US010957978B2

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

(10) **Patent No.: US 10,957,978 B2**
(45) **Date of Patent: Mar. 23, 2021**

(54) **ELECTRONIC DEVICES HAVING MULTI-FREQUENCY ULTRA-WIDEBAND ANTENNAS**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventors: **Aaron J. Cooper**, San Jose, CA (US); **Amin Tayebi**, San Jose, CA (US); **Carlo Di Nallo**, Belmont, CA (US); **Vinh T. Le**, San Jose, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 41 days.

(21) Appl. No.: **16/456,856**

(22) Filed: **Jun. 28, 2019**

(65) **Prior Publication Data**

US 2020/0411986 A1 Dec. 31, 2020

(51) **Int. Cl.**

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H01Q 5/25	(2015.01)
H01Q 1/38	(2006.01)
H01Q 1/48	(2006.01)

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

CPC ***H01Q 5/25*** (2015.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/48*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 5/25; H01Q 1/24; H01Q 1/243; H01Q 1/38; H01Q 1/48

See application file for complete search history.

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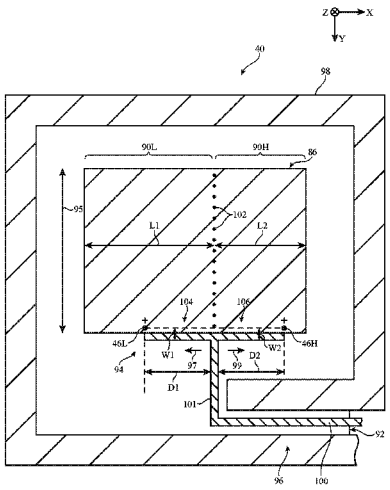
Cooper et al. U.S. Appl. No. 16/277,808, filed Feb. 15, 2019.

Primary Examiner — Hoang V Nguyen
(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; Michael H. Lyons; Matthew R. Williams

(57) **ABSTRACT**

An electronic device may be provided with an antenna for receiving signals in first and second ultra-wideband communications bands. The antenna may include a first arm that radiates in the first band and a second arm that radiates in the second band. The antenna may be fed by a stripline. A microstrip may couple the stripline to the first and second arms and may be configured to match the impedance of the stripline to the impedance of the first and second arms in the first and second bands, respectively. Sets of antennas tuned to different frequencies may be fed by the same transmission line and may collectively exhibit a relatively wide bandwidth. A conductive shielding layer or other conductive components may be layered over the antennas to mitigate cross-polarization interference at the antennas.

16 Claims, 17 Drawing Sheets



US010957980B2

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

(10) **Patent No.: US 10,957,980 B2**
(45) **Date of Patent: Mar. 23, 2021**

(54) **ANTENNA SYSTEM AND TERMINAL**

(71) Applicant: **Beijing Xiaomi Mobile Software Co., Ltd.**, Beijing (CN)

(72) Inventors: **Jiarong Liu**, Beijing (CN); **Han Lu**, Beijing (CN)

(73) Assignee: **Beijing Xiaomi Mobile Software Co., Ltd.**, Beijing (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/377,529**

(22) Filed: **Apr. 8, 2019**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Aug. 31, 2018 (CN) 201811014066.0

(51) **Int. Cl.**

H01Q 5/50	(2015.01)
H01Q 1/24	(2006.01)
H01Q 1/52	(2006.01)
H01Q 1/44	(2006.01)
H01Q 5/335	(2015.01)
H01Q 5/314	(2015.01)

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

CPC ***H01Q 5/50*** (2015.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/44*** (2013.01); ***H01Q 1/521*** (2013.01); ***H01Q 5/314*** (2015.01); ***H01Q 5/335*** (2015.01)

(58) **Field of Classification Search**

CPC H01Q 5/50

See application file for complete search history.

(56) **References Cited**

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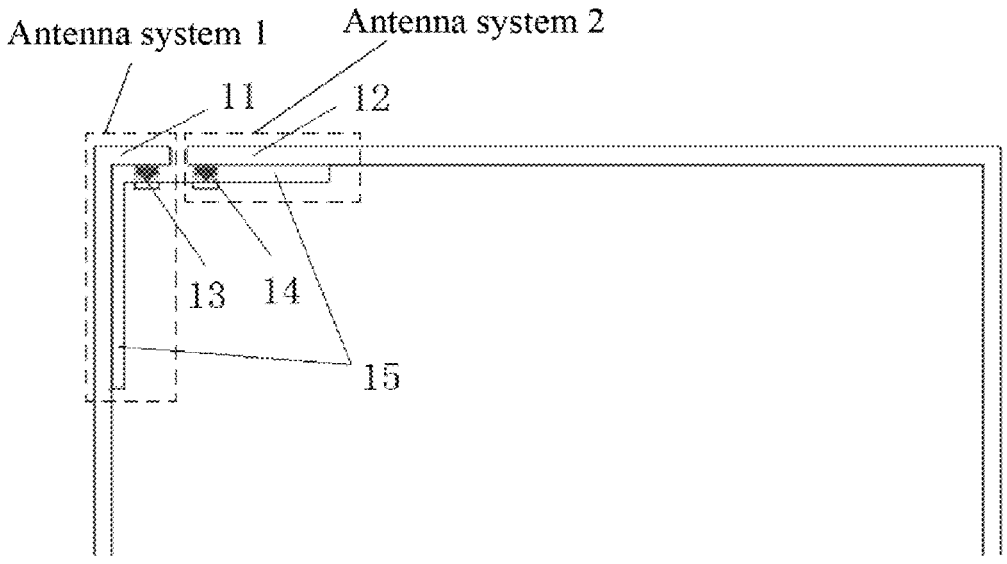
Primary Examiner — Ab Salam Alkassim, Jr.

(74) *Attorney, Agent, or Firm* — Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P.

(57) **ABSTRACT**

An antenna system is provided. The antenna system includes a first metal radiator, a second metal radiator, a first matching network, a second matching network, a first radio frequency path, and a second radio frequency path, wherein a tail end of the first metal radiator is connected with a first feed point of the antenna system and the first feed point is connected with the first radio frequency path through the first matching network; and a tail end of the second metal radiator is connected with a second feed point of the antenna system and the second feed point is connected with the second radio frequency path through the second matching network. A terminal including the antenna system is also provided.

8 Claims, 11 Drawing Sheets



US010957985B2

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

(10) **Patent No.: US 10,957,985 B2**
(45) **Date of Patent: Mar. 23, 2021**

(54) **ELECTRONIC DEVICES HAVING ANTENNA MODULE ISOLATION STRUCTURES**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventors: **Simone Paulotto**, Redwood City, CA (US); **Qishan Yu**, San Jose, CA (US); **Harish Rajagopalan**, San Jose, CA (US); **Berke Cetinoneri**, Santa Clara, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 400 days.

(21) Appl. No.: **16/146,488**

(22) Filed: **Sep. 28, 2018**

(65) **Prior Publication Data**

US 2020/0106185 A1 Apr. 2, 2020

(51) **Int. Cl.**

H01Q 1/38	(2006.01)
H01Q 11/14	(2006.01)
H01Q 3/44	(2006.01)
H01Q 1/42	(2006.01)

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

CPC ***H01Q 11/14*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/422*** (2013.01); ***H01Q 3/443*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 11/14; H01Q 1/38; H01Q 1/422; H01Q 3/443

See application file for complete search history.

(56) **References Cited**

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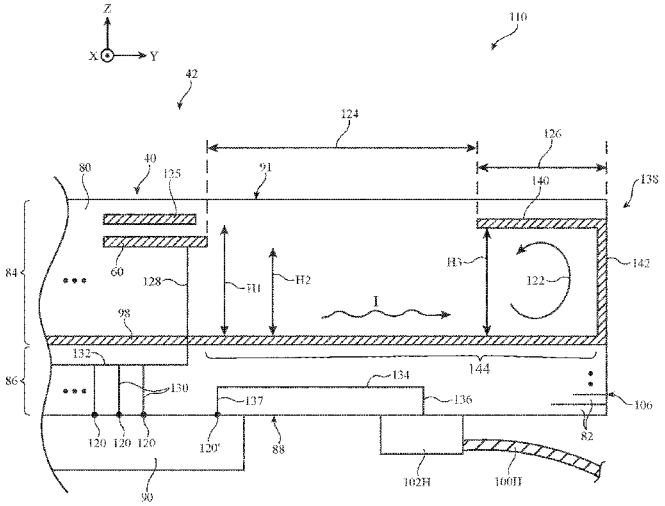
Primary Examiner — Graham P Smith

(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; Michael H. Lyons

(57) **ABSTRACT**

An electronic device may be provided with a phased antenna array controlled by phase and magnitude controllers within an integrated circuit. The array may be formed on antenna layers and the integrated circuit may be mounted to transmission line layers of a dielectric substrate. A ground plane may separate the transmission line layers from the antenna layers. A connector may be mounted to the surface of the transmission line layers and may be coupled to the integrated circuit using conductive traces. A passive resonator may be formed in the antenna layers and may include conductive structures that resonate at one-quarter of the effective wavelength of operation of the array to form an open circuit impedance for surface currents generated on the ground plane by the array. This may serve to block the surface currents from scattering at an edge of the ground plane and leaking onto the integrated circuit.

20 Claims, 10 Drawing Sheets



US010965005B2

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

(10) **Patent No.: US 10,965,005 B2**
(45) **Date of Patent: Mar. 30, 2021**

(54) **COMMUNICATION DEVICE AND ANTENNA STRUCTURE**

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

(72) Inventors: **Chun-Lin Huang**, Hsinchu (TW); **Chien-Ting Huang**, Hsinchu (TW)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 36 days.

(21) Appl. No.: **16/682,010**

(22) Filed: **Nov. 13, 2019**

(65) **Prior Publication Data**

US 2020/0287273 A1 Sep. 10, 2020

(30) **Foreign Application Priority Data**

Mar. 5, 2019 (TW) 108107200

(51) **Int. Cl.**

H01Q 21/00	(2006.01)
H01Q 1/24	(2006.01)
H01Q 9/26	(2006.01)
H01Q 1/42	(2006.01)
H01Q 9/30	(2006.01)
H01Q 5/307	(2015.01)

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

CPC ***H01Q 1/24*** (2013.01); ***H01Q 1/42*** (2013.01); ***H01Q 5/307*** (2015.01); ***H01Q 9/26*** (2013.01); ***H01Q 9/30*** (2013.01); *H01Q 21/00* (2013.01)

(58) **Field of Classification Search**

CPC H01Q 21/00; H01Q 1/24; H01Q 9/26; H01Q 1/42; H01Q 9/30; H01Q 5/307

USPC 343/725, 713, 715, 702, 895

See application file for complete search history.

(56) **References Cited**

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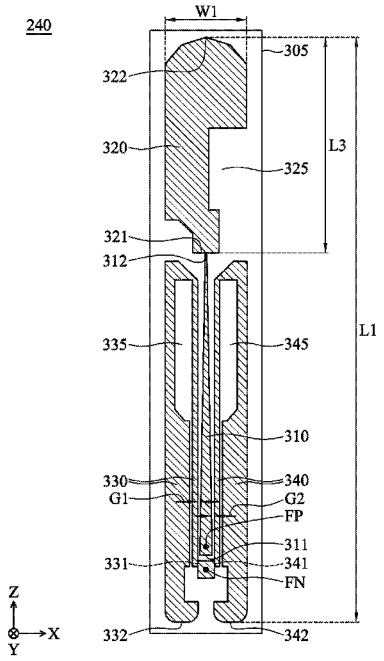
Primary Examiner — Joseph J Lauture
(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(57) **ABSTRACT**

A communication device includes a nonconductive housing, a cable, an antenna structure, and a signal source. The nonconductive housing has a hollow structure. The cable is coupled to the signal source. The cable includes a signaling conductor and a grounding conductor. The antenna structure includes an antenna body and an enclosed radiation element. The antenna body is coupled to the signaling conductor. The antenna body is disposed outside the nonconductive housing. The enclosed radiation element is coupled to the grounding conductor. The enclosed radiation element is disposed inside the nonconductive housing.

20 Claims, 8 Drawing Sheets



US010965006B2

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

(10) **Patent No.: US 10,965,006 B2**
(45) **Date of Patent: Mar. 30, 2021**

(54) **TERMINAL BACK COVER AND MOBILE TERMINAL**

(71) Applicant: **Beijing Xiaomi Mobile Software Co., Ltd.**, Beijing (CN)

(72) Inventors: **Xiaofeng Xiong**, Beijing (CN); **Linchuan Wang**, Beijing (CN); **Zonglin Xue**, Beijing (CN)

(73) Assignee: **Beijing Xiaomi Mobile Software Co., Ltd.**, Beijing (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 695 days.

(21) Appl. No.: **15/454,849**

(22) Filed: **Mar. 9, 2017**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Mar. 11, 2016 (CN) 201610141670.4

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 13/10 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 1/521*** (2013.01); ***H01Q 7/00*** (2013.01); ***H01Q 13/106*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/243–245; H01Q 13/106
See application file for complete search history.

(56) **References Cited**

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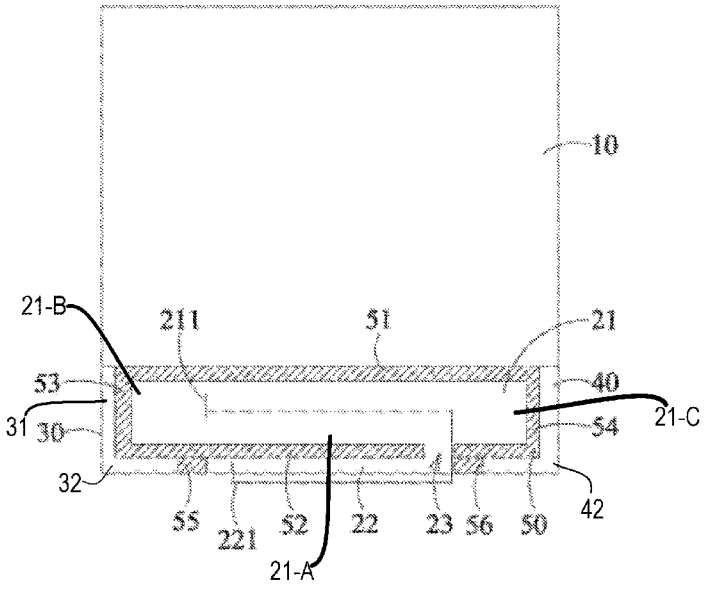
Primary Examiner — Graham P Smith
Assistant Examiner — Amal Patel
(74) *Attorney, Agent, or Firm* — Arch & Lake LLP

(57) **ABSTRACT**

A back cover includes: a back cover body, an antenna structure, a first hand-held part, and a second hand-held part arranged apart from the first hand-held part. The antenna structure includes a first part whose first side is separated from one end of the back cover body by a first slit, a second part separated from a second side of the first part by a second slit, and a third part for connecting the first and second parts. The first hand-held part extends to the second part from the back cover body and separated from a third side of the first part by a third slit. The second hand-held part extends to the second part from the back cover body and separated from a fourth side of the first part by a fourth slit, where the back cover body and the antenna structure are made of a metal material.

20 Claims, 5 Drawing Sheets



US010965008B2

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

(10) **Patent No.: US 10,965,008 B2**
(45) **Date of Patent: Mar. 30, 2021**

(54) **ELECTRONIC DEVICE WITH HOUSING SLOTS FOR ANTENNAS**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventors: **Umar Azad**, San Jose, CA (US); **Harish Rajagopalan**, San Jose, CA (US); **Mattia Pascolini**, San Francisco, CA (US); **Rodney A. Gomez Angulo**, Sunnyvale, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 159 days.

(21) Appl. No.: **16/252,311**

(22) Filed: **Jan. 18, 2019**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 14/693,274, filed on Apr. 22, 2015, now Pat. No. 10,224,602.

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 13/10	(2006.01)
H01Q 1/48	(2006.01)
H01Q 7/00	(2006.01)
H01Q 9/42	(2006.01)

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

CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 7/00*** (2013.01); ***H01Q 9/42*** (2013.01); ***H01Q 13/10*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 13/10; H01Q 9/42; H01Q 7/00; H01Q 1/48

See application file for complete search history.

(56) **References Cited**

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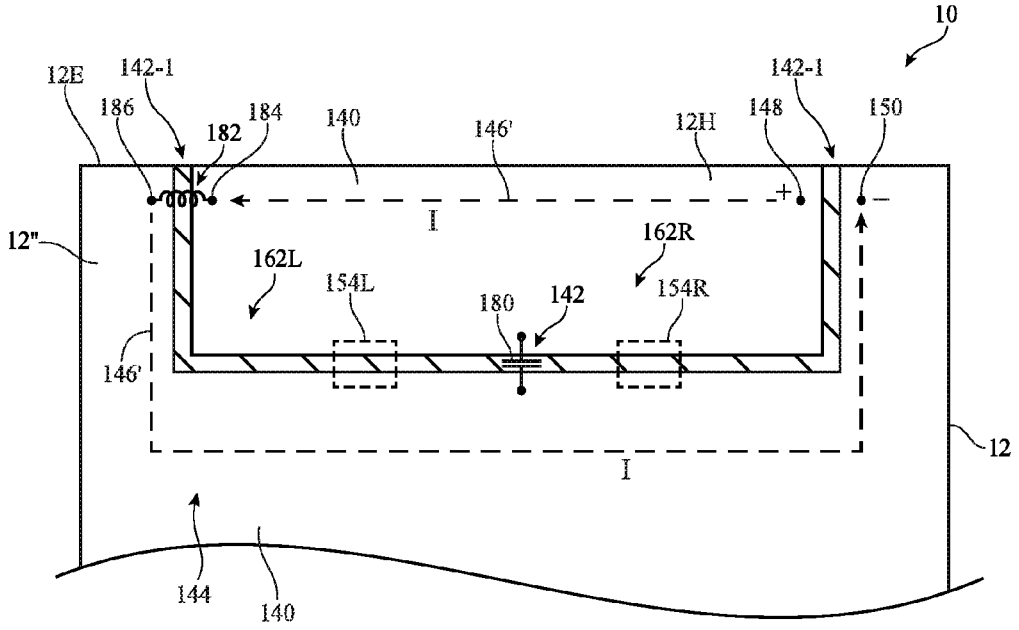
Primary Examiner — Graham P Smith
Assistant Examiner — Jae K Kim
(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; Tianyi He

(57) **ABSTRACT**

An electronic device housing may have a rear housing wall that forms a metal ground plane. A slot may be formed in the metal ground plane. The slot may have one or more open ends along an edge of the ground plane. A near-field communications loop antenna may overlap the slot. The near-field communications loop antenna may have one or more turns. A current path through the metal ground plane may form one of the turns in the near-field communications loop antenna. The slot may form portions of non-near-field-communications antennas in addition to the near-field communications loop antenna. The slot in the non-near-field-communications antennas may be fed using an indirect antenna feed structure. Components such as a capacitor and inductor may help allow non-near-field communications antenna and the near-field communications antenna to be formed from common portions of the metal ground plane.

20 Claims, 12 Drawing Sheets



US010965018B2

(12) **United States Patent**
Izawa

(10) **Patent No.: US 10,965,018 B2**
(45) **Date of Patent: Mar. 30, 2021**

(54) **ANTENNA DEVICE**

(71) Applicant: **Murata Manufacturing Co., Ltd.**, Kyoto (JP)

(72) Inventor: **Masahiro Izawa**, Kyoto (JP)

(73) Assignee: **MURATA MANUFACTURING CO., LTD.**, Kyoto (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 193 days.

(21) Appl. No.: **15/952,977**

(22) Filed: **Apr. 13, 2018**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. PCT/JP2016/076334, filed on Sep. 7, 2016.

(30) **Foreign Application Priority Data**

Oct. 14, 2015 (JP) 2015-202531

(51) **Int. Cl.**
H01Q 21/28 (2006.01)
H01Q 1/48 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/48*** (2013.01); ***H01Q 1/2291*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/46*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/48; H01Q 5/378; H01Q 5/35; H01Q 1/2291; H01Q 19/005; H01Q 1/46;
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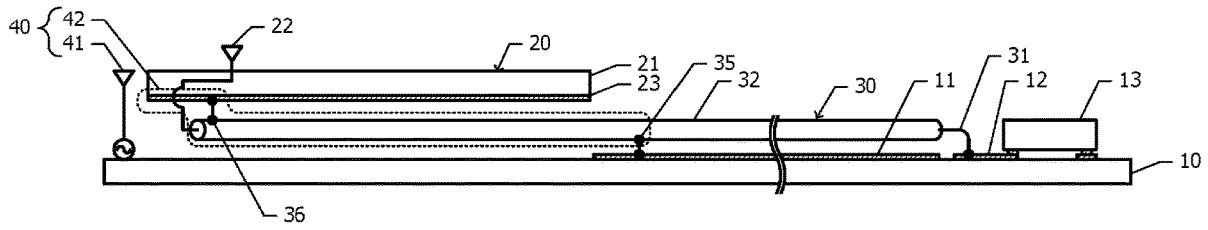
Primary Examiner — Dimary S Lopez Cruz
Assistant Examiner — Bamidele A Jegede
(74) *Attorney, Agent, or Firm* — Pearne & Gordon LLP

(57) **ABSTRACT**

A first ground conductor is disposed in or on a main substrate. In or on an antenna module, a first antenna and a second ground conductor operating as a ground electrode of the first antenna are disposed. A coaxial cable including a core wire and an outer conductor feeds power to the first antenna. The outer conductor is electrically connected to the first ground conductor at a first position, and is connected to the second ground conductor at a second position. A second antenna including a feed element and a parasitic element operates at a lower frequency than the operating frequency of the first antenna. The second ground conductor and a part of the outer conductor from the first position to the second position also serve as the parasitic element of the second antenna.

13 Claims, 8 Drawing Sheets



US010965028B2

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

(10) **Patent No.: US 10,965,028 B2**
(45) **Date of Patent: Mar. 30, 2021**

(54) **ANTENNA MODULE AND DUAL-BAND ANTENNA APPARATUS**

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

(72) Inventors: **Jeong Ki Ryoo**, Suwon-si (KR); **Sang Hyun Kim**, Suwon-si (KR); **Seung Goo Jang**, Suwon-si (KR); **Thomas A. Kim**, Suwon-si (KR); **Hong In Kim**, Suwon-si (KR); **Nam Ki Kim**, Suwon-si (KR)

(73) Assignee: **Samsung Electro-Mechanics 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 17 days.

(21) Appl. No.: **16/695,535**

(22) Filed: **Nov. 26, 2019**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 15/993,821, filed on May 31, 2018, now Pat. No. 10,770,793.

(30) **Foreign Application Priority Data**

Dec. 26, 2017 (KR) 10-2017-0179224

(51) **Int. Cl.**
H01Q 21/30 (2006.01)
H01Q 25/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 5/35*** (2015.01); ***H01Q 1/2283*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 5/35; H01Q 1/2283; H01Q 9/42; H01Q 21/062; H01Q 21/065; H01Q 21/20; H01Q 21/30; H01Q 25/00; H01Q 25/002
See application file for complete search history.

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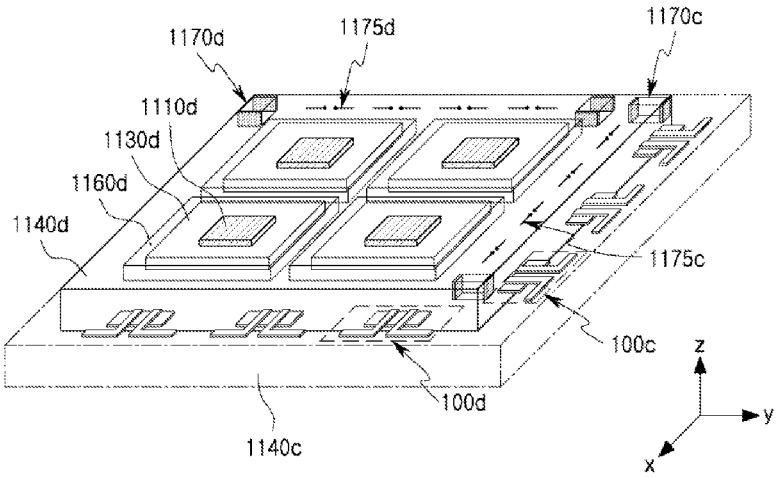
(Continued)

Primary Examiner — Hoang V Nguyen
(74) *Attorney, Agent, or Firm* — NSIP Law

(57) **ABSTRACT**

An antenna module includes a connection member including at least one wiring layer and at least one insulating layer; an IC disposed on a first surface of the connection member and electrically connected to at least one wiring layer of the connection member; and an antenna package disposed on a second surface of the connection member and including first antenna members and feed vias, wherein the connection member includes a feed line having a first end electrically connected to a corresponding wire of at least one wiring layer of the connection member; a second antenna member electrically connected to a second end of the feed line and configured to transmit or receive a radio frequency (RF) signal; and a ground member spaced apart from the feed line
(Continued)



US010965031B2

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

(10) **Patent No.: US 10,965,031 B2**
(45) **Date of Patent: Mar. 30, 2021**

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

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

(72) Inventors: **Dongsik Shin**, Suwon-si (KR); **Youngsub Kim**, Suwon-si (KR); **Seungho Choi**, Suwon-si (KR); **Jungmin Park**, Suwon-si (KR); **Jongwook Zeong**, Suwon-si (KR); **Jonghwa Kim**, Suwon-si (KR); **Youngju Lee**, 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.

(21) Appl. No.: **16/914,874**

(22) Filed: **Jun. 29, 2020**

(65) **Prior Publication Data**

US 2020/0411992 A1 Dec. 31, 2020

(30) **Foreign Application Priority Data**

Jun. 28, 2019 (KR) 10-2019-0077930

(51) **Int. Cl.**
H01Q 21/00 (2006.01)
H01Q 1/24 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 9/045*** (2013.01); ***H01Q 1/24*** (2013.01); ***H01Q 5/35*** (2015.01); ***H01Q 21/00*** (2013.01); ***H01Q 21/24*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 9/045; H01Q 5/35; H01Q 21/24; H01Q 21/00; H01Q 1/24
(Continued)

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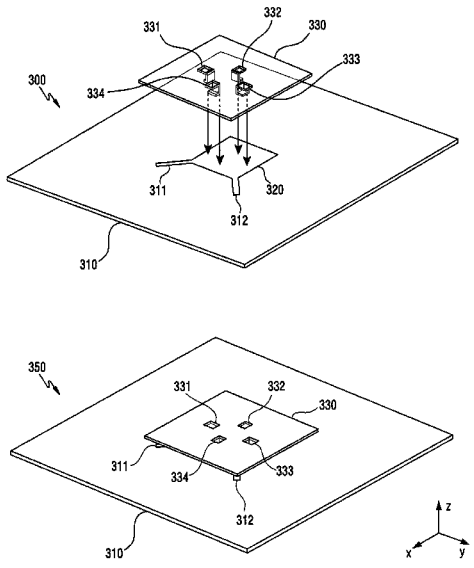
Primary Examiner — Hai V Tran
(74) *Attorney, Agent, or Firm* — Nixon & Vanderhye P.C.

(57) **ABSTRACT**

The present disclosure relates to a pre-5th-Generation (5G) or 5G communication system to be provided for supporting higher data rates Beyond 4th-Generation (4G) communication system such as Long Term Evolution (LTE). According to embodiments in the present disclosure, an antenna device for dual polarization of a wireless communication system, comprises a print circuit board (PCB); a first feeding line configured to provide a first polarization signal; a second feeding configured to provide a second polarization signal; and a patch antenna comprising a radiating region and cutting regions. Objects corresponding to the cutting regions are disposed to support the radiating region on the PCB.

20 Claims, 13 Drawing Sheets



US010965034B2

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

(10) **Patent No.: US 10,965,034 B2**
(45) **Date of Patent: Mar. 30, 2021**

(54) **MILLIMETER WAVE ANTENNA**

(71) Applicant: **SONY CORPORATION**, Tokyo (JP)

(72) Inventors: **Ying Zhinong**, Lund (SE); **Kun Zhao**, Lund (SE)

(73) Assignee: **SONY CORPORATION**, 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.

(21) Appl. No.: **16/490,426**

(22) PCT Filed: **Apr. 26, 2017**

(86) PCT No.: **PCT/US2017/029650**

§ 371 (c)(1),
(2) Date: **Aug. 30, 2019**

(87) PCT Pub. No.: **WO2018/199944**

PCT Pub. Date: **Nov. 1, 2018**

(65) **Prior Publication Data**

US 2020/0052406 A1 Feb. 13, 2020

(51) **Int. Cl.**

H01Q 5/50	(2015.01)
H01Q 9/28	(2006.01)
H01Q 1/24	(2006.01)
H01Q 1/48	(2006.01)

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

CPC ***H01Q 9/285*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 5/50*** (2015.01)

(58) **Field of Classification Search**

CPC H01Q 9/0407; H01Q 9/065; H01Q 9/285; H01Q 5/50

See application file for complete search history.

(56) **References Cited**

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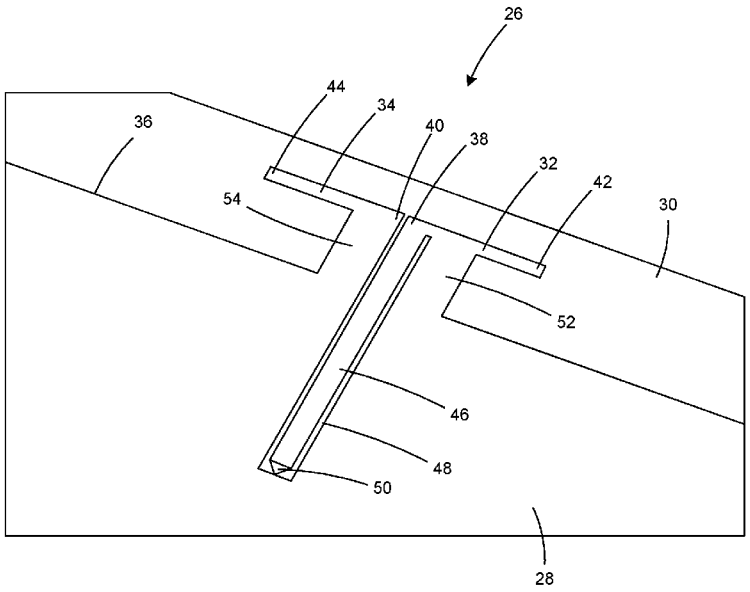
(Continued)

Primary Examiner — Jason Crawford
(74) *Attorney, Agent, or Firm* — Tucker Ellis LLP

(57) **ABSTRACT**

A balanced planar antenna having at least one mmWave resonant frequency includes a ground plane, first and second antenna elements, an arm that connects the second antenna element to the ground plane, a feed line connected to the first antenna element and for feeding a radio frequency signal to the first antenna element, and a balun that connects the first antenna element to the ground plane. The ground plane, first antenna element, second antenna element, arm, feed line and balun each are disposed on a substrate and are coplanar.

16 Claims, 8 Drawing Sheets



US010971801B2

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

(10) **Patent No.: US 10,971,801 B2**
(45) **Date of Patent: *Apr. 6, 2021**

(54) **WIRELESS COMMUNICATION DEVICE WITH AN ANTENNA ADJACENT TO AN EDGE OF THE DEVICE**

(71) Applicant: **Futurewei Technologies, Inc.**, Plano, TX (US)

(72) Inventors: **Chul Min Han**, San Diego, CA (US); **Jorge Fabrega Sanchez**, San Diego, CA (US)

(73) Assignee: **Futurewei Technologies, Inc.**, Plano, TX (US)

(*) 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.: **16/005,086**

(22) Filed: **Jun. 11, 2018**

(65) **Prior Publication Data**

US 2019/0013569 A1 Jan. 10, 2019

Related U.S. Application Data

(63) Continuation of application No. 15/263,559, filed on Sep. 13, 2016, now Pat. No. 9,997,822, which is a (Continued)

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 21/29 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/24*** (2013.01); ***H01Q 1/50*** (2013.01); ***H01Q 13/10*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/50; H01Q 13/10; H01Q 21/293; H01Q 13/106; H01Q 1/026;
(Continued)

(56) **References Cited**

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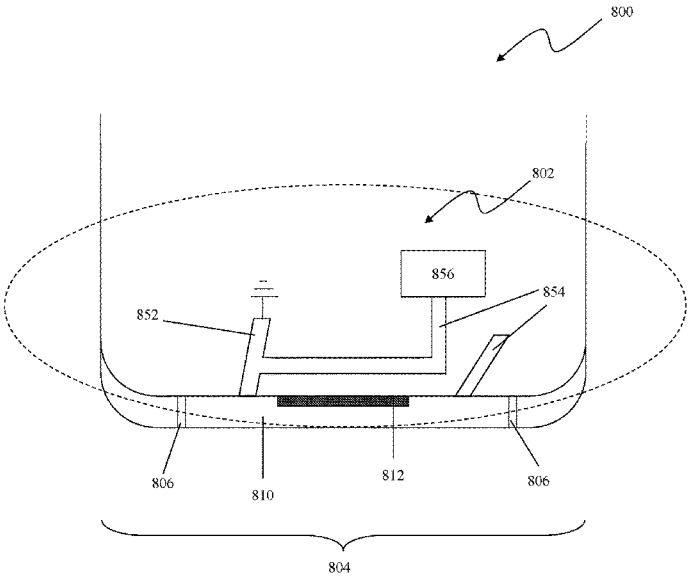
Primary Examiner — Hai V Tran
(74) *Attorney, Agent, or Firm* — Conley Rose, P.C.

(57) **ABSTRACT**

A wireless communication device comprising a housing comprising a plurality of edges and configured to serve as an external surface for the wireless communication device, and an antenna adjacent to at least a first edge of the housing, wherein the antenna comprises at least a conductive strip and at least one slot and wherein the antenna is configured to receive and transmit wireless signals, wherein the first edge of the housing is one of an edge of the housing nearest an ear piece and an edge of the housing that is opposite the edge of the housing nearest the ear piece, and wherein the conductive strip and the slot are adjacent to at least the first edge of the housing.

20 Claims, 10 Drawing Sheets



US010971807B2

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

(10) **Patent No.: US 10,971,807 B2**
(45) **Date of Patent: Apr. 6, 2021**

(54) **MOBILE DEVICE**

(71) Applicant: **Quanta Computer Inc.**, Taoyuan (TW)

(72) Inventors: **Yi-Ling Tseng**, Taoyuan (TW); **Chung-Hung Lo**, Taoyuan (TW); **Chin-Lung Tsai**, Taoyuan (TW); **Ching-Hai Chiang**, Taoyuan (TW); **Kuan-Hsien Lee**, Taoyuan (TW); **Ying-Cong Deng**, Taoyuan (TW); **Chung-Ting Hung**, Taoyuan (TW)

(73) Assignee: **QUANTA COMPUTER INC.**, Taoyuan (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/550,755**

(22) Filed: **Aug. 26, 2019**

(65) **Prior Publication Data**

US 2020/0295445 A1 Sep. 17, 2020

(30) **Foreign Application Priority Data**

Mar. 15, 2019 (TW) 10810875.5

(51) **Int. Cl.**
H01Q 1/36 (2006.01)
H01Q 5/30 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/36*** (2013.01); ***H01Q 1/2283*** (2013.01); ***H01Q 9/285*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/24; H01Q 1/241; H01Q 1/243; H01Q 1/36; H01Q 1/2283; H01Q 5/30; H01Q 13/10; H01Q 13/106
See application file for complete search history.

(56) **References Cited**

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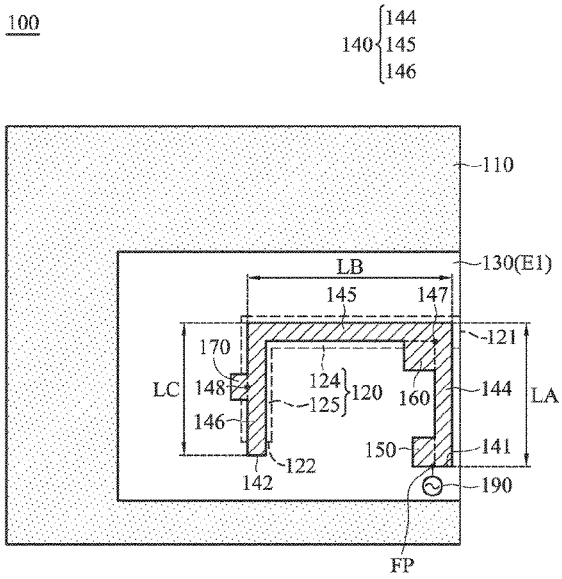
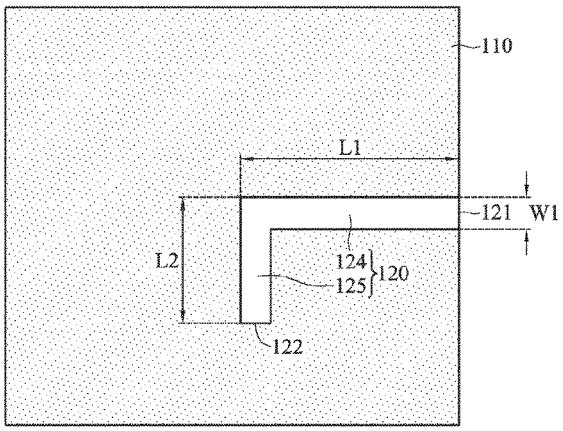
Primary Examiner — Thai Pham
(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(57) **ABSTRACT**

A mobile device includes a metal mechanism element, a dielectric substrate, and a feeding radiation element. The metal mechanism element has an open slot. The open slot substantially has an L-shape. The dielectric substrate is adjacent to the metal mechanism element. The feeding radiation element has a feeding point. The feeding radiation element is disposed on the dielectric substrate. The feeding radiation element at least partially extends along the open slot. An antenna structure is formed by the feeding radiation element and the open slot of the metal mechanism element. The antenna structure covers a first frequency band, a second frequency band, and a third frequency band.

8 Claims, 7 Drawing Sheets





US010971819B2

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

(10) **Patent No.: US 10,971,819 B2**
(45) **Date of Patent: Apr. 6, 2021**

(54) **MULTI-BAND WIRELESS SIGNALING**

(71) Applicant: **QUALCOMM Incorporated**, San Diego, CA (US)

(72) Inventors: **Guining Shi**, San Diego, CA (US); **Young Jun Song**, San Diego, CA (US); **Allen Minh-Triet Tran**, San Diego, CA (US); **Mohammad Ali Tassoudji**, San Diego, CA (US); **Elizabeth Wyrwich**, San Diego, CA (US); **Julio Zegarra**, La Jolla, CA (US); **Clinton James Wilber**, San Diego, CA (US); **Neil Burns**, San Diego, CA (US); **Jorge Fabrega Sanchez**, San Diego, CA (US)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 71 days.

(21) Appl. No.: **16/276,957**

(22) Filed: **Feb. 15, 2019**

(65) **Prior Publication Data**

US 2019/0260127 A1 Aug. 22, 2019

Related U.S. Application Data

(60) Provisional application No. 62/710,403, filed on Feb. 16, 2018.

(51) **Int. Cl.**

H01Q 1/00	(2006.01)
H01Q 5/371	(2015.01)
H01Q 1/38	(2006.01)

(Continued)

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

CPC ***H01Q 5/371*** (2015.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 5/378*** (2015.01);

(Continued)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 21/28; H01Q 9/0421; H01Q 13/10; H01Q 1/44; H01Q 5/35;

(Continued)

(56) **References Cited**

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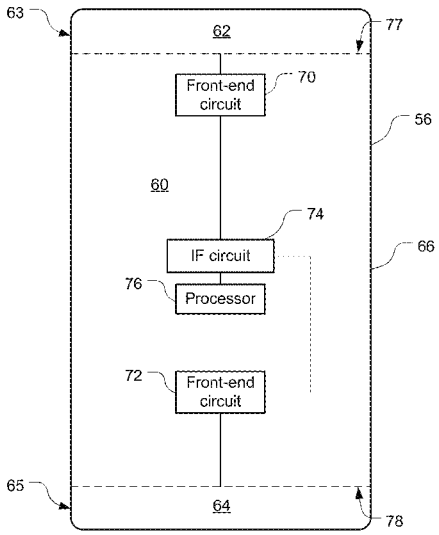
Primary Examiner — Monica C King

(74) *Attorney, Agent, or Firm* — Qualcomm Incorporated

(57) **ABSTRACT**

An antenna system for transducing radio-frequency energy includes: a first antenna sub-system comprising a plurality of radiators and a ground conductor, each of the plurality of radiators being sized and shaped to transduce millimeter-wave energy between first wireless signals and first electrical current signals; and a second antenna sub-system comprising a first radiator configured to transduce sub-6 GHz energy between second wireless signals and second electrical current signals, wherein the first radiator comprises the ground conductor.

29 Claims, 15 Drawing Sheets



US010978783B2

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

(10) **Patent No.: US 10,978,783 B2**
(45) **Date of Patent: Apr. 13, 2021**

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

(71) Applicant: **AAC Technologies Pte. Ltd.**, Singapore (SG)

(72) Inventors: **Zhimin Zhu**, Shenzhen (CN); **Xiaoyue Xia**, Shenzhen (CN); **Chao Wang**, Shenzhen (CN)

(73) Assignee: **AAC Technologies Pte. Ltd.**, Singapore (SG)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 2 days.

(21) Appl. No.: **16/524,078**

(22) Filed: **Jul. 28, 2019**

(65) **Prior Publication Data**

US 2020/0052376 A1 Feb. 13, 2020

(30) **Foreign Application Priority Data**

Aug. 12, 2018 (CN) 201810912499.1

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 13/10 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/241*** (2013.01); ***H01Q 13/106*** (2013.01); ***H01Q 21/0075*** (2013.01); ***H01Q 21/08*** (2013.01)

(58) **Field of Classification Search**
CPC .. H01Q 1/241; H01Q 13/106; H01Q 21/0075; H01Q 21/08; H01Q 3/38;
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(56) **References Cited**

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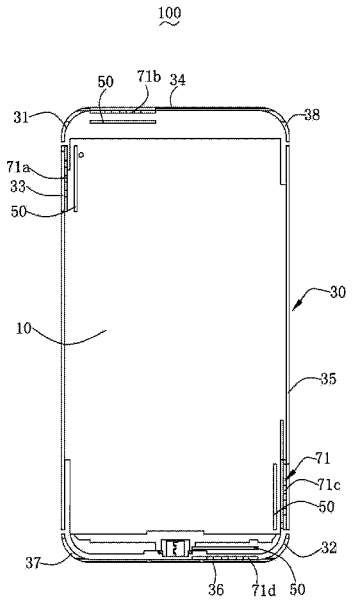
Primary Examiner — Daniel D Chang
(74) *Attorney, Agent, or Firm* — W&G Law Group LLP

(57) **ABSTRACT**

A mobile terminal includes a metal frame. The metal frame includes two corners provided diagonally, and two long frames and two short frames respectively connected to two ends of the two corners. The antenna system includes four millimeter wave antenna arrays attached to an inner surface of the metal frame. A circumferential side of each corner is respectively provided with two millimeter wave antenna arrays provided perpendicular to each other, and one of the millimeter wave antenna arrays is provided at an end of the long frame close to the connected corner while the other millimeter wave antenna array is provided at an end of the short frame close to the connected corner. Positions of the metal frame corresponding to the four millimeter wave antenna arrays are each provided with a radiation window.

8 Claims, 9 Drawing Sheets



US010978795B2

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

(10) **Patent No.: US 10,978,795 B2**
(45) **Date of Patent: Apr. 13, 2021**

(54) **ANTENNA STRUCTURE AND WIRELESS COMMUNICATION DEVICE USING THE SAME**

(71) Applicant: **Chiun Mai Communication Systems, Inc.**, New Taipei (TW)

(72) Inventors: **Chang-Je Chen**, New Taipei (TW); **Shu-Wei Jhang**, New Taipei (TW); **Tun-Yuan Tsou**, New Taipei (TW); **Yi-Te Chou**, New Taipei (TW); **Yung-Chin Chen**, New Taipei (TW); **Chang-Ching Huang**, New Taipei (TW)

(73) Assignee: **Chiun Mai Communication Systems, Inc.**, New Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 351 days.

(21) Appl. No.: **16/234,410**

(22) Filed: **Dec. 27, 2018**

(65) **Prior Publication Data**

US 2019/0214714 A1 Jul. 11, 2019

(30) **Foreign Application Priority Data**

Dec. 27, 2017 (CN) 201711448309.7

(51) **Int. Cl.**
H01Q 1/36 (2006.01)
H01Q 1/24 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/36*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/44*** (2013.01); ***H01Q 5/307*** (2015.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/44; H01Q 5/307; H01Q 5/40; H01Q 5/378; H01Q 5/371; H01Q 5/335; H01Q 9/42; H01Q 21/28
See application file for complete search history.

(56) **References Cited**

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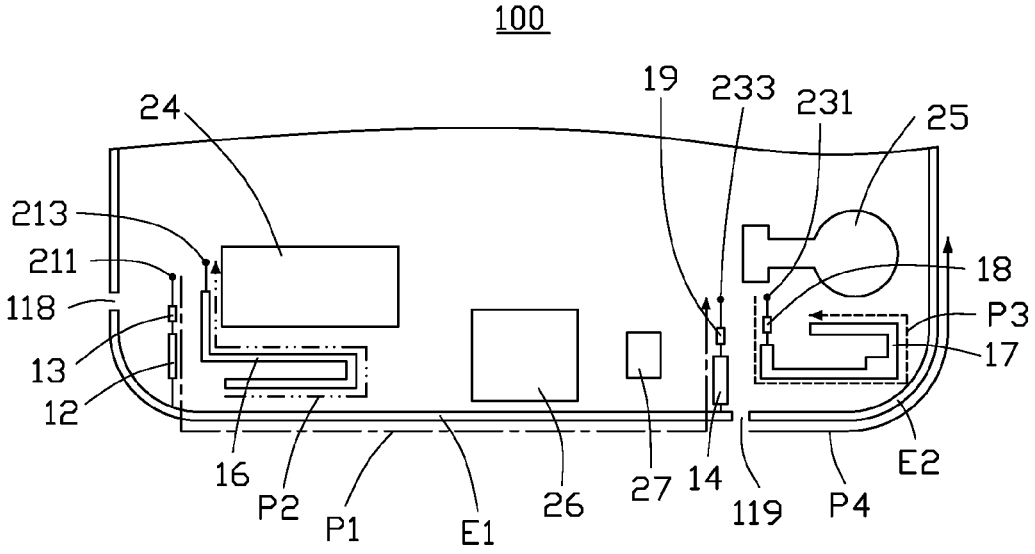
(Continued)

Primary Examiner — Ab Salam Alkassim, Jr.
(74) *Attorney, Agent, or Firm* — ScienBiziP, P.C.

(57) **ABSTRACT**

An antenna structure includes a housing, a feed portion, a ground portion, a first radiator, and a second radiator. The housing includes a first radiating portion and a second radiating portion. The first radiator and the second radiator are both positioned in the housing. When the feed portion feeds current, the current flows through the first radiating portion and is grounded through the ground portion to activate a first operating mode. When the feed portion feeds current, the current is further coupled to the first radiator through the first radiating portion, and the first radiator activates a second operating mode. When the second radiator feeds current, the second radiator activates a third operating mode. When the second radiator feeds current, the current is further coupled to the second radiating portion through the second radiator, and the second radiating portion activates a fourth operating mode.

17 Claims, 8 Drawing Sheets



US010978806B2

(12) **United States Patent**
Garrido Lopez et al.

(10) **Patent No.: US 10,978,806 B2**
(45) **Date of Patent: Apr. 13, 2021**

(54) **ELECTRONIC DEVICE SLOT ANTENNAS**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventors: **David Garrido Lopez**, Campbell, CA (US); **Harish Rajagopalan**, San Jose, CA (US); **Umar Azad**, Santa Clara, CA (US); **Rodney A. Gomez Angulo**, Santa Clara, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 390 days.

(21) Appl. No.: **16/141,793**

(22) Filed: **Sep. 25, 2018**

(65) **Prior Publication Data**

US 2020/0099138 A1 Mar. 26, 2020

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 13/10	(2006.01)
H01Q 9/04	(2006.01)
H01Q 9/42	(2006.01)
H01Q 21/28	(2006.01)
H01Q 21/30	(2006.01)

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

CPC ***H01Q 13/103*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 9/0407*** (2013.01); ***H01Q 9/42*** (2013.01); ***H01Q 21/28*** (2013.01); ***H01Q 21/30*** (2013.01)

(58) **Field of Classification Search**

CPC combination set(s) only.

See application file for complete search history.

(56) **References Cited**

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2015/0116159	A1	4/2015 Chen et al.

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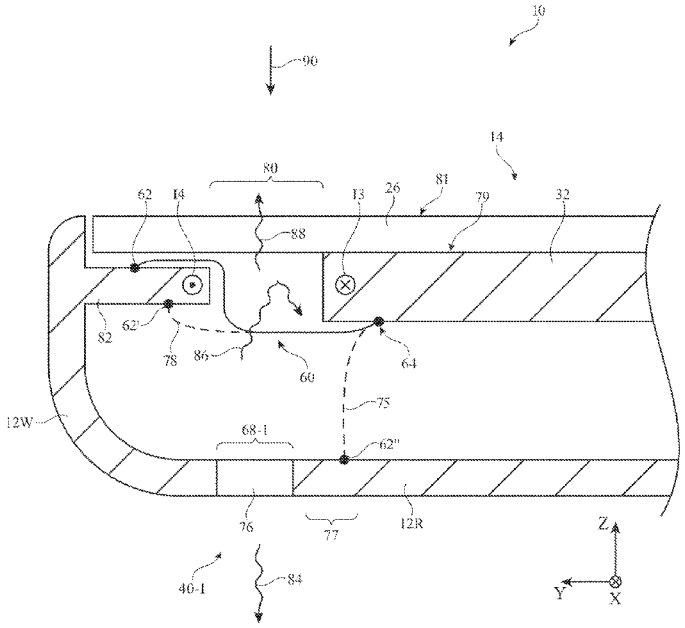
Primary Examiner — Graham P Smith

(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; Michael H. Lyons

(57) **ABSTRACT**

An electronic device may be provided an antenna, a display, and a housing. The display may include a conductive display structure and a cover layer. The housing may include peripheral conductive structures and a conductive rear wall. The peripheral structures may include a ledge separated from the conductive display structure by a gap. The peripheral structures and the rear wall may define opposing edges of a slot element for the antenna. Conductive bridging structures may be coupled between the conductive display structure and the ledge across the gap. The bridging structures may at least partially overlap locations along the length of the slot element where antenna currents around the slot element exhibit a maximum magnitude. The bridging structures may align the phase of current induced on the ledge with the phase of the current induced on the conductive display structure to maximize antenna efficiency through the cover layer.

20 Claims, 9 Drawing Sheets



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(54) **STRUCTURAL SLOT ANTENNA WITH ISOLATING ELEMENT**

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H01Q 21/06	(2006.01)
H04B 7/0413	(2017.01)

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

CPC ***H01Q 13/103*** (2013.01); ***H01Q 13/12*** (2013.01); ***H01Q 21/064*** (2013.01); ***H04B 7/0413*** (2013.01)

(58) **Field of Classification Search**

CPC H01G 13/103; H01G 13/12; H01G 21/064

See application file for complete search history.

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(57) **ABSTRACT**

The disclosed technology provides an antenna structure located in the metal casing of a computing device. A first open slot radiating structure radiates at a radiating wavelength and is located on a surface of the metal casing of the computing device. A second open slot radiating structure radiates at the radiating wavelength and is located on the surface of the metal casing of the computing device. At least one closed slot radiator element is located between the first open slot radiating structure and the second open slot radiating structure on the surface of the metal casing of the computing device. The closed slot radiator element is approximately half the length of the radiating wavelength.

17 Claims, 8 Drawing Sheets