected to the second terminal. Each of the first filter and the second filter includes a plurality of resonant lines that is not connected to each other. Each of the first filter and the second filter is arranged between the first terminal and the second terminal so as to cross a virtual line equidistant from the first terminal and the second terminal when the circuit substrate is viewed in plan from a normal direction.

Advantageous Effects

With the antenna module according to the present disclosure, the filters corresponding to the two radiation elements (sub antennas) arranged adjacent to each other are arranged between the two radiation elements (sub antennas) so as to cross the virtual line equidistant from the two radiation elements (sub antennas) and are arranged in the direction orthogonal to the direction in which the two radiation elements (sub antennas) are adjacent to each other when the antenna module is viewed in plan. With this configuration,

the filters can be appropriately arranged in a region of the antenna module, so that increase in the size of the antenna module can be suppressed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram of a communication apparatus to which an antenna module according to a first embodiment is applied.

FIG. **2** is a plan perspective view of the antenna module in FIG. **1**.

FIG. **3** is a side perspective view of a first example of the antenna module in FIG. **1**.

FIG. **4** is a side perspective view of a second example of the antenna module in FIG. **1**.

FIG. **5** is a view for explaining examples of the configuration of a resonant line-type filter.

FIG. **6** is a plan perspective view of an antenna module in a comparative example.

FIG. **7** is a plan perspective view of an antenna module in a modification.

FIG. **8** is a block diagram of a communication apparatus to which an antenna module according to a second embodiment is applied.

FIG. **9** is a plan perspective view of a first example of the antenna module in FIG. **8**.

FIG. **10** is a plan perspective view of a second example of the antenna module in FIG. **8**.

FIG. **11** is a block diagram of a communication apparatus to which an antenna module according to a third embodiment is applied.

FIG. **12** is a plan perspective view of the antenna module in FIG. **11**.

FIG. **13** is a side perspective view of the antenna module in FIG. **11**.

FIG. **14** is a block diagram of a communication apparatus to which an antenna module according to a fourth embodiment is applied.

FIG. **15** is a plan perspective view of the antenna module in FIG. **14**.

FIG. **16** is a block diagram of a communication apparatus to which an antenna module according to a fifth embodiment is applied.

FIG. **17** is a plan perspective view of the antenna module in FIG. **16**.

FIG. **18** is a side perspective view of an antenna module in a first modification.

FIG. **19** is a side perspective view of an antenna module in a second modification.

FIG. **20** is a block diagram of a communication apparatus to which an antenna module according to a sixth embodiment is applied.

FIG. **21** is a plan perspective view of the antenna module in FIG. **20**.

FIG. **22** is a side perspective view of the antenna module in FIG. **20**.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. In the accompanying drawings, the same or corresponding portions are denoted by the same reference numerals, and description thereof will not be repeated.

First Embodiment

(Basic Configuration of Communication Apparatus)

FIG. **1** is an example of a block diagram of a communication apparatus **10** to which an antenna module **100** according to a first embodiment is applied. The communication apparatus **10** is, for example, a mobile terminal such as a mobile phone, a smart phone, and a tablet or a personal computer having a communication function. As a frequency band of radio waves that are used in the antenna module **100** in the embodiment, radio waves in a millimeter wave band, which have center frequencies of 28 GHz, 39 GHz, 60 GHz, and the like, are exemplified. Radio waves in frequency bands other than the above-described ones can however be applied, such as a band up to 300 GHz.

Referring to FIG. **1**, the communication apparatus **10** includes the antenna module **100** and a BBIC **200** configuring a baseband signal processing circuit. The antenna module **100** includes an RFIC **110** that is an example of a feeding circuit, an antenna device **120**, and a filter device **105**. The communication apparatus **10** up-converts a signal transmitted from the BBIC **200** to the antenna module **100** into radio frequency signals in the RFIC **110** and radiates the signals from the antenna device **120** after passing through the filter device **105**. The communication apparatus **10** transmits radio frequency signals received by the antenna device **120** to the RFIC **110** for down conversion after passing through the filter device **105** and the down-converted signal is processed in the BBIC **200**.

FIG. **1** illustrates only configurations corresponding to four feeding elements **121** among a plurality of feeding elements **121** (radiation elements) configuring the antenna device **120** for ease of description, and illustration of configurations corresponding to the other feeding elements **121** having similar configurations is omitted. In this context "feeding element" may be construed as the radiation element itself. However, "feeding element" may also include, as a separate component, the feed path that conveys RF to/from each radiating element with other circuitry such as filter **105**. Although FIG. **1** illustrates an example in which the antenna device **120** is formed of the plurality of feeding elements **121** arranged in a two-dimensional array, a one-dimensional array in which the plurality of feeding elements **121** is arranged in a line may be used. In the embodiment, the feeding elements **121** are patch antennas having substantially square flat plate shapes.

The RFIC **110** includes switches **111**A to **111**D, **113**A to **113**D, and **117**, power amplifiers **112**AT to **112**DT, low noise amplifiers **112**AR to **112**DR, attenuators **114**A to **114**D, phase shifters **115**A to **115**D, a signal multiplexer/demultiplexer **116**, a mixer **118**, and an amplifier circuit **119**.

When the radio frequency signal is transmitted, the switches **111**A to **111**D and **113**A to **113**D are switched to the side of the power amplifiers **112**AT to **112**DT, and the switch **117** is connected to a transmission-side amplifier of the amplifier circuit **119**. When the radio frequency signals are received, the switches **111**A to **111**D and **113**A to **113**D are switched to the side of the low noise amplifiers **112**AR to **112**DR, and the switch **117** is connected to a reception-side amplifier of the amplifier circuit **119**.

The signal transmitted from the BBIC **200** is amplified by the amplifier circuit **119** and up-converted by the mixer **118**. The transmission signal, which is the up-converted radio frequency signal, is divided into four by the signal multiplexer/demultiplexer **116**, passes through four signal paths, and is fed to respective different feeding elements **121**. At this time, the directivity of the antenna device **120** can be

adjusted by individually adjusting the phase shift degrees of the phase shifters **115**A to **115**D arranged in the respective signal paths.

The reception signals, which are the radio frequency signals received by the feeding elements **121**, pass through four different signal paths and are multiplexed by the signal multiplexer/demultiplexer **116**. The multiplexed reception signal is down-converted by the mixer **118**, amplified by the amplifier circuit **119**, and transmitted to the BBIC **200**.

The filter device **105** includes filters **105**A to **105**D. The filters **105**A to **105**D are respectively connected to the switches **111**A to **111**D in the RFIC **110**. The filters **105**A to **105**D have a function of attenuating signals in a specific frequency band. The filters **105**A to **105**D may be band pass filters, high pass filters, low pass filters, or combinations thereof. The radio frequency signals from the RFIC **110** pass through the filters **105**A to **105**D and are supplied to the corresponding feeding elements **121**.

In the case of the radio frequency signal in the millimeter wave band, a longer transmission line tends to cause noise components to be easily mixed. Therefore, it is preferable that a distance between the filter device **105** and the feeding elements **121** be as short as possible. That is, it is possible to suppress unnecessary waves from being radiated from the feeding elements by causing the radio frequency signals to pass through the filter device **105** immediately before being radiated from the feeding elements **121**. It is also possible to remove unnecessary waves included in the reception signals by causing the reception signals to pass through the filter device **105** immediately after being received by the feeding elements **121**.

Although the filter device **105** and the antenna device **120** are separately illustrated in FIG. **1**, in the present disclosure, the filter device **105** is formed inside the antenna device **120**, as will be described later.

The RFIC **110** is formed as, for example, a one-chip integrated circuit component including the above-described circuit configuration. Alternatively, devices (switches, power amplifiers, low noise amplifiers, attenuators, and phase shifters) corresponding to the respective feeding elements **121** in the RFIC **110** may be formed as one-chip integrated circuit components for the corresponding feeding elements **121**.

(Configuration of Antenna Module)

Next, the configuration of the antenna module **100** in the first embodiment will be described in detail with reference to FIGS. **2** and **3**. FIG. **2** is a plan perspective view of the antenna module **100**, and FIG. **3** is a side perspective view of the antenna module.

Although the case where the antenna module **100** is an array antenna including two feeding elements **1211** and **1212** as the radiation elements will be described in FIGS. **2** and **3** as an example, the number of feeding elements may be equal to or more than three, and further, the feeding elements may be two-dimensionally arrayed. The antenna module includes, in addition to the feeding elements **1211** and **1212** and the RFIC **110**, a dielectric substrate **130**, feeding wiring **141** and feeding wiring **142**, filters **151** and **152**, connection wiring **161** and connection wiring **162**, and a ground electrode GND. In the following description, a normal direction (radiation direction of radio waves) of the dielectric substrate **130** is defined as a Z-axis direction, and a plane perpendicular to the Z-axis direction is defined by an X axis and a Y axis. In addition, a positive direction and a negative direction of the Z axis in each drawing may be referred to as an upper side and a lower side, respectively.

The dielectric substrate **130** is, for example, a low temperature co-fired ceramics (LTCC) multilayer substrate, a multilayer resin substrate formed by laminating a plurality of resin layers made of resin such as epoxy or polyimide, a multilayer resin substrate formed by laminating a plurality of resin layers made of liquid crystal polymer (LCP) having a lower dielectric constant, a multilayer resin substrate formed by laminating a plurality of resin layers made of fluorine-based resin, or a ceramic multilayer substrate other than LTCC. The dielectric substrate **130** does not necessarily have a multilayer structure and may be a single-layer substrate.

The dielectric substrate **130** has a substantially rectangular shape, and the feeding elements **1211** and **1212** are arranged on an upper surface **131** (a surface in the positive direction of the Z axis) or an internal layer thereof. The feeding elements **1211** and **1212** are patch antennas having substantially square planar shapes. The feeding elements **1211** and **1212** are arranged adjacent to each other along the X-axis direction of the dielectric substrate **130**. When the wavelength of the radio waves that are radiated from the antenna module is λ, the feeding element **1211** and the feeding element **1212** are arranged such that their plane centers (intersection points of diagonal lines) are spaced apart by substantially $\lambda/2$.

In the dielectric substrate **130**, the ground electrode GND having a flat plate shape is arranged in a layer closer to a lower surface **132** (surface in the negative direction of the Z axis) than the feeding elements **1211** and **1212** so as to face the feeding elements **1211** and **1212**. The RFIC **110** is mounted on the lower surface **132** of the dielectric substrate **130** with solder bumps **170** interposed therebetween. The RFIC **110** may be connected to the dielectric substrate **130** using a multi-pole connector instead of the solder connection.

A radio frequency signal is supplied from the RFIC **110** to a feeding point SP**1** of the feeding element **1211** after passing through the connection wiring **161**, the filter **151**, and the feeding wiring **141**. Further, a radio frequency signal is supplied from the RFIC **110** to a feeding point SP**2** of the feeding element **1212** after passing through the connection wiring **162**, the filter **152**, and the feeding wiring **142**. In the example of FIG. **2**, the feeding point of each feeding element is arranged at a position offset from the center of the feeding element in the negative direction of the Y axis. By setting the feeding point at such a position, radio waves having a polarization direction being the Y-axis direction are radiated from each feeding element.

Each of the feeding wiring and the connection wiring is formed by a wiring pattern formed between layers of the dielectric substrate **130** and a via penetrating through the layers. In the antenna module **100**, conductors configuring the radiation elements, wiring patterns, electrodes, vias, and the like are made of metal containing aluminum (Al), copper (Cu), gold (Au), silver (Ag), or an alloy thereof as a main component.

The filters **151** and **152** correspond to the filter device **105** illustrated in FIG. **1**. Although the filters **151** and **152** are arranged between the lower surface **132** of the dielectric substrate **130** and the ground electrode GND in the example of FIG. **3**, the filters **151** and **152** may be arranged in a layer between the feeding elements **1211** and **1212** and the ground electrode GND as in an example of FIG. **4**. In FIG. **2** and subsequent plan perspective views, each filter is expressed by a rectangular shape being a region that can be occupied by the filter. The region may however have a substantially square shape or a more elongated rectangular shape depend-

ing on the configuration of the filter. Here, the "region that can be occupied by each filter" is not a region that is occupied by shapes of the resonant lines but a region including all of the resonant lines and expressed by a rectangular shape.

In the configuration of an antenna module **100**A in FIG. **4**, when the thickness of the dielectric substrate **130** is the same, a distance between the radiation elements and the ground electrode GND can be made larger than that in the antenna module **100** in FIG. **3**. Therefore, an advantage such as broadening of the frequency band width of the antenna module can be obtained. On the other hand, in the antenna module **100**A, parts of the filters may face the radiation elements. Therefore, there is a possibility that directivity or the like is affected by electromagnetic coupling between the radiation elements and the filters. In the antenna module **100** in FIG. **3**, coupling between the filters and the radiation elements is suppressed by the ground electrode GND. However, it is necessary to secure a distance between the ground electrode GND and the lower surface **132**, and there is a possibility that the frequency band or the like is affected when the distance between the radiation element and the ground electrode GND cannot be secured. Which of the configurations illustrated in FIGS. **3** and **4** is to be employed is determined in consideration of desired antenna characteristics, a device size, manufacturing cost, and the like.

Referring again to FIG. **2**, when the antenna module **100** is viewed in plan from the normal direction, each of the filters **151** and **152** is arranged so as to cross a virtual line CL**1** equidistant from the feeding element **1211** and the feeding element **1212**. Here, since the virtual line CL**1** is equidistant from the two feeding elements, the virtual line CL**1** extends in a second direction (negative direction of the Y axis) orthogonal to a first direction (positive direction of the X axis) toward the feeding element **1212** from the feeding element **1211**. That is, the filter **151** and the filter **152** are arranged side by side in the second direction. The filter **151** is arranged further on the second direction side with respect to the feeding point SP**1**, and the filter **152** is arranged on the opposite side (positive direction of the Y axis) to the second direction with respect to the feeding point SP**1**.

The filter **151** and the filter **152** do not overlap with each other when the antenna module **100** is viewed in plan. Further, the filter **151** does not overlap with the feeding element **1212**, and the filter **152** does not overlap with the feeding element **1211**.

The filters **151** and **152** are so-called resonant line-type filters. The resonant line-type filters have a configuration in which a plurality of lines each having a length of λ/4 or λ/2 is adjacent to each other in a non-connected state and function as filters by electromagnetic field coupling between the resonant lines. The resonant line-type filter can be formed by a wiring pattern or a combination of a wiring pattern and a via, thereby obtaining an advantage that it can be relatively easily formed inside the dielectric substrate of the antenna array.

FIG. **5** is a view illustrating some examples of the configuration of resonant line-type filters corresponding to the filters **151** and **152**. Each of the filters illustrated in FIGS. **5**(*a*) to **5**(*c*) is formed in the dielectric substrate **130**.

A filter **150** in FIG. **5**(*a*) includes two lines **1503** and **1506** each having a length of λ/4 and a line **1505** having a length of λ/2. The lines **1503**, **1505**, and **1506** are formed in the same layer. The line **1503** is connected to an input terminal **1501**, and the line **1506** is connected to an output terminal **1502**. The line **1503** and the line **1506** have substantially L shapes, and one ends of the L shapes are connected to a ground potential by vias **1504** and **1507**, respectively. The line **1503** and the line **1506** are arranged such that the ends thereof to which the vias are connected face each other and are spaced apart from each other and the other ends thereof extend in opposite directions. The line **1505** formed of a linear line is arranged between the line **1503** and the line **1506**.

A filter **150**A in FIG. **5**(*b*) includes two lines **1503**A and **1506**A each having a length of λ/4 and a line **1505**A having a length of λ/2. The line **1503**A and the line **1506**A have substantially L shapes, and one ends of the L shapes are connected to an input terminal **1501**A and an output terminal **1502**A, respectively. The line **1505**A is formed in a layer different from that of the lines **1503**A and **1506**A. The line **1505**A has a crank shape, one end of the line **1505**A is capacitively coupled to the other end of the line **1503**A, and the other end of the line **1505**A is capacitively coupled to the other end of the line **1506**A. Additional lines are connected to an end of the line **1503**A, which is connected to the input terminal **1501**A, and an end of the line **1506**A, which is connected to the output terminal **1502**A. Characteristics of the filter **150**A can thus be adjusted by providing the additional lines between the input terminal **1501**A and the output terminal **1502**A.

A filter **150**B in FIG. **5**(*c*) includes two lines **1503**B and **1506**B each having a length of λ/4 and a line **1505**B and a line **1508**B each having a length of λ/2. The line **1505**B is formed in a layer different from that of the lines **1503**B and **1506**B. The line **1503**B and the line **1506**B have substantially C shapes and are connected to an input terminal **1501**B and an output terminal **1502**B, respectively, at substantially central portions of the C shapes. One ends of the line **1503**B and the line **1506**B are connected to a ground potential by vias **1504**B and **1507**B, respectively. The other end of the line **1503**B is capacitively coupled to one end of the linear line **1505**B, and the other end of the line **1506**B is capacitively coupled to the other end of the line **1505**B. The line **1508**B is a linear line arranged parallel to the line **1505**B, and both ends thereof are connected to the ground potential by vias. Characteristics of the filter **150**B can be adjusted by providing the line **1508**B.

In the first embodiment, a configuration other than the filter illustrated in FIG. **5** may be applied as long as the configuration is a resonant line-type filter.

As described above, since the resonant line-type filter can be easily formed inside the dielectric substrate, it is suitable for a case where the filter is formed in the immediate vicinity of the radiation element. On the other hand, the resonant line-type filter requires a larger area than that when an LC filter realized by a coiled inductor and a capacitor formed by two flat plate electrodes, which is formed in a multilayer substrate, or a chip-type filter mounted on a substrate is used. In the case of the array antenna in which the plurality of radiation elements is arranged, there is a restriction on the interval between the adjacent radiation elements. For this reason, the size of the whole array antenna possibly increases unless the filters are appropriately arranged.

FIG. **6** is a plan perspective view of an antenna module **100** #in a comparative example. In the example of the antenna module **100** #, filters **151** #and **152** #are arranged such that positions of the filters with respect to feeding elements are the same, and parts of the filters protrude from regions of λ/4 from the corresponding feeding elements. In this case, the dielectric substrate **130** needs to be enlarged such that protruding portions are encompassed in the dielec-

tric substrate **130**, and the sizes of the antenna module and the whole antenna array increase.

On the other hand, in the antenna module **100** in the first embodiment illustrated in FIG. **2**, the two filters are arranged between the feeding elements so as to cross the virtual line equidistant from the feeding elements and are arranged side by side in the direction orthogonal to the array direction of the feeding elements. With such arrangement, the filters can be formed in the regions of the distance of λ/4 from the two feeding elements, so that increase in the size of the antenna module in the array antenna can be suppressed.

(Modification)

FIG. **7** is a plan perspective view of an antenna module **100**B in a modification. The antenna module **100**B has a configuration in which a plurality of feeding points for radiating radio waves in the same polarization direction is provided for each feeding element.

To be specific, referring to FIG. **7**, a feeding point SP**1**A and a feeding point SP**1**B are provided for the feeding element **1211**, and a feeding point SP**2**A and a feeding point SP**2**B are provided for the feeding element **1212**.

The feeding point SP**1**A is arranged at a position offset from the center of the feeding element **1211** in the negative direction of the Y axis, and the feeding point SP**1**B is arranged at a position offset from the center of the feeding element **1211** in the positive direction of the Y axis. Similarly, the feeding point SP**2**A is arranged at a position offset from the center of the feeding element **1212** in the negative direction of the Y axis, and the feeding point SP**2**B is arranged at a position offset from the center of the feeding element **1212** in the positive direction of the Y axis. That is, the feeding points SP**1**B and SP**2**B are arranged at positions offset from the center points (plane centers) of the feeding elements in the direction opposite to the offset direction of the feeding points SP**1**A and SP**2**A.

All of the feeding points SP**1**A, SP**1**B, SP**2**A, and SP**2**B are offset in the Y-axis direction from the center points of the feeding elements. Therefore, when radio frequency signals are supplied to these feeding points, radio waves having the polarization direction being the Y-axis direction are emitted from the feeding elements.

The feeding point SP**1**A is connected to the feeding point SP**1**B by lines **191**. Further, the feeding point SP**2**A is connected to the feeding point SP**2**B by lines **192**. When the wavelength of the radio waves that are radiated from each radiation element is λ, the lengths of the lines **191** and **192** are set to be λ/2. Accordingly, the phase of the radio frequency signal that is supplied to the feeding point SP**1**B is inverted with respect to the phase of the radio frequency signal that is supplied to the feeding point SP**1**A. Similarly, the phase of the radio frequency signal that is supplied to the feeding point SP**2**B is inverted with respect to the phase of the radio frequency signal that is supplied to the feeding point SP**2**A. This makes it possible to improve the cross polarization discrimination (XPD) indicating the degree of separation between main polarization and cross polarization in each feeding element.

In the antenna module **100**B, a radio frequency signal from the filter **151** corresponding to the feeding element **1211** is supplied to the feeding point SP**1**A after passing through the feeding wiring **141**. On the other hand, a radio frequency signal from the filter **152** corresponding to the feeding element **1212** is supplied to the feeding point SP**2**B after passing through the feeding wiring **142**.

When the antenna module **100**B is viewed in plan (from the radiating side of the radiation elements), the filter **151** and the filter **152** are arranged side by side in a second direction (Y-axis direction) orthogonal to a first direction (positive direction of the X axis) toward the feeding element **1212** from the feeding element **1211**. With such arrangement, the filters can be formed in the regions of the distance of λ/4 from the two feeding elements, so that increase in the size of the antenna module in the array antenna can be suppressed.

In the first embodiment and the modification, the "feeding element **1211**" and the "feeding element **1212**" correspond to a "first radiation element" and a "second radiation element" in the present disclosure, respectively, and the "filter **151**" and the "filter **152**" correspond to a "first filter" and a "second filter" in the present disclosure, respectively.

Second Embodiment

In the first embodiment, the configuration has been described in which the radio waves having one polarization direction are radiated from each radiation element. A second embodiment describes filter arrangement in the case of a so-called dual polarization type in which two radio waves having different polarization directions can be radiated from each radiation element.

(Basic Configuration of Communication Apparatus)

FIG. **8** is a block diagram of a communication apparatus to which an antenna module according to the second embodiment is applied. Referring to FIG. **8**, a communication apparatus **10**A includes an antenna module **100**C and the BBIC **200**. The antenna module **100**C includes an RFIC **110**A, an antenna device **120**A, and a filter device **106**.

The antenna device **120**A is a dual polarization-type antenna device, and a radio frequency signal for first polarization and a radio frequency signal for second polarization are supplied to each feeding element **121** from the RFIC **110**A.

The RFIC **110**A includes switches **111**A to **111**H, **113**A to **113**H, **117**A, and **117**B, power amplifiers **112**AT to **112**HT, low noise amplifiers **112**AR to **112**HR, attenuators **114**A to **114**H, phase shifters **115**A to **115**H, signal multiplexers/demultiplexers **116**A and **116**B, mixers **118**A and **118**B, and amplifier circuits **119**A and **119**B. Among them, the configurations of the switches **111**A to **111**D, **113**A to **113**D, and **117**A, the power amplifiers **112**AT to **112**DT, the low noise amplifiers **112**AR to **112**DR, the attenuators **114**A to **114**D, the phase shifters **115**A to **115**D, the signal multiplexer/demultiplexer **116**A, the mixer **118**A, and the amplifier circuit **119**A are circuits for the radio frequency signals for the first polarization. The configurations of the switches **111**E to **111**H, **113**E to **113**H, and **117**B, the power amplifiers **112**ET to **112**HT, the low noise amplifiers **112**ER to **112**HR, the attenuators **114**E to **114**H, the phase shifters **115**E to **115**H, the signal multiplexer/demultiplexer **116**B, the mixer **118**B, and the amplifier circuit **119**B are circuits for the radio frequency signals for the second polarization.

When the radio frequency signals are transmitted, the switches **111**A to **111**H and **113**A to **113**H are switched to the side of the power amplifiers **112**AT to **112**HT, and the switches **117**A and **117**B are connected to transmission-side amplifiers of the amplifier circuits **119**A and **119**B. When the radio frequency signals are received, the switches **111**A to **111**H and **113**A to **113**H are switched to the side of the low noise amplifiers **112**AR to **112**HR, and the switches **117**A and **117**B are connected to reception-side amplifiers of the amplifier circuits **119**A and **119**B.

The filter device **106** includes filters **106**A to **106**H. The filters **106**A to **106**H are connected to the switches **111**A to **111**H in the RFIC **110**A, respectively. Each of the filters

106A to 106H has a function of attenuating radio frequency signals in a specific frequency band.

The signals transmitted from the BBIC 200 are amplified by the amplifier circuits 119A and 119B and up-converted by the mixers 118A and 118B. The transmission signals, which are the up-converted radio frequency signals, are divided into four by the signal multiplexers/demultiplexers 116A and 116B, pass through corresponding signal paths, and are fed to the respective different feeding elements 121.

The radio frequency signals from the switches 111A and 111E are supplied to a feeding element 121A after passing through the filters 106A and 106E, respectively. Similarly, the radio frequency signals from the switches 111B and 111F are supplied to a feeding element 121B after passing through the filters 106B and 106F, respectively. The radio frequency signals from the switches 111C and 111G are supplied to a feeding element 121C after passing through the filters 106C and 106G, respectively. The radio frequency signals from the switches 111D and 111H are supplied to a feeding element 121D after passing through the filters 106D and 106H, respectively.

The directivity of the antenna device 120A can be adjusted by individually adjusting the phase shift degrees of the phase shifters 115A to 115H arranged on the respective signal paths.

The reception signals, which are radio frequency signals received by the feeding elements 121, are transmitted to the RFIC 110 after passing through the filter device 106. Then, the reception signals pass through four different signal paths and are multiplexed in the signal multiplexers/demultiplexers 116A and 116B. The multiplexed reception signals are down-converted by the mixers 118A and 118B, amplified by the amplifier circuits 119A and 119B, and transmitted to the BBIC 200.

(Configuration of Antenna Module)

FIG. 9 is an example of a plan perspective view of the antenna module 100C in FIG. 8. Referring to FIG. 9, the antenna module 100C has a configuration in which radio wave filters 1512 and 1522 (filters X) having polarization directions being the X-axis direction are added to the configuration of the antenna module 100 in the first embodiment described with reference to FIG. 2. Filters 1511 and 1521 (filters Y) having polarization directions being the Y-axis direction in FIG. 9 correspond to the filters 151 and 152 in FIG. 2. All of the filters 1511, 1512, 1521, and 1522 are the resonant line-type filters.

In the feeding element 1211, the radio frequency signal that has passed through the filter 1511 is supplied to a feeding point SP11 after passing through feeding wiring 1411, and the radio frequency signal that has passed through the filter 1512 is supplied to a feeding point SP12 after passing through feeding wiring 1412. In the feeding element 1212, the radio frequency signal that has passed through the filter 1512 is supplied to a feeding point SP21 after passing through feeding wiring 1421, and the radio frequency signal that has passed through the filter 1522 is supplied to a feeding point SP22 after passing through feeding wiring 1422.

The feeding points SP11 and SP21 are arranged at positions offset from the centers of the feeding elements in the negative direction of the Y axis. When the radio frequency signals are supplied to the feeding points SP11 and SP21, radio waves having the polarization directions being the Y-axis direction are radiated from each of the feeding elements. Further, the feeding points SP12 and SP22 are arranged at positions offset from the centers of the feeding elements in the positive direction of the X axis. When the radio frequency signals are supplied to the feeding points SP12 and SP22, radio waves having the polarization directions being the X-axis direction are radiated from each of the feeding elements.

Each of the filters 1511, 1512, 1521, and 1522 is arranged in a layer between the lower surface 132 of the dielectric substrate 130 and the ground electrode GND as illustrated in FIG. 3 in the first embodiment or in a layer between the feeding elements 1211 and 1212 and the ground electrode GND as illustrated in FIG. 4.

Similarly to the filters 151 and 152 in the first embodiment, the filters 1511 and 1521 are arranged so as to cross the virtual line CL1 equidistant from the feeding element 1211 and the feeding element 1212 when the antenna module 100C is viewed in plan from the normal direction. The filter 1511 and the filter 1521 are arranged side by side in a second direction (negative direction of the Y-axis) orthogonal to a first direction (positive direction of the X axis) toward the feeding element 1212 from the feeding element 1211. The filter 1511 is arranged further on the second direction side with respect to the feeding point SP11, and the filter 1512 is arranged in the direction (positive direction of the Y axis) opposite to the second direction with respect to the feeding point SP12.

The filter 1512 for polarization in the X-axis direction for the feeding element 1211 is arranged in the direction (negative direction of the X axis) opposite to the first direction with respect to the feeding point SP12 in a region in the direction (positive direction of the Y axis) opposite to the second direction with respect to the center of the feeding element 1211. On the other hand, the filter 1522 for polarization in the X-axis direction for the feeding element 1212 is arranged in a region in the first direction (positive direction of the X axis) with respect to the center of the feeding element 1212.

With such arrangement, all of the filters 1511, 1512, 1521, and 1522 can be arranged in the regions of the distance of $\lambda/4$ from the feeding elements 1211 and 1212, so that increase in the size of the antenna module in the array antenna can be suppressed.

In the antenna module 100C in FIG. 9, the "filter 1511" and the "filter 1521" correspond to the "first filter" and the "second filter", respectively, in the present disclosure, and the "filter 1512" and the "filter 1522" correspond to a "third filter" and a "fourth filter", respectively, in the present disclosure.

Note that the filters arranged in the region between the feeding elements 1211 and 1212 are not required to be the filters for the same polarization. For example, as in an antenna module 100C1 illustrated in FIG. 10, the filter 1511 for polarization in the Y-axis direction for the feeding element 1211 and the filter 1522 for polarization in the X-axis direction for the feeding element 1212 may be arranged in the region between the feeding elements 1211 and 1212. Although not illustrated in the drawing, the filter 1512 for polarization in the X-axis direction for the feeding element 1211 and the filter 1521 for polarization in the Y-axis direction for the feeding element 1212 may be arranged in the region between the feeding elements 1211 and 1212.

In the antenna module 100C1 in FIG. 10, the "filter 1511" and the "filter 1522" correspond to the "first filter" and the "second filter", respectively, in the present disclosure, and the "filter 1512" and the "filter 1521" correspond to the "third filter" and the "fourth filter", respectively, in the present disclosure.

As described above, in the dual polarization-type antenna module as well, all of the filters can be formed in the regions of the distance of λ/4 from the two feeding elements by arranging any filter for one radiation element and any filter for the other radiation element side by side in the direction orthogonal to the array direction of the feeding elements. Therefore, increase in the size of the antenna module in the array antenna can be suppressed.

Third Embodiment

In the first embodiment, the configuration has been described in which the radio waves in one frequency band are radiated from each radiation element. A third embodiment describes filter arrangement in the case of a so-called dual band-type in which two radio waves having different frequency bands can be radiated from each radiation element with reference to FIGS. **11** to **13**.

FIG. **11** is a block diagram of a communication apparatus **10**B to which an antenna module **100**D according to the third embodiment is applied. FIGS. **12** and **13** are a plan perspective view and a side perspective view, respectively, of an antenna module including two radiation elements.

Referring to FIG. **11**, the communication apparatus **10**B includes the antenna module **100**D and the BBIC **200**. The antenna module **100**D includes an RFIC **110**B, an antenna device **120**B, and a filter device **107**.

The antenna device **120**B includes, as radiation elements, the plurality of feeding elements **121** and parasitic elements **122** provided so as to correspond to the respective feeding elements **121**. The antenna device **120**B is a so-called dual band-type antenna device capable of radiating radio waves in two different frequency bands.

As illustrated in FIGS. **12** and **13**, the antenna module **100**D includes, as radiation elements, the feeding elements **1211** and **1212** and parasitic elements **1221** and **1222**. The parasitic element **1221** is arranged in a layer between the feeding element **1211** and the ground electrode GND in the dielectric substrate **130**. Feeding wiring **141**A penetrates through the parasitic element **1221** and is connected to the feeding point SP**1** of the feeding element **1211**. Similarly, the parasitic element **1222** is arranged in a layer between the feeding element **1212** and the ground electrode GND in the dielectric substrate **130**. Feeding wiring **142**A penetrates through the parasitic element **1222** and is connected to the feeding point SP**2** of the feeding element **1212**.

The sizes of the parasitic elements **1221** and **1222** are larger than the sizes of the feeding elements **1211** and **1212**. Therefore, the resonant frequencies of the parasitic elements **1221** and **1222** are lower than the resonant frequencies of the feeding elements **1211** and **1212**. Radio waves having frequencies lower than those of the feeding elements **1211** and **1212** can be radiated from the parasitic elements **1221** and **1222** by supplying radio frequency signals corresponding to the resonant frequencies of the parasitic elements **1221** and **1222** to the feeding wiring **141**A and the feeding wiring **142**A, respectively.

The RFIC **110**B is configured to be able to supply radio frequency signals in two frequency bands. Since the configuration of the RFIC **110**B is basically similar to that of the RFIC **110**A described in the second embodiment, detailed description thereof will not be repeated. In the RFIC **110**B, the configurations of the switches **111**A to **111**D, **113**A to **113**D, and **117**A, the power amplifiers **112**AT to **112**DT, the low noise amplifiers **112**AR to **112**DR, the attenuators **114**A to **114**D, the phase shifters **115**A to **115**D, the signal multiplexer/demultiplexer **116**A, the mixer **118**A, and the amplifier circuit **119**A in FIG. **11** are circuits for the radio frequency signals in a low frequency band. The configurations of the switches **111**E to **111**H, **113**E to **113**H, and **117**B, the power amplifiers **112**ET to **112**HT, the low noise amplifiers **112**ER to **112**HR, the attenuators **114**E to **114**H, the phase shifters **115**E to **115**H, the signal multiplexer/demultiplexer **116**B, the mixer **118**B, and the amplifier circuit **119**B in FIG. **11** are circuits for the radio frequency signals in a high frequency band.

The filter device **107** includes diplexers **107**A to **107**D. Each diplexer includes a low pass filter (filter **107**A**1**, **107**B**1**, **107**C**1**, or **107**D**1**) that transmits the radio frequency signals in the low frequency band and a high pass filter (filter **107**A**2**, **107**B**2**, **107**C**2**, or **107**D**2**) that transmits the radio frequency signals in the high frequency band. The filters **107**A**1**, **107**B**1**, **107**C**1**, and **107**D**1** are respectively connected to the switches **111**A to **111**D in the RFIC **110**B. The filters **107**A**2**, **107**B**2**, **107**C**2**, and **107**D**2** are respectively connected to the switches **111**E to **111**H in the RFIC **110**B. Each of the diplexers **107**A to **107**D is connected to the corresponding feeding element **121**.

Transmission signals from the switches **111**A to **111**D in the RFIC **110**B are radiated from the corresponding parasitic elements **122** after passing through the filters **107**A**1** to **107**D**1**, respectively. Transmission signals from the switches **111**E to **111**H in the RFIC **110**B are radiated from the corresponding feeding elements **121** after passing through the filters **107**A**2** to **107**D**2**, respectively.

In FIGS. **12** and **13**, for example, filters **151**A and **152**A correspond to the high pass filters of the diplexers, and filters **151**B and **152**B correspond to the low pass filters of the diplexers. The radio frequency signals in the high frequency band from the RFIC **110**B are supplied to the feeding point SP**1** of the feeding element **1211** after passing through the filter **151**A and the feeding wiring **141**A and supplied to the feeding point SP**2** of the feeding element **1212** after passing through the filter **152**A and the feeding wiring **142**A. The radio frequency signals in the low frequency band from the RFIC **110**B are supplied to the feeding point SP**1** of the feeding element **1211** after passing through the filter **151**B and the feeding wiring **141**B and supplied to the feeding point SP**2** of the feeding element **1212** after passing through the filter **152**B and the feeding wiring **142**B.

Each of the filters **151**A, **151**B, **152**A, and **152**B is arranged in a layer between the lower surface **132** of the dielectric substrate **130** and the ground electrode GND or in a layer between the parasitic element **1221** or **1222** and the ground electrode GND.

In such a dual band-type antenna module as well, as illustrated in FIG. **12**, all of the filters can be formed in the regions of the distance λ/4 from two feeding elements by arranging one of the filters **151**A and **151**B for the feeding element **1211** and one of the filters **152**A and **152**B for the feeding element **1212** so as to cross the virtual line CL**1** equidistant from the feeding element **1211** and the feeding element **1212** and arranging them side by side in a second direction (negative direction of the Y axis) orthogonal to a first direction (positive direction of the X axis) toward the feeding element **1212** from the feeding element **1211**. Therefore, increase in the size of the antenna module in the array antenna can be suppressed.

In the antenna module **100**D in FIG. **12**, the "feeding element **1211**" and the "parasitic element **1221**" correspond to the "first radiation element" in the present disclosure, and the "feeding element **1212**" and the "parasitic element **1222**" correspond to the "second radiation element" in the present disclosure. In the antenna module **100**D, the "filter **151**A"

and the "filter **152**A" correspond to the "first filter" and the "second filter", respectively, in the present disclosure, and the "filter **151**B" and the "filter **152**B" correspond to the "third filter" and the "fourth filter", respectively, in the present disclosure.

Fourth Embodiment

A fourth embodiment describes a case of a dual polarization/dual band-type antenna module obtained by combining the second embodiment and the third embodiment with reference to FIGS. **14** and **15**.

FIG. **14** is a block diagram of a communication apparatus **10**C to which an antenna module **100**E according to the fourth embodiment is applied.

Referring to FIG. **14**, the communication apparatus **10**C includes the antenna module **100**E and the BBIC **200**. The antenna module **100**E includes RFICs **110**C**1** to **110**C**4**, an antenna device **120**C, and a filter device **108**.

The antenna device **120**C includes, as radiation elements, the plurality of feeding elements **121** and the parasitic elements **122** provided so as to correspond to the feeding elements **121**. In addition, a radio frequency signal for first polarization and a radio frequency signal for second polarization are supplied to each feeding element **121**. The antenna device **120**C is an antenna device capable of radiating radio waves in two different frequency bands in two different polarization directions.

As in FIG. **13**, each of the parasitic elements **122** is arranged in a layer between the corresponding feeding element **121** and the ground electrode GND. Radio frequency signals from each RFIC are transmitted to the corresponding feeding elements after passing through feeding wiring lines that penetrate through the parasitic elements **122** and reach each of the feeding elements.

The antenna module **100**E includes the RFICs **110**C**1** and **110**C**3** for supplying radio frequency signals in a low frequency band and the RFICs **110**C**2** and **110**C**4** for supplying radio frequency signals in a high frequency band. The RFIC **110**C**1** and RFIC **110**C**2** are circuits for the radio frequency signals for the first polarization, and the RFIC **110**C**3** and the RFIC **110**C**4** are circuits for the radio frequency signals for the second polarization. Since the configurations of the RFICs are the same, FIG. **14** illustrates only the circuit configuration of the RFIC **110**C**1** and omits illustration of the circuit configurations of the RFICs **110**C**2** to **110**C**4**. Since the configuration of each RFIC is similar to that of the RFIC **110** in FIG. **1**, detailed description thereof will not be repeated.

The filter device **108** includes diplexers **108**A to **108**H. Each of the diplexers includes a low pass filter (any of filters **108**A**1** to **108**H**1**) that transmits the radio frequency signals in the low frequency band and a high pass filter (any of filters **108**A**2** to **108**H**2**) that transmits the radio frequency signals in the high frequency band. Each of the filters **108**A**1** to **108**H**1** is connected to a corresponding switch in the RFIC. Output of each of the diplexers **108**A to **108**H is connected to the corresponding feeding element **121**. All of the filters included in the diplexers **108**A to **108**H are resonant line-type filters.

FIG. **15** is a plan perspective view of the antenna module **100**E including two radiation elements. Referring to FIG. **15**, the antenna module **100**E includes, as radiation elements, the feeding elements **1211** and **1212** and the parasitic elements **1221** and **1222**. As in FIG. **13** in the third embodiment, in the dielectric substrate **130**, the parasitic element **1221** is arranged in the layer between the feeding element **1211** and the ground electrode GND, and the parasitic element **1222** is arranged in the layer between the feeding element **1212** and the ground electrode GND.

A radio frequency signal from a diplexer **155**A is supplied to the feeding point SP**11** of the feeding element **1211**, and a radio frequency signal from a diplexer **155**B is supplied to the feeding point SP**12**. Similarly, a radio frequency signal from a diplexer **156**A is supplied to the feeding point SP**21** of the feeding element **1212**, and a radio frequency signal from a diplexer **156**B is supplied to the feeding point SP**22**.

The diplexers **155**A, **155**B, **156**A, and **156**B in FIG. **15** correspond to the diplexers included in the filter device **108** in FIG. **14**. Each diplexer is arranged in a layer between the lower surface **132** of the dielectric substrate **130** and the ground electrode GND or in a layer between the parasitic element **1221** or **1222** and the ground electrode GND.

The diplexer **155**A and the diplexer **156**A are arranged so as to cross the virtual line CL**1** equidistant from the feeding element **1211** and the feeding element **1212** and are arranged side by side in a second direction (negative direction of the Y axis) orthogonal to a first direction (positive direction of the X axis) toward the feeding element **1212** from the feeding element **1211**.

The diplexer **155**B for polarization in the X-axis direction for the feeding element **1211** is arranged in the direction (negative direction of the X axis) opposite to the first direction with respect to the feeding point SP**12** in a region in the direction (positive direction of the Y axis) opposite to the second direction with respect to the center of the feeding element **1211**. On the other hand, the diplexer **156**B for polarization in the X-axis direction for the feeding element **1212** is arranged in a region in the first direction (positive direction of the X-axis) with respect to the center of the feeding element **1212**.

All of the diplexers **155**A, **155**B, **156**A, and **156**B can be arranged in the regions of the distance of $\lambda/4$ from the feeding elements **1211** and **1212** by arranging the diplexers in this manner, so that increase in the size of the antenna module in the array antenna can be suppressed.

Also in the fourth embodiment, the diplexers arranged between the feeding element **1211** and the feeding element **1212** may be the diplexers **155**B and **156**B or diplexers for different polarizations.

In the antenna module **100**E in the fourth embodiment, the dual band-type antenna module in which the feeding elements **1211** and **1212** and the parasitic elements **1221** and **1222** are stacked has been described. However, a dual band-type antenna module may be configured by using radiation elements in which two feeding elements are stacked by replacing the parasitic elements **1221** and **1222** with the feeding elements.

In the antenna module **100**E in FIG. **15**, the "feeding element **1211**" and the "parasitic element **1221**" correspond to the "first radiation element" in the present disclosure, and the "feeding element **1212**" and the "parasitic element **1222**" correspond to the "second radiation element" in the present disclosure. In addition, in the antenna module **100**E, the "diplexer **155**A" and the "diplexer **156**A" correspond to the "first filter" and the "second filter" in the present disclosure, respectively, and the "diplexer **155**B" and the "diplexer **156**B" correspond to the "third filter" and the "fourth filter" in the present disclosure, respectively.

Fifth Embodiment

In the above-described embodiments, the configuration has been described in which the radio frequency signal that

has passed through each filter is supplied to one corresponding feeding element. A fifth embodiment describes a case where a radio frequency signal from each filter is supplied to a plurality of feeding elements.

FIG. **16** is a block diagram of a communication apparatus **10**D to which an antenna module **100**F according to the fifth embodiment is applied.

Referring to FIG. **16**, the communication apparatus **10**D includes the antenna module **100**F and the BBIC **200**. The antenna module **100**F includes an RFIC **110**D, an antenna device **120**D, and a filter device **109**.

The antenna device **120**D includes the plurality of feeding elements **121** as radiation elements. The antenna device **120**D is a dual polarization-type antenna device as in the second embodiment, and a radio frequency signal for first polarization and a radio frequency signal for second polarization are supplied from the RFIC **110**D to each feeding element **121**.

The RFIC **110**D includes switches **181**A to **181**D, **183**A to **183**D, **187**A, and **187**B, power amplifiers **182**AT to **182**DT, low noise amplifiers **182**AR to **182**DR, attenuators **184**A to **184**D, phase shifters **185**A to **185**D, signal multiplexers/demultiplexers **186**A and **186**B, mixers **188**A and **188**B, and amplifier circuits **189**A and **189**B. Among them, the configurations of the switches **181**A, **181**B, **183**A, **183**B, and **187**A, the power amplifiers **182**AT and **182**BT, the low noise amplifiers **182**AR and **182**BR, the attenuators **184**A and **184**B, the phase shifters **185**A and **185**B, the signal multiplexer/demultiplexer **186**A, the mixer **188**A, and the amplifier circuit **189**A are circuits for the radio frequency signals for the first polarization. In addition, the configurations of the switches **181**C, **181**D, **183**C, **183**D, and **187**B, the power amplifiers **182**CT and **182**DT, the low noise amplifiers **182**CR and **182**DR, the attenuators **184**C and **184**D, the phase shifters **185**C and **185**D, the signal multiplexer/demultiplexer **186**B, the mixer **188**B, and the amplifier circuit **189**B are circuits for the radio frequency signals for the second polarization.

When the radio frequency signal is transmitted, the switches **181**A to **181**D and **183**A to **183**D are switched to the side of the power amplifiers **182**AT to **182**DT, and the switches **187**A and **187**B are connected to transmission-side amplifiers of the amplifier circuits **189**A and **189**B. When the radio frequency signals are received, the switches **181**A to **181**D and **183**A to **183**D are switched to the side of the low noise amplifiers **182**AR to **182**DR, and the switches **187**A and **187**B are connected to reception-side amplifiers of the amplifier circuits **189**A and **189**B.

The filter device **109** includes filters **109**A to **109**D. The filters **109**A to **109**D are respectively connected to the switches **181**A to **181**D in the RFIC **110**D. Each of the filters **109**A to **109**D has a function of attenuating the radio frequency signals in a specific frequency band.

The signals transmitted from the BBIC **200** are amplified by the amplifier circuits **189**A and **189**B and up-converted by the mixers **188**A and **188**B. The transmission signals, which are up-converted radio frequency signals, are divided into two by the signal multiplexers/demultiplexers **186**A and **186**B, pass through corresponding signal paths, and are fed to the feeding elements **121**.

The radio frequency signal from the switch **181**A passes through the filter **109**A and is branched into two systems by a branch circuit **210**A to be supplied to the feeding element **121**A and the feeding element **121**B. The radio frequency signal from the switch **181**B passes through the filter **109**B and is branched into two systems by a branch circuit **210**B to be supplied to the feeding element **121**C and the feeding element **121**D. The radio frequency signal from the switch **181**C passes through the filter **109**C and is branched into two systems by a branch circuit **210**C to be supplied to the feeding element **121**A and the feeding element **121**B. The radio frequency signal from the switch **181**D passes through the filter **109**D and is branched into two systems by a branch circuit **210**D to be supplied to the feeding element **121**C and the feeding element **121**D.

The directivity of the antenna device **120**D can be adjusted by individually adjusting the phase shift degrees of the phase shifters **185**A to **185**D arranged on the respective signal paths.

In such an antenna module, one filter is provided for two feeding elements for each polarization.

FIG. **17** is a plan perspective view of the antenna module **100**F. Referring to FIG. **17**, the antenna module **100**F includes feeding elements **1211** to **1214** as radiation elements. Further, the antenna module **100**F includes filters **1571**, **1572**, **1581**, and **1582**. All of the filters **1571**, **1572**, **1581**, and **1582** are resonant line-type filters and correspond to the filters included in the filter device **109** in FIG. **16**.

The feeding elements **1211** to **1214** are two-dimensionally arrayed in 2×2. The feeding element **1211** and the feeding element **1212** form a sub antenna SA**1** arrayed in 1×2. Further, the feeding element **1213** and the feeding element **1214** form a sub antenna SA**2** arrayed in 1×2. That is, the array antenna has a configuration in which the sub antennas SA**1** and SA**2** are arranged adjacent to each other. Assuming that a direction (negative direction of the Y axis) toward the sub antenna SA**2** from the sub antenna SA**1** is a first direction, the feeding elements included in each sub antenna are arrayed in a second direction (X-axis direction) orthogonal to the first direction.

Each of the filter **1571** and the filter **1581** is connected to the feeding elements **1211** and **1212** included in the sub antenna SA**1**. The radio frequency signal that has passed through the filter **1571** is supplied to the feeding point SP**11** of the feeding element **1211** and the feeding point SP**21** of the feeding element **1212**. The radio frequency signal that has passed through the filter **1581** is supplied to the feeding point SP**12** of the feeding element **1211** and the feeding point SP**22** of the feeding element **1212**.

Each of the filter **1572** and the filter **1582** is connected to the feeding elements **1213** and **1214** included in the sub antenna SA**2**. The radio frequency signal that has passed through the filter **1572** is supplied to a feeding point SP**31** of the feeding element **1213** and a feeding point SP**41** of the feeding element **1214**. The radio frequency signal that has passed through the filter **1582** is supplied to a feeding point SP**32** of the feeding element **1213** and a feeding point SP**42** of the feeding element **1214**.

The feeding points SP**11**, SP**21**, SP**31**, and SP**41** are arranged at positions offset from the centers of the feeding elements in the negative direction of the Y axis. When the radio frequency signals are supplied to the feeding points SP**11**, SP**21**, SP**31**, and SP**41**, radio waves having the polarization direction being the Y-axis direction are radiated from each of the feeding elements. Further, the feeding points SP**12**, SP**22**, SP**32**, and SP**42** are arranged at positions offset from the centers of the feeding elements in the positive direction of the X axis. When the radio frequency signals are supplied to the feeding points SP**12**, SP**22**, SP**32**, and SP**42**, radio waves having the polarization direction being the X-axis direction are radiated from each of the feeding elements.

When the antenna module **100**F is viewed in plan from the normal direction, the filters **1571** and **1572** are arranged so

as to cross a virtual line CL2 equidistant from the feeding elements of the sub antenna SA1 and the feeding elements of the sub antenna SA2. Further, the filter **1571** and the filter **1572** are arranged side by side in the second direction (X-axis direction) orthogonal to the first direction (negative direction of Y axis) toward the sub antenna SA2 from the sub antenna SA1.

The filter **1581** for polarization in the X-axis direction for the feeding elements **1211** and **1212** is arranged between the feeding element **1211** and the feeding element **1212**. On the other hand, the filter **1582** for polarization in the X-axis direction for the feeding elements **1213** and **1214** is arranged between the feeding element **1213** and the feeding element **1214**.

As described above, all of the filters can be formed in the regions of the distance of λ/4 from the feeding elements included in the two sub antennas by arranging the filters corresponding to the adjacent sub antennas side by side in the direction orthogonal to the array direction of the sub antennas. Therefore, increase in the size of the antenna module in the array antenna can be suppressed.

In the antenna module **100**F in FIG. **17**, the "sub antenna SA1" and the "sub antenna SA2" correspond to a "first sub antenna" and a "second sub antenna" in the present disclosure, respectively. Further, the "filter **1571**" and the "filter **1572**" correspond to the "first filter" and the "second filter" in the present disclosure.

(First Modification)

In the antenna module according to each of the above-described embodiments, the configuration has been described in which the feeding elements and the ground electrode are formed in the dielectric substrate formed of a dielectric having a single dielectric constant. A first modification describes a configuration in which a dielectric substrate is formed of dielectric layers having different dielectric constants.

FIG. **18** is a side perspective view of an antenna module **100**G in the first modification. In the antenna module **100**G, the dielectric substrate **130** of the antenna module **100** illustrated in FIG. **3** is replaced by a dielectric substrate **130**A. In FIG. **18**, description of components overlapping with those in FIG. **3** will not be repeated.

Referring to FIG. **18**, the dielectric substrate **130**A of the antenna module **100**G is formed of a first dielectric **1301** and a second dielectric **1302** having different dielectric constants. The first dielectric **1301** includes an upper surface **131**A. More specifically, the second dielectric **1302** is made of a material having a dielectric constant higher than that of the first dielectric **1301**. The first dielectric **1301** is arranged above the second dielectric **1302**. The RFIC **110** is mounted on the lower surface of the second dielectric **1302** (that is, a lower surface **132**A of the dielectric substrate **130**A) with the solder bumps **170** interposed therebetween.

In the antenna module **100**G, the feeding elements **1211** and **1212** are formed in the first dielectric **1301**, and the ground electrode GND is formed in the second dielectric **1302**. The filters **151** and **152** are also formed in the second dielectric **1302**. In the example of FIG. **18**, the ground electrode GND is arranged at the boundary between the first dielectric **1301** and the second dielectric **1302**. The ground electrode GND may be arranged in an inner layer of the second dielectric **1302**.

In general, in order to broaden the frequency bandwidth of radio waves that are radiated from the feeding elements, it is preferable that the dielectric constant between the feeding elements and the ground electrode be lowered. On the other hand, in order to increase Q values of the filters, it is preferable that the dielectric constant of the dielectric in which the filters are formed be increased. As described above, antenna characteristics and filter characteristics may have a trade-off relationship for the dielectric constant. Therefore, when the dielectric substrate is formed of a dielectric having a single dielectric constant, the dielectric constant is not necessarily suitable for the two characteristics in some cases.

In the antenna module **100**G in the first modification, the dielectric (first dielectric **1301**) between the feeding elements **1211** and **1212** and the ground electrode GND is formed of the dielectric having the relatively low dielectric constant. Further, the dielectric (second dielectric **1302**) below the ground electrode GND in which the filters **151** and **152** are formed is formed of the dielectric having the higher dielectric constant than that of the first dielectric **1301**. Thus, it is possible to improve both the antenna characteristics and the filter characteristics by forming the dielectric substrate using two dielectric layers having different dielectric constants and making the dielectric constant of the dielectric in which the filters are formed higher than the dielectric constant of the dielectric formed between the feeding elements and the ground electrode.

(Second Modification)

In the antenna module according to each of the above-described embodiments, the configuration that the feeding elements and the ground electrode are formed in the same dielectric substrate has been described. A second modification describes a configuration in which feeding elements and a ground electrode are formed in different dielectric substrates separated from each other.

FIG. **19** is a side perspective view of an antenna module **100**H in the second modification. In the antenna module **100**H, the dielectric substrate **130** of the antenna module **100** illustrated in FIG. **3** is replaced by two dielectric substrates **130**B and **130**C separated from each other. The dielectric substrate **130**C includes an upper surface **131**C. In FIG. **19**, description of components overlapping with those in FIG. **3** will not be repeated.

Referring to FIG. **19**, the feeding element **1211** and the feeding element **1212** are formed in the dielectric substrate **130**B in the antenna module **100**H. On the other hand, the ground electrode GND and the filters **151** and **152** are formed in the dielectric substrate **130**C separated from the dielectric substrate **130**B. The RFIC **110** is mounted on a lower surface **132**C of the dielectric substrate **130**C with the solder bumps **170** interposed therebetween.

The dielectric substrate **130**B and the dielectric substrate **130**C are connected by a connection member. Although solder bumps **171** and **172** are used as the connection member in the example of FIG. **19**, the connection member may be a flexible cable or a connector.

The feeding wiring **141** electrically connects the filter **151** and the feeding element **1211** with the solder bump **171** interposed therebetween. Similarly, the feeding wiring **142** electrically connects the filter **152** and the feeding element **1212** with the solder bump **172** interposed therebetween. When the dielectric substrate **130**C is viewed in plan from the normal direction, each of the filters **151** and **152** is arranged between the solder bump **171** and the solder bump **172** so as to cross the virtual line CL1 equidistant from the solder bumps **171** and **172**.

As described above, the feeding elements can be flexibly arranged in the communication apparatus by separating the dielectric substrate in which the feeding elements are formed from the dielectric substrate in which the ground electrode and the filters are formed.

In addition, as in the first modification described above, both the antenna characteristics and the filter characteristics can also be improved by relatively decreasing the dielectric constant of the dielectric substrate in which the feeding elements are formed and relatively increasing the dielectric constant of the dielectric substrate in which the ground electrode and the filters are formed.

The "dielectric substrate **130**C" in the second modification corresponds to a "circuit substrate" in the present disclosure. The "solder bump **171**" and the "solder bump **172**" in the second modification correspond to a "first terminal" and a "second terminal" of the present disclosure, respectively.

Sixth Embodiment

In the above-described embodiments, the configuration has been described in which the filters are formed on the feeding wiring extending from the RFIC to the radiation elements in the antenna device. A sixth embodiment describes a configuration in which filters are formed on paths before signal branching in the RFIC.

FIG. **20** is a block diagram of a communication apparatus **10**E to which an antenna module **100**I according to the sixth embodiment is applied. Referring to FIG. **20**, the communication apparatus **10**E includes the antenna module **100**I and the BBIC **200**. The antenna module **100**I includes an RFIC **110**E, the antenna device **120**A, and filters **105**X and **105**Y.

The antenna device **120**A is a dual polarization-type antenna device similarly to the antenna module **100**C illustrated in FIG. **8**, and a radio frequency signal for first polarization and a radio frequency signal for second polarization are supplied from the RFIC **110**I to each of the feeding elements **1211** and **1212**.

In the antenna module **100**C (FIG. **8**) in the second embodiment, the radio frequency signals from the RFIC **110**A are transmitted to the antenna device **120**A after passing through the filter device **106**. In the antenna module **100**I in the sixth embodiment, the RFIC **110**E and the antenna device **120**A are directly connected to each other by feeding wiring, and each of the filters **105**X and **105**Y is connected between the signal multiplexer/demultiplexer and the switch in the RFIC **110**E. To be more specific, the filter **105**X is a filter for the first polarization and is connected between the signal multiplexer/demultiplexer **116**A and the switch **117**A. The filter **105**Y is a filter for the second polarization and is connected between the signal multiplexer/demultiplexer **116**B and the switch **117**B. The filters **105**X and **105**Y are arranged outside the RFIC **110**E. Specifically, they are formed inside the antenna device **120**A as will be described later with reference to FIGS. **21** and **22**. Other components constituting the RFIC **110**E are similar to those of the RFIC **110**A in FIG. **8**, and overlapping description of the components will not be repeated.

FIGS. **21** and **22** illustrate a detailed configuration of the antenna module **100**I in FIG. **20**. FIG. **21** is a plan perspective view of the antenna module **100**I. FIG. **22** is a side perspective view of the antenna module **100**I. In the plan view of FIG. **21**, the dielectric of the dielectric substrate **130** and the ground electrode GND are omitted for ease of description.

Referring to FIGS. **21** and **22**, the antenna module **100**I is an array antenna in which the two feeding elements **1211** and **1212** are arrayed in the X-axis direction, similarly to the antenna module **100**C illustrated in FIG. **9**. The feeding elements **1211** and **1212** are arranged on the upper surface **131** of the dielectric substrate **130** or in an internal layer thereof. In the dielectric substrate **130**, the ground electrode GND having a flat plate shape is arranged in a layer closer to the lower surface **132** than the feeding elements **1211** and **1212** so as to face the feeding elements **1211** and **1212**. The RFIC **110** is mounted on the lower surface **132** of the dielectric substrate **130** with the solder bumps **170** interposed therebetween.

In the dielectric substrate **130**, the filters **105**X and **105**Y are arranged on the lower surface **132** side of the ground electrode GND. The filter **105**X is connected to the RFIC **110** by connection wiring **1611** and connection wiring **1612**. Further, the filter **105**Y is connected to the RFIC **110** by connection wiring **1621** and connection wiring **1622**. When the antenna module **100**I is viewed in plan from the normal direction, each of the filters **105**X and **105**Y is arranged so as to cross the virtual line CL**1** equidistant from the feeding element **1211** and the feeding element **1212**. The filters **105**X and **105**Y are arranged side by side in the Y-axis direction.

The feeding points SP**11** and SP**12** of the feeding element **1211** are directly connected to the RFIC **110**E by feeding wiring **141**Y and feeding wiring **141**X, respectively. When a radio frequency signal is supplied to the feeding point SP**12**, radio waves having the polarization direction being the X-axis direction are radiated from the feeding element **1211**. When a radio frequency signal is supplied to the feeding point SP**11**, radio waves having the polarization direction being the Y-axis direction are radiated from the feeding element **1211**.

Similarly, the feeding points SP**21** and SP**22** of the feeding element **1212** are directly connected to the RFIC **110**E by feeding wiring **142**Y and feeding wiring **142**X, respectively. When a radio frequency signal is supplied to the feeding point SP**22**, radio waves having the polarization direction being the X-axis direction are radiated from the feeding element **1212**. When a radio frequency signal is supplied to the feeding point SP**21**, radio waves having the polarization direction being the Y-axis direction are radiated from the feeding element **1212**.

The filter **105**X is a filter device for radio waves having the polarization direction being the X-axis direction in the feeding elements **1211** and **1212**. The radio frequency signal that has passed through the filter **105**X is supplied to the feeding point SP**12** of the feeding element **1211** and the feeding point SP**22** of the feeding element **1212**. The filter **105**Y is a filter device for radio waves having the polarization direction being the Y-axis direction in the feeding elements **1211** and **1212**. The radio frequency signal that has passed through the filter **105**Y is supplied to the feeding point SP**11** of the feeding element **1211** and the feeding point SP**21** of the feeding element **1212**.

It is possible to reduce the number of filters formed in the antenna module by adopting the configuration in which common filters are provided for the circuits in the respective polarization directions as in the antenna module **100**I. Therefore, further miniaturization of the whole antenna module can be realized. Further, increase in the size of the antenna module can be suppressed by arranging the filters so as to cross the virtual line equidistant from two adjacent feeding elements.

In the sixth embodiment, the "feeding element **1211**" and the "feeding element **1212**" correspond to the "first radiation element" and the "second radiation element" in the present disclosure, respectively, and the "filter **105**X" and the "filter **105**Y" correspond to the "first filter" and the "second filter" in the present disclosure, respectively. The "X-axis direc-

tion" and the "Y-axis direction" in the sixth embodiment correspond to a "first direction" and a "second direction" in the present disclosure, respectively. In the sixth embodiment, the "feeding point SP**11**" and the "feeding point SP**21**" correspond to a "first feeding point" in the present disclosure, and the "feeding point SP**12**" and the "feeding point SP**22**" correspond to a "second feeding point" in the present disclosure.

It should be considered that the embodiments disclosed herein are illustrative and not restrictive in all respects. The scope of the present disclosure is defined not by description of the above-described embodiments but by the scope of the claims and is intended to include all modifications within the meaning and scope equivalent to the scope of the claims.

REFERENCE SIGNS LIST

10 AND **10**A to **10**E COMMUNICATION APPARATUS
SP**1**, SP**1**A, SP**1**B, SP**2**, SP**2**A, SP**2**B, SP**11**, SP**12**, SP**21**, SP**22**, SP**31**, SP**32**, SP**41**, AND SP**42** FEEDING POINT
100 AND **100**A to **100**I ANTENNA MODULE
105, **106**, **107**, **108**, AND **109** FILTER DEVICE
105A TO **105**D, **105**X, **105**Y, **106**A TO **106**H, **107**A**1** TO **107**D**1**, **107**A**2** TO **107**D**2**, **108**A**1**, **108**A**2**, **108**H**1**, **108**H**2**, **109**A TO **109**D, **150**, **150**A, **150**B, **151**, **151**A, **151**B, **152**, **152**A, **152**B, **156**B, **1511**, **1512**, **1521**, **1522**, **1571**, **1572**, **1581**, AND **1582** FILTER
107A to **107**D, **108**A to **108**H, **155**, AND **156** DIPLEXER
111, **113**, **117**, **181**, **183**, AND **187** SWITCH
110 AND **110**A TO **110**E RFIC
112AR TO **112**HR AND **182**AR TO **182**DR LOW NOISE AMPLIFIER
112AT to **112**HT AND **182**AT to **182**DT POWER AMPLIFIER
114 AND **184** ATTENUATOR
115 AND **185** PHASE SHIFTER
116 AND **186** SIGNAL MULTIPLEXER/DEMULTIPLEXER
118 AND **188** MIXER
119 AND **189** AMPLIFIER CIRCUIT
120 ANTENNA DEVICE
121 FEEDING ELEMENT
122 PARASITIC ELEMENT
130 AND **130**A TO **130**C DIELECTRIC SUBSTRATE
1301 AND **1302** DIELECTRIC
141 AND **142** FEEDING WIRING
161, **162**, **1611**, **1612**, **1621**, AND **1622** CONNECTION WIRING
170 to **172** SOLDER BUMP
191, **192**, **1503**, **1505**, **1506**, AND **1508** LINE
210 BRANCH CIRCUIT
1501 INPUT TERMINAL
1502 OUTPUT TERMINAL
1504 AND **1507** VIA
200 BBIC
GND GROUND ELECTRODE
SA**1** AND SA**2** SUB ANTENNA

The invention claimed is:

1. An antenna module comprising:
a first radiation element having a planar shape;
a second radiation element having a planar shape and arranged adjacent to the first radiation element;
a first filter connected to the first radiation element; and
a second filter distinct and separate from the first filter, and connected to the second radiation element, wherein
each of the first filter and the second filter includes a plurality of resonant lines not connected to each other,
each of the first filter and the second filter is arranged between the first radiation element and the second radiation element so as to cross a virtual line equidistant from the first radiation element and the second radiation element when the antenna module is viewed in plan from a normal direction,
a direction toward the second radiation element from the first radiation element is defined as a first direction,
the first filter and the second filter are arranged side-by-side in a second direction different from the first direction,
each of the first radiation element and the second radiation element is provided with a first feeding point at a position offset in the second direction from a center point of a corresponding radiation element,
the first filter is arranged further on the second direction side with respect to the first feeding point of the first radiation element, and
the second filter is arranged in a direction opposite to the second direction with respect to the first feeding point of the second radiation element.

2. The antenna module according to claim **1**, further comprising:
a ground electrode arranged so as to face the first radiation element and the second radiation element, wherein
the ground electrode is arranged in a layer between the first filter and the second filter, and
the first radiation element and the second radiation element.

3. The antenna module according to claim **1**, further comprising:
a ground electrode arranged so as to face the first radiation element and the second radiation element,
wherein the first filter and the second filter are arranged in a layer between the first radiation element and the second radiation element and the ground electrode.

4. The antenna module according to claim **1**, wherein the first filter and the second filter do not overlap with each other when the antenna module is viewed in plan from a normal direction of a radiating surface of the antenna module.

5. The antenna module according to claim **1**, wherein
when the antenna module is viewed in plan from a normal direction of a radiating surface of the antenna module,
the first filter does not overlap with the second radiation element, and
the second filter does not overlap with the first radiation element.

6. The antenna module according to claim **1**, wherein
each of the first radiation element and the second radiation element is provided with a second feeding point at a position offset in the first direction from a center point of the corresponding radiation element, and
the antenna module further comprises:
a third filter connected to the second feeding point of the first radiation element; and
a fourth filter connected to the second feeding point of the second radiation element.

7. The antenna module according to claim **1**, wherein
each of the first radiation element and the second radiation element is provided with a second feeding point at a position offset in the first direction from the center point of the corresponding radiation element,
the first filter is connected to the first feeding point of the first radiation element,

the second filter is connected to the second feeding point of the second radiation element, and

the antenna module further comprises:

a third filter connected to the second feeding point of the first radiation element; and

a fourth filter connected to the first feeding point of the second radiation element.

8. The antenna module according to claim **1**, wherein

each of the first radiation element and the second radiation element is provided with a second feeding point at a position offset in a direction opposite to the second direction from the center point of the corresponding radiation element,

for each of the first radiation element and the second radiation element, the first feeding point is connected to the second feeding point by a line having a length of λ/2 where λ is a wavelength of a radio wave to be radiated,

the first filter is connected to the first feeding point of the first radiation element, and

the second filter is connected to the second feeding point of the second radiation element.

9. The antenna module according to claim **1**, further comprising:

a third filter connected to the first radiation element;

a fourth filter connected to the second radiation element; and

a ground electrode arranged so as to face the first radiation element and the second radiation element, wherein

each of the first radiation element and the second radiation element includes:

a feeding element; and

a parasitic element arranged between the feeding element and the ground electrode so as to face the feeding element,

one of the first filter and the third filter is a filter corresponding to the feeding element of the first radiation element and another of the first filter and the third filter is a filter corresponding to the parasitic element of the first radiation element, and

one of the second filter and the fourth filter is a filter corresponding to the feeding element of the second radiation element and another of the second filter and the fourth filter is a filter corresponding to the parasitic element of the second radiation element.

10. The antenna module according to claim **9**, wherein

a size of the parasitic element is larger than a size of the feeding element in each of the first radiation element and the second radiation element,

the antenna module further comprises, for each of the first filter, the second filter, the third filter, and the fourth filter, feeding wiring configured to transmit a radio frequency signal that has passed through a filter to a corresponding feeding element, and

the feeding wiring penetrates through the parasitic element and is connected to the feeding element.

11. The antenna module according to claim **1**, further comprising:

a third filter connected to the first radiation element;

a fourth filter connected to the second radiation element; and

a ground electrode arranged so as to face the first radiation element and the second radiation element, wherein

each of the first radiation element and the second radiation element includes:

a feeding element, and

a parasitic element arranged between the feeding element and the ground electrode so as to face the feeding element,

each of the first filter, the second filter, the third filter, and the fourth filter is a diplexer including a filter element corresponding to the feeding element and a filter element corresponding to the parasitic element,

the feeding element of each of the first radiation element and the second radiation element is provided with a first feeding point for radiating a radio wave having a polarization direction being the second direction and a second feeding point for radiating a radio wave having a polarization direction being the first direction,

one of the first filter and the third filter is connected to the first feeding point of the first radiation element and another of the first filter and the third filter is connected to the second feeding point of the first radiation element, and

one of the second filter and the fourth filter is connected to the first feeding point of the second radiation element and another of the second filter and the fourth filter is connected to the second feeding point of the second radiation element.

12. The antenna module according to claim **1**, further comprising a feeding circuit configured to supply a radio frequency signal to each of the first radiation element and the second radiation element.

13. A communication apparatus comprising:

the antenna module according to claim **1**.

14. The antenna module according to claim **1**, wherein

when the antenna module is viewed in plan from a normal direction of a radiating surface of the antenna module,

the first filter does not overlap with the second radiation element, and

the second filter does not overlap with the first radiation element.

15. An antenna module comprising:

a first radiation element having a planar shape;

a second radiation element having a planar shape and arranged adjacent to the first radiation element, each of the first radiation element and the second radiation element is provided with a first feeding point at a position offset in a second direction from a center point of a corresponding radiation element and is provided with a second feeding point at a position offset in a first direction from the center point of the corresponding radiation element;

a first filter configured to filter a radio frequency signal that is supplied to the second feeding point of each of the first radiation element and the second radiation element; and

a second filter distinct and separate from the first filter, and configured to filter a radio frequency signal that is supplied to the first feeding point of each of the first radiation element and the second radiation element, wherein

each of the first filter and the second filter includes a plurality of resonant lines not connected to each other, and

each of the first filter and the second filter is arranged between the first radiation element and the second radiation element so as to cross a virtual line equidistant from the first radiation element and the second radiation element when the antenna module is viewed in plan from a normal direction.

16. An antenna module comprising:
a first radiation element having a planar shape;
a second radiation element having a planar shape and arranged adjacent to the first radiation element;
a first filter connected to the first radiation element; and
a second filter connected to the second radiation element, wherein
each of the first filter and the second filter includes a plurality of resonant lines not connected to each other,
each of the first filter and the second filter is arranged between the first radiation element and the second radiation element so as to cross a virtual line equidistant from the first radiation element and the second radiation element when the antenna module is viewed in plan from a normal direction,
a direction toward the second radiation element from the first radiation element is defined as a first direction,
the first filter and the second filter are arranged side-by-side in a second direction different from the first direction,
each of the first radiation element and the second radiation element is provided with a first feeding point at a position offset in the second direction from a center point of a corresponding radiation element,
the first filter is arranged further on the second direction side with respect to the first feeding point of the first radiation element, and
the second filter is arranged in a direction opposite to the second direction with respect to the first feeding point of the second radiation element.

17. The antenna module according to claim 16, further comprising:
a ground electrode arranged so as to face the first radiation element and the second radiation element, wherein
the ground electrode is arranged in a layer between the first filter and the second filter, and
the first radiation element and the second radiation element.

18. The antenna module according to claim 16, further comprising:
a ground electrode arranged so as to face the first radiation element and the second radiation element,
wherein the first filter and the second filter are arranged in a layer between the first radiation element and the second radiation element and the ground electrode.

19. The antenna module according to claim 16, wherein the first filter and the second filter do not overlap with each other when the antenna module is viewed in plan from a normal direction of a radiating surface of the antenna module.

20. The antenna module according to claim 16, wherein
each of the first radiation element and the second radiation element is provided with a second feeding point at a position offset in the first direction from a center point of the corresponding radiation element, and
the antenna module further comprises:
a third filter connected to the second feeding point of the first radiation element; and
a fourth filter connected to the second feeding point of the second radiation element.

* * * * *

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(12) **United States Patent**
Cai

(10) **Patent No.: US 12,255,400 B2**
(45) **Date of Patent: Mar. 18, 2025**

(54) **ARRAY ANTENNA APPARATUS AND PREPARATION METHOD THEREFOR, AND ELECTRONIC DEVICE**

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(72) Inventor: **Bo Cai**, Guangzhou (CN)

(73) Assignee: **STURMVÖGEL INNOVATION GUANGZHOU CO. LTD.**, Guangzhou (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 192 days.

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(30) **Foreign Application Priority Data**

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H01Q 9/04 (2006.01)
H01Q 1/22 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 21/065*** (2013.01); ***H01Q 1/22*** (2013.01); ***H01Q 9/0414*** (2013.01); ***H01Q 19/10*** (2013.01); ***H01Q 21/0087*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 21/065; H01Q 21/0087; H01Q 1/22; H01Q 1/50; H01Q 1/38; H01Q 9/0414
See application file for complete search history.

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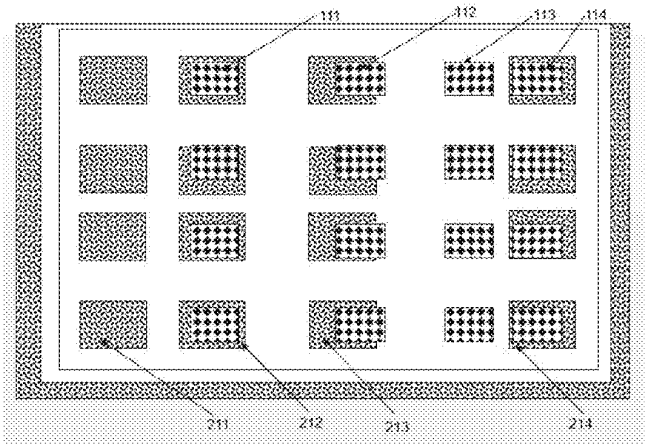
Primary Examiner — Awat M Salih

(57) **ABSTRACT**

The present invention relates to the technical field of communications, and in particular relates to an array antenna apparatus and a preparation method therefor, and an electronic device. The array antenna apparatus includes a first substrate and a second substrate which are provided from top to bottom. A first antenna is provided on the first substrate, a second antenna is provided on the second substrate, the first antenna is provided with a plurality of array elements arranged in an array, the second antenna is provided with a plurality of array elements arranged in an array, and the projections, on the second substrate, of all the array elements of the first antenna and all the array elements of the second antenna do not completely coincide. The present invention has the advantages of low sidelobe, large bandwidth, and multiple beams, etc.

13 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

H01Q 19/10	(2006.01)
H01Q 21/00	(2006.01)
H01Q 21/06	(2006.01)

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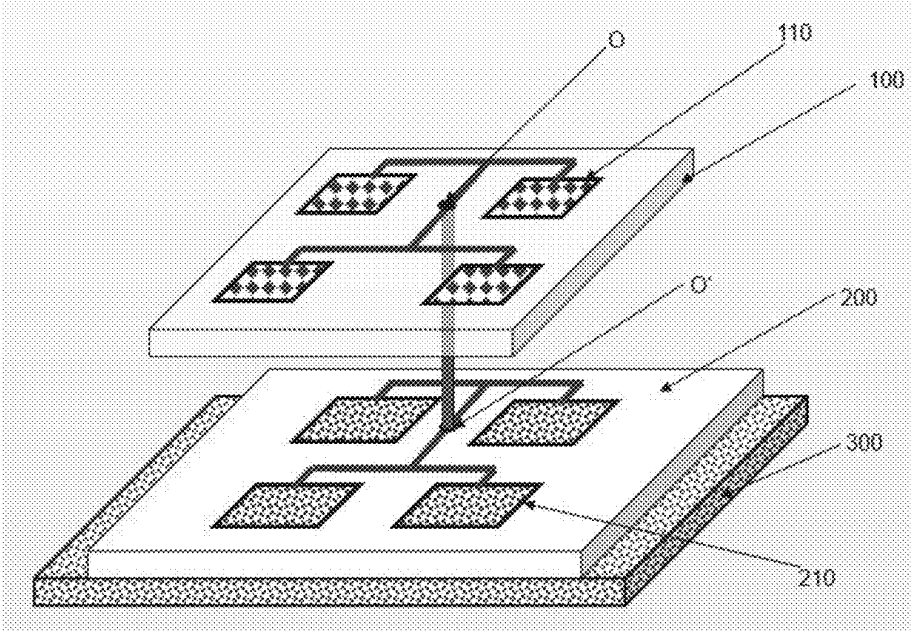

FIG. 1

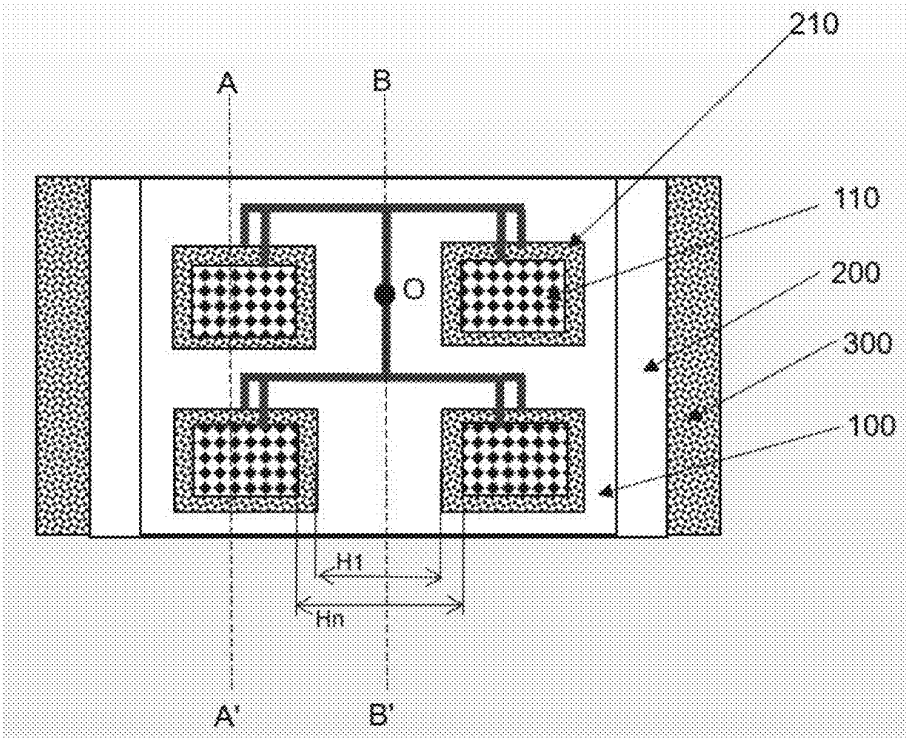

FIG. 2

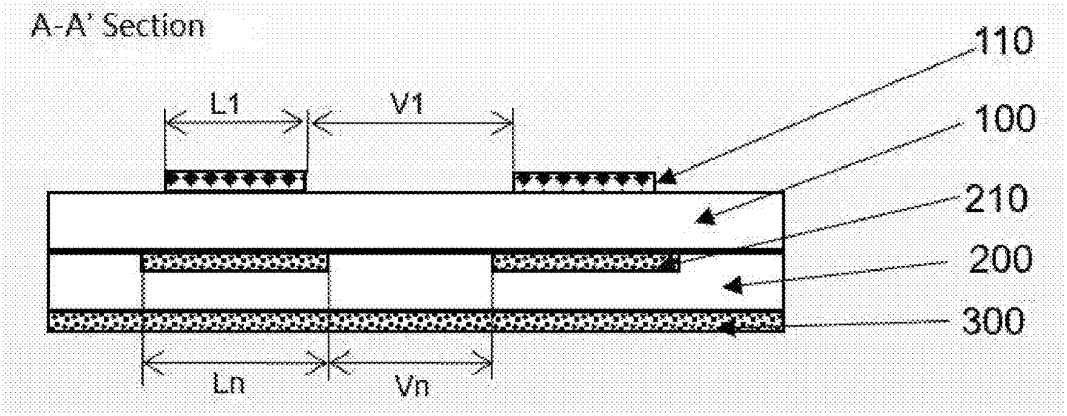
A-A' Section
L1
V1
110
100
210
200
300
Ln
Vn

FIG. 3

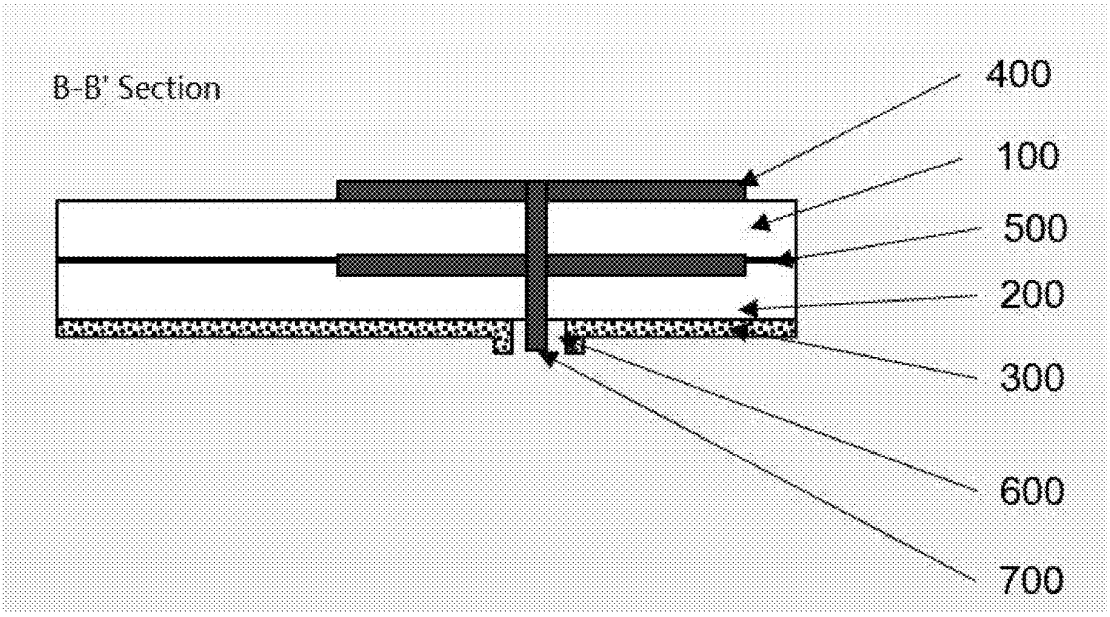
B-B' Section
400
100
500
200
300
600
700

FIG. 4

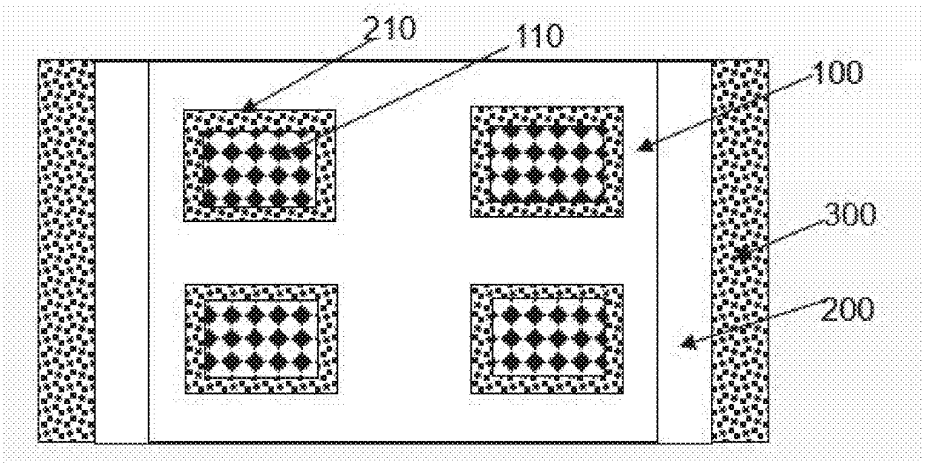

FIG. 5

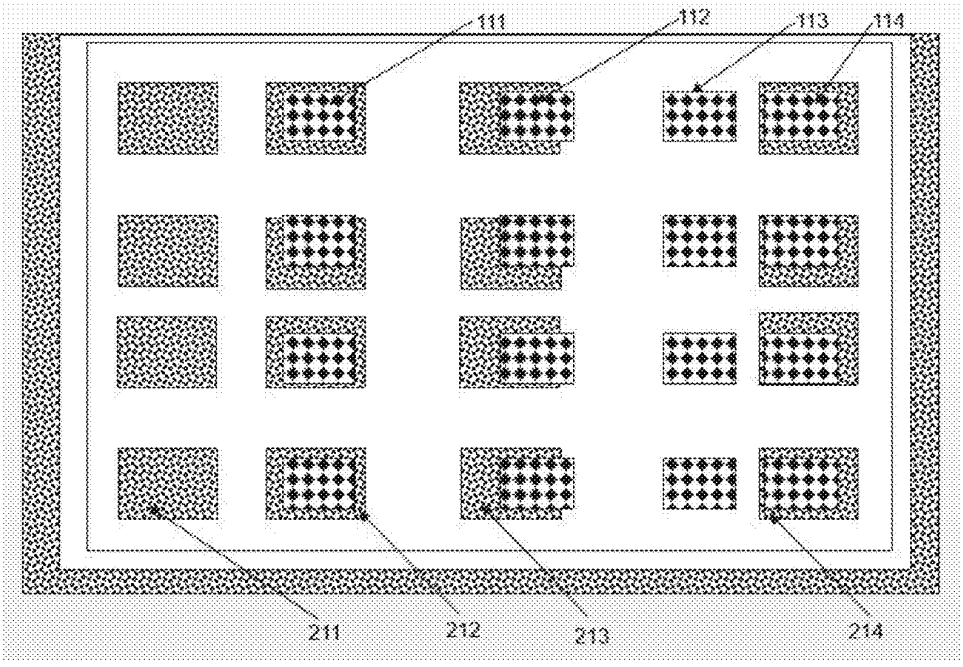

FIG. 6

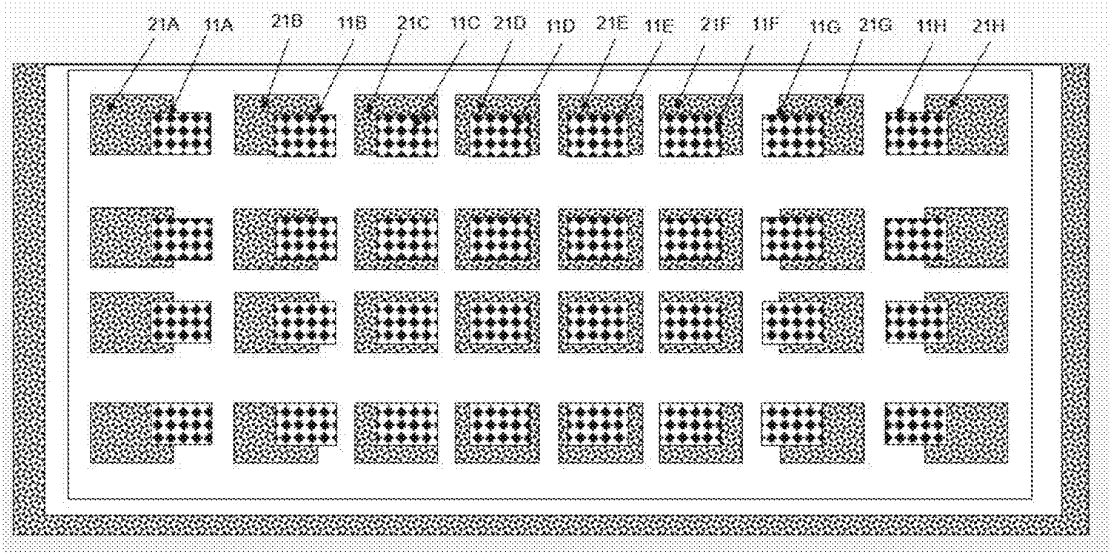
21A
11A
21B
11B
21C
11C
21D
11D
21E
11E
21F
11F
11G
21G
11H
21H

FIG. 7

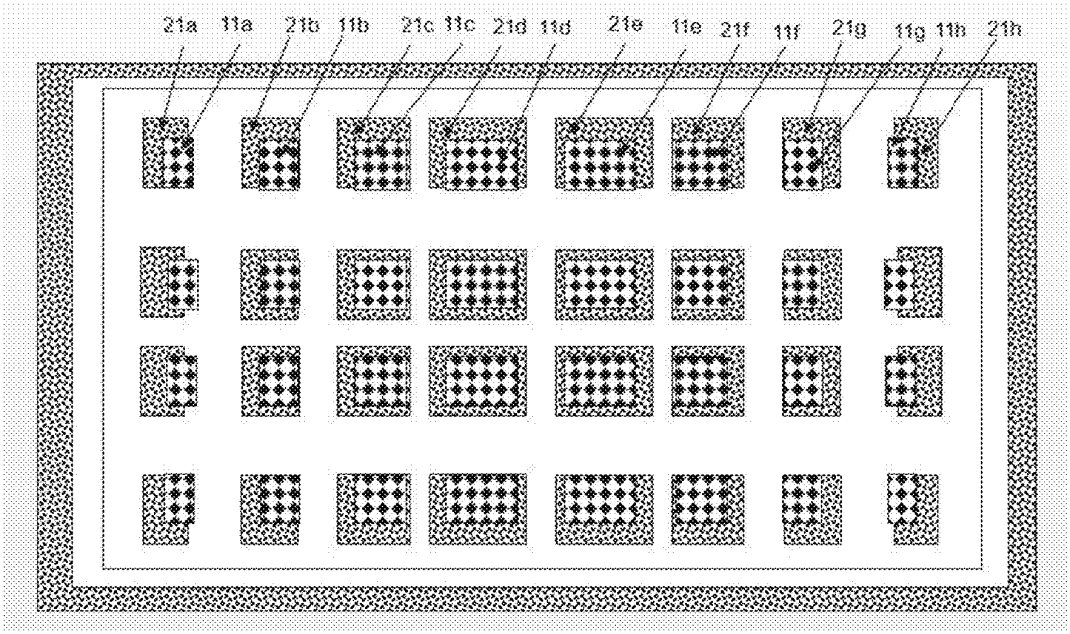
21a
11a
21b
11b
21c
11c
21d
11d
21e
11e
21f
11f
21g
11g
11h
21h

FIG. 8

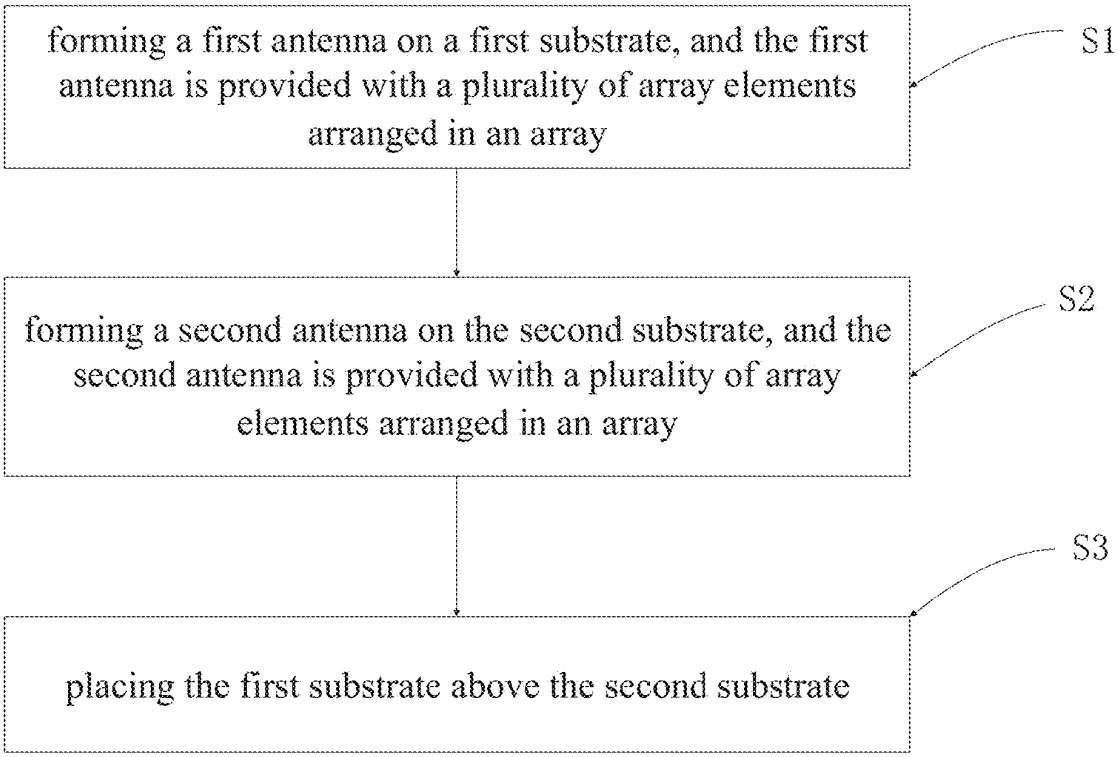
forming a first antenna on a first substrate, and the first antenna is provided with a plurality of array elements arranged in an array
S1
forming a second antenna on the second substrate, and the second antenna is provided with a plurality of array elements arranged in an array
S2
placing the first substrate above the second substrate
S3

FIG. 9

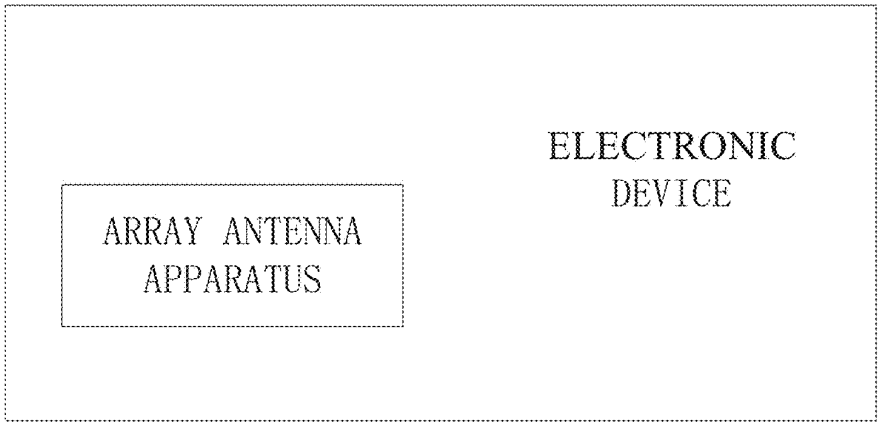
ELECTRONIC DEVICE
ARRAY ANTENNA APPARATUS

FIG. 10

ARRAY ANTENNA APPARATUS AND PREPARATION METHOD THEREFOR, AND ELECTRONIC DEVICE

BACKGROUND OF THE PRESENT INVENTION

Field of Invention

The present invention relates to the technical field of communication, in particular to an array antenna apparatus and a preparation method therefor, and an electronic device using the array antenna apparatus for communication.

Description of Related Arts

With the development of modern wireless communication technology, antennas play a very important role in mobile communication devices. With the advent of the fifth-generation mobile communication technology era (5G era), in order to meet the high-rate information transmission requirements of the 5G era, therefore, it is necessary to form an array antenna with multiple antenna elements to increase its gain, and to achieve an increase in information transmission capacity through multiple antennas. However, in the prior art, as an array antenna applied to terminal equipment and base stations, a single and fixed antenna array structure is usually adopted, and there will be sidelobe levels during operation, which will cause the signal-to-noise ratio of the signal to decrease. The single and fixed antenna array structure makes the antenna working frequency bandwidth limited and the beam direction is single, which limits the working accuracy, working band and working range of the antenna. Therefore, in the development of antennas, the development of an antenna with the advantages of low sidelobes, large bandwidth and multiple beams is particularly important in the technical field of communication, and it is also particularly necessary to meet the communication needs of the 5G era.

SUMMARY OF THE PRESENT INVENTION

The embodiment of the present invention provides an array antenna apparatus and a preparation method therefor, and an electronic device, which overcomes the technical problems of fixed beam, narrow beam width, and limited bandwidth in the traditional planar antenna array method while ensuring resolution, it also has the advantages of low sidelobes, large bandwidth, and multiple beams.

In one aspect, in order to achieve the above advantages, the present invention provides an array antenna apparatus, including:

- at least two substrates: a first substrate and a second substrate which are provided from top to bottom,
- wherein a first antenna is provided on the first substrate;
- a second antenna is provided on the second substrate;
- the first antenna is provided with a plurality of array elements arranged in an array,
- the second antenna is provided with a plurality of array elements arranged in an array;
- and the projections of all the array elements of the first antenna and all the array elements of the second antenna on the second substrate do not completely coincide.

Preferably, all the array elements of the first antenna are symmetrically distributed about a geometric center of the first substrate, and all the array elements of the second antenna are symmetrically distributed about a geometric center of the second substrate, projections of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate coincide;

Preferably, the size of each array element of the first antenna is different from the size of each array element of the second antenna.

Preferably, all the array elements of the first antenna are not symmetrically distributed about the geometric center of the first substrate, all the array elements of the second antenna are not symmetrically distributed about the geometric center of the second substrate, the projections of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate coincide.

Preferably, spacings between any two adjacent array elements, in a second direction perpendicular to a first direction which is from top to bottom, of the array elements of each row of the first antenna are unequal, and spacings between any two adjacent array elements in the second direction of the array elements of each row of the second antenna are unequal.

Preferably, the sizes of all the array elements of the first antenna are the same, the sizes of all the array elements of the second antenna are the same, and the sizes of the array elements of the first antenna are different from the sizes of the array elements of the second antenna.

Preferably, the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the first substrate among all the array elements of the first antenna gradually increases as a distance from the geometric center of the first substrate increases,

- the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the second substrate among all the array elements of the second antenna gradually decreases as the distance from the geometric center of the first substrate decreases.

Preferably, the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the first substrate among all the array elements of the first antenna gradually decreases as the distance from the geometric center of the first substrate increases, the spacing between two adjacent array elements in the transverse and longitudinal direction of the second substrate among all the array elements of the second antenna gradually increases or decreases as the distance from the geometric center of the first substrate increases.

Preferably, the width of each array element of the first antenna gradually increases or decreases as the distance from the geometric center of the first substrate increases, the width of each element of the second antenna gradually increases or decreases as the distance from the geometric center of the second substrate increases, and the length of each element of the first antenna is a first preset value, and the length of each element of the second antenna is a second preset value different from the first preset value.

Preferably, the distance between the geometric centers of any two adjacent array elements of the first antenna is a first specified value; the distance between the geometric centers of any two adjacent array elements of the second antenna is a second specified value different from the first specified value.

In another aspect, the embodiment of the present invention further provides a preparation method of array antenna, comprising:

forming a first antenna on a first substrate, and the first antenna is provided with a plurality of array elements arranged in an array;

forming a second antenna on the second substrate, and the second antenna is provided with a plurality of array elements arranged in an array; and,

placing the first substrate above the second substrate, wherein, the projections of all the array elements of the first antenna and all the array elements of the second antenna on the second substrate do not completely coincide.

In another aspect, the embodiments of the present invention further provide an electronic device, which includes the array antenna apparatus described in any one of the preceding aspects.

Preferably, the electronic device is at least one of a mobile communication device, a radar device, a satellite communication device, or an automobile.

Beneficial Effect

The array antenna apparatus, the preparation method therefore, and the electronic device of the present invention have the following beneficial effects:

1) sidelobe suppression: reducing the energy distribution of the upper sidelobe to reduce the co-frequency, adjacent frequency, cross-area interference caused by the excessive upper sidelobe, achieving the optimized zero-point cancellation effect, so as to achieve a more ideal sidelobe suppression;

2) large bandwidth or multiple channels: with high information rate, wide spectrum spreading ability, reducing multipath, clutter and enhancing anti-interference ability; in the wireless communication of adjacent frequencies, it is easy to overcome mutual interference; greatly increasing the communication volume:

3) multiple beams: forming shaped beams of different shapes, the number and shape of the beams can be flexibly set, the element beams are narrow and the gain is high, which can serve multiple users at the same time, the formed beam can cover a wide area of the designated area, and it can achieve low sidelobes by means of combined feed source.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a three-dimensional structure of an array antenna apparatus in Embodiment 1 of the present invention;

FIG. **2** is a schematic structural diagram of the array antenna apparatus in FIG. **1** drawn in perspective from a top view angle;

FIG. **3** is a schematic structural view of the A-A' section in FIG. **2**;

FIG. **4** is a schematic structural diagram of the B-B' section in FIG. **2**;

FIG. **5** is a schematic structural diagram of an array antenna apparatus in Embodiment 2 of the present invention;

FIG. **6** is a schematic structural diagram of an array antenna apparatus in Embodiment 3 of the present invention;

FIG. **7** is a schematic structural diagram of an array antenna apparatus in Embodiment 4 of the present invention;

FIG. **8** is a schematic structural diagram of an array antenna apparatus in Embodiment 5 of the present invention;

FIG. **9** is a schematic diagram of a manufacturing method of an array antenna apparatus in Embodiment 6 of the present invention;

FIG. **10** is a schematic structural diagram of an electronic device using the array antenna apparatus of the foregoing embodiments 1 to 5 in Embodiment 7 of the present invention.

ATTACHED ICON NUMBER DESCRIPTION

100—first substrate; **110**—first antenna; O is the geometric center of the first substrate;

200—second substrate; **210**—second antenna; O' is the geometric center of the second substrate;

300—reflector; **400**—first connection line; **500**—second connecting line; **600**—through hole; **700**—Feeder;

111, **112**, **113**, **114**—the array element of the first substrate;

211, **212**, **213**, **214**—array element of the second substrate;

11A, **11**B, **11**C, **11**D, **11**E, **11**F, **11**G, **11**H—array element of the first substrate;

21A, **21**B, **21**C, **21**D, **21**E, **21**F, **21**G, **21**H—array element of the second substrate;

11*a*, **11***b*, **11***c*, **11***d*, **11***e*, **11***f*, **11***g*, **11***h*-array element of the first substrate;

21*a*, **21***b*, **21***c*, **21***d*, **21***e*, **21***f*, **21***g*, **21***h*—array element of the second substrate.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In order to make the objectives, technical solutions, and advantages of the embodiments of the present invention clearer, the technical solutions in the embodiments of the present invention will be described clearly and completely in conjunction with the accompanying drawings in the embodiments of the present invention. It should be noted that, in this specification, terms like "first" and "second" are only used for descriptive purposes, and cannot be understood as indicating or implying their relative importance or implicitly indicating the number of indicated technical features. In the description of the present invention, it should be understood that the orientation or positional relationship indicated by the terms of "center", "upper", "lower", "front", "rear", "left", "right", "vertical", "horizontal" "top", "bottom", "inner", "outer", etc. are based on the orientation or positional relationship shown in the drawings, which is only for the convenience of describing the application and simplifying the description, rather than indicating or implying that the device or element referred to must have a specific orientation, be configured and operated in a specific orientation, and therefore cannot be understood as a limitation of the present invention. Moreover, the terms "comprise", "include" or any other variations thereof are intended to cover non-exclusive inclusion, so that a process, method, article or device including a series of elements not only includes those elements, but also includes other elements that are not explicitly listed, or elements inherent to the process, method, article, or equipment. If there are no more restrictions, the element defined by the sentence "including . . . " does not exclude the existence of other same elements in the process, method, article or equipment that includes the element. If there is no conflict, the embodiments of the present invention and various features in the embodiments can be combined with each other, and all fall within the protection scope of the present invention.

EMBODIMENTS OF THE PRESENT INVENTION

Embodiment 1

Referring to FIG. **1**, an array antenna apparatus in Embodiment 1 of the present invention is mainly used in high-speed communications and radar, which mainly includes:

- at least two substrates: a first substrate **100** and a second substrate **200** which are provided from top to bottom, wherein a first antenna **110** is provided on the first substrate **100**;
- a second antenna **210** is provided on the second substrate **200**;
- the first antenna **110** is provided with a plurality of array elements arranged in an array, the second antenna **210** is provided with a plurality of array elements arranged in an array; each element here can be composed of a microstrip patch, and preferably each microstrip patch has a rectangular shape. The array arrangement here can be implemented as follows:
- the matrix of the array antenna consists of at least 2*1 elements, which can be expanded to a larger scale, wherein the number of rows and columns of the matrix is an exponential multiple of 2, such as 2*2, 2*4, 4*4, 4*8, 8*8, 8*16, 16*16, 32*32 and other scales. It may also be other matrix arrangements, such as 2*3, 2*6, 2*12, etc., which also fall within the achievable scope of the present invention.

Wherein the projections of all the array elements of the first antenna **110** and all the array elements of the second antenna **210** on the second substrate **200** do not completely coincide. The incomplete coincidence here means that the size of the array element of the first antenna is different from the size of the array element of the second antenna. Or the projections of the array element of the first antenna and the array element of the second antenna on the second substrate do not coincide or partially coincide.

In addition, the size of the first substrate and the size of the second substrate are preferably the same, of course, they may be different. It should be noted that the size (size of array element, size of substrate) mentioned herein refers to the length (usually called the antenna length) on the Y-axis and the width (usually called the antenna width) on the X-axis when the device is represented by a two-dimensional plane coordinate axis without calculating the thickness of the device, the thickness of the device is the height difference between the upper surface and the lower surface of the device in the top-down direction in the present invention, namely the vertical direction.

Here, the first antenna and the second antenna may be only transmitting antennas or receiving antennas, or each may include a transmitting antenna and a receiving antenna, respectively. For example, when the first antenna or the second antenna includes a transmitting antenna and a receiving antenna at the same time, the receiving antenna and the transmitting antenna on the same substrate are connected to each other through metal wire vias. As shown in FIG. **3** and FIG. **4**, the array element of the receiving antenna and the array element of the transmitting antenna of the first antenna on the first substrate are connected by a first connecting line **400**, the array element of the receiving antenna and the array element of the transmitting antenna of the second antenna on the second substrate are connected by a second connecting line **500**. The array element of the first antenna and the array element of the second antenna pass through a through holes **600** provided on the first substrate and the second substrate through the feeder **700** and then are connected to the chip of the array antenna apparatus (not shown in the figure), and communication is realized by transmitting the signal to the chip and then processing by the chip.

In a preferred embodiment, the array elements on the same substrate are connected by connecting lines, and the array elements are arranged symmetrically on both sides of the connecting line (as shown in FIG. **1**). At the same time, the geometric center O of the first substrate **100** and the geometric center O' of the second substrate **200** are located on the connecting line, which is also the geometric center of the connecting line.

In addition, the number of substrates and the number of antennas provided on the substrate can be set to n, n is greater than or equal to 2, in this way, multiple beams can be realized, and the projections between the array elements of each layer and the array elements of other layers on the designated surface of any substrate do not completely coincide, such as staggered arrangement or partial coincidence. In this way, it is possible to realize that the main lobes of the array elements of each layer point to different directions, and the angle of each main lobe can be adjusted through the incomplete coincidence of the array elements, so as to realize a large bandwidth, and it is also possible to cancel the horizontal sidelobe levels generated by the array antennas on each substrate.

The positions of two or more layers of antenna array elements are evenly overlapped but not completely overlapped, and the sizes of the array elements (microstrip patches) are different, and multi-channel or large-bandwidth transmission can be realized in the same transmitting/receiving direction.

The length of any element of the first antenna or the second antenna is approximately equal to 0.5 times the medium wavelength λ. Usually millimeter waves are used, so the size of the antenna can be small, preferably between 0.3λ and 1.2λ.

In FIG. **2** to FIG. **4**, H is the horizontal spacing of the array element (microstrip patch), the number **1** refers to the first layer antenna, and the letter n refers to the n-th layer antenna. H**1** is the horizontal spacing between the microstrip patches of the first layer antenna, and Hn is the horizontal spacing between the microstrip patches of the n-th layer antenna; it can be seen that the size of H**1** in the figure is different from the size of Hn.

V is the longitudinal spacing of the array element (microstrip patch), the number **1** refers to the first layer antenna, and the letter n refers to the nth layer antenna. VI is the longitudinal spacing between the microstrip patches of the first layer antenna, and Vn is the longitudinal spacing between the microstrip patches of the nth layer antenna; the size of VI is also different from the size of Vn.

L is the width of the array element (microstrip patch), the number **1** refers to the first layer antenna, and the letter n refers to the nth layer antenna. L**1** is the width of the microstrip patch of the first layer antenna, and Ln is the width of the microstrip patch of the nth layer antenna. The size of L**1** is also different from the size of Ln.

After arranging according to the antenna structure disclosed in the present invention, the antenna bandwidth is increased and multi-beam is realized, and it can effectively adjust and suppress antenna side lobes, effectively reduce mutual coupling and interference between antennas, and improve communication quality and radar detection efficiency.

The array antenna apparatus according to the first embodiment of the present invention adopts an up-down design in a three-dimensional space, and the array elements of the array antenna on each substrate layer and the array elements of the array antenna on the other substrate layers are designed to be differentiated in the array element layout position and the spacing between adjacent array elements, which not only overcomes the technical prejudice in the prior art, namely the prejudice of designing upper and lower layers in three-dimensional space, but also can effectively achieve the following beneficial effects:

1) sidelobe suppression: reducing the energy distribution of the upper sidelobe to reduce the co-frequency, adjacent frequency, cross-area interference caused by the excessive upper sidelobe, achieving the optimized zero-point cancellation effect, so as to achieve a more ideal sidelobe suppression;
2) large bandwidth or multiple channels: with high information rate, wide spectrum spreading ability, reducing multipath, clutter and enhancing anti-interference ability; in the wireless communication of adjacent frequencies, it is easy to overcome mutual interference; greatly increasing the communication volume;
3) multiple beams: forming shaped beams of different shapes, the number and shape of the beams can be flexibly set, the element beams are narrow and the gain is high, which can serve multiple users at the same time, the formed beam can cover a wide area of the designated area, and it can achieve low sidelobes by means of combined feed source.

Embodiment 2

Referring to FIG. **5**, on the basis of Embodiment 1 of the present invention, Embodiment 2 of the present invention further improves and refines the array antenna apparatus, the main features are as follows: all the array elements of the first antenna are symmetrically distributed about the geometric center of the first substrate, and all the array elements of the second antenna are symmetrically distributed about the geometric center of the second substrate, the projections of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate coincide.

In a specific embodiment, the size of each array element of the first antenna is different from the size of each array element of the second antenna.

Specifically, all the array elements of the first antenna **110** on the first substrate **100** have the same size, and the spacings between any two adjacent array elements are equal, which are arranged in a center-symmetrical arrangement. All the array elements of the second antenna **210** on the second substrate **200** have the same size, and the spacings between any two adjacent array elements are equal, and the center is symmetrically arranged. The projection of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate completely coincides.

The length of each array element (microstrip patch) of the first antenna is different from the length of each array element (microstrip patch) of the second antenna, therefore each generates an outgoing wave of different frequencies to form multiple frequency bands or to be superimposed on each other in the frequency domain to achieve the effect of increasing the bandwidth.

Embodiment 3

Referring to FIG. **6**, on the basis of Embodiment 1 of the present invention, Embodiment 3 of the present invention is further improved and refined. The main feature is that all the array elements **111**, **112**, **113**, **114** of the first antenna are not symmetrically distributed about the geometric center of the first substrate, all the array elements **211**, **212**, **213**, and **214** of the second antenna are not symmetrically distributed about the geometric center of the second substrate, the geometric center of the first substrate coincides with the projection of the geometric center of the second substrate on the second substrate. All the array elements **111**, **112**, **113**, **114** of the first antenna are offset to the right by a certain distance relative to the geometric center of the first substrate, all the array elements **211**, **212**, **213**, and **214** of the second antenna are offset to the left by a certain distance relative to the geometric center of the second substrate. Even the projections of both on the second substrate have completely non-overlapping parts.

The spacings between any two adjacent array elements, in a second direction perpendicular to a first direction which is from top to bottom, of each row of the first antenna are unequal, for example, the spacing between the array element **112** and the array element **113** is not equal to the spacing between the array element **113** and the array element **114**. The spacings between any two adjacent array elements in the second direction of each row of the second antenna are unequal, for example, the spacing between the array element **211** and the array element **212** is not equal to the spacing between the array element **212** and the array element **213**.

In this embodiment, the array element of the array antenna on a certain substrate layer is not evenly spaced or the array elements are arranged asymmetrically, which can change the beam angle and main beam direction of the main beam of the antenna on this layer, at the same time, under this circumstance that the positions of the array elements of the antenna of each substrate layer are unevenly or asymmetrically distributed, the projections of the elements of the array elements of the antenna of other layers on any designated layer do not completely coincide, which allows each layer to produce its own electromagnetic field phase changes, and generate multiple outgoing beams. When these multi-layer antenna arrays are superimposed, a multi-beam antenna can be realized.

Embodiment 4

Referring to FIG. **7**, on the basis of Embodiment 1 of the present invention, Embodiment 4 of the present invention is further improved and refined. The main features are as follows: all the elements of the first antenna have the same size, and all the array elements of the second antenna have the same size, and the size of each array element of the first antenna is different from the size of each array element of the second antenna.

In a specific embodiment, the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the first substrate among all the array elements **11**A, **11**B, **11**C, **11**D, **11**E, **11**F, **11**G, **11**H of the first antenna gradually increases as the distance from the geometric center of the first substrate increases, the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the second substrate among all the array elements **21**A, **21**B, **21**C, **21**D, **21**E, **21**F, **21**G, **21**H of the second antenna gradually increases or gradually increases as the distance from the geometric center of the second substrate increases.

In a specific embodiment, the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the first substrate among all the array elements

of the first antenna gradually decreases as the distance from the geometric center of the first substrate increases, the spacing between two adjacent elements in the transverse and longitudinal directions of the second substrate among all elements of the second antenna gradually increases or decreases as the distance from the geometric center of the second substrate increases.

Embodiment 5

Referring to FIG. **8**, on the basis of Embodiment 1 of the present invention, Embodiment 5 of the present invention is further improved and refined. The main features are as follows: the sizes of all the array elements of the first antenna are the same, the sizes of all the array elements of the second antenna are the same, and the sizes of the array elements of the first antenna are different from the sizes of the array elements of the second antenna.

Further, the width of each array element **11***a*, **11***b*, **11***c*, **11***d*, **11***e*, **11***f*, **11***g*, **11***h* of the first antenna gradually increases or decreases as the distance from the geometric center of the first substrate increases, the width of each array element **21***a*, **21***b*, **21***c*, **21***d*, **21***e*, **21***f*, **21***g*, **21***h* of the second antenna gradually increases or decreases as the distance from the geometric center of the second substrate increases, and the length of each array element of the first antenna is a first preset value, and the length of each array element of the second antenna is a second preset value different from the first preset value.

In a specific embodiment, the distance between the geometric centers of any two adjacent array elements of the first antenna is a first specified value; the distance between the geometric centers of any two adjacent array elements of the second antenna is a second specified value different from the first specified value. In other words, the distance between the geometric centers of any adjacent array element of the first antenna remains unchanged, but the size of the array element is changed, and the same is true for any adjacent element of the second antenna.

Embodiment 6

Referring to FIG. **9**, embodiment 6 of the present invention also provides a PREPARATION method of an array antenna apparatus on the basis of Embodiments 1 to 5, the preparation method includes:

S**1**: forming a first antenna on a first substrate, and the first antenna is provided with a plurality of array elements arranged in an array;

S**2**: forming a second antenna on the second substrate, and the second antenna is provided with a plurality of array elements arranged in an array; and,

S**3**: placing the first substrate above the second substrate, wherein the projections of all the array elements of the first antenna and all the array elements of the second antenna on the second substrate do not completely coincide. For further features of the array antenna apparatus of the present invention, please refer to the description of Embodiments 1 to 5 of the present invention, which will not be repeated here.

Embodiment 7

Referring to FIG. **10**, on the basis of Embodiments 1 to 5 of the present invention, an electronic device is further provided, the electronic device includes the array antenna apparatus in the above-mentioned Embodiments 1 to 5. The electronic device can be a mobile communication device, a satellite communication device, a car, or a radar device.

It should be clear that the present invention is not limited to the specific configuration and processing described above and shown in the drawings. For the sake of brevity, a detailed description of the known method is omitted here. In the above embodiments, several specific steps are described and shown as examples. However, the method process of the present invention is not limited to the specific steps described and shown, and those skilled in the art can make various changes, modifications and additions, or change the order between the steps after understanding the spirit of the present invention. These should be covered within the protection scope of the present invention.

What is claimed is:

1. An array antenna apparatus, including:

at least two substrate: a first substrate and a second substrate which are provided from top to bottom,

wherein a first antenna is provided on the first substrate;

a second antenna is provided on the second substrate;

the first antenna is provided with a plurality of array elements arranged in an array, the second antenna is provided with a plurality of array elements arranged in an array; and the projections of all the array elements of the first antenna and all the array elements of the second antenna on the second substrate do not completely coincide, all the array elements of the first antenna are symmetrically distributed about a geometric center of the first substrate, and all the array elements of the second antenna are symmetrically distributed about a geometric center of the second substrate, projections of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate coincide.

2. The array antenna apparatus according to claim **1**, wherein the size of each array element of the first antenna is different from the size of each array element of the second antenna.

3. The array antenna apparatus according to claim **2**, wherein spacings between any two adjacent array elements, in a second direction perpendicular to a first direction which is from top to bottom, of each row of the first antenna are unequal, and spacings between any two adjacent array elements in the second direction of each row of the second antenna are unequal.

4. The array antenna apparatus according to claim **3**, wherein the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the first substrate among all the array elements of the first antenna gradually increases as the distance from the geometric center of the first substrate increases, the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the second substrate among all the array elements of the second antenna gradually decreases as the distance from the geometric center of the first substrate decreases.

5. The array antenna apparatus according to claim **3**, wherein the spacing between two adjacent array elements in the transverse and/or longitudinal direction of the first substrate among all the array elements of the first antenna gradually decreases as the distance from the geometric center of the first substrate increases, the spacing between two adjacent array elements in the transverse and longitudinal direction of the second substrate among all the array elements of the second antenna gradually increases or decreases as the distance from the geometric center of the first substrate increases.

6. The array antenna apparatus according to claim 5, wherein the distance between the geometric centers of any two adjacent array elements of the first antenna is a first specified value; the distance between the geometric centers of any two adjacent array elements of the second antenna is a second specified value different from the first specified value.

7. The array antenna apparatus according to claim 1, wherein all the array elements of the first antenna are not symmetrically distributed about the geometric center of the first substrate, all the array elements of the second antenna are not symmetrically distributed about the geometric center of the second substrate, the projections of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate coincide.

8. The array antenna apparatus according to claim 1, wherein the sizes of all the array elements of the first antenna are the same, the sizes of all the array elements of the second antenna are the same, and the sizes of the array elements of the first antenna are different from the sizes of the array elements of the second antenna.

9. The array antenna apparatus according to claim 1, wherein the width of each array element of the first antenna gradually increases or decreases as the distance from the geometric center of the first substrate increases, the width of each element of the second antenna gradually increases or decreases as the distance from the geometric center of the second substrate increases, and the length of each element of the first antenna is a first preset value, and the length of each element of the second antenna is a second preset value different from the first preset value.

10. A preparation method of an array antenna apparatus, comprising:

forming a first antenna on a first substrate, and the first antenna is provided with a plurality of array elements arranged in an array;

forming a second antenna on the second substrate, and the second antenna is provided with a plurality of array elements arranged in an array; and,

placing the first substrate above the second substrate, wherein, the projections of all the array elements of the first antenna and all the array elements of the second antenna on the second substrate do not completely coincide to generate an outgoing wave with different frequencies to form multiple frequency bands or to be superimpose each other in the frequency domain; the first antenna and the second antenna are one or both of a transmitting antenna and a receiving antenna, all the array elements of the first antenna are symmetrically distributed about a geometric center of the first substrate, and all the array elements of the second antenna are symmetrically distributed about a geometric center of the second substrate, projections of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate coincide to generate an outgoing wave with different frequencies to form multiple frequency bands or to be superimpose each other in the frequency domain.

11. The preparation method of an array antenna apparatus according to claim 10, wherein all the array elements of the first antenna are not symmetrically distributed about the geometric center of the first substrate, all the array elements of the second antenna are not symmetrically distributed about the geometric center of the second substrate, the projections of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate coincide.

12. An electronic device, wherein the electronic device includes an array antenna apparatus, including:

at least two substrate: a first substrate and a second substrate which are provided from top to bottom,

wherein a first antenna is provided on the first substrate;

a second antenna is provided on the second substrate;

the first antenna is provided with a plurality of array elements arranged in an array the second antenna is provided with a plurality of array elements arranged in an array; and the projections of all the array elements of the first antenna and all the array elements of the second antenna on the second substrate do not completely coincide, all the array elements of the first antenna are symmetrically distributed about a geometric center of the first substrate, and all the array elements of the second antenna are symmetrically distributed about a geometric center of the second substrate, projections of the geometric center of the first substrate and the geometric center of the second substrate on the second substrate coincide.

13. The electronic device according to claim 12, wherein the electronic device is at least one of a mobile communication device, a radar device, a satellite communication device, or an automobile.

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(54) **MINIATURIZED BROADBAND ANTENNA AND WIRELESS COMMUNICATION DEVICE USING THE SAME**

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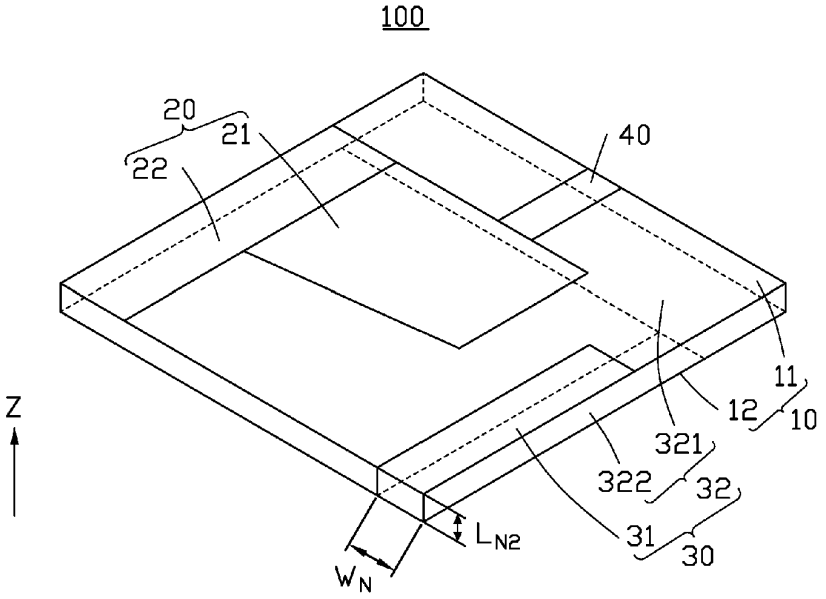
(57) **ABSTRACT**

A miniaturized antenna with broadband capabilities includes a dielectric substrate, a first radiation unit, a second radiation unit and a feed portion. The dielectric substrate includes a first surface and a second surface. The first radiation unit is arranged on the first surface, the second radiation unit extends from the second surface to the first surface, the second radiation unit includes a ground portion and a first radiation portion. The feed portion feeds current to the first radiation unit, the first radiation unit excites a first radiation frequency band, and the first radiation portion excites a second radiation frequency band. The disclosure also provides a wireless communication device. The antenna is miniaturized and achieves broadband capabilities.

20 Claims, 4 Drawing Sheets



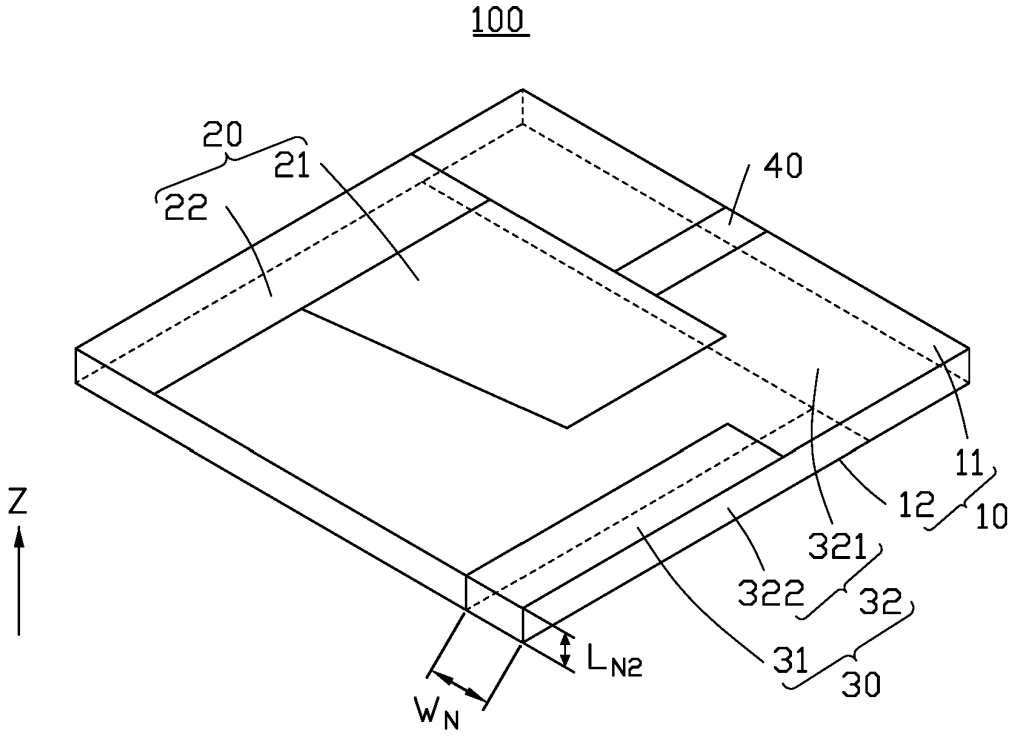


FIG. 1

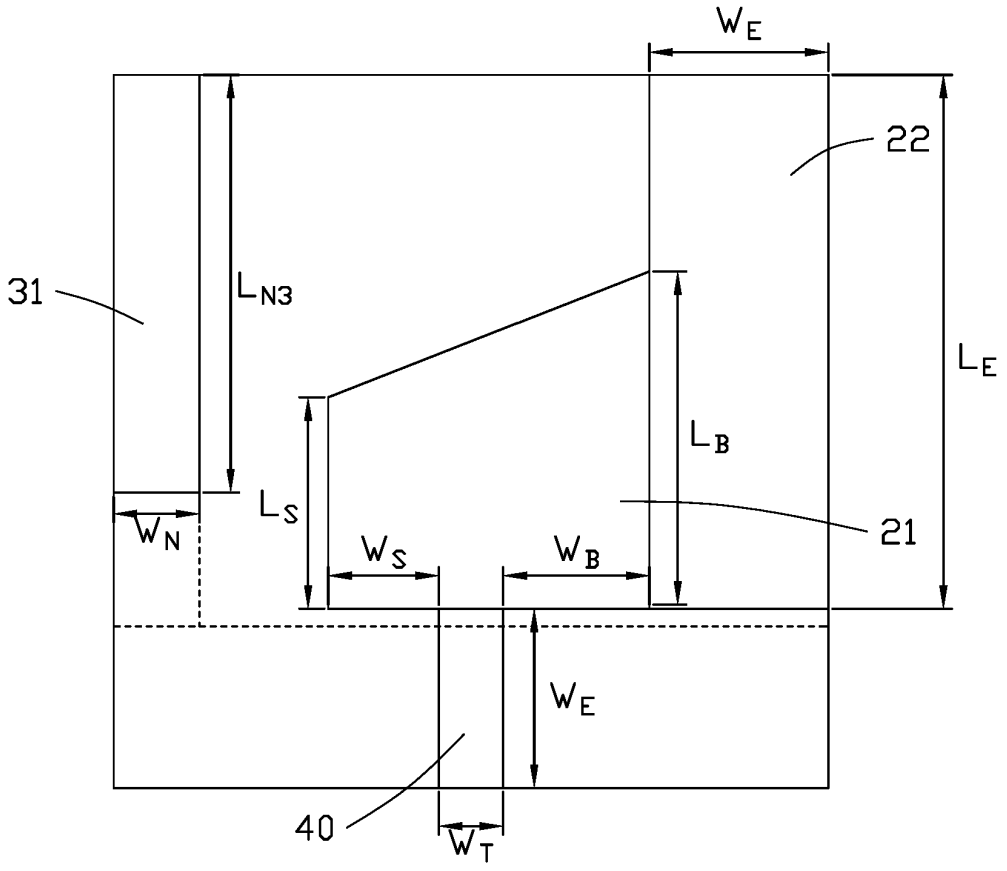


FIG. 2

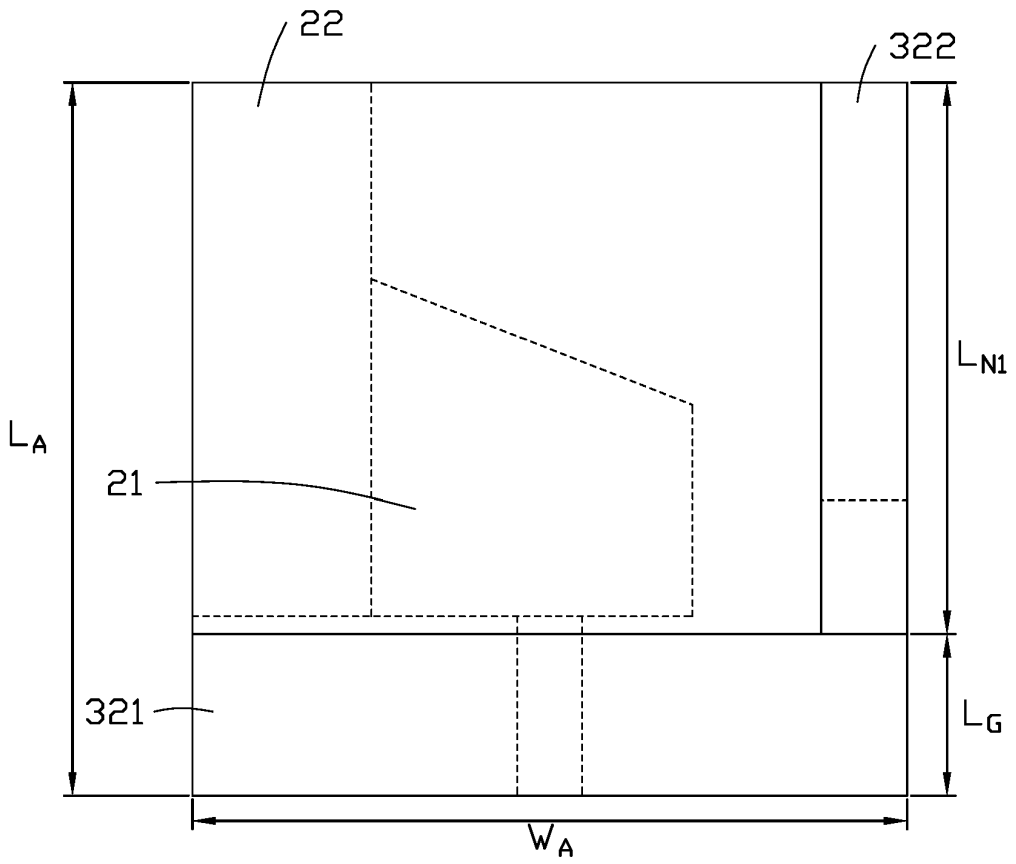


FIG. 3

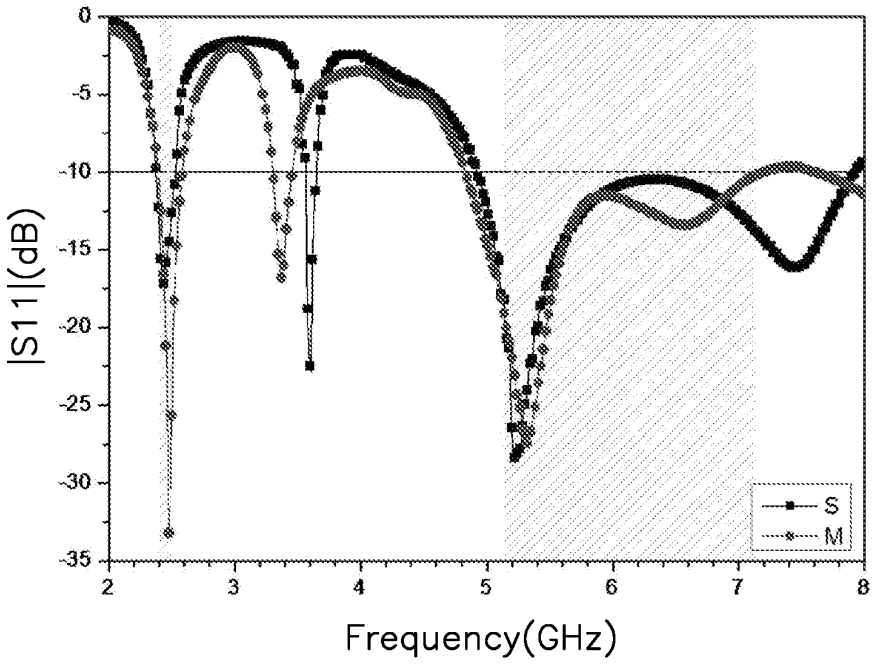


FIG. 4

MINIATURIZED BROADBAND ANTENNA AND WIRELESS COMMUNICATION DEVICE USING THE SAME

FIELD

The present disclosure relates to the field of antenna, in particular to an antenna and a wireless communication device using the same.

BACKGROUND

With the popularity of wireless devices, wireless devices are becoming smaller and smaller. Therefore, an antenna must not only fit within small wireless devices, but also have a wide bandwidth to support multiple working bands. Together, these two considerations are problematic.

Therefore, improvement is desired.

SUMMARY OF THE DISCLOSURE

The embodiment of the present disclosure provides an antenna with small size and ability to support multiple working frequency bands and a wireless communication device with the antenna.

The present disclosure provides an antenna, the antenna includes a dielectric substrate, a first radiation unit, a second radiation unit, and a feed portion. The dielectric substrate includes a first surface and a second surface. The first radiation unit is arranged on the first surface. The second radiation unit extends from the second surface to the first surface, wherein the second radiation unit comprises a ground portion and a first radiation portion, a part of the second radiation unit arranged on the first surface is used as the first radiation portion, another part of the second radiation unit arrange on the first surface is used as the ground portion, and the first radiation portion and the first radiation unit are adjacent and spaced. The feed portion is configured to feed current to the first radiation unit, the first radiation unit excites a first radiation frequency band, the current flowing through the first radiation unit is further coupled and fed into the first radiation portion, and the first radiation portion excites a second radiation frequency band.

In some embodiments, the first surface deviates from the second surface, and the first radiation unit comprises a second radiation portion and a third radiation portion, the second radiation portion is connected to the third radiation portion, the second radiation portion is a right-angled trapezoid, and the third radiation portion is rectangular, a length of a bottom edge of the second radiation portion is less than a length of the third radiation portion, a right-angle side edge of the second radiation portion is flush with one end of the third radiation portion, the first radiation portion and the second radiation portion are arranged at relative intervals, and the feed portion is connected to the second radiation portion.

In some embodiments, the first radiation portion is rectangular, and the first radiation portion is parallel to the third radiation portion.

In some embodiments, the ground portion comprises a first ground portion and a second ground portion, and the first ground portion is vertically connected to the second ground portion, the first ground portion is arranged close to the right-angle side edge of the second radiation portion, and the first ground portion is parallel to the right-angle side edge of the second radiation portion; the second ground portion is arranged at one end of the second surface away from the first radiation unit.

In some embodiments, the second ground portion is parallel to the third radiation portion, and the second ground portion is connected to the first radiation portion.

In some embodiments, the first ground portion and the second ground portion are rectangular.

In some embodiments, a dielectric coefficient of the dielectric substrate is 9.8.

In some embodiments, the first radiation frequency band comprises 5.15 GHz to 7.125 GHz, and the second radiation frequency band comprises 2.4 GHz to 2.5 GHz.

In some embodiments, a projected area of the ground portion on the second surface along a thickness direction of the antenna does not overlap a projected area of the first radiation unit on the second surface along the thickness direction of the antenna.

In some embodiments, the dielectric substrate is an alumina and ceramic substrate.

The present disclosure further provides a wireless communication device, which includes the plurality of antennas as described above.

In the present disclosure, the first radiation unit and the second radiation unit are arranged on the dielectric substrate, and the second radiation unit extends from the second surface to the first surface to form the first radiation portion and the ground portion on the second radiation unit; the first radiation unit receives the current fed by the feed portion to excite the first radiation frequency band, and the first radiation portion is coupled to the first radiation unit on the first surface to excite the second radiation frequency band. The antenna provided in the present disclosure is not only miniaturized, but also provides the ground portion of the antenna without more feeding portions requiring to be set. Thus multiple working frequency bands are stimulated, and the antenna provides broadband connections.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of an antenna according to an embodiment of the present disclosure.

FIG. **2** is a schematic diagram of a first surface of the antenna shown in FIG. **1**.

FIG. **3** is a schematic diagram of a second surface of the antenna shown in FIG. **1**.

FIG. **4** is a return loss curve diagram of the antenna shown in FIG. **1**.

DETAILED DESCRIPTION

The technical solutions in the embodiments of the present disclosure will be described in conjunction with the accompanying drawings in the embodiments of the present disclosure. Obviously, the described embodiments are part of the embodiments of the present disclosure, not all of them. Based on the embodiments of the present disclosure, all other embodiments obtained by those of ordinary skill in the art without creative work shall fall within the protection scope of the present disclosure.

It should be noted that when an element is described as "electrically connecting" to another element, it can be directly on another component or there can be a centered element. When an element is said to be "electrically connected" to another element, it can be a contact connection, for example, a wire connection, or a non-contact connection, for example, a wireless coupling.

The terms used in the description of the present disclosure herein are only for the purpose of describing specific embodiments and are not intended to limit the present disclosure. The term "and/or" as used herein includes any and all combinations of one or more related listed items.

With the popularity of wireless devices, the size of wireless devices is becoming smaller and smaller. Therefore, an antenna needs to be used in small wireless devices, but also needs to provide a wide bandwidth to support multiple working bands.

FIG. **1** illustrates an antenna **100** in accordance with an embodiment of the present disclosure.

The antenna **100** can be applied to a customer premises equipment (CPE), a router, a set top box, a mobile phone, a laptop and other wireless communication devices (not shown in the figure) to transmit and receive radio waves to transmit and exchange radio signals.

In some embodiments, the antenna **100** includes a dielectric substrate **10**, a first radiation unit **20**, a second radiation unit **30**, and a feed portion **40**.

The dielectric substrate **10** includes a first surface **11** and a second surface **12**.

The first radiation unit **20** is arranged on the first surface **11**. The second radiation unit **30** extends from the second surface **12** to the first surface **11**. The second radiation unit **30** includes a first radiation portion **31** and a ground portion **32**. The part of the second radiation unit **30** is arranged on the first surface **11** as the first radiation portion **31**. The other parts of the second radiation unit **30** except those arranged on the first surface **11** serves as the ground portion **32**. The first radiation portion **31** is adjacent to the first radiation unit **20** at intervals.

The feed portion **40** is used to feed current to the first radiation unit **20**, so that the first radiation unit **20** can excite a first radiation frequency band. The current flowing through the first radiation unit **20** is also coupled and fed to the first radiation portion **31** so that the first radiation portion **31** can excite a second radiation frequency band. In some embodiments, the feed portion **40** may be a microstrip line or other metal conductor connected to the feed line.

In the present disclosure, the first radiation unit **20** and the second radiation unit **30** are arranged on the dielectric substrate **10**, and the second radiation unit **30** extends from the second surface **12** to the first surface **11** to form the first radiation portion **31** and the ground portion **32** on the second radiation unit **30**; the first radiation unit **20** receives the current fed by the feed portion **40** to excite the first radiation frequency band, and the first radiation portion **31** is coupled to the first radiation unit **20** on the first surface **11** to excite the second radiation frequency band. The antenna **100** provided in the present disclosure not only realizes miniaturization, but also provides the ground portion **32** of the antenna **100** without setting more feeding portions, which can stimulate multiple working frequency bands for broadband.

In some embodiments, the first radiation unit **20** includes a second radiation portion **21** and a third radiation portion **22**. The second radiation portion **21** is connected to the third radiation portion **22**. The second radiation portion **21** is a right-angle trapezoid, and the third radiation portion **22** is rectangular. The right-angle side edge of the second radiation portion **21** is flush with one end of the third radiation portion **22**. The feed portion **40** is connected to the second radiation portion **21**. In this way, through the above design, the first radiation frequency band is excited by the second radiation portion **21** and the third radiation portion **22** jointly.

The first radiation portion **31** is parallel to the third radiation portion **22**. The first radiation portion **31** and the second radiation portion **21** are arranged at relative intervals. Therefore, when the feed portion **40** feeds the current to the second radiation portion **21**, the second radiation portion **21** also couples the current to the first radiation portion **31**, so that the first radiation portion **31** can excite the second radiation frequency band.

Referring to FIG. **2**, the second radiation portion **21** and the third radiation portion **22** are formed from one conductor, for example, a metal sheet. The length L_B of the bottom edge of the second radiation portion **21** is 8.5 mm, which is smaller than the length L_E of the third radiation portion **22**, such as 15 mm. The third radiation portion **22** is also arranged along the edge of the first surface **11**, and the end of the third radiation portion **22** far away from the right-angle side edge of the second radiation portion **21** is aligned with the edge of the first surface **11** of the dielectric substrate **10**.

In the embodiment, the width W_E of the third radiation portion **22** is 3.5 mm. The length L_S of the other bottom edge of the second radiation portion **21** is 6 mm. The length of the right-angle side edge of the second radiation portion **21** is 10.4 mm. The distance W_S from the end of the second radiation portion **21** away from the third radiation portion **22** to the feed portion **40** is 3 mm. The distance W_B from the end of the second radiation portion **21** close to the third radiation portion **22** to the feed portion **40** is 5.6 mm. The width W_T of the feed portion **40** is 1.8 mm. The length W_E of the feed portion **40** is 3.5 mm. The length L_{N3} of the first radiation portion **31** is 12 mm. The width W_N of the first radiation portion **31** is 2.5 mm.

Referring to FIG. **3**, in some embodiments, the ground portion **32** includes a first ground portion **321** and a second ground portion **322**. The first ground portion **321** is vertically connected to the second ground portion **322**. The first ground portion **321** is arranged near the right-angle side edge of the second radiation portion **21**, the first ground portion **321** is parallel to the right-angle side edge of the second radiation portion **21**. In some embodiments, the first ground portion **321** and the second ground portion **322** may be formed of one conductor.

The second ground portion **322** is arranged on the end of the second surface **12** far away from the first radiation unit **20**. The second ground portion **322** is parallel to the third radiation portion **22**, and the second ground portion **322** is connected to the first radiation portion **31**.

In the embodiment, the first ground portion **321** and the second ground portion **322** are rectangular. The first ground portion **321** is aligned with the second surface **12** close to the right-angle side edge of the second radiation portion **21**. The second ground portion **322** is aligned with the second surface **12** close to the edge of the second radiation portion **21**, and the second ground portion **322** is vertically connected to the first ground portion **321**. The length W_A of the first ground portion **321** is the same as the width of the dielectric substrate **10**, both of which are 20 mm. The width L_G of the first ground portion **321** is 5 mm, which is less than the distance from the right-angle side edge of the second radiation portion **21** to the edge of the adjacent second surface **12**. The length L_{N1} of the second ground portion **322** is 15 mm. The width W_N of the second ground portion **322** is 2.5 mm (shown in FIG. **1**), which is less than the distance from the end of the second radiation portion **21** away from the third radiation portion **22** to the edge of the first surface **11**. The projection area of the ground portion **32** on the second surface **12** along the thickness direction of the

antenna **100** (the direction of the Z-axis in FIG. **1**) does not overlap with the projection area of the first radiation unit **20** on the second surface **12** along the thickness direction of the antenna **100**. The first radiation unit **20** can radiate waves towards the direction where the second surface **12** is located to expand the radiation field type of the antenna **100**. In the embodiment of the present disclosure, the height L_{N2} of the dielectric substrate **10** is 1.3 mm.

The first radiation portion **31** is formed by extending one end of the second ground portion **322** away from the first ground portion **321** to the first surface **11**. Therefore, the first radiation portion **31** is aligned with the edge on the first surface **11** away from the third radiation portion **22**. In the embodiment of the present disclosure, the width of the first radiation portion **31** is the same as the width W_N of the second ground portion **322**, both of which are 2.5 mm. The length L_{N3} of the first radiation portion **31** is 12 mm.

Referring to FIG. **1**, in some embodiments, the dielectric coefficient of the dielectric substrate **10** is 9.8. Therefore, the dielectric substrate **10** can effectively reduce the field leakage and cross coupling effect of the antenna **100**, conducive to better outward radiation by the antenna **100**. For example, in the embodiment of the present disclosure, the dielectric substrate **10** is an alumina-ceramic substrate, and the dielectric coefficient of the dielectric substrate **10** is 9.8, and the hardness is 9. Therefore, the dielectric substrate **10** provided in the embodiment of the present disclosure has good drop resistance and corrosion resistance.

The present disclosure does not limit the position of the first surface **11** and the second surface **12** on the dielectric substrate **10**, as long as the first surface **11** and the second surface **12** are not on the same surface. Therefore, the area of the dielectric substrate **10** can be reduced to achieve miniaturization of the antenna **100** as much as possible. In the embodiment of the present disclosure, the first surface **11** and the second surface **12** are two surfaces that deviate from each other on the dielectric substrate **10**. For example, the first surface **11** and the second surface **12** are the upper surface and the lower surface of the dielectric substrate **10**, respectively. Therefore, the required area and volume of the dielectric substrate **10** can be further reduced, allowing a reduction in size of the antenna **100**. In other embodiments, the first surface **11** and the second surface **12** may also be two adjacent or spaced surfaces on the dielectric substrate **10**.

The present disclosure does not limit the size and shape of the dielectric substrate **10**. In other embodiments, the dielectric substrate **10** may also have other shapes. When in different shapes, each part of the first radiation unit **20** and the second radiation unit **30** does not need to be arranged at the edge of the dielectric substrate **10**, the first radiation unit **20** and the second radiation unit **30** can still together realize the required functions.

FIG. **4** shows the return loss curve of the antenna **100** provided in the present disclosure. The curve S is the return loss curve of the antenna **100** provided in the disclosure under a simulation; the curve M is the return loss curve of the antenna **100** provided in the present disclosure obtained through physical laboratory test. As shown in FIG. **4**, the return loss of the antenna **100** is lower than −10 dB in the first radiation frequency band (including 5.15 GHz to 7.125 GHz) and the second radiation frequency band (including 2.4 GHz to 2.5 GHz), which meets requirements.

The antenna **100** provided in the disclosure can be applied to a variety of Wi-Fi standards such as Wi-Fi 4 (the frequency band covering 2.4 GHz-2.5 GHz), Wi-Fi 5 (the frequency band covering 2.4 GHz-2.5 GHz and 5.15 GHz-5.85 GHz), Wi-Fi 6 (the frequency band covering 2.4 GHz-2.5 GHz and 5 GHz), and Wi-Fi 7 (the frequency band covering 2.4 GHz-2.5 GHz, 5 GHz and 5.925 GHz-7.125 GHz). In theory, Wi-Fi 7 standard can support the bandwidth of up to 30 Gbps for each access point, and the maximum network speed of Wi-Fi 7 can reach 46.4 Gbps. Therefore, the antenna **100** provided in the disclosure meets current requirements relating to development trends of Wi-Fi technology and enables the wireless communication device equipped with the antenna **100** to have a faster network speed while reducing the number of antennas.

The antenna **100** of the present disclosure can extend from the second surface **12** of the dielectric substrate **10** to the first surface **11** through the second radiation unit **30**, the first radiation portion **31** and the ground portion **32** are constructed on the second radiation unit **30**; the present disclosure also disposes the first radiation unit **20** on the first surface **11** of the dielectric substrate **10**, and the first radiation unit **20** receives the current fed by the feed portion **40** to excite the first radiation frequency band. The first radiation portion **31** is coupled to the first radiation unit **20** on the first surface **11** to excite the second radiation frequency band, thus realizing miniaturization broadband performance. The antenna **100** provided in the present disclosure can be applied to various Wi-Fi standards, especially Wi-Fi 7, so that the wireless communication device with the antenna **100** can have a faster network speed while reducing the number of antennas required.

Those of ordinary skill in the art should realize that the above embodiments are only used to illustrate the present disclosure, but not to limit the present disclosure. As long as they are within the essential spirit of the present disclosure, the above embodiments are appropriately made and changes fall within the scope of protection of the present disclosure.

What is claimed is:

1. An antenna comprising:

a dielectric substrate comprising a first surface and a second surface;

a first radiation unit arranged on the first surface;

a second radiation unit extended from the second surface to the first surface; wherein the second radiation unit comprises a ground portion and a first radiation portion, a part of the second radiation unit arranged on the first surface is used as the first radiation portion, and the first radiation portion and the first radiation unit are adjacent and spaced; and

a feed portion configured to feed current to the first radiation unit, the first radiation unit excited a first radiation frequency band, the current flowing through the first radiation unit further coupled and fed into the first radiation portion, and the first radiation portion excited a second radiation frequency band;

wherein the first radiation unit comprises a second radiation portion and a third radiation portion, the second radiation portion is connected to the third radiation portion, the second radiation portion is a right-angled trapezoid, and the third radiation portion is rectangular, a length of a bottom edge of the second radiation portion is less than a length of the third radiation portion, a right-angle side edge of the second radiation portion is flush with one end of the third radiation portion.

2. The antenna of claim **1**, wherein the first surface deviates from the second surface, the first radiation portion and the second radiation portion are arranged at relative intervals, and the feed portion is connected to the second radiation portion.

3. The antenna of claim 2, wherein the first radiation portion is rectangular, and the first radiation portion is parallel to the third radiation portion.

4. The antenna of claim 2, wherein the ground portion comprises a first ground portion and a second ground portion, and the first ground portion is vertically connected to the second ground portion, the first ground portion is arranged close to the right-angle side edge of the second radiation portion, and the first ground portion is parallel to the right-angle side edge of the second radiation portion; the second ground portion is arranged at one end of the second surface away from the first radiation unit.

5. The antenna of claim 4, wherein the second ground portion is parallel to the third radiation portion, and the second ground portion is connected to the first radiation portion.

6. The antenna of claim 5, wherein the first ground portion and the second ground portion are rectangular.

7. The antenna of claim 1, wherein a dielectric coefficient of the dielectric substrate is 9.8.

8. The antenna of claim 1, wherein the first radiation frequency band comprises 5.15 GHz to 7.125 GHz, and the second radiation frequency band comprises 2.4 GHz to 2.5 GHz.

9. The antenna of claim 1, wherein a projected area of the ground portion on the second surface along a thickness direction of the antenna does not overlap a projected area of the first radiation unit on the second surface along the thickness direction of the antenna.

10. The antenna of claim 1, wherein the dielectric substrate is an alumina ceramic substrate.

11. A wireless communication device comprising:

a plurality of antennas;

each antenna comprising:

a dielectric substrate comprising a first surface and a second surface;

a first radiation unit arranged on the first surface;

a second radiation unit extended from the second surface to the first surface; wherein the second radiation unit comprises a ground portion and a first radiation portion, a part of the second radiation unit arranged on the first surface is used as the first radiation portion, and the first radiation portion and the first radiation unit are adjacent and spaced; and

a feed portion configured to feed current to the first radiation unit, the first radiation unit excited a first radiation frequency band, the current flowing through the first radiation unit further coupled and fed into the first radiation portion, and the first radiation portion excited a second radiation frequency band;

wherein the first radiation unit comprises a second radiation portion and a third radiation portion, the second radiation portion is connected to the third radiation portion, the second radiation portion is a right-angled trapezoid, and the third radiation portion is rectangular, a length of a bottom edge of the second radiation portion is less than a length of the third radiation portion, a right-angle side edge of the second radiation portion is flush with one end of the third radiation portion.

12. The wireless communication device of claim 11, wherein the first surface deviates from the second surface, the first radiation portion and the second radiation portion are arranged at relative intervals, and the feed portion is connected to the second radiation portion.

13. The wireless communication device of claim 12, wherein the first radiation portion is rectangular, and the first radiation portion is parallel to the third radiation portion.

14. The wireless communication device of claim 12, wherein the ground portion comprises a first ground portion and a second ground portion, and the first ground portion is vertically connected to the second ground portion, the first ground portion is arranged close to the right-angle side edge of the second radiation portion, and the first ground portion is parallel to the right-angle side edge of the second radiation portion; the second ground portion is arranged at one end of the second surface away from the first radiation unit.

15. The wireless communication device of claim 14, wherein the second ground portion is parallel to the third radiation portion, and the second ground portion is connected to the first radiation portion.

16. The wireless communication device of claim 15, wherein the first ground portion and the second ground portion are rectangular.

17. The wireless communication device of claim 11, wherein a dielectric coefficient of the dielectric substrate is 9.8.

18. The wireless communication device of claim 11, wherein the first radiation frequency band comprises 5.15 GHz to 7.125 GHZ, and the second radiation frequency band comprises 2.4 GHz to 2.5 GHz.

19. The wireless communication device of claim 11, wherein a projected area of the ground portion on the second surface along a thickness direction of the antenna does not overlap a projected area of the first radiation unit on the second surface along the thickness direction of the antenna.

20. The wireless communication device of claim 11, wherein the dielectric substrate is an alumina ceramic substrate.

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