



US 20180342790A1

(19) **United States**(12) **Patent Application Publication**
Oh et al.(10) **Pub. No.: US 2018/0342790 A1**(43) **Pub. Date: Nov. 29, 2018**(54) **TRIBAND ANTENNA****H01Q 5/357** (2006.01)**H01Q 1/38** (2006.01)(71) Applicant: **Hewlett-Packard Development Company, L.P.**, Houston, TX (US)(52) **U.S. Cl.**(72) Inventors: **Sung Oh**, Palo Alto, CA (US); **Philip Wright**, San Diego, CA (US)CPC **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 5/357** (2015.01); **H01Q 7/00** (2013.01)(73) Assignee: **Hewlett-Packard Development Company, L.P.**, Houston, TX (US)

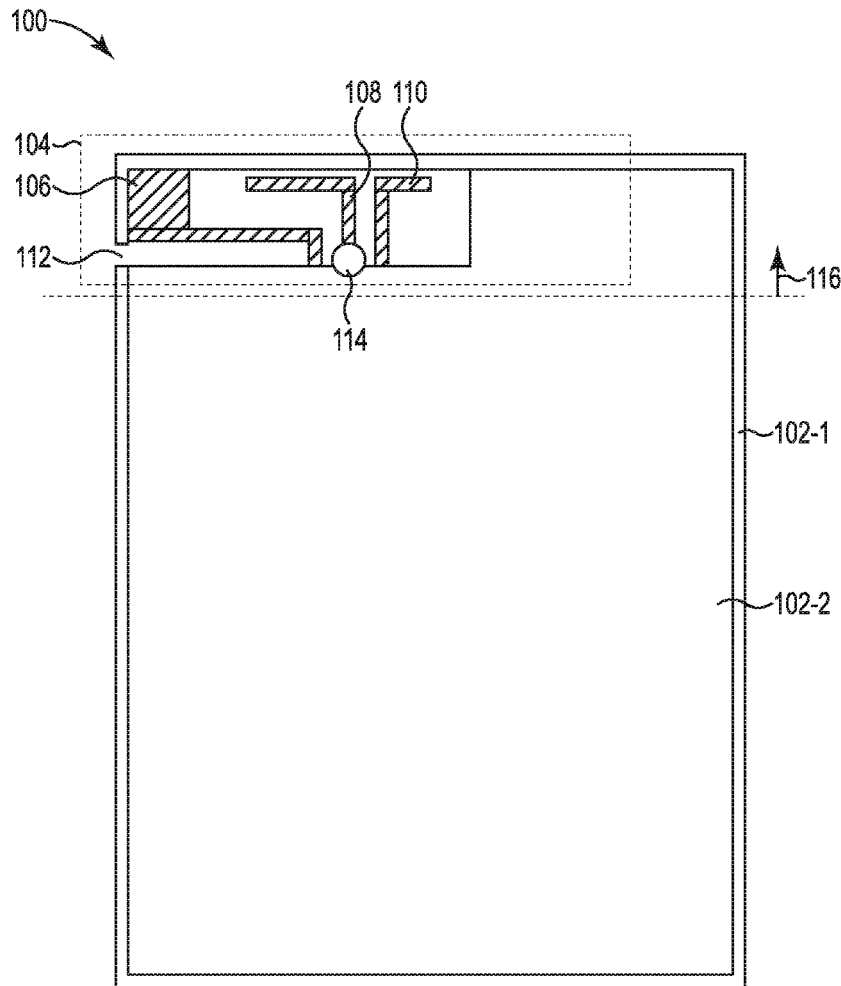
(57)

ABSTRACT(21) Appl. No.: **15/772,075**(22) PCT Filed: **Feb. 19, 2016**(86) PCT No.: **PCT/US2016/018678**

§ 371 (c)(1),

(2) Date: **Apr. 30, 2018****Publication Classification**(51) **Int. Cl.****H01Q 1/24** (2006.01)**H01Q 7/00** (2006.01)

Example implementations relate to a triband antenna. In one example, a triband antenna system as described herein can include a grounding system including a conductive housing of a wireless communication device and a ground slot structure. The triband antenna system may further include a triband antenna coupled to the grounding system, wherein the triband antenna includes a loop element coupled to the conductive housing, a feeding element, and a parasitic element located within a threshold distance of the feeding element.





US 20180342791A1

(19) **United States**(12) **Patent Application Publication****Wu et al.**(10) **Pub. No.: US 2018/0342791 A1**(43) **Pub. Date: Nov. 29, 2018**(54) **ANTENNA STRUCTURE AND ELECTRONIC DEVICE**(71) Applicant: **PEGATRON CORPORATION**, Taipei City (TW)(72) Inventors: **Chien-Yi Wu**, Taipei City (TW);
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Shih-Keng Huang, Taipei City (TW);
Ya-Jyun Li, Taipei City (TW);
Ching-Hsiang Ko, Taipei City (TW);
Cheng-Hsiung Wu, Taipei City (TW)(73) Assignee: **PEGATRON CORPORATION**,
TAIPEI CITY (TW)(21) Appl. No.: **15/972,039**(22) Filed: **May 4, 2018**(30) **Foreign Application Priority Data**

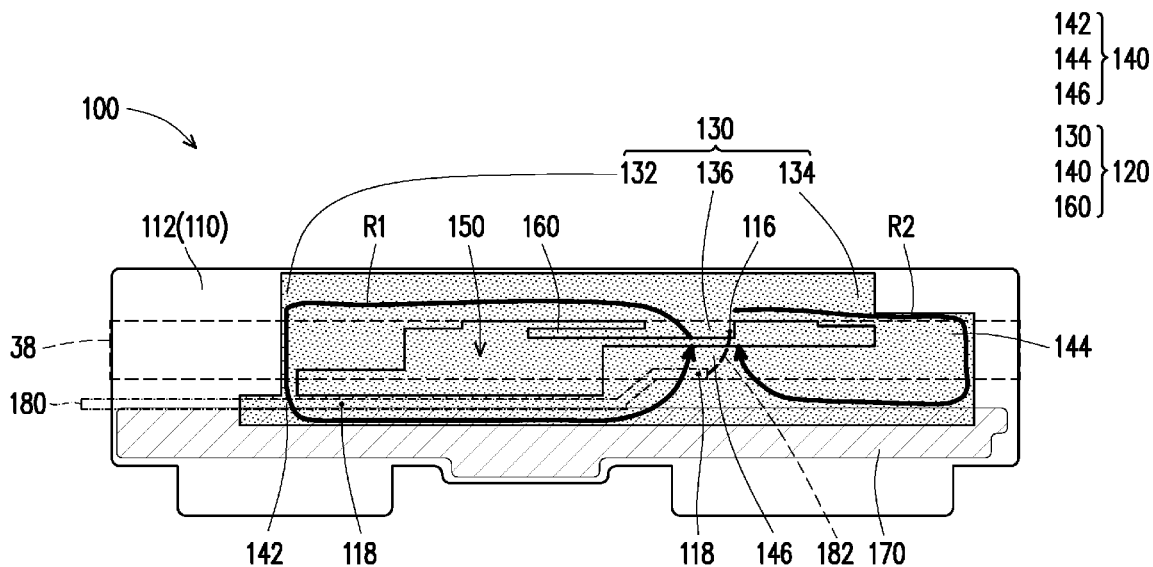
May 25, 2017 (TW) 106117461

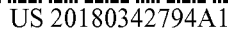
Publication Classification(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/36 (2006.01)**H01Q 13/10** (2006.01)**H01Q 1/22** (2006.01)**H01Q 5/314** (2006.01)**H05K 5/04** (2006.01)**H01Q 9/04** (2006.01)(52) **U.S. Cl.**CPC **H01Q 1/243** (2013.01); **H01Q 1/36**(2013.01); **H01Q 13/106** (2013.01); **H01Q****9/0421** (2013.01); **H01Q 5/314** (2015.01);**H05K 5/04** (2013.01); **H01Q 1/2266** (2013.01)

(57)

ABSTRACT

An antenna structure including a metal casing and an antenna assembly is provided. The metal casing has a slit and a slot adjacent to each other. A length of the slit is greater than a length of the slot, and a width of the slit is less than a width of the slot. The antenna assembly is located in the metal casing and near the slit and the slot. An antenna assembly includes a substrate and an antenna pattern. The antenna pattern is disposed on the substrate and encloses a closed zone. The antenna pattern includes a feed end and a ground end to form a first loop and a second loop. Orthographic projections of the antenna pattern and the enclosed closed zone on the metal casing overlap with the slot. The antenna pattern resonates with the slit and the slot to generate a first frequency band and a second frequency band. An electronic device having the antenna structure is further provided.





(12) **Patent Application Publication**
Han et al.

(43) **Pub. Date:** **Nov. 29, 2018**

H04B 1/401 (2006.01)

(52) U.S. Cl.

CPC **H01Q 1/245** (2013.01); **H01Q 5/35**
(2015.01); **H04W 88/06** (2013.01); **H04B**
1/401 (2013.01); **H04W 4/026** (2013.01)

(57)

ABSTRACT

An electronic device may include an antenna having a resonating element, an antenna ground, and a feed. First and second tunable components may be coupled to the resonating element. Adjustable matching circuitry may be coupled to the feed. Control circuitry may use the first tunable component to tune a midband antenna resonance when sensor circuitry identifies that the device is being held in a right hand and may use the second tunable component to tune the midband resonance when the sensor circuitry identifies that the device is being held in a left hand. For tuning a low band resonance, the control circuitry may place the antenna in different tuning states by sequentially adjusting a selected one of the matching circuitry and the tunable components, potentially reverting to a previous tuning state at each step in the sequence. This may ensure that antenna efficiency is satisfactory regardless of antenna loading conditions.

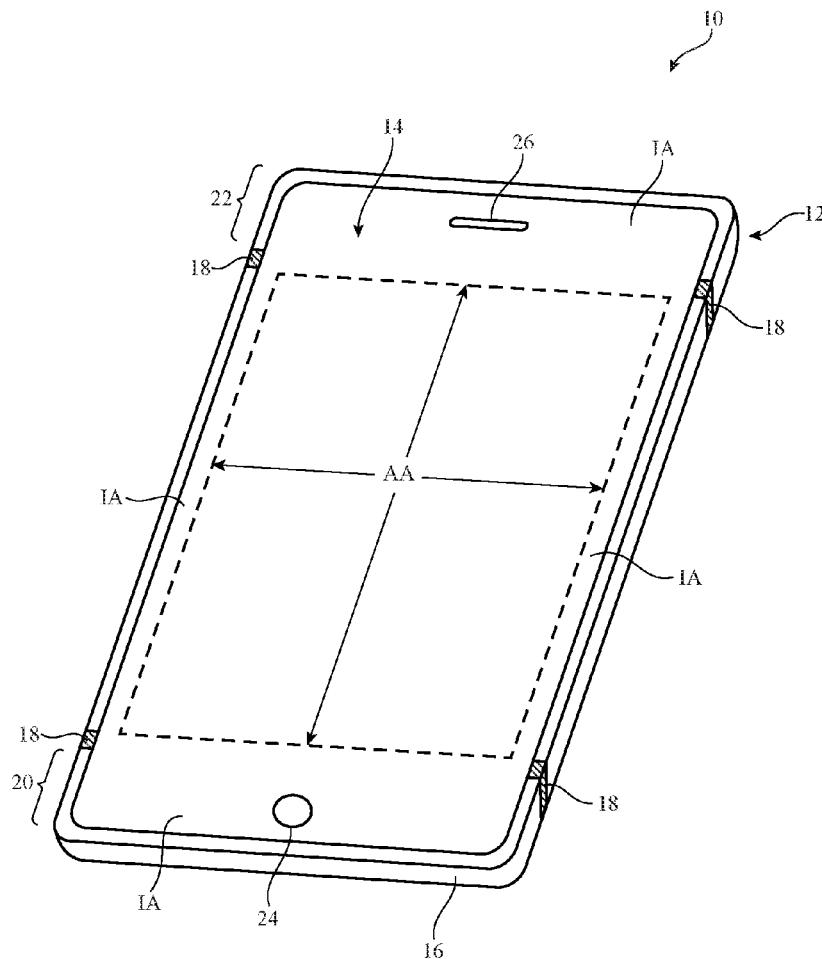
(22) Filed: **May 23, 2017**

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(51) **Int. Cl.**

H01Q 1/24 (2006.01)

H010 5/35 (2006.01)





US 20180342808A1

(19) **United States**

(12) **Patent Application Publication**
Quinlan et al.

(10) **Pub. No.: US 2018/0342808 A1**

(43) **Pub. Date: Nov. 29, 2018**

(54) **ANTENNA STRUCTURE**

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(TW); **Ming-Wei CHEN**, Taoyuan City
(TW)

(21) Appl. No.: **15/990,347**

(22) Filed: **May 25, 2018**

(30) **Foreign Application Priority Data**

May 26, 2017 (TW) 106117543

Publication Classification

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

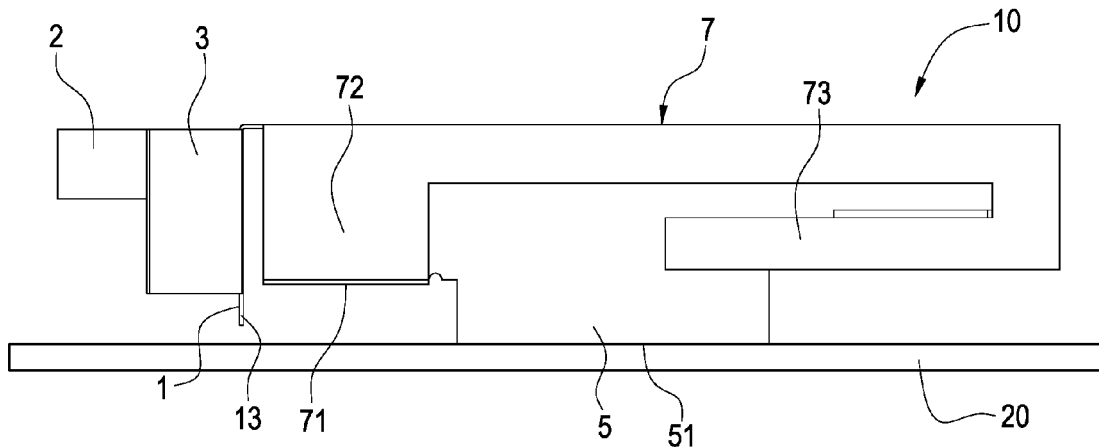
(52) **U.S. Cl.**

CPC **H01Q 9/0421** (2013.01); **H01Q 9/045**
(2013.01); **H01Q 1/243** (2013.01)

(57)

ABSTRACT

An antenna structure (10) includes an antenna feed-in element (1), a first antenna trace element (2), a second antenna trace element (3), a supporting element (4), a grounded-short-circuit element (5), a third antenna trace element (6) and a fourth antenna trace element (7). The first antenna trace element (2), the second antenna trace element (3), the third antenna trace element (6) and the fourth antenna trace element (7) which have vertical segments in different lengths form a multi-trace planar inverted-F antenna to obtain the best bandwidth covering the full band, so that the height of the antenna structure (10) is lower, the length is shorter and the structure is denser. The impedance matching of the antenna structure (10) is controlled easily. No external matching element is required. With the multi-trace and grounded-short-circuit design of the antenna structure (10), the better resonance in the LTE full band is obtained.





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(19) **United States**

(12) **Patent Application Publication**
YEOM et al.

(10) **Pub. No.: US 2018/0351234 A1**

(43) **Pub. Date: Dec. 6, 2018**

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

Publication Classification

(71) Applicant: **Samsung Electronics Co., Ltd.**,
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(51) **Int. Cl.**

H01Q 1/24 (2006.01)

H01Q 1/38 (2006.01)

(72) Inventors: **Jung-Hwan YEOM**, Gyeonggi-do
(KR); **Bong-Soo KANG**, Gyeonggi-do
(KR); **Dae-Hun JUNG**, Gyeonggi-do
(KR)

(52) **U.S. Cl.**

CPC **H01Q 1/24** (2013.01); **H04B 1/16**
(2013.01); **H01Q 1/38** (2013.01)

(21) Appl. No.: **15/775,545**

(22) PCT Filed: **Nov. 11, 2016**

(86) PCT No.: **PCT/KR2016/013021**

§ 371 (c)(1),

(2) Date: **May 11, 2018**

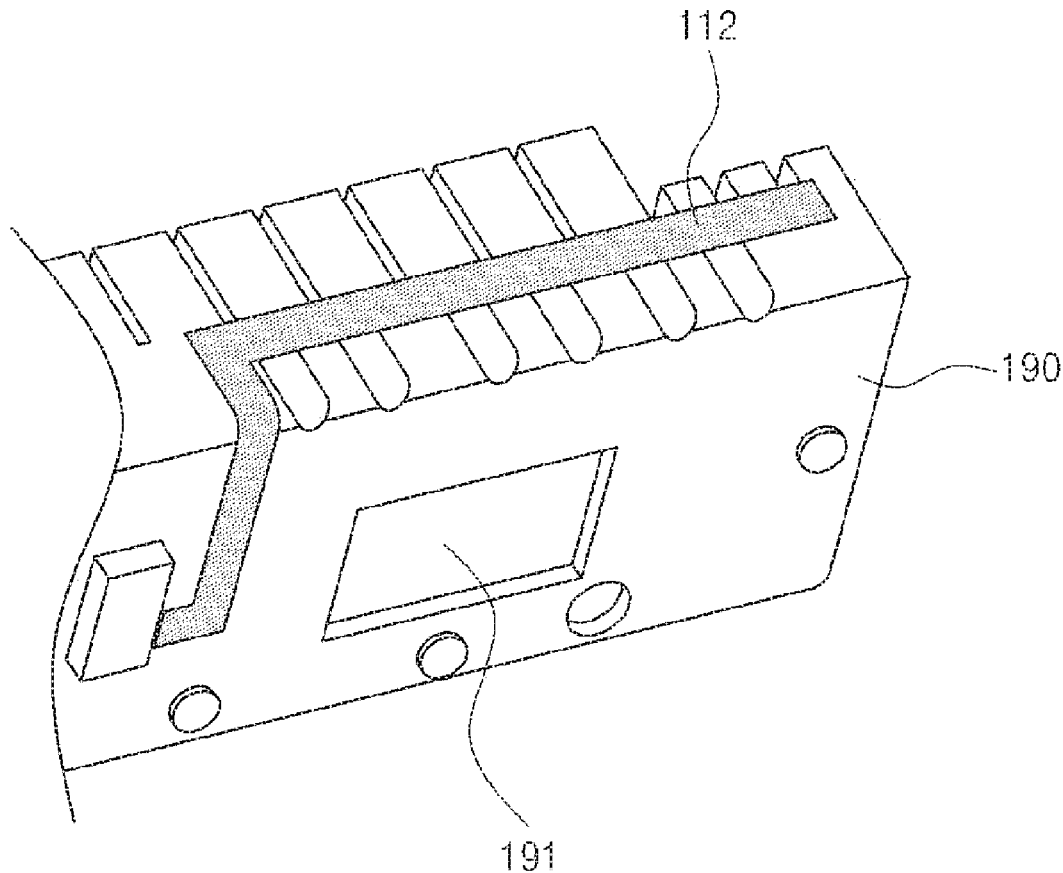
(30) **Foreign Application Priority Data**

Nov. 11, 2015 (KR) 10-2015-0158407

(57)

ABSTRACT

An electronic device according to various embodiments is provided and includes a conductive inner module in which a plurality of layers are stacked; an electrical opening formed in at least a portion of the rim of the conductive inner module when stacking the plurality of layers; and an antenna module disposed at the periphery of the electrical opening, wherein the antenna module may include a feeding part formed on at least one of a plurality of layers forming the conductive inner module, and a conductive pattern which is connected to the feeding part and disposed circumferencing at least one of the electrical openings.





US 20180351236A1

(19) **United States**(12) **Patent Application Publication****Oh et al.**(10) **Pub. No.: US 2018/0351236 A1**(43) **Pub. Date: Dec. 6, 2018**(54) **ANTENNA AND CAP**(71) Applicant: **Hewlett-Packard Development Company, L.P.**, Houston, TX (US)(72) Inventors: **Sung Oh**, Palo Alto, CA (US); **Philip Wright**, San Diego, CA (US)(73) Assignee: **Hewlett-Packard Development Company, L.P.**, Houston, TX (US)(21) Appl. No.: **15/772,080**(22) PCT Filed: **Feb. 19, 2016**(86) PCT No.: **PCT/US2016/018725**

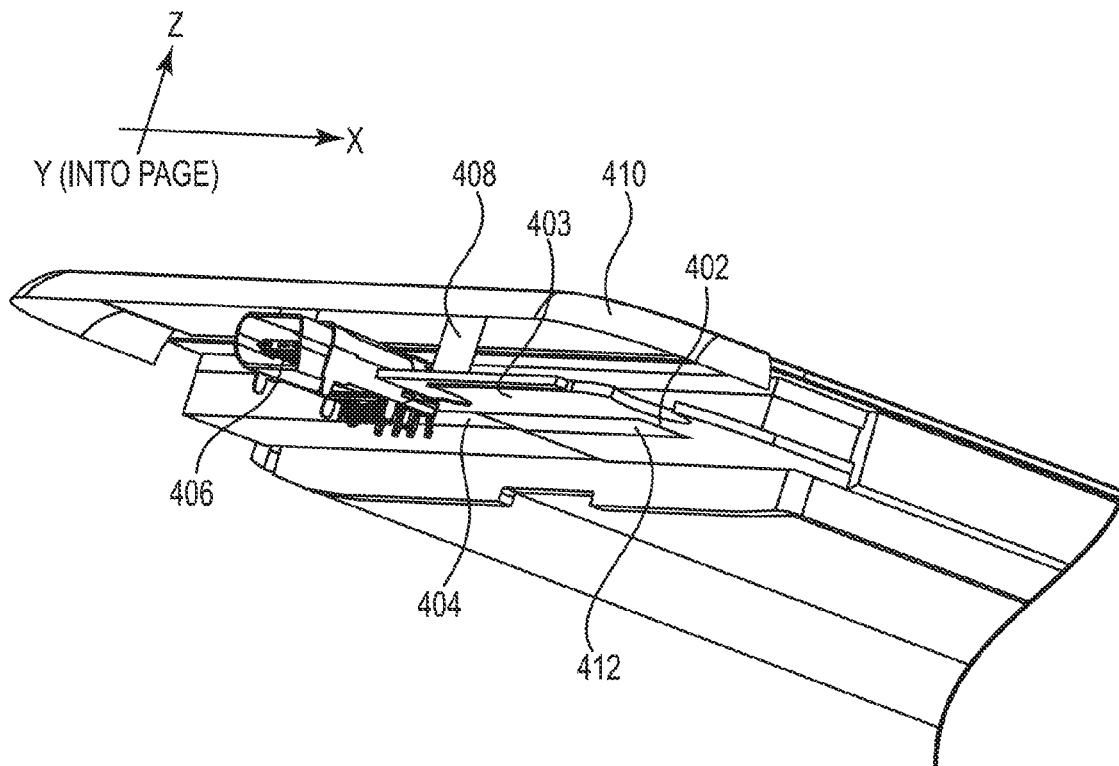
§ 371 (c)(1),

(2) Date: **Apr. 30, 2018****Publication Classification**(51) **Int. Cl.****H01Q 1/24** (2006.01)**H01Q 1/44** (2006.01)**H01Q 9/40** (2006.01)**H01Q 1/42** (2006.01)**H01Q 1/38** (2006.01)**G06F 1/16** (2006.01)(52) **U.S. Cl.**CPC **H01Q 1/243** (2013.01); **H01Q 1/44** (2013.01); **G06F 1/1698** (2013.01); **H01Q 1/42** (2013.01); **H01Q 1/38** (2013.01); **H01Q 9/40** (2013.01)

(57)

ABSTRACT

An antenna and cap, in an example implementation, can include a system, comprising a computing device, a clearance region coupled to the computing device, and an antenna comprising a first antenna portion and a second antenna portion. The first antenna portion can be coupled to the computing device and to the clearance region, and the second antenna portion can be coupled to the clearance region. The system can include a first cap coupled to the second antenna portion via a first interconnection, and a second cap coupled to the second antenna portion via a second interconnection. The first cap and the second cap can be coupled to the computing device.





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(19) **United States**

(12) **Patent Application Publication**
Wang et al.

(10) **Pub. No.: US 2018/0351238 A1**

(43) **Pub. Date: Dec. 6, 2018**

(54) **ANTENNA AND MOBILE TERMINAL**

H01Q 7/00 (2006.01)

(71) Applicant: **Huawei Device (Dongguan) Co., Ltd.**,
Dongguan (CN)

H01Q 9/04 (2006.01)

H01Q 1/36 (2006.01)

(72) Inventors: **Hanyang Wang**, Reading (GB);
Jianming Li, Shanghai (CN)

(52) **U.S. Cl.**

CPC **H01Q 1/243** (2013.01); **H01Q 5/378**

(2015.01); **H01Q 5/321** (2015.01); **H01Q 1/48**

(2013.01); **H01Q 1/38** (2013.01); **H01Q 9/42**

(2013.01); **H01Q 7/00** (2013.01); **H01Q**

9/0414 (2013.01); **H01Q 1/36** (2013.01);

H01Q 5/00 (2013.01)

(21) Appl. No.: **16/057,374**

(22) Filed: **Aug. 7, 2018**

Related U.S. Application Data

(63) Continuation of application No. 15/025,714, filed on
Mar. 29, 2016, filed as application No. PCT/CN2014/
074299 on Mar. 28, 2014.

Publication Classification

(51) **Int. Cl.**

H01Q 1/24 (2006.01)

H01Q 5/378 (2006.01)

H01Q 5/321 (2006.01)

H01Q 1/48 (2006.01)

H01Q 1/38 (2006.01)

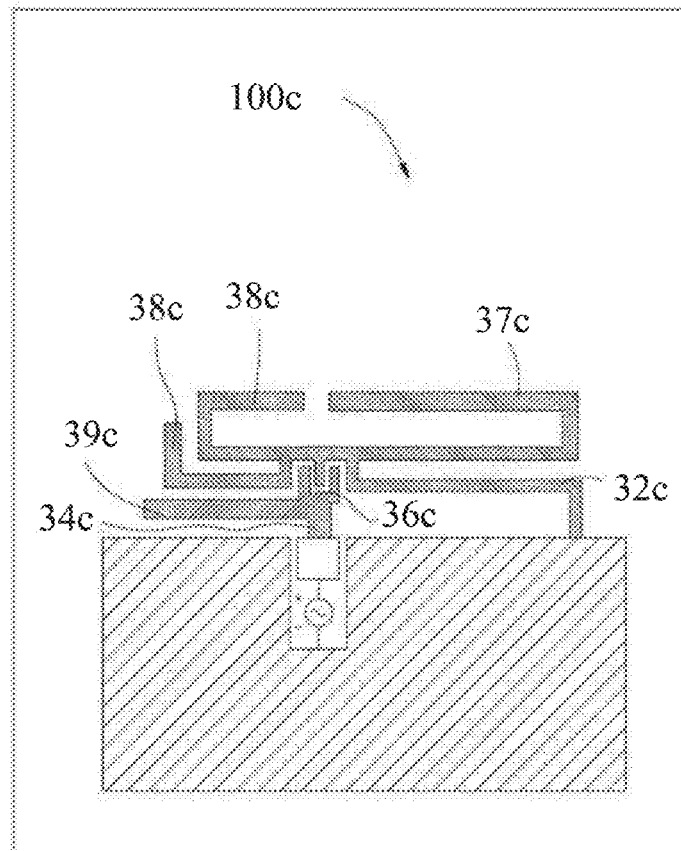
H01Q 5/00 (2006.01)

H01Q 9/42 (2006.01)

(57)

ABSTRACT

An antenna, including a first radiation part, a matching circuit, and a feed source, where the first radiation part includes a first radiator, a second radiator, and a capacitor structure, a first end of the first radiator is connected to the feed source using the matching circuit, the feed source is connected to a grounding part, a second end of the first radiator is connected to a first end of the second radiator using the capacitor structure, a second end of the second radiator is connected to the grounding part, the first radiation part is configured to generate a first resonance frequency, and a length of the second radiator is one-eighth of a wavelength corresponding to the first resonance frequency which helps to reduce an antenna length, and a volume of a mobile terminal.





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(19) **United States**

(12) **Patent Application Publication**

Yen et al.

(10) **Pub. No.: US 2018/0351254 A1**

(43) **Pub. Date: Dec. 6, 2018**

(54) **MOBILE DEVICES WITH INTEGRATED
SLOT ANTENNAS**

(52) **U.S. Cl.**

CPC **H01Q 5/371** (2015.01); **H01Q 1/2266**
(2013.01); **H01Q 21/064** (2013.01)

(71) Applicant: **Acer Incorporated**, New Taipei City
(TW)

(72) Inventors: **Ming-Ching Yen**, New Taipei City
(TW); **Kun-Sheng Chang**, New Taipei
City (TW); **Ching-Chi Lin**, New Taipei
City (TW)

(57)

ABSTRACT

Mobile devices with integrated slot antennas are provided are provided. A representative mobile device includes: an exterior housing having a front and a back and defining an interior; a display, mounted to the housing, configured to display images at the front of the housing; and an antenna structure positioned within the interior; the housing having a first portion and a second portion, each of which is formed of metal, the first portion being located at the back of the housing and defining a first slot such that the antenna structure and the first slot form a first slot antenna, the second portion being located at the front of the housing and defining a second slot such that the antenna structure and the second slot form a second slot antenna.

(21) Appl. No.: **15/784,245**

(22) Filed: **Oct. 16, 2017**

(30) **Foreign Application Priority Data**

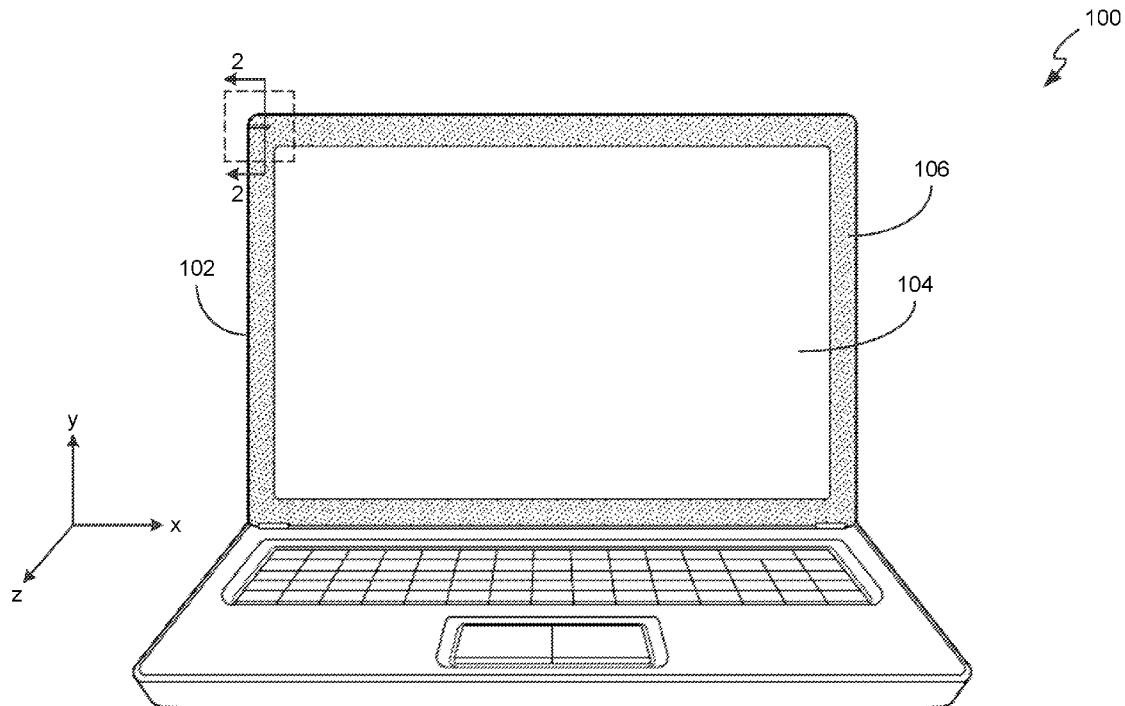
Jun. 5, 2017 (TW) 106118500

Publication Classification

(51) **Int. Cl.**

H01Q 5/371 (2006.01)

H01Q 21/06 (2006.01)





US 20180351589A1

(19) **United States**(12) **Patent Application Publication**
SHIN et al.(10) **Pub. No.: US 2018/0351589 A1**(43) **Pub. Date: Dec. 6, 2018**(54) **ELECTRONIC DEVICE INCLUDING
ANTENNA****Publication Classification**(71) Applicant: **Samsung Electronics Co., Ltd.**,
Gyeonggi-do (KR)(51) **Int. Cl.****H04B 1/04** (2006.01)**H04B 1/00** (2006.01)(72) Inventors: **Yong Joo SHIN**, Gyeonggi-do (KR);
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KIM**, Gyeonggi-do (KR)(52) **U.S. Cl.**CPC **H04B 1/0483** (2013.01); **H04B 1/006**
(2013.01)(21) Appl. No.: **15/775,507**

(57)

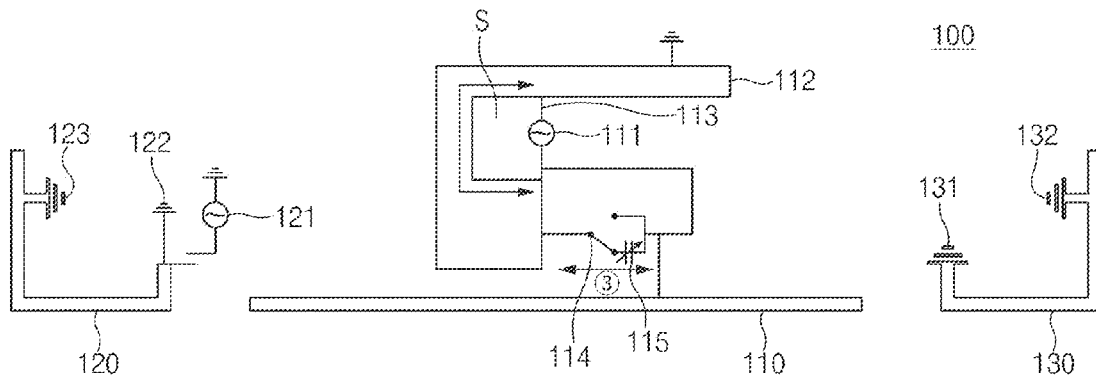
ABSTRACT(22) PCT Filed: **Nov. 3, 2016**(86) PCT No.: **PCT/KR2016/012587**

§ 371 (c)(1),

(2) Date: **May 11, 2018**(30) **Foreign Application Priority Data**

Nov. 13, 2015 (KR) 10-2015-0159948

An electronic device includes an antenna including a ground part, a feeding part, and a radiator and a first switch interposed between the feeding part and the radiator. A signal supplied through the feeding part is transmitted through a first path, a second path, or a third path that connects the feeding part to the radiator. The first switch is configured to change a connection state of the second path and the third path, and the third path includes a variable capacitor.





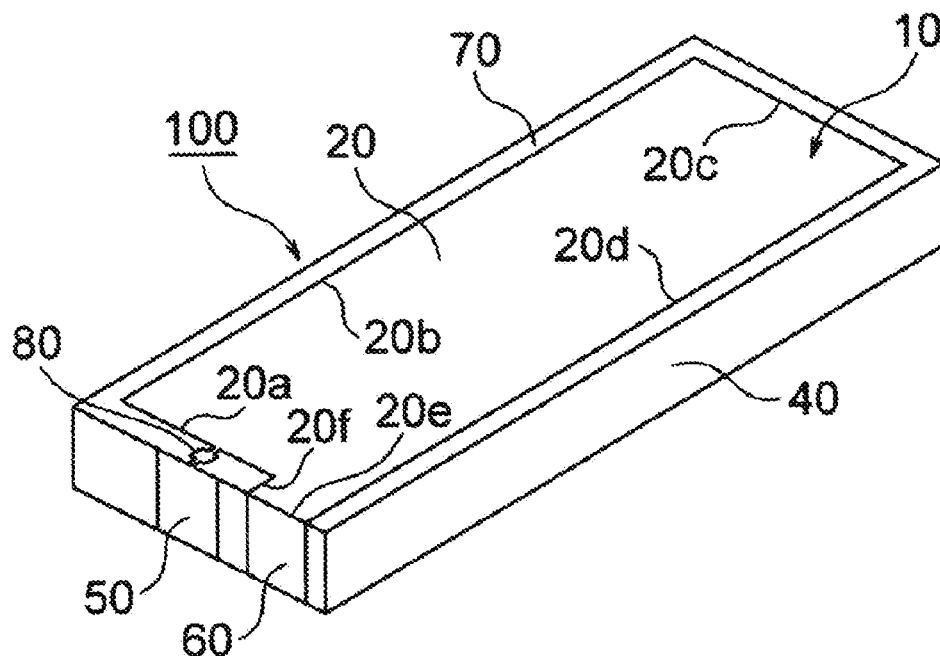
US 20180357524A1

(19) **United States**(12) **Patent Application Publication**
SUGIMURA et al.(10) **Pub. No.: US 2018/0357524 A1**(43) **Pub. Date: Dec. 13, 2018**(54) **RF TAG ANTENNA AND METHOD FOR
MANUFACTURING SAME, AND RF TAG****H01Q 1/38** (2006.01)**H01Q 13/08** (2006.01)(71) Applicant: **PHOENIX SOLUTION CO., LTD.**,
Kanazawa-shi (JP)(52) **U.S. Cl.**CPC **G06K 19/07773** (2013.01); **H01Q 9/0421**
(2013.01); **H01Q 1/2225** (2013.01); **H01Q**
13/08 (2013.01); **H01Q 1/38** (2013.01); **G06K**
19/077 (2013.01); **G06K 19/07** (2013.01)(72) Inventors: **Shiro SUGIMURA**, Kanazawa-shi
(JP); **Tatsuji NIWATA**, Kanazawa-shi
(JP)(73) Assignee: **PHOENIX SOLUTION CO., LTD.**,
Kanazawa-shi (JP)(21) Appl. No.: **16/107,793**(22) Filed: **Aug. 21, 2018****Related U.S. Application Data**(62) Division of application No. 15/550,344, filed on Aug.
10, 2017, now Pat. No. 10,089,573, filed as applica-
tion No. PCT/JP2016/053610 on Feb. 8, 2016.(30) **Foreign Application Priority Data**Feb. 10, 2015 (JP) 2015-024280
Jun. 23, 2015 (JP) 2015-125350**Publication Classification**(51) **Int. Cl.****G06K 19/077** (2006.01)**H01Q 9/04** (2006.01)**H01Q 1/22** (2006.01)**G06K 19/07** (2006.01)(57) **ABSTRACT**

[Problem to be Solved]

To provide an RF tag antenna capable of improving read-
ability and a method of manufacturing the same, and an RF
tag.

[Solution]

An RF tag antenna **10** according to an embodiment includes
a first insulating substrate **40** having a first principal surface
and a second principal surface, a first waveguide device **20**
provided on the first principal surface, a second waveguide
device **30** provided on the second principal surface, a power
feeding part **50** electrically connected to the second wave-
guide device **30** at one end thereof, and a short-circuit part
60 electrically connected to the first waveguide device **20** at
one end thereof and to the second waveguide device **30** at
another end thereof, the first insulating substrate **40**, the first
waveguide device **20**, the second waveguide device **30**, the
power feeding part **50** and the short-circuit part **60** form a
plate-shaped inverted-F antenna that receives a radio wave
transmitted from a reader, and an inductor pattern **L** formed
by the first waveguide device **20**, the short-circuit part **60**,
the second waveguide device **30** and the power feeding part
50 and a capacitor **93** formed by the first waveguide device
20, the second waveguide device **30** and the first insulating
substrate **40** form a resonant circuit that resonates in a
frequency band of the radio wave.



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(19) **United States**(12) **Patent Application Publication**
Chun et al.(10) **Pub. No.: US 2018/0358684 A1**(43) **Pub. Date: Dec. 13, 2018**(54) **PORTABLE TERMINAL WITH ANTENNA
DEVICE FOR DISPLAY ELEMENT OR
DISPLAY ASSEMBLY INCLUDING
FLEXIBLE FUNCTIONAL REGION****H01Q 1/44** (2006.01)**H01Q 21/28** (2006.01)(52) **U.S. Cl.****CPC** **H01Q 1/22** (2013.01); **H01Q 1/243**
(2013.01); **H01Q 21/28** (2013.01); **H01Q 1/44**
(2013.01)(71) Applicant: **Samsung Electronics Co., Ltd.**,
Suwon-si (KR)(72) Inventors: **Jae-Bong Chun**, Suwon-si (KR);
Jin-Woo Jung, Seongnam-si (KR)(21) Appl. No.: **15/998,479**(22) Filed: **Aug. 16, 2018****Related U.S. Application Data**(63) Continuation of application No. 14/082,900, filed on
Nov. 18, 2013, now Pat. No. 10,079,425.(30) **Foreign Application Priority Data**

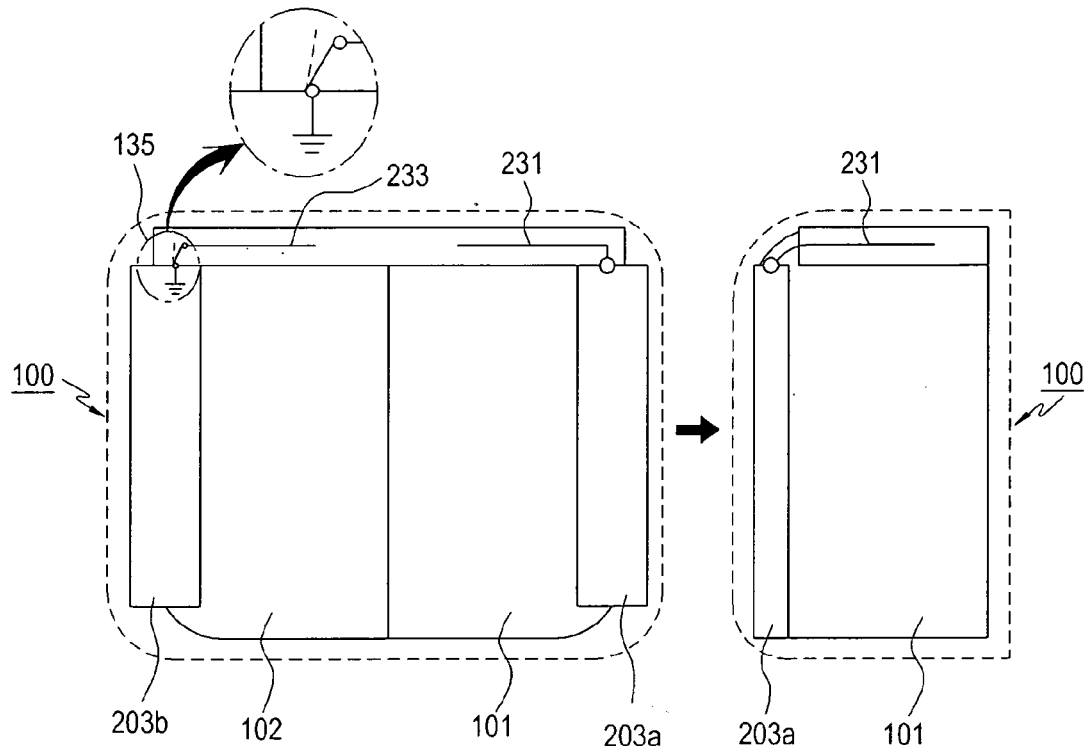
Feb. 25, 2013 (KR) 10-2013-0019585

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

(57)

ABSTRACT

A portable terminal is provided. The portable terminal includes a flexible display element, a first antenna element disposed at a first region on the display element, a second antenna element disposed at a foldable second region on the display element to face the first region, and a switch element configured to selectively connect the second antenna element. When the display element is folded or rolled, the first and second antenna elements at least partially overlap each other, and the switch element disconnects the second antenna element. The portable terminal including the antenna device as described above may maintain a stable transmission/reception performance although it includes a flexible display element or a display assembly. When a plurality of antenna elements are provided, the portable terminal may implement a Multiple Input Multiple Output (MIMO) antenna device in a state where the display element is extended.





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(19) **United States**(12) **Patent Application Publication**
PARK(10) **Pub. No.: US 2018/0358686 A1**(43) **Pub. Date: Dec. 13, 2018**(54) **ELECTRONIC DEVICE COMPRISING**
ANTENNA(71) Applicant: **SAMSUNG ELECTRONICS CO.,**
LTD., Suwon-si (KR)(72) Inventor: **Sung Chul PARK**, Seoul (KR)(21) Appl. No.: **16/003,599**(22) Filed: **Jun. 8, 2018**(30) **Foreign Application Priority Data**

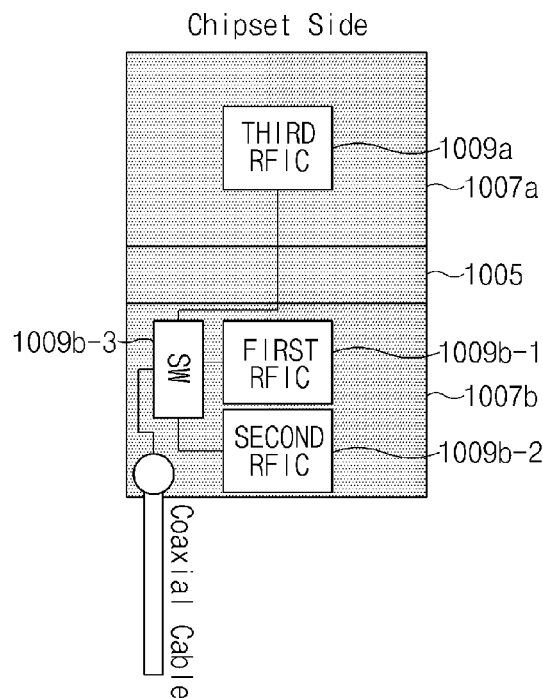
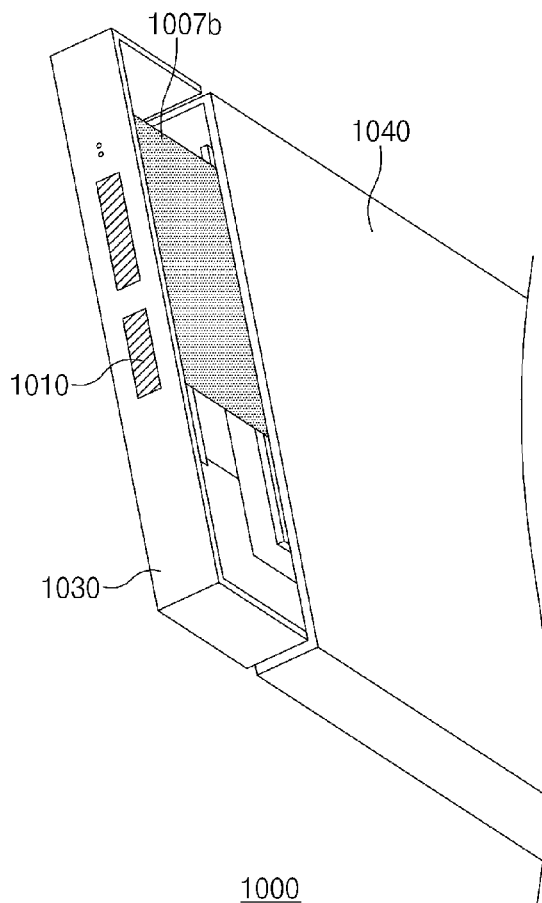
Jun. 9, 2017 (KR) 10-2017-0072359

Publication Classification(51) **Int. Cl.**
H01Q 1/22 (2006.01)
H01Q 5/307 (2006.01)(52) **U.S. Cl.**CPC **H01Q 1/2283** (2013.01); **H01Q 5/307**
(2015.01)

(57)

ABSTRACT

An electronic device includes a housing including a first plate, a second plate opposite to the first plate, and a side member surrounding a space between the first plate and the second plate, and including at least part of a conductive material, a flexible printed circuit board (FPCB) attached on an inner surface of the housing, a first antenna element which is included in the FPCB and in which a slot is formed, and a first radio frequency integrated circuit (RFIC) for the first antenna element. An opening is formed in the side member or the second plate of the housing. The FPCB is attached the inner surface of the housing such that at least part in which the slot of the first antenna element is formed is exposed through the opening. At least part of the opening is filled with an insulating material.





US 20180358687A1

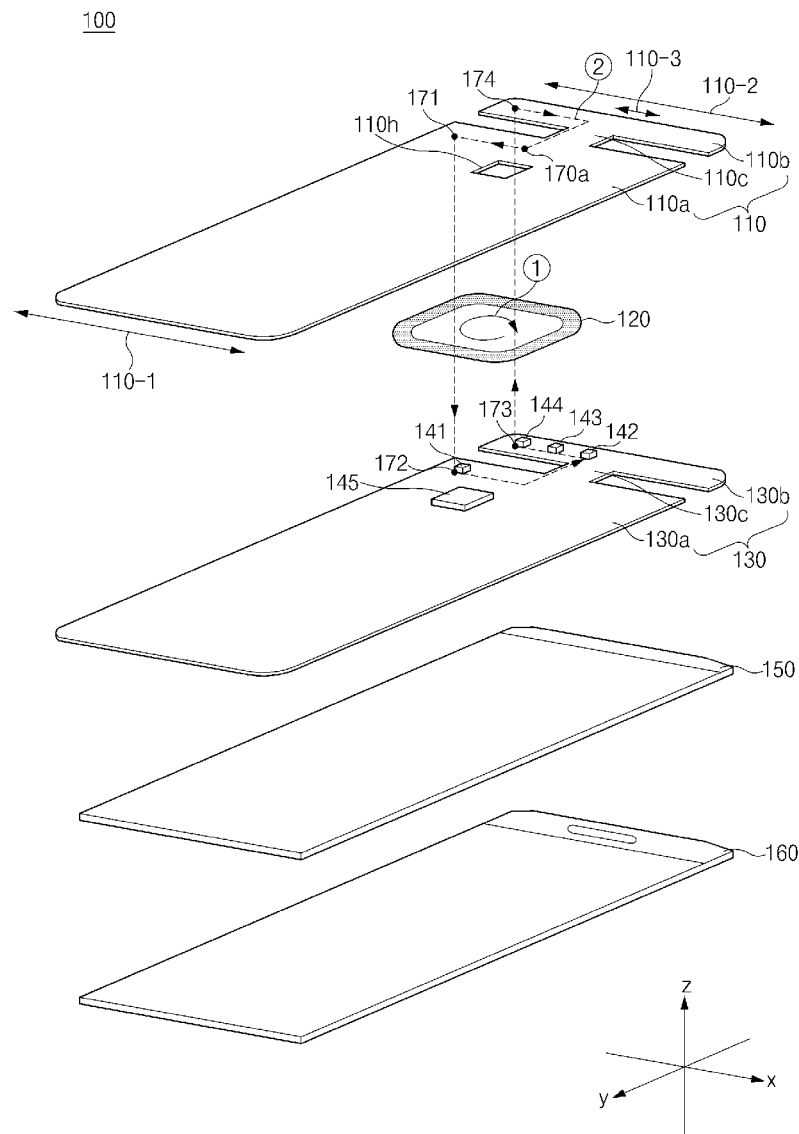
(19) **United States**(12) **Patent Application Publication**
CHO et al.(10) **Pub. No.: US 2018/0358687 A1**(43) **Pub. Date: Dec. 13, 2018**(54) **ANTENNA AND ELECTRONIC DEVICE
INCLUDING THE SAME****Publication Classification**(71) Applicant: **Samsung Electronics Co., Ltd.,**
Gyeonggi-do (KR)(72) Inventors: **Bum Jin CHO**, Gyeonggi-do (KR); **Jae
Bong CHUN**, Gyeonggi-do (KR)(51) **Int. Cl.****H01Q 1/24** (2006.01)**H01Q 7/00** (2006.01)(52) **U.S. Cl.****CPC** **H01Q 1/243** (2013.01); **H01Q 7/00**
(2013.01)(21) Appl. No.: **16/004,665**(22) Filed: **Jun. 11, 2018**(30) **Foreign Application Priority Data**

Jun. 12, 2017 (KR) 10-2017-0072888

(57)

ABSTRACT

An electronic device includes a housing including a back cover and a cover glass facing away from the back cover, a coil type radiator disposed between the back cover and the cover glass, at least one printed circuit board (PCB) disposed between the radiator and the cover glass, a communication circuit disposed on the PCB and feeding to the radiator, a first connecting member, a second connecting member, and one or more elements.





US 20180358698A1

(19) **United States**

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Wang et al.

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(54) **ANTENNA SYSTEM AND MOBILE
TERMINAL CONTAINING THE SAME**

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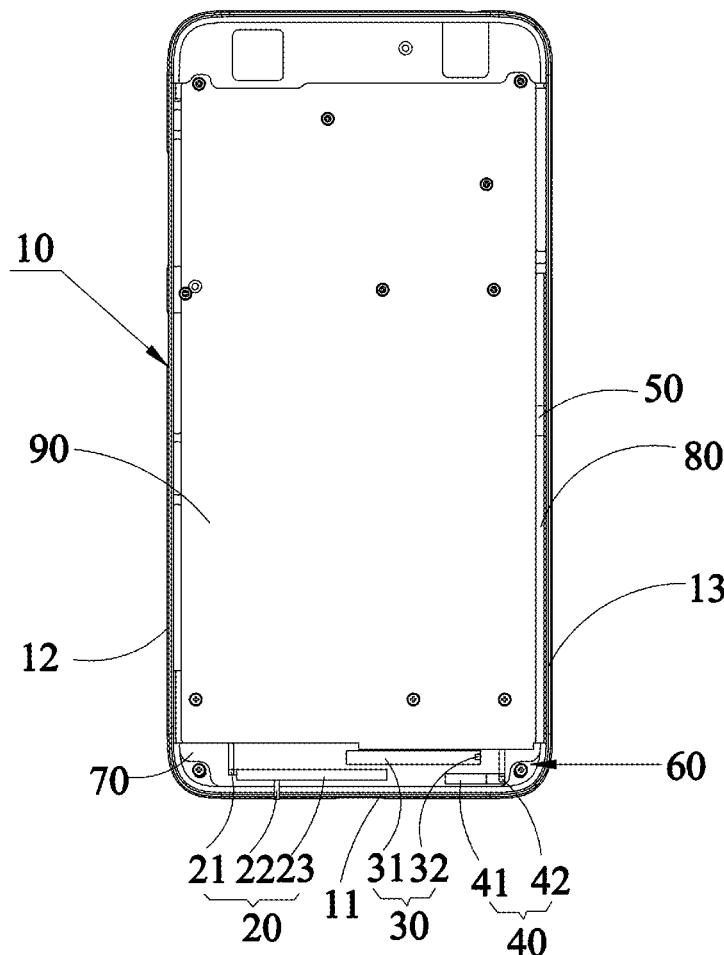
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ABSTRACT

The present disclosure relates to an antenna system and a mobile terminal containing the same. The antenna system includes a system ground, a metal frame surrounding the system ground without slit and in closed circle shape, a first radiation unit, a second radiation unit and a third radiation unit. The system ground is electrically connected with the metal frame; the first radiation unit comprises a tuning switch connected with the system ground, a first metal wiring connected with the tuning switch, and a second metal wiring connecting the first metal wiring to the metal frame; the second radiation unit comprises a feeding point and a third metal wiring connected with the feeding point, and the third metal wiring at least partially faces the first metal wiring; the third radiation unit comprises a grounding point connected with the system ground and a fourth metal wiring connected with the grounding point.





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(54) **METAL FRAME ANTENNA AND TERMINAL DEVICE**

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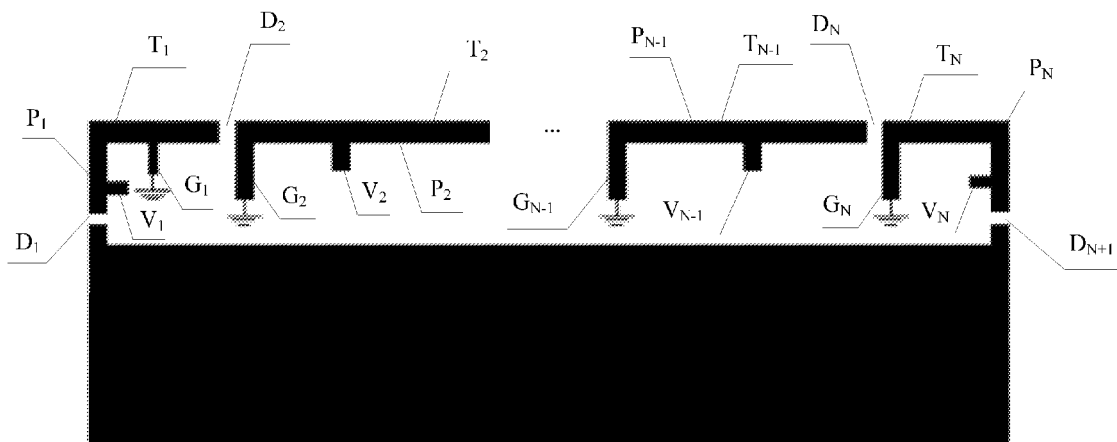
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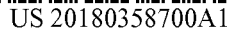
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(57)

ABSTRACT

A metal frame antenna and a terminal device are provided. The metal frame antenna includes N metal radiating elements between N+1 gaps, an end part of a metal radiating element on at least one of two sides of each of N-1 gaps between the N metal radiating elements is connected to a grounding part, the N metal radiating elements and respectively connected feeding branch circuits and grounding pails form N antennas, and N is an integer not less than 3.





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(57) **ABSTRACT**

An antenna device includes: a ground plane having an edge; a matching circuit; and a T-shaped antenna element including a first element and a second element extending from a feed point to a first and second end parts. The first element has a resonance frequency that is higher than a first frequency. The second element has a resonance frequency between a second frequency and a third frequency. A first value obtained by dividing a length from a corresponding point to a first bend part by the first wavelength is less than or equal to a second value obtained by dividing a length from the corresponding point to a second bend part by the second wavelength. An imaginary component of an impedance of the matching circuit takes a positive value at the first frequency and the second frequency and takes a negative value at the third frequency.

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