US010355339B2

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

(10) **Patent No.: US 10,355,339 B2**
(45) **Date of Patent: Jul. 16, 2019**

(54) **TUNABLE ANTENNA WITH SLOT-BASED PARASITIC ELEMENT**

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

(72) Inventors: **Nanbo Jin**, Milpitas, CA (US); **Yuehui Ouyang**, Sunnyvale, CA (US); **Yijun Zhou**, Sunnyvale, CA (US); **Enrique Ayala Vazquez**, Watsonville, CA (US); **Anand Lakshmanan**, San Jose, CA (US); **Robert W. Schlub**, Cupertino, CA (US); **Mattia Pascolini**, San Francisco, CA (US); **Matthew A. Mow**, Los Altos, 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 565 days.

(21) Appl. No.: **15/085,095**

(22) Filed: **Mar. 30, 2016**

(65) **Prior Publication Data**

US 2016/0211570 A1 Jul. 21, 2016

Related U.S. Application Data

(63) Continuation of application No. 13/846,471, filed on Mar. 18, 2013, now Pat. No. 9,331,397.

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 5/10 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/24*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 5/10*** (2015.01); ***H01Q 5/15*** (2015.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 5/378; H01Q 9/42
See application file for complete search history.

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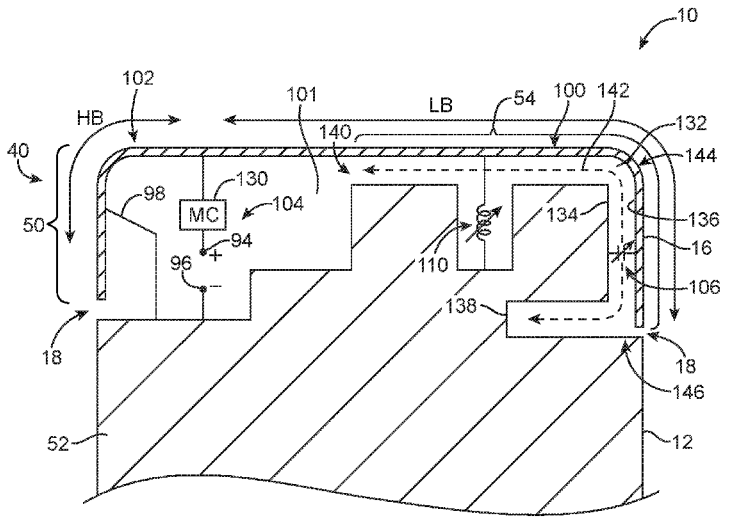
Primary Examiner — Ricardo I Magallanes
(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; G. Victor Treyz; Michael H. Lyons

(57) **ABSTRACT**

Electronic devices may be provided that contain wireless communications circuitry. The wireless communications circuitry may include radio-frequency transceiver circuitry and antenna structures. The antenna structures may form a dual arm inverted-F antenna. The antenna may have a resonating element formed from portions of a peripheral conductive electronic device housing member and may have an antenna ground that is separated from the antenna resonating element by a gap. A short circuit path may bridge the gap. An antenna feed may be coupled across the gap in parallel with the short circuit path. Low band tuning may be provided using an adjustable inductor that bridges the gap. The antenna may have a slot-based parasitic antenna resonating element with a slot formed between portions of the peripheral conductive electronic device housing member and the antenna ground. An adjustable capacitor may bridge the slot to provide high band tuning.

19 Claims, 8 Drawing Sheets



US010355357B2

(12) **United States Patent**
Wang

(10) **Patent No.: US 10,355,357 B2**
(45) **Date of Patent: *Jul. 16, 2019**

(54) **PRINTED CIRCUIT BOARD ANTENNA AND TERMINAL**

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

(72) Inventor: **Hanyang Wang**, Shenzhen (CN)

(73) Assignee: **Huawei Device Co., Ltd.**, Dongguan (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 83 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/461,297**

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

(65) **Prior Publication Data**

US 2017/0229776 A1 Aug. 10, 2017

Related U.S. Application Data

(63) Continuation of application No. 14/517,418, filed on Oct. 17, 2014, now Pat. No. 9,666,951, which is a (Continued)

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

(52) **U.S. Cl.**
CPC ***H01Q 5/357*** (2015.01); ***H01Q 1/242*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 5/314*** (2015.01);
(Continued)

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

(56) **References Cited**

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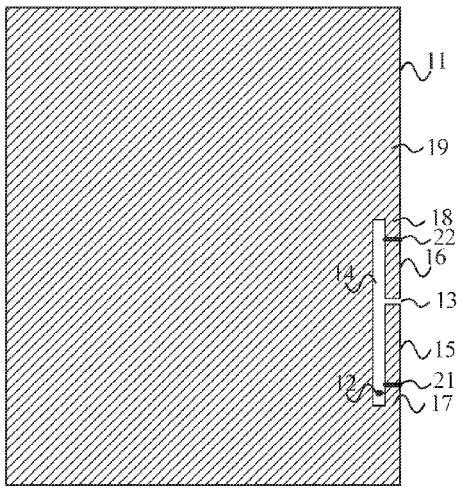
Primary Examiner — Trinh V Dinh
(74) *Attorney, Agent, or Firm* — Slater Matsil, LLP

(57) **ABSTRACT**

A printed circuit board antenna includes a printed circuit board and a feedpoint that is disposed on the printed circuit board. A copper coating is disposed on the printed circuit board. A split is disposed on the copper coating on the printed circuit board. The split is connected to a board edge of the printed circuit board. A slot perpendicular to the split is disposed on the copper coating on the printed circuit board. The slot is connected to the split. The copper coating at two sides of the split forms a first antenna and a second antenna. The feedpoint is configured to, together with the first antenna and the second antenna, form a first resonance loop and a second resonance loop. Resonance frequencies of the first resonance loop and the second resonance loop are different.

8 Claims, 8 Drawing Sheets



US010355758B2

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

(10) **Patent No.: US 10,355,758 B2**
(45) **Date of Patent: Jul. 16, 2019**

(54) **MULTI-BAND ANTENNAS AND MIMO ANTENNA ARRAYS FOR ELECTRONIC DEVICE**

(71) Applicants: **Dong Wang**, Waterloo (CA); **Enliang Wang**, Waterloo (CA)

(72) Inventors: **Dong Wang**, Waterloo (CA); **Enliang Wang**, Waterloo (CA)

(73) Assignee: **HUAWEI TECHNOLOGIES CO., LTD.**, Shenzhen (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.: **15/726,842**

(22) Filed: **Oct. 6, 2017**

(65) **Prior Publication Data**

US 2019/0109622 A1 Apr. 11, 2019

(51) **Int. Cl.**

H04B 7/0426	(2017.01)
H04B 7/0452	(2017.01)
H04B 7/0456	(2017.01)
H04B 7/0413	(2017.01)
H04W 88/02	(2009.01)

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

CPC ***H04B 7/0434*** (2013.01); ***H04B 7/0452*** (2013.01); *H04B 7/0413* (2013.01); *H04B 7/0465* (2013.01); *H04W 88/02* (2013.01)

(58) **Field of Classification Search**

CPC ... H04B 7/0413; H04B 7/0452; H04W 88/02; G05B 19/4185

USPC 375/267

See application file for complete search history.

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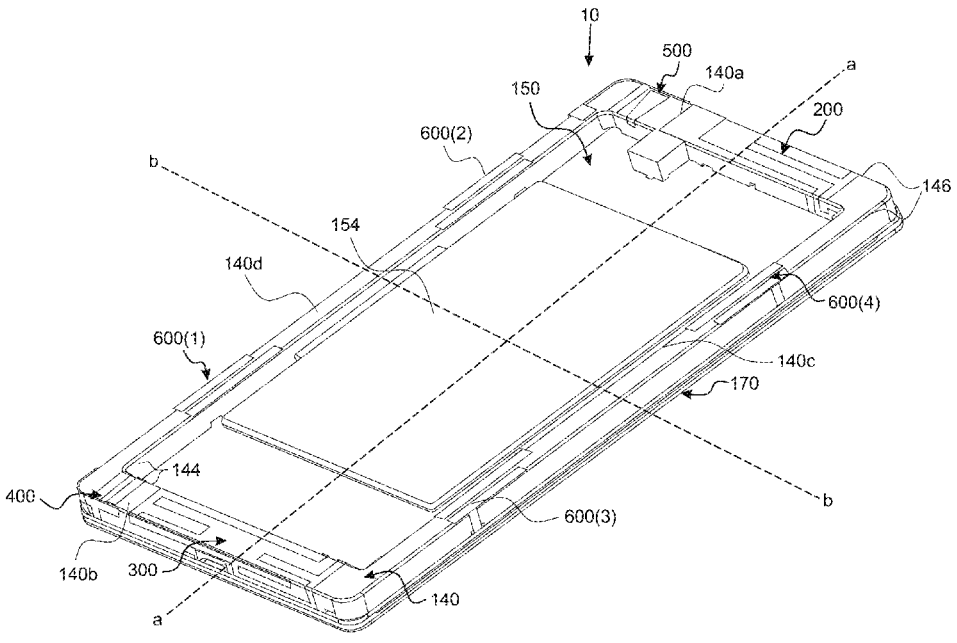
Primary Examiner — Leila Malek

(57) **ABSTRACT**

Antennas and MIMO antenna arrays in a housing of an electronic device are described. The MIMO antenna array includes a plurality of antennas. At least one of the antennas has operating frequency ranges of 700 MHz-900 MHz, 1700 MHz-2100 MHz, and 3 GHz-5 GHz. The MIMO antenna array may include 8 or 10 antennas.

24 Claims, 23 Drawing Sheets



US010361477B2

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

(10) **Patent No.: US 10,361,477 B2**
(45) **Date of Patent: Jul. 23, 2019**

(54) **ANTENNA AND MOBILE TERMINAL HAVING THE SAME**

(71) Applicant: **BYD COMPANY LIMITED**, Shenzhen (CN)

(72) Inventors: **Yijin Wang**, Shenzhen (CN); **Lianhua Li**, Shenzhen (CN); **Faping Wang**, Shenzhen (CN)

(73) Assignee: **BYD Company Limited**, Shenzhen (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 73 days.

(21) Appl. No.: **15/561,577**

(22) PCT Filed: **Mar. 28, 2016**

(86) PCT No.: **PCT/CN2016/077488**
§ 371 (c)(1),
(2) Date: **Sep. 26, 2017**

(87) PCT Pub. No.: **WO2016/155591**
PCT Pub. Date: **Oct. 6, 2016**

(65) **Prior Publication Data**

US 2018/0090819 A1 Mar. 29, 2018

(30) **Foreign Application Priority Data**

Mar. 31, 2015 (CN) 2015 1 0145639

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 5/371 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/44*** (2013.01); ***H01Q 1/521*** (2013.01); ***H01Q 5/371*** (2015.01); ***H01Q 13/10*** (2013.01); ***H04M 1/0283*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/24; H01Q 1/241; H01Q 1/242; H01Q 1/243; H01Q 1/44; H01Q 5/307;
(Continued)

(56) **References Cited**

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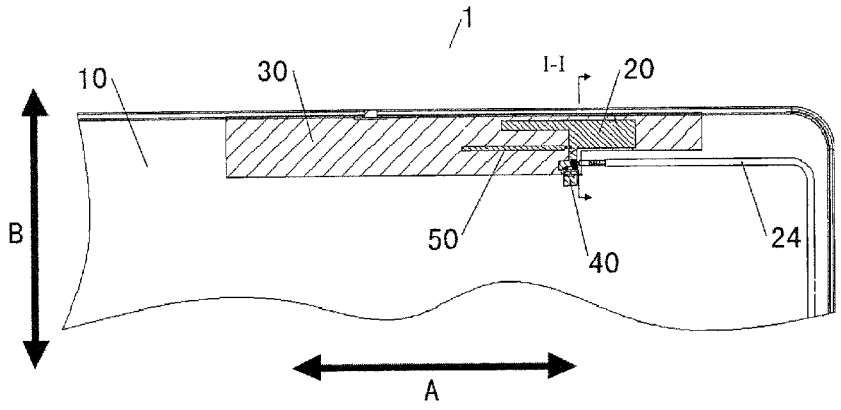
Primary Examiner — Daniel Munoz
Assistant Examiner — Patrick R Holecek
(74) *Attorney, Agent, or Firm* — DLA Piper LLP (US)

(57) **ABSTRACT**

An antenna and a mobile terminal having the same are provided. The antenna includes: a metal shell having a first slot, penetrated through the metal shell, extending in a transverse direction of the metal shell, having two ends which are closed; and a second slot, penetrated through the metal shell, extending in a longitudinal direction of the metal shell, having a first end communicated with the first slot and a second end extending to an edge of the metal shell and opened thereat; an exciting sheet disposed at an inner side of the metal shell, covering the first slot in a width direction thereof; a dielectric filling layer disposed between the exciting sheet and the metal shell, configured to fill the first and second slots; and an expanding resonance branch, disposed on a surface of the dielectric filling layer facing away from the metal shell, connected to the exciting sheet.

18 Claims, 6 Drawing Sheets



US010361480B2

(12) **United States Patent**
Harper

(10) **Patent No.: US 10,361,480 B2**
(45) **Date of Patent: Jul. 23, 2019**

(54) **ANTENNA ISOLATION USING A TUNED GROUNDPLANE NOTCH**

(71) Applicant: **Microsoft Technology Licensing, LLC**, Redmond, WA (US)

(72) Inventor: **Marc Harper**, Issaquah, WA (US)

(73) Assignee: **Microsoft Technology Licensing, LLC**, Redmond, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 263 days.

(21) Appl. No.: **14/610,898**

(22) Filed: **Jan. 30, 2015**

(65) **Prior Publication Data**

US 2015/0138036 A1 May 21, 2015

Related U.S. Application Data

(63) Continuation of application No. 14/481,699, filed as application No. PCT/GB2013/005067 on Mar. 7, 2013.

(30) **Foreign Application Priority Data**

Mar. 13, 2012 (GB) 1204373.3

(51) **Int. Cl.**
H01Q 1/52 (2006.01)
H01Q 1/48 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/48*** (2013.01); ***H01Q 1/521*** (2013.01); *Y10T 29/49018* (2015.01)

(58) **Field of Classification Search**
CPC H01Q 1/52; H01Q 1/521; H01Q 1/523; H01Q 5/00; H01Q 1/241–1/243;
(Continued)

(56) **References Cited**

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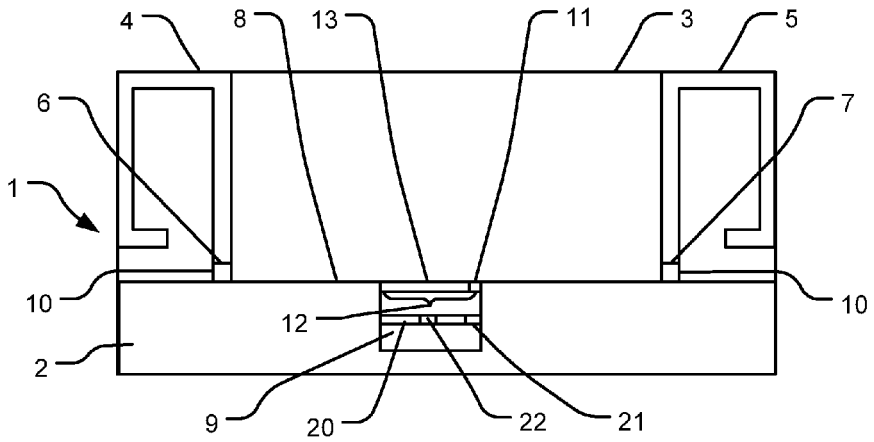
Primary Examiner — Jessica Han
Assistant Examiner — Awat M Salih
(74) *Attorney, Agent, or Firm* — Holzer Patel Drennan

(57) **ABSTRACT**

There is disclosed an antenna device relating to a single or dual band antenna system for use in mobile telecommunications devices, laptop and tablet computers, USB adapters and electrically small radio platforms comprising a pair of antennas attached to a conductive ground plane, the antennas being separated by free space in which at least one notch is formed in the conductive ground plane between the pair of antennas characterized in that the notch further includes an inductive component and a capacitive component providing good antenna isolation so as to enable MIMO operation or diversity operation.

22 Claims, 10 Drawing Sheets



US010361729B2

(12) **United States Patent**
Chiang

(10) **Patent No.: US 10,361,729 B2**
(45) **Date of Patent: Jul. 23, 2019**

(54) **DUAL-FREQUENCY ANTENNA DEVICE AND LOW-FREQUENCY ANTENNA MODULE**

(71) Applicant: **AUDEN TECHNO CORP.**, Taoyuan (TW)

(72) Inventor: **Chi-Ming Chiang**, Taoyuan (TW)

(73) Assignee: **AUDEN TECHNO CORP.**, Taoyuan (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 140 days.

(21) Appl. No.: **15/699,195**

(22) Filed: **Sep. 8, 2017**

(65) **Prior Publication Data**

US 2019/0081647 A1 Mar. 14, 2019

(51) **Int. Cl.**
H01Q 3/24 (2006.01)
H04B 1/00 (2006.01)
H01Q 5/50 (2015.01)

(52) **U.S. Cl.**
CPC ***H04B 1/006*** (2013.01); ***H01Q 5/50*** (2015.01)

(58) **Field of Classification Search**
CPC H01Q 5/20; H01Q 3/24; H04B 1/006
USPC 343/876
See application file for complete search history.

(56) **References Cited**

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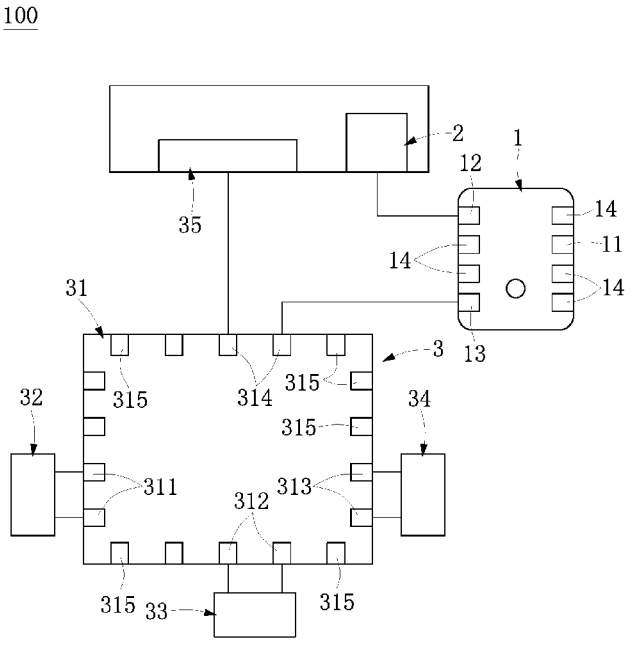
Primary Examiner — Huedung X Mancuso
(74) *Attorney, Agent, or Firm* — Li & Cai Intellectual Property (USA) Office

(57) **ABSTRACT**

A low-frequency antenna module includes two switching units, a first matching circuit, a second matching circuit, and a low-frequency antenna. Each of the two switching units includes an electrical connection point, a first switching point, and a second switching point. The first matching circuit is electrically connected to the two first switching points, the second matching circuit is electrically connected to the two second switching points, and the low-frequency antenna is electrically connected to one of the two electrical connection points. The two switching units are synchronously operated to electrically connect the two electrical connection points to the two first switching points or to the two second switching points. Thus, the low-frequency antenna can be applied to match the first matching circuit in a first low-frequency band or the second matching circuit in a second low-frequency band different from the first low-frequency band.

10 Claims, 10 Drawing Sheets



US010367250B2

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

(10) **Patent No.: US 10,367,250 B2**
(45) **Date of Patent: Jul. 30, 2019**

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

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

(72) Inventors: **Kuo Cheng Chen**, Suwon-si (KR); **You Chieh Chen**, Suwon-si (KR); **Yoon Jae Lee**, Seoul (KR); **Soon Ho Hwang**, Seoul (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 169 days.

(21) Appl. No.: **15/295,365**

(22) Filed: **Oct. 17, 2016**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Oct. 27, 2015 (KR) 10-2015-0149162

(51) **Int. Cl.**

H01Q 1/36	(2006.01)
H01Q 1/24	(2006.01)
H01Q 9/04	(2006.01)
H01Q 1/22	(2006.01)
H01Q 9/42	(2006.01)

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

CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/2291*** (2013.01); ***H01Q 1/24*** (2013.01); ***H01Q 1/36*** (2013.01); ***H01Q 9/04*** (2013.01); ***H01Q 9/0421*** (2013.01); ***H01Q 9/42*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 9/0421; H01Q 1/24; H01Q 1/36; H01Q 9/42; H01Q 1/2291; H01Q 9/04

USPC 343/702

See application file for complete search history.

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2012/0229347	A1*	9/2012	Jin	H01Q 1/243 343/702

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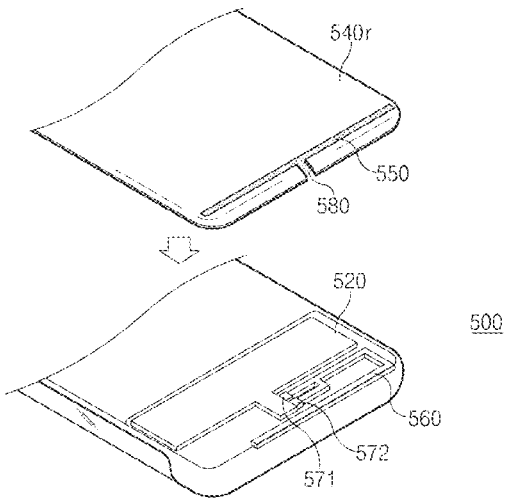
Primary Examiner — Hai V Tran

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

(57) **ABSTRACT**

An electronic device is provided. The electronic device includes a housing and an antenna radiator disposed in the housing. An opening is formed in the housing. The opening includes a first portion configured to align with a length direction of the antenna radiator at a position corresponding to the antenna radiator and penetrate the housing in a thickness direction, and a second portion connected to the first portion, the second portion being configured to form a specified angle with respect to the length direction of the antenna radiator and penetrate the housing in a thickness direction. At least a portion of the housing, which surrounds the opening, comprises a conductive member. At least a portion of a circumference of the opening comprises an electrical open curve.

20 Claims, 20 Drawing Sheets



US010367266B2

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

(10) **Patent No.: US 10,367,266 B2**
(45) **Date of Patent: Jul. 30, 2019**

(54) **MULTI-ANTENNA COMMUNICATION DEVICE**

(71) Applicant: **Industrial Technology Research Institute**, Hsinchu (TW)

(72) Inventors: **Kin-Lu Wong**, Hsinchu (TW); **Jun-Yu Lu**, Hsinchu (TW); **De-Ming Chian**, Hsinchu (TW); **Wei-Yu Li**, Hsinchu (TW); **Chih-Yu Tsai**, Hsinchu (TW)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 219 days.

(21) Appl. No.: **15/392,255**

(22) Filed: **Dec. 28, 2016**

(65) **Prior Publication Data**

US 2018/0183132 A1 Jun. 28, 2018

(30) **Foreign Application Priority Data**

Dec. 27, 2016 (TW) ..... 105143339 A

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 7/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 7/00*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 21/28*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/24; H01Q 1/48; H01Q 21/28; H01Q 7/00; H01Q 1/243; H01Q 21/06; H01Q 21/061
See application file for complete search history.

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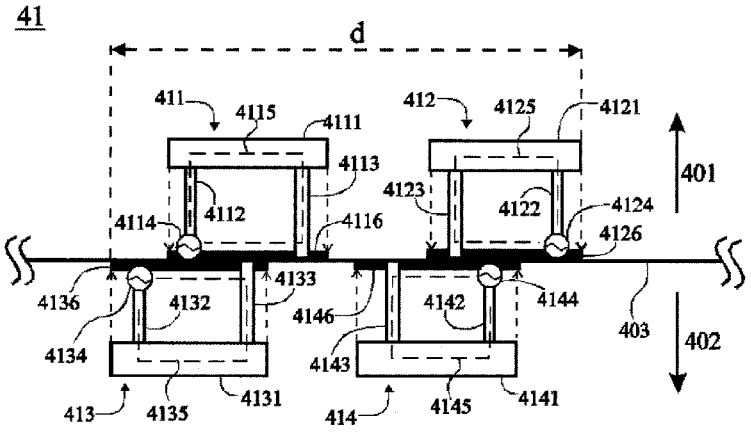
Primary Examiner — Jessica Han
Assistant Examiner — Awat M Salih
(74) *Attorney, Agent, or Firm* — Mintz Levin Cohn Ferris Glovsky and Popeo, P.C.; Peter F. Corless; Steven M. Jensen

(57) **ABSTRACT**

A multi-antenna communication device is provided, including a grounding conductor plane separating a first side space and a second side space and having a first edge. A four-antenna array including first, second, third and fourth antennas is located at the first edge, and has an overall maximum array length extending along the first edge. The first and second antennas are located in the first side space, and the third and fourth antennas are located in the second side space. Each of the first to fourth antennas includes a feeding conductor line, a grounding conductor line, and a radiating conductor portion electrically connected to a signal source through the feeding conductor line and electrically connected to the first edge through the grounding conductor line, thereby forming a loop path and generating at least one resonant mode. The radiating conductor portion has a corresponding projection line segment at the first edge.

19 Claims, 14 Drawing Sheets



US010374285B2

(12) **United States Patent**
Miura

(10) **Patent No.: US 10,374,285 B2**
(45) **Date of Patent: Aug. 6, 2019**

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

(71) Applicant: **NEC Platforms, Ltd.**, Kawasaki-shi, Kanagawa (JP)

(72) Inventor: **Ken Miura**, Kanagawa (JP)

(73) Assignee: **NEC PLATFORMS, LTD**, Kanagawa (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 110 days.

(21) Appl. No.: **14/910,348**

(22) PCT Filed: **Jul. 23, 2014**

(86) PCT No.: **PCT/JP2014/003870**

§ 371 (c)(1),
(2) Date: **Feb. 5, 2016**

(87) PCT Pub. No.: **WO2015/029322**

PCT Pub. Date: **Mar. 5, 2015**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Aug. 27, 2013 (JP) 2013-175562

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/52 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/2291*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/48*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/2291; H01Q 19/00; H01Q 9/0421; H01Q 21/28; H01Q 1/38; H01Q 1/48; H01Q 1/52; H01Q 1/521
See application file for complete search history.

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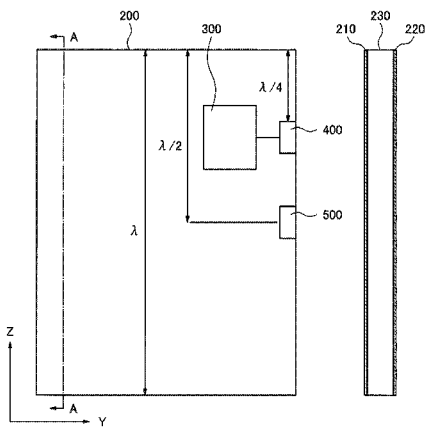
(Continued)

Primary Examiner — Dameon E Levi
Assistant Examiner — Ab Salam Alkassim, Jr.

(57) **ABSTRACT**

Provided is an antenna capable of maintaining excellent antenna characteristics even in a case where the antenna cannot be disposed at a desired position or a case where a plurality of antennas are disposed in a single apparatus. This antenna is characterized by being provided with: a printed wiring board; an antenna circuit which is disposed in a predetermined end portion of the printed wiring board and sends and receives radio waves of wavelength λ; and a series resonance circuit disposed at a position in the predetermined end portion of the printed wiring board, the position being separated from the antenna circuit by a distance depending on the wavelength λ. The antenna is also characterized by
(Continued)



US010374286B2

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

(10) **Patent No.: US 10,374,286 B2**
(45) **Date of Patent: Aug. 6, 2019**

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

(71) Applicant: **Samsung Electronics Co., Ltd.**, Gyeonggi-do (KR)

(72) Inventors: **Jung-Sik Park**, Gyeonggi-do (KR); **Yeon-Woo Kim**, Gyeonggi-do (KR); **Woo-Sup Lee**, Gyeonggi-do (KR); **Seung-Gil Jeon**, Gyeonggi-do (KR); **Ju-Seok Noh**, Gyeonggi-do (KR); **Jae-Bong Chun**, Gyeonggi-do (KR); **Hyun-Ju Hong**, Gyeonggi-do (KR)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 235 days.

(21) Appl. No.: **14/945,597**

(22) Filed: **Nov. 19, 2015**

(65) **Prior Publication Data**

US 2016/0149290 A1 May 26, 2016

(30) **Foreign Application Priority Data**

Nov. 21, 2014 (KR) 10-2014-0163512

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/44 (2006.01)
H01Q 9/42 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/44*** (2013.01); *H01Q 9/42* (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/44; H01Q 1/343; H01Q 1/243; H01Q 1/245; H01Q 9/42
See application file for complete search history.

(56) **References Cited**

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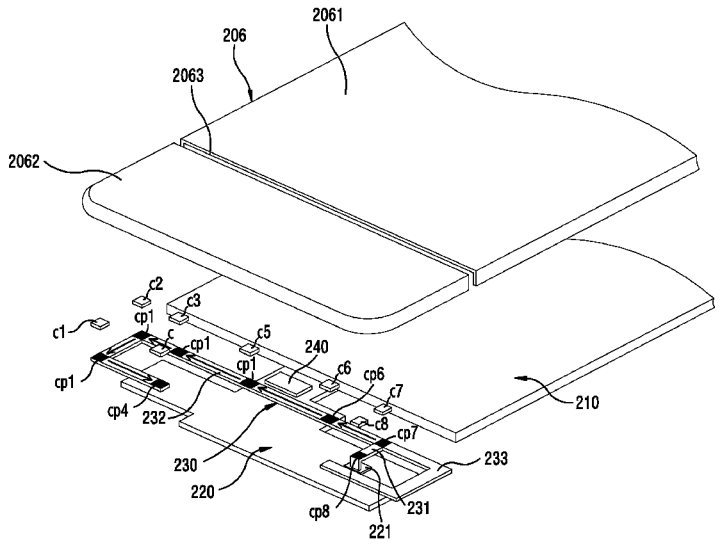
Primary Examiner — Jessica Han
Assistant Examiner — Awat M Salih
(74) *Attorney, Agent, or Firm* — Cha & Reiter, LLC.

(57) **ABSTRACT**

An electronic device comprising: a housing; a wireless communication transceiver provided within the housing; an antenna radiator provided within the housing; and a cover arranged to cover at least a portion of the antenna radiator and form at least a portion of a surface of the housing, wherein the cover includes a conductive material, and the cover is at least partially detachable from the housing.

8 Claims, 21 Drawing Sheets



US010374287B2

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

(10) **Patent No.: US 10,374,287 B2**
(45) **Date of Patent: Aug. 6, 2019**

(54) **ANTENNA SYSTEM WITH FULL METAL BACK COVER**

(71) Applicants: **Jing Wu**, Shenzhen (CN); **Jianchun Mai**, Shenzhen (CN); **Chao Wang**, Shenzhen (CN)

(72) Inventors: **Jing Wu**, Shenzhen (CN); **Jianchun Mai**, 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 34 days.

(21) Appl. No.: **15/283,530**

(22) Filed: **Oct. 3, 2016**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Oct. 26, 2015 (CN) 2015 1 0700646
May 15, 2016 (JP) 2016-119329

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 1/22	(2006.01)
H01Q 1/48	(2006.01)
H01Q 9/42	(2006.01)
H01Q 21/30	(2006.01)
H01Q 1/36	(2006.01)
H01Q 1/38	(2006.01)

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

CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/2291*** (2013.01); ***H01Q 1/36*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 9/42*** (2013.01); ***H01Q 21/30*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 1/38; H01Q 1/2291; H01Q 13/10; H01Q 9/42; H01Q 21/30

See application file for complete search history.

(56) **References Cited**

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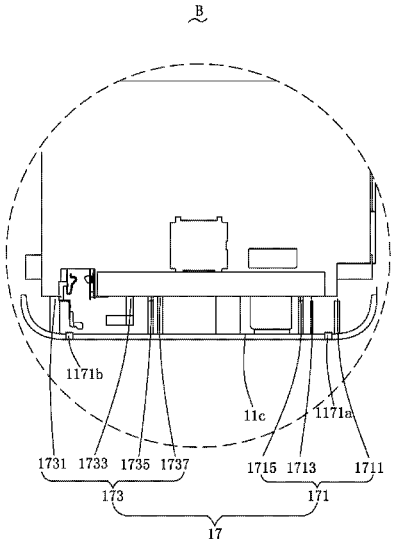
Primary Examiner — Ricardo I Magallanes
(74) *Attorney, Agent, or Firm* — Na Xu; IPro, PLLC

(57) **ABSTRACT**

An antenna system with a full metal back cover is provided in the present disclosure. The antenna system includes a metal back cover with a main body, a first sidewall and a second sidewall opposite to each other, a circuit board with a main ground point, a first antenna module and a second antenna module electrically connected to the circuit board. A first gap is formed between the first sidewall and the main body, and a second gap is formed between the second sidewall and the main body; the metal back cover is divided into a first metal portion including the first sidewall and a second metal portion including the second sidewall. The first metal portion includes a top slit penetrating through an edge of the first sidewall, and the second metal portion includes a bottom slit penetrating through an edge of the second sidewall.

13 Claims, 14 Drawing Sheets



US010374289B2

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

(10) **Patent No.: US 10,374,289 B2**
(45) **Date of Patent: Aug. 6, 2019**

(54) **RECONFIGURABLE 4-PORT MULTI-BAND MULTI-FUNCTION ANTENNA WITH A GROUNDED DIPOLE ANTENNA COMPONENT**

(71) Applicant: **Smart Antenna Technologies Ltd.**, Birmingham (GB)

(72) Inventors: **Sampson Hu**, Birmingham (GB); **Xiang Gao**, Birmingham (GB)

(73) Assignee: **Smart Antenna Technologies Ltd.**, Birmingham (GB)

(*) 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.: **15/564,613**

(22) PCT Filed: **Apr. 7, 2016**

(86) PCT No.: **PCT/GB2016/050985**
§ 371 (c)(1),
(2) Date: **Oct. 5, 2017**

(87) PCT Pub. No.: **WO2016/162685**
PCT Pub. Date: **Oct. 13, 2016**

(65) **Prior Publication Data**

US 2018/0076505 A1 Mar. 15, 2018

(30) **Foreign Application Priority Data**

Apr. 7, 2015 (GB) 1505910.8
Jul. 23, 2015 (GB) 1513043.8

(51) **Int. Cl.**
H04M 1/00 (2006.01)
H01Q 1/24 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/521*** (2013.01); ***H01Q 5/335*** (2015.01); ***H01Q 5/50*** (2015.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 21/28; H01Q 1/48; H01Q 1/50; H01Q 9/42; H01Q 1/38;
(Continued)

(56) **References Cited**

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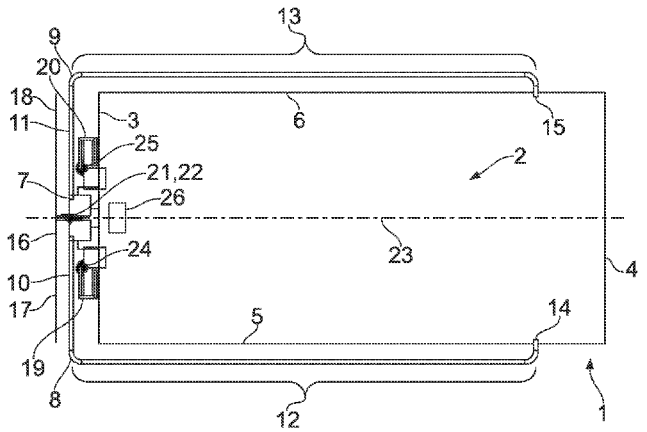
(Continued)

Primary Examiner — Ajibola A Akinyemi
(74) *Attorney, Agent, or Firm* — Shumaker & Sieffert, P.A.

(57) **ABSTRACT**

There is disclosed a reconfigurable antenna device comprising a substrate having first and second opposed ends and first and second opposed side edges, the substrate incorporating a main groundplane. The antenna device further comprises a dipole antenna having first and second arms each having
(Continued)



US010374290B2

(12) **United States Patent**
Heo

(10) **Patent No.: US 10,374,290 B2**
(45) **Date of Patent: Aug. 6, 2019**

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

(71) Applicant: **Samsung Electronics Co., Ltd.**, Gyeonggi-do (KR)

(72) Inventor: **Young Heo**, Gyeonggi-do (KR)

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

(*) 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.: **15/694,261**

(22) Filed: **Sep. 1, 2017**

(65) **Prior Publication Data**

US 2018/0076507 A1 Mar. 15, 2018

(30) **Foreign Application Priority Data**

Sep. 12, 2016 (KR) 10-2016-0117031

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 9/42	(2006.01)
H01Q 5/378	(2015.01)
H01Q 5/321	(2015.01)
H01Q 1/38	(2006.01)
H01Q 9/04	(2006.01)
H04B 1/00	(2006.01)

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

CPC ***H01Q 1/243*** (2013.01); ***H01Q 5/321*** (2015.01); ***H01Q 5/378*** (2015.01); ***H01Q 9/42*** (2013.01); *H01Q 1/38* (2013.01); *H01Q 9/0421* (2013.01); *H04B 1/006* (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 5/321; H01Q 5/378; H01Q 9/42; H01Q 9/0421; H04B 1/006

See application file for complete search history.

(56) **References Cited**

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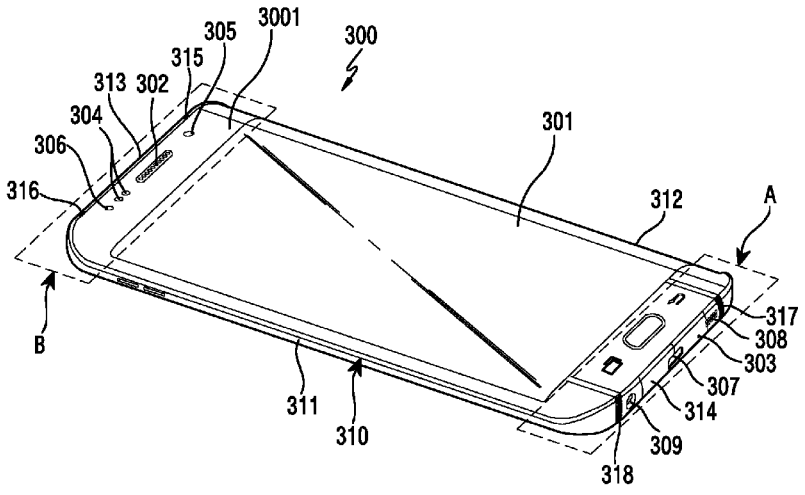
Primary Examiner — Dameon E Levi
Assistant Examiner — David E Lotter
(74) *Attorney, Agent, or Firm* — The Farrell Law Firm, P.C.

(57) **ABSTRACT**

An electronic device is provided, which includes a housing; a conductive member forming a part of the housing or disposed on an inside of the housing; a communication circuit electrically connected to a first region of the conductive member; a conductive pattern electrically connected to a second region of the conductive member; and a switching circuit disposed on an electric path between the conductive pattern and the conductive member that controls a switching operation to selectively, electrically connect and disconnect the conductive pattern to and from the conductive member.

14 Claims, 8 Drawing Sheets



US010374304B2

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

(10) **Patent No.: US 10,374,304 B2**
(45) **Date of Patent: Aug. 6, 2019**

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

(71) Applicant: **Murata Manufacturing Co., Ltd.**, Nagaokakyo-shi, Kyoto-fu (JP)

(72) Inventors: **Katsumi Taniguchi**, Nagaokakyo (JP); **Noboru Kato**, Nagaokakyo (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 175 days.

(21) Appl. No.: **15/618,223**

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

(65) **Prior Publication Data**

US 2017/0279192 A1 Sep. 28, 2017

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2016/062586, filed on Apr. 21, 2016.

(30) **Foreign Application Priority Data**

Jun. 16, 2015 (JP) 2015-121034

(51) **Int. Cl.**
H01Q 1/52 (2006.01)
H01Q 1/38 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/52*** (2013.01); ***H01P 3/085*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/52; H01Q 1/243; H01Q 1/38; H01Q 1/48; H01Q 9/0421; H01P 3/085;
(Continued)

(56) **References Cited**

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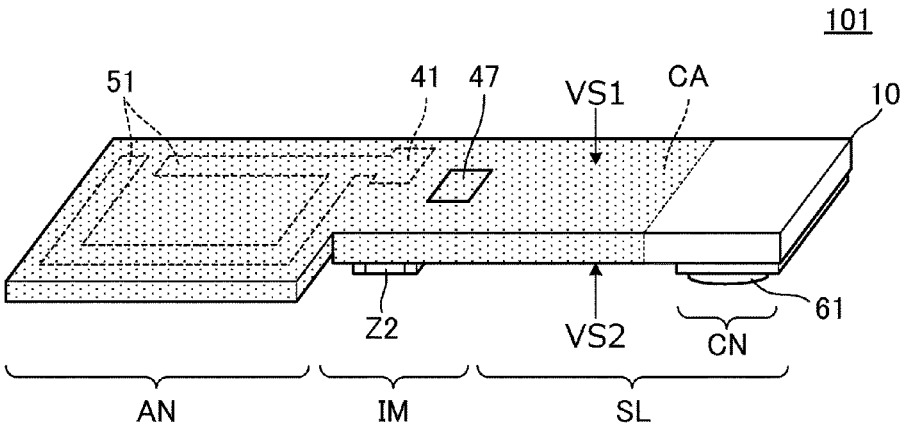
Official Communication issued in International Patent Application No. PCT/JP2016/062586, dated Jul. 19, 2016.

Primary Examiner — Dameon E Levi
Assistant Examiner — David E Lotter
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

An electronic apparatus includes an antenna device, a circuit board, and a housing containing the antenna device and the circuit board. The inner surface of the housing is spaced apart from the circuit board. The antenna device includes an antenna unit, a matching circuit unit connected to the antenna unit, a transmission line unit connected to the matching circuit unit, and a connecting portion included in the transmission line unit. The antenna device is disposed along the inner surface of the housing. The connecting portion is connected to a circuit of the circuit board. The antenna device includes a ground connection portion in the matching circuit unit in a region where the antenna device is disposed along the inner surface of the housing. The ground connection portion electrically connects a second ground conductor of the antenna device to a first ground conductor on the housing.

19 Claims, 13 Drawing Sheets



US010374305B2

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

(10) **Patent No.: US 10,374,305 B2**
(45) **Date of Patent: Aug. 6, 2019**

(54) **MULTILAYER SUBSTRATE AND ELECTRONIC DEVICE**

(71) Applicant: **Murata Manufacturing Co., Ltd.**, Nagaokakyo-shi, Kyoto-fu (JP)

(72) Inventors: **Nobou Ikemoto**, Nagaokakyo (JP); **Jun Sasaki**, Nagaokakyo (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 0 days.

(21) Appl. No.: **15/881,857**

(22) Filed: **Jan. 29, 2018**

(65) **Prior Publication Data**

US 2018/0151951 A1 May 31, 2018

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2016/069838, filed on Jul. 5, 2016.

(30) **Foreign Application Priority Data**

Jul. 30, 2015 (JP) 2015-151346

(51) **Int. Cl.**
H01Q 1/52 (2006.01)
H01Q 1/40 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/52*** (2013.01); ***H01Q 1/40*** (2013.01); ***H01Q 7/06*** (2013.01); ***H05K 1/115*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. H01Q 1/52; H01Q 1/22; H01Q 1/38; H01Q 1/40; H01Q 3/02; H01Q 7/06
See application file for complete search history.

(56) **References Cited**

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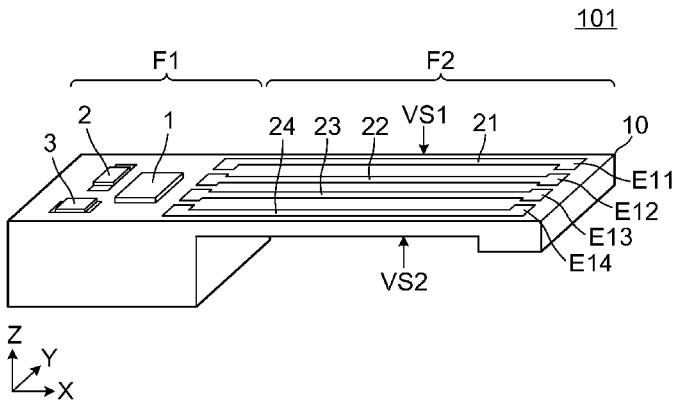
(Continued)

Primary Examiner — Hoang V Nguyen
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A multilayer substrate, in which flexible insulating base materials are laminated, includes first and second regions. The number of laminated insulating base materials in the second region is smaller than that in the first region. The multilayer substrate includes a coil antenna located in the first region, a magnetic member located in the first region, a mounting component located in the first region, a wiring pattern, and an external connection terminal. The mounting component entirely overlaps the magnetic member when viewed in a thickness direction and is located on a side opposite to the coil antenna across the magnetic member in the thickness direction. At least a portion of the coil antenna overlaps the magnetic member when viewed in the thickness direction.

20 Claims, 10 Drawing Sheets



US010381710B1

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

(10) **Patent No.: US 10,381,710 B1**
(45) **Date of Patent: Aug. 13, 2019**

(54) **SINGLE FEED PASSIVE ANTENNA FOR A METAL BACK COVER**

(71) Applicant: **AMAZON TECHNOLOGIES, INC.**, Seattle, WA (US)

(72) Inventors: **Jerry Weiming Kuo**, San Jose, CA (US); **Mudit Sunilkumar Khasgiwala**, Milpitas, CA (US); **Adrian Napoles**, Cupertino, CA (US); **Ming Zheng**, Cupertino, CA (US)

(73) Assignee: **Amazon Technologies, Inc.**, Seattle, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 393 days.

(21) Appl. No.: **15/082,883**

(22) Filed: **Mar. 28, 2016**

Related U.S. Application Data

(63) Continuation-in-part of application No. 14/967,988, filed on Dec. 14, 2015.

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 1/22	(2006.01)
H01Q 5/30	(2015.01)
H01Q 9/04	(2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/2266*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 5/30*** (2015.01); ***H01Q 9/0407*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/2266; H01Q 5/314; H01Q 5/321; H01Q 5/328; H01Q 5/335
See application file for complete search history.

(56) **References Cited**

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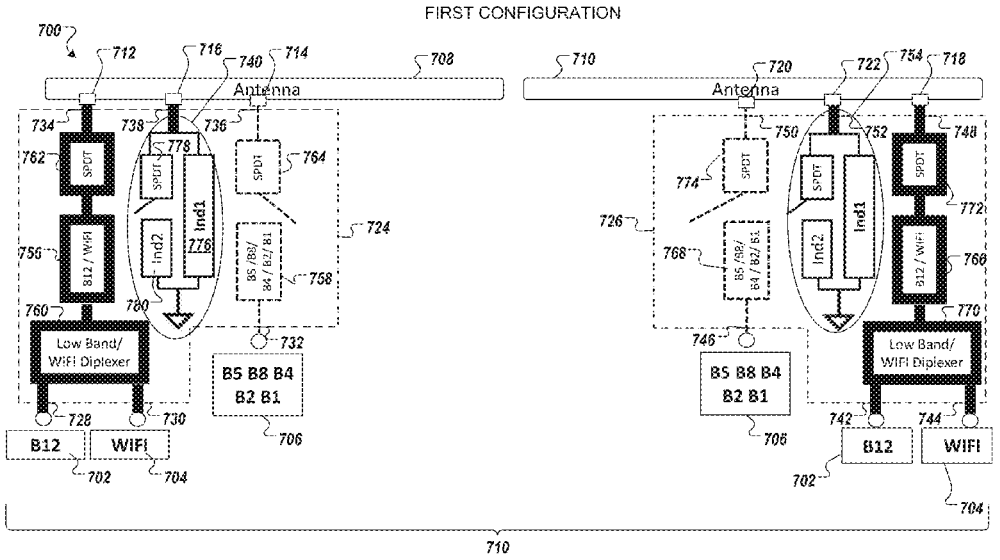
Primary Examiner — Daniel Munoz
(74) *Attorney, Agent, or Firm* — Lowenstein Sandler LLP

(57) **ABSTRACT**

Antenna structures and methods of operating the same are described. One apparatus includes a radio frequency (RF) circuitry, a housing, an antenna structure, and multi-connector switching circuitry. The RF circuitry includes a first RF feed for a first frequency and a second RF feed for a second frequency. The housing includes a first strip element disposed at a periphery of the housing, where the first strip element is physically separated from the housing by a first cutout in the housing. The antenna structure includes the first strip element with a first connector, a second connector, and a third connector coupled to the multi-connector switching circuitry. The multi-connector switching circuitry connects the first RF feed coupled to the first RF feed and the second RF feed where the first switching circuit to connect the first strip element to the first RF feed in a first mode of the first multi-connector switching circuitry.

20 Claims, 18 Drawing Sheets



US010381715B2

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

(10) **Patent No.: US 10,381,715 B2**
(45) **Date of Patent: Aug. 13, 2019**

(54) **ELECTRONIC DEVICE ANTENNAS HAVING MULTI-BAND TUNING CAPABILITIES**

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

(72) Inventors: **Liang Han**, Sunnyvale, CA (US); **Thomas E. Biedka**, San Jose, CA (US); **Matthew A. Mow**, Los Altos, CA (US); **Iyappan Ramachandran**, Santa Clara, CA (US); **Mattia Pascolini**, San Francisco, CA (US); **Xu Han**, San Jose, CA (US); **Hao Xu**, Cupertino, CA (US); **Jennifer M. Edwards**, San Francisco, CA (US); **Salih Yarga**, Sunnyvale, CA (US); **Yijun Zhou**, Sunnyvale, CA (US)

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

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H04W 4/02 (2018.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/245*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 5/328*** (2015.01); ***H01Q 9/42*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/38; H01Q 9/045; H01Q 5/371; H01Q 1/243; H01Q 1/521
(Continued)

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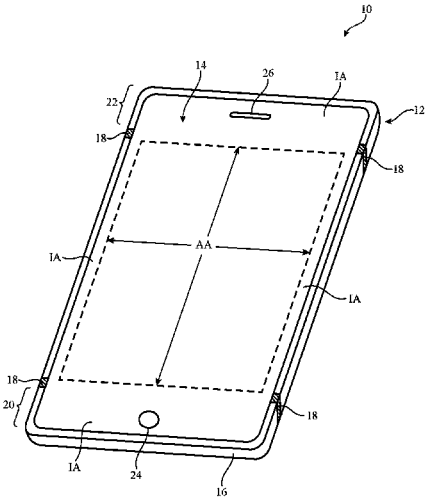
(57) **ABSTRACT**

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

20 Claims, 12 Drawing Sheets



US010381721B2

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

(10) **Patent No.: US 10,381,721 B2**
(45) **Date of Patent: Aug. 13, 2019**

(54) **HANDHELD DEVICE**

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

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

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(21) Appl. No.: **15/541,467**

(22) PCT Filed: **Jan. 4, 2015**

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§ 371 (c)(1),
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(Continued)

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(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/24; H01Q 1/241; H01Q 1/242; H01Q 1/243; H01Q 1/42; H01Q 1/44;
(Continued)

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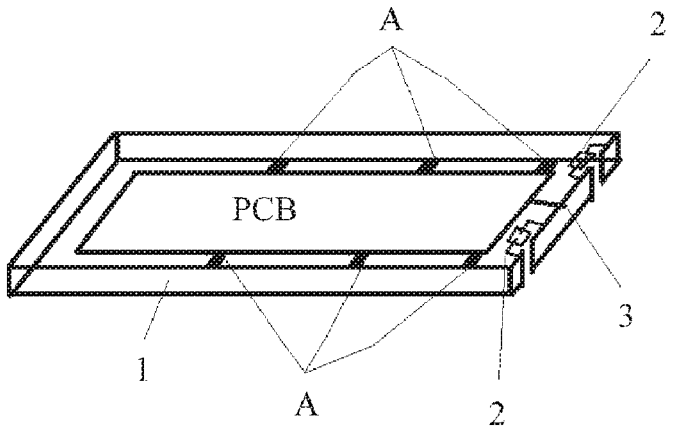
Primary Examiner — Daniel Munoz
Assistant Examiner — Patrick R Holecek

(57) **ABSTRACT**

A handheld device includes a metal frame, two switches, and an antenna feedpoint, where two slits are disposed at the metal frame; the slits divide the metal frame into a left frame, a middle frame, and a right frame; two sides of each slit are bridged by one switch, where one of the switches is in a connected state, the other of the switches is in a disconnected state, and the two switches perform state switching when a user's finger connects a slit corresponding to the switch in a disconnected state; and the antenna feedpoint is electrically connected to the middle frame, and the left frame and the right frame are grounded, to form an antenna.

15 Claims, 6 Drawing Sheets



US010381750B2

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

(10) **Patent No.: US 10,381,750 B2**
(45) **Date of Patent: Aug. 13, 2019**

(54) **ELECTRONIC DEVICE**

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(73) Assignee: **LG ELECTRONICS INC.**, Seoul (KR)

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(65) **Prior Publication Data**

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Related U.S. Application Data

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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H01Q 1/44	(2006.01)
H01Q 9/04	(2006.01)
H01Q 21/00	(2006.01)
H01Q 21/06	(2006.01)
H01Q 21/24	(2006.01)
H01Q 25/00	(2006.01)

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

CPC ***H01Q 25/001*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/44*** (2013.01); ***H01Q 9/0435*** (2013.01); ***H01Q 21/0006*** (2013.01); ***H01Q 21/065*** (2013.01); ***H01Q 21/24*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 25/001; H01Q 1/243; H01Q 21/065; H01Q 9/0435

See application file for complete search history.

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(57) **ABSTRACT**

An electronic device including a display unit; an array antenna including a transparent electrode material and being disposed within the display unit; and a radio frequency integrated circuit (RFIC) electrically connected to the array antenna. The array antenna includes an antenna element having first and second sides perpendicular to each other disposed slopingly at a predetermined angle with respect to one side of the display unit; and a feeding part connecting the antenna element and the RFIC.

19 Claims, 17 Drawing Sheets