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

(57) Embodiments of this application provide an antenna structure and an electronic device. Different media are separately provided in different regions of a medium layer in the antenna structure, to miniaturize the antenna structure. The electronic device includes: a radiator, a ground plane, a conductive bezel, and a medium layer. The bezel has a first position and a second position, where a bezel between the first position and the second position serves as at least a part of the radiator. The radiator includes a ground point, and the radiator is grounded at the ground point through the ground plane. The medium layer is located between the radiator and the ground plane. The medium layer includes a first medium and a second medium. At the ground point, the medium layer between the radiator and the ground plane includes the first medium. A relative magnetic permeability of the first medium is greater than 1, and a relative permittivity of the second medium is greater than 1.

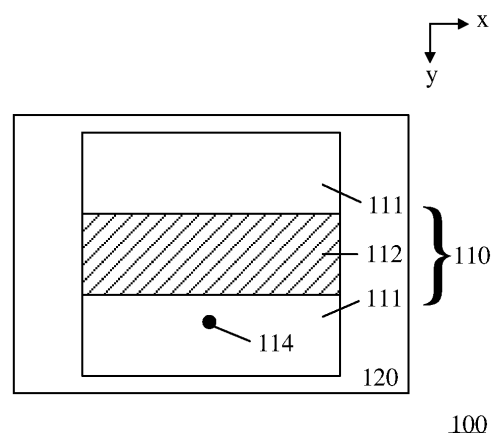


FIG. 5

Description

[0001] This application claims priority to Chinese Patent Application No. 202210155629.8, filed with the China National Intellectual Property Administration on February 21, 2022 and entitled "ANTENNA STRUCTURE AND ELECTRONIC DEVICE", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

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

BACKGROUND

[0003] For electronic devices, especially mobile phone products, with rapid development of key technologies such as curved displays and flexible displays, an industrial design (industrial design, ID) is trending towards lightness and thinness and an ultimate screen-to-body ratio. This design greatly reduces antenna space. In addition, the electronic devices have an increasingly high requirement for some functions, for example, a photographing function. This leads to a gradual increase in a quantity and sizes of cameras and complexity of an antenna design for an electronic device. Currently, communication frequency bands of the electronic device may be, for a long time, in a situation in which frequency bands of a 3rd generation mobile communication technology (3rd generation wireless systems, 3G), a 4th generation mobile communication technology (4th generation wireless systems, 4G), and a 5th generation mobile communication technology (5th generation wireless systems, 5G) coexist, and a quantity of antennas is increasing. Based on these changes, it is urgent to miniaturize an antenna in the electronic device.

SUMMARY

[0004] Embodiments of this application provide an antenna structure and an electronic device. Media with different electromagnetic parameters are separately provided in different regions of a medium layer in the antenna structure, to miniaturize the antenna structure.

[0005] According to a first aspect, an antenna structure is provided, including: a radiator, including a ground point; a ground plane, where the radiator is grounded at the ground point through the ground plane; a conductive bezel, where the bezel has a first position and a second position, and a bezel between the first position and the second position serves as at least a part of the radiator; and a medium layer located between the radiator and the ground plane, where the medium layer includes a first medium and a second medium, and at the ground point, the medium layer between the radiator and the ground plane includes the first medium; and a relative

magnetic permeability of the first medium is greater than 1, and a relative permittivity of the second medium is greater than 1.

[0006] According to technical solutions in embodiments of this application, for a bezel antenna in the electronic device, a ground point of the bezel antenna is generally a maximum current point, and corresponds to an electric field zero point or a strong magnetic field point. The first medium with the relative magnetic permeability greater than 1 is provided at the medium layer at the ground point, so that a magnetic field is loaded in a strong magnetic field region, and an electric field is loaded in a region in which the second medium with the relative permittivity greater than 1 is provided. Therefore, a same magnetic field and a same electric field can be generated in a smaller size, to miniaturize the antenna structure.

[0007] With reference to the first aspect, in some implementations of the first aspect, the radiator further includes a feed point; the bezel further has a third position, and the third position is provided between the first position and the second position; the radiator is separated from another part of the bezel at the second position by a gap; the ground point is provided at the first position, and the feed point is provided between the first position and the third position; between the first position and the third position, the medium layer between the radiator and the ground plane is a first medium layer, and the first medium layer includes the first medium; and between the second position and the third position, the medium layer between the radiator and the ground plane is a second medium layer, and the second medium layer includes the second medium.

[0008] According to the technical solutions in embodiments of this application, when the antenna structure includes an IF A, the strong magnetic field region (a region in which a magnetic field is greater than an electric field) generated by the antenna structure is close to the first position, and a strong electric field region (a region in which an electric field is greater than a magnetic field) generated by the antenna structure is close to the second position.

[0009] With reference to the first aspect, in some implementations of the first aspect, a distance L1 between the third position and a midpoint between the first position and the second position and a distance L between the first position and the second position satisfy $L1 \leq L \times 25\%$.

[0010] With reference to the first aspect, in some implementations of the first aspect, $L1 \leq L \times 12.5\%$, or $L1 \leq L \times 7\%$.

[0011] According to the technical solutions in embodiments of this application, at the third position, an electric field may be equal to a magnetic field. It should be understood that, during actual application, the third position may alternatively be close to the first position or the second position as required, and is not necessarily provided at a position where an electric field is equal to a magnetic field. It should be understood that, as the third position is close to a central position between the first position

and the second position, an electric field and a magnetic field generated by the antenna structure can be loaded more greatly, to further miniaturize the antenna structure.

[0012] With reference to the first aspect, in some implementations of the first aspect, the radiator further includes a feed point; the bezel further has a third position and a fourth position, the third position is provided between the first position and the second position, and the fourth position is provided between the second position and the third position; both the ground point and the feed point are provided between the third position and the fourth position; the radiator is separately separated from other parts of the bezel at the first position and the second position by gaps; between the third position and the fourth position, the medium layer between the radiator and the ground plane is a first medium layer, and the first medium layer includes the first medium; and between the first position and the third position and between the second position and the fourth position, the medium layer between the radiator and the ground plane is a second medium layer, and the second medium layer includes the second medium.

[0013] According to the technical solutions in embodiments of this application, when the antenna structure includes a T-shaped antenna, the antenna structure generates two strong electric field regions (regions in which an electric field is greater than a magnetic field) that are respectively close to the first position and the second position, and a strong magnetic field region (a region in which a magnetic field is greater than an electric field) generated by the antenna structure is between the two strong electric field regions.

[0014] With reference to the first aspect, in some implementations of the first aspect, the radiator further includes a feed point; the ground point includes a first ground point and a second ground point, the first ground point is provided at the first position, and the second ground point is provided at the second position; the bezel further has a third position and a fourth position, the third position is provided between the first position and the second position, and the fourth position is provided between the second position and the third position; the feed point is provided between the first position and the third position; between the first position and the third position and between the second position and the fourth position, the medium layer between the radiator and the ground plane is a first medium layer, and the first medium layer includes the first medium; and between the third position and the fourth position, the medium layer between the radiator and the ground plane is a second medium layer, and the second medium layer includes the second medium.

[0015] According to the technical solutions in embodiments of this application, when the antenna structure includes a slot antenna, the antenna structure generates two strong magnetic field regions (regions in which a magnetic field is greater than an electric field) that are respectively close to the first position and the second

position, and a strong electric field region (a region in which an electric field is greater than a magnetic field) generated by the antenna structure is between the two strong magnetic field regions.

5 [0016] With reference to the first aspect, in some implementations of the first aspect, a distance L1 between the third position and the fourth position and a distance L between the first position and the second position satisfy $(50\%-10\%) \times L \leq L1 \leq (50\%+10\%) \times L$.

10 [0017] With reference to the first aspect, in some implementations of the first aspect, a distance L2 between the third position and a midpoint between the first position and the second position satisfies $(25\%-5\%) \times L \leq L2 \leq (25\%+5\%) \times L$, and/or a distance L3 between the fourth position and the midpoint between the first position and the second position satisfies $(25\%-5\%) \times L \leq L3 \leq (25\%+5\%) \times L$.

15 [0018] According to the technical solutions in embodiments of this application, at the third position and the fourth position, an electric field may be equal to a magnetic field. It should be understood that, during actual application, the third position and the fourth position may alternatively be close to the first position or the second position as required, and are not necessarily provided at positions where electric fields are equal to magnetic fields. It should be understood that, as a third position 203 is close to a first position 201 by a distance of $\frac{1}{4}L$, and a fourth position 204 is close to a second position 202 by a distance of $\frac{1}{4}L$, an electric field and a magnetic field generated by the antenna structure can be loaded more greatly, to further miniaturize the antenna structure.

20 [0019] With reference to the first aspect, in some implementations of the first aspect, a distance between the first position and the third position is the same as a distance between the second position and the fourth position.

25 [0020] According to the technical solutions in embodiments of this application, a more symmetrical antenna structure indicates a better radiation characteristic of the antenna structure.

30 [0021] With reference to the first aspect, in some implementations of the first aspect, the relative magnetic permeability of the first medium is between 2 and 5; and/or the relative permittivity of the second medium is between 2 and 5.

35 [0022] According to the technical solutions in embodiments of this application, as the relative permittivity of the second medium and the relative magnetic permeability of the first medium increase, an electrical loss caused by the second medium and a magnetic loss of the first medium increase synchronously, affecting radiation performance of the antenna structure. Therefore, the relative permittivity of the second medium and the relative magnetic permeability of the first medium need to be controlled within appropriate ranges.

40 [0023] With reference to the first aspect, in some implementations of the first aspect, when a value of the relative magnetic permeability of the first medium is

greater than a value of the relative permittivity of the second medium, in an extension direction of the bezel, a length of the first medium layer is greater than a length of the second medium layer; or when a value of the relative magnetic permeability of the first medium is less than a value of the relative permittivity of the second medium, in an extension direction of the bezel, a length of the first medium layer is less than a length of the second medium layer.

[0024] According to the technical solutions in embodiments of this application, when the value of the relative magnetic permeability of the first medium is different from the value of the relative permittivity of the second medium, a length of a region corresponding to a higher value in the value of the relative magnetic permeability of the first medium and the value of the relative permittivity of the second medium is larger.

[0025] With reference to the first aspect, in some implementations of the first aspect, a relative permittivity of a medium in the first medium layer is greater than 1; and a relative magnetic permeability of a medium in the second medium layer is equal to 1.

[0026] With reference to the first aspect, in some implementations of the first aspect, a relative magnetic permeability of a medium in the second medium layer is greater than 1.

[0027] According to a second aspect, an antenna structure is provided, including: a medium layer; a radiator, where the radiator is provided on a surface of the medium layer, where the radiator includes at least two first regions and at least one second region, and any two adjacent first regions are separated by one second region; the radiator includes a feed point, and the feed point is provided in the first region; a medium layer in at least one first region of the first regions includes a first medium; a medium layer in at least one second region of the second region includes a second medium; and a relative permittivity of the first medium is greater than 1 and a relative magnetic permeability is equal to 1, and a relative magnetic permeability of the second medium is greater than 1.

[0028] With reference to the second aspect, in some implementations of the second aspect, a medium layer in each second region includes the second medium, and a medium layer in each first region includes the first medium.

[0029] With reference to the second aspect, in some implementations of the second aspect, the radiator is a sheet-shaped or linear radiator, the antenna structure further includes a ground plane, and the medium layer is provided between the radiator and the ground plane.

[0030] With reference to the second aspect, in some implementations of the second aspect, a region of the medium layer corresponding to the second region includes a distribution region of an electric field zero point of the antenna structure between the radiator and the ground plane.

[0031] With reference to the second aspect, in some

implementations of the second aspect, the relative magnetic permeability of the second medium is between 2 and 5; and/or the relative permittivity of the first medium is between 2 and 5.

[0032] With reference to the second aspect, in some implementations of the second aspect, the antenna structure includes a plurality of radiators, and the plurality of radiators are distributed in an array.

[0033] With reference to the second aspect, in some implementations of the second aspect, when a value of the relative magnetic permeability of the second medium is greater than a value of the relative permittivity of the first medium, an area of the second region is greater than an area of the first region; or

when a value of the relative magnetic permeability of the second medium is less than a value of the relative permittivity of the first medium, an area of the second region is less than an area of the first region.

[0034] According to a third aspect, an electronic device is provided, including an antenna structure according to any one of the second aspect.

BRIEF DESCRIPTION OF DRAWINGS

[0035]

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

FIG. 2 is a diagram of distribution of equivalent magnetic currents of a patch antenna according to an embodiment of this application;

FIG. 3 is a diagram of a structure of a patch (patch) antenna according to an embodiment of this application;

FIG. 4 is a diagram of a three-dimensional structure of an antenna structure 100 according to an embodiment of this application;

FIG. 5 is a top view of an antenna structure according to an embodiment of this application;

FIG. 6 is a diagram of a radiator of an antenna structure 100 according to an embodiment of this application;

FIG. 7 is an antenna structure of a control group according to an embodiment of this application;

FIG. 8 shows S-parameter simulation results of the antenna structures shown in FIG. 5 and FIG. 7;

FIG. 9 shows simulation results of radiation efficiency of the antenna structures shown in FIG. 5 and FIG. 7;

FIG. 10 is a diagram of an antenna structure operating in a TM_{10} mode;

FIG. 11 is a diagram of an antenna structure operating in a TM_{11} mode;

FIG. 12 is a diagram of an antenna structure operating in a TM_{12} mode;

FIG. 13 is a diagram of an antenna structure operating in a TM_{02} mode;

FIG. 14 is a diagram of an antenna structure operating in a TM₂₀ mode;
 FIG. 15 is a diagram of an antenna structure operating in a TM₂₁ mode;
 FIG. 16 is a diagram of an antenna structure operating in a TM₂₂ mode;
 FIG. 17 is a diagram of a structure of an antenna array according to an embodiment of this application;
 FIG. 18 is a diagram of a structure of an antenna structure 200 according to an embodiment of this application;
 FIG. 19 shows S-parameter simulation results of the antenna structure shown in FIG. 18;
 FIG. 20 is a diagram of a structure of another antenna structure 200 according to an embodiment of this application;
 FIG. 21 shows S-parameter simulation results of the antenna structure shown in FIG. 20;
 FIG. 22 is a diagram of a structure of still another antenna structure 200 according to an embodiment of this application; and
 FIG. 23 shows S-parameter simulation results of the antenna structure shown in FIG. 22.

DESCRIPTION OF EMBODIMENTS

[0036] The following describes terms that may occur in embodiments of this application.

[0037] 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 conductivity of components; or may be understood as a form in which different components in a line structure are connected by using a physical line that can transmit an electrical signal, like printed circuit board (printed circuit board, PCB) copper foil or a conducting wire. The "indirect coupling" may be understood as electrical conductivity of two conductors through space or a 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 equivalent capacitor through coupling of a gap between two conductive components.

[0038] Connection/Connected: The connection indicates a mechanical connection relationship or a physical connection relationship. For example, connection between A and B or A is connected to B may mean a fastened component (such as a screw, a bolt, a rivet, or the like) between A and B, or mean that A and B are in contact with each other and A and B are difficult to separate.

[0039] Connection: That two or more components are conducted or connected in the "electrical connection" or "indirect coupling" manner to perform signal/energy transmission may be referred to as connection.

[0040] Opposite/provided opposite to each other: A

and B being disposed opposite to each other may indicate that A and B are disposed face to face (opposite to each other, or face to face).

[0041] 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 component, and the distributed capacitor (or distributed capacitor) is an equivalent capacitor formed by a gap between two conductors.

[0042] Resonance/Resonance frequency: The resonance frequency is also referred to as a resonant frequency. The resonance frequency may be a frequency at which an imaginary part of an antenna input impedance is zero. The resonance frequency may have a frequency range, that is, a frequency range in which resonance occurs. The frequency corresponding to a strongest resonance point is a center frequency. A return loss of the center frequency may be less than -20 dB.

[0043] Resonance frequency band/Communication frequency band/Operating frequency band: No matter what type of antenna, the antenna operates in a specific frequency range (bandwidth). 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, an operating frequency band of an antenna includes a B40 frequency band. The frequency range that satisfies a requirement of an indicator may be regarded as the operating frequency band of the antenna.

[0044] Electrical length: The electrical length may be a ratio of a physical length (namely, a mechanical length or a geometric length) to a wavelength of a transmitted electromagnetic wave, and the electrical length may satisfy the following formula:

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

[0045] Herein, L is the physical length, and λ is the wavelength of the electromagnetic wave.

[0046] In some embodiments of this application, a physical length of a radiator may be understood as an electrical length of the radiator $\pm 25\%$ of the electrical length.

[0047] In some embodiments of this application, the physical length of the radiator may be understood as an electrical length of the radiator $\pm 10\%$ of the electrical length.

[0048] Wavelength: The wavelength, or an operating wavelength, may be a wavelength corresponding to a center frequency of a resonance frequency or a center frequency of an operating frequency band supported by an antenna. For example, it is assumed that a center frequency of a B1 uplink frequency band (with a resonance frequency ranging from 1920 MHz to 1980 MHz) is 1955 MHz, the operating wavelength may be a wavelength calculated by using the frequency of 1955 MHz.

The operating wavelength is not limited to the center frequency, and may alternatively be a wavelength corresponding to a resonance frequency or a frequency of an operating frequency band other than a center frequency.

[0049] A limitation on a position or a distance, such as middle or a middle position, mentioned in embodiments of this application, depends on a current process, and is not absolutely and strictly defined in a mathematical sense. For example, the middle (position) of a conductor may be a conductor part that is on the conductor and that includes a midpoint, or may be a conductor part that includes the midpoint between the conductor and whose length is one eighth of a wavelength, where the wavelength may be a wavelength corresponding to an operating frequency band of the antenna, may be a wavelength corresponding to a center frequency of the operating frequency band, or a wavelength corresponding to a resonance point. For another example, the middle (position) of the conductor may be a conductor part that is on the conductor and whose distance from the midpoint is less than a predetermined threshold (for example, 1 mm, 2 mm, or 2.5 mm).

[0050] Limitations such as collinearity, coaxiality, coplanarity, symmetry (for example, axisymmetry or centrosymmetry), parallelism, perpendicularity, and sameness (for example, a same length and a same width) mentioned in embodiments of this application are all for a current technology level, but are not absolutely strict definitions in a mathematical sense. A deviation less than a preset threshold (for example, 1 mm, 0.5 mm, or 0.1 mm) may exist between edges of two collinear radiation nodes or two collinear antenna elements in a line width direction. A deviation less than a preset threshold (for example, 1 mm, 0.5 mm, or 0.1 mm) may exist between edges of two coplanar radiation nodes or two coplanar antenna elements in a direction perpendicular to a coplanar plane of the two radiation nodes or the two antenna elements. A deviation of a preset angle (for example, $\pm 5^\circ$, $\pm 10^\circ$) may exist between two antenna elements that are parallel or perpendicular to each other.

[0051] Dielectric: The dielectric means a medium that can be electrically polarized. In a specific frequency band, a sub-vector value of a conduction current density generated by a time-varying electric field in a given direction in the specific frequency band is far less than a sub-vector value of a displacement current density in the direction. In embodiments of this application, it may be simply understood that a dielectric is a medium whose relative permittivity is greater than 1 and whose relative magnetic permeability is equal to 1.

[0052] Magnetic medium: Due to interaction between a magnetic field and things, a physical material is in a special state, and thus distribution of an original magnetic field is changed. Under an effect of this magnetic field, an internal state of the physical material changes, and the material affects existence or filling of the magnetic field, becoming a magnetic medium. In embodiments of this application, it may be simply understood that a mag-

netic medium is a medium whose relative magnetic permeability is greater than 1 and whose relative permittivity is equal to 1.

[0053] Magnetodielectric: The magnetodielectric is a medium that has both dielectric attributes and magnetic medium attributes. In embodiments of this application, it may be simply understood that a magnetodielectric is a medium whose relative permittivity and relative magnetic permeability are both greater than 1.

[0054] It should be understood that, because the magnetodielectric has some attributes of a magnetic medium, and also has some attributes of a dielectric, the magnetic medium in embodiments of this application may be implemented by the magnetodielectric, and a relative permittivity and a relative magnetic permeability value of the magnetodielectric may be selected based on an actual production or design requirement.

[0055] The relative permittivity of the dielectric, the relative magnetic permeability of the magnetic medium, and the relative permittivity or relative magnetic permeability of the magnetodielectric may be measured by using a post resonator method (post resonator method) or a closed cavity resonance method (or closed cavity resonator method, or shielded cavity method) or other resonator techniques (dielectric resonator techniques). In the post resonator method, a to-be-measured sample is placed in an open cavity formed by two parallel metal plates, and a vector network analyzer is electrically connected to an input port and an output port of the cavity, to change a frequency of an input signal of the input port, the cavity is enabled to generate resonance (with minimum impedance) at a specific frequency, to determine an electrical parameter (a relative permittivity or a relative magnetic permeability) of the sample by calculation. The post resonator method may be, for example, a Hakki Coleman method. In the closed cavity resonator method, a to-be-measured sample is placed in a closed cavity (for example, a cylindrical cavity), and a frequency of an input signal of an input port is changed, so that the cavity generates resonance (with minimum impedance) at a specific frequency, to determine an electrical parameter (a relative permittivity or a relative magnetic permeability) of the sample by calculation.

[0056] Total efficiency (total efficiency) of an antenna: The total efficiency is a ratio of input power to output power at an antenna port.

[0057] Radiation efficiency (radiation efficiency) of an antenna: The radiation efficiency is a ratio of power radiated by an antenna to space (that is, power for effectively converting an electromagnetic wave) to active power input to the antenna. Active power input to the antenna = Input power of the antenna - Loss power. The loss power mainly includes return loss power and metal ohmic loss power and/or medium loss power. The radiation efficiency is a value for measuring a radiation capability of an antenna. The metal loss and medium loss are both factors that affect the radiation efficiency.

[0058] A person skilled in the art may understand that

the efficiency is usually indicated by a percentage, and there is a corresponding conversion relationship between the efficiency and dB. Efficiency closer to 0 dB indicates better antenna efficiency.

[0059] 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.

[0060] The antenna return loss may be represented by an S_{11} parameter, and S_{11} is one of S-parameters. S_{11} indicates a reflection coefficient, and the parameter indicates transmit efficiency of the antenna. The S_{11} parameter is usually a negative number. A smaller value of the S_{11} parameter indicates a smaller return loss of the antenna and less energy reflected back by the antenna. In other words, more energy actually enters the antenna and the total efficiency of the antenna is higher. A larger S_{11} parameter indicates a larger return loss of the antenna and lower total efficiency of the antenna.

[0061] It should be noted that, -6 dB is usually used as a standard value of S_{11} in engineering. When the value of S_{11} of the antenna is less than -6 dB, it may be considered that the antenna can operate normally, or it may be considered that transmit efficiency of the antenna is good.

[0062] Polarization direction of an antenna: At a given point in space, electric field strength E (vector) is a unary function of time t . As time goes by, a vector endpoint periodically depicts a track in space. The track being vertical to the ground is referred to as vertical polarization. The track being horizontal to the ground is referred to as horizontal polarization.

[0063] Ground, or ground plane: The ground may generally mean at least a part of any ground layer, ground plate, ground metal layer, or the like in an electronic device (such as a mobile phone), or at least a part of any combination of the foregoing ground layer, ground plate, ground component, or the like. The "ground" may be used to ground components in the electronic device. In an embodiment, the "ground" may be a ground layer of a circuit board of an electronic device, or may be a ground plate formed by a middle frame of the electronic device or a ground metal layer formed by a metal film below a screen of the electronic device. In an embodiment, a circuit board may be a printed circuit board (printed circuit board, PCB), for example, an 8-layer board, a 10-layer board, or a 12-layer board, a 13-layer board, or a 14-layer boards respectively having 8, 10, 12, 13, or 14 layers of conductive materials, or a component that is separated and electrically insulated by a medium layer or an insulation layer, for example, glass fiber, polymer, or the like. In an embodiment, a circuit board includes a medium substrate, a ground layer, and a trace layer, where the trace layer

and the ground layer may be electrically connected through a via hole. In an embodiment, components such as a display, a touchscreen, an input button, a transmitter, a processor, a memory, a battery, a charging circuit, and a system on chip (system on chip, SoC) structure may be mounted on or connected to a circuit board, or electrically connected to a trace layer and/or a ground layer in the circuit board. For example, a radio frequency source is provided at the trace layer.

[0064] Any one of the foregoing ground layer, the ground plate, or the ground metal layer is made of a conductive material. In an embodiment, the conductive material may be any one of the following materials: copper, aluminum, stainless steel, brass and alloys thereof, copper foil on insulation laminates, aluminum foil on insulation laminates, gold foil on insulation laminates, silver-plated copper, silver-plated copper foil on insulation laminates, silver foil on insulation laminates and tin-plated copper, cloth impregnated with graphite powder, graphite-coated laminates, copper-plated laminates, brass-plated laminates and aluminum-plated laminates. A person skilled in the art may understand that the ground layer/ground plate/ground metal layer may alternatively be made of other conductive materials.

[0065] The following describes technical solutions of embodiments in this application with reference to accompanying drawings.

[0066] As shown in FIG. 1, an electronic device 10 may include a cover (cover) 13, a display/display module (display) 15, a printed circuit board (printed circuit board, PCB) 17, a middle frame (middle frame) 19, and a rear cover (rear cover) 21. It should be understood that, in some embodiments, the cover 13 may be a glass cover (cover glass), or may be replaced with a cover of another material, for example, an ultra-thin glass material cover or a PET (Polyethylene terephthalate, polyethylene terephthalate) material cover.

[0067] The cover 13 may be provided close to the display module 15, and may be mainly configured to protect and prevent dust on the display module 15.

[0068] In an embodiment, the display module 15 may include a liquid crystal display (liquid crystal display, LCD), a light-emitting diode (light-emitting diode, LED) display panel, an organic light-emitting semiconductor (organic light-emitting diode, OLED) display panel, or the like. This is not limited in this embodiment of this application.

[0069] The middle frame 19 is mainly used to support the entire electronic device. FIG. 1 shows that the PCB 17 is provided between the middle frame 19 and the rear cover 21. It should be understood that, in an embodiment, the PCB 17 may alternatively be provided between the middle frame 19 and the display module 15. This is not limited in this embodiment of this application. The printed circuit board PCB 17 may be a flame-resistant material (FR-4) medium substrate, or may be a rogers (Rogers) medium substrate, or may be a hybrid medium substrate of rogers and FR-4, or the like. The FR-4 is a grade code

name of a material that is flame resistant, and the rogers medium substrate is a high frequency substrate. An electronic component, for example, a radio frequency chip, is carried on the PCB 17. In an embodiment, a metal layer may be provided on the printed circuit board PCB 17. The metal layer may be used for grounding an electronic component carried on the printed circuit board PCB 17, or may be used for grounding another component, for example, a bracket antenna or a bezel antenna. The metal layer may be referred to as a ground plane, a ground plate, or a ground layer. In an embodiment, the metal layer may be formed by etching metal on a surface of any layer of medium substrates in the PCB 17. In an embodiment, the metal layer used for grounding may be provided on a side of the printed circuit board PCB 17 that is close to the middle frame 19. In one embodiment, an edge of the printed circuit board PCB 17 may be considered as an edge of the ground layer of the PCB 17. In one embodiment, the metal middle frame 19 may also be used for grounding the foregoing components. The electronic device 10 may further have another ground plane/ground plate/ground layer. As described above, details are not described herein again.

[0070] The electronic device 10 may further include a battery (not shown in the figure). The battery may be provided between the middle frame 19 and the rear cover 21, or may be provided between the middle frame 19 and the display module 15. This is not limited in embodiments of this application. In some embodiments, the PCB 17 is divided into a main board and a sub-board. The battery may be provided between the main board and the sub-board. The main board may be provided between the middle frame 19 and an upper edge of the battery, and the sub-board may be provided between the middle frame 19 and a lower edge of the battery.

[0071] The electronic device 10 may further include a bezel 11. The bezel 11 may be formed of a conductive material such as metal. The bezel 11 may be provided between the display module 15 and the rear cover 21, and extends circumferentially around a periphery of the electronic device 10. The bezel 11 may have four sides surrounding the display module 15 to help secure the display module 15. In an implementation, the bezel 11 made of a metal material may be directly used as a metal bezel of the electronic device 10 to form an appearance of the metal bezel, and is applicable to a metal industrial design (industrial design, ID). In another implementation, an outer surface of the bezel 11 may alternatively be made of a material other than metal, for example, a plastic bezel, to form an appearance of a non-metal bezel, and is applicable to a non-metal ID.

[0072] The middle frame 19 may include the bezel 11, and the middle frame 19 including the bezel 11 serves as an integral part, and may support electronic components in the entire electronic device. The cover 13 and the rear cover 21 are respectively snapped together along an upper edge and a lower edge of the bezel, to form a shell or a housing (housing) of the electronic de-

vice. In an embodiment, the cover 13, the rear cover 21, the bezel 11, and/or the middle frame 19 may be collectively referred to as the shell or the housing of the electronic device 10. It should be understood that, the "shell or housing" may indicate a part or all of any one of the cover 13, the rear cover 21, the bezel 11, or the middle frame 19, or indicate a part or all of any combination of the cover 13, the rear cover 21, the bezel 11, or the middle frame 19.

[0073] The bezel 11 on the middle frame 19 may be at least partially used as an antenna radiator to transmit/receive a radio frequency signal. There may be a gap between the bezel that serves as the radiator and another part of the middle frame 19, to ensure that the antenna radiator has a good radiation environment. In an embodiment, an aperture of the middle frame 19 may be provided at the bezel that serves as the radiator, to facilitate radiation of the antenna.

[0074] Alternatively, the bezel 11 may not be considered as a part of the middle frame 19. In an embodiment, the bezel 11 may be connected to the middle frame 19 and integrally formed with the middle frame 19. In another embodiment, the bezel 11 may include a protrusion extending inward, to be connected to the middle frame 19, for example, connected by using a spring or a screw, or connected through welding. The protrusion of the bezel 11 may be further configured to receive a feed signal, so that at least a part of the bezel 11 serves as the antenna radiator to transmit/receive a radio frequency signal. There is a gap 42 between the part of bezel that serves as the radiator and the middle frame 30, to ensure that the antenna radiator has a good radiation environment, so that the antenna has a good signal transmission function.

[0075] The rear cover 21 may be a rear cover made of a metal material, or a rear cover made of a non-conductive material, such as a glass rear cover, a plastic rear cover, and the like; or a rear cover made of both a conductive material and a non-conductive material.

[0076] Alternatively, the antenna of the electronic device 10 may be provided in the bezel 11. When the bezel 11 of the electronic device 10 is made of a non-conductive material, the antenna radiator may be located in the electronic device 10 and provided along the bezel 11. For example, the antenna radiator is provided adjacent to the bezel 11, to minimize a size occupied by the antenna radiator, and is closer to the outside of the electronic device 10, to better transmit a signal. It should be noted that, that the antenna radiator is provided adjacent to the bezel 11 means that the antenna radiator may be provided in close contact with the bezel 11, or may be provided close to the bezel 11. For example, there may be a small gap between the antenna radiator and the bezel 11.

[0077] Alternatively, the antenna of the electronic device 10 may be provided in the housing, for example, a bracket antenna or a millimeter wave antenna (not shown in FIG. 1). Clearance of the antenna provided in the hous-

ing may be obtained by a gap/hole in any one of the middle frame, and/or the bezel, and/or the rear cover, and/or the display, or by a non-conductive gap/aperture formed between any several of the middle frame, the bezel, the rear cover, and the display. According to the setting of the clearance of the antenna, radiation performance of the antenna is ensured. It should be understood that, the clearance of the antenna may be a non-conductive region formed by any conductive component in the electronic device 10, and the antenna radiates a signal to external space through the non-conductive region. In an embodiment, the antenna 40 may be a flexible printed circuit (flexible printed circuit, FPC)-based antenna, a laser-direct-structuring (laser-direct-structuring, LDS)-based antenna, a microstrip disk antenna (microstrip disk antenna, MDA)-based antenna, or another antenna. In an embodiment, the antenna may alternatively be in a transparent structure embedded in the screen of the electronic device 10, so that the antenna is a transparent antenna unit embedded in the screen of the electronic device 10.

[0078] FIG. 1 shows only an example of some components included in the electronic device 10. An actual shape, an actual size, and an actual configuration of the components are not limited to those in FIG. 1.

[0079] 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 bezel is located is a side surface.

[0080] It should be understood that, in this embodiment of this application, it is considered that when a user holds (usually holding the electronic device vertically and facing the screen), an orientation in which the electronic device is located includes top, bottom, left, and right.

[0081] FIG. 2 is a diagram of distribution of equivalent magnetic currents of a patch antenna according to this application. FIG. 2 describes an antenna mode in this application.

[0082] FIG. 2 is a diagram of distribution of equivalent magnetic currents in several different transverse magnetic modes (transverse magnetic modes, TM modes) of the patch (patch) antenna. A directivity pattern and a polarization mode of the patch antenna may be predicted based on the diagram of the distribution of the equivalent magnetic currents. The TM mode/TM mode may be understood as that radiation generated by the patch antenna has an electric field component but no magnetic field component in a propagation direction.

[0083] For different TM modes, distribution of equivalent magnetic currents has the following rules:

(1) In a TM_{mn} mode, equivalent magnetic currents have m zero points along an x -axis direction (because distribution of the equivalent magnetic currents is similar to sinusoidal distribution, and equivalent magnetic currents on both sides of a zero point

are reverse, a reverse point of the equivalent magnetic currents is a zero point), and n zero points along a y -axis direction.

(2) A distance between adjacent zero points in a same direction is $\lambda/2$. When there is only one zero point in the direction, a length of a patch in the direction is $\lambda/2$, where λ is an operating wavelength of the patch antenna.

[0084] For example, (a) in FIG. 2 is a diagram of distribution of equivalent magnetic currents of the patch antenna in a TM_{01} mode. The patch antenna has one zero point in the y -axis direction. Therefore, an electrical length of the patch antenna in the y -axis direction is $\lambda/2$. In (b) in FIG. 2, a diagram of distribution of equivalent magnetic currents of the patch antenna in a TM_{10} mode is shown. The patch antenna has one zero point in the x -axis direction. Therefore, an electrical length of the patch antenna in the x -axis direction is $\lambda/2$. In (c) in FIG. 2, a diagram of distribution of equivalent magnetic currents of the patch antenna in a TM_{11} mode is shown. The patch antenna has one zero point in the x -axis direction and one zero point in the y -axis direction. Therefore, electrical lengths of the patch antenna in the x -axis direction and the y -axis direction are $\lambda/2$. In (d) in FIG. 2, a diagram of distribution of equivalent magnetic currents of the patch antenna in a TM_{02} mode is shown. The patch antenna has two zero points in the y -axis direction. Therefore, an electrical length of the patch antenna in the y -axis direction is λ .

[0085] Wireless communication technologies are rapidly developing. In the past, since a second generation (second generation, 2G) mobile communication system mainly supported a call function, an electronic device was only a tool used by people to send and receive short messages and perform voice communication, and a wireless network access function was extremely slow because data was transmitted through a voice channel. With development of a 5G mobile communication system, in a current state, communication frequency bands of an electronic device may be, for a long time, in a situation in which 3G, 4G, and 5G frequency bands coexist, and a quantity of antennas is increasing. However, due to limited space of the electronic device, there is a strict requirement for a miniaturization design of an antenna.

[0086] FIG. 3 is a diagram of a structure of a patch (patch) antenna according to an embodiment of this application.

[0087] The antenna structure shown in FIG. 3 includes a ground plane, a medium substrate, and a radiator. The medium substrate is provided between the radiator and the ground plane. A feed unit may be provided on the ground plane, and is electrically connected to the radiator through a feed point. When an electrical signal is fed into the feed unit, the radiator generates radiation. In this structure, a width of the radiator of the patch antenna is approximately 0.5 operating wavelengths.

[0088] A most common technique for reducing a size

of the radiator of the patch antenna is dielectric loading. Because a wavelength of an electromagnetic wave is shortened in a medium, according to an electromagnetic field theory, a resonance frequency f of the patch antenna satisfies the following formula:

$$f \propto \frac{c}{2\pi\sqrt{\epsilon_r}}$$

[0089] Herein, c is the speed of light, and ϵ_r is a relative permittivity of a dielectric in a medium substrate.

[0090] According to the foregoing formula, if the relative permittivity of the dielectric in the medium substrate becomes larger, the resonance frequency of the patch antenna shifts towards a low frequency. This is equivalent to that the size of the radiator of the patch antenna becomes smaller at a same operating frequency.

[0091] However, as the relative permittivity of the dielectric increases, a bandwidth of the patch antenna is narrowed, and there is a problem that a broadband communication requirement cannot be met. In addition, as the relative permittivity of the dielectric increases, an electrical loss caused by the dielectric increases synchronously, and the electrical loss is directly proportional to the relative permittivity. As a result, efficiency of the patch antenna decreases.

[0092] Embodiments of this application provide an antenna structure and an electronic device. A dielectric or a magnetic medium is separately provided in different regions of a medium layer in the antenna structure, to miniaturize the antenna structure.

[0093] FIG. 4 and FIG. 5 are diagrams of a structure of an antenna structure 100 according to an embodiment of this application. FIG. 4 is a diagram of a three-dimensional structure of the antenna structure 100. FIG. 5 is a top view of the antenna structure.

[0094] As shown in FIG. 4, the antenna structure 100 may include a radiator 110 and a medium layer 120. The radiator 110 is provided on a surface of the medium layer 120 to form a patch antenna.

[0095] As shown in FIG. 5, the radiator 110 includes two first regions 111 and one second region 112, and the second region 112 is located between the two first regions 111.

[0096] The radiator 110 includes a feed point 114. The feed point 114 is provided in one of the two first regions 111. The feed point 114 is configured to feed an electrical signal into the antenna structure 100, so that the antenna structure 100 generates radiation. A medium layer in at least one of the two first regions 111 includes a first medium. In an embodiment, the first medium is a dielectric. A medium layer in the second region 112 includes a second medium. In an embodiment, the second medium is a magnetic medium.

[0097] "The medium layer in the first region/the medium layer corresponding to the first region" and "the medium layer in the second region/the medium layer corre-

sponding to the second region" should be understood as medium layer regions corresponding to regions of the radiator, for example, a medium layer region that is provided corresponding to the first region/second region of the radiator; or, for example, a medium layer region that bears the first region/second region of the radiator; or, for example, a medium layer region covered by the first region/second region of the radiator.

[0098] According to the technical solutions provided in embodiments of this application, a dielectric or a magnetic medium is provided at the medium layer 120 corresponding to different regions of the radiator 110, so that an electric field or a magnetic field in a corresponding region may be loaded, to reduce a size of the antenna structure 100. The electric field or the magnetic field being loaded may be understood as that the antenna structure 100 can generate the same magnetic field and electric field in a smaller size as the dielectric and the magnetic medium are provided. In an embodiment, it may also be understood that the dielectric and the magnetic medium are provided in different regions, so that a resonance frequency of an antenna structure in a same size is lower. This is equivalent to that a size of an antenna structure is smaller when a resonance frequency is the same.

[0099] In an embodiment, the antenna structure 100 further includes a ground plane, and the medium layer 120 is provided between the radiator 110 and the ground plane. In other words, the medium layer 120 is filled between the ground plane and the radiator 110.

[0100] In an embodiment, a medium layer in each first region 111 includes a dielectric.

[0101] In an embodiment, a medium layer in each first region 111 does not include a magnetic medium, and includes only a dielectric. In an embodiment, a medium layer in the second region 112 does not include a dielectric, and includes only a magnetic medium.

[0102] In this embodiment of this application, the second medium may be a magnetodielectric. It should be understood that, in this embodiment of this application, an example in which the second medium is a magnetic medium is used for description. The magnetic medium loads the magnetic field in the second region 112. Because the magnetodielectric has a characteristic of the magnetic medium, during actual application, the second medium may be the magnetodielectric. In an embodiment, the medium layer in the second region 112 may be filled with the magnetodielectric.

[0103] In this embodiment of this application, the first medium may be a magnetodielectric. It should be understood that, in this embodiment of this application, an example in which the first medium is a dielectric is used for description. The dielectric loads the electric field in the first region 111. Because the magnetodielectric has a characteristic of the dielectric, during actual application, the first medium may be the magnetodielectric. In an embodiment, the medium layer in the first region 111 may be filled with the magnetodielectric.

[0104] In an embodiment, the medium layer in the first

region 111 includes the first medium, the medium layer in the second region 112 includes the second medium, a relative permittivity of the first medium is greater than 1, and a relative magnetic permeability of the second medium is greater than 1. When the medium layer in the first region includes a dielectric (where the first medium is the dielectric), the relative permittivity of the first medium is greater than 1, and a relative magnetic permeability is equal to 1. When the medium layer in the first region includes a magnetodielectric (where the first medium is the magnetodielectric), the relative permittivity of the first medium is greater than 1, and a relative magnetic permeability is greater than 1. When the medium layer in the second region includes a magnetic medium (where the second medium is the magnetic medium), a relative permittivity of the second medium is equal to 1, and the relative magnetic permeability is greater than 1. When the medium layer in the second region includes a magnetodielectric (where the second medium is the magnetodielectric), a relative permittivity of the second medium is greater than 1, and the relative magnetic permeability is greater than 1.

[0105] In an embodiment, in the medium layer region corresponding to the second region 112, a magnetic field generated by the antenna structure 100 is greater than or equal to an electric field generated by the antenna structure 100. In the medium layer region corresponding to the first region 111, an electric field generated by the antenna structure 100 is greater than or equal to a magnetic field generated by the antenna structure 100. It should be understood that a dielectric and a magnetic medium are respectively provided in each strong electric field region (a region in which an electric field is greater than a magnetic field) and each strong magnetic field region (a region in which a magnetic field is greater than an electric field) of the antenna structure 100, so that an electric field or a magnetic field in a corresponding region can be loaded to a maximum extent. The dielectric is provided in each strong electric field region and the magnetic medium is provided in each strong magnetic field region, so that the antenna structure 100 may generate the same magnetic field and electric field in a minimum size. In an embodiment, it may also be understood that the dielectric and the magnetic medium are provided in different regions, so that a resonance frequency of an antenna structure in a same size is lowest. This is equivalent to that a size of an antenna structure is smallest when a resonance frequency is the same.

[0106] In an embodiment, the medium layer region corresponding to the second region 112 includes a distribution region of an electric field zero point of the antenna structure 100 between the radiator 110 and the ground plane. For example, the medium layer region corresponding to the second region 112 may include at least one electric field zero point generated between the radiator 110 and the ground plane by the antenna structure 100. It should be understood that the electric field zero point may correspond to a maximum current point or a

strong magnetic field point that is generated by the antenna structure 100. In this case, the medium layer region corresponding to the second region 112 also includes a region in which the maximum current point or the strong magnetic field point that is generated between the radiator 110 and the ground plane by the antenna structure 100 is located.

[0107] In an embodiment, the radiator 110 may be a regular or irregular square, rectangle, triangle, or circle, or another regular or irregular polygon, where "irregular" indicates that the radiator 110 may be a square, rectangle, triangle, circle, or another polygon as a whole, and a part of the radiator 110 includes a protruding part and/or a concave part. For brevity of description, in embodiments of this application, an example in which the radiator 110 is a square is merely used for description, and a shape of the radiator is not limited in embodiments of this application.

[0108] In an antenna structure 100 shown in FIG. 6, an example in which a value of a relative magnetic permeability of a magnetic medium is the same as a value of a relative permittivity of a dielectric is used for description.

[0109] When an electrical signal is fed into a feed point 114, the antenna structure 100 may operate in a TM_{01} mode, a generated electric field (E_z) is along a direction z, and a generated magnetic field (H_x) is along a direction x. In this case, a ratio of the electric field to the magnetic field satisfies the following formula 1:

$$\frac{E_z}{H_x} = \frac{j\eta_0}{\sqrt{\epsilon_r}} \cot \frac{\pi y}{b} = j\eta_r \cot \frac{\pi y}{b}$$

[0110] Herein, η_0 is wave impedance in a vacuum, η_r is wave impedance in a dielectric, ϵ_r is a relative permittivity of a dielectric in a medium layer 120, and b is a side length of a radiator 110.

[0111] When y is equal to b/4 or y is equal to 3b/4, $\cot \pi y/b$ is equal to 1, and the electric field is equal to the magnetic field.

[0112] When $y < b/4$ or $y > 3b/4$, $|\cot \pi y/b| > 1$, and the electric field is greater than the magnetic field.

[0113] When $b/4 < y < 3b/4$, $|\cot \pi y/b| > 1$, and the magnetic field is greater than the electric field.

[0114] In the TM_{01} mode, according to the foregoing formula, $y=b/4$ and $y=3b/4$ serve as boundary lines of the electric field and the magnetic field generated by the antenna structure 100, a region in which $b/4 < y < 3b/4$ is a strong magnetic field region (a region in which a magnetic field is greater than an electric field). A region in which $y < b/4$ and a region in which $y > 3b/4$ are strong electric field regions (regions in which an electric field is greater than a magnetic field).

[0115] In an embodiment, when a second region is the region in which $b/4 < y < 3b/4$, the second region 112 includes a region in which the strong magnetic field region of the antenna structure 100 is distributed on the radiator

110. When first regions 111 are the region in which $y < b/4$ and the region in which $y > 3b/4$, the first regions 111 include a region in which the strong electric field regions of the antenna structure 100 are distributed on the radiator 110. A virtual axis of the second region 112 may be a central axis of the second region 112.

[0116] In an embodiment, two first regions 111 are symmetrical along the virtual axis of the second region 112.

[0117] In an embodiment, a field (the electric field or the magnetic field) generated by the antenna structure 100 is symmetrically distributed along a medium layer region corresponding to the virtual axis of the second region 112.

[0118] In an embodiment, an electric field zero point generated by the antenna structure 100 may be located in the medium layer region corresponding to the virtual axis of the second region 112. Correspondingly, a strong magnetic field point or a maximum current point may also be located in the medium layer region corresponding to the virtual axis of the second region 112.

[0119] In an embodiment, a width of the second region 112 is a half of a width of the radiator, the strong electric field regions are divided into the two first regions 111 by the second region 112, and a width of each first region 111 is a quarter of the width of the radiator, as shown in FIG. 6.

[0120] In an embodiment, a relative magnetic permeability of a second medium is between 2 and 5. The second medium may be a magnetic medium. In an embodiment, a relative permittivity of a first medium is between 2 and 5. The first medium may be a dielectric. As the relative permittivity of the dielectric and the relative magnetic permeability of the magnetic medium increase, an electrical loss caused by the dielectric and a magnetic loss of the magnetic medium increase synchronously, affecting radiation performance of the antenna structure. Therefore, the relative permittivity of the dielectric and the relative magnetic permeability of the magnetic medium need to be controlled within appropriate ranges. It should be understood that, during engineering application, the relative magnetic permeability of the magnetic medium or the relative permittivity of the dielectric may have a specific error (for example, 10%), and when the error is within an error range, the relative magnetic permeability of the magnetic medium or the relative permittivity of the dielectric should be considered as satisfying a range of the relative magnetic permeability of the magnetic medium or a range of the relative permittivity of the dielectric. It should be understood that, because the magnetodielectric has characteristics of both the magnetic medium and the dielectric, for a case in which the medium layer includes the magnetodielectric, the range of the relative magnetic permeability of the magnetic medium or the range of the relative permittivity of the dielectric may also be applied.

[0121] In the foregoing embodiments, the example in which the value of the relative magnetic permeability of

the magnetic medium is the same as the value of the relative permittivity of the dielectric is used for description. During actual application, the value of the relative magnetic permeability of the magnetic medium and the value of the relative permittivity of the dielectric may be different, and may be adjusted based on an actual production or design requirement.

[0122] When the value of the relative magnetic permeability of the magnetic medium is the same as the value of the relative permittivity of the dielectric, the width of the second region 112 is a half of the width of the radiator, and a sum of widths of the two first regions 111 is a half of the width of the radiator, the sum of the widths of the two first regions 111 of the radiator 110 is the same as the width of the second region. It should be understood that, during engineering application, the width of the second region 112 or the sum of the widths of the two first regions 111 may have a partial error (for example, 10%), and when the error is within an error range, it should be considered that the width of the second region 112 is the same as the sum of the widths of the two first regions 111.

[0123] Alternatively, for an irregular radiator, when a value of a relative magnetic permeability of a magnetic medium is the same as a value of a relative permittivity of a dielectric, an area occupied by the first region 111 may be equal to an area occupied by a second region.

[0124] When the value of the relative magnetic permeability of the magnetic medium is different from the value of the relative permittivity of the dielectric, a region corresponding to a higher value in the value of the relative magnetic permeability of the magnetic medium and the value of the relative permittivity of the dielectric has a larger width. For example, the value of the relative magnetic permeability of the magnetic medium is greater than the value of the relative permittivity of the dielectric, and the width of the second region 112 is greater than the sum of the widths of the two first regions 111. In an embodiment, when a value of the relative magnetic permeability of the second medium is greater than a value of the relative permittivity of the first medium, an area of the second region is larger than an area of the first region. When a value of the relative magnetic permeability of the second medium is less than a value of the relative permittivity of the first medium, an area of the second region is smaller than an area of the first region. Energy of a magnetic field loaded by the magnetic medium is used to supplement energy of an electric field loaded by the dielectric, so that energy of the field generated by the antenna structure 100 is consistent with energy generated when the value of the relative magnetic permeability of the magnetic medium is the same as the value of the relative permittivity of the dielectric.

[0125] Alternatively, for an irregular radiator, when the value of the relative magnetic permeability of the magnetic medium is different from the value of the relative permittivity of the dielectric, an area of a corresponding region with a higher value in the value of the relative magnetic permeability of the magnetic medium and the

value of the relative permittivity of the dielectric is larger.

[0126] In an embodiment, the magnetic medium or the dielectric may be isotropic materials. The isotropic material may be understood as that relative magnetic permeabilities of the magnetic medium in all directions are the same, or relative permittivities of the dielectric in all directions are the same.

[0127] In an embodiment, the magnetic medium or the dielectric may be anisotropic materials. The anisotropic material may be understood as that relative magnetic permeabilities of the magnetic medium in all directions are different or relative permittivities of the dielectric in all directions are different. In embodiments of this application, "the relative magnetic permeability of the magnetic medium" may represent the relative magnetic permeability of the magnetic medium in a direction of the magnetic field generated by the antenna structure 100, and "the relative permittivity of the dielectric" may represent the relative permittivity of the dielectric in a direction of the electric field generated by the antenna structure 100. For example, in the foregoing embodiment, the electric field generated by the antenna structure is along the direction z, and the electric field is affected by the relative permittivity of the dielectric in the direction z, to load the dielectric. The magnetic field generated by the antenna structure is along the direction x, and the magnetic field is affected by the relative magnetic permeability of the magnetic medium in the direction x, to load the magnetic medium. Similar understanding should be made for a magnetodielectric, and details are not described herein again.

[0128] FIG. 7 to FIG. 9 show a control group antenna and simulation results according to an embodiment of this application. FIG. 7 is an antenna structure of a control group according to this embodiment of this application. FIG. 8 shows S-parameter simulation results of the antenna structures shown in FIG. 5 and FIG. 7. FIG. 9 shows simulation results of radiation efficiency of the antenna structures shown in FIG. 5 and FIG. 7.

[0129] As shown in FIG. 7, a difference between the antenna structure and the antenna structure shown in FIG. 5 lies only in that no magnetic medium is provided at a medium layer, and the medium layer is filled with a dielectric. In addition, to ensure that resonance frequencies of antenna structures of two structures are approximately the same, a side length of a radiator of the antenna structure shown in FIG. 7 is different from the side length of the radiator of the antenna structure shown in FIG. 5.

[0130] A relative permittivity of the dielectric at the medium layer in the antenna structure shown in FIG. 7 and a relative permittivity of the dielectric at the medium layer in the first area in the antenna structure shown in FIG. 5 are both 4. A relative magnetic permeability of the magnetic medium at the medium layer in the second area of the antenna structure shown in FIG. 5 is 4.

[0131] As shown in FIG. 8, a resonance point of the antenna structure shown in FIG. 5 is 1.97 GHz, and a

resonance point of the antenna structure shown in FIG. 7 is 1.98 GHz.

[0132] The antenna structure shown in FIG. 5 and the antenna structure shown in FIG. 7 resonate at a same resonance frequency. However, a size of the radiator in the antenna structure shown in FIG. 5 is 24 mm×24 mm, and a size of the radiator in the antenna structure shown in FIG. 7 is 36 mm×36 mm. The dielectric and the magnetic medium are provided at the medium layer in different regions of the radiator, so that the size of the antenna structure is effectively reduced by 55.6%. In addition, by using $S_{11} < -6$ dB as a standard, a bandwidth of the antenna structure shown in FIG. 5 is equivalent to a bandwidth of the antenna structure shown in FIG. 7, and no bandwidth is lost due to reduction of the size of the antenna structure.

[0133] As shown in FIG. 9, radiation efficiency of the antenna structure shown in FIG. 5 is similar to that of the antenna structure shown in FIG. 7 when the antenna structure shown in FIG. 5 and the antenna structure shown in FIG. 7 resonates at the resonance points, and the radiation efficiency of the antenna structure shown in FIG. 5 is only 0.3 dB lower.

[0134] FIG. 10 to FIG. 16 are diagrams of another antenna structure according to an embodiment of this application.

[0135] A difference between antenna structures shown in FIG. 10 to FIG. 16 and the antenna structure shown in FIG. 5 lies in that operating modes of the antenna structures are different, and layouts of first regions and second regions on radiators of the antenna structures in the different operating modes are different. FIG. 10 is a diagram of an antenna structure operating in a TM_{10} mode. FIG. 11 is a diagram of an antenna structure operating in a TM_{11} mode. FIG. 12 is a diagram of an antenna structure operating in a TM_{12} mode. FIG. 13 is a diagram of an antenna structure operating in a TM_{02} mode. FIG. 14 is a diagram of an antenna structure operating in a TM_{20} mode. FIG. 15 is a diagram of an antenna structure operating in a TM_{21} mode. FIG. 16 is a diagram of an antenna structure operating in a TM_{22} mode.

[0136] As shown in FIG. 10 to FIG. 16, the antenna structure may include at least two first regions and at least one second region, and any two adjacent first regions are separated by one second region. A medium layer in at least one first region includes a dielectric, and a medium layer in at least one second region includes a magnetic medium.

[0137] In an embodiment, the medium layer region corresponding to the second region includes a region in which an electric field zero point of the antenna structure is distributed on the radiator. For example, electric field zero points generated by the antenna structures shown in FIG. 10 to FIG. 16 are located in medium layer regions corresponding to dashed lines shown in the figures, and the electric field zero points may correspond to maximum current points or strong magnetic field points. In this case, the maximum current points or the strong magnetic field

points generated by the antenna structures are also in the medium layer regions corresponding to the dashed lines shown in the figures.

[0138] It should be understood that, in the second region, a magnetic field generated by the antenna structure is greater than or equal to an electric field. In the first region, an electric field generated by the antenna structure is greater than or equal to a magnetic field. A dielectric and a magnetic medium are respectively provided in a strong electric field region (a region in which an electric field is greater than a magnetic field) and a strong magnetic field region (a region in which a magnetic field is greater than an electric field) of the antenna structure, so that an electric field or a magnetic field in the corresponding region may be loaded, to reduce a size of the antenna structure.

[0139] In an embodiment, a medium layer in each second region includes a magnetic medium. A medium layer in each first region includes a dielectric. It should be understood that a dielectric and a magnetic medium are respectively provided in each strong electric field region (a region in which an electric field is greater than a magnetic field) and each strong magnetic field region (a region in which a magnetic field is greater than an electric field) of the antenna structure, so that an electric field or a magnetic field in the corresponding region may be loaded to a maximum extent, to obtain the same magnetic field and electric field in a minimum size of the antenna structure.

[0140] FIG. 17 is a diagram of a structure of an antenna array according to an embodiment of this application.

[0141] It should be understood that, in the foregoing embodiments, examples in which the antenna structure includes only one radiator are used for description. During actual application, the antenna structure may include a plurality of radiators to form an array antenna, and may be applied to a multi-input multi-output (multi-input multi-output, MIMO) system, to improve a data transmission rate of an electronic device. In the embodiment shown in FIG. 17, only an example in which a radiator operates in a mode TM_{11} is used. It should be understood that any one or more radiators in an antenna array may operate in a same TM mode or different TM modes.

[0142] As shown in (a) in FIG. 17, an antenna structure may include two radiators, and the two radiators may be distributed in a 1×2 array. As shown in (b) or (c) in FIG. 17, an antenna structure may include four radiators, and the four radiators may be distributed in a 1×4 or 2×2 array. As shown in (d) in FIG. 17, an antenna structure may include 16 radiators, and the 16 radiators may be distributed in a 4×4 array. The antenna array shown in FIG. 17 is merely used as an example. During actual application, a quantity of radiators and an arrangement manner may be adjusted based on a design requirement. This is not limited in this embodiment of this application.

[0143] It should be understood that, in the foregoing embodiments, examples in which the antenna structure is a patch antenna are used. The technical solutions pro-

vided in embodiments of this application may be applied not only to a patch antenna, but also to the following wire antenna. The following representative embodiments are used for description.

[0144] FIG. 18 is a diagram of a structure of an antenna structure 200 according to an embodiment of this application.

[0145] As shown in FIG. 18, the antenna structure 200 includes a radiator 210, a ground plane 220, a conductive bezel 11, and a medium layer 230.

[0146] The radiator 210 includes a ground point 211, and the radiator 210 is grounded by being electrically connected to the ground plane 220 at the ground point 211. The bezel 11 has a first position 201 and a second position 202. A bezel 11 between the first position 201 and the second position 202 serves as at least a part of the radiator 210. The medium layer 230 is located between the radiator 210 and the ground plane 220, or it may be understood that a medium is filled between the radiator 210 and the ground plane 220 to form the medium layer 230. The medium layer 230 includes a first medium and a second medium. A relative magnetic permeability of the first medium is greater than 1, and a relative permittivity of the second medium is greater than 1. In an embodiment, the first medium is a magnetic medium. In an embodiment, the second medium is a dielectric. At the ground point 211, the medium layer 230 between the radiator 210 and the ground plane 220 includes the first medium.

[0147] It should be understood that, the bezel 11 between the first position 201 and the second position 202 serving as the at least a part of the radiator 210 may be understood as that the bezel 11 between the first position 201 and the second position 202 serves as a main radiator of the radiator 210, and the radiator 210 of the antenna structure 200 may further include a stub electrically connected to the bezel 11, or a parasitic stub separated from the bezel 11.

[0148] According to the technical solutions provided in embodiments of this application, a dielectric or a magnetic medium is provided at different positions of the radiator 210, so that an electric field or a magnetic field in the corresponding region may be loaded, to reduce a size of the antenna structure 200. For a bezel antenna in an electronic device, a ground point of the bezel antenna is generally a maximum current point, and corresponds to an electric field zero point or a strong magnetic field point. The magnetic medium is provided at the ground point of the radiator 210, so that a magnetic field may be loaded in a strong magnetic field region, and a same magnetic field can be generated in a smaller size, to miniaturize the antenna structure 200. In another region in which the dielectric is provided in the radiator 210, an electric field may be loaded, and a same electric field may be generated in the smaller size, to miniaturize the antenna structure 200.

[0149] In an embodiment, the radiator 210 further includes a feed point 212. The bezel 11 further has a third

position 203, and the third position 203 is provided between the first position 201 and the second position 202. The radiator 210 is separated from another part of the bezel 11 at the second position 202 by a gap. The ground point 211 is provided at the first position 201, and the feed point 212 is provided between the first position 201 and the third position 203. In this case, the antenna structure 200 includes an inverted-F antenna (inverted-F antenna, IFA).

[0150] In an embodiment, when the antenna structure includes the IFA, a strong magnetic field region (a region in which a magnetic field is greater than an electric field) generated by the antenna structure is close to the first position 201, and a strong electric field region (a region in which an electric field is greater than a magnetic field) generated by the antenna structure is close to the second position 202. In an embodiment, between the first position 201 and the third position 203, a medium layer 230 between the radiator 210 and the ground plane 220 is a first medium layer, and the first medium layer includes the first medium. In an embodiment, the first medium is a magnetic medium. Between the second position 202 and the third position 203, a medium layer 230 between the radiator 210 and the ground plane 220 is a second medium layer, and the second medium layer includes a second medium. In an embodiment, the second medium is a dielectric.

[0151] In an embodiment, between the first position 201 and the third position 203 (the first medium layer), the medium layer 230 between the radiator 210 and the ground plane 220 does not include the second medium, and between the second position 202 and the third position 203, the medium layer 230 (the second medium layer) between the radiator 210 and the ground plane 220 does not include the first medium.

[0152] In an embodiment, between the first position 201 and the third position 203, the medium layer 230 (the first medium layer) between the radiator 210 and the ground plane 220 includes only the first medium, and between the second position 202 and the third position 203, the medium layer 230 (the second medium layer) between the radiator 210 and the ground plane 220 includes only the second medium.

[0153] In this embodiment of this application, the first medium may be a magnetodielectric. It should be understood that, in this embodiment of this application, an example in which the first medium is a magnetic medium is used for description. The magnetic medium loads the magnetic field between the first position 201 and the third position 203. Because the magnetodielectric has a characteristic of the magnetic medium, during actual application, the first medium may be the magnetodielectric. In an embodiment, the first medium layer may be filled with a magnetodielectric.

[0154] In this embodiment of this application, the second medium may be a magnetodielectric. It should be understood that, in this embodiment of this application, an example in which the second medium is a dielectric

is used for description. The dielectric loads the electric field between the second position 202 and the third position 203. Because the magnetodielectric has a characteristic of the dielectric, during actual application, the second medium may be the magnetodielectric. In an embodiment, the second medium layer may be filled with a magnetodielectric.

[0155] In an embodiment, a relative magnetic permeability of the first medium is greater than 1, and a relative permittivity of the second medium is greater than 1. When the first medium layer includes a magnetic medium (where the first medium is the magnetic medium), a relative permittivity of the first medium is equal to 1, and the relative magnetic permeability is greater than 1. When the first medium layer includes a magnetodielectric (where the first medium is the magnetodielectric), the relative permittivity of the first medium is greater than 1, and the relative magnetic permeability is greater than 1. When the second medium layer includes a dielectric (where the second medium is the dielectric), the relative permittivity of the second medium is greater than 1, and a relative magnetic permeability is equal to 1. When the second medium layer includes a magnetodielectric (where the second medium is the magnetodielectric), the relative permittivity of the second medium is greater than 1, and the relative magnetic permeability is greater than 1.

[0156] The antenna structure shown in FIG. 18 and the following antenna structures (antenna structures shown in FIG. 20 and FIG. 22) in which a bezel serves as a radiator are used as examples. In an embodiment, a relative magnetic permeability of a first medium (for example, a magnetic medium) is between 2 and 5. In an embodiment, a relative permittivity of a second medium (for example, a dielectric) is between 2 and 5. As the relative permittivity of the second medium and the relative magnetic permeability of the first medium increase, an electrical loss and a magnetic loss caused by media increase synchronously, affecting radiation performance of the antenna structure. Therefore, the relative permittivity and relative magnetic permeability of the media need to be controlled within appropriate ranges. It should be understood that, during engineering application, the relative magnetic permeability of the first medium or the relative permittivity of the second medium may have a partial error (for example, 10%), and when the error is within an error range, the relative magnetic permeability of the first medium or the relative permittivity of the second medium should be considered as satisfying a range of the relative magnetic permeability or a range of the relative permittivity.

[0157] In the following embodiment, an example in which a value of the relative magnetic permeability of the magnetic medium is the same as a value of the relative permittivity of the dielectric is used for description. During actual application, the value of the relative magnetic permeability of the magnetic medium and the value of the relative permittivity of the dielectric may be different, and

may be adjusted based on an actual production or design requirement.

[0158] When the value of the relative magnetic permeability of the first medium is the same as the value of the relative permittivity of the second medium, in an extension direction of the bezel, a length of the first medium layer is equal to a length of the second medium layer. It should be understood that, during engineering application, the length of the first medium layer or the length of the second medium layer may have a partial error (for example, 10%), and when the error is within an error range, it should be considered that the length of the first medium layer is the same as the length of the second medium layer.

[0159] When the value of the relative magnetic permeability of the first medium is different from the value of the relative permittivity of the second medium, and the value of the relative magnetic permeability of the first medium is greater than the value of the relative permittivity of the second medium, in the extension direction of the bezel, the length of the first medium layer is greater than the length of the second medium layer. When the value of the relative magnetic permeability of the first medium is less than the value of the relative permittivity of the second medium, in the extension direction of the bezel, the length of the first medium layer is less than the length of the second medium layer. Energy of a magnetic field loaded by the magnetic medium is used to supplement energy of an electric field loaded by the dielectric, so that energy of the field generated by the antenna structure 200 is consistent with energy generated when the value of the relative magnetic permeability of the magnetic medium is the same as the value of the relative permittivity of the dielectric.

[0160] In an embodiment, the third position 203 is provided near a central position between the first position 201 and the second position 202. In the IFA structure, a strong magnetic field region is close to the first position 201, and a strong electric field region is close to the second position. When the third position 203 is provided at the central position between the first position 201 and the second position 202, it can be learned from the foregoing formula 1 that an electric field may be approximately equal to a magnetic field, so that the first medium layer and the second medium layer on two sides of the position may load, to a maximum extent, the electric field and the magnetic field generated by the antenna structure. However, during actual engineering application, due to an internal layout of an electronic device, the third position 203 may be adjusted to deviate from the central position between the first position 201 and the second position 202.

[0161] In an embodiment, a distance L_1 between the third position 203 and a midpoint between the first position 201 and the second position 202 and a distance L between the first position 201 and the second position 202 satisfy $L_1 \leq L \times 25\%$.

[0162] It should be understood that, because the bezel

of the electronic device includes a bending region, a distance between positions described in embodiments of this application may be understood as a distance along the bezel 11 rather than a straight-line distance between two positions. For example, the distance L between the first position 201 and the second position 202 may be understood as a distance from the first position 201 to the second position 202 along the bezel rather than a straight-line distance between the first position 201 and the second position 202. The following embodiments may also be correspondingly understood.

[0163] In an embodiment, $L_1 \leq L \times 12.5\%$, or $L_1 \leq L \times 7\%$.

[0164] It should be understood that, as the third position 203 is close to a central position between the first position 201 and the second position 202, the electric field and the magnetic field generated by the antenna structure can be loaded more greatly, to further miniaturize the antenna structure.

[0165] FIG. 19 shows S-parameter simulation results of the antenna structure shown in FIG. 18.

[0166] It should be understood that, in the S-parameter simulation results of the antenna structure shown in FIG. 19, simulation is performed by using an example in which L is equal to 58 mm. Different simulation results are obtained as the distance L_2 between the first position 201 and the third position 203 changes.

[0167] As shown in FIG. 19, when a medium layer does not include a magnetic medium ($L_2=0$ mm), a resonance point generated by the antenna structure is approximately 0.82 GHz. When L_2 is between 10 mm and 40 mm, as a magnetic medium increases, and when L_2 is equal to 28 mm, a frequency of a resonance point generated by the antenna structure is the lowest, and distribution of a dielectric and the magnetic medium at the medium layer of the antenna structure is optimal. As the magnetic medium continues to increase, a frequency of a resonance point generated by the antenna structure gradually becomes a high frequency, but the frequency of the resonance point is still lower than a frequency of the resonance point generated by the antenna structure in which no magnetic medium is provided.

[0168] In the antenna structure shown in FIG. 18, an example in which the antenna structure 200 is the IFA is used for description. The antenna structure 200 may alternatively be a T-shaped antenna, as shown in FIG. 20.

[0169] FIG. 20 is a diagram of a structure of another antenna structure 200 according to an embodiment of this application.

[0170] As shown in FIG. 20, the antenna structure 200 includes a radiator 210, a ground plane 220, a conductive bezel 11, and a medium layer 230.

[0171] The radiator 210 includes a ground point 211, and the radiator 210 is grounded by being electrically connected to the ground plane 220 at the ground point 211. The bezel 11 has a first position 201 and a second position 202. A bezel 11 between the first position 201 and the second position 202 serves as at least a part of the radiator 210. The medium layer 230 is located be-

tween the radiator 210 and the ground plane 220, or it may be understood that a medium is filled between the radiator 210 and the ground plane 220 to form the medium layer 230. The medium layer 230 includes a first medium and a second medium, where at the ground point 211, the medium layer 230 between the radiator 210 and the ground plane 220 includes the first medium. In an embodiment, the first medium is a magnetic medium. In an embodiment, the second medium is a dielectric.

[0172] It should be understood that, the bezel 11 between the first position 201 and the second position 202 serving as the at least a part of the radiator 210 may be understood as that the bezel 11 between the first position 201 and the second position 202 serves as a main radiator of the radiator 210, and the radiator 210 of the antenna structure 200 may further include a stub electrically connected to the bezel 11, or a parasitic stub separated from the bezel 11.

[0173] As shown in FIG. 20, the radiator 210 further includes a feed point 212. The bezel 11 further has a third position 203 and a fourth position 204. The third position 203 is provided between the first position 201 and the second position 202, and the fourth position 204 is provided between the second position 202 and the third position 203. The radiator 210 is separated from another part of the bezel 11 at the first position 201 and the second position 202 by gaps. The ground point 211 is provided between the third position 203 and the fourth position 204, and the feed point 212 is provided between the third position 203 and the fourth position 204. In this case, the antenna structure 200 includes a T antenna/a T-shaped antenna.

[0174] In an embodiment, when the antenna structure includes the T antenna, the antenna structure generates two strong electric field regions (regions in which an electric field is greater than a magnetic field) that are respectively close to the first position 201 and the second position 202, and a strong magnetic field region (a region in which a magnetic field is greater than an electric field) generated by the antenna structure is between the two strong electric field regions. In an embodiment, between the third position 203 and the fourth position 204, a medium layer 230 between the radiator 210 and the ground plane 220 is a first medium layer, and the first medium layer includes the first medium. Between the first position 201 and the third position 203 and between the second position 202 and the fourth position 204, the medium layer 230 between the radiator 210 and the ground plane 220 is a second medium layer, and the second medium layer includes the second medium.

[0175] In an embodiment, between the third position 203 and the fourth position 204, the medium layer 230 (the first medium layer) between the radiator 210 and the ground plane 220 does not include the second medium, and between the first position 201 and the third position 203 and between the second position 202 and the fourth position 204, the medium layer 230 (the second medium layer) between the radiator 210 and the ground plane

220 does not include the first medium.

[0176] In an embodiment, between the third position 203 and the fourth position 204, the medium layer 230 (the first medium layer) between the radiator 210 and the ground plane 220 includes only the first medium, and between the first position 201 and the third position 203 and between the second position 202 and the fourth position 204, the medium layer 230 (the second medium layer) between the radiator 210 and the ground plane 220 includes only the second medium.

[0177] In this embodiment of this application, the first medium may be a magnetodielectric. It should be understood that, in this embodiment of this application, an example in which the first medium is a magnetic medium is used for description. The magnetic medium loads a magnetic field between the third position 203 and the fourth position 204. Because the magnetodielectric has a characteristic of the magnetic medium, during actual application, the first medium may be the magnetodielectric. In an embodiment, the first medium layer may be filled with a magnetodielectric.

[0178] In this embodiment of this application, the second medium may be a magnetodielectric. It should be understood that, in this embodiment of this application, an example in which the second medium is a dielectric is used for description. The dielectric loads an electric field between the first position 201 and the third position 203 and an electric field between the second position 202 and the fourth position 204. Because the magnetodielectric has a characteristic of the dielectric, during actual application, the second medium may be the magnetodielectric. In an embodiment, the second medium layer may be filled with a magnetodielectric.

[0179] In an embodiment, a relative magnetic permeability of the first medium is greater than 1, and a relative permittivity of the second medium is greater than 1. When the first medium layer includes a magnetic medium (where the first medium is the magnetic medium), a relative permittivity of the first medium is equal to 1, and the relative magnetic permeability is greater than 1. When the first medium layer includes a magnetodielectric (where the first medium is the magnetodielectric), the relative permittivity of the first medium is greater than 1, and the relative magnetic permeability is greater than 1. When the second medium layer includes a dielectric (where the second medium is the dielectric), the relative permittivity of the second medium is greater than 1, and a relative magnetic permeability is equal to 1. When the second medium layer includes a magnetodielectric (where the second medium is the magnetodielectric), the relative permittivity of the second medium is greater than 1, and the relative magnetic permeability is greater than 1.

[0180] In an embodiment, the third position 203 is provided near the first position 201 by a distance of $14L$, and the fourth position 204 is provided near the second position 202 by a distance of $14L$, where L is a distance between the first position 201 and the second position

202. In the T antenna structure, the two strong electric field regions are respectively close to the first position 201 and the second position 202, and the strong magnetic field region is between the two strong electric field regions. When the third position 203 and the fourth position 204 are respectively provided at distances of approximately $\frac{1}{4}L$ from the first position 201 and the second position 202, it can be learned from the foregoing formula 1 that an electric field may be approximately equal to a magnetic field, so that the first medium layer and the second medium layer on two sides of the third position 203 and those of the fourth position 204 may load, to a maximum extent, the electric field and the magnetic field generated by the antenna structure. However, during actual engineering application, due to an internal layout of an electronic device, the third position 203 and the fourth position 204 may be adjusted.

[0181] In an embodiment, a distance L_1 between the third position 203 and the fourth position 204 and the distance L between the first position 201 and the second position 202 satisfy $(50\%-10\%) \times L \leq L_1 \leq (50\%+10\%) \times L$.

[0182] In an embodiment, a distance L_2 between the third position 203 and a midpoint between the first position 201 and the second position 202 satisfies $(25\%-5\%) \times L \leq L_2 \leq (25\%+5\%) \times L$.

[0183] In an embodiment, a distance L_3 between the fourth position 204 and the midpoint between the first position 201 and the second position 202 satisfies $(25\%-5\%) \times L \leq L_3 \leq (25\%+5\%) \times L$.

[0184] It should be understood that, as a third position 203 is close to a first position 201 by a distance of $\frac{1}{4}L$, and a fourth position 204 is close to a second position 202 by a distance of $\frac{1}{4}L$, an electric field and a magnetic field generated by the antenna structure can be loaded more greatly, to further miniaturize the antenna structure.

[0185] In an embodiment, a distance L_4 between the first position 201 and the third position 203 is the same as a distance L_5 between the second position 202 and the fourth position 204. It should be understood that, during actual engineering application, the distance L_4 between the first position 201 and the third position 203 and the distance L_5 between the second position 202 and the fourth position 204 may be adaptively adjusted. Therefore, when $90\% \times L_4 \leq L_5 \leq 110\% \times L_4$, that the distance L_4 between the first position 201 and the third position 203 is the same as the distance L_5 between the second position 202 and the fourth position 204 may be defined. In this case, a more symmetric antenna structure 200 indicates better radiation characteristic of the antenna structure 200.

[0186] FIG. 21 shows S-parameter simulation results of the antenna structure shown in FIG. 20.

[0187] It should be understood that, in the S-parameter simulation results of the antenna structure shown in FIG. 20, simulation is performed by using an example in which the distance L between the first position 201 and the second position 202 is equal to 76 mm, and the distance between the first position 201 and the third position 203

is the same as the distance between the second position 202 and the fourth position 204. Different simulation results are obtained as the distance L_1 between the third position 203 and the fourth position 204 changes.

[0188] As shown in FIG. 21, when a medium layer does not include a magnetic medium ($L_1=0$ mm), a resonance point generated by the antenna structure is approximately 1.24 GHz and 1.28 GHz. When L_1 is between 30 mm and 45 mm, a frequency of a resonance point generated by the antenna structure is far lower than a frequency of a resonance point generated by the antenna structure in which no magnetic medium is provided. When L_1 is equal to 36 mm, a frequency of a resonance point generated by the antenna structure is the lowest, and distribution of a dielectric and the magnetic medium at the medium layer of the antenna structure is optimal.

[0189] In the antenna structures shown in FIG. 18 and FIG. 20, examples in which the antenna structures 200 are the IFA and the T antenna are used for description. The antenna structure 200 may alternatively be a slot antenna, as shown in FIG. 22.

[0190] FIG. 22 is a diagram of a structure of still another antenna structure 200 according to an embodiment of this application.

[0191] As shown in FIG. 22, the antenna structure 200 includes a radiator 210, a ground plane 220, a conductive bezel 11, and a medium layer 230.

[0192] The radiator 210 includes a ground point, and the radiator 210 is grounded by being electrically connected to the ground plane 220 at the ground point. The bezel 11 has a first position 201 and a second position 202. A bezel 11 between the first position 201 and the second position 202 serves as at least a part of the radiator 210. The medium layer 230 is located between the radiator 210 and the ground plane 220, or it may be understood that a medium is filled between the radiator 210 and the ground plane 220 to form the medium layer 230. The medium layer 230 includes a first medium and a second medium, where at the ground point 211, the medium layer 230 between the radiator 210 and the ground plane 220 includes the first medium. In an embodiment, the first medium is a magnetic medium. In an embodiment, the second medium is a dielectric.

[0193] It should be understood that, the bezel 11 between the first position 201 and the second position 202 serving as the at least a part of the radiator 210 may be understood as that the bezel 11 between the first position 201 and the second position 202 serves as a main radiator of the radiator 210, and the radiator 210 of the antenna structure 200 may further include a stub electrically connected to the bezel 11, or a parasitic stub separated from the bezel 11. As shown in FIG. 22, the radiator 210 further includes a feed point 212, and the ground point of the radiator 210 includes a first ground point 213 and a second ground point 214. The bezel 11 further has a third position 203 and a fourth position 204. The third position 203 is provided between the first position 201 and the second position 202, and the fourth position 204

is provided between the second position 202 and the third position 203. The first ground point 213 is provided at the first position 201, and the second ground point 214 is provided at the second position 202. The feed point 212 is provided between the first position 201 and the third position 203. In this case, the antenna structure 200 includes a slot antenna/slot antenna.

[0194] In an embodiment, when the antenna structure includes the slot antenna, the antenna structure generates two strong magnetic field regions (regions in which a magnetic field is greater than an electric field) that are respectively close to the first position 201 and the second position 202, and a strong electric field region (a region in which an electric field is greater than a magnetic field) generated by the antenna structure is between the two strong magnetic field regions. In an embodiment, between the third position 203 and the fourth position 204, a medium layer 230 between the radiator 210 and the ground plane 220 is a second medium layer, and the second medium layer includes the second medium. Between the first position 201 and the third position 203 and between the second position 202 and the fourth position 204, the medium layer 230 between the radiator 210 and the ground plane 220 is a first medium layer, and the first medium layer includes the first medium.

[0195] In an embodiment, the antenna structure may include a closed slot antenna. As shown in FIG. 22, the radiator is not provided with a gap between the first position 201 and the second position 202. Alternatively, the antenna structure may include an open slot antenna, and the radiator is provided with at least one gap between the first position 201 and the second position 202. This is not limited in this embodiment of this application.

[0196] In an embodiment, between the third position 203 and the fourth position 204, the medium layer 230 (the second medium layer) between the radiator 210 and the ground plane 220 does not include the first medium, and between the first position 201 and the third position 203 and between the second position 202 and the fourth position 204, the medium layer 230 (the first medium layer) between the radiator 210 and the ground plane 220 does not include the second medium.

[0197] In an embodiment, between the third position 203 and the fourth position 204, the medium layer 230 (the second medium layer) between the radiator 210 and the ground plane 220 includes only the second medium, and between the first position 201 and the third position 203 and between the second position 202 and the fourth position 204, the medium layer 230 (the first medium layer) between the radiator 210 and the ground plane 220 includes only the first medium.

[0198] In this embodiment of this application, the first medium may be a magnetodielectric. It should be understood that, in this embodiment of this application, an example in which the first medium is a magnetic medium is used for description. The magnetic medium loads a magnetic field between the first position 201 and the third position 203 and a magnetic field between the second

position 202 and the fourth position 204. Because the magnetodielectric has a characteristic of the magnetic medium, during actual application, the first medium may be the magnetodielectric. In an embodiment, the first medium layer may be filled with a magnetodielectric.

[0199] In this embodiment of this application, the second medium may be a magnetodielectric. It should be understood that, in this embodiment of this application, an example in which the second medium is a dielectric is used for description. The dielectric loads an electric field between the third position 203 and the fourth position 204. Because the magnetodielectric has a characteristic of the dielectric, during actual application, the second medium may be the magnetodielectric. In an embodiment, the second medium layer may be filled with a magnetodielectric.

[0200] In an embodiment, a relative magnetic permeability of the first medium is greater than 1, and a relative permittivity of the second medium is greater than 1. When the first medium layer includes a magnetic medium (where the first medium is the magnetic medium), a relative permittivity of the first medium is equal to 1, and the relative magnetic permeability is greater than 1. When the first medium layer includes a magnetodielectric (where the first medium is the magnetodielectric), the relative permittivity of the first medium is greater than 1, and the relative magnetic permeability is greater than 1. When the second medium layer includes a dielectric (where the second medium is the dielectric), the relative permittivity of the second medium is greater than 1, and a relative magnetic permeability is equal to 1. When the second medium layer includes a magnetodielectric (where the second medium is the magnetodielectric), the relative permittivity of the second medium is greater than 1, and the relative magnetic permeability is greater than 1.

[0201] In an embodiment, the third position 203 is provided near the first position 201 by a distance of $\frac{1}{4}L$, and the fourth position 204 is provided near the second position 202 by a distance of $\frac{1}{4}L$, where L is a distance between the first position 201 and the second position 202. In the slot antenna structure, the two strong magnetic field regions are respectively close to the first position 201 and the second position 202, and the strong electric field region is between the two strong magnetic field regions. When the third position 203 and the fourth position 204 are respectively provided at distances of approximately $\frac{1}{4}L$ from the first position 201 and the second position 202, it can be learned from the foregoing formula 1 that an electric field may be approximately equal to a magnetic field, so that the first medium layer and the second medium layer on two sides of the third position 203 and those of the fourth position 204 may load, to a maximum extent, the electric field and the magnetic field generated by the antenna structure. However, during actual engineering application, due to an internal layout of an electronic device, the third position 203 and the fourth position 204 may be adjusted.

[0202] In an embodiment, a distance L1 between the third position 203 and the fourth position 204 and the distance L between the first position 201 and the second position 202 satisfy $(50\%-10\%) \times L \leq L1 \leq (50\%+10\%) \times L$.

[0203] In an embodiment, a distance L2 between the third position 203 and a midpoint between the first position 201 and the second position 202 satisfies $(25\%-5\%) \times L \leq L2 \leq (25\%+5\%) \times L$.

[0204] In an embodiment, a distance L3 between the fourth position 204 and the midpoint between the first position 201 and the second position 202 satisfies $(25\%-5\%) \times L \leq L3 \leq (25\%+5\%) \times L$.

[0205] In an embodiment, a distance L4 between the first position 201 and the third position 203 is the same as a distance L5 between the second position 202 and the fourth position 204. It should be understood that, during actual engineering application, the distance L4 between the first position 201 and the third position 203 and the distance L5 between the second position 202 and the fourth position 204 may be adaptively adjusted. Therefore, when $90\% \times L4 \leq L5 \leq 110\% \times L4$, that the distance L4 between the first position 201 and the third position 203 is the same as the distance L5 between the second position 202 and the fourth position 204 may be defined. In this case, a more symmetric antenna structure 200 indicates better radiation characteristic of the antenna structure 200.

[0206] FIG. 23 shows S-parameter simulation results of the antenna structure shown in FIG. 22.

[0207] It should be understood that, in the S-parameter simulation results of the antenna structure shown in FIG. 22, simulation is performed by using an example in which the distance L between the first position 201 and the third position 203 is equal to 76 mm (where a length of a gap is 74 mm), and the distance between the first position 201 and the third position 203 is the same as the distance between the second position 202 and the fourth position 204. Different simulation results are obtained as the distance L1 between the third position 203 and the fourth position 204 changes.

[0208] As shown in FIG. 21, the antenna structure may generate three resonances simultaneously. When L1 is between 26 mm and 50 mm, and when L1 is equal to 42 mm, a lowest frequency of a resonance point generated by the antenna structure is 1.21 GHz. When L1 is equal to 42 mm, distribution of a dielectric and the magnetic medium at the medium layer of the antenna structure is optimal.

[0209] A person skilled in the art may use different methods to implement the described functions for each specific application, but such implementation should not be considered beyond the scope of this application.

[0210] It may be clearly understood by a person skilled in the art that, for the purpose of convenient and brief descriptions, for a detailed working process of the foregoing system, apparatus, and unit, refer to a corresponding process in the foregoing method embodiments. Details are not described herein again.

[0211] In the several embodiments provided in this application, it should be understood that the disclosed system, apparatus, and method may be implemented in other manners. For example, the described apparatus embodiments are only examples. For example, division into the units is only logical function division or may be other division during actual implementation. For example, a plurality of units or components may be combined or integrated into another system, or some features may be ignored or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be implemented through some interfaces. The indirect couplings or communication connections between the apparatuses or units may be implemented in electronic or other forms.

[0212] The foregoing descriptions are merely specific implementations of this application, but are not intended to limit the protection scope of this application. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in this application shall fall within the protection scope of this application. Therefore, the protection scope of this application shall be subject to the protection scope of the claims.

Claims

1. An electronic device, comprising:

a radiator, comprising a ground point;
a ground plane, wherein the radiator is grounded at the ground point through the ground plane;
a conductive bezel, wherein the bezel has a first position and a second position, and a bezel between the first position and the second position serves as at least a part of the radiator; and
a medium layer located between the radiator and the ground plane, wherein
the medium layer comprises a first medium and a second medium, and at the ground point, the medium layer between the radiator and the ground plane comprises the first medium; and
a relative magnetic permeability of the first medium is greater than 1, and a relative permittivity of the second medium is greater than 1.

2. The electronic device according to claim 1, wherein

the radiator further comprises a feed point;
the bezel further has a third position, and the third position is provided between the first position and the second position;
the radiator is separated from another part of the bezel at the second position by a gap;
the ground point is provided at the first position, and the feed point is provided between the first position and the third position;

- between the first position and the third position, the medium layer between the radiator and the ground plane is a first medium layer, and the first medium layer comprises the first medium; and
 between the second position and the third position, the medium layer between the radiator and the ground plane is a second medium layer, and the second medium layer comprises the second medium.
3. The electronic device according to claim 2, wherein a distance L_1 between the third position and a midpoint between the first position and the second position and a distance L between the first position and the second position satisfy $L_1 \leq L \times 25\%$.
4. The electronic device according to claim 2 or 3, wherein $L_1 \leq L \times 12.5\%$, or $L_1 \leq L \times 7\%$.
5. The electronic device according to claim 1, wherein
 the radiator further comprises a feed point;
 the bezel further has a third position and a fourth position, the third position is provided between the first position and the second position, and the fourth position is provided between the second position and the third position;
 both the ground point and the feed point are provided between the third position and the fourth position;
 the radiator is separately separated from other parts of the bezel at the first position and the second position by gaps;
 between the first position and the third position and between the second position and the fourth position, the medium layer between the radiator and the ground plane is a first medium layer, and the first medium layer comprises the first medium; and
 between the third position and the fourth position, the medium layer between the radiator and the ground plane is a second medium layer, and the second medium layer comprises the second medium.
6. The electronic device according to claim 1, wherein
 the radiator further comprises a feed point;
 the ground point comprises a first ground point and a second ground point, the first ground point is provided at the first position, and the second ground point is provided at the second position;
 the bezel further has a third position and a fourth position, the third position is provided between the first position and the second position, and the fourth position is provided between the second position and the third position;
- the feed point is provided between the first position and the third position;
 between the third position and the fourth position, the medium layer between the radiator and the ground plane is a first medium layer, and the first medium layer comprises the first medium; and
 between the first position and the third position and between the second position and the fourth position, the medium layer between the radiator and the ground plane is a second medium layer, and the second medium layer comprises the second medium.
7. The electronic device according to claim 5 or 6, wherein
 a distance L_1 between the third position and the fourth position and a distance L between the first position and the second position satisfy $(50\% - 10\%) \times L \leq L_1 \leq (50\% + 10\%) \times L$.
8. The electronic device according to any one of claims 5 to 7, wherein
 a distance L_2 between the third position and a midpoint between the first position and the second position satisfies $(25\% - 5\%) \times L \leq L_2 \leq (25\% + 5\%) \times L$, and/or
 a distance L_3 between the fourth position and the midpoint between the first position and the second position satisfies $(25\% - 5\%) \times L \leq L_3 \leq (25\% + 5\%) \times L$.
9. The electronic device according to any one of claims 5 to 8, wherein a distance between the first position and the third position is the same as a distance between the second position and the fourth position.
10. The electronic device according to any one of claims 1 to 9, wherein
 the relative magnetic permeability of the first medium is between 2 and 5; and/or
 the relative permittivity of the second medium is between 2 and 5.
11. The electronic device according to any one of claims 2 to 10, wherein when a value of the relative magnetic permeability of the first medium is greater than a value of the relative permittivity of the second medium, in an extension direction of the bezel, a length of the first medium layer is greater than a length of the second medium layer; or when a value of the relative magnetic permeability of the first medium is less than a value of the relative permittivity of the second medium, in an extension direction of the bezel, a length of the first medium layer is less than a length of the second medium layer.

12. The electronic device according to any one of claims 2 to 11, wherein
a relative permittivity of a medium in the first medium layer is greater than 1; and a relative magnetic permeability of a medium in the second medium layer is equal to 1. 5
13. An antenna structure, comprising:
a medium layer; and 10
a radiator, wherein the radiator is provided on a surface of the medium layer, wherein the radiator comprises at least two first regions and at least one second region, and any two adjacent first regions are separated by one second region; 15
the radiator comprises a feed point, and the feed point is provided in the first region;
a medium layer in at least one first region of the first regions comprises a first medium; 20
a medium layer in at least one second region of the second region comprises a second medium;
and
a relative permittivity of the first medium is greater than 1 and a relative magnetic permeability is equal to 1, and a relative magnetic permeability of the second medium is greater than 1. 25
14. The antenna structure according to claim 13, wherein a medium layer in each second region comprises the second medium, and a medium layer in each first region comprises the first medium. 30
15. The antenna structure according to claim 13 or 14, wherein the radiator is a sheet-shaped or linear radiator, the antenna structure further comprises a ground plane, and the medium layer is provided between the radiator and the ground plane. 35
16. The antenna structure according to claim 15, wherein a region of the medium layer corresponding to the second region comprises a distribution region of an electric field zero point of the antenna structure between the radiator and the ground plane. 40
17. The antenna structure according to any one of claims 13 to 16, wherein 45
the relative magnetic permeability of the second medium is between 2 and 5; and/or 50
the relative permittivity of the first medium is between 2 and 5.
18. The antenna structure according to any one of claims 13 to 17, wherein the antenna structure comprises a plurality of radiators, and the plurality of radiators are distributed in an array. 55
19. The antenna structure according to any one of claims 13 to 18, wherein when a value of the relative magnetic permeability of the second medium is greater than a value of the relative permittivity of the first medium, an area of the second region is greater than an area of the first region; or
when a value of the relative magnetic permeability of the second medium is less than a value of the relative permittivity of the first medium, an area of the second region is less than an area of the first region.
20. An electronic device, comprising the antenna structure according to any one of claims 13 to 19.

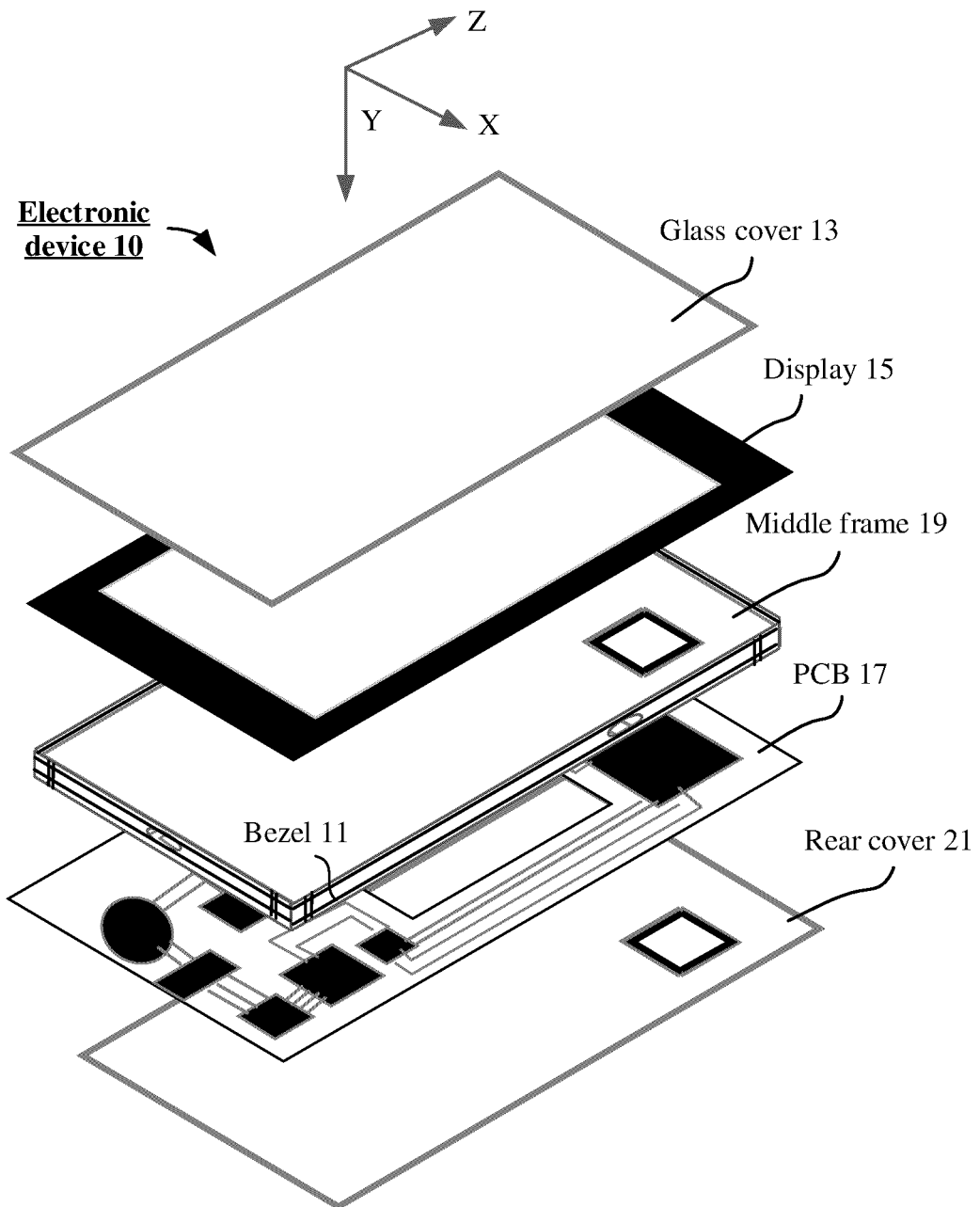


FIG. 1

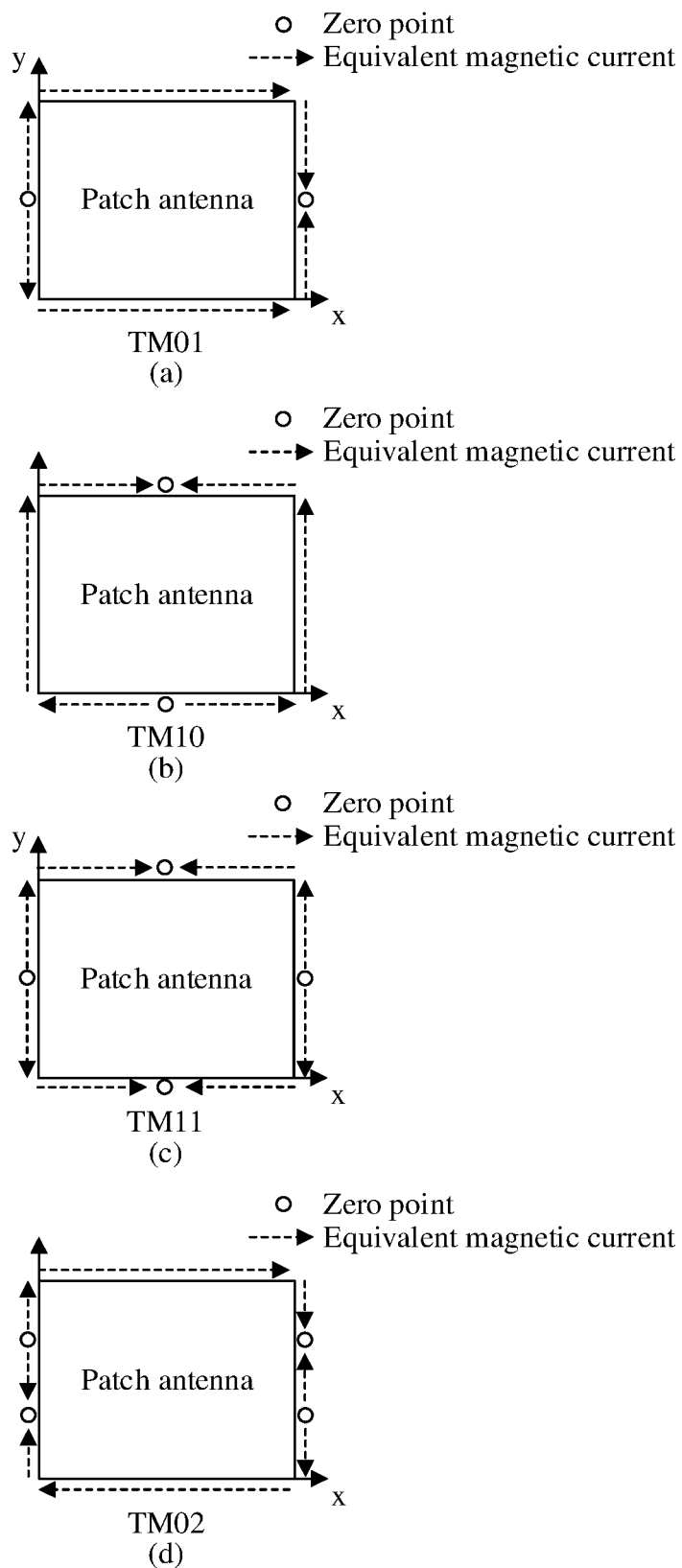


FIG. 2

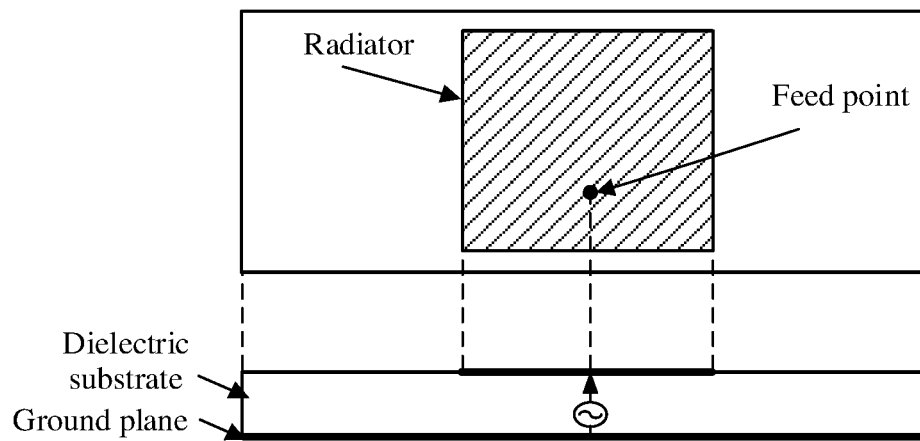


FIG. 3

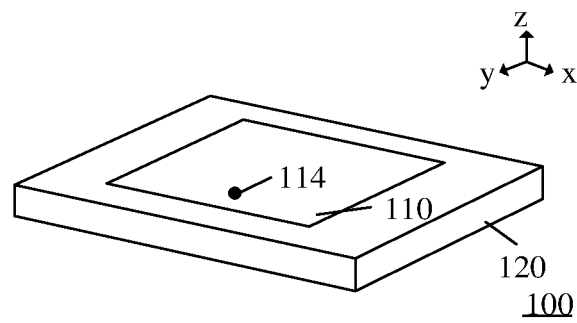


FIG. 4

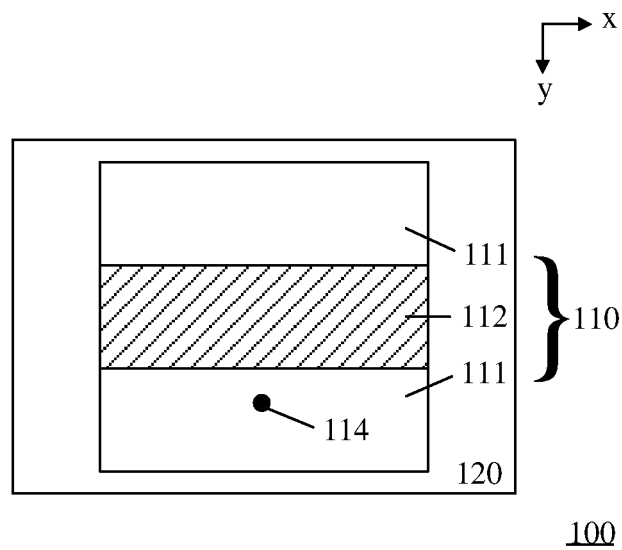


FIG. 5

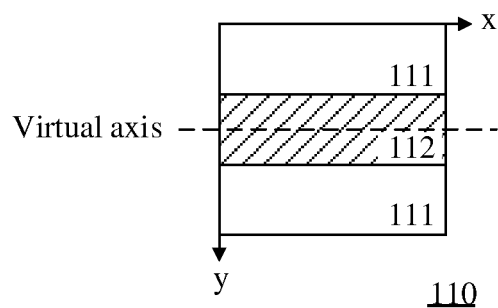


FIG. 6

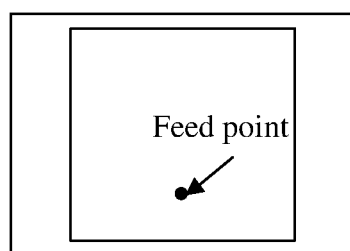


FIG. 7

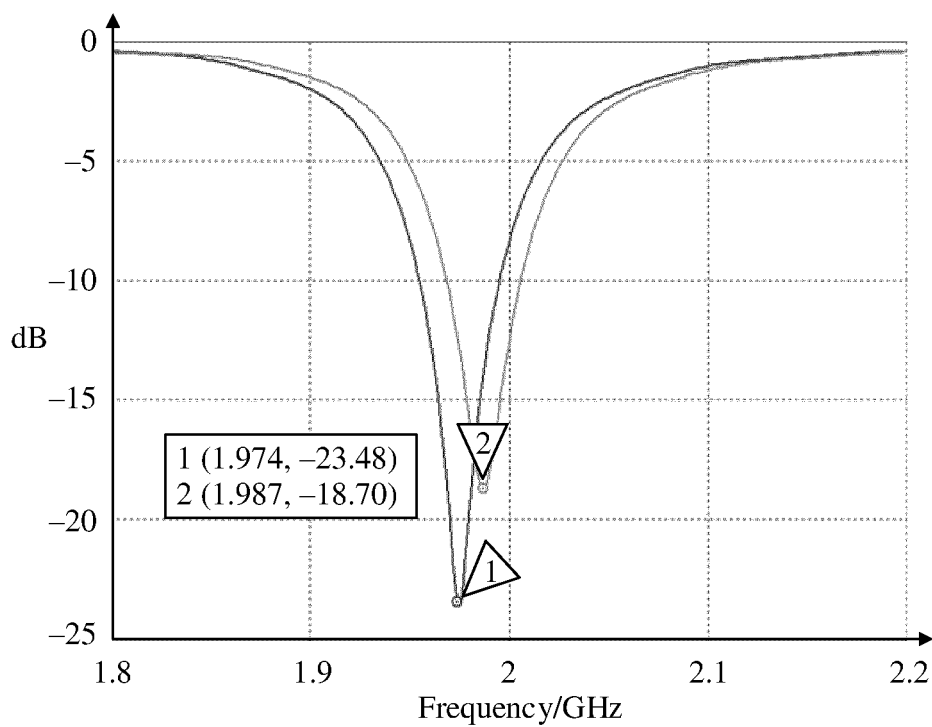


FIG. 8

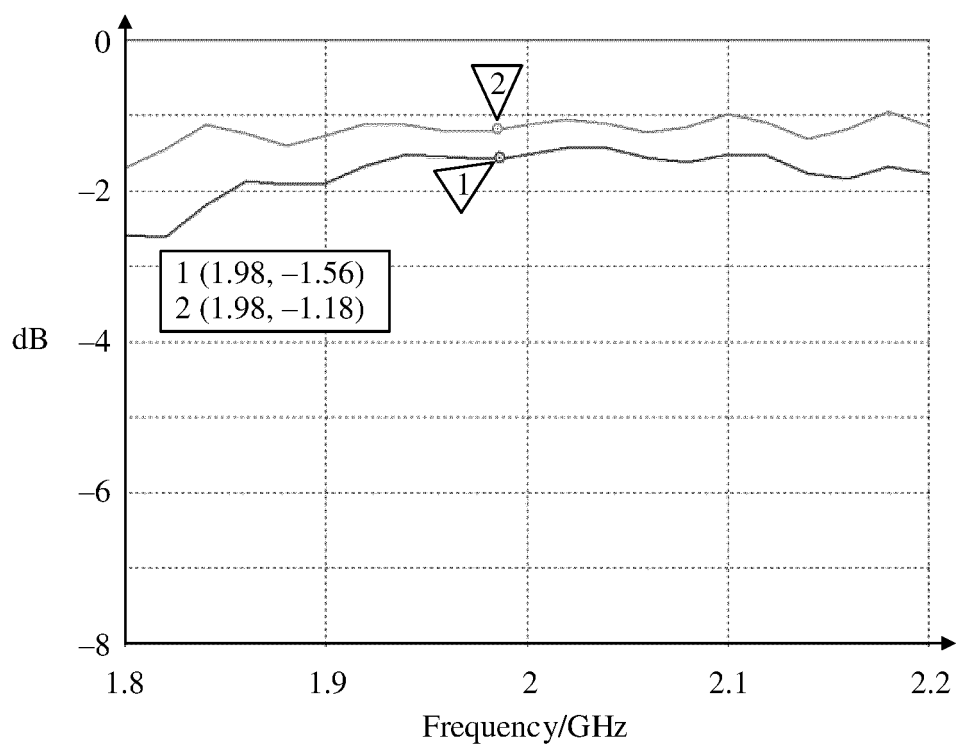


FIG. 9

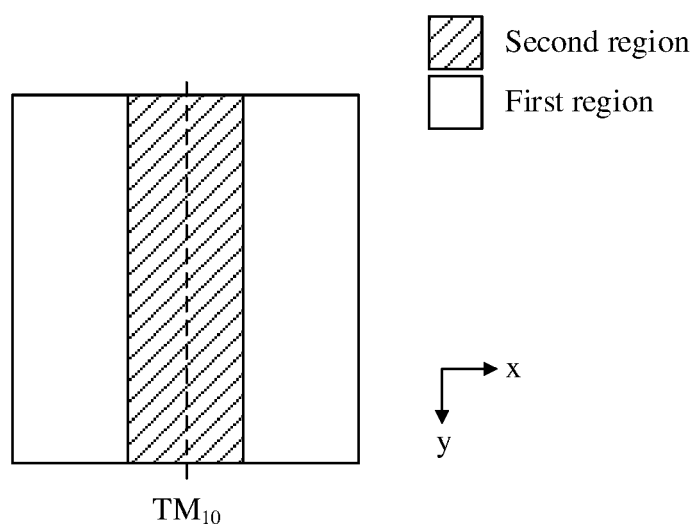


FIG. 10

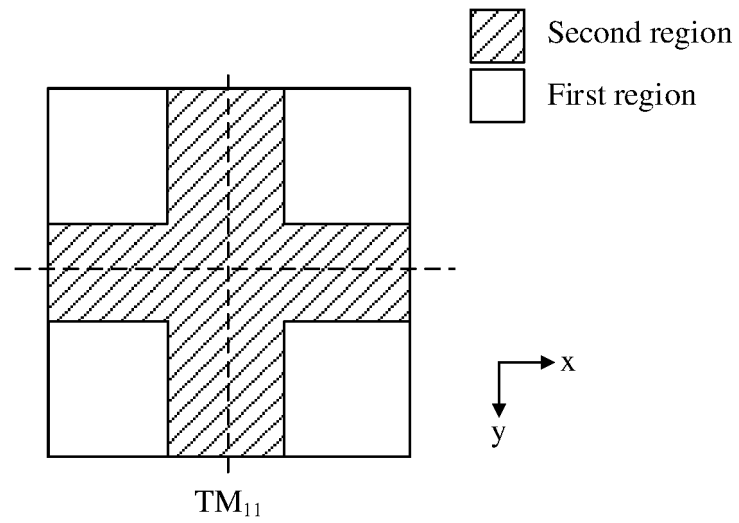


FIG. 11

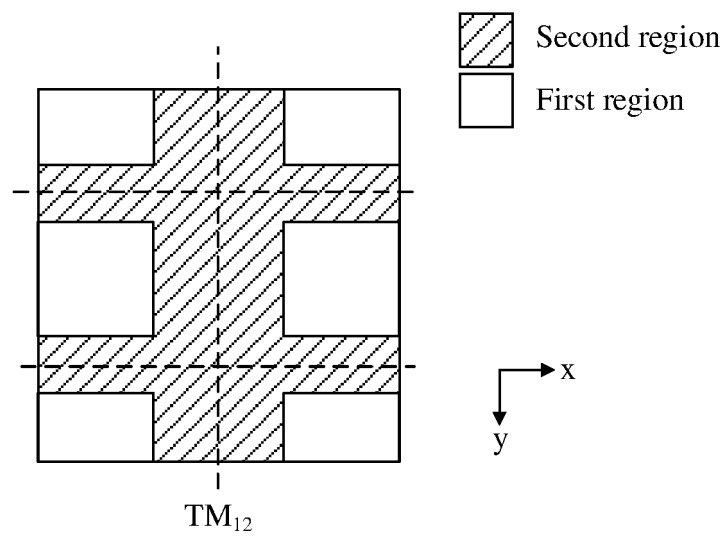


FIG. 12

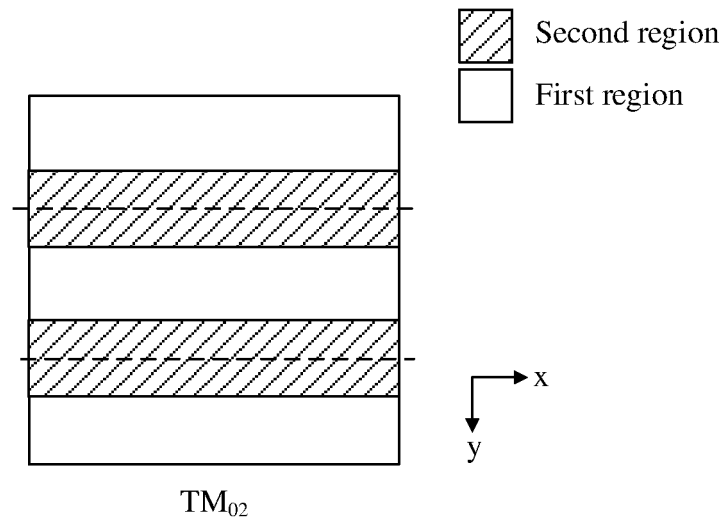


FIG. 13

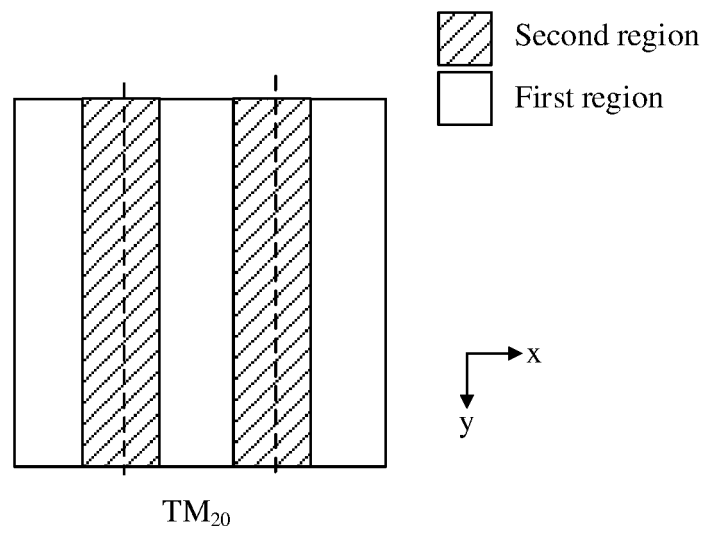


FIG. 14

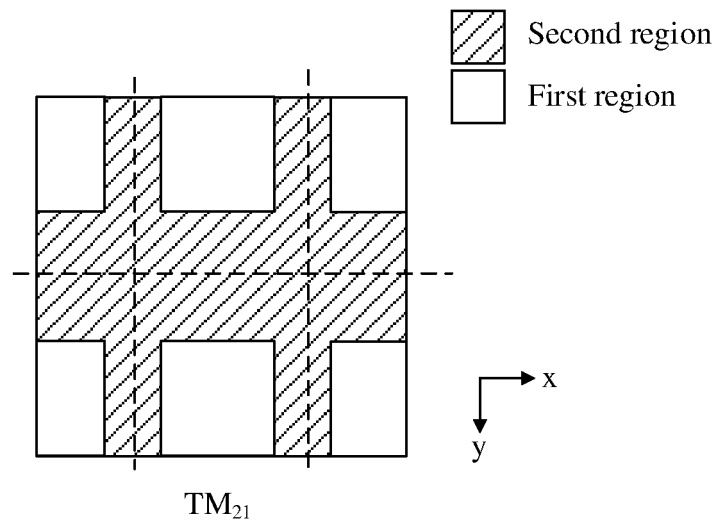


FIG. 15

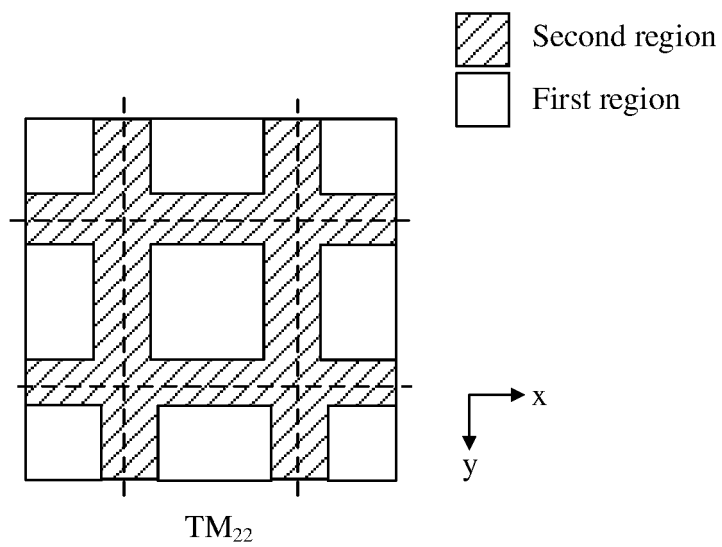


FIG. 16

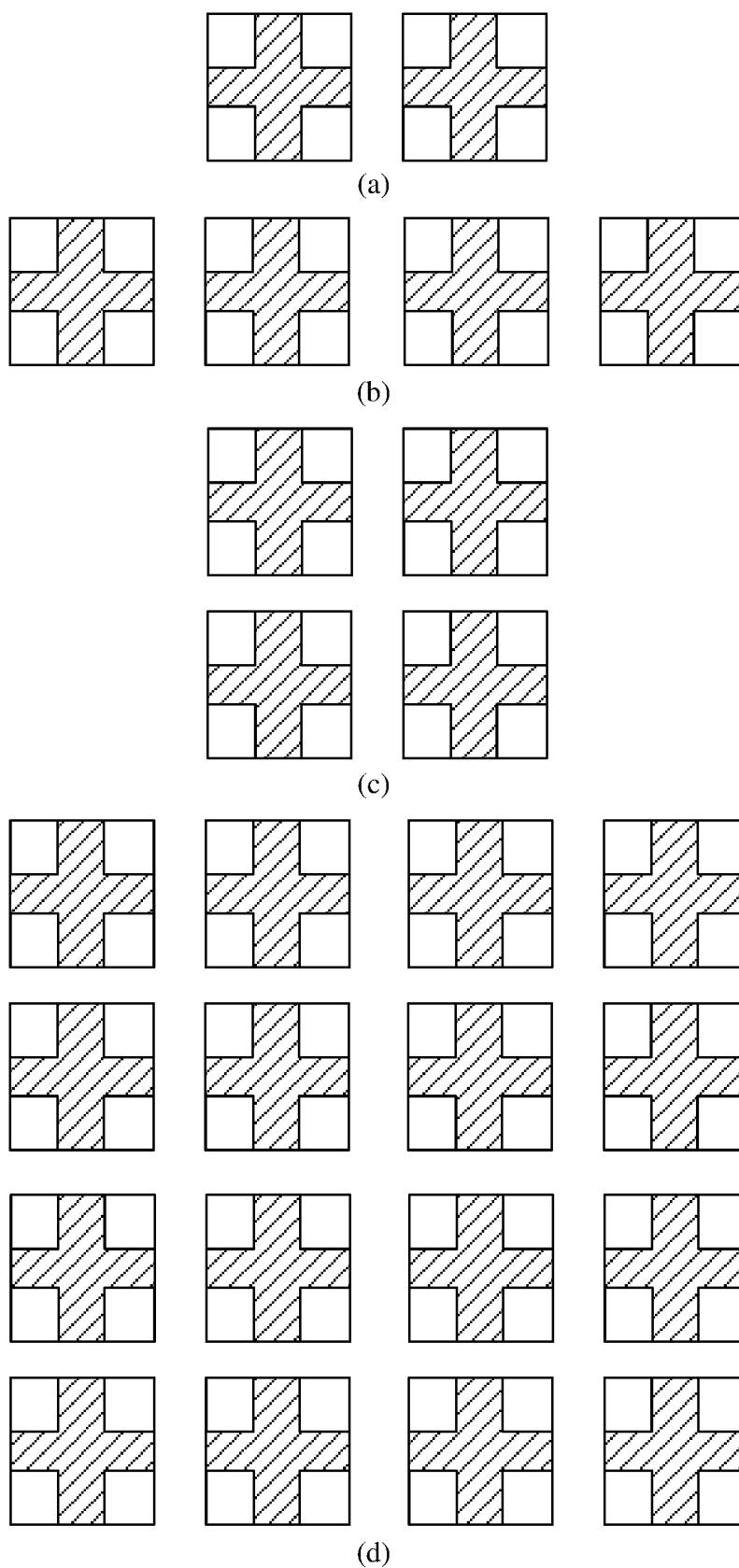


FIG. 17

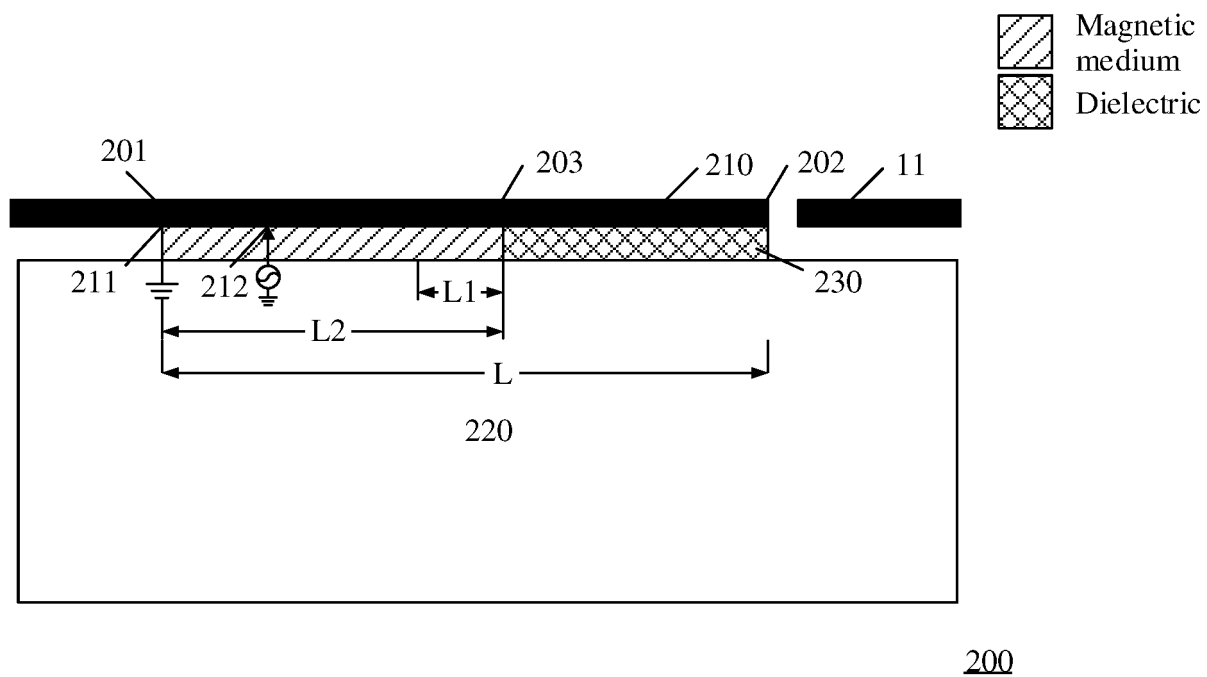


FIG. 18

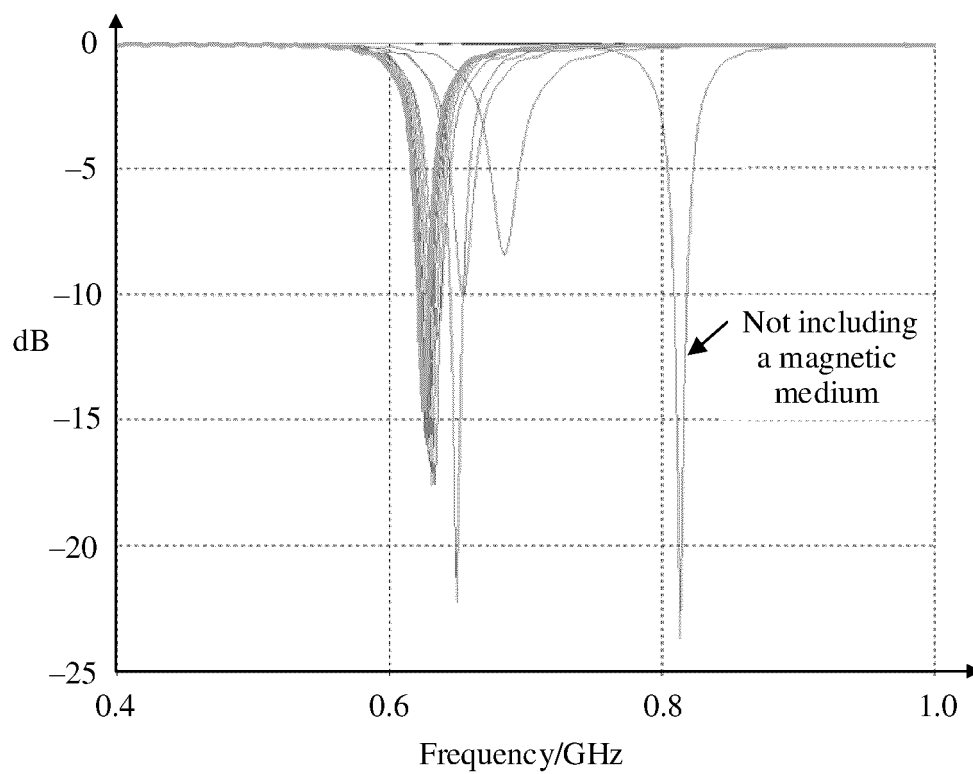


FIG. 19

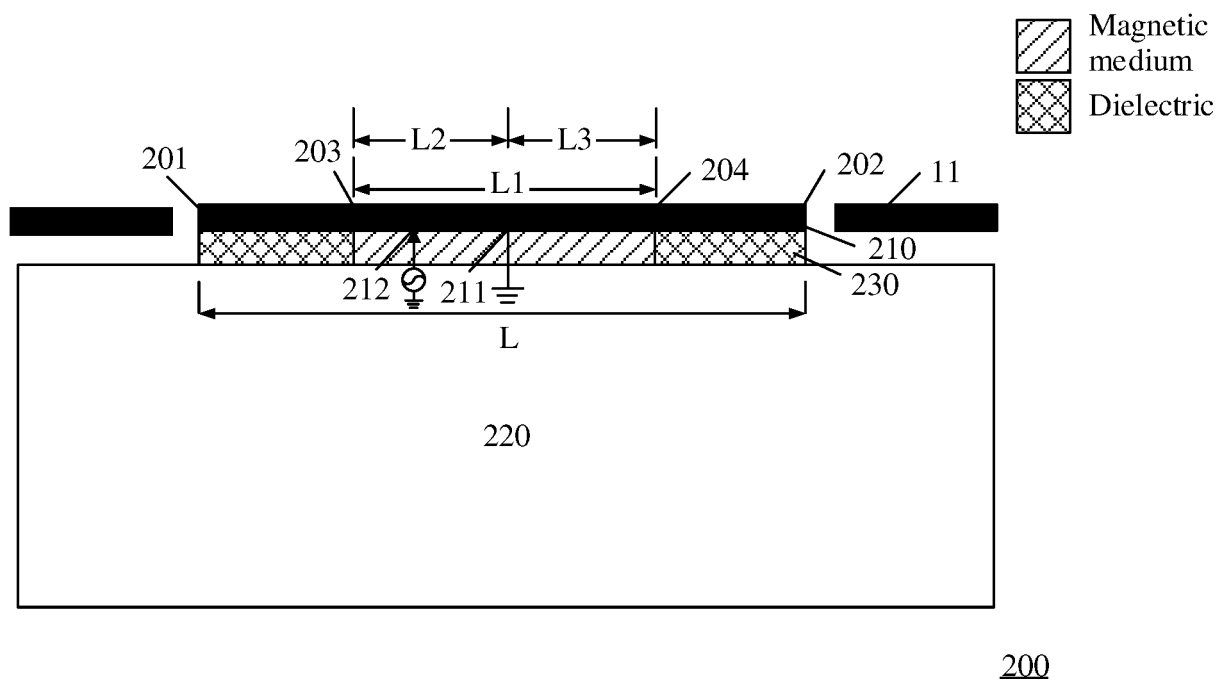


FIG. 20

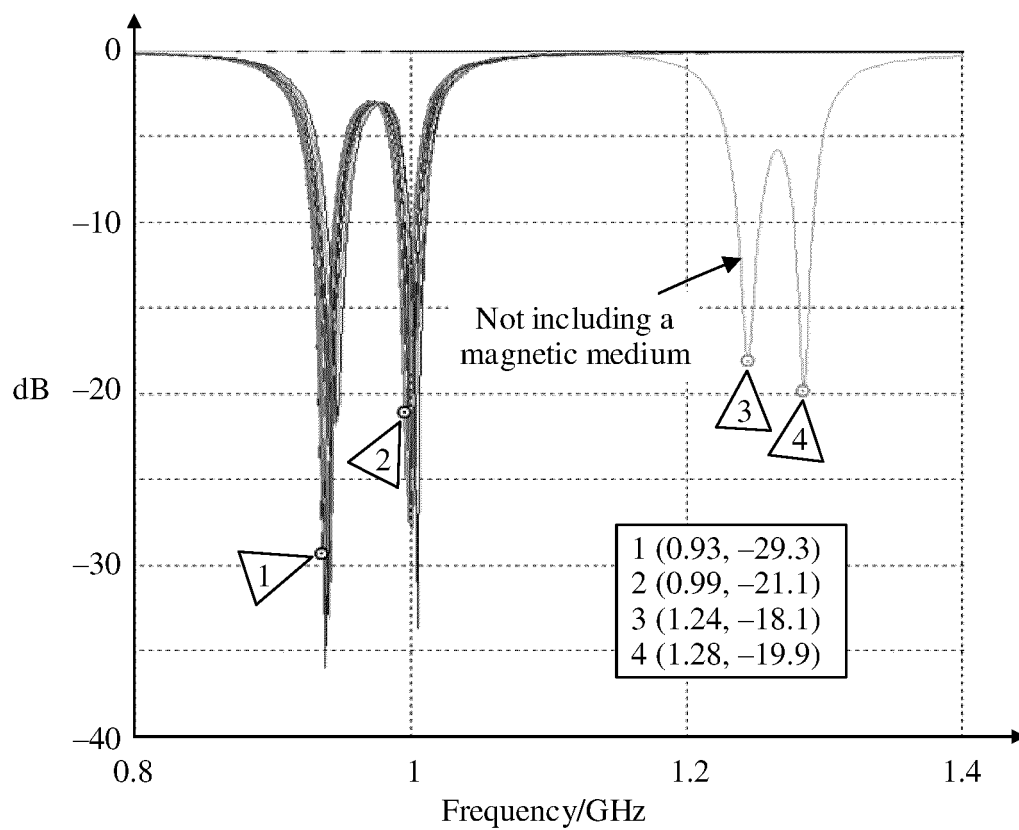


FIG. 21

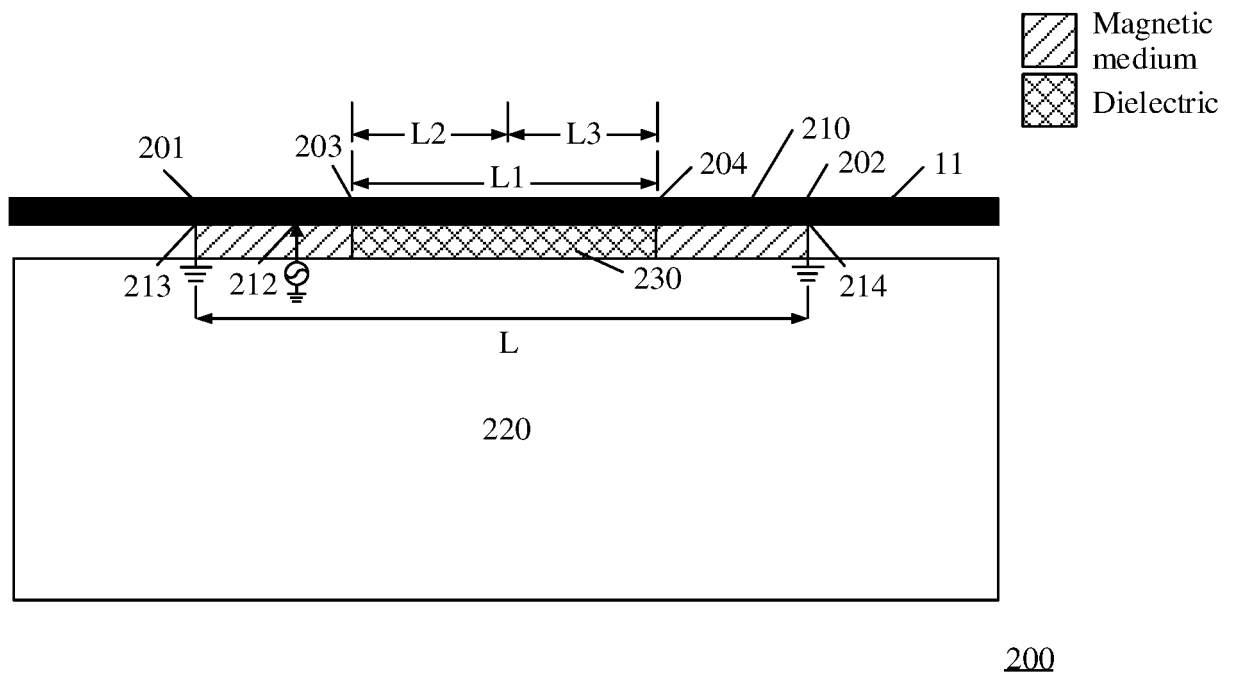


FIG. 22

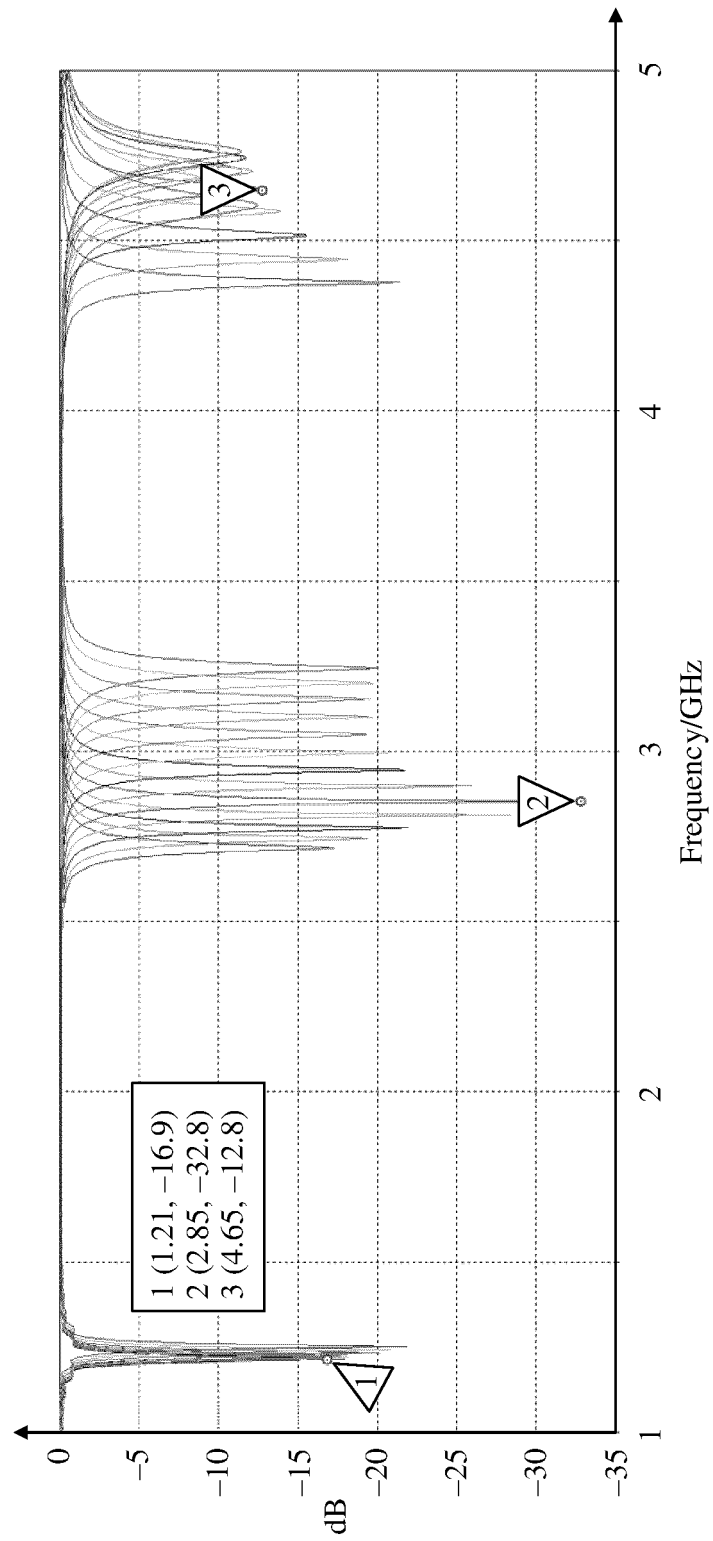


FIG. 23

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/072298

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/38(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)

CNXTX, ENTXTX, CJFD, CNKI, VEN, ENTXT, IEEE: 天线, 边框, 微带, 单极, 贴片, 补丁, 小型化, 减小, 缩小, 尺寸, 大小, 介质, 基底, 衬底, 基板, 基材, 磁场, 磁介质, 磁性介质, 磁材料, 磁性材料, 磁介电材料, 磁电介质, 铁磁材料, 铁氧体, 磁导率, 导磁系数, 电场, 电介质, 电性介质, 介电材料, 聚四氟乙烯, 介电常数; antenna, aerial, frame, bezel, microstrip, patch, size, medium, substrate, magnetic material, magnetic permeability, ferrite, electric field, dielectric, FR4, dielectric constant

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 101807744 A (SOUTHWEST JIAOTONG UNIVERSITY) 18 August 2010 (2010-08-18) description, paragraph 12, and figure 1	1-4, 10, 12
X	CN 202871983 U (SHENZHEN TINNO WIRELESS TECHNOLOGY CO., LTD.) 10 April 2013 (2013-04-10) description, paragraphs 27-31, and figure 2	1
X	CN 102113174 A (EMW ANTENNA CO., LTD.) 29 June 2011 (2011-06-29) description, paragraphs 37-39, and figure 2	13-18, 20
A	CN 101019142 A (INFINEON TECHNOLOGIES AG) 15 August 2007 (2007-08-15) entire document	1-20
A	CN 112864615 A (BEIJING BOE TECHNOLOGY DEVELOPMENT CO., LTD. et al.) 28 May 2021 (2021-05-28) entire document	1-20
A	GB 0800952 D0 (ZARLINK SEMICONDUCTOR LTD.) 27 February 2008 (2008-02-27) entire document	1-20

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

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“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

11 May 2023

Date of mailing of the international search report

15 May 2023

Name and mailing address of the ISA/CN

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

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/072298

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	CN 101800107 A (SOUTHWEST JIAOTONG UNIVERSITY) 11 August 2010 (2010-08-11) entire document	1-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2023/072298

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CN 101800107 A	11 August 2010	None	

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

REFERENCES CITED IN THE DESCRIPTION

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