



US009219302B2

(12) **United States Patent**  
**Jenwatanavet**

(10) **Patent No.:** **US 9,219,302 B2**  
(45) **Date of Patent:** **Dec. 22, 2015**

- (54) **COMPACT ANTENNA SYSTEM**
- (75) Inventor: **Jatupum Jenwatanavet**, San Diego, CA (US)
- (73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 564 days.

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(21) Appl. No.: **13/594,571**

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(22) Filed: **Aug. 24, 2012**

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(65) **Prior Publication Data**

US 2014/0055309 A1 Feb. 27, 2014

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(51) **Int. Cl.**

- H01Q 21/00** (2006.01)
- H01Q 1/24** (2006.01)
- H01Q 5/01** (2006.01)
- H01Q 1/38** (2006.01)
- H01Q 1/27** (2006.01)
- H01Q 9/42** (2006.01)
- H01Q 21/28** (2006.01)
- H01Q 5/371** (2015.01)

*Primary Examiner* — Dameon E Levi  
*Assistant Examiner* — Andrea Lindgren Baltzell  
(74) *Attorney, Agent, or Firm* — Rupit M. Patel

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

CPC ..... **H01Q 1/273** (2013.01); **H01Q 5/371** (2015.01); **H01Q 9/42** (2013.01); **H01Q 21/28** (2013.01)

(57) **ABSTRACT**

The various embodiments include multiple antenna system designs for use in smaller sized mobile computing devices where spatial isolation of antennas may not be feasible. The various embodiments include at least an embodiment first antenna having a first arm and a second arm. The first arm and the second arm are positioned proximate to one another in an intersecting perpendicular configuration. The at least first arm and second arm may be formed a plane that is laterally offset from a plane containing a printed circuit board operating as a ground plane. The at least first arm and second arm may also be positioned in a corner of the printed circuit board. Additional embodiments include a second monopole antenna formed in the same plane as the printed circuit board and having a feed contact positioned proximate to a feed and ground contact of the first antenna.

(58) **Field of Classification Search**

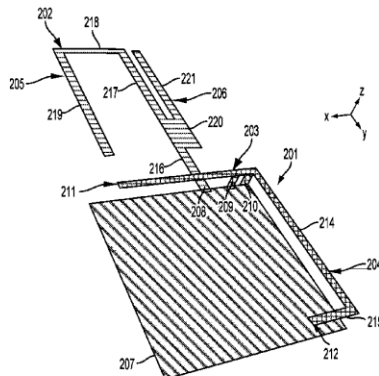
CPC ..... H01Q 21/00; H01Q 1/24; H01Q 5/01; H01Q 1/38  
USPC ..... 343/718  
See application file for complete search history.

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**34 Claims, 12 Drawing Sheets**





US009219305B2

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

(10) **Patent No.:** **US 9,219,305 B2**  
(45) **Date of Patent:** **Dec. 22, 2015**

(54) **BUILT-IN ANTENNA FOR ELECTRONIC DEVICE**

(71) Applicant: **Samsung Electronics Co., Ltd.**,  
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(72) Inventors: **Kyung-Jong Lee**, Gyeonggi-do (KR);  
**Seung-Hwan Kim**, Seoul (KR);  
**Dong-Hwan Kim**, Gyeonggi-do (KR);  
**Austin Kim**, Gyeonggi-do (KR);  
**Young-Sung Lee**, Gyeonggi-do (KR);  
**Jae-Ho Lee**, Gyeonggi-do (KR);  
**Jae-Bong Chun**, Gyeonggi-do (KR)

(73) Assignee: **Samsung Electronics Co., Ltd.**,  
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patent is extended or adjusted under 35  
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(21) Appl. No.: **13/761,289**

(22) Filed: **Feb. 7, 2013**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Mar. 19, 2012 (KR) ..... 10-2012-0027681

(51) **Int. Cl.**

**H01Q 1/50** (2006.01)  
**H01Q 1/24** (2006.01)  
**H01Q 9/42** (2006.01)  
**H01Q 21/30** (2006.01)  
**H01Q 5/364** (2015.01)  
**H01Q 5/371** (2015.01)  
**H01Q 5/378** (2015.01)

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

CPC ..... **H01Q 1/50** (2013.01); **H01Q 1/243**  
(2013.01); **H01Q 5/364** (2015.01); **H01Q 5/371**  
(2015.01); **H01Q 5/378** (2015.01); **H01Q 9/42**  
(2013.01); **H01Q 21/30** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/50; H01Q 21/30  
See application file for complete search history.

(56)

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*Primary Examiner* — Robert Karacsony

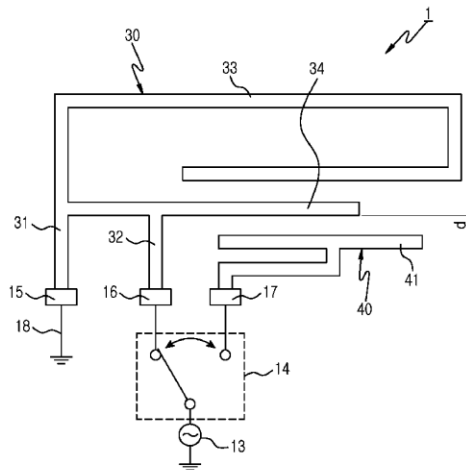
(74) *Attorney, Agent, or Firm* — Cha & Reiter, LLC

(57)

**ABSTRACT**

A built-in antenna for an electronic device is provided. The built-in antenna includes a substrate, a 1st antenna radiator with at least two radiating portions, a 2nd antenna radiator, and a switching means. The substrate has a conductive area and a non-conductive area. The 2nd antenna radiator is arranged within the non-conductive area of the substrate and fed by a Radio Frequency (RF) end of the substrate. The 2nd antenna radiator is configured to operate at a band different from at least one operating band of the 1st antenna radiator, and is fed by the RF end in a position adjacent the 1st antenna radiator. The switching means switches to selectively feed the 1st antenna radiator and the 2nd antenna radiator.

**1 Claim, 5 Drawing Sheets**





US009219306B2

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

(10) **Patent No.:** **US 9,219,306 B2**  
(45) **Date of Patent:** **Dec. 22, 2015**

(54) **PRINTED CIRCUIT BOARD ANTENNA, PRINTED CIRCUIT BOARD, AND ELECTRONIC DEVICE**

(71) Applicants: **AMBIT MICROSYSTEMS (SHANGHAI) LTD.**, Shanghai (CN); **HON HAI PRECISION INDUSTRY CO., LTD.**, New Taipei (TW)

(72) Inventors: **Ai-Ning Song**, Shanghai (CN); **Xiao-Yan Liu**, Shanghai (CN); **Cho-Ju Chung**, New Taipei (TW)

(73) Assignees: **AMBIT MICROSYSTEMS (SHANGHAI) LTD.**, Shanghai (CN); **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 323 days.

(21) Appl. No.: **13/952,786**

(22) Filed: **Jul. 29, 2013**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Nov. 13, 2012 (CN) ..... 2012 2 05962521 U

(51) **Int. Cl.**  
**H01Q 1/50** (2006.01)  
**H01Q 1/38** (2006.01)

(52) **U.S. Cl.**  
CPC ... **H01Q 1/50** (2013.01); **H01Q 1/38** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/50; H01Q 1/38; H01Q 1/243  
USPC ..... 343/700 MS, 702, 841, 860, 703  
See application file for complete search history.

(56) **References Cited**

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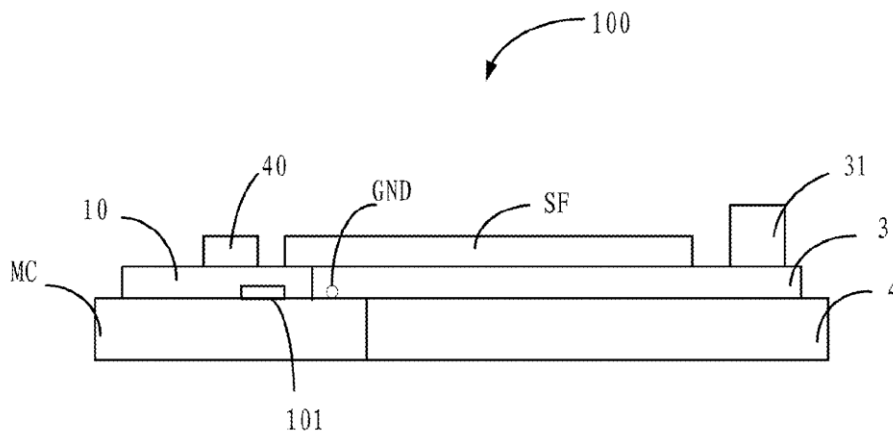
*Primary Examiner* — Hoanganh Le

(74) *Attorney, Agent, or Firm* — Novak Druce Connolly Bove + Quigg LLP

(57) **ABSTRACT**

A printed circuit board (PCB) antenna includes an antenna matching network, an antenna body, and a high frequency (HF) connector. The antenna matching network is used to electrically connect to a signal processing circuit. The antenna body is connected to the antenna matching network, the antenna body includes a bared area, the bared area is used to electrically connect to a conductive object and then to be grounded when the signal processing circuit is needed to be tested. The high frequency (HF) connector is electrically connected to the antenna body and is used to connect to a test device when the signal processing circuit is needed to be tested.

**10 Claims, 5 Drawing Sheets**





US009223342B2

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

(10) **Patent No.:** **US 9,223,342 B2**  
(45) **Date of Patent:** **Dec. 29, 2015**

(54) **RADIO-FREQUENCY SYSTEM**

- (71) Applicant: **Wistron NeWeb Corporation**, Hsinchu (TW)
- (72) Inventors: **Chia-Hao Chang**, Hsinchu (TW); **Shau-Jiun Yu**, Hsinchu (TW); **Chih-Sen Hsieh**, Hsinchu (TW); **Chih-Ming Wang**, Hsinchu (TW)
- (73) Assignee: **Wistron NeWeb Corporation**, Hsinchu Science Park, Hsinchu (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.

(21) Appl. No.: **14/333,494**

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

(65) **Prior Publication Data**  
US 2015/0133188 A1 May 14, 2015

(30) **Foreign Application Priority Data**  
Nov. 8, 2013 (TW) ..... 102140714 A

(51) **Int. Cl.**  
**H04M 1/00** (2006.01)  
**G06F 1/16** (2006.01)  
**H01Q 1/22** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **G06F 1/1618** (2013.01); **G06F 1/162** (2013.01); **G06F 1/1698** (2013.01); **H01Q 1/2266** (2013.01)

(58) **Field of Classification Search**  
CPC H04W 88/02; H04M 1/72527; G06F 1/1633; G06F 1/1639; G06F 1/1649; G06F 3/0488  
USPC ..... 455/90.3, 556.1, 557, 575.1, 575.3, 455/575.4, 575.7; 361/679.01, 679.02, 361/679.06–679.09, 679.15, 679.21, 361/679.06–679.08, 679.55; 713/1, 100  
See application file for complete search history.

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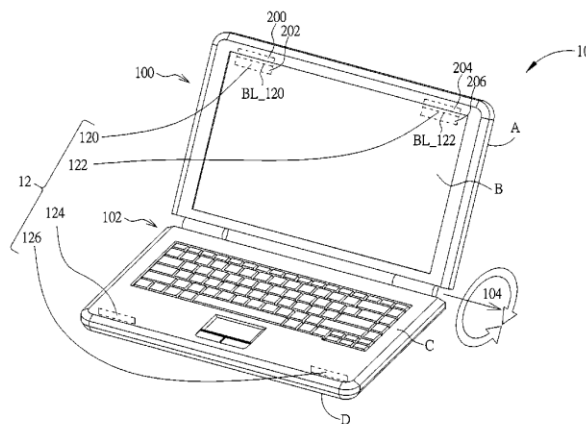
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*Primary Examiner* — Quochien B Vuong  
(74) *Attorney, Agent, or Firm* — Winston Hsu; Scott Margo

(57) **ABSTRACT**

A radio-frequency system for a wireless communication device is disclosed. The wireless communication device includes a first board body and a second board body, capable of operating in a pad mode. The radio-frequency system includes at least one antenna disposed in the first board body and extending along a first plane, and at least one metal wall electrically connected to a system ground, disposed on the second board body related to locations of the at least one antenna disposed in the first board body, extending along a second plane. When the wireless communication device operates in the pad mode, the second plane is substantially perpendicular to the first plane, such that each of the metal walls has a height in comparison to the first plane, and a projecting result of each of the metal walls corresponding to the first plane is adjacent to a radiating element of an antenna.

**7 Claims, 32 Drawing Sheets**







US009223345B2

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

(10) **Patent No.:** **US 9,223,345 B2**  
(45) **Date of Patent:** **Dec. 29, 2015**

(54) **ASSEMBLY OF A HANDHELD ELECTRONIC DEVICE**

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

(72) Inventors: **Teodor Dabov**, Mountain View, CA (US); **Fletcher R. Rothkopf**, Mountain View, CA (US); **Philippe R. Manoux**, Oakland, 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 238 days.

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(22) Filed: **Jun. 21, 2013**

(65) **Prior Publication Data**

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**Related U.S. Application Data**

(63) Continuation of application No. 12/204,350, filed on Sep. 4, 2008, now Pat. No. 8,472,203.

(60) Provisional application No. 60/967,565, filed on Sep. 4, 2007.

(51) **Int. Cl.**

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**H05K 7/18** (2006.01)  
**H01Q 1/24** (2006.01)  
**G06F 1/16** (2006.01)  
**H01Q 1/42** (2006.01)  
**H05K 7/00** (2006.01)

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

CPC ..... **G06F 1/1633** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/42** (2013.01); **H05K 7/00** (2013.01); **H05K 9/0016** (2013.01); **H05K 9/0026** (2013.01); **H05K 9/0037** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/243; H01Q 1/42; H05K 9/0016; H05K 9/0026  
USPC ..... 174/351; 361/799, 800, 816, 818; 343/702

See application file for complete search history.

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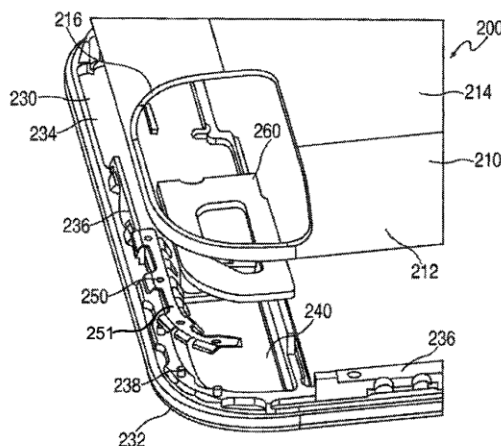
*Primary Examiner* — Sherman Ng

(74) *Attorney, Agent, or Firm* — Downey Brand LLP

(57) **ABSTRACT**

This invention is directed to several mechanical features of an electronic device. The electronic device may include a spring for simultaneously grounding several components. The electronic device may include several interlocking fences for protecting electronic device components from RF radiation. The electronic device may include an antenna assembly that includes distinct components for functional and aesthetic purposes. The electronic device may include a window for permitting RF transmissions. The electronic device may include a metal frame for stiffening the electronic device. The electronic device may include a bezel used for aesthetic purposes and to support numerous electronic device components. The electronic device may include a flexible housing operative to elastically deform to assemble the electronic device. The electronic device may include an unsupported button.

**14 Claims, 18 Drawing Sheets**





US009225057B2

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

(10) **Patent No.:** **US 9,225,057 B2**  
(45) **Date of Patent:** **Dec. 29, 2015**

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

(75) Inventors: **Naoaki Utagawa**, Tokyo (JP); **Manabu Kitami**, Tokyo (JP); **Masaki Matsushima**, Tokyo (JP); **Takeshi Oohashi**, Tokyo (JP); **Yasumasa Harihara**, Tokyo (JP)

(73) Assignee: **TDK CORPORATION**, Tokyo (JP)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 482 days.

(21) Appl. No.: **13/637,836**

(22) PCT Filed: **Mar. 30, 2011**

(86) PCT No.: **PCT/JP2011/057961**

§ 371 (c)(1),  
(2), (4) Date: **Dec. 10, 2012**

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(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**  
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**H01Q 1/38** (2006.01)  
**H05K 1/02** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/38** (2013.01); **H05K 1/0243**  
(2013.01); **H05K 2201/10098** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/38; H05K 1/0243; H05K  
2201/10098

See application file for complete search history.

(56) **References Cited**

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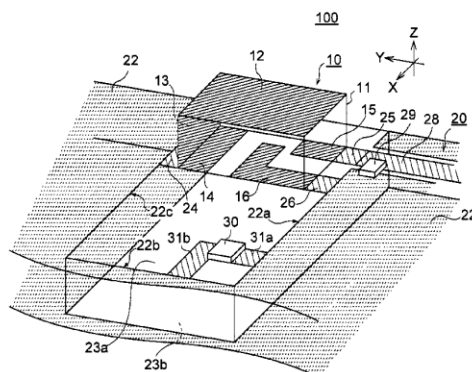
*Primary Examiner* — Trinh Dinh

(74) *Attorney, Agent, or Firm* — McDermott Will & Emery LLP

(57) **ABSTRACT**

An antenna device includes an antenna element **10** and a printed circuit board **20** on which the antenna element **10** is mounted. The antenna element **10** includes a base **11** which is made of a dielectric material and a radiation conductor formed on at least one surface of the base **11**. The printed circuit board **20** includes ground clearance region **23a** having substantially a rectangular shape and having one side contacting an edge of the printed circuit board and other three sides surrounded by an edge line of a ground pattern, an antenna mounting region **27** provided within the ground clearance region **23a**, and at least one frequency adjusting element **30** provided within the ground clearance region **27**. The frequency adjusting element **30** is provided on the far side of the antenna mounting region **27** as viewed from an edge **20e** of the printed circuit board **20**.

**11 Claims, 24 Drawing Sheets**





US009225058B2

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

(10) **Patent No.:** **US 9,225,058 B2**  
(45) **Date of Patent:** **Dec. 29, 2015**

(54) **FLEX PCB FOLDED ANTENNA**

- (71) Applicant: **BlackBerry Limited**, Waterloo (CA)
- (72) Inventors: **Christopher Andrew DeVries**, Waterloo (CA); **Houssam Kanj**, Waterloo (CA)
- (73) Assignee: **BlackBerry Limited**, Waterloo, Ontario (CA)
- (\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 294 days.

- (21) Appl. No.: **13/834,714**
- (22) Filed: **Mar. 15, 2013**

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*H01Q 21/06* (2006.01)  
*H01P 11/00* (2006.01)  
*H01Q 21/24* (2006.01)
- (52) **U.S. Cl.**  
CPC ..... *H01Q 1/38* (2013.01); *H01P 11/001* (2013.01); *H01Q 21/067* (2013.01); *H01Q 21/24* (2013.01); *Y10T 29/49018* (2015.01)
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CPC ... H01Q 21/06; H01Q 21/061; H01Q 21/067; H01Q 21/24; H01Q 1/38  
USPC ..... 343/700 MS, 893  
See application file for complete search history.

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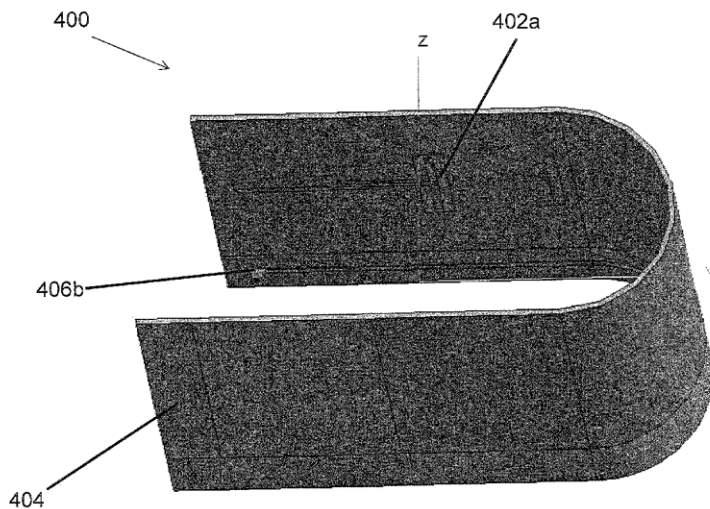
*Primary Examiner* — Hoang V Nguyen

(74) *Attorney, Agent, or Firm* — Conley Rose, P.C.; J. Robert Brown, Jr.

(57) **ABSTRACT**

Embodiments are directed to a flexible substrate, and an end-fire antenna array mounted on the flexible substrate, wherein the flexible substrate is configured to be oriented so that array gain is oriented in a direction perpendicular to a plane of the flexible substrate. Embodiments are directed to mounting an end-fire antenna array on a flexible substrate, and orienting the flexible substrate so that array gain is oriented in a direction perpendicular to a plane of the flexible substrate.

**21 Claims, 20 Drawing Sheets**





US009225059B2

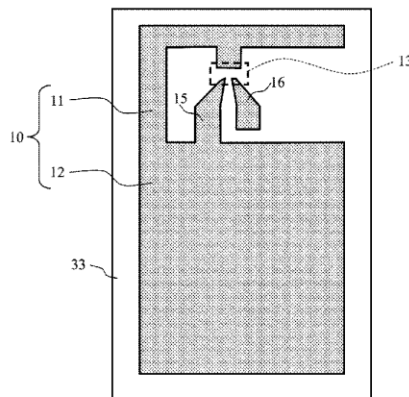
(12) **United States Patent**  
**Takigahira et al.**

(10) **Patent No.:** **US 9,225,059 B2**  
(45) **Date of Patent:** **Dec. 29, 2015**

- (54) **ANTENNA UNIT AND PLANAR WIRELESS DEVICE**
- (71) Applicant: **Fujikura Ltd.**, Tokyo (JP)
- (72) Inventors: **Masato Takigahira**, Sakura (JP);  
**Hiroyuki Hayashi**, Sakura (JP)
- (73) Assignee: **FUJIKURA LTD.**, Tokyo (JP)
- (\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 178 days.
- (21) Appl. No.: **14/011,039**
- (22) Filed: **Aug. 27, 2013**
- (65) **Prior Publication Data**  
US 2013/0342419 A1 Dec. 26, 2013
- Related U.S. Application Data**
- (63) Continuation of application No. PCT/JP2012/050700, filed on Jan. 16, 2012.
- (30) **Foreign Application Priority Data**  
Mar. 2, 2011 (JP) ..... 2011-045167
- (51) **Int. Cl.**  
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**H01Q 1/48** (2006.01)  
(Continued)
- (52) **U.S. Cl.**  
CPC ..... **H01Q 1/48** (2013.01); **H01M 10/0436** (2013.01); **H01M 10/425** (2013.01); **H01Q 1/243** (2013.01); **H01Q 9/0421** (2013.01); **H01M 6/40** (2013.01)
- (58) **Field of Classification Search**  
CPC . H01M 10/0436; H01M 10/425; H01M 6/40; H01Q 1/243; H01Q 1/48; H01Q 1/44; H01Q 9/0421; Y02E 60/12  
USPC ..... 343/700 MS, 829, 846, 848  
See application file for complete search history.

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- Primary Examiner* — Tho G Phan  
(74) *Attorney, Agent, or Firm* — Westerman, Hattori, Daniels & Adrian, LLP

- (57) **ABSTRACT**  
An object of the present invention is to provide a planar type antenna unit and a planar type wireless device capable of reducing a projecting area of the wireless device. To achieve the above object, the planar type wireless device of the present invention is provided with a grounded planar antenna **10** which includes a radiating element **11** and a ground plate **12**, a thin-film battery **20** which includes a positive-electrode current collector **21** opposing a negative-electrode current collector which is formed by the ground plate **12**, and a transmitter/receiver IC arranged at a power feeding point **13** of the grounded planar antenna **10** and including a transmitter-receiver circuit which receives power from the negative-electrode current collector of the thin-film battery **20** and the positive-electrode current collector **21** of the thin-film battery **20**, and transmits and receives signals by operating the radiating element **11** of the grounded planar antenna **10**.
- 15 Claims, 9 Drawing Sheets**





US009225063B2

(12) **United States Patent**  
**Lee**

(10) **Patent No.:** **US 9,225,063 B2**

(45) **Date of Patent:** **Dec. 29, 2015**

(54) **MULTI-BAND ANTENNA**

(71) Applicant: **AMAZON TECHNOLOGIES, INC.**,  
Reno, NV (US)

(72) Inventor: **Chen-Jung Lee**, San Jose, CA (US)

(73) Assignee: **Amazon Technologies, Inc.**, Reno, NV  
(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.: **14/495,462**

(22) Filed: **Sep. 24, 2014**

(65) **Prior Publication Data**

US 2015/0009087 A1 Jan. 8, 2015

**Related U.S. Application Data**

(63) Continuation of application No. 13/211,138, filed on  
Aug. 16, 2011, now Pat. No. 8,872,712.

(60) Provisional application No. 61/494,799, filed on Jun.  
8, 2011.

(51) **Int. Cl.**

**H01Q 7/00** (2006.01)

**H01Q 5/00** (2015.01)

**H01Q 1/24** (2006.01)

**H01Q 5/378** (2015.01)

**H01Q 5/392** (2015.01)

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

CPC ..... **H01Q 5/0062** (2013.01); **H01Q 1/243**  
(2013.01); **H01Q 5/378** (2015.01); **H01Q 5/392**  
(2015.01); **H01Q 7/00** (2013.01)

(58) **Field of Classification Search**

USPC ..... 343/729, 846, 848, 850, 852, 866,  
343/700 MS, 702

See application file for complete search history.

(56) **References Cited**

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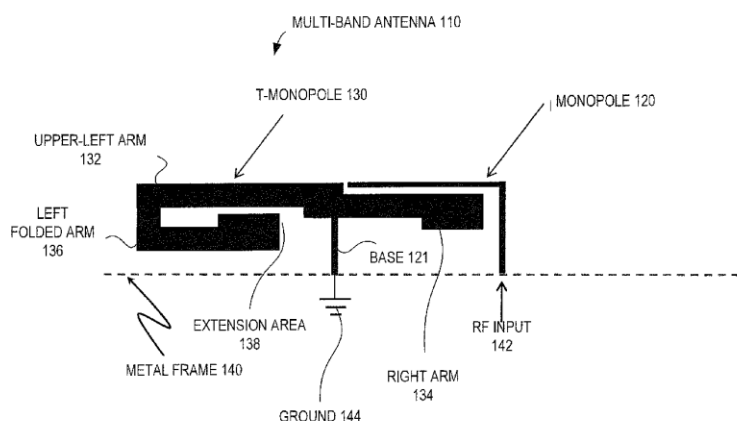
*Primary Examiner* — Huedung Mancuso

(74) *Attorney, Agent, or Firm* — Lowenstein Sandler LLP

(57) **ABSTRACT**

Methods and systems for extending a bandwidth of a multi-band antenna of a user device are described. A multi-band antenna includes a single radio frequency (RF) input coupled to a first loop antenna, the first loop antenna configured to provide a first resonant mode. The multi-band antenna also includes a second antenna parasitically coupled to the first loop antenna to provide additional resonant modes of the multi-band antenna. The second antenna is a T-monopole antenna with a base coupled to the ground plane, a first arm extending out from a first side of the base, a second arm extending out from a second side of the base and a folded arm extending back towards the second side of the base from a distal end of the second arm.

**20 Claims, 8 Drawing Sheets**





US009225065B2

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

(10) **Patent No.:** **US 9,225,065 B2**  
(45) **Date of Patent:** **Dec. 29, 2015**

- (54) **ADAPTIVE ANTENNA MODULE**
- (75) Inventors: **Kevin R. Boyle**, Horsham (GB);  
**Maurice de Jongh**, Nijmegen (NL);  
**Adrianus van Bezooijen**, Molenhoek (NL)
- (73) Assignee: **Qualcomm Technologies, 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 572 days.
- (21) Appl. No.: **13/695,396**
- (22) PCT Filed: **Apr. 30, 2010**
- (86) PCT No.: **PCT/EP2010/055932**  
§ 371 (c)(1),  
(2), (4) Date: **Jan. 17, 2013**
- (87) PCT Pub. No.: **WO2011/134534**  
PCT Pub. Date: **Nov. 3, 2011**
- (65) **Prior Publication Data**  
US 2013/0113677 A1 May 9, 2013
- (51) **Int. Cl.**  
**H01Q 1/50** (2006.01)  
**H03H 7/40** (2006.01)  
**H01Q 9/04** (2006.01)
- (52) **U.S. Cl.**  
CPC ..... **H01Q 9/0442** (2013.01); **H03H 7/40** (2013.01)
- (58) **Field of Classification Search**  
CPC ..... H03H 7/40; H01Q 9/0442  
USPC ..... 343/860  
See application file for complete search history.

- (56) **References Cited**
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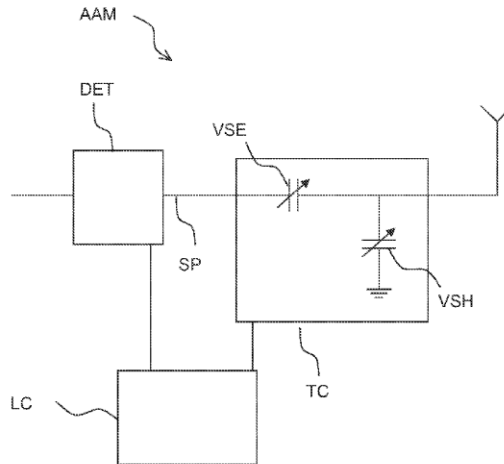
(Continued)

*Primary Examiner* — Sue A Purvis  
*Assistant Examiner* — Michael Bouizza  
(74) *Attorney, Agent, or Firm* — Smith Risley Tempel Santos LLC

(57) **ABSTRACT**

A cheaper to produce, smaller and easy to drive adaptive antenna module is presented. The module comprises a signal path, an antenna, and a tuning circuit with two variable impedance elements. The tuning circuit operates over a restricted range of impedances and maintains the series resonance characteristic of the antenna.

**16 Claims, 3 Drawing Sheets**





US009231293B2

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

(10) **Patent No.:** **US 9,231,293 B2**  
(45) **Date of Patent:** **Jan. 5, 2016**

(54) **INTEGRATED ANTENNA AND SENSOR ELEMENT APPARATUS FOR A PORTABLE WIRELESS TERMINAL**

(75) Inventors: **Gyu-Bok Park**, Gyeonggi-do (KR); **Hee-Jun Lee**, Gyeonggi-do (KR); **Cheol-Hong Son**, Seoul (KR); **Austin Kim**, Gyeonggi-do (KR); **Joon-Ho Byun**, Gyeonggi-do (KR); **Se-Hyun Park**, Gyeonggi-do (KR); **Seong-Tae Jeong**, 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 605 days.

(21) Appl. No.: **13/441,992**

(22) Filed: **Apr. 9, 2012**

(65) **Prior Publication Data**  
US 2013/0029625 A1 Jan. 31, 2013

(30) **Foreign Application Priority Data**  
Jul. 27, 2011 (KR) ..... 10-2011-0074503

(51) **Int. Cl.**  
**H04B 5/00** (2006.01)  
**H04M 1/00** (2006.01)  
**H01Q 1/24** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/44** (2013.01); **H01Q 9/42** (2013.01); **H03K 17/955** (2013.01); **H03K 2017/9606** (2013.01); **H03K 2217/960755** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/242; H01Q 1/243; H01Q 3/24; H01Q 1/24; H04B 7/0814; H04B 1/3838; H04B 7/0608; H04B 1/38; H04B 5/00; H04M 1/00  
USPC ..... 455/41.1, 41.2, 41.3, 550.1, 90.3, 455/575.1, 575.5, 575.6, 562.1, 575.7; 343/872; 379/388  
See application file for complete search history.

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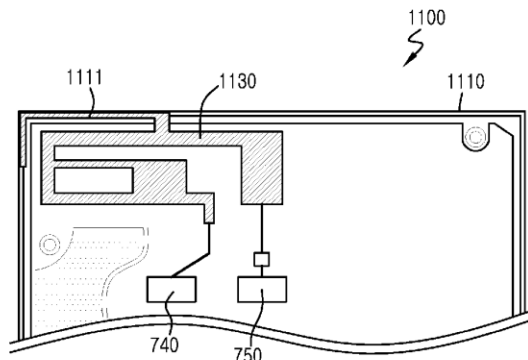
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*Primary Examiner* — Pablo Tran  
(74) *Attorney, Agent, or Firm* — Cha & Reiter, LLC

(57) **ABSTRACT**  
An apparatus with a metal member used as at least one of an antenna and a sensor element in a portable terminal is disclosed. The apparatus includes the metal member, responsive to a sensed body, and for transmitting and receiving a signal in at least one or more communication service bands, and a main board having a communication module for processing a signal transmitted and received by the metal member and a sensor module for obtaining information in response to the approach of a sensed body.

**20 Claims, 14 Drawing Sheets**





US009231294B2

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

(10) **Patent No.:** **US 9,231,294 B2**  
(45) **Date of Patent:** **Jan. 5, 2016**

(54) **METHOD AND APPARATUS FOR  
COMPENSATING FREQUENCY SHIFTING  
OF ANTENNA**

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(71) Applicant: **LENOVO (BEIJING) CO., LTD.**,  
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(72) Inventors: **Kai Lu**, Beijing (CN); **Zhaowei Hu**,  
Beijing (CN); **Dafei Mo**, Beijing (CN);  
**Chunmei Ye**, Beijing (CN)

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pages.

(73) Assignee: **LENOVO (BEIJING) CO., LTD.**,  
Beijing (CN)

Chinese Patent Application No. 201210081014.1, Chinese Patent  
Office, Second Office Action mailed Aug. 25, 2015; 8 pages.

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No. 201210081014.1, Chinese Patent Office, Second Office Action  
mailed Aug. 25, 2015; 10 pages.

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

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(21) Appl. No.: **13/845,794**

Primary Examiner — Junpeng Chen

(22) Filed: **Mar. 18, 2013**

(74) Attorney, Agent, or Firm — Dentons US LLP

(65) **Prior Publication Data**

US 2013/0252662 A1 Sep. 26, 2013

(57) **ABSTRACT**

(30) **Foreign Application Priority Data**

Mar. 23, 2012 (CN) ..... 2012 1 0081014

The present invention provides a method and an apparatus for  
compensating frequency shifting of an antenna, applicable to  
a wireless communication device having at least one fre-  
quency shifted operating mode, in which a frequency shifting  
exists due to a variation of a device use mode or an environ-  
mental condition, wherein the method comprises setting in  
the antenna at least one compensation matching circuit cor-  
responding to the at least one frequency shifted operating  
mode; detecting the use mode, in which the wireless commu-  
nication device operates; when the wireless communication  
device is in the frequency shifted operating mode, switching  
to a compensation matching circuit corresponding to the fre-  
quency shifted operating mode as detected. In the present  
invention, the difficulty in the bandwidth design of the  
antenna is reduced, and the effect of the variation of the use  
mode or environmental condition on the performance of the  
antenna is compensated adaptively.

(51) **Int. Cl.**

**H01Q 1/24** (2006.01)  
**H01Q 1/22** (2006.01)

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

CPC ..... **H01Q 1/245** (2013.01); **H01Q 1/2266**  
(2013.01)

(58) **Field of Classification Search**

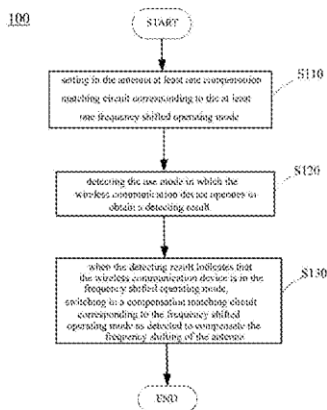
USPC ..... 455/552.1; 333/32  
See application file for complete search history.

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**8 Claims, 3 Drawing Sheets**







US009231295B2

(12) **United States Patent  
Chang**

(10) **Patent No.: US 9,231,295 B2**  
(45) **Date of Patent: Jan. 5, 2016**

- (54) **WEARABLE DEVICE FOR WIRELESS COMMUNICATION**
- (71) Applicant: **Acer Incorporated**, New Taipei (TW)
- (72) Inventor: **Chih-Hua Chang**, 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 252 days.
- (21) Appl. No.: **13/970,822**
- (22) Filed: **Aug. 20, 2013**

(65) **Prior Publication Data**  
US 2014/0320357 A1 Oct. 30, 2014

(30) **Foreign Application Priority Data**  
Apr. 29, 2013 (TW) ..... 102115202 A

(51) **Int. Cl.**  
**H01Q 1/27** (2006.01)  
**H01Q 5/378** (2015.01)  
**H01Q 1/24** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/273** (2013.01); **H01Q 1/243** (2013.01); **H01Q 5/378** (2015.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/273; H01Q 1/243; H01Q 5/378  
USPC ..... 343/702  
See application file for complete search history.

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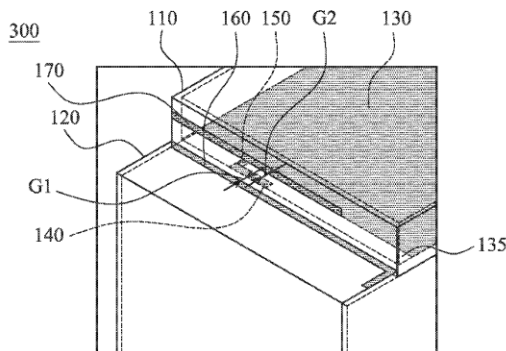
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*Primary Examiner* — Dameon E Levi  
*Assistant Examiner* — Jennifer F Hu  
(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(57) **ABSTRACT**  
A wearable device for wireless communication includes a device body, a wearable belt, a ground element, a feeding element, and a radiation element. The device body substantially has a central hollow structure. The ground element and the feeding element are both disposed in the device body. The feeding element is coupled to a signal source. The radiation element is disposed on a surface of the wearable belt or in the wearable belt, and is disposed adjacent to the feeding element. A coupled-fed antenna structure is formed by the feeding element and the radiation element.

**10 Claims, 4 Drawing Sheets**





US009231298B2

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

(10) **Patent No.:** **US 9,231,298 B2**  
(45) **Date of Patent:** **Jan. 5, 2016**

(54) **ANTENNA DEVICE OF MOBILE COMMUNICATION TERMINAL**

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

(72) Inventors: **Joon-Ho Byun**, Yongin-si (KR);  
**Seong-Tae Jeong**, Yongin-si (KR);  
**Bum-Jin Cho**, Hwaseong-si (KR);  
**Soon-Ho Hwang**, Seoul (KR);  
**Yong-Soo Kwak**, Suwon-si (KR);  
**Austin Kim**, Seongnam-si (KR);  
**Jae-Hoon Jo**, Seoul (KR); **Jae-Hyung Kim**, Seoul (KR); **A-Hyun Sin**, Busan (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 292 days.

(21) Appl. No.: **13/686,555**

(22) Filed: **Nov. 27, 2012**

(65) **Prior Publication Data**  
US 2013/0082888 A1 Apr. 4, 2013

**Related U.S. Application Data**

(63) Continuation of application No. 12/841,389, filed on Jul. 22, 2010, now Pat. No. 8,353,097.

(30) **Foreign Application Priority Data**

Jul. 22, 2009 (KR) ..... 10-2009-0066760

(51) **Int. Cl.**  
**H01Q 9/00** (2006.01)  
**H01Q 1/50** (2006.01)

(Continued)

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

CPC ..... **H01Q 1/38** (2013.01); **H01Q 1/243** (2013.01); **Y10T 29/49002** (2015.01); **Y10T 29/49016** (2015.01)

(58) **Field of Classification Search**

CPC .... **H01Q 1/243**; **H01Q 1/38**; **Y10T 29/49016**; **Y10T 29/49002**  
See application file for complete search history.

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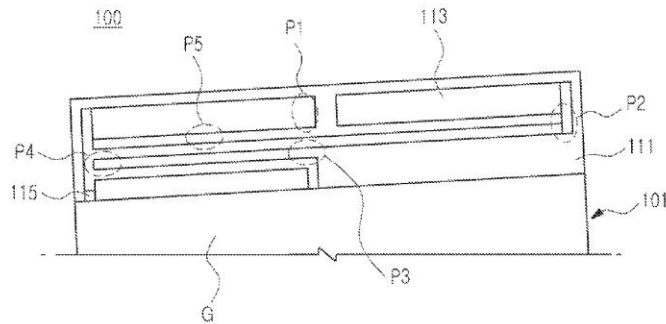
*Primary Examiner* — Trinh Dinh

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

(57) **ABSTRACT**

An antenna device of a mobile communication terminal is provided, the device including at least one radiation pattern and at least one magneto dielectric module or dielectric module installed in a selected position on the radiation pattern to tune one or more resonance frequencies of the radiation pattern according to resonance frequencies required for the terminal. The radiation pattern is selected from among one or more radiation patterns fabricated according to a usable frequency band. The one or more radiation patterns each include one or more resonance frequencies. The magneto dielectric module is selected from among one or more magneto dielectric modules fabricated for controlling the one or more resonance frequencies of the one or more radiation patterns. The dielectric module is selected from among one or more dielectric modules fabricated for controlling the one or more resonance frequencies of the one or more radiation patterns.

**16 Claims, 29 Drawing Sheets**





US009231301B2

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

(10) **Patent No.:** **US 9,231,301 B2**  
(45) **Date of Patent:** **Jan. 5, 2016**

- (54) **MULTI-BAND MIMO ANTENNA**
- (71) Applicants: **Laurent Desclos**, San Diego, CA (US); **Sebastian Rowson**, San Diego, CA (US); **Jeffrey Shamblin**, San Marcos, CA (US); **Young Cha**, San Diego, CA (US)
- (72) Inventors: **Laurent Desclos**, San Diego, CA (US); **Sebastian Rowson**, San Diego, CA (US); **Jeffrey Shamblin**, San Marcos, CA (US); **Young Cha**, San Diego, 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.
- (21) Appl. No.: **14/553,920**
- (22) Filed: **Nov. 25, 2014**
- (65) **Prior Publication Data**  
US 2015/0155621 A1 Jun. 4, 2015

**Related U.S. Application Data**

- (60) Division of application No. 13/966,074, filed on Aug. 13, 2013, now Pat. No. 8,952,861, which is a division of application No. 13/548,221, filed on Jul. 13, 2012, now Pat. No. 8,542,158, which is a continuation-in-part of application No. 13/289,901, filed on Nov. 4, 2011, now Pat. No. 8,717,241, which is a continuation of application No. 12/894,052, filed on Sep. 29, 2010, now Pat. No. 8,077,116, which is a continuation of application No. 11/841,207, filed on Aug. 20, 2007, now Pat. No. 7,830,320.

- (51) **Int. Cl.**  
**H01Q 21/00** (2006.01)  
**H01Q 1/52** (2006.01)  
**H01Q 21/28** (2006.01)  
**H01Q 9/04** (2006.01)
- (52) **U.S. Cl.**  
CPC ..... **H01Q 1/523** (2013.01); **H01Q 9/0442** (2013.01); **H01Q 21/28** (2013.01)
- (58) **Field of Classification Search**  
CPC ..... H01Q 21/28; H01Q 9/0442  
USPC ..... 343/893, 702, 853, 858, 876  
See application file for complete search history.

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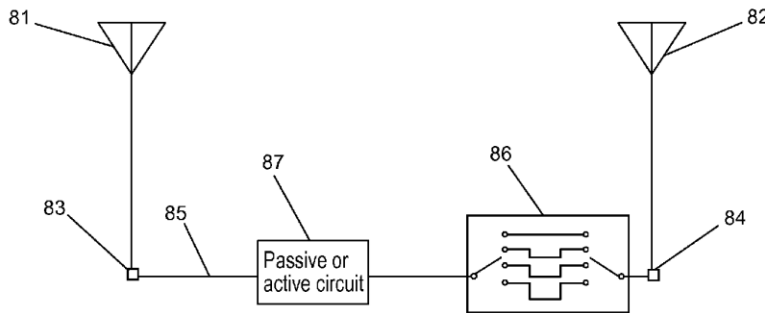
Primary Examiner — Hoanganh Le

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

(57) **ABSTRACT**

A multi-band antenna system for MIMO applications is adapted to provide high isolation between antennas across a wide range of frequencies. Multiple Isolated Magnetic Dipole (IMD) antennas are co-located and connected with a feed network that can include switches that adjust phase length for transmission lines connecting the antennas. Filtering is integrated into the feed network to improve rejection of unwanted frequencies. Filtering can also be implemented on the antenna structure. Either one or multi-port antennas can be used.

**6 Claims, 9 Drawing Sheets**





US009231304B2

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

(10) **Patent No.:** **US 9,231,304 B2**  
(45) **Date of Patent:** **Jan. 5, 2016**

(54) **WIDEBAND LOOP ANTENNA AND AN ELECTRONIC DEVICE INCLUDING THE SAME**

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(71) Applicant: **Nvidia Corporation**, Santa Clara, CA (US)

(72) Inventors: **Sung Hoon Oh**, Santa Clara, CA (US);  
**Joselito Gavilan**, Santa Clara, CA (US);  
**Warren Lee**, Santa Clara, CA (US)

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(73) Assignee: **NVIDIA CORPORATION**, Santa Clara, CA (US)

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 222 days.

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(21) Appl. No.: **14/160,036**

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(Continued)

(22) Filed: **Jan. 21, 2014**

*Primary Examiner* — Huedung Mancuso

(65) **Prior Publication Data**

US 2015/0207230 A1 Jul. 23, 2015

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 7/00** (2006.01)  
**H01Q 9/04** (2006.01)

(57) **ABSTRACT**

Provided is an antenna. In one aspect, the antenna includes a feed element having a first feed element end and a second feed element end, the first feed element end configured to electrically connect to a positive terminal of a transmission line. The antenna, in this aspect, further includes a loop antenna element having a first loop antenna element end and a second loop antenna element end, wherein the first loop antenna element end is coupled to the second feed element end and the second loop antenna element end is configured to electrically connect to a negative terminal of the transmission line. The antenna, of this aspect, further includes a monopole antenna element having a first monopole antenna element end and a second monopole antenna element end, wherein the first monopole antenna element end is coupled to the second feed element end.

(52) **U.S. Cl.**  
CPC ..... **H01Q 7/00** (2013.01); **H01Q 1/243** (2013.01); **H01Q 9/0407** (2013.01)

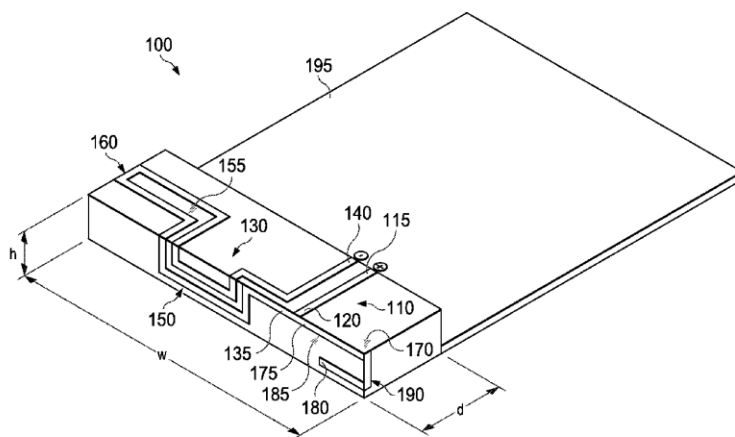
(58) **Field of Classification Search**  
CPC ..... H01Q 1/24; H01Q 13/10  
USPC ..... 343/702, 722, 700 MS  
See application file for complete search history.

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**20 Claims, 3 Drawing Sheets**





US009231306B2

(12) **United States Patent**  
**Abe**

(10) **Patent No.:** **US 9,231,306 B2**

(45) **Date of Patent:** **Jan. 5, 2016**

(54) **PATCH ANTENNA AND WIRELESS COMMUNICATIONS DEVICE**

(71) Applicant: **CASIO COMPUTER CO., LTD.**,  
Tokyo (JP)

(72) Inventor: **Kazuaki Abe**, Iruma (JP)

(73) Assignee: **CASIO COMPUTER CO., LTD.**,  
Tokyo (JP)

(\* ) 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.: **13/953,445**

(22) Filed: **Jul. 29, 2013**

(65) **Prior Publication Data**

US 2014/0078007 A1 Mar. 20, 2014

(30) **Foreign Application Priority Data**

Sep. 20, 2012 (JP) ..... 2012-206784  
Sep. 20, 2012 (JP) ..... 2012-206864

(51) **Int. Cl.**

**H01Q 1/12** (2006.01)  
**H01Q 9/04** (2006.01)  
**H01Q 1/38** (2006.01)  
**H01Q 1/27** (2006.01)

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

CPC ..... **H01Q 9/0407** (2013.01); **H01Q 1/273** (2013.01); **H01Q 1/38** (2013.01); **H01Q 9/0442** (2013.01); **H01Q 9/0471** (2013.01)

(58) **Field of Classification Search**

CPC ... H01Q 1/273; H01Q 9/0442; H01Q 9/0407; H01Q 1/38; H01Q 9/0471  
USPC ..... 343/702, 700 MS, 718  
See application file for complete search history.

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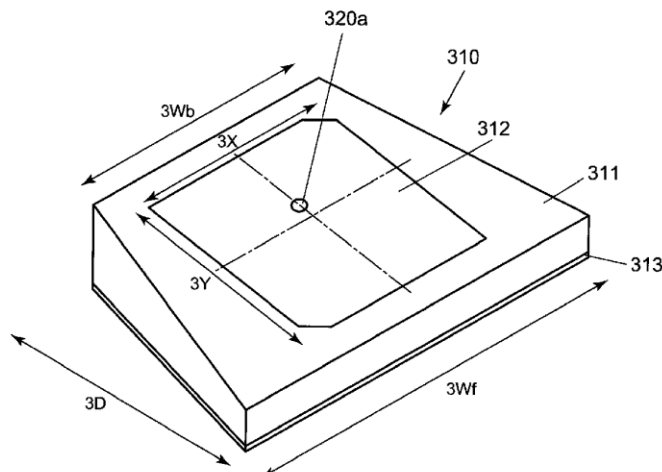
*Primary Examiner* — Hoanganh Le

(74) *Attorney, Agent, or Firm* — Holtz, Holtz, Goodman & Chick PC

(57) **ABSTRACT**

A patch antenna includes a dielectric body, radiation element, earth conductor and feed member. The dielectric body increases in cross-sectional area from a first end toward a second end thereof. The radiation element is disposed on a surface of the dielectric body, and each side of the radiation element has a length adjusted based on the frequency of a radio wave to be received and the effective permittivity of the dielectric body. The earth conductor is disposed on the bottom surface of the dielectric body. The feed member is electrically connected to the radiation element.

**4 Claims, 24 Drawing Sheets**





US009231307B2

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

(10) **Patent No.:** **US 9,231,307 B2**  
(45) **Date of Patent:** **Jan. 5, 2016**

- (54) **MONOPOLE ANTENNA**
- (71) Applicant: **Arcadyan Technology Corporation**,  
Hsinchu (TW)
- (72) Inventors: **Chih-Yung Huang**, Taichung (TW);  
**Jian-Jih Du**, Taipei (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 196 days.

- (21) Appl. No.: **14/188,662**
- (22) Filed: **Feb. 24, 2014**
- (65) **Prior Publication Data**  
US 2014/0285392 A1 Sep. 25, 2014

- (30) **Foreign Application Priority Data**  
Mar. 20, 2013 (TW) ..... 102109902 A

- (51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 9/30** (2006.01)  
**H01Q 5/371** (2015.01)

- (52) **U.S. Cl.**  
CPC . **H01Q 9/30** (2013.01); **H01Q 5/371** (2015.01)

- (58) **Field of Classification Search**  
CPC ..... H01Q 5/371; H01Q 5/357; H01Q 5/364;  
H01Q 9/0407; H01Q 90/06; H01Q 9/30  
USPC ..... 343/702, 795, 825, 826, 828, 829, 830,  
343/843

See application file for complete search history.

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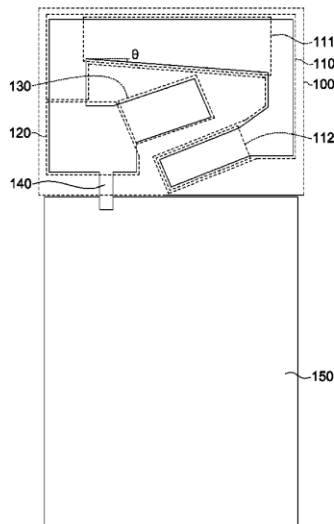
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*Primary Examiner* — Khai M Nguyen  
(74) *Attorney, Agent, or Firm* — Rabin & Berdo, P.C.

- (57) **ABSTRACT**  
A monopole antenna printed on a substrate is provided. The monopole antenna includes a main body, an extension part, a connection part, a signal feeding terminal, and a ground plane. The main body has a first terminal and a second terminal, and further includes a width varying part and two folds, wherein the width varying part is disposed between the two folds. The extension part is extended toward a first inclined direction of the monopole antenna. The connection part connects the first terminal of the main body and the extension part. The signal feeding terminal is electrically connected to the connection part. The ground plane is adjacent to the signal feeding terminal.

**12 Claims, 2 Drawing Sheets**





US009236648B2

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

(10) **Patent No.:** **US 9,236,648 B2**  
(45) **Date of Patent:** **Jan. 12, 2016**

(54) **ANTENNA STRUCTURES HAVING  
RESONATING ELEMENTS AND PARASITIC  
ELEMENTS WITHIN SLOTS IN  
CONDUCTIVE ELEMENTS**

(75) Inventors: **Jerzy Guterman**, Mountain View, CA (US); **Hao Xu**, Cupertino, CA (US); **Douglas Blake Kough**, San Jose, CA (US); **Eduardo Lopez Camacho**, Watsonville, CA (US); **Mattia Pascolini**, Campbell, CA (US); **Robert W. Schlub**, Cupertino, CA (US); **Ruben Caballero**, San Jose, CA (US)

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

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 492 days.

(21) Appl. No.: **12/888,350**

(22) Filed: **Sep. 22, 2010**

(65) **Prior Publication Data**  
US 2012/0068893 A1 Mar. 22, 2012

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 1/22** (2006.01)  
**H01Q 5/357** (2015.01)  
**H01Q 5/378** (2015.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/2266** (2013.01); **H01Q 5/357** (2015.01); **H01Q 5/378** (2015.01)

(58) **Field of Classification Search**  
USPC ..... 343/702, 700 MS, 767  
See application file for complete search history.

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*Primary Examiner* — Hoang V Nguyen

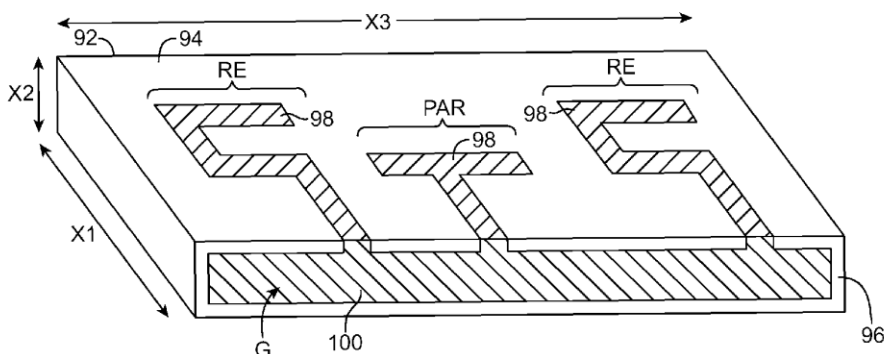
*Assistant Examiner* — Hai Tran

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

(57) **ABSTRACT**

Electronic devices may include radio-frequency transceiver circuitry and antenna structures. The antenna structures may include antenna resonating elements such as dual-band antenna resonating elements that resonate in first and second communications bands. The antenna structures may also contain parasitic antenna elements such as elements that are operative in only the first or second communications band and elements that are operative in both the first and second communications bands. The antenna resonating elements and parasitic elements may be mounted on a common dielectric carrier. The dielectric carrier may be mounted within a slot or other opening in a conductive element. The conductive element may be formed from conductive housing structures in an electronic device such as a portable computer. The portable computer may have a clutch barrel with a dielectric cover. The dielectric cover may overlap and cover the slot and the dielectric carrier.

**22 Claims, 24 Drawing Sheets**





US009236657B2

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

(10) **Patent No.:** **US 9,236,657 B2**  
(45) **Date of Patent:** **Jan. 12, 2016**

(54) **ANTENNA DEVICE AND MATCHING CIRCUIT MODULE FOR ANTENNA DEVICE**

(56) **References Cited**

U.S. PATENT DOCUMENTS

(71) Applicant: **MURATA MANUFACTURING CO., LTD.**, Kyoto (JP)  
(72) Inventors: **Shoji Nagumo**, Kyoto (JP); **Minoru Iwanaga**, Kyoto (JP); **Masahi Nakazato**, Kyoto (JP); **Tomohiro Nagai**, Kyoto (JP)

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

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 250 days.

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(21) Appl. No.: **14/150,511**

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(22) Filed: **Jan. 8, 2014**

*Primary Examiner* — Hoang V Nguyen

(65) **Prior Publication Data**

US 2014/0198009 A1 Jul. 17, 2014

(74) *Attorney, Agent, or Firm* — Studebaker & Brackett PC

(30) **Foreign Application Priority Data**

Jan. 17, 2013 (JP) ..... 2013-006115

(57) **ABSTRACT**

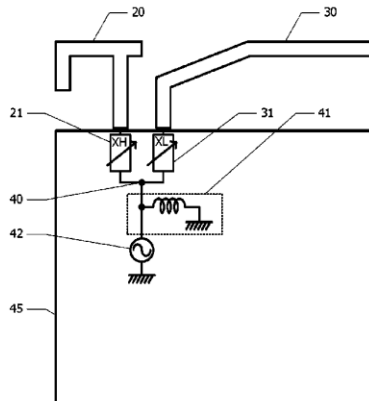
(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 5/335** (2015.01)  
**H01Q 21/30** (2006.01)

A low-frequency radiating element and a high-frequency radiating element are configured so as to respectively operate in a relatively low frequency band and a relatively high frequency band that are non-contiguous with each other. A matching circuit is inserted between a transmission/reception circuit and a branching point. A high-frequency variable reactance circuit is inserted between the branching point and the high-frequency radiating element. A low-frequency variable reactance circuit is inserted between the branching point and the low-frequency radiating element. The high-frequency variable reactance circuit and the low-frequency variable reactance circuit are configured such that their reactances can be adjusted independently of each other.

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

(58) **Field of Classification Search**  
CPC ..... H01Q 5/335; H01Q 21/30; H01Q 1/243  
See application file for complete search history.

**12 Claims, 18 Drawing Sheets**







US009236659B2

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

(10) **Patent No.:** **US 9,236,659 B2**  
(45) **Date of Patent:** **Jan. 12, 2016**

(54) **ELECTRONIC DEVICE WITH HYBRID  
INVERTED-F SLOT ANTENNA**

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

(72) Inventors: **Enrique Ayala Vazquez**, Watsonville, CA (US); **Hongfei Hu**, Santa Clara, CA (US); **Mattia Pascolini**, San Mateo, CA (US); **Yuehui Ouyang**, Sunnyvale, CA (US); **Yijun Zhou**, Sunnyvale, CA (US); **Matthew A. Mow**, Los Altos, CA (US); **Robert W. Schlub**, Cupertino, CA (US); **Erdinc Irci**, Sunnyvale, CA (US); **Salih Yarga**, Sunnyvale, CA (US); **Ming-Ju Tsai**, Cupertino, CA (US); **Liang Han**, Sunnyvale, CA (US); **Thomas E. Biedka**, San Jose, CA (US); **Nicholas S. Reimnitz**, Campbell, 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 222 days.

(21) Appl. No.: **14/096,417**

(22) Filed: **Dec. 4, 2013**

(65) **Prior Publication Data**  
US 2014/0266941 A1 Sep. 18, 2014

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 13/10** (2006.01)  
**H01Q 9/14** (2006.01)  
**H01Q 9/42** (2006.01)  
**H01Q 5/357** (2015.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 13/103** (2013.01); **H01Q 1/243** (2013.01); **H01Q 5/357** (2015.01); **H01Q 9/145** (2013.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**  
USPC ..... 343/700 MS, 702, 729, 746, 767  
See application file for complete search history.

(56) **References Cited**

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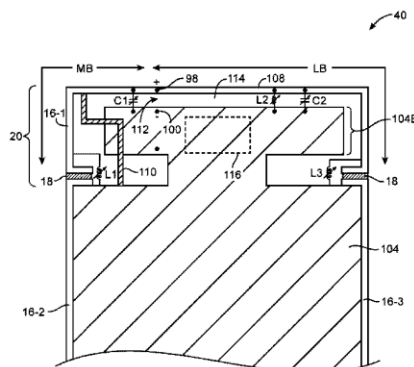
*Primary Examiner* — Tan Ho

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

(57) **ABSTRACT**

An electronic device may be provided with a housing. The housing may have a periphery that is surrounded by peripheral conductive structures such as a segmented peripheral metal member. A segment of the peripheral metal member may be separated from a ground by a slot. An antenna feed may have a positive antenna terminal coupled to the peripheral metal member and a ground terminal coupled to the ground and may feed both an inverted-F antenna structure that is formed from the peripheral metal member and the ground and a slot antenna structure that is formed from the slot. Control circuitry may tune the antenna by controlling adjustable components that are coupled to the peripheral metal member. The adjustable components may include adjustable inductors and adjustable capacitors.

**20 Claims, 11 Drawing Sheets**





US009240627B2

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

(10) **Patent No.:** **US 9,240,627 B2**  
(45) **Date of Patent:** **Jan. 19, 2016**

(54) **HANDHELD DEVICE AND PLANAR ANTENNA THEREOF**

(75) Inventors: **Chun-Wei Tseng**, Taoyuan County (TW); **Chien-Chih Chen**, Taoyuan County (TW); **Yen-Liang Kuo**, Taoyuan County (TW); **Wan-Ming Chen**, Taoyuan County (TW)

(73) Assignee: **HTC CORPORATION** (TW)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 150 days.

(21) Appl. No.: **13/277,539**

(22) Filed: **Oct. 20, 2011**

(65) **Prior Publication Data**  
US 2013/0099996 A1 Apr. 25, 2013

(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**  
USPC ..... 343/876, 700 MS, 702  
See application file for complete search history.

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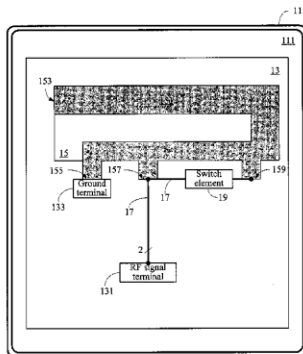
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*Primary Examiner* — Hoang V Nguyen  
*Assistant Examiner* — Hai Tran  
(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

A handheld device and a planar antenna thereof are provided. The planar antenna comprises a radiator with an open terminal, a short terminal, a first feeding terminal and a second feeding terminal. The short terminal is coupled to a ground terminal. The first feeding terminal is formed between the open terminal and the short terminal, and coupled to a radio frequency (RF) signal terminal. The second feeding terminal is formed between the open terminal and the first feeding terminal, and coupled to the first feeding terminal by a transmission line and a switch element. The radiator resonates at the first central frequency when the switch element is turned off, and resonates at the second central frequency when the switch element is turned on.

**12 Claims, 6 Drawing Sheets**





US009241050B1

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

(10) **Patent No.:** **US 9,241,050 B1**  
(45) **Date of Patent:** **Jan. 19, 2016**

(54) **SELF-HEALING ANTENNA SYSTEM**

(71) Applicant: **GOOGLE TECHNOLOGY HOLDINGS LLC**, Mountain View, CA (US)

(72) Inventors: **Vijay L. Asrani**, Round Lake, IL (US); **Krishna Katragadda**, Mundelein, IL (US); **Peruvemba Ranganathan Sai Ananthanarayanan**, Naperville, IL (US)

(73) Assignee: **Google Technology Holdings LLC**, Mountain View, 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.: **14/488,709**

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

**Related U.S. Application Data**

(60) Provisional application No. 62/046,211, filed on Sep. 5, 2014.

(51) **Int. Cl.**  
**H04M 1/02** (2006.01)  
**H04B 1/3827** (2015.01)  
**H04W 88/02** (2009.01)

(52) **U.S. Cl.**  
CPC ..... **H04M 1/026** (2013.01); **H04B 1/3833** (2013.01); **H04W 88/02** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H04B 1/0458  
USPC ..... 455/73, 77, 87, 550.1  
See application file for complete search history.

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(57) **ABSTRACT**

A mobile communication device is provided that uses an accelerometer to sense when the mobile communication device is dropped and impacts a hard surface, such as a floor or table, with a force hard enough to bend or deform an external metal antenna. Once such an impact is detected by the mobile communication device, the mobile communication device is further configured to determine whether an antenna has become detuned from its respective transceiver and then retune the antenna prior to the user picking up the dropped mobile communication device.

**15 Claims, 5 Drawing Sheets**

