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(54) **ANTENNA AND ELECTRONIC DEVICE**

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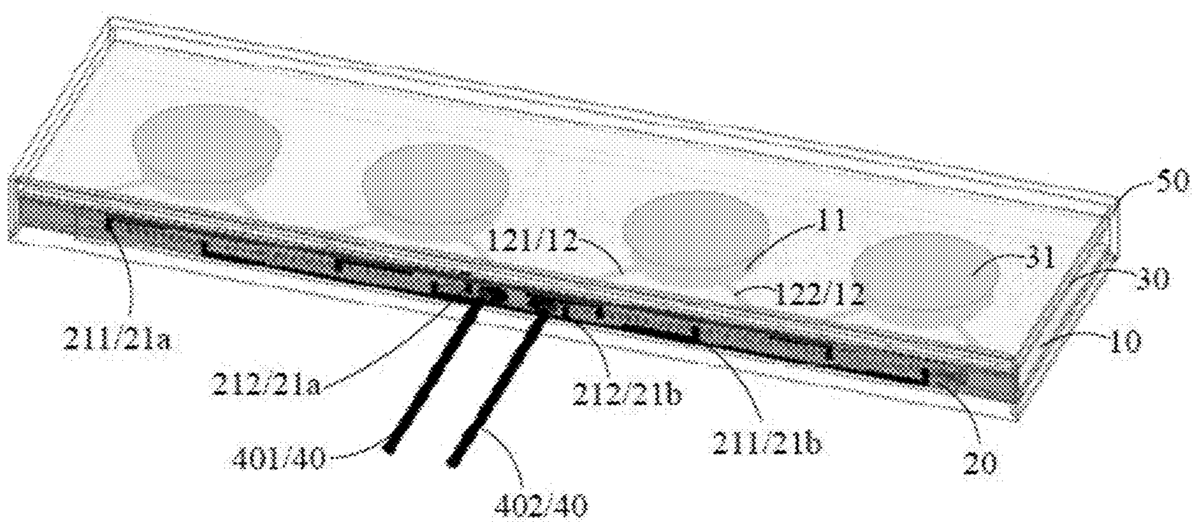
(57) **ABSTRACT**

An antenna includes: a first substrate and a second substrate. The first substrate includes: a first dielectric substrate, a first reference electrode layer, a first radiation part, and a feeder group. The first dielectric substrate includes a main substrate and a side substrate, the feeder group includes at least one feeder, in each of which, each feeder is electrically connected to one first radiation part, and different feeders are electrically connected to different first radiation parts. The second substrate includes: a second dielectric substrate, a second reference electrode layer, and a feed structure. The feed structure corresponds to the feeder group, and for corresponding feed structure and feeder group, each first feed port in the feed structure is electrically connected to one feeder in the feeder group through a first connection via which runs through at least the side substrate, the second reference electrode layer, and the second dielectric substrate.



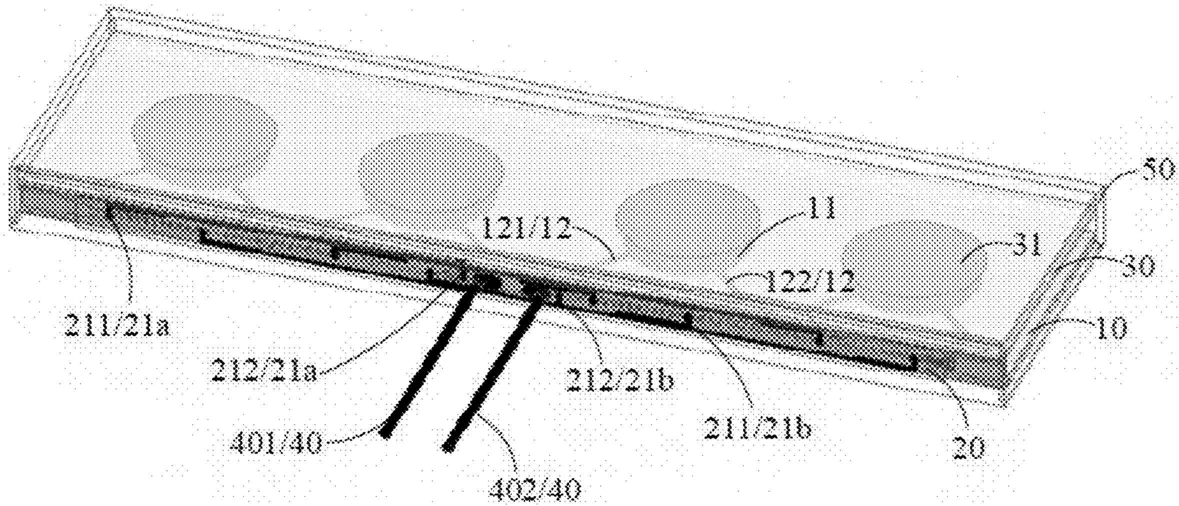


FIG. 1

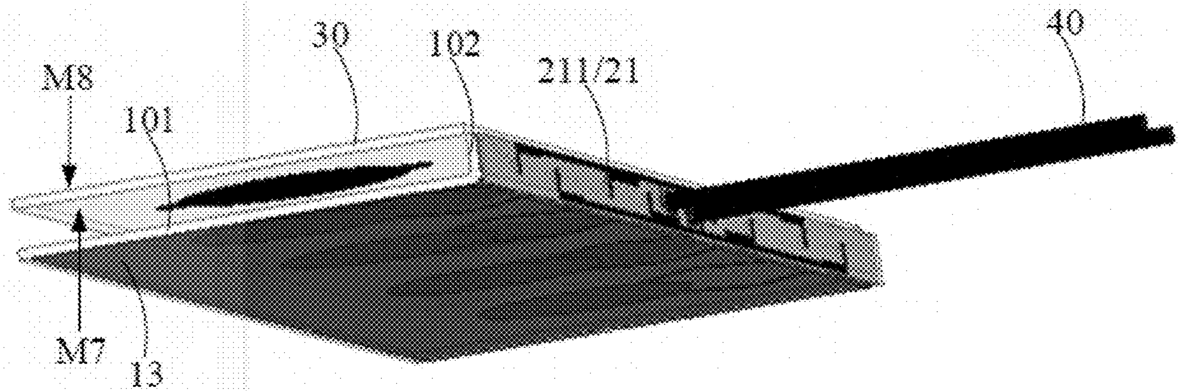


FIG. 2

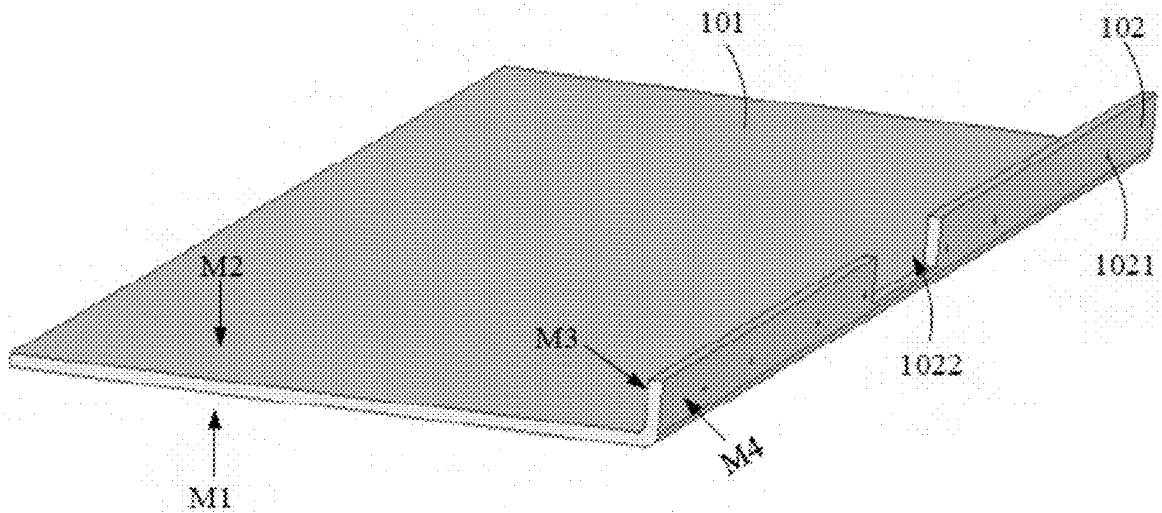


FIG. 3

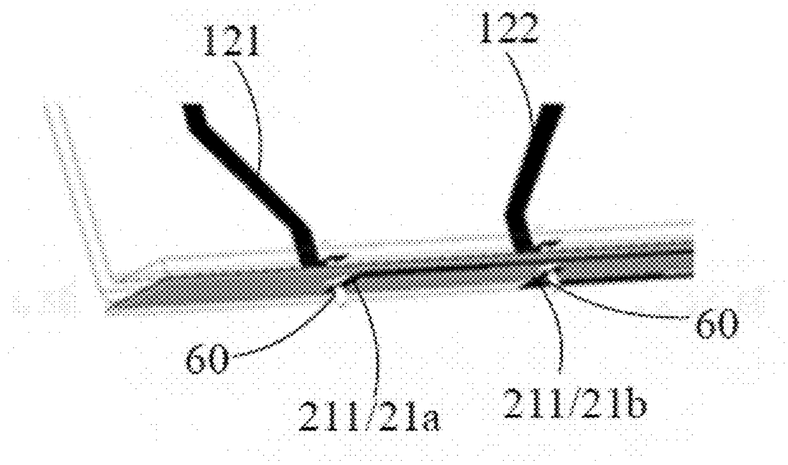


FIG. 4

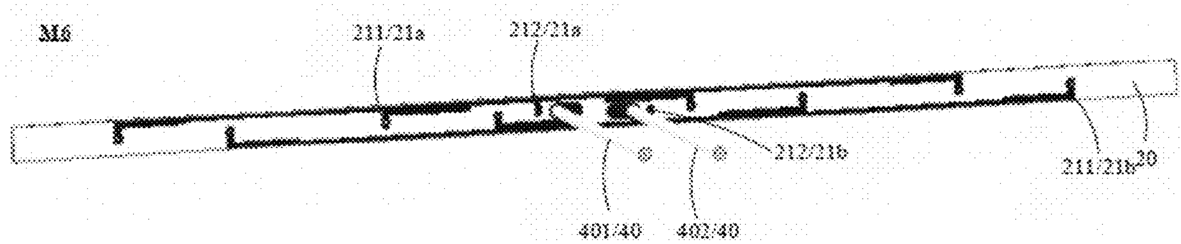


FIG. 5

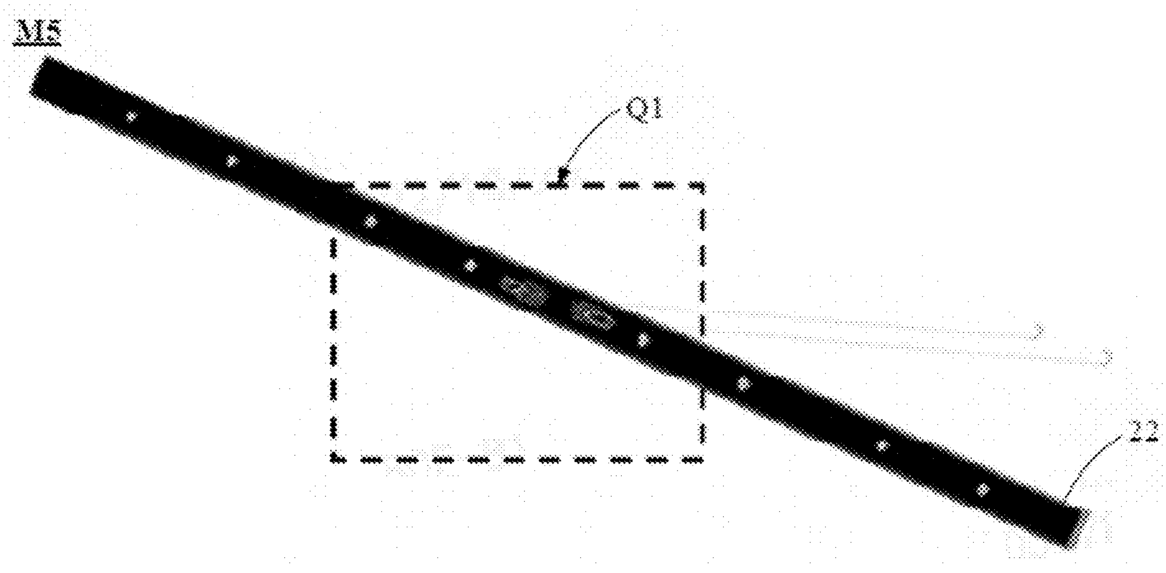


FIG. 6

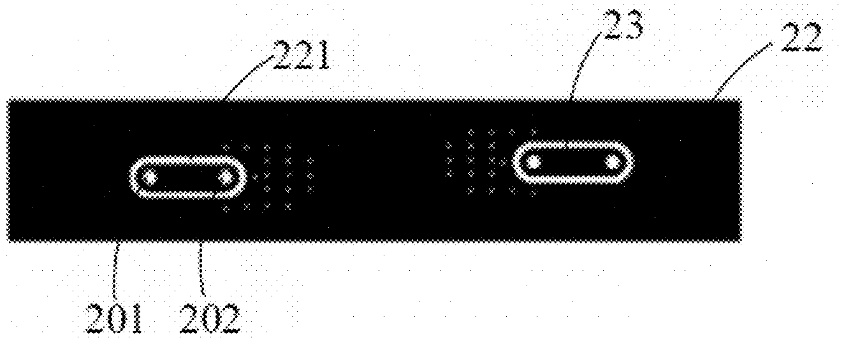


FIG. 7

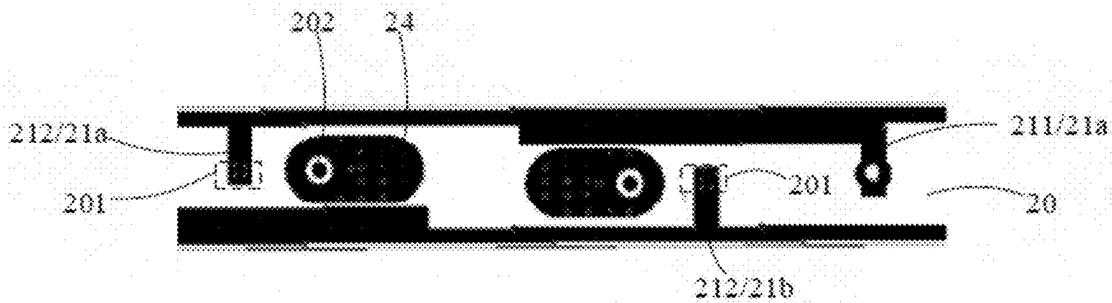


FIG. 8

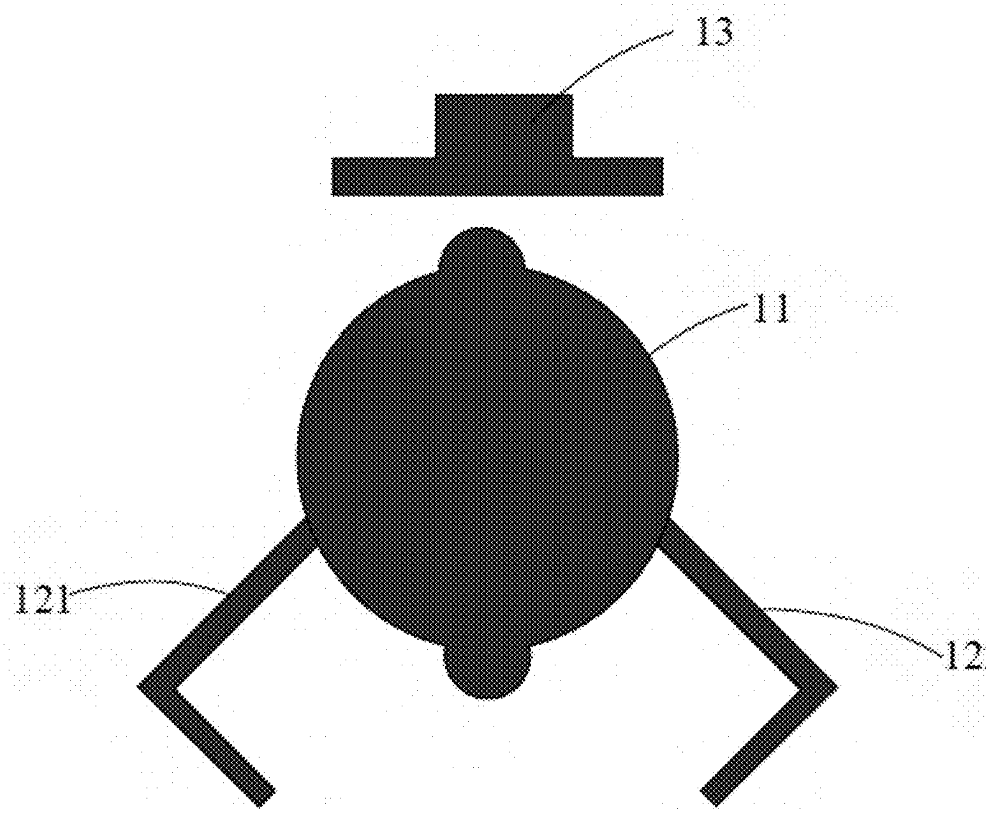


FIG. 9a

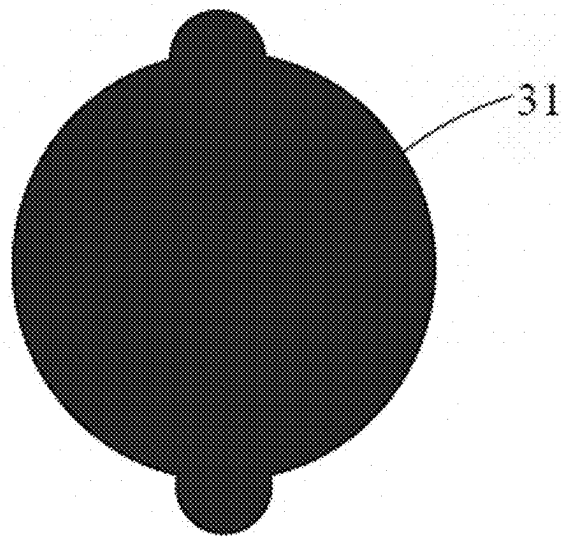


FIG. 9b

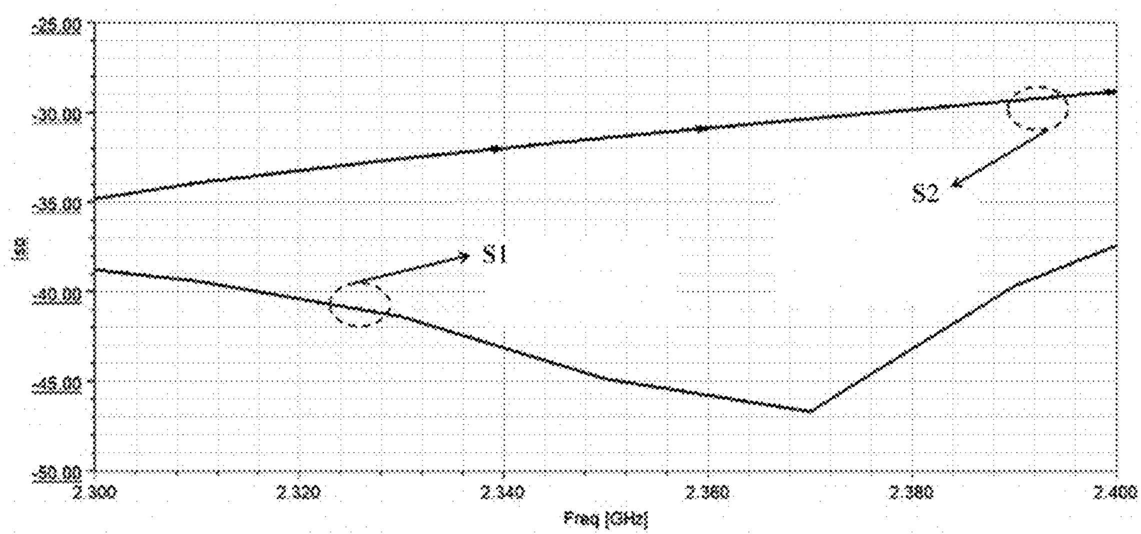


FIG. 10

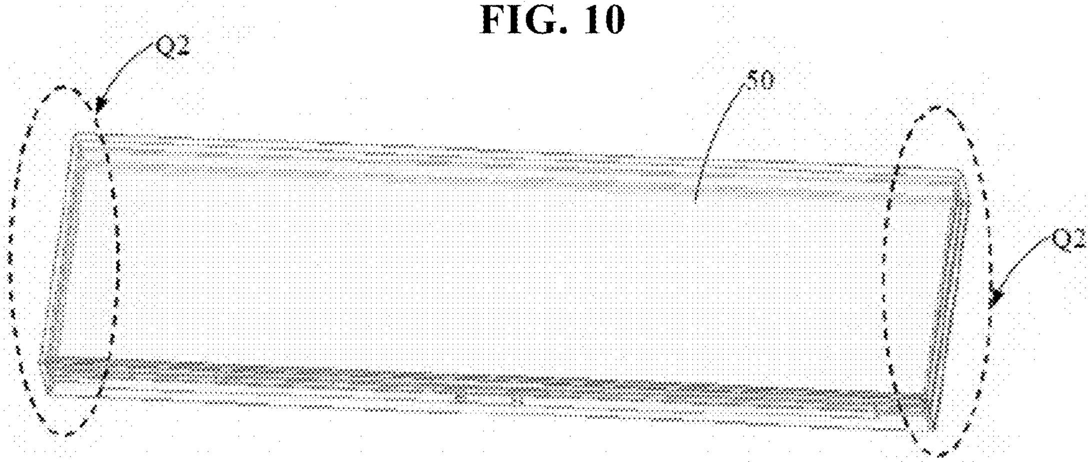


FIG. 11

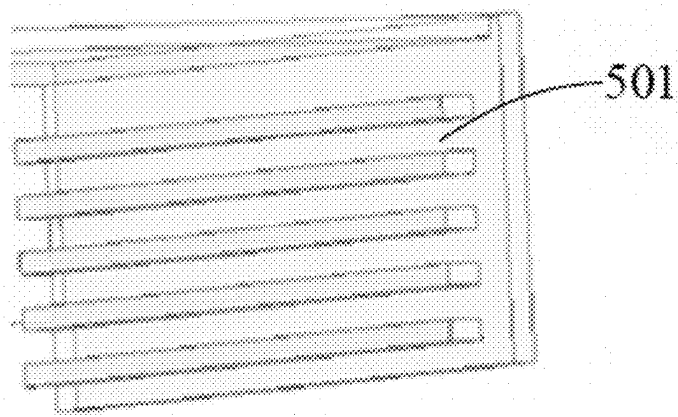


FIG. 12

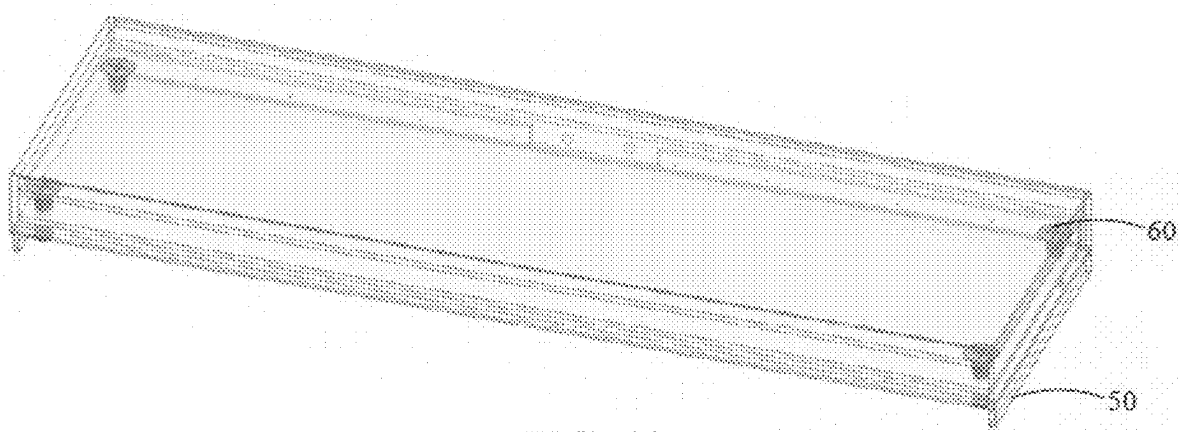


FIG. 13

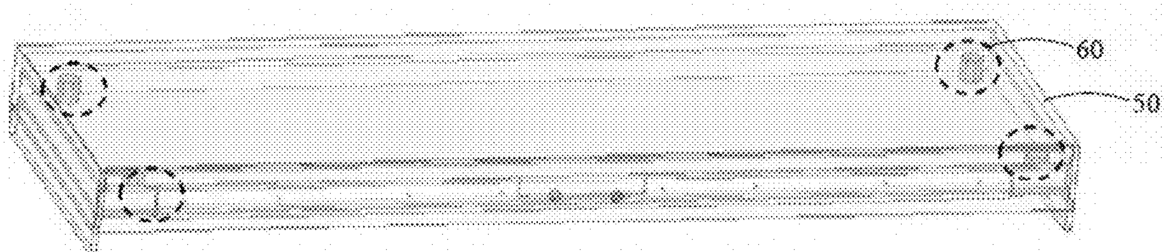


FIG. 14

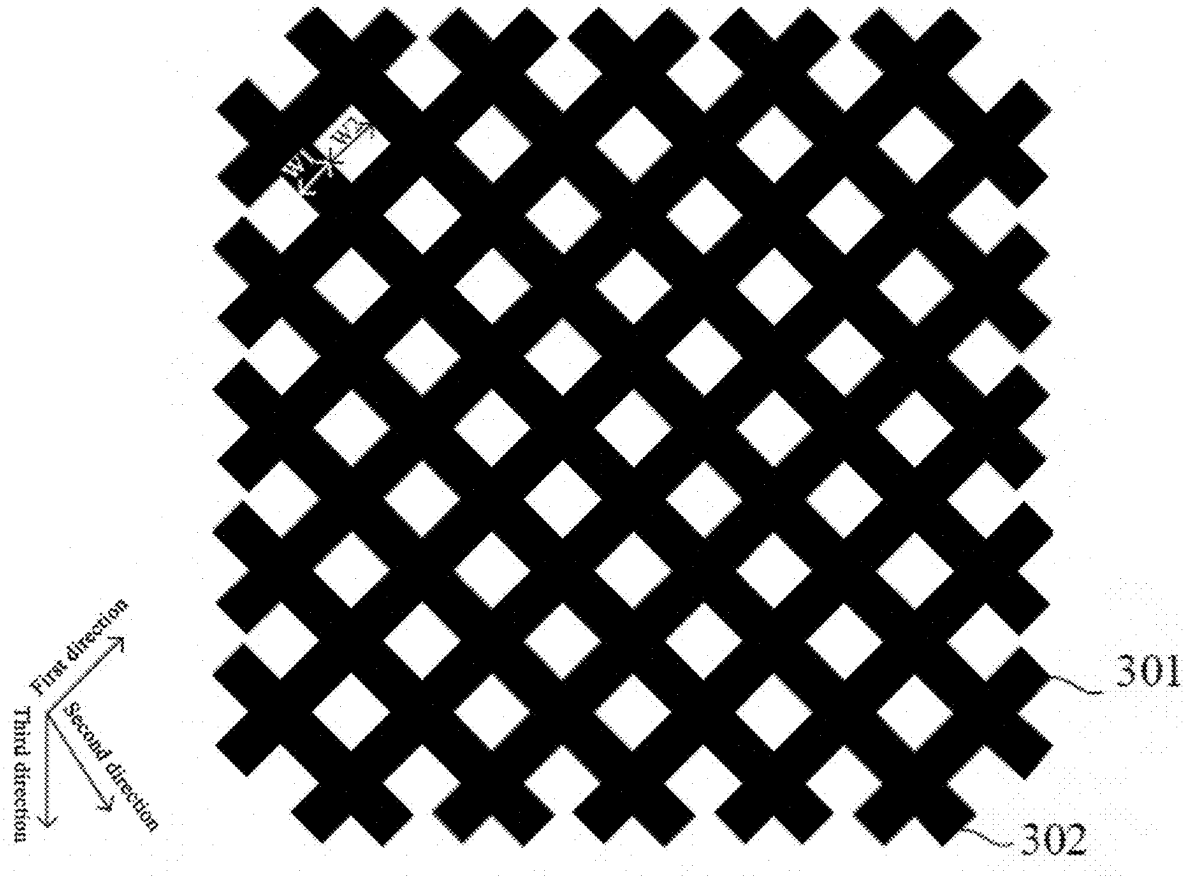

W1
W2
First direction
Second direction
Third direction
301
302

FIG. 15

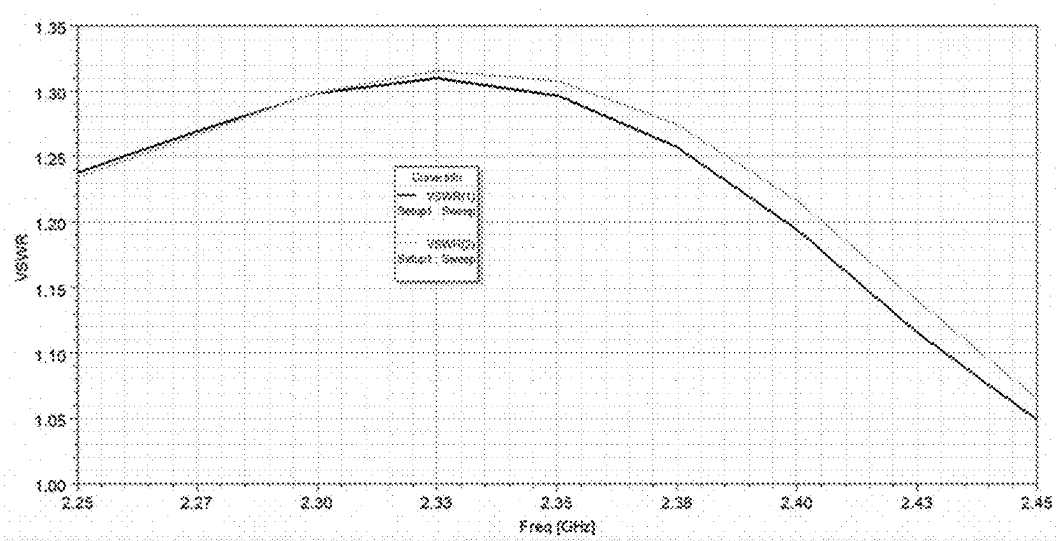

1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
VSWR
2.25
2.27
2.30
2.33
2.35
2.38
2.40
2.43
2.45
Freq [GHz]

FIG. 16

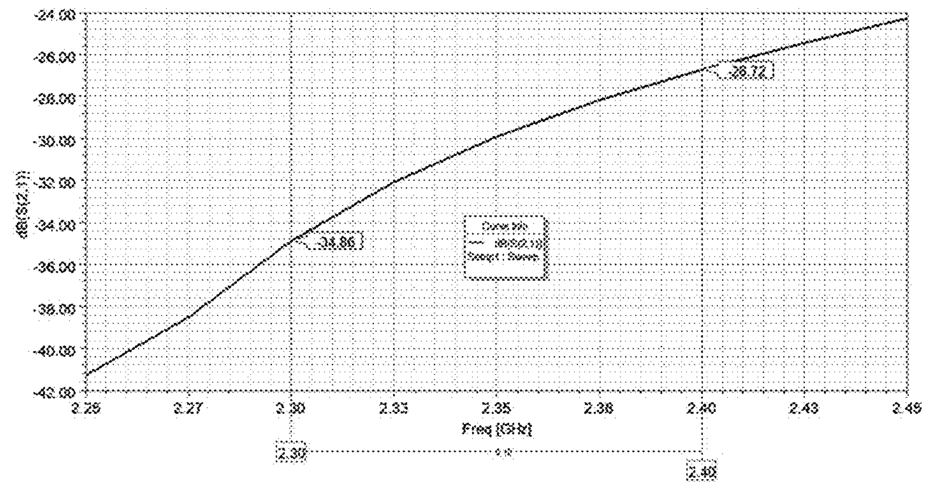


FIG. 17

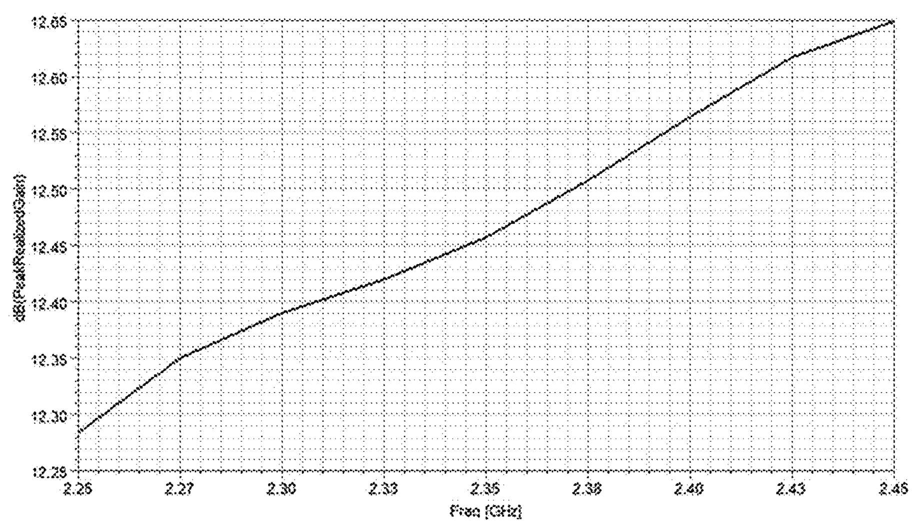


FIG. 18

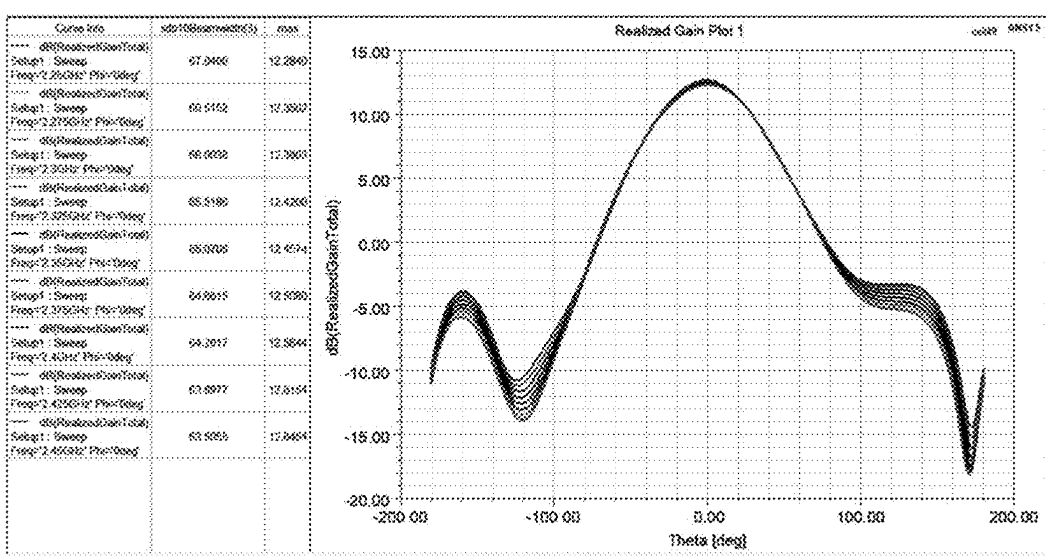


FIG. 19

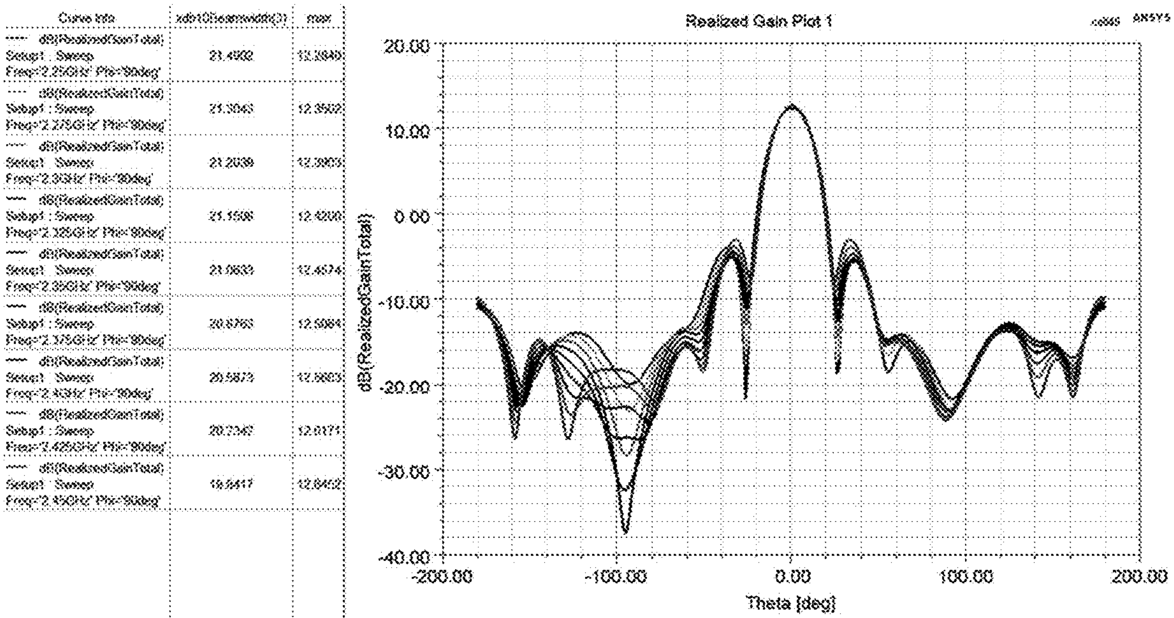

Realized Gain Plot 1
ANSYS
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
dB(RealizedGainTotal)
-200.00
-100.00
0.00
100.00
200.00
Theta [deg]

FIG. 20

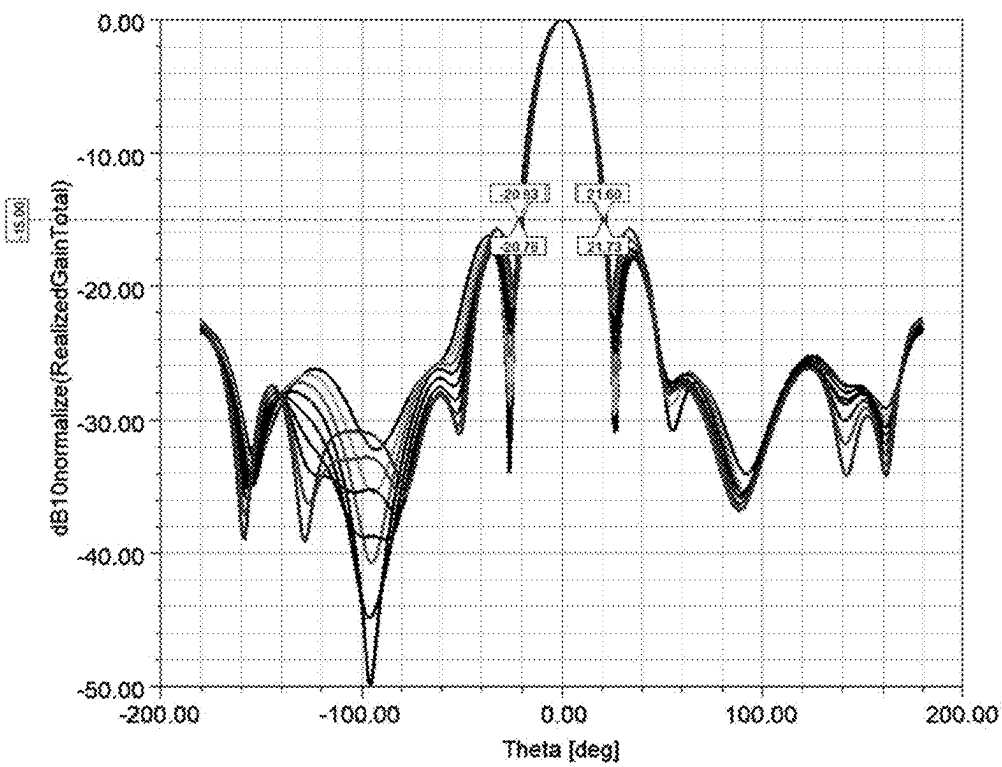

0.00
-10.00
-20.00
-30.00
-40.00
-50.00
dB10normalize(RealizedGainTotal)
-200.00
-100.00
0.00
100.00
200.00
Theta [deg]

FIG. 21

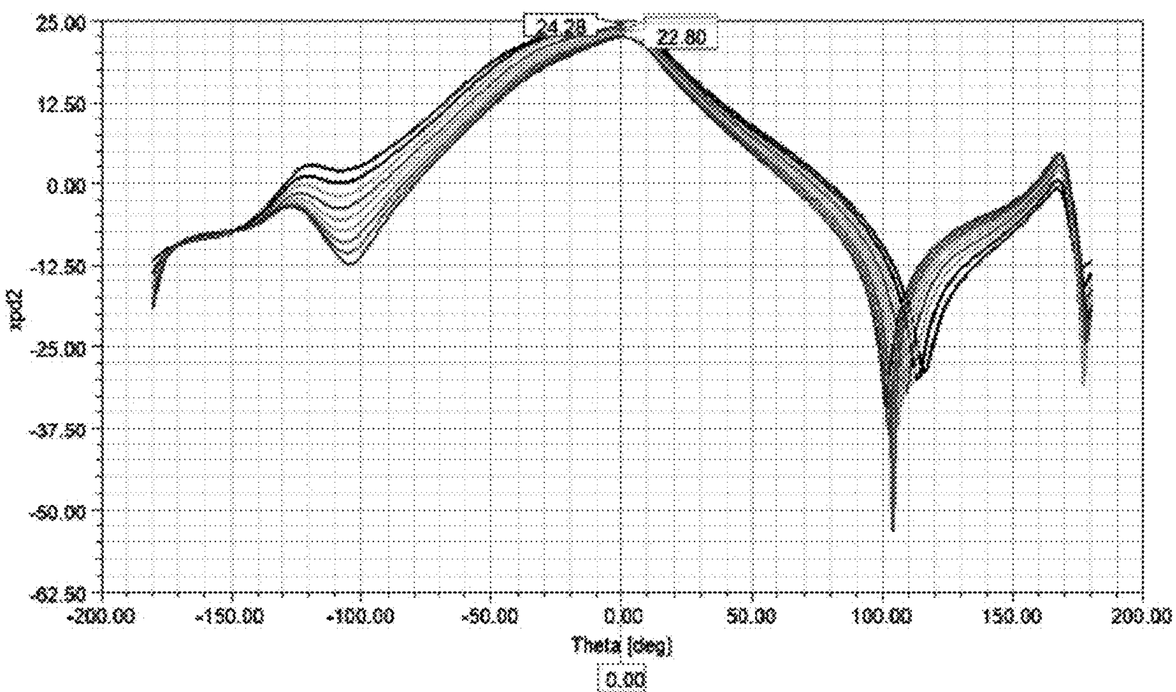

25.00
12.50
0.00
-12.50
-25.00
-37.50
-50.00
-62.50
xpd2
24.28
22.80
-200.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00
200.00
Theta [deg]
0.00

FIG. 22

ANTENNA AND ELECTRONIC DEVICE

TECHNICAL FIELD

[0001] The present disclosure belongs to the field of communication technology, and specifically relates to an antenna and an electronic device.

BACKGROUND

[0002] With the continuous development of the mobile communication technology, additional functional attributes of glazing are increasingly remarkable. Among them, the fusion application of antenna and glazing has become one of the most representative applications. Unable to be transparent, traditional antennas will firstly affect the aesthetic appearance of the whole glazing when used with a transparent glazing.

[0003] Secondly, due to the strong attenuation of glass to electromagnetic waves, the antenna cannot achieve effective electromagnetic energy radiation when tightly bonded to the glazing, finally causing a low antenna gain. Therefore, an antenna design scheme that can ensure a high gain of the antenna while achieving transparency of the antenna will become a trend for 5G embellished antennas.

SUMMARY

[0004] To solve at least one of the problems in the existing art, the present disclosure provides an antenna and an electronic device.

[0005] In a first aspect, an embodiment of the present disclosure provides an antenna, including a first substrate and a second substrate; wherein

- **[0006]** the first substrate includes:
- **[0007]** a first dielectric substrate including a main substrate and a side substrate, where the main substrate has a first surface and a second surface opposite to each other in a thickness direction thereof, and the side substrate includes a third surface and a fourth surface opposite to each other in a thickness direction of the side substrate; and the second surface of the main substrate is connected to the third surface of the side substrate, and the side substrate protrudes out of the second surface of the main substrate;
- **[0008]** a first reference electrode layer on the first surface and the fourth surface;
- **[0009]** at least one first radiation part on the second surface; and
- **[0010]** at least one feeder group including at least one feeder, wherein the feeder is provided on the second surface and extends toward the third surface, each feeder in each feeder group is electrically connected to one first radiation part, and different feeders in the feeder group are electrically connected to different first radiation parts; and
- **[0011]** the second substrate includes:
- **[0012]** a second dielectric substrate having a fifth surface and a sixth surface opposite to each other in a thickness direction of the second dielectric substrate; wherein the fifth surface is opposite to the fourth surface;
- **[0013]** a second reference electrode layer on the fifth surface; and
- **[0014]** at least one feed structure on the sixth surface, wherein the feed structure corresponds to the feeder group, and for the corresponding feed structure and feeder group, each first feed port in the feed structure is electrically connected to one feeder in the feeder group through a first connection via; and the first connection via runs through at least the side substrate, the second reference electrode layer, and the second dielectric substrate.

[0015] The first reference electrode layer includes a first reference sub-electrode and a second reference sub-electrode connected to each other, the first reference sub-electrode is on the first surface, and the second reference sub-electrode is on the fourth surface;

- **[0016]** the second reference sub-electrode is electrically connected to the second reference electrode layer; and
- **[0017]** the antenna further includes:
- **[0018]** at least one first opening running through the second reference sub-electrode and the second reference electrode layer;
- **[0019]** at least one first connection electrode on the fifth surface, wherein each first connection electrode is in one first opening, and a second feed port of one feed structure is electrically connected to the first connection electrode through a second connection via; and the second connection via runs through at least the second dielectric substrate; and
- **[0020]** at least one radio frequency line, a core of each of which is electrically connected to the first connection electrode through a third connection via; wherein the third connection via at least runs through the second dielectric substrate.

[0021] The antenna further includes:

- **[0022]** at least one second connection electrode on the sixth surface and electrically connected to the second reference electrode layer through a fourth connection via running through the second dielectric substrate; wherein
- **[0023]** the third connection via further runs through the second connection electrode, and the reference electrode layer of the radio frequency line is electrically connected to the second connection electrode.

[0024] The antenna further includes a second opening running through the side substrate, wherein an orthographic projection of the second opening on a plane where the second dielectric substrate is located covers an orthographic projection of the first opening on the plane where the second dielectric substrate is located.

[0025] The second connection via and the third connection via each further run through the first connection electrode, the first connection electrode is welded to the second feed port of the feed structure through the second connection via, and a core of the radio frequency line is welded to the third connection via through the third connection via.

[0026] The first feed port is riveted or welded with the feeder by a connector through the first connection via.

[0027] The at least one feeder group includes a first feeder group and a second feeder group; a plurality of first feeders are provided in the first feeder group, and a plurality of second feeders are provided in the second feeder group; the at least one feed structure includes a first feed structure and a second feed structure; the first feed structure and the second feed structure each include a plurality of first feed ports and one second feed port, each of the first feed ports in the first feed structure is electrically connected to one of the first feeders, and each of the first feed ports in the second feed structure is electrically connected to one of the second feeders.

[0028] The antenna further includes: at least one director on the second surface and in one-to-one correspondence with the first radiation part, wherein the director is on a side of the corresponding first radiation part away from the side substrate.

[0029] The antenna further includes:

[0030] a third dielectric substrate having a seventh surface and an eighth surface opposite to each other in a thickness direction of the third dielectric substrate, wherein the seventh surface is opposite to, and spaced by a spacing from, the second surface; and

[0031] at least one second radiation part on the seventh surface or the eighth surface, wherein orthographic projections of each second radiation part and one corresponding first radiation part on the first surface are at least partially overlapped.

[0032] The antenna further includes:

[0033] a plurality of support components between the second surface and the seventh surface to provide a spacing between the first radiation part and the second radiation part.

[0034] Each support component is a height-adjustable support component to adjust the spacing between the first radiation part and the second radiation part.

[0035] The antenna further includes:

[0036] a radome, wherein two opposite side walls of the radome are provided with a plurality of sets of slide rails; and the main substrate and the third dielectric substrate are insertable into different sets of slide rails.

[0037] The antenna further includes:

[0038] a radome including a first base material and a second base material opposite to each other; wherein the first dielectric substrate with the first reference electrode layer is on a side of the first base material close to the second base material; and the third dielectric substrate with the second radiation part is on a side of the second base material close to the first base material.

[0039] At least one of the first radiation part, the second radiation part, the first reference electrode layer, or the feeder includes a metal mesh.

[0040] The metal mesh has a line width in a range of 2 μm to 30 μm; a line spacing in a range of 50 μm to 250 μm; and a line thickness in a range of 1 μm to 10 μm.

[0041] The third dielectric substrate includes any one of polycarbonate plastic, cyclic olefin polymer plastic, or polymethyl methacrylate.

[0042] The first dielectric substrate includes any one of polycarbonate plastic, cyclic olefin polymer plastic, or polymethyl methacrylate.

[0043] The second substrate is a printed circuit board.

[0044] The main substrate and the side substrate form an integral structure.

[0045] In a second aspect, an embodiment of the present disclosure provides an electronic device, including any antenna as described above.

BRIEF DESCRIPTION OF DRAWINGS

[0046] FIG. **1** is a schematic structural diagram of an antenna according to an embodiment of the present disclosure.

[0047] FIG. **2** is a schematic structural diagram of an antenna without any radome according to an embodiment of the present disclosure.

[0048] FIG. **3** is a schematic structural diagram of a first dielectric substrate in an antenna according to an embodiment of the present disclosure.

[0049] FIG. **4** is a schematic diagram illustrating a connection of a feeder with a first feed port of a feed structure in an antenna according to an embodiment of the present disclosure.

[0050] FIG. **5** is a schematic structural diagram showing a sixth surface side of a second dielectric substrate in an antenna according to an embodiment of the present disclosure.

[0051] FIG. **6** is a schematic structural diagram showing a fifth surface side of a second dielectric substrate in an antenna according to an embodiment of the present disclosure.

[0052] FIG. **7** is a partially enlarged view at position Q**1** in FIG. **6**.

[0053] FIG. **8** is a partial structural diagram of a sixth surface side of a second dielectric substrate in an antenna according to an embodiment of the present disclosure.

[0054] FIG. **9***a* is a schematic diagram showing a positional relationship between a first radiation part and a director in an antenna according to an embodiment of the present disclosure.

[0055] FIG. **9***b* is a top view of a second radiation part in an antenna according to an embodiment of the present disclosure.

[0056] FIG. **10** is an isolation plot of an antenna with and without a director according to an embodiment of the present disclosure.

[0057] FIG. **11** is a schematic diagram showing a fixation manner of a first dielectric substrate and a third dielectric substrate in an antenna according to an embodiment of the present disclosure.

[0058] FIG. **12** is a partially enlarged view at position Q**2** in FIG. **11**.

[0059] FIG. **13** is a schematic diagram showing another fixation manner of a first dielectric substrate and a third dielectric substrate in an antenna according to an embodiment of the present disclosure.

[0060] FIG. **14** is a schematic diagram showing yet another fixation manner of a first dielectric substrate and a third dielectric substrate in an antenna according to an embodiment of the present disclosure.

[0061] FIG. **15** is a schematic structural diagram of a metal mesh according to an embodiment of the present disclosure.

[0062] FIG. **16** is a standing wave plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz.

[0063] FIG. **17** is an isolation plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz.

[0064] FIG. **18** is a gain plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz.

[0065] FIG. **19** is a 0° direction plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz.

[0066] FIG. **20** is a 900 direction plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz.

[0067] FIG. **21** is a side lobe and back lobe plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz.

[0068] FIG. **22** is a cross-polarization ratio plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz.

DETAIL DESCRIPTION OF EMBODIMENTS

[0069] To improve understanding of the technical solution of the present disclosure for one of ordinary skill in the art, the present disclosure will be described in detail with reference to accompanying drawings and specific implementations.

[0070] Unless otherwise defined, technical or scientific terms used in the present disclosure are intended to have general meanings as understood by one of ordinary skill in the art to which the present disclosure belongs. The words "first", "second" and similar terms used in the present disclosure do not denote any order, quantity, or importance, but are used merely for distinguishing different components from each other. Likewise, the words "a", "an", or "the" and similar referents do not denote a limitation of quantity, but rather denote the presence of at least one. The word "comprising" or "including" or the like means that the element or item preceding the word contains elements or items that appear after the word or equivalents thereof, but does not exclude other elements or items. The terms "connected" or "coupled" and the like are not restricted to physical or mechanical connections, but may include electrical connections, whether direct or indirect. The words "upper", "lower", "left", "right", and the like are merely used to indicate a relative positional relationship, and when an absolute position of the described object is changed, the relative positional relationship may be changed accordingly.

[0071] In a first aspect, an embodiment of the present disclosure provides an antenna, including a first substrate and a second substrate. The first substrate is provided with a radiation structure, and the second substrate is provided with a feed structure feeding the radiation structure.

[0072] Specifically, FIG. **1** is a schematic structural diagram of an antenna according to an embodiment of the present disclosure; FIG. **2** is a schematic structural diagram of an antenna without any radome according to an embodiment of the present disclosure; and FIG. **3** is a schematic structural diagram of a first dielectric substrate in an antenna according to an embodiment of the present disclosure. As shown in FIGS. **1** to **3**, the first substrate includes a first dielectric substrate **10**, a first reference electrode layer **13**, at least one first radiation part **11**, and at least one feeder group. The first dielectric substrate **10** includes a main substrate **101** and a side substrate **102**, the main substrate **101** includes a first surface M**1** and a second surface M**2** disposed opposite to each other in a thickness direction of the main substrate **101**, and the side substrate **102** includes a third surface M**3** and a fourth surface M**4** disposed opposite to each other in a thickness direction of the side substrate. The second surface M**2** of the main substrate **101** is connected to the third surface M**3** of the side substrate **102**, and the side substrate **102** protrudes out of the main substrate **101**. In other words, the main substrate **101** and the side substrate **102** are connected to form an L-shaped first dielectric substrate **10**. The first radiation part **11** is provided on the second surface M**2** of the main substrate **101**. The feeder group includes at least one feeder **12** on the second surface M**2** of the main substrate **101** and extending toward the third surface M**3** of the side substrate **102** (specifically, the feeder **12** may extend onto the third surface M**3**). One feeder **12** in each feeder group is electrically connected to one first radiation part **11**, and different feeders **12** in the feeder group are electrically connected to different radiation parts. For example, for one feeder group, the feeders **12** therein are connected to the first radiation parts **11** in one-to-one correspondence. Specifically, in the embodiments of the present disclosure, only the case where the feeder **12** in each feeder group is directly connected to the first radiation part **11** is taken as an example, but in actual products, the feeder **12** and the first radiation part **11** may be electrically connected in any manner such as coupling.

[0073] FIG. **5** is a schematic structural diagram showing a sixth surface side of a second dielectric substrate in an antenna according to an embodiment of the present disclosure; and FIG. **6** is a schematic structural diagram showing a fifth surface side of a second dielectric substrate in an antenna according to an embodiment of the present disclosure. As shown in FIGS. **5** and **6**, the second substrate includes a second dielectric substrate **20**, a second reference electrode layer **22** and at least one feed structure **21**. The second dielectric substrate **20** includes a fifth surface M**5** and a sixth surface M**6** disposed opposite to each other in a thickness direction of the second dielectric substrate **20**. The fifth surface M**5** of the second dielectric substrate **20** is disposed opposite to the fourth surface M**4** of the side substrate **102**, the second reference electrode layer **22** is disposed on the fifth surface M**5** of the second dielectric substrate **20**, and the feed structure **21** is disposed on the sixth surface M**6** of the second dielectric substrate **20**. The feed structures **21** and the feeder groups are connected in one-to-one correspondence, which means that one feed structure **21** feeds the feeders **12** in one feeder group. Further, since the feed structure **21** has at least one first feed port **211** and one second feed port **212**, one first feed port **211** in each feed structure **21** feeds one feeder **12** in one feeder group. In other words, a microwave signal fed from the second feed port **212** of the feed structure **21** is fed to the feeder **12** connected to the feed structure **21** through the first feed port **211**. In an embodiment of the present disclosure, the feeder **12** extends from the second surface M**2** of the main substrate **101** to the third surface M**3** of the side substrate **102**, while the feed structure **21** is disposed on the sixth surface M**6** of the second dielectric substrate **20**, and the antenna includes a first connection via **1021** running through at least the second reference electrode, the second dielectric substrate **20** and the side substrate **102**. In this case, the first feed port **211** of the feed structure **21** is electrically connected to the corresponding feeder **12** through the first connection via **1021**, to transmit electromagnetic waves to the first radiation part **11** electrically connected to the feeder **12**.

[0074] In an embodiment of the present disclosure, the main substrate **101** and the side substrate **102** are formed into the L-shaped first dielectric substrate **10**, and the feeder **12** connected to the first radiation part **11** extends from the main substrate **101** to the side substrate **102**, while the second substrate is disposed on a side of the side substrate **102**, a portion of the feeder **12** on the side substrate **102** is connected to the first feed port **211** of the feed structure **21** on the second substrate through the first connection via **1021**, where the first connection via **1021** is a hole running through the side substrate **102** and the second dielectric substrate **20** of the second substrate. Therefore, the alignment between the feeder **12** and the corresponding first feed port **211** is facilitated, precise connection is achieved, and the problem of the mis-connection can be avoided.

[0075] It should be noted that although FIG. **1** in the embodiments of the present disclosure only shows the example of four first radiation parts **11**, the number of first radiation parts **11** may be set as required in an actual product. Since there are four first radiation parts **11**, four feeders **12** are also provided in the corresponding feeder group, and also four first feed ports **211** are provided in each feed structure **21**. That is, the feed structure **21** may be a one-to-four power divider.

[0076] Specifically, the one-to-four power divider may include a main path and four branches, where a first end of the main path is used as the second feed port **212**, a second end of the main path is connected to first ends of the four branches, and second ends of the four branches are used as the first feed ports **211**, respectively. In the embodiment of the present disclosure, line widths of the main path and the branches may be designed such that each of the four first feed ports **211** of the one-to-four power divider has an impedance of **50**Q.

[0077] With continued reference to FIG. **1**, in an embodiment of the present disclosure, taking the antenna being a dual-polarized antenna as an example, the antenna includes two feeder groups, i.e., a first feeder group and a second feeder group, and for convenience of description, the feeder **12** in the first feeder group is referred to as a first feeder **121**, and the feeder **12** in the second feeder group is referred to as a second feeder **122**. Accordingly, two corresponding feed structures **21** are provided, which are referred to as a first feed structure **21***a* and a second feed structure **21***b*, respectively, and each of the first feed structure **21***a* and the second feed structure **21***b* may be a one-to-four power divider. Specifically, FIG. **4** is a schematic diagram illustrating a connection of a feeder with a first feed port of a feed structure in an antenna according to an embodiment of the present disclosure. As shown in FIG. **4**, one first feed port **211** of the first feed structure **21***a* is electrically connected to one first feeder **121**, and one first feed port **211** of the second feed structure **21***b* is electrically connected to one second feeder **122**. One first radiation part **11** is electrically connected to one first feeder **121** and one second feeder **122**. For one first radiation part **11** and the first feeder **121** and second feeder **122** electrically connected thereto, a connection node between the first feeder **121** and the first radiation part **11** is a first node, and a connection node between the second feeder **122** and the first radiation part **11** is a second node. In this case, a connection line between the first node and the center of the first radiation part **11** is a first line segment, a connection line between the second node and the center of the first radiation part **11** is a second line segment, and an extending direction of the first line segment is intersected with an extending direction of the second line segment. For example: the extending direction of the first line segment is perpendicular to the extending direction of the second line segment, in which case the antenna can realize polarization directions of 0°/90°.

[0078] Further, with continued reference to FIG. **1**, in addition to the above structures, the dual-polarized antenna in the embodiment of the present disclosure further includes a third substrate including a third dielectric substrate **30**, and a second radiation part **31** on the third dielectric substrate **30**. Specifically, the third dielectric substrate **30** includes a seventh surface M**7** and an eighth surface M**8** disposed opposite to each other. The second radiation part **31** may be disposed on the seventh surface M7, or on the eighth surface M**8**, and a certain spacing is provided between the seventh surface M**7** of the third dielectric substrate **30** and the second surface M**2** of the main substrate **101**. Orthographic projections of one second radiation part **31** and one first radiation part **11** on a plane where the main substrate **101** is located are at least partially overlapped. The opposite first radiation part **11** and second radiation part **31** increase the radiation area of the radiating elements, thereby effectively improving the radiation efficiency.

[0079] The embodiment of the present disclosure only shows the example of the antenna being a dual-polarized antenna, and since a connection between the first feed structure **21***a* and the first feeder **121**, and a connection between the first feeder **121** and the first radiation part **11**, are the same as a connection between the second feed structure **21***b* and the second feeder **122**, and a connection between the second feeder **122** and the first radiation part **11**, respectively, and for convenience of description, the following description will be made by only taking the case where the first feed structure **21***a* is electrically connected to the first radiation part **11** through the first feeder **121** as an example.

[0080] In some examples, FIG. **7** is a partially enlarged view at position Q**1** in FIG. **6**; and FIG. **8** is a partial structural diagram of a sixth surface side of a second dielectric substrate in an antenna according to an embodiment of the present disclosure. As shown in FIGS. **5** to **8**, the first reference electrode layer **13** in the first substrate includes a first reference sub-electrode and a second reference sub-electrode connected to each other, the first reference sub-electrode is disposed on the first surface M**1** of the main substrate **101**, and the second reference sub-electrode is disposed on the fourth surface M**4** of the side substrate **102**. In this case, the second reference sub-electrode and the second reference electrode layer **22** are bonded and electrically connected to each other. The antenna includes at least one first opening **221** and at least one radio frequency line **40**. The number of first openings **221** and the number of radio frequency lines **40** both correspond to the number of feed structures **21**, and since the antenna includes two feed structures **21**, two first openings **221** and two radio frequency lines **40** are also provided.

[0081] Specifically, the two first openings **221** each run through the first reference sub-electrode and the second reference electrode layer **22**, and are each provided with a first connection electrode **23**. The first connection electrode **23** is disposed on the third surface M**3** of the second dielectric substrate **20**. For the first connection electrode **23** in one of the first openings **221**, the second feed port of the first feed structure **21***a* is connected to the first connection electrode **23** through a second connection via **201** running through at least the second dielectric substrate **20**, while the first connection electrode **23** is further connected to a core of one radio frequency line **40** through a third connection via **202** running through at least the second dielectric substrate **20**. For the first connection electrode **23** in the other first opening **221**, the second feed port of the second feed structure **21***b* is connected to the first connection electrode **23** through a second connection via **201** running through at least the second dielectric substrate **20**, while the first connection electrode **23** is further connected to a core of the other radio frequency line **40** through a third connection via **202** running through at least the second dielectric substrate **20**. In this manner, it is achieved that one radio frequency line **40** feeds the first feeder **121** through the first feed structure **21***a*, and the other radio frequency line **40** feeds the second feeder **122** through the second feed structure **21***b*.

[0082] Further, the antenna further includes two second connection electrodes **24** on the second dielectric substrate **20**, and the two second connection electrodes **24** are each connected to the second reference electrode layer **22** through a fourth connection via running through the second dielectric substrate **20**. The third connection via **202**, electrically connecting the core of the radio frequency line **40** and the first connection electrode **23**, runs through not only the second dielectric substrate **20** as described above, but also the second connection electrode **24**. A reference electrode layer (e.g., ground layer) of the radio frequency line **40** is electrically connected to the second reference electrode layer **22** through the second connection electrode **24**. A plurality of fourth connection vias electrically connecting each second connection electrode **24** and the second reference electrode layer **22** may be provided to ensure stable connection between the second reference electrode layer **22** and the second connection electrode **24**.

[0083] Still further, with continued reference to FIG. **3**, a second opening **1022** is formed in the side substrate **102** of the first dielectric substrate **10**, and an orthographic projection of the second opening **1022** on a plane where the second dielectric substrate **20** is located covers an orthographic projection of the first opening **221** on the plane where the second dielectric substrate **20** is located. In this manner, the second opening **1022** in the side substrate **102** can facilitate connection between the first connection electrode **23** and the second feed port **212** of the feed structure **21**. Particularly, when the feed port of the feed structure **21** is welded to the first connection electrode **23**, the second opening **1022** formed at such a position of the side substrate **102** can prevent short circuit between the first connection electrode **23** and the first reference electrode layer **13**. The second opening **1022** may be a U-shaped opening formed in the side substrate **102**, and an orthographic projection of the U-shaped opening on the plane where the second dielectric substrate **20** is located covers orthographic projections of the two first openings **221** on the plane where the second dielectric substrate **20** is located. The second opening **1022** may alternatively be an annular opening. Apparently, the second opening **1022** may further include two sub-openings arranged in one-to-one correspondence with the two first openings **221**. The sub-openings may be U-shaped or annular openings.

[0084] Specifically, the second connection via **201** runs through not only the second dielectric substrate **20**, but also the first connection electrode **23**, while the third connection via **202** runs through not only the second dielectric substrate **20**, but also the first connection electrode **23**. The first connection electrode **23** is welded to the second feed port **212** of the feed structure **21** through the second connection via **201**, and the core of the radio frequency line **40** is welded to the first connection electrode **23** through the third connection via **202**. In other words, the second feed port **212** of the feed structure **21** is connected to the first connection electrode **23** by welding, and the radio frequency line **40** is also connected to the first connection electrode **23** by welding, so that secure fixation and stable connection are implemented.

[0085] In some examples, with continued reference to FIG. **4**, the first feed port **211** of the feed structure **21** is connected to the feeder **12** by a rivet **60** running through the first connection via **1021**. In other words, the first connection via **1021** will run through the first feed port **211** and the feeder **12**, and then the rivet **60** is inserted into the first connection via **1021** to connect the first feed port **211** and the feeder **12**. Specifically, the first feed port **211** of the first feed structure **21***a* is connected to the first feeder **121** by a rivet **60** running through a first connection via **1021**, and the first feed port **211** of the second feed structure **21***b* is connected to the second feeder **122** by a rivet **60** running through a first connection via **1021**.

[0086] In some examples, the first feed port **211** of the feed structure **21** is connected to the feeder **12** by welding together through the first connection via **1021**. Specifically, the first feed port **211** of the first feed structure **21***a* is welded to the first feeder **121** through a first connection via **1021**, and the first feed port **211** of the second feed structure **21***b* is welded to the second feeder **122** through a first connection via **1021**.

[0087] In some examples, FIG. **9***a* is a schematic diagram showing a positional relationship between a first radiation part and a director in an antenna according to an embodiment of the present disclosure. As shown in FIG. **9***a*, the antenna further includes at least one director **13** on the second surface **M2** of the main substrate **101** and in one-to-one correspondence with the first radiation part **11**. The director **13** is located on a side of the first radiation part **11** away from the side substrate **102**. Since four first radiation parts **11** are provided in FIG. **1**, also four directors **13** are provided. Each director **13** is configured to change current distribution at an edge of the corresponding first radiation part **11**, so that the current is restrained and further regularized, and thereby isolation of the antenna is improved. FIG. **10** is an isolation plot of an antenna with and without a director according to an embodiment of the present disclosure. As shown in FIG. **10**, **S1** is an isolation curve of an antenna with a director **13**, while S2 is an isolation curve of an antenna without any director **13**. It can be seen that the isolation of the antenna is significantly improved by introducing the director **13**.

[0088] Further, FIG. **9***a* only shows an exemplary structure of the director **13**, including a first sub-electrode and a second sub-electrode, where the first sub-electrode is located on a side of the first radiation part **11** away from a side substrate, and the second sub-electrode is connected to a side of the first sub-electrode away from the first radiation part **11**. It should be understood that the director **13** is not limited to the structure shown in FIG. **9***a*, and other structures of the director **13** is also possible.

[0089] In some examples, in addition to the above structures, the antenna further includes a radome **50**, and the first substrate, the second substrate, and the third substrate of the antenna are all located within an accommodation space defined by the radome **50**. The first substrate and the third substrate are disposed on upper and lower surfaces of the radome **50**, and bonded to the upper and lower surfaces of the radome **50**, respectively, by an optical clear adhesive (OCA), for example. Specifically, the radome **50** includes a first base material and a second base material disposed opposite to each other, the first dielectric substrate **10** with the first reference electrode layer **13** is disposed on a side of the first base material close to the second base material, and the third dielectric substrate **30** with the second radiation part **31** is disposed on a side of the second base material close to the first base material.

[0090] Further, the radome **50** may be made of a material including plastic, such as: polycarbonate (PC), copolymers of cycloolefin (COP), or acrylic/polymethyl methacrylate (PMMA).

[0091] In some examples, FIG. **11** is a schematic diagram showing a fixation manner of a first dielectric substrate and a third dielectric substrate in an antenna according to an embodiment of the present disclosure; and FIG. **12** is a partially enlarged view at position Q2 in FIG. **11**. As shown in FIGS. **11** and **12**, a plurality of sets of slide rails **501** are provided on two opposite side walls of the radome **50**, and the main substrate **101** and the third dielectric substrate **30** are insertable into different sets of slide rails **501**, so that a certain spacing is provided between the main substrate **101** and the third dielectric substrate **30**. In this case, the slide rails **501** on the side walls of the radome **50** can be used as supports for the main substrate **101** and the third dielectric substrate **30**. Apparently, where three or more sets of slide rails **501** are provided, a distance between the main substrate **101** and the first dielectric substrate **10** can be adjusted by selecting different sets of slide rails **501** to support the main substrate **101** and the third dielectric substrate **30**, so that a relative distance between the first substrate and the third substrate in the antenna is adjustable, and thus one set of antennas can be shared by multiple bands.

[0092] In some examples, FIG. **13** is a schematic diagram showing another fixation manner of a first dielectric substrate and a third dielectric substrate in an antenna according to an embodiment of the present disclosure. As shown in FIG. **13**, the adjustment of the distance between the first substrate and the third substrate can also be implemented by supporting the main substrate **101** of the first dielectric substrate **10** and the third dielectric substrate **30** with support components. Each support component may be a height-adjustable support component to adjust the spacing between the first substrate and the third substrate, that is, adjust a spacing between the first radiation part **11** and the second radiation part **31**. For example: the support components are rotating screws. Apparently, FIG. **14** is a schematic diagram showing yet another fixation manner of a first dielectric substrate and a third dielectric substrate in an antenna according to an embodiment of the present disclosure. As shown in FIG. **14**, the support components may include multiple groups of support components of different heights, and the distance between the first substrate and the third substrate is maintained by selecting different groups of support components.

[0093] Further, the support components may be provided at four corners of the main substrate **101**, thereby providing stable support for the first substrate and the third substrate.

[0094] In some examples, the first radiation parts **11** and the second radiation parts **31** are arranged in one-to-one correspondence, and have the same pattern. For example: the first radiation part **11** and the second radiation part **31** each have a circular or polygonal shape or the like. In one example, the first radiation part **11** and the second radiation part **31** each have a centrosymmetric pattern, and orthographic projections of centers of the first radiation part **11** and the second radiation part **31** on the first surface **M1** of the main substrate **101** coincide.

[0095] Further, referring to FIG. **9***a*, a protrusion is connected to the first radiation part **11**, forms an integral structure with the first radiation part **11**, and functions to improve a cross-polarization ratio of the antenna. Two protrusions may be provided and connected to the first radiation part **11**, and disposed opposite to each other. For one first radiation part **11** and the first feeder **121**, the second feeder **122** and the two protrusions electrically connected to the first radiation part **11**, a connection node between the first feeder **121** and the first radiation part **11** is a first node, a connection node between the second feeder **122** and the first radiation part **11** is a second node, the first node and the second node divide an outline of the first radiation part **11** into a first portion and a second portion, one of the two protrusions is connected to the first portion, and the other is connected to the second portion. Specifically, one of the protrusions is connected to a center of the first portion, and the other is connected to a center of the second portion.

[0096] FIG. **9***b* is a top view of a second radiation part in an antenna according to an embodiment of the present disclosure. As shown in FIG. **9***b*, a protrusion is connected to the second radiation part **31**, forms an integral structure with the second radiation part **31**, and functions to improve a cross-polarization ratio of the antenna. Two protrusions may be provided and connected to the second radiation part **31**, and disposed opposite to each other. The protrusions connected to the second radiation part **31** may correspond to the protrusions connected to the first radiation part **11**. Apparently, where the protrusions are connected to the second radiation part **31**, the protrusions connected to the first radiation part **11** may be omitted.

[0097] In some embodiments, the antenna in the embodiments of the present disclosure may be a transparent antenna, and in this case, the conductive structures on the first substrate and the third substrate of the antenna are all transparent structures. Specifically, in an embodiment of the present disclosure, the first reference electrode layer **13**, the first radiation part **11**, the second radiation part **31**, the first feeder **121**, and the second feeder **122** each have a metal mesh structure, or are each made of a transparent conductive material, such as graphene or indium tin oxide or other transparent materials.

[0098] Further, FIG. **15** is a schematic structural diagram of a metal mesh according to an embodiment of the present disclosure. As shown in FIG. **15**, where the first reference electrode layer **13**, the first radiation part **11**, the second radiation part **31**, the first feeder **121**, and the second feeder **122** each adopt a metal mesh, the metal mesh may include a plurality of first metal lines and a plurality of second metal lines arranged crosswise with each other. The first metal lines are arranged side by side in a first direction and extend in a second direction; while the second metal lines are arranged side by side in the first direction and extend in a third direction. Extending directions of the first metal lines and the second metal lines of the metal mesh may be perpendicular to each other, and in this case, square or rectangular hollowed-out portions are formed. Apparently, the extending directions of the first metal lines and the second metal lines of the metal mesh may be not perpendicular to each other. For example: the extending directions of the first metal lines and the second metal lines form an angle of 45°, and in this case, diamond hollowed-out portions are formed.

[0099] In some examples, the first metal lines **301** and the second metal lines **302** of the metal mesh preferably have the same line width, line thickness and line spacing, but apparently, different line widths, line thicknesses and line spacings are also possible. For example: the first metal line and the second metal line each have a line width W1 of about 1 μm to 30 μm, a line spacing W2 of about 50 μm to 250 μm, and a line thickness of about 0.5 μm to 10 μm. The metal mesh in the embodiments of the present disclosure may be formed on a flexible base material by a process including, but not limited to, imprinting or etching, and then bonded to the first dielectric substrate **10**/the third dielectric substrate **30**. For example: the first reference electrode layer **13** is formed on a first flexible base material by a process including, but not limited to, imprinting or etching, the first radiation part **11** and the feeder **12** are formed on a second flexible base material by a process including, but not limited to, imprinting or etching, the first flexible base material is bonded to the first surface M**1** of the main substrate **101** and the fourth surface M**4** of the side substrate **102**, and the second flexible base material is bonded to the second surface M**2** of the main substrate **101** and the third surface M**3** of the side substrate **102**. The second radiation part **31** is formed on a third flexible base material by a process including, but not limited to, imprinting or etching, and the third flexible base material is bonded to the eighth surface M**8** of the third dielectric substrate **30**. Each of the first flexible base material, the second flexible base material, and the third flexible base material may be a flexible film made of a material including, but not limited to, polyethylene terephthalate (PET), polyimide (PI), or the like.

[0100] In some examples, each of the first dielectric substrate **10** and the third dielectric substrate **30** is a support for a flexible base material, and is made of a material including, but not limited to, polycarbonate (PC), copolymers of cycloolefin (COP), or acrylic/polymethyl methacrylate (PMMA) or the like. In addition, the first flexible base material and the second flexible base material may be bonded to the first dielectric substrate **10** by an optical clear adhesive, and likewise, the third flexible base material may also be bonded to the third dielectric substrate **30** by an optical clear adhesive.

[0101] In some examples, the second substrate is a printed circuit board (PCB).

[0102] In some examples, the antenna in the embodiments of the present disclosure may be a transparent antenna that can be applied to glazing systems including, but not limited to, those for automobiles, trains (including high-speed trains), aircrafts, buildings, and the like. The transparent antenna may be fixed to an inner side of the glazing (a side close to the room). Since the transparent antenna has high optical transmittance, it has little influence on the transmittance of the glazing while enabling a communication function, and the transparent antenna also represents a trend of beautified antennas.

[0103] To better clarify the performance of the embodiments of the present disclosure, the antenna shown in FIG. **1** is taken as an example for simulation of the antenna at the operating frequencies of 2.25 GHz to 2.45 GHz.

[0104] FIG. **16** is a standing wave plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz. As shown in FIG. **16**, it can be seen that the antenna has excellent broadband characteristics, and can cover the frequency band of 2.25 GHz to 2.45 GHz under the standard of a standing-wave ratio less than 1.5 in the example, thereby ensuring wider application scenarios of the antenna.

[0105] FIG. **17** is an isolation plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz. As shown in FIG. **17**, it can be seen that the antenna has excellent isolation, and has an isolation ratio less than −24 dB in the example, thereby ensuring wider application scenarios of the antenna.

[0106] FIG. **18** is a gain plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz. As shown in FIG. **18**, it can be seen that the antenna has excellent gain characteristics, and has a gain higher than 12 dBi in the example, thereby ensuring wider application scenarios of the antenna.

[0107] FIG. **19** is a 0° direction plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz. As shown in FIG. **19**, it can be seen that the transparent antenna of the present disclosure has excellent radiation characteristics, i.e., 65±2° in the 0° direction in the example, thereby ensuring wider application scenarios of the antenna.

[0108] FIG. **20** is a 900 direction plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz. As shown in FIG. **20**, it can be seen that the antenna has excellent radiation characteristics, i.e., 20.5±0.5° in the 90° direction in the example, thereby ensuring wider application scenarios of the antenna.

[0109] FIG. **21** is a side lobe and back lobe plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz. As shown in FIG. **21**, it can be seen that the antenna has excellent radiation characteristics, with an antenna side lobe less than 15 dB and a back lobe less than 23 dB.

[0110] FIG. **22** is a cross-polarization ratio plot of the antenna in FIG. **1** at 2.25 GHz to 2.45 GHz. As shown in FIG. **22**, it can be seen that the antenna has an excellent cross-polarization ratio, with an axial cross-polarization ratio greater than 22.

[0111] In a second aspect, an embodiment of the present disclosure provides an electronic device, including any antenna as described above.

[0112] In some examples, the antenna further includes a transceiver unit, a radio frequency transceiver, a signal amplifier, a power amplifier, and a filter unit. The antenna may be used as a transmitting antenna or a receiving antenna in a communication device. The transceiver unit may include a baseband and a receiving end. The baseband provides signals of at least one frequency band, for example, 2G signals, 3G signals, 4G signals, 5G signals, or the like, and transmits the signals of the at least one frequency band to the radio frequency transceiver. After being received by the antenna in the communication system, the signals may be processed by the filter unit, the power amplifier, the signal amplifier, and the radio frequency transceiver, and then transmitted to the receiving end in the transceiver unit. The receiving end may be, for example, an intelligent gateway, or the like.

[0113] Further, the radio frequency transceiver is connected to the transceiver unit, and configured to modulate a signal sent from the transceiver unit, or demodulate a signal received by the antenna and transmit the demodulated signal to the transceiver unit. Specifically, the radio frequency transceiver may include a transmitting circuit, a receiving circuit, a modulation circuit, and a demodulation circuit. After being received by the transmitting circuit, multiple types of signals provided by the baseband can be modulated by the modulation circuit and then transmitted to the antenna. Then, the antenna receives and transmits the signals to the receiving circuit of the radio frequency transceiver which further transmits the signals to the demodulation circuit, where the signals are demodulated by the demodulation circuit and then transmitted to the receiving end.

[0114] Further, the radio frequency transceiver is connected to the signal amplifier and the power amplifier which are further connected to the filter unit, and the filter unit is connected to at least one antenna. In the process of transmitting signals by a communication system, the signal amplifier is configured to increase signal-to-noise ratio of signals output from the radio frequency transceiver, and then transmit the signals to the filter unit. The power amplifier is configured to amplify power of the signals output from the radio frequency transceiver, and then to transmit the signals to the filter unit. The filter unit may specifically include a duplexer and a filter circuit. The filter unit combines the signals output from the signal amplifier and the power amplifier, filters noise waves, and then transmits the signals to the antenna to be radiated. In the process of receiving signals by a communication system, after being received by the antenna, the signals are transmitted to the filter unit, where the signals received by the antenna are filtered to remove noise waves by the filter unit and then transmitted to the signal amplifier and the power amplifier. The signal amplifier increases a gain of the signals received by the antenna to increase a signal-to-noise ratio of the signals; while the power amplifier amplifies a power of the signals received by the antenna. After being processed by the power amplifier and the signal amplifier, the signals received by the antenna are transmitted to the radio frequency transceiver, and then to the transceiver unit.

[0115] In some examples, the signal amplifier may include various types of signal amplifiers, such as a low noise amplifier, which is not limited herein.

[0116] In some examples, the antenna provided in the embodiments of the present disclosure further includes a power management unit, which is connected to the power amplifier and provides a voltage for signal amplification for the power amplifier.

[0117] It will be appreciated that the above implementations are merely exemplary implementations for the purpose of illustrating the principle of the present disclosure, and the present disclosure is not limited thereto. It will be apparent to one of ordinary skill in the art that various modifications and variations may be made without departing from the spirit or essence of the present disclosure. Such modifications and variations should also be considered as falling into the protection scope of the present disclosure.

1. An antenna, comprising a first substrate and a second substrate; wherein

the first substrate comprises:

a first dielectric substrate comprising a main substrate and a side substrate, wherein the main substrate has a first surface and a second surface opposite to each other in a thickness direction of the main substrate, and the side substrate comprises a third surface and a fourth surface opposite to each other in a thickness direction of the side substrate; and the second surface of the main substrate is connected to the third surface of the side substrate, and the side substrate protrudes out of the second surface of the main substrate;

a first reference electrode layer on the first surface and the fourth surface;

at least one first radiation part on the second surface; and

at least one feeder group comprising at least one feeder, wherein the feeder is provided on the second surface and extends toward the third surface, each feeder in each feeder group is electrically connected to one first radiation part, and different feeders in the feeder group are electrically connected to different first radiation parts; and

the second substrate comprises:

a second dielectric substrate having a fifth surface and a sixth surface opposite to each other in a thickness direction of the second dielectric substrate; wherein the fifth surface is opposite to the fourth surface;

a second reference electrode layer on the fifth surface; and

at least one feed structure on the sixth surface, wherein the feed structure corresponds to the feeder group, and for the corresponding feed structure and feeder group, each first feed port in the feed structure is electrically connected to one feeder in the feeder group through a first connection via; and the first connection via runs through at least the side substrate, the second reference electrode layer, and the second dielectric substrate.

2. The antenna according to claim **1**, wherein the first reference electrode layer comprises a first reference sub-electrode and a second reference sub-electrode connected to each other, the first reference sub-electrode is on the first surface, and the second reference sub-electrode is on the fourth surface;

the second reference sub-electrode is electrically connected to the second reference electrode layer; and

the antenna further comprises:

at least one first opening running through the second reference sub-electrode and the second reference electrode layer;

at least one first connection electrode on the fifth surface, wherein each first connection electrode is in one first opening, and a second feed port of one feed structure is electrically connected to the first connection electrode through a second connection via; and the second connection via runs through at least the second dielectric substrate; and

at least one radio frequency line, a core of each of which is electrically connected to the first connection electrode through a third connection via; wherein the third connection via runs through at least the second dielectric substrate.

3. The antenna according to claim **2**, further comprising:

at least one second connection electrode on the sixth surface and electrically connected to the second reference electrode layer through a fourth connection via running through the second dielectric substrate; wherein

the third connection via further runs through the second connection electrode, and a reference electrode layer of the radio frequency line is electrically connected to the second connection electrode.

4. The antenna according to claim **2**, further comprising a second opening running through the side substrate, wherein an orthographic projection of the second opening on a plane where the second dielectric substrate is located covers an orthographic projection of the first opening on the plane where the second dielectric substrate is located.

5. The antenna according to claim **3**, wherein the second connection via and the third connection via each further run through the first connection electrode, the first connection electrode is welded to the second feed port of the feed structure through the second connection via, and a core of the radio frequency line is welded to the first connection electrode through the third connection via.

6. The antenna according to claim **1**, wherein the first feed port is riveted or welded with the feeder by a connector through the first connection via.

7. The antenna according to claim **1**, wherein the at least one feeder group comprises a first feeder group and a second feeder group; a plurality of first feeders are provided in the first feeder group, and a plurality of second feeders are provided in the second feeder group; the at least one feed structure comprises a first feed structure and a second feed structure; the first feed structure and the second feed structure each comprise a plurality of first feed ports and one second feed port, each of the first feed ports in the first feed structure is electrically connected to one of the first feeders, and each of the first feed ports in the second feed structure is electrically connected to one of the second feeders.

8. The antenna according to claim **1**, further comprising: at least one director on the second surface and in one-to-one correspondence with the first radiation part, wherein the director is on a side of the corresponding first radiation part away from the side substrate.

9. The antenna according to claim **1**, further comprising:

a third dielectric substrate having a seventh surface and an eighth surface opposite to each other in a thickness direction of the third dielectric substrate, wherein the seventh surface is opposite to, and spaced by a spacing from, the second surface; and

at least one second radiation part on the seventh surface or the eighth surface, wherein orthographic projections of each second radiation part and one corresponding first radiation part on the first surface are at least partially overlapped.

10. The antenna according to claim **9**, further comprising:

a plurality of support components between the second surface and the seventh surface to provide a spacing between the first radiation part and the second radiation part.

11. The antenna according to claim **10**, wherein each support component is a height-adjustable support component to adjust the spacing between the first radiation part and the second radiation part.

12. The antenna according to claim **9**, further comprising:

a radome, wherein two opposite side walls of the radome are provided with a plurality of sets of slide rails; and the main substrate and the third dielectric substrate are insertable into different sets of slide rails.

13. The antenna according to claim **9**, further comprising:

a radome comprising a first base material and a second base material opposite to each other; wherein the first dielectric substrate with the first reference electrode layer is on a side of the first base material close to the second base material; and the third dielectric substrate with the second radiation part is on a side of the second base material close to the first base material.

14. The antenna according to claim **9**, wherein at least one of the first radiation part, the second radiation part, the first reference electrode layer, or the feeder comprises a metal mesh.

15. The antenna according to claim **14**, wherein the metal mesh has a line width in a range of 2 μm to 30 μm, a line spacing in a range of 50 μm to 250 μm, and a line thickness in a range of 1 μm to 10 μm.

16. The antenna according to claim **9**, wherein the third dielectric substrate comprises any one of polycarbonate plastic, cyclic olefin polymer plastic, or polymethyl methacrylate.

17. The antenna according to claim **1**, wherein the first dielectric substrate comprises any one of polycarbonate plastic, cyclic olefin polymer plastic, or polymethyl methacrylate.

18. The antenna according to claim **1**, wherein the second substrate is a printed circuit board.

19. The antenna according to claim **1**, wherein the main substrate and the side substrate form an integral structure.

20. An electronic device, comprising the antenna according to claim **1**.

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