(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 557 519 A1

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

(43) Date of publication:
21.05.2025 Bulletin 2025/21

(21) Application number: **24763086.6**

(22) Date of filing: **26.02.2024**

(51) International Patent Classification (IPC):
H01Q 1/50 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
H01Q 1/24; H01Q 1/36; H01Q 1/48; H01Q 1/50; H01Q 5/30; H01Q 5/50

(86) International application number:
PCT/CN2024/078548

(87) International publication number:
WO 2024/179404 (06.09.2024 Gazette 2024/36)

(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:
GE KH MA MD TN

(30) Priority: **28.02.2023 CN 202310223138**
25.09.2023 CN 202311249133

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

(72) Inventors:
- **WU, Pengfei**
  Shenzhen, Guangdong 518129 (CN)
- **LIU, Zhaoxuan**
  Shenzhen, Guangdong 518129 (CN)
- **FENG, Kun**
  Shenzhen, Guangdong 518129 (CN)
- **WANG, Hanyang**
  80992 Munich (DE)
- **HOU, Meng**
  Shenzhen, Guangdong 518129 (CN)

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

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

(57) Embodiments of this application provide an antenna structure and an electronic device. The antenna structure is coupled between a first radiator and a second radiator through a metal connector with a short length. When an electrical signal is fed at a feed point disposed on the first radiator, the electrical signal is transmitted to the second radiator through the metal connector, so that a first resonance and a second resonance are generated through the first radiator and the second radiator, and total efficiency and radiation efficiency are good at frequencies covered by the first resonance and the second resonance.

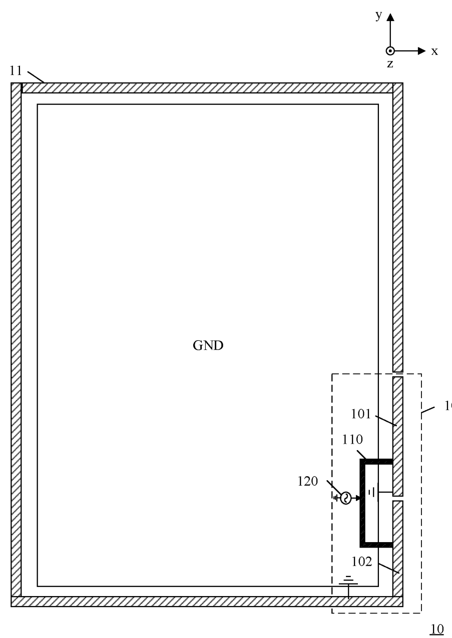


FIG. 2

EP 4 557 519 A1

Description

TECHNICAL FIELD

[0001] This application relates to the field of wireless communication, and in particular, to an antenna structure and an electronic device.

BACKGROUND

[0002] As people's demands for high-speed data transmission increase, a development trend of an industrial design (industrial design, ID) of an electronic device is to have a large screen-to-body ratio and a plurality of cameras. Consequently, antenna clearance is greatly reduced, and space for layout is increasingly limited.

[0003] In this context, frequency bands of a 3rd mobile communication technology (a 3rd generation wireless system, 3G), a 4th mobile communication technology (a 4th generation wireless system, 4G), and a 5th mobile communication technology (a 5th generation wireless system, 5G) will coexist as communication frequency bands of the electronic device for a long time. This leads to an increasing quantity of antennas.

[0004] However, a conventional method such as increasing a size of a radiator of an antenna to expand an efficiency bandwidth of the antenna has reached a bottleneck. Therefore, in a case in which the size of the radiator remains unchanged, it is urgent to improve the efficiency bandwidth of the antenna.

SUMMARY

[0005] Embodiments of this application provide an antenna structure and an electronic device. The antenna structure is coupled between a first radiator and a second radiator through a metal connector with a short length. When an electrical signal is fed at a feed point disposed on the first radiator, the electrical signal is transmitted to the second radiator through the metal connector, so that the antenna structure generates a first resonance and a second resonance, and has good total efficiency and radiation efficiency at frequencies covered by the first resonance and the second resonance.

[0006] According to a first aspect, an antenna structure is provided, and includes: a radiator, including a first radiator and a second radiator; a feed element, where the first radiator includes a feed point, and the feed element is coupled to the feed point; and a first metal connector, where the first radiator includes a first connection point, the second radiator includes a second connection point, a first end of the first metal connector is coupled to the first connection point, a second end of the first metal connector is coupled to the second connection point, the radiator is configured to generate a first resonance and a second resonance, and a frequency of the first resonance is lower than a frequency of the second resonance, where a length L of the first metal connector, a length L1 of the first radiator, and a length L2 of the second radiator satisfy the following: $(L1+L2)/32 \leq L \leq (L1+L2)/2$.

[0007] In an embodiment, an electrical length Le of the first metal connector satisfies the following: one thirty-second of a first wavelength≤Le≤one quarter of the first wavelength, where the first wavelength is a wavelength corresponding to the second resonance.

[0008] In an embodiment, the first metal connector is configured to transmit, to the second radiator, the electrical signal fed by the feed element at the feed point, where no other feed point coupled to the feed element is disposed on the second radiator.

[0009] According to this embodiment of this application, when the feed element feeds the electrical signal at the feed point, at the frequency covered by the first resonance and the frequency covered by the second resonance, currents or electric fields generated by the antenna structure are mainly concentrated on different radiators and surrounding areas. This can reduce a conductor loss and a dielectric loss that are generated when the antenna structure generates a resonance, thereby improving total efficiency and radiation efficiency of the antenna structure. In addition, because a length of a metal connector in the antenna structure is short, the metal connector does not occupy large space. This helps dispose the metal connector in an electronic device.

[0010] It should be understood that, in the antenna structure in this embodiment of this application, the feed point coupled to the feed element is disposed only on the first radiator, and no feed point coupled to the feed element is disposed on other radiators. However, when another antenna structure reuses the radiators, a feed point for another antenna may be disposed for coupling, for example, another feed element different from the feed element. In engineering implementation, provided that two feed elements on a radiator are electrically connected to two independent radio frequency bases or radio frequency test bases, it may be considered that the two feed elements are electrically connected to different radio frequency channels, and are different feed elements.

[0011] With reference to the first aspect, in some implementations of the first aspect, a first end of the first radiator includes a first ground point, the first radiator is grounded at the first ground point, and a second end of the first radiator is an open end; and a first end of the second radiator is an open end, a second end of the second radiator includes a second ground point, and the second radiator is grounded at the second ground point.

[0012] According to this embodiment of this application, the first radiator may form a structure similar to an IFA, and the second radiator may form a structure similar to a CRLH structure.

[0013] With reference to the first aspect, in some implementations of the first aspect, the radiator includes a first ground point, and the radiator is grounded at the first ground point; and both a first end of the first radiator and a first end of the second radiator are electrically connected to the first ground point, and a second end of the first radiator and a second end of the second radiator are open ends. According to this embodiment of this application, the first radiator and the second radiator may form a structure similar to a T antenna or a T-shaped antenna.

[0014] With reference to the first aspect, in some implementations of the first aspect, a first end of the first radiator is an open end, a second end of the first radiator includes a first ground point, and the first radiator is grounded at the first ground point; and a first end of the second radiator is an open end, a second end of the second radiator includes a second ground point, and the second radiator is grounded at the second ground point.

[0015] According to this embodiment of this application, according to this embodiment of this application, the first radiator and the second radiator may form a structure similar to a slot antenna.

[0016] 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 opposite to, but do not touch each other. 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 coincide with or are directly connected to the first ground point.

[0017] With reference to the first aspect, in some implementations of the first aspect, at a first resonance point of the first resonance, a current on the first radiator and a current on the second radiator are reverse in direction; and at a second resonance point of the second resonance, a current on the first radiator and a current on the second radiator are in a same direction.

[0018] With reference to the first aspect, in some implementations of the first aspect, at a first resonance point of the first resonance, a current on the first radiator and a current on the second radiator are in a same direction; and at a second resonance point of the second resonance, a current on the first radiator and a current on the second radiator are reverse in direction.

[0019] With reference to the first aspect, in some implementations of the first aspect, the first connection point is located between the first end of the first radiator and the feed point, and a length of a radiator between the feed point and the first ground point is less than a half of the length L1 of the first radiator.

[0020] With reference to the first aspect, in some implementations of the first aspect, a length D1 of a radiator between the feed point and the first connection point and the length L1 of the first radiator satisfy the following: $L1\times10\%\leq D1\leq L1\times25\%$.

[0021] With reference to the first aspect, in some implementations of the first aspect, the first end of the first metal connector is connected to the first connection point, the second end of the first metal connector is connected to the second connection point, and the length D2 of the first metal connector, the length L1 of the first radiator, and the length L2 of the second radiator satisfy the following: $(L1+L2)\times30\%\leq D2\leq(L1+L2)\times50\%$, where the first connection point is located between the first end of the first radiator and the feed point.

[0022] It should be understood that the first end of the first radiator and the first end of the second radiator are opposite to, but do not touch each other. When both the first end of the first radiator and the first end of the second radiator are open ends or are ground ends, the first metal connector also needs to at least have a length for connecting two radiators near the first end of the first radiator and near the first end of the second radiator. Because first impedance conditions at the first end of the first radiator and the first end of the second radiator are the same or similar, the first metal connector may be set to an electrical length which is an odd multiple of a 1/4 wavelength. In an embodiment during actual application, the length D2 of the first metal connector, the length L1 of the first radiator, and the length L2 of the second radiator satisfy the following: $(L1+L2)\times530\%\leq D2\leq(L1+L2)\times50\%$.

[0023] With reference to the first aspect, in some implementations of the first aspect, the first end of the first metal connector is connected to the first connection point, the second end of the first metal connector is connected to the second connection point, and the length D2 of the first metal connector, the length L1 of the first radiator, and the length L2 of the second radiator satisfy the following: $0<D2\leq(L1+L2)\times30\%$, where the first connection point is located between the first end of the first radiator and the feed point.

[0024] It should be understood that the first end of the first radiator and the first end of the second radiator are opposite to, but do not touch each other. When one of the first end of the first radiator and the first end of the second radiator is an open end and the other one is a ground end, the first metal connector also needs to at least have a length for connecting two radiators near the first end of the first radiator and near the first end of the second radiator. Because first impedance conditions at the first end of the first radiator and the first end of the second radiator are not the same or not similar, the first metal connector may be set to an electrical length which is less than a 1/4 wavelength. In an embodiment during actual application, the length D2 of the first metal connector, the length L1 of the first radiator, and the length L2 of the second radiator satisfy the following: $0<L\leq(L1+L2)\times30\%$.

[0025] According to this embodiment of this application, when the metal connector 230, the first radiator 210, and the second radiator 220 are of an integrated structure, the first connection point may be located between the second end (the first end of the radiator 202) of the first radiator 210 and the feed point 212. No electronic element is disposed between the metal connector 230 and the first radiator 210 or the second radiator 220.

[0026] With reference to the first aspect, in some implementations of the first aspect, the first metal connector, the first radiator, and the second radiator are of an integrated structure.

[0027] With reference to the first aspect, in some implementations of the first aspect, a width of a slot formed by the first metal connector, the first radiator, and the second radiator is less than or equal to 1 mm.

[0028] With reference to the first aspect, in some implementations of the first aspect, the length D1 of the radiator between the feed point and the first connection point is greater than or equal to 0.5 mm.

[0029] According to this embodiment of this application, the length D1 of the radiator between the feed point and the first connection point may be used to adjust excitation degrees of the first radiator and the second radiator when the antenna structure generates a resonance. In an embodiment, the foregoing excitation degree may be understood as a balance degree between the first resonance and the second resonance. Adjusting D1 makes the antenna structure have good radiation performance (for example, an operating bandwidth, total efficiency, and radiation efficiency).

[0030] With reference to the first aspect, in some implementations of the first aspect, the antenna structure further includes a first electronic element and a second electronic element; the first electronic element is electrically connected between the first end of the first metal connector and the first connection point; and the second electronic element is electrically connected between the second end of the first metal connector and the second connection point.

[0031] According to this embodiment of this application, the first electronic element and the second electronic element may be configured to determine an impedance between the metal connector and the first radiator and an impedance between the metal connector and the second radiator for matching the first radiator and the second radiator. The first electronic element and the second electronic element may be configured to increase a degree of freedom for adjusting a radiation characteristic of the antenna structure.

[0032] With reference to the first aspect, in some implementations of the first aspect, the first connection point is the same as the first ground point; and the antenna structure further includes a third electronic element, where the third electronic element is electrically connected between the first ground point and a ground plane.

[0033] According to this embodiment of this application, when a joint between the first end of the metal connector and the first radiator is the same as a ground position of the first radiator, a length of the metal connector may be reduced. However, the third electronic element needs to be disposed between the ground position of the first radiator and the ground plane, so that the antenna structure can have a good radiation characteristic.

[0034] With reference to the first aspect, in some implementations of the first aspect, the antenna structure further includes a fourth electronic element, where the fourth electronic element is electrically connected between the feed element and the feed point.

[0035] With reference to the first aspect, in some implementations of the first aspect, the length of the first metal connector is less than one tenth of the first wavelength.

[0036] According to this embodiment of this application, the length of the first metal connector may be further shortened for flexibly arranging the first metal connector in the electronic device.

[0037] With reference to the first aspect, in some implementations of the first aspect, the length L1 of the first radiator and the length L2 of the second radiator satisfy the following: $L2\times90\%\leq L1\leq L2\times120\%$.

[0038] According to this embodiment of this application, the length L1 of the first radiator and the length L2 of the second radiator may be used to determine an impedance of the antenna structure 200 at the feed point, and may be used to adjust a radiation characteristic (for example, an operating bandwidth, radiation efficiency, or total efficiency) of the antenna structure.

[0039] With reference to the first aspect, in some implementations of the first aspect, the antenna structure further includes a second metal connector, and the radiator further includes a third radiator, where the second radiator includes a third connection point, and the third radiator includes a fourth connection point; a first end of the second metal connector is coupled to the third connection point, and a second end of the second metal connector is coupled to the fourth connection point; and the length L1 of the first radiator and a length L3 of the third radiator satisfy the following: $L3\times90\%\leq L1\leq L3\times120\%$. In an embodiment, the second metal connector is configured to transmit, to the third radiator, the electrical signal fed by the feed element at the feed point, where no other feed point coupled to the feed element is disposed on the third radiator.

[0040] According to this embodiment of this application, a plurality of radiators may be cascaded through the first metal connector and the second metal piece, so that the antenna structure generates a plurality of resonances, to expand an operating frequency band of the antenna structure.

[0041] According to a second aspect, an electronic device is provided, including the antenna structure according to any one of implementations of the first aspect.

[0042] With reference to the second aspect, in some implementations of the second aspect, the electronic device further includes a conductive side frame, where the side frame has a first position, a second position, and a third position, the second position is located between the first position and the third position, the first radiator includes at least a part of a first side frame between the first position and the second position, and the second radiator includes at least a part of a second side frame between the second position and the third position.

[0043] With reference to the second aspect, in some implementations of the second aspect, the first radiator is

L-shaped, and the second radiator is in a straight line shape, where

the first position and the second position are located on a long side frame of the side frame, and the third position is located on a short side frame of the side frame.

BRIEF DESCRIPTION OF DRAWINGS

[0044]

FIG. 1 is a diagram of an electronic device 10 according to an embodiment of this application;

FIG. 2 is a diagram of an electronic device 10 according to an embodiment of this application;

FIG. 3 shows an S parameter simulation result of an antenna structure 100 in the electronic device shown in FIG. 2;

FIG. 4 is a Smith chart of an antenna structure 100 in the electronic device shown in FIG. 2;

FIG. 5 is a diagram of current distribution of an antenna structure 100 in the electronic device shown in FIG. 2;

FIG. 6 is a diagram of electric field distribution of an antenna structure 100 in the electronic device shown in FIG. 2;

FIG. 7 shows simulation results of total efficiency and radiation efficiency of an antenna structure 100 in the electronic device shown in FIG. 2;

FIG. 8 is a diagram of an antenna structure 200 according to an embodiment of this application;

FIG. 9 is a diagram of another antenna structure 200 according to an embodiment of this application;

FIG. 10 is a diagram of another electronic device 10 according to an embodiment of this application;

FIG. 11 shows S parameter simulation results of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2;

FIG. 12 is a Smith chart of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2;

FIG. 13 is a diagram of current distribution of an antenna structure 200 in the electronic device shown in FIG. 10;

FIG. 14 is a diagram of electric field distribution of an antenna structure 200 in the electronic device shown in FIG. 10;

FIG. 15 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2;

FIG. 16 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2 in a hand left (hand left, HL) model;

FIG. 17 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2 in a hand right (hand right, HR) model;

FIG. 18 shows S parameter simulation results of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2;

FIG. 19 is a Smith chart of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2;

FIG. 20 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2;

FIG. 21(a) to FIG. 21(c) are diagrams of still another electronic device 10 according to an embodiment of this application;

FIG. 22 shows an S parameter simulation result of an antenna structure in the electronic device shown in FIG. 21(a) to FIG. 21(c);

FIG. 23 is a Smith chart of an antenna structure in the electronic device shown in FIG. 21(a) to FIG. 21(c);

FIG. 24 shows simulation results of total efficiency and radiation efficiency of an antenna structure in the electronic device shown in FIG. 21(a) to FIG. 21(c);

FIG. 25 shows an S parameter simulation result of an antenna structure in the electronic device shown in FIG. 21(a);

FIG. 26 is a Smith chart of an antenna structure in the electronic device shown in FIG. 21(a);

FIG. 27 shows simulation results of total efficiency and radiation efficiency of an antenna structure in the electronic device shown in FIG. 21(a);

FIG. 28 is a diagram of still another antenna structure 200 according to an embodiment of this application;

FIG. 29 is a diagram of an electronic device 10 according to an embodiment of this application;

FIG. 30 is a diagram of still another electronic device

10 according to an embodiment of this application;

FIG. 31 shows S parameter simulation results of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30;

FIG. 32 is a Smith chart of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30;

FIG. 33(a) to FIG. 33(d) are diagrams of current distribution of an antenna structure 200 in the electronic device shown in FIG. 29;

FIG. 34(a) to FIG. 34(d) are diagrams of electric field distribution of an antenna structure 200 in the electronic device shown in FIG. 29;

FIG. 35 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30;

FIG. 36 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30 in an HL model;

FIG. 37 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30 in an HR model;

FIG. 38 is a diagram of still another antenna structure 200 according to an embodiment of this application;

FIG. 39 is a diagram of still another antenna structure 200 according to an embodiment of this application;

FIG. 40 is a diagram of an electronic device 10 according to an embodiment of this application;

FIG. 41 is a diagram of an electronic device 10 according to an embodiment of this application;

FIG. 42 is a diagram of still another electronic device 10 according to an embodiment of this application;

FIG. 43 is a diagram of still another electronic device 10 according to an embodiment of this application;

FIG. 44 shows S parameter simulation results of antenna structures in the electronic devices shown in FIG. 40, FIG. 42, and FIG. 43;

FIG. 45 is a diagram of current distribution of an antenna structure 200 in the electronic device shown in FIG. 40;

FIG. 46 is a diagram of electric field distribution of an antenna structure 200 in the electronic device shown in FIG. 40;

FIG. 47 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 40, FIG. 42, and FIG. 43;

FIG. 48 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 40 and FIG. 43 in an HL model;

FIG. 49 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 40 and FIG. 43 in an HR model;

FIG. 50 shows S parameter simulation results of antenna structures in the electronic devices shown in FIG. 41 and FIG. 43;

FIG. 51 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 41 and FIG. 43;

FIG. 52 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 41 and FIG. 43 in an HL model;

FIG. 53 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 41 and FIG. 43 in an HR model;

FIG. 54 is a diagram of still another antenna structure 200 according to an embodiment of this application;

FIG. 55 is a diagram of still another antenna structure 200 according to an embodiment of this application;

FIG. 56 is a diagram of still another antenna structure 200 according to an embodiment of this application;

FIG. 57 is a diagram of still another antenna structure 200 according to an embodiment of this application;

FIG. 58 is a diagram of still another antenna structure 200 according to an embodiment of this application;

FIG. 59 is a diagram of still another antenna structure 200 according to an embodiment of this application; and

FIG. 60 is a diagram of still another antenna structure 200 according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0045] The following describes terms that may appear in embodiments of this application.

[0046] It should be understood that the term "and/or" in this specification is merely a same field for describing associated objects, and represents that three relationships may exist. For example, A and/or B may represent the following three cases: Only A exists, both A and B exist, and only B exists. In addition, the character "/" in this specification generally indicates an "or" relationship between the associated objects.

[0047] In this application, "within a range of..." is used, except when it is separately indicated that no end value is included, end values at both ends of the range are included by default. For example, within a range from 1 to 5, two values 1 and 5 are included.

[0048] 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 physical contact and electrical conduction of components, or may be understood as a form of connection between different components in a line structure through a physical line that can transmit an electrical signal, like a printed circuit board (printed circuit board, PCB) copper foil, or a conducting wire. The "indirect coupling" may be understood as electrical conduction of two conductors in a spaced or 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 components.

[0049] Lumped element/component: The lumped element/component is a general name of all elements whose sizes are far less than a wavelength corresponding to an operating frequency of a circuit. For a signal, an element characteristic is always fixed at any time, regardless of a frequency. Distributed element/component: A difference between the distributed element/component and the lumped element/component lies in that if a size of an element is close to or greater than a wavelength corresponding to an operating frequency of a circuit, a characteristic of each point of the element varies with a signal when the signal passes through the element. In this case, the element cannot be considered as a single body with a fixed characteristic, but should be referred to as a distributed element.

[0050] 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. The distributed capacitor (or distributed type capacitor) is an equivalent capacitor formed in a slot between two conductive members.

[0051] 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 inductive element. The distributed inductor (or distributed type inductor) is an equivalent inductor formed by using a conductive member of a specific length.

[0052] Radiator: The radiator is an apparatus configured to receive/send electromagnetic wave radiation in an antenna. In some cases, an "antenna" is a radiator in a narrow sense. The radiator converts guided wave energy from a transmitter into a radio wave, or converts a radio wave into guided wave energy to radiate and receive a radio wave. Modulated high-frequency current energy (or guided wave energy) generated by the transmitter is transmitted to a transmit radiator through a feed line. The radiator converts the energy into specific polarized electromagnetic wave energy and transmits the energy in a required direction. A receive radiator converts specific polarized electromagnetic wave energy from a specific direction in space into modulated high-frequency current energy, and transmits the energy to an input end of a receiver through the feed line.

[0053] The radiator may include a conductor having a specific shape and size, for example, a linear radiator or a sheet-like radiator. A specific shape is not limited in this application. In an embodiment, the linear radiator may be referred to as a wire antenna for short. In an embodiment, the linear radiator may be implemented by using a conductive side frame, and may also be referred to as a side frame antenna. In an embodiment, the linear radiator may be implemented by a bracketed conductor, and may also be referred to as a bracketed antenna. In an embodiment, a wire diameter (for example, including a thickness and a width) of the linear radiator or a radiator of a wire antenna is much less than a wavelength (for example, a medium wavelength) (for example, is less than 1/16 of the wavelength), and a length may be compared with the wavelength (for example, the medium wavelength) (for example, the length is near 1/8 of the wavelength, or 1/8 to 1/4 of the wavelength, or 1/4 to 1/2 of the wavelength, or greater). Main forms of the wire antenna include the following: a dipole antenna, a half-wave dipole antenna, a monopole antenna, a loop antenna, an inverted F antenna (also referred to an IFA, inverted F antenna), and a planar inverted F antenna (also referred to a PIFA, planar inverted F antenna). For example, for the dipole antenna, each dipole antenna usually includes two radiation stubs, and each stub is fed by a feed part from a feed end of the radiation stub. For example, the inverted F antenna (Inverted F Antenna, IFA) may be considered as being obtained by adding a grounding path to the monopole antenna. The IFA antenna has a feed point and a ground point. A side view of the IFA antenna is inverted F-shaped, and therefore, the IFA antenna is referred to an inverted F antenna. In an embodiment, the sheet-like radiator may include a microstrip antenna or a patch (patch) antenna. In an embodiment, the sheet-like radiator may be implemented by a planar conductor (for example, a conductive sheet or a conductive coating). In an embodiment, the sheet-like radiator may include a conductive sheet, for example, a copper sheet. In an embodiment, the sheet-like radiator may include a conductive coating, for example, silver paste. A shape of the sheet-like radiator includes a circular shape, a rectangular shape, a ring shape, and the like. A specific shape is not limited in this application. A structure of the microstrip antenna generally includes a dielectric substrate, a radiator, and a ground plane, where the dielectric substrate is disposed between the radiator and the ground plane.

[0054] The radiator may also include a slot or a slit formed on a conductor, for example, a closed or semi-closed slot or slit formed on a grounded conductor surface. In an embodiment, a radiator with a slot or slit may be referred to as a slot antenna or a slotted antenna for short. In an embodiment, a radiator having a closed slot or slit may be referred to as a closed slot antenna for short. In an embodiment, a radiator having a semi-closed slot or slit (for example, an opening is additionally provided on the closed slot or slit) may be referred to as an open slot antenna for short. In some embodiments, the slot is long strip-shaped. In some embodiments, a length of the slot is approximately half a wavelength (for example, a medium wavelength). In some embodiments, a length of the slot is approximately an integer multiple of a wavelength (for example, one time a medium wavelength). In some embodiments, the slot may be used for feeding through a transmission line bridged on one side or two sides of the slot. In this way, a radio frequency electromagnetic field is excited on the slot, and an electromagnetic wave is radiated to space. In an embodiment, a radiator of the slot antenna or the slotted antenna may be implemented by a conductive side frame that is grounded at two ends, and may also be referred to as a side frame antenna. In this embodiment, it may be considered that the slot antenna or the slotted antenna includes a linear radiator, and the linear radiator is spaced from the ground plane and is grounded at two ends of the radiator, to form a closed or semi-closed slot or slit. In an embodiment, the radiator of the slot antenna or the slotted antenna may be implemented by a bracketed conductor that is grounded at both ends, and may also be referred to as a bracketed antenna.

[0055] Feed element/feed circuit/feed structure is a combination of all components of an antenna for receiving and transmitting radio frequency waves. In a case of a receive antenna, the feed element may be considered as an antenna part from a first amplifier to a front-end transmitter. In a transmit antenna, the feed element may be considered as a part after the last power amplifier. In some cases, the "feed element" is understood in a narrow sense as a radio frequency chip, or includes a transmission path from the radio frequency chip to a radiator or a feed point on a transmission line. The feed element has a function of converting a radio wave into an electrical signal and sending the electrical signal to a receiver component. Usually, the feed element is considered as a part of an antenna, and is configured to convert a radio wave into an electrical signal, and vice versa. A maximum power transmission possibility and efficiency should be considered during antenna design. Therefore, a feed impedance of an antenna should match a load resistance. The feed impedance of the antenna is a combination of resistance, capacitance, and inductance. To ensure a maximum power transmission condition, the two impedances (the load resistance and the feed impedance) should match. The matching may be implemented by considering a frequency requirement and an antenna design parameter (for example, a gain, directivity, and radiation efficiency).

[0056] End/point: An "end/point" in a first end/second end/feed end/ground end/feed point/ground point/connection point of an antenna radiator cannot be understood as an endpoint or an end part that is physically disconnected from another radiator, and may be considered as a point or a section on a continuous radiator. In an embodiment, the "end/point" may include a connection/-coupling area that is on the antenna radiator and that is coupled to another conductive structure. For example, the feed end/feed point may be a coupling area (for example, an area opposite to a part of the feed circuit) that is on the antenna radiator and that is coupled to the feed structure or the feed circuit. For another example, the ground end/ground point may be a connection/coupling area that is on the antenna radiator and that is coupled to the ground structure or the ground circuit.

[0057] Open end and closed end: In some embodiments, the open end and the ground end are defined based on grounding, for example, the closed end is grounded, and the open end is not grounded. In some embodiments, 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 a free end, 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. It should be understood that, in some embodiments, another conductor may be coupled and connected by using an open end, to transfer coupling energy (which may be understood as transferring a current).

[0058] Resonance/resonant frequency: The resonant frequency is also referred to as a resonance frequency. The resonant frequency may be a frequency at which an imaginary part of an input impedance of an antenna is zero. The resonant frequency may have a frequency range, namely, a frequency range in which a resonance occurs. The frequency corresponding to a strongest resonance point is a center frequency. A return loss of the center frequency may be less than -20 dB. It should be understood that, unless otherwise specified, in the "generating a first resonance" by the antenna/radiator mentioned in this application, the first resonance should be a basic mode resonance generated by the antenna/radiator, or a resonance with a lowest frequency generated by the antenna/radiator.

[0059] Resonant 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.

[0060] 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:

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

where

L is the physical length, and λ 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 resonant 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 resonant 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 also be a wavelength corresponding to a resonant frequency or a non-center frequency of the operating frequency band. It should be understood that a wavelength of a radiation signal in the air may be calculated as follows: (Air wavelength or vacuum wavelength)=Speed of light/Frequency, where the frequency is a frequency (MHz) of the radiation signal, and the speed of light may be 3×108 m/s. A wavelength of a radiation signal in a medium may be calculated as follows: Wavelength=(Speed $\text{of light}/\sqrt{\varepsilon})/\text{Frequency}$, where ε is a relative dielectric constant of the medium. The wavelength in embodiments of this application is usually a medium wavelength, and may be a medium wavelength corresponding to the center frequency of the resonant frequency, or a medium wavelength corresponding to the center frequency of the operating frequency band supported by the antenna. For example, it is assumed that a center frequency of a B1 uplink frequency band (with a resonant frequency ranging from 1920 MHz to 1980 MHz) is 1955 MHz, the wavelength may be a medium wavelength calculated by using the frequency of 1955 MHz. The "medium wavelength" is not limited to the center frequency, and may also be a medium wavelength corresponding to a resonant frequency or a non-center frequency of the operating frequency band. For ease of understanding, the medium wavelength mentioned in embodiments of this application may be simply calculated by using a relative dielectric constant of the medium filled on one or more sides of the radiator.

[0061] 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.

[0062] Radiation efficiency (radiation efficiency) of an antenna: The radiation efficiency of the antenna is a ratio of power (namely, power for effectively converting an electromagnetic wave) radiated by the antenna to space 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.

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] Smith (Smith) chart: The Smith (Smith) chart is a calculation chart with equivalent circles for normalized input impedance (or admittance) plotted on a reflection coefficient plane. The chart includes three circles for solving a problem with a transmission line and some waveguide problems by using a graphical method, avoid a complex operation.

[0070] Ground (ground plane) (ground, GND): The ground (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. 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. In an embodiment, the circuit board includes a dielectric substrate, a grounding plane, and a wiring layer, where the wiring layer and the grounding plane may be electrically connected through a via hole. In an embodiment, components such as a display, a touchscreen, an input button, a transmitter, a processor, a memory, a battery, a charging circuit, and a system on chip (system on chip, SoC) structure may be mounted on or connected to the circuit board, or electrically connected to the wiring layer and/or the grounding plane in the circuit board. For example, a radio frequency source is provided at the wiring layer.

[0071] 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.

[0072] Grounding: The grounding refers to coupling with the ground or ground plane in any manner. In an embodiment, the grounding may be grounding by using an entity, for example, grounding by using an entity (or referred to as entity grounding) at a specific position on the side frame is implemented by using some mechanical parts of the middle frame. In an embodiment, the grounding may be grounding by using a component, for example, grounding (or referred to as component grounding) by using a component like a capacitor/inductor/resistor connected in series or in parallel.

[0073] The following describes technical solutions of embodiments in this application with reference to accompanying drawings.

[0074] As shown in FIG. 1, an electronic device 10 may include a cover (cover) 13, a display/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, a cover of a PET (Polyethylene terephthalate, polyethylene terephthalate) material.

[0075] 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.

[0076] 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.

[0077] 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 side 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.

[0078] The electronic device 10 may further include a battery (not shown in the figure). The battery may be provided between the middle frame 19 and the rear cover 21, or may be provided 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.

[0079] The electronic device 10 may further include a side frame 11. The side frame 11 may be made of a conductive material such as 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 implementation, 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.

[0080] 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.

[0081] 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 middle frame 19 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. 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. 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 with the middle frame 19. 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 an elastic sheet 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.

[0082] 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.

[0083] 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.

[0084] The antenna of the electronic device 10 may be further 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.

[0085] The antenna of the electronic device 10 may be further 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.

[0086] 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.

[0087] 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.

[0088] 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. 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. For indirect description, all antenna structures provided in embodiments of this application are wire antennas. During actual application, another antenna structure, for example, a patch (patch) antenna may be adopted. This is not limited in embodiments of this application.

[0089] FIG. 2 is a diagram of the electronic device 10.

[0090] As shown in FIG. 2, the electronic device 10 may include an antenna structure 100. The antenna structure 100 may include a first radiator 101, a second radiator 102, a metal connector 110, and a feed element 120.

[0091] A side frame 11 of the electronic device 10 may have a first position, a second position, and a third position. The second position is located between the first position and the third position. A side frame between the first position and the second position may be used as a first side frame (the first radiator 101 includes the first side frame), and a side frame between the second position and the third position may be used as a second side frame (the second radiator 102 includes the second side frame). A first end (a ground end) of the first radiator 101 is coupled to a ground plane for grounding, and a second end (a ground end) of the second radiator 102 is coupled to the ground plane for grounding. The side frame 11 is provided with a gap between the first position and the second position, so that a second end of the first radiator 101 and a first end of the second radiator 102 are ground ends.

[0092] A first end of the metal connector 110 is coupled to the first radiator 101, and a second end of the metal connector 110 is coupled to the second radiator 102. The feed element 120 is connected to the metal connector 110, an electrical signal is fed into the first radiator 101 through the first end of the metal connector 110, and the electrical signal is transmitted to the second radiator 102 through the second end of the metal connector 110, so that the antenna structure 100 generates a resonance.

[0093] It should be understood that, when the electrical signal is fed into the first radiator 101 through the first end of the metal connector 110, the first radiator 101 may form a structure similar to an inverted F antenna (inverted F antenna, IFA). When the electrical signal is transmitted to the second radiator 102 through the second end of the metal connector 110, the second radiator 102 may form a structure similar to a left-hand antenna, and the left-hand antenna may be, for example, an antenna that meets a composite left and right hand (composite right and left hand, CRLH) transmission line structure.

[0094] FIG. 3 shows an S parameter simulation result of the antenna structure 100 in the electronic device shown in FIG. 2. When the feed element feeds the electrical signal, the antenna structure may generate a resonance (a first resonance) near 0.8 GHz and a resonance (a second resonance) near 0.9 GHz.

[0095] FIG. 4 is a Smith chart of the antenna structure 100 in the electronic device shown in FIG. 2. On a resonant frequency band of the antenna structure, an impedance curve of the antenna structure is located in an area on an upper left corner of the chart, an impedance matching effect of the antenna structure is poor (when the impedance curve corresponding to the resonant frequency band is close to a virtual center of circle of the chart, the impedance matching effect is good), and correspondingly, radiation performance of the antenna structure is poor. Because the antenna structure has a large impedance difference between the first resonance and the second resonance, it is difficult for the antenna structure to implement balance between the double resonances and have good impedance matching.

[0096] (a) and (b) in FIG. 5 are diagrams of current distribution in a case in which the antenna structure separately generates a first resonance (for example, at 0.79 GHz) and generates a second resonance (for example, at 0.9 GHz). As shown in (a) in FIG. 5, there are strong currents on the first radiator, the second radiator, and a ground plane close to the radiator, and current intensity on the first radiator is approximately the same as current intensity on the second radiator. As shown in (b) in FIG. 5, there are strong currents on the first radiator and a ground plane close to the first radiator.

[0097] (a) and (b) in FIG. 6 are diagrams of electric field distribution in a case in which the antenna structure separately generates the first resonance (for example, at 0.79 GHz) and the second resonance (for example, at 0.9 GHz). As shown in (a) in FIG. 6, there are strong electric fields near the first radiator and near the second radiator, and electric field strength near the first radiator is approximately the same as electric field strength near the second radiator. As shown in (b) in FIG. 6, there is a strong electric field near the first radiator.

[0098] FIG. 7 shows simulation results of total efficiency and radiation efficiency of the antenna structure 100 in the electronic device shown in FIG. 2. In comparison with a case in which the second resonance is generated, in a case in which the antenna structure generates the first resonance, the current intensity on the first radiator is approximately the same as the current intensity on the second radiator, and the electric field strength near the first radiator is approximately the same as the electric field strength near the second radiator. This increases a conductor loss and a dielectric loss of the antenna structure, and consequently, efficiency of the antenna structure on a resonant frequency band of the first resonance is low.

[0099] Embodiments of this application provide an antenna structure and an electronic device. The antenna structure is coupled between a first radiator and a second radiator through a metal connector with a short length. When an electrical signal is fed at a feed point disposed on the first radiator, the electrical signal is transmitted to the second radiator through the metal connector, so that the antenna structure generates a first resonance and a second resonance, and has good total efficiency and radiation efficiency at frequencies covered by the first resonance and the second resonance.

[0100] FIG. 8 is a diagram of an antenna structure 200 according to an embodiment of this application. As shown in FIG. 8, the antenna structure 200 may include a radiator (including a first radiator 210 and a second radiator 220), a metal connector 230, and a feed element 240.

[0101] The first radiator 210 includes a first connection point 211, and the second radiator 220 includes a second connection point 221. A first end of the metal connector 230 is coupled to the first connection point 211, and a second end of the metal connector 230 is coupled to the second connection point 221.

[0102] The first radiator 210 further includes a feed point 212. The feed element 240 is coupled to the feed point 212, and feeds an electrical signal into the antenna structure 200 at the feed point 212. In an embodiment, the first metal connector 230 is configured to transmit, to the second radiator 220, the electrical signal fed by the feed element 240 at the feed point 212, where no other feed point coupled to the feed element 212 is disposed on the second radiator 220. It should be understood that the feed element 212 may correspond to a feed element of a single antenna in a radio frequency channel.

[0103] It should be understood that, in embodiments of this application, the coupling may be implemented through direct coupling or indirect coupling. For brevity of description, direct coupling (an electrical connection) is used as an example for description. During actual application, adjustment may be performed based on different layout manners. This is not limited in embodiments of this application.

[0104] When the electrical signal is fed at the feed point 212, the antenna structure 200 may generate a first resonance and a second resonance, and a resonant frequency of the first resonance is lower than a resonant frequency of the second resonance. A target frequency band of the antenna structure 200 may include a first frequency band and a second frequency band. The first frequency band may correspond to a resonant frequency band of the first resonance, and the second frequency band may correspond to a resonant frequency band of the second resonance. It should be understood that each of the first frequency band and the second frequency band may include a plurality of operating frequency bands. For example, the first frequency band includes a Band 5 and a Band 9, and the second frequency band includes a Band 28A, a Band 28B, and the like.

[0105] A length L of the metal connector 230, a length L1 of the first radiator 210, and a length L2 of the second radiator 220 satisfy the following: $(L1+L2)/32 \leq L \leq (L1+L2)/2$.

[0106] In an embodiment, the metal connector 230 is separately connected near an open end of the first radiator 210 and a ground end of the second radiator 220, or the metal connector 230 is separately connected near a ground end of the first radiator 210 and an open end of the second radiator 220. The length L of the metal connector 230, the length L1 of the first radiator 210, and the length L2 of the second radiator 220 satisfy the following: $0<L \leq (L1+L2)\times 30\%$.

[0107] It should be understood that the first end of the first radiator 210 and the first end of the second radiator 220 are opposite to, but do not touch each other. When one of the first end of the first radiator 210 and the first end of the second radiator 220 is an open end and the other one is a ground end, the first metal connector 230 also needs to at least have a length for connecting two radiators near the first end of the first radiator 210 and near the first end of the second radiator 220. Because first impedance conditions at the first end of the first radiator 210 and the first end of the second radiator 220 are not the same or not similar, the metal connector 230 may be set to an electrical length which is less than a 1/4 wavelength. In an embodiment during actual application, a length D2 of the metal connector 230, the length L1 of the first radiator 210, and the length L2 of the second radiator 220 satisfy the following: 0<L≤(L1+L2)×30%.

[0108] In an embodiment, the length L of the metal connector 230, the length L1 of the first radiator 210, and the length L2 of the second radiator 220 satisfy the following: L≤(L1+L2)/4.

[0109] Still in an embodiment, the length L of the metal connector 230, the length L1 of the first radiator 210, and the length L2 of the second radiator 220 satisfy the following: L≤(L1+L2)/5.

[0110] An electrical length Le of the metal connector 230 may be less than or equal to one half of the first wavelength, and is greater than or equal to one thirty-second of the first wavelength. The first wavelength may be understood as a wavelength corresponding to the second resonance. The wavelength corresponding to the second resonance may be understood as a medium wavelength corresponding to a center frequency of the target frequency band corresponding to a second resonance, or a medium wavelength corresponding to a resonance point of the second resonance. It should be understood that because there is a specific conversion relationship between the medium wavelength and a vacuum wavelength, the medium wavelength may be converted by using the vacuum wavelength. For brevity of description, details are not described in this embodiment of this application.

[0111] In an embodiment, the length L of the metal connector 230 is at least greater than or equal to 2 mm. In an embodiment, the length L of the metal connector 230 is greater than or equal to 3 mm. In an embodiment, the length L of the metal connector 230 may be set to about 5 mm (for example, 5 mm±50%). In an embodiment, the metal connector and the radiator need to be connected via an elastic sheet. A width of the elastic sheet is generally within a range of 1 mm to 4 mm, and a slot between radiators is within a range of 1 mm to 3 mm. Therefore, the metal connector needs to have a specific length for connecting the two radiators across the slot in engineering.

[0112] It should be understood that, for the electrical length of the metal connector 230, it may be considered as that the electrical length is jointly affected by a component connected in series or in parallel between the metal connector 230 and the radiator. In an embodiment, when the first connection point 211 between the metal connector 230 and the radiator is close to or coincides with the first ground point 213 between the radiator and a ground plane, a component connected in series or in parallel between the first ground point 213 and the ground plane should also affect the electrical length of the metal connector 230. In the following embodiment shown in FIG. 9, the first ground point 213 is in series connected to an inductive component for grounding. In this case, a physical length of the metal connector 230, for example, a transmission line, may be correspondingly reduced, and the electrical length of the metal connector 230 within the foregoing range may also be obtained.

[0113] In an embodiment, the electrical length of the metal connector 230 may be less than or equal to one tenth of the first wavelength and greater than or equal to one thirty-second of the first wavelength. In an embodiment, the electrical length of the metal connector 230 may be less than or equal to one tenth of the first wavelength and greater than or equal to one sixteenth of the first wavelength. It should be understood that the length of the metal connector 230 may be further reduced based on a spatial layout in the electronic device, and radiation performance of the antenna structure 200 is not greatly affected.

[0114] In this embodiment of this application, the length of the metal connector 230 may be understood as a total length of the metal connector 230. For example, when the metal connector 230 is in a fold-line shape, the length of the metal connector 230 may be a sum of lengths of all bent parts.

[0115] In an embodiment, the metal connector 230 may be a combination of one or more of the following: a radio frequency transmission line, for example, a cable (cable), a microstrip line (microstrip line), or a coaxial line (coaxial line); a metal wire on a dielectric board (for example, a PCB of the electronic device); a metal wire on a flexible circuit board FPC; a metal piece (for example, a metal wire and/or a metal sheet) on an antenna support (for example, based on laser-direct-structuring LDS); a metal piece disposed on another insulating part, for example an insulating rear cover (which may include insulating materials such as glass and ceramic) of the electronic device; and another conductive connector like an elastic sheet, a spring plate, and conductive foam.

[0116] Any end of the metal connector 230 may be connected to the radiator in series, or the metal connector 230 may be connected to an electronic element in series and/or in parallel, like a capacitor or an inductor.

[0117] **In** an embodiment, the metal connector 230 may alternatively be an integrated structure with the first radiator 210 and the second radiator 220. When the metal connector 230 is an integrated structure with the first radiator 210 and the second radiator 220, no electronic element is disposed between the metal connector 230 and the first radiator 210 or the second radiator 220. It should be understood that this is not limited in this embodiment of this application, and may be determined based on actual production or design. The length of the metal connector may be understood as a total length of metal connectors with one or more different structures. It should be understood that, in an embodiment, when the metal connector is mainly made of one material, a length of the main material may also be used as a total length of the metal connector, for example, a total length of a metal part on the antenna support. It should also be understood that, when a plurality of structures of different materials are sequentially connected as a metal connector, it may also be understood that a total length of the plurality of connectors is used as a total length of the metal connector. For example, when a length of one material is greater than 1 mm, the total length is calculated. In an embodiment, when the metal connector and the radiator are integrated, a total length of the metal connector is understood as a total length of the metal connector that is bent and extended between two connection points of the radiator.

[0118] It should be further understood that, in an embodiment, a maximum cross-sectional area of the metal connector should be less than a cross-sectional area of the radiator. For example, the cross-sectional area of the metal connector is less than or equal to 60% of the cross-sectional area of the radiator.

[0119] It should be understood that when the feed element 240 feeds an electrical signal at the feed point 212, at a frequency covered by the first frequency band (a resonant frequency covered by the first resonance) and a frequency covered by the second frequency band (a resonant frequency covered by the second resonance), currents or electric fields generated by the antenna structure 200 are mainly concentrated on different radiators and surrounding areas. In comparison with the antenna structure 100 shown in FIG. 2, when the antenna structure 200 generates a resonance, the first radiator 210 and an area around the first radiator 210, the second radiator 220 and an area around the second radiator 220 do not have currents or electric fields of approximately the same strength at the same time. Therefore, a conductor loss and a dielectric loss that occur when the antenna structure generates a resonance can be reduced, thereby improving total efficiency and radiation efficiency of the antenna structure. In addition, because a length of the metal connector 230 in the antenna structure 200 is short, the metal connector 230 does not occupy large space. This helps dispose the metal connector 230 in the electronic device.

[0120] It should be understood that the first radiator 210 and the second radiator 220 may be arranged based on space inside the electronic device. In an embodiment, the first radiator 210 and the second radiator 220 may be placed close to each other, for example, integrated. For example, two ends of that are of the radiators and that are close to each other are spaced by one slot, and a width of the slot is within a range of (0.5 mm to 2 mm), and the two ends are opposite to, but do not touch each other. For example, the radiator extends on a side frame, and is generally in a straight-line shape, an L shape, or a U shape. In an embodiment, the first radiator 210 may be disposed on the side frame, the second radiator 220 may be disposed on the PCB or the rear cover, or both the first radiator 210 and the second radiator 220 are disposed on the PCB or the rear cover, or the like, provided that the metal connector 230 meets a corresponding limitation. Certainly, both the first radiator 210 and the second radiator 220 are disposed on the side frame. For example, the first radiator 210 and the second radiator 220 are disposed inside the side frame to be as close as possible to external space, to further optimize radiation efficiency, or a metal side frame is reused as a radiator.

[0121] In an embodiment, inside the electronic device, because layout space is compact, the antenna structure 200 may reuse a radiator with another antenna structure. In an embodiment, the first radiator 210 or the second radiator 220 may be further provided with another feed point, configured to be coupled to a feed element of another antenna structure for radiation. In an embodiment, the antenna structure 200 and another antenna structure may implement radiator reuse via a component like a switch. Alternatively, in an embodiment, the another antenna structure may operate with the antenna structure 200 at the same time.

[0122] It should be understood that, in the antenna structure 200 in this embodiment of this application, the feed point coupled to the feed element 240 is disposed only on the first radiator 210, and no feed point coupled to the feed element 240 is disposed on other radiators. However, when another antenna structure reuses the radiators, a feed point for another antenna may be disposed for coupling, for example, another feed element different from the feed element 240. In engineering implementation, provided that two feed elements on a radiator are electrically connected to independent radio frequency bases or radio frequency test bases, it may be considered that the two feed elements are electrically connected to different radio frequency channels, and are different feed elements.

[0123] For brevity of description, in this embodiment of this application, only an example in which at least a part of the first radiator 210 and at least a part of the second radiator 220 are located on a same straight line (arranged collinearly) is used for description. In an actual layout, positions of the first radiator 210 and the second radiator 220 are not used to limit this application. Under different stacking requirements of the electronic device, the first radiator 210 and the second radiator 220 may be disposed as required, so that a distributed antenna structure is implemented via the metal connector 230. In an embodiment, at least a part of the first radiator 210 and at least a part of the second radiator 220 may extend in a first direction and be spaced part (arranged in parallel), or there is an included angle between an extension direction of at least a part of the first radiator 210 and an extension direction of at least a part of the second radiator 220 or an extension direction of at least a part of the first radiator 210 and an extension direction of at least a part of the second radiator 220 are perpendicular to each other. This is not limited in this embodiment of this application.

[0124] In an embodiment, the first resonance and the second resonance may be located on a low frequency band (a frequency of a resonance point is less than 960 MHz), and a frequency difference between the resonance point of the second resonance and the resonance point of the first resonance may be greater than or equal to 100 MHz and less than or equal to 200 MHz, so that the antenna structure 200 has a good operating bandwidth.

[0125] In an embodiment, the first end of the first radiator 210 and the first end of the second radiator 220 are opposite to, but do not touch each other, and form a first slot 251. The first end of the first radiator 210 includes a first ground point 213, and the first radiator 210 is coupled to a ground plane 201 at the first ground point 213 for grounding. A second end of the first radiator 210 is an open end. The first end of the second radiator 220 is an open end, a second end of the second radiator 220 includes a second ground point 223, and the second radiator 220 is coupled to the ground plane 201 at the second ground point 223 for grounding.

[0126] It should be understood that a length of a radiator may be understood as a length of the radiator between an open end and a ground point. In an embodiment, the ground point may be an area in which a ground member with a specific width is coupled to the radiator, and a length of the radiator between a center point of the coupled area and an end part (an end face on one side of a slot) of the open end may be used as a length of the radiator.

[0127] In an embodiment, a length of a radiator between the feed point 212 and the first ground point 213 is less than a half of a length L1 of the first radiator 210 (a length between the second end of the first radiator 210 and the first ground point 213). In an embodiment, a length of a radiator between the second connection point 221 and the second ground point 223 is greater than a half of a length L2 of the second radiator 220.

[0128] It should be understood that when the feed element 240 feeds an electrical signal, the first radiator 210 may form a structure similar to an IFA, and the second radiator 220 may form a structure similar to a CRLH.

[0129] In an embodiment, the first connection point 211 is located between the first end of the first radiator 210 and the feed point 212.

[0130] It should be understood that, in this embodiment of this application, being located between A and B may be understood as being located on a position including A and B.

[0131] In an embodiment, a length of a radiator between the feed point 212 and the first ground point 213 is less than a half of a length L1 of the first radiator.

[0132] In an embodiment, a length D1 of the radiator between the feed point 212 and the first connection point 211 is greater than or equal to 0.5 mm. In an embodiment, a length of a radiator between the first ground point 213 and the first connection point 211 is greater than or equal to 0.

[0133] In an embodiment, the length D1 of the radiator between the feed point 212 and the first connection point 211 and the length L1 of the first radiator 210 satisfy the following: $L1\times10\%\leq D1\leq L1\times25\%$. In an embodiment, the length L1 of the first radiator 210 and the length L2 of the second radiator 220 (a length between the first end of the second radiator 220 and the second ground point 223) satisfy the following: $L2\times90\%\leq L1\leq L2\times120\%$. In an embodiment, $L2\times95\%\leq L1\leq L2\times110\%$.

[0134] It should be understood that the length L1 of the first radiator 210, the length L2 of the second radiator 220, positions of the first connection point 211 and the feed point 212 on the first radiator 210, and a position of the second connection point 212 on the second radiator 220 may determine an impedance of the antenna structure 200 at the feed point, and may be used to adjust a radiation characteristic (for example, an operating bandwidth, radiation efficiency, and total efficiency) of the antenna structure 200. In addition, relative positions (the length D1 of the radiator between the feed point 212 and the first connection point 211) between the first connection point 211 and the feed point 212 may be used to adjust an excitation degree (for example, current or electric field distribution) on the first radiator 210 and the second radiator 220 when the antenna structure 200 generates a resonance.

[0135] In an embodiment, the antenna structure 200 further includes a first electronic element 261 and a second electronic element 262. The first electronic element 261 is electrically connected between the first end of the metal connector 230 and the first connection point 211, and the second electronic element 262 is electrically connected between the second end of the metal connector 220 and the second connection point 221.

[0136] In an embodiment, the first electronic element 261 may be inductive, for example, may be an inductor, or an element equivalent to an inductor. In an embodiment, an inductance value (an equivalent inductance value) of the first electronic element 261 may be less than or equal to 10 nH. In an embodiment, the first electronic element 261 may be a 0-Ω resistor.

[0137] In an embodiment, the second electronic element 262 may be capacitive, for example, may be a capacitor, or an element equivalent to a capacitor. In an embodiment, a capacitance value (an equivalent capacitance value) of the second electronic element 262 may be greater than or equal to 1 pF and less than or equal to 3 pF.

[0138] It should be understood that the first electronic element 261 and the second electronic element 262 may be configured to: determine an impedance between the first radiator 210 and the metal connector 230, and an impedance between the second radiator 220 and the metal connector 230, and are configured to match the first radiator 210 and the second radiator 220. The first electronic element 261 and the second electronic element 262 may be configured to increase a degree of freedom for adjusting a radiation characteristic of the antenna structure 200.

[0139] It should be understood that, in the foregoing embodiments, a low frequency band (700 MHz to 960 MHz) is used as an example for description of a parameter of the electronic element. In actual application, the foregoing parameter may be adjusted based on different target frequency bands. This may also be correspondingly understood in another embodiment of this application.

[0140] In an embodiment, the first connection point 211 is located at a midpoint between the first ground point 213 and the feed point 212, and the length of the radiator between the first connection point 211 and the first ground point 213 is the same as the length of the radiator between the first connection point 211 and the feed point 212.

[0141] In an embodiment, as shown in FIG. 9, the first connection point 211 is the same as the first ground point 213 ("same" may be considered as that two connection points use a same conductive member, for example, an elastic sheet, for connection/grounding, or a conductive connector is coupled to the radiator to cover the first connection point 211 and the first ground point 213 on the radiator). In an embodiment, the antenna structure 200 further includes a third electronic element 263, and the third electronic element 263 is electrically connected between the first ground point 213 and the ground plane 201.

[0142] It should be understood that, when a joint between the first end of the metal connector 230 and the first radiator 210 is the same as a ground position of the first radiator 210, a length of the metal connector 230 may be reduced. However, the third electronic element 263 needs to be disposed between the ground position of the first radiator 210 and the ground plane 201, so that the antenna structure 200 can have a good radiation characteristic.

[0143] In an embodiment, the third electronic element 263 may be inductive, for example, may be an inductor, or an element equivalent to an inductor. In an embodiment, an inductance value (an equivalent inductance value) of the third electronic element 263 may be less than or equal to 10 nH.

[0144] In an embodiment, the antenna structure 200 further includes a fourth electronic element, which may be electrically connected between the feed point 212 and the feed element 240.

[0145] It should be understood that the fourth electronic element may be configured to match an impedance between the feed element and the radiator, to improve a radiation characteristic of the antenna structure 200.

[0146] In an embodiment, the antenna structure 200 may be used in the electronic device 10 shown in FIG. 1, as shown in FIG. 10.

[0147] In an embodiment, the side frame 11 of the electronic device 10 may have a first position 111, a second position 112, and a third position 113, and the second position 112 is located between the first position 111 and the third position 113. The first radiator 210 may include at least a part of a first side frame between the first position 111 and the second position 112, and the second radiator 220 may include at least a part of a second side frame between the second position 112 and the third position 113. The side frame 11 may include a first gap and a second gap at the first position 111 and the second position 112, so that the second end of the first radiator 210 and the first end of the second radiator 220 are open ends. In addition, the second gap included in the second position 112 may be used as the first slot in the foregoing embodiment.

[0148] It should be understood that, in this embodiment of this application, the side frame (for example, the first side frame and the second side frame) may be a conductive side frame, or may be a non-conductive side frame having a conductive patch (disposed on an inner surface or disposed in an embedded manner), and conductive parts of the first side frame and the second side frame are used as radiators of the antenna structure 200.

[0149] It should be understood that, for brevity of description, in this embodiment of this application, only an example in which the antenna structure 200 is a side frame antenna is used for description. In actual application, the antenna structure 200 in this embodiment of this application may alternatively be an antenna structure based on a flexible mainboard (flexible printed circuit, FPC), an antenna structure based on laser-direct-structuring (laser-direct-structuring, LDS), an antenna structure such as a microstrip disk antenna (microstrip disk antenna, MDA), or the like. This is not limited in this embodiment of this application.

[0150] In an embodiment, the side frame 11 may include a first side 121 and a second side 122 that intersect at an angle. The first position 111 and the second position 112 may be located on the first side 121, and the third position 113 may be located on the second side 122. It should be understood that the first position 111, the second position 112, and the third position 113 on the side frame 11 are not limited in this embodiment of this application, and may be determined based on actual production or design.

[0151] FIG. 11 to FIG. 17 are diagrams of a simulation result of the antenna structure 200 in the electronic device shown in FIG. 10. FIG. 11 shows S parameter simulation results of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2. FIG. 12 is a Smith chart of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2. FIG. 13 is a diagram of current distribution of the antenna structure 200 in the electronic device shown in FIG. 10. FIG. 14 is a diagram of electric field distribution of the antenna structure 200 in the electronic device shown in FIG. 10.

[0152] FIG. 15 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2. FIG. 16 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2 in a hand left (hand left, HL) model. FIG. 17 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2 in a hand right (hand right, HR) model.

[0153] It should be understood that a difference between the antenna structure 100 shown in FIG. 2 and the antenna structure 200 shown in FIG. 10 lies only in that a position of a feed point is different. In the antenna structure 100, the feed point is disposed on a metal connector, and the feed element is coupled to the metal connector. For brevity of description, only an example in which both a length of the first side frame and a length of the second side frame are 51.5 mm, a width of the first slot is 2 mm, the first electronic element is a 0-Ω resistor, and the second electronic element is a 1-pF capacitor is used for description in this embodiment of this application.

[0154] It should be understood that a first resonance and a second resonance generated by the antenna structure in this embodiment of this application are close (for example, a frequency of a resonance point is less than 960 MHz, and a frequency difference between a resonance point of the second resonance and a resonance point of the first resonance is less than or equal to 200 MHz), and are used to expand a bandwidth through the two resonances. The first resonance and the second resonance may have a connection frequency, and the connection frequency may be understood as a point with a maximum S11 value between the resonance point of the first resonance and the resonance point of the second resonance. When the connection frequency meets a bandwidth requirement (for example, S11<-6 dB is a boundary), it may be considered that the first resonance and the second resonance are connected resonances. It should be understood that the connected resonances may be used to cover a same target frequency band or a same group of target frequency bands (which may include a plurality of communications frequency bands, for example, Band 5, Band 8, Band 28A, and Band 28B).

[0155] As shown in FIG. 11, both the antenna structure 200 shown in FIG. 10 and the antenna structure 100 shown in FIG. 2 may generate the first resonance and the second resonance near 0.8 GHz and 0.9 GHz. S11<-6 dB is used as a boundary. An operating bandwidth (and the connection frequency is less than -6 dB) of the antenna structure 200 shown in FIG. 10 is greater than an operating bandwidth of the antenna structure 100 shown in FIG. 2.

[0156] As shown in FIG. 12, on a resonant frequency band corresponding to the first resonance and the second resonance, an impedance curve of the antenna structure 100 shown in FIG. 2 is located in an upper left corner area of the chart, and an impedance curve of the antenna structure 200 shown in FIG. 10 is closer to a virtual circle center of the chart. Compared with the antenna structure 100 shown in FIG. 2, the antenna structure 200 shown in FIG. 10 has good impedance matching (a wider operating bandwidth) on the resonant frequency band corresponding to the first resonance and the second resonance, and the corresponding antenna structure 200 has good radiation performance.

[0157] (a) and (b) in FIG. 13 are diagrams of current distribution in a case in which the antenna structure 200 in FIG. 10 separately generates the first resonance (for example, at 0.79 GHz) and generates the second resonance (for example, at 0.9 GHz).

[0158] At a first resonance point of the first resonance, a current on the first radiator and a current on the second radiator are reverse in direction, as shown in (a) in FIG. 13. In addition, there are strong currents on both the second radiator and a ground plane close to the second radiator.

[0159] At a second resonance point of the second resonance, a current on the first radiator and a current on the second radiator are in a same direction, as shown in (b) in FIG. 13. In addition, there are strong currents on the first radiator and a ground plane close to the first radiator.

[0160] It should be understood that the foregoing current characteristic (being in a same direction or reverse in direction) may be understood as a current characteristic presented by a main current (current intensity exceeds 50%) on a frequency band. In addition, as a frequency approaches the resonance point, strength of the current with the characteristic increases.

[0161] In the current distribution shown in FIG. 13, it may be understood that the first radiator and the second radiator that are connected to the metal connector present two modes: a half-wavelength mode (which may be referred to as a half-wavelength mode of a common mode) corresponding to the current distribution shown in (a) in FIG. 13 and a half-wavelength mode (which may be referred to as a half-wavelength mode of a differential mode) corresponding to the current distribution shown in (b) in FIG. 13. A half wavelength may be understood as that a sum of electrical lengths of the first radiator and the second radiator is approximately a half wavelength.

[0162] (a) and (b) in FIG. 14 are diagrams of electric field distribution in a case in which the antenna structure 200 in FIG. 10 separately generates the first resonance (for example, at 0.79 GHz) and generates the second resonance (for example, at 0.9 GHz).

[0163] As shown in (a) in FIG. 14, there is a strong electric field near the second radiator. As shown in (b) in FIG. 14, there is a strong electric field near the first radiator.

[0164] It should be understood that, refer to the diagrams of current and electric field distribution shown in FIG. 5 and FIG. 6. When the antenna structure 100 shown in FIG. 2 is in the first resonance, current intensity on the first radiator is approximately the same as current intensity on the second radiator, and electric field strength near the first radiator is approximately the same as electric field strength near the second radiator. However, in the antenna structure 200 shown in FIG. 10, in the first resonance, a current and an electric field are mainly concentrated on the second radiator and a nearby area. Compared with those of the antenna structure 100 shown in FIG. 2, a conductor loss and a dielectric loss of the antenna structure 200 shown in FIG. 10 in the first resonance are reduced, thereby improving radiation efficiency and total efficiency of the antenna structure.

[0165] As shown in FIG. 15, compared with those of the antenna structure 100 shown in FIG. 2, a conductor loss and a dielectric loss of the antenna structure 200 shown in FIG. 10 in the first resonance are reduced, and therefore, on a resonant frequency band (for example, at 0.79 GHz) corresponding to the first resonance, radiation efficiency is improved by about 1 dB, and an efficiency pit of the radiation efficiency is improved by about 3 dB.

[0166] In addition, compared with the antenna structure 100 shown in FIG. 2, the antenna structure 200 shown in FIG. 10 has better impedance matching and improved radiation efficiency, so that total efficiency on the resonant frequency band (for example, at 0.79 GHz) corresponding to the first resonance is improved by about 3 dB.

[0167] In addition, on a resonant frequency band (for example, at 0.9 GHz) corresponding to the second resonance, compared with those of the antenna structure 100 shown in FIG. 2, radiation efficiency and total efficiency of the antenna structure 200 shown in FIG. 10 are also improved to a specific extent.

[0168] As shown in FIG. 15, in a case of using a boundary that total efficiency is greater than -5 dB, a bandwidth of total efficiency of the antenna structure 200 shown in FIG. 10 is wider.

[0169] As shown in FIG. 16 and FIG. 17, in the HL model and the HR model, compared with those of the antenna structure 100 shown in FIG. 2, total efficiency and radiation efficiency of the antenna structure 200 shown in FIG. 10 are still better.

[0170] FIG. 18 to FIG. 20 are diagrams of a simulation result of the antenna structure 200 in the electronic device shown in FIG. 10. FIG. 18 shows S parameter simulation results of antenna structures in electronic devices shown in FIG. 10 and FIG. 2. FIG. 19 is a Smith chart of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2. FIG. 20 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 10 and FIG. 2.

[0171] It should be understood that, in the simulation results shown in FIG. 18 to FIG. 20, simulation results in a case in which a feed element feeds an electrical signal at different positions (a feed position 1: a first end of the metal connector, a feed position 2: a central area (an area within a specific range from a midpoint) of the metal connector, and a feed position 3: a second end of the metal connector) of the metal connector in the antenna structure 100 shown in FIG. 2 are shown. As shown in FIG. 18, S11<-6 dB is used as a boundary. Compared with the antenna structure 100 shown in FIG. 2 in which an electrical signal is fed at three different feed positions, the antenna structure 200 shown in FIG. 10 has a better operating bandwidth.

[0172] As shown in FIG. 19, compared with that of the antenna structure 100 shown in FIG. 2 in which an electrical signal is fed at three different feed positions, on a resonant frequency band corresponding to a first resonance and a second resonance, an impedance curve of the antenna structure 200 shown in FIG. 10 is closer to a virtual circle center of chart. The resonant frequency band corresponding to the first resonance and the second resonance has good impedance matching (a wider operating bandwidth), so that radiation performance of the corresponding antenna structure 200 is better.

[0173] As shown in FIG. 20, compared with the antenna structure 100 shown in FIG. 2 in which an electrical signal is fed at three different feed positions, the antenna structure 200 shown in FIG. 10 has better total efficiency and radiation efficiency on the resonant frequency band corresponding to the first resonance and the second resonance.

[0174] FIG. 21(a) to FIG. 21(c) are a diagram of another electronic device 10 according to an embodiment of this application.

[0175] As shown in FIG. 21(a), the antenna structure 200 may be the antenna structure shown in FIG. 9 (the first connection point is the same as the first ground point). As shown FIG. 21(b), a second side frame is not included, only at least a part of a first side frame is used as a radiator of an IFA structure, and a feed point is disposed on the first side frame. As shown in FIG. 21(c), a first side frame is not included, only at least a part of a second side frame is used as a radiator of a CRLH structure, and a feed point is disposed on the second side frame.

[0176] FIG. 22 to FIG. 24 are diagrams of a simulation result of an antenna structure in the electronic device shown in FIG. 21(a) to FIG. 21(c). FIG. 22 shows an S parameter simulation result of the antenna structure in the electronic device shown in FIG. 21(a) to FIG. 21(c). FIG. 23 is a Smith chart of an antenna structure in the electronic device shown in FIG. 21(a) to FIG. 21(c). FIG. 24 shows simulation results of total efficiency and radiation efficiency of an antenna structure in the electronic device shown in FIG. 21(a) to FIG. 21(c).

[0177] As shown in FIG. 22, a resonant frequency of a resonance generated by the antenna structure shown FIG. 21(b) is approximately the same as a resonant frequency of a first resonance generated by the antenna structure 200 shown in FIG. 21(a), and is about 0.77 GHz. In addition, an operating bandwidth corresponding to the first resonance of the antenna structure 200 shown in FIG. 21(a) is wider. A resonant frequency of a resonance generated by the antenna structure shown in FIG. 21(c) is approximately the same as a resonant frequency of a second resonance generated by the antenna structure 200 shown in FIG. 21(a), and is about 0.87 GHz. In addition, an operating bandwidth corresponding to the second resonance of the antenna structure 200 shown in FIG. 21(a) is wider.

[0178] As shown in FIG. 23, on a resonant frequency band corresponding to the generated resonance, compared with those of the antenna structures shown in FIG. 21(b) and FIG. 21(c), an impedance curve of the antenna structure 200 shown in FIG. 21(a) is closer to a virtual circle center of the chart, and has good impedance matching (a wider operating bandwidth).

[0179] As shown in FIG. 24, on a resonant frequency band corresponding to the first resonance and the second resonance, compared with the antenna structures shown in FIG. 21(b) and FIG. 21(c), the antenna structure 200 shown in FIG. 21(a) has better total efficiency and radiation efficiency.

[0180] It should be understood that, compared with a case in which the first radiator and the second radiator are respectively used as a radiator of an IFA structure and a radiator of a CRLH structure, in this case, the antenna structure 200 has a better impedance characteristic, a wider operating bandwidth, and better total efficiency and radiation efficiency within the bandwidth range.

[0181] FIG. 25 to FIG. 27 are diagrams of a simulation result of the antenna structure 200 in the electronic device shown in FIG. 21(a). FIG. 25 shows an S parameter simulation result of an antenna structure in the electronic device shown in FIG. 21(a). FIG. 26 is a Smith chart of an antenna structure in the electronic device shown in FIG. 21(a). FIG. 27 shows simulation results of total efficiency and radiation efficiency of an antenna structure in the electronic device shown in FIG. 21(a).

[0182] It should be understood that FIG. 25 to FIG. 27 show simulation results of the antenna structure 200 when lengths D1 of a radiator between the feed point and the first connection point in the antenna structure 200 shown in FIG. 21(a) are different.

[0183] As shown in FIG. 25, as D1 increases, a depth (S11) of a resonance point of a first resonance and a depth (S11) of a resonance point of a second resonance change relatively.

[0184] As shown in FIG. 26, as D1 increases, on a resonant frequency band corresponding to the first resonance and the second resonance, an impedance curve of the antenna structure 200 gradually approaches a virtual circle center of the chart.

[0185] As shown in FIG. 27, as D1 increases, total efficiency and total efficiency on a resonant frequency band corresponding to the first resonance and a resonant frequency band corresponding to the second resonance change relatively.

[0186] It should be understood that, as shown in FIG. 25 to FIG. 27, the length D1 of the radiator between the feed point 212 and the first connection point 211 may be used to adjust excitation degrees of the first radiator 210 and the second radiator 220 when the antenna structure 200 generates a resonance. In an embodiment, the foregoing excitation degree may be understood as a balance degree between the first resonance and the second resonance. Adjusting D1 makes the antenna structure have good radiation performance (for example, an operating bandwidth, total efficiency, and radiation efficiency).

[0187] FIG. 28 is a diagram of still another antenna structure 200 according to an embodiment of this application;

[0188] As shown in FIG. 28, the antenna structure 200 may include a radiator (including a first radiator 210 and a second radiator 220), a metal connector 230, and a feed element 240.

[0189] The first radiator 210 includes a first connection point 211, and the second radiator 220 includes a second connection point 221. A first end of the metal connector 230 is coupled to the first connection point 211, and a second end of the metal connector 230 is coupled to the second connection point 221. The first radiator 210 further includes a feed point 212. The feed element 240 is coupled to the feed point 212, and feeds an electrical signal into the antenna structure 200 at the feed point 212. A second end of the first radiator 210 includes a first ground point 213, and the first radiator 210 is coupled to a ground plane 201 at the first ground point 213 for grounding. A first end of the first radiator 210 is an open end. A first end of the second radiator 220 is an open end, a second end of the second radiator 220 includes a second ground point 223, and the second radiator 220 is coupled to the ground plane 201 at the second ground point 223 for grounding.

[0190] It should be understood that the antenna structure 200 shown in FIG. 28 is the same as the metal connector 230 in the antenna structure 200 shown in FIG. 8. A difference between the two antenna structures lies only in that the first radiator 210 and the second radiator 220 have different open ends and ground ends. In an embodiment, the first end of the first radiator 210 and the first end of the second radiator 220 are opposite to, but do not touch each other, and form a first slot 251. The antenna structure 200 shown in FIG. 28 may be similar to a slot antenna (slot antenna), for example, an open-slot antenna (open-slot antenna).

[0191] In an embodiment, the metal connector 230 is separately connected near an open end of the first radiator 210 and an open end of the second radiator 220, or the metal connector 230 is separately connected near a ground end of the first radiator 210 and a ground end of the second radiator 220. A length L of the metal connector 230, a length L1 of the first radiator 210, and a length L2 of the second radiator 220 satisfy the following: $(L1+L2)\times30\%\leq L\leq(L1+L2)\times50\%$.

[0192] It should be understood that the first end of the first radiator 210 and the first end of the second radiator 220 are opposite to, but do not touch each other. When both the first end of the first radiator 210 and the first end of the second radiator 220 are open ends or ground ends, the metal connector 230 also needs to at least have a length for connecting two radiators near the first end of the first radiator 210 and near the first end of the second radiator 220. Because first impedance conditions at the first end of the first radiator 210 and the first end of the second radiator 220 are the same or similar, the metal connector 230 may be set to an electrical length which is an odd multiple of a 1/4 wavelength. In an embodiment during actual application, a length D2 of the metal connector 230, the length L1 of the first radiator 210, and the length L2 of the second radiator 220 satisfy the following:

(L1+L2) ×30%≤D2≤ (L1+L2) ×50%.

[0193] In an embodiment, the first metal connector 230 is configured to transmit, to the second radiator 220, the electrical signal fed by the feed element 240 at the feed point 212, where no other feed point coupled to the feed element 212 is disposed on the second radiator 220. It should be understood that the feed element 212 may correspond to a feed element of a single antenna in a radio frequency channel.

[0194] By disposing the first metal connector 230, the antenna structure 200 shown in FIG. 28 is similar to the antenna structure 200 shown in FIG. 8. The first radiator 210 and the second radiator 220 are configured to generate a first resonance and a second resonance, where the first resonance and the second resonance are connected resonances and have a connection frequency.

[0195] It should be understood that, because the antenna structure 200 shown in FIG. 28 is different from the antenna structure 200 shown in FIG. 8, in the antenna structure shown in FIG. 28, the feed point 212, the first electronic element 261, and the second electronic element 262 are disposed differently.

[0196] In an embodiment, the first electronic element 261 may be capacitive, for example, may be a capacitor, or an element equivalent to a capacitor. In an embodiment a capacitance value (an equivalent capacitance value) of the first electronic element 261 may be greater than or equal to 1 pF and less than or equal to 3 pF.

[0197] In an embodiment, the second electronic element 262 may be capacitive, for example, may be a capacitor, or an element equivalent to a capacitor. In an embodiment, a capacitance value (an equivalent capacitance value) of the second electronic element 262 may be greater than or equal to 0.1 pF and less than or equal to 1 pF.

[0198] In an embodiment, the antenna structure 200 may be used in the electronic device 10 shown in FIG. 1, as shown in FIG. 29.

[0199] In an embodiment, the side frame 11 of the electronic device 10 may have a first position 111, a second position 112, and a third position 113, and the second position 112 is located between the first position 111 and the third position 113. The first radiator 210 includes at least a part of a first side frame between the first position 111 and the second position 112, and the second radiator 220 includes at least a part of a second side frame between the second position 112 and the third position 113. The side frame 11 may be provided with a gap at the second position 112, and the gap may be used as the first slot in the foregoing embodiment, so that the first end of the first radiator 210 and the first end of the second radiator 220 are open ends.

[0200] In an embodiment, the side frame 11 may include a first side 121. The first position 111, the second position 112, and the third position 113 may be located on the first side 121 of the side frame 11. It should be understood that the first position 111, the second position 112, and the third position 113 on the side frame 11 are not limited in this embodiment of this application, and may be determined based on actual production or design.

[0201] FIG. 30 is a diagram of still another electronic device 10 according to an embodiment of this application.

[0202] As shown in FIG. 30, the electronic device 10 may include an antenna structure 300.

[0203] It should be understood that a difference between the antenna structure 300 shown in FIG. 30 and the antenna structure 200 shown in FIG. 29 lies only in that a metal connector is not included, and this embodiment may be used as a comparison embodiment of the electronic device shown in FIG. 29.

[0204] FIG. 31 to FIG. 37 are diagrams of a simulation result of the antenna structure 200 in the electronic device shown in FIG. 29. FIG. 31 shows S parameter simulation results of the antenna structures in the electronic devices shown in FIG. 29 and FIG. 30. FIG. 32 is a Smith chart of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30. FIG. 33(a) to FIG. 33(d) are a diagram of current distribution of the antenna structure 200 in the electronic device shown in FIG. 29. FIG. 34(a) to FIG. 34(d) are a diagram of electric field distribution of the antenna structure 200 in the electronic device shown in FIG. 29. FIG. 35 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30. FIG. 36 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30 in an HL model. FIG. 37 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 29 and FIG. 30 in an HR model.

[0205] It should be understood that, for brevity of description, only an example in which a length of the first side frame is 40 mm, a length of the second side frame is 39 mm, a width of the first slot is 2 mm, a first electronic element is a 1.5-pF capacitor, and a second electronic element is a 0.3-pF capacitor is used for description in this embodiment of this application.

[0206] As shown in FIG. 31, both the antenna structure 200 shown in FIG. 29 and the antenna structure 300 shown in FIG. 30 may generate a first resonance and a second resonance near 0.9 GHz and 1 GHz. S11<-4 dB is used as a boundary. An operating bandwidth of the antenna structure 200 shown in FIG. 29 is greater than an operating bandwidth of the antenna structure 300 shown in FIG. 30.

[0207] As shown in FIG. 32, on a resonant frequency band corresponding to the first resonance and the second resonance, both an impedance curve of the antenna structure 300 shown in FIG. 30 and an impedance curve of the antenna structure 200 shown in FIG. 29 are close to a virtual circle center of the chart. The antenna structure 200 shown in FIG. 29 and the antenna structure 300 shown in FIG. 30 have good impedance matching on the resonant frequency band corresponding to the first resonance and the second resonance.

[0208] FIG. 33(a) and FIG. 33(b) are diagrams of current distribution in a case in which the antenna structure 200 in FIG. 29 separately generates the first resonance (for example, at 0.89 GHz) and generates the second resonance (for example, at 1.07 GHz).

[0209] At a first resonance point of the first resonance, a current on the first radiator and a current on the second radiator are in a same direction, as shown in FIG. 33(a). In addition, there are strong currents on the first radiator, the second radiator and a ground plane close to the radiator.

[0210] At a second resonance point of the second resonance, a current on the first radiator and a current on the second radiator are reverse in direction, as shown in FIG. 34(b). In addition, there are strong currents on both the second radiator and a ground plane close to the second radiator.

[0211] FIG. 33(c) and FIG. 33(d) are diagrams of current distribution in a case in which the antenna structure 300 in FIG. 30 separately generates the first resonance (for example, at 0.86 GHz) and generates the second resonance (for example, at 0.98 GHz).

[0212] At a first resonance point of the first resonance, a current on the first radiator and a current on the second radiator are in a same direction, as shown in FIG. 33(c). In addition, there are strong currents on both the first radiator and a ground plane close to the first radiator.

[0213] At a second resonance point of the second resonance, a current on the first radiator and a current on the second radiator are reverse in direction, as shown in FIG. 34(d). In addition, there are strong currents on both the second radiator and a ground plane close to the second radiator.

[0214] In the current distribution shown in FIG. 33(a) to FIG. 33(d), it may be understood that the first radiator and the second radiator that are connected to the metal connector present two modes, and may correspond to a half-wavelength mode of a common mode (current distribution shown in FIG. 33(a) and FIG. 33(c)) and a half-wavelength mode of a differential mode (current distribution shown in FIG. 33(b) and FIG. 33(d)).

[0215] FIG. 34(a) and FIG. 34(b) are diagrams of electric field distribution in a case in which the antenna structure 200 in FIG. 29 separately generates the first resonance (for example, at 0.89 GHz) and generates the second resonance (for example, at 1.07 GHz). FIG. 34(c) and FIG. 34(d) are diagrams of electric field distribution in a case in which the antenna structure 300 in FIG. 30 separately generates the first resonance (for example, at 0.86 GHz) and generates the second resonance (for example, at 0.98 GHz).

[0216] As shown in FIG. 34(a) to FIG. 34(d), an electric field of the antenna structure is mainly concentrated near a slot formed between the first radiator and the second radiator.

[0217] As shown in FIG. 35, compared with those of the antenna structure 300 shown in FIG. 30, the first resonance and the second resonance generated by the antenna structure 200 shown in FIG. 29 are more balanced, and an efficiency pit of radiation efficiency of the antenna structure 200 is shallower. In addition, in a case of using a boundary that total efficiency is greater than -5 dB, a bandwidth of the total efficiency of the antenna structure 200 shown in FIG. 29 is wider.

[0218] As shown in FIG. 36 and FIG. 37, in an HL model and an HR model, compared with those of the antenna structure 300 shown in FIG. 30, the bandwidth of the total efficiency and the pit of the radiation efficiency of the antenna structure 200 shown in FIG. 29 are still better.

[0219] FIG. 38 is a diagram of still another antenna structure 200 according to an embodiment of this application.

[0220] As shown in FIG. 38, the antenna structure 200 may include a radiator 202, a metal connector 230, and a feed element 240.

[0221] The radiator 202 may include a first ground point 213. Both a first end of a first radiator 210 and a first end of a second radiator 220 are electrically connected to the first ground point 213. The radiator 202 is coupled to a ground plane 201 at the first ground point 213 for grounding. In an embodiment, the radiator 202 may be an integrated structure. A first end (a second end of the first radiator 210) and a second end (a second end of the second radiator 220) of the radiator 202 are open ends.

[0222] In an embodiment, the radiator 202 is an integrated structure. In an embodiment, the first end of the first radiator 210 and the first end of the second radiator 220 coincide with or are directly connected to the first ground point 213.

[0223] The first radiator 210 includes a first connection point 211, and the second radiator 220 includes a second connection point 221. A first end of the metal connector 230 is coupled to the first connection point 211, and a second end of the metal connector 230 is coupled to the second connection point 221. The first radiator 210 further includes a feed point 212. The feed element 240 is coupled to the feed point 212, and feeds an electrical signal into the antenna structure 200 at the feed point 212.

[0224] It should be understood that the antenna structure 200 shown in FIG. 38 is the same as the metal connector 230 in the antenna structure 200 shown in FIG. 8. A difference between the two antenna structures lies only in that the first radiator 210 and the second radiator 220 have different open ends and ground ends. The antenna structure 200 shown in FIG. 38 may be similar to a T antenna. In an embodiment, the metal connector 230 is separately connected near an open end of the first radiator 210 and an open end of the second radiator 220, or the metal connector 230 is separately connected near a ground end of the first radiator 210 and a ground end of the second radiator 220. A length L of the metal connector 230, a length L1 of the first radiator 210, and a length L2 of the second radiator 220 satisfy the following: $(L1+L2)\times 30\% \leq L \leq (L1+L2)\times 50\%$.

[0225] It should be understood that the first end of the first radiator 210 and the first end of the second radiator

220 are opposite to, but do not touch each other. When both the first end of the first radiator 210 and the first end of the second radiator 220 are open ends or ground ends, the metal connector 230 also needs to at least have a length for connecting two radiators near the first end of the first radiator 210 and near the first end of the second radiator 220. Because first impedance conditions at the first end of the first radiator 210 and the first end of the second radiator 220 are the same or similar, the metal connector 230 may be set to an electrical length which is an odd multiple of a 1/4 wavelength. In an embodiment during actual application, a length D2 of the metal connector 230, the length L1 of the first radiator 210, and the length L2 of the second radiator 220 satisfy the following: $(L1+L2) \times 30\% \leq D2 \leq (L1+L2) \times 50\%$.

[0226] In an embodiment, the first metal connector 230 is configured to transmit, to the second radiator 220, the electrical signal fed by the feed element 240 at the feed point 240, where no other feed point coupled to the feed element 240 is disposed on the second radiator 220. It should be understood that the feed element 240 may correspond to a feed element of a single antenna in a radio frequency channel.

[0227] By disposing the first metal connector 230, the antenna structure 200 shown in FIG. 38 is similar to the antenna structure 200 shown in FIG. 8. The first radiator 210 and the second radiator 220 are configured to generate a first resonance and a second resonance, where the first resonance and the second resonance are connected resonances and have a connection frequency.

[0228] In the antenna structure 200, the first connection point 211 may be located between the first end of the first radiator 210 and the feed point 212, as shown in FIG. 38. Alternatively, the first connection point 211 may be located between the second end of the first radiator 210 and the feed point 212, as shown in FIG. 39.

[0229] As shown in FIG. 38, the first connection point 211 is located between the first end (the first ground point 213) of the first radiator 210 and the feed point 212.

[0230] In an embodiment, a length of a radiator between the feed point 212 and the first ground point 213 is less than a half of a length L1 of the first radiator.

[0231] In an embodiment, a length D1 of the radiator between the feed point 212 and the first connection point 211 is greater than or equal to 0.5 mm.

[0232] In an embodiment, the length of the radiator between the first ground point 213 and the first connection point 211 is greater than or equal to 0, or the length of the radiator between the first ground point 213 and the second connection point 221 is greater than or equal to 0. It should be understood that in the antenna structure 200 shown in FIG. 38, the first connection point 211 or the second connection point 221 may be the same as the first ground point 213. For example, a length of a radiator between the first connection point 211 or the second connection point 221 and the first ground point 213 is 0. When the connection point is the same as the first ground point 213, a third electronic element needs to be disposed between a ground position of the first radiator 210 and the ground plane 201, so that the antenna 200 can have a good radiation characteristic. In an embodiment, the third electronic element may be inductive, for example, may be an inductor, or an element equivalent to an inductor. In an embodiment, an inductance value (an equivalent inductance value) of the third electronic element may be less than or equal to 10 nH.

[0233] In an embodiment, the length D1 of the radiator between the feed point 212 and the first connection point 211 and the length L1 of the first radiator 210 satisfy the following: $L1 \times 10\% \leq D1 \leq L1 \times 25\%$. When the metal connector 230, the first radiator 210, and the second radiator 220 are of an integrated structure, the first connection point 211 may be located between the second end (the first end of the radiator 202) of the first radiator 210 and the feed point 212. No electronic element is disposed between the metal connector 230 and the first radiator 210 or the second radiator 220. In an embodiment, the first end of the metal connector 230 is connected to the first connection point, the second end of the metal connector 230 is connected to the second connection point, and the length D2 of the metal connector 230, the length L1 of the first radiator, and the length L2 of the second radiator satisfy the following: $(L1+L2) \times 30\% \leq D2 \leq (L1+L2) \times 50\%$.

[0234] In an embodiment, a width of a slot formed by the metal connector 230, the first radiator 210, and the second radiator 220 is less than or equal to 1 mm. In an embodiment, that a width of a slot is less than or equal to 1 mm may be understood as that a maximum distance between any point on the metal connector 230 and the first radiator 210 or the second radiator 220 is less than or equal to 1 mm. In an embodiment, that a width of a slot is less than or equal to 1 mm may be understood as that a width of an area occupied by the metal connector 230 is less than 1 mm.

[0235] In an embodiment, the length D1 of the radiator between the feed point 212 and the first connection point 211 is greater than or equal to 0.5 mm.

[0236] In an embodiment, the antenna structure 200 shown in FIG. 38 and FIG. 39 may be used in the electronic device 10 shown in FIG. 1, as shown in FIG. 40 and FIG. 41.

[0237] In an embodiment, the side frame 11 of the electronic device 10 may have a first position 111, a second position 112, and a third position 113, and the second position 112 is located between the first position 111 and the third position 113. The radiator 202 may include at least a part of a side frame between the first position 111 and the third position 113, and the second position 112 may be the first ground point 213. The first radiator 210 includes at least a part of a first side frame between the first position 111 and the second position 112, and the second radiator 220 includes at least a part of a second side frame between the second position 112 and the third position 113. The side frame 11 may be provided with a gap at each of the first position 111 and the third position 113, so that the second end (the first end of the radiator 202) of the first radiator 210 and the second end (the second end of the radiator 202) of the second radiator 220 are open ends.

[0238] In an embodiment, the side frame 11 may include a first side 121 and a second side 122 that intersect at an angle. The first position 111 may be located on the first side 121, and the second position 112 and the third position 113 may be located on the second side 122. When the first side frame is in an L shape, a transverse mode on the ground plane 201 may be excited when the feed element feeds an electrical signal, to improve radiation performance of the antenna structure 200. It should be understood that the first position 111, the second position 112, and the third position 113 on the side frame 11 are not limited in this embodiment of this application, and may be determined based on actual production or design.

[0239] FIG. 42 and FIG. 43 are diagrams of still another electronic device 10 according to an embodiment of this application.

[0240] As shown in FIG. 42, the electronic device 10 may include an antenna structure 400.

[0241] It should be understood that a difference between the antenna structure 400 shown in FIG. 42 and the antenna structure 200 shown in FIG. 40 or FIG. 41 lies only in that a feed point is disposed on a metal connector, and a feed element is coupled to the metal connector to feed an electrical signal. This embodiment may be used as a comparison embodiment of the electronic device shown in FIG. 40 or FIG. 41.

[0242] As shown in FIG. 43, the electronic device 10 may include an antenna structure 500.

[0243] It should be understood that a difference between the antenna structure 400 shown in FIG. 43 and the antenna structure 200 shown in FIG. 40 or FIG. 41 lies only in that a metal connector is not included, a feed point is disposed on a first radiator, and a feed element is coupled to the first radiator to feed an electrical signal. This embodiment may be used as a comparison embodiment of the electronic device shown in FIG. 40 or FIG. 41.

[0244] FIG. 44 to FIG. 49 are diagrams of a simulation result of the antenna structure 200 in the electronic device shown in FIG. 40. FIG. 44 shows S parameter simulation results of antenna structures in the electronic devices shown in FIG. 40, FIG. 42, and FIG. 43. FIG. 45 is a diagram of current distribution of the antenna structure 200 in the electronic device shown in FIG. 40. FIG. 46 is a diagram of electric field distribution of the antenna structure 200 in the electronic device shown in FIG. 40. FIG. 47 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 40, FIG. 42, and FIG. 43. FIG. 48 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 40 and FIG. 43 in an HL model. FIG. 49 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 40 and FIG. 43 in an HR model.

[0245] It should be understood that, for brevity of description, only an example in which a length of a side frame between the first position and the third position is 111 mm, and a width of a gap between the first position and the third position is 2 mm is used for description in this embodiment of this application.

[0246] As shown in FIG. 44, the antenna structure 200 shown in FIG. 40, the antenna structure 400 shown in FIG. 42, and the antenna structure 500 shown in FIG. 43 all may generate a first resonance and a second resonance near 0.85 GHz and 0.95 GHz. S11<-4 dB is used as a boundary. An operating bandwidth of the antenna structure 200 shown in FIG. 40 is greater than an operating bandwidth of the antenna structure 500 shown in FIG. 43, and is greater than an operating bandwidth of the antenna structure 400 shown in FIG. 42.

[0247] (a) and (b) in FIG. 45 are diagrams of current distribution in a case in which the antenna structure 200 in FIG. 40 separately generates the first resonance (for example, at 0.84 GHz) and generates the second resonance (for example, at 0.93 GHz).

[0248] At a first resonance point of the first resonance, a current on the first radiator and a current on the second radiator are reverse in direction, as shown in (a) in FIG. 45. In addition, there are strong currents on both the first radiator and a ground plane close to the first radiator.

[0249] At a second resonance point of the second resonance, a current on the first radiator and a current on the second radiator are in a same direction, as shown in (b) in FIG. 45. In addition, there are strong currents on both the second radiator and a ground plane close to the second radiator.

[0250] In the current distribution shown in FIG. 45, it may be understood that the first radiator and the second radiator that are connected to the metal connector present two modes, and may correspond to a half-wavelength mode of a common mode (current distribution shown in (a) in FIG. 45) and a half-wavelength mode of a differential mode (current distribution shown in (b) in FIG. 45).

[0251] (a) and (b) in FIG. 46 are diagrams of electric field distribution in a case in which the antenna structure 200 in FIG. 40 separately generates the first resonance (for example, at 0.84 GHz) and generates the second resonance (for example, at 0.93 GHz).

[0252] As shown in (a) in FIG. 46, there is a strong electric field near the first radiator. As shown in (b) in FIG. 46, there is a strong electric field near the second radiator.

[0253] It should be understood that, in the antenna structure 200 shown in FIG. 40, in the first resonance, a current and an electric field are mainly concentrated on the first radiator and a nearby area, and in the second resonance, a current and an electric field are mainly concentrated on the second radiator and a nearby area. Compared with those of the antenna structure 400 shown in FIG. 42 and the antenna structure 500 shown in FIG. 43, a conductor loss and a dielectric loss of the antenna structure 200 shown in FIG. 40 in the first resonance are smaller.

[0254] As shown in FIG. 47, compared with those of the antenna structure 400 shown in FIG. 42 and the antenna structure 500 shown in FIG. 43, the first resonance and the second resonance generated by the antenna structure 200 shown in FIG. 40 are more balanced, and an efficiency pit of radiation efficiency of the antenna structure 200 is shallower. In addition, in a case of using a boundary that total efficiency is greater than -5 dB, a bandwidth of the total efficiency of the antenna structure 200 shown in FIG. 40 is wider.

[0255] As shown in FIG. 48 and FIG. 49, in an HL model and an HR model, compared with those of the antenna structure 500 shown in FIG. 43, the bandwidth of the total efficiency and the pit of the radiation efficiency of the antenna structure 200 shown in FIG. 40 are still better.

[0256] FIG. 50 to FIG. 53 are diagrams of a simulation result of the antenna structure 200 in the electronic device shown in FIG. 41. FIG. 50 shows S parameter simulation results of antenna structures in the electronic devices shown in FIG. 41 and FIG. 43. FIG. 51 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 41 and FIG. 43. FIG. 52 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 41 and FIG. 43 in an HL model. FIG. 53 shows simulation results of total efficiency and radiation efficiency of antenna structures in the electronic devices shown in FIG. 41 and FIG. 43 in an HR model.

[0257] As shown in FIG. 50, both the antenna structure 200 shown in FIG. 41 and the antenna structure 500 shown in FIG. 43 may generate a first resonance and a second resonance near 0.85 GHz and 0.93 GHz. S11<-4 dB is used as a boundary. An operating bandwidth of the antenna structure 200 shown in FIG. 41 is greater than an operating bandwidth of the antenna structure 500 shown in FIG. 43.

[0258] As shown in FIG. 51, compared with those of the antenna structure 500 shown in FIG. 43, the first resonance and the second resonance generated by the antenna structure 200 shown in FIG. 41 are more balanced, and an efficiency pit of radiation efficiency of the antenna structure 200 is shallower. In addition, in a case of using a boundary that total efficiency is greater than -5 dB, a bandwidth of the total efficiency of the antenna structure 200 shown in FIG. 29 is wider. In addition, on a resonant frequency band corresponding to the first resonance and the second resonance, compared with those of the antenna structure 500 shown in FIG. 43, both system efficiency and radiation efficiency of the antenna structure 200 shown in FIG. 41 are improved.

[0259] As shown in FIG. 52 and FIG. 53, in an HL model and an HR model, compared with those of the antenna structure 500 shown in FIG. 43, the bandwidth of the total efficiency and the pit of the radiation efficiency of the antenna structure 200 shown in FIG. 41 are still better.

[0260] FIG. 54 and FIG. 55 are diagrams of still another antenna structure 200 according to an embodiment of this application.

[0261] As shown in FIG. 54, a difference between the antenna structure 200 and the antenna structure 200 shown in FIG. 8 lies only in that a position of the feed point 212 is different. In the antenna structure 200 shown in FIG. 8, a length of a radiator between the feed point 212 and the first ground point 213 is less than a half of a length L1 of the first radiator 210, so that the first radiator 210 may form a structure similar to an IFA.

[0262] It should be understood that, in actual application, the feed point 212 may alternatively be disposed at a second end close to the first radiator 210 based on an internal layout of the electronic device (a length of a radiator between the feed point 212 and the first ground point 213 is greater than a half of a length L1 of the first radiator 210), so that the first radiator 210 may form a structure similar to a CRLH.

[0263] Similarly, as shown in FIG. 55, a difference between the antenna structure 200 and the antenna structure 200 shown in FIG. 38 lies only in that a position of the feed point 212 is different, and a length of a radiator between the feed point 212 and the first ground point 213 is greater than a half of a length L1 of the first radiator 210.

[0264] It should be understood that the position of the feed point is not limited in this embodiment of this application, and may be flexibly adjusted based on a design or production requirement.

[0265] FIG. 56 and FIG. 57 are diagrams of still another antenna structure 200 according to an embodiment of this application.

[0266] As shown in FIG. 56, a difference between the antenna structure 200 and the antenna structure 200 shown in FIG. 8 lies only in that a position of the first ground point 213 is different. In the antenna structure 200 shown in FIG. 8, the first ground point 213 is disposed at a first end of the first radiator 210, so that the first radiator 210 may form a structure similar to an IFA. In the antenna structure 200 shown in FIG. 56, the first radiator 210 is divided into a first part and a second part by using the first ground point 213, to form a structure similar to a T-shaped antenna.

[0267] In an embodiment, a length of the first part is greater than a length of the second part (for example, a length difference is greater than or equal to 5 mm), and the feed point 212 is disposed on the first part. In an embodiment, when an electrical signal is fed at the feed point 212, a resonance may be separately generated by the first part and the second part, and a frequency of the resonance generated by the second part is greater than a frequency of the resonance generated by the first part, to expand an operating frequency band of the antenna structure 200.

[0268] As shown in FIG. 57, a difference between the antenna structure 200 and the antenna structure 200 shown in FIG. 8 lies only in that a position of the second ground point 223 is different. Similarly, the second radiator 220 is divided into a first part and a second part by using the second ground point 223, to form a structure similar to a T-shaped antenna. In an embodiment, when a length of the first part is greater than a length of the second part (for example, a length difference is greater than or equal to 5 mm), the first part and the second part separately generate a resonance, to expand an operating frequency band of the antenna structure 200.

[0269] It should be understood that a difference between the antenna structure 200 shown in FIG. 56 and FIG. 57 and the antenna structure 200 in the foregoing embodiment lies only in that a radiator at one end on one side of the ground point is extended for generating a high-frequency resonance (for example, a 1/4 mode of a monopole antenna), does not affect the antenna structure in the foregoing embodiment, and may be used in all structures provided in the embodiments of this application.

[0270] FIG. 58 and FIG. 59 are diagrams of still another antenna structure 200 according to an embodiment of this application.

[0271] As shown in FIG. 58, a difference between the antenna structure 200 and the antenna structure 200 shown in FIG. 8 lies only in that the antenna structure may further include a third radiator 310.

[0272] In an embodiment, the third radiator 310 may be used as a parasitic stub of the first radiator 210 or the second radiator 220, and is configured to generate an additional resonance. In an embodiment, the third radiator 310 is not configured to generate an additional resonance, or in other words, is not configured to generate an additional in-band resonance. The third radiator 310 may be completely disposed between the first radiator 210 and the second radiator 220. In an embodiment, at least a part of the first radiator 210 and at least a part of the second radiator 220 are disposed close to a bottom edge of the electronic device, or include a first bottom edge part of a conductive side frame. The third radiator 310 may be disposed close to the bottom edge of the electronic device, or include a second bottom edge part of the conductive side frame.

[0273] In an embodiment, as shown in FIG. 58, a first end of the third radiator 310 and a first end of the first radiator 210 are opposite to, but do not touch each other; and a second end of the third radiator 310 and a first end of the second radiator 220 are opposite to, but do not touch each other. In an embodiment, a first gap is formed between the first radiator 210 and the third radiator 310, a second gap is formed between the second radiator 220 and the third radiator 310, and the first gap and the second gap may be symmetrical gaps provided on the bottom edge of the conductive side frame. **In** an embodiment, the first end of the third radiator 310 may be a ground end, and the second end of the third radiator 320 may be an open end, as shown in FIG. 58.

[0274] In an embodiment, both the first end and the second end of the third radiator 310 may be open ends, as shown in FIG. 59.

[0275] In an embodiment, a length of the third radiator 310 may be approximately the same as a length of the second radiator 220 (the length L3 of the third radiator 310 and the length L2 of the second radiator 220 satisfy the following: $L2\times90\%\leq L3\leq L2\times120\%$).

[0276] In an embodiment, the third radiator 310 and the second radiator 220 may jointly generate two co-frequency resonances with high isolation (the co-frequency may be understood as including a same operating frequency band), and may be used in a multi-input multi-output (multi-input multi-output, MIMO) system.

[0277] In an embodiment, the length of the third radiator 310 is less than a length of the second radiator 220. A resonant frequency of a resonance generated by the third radiator 310 may be higher than a resonant frequency of a resonance generated by the second radiator 220. In an embodiment, a frequency of a resonance point of the resonance generated by the second radiator 220 may be between 700 MHz and 2.7 GHz, and a frequency of a resonance point of the resonance generated by the third radiator 310 may be greater than 3 GHz, so that there is good isolation between the resonance generated by the third radiator 310 and the resonance generated by the second radiator 220.

[0278] It should be understood that a difference between the antenna structure 200 shown in FIG. 58 and FIG. 59 and the antenna structure 200 in the foregoing embodiment lies only in that the third radiator 310 is disposed between the first radiator 210 and the second radiator 220. Whether the third radiator 310 generates an additional in-band resonance does not affect the antenna structure in the foregoing embodiment, and the third radiator 310 may be used in all structures provided in this embodiment of this application.

[0279] FIG. 60 is a diagram of still another antenna structure 200 according to an embodiment of this application.

[0280] As shown in FIG. 60, a difference between the antenna structure 200 and the antenna structure 200 shown in FIG. 8 lies only in that the antenna structure may further include a third radiator 310 and a metal connector 320.

[0281] As shown in FIG. 60, a first end of the third radiator 310 and a second end of the second radiator 220 may be opposite to, but do not touch each other. The second radiator 220 includes a third connection point 224 (the third connection point 224 is located between a second connection point and a second ground element), and the third radiator 310 includes a fourth connection point 311.

[0282] A first end of the metal connector 320 is coupled to the third connection point 224, and a second end of the metal connector 320 is coupled to the fourth connection point 311. A second end of the third radiator 310 includes a third ground point 313 and the third radiator 310 is coupled to a ground plane 201 at the third ground point 313 for grounding. The first end of the third radiator 310 may be an open end, and the second end of the third radiator 320 may be a ground end. In an embodiment, the third radiator 310 may form a structure similar to a CRLH.

[0283] When an electrical signal is fed at the feed point 212, the antenna structure 200 may generate a first resonance, a second resonance, and a third resonance, and a resonant frequency of the first resonance is lower than a resonant frequency of the second resonance and is lower than a resonant frequency of the third resonance. An operating frequency band of the antenna structure 200 may include a first frequency band, a second frequency band, and a third frequency band. The first frequency band may correspond to a resonant frequency band of the first resonance, the second frequency band may correspond to a resonant frequency band of the second resonance, and the third frequency band may correspond to a resonant frequency band of the third resonance.

[0284] Lengths of the metal connectors 230 and 320 may be less than a quarter of a third wavelength, and the third wavelength may be understood as a wavelength corresponding to the third resonance. The metal connectors 230 and 320 are configured to transmit, to the second radiator 220 and the third radiator 310, the electrical signal fed at the feed point 212.

[0285] It should be understood that a plurality of radiators may be cascaded via the metal connectors 230 and 320, so that the antenna structure generates a plurality of resonances, to expand an operating frequency band of the antenna structure 200. In this embodiment of this application, a quantity of metal connectors 230 and specific settings of the open end and the ground end of the third radiator 310 are not limited (for example, positions of the open end and the ground end may be interchanged, or both the first end and the second end are ground ends or open ends), and may be determined based on actual production or design.

[0286] In addition, the foregoing cascaded structure may be used in any antenna structure in the foregoing embodiments, or a structure formed by some radiators of any antenna structure. This is not limited in this embodiment of this application, and may be adjusted based on an actual layout.

[0287] 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 the units is merely logical functional division and may be other division in 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.

[0288] 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 antenna structure, comprising:

a radiator, comprising a first radiator and a second radiator;

a feed element, wherein the first radiator comprises a feed point, and the feed element is coupled to the feed point; and

a first metal connector, wherein the first radiator comprises a first connection point, the second radiator comprises a second connection point, a first end of the first metal connector is coupled to the first connection point, a second end of the first metal connector is coupled to the second connection point, the radiator is configured to generate a first resonance and a second resonance, and a frequency of the first resonance is lower than a frequency of the second resonance, wherein

a length L of the first metal connector, a length L1 of the first radiator, and a length L2 of the second radiator satisfy the following: $(L1+L2)/32 \le L \le (L1+L2)/2$.

2. The antenna structure according to claim 1, wherein

a first end of the first radiator comprises a first ground point, the first radiator is grounded at the first ground point, and a second end of the first radiator is an open end; and

a first end of the second radiator is an open end, a second end of the second radiator comprises a second ground point, and the second radiator is grounded at the second ground point.

3. The antenna structure according to claim 1, wherein

the radiator comprises a first ground point, and the radiator is grounded at the first ground point; and

both a first end of the first radiator and a first end of the second radiator are electrically connected to the first ground point, and a second end of the first radiator and a second end of the second radiator are open ends.

4. The antenna structure according to claim 1, wherein a first end of the first radiator is an open end, a second end of the first radiator comprises a first ground point, and the first radiator is grounded at the first ground point; and

a first end of the second radiator is an open end, a second end of the second radiator comprises a second ground point, and the second radiator is grounded at the second ground point.

5. The antenna structure according to claim 2 or 4, wherein the first end of the first radiator and the first end of the second radiator are opposite to, and do not touch each other.

6. The antenna structure according to claim 3, wherein the first end of the first radiator and the first end of the second radiator coincide with or are directly connected to the first ground point.

7. The antenna structure according to claim 2 or 3, wherein

at a first resonance point of the first resonance, a current on the first radiator and a current on the second radiator are reverse in direction; and

at a second resonance point of the second resonance, the current on the first radiator and the current on the second radiator are in a same direction.

8. The antenna structure according to claim 4, wherein

at a first resonance point of the first resonance, a current on the first radiator and a current on the second radiator are in a same direction; and

at a second resonance point of the second resonance, the current on the first radiator and the current on the second radiator are reverse in direction.

9. The antenna structure according to any one of claims 2 to 8, wherein
the first connection point is located between the first end of the first radiator and the feed point, and a length of a radiator between the feed point and the first ground point is less than a half of the length L1 of the first radiator.

10. The antenna structure according to claim 9, wherein a length D1 of a radiator between the feed point and the first connection point and the length L1 of the first radiator satisfy the following: $L1\times10\%\leq D1\leq L1\times25\%$.

11. The antenna structure according to claim 3 or 4, wherein

the first end of the first metal connector is connected to the first connection point, the second end of the first metal connector is connected to the second connection point, and the length L of the first metal connector, the length L1 of the first radiator, and the length L2 of the second radiator satisfy the following: $(L1+L2)\times30\%\leq L\leq(L1+L2)\times50\%$, wherein

the first connection point is located between the first end of the first radiator and the feed point.

12. The antenna structure according to claim 2, wherein

the first end of the first metal connector is connected to the first connection point, the second end of the first metal connector is connected to the second connection point, and the length L of the first metal connector, the length L1 of the first radiator, and the length L2 of the second radiator satisfy the following: $0<L\leq(L1+L2)\times30\%$, wherein

the first connection point is located between the first end of the first radiator and the feed point.

13. The antenna structure according to claim 11 or 12, wherein the first metal connector, the first radiator, and the second radiator are of an integrated structure.

14. The antenna structure according to any one of claims 1 to 13, wherein
the length D1 of the radiator between the feed point and the first connection point is greater than or equal to 0.5 mm.

15. The antenna structure according to any one of claims 1 to 14, wherein

the antenna structure further comprises a first electronic element and a second electronic element;

the first electronic element is electrically connected between the first end of the first metal connector and the first connection point; and

the second electronic element is electrically connected between the second end of the first metal connector and the second connection point.

16. The antenna structure according to any one of claims 1 to 15, wherein

the first connection point is the same as the first ground point; and

the antenna structure further comprises a third electronic element, and the third electronic element is electrically connected between the first ground point and a ground plane.

17. The antenna structure according to any one of claims 1 to 16, wherein
the length L1 of the first radiator and the length L2 of the second radiator satisfy the following: $L2\times90\%\leq L1\leq L2\times120\%$.

18. The antenna structure according to any one of claims 1 to 17, wherein

the antenna structure further comprises a second metal connector, and the radiator further comprises a third radiator, wherein
a first end of the third radiator comprises a third ground point, the third radiator is grounded at the third ground point, a second end of the third radiator is an open end, the second radiator comprises a third connection point, and the third radiator comprises a fourth connection point;
a first end of the second metal connector is coupled to the third connection point, and a second end of the second metal connector is coupled to the fourth connection point; and
the length L1 of the first radiator and a length L3 of the third radiator satisfy the following: $L3\times90\%\leq L1\leq L3\times120\%$.

19. An electronic device, comprising the antenna structure according to any one of claims 1 to 18.

20. The electronic device according to claim 19, wherein

the electronic device further comprises a conductive side frame, wherein
the side frame has a first position, a second position, and a third position, the second position is located between the first position and the third position, the first radiator comprises at least a part of a first side frame between the first position and the second position, and the second radiator comprises at least a part of a second side frame between the second position and the third position.

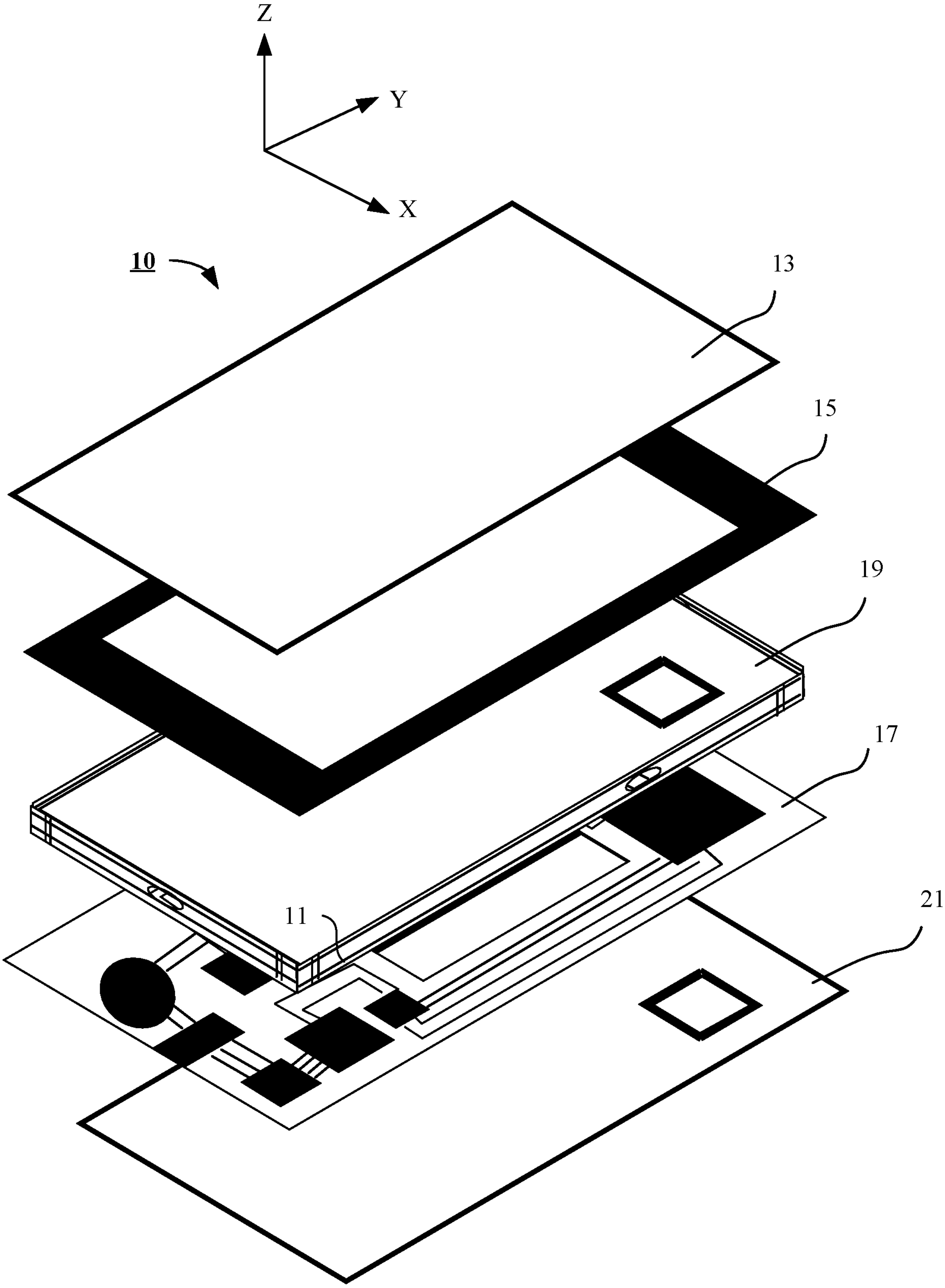


FIG. 1

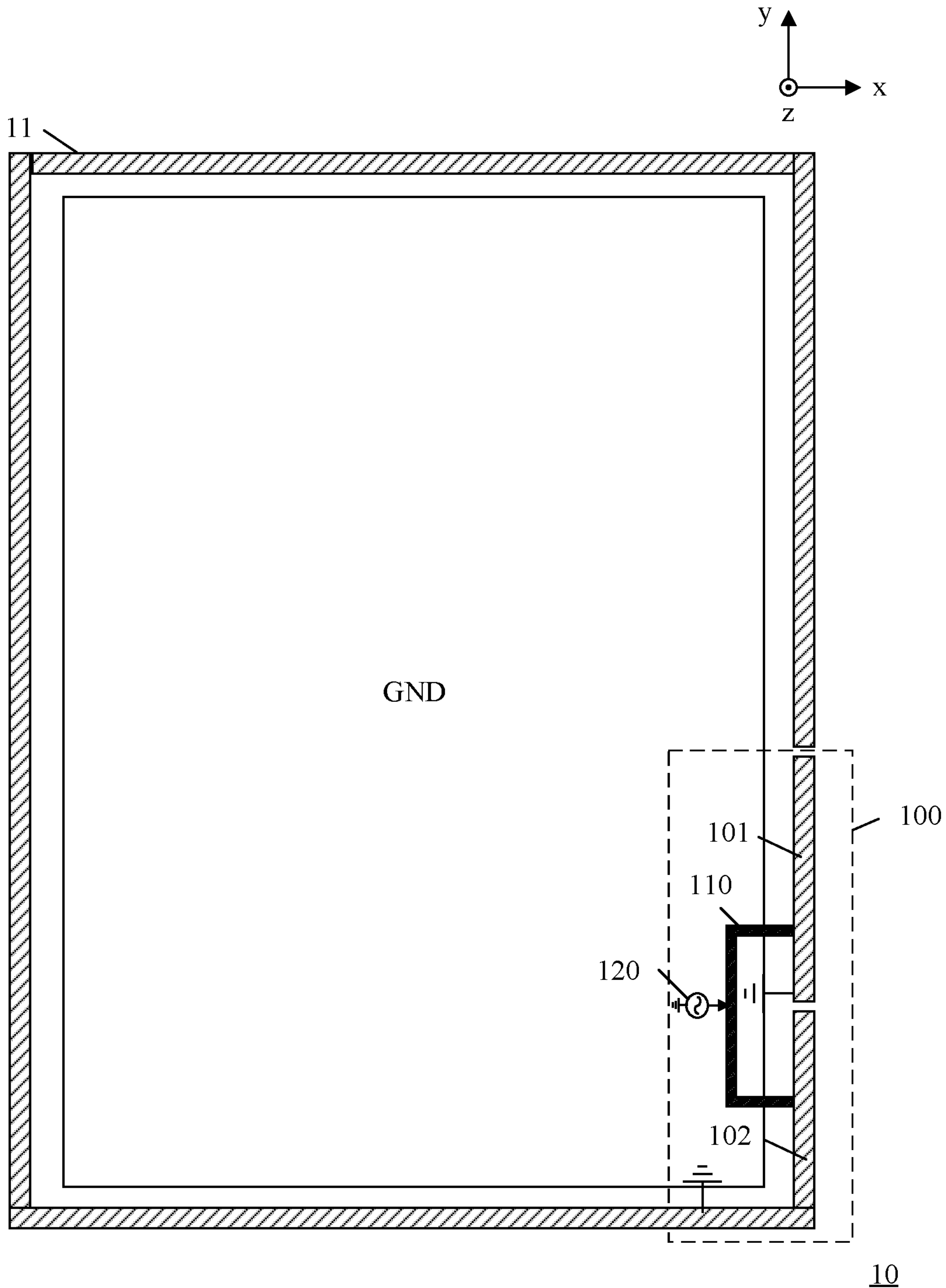


FIG. 2

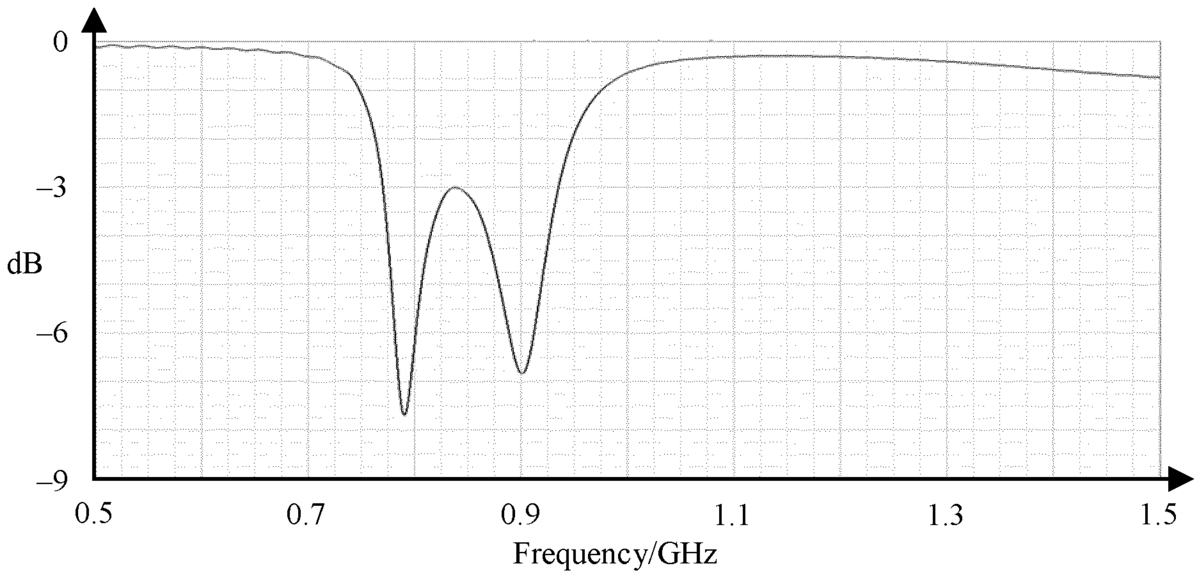

0
−3
dB
−6
−9
0.5
0.7
0.9
1.1
1.3
1.5
Frequency/GHz

FIG. 3

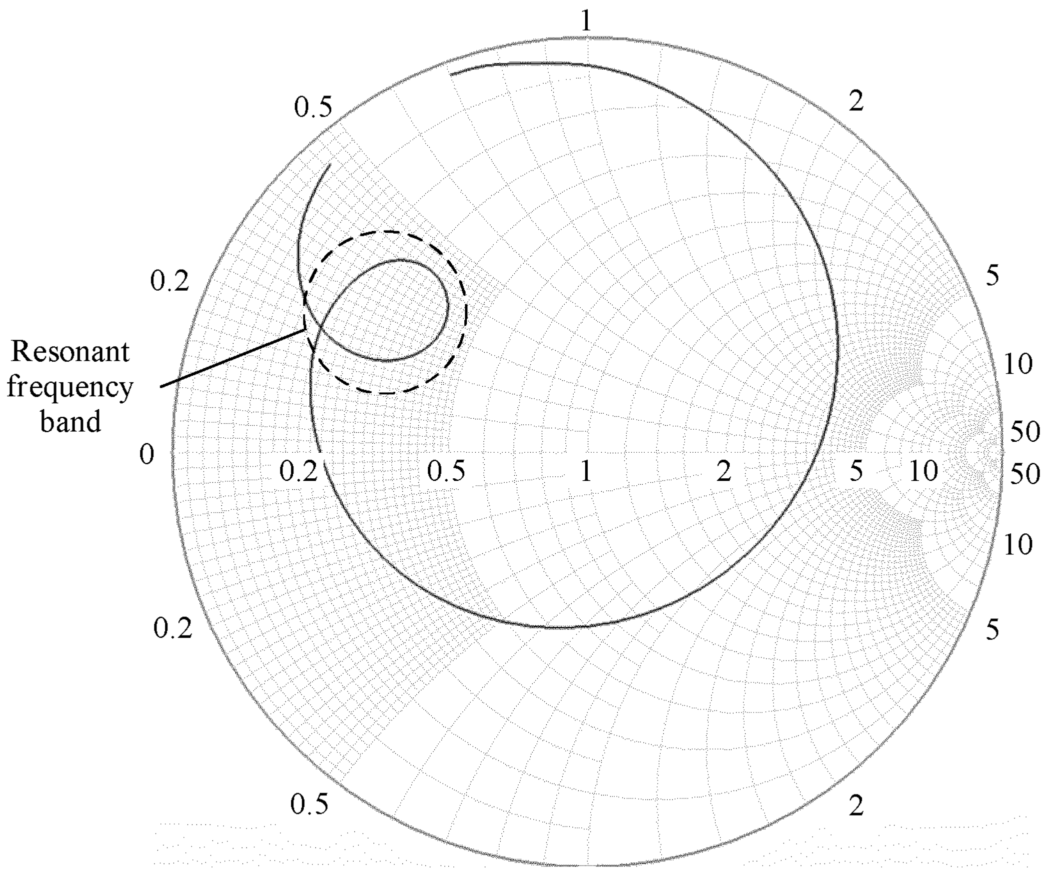
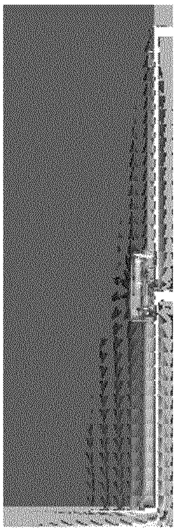
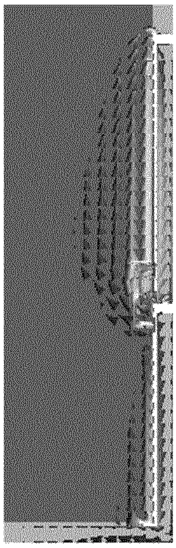

1
0.5
2
0.2
5
Resonant frequency band
10
0
50
0.2
0.5
1
2
5
10
50
10
0.2
5
0.5
2

FIG. 4

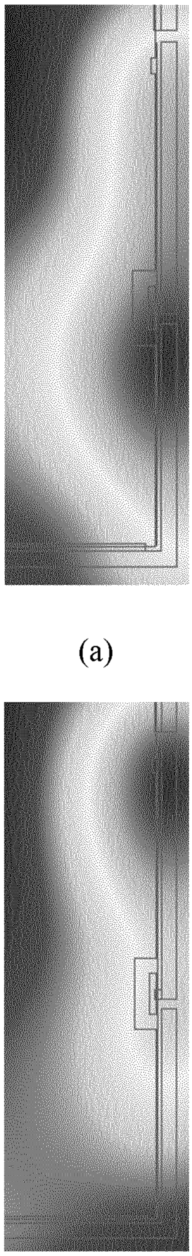


(a)



(b)

FIG. 5



(a)

(b)

FIG. 6

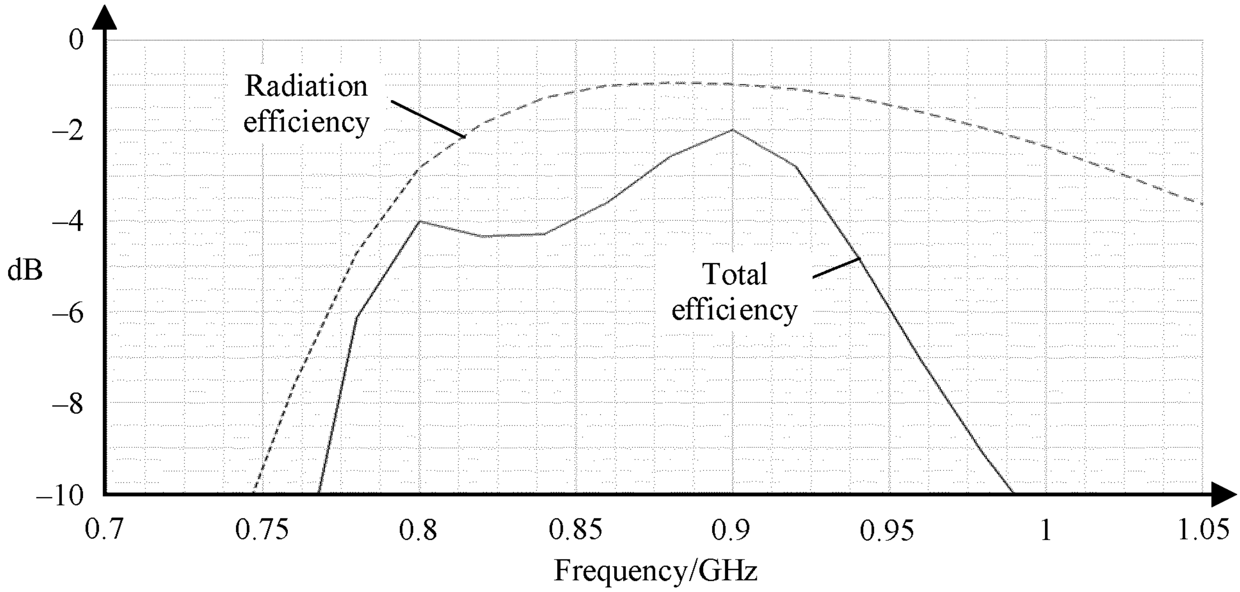

0
−2
−4
dB
−6
−8
−10
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
Frequency/GHz
Radiation efficiency
Total efficiency

FIG. 7

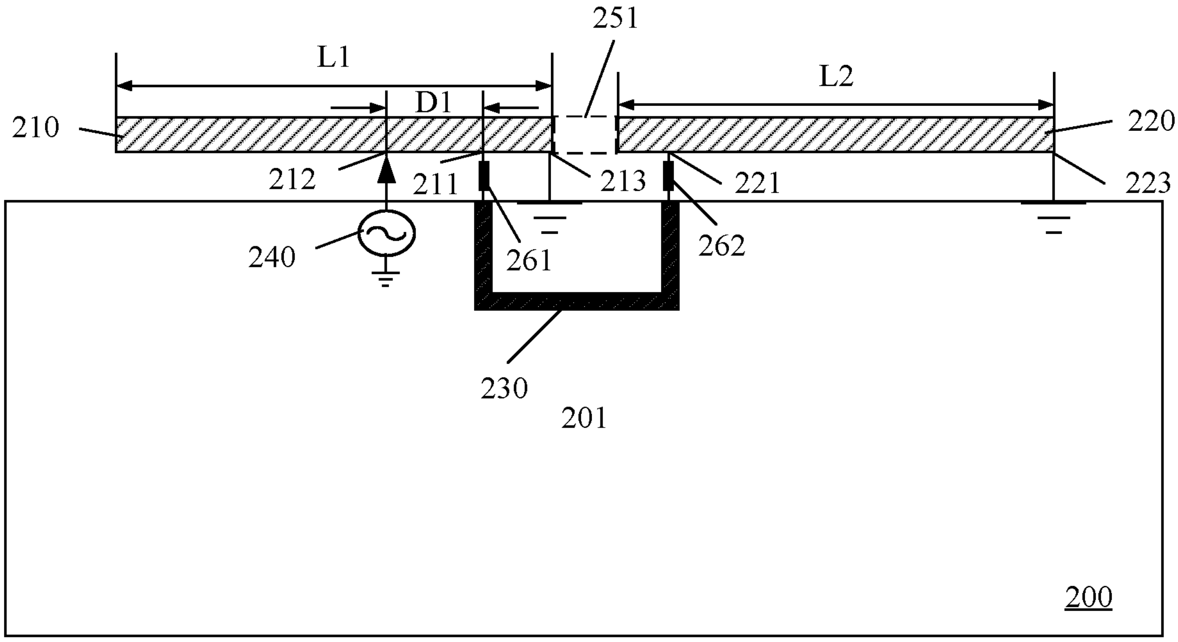

251
L1
L2
D1
210
220
212
211
213
221
223
240
261
262
230
201
200

FIG. 8

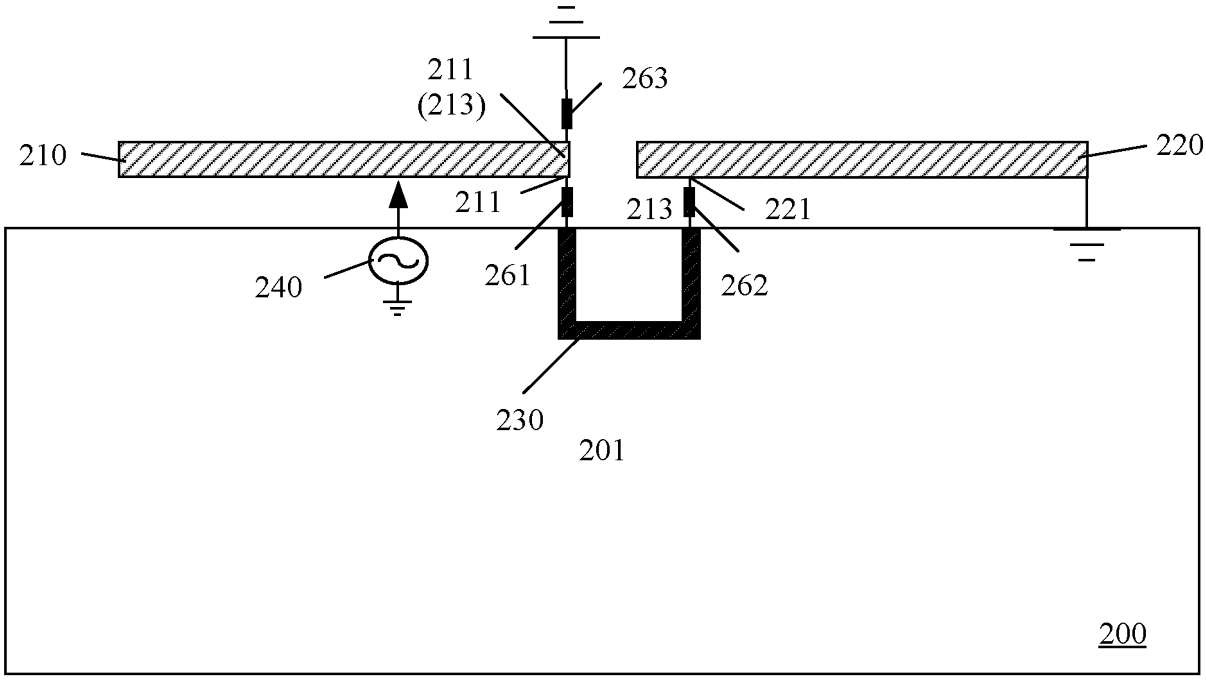


FIG. 9

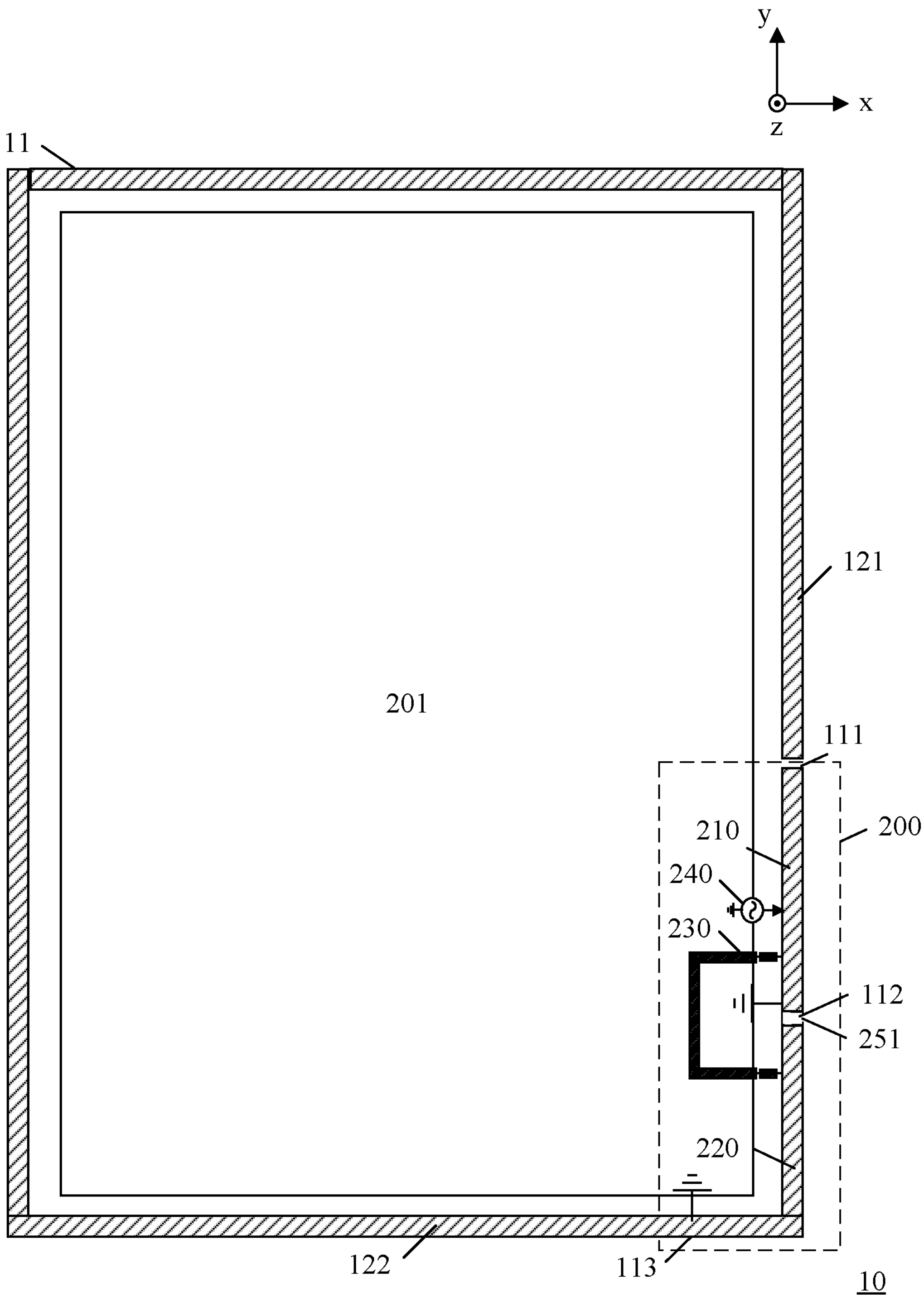
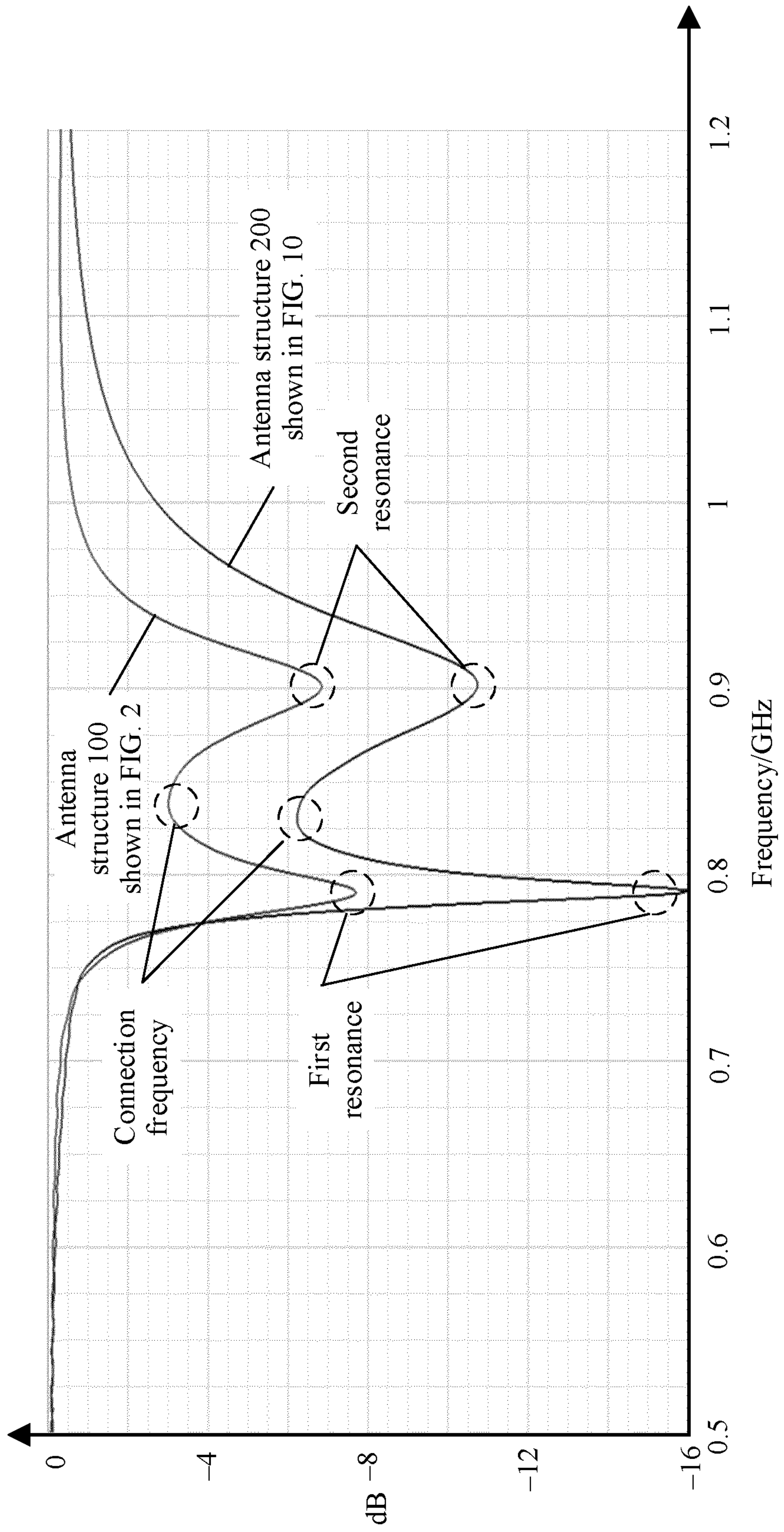


FIG. 10



dB
0
−4
−8
−12
−16
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
Frequency/GHz
Antenna structure 200 shown in FIG. 10
Antenna structure 100 shown in FIG. 2
Second resonance
Connection frequency
First resonance

FIG. 11

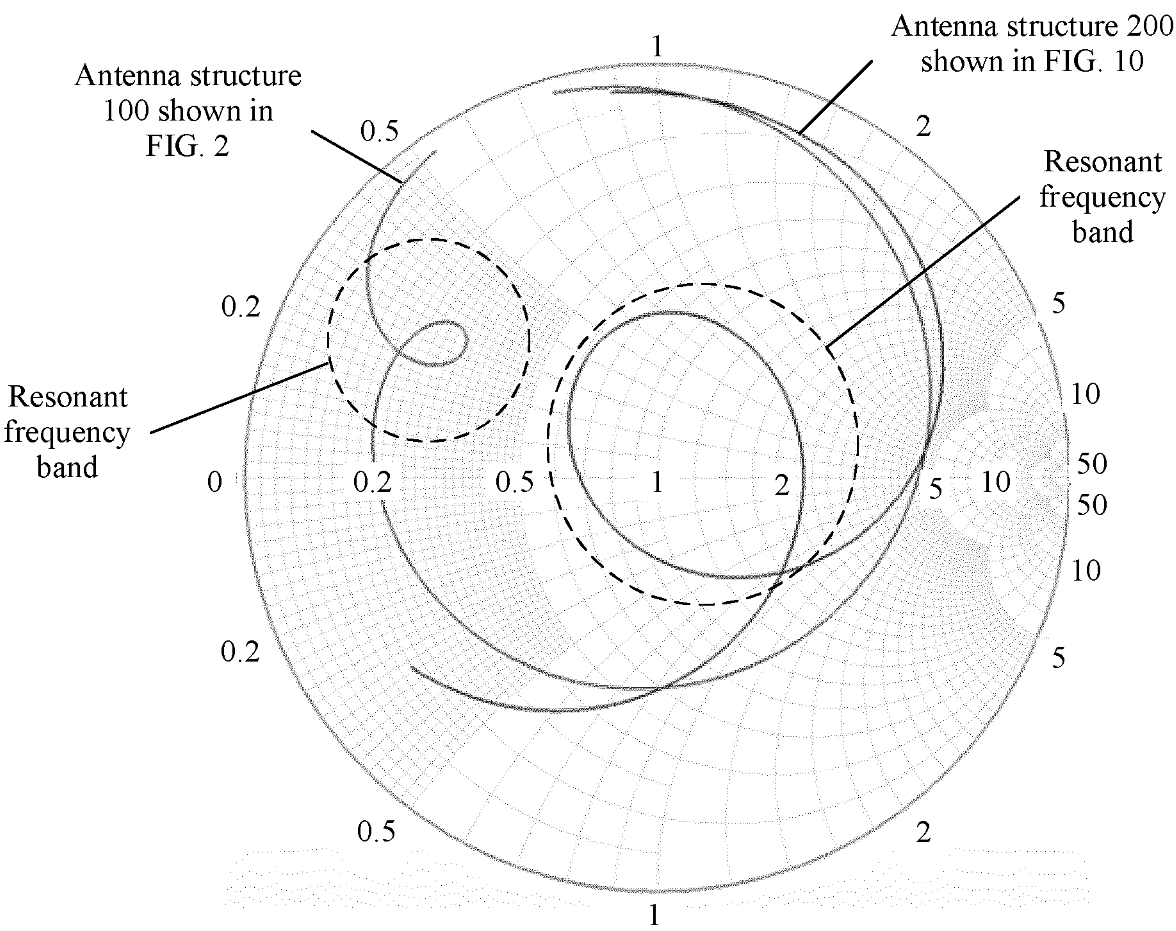
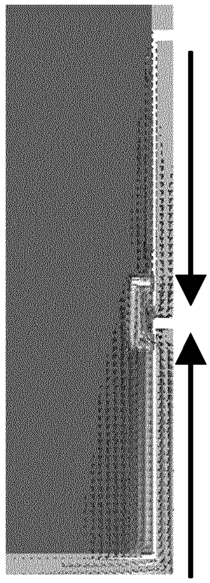
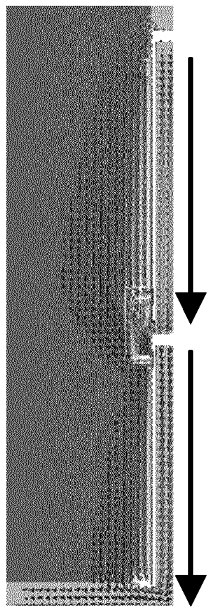

Antenna structure 200 shown in FIG. 10
Antenna structure 100 shown in FIG. 2
Resonant frequency band
Resonant frequency band
1
0.5
2
0.2
5
10
0
0.2
0.5
1
2
5
10
50
50
10
0.2
5
0.5
2
1

FIG. 12

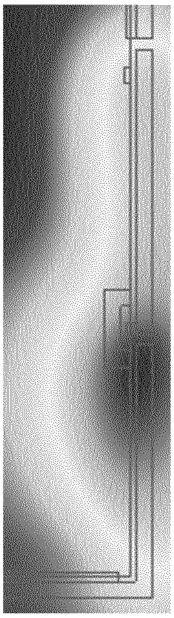


(a)

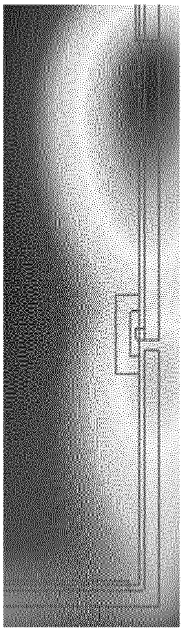


(b)

FIG. 13



(a)



(b)

FIG. 14

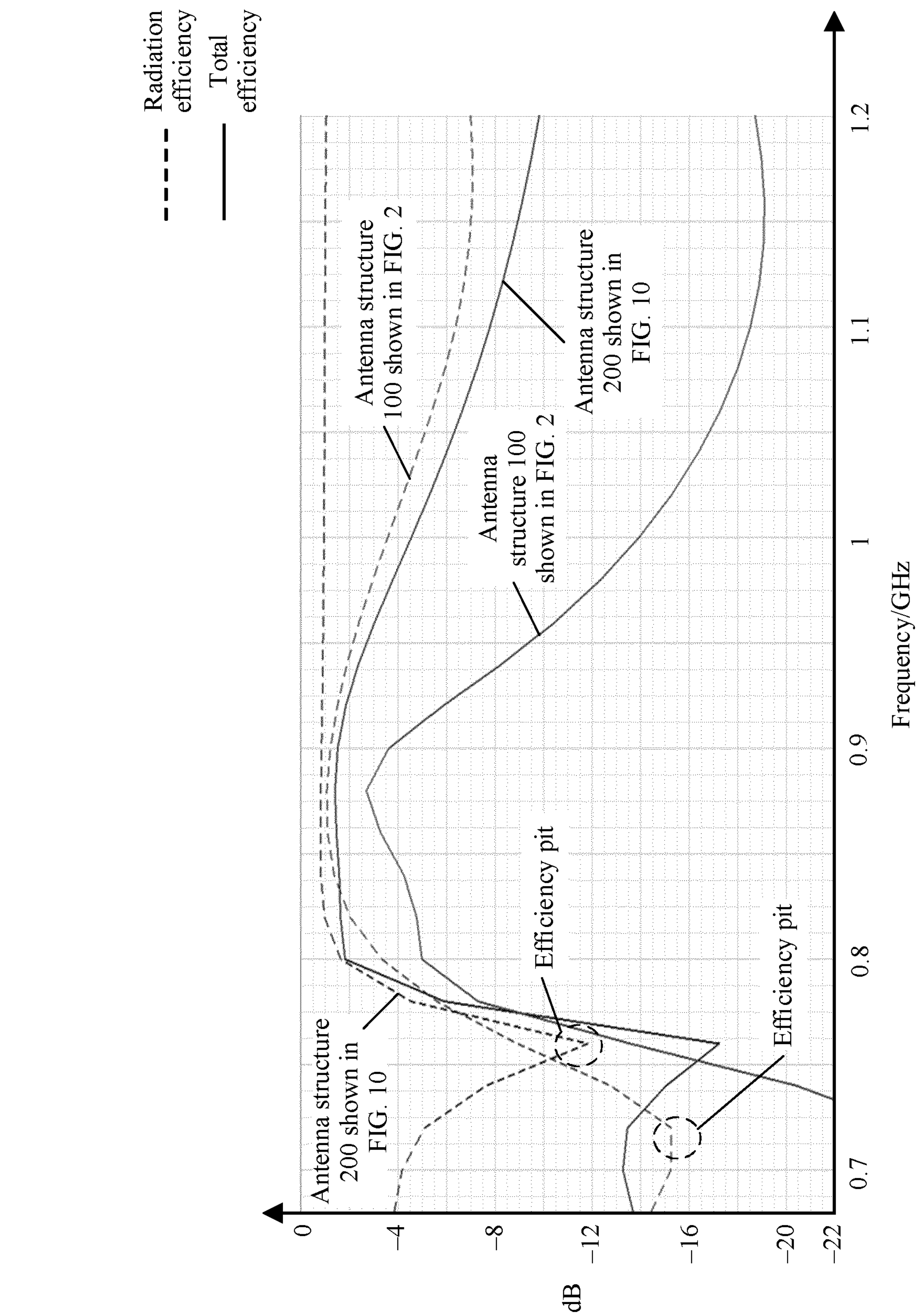

Radiation efficiency
Total efficiency
dB
0
−4
−8
−12
−16
−20
−22
0.7
0.8
0.9
1
1.1
1.2
Frequency/GHz
Antenna structure 100 shown in FIG. 2
Antenna structure 200 shown in FIG. 10
Antenna structure 100 shown in FIG. 2
Antenna structure 200 shown in FIG. 10
Efficiency pit
Efficiency pit

FIG. 15

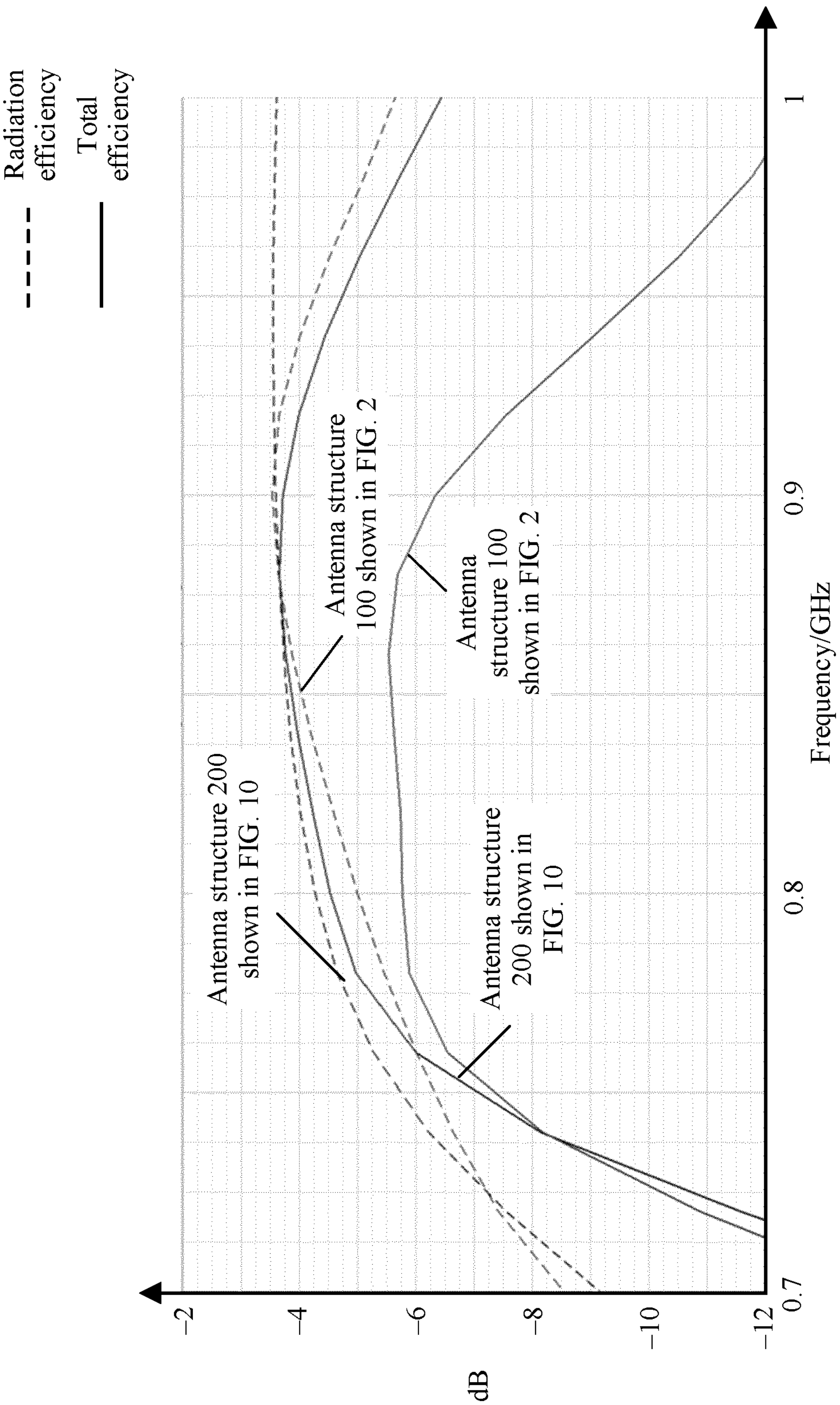

Radiation efficiency
Total efficiency
dB
−2
−4
−6
−8
−10
−12
0.7
0.8
0.9
1
Frequency/GHz
Antenna structure 200 shown in FIG. 10
Antenna structure 200 shown in FIG. 10
Antenna structure 100 shown in FIG. 2
Antenna structure 100 shown in FIG. 2

FIG. 16

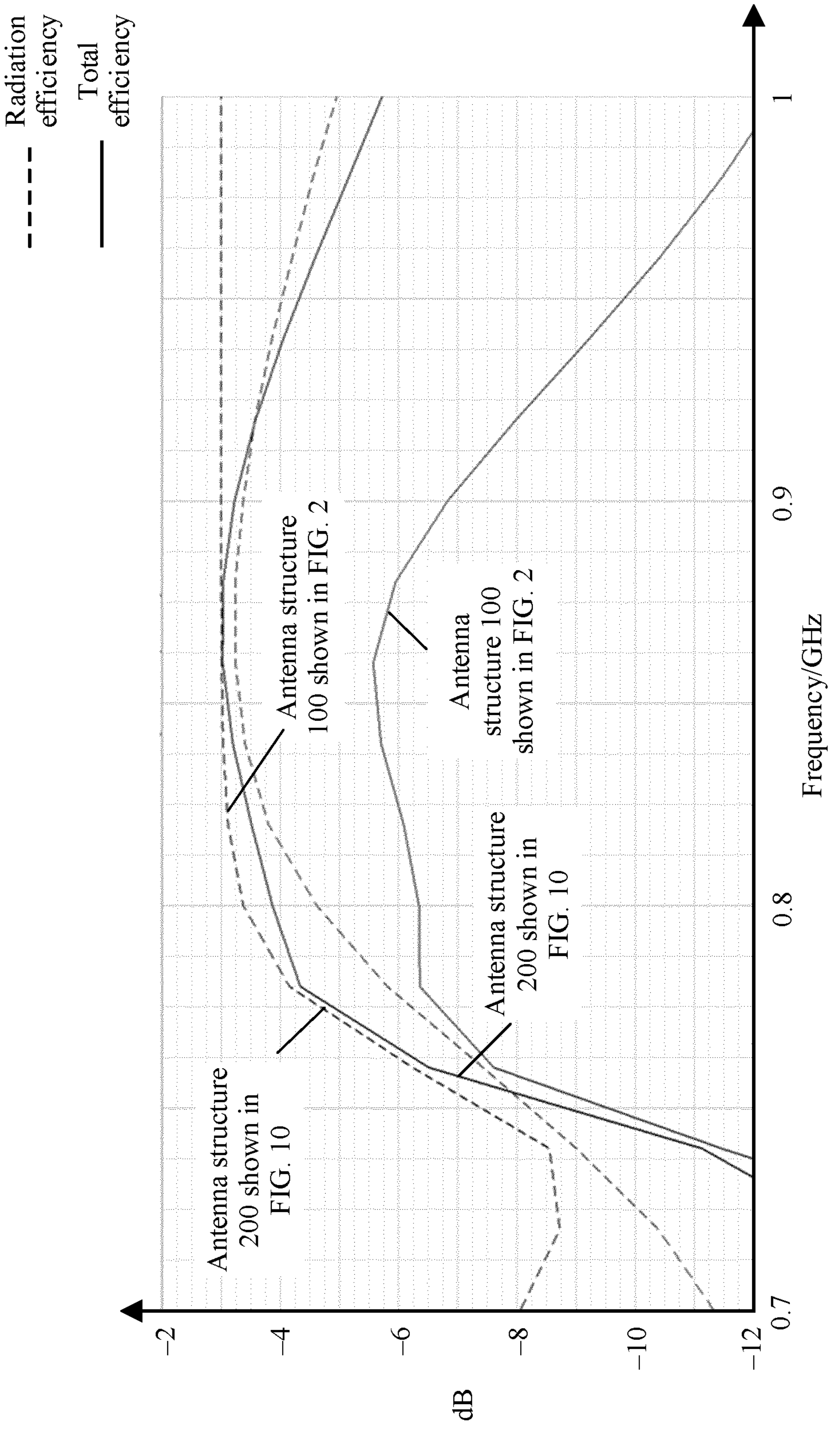

Radiation efficiency
Total efficiency
Antenna structure 100 shown in FIG. 2
Antenna structure 100 shown in FIG. 2
Antenna structure 200 shown in FIG. 10
Antenna structure 200 shown in FIG. 10
dB
−2
−4
−6
−8
−10
−12
0.7
0.8
0.9
1
Frequency/GHz

FIG. 17

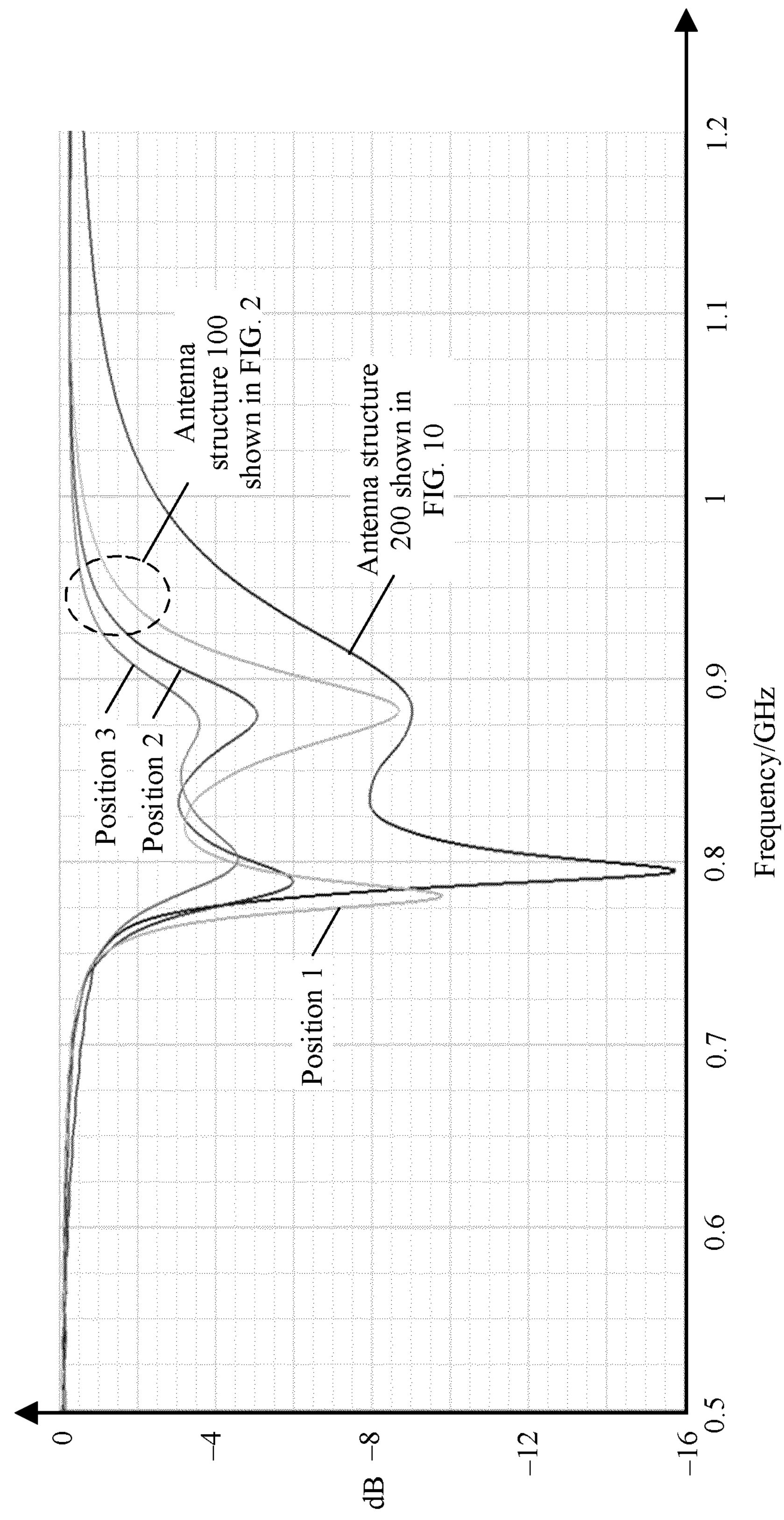

dB
0
−4
−8
−12
−16
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
Frequency/GHz
Antenna structure 100 shown in FIG. 2
Antenna structure 200 shown in FIG. 10
Position 3
Position 2
Position 1

FIG. 18

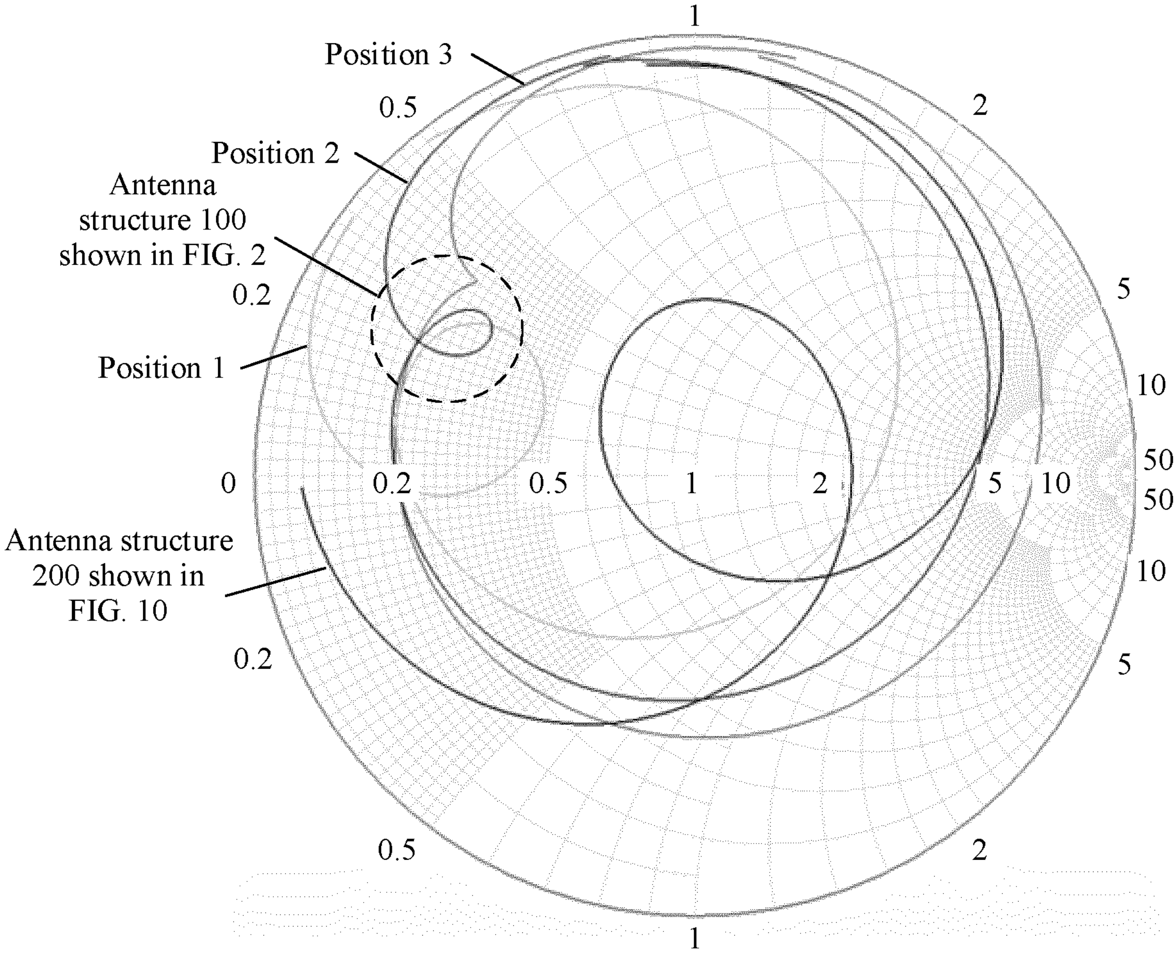

Position 3
Position 2
Antenna structure 100 shown in FIG. 2
Position 1
Antenna structure 200 shown in FIG. 10
1
0.5
2
0.2
5
10
50
0
0.2
0.5
1
2
5
10
50
10
0.2
5
0.5
2
1

FIG. 19

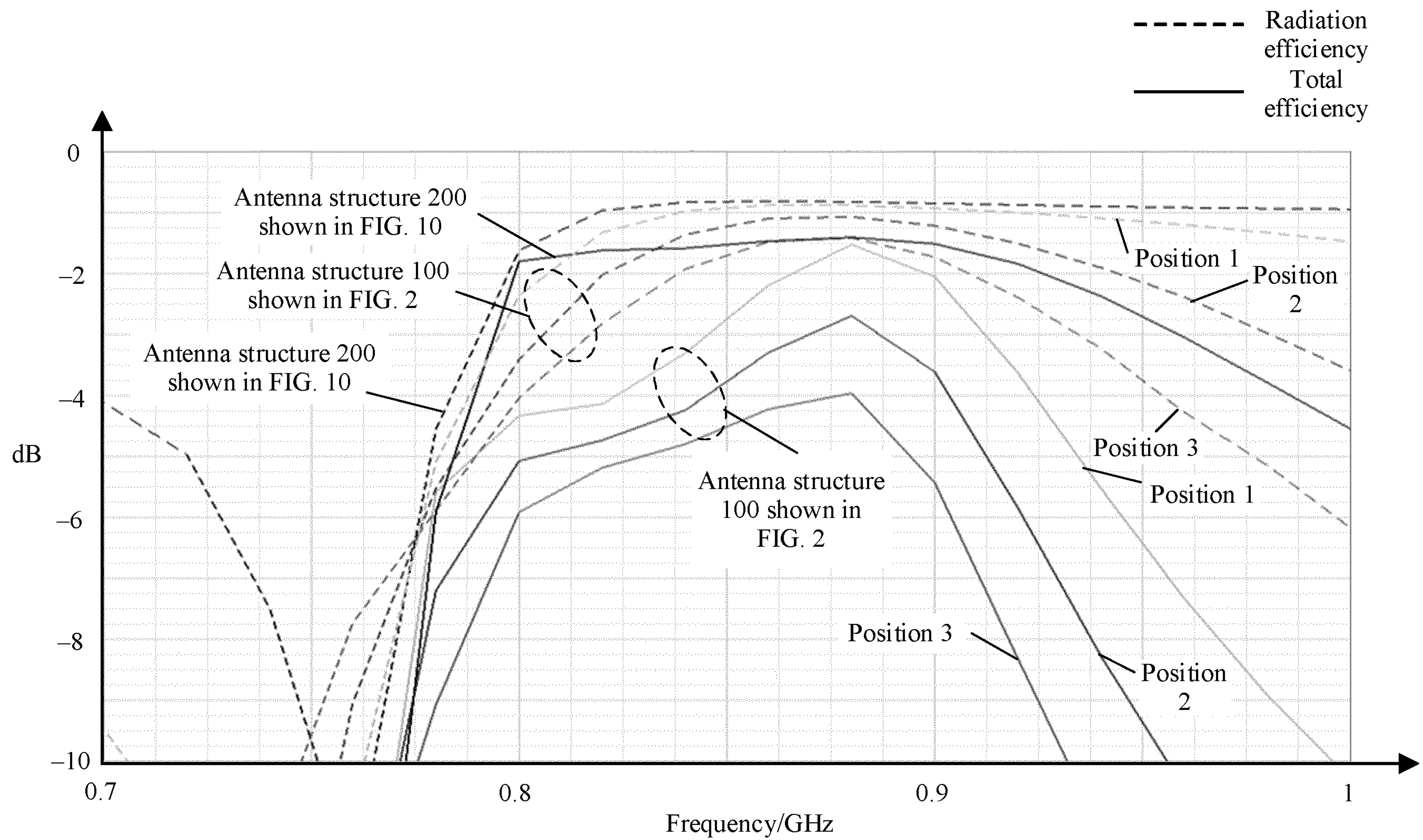

Radiation efficiency
Total efficiency
Antenna structure 200 shown in FIG. 10
Antenna structure 100 shown in FIG. 2
Antenna structure 200 shown in FIG. 10
Antenna structure 100 shown in FIG. 2
Position 1
Position 2
Position 3
Position 1
Position 3
Position 2
dB
0
−2
−4
−6
−8
−10
0.7
0.8
0.9
1
Frequency/GHz

FIG. 20

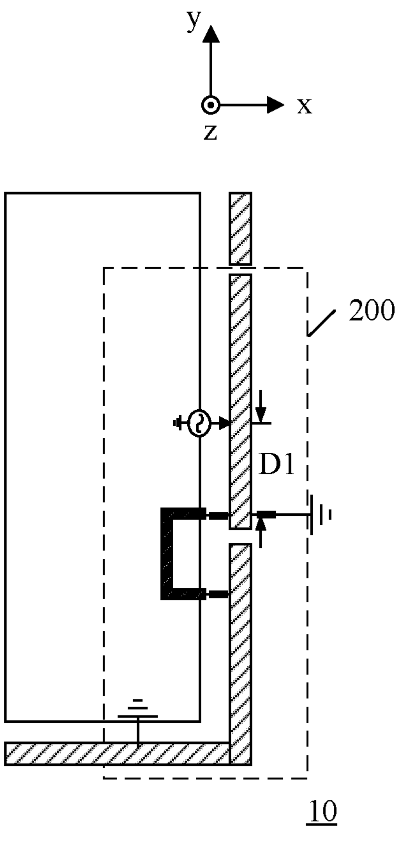


FIG. 21(a)

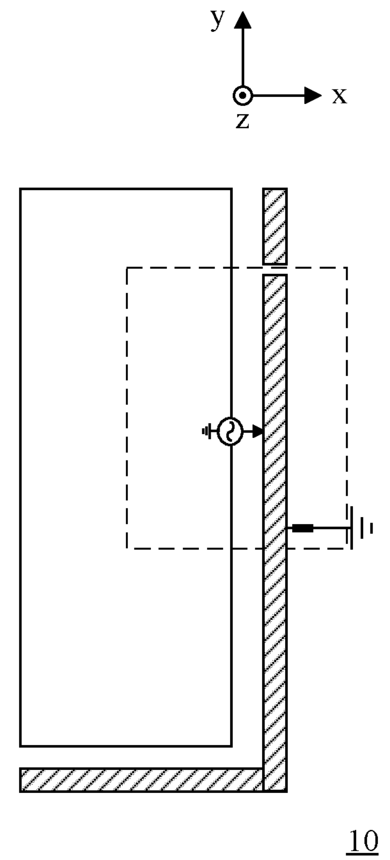


FIG. 21(b)

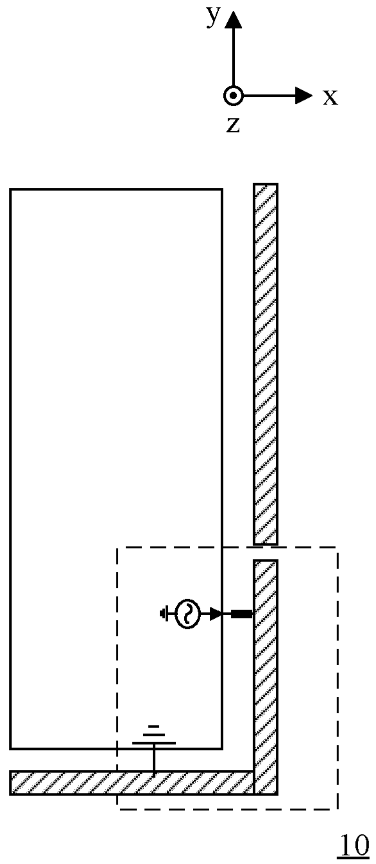


FIG. 21(c)

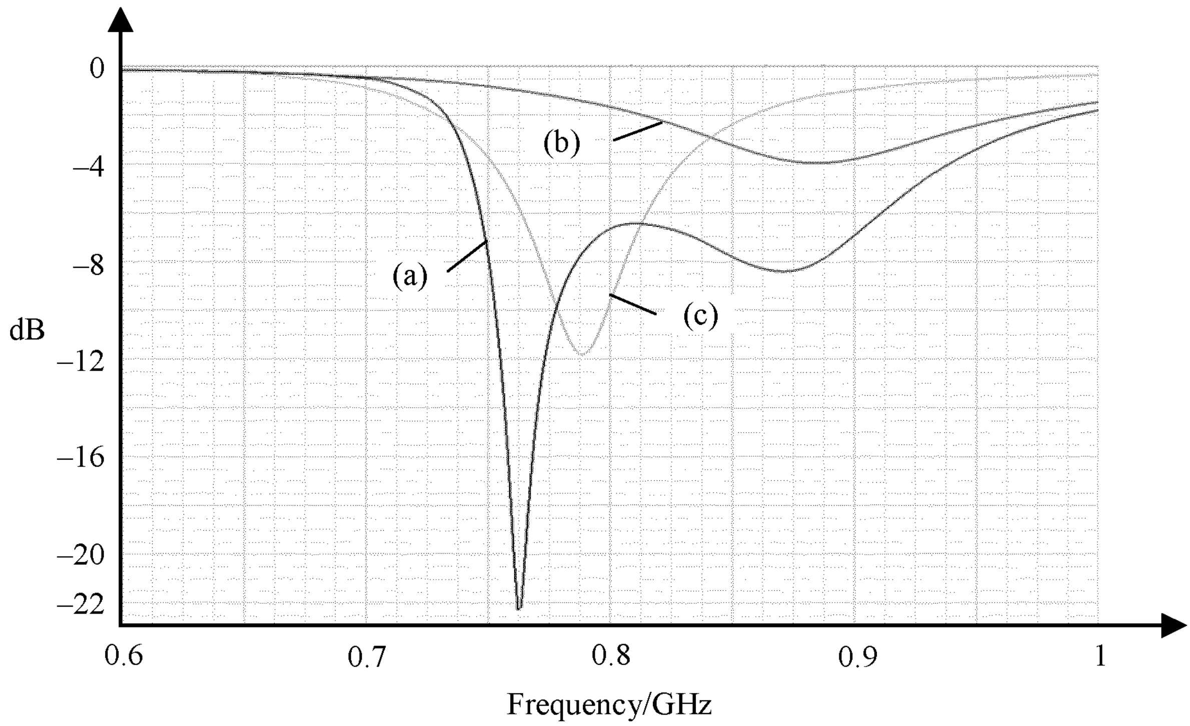


FIG. 22

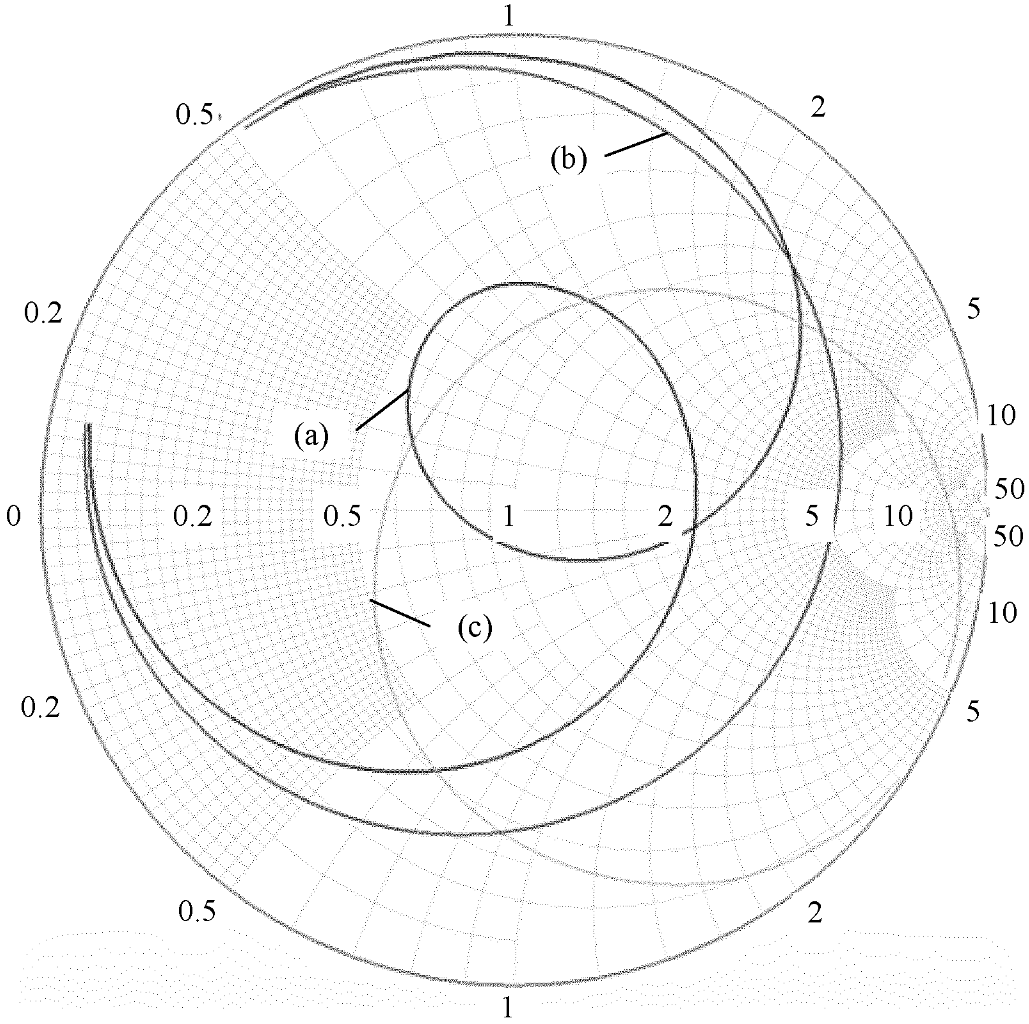


FIG. 23

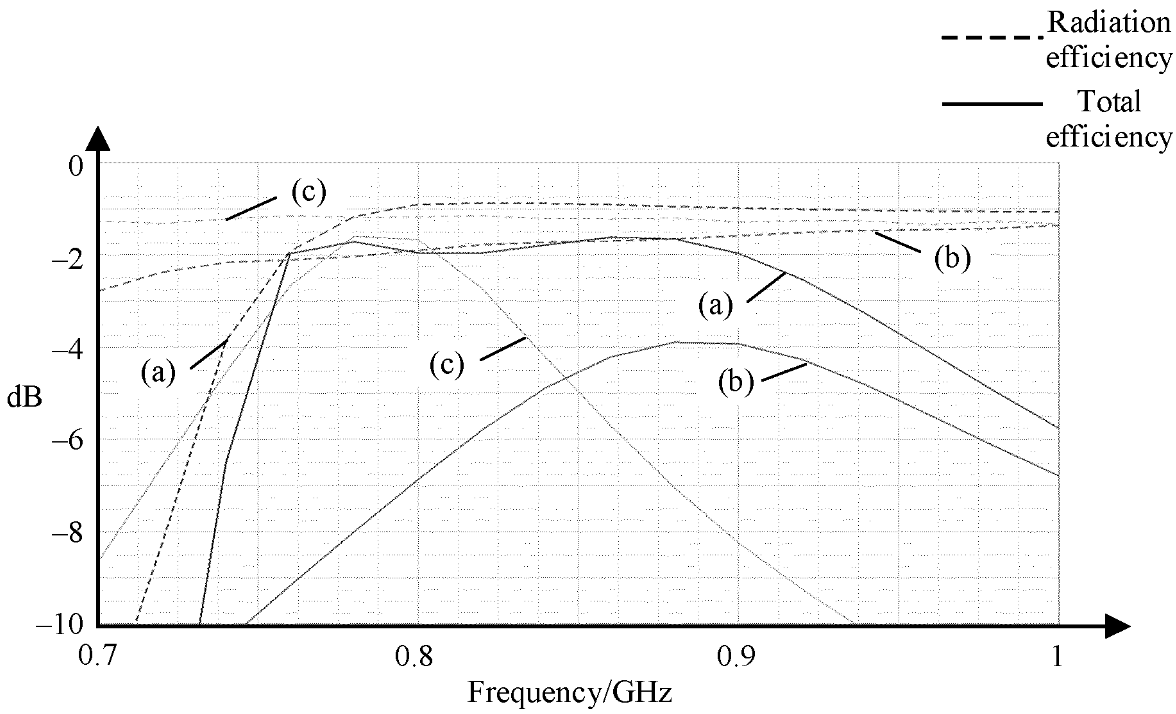

Radiation efficiency
Total efficiency
0
−2
−4
−6
−8
−10
dB
(a)
(b)
(c)
0.7
0.8
0.9
1
Frequency/GHz

FIG. 24

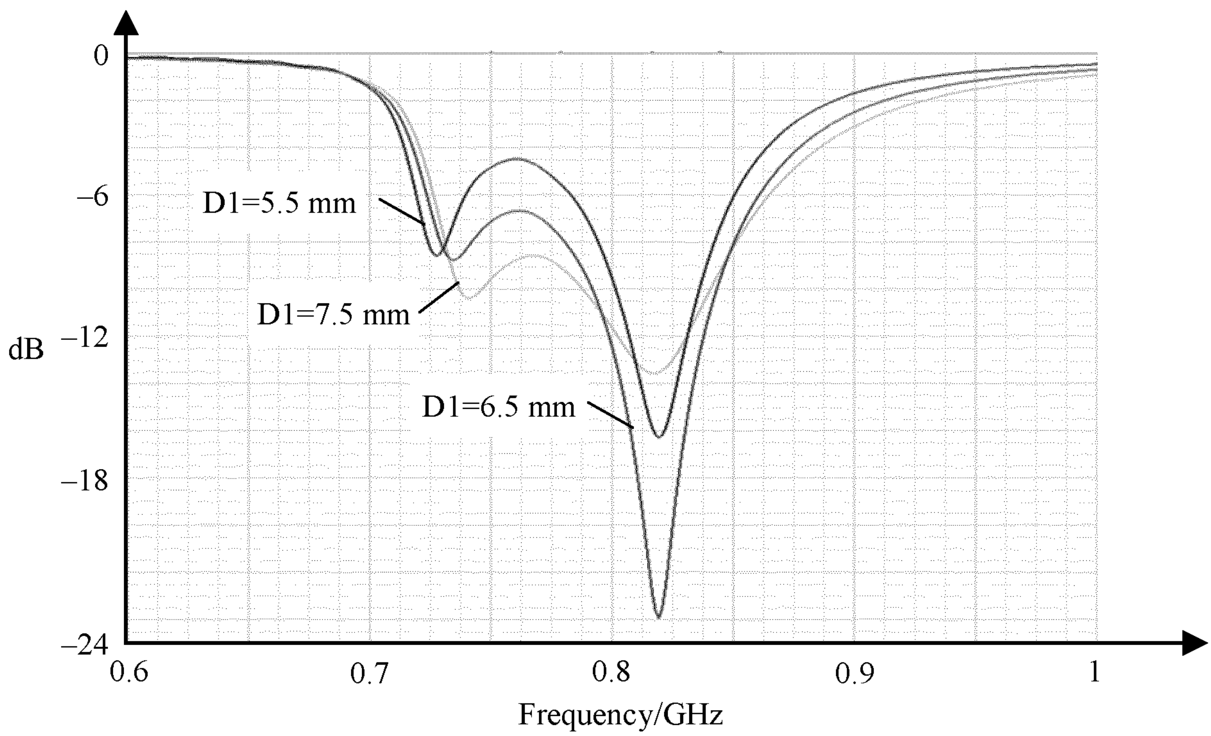

0
−6
−12
−18
−24
dB
D1=5.5 mm
D1=7.5 mm
D1=6.5 mm
0.6
0.7
0.8
0.9
1
Frequency/GHz

FIG. 25

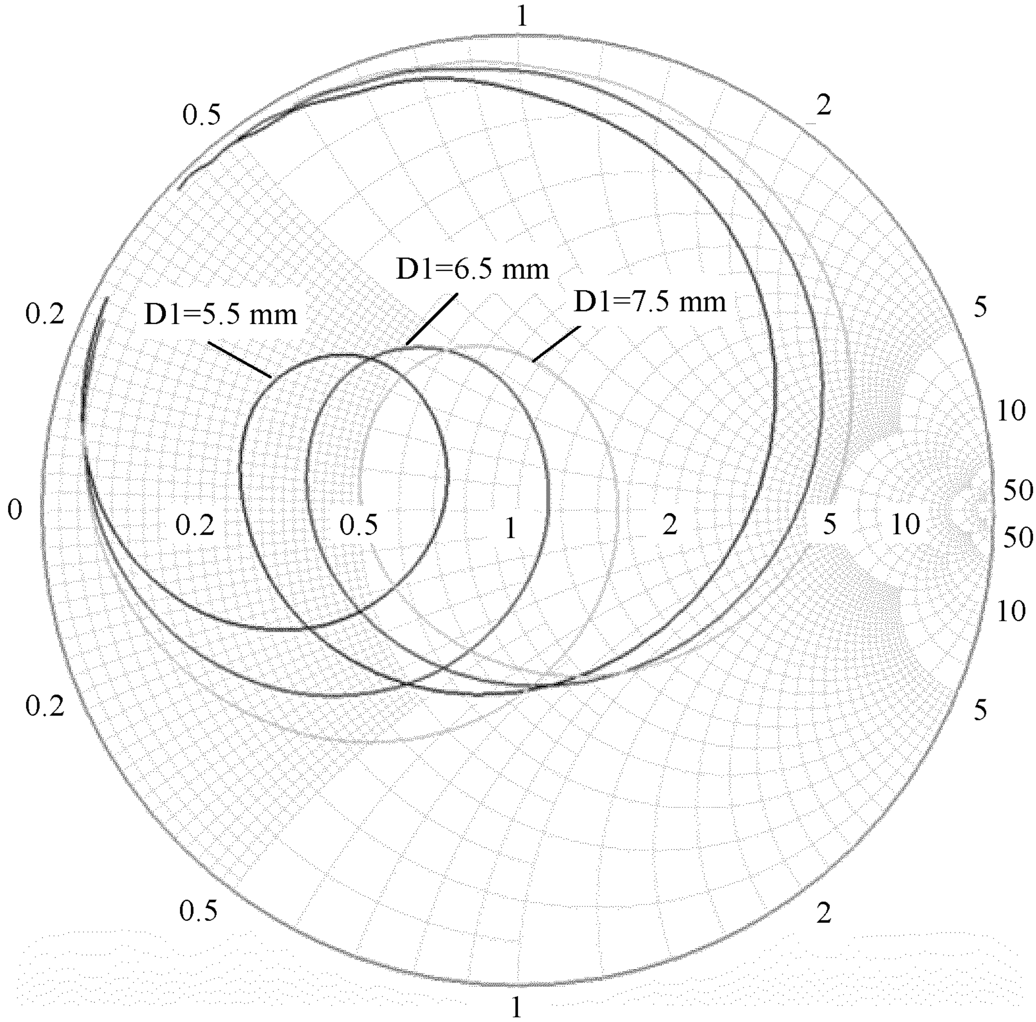

1
0.5
2
0.2
D1=5.5 mm
D1=6.5 mm
D1=7.5 mm
5
10
50
0
0.2
0.5
1
2
5
10
50
10
0.2
5
0.5
2
1

FIG. 26

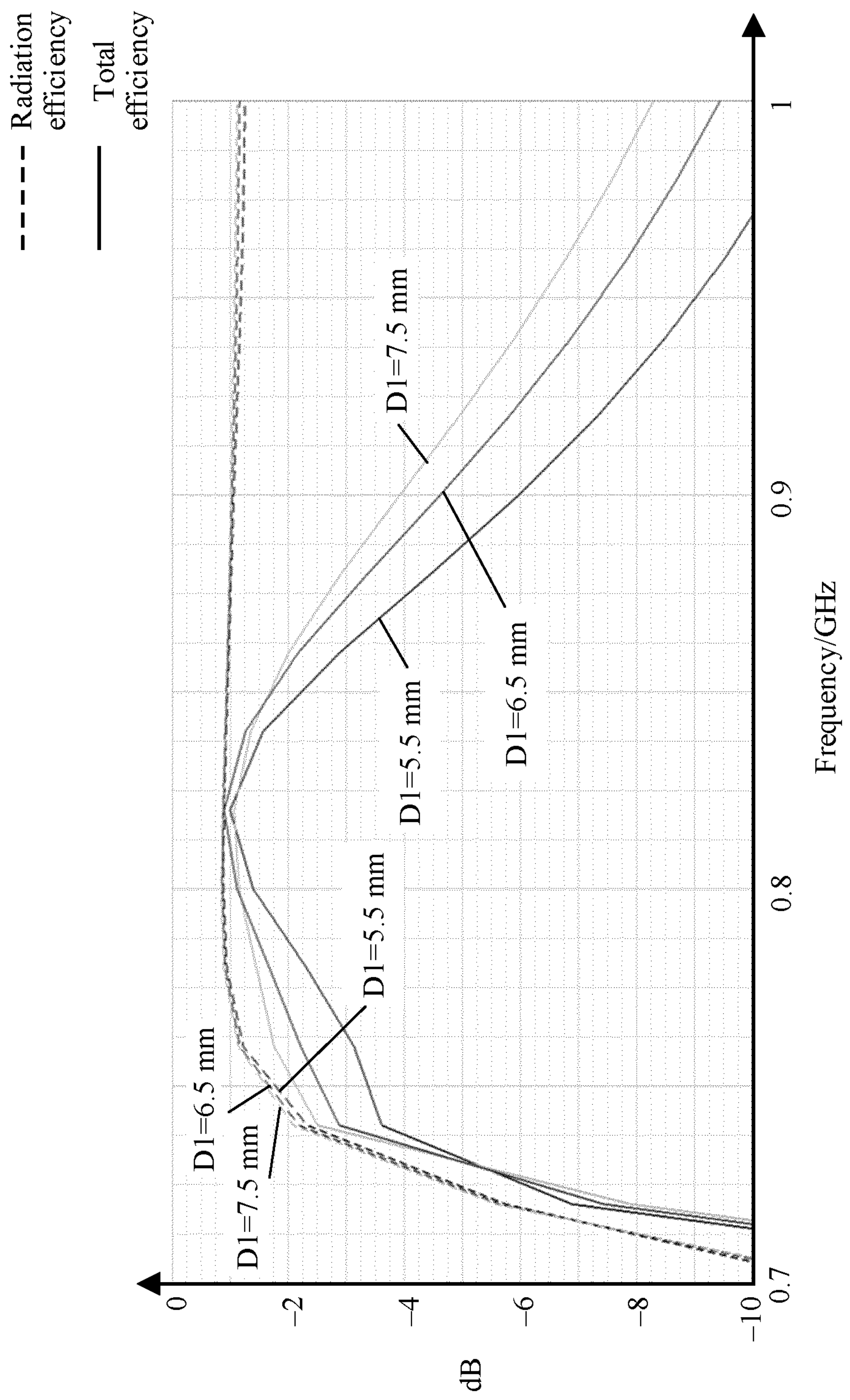

Radiation efficiency
Total efficiency
dB
0
−2
−4
−6
−8
−10
0.7
0.8
0.9
1
Frequency/GHz
D1=7.5 mm
D1=6.5 mm
D1=5.5 mm
D1=5.5 mm
D1=6.5 mm
D1=7.5 mm

FIG. 27

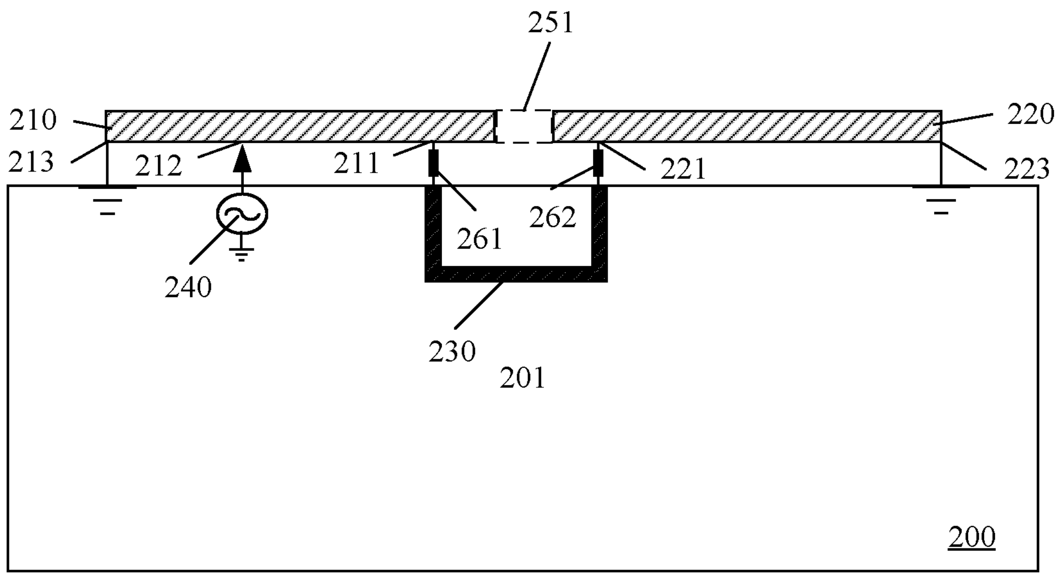


FIG. 28

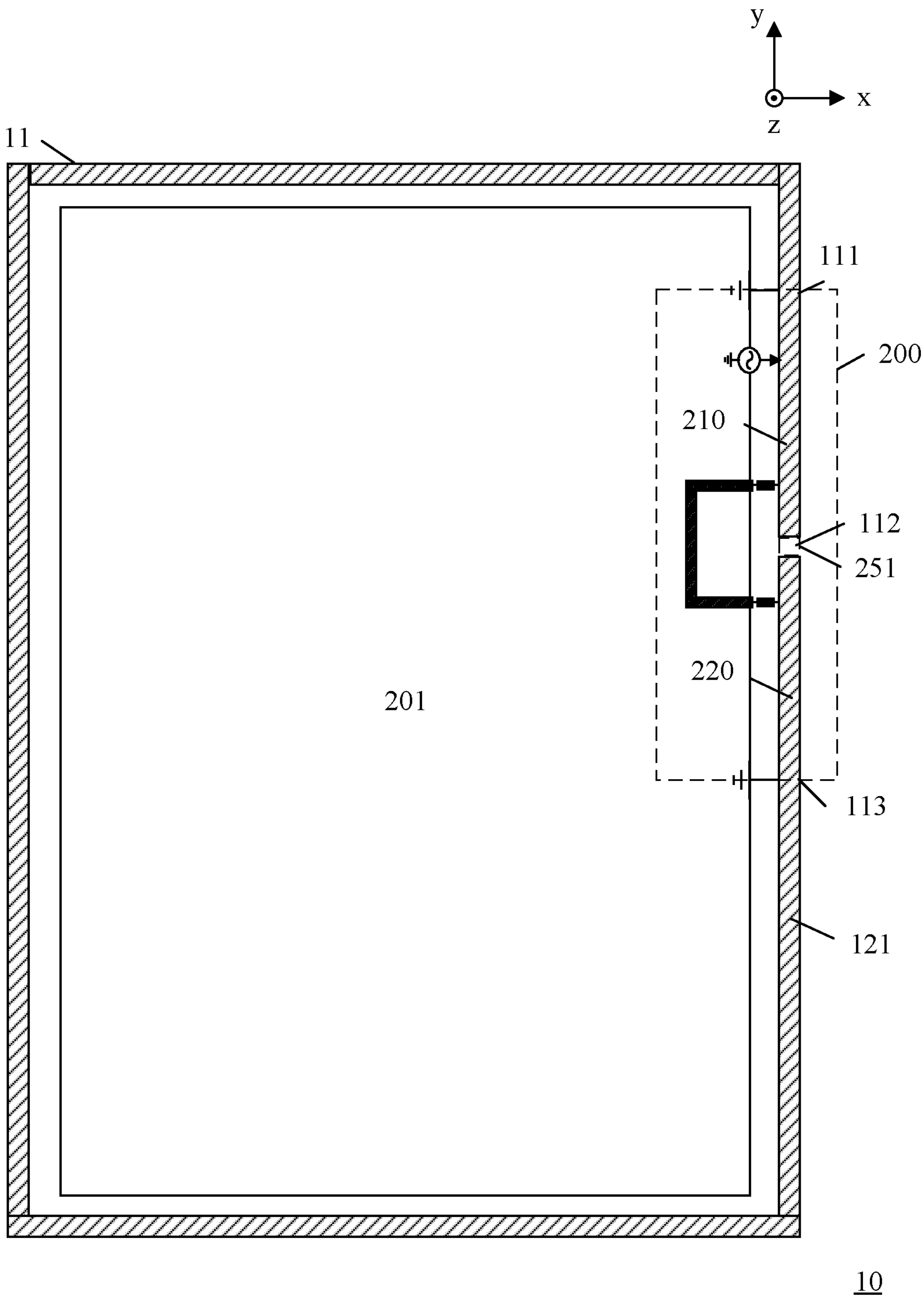


FIG. 29

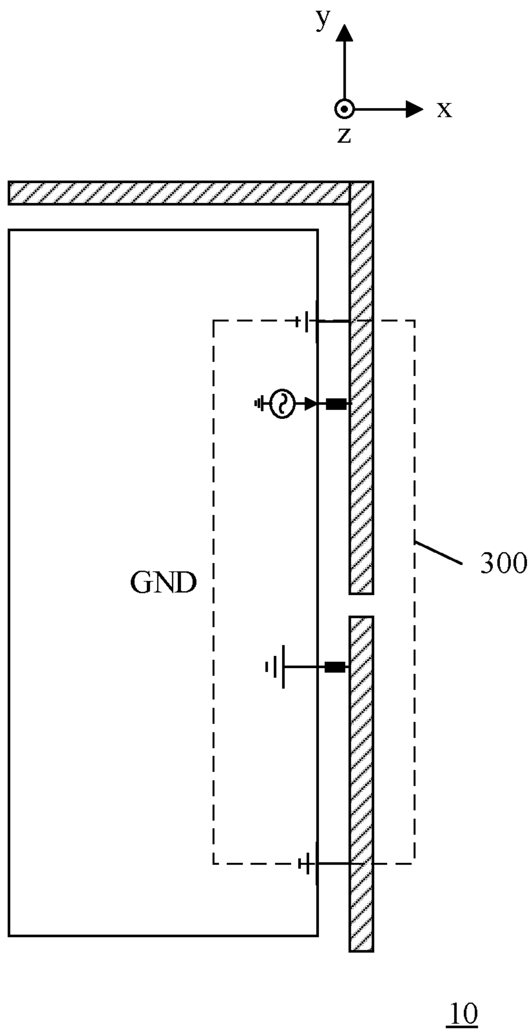


FIG. 30

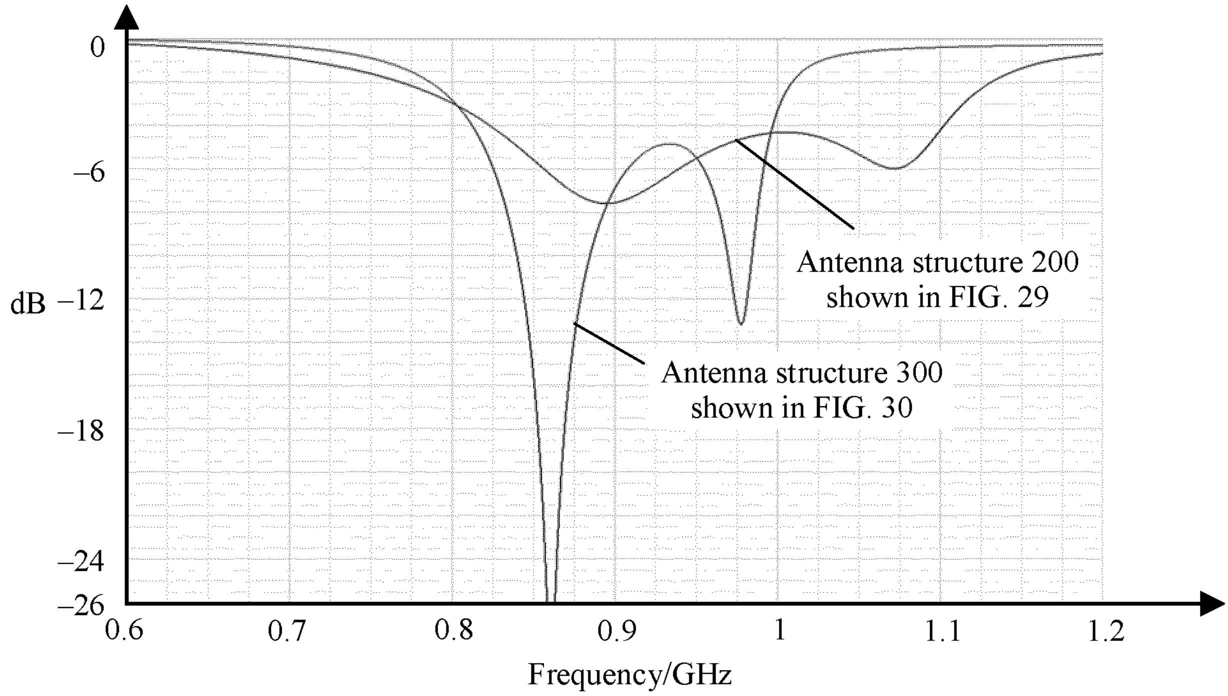
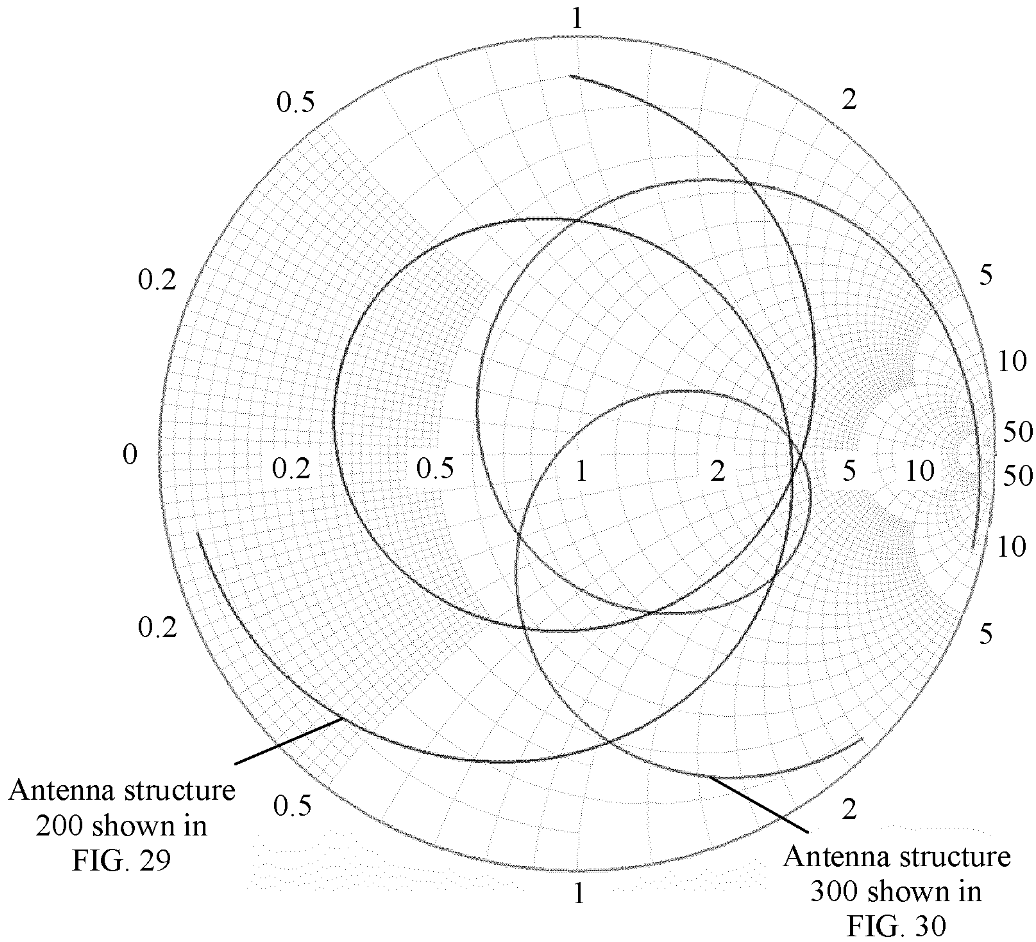

0
−6
dB −12
−18
−24
−26
0.6
0.7
0.8
0.9
1
1.1
1.2
Frequency/GHz
Antenna structure 200
shown in FIG. 29
Antenna structure 300
shown in FIG. 30

FIG. 31



1
0.5
2
0.2
5
10
50
0
0.2
0.5
1
2
5
10
50
10
0.2
5
Antenna structure 200 shown in FIG. 29
0.5
2
1
Antenna structure 300 shown in FIG. 30

FIG. 32

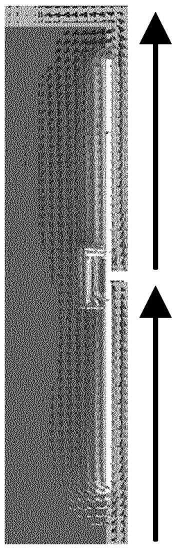


FIG. 33(a)

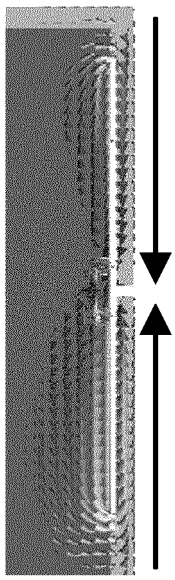


FIG. 33(b)

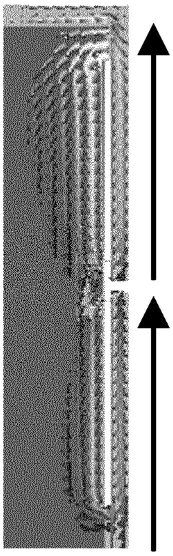


FIG. 33(c)

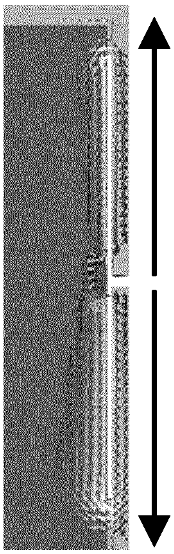


FIG. 33(d)

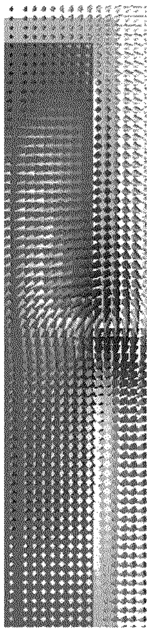


FIG. 34(a)

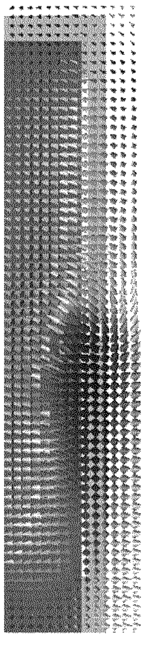


FIG. 34(b)

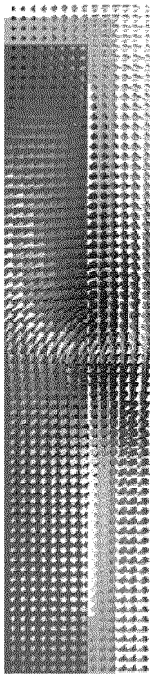


FIG. 34(c)

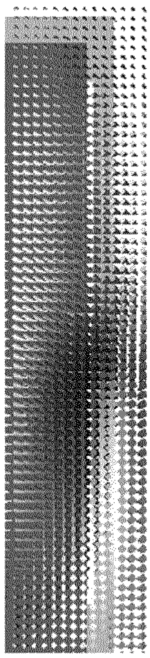


FIG. 34(d)

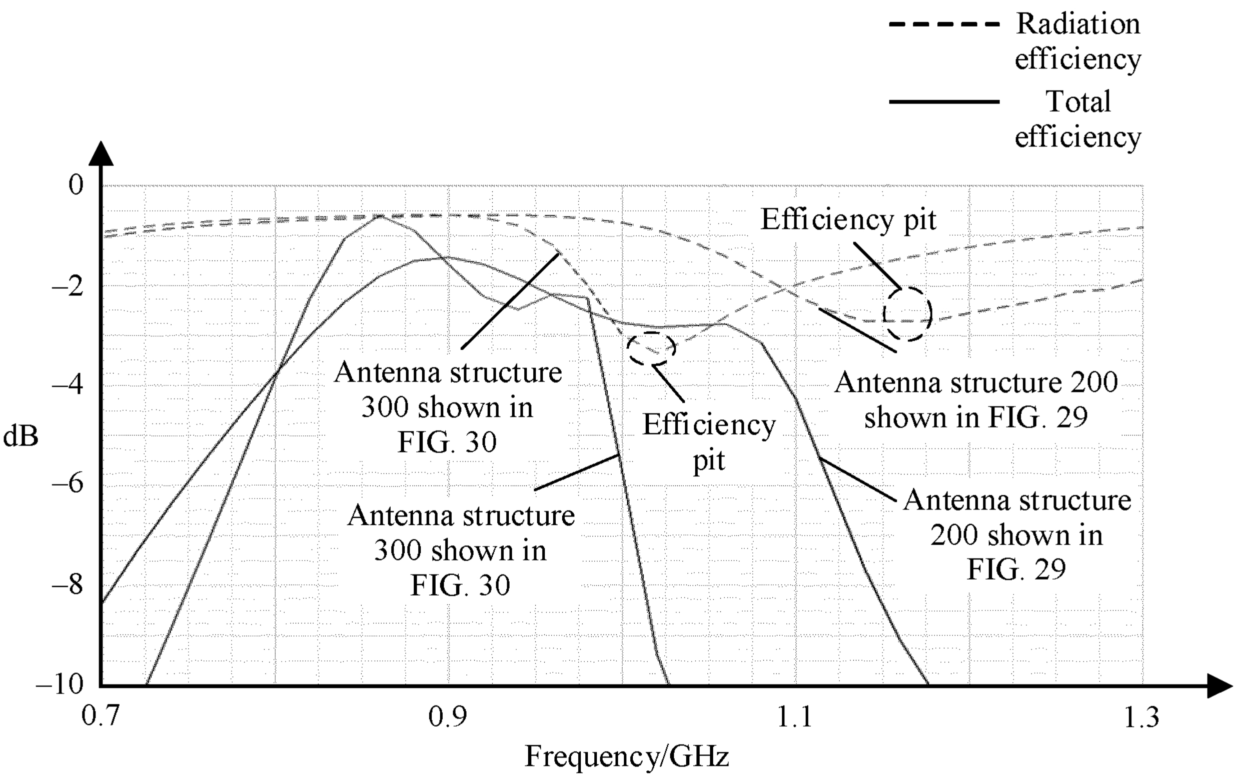

Radiation efficiency
Total efficiency
0
−2
−4
−6
−8
−10
dB
0.7
0.9
1.1
1.3
Frequency/GHz
Efficiency pit
Antenna structure 300 shown in FIG. 30
Efficiency pit
Antenna structure 200 shown in FIG. 29
Antenna structure 300 shown in FIG. 30
Antenna structure 200 shown in FIG. 29

FIG. 35

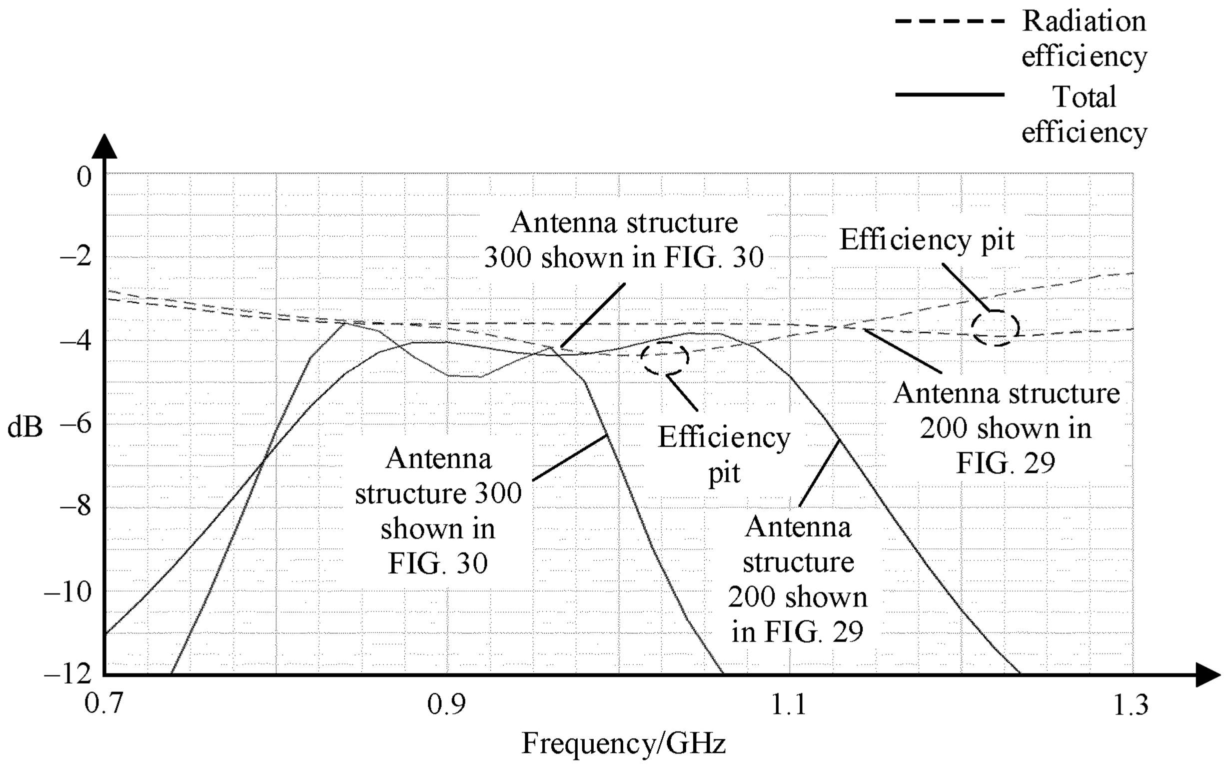

Radiation efficiency
Total efficiency
0
−2
−4
−6
−8
−10
−12
dB
0.7
0.9
1.1
1.3
Frequency/GHz
Antenna structure 300 shown in FIG. 30
Efficiency pit
Antenna structure 200 shown in FIG. 29
Efficiency pit
Antenna structure 300 shown in FIG. 30
Antenna structure 200 shown in FIG. 29

FIG. 36

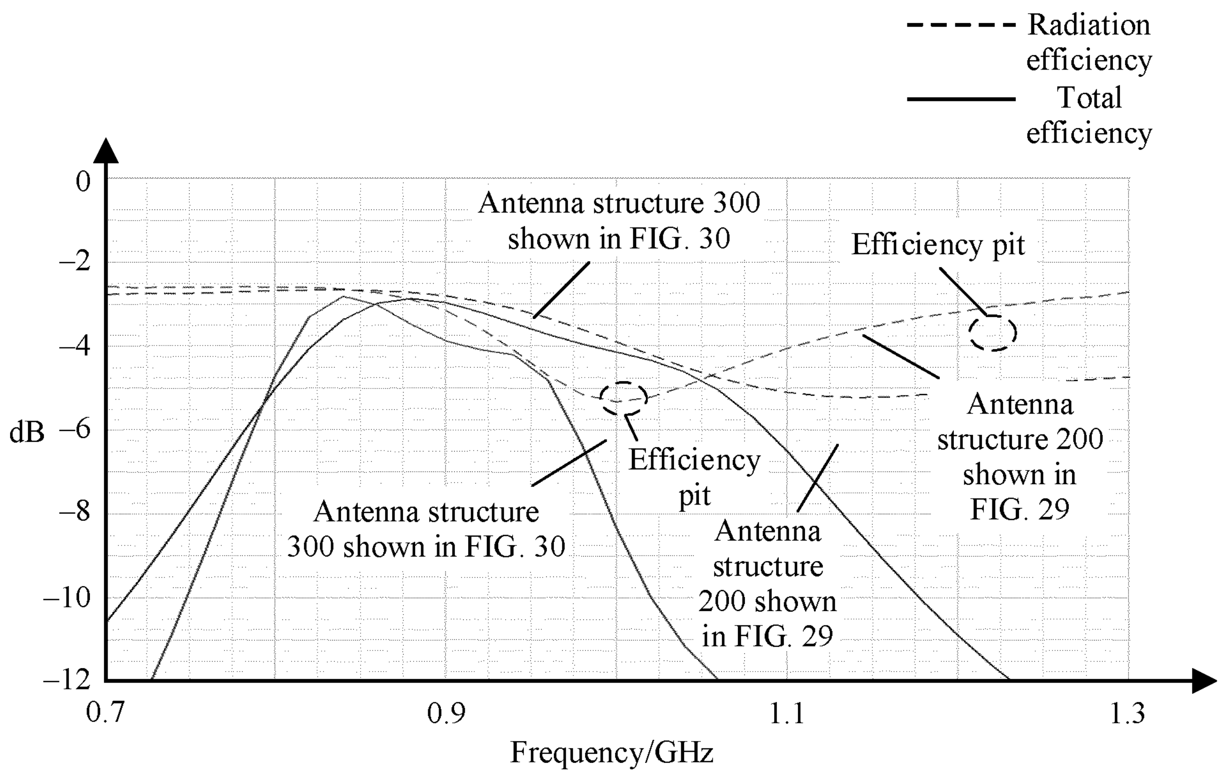

Radiation efficiency
Total efficiency
0
−2
−4
dB −6
−8
−10
−12
0.7
0.9
1.1
1.3
Frequency/GHz
Antenna structure 300 shown in FIG. 30
Efficiency pit
Efficiency pit
Antenna structure 300 shown in FIG. 30
Antenna structure 200 shown in FIG. 29
Antenna structure 200 shown in FIG. 29

FIG. 37

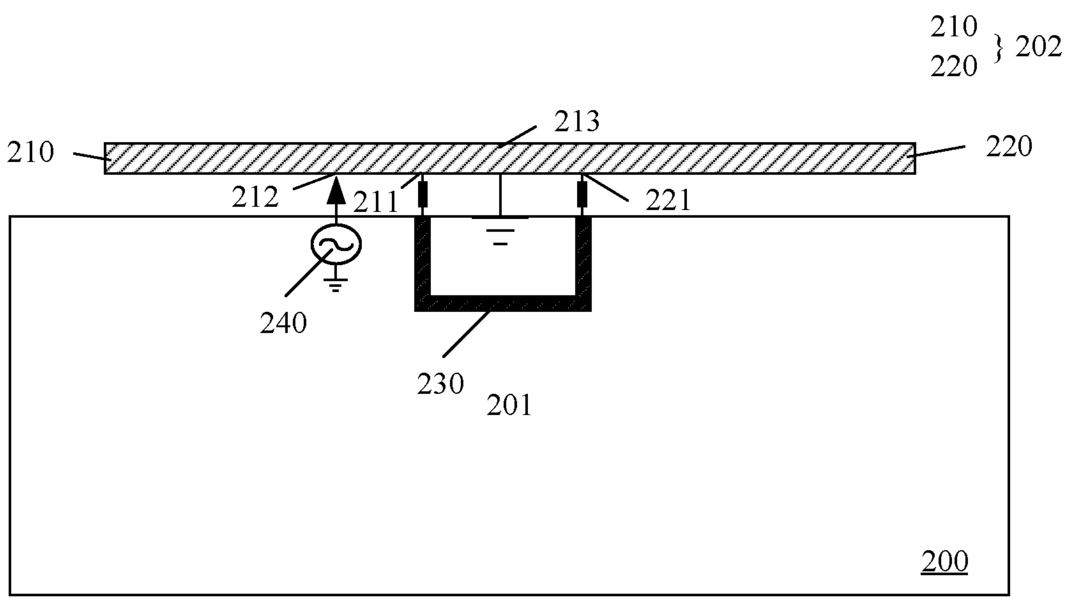

210
220
} 202
213
210
220
212
211
221
240
230
201
200

FIG. 38

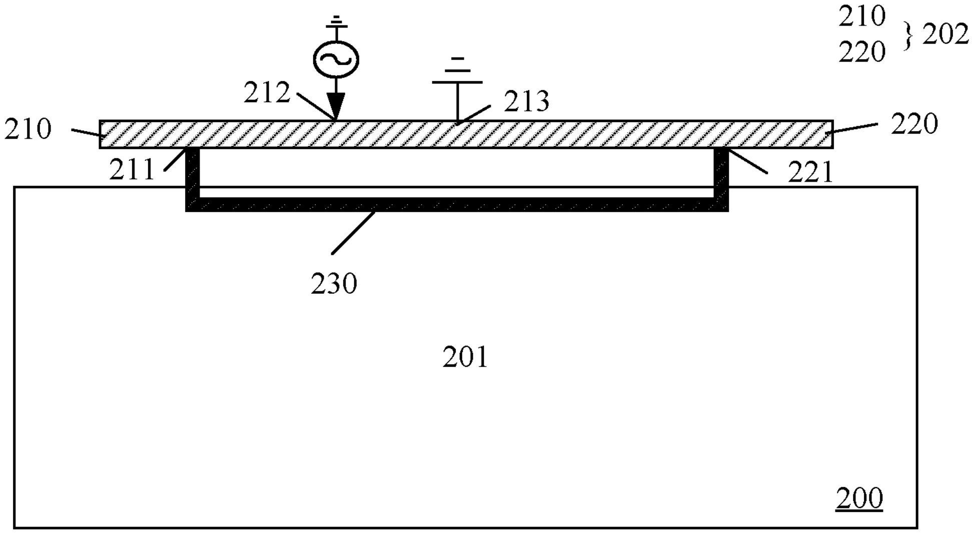


FIG. 39

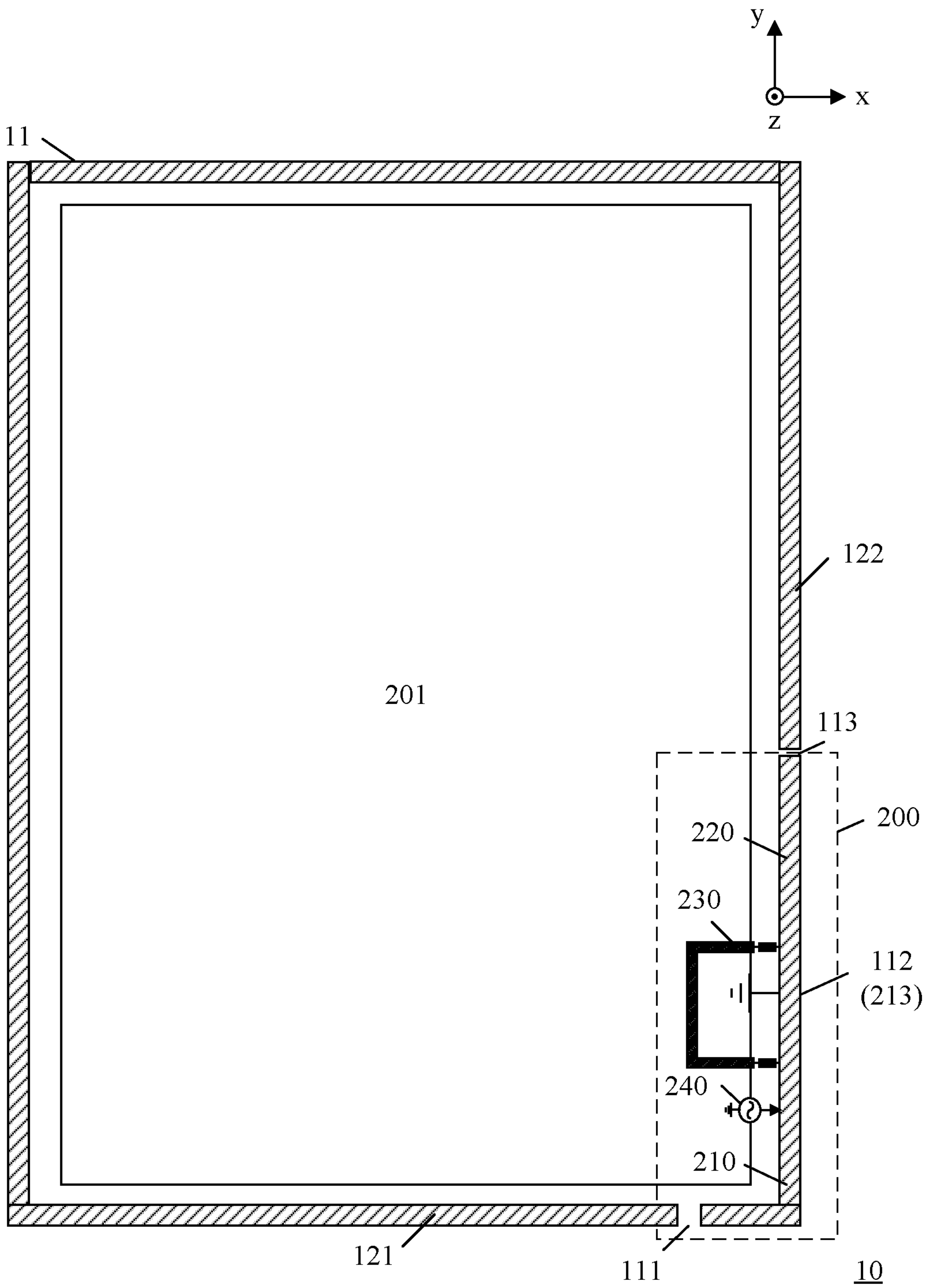


FIG. 40

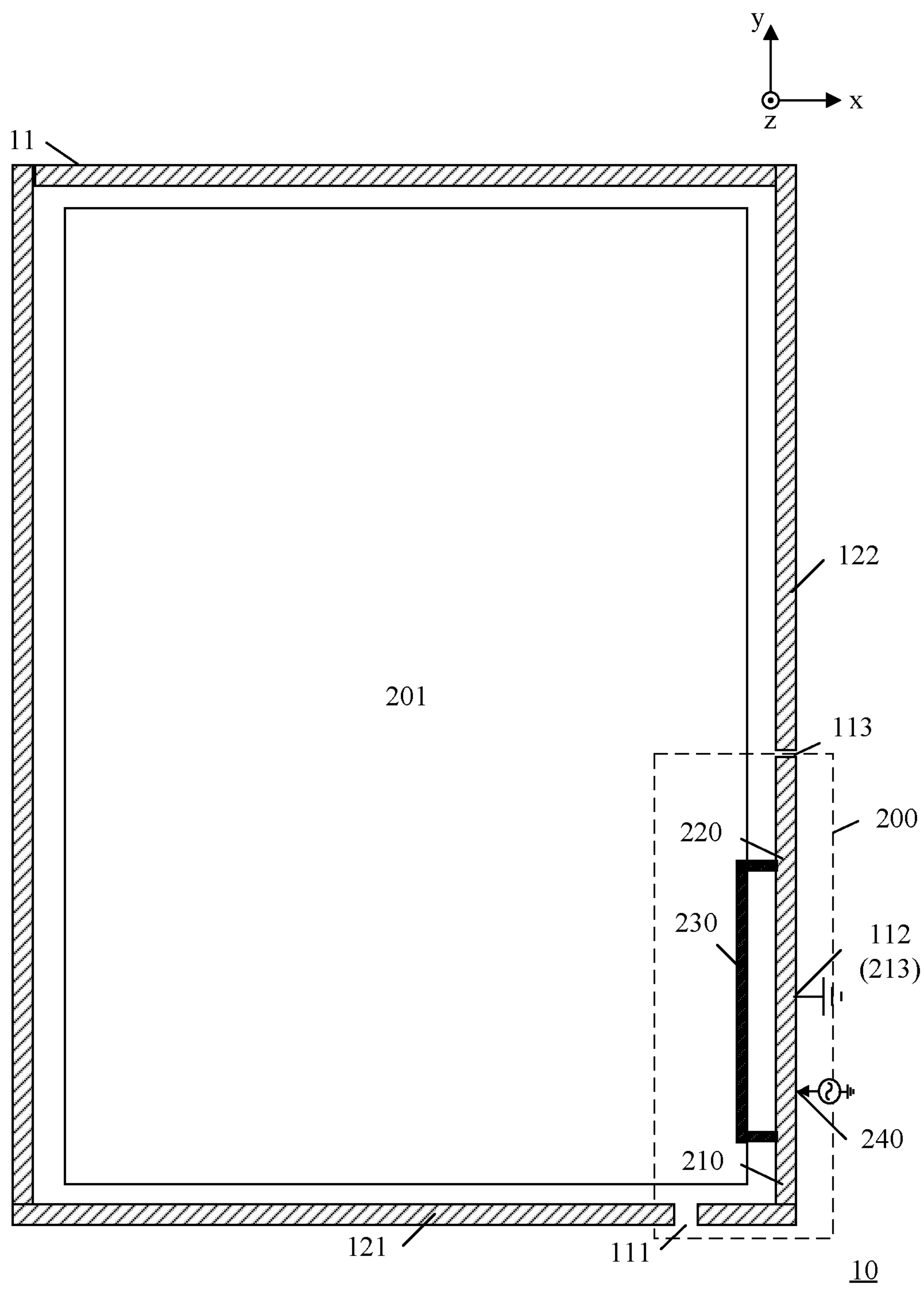


FIG. 41

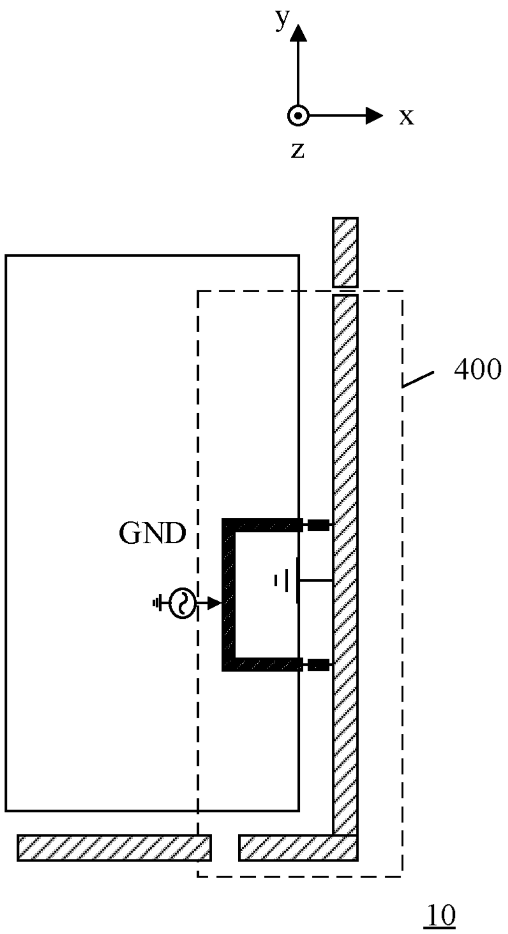


FIG. 42

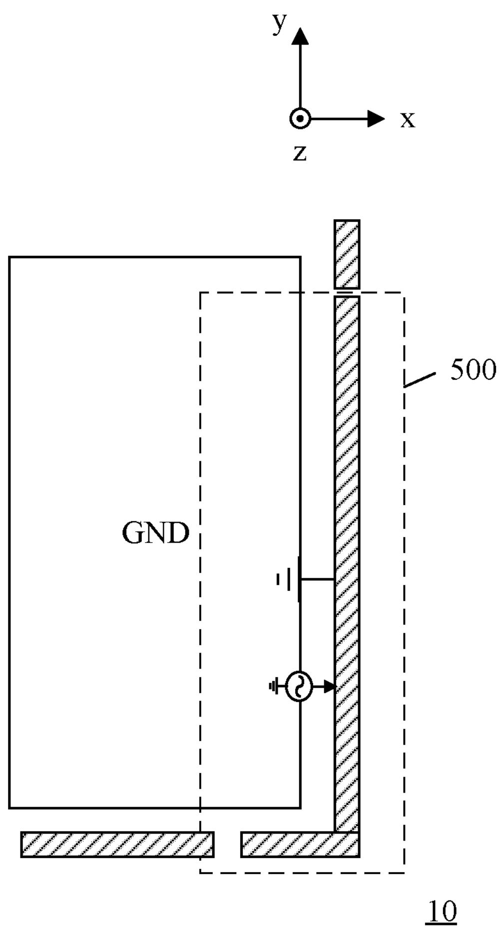


FIG. 43

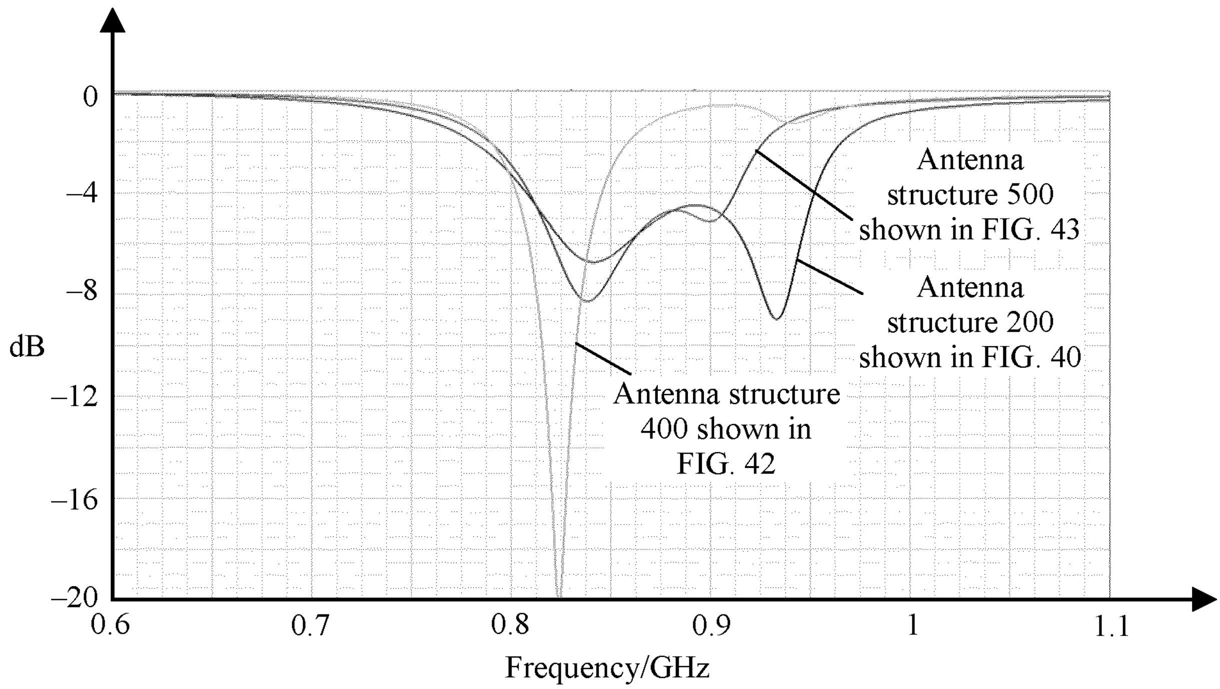
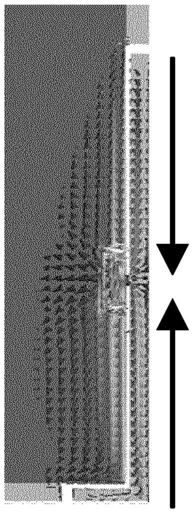
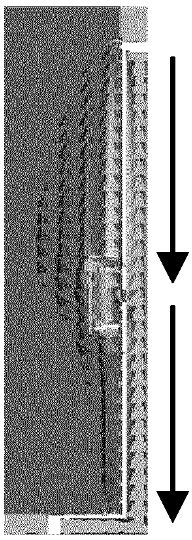

0
−4
−8
dB
−12
−16
−20
0.6
0.7
0.8
0.9
1
1.1
Frequency/GHz
Antenna structure 500 shown in FIG. 43
Antenna structure 200 shown in FIG. 40
Antenna structure 400 shown in FIG. 42

FIG. 44

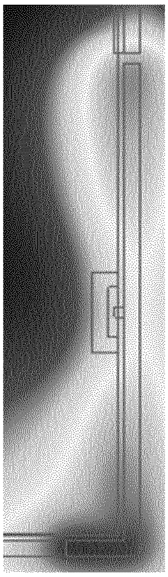


(a)

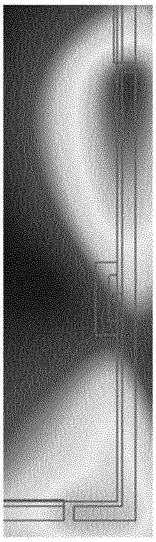


(b)

FIG. 45



(a)



(b)

FIG. 46

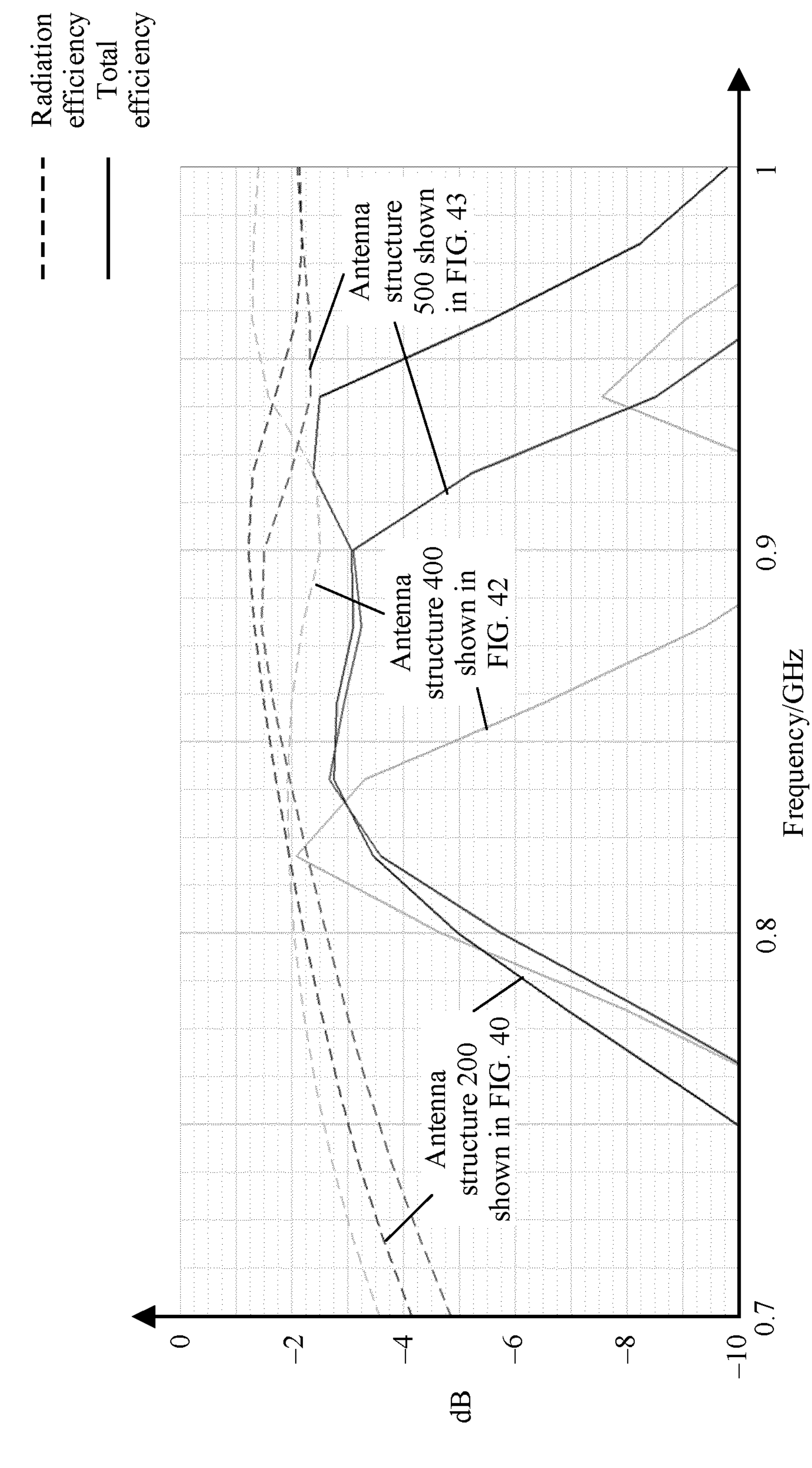

Radiation efficiency
Total efficiency
dB
0
−2
−4
−6
−8
−10
0.7
0.8
0.9
1
Frequency/GHz
Antenna structure 200 shown in FIG. 40
Antenna structure 400 shown in FIG. 42
Antenna structure 500 shown in FIG. 43

FIG. 47

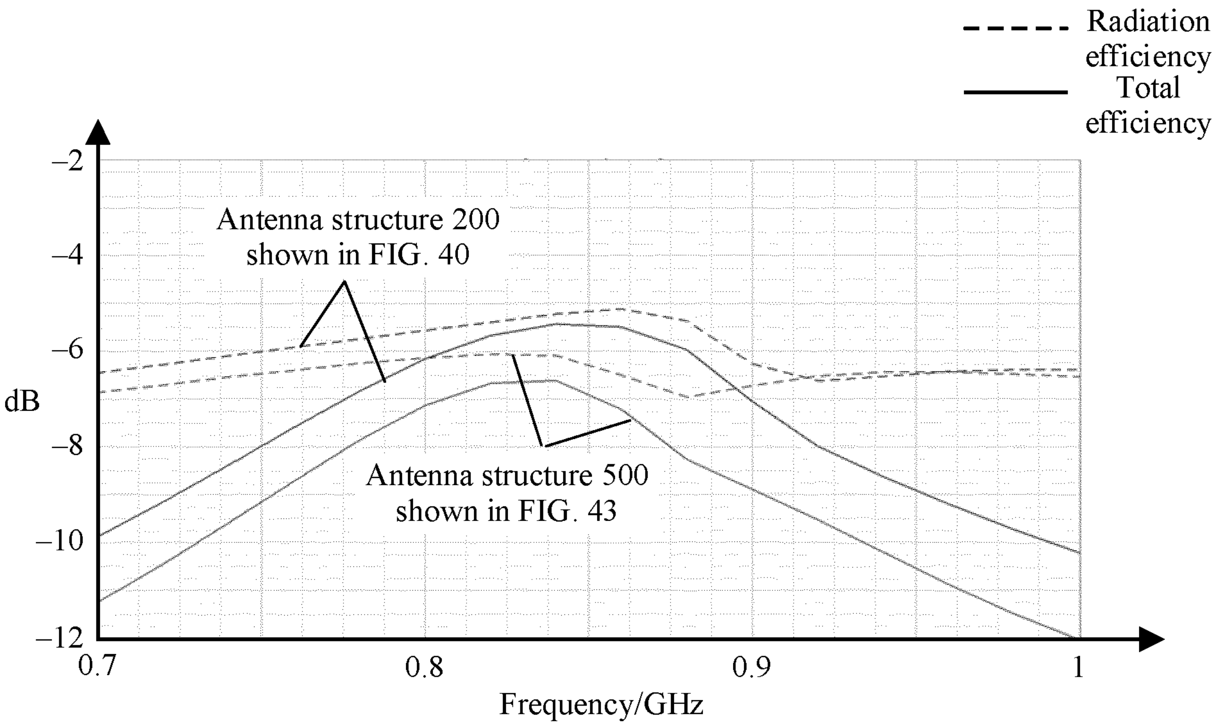

Radiation efficiency
Total efficiency
dB
−2
−4
−6
−8
−10
−12
0.7
0.8
0.9
1
Frequency/GHz
Antenna structure 200 shown in FIG. 40
Antenna structure 500 shown in FIG. 43

FIG. 48

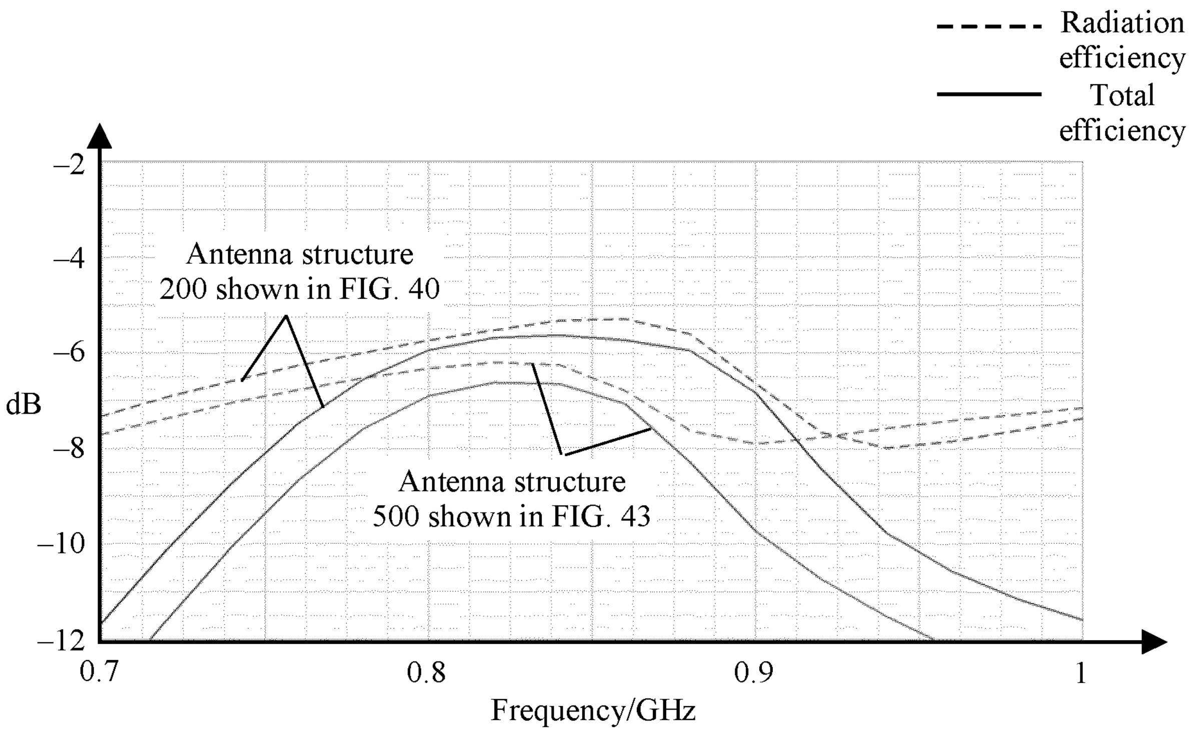

Radiation efficiency
Total efficiency
dB
−2
−4
−6
−8
−10
−12
0.7
0.8
0.9
1
Frequency/GHz
Antenna structure 200 shown in FIG. 40
Antenna structure 500 shown in FIG. 43

FIG. 49

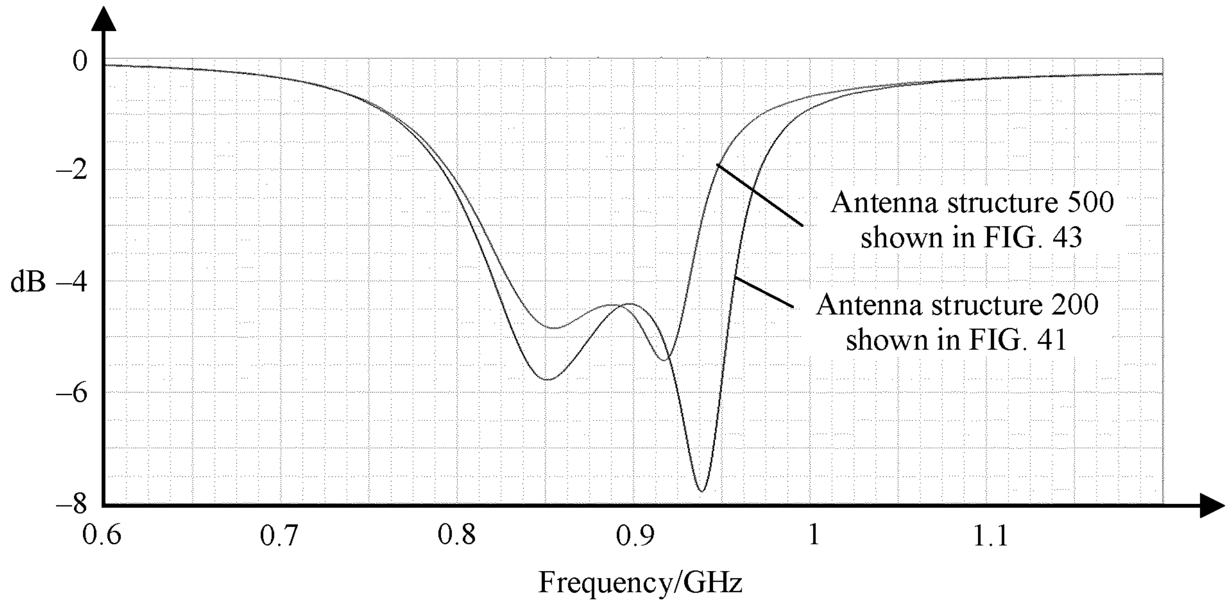

0
−2
dB −4
−6
−8
0.6
0.7
0.8
0.9
1
1.1
Frequency/GHz
Antenna structure 500 shown in FIG. 43
Antenna structure 200 shown in FIG. 41

FIG. 50

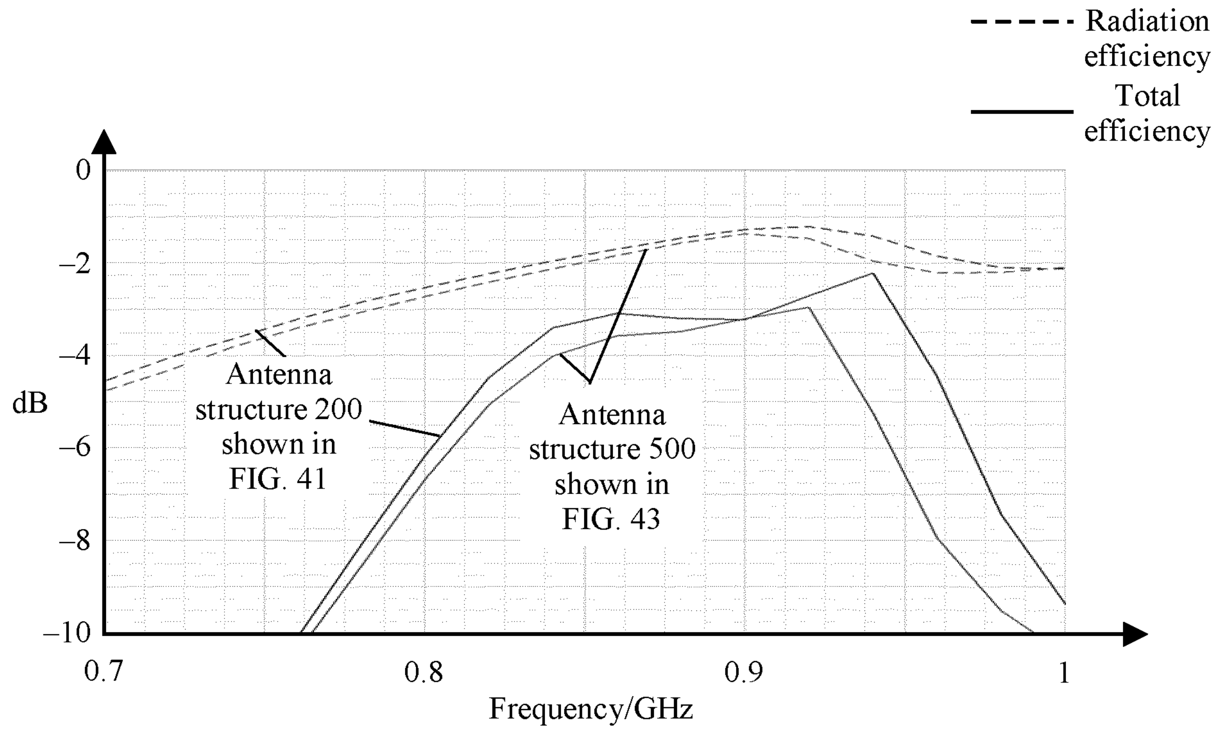

Radiation efficiency
Total efficiency
0
−2
−4
dB
−6
−8
−10
0.7
0.8
0.9
1
Frequency/GHz
Antenna structure 200 shown in FIG. 41
Antenna structure 500 shown in FIG. 43

FIG. 51

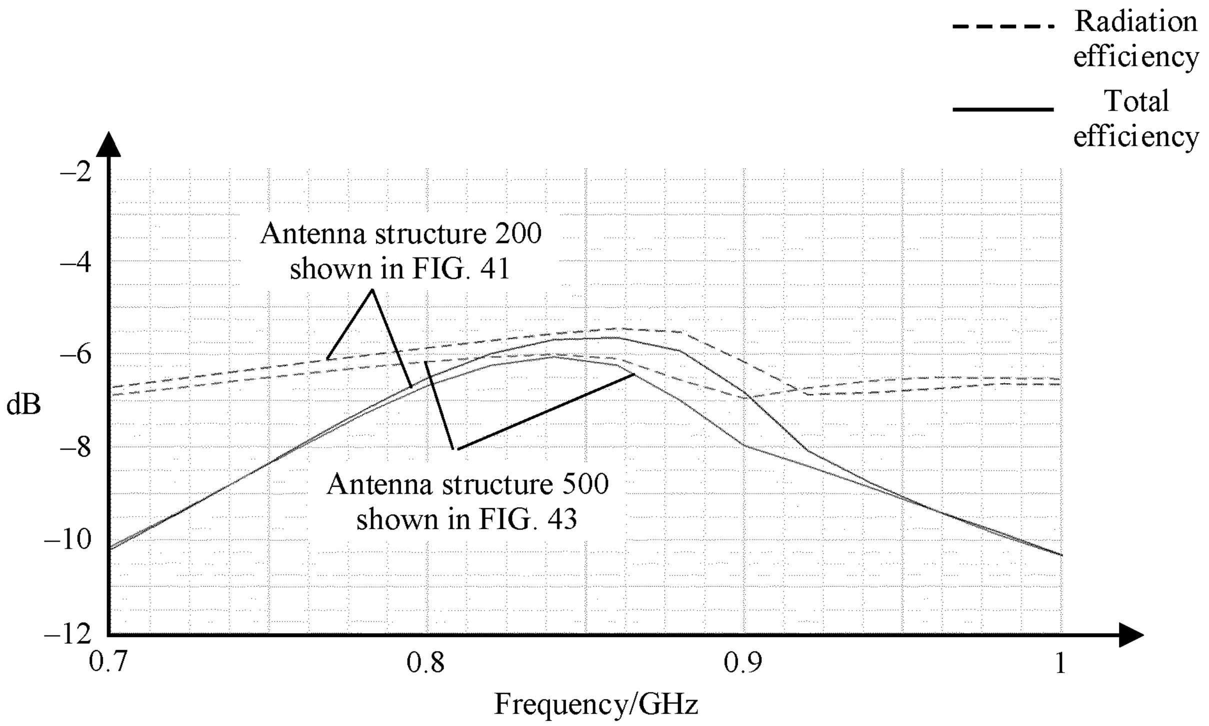

Radiation efficiency
Total efficiency
dB
–2
–4
–6
–8
–10
–12
0.7
0.8
0.9
1
Frequency/GHz
Antenna structure 200 shown in FIG. 41
Antenna structure 500 shown in FIG. 43

FIG. 52

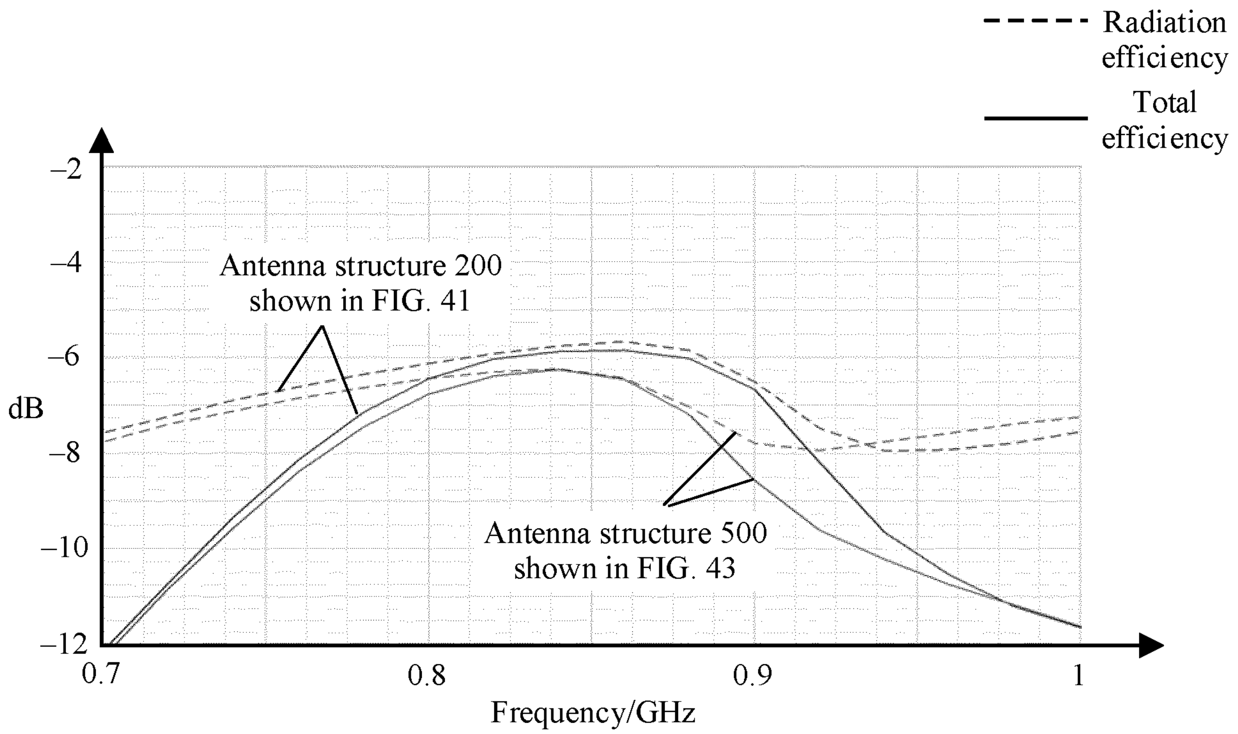

Radiation efficiency
Total efficiency
dB
–2
–4
–6
–8
–10
–12
0.7
0.8
0.9
1
Frequency/GHz
Antenna structure 200 shown in FIG. 41
Antenna structure 500 shown in FIG. 43

FIG. 53

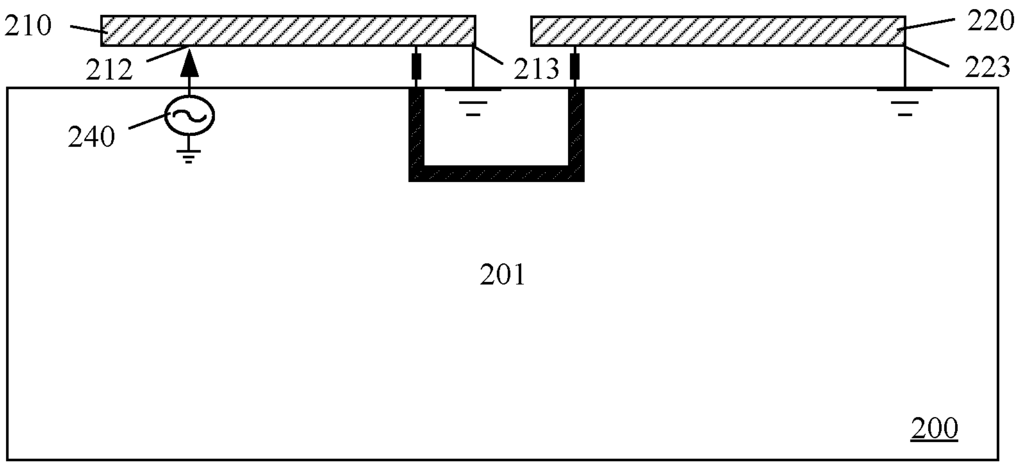


FIG. 54

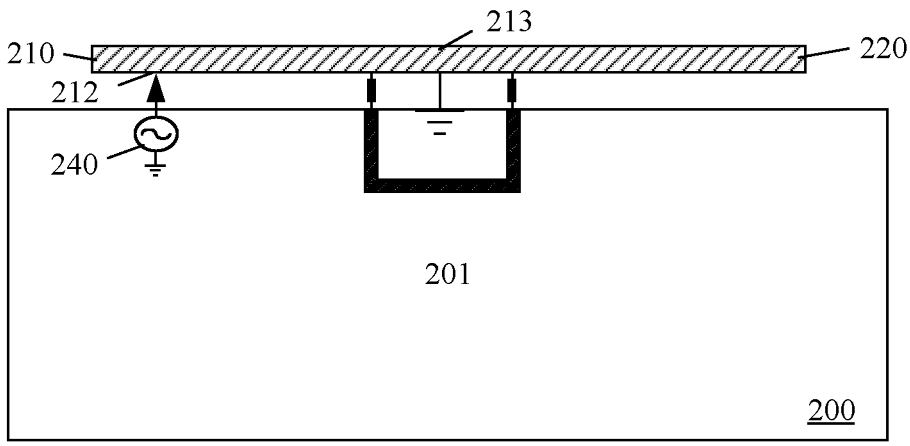


FIG. 55

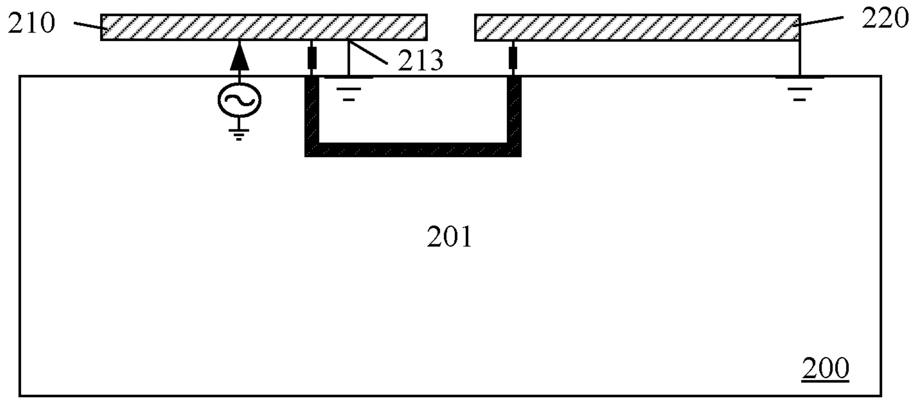


FIG. 56

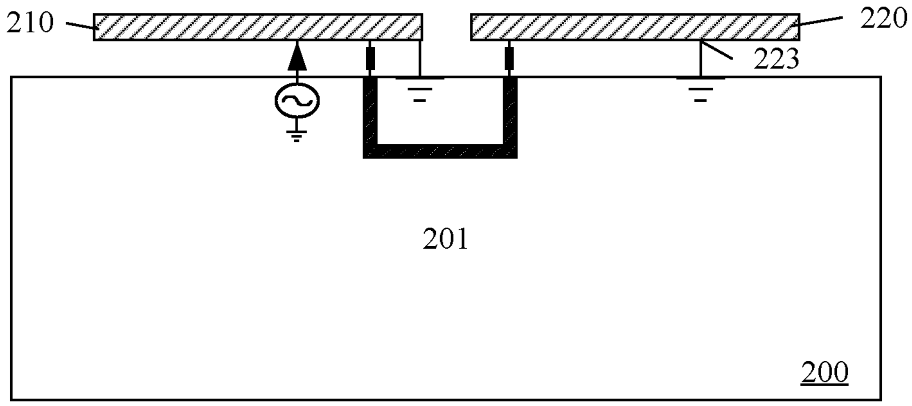


FIG. 57

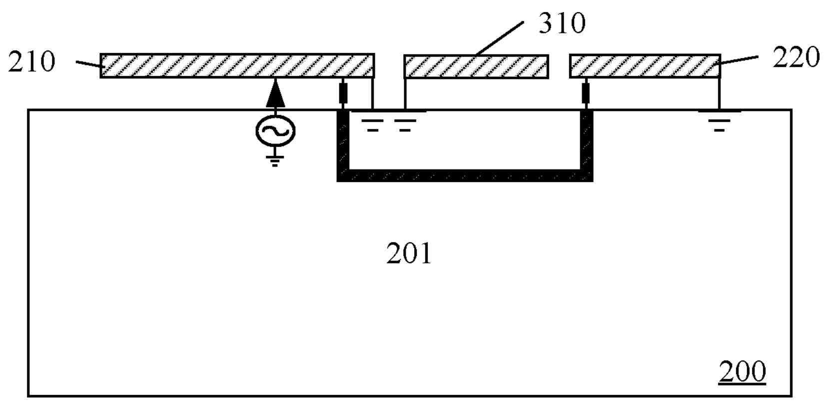


FIG. 58

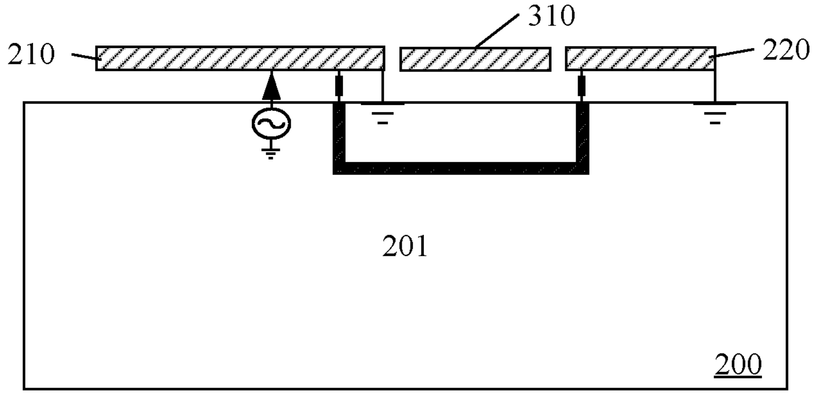


FIG. 59

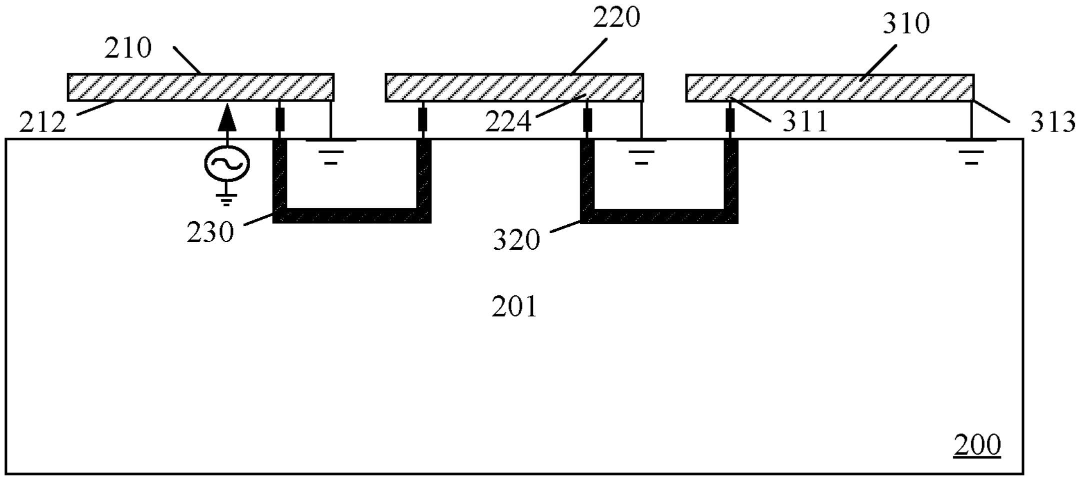


FIG. 60

INTERNATIONAL SEARCH REPORT

International application No. **PCT/CN2024/078548**

A. CLASSIFICATION OF SUBJECT MATTER

H01Q1/50(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)

CNTXT, CNKI, IEEE, EPTXT, USTXT, WOTXT, VEN: 天线, 辐射体, 馈电单元, 馈电点, 金属, 连接件, 耦合, 谐振, 低于, 开放端; antenna, radiat+, feed+, unit, metal, connector, coupl+, resonance, lower, lesser, open end

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 112736432 A (GUANGDONG OPPO MOBILE TELECOMMUNICATIONS CORP., LTD.) 30 April 2021 (2021-04-30) description, paragraphs 0032-0091, and figures 1-12	1-20
A	CN 112928456 A (GUANGDONG OPPO MOBILE TELECOMMUNICATIONS CORP., LTD.) 08 June 2021 (2021-06-08) entire document	1-20
A	CN 114976600 A (GUANGDONG OPPO MOBILE TELECOMMUNICATIONS CORP., LTD.) 30 August 2022 (2022-08-30) entire document	1-20
A	US 2019363425 A1 (ACER INC.) 28 November 2019 (2019-11-28) entire document	1-20
A	US 2022123456 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 21 April 2022 (2022-04-21) entire document	1-20

☐ 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
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 May 2024	**20 May 2024**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/078548

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	112736432	A	30 April 2021	None			
CN	112928456	A	08 June 2021	None			
CN	114976600	A	30 August 2022	None			
US	2019363425	A1	28 November 2019	TWI	669852	B	21 August 2019
				TW	202005163	A	16 January 2020
				US	10530044	B2	07 January 2020
US	2022123456	A1	21 April 2022	WO	2020133111	A1	02 July 2020
				US	11876285	B2	16 January 2024
				EP	3883061	A1	22 September 2021
				EP	3883061	A4	01 December 2021

Form PCT/ISA/210 (patent family annex) (July 2022)