



US011588220B2

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

(10) **Patent No.:** **US 11,588,220 B2**
(45) **Date of Patent:** **Feb. 21, 2023**

(54) **ELECTRONIC DEVICE INCLUDING
ANTENNA MODULE TO WHICH
DIELECTRIC SHEET IS ATTACHED**

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Suwon-si (KR)

(72) Inventors: **Yunbum Lee**, Suwon-si (KR);
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(73) Assignee: **Samsung Electronics Co., Ltd.**,
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(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
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(21) Appl. No.: **17/162,110**

(22) Filed: **Jan. 29, 2021**

(65) **Prior Publication Data**
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(30) **Foreign Application Priority Data**
Feb. 6, 2020 (KR) 10-2020-0014429

(51) **Int. Cl.**
H01Q 1/02 (2006.01)
H01Q 9/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01Q 1/02** (2013.01); **H01Q 1/2283**
(2013.01); **H01Q 1/243** (2013.01); **H01Q 1/40**
(2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/02; H01Q 1/243; H01Q 1/2283;
H01Q 1/40; H01Q 9/0407; H01Q 19/09;
H01Q 21/08; H01Q 21/28; H01Q 23/00
See application file for complete search history.

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2021, issued in International Application No. PCT/KR2021/
001235.

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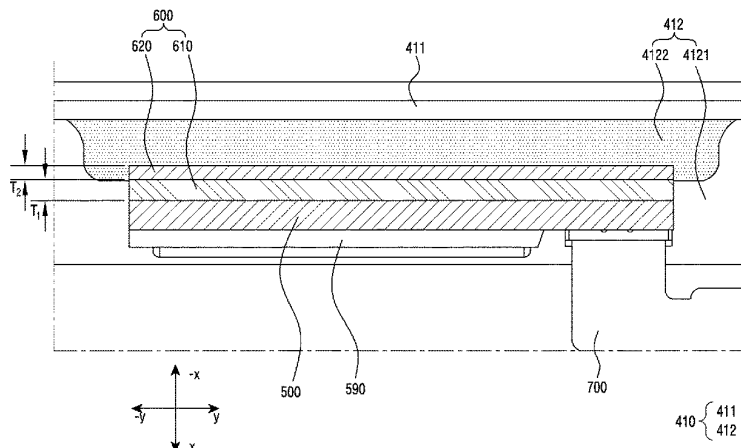
Primary Examiner — Robert Karacsony

(74) *Attorney, Agent, or Firm* — Jefferson IP Law, LLP

(57) **ABSTRACT**

An electronic device is provided. The electronic device includes a display having a first surface, a metal frame structure configured to form a side surface of the electronic device, a rear plate having a second surface facing a third direction, at least one antenna module disposed inside the side surface and having a radiation surface, at least one dielectric layer having at least a partial region attached to the radiation surface, and a wireless communication circuit configured to transmit or receive an radio frequency (RF) signal to or from the at least one antenna module, in which the at least one dielectric layer includes a first dielectric sheet and a second dielectric sheet, in which the first dielectric sheet is made of a thermal conductive material having a first permittivity and the second dielectric sheet is

(Continued)





US011588244B2

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

(10) **Patent No.:** **US 11,588,244 B2**
(45) **Date of Patent:** **Feb. 21, 2023**

(54) **ANTENNA STRUCTURE**

(71) Applicants: **Chun-Cheng Chan**, Taipei (TW);
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Jui-Hung Lai, Taipei (TW);
Chih-Heng Lin, Taipei (TW)

(72) Inventors: **Chun-Cheng Chan**, Taipei (TW);
Shih-Chia Liu, Taipei (TW); **Yen-Hao Yu**, Taipei (TW); **Li-Chun Lee**, Taipei (TW); **Chao-Lin Wu**, Taipei (TW);
Jui-Hung Lai, Taipei (TW);
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(73) Assignee: **COMPAL ELECTRONICS, INC.**,
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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 278 days.

(21) Appl. No.: **16/995,784**

(22) Filed: **Aug. 17, 2020**

(65) **Prior Publication Data**
US 2021/0280973 A1 Sep. 9, 2021

(30) **Foreign Application Priority Data**
Mar. 3, 2020 (TW) 109106932

(51) **Int. Cl.**
H01Q 1/52 (2006.01)
H01Q 5/371 (2015.01)
H01Q 9/42 (2006.01)

(52) **U.S. Cl.**
CPC **H01Q 5/371** (2015.01); **H01Q 1/521** (2013.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 5/371; H01Q 1/38; H01Q 9/0407;
H01Q 9/42; H01Q 1/521; H01Q 1/12;
(Continued)

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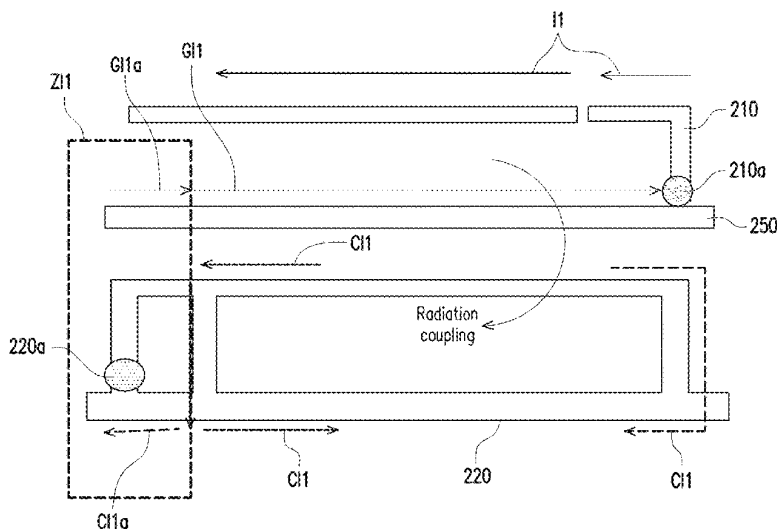
Primary Examiner — David E Lotter

(74) Attorney, Agent, or Firm — JCIPRNET

(57) **ABSTRACT**

The disclosure provides an antenna structure, including at least one supporting module, a first antenna, and a second antenna. The first antenna is disposed on the at least one supporting module and includes a first feeding point and a first zero-current zone. The first antenna is connected to a ground plane. The second antenna is disposed on the at least one supporting module and includes a second feeding point and a second zero-current zone. The second antenna is connected to the ground plane. The first feeding point of the first antenna is disposed in the second zero-current zone of the second antenna, and the second feeding point of the second antenna is disposed in the first zero-current zone of the first antenna.

22 Claims, 24 Drawing Sheets





US011588245B2

(12) **United States Patent**
Wei

(10) **Patent No.:** **US 11,588,245 B2**
(45) **Date of Patent:** **Feb. 21, 2023**

(54) **MOBILE DEVICE**

USPC 343/700 MS
See application file for complete search history.

(71) Applicant: **Wistron NeWeb Corp.**, Hsinchu (TW)

(56) **References Cited**

(72) Inventor: **Shih-Chiang Wei**, Hsinchu (TW)

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(73) Assignee: **WISTRON NEWEB CORP.**, Hsinchu (TW)

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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 785 days.

(Continued)

(21) Appl. No.: **16/655,926**

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(22) Filed: **Oct. 17, 2019**

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(65) **Prior Publication Data**

US 2020/0168993 A1 May 28, 2020

Primary Examiner — Hai V Tran

(30) **Foreign Application Priority Data**

Nov. 28, 2018 (TW) 107142393

(74) Attorney, Agent, or Firm — McClure, Qualey & Rodack, LLP

(51) **Int. Cl.**

H01Q 5/392 (2015.01)

H01Q 1/24 (2006.01)

H01Q 1/38 (2006.01)

H01Q 1/48 (2006.01)

H01Q 5/15 (2015.01)

H01Q 13/10 (2006.01)

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

CPC **H01Q 5/392** (2015.01); **H01Q 1/24** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 1/48** (2013.01); **H01Q 5/15** (2015.01); **H01Q 13/10** (2013.01); **H01Q 13/106** (2013.01)

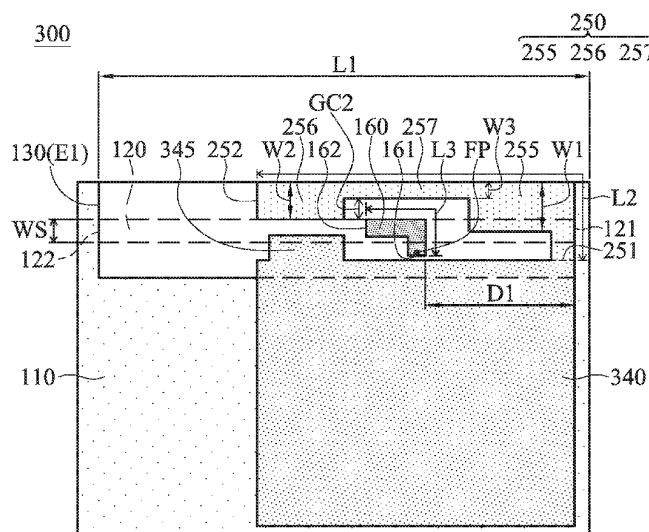
(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 1/48; H01Q 1/38; H01Q 5/392; H01Q 5/15; H01Q 13/106; H01Q 1/24; H01Q 13/10

(57) **ABSTRACT**

A mobile device includes a metal mechanism element, a dielectric substrate, a ground plane, a parasitic radiation element, and a feeding radiation element. A connection end of the parasitic radiation element is coupled to the ground plane. The parasitic radiation element includes a first widening portion, which is positioned at a bend of the parasitic radiation element. The parasitic radiation element has a vertical projection on the metal mechanism element. The vertical projection at least partially overlaps a first closed end of the slot. The feeding radiation element is disposed between the parasitic radiation element and the ground plane. The dielectric substrate is adjacent to the metal mechanism element. The parasitic radiation element and the feeding radiation element are disposed on the dielectric substrate. An antenna structure is formed by the parasitic radiation element, the feeding radiation element, and the slot of the metal mechanism element.

19 Claims, 7 Drawing Sheets





US011588247B2

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

(10) **Patent No.:** **US 11,588,247 B2**
(45) **Date of Patent:** **Feb. 21, 2023**

(54) **ANTENNA APPARATUS**

(56)

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(71) Applicant: **Samsung Electro-Mechanics Co., Ltd.**,
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U.S. PATENT DOCUMENTS

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(KR)

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(73) Assignee: **Samsung Electro-Mechanics Co., Ltd.**,
Suwon-si (KR)

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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 58 days.

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Technology Letters*, vol. 55, Issue 4, 2013 (pp. 917-922).

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(21) Appl. No.: **17/031,163**

(22) Filed: **Sep. 24, 2020**

Primary Examiner — Dieu Hien T Duong

(74) *Attorney, Agent, or Firm* — NSIP Law

(65) **Prior Publication Data**

US 2022/0013911 A1 Jan. 13, 2022

(30) **Foreign Application Priority Data**

Jul. 9, 2020 (KR) 10-2020-0084527

(51) **Int. Cl.**
H01Q 1/48 (2006.01)
H01Q 9/04 (2006.01)
H01Q 5/35 (2015.01)

(52) **U.S. Cl.**
CPC **H01Q 9/0414** (2013.01); **H01Q 1/48**
(2013.01); **H01Q 5/35** (2015.01)

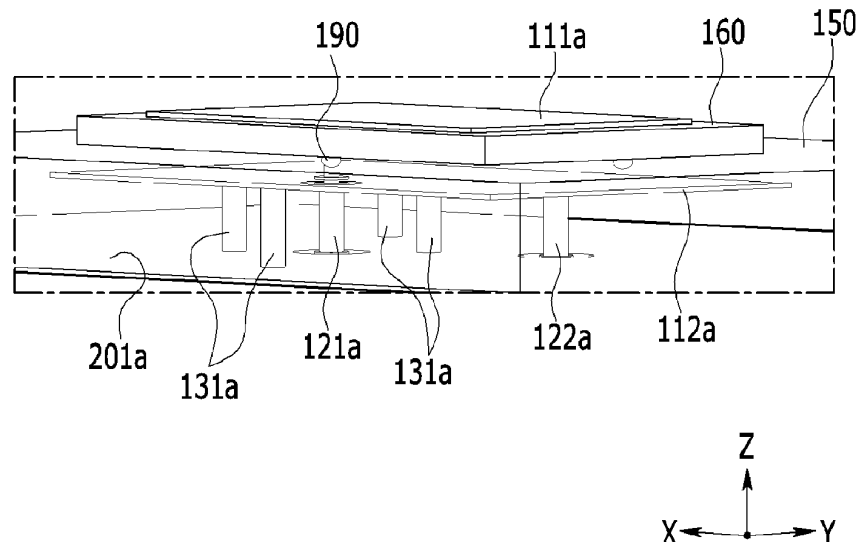
(58) **Field of Classification Search**
CPC H01Q 9/0414; H01Q 1/48; H01Q 5/35
See application file for complete search history.

(57)

ABSTRACT

An antenna apparatus includes: a first dielectric layer having
a first dielectric constant; a first patch antenna pattern
disposed in the first dielectric layer; a second dielectric layer
having a second dielectric constant; a second patch antenna
pattern disposed on the second dielectric layer; a first feed
via coupled to the first patch antenna pattern; and a second
feed via coupled to the second patch antenna pattern. The
first dielectric constant is higher than the second dielectric
constant, and a frequency of a signal transmitted/received by
the first patch antenna pattern is lower than a frequency of
a signal transmitted/received by the second patch antenna
pattern.

17 Claims, 12 Drawing Sheets





US011588253B2

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

(10) **Patent No.:** **US 11,588,253 B2**
(45) **Date of Patent:** **Feb. 21, 2023**

(54) **ANTENNA INCLUDING CONDUCTIVE PATTERN AND ELECTRONIC DEVICE INCLUDING ANTENNA**

(52) **U.S. Cl.**
CPC **H01Q 21/062** (2013.01); **H01Q 1/38** (2013.01); **H01Q 21/065** (2013.01); **H01Q 1/24** (2013.01);

(71) Applicant: **Samsung Electronics Co., Ltd.**,
Suwon-si (KR)

(Continued)

(58) **Field of Classification Search**
CPC H01Q 21/062; H01Q 1/38; H01Q 21/065; H01Q 1/243; H01Q 21/28
See application file for complete search history.

(72) Inventors: **Donghun Shin**, Suwon-si (KR);
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Hosaeng Kim, Suwon-si (KR);
Yoonjae Lee, Suwon-si (KR);
Byungman Lim, Suwon-si (KR);
Jaebong Chun, Suwon-si (KR)

(56) **References Cited**

U.S. PATENT DOCUMENTS

(73) Assignee: **Samsung Electronics Co., Ltd.**,
Suwon-si (KR)

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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 0 days.

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(21) Appl. No.: **17/748,670**

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(22) Filed: **May 19, 2022**

Extended European Search Report dated Jun. 30, 2020, issued in European Patent Application No. 20158178.2.

(65) **Prior Publication Data**
US 2022/0285854 A1 Sep. 8, 2022

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Primary Examiner — Joseph J Lauture

(74) *Attorney, Agent, or Firm* — Jefferson IP Law, LLP

Related U.S. Application Data

(63) Continuation of application No. 17/397,113, filed on Aug. 9, 2021, now Pat. No. 11,367,966, which is a
(Continued)

(57) **ABSTRACT**

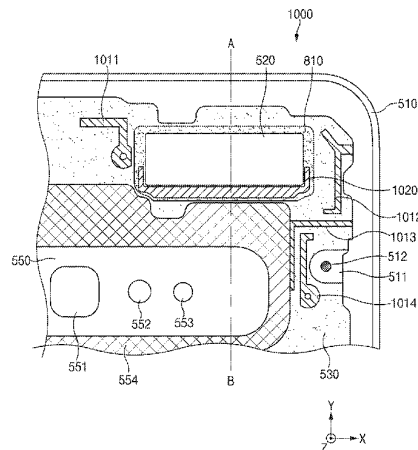
An electronic device including an antenna and a conductive pattern formed around the antenna is provided. The electronic device includes a housing including a first plate, a second plate facing away from the first plate, and a side member surrounding a space between the first plate and the second plate, connected to the second plate or integrally formed with the second plate, and including a conductive material, an injection-molding material disposed in the space between the first plate and the second plate in the housing and formed of a non-conductive material, an

(Continued)

(30) **Foreign Application Priority Data**

Feb. 19, 2019 (KR) 10-2019-0019113

(51) **Int. Cl.**
H01Q 9/44 (2006.01)
H01Q 21/06 (2006.01)
(Continued)





US011594157B2

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

(10) **Patent No.:** **US 11,594,157 B2**
(45) **Date of Patent:** ***Feb. 28, 2023**

(54) **FOLDABLE ELECTRONIC DEVICE INCLUDING ANTENNA**

(71) Applicant: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

(72) Inventors: **Hojin Jung**, Suwon-si (KR); **Boochul Bae**, Suwon-si (KR); **Jongoh Lim**, 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 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **17/377,501**

(22) Filed: **Jul. 16, 2021**

(65) **Prior Publication Data**

US 2021/0343195 A1 Nov. 4, 2021

Related U.S. Application Data

(63) Continuation of application No. 16/536,558, filed on Aug. 9, 2019, now Pat. No. 11,069,265.

(30) **Foreign Application Priority Data**

Aug. 10, 2018 (KR) 10-2018-0093954
Aug. 2, 2019 (KR) 10-2019-0094397

(51) **Int. Cl.**
G06F 1/16 (2006.01)
G09F 9/30 (2006.01)
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(52) **U.S. Cl.**
CPC **G09F 9/301** (2013.01); **G06F 1/1656** (2013.01); **G06F 1/1681** (2013.01); **H01Q 1/08** (2013.01); **H01Q 1/22** (2013.01); **H04M 1/0214** (2013.01)

(58) **Field of Classification Search**

CPC G06F 1/1652; G06F 1/1681; G06F 1/1698
See application file for complete search history.

(56) **References Cited**

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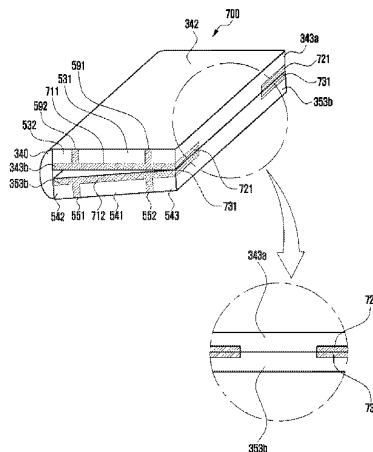
Primary Examiner — Adrian S Wilson

(74) *Attorney, Agent, or Firm* — Nixon & Vanderhye P.C.

(57) **ABSTRACT**

Various embodiments relate to an electronic device including an antenna. The electronic device may include: a foldable housing; a flexible display disposed on the foldable housing wherein at least a part of the flexible display is configured to be folded; and a frame disposed on a boundary portion of the flexible display and coupled to a side member of the foldable housing. The side member may include a conductive portion electrically connected to a communication circuit, and the frame may include a low-permittivity material.

18 Claims, 16 Drawing Sheets





US011594806B2

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

(10) **Patent No.:** **US 11,594,806 B2**
(45) **Date of Patent:** **Feb. 28, 2023**

(54) **ELECTRONIC DEVICE INCLUDING ANTENNA MODULE**

(71) Applicant: **Samsung Electronics Co., Ltd.**,
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(72) Inventors: **Jaewoong Jeon**, Suwon-si (KR);
Jaewun Lee, Suwon-si (KR); **Jaeyoung Huh**,
Suwon-si (KR); **Chanyoul Park**, Suwon-si (KR);
Hojong Kim, 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 221 days.

(21) Appl. No.: **17/154,811**

(22) Filed: **Jan. 21, 2021**

(65) **Prior Publication Data**
US 2021/0249759 A1 Aug. 12, 2021

(30) **Foreign Application Priority Data**
Feb. 6, 2020 (KR) 10-2020-0014327

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/42 (2006.01)
H05K 7/14 (2006.01)
H05K 5/00 (2006.01)
H04B 1/3827 (2015.01)
(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/42**
(2013.01); **H05K 5/0017** (2013.01); **H05K**
7/1427 (2013.01); **H04B 1/3827** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/24; H01Q 1/42; H05K 5/00;
H05K 7/14; H04B 1/38
See application file for complete search history.

(56) **References Cited**

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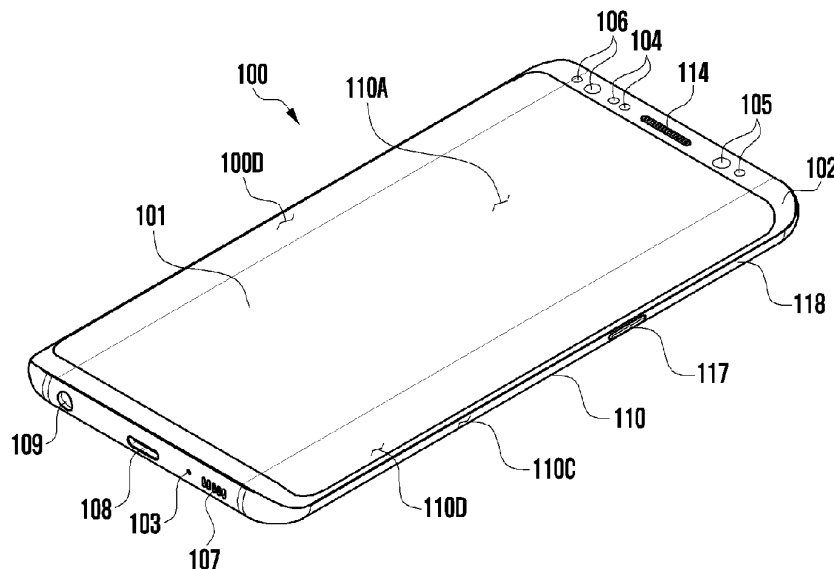
International Search Report and Written Opinion of the International Searching Authority in connection with International Application No. PCT/KR2020/017911 dated Mar. 15, 2021, 6 pages.

Primary Examiner — Andrea Lindgren Baltzell

(57) **ABSTRACT**

Provided is an electronic device including an antenna module. The electronic device may include: a housing constituting an external appearance of the electronic device, a support member including a first bridge, a printed circuit board coupled to one surface of the support member, a first antenna constituting a first part of the housing and connected to the support member through the first bridge, a second antenna constituting a second part of the housing, a cut-off portion separating the first antenna and the second antenna, and a first connection member and a second connection member coupled to the first bridge. The first connection member may be connected to a ground of the printed circuit board through a first capacitor and may be disposed closer to the cut-off portion than the second connection member connected to the ground of the printed circuit board through a second capacitor. Other embodiments are also possible.

20 Claims, 14 Drawing Sheets





US011600913B2

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

(10) **Patent No.:** **US 11,600,913 B2**
(45) **Date of Patent:** **Mar. 7, 2023**

(54) **ANTENNA BOARD**

(71) Applicant: **SAMSUNG**
ELECTRO-MECHANICS CO., LTD.,
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(72) Inventors: **Ju Ho Kim**, Suwon-si (KR); **Chan Jin Park**, Suwon-si (KR)

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

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(65) **Prior Publication Data**
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Dec. 30, 2020 (KR) 10-2020-0187396

(51) **Int. Cl.**
H01Q 1/38 (2006.01)
H01Q 5/335 (2015.01)
H01Q 9/04 (2006.01)
H01Q 1/24 (2006.01)
(52) **U.S. Cl.**
CPC **H01Q 1/38** (2013.01); **H01Q 1/243** (2013.01); **H01Q 5/335** (2015.01); **H01Q 9/0407** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/38; H01Q 1/243; H01Q 5/335;

H01Q 9/0407; H01Q 1/2283; H01Q 21/28; H01Q 9/0414; H05K 1/0298; H05K 1/03; H05K 1/16; H05K 1/18
See application file for complete search history.

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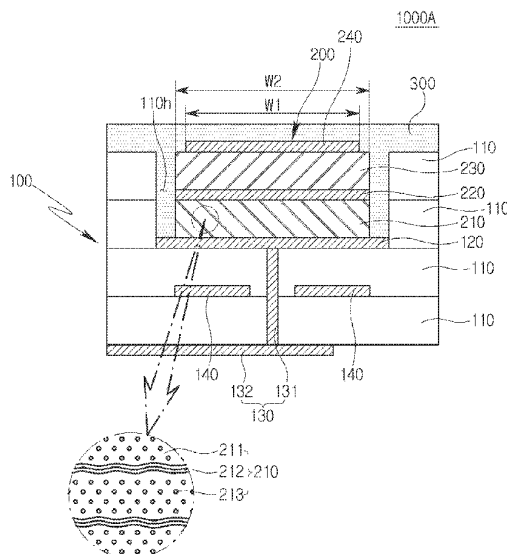
Primary Examiner — David E Lotter

(74) *Attorney, Agent, or Firm* — Morgan, Lewis & Bockius LLP

(57) **ABSTRACT**

An antenna board includes a first base board unit including a first insulating layer having a first receiving groove; a first antenna board unit disposed in the first receiving groove, including a second insulating layer and a third insulating layer disposed on the second insulating layer, and further including at least one of a first patch pattern disposed on the second insulating layer and covered by the third insulating layer and a second patch pattern disposed on the third insulating layer; and a first encapsulant covering at least a portion of the first antenna board unit and filling at least a portion of the first receiving groove, wherein a dielectric constant of the second insulating layer is different from a dielectric constant of the third insulating layer.

17 Claims, 8 Drawing Sheets





US011600921B1

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

(10) **Patent No.:** **US 11,600,921 B1**
(45) **Date of Patent:** **Mar. 7, 2023**

(54) **DUAL BAND ANTENNA AND ELECTRONIC DEVICE USING THE SAME**

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(58) **Field of Classification Search**
CPC H01Q 5/364; H01Q 1/243; H01Q 7/00; H01Q 9/40

See application file for complete search history.

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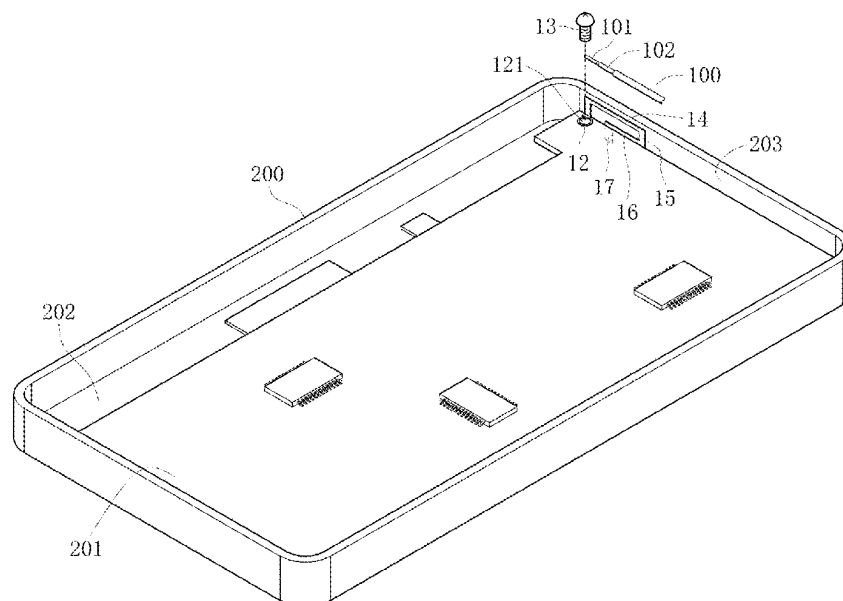
Primary Examiner — Daniel Munoz

(74) *Attorney, Agent, or Firm* — Li & Cai Intellectual Property (USA) Office

(57) **ABSTRACT**

A dual band antenna and an electronic device are provided. The dual band antenna includes a feed end, an annular connection end, a metal screw, a first extension path, a second extension path, a third extension path, and a grounding part. The annular connection end has an opening and is connected to the feed end. The metal screw has a threaded stud passing through the opening, so that the metal screw is electrically connected to the annular connection end. The feed end, the first extension path, the second extension path, the third extension path, and the grounding part are sequentially connected to each other. The dual band antenna is configured to have a monopole antenna and a loop antenna, so that the dual band antenna has a wide operating frequency band, and the monopole antenna operates at 3.6 GHz and the loop antenna operates at 4.6 GHz.

11 Claims, 6 Drawing Sheets





US011600925B2

(12) **United States Patent**
Huang

(10) **Patent No.:** **US 11,600,925 B2**
(45) **Date of Patent:** **Mar. 7, 2023**

(54) **ANTENNA STRUCTURE**

(56)

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(71) Applicant: **Wistron NeWeb Corp.**, Hsinchu (TW)

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(72) Inventor: **Chun-Lin Huang**, Hsinchu (TW)

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(73) Assignee: **WISTRON NEWEB CORP.**, Hsinchu (TW)

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(65) **Prior Publication Data**

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Primary Examiner — Ab Salam Alkassim, Jr.

Assistant Examiner — Leah Rosenberg

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(30) **Foreign Application Priority Data**

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(57)

ABSTRACT

(51) **Int. Cl.**

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

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(58) **Field of Classification Search**

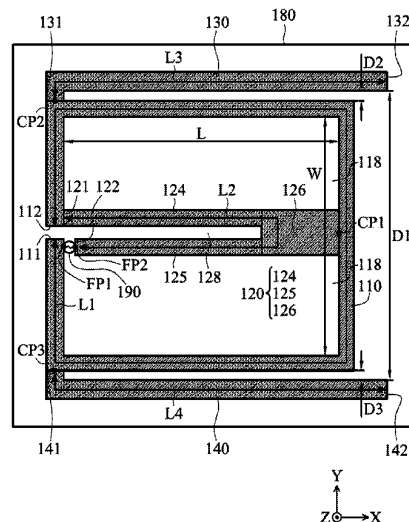
CPC .. H01Q 1/36; H01Q 1/38; H01Q 5/10; H01Q 5/20; H01Q 5/307; H01Q 5/385; H01Q 7/00; H01Q 7/04; H01Q 9/30; H01Q 9/42; H01Q 13/10

See application file for complete search history.

An antenna structure includes a loop radiation element, a balance radiation element, a first additional radiation element, and a second additional radiation element. The loop radiation element has a first feeding point. The balance radiation element has a second feeding point. The balance radiation element is coupled to at least a first connection point on the loop radiation element. The balance radiation element is substantially surrounded by the loop radiation element. The first additional radiation element is coupled to a second connection point on the loop radiation element. The second additional radiation element is coupled to a third connection point on the loop radiation element. The loop radiation element is disposed between the first additional radiation element and the second additional radiation element.

20 Claims, 9 Drawing Sheets

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US011604273B2

(12) **United States Patent**
Wintermantel

(10) **Patent No.:** **US 11,604,273 B2**
(45) **Date of Patent:** **Mar. 14, 2023**

(54) **RADAR SYSTEM FOR DETECTING THE ENVIRONMENT OF A MOTOR VEHICLE HAVING A PLASTIC ANTENNA**

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(72) Inventor: **Markus Wintermantel**, Lindau (DE)

(73) Assignee: **Conti Temic microelectronic GmbH**,
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(22) Filed: **Aug. 31, 2020**

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Related U.S. Application Data

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(30) **Foreign Application Priority Data**

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(Continued)

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(58) **Field of Classification Search**
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See application file for complete search history.

(56) **References Cited**

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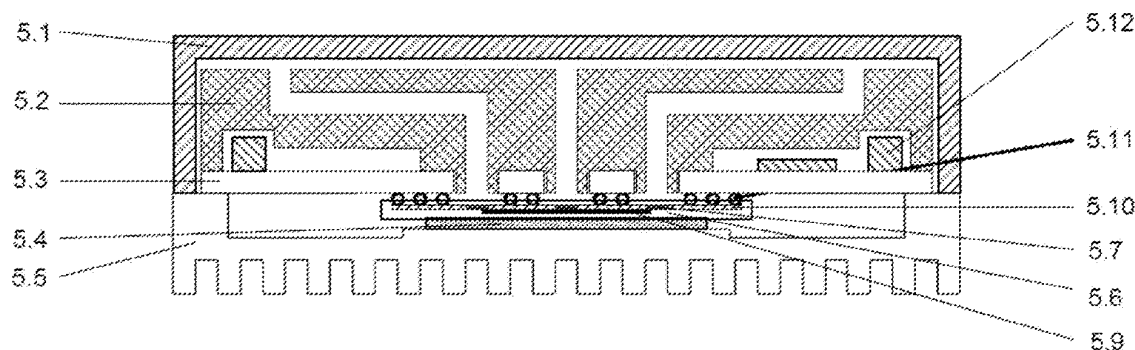
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Primary Examiner — Bernarr E Gregory

(57) **ABSTRACT**

A radar system for detecting the environment of a motor vehicle includes an antenna assembly comprising plastic and including one or more individual antennas for transmitting and/or receiving radar signals. A circuit board includes at least one area that is permeable by radar waves. At least one high-frequency component is coupled to one side of the circuit board and includes at least one radiating element for direct emission or receipt of radar waves in the direction of the circuit board in the least one area that is permeable by radar waves. The antenna assembly is disposed on the other side of the circuit board opposite the at least one high-frequency component. The antenna assembly includes a coupling/decoupling point disposed in the at least one area of the circuit board permeable by radar waves.

7 Claims, 4 Drawing Sheets





US011605888B2

(12) **United States Patent**
Li

(10) **Patent No.:** **US 11,605,888 B2**
(45) **Date of Patent:** **Mar. 14, 2023**

(54) **ANTENNA CIRCUIT AND MOBILE
TERMINAL**

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(72) Inventor: **Rihui Li**, Chang'an Dongguan (CN)

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(*) Notice: Subject to any disclaimer, the term of this
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§ 371 (c)(1),

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(30) **Foreign Application Priority Data**

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(Continued)

(52) **U.S. Cl.**
CPC **H01Q 5/335** (2015.01); **H01Q 1/243**
(2013.01); **H01Q 5/328** (2015.01); **H01Q 9/42**
(2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 5/328; H01Q 5/335
See application file for complete search history.

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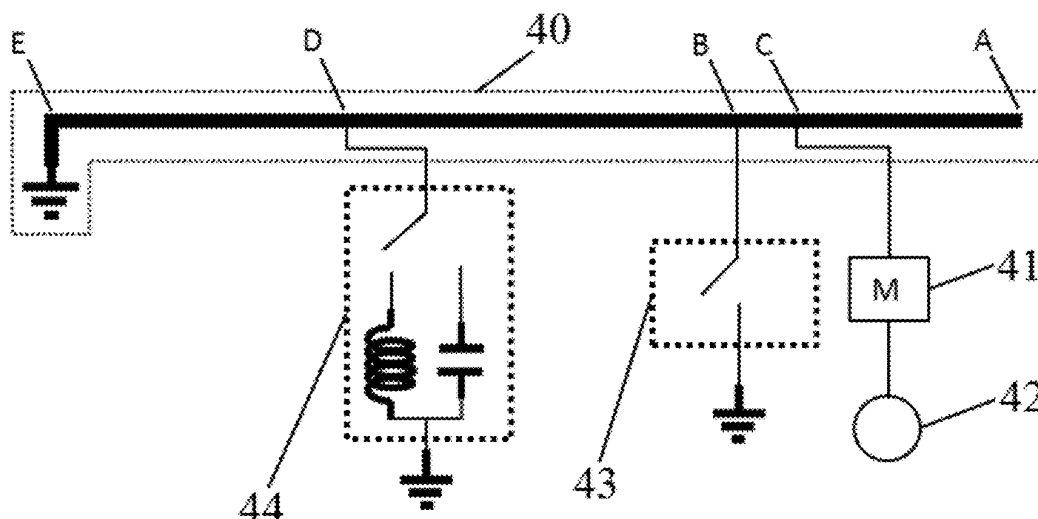
Primary Examiner — Graham P Smith

(74) *Attorney, Agent, or Firm* — von Briesen & Roper,
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(57) **ABSTRACT**

The present disclosure provides an antenna circuit and a mobile terminal. The antenna circuit includes: an antenna unit; a switching circuit connection point and a feed point are arranged on the antenna unit; an antenna feed is connected with the feed point; a first tuning circuit is connected with the switching circuit connection point, the first tuning circuit is configured to increase a bandwidth of a single resonant mode in an intermediate-high frequency and/or to tune a resonant frequency in the intermediate-high frequency; wherein a distance from the feed point to the end of the antenna unit is larger than a distance from the switching circuit connection point to the end of the antenna unit.

19 Claims, 14 Drawing Sheets





US011605903B2

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

(10) **Patent No.:** **US 11,605,903 B2**
(45) **Date of Patent:** **Mar. 14, 2023**

(54) **ARRAY ANTENNA APPARATUS AND
METHOD FOR MANUFACTURING ARRAY
ANTENNA APPARATUS**

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(73) Assignee: **Mitsubishi Electric Corporation,**
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(65) **Prior Publication Data**

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(58) **Field of Classification Search**

CPC **H01Q 21/005**; **H01Q 5/42**; **H01Q 13/22**;
H01Q 21/24; **H01P 3/123**

See application file for complete search history.

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Primary Examiner — Hoang V Nguyen

(74) *Attorney, Agent, or Firm* — Oblon, McClelland,
Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

Waveguide slot array antennas each having slots, that transmit or receive electromagnetic waves and that are formed in a front surface of a waveguide and waveguide slot array antennas each having slots that transmit or receive electromagnetic waves and that are formed in a front surface of a waveguide, and the waveguide slot array antennas and the waveguide slot array antennas are alternately arranged, the waveguide is a ridge waveguide having a ridge formed inside the waveguide, and the waveguide is a ridge waveguide having ridges, formed inside the waveguide.

4 Claims, 13 Drawing Sheets

