

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

(10) **Patent No.:** **US 10,290,922 B2**
(45) **Date of Patent:** **May 14, 2019**

(54) **ELECTRONIC DEVICE**

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

(72) Inventors: **Jianming Li**, Taipei (TW); **Kun Feng**, Shanghai (CN); **Xuefei Zhang**, Shenzhen (CN); **Hanyang Wang**, Reading (GB)

(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 8 days.

(21) Appl. No.: **15/124,449**

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

(86) PCT No.: **PCT/CN2015/073649**
§ 371 (c)(1),
(2) Date: **Sep. 8, 2016**

(87) PCT Pub. No.: **WO2015/139558**
PCT Pub. Date: **Sep. 24, 2015**

(65) **Prior Publication Data**
US 2017/0025740 A1 Jan. 26, 2017

(30) **Foreign Application Priority Data**
Mar. 21, 2014 (CN) 2014 1 0109571

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

(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 1/50** (2013.01); **H01Q 5/328** (2015.01); **H01Q 5/335** (2015.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 9/42; H01Q 5/328; H01Q 5/335; H01Q 1/48; H01Q 1/50
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2003/0025637 A1* 2/2003 Mendolia H01Q 9/0421 343/702
2004/0041734 A1 3/2004 Shiotsu et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 102956954 A 3/2013
CN 103296385 A 9/2013
(Continued)

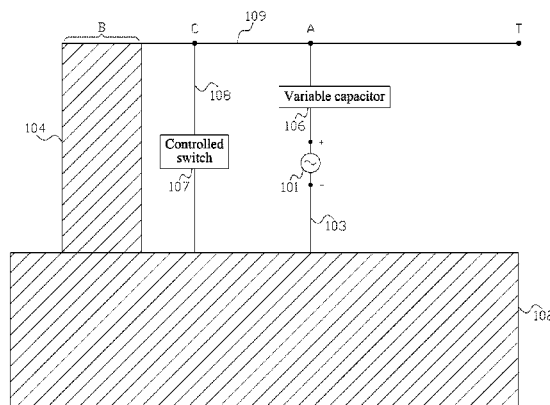
OTHER PUBLICATIONS

International Search Report (including English translation) issued in corresponding International Application No. PCT/CN2015/073649, dated Jun. 12, 2015, 6 pages.
(Continued)

Primary Examiner — Dieu Hien T Duong
(74) *Attorney, Agent, or Firm* — Conley Rose, P.C.

(57) **ABSTRACT**

An electronic device is disclosed, where the electronic device is provided with a metal frame, the electronic device further includes an antenna feeding point, an antenna ground, a feeding branch, a grounding branch, an antenna resonance arm, a variable capacitor, and a control circuit. The antenna resonance arm is a part of the metal frame after segmentation, the antenna feeding point is disposed on the feeding branch, a first connection portion and a second connection portion are disposed on the antenna resonance arm, the feeding branch is disposed between the second connection portion and the antenna ground, the grounding branch is disposed between the first connection portion and the antenna ground, the variable capacitor is disposed on the feeding branch, the variable capacitor is disposed between
(Continued)





US010290923B2

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

(10) **Patent No.:** **US 10,290,923 B2**

(45) **Date of Patent:** **May 14, 2019**

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

USPC 343/702, 904; 455/41.1
See application file for complete search history.

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

(56) **References Cited**

(72) Inventors: **Dong-Uk Choi**, Gyeonggi-do (KR);
Sang-Pil Lee, Gyeonggi-do (KR);
Jangje Park, Gyeonggi-do (KR); **Jinu Kim**, Seoul (KR); **Bumjin Cho**,
Gyeonggi-do (KR); **Inyong Hwang**,
Gyeonggi-do (KR)

U.S. PATENT DOCUMENTS

2012/0214412 A1* 8/2012 Schlub G01B 7/023
455/41.1
2013/0100030 A1* 4/2013 Los G06F 3/023
345/169
2013/0267284 A1* 10/2013 Ryu H04W 88/06
455/575.7

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

FOREIGN PATENT DOCUMENTS

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

KR 10-0720939 5/2007

* cited by examiner

(21) Appl. No.: **15/217,411**

Primary Examiner — Hai V Tran

(22) Filed: **Jul. 22, 2016**

(74) *Attorney, Agent, or Firm* — The Farrell Law Firm, P.C.

(65) **Prior Publication Data**

US 2017/0033442 A1 Feb. 2, 2017

(57) **ABSTRACT**

(30) **Foreign Application Priority Data**

Jul. 31, 2015 (KR) 10-2015-0109186

An electronic device is provided. The electronic device includes a housing including a window that forms a first side of the electronic device, and a second side that is disposed opposite to the first side, a touch sensor disposed adjacent to the window and configured to generate a capacitance, an input circuit operably connected to the touch sensor and configured to detect an input based on a variation in the capacitance, an antenna radiator at least one of partially disposed inside the housing and a part of the housing, a ground operably disposed between the first side and the second side, a communication circuit operably connected to the antenna radiator and the ground, and an antenna matching circuit operably connected to the touch sensor and the input circuit.

(51) **Int. Cl.**

H01Q 1/24 (2006.01)
G06F 3/044 (2006.01)
H01Q 1/38 (2006.01)
H04W 88/06 (2009.01)

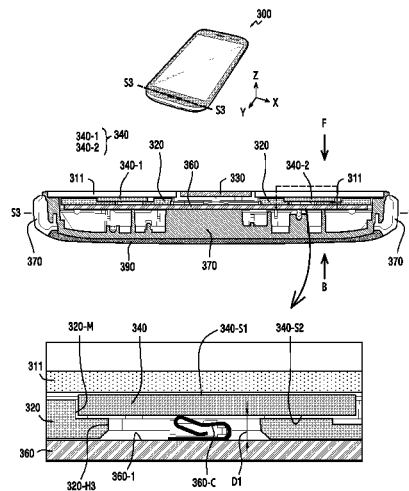
(52) **U.S. Cl.**

CPC **H01Q 1/243** (2013.01); **G06F 3/044** (2013.01); **H01Q 1/24** (2013.01); **H01Q 1/38** (2013.01); **H04W 88/06** (2013.01)

(58) **Field of Classification Search**

CPC H04W 88/06; H01Q 1/243; H01Q 1/48; H01Q 5/001; H01Q 1/24; H01Q 1/38; G06F 3/044

16 Claims, 20 Drawing Sheets



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

(10) **Patent No.:** **US 10,290,924 B2**
(45) **Date of Patent:** **May 14, 2019**

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

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/36; H01Q 1/48;
H01Q 9/42; H01Q 13/106; H01Q 19/26
See application file for complete search history.

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

(56) **References Cited**

(72) Inventors: **Ming-Yu Chou**, New Taipei (TW);
Yu-Kai Tseng, New Taipei (TW);
Kuo-Lun Huang, New Taipei (TW)

U.S. PATENT DOCUMENTS

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

9,337,528 B2 * 5/2016 Hammond H01Q 1/243
2013/0285870 A1 * 10/2013 Hotta H01Q 1/243
343/843
2017/0040668 A1 * 2/2017 Ayala Vazquez H01Q 9/42
2017/0117620 A1 * 4/2017 Lapushin H01Q 1/38
2017/0194709 A1 * 7/2017 Jansson H01Q 7/00

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 130 days.

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **15/399,749**

TW 1274439 2/2007
TW M463914 U 10/2013

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

* cited by examiner

(65) **Prior Publication Data**

US 2017/0244154 A1 Aug. 24, 2017

Primary Examiner — Dameon E Levi

Assistant Examiner — David E Lotter

(30) **Foreign Application Priority Data**

(74) *Attorney, Agent, or Firm* — ScienBiziP, P.C.

Feb. 19, 2016 (CN) 2016 1 0093269
May 19, 2016 (CN) 2016 1 0339153

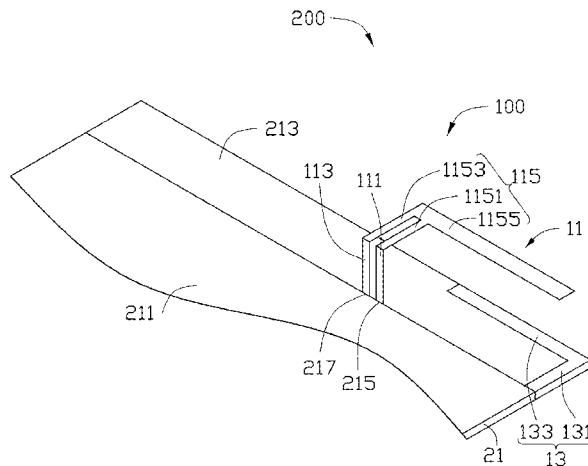
(57) **ABSTRACT**

(51) **Int. Cl.**
H01Q 1/22 (2006.01)
H01Q 1/24 (2006.01)
H01Q 13/10 (2006.01)
H01Q 1/48 (2006.01)
H01Q 1/36 (2006.01)
H01Q 9/42 (2006.01)
H01Q 19/26 (2006.01)

An antenna structure includes a metallic frame and a stub antenna. The metallic frame defines a slot and two gaps. The two gaps are positioned at two ends of the slot and are substantially perpendicular to the slot. The metallic frame is divided into a first portion and a second portion by the slot and the two gaps. A portion of the metallic frame surrounded by the slot and the two gaps forms the first portion. The first portion serves as a radiator of the antenna structure and is grounded through the second portion. The stub antenna is positioned at an interior of the metallic frame and is spaced from the radiator.

(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/36** (2013.01); **H01Q 1/48** (2013.01); **H01Q 9/42** (2013.01); **H01Q 13/106** (2013.01); **H01Q 19/26** (2013.01)

19 Claims, 9 Drawing Sheets



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

(10) **Patent No.:** **US 10,290,925 B2**
(45) **Date of Patent:** **May 14, 2019**

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

H01Q 5/35 (2015.01)
H01Q 5/378 (2015.01)
(52) **U.S. Cl.**
CPC *H01Q 1/243* (2013.01); *H01Q 5/10* (2015.01); *H01Q 5/35* (2015.01); *H01Q 5/371* (2015.01); *H01Q 9/42* (2013.01); *H01Q 13/10* (2013.01); *H01Q 5/378* (2015.01)
(58) **Field of Classification Search**
CPC H01Q 1/242; H01Q 1/243
See application file for complete search history.

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

(72) Inventors: **Kuo-Lun Huang**, New Taipei (TW);
Ming-Yu Chou, New Taipei (TW);
Yu-Kai Tseng, 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 13 days.

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,813,532 B2 * 11/2017 Kim H04M 1/026
10,038,234 B2 * 7/2018 Tseng H01Q 9/42
2011/0183633 A1 * 7/2011 Ohba H01Q 1/243
455/77

(21) Appl. No.: **15/653,668**

(22) Filed: **Jul. 19, 2017**

(65) **Prior Publication Data**

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Related U.S. Application Data

(60) Provisional application No. 62/382,762, filed on Sep. 1, 2016, provisional application No. 62/364,881, filed on Jul. 21, 2016.

(30) **Foreign Application Priority Data**

Jun. 23, 2017 (CN) 2017 1 0487851

(51) **Int. Cl.**

H01Q 1/00 (2006.01)
H01Q 1/24 (2006.01)
H01Q 5/10 (2015.01)
H01Q 5/371 (2015.01)
H01Q 13/10 (2006.01)
H01Q 9/42 (2006.01)

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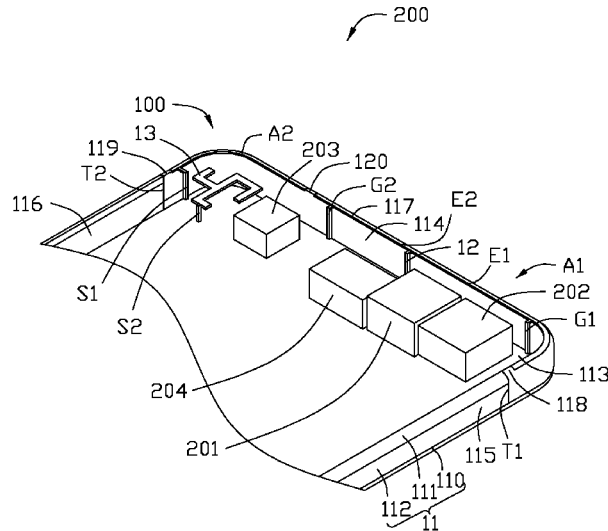
Primary Examiner — Wen W Huang

(74) Attorney, Agent, or Firm — ScienBiziP, P.C.

(57) **ABSTRACT**

An antenna structure which is switchable between low, middle, and high frequencies includes a metal housing, a feed portion, a resonance portion, and a connecting portion. The metal housing includes a front frame, a backboard, and a side frame. The side frame defines a slot and the front frame defines a first gap and a second gap. The slot, the first gap, and the second gap separate a continuous antenna portion from the metal housing. The feed portion is electrically connected to the antenna portion for feeding current to the antenna portion. One end of the resonance portion is electrically connected to a first location of the antenna portion and another end grounded. One end of the connecting portion is electrically connected to a second location of the antenna portion and another end is electrically connected to the resonance portion.

27 Claims, 27 Drawing Sheets



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

(10) **Patent No.:** **US 10,290,940 B2**
(45) **Date of Patent:** **May 14, 2019**

(54) **BROADBAND SWITCHABLE ANTENNA**

USPC 343/772, 846, 724, 876
See application file for complete search history.

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

(56) **References Cited**

(72) Inventors: **Wee Kian Toh**, San Diego, CA (US);
Ping Shi, San Diego, CA (US)

U.S. PATENT DOCUMENTS

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

7,420,513 B2 * 9/2008 Tsutsumi H01Q 9/0428
343/700 MS
8,217,841 B2 * 7/2012 Hossain H01Q 1/243
343/700 MS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 122 days.

(Continued)

(21) Appl. No.: **14/219,292**

(22) Filed: **Mar. 19, 2014**

OTHER PUBLICATIONS

Komulainen, M. et al, "A Frequency Tuning Method for a Planar Inverted-F Antenna," IEEE Transactions on Antennas and Propagation, vol. 56, No. 4, Apr. 2008, pp. 944-950.

(65) **Prior Publication Data**

US 2015/0270613 A1 Sep. 24, 2015

(Continued)

(51) **Int. Cl.**

H01Q 9/04 (2006.01)
H01Q 5/30 (2015.01)
H01Q 5/328 (2015.01)
H01Q 5/357 (2015.01)
H01Q 5/307 (2015.01)
H01Q 5/364 (2015.01)
H01Q 5/371 (2015.01)

Primary Examiner — Dameon E Levi

Assistant Examiner — Ab Salam Alkassim, Jr.

(74) *Attorney, Agent, or Firm* — Jinghua Karen Tang

(Continued)

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

CPC **H01Q 5/30** (2015.01); **H01Q 1/243** (2013.01); **H01Q 5/307** (2015.01); **H01Q 5/314** (2015.01); **H01Q 5/328** (2015.01); **H01Q 5/357** (2015.01); **H01Q 5/364** (2015.01); **H01Q 5/371** (2015.01); **H01Q 9/0421** (2013.01); **H01Q 9/0442** (2013.01); **H01Q 9/42** (2013.01)

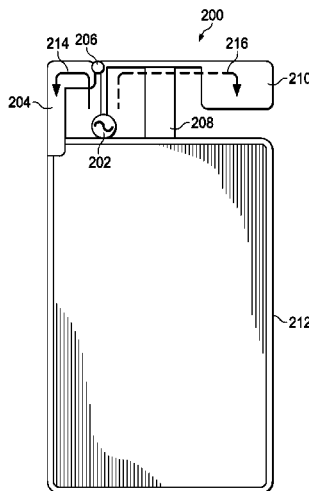
(57) **ABSTRACT**

System and method embodiments are provided for a broadband switchable antenna. The embodiments enable an easily tunable, temporally switchable antenna with good low- and high-band performance with controlled high impedance loci that easily coexists with other wireless device components. In an embodiment, a broadband switchable antenna includes an antenna feed; a high-band antenna arm comprising a first end electrically coupled to an antenna feed and a second end electrically coupled to ground; a switch coupled to the antenna feed at a position proximate to the first end of the high-band antenna arm; and a low-band antenna arm comprising a first end electrically coupled to the switch, wherein the antenna is configured to operate in a high-band mode when the switch is open and to operate in a low-band mode when the switch is closed.

(58) **Field of Classification Search**

CPC H01Q 5/328; H01Q 5/364; H01Q 5/314; H01Q 5/307; H01Q 5/357; H01Q 5/371; H01Q 9/0442

19 Claims, 12 Drawing Sheets





US010290941B2

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

(10) **Patent No.:** **US 10,290,941 B2**
(45) **Date of Patent:** **May 14, 2019**

(54) **ELECTRONIC DEVICE HAVING MULTIBAND ANTENNA WITH EMBEDDED FILTER**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)
(72) Inventors: **Erdinc Irci**, Santa Clara, CA (US); **Carlo Di Nallo**, San Carlos, CA (US); **Jayesh Nath**, Milpitas, CA (US); **Zheyu Wang**, Cupertino, CA (US); **Eduardo Da Costa Bras Lima**, Sunnyvale, CA (US); **Hongfei Hu**, Santa Clara, CA (US); **Mario Martinis**, Cupertino, CA (US); **Mattia Pascolini**, San Francisco, 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 364 days.

(21) Appl. No.: **15/008,130**

(22) Filed: **Jan. 27, 2016**

(65) **Prior Publication Data**
US 2017/0214136 A1 Jul. 27, 2017

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

(52) **U.S. Cl.**
CPC **H01Q 5/321** (2015.01); **H01Q 1/243** (2013.01); **H01Q 5/10** (2015.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/243-1/244; H01Q 5/321
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,436,365 B1 * 10/2008 Tan H01Q 1/243 343/702
9,190,713 B2 * 11/2015 Eom H01Q 1/243
(Continued)

FOREIGN PATENT DOCUMENTS

CN 101501926 A 8/2009
CN 202977704 U 6/2013
(Continued)

OTHER PUBLICATIONS

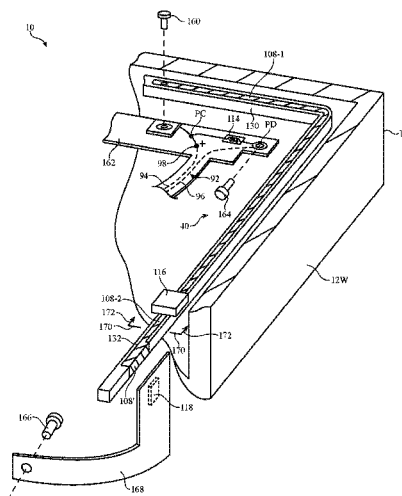
Chaudhary, G. et al., "Dual-Band Bandpass Filter with Independently Tunable Centre Frequencies and Bandwidths", IEEE Transactions on Microwave Theory and Techniques, vol. 61, No. 1, Jan. 2013.

Primary Examiner — Jessica Han
Assistant Examiner — Amal Patel
(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; G. Victor Treyz; David K. Cole

(57) **ABSTRACT**

An electronic device may have a display in a housing with a metal wall. An antenna may have an antenna ground formed from the wall and an antenna resonating element. Transceiver circuitry may be coupled to an antenna feed that extends between the antenna resonating element and the antenna ground. A return path may extend between the antenna resonating element and the antenna ground in parallel with the feed. The antenna resonating element may have segments that are coupled by a frequency dependent filter. At a first frequency, the filter may have a low impedance so that the antenna resonating element has a first effective length. At a second frequency that is greater than the first frequency, the filter may have a high impedance so that the antenna resonating element has a second effective length that is shorter than the first effective length.

20 Claims, 12 Drawing Sheets





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

(10) **Patent No.:** **US 10,290,946 B2**

(45) **Date of Patent:** **May 14, 2019**

(54) **HYBRID ELECTRONIC DEVICE ANTENNAS HAVING PARASITIC RESONATING ELEMENTS**

(56) **References Cited**

U.S. PATENT DOCUMENTS

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

4,016,490 A 4/1977 Weckenmann et al.

4,614,937 A 9/1986 Poujois

(Continued)

(72) Inventors: **Pietro Romano**, Mountain View, CA (US); **Harish Rajagopalan**, San Jose, CA (US); **Umar Azad**, San Jose, CA (US); **Lu Zhang**, West Lafayette, IN (US); **Rodney A. Gomez Angulo**, Sunnyvale, CA (US); **Mattia Pascolini**, San Francisco, CA (US)

FOREIGN PATENT DOCUMENTS

CN 1343380 4/2002

CN 1543010 11/2004

(Continued)

OTHER PUBLICATIONS

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

Myllmaki et al., "Capacitive recognition of the user's hand grip position in mobile handsets", Progress in Electromagnetics Research B, vol. 22, 2010, pp. 203-220.

(Continued)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 201 days.

(21) Appl. No.: **15/274,328**

Primary Examiner — Jessica Han

(22) Filed: **Sep. 23, 2016**

Assistant Examiner — Patrick R Holecek

(65) **Prior Publication Data**

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

Michael H. Lyons; Tianyi He

US 2018/0090847 A1 Mar. 29, 2018

(57) **ABSTRACT**

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 5/30 (2015.01)

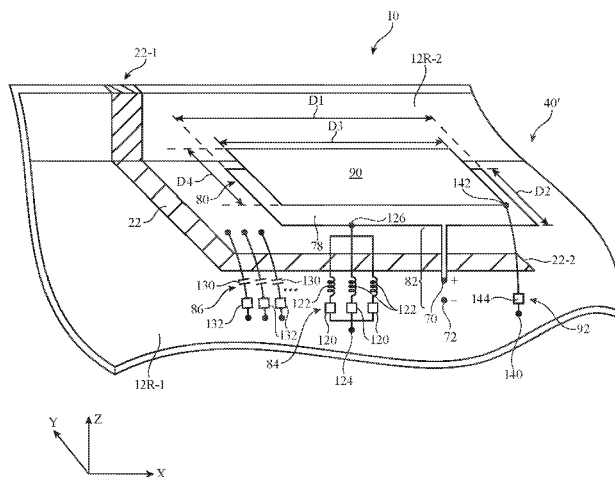
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An electronic device may have a hybrid antenna that includes a slot resonating element formed from a slot in a ground plane and a planar resonating element formed over the slot. A parasitic element may be disposed over the planar element. A switch may couple the parasitic element to the ground. A tunable circuit may couple the planar element to the ground. The switch and tunable circuit may be placed in different tuning states. In a first state, the tunable circuit and switch form open circuits. In a second state, the tunable circuit may an open circuit and the switch is closed. In a third state, the tunable circuit forms a return path and the switch forms an open circuit. This may allow the antenna to operate with satisfactory efficiency in low, mid, and high bands despite volume constraints imposed on the antenna.

(52) **U.S. Cl.**
CPC **H01Q 13/10** (2013.01); **H01Q 1/241** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 5/328** (2015.01); **H01Q 5/385** (2015.01); **H01Q 9/0414** (2013.01); **H01Q 9/285** (2013.01); **H01Q 13/16** (2013.01); **H01Q 13/18** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 5/30; H01Q 5/307; H01Q 5/314; H01Q 5/328; H01Q 5/342; H01Q 5/357;
(Continued)

20 Claims, 10 Drawing Sheets



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

(10) **Patent No.:** **US 10,297,902 B2**
(45) **Date of Patent:** ***May 21, 2019**

(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**, 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 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/704,471**

(22) Filed: **Sep. 14, 2017**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 14/691,304, filed on Apr. 20, 2015, now Pat. No. 9,768,491.

(51) **Int. Cl.**

H01Q 1/24 (2006.01)
H01Q 1/48 (2006.01)

(Continued)

(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 13/103; H01Q 21/28
See application file for complete search history.

(56)

References Cited

U.S. PATENT DOCUMENTS

6,373,439 B1 4/2002 Zurcher et al.
6,903,693 B1 6/2005 Lee et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 102110887 A 6/2011
CN 102394372 A 3/2012
(Continued)

Primary Examiner — Dieu Hien T Duong

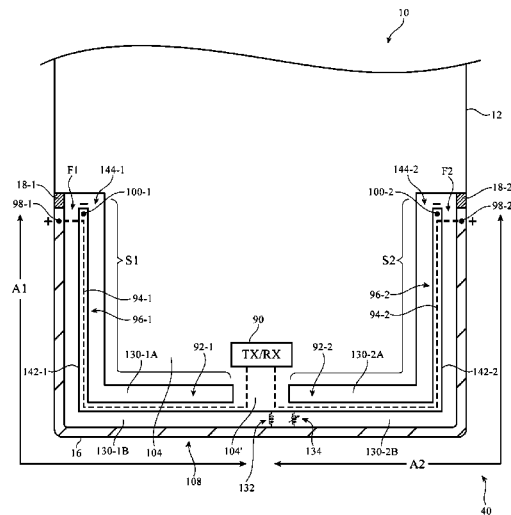
(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; G. Victor Treyz; Michael H. Lyons

(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.

20 Claims, 9 Drawing Sheets



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

(10) **Patent No.:** **US 10,297,905 B2**
(45) **Date of Patent:** **May 21, 2019**

(54) **MOBILE DEVICE**
(71) Applicant: **Quanta Computer Inc.**, Taoyuan (TW)
(72) Inventors: **Yu-Chun Lu**, Taoyuan (TW);
Chun-Yuan Wang, Taoyuan (TW);
Chi-Hsuan Lee, Taoyuan (TW)
(73) Assignee: **QUANTA COMPUTER INC.**,
Guishan Dist., Taoyuan (TW)
(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

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

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,079,079 B2 *	7/2006	Jo	.....	H01Q 1/243
				343/700 MS
2014/0139379 A1 *	5/2014	Bolin	.....	H01Q 1/243
				343/702
2014/0292590 A1 *	10/2014	Yoo	.....	H01Q 1/243
				343/702
2015/0022422 A1 *	1/2015	Chang	.....	H01Q 1/243
				343/861
2015/0123871 A1 *	5/2015	Chang	.....	H01Q 1/243
				343/872

(Continued)

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

(21) Appl. No.: **15/828,668**
(22) Filed: **Dec. 1, 2017**
(65) **Prior Publication Data**
US 2019/0067796 A1 Feb. 28, 2019

(30) **Foreign Application Priority Data**
Aug. 22, 2017 (TW) 106128391 A

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 5/328 (2015.01)
H01Q 5/321 (2015.01)
H01Q 5/335 (2015.01)
H01Q 21/30 (2006.01)
H01Q 1/44 (2006.01)

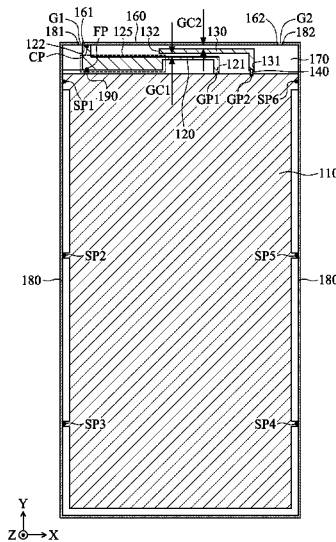
(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/44**
(2013.01); **H01Q 5/321** (2015.01); **H01Q**
5/328 (2015.01); **H01Q 5/335** (2015.01);
H01Q 21/30 (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/24-243; H01Q 1/44; H01Q
5/30-35; H01Q 21/30

(57) **ABSTRACT**

A mobile device includes a ground element, a first radiation element, a second radiation element, a matching circuit, and a first metal frame. The first radiation element is coupled to a first grounding point on the ground element. The second radiation element is coupled through the matching circuit to a second grounding point on the ground element. A first coupling gap is formed between the second radiation element and the first radiation element. The first metal frame is coupled to a connection point on the first radiation element. A second coupling gap is formed between the second radiation element and the first metal frame. An antenna structure is formed by the first radiation element, the second radiation element, the matching circuit, and the first metal frame. A signal source is coupled to a feeding point on the first radiation element, so as to excite the antenna structure.

7 Claims, 6 Drawing Sheets



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

(10) **Patent No.:** **US 10,297,907 B2**
(45) **Date of Patent:** **May 21, 2019**

(54) **MOBILE DEVICE**

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

(72) Inventors: **Ching-Wen Chen**, Hsinchu (TW);
Chia-Hao Chang, Hsinchu (TW)

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

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

(21) Appl. No.: **15/935,347**

(22) Filed: **Mar. 26, 2018**

(65) **Prior Publication Data**
US 2019/0027811 A1 Jan. 24, 2019

Related U.S. Application Data

(60) Provisional application No. 62/534,642, filed on Jul. 19, 2017.

(30) **Foreign Application Priority Data**

Feb. 26, 2018 (TW) 107106337 A

(51) **Int. Cl.**
H01Q 13/10 (2006.01)
H01Q 1/24 (2006.01)
H01Q 5/371 (2015.01)
H04M 1/26 (2006.01)
H04M 1/02 (2006.01)

(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 5/371** (2015.01); **H01Q 13/10** (2013.01); **H04M 1/26** (2013.01); **H04M 1/0283** (2013.01)

(58) **Field of Classification Search**

None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

10,056,696 B2* 8/2018 Tseng H01Q 13/10
2013/0115884 A1* 5/2013 Zhang H01Q 1/243
455/41.2
2013/0207861 A1* 8/2013 Huang H01Q 13/10
343/767

(Continued)

FOREIGN PATENT DOCUMENTS

TW 201703350 A 1/2017
TW 201705610 A 2/2017

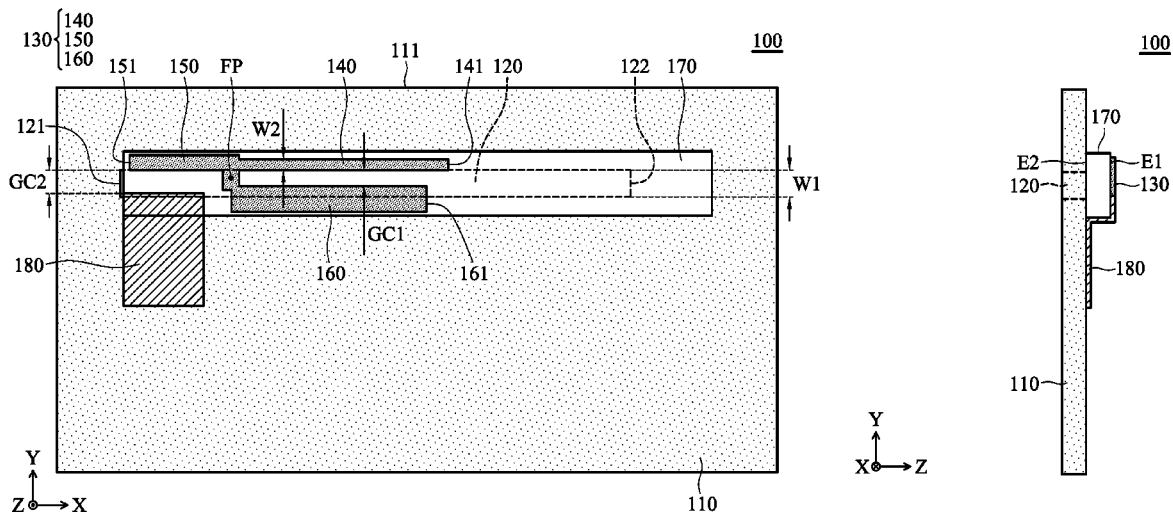
Primary Examiner — Trinh V Dinh

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

(57) **ABSTRACT**

A mobile device includes a metal back cover, a ground metal element, a feeding radiation element, and a dielectric substrate. The metal back cover has a slot. The feeding radiation element has a feeding point, and includes a first feeding branch, a second feeding branch, and a third feeding branch. The second feeding branch and the first feeding branch extend in opposite directions. The third feeding branch and the first feeding branch extend in the same direction. The feeding radiation element has a vertical projection on the metal back cover, and the vertical projection at least partially overlaps the slot. The dielectric substrate is disposed adjacent to the metal back cover. The ground metal element and the feeding radiation element are disposed on the dielectric substrate. An antenna structure is formed by the feeding radiation element and the slot of the metal back cover.

17 Claims, 7 Drawing Sheets



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

(10) **Patent No.:** **US 10,297,928 B2**
(45) **Date of Patent:** **May 21, 2019**

(54) **MULTI-PORT, MULTI-BAND, SINGLE CONNECTED MULTIPLE-INPUT, MULTIPLE-OUTPUT ANTENNA**

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

(72) Inventors: **Mohammad S Sharawi, Amman (JO); Muhammad Ikram, Okara (PK)**

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 58 days.

(21) Appl. No.: **15/437,783**

(22) Filed: **Feb. 21, 2017**

(65) **Prior Publication Data**
US 2018/0241136 A1 Aug. 23, 2018

(51) **Int. Cl.**
H01Q 1/12 (2006.01)
H01Q 1/48 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01Q 21/30** (2013.01); **H01Q 1/1207** (2013.01); **H01Q 1/48** (2013.01); **H01Q 5/314** (2015.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 13/106
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,432,860 B2 10/2008 Huynh
7,864,126 B2* 1/2011 Boisbouvier H01Q 3/38
343/700 MS

(Continued)

FOREIGN PATENT DOCUMENTS

WO 2016003173 A1 1/2016

OTHER PUBLICATIONS

Sharawi et al. "A Two Concentric Slot Loop Based Connected Array MIMO Antenna System for 4G/5G Terminals"; IEEE Transactions on Antennas and Propagation, vol. 65, No. 12, Dec. 2017; pp. 6679-6686 (Year: 2017).*

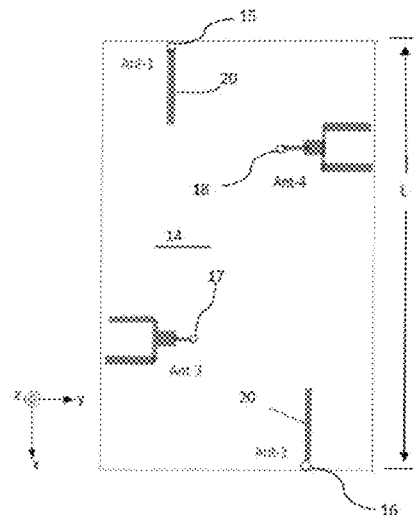
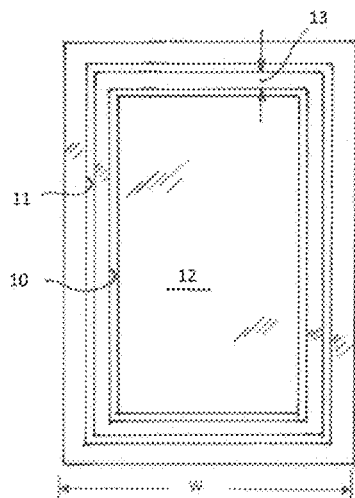
(Continued)

Primary Examiner — Ricardo I Magallanes
(74) *Attorney, Agent, or Firm* — Hauptham Ham, LLP

(57) **ABSTRACT**

A compact MIMO antenna system having connected arrays supporting multi-bands with multiple configurations. Two low band microwave MIMO antenna arrays operate at frequency bands below 6 GHz, and two high band microwave MIMO antenna arrays operate at frequencies above 10 GHz. The antenna arrays are connected together as connected arrays and support 4G as well as 5G bands. The antenna arrays are carried by an overlying layer of dielectric material and overlie two slots formed as rectangularly shaped closed loop in an underlying ground plane. The low band arrays each have a feeding arm that spans across the slots to act as a single antenna element, and the high band antenna arrays are power combiners/dividers with a single feeding point and four elements forming a two-to-one structure exciting the underlying slots, wherein the slots are excited and shared for compact design and wide operating bandwidth.

4 Claims, 5 Drawing Sheets
(5 of 5 Drawing Sheet(s) Filed in Color)



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

(10) **Patent No.:** **US 10,305,166 B2**
(45) **Date of Patent:** **May 28, 2019**

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

1/245; H01Q 1/48; H01Q 21/28; H03K 17/955; H03K 2217/94026; H03K 2017/9455; G06F 3/044; G06F 3/0418; G01R 27/2605; H04M 1/0202; H04M 2250/12; G04G 21/08

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

See application file for complete search history.

(72) Inventors: **Ki-Man Kim**, Gumi-si (KR); **Jaehwan Kim**, Gyeongju-si (KR); **Min-Soo Kim**, Gumi-si (KR); **Chulhyung Yang**, Gumi-si (KR); **Ji-Woo Lee**, Gumi-si (KR)

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,490,885 B1 * 11/2016 Zheng H04W 52/42
9,843,091 B2 * 12/2017 Mow H01Q 1/243
(Continued)

(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 253 days.

FOREIGN PATENT DOCUMENTS

KR 10-2008-0112502 A 12/2008
KR 10-2013-0077362 A 7/2013
KR 10-2015-0001072 A 1/2015

(21) Appl. No.: **15/211,653**

Primary Examiner — Ryan Johnson

(22) Filed: **Jul. 15, 2016**

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

(65) **Prior Publication Data**

US 2017/0047637 A1 Feb. 16, 2017

(30) **Foreign Application Priority Data**

Aug. 13, 2015 (KR) 10-2015-0114240

(57) **ABSTRACT**

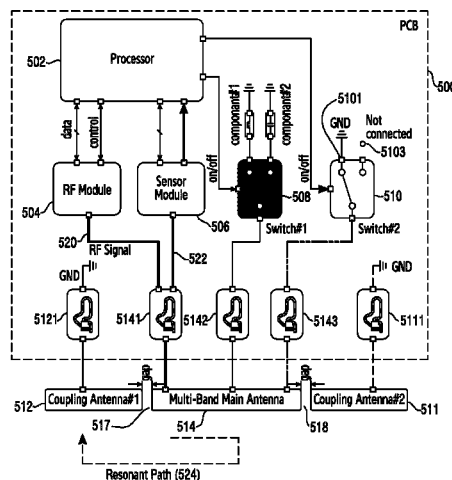
An electronic device is provided. The electronic device includes a housing that includes a first face, a second face that is directed opposite to the first face, and a side face that at least partially enclose a space between the first face and the second face, a first metallic member, a second metallic member, and a third metallic member that form a side face, a sensor configured to detect whether an external object comes in contact with at least one of the first metallic member, the second metallic member, and the third metallic member, and to generate a signal, and a circuit configured to change an electric path between at least one of the first metallic member, the second metallic member, and the third metallic member, and the ground member, at least partially based on the generated signal.

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/27 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **G06F 3/044** (2013.01); **H01Q 1/273** (2013.01); **H01Q 1/44** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/44; H01Q 1/27; H01Q

20 Claims, 37 Drawing Sheets



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

(10) **Patent No.:** **US 10,305,168 B2**
(45) **Date of Patent:** **May 28, 2019**

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

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

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

(56) **References Cited**

(72) Inventors: **Wendong Liu**, Beijing (CN); **Wei Kuang**, Beijing (CN); **Xu Zhang**, Beijing (CN)

U.S. PATENT DOCUMENTS

9,203,456 B2 * 12/2015 Teng H01Q 5/35
2013/0027254 A1 1/2013 Korva et al.
2013/0050038 A1 2/2013 Eom et al.
(Continued)

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

FOREIGN PATENT DOCUMENTS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 96 days.

CN 103236583 A1 8/2013
CN 104269609 A1 1/2015
(Continued)

(21) Appl. No.: **15/414,943**

OTHER PUBLICATIONS

(22) Filed: **Jan. 25, 2017**

Extended European Search Report issued in corresponding EP Application No. 17153128, dated Jun. 21, 2017, 9 pages.

(65) **Prior Publication Data**

US 2017/0222305 A1 Aug. 3, 2017

(Continued)

(30) **Foreign Application Priority Data**

Jan. 29, 2016 (CN) 2016 1 0064948

Primary Examiner — Hai V Tran

(74) *Attorney, Agent, or Firm* — Arch & Lake LLP

(51) **Int. Cl.**

H01Q 1/38 (2006.01)
H01Q 1/24 (2006.01)
H01Q 21/30 (2006.01)
H01Q 13/10 (2006.01)
H01Q 1/48 (2006.01)

(57) **ABSTRACT**

The present disclosure relates to an antenna assembly and an electronic device in the field of antennas. The antenna assembly includes: a first antenna, a second antenna and a metal frame. The metal frame includes: a metal plate; and a first side frame, a second side frame, a top frame and a bottom frame which enclose the metal plate. The first antenna is connected to a first radiation part of the bottom frame via a first connection point, the first radiation part being connected to the first side frame which is separated from the metal plate by a slot. The second antenna is connected to a second radiation part of the bottom frame via a second connection point, the second radiation part being disconnected from the first radiation part and the second side frame.

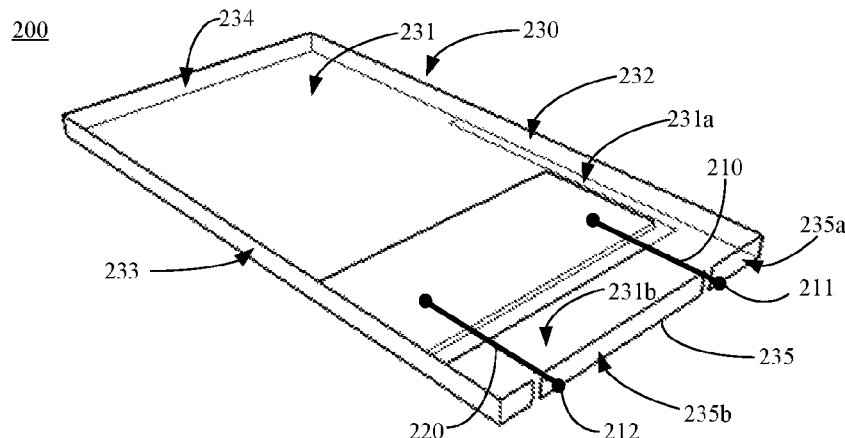
(52) **U.S. Cl.**

CPC **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 1/48** (2013.01); **H01Q 13/10** (2013.01); **H01Q 21/30** (2013.01)

19 Claims, 4 Drawing Sheets

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 13/10; H01Q 1/38; H01Q 21/30; H01Q 1/48





US010305169B2

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

(10) **Patent No.:** **US 10,305,169 B2**

(45) **Date of Patent:** **May 28, 2019**

(54) **ANTENNA APPARATUS AND TERMINAL**

(58) **Field of Classification Search**

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

CPC H01Q 1/243; H01Q 5/335; H01Q 5/357;
H01Q 1/24; H01Q 21/30

(Continued)

(72) Inventors: **Chen Zhang**, Xi'an (CN); **Jianfei Wang**, Shenzhen (CN); **Bing Liu**, Xi'an (CN); **Shuhui Sun**, Shenzhen (CN)

(56) **References Cited**

U.S. PATENT DOCUMENTS

(73) Assignee: **HUAWEI TECHNOLOGIES CO., LTD.**, Shenzhen (CN)

6,198,442 B1 3/2001 Rutkowski et al.
7,642,981 B2* 1/2010 Kanno H01Q 13/10
343/767

(Continued)

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

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **15/575,247**

CN 1364326 A 8/2002
CN 1661855 A 8/2005

(Continued)

(22) PCT Filed: **May 18, 2015**

OTHER PUBLICATIONS

(86) PCT No.: **PCT/CN2015/079205**

§ 371 (c)(1),
(2) Date: **Nov. 17, 2017**

Foreign Communication From a Counterpart Application, PCT Application No. PCT/CN2015/079205, English Translation of International Search Report dated Feb. 23, 2016, 2 pages.

(Continued)

(87) PCT Pub. No.: **WO2016/183777**

PCT Pub. Date: **Nov. 24, 2016**

Primary Examiner — Jean B Jeanglaude

(74) *Attorney, Agent, or Firm* — Conley Rose, P.C.

(65) **Prior Publication Data**

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(57) **ABSTRACT**

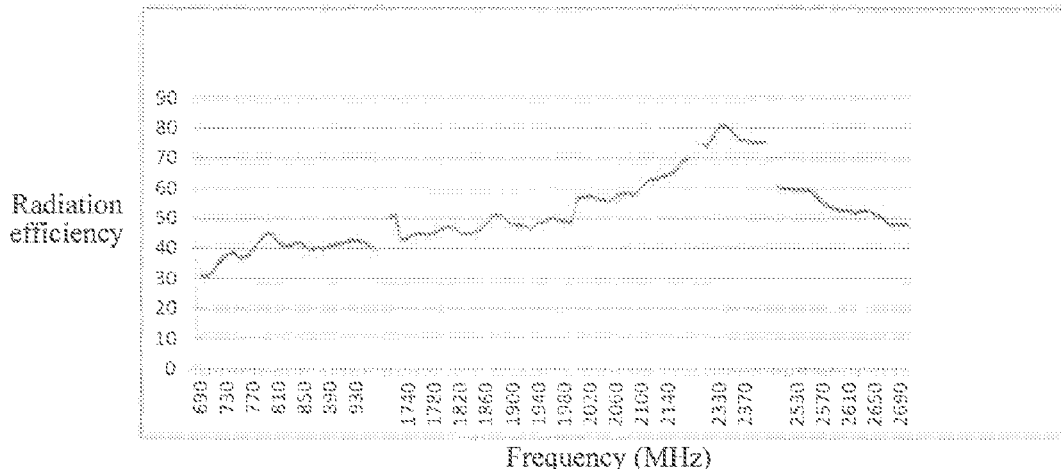
(51) **Int. Cl.**
H01Q 21/00 (2006.01)
H01Q 1/24 (2006.01)

(Continued)

An antenna apparatus includes a feeding terminal, a high-pass low-cut device, a first low-pass high-cut device, and an antenna body, where the high-pass low-cut device is electrically connected in series between a first free end of the antenna body and the feeding terminal, and the first low-pass high-cut device is electrically connected in series between a second free end of the antenna body and the feeding terminal.

(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/24** (2013.01); **H01Q 5/335** (2015.01); **H01Q 5/357** (2015.01); **H01Q 21/30** (2013.01)

18 Claims, 5 Drawing Sheets



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

(10) **Patent No.:** **US 10,305,170 B2**
(45) **Date of Patent:** **May 28, 2019**

(54) **ELECTRONIC DEVICE COMPRISING ANTENNA**

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

(72) Inventors: **Yong Soo Kwak**, Seoul (KR); **Gyu Sub Kim**, Seoul (KR); **Hae Yeon Kim**, Suwon-si (KR); **Se Hyun Park**, Suwon-si (KR); **Kyung Il Seo**, Daegu (KR); **Jung Hoon Seo**, Hwaseong-si (KR); **Dong Min Shin**, Yongin-si (KR); **Ui Chul Jeong**, Anyang-si (KR); **Jin Woo Jung**, Seoul (KR); **Young Jun Cho**, 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.: **15/665,933**

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

(65) **Prior Publication Data**

US 2018/0034135 A1 Feb. 1, 2018

(30) **Foreign Application Priority Data**

Aug. 1, 2016 (KR) 10-2016-0098238

(51) **Int. Cl.**

H01Q 1/24 (2006.01)

H01Q 5/35 (2015.01)

(Continued)

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

CPC **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 5/35** (2015.01); **H01Q 21/30** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 13/10; H01Q 9/0421; H01Q 9/42; H01Q 5/307; H01Q 13/106; H01Q 21/29; H01Q 5/00; H01Q 5/321
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,108,308 A 8/2000 Flavin et al.

7,058,373 B2 6/2006 Grigore

(Continued)

FOREIGN PATENT DOCUMENTS

KR 1990-0008877 A 6/1990

KR 10-0269530 B1 10/2000

(Continued)

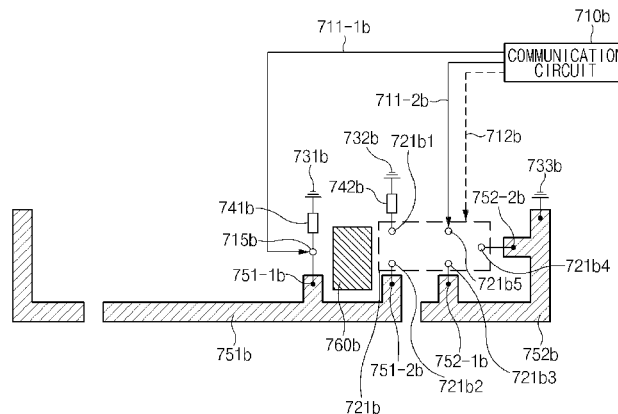
Primary Examiner — Linh V Nguyen

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

(57) **ABSTRACT**

An electronic device is provided. The electronic device includes a housing, a wireless communication circuit, a first antenna radiator electrically connected with a first ground, a second antenna radiator electrically connected with a second ground, a feeding unit that feeds at least one of the first antenna radiator or the second antenna radiator, and a first switch that operates at a first connection state where the feeding unit and the first antenna radiator are electrically connected to each other, at a second connection state where the feeding unit and the second antenna are electrically connected to each other, or at a third connection state where the feeding unit and the first antenna radiator are connected to each other and the feeding unit and the second antenna radiator are electrically connected to each other, based on a first control signal from the wireless communication circuit.

19 Claims, 17 Drawing Sheets





US010305172B2

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

(10) **Patent No.:** **US 10,305,172 B2**
(45) **Date of Patent:** **May 28, 2019**

(54) **ELECTRONIC DEVICE WITH MILLIMETER WAVE ANTENNAS ON STACKED PRINTED CIRCUITS**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)
(72) Inventors: **Basim H. Noori**, Scotts Valley, CA (US); **Boon W. Shiu**, San Francisco, CA (US); **Kevin M. Marks**, San Francisco, CA (US); **Matthew A. Mow**, Los Altos, CA (US); **Mattia Pascolini**, San Francisco, CA (US); **Ming-Ju Tsai**, Sunnyvale, CA (US); **Ruben Caballero**, San Jose, CA (US); **Yuehui Ouyang**, Sunnyvale, CA (US); **Khan Salam**, Dublin, CA (US)

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

(21) Appl. No.: **15/952,115**
(22) Filed: **Apr. 12, 2018**

(65) **Prior Publication Data**
US 2018/0233808 A1 Aug. 16, 2018
Related U.S. Application Data

(63) Continuation of application No. 15/138,689, filed on Apr. 26, 2016, now Pat. No. 9,972,892.

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/22 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/2258** (2013.01); **H01Q 1/2266** (2013.01); **H01Q 1/24** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/24; H01Q 1/241; H01Q 1/242; H01Q 1/243; H01Q 1/2258; H01Q 1/2266; H01Q 19/10; H01Q 19/30; H01Q 21/065
See application file for complete search history.

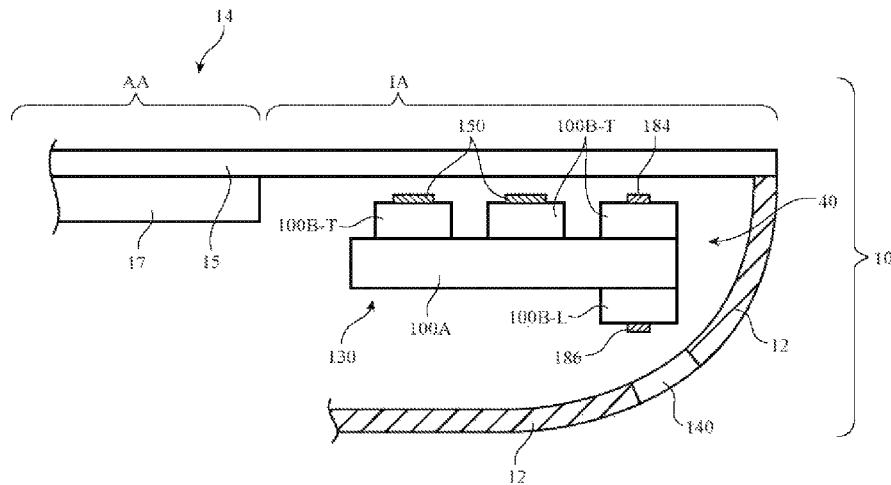
(56) **References Cited**
U.S. PATENT DOCUMENTS
7,812,775 B2 10/2010 Babakhani et al.
8,854,277 B2 10/2014 De Grauw et al.
(Continued)

FOREIGN PATENT DOCUMENTS
CN 101728369 A 6/2010
CN 102255134 A 11/2011
(Continued)

Primary Examiner — Hoang V Nguyen
(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. The wireless circuitry may include one or more antennas and transceiver circuitry such as millimeter wave transceiver circuitry. The antennas may be formed from metal traces on a printed circuit. The printed circuit may be a stacked printed circuit including multiple stacked substrates. Metal traces may form an array of patch antennas, Yagi antennas, and other antennas. Antenna signals associated with the antennas may pass through an inactive area in a display and through a dielectric-filled slot in a metal housing for the electronic device. Waveguide structures may be used to guide antenna signals within interior portions of the electronic device.

20 Claims, 17 Drawing Sheets



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

(10) **Patent No.:** **US 10,305,453 B2**
(45) **Date of Patent:** **May 28, 2019**

(54) **ELECTRONIC DEVICE ANTENNAS HAVING MULTIPLE OPERATING MODES**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)
(72) Inventors: **Jennifer M. Edwards**, San Francisco, CA (US); **Yijun Zhou**, Mountain View, CA (US); **Yiren Wang**, Santa Clara, CA (US); **Hao Xu**, Cupertino, CA (US); **Ming-Ju Tsai**, Sunnyvale, CA (US); **Victor C. Lee**, Sunnyvale, CA (US); **Liang Han**, Sunnyvale, CA (US); **Matthew A. Mow**, Los Altos, CA (US); **Mattia Pascolini**, San Francisco, 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 79 days.

(21) Appl. No.: **15/700,580**

(22) Filed: **Sep. 11, 2017**

(65) **Prior Publication Data**
US 2019/0081615 A1 Mar. 14, 2019

(51) **Int. Cl.**
H03J 1/00 (2006.01)
H03J 7/18 (2006.01)
H04B 7/12 (2006.01)

(52) **U.S. Cl.**
CPC **H03J 1/0083** (2013.01); **H03J 7/186** (2013.01); **H03J 2200/01** (2013.01); **H03J 2200/06** (2013.01)

(58) **Field of Classification Search**
CPC H03J 1/0083; H03J 7/186; H03J 2200/01; H03J 2200/06

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,984,296 A * 1/1991 Schotz H04B 1/18 343/715
5,768,691 A * 6/1998 Matero H01Q 1/24 333/101

(Continued)

FOREIGN PATENT DOCUMENTS

WO 03096474 A1 11/2003

OTHER PUBLICATIONS

Petosa, "An Overview of Tuning Techniques for Frequency-Agile Antennas", IEEE Antennas and Propagation Magazine 545 (2012): 271-296.

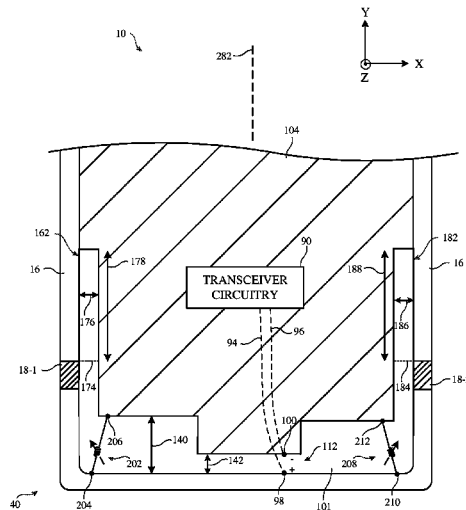
(Continued)

Primary Examiner — Hai V Nguyen
(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; Joseph F. Guihan

(57) **ABSTRACT**

An electronic device may be provided with wireless circuitry and control circuitry. The wireless circuitry may include an antenna with an inverted-F antenna resonating element formed from portions of a peripheral conductive electronic device housing structure and may have an antenna ground that is separated from the antenna resonating element by a gap. The antenna may include a first adjustable component coupled between the antenna resonating element arm and the antenna ground on a first side of the antenna feed and a second adjustable component coupled between the antenna resonating element arm and the antenna ground on a second side of the antenna feed. Control circuitry in the electronic device may adjust the first and second adjustable components between a first tuning mode, a second tuning mode, and a third tuning mode.

20 Claims, 11 Drawing Sheets





US010306029B1

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

(10) **Patent No.:** **US 10,306,029 B1**
(45) **Date of Patent:** **May 28, 2019**

(54) **MOBILE TERMINAL**

(71) Applicant: **LG ELECTRONICS INC.**, Seoul (KR)
(72) Inventors: **Kyongsun Hwang**, Seoul (KR); **Moonsoo Song**, Seoul (KR); **Yoonjae Won**, Seoul (KR); **Deuksu Choi**, Seoul (KR); **Chisang You**, Seoul (KR)

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

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

(21) Appl. No.: **16/022,512**

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

Related U.S. Application Data

(60) Provisional application No. 62/653,550, filed on Apr. 5, 2018.

Foreign Application Priority Data

May 3, 2018 (KR) 10-2018-0051314

(51) **Int. Cl.**
H04M 1/00 (2006.01)
H04M 1/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H04M 1/0202** (2013.01); **H01Q 1/243** (2013.01); **H01Q 13/10** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04M 1/0202; H01Q 1/243; H01Q 13/10; H01Q 21/28; H01Q 5/35; H01Q 5/357; H01Q 1/44; H04B 1/3833; H04W 88/02
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0074329 A1* 3/2008 Caballero H01Q 1/088 343/702
2010/0073242 A1* 3/2010 Ayala Vazquez H01Q 1/2266 343/702

(Continued)

FOREIGN PATENT DOCUMENTS

JP 5712361 5/2015
KR 1020080063506 7/2008

OTHER PUBLICATIONS

PCT International Application No. PCT/KR2018/007330, Notification of Transmittal of the International Search Report and the Written Opinion of the International Searching AUTHORITY, or Declaration dated Dec. 27, 2018, 9 pages.

(Continued)

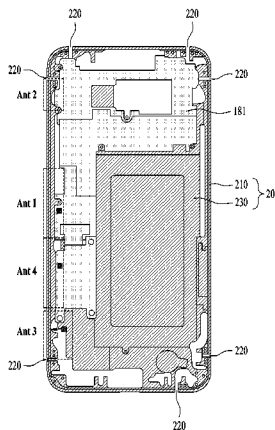
Primary Examiner — Barry W Taylor

(74) *Attorney, Agent, or Firm* — Lee, Hong, Degerman, Kang & Waimey

(57) **ABSTRACT**

There is disclosed a mobile terminal including: a display; a middle frame including a supporting portion and a side portion provided around the supporting portion to define a lateral appearance; a main board including a ground; a first wireless communication unit configured to transceive a first signal; a second wireless communication unit configured to transceive a second signal; and a rear case configured to cover a rear surface of the main board, wherein the side portion includes a plurality of conductive members of which ends are divided into slits, and the plurality of the conductive members includes a common antenna electrically connectable with the first wireless communication unit and the second wireless communication unit and configured to receive the first signal and the second signal; and an independent antenna electrically connectable with the first

(Continued)





US010312571B2

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

(10) **Patent No.:** **US 10,312,571 B2**
(45) **Date of Patent:** **Jun. 4, 2019**

(54) **ELECTRONIC DEVICE HAVING ISOLATED ANTENNA STRUCTURES**

(56) **References Cited**

U.S. PATENT DOCUMENTS

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)
(72) Inventors: **Jennifer M. Edwards**, San Francisco, CA (US); **Yijun Zhou**, Mountain View, CA (US); **Yiren Wang**, Santa Clara, CA (US); **Hao Xu**, Cupertino, CA (US); **Mattia Pascolini**, San Francisco, CA (US)

9,337,537 B2 5/2016 Hu et al.
9,559,433 B2 1/2017 Zhou et al.
9,621,230 B2 4/2017 Ouyang et al.
2012/0229347 A1* 9/2012 Jin H01Q 1/243
343/702
2015/0145734 A1 5/2015 Caballero et al.
2016/0344439 A1* 11/2016 Seol H01Q 1/243
2017/0194709 A1 7/2017 Jansson

* cited by examiner

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

Primary Examiner — Robert Karacsony

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 61 days.

(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.; Joseph F. Guihan

(21) Appl. No.: **15/700,636**

(57) **ABSTRACT**

(22) Filed: **Sep. 11, 2017**

An electronic device may be provided with wireless circuitry. The wireless circuitry may include multiple antennas and transceiver circuitry. The antenna structures at a first end of the electronic device may include an inverted-F antenna resonating element for a first antenna formed from portions of a peripheral conductive electronic device housing structure and an antenna ground that is separated from the antenna resonating element by a gap. The inverted-F antenna resonating element arm may have a first end adjacent a first dielectric-filled gap and an opposing second end adjacent a second dielectric-filled gap. A second antenna may include an additional antenna resonating element arm and the antenna ground. A second end of the additional antenna resonating element arm may be interposed between the first dielectric-filled gap and a first end of the additional antenna resonating element arm. This type of arrangement may ensure the first and second antennas are isolated.

(65) **Prior Publication Data**

US 2019/0081386 A1 Mar. 14, 2019

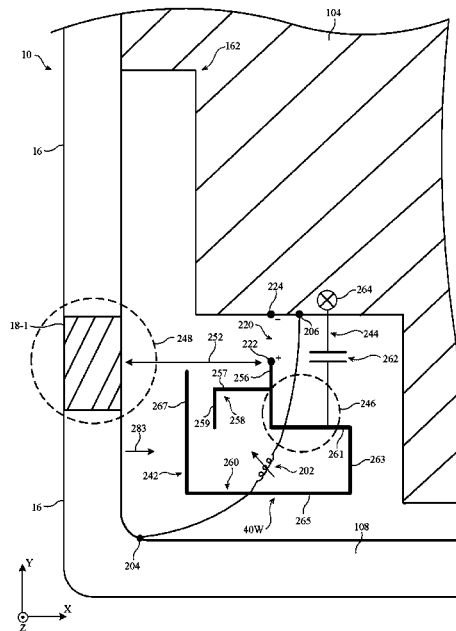
(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/38 (2006.01)

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

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 5/335; H01Q 5/35; H01Q 5/371

See application file for complete search history.

15 Claims, 9 Drawing Sheets





US010312589B2

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

(10) **Patent No.:** **US 10,312,589 B2**

(45) **Date of Patent:** **Jun. 4, 2019**

(54) **ANTENNA DIRECTIVITY CONTROL SYSTEM AND RADIO DEVICE**

(56) **References Cited**

(71) Applicant: **AGC Inc.**, Chiyoda-ku (JP)

U.S. PATENT DOCUMENTS

(72) Inventors: **Toshiki Sayama**, Chiyoda-ku (JP);
Ryuta Sonoda, Chiyoda-ku (JP); **Koji Ikawa**, Chiyoda-ku (JP)

7,233,289 B2 6/2007 Chung et al.
2002/0044099 A1* 4/2002 Yamamoto H01Q 1/007
343/789

(Continued)

(73) Assignee: **AGC Inc.**, Chiyoda-ku (JP)

FOREIGN PATENT DOCUMENTS

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

CN 1496595 A 5/2004
CN 101197465 A 6/2008

(Continued)

(21) Appl. No.: **15/207,849**

OTHER PUBLICATIONS

(22) Filed: **Jul. 12, 2016**

International Search Report dated Apr. 21, 2015 in PCT/JP2015/051017, filed on Jan. 16, 2015 (with English Translation).

(65) **Prior Publication Data**

US 2016/0322702 A1 Nov. 3, 2016

(Continued)

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2015/051017, filed on Jan. 16, 2015.

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

(30) **Foreign Application Priority Data**

Jan. 20, 2014 (JP) 2014-008169

(57) **ABSTRACT**

(51) **Int. Cl.**
H01Q 3/28 (2006.01)
H01Q 19/26 (2006.01)

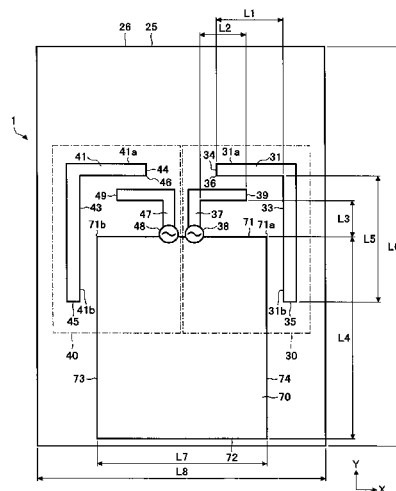
(Continued)

An antenna directivity control system includes an antenna including a plurality of antenna elements, feeding points for the plurality of antenna elements being mutually different; and a controller for controlling weight for each of the plurality of antenna elements, wherein each of the plurality of antenna elements includes a feed element connected to the feed point, and a radiating element that functions, upon power being fed by establishing electromagnetic field coupling with the feed element, as a radiating conductor, and wherein the controller controls a directivity of the antenna by adjusting an amplitude of a signal at each of the feeding points.

(52) **U.S. Cl.**
CPC **H01Q 3/28** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 19/26** (2013.01); **H01Q 21/28** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 3/28; H01Q 19/22; H01Q 19/26
See application file for complete search history.

19 Claims, 8 Drawing Sheets



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

(10) **Patent No.:** **US 10,312,593 B2**
(45) **Date of Patent:** **Jun. 4, 2019**

(54) **ANTENNAS FOR NEAR-FIELD AND NON-NEAR-FIELD COMMUNICATIONS**

6,308,051 B1 * 10/2001 Atokawa H01P 1/213
333/207

(Continued)

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

FOREIGN PATENT DOCUMENTS

(72) Inventors: **Salih Yarga**, Sunnyvale, CA (US);
Miroslav Samardzija, Mountain View, CA (US); **Robert W. Schlub**,
Cupertino, CA (US)

EP 2498336 9/2012
EP 2528165 11/2012

(Continued)

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

OTHER PUBLICATIONS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 196 days.

Abbaspour-Tamijani et al. "Antenna-Filter-Antenna Arrays as a Class of Bandpass Frequency-Selective Surfaces", IEEE Transactions on Microwave Theory and Techniques, vol. 52, No. 8, Aug. 2004.*

(Continued)

(21) Appl. No.: **14/254,604**

(22) Filed: **Apr. 16, 2014**

Primary Examiner — Dieu Hien T Duong

Assistant Examiner — Bamidele A Jegede

(65) **Prior Publication Data**

US 2015/0303568 A1 Oct. 22, 2015

(74) *Attorney, Agent, or Firm* — Treyz Law Group, P.C.;
G. Victor Treyz; Tianyi He

(51) **Int. Cl.**

H01Q 5/00 (2015.01)
H01Q 7/00 (2006.01)

(Continued)

(57) **ABSTRACT**

An electronic device may be provided with antenna structures. The antenna structures may be coupled to non-near-field communications circuitry such as cellular telephone transceiver circuitry or wireless local area network circuitry. When operated at non-near-field communication frequencies, the antenna structures may be configured to serve as one or more inverted-F antennas or other antennas for supporting far field wireless communications. Proximity sensor circuitry and near-field communications circuitry may also be coupled to the antenna structures. When operated at proximity sensor frequencies, the antenna structures may be used in forming capacitive proximity sensor electrode structures. When operated at near-field communications frequencies, the antenna structures may be used in forming an inductive near-field communications loop antenna.

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

CPC **H01Q 7/005** (2013.01); **H01Q 1/245** (2013.01); **H01Q 5/321** (2015.01);
(Continued)

(58) **Field of Classification Search**

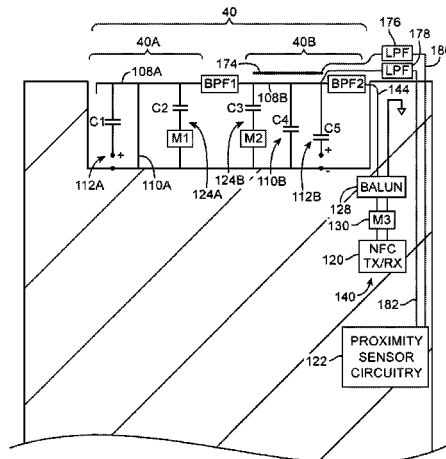
CPC H01Q 1/245; H01Q 5/0034; H01Q 9/0421;
H01Q 9/42; H01Q 7/005; H01Q 1/2266;
H01Q 1/243; H01Q 21/28
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,936,583 A 8/1999 Sekine et al.

20 Claims, 9 Drawing Sheets





US010313497B2

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

(10) **Patent No.:** **US 10,313,497 B2**
(45) **Date of Patent:** ***Jun. 4, 2019**

(54) **HANDHELD ELECTRONIC DEVICE WITH CABLE GROUNDING**

(22) Filed: **Jan. 17, 2014**

(71) Applicants: **Apple Inc.**, Cupertino, CA (US);
Vincent Keane Seid, Los Gatos, CA (US)

(65) **Prior Publication Data**

US 2014/0132463 A1 May 15, 2014

(72) Inventors: **Phillip Michael Hobson**, Menlo Park, CA (US); **Erik L. Wang**, Redwood City, CA (US); **Kenneth A. Jenks**, Capitola, CA (US); **Robert J. Hill**, Salinas, CA (US); **Robert W. Schlub**, Cupertino, CA (US); **Richard H. Dinh**, San Jose, CA (US); **Tang Yew Tan**, Palo Alto, CA (US); **Adam D. Mittleman**, San Francisco, CA (US); **Bartley K. Andre**, Palo Alto, CA (US); **Daniel J. Coster**, San Francisco, CA (US); **Daniele De Iullis**, San Francisco, CA (US); **Richard P. Howarth**, San Francisco, CA (US); **Jonathan P. Ive**, San Francisco, CA (US); **Steven P. Jobs**, Palo Alto, CA (US); **Duncan Robert Kerr**, San Francisco, CA (US); **Shin Nishibori**, Kailua, HI (US); **Matthew Dean Rohrbach**, San Francisco, CA (US); **Douglas B. Satzger**, San Francisco, CA (US); **Calvin Q. Seid**, Palo Alto, CA (US); **Christopher J. Stringer**, Woodside, CA (US); **Eugene Antony Whang**, San Francisco, CA (US); **Rico Zorkendorfer**, San Francisco, CA (US)

Related U.S. Application Data

(63) Continuation of application No. 13/021,689, filed on Feb. 4, 2011, now Pat. No. 8,681,056, which is a (Continued)

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H04M 1/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H04M 1/0202** (2013.01); **H01Q 1/243** (2013.01); **H01Q 9/0421** (2013.01); **H04M 1/0266** (2013.01); **H05K 5/0247** (2013.01)

(58) **Field of Classification Search**
CPC ... H01Q 1/243; H01Q 9/0421; H04M 1/0202; H04M 1/0266; H05K 5/0247
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,414,902 A 12/1968 Shaw, Jr.
3,453,377 A 7/1969 Gillespie
(Continued)

FOREIGN PATENT DOCUMENTS

KR 3004523050000 6/2007

OTHER PUBLICATIONS

Hobson et al. U.S. Appl. No. 60/883,537, filed Jan. 5, 2007.
(Continued)

Primary Examiner — Huedung X Mancuso

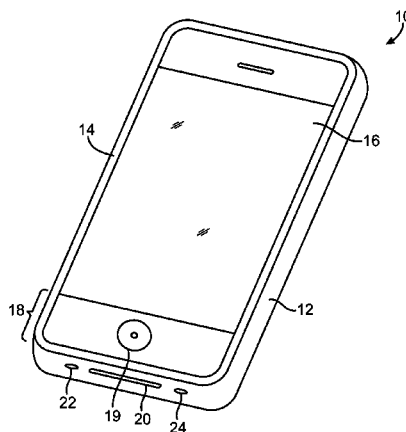
(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton LLP

(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 829 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/158,403**



(12) **United States Patent**
Ho

(10) **Patent No.:** **US 10,320,056 B2**
(45) **Date of Patent:** **Jun. 11, 2019**

(54) **ANTENNA STRUCTURE**

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

(72) Inventor: **Chao-Wei Ho**, 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.: **15/690,284**

(22) Filed: **Aug. 30, 2017**

(65) **Prior Publication Data**

US 2019/0051973 A1 Feb. 14, 2019

(30) **Foreign Application Priority Data**

Aug. 8, 2017 (CN) 2017 1 0673234

(51) **Int. Cl.**

H01Q 1/12 (2006.01)
H01Q 1/22 (2006.01)
H01Q 21/24 (2006.01)
H01Q 21/28 (2006.01)
H01Q 21/00 (2006.01)
H01Q 1/36 (2006.01)
H04B 1/44 (2006.01)

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

CPC **H01Q 1/2291** (2013.01); **H01Q 1/36** (2013.01); **H01Q 21/0006** (2013.01); **H01Q 21/24** (2013.01); **H01Q 21/28** (2013.01); **H04B 1/44** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/2291; H01Q 1/36; H01Q 21/28; H01Q 21/24; H01Q 21/0006; H04B 1/44
USPC 343/878, 718
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,926,075 A * 7/1999 Hayashi H01P 1/15
333/101
7,170,462 B2 * 1/2007 Ihara G04G 21/04
343/718
2014/0217564 A1 * 8/2014 Gaynor H01L 21/565
257/664

* cited by examiner

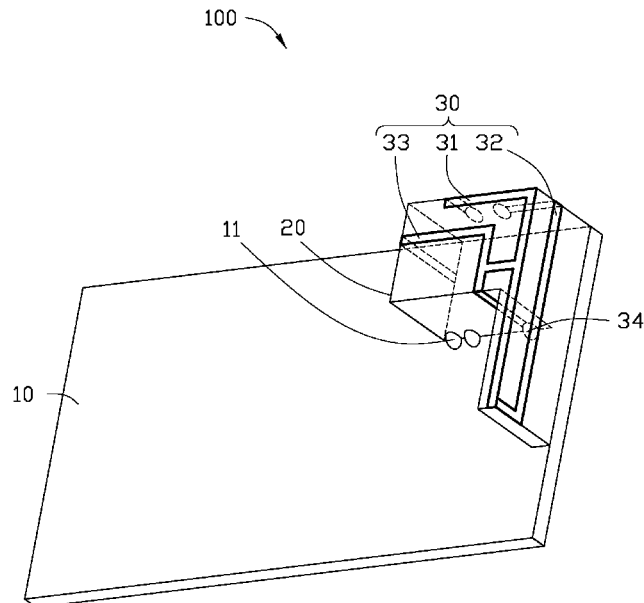
Primary Examiner — Jean B Jeanglaude

(74) *Attorney, Agent, or Firm* — ScienBiziP, P.C.

(57) **ABSTRACT**

An antenna structure of multi-band frequency and simple structure includes a base plate, a supporting portion and an antenna mounted on the supporting portion. The base plate has a signal source thereon. The antenna has an input end. The antenna includes a first antenna, a second antenna and a connecting portion coupled with the first antenna and the second antenna, the antenna also has a first switch portion, a second switch portion and a third switch portion, the base plate has a first circuit and a second circuit. The input end is mounted on the connecting portion, the first switch portion is mounted between the signal source and the input end, the second switch portion is mounted on the first antenna, and the third switch portion is mounted on the second antenna.

14 Claims, 4 Drawing Sheets





US010320057B2

(12) **United States Patent**
Miura

(10) **Patent No.:** **US 10,320,057 B2**

(45) **Date of Patent:** **Jun. 11, 2019**

(54) **ANTENNA DEVICE, WIRELESS COMMUNICATION DEVICE, AND BAND ADJUSTMENT METHOD**

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

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

(56) **References Cited**

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

U.S. PATENT DOCUMENTS

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

6,147,651 A 11/2000 Yamazaki et al.
7,528,783 B2 5/2009 Takagi
(Continued)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 44 days.

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **15/314,012**

CN 102763398 A 10/2012
CN 202759016 U 2/2013
(Continued)

(22) PCT Filed: **Jun. 11, 2015**

OTHER PUBLICATIONS

(86) PCT No.: **PCT/JP2015/002929**
§ 371 (c)(1),
(2) Date: **Nov. 25, 2016**

International Search Report for PCT Application No. PCT/JP2015/002929, dated Sep. 1, 2015.
(Continued)

(87) PCT Pub. No.: **WO2015/198549**
PCT Pub. Date: **Dec. 30, 2015**

Primary Examiner — Graham P Smith

(65) **Prior Publication Data**
US 2017/0201007 A1 Jul. 13, 2017

(57) **ABSTRACT**

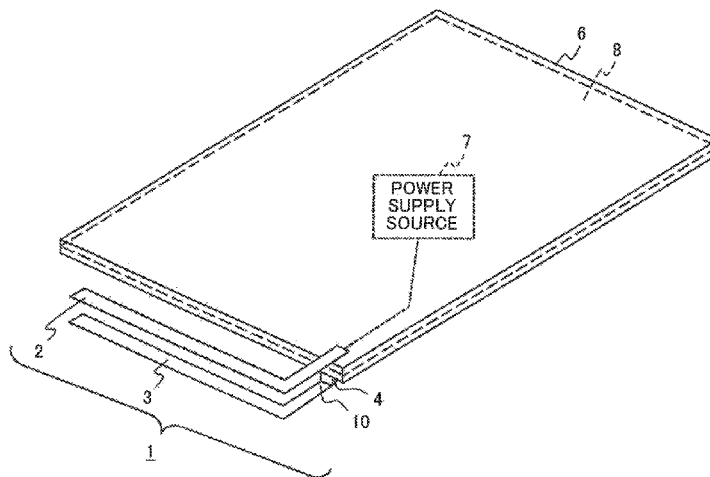
(30) **Foreign Application Priority Data**
Jun. 26, 2014 (JP) 2014-131195

In order to provide an antenna technology capable of easily achieving, with a simple structure, a wide bandwidth in which wireless communication can be performed, an antenna device is provided with a feed antenna element, and a parasitic antenna element. The feed antenna element is provided on a circuit board, and is electrically coupled to a power supply that is provided on the circuit board. The parasitic antenna element is electrically coupled to the feed antenna element. The parasitic antenna element has a grounding portion. The grounding portion is electrically coupled to a ground layer via an inductive element, said ground layer being formed on the circuit board and having a reference potential.

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

(52) **U.S. Cl.**
CPC **H01Q 1/24** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 1/48** (2013.01);
(Continued)

5 Claims, 13 Drawing Sheets



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

(10) **Patent No.:** **US 10,320,060 B2**
(45) **Date of Patent:** ***Jun. 11, 2019**

(54) **ANTENNA AND MOBILE TERMINAL**
(71) Applicant: **Huawei Device Co., Ltd.**, Dongguan, Guandong (CN)
(72) Inventors: **Hanyang Wang**, Reading (GB); **Jianming Li**, Shanghai (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 0 days.
This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/057,374**
(22) Filed: **Aug. 7, 2018**

(65) **Prior Publication Data**
US 2018/0351238 A1 Dec. 6, 2018

Related U.S. Application Data
(63) Continuation of application No. 15/025,714, filed as application No. PCT/CN2014/074299 on Mar. 28, 2014.

(51) **Int. Cl.**
H01Q 5/378 (2015.01)
H01Q 5/321 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/36** (2013.01); **H01Q 1/38** (2013.01); **H01Q 1/48** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 9/42; H01Q 5/00; H01Q 1/36; H01Q 5/378; H01Q 5/321; H01Q 1/48
(Continued)

(56) **References Cited**
U.S. PATENT DOCUMENTS
6,466,170 B2 10/2002 Zhou
7,768,466 B2 8/2010 Chi et al.
(Continued)
FOREIGN PATENT DOCUMENTS
CN 101835282 A 9/2010
CN 102315513 A 1/2012
(Continued)

OTHER PUBLICATIONS
Machine Translation and Abstract of Chinese Publication No. CN102315513, Jan. 11, 2012, 16 pages.
(Continued)

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

(57) **ABSTRACT**
An antenna, including a first radiation part, a matching circuit, and a feed source, where the first radiation part includes a first radiator, a second radiator, and a capacitor structure, a first end of the first radiator is connected to the feed source using the matching circuit, the feed source is connected to a grounding part, a second end of the first radiator is connected to a first end of the second radiator using the capacitor structure, a second end of the second radiator is connected to the grounding part, the first radiation part is configured to generate a first resonance frequency, and a length of the second radiator is one-eighth of a wavelength corresponding to the first resonance frequency which helps to reduce an antenna length, and a volume of a mobile terminal.

20 Claims, 7 Drawing Sheets

