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

(72) Inventors:
- **XUE, Liang**
  Shenzhen, Guangdong 518129 (CN)
- **CHU, Jiahui**
  Shenzhen, Guangdong 518129 (CN)
- **LIU, Huatao**
  Shenzhen, Guangdong 518129 (CN)

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

(54) **ELECTRONIC DEVICE**

(57) This application provides an electronic device, including a first antenna feed circuit, a second antenna feed circuit, a radiator, and a first component. The first antenna feed circuit and the second antenna feed circuit feed the radiator through a first feed point and a second feed point respectively, and the radiator may receive/-transmit a signal in a first operating frequency band through feeding of the first feed point, and may receive/-transmit a signal in a second operating frequency band through feeding of the second feed point. A gap is disposed on the radiator, the first component is connected across the gap, and the second feed point is disposed at a position that is on the radiator and that is close to the gap. According to the electronic device provided in this application, a co-radiator dual-antenna design with high isolation can be implemented.

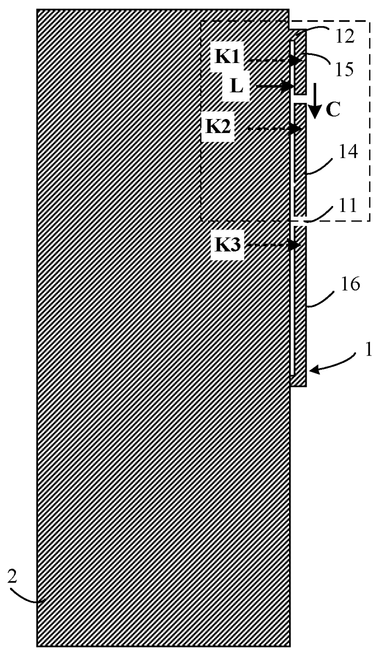

FIG. 24

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Description

TECHNICAL FIELD

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

BACKGROUND

[0002] In an antenna design of a terminal product, how to implement wider frequency band coverage of an antenna in compact space or implement multiple antennas with high isolation is a design difficulty of the antenna. It is expected that a co-radiator antenna can achieve a miniaturization design and isolation in different frequency bands and/or different modes.

SUMMARY

[0003] An objective of this application is to provide an electronic device, to implement decoupling between two antennas in different frequency bands and different modes, and improve isolation.

[0004] A first aspect of this application provides an electronic device, including:

- a first antenna feed circuit and a second antenna feed circuit;
- a radiator, including an open end and a ground end, where a gap is disposed on the radiator, the gap is disposed between the open end and the ground end, the radiator is divided into a first radiator and a second radiator through the gap, the first radiator is a radiator part between the gap and the open end, the second radiator is a radiator part between the gap and the ground end, and a length of the first radiator is one to three times a length of the second radiator; and
- a first component, connected across the gap and coupled in series between the first radiator and the second radiator.

[0005] The radiator further includes a first feed point and a second feed point. The radiator is coupled to the first antenna feed circuit through the first feed point, the first antenna feed circuit is configured to feed a signal in a first operating frequency band into the radiator, and the first radiator and the second radiator are configured to jointly generate a first resonance corresponding to the first operating frequency band. The radiator is coupled to the second antenna feed circuit through the second feed point, the second antenna feed circuit is configured to feed a signal in a second operating frequency band into the radiator, and the first radiator and the second radiator are configured to jointly generate a second resonance corresponding to the second operating frequency band. The second feed point is disposed on the first radiator, and a length of the first radiator between the second feed point and the open end is greater than or equal to a length of the first radiator between the second feed point and the gap.

[0006] A center frequency of the second operating frequency band is higher than a center frequency of the first operating frequency band, and a highest frequency of the first operating frequency band is lower than a lowest frequency of the second operating frequency band.

[0007] In this application, the gap is disposed on a part that is of the radiator and that is located between the open end and the ground end, and the length of the first radiator is one to three times the length of the second radiator, so that an electric field reverse point can be generated on the first radiator. In addition, the second feed point is disposed at a position that meets a condition in which the length of the first radiator between the second feed point and the open end is greater than or equal to the length of the first radiator between the second feed point and the gap. In this way, it can be ensured that the second feed point is located at the electric field reverse point or at a position close to the electric field reverse point, so that excitation of a quarter antenna mode can be naturally suppressed through impedance mismatching, and only a three-quarter antenna mode can be excited. Therefore, when the second feed point operates in the second operating frequency band, decoupling in the first operating frequency band can be implemented. In addition, the first feed point may be used to excite the quarter antenna mode, and suppress the three-quarter antenna mode, so that decoupling in the second operating frequency band can be implemented. Therefore, in this application, co-radiator dual-antenna decoupling in different frequency bands and different modes can be implemented, and isolation can be improved.

[0008] In a possible implementation, the first feed point is located on the second radiator, and a length of the second radiator between the first feed point and the ground end is less than a length of the second radiator between the first feed point and the gap. This helps excite the quarter antenna mode through the first feed point, and excite the three-quarter antenna mode through the second feed point.

[0009] In a possible implementation, the length of the second radiator between the first feed point and the ground end is less than or equal to 10 mm. This helps excite the quarter antenna mode through the first feed point, and excite the three-quarter antenna mode through the second feed point.

[0010] In a possible implementation, the first feed point is located on the first radiator, and a length of the first radiator between the first feed point and the open end is less than a length of the first radiator between the first feed point and the gap. An electric field reverse point in the quarter antenna mode is located at a position that is on the first radiator and that is close to the gap, and a position of the electric field reverse point or a position close to the electric field reverse point is a position at which the second feed point is disposed. The first feed point and the second feed point cannot overlap. Otherwise, the quarter antenna mode cannot be excited. Therefore, in an embodiment, the first feed point is located at a position close to the open end, so that the quarter antenna mode may be excited through the first feed point, and the three-quarter antenna mode may be excited through the second feed point.

[0011] In a possible implementation, the length of the first radiator between the first feed point and the open end is less than 10 mm, so that the first feed point and the second feed point can be respectively located on two sides of a middle position of the first radiator. This helps excite the quarter antenna mode through the first feed point, and excite the three-quarter antenna mode through the second feed point.

[0012] In a possible implementation, the first component includes a capacitor and/or an inductor and/or a radio frequency switch, so that a frequency ratio of the quarter antenna mode to the three-quarter antenna mode can be easily tuned, the quarter antenna mode can cover the first operating frequency band, and the three-quarter antenna mode can cover the second operating frequency band.

[0013] In a possible implementation, the radio frequency switch includes a switch and a plurality of circuit branches, a first end of the switch is coupled to a radiator at one end of the gap, a second end of the switch is coupled to a radiator at the other end of the gap through at least a part of the circuit branches, and the at least part of the circuit branches has different capacitance values or inductance values. The switch 31 may be selectively connected to one of the circuit branches based on a capacitance value or an inductance value to be matched by a circuit, to facilitate adjustment of the frequency ratio of the two modes.

[0014] In a possible implementation, when a frequency of a resonance point of the first resonance is less than or equal to 1 GHz, an equivalent capacitance value of the first component is less than or equal to 10 pF. This can ensure that the radiator has good radiation performance at a low frequency. When a frequency of a resonance point of the first resonance is greater than 1 GHz, an equivalent capacitance value of the first component is less than or equal to 2 pF. This can ensure that the radiator has good radiation performance at a medium frequency and/or a high frequency.

[0015] In a possible implementation, the electronic device further includes at least one second component, where a first end of each of the at least one second component is coupled to the first radiator or the second radiator, and a second end of each of the at least one second component is grounded. The second component cooperates with the first component. This helps adjust the frequency ratio of two antenna modes.

[0016] In a possible implementation, the at least one second component includes an inductor, and a length of a radiator between the gap and a position at which the inductor is coupled to the first radiator or the second radiator is less than or equal to 20 mm. The inductor is connected in parallel, so that performance of the three-quarter antenna mode can be improved, and a degree of freedom of tuning in the three-quarter antenna mode can be increased.

[0017] In a possible implementation, when the frequency of the resonance point of the first resonance is less than or equal to 1 GHz, an inductance value of the inductor is less than 20 nH, to facilitate tuning in a low frequency band; or when the frequency of the resonance point of the first resonance is greater than 1 GHz, an inductance value of the inductor is less than 10 nH, to facilitate tuning in a high frequency band.

[0018] In a possible implementation, the electronic device further includes a second capacitor, where the second capacitor is coupled in series between the second feed point and the second antenna feed circuit. When the frequency of the resonance point of the first resonance is less than or equal to 1 GHz, a capacitance value of the second capacitor is less than or equal to 5 pF; or when the frequency of the resonance point of the first resonance is greater than 1 GHz, a capacitance value of the second capacitor is less than or equal to 3 pF. Therefore, high-impedance feeding can be implemented at the second feed point K2, so that excitation of the quarter antenna mode can be effectively suppressed, and a decoupling effect in the quarter antenna mode can be improved.

[0019] In a possible implementation, the electronic device further includes a matching circuit, where a first end of the matching circuit is coupled to the second feed point, a second end of the matching circuit is coupled to the second antenna feed circuit, the matching circuit in the first operating frequency band is equivalent to a first equivalent capacitance value, the matching circuit in the second operating frequency band is equivalent to a second equivalent capacitance value, and the first equivalent capacitance value is less than the second equivalent capacitance value. The matching circuit is disposed, so that excitation of the quarter antenna mode can be naturally suppressed through impedance mismatching, and only the three-quarter antenna mode can be excited. Therefore, when the matching circuit operates in the second operating frequency band, decoupling in the first operating frequency band can be implemented. In addition, the first equivalent capacitance value is less than the second equivalent capacitance value. This helps suppress a low-frequency signal in the first operating frequency band, to implement high isolation in the first operating frequency band, and helps expand a bandwidth of the second operating frequency band.

[0020] In a possible implementation, the electronic device further includes a filter circuit, where the filter circuit is coupled to the first feed point, and the filter circuit is configured to: pass, between the radiator and the first antenna feed circuit, the signal in the first operating frequency band, and suppress the signal in the second operating frequency band. This can implement self-decoupling in the three-quarter antenna mode.

[0021] In a possible implementation, the filter circuit is a high-pass low-cut filter circuit, a first end of the high-pass low-cut filter circuit is coupled to the first feed point, and a second end of the high-pass low-cut filter circuit is grounded. The filter circuit can pass a high-frequency signal in the second operating frequency band to ground, and can pass, in the first antenna feed circuit, a low-frequency signal in the first operating frequency band, so that the three-quarter antenna mode can be suppressed, and decoupling in the second operating frequency band can be implemented.

[0022] In a possible implementation, both the filter circuit and the matching circuit include a capacitor and/or an inductor. The matching circuit can implement a high-impedance feeding function by using the capacitor, the inductor, or a combination thereof, so that excitation of the quarter antenna mode can be suppressed through impedance mismatching, to implement self-decoupling in the first operating frequency band. In addition, the filter circuit can pass the signal in the first operating frequency band and suppress the signal in the second operating frequency band, so that the quarter antenna mode can be excited, and the three-quarter antenna mode can be suppressed, thereby implementing decoupling in the second operating frequency band.

[0023] In a possible implementation, the radiator excites a quarter antenna mode of the radiator through the first antenna feed circuit, the radiator excites a three-quarter antenna mode of the radiator through the second antenna feed circuit, the radiator generates the first resonance in the quarter antenna mode, and the radiator generates the second resonance in the three-quarter antenna mode. In the quarter antenna mode, an electric field reverse point is generated on the second radiator, and the second feed point is disposed at a position that is on the radiator and that is less than or equal to 10 mm away from the electric field reverse point.

[0024] The second feed point is disposed at the electric field reverse point or at a position close to the electric field reverse point, so that excitation of the quarter antenna mode can be naturally suppressed through impedance mismatching, and only the three-quarter antenna mode can be excited. Therefore, when the second feed point operates in the second operating frequency band, decoupling in the first operating frequency band can be implemented. The second feed point may be disposed at the electric field reverse point or in a range +/-10 mm of the electric field reverse point, so that a position of the second feed point is flexible.

[0025] In a possible implementation, a sum of electrical lengths of the first radiator and the second radiator is greater than a quarter wavelength of the first operating frequency band and less than a three-quarter wavelength of the first operating frequency band. This helps tune a frequency ratio of two antennas, and can form the electric field reverse point on the first radiator, so that the second feed point can be disposed at or near the electric field reverse point, to implement decoupling between the two antennas.

[0026] In a possible implementation, the first operating frequency band includes at least one communication frequency band in a range of 698 MHz to 960 MHz; or the first operating frequency band includes at least one communication frequency band in a range of 1.7 GHz to 2 GHz; or the first operating frequency band includes at least one communication frequency band in a range of 2.3 GHz to 2.7 GHz.

[0027] In a possible implementation, a frequency difference between the resonance point of the first resonance and the resonance point of the second resonance ranges from 100 MHz to 1 GHz.

[0028] In a possible implementation, the electronic device includes a side frame, the side frame includes a first position, a second position, and a third position that are sequentially disposed, and the side frame is grounded at the first position, and is provided with an insulation slot at each of the second position and the third position. The first radiator includes a conductive part that is of the side frame and that is between the second position and the third position, and the second radiator includes a conductive part that is of the side frame and that is between the first position and the second position. Therefore, the metal side frame is reused, so that space, in the electronic device, occupied by a co-radiator antenna can be reduced.

[0029] In a possible implementation, the electronic device includes a housing, and the radiator, the circuit board, and the first component are all disposed in the housing. When internal space of the electronic device is large enough, the entire co-radiator antenna may be installed in the housing, to facilitate disassembly, assembly, and maintenance of the co-radiator antenna.

[0030] A second aspect of this application further provides an electronic device, including:

a first antenna feed circuit and a second antenna feed circuit;

a radiator, including an open end and a ground end, where a gap is disposed on the radiator, the gap is disposed between the open end and the ground end, the radiator is divided into a first radiator and a second radiator through the gap, the first radiator is a radiator part between the gap and the open end, the second radiator is a radiator part between the gap and the ground end, and a length of the first radiator is one to three times a length of the second radiator; and

a first component, connected across the gap and coupled in series between the first radiator and the second radiator.

[0031] The radiator further includes a first feed point and a second feed point, the radiator is coupled to the first antenna feed circuit through the first feed point, and the radiator is coupled to the second antenna feed circuit through the second feed point.

[0032] The first antenna feed circuit is configured to feed the radiator through the first feed point, so that the radiator excites a quarter antenna mode, and in the quarter antenna mode, the first radiator and the second radiator are configured to jointly generate a first resonance corresponding to the first operating frequency band. The second antenna feed circuit is configured to feed the radiator through the second feed point, so that the radiator excites a three-quarter antenna mode, and in the three-quarter antenna mode, the first radiator and the second radiator are configured to jointly generate a second resonance corresponding to the second operating frequency band. A center frequency of the second operating frequency band is higher than a center frequency of the first operating frequency band, and a highest frequency of the first operating frequency band is lower than a lowest frequency of the second operating frequency band.

[0033] In the quarter antenna mode, an electric field reverse point is generated on the first radiator, and the second feed point is disposed at a position that is on the first radiator and that is at a preset distance away from the electric field reverse point.

[0034] It should be understood that the foregoing general descriptions and the following detailed descriptions are merely used as an example, and do not limit this application.

BRIEF DESCRIPTION OF DRAWINGS

[0035]

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

FIG. 1(b) is a diagram of current and electric field distribution obtained when no gap is disposed on a radiator according to an embodiment of this application;

FIG. 1(c) is a diagram of current and electric field distribution obtained when a gap is disposed on a radiator according to an embodiment of this application;

FIG. 2 is a diagram of a structure of a capacitor according to an embodiment of this application;

FIG. 3 is a diagram of an antenna in an electronic device according to an embodiment of this application;

FIG. 4 is a diagram of electric field effects of an antenna in an electronic device in a quarter antenna mode and a three-quarter antenna mode according to an embodiment of this application;

FIG. 5 is a diagram of an antenna in an electronic device according to another embodiment of this application;

FIG. 6 is a diagram of an antenna in an electronic device according to still another embodiment of this application;

FIG. 7 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a capacitor is connected in series at a second feed point according to an embodiment of this application;

FIG. 8 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a capacitor is connected in series at a second feed point according to another embodiment of this application;

FIG. 9 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a capacitor is connected in series at a second feed point according to still another embodiment of this application;

FIG. 10 is a diagram of a structure in which a first component is a radio frequency switch according to an embodiment of this application;

FIG. 11 is a diagram of a structure in which a first component is a radio frequency switch according to another embodiment of this application;

FIG. 12 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a co-radiator antenna in an electronic device switches to a different frequency band in a first operating frequency band according to an embodiment of this application;

FIG. 13 is a curve diagram of efficiency obtained when a co-radiator antenna in an electronic device switches to a different frequency band in a first operating frequency band according to an embodiment of this application;

FIG. 14 is a partial enlarged view of a filter circuit and a matching circuit on an electronic device according to an embodiment of this application;

FIG. 15 is a diagram of a co-radiator antenna in an electronic device according to another embodiment of this application;

FIG. 16 is a diagram of electric field effects of a co-radiator antenna in an electronic device in a first quarter antenna mode and a second three-quarter antenna mode according to another embodiment of this application;

FIG. 17 is a partial enlarged view of a filter circuit and a matching circuit on an electronic device according to another embodiment of this application;

FIG. 18 is a curve diagram of a corresponding return loss coefficient (S11) and corresponding isolation obtained when a filter circuit and a matching circuit are used according to an embodiment of this application;

FIG. 19 is a curve diagram of a corresponding return loss coefficient (S11) and corresponding isolation obtained when a filter circuit and a matching circuit are used according to another embodiment of this application;

FIG. 20 is a curve diagram of a corresponding return loss coefficient (S11) and corresponding isolation obtained when a filter circuit and a matching circuit are used according to still another embodiment of this application;

FIG. 21 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a third inductor is connected in parallel near a gap and a first operating frequency band is switched to a different frequency band;

FIG. 22 is a curve diagram of efficiency obtained when a third inductor is connected in parallel near a gap and a first operating frequency band is switched to a different frequency band;

FIG. 23 is a diagram of a co-radiator antenna in an electronic device according to still another embodiment of this application;

FIG. 24 is a diagram of a co-radiator antenna in an electronic device according to yet another embodiment of this application;

FIG. 25 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a co-radiator antenna in an electronic device switches to a different frequency band in a first operating frequency band according to another embodiment of this application;

FIG. 26 is a curve diagram of efficiency obtained when a co-radiator antenna in an electronic device switches to a different frequency band in a first operating frequency band according to another embodiment of this application;

FIG. 27 is a partial enlarged view of a filter circuit on an electronic device according to an embodiment of this application;

FIG. 28 is a partial enlarged view of a filter circuit on an electronic device according to another embodiment of this application;

FIG. 29 is a simulation diagram of a radiation direction of an antenna when an electronic device is in a free space state;

FIG. 30 is a simulation diagram of a radiation direction of an antenna when an electronic device is in a left-hand holding state;

FIG. 31 is a simulation diagram of a radiation direction of an antenna when an electronic device is in a right-hand holding state;

FIG. 32 is a curve diagram of a return loss coefficient (S11) and isolation of an antenna when an electronic device is in a free space state, a left-hand holding state, and a right-hand holding state;

FIG. 33 is a curve diagram of efficiency of an antenna in a first mode when an electronic device is in a free space state, a left-hand holding state, and a right-hand holding state;

FIG. 34 is a curve diagram of efficiency of an antenna in a second mode when an electronic device is in a free space state, a left-hand holding state, and a right-hand holding state;

FIG. 35 is a curve diagram of a return loss coefficient (S11) of an antenna obtained when an electronic device is held in hand and a position of a gap is held; and

FIG. 36 is a curve diagram of efficiency of an antenna obtained when an electronic device is held in hand and a position of a gap is held.

[0036] Reference numerals:

1: radiator;

- 11: open end;
- 12: ground end;
- 13: gap;
- 14: first radiator;
- 15: second radiator;
- 16: third radiator;

2: circuit board;

3: first component;

- 31: switch;
- 32: capacitor;
- 33: inductor;

K1: first feed point;

K2: second feed point;

K3: third feed point;

4: filter circuit;

- 41: first capacitor;
- 42: first inductor;

5: matching circuit;

- 51: second capacitor;
- 52: second inductor;
- 53: fourth inductor;

6: third inductor; and

7: housing.

[0037] The accompanying drawings herein are incorporated into this specification and constitute a part of this specification, to show embodiments in accordance with this application, and are used, together with this specification, to explain the principle of this application.

DESCRIPTION OF EMBODIMENTS

[0038] To better understand technical solutions of this application, the following describes embodiments of this application in detail with reference to the accompanying drawings. It should be understood that the specific embodiments described herein are merely used to explain this application but are not intended to limit this application.

[0039] In the descriptions of this application, unless otherwise explicitly specified or defined, the terms "first" and "second" are merely used for a purpose of description, and shall not be understood as an indication or implication of relative importance. Unless otherwise specified or explained, the term "a plurality of" refers to two or more. The terms "connection", "fixed", and the like should be understood in a broad sense. For example, the "connection" may be a fixed connection, or may be a detachable connection, an integrated connection, or an electrical connection; or the "connection" may be a direct connection, or an indirect connection through an intermediary. For a person of ordinary skill in the art, a specific meaning of the foregoing terms in this application may be understood according to a specific situation.

[0040] 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 in which different components in a line structure are connected through a physical line that can transmit an electrical signal, for example, a copper foil or a conducting wire of a printed circuit board (printed circuit board, PCB). The "indirect coupling" may be understood as electrical conduction of two conductors in a mid-air/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 of a gap between two spaced conductive components.

[0041] Lumped element/component: A lumped element/component is a collective name for components whose sizes are far less than a wavelength corresponding to a circuit operating frequency. For a signal, component characteristics are always fixed at any time, regardless of a frequency.

[0042] Distributed element/component: Different from the lumped element, if an element has a size close to or greater than a wavelength of a circuit operating frequency, characteristics of the element vary according to a signal when the signal passes through the element. In this case, the element cannot be regarded as a single entity with fixed characteristics, but should be referred to as a distributed element.

[0043] 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 capacitor) is an equivalent capacitor formed between two conductive parts that are spaced by a specific gap.

[0044] 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 inductor) is an equivalent inductor formed by using a conductive part of a specific length, for example, an equivalent inductor formed by a conductor due to curling or rotation.

[0045] Radiator or antenna stub: The radiator or antenna stub 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. A modulated high-frequency current energy (or guided wave energy) generated by the transmitter is transmitted to a transmit radiator through a feeder. 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 a feeder.

[0046] The radiator (or antenna stub) may include a conductor having a specific shape and size, for example, a linear conductor or a sheet conductor. A specific shape is not limited in this application. In an embodiment, a linear radiator may be referred to as a linear 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 frame antenna. In an embodiment, the linear radiator may be implemented by using a support conductor, and may also be referred to as a support antenna. In an embodiment, for a radiator of the linear radiator or the linear antenna, a diameter (for example, including a thickness and a width) is much less than a wavelength (for example, a dielectric wavelength) (for example, the diameter is less than 1/16 of the wavelength), and a length may be comparable to the wavelength (for example, the dielectric wavelength) (for example, the length is approximately 1/8 of the wavelength, or is 1/8 to 1/4 or 1/4 to 1/2 of the wavelength, or is longer). Main forms of the linear antenna are a dipole antenna, a half-wave dipole antenna, a monopole antenna, a loop antenna, and an inverted F antenna (which is also referred to as an IFA, 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 ground path to a monopole antenna. The IFA has a feed point and a ground point. A side view of the IFA is inverted F-shaped. Therefore, the IFA is referred to as an inverted F antenna. In an embodiment, a sheet-like radiator may include a microstrip antenna or a patch (patch) antenna, for example, a planar inverted F antenna (which is also referred to as a PIFA, Planar Inverted F Antenna). In an embodiment, the sheet-like radiator may be implemented by using 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 circle, a rectangle, a ring, 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.

[0047] The radiator (or antenna stub) may also include a slot or a silt formed on the conductor, for example, a closed or semi-closed slot or silt formed on a grounded conductor surface. In an embodiment, a radiator having a slot or slit may be referred to as a slot antenna or a slotted antenna for short. In an embodiment, for the slot or the slit of the slot antenna/slotted antenna, a radial size (for example, including a width) is much less than a wavelength (for example, a dielectric wavelength) (for example, the radial size is less than 1/16 of the wavelength), and a length size may be comparable to the wavelength (for example, the dielectric wavelength) (for example, the length is approximately 1/8 of the wavelength, or is 1/8 to 1/4 or 1/4 to 1/2 of the wavelength, or is longer). 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 added to a closed slot or slit) may be referred to as an open slot antenna for short. In some embodiments, a shape of the slot is a long strip. In some embodiments, a length of the slot is about half a wavelength (for example, a dielectric wavelength). In some embodiments, a length of the slot is about an integer multiple of a wavelength (for example, one time a dielectric wavelength). In some embodiments, the slot may be fed through a transmission line that is cross-connected to 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 using 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 using a support conductor that is grounded at two ends, and may also be referred to as a support antenna.

[0048] A feed circuit is a combination of all circuits configured to receive and transmit radio frequency signals. The feed circuit may include a transceiver (transceiver) and a radio frequency front end (RF front end). In some cases, in a narrow sense, the "feed circuit" is a radio frequency integrated circuit (RFIC, Radio Frequency Integrated Circuit), and the RFIC may be considered to include a radio frequency front-end chip and the transceiver. The feed circuit has a function of converting a radio wave (for example, a radio frequency signal) and an electrical signal (for example, a digital signal). Usually, the feed circuit is considered as a part of radio frequency.

[0049] In some embodiments, an electronic device may further include a test base (which is also referred to as a radio frequency base or a radio frequency test base). A coaxial cable may be inserted into the test base, to test a characteristic of the radio frequency front end or the radiator of the antenna through the cable. The radio frequency front end may be considered as a circuit part coupled between the test base and the transceiver.

[0050] In some embodiments, the radio frequency front end may be integrated into the radio frequency front-end chip in the electronic device, or the radio frequency front end and the transceiver may be integrated into the radio frequency integrated circuit in the electronic device.

[0051] It should be understood that any two of a first feed circuit, a second feed circuit, ..., and an Nth feed circuit in this application may share a same transceiver, for example, transmit a signal through a radio frequency channel in the transceiver (for example, a pin (pin) of the radio frequency integrated circuit); and may further share a radio frequency front end, for example, process the signal via a switch or an amplifier in the radio frequency front end.

[0052] It should be further understood that two of the first feed circuit, the second feed circuit, ..., and the Nth feed circuit in this application usually correspond to two radio frequency test bases in the electronic device.

[0053] The matching circuit is a circuit related to adjustment of a radiation characteristic of an antenna. In an embodiment, the matching circuit is coupled between the feed circuit and a corresponding radiator. Generally, the matching circuit is coupled between the test base and the radiator. In an embodiment, the matching circuit has a function of impedance matching and/or frequency tuning. Usually, the matching circuit is considered as a part of an antenna.

[0054] A tuning circuit is a circuit related to adjustment of a resonance frequency of an antenna. In an embodiment, the tuning circuit is coupled between the radiator and the ground plane. In an embodiment, the tuning circuit is coupled between the feed circuit and the radiator. In an embodiment, the tuning circuit has a function of impedance matching and/or frequency tuning. Usually, the tuning circuit is considered as a part of an antenna.

[0055] In an embodiment, the matching circuit/tuning circuit may include a switch and/or an electronic element/component, and the switch may be an electronic element/component configured to enable a coupling connection of the radiator. The switch in the matching circuit/tuning circuit may also be referred to as an antenna switch. In an embodiment, the matching circuit/tuning circuit may include a filter circuit.

[0056] Ground/ground plane: The ground/ground plane may generally represent at least a part of any grounding plane, or grounding plate, or grounding metal layer of an electronic device (for example, a mobile phone), or at least a part of any combination of any grounding plane, grounding plate, ground part, or the like. The "ground/ground plane" may be configured to ground a component of the electronic device. In an embodiment, the "ground/ground plane" may include any one or more of the following: a grounding plane of a circuit board of the electronic device, a grounding plate formed in a middle frame of the electronic device, a grounding metal layer formed by a metal film under a display, a conductive grounding plate of a battery, and a conductive member or a metal member electrically connected to the grounding plane/grounding plate/metal layer. In an embodiment, the circuit board may be a printed circuit board (printed circuit board, PCB), for example, an 8-layer, 10-layer, or 12-layer to 14-layer board having 8, 10, 12, 13, or 14 layers of conductive materials, or an element that is separated and electrically insulated by using a dielectric layer or an insulation layer such as glass fiber or polymer. In an embodiment, the circuit board includes a dielectric substrate, the grounding plane, and a wiring layer. The wiring layer and the grounding plane are electrically connected through a via. In an embodiment, parts 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 installed 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 disposed at the wiring layer.

[0057] Any of the foregoing grounding plane, grounding plate, or grounding 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 foils on insulation laminates, aluminum foils on insulation laminates, gold foils on insulation laminates, silver-plated copper, silver-plated copper foils on insulation laminates, silver foils on insulation laminates and tin-plated copper, cloth impregnated with graphite powder, graphite-coated laminates, copperplated laminates, and brass-plated laminates and aluminum-plated laminates. A person skilled in the art may understand that the grounding plane/grounding plate/grounding metal layer may alternatively be made of other conductive materials.

[0058] Grounding: The grounding is coupling to the ground/ground plane through a grounding structure and/or a grounding circuit. In an embodiment, the grounding may be grounding through an entity, for example, grounding through an entity at a specific position on the side frame that is implemented through some mechanical parts of the middle frame (which is also referred to as entity grounding). In an embodiment, the grounding may be grounding through a component, for example, grounding through a component like a capacitor/an inductor/a resistor connected in series or in parallel (which is also referred to as component grounding).

[0059] Resonance frequency: The resonance frequency is also referred to as a resonant frequency. The resonance frequency may have a frequency range, namely, a frequency range in which resonance occurs. The resonant frequency may be a frequency range in which a return loss characteristic is less than -6 dB. A strongest resonance point may be referred to as a resonance point, and a frequency corresponding to the resonance point is a center frequency or a point frequency. A return loss characteristic of the center frequency may be less than -20 dB. It should be understood that, unless otherwise specified, an antenna/a radiator generates a "first/second resonance" in this application, where the first resonance should be a fundamental mode resonance generated by the antenna/radiator, or a resonance that is generated by the antenna/radiator and that has a lowest frequency. It should be understood that the antenna/radiator may generate one or more antenna modes based on specific design, and one fundamental mode resonance may be correspondingly generated in each antenna mode.

[0060] Resonance frequency band: A range of a resonance frequency is the resonance frequency band. A return loss characteristic of any frequency in the resonance frequency band may be less than -6 dB or -5 dB.

[0061] Communication frequency band/Operating frequency band: An antenna, regardless of a type, always operates in a specific frequency range (frequency band width). For example, an operating frequency band of an antenna supporting a B40 frequency band includes a frequency ranging from 2300 MHz to 2400 MHz. In other words, the operating frequency band of the antenna includes the B40 frequency band. A frequency range that meets a specification requirement can be considered as the operating frequency band of the antenna. A width of the operating frequency band is referred to as an operating bandwidth. An operating bandwidth of an omnidirectional antenna may reach 3% to 5% of the center frequency. An operating bandwidth of a directional antenna may reach 5% to 10% of the center frequency. The bandwidth may be considered as a range of frequencies on both sides of the center frequency (for example, a resonance frequency of a dipole), where an antenna characteristic is within an acceptable range of values for the center frequency.

[0062] A resonant frequency band and the operating frequency band may be the same, or may partially overlap. In an embodiment, one or more resonant frequency bands of the antenna may cover one or more operating frequency bands of the antenna.

[0063] 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 1955 MHz. The operating wavelength is not limited to the center frequency, and may alternatively be a wavelength corresponding to a resonant frequency or a frequency of an operating frequency band other than a center frequency.

[0064] It should be understood that a wavelength of a radiated 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 radiated signal, and the speed of light may be 3×108 m/s. A wavelength of the radiated signal in a dielectric may be calculated as follows: dielectric wavelength=(speed of $\text{light}/\sqrt{\varepsilon})/\text{frequency}$, where ε is a relative dielectric constant of the dielectric. The wavelength in embodiments of this application is usually a dielectric wavelength, and may be a dielectric wavelength corresponding to the center frequency of the resonant frequency, or a dielectric wavelength corresponding to the center frequency of the operating frequency band supported by the antenna. For example, if 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 dielectric wavelength calculated by using the frequency 1955 MHz. The "dielectric wavelength" is not limited to the center frequency, and may alternatively be a dielectric wavelength corresponding to a non-center frequency of the operating frequency band or a resonant frequency. For ease of understanding, the dielectric wavelength mentioned in embodiments of this application may be simply calculated by using a relative dielectric constant of a dielectric filled on one or more sides of a radiator.

[0065] End/point: The "end/point" in a first end/second end/feed end/ground end/feed point/ground point/connection point of an antenna radiator cannot be certainly understood in a narrow sense as an end point or an end part that is physically disconnected from another radiator, but may also be considered as a point or a section on the 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 that is on the antenna radiator and that is coupled to a feed structure (for example, an area opposite to a part of the feed structure). 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 grounding structure.

[0066] Open end and closed end: In some embodiments, whether it is the open end or the closed end depends on, for example, whether the open end and the closed end are grounded, the closed end is grounded, and the open end is not grounded. In some embodiments, whether it is the open end or the closed end depends on, for example, another conductor. 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 floating end, 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 through the open end, to transfer coupling energy (which may be understood as transferring a current).

[0067] That currents are co-directional/counter-directional in embodiments of this application should be understood as that directions of main currents on conductors on a same side are codirectional/reverse. For example, when currents distributed in a same direction are excited on a bent conductor or an annular conductor (for example, a current path is also bent or annular), it should be understood that although main currents excited on conductors on two sides of the annular conductor (for example, on conductors around a slot, or on conductors on two sides of a slot) are in reverse directions, the main currents still meet a definition of the currents distributed in a same direction in this application. In an embodiment, that currents on a conductor are in a same direction may mean that the currents on the conductor have no reverse point. In an embodiment, that currents on a conductor are in reverse directions may mean that the currents on the conductor have at least one reverse point. In an embodiment, that currents on two conductors are in a same direction may mean that none of the currents on the two conductors has a reverse point and the currents flow in the same direction. In an embodiment, that currents on two conductors are in reverse directions may mean that none of the currents on the two conductors has a reverse point and the currents flow in the reverse directions. It may be correspondingly understood that directions of currents on a plurality of conductors are codirectional/-reverse.

[0068] System efficiency: The system efficiency is a ratio of power (namely, power that is effectively converted into an electromagnetic wave) radiated by an antenna to space to input power of the antenna. The system efficiency is actual efficiency obtained by matching an antenna port. In other words, the system efficiency of the antenna is actual efficiency (namely, efficiency) of the antenna.

[0069] Radiation efficiency: The radiation efficiency is a ratio of power radiated by an antenna to space (namely, power that is effectively converted into an electromagnetic wave) to active power input to the antenna. Active power input to an 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. A metal loss and a dielectric loss are factors that affect the radiation efficiency.

[0070] A person skilled in the art may understand that 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.

[0071] dB: The dB is a decibel, and is a logarithmic concept with ten as the base. The decibel is only used to evaluate a proportional relationship between a physical quantity and another physical quantity, and has no physical dimension. Each time a ratio between the two quantities increases by 10 times, a difference between the two quantities may be expressed as 10 decibels. For example, if A=" 100", B="10", C="5", and D="1", A/D=20 dB, B/D=10 dB, C/D=7 dB, and B/C=3 dB. In other words, a difference of 10 decibels between the two quantities indicates that the difference is 10 times, a difference of 20 decibels between the two quantities indicates that the difference is 100 times, and the rest may be deduced by analogy. A difference of 3 dB indicates that the difference between the two quantities is twice.

[0072] dBi: The dBi is generally mentioned together with dBd. Herein, dBi and dBd are units of a power gain, and are relative values with different references. The reference for dBi is an omnidirectional antenna, and the reference for dBd is a dipole antenna. Generally, dBi and dBd indicate a same gain. A value indicated by dBi is greater than that indicated by dBd by 2.15 dBi. For example, for an antenna with a gain of 16 dBd, the gain is 18.15 dBi when measured in dBi, and is generally 18 dBi when decimal places are ignored.

[0073] 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.

[0074] The return loss of the antenna may be indicated by an S11 parameter. S11 is a type of S-parameter. S11 indicates a reflection coefficient, and the parameter can indicate whether transmit efficiency of the antenna is high.

[0075] In an embodiment, an S11 diagram may be understood as a diagram of a resonance generated by an antenna. In an embodiment, a resonance shown in the S11 diagram in a part in which a value of S11 less than -6 dB may be understood as a resonance frequency/a frequency range/an operating frequency band generated by the antenna. The S11 parameter is usually a negative number. A smaller value of the S11 parameter indicates a smaller return loss of the antenna and less energy reflected by the antenna, that is, more energy actually entering the antenna and higher total efficiency of the antenna. A larger value of the S11 parameter indicates a larger return loss of the antenna and lower total efficiency of the antenna.

[0076] It should be noted that -4 dB may be used as a standard value of S11. When the value of S11 of the antenna is less than -4 dB, it may be considered that the antenna can operate normally. It should be understood that, -6 dB may alternatively be 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 transmit efficiency of the antenna is good.

[0077] Isolation: The isolation means a ratio of a signal received by another antenna from a transmit antenna to a signal of the transmit antenna. The isolation is a physical quantity used to measure a degree of mutual coupling between antennas. If two antennas form a dual-port network, isolation between the two antennas is S21 and S12 for the antennas. The isolation between antennas may be represented by parameters S21 and S12, and is also one of the S parameters. The parameters S21 and S12 are usually negative numbers. Smaller parameters S21 and S12 indicate higher isolation between the antennas and a lower degree of mutual coupling between the antennas. Larger parameters S21 and S12 indicate lower isolation between the antennas and a higher degree of mutual coupling between the antennas. The antenna isolation depends on an antenna radiation pattern, a spatial distance between antennas, an antenna gain, and the like.

[0078] Antenna mode: The antenna mode in this application includes a 1/4λ mode and a 3/4λ mode, where λ represents a wavelength. In embodiments of this application, the 1/4λ mode is also referred to as a quarter wavelength mode or a quarter antenna mode, and the 3/4λ mode is also referred to as a three-quarter wavelength mode or a three-quarter antenna mode. For a radiator whose one end is an open end 11 and the other end is a ground end 12, the 1/4λ mode is a ground state of the radiator, and the 3/4λ mode is a higher-order modality. In embodiments of this application, the 1/4λ mode includes a quarter antenna mode generated when no gap is disposed on the radiator or a gap is disposed on the radiator. In embodiments of this application, the 3/4λ mode includes a three-quarter antenna mode generated when no gap is disposed on the radiator or a gap is disposed on the radiator. FIG. 1(b) is a diagram of current and electric field distribution obtained when no gap is disposed on a radiator according to an embodiment of this application. Refer to FIG. 1(b). When no gap 13 is disposed on the radiator, the 1/4λ mode of the radiator has a high current point and a strong electric field point, currents are distributed in a same direction on the radiator (in other words, there is no current reverse point), and electric fields are distributed in a same direction on the radiator (in other words, there is no electric field reverse point); and the 3/4λ mode of the radiator has two high current points and two strong electric field points, and currents and electric fields are separately distributed in a same direction.

[0079] FIG. 1(c) is a diagram of current and magnetic current distribution obtained when a gap is disposed on a radiator according to an embodiment of this application. It should be understood that a distribution direction of a magnetic current in FIG. 1(c) corresponds to an electric field distribution status. Refer to FIG. 1(c). When a gap 13 is disposed on the radiator, the 1/4λ mode of the radiator has two high current points and two strong electric field points, and the currents are distributed in a same direction on the radiator (in other words, there is no current reverse point). The radiator has a first high current point at the ground end 12, and the radiator has a second high current point at a part between the open end 11 and the gap 13. An electric field direction of a part of the radiator between the second high current point and the gap 13 is opposite to an electric field direction of a part of the radiator between the second high current point and the open end 11 (for example, as shown in the figure, magnetic current directions are opposite), and an electric field direction of a part of the radiator between the ground end 12 and the gap 13 is opposite to an electric field direction of a part of the radiator between the second high current point and the gap 13. The two strong electric field points of the 1/4λ mode of the radiator are respectively located near the gap 13 and at the open end of the radiator. In addition, the 3/4λ mode of the radiator has two high current points and two strong electric field points. Current directions of parts that are on the radiator and that are located on two sides of the gap 13 are opposite, electric field directions of the parts that are on the radiator and that are located on the two sides of the gap 13 are also opposite (for example, as shown in the figure, magnetic current directions are opposite). The two strong electric field points of the 3/4λ mode of the radiator are respectively located near the gap 13 and at the open end of the radiator. In an embodiment, as shown in FIG. 1(c), when a gap is disposed on the radiator, a position of the second high current point newly added in the 1/4λ mode on the radiator is different from a position of the high current point in the 3/4λ mode.

[0080] Ground state: The ground state corresponds to a resonance with a lowest frequency generated by a segment of radiator or a radiator in a specific antenna mode. A "ground state position" or a "ground state resonance frequency" is a frequency range or a resonance frequency corresponding to a ground state (for example, a generated resonance with a lowest frequency) of the radiator in a specific antenna mode. The "ground state" may also be referred to as a "fundamental mode." The "ground state" corresponds to a "high order" or a "high-order mode/high-order modality", or may be referred to as "frequency multiplication" (for example, triple frequency multiplication or quintuple frequency multiplication). Unless otherwise specified, the "resonance" in embodiments of this application is resonance in the ground state, or resonance generated in the fundamental mode.

[0081] In an antenna design of a terminal product, how to implement wider frequency band coverage of an antenna in compact space or implement multiple antennas with high isolation has always been an important research topic in the industry.

[0082] The technical solutions provided in embodiments of this application are applicable to an electronic device that uses one or more of the following communication technologies: a Bluetooth (Bluetooth, BT) communication technology, a global positioning system (global positioning system, GPS) communication technology, a wireless fidelity (wireless fidelity, Wi-Fi) communication technology, a global system for mobile communications (global system for mobile communications, GSM) communication technology, a wideband code division multiple access (wideband code division multiple access, WCDMA) communication technology, a long term evolution (long term evolution, LTE) communication technology, a 5G communication technology, and other future communication technologies. The electronic device in embodiments of this application may be a mobile phone, a tablet computer, a notebook computer, a smart household, a smart band, a smart watch, a smart helmet, smart glasses, or the like. Alternatively, the electronic device may be a handheld device with a wireless communication function, a computing device or another processing device connected to a wireless modem, a vehicle-mounted device, an electronic device in a 5G network, an electronic device in a future evolved public land mobile network (public land mobile network, PLMN), or the like. This is not limited in embodiments of this application. FIG. 1(a) shows an example of an electronic device according to an embodiment of this application. An example in which the electronic device is a mobile phone is used for description.

[0083] As shown in FIG. 1(a), an electronic device 10 may include a cover (cover) 110, a display/module (display) 120, a printed circuit board (printed circuit board, PCB) 140, a middle frame (middle frame) 130, and a rear cover (rear cover) 150. It should be understood that, in some embodiments, the cover 110 may be a cover glass (cover glass), or may be replaced with a cover made of another material, for example, an ultra-thin glass cover or a cover made of a PET (Polyethylene terephthalate, polyethylene terephthalate) material.

[0084] The cover 110 may be disposed against the display 120, and may be mainly configured to protect the display 120 and prevent dust.

[0085] In an embodiment, the display 120 may include a liquid crystal display (liquid crystal display, LCD) panel, 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 this application.

[0086] The middle frame 130 mainly supports the entire device. FIG. 1(a) shows that the PCB 140 is disposed between the middle frame 130 and the rear cover 150. It should be understood that, in an embodiment, the PCB 140 may alternatively be disposed between the middle frame 130 and the display 120. This is not limited in this application. The printed circuit board PCB 140 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 140.

[0087] In an embodiment, a metal layer may be disposed on the printed circuit board PCB 140. The metal layer may be used to ground the electronic element carried on the printed circuit board PCB 140, or may be used to ground another element, for example, a support 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 140. In an embodiment, the metal layer used for grounding may be disposed on a side that is of the printed circuit board PCB 140 and that is close to the middle frame 130. In an embodiment, an edge of the printed circuit board PCB 140 may be considered as an edge of the grounding plane of the printed circuit board PCB 140. In an embodiment, the metal middle frame 130 may also be configured to ground 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.

[0088] Due to internal compactness of the electronic device, a ground plane/grounding plate/grounding plane (for example, a printed circuit board, a middle frame, a screen metal layer, and a battery may all be considered as a part of the ground plane) is usually disposed in internal space 0 mm to 2 mm away from an inner surface of the side frame. In an embodiment, a dielectric is filled between the side frame and the ground plane. A length and a width of a rectangle enclosed by an inner surface contour of the filled dielectric may be simply considered as a length and a width of the ground plane. Alternatively, a length and a width of a rectangle enclosed by a contour formed by superposing all conductive parts inside the side frame may be considered as a length and a width of the ground plane.

[0089] The electronic device 100 may further include a battery (not shown in the figure). The battery may be disposed between the middle frame 130 and the rear cover 150, or may be disposed between the middle frame 130 and the display 120. This is not limited in this application. In some embodiments, the PCB 140 is divided into a main board and a sub-board. The battery may be disposed between the main board and the sub-board. The main board may be disposed between the middle frame 130 and an upper edge of the battery, and the sub-board may be disposed between the middle frame 130 and a lower edge of the battery.

[0090] The electronic device 100 may further include a side frame 131, and the side frame 131 may be made of a conductive material like metal. The side frame 131 may be disposed between the display 120 and the rear cover 150 and extend around a periphery of the electronic device 100. The side frame 131 may have four sides surrounding the display 120, to help fasten the display 120.

[0091] In an implementation, the side frame 131 made of the conductive material may be directly used as a conductive side frame of the electronic device 100, to form, for example, an appearance of a metal side frame, which is applicable to a metal industrial design (industrial design, ID). In an implementation, an outer surface of the side frame 131 may be a conductive material, for example, a metal material, to form an appearance of the metal side frame. In these implementations, the conductive part of the side frame 131 may be used as an antenna radiator of the electronic device 100.

[0092] In another implementation, an outer surface of the side frame 131 may be a non-conductive material, for example, plastic, to form an appearance of a non-metal side frame, which is applicable to a non-metal ID. In an implementation, the inner surface of the side frame 131 may include a conductive material, for example, a metal material. In this implementation, the conductive part of the side frame 131 may be used as an antenna radiator of the electronic device 100. It should be understood that a radiator disposed on the inner surface of the side frame 131 (which is also referred to as a conductive material on the inner surface) is attached to a non-conductive material of the side frame 131, to facilitate antenna radiation. Each of the conductive material and the non-conductive material should be considered as a part of the side frame 131.

[0093] The middle frame 130 may include the side frame 131. As an integrated component, the middle frame 130 including the side frame 131 may support an electronic component in the entire device. The cover 110 and the rear cover 150 are separately closed along an upper edge and a lower edge of the side frame, to enclose a casing or a housing (housing) of the electronic device. Alternatively, the side frame 131 may not be considered as a part of the middle frame 130. In an embodiment, the side frame 131 may be connected to and integrally formed with the middle frame 130. In another embodiment, the side frame 131 may include a protruding member extending inward, to be connected to the middle frame 130, for example, connected by using a spring or a screw, through welding, or the like. In an embodiment, the cover 110, the rear cover 150, the side frame 131, and the middle frame 130 may be collectively referred to as the casing or the housing of the electronic device 100. It should be understood that the "casing or housing" may mean a part or all of any one of the cover 110, the rear cover 150, the side frame 131, or the middle frame 130, or mean a part or all of any combination of the cover 110, the rear cover 150, the side frame 131, or the middle frame 130.

[0094] The rear cover 150 may be a rear cover made of a metal material; or may be a rear cover made of a non-conductive material, for example, a glass rear cover, a plastic rear cover, or another non-metal rear cover; or may be a rear cover made of both a conductive material and a non-conductive material.

[0095] In an embodiment, the rear cover 150 including the conductive material may replace the middle frame

130, and serve as an integrated component with the side frame 131, to support an electronic component in the entire device.

[0096] In an embodiment, the middle frame 130 and/or the conductive part in the rear cover 150 may be used as reference ground of the electronic device 100. The side frame 131, the PCB 140, and the like of the electronic device may be electrically connected to the middle frame for grounding.

[0097] In an embodiment, at least a part of the side frame 131 may be used as an antenna radiator to receive/transmit a radio frequency signal. There may be a gap between the part of the side frame used as the radiator and another part of the middle frame 130 or between the part of the side frame and the middle frame 130, to ensure that the antenna radiator has a good radiation environment. In an embodiment, an aperture may be provided near the part of the side frame that is used as the antenna radiator. In an embodiment, the aperture may include an aperture provided inside the electronic device 100, for example, an aperture that is invisible from an appearance surface of the electronic device 100. In an embodiment, the internal aperture may be formed by any one of or jointly formed by a plurality of the middle frame, the battery, the circuit board, the rear cover, the display, and another internal conductive part. For example, the internal aperture may be formed by a mechanical part of the middle frame. In an embodiment, the aperture may further include a slot/slit/hole provided on the side frame 131. In an embodiment, the slot/slit/hole on the side frame 131 may be a gap formed on the side frame, and the side frame 131 is divided, at the gap, into two parts that have no direct connection relationship. In an embodiment, the aperture may further include a slot/slit/hole provided on the rear cover 150 or the display 120. In an embodiment, the rear cover 150 includes a conductive material, and an aperture provided on the conductive material may be connected to the slit or the gap of the side frame, to form a coherent aperture on the appearance surface of the electronic device 100.

[0098] In an embodiment, the side frame 131 includes a protruding member extending inward, and is configured to connect to another part of the middle frame 130, or is configured to connect to the middle frame 130 (or may be integrally formed in an embodiment). In an embodiment, the protruding member includes a conductive material, and may be further configured to receive a feed signal or connect to a ground plane, so that a corresponding part of the side frame receives/transmits a radio frequency signal.

[0099] In an embodiment, the antenna of the electronic device 100 may alternatively be disposed in the side frame 1311. The side frame 1311 includes a non-conductive material. The antenna radiator may be located in the electronic device 100 and disposed along the side frame 1311, or at least a part of the antenna radiator may be embedded in the non-conductive material of the side frame. In an embodiment, the antenna radiator is disposed against the non-conductive material of the side frame 1311, to minimize a volume occupied by the antenna radiator, and enable the antenna radiator to be closer to the outside of the electronic device 100, so as to achieve a better signal transmission effect. It should be noted that, that the antenna radiator is disposed against the side frame 1311 means that the antenna radiator may be tightly attached to the side frame 1311, or may be disposed close to the side frame 1311. For example, there may be a specific small slot between the antenna radiator and the side frame 1311.

[0100] In an embodiment, the antenna of the electronic device 100, for example, a support antenna or a millimeter-wave antenna (not shown in FIG. 1(a)), may alternatively be disposed in the casing. There may be a gap between the antenna disposed in the casing and another conductive part in the casing, to ensure that the antenna radiator has a good radiation environment. In an embodiment, an aperture may be provided near the antenna radiator. In an embodiment, the aperture may include an aperture provided inside the electronic device 100, for example, an aperture that is invisible from an appearance surface of the electronic device 100. In an embodiment, the internal aperture may be formed by any one of or jointly formed by a plurality of the side frame, the middle frame, the battery, the circuit board, the rear cover, the display, and another internal conductive part. For example, the internal aperture may be formed by a mechanical part of the middle frame. In an embodiment, the aperture may further include a slot/slit/hole provided on the side frame 1311. In an embodiment, the slot/slit/hole on the side frame 1311 may be a gap formed on the side frame, and the side frame 1311 is divided, at the gap, into two parts that have no direct connection relationship. In an embodiment, the aperture may further include a slot/slit/hole provided on the rear cover 150 or the display 120. In an embodiment, the rear cover 150 includes a conductive material, and an aperture provided on the conductive material may be connected to the slit or the gap of the side frame, to form a coherent aperture on the appearance surface of the electronic device 100. In an embodiment, the aperture on the rear cover 150 or the display may be further used to place another component, for example, a camera, and/or a sensor, and/or a microphone, and/or a speaker.

[0101] In an embodiment, the antenna may be in an antenna form based on a flexible printed circuit (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 or translucent structure embedded in the screen of the electronic device 100, so that the antenna is a transparent antenna element embedded in the screen of the electronic device 100.

[0102] FIG. 1(a) shows only an example of some components included in the electronic device 10. Actual shapes, actual sizes, and actual structures of these components are not limited in FIG. 1(a).

[0103] 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.

[0104] It should be understood that, in embodiments of this application, it is considered that when a user holds the electronic device (for example, when the user holds the electronic device and unlocks the electronic device, or when the user holds the electronic device vertically and faces the screen), an orientation of the electronic device includes the top, the bottom, a left side, and a right side.

[0105] The capacitor mentioned in embodiments of this application 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 the distributed capacitor) is an equivalent capacitor formed by a gap between two conductors. The lumped capacitor may include an invariable capacitor C1 and/or a variable capacitor VAC. The distributed capacitor may include an interdigital capacitor and/or a distributed capacitor formed in another form (for example, the distributed capacitor as shown in FIG. 2).

[0106] FIG. 3 is a diagram of an antenna in an electronic device according to an embodiment of this application. Refer to FIG. 3. The electronic device includes a radiator 1. The radiator 1 is spaced from a ground plane of the electronic device. In FIG. 3, the ground plane of the electronic device is simply shown by using a rectangular area. It should be understood that this is not intended to limit embodiments of this application. The ground plane may be configured to ground a component in the electronic device. The ground plane may be a printed circuit board (printed circuit board, PCB) or a part of a middle frame. For brevity of description, in this embodiment of this application, an example in which the ground plane is a circuit board 2 is used for description.

[0107] A first antenna feed circuit and a second antenna feed circuit are disposed on the circuit board 2, and are configured to feed the radiator 1.

[0108] In an embodiment, the radiator 1 may be disposed on one side of the circuit board 2, and the side may be specifically a side edge or a bottom edge of the electronic device. In an embodiment, the radiator 1 may be disposed on a plurality of sides of the circuit board 2, and the sides may be specifically a side edge and a bottom edge of the electronic device.

[0109] One end of the radiator 1 is open-circuited, and the other end of the radiator 1 is grounded. The ground end 12 of the radiator 1 may be coupled to a grounding plane of the circuit board 2 or coupled to the middle frame for grounding.

[0110] In an embodiment, the radiator 1 may excite a quarter antenna mode of the radiator 1 through the first antenna feed circuit, and excite a three-quarter antenna mode of the radiator 1 through the second antenna feed circuit.

[0111] Refer to FIG. 3. The radiator includes an open end 11 and the ground end 12. The radiator is not in contact with the grounding plane at the open end 11, and the ground end 12 is coupled to the grounding plane to implement grounding. In an embodiment, the ground plane may include the circuit board 2. The radiator is not in contact with the circuit board 2 at the open end 11, and is coupled to the grounding plane of the circuit board 2 at the ground end 12, or coupled to the middle frame (for example, the radiator 1 is connected to the middle frame through a mechanical part, or the radiator 1 and the middle frame are integrally formed). A gap 13 is disposed on the radiator. The gap 13 is disposed between the open end 11 and the ground end 12. The radiator is divided into a first radiator 14 and a second radiator 15 through the gap 13. The first radiator 14 is a radiator part between the gap 13 and the open end 11, and the second radiator 15 is a radiator part between the gap 13 and the ground end 12. A length of the first radiator 14 is one to three times a length of the second radiator 15. The range includes endpoint values one time and three times. For example, the length of the first radiator 14 is one, two, or three times the length of the second radiator 15. In an embodiment, a width of the gap 13 is less than or equal to 2 mm.

[0112] The electronic device further includes a first feed point K1 and a second feed point K2. The radiator is coupled to the first antenna feed circuit through the first feed point K1, and the radiator is coupled to the second antenna feed circuit through the second feed point K2. The first antenna feed circuit is configured to feed a signal in a first operating frequency band into the radiator, and the first radiator and the second radiator are configured to jointly generate a first resonance corresponding to the first operating frequency band. The second antenna feed circuit is configured to feed a signal in a second operating frequency band into the radiator, and the first radiator and the second radiator are configured to jointly generate a second resonance corresponding to the second operating frequency band. In other words, the radiator 1 may implement functions of two antennas, to form a co-radiator dual-antenna structure.

[0113] The second feed point K2 is disposed on the first radiator 14, and a length of the first radiator 14 between the second feed point K2 and the open end 11 is greater than or equal to a length of the first radiator 14 between the second feed point K2 and the gap 13.

[0114] When the radiator 1 operates in the quarter antenna mode, the radiator 1 can cover the first operating frequency band. When the radiator 1 operates in the three-quarter antenna mode, the radiator 1 can cover the second operating frequency band. A center frequency of the second operating frequency band is higher than a center frequency of the first operating frequency band, and a highest frequency of the first operating frequency band is lower than a lowest frequency of the second operating frequency band. In other words, the first operating frequency band and the second operating frequency band are two different frequency bands, and there is no same frequency in the two frequency bands.

[0115] In an embodiment, the first operating frequency band includes at least one communication frequency band in a range of 698 MHz to 960 MHz. In an embodiment, the first operating frequency band includes at least one communication frequency band in a range of 1.7 GHz to 2 GHz. In an embodiment, the first operating frequency band includes at least one communication frequency band in a range of 2.3 GHz to 2.7 GHz.

[0116] For example, specifically, the first operating frequency band may be a low frequency band, and also referred to as an LB band (for example, may be at least one communication frequency band in the range of 698 MHz to 960 MHz), and the second operating frequency band may be a medium/high frequency band, and also referred to as an MB/HB band, or referred to as an MHB band (for example, may be at least one communication frequency band in the range of 1.7 GHz to 2 GHz, and/or at least one communication frequency band in the range of 2.3 GHz to 2.7 GHz). For another example, specifically, the first operating frequency band may be an LB band, and the second operating frequency band may be a GPS L5 band. For another example, specifically, the first operating frequency band may alternatively be an MHB band, and the second operating frequency band may alternatively be an N77 band. In an embodiment, that the length of the first radiator 14 is one to three times the length of the second radiator 15 may also be understood as that the gap 13 may be disposed between a middle position on the radiator 1 and a position close to 1/4 of a total length of the ground end 12. Therefore, a position of the gap 13 may be close to a strong electric field point of the three-quarter antenna mode, which may affect a frequency of the quarter antenna mode, so that the frequency of the quarter antenna mode shifts higher. Alternatively, when a frequency of the quarter antenna mode remains unchanged, a radiation aperture of the quarter antenna mode is enlarged, and impact on the three-quarter antenna mode is far less than impact on the quarter antenna mode.

[0117] In an embodiment, a frequency difference between a frequency of a resonance point corresponding to the first resonance in the first operating frequency band and a frequency of a resonance point corresponding to the second resonance in the second operating frequency band may range from 100 MHz to 1 GHz.

[0118] In an embodiment, the electronic device further includes a first component 3. The first component 3 may be a capacitor, an inductor, or the like. The first component 3 is connected across the gap 13, and is coupled in series between the first radiator and the second radiator. In an embodiment, the first component 3 may be disposed on the circuit board 2. In an embodiment, the first component 3 may be disposed on a substrate (for example, a circuit sub-board or a flexible board) coupled to the circuit board 2.

[0119] In an embodiment, the first component 3 is disposed, so that a frequency ratio of the quarter antenna mode to the three-quarter antenna mode can be tuned, and resonances of the quarter antenna mode and the three-quarter antenna mode respectively cover different operating frequency bands.

[0120] Optionally, one or more second components may be connected in parallel on two sides of the gap 13, a first end of each of the at least one second component is coupled to the first radiator 14 or the second radiator 15, and a second end of each of the at least one second component is grounded. The second component cooperates with the first component 3. This helps adjust the frequency ratio of two antenna modes.

[0121] For example, the at least one second component may be an inductor, and a length of a radiator between the gap 13 and a position at which the inductor is coupled to the first radiator 14 or the second radiator 15 is less than or equal to 20 mm. The inductor is connected in parallel, so that performance of the three-quarter antenna mode can be improved, and a degree of freedom of tuning in the three-quarter antenna mode can be increased.

[0122] When the second component is an inductor, an inductance value of the second component is less than 20 nH.

[0123] For example, when the co-radiator antenna operates in a high frequency band (for example, the frequency of the resonance point of the first resonance is greater than 1 GHz), in an embodiment, the high frequency band may be in a range of 1.7 GHz to 2.7 GHz. In this case, the inductance value of the second component may be less than 10 nH. In an embodiment, when the frequency of the resonance point of the first resonance is greater than 1 GHz, the second component whose equivalent inductance value is less than 10 nH may be configured to adjust the frequency of the resonance point of the first resonance. In an embodiment, when the frequency of the resonance point of the first resonance is greater than 1 GHz, the second component whose equivalent inductance value is less than 10 nH may be configured to further increase the radiation aperture in the quarter antenna mode (which is configured to generate the first resonance). In an embodiment, the second component whose equivalent inductance value is less than 10 nH may be further configured to adjust the frequency of the resonance point of the second resonance.

[0124] For example, when the co-radiator antenna operates in a low frequency band (for example, the frequency of the resonance point of the first resonance is less than or equal to 1 GHz), in an embodiment, the low frequency band may be in a range of 698 MHz to 960 MHz. In this case, the inductance value of the second component may be less than 20 nH. In an embodiment, when the frequency of the resonance point of the first resonance is less than or equal to 1 GHz, the second component whose equivalent inductance value is less than 20 nH may be configured to adjust the frequency of the resonance point of the first resonance. In an embodiment, when the frequency of the resonance point of the first resonance is less than or equal to 1 GHz, the second component whose equivalent inductance value is less than 20 nH may be configured to further increase the radiation aperture in the quarter antenna mode (which is configured to generate the first resonance). In an embodiment, the second component whose equivalent inductance value is less than 20 nH may be further configured to adjust the frequency of the resonance point of the second resonance.

[0125] In an embodiment, a gap 13 is disposed on a part that is of the radiator 1 and that is located between the open end 11 and the ground end 12, and a length of the first radiator 14 is one to three times a length of the second radiator 15. In the quarter antenna mode of the radiator 1, an electric field reverse point is generated on the first radiator 14, and the electric field reverse point is located at a position that is on the first radiator 14 and that is close to the gap 13. At the electric field reverse point, currents of the first radiator 14 in parts on two sides of the electric field reverse point are reverse. In an embodiment, the second feed point K2 is disposed at a position that meets a condition in which the length of the first radiator 14 between the second feed point K2 and the open end 11 is greater than or equal to the length of the first radiator 14 between the second feed point K2 and the gap 13. In an embodiment, the second feed point K2 is located at an electric field reverse point in the quarter antenna mode or at a position close to the electric field reverse point.

[0126] The second feed point K2 is disposed at the electric field reverse point in the quarter antenna mode or at a position close to the electric field reverse point, so that excitation of the quarter antenna mode at the second feed point K2 can be suppressed through impedance mismatching. The second feed point K2 and the second antenna feed circuit excite the three-quarter antenna mode of the radiator 1, so that the radiator 1 can generate the second resonance corresponding to the second operating frequency band, and decoupling in the first operating frequency band can be implemented. In an embodiment, a component like a capacitor is disposed at the second feed point K2, so that high-impedance feeding can be implemented, and excitation of the quarter antenna mode at the second feed point K2 can be suppressed through impedance mismatching. For example, the second capacitor may be coupled (for example, connected in series) between the second feed point K2 and the second antenna feed circuit. When the frequency of the resonance point of the first resonance is less than or equal to 1 GHz, a capacitance value of the second capacitor is less than or equal to 5 pF, and when the frequency of the resonance point of the first resonance is greater than 1 GHz, the capacitance value of the second capacitor is less than or equal to 3 pF. Therefore, high-impedance feeding can be implemented at the second feed point K2, and excitation of the quarter antenna mode at the second feed point K2 can be effectively suppressed. This improves a decoupling effect between a quarter antenna mode when the first feed circuit performs feeding at the first feed point K1 and a decoupling effect when the second feed circuit performs feeding at the second feed point K2.

[0127] In an embodiment, refer to FIG. 3. The first feed point K1 is located between the gap 13 and the open end 11 on the first radiator 14, and a length of the first radiator 14 between the first feed point K1 and the open end 11 is less than a length of the first radiator 14 between the first feed point K1 and the gap 13. FIG. 4 is a diagram of electric field effects of an antenna in an electronic device in a quarter antenna mode and a three-quarter antenna mode according to an embodiment of this application. Refer to FIG. 4. An electric field reverse point E1 in the quarter antenna mode is located at a position that is on the first radiator 14 and that is close to the gap 13, and a position of the electric field reverse point E1 or a position close to the electric field reverse point E1 is a disposing position of the second feed point K2. The first feed point K1 and the second feed point K2 cannot overlap. Otherwise, the quarter antenna mode and the three-quarter antenna mode cannot be separately excited. Therefore, in an embodiment, the first feed point K1 is located at a position close to the open end 11, the quarter antenna mode may be excited through the first feed point K1, and the three-quarter antenna mode may be excited through the second feed point K2. In this way, the first antenna feed circuit and the second antenna feed circuit can be decoupled in the two-antenna mode.

[0128] In an embodiment, the length of the first radiator 14 between the first feed point K1 and the open end 11 is less than or equal to 10 mm. This helps excite the quarter antenna mode through the first feed point K1. In addition, in some other embodiments, the position of the first feed point K1 may alternatively be adjusted based on an actual situation. For example, if a length of a radiator between the first feed point K1 and the open end 11 is greater than 10 mm, the quarter antenna mode and the three-quarter antenna mode can be separately excited provided that the first feed point K1 and the second feed point K2 do not overlap. A specific position of the first feed point K1 affects an excitation effect of the quarter antenna mode, and it should be considered that the first feed point K1 falls within the scope of embodiments of this application provided that the quarter antenna mode can be excited. Therefore, a position of the first feed point K1 may not be limited in this application.

[0129] In an embodiment, a sum of electrical lengths of the first radiator 14 and the second radiator 15 is greater than a quarter wavelength of the first operating frequency band and less than a three-quarter wavelength of the first operating frequency band. This helps tune a frequency ratio of two antennas. The wavelength is a wavelength of an electromagnetic wave corresponding to the first operating frequency band that is propagated in an actual environment (for example, in air and/or a dielectric).

[0130] FIG. 4 shows electric field distribution obtained when the radiator is fed through the first feed point K1 before the second feed point K2 is disposed. In the embodiment shown in FIG. 4, the radiator 1 has the ground end 12 and the open end 11, and the radiator 1 is provided with the first feed point K1. The radiator 1 is divided into two radiators through the gap 13, and a capacitor may be connected across the gap 13. When feeding is performed at the first feed point K1, both the 1/4 antenna mode and the 3/4 antenna mode may be excited. Electric field distribution is shown in a halo pattern in FIG. 4. Based on the electric field distribution in FIG. 4, the second feed point K2 may be properly disposed. For example, the second feed point K2 is disposed at or near the electric field reverse point E1 in the quarter antenna mode, so that the two modes can respectively correspond to two feed points, and decoupling between the two antennas can be implemented.

[0131] Refer to FIG. 4. In the quarter antenna mode, the radiator 1 generates an electric field reverse point between the open end 11 and the gap 13. In other words, the electric field reverse point is located on the first radiator 14. Electric fields of the first radiator 14 on two sides of the electric field reverse point are reverse. After the electric field reverse point is determined, the second feed point K2 may be disposed at the electric field reverse point or near the electric field reverse point, so that excitation of the quarter antenna mode can be suppressed through impedance mismatching. The second feed point K2 and the second antenna feed circuit excite the three-quarter antenna mode of the radiator 1, so that the resonance corresponding to the second operating frequency band can be generated. Because the feeding at the second feed point K2 mismatches the impedance of the radiator 1 in the quarter antenna mode, decoupling of the radiator 1 in the first operating frequency band corresponding to the quarter antenna mode is implemented.

[0132] The position adjacent to the electric field reverse point is a position that is less than or equal to 10 mm away from the electric field reverse point. In other words, the second feed point K2 may be disposed within a range +/-10 mm of the electric field reverse point, so that a position of the second feed point K2 is flexible. Optionally, when the first operating frequency band corresponds to a communication frequency band in a low frequency (for example, less than 1 GHz), for example, the low frequency may be in a range of 698 MHz to 960 MHz, and the second feed point K2 may be disposed at a position +/-10 mm away from the electric field reverse point in the quarter antenna mode. Optionally, when the first operating frequency band corresponds to a communication frequency band in a medium/high frequency (for example, greater than 1 GHz), for example, the medium/high frequency may be in a range of 1.7 GHz to 2.7 GHz, and the second feed point K2 may be disposed at a position +/-5 mm away from the electric field reverse point in the quarter antenna mode.

[0133] Therefore, according to the electronic device provided in this application, a dual-mode co-radiator dual-antenna design with different frequencies can be implemented, and miniaturization can be implemented. In addition, the second feed point K2 is disposed at or near the electric field reverse point in the quarter antenna mode, self-decoupling can be implemented in the quarter antenna mode, to improve isolation between two co-radiator antennas.

[0134] Refer to FIG. 4. Between the open end 11 and the gap 13, the electric field reverse point can be generated in both modes. Specifically, in the quarter antenna mode, the electric field reverse point E1 may be generated. In the three-quarter antenna mode, the electric field reverse point E2 may be generated. Because the first operating frequency band covered by the quarter antenna mode and the second operating frequency band covered by the three-quarter antenna mode have different frequencies, the two generated electric field reverse points E1 and E2 are staggered in space. In this way, the two modes can operate normally. In an embodiment, the second feed point K2 is disposed at the electric field reverse point E1 in the quarter antenna mode, so that excitation of feeding at the second feed point K2 to the quarter antenna mode can be suppressed, and self-decoupling can be implemented in the quarter antenna mode.

[0135] In an implementation, the electronic device further includes a filter circuit, where the filter circuit is coupled to the first feed point K1, and is configured to: pass, between the radiator and the first antenna feed circuit, the signal in the first operating frequency band, and suppress the signal in the second operating frequency band. In an embodiment, the signal in the first operating frequency band may be a low frequency signal. For example, the low frequency may be within a range of 698 MHz to 960 MHz, and the signal in the second operating frequency band may be a medium/high frequency signal. For example, the medium/high frequency may be within a range of 1.7 GHz to 2.7 GHz.

[0136] In an embodiment, a frequency difference between a frequency of a resonance point corresponding to the first resonance in the first operating frequency band and a frequency of a resonance point corresponding to the second resonance in the second operating frequency band may range from 100 MHz to 1 GHz.

[0137] Therefore, in an embodiment, the second feed point K2 is disposed at or near the electric field reverse point in the quarter antenna mode, so that self-decoupling can be implemented in the quarter antenna mode, the filter circuit is configured at the first feed point K1, so that self-decoupling can be implemented in the three-quarter antenna mode, and mutual decoupling of the two co-radiator antennas is implemented in a split feeding manner of the first antenna feed circuit and the second antenna feed circuit. This implements miniaturization of the two co-radiator antennas different frequencies, and improves isolation.

[0138] In some other embodiments, for an antenna structure in which the first operating frequency band corresponds to a communication frequency band in a low frequency band (for example, less than 1 GHz), for example, the first operating frequency band corresponds to a communication frequency band in a range of 698 MHz to 960 MHz, for example, B17, B20, B5, or B8. At least a part of the radiator is located on at least one of a bottom edge and a side edge of the electronic device, so that full-band decoupling of the first radiator and the second radiator can still be implemented in the first operating frequency band and the second operating frequency band. For example, the radiator extends at a bending position of a bottom edge and a side edge of the electronic device, or the entire radiator is located in a lower half of the electronic device.

[0139] FIG. 5 is a diagram of an antenna in an electronic device according to another embodiment of this application. Refer to FIG. 5. In an embodiment, the radiator is disposed on both a side edge and a bottom edge of the electronic device, and the first component 3 may be a capacitor and is disposed on the bottom edge of the electronic device.

[0140] FIG. 6 is a diagram of an antenna in an electronic device according to still another embodiment of this application. Refer to FIG. 6. In an embodiment, the radiator is disposed on both a side edge and a bottom edge of the electronic device, and the first component 3 may be a capacitor and is disposed on the bottom edge of the electronic device. In addition, an inductor may be connected in parallel near (for example, within 20 mm) the first component 3.

[0141] FIG. 7 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a capacitor is connected in series at a second feed point K2 according to an embodiment of this application. A horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is the return loss coefficient (S11) or the isolation (S21) in a unit of dB. A curve p1 is an S11 curve obtained when the radiator is fed through the first feed point K1, a curve q1 is an S11 curve obtained when the radiator is fed through the second feed point K2, and a curve r1 is an isolation curve. The second feed point K2 may be connected to another component. In FIG. 7, only an example in which the second feed point K2 is connected to a capacitor in series is used. Refer to FIG. 7. The first component 3 is a capacitor with a capacitance value of 0.4 pF, and a capacitance value of the capacitor connected in series to the second feed point K2 is 3 pF. FIG. 8 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a capacitor is connected in series at a second feed point K2 according to another embodiment of this application. A horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is the return loss coefficient (S11) or the isolation (S21) in a unit of dB. A curve p2 is an S11 curve obtained when the radiator is fed through the first feed point K1, a curve q2 is an S11 curve obtained when the radiator is fed through the second feed point K2, and a curve r2 is an isolation curve. The second feed point K2 may be connected to another component. In FIG. 8, only an example in which the second feed point K2 is connected to a capacitor in series is used. Refer to FIG. 8. The first component 3 is a capacitor with a capacitance value of 0.4 pF, and a capacitance value of the capacitor connected in series to the second feed point K2 is 0.5 pF. In addition, in comparison with FIG. 7 and FIG. 8, when the capacitance value of the first component 3 remains unchanged, the impedance at the second feed point K2 increases when the capacitance value of the capacitor connected in series at the second feed point K2 decreases. In other words, FIG. 7 shows low-impedance feeding, and FIG. 8 shows high-impedance feeding, and isolation between the two frequency bands shown in FIG. 8 is better.

[0142] FIG. 9 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a capacitor is connected in series at a second feed point K2 according to still another embodiment of this application. A horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is the return loss coefficient (S11) or the isolation (S21) in a unit of dB. A curve p3 is an S11 curve obtained when the radiator is fed through the first feed point K1, a curve q3 is an S11 curve obtained when the radiator is fed through the second feed point K2, and a curve r3 is an isolation curve. The second feed point K2 may be connected to another component. In FIG. 9, only an example in which the second feed point K2 is connected to a capacitor in series is used. Refer to FIG. 9. The first component 3 is a capacitor with a capacitance value of 0.8 pF, and a capacitance value of the capacitor connected in series to the second feed point K2 is 0.5 pF. Refer to FIG. 8 and FIG. 9. When a capacitance value of a capacitor connected in series to the second feed point K2 remains unchanged, the capacitance value of the first component 3 in FIG. 9 is increased, so that the resonance of the first operating frequency band can be shifted to a low frequency. A resonance of the first operating frequency band shown in FIG. 8 is at 0.9 GHz, and a resonance of the first operating frequency band shown in FIG. 9 is at 0.83 GHz.

[0143] Still refer to FIG. 3. In an implementation, the first component 3 may include a capacitor and/or an inductor and/or a radio frequency switch. Optionally, the first component 3 is a capacitor, and the capacitor may be connected across the gap 13, and is coupled in series between the first radiator 14 and the second radiator 15. Optionally, the first component 3 may alternatively be a radio frequency switch. The radio frequency switch is connected across the gap 13, and is coupled in series between the first radiator 14 and the second radiator 15. The first component 3 may tune a frequency ratio of the quarter antenna mode to the three-quarter antenna mode, so that the quarter antenna mode can cover the first operating frequency band, and the three-quarter antenna mode can cover the second operating frequency band. The electric field distribution shown in FIG. 4 may alternatively be electric field distribution after the first component 3 is disposed. Therefore, after the first component 3 is disposed, the second feed point K2 is disposed at the electric field reverse point E1 corresponding to the radiator in the quarter antenna mode. This can suppress excitation of the quarter antenna mode, and implement self-decoupling in the quarter antenna mode.

[0144] In an embodiment, when a frequency of a resonance point of the first resonance is less than or equal to 1 GHz, an equivalent capacitance value of the first component 3 is less than or equal to 10 pF. This can ensure that the radiator has good radiation performance at a low frequency. In an embodiment, when a frequency of a resonance point of the first resonance is greater than 1 GHz, an equivalent capacitance value of the first component 3 is less than or equal to 2 pF. This can ensure that the radiator has good radiation performance at a medium frequency and/or a high frequency.

[0145] For example, when the first operating frequency band includes at least one communication frequency band in a range of 698 MHz to 960 MHz (which may be referred to as a low band, LB), and the first component 3 includes a capacitor, a capacitance value of the capacitor is less than or equal to 10 pF. This can ensure that the radiator has good radiation performance at a low frequency.

[0146] For example, when the first operating frequency band includes at least one communication frequency band in a range of 1.7 GHz to 2 GHz (which may be referred to as a medium frequency, MB), or the first operating frequency band includes at least one communication frequency band in a range of 2.3 GHz to 2.7 GHz (which may be referred to as a high frequency, HB), and the first component 3 includes a capacitor, a capacitance value of the capacitor is less than or equal to 2 pF. This can ensure that the radiator has good radiation performance at a medium frequency and/or a high frequency.

[0147] In addition, if the capacitance value of the first component 3 is greater than 10 pF, although the aperture of the radiator can be reduced, radiation performance of the radiator deteriorates.

[0148] In an embodiment, the first component 3 may be a radio frequency switch. The radio frequency switch may be a single-pole single-throw (SPST) switch, a single-pole double-throw (SPDT) switch, a single-pole multi-throw (SPNT) switch, or a multi-pole multi-throw (NPNT) switch, and the radio frequency switch is connected across the gap 13, and is coupled and connected in series between the first radiator 14 and the second radiator 15, so that switching of the first operating frequency band in the quarter antenna mode can be implemented, the first feed point K1 is connected to the filter circuit, and the second feed point K2 is disposed at the electric field reverse point E1 in the quarter antenna mode. In this way, an electric field in the gap 13 in the quarter antenna mode is strong, and an electric field in the gap 13 in the three-quarter antenna mode is weak. Therefore, when the first operating frequency band is switched through the radio frequency switch, the second operating frequency band is basically not affected, so that problems such as a frequency offset and a decrease in isolation can be avoided.

[0149] In an embodiment, the first operating frequency band includes at least one communication frequency band in a range of 698 MHz to 960 MHz. The radio frequency switch connected in series between the two radiators is disposed, so that the first resonance corresponding to the first operating frequency band is switched/tuned between low-frequency communication frequency bands such as B17, B20, B5, and B8. In an embodiment, an equivalent capacitance value of the first component 3 is less than or equal to 10 pF. This can ensure radiation performance of the radiator, and can facilitate switching/tuning of the first operating frequency band.

[0150] In an embodiment, the first operating frequency band includes at least one communication frequency band in a range of 1.7 GHz to 2.7 GHz. The radio frequency switch connected in series between the two radiators is disposed, so that the first resonance corresponding to the first operating frequency band is switched/tuned between medium/high frequency communication frequency bands such as B1, B3, and B7. In an embodiment, an equivalent capacitance value of the first component 3 is less than or equal to 2 pF. This can ensure radiation performance of the radiator, and can facilitate switching/tuning of the first operating frequency band.

[0151] In an embodiment, the radio frequency switch includes a switch 31 and a plurality of circuit branches. A first end of the switch 31 is coupled to a radiator at one end of the gap 13, and a second end of the switch 31 is coupled to a radiator at the other end of the gap 13 through at least a part of the circuit branches. The at least part of the circuit branches have different capacitance values or inductance values. The switch 31 may be selectively connected to one of the circuit branches based on a capacitance value or an inductance value to be matched by a circuit, to facilitate adjustment of the frequency ratio of the two modes.

[0152] FIG. 10 is a diagram of a structure in which a first component is a radio frequency switch according to an embodiment of this application. FIG. 10 shows an example in which the radio frequency switch includes two circuit branches, and a capacitor 32 is connected in series on both the two circuit branches, capacitance values of the capacitors 32 on the two circuit branches may be different, and the switch 31 may be selectively connected to at least one of the two circuit branches.

[0153] FIG. 11 is a diagram of a structure in which a first component is a radio frequency switch according to another embodiment of this application. FIG. 11 shows an example in which the radio frequency switch includes three circuit branches. A capacitor 32 is connected in series on two of the three circuit branches, an inductor 33 is connected in parallel on the other circuit branch, and the switch 31 may be selectively connected to at least one of the three circuit branches.

[0154] A quantity of circuit branches and a specific component form are not limited. The accompanying drawings provided in this application are merely used as examples. It should be understood that, for a case in which there are two circuit branches shown in FIG. 10, the two circuit branches may provide three switching states, for example, only one of the circuit branches is connected, or both the circuit branches are connected. In addition, for a case in which there are more than three circuit branches, more switching states may be provided. Details are not described herein.

[0155] FIG. 12 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a co-radiator antenna in an electronic device switches to a different frequency band in a first operating frequency band according to an embodiment of this application. A horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is the return loss coefficient (S11) or the isolation (S21) in a unit of dB. Refer to FIG. 12. A curve a1 is an S11 curve of resonance in the quarter antenna mode near 0.9 GHz, and a curve a2 is a corresponding isolation curve. A curve b1 is an S11 curve obtained when resonance in the quarter antenna mode is near 0.8 GHz, and a curve b2 is a corresponding isolation curve. A curve c1 is an S11 curve obtained when resonance in the quarter antenna mode is near 0.72 GHz, and a curve c2 is a corresponding isolation curve. It can be learned that, when the quarter antenna mode is switched to different frequency bands, isolation in the three-quarter antenna mode (resonance is near 1.15 GHz) is not affected.

[0156] FIG. 13 is a curve diagram of efficiency obtained when a co-radiator antenna in an electronic device switches to a different frequency band in a first operating frequency band according to an embodiment of this application. A dashed line is radiation efficiency, and a solid line is system efficiency. Refer to FIG. 12 and FIG. 13. When the quarter antenna mode is switched to a different frequency band, neither radiation efficiency nor system efficiency in the three-quarter antenna mode (the resonance is at 1.15 GHz) is affected.

[0157] In an implementation, the electronic device further includes a matching circuit. A first end of the matching circuit is coupled to the second feed point K2, and a second end of the matching circuit is coupled to the second antenna feed circuit. The second antenna feed circuit includes a chip or a component such as a radio frequency front-end chip or a transceiver. The matching circuit may include a component such as a capacitor or an inductor. A first end of the matching circuit may be connected to the second antenna feed circuit, and a second end may be connected to a second feed point of the radiator. In other words, the matching circuit is located between the second antenna feed circuit and the feed point of the radiator.

[0158] In an implementation, the filter circuit coupled to the first feed point K1 may be specifically located between the first antenna feed circuit and the first feed point K1 of the radiator. The first antenna feed circuit and the second antenna feed circuit have similar structures, and may also include a chip or a component such as a radio frequency front-end chip or a transceiver. The filter circuit may also include a component such as a capacitor or an inductor. In an embodiment, a first end of the filter circuit is coupled to the first feed point K1, and a second end of the filter circuit is coupled to the first antenna feed circuit. In other words, the filter circuit is coupled in series between the first antenna feed circuit and the radiator, the filter circuit may be a low-pass high-cut filter circuit. In an embodiment, a first end of the filter circuit is coupled to the first feed point K1, and a second end of the filter circuit is grounded. In other words, the filter circuit is coupled in parallel between the first antenna feed circuit and the radiator. The filter circuit may be a high-pass low-cut filter circuit. It should be understood that a form of the filter circuit is not intended to limit this application. In an embodiment, the filter circuit may include a first part coupled in series between the first antenna feed circuit and the radiator, or may include a second part coupled in parallel between the first antenna feed circuit and the radiator, provided that the filter circuit has a function of suppressing the signal in the second operating frequency band by using the signal in the first operating frequency band between the radiator and the first antenna feed circuit.

[0159] The matching circuit and the filter circuit are respectively connected to two feed circuits that are independent of each other, in other words, the radiator may be fed by using the two feeds through the corresponding first feed point K1 and the corresponding second feed point K2, the quarter antenna mode and the three-quarter antenna mode can be separately excited on the radiator in this split-feed manner, and can be selected by using a position of the second feed point K2, and impedance matching and signal frequency selection can be performed through the matching circuit and the filter circuit, to implement decoupling of the antenna in two modes.

[0160] For example, the matching circuit is used as an example. Optionally, the matching circuit may include only a capacitor, or may include only an inductor, or may be a combination of a capacitor and an inductor. When the matching circuit includes only a capacitor, the capacitor may be connected in series between the second feed point K2 of the radiator 1 and the second feed circuit. When the matching circuit includes only an inductor, one end of the inductor may be connected to the second feed point K2, and the other end may be grounded. When the matching circuit is a combination of a capacitor and an inductor, the capacitor and the inductor may be connected in parallel, and then connected in series between the second feed point K2 and the second feed circuit. Certainly, in some other embodiments, there may be a plurality of capacitors and a plurality of inductors, and there may also be a plurality of combinations of capacitors and inductors. For example, a capacitor and an inductor are connected in parallel, and then the capacitor and the inductor are connected in parallel to another inductor, provided that the matching circuit can implement a high-impedance feeding function, excitation of the quarter antenna mode can be suppressed through impedance mismatching, to implement self-decoupling in the first operating frequency band. For the filter circuit, a configuration form of the capacitor and the inductor can ensure that the filter circuit suppresses the signal in the second operating frequency band by using the signal in the first operating frequency band, so that a quarter antenna mode can be excited, and a three-quarter antenna mode can be suppressed, thereby implementing decoupling in the second operating frequency band. For example, FIG. 14 is a partial enlarged view of a filter circuit 4 and a matching circuit 5 on an electronic device according to an embodiment of this application. Refer to FIG. 14. In an embodiment, the matching circuit 5 may include a second capacitor 51 and a second inductor 52, and the second capacitor 51 and the second inductor 52 are connected in parallel, and then may be connected in series to the second feed point K2, so that high-impedance feeding at the second feed point K2 can effectively suppress excitation of the quarter antenna mode, and a decoupling effect in the quarter antenna mode can be improved.

[0161] Specifically, the matching circuit 5 in the first operating frequency band is equivalent to a first equivalent capacitance value, and the matching circuit 5 in the second operating frequency band is equivalent to a second equivalent capacitance value. The first equivalent capacitance value is less than the second equivalent capacitance value.

[0162] In an embodiment, the first equivalent capacitance value is less than the second equivalent capacitance value. This helps suppress a low-frequency signal in the first operating frequency band, to implement high isolation in the first operating frequency band, and helps expand a bandwidth of the second operating frequency band.

[0163] For example, refer to FIG. 14. In a solution in which the matching circuit 5 includes the second capacitor 51 and the second inductor 52 that are connected in parallel, a capacitance value of the second capacitor 51 is 1.8 pF, an inductance value of the second inductor 52 is 34 nH, a first equivalent capacitance value of the matching circuit in the first operating frequency band is 0.88 pF, and a second equivalent capacitance value of the matching circuit in the second operating frequency band is 1.2 pF. In this way, high isolation can be implemented when a small capacitance value is equivalent in the first operating frequency band, and bandwidth of the second operating frequency band can be considered when a large capacitance value is equivalent in the second operating frequency band.

[0164] In an implementation, as described above, the filter circuit may alternatively include a capacitor and/or an inductor. Optionally, the filter circuit may include only a capacitor, or may include only an inductor, or may be a combination of a capacitor and an inductor. When the filter circuit includes only a capacitor, the capacitor may be connected in series between the first feed point K1 of the radiator and the first antenna feed circuit. When the filter circuit is a combination of a capacitor and an inductor, one end of the capacitor that is connected in series to the inductor is connected in parallel to the first feed point K1, and the other end of the capacitor is grounded. Certainly, in some other embodiments, there may be a plurality of capacitors and a plurality of inductors, and there may be a plurality of combinations of capacitors and inductors. For example, the capacitor and the inductor are connected in series and then connected in series to another capacitor, or then connected in parallel to another inductor, provided that the signal in the first operating frequency band the filter circuit can pass and the signal in the second operating frequency band can be suppressed, so that a decoupling pit can be formed in the three-quarter antenna mode, and self-decoupling can be implemented in the three-quarter antenna mode.

[0165] In an embodiment, refer to FIG. 14. The filter circuit 4 includes a first capacitor 41 and a first inductor 42. The first capacitor 41 and the first inductor 42 are connected in series, and then may be connected in parallel to the first feed point K1, so that the signal in the first operating frequency band can pass and the signal in the second operating frequency band can be suppressed, thereby tuning a position and bandwidth of a decoupling pit in the three-quarter antenna mode.

[0166] For example, refer to FIG. 14. In a solution in which the filter circuit 4 is a solution in which the first capacitor 41 and the first inductor 42 are connected in series, a capacitance value of the first capacitor 41 may be 1 pF, and an inductance value of the second inductor 52 may be 19 nH, so that a position and a bandwidth of a decoupling pit in the three-quarter antenna mode can be tuned.

[0167] In another embodiment, FIG. 15 is a diagram of a co-radiator antenna in an electronic device according to another embodiment of this application, and FIG. 16 is a diagram of electric field effects of a co-radiator antenna in an electronic device in a first quarter antenna mode and a second three-quarter antenna mode according to another embodiment of this application. Refer to FIG. 15 and FIG. 16. The first component 3 connected across the gap 13 is a capacitor, and the third inductor 6 may be connected in parallel near the gap 13, so that an aperture of the radiator 1 can be further increased, efficiency and bandwidth of the three-quarter antenna mode can be improved, and a degree of freedom of frequency ratio tuning of the quarter antenna mode and the three-quarter antenna mode can be increased. Proper values of the third inductor 6 and the capacitor are selected, so that the quarter antenna mode is resonant in the first operating frequency band, and the three-quarter antenna mode is resonant in the second operating frequency band. FIG. 16 shows electric field distribution obtained when the radiator is fed through the first feed point K1 before the second feed point K2 is disposed. In the embodiment shown in FIG. 16, the radiator 1 has the ground end 12 and the open end 11, and the first feed point K1 is disposed on the radiator 1. The radiator 1 is divided into two radiators through the gap 13, and a capacitor may be connected across radiators on two sides of the gap 13 and at least one inductor may be connected in parallel to the radiators. When feeding is performed at the first feed point K1, both the 1/4 antenna mode and the 3/4 antenna mode may be excited. Electric field distribution is shown in a halo pattern in FIG. 16. Based on the electric field distribution in FIG. 16, the second feed point K2 may be properly disposed. For example, the second feed point K2 is disposed at or near the electric field reverse point E1 in the quarter antenna mode, so that the two modes can respectively correspond to two feed points, and decoupling between the two antennas can be implemented.

[0168] For example, FIG. 17 is a partial enlarged diagram of the filter circuit 4 and the matching circuit 5 on an electronic device according to another embodiment of this application. Refer to FIG. 17. In a connection solution in which the filter circuit 4 is a first capacitor 41 and a first inductor 42 that are connected in series and then connected in parallel to a first feed point K1, a capacitance value of the first capacitor 41 is 1.5 pF, and an inductance value of the second inductor 52 is 12 nH, so that a position and bandwidth of a decoupling pit in the three-quarter antenna mode can be tuned.

[0169] In addition, refer to FIG. 17. In a connection solution in which the matching circuit 5 includes the second capacitor 51 and the second inductor 52 that are connected in parallel and then connected in series to the fourth inductor 53, a capacitance value of the second capacitor 51 is 2 pF, an inductance value of the second inductor 52 is 35 nH, an inductance value of the fourth inductor 53 is 6 nH, a first equivalent capacitor of the matching circuit 5 in the first operating frequency band is 1.4 pF, and a second equivalent capacitor of the matching circuit 5 in the second operating frequency band is 2.9 pF. In this way, high isolation can be implemented when a small capacitance is equivalent in the first operating frequency band, and bandwidth of the second operating frequency band can be considered when a large capacitance is equivalent in the second operating frequency band.

[0170] FIG. 18 is a curve diagram of a corresponding return loss coefficient (S11) and corresponding isolation obtained when a filter circuit and a matching circuit are used according to an embodiment of this application. A horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is the return loss coefficient (S11) or the isolation (S21) in a unit of dB. A curve s1 is an S11 curve obtained when the radiator is fed through the first feed point K1, a curve t1 is an S11 curve obtained when the radiator is fed through the second feed point K2, and a curve d1 is an isolation curve. FIG. 18 corresponds to the antenna shown in FIG. 15. To be specific, the first component 3 connected across the gap 13 is a capacitor, and a third inductor 6 may be connected in parallel near the gap 13. The filter circuit is that the first capacitor 41 and the first inductor 42 are connected in series, in the matching circuit, the second capacitor 51 and the second inductor 52 are connected in parallel, and then the fourth inductor 53 is connected in series. Refer to FIG. 18. For isolation at a frequency of 0.9 GHz and a frequency of 1.18 GHz, refer to the curve d1. A value of the isolation at the frequency of 0.9 GHz is less than -20 dB, and a value of the isolation at the frequency of 1.18 GHz is less than -30 dB.

[0171] FIG. 19 is a curve diagram of a corresponding return loss coefficient (S11) and corresponding isolation obtained when a filter circuit and a matching circuit are used according to another embodiment of this application. A horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is the return loss coefficient (S11) or the isolation (S21) in a unit of dB. A curve s2 is an S11 curve obtained when the radiator is fed through the first feed point K1, a curve t2 is an S11 curve obtained when the radiator is fed through the second feed point K2, and a curve d2 is an isolation curve. Refer to FIG. 19. A filter circuit at the first feed point K1 is connected to a capacitor in series and connected to an inductor in parallel, and a direct feeding manner is used at the second feed point K2. In other words, no matching circuit is used. Refer to FIG. 19. For isolation of the co-radiator antenna in this connection form at a frequency of 0.9 GHz and a frequency of 1.19 GHz, refer to the curve d2. A value of the isolation at the frequency of 0.9 GHz is greater than -15 dB, and a value of the isolation at the frequency of 1.19 GHz is greater than - 5 dB.

[0172] FIG. 20 is a curve diagram of a corresponding return loss coefficient (S11) and corresponding isolation obtained when a filter circuit and a matching circuit are used according to still another embodiment of this application. A horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is the return loss coefficient (S11) or the isolation (S21) in a unit of dB. A curve s3 is an S11 curve obtained when the radiator is fed through the first feed point K1, a curve t3 is an S11 curve obtained when the radiator is fed through the second feed point K2, and a curve d3 is an isolation curve. Refer to FIG. 20. The filter circuit at the first feed point K1 is arranged in a same form as that in FIG. 19, that is, in a form of connecting a capacitor in series and connecting an inductor in parallel. A difference from FIG. 19 lies in that a capacitive feeding series capacitor manner is used at the second feed point K2. Refer to FIG. 20. For isolation of the co-radiator antenna in this connection form at a frequency of 0.9 GHz and a frequency of 1.19 GHz, refer to the curve d3. A value of the isolation at the frequency of 0.9 GHz is less than -20 dB, and a value of the isolation at the frequency of 1.19 GHz is less than -5 dB.

[0173] Therefore, refer to both FIG. 19 and FIG. 20.

When the first feed point K1 uses a same filter circuit, compared with using the direct feeding manner, using a capacitive feeding manner at the second feed point K2 has better isolation. In addition, refer to FIG. 18 to FIG. 20. In FIG. 18, different capacitor-inductor combination forms are used at the first feed point K1 and the second feed point K2. Compared with the filtering feeding forms at the first feed point K1 and the second feed point K2 in FIG. 19 and FIG. 20, in the filter feeding form shown in FIG. 18, obtained isolation is obviously better.

[0174] FIG. 21 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a third inductor 6 is connected in parallel near the gap 13 and the first operating frequency band is switched to a different frequency band. Refer to FIG. 21. A curve e1 is an S11 curve of resonance in the quarter antenna mode at 0.9 GHz (the B8 band), and a curve e2 is an S11 curve of resonance in the quarter antenna mode at 0.72 GHz (the B28 band). It can be learned from FIG. 21 that, when the quarter antenna mode is switched to different frequency bands, isolation of the three-quarter antenna mode (the resonance is in the L5 band) is not affected. In FIG. 21, only two frequency bands B8 and B28 are used as an example for description. Certainly, switching between other low frequency bands may also be performed, and has an effect brought by switching between the two frequency bands B8 and B28.

[0175] FIG. 22 is a curve diagram of efficiency obtained when a third inductor 6 is connected in parallel near a gap 13 and a first operating frequency band is switched to a different frequency band. A dashed line is radiation efficiency, and a solid line is system efficiency. Refer to FIG. 21 and FIG. 22. When the quarter antenna mode is switched between the B8 band and the B28 band, radiation efficiency and system efficiency of the L5 band are not affected.

[0176] For example, the resonance in the quarter antenna mode may be located at 0.9 GHz (698 MHz to 960 MHz), that is, in the B8 band, and the resonance in the three-quarter antenna mode may be located at 1.15 GHz (1176.45 MHz$\pm$1.023 MHz), that is, in the L5 band. The B8 band and the L5 band are two frequency bands closest to each other in different frequency bands. In an embodiment, the second feed point K2 and the matching circuit are added to an electric field reverse point that is on the first radiator 14 and that corresponds to the quarter antenna mode, a quarter antenna mode can be suppressed. The filter circuit is connected to the first feed point K1, so that the first antenna feed circuit and the second antenna feed circuit can be decoupled in the three-quarter antenna mode.

[0177] In an embodiment, when the co-radiator antenna implements self-decoupling in the frequency band B8 and the frequency band L5, refer to FIG. 3. The first feed point K1 may be located between the gap 13 and the open end 11 on the first radiator 14, and a length of the first radiator 14 between the first feed point K1 and the open end 11 is less than a length of the first radiator 14 between the first feed point K1 and the gap 13. An electric field reverse point E1 (refer to FIG. 4) in the quarter antenna mode is located at a position that is on the first radiator 14 and that is close to the gap 13, and a position of the electric field reverse point E1 or a position close to the electric field reverse point E1 is a position at which the second feed point K2 is disposed. The first feed point K1 and the second feed point K2 cannot overlap. Otherwise, the quarter antenna mode cannot be excited. Therefore, in an embodiment, the first feed point K1 is located at a position close to the open end 11, so that the quarter antenna mode may be excited through the first feed point K1, and the three-quarter antenna mode may be excited through the second feed point K2.

[0178] In some other embodiments, resonances in the quarter antenna mode and the three-quarter antenna mode may alternatively be located in other different frequency bands, to implement dual-antenna decoupling in other different frequency bands. For example, the resonance in the quarter antenna mode may be located in any communication frequency band in the MB band (1.7 GHz to 2 GHz) or the HB band (2.3 GHz to 2.7 GHz). The MB band and the HB band may be collectively referred to as an MHB band (1.7 GHz to 2.7 GHz). The resonance in the three-quarter antenna mode may be located in the N77 band (3300 MHz to 4200 MHz). Based on the foregoing solution in this embodiment, full-band decoupling of the co-radiator antenna can be implemented in the MHB band and the N77 band.

[0179] FIG. 23 is a diagram of an antenna in an electronic device according to still another embodiment of this application. An antenna structure shown in FIG. 23 is similar to the antenna structure shown in FIG. 3. In other words, the antenna structure shown in FIG. 23 also includes the radiator 1, the first component 3, the first antenna feed circuit, and the second antenna feed circuit. The radiator 1 includes the open end 11 and the ground end 12. A part that is of the radiator 1 and that is located between the open end 11 and the ground end 12 is provided with the gap 13. A part that is of the radiator 1 and that is located between the gap 13 and the open end 11 is the first radiator 14. A part that is of the radiator 1 and that is located between the gap 13 and the ground end 12 is the second radiator 15. A length of the first radiator 14 is one to three times a length of the second radiator 15. The first component 3 is connected across the gap 13, and is coupled in series between the first radiator 14 and the second radiator 15. The radiator 1 further includes a first feed point K1 and a second feed point K2. The radiator 1 is coupled to the first antenna feed circuit through the first feed point, the first antenna feed circuit is configured to feed a signal in a first operating frequency band into the radiator, and the first radiator 14 and the second radiator 15 are configured to jointly generate a first resonance corresponding to a first operating frequency band. The radiator 1 is coupled to the second antenna feed circuit through the second feed point K1, the second antenna feed circuit is configured to feed a signal in a second operating frequency band into the radiator, and the first radiator 14 and the second radiator 15 are configured to jointly generate a second resonance corresponding to the second operating frequency band. The second feed point is disposed on the first radiator 14, and a length of the first radiator 14 between the second feed point and the open end is greater than or equal to a length of the first radiator 14 between the second feed point and the gap. A center frequency of the second operating frequency band is higher than a center frequency of the first operating frequency band, and a highest frequency of the first operating frequency band is lower than a lowest frequency of the second operating frequency band.

[0180] A difference between the antenna structure shown in FIG. 3 and the antenna structure shown in FIG. 23 lies in that the first feed point K1 is disposed on the second radiator 15, and the second feed point K2 is disposed on the first radiator 14. In addition, a length of the second radiator 15 between the first feed point and the ground end is less than a length of the second radiator 15 between the first feed point and the gap, and the length of the second radiator 15 between the first feed point and the ground end is less than or equal to 10 mm.

[0181] In an embodiment, the first operating frequency band includes at least one communication frequency band in a range of 698 MHz to 960 MHz. In an embodiment, the first operating frequency band includes at least one communication frequency band in a range of 1.7 GHz to 2 GHz. In an embodiment, the first operating frequency band includes at least one communication frequency band in a range of 2.3 GHz to 2.7 GHz.

[0182] For example, specifically, the first operating frequency band of the antenna structure shown in FIG. 23 may correspond to a communication frequency band greater than 1 GHz, for example, a medium and high frequency band. In an embodiment, a frequency band corresponding to the medium and high frequency is any communication frequency band within 1.7 GHz to 2.7 GHz. In an embodiment, the second operating frequency band of the antenna structure shown in FIG. 23 may correspond to the N77 band, and full-band decoupling of a co-radiator antenna with the structure may be implemented in the MHB band and the N77 band.

[0183] In an embodiment, a frequency difference between a frequency of a resonance point corresponding to the first resonance in the first operating frequency band and a frequency of a resonance point corresponding to the second resonance in the second operating frequency band may range from 100 MHz to 1 GHz.

[0184] In addition, as described above, in embodiments of this application, it is considered that when a user holds the electronic device (for example, when the user holds the electronic device and unlocks the electronic device, or when the user holds the electronic device vertically and faces the screen), an orientation of the electronic device includes the top, the bottom, a left side, and a right side. The antenna structure shown in FIG. 23 is located on a right side edge of the electronic device and is close to a position of a top edge of the electronic device, so that the antenna structure can obtain good radiation performance when radiating the foregoing medium- and high-frequency signals.

[0185] In an embodiment, for the antenna structure shown in FIG. 3, the first operating frequency band of the antenna structure corresponds to a low frequency band. For example, the low frequency band corresponds to any communication frequency band within 698 MHz to 960 MHz. The antenna structure shown in FIG. 3 may be disposed on a left side edge of the electronic device, and is close to a bottom edge of the electronic device, so that the antenna structure can obtain good radiation performance when radiating the low-frequency signal.

[0186] FIG. 24 is a diagram of an antenna in an electronic device according to yet another embodiment of this application. An antenna structure shown in FIG. 24 is similar to the antenna structure shown in FIG. 23. The antenna structure shown in FIG. 24 includes a radiator, a first component 3, a first antenna feed circuit, and a second antenna feed circuit. The radiator 1 includes an open end 11 and a ground end 12. A part that is of the radiator 1 and that is located between the open end 11 and the ground end 12 is provided with a gap 13. A part that is of the radiator 1 and that is located between the gap 13 and the open end 11 is a first radiator 14. A part that is of the radiator and that is located between the gap and the ground end is the second radiator 15. A length of the first radiator 14 is one to three times a length of the second radiator 15. The first component is connected across the gap, and is coupled in series between the first radiator 14 and the second radiator 15. In an embodiment, a width of the gap 13 is less than or equal to 2 mm. The radiator 1 further includes a first feed point K1 and a second feed point K2. The radiator 1 is coupled to the first antenna feed circuit through the first feed point K1, the first antenna feed circuit is configured to feed a signal in a first operating frequency band into the radiator, and the first radiator 14 and the second radiator 15 are configured to jointly generate a first resonance corresponding to a first operating frequency band. The radiator 1 is coupled to the second antenna feed circuit through the second feed point K2, the second antenna feed circuit is configured to feed a signal in a second operating frequency band into the radiator, and the first radiator 14 and the second radiator 15 are configured to jointly generate a second resonance corresponding to the second operating frequency band. The second feed point K2 is disposed on the first radiator 14, and a length of the first radiator 14 between the second feed point and the open end 11 is greater than or equal to a length of the first radiator 14 between the second feed point K2 and the gap 13. A center frequency of the second operating frequency band is higher than a center frequency of the first operating frequency band, and a highest frequency of the first operating frequency band is lower than a lowest frequency of the second operating frequency band.

[0187] A difference between the antenna structure shown in FIG. 23 and the antenna structure shown in FIG. 24 lies in that the antenna structure shown in FIG. 24 may further include a third radiator 16. The third radiator 16 is disposed on a side of the open end of the first radiator 14. One end of the third radiator 16 is the open end, and the other end of the third radiator 16 is the ground end. There is a gap between an open end of the third radiator 16 and the open end 11 of the first radiator 14. In an embodiment, a width of the gap is less than or equal to 2 mm. In an embodiment, a third feed point K3 is disposed on the third radiator 16, and the third radiator 16 may be coupled to a third antenna feed circuit through the third feed point K3. The third antenna feed circuit is different from the first antenna feed circuit or the second antenna feed circuit. The third radiator 16 may be fed through the third feed point K3. In other words, the third radiator 16 may operate as an independent antenna. For example, when the first radiator 14 and the second radiator 15 jointly receive/-transmit the medium- and high-frequency (1.7 GHz to 2.7 GHz) signal, the third radiator 16 may be configured to receive/transmit a low-frequency signal in the LB band (698 MHz to 960 MHz), so that the third radiator 16 forms a low-frequency antenna. In this embodiment, when all of the first radiator 14, the second radiator 15, and the third radiator 16 are used, full-band decoupling of the first radiator 14 and the second radiator 15 can still be implemented in the MHB band and the N77 band.

[0188] In some other embodiments, for an antenna structure in which the first operating frequency band corresponds to a communication frequency band in a medium and high frequency (greater than 1 GHz), for example, the first operating frequency band corresponds to a communication frequency band in a range of 1.7 GHz to 2.7 GHz, for example, B1, B3, or B7. At least a part of the radiator is located on at least one of a top edge and a side edge of the electronic device, so that full-band decoupling of the first radiator and the second radiator can still be implemented in the MHB band and the N77 band. For example, the radiator extends at a bending position of a top edge and a side edge of the electronic device, or the entire radiator is located in an upper half of the electronic device.

[0189] In an embodiment, refer to FIG. 1(a). The electronic device 10 includes the side frame 131. The side frame 131 includes a first position, a second position, and a third position that are sequentially disposed. The side frame 131 is grounded at the first position, and is provided with an insulating slot at each of the second position and the third position. The first radiator 14 includes a conductive part that is of the side frame 131 and that is between the second position and the third position, and the second radiator 15 includes a conductive part that is of the side frame 131 and that is between the first position and the second position. In other words, at least a part of the side frame 131 of the electronic device may be reused as the radiator 1, so that space occupied by the antenna structure in the electronic device can be reduced. This helps implement a miniaturization design of the electronic device.

[0190] In another embodiment, the electronic device includes a housing. The housing may be a plastic housing or a metal housing, or a housing formed by disposing a metal layer in the plastic housing. Both the radiator 1 and the circuit board 2 may be disposed in the housing. When internal space of the electronic device is large enough, the entire antenna may be installed in the housing, to facilitate disassembly, assembly, and maintenance of the antenna.

[0191] FIG. 25 is a curve diagram of a return loss coefficient (S11) and isolation obtained when a co-radiator antenna in an electronic device switches to a different frequency band in a first operating frequency band according to another embodiment of this application. FIG. 25 corresponds to the antenna structure shown in FIG. 24. In FIG. 25, a horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is the return loss coefficient (S11) or the isolation (S21) in a unit of dB. For ease of description, in this embodiment, in the co-radiator antenna, an antenna that operates in the first operating frequency band is defined as an MHB antenna, and an antenna that operates in the second operating frequency band is defined as an N77 antenna. Refer to FIG. 25. A curve j1 is an S11 curve obtained when the MHB antenna operates in the HB band, a curve j2 is an S11 curve obtained when the N77 antenna operates in the HB band, and j3 is an S21 curve obtained when the MHB antenna and the N77 antenna, and the MHB antenna operate in the HB band. A curve k1 is an S11 curve obtained when the MHB antenna operates in the MB band, a curve k2 is an S11 curve obtained when the N77 antenna operates in the MB band, and k3 is an S21 curve obtained when the MHB antenna and the N77 antenna, and the MHB antenna operate in the MB band. It can be learned from FIG. 25 that, when the MHB antenna switches between the MB band and the HB band, the N77 antenna is not affected and isolation meets a requirement.

[0192] FIG. 26 is a curve diagram of efficiency obtained when a co-radiator antenna in an electronic device switches to a different frequency band in a first operating frequency band according to another embodiment of this application. FIG. 26 corresponds to the antenna structure shown in FIG. 24. In FIG. 26, a horizontal coordinate is a frequency in a unit of GHz, and a vertical coordinate is efficiency in a unit of dBi. The dotted line indicates the radiation efficiency, and the solid line indicates the system efficiency. A curve m1 is radiation efficiency obtained when the MHB antenna operates in the HB band, a curve m2 is system efficiency obtained when the MHB antenna operates in the HB band, a curve n1 is radiation efficiency obtained when the N77 antenna operates in the HB band, and a curve n2 is system efficiency obtained when the N77 antenna operates in the HB band. A curve m3 is radiation efficiency obtained when the MHB antenna operates in the MB band, a curve m4 is system efficiency obtained when the MHB antenna operates in the MB band, a curve n is radiation efficiency obtained when the N77 antenna operates in the MB band, and a curve n4 is system efficiency obtained when the N77 antenna operates in the MB band. It can be learned from FIG. 26 that, when the MHB antenna is switched between MB and HB, the N77 antenna has no frequency offset, and efficiency is not affected.

[0193] For example, FIG. 27 is a partial enlarged view of a filter circuit on an electronic device according to an embodiment of this application. Refer to FIG. 27. The filter circuit includes a capacitor C1 and an inductor L1. One end of the capacitor C1 that is connected in series to the inductor L1 is connected in parallel to a first feed point K1. The other end of the capacitor C1 is connected to a circuit board 2 and is configured to be grounded, so that high-pass low-cut filtering can be implemented through the filter circuit. To be specific, the filter circuit can pass a high-frequency signal in the second operating frequency band to ground, and can pass, in the first antenna feed circuit, a low-frequency signal in the first operating frequency band, so that the three-quarter antenna mode can be suppressed, and decoupling in the second operating frequency band can be implemented.

[0194] For example, FIG. 28 is a partial enlarged view of a filter circuit on an electronic device according to another embodiment of this application. Refer to FIG. 28. The filter circuit includes a capacitor C2 and an inductor L2. The capacitor C2 and the inductor L2 are connected in parallel and then connected in series to a first feed point K1, so that high-impedance and low-pass filtering can be implemented through the filter circuit. To be specific, the filter circuit can suppress, in the first antenna feed circuit, a high-frequency signal in the second operating frequency band, and can pass a low-frequency signal in the first operating frequency band, so that the three-quarter antenna mode can be suppressed, and decoupling in the second operating frequency band can be implemented.

[0195] When the co-radiator antenna implements self-decoupling in the MHB band and the N77 band, refer to FIG. 23 and FIG. 24. The first feed point K1 may be located on the second radiator 15 between the gap 13 and the ground end 12, and a length of the second radiator 15 between the first feed point K1 and the ground end 12 is less than a length of the second radiator 15 between the first feed point K1 and the gap 13. This helps excite the quarter antenna mode through the first feed point K1, and excite the three-quarter antenna mode through the second feed point K2.

[0196] Specifically, the length of the second radiator 15 between the first feed point K1 and the ground end 12 is less than or equal to 10 mm. This helps excite the quarter antenna mode through the first feed point K1, and excite the three-quarter antenna mode through the second feed point K2. In addition, in some other embodiments, a position of the first feed point K1 may alternatively be adjusted based on an actual situation. For example, a length of a radiator between the first feed point K1 and the ground end 12 is greater than 10 mm. This is not limited in this embodiment.

[0197] FIG. 29 is a simulation diagram of a radiation direction of an antenna when an electronic device is in a free space (Free Style, FS) state. The simulation diagram shown in FIG. 29 is a simulation diagram when a first operating frequency band corresponds to an LB band (698 MHz to 960 MHz) and a second operating frequency band corresponds to an L5 band (1176.45 MHz±1.023 MHz). Refer to FIG. 29. In the FS state, an upper hemisphere proportion of an antenna field pattern is 62%.

[0198] FIG. 30 is a simulation diagram of a radiation direction of an antenna when an electronic device is in a left-hand holding state. The simulation diagram shown in FIG. 30 is a simulation diagram when a first operating frequency band corresponds to an LB band (698 MHz to 960 MHz) and a second operating frequency band corresponds to an L5 band (1176.45 MHz±1.023 MHz). Refer to FIG. 30. In the left-hand holding state, an upper hemisphere proportion of an antenna field pattern is 67%.

[0199] FIG. 31 is a simulation diagram of a radiation direction of an antenna when an electronic device is in a right-hand holding state. The simulation diagram shown in FIG. 31 is a simulation diagram when a first operating frequency band corresponds to an LB band (698 MHz to 960 MHz) and a second operating frequency band corresponds to an L5 band (1176.45 MHz±1.023 MHz). Refer to FIG. 31. In the right-hand holding state, an upper hemisphere proportion of an antenna field pattern is 53%.

[0200] FIG. 32 is a curve diagram of a return loss coefficient (S11) and isolation of an antenna when an electronic device is in a free space state, a left-hand holding state, a right-hand holding state. For example, a quarter antenna mode is described by using an example in which a first operating frequency band corresponds to a B8 band, and a three-quarter antenna mode is described by using an example in which a second operating frequency band corresponds to an L5 band. Refer to FIG. 32. A curve f1 is an S11 curve in the FS state, and f2 is a corresponding isolation curve; a curve g1 is an S11 curve in the left-hand holding state, and g2 is a corresponding isolation curve; and a curve h1 is an S11 curve in the left-hand holding state, and h2 is a corresponding isolation curve. In the FS state, and in the left-hand holding state and the right-hand holding state, both the modes have good isolation, and isolation in the left-hand holding state is similar to that in the right-hand holding state.

[0201] FIG. 33 is a curve diagram of efficiency of an antenna in a quarter antenna mode (a first operating frequency band corresponds to a B8 band) when an electronic device is in a free space state, a left-hand holding state, and a right-hand holding state. Refer to FIG. 33. A curve f3 is system efficiency in the quarter antenna mode in the FS state, g3 is system efficiency in the quarter antenna mode in the left-hand holding state, and h3 is system efficiency in the quarter antenna mode in the right-hand holding state. It can be learned from FIG. 33 that, system efficiency in the FS state is the highest, system efficiency in the left-hand holding state is similar to that in the right-hand holding state, and both the left-hand holding state and the right-hand holding state have good efficiency.

[0202] FIG. 34 is a curve diagram of efficiency of an antenna in a three-quarter antenna mode (a second operating frequency band corresponds to an L5 band) when an electronic device is in a free space state, a left-hand holding state, and a right-hand holding state. Refer to FIG. 34. A curve f4 is system efficiency in the three-quarter antenna mode in the FS state, g4 is system efficiency in the three-quarter antenna mode in the left-hand holding state, and h4 is system efficiency in the three-quarter antenna mode in the right-hand holding state. It can be learned from FIG. 34 that, system efficiency in the FS state is the highest, system efficiency in the left-hand holding state is similar to that in the right-hand holding state, and both the left-hand holding state and the right-hand holding state have good efficiency.

[0203] FIG. 35 is a curve diagram of a return loss coefficient (S11) of an antenna obtained when an electronic device is held in hand and a position of a gap 13 is held. FIG. 36 is a curve diagram of efficiency of an antenna obtained when the electronic device is held in hand and a position of a gap 13 is held. Refer to FIG. 35 and FIG. 36. When the electronic device is held in hand and the hand shields the gap 13, no frequency offset occurs in the three-quarter antenna mode (3/4 mode), and when a low frequency band of the one-quarter antenna mode (1/4 mode) is switched, no frequency offset occurs in the three-quarter antenna mode.

[0204] The foregoing descriptions are merely preferred embodiments of this application, and are not intended to limit this application. For a person skilled in the art, this application may have various modifications and variations. Any modification, equivalent replacement, or improvement made without departing from the spirit and principle of this application shall fall within the protection scope of this application.

Claims

1. An electronic device, comprising:

    a first antenna feed circuit and a second antenna feed circuit;
    a radiator, comprising an open end and a ground end, wherein a gap is disposed on the radiator, the gap is disposed between the open end and the ground end, the radiator is divided into a first radiator and a second radiator through the gap, the first radiator is a radiator part between the gap and the open end, the second radiator is a radiator part between the gap and the ground end, and a length of the first radiator is one to three times a length of the second radiator; and
    a first component, connected across the gap and coupled in series between the first radiator and the second radiator, wherein
    the radiator further comprises a first feed point and a second feed point;
    the radiator is coupled to the first antenna feed circuit through the first feed point, the first antenna feed circuit is configured to feed a signal in a first operating frequency band into the radiator, and the first radiator and the second radiator are configured to jointly generate a first resonance corresponding to the first operating frequency band;
    the radiator is coupled to the second antenna feed circuit through the second feed point, the second antenna feed circuit is configured to feed a signal in a second operating frequency band into the radiator, the first radiator and the second radiator are configured to jointly generate a second resonance corresponding to the second operating frequency band, the second feed point is disposed on the first radiator, and a length of the first radiator between the second feed point and the open end is greater than or equal to a length of the first radiator between the second feed point and the gap; and
    a center frequency of the second operating frequency band is higher than a center frequency of the first operating frequency band, and a highest frequency of the first operating frequency band is lower than a lowest frequency of the second operating frequency band.

2. The electronic device according to claim 1, wherein the first feed point is located on the second radiator, and a length of the second radiator between the first feed point and the ground end is less than a length of the second radiator between the first feed point and the gap.

3. The electronic device according to claim 2, wherein the length of the second radiator between the first feed point and the ground end is less than or equal to 10 mm.

4. The electronic device according to claim 1, wherein the first feed point is located on the first radiator, and a length of the first radiator between the first feed point and the open end is less than a length of the first radiator between the first feed point and the gap.

5. The electronic device according to claim 4, wherein the length of the first radiator between the first feed point and the open end is less than 10 mm.

6. The electronic device according to any one of claims 1 to 5, wherein the first component comprises a capacitor and/or an inductor and/or a radio frequency switch.

7. The electronic device according to claim 6, wherein the radio frequency switch comprises a switch and a plurality of circuit branches, a first end of the switch is coupled to a radiator at one end of the gap, a second end of the switch is coupled to a radiator at the other end of the gap through at least a part of the circuit branches, and the at least part of the circuit branches has different capacitance values or inductance values.

8. The electronic device according to any one of claims 1 to 7, wherein when a frequency of a resonance point of the first resonance is less than or equal to 1 GHz, an equivalent capacitance value of the first component is less than or equal to 10 pF; or when a frequency of a resonance point of the first resonance is greater than 1 GHz, an equivalent capacitance value of the first component is less than or equal to 2 pF.

9. The electronic device according to any one of claims 1 to 8, further comprising at least one second component, wherein a first end of each of the at least one second component is coupled to the first radiator or the second radiator, and a second end of each of the at least one second component is grounded.

10. The electronic device according to claim 9, wherein the at least one second component comprises an inductor, and a length of a radiator between the gap and a position at which the inductor is coupled to the first radiator or the second radiator is less than or equal to 20 mm.

11. The electronic device according to claim 10, wherein when the frequency of the resonance point of the first resonance is less than or equal to 1 GHz, an inductance value of the inductor is less than 20 nH; or when the frequency of the resonance point of the first resonance is greater than 1 GHz, an inductance value of the inductor is less than 10 nH.

12. The electronic device according to any one of claims 1 to 11, further comprising a second capacitor, wherein the second capacitor is coupled in series between the second feed point and the second antenna feed circuit; and
when the frequency of the resonance point of the first resonance is less than or equal to 1 GHz, a capacitance value of the second capacitor is less than or equal to 5 pF; or when the frequency of the resonance point of the first resonance is greater than 1 GHz, a capacitance value of the second capacitor is less than or equal to 3 pF.

13. The electronic device according to any one of claims 1 to 12, further comprising a matching circuit, wherein a first end of the matching circuit is coupled to the second feed point, a second end of the matching circuit is coupled to the second antenna feed circuit, the matching circuit in the first operating frequency band is equivalent to a first equivalent capacitance value, the matching circuit in the second operating frequency band is equivalent to a second equivalent capacitance value, and the first equivalent capacitance value is less than the second equivalent capacitance value.

14. The electronic device according to any one of claims 1 to 13, further comprising a filter circuit, wherein the filter circuit is coupled to the first feed point, and the filter circuit is configured to: pass, between the radiator and the first antenna feed circuit, the signal in the first operating frequency band, and suppress the signal in the second operating frequency band.

15. The electronic device according to claim 14, wherein the filter circuit is a high-pass low-cut filter circuit, a first end of the high-pass low-cut filter circuit is coupled to the first feed point, and a second end of the high-pass low-cut filter circuit is grounded.

16. The electronic device according to any one of claims 1 to 15, wherein the radiator excites a quarter antenna mode of the radiator through the first antenna feed circuit, the radiator excites a three-quarter antenna mode of the radiator through the second antenna feed circuit, the radiator generates the first resonance in the quarter antenna mode, and the radiator generates the second resonance in the three-quarter antenna mode; and
in the quarter antenna mode, an electric field reverse point is generated on the second radiator, and the second feed point is disposed at a position that is on the radiator and that is less than or equal to 10 mm away from the electric field reverse point.

17. The electronic device according to any one of claims 1 to 16, wherein a sum of electrical lengths of the first radiator and the second radiator is greater than a quarter wavelength of the first operating frequency band and less than a three-quarter wavelength of the first operating frequency band.

18. The electronic device according to any one of claims 1 to 17, wherein

the first operating frequency band comprises at least one communication frequency band in a range of 698 MHz to 960 MHz; or
the first operating frequency band comprises at least one communication frequency band in a range of 1.7 GHz to 2 GHz; or
the first operating frequency band comprises at least one communication frequency band in a range of 2.3 GHz to 2.7 GHz.

19. The electronic device according to any one of claims 1 to 18, wherein a frequency difference between the resonance point of the first resonance and the resonance point of the second resonance ranges from 100 MHz to 1 GHz.

20. An electronic device, comprising:

a first antenna feed circuit and a second antenna feed circuit;
a radiator, comprising an open end and a ground end, wherein a gap is disposed on the radiator, the gap is disposed between the open end and the ground end, the radiator is divided into a first radiator and a second radiator through the gap, the first radiator is a radiator part between the gap and the open end, the second radiator is a radiator part between the gap and the ground end, and a length of the first radiator is one to three times a length of the second radiator; and
a first component, connected across the gap and coupled in series between the first radiator and the second radiator, wherein
the radiator further comprises a first feed point and a second feed point, the radiator is coupled to the first antenna feed circuit through the first feed point, and the radiator is coupled to the second antenna feed circuit through the second feed point;
the first antenna feed circuit is configured to feed the radiator through the first feed point, so that the radiator excites a quarter antenna mode, and in the quarter antenna mode, the first radiator and the second radiator are configured to jointly generate a first resonance corresponding to the first operating frequency band; the second antenna feed circuit is configured to feed the radiator through the second feed point, so that the radiator excites a three-quarter antenna mode, and in the three-quarter antenna mode, the first radiator and the second radiator are configured to jointly generate a second resonance corresponding to the second operating frequency band; and a center frequency of the second operating frequency band is higher than a center frequency of the first operating frequency band, and a highest frequency of the first operating frequency band is lower than a lowest frequency of the second operating frequency band; and
in the quarter antenna mode, an electric field reverse point is generated on the first radiator, and the second feed point is disposed at a position that is on the first radiator and that is at a preset distance away from the electric field reverse point.

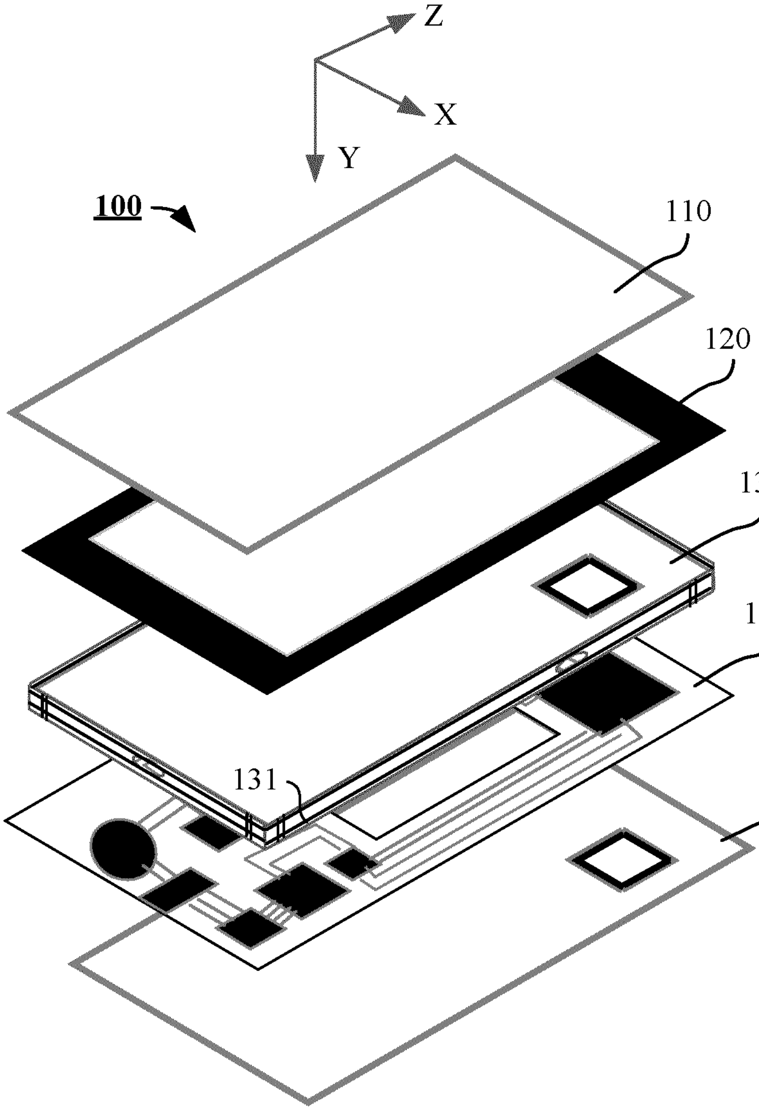


FIG. 1(a)

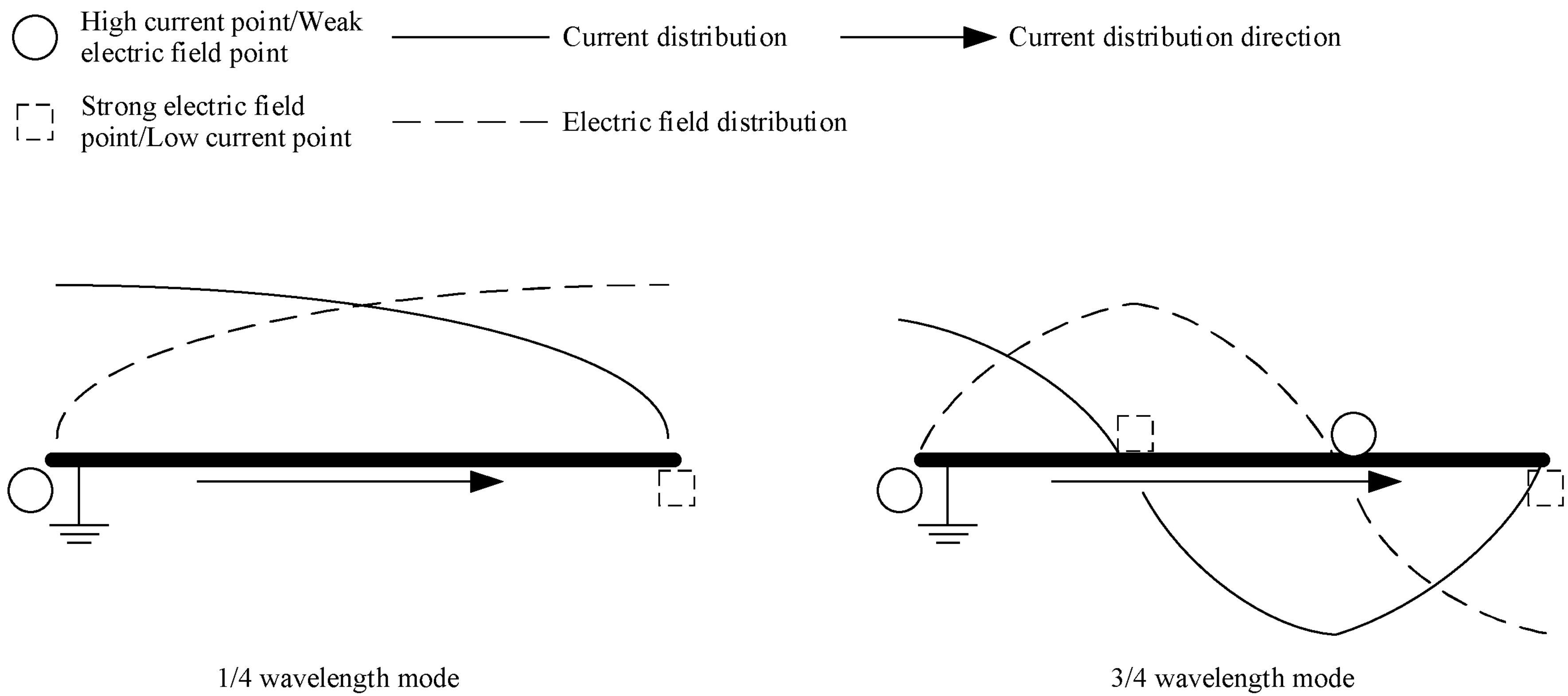

High current point/Weak electric field point
Strong electric field point/Low current point
Current distribution
Electric field distribution
Current distribution direction
1/4 wavelength mode
3/4 wavelength mode

FIG. 1(b)

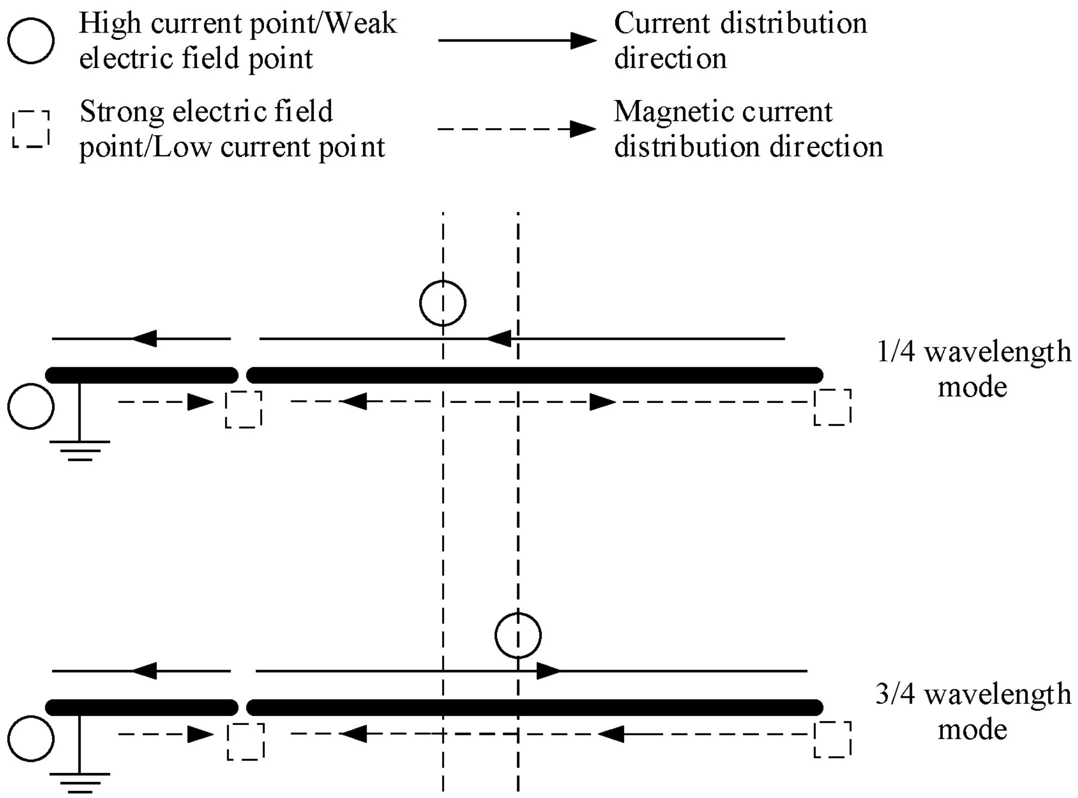

High current point/Weak electric field point
Current distribution direction
Strong electric field point/Low current point
Magnetic current distribution direction
1/4 wavelength mode
3/4 wavelength mode

FIG. 1(c)

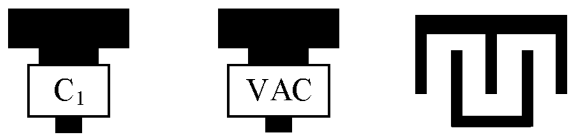

C1
VAC

FIG. 2

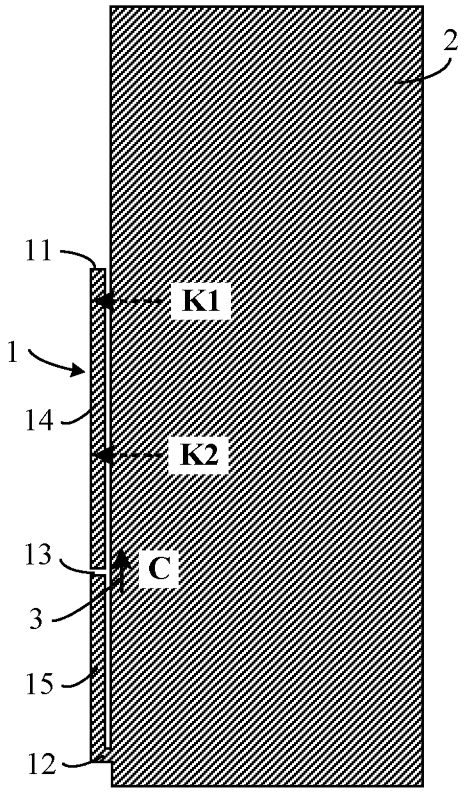


FIG. 3

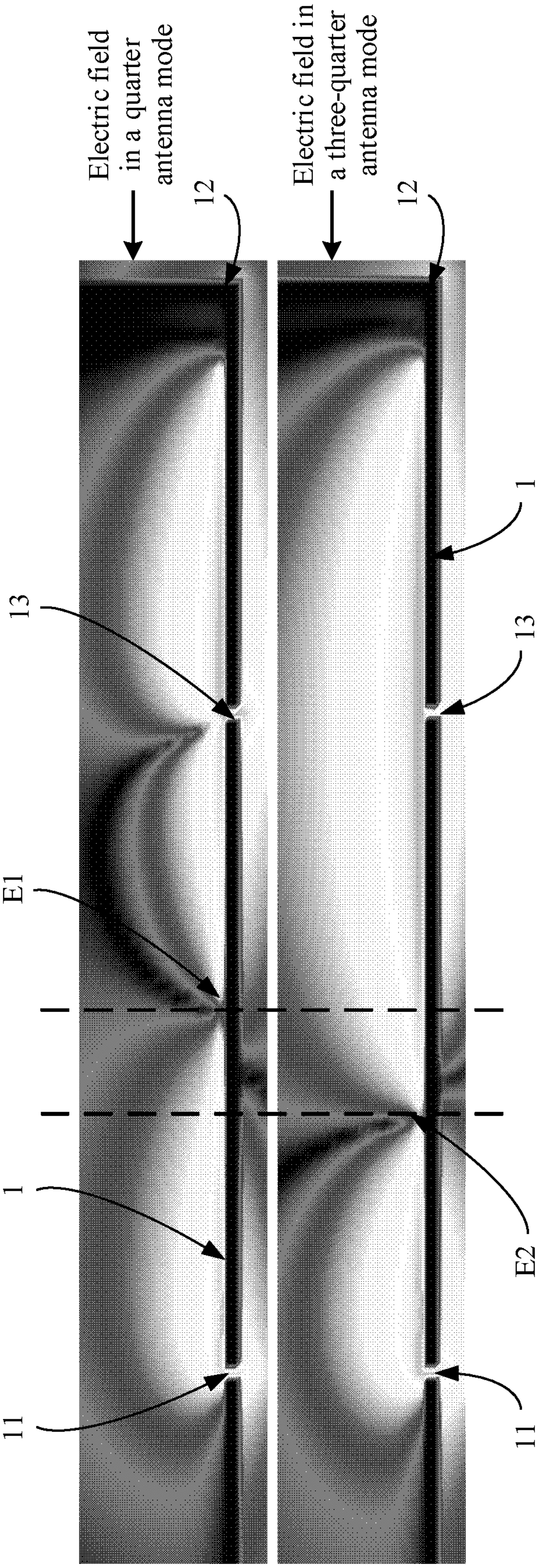

Electric field in a quarter antenna mode
Electric field in a three-quarter antenna mode
12
12
13
13
E1
E2
1
1
11
11

FIG. 4

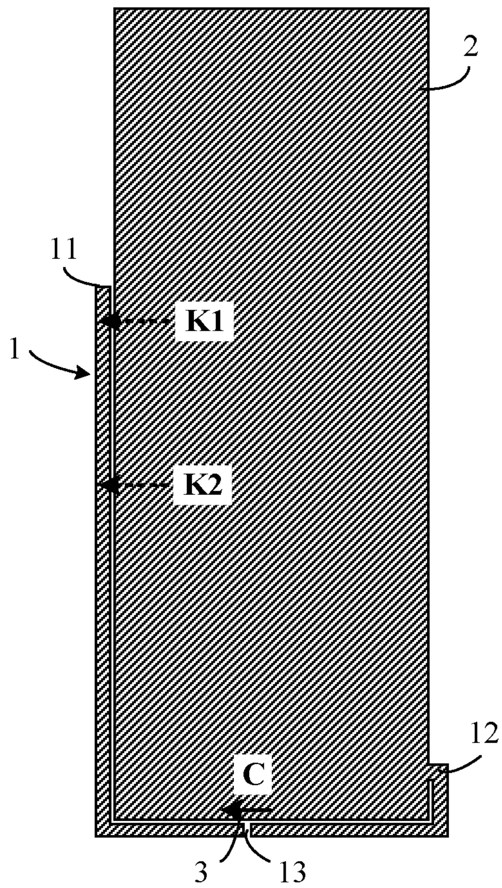


FIG. 5

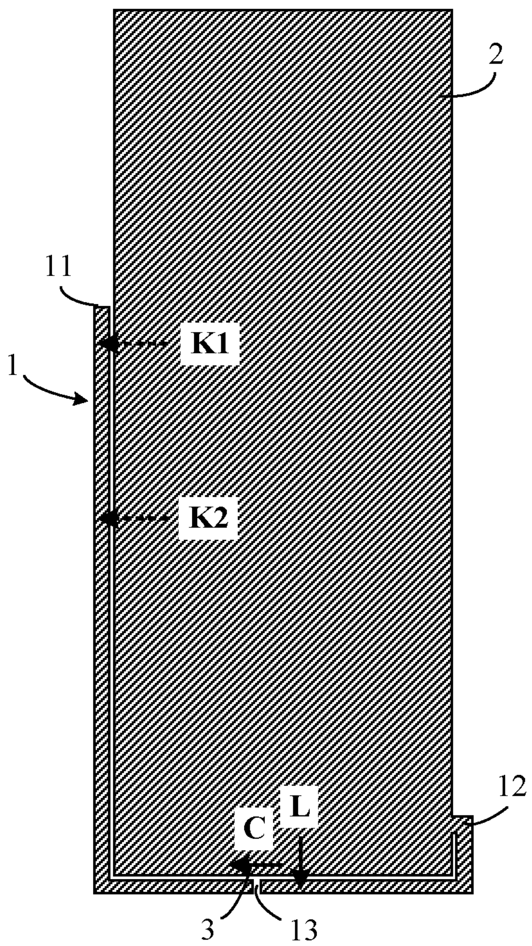


FIG. 6

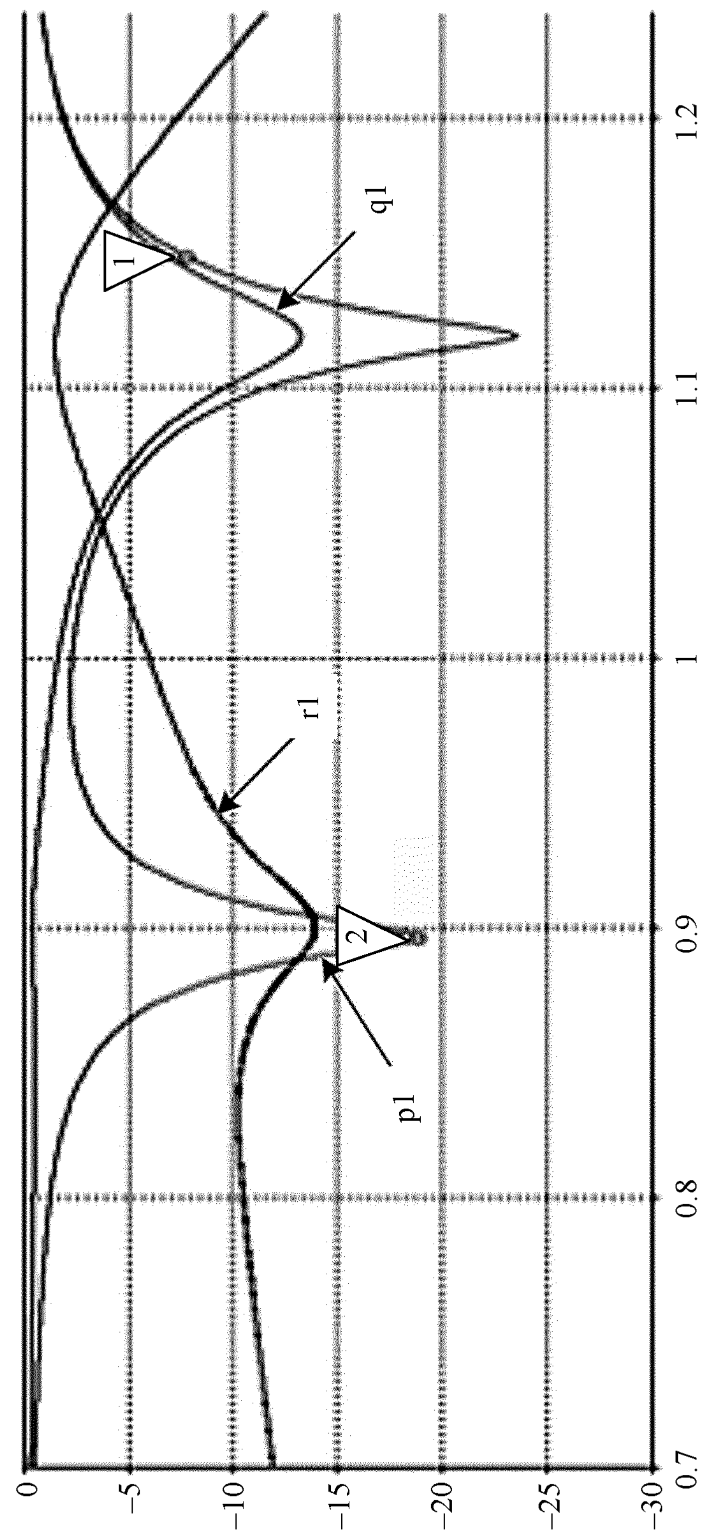


FIG. 7

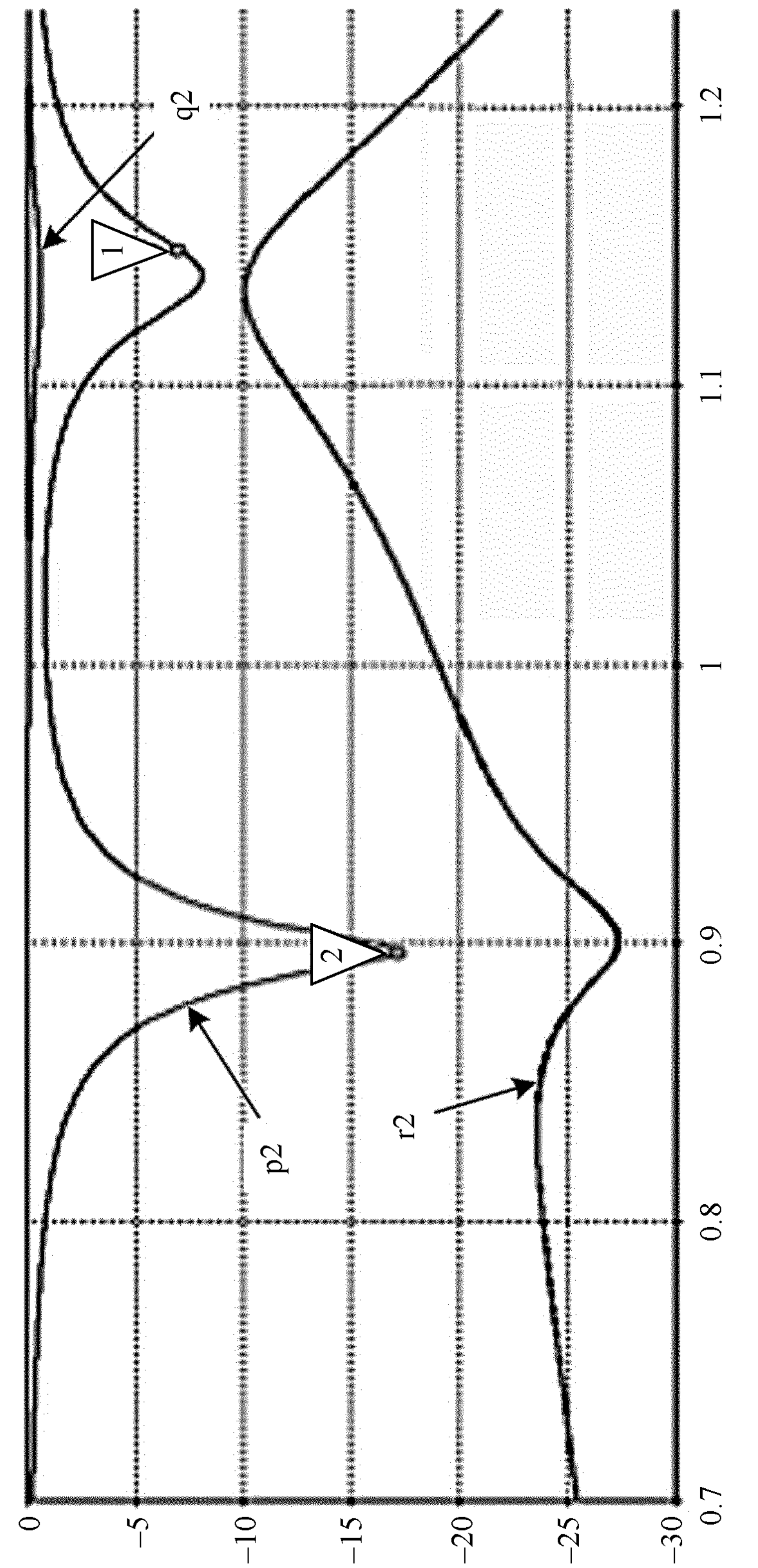


FIG. 8

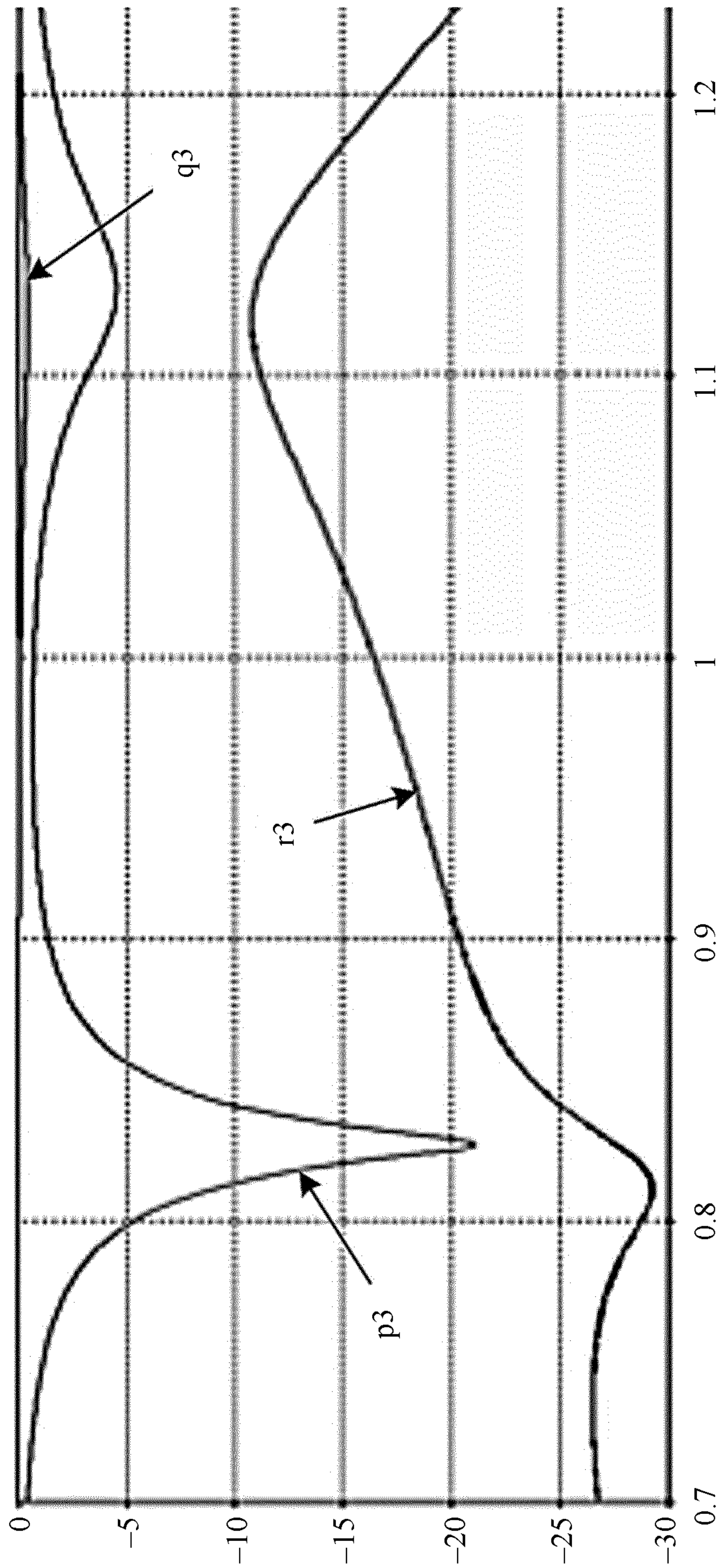


FIG. 9

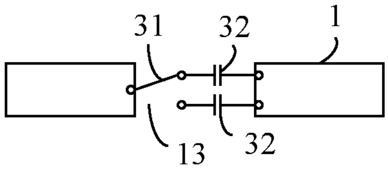


FIG. 10

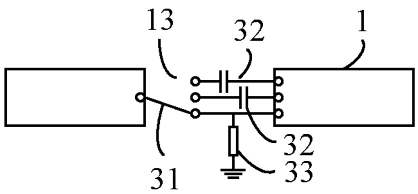


FIG. 11

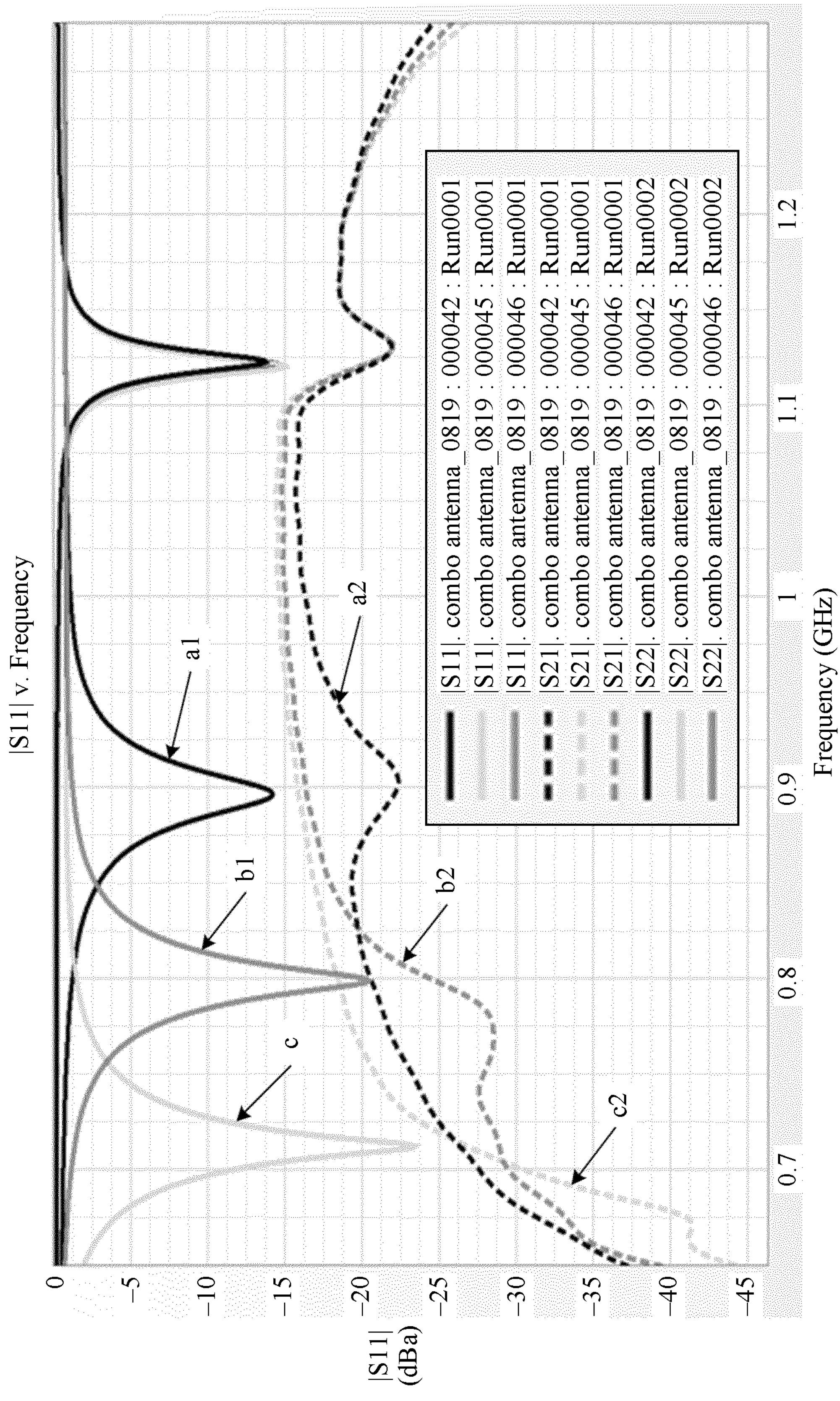

|S11| v. Frequency
|S11| (dBa)
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
0.7
0.8
0.9
1
1.1
1.2
Frequency (GHz)
a1
b1
c
a2
b2
c2
|S11|. combo antenna_0819 : 000042 : Run0001
|S11|. combo antenna_0819 : 000045 : Run0001
|S11|. combo antenna_0819 : 000046 : Run0001
|S21|. combo antenna_0819 : 000042 : Run0001
|S21|. combo antenna_0819 : 000045 : Run0001
|S21|. combo antenna_0819 : 000046 : Run0001
|S22|. combo antenna_0819 : 000042 : Run0002
|S22|. combo antenna_0819 : 000045 : Run0002
|S22|. combo antenna_0819 : 000046 : Run0002

FIG. 12

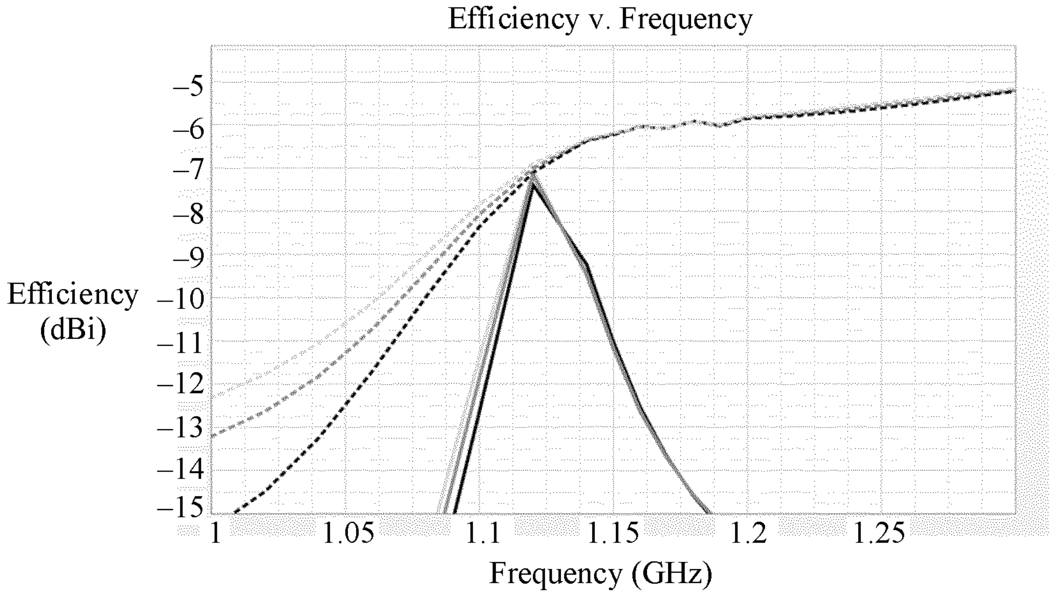

Efficiency v. Frequency
Efficiency (dBi)
−5
−6
−7
−8
−9
−10
−11
−12
−13
−14
−15
1
1.05
1.1
1.15
1.2
1.25
Frequency (GHz)

FIG. 13

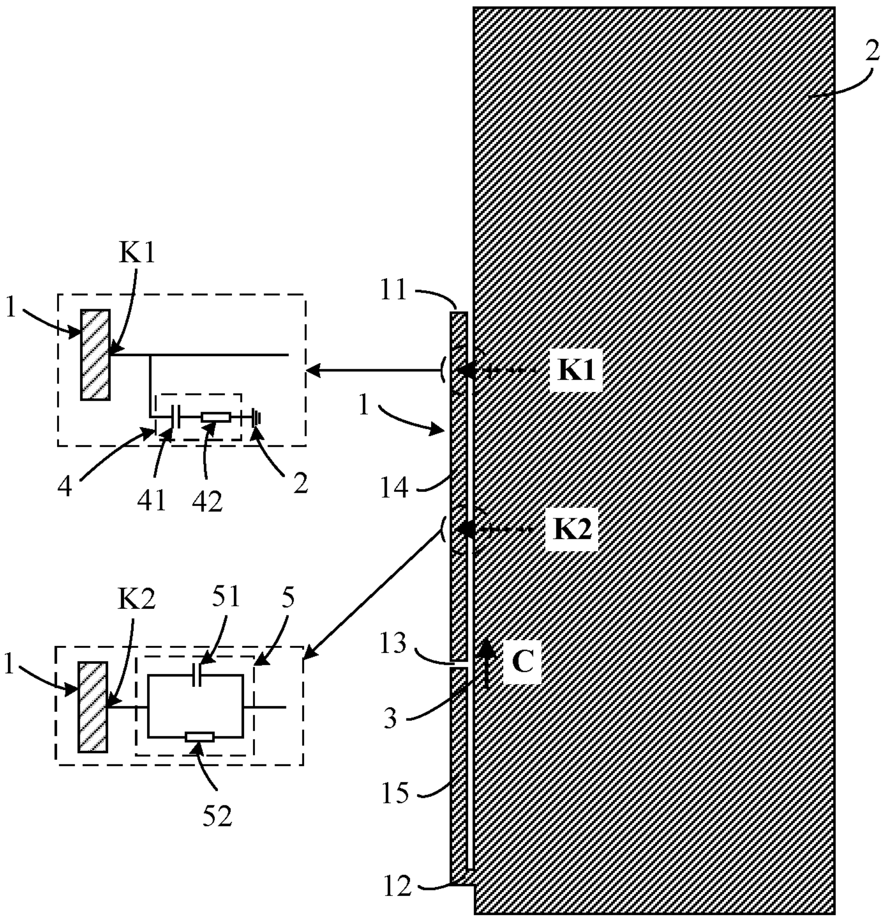

2
K1
1
11
K1
1
4
41
42
2
14
K2
K2
51
5
1
13
C
3
52
15
12

FIG. 14

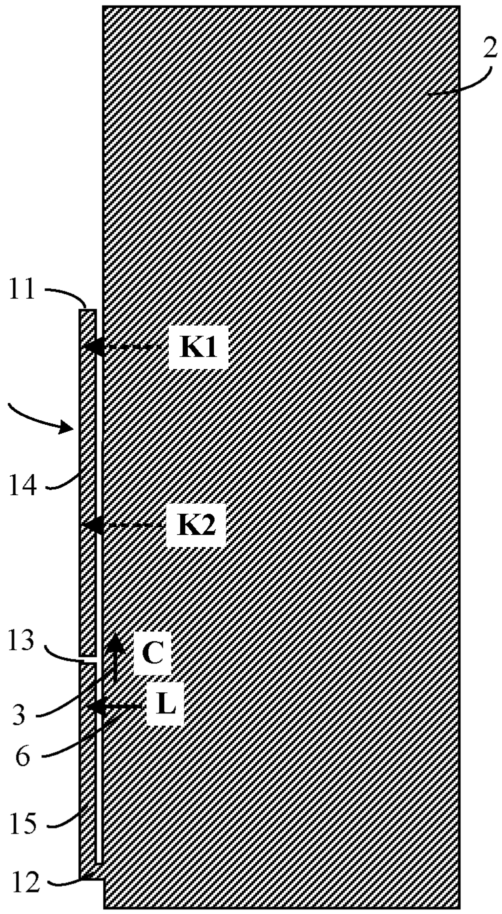


FIG. 15

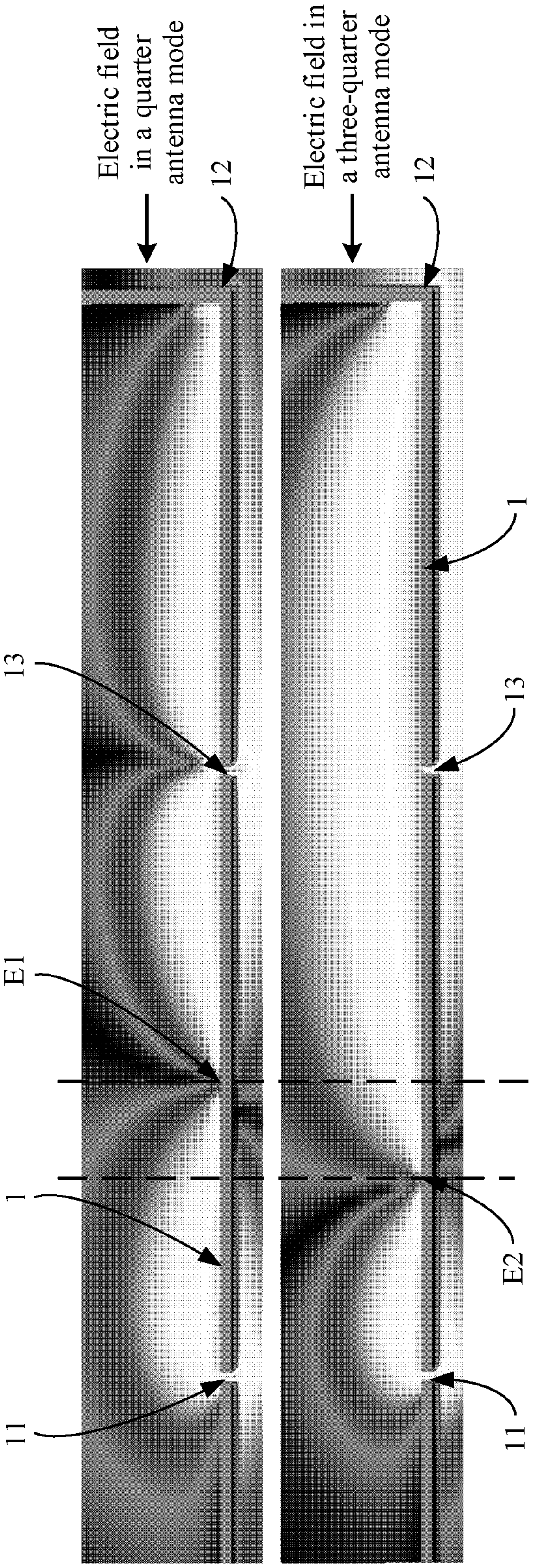

Electric field in a quarter antenna mode
Electric field in a three-quarter antenna mode
12
12
1
13
13
E1
1
E2
11
11

FIG. 16

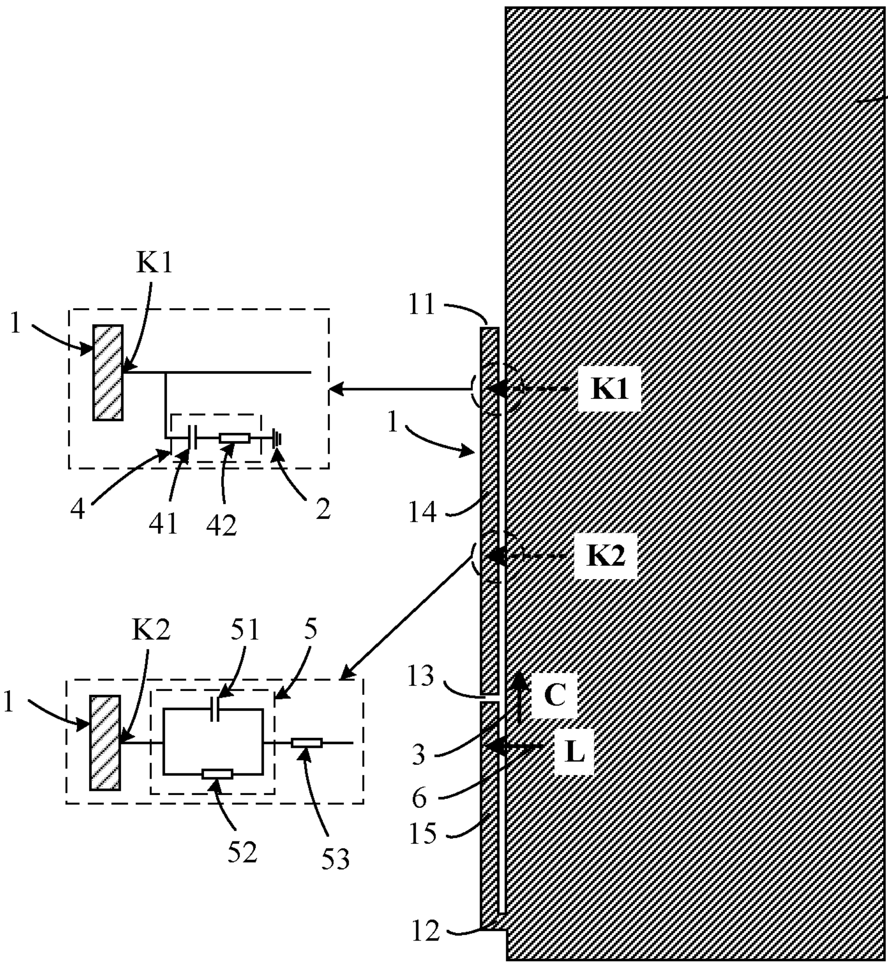
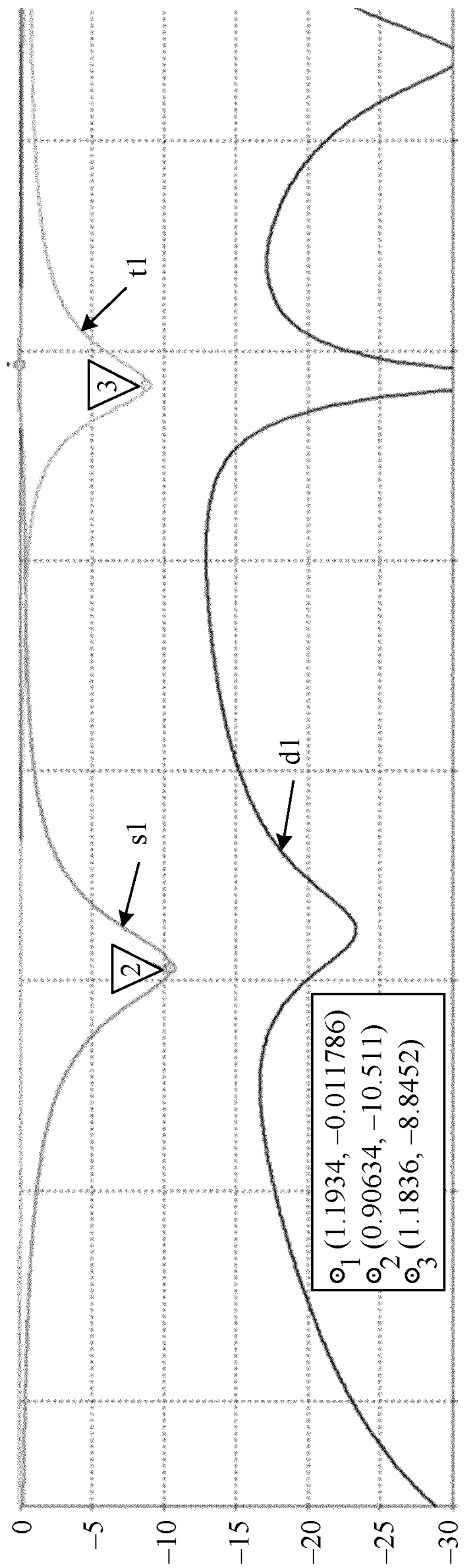


FIG. 17



0
−5
−10
−15
−20
−25
−30
0.65
0.7
0.8
0.9
1
1.1
1.2
1.3
s1
t1
d1
2
3
⊙1 (1.1934, −0.011786)
⊙2 (0.90634, −10.511)
⊙3 (1.1836, −8.8452)

FIG. 18

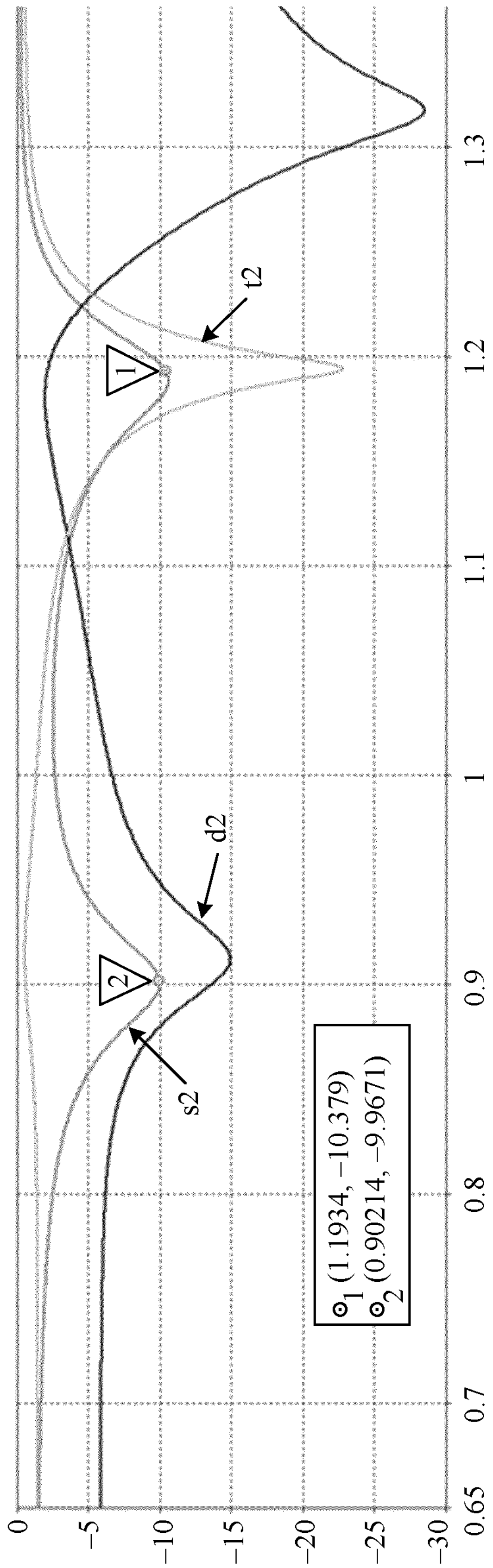

⊙1 (1.1934, −10.379)
⊙2 (0.90214, −9.9671)
s2
d2
t2
1
2
0
−5
−10
−15
−20
−25
−30
0.65
0.7
0.8
0.9
1
1.1
1.2
1.3

FIG. 19

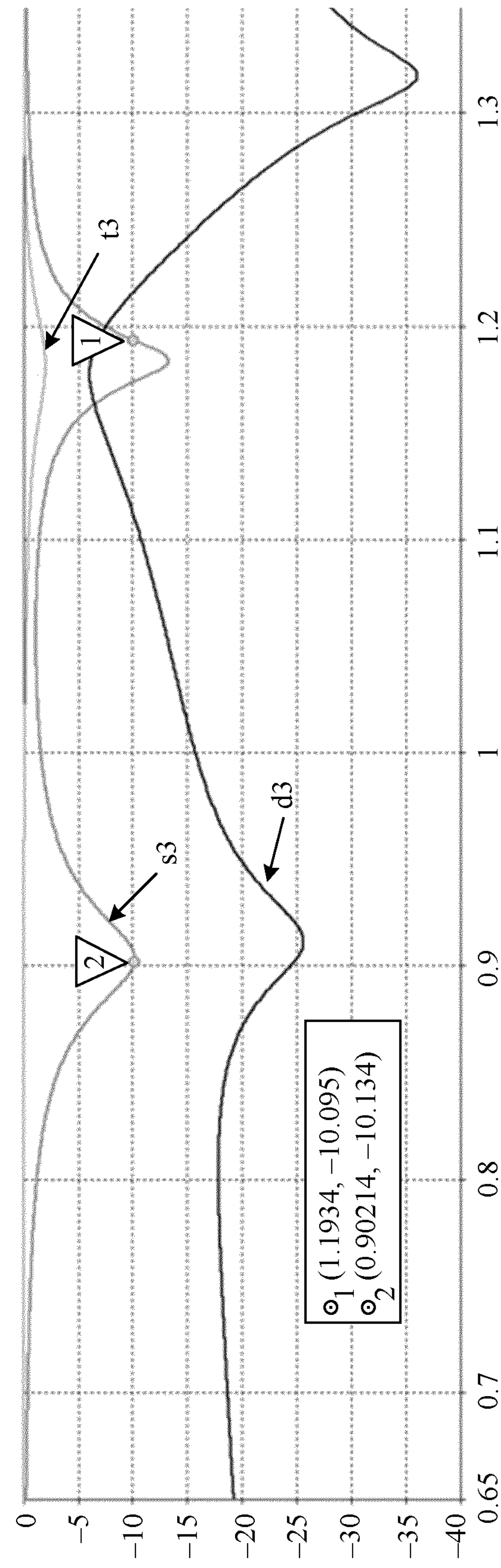

t3
s3
d3
1
2
⊙1 (1.1934, −10.095)
⊙2 (0.90214, −10.134)
0
−5
−10
−15
−20
−25
−30
−35
−40
0.65
0.7
0.8
0.9
1
1.1
1.2
1.3

FIG. 20

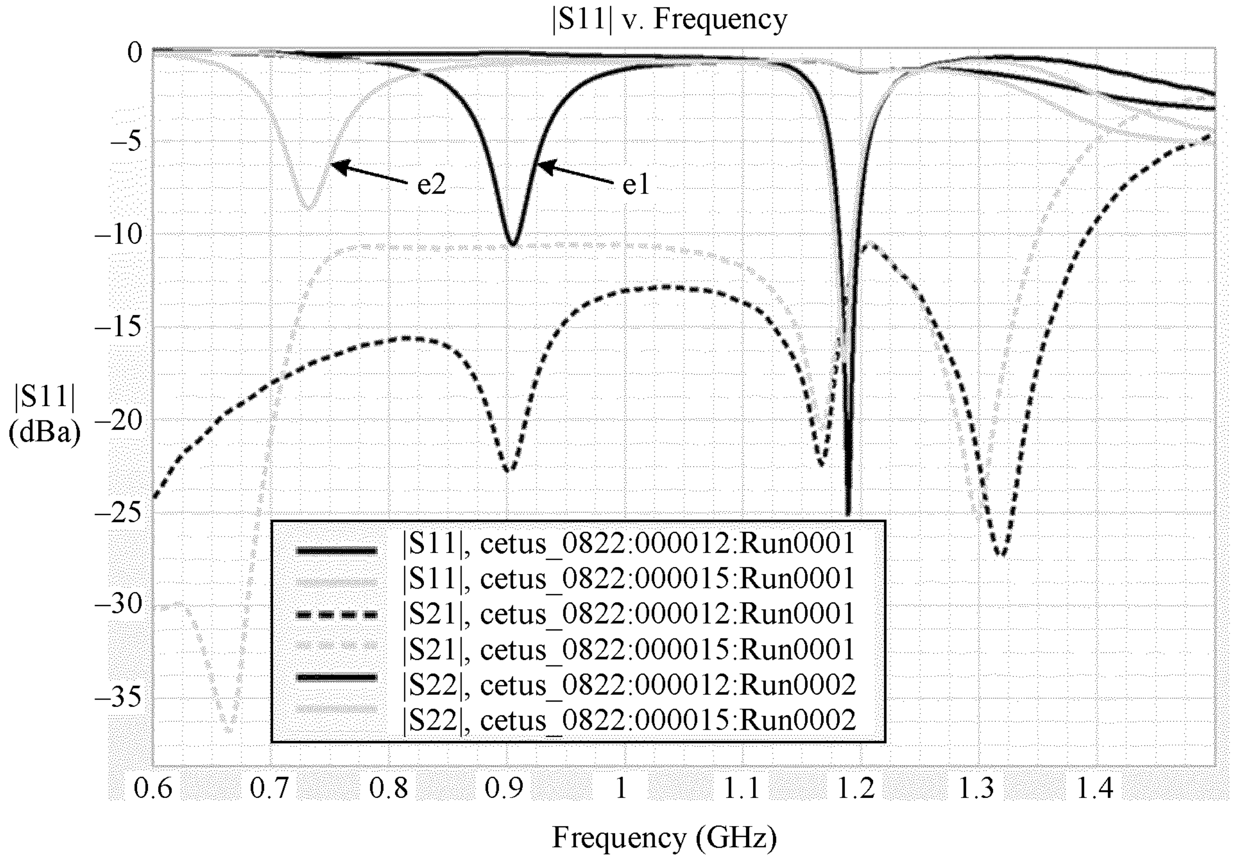

|S11| v. Frequency
0
−5
−10
−15
−20
−25
−30
−35
|S11| (dBa)
e2
e1
|S11|, cetus_0822:000012:Run0001
|S11|, cetus_0822:000015:Run0001
|S21|, cetus_0822:000012:Run0001
|S21|, cetus_0822:000015:Run0001
|S22|, cetus_0822:000012:Run0002
|S22|, cetus_0822:000015:Run0002
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Frequency (GHz)

FIG. 21

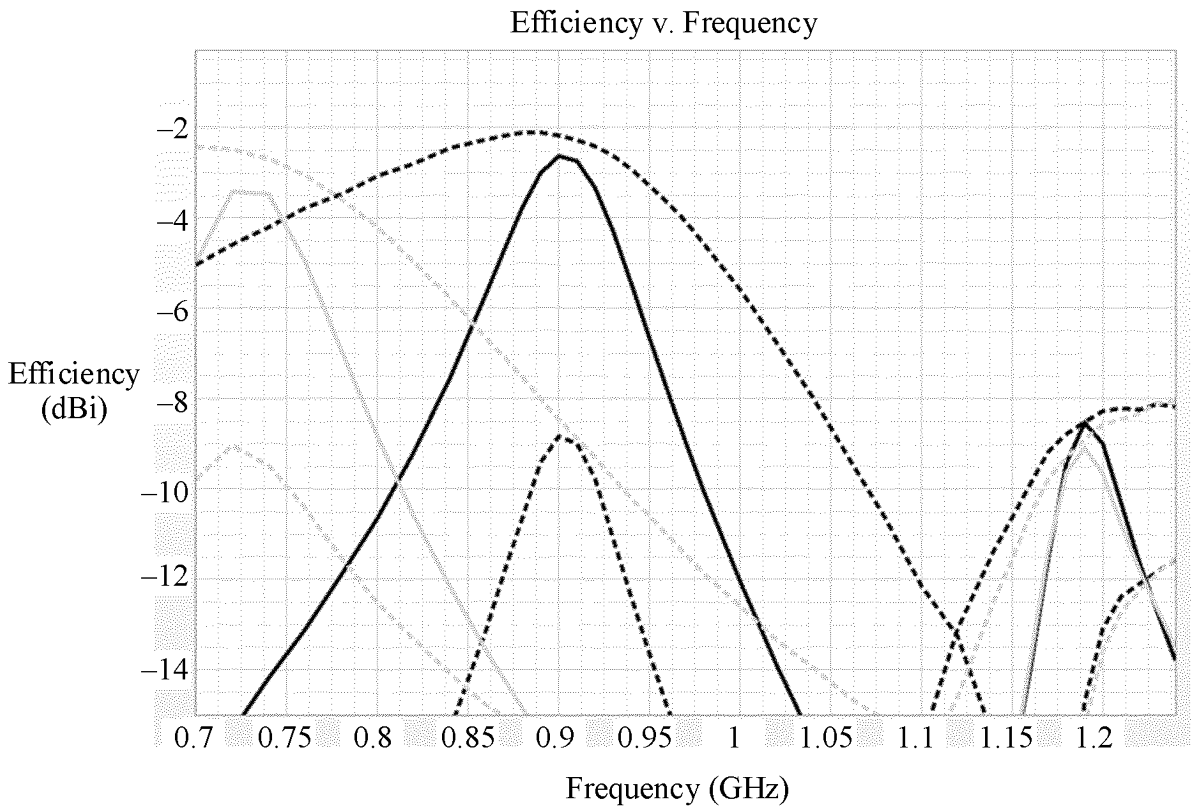

Efficiency v. Frequency
Efficiency (dBi)
−2
−4
−6
−8
−10
−12
−14
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
Frequency (GHz)

FIG. 22

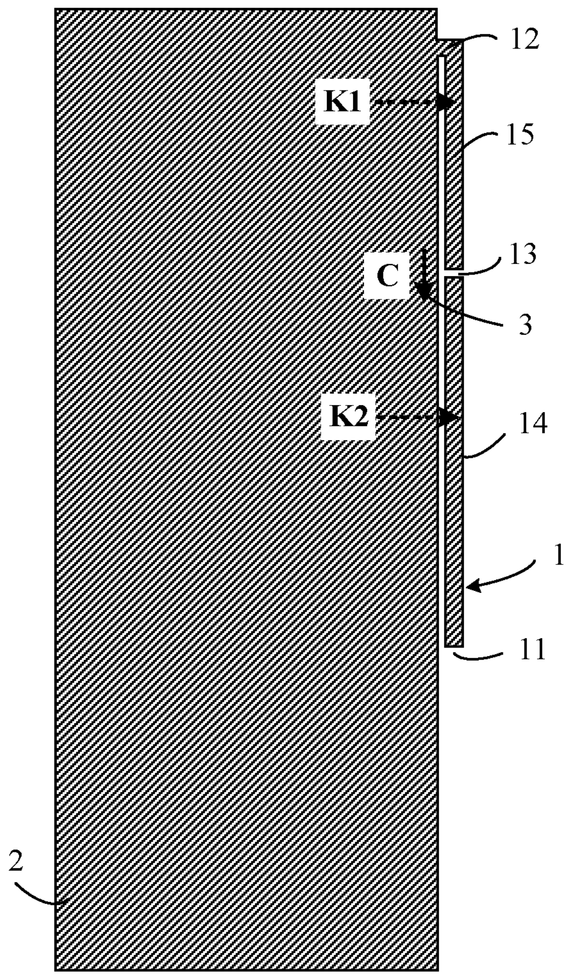


FIG. 23

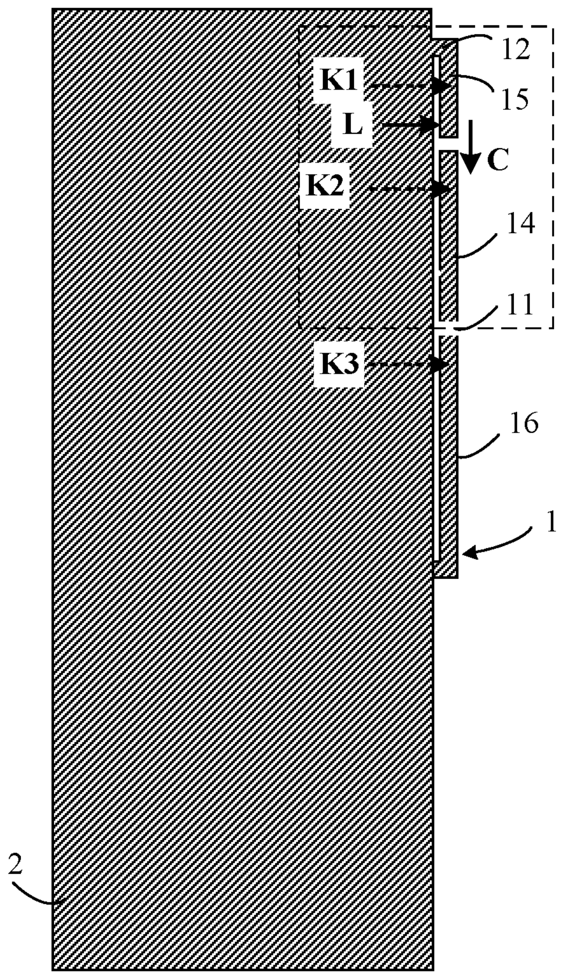


FIG. 24

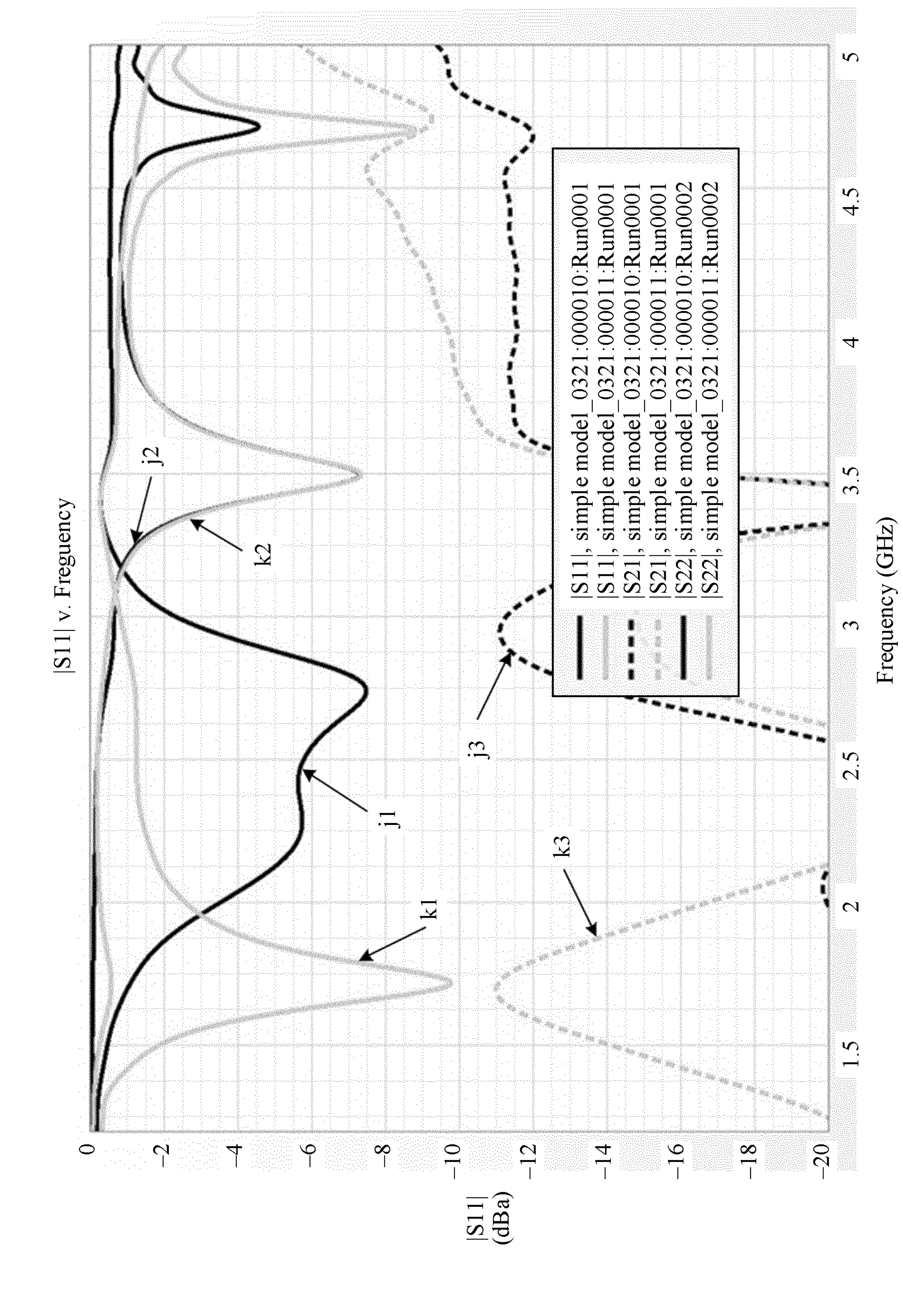

|S11| v. Frequency
|S11| (dBa)
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20
1.5
2
2.5
3
3.5
4
4.5
5
Frequency (GHz)
j1
j2
j3
k1
k2
k3
|S11|, simple model_0321:000010:Run0001
|S11|, simple model_0321:000011:Run0001
|S21|, simple model_0321:000010:Run0001
|S21|, simple model_0321:000011:Run0001
|S22|, simple model_0321:000010:Run0002
|S22|, simple model_0321:000011:Run0002

FIG. 25

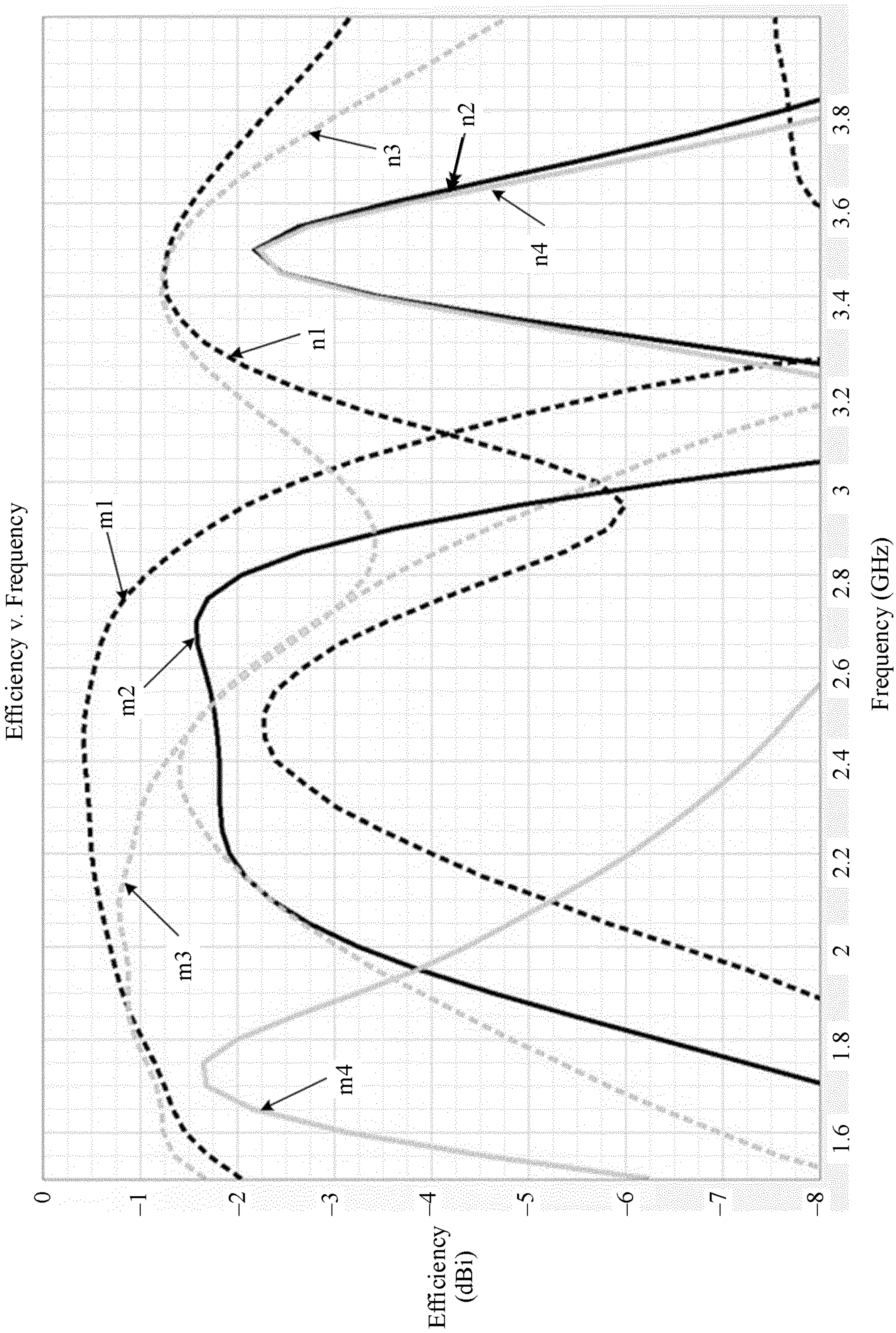

Efficiency v. Frequency
Efficiency (dBi)
0
−1
−2
−3
−4
−5
−6
−7
−8
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
Frequency (GHz)
m1
m2
m3
m4
n1
n2
n3
n4

FIG. 26

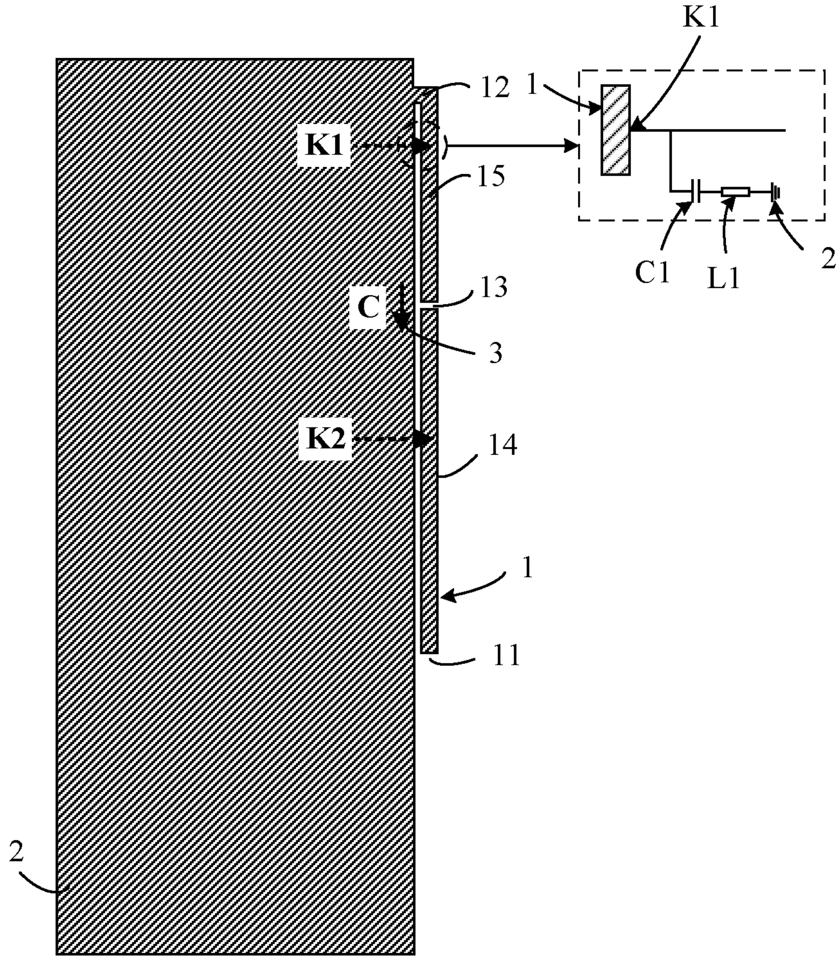


FIG. 27

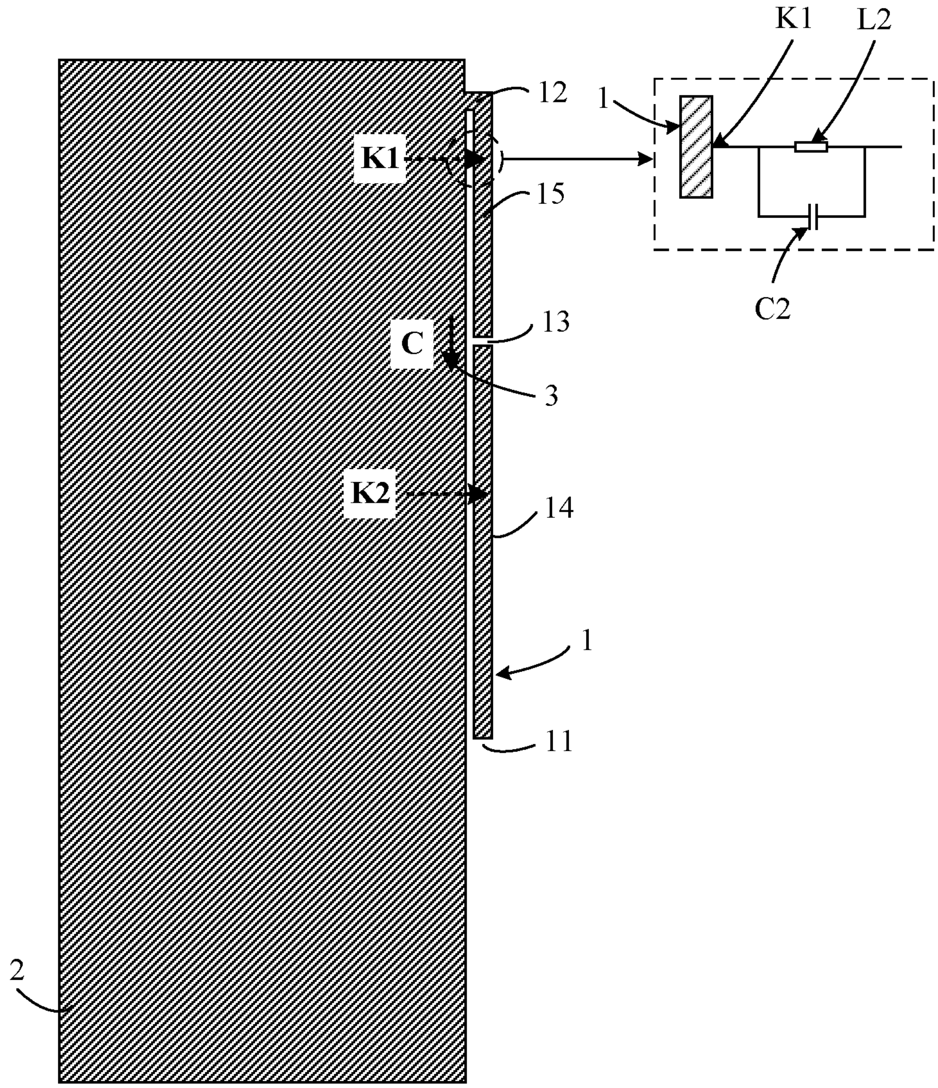


FIG. 28

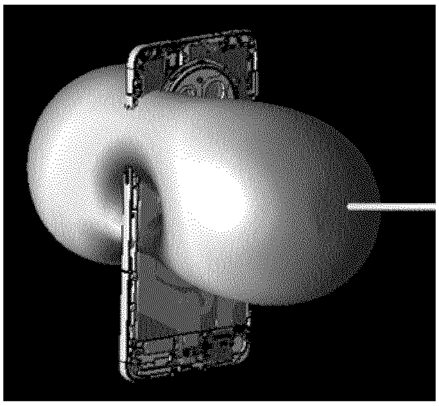


FIG. 29

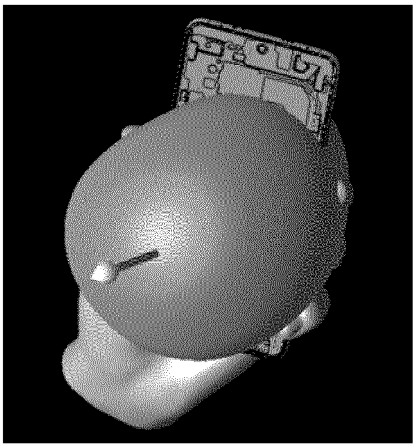


FIG. 30

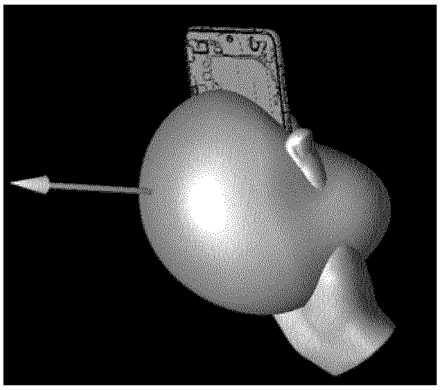


FIG. 31

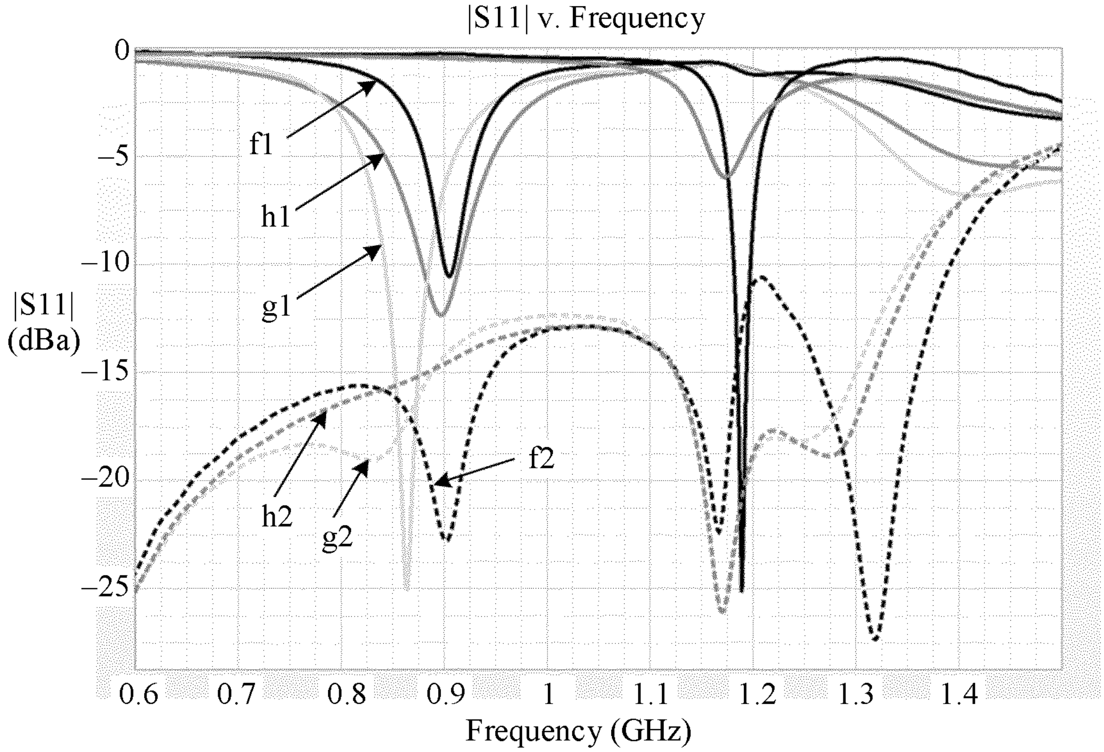

|S11| v. Frequency
0
−5
−10
−15
−20
−25
|S11|
(dBa)
f1
h1
g1
f2
h2
g2
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Frequency (GHz)

FIG. 32

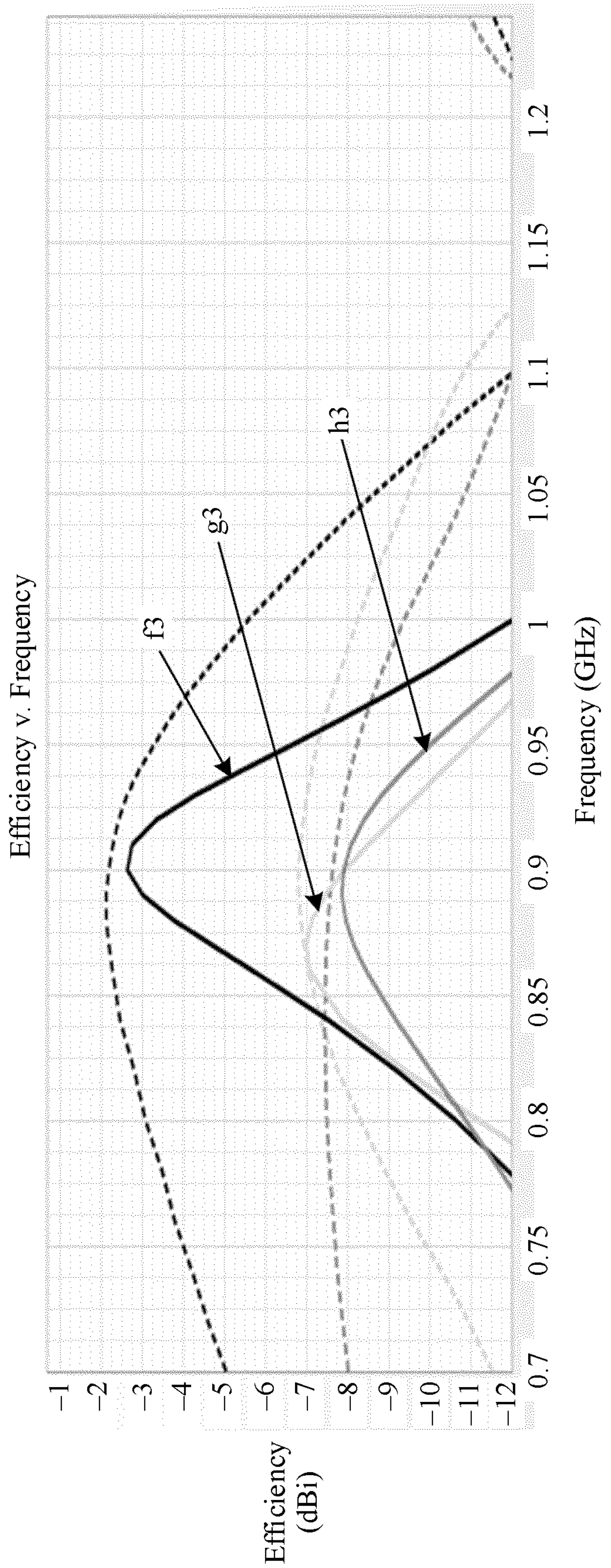
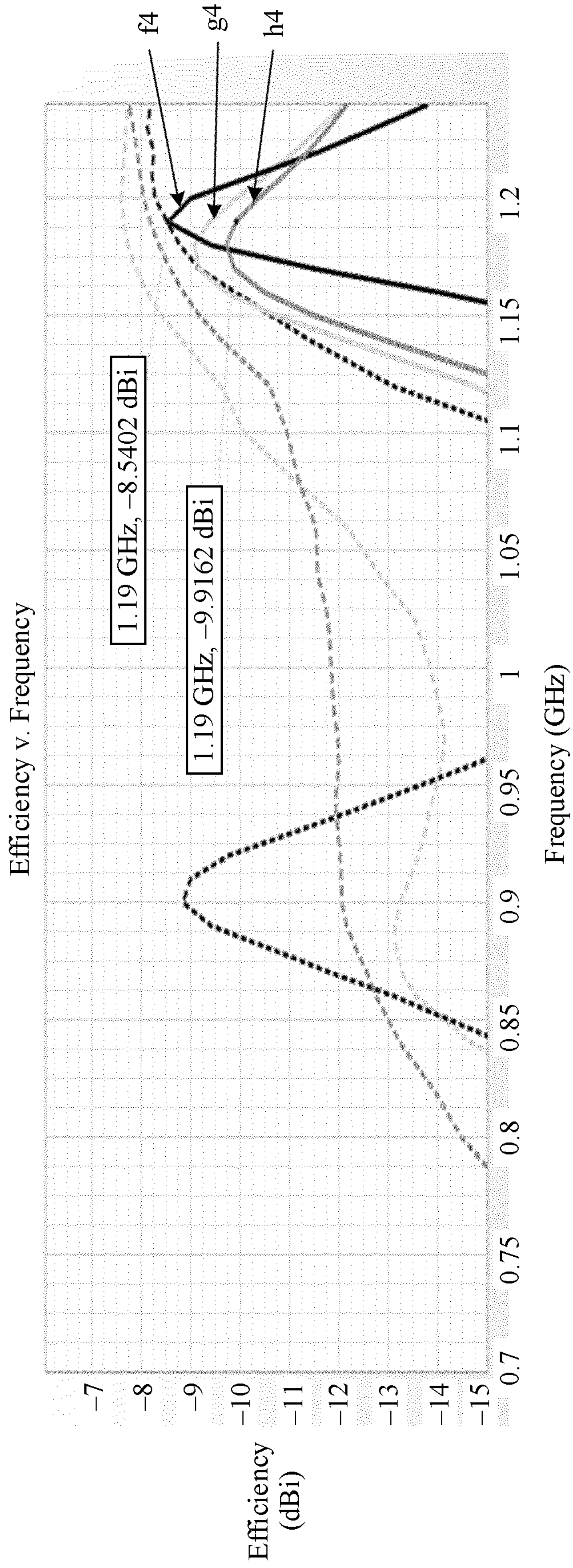

Efficiency v. Frequency
Efficiency (dBi)
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
Frequency (GHz)
f3
g3
h3

FIG. 33



Efficiency v. Frequency
1.19 GHz, −8.5402 dBi
1.19 GHz, −9.9162 dBi
f4
g4
h4
Efficiency (dBi)
−7
−8
−9
−10
−11
−12
−13
−14
−15
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
Frequency (GHz)

FIG. 34

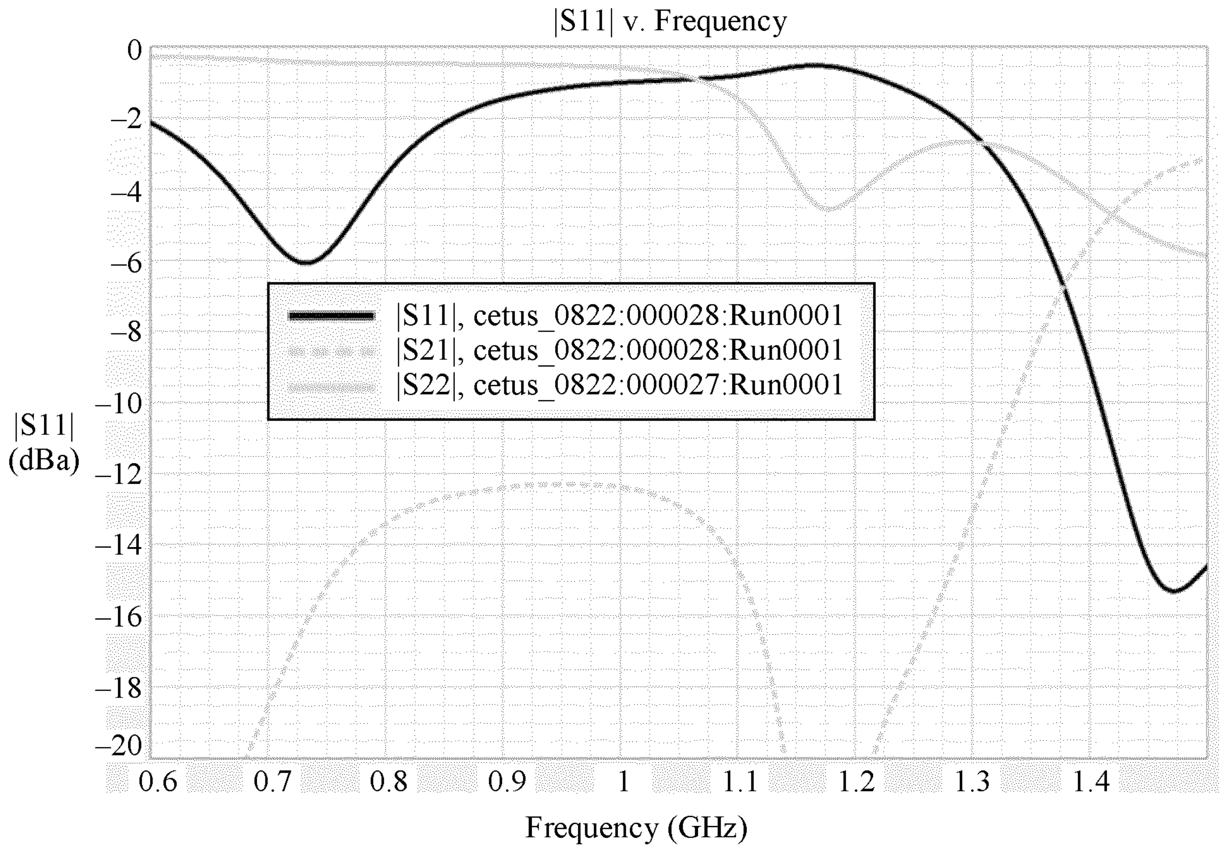

|S11| v. Frequency
0
–2
–4
–6
–8
–10
–12
–14
–16
–18
–20
|S11| (dBa)
|S11|, cetus_0822:000028:Run0001
|S21|, cetus_0822:000028:Run0001
|S22|, cetus_0822:000027:Run0001
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Frequency (GHz)

FIG. 35

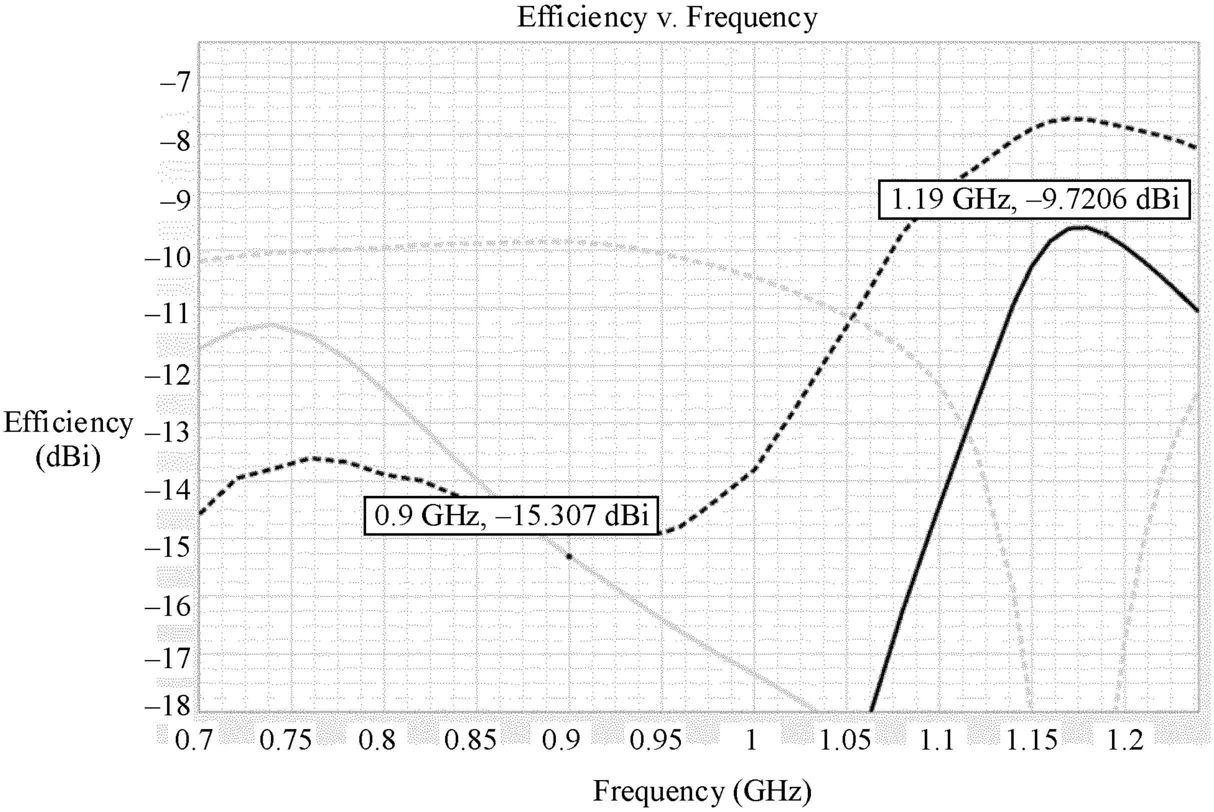

Efficiency v. Frequency
−7
−8
−9
−10
−11
−12
−13
−14
−15
−16
−17
−18
Efficiency (dBi)
1.19 GHz, −9.7206 dBi
0.9 GHz, −15.307 dBi
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
Frequency (GHz)

FIG. 36

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/134263

A. CLASSIFICATION OF SUBJECT MATTER

H01Q1/36(2006.01)i； 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, VEN, EPTXT, USTXT, USTXT, IEEE: 辐射, 复用, 共体, 接地, 缝, 耦合, 串联, 谐振, 频段, 长度, radiat+, multiplex+, common, ground+, slot, gap, coupl+, resonance, frequency, length

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 114079148 A (GUANGDONG OPPO MOBILE COMMUNICATIONS CO., LTD.) 22 February 2022 (2022-02-22) description, paragraphs 28-119, and figures 1-9	1-20
A	CN 110459859 A (OPPO (CHONGQING) INTELLIGENT TECHNOLOGY CO., LTD.) 15 November 2019 (2019-11-15) entire document	1-20
A	CN 113823899 A (HUAWEI TECHNOLOGIES CO., LTD.) 21 December 2021 (2021-12-21) entire document	1-20
A	KR 20200144686 A (LS MTRON LTD.) 30 December 2020 (2020-12-30) entire document	1-20
A	US 2016365623 A1 (SAMSUNG ELECTRONICS CO., LTD.) 15 December 2016 (2016-12-15) 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
23 February 2024	**23 February 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/CN2023/134263

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 114079148 A	22 February 2022	None	
CN 110459859 A	15 November 2019	None	
CN 113823899 A	21 December 2021	US 2023216196 A1	06 July 2023
		WO 2019129098 A1	04 July 2019
		EP 3709441 A1	16 September 2020
		EP 3709441 A4	09 December 2020
		EP 3709441 B1	01 November 2023
		US 2021021034 A1	21 January 2021
		US 11626662 B2	11 April 2023
KR 20200144686 A	30 December 2020	None	
US 2016365623 A1	15 December 2016	EP 3104456 A1	14 December 2016
		EP 3104456 B1	05 August 2020
		KR 20160146138 A	21 December 2016
		KR 102352490 B1	18 January 2022
		US 9935359 B2	03 April 2018

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