US009742063B2

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

(10) **Patent No.: US 9,742,063 B2**
(45) **Date of Patent: Aug. 22, 2017**

(54) **EXTERNAL LTE MULTI-FREQUENCY BAND ANTENNA**

(71) Applicant: **ARCADYAN TECHNOLOGY CORPORATION**, Hsinchu (TW)

(72) Inventors: **Wen-Szu Tao**, Hsinchu (TW); **Shin-Lung Kuo**, Hsinchu (TW); **Yi-Cheng Lin**, Hsinchu (TW); **Po-Hsun Wei**, Hsinchu (TW)

(73) Assignee: **ARCADYAN TECHNOLOGY CORPORATION**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 237 days.

(21) Appl. No.: **14/536,629**

(22) Filed: **Nov. 9, 2014**

(65) **Prior Publication Data**

US 2015/0364821 A1 Dec. 17, 2015

Related U.S. Application Data

(60) Provisional application No. 62/012,108, filed on Jun. 13, 2014.

(30) **Foreign Application Priority Data**

Jul. 11, 2014 (TW) ..... 103124037 A

(51) **Int. Cl.**
H01Q 5/307 (2015.01)
H01Q 1/48 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 5/307*** (2015.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 5/378*** (2015.01);
(Continued)

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

(56) **References Cited**

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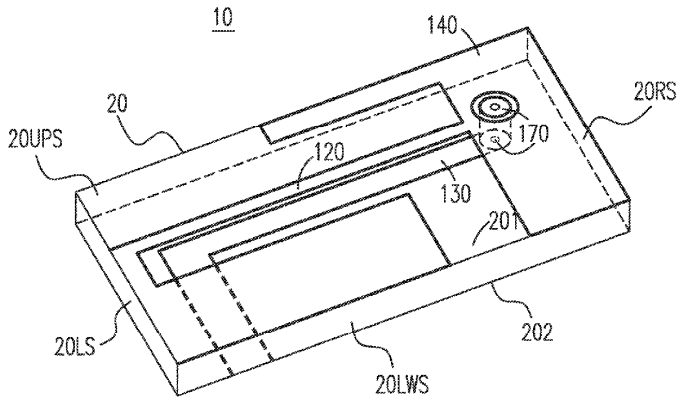
Primary Examiner — Robert Karacsony
(74) *Attorney, Agent, or Firm* — The PL Law Group, PLLC

(57) **ABSTRACT**

An antenna is provided. The antenna includes a substrate having a first end and a second end opposite to the first end, wherein a direction from the first end to the second end is an extending direction of the antenna; a radiating portion; a feed-in conductor; and a ground portion electrically connected to the radiating portion, coupled to the feed-in conductor, disposed on the substrate from the first end along the extending direction, and including a main ground conductor; and a high frequency band bandwidth adjusting conductor extended from the main ground conductor along the extending direction.

13 Claims, 14 Drawing Sheets



US009742067B2

(12) **United States Patent**
Kim

(10) **Patent No.: US 9,742,067 B2**
(45) **Date of Patent: Aug. 22, 2017**

(54) **ANTENNA APPARATUS**

(71) Applicant: **LG INNOTEK CO., LTD.**, Seoul (KR)

(72) Inventor: **Chang Wook Kim**, Seoul (KR)

(73) Assignee: **LG INNOTEK CO., LTD.**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 225 days.

(21) Appl. No.: **13/928,596**

(22) Filed: **Jun. 27, 2013**

(65) **Prior Publication Data**

US 2014/0002310 A1 Jan. 2, 2014

(30) **Foreign Application Priority Data**

Jun. 28, 2012 (KR) 10-2012-0070373

(51) **Int. Cl.**

H01Q 9/04	(2006.01)
H01Q 1/22	(2006.01)
H01Q 1/24	(2006.01)
H01Q 9/42	(2006.01)
H01Q 5/364	(2015.01)

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

CPC ***H01Q 9/04*** (2013.01); ***H01Q 1/2283*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 5/364*** (2015.01); ***H01Q 9/42*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 9/04
USPC ..... 343/700 MS
See application file for complete search history.

(56) **References Cited**

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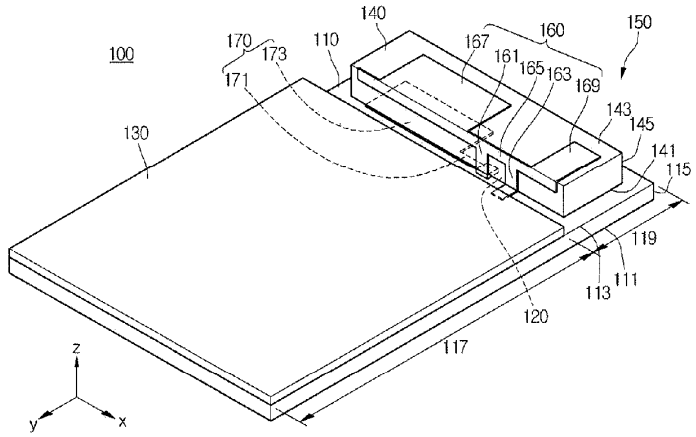
(Continued)

Primary Examiner — Dameon E Levi
Assistant Examiner — Walter Davis
(74) *Attorney, Agent, or Firm* — Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

Disclosed is an antenna apparatus. The antenna apparatus includes a feeding pad for supplying a signal, a main device extended from the feeding pad, and a sub-device extended from the feeding pad and spaced apart from the main device while overlapping with the main device. The antenna apparatus includes the sub-device overlapped with the main device, so that the resonance frequency band of the antenna apparatus is enlarged.

5 Claims, 5 Drawing Sheets



US009742076B2

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

(10) **Patent No.: US 9,742,076 B2**
(45) **Date of Patent: Aug. 22, 2017**

(54) **SPACE EFFICIENT MULTI-BAND ANTENNA**

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

(72) Inventors: **Jatupum Jenwatanavet**, San Diego, CA (US); **Yuandan Dong**, San Diego, CA (US); **Andrew PuayHoe See**, San Diego, CA (US); **Allen Minh-Triet Tran**, San Diego, CA (US)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 76 days.

(21) Appl. No.: **14/828,360**

(22) Filed: **Aug. 17, 2015**

(65) **Prior Publication Data**

US 2017/0054220 A1 Feb. 23, 2017

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 21/06	(2006.01)
H01Q 9/42	(2006.01)
H01Q 5/321	(2015.01)
H01Q 5/335	(2015.01)
H01Q 5/378	(2015.01)
H01Q 1/38	(2006.01)

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

CPC ***H01Q 21/06*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 5/321*** (2015.01); ***H01Q 5/335*** (2015.01); ***H01Q 5/378*** (2015.01); ***H01Q 9/42*** (2013.01); *H01Q 1/243* (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/24; H01Q 21/28; H01Q 1/243; H01Q 5/10; H01Q 5/15; H01Q 5/314; H01Q 9/06; H01Q 21/06

USPC ..... 343/700 MS, 702, 725, 727, 745, 876

See application file for complete search history.

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Co-pending U.S. Appl. No. 14/592,746, filed Jan. 8, 2015.

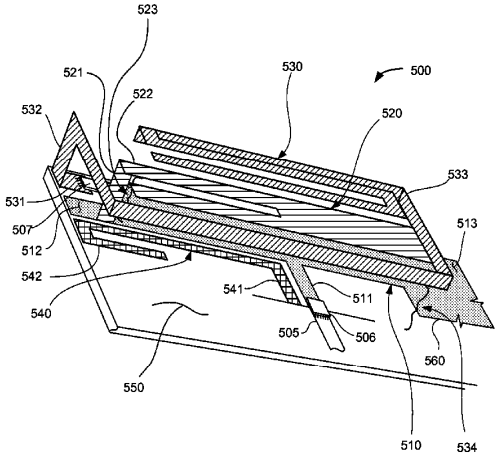
Primary Examiner — Tho G Phan

(74) *Attorney, Agent, or Firm* — Paradice and Li LLP/Qualcomm

(57) **ABSTRACT**

A multi-band antenna having an aperture tuner is disclosed. The multi-band antenna may simultaneously transmit a first radio frequency (RF) signal and a second RF signal. The aperture tuner may modify a resonant frequency associated with one or more antenna elements of the multiband antenna in accordance with the first RF signal or the second RF signal. One or more of the antenna elements of the multi-band antenna may be disposed above and/or substantially parallel to other antenna elements. In some exemplary embodiments, an air gap may be formed between one or more antenna elements.

16 Claims, 8 Drawing Sheets



US009742459B2

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

(10) **Patent No.: US 9,742,459 B2**
(45) **Date of Patent: Aug. 22, 2017**

(54) **ELECTRONIC DEVICE HAVING SENSORS AND ANTENNA MONITOR FOR CONTROLLING WIRELESS OPERATION**

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

(72) Inventors: **Enrique Ayala Vazquez**, Watsonville, CA (US); **Hongfei Hu**, Santa Clara, CA (US); **Mattia Pascolini**, San Francisco, CA (US); **Yuehui Ouyang**, Sunnyvale, CA (US); **Salih Yarga**, Sunnyvale, CA (US); **Yijun Zhou**, Sunnyvale, CA (US); **Erdinc Irci**, Sunnyvale, CA (US); **Jayesh Nath**, Milpitas, CA (US); **Ming-Ju Tsai**, Cupertino, CA (US); **Matthew A. Mow**, Los Altos, CA (US); **Liang Han**, Sunnyvale, CA (US); **James G. Judkins**, Campbell, CA (US); **Robert W. Schlub**, Cupertino, 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 154 days.

(21) Appl. No.: **14/283,039**

(22) Filed: **May 20, 2014**

(65) **Prior Publication Data**

US 2015/0341073 A1 Nov. 26, 2015

(51) **Int. Cl.**
H04B 1/04 (2006.01)
H01Q 11/12 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04B 1/40*** (2013.01); ***H04B 1/0458*** (2013.01); ***H04B 1/18*** (2013.01)

(58) **Field of Classification Search**
CPC H04B 1/40; H04B 1/3822; H04B 1/406; H04B 1/44; H04B 1/54; H04B 1/0458;
(Continued)

(56) **References Cited**

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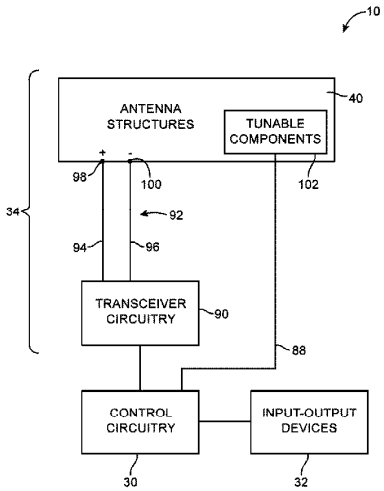
Schlub et al., U.S. Appl. No. 13/865,578, filed Apr. 18, 2013.
Mow et al., U.S. Appl. No. 14/310,240, filed Jun. 20, 2014.

Primary Examiner — Nhan Le
(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; G. Victor Treyz; Joseph F. Guihan

(57) **ABSTRACT**

An electronic device may be provided with wireless circuitry. Control circuitry may be used to adjust the wireless circuitry. The wireless circuitry may include an antenna that is tuned using tunable components. The control circuitry may gather information on the current operating mode of the electronic device, sensor data from a proximity sensor, accelerometer, microphone, and other sensors, antenna impedance information for the antenna, and information on the use of connectors in the electronic device. Based on this gathered data, the control circuitry can adjust the tunable components to compensate for antenna detuning due to loading from nearby external objects, may adjust transmit power levels, and may make other wireless circuit adjustments.

19 Claims, 6 Drawing Sheets



US009746571B2

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

(10) **Patent No.: US 9,746,571 B2**
(45) **Date of Patent: Aug. 29, 2017**

(54) **PROXIMITY SENSOR ANTENNA DEVICE AND ANTENNA STRUCTURE THEREOF**

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

(72) Inventors: **Peng-Hao Juan**, Taipei (TW); **Yu-Tsung Huang**, Kaohsiung (TW)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 47 days.

(21) Appl. No.: **14/959,352**

(22) Filed: **Dec. 4, 2015**

(65) **Prior Publication Data**

US 2017/0160416 A1 Jun. 8, 2017

(51) **Int. Cl.**

H01Q 1/44	(2006.01)
G01V 3/08	(2006.01)
H01Q 1/38	(2006.01)
H01Q 1/24	(2006.01)
H01Q 5/378	(2015.01)
H01Q 5/328	(2015.01)
H01Q 9/42	(2006.01)

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

CPC ***G01V 3/08*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 5/328*** (2015.01); ***H01Q 5/378*** (2015.01); ***H01Q 9/42*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 1/44; H01Q 5/328; H01Q 5/378; H01Q 9/42

See application file for complete search history.

(56) **References Cited**

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2016/0087343	A1 *	3/2016	Chang	H01Q 1/245 343/720

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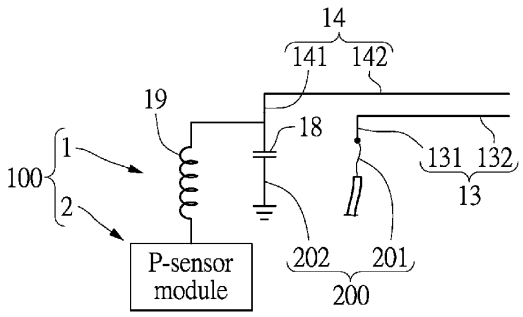
Primary Examiner — Hoang Nguyen

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

(57) **ABSTRACT**

A P-sensor device includes an antenna structure and a P-sensor module. The antenna structure includes a first conductor, a second conductor, a capacitance member, and an inductance member. The capacitance member and inductance member are electrically connected to the second conductor. When the second conductor is in a capacitance electrode mode, a capacitance value between the second conductor and an external object is variable, and the capacitance member is configured to block a detecting signal, which travels in the second conductor. When the second conductor is in a coupling antenna mode, the inductance member is configured to block a RF signal, which travels in the second conductor. The P-sensor module is electrically connected to the inductance member and is electrically connected to the second conductor via the inductance member.

6 Claims, 3 Drawing Sheets



US009748633B2

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

(10) **Patent No.: US 9,748,633 B2**
(45) **Date of Patent: Aug. 29, 2017**

(54) **ANTENNA STRUCTURE**

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

(72) Inventors: **Yi-Ting Chen**, New Taipei (TW); **Cho-Kang Hsu**, New Taipei (TW)

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

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

(21) Appl. No.: **14/011,925**

(22) Filed: **Aug. 28, 2013**

(65) **Prior Publication Data**

US 2014/0118195 A1 May 1, 2014

(30) **Foreign Application Priority Data**

Oct. 26, 2012 (TW) ..... 101139597 A

(51) **Int. Cl.**

H01Q 5/00	(2015.01)
H01Q 1/24	(2006.01)
H01Q 9/42	(2006.01)
H01Q 5/371	(2015.01)
H01Q 5/378	(2015.01)

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

CPC ***H01Q 1/243*** (2013.01); ***H01Q 5/371*** (2015.01); ***H01Q 5/378*** (2015.01); ***H01Q 9/42*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/242; H01Q 1/243; H01Q 5/30; H01Q 5/307; H01Q 5/378; H01Q 1/2258; H01Q 1/2266; H01Q 1/2275; H01Q 1/24; H01Q 5/342; H01Q 5/371; H01Q 5/392; H01Q 9/42; H01Q 19/22; H01Q 19/28; H01Q 1/22; H01Q 1/241; H01Q 5/357; H01Q 5/364

USPC 343/702

See application file for complete search history.

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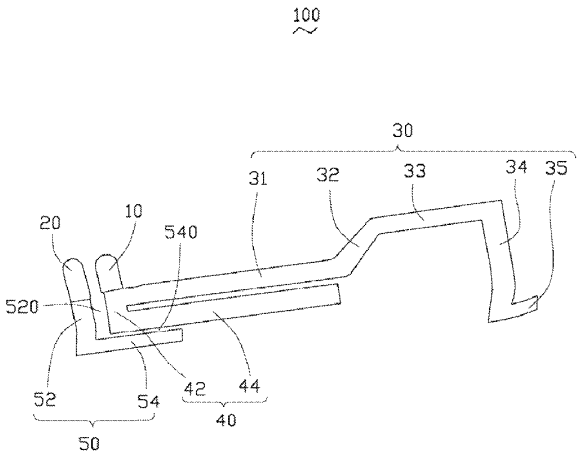
Primary Examiner — Tho G Phan
Assistant Examiner — Patrick Holecek
(74) *Attorney, Agent, or Firm* — Steven Reiss

(57) **ABSTRACT**

An antenna structure includes a feed end, a ground end, a first radiator, a second radiator, and a third radiator. Both of the first radiator and the second radiator are connected to the feed end. The second radiator includes a first connection section and a second connection section. The third radiator is connected to the ground end, and includes a first coupling section separated from the first connection section and a second coupling section separated from the second connection section. A first gap is defined between the first coupling section and the first connection section; and a second gap is defined between the second coupling section and the second connection section.

16 Claims, 2 Drawing Sheets



US009748637B2

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

(10) **Patent No.: US 9,748,637 B2**
(45) **Date of Patent: *Aug. 29, 2017**

(54) **ANTENNA AND METHOD FOR STEERING ANTENNA BEAM DIRECTION FOR WIFI APPLICATIONS**

(71) Applicant: **Ethertronics, Inc.**, San Diego, CA (US)

(72) Inventors: **Sebastian Rowson**, San Diego, CA (US); **Laurent Desclos**, San Diego, CA (US); **Jeffrey Shamblin**, San Marcos, CA (US)

(73) Assignee: **ETHERTRONICS, 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.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/965,881**

(22) Filed: **Dec. 10, 2015**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 14/144,461, filed on Dec. 30, 2013, now Pat. No. 9,240,634, which is a continuation of application No. 13/726,477, filed on Dec. 24, 2012, now Pat. No. 8,648,755, which is a continuation of application No. 13/029,564, filed on Feb. 17, 2011, now Pat. No. 8,362,962, which is a continuation of application No. 12/043,090, filed on Mar. 5, 2008, now Pat. No. 7,911,402.

(51) **Int. Cl.**

H01Q 3/00	(2006.01)
H01Q 1/24	(2006.01)
H01Q 9/04	(2006.01)

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

CPC ***H01Q 1/243*** (2013.01); ***H01Q 3/00*** (2013.01); ***H01Q 9/0421*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 3/00; H01Q 9/0421; H01Q 9/00

USPC ..... 343/700 MS, 745, 815, 817, 833, 834, 343/876

See application file for complete search history.

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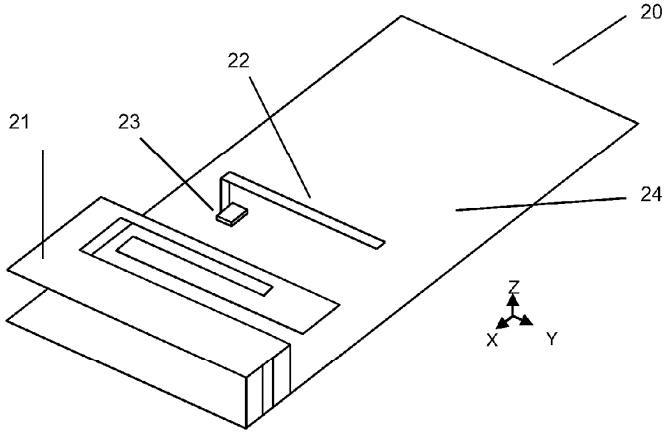
Primary Examiner — Tho G Phan

(74) *Attorney, Agent, or Firm* — Coastal Patent Law Group, P.C.

(57) **ABSTRACT**

An antenna comprising an IMD element and one or more parasitic and active tuning elements is disclosed. The IMD element, when used in combination with the active tuning and parasitic elements, allows antenna operation at multiple resonant frequencies. In addition, the direction of antenna radiation pattern may be arbitrarily rotated in accordance with the parasitic and active tuning elements. Unique antenna architectures for beam steering in Wi-Fi band applications is further described.

11 Claims, 16 Drawing Sheets



US009748650B2

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

(10) **Patent No.: US 9,748,650 B2**
(45) **Date of Patent: Aug. 29, 2017**

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

(71) Applicant: **FIH (HONG KONG) LIMITED**, Kowloon (HK)

(72) Inventors: **Chuan-Chou Chi**, New Taipei (TW); **Chi-Sheng Liu**, New Taipei (TW); **Cheng-Hung Ko**, New Taipei (TW); **Hao-Ying Chang**, New Taipei (TW)

(73) Assignee: **FIH (HONG KONG) LIMITED**, Kowloon (HK)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 128 days.

(21) Appl. No.: **14/685,027**

(22) Filed: **Apr. 13, 2015**

(65) **Prior Publication Data**

US 2016/0190689 A1 Jun. 30, 2016

(30) **Foreign Application Priority Data**

Dec. 31, 2014 (TW) ..... 103146459 A

(51) **Int. Cl.**

H01Q 5/00	(2015.01)
H01Q 5/371	(2015.01)
H01Q 1/24	(2006.01)
H01Q 9/04	(2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 5/371*** (2015.01); ***H01Q 1/243*** (2013.01); ***H01Q 9/0421*** (2013.01)

(58) **Field of Classification Search**
USPC ..... 343/700 MS, 702, 843
See application file for complete search history.

(56) **References Cited**

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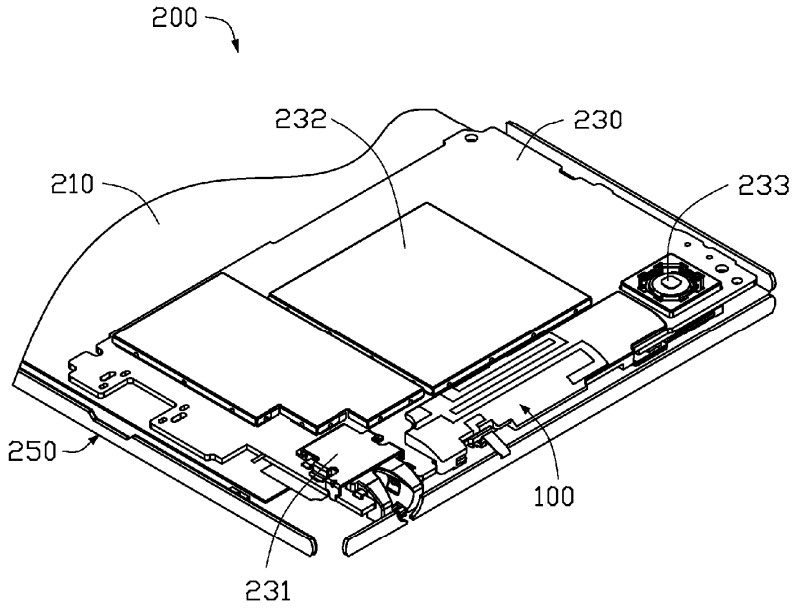
Primary Examiner — Hoang Nguyen
Assistant Examiner — Hai Tran
(74) *Attorney, Agent, or Firm* — Steven Reiss

(57) **ABSTRACT**

An antenna structure includes a feed unit, a grounding unit, a first radiating unit, a second radiating unit, third radiating unit, fourth radiating unit, and a fifth radiating unit. The grounding unit is spaced apart from the feed unit. The first radiating unit is electrically connected to the feed unit. The second radiating unit is electrically connected to the grounding unit. The third radiating unit is electrically connected to the first radiating unit, the second radiating unit, and the fourth radiating unit. The fifth radiating unit is electrically connected to the feed unit and couples with the fourth radiating unit.

20 Claims, 6 Drawing Sheets



US009748661B2

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

(10) **Patent No.: US 9,748,661 B2**
(45) **Date of Patent: Aug. 29, 2017**

(54) **ANTENNA FOR ACHIEVING EFFECTS OF MIMO ANTENNA**

(71) Applicant: **HON HAI PRECISION INDUSTRY CO., LTD.**, New Taipei (TW)

(72) Inventors: **Chun-Jui Pan**, New Taipei (TW); **Sheng-Hsiung Yang**, New Taipei (TW); **Wen-Chieh Tsai**, New Taipei (TW)

(73) Assignee: **HON HAI PRECISION INDUSTRY CO., LTD.**, New Taipei (TW)

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

(21) Appl. No.: **15/142,621**

(22) Filed: **Apr. 29, 2016**

(65) **Prior Publication Data**

US 2016/0248163 A1 Aug. 25, 2016

Related U.S. Application Data

(62) Division of application No. 13/656,753, filed on Oct. 22, 2012.

(30) **Foreign Application Priority Data**

Oct. 28, 2011 (TW) ..... 100139312 A

(51) **Int. Cl.**

H01Q 9/42	(2006.01)
H01Q 1/50	(2006.01)
H01Q 5/35	(2015.01)
H01Q 5/378	(2015.01)
H01Q 1/38	(2006.01)

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

CPC ***H01Q 9/42*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/50*** (2013.01); ***H01Q 5/35*** (2015.01); ***H01Q 5/378*** (2015.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

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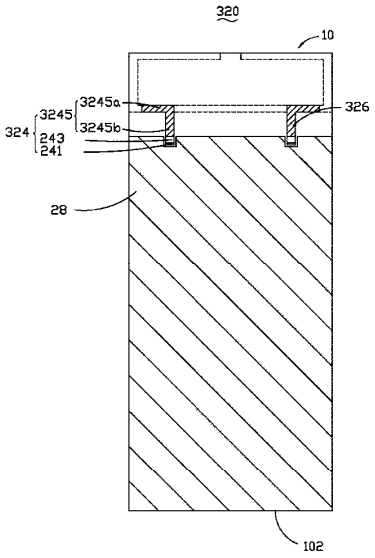
Primary Examiner — Robert Karacsony

(74) *Attorney, Agent, or Firm* — Steven Reiss

(57) **ABSTRACT**

An antenna disposed on a substrate includes a radiating portion, a first coupling and feeding portion, and a second coupling and feeding portion. A length of the radiating portion is substantially equal to a half wavelength of electromagnetic signals radiated by the radiating portion. Each coupling and feeding portion includes a feeding part and a coupling part. The feeding part feeds the electromagnetic signals to the radiating portion via the coupling part so as to achieve effects of a multiple-input multiple-output (MIMO) antenna.

4 Claims, 29 Drawing Sheets



US009755302B2

(12) **United States Patent**
Flores-Cuadras et al.

(10) **Patent No.: US 9,755,302 B2**
(45) **Date of Patent: Sep. 5, 2017**

(54) **MULTIPATH OPEN LOOP ANTENNA WITH WIDEBAND RESONANCES FOR WAN COMMUNICATIONS**

(71) Applicant: **Taoglas Group Holdings Limited**, Enniscorthy (IE)

(72) Inventors: **Javier Ruben Flores-Cuadras**, Tijuana (MX); **Ming Wei-Chen**, Zhongli (TW)

(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.: **14/603,201**

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

(65) **Prior Publication Data**

US 2015/0303556 A1 Oct. 22, 2015

Related U.S. Application Data

(60) Provisional application No. 61/930,143, filed on Jan. 22, 2014.

(51) **Int. Cl.**

H01Q 21/00	(2006.01)
H01Q 1/38	(2006.01)
H01Q 1/08	(2006.01)
H01Q 1/24	(2006.01)
H01Q 7/00	(2006.01)
H01Q 5/364	(2015.01)
H01Q 5/392	(2015.01)

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

CPC ***H01Q 1/38*** (2013.01); ***H01Q 1/085*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 5/364*** (2015.01); ***H01Q 5/392*** (2015.01); ***H01Q 7/00*** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

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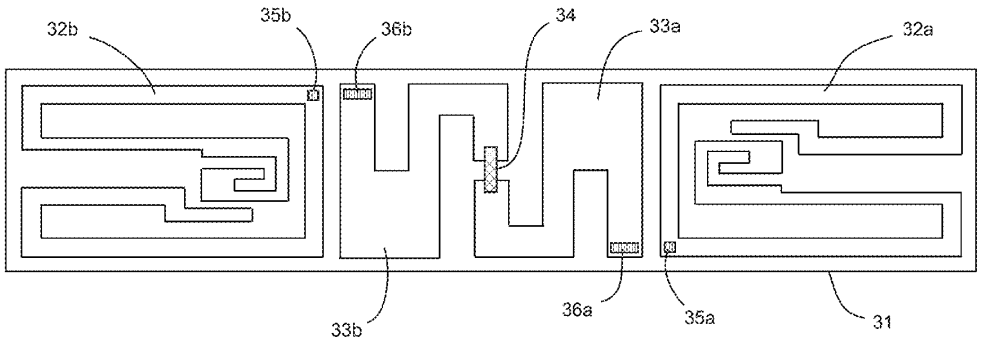
Primary Examiner — Trinh Dinh

(74) *Attorney, Agent, or Firm* — Coastal Patent Law Group, P.C.

(57) **ABSTRACT**

The disclosure concerns an antenna with open loops and multipath current distribution to achieve ultra wideband characteristics and antenna miniaturization, while simultaneously keeping high performance for a more reliable WAN communication, with higher data transfer, less dropping connections and improved sensitivity. To further reduce spatial requirements, the antenna may be incorporated on a flex substrate for bending with the contour of a device housing or the like.

5 Claims, 7 Drawing Sheets



US009755307B2

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

(10) **Patent No.: US 9,755,307 B2**
(45) **Date of Patent: Sep. 5, 2017**

(54) **ANTENNA STRUCTURE AND WIRELESS COMMUNICATION DEVICE EMPLOYING SAME**

(71) Applicant: **FIH (Hong Kong) Limited**, Kowloon (HK)

(72) Inventors: **Chuan-chou Chi**, New Taipei (TW); **Hao-Ying Chang**, New Taipei (TW)

(73) Assignee: **FIH (HONG KONG) LIMITED**, Kowloon (HK)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 266 days.

(21) Appl. No.: **14/469,881**

(22) Filed: **Aug. 27, 2014**

(65) **Prior Publication Data**

US 2015/0061943 A1 Mar. 5, 2015

(30) **Foreign Application Priority Data**

Aug. 29, 2013 (TW) ..... 102131141 A

(51) **Int. Cl.**

H01Q 5/00	(2015.01)
H01Q 21/30	(2006.01)
H01Q 5/371	(2015.01)
H01Q 5/378	(2015.01)

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

CPC ***H01Q 5/371*** (2015.01); ***H01Q 5/378*** (2015.01); ***H01Q 21/30*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 5/371; H01Q 5/378; H01Q 21/30

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

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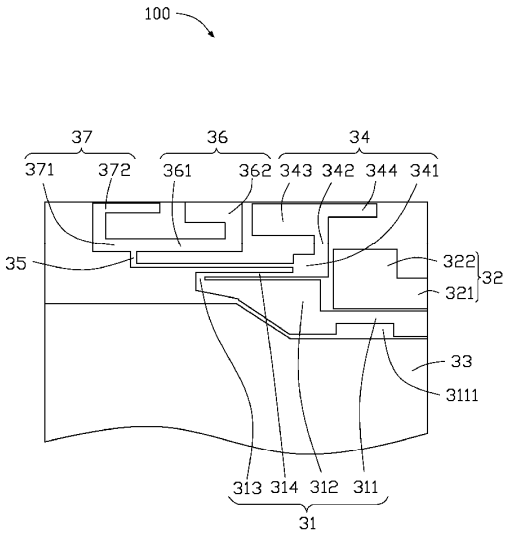
Primary Examiner — Robert Karacsony
Assistant Examiner — Amal Patel
(74) *Attorney, Agent, or Firm* — Steven Reiss

(57) **ABSTRACT**

An antenna structure includes a feeding portion, a first grounding portion, a second grounding portion, a first radiating portion, a second radiating portion, a third radiating portion, and a fourth radiating portion. The feeding portion is configured to feed current signals. The first and second grounding portions are positioned at two opposite sides of the feeding portion respectively. The first, second and third radiating portions cooperatively form a first current path to excite a low-frequency resonate mode and a first high-frequency resonate mode; the first radiating portion resonates with the first grounding portion to excite a second high-frequency resonate mode; the second, third and fourth radiating portion cooperatively form a second current path to excite a third high-frequency resonate mode.

6 Claims, 4 Drawing Sheets



US009755308B2

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

(10) **Patent No.: US 9,755,308 B2**
(45) **Date of Patent: Sep. 5, 2017**

(54) **ANTENNA STRUCTURE AND WIRELESS COMMUNICATION DEVICE EMPLOYING SAME**

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

(72) Inventors: **Geng-Hong Liou**, New Taipei (TW); **Yen-Hui Lin**, New Taipei (TW)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 157 days.

(21) Appl. No.: **14/508,261**

(22) Filed: **Oct. 7, 2014**

(65) **Prior Publication Data**

US 2015/0097753 A1 Apr. 9, 2015

(30) **Foreign Application Priority Data**

Oct. 9, 2013 (CN) 2013 1 0466065

(51) **Int. Cl.**

H01Q 21/00 (2006.01)
H01Q 7/00 (2006.01)
H01Q 5/40 (2015.01)
H01Q 1/50 (2006.01)

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

CPC ***H01Q 7/00*** (2013.01); ***H01Q 5/40*** (2015.01); *H01Q 1/50* (2013.01); *H01Q 21/00* (2013.01)

(58) **Field of Classification Search**

USPC ..... 343/700 MS, 702, 867, 795
See application file for complete search history.

(56) **References Cited**

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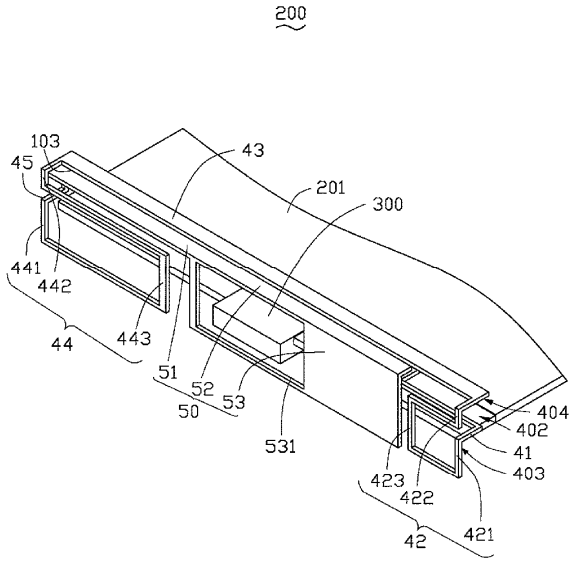
Primary Examiner — Jessica Han
Assistant Examiner — Hai Tran
(74) *Attorney, Agent, or Firm* — Steven Reiss

(57) **ABSTRACT**

An antenna structure includes a feeding portion, a first grounding portion, a second grounding portion, a first loop antenna and a second loop antenna. The feeding portion has a first side and a second side parallel to the first side. The first grounding portion is positioned adjacent and apart from the first side of the feeding portion. The second grounding portion is positioned adjacent and apart from the second side of the grounding portion. The first loop antenna is defined to accept a second loop antenna therein, and is electronically coupled to the first and second grounding portions. The second loop antenna is positioned inside and apart from the first loop antenna, and further electronically coupled to the feeding portion.

18 Claims, 5 Drawing Sheets



US009755310B2

(12) **United States Patent**
Quinlan

(10) **Patent No.: US 9,755,310 B2**
(45) **Date of Patent: Sep. 5, 2017**

(54) **TEN-FREQUENCY BAND ANTENNA**

(71) Applicant: **TAOGLAS LIMITED**, Taoyuan (TW)

(72) Inventor: **Ronan Quinlan**, Taoyuan (TW)

(73) Assignee: **TAOGLAS LIMITED**, Taoyuan (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 164 days.

(21) Appl. No.: **14/948,226**

(22) Filed: **Nov. 20, 2015**

(65) **Prior Publication Data**

US 2017/0149138 A1 May 25, 2017

(51) **Int. Cl.**
H01Q 1/38 (2006.01)
H01Q 9/04 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 9/04*** (2013.01); ***H01Q 1/38*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 5/10; H01Q 5/30; H01Q 5/307; H01Q 5/342; H01Q 5/357; H01Q 5/364; H01Q 5/371; H01Q 1/22; H01Q 1/2258–1/243; H01Q 1/245; H01Q 1/38; H01Q 9/04; H01Q 9/40; H01Q 9/42
See application file for complete search history.

(56) **References Cited**

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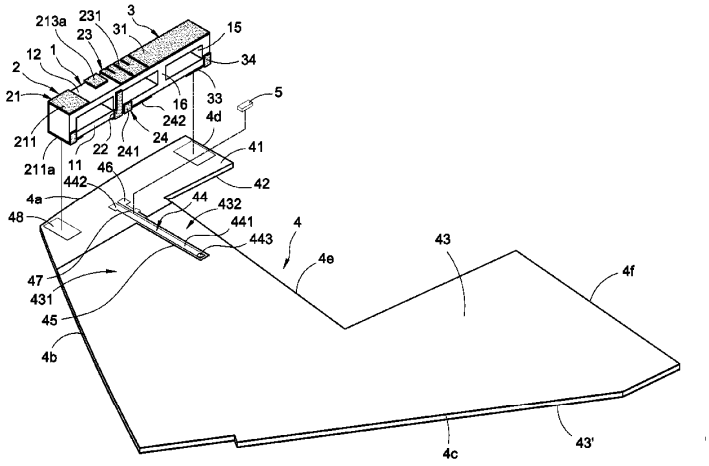
Primary Examiner — Tho G Phan
Assistant Examiner — Patrick Holecek
(74) *Attorney, Agent, or Firm* — Chun-Ming Shih; HDLS IPR Services

(57) **ABSTRACT**

A ten-frequency band antenna includes a carrier, a high-frequency segment, a low-frequency segment, a printed circuit board (PCB) and an inductor. The high-frequency segment is arranged on left side of the carrier and the low-frequency segment is arranged on right side of the carrier. The radiator on the bottom face of the carrier electrically connects with the micro strip of the PCB and the ground line of the ground metal when the carrier is fixed to the PCB. The low-frequency segment is located at an opened area and corresponding to a metal face with smaller area such that the low-frequency segment is at a free space to enhance the frequency response of the low-frequency segment and the bandwidth of the high-frequency segment. The area and the volume of blind hole on the carrier can adjust the effective dielectric constant to adjust the resonant frequency and bandwidth of the antenna.

14 Claims, 9 Drawing Sheets



US009755684B2

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

(10) **Patent No.: US 9,755,684 B2**
(45) **Date of Patent: Sep. 5, 2017**

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

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

(72) Inventors: **Chae-Up Yoo**, Seoul (KR); **Jung-Kyu Lee**, Gyeonggi-do (KR); **Byung-Man Lim**, Seoul (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 0 days.

(21) Appl. No.: **15/055,096**

(22) Filed: **Feb. 26, 2016**

(65) **Prior Publication Data**

US 2016/0254832 A1 Sep. 1, 2016

(30) **Foreign Application Priority Data**

Feb. 26, 2015 (KR) 10-2015-0027594

(51) **Int. Cl.**
H04M 1/00 (2006.01)
H04B 1/3827 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04B 1/3838*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 5/35*** (2015.01); ***H01Q 5/378*** (2015.01); ***H01Q 9/42*** (2013.01)

(58) **Field of Classification Search**
CPC H04M 1/0277; H05K 13/0023; H05K 5/0017; H05K 5/0217; H05K 5/03; H05K 5/04; H05K 7/1417; H05K 9/0015
(Continued)

(56) **References Cited**

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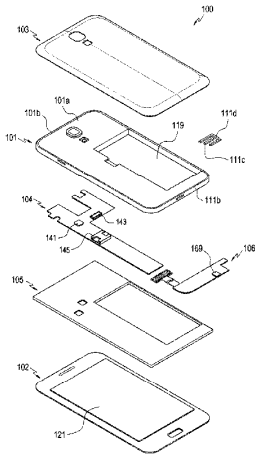
Primary Examiner — Tu X Nguyen
(74) *Attorney, Agent, or Firm* — The Farrell Law Firm, P.C.

(57) **ABSTRACT**

An electronic device including an antenna device is provided. The electronic device includes a case member, a frame disposed around a periphery of one surface of the case member, forming sidewalls, and an antenna device for transmitting and receiving wireless signals. The antenna device includes a first radiation conductor forming a first part of the frame, a second radiation conductor disposed in a vicinity of the first radiation conductor, forming a second part of the frame, a third radiation conductor provided on the case member and connected to a first power supply of the electronic device, together with the first radiation conductor, and a fourth radiation conductor provided on the case member and connected to a ground of the electronic device. At least a part of the fourth radiation conductor is disposed in a vicinity of the second radiation conductor.

28 Claims, 11 Drawing Sheets



US009761925B2

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

(10) **Patent No.: US 9,761,925 B2**
(45) **Date of Patent: Sep. 12, 2017**

(54) **MULTI-BAND ANTENNA AND TERMINAL DEVICE**

(71) Applicant: **SONY MOBILE COMMUNICATIONS AB**, Lund (SE)

(72) Inventors: **Takahiro Sato**, Tokyo (JP); **Tomihiro Omuro**, Tokyo (JP)

(73) Assignees: **Sony Corporation**, Tokyo (JP); **Sony Mobile Communications 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 574 days.

(21) Appl. No.: **13/765,319**

(22) Filed: **Feb. 12, 2013**

(65) **Prior Publication Data**

US 2014/0225781 A1 Aug. 14, 2014

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 9/42 (2006.01)
H01Q 5/371 (2015.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 5/371*** (2015.01); ***H01Q 9/42*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 5/371; H01Q 9/42
USPC 343/702, 828
See application file for complete search history.

(56) **References Cited**

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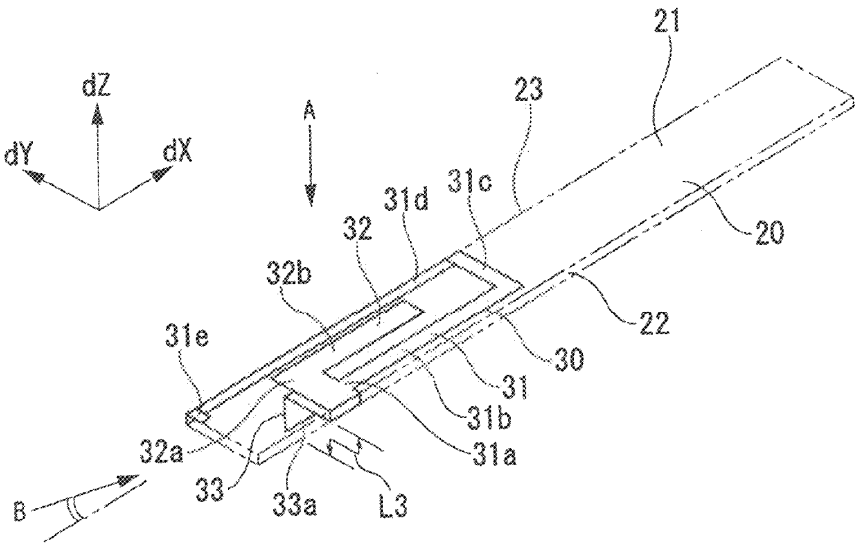
* cited by examiner

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

(57) **ABSTRACT**

An antenna that includes a first element extending from a connection point, and has a curvature such that a first tip end of the first element extends in a direction toward the connection point. A second element is connected to the connection point, and has a second tip end that extends in a direction away from the connection point, the second tip being disposed within an outer periphery of the first element. A distance between a portion of the first element that is parallel to the second element is greater than $\lambda_{gx}/100$, where λ_{gx} represents an effective wavelength of a first anti-resonance frequency.

21 Claims, 46 Drawing Sheets



US009761926B2

(12) **United States Patent**
Suh

(10) **Patent No.: US 9,761,926 B2**
(45) **Date of Patent: Sep. 12, 2017**

(54) **ANTENNA AND MOBILE DEVICE THEREWITH**

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

(72) Inventor: **Young-Hoon Suh**, Gyeonggi-do (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 96 days.

(21) Appl. No.: **14/792,323**

(22) Filed: **Jul. 6, 2015**

(65) **Prior Publication Data**

US 2016/0006126 A1 Jan. 7, 2016

(30) **Foreign Application Priority Data**

Jul. 4, 2014 (KR) 10-2014-0083862

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 21/30 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/245*** (2013.01); ***H01Q 21/30*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/245; H01Q 21/30; H01Q 9/0407
USPC ..... 343/700 MS, 702, 872, 873
See application file for complete search history.

(56) **References Cited**

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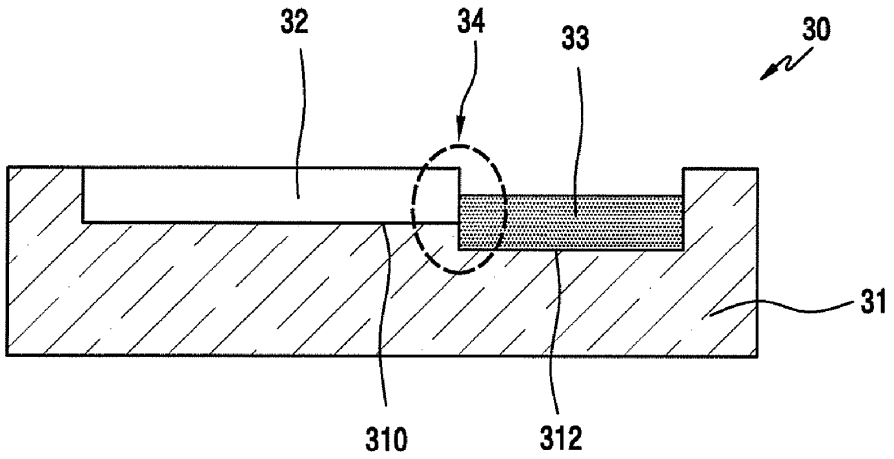
Primary Examiner — Tho G Phan

(57) **ABSTRACT**

An antenna of a mobile device is provided. The antenna includes two antennas that are disposed to be stepped from each other, thereby preventing degradation of an OTA characteristic and reducing an SAR. The antenna includes first and second surfaces stepped from each other on the top surface of an antenna carrier, and a low-band antenna emitter disposed on the first surface and a high-band antenna emitter disposed on the recessed second surface.

16 Claims, 14 Drawing Sheets



US009761927B2

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

(10) **Patent No.: US 9,761,927 B2**
(45) **Date of Patent: Sep. 12, 2017**

(54) **BATTERY CASE WITH SUPPLEMENTAL ANTENNA FEATURES FOR CELLULAR TELEPHONE**

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

(72) Inventors: **Darshan R. Kasar**, San Francisco, CA (US); **Kirill Kalinichev**, San Francisco, CA (US); **Ian P. Colahan**, Menlo Park, CA (US); **Timothy J. Rasmussen**, Sunnyvale, CA (US)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 88 days.

(21) Appl. No.: **14/848,034**

(22) Filed: **Sep. 8, 2015**

(65) **Prior Publication Data**

US 2017/0069955 A1 Mar. 9, 2017

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 9/04	(2006.01)
H01Q 1/40	(2006.01)
H01Q 1/42	(2006.01)

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

CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/40*** (2013.01); ***H01Q 1/42*** (2013.01); ***H01Q 9/0442*** (2013.01)

(58) **Field of Classification Search**

CPC .. H01Q 1/40; H01Q 1/42; H01Q 1/24; H01Q 1/241; H01Q 1/242; H01Q 1/243; H04M 1/0237; H04M 1/0264; H04M 1/0272; H04M 1/0283; H04M 1/03; H04M 1/21; H04M 1/72522

See application file for complete search history.

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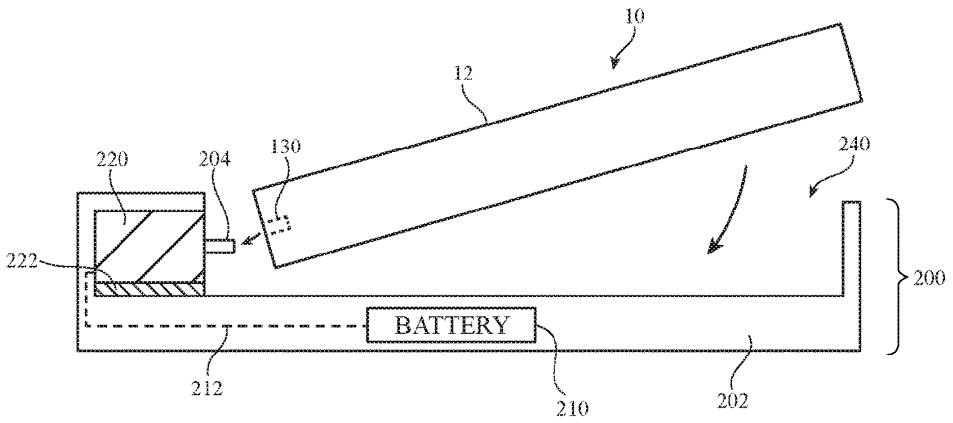
Primary Examiner — Hoang Nguyen

(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; G. Victor Treyz; Zachary D. Hadd

(57) **ABSTRACT**

A removable case may receive an electronic device. A male connector in the case may mate with a female connector in the device. A battery in the case may supply power to the device through the male connector. The electronic device may have an antenna. The case may have a supplemental antenna that compensates for variations in performance in the antenna when the device is received within the case. The supplemental antenna may be a parasitic antenna resonating element that is formed from metal traces on a flexible printed circuit. The flexible printed circuit, a metal trim structure, and a plastic support structure may form portions of a connector support structure in the case.

20 Claims, 6 Drawing Sheets



US009761936B2

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

(10) **Patent No.: US 9,761,936 B2**
(45) **Date of Patent: Sep. 12, 2017**

(54) **PLANAR INVERTED-F ANTENNA**

(71) Applicant: **FOXCONN INTERCONNECT TECHNOLOGY LIMITED**, Grand Cayman (KY)

(72) Inventors: **Tzu-Yao Hwang**, New Taipei (TW); **Lung-Sheng Tai**, New Taipei (TW)

(73) Assignee: **FOXCONN INTERCONNECT TECHNOLOGY LIMITED**, Grand Cayman (KY)

(*) 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.: **14/810,725**

(22) Filed: **Jul. 28, 2015**

(65) **Prior Publication Data**

US 2016/0036129 A1 Feb. 4, 2016

(30) **Foreign Application Priority Data**

Jul. 30, 2014 (TW) ..... 103213468 U

(51) **Int. Cl.**
H01Q 1/48 (2006.01)
H01Q 9/04 (2006.01)
H01Q 5/371 (2015.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/48*** (2013.01); ***H01Q 9/0421*** (2013.01); *H01Q 5/371* (2015.01)

(58) **Field of Classification Search**
CPC H01Q 9/045; H01Q 1/48
USPC 343/848
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

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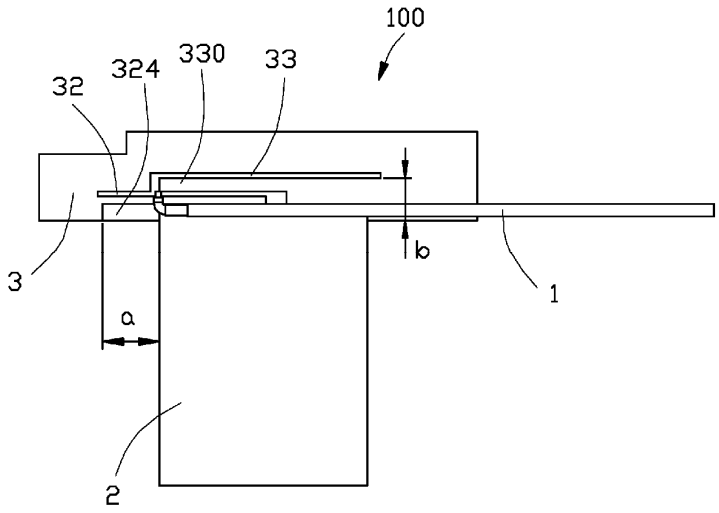
Primary Examiner — Dameon E Levi
Assistant Examiner — Andrea Lindgren Baltzell
(74) *Attorney, Agent, or Firm* — Wei Te Chung; Ming Chieh Chang

(57) **ABSTRACT**

A planar inverted-F antenna includes an antenna body including a grounding portion, a first and a second radiating arm extending in a lengthwise direction substantially, a coaxial cable and a metal foil attached the grounding portion. The first radiating arm and the second radiating arm extend in opposite directions from a joint point thereof, the joint point and the grounding portion connect with each other by a connecting portion. A first slot is defined between the first radiating arm and the grounding arm, a second slot is defined between the second radiating arm and the grounding portion. A coaxial cable includes a core soldered to the joint point and a shielding layer soldered to the grounding portion. The metal foil covers a most portion of the grounding portion, thereby exposes a first end of the grounding portion near to the first radiating arm to an exterior.

18 Claims, 4 Drawing Sheets



US009761943B2

(12) **United States Patent**
Yang

(10) **Patent No.: US 9,761,943 B2**
(45) **Date of Patent: Sep. 12, 2017**

(54) **ANTENNA STRUCTURE**

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

(72) Inventor: **Chung-Wen Yang**, New Taipei (TW)

(73) Assignee: **ACER INCORPORATED**, New Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 30 days.

(21) Appl. No.: **14/828,797**

(22) Filed: **Aug. 18, 2015**

(65) **Prior Publication Data**

US 2016/0359231 A1 Dec. 8, 2016

(30) **Foreign Application Priority Data**

Jun. 3, 2015 (TW) ..... 104117909 A

(51) **Int. Cl.**

H01Q 1/48	(2006.01)
H01Q 5/371	(2015.01)
H01Q 1/24	(2006.01)
H01Q 7/00	(2006.01)
H01Q 5/40	(2015.01)

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

CPC ***H01Q 5/371*** (2015.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 5/40*** (2015.01); ***H01Q 7/00*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 5/371; H01Q 1/38; H01Q 5/307; H01Q 1/243

USPC ..... 343/845, 700 MS, 720, 702

See application file for complete search history.

(56) **References Cited**

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European Search Report dated Oct. 18, 2016, issued in application No. 15191180.7-1811.

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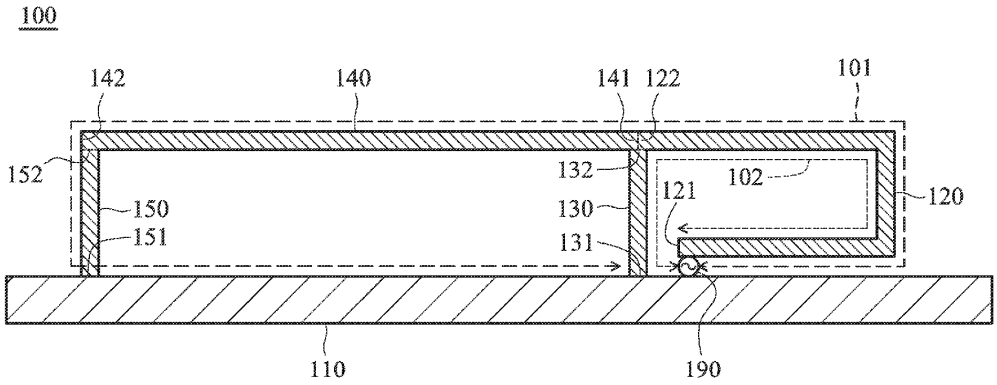
Primary Examiner — Dameon E Levi
Assistant Examiner — Collin Dawkins
(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(57) **ABSTRACT**

An antenna structure includes a ground element, a first radiation branch, a first ground branch, a second radiation branch, and a second ground branch. A first end of the first radiation branch is coupled to a signal source. A first end of the first ground branch is coupled to the ground element. A second end of the first ground branch is coupled to a second end of the first radiation branch. A first end of the second radiation branch is coupled to the second end of the first radiation branch. A first end of the second ground branch is coupled to the ground element. A second end of the second ground branch is coupled to a second end of the second radiation branch.

8 Claims, 8 Drawing Sheets



US009762710B2

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

(10) **Patent No.: US 9,762,710 B2**
(45) **Date of Patent: Sep. 12, 2017**

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

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

(72) Inventors: **Hyung Joo Lee**, Seongnam-si (KR); **Gyu Sub Kim**, Seoul (KR); **Dong Yeon Kim**, Suwon-si (KR); **Chae Up Yoo**, 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 0 days.

(21) Appl. No.: **15/234,547**

(22) Filed: **Aug. 11, 2016**

(65) **Prior Publication Data**

US 2017/0048363 A1 Feb. 16, 2017

(30) **Foreign Application Priority Data**

Aug. 13, 2015 (KR) 10-2015-0114638

(51) **Int. Cl.**
H04B 1/44 (2006.01)
H04M 1/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04M 1/0202*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 1/521*** (2013.01); ***H01Q 5/314*** (2015.01); ***H01Q 5/328*** (2015.01); ***H01Q 5/35*** (2015.01); ***H04B 1/3833*** (2013.01); ***H04B 1/48*** (2013.01); *H04B 2001/485* (2013.01); *H04W 4/008* (2013.01); *H04W 84/042* (2013.01); *H04W 84/12* (2013.01)

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

(56) **References Cited**

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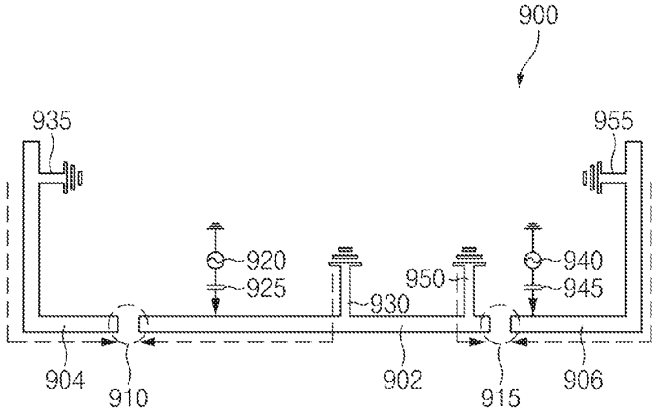
Primary Examiner — Tuan A Tran
(74) *Attorney, Agent, or Firm* — Jefferson IP Law, LLP

(57) **ABSTRACT**

An electronic device is provided. The electronic device includes a housing including a first surface, a second surface disposed facing an opposite side of the first surface, and a side surface configured to surround at least a portion of a space between the first surface and the second surface, a first elongated metal member configured to form a first portion of the side surface and including a first end and a second end, at least one communication circuit electrically connected to a first point of the first elongated metal member through a capacitive element, at least one ground member disposed in an interior of the housing, and a first conductive member configured to electrically connect a second point of the first elongated metal member to the ground member. The second point of the first elongated metal member is disposed closer to the second end than to the first point.

17 Claims, 42 Drawing Sheets



US009768491B2

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

(10) **Patent No.: US 9,768,491 B2**
(45) **Date of Patent: Sep. 19, 2017**

(54) **ELECTRONIC DEVICE WITH PERIPHERAL HYBRID ANTENNA**

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

(72) Inventors: **Nanbo Jin**, Milpitas, CA (US); **Anand Lakshmanan**, San Jose, CA (US); **Enrique Ayala Vazquez**, Watsonville, CA (US); **Erica J. Tong**, Pacifica, CA (US); **Hongfei Hu**, Santa Clara, CA (US); **Matthew A. Mow**, Los Altos, CA (US); **Mattia Pascolini**, San Francisco, CA (US); **Ming-Ju Tsai**, Cupertino, 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 120 days.

(21) Appl. No.: **14/691,304**

(22) Filed: **Apr. 20, 2015**

(65) **Prior Publication Data**

US 2016/0308271 A1 Oct. 20, 2016

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 1/48	(2006.01)
H01Q 1/50	(2006.01)
H04B 1/3888	(2015.01)
H01Q 13/10	(2006.01)
H01Q 21/28	(2006.01)

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

CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 1/50*** (2013.01); ***H01Q 13/103*** (2013.01); ***H01Q 21/28*** (2013.01); ***H04B 1/3888*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 1/48; H01Q 1/50; H01Q 21/28; H01Q 13/103

USPC 343/846, 848, 702

See application file for complete search history.

(56) **References Cited**

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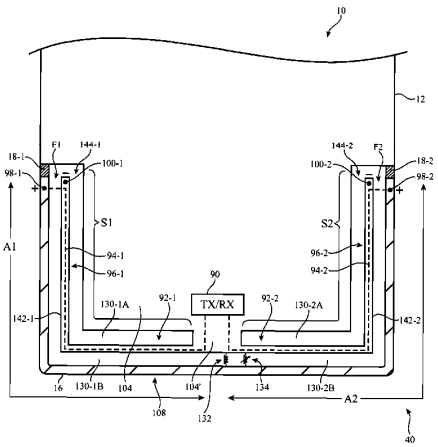
Primary Examiner — Dieu H Duong

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

(57) **ABSTRACT**

An electronic device may have wireless circuitry with antennas. An antenna resonating element arm for an antenna may be formed from peripheral conductive structures running along the edges of a device housing. Elongated conductive members may longitudinally divide openings between the peripheral conductive housing structures and the ground. The elongated conductive members may extend from an internal ground to outer ends of the elongated conductive members that are located adjacent to the gaps. Transmission lines may extend along the elongated conductive members to antenna feeds at the outer ends. The elongated conductive members may form open slots that serve as slot antenna resonating elements for the antenna.

21 Claims, 9 Drawing Sheets



US009768492B2

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

(10) **Patent No.: US 9,768,492 B2**
(45) **Date of Patent: *Sep. 19, 2017**

(54) **ANTENNA APPARATUS FOR PORTABLE TERMINAL**

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

(72) Inventors: **Jae-Hee Kim**, Gyeonggi-do (KR); **Joon-Ho Byun**, Gyeonggi-do (KR); **Se-Hyun Park**, Gyeonggi-do (KR); **Dong-Hyun Lee**, Gyeonggi-do (KR); **Austin Kim**, 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 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/180,326**

(22) Filed: **Jun. 13, 2016**

(65) **Prior Publication Data**

US 2016/0285156 A1 Sep. 29, 2016

Related U.S. Application Data

(63) Continuation of application No. 14/719,642, filed on May 22, 2015, now Pat. No. 9,385,418, which is a (Continued)

(30) **Foreign Application Priority Data**

Apr. 14, 2011 (KR) 10-2011-0034548

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

(52) **U.S. Cl.**
CPC ***H01Q 1/243*** (2013.01); ***H01Q 1/44*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 1/50*** (2013.01); ***H01Q 21/28*** (2013.01); ***H01Q 21/29*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/50; H01Q 1/48; H01Q 1/44; H01Q 21/29; H01Q 21/28
(Continued)

(56) **References Cited**

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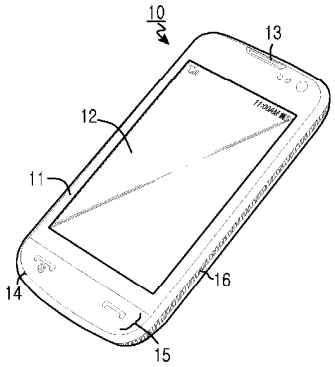
Chinese Search Report dated Aug. 3, 2016.

Primary Examiner — Huedung Mancuso
(74) *Attorney, Agent, or Firm* — Cha & Reiter, LLC

(57) **ABSTRACT**

An antenna apparatus for a portable terminal having a main board is provided. The antenna apparatus includes a main antenna that electrically connects to a feed line of the main board. A metal frame is constructed as part of a case frame forming an exterior of the portable terminal. The metal frame is divided into first and second parts that are separated. The first part electrically connects to the main antenna or to the main board feed line, and is designed to radiate. The second part electrically connects to a ground surface of the
(Continued)



US009768505B2

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

(10) **Patent No.: US 9,768,505 B2**
(45) **Date of Patent: Sep. 19, 2017**

(54) **MIMO ANTENNA WITH NO PHASE CHANGE**

(75) Inventors: **Jeong Hoon Cho**, Seoul (KR); **Kyung Suk Kim**, Seoul (KR); **Ja Kwon Ku**, Seoul (KR); **Sung Tek Kahng**, Seoul (KR); **Geon Ho Jang**, Seoul (KR); **Seong Ryong Yoo**, Seoul (KR)

(73) Assignees: **LG INNOTEK CO., LTD.**, Seoul (KR); **INDUSTRY-ACADEMIC COOPERATION FOUNDATION INCHEON NATIONAL UNIVERSITY**, Incheon (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 394 days.

(21) Appl. No.: **13/978,359**

(22) PCT Filed: **Oct. 10, 2011**

(86) PCT No.: **PCT/KR2011/007493**
§ 371 (c)(1),
(2), (4) Date: **Nov. 12, 2013**

(87) PCT Pub. No.: **WO2012/093766**
PCT Pub. Date: **Jul. 12, 2012**

(65) **Prior Publication Data**

US 2014/0055319 A1 Feb. 27, 2014

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/38 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 5/0093*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 3/24*** (2013.01); ***H01Q 5/50*** (2015.01); ***H01Q 21/28*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/38; H01Q 1/243; H01Q 5/50; H01Q 5/0093; H01Q 3/24; H01Q 1/36;
(Continued)

(56) **References Cited**

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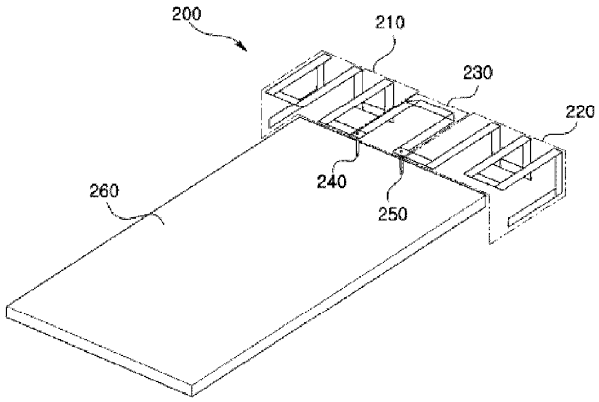
Primary Examiner — Jessica Han
Assistant Examiner — Awat Salih
(74) *Attorney, Agent, or Firm* — Saliwanchik, Lloyd & Eisenschenk

(57) **ABSTRACT**

A multi input multi output (MIMO) antenna with no phase change is provided. The MIMO antenna having no phase change constituting one antenna structure overall, wherein unit structures at both sides are symmetrical to each other in a meander form with respect to the center; the unit structures having the meander form are connected to a ground plate by using as a medium power feeding units **240** and **250** supplying an electric energy to the respective unit structures; and the unit structures are installed with a three-dimensional structure, being adjacent to the ground plate.

8 Claims, 5 Drawing Sheets



US009768506B2

(12) **United States Patent**
Krogerus

(10) **Patent No.: US 9,768,506 B2**
(45) **Date of Patent: Sep. 19, 2017**

(54) **MULTI-ANTENNNA ISOLATION ADJUSTMENT**

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

(72) Inventor: **Joonas Krogerus**, Espoo (FI)

(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 72 days.

(21) Appl. No.: **14/854,353**

(22) Filed: **Sep. 15, 2015**

(65) **Prior Publication Data**

US 2017/0077603 A1 Mar. 16, 2017

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 5/30	(2015.01)
H01Q 5/10	(2015.01)
H01Q 1/38	(2006.01)
H01Q 1/50	(2006.01)
H01Q 5/328	(2015.01)
H01Q 1/42	(2006.01)
H01Q 1/52	(2006.01)
H01Q 13/10	(2006.01)
H01Q 21/28	(2006.01)

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

CPC ***H01Q 5/30*** (2015.01); ***H01Q 1/24*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 1/42*** (2013.01); ***H01Q 1/50*** (2013.01); ***H01Q 1/52*** (2013.01); ***H01Q 5/10*** (2015.01); ***H01Q 5/328*** (2015.01); ***H01Q 13/10*** (2013.01); ***H01Q 21/28*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 13/10; H01Q 1/243; H01Q 5/35; H01Q 5/357

See application file for complete search history.

(56) **References Cited**

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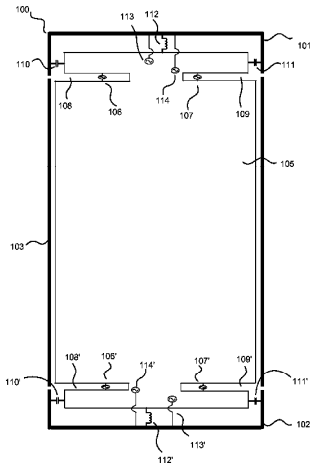
Primary Examiner — Hoang Nguyen

(57) **ABSTRACT**

In an embodiment, isolation between antennas of a multi antenna system is disclosed. According to another embodiment, a device is disclosed comprising a conductive portion of a cover of the device; a first antenna feed configured to a first radio frequency band; a second antenna feed configured to a second radio frequency band; at least two slots of a printed wiring board, feeds being coupled to the slots and slots being coupled to the conductive portion; a first capacitive component; a second capacitive component; wherein the first and the second capacitive component are configured between the printed wiring board and the conductive portion.

20 Claims, 10 Drawing Sheets



US009768507B2

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

(10) **Patent No.: US 9,768,507 B2**
(45) **Date of Patent: Sep. 19, 2017**

(54) **ANTENNA DEVICES HAVING FREQUENCY-DEPENDENT CONNECTION TO ELECTRICAL GROUND**

(71) Applicant: **Tyco Electronics Services GmbH**, Schaffhausen (CH)

(72) Inventors: **Sunil Kumar Rajgopal**, San Diego, CA (US); **Cheng Jung Lee**, Santa Clara, CA (US); **Ajay Gummalla**, Sunnyvale, CA (US)

(73) Assignee: **Tyco Electronics Services GmbH** (CH)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 237 days.

(21) Appl. No.: **14/467,708**

(22) Filed: **Aug. 25, 2014**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(58) **Field of Classification Search**

None

See application file for complete search history.

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(57) **ABSTRACT**

Antenna devices and techniques that provide specific control of the spatial distributions of DC and RF signals at various positions in a wireless apparatus are disclosed. The wireless apparatus includes various device components each having specifications for achieving desired operations in antenna devices.

13 Claims, 41 Drawing Sheets