



US010847870B2

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

(10) **Patent No.:** **US 10,847,870 B2**  
(45) **Date of Patent:** **Nov. 24, 2020**

(54) **FREQUENCY RECONFIGURABLE MIMO ANTENNA WITH UWB SENSING ANTENNA**

USPC ..... 343/745, 767-771  
See application file for complete search history.

(71) Applicant: **King Fahd University of Petroleum and Minerals, Dhahran (SA)**

(56) **References Cited**

(72) Inventors: **Mohammad S. Sharawi, Dhahran (SA); Rifaqat Hussain, Dhahran (SA)**

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(73) Assignee: **King Fahd University of Petroleum and Minerals, Dhahran (SA)**

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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.: **15/995,982**

Hussain, Rifaqat, et al. ; Annular slot-based miniaturized frequency-agile MIMO antenna system ; Jul. 12, 2017 ; IEEE Antennas and Wireless Propagation Letters, vol. 16, ; 4 pages.  
Zhang, Yan, et al. ; Compact ultrawideband (UWB) slot antenna with wideband and high isolation for mimo applications ; Jul. 23, 2014 ; Progress in Electromagnetics Research C, vol. 54, 9-16 ; 8 pages.

(22) Filed: **Jun. 1, 2018**

\* cited by examiner

(65) **Prior Publication Data**

US 2019/0372200 A1 Dec. 5, 2019

Primary Examiner — Binh B Tran

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 5/321** (2015.01)  
**H01Q 21/28** (2006.01)  
**H01Q 1/38** (2006.01)

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

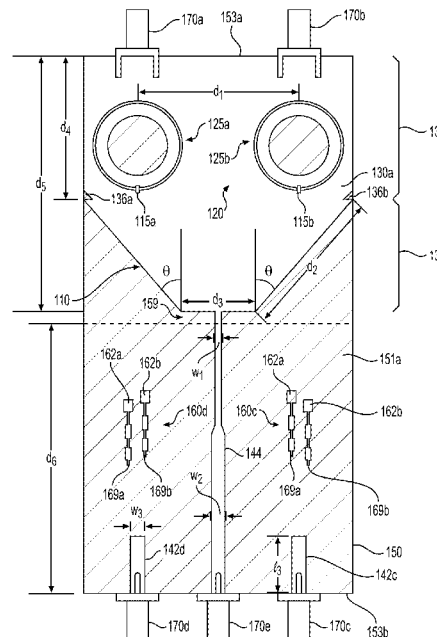
(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 5/321** (2015.01); **H01Q 21/28** (2013.01)

(57) **ABSTRACT**

A dielectric substrate for a configurable antenna has an upper surface and an opposing lower surface. An upper conductor patch is disposed on the upper surface of the substrate and a lower conductor patch is disposed on the lower surface of the substrate. A sensing antenna is formed in the upper conductor patch. An upper set of slot antennas is formed in the upper conductor patch and a lower set of slot antennas is formed in the lower conductor patch. Each of the slot antennas is loaded with a variable reactance component.

(58) **Field of Classification Search**  
CPC ..... H01Q 7/005; H01Q 13/103; H01Q 13/16; H01Q 13/10; H01Q 3/443; H01Q 13/18; H01Q 7/00; H01Q 21/064; H01Q 21/0043; H01Q 21/005; H01Q 21/0056; H01Q 21/0062

**20 Claims, 12 Drawing Sheets**





US010847871B2

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

(10) **Patent No.:** **US 10,847,871 B2**  
(45) **Date of Patent:** **Nov. 24, 2020**

(54) **THREE-SLOTTED ANTENNA APPARATUS AND METHOD**

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 5/35** (2015.01); **H01Q 5/371** (2015.01);

(71) Applicant: **Huawei Technologies Co., Ltd.**,  
Shenzhen (CN)

(Continued)

(72) Inventors: **Chulmin Han**, San Diego, CA (US);  
**Wee Kian Toh**, San Diego, CA (US);  
**Wei Huang**, San Diego, CA (US);  
**Hongwei Liu**, San Diego, CA (US)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/243; H01Q 5/50; H01Q 13/18;  
H01Q 1/48; H01Q 1/24; H04B 7/0413;  
H04B 7/0404; H04B 7/04  
(Continued)

(73) Assignee: **Huawei Technologies Co., Ltd.**,  
Shenzhen (CN)

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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.: **16/604,962**

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(22) PCT Filed: **Apr. 10, 2018**

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(86) PCT No.: **PCT/CN2018/082450**

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§ 371 (c)(1),

(2) Date: **Oct. 11, 2019**

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(87) PCT Pub. No.: **WO2018/188575**

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PCT Pub. Date: **Oct. 18, 2018**

(Continued)

(65) **Prior Publication Data**

*Primary Examiner* — Jean B Jeanglaude

US 2020/0194872 A1 Jun. 18, 2020

(74) *Attorney, Agent, or Firm* — Slater Matsil, LLP

**Related U.S. Application Data**

(57) **ABSTRACT**

(63) Continuation of application No. 15/488,308, filed on Apr. 14, 2017, now Pat. No. 10,236,559.

An apparatus and associated method are provided involving a housing having a periphery configured to operate as a second antenna, a third antenna, and a fourth antenna. The periphery includes a top wall having a first slot formed therein, a first side wall having a second slot formed therein, and a second side wall having a third slot formed therein. The top wall is arranged between the first side wall and the

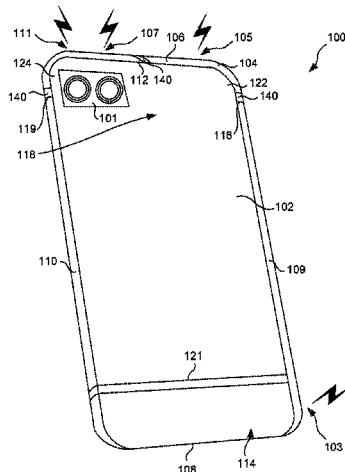
(51) **Int. Cl.**

**H01Q 1/24** (2006.01)

**H01Q 5/371** (2015.01)

(Continued)

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

(10) **Patent No.:** **US 10,847,885 B2**  
(45) **Date of Patent:** **Nov. 24, 2020**

(54) **MINIATURIZED UWB BI-PLANAR YAGI-BASED MIMO ANTENNA SYSTEM**

(56) **References Cited**

(71) Applicant: **King Fahd University of Petroleum and Minerals, Dhahran (SA)**

(72) Inventors: **Mohammad S. Sharawi, Dhahran (SA); Syed Shahan Jehangir, Dhahran (SA)**

(73) Assignee: **King Fahd University of Petroleum and Minerals, Dhahran (SA)**

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343/815

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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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*Primary Examiner* — Dameon E Levi

*Assistant Examiner* — Hasan Z Islam

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

(21) Appl. No.: **16/000,333**

(22) Filed: **Jun. 5, 2018**

(65) **Prior Publication Data**

US 2019/0372226 A1 Dec. 5, 2019

(51) **Int. Cl.**

**H01Q 5/49** (2015.01)  
**H01Q 1/24** (2006.01)  
**H01Q 7/00** (2006.01)  
**H01Q 19/30** (2006.01)

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

CPC ..... **H01Q 5/49** (2015.01); **H01Q 1/243** (2013.01); **H01Q 7/00** (2013.01); **H01Q 19/30** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 5/378; H01Q 5/40–5/49; H01Q 19/30; H01Q 7/00; H01Q 1/38; H01Q 9/04–9/28

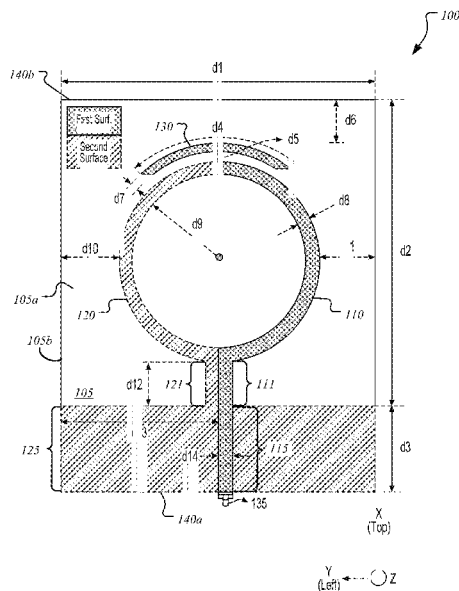
See application file for complete search history.

(57)

**ABSTRACT**

A miniature antenna device includes a dielectric substrate having an upper side and an opposing lower side and at least one antenna element. The antenna element includes a first half-loop conductor strip disposed on the upper side of the substrate and a second half-loop conductor strip disposed on the lower side of the substrate. The first and second half-loop conductor strips are aligned complementarily one with the other to have a common center of curvature that is void of a ground plane. The antenna element further includes a director element disposed on the upper side of the substrate and spanning the first and second half-loop conductor strips, an input terminal disposed on the upper side of the substrate being electrically coupled to the first half-loop conductor strip, and a ground plane disposed on the lower side of the substrate being electrically coupled to the second half-loop conductor strip.

**16 Claims, 8 Drawing Sheets**





US010847901B1

(12) **United States Patent**  
**Ayala Vazquez et al.**

(10) **Patent No.:** **US 10,847,901 B1**  
(45) **Date of Patent:** **Nov. 24, 2020**

(54) **ELECTRONIC DEVICE ANTENNAS HAVING ISOLATION ELEMENTS**

FOREIGN PATENT DOCUMENTS

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

EP 2885839 4/2017  
EP 3041084 4/2019

(72) Inventors: **Enrique Ayala Vazquez**, Watsonville, CA (US); **Hongfei Hu**, Cupertino, CA (US); **Mattia Pascolini**, San Francisco, CA (US)

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U.S. Appl. No. 15/902,907, filed Feb. 22, 2017.

\* cited by examiner

(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 20 days.

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

(21) Appl. No.: **16/446,503**

(57) **ABSTRACT**

(22) Filed: **Jun. 19, 2019**

(51) **Int. Cl.**  
**H01Q 21/28** (2006.01)  
**H01Q 1/24** (2006.01)

An electronic device may include an antenna and peripheral conductive housing structures. A dielectric gap may divide the peripheral conductive housing structures into first and second segments. The first and second segments may be separated from the antenna ground by respective first and second slots and may be fed using respective first and second feeds. An antenna isolation element may be coupled to the antenna ground and may separate the first slot element from the second slot element. The antenna isolation element may include a metal strip having an end coupled to the antenna ground and an opposing tip that extends into the dielectric gap. The antenna isolation element may electromagnetically isolate first radio-frequency signals conveyed by the first antenna feed in a cellular midband from second radio-frequency signals conveyed by the second antenna feed in a cellular high band.

(52) **U.S. Cl.**  
CPC ..... **H01Q 21/28** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/245** (2013.01)

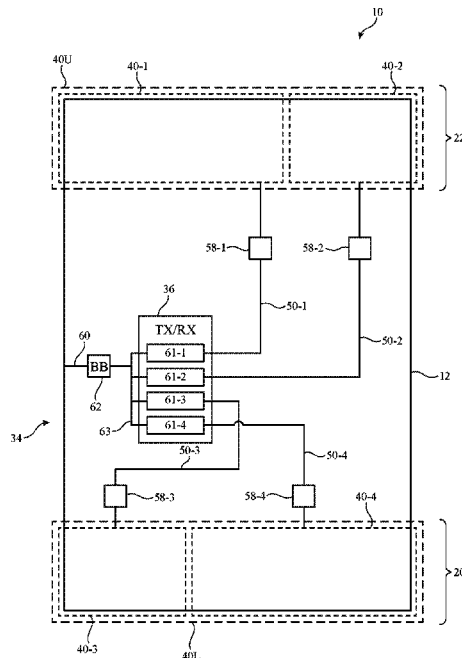
(58) **Field of Classification Search**  
CPC ..... H01Q 21/28; H01Q 1/24  
USPC ..... 343/702  
See application file for complete search history.

(56) **References Cited**

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**20 Claims, 10 Drawing Sheets**





US010852782B2

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

(10) **Patent No.:** **US 10,852,782 B2**  
(45) **Date of Patent:** **Dec. 1, 2020**

(54) **INFORMATION HANDLING SYSTEM  
ANTENNA ISOLATION WITH INTEGRATED  
COOLING FAN**

USPC ..... 361/688  
See application file for complete search history.

(71) Applicant: **Dell Products L.P.**, Round Rock, TX (US)

(56) **References Cited**

(72) Inventors: **Ching Wei Chang**, Cedar Park, TX (US); **Suresh Ramasamy**, Cedar Park, TX (US); **Allen B. McKittrick**, Cedar Park, TX (US); **Jeffery D. Kane**, Austin, TX (US)

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(73) Assignee: **Dell Products L.P.**, Round Rock, TX (US)

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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.: **16/220,653**

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(22) Filed: **Dec. 14, 2018**

International Search Report and Written Opinion for PCT/US2019/064506, dated Feb. 14, 2020, 13 pages.

(65) **Prior Publication Data**

US 2020/0192438 A1 Jun. 18, 2020

(Continued)

(51) **Int. Cl.**  
**H05K 7/20** (2006.01)  
**H05K 5/03** (2006.01)  
**H05K 5/02** (2006.01)  
**G06F 1/16** (2006.01)  
**G06F 1/20** (2006.01)

*Primary Examiner* — Anatoly Vortman  
(74) *Attorney, Agent, or Firm* — Zagorin Cave LLP; Robert W. Holland

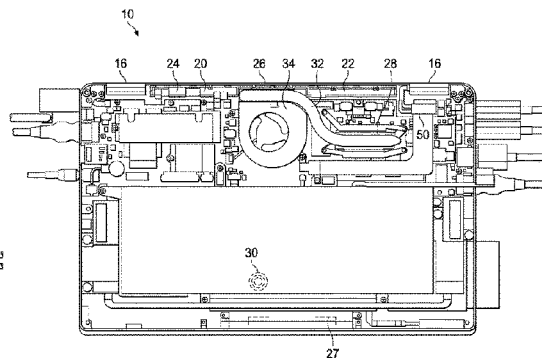
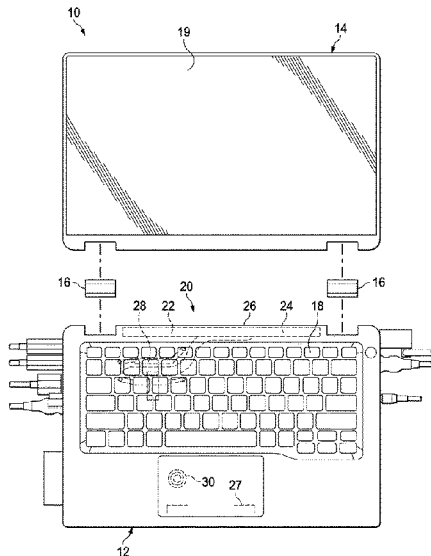
(52) **U.S. Cl.**  
CPC ..... **G06F 1/1698** (2013.01); **G06F 1/1662** (2013.01); **G06F 1/1681** (2013.01); **G06F 1/203** (2013.01); **H05K 5/0226** (2013.01); **H05K 5/0239** (2013.01); **H05K 5/03** (2013.01); **H05K 7/20163** (2013.01)

(57) **ABSTRACT**

(58) **Field of Classification Search**  
CPC .... G06F 1/1698; G06F 1/1662; G06F 1/1681; G06F 1/203; H05K 5/0226; H05K 5/0239; H05K 5/03; H05K 7/20163

A portable information handling system structure located between housing hinges along one side of the housing has first and second antenna disposed at opposing ends with a cooling fan between the first and second antenna and over the antenna structure to isolate the first and second antenna. In one embodiment, a parasitic element disposed between the first and second antenna and under the cooling fan has resonance tuned to isolate wireless signals of a frequency supported by the first and second antenna.

**7 Claims, 9 Drawing Sheets**





US010854953B2

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

(10) **Patent No.:** **US 10,854,953 B2**

(45) **Date of Patent:** **Dec. 1, 2020**

(54) **ELECTRONIC DEVICES HAVING HOUSING-INTEGRATED ANTENNAS**

(58) **Field of Classification Search**  
CPC combination set(s) only.  
See application file for complete search history.

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

(56) **References Cited**

(72) Inventors: **Pietro Romano**, Foster City, CA (US);  
**Umar Azad**, Santa Clara, CA (US);  
**Harish Rajagopalan**, San Jose, CA (US);  
**David Garrido Lopez**, Campbell, CA (US);  
**Lu Zhang**, Shanghai (CN);  
**Rodney A. Gomez Angulo**, Santa Clara, CA (US);  
**Mattia Pascolini**, San Francisco, CA (US)

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

*Primary Examiner* — Graham P Smith  
*Assistant Examiner* — Jae K Kim  
(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.;  
Michael H. Lyons; Matthew R. Williams

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 445 days.

(21) Appl. No.: **15/717,821**

(22) Filed: **Sep. 27, 2017**

(65) **Prior Publication Data**

US 2019/0097306 A1 Mar. 28, 2019

(51) **Int. Cl.**

**H01Q 1/24** (2006.01)  
**H01Q 13/10** (2006.01)  
**H01Q 1/52** (2006.01)  
**H04B 1/3827** (2015.01)  
**H01Q 21/06** (2006.01)

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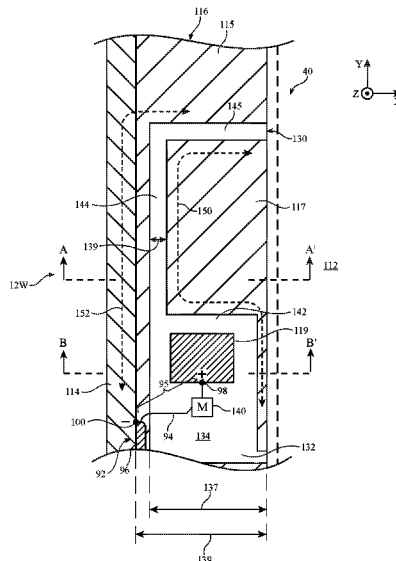
(52) **U.S. Cl.**

CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/52** (2013.01); **H01Q 13/10** (2013.01); **H01Q 21/064** (2013.01); **H01Q 21/28** (2013.01); **H04B 1/3827** (2013.01); **H04M 1/026** (2013.01); **H04M 1/0262** (2013.01); **H04M 1/0266** (2013.01)

(57) **ABSTRACT**

An electronic device may include a peripheral conductive housing sidewall with an integral ledge extending towards the device interior. A display cover layer may be supported by the integral ledge. A slot antenna may be formed from a slot in the integral ledge. The integral ledge may be mounted to a surface of a substrate and coupled to a conductive rear housing wall by a conductive layer extending over an additional surface of the substrate. The sidewall may include a vertical portion extending from the ledge to the rear wall. The slot antenna may be fed via near-field coupling using a conductive patch that is located within the slot at the surface of the substrate. The conductive layer, rear housing wall, and vertical portion may form a cavity for the slot antenna. The conductive layer may isolate the slot from interference with a battery, display circuitry, or other components.

**18 Claims, 7 Drawing Sheets**





US010854973B2

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

(10) **Patent No.:** **US 10,854,973 B2**  
(45) **Date of Patent:** **Dec. 1, 2020**

(54) **ANTENNA APPARATUS AND ELECTRONIC APPARATUS**

(58) **Field of Classification Search**  
CPC .. H01L 2924/30111; H03H 7/40; H02J 50/10;  
H02J 50/12; H01Q 5/307; H01Q 5/35;  
H01Q 5/50

(71) Applicants: **An-Yao Chou**, Taipei (TW); **Shih-Chia Liu**, Taipei (TW); **Yen-Hao Yu**, Taipei (TW); **Li-Chun Lee**, Taipei (TW); **Jhin-Ciang Chen**, Taipei (TW); **Chao-Lin Wu**, Taipei (TW); **Jui-Hung Lai**, Taipei (TW)

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*Primary Examiner* — Thuy Vinh Tran

(74) *Attorney, Agent, or Firm* — JCIPRNET

(72) Inventors: **An-Yao Chou**, Taipei (TW); **Shih-Chia Liu**, Taipei (TW); **Yen-Hao Yu**, Taipei (TW); **Li-Chun Lee**, Taipei (TW); **Jhin-Ciang Chen**, Taipei (TW); **Chao-Lin Wu**, Taipei (TW); **Jui-Hung Lai**, Taipei (TW)

(73) Assignee: **COMPAL ELECTRONICS, INC.**, Taipei (TW)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 25 days.

(21) Appl. No.: **16/409,879**

(22) Filed: **May 13, 2019**

(65) **Prior Publication Data**

US 2019/0348762 A1 Nov. 14, 2019

**Related U.S. Application Data**

(60) Provisional application No. 62/670,851, filed on May 13, 2018, provisional application No. 62/748,533, filed on Oct. 22, 2018.

(51) **Int. Cl.**  
**H01Q 1/50** (2006.01)  
**H01Q 5/335** (2015.01)

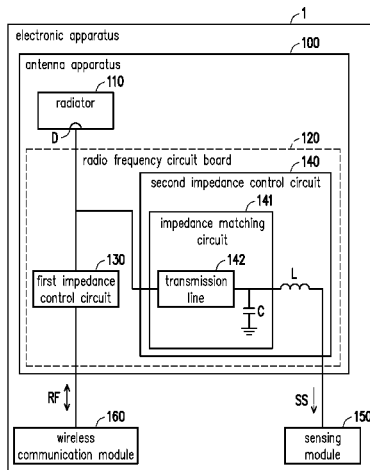
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(52) **U.S. Cl.**  
CPC ..... **H01Q 5/335** (2015.01); **H01Q 5/328** (2015.01); **H01Q 5/385** (2015.01);  
(Continued)

(57) **ABSTRACT**

An antenna apparatus and an electronic apparatus are provided. The electronic apparatus includes the antenna apparatus. The antenna apparatus includes a radiator, a first and a second impedance control circuit. The radiator receives and transmits a radio frequency (RF) signal. The first impedance control circuit is electrically connected to the radiator and transmits the RF signal. The second impedance control circuit includes an impedance matching circuit and an inductor. The first end of the impedance matching circuit is electrically connected to the radiator. The impedance matching circuit adjusts the impedance matching of the radiator and transmits a sensing signal. The inductor is electrically connected to the second end of the impedance matching circuit. The inductor transmits a sensing signal, and blocks the RF signal. Accordingly, the structures of the

(Continued)





US010854974B2

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

(10) **Patent No.:** **US 10,854,974 B2**

(45) **Date of Patent:** **Dec. 1, 2020**

(54) **ANTENNA PORTIONS**

(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.**, Spring, 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.

(21) Appl. No.: **15/772,180**

(22) PCT Filed: **Feb. 19, 2016**

(86) PCT No.: **PCT/US2016/018736**

§ 371 (c)(1),

(2) Date: **Apr. 30, 2018**

(87) PCT Pub. No.: **WO2017/142561**

PCT Pub. Date: **Aug. 24, 2017**

(65) **Prior Publication Data**

US 2019/0067817 A1 Feb. 28, 2019

(51) **Int. Cl.**

**H01Q 1/24** (2006.01)

**H01Q 5/392** (2015.01)

(Continued)

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

CPC ..... **H01Q 5/392** (2015.01); **H01Q 1/2266** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/44** (2013.01); **H01Q 5/385** (2015.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 5/392; H01Q 1/44; H01Q 1/243; H01Q 1/2266; H01Q 5/385; H01Q 9/42

See application file for complete search history.

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*Primary Examiner* — Dimary S Lopez Cruz

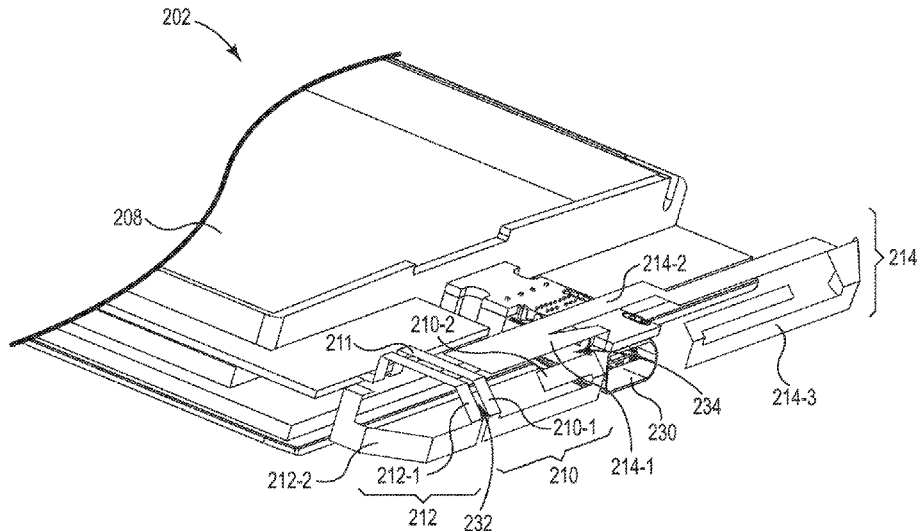
*Assistant Examiner* — Bamidele A Jegede

(74) *Attorney, Agent, or Firm* — Brooks, Cameron & Huebsch, PLLC

(57) **ABSTRACT**

An antenna system, in one example implementation, can include antenna portions including a first portion of the antenna to receive a radio frequency (RF) signal. The antenna can include a second portion capacitively coupled to the first portion, wherein the capacitive coupling of the second portion to the first portion increases the high-band resonances. The antenna can include a third portion of the antenna connected to a connector. The third portion can be capacitively coupled to the first portion to excite wide low-band resonances and high-band resonances. The connector can be a ground for the third portion.

**14 Claims, 4 Drawing Sheets**







US010854977B2

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

(10) **Patent No.:** **US 10,854,977 B2**  
(45) **Date of Patent:** **Dec. 1, 2020**

(54) **COMPACT INTEGRATED  
THREE-BROADSIDE-MODE PATCH  
ANTENNA**

(71) Applicant: **The Hong Kong University of Science  
and Technology**, Hong Kong (CN)

(72) Inventors: **Chi Yuk Chiu**, Hong Kong (CN); **Ross  
David Murch**, Hong Kong (CN)

(73) Assignee: **THE HONG KONG UNIVERSITY  
OF SCIENCE & TECHNOLOGY**,  
Hong Kong (CN)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 26 days.

(21) Appl. No.: **16/220,916**

(22) Filed: **Dec. 14, 2018**

(65) **Prior Publication Data**  
US 2019/0198998 A1 Jun. 27, 2019

**Related U.S. Application Data**

(60) Provisional application No. 62/708,755, filed on Dec.  
21, 2017.

(51) **Int. Cl.**  
**H01Q 9/04** (2006.01)  
**H01Q 9/26** (2006.01)  
**H01Q 1/42** (2006.01)  
**H01Q 15/24** (2006.01)  
**H04B 7/10** (2017.01)  
**H01Q 21/06** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 9/0414** (2013.01); **H01Q 1/428**  
(2013.01); **H01Q 9/26** (2013.01); **H01Q 15/24**  
(2013.01); **H01Q 21/065** (2013.01); **H04B**  
**7/10** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/42; H01Q 1/428; H01Q 9/04;  
H01Q 9/0414; H01Q 9/26; H01Q 15/24;  
H01Q 1/36; H01Q 1/48; H01Q 1/50;  
H01Q 15/521; H01Q 21/06; H01Q  
21/065; H01Q 21/0087  
See application file for complete search history.

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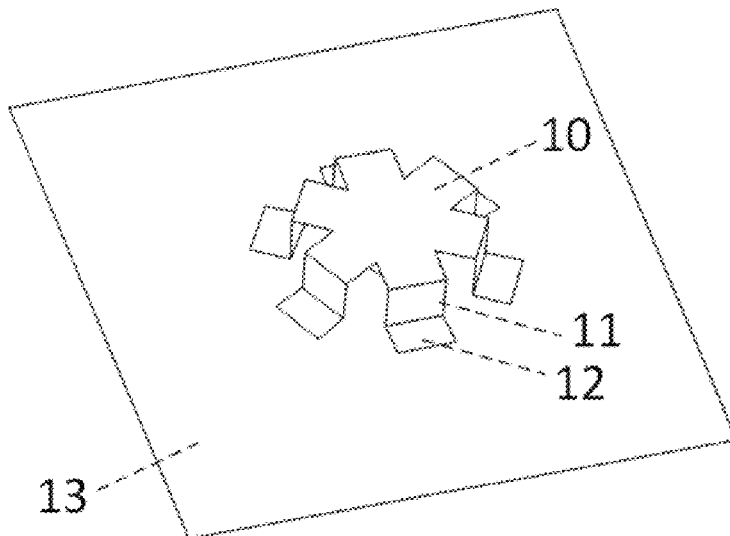
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*Primary Examiner* — Hoang V Nguyen  
(74) *Attorney, Agent, or Firm* — Leydig, Voit & Mayer,  
Ltd.

(57) **ABSTRACT**  
A three-broadside-mode patch antenna includes: a rotation-  
ally symmetric radiator; a patch, wherein the patch is  
separated from the rotationally symmetric radiator by a  
dielectric and configured to capacitively feed the rotationally  
symmetric radiator; and three antenna probes, connected to  
the patch, configured to provide three antenna ports cor-  
responding to three respective broadside radiation polariza-  
tions.

**22 Claims, 14 Drawing Sheets**





(12) **United States Patent**  
**Furlan**

(10) **Patent No.:** **US 10,854,980 B2**  
(45) **Date of Patent:** **Dec. 1, 2020**

- (54) **PLANAR INVERTED F-ANTENNA**
- (71) Applicant: **Taoglas Group Holdings Limited**, San Diego, CA (US)
- (72) Inventor: **Vladimir Furlan**, Munich (DE)
- (73) Assignee: **TAOGLAS GROUP HOLDINGS LIMITED**, Enniscorthy (IE)

(\* ) 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.: **16/572,270**
- (22) Filed: **Sep. 16, 2019**

(65) **Prior Publication Data**  
US 2020/0014111 A1 Jan. 9, 2020

**Related U.S. Application Data**  
(63) Continuation of application No. 15/904,751, filed on Feb. 26, 2018, now Pat. No. 10,418,709.

- (51) **Int. Cl.**  
*H01Q 1/24* (2006.01)  
*H01Q 9/04* (2006.01)  
*H01Q 9/42* (2006.01)  
*H01Q 5/371* (2015.01)
- (52) **U.S. Cl.**  
CPC ..... *H01Q 9/0421* (2013.01); *H01Q 1/244* (2013.01); *H01Q 5/371* (2015.01); *H01Q 9/42* (2013.01)

(58) **Field of Classification Search**  
None  
See application file for complete search history.

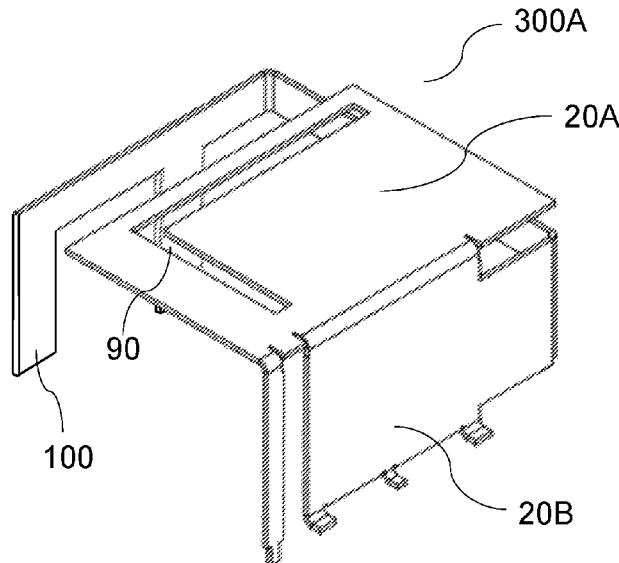
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*Primary Examiner* — Howard Williams  
(74) *Attorney, Agent, or Firm* — Garson & Gutierrez, PC

(57) **ABSTRACT**  
A Planar Inverted-F Antenna, PIFA, comprises a sheet of conductive material including first, second, third and fourth contiguous sections, the first and third sections extending orthogonally away from the second section and the fourth section extending away from the third section. The sections are folded relative to one another to define a volume with a heights of the second section, a width of the second section, and a depth of the third section extending away from the second section. A supporting pin and a feed pin extend from the second section along an outer edge. A supporting leg extends from either the third or fourth sections, the supporting leg lying outside the plane of the supporting pin to support the PIFA when mounted on a printed circuit board, while allowing components to at least partially occupy the volume under the PIFA.

**20 Claims, 5 Drawing Sheets**





US010854981B2

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

(10) **Patent No.:** **US 10,854,981 B2**

(45) **Date of Patent:** **Dec. 1, 2020**

(54) **COMMUNICATION APPARATUS**

(71) Applicant: **Sony Interactive Entertainment Inc.**,  
Tokyo (JP)

(72) Inventors: **Masayuki Pak**, Kanagawa (JP);  
**Tetsufumi Nozawa**, Chiba (JP)

(73) Assignee: **Sony Interactive Entertainment Inc.**,  
Tokyo (JP)

(\* ) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 265 days.

(21) Appl. No.: **15/887,413**

(22) Filed: **Feb. 2, 2018**

(65) **Prior Publication Data**  
US 2018/0233825 A1 Aug. 16, 2018

(30) **Foreign Application Priority Data**  
Feb. 16, 2017 (JP) ..... 2017-027025

(51) **Int. Cl.**  
**H01Q 9/04** (2006.01)  
**H01Q 1/48** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01Q 9/045** (2013.01); **H01P 3/006**  
(2013.01); **H01P 5/028** (2013.01); **H01P**  
**11/001** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
CPC ..... H01Q 9/045; H01Q 1/48; H01Q 9/0421;  
H05K 1/0237; H05K 1/10268;  
(Continued)

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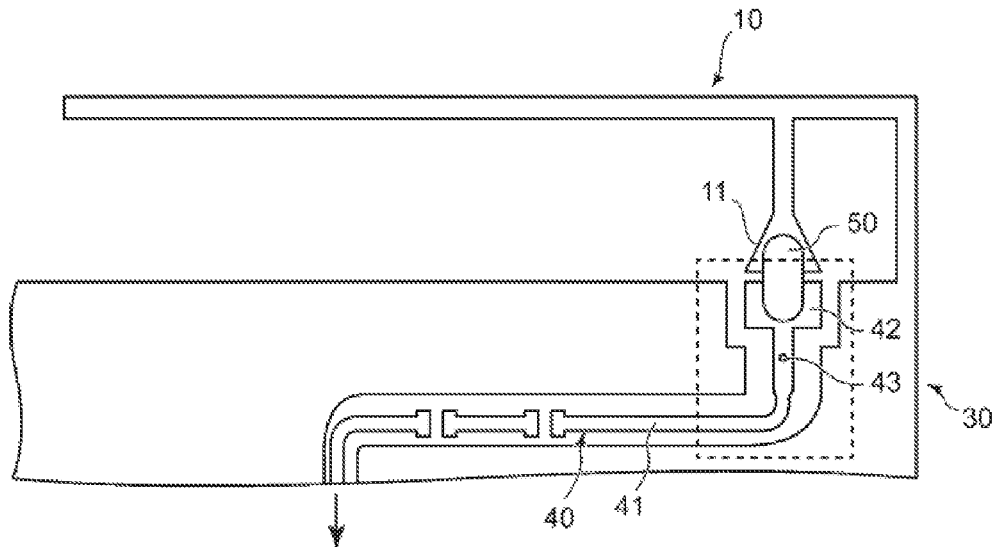
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*Primary Examiner* — Hoang V Nguyen  
(74) *Attorney, Agent, or Firm* — Matthew B. Dernier,  
Esq.

(57) **ABSTRACT**

A communication apparatus includes a signal line that connects an antenna and a wireless communication module to each other, the signal line having a portion where the signal line is divided in part into sections, with an adjacent portion adjacent to the divided portion of the signal line being greater in line width than a main body portion of the signal line; a first ground pattern disposed to face the main body portion; and a second ground pattern disposed to face the adjacent portion. The distance from the adjacent portion to the second ground pattern is longer than the distance from the main body portion to the first ground pattern. The antenna and the wireless communication module are connected to each other through the signal line and a solder adhered to the adjacent portion.

**8 Claims, 3 Drawing Sheets**



TO WIRELESS COMMUNICATION MODULE 20



US010862191B2

(12) **United States Patent**  
**Nguyen**

(10) **Patent No.:** **US 10,862,191 B2**

(45) **Date of Patent:** **Dec. 8, 2020**

(54) **RADIO FREQUENCY ANTENNA FOR SHORT RANGE COMMUNICATIONS**

(71) Applicant: **DISH Technologies L.L.C.**,  
Englewood, CO (US)

(72) Inventor: **Phuc H. Nguyen**, Parker, CO (US)

(73) Assignee: **DISH Technologies L.L.C.**,  
Englewood, CO (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.

(21) Appl. No.: **16/393,873**

(22) Filed: **Apr. 24, 2019**

(65) **Prior Publication Data**

US 2019/0252761 A1 Aug. 15, 2019

**Related U.S. Application Data**

(63) Continuation of application No. 15/582,360, filed on Apr. 28, 2017, now Pat. No. 10,320,055.

(51) **Int. Cl.**  
**H01Q 1/22** (2006.01)  
**H01Q 5/30** (2015.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/2266** (2013.01); **H01Q 1/42** (2013.01); **H01Q 1/521** (2013.01); **H01Q 5/30** (2015.01);  
(Continued)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/2266; H01Q 5/30; H01Q 1/42; H01Q 1/521; H01Q 9/40; H01Q 9/42; H01Q 21/24

See application file for complete search history.

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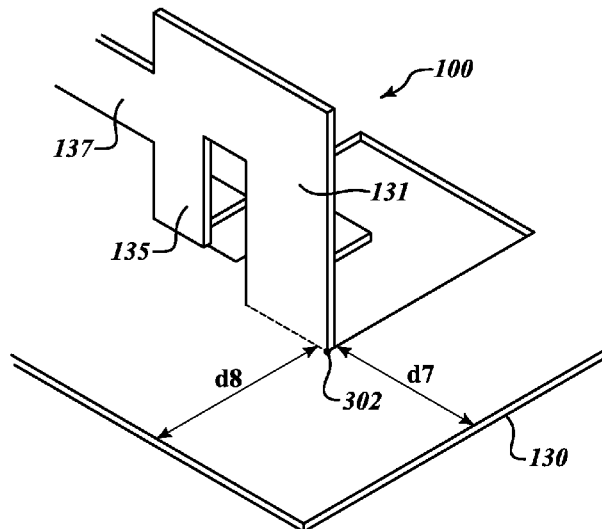
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*Primary Examiner* — Dameon E Levi  
*Assistant Examiner* — David E Lotter  
(74) *Attorney, Agent, or Firm* — Seed IP Law Group LLP

(57) **ABSTRACT**

An antenna assembly includes a substrate, a first antenna having a first, second, third, fourth sections, which have different configuration respectively, and a first transmission cable, a second antenna having a fifth, sixth, seventh, eighth sections, which have different configuration respectively, and a second transmission cable. The first and fifth sections extend vertically from a surface of the substrate respectively. The second, third and fourth sections extend in parallel with the first section and extend from its next section. The sixth, seventh, eighth sections extend in parallel with the fifth section and extend from its next section. The first and second transmission cables physically and electrically are connected to the first and second antenna respectively. The second antenna is spaced away from the first antenna a selected distance. The first antenna is arranged having each of its sections extending perpendicular to each of its sections of the second antenna.

**10 Claims, 13 Drawing Sheets**





US010862195B2

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

(10) **Patent No.:** **US 10,862,195 B2**  
(45) **Date of Patent:** **Dec. 8, 2020**

(54) **ELECTRONIC DEVICES WITH MILLIMETER WAVE ANTENNAS AND METAL HOUSINGS**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)  
(72) Inventors: **Yuehui Ouyang**, Sunnyvale, CA (US);  
**Yi Jiang**, Cupertino, CA (US);  
**Matthew A. Mow**, Los Altos, CA (US);  
**Mattia Pascolini**, San Francisco, CA (US);  
**Ruben Caballero**, San Jose, CA (US);  
**Basim Noori**, Scotts Valley, 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 0 days.

(21) Appl. No.: **16/357,165**

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

(65) **Prior Publication Data**

US 2019/0214708 A1 Jul. 11, 2019

**Related U.S. Application Data**

(62) Division of application No. 14/883,495, filed on Oct. 14, 2015, now abandoned.

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 1/40** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/40** (2013.01); **H01Q 1/42** (2013.01); **H01Q 21/28** (2013.01); **H01Q 9/0421** (2013.01); **H01Q 9/16** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/243; H01Q 21/28; H01Q 1/40; H01Q 1/42; H01Q 9/0421; H01Q 9/16  
See application file for complete search history.

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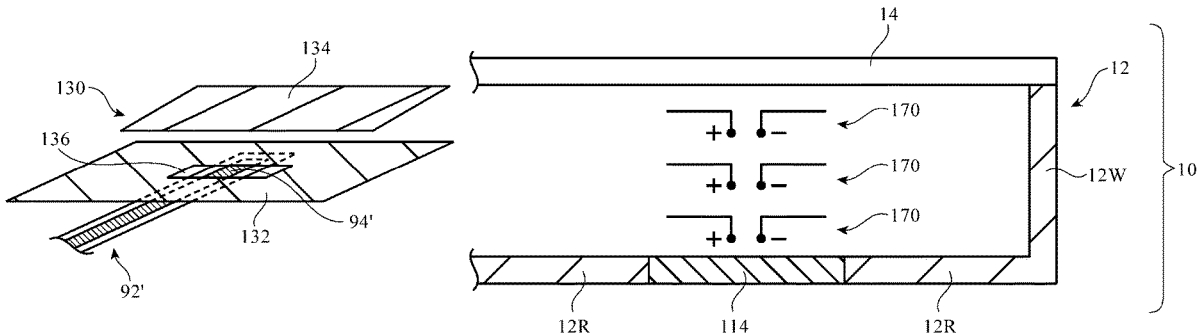
*Primary Examiner* — Dieu Hien T Duong

(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.;  
G. Victor Treyz; Matthew R. Williams

(57) **ABSTRACT**

An electronic device may be provided with wireless circuitry. The wireless circuitry may include one or more antennas. The antennas may include millimeter wave antenna arrays. Non-millimeter-wave antennas such as cellular telephone antennas may have conductive structures separated by a dielectric gap. In a device with a metal housing, a plastic-filled slot may form the dielectric gap. The conductive structures may be slot antenna structures, inverted-F antenna structures such as an inverted-F antenna resonating element and a ground, or other antenna structures. The plastic-filled slot may serve as a millimeter wave antenna window. A millimeter wave antenna array may be mounted in alignment with the millimeter wave antenna window to transmit and receive signals through the window. Millimeter wave antenna windows may also be formed from air-filled openings in a metal housing such as audio port openings.

**9 Claims, 13 Drawing Sheets**





US010862212B2

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

(10) **Patent No.:** **US 10,862,212 B2**

(45) **Date of Patent:** **Dec. 8, 2020**

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

(71) Applicant: **FUJITSU LIMITED**, Kawasaki (JP)

(72) Inventors: **Takashi Yamagajo**, Yokosuka (JP); **Manabu Kai**, Yokohama (JP); **Yohei Koga**, Kawasaki (JP); **Tabito Tonooka**, Kawasaki (JP); **Hirotake Sumi**, Kawasaki (JP)

(73) Assignee: **FUJITSU LIMITED**, Kawasaki (JP)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 27 days.

(21) Appl. No.: **16/228,734**

(22) Filed: **Dec. 20, 2018**

(65) **Prior Publication Data**

US 2019/0214726 A1 Jul. 11, 2019

(30) **Foreign Application Priority Data**

Jan. 5, 2018 (JP) ..... 2018-000721

(51) **Int. Cl.**

**H01Q 1/24** (2006.01)  
**H01Q 5/321** (2015.01)  
**H01Q 9/06** (2006.01)  
**H01Q 9/40** (2006.01)  
**H01Q 1/38** (2006.01)

(Continued)

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

CPC ..... **H01Q 5/321** (2015.01); **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 5/307** (2015.01); **H01Q 9/065** (2013.01); **H01Q 9/40** (2013.01); **H01Q 9/42** (2013.01); **H01Q 21/12** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 5/321; H01Q 5/307; H01Q 1/241-244; H01Q 1/38; H01Q 9/42; H01Q 9/065; H01Q 9/40; H01Q 21/12  
See application file for complete search history.

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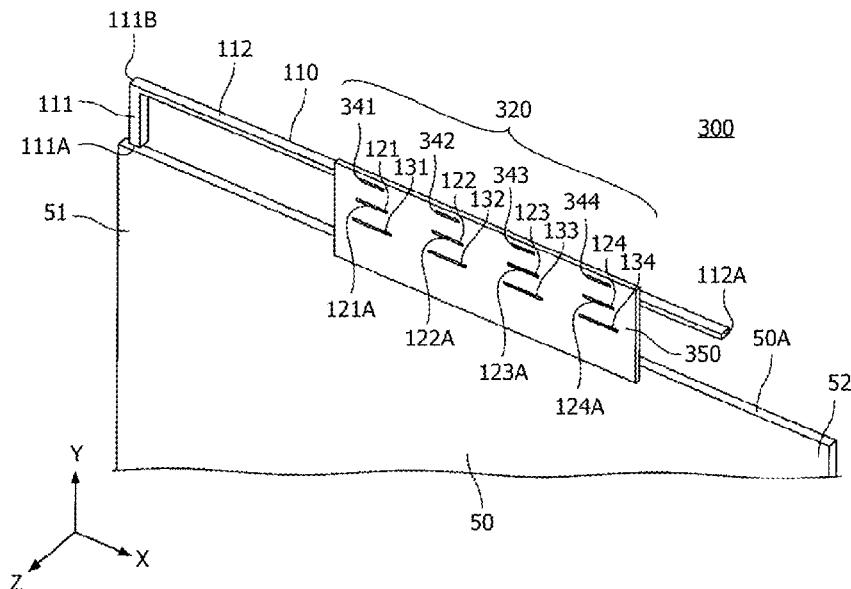
*Primary Examiner* — Awat M Salih

(74) *Attorney, Agent, or Firm* — Arent Fox LLP

(57) **ABSTRACT**

An antenna device includes a ground plane having an edge side, a monopole antenna element that communicates in a first frequency, and that has a first feeding point, a first line that extends from the first feeding point in a direction away from the edge side of the ground plane, and a second line that is coupled to the first line and extends along the edge side, a plurality of dipole feeding elements that communicate at a second frequency higher than the first frequency, and are disposed, with respect to the ground plane, in positions that match the positions of the second line with respect to the ground plane, and a plurality of reflectors that reflect electromagnetic waves radiated by the plurality of feeding elements, and are disposed respectively in correspondence to the plurality of feeding elements between the ground plane and the plurality of feeding elements.

**11 Claims, 26 Drawing Sheets**





US010862214B2

(12) **United States Patent**  
**Sakurai**

(10) **Patent No.:** **US 10,862,214 B2**  
(45) **Date of Patent:** **Dec. 8, 2020**

(54) **ANTENNA**

(71) Applicant: **Tyco Electronics Japan G.K.**,  
Kanagawa (JP)

(72) Inventor: **Yohei Sakurai**, Kawasaki (JP)

(73) Assignee: **Tyco Electronics Japan G.K.**,  
Kawasaki (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.: **15/788,898**

(22) Filed: **Oct. 20, 2017**

(65) **Prior Publication Data**  
US 2018/0115073 A1 Apr. 26, 2018

(30) **Foreign Application Priority Data**  
Oct. 21, 2016 (JP) ..... 2016-206636

(51) **Int. Cl.**  
**H01Q 9/42** (2006.01)  
**H01Q 9/28** (2006.01)  
**H01Q 1/24** (2006.01)  
**H01Q 1/38** (2006.01)  
**H01Q 21/00** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 9/285** (2013.01); **H01Q 1/242** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 21/0006** (2013.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 9/285; H01Q 1/242; H01Q 1/243; H01Q 1/38; H01Q 21/0006; H01Q 9/42  
See application file for complete search history.

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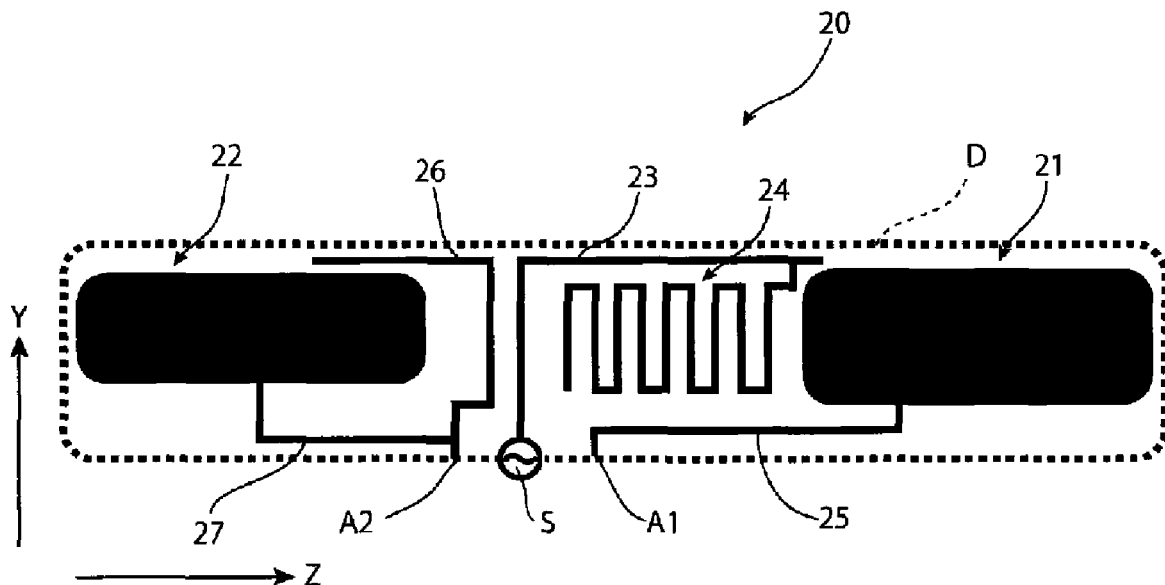
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*Primary Examiner* — Dimary S Lopez Cruz  
*Assistant Examiner* — Bamidele A Jegede  
(74) *Attorney, Agent, or Firm* — Barley Snyder

(57) **ABSTRACT**

An antenna comprises a first pad, a second pad, a radiating element, a meandering element, and a third pad disposed in an antenna region on a circuit board. The first pad and the second pad are spaced apart and disposed at opposite ends of the antenna region. The radiating element is disposed between the first pad and the second pad and is capacitively coupled to the first pad. The meandering element is connected to the radiating element at a position adjacent the first pad. The meandering element extends in the first direction away from the first pad while meandering reciprocally in the second direction. The third pad is capacitively coupled to the second pad.

**11 Claims, 4 Drawing Sheets**





US010862216B1

(12) **United States Patent**  
**Ayala Vazquez et al.**

(10) **Patent No.:** **US 10,862,216 B1**  
(45) **Date of Patent:** **Dec. 8, 2020**

(54) **ELECTRONIC DEVICES HAVING INDIRECTLY-FED SLOT ANTENNA ELEMENTS**  
(71) Applicant: **Apple Inc.**, Cupertino, CA (US)  
(72) Inventors: **Enrique Ayala Vazquez**, Watsonville, CA (US); **Erdinc Irci**, Sunnyvale, CA (US); **Georgios Atmatzakis**, Cupertino, CA (US); **Hongfei Hu**, Cupertino, CA (US)

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

U.S. Appl. No. 16/019,322, filed Jun. 26, 2018.

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 49 days.

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*Primary Examiner* — Hoang V Nguyen

(21) Appl. No.: **16/457,515**

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

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

(51) **Int. Cl.**  
**H01Q 13/10** (2006.01)  
**H01Q 9/14** (2006.01)  
**H01Q 1/24** (2006.01)

(57) **ABSTRACT**

An electronic device may include ground structures and peripheral conductive housing structures defining opposing edges of a slot element. A monopole element may overlap the slot element. The monopole element may be directly fed radio-frequency signals by an antenna feed coupled to the monopole element. The monopole element may radiate the radio-frequency signals in a first frequency band while indirectly feeding the radio-frequency signals to the slot element via near-field electromagnetic coupling. The slot element may radiate the radio-frequency signals in a second frequency band that is lower than the first frequency band. The monopole element and the slot element may collectively form a multi-band antenna that exhibits a relatively wide bandwidth.

(52) **U.S. Cl.**  
CPC ..... **H01Q 13/103** (2013.01); **H01Q 1/243** (2013.01); **H01Q 9/145** (2013.01)

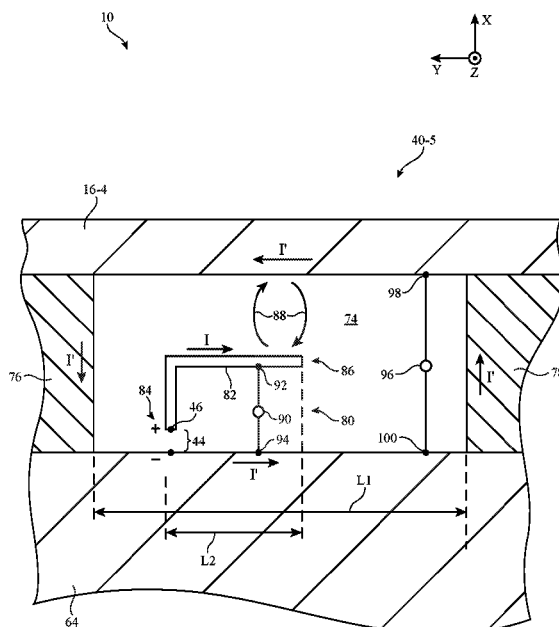
(58) **Field of Classification Search**  
CPC ..... H01Q 13/10; H01Q 13/103; H01Q 1/243; H01Q 9/145  
See application file for complete search history.

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**20 Claims, 13 Drawing Sheets**







US010862568B2

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

(10) **Patent No.:** **US 10,862,568 B2**

(45) **Date of Patent:** **Dec. 8, 2020**

(54) **METHOD AND ELECTRONIC DEVICE FOR CONFIGURING RADIO FREQUENCY SETTING**

(58) **Field of Classification Search**  
CPC ... H04B 7/0814; H04B 7/0691; H04L 5/0023; H04L 5/001; H04L 5/0098  
See application file for complete search history.

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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 U.S.C. 154(b) by 0 days.

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(22) Filed: **May 25, 2020**

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(65) **Prior Publication Data**

US 2020/0287613 A1 Sep. 10, 2020

**Related U.S. Application Data**

(63) Continuation of application No. 15/699,575, filed on Sep. 8, 2017, now Pat. No. 10,666,344.

*Primary Examiner* — Kabir A Timory

(30) **Foreign Application Priority Data**

Sep. 8, 2016 (KR) ..... 10-2016-0115903

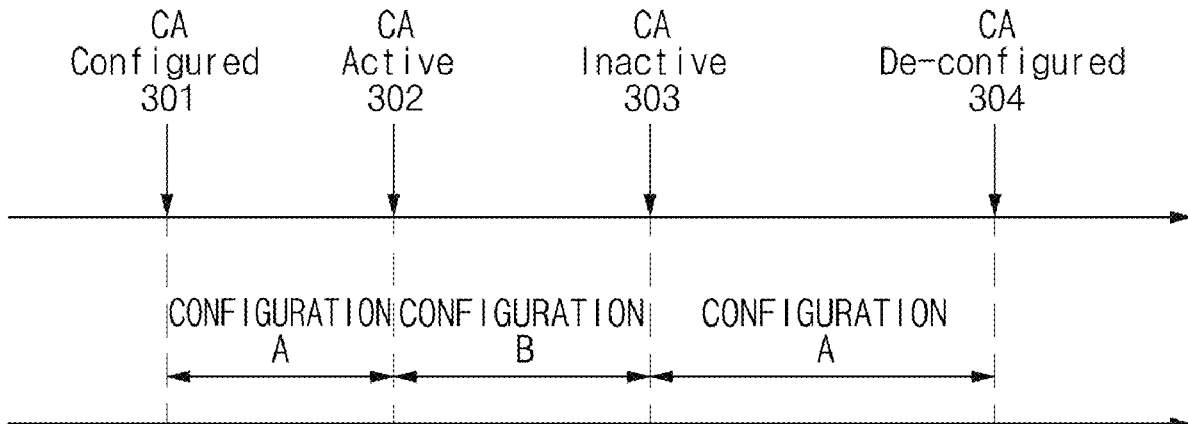
(57) **ABSTRACT**

(51) **Int. Cl.**  
**H04B 7/08** (2006.01)  
**H04L 5/00** (2006.01)  
**H04B 7/06** (2006.01)

An electronic device includes a communication circuit, a plurality of antennas that are fed with power from the communication circuit, and a processor that controls the communication circuit. The processor is configured to receive a first signal for indicating initiation of configuration for carrier aggregation. The processor is also configured to change the configuration of at least one of the antennas or the communication circuit to perform the carrier aggregation if a second signal for indicating operation initiation of the carrier aggregation is received from a base station.

(52) **U.S. Cl.**  
CPC ..... **H04B 7/0814** (2013.01); **H04L 5/001** (2013.01); **H04L 5/0023** (2013.01); **H04B 7/0691** (2013.01); **H04L 5/0098** (2013.01)

**20 Claims, 12 Drawing Sheets**





US010868354B1

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

(10) **Patent No.:** **US 10,868,354 B1**  
(45) **Date of Patent:** **Dec. 15, 2020**

- (54) **5G BROADBAND ANTENNA**
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- (72) Inventors: **Ziming He**, Irvine, CA (US); **Alven Jan Delos Santos Eusantos**, San Diego, CA (US)
- (73) Assignee: **Airgain, Inc.**, 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 0 days.
- (21) Appl. No.: **16/258,611**
- (22) Filed: **Jan. 27, 2019**

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**Related U.S. Application Data**

- (60) Provisional application No. 62/793,871, filed on Jan. 17, 2019.

- (51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 5/357** (2015.01)  
**H01Q 1/48** (2006.01)

- (52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 5/357** (2015.01)

- (58) **Field of Classification Search**  
CPC ..... H01Q 5/371; H01Q 5/15; H01Q 5/364; H01Q 5/357; H01Q 1/243; H01Q 5/30; H01Q 1/48  
See application file for complete search history.

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*Primary Examiner* — Dameon E Levi

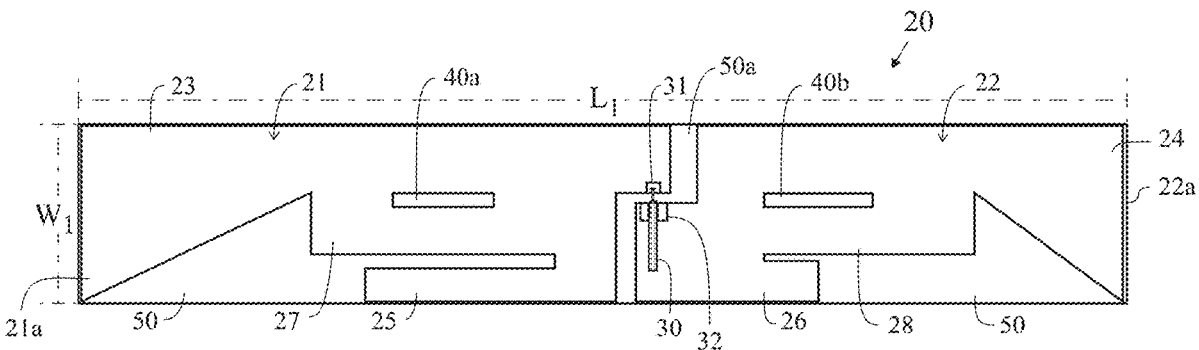
*Assistant Examiner* — Jennifer F Hu

(74) *Attorney, Agent, or Firm* — Clause Eight IPS; Michael Catania

(57) **ABSTRACT**

A 5G broadband antenna is disclosed herein. The 5G broadband antenna comprises a first antenna element and a second antenna element. Each of the first antenna element and the second antenna element has a middle section with a slot therein. The antenna apparatus covers a first frequency band of 617-960 MegaHertz, a second frequency band of 1.4-1.6 GigaHertz (GHZ), a third frequency band of 1.71-2.7 GHz, and a fourth frequency band of 3.3 to 4.2 GHz.

**9 Claims, 8 Drawing Sheets**



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

(10) **Patent No.:** **US 10,868,355 B2**  
(45) **Date of Patent:** **Dec. 15, 2020**

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

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(72) Inventors: **Xiaojun Qiu**, Shenzhen (CN); **Bo Zhu**,  
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(73) Assignee: **AAC Technologies Pte. Ltd.**,  
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(21) Appl. No.: **16/525,590**

(22) Filed: **Jul. 30, 2019**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Aug. 20, 2018 (CN) ..... 2018 1 0947841

(51) **Int. Cl.**

**H01Q 1/24** (2006.01)  
**H01Q 5/328** (2015.01)  
**H01Q 1/50** (2006.01)

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

CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/50**  
(2013.01); **H01Q 5/328** (2015.01)

(58) **Field of Classification Search**

CPC ..... H01Q 9/42; H01Q 1/243; H01Q 1/38;  
H01Q 21/28; H01Q 1/50; H01Q 9/04;  
H01Q 1/521; H01Q 3/24; H01Q 13/10;  
H01Q 13/103; H01Q 1/2291; H01Q  
21/00; H01Q 21/0006; H01Q 21/12;  
H01Q 21/29; H01Q 3/34; H01Q 5/00;  
H01Q 5/22; H01Q 5/371; H01Q 5/40;  
H01Q 5/48; H01Q 9/0442; H01Q 9/145;

H01Q 9/16; H01Q 9/28; H01Q 9/30;  
H01Q 9/40; H01Q 1/1228; H01Q 1/2283;  
H01Q 13/24; H01Q 19/08; H01Q 1/04;  
H01Q 1/12; H01Q 1/246; H01Q 1/44;  
H01Q 21/067; H01Q 21/205; H01Q 3/08;  
H01Q 3/10; H01Q 3/20; H01Q 3/26;  
H01Q 3/46; H01Q 19/09; H01Q 3/44;  
H01Q 5/335; H01Q 7/00; H01Q 1/007;  
H01Q 1/088; H01Q 1/103; H01Q 1/1207;  
H01Q 21/0025; H01Q 21/065; H01Q  
25/005; H01Q 5/328; H01Q 9/06; H01Q  
1/02; H01Q 1/364; H01Q 1/48; H01Q  
1/523; H01Q 1/526; H01Q 21/24;  
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*Primary Examiner* — Monica C King

(74) *Attorney, Agent, or Firm* — W&G Law Group LLP

(57) **ABSTRACT**

An antenna module includes a first antenna and a second antenna. The first antenna forms multiple operating states. By switching the multiple operating states, the first antenna supports an LTE low frequency of 698-960 MHz and an LTE medium-high frequency of 1710-2690 MHz, and supports multi-carrier aggregation in the band. In each operating state, the first antenna also operates in 5G bands of 3300-3800 MHz and 4800-5000 MHz, the second antenna operates in 5G bands of 3300-3800 MHz and 4800-5000 MHz and a new TDD-LTE band of 5150-5925 MHz. The first antenna and the second antenna together form a 2x2 MIMO of 5G bands of 3300-3800 MHz and 4800-5000 MHz. The antenna module provided by the disclosure has better communication performance.

**18 Claims, 6 Drawing Sheets**

