

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

(10) **Patent No.:** **US 10,784,565 B2**
(45) **Date of Patent:** **Sep. 22, 2020**

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

(71) Applicant: **Wistron Corp.**, New Taipei (TW)

(72) Inventors: **Wan Chu Wei**, New Taipei (TW);
Hsieh Chih Lin, New Taipei (TW);
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Jung-Chin Hsieh, New Taipei (TW);
Wen-Chieh Wu, New Taipei (TW)

(73) Assignee: **WISTRON CORP.**, 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 120 days.

(21) Appl. No.: **16/112,443**

(22) Filed: **Aug. 24, 2018**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Jul. 5, 2018 (TW) 107123302 A

(51) **Int. Cl.**

H01Q 1/24 (2006.01)
H01Q 1/22 (2006.01)
H01Q 1/42 (2006.01)
H01Q 5/30 (2015.01)
H01Q 9/04 (2006.01)
H04M 1/02 (2006.01)

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

CPC **H01Q 1/242** (2013.01); **H01Q 1/2266** (2013.01); **H01Q 1/42** (2013.01); **H01Q 5/30** (2015.01); **H01Q 9/0421** (2013.01); **H04M 1/0283** (2013.01)

(58) **Field of Classification Search**

CPC **H01Q 1/242**; **H01Q 1/42**; **H01Q 1/2266**;
H01Q 5/30; **H01Q 9/0421**; **H01Q 9/0414**;
H01Q 5/378; **H01Q 1/40**; **H01Q 1/2258**;
H01Q 1/36; **H01Q 1/50**; **H01Q 1/526**;
H04M 1/0283

See application file for complete search history.

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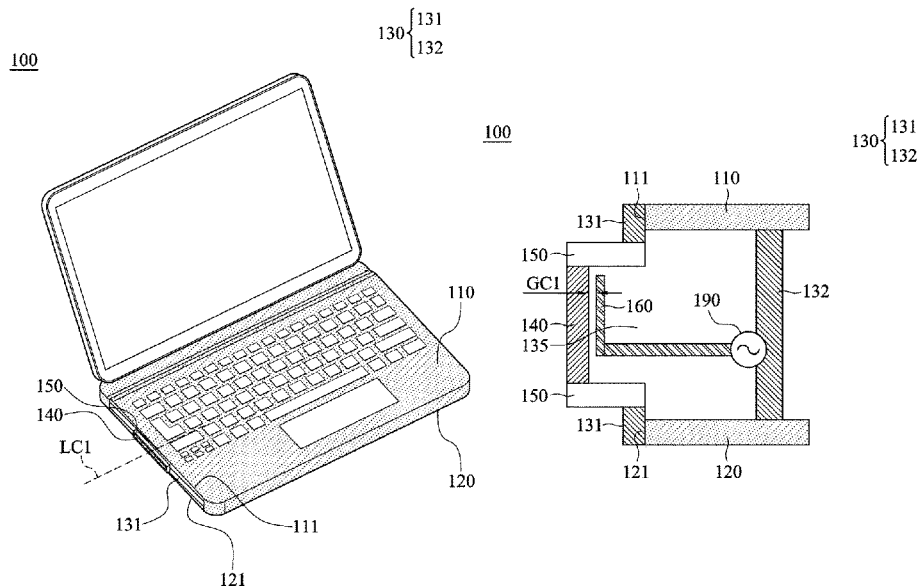
Primary Examiner — Hai V Tran

Assistant Examiner — Michael M Bouizza

(57) **ABSTRACT**

A mobile device includes a host upper cover, a host lower cover, a metal cavity structure, a protruding radiation element, a nonconductive connection element, and a feeding element. The metal cavity structure is coupled between the host upper cover and the host lower cover. The metal cavity structure includes a first metal partition and a second metal partition. The first metal partition has an opening. The nonconductive connection element is connected to the edge of the opening of the first metal partition. The nonconductive connection element is configured to support and surround the protruding radiation element. The feeding element is coupled to a signal source and is disposed adjacent to the protruding radiation element. An antenna structure is formed by the feeding element and the protruding radiation element.

18 Claims, 12 Drawing Sheets



(12) **United States Patent**
Chou

(10) **Patent No.:** **US 10,784,578 B2**
(45) **Date of Patent:** **Sep. 22, 2020**

(54) **ANTENNA SYSTEM**
(71) Applicant: **Wistron Corp.**, New Taipei (TW)
(72) Inventor: **Chen-Yu Chou**, New Taipei (TW)
(73) Assignee: **WISTRON CORP.**, 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 46 days.
(21) Appl. No.: **16/186,434**
(22) Filed: **Nov. 9, 2018**
(65) **Prior Publication Data**
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(30) **Foreign Application Priority Data**
Oct. 2, 2018 (TW) 107134801 A
(51) **Int. Cl.**
H01Q 21/00 (2006.01)
H01Q 5/20 (2015.01)
H01Q 1/22 (2006.01)
H01Q 1/24 (2006.01)
(52) **U.S. Cl.**
CPC **H01Q 5/20** (2015.01); **H01Q 1/2291** (2013.01); **H01Q 1/243** (2013.01); **H01Q 21/0006** (2013.01)
(58) **Field of Classification Search**
None
See application file for complete search history.

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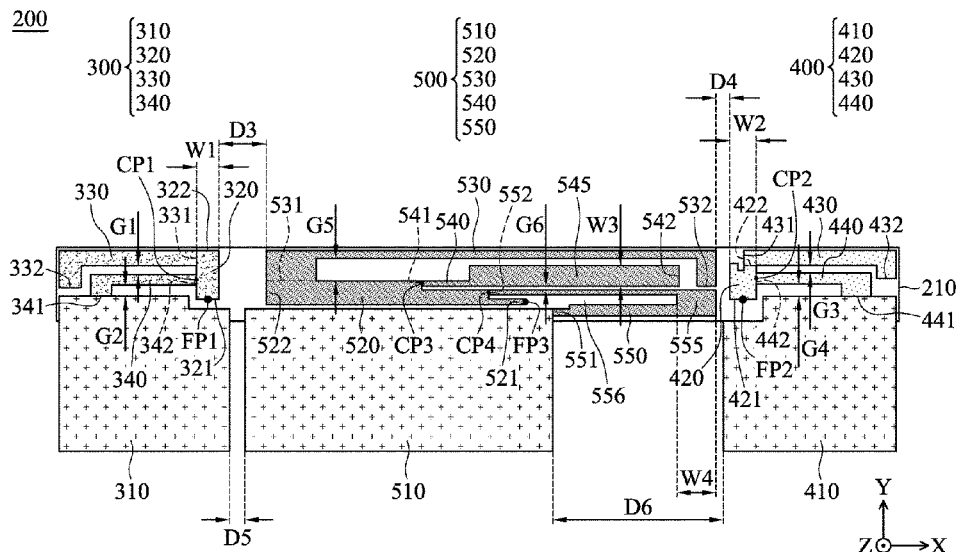
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Primary Examiner — Trinh V Dinh

(57) **ABSTRACT**

An antenna system includes a first antenna, a second antenna, and a third antenna. The third antenna is disposed between the first antenna and the second antenna. Both the first antenna and the second antenna operate in a first frequency band. The third antenna operates in a second frequency band which is different from the first frequency band. The first antenna, the second antenna, and the third antenna are all disposed on the same plane.

17 Claims, 5 Drawing Sheets





US010784592B2

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

(10) **Patent No.:** **US 10,784,592 B2**

(45) **Date of Patent:** **Sep. 22, 2020**

(54) **ISOLATED GROUND FOR WIRELESS
DEVICE ANTENNA**

(71) Applicant: **GALTRONICS USA, INC.**, Tempe,
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(72) Inventors: **Matti Martiskainen**, Upper Tiberias
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Kim**, Busan (KR); **Jaeyun Hwang**,
Suwon-si (KR); **Bumjin Kim**, Suwon-si
(KR); **Yeonhyeon Song**, Suwon-si
(KR); **Suhyun Kim**, Suwon-si (KR);
Sangyup Kim, Suwon-si (KR)

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patent is extended or adjusted under 35
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(21) Appl. No.: **15/126,715**

(22) Filed: **Sep. 16, 2016**

(65) **Prior Publication Data**

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(51) **Int. Cl.**

H01Q 21/30 (2006.01)
H01Q 1/24 (2006.01)
H01Q 21/28 (2006.01)
H01Q 1/52 (2006.01)

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

CPC **H01Q 21/30** (2013.01); **H01Q 1/243**
(2013.01); **H01Q 1/521** (2013.01); **H01Q**
21/28 (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/366; H01Q 1/243; H01Q 1/38;
H01Q 9/0421; H01Q 1/42; H01Q 1/1207
USPC 343/701, 702, 872, 878
See application file for complete search history.

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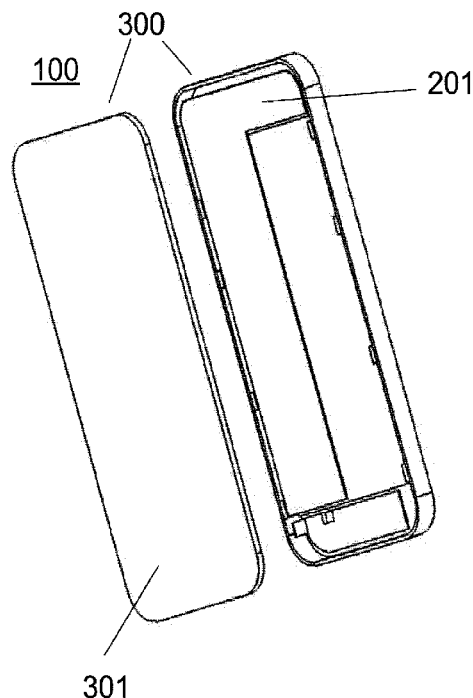
Primary Examiner — Graham P Smith

(74) *Attorney, Agent, or Firm* — Brion Raffoul

(57) **ABSTRACT**

A wireless device including multiple counterpoises or ground planes is provided. The wireless device may provide improved multiple input multiple output (MIMO) communication capability through the use of the multiple counterpoises. Multiple counterpoises of the wireless device may be galvanically isolated from one another. Multiple counterpoises may each be coupled to separate antenna elements.

6 Claims, 3 Drawing Sheets



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

(10) **Patent No.:** **US 10,797,376 B2**
(45) **Date of Patent:** **Oct. 6, 2020**

(54) **COMMUNICATION DEVICE**

(56) **References Cited**

(71) Applicant: **Quanta Computer Inc.**, Taoyuan (TW)

U.S. PATENT DOCUMENTS

(72) Inventors: **Shu-Yang Tu**, Taoyuan (TW); **Chun-I Lin**, Taoyuan (TW); **Hui Lin**, Taoyuan (TW)

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2009/0322639 A1 12/2009 Lai
2018/0048076 A1 * 2/2018 Wei H01Q 9/045

(73) Assignee: **QUANTA COMPUTER INC.**,
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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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(21) Appl. No.: **16/517,888**

Chinese language office action dated Feb. 12, 2020, issued in application No. TW 108106135.

(22) Filed: **Jul. 22, 2019**

* cited by examiner

(65) **Prior Publication Data**

US 2020/0274227 A1 Aug. 27, 2020

Primary Examiner — Haissa Philogene

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

(30) **Foreign Application Priority Data**

Feb. 23, 2019 (TW) 108106135 A

(57) **ABSTRACT**

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

A communication device includes a ground element, a dielectric substrate, and an antenna element. The dielectric substrate is disposed adjacent to an edge of the ground element. The antenna element is disposed on the dielectric substrate. The antenna element includes a feeding metal element, a shorting metal element, a first radiation metal element, a second radiation metal element, and an inductive element. The feeding metal element has a feeding point. The shorting metal element is coupled to the ground element. The first radiation metal element is coupled to the shorting metal element, and is disposed adjacent to the feeding metal element. The second radiation metal element is coupled through the inductive element to the feeding metal element. The second radiation metal element is further coupled to the ground element.

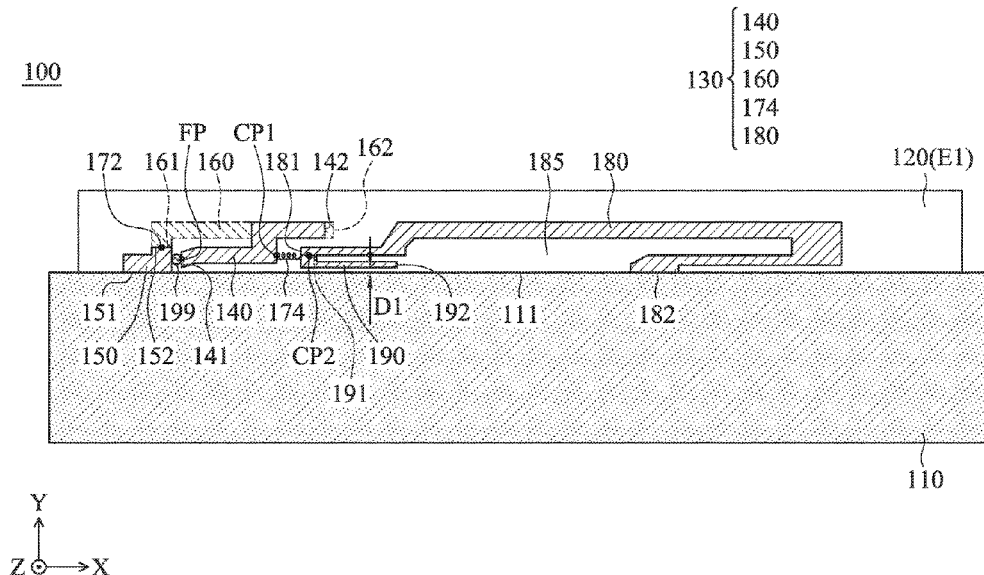
(52) **U.S. Cl.**
CPC **H01Q 1/24** (2013.01); **H01Q 1/38** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/24; H01Q 1/241; H01Q 1/242; H01Q 1/243; H01Q 1/38; H01Q 1/226; H01Q 9/045; H01Q 9/0421; H01Q 9/0435; H01Q 9/30; H01Q 5/335; H01Q 5/357; H01Q 5/328; H01Q 13/10

See application file for complete search history.

10 Claims, 6 Drawing Sheets





US010797391B2

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

(10) **Patent No.:** **US 10,797,391 B2**
(45) **Date of Patent:** **Oct. 6, 2020**

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

(58) **Field of Classification Search**

CPC H01Q 5/314; H01Q 21/06; H04B 1/40

USPC 455/73

See application file for complete search history.

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

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Primary Examiner — Lee Nguyen

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

(72) Inventors: **Jongpil Lee**, Gyeonggi-do (KR);
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(73) Assignee: **Samsung Electronics Co., Ltd.**,
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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.

(21) Appl. No.: **16/687,881**

(22) Filed: **Nov. 19, 2019**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Nov. 19, 2018 (KR) 10-2018-0142801

(51) **Int. Cl.**

H01Q 5/314 (2015.01)

H04B 1/40 (2015.01)

H01Q 21/06 (2006.01)

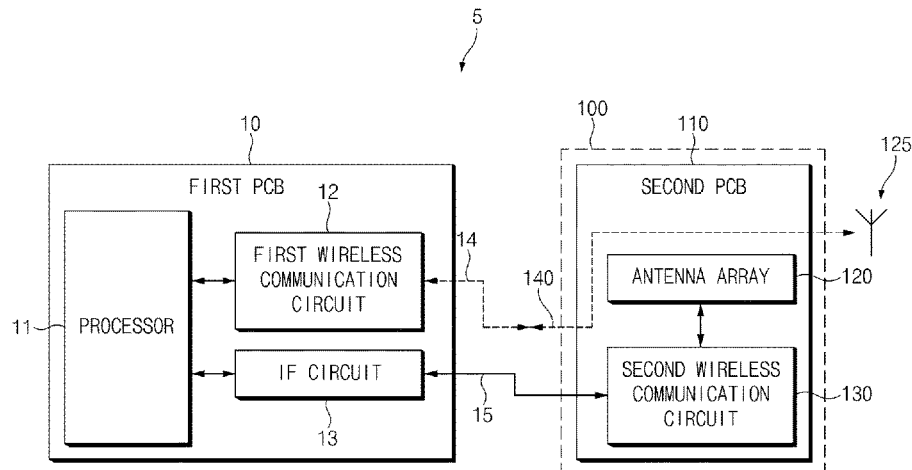
(52) **U.S. Cl.**

CPC **H01Q 5/314** (2015.01); **H01Q 21/06**
(2013.01); **H04B 1/40** (2013.01)

(57) **ABSTRACT**

Disclosed herein is an electronic device. The electronic device may include an electronic device may comprising a housing, a first PCB disposed inside the housing, a first wireless communication circuit disposed on the first PCB to transmit and receive signals of a first frequency band, a second PCB disposed inside the housing, wherein the second PCB includes a signal line, an antenna array disposed on the second PCB, a second wireless communication circuit disposed on the second PCB to transmit and receive a signal of a second frequency band using the antenna array, and a conductive member electrically connected to the first wireless communication circuit by the signal line of the second PCB via a feed point for the conductive member.

20 Claims, 12 Drawing Sheets



(12) **United States Patent**
Higaki

(10) **Patent No.:** **US 10,797,395 B2**
(45) **Date of Patent:** **Oct. 6, 2020**

(54) **ANTENNA AND ANTENNA APPARATUS**

(56) **References Cited**

(71) Applicant: **KABUSHIKI KAISHA TOSHIBA**,
Minato-ku, Tokyo (JP)

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(72) Inventor: **Makoto Higaki**, Tokyo (JP)

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2020/0103833 A1 * 4/2020 Kita H01Q 9/30

(73) Assignee: **KABUSHIKI KAISHA TOSHIBA**,
Tokyo (JP)

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(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
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JP 2004266419 A 9/2004

(21) Appl. No.: **16/291,574**

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(22) Filed: **Mar. 4, 2019**

Primary Examiner — Haissa Philogene

(65) **Prior Publication Data**

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

(30) **Foreign Application Priority Data**

Sep. 12, 2018 (JP) 2018-170783

(57) **ABSTRACT**

(51) **Int. Cl.**

H01Q 9/04 (2006.01)
H01Q 9/16 (2006.01)
H01Q 21/29 (2006.01)
H01Q 21/24 (2006.01)
H01Q 1/36 (2006.01)

An antenna as an embodiment of the present invention is provided with an exciting element and a plurality of non-exciting elements. In a plan view, the exciting element includes a central region having a feeding point and at least three extending regions that extend radially from the central region. In the plan view, each non-exciting element includes a short circuit region having a short circuit point and a power receiving region located at a position where it is allowed to be capacitively coupled with corresponding one of the extending regions. In the plan view, a current path from the short circuit region to the power receiving region in each non-exciting element has a vertical component with respect to the extending direction of the corresponding one of the extending regions.

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

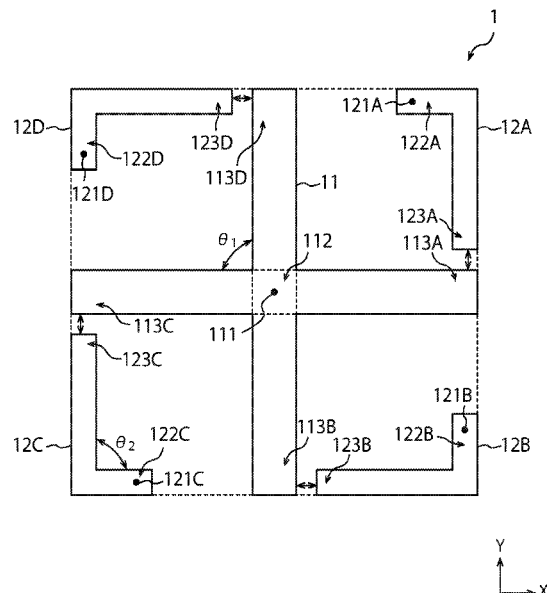
CPC **H01Q 9/0428** (2013.01); **H01Q 1/36**
(2013.01); **H01Q 9/16** (2013.01); **H01Q 21/24**
(2013.01); **H01Q 21/29** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 9/0428; H01Q 9/0435; H01Q 9/16;
H01Q 9/18; H01Q 21/24; H01Q 21/29;
H01Q 1/36; H01Q 1/52; G04R 60/02;
G04G 21/04

See application file for complete search history.

12 Claims, 13 Drawing Sheets



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

(10) **Patent No.: US 10,797,396 B2**
(45) **Date of Patent: Oct. 6, 2020**

(54) **APERTURE COUPLED PATCH ANTENNA ARRANGEMENT**

(71) Applicant: **Telefonaktiebolaget LM Ericsson (publ)**, Stockholm (SE)

(72) Inventors: **Ola Kaspersson**, Varberg (SE); **Anders Ek**, Hisings Backa (SE); **Håkan Karlsson**, Gothenburg (SE)

(73) Assignee: **Telefonaktiebolaget LM Ericsson (Publ)**, Stockholm (SE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 56 days.

(21) Appl. No.: **16/320,341**

(22) PCT Filed: **Jul. 25, 2016**

(86) PCT No.: **PCT/EP2016/067643**

§ 371 (c)(1),

(2) Date: **Jan. 24, 2019**

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PCT Pub. Date: **Feb. 1, 2018**

(65) **Prior Publication Data**

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(51) **Int. Cl.**

H01Q 13/00 (2006.01)

H01Q 9/04 (2006.01)

(Continued)

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

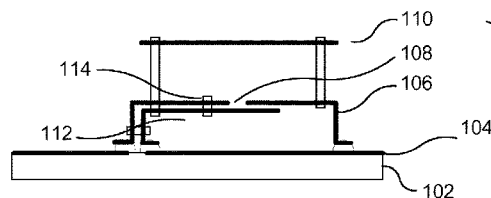
CPC **H01Q 9/0478** (2013.01); **H01Q 1/523** (2013.01); **H01Q 9/0407** (2013.01);

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(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 1/38; H01Q 9/0421; H01Q 1/244; H01Q 1/242; H01Q 9/145;

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Primary Examiner — Minh D A

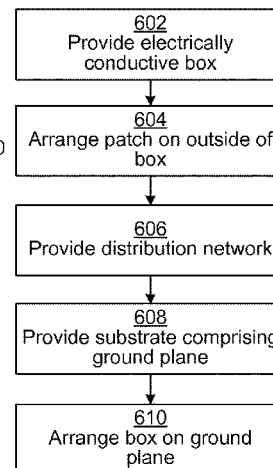
(74) *Attorney, Agent, or Firm* — Patent Portfolio Builders, PLLC

(57)

ABSTRACT

It is provided an aperture coupled patch antenna comprising a substrate comprising a planar electrically conductive ground plane, an electrically conductive box arranged on and electrically connected to the ground plane to form an air filled cavity between the box and the ground plane, the box comprising an aperture in the form of at least one elongate slot. The antenna further comprises an electrically conductive patch arranged in parallel with the ground plane and at a distance from the box such that the aperture of the box is located between the patch and the ground plane and a distribution network comprising at least one elongate distribution element arranged in parallel with the ground plane between the ground plane and the patch, at a distance from the substrate and the ground plane and at a distance from the box such that a gap is formed between the distribution element and the box, wherein the extension of the distribution element intersects the extension of the aperture.

15 Claims, 4 Drawing Sheets





US010804602B2

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

(10) **Patent No.:** **US 10,804,602 B2**
(45) **Date of Patent:** **Oct. 13, 2020**

(54) **5G MIMO ANTENNA SYSTEM AND HANDHELD DEVICE**

(71) Applicant: **SHENZHEN SUNWAY COMMUNICATION CO., LTD.**,
Shenzhen, Guangdong (CN)

(72) Inventors: **Anping Zhao**, Shenzhen (CN);
Zhouyou Ren, Shenzhen (CN)

(73) Assignee: **SHENZHEN SUNWAY COMMUNICATION CO., LTD.**,
Shenzhen (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.: **16/462,030**

(22) PCT Filed: **Mar. 4, 2019**

(86) PCT No.: **PCT/CN2019/076806**

§ 371 (c)(1),
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(30) **Foreign Application Priority Data**

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H01Q 7/00 (2006.01)
H01Q 1/38 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01Q 1/521** (2013.01); **H01Q 1/243**
(2013.01); **H01Q 9/30** (2013.01); **H04B**
7/0413 (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/521; H01Q 1/243; H01Q 9/30;
H01Q 5/10; H01Q 1/38; H01Q 21/06;
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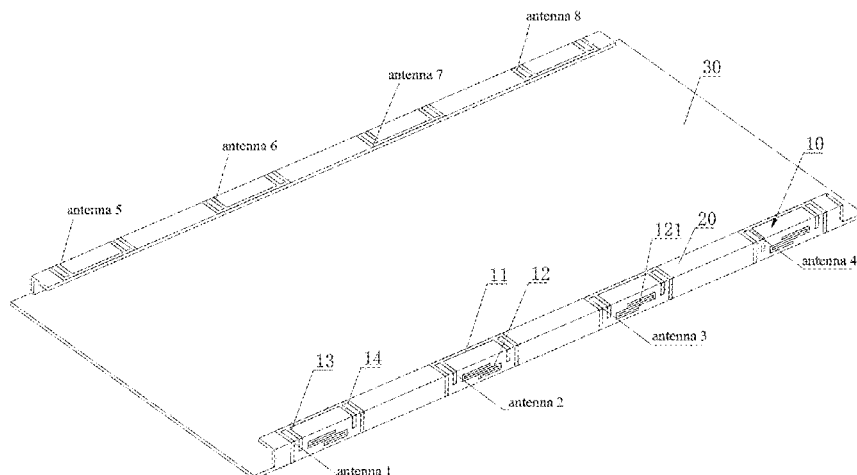
Primary Examiner — Pablo N Tran

(74) *Attorney, Agent, or Firm* — Oliff PLC

(57) **ABSTRACT**

A 5G MIMO antenna system includes at least four antenna units which are arrayed at intervals. Each antenna unit includes a first branch and a second branch, wherein the first branch is of an inverted-U structure, and two ends of an opening of the first branch are grounded; the second branch is located in an area defined by the first branch and is a monopole branch, and a feed point is arranged at an end, close to the opening of the first branch, of the second branch. The first branches and the second branches generate two different resonances, so that the 5G antenna system has a broadband operation. Meanwhile, the 5G MIMO antenna system has the characteristics of being small in size, good in isolation and broad in frequency band.

12 Claims, 5 Drawing Sheets





US010804607B2

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

(10) **Patent No.:** **US 10,804,607 B2**
(45) **Date of Patent:** **Oct. 13, 2020**

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

(58) **Field of Classification Search**

CPC H01Q 5/30; H01Q 21/30; H01Q 5/328;
H01Q 1/48; H01Q 9/42; H01Q 7/00;
(Continued)

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

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

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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 79 days.

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(21) Appl. No.: **16/109,699**

Primary Examiner — Hai V Tran

Assistant Examiner — Michael M Bouzza

(22) Filed: **Aug. 22, 2018**

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

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Sep. 27, 2017 (CN) 2017 1 0891620

(51) **Int. Cl.**

H01Q 5/30 (2015.01)

H01Q 1/24 (2006.01)

(Continued)

(57) **ABSTRACT**

An antenna structure includes a housing, a radiator, a first feed portion, and a first ground portion. The housing includes a coupling portion and a coupling section. The first feed portion, the first ground portion, and the radiator are all positioned in the housing. When a first feed point supplies current, the current flows through the first feed portion and the radiator, and is coupled to one of the coupling portion and the coupling section through the radiator. The current is further coupled to the other one of the coupling portion and the coupling section through the one of the coupling portion and the coupling section. The radiator, the coupling portion, and the coupling section activate three different operating modes. Each mode operating generates radiation signals in one of three different radiation frequency bands.

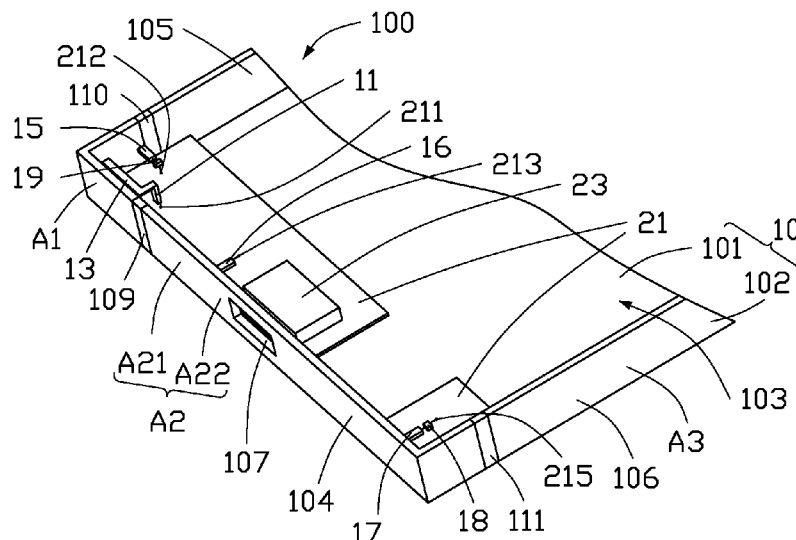
(52) **U.S. Cl.**

CPC **H01Q 5/30** (2015.01); **H01Q 1/243**
(2013.01); **H01Q 1/48** (2013.01); **H01Q 5/328**
(2015.01);

(Continued)

27 Claims, 11 Drawing Sheets

200



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

(10) **Patent No.:** US 10,804,612 B2
(45) **Date of Patent:** Oct. 13, 2020

(54) **ELECTRONIC DEVICE AND ANTENNA STRUCTURE THEREOF**

(71) Applicant: **PEGATRON CORPORATION**, Taipei (TW)

(72) Inventors: **Chien-Yi Wu**, Taipei (TW); **Ching-Hsiang Ko**, Taipei (TW); **Ya-Jyun Li**, Taipei (TW); **Chao-Hsu Wu**, Taipei (TW); **Shih-Keng Huang**, Taipei (TW); **Cheng-Hsiung Wu**, Taipei (TW)

(73) Assignee: **PEGATRON CORPORATION**, Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 380 days.

(21) Appl. No.: **15/961,775**

(22) Filed: **Apr. 24, 2018**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

May 26, 2017 (TW) 106117491 A

(51) **Int. Cl.**

H01Q 1/36 (2006.01)

H01Q 13/10 (2006.01)

H05K 5/02 (2006.01)

H05K 5/00 (2006.01)

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

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(Continued)

(58) **Field of Classification Search**

CPC H01Q 13/10; H01Q 5/371; H01Q 1/2266; H01Q 9/42; H01Q 5/364; H01Q 13/106;

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Primary Examiner — Dimary S Lopez Cruz

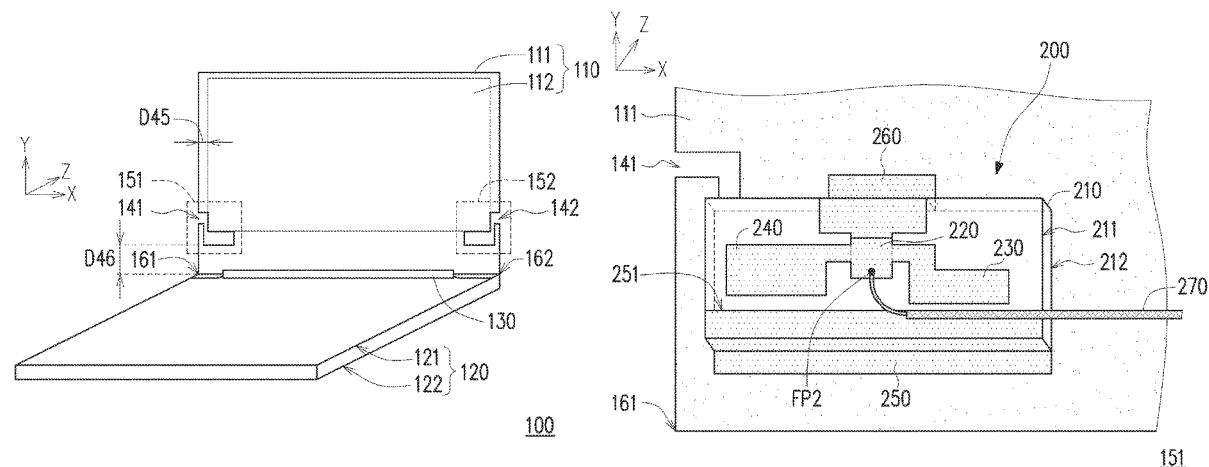
Assistant Examiner — Bamidele A Jegede

(74) *Attorney, Agent, or Firm* — J.C. Patents

(57) **ABSTRACT**

An antenna structure includes a conductive housing and a feed element. The conductive housing includes an open slot. The feed element includes a substrate, a grounding portion, a shorting portion, a first feeding portion and a second feeding portion. The grounding portion and the shorting portion are connected with the conductive housing. The first feeding portion has a feeding point and is connected with the conductive housing via the shorting portion. The orthographic projections of the first and second feeding portions are within the open slot, and the orthographic projections of the grounding portion and the shorting portion are located at two sides of the open slot, respectively. The antenna structure operates at a first frequency band via a first path formed by the open slot, and operates at a second frequency band via a second path formed by the first and second feeding portions.

19 Claims, 4 Drawing Sheets





US010804613B2

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

(10) **Patent No.:** **US 10,804,613 B2**
(45) **Date of Patent:** **Oct. 13, 2020**

(54) **5G MIMO ANTENNA STRUCTURE**

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(21) Appl. No.: **16/474,825**

(22) PCT Filed: **May 29, 2018**

(86) PCT No.: **PCT/CN2018/088831**

§ 371 (c)(1),

(2) Date: **Jun. 28, 2019**

(87) PCT Pub. No.: **WO2019/196172**

PCT Pub. Date: **Oct. 17, 2019**

(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)

(Continued)

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

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(2013.01); **H01Q 1/242** (2013.01); **H04B**

7/0413 (2013.01)

(58) **Field of Classification Search**

CPC **H01Q 1/521**; **H01Q 1/243**; **H01Q 9/30**;
H01Q 5/10; **H01Q 1/38**; **H01Q 21/06**;

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Primary Examiner — Pablo N Tran

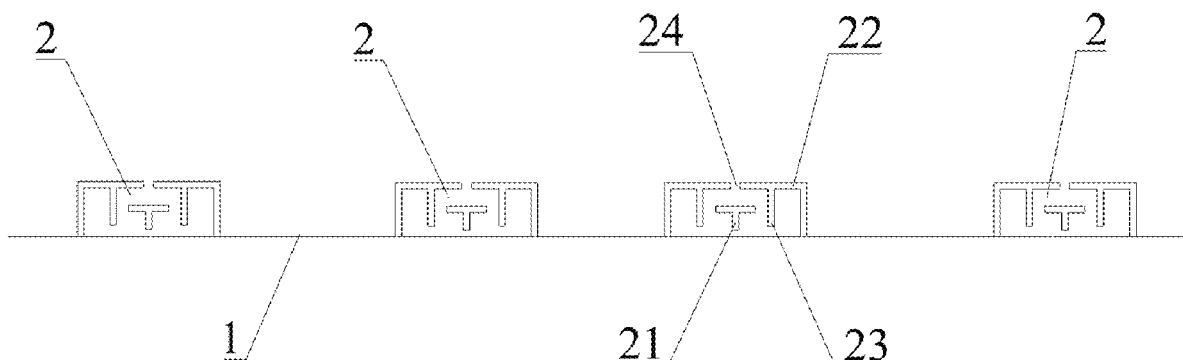
(74) Attorney, Agent, or Firm — Oliff PLC

(57)

ABSTRACT

A 5G MIMO antenna structure includes a PCB and more than one first antenna assembly arranged on the PCB at intervals. Each first antenna assembly includes a feed branch, a first radiator and two second radiators, wherein the first radiator and the two second radiators are coupled to the feed branch, the first radiator is of an inverted U-structure and has two tail ends connected to grounding points of the PCB, the feed branch is located in the first radiator and corresponds to a feed point of the PCB in position, and the two second radiators are arranged in the first radiator, connected to the first radiator, and respectively located on two sides of the feed branch. The 5G MIMO antenna structure has a good radiation effect, a good isolation effect and a smaller size, and can meet the usage requirements of a 5G system below 6 GHz.

8 Claims, 5 Drawing Sheets





US010804617B2

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

(10) **Patent No.:** **US 10,804,617 B2**
(45) **Date of Patent:** **Oct. 13, 2020**

(54) **ELECTRONIC DEVICES HAVING SHARED ANTENNA STRUCTURES AND SPLIT RETURN PATHS**

(56) **References Cited**

U.S. PATENT DOCUMENTS

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

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

Primary Examiner — Ricardo I Magallanes

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 486 days.

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Joseph F. Guihan

(21) Appl. No.: **15/700,618**

(57) **ABSTRACT**

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

Antenna structures at a given end of an electronic device may include antenna structures that are shared between multiple antennas. The device may include an antenna with an inverted-F antenna resonating element formed from portions of a peripheral conductive electronic device housing structure and may have an antenna ground that is separated from the antenna resonating element by a gap. A short circuit path may bridge the gap. The short circuit path may be a split return path coupled between a first point on the inverted-F antenna resonating element arm and second and third points on the antenna ground. The electronic device may include an additional antenna that includes the antenna ground and metal traces that form an antenna resonating element arm. The antenna resonating element arm of the additional antenna may be parasitically coupled to the inverted-F antenna resonating element and a portion of the split return path.

(65) **Prior Publication Data**

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H01Q 1/22 (2006.01)
(Continued)

(52) **U.S. Cl.**
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(2013.01); **H01Q 1/243** (2013.01); **H01Q**
5/371 (2015.01);
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(58) **Field of Classification Search**
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H01Q 5/35; H01Q 5/392; H01Q 5/314;
(Continued)

16 Claims, 8 Drawing Sheets

