



US009954270B2

(12) **United States Patent**  
**Nakayama**

(10) **Patent No.:** **US 9,954,270 B2**  
(45) **Date of Patent:** **Apr. 24, 2018**

- (54) **MOBILE TERMINAL TO PREVENT DEGRADATION OF ANTENNA CHARACTERISTICS**
- (71) Applicant: **SONY CORPORATION**, Tokyo (JP)
- (72) Inventor: **Takashi Nakayama**, Chiba (JP)
- (73) Assignee: **SONY 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 0 days.

- (21) Appl. No.: **14/903,328**
- (22) PCT Filed: **Jun. 12, 2014**
- (86) PCT No.: **PCT/JP2014/003120**  
§ 371 (c)(1),  
(2) Date: **Jan. 7, 2016**
- (87) PCT Pub. No.: **WO2015/033498**  
PCT Pub. Date: **Mar. 12, 2015**
- (65) **Prior Publication Data**  
US 2016/0380334 A1 Dec. 29, 2016

- (30) **Foreign Application Priority Data**  
Sep. 3, 2013 (JP) ..... 2013-181765
- (51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H04M 1/02** (2006.01)  
(Continued)
- (52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **G06F 1/1626** (2013.01); **G06F 1/1698** (2013.01); **H01P 5/10** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/241–1/243  
See application file for complete search history.

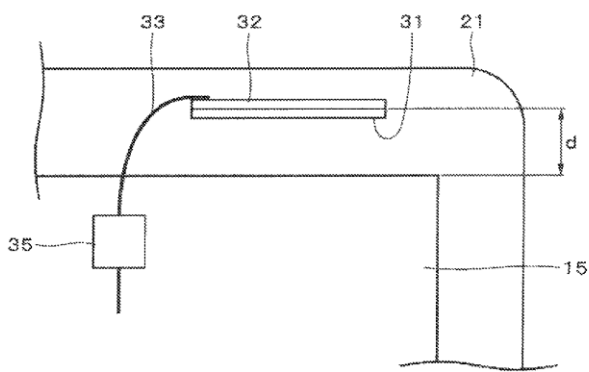
- (56) **References Cited**  
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*Primary Examiner* — Dameon E Levi  
*Assistant Examiner* — Hasan Islam  
(74) *Attorney, Agent, or Firm* — Chip Law Group

(57) **ABSTRACT**  
A mobile terminal includes: a plurality of antenna inputs; a selecting unit configured to select one of the plurality of antenna inputs; a metal chassis used for holding a panel for display and maintaining mechanical strength of the panel; and a PIFA type antenna having a resonance pattern and a coaxial cable in which a coating removed portion is provided in a part in a manner that an external conductor is exposed, the PIFA type antenna being configured to fix the coating removed portion in a vicinity of an upper end of the metal chassis.

**5 Claims, 8 Drawing Sheets**





US009954275B2

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

(10) **Patent No.:** **US 9,954,275 B2**  
(45) **Date of Patent:** **Apr. 24, 2018**

(54) **MULTIPLE-INPUT MULTIPLE-OUTPUT ANTENNA, SYSTEM AND MOBILE TERMINAL**

(71) Applicant: **ZTE Corporation**, Shenzhen, Guangdong (CN)

(72) Inventors: **Yu Zhang**, Shenzhen (CN); **Biao Li**, Shenzhen (CN)

(73) Assignee: **ZTE CORPORATION**, Shenzhen (CN)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 22 days.

(21) Appl. No.: **14/431,612**

(22) PCT Filed: **Jun. 19, 2013**

(86) PCT No.: **PCT/CN2013/077510**

§ 371 (c)(1),

(2) Date: **Mar. 26, 2015**

(87) PCT Pub. No.: **WO2013/170798**

PCT Pub. Date: **Nov. 21, 2013**

(65) **Prior Publication Data**

US 2015/0255864 A1 Sep. 10, 2015

(30) **Foreign Application Priority Data**

Sep. 27, 2012 (CN) ..... 2012 1 0374387

(51) **Int. Cl.**

**H01Q 1/52** (2006.01)

**H01Q 7/00** (2006.01)

**H01Q 21/28** (2006.01)

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

CPC ..... **H01Q 1/521** (2013.01); **H01Q 1/52** (2013.01); **H01Q 7/00** (2013.01); **H01Q 21/28** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/52; H01Q 7/00; H01Q 21/28

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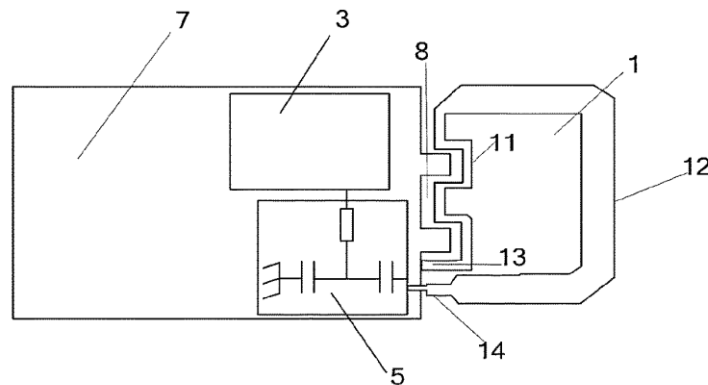
*Primary Examiner* — Huedung Mancuso

(74) *Attorney, Agent, or Firm* — Oppedahl Patent Law Firm LLC

(57) **ABSTRACT**

A Multiple-Input Multiple-Output (MIMO) antenna is provided, which includes a Printed Circuit Board (PCB), an antenna connected with the PCB, a feed system, and a match circuit, wherein the antenna is connected with the feed system through the match circuit, the antenna connected with the PCB is the antenna having a Loop structure, and a gap having a fixed width is provided between a ground loop of the antenna connected with the PCB and the PCB. An MIMO antenna system and a mobile terminal are also provided. By adopting the MIMO antenna, system and mobile terminal, a coupling current between the MIMO antenna and the PCB can be relatively concentrated and current amplitude is small, thereby isolation between antennas is improved.

**2 Claims, 1 Drawing Sheet**





US009954285B2

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

(10) **Patent No.:** **US 9,954,285 B2**  
(45) **Date of Patent:** **Apr. 24, 2018**

(54) **WIFI PATCH ANTENNA WITH DUAL U-SHAPED SLOTS**  
(71) Applicant: **Taoglas Group Holdings Limited**, Wexford (IE)  
(72) Inventors: **Chen-yi Chuang**, Zhongli (TW); **Ronan Quinlan**, Wexford (IE)  
(73) Assignee: **TAOGLAS GROUP HOLDINGS LIMITED**, Wexford (IE)  
(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(58) **Field of Classification Search**  
CPC ..... H01Q 13/10; H01Q 21/064; H01Q 21/24; H01Q 1/38  
USPC ..... 343/770, 768, 767, 746  
See application file for complete search history.

(21) Appl. No.: **14/853,996**  
(22) Filed: **Sep. 14, 2015**  
(65) **Prior Publication Data**  
US 2016/0079676 A1 Mar. 17, 2016

(56) **References Cited**  
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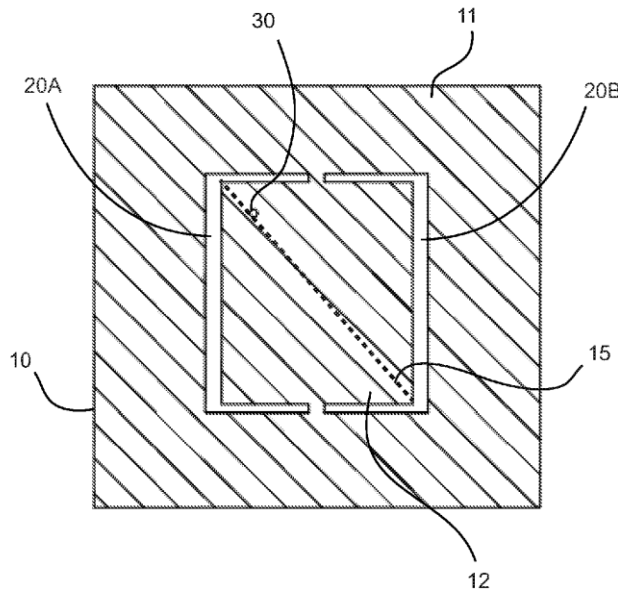
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*Primary Examiner* — Dameon E Levi  
*Assistant Examiner* — Collin Dawkins  
(74) *Attorney, Agent, or Firm* — Coastal Patent Law Group, P.C.

**Related U.S. Application Data**  
(60) Provisional application No. 62/049,873, filed on Sep. 12, 2014.  
(51) **Int. Cl.**  
**H01Q 13/10** (2006.01)  
**H01Q 5/357** (2015.01)  
**H01Q 9/04** (2006.01)  
(52) **U.S. Cl.**  
CPC ..... **H01Q 13/106** (2013.01); **H01Q 5/357** (2015.01); **H01Q 9/0407** (2013.01)

(57) **ABSTRACT**  
The disclosure concerns a microstrip patch antenna configured for operation in the WiFi bands, including 2.4 GHz and 5.2/5.8 GHz. The microstrip patch antenna includes a pair of opposing u-shaped slots embedded in the patch conductor. The patch includes a patch width configured to provide a resonance at 2.4 GHz, and a slot width configured to provide a resonance at 5.2/5.8 GHz. Thus, the antenna provides a dual band WiFi patch antenna.

**8 Claims, 6 Drawing Sheets**





US009961173B2

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

(10) **Patent No.:** **US 9,961,173 B2**  
(45) **Date of Patent:** **May 1, 2018**

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

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

(72) Inventors: **Zonglin Xue**, Beijing (CN); **Linchuan Wang**, Beijing (CN); **Xiaofeng Xiong**, Beijing (CN)

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

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

(21) Appl. No.: **15/411,705**

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

(65) **Prior Publication Data**  
US 2017/0272557 A1 Sep. 21, 2017

(30) **Foreign Application Priority Data**  
Mar. 16, 2016 (CN) ..... 2016 1 0151308

(51) **Int. Cl.**  
**H04M 1/02** (2006.01)  
**H04M 1/725** (2006.01)  
**H01Q 1/24** (2006.01)  
**H01Q 5/371** (2015.01)  
**H01Q 5/385** (2015.01)

(52) **U.S. Cl.**  
CPC ..... **H04M 1/026** (2013.01); **H01Q 1/243** (2013.01); **H01Q 5/371** (2015.01); **H01Q 5/385** (2015.01); **H04M 1/725** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/243; H01Q 5/385  
USPC ..... 455/66.1, 550.1, 63.4, 575.5, 575.7  
See application file for complete search history.

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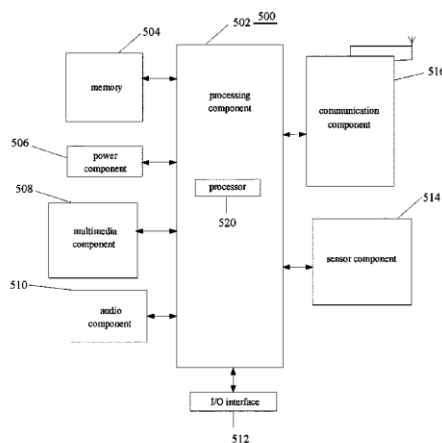
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*Primary Examiner* — John J Lee

(57) **ABSTRACT**

An antenna and a mobile terminal are provided. The antenna may include a radiation unit and at least one parasitic unit. The radiation unit includes a first radiation sub-unit and a second radiation sub-unit. A first terminal of the first radiation sub-unit is connected to a bottom edge of a rear cover of the mobile terminal. A second terminal of the first radiation sub-unit is provided with a feed point, a first terminal of the second radiation sub-unit is connected to the bottom edge. A second terminal of the second radiation sub-unit is provided with a ground point. A distance from the feed point to the ground point is greater than zero and less than a preset value. The at least one parasitic unit is coupleable with the radiation unit via the feed point.

**10 Claims, 6 Drawing Sheets**





US009966653B2

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

(10) **Patent No.:** **US 9,966,653 B2**  
(45) **Date of Patent:** **May 8, 2018**

(54) **ANTENNAS FOR ELECTRONIC DEVICE WITH HEAT SPREADER**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)  
(72) Inventors: **Erin A. McAuliffe**, Campbell, CA (US); **James W. Jervis**, Santa Clara, CA (US); **Andrea Ruaro**, Copenhagen (DK); **Mattia Pascolini**, San Francisco, CA (US); **Jerzy S. Guterman**, Mountain View, 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 175 days.

(21) Appl. No.: **14/839,619**

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

(65) **Prior Publication Data**

US 2017/0062906 A1 Mar. 2, 2017

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 9/42** (2006.01)  
**H01Q 5/371** (2015.01)  
**H01Q 1/06** (2006.01)  
**H01Q 1/38** (2006.01)  
**H01Q 9/04** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/24** (2013.01); **H01Q 1/06** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 5/371** (2015.01); **H01Q 9/04** (2013.01); **H01Q 9/42** (2013.01)

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

(56) **References Cited**

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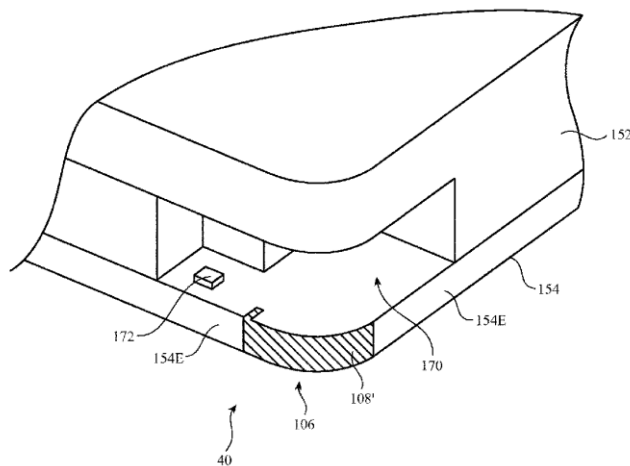
*Primary Examiner* — Trinh Dinh

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

(57) **ABSTRACT**

An electronic device may have wireless circuitry with antennas. The electronic device may have a dielectric housing. A printed circuit board with electrical components may be mounted in the dielectric housing. Heat spreader structures may be used to dissipate heat from the electrical components. The heat spreader structures be configured to form antenna cavities. The antennas in the electronic device may be formed from the antenna cavities and may have antenna resonating elements formed on the printed circuit. An electrical component such as a light-emitting diode may be mounted in one of the antenna cavities. Each antenna element may be an inverted-F antenna resonating element with short and long arms. The short arm of each antenna resonating element may be formed from edge plated metal traces on an edge of the printed circuit.

**19 Claims, 9 Drawing Sheets**





US009966655B2

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

(10) **Patent No.:** **US 9,966,655 B2**  
(45) **Date of Patent:** **May 8, 2018**

(54) **ANTENNA STRUCTURE AND MOBILE TERMINAL DEVICE**

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

(72) Inventors: **Yuanpeng Li**, Beijing (CN); **Yafang Yu**, Beijing (CN); **Meng Hou**, Shanghai (CN)

(73) Assignee: **Huawei Device (Dongguan) 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 62 days.

(21) Appl. No.: **15/173,086**

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

(65) **Prior Publication Data**  
US 2016/0285153 A1 Sep. 29, 2016

**Related U.S. Application Data**

(63) Continuation of application No. PCT/CN2014/092945, filed on Dec. 3, 2014.

(30) **Foreign Application Priority Data**  
Dec. 6, 2013 (CN) ..... 2013 1 0656510

(51) **Int. Cl.**  
**H01Q 1/50** (2006.01)  
**H01Q 1/24** (2006.01)  
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(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/50** (2013.01); **H01Q 5/385** (2015.01); **H01Q 7/00** (2013.01); **H01Q 9/0421** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/243; H01Q 5/385; H01Q 1/50; H01Q 7/00; H01Q 9/0421  
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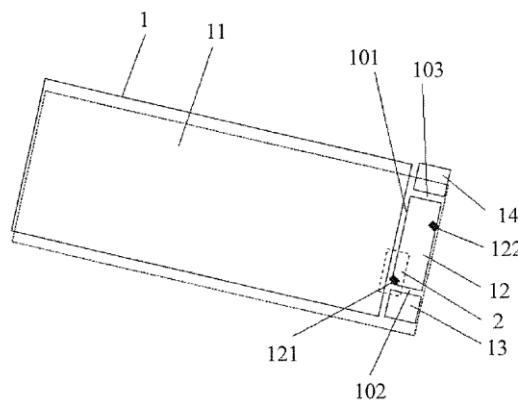
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Rohith K. Raj et al., "A New Compact Microstrip-Fed Dual-Band Coplanar Antenna for WLAN Applications", IEEE Transactions on Antennas and Propagation, vol. 54, No. 12, Dec. 2006, p. 3755-3762.

*Primary Examiner* — Andrea Lindgren Baltzell

(57) **ABSTRACT**  
The present invention discloses an antenna structure and ensures an all-metal housing feature of the mobile terminal device. The antenna structure includes a housing and a feed plate, where the housing includes a main housing, a first floating object, a second floating object, and an antenna radiator; and the first floating object, the second floating object, and the antenna radiator are separated from the main housing by a first slot; there is a second slot between the first floating object and one side of the antenna radiator, and a third slot between the second floating object and the other side of the antenna radiator; the main housing, the first floating object, the second floating object, and the antenna radiator are connected as a whole by an insulator; and the feed plate is disposed opposite to the main housing, the first floating object, and the antenna radiator at an interval.

**13 Claims, 3 Drawing Sheets**





US009966663B1

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

(10) **Patent No.:** **US 9,966,663 B1**  
(45) **Date of Patent:** **May 8, 2018**

(54) **DUAL-BAND ANTENNA MODULE**

(71) Applicant: **UNIVERSAL SCIENTIFIC INDUSTRIAL (SHANGHAI) CO., LTD.**, Shanghai (CN)

(72) Inventors: **Hsin-Hong Chen**, Shanghai (CN);  
**Jui-Kun Shih**, Shanghai (CN);  
**Chun-Huan Lee**, Shanghai (CN);  
**Jui-Chih Chien**, Shanghai (CN);  
**Chih-Sen Hsieh**, Shanghai (CN)

(73) Assignee: **UNIVERSAL SCIENTIFIC INDUSTRIAL (SHANGHAI) CO., LTD.**, Shanghai (CN)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 22 days.

(21) Appl. No.: **15/386,598**

(22) Filed: **Dec. 21, 2016**

(30) **Foreign Application Priority Data**

Oct. 21, 2016 (CN) ..... 2016 1 0919775

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 5/307** (2015.01)  
**H01Q 1/22** (2006.01)  
**H01Q 1/48** (2006.01)  
**H01Q 1/38** (2006.01)

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(52) **U.S. Cl.**  
CPC ..... **H01Q 5/307** (2015.01); **H01Q 1/2291** (2013.01); **H01Q 1/36** (2013.01); **H01Q 1/38** (2013.01); **H01Q 1/48** (2013.01); **H01Q 5/35** (2015.01); **H01Q 21/28** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/24; H01Q 1/241; H01Q 1/243; H01Q 5/307; H01Q 5/35; H01Q 1/2291; H01Q 21/28

See application file for complete search history.

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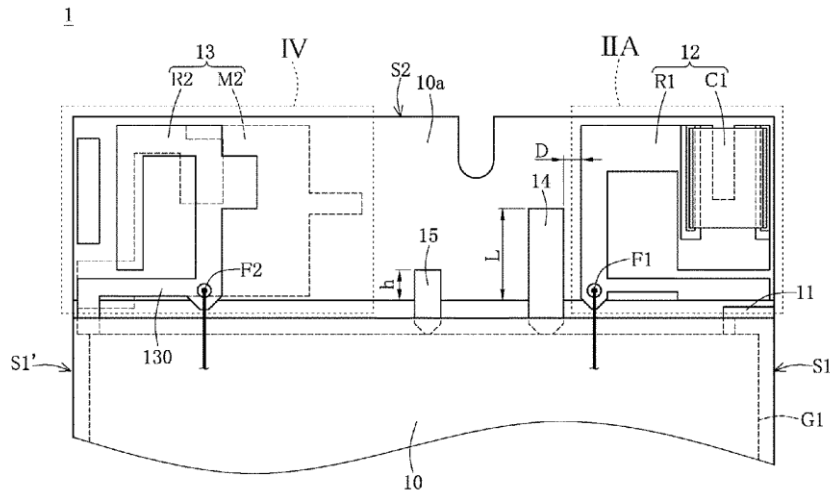
*Primary Examiner* — Hoang Nguyen

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

(57) **ABSTRACT**

A dual-band antenna module is provided. The dual-band antenna module includes a circuit board, a ground coupling portion electrically connected to a reference ground plane of the circuit board, a first antenna, and a second antenna spaced from the first antenna. The first antenna and the ground coupling portion are disposed on the circuit board and configured to couple each other. The first antenna includes a first radiation unit, a U-shaped conductive frame, and a first feeding portion. The U-shaped conductive frame is disposed on the first radiation unit and opens toward the circuit board. The second antenna includes a second radiation unit, a high-frequency impedance portion, and a second feeding portion. The second radiation unit and the high-frequency impedance portion are respectively disposed on two opposite surfaces of the circuit board to resonate to each other. The second radiation unit includes a ground extension portion electrically grounded.

**11 Claims, 6 Drawing Sheets**





US00996666B2

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

(10) **Patent No.:** **US 9,966,666 B2**  
(45) **Date of Patent:** **May 8, 2018**

(54) **ANTENNA DEVICE AND ELECTRONIC APPARATUS HAVING THE SAME**

(71) Applicant: **Samsung Electronics Co., Ltd.**,  
Suwon-si, Gyeonggi-do (KR)  
(72) Inventors: **Hyun-Jin Kim**, Seoul (KR); **Goudelev Alexander**, Suwon-si (KR); **Anton S. Lukyanov**, Suwon-si (KR); **Won-Bin Hong**, Seoul (KR); **Byung-Chul Kim**, Hwaseong-si (KR); **Young-Ju Lee**, 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 166 days.

(21) Appl. No.: **14/341,194**

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

(65) **Prior Publication Data**  
US 2015/0035715 A1 Feb. 5, 2015

(30) **Foreign Application Priority Data**  
Aug. 1, 2013 (KR) ..... 10-2013-0091551

(51) **Int. Cl.**  
**H01Q 9/04** (2006.01)  
(52) **U.S. Cl.**  
CPC ..... **H01Q 9/0421** (2013.01)  
(58) **Field of Classification Search**  
CPC ..... H01Q 9/0421  
USPC ..... 343/787  
See application file for complete search history.

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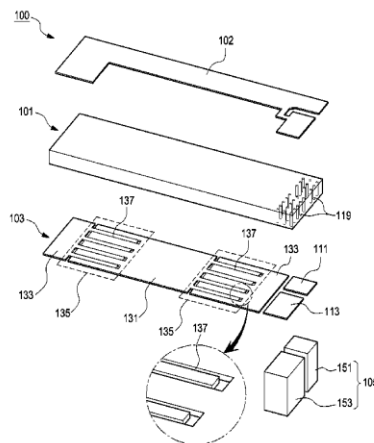
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*Primary Examiner* — Dieu H Duong  
*Assistant Examiner* — Bamidele A Jegede  
(74) *Attorney, Agent, or Firm* — Jefferson IP Law, LLP

(57) **ABSTRACT**

An antenna device is provided. The antenna device may include a conductive radiator pattern formed on one surface of a dielectric substrate, an artificial magnetic conductor layer including at least one unit cell formed on the other surface of the dielectric substrate, and a shorting pin connected to the unit cell. The artificial magnetic conductor layer may be configured to form an induction current of the same phase with regard to a signal current flowing through the conductive radiator pattern.

**17 Claims, 6 Drawing Sheets**







US009966667B2

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

(10) **Patent No.:** **US 9,966,667 B2**  
(45) **Date of Patent:** **May 8, 2018**

(54) **ELECTRONIC DEVICE ANTENNA WITH SWITCHABLE RETURN PATHS**

(58) **Field of Classification Search**  
CPC ..... H01Q 13/103; H01Q 1/245  
USPC ..... 343/702  
See application file for complete search history.

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

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(72) Inventors: **Enrique Ayala Vazquez**, Watsonville, CA (US); **Hongfei Hu**, Cupertino, CA (US); **Nanbo Jin**, San Jose, CA (US); **Matthew A. Mow**, Los Altos, CA (US); **Liang Han**, Sunnyvale, CA (US); **Ming-Ju Tsai**, Sunnyvale, CA (US); **Erica J. Tong**, Pacifica, CA (US); **Erdinc Irci**, Sunnyvale, CA (US); **Salih Yarga**, Sunnyvale, CA (US); **Mattia Pascolini**, San Francisco, CA (US); **Benjamin Shane Bustle**, Cupertino, CA (US); **Ruben Caballero**, San Jose, CA (US)

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*Primary Examiner* — Andrea Lindgren Baltzel

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

(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. days.

(21) Appl. No.: **15/806,986**

(57) **ABSTRACT**

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

An electronic device may have wireless circuitry with antennas. An antenna resonating element arm for an antenna may be formed from conductive housing structures running along the edges of a device. The antenna may have a pair of switchable return paths that bridge a slot between the antenna resonating element and an antenna ground. An adjustable component and a feed may be coupled in parallel across the slot. The adjustable component may switch a capacitor into use or out of use and the return paths may be selectively opened and closed to compensate for antenna loading due to the presence of external objects near the electronic device.

(65) **Prior Publication Data**

US 2018/0069317 A1 Mar. 8, 2018

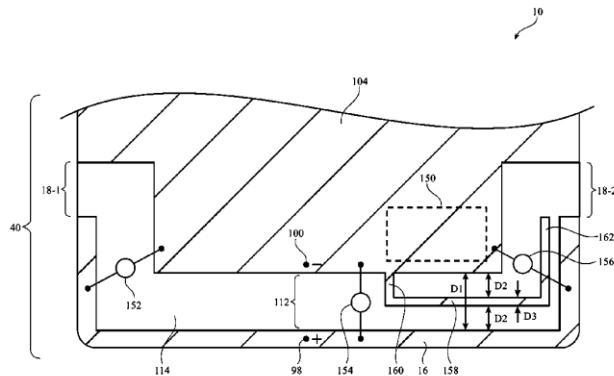
**Related U.S. Application Data**

(63) Continuation of application No. 14/811,714, filed on Jul. 28, 2015.

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

(52) **U.S. Cl.**  
CPC ..... **H01Q 13/103** (2013.01); **H01Q 1/245** (2013.01)

**20 Claims, 10 Drawing Sheets**





US009972891B2

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

(10) **Patent No.:** **US 9,972,891 B2**  
(45) **Date of Patent:** **May 15, 2018**

(54) **ELECTRONIC DEVICE ANTENNA WITH ISOLATION MODE**

USPC ..... 343/702, 700 MS, 767  
See application file for complete search history.

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

(56) **References Cited**

(72) Inventors: **Enrique Ayala Vazquez**, Watsonville, CA (US); **Hongfei Hu**, Santa Clara, CA (US); **Nanbo Jin**, Milpitas, CA (US); **Matthew A. Mow**, Los Altos, CA (US); **Liang Han**, Sunnyvale, CA (US); **Mattia Pascolini**, San Francisco, CA (US)

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(73) Assignee: **Apple Inc.**, Cupertino, 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 26 days.

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(21) Appl. No.: **14/819,280**

*Primary Examiner* — Hoang Nguyen

(22) Filed: **Aug. 5, 2015**

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

(65) **Prior Publication Data**

US 2017/0040668 A1 Feb. 9, 2017

(57) **ABSTRACT**

(51) **Int. Cl.**

<b><i>H01Q 1/24</i></b>	(2006.01)
<b><i>H01Q 9/42</i></b>	(2006.01)
<b><i>H01Q 13/10</i></b>	(2006.01)
<b><i>H01Q 5/328</i></b>	(2015.01)
<b><i>H01Q 5/335</i></b>	(2015.01)
<b><i>H01Q 5/378</i></b>	(2015.01)

An electronic device may have wireless circuitry with antennas. An antenna resonating element arm for a given antenna may be formed from metal structures supported by a plastic carrier. The antenna resonating element arm may be coupled to switching circuitry to isolate the antenna resonating element arm when the antenna resonating element arm is not being used to handle communications in a communications band. The electronic device may have a metal housing. A slot may separate a peripheral portion of the housing such as a sidewall portion from a planar rear portion. The sidewall portion and the planar rear portion may form an additional antenna that operates at communications frequencies outside of the communications band handled by the given antenna. A parasitic antenna resonating element arm may be formed in the slot to enhance the frequency response of the additional antenna.

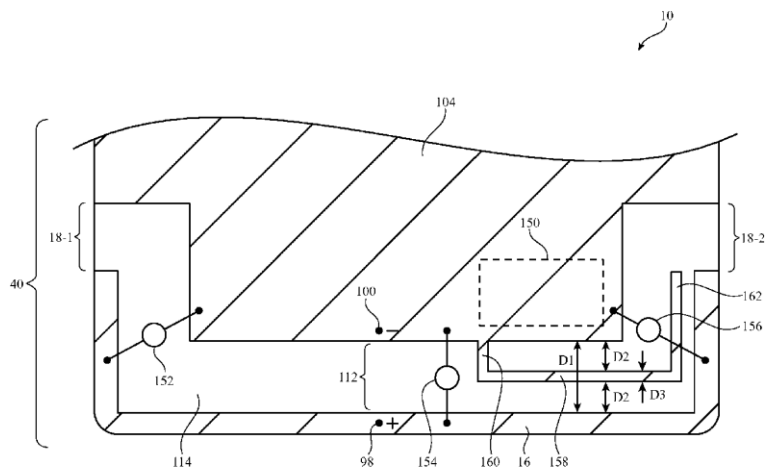
(52) **U.S. Cl.**

CPC ..... ***H01Q 1/243*** (2013.01); ***H01Q 5/328*** (2015.01); ***H01Q 5/335*** (2015.01); ***H01Q 5/378*** (2015.01); ***H01Q 9/42*** (2013.01); ***H01Q 13/106*** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/243; H01Q 7/00; H01Q 9/14; H01Q 21/28; H01Q 9/42; H01Q 1/44; H01Q 5/328; H01Q 5/335; H01Q 5/378

**21 Claims, 10 Drawing Sheets**





US009972892B2

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

(10) **Patent No.:** **US 9,972,892 B2**  
(45) **Date of Patent:** **May 15, 2018**

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

*1/242* (2013.01); *H01Q 19/10* (2013.01);  
*H01Q 19/30* (2013.01); *H01Q 21/065*  
(2013.01)

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

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

(72) Inventors: **Basim H. Noori**, San Jose, CA (US);  
**Boon W. Shiu**, San Jose, CA (US);  
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(US); **Mattia Pascolini**, San Francisco,  
CA (US); **Ming-Ju Tsai**, Cupertino, CA  
(US); **Ruben Caballero**, San Jose, CA  
(US); **Yuehui Ouyang**, Sunnyvale, CA  
(US); **Khan Salam**, Dublin, CA (US)

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

(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 112 days.

(21) Appl. No.: **15/138,689**

(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.

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

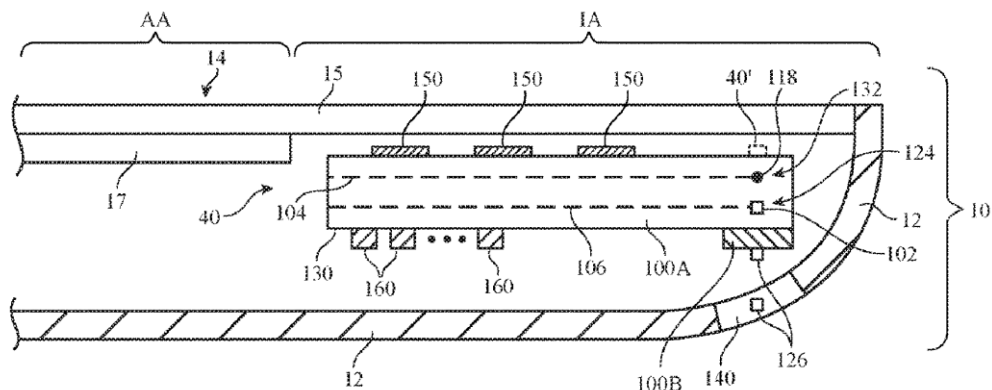
**9 Claims, 17 Drawing Sheets**

(65) **Prior Publication Data**

US 2017/030992 A1 Oct. 26, 2017

(51) **Int. Cl.**  
*H01Q 1/24* (2006.01)  
*H01Q 21/06* (2006.01)  
*H01Q 19/10* (2006.01)  
*H01Q 1/22* (2006.01)  
*H01Q 19/30* (2006.01)

(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); *H01Q 1/241* (2013.01); *H01Q*





US009972908B2

(12) **United States Patent**  
**Sanchez**

(10) **Patent No.:** **US 9,972,908 B2**  
(45) **Date of Patent:** **May 15, 2018**

(54) **CAPACITIVELY COUPLED LOOP  
INVERTED F RECONFIGURABLE ANTENNA**

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

(72) Inventor: **Jorge Fabrega Sanchez**, San Diego,  
CA (US)

(73) Assignee: **FUTUREWEI TECHNOLOGIES,  
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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 294 days.

(21) Appl. No.: **13/939,631**

(22) Filed: **Jul. 11, 2013**

(65) **Prior Publication Data**

US 2015/0015445 A1 Jan. 15, 2015

(51) **Int. Cl.**  
**H01Q 5/00** (2015.01)  
**H01Q 7/00** (2006.01)  
**H01Q 5/364** (2015.01)  
**H01Q 5/328** (2015.01)  
**H01Q 9/04** (2006.01)  
**H01Q 5/321** (2015.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 5/364** (2015.01); **H01Q 5/321**  
(2015.01); **H01Q 5/328** (2015.01); **H01Q 7/00**  
(2013.01); **H01Q 9/0421** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 5/328; H01Q 5/364  
See application file for complete search history.

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Primary Examiner — Jessica Han

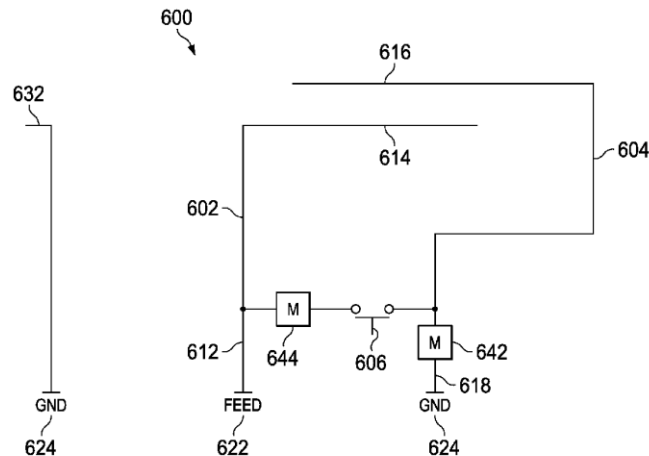
Assistant Examiner — Amal Patel

(74) Attorney, Agent, or Firm — Futurewei Technologies,  
Inc.

(57) **ABSTRACT**

System and method embodiments are provided for capaci-  
tive coupled loop inverted F reconfigurable multiband  
antenna. The embodiments enable tuning and adjustment of  
the low frequency response of the antenna without appre-  
ciably effecting the high frequency response of the antenna.  
In an embodiment, a reconfigurable multiband antenna  
includes a first antenna section comprising a first end and a  
second end, wherein the second end is coupled to an antenna  
feed, a second antenna section comprising a third end and a  
fourth end, wherein the third end is coupled to ground, and  
a switch coupling the second end to the third end, wherein  
the first end and the fourth end are capacitively coupled.

**18 Claims, 7 Drawing Sheets**





US009972911B1

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

(10) **Patent No.:** **US 9,972,911 B1**  
(45) **Date of Patent:** **May 15, 2018**

(54) **WIDE BAND FREQUENCY AGILE MIMO ANTENNA**

(71) Applicant: **KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS, Dhahran (SA)**

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

(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 29 days.

(21) Appl. No.: **15/333,157**

(22) Filed: **Oct. 24, 2016**

(51) **Int. Cl.**  
**H01Q 21/06** (2006.01)  
**H01Q 13/10** (2006.01)  
**H01Q 21/00** (2006.01)  
**H01Q 1/38** (2006.01)  
**H01Q 1/48** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 13/106** (2013.01); **H01Q 1/38** (2013.01); **H01Q 1/48** (2013.01); **H01Q 21/00** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/38; H01Q 1/48; H01Q 21/00  
USPC ..... 343/700 MS, 702, 749-751, 846, 850  
See application file for complete search history.

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Primary Examiner — Dameon E Levi

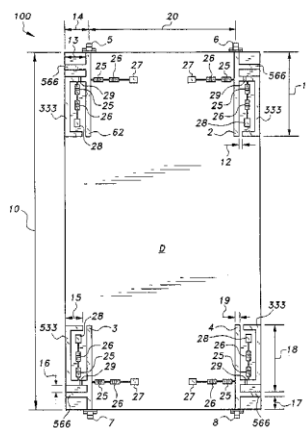
Assistant Examiner — Hasan Islam

(74) Attorney, Agent, or Firm — Richard C. Litman

(57) **ABSTRACT**

The wide band frequency agile MIMO antenna is a 4-element, reconfigurable multi-input multi-output (MIMO) antenna system. Frequency agility in the design is achieved using varactor diodes tuned for various capacitance loadings. The MIMO antennas operate over a wide band, covering several well-known wireless standards between 1610-2710 MHz. The present design is simple in structure with low profile antenna elements. The design is prototyped on commercial plastic material with board dimensions 60x100x0.8 mm<sup>3</sup> and is highly suitable to be used in frequency reconfigurable and cognitive radio based wireless handheld devices.

**5 Claims, 6 Drawing Sheets**





US009973232B1

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

(10) **Patent No.:** **US 9,973,232 B1**  
(45) **Date of Patent:** **May 15, 2018**

- (54) **LOW SPECIFIC ABSORPTION RATE (SAR) DUAL-BAND ANTENNA STRUCTURE**
- (71) Applicant: **AMAZON TECHNOLOGIES, INC.**, Reno, NV (US)
- (72) Inventors: **Jerry Weiming Kuo**, San Jose, CA (US); **Ming Zheng**, Cupertino, 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 287 days.
- (21) Appl. No.: **14/298,470**
- (22) Filed: **Jun. 6, 2014**
- (51) **Int. Cl.**  
**H04B 1/50** (2006.01)
- (52) **U.S. Cl.**  
CPC ..... **H04B 1/50** (2013.01)
- (58) **Field of Classification Search**  
CPC ..... H01Q 7/00; H01Q 9/42; H01Q 21/30; H01Q 9/30; H01Q 21/24  
USPC ..... 343/728  
See application file for complete search history.

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*Primary Examiner* — Jessica Han  
*Assistant Examiner* — Bamidele A Jegede

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

(57) **ABSTRACT**

Dual-band antenna structures and methods of operating the same of an electronic device are described. One apparatus includes a radio frequency (RF) feed and a dual-band antenna structure coupled to the RF feed at a feeding point and coupled to a ground plane at a grounding point. The structure includes a first loop antenna and a second loop antenna, both coupled to the feeding point and the grounding point. The first loop antenna radiates electromagnetic energy in a first resonant mode in a first frequency band and the second loop antenna radiates electromagnetic energy in a second resonant mode in a second frequency band and radiates electromagnetic energy in a third resonant mode in the first frequency band. Surface currents create three or more hot spots of magnetic field.

**23 Claims, 10 Drawing Sheets**

