



US010164323B2

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

(10) **Patent No.:** **US 10,164,323 B2**
(45) **Date of Patent:** **Dec. 25, 2018**

(54) **MOBILE TERMINAL**

(71) Applicant: **LG ELECTRONICS INC.**, Seoul
(KR)

(72) Inventors: **Youngbae Kwon**, Seoul (KR); **Kangjae Jung**, Seoul (KR); **Sungjung Rho**, Seoul (KR); **Changwon Yun**, Seoul (KR); **Duckyun Kim**, Seoul (KR); **Yunmo Kang**, Seoul (KR)

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

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

(21) Appl. No.: **15/434,720**

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

(65) **Prior Publication Data**

US 2017/0201016 A1 Jul. 13, 2017

Related U.S. Application Data

(63) Continuation of application No. 15/240,715, filed on Aug. 18, 2016, now Pat. No. 9,608,314.

(30) **Foreign Application Priority Data**

Jan. 11, 2016 (KR) 10-2016-0003386

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 5/307 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/242**
(2013.01); **H01Q 1/38** (2013.01); **H01Q 1/521**
(2013.01);
(Continued)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 5/30; H01Q 13/18;
H01Q 1/242; H01Q 5/307; H01Q 5/35;
H01Q 1/521

See application file for complete search history.

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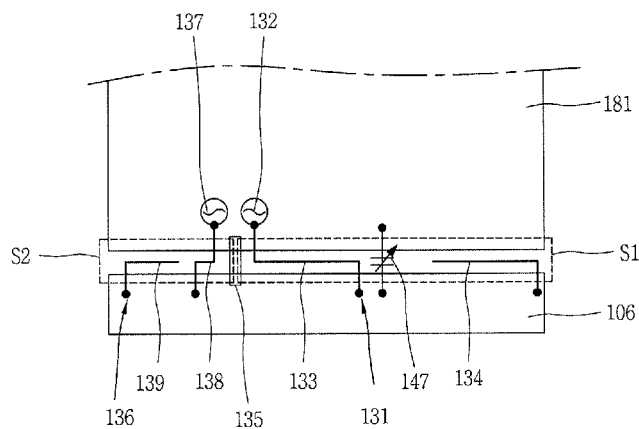
Primary Examiner — Hoang Nguyen

(74) *Attorney, Agent, or Firm* — Birch, Stewart, Kolasch
& Birch, LLP

(57) **ABSTRACT**

A mobile terminal, comprising of a terminal body having a front surface, a rear surface, and side surfaces extending from end portions of the rear surface toward the front surface, the terminal body being made of a metal, a lower module coupled to a lower end of the terminal body and externally exposed to operate as a radiator of an antenna apparatus and a non-metal member interposed between the terminal body and the lower module and forming a slot by spacing the terminal body and the lower module apart from each other, and wherein the antenna apparatus comprises first and second antenna resonating different frequency bands wherein the first antenna and the second antenna comprise a first feeder and a second feeder, respectively, connected to a main printed circuit board provided in the terminal body and generating the electric fields on the first slot and the second slot, respectively, and wherein the lower module comprises first and second member and a connecting portion connecting end portions of the first and second members each other, and wherein the first member is

(Continued)





US010164330B2

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

(10) **Patent No.:** **US 10,164,330 B2**

(45) **Date of Patent:** **Dec. 25, 2018**

(54) **ANTENNA ASSEMBLY AND SELF-CURING DECOUPLING METHOD FOR REDUCING MUTUAL COUPLING OF COUPLED ANTENNAS**

(71) Applicant: **The Chinese University of Hong Kong**, Shatin, New Territories, Hong Kong (CN)

(72) Inventors: **Ke-Li Wu**, Hong Kong (CN); **Jiangwei Sui**, Nanyang (CN); **Dacheng Wei**, Guangzhou (CN)

(73) Assignee: **The Chinese University of Hong Kong**, Shatin, N.T., Hong Kong SAR (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 68 days.

(21) Appl. No.: **15/295,552**

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

(65) **Prior Publication Data**

US 2018/0108984 A1 Apr. 19, 2018

(51) **Int. Cl.**

H01Q 1/52 (2006.01)

H01Q 5/392 (2015.01)

H01Q 9/04 (2006.01)

H01Q 9/42 (2006.01)

H01Q 5/371 (2015.01)

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

CPC **H01Q 1/52** (2013.01); **H01Q 1/521** (2013.01); **H01Q 5/371** (2015.01); **H01Q 5/392** (2015.01); **H01Q 9/0421** (2013.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/48; H01Q 1/243; H01Q 9/0421; H01Q 1/52; H01Q 1/24; H01Q 5/932

USPC 343/846, 702, 850
See application file for complete search history.

(56) **References Cited**

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Primary Examiner — Jessica Han

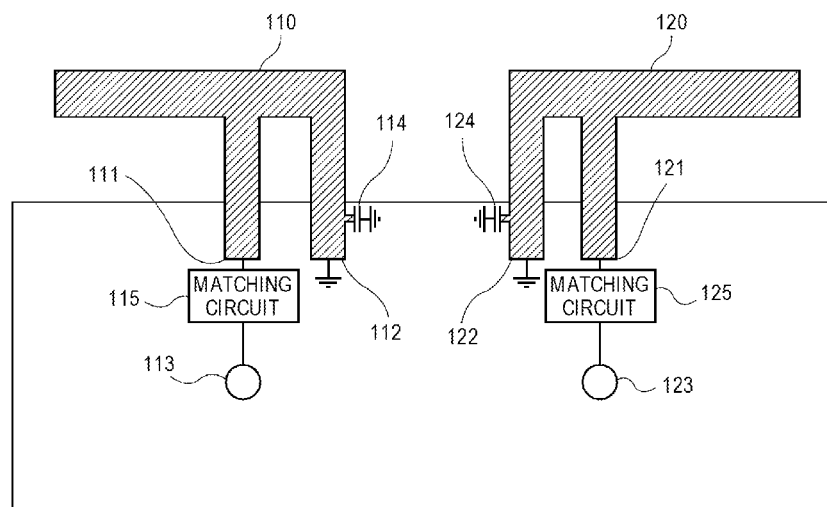
Assistant Examiner — Hai V Tran

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

(57) **ABSTRACT**

The disclosure provides antenna assemblies and methods for reducing mutual coupling of coupled antennas. According to an embodiment, the antenna assembly, comprises: a first antenna; and a second antenna coupled with the first antenna; wherein a first capacitive load is provided to the first antenna at a first position of the first antenna so that a mutual coupling between the first antenna and the second antenna is reduced. According to the present disclosure, at least some of the following advantages may be achieved: 1) no any component that connects or structure between coupled antennas is required; 2) the capacitive load is very little frequency dependent so that the method is highly suitable for antenna decoupling at low frequencies; 3) the required capacitive load takes almost no space in the circuit layout; and 4) the load does not noticeably change antenna radiation patterns.

22 Claims, 21 Drawing Sheets





US010170837B2

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

(10) **Patent No.:** **US 10,170,837 B2**

(45) **Date of Patent:** **Jan. 1, 2019**

(54) **SEGMENTED ANTENNA**

(56) **References Cited**

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

U.S. PATENT DOCUMENTS

(72) Inventors: **Wee Kian Toh**, San Diego, CA (US);
Daejong Kim, San Diego, CA (US);
Shing Lung Steven Yang, San Diego, CA (US); **Ping Shi**, San Diego, CA (US)

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				343/702	
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				343/700 MS	

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 106 days.

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Primary Examiner — Dameon E Levi

Assistant Examiner — Hasan Islam

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

(21) Appl. No.: **13/792,613**

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

(65) **Prior Publication Data**

US 2014/0253406 A1 Sep. 11, 2014

(57) **ABSTRACT**

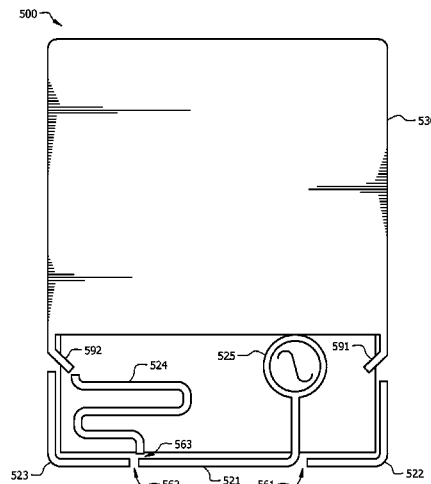
An antenna comprising a main arm comprising conductive material, wherein the main arm is connected to a signal feed, and a first coupling arm comprising conductive material, wherein the first coupling arm is electrically coupled to a ground, and wherein the first coupling arm is electrically coupled to the main arm across a first span of nonconductive material. Also disclosed is a mobile node (MN) comprising a signal feed, a ground, and an antenna comprising a main arm comprising conductive material, wherein the main arm is connected to the signal feed, and a first coupling arm comprising conductive material, wherein the first coupling arm is connected to the ground, and wherein the first coupling arm is electrically coupled to the main arm across a first span of nonconductive material.

(51) **Int. Cl.**
H01Q 9/04 (2006.01)
H01Q 7/00 (2006.01)
H01Q 1/24 (2006.01)
H01Q 9/42 (2006.01)

(52) **U.S. Cl.**
CPC **H01Q 9/0407** (2013.01); **H01Q 1/243** (2013.01); **H01Q 7/00** (2013.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 9/04–9/0407; H01Q 1/243; H01Q 7/00; H01Q 9/42
USPC 343/867, 700, 866, 702
See application file for complete search history.

10 Claims, 7 Drawing Sheets





US010171125B2

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

(10) **Patent No.:** **US 10,171,125 B2**
(45) **Date of Patent:** ***Jan. 1, 2019**

(54) **TUNABLE ANTENNA SYSTEMS**

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

(72) Inventors: **Matthew A. Mow**, Los Altos, CA (US);
Robert W. Schlub, Cupertino, CA
(US); **Mattia Pascolini**, San Francisco,
CA (US); **Robert J. Hill**, Salinas, 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 0 days.

This patent is subject to a terminal dis-
claimer.

(21) Appl. No.: **15/871,388**

(22) Filed: **Jan. 15, 2018**

(65) **Prior Publication Data**

US 2018/0152220 A1 May 31, 2018

Related U.S. Application Data

(63) Continuation of application No. 14/737,394, filed on
Jun. 11, 2015, now Pat. No. 9,893,755, which is a
(Continued)

(51) **Int. Cl.**
H01Q 9/00 (2006.01)
H04B 1/40 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC **H04B 1/40** (2013.01); **H01Q 1/243**
(2013.01); **H01Q 1/48** (2013.01); **H01Q 7/005**
(2013.01);
(Continued)

(58) **Field of Classification Search**

CPC H04B 1/40; H01Q 13/103; H01Q 1/48;
H01Q 9/0442; H01Q 1/243; H01Q 9/145;
H01Q 7/005; H01Q 9/0421

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(56) **References Cited**

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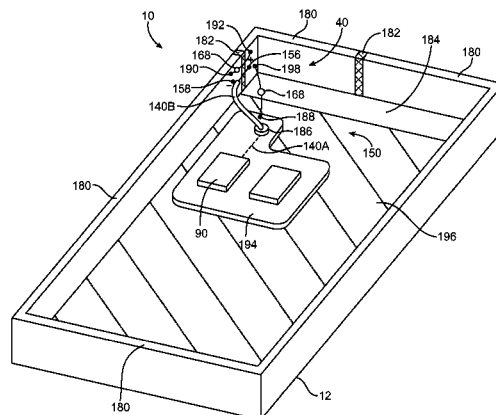
Primary Examiner — Jean B Jeanglaude

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

(57) **ABSTRACT**

An electronic device has wireless communications circuitry
including an adjustable antenna system coupled to a radio-
frequency transceiver. The adjustable antenna system may
include one or more adjustable electrical components that
are controlled by storage and processing circuitry in the
electronic device. The adjustable electrical components may
include switches and components that can be adjusted
between numerous different states. The adjustable electrical
components may be coupled between antenna system com-
ponents such as transmission line elements, matching net-
work elements, antenna elements and antenna feeds. By

(Continued)





US010177439B2

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

(10) **Patent No.:** **US 10,177,439 B2**
(45) **Date of Patent:** **Jan. 8, 2019**

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

(2015.01); **H01Q 5/371** (2015.01); **H01Q 5/50** (2015.01); **H01Q 13/18** (2013.01); **H01Q 21/28** (2013.01)

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

(58) **Field of Classification Search**

CPC H01Q 13/18; H01Q 1/24; H01Q 1/242; H01Q 1/48; H01Q 5/50; H01Q 1/243; H01Q 21/28; H01Q 5/314; H01Q 5/371
See application file for complete search history.

(72) Inventors: **Chih-Ho Lee**, New Taipei (TW);
Tun-Yuan Tsou, New Taipei (TW);
Hsi-Chieh Chen, New Taipei (TW)

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

(56) **References Cited**

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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 0 days.

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9,331,397 B2 * 5/2016 Jin H01Q 21/28
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(21) Appl. No.: **15/655,898**

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

(65) **Prior Publication Data**

US 2018/0026335 A1 Jan. 25, 2018

Related U.S. Application Data

(60) Provisional application No. 62/365,340, filed on Jul. 21, 2016.

(30) **Foreign Application Priority Data**

Jul. 18, 2017 (CN) 2017 1 0586521

(51) **Int. Cl.**

H01Q 1/24 (2006.01)
H01Q 13/18 (2006.01)
H01Q 5/50 (2015.01)
H01Q 1/48 (2006.01)
H01Q 21/28 (2006.01)

(Continued)

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

CPC **H01Q 1/242** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 5/314**

Primary Examiner — Tho G Phan

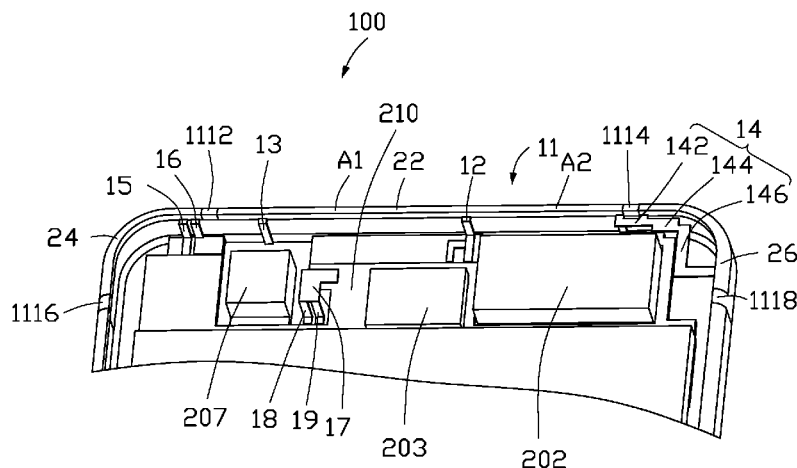
(74) Attorney, Agent, or Firm — ScienBiziP, P.C.

(57)

ABSTRACT

An antenna structure includes a metallic member, a first matching circuit, and a second matching circuit. The metallic member includes a front frame, a backboard, and a side frame. The side frame defines a slot. The front frame defines a first gap and a second gap communicating with the slot and extending across the front frame. A portion of the front frame between the first gap and the second gap forms a first radiating section. One end of the first feed portion connects to the first radiating section, the other end connects to a first feed source and a second feed source through an extractor of the first matching circuit; an end of the first radiating section adjacent to the second gap connects to a ground through an third inductor and an third capacitor of the second matching circuit. A wireless communication device using the antenna structure is provided.

20 Claims, 24 Drawing Sheets



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

(10) **Patent No.:** **US 10,177,440 B2**
(45) **Date of Patent:** ***Jan. 8, 2019**

(54) **MOBILE TERMINAL**

(71) Applicant: **LG ELECTRONICS INC.**, Seoul (KR)

(72) Inventors: **Byungwoon Jung**, Seoul (KR); **Jaewoo Lee**, Seoul (KR); **Sungjung Rho**, Seoul (KR); **Changwon Yun**, Seoul (KR); **Daeyong Kwak**, Seoul (KR); **Sungjoon Hong**, Seoul (KR)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 305 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/150,068**

(22) Filed: **May 9, 2016**

(65) **Prior Publication Data**

US 2016/0254591 A1 Sep. 1, 2016

Related U.S. Application Data

(63) Continuation of application No. 14/693,539, filed on Apr. 22, 2015, now Pat. No. 9,363,341.

(30) **Foreign Application Priority Data**

Sep. 19, 2014 (KR) 10-2014-0125062

(51) **Int. Cl.**

H01Q 1/24 (2006.01)

G06F 1/16 (2006.01)

(Continued)

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

CPC **H01Q 1/243** (2013.01); **G06F 1/1626** (2013.01); **G06F 1/1698** (2013.01); **H01Q 1/52** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC H04M 1/0214; H04M 1/23; H04M 1/03; H04B 1/3833

(Continued)

(56) **References Cited**

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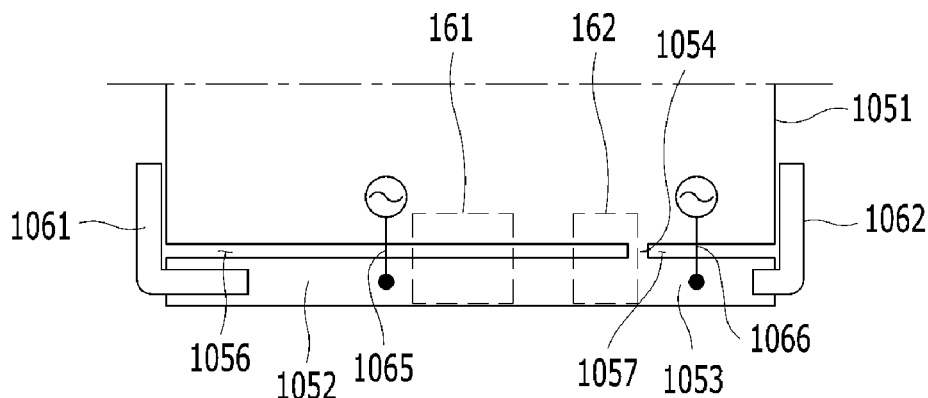
Primary Examiner — Sam Bhattacharya

(74) Attorney, Agent, or Firm — Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

According to the present invention, a mobile terminal includes a main body including a front side with which a display unit is combined, a first antenna mounted on the main body, extended in a first direction and including a first slot of which one end is closed and another end is opened, a second antenna mounted on the main body, extended in a second direction corresponding to a direction opposite to the direction to which the first slot is extended and including a second slot of which one end is closed and another end is opened, a power supply unit mounted in the inside of the main body, a first feeder configured to supply power to the first antenna from the power supply unit and a second feeder configured to supply power to the second antenna from the power supply unit.

15 Claims, 18 Drawing Sheets





US010177443B2

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

(10) **Patent No.:** **US 10,177,443 B2**
(45) **Date of Patent:** **Jan. 8, 2019**

(54) **COMMUNICATION ANTENNA, METHOD FOR CONTROLLING THE SAME AND TERMINAL**

(56) **References Cited**

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

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

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

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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 93 days.

International Search Report and Written Opinion issued in corresponding International Application No. PCT/CN2016/095644, dated Feb. 6, 2017, 11 pages.

(Continued)

(21) Appl. No.: **15/378,635**

(22) Filed: **Dec. 14, 2016**

Primary Examiner — Dieu Hien T Duong

Assistant Examiner — Bamidele A Jegede

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

(65) **Prior Publication Data**

US 2017/0346159 A1 Nov. 30, 2017

(30) **Foreign Application Priority Data**

May 30, 2016 (CN) 2016 1 0371760

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 5/314 (2015.01)

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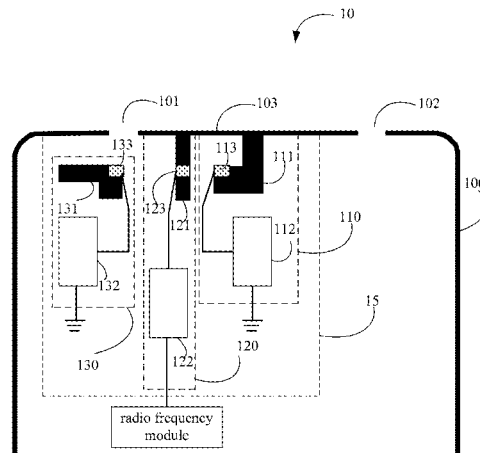
(52) **U.S. Cl.**
CPC **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 1/50** (2013.01); **H01Q 5/314** (2015.01); **H01Q 5/371** (2015.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 19/00; H01Q 19/005; H01Q 5/378; H01Q 5/49; H01Q 5/30
See application file for complete search history.

(57) **ABSTRACT**

A communication antenna, a method for controlling a communication antenna and a terminal are provided. The communication antenna includes a first passive unit, a stimulation receiving unit, and a second passive unit. The first passive unit and the second passive unit are respectively coupled to ground. The stimulation receiving unit is electrically coupled to a radio frequency module so as to receive an electrical signal transmitted by the radio frequency module. The first passive unit includes a regulating circuit that includes a switch, a controller, and a regulating assembly. The regulating assembly includes a plurality of electronic components. The controller is configured to control the switch to connect one or more electronic components of the regulating assembly to the circuit. The connected electronic components make the communication antenna resonate in one of a plurality of frequency ranges.

20 Claims, 5 Drawing Sheets





US010177744B2

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

(10) **Patent No.:** **US 10,177,744 B2**
(45) **Date of Patent:** **Jan. 8, 2019**

(54) **WIRELESS COMMUNICATION UNIT,
INTEGRATED CIRCUIT AND METHOD FOR
ANTENNA TUNING**

H04B 1/0458 (2013.01); **H04B 1/18**
(2013.01); **H04B 17/102** (2015.01); **H04B**
17/12 (2015.01)

(71) Applicant: **MediaTek Singapore Pte. Ltd.,**
Singapore (SG)

(58) **Field of Classification Search**

CPC H01Q 1/50; H01Q 5/50
USPC 343/745
See application file for complete search history.

(72) Inventors: **Bernard Mark Tenbroek**, West
Malling (GB); **Walid Youssef**
Ali-Ahmad, Beirut (LB)

(56) **References Cited**

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No. 4, pp. 944-950, Apr. 2008.

Primary Examiner — Dameon E Levi

Assistant Examiner — Ab Salam Alkassim, Jr.

(74) *Attorney, Agent, or Firm* — Optimus Patents US,
LLC

(57) **ABSTRACT**

A wireless communication unit includes an antenna arrange-
ment; an aperture tuner operably coupled to a first port of the
antenna arrangement; a measurement circuit operably
coupled to an antenna input feed point of the antenna
arrangement and arranged to measure a parameter. A con-
troller, operably coupled to the aperture tuner, is arranged to
perform closed loop aperture tuning using the measured
parameter.

13 Claims, 6 Drawing Sheets

(21) Appl. No.: **14/612,297**

(22) Filed: **Feb. 3, 2015**

(65) **Prior Publication Data**

US 2016/0126619 A1 May 5, 2016

Related U.S. Application Data

(60) Provisional application No. 62/072,454, filed on Oct.
30, 2014.

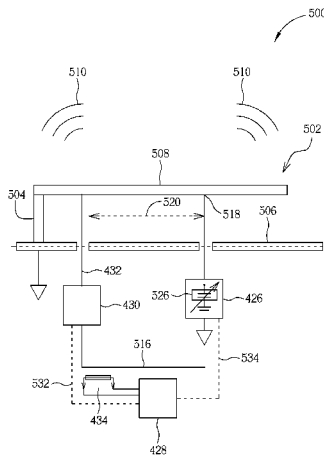
(51) **Int. Cl.**

H01Q 1/50 (2006.01)
H03J 7/04 (2006.01)
H03H 7/40 (2006.01)
H04B 17/10 (2015.01)
H01Q 13/10 (2006.01)
H01Q 9/04 (2006.01)
H04B 17/12 (2015.01)
H04B 1/04 (2006.01)

(Continued)

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

CPC **H03J 7/04** (2013.01); **H01Q 5/50**
(2015.01); **H01Q 9/0442** (2013.01); **H01Q**
13/103 (2013.01); **H03H 7/40** (2013.01);





US010181640B2

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

(10) **Patent No.:** **US 10,181,640 B2**
(45) **Date of Patent:** **Jan. 15, 2019**

(54) **ELECTRONIC DEVICE ANTENNAS**

(71) Applicant: **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 204 days.

(21) Appl. No.: **15/234,907**

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

(65) **Prior Publication Data**

US 2018/0048057 A1 Feb. 15, 2018

(51) **Int. Cl.**
H01Q 1/12 (2006.01)
H01Q 1/27 (2006.01)
(Continued)

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

CPC **H01Q 1/273** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/48** (2013.01); **H01Q 1/50** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 1/273; H01Q 1/48; H01Q 1/50

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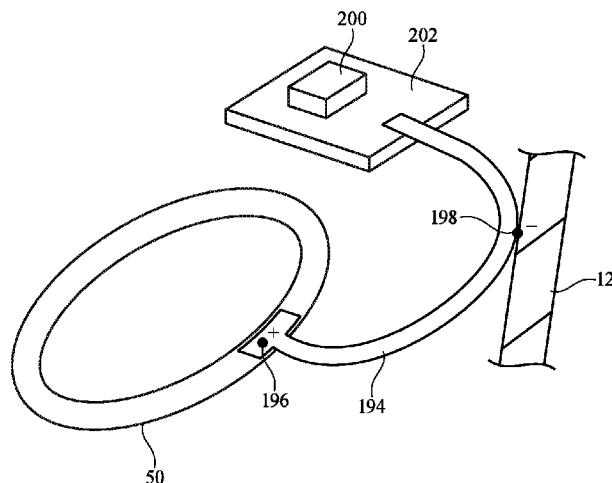
Primary Examiner — Huedung X Mancuso

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(57) **ABSTRACT**

An electronic device such as a wristwatch may have a housing with metal portions such as metal sidewalls. The housing may form an antenna ground for an antenna. An antenna resonating element for the antenna may be formed from a stack of capacitively coupled component layers such as a display layer, touch sensor layer, and near-field communications antenna layer at a front face of the device. An additional antenna may be formed from a peripheral resonating element that runs along a peripheral edge of the device and the antenna ground. A rear face antenna may be formed using a wireless power receiving coil as a radio-frequency antenna resonating element or may be formed from metal antenna traces on a plastic support for light-based components.

20 Claims, 16 Drawing Sheets





US010181648B2

(12) **United States Patent**
Liu

(10) **Patent No.:** **US 10,181,648 B2**
(45) **Date of Patent:** **Jan. 15, 2019**

(54) **SELF-ADAPTIVE ANTENNA SYSTEM FOR RECONFIGURABLE DEVICE**

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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 156 days.

(21) Appl. No.: **15/097,106**

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

(65) **Prior Publication Data**

US 2017/0294713 A1 Oct. 12, 2017

(51) **Int. Cl.**

H01Q 1/24 (2006.01)

H01Q 9/14 (2006.01)

H01Q 1/22 (2006.01)

H01Q 7/00 (2006.01)

H01Q 5/378 (2015.01)

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

CPC **H01Q 9/145** (2013.01); **H01Q 1/2266**
(2013.01); **H01Q 5/378** (2015.01); **H01Q 7/00**
(2013.01); **H01Q 9/14** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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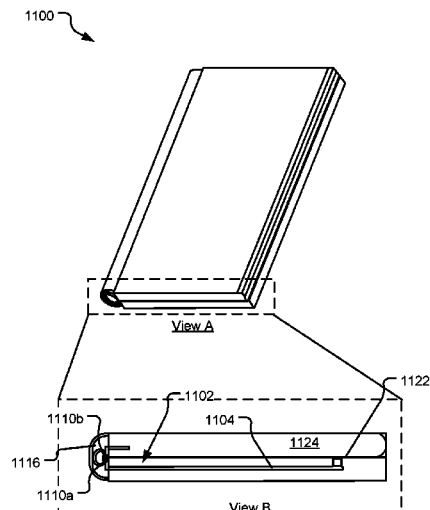
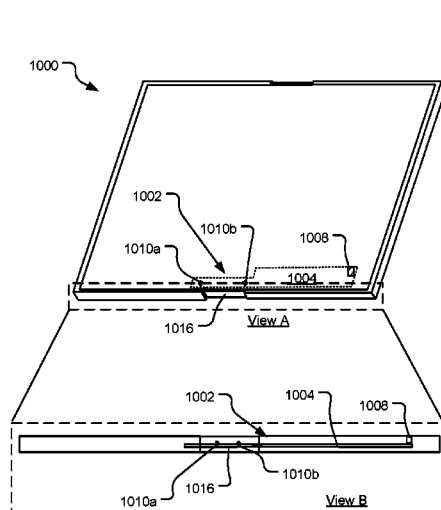
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(74) Attorney, Agent, or Firm — Holzer Patel Drennan

(57) **ABSTRACT**

An electronic device disclosed herein includes an antenna that self-tunes frequency responsive to changes to a physical configuration of the electronic device to negate a shift in the resonant frequency attributable to the change in physical configuration.

8 Claims, 13 Drawing Sheets





US010181649B2

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

(10) **Patent No.:** **US 10,181,649 B2**
(45) **Date of Patent:** **Jan. 15, 2019**

(54) **ANTENNA AND MOBILE TERMINAL**

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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 304 days.

(21) Appl. No.: **15/037,227**

(22) PCT Filed: **Nov. 18, 2013**

(86) PCT No.: **PCT/CN2013/087366**

§ 371 (c)(1),

(2) Date: **May 17, 2016**

(87) PCT Pub. No.: **WO2015/070467**

PCT Pub. Date: **May 21, 2015**

(65) **Prior Publication Data**

US 2016/0294064 A1 Oct. 6, 2016

(51) **Int. Cl.**

H01Q 1/36 (2006.01)

H01Q 9/16 (2006.01)

H01Q 1/24 (2006.01)

H01Q 1/48 (2006.01)

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

CPC **H01Q 9/16** (2013.01); **H01Q 1/243**
(2013.01); **H01Q 1/36** (2013.01); **H01Q 1/48**
(2013.01)

(58) **Field of Classification Search**

CPC H01Q 9/16; H01Q 9/243; H01Q 9/36;
H01Q 9/48

USPC 343/795
See application file for complete search history.

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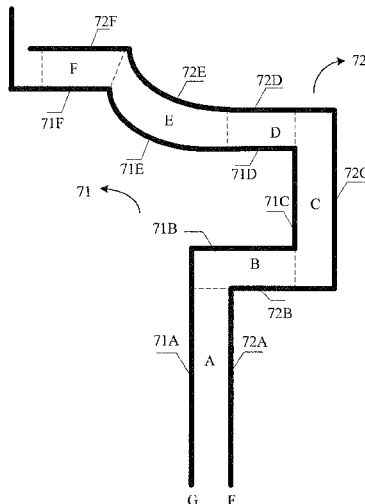
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Primary Examiner — Lam T Mai

(57) **ABSTRACT**

Embodiments of the present invention disclose an antenna and a mobile terminal, which are relate to the field of antenna technologies, so as to improve radiation performance of the antenna. The antenna includes a first antenna arm and a second antenna arm that are not in contact with each other, where one end of the first antenna arm is configured for grounding, one end of the second antenna arm is configured to connect to a feed point, and the first antenna arm and the second antenna arm have at least one relative area.

9 Claims, 4 Drawing Sheets





US010181657B2

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

(10) **Patent No.:** **US 10,181,657 B2**
(45) **Date of Patent:** **Jan. 15, 2019**

(54) **ANTENNA ARRAY, ANTENNA APPARATUS,
AND BASE STATION**

(56) **References Cited**

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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 243 days.

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(21) Appl. No.: **14/554,765**

(22) Filed: **Nov. 26, 2014**

(65) **Prior Publication Data**

US 2015/0084832 A1 Mar. 26, 2015

Related U.S. Application Data

(63) Continuation of application No.
PCT/CN2012/076278, filed on May 30, 2012.

(51) **Int. Cl.**
H01Q 21/30 (2006.01)
H01Q 21/06 (2006.01)

(Continued)

(52) **U.S. Cl.**
CPC **H01Q 21/30** (2013.01); **H01Q 1/246**
(2013.01); **H01Q 21/061** (2013.01); **H01Q**
3/40 (2013.01);

(Continued)

(58) **Field of Classification Search**
CPC H01Q 21/30; H01Q 1/246; H01Q 21/061;
H01Q 3/40; H01Q 21/062; H01Q 21/064
See application file for complete search history.

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Assistant Examiner — Michael Bouizza

(74) *Attorney, Agent, or Firm* — Staas & Halsey LLP

(57) **ABSTRACT**

Embodiments of the present invention relate to an antenna array, an antenna apparatus, and a base station. The antenna array includes: at least two antenna sub-arrays, where the at least two antenna sub-arrays are arranged in a vertical direction, each of the antenna sub-arrays includes multiple radiating elements, and in at least two adjacent antenna sub-arrays in the vertical direction, radiating elements at corresponding positions in the respective antenna sub-arrays are arranged in a staggered manner in a horizontal direction. In the embodiments of the present invention, horizontal side lobes and vertical far side lobes in an antenna array pattern are reduced, and the ultra-wideband performance is improved.

14 Claims, 14 Drawing Sheets

