US011616283B2

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

(10) **Patent No.: US 11,616,283 B2**
(45) **Date of Patent: Mar. 28, 2023**

(54) **5G MMWAVE ANTENNA ARCHITECTURE WITH THERMAL MANAGEMENT**

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

(72) Inventors: **Omkar Karhade**, Chandler, AZ (US); **William J. Lambert**, Chandler, AZ (US); **Xiaoqian Li**, Chandler, AZ (US); **Sidharth Dalmia**, Portland, OR (US)

(73) Assignee: **Intel Corporation**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1037 days.

(21) Appl. No.: **16/122,609**

(22) Filed: **Sep. 5, 2018**

(65) **Prior Publication Data**

US 2020/0076046 A1 Mar. 5, 2020

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H01Q 1/22	(2006.01)
H03F 3/195	(2006.01)
H03F 3/24	(2006.01)
H01Q 1/02	(2006.01)
H05K 1/03	(2006.01)

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

CPC ***H01Q 1/02*** (2013.01); ***H01Q 1/22*** (2013.01); ***H01Q 1/2283*** (2013.01); ***H03F 3/195*** (2013.01); ***H03F 3/24*** (2013.01); ***H03F 3/245*** (2013.01); *H05K 1/0393* (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/02; H01Q 1/2283; H01Q 1/22; H03F 3/195; H03F 33/245; H03F 3/24; H05K 1/0393

USPC 343/702

See application file for complete search history.

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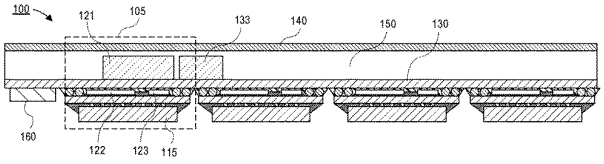
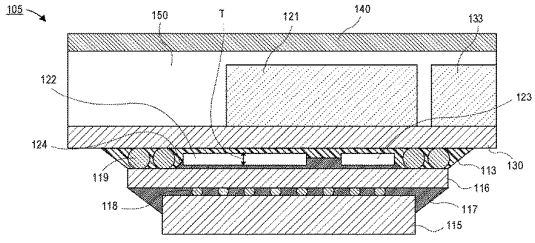
(74) *Attorney, Agent, or Firm* — Schwabe, Williamson & Wyatt, P.C.

(57) **ABSTRACT**

Embodiments include an electronic package that includes a radio frequency (RF) front end. In an embodiment, the RF front end may comprise a package substrate and a first die attached to a first surface of the package substrate. In an embodiment, the first die may include CMOS components. In an embodiment, the RF front end may further comprise a second die attached to the first surface of the package substrate. In an embodiment, the second die may comprise amplification circuitry. In an embodiment, the RF front end may further comprise an antenna attached to a second surface of the package substrate. In an embodiment, the second surface is opposite from the first surface.

9 Claims, 7 Drawing Sheets





US011616301B2

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

(10) **Patent No.: US 11,616,301 B2**
(45) **Date of Patent: Mar. 28, 2023**

(54) **ANTENNA STRUCTURE**

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(72) Inventors: **Shih-Chieh Cheng**, Hsinchu (TW); **Shin-Lung Kuo**, Hsinchu (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 42 days.

(21) Appl. No.: **17/372,235**

(22) Filed: **Jul. 9, 2021**

(65) **Prior Publication Data**

US 2022/0173514 A1 Jun. 2, 2022

(30) **Foreign Application Priority Data**

Nov. 30, 2020 (TW) 109142103

(51) **Int. Cl.**
H01Q 5/50 (2015.01)
H01Q 9/04 (2006.01)
H04W 84/12 (2009.01)

(52) **U.S. Cl.**
CPC ***H01Q 9/0407*** (2013.01); ***H01Q 5/50*** (2015.01); *H04W 84/12* (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 1/38; H01Q 5/30–50; H01Q 9/0407
See application file for complete search history.

(56) **References Cited**

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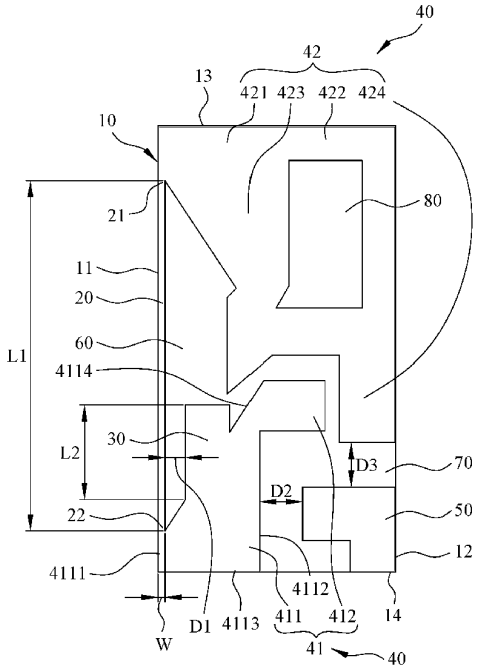
(57) **ABSTRACT**

An antenna structure is provided, including a substrate, an impedance control line, a first impedance control area, and a metal element. The impedance control line is located on the first side of the substrate. The first impedance control area is arranged on the substrate, located on one side of the impedance control line, close to the second end of the impedance control line, and separated from the impedance control line by a first hollow part. The metal element is arranged on the substrate and connected to the first end and the second end of the impedance control line, and the first impedance control area. As such, the present invention controls the impedance in the high frequency range between 5.85 and 7.25 GHz through the impedance control line and the first impedance control area, provides a complete current flow area, and improves the impedance control effect, efficiency, and gain.

13 Claims, 5 Drawing Sheets



US011621473B2

(12) **United States Patent**
Tsai

(10) **Patent No.: US 11,621,473 B2**
(45) **Date of Patent: Apr. 4, 2023**

(54) **ANTENNA STRUCTURE AND ELECTRONIC DEVICE USING SAME**

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

(72) Inventor: **Pang-Chun Tsai**, New Taipei (TW)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 71 days.

(21) Appl. No.: **17/332,334**

(22) Filed: **May 27, 2021**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Jun. 17, 2020 (CN) 202010552493.5

(51) **Int. Cl.**

H01Q 1/28	(2006.01)
H01Q 1/22	(2006.01)
H01Q 21/28	(2006.01)
H01Q 1/38	(2006.01)
H01Q 1/24	(2006.01)

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

CPC ***H01Q 1/2266*** (2013.01); ***H01Q 21/28*** (2013.01); *H01Q 1/2283* (2013.01); *H01Q 1/243* (2013.01); *H01Q 1/38* (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/38; H01Q 1/243; H01Q 21/28; H01Q 1/2266

See application file for complete search history.

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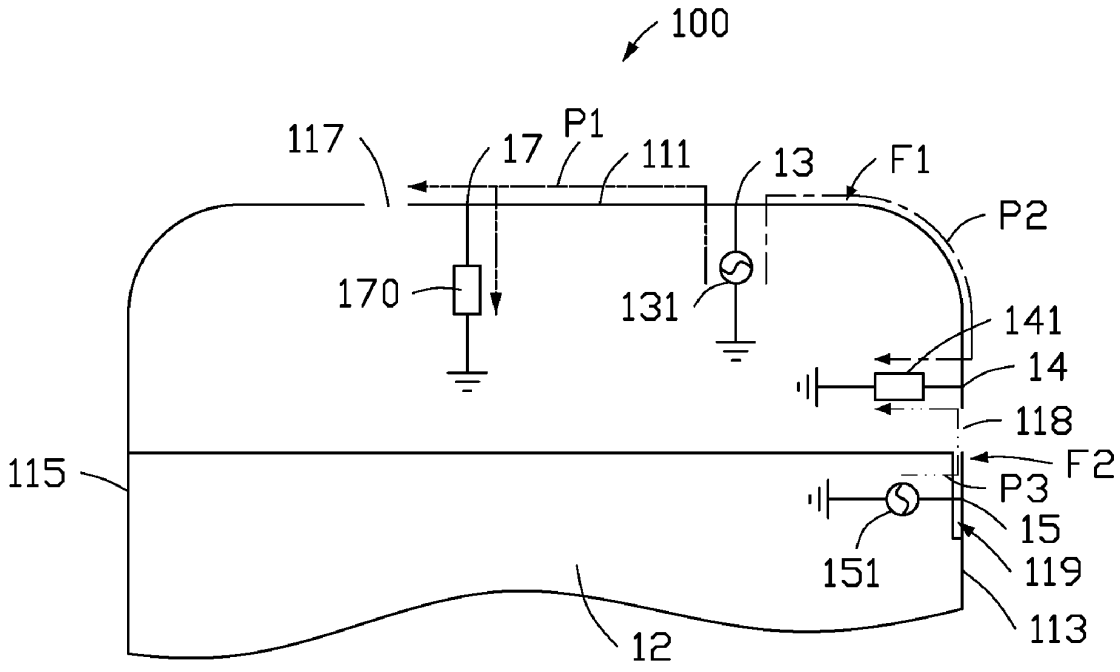
(57) **ABSTRACT**

An antenna structure of reduced size but able to operate at multiple frequencies, and applied to an electronic device, includes a housing, a first feed point, a first radiation portion, a first ground point, a second radiation portion, and a second feed point. The housing has at least one portion made of metal material with first and second gaps therein. The housing between first and second gaps forms the first radiation portion. The first feed point feeds current and signal to the first radiation portion. The first ground point is spaced from the first feed point and is grounded through a first inductive element. The second radiation portion is adjacent to the first radiation portion. The second feed point is electrically connected to a second signal point and feeds current and signal to the second radiation portion.

18 Claims, 15 Drawing Sheets



US011621498B2

(12) **United States Patent**
Chen

(10) **Patent No.: US 11,621,498 B2**
(45) **Date of Patent: Apr. 4, 2023**

(54) **ANTENNA STRUCTURE AND ELECTRONIC DEVICE USING SAME**

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

(72) Inventor: **Yi-Ting Chen**, New Taipei (TW)

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

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 51 days.

(21) Appl. No.: **17/313,305**

(22) Filed: **May 6, 2021**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Jun. 12, 2020 (CN) 202010537241.5

(51) **Int. Cl.**
H01Q 21/06 (2006.01)
H01Q 1/24 (2006.01)
H01Q 1/48 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 21/064*** (2013.01); ***H01Q 1/242*** (2013.01); ***H01Q 1/48*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/242; H01Q 1/243; H01Q 1/44; H01Q 1/48; H01Q 5/30; H01Q 5/328; H01Q 5/335; H01Q 5/378; H01Q 9/42; H01Q 13/106; H01Q 21/064; H01Q 21/28
See application file for complete search history.

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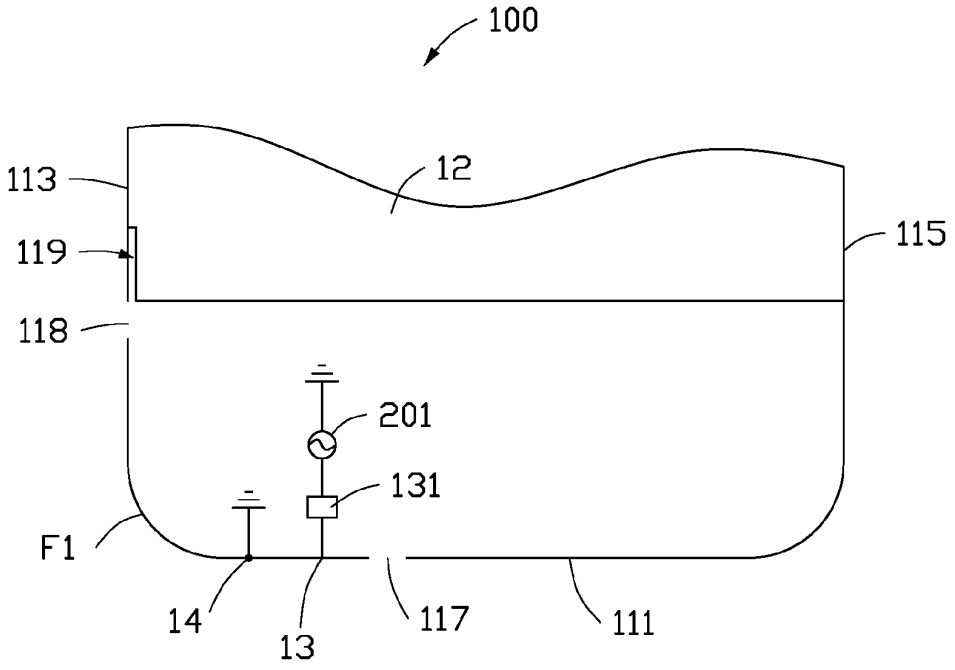
(74) *Attorney, Agent, or Firm* — ScienBiziP, P.C.

(57) **ABSTRACT**

An antenna structure of reduced size but operating at multiple frequencies, applied to an electronic device, includes a housing, a system ground plane, and a first feed point. The housing has at least one portion made of metal material and defines a first gap and a second gap. The housing between the first gap and the second gap forms a first radiation portion. The system ground plane is positioned in the housing and defines a first slit. The first slit corresponds to the first radiation portion and communicates with the second gap. The first feed point is positioned on the first radiation portion and is electrically connected to a first feed source for feeding current and signal to the first radiation portion.

18 Claims, 14 Drawing Sheets



US011626662B2

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

(10) **Patent No.: US 11,626,662 B2**
(45) **Date of Patent: Apr. 11, 2023**

(54) **MULTI-BAND ANTENNA AND MOBILE TERMINAL**

(71) Applicant: **HUAWEI TECHNOLOGIES CO., LTD.**, Shenzhen (CN)

(72) Inventors: **Liang Xue**, Shanghai (CN); **Dong Yu**, Shanghai (CN); **Lijun Ying**, Shanghai (CN); **Meng Hou**, Shanghai (CN); **Jiaqing You**, Shanghai (CN)

(73) Assignee: **HUAWEI TECHNOLOGIES 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 84 days.

(21) Appl. No.: **16/957,492**

(22) PCT Filed: **Dec. 26, 2018**

(86) PCT No.: **PCT/CN2018/124026**
§ 371 (c)(1),
(2) Date: **Jun. 24, 2020**

(87) PCT Pub. No.: **WO2019/129098**
PCT Pub. Date: **Jul. 4, 2019**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
H01Q 5/25 (2015.01)
H01Q 5/335 (2015.01)

(52) **U.S. Cl.**
CPC ***H01Q 5/335*** (2015.01); ***H01Q 5/25*** (2015.01)

(58) **Field of Classification Search**
CPC H01Q 5/335; H01Q 5/25; H01Q 1/52; H01Q 9/42; H01Q 5/392; H01Q 1/44;
(Continued)

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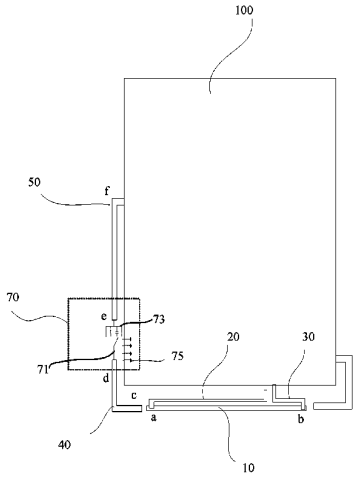
Primary Examiner — Hai V Tran
Assistant Examiner — Michael M Bouizza
(74) *Attorney, Agent, or Firm* — Rimon PC

(57) **ABSTRACT**

This application provides a multi-band antenna. The antenna includes a feeder and a radiating element connected to the feeder, and further includes: a first notch structure, where the first notch structure is located on a side of the radiating element and is coupled to the radiating element; and a second notch structure, where the second notch structure is located on a side of the first notch structure and far from the radiating element, and an end that is of the second notch structure and that is far from the radiating element is grounded. The first notch structure may be selectively connected to the ground or to the second notch structure. The first notch structure may be connected to the second notch structure in some embodiments using a first tuning device.

16 Claims, 13 Drawing Sheets



US011611148B2

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

(10) **Patent No.: US 11,611,148 B2**
(45) **Date of Patent: Mar. 21, 2023**

(54) **OPEN-APERTURE WAVEGUIDE FED SLOT ANTENNA**

(71) Applicant: **City University of Hong Kong**, Hong Kong (HK)

(72) Inventors: **Hang Wong**, Hong Kong (HK); **Qingyi Guo**, Hong Kong (HK)

(73) Assignee: **City University of Hong Kong**, Hong Kong (HK)

(*) 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.: **17/527,077**

(22) Filed: **Nov. 15, 2021**

(65) **Prior Publication Data**

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Related U.S. Application Data

(60) Provisional application No. 63/130,547, filed on Dec. 24, 2020.

(51) **Int. Cl.**
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H01Q 13/22 (2006.01)
H01Q 13/10 (2006.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
CPC H01Q 13/18; H01Q 13/22; H01Q 13/16; H01Q 13/106
See application file for complete search history.

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Assistant Examiner — Anh N Ho
(74) *Attorney, Agent, or Firm* — Idea Intellectual Limited; Margaret A. Burke; Sam T. Yip

(57) **ABSTRACT**

The present invention provides an open-aperture waveguide fed slot antenna including a feeding section on a substrate integrated waveguide, an H-shaped slot, a matched end, and a bottom metal layer. One end of the feeding section is open and connected to the slot, providing energy feeding to the slot. A long side of the center section of the slot is connected to a top metal part of the feeding section. Another side is connected to the matching end. The matching end includes metal which is connected to the slot, the metallic via wall and the bottom metal of the feeding section which is connected to the metallic via wall. The antenna has high gain, wide gain bandwidth, a simple structure, and low processing cost and can be applied to millimeter-wave frequency bands as well as other frequency bands.

9 Claims, 9 Drawing Sheets