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Fan et al.

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(45) Date of Patent: Aug. 19, 2025

(54) **ANTENNA AND ELECTRONIC DEVICE**

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(73) Assignees: **Beijing BOE Technology Development Co., Ltd.**, Beijing (CN); **BOE Technology Group 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.

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PCT Pub. Date: **Aug. 24, 2023**

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(51) **Int. Cl.**
H01Q 13/02 (2006.01)
H01Q 1/36 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 13/0233*** (2013.01); ***H01Q 1/36*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 1/50*** (2013.01); ***H01Q 13/10*** (2013.01)

(58) **Field of Classification Search**
CPC .. H01Q 13/0233; H01Q 13/10; H01Q 13/085; H01Q 1/36; H01Q 1/48; H01Q 1/50; H01Q 15/0006
See application file for complete search history.

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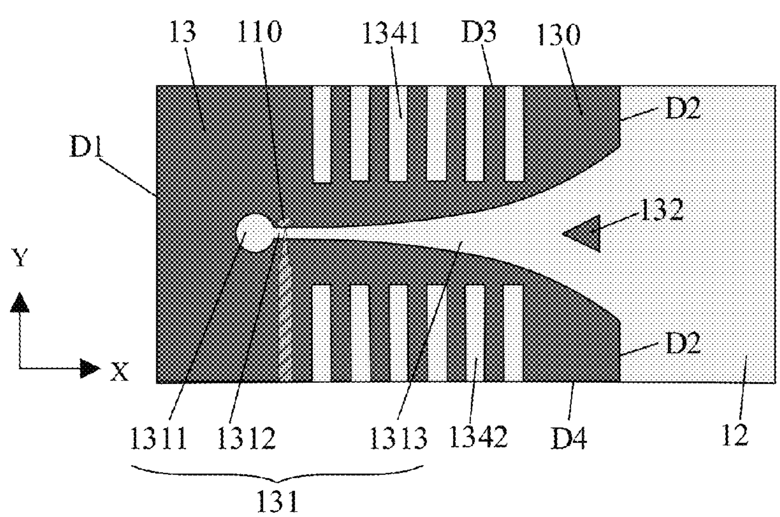
Primary Examiner — Hai V Tran
(74) *Attorney, Agent, or Firm* — Ling Wu; Stephen Yang; Ling and Yang Intellectual Property

(57) **ABSTRACT**

An antenna and an electronic device are provided in the present disclosure. The antenna includes a first conductive layer, a dielectric layer, and a second conductive layer which are stacked; the first conductive layer is provided as a microstrip line structure; the second conductive layer is provided with a radiation structure and a director; the radiation structure includes a first edge and a second edge disposed oppositely along a first direction; the radiation structure is provided with a first slot, a second slot, and a third slot that are sequentially communicated along the first direction and away from the first edge, the first slot is circular, the second slot is rectangular, and the third slot gradually increases in dimension in the second direction; the director is disposed on the second conductive layer and located at a side of the third slot away from the second slot.

19 Claims, 27 Drawing Sheets



(51) **Int. Cl.**

H01Q 1/48	(2006.01)
H01Q 1/50	(2006.01)
H01Q 13/10	(2006.01)

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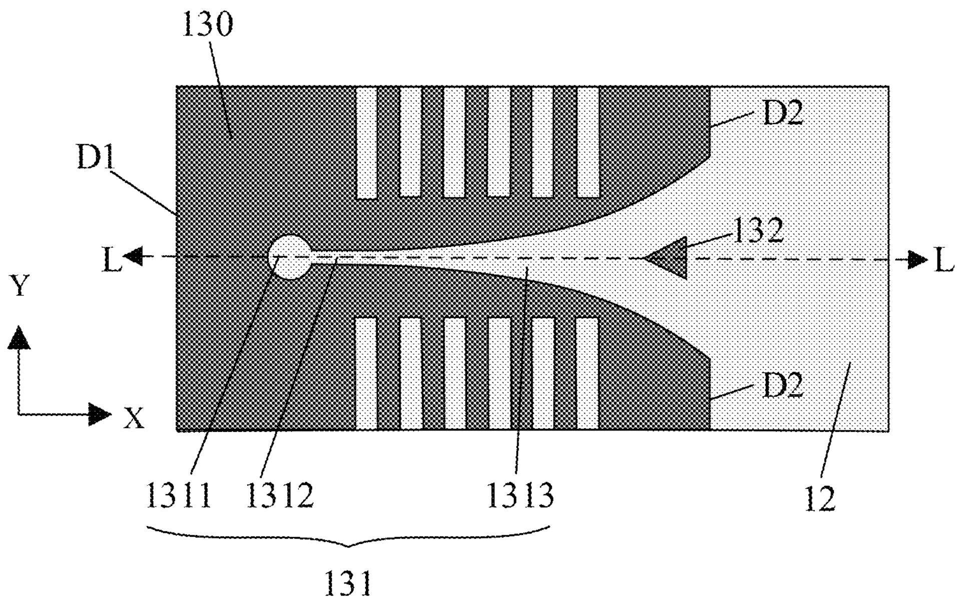
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D1
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132
L
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X
D2
1311
1312
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131

FIG. 1 a

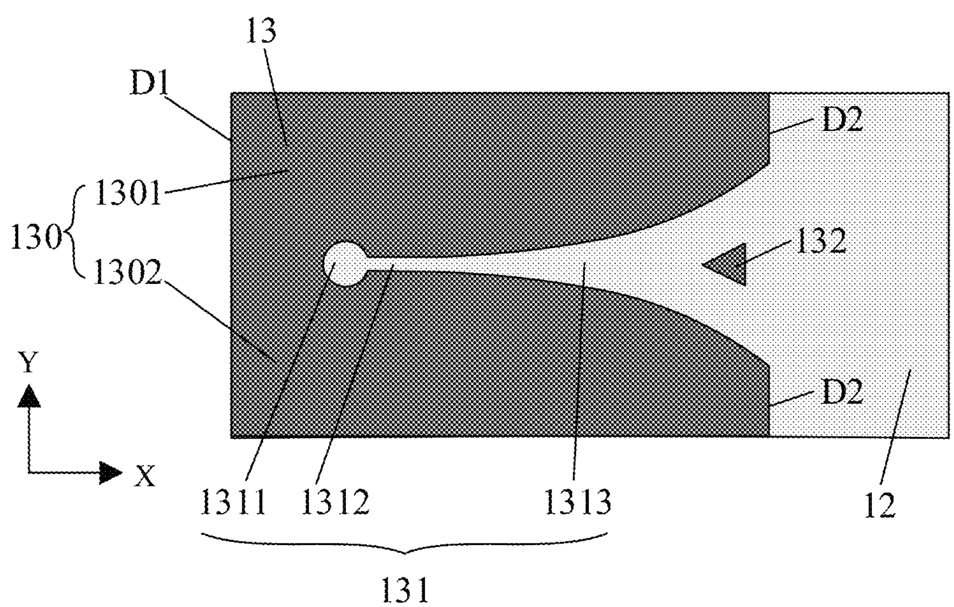
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FIG. 1 b

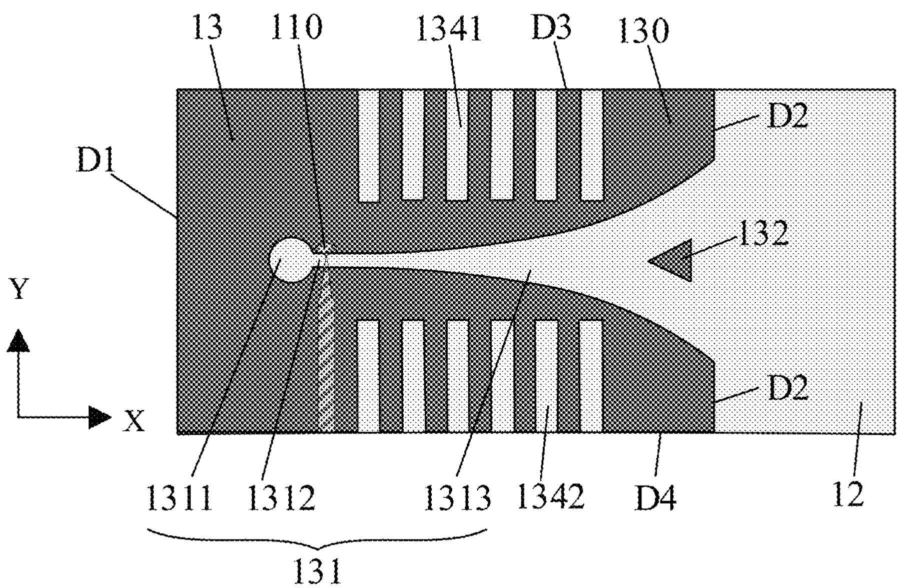


FIG. 1 c

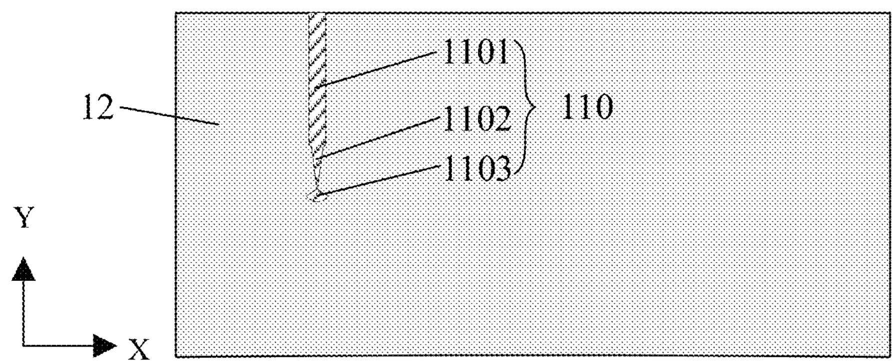


FIG. 2

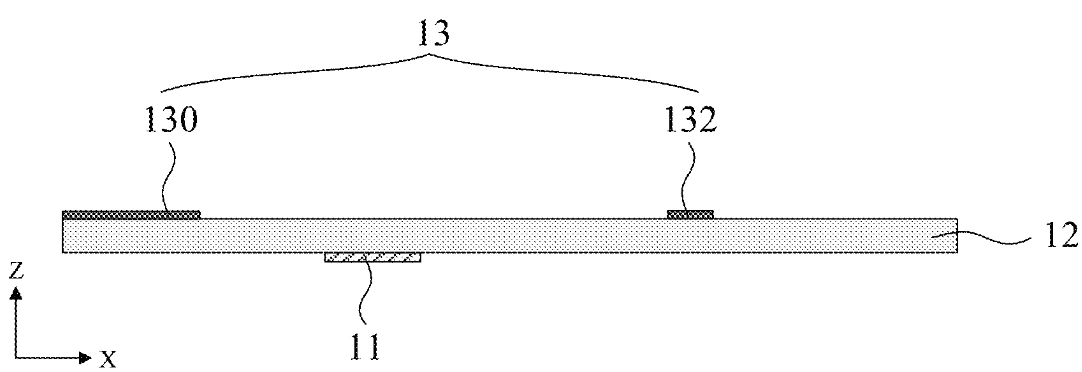
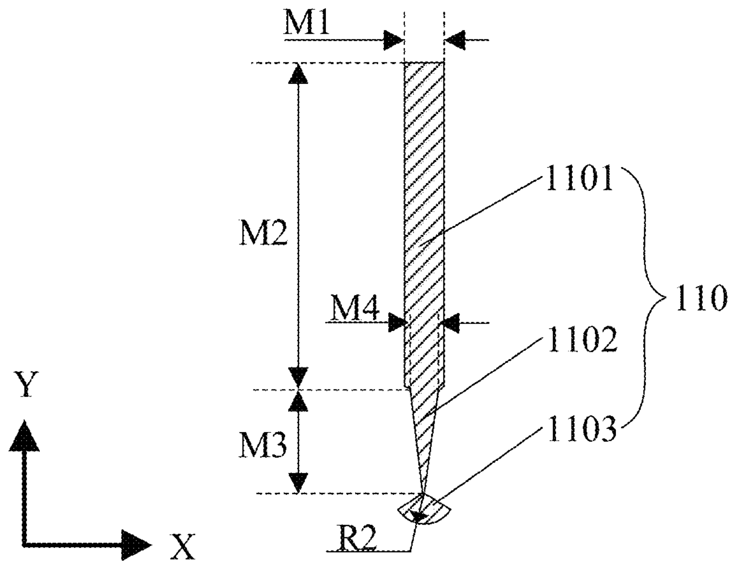


FIG. 3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M3
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1101
1102
1103
110
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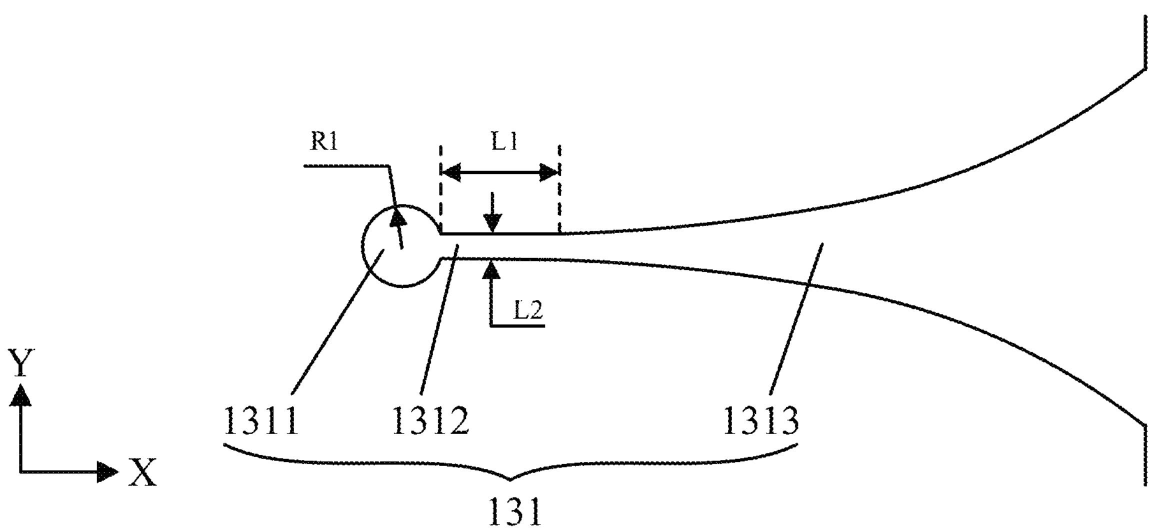
X

FIG. 4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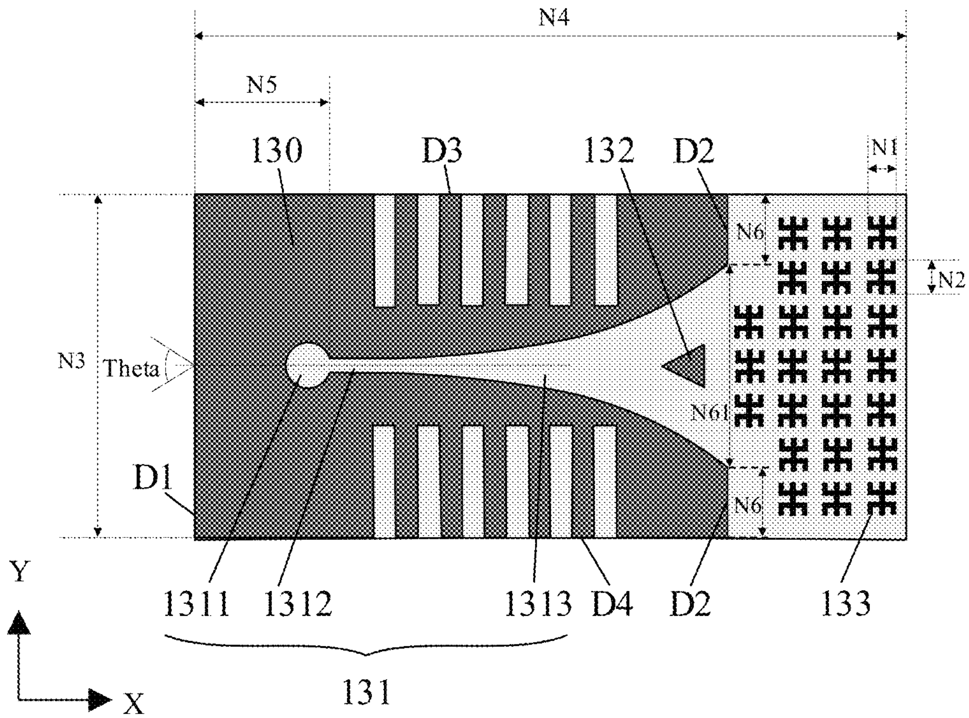
Y
X
1311
1312
1313
131

FIG. 5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N5
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D3
132
D2
N1
N6
N2
N3
Theta
N61
D1
N6
Y
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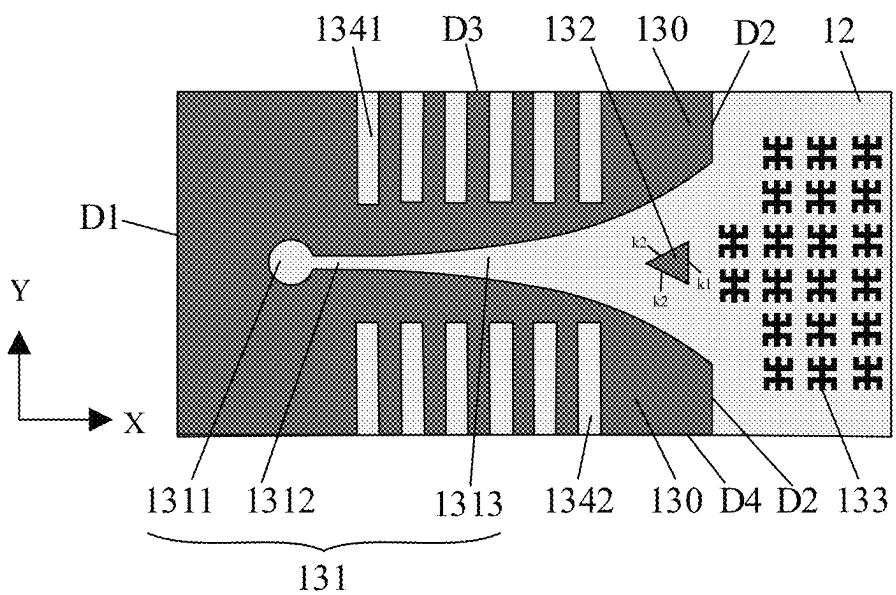
1311
1312
1313
D4
D2
133
131

FIG. 6a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D2
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D1
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1342
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D4
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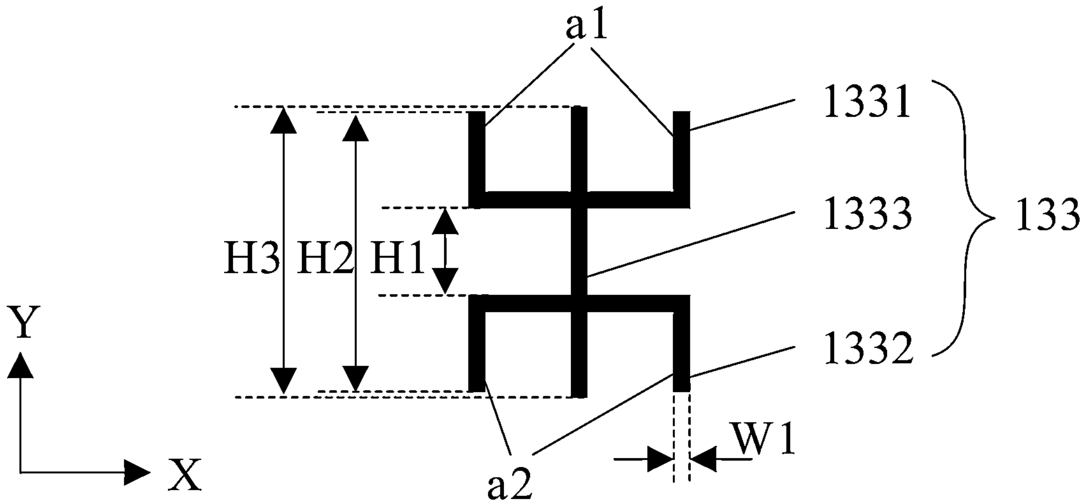
133
131

FIG. 6b



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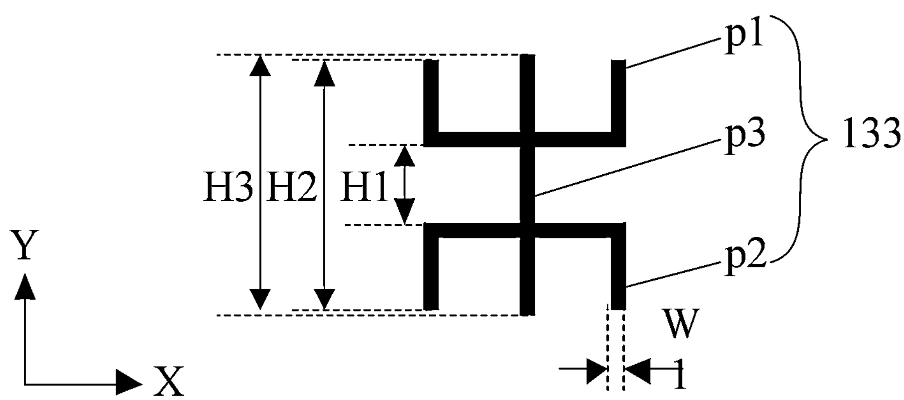
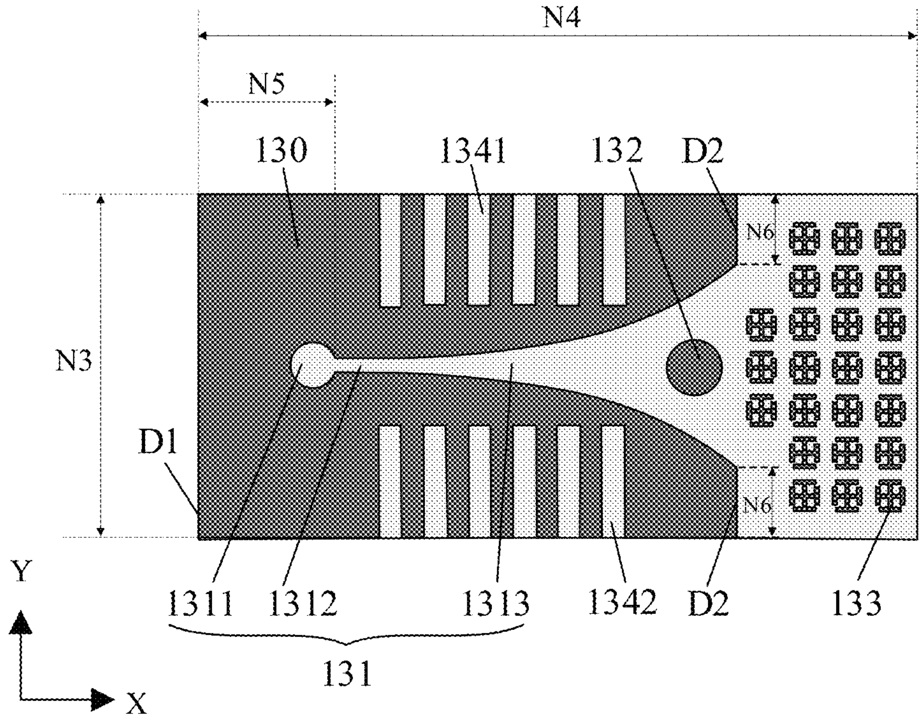


FIG. 6d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D2
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D1
N6
Y
X
1311
1312
1313
1342
D2
133
131

FIG. 7a

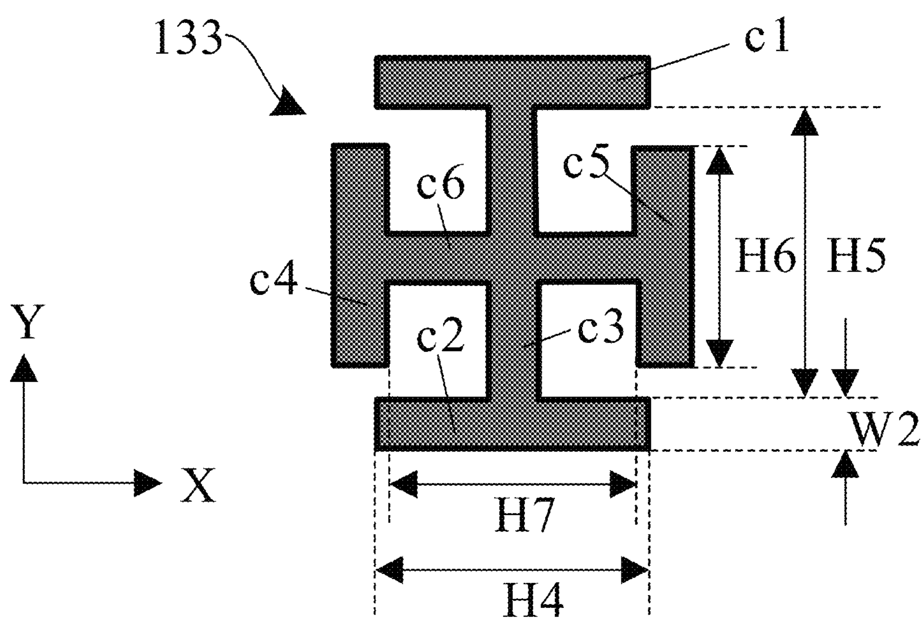
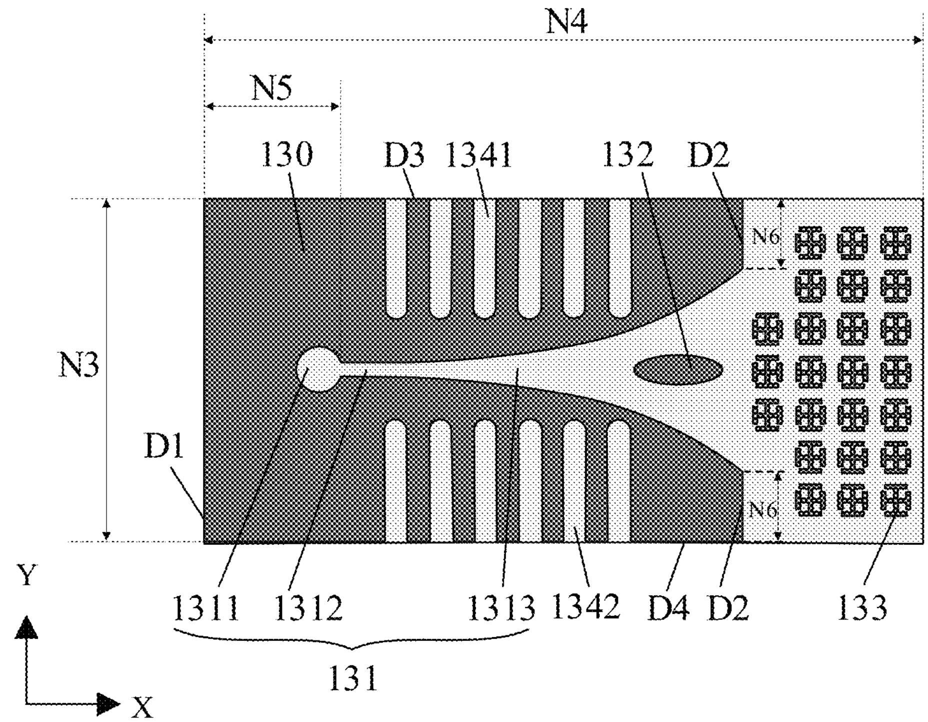

133
c1
c6
c5
H6
H5
c4
c2
c3
Y
X
W2
H7
H4

FIG. 7b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D2
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N6
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X
1311
1312
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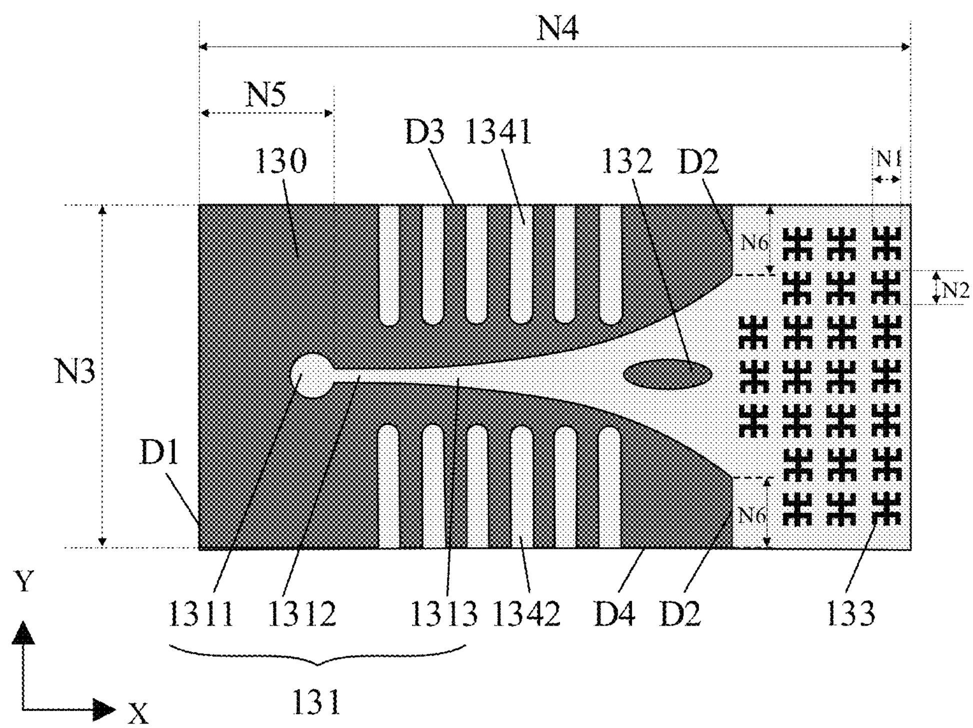
1342
D4
D2
133
131

FIG. 8a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D2
133
131

FIG. 8b

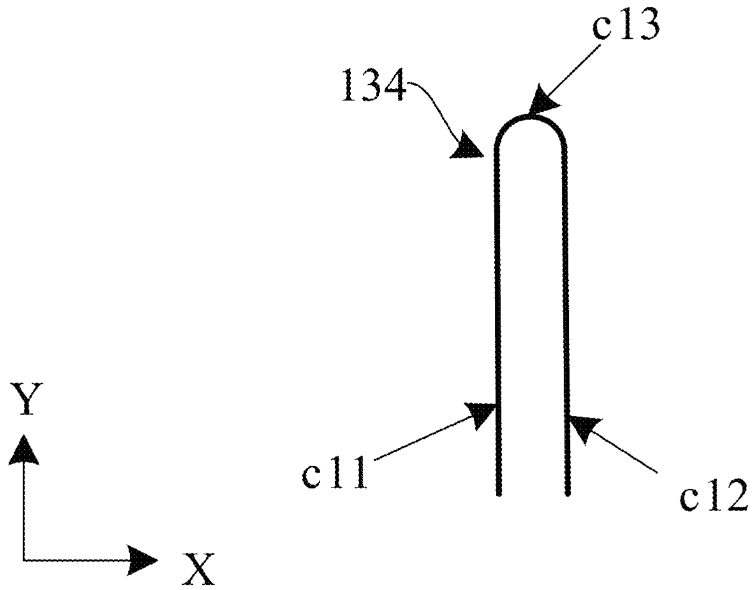


FIG. 8c

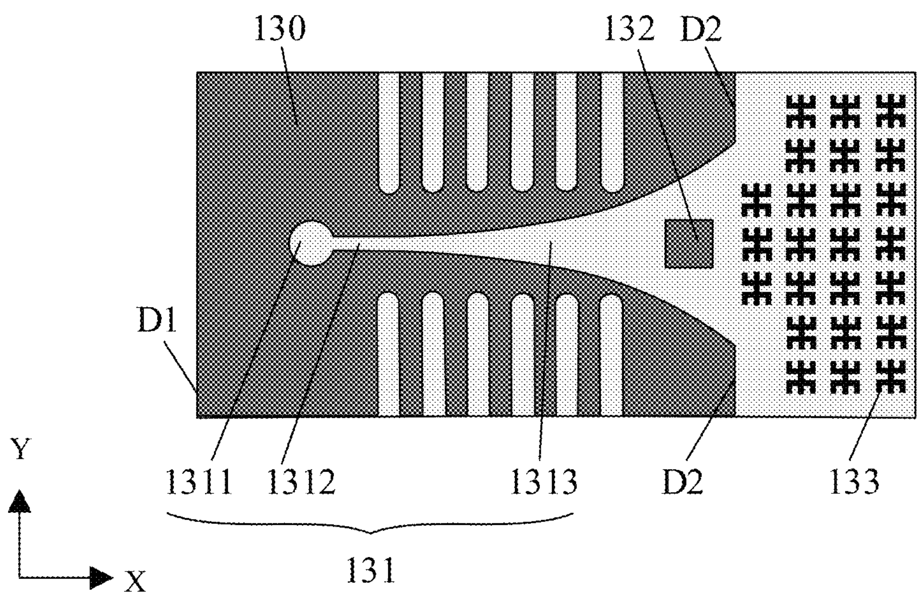


FIG. 9

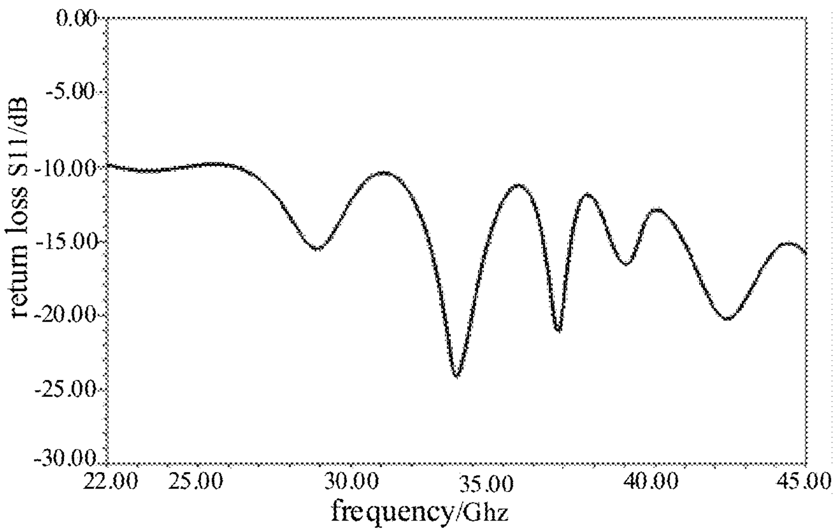


FIG. 10a

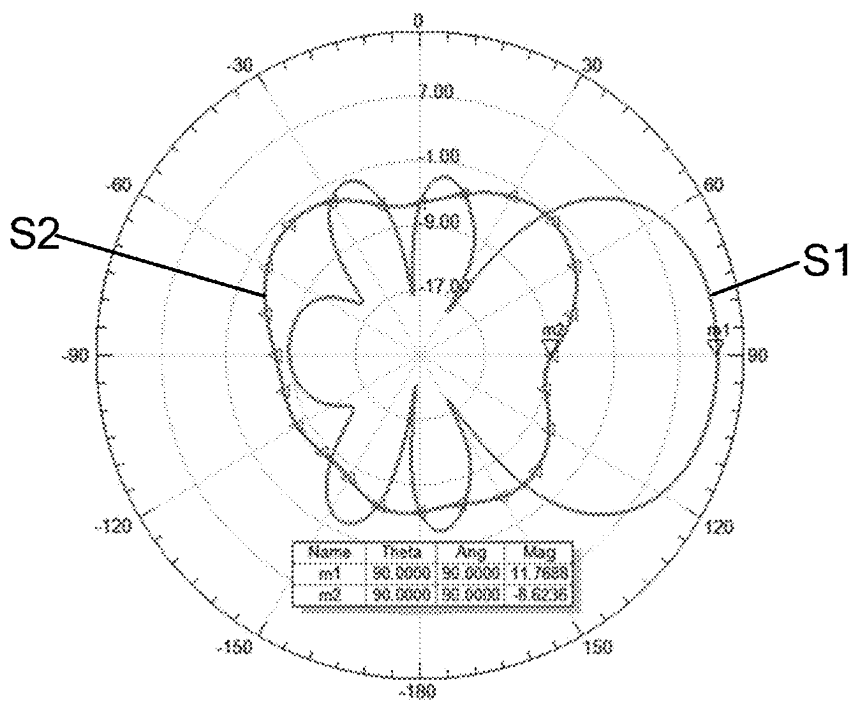


FIG. 10b

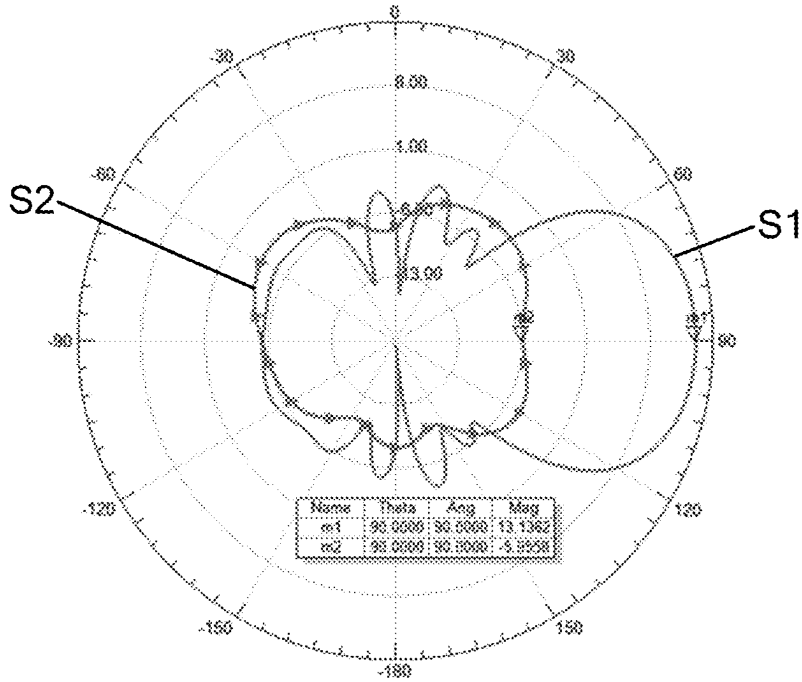


FIG. 10c

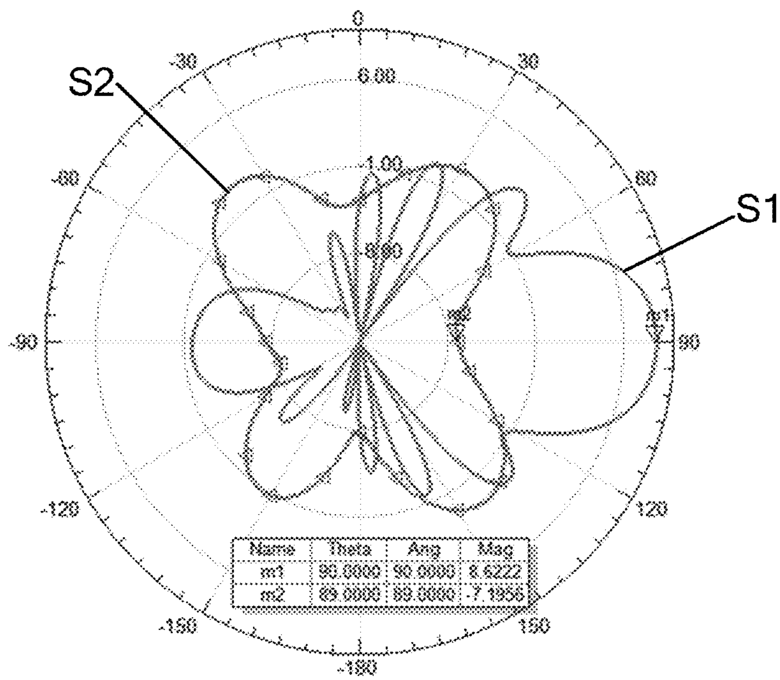


FIG. 10d

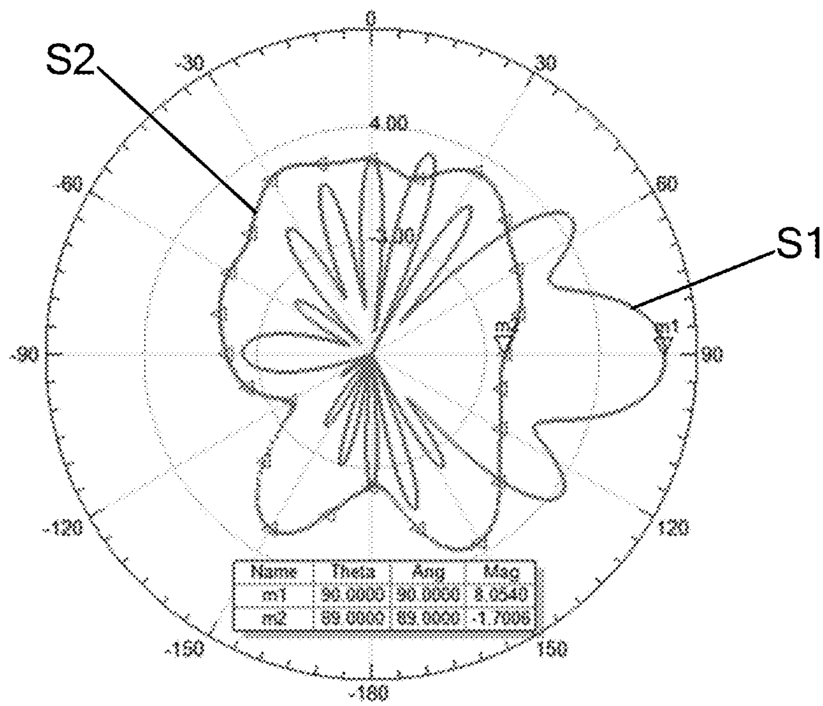


FIG. 10e

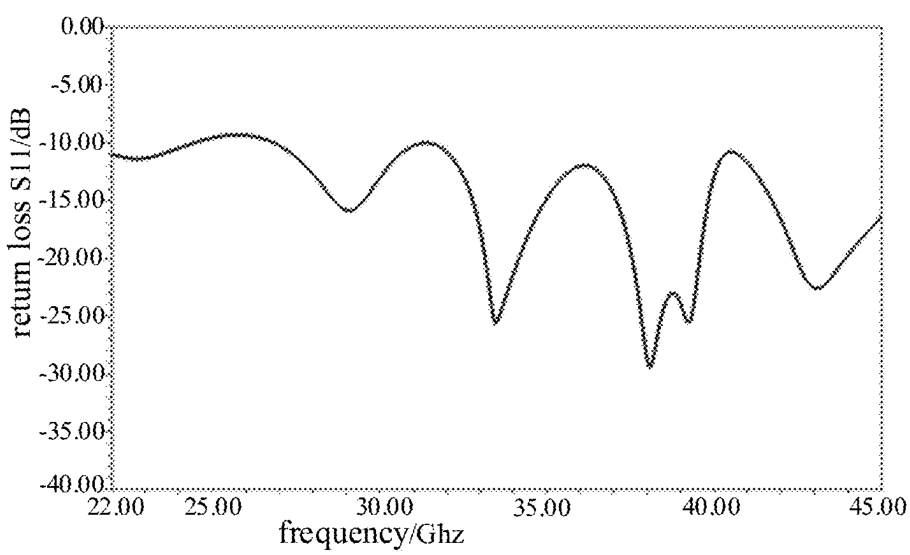


FIG. 11a

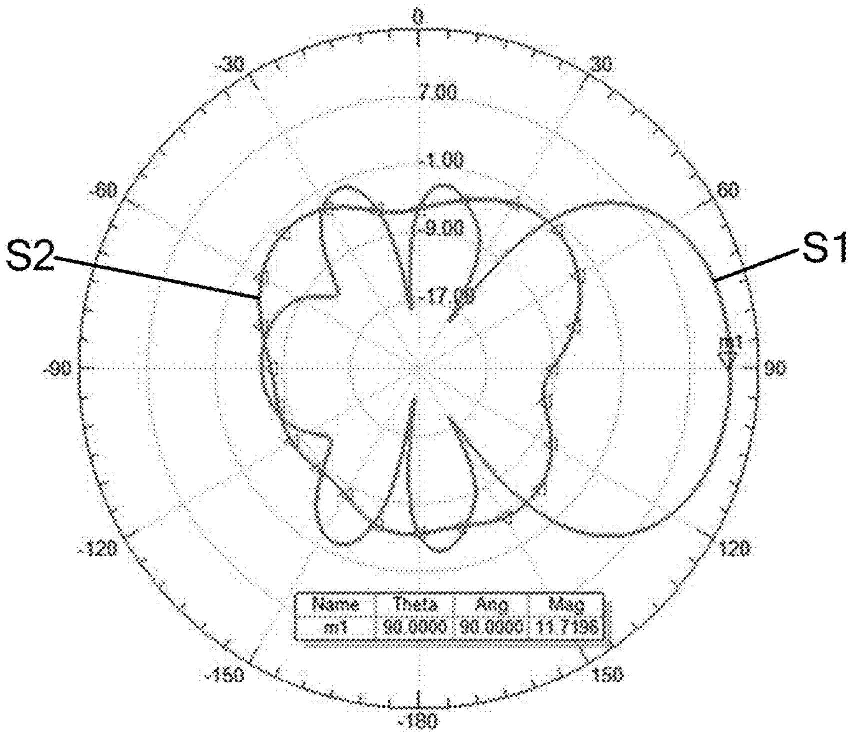


FIG. 11b

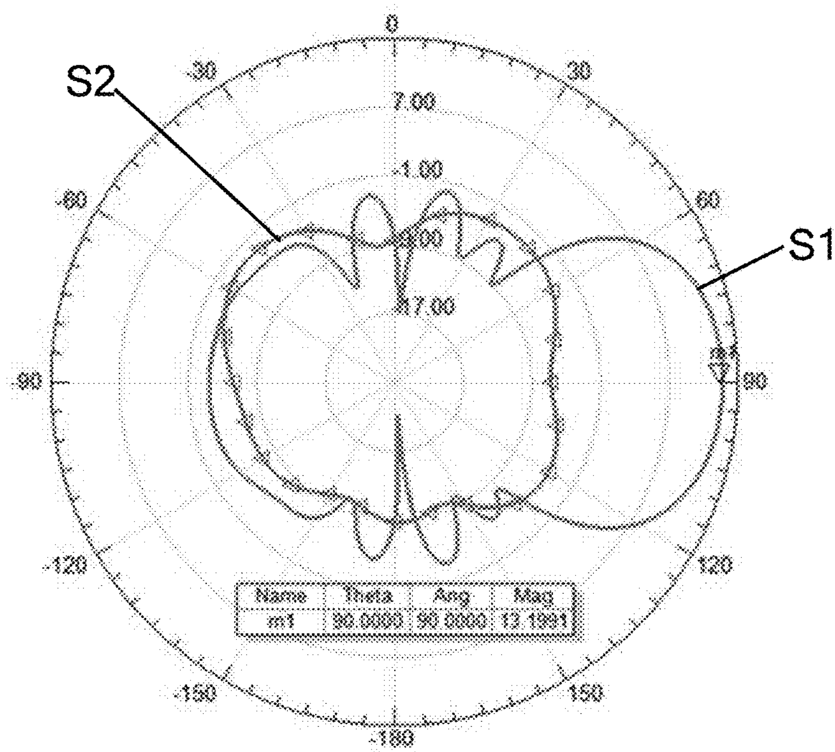


FIG. 11c

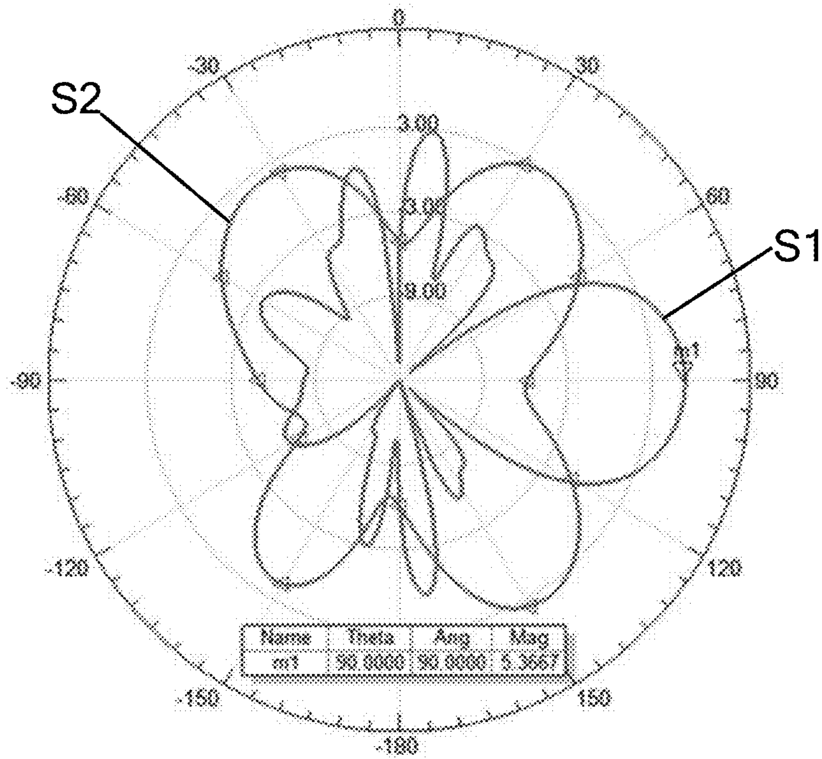


FIG. 11d

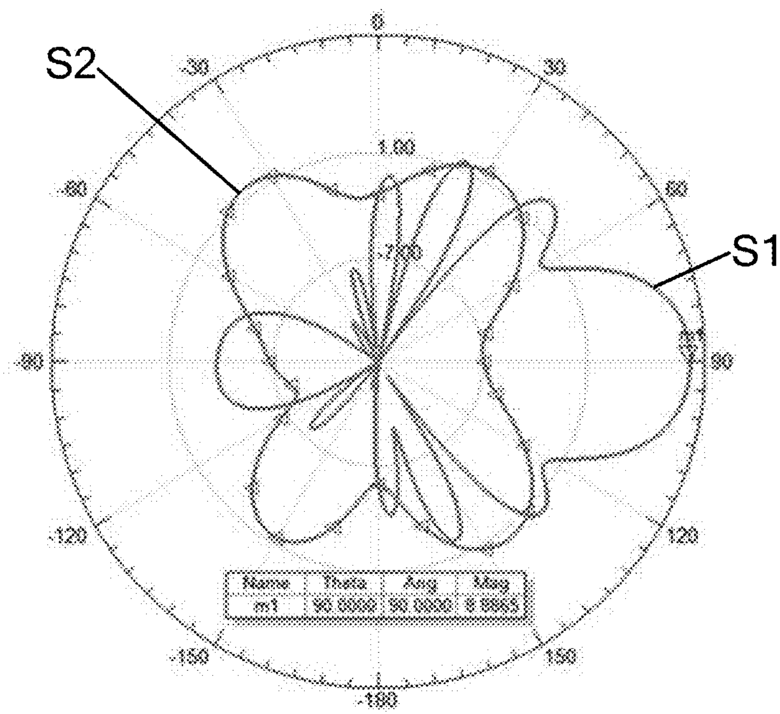


FIG. 11e

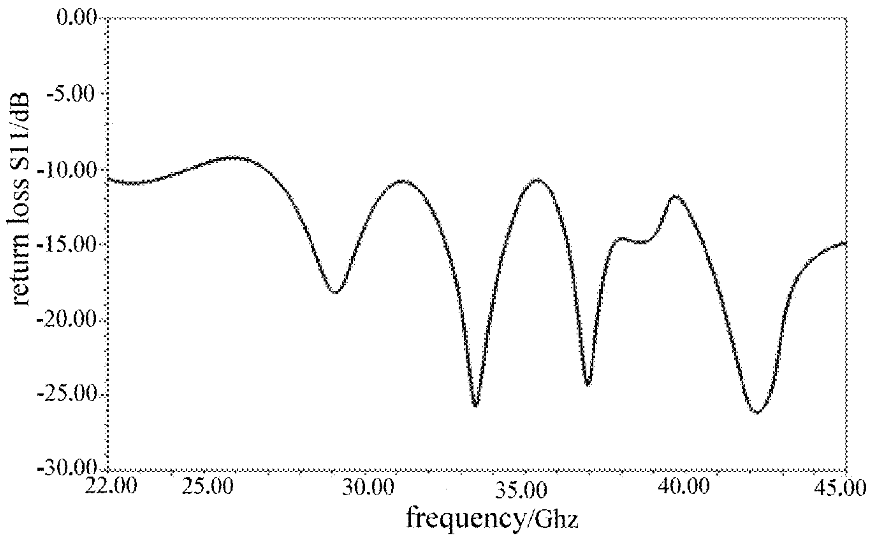
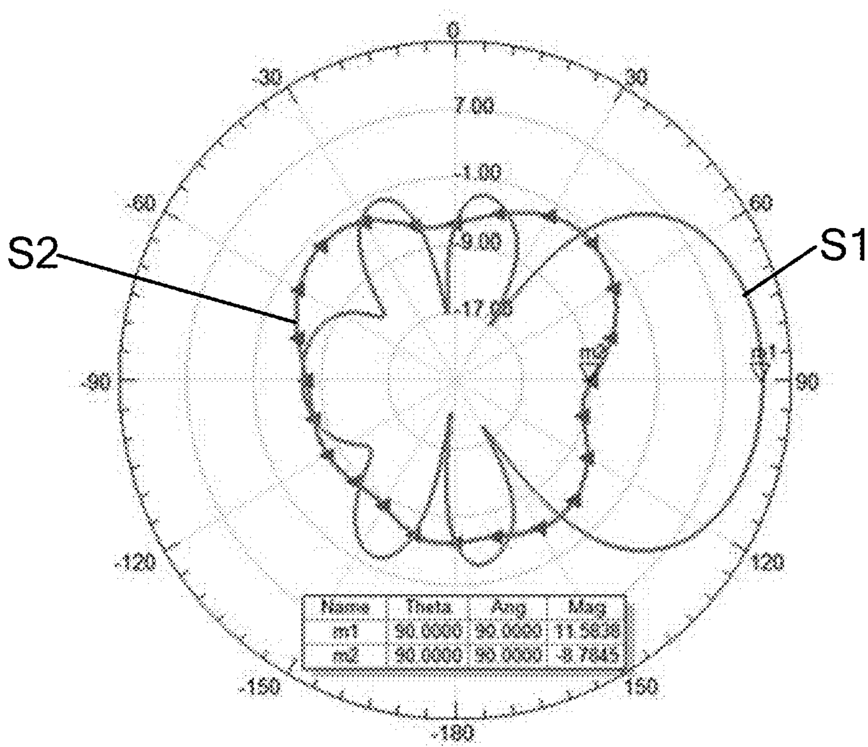


FIG. 12a



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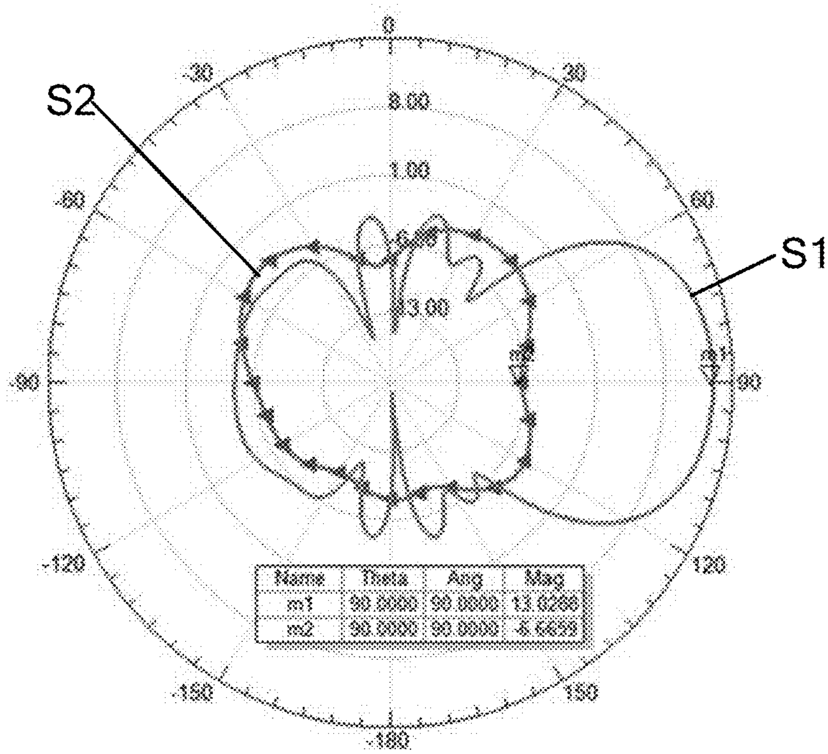


FIG. 12c

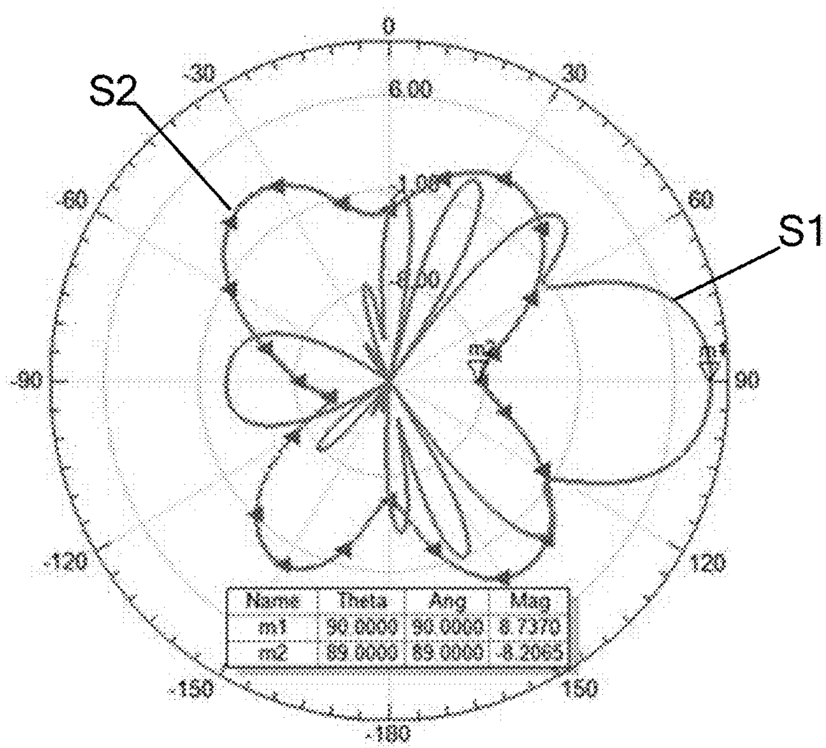


FIG. 12d

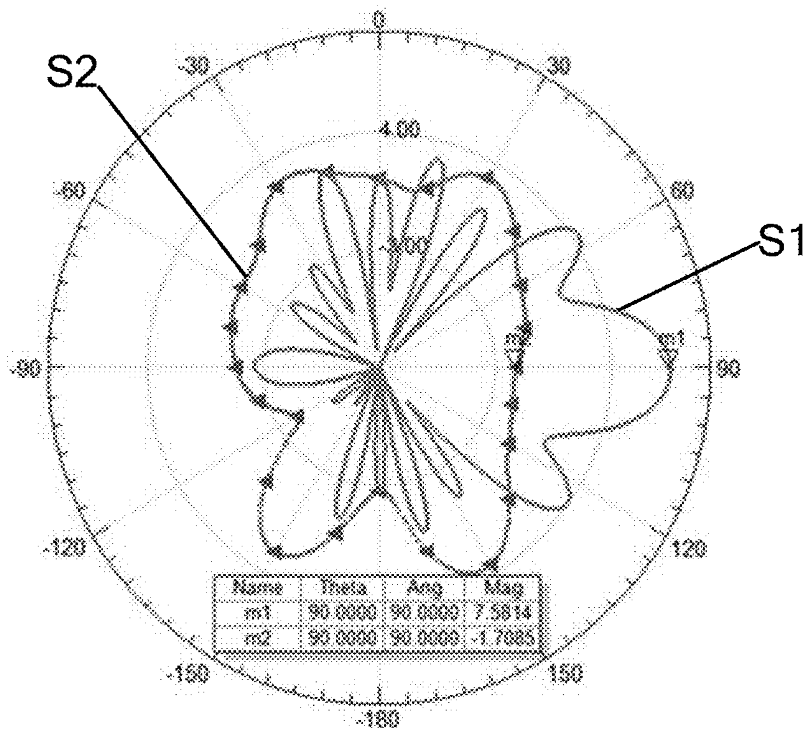


FIG. 12e

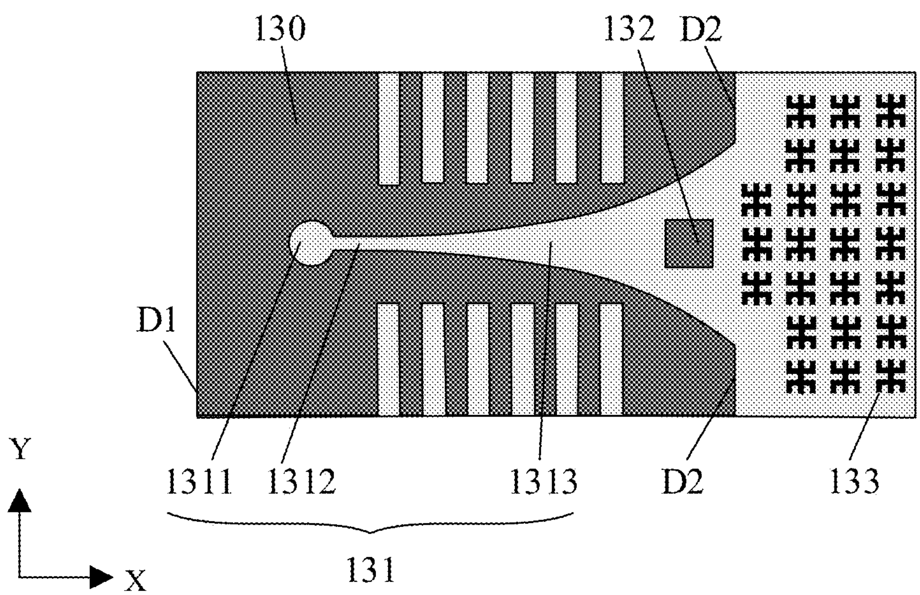
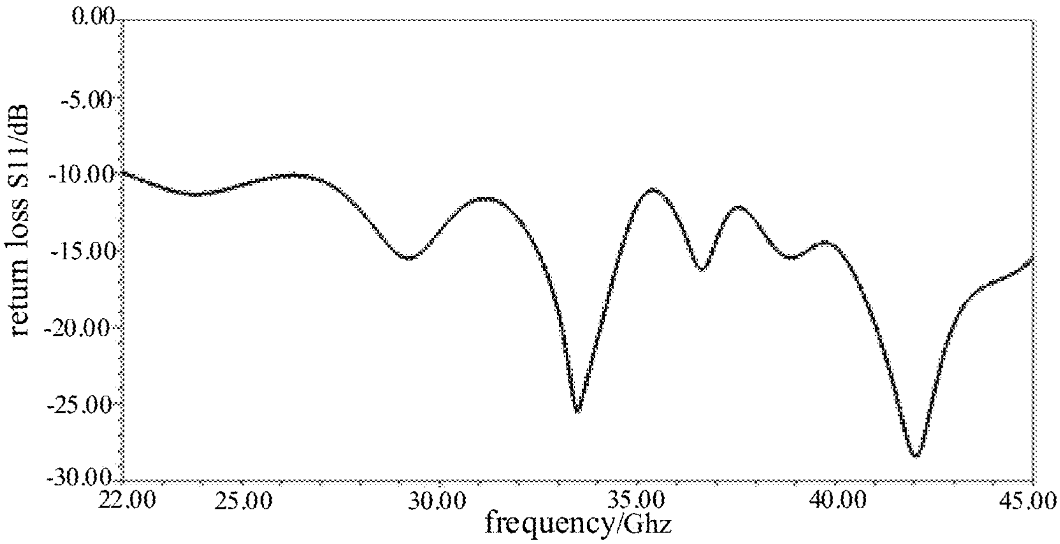


FIG. 12f



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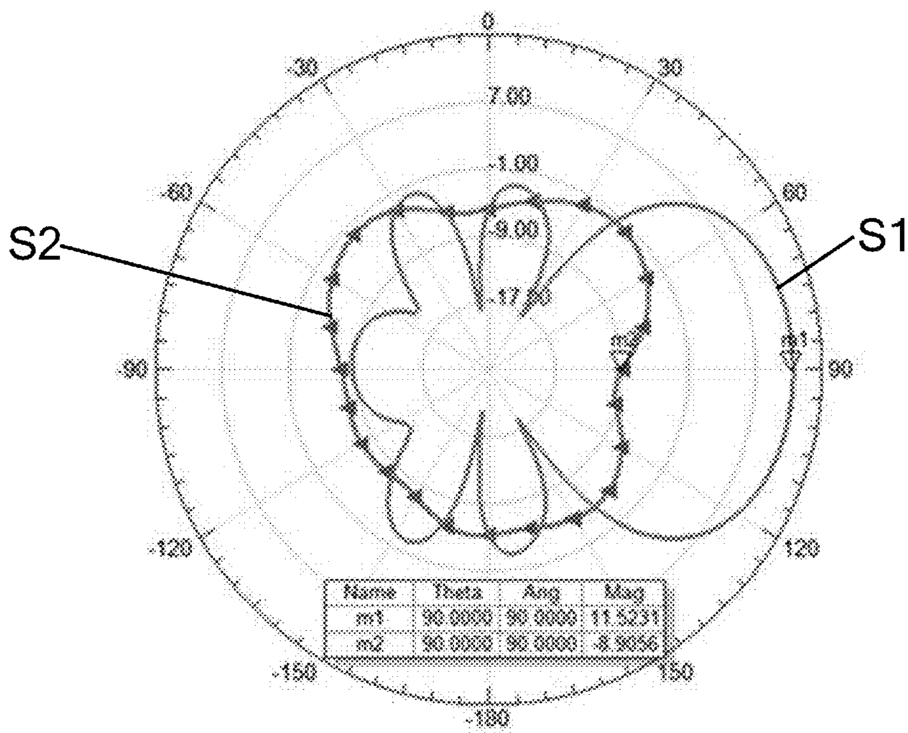

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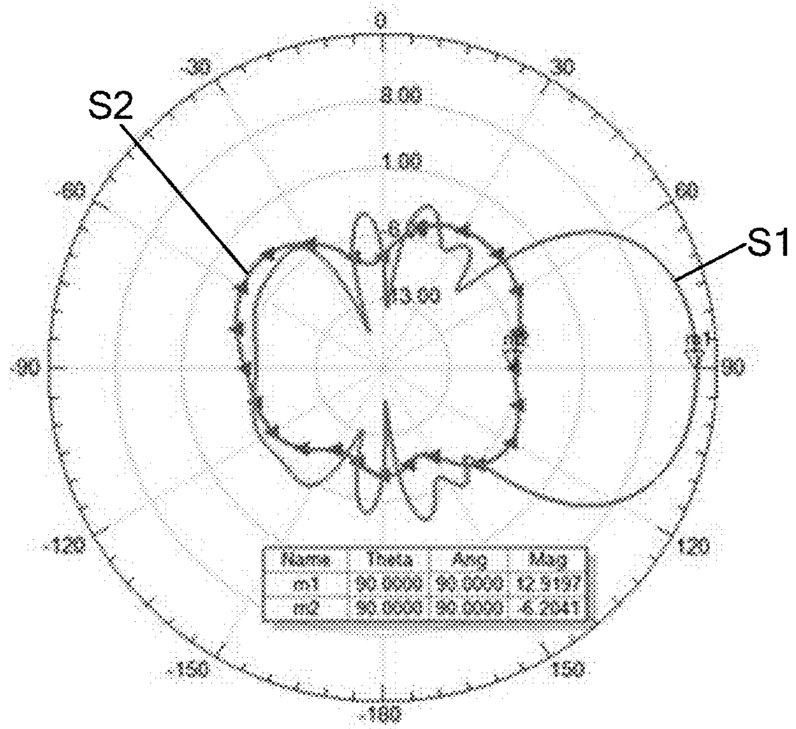

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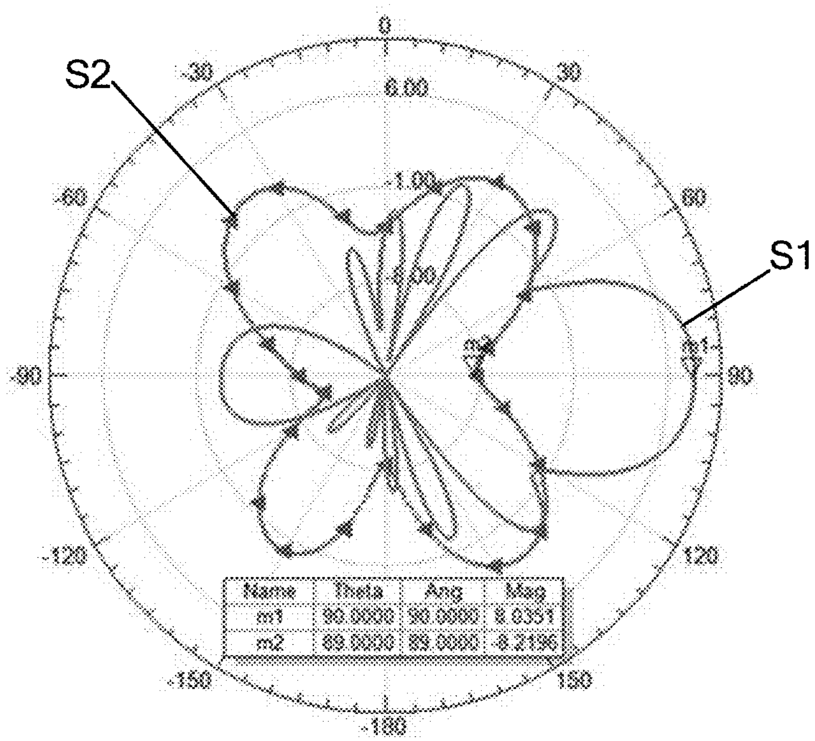
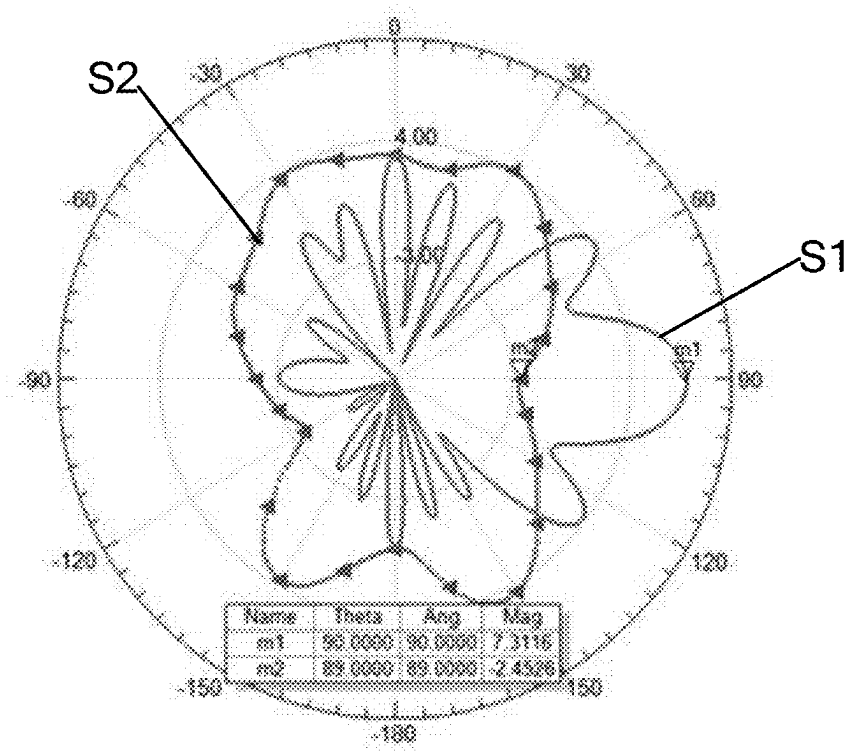


FIG. 13d



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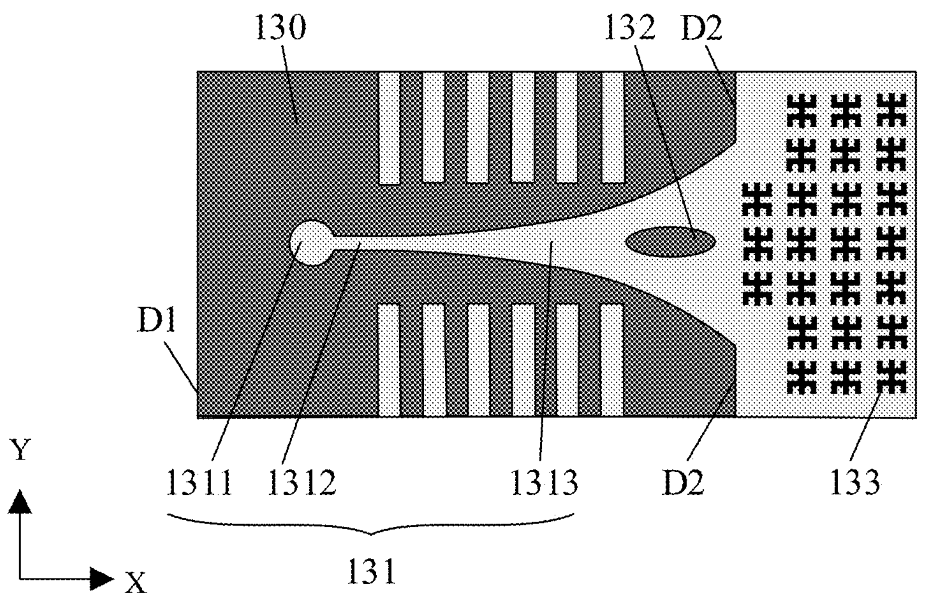

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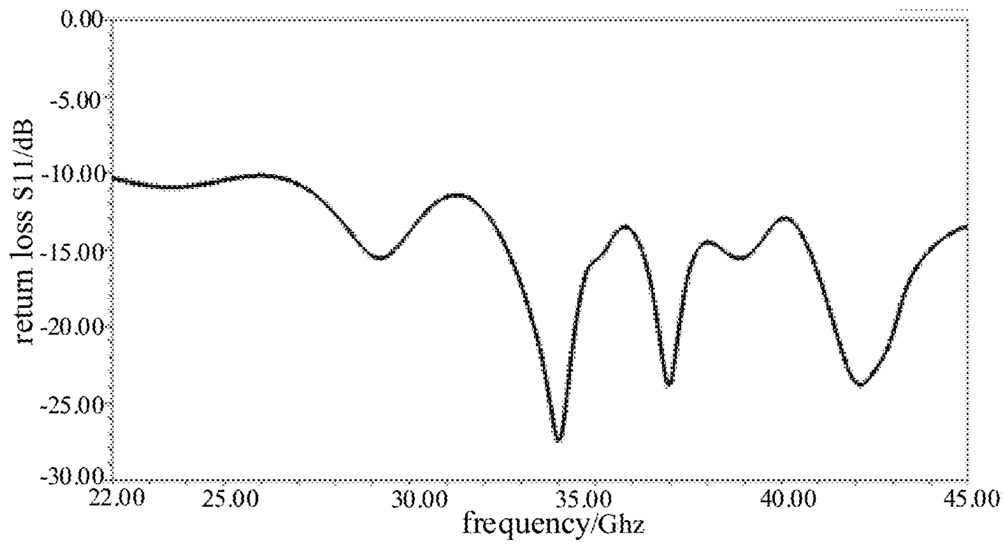

FIG. 14a

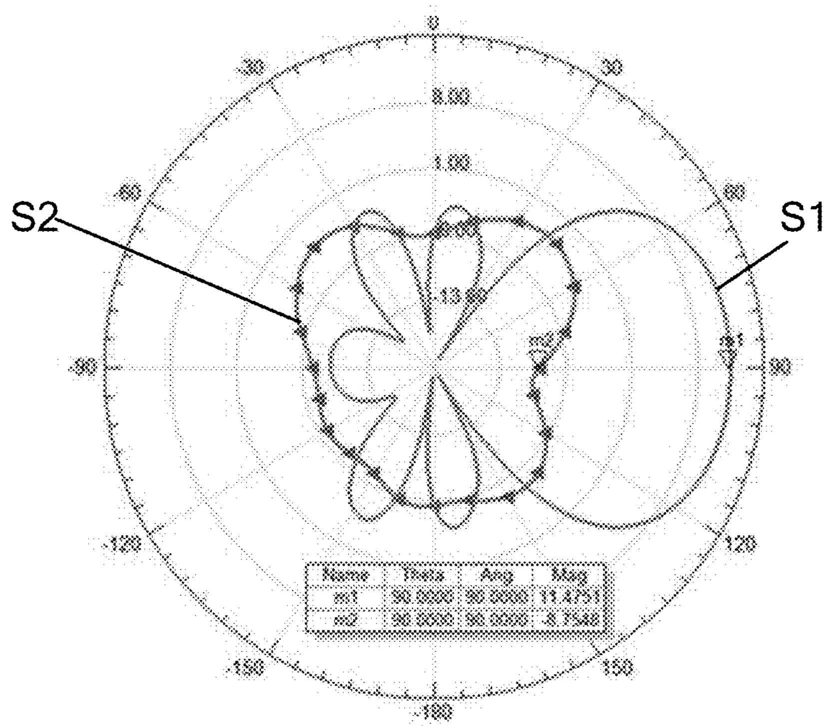

FIG. 14b

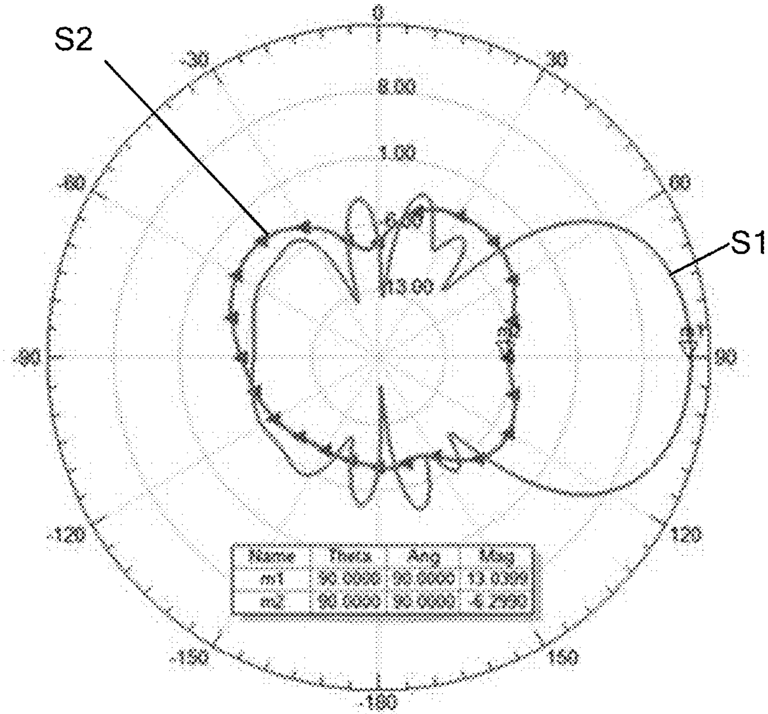

FIG. 14c

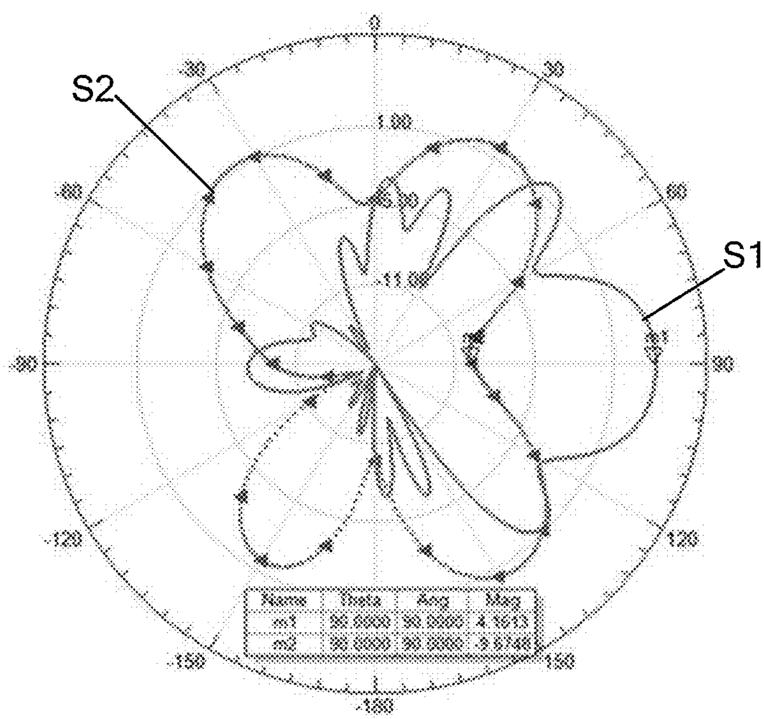

FIG. 14d

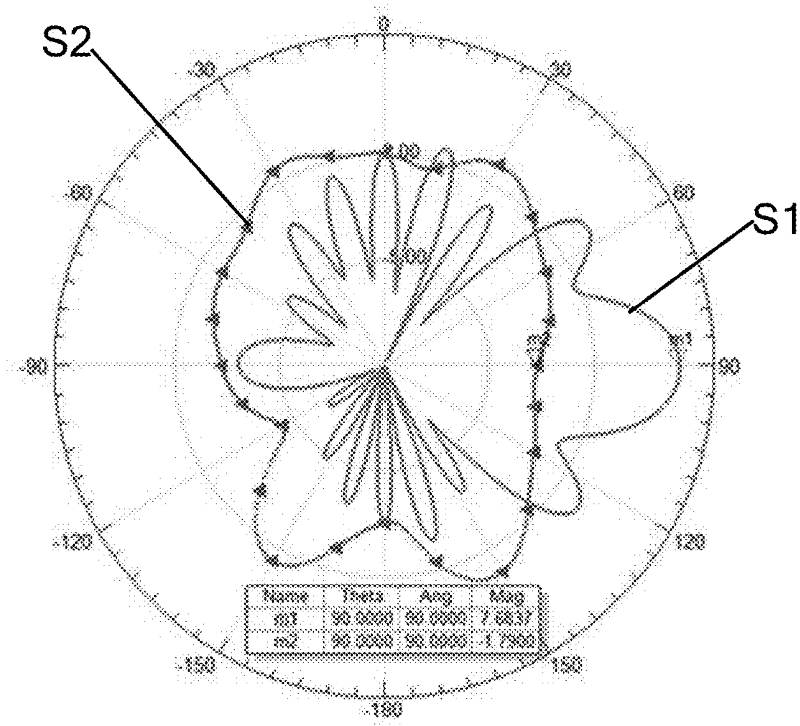

FIG. 14e

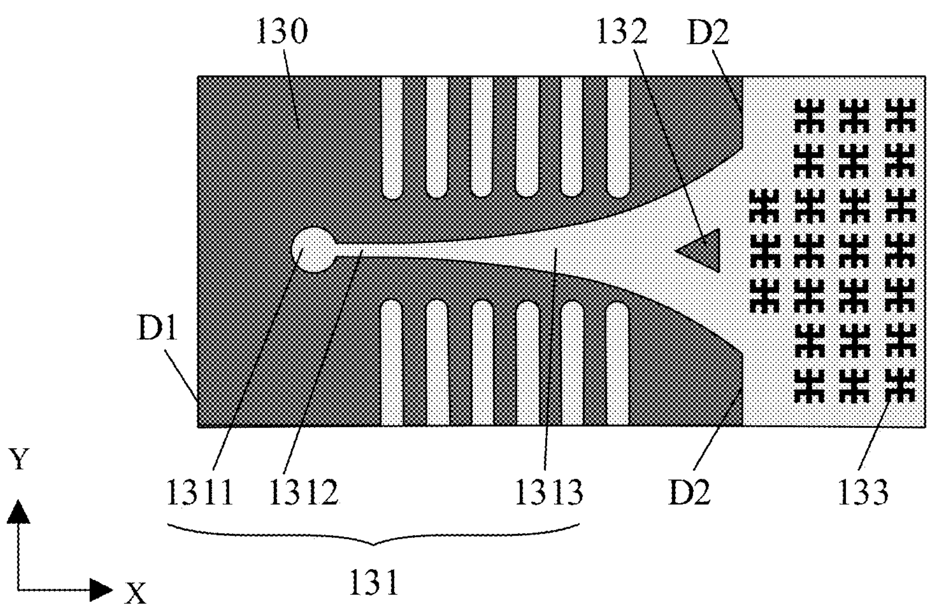

FIG. 14f

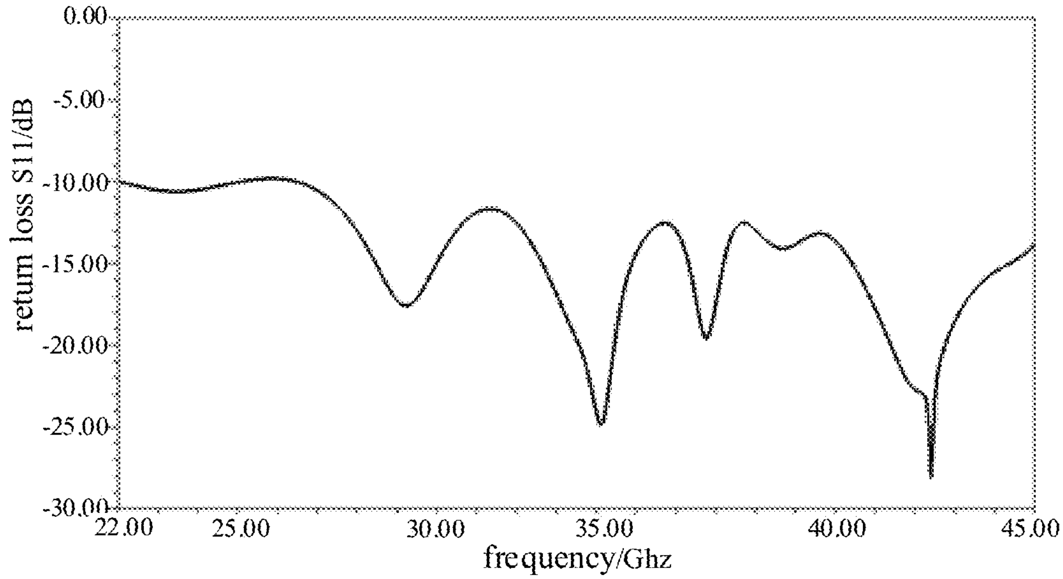

FIG. 15a

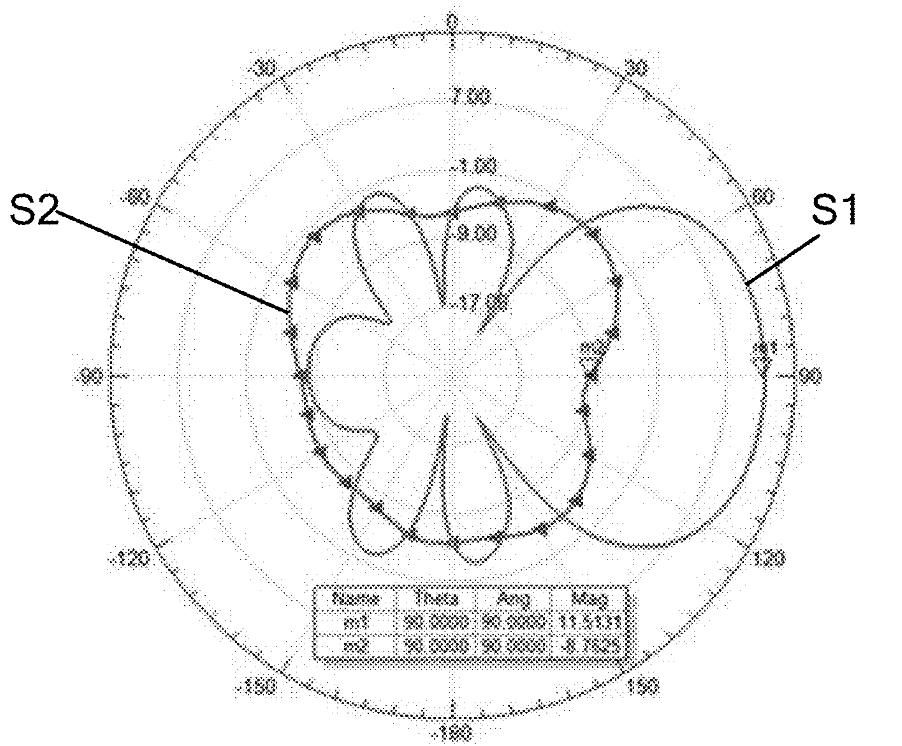

FIG. 15b

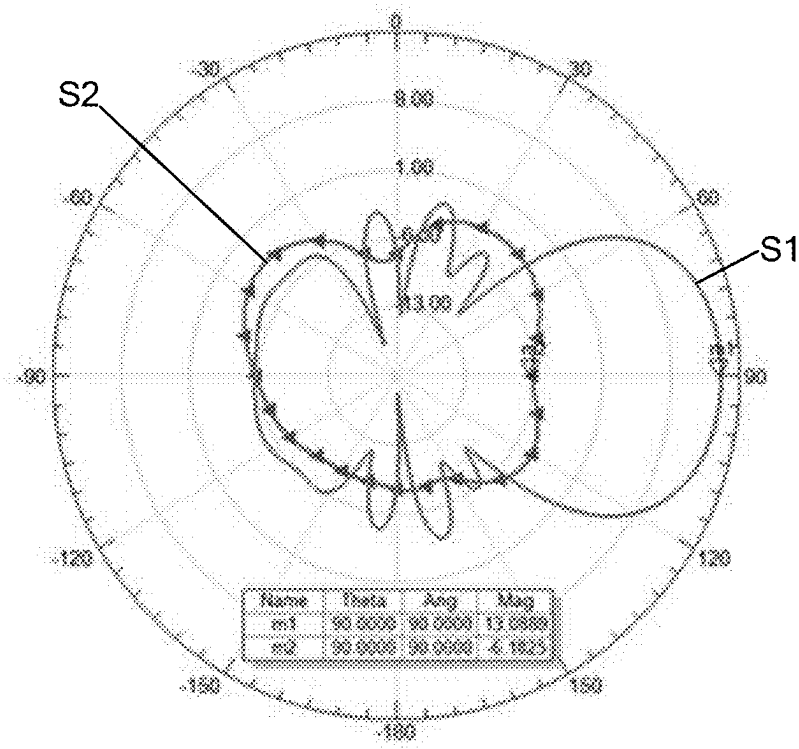

FIG. 15c

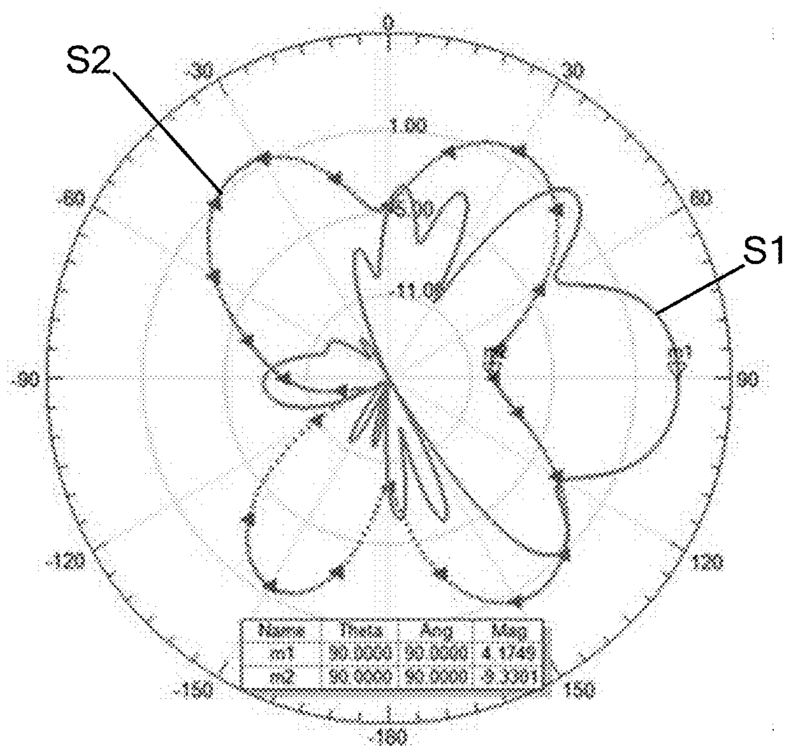

FIG. 15d

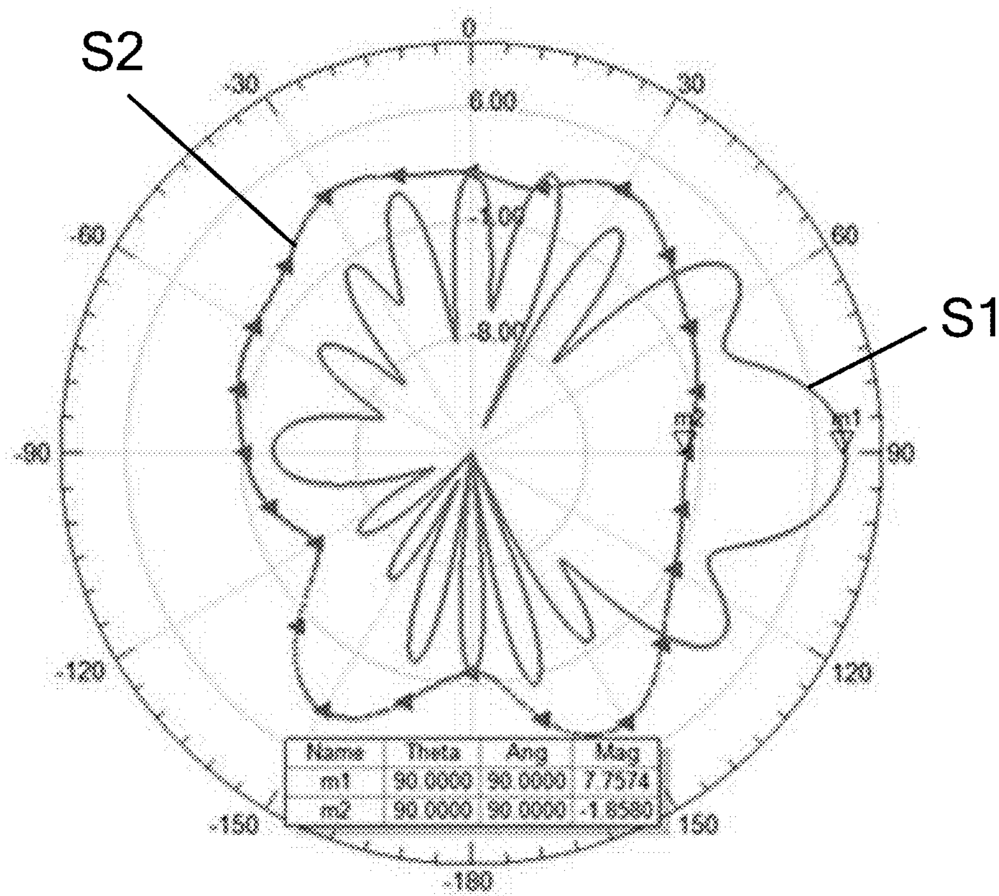

FIG. 15e

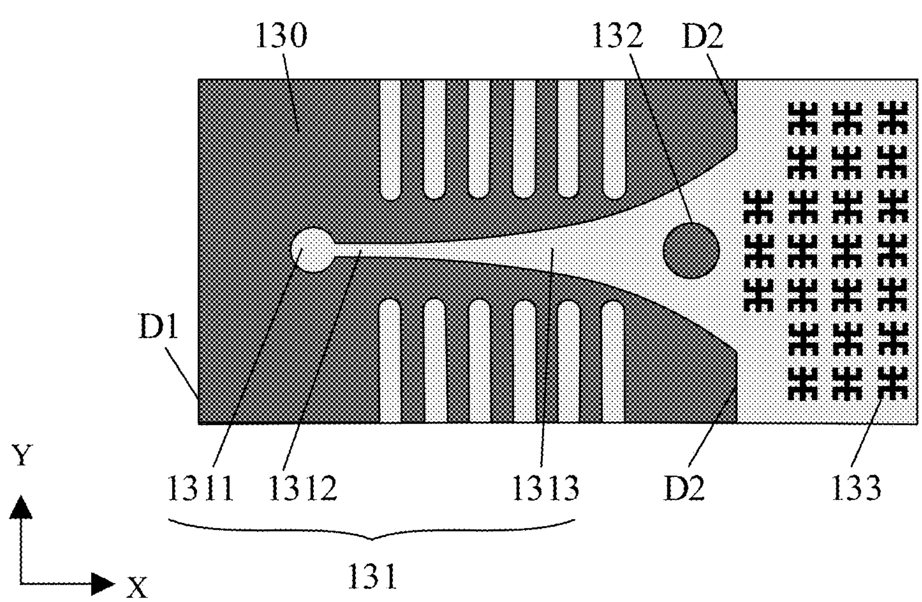

FIG. 15f

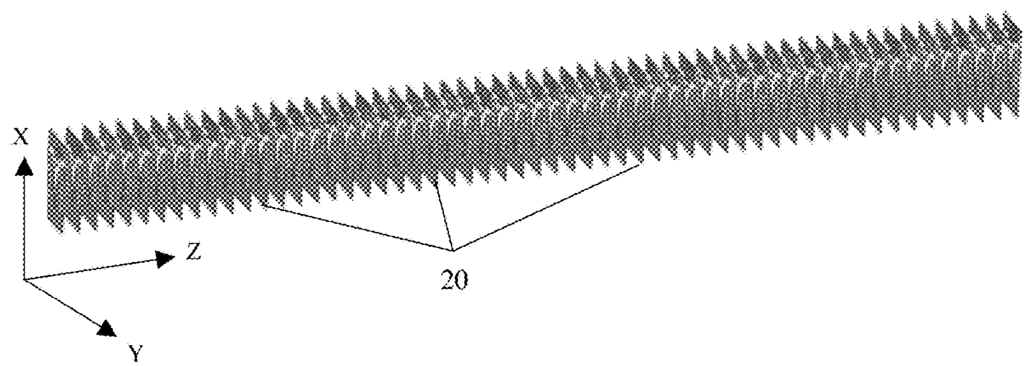

FIG. 16

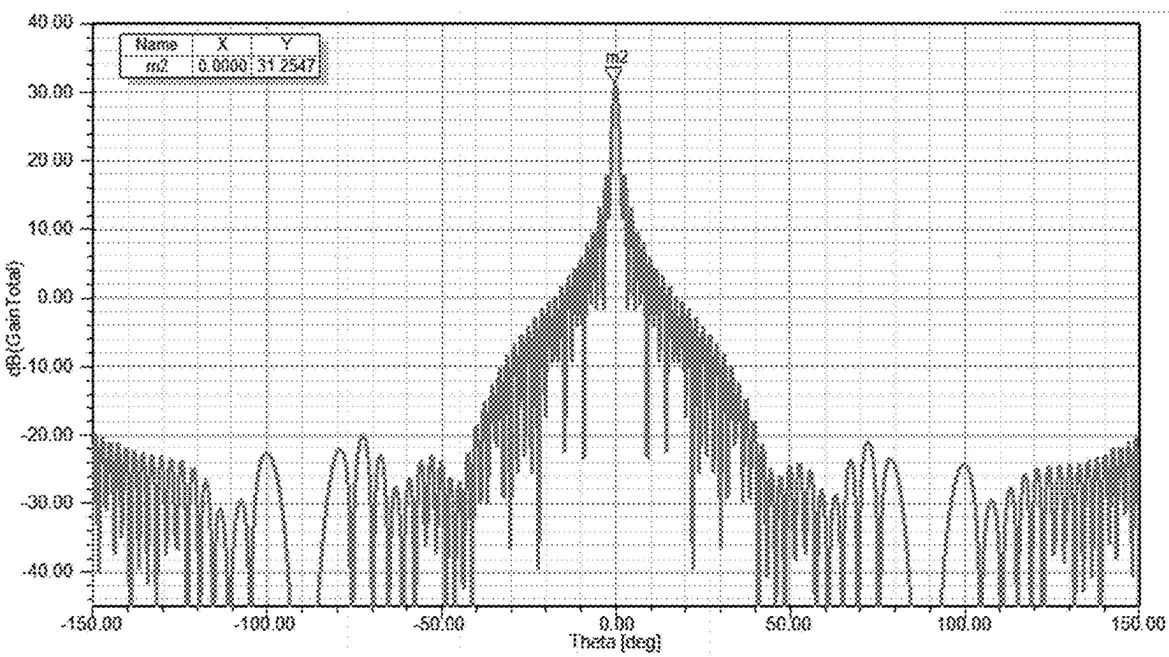

FIG. 17a

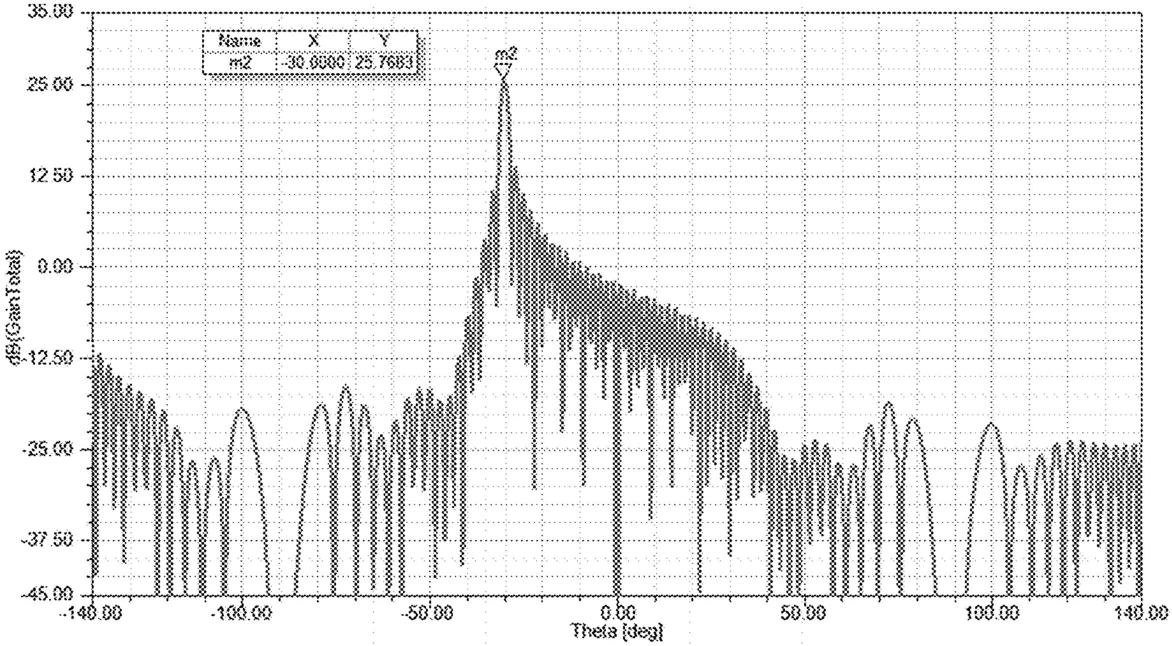

FIG. 17b

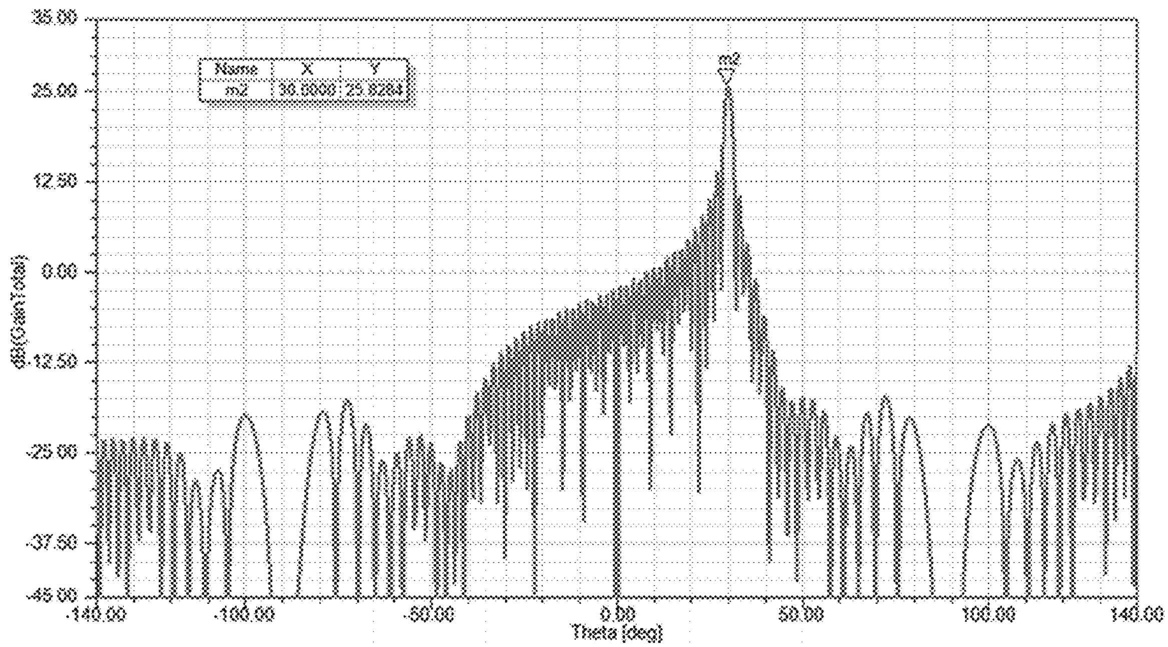

FIG. 17c

ANTENNA AND ELECTRONIC DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a U.S. National Phase Entry of International Application PCT/CN2022/077115 having an international filing date of Feb. 21, 2022, and the contents disclosed in the above-mentioned application are hereby incorporated as a part of this application.

TECHNICAL FIELD

Embodiments of the present disclosure relate to, but are not limited to, the field of communication technologies, and in particular to an antenna and an electronic device.

BACKGROUND

With development of wireless communication technology and advent of the fifth generation mobile communication technology (5G), wireless communication technology plays an increasingly important role in the satellite industry. Since antenna is a key component in a satellite transceiver system, with the layout of the satellite industry, research and development of high-gain broadband antenna has been paid more and more attention in the field of satellite communication.

Vivaldi antenna is an end-fire tapered slot antenna, which has advantages such as wide band, wide beam, low profile, good radiation orientation and easy array integration. It has a wide application prospect in millimeter wave radar, satellite technology and other communication fields.

SUMMARY

The following is a summary of subject matter described herein in detail. The summary is not intended to limit the protection scope of claims.

An embodiment of the present disclosure provides an antenna, including a first conductive layer, a dielectric layer and a second conductive layer which are stacked;

- the first conductive layer is provided as a microstrip line structure;
- the second conductive layer is provided with a radiation structure and a director; the radiation structure includes a first edge and a second edge opposite to each other along a first direction in a plane where the second conductive layer is located; the radiation structure is provided with a radiation slot away from the first edge, and the radiation slot includes a first slot, a second slot and a third slot which are sequentially communicated along a first direction in a plane where the second conductive layer is located, a shape of the first slot is circular, a shape of the second slot is rectangular, the third slot gradually increases in dimension in a second direction from an end connected with the second slot to an end away from the second slot, and the third slot extends in the first direction from the second slot to the second edge of the radiation structure; and
- the director is disposed on the second conductive layer and located at a side of the third opening away from the second slot, and an orthographic projection of the director on the dielectric layer is at least partially overlapped with an orthographic projection of the third slot on the dielectric layer.

In an exemplary implementation, in a plane where the second conductive layer is located, the radiation slot is disposed symmetrically with respect to a first centerline, and the director is disposed symmetrically with respect to the first centerline, and the first centerline is a centerline of the antenna along the first direction.

In an exemplary implementation, the microstrip line structure includes a first conductive structure, a second conductive structure and a third conductive structure sequentially connected along the second direction in a plane where the first conductive layer is located, a shape of the first conductive structure is rectangular, the third conductive structure is fan-shaped, the second conductive structure gradually decreases in dimension in a first direction from an end connected with the first conductive structure to an end connected with the third conductive structure, the third conductive structure gradually increases in dimension in a first direction from an end connected with the second conductive structure to an end away from the second conductive structure; and

- in the plane where the first conductive layer is located, the microstrip line structure is symmetrically disposed along the first direction with respect to a second centerline, the second centerline is a centerline of the microstrip line structure along the second direction, an orthographic projection of the second centerline on the dielectric layer is perpendicular to an orthographic projection of the first centerline on the dielectric layer, and an orthographic projection of the second conductive structure on the dielectric layer is at least partially overlapped with an orthographic projection of the second slot on the dielectric layer.

In an exemplary implementation, the first conductive structure has a dimension of 0.65 mm to 0.85 mm along the first direction and a dimension of 5 mm to 7 mm along the second direction in a plane where the first conductive layer is located; the second conductive structure has a dimension of 1.6 mm to 2.2 mm along the second direction, and an end of the second conductive structure connected with the first conductive structure has a dimension of 0.45 mm to 0.6 mm along the first direction; the third conductive structure has a sector radius of 0.4 mm to 0.7 mm.

In an exemplary implementation, the first slot has a radius of 0.8 mm to 1.2 mm, the second slot has a dimension of 2.5 mm to 3.5 mm in a first direction, and the second slot has a dimension of 0.4 mm to 0.8 mm in the second direction in a plane where the second conductive layer is located.

In an exemplary implementation, the second conductive layer is further provided with multiple metamaterial structures arranged in an array;

- in the plane where the second conductive layer is located, in the first direction, the multiple metamaterial structures are disposed at a side of the director away from the third slot, and an orthographic projection of the multiple metamaterial structures on the dielectric layer is not overlapped with an orthographic projection of the radiation structure on the dielectric layer, the multiple metamaterial structures are disposed symmetrically with respect to the first centerline.

In an exemplary implementation, dimensions of anyone of the metamaterial structures in the first direction and the second direction are each less than a length of half of the dielectric wavelength;

- in the first direction, a distance between two adjacent metamaterial structures is less than the length of a half of the dielectric wavelength; and
- in the second direction, a distance between two adjacent metamaterial structures is less than the length of a half of the dielectric wavelength;

wherein, the dielectric wavelength is a wavelength of the wave transmitted or received by the antenna in the dielectric layer.

In an exemplary implementation, in the plane where the second conductive layer is located, any one of the metamaterial structures has a dimension of 1.1 mm to 1.7 mm in the first direction, any one of the metamaterial structures has a dimension of 1 mm to 1.6 mm in the second direction, the distance between two adjacent metamaterial structures in the first direction is 0.3 mm to 0.7 mm, and the distance between two adjacent metamaterial structures in the second direction is 0.3 mm to 0.7 mm;

the antenna has a dimension of 14.8 mm to 15.6 mm in the second direction, the antenna has a dimension of 28 mm to 34 mm in the first direction, and a distance from the first edge of the radiation structure to the junction of the first slot and the second slot in the first direction is 5 mm to 7 mm; and

the third slot has a maximum dimension of 8 mm to 10 mm in the second direction.

In an exemplary implementation, a metamaterial structure includes a first E-type structure, a second E-type structure and a first connection line connecting the first E-type structure with the second E-type structure. In the plane where the second conductive layer is located, the first E-shaped structure and the second E-shaped structure are symmetrically disposed with respect to a midperpendicular line of the first connection line, the first connection line extends along the second direction and is located at a position of a third centerline, the first E-shaped structure is disposed symmetrically with respect to the third centerline along the first direction, and the second E-shaped structure is disposed symmetrically with respect to the third centerline along the first direction, an opening of the first E-shaped structure faces a side away from the second E-shaped structure, and an opening of the second E-shaped structure faces a side away from the first E-shaped structure.

In an exemplary implementation, the first connection line has a dimension of 0.2 mm to 0.6 mm along the second direction; for ends located at a same side of the third centerline in the first direction, a distance between an end of the first E-shaped structure away from the second E-shaped structure and an end of the second E-shaped structure away from the first E-shaped structure in the second direction is 1 mm to 1.6 mm; at the position of the third centerline, a distance between an end of the first E-type structure away from the second E-type structure and an end of the second E-type structure away from the first E-type structure in the second direction is 1.1 mm to 1.7 mm; a width dimension of lines constituting the first E-shaped structure and the second E-shaped structure and a width dimension of a line constituting the first connection line are both 0.1 mm to 0.3 mm.

In an exemplary implementation, a metamaterial structure includes a first I-shaped structure and a second I-shaped structure, in the plane where the second conductive layer is located, the first I-shaped structure includes a first connection line and a second connection line extending along the first direction and a third connection line extending along the second direction, wherein the third connection line is positioned at a midperpendicular line of the first connection line and the second connection line;

in the plane where the second conductive layer is located, the second I-shaped structure includes a fourth connection line and a fifth connection line extending along the second direction and a sixth connection line extending along the first direction, wherein the sixth connection line is located at the midperpendicular line of the fourth connection line and the fifth connection line; and

the third connection line is located at a centerline of the sixth connection line, and the sixth connection line is located at a centerline of the third connection line.

In an exemplary implementation, line widths of the first connection line to the sixth connection line are each 0.1 mm to 0.3 mm; in the plane where the second conductive layer is located, the first connection line and second connection line have a dimension from 0.8 mm to 1.3 mm along the first direction, the third connection line has a dimension from 0.7 mm to 1.5 mm along the second direction, the fourth connection line and the fifth connection line have a dimension from 0.8 mm to 1.3 mm along the second direction, and the sixth connection line has a dimension from 0.7 mm to 1.5 mm along the first direction.

In an exemplary implementation, the radiation structure further includes a third edge and a fourth edge opposite to each other along the second direction in the plane where the second conductive layer is located. On the plane where the second conductive layer is located, the radiation structure is provided with multiple flow suppression grooves, and the flow suppression grooves include multiple first flow suppression grooves arranged along the first direction and multiple second flow suppression grooves arranged along the first direction, wherein the first flow suppression grooves and the second flow suppression grooves are symmetrically disposed with respect to the centerline of the antenna along the first direction; the multiple first flow suppression grooves are disposed at a side of the third opening slot, and the multiple second flow suppression grooves are disposed at a side of the third slot away from the multiple first flow suppression grooves; the first flow suppression grooves extend to the third edge, and the second flow suppression grooves extend to the fourth edge.

In an exemplary implementation, extension directions of the first flow suppression grooves and the second flow suppression grooves are perpendicular to the centerline of the antenna along the first direction.

In an exemplary implementation, a shape of a flow suppression groove is rectangular; on the plane where the second conductive layer is located, a dimension of the flow suppression groove along the second direction satisfies a following formula: $0.25*\lambda g/\mathrm{sqrt}(\varepsilon 0)$, wherein λg is a wavelength of the antenna's low-frequency dielectric frequency, $\varepsilon 0$ is a dielectric constant of the dielectric plate, and sqrt ($\varepsilon 0$) is an arithmetic square root of the dielectric constant 80 of the dielectric plate.

In an exemplary implementation, on the plane where the second conductive layer is located, a flow suppression groove has a dimension of 4.5 mm to 5.5 mm along the second direction, and the flow suppression grooves has a dimension of 0.5 mm to 1.5 mm along first direction.

In an exemplary implementation, in the plane where the second conductive layer is located, any one of the flow suppression grooves includes a first groove edge, a second groove edge and a third groove edge, a shape of the first groove edge and the second groove edge is a linear shape extending along the second direction, a shape of the third groove edge is an arc shape protruding toward the radiation groove, and two ends of the third groove edge are respectively connected with one end of the first groove edge and one end of the second groove edge close to the radiation groove.

In an exemplary implementation, a shape of the director is rectangular and the rectangular director is disposed symmetrically with respect to the first centerline; or the shape of the director is elliptical, and the elliptical director is symmetrically disposed with respect to the first centerline; or

the shape of the director is circular, and the circular director is symmetrically disposed with respect to the first centerline; or

the shape of the director is isosceles triangular, and the isosceles triangular director is symmetrically disposed with respect to the first centerline, an apex angle of the isosceles triangle is located between the radiation slot and a bottom edge of the isosceles triangle, a length of the bottom edge of the isosceles triangle is 1.8 mm to 2.2 mm, and a length of two waists of the isosceles triangle is 2 mm to 4 mm.

An embodiment of the present disclosure further provides an electronic device, which includes at least one array antenna in any one of the embodiments described above.

In an exemplary implementation, the electronic device includes multiple the antennas, the multiple the antennas are arranged in a third direction to form an antenna array, and orthographic projections of the multiple antennas on a plane where the first direction and the second direction are located are overlapped, and orthographic projections of radiation slots in the multiple antennas on a plane where the first direction and the second direction are located are overlapped.

Other aspects may be understood upon reading and understanding of the drawings and the detailed description.

BRIEF DESCRIPTION OF DRAWINGS

Accompanying drawings are intended to provide a further understanding of technical solutions of the present disclosure and form a part of the specification, and are used to explain the technical solutions of the present disclosure together with embodiments of the present disclosure, and not intended to form limitations on the technical solutions of the present disclosure. Shapes and sizes of each component in the drawings do not reflect actual scales, and are only intended to schematically illustrate contents of the present disclosure.

FIG. **1***a* is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an embodiment of the present disclosure.

FIG. **1***b* is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an embodiment of the present disclosure.

FIG. **1***c* is a schematic diagram of a planar structure of an antenna according to an embodiment of the present disclosure located at a side of a second conductive layer.

FIG. **2** is a schematic diagram of a planar structure of an antenna located at a side of a first conductive layer according to an embodiment of the present disclosure.

FIG. **3** is a schematic diagram of a sectional structure of L-L position in FIG. **1***a* in FIG. **1**.

FIG. **4** is a schematic diagram of a planar structure of a microstrip line structure in an antenna according to an exemplary embodiment of the present disclosure.

FIG. **5** is a schematic diagram of a planar structure of a radiation slot in an antenna according to an exemplary implementation of the present disclosure.

FIG. **6***a* is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **6***b* is another schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **6***c* is an enlarged schematic diagram of a structure of a metamaterial structure according to an exemplary embodiment of the present disclosure.

FIG. **6***d* is an enlarged schematic diagram of a structure of a metamaterial structure according to an exemplary embodiment of the present disclosure.

FIG. **7***a* is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **7***b* is an enlarged schematic diagram of a structure of a metamaterial structure according to an exemplary embodiment of the present disclosure.

FIG. **8***a* is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **8***b* is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **8***c* is a schematic diagram of a planar structure of a flow suppression groove according to an exemplary embodiment of the present disclosure.

FIG. **9** is another schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **10***a* is a diagram showing simulation results of a return loss of the antenna shown in FIG. **6***a* as a function of frequency.

FIG. **10***b* to FIG. **10***e* are respectively simulation results of gains of the antenna shown in FIG. **6***a* at different frequencies.

FIG. **11***a* is a diagram showing simulation results of a return loss of the antenna shown in FIG. **7***a* as a function of frequency.

FIG. **11***b* to FIG. **11***e* are respectively simulation results of gains of the antenna shown in FIG. **7***a* at different frequencies.

FIG. **12***a* is a diagram showing simulation results of a return loss of an antenna shown in FIG. **12***f* as a function of frequency;

FIG. **12***b* to FIG. **12***e* are respectively simulation results of gains of the antenna shown in FIG. **12***f* at different frequencies.

FIG. **12***f* is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **13***a* is a diagram showing simulation results of a return loss of an antenna shown in FIG. **13***f* as a function of frequency.

FIG. **13***b* to FIG. **13***e* are respectively simulation results of gains of the antenna shown in FIG. **13***f* at different frequencies.

FIG. **13***f* is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **14***a* is a diagram showing simulation results of a return loss of an antenna shown in FIG. **14***f* as a function of frequency;

FIG. **14**b to FIG. **14**e are respectively simulation results of gains of the antenna shown in FIG. **14**f at different frequencies.

FIG. **14**f is a schematic diagram of a planar structure of an antenna located at a side of a second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **15**a is a diagram showing simulation results of a return loss of an antenna shown in FIG. **15**f as a function of frequency;

FIG. **15**b to FIG. **15**e are respectively simulation results of gains of the antenna shown in FIG. **15**f at different frequencies.

FIG. **15**f is a schematic diagram of a planar structure of an antenna located at a side of the second conductive layer according to an exemplary embodiment of the present disclosure.

FIG. **16** is a schematic diagram of an antenna array structure according to an embodiment of the present disclosure.

FIG. **17**a to FIG. **17**c are diagrams of several simulated gain results of the antenna array shown in FIG. **16** according to exemplary implementations of the present disclosure.

DETAILED DESCRIPTION

The embodiments of the present disclosure will be described in detail below with reference to the drawings. Implementation modes may be implemented in multiple different forms. Those of ordinary skills in the art may easily understand such a fact that implementation modes and contents may be transformed into various forms without departing from the purpose and scope of the present disclosure. Therefore, the present disclosure should not be explained as being limited to contents described in following implementation modes only. The embodiments in the present disclosure and features in the embodiments may be combined randomly with each other without conflict. In order to keep following description of the embodiments of the present disclosure clear and concise, detailed descriptions about part of known functions and known components are omitted in the present disclosure. The drawings of the embodiments of the present disclosure only involve structures involved in the embodiments of the present disclosure, and other structures may refer to conventional designs.

Scales of the drawings in the present disclosure may be used as a reference in the actual process, but are not limited thereto. For example, a thickness and a distance of each film layer, and a width and a distance of each signal line may be adjusted according to an actual situation. The drawings described in the present disclosure are only schematic diagrams of structures, and one implementation mode of the present disclosure is not limited to shapes or numerical values or the like shown in the drawings.

Ordinal numerals such as "first", "second", and "third" in the specification are set to avoid confusion between constituent elements, but not to set a limit in quantity.

In the specification, for convenience, wordings indicating orientation or positional relationships, such as "middle", "upper", "lower", "front", "back", "vertical", "horizontal", "top", "bottom", "inside", and "outside", are used for illustrating positional relationships between constituent elements with reference to the drawings, and are merely for facilitating the description of the specification and simplifying the description, rather than indicating or implying that a referred apparatus or element must have a particular orientation and be constructed and operated in the particular orientation. Therefore, they cannot be understood as limitations on the present disclosure. The positional relationships between the constituent elements may be changed as appropriate according to a direction according to which each constituent element is described. Therefore, appropriate replacements may be made according to situations without being limited to the wordings described in the specification.

In the specification, unless otherwise specified and defined explicitly, terms "mount", "mutually connect", and "connect" should be understood in a broad sense. For example, a connection may be a fixed connection, or a detachable connection, or an integrated connection. It may be a mechanical connection or an electrical connection. It may be a direct mutual connection, or an indirect connection through middleware, or internal communication between two components. Those of ordinary skills in the art may understand specific meanings of these terms in the present disclosure according to specific situations.

In the specification, "electrical connection" includes a case that constituent elements are connected together through an element with a certain electrical effect. The "element with the certain electrical effect" is not particularly limited as long as electrical signals may be sent and received between the connected constituent elements. Examples of the "element having some electrical function" not only include an electrode and a wiring, but also a switch element such as a transistor, a resistor, an inductor, a capacitor, another element having one or more functions, and the like.

In the specification, "parallel" refers to a state in which an angle formed by two straight lines is above −10° and below 10°, and thus may include a state in which the angle is above −5° or more and below 5°. In addition, "perpendicular" refers to a state in which an angle formed by two straight lines is above 80° and below 100°, and thus may include a state in which the angle is above 85° and below 95°.

In the specification, a "film" and a "layer" are interchangeable. For example, a "conductive layer" may be replaced with a "conductive film" sometimes. Similarly, an "insulating film" may be replaced with an "insulation layer" sometimes.

Triangle, rectangle, trapezoid, pentagon and hexagon in this specification are not strictly defined, and they may be approximate triangle, rectangle, trapezoid, pentagon or hexagon, etc. There may be some small deformation caused by tolerance, and there may be guide angle, arc edge and deformation, etc.

In the present disclosure, "about" refers to that a boundary is defined not so strictly and numerical values within process and measurement error ranges are allowed.

In the present disclosure, a "thickness" is a dimension of a film layer in a direction perpendicular to a base substrate.

Vivaldi antenna usually has a problem of insufficient gain in wireless communication. Increasing the gain by forming an array will greatly increase the antenna's dimension, which is not conducive to miniaturization design of the system, thus increasing the system cost. As a result, Vivaldi antenna is often limited because of its insufficient gain in application scenarios with high gain requirements (such as satellite communication, radar, etc.).

An embodiment of the present disclosure provides an antenna, as shown in FIG. **1**a, FIG. **1**b, FIG. **2** and FIG. **3**, including a first conductive layer **11**, a dielectric layer **12**, and a second conductive layer **13** which are stacked. FIG. **1**a-FIG. **1**b show a schematic diagram of a planar structure located at a side of the second conductive layer **13**, FIG. **2** shows a schematic diagram of a sectional structure at position L-L in FIG. **1***a*, and FIG. **3** shows a schematic diagram of a planar structure located at a side of the first conductive layer **11**;

the first conductive layer **11** is provided as a microstrip line structure **110**;

the second conductive layer **13** is provided with a radiation structure **130** and a director **132**; the radiation structure **130** includes a first edge D**1** and a second edge D**2** disposed oppositely along a first direction in a plane where the second conductive layer is located;

the radiation structure **130** is provided with a radiation slot **131** away from the first edge D**1**, wherein the radiation slot **131** includes a first slot **1311**, a second slot **1312**, and a third slot **1313** that are sequentially communicated along the first direction X in the plane where the second conductive layer **13** is located, a shape of the first slot **1311** is circular, a shape of the second slot **1312** is rectangular, the third slot **1313** gradually increases in dimension along a second direction Y from an end connected with the second slot **1312** to an end away from the second slot **1312**, and the third slot **1313** extends from the second slot **1312** in the first direction X to the second edge D**2** of the radiation structure;

the director **132** is disposed in the second conductive layer **13** and located at a side of the third slot **1313** away from the second slot **1312**, and an orthographic projection of the director **132** on the dielectric layer **12** is at least partially overlapped with an orthographic projection of the third slot **1313** on the dielectric layer.

In the antenna according to embodiment of the present disclosure, the second conductive layer is provided with the director and the radiation slot, the radiation slot is provided as the first slot, the second slot and the third slot which are communicated sequentially along the first direction in the plane where the second conductive layer is located, the director is disposed at the second conductive layer and located the side of the third slot away from the second slot, and an orthographic projection of the director on the dielectric layer is at least partially overlapped with an orthographic projection of the third slot on the dielectric layer. The director is disposed at the second conductive layer and located at the side of the third slot away from the second slot and plays a guiding role on electromagnetic waves, thus improving the gain of the antenna to a great extent.

In the embodiment of the present disclosure, in the plane where the second conductive layer **13** is located, the first direction X intersects with the second direction Y. In an exemplary implementation, the first direction X may be perpendicular to the second direction Y in the plane where the second conductive layer **13** is located.

In the embodiment of the present disclosure, the first slot **1311** in circular structure may act as impedance matching to the microstrip line structure **110**, the second slot **1312** in rectangular structure may be coupled with the microstrip line structure **110** to transmit electromagnetic waves, the third slot **1313** may be horn-shaped, and the third slot **1313** may guide electromagnetic waves radiated by the antenna.

In an exemplary implementation, as shown in FIG. **1***b*-FIG. **1***c*, in the plane where the second conductive layer **13** is located, the radiation slot **131** may be disposed symmetrically with respect to a first centerline, and the director **132** may be disposed symmetrically with respect to the first centerline, wherein the first centerline is a centerline of the antenna along the first direction X.

In an exemplary implementation, as shown in FIG. **2**, the microstrip line structure **110** may include a first conductive structure **1101**, a second conductive structure **1102**, and a third conductive structure **1103** sequentially connected along the second direction Y in a plane where the first conductive layer **11** is located. A shape of the first conductive structure **1101** rectangular, the third conductive structure **1103** is fan-shaped, and the second conductive structure **1102** gradually decreases in dimension in the first direction X from one end connected with the first conductive structure **1101** to one end connected with the third conductive structure **1103**. The third conductive structure **1103** gradually increases in dimension in the first direction X from one end connected with the second conductive structure **1102** to one end away from the second conductive structure **1102**.

In the plane where the antenna is located, as shown in FIG. **1** and FIG. **2**, which are schematic diagrams of an antenna structure, arrangement directions of the first conductive structure **1101**, the second conductive structure **1102** and the third conductive structure **1103** are perpendicular to arrangement directions of the first slot **1311**, the second slot **1312** and the third slot **1313**. The microstrip line structure **110** is symmetrical with respect to a centerline of the microstrip line structure **110** extending along the second direction Y.

In the plane where the first conductive layer **11** is located, the microstrip line structure **110** is disposed symmetrically along the first direction X with respect to a second centerline, and the second centerline is a centerline of the microstrip line structure **110** along the second direction Y. An orthographic projection of the second centerline on the dielectric layer **12** is perpendicular to an orthographic projection of the first centerline on the dielectric layer **12**, and an orthographic projection of the second conductive structure **1102** on the dielectric layer **12** is at least partially overlapped with an orthographic projection of the second slot **1312** on the dielectric layer **12**.

In an exemplary implementation, a shape of the second conductive structure **1102** may be triangular.

In an exemplary implementation, as shown in FIG. **4**, in the plane where the first conductive layer **11** is located, the first conductive structure **1101** has a dimension M**1** of 0.65 mm to 0.85 mm along the first direction X and a dimension M**2** of 5 mm to 7 mm along the second direction Y.

The second conductive structure **1102** has a dimension M**3** of 1.6 mm to 2.2 mm along the second direction Y, and the end of the second conductive structure **1102** connected with the first conductive structure **1101** has a dimension M**4** of 0.45 mm to 0.6 mm in the first direction X.

The third conductive structure **1103** has a sector radius R**2** of 0.4 mm to 0.7 mm.

For example, in the plane where the first conductive layer **11** is located, the first conductive structure **1101** has a dimension M**1** of 0.75 mm along the first direction X and a dimension M**2** of 6 mm in the second direction Y. The second conductive structure **1102** has a dimension M**3** of 1.9 mm along the second direction Y, and the end of the second conductive structure **1102** connected with the first conductive structure **1101** has a dimension M**4** of 0.55 mm in the first direction X. The third conductive structure **1103** has a sector radius R of 0.6 mm.

In the embodiment of the present disclosure, the gradually deformed microstrip line structure **110** is adopted, which is easy to process, thus costs and difficulty of preparing the antenna is reduced, and feed is performed through the coupling structure of the gradually deformed microstrip line structure **110** and the radiation slot **131**, thus realizing the transformation from an unbalanced structure to a balanced structure. An terminal of the microstrip line structure **110** (the third conductive structure **1103**) has a fan-shaped structure, which mainly serves as a function of terminal load matching, and the microstrip line is coupled and fed to the radiation slot **131** through the dielectric layer.

In an exemplary implementation, as shown in FIG. **5**, in the plane where the second conductive layer **12** is located, a radius R**1** of the first slot **1311** is 0.8 mm to 1.2 mm, a dimension L**1** of the second slot **1312** in the first direction X is 2.5 mm to 3.5 mm, and a dimension L**2** of the second slot **1312** in the second direction Y is 0.4 mm to 0.8 mm. For example, in the plane where the second conductive layer **12** is located, a radius R**1** of the circular structure in which the first slot **1311** is located is 1 mm, a dimension L**1** of the second groove **1312** in the first direction X is 3 mm, and a dimension L**2** of the second groove **1312** in the second direction Y is 0.6 mm.

In an exemplary implementation, as shown in FIG. **6***a* and FIG. **6***b*, the second conductive layer **13** is further provided with multiple metamaterial structures **133** arranged in an array.

In the plane where the second conductive layer **13** is located, in the first direction X, multiple metamaterial structures **133** are disposed at a side of the director **132** away from the third slot **1313**, and an orthographic projection of the multiple metamaterial structures **133** on the dielectric layer **12** is not overlapped with an orthographic projection of the radiation structure **130** on the dielectric layer **12**, and the multiple metamaterial structures **133** are disposed symmetrically with respect to the first centerline. As shown in FIG. **6***a*, among the multiple metamaterial structures **133**, a part of the metamaterial structures **133** are located at a centerline of the antenna in the first direction X, and a part of the metamaterial structures **133** are symmetrically disposed at two sides of the first centerline. The metamaterial structures **133** located at the first centerline are symmetrically disposed with respect to the first centerline, and the multiple metamaterial structures **133** located on the two sides of the first centerline are symmetrically disposed with respect to the first centerline. As shown in FIG. **6***b*, the antenna is not provided with the metamaterial structure **133** at the first centerline and the multiple metamaterial structures **133** are disposed symmetrically with respect to the first centerline.

In an exemplary implementation, the multiple metamaterial structures **133** are periodically arranged in the first direction X and the second direction Y in the plane where the second conductive layer **13** is located.

In an exemplary implementation, in the plane where the second conductive layer **13** is located, dimensions of any one of the metamaterial structures **133** in the first direction X and the second direction Y are each less than a length of a half of a dielectric wavelength.

In the first direction X, a distance between two adjacent metamaterial structures **133** is less than a length of the half of the dielectric wavelength.

In the second direction Y, a distance between two adjacent metamaterial structures **133** is less than the length of the half of the dielectric wavelength.

Here, the dielectric wavelength is a wavelength of waves transmitted or received by the antenna that are transmitted in the dielectric layer **12**.

In an exemplary implementation, as shown in FIG. **6***a*, in the plane where the second conductive layer **13** is located, any one of the metamaterial structures **133** has a dimension N**1** of 1.1 mm to 1.7 mm in the first direction X, and any one of the metamaterial structures **133** has a dimension N**2** of 1 mm to 1.6 mm in the second direction Y. For example, any one of the metamaterial structures **133** has a dimension N**1** of 1.3 mm in the first direction X, and any one of the metamaterial structures **133** has a dimension N**2** of 1.4 mm in the second direction Y.

In an exemplary implementation, as shown in FIG. **6***a*, in the plane where the second conductive layer **13** is located, the antenna has a dimension N**3** of 14.8 mm to 15.6 mm in the second direction Y, the antenna has a dimension N**4** of 28 mm to 34 mm in the first direction, and a distance from the first edge D**1** of the radiation structure **130** to a junction of the first slot **13111** and the second slot **1312** in the first direction X is 5 mm to 7 mm.

The third slot **1313** has a maximum dimension N**61** of 8 mm to 10 mm in the second direction Y. In the structure shown in FIG. **6***a*, the second edge D**2** of the radiation structure **130** has a dimension N**6** of 3 mm to 3.6 mm in the second direction Y.

For example, in the plane where the second conductive layer **13** is located, the antenna has a dimension N**3** of 15.2 mm in the second direction Y, the antenna has a dimension N**4** of 31.2 mm in the first direction, and a distance N**5** from the first edge D**1** of the radiation structure **130** to the junction of the first slot **1311** and the second slot **1312** in the first direction X is 6 mm. The second edge D**2** of the radiation structure **130** has a length N**6** of 3.32 mm in the second direction Y, and the third slot **1313** has a maximum dimension of 8.56 mm in the second direction Y.

In an exemplary implementation, as shown in FIG. **6***d*, a metamaterial structure **133** may include a first E-type structure **p1**, a second E-type structure **p2** and a first connection line **p3** connected with the first E-type structure and the second E-type structure. In the plane where the second conductive layer **12** is located, the first E-shaped structure **p1** and the second E-shaped structure **p2** are disposed symmetrically with respect to a midperpendicular line of the first connection line **p3**, and the first connection line **p3** extends along the second direction Y and is located at a third centerline. The first E-shaped structure **p1** is disposed symmetrically with respect to the third centerline along the first direction X, and the second E-shaped structure **p2** is disposed symmetrically with respect to the third centerline along the first direction X, an opening of the first E-shaped structure **p1** faces a side away from the second E-shaped structure **p2**, and an opening of the second E-shaped structure **p2** faces a side away from the first E-shaped structure **p1**.

In an exemplary implementation, the first connection line **p3** has a dimension H**1** of 0.2 mm to 0.6 mm in the second direction Y. For ends located at a same side of the third centerline in the first direction X, a distance H**2** between an end of the first E-type structure **p1** away from the second E-type structure **p2** and an end of the second E-type structure **p2** away from the first E-type structure **p1** in the second direction Y is 1 mm to 1.6 mm. At the third centerline, a distance H**3** between the end of the first E-type structure **p1** away from the second E-type structure **p2** and the end of the second E-type structure **p2** away from the first E-type structure **p1** in the second direction Y is 1.1 mm to 1.7 mm. A width W**1** of lines constituting the first E-shaped structure **p1** and the second E-shaped structure **p2** and a width W**1** of lines the constituting first connection line **p3** are both 0.1 mm to 0.3 mm. For example, the first connection line **p3** has a dimension H**1** of 0.4 mm in the second direction Y, and for ends located at a same side of the third centerline in the first direction X, and a distance H**2** between the end of the first E-type structure **p1** away from the second E-type structure **p2** and the end of the second E-type structure **p2** away from the first E-type structure **p1** in the second direction Y is 1.3

mm. At the third centerline, a distance H**3** between the end of the first E-type structure **p1** away from the second E-type structure **p2** and the end of the second E-type structure **p2** away from the first E-type structure **p1** in the second direction Y is 1.4 mm. A width W**1** of the lines constituting the first E-shaped structure **p1** and the second E-shaped structure **p2** and a width W**1** of the lines constituting the first connection line **p3** are both 0.2 mm.

In the embodiment of the present disclosure, centerlines of the first E-type structure **p1** and the second E-type structure **p2** in FIG. **6***d* along the second direction Y in the plane where the second conductive layer **13** is located are both the third centerline.

In an exemplary implementation, as shown in FIG. **6***a* to FIG. **6***c*, a metamaterial structure **133** may include a first bent structure **1331**, a second bent structure **1332**, and a connection structure **1333**. In the plane where the second conductive layer **13** is located, the first bent structure **1331** is symmetrical with respect to the connection structure **1333**, the second bent structure **1332** is symmetrical with respect to the connection structure **1333**, and the first bent structure **1331** and the second bent structure **1332** are disposed symmetrically with respect to the connection structure **1333**. The connection structure **1333** extends along the second direction Y and is disposed at a centerline of the first bent structure **1331** extending along the second direction Y, and the centerline of the first bent structure **1331** along the second direction Y is coincident with a centerline of the second bent structure **1332** along the second direction Y. A midperpendicular line of the connection structure **1333** is coincident with centerlines of the first bent structure **1331** and the second bent structure **1332** along the first direction X. Two ends of the first bent structure **1331** are bent toward a side facing away from the second bent structure **1332** to form two first bent portions **a1** extending along the second direction Y, two ends of the second bent structure **1332** are bent toward a side facing away from the first bent structure **1331** to form two second bent portions **a2** extending along the second direction, and a distance H2 between an end of the first bent portion a**1** and an end of the second bent portion a**2** located at a same side of the connection structure **1333** is 1 mm to 1.6 mm. For example, the distance H2 between the end of the first bent portion a**1** and the end of the second bent portion a**2** located at the same side of the connection structure **1333** is 1.3 mm.

In an exemplary implementation, in the plane where the second conductive layer **13** is located, the distance H**1** between the first bent structure **1331** and the second bent structure **1332** along the second direction Y is 0.2 mm to 0.6 mm, the width W**1** of the first bent structure **1331**, the second bent structure **1332** and the connection structure **1333** is 0.1 mm to 0.3 mm, and the length H**3** of the connection structure **1333** along the second direction Y is 1.1 mm to 1.7 mm. For example, in the plane where the second conductive layer **13** is located, the distance H**1** of the first bent structure **1331** and the second bent structure **1332** along the second direction Y is 0.4 mm, the width W**1** of the first bent structure **1331**, the second bent structure **1332** and the connection structure **1333** is 0.2 mm, and the length H**3** of the connection structure **1333** along the second direction Y is 1.4 mm.

In an exemplary implementation, as shown in FIG. **7***a* and FIG. **7***b*, the metamaterial structure **133** may include a first I-shaped structure and a second I-shaped structure. In the plane where the second conductive layer **13** is located, the first I-shaped structure may include a first connection line **c1** and a second connection line **c2** extending along the first direction X and a third connection line **c3** extending along the second direction Y, and the third connection line **c3** is located at a midperpendicular line of the first connection line **c1** and the second connection line **c2**.

In the plane where the second conductive layer **13** is located, the second I-shaped structure may include a fourth connection line **c4** and a fifth connection line **c5** extending along the second direction Y and a sixth connection line **c6** extending along the first direction X, and the sixth connection line **c6** is located at a midperpendicular line of the fourth connection line **c4** and the fifth connection line **c5**.

The third connection line **c3** is located at a centerline of the sixth connection line **c6**, and the sixth connection line **c6** is located at a centerline of the third connection line **c3**.

In an exemplary implementation, as shown in FIG. **7***b*, line widths **W2** of the first connection **c1** to the sixth connection **c6** may each be 0.1 mm to 0.3 mm. In the plane where the second conductive layer **13** is located, the first connection line **c1** and second connection line **c2** have a dimension H**4** of 0.8 mm to 1.3 mm along the first direction X, the third connection line **c3** has a dimension H**5** of 0.7 mm to 1.5 mm along the second direction, the fourth connection line **c4** and fifth connection line **c5** have a dimension H**6** of 0.8 mm to 1.3 mm along the second direction Y, and the sixth connection line **c6** has a dimension H**7** of 0.7 mm to 1.5 mm along the first direction X.

For example, the line widths **W2** of the first connection line **c1** to the sixth connection line **c6** may each be 0.2 mm, in the plane where the second conductive layer **13** is located, the first connection line **c1** and second connection line **c2** have a dimension H**4** of 1.1 mm along the first direction X, the third connection line **c3** a dimension H**5** of 0.9 mm along the second direction, the fourth connection line **c4** and fifth connection line **c5** have a dimension H**6** of 1.1 mm along the second direction Y, and the sixth connection line **c6** has a dimension H**7** of 0.9 mm along the first direction X.

In the embodiment of the present disclosure, the periodically arranged metamaterial structures **132** are loaded at a side of the director **130** away from the radiation slot **131** to improve directivity of electromagnetic radiation, thereby further improving the gain of the antenna.

In the embodiments of the present disclosure, the metamaterial structures **132** may be equivalent to LC circuits, a plate provided with the metamaterial structures **132** may generate an inductance, the metamaterial structures **132** themselves and space between the multiple metamaterial structures **132** may generate capacitance, a metamaterial structure **132** has a structure with a quasi-zero dielectric constant refractive index, and a zero frequency has a certain relationship with structural parameters. By adjusting structure dimensions, the zero refractive index characteristic at a specific frequency point can be realized. Typically, the dimension of the metamaterial structure is not larger than a half of the dielectric wavelength, and the distribution of the multiple metamaterial structures is periodic.

In an exemplary implementation, as shown in FIG. **1***a*, FIG. **1***c* and FIG. **6**A-FIG. **6***b*, the radiation structure **130** may further include a third edge D**3** and a fourth edge D**4** disposed oppositely along the second direction Y in the plane where the second conductive layer **13** is located. On the plane where the second conductive layer **13** is located, the radiation structure **130** is provided with multiple flow suppression grooves **134**. The flow suppression grooves **134** may include multiple first flow suppression grooves **1341** arranged along the first direction X and multiple second flow suppression grooves **1342** arranged along the first direction X. The multiple first flow suppression grooves **1341** and the multiple second flow suppression grooves **1342** are symmetrically disposed with respect to the centerline of the antenna in the first direction X. The multiple first flow suppression grooves **1341** are disposed at a side of the third slot **1313**, and the multiple second flow suppression grooves **1342** are disposed at a side of the third slot **1313** away from the multiple first flow suppression grooves **1341**. The first suppression grooves **1341** extend to the third edge D**3**, and the second suppression grooves **1342** extend to the fourth edge D**4**.

In an exemplary implementation, extension directions of the first flow suppression grooves **1341** and the second flow suppression grooves **1342** are perpendicular to the centerline of the antenna along the first direction.

In an exemplary implementation, as shown in FIG. **1***a*, FIG. **1***c*, and FIG. **6***a*-FIG. **6***b*, a shape of a flow suppression groove **134** is rectangular; on the plane where the second conductive layer **13** is located, a dimension of the flow suppression groove **134** along the second direction Y satisfies the following formula: $0.25*\lambda g/\mathrm{sqrt}(\varepsilon 0)$, wherein λg is a wavelength of the antenna's low-frequency dielectric frequency, $\varepsilon 0$ is the dielectric constant of the dielectric plate, and sqrt ($\varepsilon 0$) is an arithmetic square root of the dielectric constant $\varepsilon 0$ of the dielectric plate.

In an exemplary implementation, in the plane where the second conductive layer **13** is located, the flow suppression groove **134** has a dimension of 4.5 mm to 5.5 mm along the second direction Y, and the flow suppression groove **134** has a dimension of 0.5 mm to 1.5 mm along the first direction X. For example, in the plane where the second conductive layer **13** is located, the flow suppression groove **134** has a dimension of 5 mm along the second direction Y, and the flow suppression groove **134** has a dimension of 1 mm along the first direction X.

In an exemplary implementation, as shown in FIG. **8***a*-FIG. **8***c*, in the plane where the second conductive layer **13** is located, any one of the flow suppression grooves **134** may include a first groove edge **c11**, a second groove edge **c12**, and a third groove edge **c13**. A shape of the first groove edge **c11** and the second groove edge **c12** is a straight line extending along the second direction, a shape of the third groove edge **c13** is an arc projecting toward the radiation slot **131**, two ends of the third groove edge **c13** are respectively connected with one end of the first groove edge **c11** and one end of the second groove edge **c12** close to the radiation slot **131**.

As shown in FIG. **8***a* and FIG. **8***b*, in a first flow suppression groove **1341**, one end of the first groove edge **c11** and one end of the second groove edge **c12** are respectively connected with two ends of the third groove edge **c13**, and the other end of the first groove edge **c11** and the other end of the second groove edge **c12** extend to the third edge D**3** of the radiation structure **130**. In a second flow suppression groove **1324**, one end of the first groove edge **c11** and one end of the second groove edge **c12** are respectively connected with two ends of the third groove edge **c13**, and the other end of the first groove edge **c11** and the other end of the second groove edge **c12** extend to the fourth edge D4 of the radiation structure **130**. In an exemplary implementation, the first groove edge **c12** and the second groove edge **c13** are parallel to each other in the plane where the second conductive layer **13** is located.

In the embodiment of the present disclosure, the flow suppression slots **134** are disposed on the second conductive layer **13**. The flow suppression slots **134** are mainly used for suppressing the current backflow on the antenna surface, so that the radiation of the antenna is superposition of the radiation from the flow suppression slots **134** and the radiation from the radiation slot **131**. Since such two kinds of radiation have end-fire effect, the gain of the antenna is increased. The length of a rectangular groove satisfies $0.25*\lambda$ g/sqrt ($\varepsilon 0$), where λ g is the wavelength of the antenna's low-frequency dielectric frequency, $\varepsilon 0$ is the dielectric constant of the dielectric plate, and sqrt ($\varepsilon 0$) is the arithmetic square root of the dielectric constant $\varepsilon 0$ of the dielectric plate. The number and spacing of the flow suppression slots **134** can satisfy requirements the antenna, which is not limited in the embodiments of the present disclosure.

In an exemplary implementation, the director **132** may be symmetrical with respect to the centerline along the first direction X.

In an exemplary implementation, as shown in FIG. **9**, the shape of the director **132** is rectangular and the rectangular director **132** is disposed symmetrically with respect to the first centerline, wherein the first centerline is the centerline of the antenna along the first direction X.

Alternatively, as shown in FIG. **8***a*, the shape of the director **132** is elliptical and the elliptical director **132** is disposed symmetrically with respect to the first centerline;

- alternatively, as shown in FIG. **7***a*, the shape of the director **132** is circular and the circular director **132** is disposed symmetrically with respect to the first centerline;
- alternatively, as shown in FIG. **6***a* and FIG. **6***b*, the shape of the director **132** is isosceles triangular, and the isosceles triangular director **132** is disposed symmetrically with respect to the first centerline, an apex angle of the isosceles triangle is located between the radiation slot **131** and a bottom edge of the isosceles triangle, a length of the bottom edge k**1** of the isosceles triangle is 1.8 mm to 2.2 mm, and a length of the waists k**2** of the isosceles triangle is 2 mm to 4 mm. For example, the bottom edge k**1** of the isosceles triangle has a length of 2 mm, and the waists k**2** of the isosceles triangle has a length of 2.24 mm.

As shown in FIG. **10***a*, and FIG. **10***a* is a simulation result diagram of a return loss of the antenna shown in FIG. **6***a* as function of frequency. Curves **S1** in FIG. **10***b* to FIG. **10***e* are respectively E-plane patterns of the Viadldi antenna shown in FIG. **6***a* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz, and curves **S2** in FIG. **10***b* to FIG. **10***e* are respectively H-plane patterns of the Viadldi antenna shown in FIG. **6***a* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz. It can be seen from FIG. **10***a* to FIG. **10***e* that the antenna shown in FIG. **6***a* works at a frequency from 22 GHz to 45 GHz, with the return loss **S11**<−10 dB. On the curve **S1**, the antenna has a gain of 11.8 dB at 25 GHz, 13.1 dB at 30 GHz, 8.6 dB at 35 GHz and 8.0 dB at 40 GHz.

As shown in FIG. **11***a*, and FIG. **11***a* is a simulation result diagram of a return loss of the antenna shown in FIG. **7***a* as function of frequency. Curves **S1** in FIG. **11***b* to FIG. **11***e* are respectively E-plane patterns of the Viadldi antenna shown in FIG. **7***a* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz, and curves **S2** in FIG. **11***b* to FIG. **11***e* are respectively H-plane patterns of the Viadldi antenna shown in FIG. **7***a* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz. It can be seen from FIG. **11***a* to FIG. **11***e* that the antenna shown in FIG. **7***a* works at a frequency from 22 GHz to 45 GHz, with the return loss **S11**<−11 dB. On the curve **S1**, the antenna has a gain of 11.7 dB at 25 GHz, 13.2 dB at 30 GHz, 5.4 dB at 35 GHz and 8.8 dB at 40 GHz.

As shown in FIG. **12***a*, and FIG. **12***a* is a simulation result diagram of a return loss of the antenna shown in FIG. **12***f* as function of frequency. Curves S1 in FIG. 12*b* to FIG. 12*e* are respectively E-plane patterns of the Viadldi antenna shown in FIG. 12*f* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz, and curves S2 in FIG. 12*b* to FIG. 12*e* are respectively H-plane patterns of the Viadldi antenna shown in FIG. 12*f* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz. It can be seen from FIG. 12*a* to FIG. 12*e* that the antenna shown in FIG. 12*f* works at a frequency from 22 GHz to 45 GHz, with the return loss S12<−11 dB. On the curve S1, the antenna has a gain of 11.6 dB at 25 GHz, 13.03 dB at 30 GHz, 8.7 dB at 35 GHz and 7.58 dB at 40 GHz.

As shown in FIG. 13*a*, and FIG. 13*a* is a simulation result diagram of a return loss of the antenna shown in FIG. 13*f* as function of frequency. Curves S1 in FIG. 13*b* to FIG. 13*e* are respectively E-plane patterns of the Viadldi antenna shown in FIG. 13*f* at 25 GHz, 30 GHZ, 35 GHz, and 40 Ghz, and curves S2 in FIG. 13*b* to FIG. 13*e* are respectively H-plane patterns of the Viadldi antenna shown in FIG. 13*f* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz. It can be seen from FIG. 13*a* to FIG. 13*e* that the antenna shown in FIG. 13*f* works at a frequency from 22 GHz to 45 GHz, with the return loss S13<−10 dB. On the curve S1, the antenna has a gain of 11.5 dB at 25 GHz, 12.9 dB at 30 GHz, 8 dB at 35 GHz and 7.3 dB at 40 GHz.

As shown in FIG. 14*a*, and FIG. 14*a* is a simulation result diagram of a return loss of the antenna shown in FIG. 14*f* as function of frequency. Curves S1 in FIG. 14*b* to FIG. 14*e* are respectively E-plane patterns of the Viadldi antenna shown in FIG. 14*f* at 25 GHz, 30 GHZ, 35 GHz, and 40 Ghz, and curves S2 in FIG. 14*b* to FIG. 14*e* are respectively H-plane patterns of the Viadldi antenna shown in FIG. 14*f* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz. It can be seen from FIG. 14*a* to FIG. 14*e* that the antenna shown in FIG. 14*f* works at a frequency from 22 GHz to 45 GHz, and with return loss S14<−10 dB. On the curve S1, the antenna has a gain of 11.5 dB at 25 GHz, 13.04 dB at 30 GHz, 4.2 dB at 35 GHz and 7.68 dB at 40 GHz.

As shown in FIG. 15*a*, and FIG. 15*a* is a simulation result diagram of a return loss of the antenna shown in FIG. 15*f* as function of frequency. Curves S1 in FIG. 15*b* to FIG. 15*e* are respectively E-plane patterns of the Viadldi antenna shown in FIG. 15*f* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz, and curves S2 in FIG. 15*b* to FIG. 15*e* are respectively H-plane patterns of the Viadldi antenna shown in FIG. 15*f* at 25 GHz, 30 GHz, 35 GHz, and 40 Ghz. It can be seen from FIG. 15*a* to FIG. 15*e* that the antenna shown in FIG. 15*f* works at a frequency from 22 GHz to 45 GHz, with the return loss S15<−10 dB. On the curve S1, the antenna has a gain of 11.5 dB at 25 GHz, 13.04 dB at 30 GHz, 4.2 dB at 35 GHz and 7.68 dB at 40 GHz.

In the embodiment of the present disclosure, the larger the return loss of the antenna, the smaller the gain of the antenna, and the smaller the return loss of the antenna, the greater the gain of the antenna.

In the embodiment of the present disclosure, the S1 curve in FIG. 10 to FIG. 15 is an E-plane pattern of the antenna, and the S2 curve is an H-plane pattern of the antenna, wherein the E-plane may be referred to as an electric plane, referring to a directional plane parallel to the electric field direction, and the H plane may be referred to as a magnetic plane, meaning a directional plane parallel to the direction of magnetic field. In the drawings shown in FIG. 10 to FIG. 15, Mag may be gain of the antenna.

In the antenna according to an embodiment of the present disclosure, the second conductive layer 13 is provided with a director 132 and a radiation slot 131. The radiation slot 131 is provided as a first slot 1311, a second slot 1312, and a third slot 1313 which are communicated in sequence along a first direction X in a plane where the second conductive layer 13 is located. The director 132 is disposed on the second conductive layer 13 and located a side of the third slot 1313 away from the second slot 1312. An orthographic projection of the director 132 on the dielectric layer 12 is within a range of an orthographic projection of the third slot 1313 on the dielectric layer 12. The director 13 is disposed on the second conductive layer 13 and located at a side of the third slot 1313 away from the second slot 1312 and plays a guiding role on electromagnetic waves, thus improving the gain of the antenna to a great extent.

An embodiment of the present disclosure further provides an electronic device, which includes the antenna in any one of the embodiments described above.

In the embodiments of the present disclosure, since the above antenna is provided with the director 132 on the second conductive layer 13 located at the side of the third slot 1313 away from the second slot 1312, which plays a guiding role on electromagnetic waves, thus improving the gain of the antenna to a great extent, thereby the gain of the electronic device including the antenna is increased in the process of wireless communication through the antenna, and the communication effect of the electronic device is improved.

In the embodiments of the present disclosure, the electronic device may be any product or component having the antenna of any one of the above embodiments, such as a display device, a wearable device, radar, a satellite, or the like.

In an exemplary implementation, as shown in FIG. 16, the electronic device may include multiple the antennas mentioned above, the plurality of antennas are arranged along a third direction Z to form an antenna array, and orthographic projections of the multiple antennas on a plane where the first direction X and the second direction Y are located are overlapped, and orthographic projections of the radiation slots in the multiple antennas on a plane where the first direction X and the second direction Y are located are overlapped.

As shown in FIG. 17*a* to FIG. 17*c*, which are graphs of gain results simulated within positive or negative 30° at a frequency of 30 Ghz of the antenna array shown in FIG. 16 formed by arranging the plurality of antennas shown in FIG. 6*a* along the third direction Z. Positive or negative 30° refers to positive or negative 30 degrees with respect to a radiation direction of the antenna, that is, the value of the angle Theta in FIG. 6*a* ranges from positive 30° to negative 30°, and the value of Theta located at the centerline of the antenna along the first direction is 0°. FIG. 17*a* to FIG. 17*c* show the gain results simulated at 0°, −30° and 30°, respectively. The gain varies from 25.8 dB to 31.3 dB, which can meet the gain requirements of low-orbit Q-BAND satellites, wherein the Q-BAND can be called Q band, and typically the satellite communication band is at the frequency of 30 GHz to 50 GHz.

In the coordinate diagram shown in FIG. 17*a* to FIG. 17*c*, the ordinate is the gain and the abscissa is the angle.

The drawings of the embodiments of the present disclosure only involve structures involved in the embodiments of the present disclosure, and other structures may refer to usual designs.

The embodiments of the present disclosure, that is, features in the embodiments, may be combined with each other to obtain new embodiments if there is no conflict.

Although the implementation modes disclosed in the embodiments of the present disclosure are described above, the described contents are only implementation modes for facilitating understanding of the embodiments of the present disclosure, which are not intended to limit the embodiments of the present disclosure. Those skilled in the art to which the embodiments of the present disclosure pertain may make any modifications and variations in forms and details of implementation without departing from the spirit and scope of the embodiments of the present disclosure. Nevertheless, the scope of patent protection of the embodiments of the present disclosure shall still be subject to the scope defined by the appended claims.

The invention claimed is:

1. An antenna comprising a first conductive layer, a dielectric layer, and a second conductive layer which are stacked;

wherein the first conductive layer is provided as a microstrip line structure;

the second conductive layer is provided with a radiation structure and a director; the radiation structure comprises a first edge and a second edge opposite to each other along a first direction in a plane where the second conductive layer is located; the radiation structure is provided with a radiation slot away from the first edge, and the radiation slot comprises a first slot, a second slot and a third slot which are sequentially communicated along the first direction in the plane where the second conductive layer is located, a shape of the first slot is circular, a shape of the second slot is rectangular, the third slot gradually increases in dimension in a second direction from an end connected with the second slot to an end away from the second slot, and the third slot extends in the first direction from the second slot to the second edge of the radiation structure;

the director is disposed on the second conductive layer and located at a side of the third slot away from the second slot, and an orthographic projection of the director on the dielectric layer is at least partially overlapped with an orthographic projection of the third slot on the dielectric layer;

the second conductive layer is further provided with a plurality of metamaterial structures arranged in an array; and

in the plane where the second conductive layer is located, in the first direction, the plurality of metamaterial structures are disposed at a side of the director away from the third slot, and an orthographic projection of the plurality of metamaterial structures on the dielectric layer is not overlapped with an orthographic projection of the radiation structure on the dielectric layer, and the plurality of metamaterial structures are disposed symmetrically with respect to a first centerline.

2. The antenna according to claim **1**, wherein in the plane where the second conductive layer is located, the radiation slot is disposed symmetrically with respect to the first centerline and the director is disposed symmetrically with respect to the first centerline, and the first centerline is a centerline of the antenna along the first direction.

3. The antenna according to claim **1**, wherein the microstrip line structure comprises a first conductive structure, a second conductive structure and a third conductive structure sequentially connected along the second direction in a plane where the first conductive layer is located, a shape of the first conductive structure is rectangular, the third conductive structure is fan-shaped, the second conductive structure gradually decreases in dimension in the first direction from an end connected with the first conductive structure to an end connected with the third conductive structure, the third conductive structure gradually increases in dimension in the first direction from an end connected with the second conductive structure to an end away from the second conductive structure; and

in the plane where the first conductive layer is located, the microstrip line structure is symmetrically disposed along the first direction with respect to a second centerline, the second centerline is a centerline of the microstrip line structure along the second direction, an orthographic projection of the second centerline on the dielectric layer is perpendicular to an orthographic projection of the first centerline on the dielectric layer, and an orthographic projection of the second conductive structure on the dielectric layer is at least partially overlapped with an orthographic projection of the second slot on the dielectric layer.

4. The antenna according to claim **3**, wherein in the plane where the first conductive layer is located, the first conductive structure has a dimension of **0**.**65** mm to **0**.**85** mm along the first direction and a dimension of 5 mm to 7 mm along the second direction;

the second conductive structure has a dimension of 1.6 mm to 2.2 mm along the second direction, and the end of the second conductive structure connected with the first conductive structure has a dimension of 0.45 mm to 0.6 mm along the first direction; the third conductive structure has a sector radius of 0.4 mm to 0.7 mm.

5. The antenna according to claim **1**, wherein in the plane where the second conductive layer is located, the first slot has a radius of 0.8 mm to 1.2 mm, the second slot has a dimension of 2.5 mm to 3.5 mm in the first direction, and the second slot has a dimension of 0.4 mm to 0.8mm in the second direction.

6. The antenna according to claim **1**, wherein dimensions of anyone of the metamaterial structures in the first direction and the second direction are each less than a length of half of a dielectric wavelength;

in the first direction, a distance between two adjacent metamaterial structures is less than the length of half of the dielectric wavelength; and

in the second direction, a distance between two adjacent metamaterial structures is less than the length of half of the dielectric wavelength;

wherein the dielectric wavelength is a wavelength of a wave transmitted or received by the antenna in the dielectric layer.

7. The antenna according to claim **6**, wherein in the plane where the second conductive layer is located, any one of the metamaterial structures has a dimension of 1.1 mm to **1**.**7** mm in the first direction, any one of the metamaterial structures has a dimension of 1 mm to 1.6 mm in the second direction, the distance between two adjacent metamaterial structures in the first direction is 0.3 mm to 0.7 mm, and the distance between two adjacent metamaterial structures in the second direction is 0.3 mm to 0.7 mm;

the antenna has a dimension of 14.8 mm to 15.6 mm in the second direction, the antenna has a dimension of 28 mm to 34 mm in the first direction, and a distance from the first edge of the radiation structure to a junction of the first slot and the second slot in the first direction is 5 mm to 7 mm; and

the third slot has a maximum dimension of 8mm to 10 mm in the second direction.

8. The antenna according to claim **1**, wherein a metamaterial structure comprises a first E-type structure, a second E-type structure and a first connection line connected with the first E-type structure and the second E-type structure, in the plane where the second conductive layer is located, the first E-shaped structure and the second E-shaped structure are symmetrically disposed with respect to a midperpendicular line of the first connection line, the first connection line extends along the second direction and is located at a position of a third centerline, the first E-shaped structure is disposed symmetrically with respect to the third centerline along the first direction, and the second E-shaped structure is disposed symmetrically with respect to the third centerline along the first direction, an opening of the first E-shaped structure faces a side away from the second E-shaped structure, and an opening of the second E-shaped structure faces a side away from the first E-shaped structure.

9. The antenna according to claim **8**, wherein the first connection line has a dimension of 0.2 mm to 0.6 mm along the second direction; for ends located at a same side of the third centerline in the first direction, a distance between an end of the first E-shaped structure away from the second E-shaped structure and an end of the second E-shaped structure away from the first E-shaped structure in the second direction is 1 mm to 1.6 mm; at the position of the third centerline, a distance between an end of the first E-type structure away from the second E-type structure and an end of the second E-type structure away from the first E-type structure in the second direction is 1.1 mm to 1.7 mm; a width dimension of lines constituting the first E-shaped structure and the second E-shaped structure and a width dimension of a line constituting the first connection line are both 0.1 mm to 0.3 mm.

10. The antenna according to claim **1**, wherein a metamaterial structure comprises a first I-shaped structure and a second I-shaped structure; in the plane where the second conductive layer is located, the first I-shaped structure comprises a first connection line and a second connection line extending along the first direction and a third connection line extending along the second direction, the third connection line is positioned at a midperpendicular line of the first connection line and the second connection line;

in the plane where the second conductive layer is located, the second I-shaped structure comprises a fourth connection line and a fifth connection line extending along the second direction and a sixth connection line extending along the first direction, the sixth connection line is located at a midperpendicular line of the fourth connection line and the fifth connection line; and

the third connection line is located at a centerline of the sixth connection line, and the sixth connection line is located at a centerline of the third connection line.

11. The antenna according to claim **10**, wherein line widths of the first connection line to the sixth connection line are each 0.1 mm to 0.3 mm; in the plane where the second conductive layer is located, the first connection line and second connection line have a dimension from 0.8 mm to 1.3 mm along the first direction, the third connection line has a dimension from 0.7 mm to 1.5 mm along the second direction, the fourth connection line and the fifth connection line have a dimension from 0.8 mm to 1.3 mm along the second direction, and the sixth connection line has a dimension from 0.7 mm to 1.5 mm along the first direction.

12. The antenna according to claim **1**, wherein the radiation structure further comprises a third edge and a fourth edge opposite to each other along the second direction in the plane where the second conductive layer is located; on the plane where the second conductive layer is located, the radiation structure is provided with a plurality of flow suppression grooves, and the flow suppression grooves comprise a plurality of first flow suppression grooves arranged along the first direction and a plurality of second flow suppression grooves arranged along the first direction, the plurality of first flow suppression grooves and the plurality of second flow suppression grooves are symmetrically disposed with respect to a centerline of the antenna along the first direction; the plurality of first flow suppression grooves are disposed at a side of the third slot, and the plurality of second flow suppression grooves are disposed at a side of the third slot away from the plurality of first flow suppression grooves; the first flow suppression grooves extend to the third edge, and the second flow suppression grooves extend to the fourth edge.

13. The antenna according to claim **12**, wherein extension directions of the first flow suppression grooves and the second flow suppression grooves are perpendicular to the centerline of the antenna along the first direction.

14. The antenna according to claim **12**, wherein a shape of a flow suppression groove is rectangular; on the plane where the second conductive layer is located, a dimension of the flow suppression groove along the second direction satisfies a following formula: $0.25*\lambda/g/\mathrm{sqrt}(\varepsilon 0)$, where λg is a wavelength of the antenna's low-frequency dielectric frequency, $\varepsilon 0$ is a dielectric constant of a dielectric plate, and sqrt $(\varepsilon 0)$ is an arithmetic square root of the dielectric constant $\varepsilon 0$ of the dielectric plate.

15. The antenna according to claim **14**, wherein on the plane where the second conductive layer is located, a flow suppression groove has a dimension of 4.5 mm to 5.5 mm along the second direction, and the flow suppression groove has a dimension of 0.5 mm to 1.5mm along first direction.

16. The antenna according to claim **12**, wherein in the plane where the second conductive layer is located, any one of the flow suppression grooves comprises a first groove edge, a second groove edge and a third groove edge, a shape of the first groove edge and the second groove edge is a linear shape extending along the second direction, a shape of the third groove edge is an arc shape protruding toward the radiation groove, and two ends of the third groove edge are respectively connected with one end of the first groove edge and one end of the second groove edge close to the radiation groove.

17. The antenna according to claim **1**, wherein a shape of the director is rectangular, and the rectangular director is symmetrically disposed with respect to the first centerline; or

the shape of the director is elliptical, and the elliptical director is symmetrically disposed with respect to the first centerline; or

the shape of the director is circular, and the circular director is symmetrically disposed with respect to the first centerline; or

the shape of the director is isosceles triangular, and the isosceles triangular director is symmetrically disposed with respect to the first centerline, an apex angle of the isosceles triangle is located between the radiation slot and a bottom edge of the isosceles triangle, a length of the bottom edge of the isosceles triangle is 1.8 mm to 2.2 mm, and a length of two waists of the isosceles triangle is 2 mm to 4 mm.

18. An electronic device, comprising at least one antenna according to claim **1**.

19. The electronic device according to claim **18**, comprising a plurality of the antennas, the plurality of the antennas are arranged along a third direction to form an antenna array, and orthographic projections of the plurality of antennas on a plane where the first direction and the second direction are located are overlapped, and orthographic projections of radiation slots in the plurality of the antennas on a plane where the first direction and the second direction are located are overlapped.

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