



(11)

**EP 4 531 205 A1**

(12)

**EUROPEAN PATENT APPLICATION**  
published in accordance with Art. 153(4) EPC

(43) Date of publication:  
**02.04.2025 Bulletin 2025/14**

(51) International Patent Classification (IPC):  
**H01Q 1/36** <sup>(2006.01)</sup> **H01Q 1/52** <sup>(2006.01)</sup>

(21) Application number: **23859232.3**

(52) Cooperative Patent Classification (CPC):  
**H01Q 1/22; H01Q 1/36; H01Q 1/48; H01Q 1/50; H01Q 1/52**

(22) Date of filing: **24.08.2023**

(86) International application number:  
**PCT/CN2023/114654**

(87) International publication number:  
**WO 2024/046199 (07.03.2024 Gazette 2024/10)**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA**  
Designated Validation States:  
**KH MA MD TN**

(72) Inventors:  
• **WANG, Hanyang**  
Shenzhen, Guangdong 518129 (CN)  
• **XUE, Liang**  
Shenzhen, Guangdong 518129 (CN)  
• **SUN, Sining**  
Shenzhen, Guangdong 518129 (CN)  
• **HOU, Meng**  
Shenzhen, Guangdong 518129 (CN)

(30) Priority: **29.08.2022 CN 202211040416**

(74) Representative: **Epping - Hermann - Fischer**  
**Patentanwalts-gesellschaft mbH**  
**Schloßschmidstraße 5**  
**80639 München (DE)**

(71) Applicant: **Huawei Technologies Co., Ltd.**  
**Shenzhen, Guangdong 518129 (CN)**

(54) **ELECTRONIC DEVICE**

(57) Embodiments of this application provide an electronic device, including a plurality of antenna elements. The plurality of antenna elements are arranged in different manners for high isolation in a case of a small spacing, to meet a requirement of a MIMO system. The electronic device includes a first antenna element, a second antenna element, a first resonant connector, and a first electronic element. The first antenna element includes a first radiator and a first feed element, the second antenna element includes a second radiator and a second feed element, and the first feed element is different from the second feed element. A first end of the first resonant connector is electrically connected to the first radiator, a second end of the first resonant connector is electrically connected to the second radiator, and the first electronic element is electrically connected between a ground plane and the first resonant connector. The first radiator and the second radiator are disposed in parallel and non-collinearly, and ground ends of the first radiator and the second radiator are away from each other.

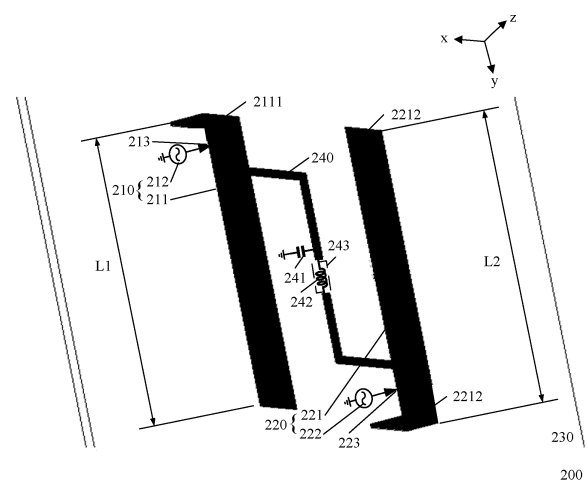


FIG. 25

## Description

[0001] This application claims priority to Chinese Patent Application No. 202211040416.7, filed with the China National Intellectual Property Administration on August 29, 2022 and entitled "ELECTRONIC DEVICE", which is incorporated herein by reference in its entirety.

## TECHNICAL FIELD

[0002] This application relates to the field of wireless communication, and in particular, to an electronic device.

## BACKGROUND

[0003] With rapid development of wireless communication technologies, in addition to making calls, sending SMS messages, and taking photos, an electronic device can be further used for listening to music online, watching online movies, making real-time video calls, and the like, which covers various applications such as a call application, a movie and television entertainment application, and an e-commerce application in people's life. In this case, a plurality of functional applications need to upload and download data over a wireless network. Therefore, high-speed data transmission becomes extremely important.

[0004] A multi-input multi-output (multi-input multi-output, MIMO) technology plays a very important role in a 5th generation (5th generation, 5G) wireless communication system. MIMO is a technology for sending and receiving signals through a plurality of antennas in the field of wireless communication. A MIMO system includes a plurality of antenna elements that can operate simultaneously for sending and receiving data within a same time periodicity, so that a data throughput (throughput) can be greatly increased, and a higher data transmission rate is provided. However, in an increasingly compact layout, it is still a great challenge for the electronic device, for example, a mobile phone, to send and receive signals through a plurality of antennas to obtain good MIMO performance.

## SUMMARY

[0005] Embodiments of this application provide an electronic device. The electronic device may include a plurality of antenna elements. The plurality of antenna elements are arranged in different manners for high isolation in a case of a small spacing, to meet a requirement of a MIMO system.

[0006] According to a first aspect, an electronic device is provided, including: a ground plane; a first antenna element, including a first parasitic stub, a first radiator, and a first feed element, where the first radiator includes a first feed point, and the first feed element is coupled to the first radiator through the first feed point; and a second antenna element, including a second radiator and a

second feed element, where the second radiator includes a second feed point, the second feed element is coupled to the second radiator through the second feed point, the first feed element is different from the second feed element, and a first end of the first radiator, a first end of the second radiator, and a second end of the first parasitic stub are all coupled to the ground plane; and the first end of the first radiator and the first end of the second radiator are ground ends disposed on a same side, and the first end of the first radiator and the second end of the first parasitic stub are ground ends disposed on different sides.

[0007] According to the technical solution in embodiments of this application, the ground end of the first radiator and the ground end of the second radiator are disposed on the same side, to form a weakly-coupled structure. The ground end of the first radiator and the ground end of the first parasitic stub are disposed on different sides, to form a strongly-coupled structure. The first parasitic stub generates a resonance by using an electrical signal fed by the first radiator, to expand an operating frequency band of the first antenna element.

[0008] With reference to the first aspect, in some implementations of the first aspect, the first radiator and the second radiator are serialized.

[0009] In some implementations of the first aspect, the first radiator and the second radiator are disposed collinearly.

[0010] With reference to the first aspect, in some implementations of the first aspect, the first radiator and the second radiator are juxtaposed.

[0011] According to the technical solutions in embodiments of this application, the first radiator and the second radiator are disposed in parallel and non-collinearly.

[0012] With reference to the first aspect, in some implementations of the first aspect, the first radiator and the first parasitic stub are juxtaposed.

[0013] According to the technical solutions in embodiments of this application, the first radiator and the first parasitic stub are disposed in parallel and non-collinearly.

[0014] With reference to the first aspect, in some implementations of the first aspect, the first radiator and the first parasitic stub are serialized.

[0015] According to the technical solutions in embodiments of this application, the first radiator and the first parasitic stub are disposed collinearly.

[0016] With reference to the first aspect, in some implementations of the first aspect, both the first radiator and the second radiator extend in a first direction, a second end of the first radiator is an open end, and a second end of the second radiator is an open end, where that the first end of the first radiator and the first end of the second radiator are ground ends disposed on a same side means that the first end of the first radiator is on a first side in the first direction, the second end of the first radiator is on a second side in the first direction, the first end of the second radiator is on the first side in the first direction, and the second end of the second radiator is on

the second side in the first direction.

**[0017]** With reference to the first aspect, in some implementations of the first aspect, the first end of the first radiator and the first end of the second radiator are ground ends disposed on a same side, the first end of the first radiator is located on a first side of a virtual axis of the first radiator, and the first end of the second radiator is located on a first side of a virtual axis of the second radiator.

**[0018]** With reference to the first aspect, in some implementations of the first aspect, both the first radiator and the first parasitic stub extend in the first direction, the second end of the first radiator is an open end, and a first end of the first parasitic stub is an open end, where that the first end of the first radiator and the second end of the first parasitic stub are ground ends disposed on different sides means that the first end of the first radiator is on the first side in the first direction, the second end of the first radiator is on the second side in the first direction, the first end of the first parasitic stub is on the first side in the first direction, and the second end of the first parasitic stub is on the second side in the first direction.

**[0019]** With reference to the first aspect, in some implementations of the first aspect, the first end of the first radiator and the second end of the first parasitic stub are ground ends disposed on different sides, the first end of the first radiator is located on a first side of a virtual axis of the first radiator, and the second end of the first parasitic stub is located on a second side of a virtual axis of the first parasitic stub.

**[0020]** With reference to the first aspect, in some implementations of the first aspect, the electronic device further includes a first resonant connector and a first electronic element, where a first end of the first resonant connector is coupled to the first radiator, and a second end of the first resonant connector is coupled to the first parasitic stub; and a first end of the first electronic element is coupled to the first resonant connector, and a second end of the first electronic element is coupled to the ground plane for grounding.

**[0021]** According to the technical solutions in embodiments of this application, it should be understood that a frequency of a resonance generated in a first resonance mode (for example, an HWM) of the first antenna element and a frequency of a resonance generated in a second resonance mode (for example, an OWM) of the first antenna element may be adjusted through the first resonant connector disposed between the first radiator and the first parasitic stub and the first electronic element connected in parallel between the first resonant connector and the ground plane, so that the resonances generated in the two resonance modes are close to each other to form a wide resonance frequency band, to expand an operating bandwidth of the first antenna element. Alternatively, the frequencies of the resonances generated in the two resonance modes may be away from each other, so that the resonances generated in the two resonance modes are away from each other. In this case, an oper-

ating frequency band of the first antenna element includes two different communication frequency bands.

**[0022]** Similarly, in a case in which no first resonant connector is disposed between the first radiator and the first parasitic stub, same technical effect may also be achieved by adjusting the distance between the first radiator and the first parasitic stub.

**[0023]** With reference to the first aspect, in some implementations of the first aspect, the second antenna element further includes a second parasitic stub, and a second end of the second parasitic stub is coupled to the ground plane for grounding; the first radiator and the first parasitic stub are juxtaposed, and the second radiator and the second parasitic stub are juxtaposed. Alternatively, the second radiator and the second parasitic stub are serialized, and the first end of the second radiator and the second end of the second parasitic stub are ground ends disposed on different sides.

**[0024]** In some implementations of the first aspect, a first projection and a third projection are parallel to each other in the first direction and at least partially overlap in a second direction; a second projection and a fourth projection are parallel to each other in the first direction and at least partially overlap in the second direction, or a second projection and a fourth projection are disposed along a same straight line in the first direction, where the fourth projection is a projection of the second parasitic stub on a plane on which the ground plane is located; and a distance between the first end of the second radiator and the first end of the second parasitic stub is less than a distance between the first end of the second radiator and the second end of the second parasitic stub.

**[0025]** According to the technical solution in embodiments of this application, the ground end of the second radiator and the ground end of the second parasitic stub are away from each other, and are arranged on different sides, to form a strongly-coupled structure. The second parasitic stub generates a resonance by using an electrical signal fed by the second radiator, to expand an operating frequency band of the second antenna element.

**[0026]** With reference to the first aspect, in some implementations of the first aspect, the first end of the first resonant connector is located between the first end of the first radiator and a midpoint of the first radiator; and/or the second end of the first resonant connector is located between the second end of the first parasitic stub and a midpoint of the first parasitic stub.

**[0027]** With reference to the first aspect, in some implementations of the first aspect, a physical length L1 of the first radiator and a physical length L2 of the second radiator satisfy the following:  $L1 \times 80\% \leq L2 \leq L1 \times 120\%$ ; and the physical length L1 of the first radiator and a physical length L3 of the first parasitic stub satisfy the following:  $L1 \times 80\% \leq L3 \leq L1 \times 120\%$ .

**[0028]** According to the technical solutions in embodiments of this application, as lengths of the first radiator and the first parasitic stub are closer to each other, and

lengths of the first radiator and the second radiator are closer to each other, radiation performance of the antenna element is better.

**[0029]** With reference to the first aspect, in some implementations of the first aspect, the electronic device further includes a second electronic element; and the first resonant connector includes a slot, and the second electronic element is connected in series to the first resonant connector through the slot. With reference to the first aspect, in some implementations of the first aspect, the first parasitic stub and the first radiator are configured to: jointly generate a first resonance and jointly generate a second resonance; and the second radiator is configured to generate a third resonance.

**[0030]** With reference to the first aspect, in some implementations of the first aspect, an operating frequency band of the first antenna element and an operating frequency band of the second antenna element each include a first frequency band.

**[0031]** According to the technical solution in embodiments of this application and the first antenna element, the second antenna element may be used in a MIMO system as subunits in the MIMO system.

**[0032]** With reference to the first aspect, in some implementations of the first aspect, both the first radiator and the second radiator extend in the first direction, a second end of the first radiator is an open end, and the first end of the second radiator is an open end. That the first end of the first radiator and the second end of the second radiator are ground ends disposed on different sides means that the first end of the first radiator is on a first side in the first direction, the second end of the first radiator is on a second side in the first direction, the first end of the second radiator is on the first side in the first direction, and the second end of the second radiator is on the second side in the first direction.

**[0033]** According to a second aspect, an electronic device is provided, including: a ground plane; a first antenna element, including a first parasitic stub, a first radiator, and a first feed element, where the first radiator includes a first feed point, and the first feed element is coupled to the first radiator through the first feed point; and a second antenna element, including a second radiator and a second feed element, where the second radiator includes a second feed point, the second feed element is coupled to the second radiator through the second feed point, and the first feed element is different from the second feed element; a first end of the first radiator is coupled to the ground plane for grounding, a first end of the second radiator is coupled to the ground plane for grounding, and a second end of the first parasitic stub is coupled to the ground plane for grounding; a first projection and a second projection extend in a first direction and do not overlap in a second direction, the second direction is perpendicular to the first direction, the first projection is a projection of the first radiator on a plane on which the ground plane is located, and the second projection is a projection of the second radiator

on the plane on which the ground plane is located; the first end of the first radiator and the first end of the second radiator are ground ends disposed on different sides; and the first end of the first radiator and the second end of the first parasitic stub are ground ends disposed on different sides.

**[0034]** With reference to the second aspect, in some implementations of the second aspect, the first radiator and the first parasitic stub are juxtaposed.

**[0035]** With reference to the second aspect, in some implementations of the second aspect, the first radiator and the first parasitic stub are serialized.

**[0036]** In some implementations of the second aspect, the first projection and a third projection are disposed along a same straight line in the first direction, the second projection and the third projection are parallel in the first direction, and at least partially overlap in the second direction, where the third projection is a projection of the first parasitic stub on a plane on which the ground plane is located; a distance between the first end of the first radiator and the first end of the first parasitic stub is less than a distance between the first end of the first radiator and the second end of the first parasitic stub; and a distance between the first end of the second radiator and the second end of the first parasitic stub is less than a distance between the first end of the second radiator and a first end of the first parasitic stub.

**[0037]** In some implementations of the second aspect, the first radiator and the second radiator are parallel and non-collinearly in the first direction, and do not overlap in the second direction, to form a weakly-coupled structure. The first radiator and the first parasitic stub are collinear in the first direction, and the ground end of the first radiator and the ground end of the first parasitic stub are away from each other, and are disposed on different sides, to form a strongly-coupled structure. The second radiator and the first parasitic stub are disposed in parallel and non-collinearly, and the ground end of the second radiator and the ground end of the first parasitic stub are close to each other and are disposed on a same side, to form a weakly-coupled structure.

**[0038]** With reference to the second aspect, in some implementations of the second aspect, the electronic device further includes a first resonant connector and a first electronic element, where a first end of the first resonant connector is coupled to the first radiator, and a second end of the first resonant connector is coupled to the first parasitic stub; and a first end of the first electronic element is coupled to the first resonant connector, and a second end of the first electronic element is coupled to the ground plane for grounding.

**[0039]** With reference to the second aspect, in some implementations of the second aspect, the second antenna element further includes a second parasitic stub, a second end of the second parasitic stub is coupled to the ground plane for grounding, and the first end of the second radiator and the second end of the second parasitic stub are ground ends disposed on different sides.



**[0040]** With reference to the second aspect, in some implementations of the second aspect, the second projection and a fourth projection are disposed along a same straight line in the first direction, the first projection and the fourth projection are parallel in the first direction, and at least partially overlap in the second direction, where the fourth projection is a projection of the second parasitic stub on a plane on which the ground plane is located; a distance between the first end of the first radiator and the second end of the second parasitic stub is less than a distance between the first end of the first radiator and the first end of the second parasitic stub; and a distance between the first end of the second radiator and the first end of the second parasitic stub is less than a distance between the first end of the second radiator and the second end of the second parasitic stub.

**[0041]** With reference to the second aspect, in some implementations of the second aspect, the first end of the first resonant connector is located between the first end of the first radiator and a midpoint of the first radiator; and/or the second end of the first resonant connector is located between the second end of the first parasitic stub and a midpoint of the first parasitic stub.

**[0042]** With reference to the second aspect, in some implementations of the second aspect, the first radiator and the second radiator are sheet-like radiators.

**[0043]** With reference to the second aspect, in some implementations of the second aspect, the first parasitic stub and the first radiator are configured to: jointly generate a first resonance and jointly generate a second resonance; and the second radiator is configured to generate a third resonance. With reference to the second aspect, in some implementations of the second aspect, an operating frequency band of the first antenna element and an operating frequency band of the second antenna element each include a first frequency band.

**[0044]** According to a third aspect, an electronic device is provided, including: a ground plane; a first antenna element, including a first parasitic stub, a first radiator, and a first feed element, where the first radiator includes a first feed point, and the first feed element is coupled to the first radiator through the first feed point; and a second antenna element, including a second radiator and a second feed element, where the second radiator includes a second feed point, the second feed element is coupled to the second radiator through the second feed point, and the first feed element is different from the second feed element; a first end of the first radiator is coupled to the ground plane for grounding, a first end of the second radiator is coupled to the ground plane for grounding, a second end of the first parasitic stub is coupled to the ground plane for grounding, and a distance between the first end of the second radiator and the second end of the first parasitic stub is greater than a distance between the first end of the second radiator and a first end of the first parasitic stub; a first projection is perpendicular to a second projection, an extension line of the second radiator intersects an extension line of the first radiator on

the first radiator, the first projection is a projection of the first radiator on a plane on which the ground plane is located, and the second projection is a projection of the second radiator on the plane on which the ground plane is located; the first projection and a third projection are disposed along a same straight line in a first direction, and the third projection is a projection of the first parasitic stub on the plane on which the ground plane is located; and a distance between the first end of the first radiator and the first end of the first parasitic stub is less than a distance between the first end of the first radiator and the second end of the first parasitic stub.

**[0045]** According to the technical solution in embodiments of this application, the first radiator and the second radiator are perpendicular to each other, to form a weakly-coupled structure. The first radiator and the first parasitic stub are collinear in the first direction, and a ground end of the first radiator and a ground end of the first parasitic stub are away from each other, and are disposed on different sides, to form a strongly-coupled structure.

**[0046]** With reference to the third aspect, in some implementations of the third aspect, the electronic device further includes a first resonant connector and a first electronic element, where a first end of the first resonant connector is coupled to the first radiator, and a second end of the first resonant connector is coupled to the first parasitic stub; and a first end of the first electronic element is coupled to the first resonant connector, and a second end of the first electronic element is coupled to the ground plane for grounding.

**[0047]** With reference to the third aspect, in some implementations of the third aspect, the second antenna element further includes a second parasitic stub, a second end of the second parasitic stub is coupled to the ground plane for grounding, the second projection and a fourth projection are disposed along a same straight line in a second direction, the fourth projection is a projection of the second parasitic stub on a plane on which the ground plane is located, and the second direction is perpendicular to the first direction; and a distance between the first end of the second radiator and a first end of the second parasitic stub is less than a distance between the first end of the second radiator and the second end of the second parasitic stub.

**[0048]** With reference to the third aspect, in some implementations of the third aspect, the electronic device further includes a third antenna element, the third antenna element includes a third radiator and a third feed element, the third radiator includes a third feed point, the third feed element is coupled to the third radiator through the third feed point, the third feed element is different from the first feed element and the second feed element, and the first radiator is located between the second radiator and the third radiator; and a third projection is perpendicular to the second projection, an extension line of the third radiator intersects an extension line of the first radiator on the first radiator, and the third

projection is a projection of the third radiator on the plane on which the ground plane is located.

[0049] With reference to the third aspect, in some implementations of the third aspect, the first end of the first resonant connector is located between the first end of the first radiator and a midpoint of the first radiator; and/or the second end of the first resonant connector is located between the second end of the first parasitic stub and a midpoint of the first parasitic stub.

[0050] With reference to the third aspect, in some implementations of the third aspect, the first radiator and the second radiator are sheet-like radiators.

[0051] With reference to the third aspect, in some implementations of the third aspect, the first parasitic stub and the first radiator are configured to: jointly generate a first resonance and jointly generate a second resonance; and the second radiator is configured to generate a third resonance.

[0052] With reference to the third aspect, in some implementations of the third aspect, an operating frequency band of the first antenna element, and an operating frequency band of the second antenna element each include a first frequency band.

#### BRIEF DESCRIPTION OF DRAWINGS

[0053]

FIG. 1 is a diagram of an electronic device according to an embodiment of this application;

FIG. 2 is a diagram of current distribution corresponding to an HWM of a dipole antenna according to this application;

FIG. 3 is a diagram of current distribution corresponding to an OWM of a dipole antenna according to this application;

FIG. 4 is a diagram of current distribution of a bent dipole antenna according to an embodiment of this application;

FIG. 5 is a diagram of current distribution of a bent dipole antenna according to an embodiment of this application;

FIG. 6 is a diagram of current distribution of a bent dipole antenna to which a ground plane is added according to an embodiment of this application;

FIG. 7 is a diagram of current distribution of a bent dipole antenna to which a ground plane is added according to an embodiment of this application;

FIG. 8 is a diagram of current distribution of a bent dipole antenna to which a ground plane perpendicular to an antenna element is added according to an

embodiment of this application;

FIG. 9 is a diagram of current distribution of a bent dipole antenna to which a ground plane perpendicular to an antenna element is added according to an embodiment of this application;

FIG. 10 is a diagram of a group of antenna structures according to an embodiment of this application;

FIG. 11 is a diagram of current distribution of an antenna structure shown in (a) in FIG. 10;

FIG. 12 is a diagram of current distribution of an antenna structure shown in (b) in FIG. 10;

FIG. 13 is a diagram of an antenna structure according to an embodiment of this application;

FIG. 14 shows an S11 simulation result of an antenna element 111 in the antenna structure shown in FIG. 13;

FIG. 15 shows a simulation result of isolation between antenna elements in the antenna structure shown in FIG. 13;

FIG. 16 is a diagram of current distribution corresponding to a case in which an electrical signal is fed into an antenna element 111 in the antenna structure shown in FIG. 13;

FIG. 17 is a diagram of an antenna structure according to an embodiment of this application;

FIG. 18 shows an S11 simulation result of an antenna element 113 in the antenna structure shown in FIG. 17;

FIG. 19 shows a simulation result of isolation between antenna elements in the antenna structure shown in FIG. 17;

FIG. 20 is a diagram of current distribution corresponding to a case in which an electrical signal is fed into an antenna element 113 in the antenna structure shown in FIG. 17;

FIG. 21 is a diagram of an antenna structure according to an embodiment of this application;

FIG. 22 is a diagram of an S parameter of the antenna structure shown in FIG. 21;

FIG. 23 is a diagram of current distribution corresponding to a case in which an electrical signal is fed into a first antenna element in an antenna structure;

FIG. 24 is a diagram of current distribution corresponding to a case in which an electrical signal is fed into a second antenna element in an antenna structure;

FIG. 25 is a diagram of an electronic device 200 according to an embodiment of this application;

FIG. 26 is a top view of an electronic device 200 according to an embodiment of this application;

FIG. 27 is a partial diagram of an electronic device 200 according to an embodiment of this application;

FIG. 28 is a diagram of an electronic device 300 according to an embodiment of this application;

FIG. 29 shows an S parameter of an antenna element shown in FIG. 28;

FIG. 30 shows radiation efficiency and total efficiency of an antenna element shown in FIG. 28;

FIG. 31 is a diagram of electric field distribution of an antenna element shown in FIG. 28;

FIG. 32 is a pattern of an antenna element shown in FIG. 28;

FIG. 33 is a diagram of another electronic device 300 according to an embodiment of this application;

FIG. 34 shows an S11 simulation result of an antenna element shown in FIG. 33;

FIG. 35 shows isolation between antenna elements shown in FIG. 33;

FIG. 36 shows radiation efficiency and total efficiency of an antenna element shown in FIG. 33;

FIG. 37(a) to FIG. 37(e) are a diagram of electric field distribution of an antenna element shown in FIG. 33;

FIG. 38(a) to FIG. 38(e) are a pattern of an antenna element shown in FIG. 33;

FIG. 39 is a diagram of an antenna structure according to an embodiment of this application;

FIG. 40 is a diagram of a structure of an electronic device 500 according to an embodiment of this application;

FIG. 41 shows an S parameter of an antenna element shown in FIG. 40;

FIG. 42 shows radiation efficiency and total effi-

ciency of an antenna element shown in FIG. 40;

FIG. 43(a) to FIG. 43(f) are a diagram of electric field distribution of an antenna element shown in FIG. 40;

FIG. 44(a) to FIG. 44(f) are a pattern of an antenna element shown in FIG. 40;

FIG. 45 is a diagram of a structure of an electronic device 600 according to an embodiment of this application;

FIG. 46 shows an S parameter of an antenna element shown in FIG. 45;

FIG. 47 is a diagram of a structure of an electronic device 600 according to an embodiment of this application;

FIG. 48 shows an S parameter of an antenna element shown in FIG. 47;

FIG. 49 is a diagram of a structure of an electronic device 600 according to an embodiment of this application;

FIG. 50 shows an S parameter of an antenna element shown in FIG. 49;

FIG. 51 is a diagram of a structure of an electronic device 600 according to an embodiment of this application;

FIG. 52 shows an S parameter of an antenna element shown in FIG. 51;

FIG. 53 is a diagram of a structure of an electronic device 600 according to an embodiment of this application;

FIG. 54 shows an S parameter of an antenna element shown in FIG. 53;

FIG. 55 is a diagram of a structure of an electronic device 600 according to an embodiment of this application;

FIG. 56 shows an S parameter of an antenna element shown in FIG. 55; and

FIG. 57 is a diagram of a structure of an electronic device 600 according to an embodiment of this application.

## DESCRIPTION OF EMBODIMENTS

[0054] The following describes terms that may appear in embodiments of this application.

**[0055]** Coupling: The coupling may be understood as direct coupling and/or indirect coupling, and a "coupling connection" may be understood as a direct coupling connection and/or an indirect coupling connection. The direct coupling may also be referred to as an "electrical connection", which may be understood as components are in physical contact and are electrically conductive, or may be understood as a form in which different components in a line structure are connected through physical lines that can transmit an electrical signal, such as a printed circuit board (printed circuit board, PCB) copper foil or a conducting wire. The "indirect coupling" may be understood as that two conductors are electrically conducted in a spaced/non-contact manner. In an embodiment, the indirect coupling may also be referred to as capacitive coupling. For example, signal transmission is implemented by forming an equivalent capacitor through coupling in a slot between two conductive members.

**[0056]** Connection/Being connected to: The connection/being connected to may mean a mechanical connection relationship or a physical connection relationship, that is, a connection between A and B or that A is connected to B may mean that there is a fastening component (like a screw, a bolt, or a rivet) between A and B, or A and B are in contact with each other and A and B are difficult to be separated.

**[0057]** Capacitor: The capacitor may be understood as a lumped capacitor and/or a distributed capacitor. The lumped capacitor is a capacitive component, for example, a capacitive element, and the distributed capacitor (or distributed type capacitor) is an equivalent capacitor formed by a slot between two conductive members.

**[0058]** Inductor: The inductor may be understood as a lumped inductor and/or a distributed inductor. The lumped inductor is an inductive component, for example, an inductor element. The distributed inductor (or distributed type inductor) is an equivalent inductor formed by a conductor due to curling or rotation, or by a section of wiring in any form.

**[0059]** Resonance/Resonance frequency: The resonance frequency is also referred to as a resonant frequency. The resonance frequency may be a frequency at which an imaginary part of an input impedance of an antenna is zero. The resonance frequency may have a frequency range, namely, a frequency range in which a resonance occurs. A frequency corresponding to a strongest resonance point is a center frequency. A return loss of the center frequency may be less than -20 dB.

**[0060]** Resonance frequency band/Communication frequency band/Operating frequency band: Regardless of a type of antenna, the antenna operates in a specific frequency range (a frequency band width). For example, an operating frequency band of an antenna supporting a B40 frequency band includes a frequency in a range of 2300 MHz to 2400 MHz. In other words, an operating frequency band of the antenna includes a B40 frequency band. A frequency range that meets a requirement of an indicator may be considered as an operating frequency

band of the antenna. Electrical length: The electrical length may be a ratio of a physical length (namely, a mechanical length or a geometric length) to a wavelength of a transmitted electromagnetic wave, and the electrical length may satisfy the following formula:

$$\bar{L} = \frac{L}{\lambda},$$

where

L is the physical length, and  $\lambda$  is the wavelength of the electromagnetic wave. Wavelength: The wavelength or an operating wavelength may be a wavelength corresponding to a center frequency of a resonance frequency or a center frequency of an operating frequency band supported by an antenna. For example, it is assumed that a center frequency of a B1 uplink frequency band (with a resonance frequency ranging from 1920 MHz to 1980 MHz) is 1955 MHz, the operating wavelength may be a wavelength calculated by using the frequency of 1955 MHz. The "operating wavelength" is not limited to the center frequency, and may alternatively be a wavelength corresponding to a non-center frequency of the resonance frequency or the operating frequency band.

**[0061]** End: A first end (a second end) of a radiator of an antenna, and a ground end or an open end cannot be understood as a point in a narrow sense, and may alternatively be considered as a section of the radiator that includes a first endpoint on the radiator of the antenna. In an embodiment, the first endpoint is an endpoint of the radiator of the antenna at a first slot. For example, the first end of the radiator of the antenna may be considered as a radiator section in a first wavelength range that is one-sixteenth of a distance from the first endpoint. The first wavelength may be a wavelength corresponding to an operating frequency band of the antenna structure, or may be a wavelength corresponding to a center frequency of an operating frequency band, or a wavelength corresponding to a resonance point.

**[0062]** Open end and closed end: In some embodiments, the open end and the closed end are defined based on ground, for example, the closed end is grounded, and the open end is not grounded. Alternatively, for example, the open end and the closed end are defined based on another conductor, for example, the closed end is electrically connected to the another conductor, and the open end is not electrically connected to the another conductor. In an embodiment, the open end may also be referred to as an opening end or an open-circuit end. In an embodiment, the closed end may also be referred to as a ground end or a short-circuit end.

**[0063]** A limitation on a position and a distance, such as middle or a middle position, mentioned in embodiments of this application represents a specific range. For example, a middle (position) of a conductor may be a section of a conductor part including a midpoint on the conductor, for example, the middle (position) of the con-

ductor may be a section of the conductor part whose distance from the midpoint on the conductor is less than a predetermined threshold (for example, 1 mm, 2 mm, or 2.5 mm).

**[0064]** Such limitations as collinearity, coplanarity (for example, axisymmetry or centrosymmetry), parallelism, verticality, and sameness (for example, a same length and a same width) mentioned in embodiments of this application are all for a current process level, and are not absolutely-strict definitions in mathematics. A deviation less than a predetermined threshold (for example, 1 mm, 0.5 mm, or 0.1 mm) may exist between edges of two collinear radiation stubs or two collinear antenna elements in a width direction. A deviation less than a predetermined threshold may exist between edges of the two coplanar radiation stubs or two coplanar antenna elements in a direction perpendicular to a plane on which two coplanar radiation stubs or two coplanar antenna elements are located. A deviation of a predetermined angle may exist between two antenna elements that are parallel or perpendicular to each other. In an embodiment, the predetermined threshold may be less than or equal to a threshold of 1 mm. For example, the predetermined threshold may be 0.5 mm, or may be 0.1 mm. In an embodiment, the predetermined angle may be an angle within a range of  $\pm 10^\circ$ , for example, a deviation of the predetermined angle is  $\pm 5^\circ$ .

**[0065]** Total efficiency (total efficiency) of an antenna: The total efficiency of the antenna is a ratio of input power to output power at an antenna port.

**[0066]** Radiation efficiency (radiation efficiency) of an antenna: The radiation efficiency of the antenna is a ratio of power radiated by the antenna to space (namely, power for effectively converting an electromagnetic wave) to active power input to the antenna. Active power input to the antenna = Input power of the antenna - Loss power. The loss power mainly includes return loss power and metal ohmic loss power and/or dielectric loss power. The radiation efficiency is a value for measuring a radiation capability of an antenna. Both a metal loss and a dielectric loss are factors that affect the radiation efficiency.

**[0067]** A person skilled in the art may understand that the efficiency is usually indicated by a percentage, and there is a corresponding conversion relationship between the efficiency and dB. Efficiency closer to 0 dB indicates better antenna efficiency.

**[0068]** Antenna pattern: The antenna pattern is also referred to as a radiation pattern. The antenna pattern refers to a pattern in which relative field strength (a normalized modulus value) of an antenna radiation field changes with a direction at a specific distance from an antenna. The antenna pattern is usually represented by two plane patterns that are perpendicular to each other in a maximum radiation direction of the antenna.

**[0069]** The antenna pattern usually includes a plurality of radiation beams. A radiation beam with highest radiation strength is referred to as a main lobe, and another

radiation beam is referred to as a minor lobe or side lobe. In minor lobes, a minor lobe in a reverse direction of the main lobe is also referred to as a back lobe.

**[0070]** Antenna return loss: The antenna return loss may be understood as a ratio of power of a signal reflected back to an antenna port through an antenna circuit to transmit power of the antenna port. A smaller reflected signal indicates a larger signal radiated by the antenna to space and higher radiation efficiency of the antenna. A larger reflected signal indicates a smaller signal radiated by the antenna to space and lower radiation efficiency of the antenna.

**[0071]** The antenna return loss may be represented by an S11 parameter, and S11 is one of S parameters. S11 indicates a reflection coefficient, and the parameter indicates transmit efficiency of the antenna. The S11 parameter is usually a negative number. A smaller S11 parameter indicates a smaller return loss of the antenna, less energy reflected back by the antenna, namely, more energy that actually enters the antenna, and higher total efficiency of the antenna. A larger S11 parameter indicates a larger return loss of the antenna and lower total efficiency of the antenna.

**[0072]** It should be noted that, -6 dB is usually used as a standard value of S11 in engineering. When the value of S11 of the antenna is less than -6 dB, it may be considered that the antenna can operate normally, or it may be considered that transmit efficiency of the antenna is good.

**[0073]** Ground or ground plane: The ground or ground plane may generally mean at least a part of any grounding plane, grounding plate, ground metal layer, or the like in an electronic device (like a mobile phone), or at least a part of any combination of the foregoing grounding plane, grounding plate, ground component, or the like. The "ground" may be used to ground components in the electronic device. In an embodiment, the "ground" may be a grounding plane of a circuit board of the electronic device, or may be a grounding plate formed by a middle frame of the electronic device or a ground metal layer formed by a metal film below a screen of the electronic device. In an embodiment, the circuit board may be a printed circuit board (printed circuit board, PCB), for example, an 8-layer board, a 10-layer board, a 12-layer board, a 13-layer board, or a 14-layer board respectively having 8, 10, 12, 13, or 14 layers of conductive materials, or an element that is separated and electrically insulated by a dielectric layer or an insulation layer, for example, glass fiber, polymer, or the like.

**[0074]** Any of the foregoing grounding plane, or grounding plate, or ground metal layer is made of a conductive material. In an embodiment, the conductive material may be any one of the following materials: copper, aluminum, stainless steel, brass and alloys thereof, copper foil on an insulation laminate, aluminum foil on an insulation laminate, gold foil on an insulation laminate, silver-plated copper, silver-plated copper foil on an insulation laminate, silver foil on an insulation

laminate and tin-plated copper, cloth impregnated with graphite powder, a graphite-coated laminate, a copper-plated laminate, a brass-plated laminate and an aluminum-plated laminate. A person skilled in the art may understand that the grounding plane/grounding plate/-ground metal layer may alternatively be made of another conductive material.

**[0075]** It should be understood that, as mentioned in this specification, that a first resonance and a second resonance have a same resonance frequency band (also referred to as an intra-frequency resonance frequency band) may be understood as any one of the following cases.

**[0076]** The resonance frequency band of the first resonance and the resonance frequency band of the second resonance include a same communication frequency band. In an embodiment, the first resonance and the second resonance may be applied to a MIMO antenna system. For example, if the resonance frequency band of the first resonance and the resonance frequency band of the second resonance each include a sub-6G frequency band in 5G, it may be considered that the resonance frequency band of the first resonance and the resonance frequency band of the second resonance are intra-frequency resonance frequency bands.

**[0077]** The resonance frequency band of the first resonance and the resonance frequency band of the second resonance at least partially overlap. For example, the resonance frequency band of the first resonance includes a B35 frequency band (1.85 GHz to 1.91 GHz) in LTE, the resonance frequency band of the second resonance includes a B39 frequency band (1.88 GHz to 1.92 GHz) in LTE, and a frequency of the resonance frequency band of the first resonance and a frequency of the resonance frequency band of the second resonance partially overlap. In this case, it may be considered that the resonance frequency band of the first resonance and the resonance frequency band of the second resonance are intra-frequency resonance frequency bands.

**[0078]** As shown in FIG. 1, an electronic device 10 may include a cover (cover) 13, a display/module (display) 15, a printed circuit board (printed circuit board, PCB) 17, a middle frame (middle frame) 19, and a rear cover (rear cover) 21. It should be understood that, in some embodiments, the cover 13 may be a cover glass (cover glass), or may be replaced with a cover of another material, for example, an ultra-thin glass material cover or a PET (Polyethylene terephthalate, polyethylene terephthalate) material cover.

**[0079]** The cover 13 may be tightly attached to the display module 15, and may be mainly configured to protect the display module 15 for dust resistance.

**[0080]** In an embodiment, the display module 15 may include a liquid crystal display (liquid crystal display, LCD), a light-emitting diode (light-emitting diode, LED) display panel, an organic light-emitting semiconductor (organic light-emitting diode, OLED) display panel, or the like. This is not limited in embodiments of this application.

**[0081]** The middle frame 19 is mainly used to support the entire electronic device. FIG. 1 shows that the PCB 17 is disposed between the middle frame 19 and the rear cover 21. It should be understood that, in an embodiment, the PCB 17 may alternatively be disposed between the middle frame 19 and the display module 15. This is not limited in embodiments of this application. The printed circuit board PCB 17 may be a flame-resistant material (FR-4) dielectric board, or may be a Rogers (Rogers) dielectric board, or may be a hybrid dielectric board of Rogers and FR-4, or the like. Herein, FR-4 is a grade designation for a flame-resistant material, and the Rogers dielectric board is a high-frequency board. An electronic element, for example, a radio frequency chip, is carried on the PCB 17. In an embodiment, a metal layer may be disposed on the printed circuit board PCB 17. The metal layer may be used for grounding an electronic element carried on the printed circuit board PCB 17, or may be used for grounding another element, for example, a bracketed antenna or a frame antenna. The metal layer may be referred to as a ground plane, a grounding plate, or a grounding plane. In an embodiment, the metal layer may be formed by etching metal on a surface of any layer of dielectric board in the PCB 17. In an embodiment, the metal layer used for grounding may be disposed on a side that is of the printed circuit board PCB 17 and that is close to the middle frame 19. In an embodiment, an edge of the printed circuit board PCB 17 may be considered as an edge of the grounding plane of the PCB 17. In an embodiment, the metal middle frame 19 may also be used for grounding the foregoing element. The electronic device 10 may further have another ground plane/grounding plate/grounding plane. As described above, details are not described herein again.

**[0082]** The electronic device 10 may further include a battery (not shown in the figure). The battery may be disposed between the middle frame 19 and the rear cover 21, or may be disposed between the middle frame 19 and the display module 15. This is not limited in embodiments of this application. In some embodiments, the PCB 17 is divided into a mainboard and a sub-board. The battery may be disposed between the mainboard and the sub-board. The mainboard may be disposed between the middle frame 19 and an upper edge of the battery, and the sub-board may be disposed between the middle frame 19 and a lower edge of the battery.

**[0083]** The electronic device 10 may further include a side frame 11, and the side frame 11 may be made of a conductive material like metal. The side frame 11 may be disposed between the display module 15 and the rear cover 21, and extends around a periphery of the electronic device 10. The side frame 11 may have four sides surrounding the display module 15, to help fasten the display module 15. In an implementation, the side frame 11 made of a metal material may directly serve as a metal side frame of the electronic device 10 to form an appearance of the metal side frame, and is applicable to a metal industrial design (industrial design, ID). In another im-

plementation, an outer surface of the side frame 11 may alternatively be made of a non-metal material, for example, is a plastic side frame, to form an appearance of a non-metal side frame, and is applicable to a non-metal ID.

**[0084]** The middle frame 19 may include the side frame 11, and the middle frame 19 including the side frame 11 serves as an integrated part, and may support an electronic component in the entire electronic device. The cover 13 and the rear cover 21 respectively fit upper edges and lower edges of the side frame, to enclose a casing or a housing (housing) of the electronic device. In an embodiment, the cover 13, the rear cover 21, the side frame 11, and/or the middle frame 19 may be collectively referred to as a casing or a housing of the electronic device 10. It should be understood that, the "casing or housing" may be used to refer to a part or all of any one of the cover 13, the rear cover 21, the side frame 11, or the middle frame 19, or refer to a part or all of any combination of the cover 13, the rear cover 21, the side frame 11, or the middle frame 19.

**[0085]** At least a part of the side frame 11 on the middle frame 19 may serve as a radiator of an antenna to receive/transmit a radio frequency signal. A slot may exist between the part of the side frame that serves as the radiator and another part of the middle frame 19, to ensure that the radiator of the antenna has a good radiation environment. In an embodiment, an aperture of the middle frame 19 may be disposed at the part of the side frame that serves as the radiator, to facilitate radiation of the antenna.

**[0086]** Alternatively, the side frame 11 may not be considered as a part of the middle frame 19. In an embodiment, the side frame 11 may be connected to the middle frame 19 and integrally formed. In another embodiment, the side frame 11 may include a protruding part extending inward, to be connected to the middle frame 19, for example, connected by using a spring plate or a screw, or connected through welding. The protruding part of the side frame 11 may be further configured to receive a feeding signal, so that at least a part of the side frame 11 serves as a radiator of an antenna to receive/transmit a radio frequency signal. A slot 42 may exist between the middle frame 30 and the part of the side frame that serves as the radiator, to ensure that the radiator of the antenna has a good radiation environment, and the antenna has a good signal transmission function.

**[0087]** The rear cover 21 may be a rear cover made of a metal material, or may be a rear cover made of a non-conductive material, for example, may be a non-metal rear cover like a glass rear cover and a plastic rear cover, or may be a rear cover made of both a conductive material and a non-conductive material. In an embodiment, the rear cover 21 including the conductive material may replace the middle frame 19, and serves as an integrated part with the side frame 11, to support an electronic component in the entire electronic device.

**[0088]** In an embodiment, the middle frame 19 and/or a conductive part of the rear cover 21 may serve as a

reference ground of the electronic device 10. The side frame 11, the PCB 17, and the like of the electronic device may be grounded by being electrically connected to the middle frame.

**[0089]** The antenna of the electronic device 10 may be disposed in the side frame 11. When the side frame 11 of the electronic device 10 is made of a non-conductive material, the radiator of the antenna may be located in the electronic device 10 and disposed along the side frame 11. For example, the radiator of the antenna is disposed close to the side frame 11, to reduce a volume occupied by the radiator of the antenna as much as possible, and is closer to the outside of the electronic device 10, to achieve better signal transmission effect. It should be noted that, that the radiator of the antenna is disposed close to the side frame 11 means that the radiator of the antenna may be tightly attached to the side frame 11, or may be disposed close to the side frame 11. For example, there may be a specific small slot between the radiator of the antenna and the side frame 11.

**[0090]** The antenna of the electronic device 10 may alternatively be disposed in the casing, for example, a bracketed antenna or a millimeter wave antenna (not shown in FIG. 1). Clearance of the antenna disposed in the housing may be obtained by using a slit/hole in any one of the middle frame, and/or the side frame, and/or the rear cover, and/or the display, or by using a non-conductive slot/aperture formed between any several of the middle frame, the side frame, the rear cover, and the display. The clearance of the antenna may be provided, to ensure radiation performance of the antenna. It should be understood that, the clearance of the antenna may be a non-conductive area formed by any conductive component in the electronic device 10, and the antenna radiates a signal to external space through the non-conductive area. In an embodiment, a form of the antenna 40 may be an antenna form based on a flexible mainboard (flexible printed circuit, FPC), an antenna form based on laser-direct-structuring (laser-direct-structuring, LDS), or an antenna form like a microstrip disk antenna (microstrip disk antenna, MDA). In an embodiment, the antenna may alternatively use a transparent structure embedded into a display of the electronic device 10, so that the antenna is a transparent antenna element embedded into the display of the electronic device 10.

**[0091]** FIG. 1 shows only an example of some parts included in the electronic device 10. Actual shapes, actual sizes, and actual structures of the parts are not limited to those in FIG. 1.

**[0092]** It should be understood that, in embodiments of this application, it may be considered that a surface on which the display of the electronic device is located is a front surface, a surface on which the rear cover is located is a rear surface, and a surface on which the side frame is located is a side surface.

**[0093]** It should be understood that, in embodiments of this application, it is considered that when a user holds (the user usually holds the electronic device vertically

and faces the display), an orientation in which the electronic device is located has a top part, a bottom part, a left part, and a right part. Embodiments of this application provide an electronic device. The electronic device may include a plurality of antenna elements. The plurality of antenna elements are arranged in different manners for high isolation in a case of a small spacing, to meet a requirement of a MIMO system.

**[0094]** FIG. 2 and FIG. 3 describe two antenna modes in this application. In embodiments in FIG. 2 and FIG. 3, a dipole antenna is used as an example. It should be understood that a specific antenna form and/or antenna shape are/is not used to limit descriptions of the antenna mode in this application. FIG. 2 is a diagram of current distribution corresponding to a half wavelength mode (half wavelength mode, HWM, also referred to as a one half wavelength mode or a one half mode) of the dipole antenna according to an embodiment. FIG. 3 is a diagram of current distribution corresponding to a one wavelength mode (one wavelength mode, OWM) of the dipole antenna according to an embodiment. In another embodiment of this application, the half wavelength mode and the one wavelength mode are applicable to another antenna form, and is not only applicable to a wire antenna (wire antenna), but also applicable to a patch antenna (patch antenna). The specific antenna form may be, for example, a planar inverted-L antenna (planar inverted-L antenna, PILA), a planar inverted-F antenna (planar inverted-F antenna, PIFA), an inverted-F antenna (inverted-F antenna, IFA), an inverted-L antenna (inverted-L antenna, ILA), or a monopole (monopole) antenna. In addition, in another embodiment of this application, a radiator of the antenna may be in any shape/form (for example, a straight form, a bent form, a linear form, a sheet-like form, a split form, or an integrated form), and an operating mode of the antenna is not affected.

#### 1. Half wavelength mode

**[0095]** As shown in FIG. 2, a dipole antenna 101 is in an HWM. In this mode, currents are the same in direction on a radiator of the antenna, and have a current strong point. For example, an amplitude of the current is largest at the center of the radiator of the antenna, and is smallest at two ends of the radiator of the antenna.

#### 2. One wavelength mode

**[0096]** As shown in FIG. 3, the dipole antenna 101 is in an OWM. In this mode, currents are reverse in direction on two sides (for example, two sides of a middle position of the radiator) of the radiator of the antenna, and have two current strong points, and three current zero points. For example, an amplitude of the current is smallest at the two ends and the center of the radiator, and is largest at the middle positions between the two ends and a center point of the radiator.

**[0097]** That the currents are the same/reverse in direc-

tion mentioned in embodiments of this application should be understood as that directions of main currents on the radiator are the same/reverse. For example, the currents are integrally the same/reverse in direction. When a co-directionally distributed current (for example, a current path is also annular) is excited on an annular radiator, it should be understood that, although main currents excited on conductors on two sides in the annular conductor (for example, for conductors around a slot, on conductors on two sides of the slot) are reverse in direction, the main currents still satisfy a definition of the co-directionally distributed currents in this application.

**[0098]** It can be learned from an electromagnetic induction theorem that the current strong point mentioned in embodiments of this application may correspond to an electric field zero point, and the current zero point may correspond to an electric field strong point. A strong point and a zero point are relative concepts, are conventionally understood by a person skilled in the art, are not the largest and smallest in a strict sense, and are not merely a point, but an area. For example, an area in which an amplitude is far greater than an average value may be a strong point, and an area in which an amplitude is far less than the average value may be a zero point. A largest/smallest amplitude and the like should be accordingly understood. A person skilled in the art may understand that a ground end generally corresponds to a current strong point (or an electric field zero point), an open end generally corresponds to an electric field strong point (or a current zero point), a current reverse area generally corresponds to a current zero point (or an electric field strong point), and an electric field reverse area generally corresponds to an electric field zero point (or a current strong point).

**[0099]** It should be understood that a diagram of current distribution shown in each embodiment of this application shows only a general current direction of an antenna structure at a moment when an electrical signal is fed into a radiator. The schematic current distribution is a distribution diagram of currents (for example, a current whose current amplitude exceeds 50%) that are simplified for ease of understanding. For example, current distribution on a ground plane is simplified to current distribution in some areas close to the radiator, and only a general direction of the current distribution is shown. It should be noted that a current distribution arrow is merely used as an example of a current direction, and does not indicate that a current flow area is limited to a position shown by the arrow.

**[0100]** FIG. 4 and FIG. 5 are diagrams of current distribution on a radiator of a bent antenna according to an embodiment of this application.

**[0101]** Two ends of the dipole antenna shown in FIG. 2 and FIG. 3 are bent inward to form shapes shown in FIG. 4 and FIG. 5. The HWM and the OWM still exist. In this case, currents generated by the dipole antenna 101 in the HWM are shown in FIG. 4, and the currents are co-directionally distributed around a middle slot. Currents



generated by the dipole antenna 101 in the OWM are shown in FIG. 5, and the currents are reversely distributed around the middle slot. Current amplitude features are the same as or similar to those shown in FIG. 2 and FIG. 3.

**[0102]** FIG. 6 and FIG. 7 are diagrams of current distribution of a bent dipole antenna to which a ground plane is added according to an embodiment of this application. In an embodiment, a radiator of the antenna and the ground plane may be disposed on a same plane (for example, the radiator is disposed outside a side of the ground plane).

**[0103]** Based on the bent dipole antenna shown in FIG. 4 and FIG. 5, a ground plane 102 electrically connected to the dipole antenna is added. As shown in FIG. 6 and FIG. 7, the ground plane 102 may be a PCB, a middle frame, or another metal layer of an electronic device. In this case, the dipole antenna includes antenna elements 103 and a part of the ground plane 102, and the HWM and the OWM still exist. In this case, currents generated by the dipole antenna in the HWM are shown in FIG. 6, and the currents are co-directionally distributed around a middle slot 104. Currents generated by the dipole antenna in the OWM are shown in FIG. 7, and the currents are reversely distributed around the middle slot. Current amplitude features are the same as or similar to those in the foregoing figures. In this case, the ground plane 102 carries a part of a mode current of the dipole antenna, that is, the ground plane 102 carries a mode current between two antenna elements at ends (connection points with the ground plane 102) of the two bent antenna elements. In an embodiment, the radiator of the antenna and the ground plane may be stacked (for example, the radiator is disposed on a side surface of the ground plane). FIG. 8 and FIG. 9 are diagrams of current distribution of a bent dipole antenna to which a ground plane stacked with an antenna element is added according to an embodiment of this application.

**[0104]** Based on the bent dipole antenna shown in FIG. 4 and FIG. 5, a ground plane 107 is added to connect to the antenna. After the connection, antenna elements 108 are disposed above the ground plane 107, and it may be considered that two antenna elements are placed on the ground plane, as shown in FIG. 8 and FIG. 9. The ground plane 107 may be a PCB, a middle frame, or another metal layer of an electronic device. In this case, the antenna element is still in the two modes: the HWM and the OWM. In this case, currents generated by the dipole antenna in the HWM are shown in FIG. 8, and the currents are co-directionally distributed around a middle slot. Currents generated by the dipole antenna in the OWM are shown in FIG. 9, and the currents are reversely distributed around the middle slot. Current amplitude features are the same as those in the foregoing figures. In this case, the ground plane 107 carries a part of a mode current of the antenna, that is, the ground plane 107 carries a mode current between two antenna elements at ends (connection points with the ground plane 107) of

the two bent antenna elements.

**[0105]** FIG. 10 is a diagram of a group of antenna structures according to an embodiment of this application.

**[0106]** As shown in (a) and (b) in FIG. 10, the antenna structure includes two radiators 110 that are juxtaposed (juxtaposed, or placed side by side) or arranged in parallel (arranged in parallel). Being juxtaposed or arranged in parallel may be understood as that the two radiators 110 are disposed close to each other (for example, a distance between the radiators is less than 5 mm), and extension directions (for example, the extension directions may be specifically directions from ground ends of the radiators to open ends of the radiators) of the radiators are generally consistent (for example, an included angle between the extension directions is within a range of  $0^\circ$  to  $10^\circ$ , or within a range of  $170^\circ$  to  $180^\circ$ ). In addition, a majority of one radiator may be projected on the other radiator (in other words, in an extension direction perpendicular to the radiators, the two radiators 110 generally overlap). "A majority of one radiator may be projected on the other radiator" or "the two radiators 110 generally overlap" may indicate projections or overlapping of the radiators in the extension directions, and does not necessarily indicate overall projections or overlapping of the radiators. For example, both a first radiator and a second radiator extend in an X direction, where the first radiator may be sheet-like on an XY plane, and the second radiator may be sheet-like on an XZ plane (where the XY plane and the XZ plane are two perpendicular planes). However, parts that are of the two radiators and that extend in the X direction may be considered as being generally overlapped. Alternatively, a projection of the first radiator on the second radiator may be considered as that a majority (for example, more than 80% of a length in the extension direction) of the first radiator is projected on the second radiator. It should be understood that "A is projected on B" or "A projection of A on B" means that A is projected on B in an extension direction perpendicular to B.

**[0107]** In an embodiment, projections, on a ground plane, of the two radiators that are juxtaposed, or arranged in parallel are juxtaposed, or arranged in parallel. In an embodiment, projections, on a ground plane, of the two radiators that are juxtaposed, or arranged in parallel may be disposed in parallel and non-collinearly. Specifically, the two radiators 110 are parallel in a length direction and at least partially overlap left and right in the length direction. An end of each radiator 110 is connected to a ground plane 120. For example, a black dot in the figure is a schematic ground point of the radiator.

**[0108]** For the radiators that are arranged in parallel and shown in (a) and (b) in FIG. 10, a difference lies in that ground ends of the two radiators 110 are close to each other and are located on a same side, as shown in (a) in FIG. 10, or ground ends of the two radiators 110 are away from each other and are located on different sides, as shown in (b) in FIG. 10.

**[0109]** In the embodiment shown in FIG. 10, first, in a case of not considering feeding, the two radiators 110 that are parallel and non-collinearly and that overlap left and right in parallel directions are disposed. The two radiators are separately connected to the same ground plane 120. The two radiators 110 and at least a part of the ground plane jointly form the antenna structure in FIG. 10. It should be understood that the antenna structure in the embodiment shown in FIG. 10 may serve as an antenna structure (for example, only one radiator is provided with a feed point) including a single antenna element, or may serve as an antenna structure (for example, each of the two radiators includes a feed point) including two antenna elements (for example, each antenna element includes a feed point). Positions on which the two radiators 110 are disposed in the embodiment shown in FIG. 10 may shift relative to each other. For example, one of the two radiators 110 may translate, or may rotate along an end part of the radiator 110.

**[0110]** To analyze a mode in this embodiment of this application, it is assumed that current distribution of the antenna structure shown in (a) in FIG. 10 in the HWM is shown in (a) in FIG. 11, and current distribution in the OWM is shown in (b) in FIG. 11.

**[0111]** As shown in (a) in FIG. 11, reverse mode currents (which may be understood as currents corresponding to an operating mode in which the antenna element generates a resonance) may be generated on the two radiators 110, and a mode current may be generated on the ground plane 120 between the two radiators 110. Being between the two radiators 110 may be understood as being between connection points (ground points) of the radiators 110 and the ground plane. In addition, the mode current on the radiator excites an induced current (which may be understood as a current generated by coupling, on the ground plane, the mode current on the radiator) on the ground plane 120. It can be learned from an electromagnetic induction theorem that a mode current is reverse to a corresponding induced current. When two ground ends are located on a same side, the mode current on the ground plane 120 may be perpendicular and orthogonal to the mode current on the radiator of the antenna element, and the induced current on the ground plane 120 may be parallel to and reverse to the mode current on the radiator. Therefore, the mode current and the induced current that are on the ground plane 120 are also orthogonal to each other. For a mode current between two ground points on the ground plane 120, because the mode current and the induced current that are on the ground plane are orthogonal to each other, the mode current does not have a component that is in a same direction as the induced current. In an embodiment, a dashed-line area on the ground plane 120 is a current strong point area (the area includes a current strong point) of the mode current, but for the induced current, the dashed-line area is a current zero point area (the area includes a current zero point). The induced current on the ground plane 120 cannot support genera-

tion of the mode current on the ground plane 120. This indicates that the mode does not meet a boundary condition. Therefore, there is no HWM in the antenna structure shown in (a) in FIG. 10.

**[0112]** It should be understood that, for the boundary condition, if components in a same direction exist between the induced current and the mode current that are generated on the antenna element, the boundary condition is met.

**[0113]** Similarly, as shown in (b) in FIG. 11, mode currents in a same direction may be generated on the two radiators 110, and a mode current may be generated on the ground plane 120 between the two radiators 110. The mode current on the radiator excites an induced current on the ground plane 120. It can be learned from an electromagnetic induction theorem that a mode current is reverse to a corresponding induced current. When two ground ends are located on a same side, the mode current on the ground plane 120 may be perpendicular and orthogonal to the mode current on the radiator of the antenna element, and the induced current on the ground plane 120 may be parallel to and reverse to the mode current on the radiator. Therefore, the mode current and the induced current that are on the ground plane 120 are also orthogonal to each other. For a mode current between two ground points on the ground plane 120, because the mode current and the induced current that are on the ground plane are orthogonal to each other, the mode current does not have a component that is in a same direction as the induced current. In an embodiment, a dashed-line area on the ground plane 120 is a current zero point area of the mode current, but for the induced current, the dashed-line area is a current strong point area. The induced current on the ground plane 120 cannot support generation of the mode current on the ground plane. This indicates that the mode does not meet a boundary condition. Therefore, there is no OWM in the antenna structure shown in (a) in FIG. 10.

**[0114]** To further analyze a mode in this embodiment of this application, it is assumed that current distribution of the antenna structure shown in (b) in FIG. 10 in the HWM is shown in (a) in FIG. 12, and current distribution in the OWM is shown in (b) in FIG. 12.

**[0115]** As shown in (a) in FIG. 12, mode currents in a same direction may be generated on the two radiators 110, and a mode current may be generated on the ground plane 120 between the two radiators 110. The mode current on the radiator excites an induced current on the ground plane 120. It can be learned from an electromagnetic induction theorem that a mode current is reverse to a corresponding induced current. For a mode current between two ground points on the ground plane 120, the mode current has a component in a same direction as the induced current, and the mode current and the induced current may be superimposed. In an embodiment, a dashed-line area on the ground plane 120 is a current strong point area of the mode current and the induced current.

**[0116]** This indicates that the mode meets a boundary condition. Therefore, an HWM exists in the antenna structure shown in (b) in FIG. 10.

**[0117]** Similarly, as shown in (b) in FIG. 12, mode currents 122 in reverse directions may be generated on the two radiators 110, and a mode current may be generated on the ground plane 120 between the two radiators 110. The mode current on the radiator excites an induced current on the ground plane 120. It can be learned from an electromagnetic induction theorem that a mode current is reverse to a corresponding induced current. For a mode current between two ground points on the ground plane 120, the mode current has a component in a same direction as the induced current, and the mode current and the induced current may be superimposed. In an embodiment, a dashed-line area on the ground plane 120 is a current zero point area of the mode current and the induced current. This indicates that the mode meets a boundary condition. Therefore, an OWM exists in the antenna structure shown in (b) in FIG. 10.

**[0118]** It should be understood that, in the antenna structure shown in (b) in FIG. 10 and FIG. 11, because the HWM and the OWM may not exist in the two radiators 110, a spatial distance/physical distance between the radiators 110 has large impact on isolation between the two radiators. The antenna structure may be referred to as a weakly-coupled antenna structure. In the antenna structure shown in (a) in FIG. 10 and FIG. 12, because the HWM and the OWM may exist in the two radiators 110, a spatial distance/physical distance between the radiators 110 has small impact on isolation between the two radiators. The antenna structure may be referred to as a strongly-coupled antenna structure. The following describes some features of the weakly-coupled antenna structure and the strongly-coupled antenna structure.

**[0119]** FIG. 13 to FIG. 16 show an antenna structure and a simulation result of the antenna structure according to an embodiment of this application. FIG. 13 is a diagram of the antenna structure according to an embodiment of this application. FIG. 14 shows an S11 simulation result of an antenna element 111 in the antenna structure shown in FIG. 13. FIG. 15 shows a simulation result of isolation between antenna elements in the antenna structure shown in FIG. 13. FIG. 16 is a diagram of current distribution corresponding to a case in which an electrical signal is fed into the antenna element 111 in the antenna structure shown in FIG. 13.

**[0120]** As shown in FIG. 13, the antenna structure may include the antenna element 111 and an antenna element 112. Ground ends of the antenna element 111 and the antenna element 112 are ground ends disposed on a same side. The same side may be understood as that positions of the ground ends on radiators are on a left side or on a right side, or on an upper side or on a lower side. In an embodiment, two radiators that are juxtaposed have ground ends disposed on a same side, and the ground ends of the two radiators are close to each other. Being close to each other may be understood as that a distance

between the ground ends of the antenna element 111 and the antenna element 112 is greater than a distance between any ground end and any open end that are of the antenna element 111 and the antenna element 112.

**[0121]** In this embodiment of this application, both a first radiator and a second radiator (or a first parasitic stub) extend in a first direction, a first end of the first radiator is a ground end, a second end of the first radiator is an open end, a first end of the second radiator is an open end, and a second end of the second radiator is a ground end. That the first end of the first radiator and the second end of the second radiator are ground ends disposed on different sides may be understood as that the first end of the first radiator is on a first side in the first direction, the second end of the first radiator is on a second side in the first direction, the first end of the second radiator is on the first side in the first direction, and the second end of the second radiator is on the second side in the first direction. That the first end of the first radiator and the second end of the second radiator are ground ends disposed on a same side may be understood as that the first end of the first radiator is on a first side in the first direction, the second end of the first radiator is on a second side in the first direction, the first end of the second radiator is on the second side in the first direction, and the second end of the second radiator is on the first side in the first direction.

**[0122]** In an embodiment, that the ground ends are located on a same side may be understood as that the ground ends are located on a same side of a virtual axis of a radiator, and distances between the virtual axis, and an open end and a ground end of the radiator are the same.

**[0123]** Compared with the antenna structure shown in (a) in FIG. 10, the antenna structure shown in the embodiment in FIG. 13 further shows feeding. In an embodiment, a feed point may be added on a ground end of an antenna element, to feed an electrical signal at the feed position through a feed element. In another embodiment, the feed position may alternatively be adjusted based on an actual design requirement. For example, the feed point may be located at a center of the radiator, or located between a center of the radiator and the ground end. This is not limited in this application. As shown in FIG. 14, when the electrical signal is fed into the antenna element 111, a resonance may be generated. As a distance D1 between a center (which may be understood as a geometric center of the radiator) of the antenna element 111 and a center of the antenna element 112 increases (for example, D1 gradually increases from 5 mm to 20 mm), the resonance slightly changes.

**[0124]** As shown in FIG. 15, as the distance D1 between the center of the antenna element 111 and the center of the antenna element 112 increases, isolation between the antenna element 111 and the antenna element 112 becomes better.

**[0125]** Refer to FIG. 16. For ease of understanding, a relative position of the antenna structure, a feed position, and a relative position of a grounding position on a

radiator that are shown in FIG. 16 are the same as or similar to those of the antenna structure shown in FIG. 13. As shown in FIG. 16, when the electrical signal is fed into the antenna element 111, a mode current is mainly concentrated on a radiator of the antenna element 111, and a current on a radiator of the antenna element 112 is an induced current that is generated through spatial coupling between the radiator of the antenna element 111 and the radiator of the antenna element 112, instead of being generated through excitation by a mode current on a ground plane. When the distance D1 between the center of the antenna element 111 and the center of the antenna element 112 becomes small (for example, D1 gradually decreases from 20 mm to 5 mm), an induced current generated through coupling of the radiator of the antenna element 112 increases, and isolation between the antenna element 111 and the antenna element 112 becomes poor accordingly. When the distance D1 between the center of the antenna element 111 and the center of the antenna element 112 increases, an induced current generated through coupling of the radiator of the antenna element 112 decreases, and isolation between the antenna element 111 and the antenna element 112 becomes good accordingly.

**[0126]** Therefore, for the antenna structure shown in FIG. 13 (the ground ends are located on the same side), isolation between the antenna elements is mainly determined by a spatial distance/physical distance between the two antenna elements. In the antenna structure, coupling between the two antenna elements is in a negative correlation relationship with a distance between the two antenna elements. Therefore, this type of antenna structure may be considered as a weakly-coupled antenna structure.

**[0127]** FIG. 17 to FIG. 20 show an antenna structure and a simulation result of the antenna structure according to an embodiment of this application. FIG. 17 is a diagram of the antenna structure according to an embodiment of this application. FIG. 18 shows an S11 simulation result of an antenna element 113 in the antenna structure shown in FIG. 17. FIG. 19 shows a simulation result of isolation between antenna elements in the antenna structure shown in FIG. 17. FIG. 20 is a diagram of current distribution corresponding to a case in which an electrical signal is fed into the antenna element 113 in the antenna structure shown in FIG. 17.

**[0128]** As shown in FIG. 17, the antenna structure may include the antenna element 113 and an antenna element 114. Ground ends of the antenna element 113 and the antenna element 114 are ground ends disposed on different sides. The different sides may be understood as that positions of the ground ends on radiators are respectively on a left side and a right side, or on an upper side and a lower side. In an embodiment, two radiators that are juxtaposed have ground ends disposed on different sides, and ground ends of the two radiators are away from each other. Being away from each other may be understood as that a distance between the ground

ends of the antenna element 113 and the antenna element 114 is greater than a distance between any ground end and any open end that are of the antenna element 113 and the antenna element 114. In an embodiment, that the ground ends are located on different sides may be understood as that the ground ends are located on different sides of a virtual axis of a radiator, and distances between the virtual axis, and an open end and a ground end of the radiator are the same. Compared with the antenna structure shown in (b) in FIG. 10, the antenna structure shown in the embodiment in FIG. 17 further shows feeding. In an embodiment, a feed point may be added on a ground end of an antenna element, to feed an electrical signal at the feed position through a feed element. In another embodiment, the feed position may alternatively be adjusted based on an actual design requirement. For example, the feed point may be located at a center of the radiator, or located between a center of the radiator and the ground end. This is not limited in this application.

**[0129]** As shown in FIG. 18, when the electrical signal is fed into the antenna element 113, two resonances may be generated, for example, one is referred to as a low-frequency resonance, and the other is referred to as a high-frequency resonance. As a distance D2 between a center of the antenna element 113 and a center of the antenna element 114 increases (for example, D2 gradually increases from 5 mm to 20 mm), the low-frequency resonance shifts toward a high frequency, the high-frequency resonance shifts toward a low frequency, and a frequency difference between the two resonances decreases.

**[0130]** As shown in FIG. 19, isolation between the antenna element 113 and the antenna element 114 does not change with the distance D2 between the center of the antenna element 113 and the center of the antenna element 114.

**[0131]** Refer to FIG. 20. For ease of understanding, a relative position of the antenna structure, a feed position, and a relative position of a grounding position on a radiator that are shown in FIG. 20 are the same as or similar to those of the antenna structure shown in FIG. 17. As shown in FIG. 20, when the electrical signal is fed into the antenna element 113, a first mode and a second mode may be included. The first mode may be the HWM shown in (a) in FIG. 12, and the second mode may be the OWM shown in (b) in FIG. 12.

**[0132]** As shown in (a) and (b) in FIG. 20, in the first mode, a mode current flows from the open end (an ungrounded end) of the antenna element 114 to the ground end, flows through a ground plane to the ground end of the antenna element 113, and then flows to the open end of the antenna element 113. In distribution of the mode current, a current direction remains unchanged. When the electrical signal is fed into the antenna element 113, the mode current on the antenna element 114 is not in a positive or negative correlation relationship with the distance D2 between the antenna

elements. Similarly, as shown in (c) and (d) in FIG. 20, in the second mode, a mode current flows from the open end (an ungrounded end) of the antenna element 113 to the ground end, flows through the ground plane to the ground end of the antenna element 114, and then flows to the open end of the antenna element 114. In distribution of the mode current, a reversal occurs on the ground plane. When the electrical signal is fed into the antenna element 113, the mode current on the antenna element 114 is not in a positive or negative correlation relationship with the distance D2 between the antenna elements.

**[0133]** Therefore, for the antenna structure shown in FIG. 17 (the ground ends are located on different sides), a spatial distance/physical distance between the two antenna elements has little impact on isolation. In the antenna structure, coupling between the two antenna elements is in a small correlation, not in a positive or negative correlation relationship with a distance between the two antenna elements. Therefore, this type of antenna structure may be considered as a strongly-coupled antenna structure.

**[0134]** FIG. 21 to FIG. 24 show an antenna structure and a simulation result of the antenna structure according to this application. FIG. 21 is a diagram of the antenna structure according to this application. FIG. 22 is a diagram of an S parameter of the antenna structure shown in FIG. 21. FIG. 23 is a diagram of current distribution corresponding to a case in which an electrical signal is fed into a first antenna element in the antenna structure. FIG. 24 is a diagram of current distribution corresponding to a case in which an electrical signal is fed into a second antenna element in the antenna structure.

**[0135]** Compared with that in the antenna structure shown in FIG. 17, in the antenna structure in an embodiment shown in FIG. 21, a resonant connector (which may also be referred to as a resonant line/tuning line (tuning line)) is disposed between two antenna elements, and an electronic element is disposed in a slot provided in the resonant connector.

**[0136]** An equivalent inductance value of the electronic element is related to a frequency of a resonance generated in an HWM of the antenna element. For example, when the equivalent inductance value of the electronic element is small, the frequency of the resonance generated in the HWM of the antenna element is high, and vice versa. In an embodiment, equivalent inductance values of the resonant connector may be different by changing the equivalent inductance value of the electronic element, and the frequency of the resonance generated in the HWM of the antenna element may shift. For example, when the electronic element is adjusted to reduce an inductance value of an equivalent inductor of the resonant connector, the frequency of the resonance generated in the HWM of the antenna element shifts toward a high frequency, but a frequency of a resonance generated in an OWM basically does not change. In an embodiment, when the frequency of the resonance generated in the HWM is as high as the frequency of the resonance

generated in the OWM, the resonances generated in the two modes are fused, for example, the two resonances are combined into one (S11 or S22), as shown in FIG. 22.

**[0137]** It should be understood that, when the resonant connector is not provided with a slot (not electrically connected to the electronic element), an equivalent inductance value of the resonant connector may be correspondingly set by setting a length, a width, and a thickness of the resonant connector, so that the frequency of the resonance generated in the HWM of the antenna element is on a target frequency/frequency band.

**[0138]** When the electrical signals are simultaneously fed into the two antenna elements, isolation (S12 or S21) between the two antenna elements is below -20 dB, as shown in FIG. 22.

**[0139]** Refer to FIG. 23. For ease of understanding, a relative position of the antenna structure, a feed position, and a relative position of a grounding position on a radiator that are shown in FIG. 23 are the same as or similar to those of the antenna structure shown in FIG. 21. As shown in FIG. 23, when the electrical signal is fed into the first antenna element, a mode current is mainly concentrated on a radiator of the first antenna element. In an embodiment, a mode current is generated on both the radiator of the first antenna element and a ground plane near the radiator. On a radiator of the second antenna element, a mode current generated in a first resonance mode and a mode current generated in a second resonance mode counteract each other. In this case, a current on the second antenna element is weak. In an embodiment, on a ground plane near the radiator of the second antenna element, a mode current generated in the first resonance mode and a mode current generated in the second resonance mode counteract each other. In this case, a current on the ground plane is weak.

**[0140]** Similarly, as shown in FIG. 24, when the electrical signal is fed into the second antenna element, a mode current is mainly concentrated on a radiator of the second antenna element. In an embodiment, a mode current is generated on both the radiator of the second antenna element and a ground plane near the radiator. On a radiator of the first antenna element, a mode current generated in a first resonance mode and a mode current generated in a second resonance mode counteract each other. In this case, a current on the first antenna element is weak. In an embodiment, on the ground plane near the radiator of the first antenna element, a mode current generated in the first resonance mode and a mode current generated in the second resonance mode counteract each other. In this case, a current on the ground plane is weak.

**[0141]** Therefore, there is good isolation between the first antenna element and the second antenna element. In addition, it can be learned from the foregoing analysis that isolation between the first antenna element and the second antenna element is not closely related to a physical distance between the two radiators, for example, there is no positive or negative correlation relationship.

**[0142]** FIG. 25 is a diagram of an electronic device 200 according to an embodiment of this application.

**[0143]** As shown in FIG. 25, the electronic device 200 may include a first antenna element 210, a second antenna element 220, a ground plane 230, a resonant connector 240, and a first electronic element 241.

**[0144]** The first antenna element 210 may include a first radiator 211 and a first feed element 212. The first radiator 211 includes a first feed point 213, and the first feed element 212 is coupled (for example, is in spaced coupling or an electrical connection) with the first radiator 211 through the first feed point 213.

**[0145]** The second antenna element 220 may include a second radiator 221 and a second feed element 222. The second radiator 221 includes a second feed point 223, the second feed element 222 is coupled (for example, is in spaced coupling or an electrical connection) to the second radiator 221 through the second feed point 223, and the first feed element 212 is different from the second feed element 222. In an embodiment, that the first feed element 212 is different from the second feed element 222 may be understood as that an electrical signal generated by the first feed element 212 and an electrical signal generated by the second feed element 222 are different, and are not generated by a same feed by using a feed network. For example, the first feed element 212 and the second feed element 222 may be different radio frequency channels of a same power supply chip. It should be understood that in the technical solutions provided in embodiments of this application, an electrical connection (direct coupling) is used as an example for description. During actual design or production, indirect coupling may be used for replacement, and same technical effect may be obtained. This is not limited in this application. In an embodiment in which the first feed element 212 is indirectly coupled to the first radiator 211 through the first feed point 213, the first feed point 213 may be understood as an area that is on the first radiator 211 and that is disposed face to face (face to face) with a feeding structure. A same or similar understanding should be made for "indirect coupling" in embodiments of this application.

**[0146]** It should be understood that, that the first feed element 212 and the second feed element 222 are different may be understood as that the first feed element 212 and the second feed element 222 are different radio frequency channels in a radio frequency chip. A frequency of a first electrical signal fed by the first feed element 212 may be the same as or different from a frequency of a second electrical signal fed by the second feed element 222. In an embodiment, the frequency of the first electrical signal fed by the first feed element 212 is the same as the frequency of the second electrical signal fed by the second feed element 222. The first antenna element 210 and the second antenna element 220 may serve as subunits in a MIMO system. Operating frequency bands of the first antenna element 210 and the second antenna element 220 each include a first fre-

quency band, and an electrical signal is received or transmitted in the first frequency band. Alternatively, the first antenna element 210 serves as a transmit unit, and the second antenna element 220 serves as a receive unit. In an embodiment, the frequency of the first electrical signal fed by the first feed element 212 is different from the frequency of the second electrical signal fed by the second feed element 222. The first antenna element 210 and the second antenna element 220 may serve as two independent antenna elements to transmit or receive electrical signals of different frequency bands. A first end of the resonant connector 240 is electrically connected to the first radiator 211, and a second end of the resonant connector 240 is electrically connected to the second radiator 221.

**[0147]** In an embodiment, the resonant connector 240 may be disposed between the first radiator 211 and the second radiator 221. It should be understood that, the resonant connector 240 may be disposed on a same plane as the first radiator 211 and the second radiator 221. In an embodiment, the first radiator 211, the second radiator 221, and the resonant connector 240 are disposed on a same support. Alternatively, the resonant connector 240 may be disposed on a PCB. In an embodiment, two ends of the resonant connector 240 may be electrically connected to the first radiator 211 and the second radiator 221 via a spring plate. It should be understood that the resonant connector 240 and the radiator may be made of a same material or different materials, and may be integrated or separately formed. In an embodiment, a width/thickness of the resonant connector 240 is smaller than that of the radiator. In an embodiment, the resonant connector 240 is linear relative to the radiator, for example, a length of the resonant connector 240 is greater than five times a width of the resonant connector 240.

**[0148]** A first end of the first electronic element 241 is electrically connected to the resonant connector 240, and a second end of the first electronic element 241 is grounded (grounding may be understood as being coupled to the ground plane 230 at the position, and may also be correspondingly understood in the following embodiment). For example, grounding is implemented by electrically connecting to the ground plane 230, or coupling to the ground plane 230 is implemented by using a ground component.

**[0149]** A first end 2111 of the first radiator 211 is grounded, and a second end 2212 of the second radiator 221 is grounded. The first radiator 211 and the second radiator 221 are juxtaposed, and the first end 2111 of the first radiator 211 and the second end 2212 of the second radiator 221 are ground ends disposed on different sides.

**[0150]** In an embodiment, a projection of the first radiator 211 on a plane on which the ground plane 230 is located is a first projection, and a projection of the second radiator 221 on the plane on which the ground plane 230 is located is a second projection. The first projection and the second projection extend (for example, in parallel) in

a first direction (for example, a y direction), and at least partially overlap in a second direction (for example, an x direction), where the second direction is perpendicular to the first direction. In an embodiment, the first radiator 211 and the second radiator 221 are disposed in parallel and non-collinearly. In an embodiment, the first radiator 211 and the second radiator 221 are disposed on a same plane.

**[0151]** It should be understood that a direction of the first radiator 211 from the ground end to an open end is a third direction, and a direction of the second radiator 221 from the ground end to the open end is a fourth direction. That the first projection and the second projection are parallel in a first direction (for example, a y direction) may be understood as that the third direction is parallel to the fourth direction. In the following embodiment, that projections are parallel to each other and projections are perpendicular to each other may also be understood as that directions of corresponding radiators from ground ends to open ends are parallel to each other or perpendicular to each other.

**[0152]** In an embodiment, a distance between the first end 2111 of the first radiator 211 and the second end 2212 of the second radiator 221 is greater than a distance between the first end 2111 of the first radiator 211 and the first end 2211 of the second radiator 221, and the ground end of the first radiator 211 and the ground end of the second radiator 221 are ground ends disposed on different sides. In an embodiment, the ground end of the first radiator 211 and the ground end of the second radiator 221 are away from each other.

**[0153]** It should be understood that a radiator of the first antenna element 210 and a radiator of the second antenna element 220 are disposed in parallel, a ground end (a first end) of the first antenna element 210 and a ground end (a second end) of the second antenna element 220 are located on different sides, and the first antenna element 210 and the second antenna element 220 are of a strongly-coupled antenna structure.

**[0154]** In an embodiment, a frequency of a resonance generated in an OWM is related to an equivalent capacitance value of the first electronic element 241. In an embodiment, a frequency of a resonance generated in an HWM is basically irrelevant to an equivalent capacitance value of the first electronic element 241.

**[0155]** It should be understood that, as mentioned in embodiments of this application, that a frequency is "related" to an element may be understood as that an equivalent value (for example, an equivalent capacitance value or an equivalent inductance value) of the element affects a resonance frequency, and/or existence or absence of the element affects the resonance frequency. In other words, an expected resonance frequency may be obtained by selecting a proper element, or a resonance frequency caused by existence or absence of the element may cover a completely different frequency range before and after a change, which is referred to as "correlation".

**[0156]** It should be understood that, as mentioned in embodiments of this application, that a frequency is "basically irrelevant to" an element may be understood as that an equivalent value (for example, an equivalent capacitance value or an equivalent inductance value) of the element basically does affect a frequency of a resonance generated in the OWM, and/or existence or absence of the element basically does not affect the frequency of the resonance generated in the OWM. That the frequency of the resonance is basically not affected may be understood as that the frequency of the resonance may cover at least a part of a same frequency range before and after a change, which is referred to as "basically irrelevant".

**[0157]** The equivalent capacitance value of the first electronic element 241 is related to the frequency of the resonance generated in the OWM of the antenna element. For example, when the equivalent capacitance value of the electronic element is large, the frequency of the resonance generated in the OWM of the antenna element is low, and vice versa. In an embodiment, the frequency of the resonance generated in the OWM of the antenna element shifts by changing the equivalent capacitance value of the first electronic element 241. For example, when the first electronic element 241 is adjusted to increase a capacitance value of an equivalent capacitor of the first electronic element 241, the frequency of the resonance generated in the OWM of the antenna element shifts toward a low frequency, but a frequency of a resonance generated in the HWM basically does not change. When the frequency of the resonance generated in the HWM is as high as the frequency of the resonance generated in the OWM, the resonances generated in the two modes are fused, for example, the two resonances are combined into one.

**[0158]** Through the resonant connector 240 disposed between the first radiator 211 and the second radiator 221 and the first electronic element 241 between the resonant connector 240 and the ground plane 230, a frequency of a resonance generated in a first resonance mode (for example, the HWM) and a frequency of a resonance generated in a second resonance mode (for example, the OWM) that are of each of the first antenna element 210 and the second antenna element 220 may be separately adjusted. In this case, a resonance frequency band in the first resonance mode and a resonance frequency band in the second resonance mode are intra-frequency resonance frequency bands, and a mode current in the first resonance mode and a mode current in the second resonance mode counteract each other, to improve isolation between the first antenna element 210 and the second antenna element 220. It should be understood that the first radiator 211 and the second radiator 221 may be configured to: jointly generate a first resonance and jointly generate a second resonance.

**[0159]** When an electrical signal is fed into the first antenna element 210, current distribution corresponding to the first resonance mode is approximately shown in (a)

in FIG. 12, and current distribution corresponding to the second resonance mode is approximately shown in (b) in FIG. 12. In the first resonance mode and the second resonance mode, mode currents on the first radiator 211 and the ground plane at one side of the first antenna element 210 are the same in direction, and mode currents on the second radiator 221 and the ground plane at one side of the second antenna element 220 are reverse in direction. When the resonance frequency band generated in the first resonance mode and the resonance frequency band generated in the second resonance mode are intra-frequency resonance frequency bands, the mode currents that are generated in the first resonance mode and the second resonance mode and that are on the second radiator 221 and the ground plane at one side of the second antenna element 220 counteract each other. When the electrical signal is fed into the first antenna element 210, the mode currents are mainly concentrated on the ground plane at one side of the first antenna element 210 and the first radiator 211. Similarly, when an electrical signal is fed into the second antenna element 220, the mode currents are mainly concentrated on the ground plane at one side of the second antenna element 220 and the second radiator 221.

**[0160]** Therefore, there is good isolation between the first antenna element 210 and the second antenna element 220. When the operating frequency band of the first antenna element 210 and the operating frequency band of the second antenna element 220 are intra-frequency resonance frequency bands, the first antenna element 210 and the second antenna element 220 may be used in the MIMO system.

**[0161]** In an embodiment, the electronic device 200 may further include a second electronic element 242. The resonant connector 240 may include a slot 243, and the second electronic element 242 may be disposed in the slot 243. In an embodiment, the second electronic element 242 is connected in series on the resonant connector 240 through the slot 243. In an embodiment, two ends of the second electronic element 242 are electrically connected to portions that are of the resonant connector 240 and that are on the two sides of the slot respectively.

**[0162]** In an embodiment, the frequency of the resonance generated in the first resonance mode (for example, the HWM) is related to an equivalent inductance value of the second electronic element 242. In an embodiment, the frequency of the resonance generated in the second resonance mode (for example, the OWM) is basically irrelevant to the equivalent inductance value of the second electronic element 242.

**[0163]** In an embodiment, the first electronic element 241 may be a capacitor or an inductor.

**[0164]** In an embodiment, the second electronic element 242 may be a capacitor or an inductor.

**[0165]** It should be understood that the resonant connector 240 may be equivalent to an inductor, and an inductance value of the equivalent inductor of the resonant connector 240 is related to a length, a width, and a

thickness of the resonant connector 240. An equivalent inductance value of the resonant connector 240 is further related to the second electronic element 242, or in other words, the frequency of the resonance corresponding to the first resonance mode is related to the length, the width, and the thickness of the resonant connector 240, and the second electronic element 242. For example, when the second electronic element 242 is a capacitor (the inductance value of the equivalent inductor of the resonant connector decreases), the frequency of the resonance corresponding to the first resonance mode is high; and when the second electronic element 241 is an inductor (the inductance value of the equivalent inductor of the resonant connector increases), the frequency of the resonance corresponding to the first resonance mode is low.

**[0166]** The first electronic element 241 between the ground plane 230 and the resonant connector 240 is related to the second resonance mode (for example, the OWM) of the antenna element. For example, when the first electronic element 241 is a capacitor, the frequency of the resonance corresponding to the second resonance mode is low, and when the first electronic element 241 is an inductor, the frequency of the resonance corresponding to the second resonance mode is high. In an embodiment, the first end of the resonant connector 240 is located between the first end of the first radiator 211 and a midpoint of the first radiator 211, the midpoint may be a geometric center of the first radiator 211, and distances between the midpoint, and the first end and the second end of the first radiator 211 are the same. The following midpoint may also be understood correspondingly.

**[0167]** In an embodiment, the second end of the resonant connector 240 is located between the second end of the second radiator 221 and a midpoint of the second radiator 221.

**[0168]** In an embodiment, an electrical length of the first radiator 211 may be a quarter of a first wavelength, and the first wavelength may be a wavelength corresponding to a resonance frequency of the first antenna element 210, for example, may be a wavelength corresponding to a resonance point or a center frequency of a resonance frequency band.

**[0169]** In an embodiment, an electrical length of the second radiator 221 may be a quarter of a second wavelength, and the second wavelength may be a wavelength corresponding to a resonance frequency of the second antenna element 220.

**[0170]** In an embodiment, an electrical length E1 of the first radiator 211 and an electrical length E2 of the second radiator 221 satisfy the following:  $E1 \times 80\% \leq E2 \leq E1 \times 120\%$ .

**[0171]** It should be understood that an electrical length of a radiator of the first antenna element 210 and an electrical length of a radiator of the second antenna element 220 should be approximately the same, so that the operating frequency band of the first antenna element



210 and the operating frequency band of the second antenna element 220 are the same. The first antenna element 210 and the second antenna element 220 may serve as subunits in the MIMO system.

**[0172]** It should be understood that a physical length of the radiator is associated with an electrical length of the radiator to a specific extent. In an embodiment, a physical length L1 of the first radiator 211 and a physical length L2 of the second radiator 221 satisfy the following:  $L1 \times 80\% \leq L2 \leq L1 \times 120\%$ . In an embodiment, the first radiator 211 and the second radiator 221 are juxtaposed. In an embodiment, a projection (the first projection) of the first radiator 211 on the ground plane and a projection (the second projection) of the second radiator 221 on the ground plane may at least partially overlap in the second direction (for example, the x direction). As shown in FIG. 26, the first radiator 211 and the second radiator 221 are disposed in parallel and non-collinearly, and only partially overlap in the second direction. For example, the first radiator 211 and the second radiator 221 have a specific misplacement in the first direction (for example, the y direction). In an embodiment, a length L3 of an overlapping part between the projection (the first projection) of the first radiator 211 on the ground plane and the projection (the second projection) of the second radiator 221 on the ground plane in the second direction and a length L4 of the first projection satisfy the following:  $L4 \times 80\% \leq L3$ .

**[0173]** In this embodiment of this application, because the radiator is not necessarily in a regular shape, the length of the projection of the radiator on the ground plane may be understood as lengths of the ground end and the open end of the radiator in an extension direction of the radiator.

**[0174]** It should be understood that, a larger overlapping part between the first projection and the second projection in the second direction indicates better radiation performance. When the first projection and the second projection completely overlap in the second direction, the performance is optimal. It should be further understood that, a larger overlapping part between the first projection and the second projection in the second direction indicates smaller space occupied by the first radiator 211 and the second radiator 221, and a more compact structure.

**[0175]** In an embodiment, the first feed element 212 of the first antenna element 210 may be electrically connected to the first radiator 211 on a side close to the ground end of the first radiator 211. The first radiator 211 may be a linear radiator (for example, a length is three times or more of a width). The first antenna element 210 may be an inverted F antenna (inverted F antenna, IFA), or the first radiator 211 may be a sheet-like radiator (for example, a length is less than three times of a width). The first antenna element 210 may be a planar inverted F antenna (planar inverted F antenna, PIFA). Alternatively, in an embodiment, the first feed element 212 of the first antenna element 210 may be electrically con-

nected to the first radiator 211 on a side close to the open end of the first radiator 211. In an embodiment, the second antenna element 220 may also be any one of the foregoing antenna types.

**[0176]** In an embodiment, a distance between the first radiator 211 and the second radiator 221 is less than 5 mm. The first antenna element 210 and the second antenna element 220 may be compactly arranged inside an electronic device, thereby saving internal space. It should be understood that, when the first radiator 211 and the second radiator 221 are sheet-like radiators (for example, a length is less than three times a width), the distance between the first radiator 211 and the second radiator 221 may be further reduced with widths (which may be understood as lengths of the radiators in the second direction, or lengths in a direction perpendicular to a direction from the ground ends of the radiators to the open ends) of the radiators. In an embodiment, the distance between the first radiator 211 and the second radiator 221 is less than 2 mm.

**[0177]** In an embodiment, the first radiator 211 may be a part of the side frame 11 of the electronic device. As shown in FIG. 27, the part of the side frame 11 is a conductive side frame. In an embodiment, the first radiator 211 may further be a conductor (for example, a liquid crystal polymer (liquid crystal polymer, LCP)) inside the side frame 11 of the electronic device, and the part of the side frame 11 is a non-conductive side frame. For example, the side frame 11 has a first position and a second position, the first position is provided with a slot, the second position is electrically connected to the ground plane, a side frame between the first position and the second position is a first side frame, and the first side frame may serve as the first radiator 211. In an embodiment, the second radiator 221 may be disposed inside the side frame 11, and may be disposed on a surface of a support.

**[0178]** In an embodiment, the first radiator 211 and the second radiator 221 may be disposed on a rear cover of the electronic device. For example, the first radiator 211 and the second radiator 221 are a part of a conductive rear cover, or are disposed on a surface of or inside a non-conductive rear cover.

**[0179]** In an embodiment, the first radiator 211 and the second radiator 221 may be disposed on a support in the electronic device, for example, may be separately disposed on different support bodies, or may be disposed on a same support body and on a same plane.

**[0180]** It should be understood that layouts of the first antenna element and the second antenna element inside the electronic device are not limited in embodiments of this application, and may be adjusted based on an actual production design requirement.

**[0181]** FIG. 28 is a diagram of a structure of an electronic device 300 according to an embodiment of this application.

**[0182]** As shown in FIG. 28, the electronic device 300 may include a first antenna element 310, a second an-

tenna element 320, a third antenna element 330, a ground plane 340, a first resonant connector 351, a second resonant connector 352, a first electronic element 361, and a second electronic element 362.

**[0183]** The first antenna element 310 may include a first radiator 311 and a first feed element 312. The first radiator 311 includes a first feed point 313, and the first feed element 312 is electrically connected to the first radiator 311 at the first feed point 313.

**[0184]** The second antenna element 320 may include a second radiator 321 and a second feed element 322. The second radiator 321 includes a second feed point 323, and the second feed element 322 is electrically connected to the second radiator 321 at the second feed point 323.

**[0185]** The third antenna element 330 may include a third radiator 331 and a third feed element 332. The second radiator 321 is located between the first radiator 311 and the third radiator 331. The third radiator 331 includes a third feed point 333, and the third feed element 332 is electrically connected to the third radiator 331 at the third feed point 333.

**[0186]** The first feed element 312, the second feed element 322, and the third feed element 332 are different from each other. In an embodiment, that the first feed element 312, the second feed element 322, and the third feed element 332 are different from each other may be understood as that an electrical signal generated by the first feed element 312, an electrical signal generated by the second feed element 322, and an electrical signal generated by the third feed element 332 are different, and are not generated by a same feed by using a feed network. For example, the first feed element 312, the second feed element 322, and the third feed element 332 may be different radio frequency channels of a same power supply chip.

**[0187]** It should be understood that, that the second radiator 321 is located between the first radiator 311 and the third radiator 331 may be understood as that the second radiator 321 is located between the first radiator 311 and the third radiator 331 in space, and the second radiator 321 is not necessarily coplanar with the first radiator 311 and the third radiator 331, and may be adjusted based on an actual design.

**[0188]** A first end of the first resonant connector 351 is electrically connected to the first radiator 311, and a second end of the first resonant connector 351 is electrically connected to the second radiator 322. A first end of the first electronic element 361 is electrically connected to the first resonant connector 351, and a second end of the first electronic element 361 is grounded.

**[0189]** A first end of the second resonant connector 352 is electrically connected to the second radiator 322, and a second end of the second resonant connector 352 is electrically connected to the third radiator 332. A first end of the second electronic element 362 is electrically connected to the second resonant connector 352, and a second end of the second electronic element 362 is

grounded. Disposing positions and implementation forms of the first resonant connector 351 and the second resonant connector 352 are similar to those in the foregoing embodiments. Details are not described again.

**[0190]** A first end of the first radiator 311 is grounded, a second end of the second radiator 321 is grounded, and a first end of the third radiator 331 is grounded. The first radiator 311 and the second radiator 321 are juxtaposed, and the first end of the first radiator 311 and the second end of the second radiator 321 are ground ends disposed on different sides. The third radiator 331 and the second radiator 321 are juxtaposed, and the first end of the third radiator 331 and the second end of the second radiator 321 are ground ends disposed on different sides.

**[0191]** In an embodiment, the first radiator 311 and the second radiator 321 are juxtaposed.

**[0192]** In an embodiment, a projection of the first radiator 311 on a plane on which the ground plane 340 is located is a first projection, and a projection of the second radiator 321 on the plane on which the ground plane 340 is located is a second projection. The first projection and the second projection are parallel in a first direction (for example, a y direction), and at least partially overlap in a second direction (for example, an x direction), where the second direction is perpendicular to the first direction. In an embodiment, the first radiator 311 and the second radiator 321 are disposed in parallel and non-collinearly. In an embodiment, the first radiator 311 and the second radiator 321 are disposed on a same plane.

**[0193]** In an embodiment, the second radiator 321 and the third radiator 331 are juxtaposed.

**[0194]** In an embodiment, a third projection is a projection of the third radiator 331 on the plane on which the ground plane 340 is located, and the second projection and the third projection are parallel in the first direction (for example, the y direction), and at least partially overlap in the second direction (for example, the x direction). In an embodiment, the second radiator 321 and the third radiator 331 are disposed in parallel and non-collinearly. In an embodiment, the second radiator 321 and the third radiator 331 are disposed on a same plane.

**[0195]** In an embodiment, the ground end of the first radiator 311 and the ground end of the second radiator 321 are ground ends disposed on different sides. A distance between the first end of the first radiator 311 and the second end of the second radiator 321 is greater than a distance between the first end of the first radiator 311 and the first end of the second radiator 321. In an embodiment, the ground end of the first radiator 311 and the ground end of the second radiator 321 are away from each other.

**[0196]** In an embodiment, the ground end of the third radiator 331 and the ground end of the second radiator 321 are ground ends disposed on different sides. A distance between the first end of the third radiator 331 and the second end of the second radiator 321 is greater than a distance between the first end of the third radiator 331 and the first end of the second radiator 321. In an

embodiment, the ground end of the third radiator 331 and the ground end of the second radiator 321 are away from each other. The ground end of the third radiator 331 and the ground end of the first radiator 311 are close to each other, and are disposed on a same side.

**[0197]** It should be understood that, a difference between an antenna structure including the first antenna element, the second antenna element, and the third antenna element shown in FIG. 28 and an antenna structure including the antenna structure including the first antenna element and the second antenna element shown in FIG. 25 lies in that the third antenna element is added. The technical solutions provided in embodiments of this application may also be applied to an antenna structure including three or more antenna elements, and a quantity of antenna elements is not limited, and may be set based on an actual production or design requirement.

**[0198]** The radiator of the first antenna element 310, the radiator of the second antenna element 320, and the radiator of the third antenna element 330 are disposed in parallel. The ground end (the first end) of the first antenna element 310 and the ground end (the second end) of the second antenna element 320 are located on different sides, and the first antenna element 310 and the second antenna element 320 form a strongly-coupled antenna structure. The ground end (the second end) of the second antenna element 320 and the ground end (the first end) of the third antenna element 330 are located on different sides, and the second antenna element 320 and the third antenna element 330 form a strongly-coupled antenna structure.

**[0199]** Through a resonant connector disposed between radiators of adjacent antenna elements and an electronic element connected in parallel between the resonant connector and the ground plane 240, a frequency of a resonance generated in a first resonance mode (for example, an HWM) of the antenna element and a frequency of a resonance generated in a second resonance mode (for example, an OWM) of the antenna element may be separately adjusted. In this case, a resonance frequency band in the first resonance mode and a resonance frequency band in the second resonance mode are intra-frequency resonance frequency bands, and a mode current in the first resonance mode and a mode current in the second resonance mode counteract each other, to improve isolation between adjacent antenna elements.

**[0200]** In addition, for two antenna elements (for example, the first antenna element 310 and the third antenna element 330) that are spaced away from each other, because the ground end (the first end) of the first antenna element 310 and the ground end (the first end) of the third antenna element 330 are located on a same side, a weakly-coupled antenna structure similar to that shown in (a) in FIG. 10 may be formed between the two antenna elements. Isolation between antenna elements is mainly determined by the distance between the antenna elements. Antenna elements whose ground ends are

located on a same side are disposed at intervals, and antenna elements whose ground ends are located on different sides are disposed between two antenna elements whose ground ends are located on the same side.

Therefore, sufficient spacing may be maintained between the antenna elements whose ground ends are located on the same side, to achieve good isolation between the antenna elements.

**[0201]** In an embodiment, the first radiator 311 and the second radiator 321 are linear radiators (for example, a length is three times or more of a width), and a distance between the first radiator 311 and the second radiator 321 is less than 5 mm. In an embodiment, the third radiator 331 is a linear radiator (for example, a length is three times or more of a width), and a distance between the second radiator 321 and the third radiator 331 is less than 5 mm. In an embodiment, the first radiator 311 and the second radiator 321 are sheet-like radiators (for example, a length is less than three times of a width), and the distance between the first radiator 311 and the second radiator 321 is less than 2 mm. In an embodiment, the third radiator 331 is a sheet-like radiator (for example, a length is less than three times of a width), and the distance between the second radiator 321 and the third radiator 331 is less than 2 mm. The first antenna element 310, the second antenna element 320 and the third antenna element 330 may be compactly arranged inside an electronic device, thereby saving internal space.

**[0202]** It should be understood that the distance between the first radiator 311 and the second radiator 321 and/or the distance between the second radiator 321 and the third radiator 331 may be understood as a smallest value of straight-line distances between points on adjacent radiators.

**[0203]** In an embodiment, the electronic device 300 may further include a third electronic element 363 and a fourth electronic element 364. A slot may be formed on each of the first resonant connector 351 and the second resonant connector 352. The third electronic element 363 may be disposed in the slot of the first resonant connector 351, and is connected in series between portions that are of the first resonant connector 351 and that are on the two sides of the slot. Two ends of the third electronic element 363 are electrically connected to the portions that are of the first resonant connector 351 and that are on the two sides of the slot respectively. The fourth electronic element 364 may be disposed in the slot of the second resonant connector 352, and is connected in series between portions that are of the second resonant connector 352 and that are on the two sides of the slot. Two ends of the fourth electronic element 364 are electrically connected to the portions that are of the second resonant connector 352 and that are on the two sides of the slot respectively.

**[0204]** It should be understood that, during an actual application, the third electronic element 363 and the fourth electronic element 364 may not coexist, and may be adjusted according to an actual design or pro-

duction requirement. In an embodiment, the electronic device 300 may include only the third electronic element, or the electronic device 300 may include both the third electronic element 363 and the fourth electronic element 364.

**[0205]** Similarly, during an actual application, the first electronic element 361 and the second electronic element 362 may not coexist, and may be adjusted according to an actual design or production requirement. In an embodiment, the electronic device 300 may include only the first electronic element 361, or the electronic device 300 may include both the first electronic element 361 and the second electronic element 362.

**[0206]** Impact of the resonant connector, the electronic element connected in series to the resonant connector, and the electronic element connected in parallel on the resonance mode is the same as or similar to that in the foregoing embodiment. Details are not described again.

**[0207]** In an embodiment, the first end of the first resonant connector 351 is located between the first end of the first radiator 311 and a midpoint of the first radiator 311. In an embodiment, the second end of the first resonant connector 351 is located between the second end of the second radiator 321 and a midpoint of the second radiator 321.

**[0208]** In an embodiment, the first end of the second resonant connector 352 is located between the first end of the third radiator 331 and a midpoint of the third radiator 331. In an embodiment, the second end of the second resonant connector 352 is located between the second end of the second radiator 321 and a midpoint of the second radiator 321.

**[0209]** An electrical length is the same as or similar to that in the foregoing embodiment. Details are not described again.

**[0210]** In an embodiment, a physical length L1 of the first radiator 311 and a physical length L2 of the second radiator 321 satisfy the following:  
 $L1 \times 80\% \leq L2 \leq L1 \times 120\%$ .

**[0211]** In an embodiment, a physical length L3 of the third radiator 331 and a physical length L2 of the second radiator 321 satisfy the following:  
 $L3 \times 80\% \leq L2 \leq L3 \times 120\%$ .

**[0212]** It should be understood that, electrical length/s/physical lengths of the radiator of the first antenna element 310, the radiator of the second antenna element 320, and the radiator of the third antenna element 330 should be approximately the same, so that an operating frequency band of the first antenna element 310, an operating frequency band of the second antenna element 320, and an operating frequency band of the third antenna element 330 are the same. The first antenna element 310, the second antenna element 320, and the third antenna element 330 may serve as subunits in a MIMO system.

**[0213]** In an embodiment, two adjacent radiators may be juxtaposed. In an embodiment, two adjacent radiators may be disposed in parallel and non-collinearly. In an

embodiment, two adjacent radiators may be disposed on a same plane. In an embodiment, two adjacent radiators may be disposed as shown in the embodiment in FIG. 26. Details are not described again.

**[0214]** In an embodiment, the first radiator 311 may be a linear radiator, and the first antenna element 310 may be an IFA; or the first radiator 311 may be a sheet-like radiator, and the first antenna element 310 may be a PIFA. In an embodiment, the second antenna element 320 or the third antenna element 330 may also be any one of the foregoing antenna types.

**[0215]** An implementation form and a position of the radiator disposed in the electronic device are the same as or similar to those in the foregoing embodiments. Details are not described again.

**[0216]** FIG. 29 to FIG. 32 show simulation results of the antenna element shown in FIG. 28. FIG. 29 shows an S parameter of the antenna element shown in FIG. 28. FIG. 30 shows radiation efficiency and total efficiency of the antenna element shown in FIG. 28. FIG. 31 is a diagram of electric field distribution of the antenna element shown in FIG. 28. FIG. 32 is a pattern of the antenna element shown in FIG. 28.

**[0217]** Through a resonant connector disposed between radiators of adjacent antenna elements and an electronic element connected in parallel between the resonant connector and a ground plane, frequencies of a resonance generated in a first resonance mode and a second resonance mode of the antenna element may be separately adjusted, so that a resonance frequency band in the first resonance mode and a resonance frequency band in the second resonance mode are intra-frequency resonance frequency bands, and the resonance frequency bands generated in the two modes are combined into one. As shown in FIG. 29, the first antenna element, the second antenna element, and the third antenna element generate a resonance near 4G (by using  $S_{11}/S_{22}/S_{33} \leq -5$  dB as a boundary). In addition, isolation between the first antenna element and the third antenna element (spaced antenna elements) is less than -15 dB. Isolation between the first antenna element and the second antenna element, and between the second antenna element and the third antenna element (adjacent antenna elements) is less than -20 dB.

**[0218]** As shown in FIG. 30, efficiency (total efficiency and radiation efficiency) of the first antenna element, the second antenna element, and the third antenna element can all meet a communication requirement in the resonance frequency band.

**[0219]** Herein, (a), (b), and (c) in FIG. 31 are respectively diagrams of electric field distribution corresponding to a case in which the first feed element performs feeding, a case in which the second feed element performs feeding, and a case in which the third feed element performs feeding. As shown in FIG. 31, when feeding is performed on the antenna elements, mode currents on radiators of adjacent antenna elements counteract each other. Therefore, electric fields are concentrated on a radiator

of an antenna element into which an electrical signal is fed and a corresponding ground plane area, and good isolation can be formed between the antenna element into which the electrical signal is fed and an adjacent antenna element.

**[0220]** Herein, (a), (b), and (c) in FIG. 32 are respectively patterns generated when the first feed element performs feeding, the second feed element performs feeding, and the third feed element performs feeding. A maximum radiation direction is in a z direction (perpendicular to a direction in which the ground plane is located).

**[0221]** FIG. 33 is a diagram of a structure of another electronic device 300 according to an embodiment of this application.

**[0222]** As shown in FIG. 33, a difference from the antenna structure that is shown in FIG. 28 and that includes the first antenna element 310, the second antenna element 320, and the third antenna element 330 lies in that a fourth antenna element 350 and a fifth antenna element 360 are added, a resonant connector is disposed between the third antenna element 330 and the fourth antenna element 350, and a resonant connector is disposed between the fourth antenna element 350 and the fifth antenna element 360. The technical solutions provided in embodiments of this application may also be applied to an antenna structure including three or more antenna elements, and a quantity of antenna elements is not limited, and may be adjusted based on an actual production or design requirement.

**[0223]** As shown in FIG. 33, a radiator of the first antenna element 310, a radiator of the second antenna element 320, a radiator of the third antenna element 330, a radiator of the fourth antenna element 350, and a radiator of the fifth antenna element 360 are juxtaposed on a ground plane. A ground end of the radiator of the first antenna element 310, a ground end of the radiator of the second antenna element 320, a ground end of the radiator of the third antenna element 330, a ground end of the radiator of the fourth antenna element 350, and a ground end of the radiator of the fifth antenna element 360 are arranged in a staggered manner, and adjacent ground ends are ground ends disposed on different sides. The ground end of the radiator of the first antenna element 310, the ground end of the radiator of the third antenna element 330, and the ground end of the radiator of the fifth antenna element 360 are arranged on a same side, the ground end of the radiator of the second antenna element 320, and the ground end of the radiator of the fourth antenna element 350 are arranged on a same side, and spaced ground ends (being spaced by one ground end) are ground ends disposed on a same side.

**[0224]** FIG. 34 to FIG. 38(e) show simulation results of the antenna element shown in FIG. 33. FIG. 34 shows an S11 simulation result of the antenna element shown in FIG. 33. FIG. 35 shows isolation between the antenna elements shown in FIG. 33. FIG. 36 shows radiation efficiency and total efficiency of the antenna element

shown in FIG. 33. FIG. 37(a) to FIG. 37(e) are a diagram of electric field distribution of the antenna element shown in FIG. 33. FIG. 38(a) to FIG. 38(e) are a pattern of the antenna element shown in FIG. 33.

**[0225]** As shown in FIG. 34, the first antenna element, the second antenna element, the third antenna element, the fourth antenna element, and the fifth antenna element generate a resonance frequency band (with a boundary of  $S_{11}/S_{22}/S_{33}/S_{44}/S_{55} \leq -5$  dB) near 3.95 GHz.

**[0226]** In addition, as shown in FIG. 35, isolation between two antenna elements (for example, the first antenna element and the third antenna element ( $S_{31}/S_{13}$ )) spaced by one antenna element is less than -15 dB. Isolation between two antenna elements (for example, the first antenna element and the fourth antenna element ( $S_{41}/S_{14}$ )) spaced by two antenna elements is less than -20 dB. Isolation between two antenna elements (for example, the first antenna element and the fifth antenna element ( $S_{51}/S_{15}$ )) spaced by three antenna elements is less than -20 dB. Isolation between two adjacent antenna elements (for example, the first antenna element and the second antenna element ( $S_{12}/S_{21}$ )) is less than -20 dB.

**[0227]** As shown in FIG. 36, efficiency (total efficiency and radiation efficiency) of the first antenna element, the second antenna element, the third antenna element, the fourth antenna element, and the fifth antenna element can all meet a communication requirement in the resonance frequency band.

**[0228]** FIG. 37(a) to FIG. 37(e) are respectively diagrams of electric field distribution corresponding to a case in which a first feed element performs feeding, a case in which a second feed element performs feeding, a case in which a third feed element performs feeding, a case in which a fourth feed element performs feeding, and a case in which a fifth feed element performs feeding. As shown in FIG. 37(a) to FIG. 37(e), when feeding is performed on the antenna element, mode currents on radiators of adjacent antenna elements counteract each other. Therefore, electric fields are concentrated on a radiator of the antenna element into which an electrical signal is fed and a corresponding ground plane, and good isolation can be formed between the antenna element into which the electrical signal is fed and an adjacent antenna element.

**[0229]** FIG. 38(a) to FIG. 38(e) are respectively patterns generated when the first feed element performs feeding, the second feed element performs feeding, the third feed element performs feeding, the fourth feed element performs feeding, and the fifth feed element performs feeding. A maximum radiation direction is in a z direction (perpendicular to a direction in which the ground plane is located).

**[0230]** In the foregoing embodiments, a strongly-coupled antenna structure formed by antenna elements in which radiators are parallel and non-collinearly is used as an example for description. During actual application, the technical solutions provided in embodiments of this application may also be applied to a strongly-coupled

antenna structure formed by antenna elements in which radiators are collinearly disposed.

**[0231]** It should be understood that, in embodiments of this application, resonances generated in two modes of each antenna element are fused. For example, two resonances are fused into one, to form a single resonance. During actual production or design, resonances generated in two modes may not be presented as a single resonance, but a resonance frequency band formed through fusion of two resonances. For example, there are two resonance points in the resonance frequency band. However, resonance frequency bands generated by a plurality of antenna elements may be very close, or may be slightly different from each other actually, to meet an intra-frequency resonance frequency band defined in embodiments of this application.

**[0232]** FIG. 39 is a diagram of an antenna structure according to an embodiment of this application;

As shown in FIG. 39, the antenna structure includes two radiators that are serialized, or placed/arranged in series (serialized, or placed/arranged in series).

**[0233]** In an embodiment, being serialized, or placed/arranged in series may be understood as that the two radiators are disposed at positions close to each other (for example, a distance between the radiators is less than 5 mm), end parts of the two radiators are disposed face to face (face to face), but are not in contact with each other, and the two radiators are generally disposed along a same straight line in extension directions of the radiators. "Being generally disposed along a same straight line" may indicate that extension directions of main body parts of the two radiators may be approximately set along a same straight line, and do not necessarily need to be set along a same straight line. For example, a first radiator extends in an X direction, and a second radiator extends in a direction that is within 10° away from the X direction. Alternatively, the first radiator and the second radiator may be in a fold line shape, and extension directions of main body parts (for example, lengths of the main body parts account for 90% or more of total lengths of the radiators) of the radiators are approximately disposed along a same straight line. The foregoing may be considered as being approximately disposed along a same straight line.

**[0234]** In an embodiment, being serialized, or placed/arranged in series may alternatively be understood as that the two radiators extend in a first direction and do not overlap in a second direction, where the second direction is perpendicular to the first direction, and the two radiators at least partially overlap in the first direction.

**[0235]** In an embodiment, projections, on a ground plane, of the two radiators that are serialized, or placed/arranged in series are serialized, or placed/arranged in series. In an embodiment, projections of two radiators that are serialized, or placed/arranged in series on a ground plane may be disposed along a same straight line. Specifically, the two radiators are collinear in extension directions of the radiators. An end of each radiator is

connected to the ground plane. For example, a black dot in the figure is a schematic ground point of the radiator.

**[0236]** In an embodiment, the two radiators are linear radiators, and that projections of the two radiators on the ground plane are disposed along a same straight line may be understood as that an included angle between extension directions of sides of the two radiators in a length direction is within a range of 0° to 10° or a range of 170° to 180°. In an embodiment, the two radiators are sheet-like radiators, and that projections of the two radiators on the ground plane are disposed along a same straight line may be understood as that an included angle between extension directions of connection lines between open ends and ground ends of the two radiators is within a range of 0° to 10° or a range of 170° to 180°.

**[0237]** It should be understood that two radiators that are spaced along a same straight line are connected to a same ground plane, and the two radiators and a part of the ground plane jointly form a dipole antenna.

**[0238]** According to an eigenmode feature of the dipole antenna, as shown in (a) in FIG. 39, the two radiators may generate mode currents in a same direction, and a mode current may be generated between the two radiators on the ground plane between the two radiators. The mode current on the radiator excites an induced current on the ground plane. It can be learned from an electromagnetic induction theorem that a mode current is reverse to a corresponding induced current. For a mode current between two ground points on the ground plane, the mode current has a component in a same direction as the induced current, and the mode current and the induced current may be superimposed. In an embodiment, a dashed-line area on the ground plane is a current strong point area of the mode current and the induced current. This indicates that the mode meets a boundary condition, and may exist. Therefore, the antenna structure shown in FIG. 39 may excite an HWM. It should be understood that, for the boundary condition, the induced current and the mode current that are generated on the antenna element have components in a same direction, and do not have components in reverse directions, in other words, the boundary condition is met.

**[0239]** Similarly, as shown in (b) in FIG. 39, radiators of two antenna elements may generate reverse mode currents, and a mode current may be generated on the ground plane between the two radiators. The mode current on the radiator excites an induced current on the ground plane 120. It can be learned from an electromagnetic induction theorem that a mode current is reverse to a corresponding induced current. For a mode current between two ground points on the ground plane 120, the mode current has a component in a same direction as the induced current, and the mode current and the induced current may be superimposed. In an embodiment, a dashed-line area on the ground plane is a current zero point area of the mode current and the induced current. This indicates that the mode meets a boundary condition, and may exist. Therefore, the antenna structure shown in

FIG. 39 may excite an OWM.

**[0240]** Therefore, for the antenna structure (the radiators of the antenna elements are arranged in series, and the ground ends are located on different sides) shown in FIG. 39, isolation between the antenna elements is mainly determined by mode currents of the two antenna elements, and a spatial distance between the two antenna elements has small impact on isolation. In the antenna structure, coupling between two antenna elements is in a small relationship with a distance between the two antenna elements. Therefore, this type of antenna structure may be considered as a strongly-coupled antenna structure.

**[0241]** FIG. 40 is a diagram of a structure of an electronic device 500 according to an embodiment of this application.

**[0242]** As shown in FIG. 40, the electronic device 500 includes a first antenna element 510, a second antenna element 520, and a third antenna element 530.

**[0243]** The first antenna element 510 includes a first radiator 511 and a first parasitic stub 512. The second antenna element 520 includes a second radiator 521 and a second parasitic stub 522. The third antenna element 530 includes a third radiator 531 and a third parasitic stub 532. The second radiator 521 is located between the first radiator 511 and the third radiator 531. The first radiator 511, the second radiator 521, and the third radiator 531 are juxtaposed. A ground end (a first end) of the first radiator 511 and a ground end (a first end) of the third radiator 531 are ground ends disposed on a same side, and a ground end (a second end) of the second radiator 521, the ground end of the first radiator 511, and the ground end of the third radiator 531 are ground ends disposed on different sides.

**[0244]** It should be understood that the first radiator 511 and the first parasitic stub 512 are juxtaposed, and the ground end of the first radiator 511 and a ground end of the first parasitic stub 512 are ground ends disposed on different sides, to form a strongly-coupled antenna structure. The first parasitic stub 512 generates a resonance by using an electrical signal fed by the first radiator 511, to expand an operating frequency band of the first antenna element 510.

**[0245]** It should be understood that, a difference between an antenna structure including the first antenna element 510, the second antenna element 520, and the third antenna element 530 shown in FIG. 40 and the antenna structure including the first antenna element 310, the second antenna element 320, and the third antenna element 330 shown in FIG. 28 lies in that a parasitic stub is separately added to the first antenna element 310, the second antenna element 320, and the third antenna element 330, to expand an operating frequency band of the antenna element.

**[0246]** In an embodiment, the first radiator 511 is located between the first parasitic stub 512 and the second radiator 521. A projection of the first parasitic stub 512 on a plane on which a ground plane 540 is located and a

projection of the first radiator 511 on the plane on which the ground plane 540 is located are parallel to each other in a first direction (for example, a y direction), and at least partially overlap in a second direction (for example, an x direction). A distance between the first end (the ground end) of the first radiator 511 and a second end (the ground end) of the first parasitic stub 512 is greater than a distance between the first end of the first radiator 511 and a first end of the first parasitic stub 512.

**[0247]** In addition, the first radiator 511, the first parasitic stub 512, and a part of the ground plane may form a dipole antenna, and two resonances may be respectively generated in an HWM and an OWM. A relative position relationship (for example, a distance between the first radiator 511 and the first parasitic stub 512) between the first radiator 511 and the first parasitic stub 512 is related to a frequency of a resonance generated in each of the HWM and the OWM.

**[0248]** In an embodiment, the second parasitic stub 522 and the second radiator 521 are serialized, and a ground end of the second parasitic stub 522 and the ground end of the second radiator 521 are ground ends disposed on different sides. In an embodiment, a first end of the second parasitic stub 522 and the first end of the second radiator 521 are disposed face to face, but are not in contact with each other, and a second end of the second parasitic stub is grounded. A projection of the second parasitic stub 522 on the plane on which the ground plane 540 is located and a projection of the second radiator 521 on the plane on which the ground plane 540 is located are disposed along a same straight line.

**[0249]** It should be understood that the second radiator 521 and the second parasitic stub 522 are serialized, and ground ends are disposed on different sides, to form a strongly-coupled antenna structure. The second parasitic stub 522 generates a resonance by using an electrical signal fed by the second radiator 521, to expand an operating frequency band of the second antenna element 520.

**[0250]** In addition, the second radiator 521, the second parasitic stub 522, and a part of the ground plane may form a dipole antenna, and two resonances may be respectively generated in the HWM and the OWM. An inductor may be connected in series between the first end of the second parasitic stub 522 and the first end of the second radiator 521, or a capacitor connected in parallel to the ground plane may be disposed at this position, to adjust the frequency of the resonance generated in each of the HWM and the OWM. For example, when an inductance value of the inductor connected in series between the first end of the second parasitic stub 522 and the first end of the second radiator 521 decreases, the frequency of the resonance generated in the HWM shifts toward a high frequency, and the frequency of the resonance generated in the OWM remains unchanged. When a capacitance value of the capacitor connected in parallel to the ground plane increases, the frequency of the

resonance generated in the OWM shifts toward a low frequency, and the frequency of the resonance generated in the HWM remains unchanged.

**[0251]** In an embodiment, the third radiator 531 is located between the third parasitic stub 532 and the second radiator 521. The third parasitic stub 532 and the third radiator 531 are juxtaposed, and a ground end of the third parasitic stub 532 and a ground end of the third radiator 531 are ground ends disposed on different sides. In an embodiment, a projection of the third parasitic stub 532 on the plane on which the ground plane 540 is located and a projection of the third radiator 531 on the plane on which the ground plane 540 is located are parallel to each other in the first direction (for example, the y direction), and at least partially overlap in the second direction (for example, the x direction). A distance between the first end (the ground end) of the third radiator 531 and a second end (the ground end) of the third parasitic stub 532 is greater than a distance between the first end of the third radiator 531 and a first end of the third parasitic stub 532.

**[0252]** It should be understood that the third radiator 531 and the third parasitic stub 532 are juxtaposed, and ground ends are disposed on different sides, to form a strongly-coupled antenna structure. The third parasitic stub 532 generates a resonance by using an electrical signal fed by the third radiator 531, to expand an operating frequency band of the third antenna element 530.

**[0253]** For brevity of description, in this application, only an example in which the first antenna element 510, the second antenna element 520, and the third antenna element 530 each include a parasitic stub is used for description. During actual application, a parasitic stub may be disposed for at least one of a plurality of antenna elements based on an internal layout of the electronic device, and a strongly-coupled structure (for example, being serialized or juxtaposed) formed between the parasitic stub and the radiator may be selected based on an actual design requirement, to expand an operating frequency band of the antenna element. This is not limited in embodiments of this application.

**[0254]** FIG. 41 to FIG. 44(f) show simulation results of the antenna element shown in FIG. 40. FIG. 41 shows an S parameter of the antenna element shown in FIG. 40. FIG. 42 shows radiation efficiency and total efficiency of the antenna element shown in FIG. 40. FIG. 43(a) to FIG. 43(f) are a diagram of electric field distribution of the antenna element shown in FIG. 40. FIG. 44(a) to FIG. 44(f) are a pattern of the antenna element shown in FIG. 40.

**[0255]** As shown in FIG. 41, because the parasitic stub is disposed in the antenna element, an additional resonance may be generated. Therefore, the first antenna element, the second antenna element, and the third antenna element may generate two resonance frequency bands (with a boundary of  $S_{11}/S_{22}/S_{33} \leq -5$  dB) near 3.95 GHz and 4.3 GHz.

**[0256]** In addition, as shown in FIG. 41, isolation be-

tween two spaced antenna elements (for example, the first antenna element and the third antenna element (S31/S13)) is less than -18 dB. Isolation between two adjacent antenna elements (for example, the first antenna element and the second antenna element (S12/S21)) is less than -15 dB.

**[0257]** As shown in FIG. 42, efficiency (total efficiency and radiation efficiency) of the first antenna element, the second antenna element, and the third antenna element can all meet a communication requirement in the resonance frequency band.

**[0258]** As shown in FIG. 43(a) and FIG. 43(b), when the first feed element performs feeding, FIG. 43(a) and FIG. 43(b) are diagrams of electric field distribution corresponding to resonance points of two resonance frequency bands generated by the first antenna element in the HWM (electric fields on the radiator and the parasitic stub are reverse in direction) and OWM (electric fields on the radiator and the parasitic stub are the same in direction). The electric fields are mainly concentrated on the first radiator, the first parasitic stub, and a corresponding ground plane area, to form good isolation with an adjacent antenna element.

**[0259]** As shown in FIG. 43(c) and FIG. 43(d), when the second feed element performs feeding, FIG. 43(c) and FIG. 43(d) are diagrams of electric field distribution corresponding to resonance points of two resonance frequency bands generated by the second antenna element in the HWM (electric fields on the radiator and the parasitic stub are reverse in direction) and OWM (electric fields on the radiator and the parasitic stub are the same in direction). The electric fields are mainly concentrated on the second radiator, the second parasitic stub, and a corresponding ground plane area, to form good isolation with an adjacent antenna element.

**[0260]** As shown in FIG. 43(e) and FIG. 43(f), when the third feed element performs feeding, FIG. 43(e) and FIG. 43(f) are diagrams of electric field distribution corresponding to resonance points of two resonance frequency bands generated by the third antenna element in the HWM (electric fields on the radiator and the parasitic stub are reverse in direction) and OWM (electric fields on the radiator and the parasitic stub are the same in direction). The electric fields are mainly concentrated on the third radiator, the third parasitic stub, and a corresponding ground plane area, to form good isolation with an adjacent antenna element.

**[0261]** FIG. 44(a) to FIG. 44(f) are respectively patterns generated by the first antenna element, the second antenna element, and the third antenna element in the HWM (electric fields on the radiator and the parasitic stub are reverse in direction) and OWM (electric fields on the radiator and the parasitic stub are the same in direction) when the first feed element performs feeding, the second feed element performs feeding, and the third feed element performs feeding. A maximum radiation direction is in a z direction (perpendicular to a direction in which the ground plane is located).



**[0262]** In the foregoing embodiments, an example in which a strongly-coupled structure is formed between radiators of adjacent antenna elements is used for description. In an actual design, a weakly-coupled structure may alternatively be formed between radiators of adjacent antenna elements, and the radiators of the antenna elements and corresponding parasitic stubs form a strongly-coupled structure, to expand a bandwidth of the antenna element.

**[0263]** FIG. 45 is a diagram of a structure of an electronic device 600 according to an embodiment of this application.

**[0264]** As shown in FIG. 45, the electronic device 600 may include a first antenna element 610, a second antenna element 620, and a ground plane 630.

**[0265]** The first antenna element 610 includes a first radiator 611, a first parasitic stub 612, and a first feed element 613. The first radiator 611 includes a first feed point 614, and the first feed element 613 is electrically connected to the first radiator 611 at the first feed point 614.

**[0266]** It should be understood that in the technical solutions provided in embodiments of this application, an electrical connection (direct coupling) is used as an example for description. During actual design or production, indirect coupling may be used for replacement, and same technical effect may be obtained. This is not limited in this application.

**[0267]** The second antenna element 620 may include a second radiator 621 and a second feed element 623. The second radiator 621 includes a second feed point 624, the second feed element 623 is electrically connected to the second radiator 621 at the second feed point 624, and the first feed element 613 is different from the second feed element 623. In an embodiment, that the first feed element 613 is different from the second feed element 623 may be understood as that an electrical signal generated by the first feed element 613 and an electrical signal generated by the second feed element 623 are different, and are not generated by a same feed by using a feed network. For example, the first feed element 613 and the second feed element 623 may be different radio frequency channels of a same power supply chip.

**[0268]** A first end of the first radiator 611 is grounded, a first end of the second radiator 621 is grounded, and a second end of the first parasitic stub 612 is grounded. A ground end of the first radiator 611 and a ground end of the second radiator 621 are ground ends disposed on a same side, or a ground end of the first radiator 611 and a ground end of the first parasitic stub 612 are ground ends disposed on different sides.

**[0269]** In an embodiment, the first radiator 611 and the second radiator 621 are juxtaposed. In an embodiment, a projection (a first projection) of the first radiator 611 on a plane on which the ground plane 630 is located, and a projection (a second projection) of the second radiator 621 on the plane on which the ground plane 630 is located are parallel in a first direction (for example, a y direction),

and at least partially overlap in a second direction (for example, an x direction), where the second direction is perpendicular to the first direction. The first radiator 611 and the second radiator 621 are disposed in parallel and non-collinearly.

**[0270]** In an embodiment, the first radiator 611 and the first parasitic stub 612 are juxtaposed. In an embodiment, the first radiator 611 is located between the first parasitic stub 612 and the second radiator 621. The projection (the first projection) of the first radiator 611 on the plane on which the ground plane 630 is located and a projection (a third projection) of the first parasitic stub 612 on the plane on which the ground plane 630 is located are parallel to each other in the first direction, and at least partially overlap in the second direction.

**[0271]** In an embodiment, the ground end of the first radiator 611 and the ground end of the second radiator 621 are ground ends disposed on a same side, and a distance between the first end (the ground end) of the first radiator 611 and the first end (the ground end) of the second radiator 621 is less than a distance between the first end (the ground end) of the first radiator 611 and a second end of the second radiator 621.

**[0272]** In an embodiment, the ground end of the first radiator 611 and the ground end of the first parasitic stub 612 are ground ends disposed on different sides, and a distance between the first end (the ground end) of the first radiator 611 and the first end of the first parasitic stub 612 is less than a distance between the first end (the ground end) of the first radiator 611 and the second end (the ground end) of the first parasitic stub 612.

**[0273]** It should be understood that the ground end of the first radiator 611 and the ground end of the second radiator 621 are disposed on a same side, to form a weakly-coupled structure. Therefore, isolation between the first antenna element 610 and the second antenna element 620 is mainly determined by the distance between the first radiator 611 and the second radiator 621. In addition, the ground end of the first radiator 611 and the ground end of the first parasitic stub 612 are disposed on different sides, to form a strongly-coupled structure. The first parasitic stub 612 generates a resonance by using an electrical signal fed by the first radiator 611, to expand an operating frequency band of the first antenna element 610.

**[0274]** In an embodiment, the distance between the first radiator 611 and the second radiator 621 is less than 5 mm. The first antenna element 610 and the second antenna element 620 may be compactly arranged inside an electronic device, thereby saving internal space.

**[0275]** In an embodiment, the first radiator 611 and the first parasitic stub 612 are linear radiators, and a distance between the first radiator 611 and the first parasitic stub 612 is less than 5 mm; or the first radiator 611 and the first parasitic stub 612 are sheet-like, and a distance between the first radiator 611 and the first parasitic stub 612 is less than 2 mm. In an embodiment, the second radiator 621 and the second parasitic stub 622 are linear radiators,

and a distance between the second radiator 621 and the second parasitic stub 622 is less than 5 mm; or the second radiator 621 and the second parasitic stub 622 are sheet-like radiators, and a distance between the second radiator 621 and the second parasitic stub 622 is less than 2 mm. The first antenna element 610 and the second antenna element 620 may be compactly arranged inside an electronic device, thereby saving internal space. It should be understood that the distance between the first radiator 611 and the second radiator 621 may be understood as a smallest value of straight-line distances between points on the first radiator 611 and points on the second radiator 621, and the distance between the first radiator 611 and the first parasitic stub 612 and the distance between the second radiator 621 and the second parasitic stub 622 may also be understood correspondingly.

**[0276]** It should be understood that, when the first radiator 611 and the second radiator 621 are sheet-like radiators, the distance between the first radiator 611 and the second radiator 621 may be further reduced with widths (which may be understood as lengths of the radiators in the second direction, or lengths in a direction perpendicular to a direction from the ground ends of the radiators to the open ends) of the radiators. In an embodiment, the distance between the first radiator 611 and the second radiator 621 is less than 2 mm or less than 1 mm.

**[0277]** In an embodiment, the electronic device 600 may further include a first resonant connector 631 and a first electronic element 641. The first resonant connector 631 may be disposed between the first radiator 611 and the first parasitic stub 612. A first end of the first resonant connector 631 is electrically connected to the first radiator 611, and a second end of the first resonant connector 631 is electrically connected to the first parasitic stub 612. A first end of the first electronic element 641 is electrically connected to the first resonant connector 631, a second end of the first electronic element 641 is electrically connected to the ground plane 630 for grounding, and the first electronic element 641 is connected in parallel between the first resonant connector 631 and the ground plane 630.

**[0278]** It should be understood that a frequency of a resonance generated in a first resonance mode (for example, an HWM) of the first antenna element 610 and a frequency of a resonance generated in a second resonance mode (for example, an OWM) of the first antenna element 610 may be adjusted by using the first resonant connector 631 disposed between the first radiator 611 and the first parasitic stub 612 and the first electronic element 641 connected in parallel between the first resonant connector 631 and the ground plane 630, so that the resonances generated in the two resonance modes are close to each other to form a wide resonance frequency band, to expand an operating bandwidth of the first antenna element 610. Alternatively, the frequencies of the resonances generated in the two resonance

modes may be away from each other, so that the resonances generated in the two resonance modes are away from each other. In this case, an operating frequency band of the first antenna element 610 includes two different communication frequency bands.

**[0279]** Similarly, in a case in which no first resonant connector 631 is disposed between the first radiator 611 and the first parasitic stub 612, same technical effect may also be achieved by adjusting the distance between the first radiator 611 and the first parasitic stub 612.

**[0280]** In an embodiment, the first end of the first resonant connector 631 is located between the first end of the first radiator 611 and a midpoint of the first radiator 611. In an embodiment, the second end of the first resonant connector 631 is located between the second end of the first parasitic stub 612 and a midpoint of the first parasitic stub 612.

**[0281]** In an embodiment, the second antenna element 620 further includes a second parasitic stub 622, and the second radiator 621 and the second parasitic stub 622 are juxtaposed. In an embodiment, the second radiator 621 is located between the first radiator 611 and the second parasitic stub 622. The projection (the second projection) of the second radiator 621 on the plane on which the ground plane 630 is located and a projection (a fourth projection) of the second parasitic stub 622 on the plane on which the ground plane 630 is located are parallel to each other in the first direction, and at least partially overlap in the second direction.

**[0282]** In an embodiment, the ground end of the second radiator 621 and the ground end of the second parasitic stub 622 are ground ends disposed on different sides, the second end of the second parasitic stub 622 is grounded, and a distance between the first end (the ground end) of the second radiator 621 and the first end of the second parasitic stub 622 is less than a distance between the first end (the ground end) of the second radiator 621 and the second end (the ground end) of the second parasitic stub 622.

**[0283]** It should be understood that, the ground end of the second radiator 621 and the ground end of the second parasitic stub 622 are disposed on different sides, to form a strongly-coupled structure. The second parasitic stub 622 generates a resonance by using an electrical signal fed by the second radiator 621, to expand an operating frequency band of the second antenna element 620.

**[0284]** In embodiments of this application, a quantity of parasitic stubs is not limited. The parasitic stub may be disposed on the radiator of the antenna element according to an actual design requirement. The parasitic stub and the radiator form a strongly-coupled structure, to form a plurality of resonance frequency bands, and expand an operating bandwidth of an antenna structure.

**[0285]** In an embodiment, the electronic device 600 may further include a second resonant connector 632 and a second electronic element 642. The second resonant connector 632 may be disposed between the second radiator 621 and the second parasitic stub 622. A first

end of the second resonant connector 632 is electrically connected to the second radiator 621, and a second end of the second resonant connector 632 is electrically connected to the second parasitic stub 622. A first end of the second electronic element 642 is electrically connected to the second resonant connector 632, a second end of the second electronic element 642 is electrically connected to the ground plane 630 for grounding, and the second electronic element 642 is connected in parallel between the second resonant connector 632 and the ground plane 630.

**[0286]** It should be understood that a frequency of a resonance generated in the first resonance mode (for example, the HWM) of the second antenna element 620 and a frequency of a resonance generated in the second resonance mode (for example, the OWM) of the second antenna element 620 may be adjusted through the second resonant connector 632 disposed between the second radiator 621 and the second parasitic stub 622 and the second electronic element 642 connected in parallel between the second resonant connector 632 and the ground plane 630, so that the resonances generated in the two resonance modes are close to each other to form a wide resonance frequency band, to expand an operating bandwidth of the second antenna element 620. Alternatively, the frequencies of the resonances generated in the two resonance modes may be away from each other, so that the resonances generated in the two resonance modes are away from each other. In this case, an operating frequency band of the second antenna element 620 includes two different communication frequency bands.

**[0287]** Similarly, in a case in which no second resonant connector 632 is disposed between the second radiator 621 and the second parasitic stub 622, same technical effect may also be achieved by adjusting the distance between the second radiator 621 and the second parasitic stub 622.

**[0288]** In an embodiment, the first end of the second resonant connector 632 is located between the first end of the second radiator 621 and a midpoint of the second radiator 621. In an embodiment, the second end of the second resonant connector 632 is located between the second end of the second parasitic stub 622 and a midpoint of the second parasitic stub 622.

**[0289]** In an embodiment, the electronic device 600 may further include a third electronic element 643. The first resonant connector 631 may be provided with a slot. The third electronic element 643 may be disposed in the slot of the first resonant connector 631, and is connected in series between portions that are of the first resonant connector 631 and that are on the two sides of the slot. Two ends of the third electronic element 643 are electrically connected to the portions that are of the first resonant connector 631 and that are on the two sides of the slot respectively.

**[0290]** In an embodiment, the electronic device 600 may further include a fourth electronic element 644. The second resonant connector 632 may be provided with a

slot. The fourth electronic element 644 may be disposed in the slot of the second resonant connector 632, and is connected in series between portions that are of the second resonant connector 632 and that are on the two sides of the slot. Two ends of the fourth electronic element 644 are electrically connected to the portions that are of the second resonant connector 632 and that are on the two sides of the slot respectively.

**[0291]** It should be understood that the resonant connector may be equivalent to an inductor, and an inductance value of the equivalent inductor of the resonant connector may be adjusted by using a length or a width of the resonant connector. The equivalent inductor of the resonant connector may be adjusted through an electronic element connected in series to the resonant connector, to adjust the frequency of the resonance corresponding to the first resonance mode of the antenna element. It should be understood that electrical lengths of the radiator and the resonant stub of the antenna element should be approximately the same, so that resonance frequency bands of the antenna element are close to each other, to expand an operating frequency band of the antenna element. In an embodiment, the first radiator 611 and the first parasitic stub 612 are disposed in parallel and non-collinearly. The projection (the first projection) of the first radiator 611 on the ground plane and the projection (the third projection) of the first parasitic stub 612 on the ground plane only partially overlap in the second direction (for example, the x direction). For example, the first radiator 611 and the first parasitic stub 612 have a specific misplacement in the first direction (for example, the y direction). This is the same as or similar to that in the foregoing embodiments. Details are not described again.

**[0292]** In an embodiment, the first radiator 611 or the first parasitic stub 612 may be a linear radiator, and the first antenna element 610 may be an IFA. Alternatively, the first radiator 611 or the first parasitic stub 612 may be a sheet-like radiator, and the first antenna element 610 may be a PIFA. In an embodiment, the second antenna element 620 may also be any one of the foregoing antenna types.

**[0293]** In an embodiment, the radiator and the parasitic stub are disposed on a support or a rear cover in the electronic device. Details are not described herein again.

**[0294]** FIG. 46 shows an S parameter of the antenna element shown in FIG. 45.

**[0295]** As shown in FIG. 46, the first antenna element and the second antenna element may respectively generate two resonances at 4.3 GHz and 4.4 GHz, which may correspond to two resonance modes (for example, the OWM and the HWM) in which the radiator and the parasitic stub of the antenna element operate.

**[0296]** In addition, the ground end of the first radiator and the ground end of the second radiator are arranged on a same side, to form a weakly-coupled structure. In a resonance frequency band, isolation between the first antenna element and the second antenna element is less than -24 dB. FIG. 47 is a diagram of still another electronic

device 600 according to an embodiment of this application.

**[0297]** Similarly, the first radiator 611 and the second radiator 621 have ground ends on a same side, for example, to form a weakly-coupled structure. In the first antenna element 610, the first radiator 611 and the first parasitic stub 612 have ground ends on different sides, for example, to form a strongly-coupled structure. In the second antenna element 620, the second radiator 621 and the second parasitic stub 622 form a strongly-coupled structure. For a strongly-coupled structure, refer to relative positions between radiators in the foregoing embodiments. Details are not described again in embodiments of this application.

**[0298]** As shown in FIG. 47, in this embodiment, only an example in which the first radiator 611 and the second radiator 621 are juxtaposed, and ground ends are arranged on a same side, for example, to form a weakly-coupled structure, and the radiator and the parasitic stub are serialized, and ground ends are arranged on different sides, for example, to form a strongly-coupled structure is used for description.

**[0299]** FIG. 48 shows an S parameter of the antenna element shown in FIG. 47.

**[0300]** As shown in FIG. 48, the first antenna element and the second antenna element may respectively generate two resonances at 4.3 GHz and 4.45 GHz, which may correspond to two resonance modes (for example, the OWM and the HWM) in which the radiator and the resonant stub of the antenna element operate.

**[0301]** In addition, the ground end of the first radiator and the ground end of the second radiator are arranged on a same side, for example, to form a weakly-coupled structure. In a resonance frequency band, isolation between the first antenna element and the second antenna element is less than -12 dB.

**[0302]** FIG. 49 is a diagram of still another electronic device 600 according to an embodiment of this application.

**[0303]** Similarly, the first radiator 611 and the second radiator 621 have ground ends disposed on a same side, for example, to form a weakly-coupled structure. In the first antenna element 610, the first radiator 611 and the first parasitic stub 612 have ground ends disposed on different sides, for example, to form a strongly-coupled structure. In the second antenna element 620, the second radiator 621 and the second parasitic stub 622 have ground ends disposed on different sides, for example, to form a strongly-coupled structure. For a strongly-coupled structure, refer to relative positions between radiators in the foregoing embodiments. Details are not described again in embodiments of this application.

**[0304]** As shown in FIG. 49, in this embodiment, only an example in which the first radiator 611 and the second radiator 621 are serialized, and ground ends are arranged on a same side, for example, to form a weakly-coupled structure, and the radiator and the parasitic stub are juxtaposed, and ground ends are arranged on differ-

ent sides, for example, to form a strongly-coupled structure is used for description.

**[0305]** A difference between the first antenna element 610 and the second antenna element 620 shown in FIG. 49 and the first antenna element 610 and the second antenna element 620 shown in FIG. 45 lies in different arrangements of radiators and parasitic stubs. An arrangement manner shown in FIG. 49 is a 2x2 array arrangement (radiators of the two antenna elements are collinearly disposed), and an arrangement manner shown in FIG. 45 is a 1x4 array arrangement (radiators of the two antenna elements are disposed in parallel and non-collinearly).

**[0306]** It should be understood that, for a radiator and a parasitic stub that are disposed collinearly, a specific offset may exist based on an actual spatial layout. For example, a collinear direction of the radiator and the parasitic stub is a y direction, and the radiator and the parasitic stub may move in a positive direction or a negative direction of an x direction, provided that the radiator and the parasitic stub partially overlap only in a direction reverse to the y direction. FIG. 50 shows an S parameter of the antenna element shown in FIG. 49.

**[0307]** As shown in FIG. 50, the first antenna element and the second antenna element may respectively generate two resonances at 4.3 GHz and 4.4 GHz, which may correspond to two resonance modes (for example, the OWM and the HWM) in which the radiator and the resonant stub of the antenna element operate.

**[0308]** In addition, the ground end of the first radiator is close to a non-ground end of the second radiator, to form a weakly-coupled structure. In a resonance frequency band, isolation between the first antenna element and the second antenna element is less than -12 dB.

**[0309]** A difference between the first antenna element 610 and the second antenna element 620 shown in FIG. 51 and the first antenna element 610 and the second antenna element 620 shown in FIG. 49 lies in different arrangements of radiators and parasitic stubs. An arrangement manner shown in FIG. 51 is a straight-line type arrangement (radiators and parasitic stubs of the two antenna elements are serialized), and an arrangement manner shown in FIG. 49 is a 2x2 array arrangement (radiators of the two antenna elements are serialized, and the radiators and the parasitic stubs are juxtaposed).

**[0310]** It should be understood that, in the antenna structure shown in FIG. 49, the first radiator 611 and the second radiator 621 are adjacent to each other. In the antenna structure shown in FIG. 51, the first parasitic stub 612 is disposed between the first radiator 611 and the second radiator 621, and the first radiator 611 and the second radiator 621 are spaced from each other. A specific form of the weakly-coupled structure formed between the radiators, and a specific form of the strongly-coupled structure formed between the radiator and a corresponding parasitic stub are not limited in embodiments of this application, and may be adjusted

based on an actual design.

**[0311]** FIG. 52 shows an S parameter of the antenna element shown in FIG. 51.

**[0312]** As shown in FIG. 52, the first antenna element and the second antenna element each may generate a resonance at 4.4 GHz, and the ground end of the first radiator is close to the non-ground end of the second radiator, to form a weakly-coupled structure. In a resonance frequency band, isolation between the first antenna element and the second antenna element is less than -20 dB.

**[0313]** FIG. 53 is a diagram of still another electronic device 600 according to an embodiment of this application.

**[0314]** A difference between the first antenna element 610 and the second antenna element 620 shown in FIG. 53 and the first antenna element 610 and the second antenna element 620 shown in FIG. 47 lies in different arrangements of radiators and parasitic stubs. An arrangement manner shown in FIG. 47 is that a radiator and a parasitic stub of each antenna element are serialized, and radiators of the two antenna elements are arranged in parallel and non-collinearly. An arrangement manner shown in FIG. 53 is that a radiator and a parasitic stub of each antenna element are disposed collinearly, and radiators of the two antenna elements are disposed in a staggered manner.

**[0315]** FIG. 54 shows an S parameter of the antenna element shown in FIG. 53.

**[0316]** As shown in FIG. 54, the first antenna element and the second antenna element may respectively generate two resonances at 4.3 GHz and 4.45 GHz, which may correspond to two resonance modes (for example, the OWM and the HWM) in which the radiator and the resonant stub of the antenna element operate.

**[0317]** In addition, the first radiator and the second radiator are arranged in a staggered manner, to form a weakly-coupled structure. In a resonance frequency band, isolation between the first antenna element and the second antenna element is less than -12 dB.

**[0318]** FIG. 55 is a diagram of still another electronic device 600 according to an embodiment of this application.

**[0319]** As shown in FIG. 55, the electronic device 600 may include the first antenna element 610, the second antenna element 620, and the ground plane 630.

**[0320]** The first antenna element 610 includes the first radiator 611 and the first feed element 613. The first radiator 611 includes the first feed point 614, and the first feed element 613 is electrically connected to the first radiator 611 at the first feed point 614.

**[0321]** The second antenna element 620 may include the second radiator 621 and the second feed element 623. The second radiator 621 includes a second feed point 624, the second feed element 623 is electrically connected to the second radiator 621 at the second feed point 624, and the first feed element 613 is different from the second feed element 623. In an embodiment, that the

first feed element 613 is different from the second feed element 623 may be understood as that an electrical signal generated by the first feed element 613 and an electrical signal generated by the second feed element 623 are different, and are not generated by a same feed by using a feed network. For example, the first feed element 613 and the second feed element 623 may be different radio frequency channels of a same power supply chip.

**[0322]** A projection (a first projection) of the first radiator 611 on a plane on which the ground plane 630 is located is perpendicular to a projection (a second projection) of the second radiator 621 on the plane on which the ground plane 630 is located. In addition, an extension line of the second radiator 621 intersects an extension line of the first radiator 611 on the first radiator 611.

**[0323]** It should be understood that, that the first projection is perpendicular to the second projection may be understood as that a direction from a ground end of the first radiator 611 to an open end is perpendicular to a direction from a ground end of the second radiator 621 to an open end.

**[0324]** A second end of the first radiator 611 is grounded, a second end of the second radiator 621 is grounded, and a distance between the second end (the ground end) of the second radiator 621 and the second end (the ground end) of the first radiator 611 is less than a distance between the second end (the ground end) of the second radiator 621 and a first end of the first radiator 611.

**[0325]** It should be understood that the first radiator 611 and the second radiator 621 are vertically disposed to form a weakly-coupled structure. Therefore, there is good isolation between the first antenna element 610 and the second antenna element 620. As shown in FIG. 56, in a resonance frequency band, isolation between the first antenna element 610 and the second antenna element 620 is less than -12 dB.

**[0326]** In an embodiment, the antenna structure may further include more antenna elements, adjacent antenna elements are vertically arranged, and good isolation may exist between every two antenna elements.

**[0327]** In an embodiment, operating frequency bands of two or more antenna elements are the same (for example, each include a first frequency band).

**[0328]** In an embodiment, to expand an operating frequency band of the antenna element, the antenna element may include a parasitic stub, as shown in FIG. 57.

**[0329]** For example, the first antenna element 610 may include the first parasitic stub 612. In an embodiment, the ground end of the first radiator 611 and the ground end of the first parasitic stub 612 are ground ends disposed on different sides, to form a strongly-coupled structure. The first radiator 611 may be located between the first parasitic stub 612 and the second radiator 621. The first end of the first radiator 611 and a first end of the first parasitic stub 612 are disposed face to face, but are not in contact with each other, the second end of the first radiator 611 is

grounded, and a second end of the first parasitic stub 612 is grounded. The projection (the first projection) of the first radiator 611 on the plane on which the ground plane 630 is located and a projection (a third projection) of the first parasitic stub 612 on the plane on which the ground plane 630 is located are disposed along a same straight line in a first direction (for example, an x direction). A distance between the second end (the ground end) of the second radiator 621 and a second end (the ground end) of the first parasitic stub 612 is greater than a distance between the second end (the ground end) of the second radiator 621 and a first end of the first parasitic stub 612.

**[0330]** In an embodiment, the second antenna element 620 may include the second parasitic stub 622. In an embodiment, the ground end of the second radiator 621 and the ground end of the second parasitic stub 622 are ground ends disposed on different sides, to form a strongly-coupled structure. The first end of the second radiator 621 and a first end of the second parasitic stub 622 are disposed face to face, but are not in contact with each other, the second end of the second radiator 621 is grounded, and a second end of the second parasitic stub 622 is grounded. The projection (the second projection) of the second radiator 621 on the plane on which the ground plane 630 is located and a projection (a fourth projection) of the second parasitic stub 622 on the plane on which the ground plane 630 is located are disposed along a same straight line in a second direction (for example, a y direction). A distance between the second end (the ground end) of the first radiator 611 and a second end (the ground end) of the second parasitic stub 622 is greater than a distance between the second end (the ground end) of the first radiator 611 and the first end of the second parasitic stub 622.

**[0331]** In an embodiment, the third antenna element 640 may include a third parasitic stub 642.

**[0332]** It should be understood that a quantity of parasitic stubs in the electronic device is not limited in embodiments of this application. Each antenna element may include a parasitic stub, and a position of the parasitic stub may be selected based on actual internal space of the electronic device, to form a strongly-coupled structure. For example, the parasitic stub and the radiator may be disposed along a same straight line, and ground points are disposed away from each other and arranged on different sides; or the parasitic stub and the radiator may be disposed in parallel and non-collinearly, and ground points are disposed away from each other and arranged on different sides. This is not limited in this application.

**[0333]** In an embodiment, the electronic device 600 may further include a resonant connector disposed between a radiator and a parasitic stub of the antenna element and an electronic element disposed between the resonant connector and the ground plane. For example, the first resonant connector 631 may be disposed between the first radiator 611 and the first parasitic stub 612. A first end of the first resonant connector 631 is

electrically connected to the first radiator 611, and a second end of the first resonant connector 631 is electrically connected to the first parasitic stub 612. A first end of the first electronic element 641 is electrically connected to the first resonant connector 631, a second end of the first electronic element 641 is electrically connected to the ground plane 630 for grounding, and the first electronic element 641 is connected in parallel between the first resonant connector 631 and the ground plane 630.

**[0334]** It should be understood that a frequency of a resonance generated in the first resonance mode (for example, the HWM) of the antenna element and a frequency of a resonance generated in the second resonance mode (for example, the OWM) may be adjusted through the resonant connector disposed between the radiator and the parasitic stub of the antenna element and the electronic element disposed between the resonant connector and the ground plane, so that the frequencies of the resonances generated in the two resonance modes are close to each other, to expand an operating bandwidth of the antenna element.

**[0335]** In the several embodiments provided in this application, it should be understood that the disclosed system, apparatus and method may be implemented in other manners. For example, the described apparatus embodiments are merely examples. For example, division into units is merely logical functional division and may be other division during actual implementation. For example, a plurality of units or components may be combined or integrated into another system, or some features may be ignored or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be implemented through some interfaces. The indirect couplings or communication connections between the apparatuses or units may be implemented in electronic or other forms.

**[0336]** The foregoing descriptions are merely specific implementations of this application, but are not intended to limit the protection scope of this application. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in this application shall fall within the protection scope of this application. Therefore, the protection scope of this application shall be subject to the protection scope of the claims.

## Claims

1. An electronic device, comprising:

a ground plane;  
a first antenna element, comprising a first parasitic stub, a first radiator, and a first feed element, wherein the first radiator comprises a first feed point, and the first feed element is coupled to the first radiator through the first feed point; and

- a second antenna element, comprising a second radiator and a second feed element, wherein the second radiator comprises a second feed point, the second feed element is coupled to the second radiator through the second feed point, and the first feed element is different from the second feed element, wherein
- a first end of the first radiator, a first end of the second radiator, and a second end of the first parasitic stub are all coupled to the ground plane for grounding;
- the first end of the first radiator and the first end of the second radiator are ground ends disposed on a same side; and
- the first end of the first radiator and the second end of the first parasitic stub are ground ends disposed on different sides.
2. The electronic device according to claim 1, wherein the first radiator and the second radiator are serialized.
  3. The electronic device according to claim 1, wherein the first radiator and the second radiator are juxtaposed.
  4. The electronic device according to any one of claims 1 to 3, wherein the first radiator and the first parasitic stub are juxtaposed.
  5. The electronic device according to any one of claims 1 to 3, wherein the first radiator and the first parasitic stub are serialized.
  6. The electronic device according to any one of claims 1 to 5, wherein both the first radiator and the second radiator extend in a first direction, a second end of the first radiator is an open end, and a second end of the second radiator is an open end, wherein that the first end of the first radiator and the first end of the second radiator are ground ends disposed on a same side means that the first end of the first radiator is on a first side in the first direction, the second end of the first radiator is on a second side in the first direction, the first end of the second radiator is on the first side in the first direction, and the second end of the second radiator is on the second side in the first direction.
  7. The electronic device according to any one of claims 1 to 6, wherein both the first radiator and the first parasitic stub extend in the first direction, the second end of the first radiator is an open end, and a first end of the first parasitic stub is an open end, wherein that the first end of the first radiator and the second end of the first parasitic stub are ground ends disposed on different sides means that the first end of the first radiator is on the first side in the first direction, the second end of the first radiator is on the second side in the first direction, the first end of the first parasitic stub is on the first side in the first direction, and the second end of the first parasitic stub is on the second side in the first direction.
  8. The electronic device according to any one of claims 1 to 7, wherein the electronic device further comprises a first resonant connector and a first electronic element, wherein a first end of the first resonant connector is coupled to the first radiator, and a second end of the first resonant connector is coupled to the first parasitic stub; and a first end of the first electronic element is coupled to the first resonant connector, and a second end of the first electronic element is coupled to the ground plane for grounding.
  9. The electronic device according to any one of claims 1 to 8, wherein the first end of the first resonant connector is located between the first end of the first radiator and a midpoint of the first radiator; and/or the second end of the first resonant connector is located between the second end of the first parasitic stub and a midpoint of the first parasitic stub.
  10. The electronic device according to any one of claims 1 to 9, wherein a physical length L1 of the first radiator and a physical length L2 of the second radiator satisfy the following:  $L1 \times 80\% \leq L2 \leq L1 \times 120\%$ ; and the physical length L1 of the first radiator and a physical length L3 of the first parasitic stub satisfy the following:  $L1 \times 80\% \leq L3 \leq L1 \times 120\%$ .
  11. The electronic device according to any one of claims 8 to 10, wherein the electronic device further comprises a second electronic element; and the first resonant connector comprises a slot, and the second electronic element is connected in series to the first resonant connector through the slot.
  12. The electronic device according to any one of claims 7 to 11, wherein

the first parasitic stub and the first radiator are configured to: jointly generate a first resonance and jointly generate a second resonance; and the second radiator is configured to generate a third resonance.

13. The electronic device according to any one of claims 1 to 12, wherein

an operating frequency band of the first antenna element and an operating frequency band of the second antenna element each comprise a first frequency band.

14. An electronic device, comprising:

a ground plane;

a first antenna element, comprising a first parasitic stub, a first radiator, and a first feed element, wherein the first radiator comprises a first feed point, and the first feed element is coupled to the first radiator through the first feed point; and a second antenna element, comprising a second radiator and a second feed element, wherein the second radiator comprises a second feed point, the second feed element is coupled to the second radiator through the second feed point, and the first feed element is different from the second feed element, wherein

a first end of the first radiator, a first end of the second radiator, and a second end of the first parasitic stub are all coupled to the ground plane for grounding;

a first projection and a second projection extend in a first direction and do not overlap in a second direction, the second direction is perpendicular to the first direction, the first projection is a projection of the first radiator on a plane on which the ground plane is located, and the second projection is a projection of the second radiator on the plane on which the ground plane is located; and

the first end of the first radiator and the first end of the second radiator are ground ends disposed on different sides; and the first end of the first radiator and the second end of the first parasitic stub are ground ends disposed on different sides.

15. The electronic device according to claim 14, wherein the first radiator and the first parasitic stub are juxtaposed.

16. The electronic device according to claim 15, wherein the first radiator and the first parasitic stub are serialized.

17. The electronic device according to any one of claims 13 to 16, wherein

the electronic device further comprises a first resonant connector and a first electronic element, wherein

a first end of the first resonant connector is coupled to the first radiator, and a second end of the first resonant connector is coupled to the first parasitic stub; and

a first end of the first electronic element is coupled to the first resonant connector, and a second end of the first electronic element is coupled to the ground plane for grounding.

18. The electronic device according to any one of claims 13 to 17, wherein

the first end of the first resonant connector is located between the first end of the first radiator and a midpoint of the first radiator; and/or the second end of the first resonant connector is located between the second end of the first parasitic stub and a midpoint of the first parasitic stub.

19. The electronic device according to any one of claims 13 to 18, wherein

the first parasitic stub and the first radiator are configured to: jointly generate a first resonance and jointly generate a second resonance; and the second radiator is configured to generate a third resonance.

20. The electronic device according to any one of claims 13 to 19, wherein

an operating frequency band of the first antenna element and an operating frequency band of the second antenna element each comprise a first frequency band.

21. An electronic device, comprising:

a ground plane;

a first antenna element, comprising a first parasitic stub, a first radiator, and a first feed element, wherein the first radiator comprises a first feed point, and the first feed element is coupled to the first radiator through the first feed point; and a second antenna element, comprising a second radiator and a second feed element, wherein the second radiator comprises a second feed point, the second feed element is coupled to the second radiator through the second feed point, and the first feed element is different from the second feed element, wherein

a first end of the first radiator, a first end of the second radiator, and a second end of the first parasitic stub are all coupled to the ground plane for grounding, and a distance between the first



end of the second radiator and the second end of the first parasitic stub is greater than a distance between the first end of the second radiator and a first end of the first parasitic stub;  
 a first projection is perpendicular to a second projection, an extension line of the second radiator intersects the first radiator on the first radiator, the first projection is a projection of the first radiator on a plane on which the ground plane is located, and the second projection is a projection of the second radiator on the plane on which the ground plane is located;  
 the first projection and a third projection are disposed along a same straight line in a first direction, and the third projection is a projection of the first parasitic stub on the plane on which the ground plane is located; and  
 a distance between the first end of the first radiator and the first end of the first parasitic stub is less than a distance between the first end of the first radiator and the second end of the first parasitic stub.

21 to 24, wherein

an operating frequency band of the first antenna element and an operating frequency band of the second antenna element each comprise a first frequency band.

22. The electronic device according to claim 21, wherein

the electronic device further comprises a first resonant connector and a first electronic element, wherein  
 a first end of the first resonant connector is coupled to the first radiator, and a second end of the first resonant connector is coupled to the first parasitic stub; and  
 a first end of the first electronic element is coupled to the first resonant connector, and a second end of the first electronic element is coupled to the ground plane for grounding.

23. The electronic device according to claim 21 or 22, wherein

the first end of the first resonant connector is located between the first end of the first radiator and a midpoint of the first radiator; and/or  
 the second end of the first resonant connector is located between the second end of the first parasitic stub and a midpoint of the first parasitic stub.

24. The electronic device according to any one of claims 21 to 23, wherein

the first parasitic stub and the first radiator are configured to: jointly generate a first resonance and jointly generate a second resonance; and  
 the second radiator is configured to generate a third resonance.

25. The electronic device according to any one of claims

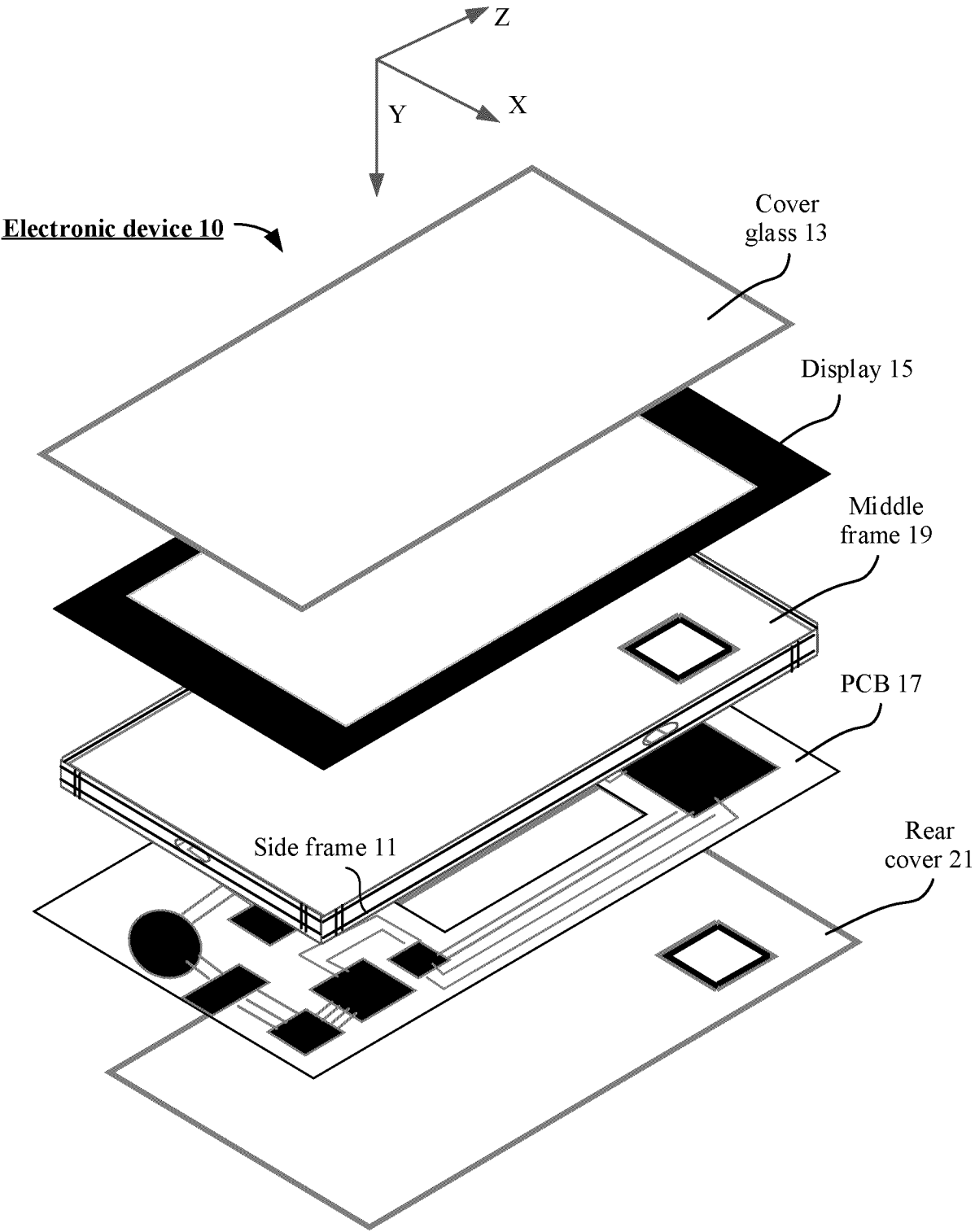


FIG. 1

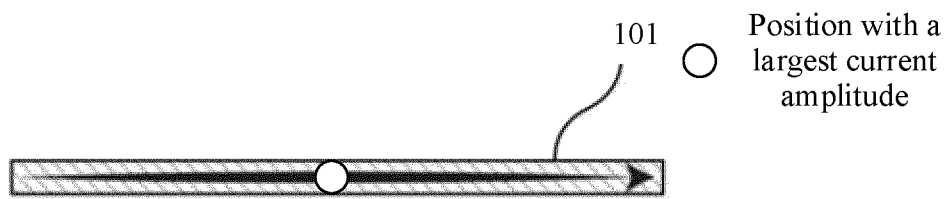


FIG. 2

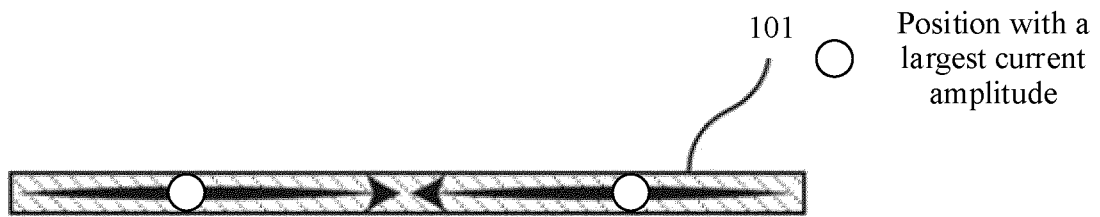


FIG. 3

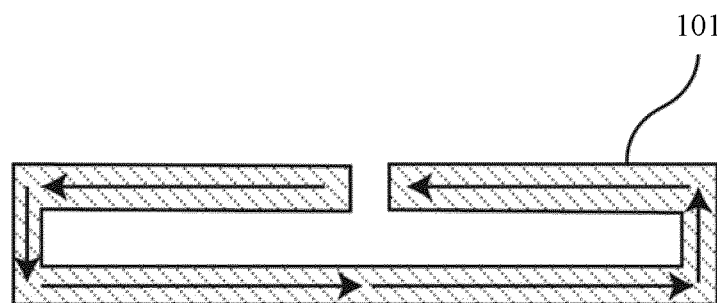


FIG. 4

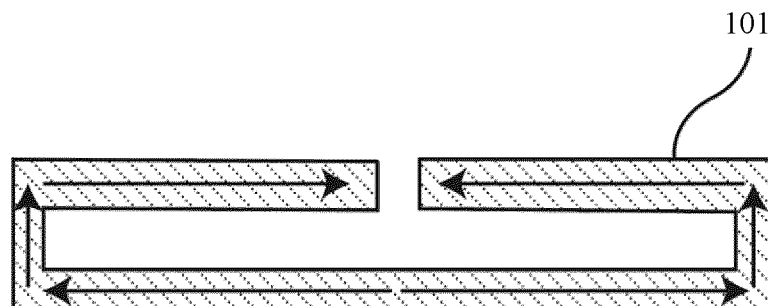


FIG. 5

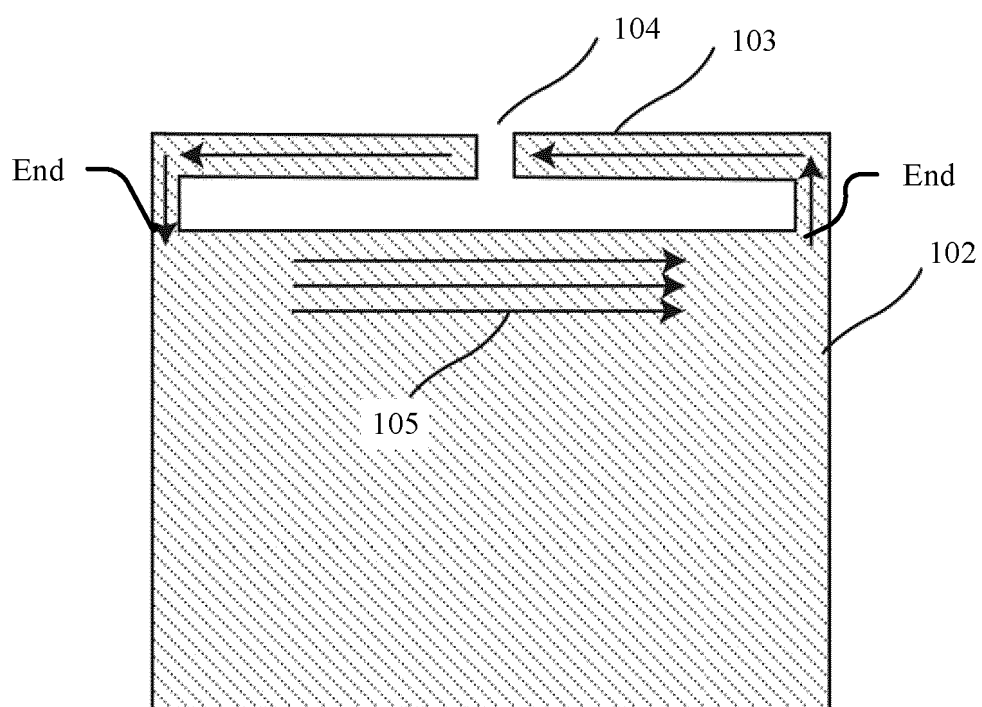


FIG. 6

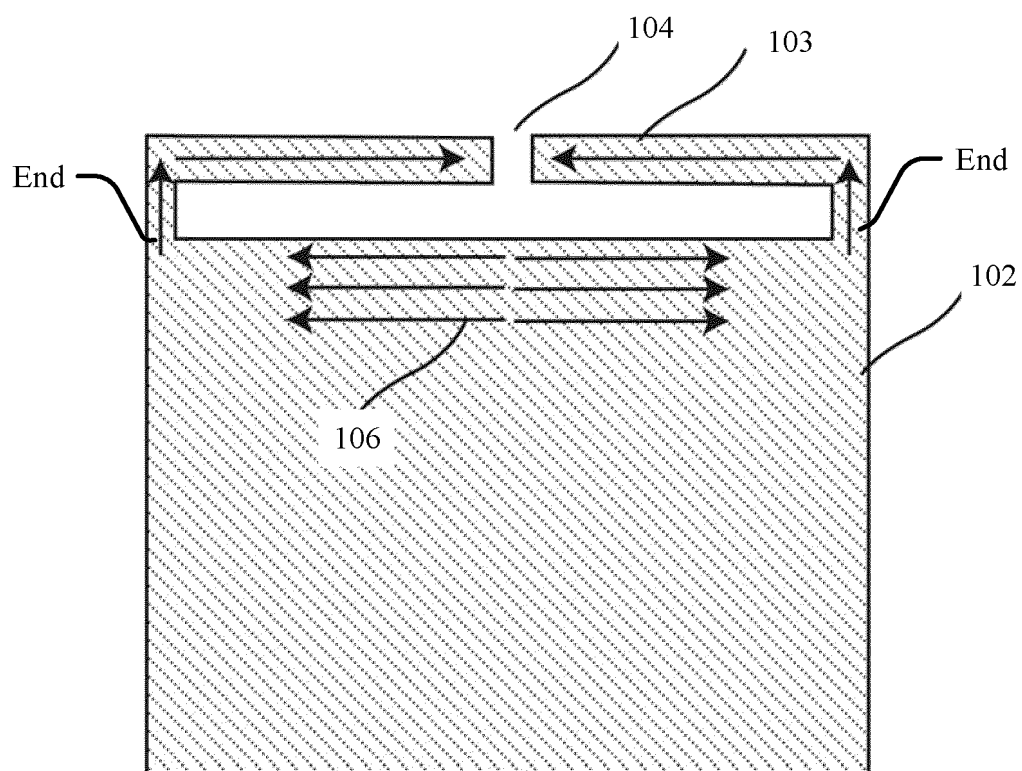


FIG. 7

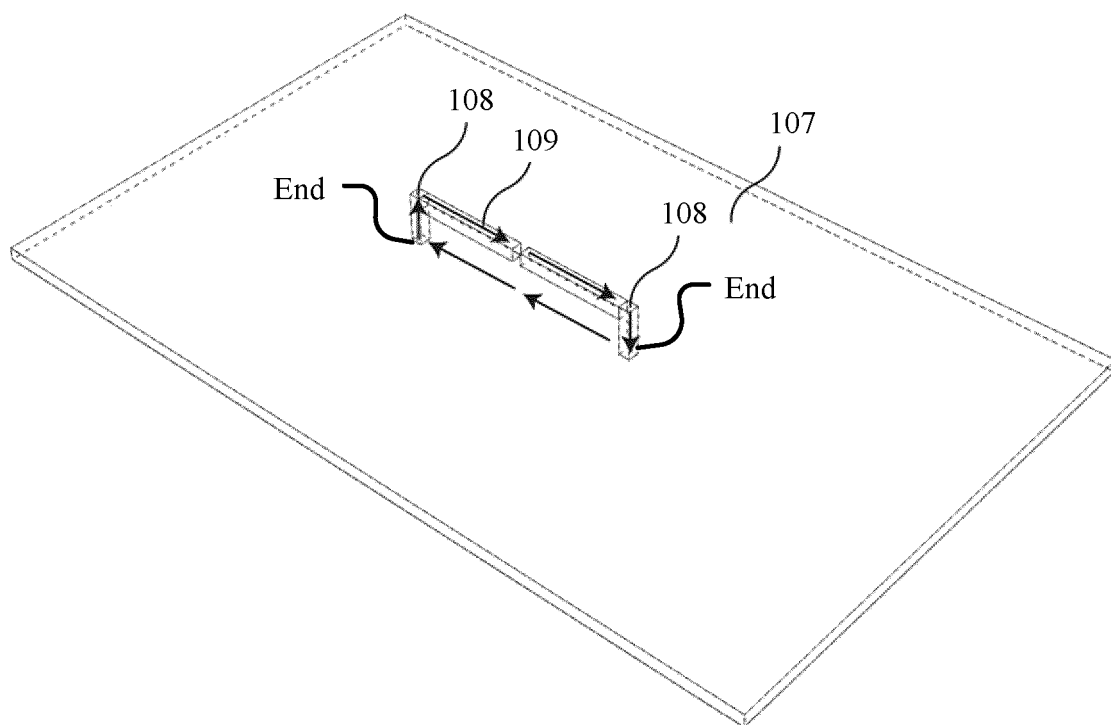


FIG. 8

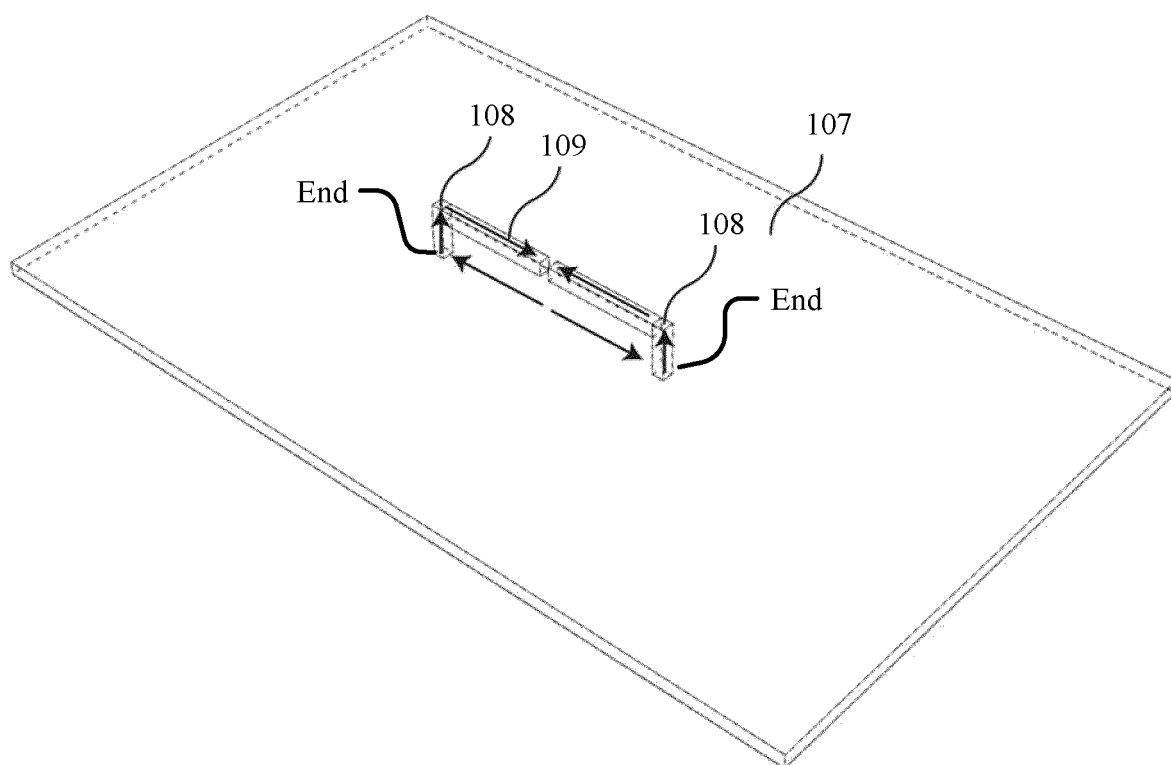
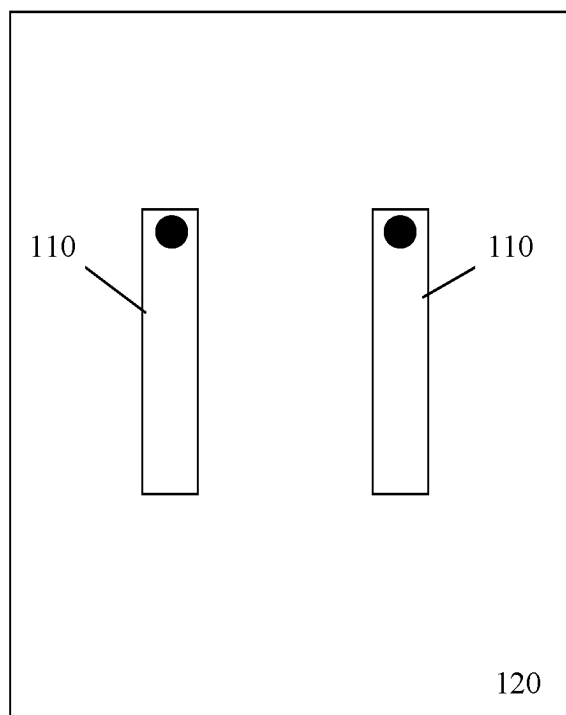
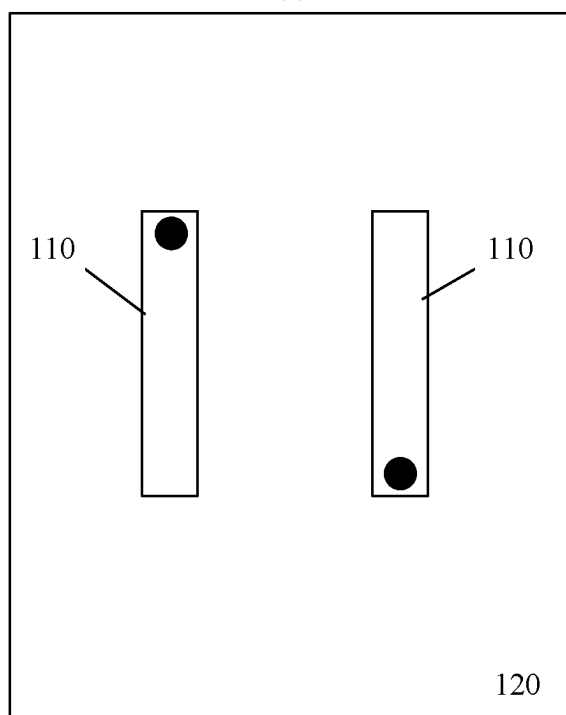


FIG. 9



(a)



(b)

FIG. 10

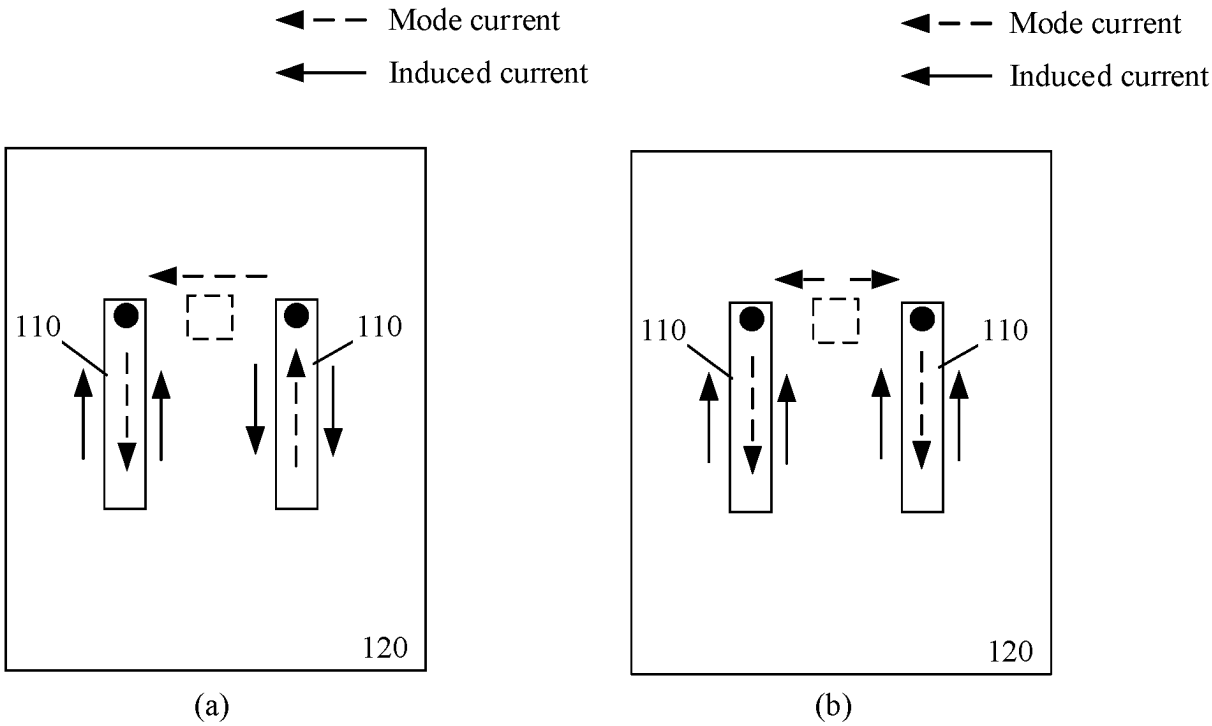


FIG. 11

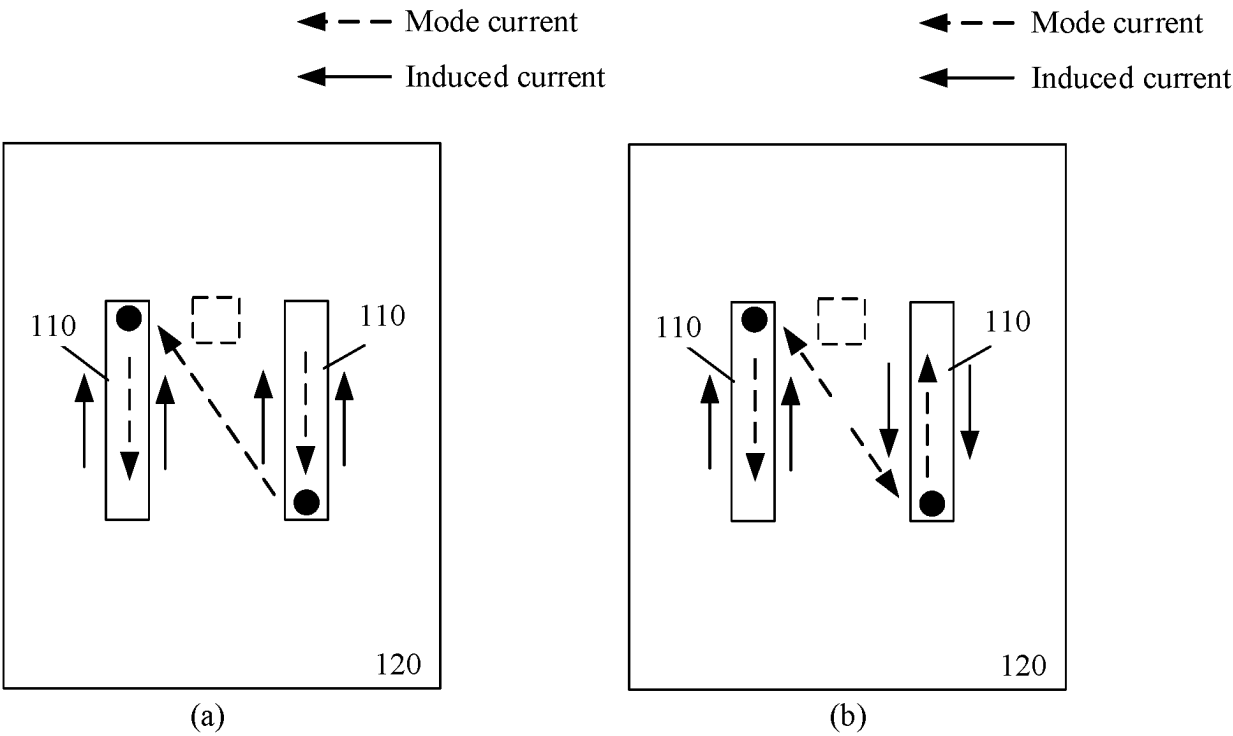


FIG. 12

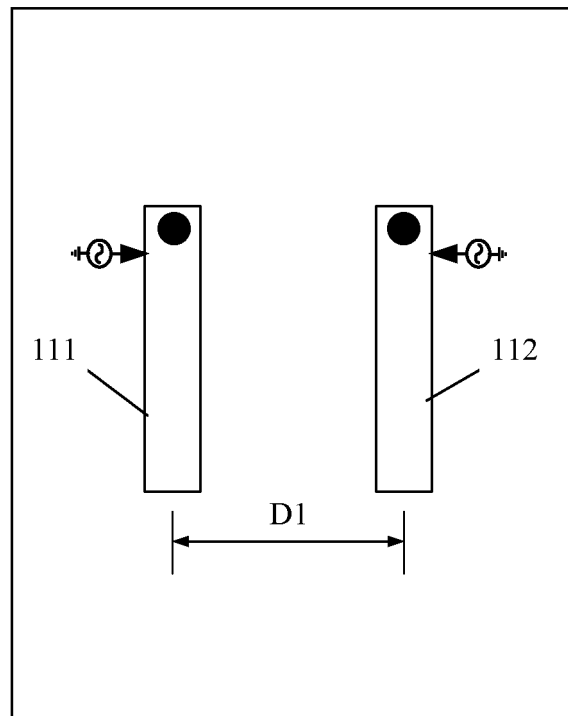


FIG. 13

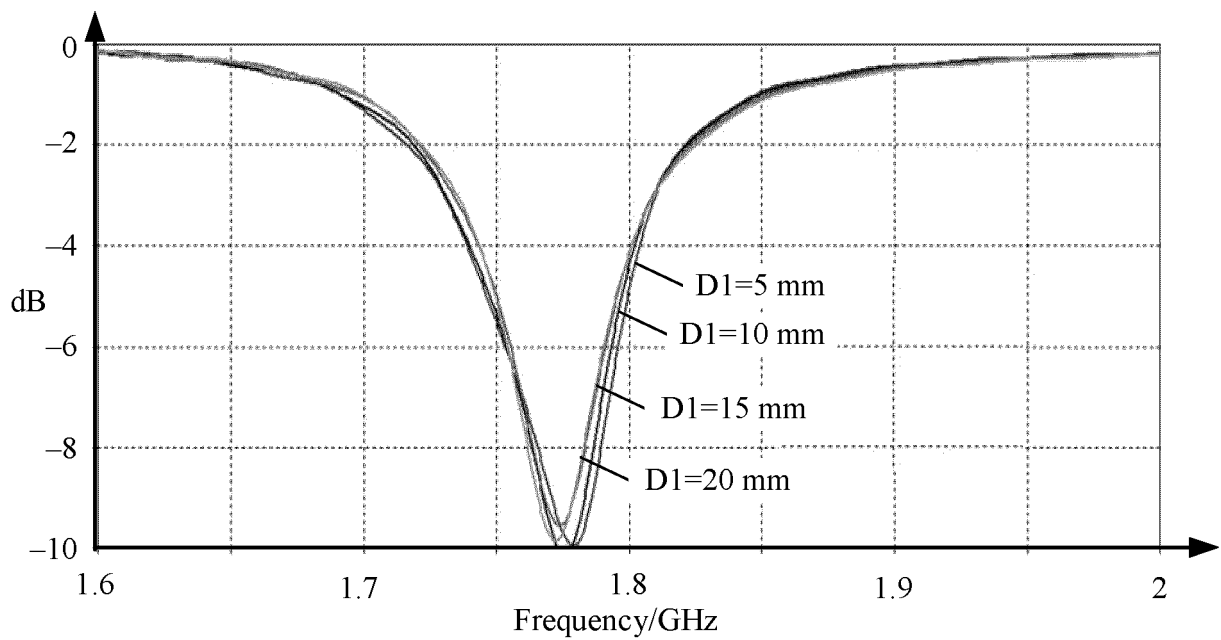


FIG. 14



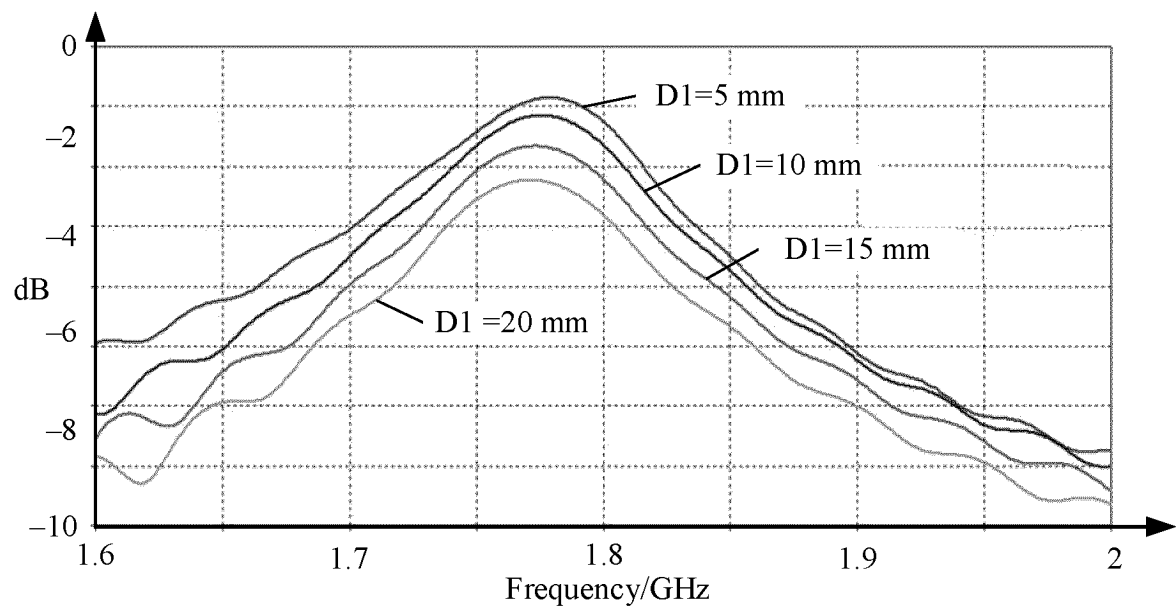


FIG. 15

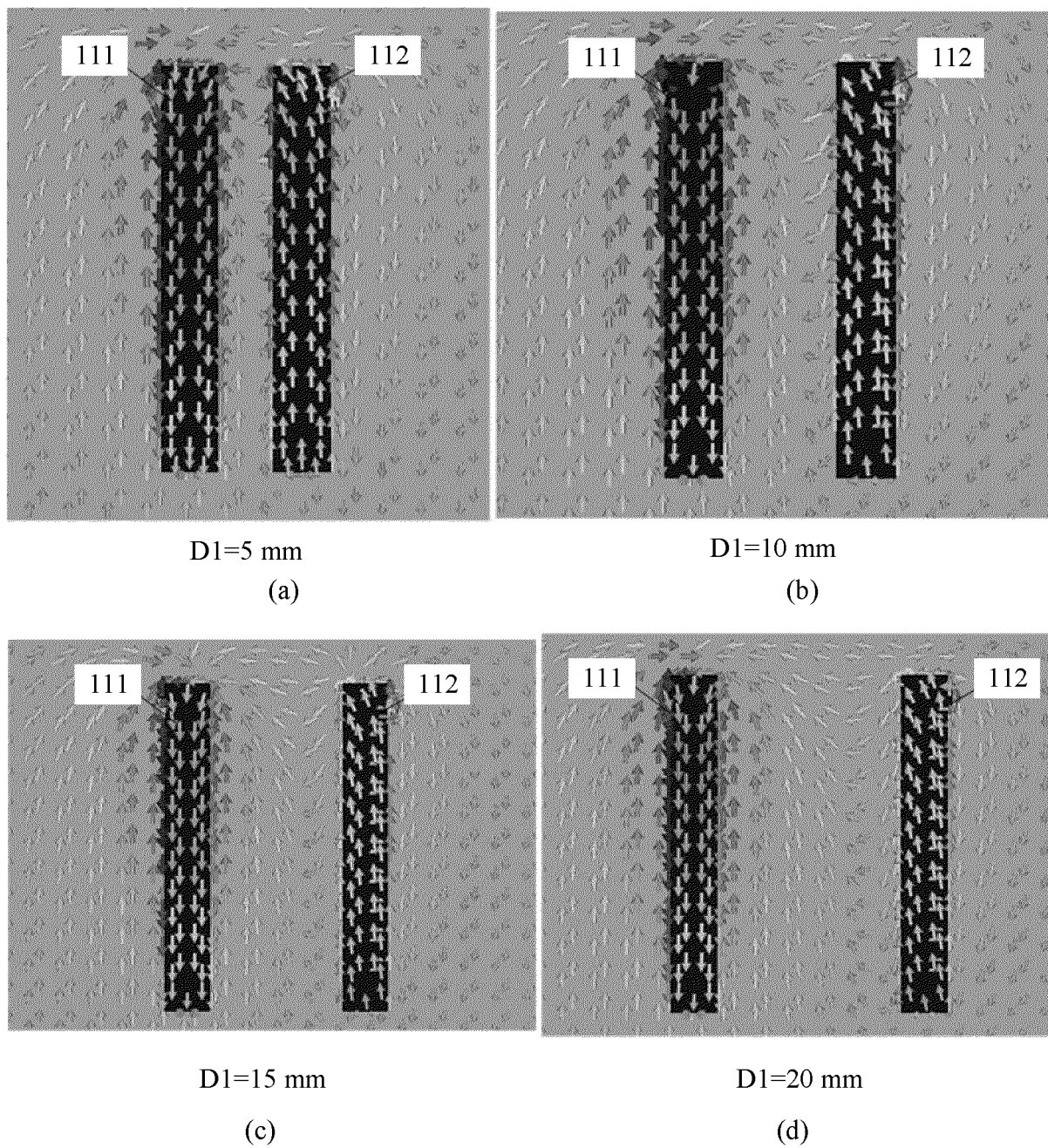


FIG. 16

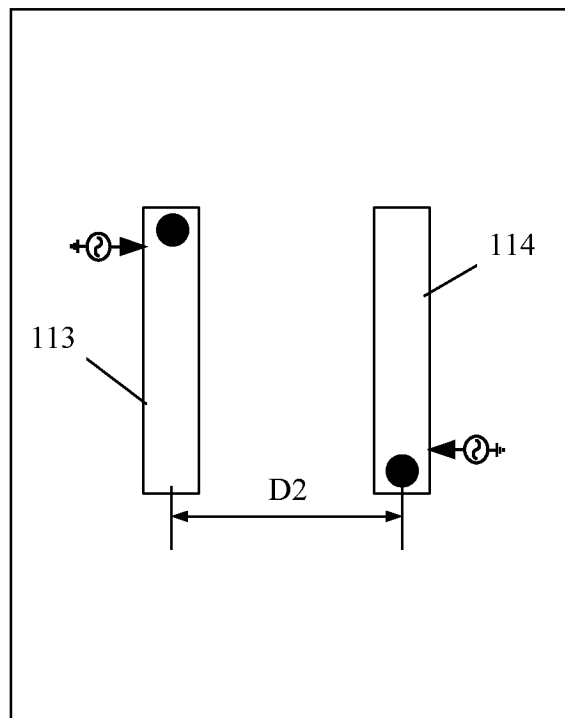


FIG. 17

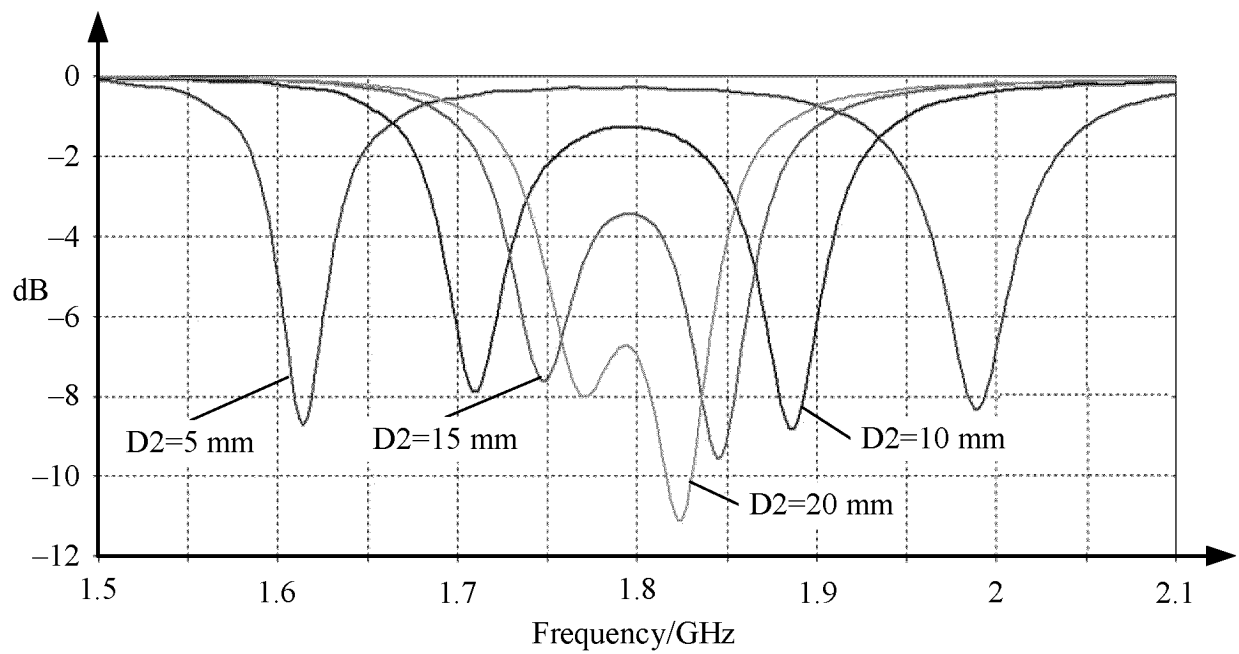


FIG. 18

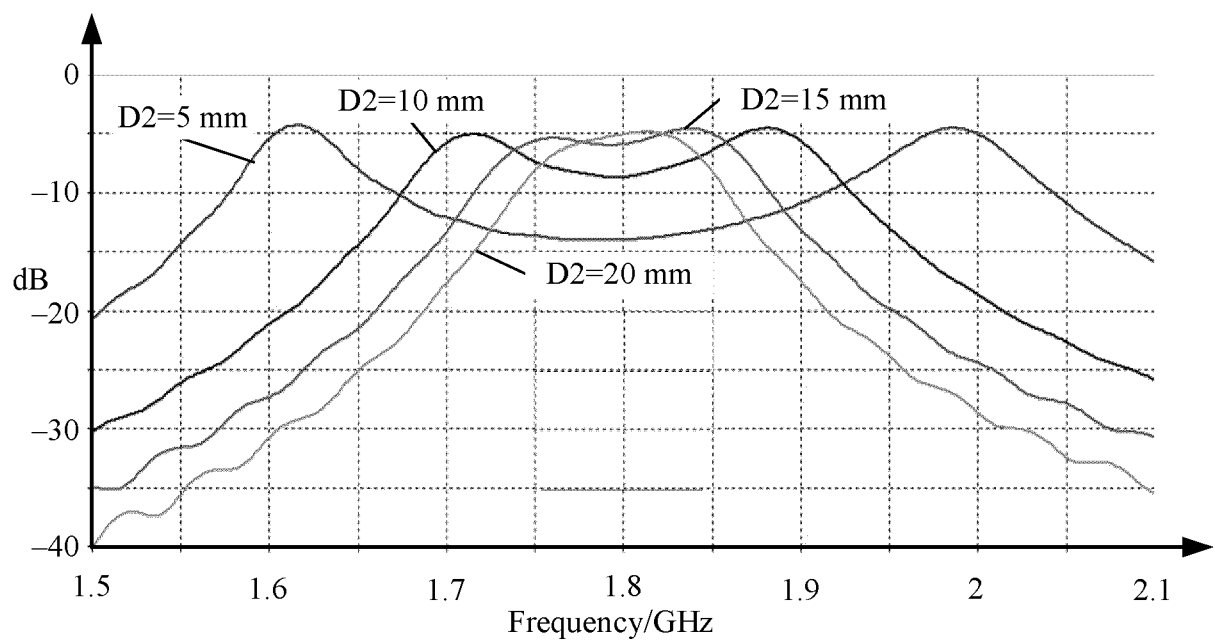


FIG. 19

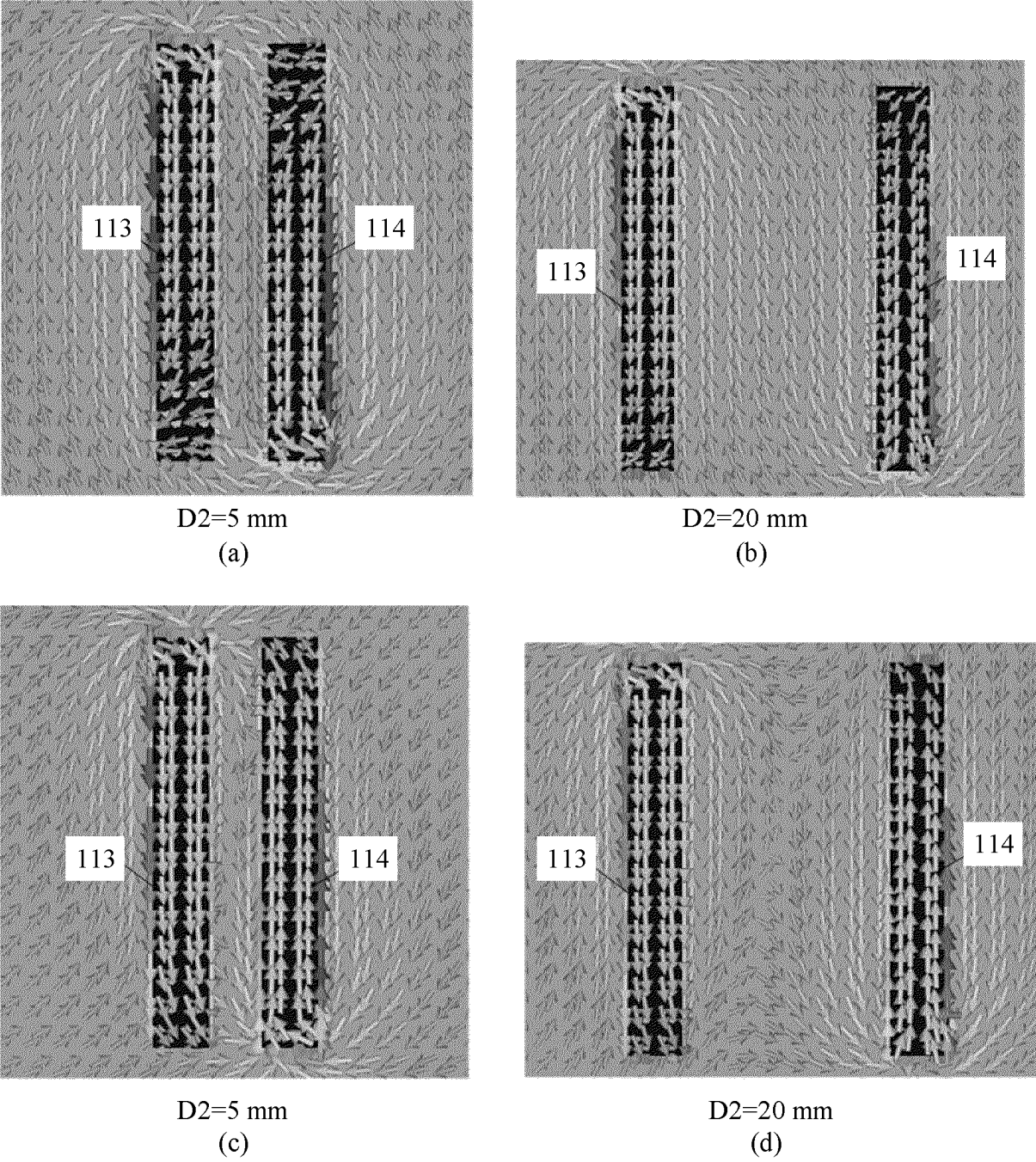


FIG. 20

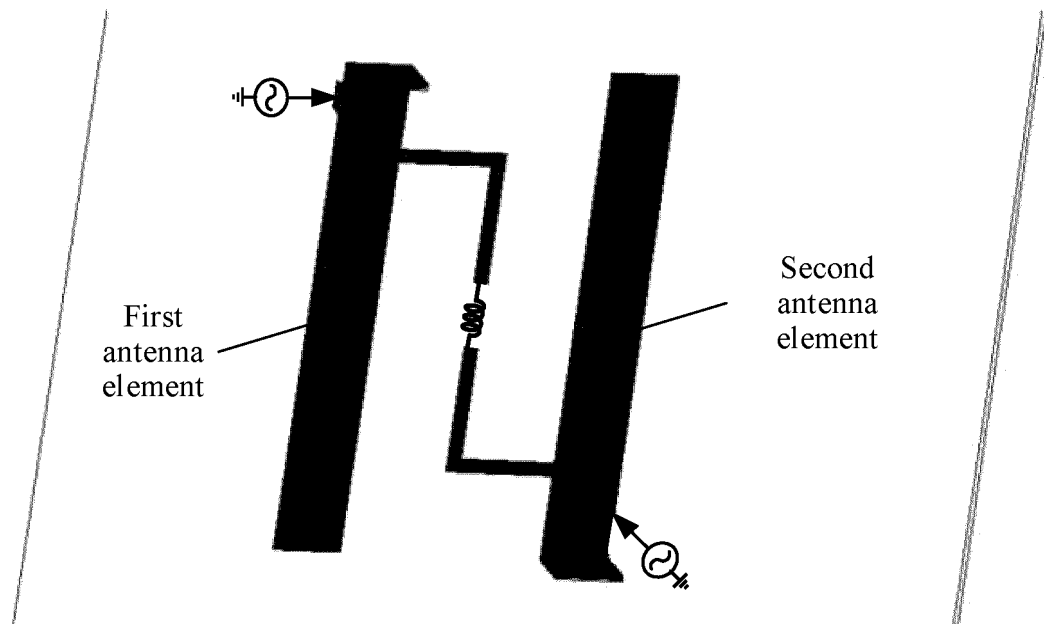


FIG. 21

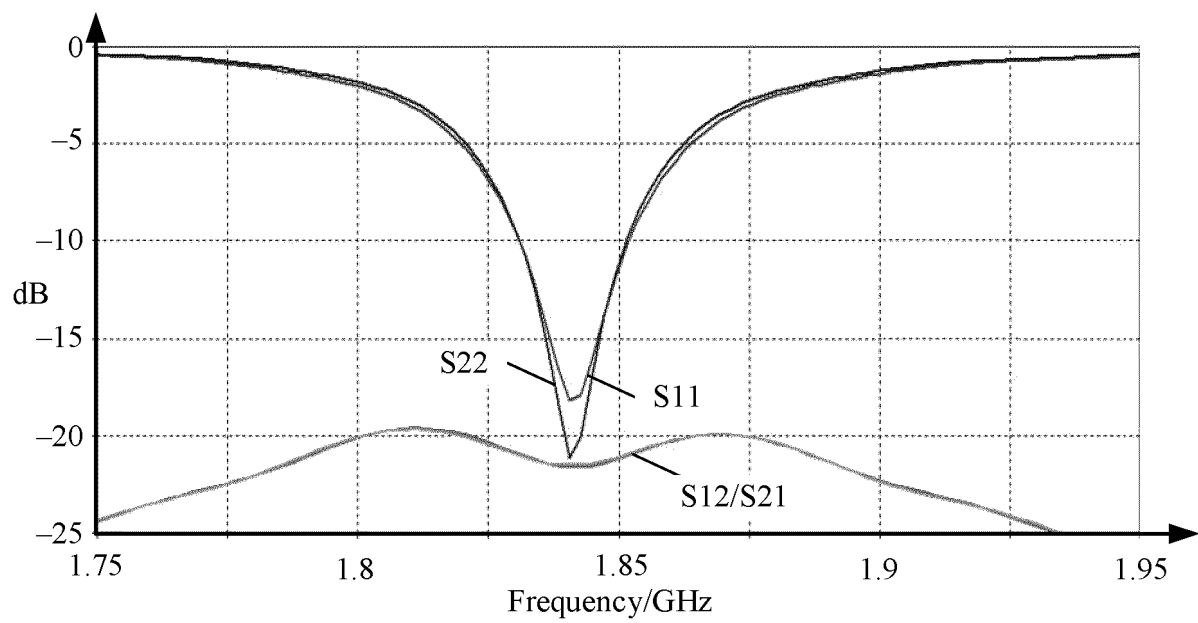


FIG. 22

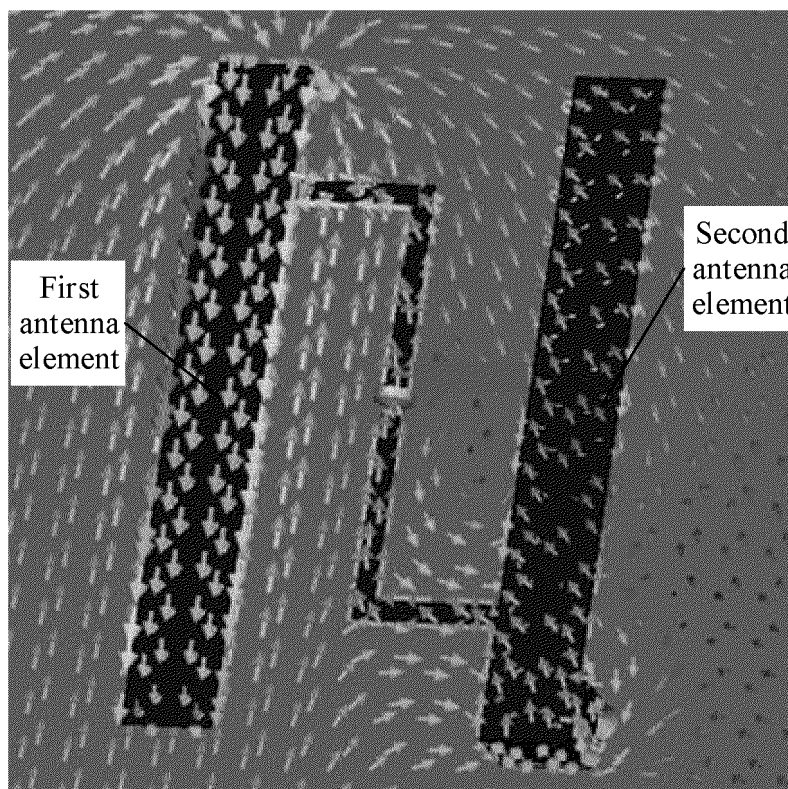


FIG. 23

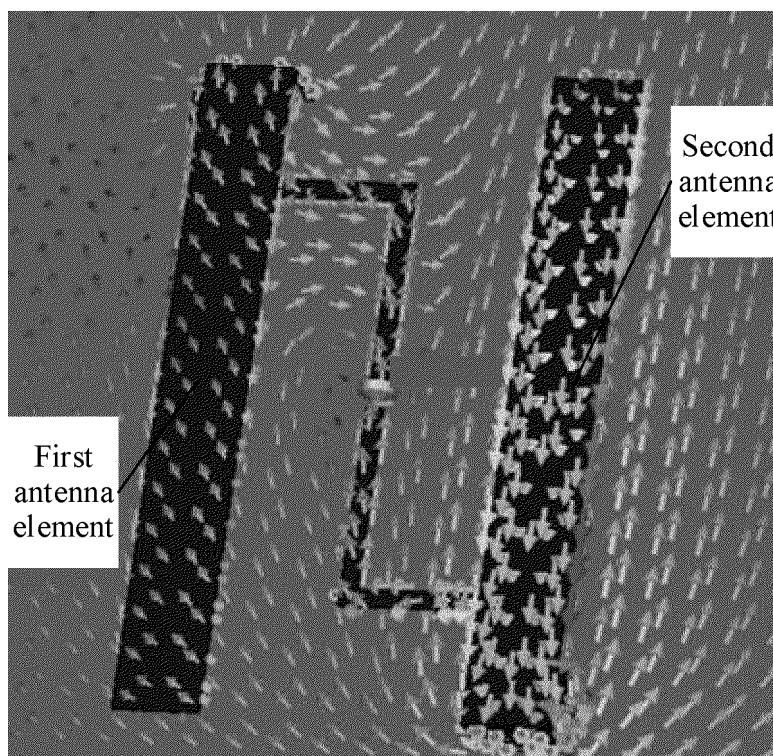


FIG. 24

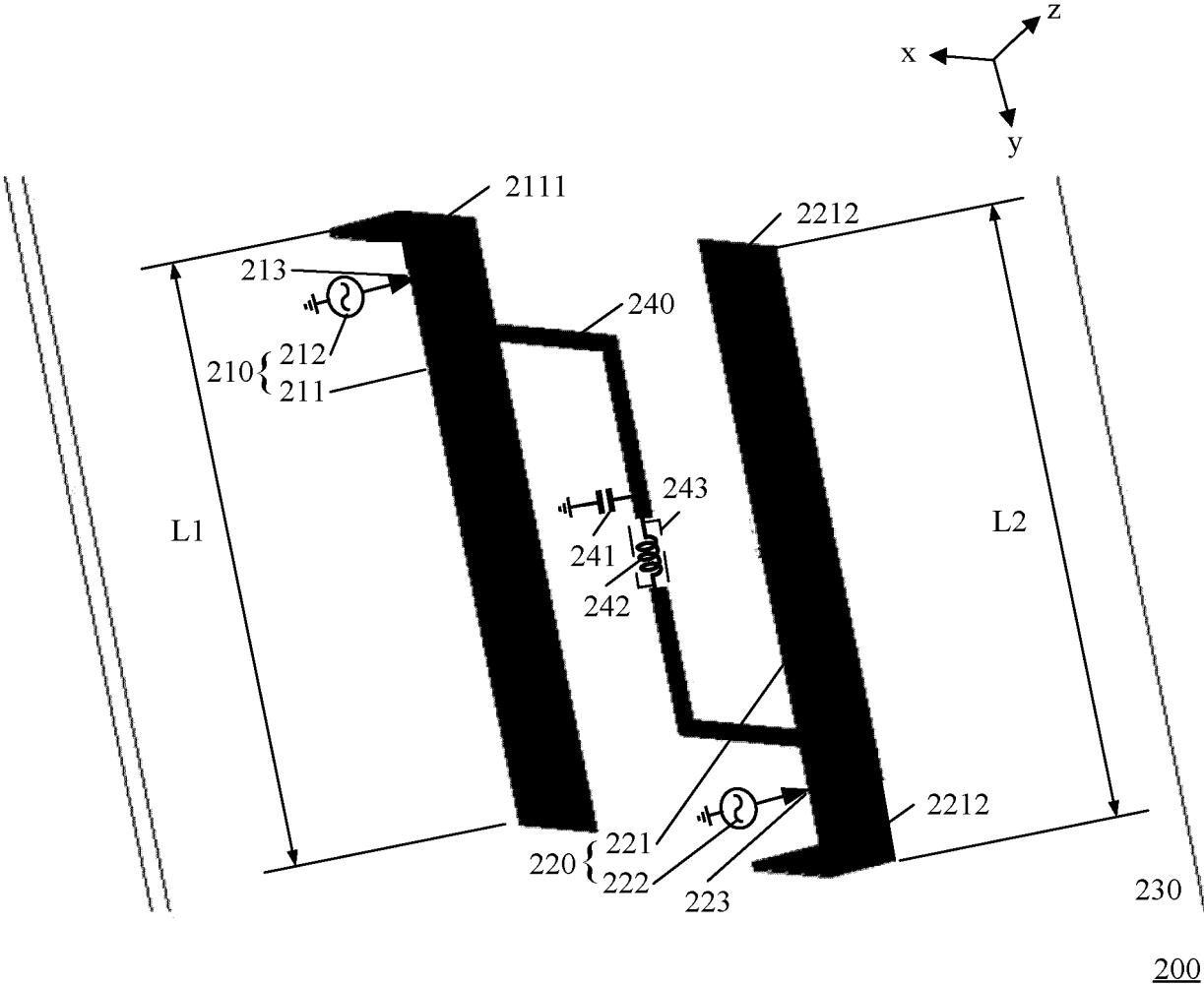


FIG. 25



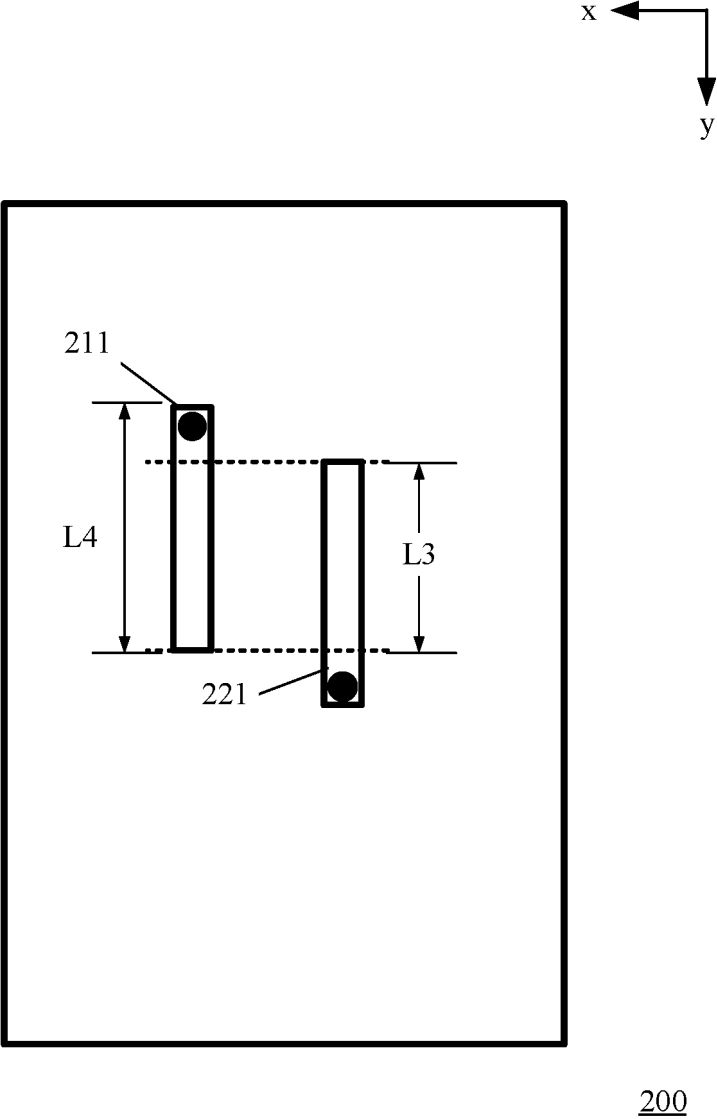


FIG. 26

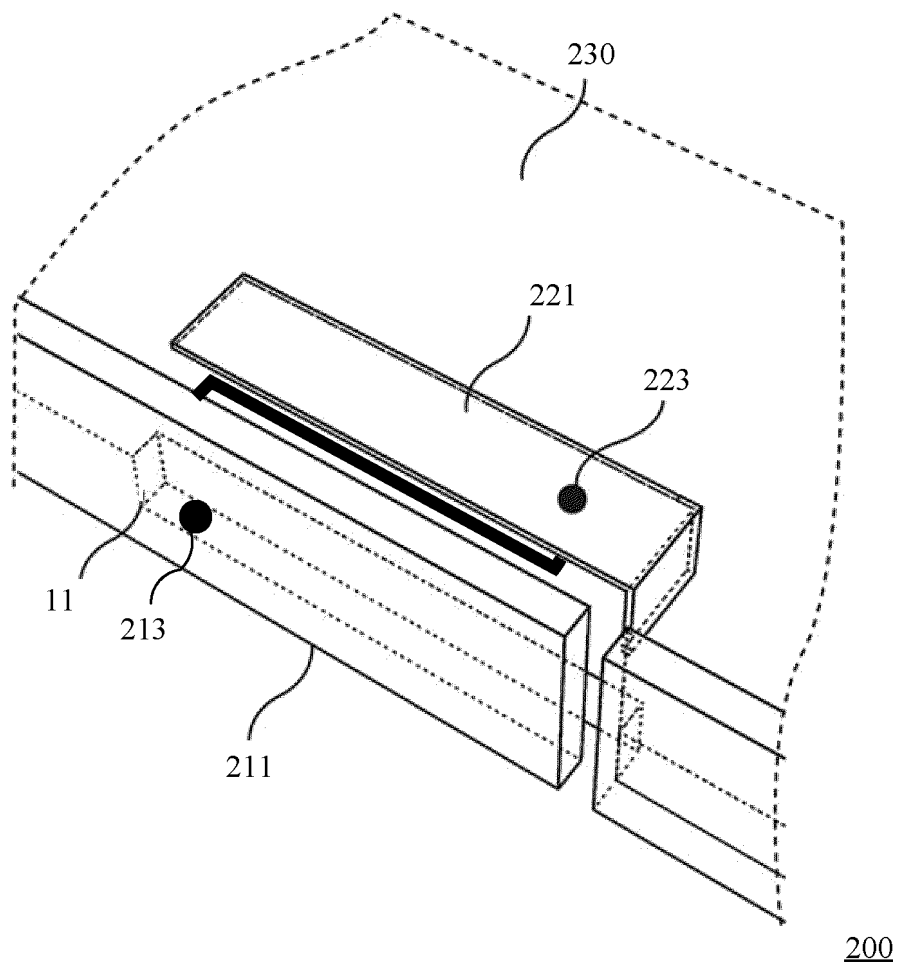
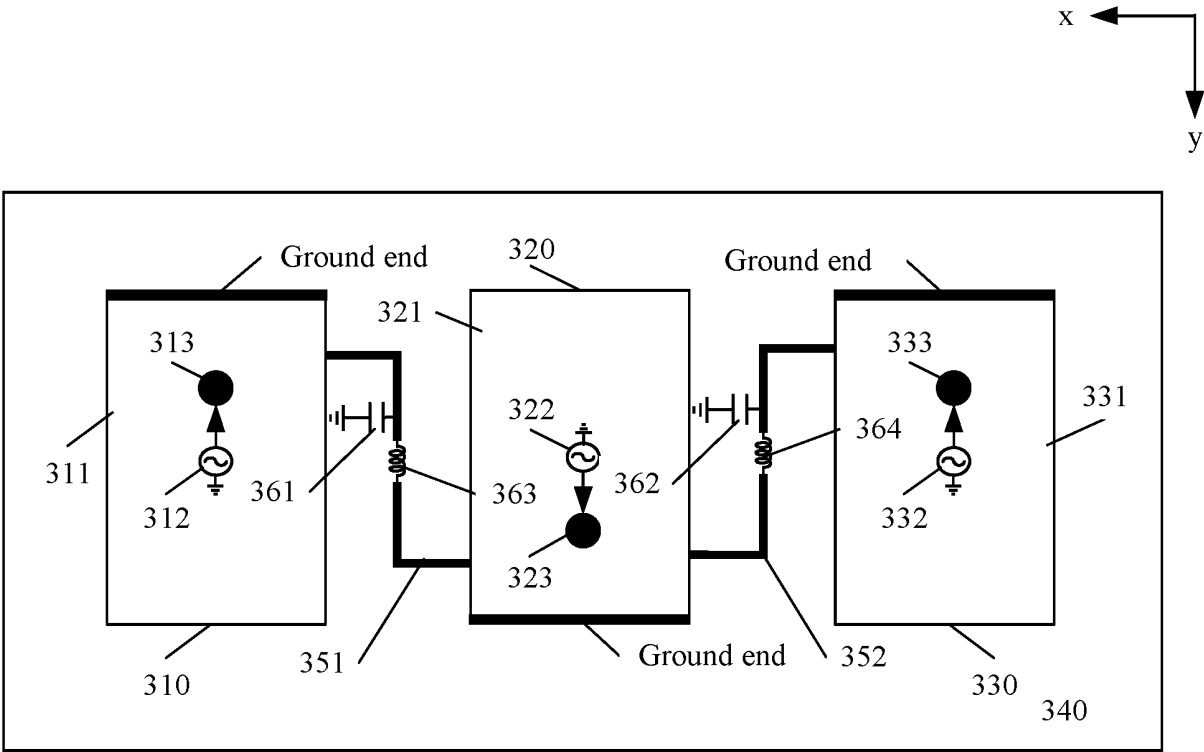


FIG. 27



300

FIG. 28

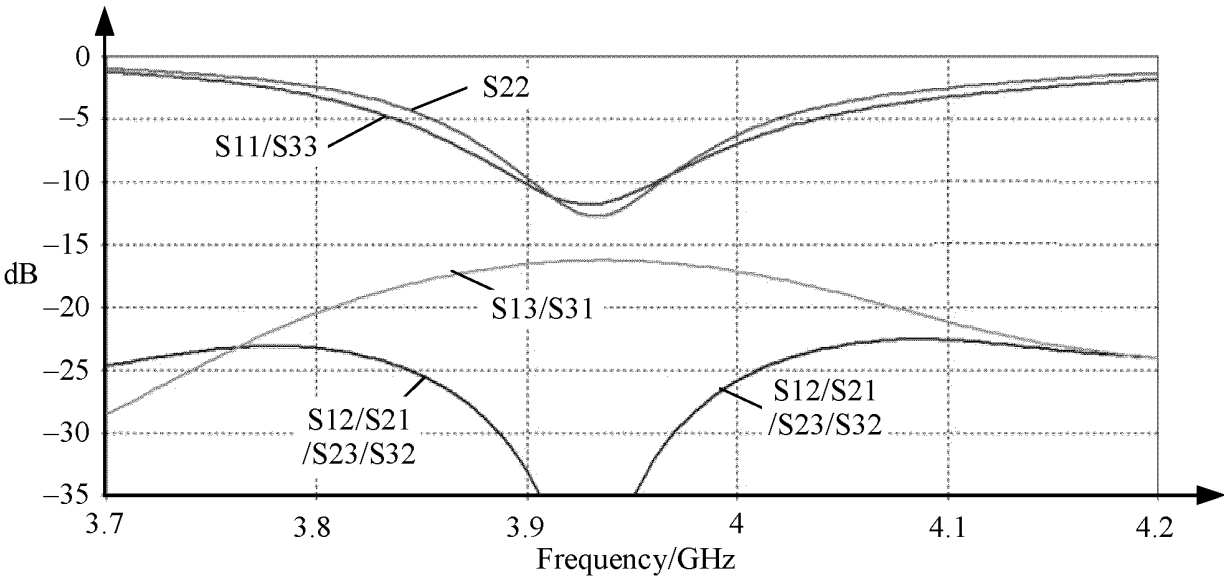


FIG. 29

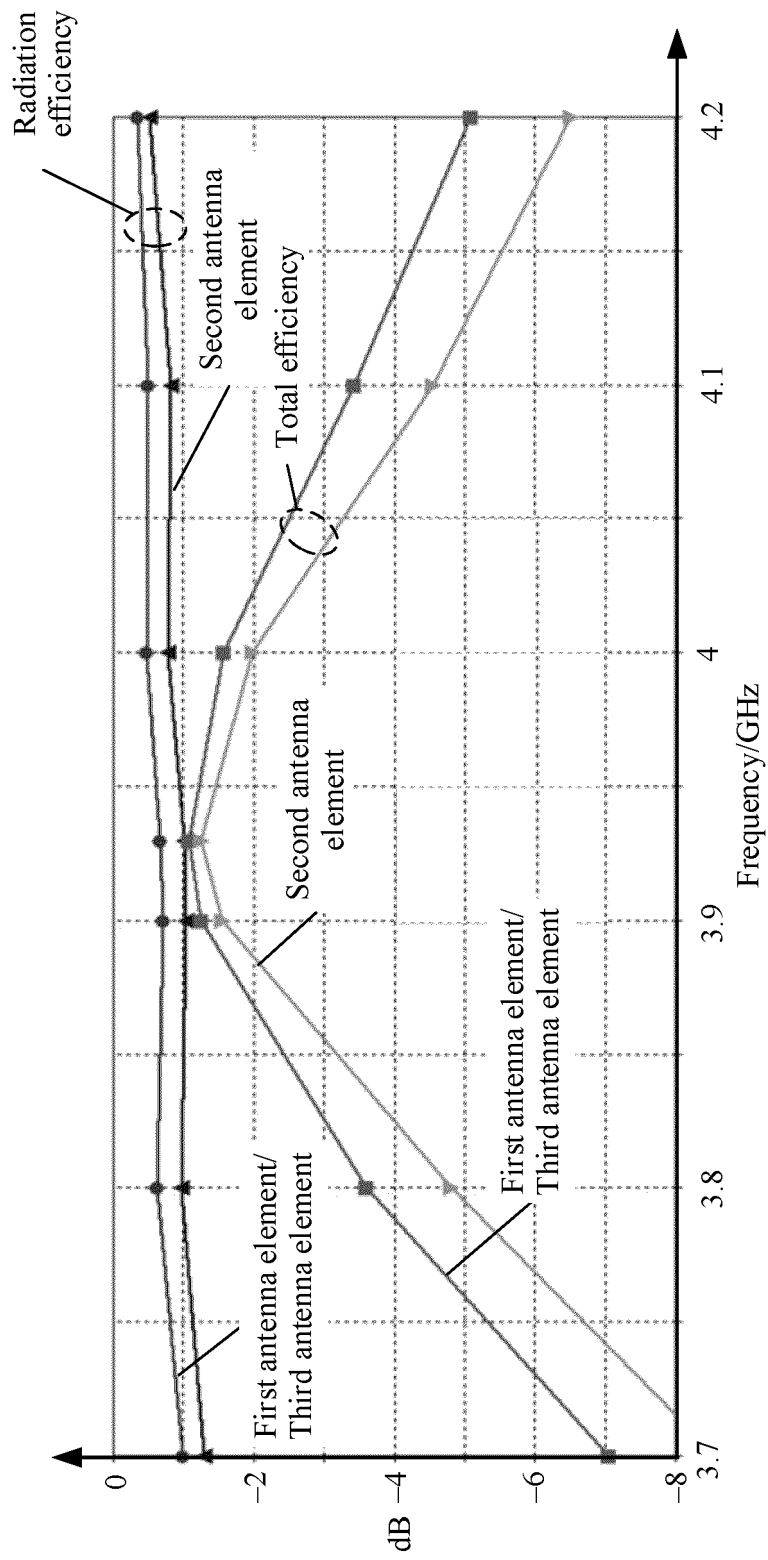
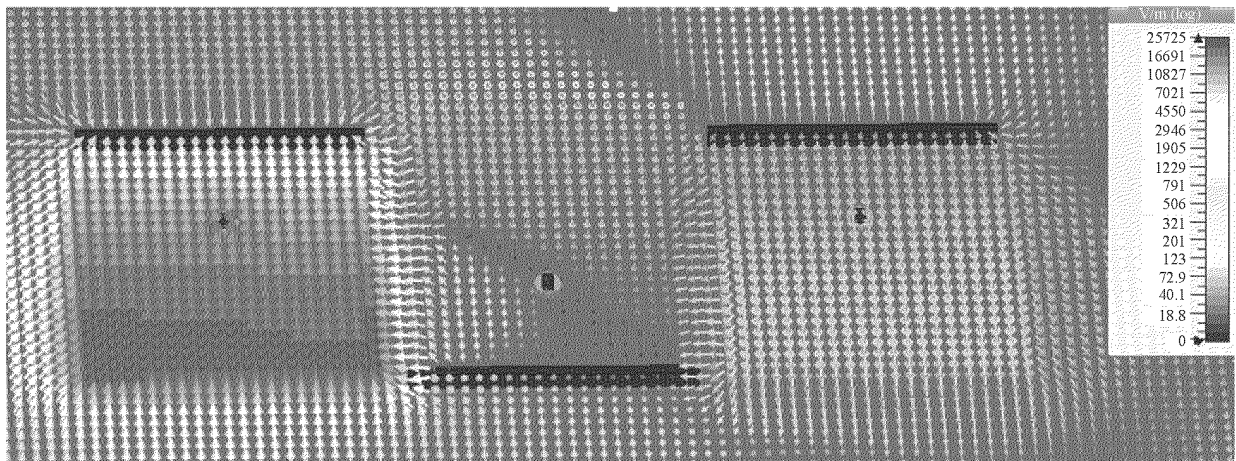
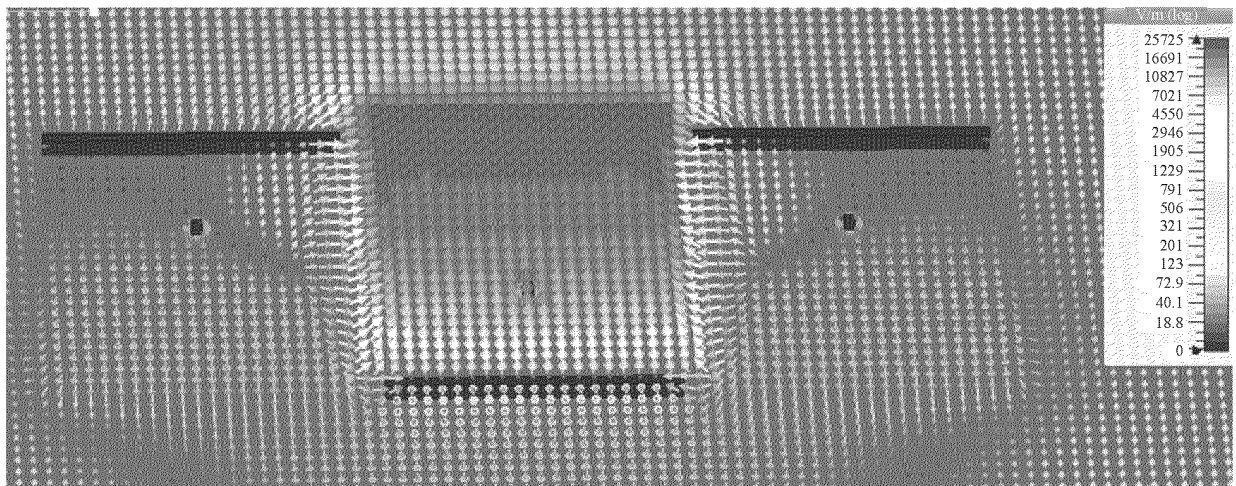


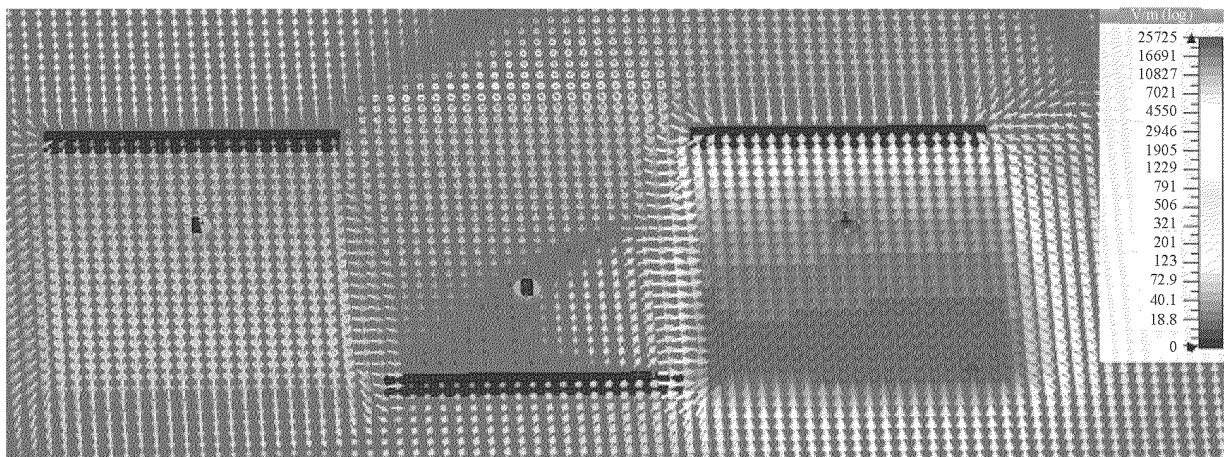
FIG. 30



(a)

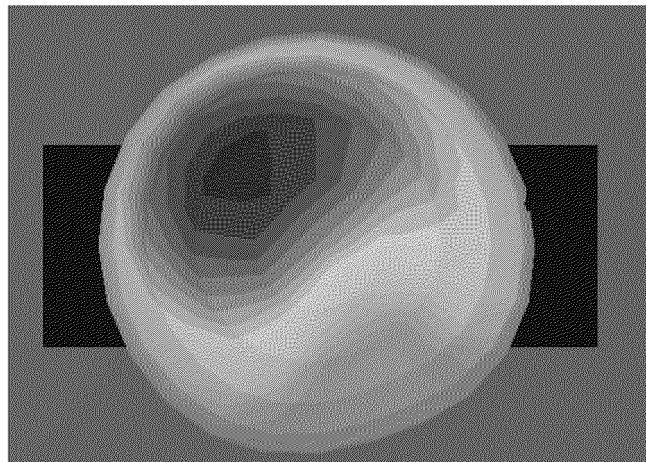


(b)

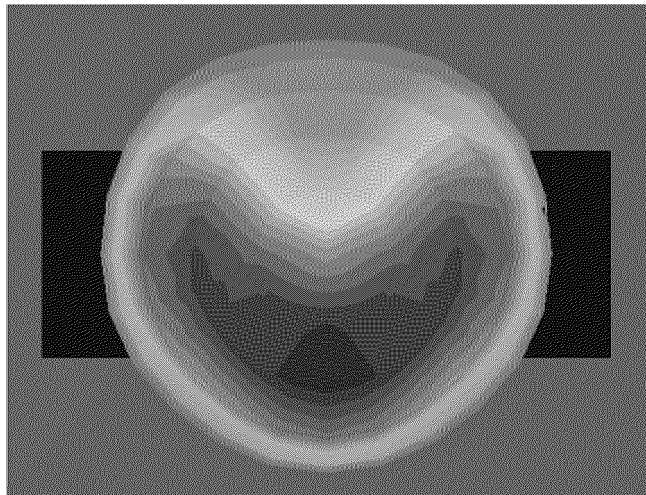


(c)

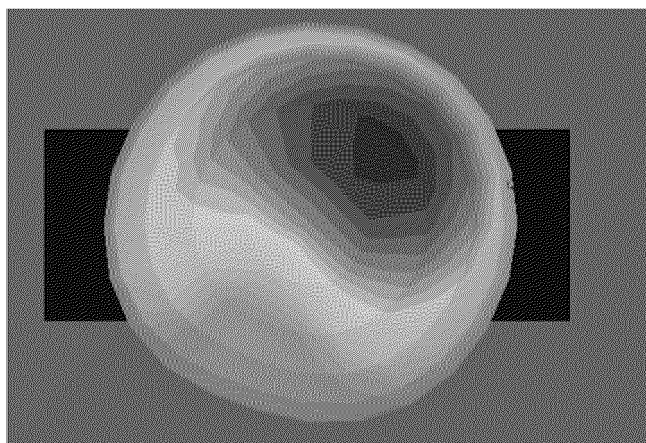
FIG. 31



(a)



(b)



(c)

FIG. 32

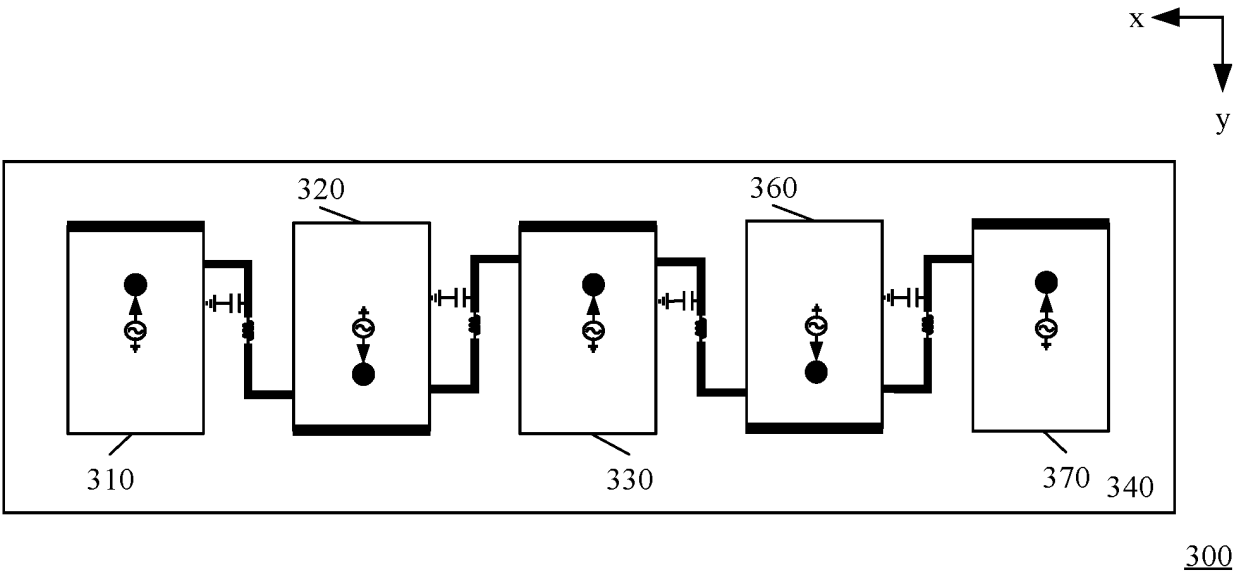


FIG. 33

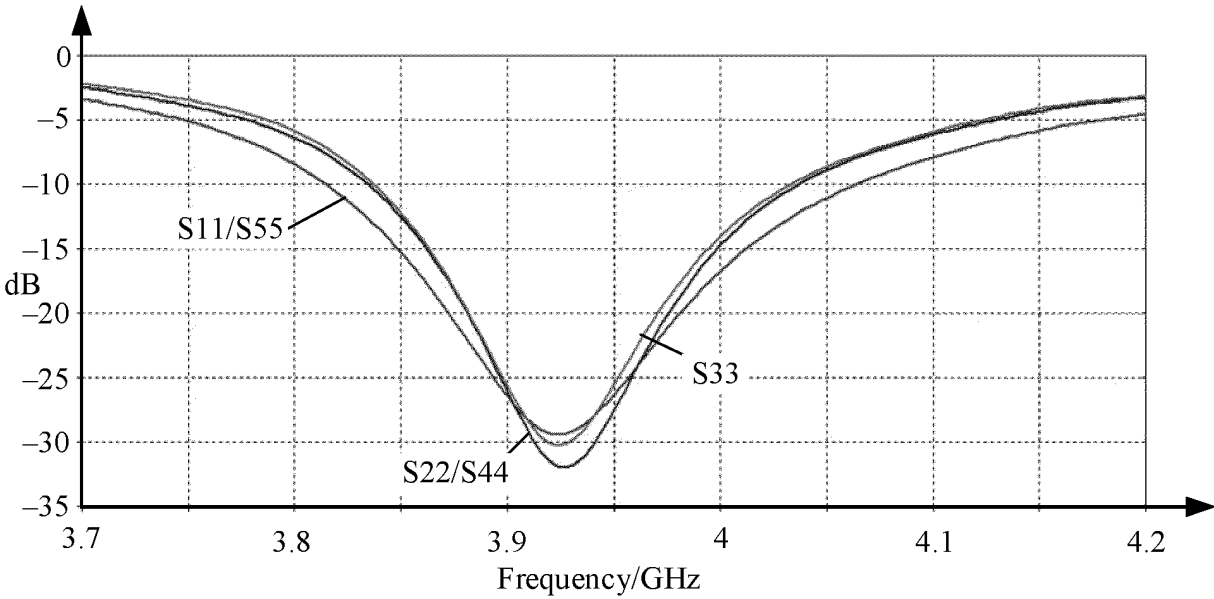


FIG. 34

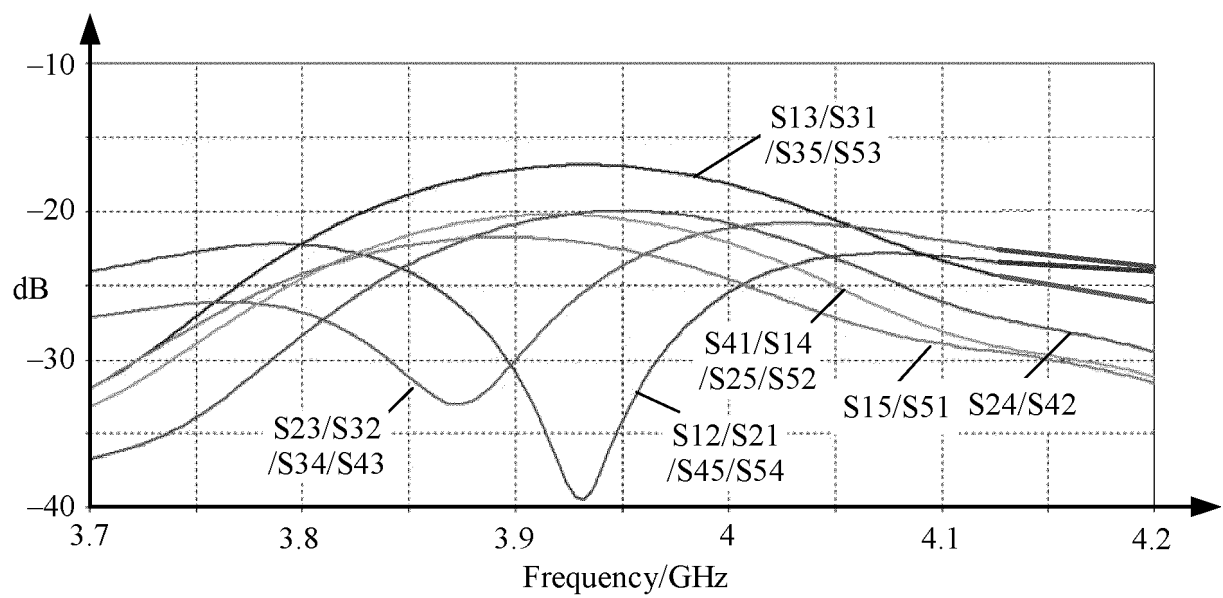


FIG. 35



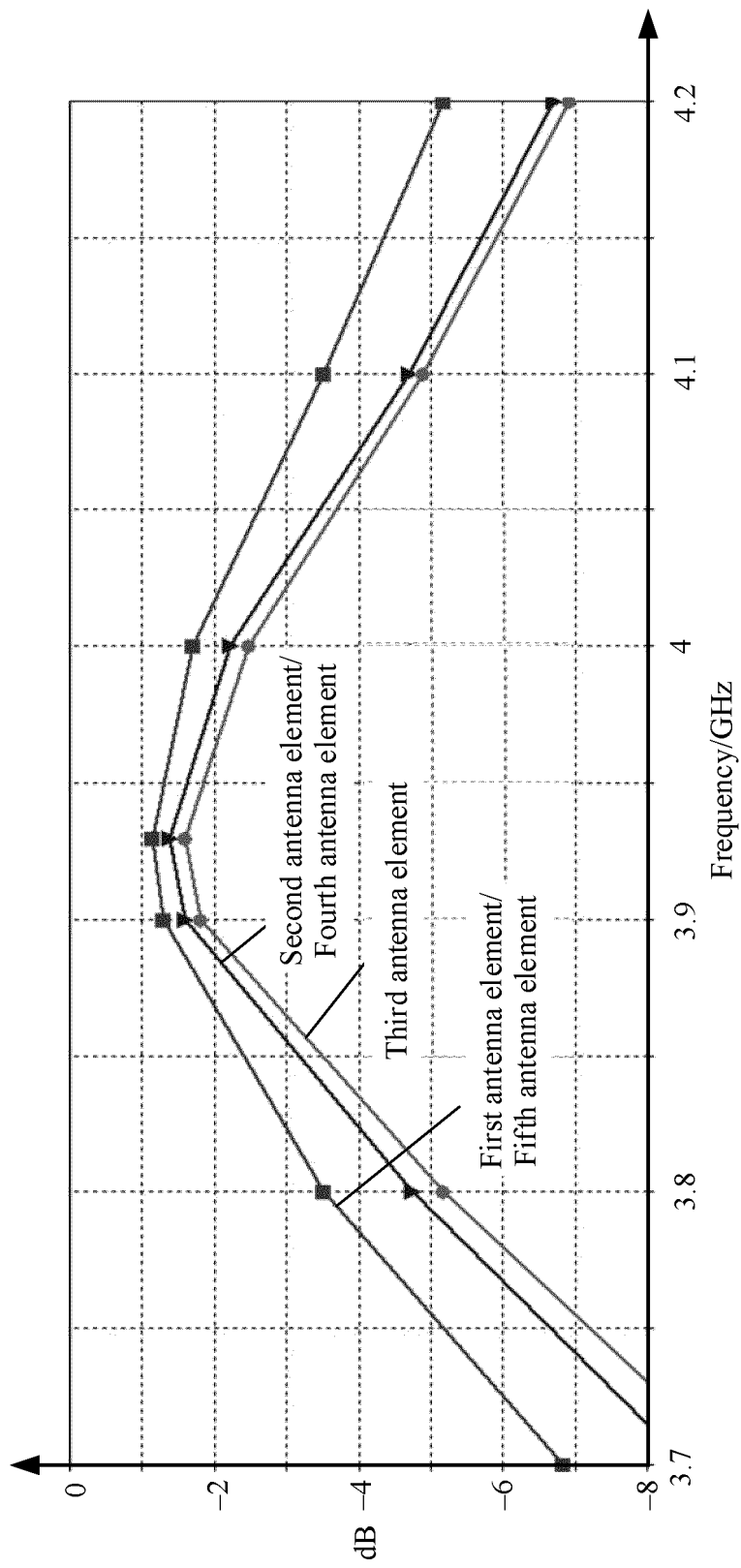


FIG. 36

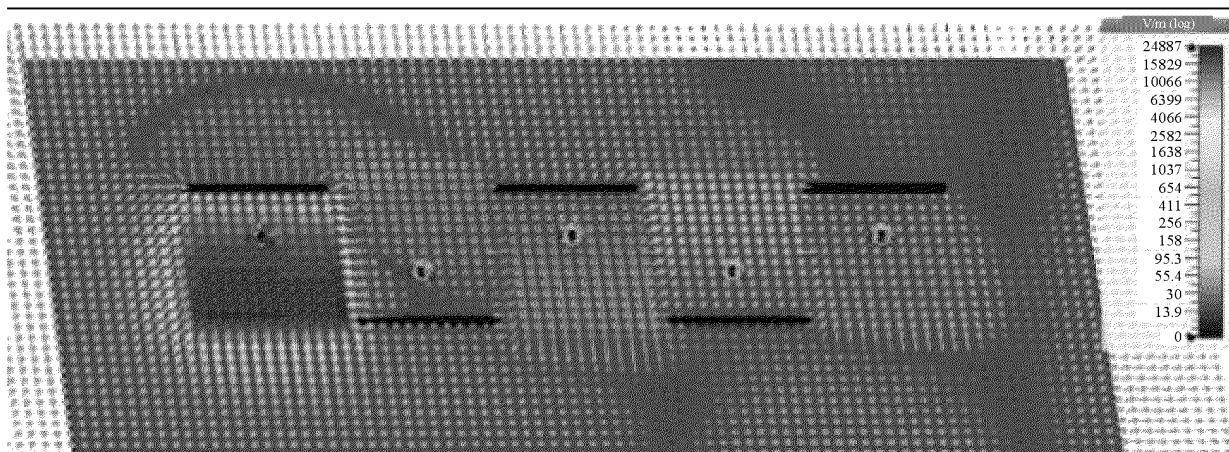


FIG. 37(a)

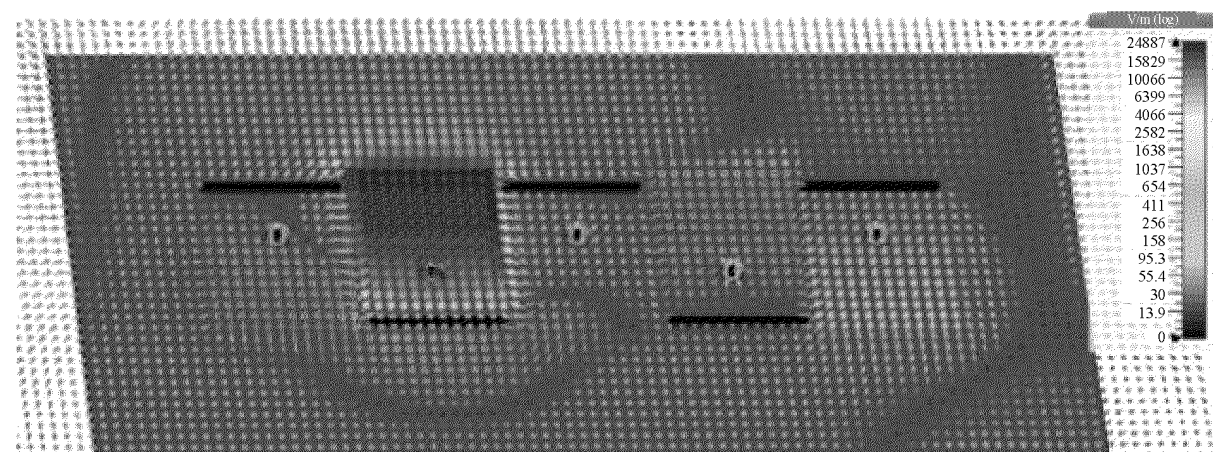


FIG. 37(b)

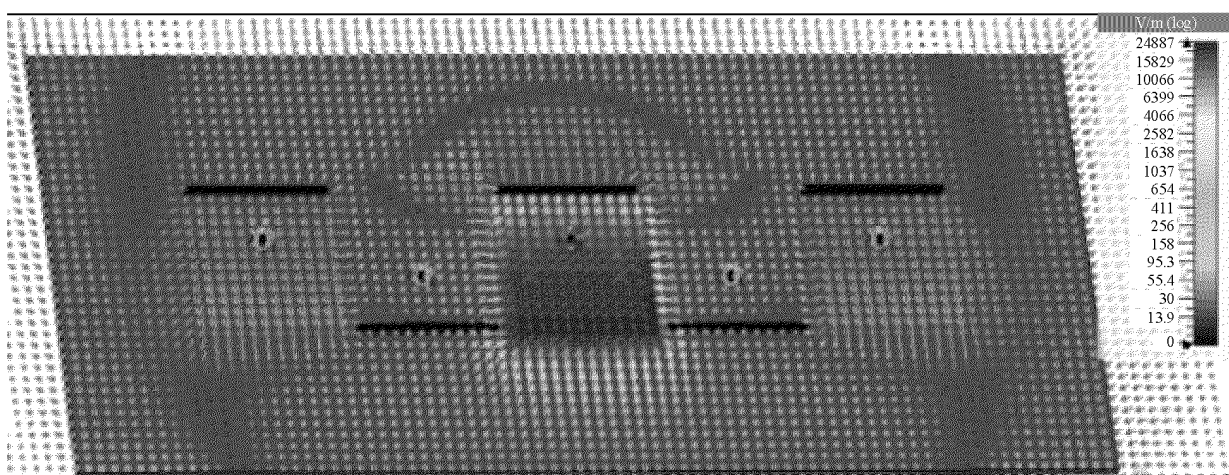


FIG. 37(c)

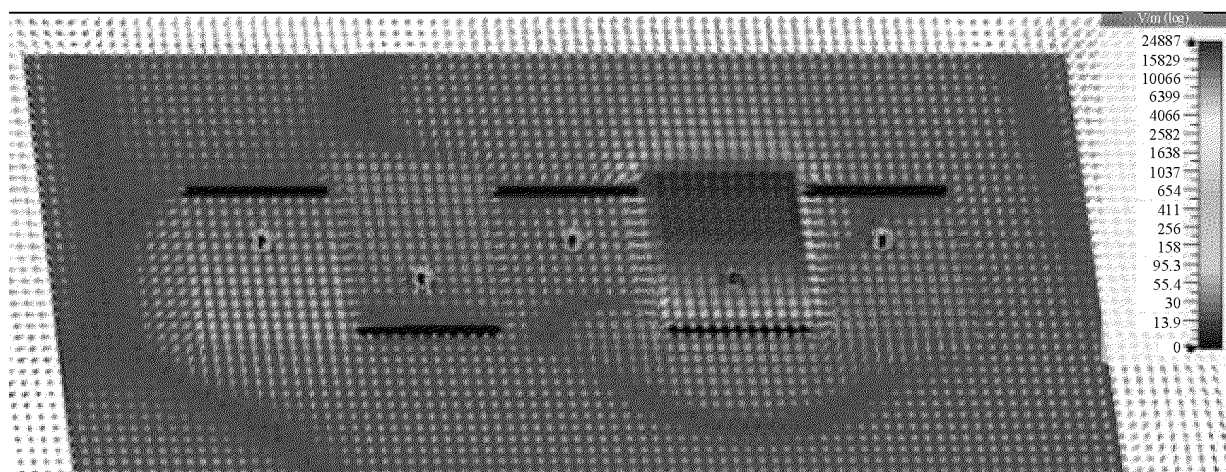


FIG. 37(d)

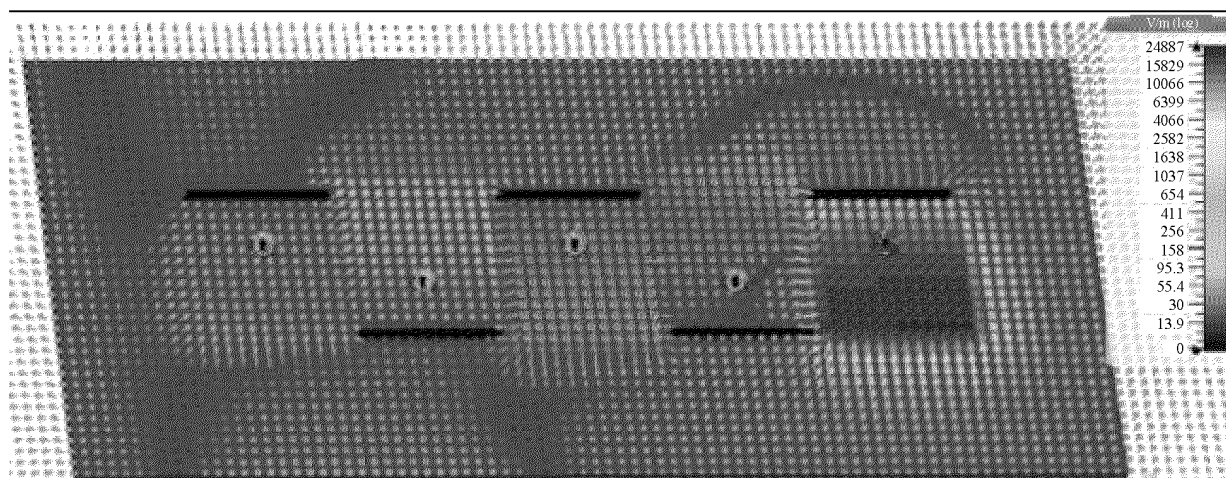


FIG. 37(e)

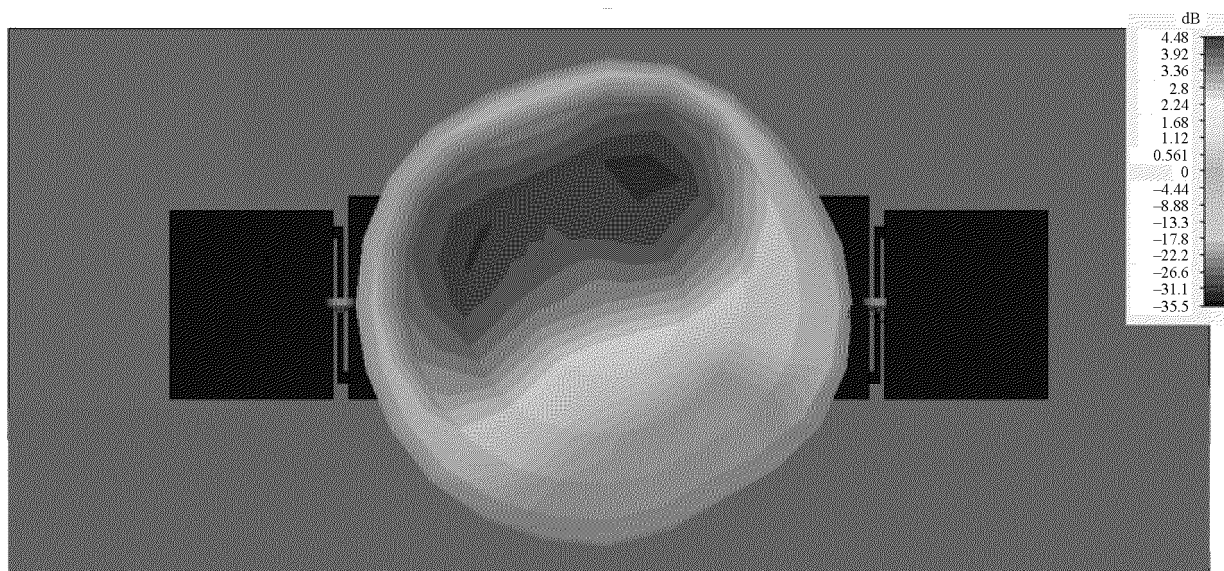


FIG. 38(a)

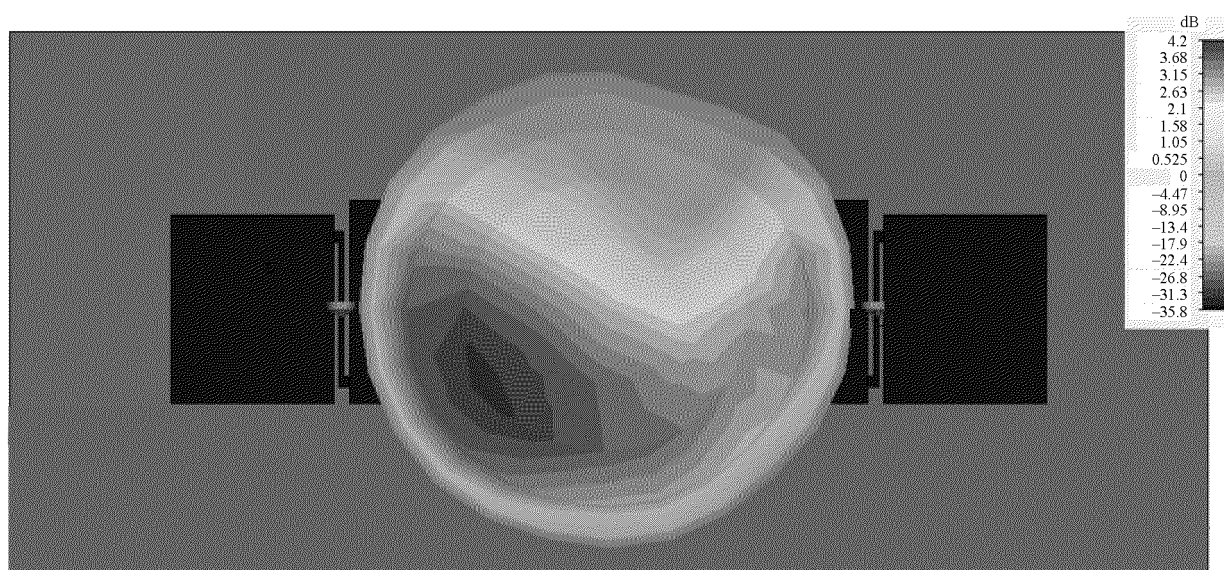


FIG. 38(b)



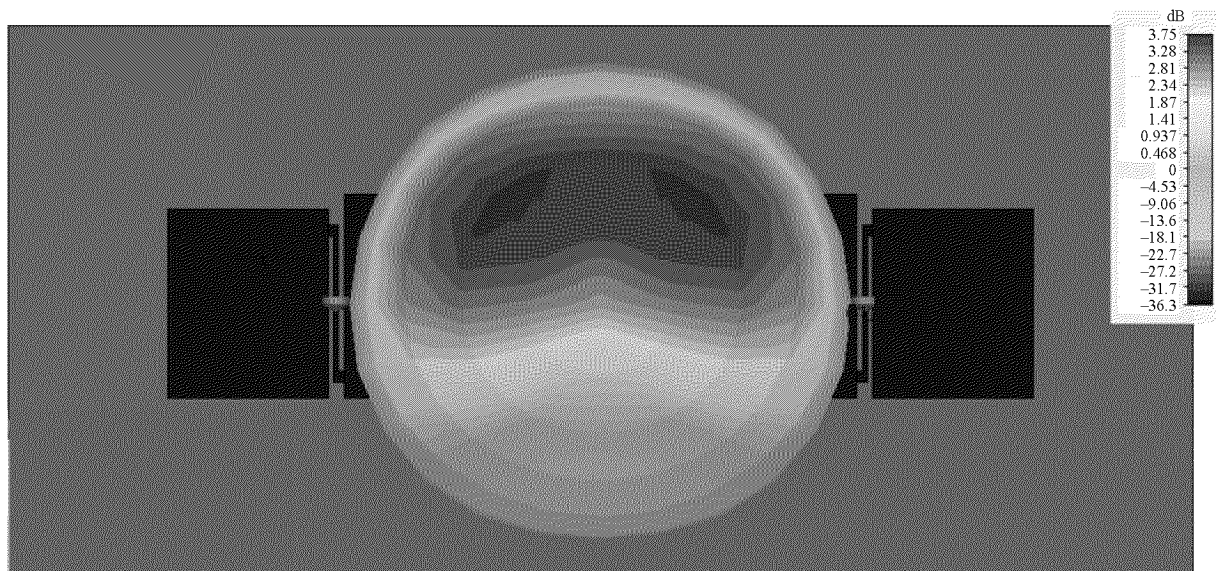


FIG. 38(c)

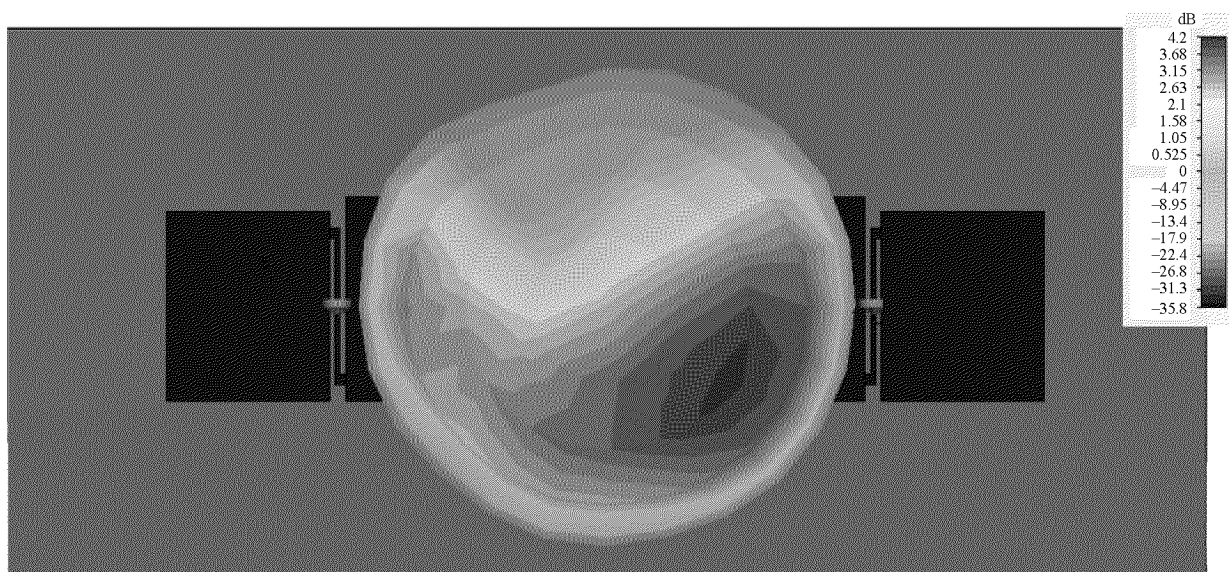


FIG. 38(d)

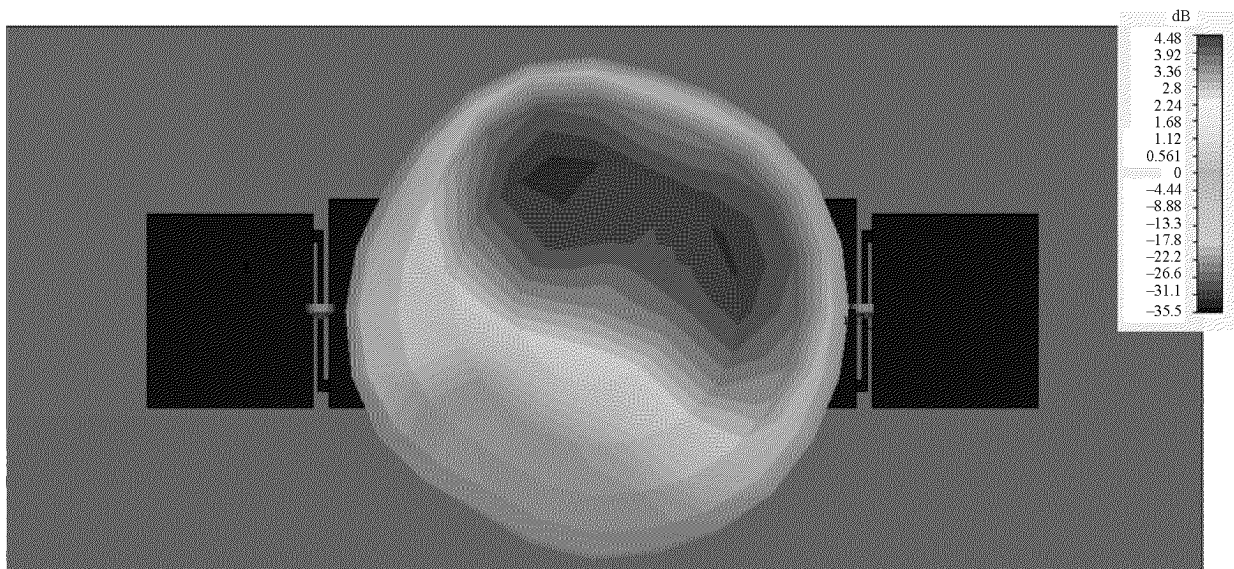
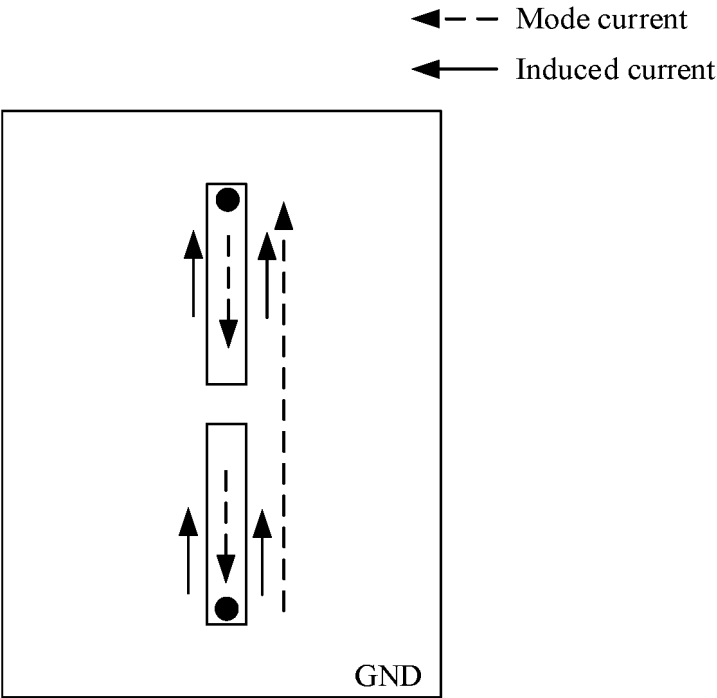
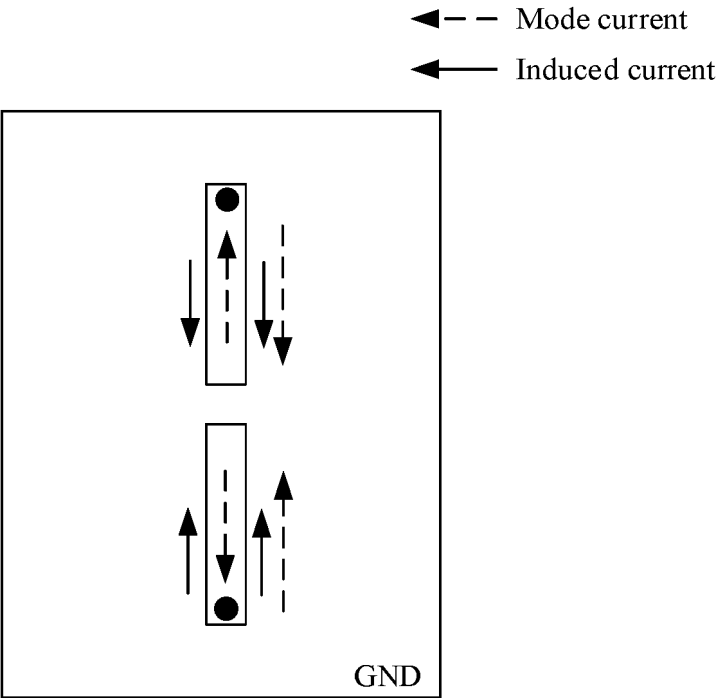


FIG. 38(e)



(a)



(b)

FIG. 39

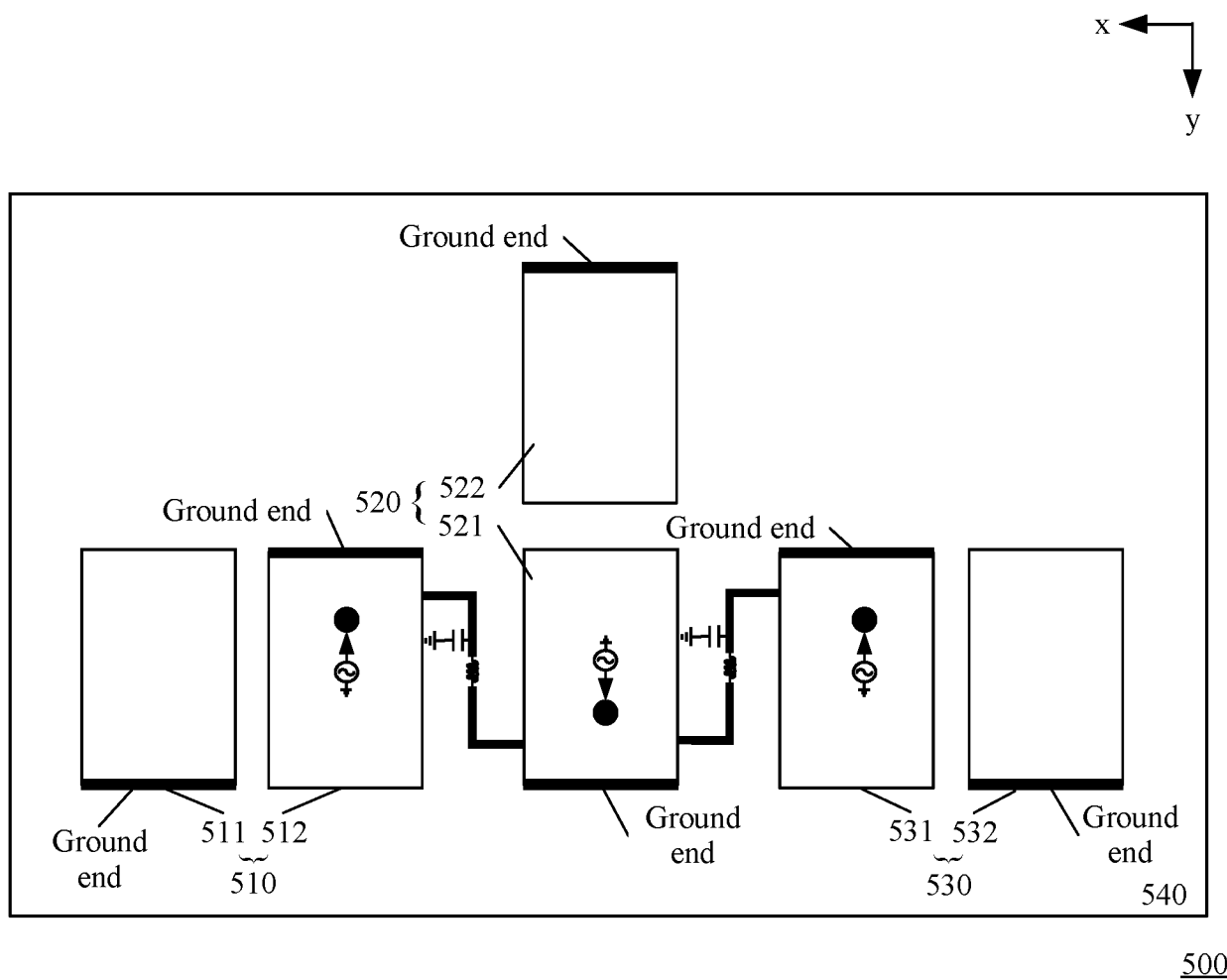


FIG. 40



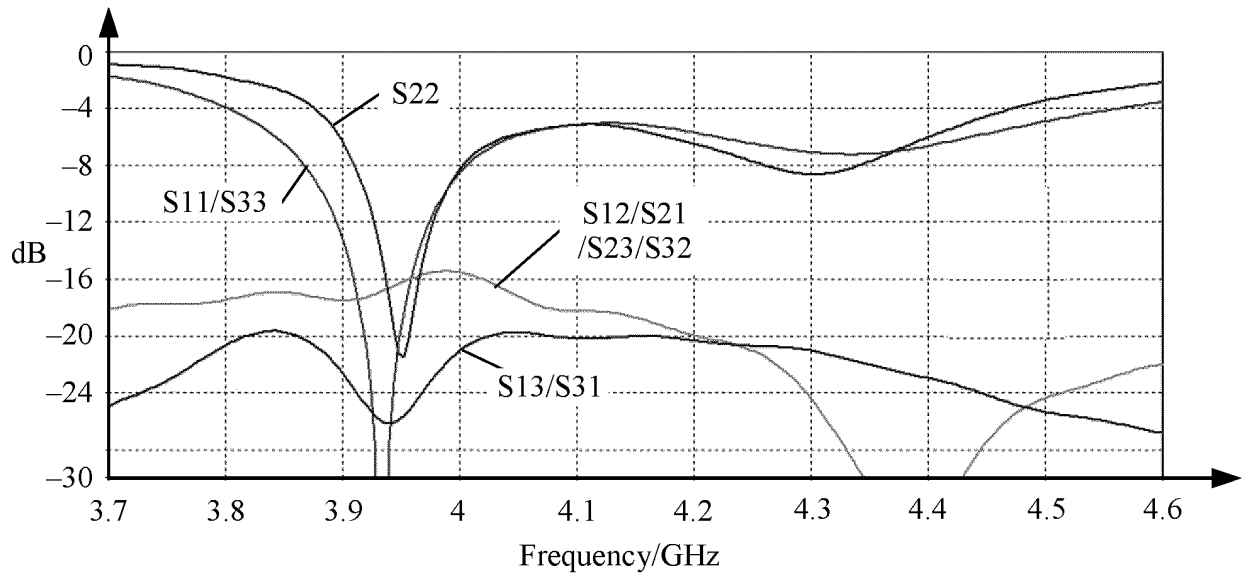


FIG. 41

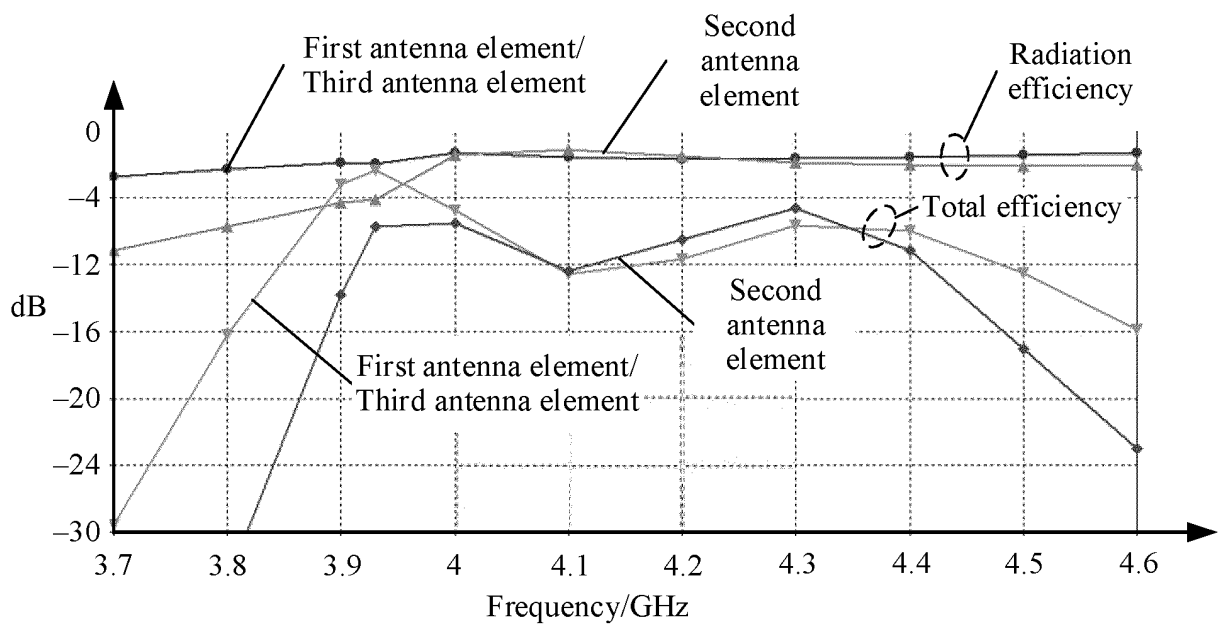
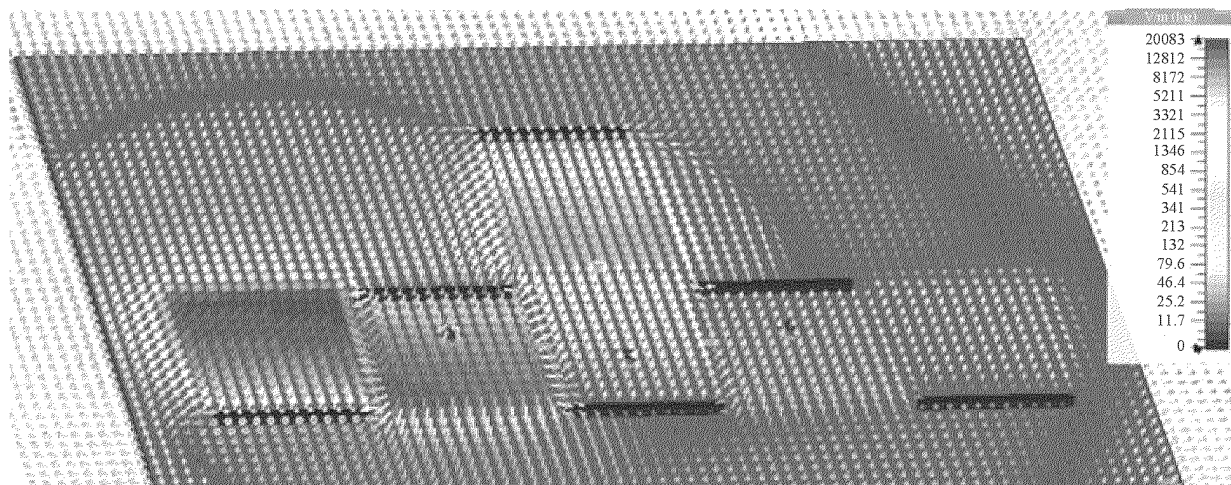
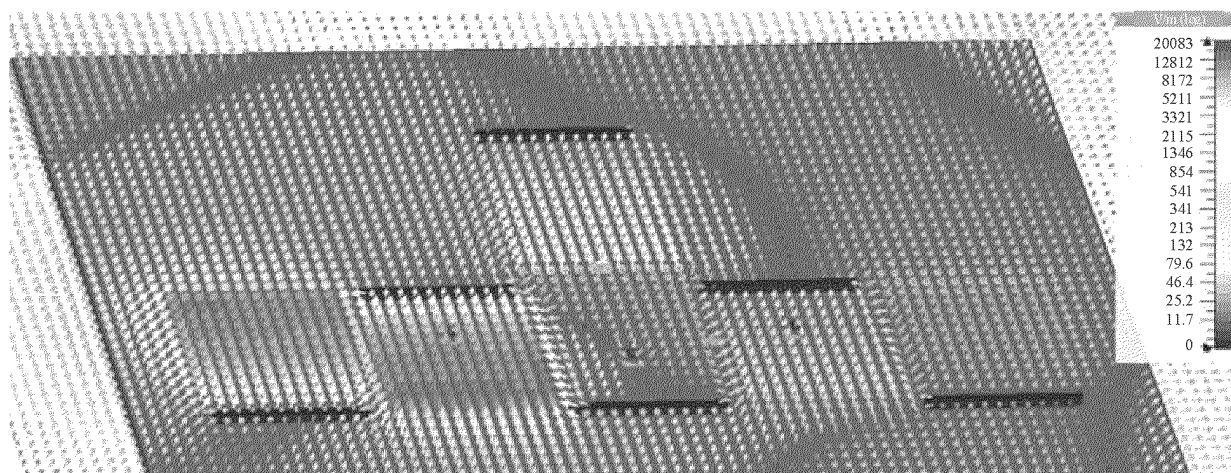


FIG. 42



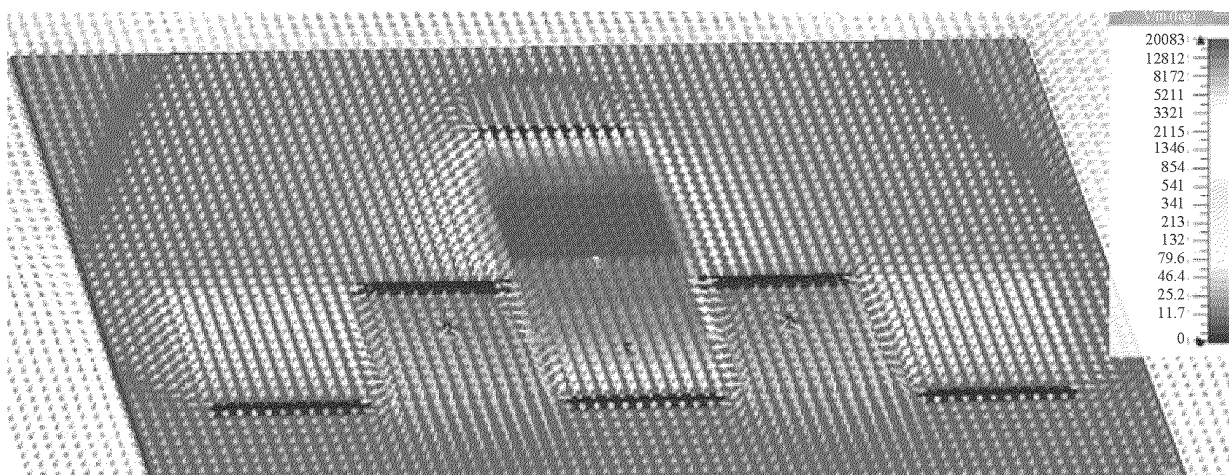
3.93 GHz

FIG. 43(a)



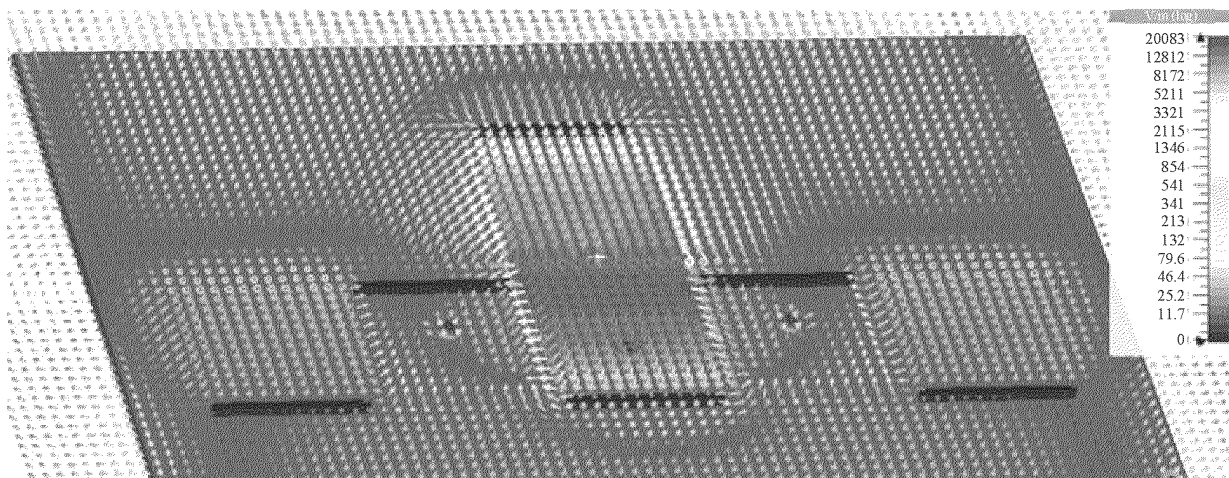
4.33 GHz

FIG. 43(b)



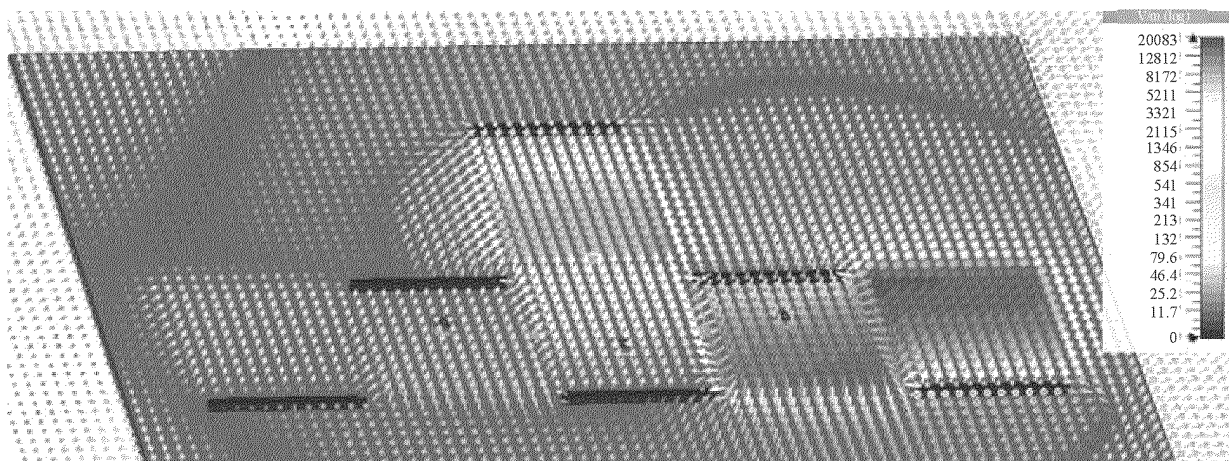
3.95 GHz

FIG. 43(c)



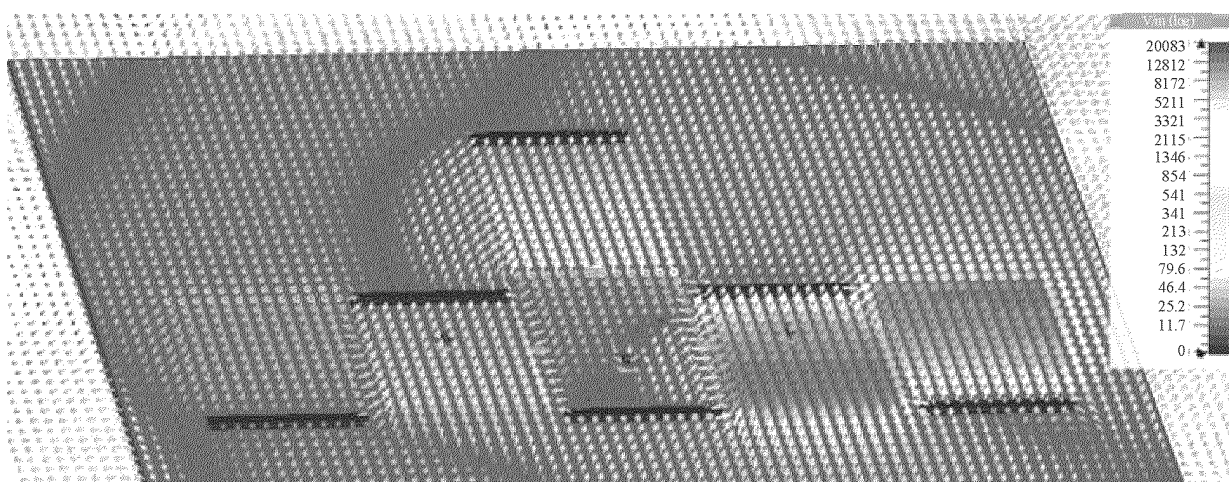
4.31 GHz

FIG. 43(d)



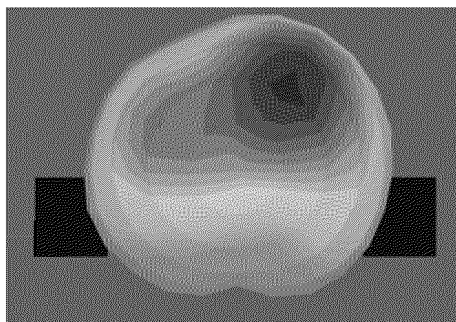
3.93 GHz

FIG. 43(e)



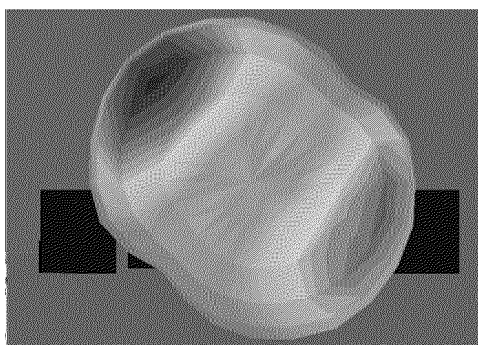
4.33 GHz

FIG. 43(f)



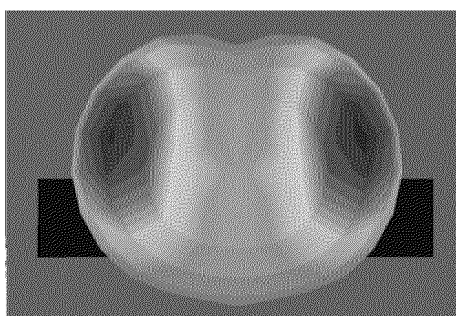
3.93 GHz

FIG. 44(a)



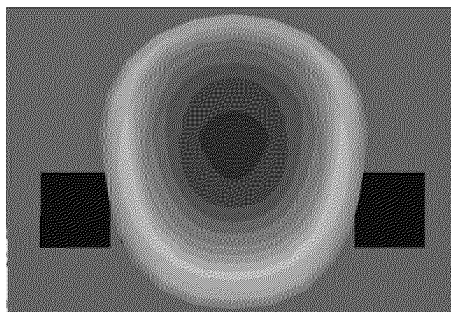
4.33 GHz

FIG. 44(b)



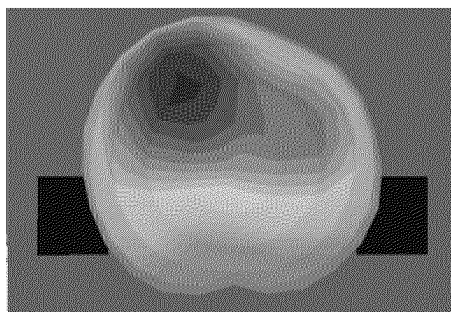
3.95 GHz

FIG. 44(c)



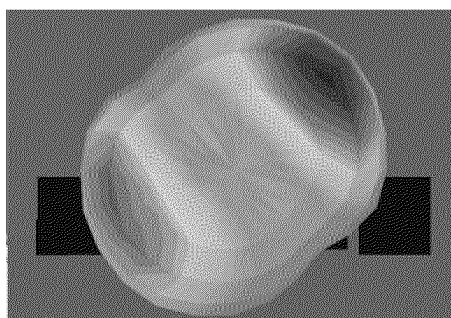
4.31 GHz

FIG. 44(d)



3.93 GHz

FIG. 44(e)



4.33 GHz

FIG. 44(f)

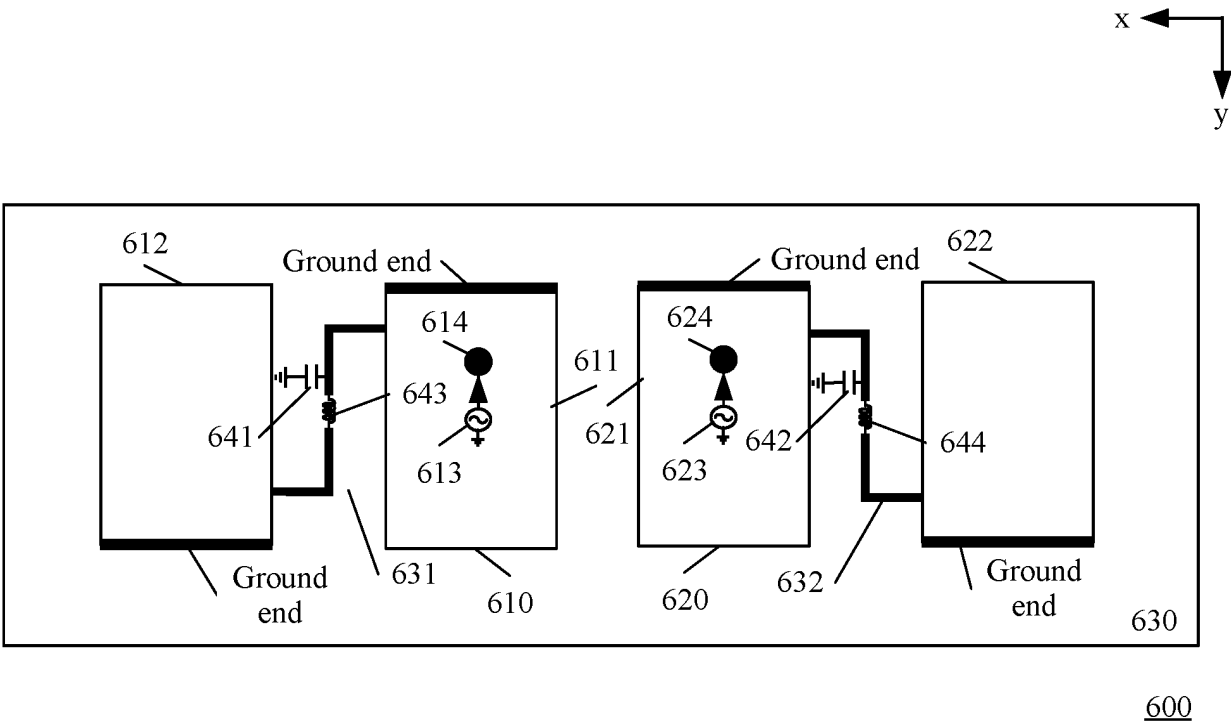


FIG. 45

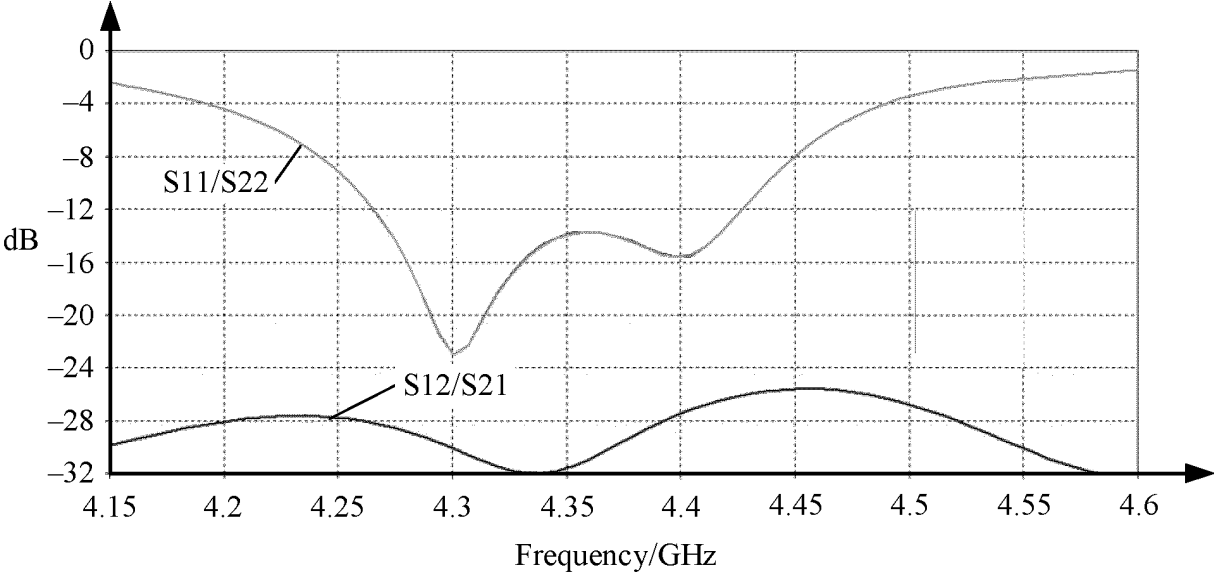


FIG. 46

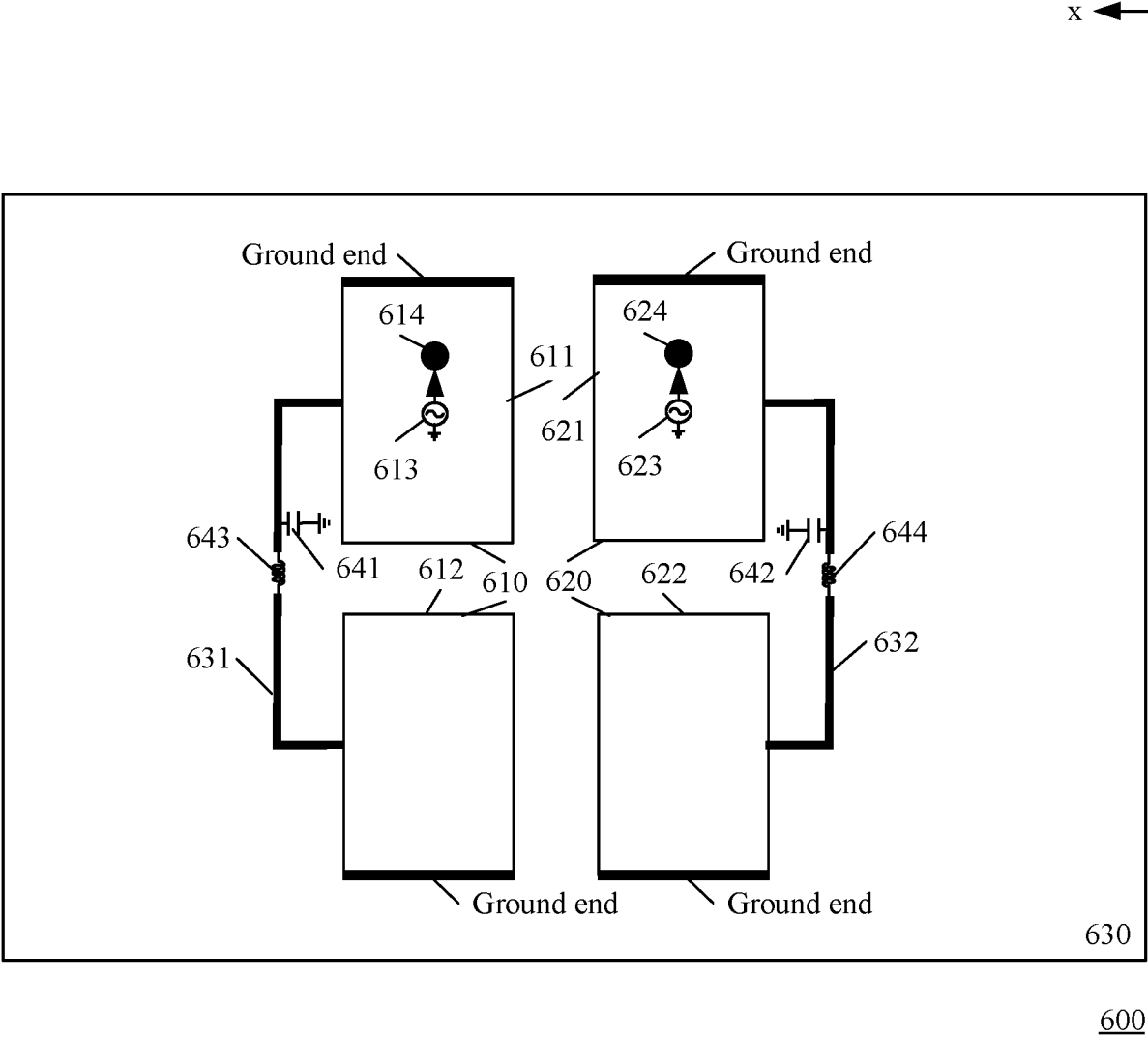


FIG. 47



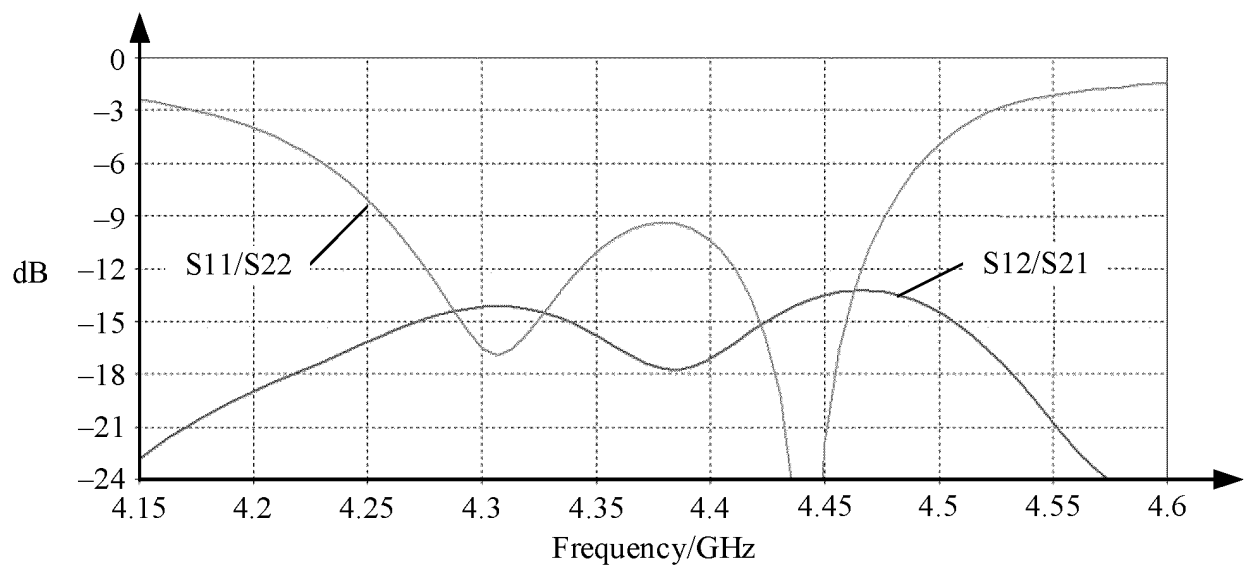


FIG. 48

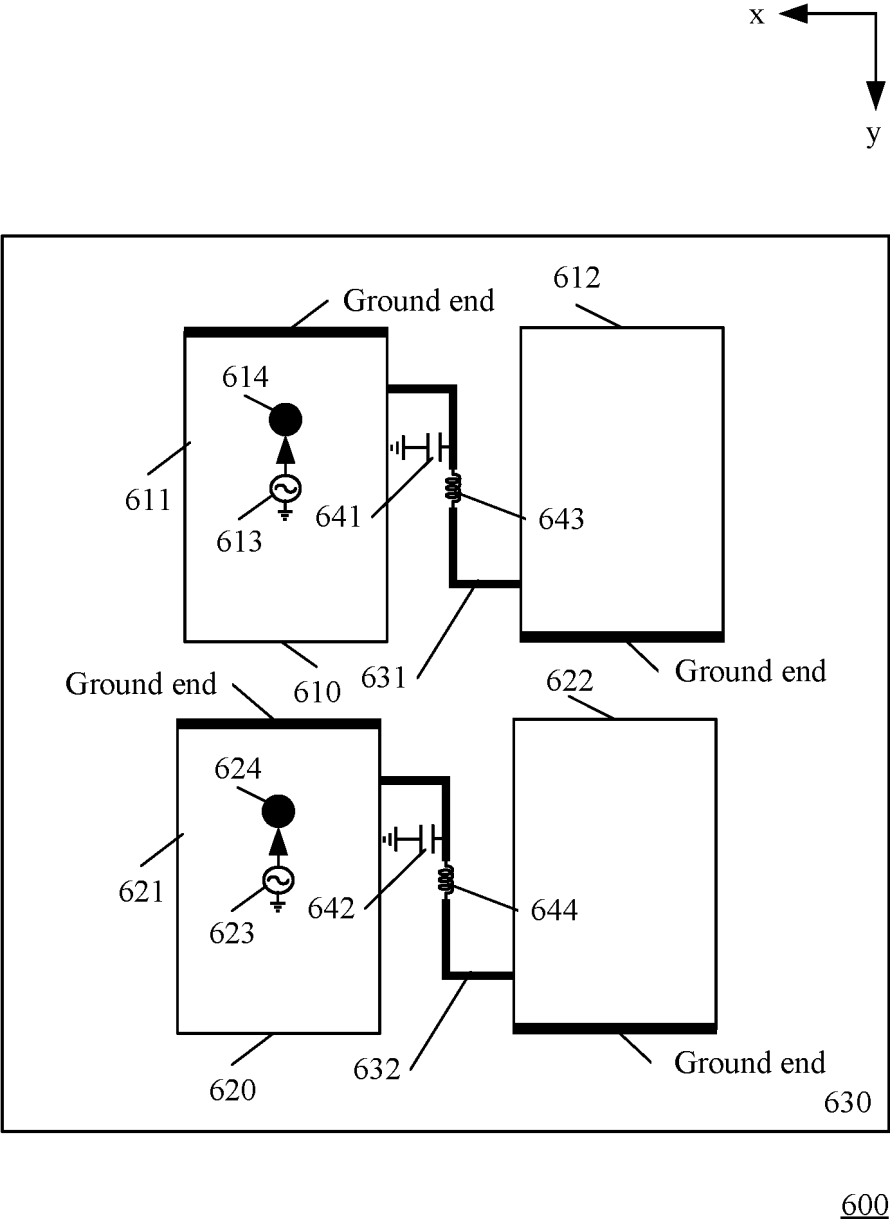


FIG. 49

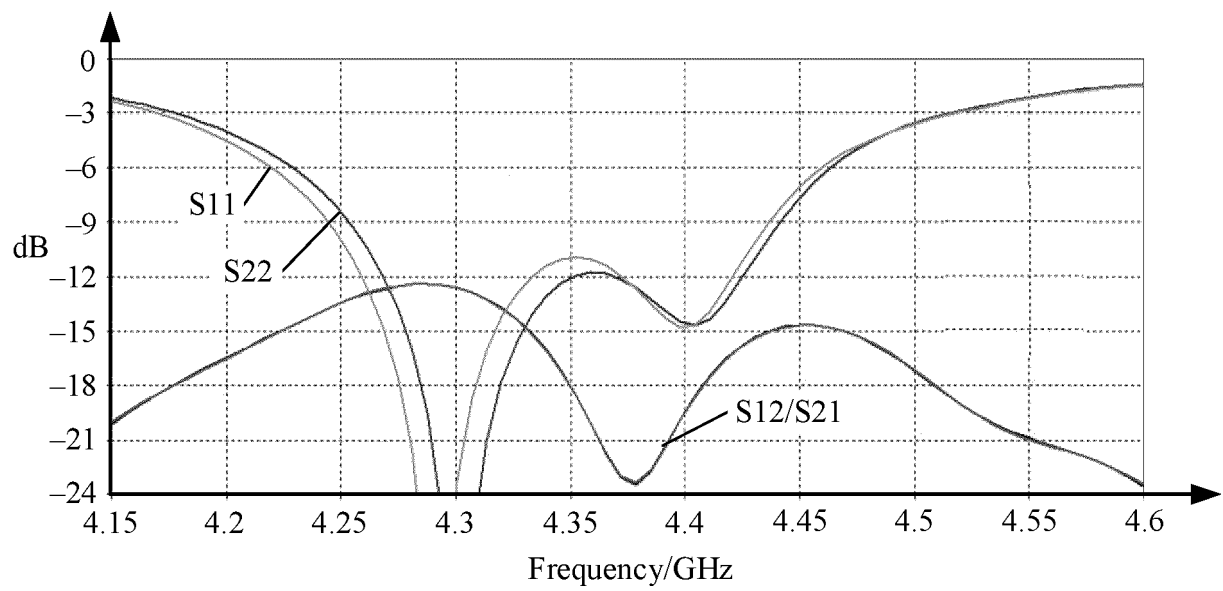


FIG. 50

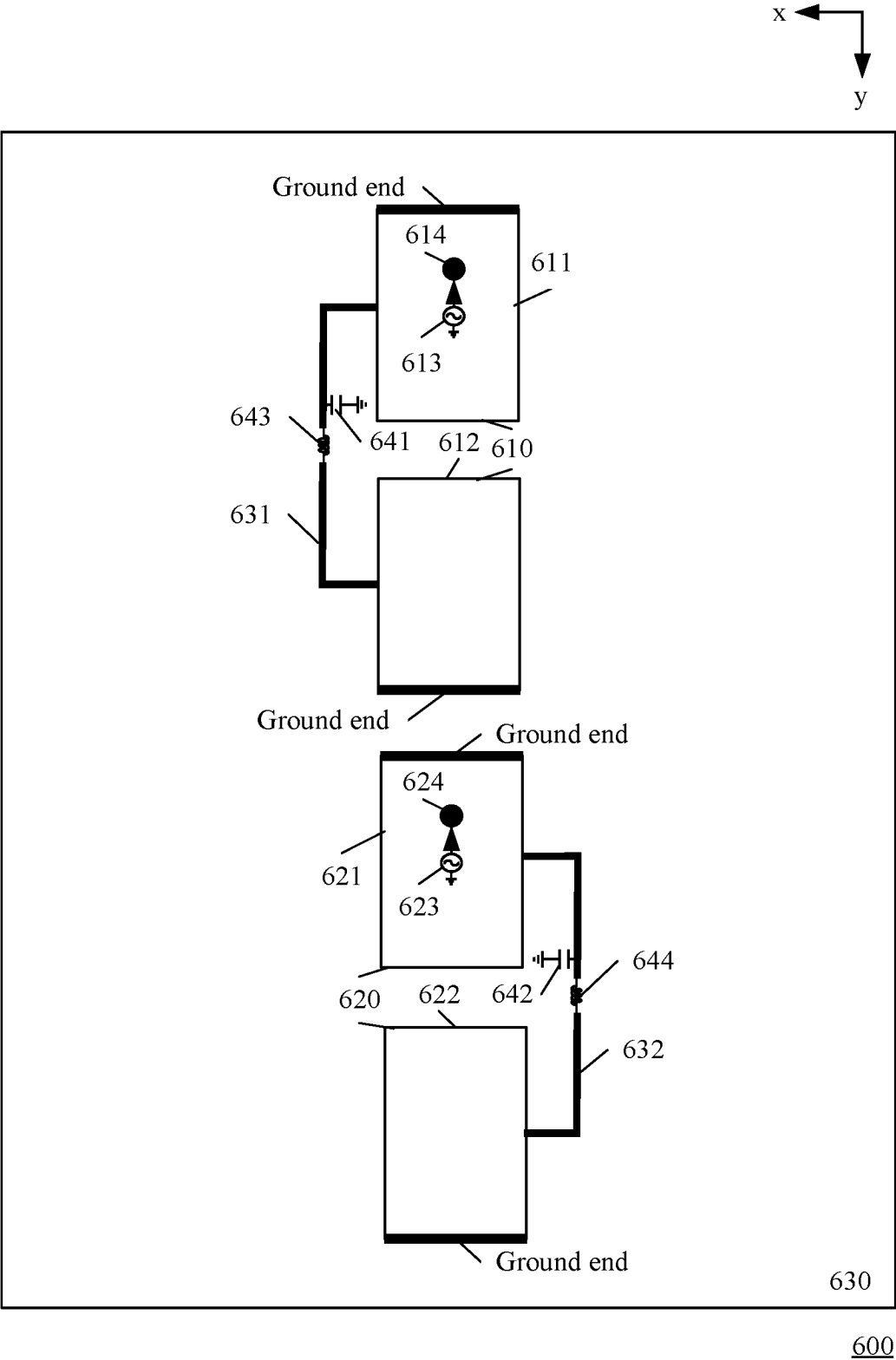


FIG. 51

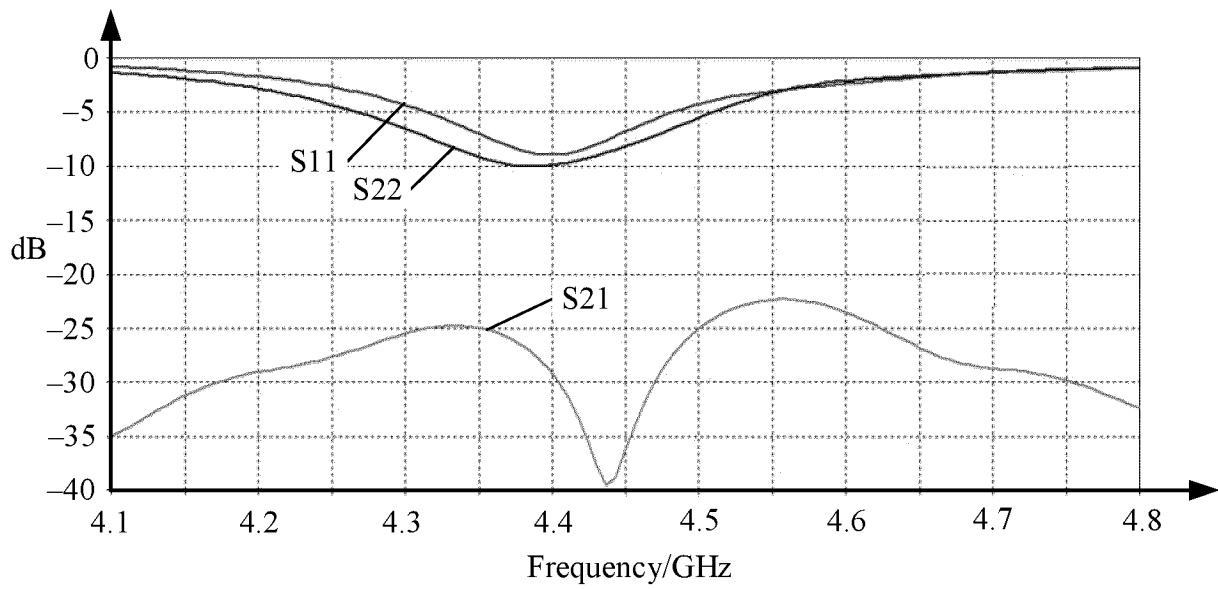


FIG. 52

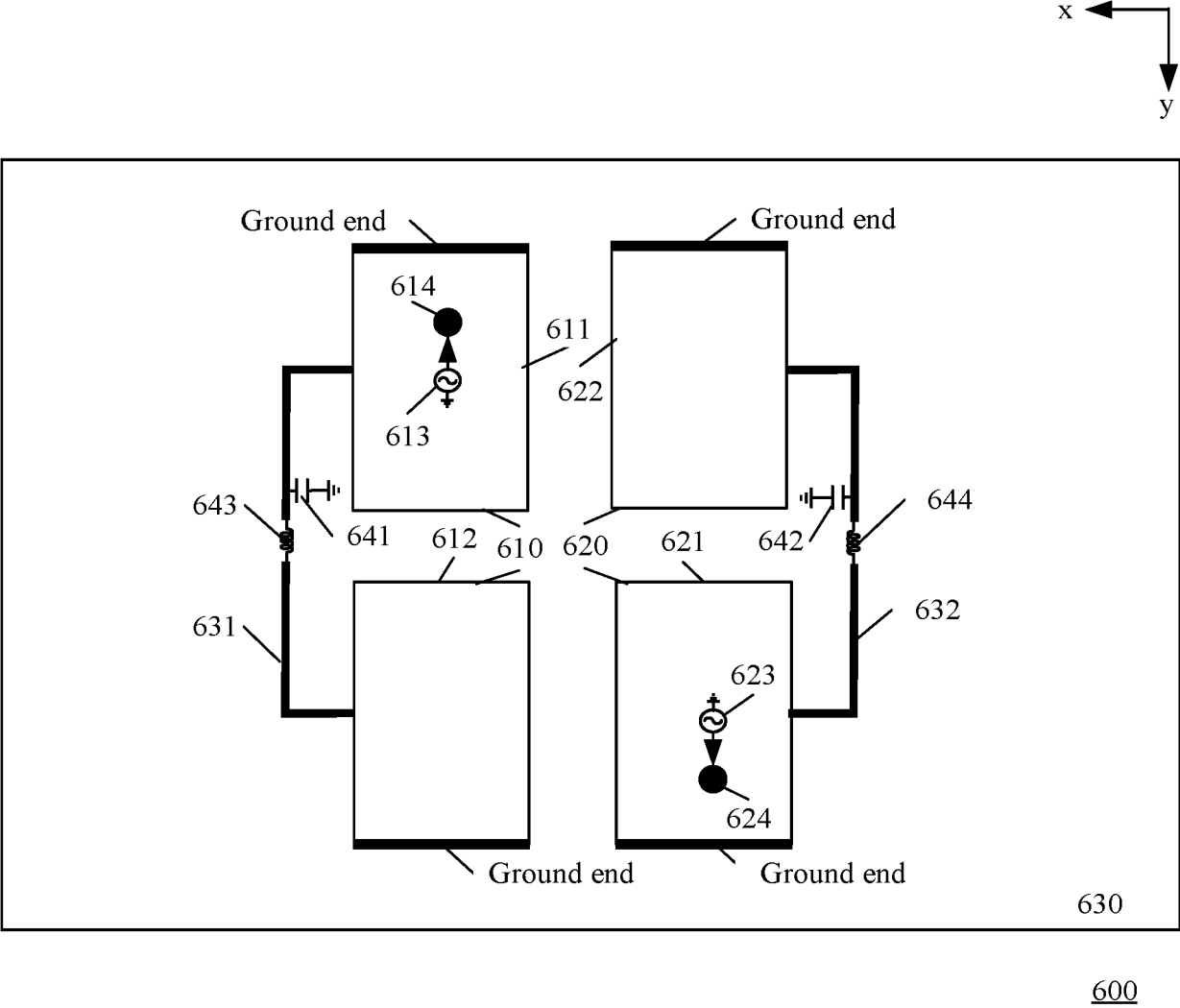


FIG. 53

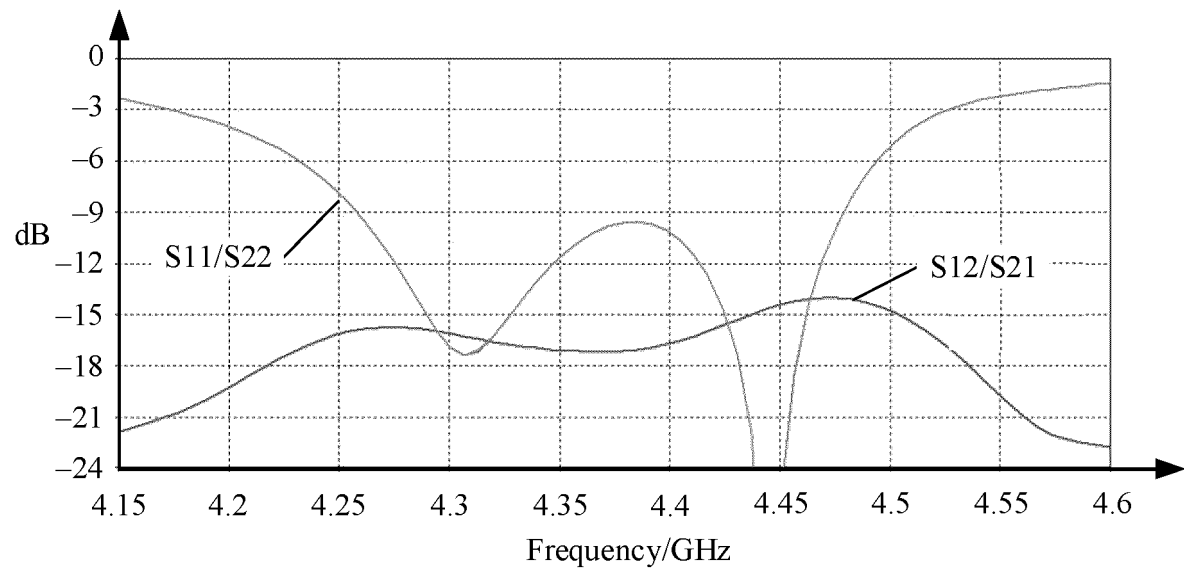


FIG. 54

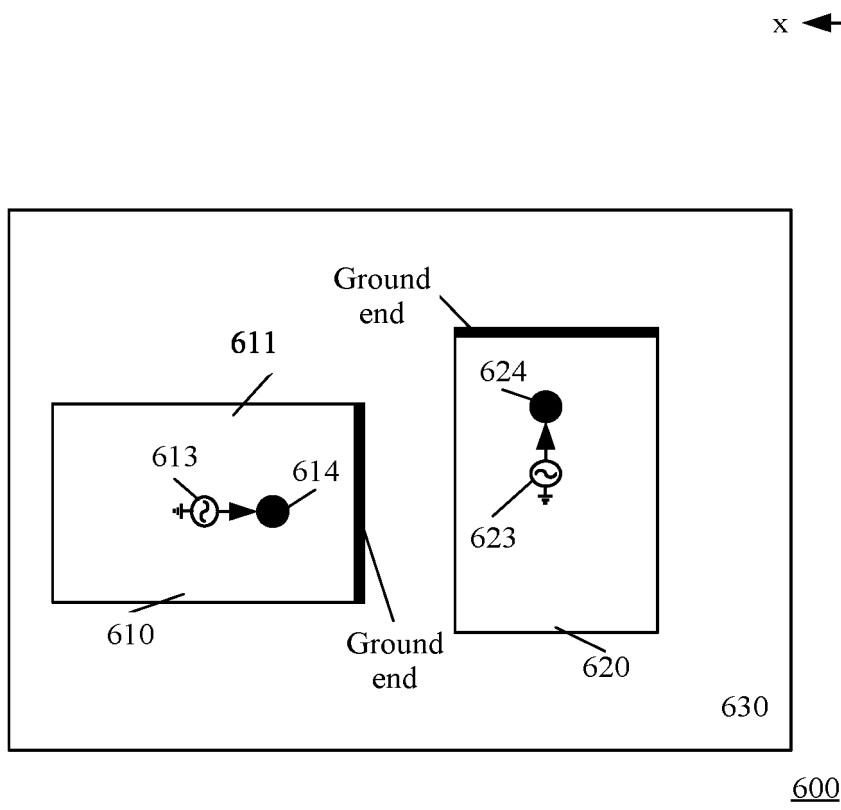


FIG. 55

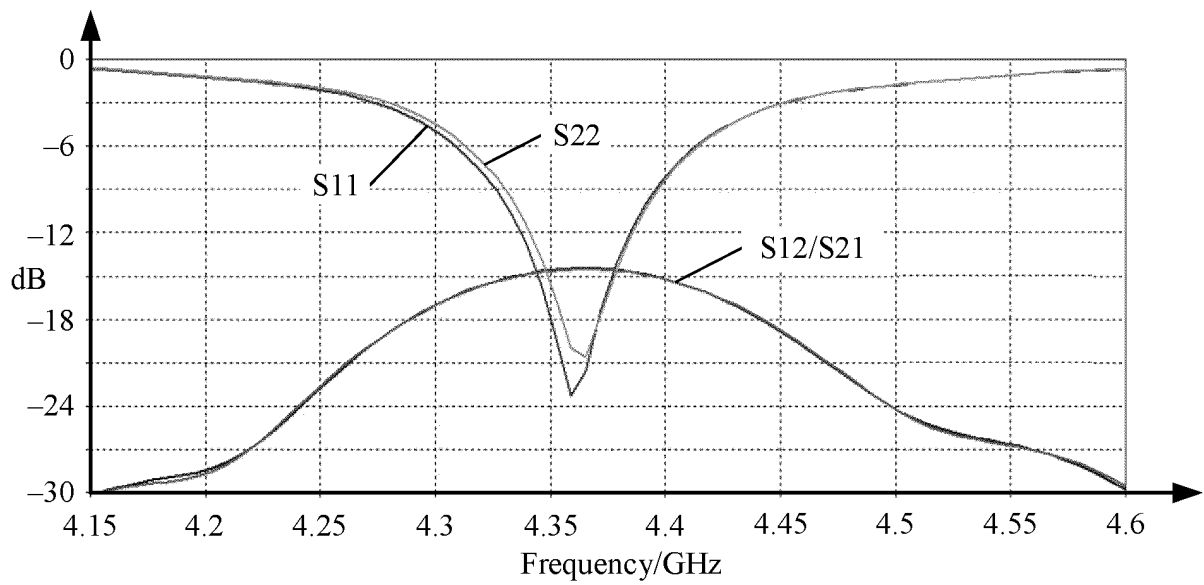


FIG. 56

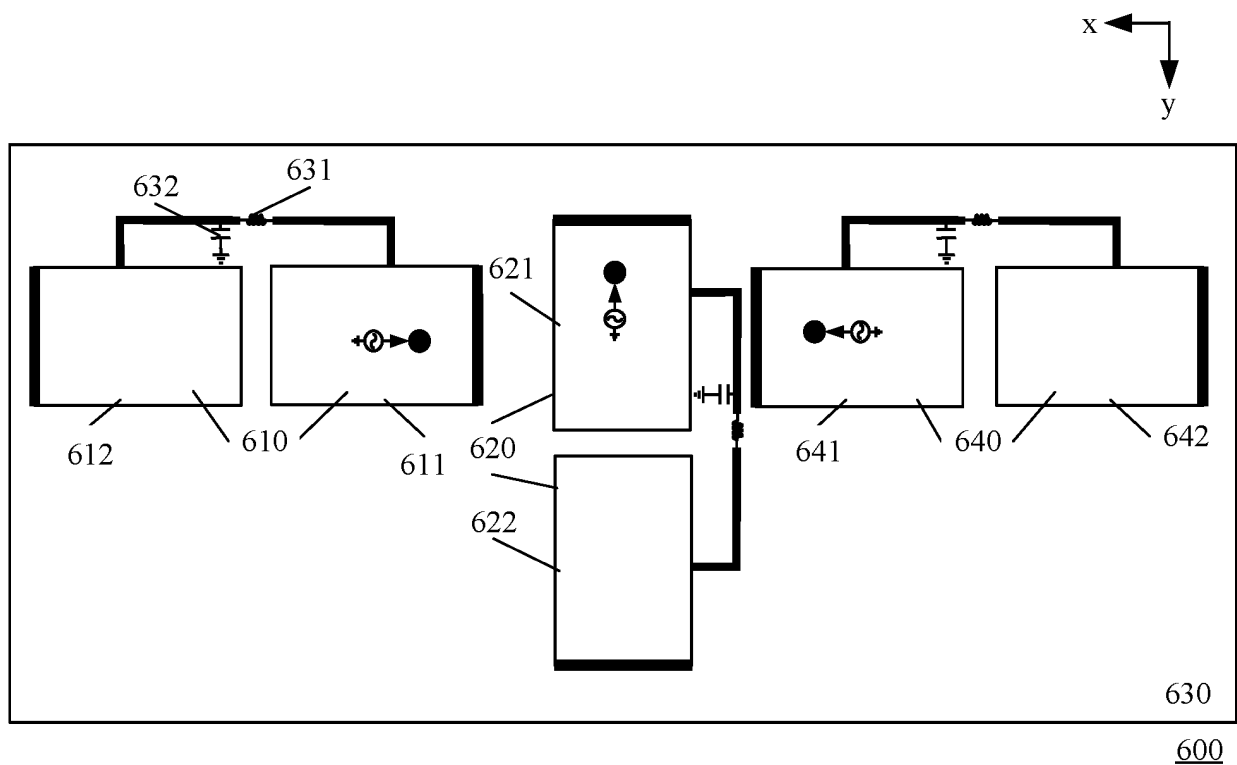


FIG. 57



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/114654

**A. CLASSIFICATION OF SUBJECT MATTER**

H01Q 1/36(2006.01)i; H01Q 1/52(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC: H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNKI, CNTXT, ENTXT, ENTXTC, DWPI, IEEE: 天线, 辐射, 枝节, 寄生, 第一, 第二, 馈电, 接地, 地板, 同侧, 异侧, 相对, 投影, 距离, 谐振, 频段, 连接, antenna, radiation, branch, parasitic, first, second, feed, ground, same, different, opposite, side, projection, distance, resonance, frequency band, connection

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                         | Relevant to claim No. |
|-----------|----------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | CN 114221127 A (HONOR TERMINAL CO., LTD.) 22 March 2022 (2022-03-22)<br>description, paragraphs 0048-0091, and figures 1-5 | 1-20                  |
| A         | CN 112531331 A (HUAWEI TECHNOLOGIES CO., LTD.) 19 March 2021 (2021-03-19)<br>entire document                               | 1-25                  |
| A         | CN 114566785 A (HONOR TERMINAL CO., LTD.) 31 May 2022 (2022-05-31)<br>entire document                                      | 1-25                  |
| A         | US 2021126356 A1 (WISTRON CORP.) 29 April 2021 (2021-04-29)<br>entire document                                             | 1-25                  |

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

\* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&amp;” document member of the same patent family

Date of the actual completion of the international search

17 November 2023

Date of mailing of the international search report

22 November 2023

Name and mailing address of the ISA/CN

China National Intellectual Property Administration (ISA/  
CN)  
China No. 6, Xitucheng Road, Jimenqiao, Haidian District,  
Beijing 100088

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT  
Information on patent family members

International application No.  
**PCT/CN2023/114654**

| Patent document<br>cited in search report |            |    | Publication date<br>(day/month/year) | Patent family member(s) |            |    | Publication date<br>(day/month/year) |
|-------------------------------------------|------------|----|--------------------------------------|-------------------------|------------|----|--------------------------------------|
| CN                                        | 114221127  | A  | 22 March 2022                        | WO                      | 2023098162 | A1 | 08 June 2023                         |
| CN                                        | 112531331  | A  | 19 March 2021                        | WO                      | 2021052158 | A1 | 25 March 2021                        |
| CN                                        | 114566785  | A  | 31 May 2022                          | None                    |            |    |                                      |
| US                                        | 2021126356 | A1 | 29 April 2021                        | TW                      | 202118149  | A  | 01 May 2021                          |
|                                           |            |    |                                      | CN                      | 112736419  | A  | 30 April 2021                        |

**REFERENCES CITED IN THE DESCRIPTION**

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

**Patent documents cited in the description**

- CN 202211040416 [0001]