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(72) Inventors:
• **ZHANG, Xiang**
Shenzhen, Guangdong 518129 (CN)
• **ZHANG, Chen**
Shenzhen, Guangdong 518129 (CN)
• **LI, Xiaofeng**
Shenzhen, Guangdong 518129 (CN)

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(74) Representative: **Goddard, Heinz J.**
Boehmert & Boehmert
Anwaltpartnerschaft mbB
Pettenkoferstrasse 22
80336 München (DE)

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

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

(57) This application provides an antenna structure and an electronic device. The antenna structure includes a first radiator and a second radiator. A first slot extending along a first direction is provided on the first radiator, at least one end of the first slot in the first direction is closed, and a feed point is provided in the first slot. A second slot is provided on the second radiator along a second direction, two ends of the second slot are open, and the second direction is perpendicular to the first direction. A first end of the second radiator is electrically connected to one end of the first radiator in the second direction, a second end of the second radiator is connected to the other end of the first radiator in the second direction, and the second radiator and the first radiator form a conductive loop structure. The antenna structure provided in embodiments of this application is simple in structure, small in size, and convenient for engineering application.

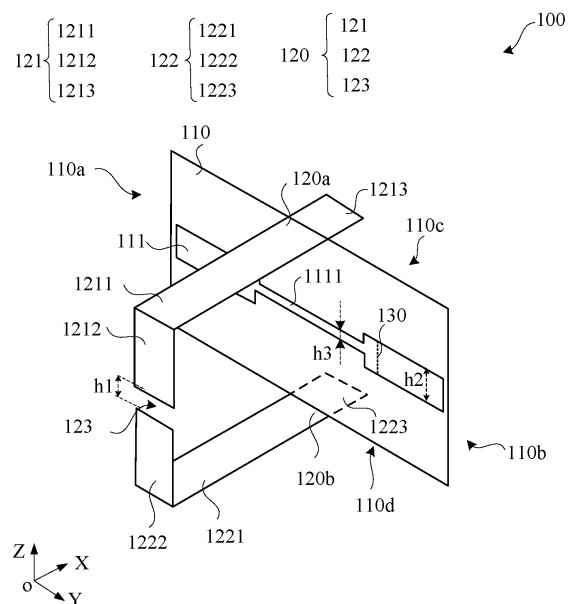


FIG. 10

Description

[0001] This application claims priority to Chinese Patent Application No. 202211198938.X, filed with the China National Intellectual Property Administration on September 29, 2022 and entitled "ANTENNA STRUCTURE AND ELECTRONIC DEVICE", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments of this application relate to the field of antenna technologies, and in particular, to an antenna structure and an electronic device.

BACKGROUND

[0003] A customer premises equipment (Customer Premises Equipment, CPE) is a mobile signal access device that receives a mobile signal and forwards the mobile signal through a Wi-Fi signal. The customer premises equipment is also a device that converts a high-speed 4G or 5G signal into a Wi-Fi signal, and may support a large quantity of mobile terminals that simultaneously access the Internet. CPEs can be widely used in rural areas, towns, hospitals, organizations, factories, residential communities, and the like for wireless network access, to reduce costs of wired network deployment. In a CPE product, a radiation pattern of a Wi-Fi signal is a key to ensuring signal coverage of the product. When radiation on the radiation pattern of the Wi-Fi signal is relatively uniform in all directions, a radiation blind zone can be avoided, thereby improving user experience.

[0004] In a related technology, as shown in FIG. 1, an antenna 10 includes a first radiating arm 11 and a second radiating arm 12, and the first radiating arm 11 and the second radiating arm 12 are disposed at an included angle. The antenna 10 further includes a plurality of parasitic stubs 13 disposed along a y direction. The parasitic stubs 13 disposed along the y direction are configured to increase orthogonal components of the first radiating arm 11 and the second radiating arm 12 in the y direction, to supplement a radiation pattern in axial directions of the first radiating arm 11 and the second radiating arm 12, to achieve quasi-isotropy of the antenna 10.

[0005] However, an antenna structure in the related technology is complex and inconvenient for engineering application.

SUMMARY

[0006] This application provides an antenna structure and an electronic device. The antenna structure is simple in structure and convenient for engineering application, so that a technical problem of a complex antenna structure and inconvenient engineering application in a related technology can be resolved.

[0007] According to a first aspect, this application pro-

vides an antenna structure, including a first radiator and a second radiator. A first slot extending along a first direction is provided on the first radiator, at least one end of the first slot in the first direction is closed, and a feed point is provided in the first slot. A second slot is provided on the second radiator along a second direction, two ends of the second slot are open, and the second direction is perpendicular to the first direction. A first end of the second radiator is electrically connected to one end of the first radiator in the second direction, a second end of the second radiator is connected to the other end of the first radiator in the second direction, and the second radiator and the first radiator form a conductive loop structure.

[0008] According to the antenna structure provided in this embodiment of this application, the first radiator and the second radiator are disposed, the first slot is provided on the first radiator, and the second slot is provided on the second radiator, so that the first radiator and the second radiator can radiate an electromagnetic signal after being powered on. The first radiator and the second radiator form a conductive loop structure, so that a current may flow along the loop structure after the current is supplied to the first radiator and the second radiator. In this way, currents on the antenna structure are distributed in different directions, to optimize a radiation pattern of the antenna structure, so that the antenna structure can radiate a spherical quasi-isotropic radiation pattern. The first slot extending along the first direction is provided on the first radiator, so that currents on different directions may be generated around the first slot after the first radiator is powered on. In this way, a signal radiated by the first radiator in all directions is relatively uniform, and the radiation pattern of the antenna structure is further optimized. In this way, the antenna structure can radiate the spherical quasi-isotropic radiation pattern. In addition, the first radiator and the second radiator form a conductive loop structure, and the second slot is provided on the second radiator, so that the antenna structure can excite a 2.4 GHz frequency band, and a standing wave of the 2.4 GHz frequency band is better, thereby improving applicability of the antenna structure. The antenna structure in this embodiment of this application is simple in structure, easy to feed, and convenient for engineering application. Because the antenna structure is provided with the second slot, when the antenna structure is used in a product like a CPE, a circuit board may pass through the second slot, achieving effect of covering two sides of the circuit board by crossing the circuit board. This further ensures that the product like the CPE can radiate a spherical quasi-isotropic radiation pattern, to improve performance of the product like the CPE.

[0009] In a possible implementation, at least one constricted segment is provided in the first slot along the first direction. A portion, other than the constricted segment, of the first slot in the second direction has a spacing greater than a spacing of the constricted segment in the second direction.

[0010] The constricted segment is provided, so that

effect of capacitive loading can be generated on the first slot, and a 5 GHz frequency band can be excited. In this way, the antenna structure can implement dual-band coverage of the 2.4 GHz frequency band and the 5 GHz frequency band, thereby improving performance and applicability of the antenna structure. In addition, the constricted segment is provided, so that a length of the first slot in the second direction may be extended at a corner of the constricted segment. When a total length of an inner border of the first slot remains unchanged, extending the length of the first slot in the second direction can reduce a length of the first slot in the first direction, to reduce a length of the first radiator in the first direction, thereby reducing a size of the antenna structure. This facilitates miniaturization of the antenna structure.

[0011] In a possible implementation, the second radiator includes a first radiating stub and a second radiating stub. The first radiator is located between the first radiating stub and the second radiating stub. One end of the first radiating stub is electrically connected to one end of the first radiator in the second direction. The second slot is provided between the other end of the first radiating stub and one end of the second radiating stub. The other end of the second radiating stub is electrically connected to the other end of the first radiator in the second direction.

[0012] The second radiator is arranged as a structure including the first radiating stub and the second radiating stub, the first radiator is disposed between the first radiating stub and the second radiating stub, and the second slot is provided between the other end of the first radiating stub and one end of the second radiating stub. In comparison with a related technology in which a second slot is provided in an extension direction of a first radiating stub and a second radiating stub, lengths of the first radiating stub and the second radiating stub may be reduced, facilitating miniaturization of the antenna structure.

[0013] In a possible implementation, the first radiating stub includes a first extension segment and a first bent portion. One end of the first extension segment is electrically connected to one end of the first radiator in the second direction. The other end of the first extension segment extends away from the first radiator and is connected to one end of the first bent portion. The other end of the first bent portion extends toward the second radiating stub in the second direction.

[0014] The first radiating stub is disposed to include the first extension segment and the first bent portion, so that different portions of the first radiating stub may be located in different directions. In this case, a current flowing through the first radiating stub may be located in different directions, and an electromagnetic signal radiated by the first radiating stub may be located in different directions, thereby improving radiation pattern performance of the antenna structure. In this way, the antenna structure can radiate a spherical quasi-isotropic radiation pattern. In addition, a length of the first radiating stub in an extension

direction of the first extension segment may be reduced by disposing the first bent portion, facilitating miniaturization of the antenna structure.

[0015] In a possible implementation, the second radiating stub includes a second extension segment and a second bent portion. One end of the second extension segment is electrically connected to the other end of the first radiator in the second direction. The other end of the second extension segment extends away from the first radiator and is connected to one end of the second bent portion. The other end of the second bent portion extends toward the first radiating stub in the second direction. The second slot is provided between the other end of the first bent portion and the other end of the second bent portion.

[0016] The second radiating stub is disposed to include the second extension segment and the second bent portion, so that different portions of the second radiating stub may be located in different directions. In this way, currents flowing through the second radiating stub may be located in different directions, and an electromagnetic signal radiated by the second radiating stub may be located in different directions, thereby improving radiation pattern performance of the antenna structure. In this way, the antenna structure can radiate a spherical quasi-isotropic radiation pattern. In addition, a length of the second radiating stub in an extension direction of the second extension segment may be reduced by disposing the second bent portion, facilitating miniaturization of the antenna structure.

[0017] In a possible implementation, the antenna structure is a three-dimensional structure, the antenna structure is a three-dimensional structure. The second radiator and a plane on which the first radiator is located are disposed at an included angle. The included angle between the second radiator and the plane on which the first radiator is located is greater than or equal to 0 and less than or equal to 90 degrees.

[0018] In a possible implementation, the second radiator is perpendicular to the plane on which the first radiator is located.

[0019] The antenna is arranged as the three-dimensional structure, so that an area occupied by the antenna structure in a plane can be reduced, thereby reducing an installation area of the antenna structure in the plane, and facilitating assembly. The first radiator is disposed perpendicular to the second radiator, so that currents on the first radiator and the second radiator may be distributed in different directions, thereby improving radiation pattern performance of the antenna structure. In this way, the antenna structure can radiate a spherical quasi-isotropic radiation pattern.

[0020] In a possible implementation, both ends of the first slot in the first direction are closed, the total length of the inner border of the first slot is λ , and a length of the first radiator in the first direction is at least $\lambda/2$, where λ is a wavelength corresponding to a center frequency of a resonance frequency of 5 GHz.

[0021] In a possible implementation, the second radiator

tor is located at a middle part of the first radiator in the first direction.

[0022] Both ends of the first slot in the first direction are closed, and the total length of the inner border of the first slot is λ , where λ is the wavelength corresponding to the center frequency of the resonance frequency of 5 GHz, so that the first radiator can excite the resonance frequency of 5 GHz, and the length of the first radiator in the first direction is increased, thereby increasing a radiation area, and improving radiation efficiency of the first radiator. The second radiator is disposed at the middle part of the first radiator in the first direction, so that the antenna structure may be a symmetric structure, and the electromagnetic signal radiated by the antenna structure is more symmetric, thereby improving radiation pattern performance of the antenna structure. In this way, the antenna structure can radiate a spherical quasi-isotropic radiation pattern.

[0023] In a possible implementation, the second radiator is located at one end of the first radiator along the first direction. One end of the first slot in the first direction is closed, the total length of the inner border of the first slot is $\lambda/2$, and the length of the first radiator in the first direction is at least $\lambda/4$, where λ is the wavelength corresponding to the center frequency of the resonance frequency of 5 GHz.

[0024] The second radiator is disposed at one end of the first radiator, and one end of the first slot is disposed in an open state. In this way, the length of the first radiator in the first direction can be reduced, thereby reducing the size and an installation space of the antenna structure, and facilitating assembly.

[0025] In a possible implementation, one end that is of the first slot and that is close to the second radiator in the first direction is open, and one end that is of the first slot and that is away from the second radiator in the first direction is closed. Alternatively, one end that is of the first slot and that is close to the second radiator in the first direction is closed, and one end that is of the first slot and that is away from the second radiator in the first direction is open.

[0026] In a possible implementation, the second radiator further includes a third extension segment, and the third extension segment extends from the first end of the second radiator in a direction away from the second radiator.

[0027] In a possible implementation, the second radiator further includes a fourth extension segment, and the fourth extension segment extends from the second end of the second radiator in a direction away from the second radiator.

[0028] A bandwidth of the 5 GHz frequency band may be increased by disposing the third extension segment and the fourth extension segment.

[0029] In a possible implementation, the antenna structure is a planar structure, and the second radiator is located at one end of the first radiator in the first direction.

[0030] The antenna structure is arranged as the planar structure, so that the antenna structure can be further simplified, thereby reducing costs.

[0031] In a possible implementation, the total length of the inner border of the first slot is $\lambda/2$, and the length of the first radiator in the first direction is at least $\lambda/4$, where λ is the wavelength corresponding to the center frequency of the resonance frequency of 5 GHz. One end that is of the first slot and that is close to the second radiator in the first direction is closed, and one end that is of the first slot and that is away from the second radiator in the first direction is open.

[0032] The end that is of the first slot and that is close to the second radiator in the first direction is closed, and the end that is of the first slot and that is away from the second radiator in the first direction is open. In this way, there is no other radiator at the open end of the first slot. Therefore, interference caused by another radiator to the first radiator can be reduced, thereby improving radiation efficiency of the antenna structure.

[0033] In a possible implementation, the antenna structure is a symmetric structure.

[0034] The antenna structure is arranged as the symmetric structure, so that the signal radiated by the antenna structure is relatively uniform in all directions, thereby improving radiation pattern performance of the antenna structure. In this way, the antenna structure can radiate a spherical quasi-isotropic radiation pattern.

[0035] According to a second aspect, an embodiment of this application provides an electronic device, including at least a circuit board and the foregoing antenna structure.

[0036] The antenna structure in the first aspect is disposed on the electronic device, so that a signal radiated by the electronic device may be relatively uniform in all directions, thereby improving performance of the electronic device.

[0037] In a possible implementation, a partial structure of the circuit board passes through a second slot of the antenna structure.

[0038] The circuit board is disposed in the second slot of the antenna structure, achieving effect of covering two sides of the circuit board by crossing the circuit board. This further ensures that the electronic device can radiate a spherical quasi-isotropic radiation pattern, to improve performance of the electronic device.

BRIEF DESCRIPTION OF DRAWINGS

[0039]

FIG. 1 is a diagram of a structure of an antenna structure;

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

FIG. 3 is a radiation pattern of the structure shown in FIG. 2;

FIG. 4 is an S-parameter diagram of the structure shown in FIG. 2;

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

FIG. 6 is a radiation pattern of the structure shown in FIG. 5;

FIG. 7 is an S-parameter diagram of the structure shown in FIG. 5;

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

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

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

FIG. 11 is a diagram of current distribution of the structure shown in FIG. 10 in a 2.4 GHz frequency band;

FIG. 12 is a radiation pattern of the structure shown in FIG. 10 in a 2.4 GHz frequency band;

FIG. 13 is a diagram of current distribution of the structure shown in FIG. 10 in a 5 GHz frequency band;

FIG. 14 is a radiation pattern of the structure shown in FIG. 10 in a 5 GHz frequency band;

FIG. 15 is an S-parameter diagram of the structure shown in FIG. 10;

FIG. 16 is a diagram of a structure of an antenna structure according to an embodiment of this application;

FIG. 17 is an S-parameter diagram of the structure shown in FIG. 16;

FIG. 18 is a radiation pattern of the structure shown in FIG. 16 in a 2.4 GHz frequency band;

FIG. 19 is a radiation pattern of the structure shown in FIG. 16 in a 5 GHz frequency band;

FIG. 20 is a diagram of a structure of an antenna structure according to an embodiment of this application;

FIG. 21 is a diagram of current distribution of the structure shown in FIG. 20 in a 2.4 GHz frequency band;

FIG. 22 is a radiation pattern of the structure shown in FIG. 20 in a 2.4 GHz frequency band;

FIG. 23 is a diagram of current distribution of the structure shown in FIG. 20 in a 5 GHz frequency band;

FIG. 24 is a radiation pattern of the structure shown in FIG. 20 in a 5 GHz frequency band;

FIG. 25 is an S-parameter diagram of the structure shown in FIG. 20;

FIG. 26 is a diagram of a structure of an antenna structure according to an embodiment of this application;

FIG. 27 is a diagram of current distribution of the

structure shown in FIG. 26 in a 2.4 GHz frequency band;

FIG. 28 is a radiation pattern of the structure shown in FIG. 26 in a 2.4 GHz frequency band;

FIG. 29 is a diagram of current distribution of the structure shown in FIG. 26 in a 5 GHz frequency band;

FIG. 30 is a radiation pattern of the structure shown in FIG. 26 in a 5 GHz frequency band;

FIG. 31 is an S-parameter diagram of the structure shown in FIG. 26;

FIG. 32 is a diagram of a structure of an antenna structure disposed on a circuit board according to an embodiment of this application;

FIG. 33 is a radiation pattern of the structure shown in FIG. 32 in a 2.4 GHz frequency band; and

FIG. 34 is a radiation pattern of the structure shown in FIG. 32 in a 5 GHz frequency band.

Reference numerals:

[0040]

100: Antenna structure; 110: First radiator; 110a: First end of the first radiator;

110b: Second end of the first radiator; 110c: Third end of the first radiator; 110d: Fourth end of the first radiator;

111: First slot; 1111: Constricted segment; 120: Second radiator;

120a: First end of the second radiator; 120b: Second end of the second radiator; 121: First radiating stub; 1211: First extension segment; 1212: First bent portion; 1213: Third extension segment;

122: Second radiating stub; 1221: Second extension segment; 1222: Second bent portion;

1223: Fourth extension segment; 123: Second slot;

130: Feed point;

200: Circuit board.

DESCRIPTION OF EMBODIMENTS

[0041] Terms used in implementations of this application are merely used to explain specific embodiments of this application, but are not intended to limit this application.

[0042] CPEs can support access of a plurality of mobile terminals simultaneously, and are widely used in homes, hospitals, factories, shopping malls, and offices. In comparison with wired networks, application scenarios of the CPEs are more flexible, and network construction is more convenient. In a CPE product, a spherical radiation pattern of a Wi-Fi antenna is a key to ensuring signal coverage. If an antenna with a spherical omnidirectional radiation pattern can be designed, a radiation blind zone can be avoided, thereby improving user experience.

[0043] In a related technology, two arms of a dipole may be bent at a specific ratio, so that when transverse

and longitudinal currents are at a specific ratio, a spherical isotropic radiation pattern may be implemented by superposing radiation patterns of all parts. However, in this case, a large quantity of lumped devices such as capacitors and inductors need to be introduced, which increases performance loss and manufacturing cost of an antenna. In addition, only a single frequency is implemented in this solution.

[0044] Alternatively, in a related technology, radiation traces in horizontal and vertical directions are disposed on an outer surface of a dielectric cube. Radiation components of an antenna in the vertical and horizontal directions can implement radiation pattern quasi-isotropy by adjusting a ratio of the radiation traces of the antenna in the horizontal and vertical directions. For example, a size of the antenna may be 20 mm×20 mm×20 mm, covering a frequency of 2.4 GHz, and a spherical ellipticity of a radiation pattern is approximately 6 dB. In this technical solution, the dielectric block is added, and the radiation spherical ellipticity deteriorates. In addition, the solution is complex in design and difficult in debugging, and implements coverage only at the single frequency of 2.4 GHz.

[0045] However, in a related technology in FIG. 1, an included angle α between a first radiating arm 11 and a second radiating arm 12, and a length L of a parasitic stub 13 needs to be adjusted during design. The adjustment is relatively complex, and consequently, it is inconvenient for engineering application.

[0046] For the foregoing technical problems, embodiments of this application provide an antenna structure. The antenna structure is simple in structure and convenient for engineering application, and can excite a 2.4 GHz resonance frequency band and a 5 GHz resonance frequency band. In addition, radiation patterns of the antenna structure in both frequency bands are of good spherical ellipticity.

[0047] It should be noted that, the spherical ellipticity is a difference between a maximum gain value and a minimum gain value of the radiation pattern.

[0048] The following describes the antenna structure in embodiments of this application with reference to the accompanying drawings.

[0049] For ease of description, in embodiments of this application, an extension direction of a first slot 111 is used as a first direction, that is, a direction Y in the figure, which is a direction from a first end 110a of a first radiator to a second end 110b of the first radiator, and is also referred to as a horizontal direction. A second direction is a vertical direction, that is, a Z direction in the figure, which is a direction from a third end 110c to a fourth end 110d of the first radiator 110. An X direction may be used as a third direction.

[0050] As shown in FIG. 2, in an embodiment, an antenna structure 100 provided in this application may include the first radiator 110 and a second radiator 120. The first slot 111 extending along the Y direction may be provided on the first radiator 110, and at least one end of

the first slot 111 in the Y direction is closed. For example, one end or two ends of the first slot 111 in the Y direction are closed. A feed point 130 is provided in the first slot 111, and the antenna structure 100 may feed the first radiator 110 and the second radiator 120 by using the feed point 130. A second slot 123 is provided on the second radiator 120 along the Z direction, two ends of the second slot 123 are open, and the Z direction is perpendicular to the Y direction. A first end 120a of the second radiator is electrically connected to one end of the first radiator 110 in the Z direction, a second end 120b of the second radiator is connected to the other end of the first radiator 110 in the Z direction, and the second radiator 120 and the first radiator 110 form a conductive loop structure.

[0051] The end of the first radiator 110 in the Z direction may be the third end 110c of the first radiator, and the other end of the first radiator 110 in the Z direction may be the fourth end 110d of the first radiator.

[0052] It should be noted that, in this embodiment, "closed" means that there is a side wall on an outer side of the slot, and "open" means that there is no side wall on the outer side of the slot. The side wall is a wall of the first radiator 110.

[0053] According to the antenna structure 100 provided in this embodiment of this application, the first radiator 110 and the second radiator 120 are disposed, the first slot 111 is provided on the first radiator 110, and the second slot 123 is provided on the second radiator 120, so that the first radiator 110 and the second radiator 120 can radiate an electromagnetic signal after being powered on. The first radiator 110 and the second radiator 120 form a conductive loop structure, so that a current may flow along the loop structure after the current is supplied to the first radiator 110 and the second radiator 120. In this way, currents on the antenna structure 100 are distributed in different directions, to optimize a radiation pattern of the antenna structure 100, so that the antenna structure 100 can radiate a spherical quasi-isotropic radiation pattern (as shown in FIG. 3). The first slot 111 extending along the Y direction is provided on the first radiator 110, so that currents on different directions may be generated around the first slot 111 after the first radiator 110 is powered on. In this way, a signal radiated by the first radiator 110 in all directions is relatively uniform, and the radiation pattern of the antenna structure 100 is further optimized. In this way, the antenna structure 100 can radiate the spherical quasi-isotropic radiation pattern.

[0054] In addition, the first radiator 110 and the second radiator 120 form a conductive loop structure and the second slot 123, so that the antenna structure 100 excites the 2.4 GHz frequency band and has a good standing wave (as shown in FIG. 4), thereby improving applicability of the antenna structure 100. The antenna structure 100 in this embodiment of this application is simple in structure, easy to feed, and convenient for engineering application. Because the antenna structure 100 is pro-

vided with the second slot 123, when the antenna structure 100 is used in a product like a CPE, a circuit board may pass through the second slot 123, achieving effect of covering two sides of the circuit board by crossing the circuit board. This further ensures that the product like the CPE can radiate a spherical quasi-isotropic radiation pattern, to improve performance of the product like the CPE.

[0055] As an explanation, in an S-parameter diagram, a horizontal axis represents a frequency in GHz, and a vertical axis represents a return loss characteristic in dBa.

[0056] As an explanation, according to a principle of an antenna, to enable the antenna to radiate a spherical quasi-isotropic radiation pattern, currents on the antenna need to be properly distributed in different directions. In this way, the radiation pattern of the antenna can achieve spherical isotropic effect by superimposing radiation patterns of currents on different directions.

[0057] As shown in FIG. 5, an antenna structure 100 includes the first radiator 110, the first slot 111 extending along the Y direction is provided on the first radiator 110, and two ends of the first slot 111 are closed in the Y direction. A second radiator 120 includes a first radiating stub 121 and a second radiating stub 122. One end of the first radiating stub 121 is electrically connected to the first radiator 110, one end of the second radiating stub 122 is electrically connected to the first radiator 110, and a second slot 123 is formed between the first radiating stub 121 and the second radiating stub 122. The second slot 123 extends along an extension direction of the first radiating stub 121 and the second radiating stub 122, and both ends of the second slot 123 are open. A feed point 130 is provided at a middle part of the first slot 111. Currents on the antenna structure 100 may be distributed in different directions on the first slot 111 and the second slot 123 after the feed point 130 is powered on. Finally, a spherical quasi-isotropic radiation pattern is formed by current radiation (as shown in FIG. 6). A spherical ellipticity of the radiation pattern shown in FIG. 6 is 3.6 dB (where a maximum gain value is approximately 1.28 dBi, and a minimum gain value is approximately -2.32 dBi).

[0058] As shown in FIG. 7, the antenna structure 100 may excite a resonance frequency of 2.4 GHz, but a standing wave is poor and a resonance depth is relatively small. In addition, in the antenna structure 100 in FIG. 5, because a length of the second slot 123 in the extension direction (X direction) needs to be 1/4 of a wavelength of the resonance frequency of 2.4 GHz (approximately 30 mm), a size of the antenna structure 100 is relatively large. Therefore, on this basis, the second radiator 120 is arranged as an open loop antenna (as shown in FIG. 2). The second slot 123 is an "opening" of the open loop antenna, and the conductive loop structure is a "loop" of the open loop antenna. In this case, a length of the loop structure in the extension direction (X direction) may be 16 mm (approximately 1/8 of a wavelength), and the size of the antenna structure 100 is effectively reduced, facil-

itating miniaturization of the antenna structure 100. In addition, as shown in FIG. 3, a spherical ellipticity of the radiation pattern of the antenna structure 100 is 2.65 dB (where a maximum gain value is approximately 1.58 dBi, and a minimum gain value is approximately -1.07 dBi). In comparison with the antenna structure 100 in FIG. 5, radiation pattern performance of the antenna structure 100 in FIG. 2 is improved, and the antenna standing wave is better.

[0059] Still refer to FIG. 2. For example, the antenna structure 100 provided in this embodiment of this application may be a three-dimensional structure. The second radiator 120 is perpendicular to a plane on which the first radiator 110 is located. Certainly, in another embodiment, there may be a specific included angle between the second radiator 120 and the plane on which the first radiator 110 is located. The included angle is greater than or equal to 0 and less than or equal to 90 degrees. In this embodiment of this application, the included angle between the first radiator 110 and the second radiator 120 is not further limited.

[0060] Both ends of the first slot 111 in the Y direction are closed. The second radiator 120 may be located at a middle part of the first radiator 110 in the Y direction, so that the antenna structure 100 may be a symmetric structure. In this way, an electromagnetic signal radiated by the antenna structure 100 is more symmetric, thereby improving radiation pattern performance of the antenna structure 100. In this way, the antenna structure 100 can radiate the spherical quasi-isotropic radiation pattern.

[0061] As shown in FIG. 2, the second radiator 120 may include a first radiating stub 121 and a second radiating stub 122. The first radiator 110 is located between the first radiating stub 121 and the second radiating stub 122. One end of the first radiating stub 121 is electrically connected to the third end 110c of the first radiator. The second slot 123 is provided between the other end of the first radiating stub 121 and one end of the second radiating stub 122. The other end of the second radiating stub 122 is electrically connected to the fourth end 110d of the first radiator.

[0062] For example, the first radiating stub 121 and the second radiating stub 122 each may be of a strip structure or a linear structure, and widths of the first radiating stub 121 and the second radiating stub 122 in the Y direction are the same as a length of the second slot 123 in the Y direction. Therefore, the length of the second slot 123 in the Y direction may be adjusted by adjusting the length of the strip structure in the Y direction, so that a bandwidth of a resonance frequency of 2.4 GHz may be adjusted. A specific adjustment manner is not further limited in this embodiment of this application.

[0063] In this embodiment, the first radiating stub 121, the second radiating stub 122, and a part that is of the first radiator 110 and that is located between the first radiating stub 121 and the second radiating stub 122 form a conductive loop structure. As shown in FIG. 2, the conductive loop structure is distributed in the X direction and the Z

direction, so that the currents on the antenna structure 100 may be distributed in different directions, thereby improving radiation pattern performance of the antenna structure 100. In this way, the antenna structure 100 can radiate the spherical quasi-isotropic radiation pattern.

[0064] In a possible implementation, the first radiating stub 121 may include a first extension segment 1211 and a first bent portion 1212. One end of the first extension segment 1211 is electrically connected to the third end 110c of the first radiator. The other end of the first extension segment 1211 extends away from the first radiator 110 and is connected to one end of the first bent portion 1212. The other end of the first bent portion 1212 extends toward the second radiating stub 122 in the direction Z.

[0065] The first radiating stub 121 is disposed to include the first extension segment 1211 and the first bent portion 1212, so that different portions of the first radiating stub may be located in different directions. In this way, currents flowing through the first radiating stub 121 may be located in different directions, and an electromagnetic signal radiated by the first radiating stub 121 may be located in different directions, thereby improving radiation pattern performance of the antenna structure 100. In this way, the antenna structure 100 can radiate the spherical quasi-isotropic radiation pattern. In addition, a length of the first radiating stub 121 in an extension direction of the first extension segment 1211 may be reduced by disposing the first bent portion 1212, facilitating miniaturization of the antenna structure 100.

[0066] The second radiating stub 122 may include a second extension segment 1221 and a second bent portion 1222. One end of the second extension segment 1221 is electrically connected to the fourth end of the first radiator 110. The other end of the second extension segment 1221 extends away from the first radiator 110 and is connected to one end of the second bent portion 1222. The other end of the second bent portion 1222 extends toward the first radiating stub 121 in the direction Z. The second slot 123 is provided between the other end of the first bent portion 1212 and the other end of the second bent portion 1222.

[0067] The second radiating stub 122 is disposed to include the second extension segment 1221 and the second bent portion 1222, so that different portions of the second radiating stub may be located in different directions. In this way, currents flowing through the second radiating stub 122 may be located in different directions, and an electromagnetic signal radiated by the second radiating stub 122 may be located in different directions, thereby improving radiation pattern performance of the antenna structure 100. In this way, the antenna structure 100 can radiate the spherical quasi-isotropic radiation pattern. In addition, a length of the second radiating stub 122 in an extension direction of the second extension segment 1221 may be reduced by disposing the second bent portion 1222, facilitating miniaturization of the antenna structure 100.

[0068] A circumference of the conductive loop struc-

ture of the antenna structure 100 in FIG. 2 may be $1/2$ of a wavelength of the resonance frequency of 2.4 GHz, to excite the resonance frequency of 2.4 GHz.

[0069] In some embodiments, the conductive loop structure may be a square structure. For example, the conductive loop structure is a square structure whose side length is $1/8$ of a wavelength of the resonance frequency of 2.4 GHz (approximately 15 mm), and a sum of four side lengths is $1/2$ of a wavelength of the resonance frequency of 2.4 GHz (approximately 60 mm), to excite the resonance frequency of 2.4 GHz. Certainly, in another embodiment, the loop structure may alternatively be in another shape. A specific shape of the loop structure is not further limited in this embodiment of this application.

[0070] For example, the conductive loop structure may alternatively be a rectangular structure. For example, a structure of the first extension segment 1211 is the same as that of the second extension segment 1221. In addition, lengths of the first extension segment 1211 and the second extension segment 1221 in the X direction may be the same, and lengths of the first extension segment 1211 and the second extension segment 1221 in the Y direction may also be the same. Lengths of the first bent portion 1212 and the second bent portion 1222 in the Z direction are the same, and the second slot 123 is located between the first bent portion 1212 and the second bent portion 1222. In this way, the conductive loop structure may be a symmetric structure, to improve radiation pattern performance of the antenna structure 100.

[0071] Certainly, in some embodiments, the lengths of the first bent portion 1212 and the second bent portion 1222 in the Z direction may be different. In this embodiment of this application, specific lengths of the first bent portion 1212 and the second bent portion 1222 in the Z direction are not further limited.

[0072] For example, a spacing $h1$ of the second slot 123 in the Z direction may range from 0.5 mm to 3 mm, for example, may be 0.5 mm, 1 mm, 1.5 mm, 2 mm, 2.5 mm or 3 mm. A resonance frequency and a radiation pattern ellipticity may be adjusted by adjusting the spacing $h1$ of the second slot 123 in the Z direction. Specifically, the spacing $h1$ of the second slot 123 in the Z direction may be set based on a specific situation. This is not further limited in this embodiment.

[0073] In this embodiment of this application, the feed point 130 is provided in the first slot 111. As shown in FIG. 2, the feed point 130 may be provided at the middle part of the first slot 111. Certainly, in another embodiment, the feed point 130 may be provided in another position, for example, may be provided on one side of the first slot 111.

[0074] As shown in FIG. 8, the antenna apparatus includes the first radiator 110 and a second radiator 120. The first slot 111 is provided on the first radiator 110, and the first slot 111 extends along the Y direction. The second radiator 120 is perpendicular to the first radiator 110. A second slot 123 is provided in the Z direction at an end that is of the second radiator 120

and that is away from the first radiator 110.

[0075] A first radiating stub 121 may include a first extension segment 1211 and a first bent portion 1212. One end of the first extension segment 1211 is electrically connected to the third end 110c of the first radiator. The other end of the first extension segment 1211 extends away from the first radiator 110 and is connected to one end of the first bent portion 1212. The other end of the first bent portion 1212 extends toward a second radiating stub 122 in the direction Z. The second radiating stub 122 may include a second extension segment 1221 and a second bent portion 1222. One end of the second extension segment 1221 is electrically connected to the fourth end 110d of the first radiator. The other end of the second extension segment 1221 extends away from the first radiator 110 and is connected to one end of the second bent portion 1222. The other end of the second bent portion 1222 extends toward the first radiating stub 121 in the direction Z. The second slot 123 is provided between the other end of the first bent portion 1212 and the other end of the second bent portion 1222.

[0076] In this embodiment, as shown in FIG. 9, both ends of the first slot 111 in the Y direction are closed. In some embodiments, when both ends of the first slot 111 in the Y direction are closed, a total length of an inner border of the first slot 111 may be λ . A length of the first radiator 110 in the Y direction is at least $\lambda/2$, where λ is a wavelength corresponding to a center frequency of a resonance frequency of 5 GHz.

[0077] The length of the first radiator 110 in the Y direction is at least $\lambda/2$, so that the total length of the inner border of the first slot 111 may be λ . In addition, it is ensured that a size of the first radiator 110 is relatively small, so that the resonance frequency of 5 GHz can be excited, and miniaturization of an antenna structure 100 can be promoted.

[0078] It should be noted that the total length of the inner border of the first slot 111 is a sum of lengths of inner borders that form the first slot 111 in different directions, including a length of the inner border in the Z direction and a length of the inner border in the Y direction. Both ends of the first slot 111 in the Y direction are closed, and the total length of the inner border of the first slot 111 is λ , where λ is the wavelength corresponding to the center frequency of the resonance frequency of 5 GHz. In this way, the first radiator 110 can excite the resonance frequency of 5 GHz, and the antenna structure 100 may be a dual-band antenna structure 100. In other words, the antenna structure 100 may excite a resonance frequency of 2.4 GHz, and may further excite the resonance frequency of 5 GHz.

[0079] In this embodiment, as shown in FIG. 9, a feed point 130 is provided on one side of the first slot 111, and a constricted segment 1111 extending along the Y direction is provided at a middle part of the first slot 111. A portion, other than the constricted segment 1111, of the first slot 111 in the Z direction has a spacing $h2$ greater than a spacing $h3$ of the constricted segment 1111 in the Z

direction.

[0080] The constricted segment 1111 is equivalent to narrowing, in the Z direction, the first slot 111 with a specific length in the Y direction. In this way, the constricted segment 1111 may be equivalent to a capacitor that allows the antenna structure 100 to achieve effect of capacitive loading, so as to adjust the resonance frequency of 5 GHz. In this case, the antenna structure 100 can excite the resonance frequency of 2.4 GHz and the resonance frequency of 5 GHz, so that the antenna structure 100 can be used as a dual-band antenna, thereby improving performance and applicability of the antenna structure 100.

[0081] In some embodiments, the spacing $h3$ of the constricted segment 1111 in the Z direction may be greater than or equal to 0.5 mm. The spacing $h2$ of the portion, other than the constricted segment 1111, of the first slot 111 in the Z direction may be less than or equal to 3 mm, that is, $0.5 \text{ mm} \leq h3 \leq h2 \leq 3 \text{ mm}$. For example, $h3=0.5 \text{ mm}$, $h2=3 \text{ mm}$; or $h3=1 \text{ mm}$, $h2=3 \text{ mm}$. Specific values of $h2$ and $h3$ are not further limited in this embodiment.

[0082] It should be noted that a length of the constricted segment 1111 in the Y direction may be specifically set based on a specific situation, and this is not further limited in this embodiment of this application. In addition, a quantity of constricted segments 1111 may be one, two, three, or more, and may be specifically set based on a specific situation. The quantity of the constricted segments 1111 is not further limited in this embodiment of this application.

[0083] The constricted segment 1111 is provided, so that a length of the first slot 111 in the Z direction may be extended at a corner of the constricted segment 1111. When the total length of the inner border of the first slot 111 remains unchanged, extending the length of the first slot 111 in the Z direction can reduce a length of the first slot 111 in the Y direction, to reduce the length of the first radiator 110 in the Y direction, thereby reducing a size of the antenna structure 100. This facilitates miniaturization of the antenna structure 100.

[0084] In some embodiments, as shown in FIG. 10, the second radiator 120 may further include a third extension segment 1213, and the third extension segment 1213 extends from a first end 120a of the second radiator in a direction away from the second radiator 120. The second radiator 120 may further include a fourth extension segment 1223, and the fourth extension segment 1223 extends from a second end 120b of the second radiator in a direction away from the second radiator 120.

[0085] For example, a size of the antenna structure 100 may be $20 \text{ mm} \times 28 \text{ mm} \times 15 \text{ mm}$. A size of the second radiator 120 in the X direction is 20 mm, a size of the first radiator 110 in the Y direction is 28 mm, and a size of the first radiator 110 in the Z direction is 15 mm. Sizes of the third extension segment 1213 and the fourth extension segment 1223 in the X direction may be 5 mm. In this way, a conductive loop structure on the antenna structure 100 may be a square structure with a side length of 15 mm,

that is, a circumference of the loop structure is 1/2 of a wavelength of a resonance frequency of 2.4 GHz, to excite the resonance frequency of 2.4 GHz. In addition, the loop structure is a symmetric structure, and currents distributed in the X direction and the Z direction are relatively uniform, so that an electromagnetic signal can be uniformly radiated in all directions, thereby improving radiation pattern performance of the antenna structure 100 (as shown in FIG. 12). In this way, the antenna structure 100 can radiate a spherical quasi-isotropic radiation pattern. For example, a spherical ellipticity is approximately 3.28 dB at 2.4 GHz (a maximum gain value is approximately 1.72 dBi and a minimum gain value is approximately -1.56 dBi).

[0086] A bandwidth of the 5 GHz frequency band may be increased by disposing the third extension segment 1213 and the fourth extension segment 1223. As shown in FIG. 11, after a radio frequency signal of the 2.4 GHz frequency band is fed into a feed point 130, currents are mainly distributed on the conductive loop structure of the antenna structure 100. At the second slot 123, a first bent portion 1212 and a second bent portion 1222 may be coupled and connected. Currents on the third extension segment 1213 and the fourth extension segment 1223 are very small. It may be considered that both the third extension segment 1213 and the fourth extension segment 1223 are open circuits. Currents on the antenna structure 100 are mainly distributed in a first extension segment 1211, the first bent portion 1212, the second bent portion 1222, a second extension segment 1221, and a part that is of the first radiator 110 and that is located between the first extension segment 1211 and the second extension segment 1221 of the antenna structure 100.

[0087] It should be noted that a solid line with an arrow in the diagram of current distribution indicates a current direction.

[0088] As shown in FIG. 13, after a radio frequency signal of the 5 GHz frequency band is fed into the feed point 130, currents are mainly distributed around the first slot 111, and in some structures of the first extension segment 1211, the second extension segment 1221, the third extension segment 1213, and the fourth extension segment 1223. In this way, the currents on the antenna structure 100 may be distributed in different directions, for example, the X direction and the Z direction (currents in the Y direction are opposite and close to each other, and may be considered to cancel each other). Therefore, the signal radiated by the antenna structure 100 may be relatively uniform in all directions, thereby improving radiation pattern performance of the antenna structure 100 (as shown in FIG. 14). In this way, the antenna structure 100 can radiate a spherical quasi-isotropic radiation pattern. For example, a spherical ellipticity is approximately 6.51 dB at 5 GHz (a maximum gain value is approximately 2.98 dBi, and a minimum gain value is approximately -3.53 dBi).

[0089] As shown in FIG. 15, the antenna structure 100

in this embodiment of this application can cover dual-band Wi-Fi of 2.4 GHz and 5 GHz. Moreover, in the two frequency bands, bandwidths are relatively wide, standing waves are good, and a resonance depth is relatively large (for example, both are less than -20 dB). In addition, the signal radiated by the antenna structure 100 is relatively uniform in all directions. Therefore, radiation efficiency and applicability of the antenna structure 100 can be improved.

[0090] The antenna structure 100 provided in this embodiment of this application is simple in structure, easy to feed, and convenient for engineering application.

[0091] It should be noted that, in some embodiments, as shown in FIG. 16, a feed point 130 may alternatively be provided at another position of the first slot 111, for example, may be provided at a middle part of the first slot 111. For example, a constricted segment 1111 is located at the middle part of the first slot 111, and the feed point 130 is provided at a middle part of the constricted segment 1111. A lumped device (not shown in the figure) may be loaded at the feed point 130, to ensure dual-band effect of the antenna structure 100. The lumped device may be a device like a capacitor or an inductor. In this embodiment, the lumped device is not further limited.

[0092] As shown in FIG. 17, the antenna structure 100 may cover two frequency bands of 2.4 GHz and 5 GHz. Moreover, in the two frequency bands, bandwidths are relatively wide, standing waves are good, and a resonance depth is relatively large (for example, both are less than -20 dB). Radiation patterns of the antenna structure 100 are shown in FIG. 18 and FIG. 19. A spherical ellipticity of the radiation pattern at the resonance frequency of 2.4 GHz is approximately 3.35 dB (a maximum gain value is approximately 1.73 dBi, and a minimum gain value is approximately -1.62 dBi), and a spherical ellipticity of the radiation pattern at the resonance frequency of 5 GHz is approximately 5.39 dB (a maximum gain value is approximately 2.79 dBi, and a minimum gain value is approximately -2.6 dBi).

[0093] As shown in FIG. 18 and FIG. 19, a signal radiated by the antenna structure 100 is relatively uniform in all directions. Therefore, radiation efficiency and applicability of the antenna structure 100 can be improved. In addition, when the antenna structure 100 is used in a product like a CPE, a circuit board may pass through the second slot 123, achieving effect of covering two sides of the circuit board by crossing the circuit board. This further ensures that the product like the CPE can radiate a spherical quasi-isotropic radiation pattern, to improve performance of the product like the CPE.

[0094] In some other embodiments, the antenna structure 100 may alternatively be arranged as a structure of another shape.

[0095] As shown in FIG. 20, in an embodiment, an antenna structure 100 includes a first radiator 110 and a second radiator 120. A first slot 111 is provided on the first radiator 110, and the first slot 111 extends along a Y

direction. The second radiator 120 is perpendicular to the first radiator 110. A second slot 123 is provided in a Z direction at an end that is of the second radiator 120 and that is away from the first radiator 110.

[0096] For example, the second radiator 120 is located at one end of the first radiator 110 in the Y direction, and one end of the first slot 111 in the Y direction is closed. For example, one end that is of the first slot 111 and that is close to the second radiator 120 in the Y direction is open, and one end that is of the first slot 111 and that is away from the second radiator 120 in the Y direction is closed. Alternatively, one end that is of the first slot 111 and that is close to the second radiator 120 in the Y direction is closed, and one end that is of the first slot 111 and that is away from the second radiator 120 in the Y direction is open. In this embodiment, an example in which the end that is of the first slot 111 and that is close to the second radiator 120 in the Y direction is open, and the end that is of the first slot 111 and that is away from the second radiator 120 in the Y direction is closed is used for description.

[0097] In some embodiments, a total length of an inner border of the first slot 111 may be $\lambda/2$, and a length of the first radiator 110 in the Y direction is at least $\lambda/4$, where λ is a wavelength corresponding to a center frequency of a resonance frequency of 5 GHz. In this way, the first slot 111 of the antenna structure 100 can excite the resonance frequency of 5 GHz.

[0098] The second radiator 120 is disposed at one end of the first radiator 110, and one end of the first slot 111 is disposed in an open state. In this way, a length of the first radiator 110 in the Y direction can be reduced. For example, in comparison with the antenna structure 100 shown in FIG. 10, in the antenna structure 100 in FIG. 20, a size of the first radiator 110 in the Y direction is reduced by approximately 1/2. This can reduce a size of the entire antenna structure 100, thereby reducing installation space of the antenna structure 100 and facilitating assembly.

[0099] For example, the size of the antenna structure 100 may be 14 mm×13 mm×15 mm. For example, the size of the first radiator 110 in the Y direction is 14 mm, a size of the first radiator 110 in the Z direction is 13 mm, and a size of the second radiator 120 in the X direction is 15 mm. Certainly, in another embodiment, the antenna structure 100 may be in another size. In this embodiment of this application, the size of the antenna is not further limited.

[0100] As shown in FIG. 20, a first end 120a of the second radiator is electrically connected to one end (a side of a third end of the first radiator 110) of the first radiator 110 in the Z direction. A second end 120b of the second radiator is electrically connected to the other end (a side of a fourth end of the first radiator 110) of the first radiator 110 in the Z direction. The second radiator 120 and a part that is of the first radiator 110 and that is located between the first end 120a and the second end 120b of the second radiator may form a conductive loop struc-

ture. A feed point 130 is provided on one side of the first slot 111. Certainly, in another embodiment, the feed point 130 may alternatively be located at another position. In this embodiment of this application, a position of the feed point 130 is not further limited. In addition, a part that is of the first slot 111 and that is close to an open end is a constricted segment 1111. In this embodiment of this application, a length of the constricted segment 1111 in the Y direction is not further limited.

[0101] As shown in FIG. 21, after a radio frequency signal of the 2.4 GHz frequency band is fed into the feed point 130, currents are mainly distributed on the conductive loop structure of the antenna structure 100. At the second slot 123, a first bent portion 1212 and a second bent portion 1222 may be coupled and connected. Currents on the antenna structure 100 are mainly distributed in a first extension segment 1211, the first bent portion 1212, the second bent portion 1222, a second extension segment 1221, and a part that is of the first radiator 110 and that is located between the first extension segment 1211 and the second extension segment 1221 of the antenna structure 100. Currents on the loop structure are distributed in the X direction and the Y direction, so that a signal radiated by the antenna structure 100 may be relatively uniform in all directions, thereby improving radiation pattern performance of the antenna structure 100 (as shown in FIG. 22). In this way, the antenna structure 100 can radiate a spherical quasi-isotropic radiation pattern. For example, a spherical ellipticity is approximately 3.12 dB at 2.4 GHz (a maximum gain value is approximately 1.51 dBi and a minimum gain value is approximately -1.61 dBi).

[0102] As shown in FIG. 23, after a radio frequency signal of the 5 GHz frequency band is fed into the feed point 130, currents are mainly distributed around the first slot 111, and in some structures of the first extension segment 1211 and the second extension segment 1221. In this way, the currents on the antenna structure 100 may be distributed in different directions, for example, the X direction and the Z direction (currents in the Y direction are opposite and close to each other, and may be considered to cancel each other). Therefore, the signal radiated by the antenna structure 100 may be relatively uniform in all directions, thereby improving radiation pattern performance of the antenna structure 100 (as shown in FIG. 24). In this way, the antenna structure 100 can radiate a spherical quasi-isotropic radiation pattern. For example, a spherical ellipticity is approximately 6.99 dB at 5 GHz (a maximum gain value is approximately 3.28 dBi, and a minimum gain value is approximately -3.71 dBi).

[0103] As shown in FIG. 25, the antenna structure 100 in this embodiment of this application can cover dual-band Wi-Fi of 2.4 GHz and 5 GHz. Moreover, in the two frequency bands, bandwidths are relatively wide, standing waves are good, and a resonance depth is relatively large (for example, both are less than -20 dB). In addition, the signal radiated by the antenna structure 100 is rela-

tively uniform in all directions. Therefore, radiation efficiency and applicability of the antenna structure 100 can be improved.

[0104] In comparison with the embodiment in FIG. 10, the antenna structure 100 provided in this embodiment of this application has a smaller size, easier to assemble, and is more applicable. When the antenna structure 100 is used in a product like a CPE, a circuit board may pass through the second slot 123, achieving effect of covering two sides of the circuit board by crossing the circuit board. This further ensures that the product like the CPE can radiate a spherical quasi-isotropic radiation pattern, to improve performance of the product like the CPE.

[0105] The antenna structures 100 in the foregoing embodiments are of a three-dimensional structure. Certainly, in some other embodiments, an antenna structure 100 may alternatively be a planar structure. As shown in FIG. 26, the antenna structure 100 includes a first radiator 110 and a second radiator 120. A first slot 111 is provided on the first radiator 110, and the first slot 111 extends along a Y direction. The first radiator 110 and the second radiator 120 are both located on a same plane (for example, a ZoY plane). In addition, the second radiator 120 is located at a first end 110a of the first radiator, and a second slot 123 is provided in a Z direction at an end that is of the second radiator 120 and that is away from the first radiator 110.

[0106] For example, a size of the antenna structure 100 may be 23 mm×17 mm. For example, a size of the antenna structure 100 in the Y direction is 23 mm, and a size of the antenna structure 100 in the Z direction is 17 mm. Certainly, in another embodiment, the antenna structure 100 may be in another size. In this embodiment of this application, the size of the antenna is not further limited.

[0107] For example, one end of the first slot 111 in the Y direction is closed. For example, one end that is of the first slot 111 and that is close to the second radiator 120 in the Y direction is closed, and one end that is of the first slot 111 and that is away from the second radiator 120 in the Y direction is open. Certainly, in another embodiment, one end that is of the first slot 111 and that is close to the second radiator 120 in the Y direction may be open, and one end that is of the first slot 111 and that is away from the second radiator 120 in the Y direction may be closed.

[0108] The end that is of the first slot 111 and that is close to the second radiator 120 in the Y direction is closed, and the end that is of the first slot 111 and that is away from the second radiator 120 in the Y direction is open. In this way, there is no other radiator at the open end of the first slot 111. Therefore, interference caused by another radiator to the first radiator 110 can be reduced, thereby improving radiation efficiency of the antenna structure 100.

[0109] In some embodiments, a total length of an inner border of the first slot 111 may be $\lambda/2$, and a length of the first radiator 110 in the Y direction is at least $\lambda/4$, where λ is a wavelength corresponding to a center frequency of a

resonance frequency of 5 GHz. In this way, the first slot 111 of the antenna structure 100 can excite the resonance frequency of 5 GHz.

[0110] As shown in FIG. 26, a first end 120a of the second radiator is electrically connected to a top end of the first end 110a of the first radiator. A second end 120b of the second radiator is electrically connected to a bottom end of the first end 110a of the first radiator. The second radiator 120 and a part that is of the first radiator 110 and that is located between the first end 120a and the second end 120b of the second radiator may form a conductive loop structure. A feed point 130 is provided on a side that is of the first slot 111 and that is close to the closed end.

[0111] As shown in FIG. 27, after a radio frequency signal of the 2.4 GHz frequency band is fed into the feed point 130, currents are mainly distributed on the conductive loop structure of the antenna structure 100. At the second slot 123, a first bent portion 1212 and a second bent portion 1222 may be coupled and connected. Currents on the antenna structure 100 are mainly distributed in a first extension segment 1211, the first bent portion 1212, the second bent portion 1222, a second extension segment 1221, and the part that is of the first radiator 110 and that is located between the first extension segment 1211 and the second extension segment 1221 of the antenna structure 100. Currents on the loop structure are distributed in the X direction and the Y direction, so that the signal radiated by the antenna structure 100 may be relatively uniform in all directions, thereby improving radiation pattern performance of the antenna structure 100 (as shown in FIG. 28). In this way, the antenna structure 100 can radiate a spherical quasi-isotropic radiation pattern. For example, a spherical ellipticity is approximately 3.38 dB at 2.4 GHz (a maximum gain value is approximately 1.36 dBi and a minimum gain value is approximately -2.02 dBi).

[0112] As shown in FIG. 29, after a radio frequency signal of the 5 GHz frequency band is fed into the feed point 130, currents are mainly distributed around the first slot 111, and in some structures of the first extension segment 1211 and the second extension segment 1221. In this way, the currents on the antenna structure 100 may be distributed in different directions, for example, the X direction and the Z direction (currents in the Y direction are opposite and close to each other, and may be considered to cancel each other). Therefore, the signal radiated by the antenna structure 100 may be relatively uniform in all directions, thereby improving radiation pattern performance of the antenna structure 100 (as shown in FIG. 30). In this way, the antenna structure 100 can radiate a spherical quasi-isotropic radiation pattern. For example, a spherical ellipticity is approximately 5.39 dB at 5 GHz (a maximum gain value is approximately 1.53 dBi, and a minimum gain value is approximately -3.86 dBi).

[0113] As shown in FIG. 31, the antenna structure 100 in this embodiment of this application can cover dual-

band Wi-Fi of 2.4 GHz and 5 GHz. Moreover, in the two frequency bands, bandwidths are relatively wide, standing waves are good, and a resonance depth is relatively large (for example, both are less than -15 dB). In addition, the signal radiated by the antenna structure 100 is relatively uniform in all directions. Therefore, radiation efficiency and applicability of the antenna structure 100 can be improved. In comparison with the embodiment in FIG. 10, the antenna structure 100 provided in this embodiment of this application has a smaller size, so that the antenna structure 100 can be further simplified, thereby reducing costs.

[0114] It should be noted that, in this embodiment, the feed point 130 may alternatively be provided at another position, for example, a position close to the center of the first slot 111, or a position close to the other end of the first slot 111. The position of the feed point 130 is not further limited in this embodiment of this application.

[0115] In this embodiment, the first radiator 110 may be of a metal planar structure, and the first slot 111 may be formed through etching. Certainly, in another embodiment, the first slot 111 may alternatively be formed in another manner. In this embodiment, a manner of forming the first slot 111 is not further limited. In addition, a connection manner between the first radiator 110 and the second radiator 120 is not further limited, provided that an electrical connection can be implemented.

[0116] The antenna structure 100 in this embodiment of this application may excite a dual-band Wi-Fi signal of 2.4 GHz and 5 GHz, and the antenna structure 100 can radiate a spherical quasi-isotropic radiation pattern on both frequency bands, thereby improving performance of an electronic device to which the antenna structure 100 is applied. In addition, the antenna structure 100 is simple in structure, easy to feed, and convenient for engineering application, and has a relatively small size to facilitate assembly. When the antenna structure 100 is used in a product like a CPE, a circuit board may pass through the second slot 123, achieving effect of covering two sides of the circuit board by crossing the circuit board. This further ensures that the product like the CPE can radiate a spherical quasi-isotropic radiation pattern, to improve performance of the product like the CPE.

[0117] It should be noted that the antenna structure 100 provided in this embodiment of this application may not only be used as a Wi-Fi antenna, but is also applicable to any scenario in which an isotropic radiation pattern needs to be used. Specifically, a design may be modified based on a specific application scenario, as long as the antenna structure 100 includes the conductive loop structure, and the loop structure is provided with an open slot (the second slot 123), to be specific, the antenna structure 100 is provided with an open loop antenna, and the antenna structure 100 is provided with a slot with at least one end closed, that is, the antenna structure 100 is provided with a slot antenna. Such a design falls within the protection scope of the technical solutions of this application. In this embodiment of this application, sizes

of the antenna structure 100, the first slot 111, and the second slot 123 are not further limited in this embodiment of this application, an included angle between the first radiator 110 and the second radiator 120 is not further limited, and the position of the feed point 130 is not further limited either.

[0118] According to a second aspect, as shown in FIG. 32, an embodiment of this application provides an electronic device, including at least a circuit board 200 and the foregoing antenna structure 100. In some embodiments, a partial structure of the circuit board 200 passes through a second slot 123 (not shown in the figure) of the antenna structure 100. As shown in FIG. 33, a radiation pattern of the antenna structure 100 is slightly affected by the PCB board, and a good spherical isotropic radiation pattern can still be obtained on the PCB. A spherical ellipticity at a resonance frequency of 2.4 GHz is approximately 3.15 dB (a maximum gain value is approximately 1.78 dBi, and a minimum gain value is approximately -1.37 dBi). As shown in FIG. 34, a spherical ellipticity at a resonance frequency of 5 GHz is approximately 6.27 dB (a maximum gain value is approximately 2.84 dBi and a minimum gain value is approximately -3.43 dBi).

[0119] Because a magnetic field of the radiation pattern of the antenna structure 100 provided in the first aspect is parallel to the PCB, it can be learned from an electromagnetic field interface condition that the PCB basically does not affect a radiation characteristic of the antenna structure 100. In other words, the antenna structure 100 provided in the first aspect has a good cross-PCB radiation characteristic. Therefore, when the antenna structure 100 is used in a product like a CPE, coverage performance of the product like the CPE can be improved.

[0120] The antenna structure 100 in the first aspect is disposed on the electronic device, so that a signal radiated by the electronic device may be relatively uniform in all directions, thereby improving performance of the electronic device. The circuit board 200 is disposed in the second slot 123 of the antenna structure 100, achieving effect of covering two sides of the circuit board 200 by crossing the circuit board 200. This further ensures that the electronic device can radiate a spherical quasi-isotropic radiation pattern, to improve performance of the electronic device.

[0121] The technical solutions provided in embodiments of this application are applicable to an electronic device that uses one or more of the following communication technologies: a Bluetooth (Bluetooth, BT) communication technology, a global positioning system (global positioning system, GPS) communication technology, a wireless fidelity (wireless fidelity, Wi-Fi) communication technology, a global system for mobile communications (global system for mobile communications, GSM) communication technology, a wideband code division multiple access (wideband code division multiple access, WCDMA) communication technology, a long term evolution (long term evolution, LTE) communication

technology, a 5G communication technology, and other future communication technologies. The electronic device in embodiments of this application may be a CPE product, a router, a mobile phone, a tablet computer, a notebook computer, a smart household, a smart band, a smart watch, a smart helmet, smart glasses, or the like. Alternatively, the electronic device may be a handheld device that has a wireless communication function, a computing device, another processing device connected to a wireless modem, a vehicle-mounted device, an electronic device in a 5G network, an electronic device in a future evolved public land mobile network (public land mobile network, PLMN), or the like. This is not limited in embodiments of this application.

[0122] It should be noted that, in this embodiment, both the first radiator and the second radiator are radiators of the antenna. The radiator is an apparatus configured to receive/send electromagnetic wave radiation in an antenna. In some cases, an "antenna" is a radiator in a narrow sense. The radiator converts guided wave energy from a transmitter into a radio wave, or converts a radio wave into guided wave energy to radiate and receive the radio wave. A modulated high-frequency current energy (or guided wave energy) generated by the transmitter is transmitted to a transmit radiator through a feeder. The radiator converts the modulated high-frequency current energy into specific polarized electromagnetic wave energy for radiation toward a required direction. A receive radiator converts specific polarized electromagnetic wave energy from a specific direction in space into modulated high-frequency current energy, and transmits the modulated high-frequency current energy to an input end of a receiver through the feeder.

[0123] The radiator may be a conductor in a specific shape and size, for example, a linear conductor or a sheet conductor. A specific shape is not limited in this application. In some embodiments, a sheet radiator may be implemented by using a conductive/metal sheet, for example, a copper sheet. In an embodiment, a sheet radiator may be implemented by using a conductive coating, for example, a silver paste antenna. The sheet radiator may be in the shape of a circle, a rectangle, a loop, or the like. A specific shape is not limited in this application. In addition, the radiator may further include a slot or a slit formed on the conductor. For example, in this embodiment, the second slot is a slot on the radiator. In some embodiments, the slot may be in the shape of a long strip. In some embodiments, a radio frequency electromagnetic field is excited on the slot, and an electromagnetic wave is radiated to space.

[0124] In some embodiments, the circuit board may be a printed circuit board (printed circuit board, PCB), or elements that are separated and electrically insulated by a dielectric layer or an insulation layer like glass fiber or polymer.

[0125] It should be noted that a resonance frequency is also referred to as a resonant frequency. The resonance frequency may have a frequency range, for example, a

frequency range in which resonance occurs. The resonance frequency may be a frequency range in which a return loss characteristic is less than -6 dB. A frequency corresponding to a strongest resonance point is a center frequency or a point frequency. A return loss characteristic of the center frequency may be less than -20 dB.

[0126] Resonance frequency band: A range of a resonance frequency is the resonance frequency band. A return loss characteristic of any frequency in the resonance frequency band may be less than -6 dB or -5 dB.

[0127] 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" that may be understood as physical contact and electrical conduction of components, and may also be understood as a form in which different components in a line structure are connected through physical lines that can transmit an electrical signal, such as a printed circuit board (printed circuit board, PCB) copper foil or a conducting wire. The "indirect coupling" may be understood as electrical conduction of two conductors through space or in 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 an equivalent capacitor through coupling in a gap between two spaced conductive members.

[0128] In the descriptions of embodiments of this application, it should be noted that, unless otherwise clearly specified and limited, the terms "mount", "connect to", and "connection" should be understood in a broad sense. For example, the connection may be a fixed connection, may be an indirect connection by using an intermediate medium, or may be an internal connection between two elements or an interaction relationship between two elements. A person of ordinary skill in the art may understand specific meanings of the foregoing terms in embodiments of this application based on a specific situation.

[0129] In the specification, claims, and accompanying drawings of embodiments of this application, the terms "first", "second", "third", "fourth", and the like (if present) are intended to distinguish between similar objects but do not necessarily indicate a specific order or sequence.

Claims

1. An antenna structure, comprising a first radiator and a second radiator, wherein

a first slot extending along a first direction is provided on the first radiator, at least one end of the first slot in the first direction is closed, and a feed point is provided in the first slot;
a second slot is provided on the second radiator along a second direction, two ends of the second slot are open, and the second direction is per-

- pendicular to the first direction; and
a first end of the second radiator is electrically connected to one end of the first radiator in the second direction, a second end of the second radiator is connected to the other end of the first radiator in the second direction, and the second radiator and the first radiator form a conductive loop structure.
2. The antenna structure according to claim 1, wherein at least one constricted segment is provided in the first slot along the first direction; and a portion, other than the constricted segment, of the first slot has a spacing in the second direction greater than a spacing of the constricted segment in the second direction.
 3. The antenna structure according to claim 1 or 2, wherein the second radiator comprises a first radiating stub and a second radiating stub, and the first radiator is located between the first radiating stub and the second radiating stub; and one end of the first radiating stub is electrically connected to one end of the first radiator in the second direction, the second slot is provided between the other end of the first radiating stub and one end of the second radiating stub, and the other end of the second radiating stub is electrically connected to the other end of the first radiator in the second direction.
 4. The antenna structure according to claim 3, wherein the first radiating stub comprises a first extension segment and a first bent portion, wherein one end of the first extension segment is electrically connected to one end of the first radiator in the second direction; and the other end of the first extension segment extends away from the first radiator and is connected to one end of the first bent portion, and the other end of the first bent portion extends toward the second radiating stub in the second direction.
 5. The antenna structure according to claim 4, wherein the second radiating stub comprises a second extension segment and a second bent portion, wherein one end of the second extension segment is electrically connected to the other end of the first radiator in the second direction; the other end of the second extension segment extends away from the first radiator and is connected to one end of the second bent portion, and the other end of the second bent portion extends toward the first radiating stub in the second direction; and the second slot is provided between the other end of the first bent portion and the other end of the second bent portion.
 6. The antenna structure according to any one of claims 1 to 5, wherein the antenna structure is a three-dimensional structure; and the second radiator and a plane on which the first radiator is located are disposed at an included angle, and the included angle between the second radiator and the plane on which the first radiator is located is greater than or equal to 0 and less than or equal to 90 degrees.
 7. The antenna structure according to claim 6, wherein two ends of the first slot in the first direction are closed, and a total length of an inner border of the first slot is λ ; and a length of the first radiator in the first direction is at least $\lambda/2$, wherein λ is a wavelength corresponding to a center frequency of a resonance frequency of 5 GHz.
 8. The antenna structure according to claim 6 or 7, wherein the second radiator is located at a middle part of the first radiator in the first direction.
 9. The antenna structure according to claim 6, wherein the second radiator is located at one end of the first radiator in the first direction; and one end of the first slot in the first direction is closed, a total length of an inner border of the first slot is $\lambda/2$, and a length of the first radiator in the first direction is at least $\lambda/4$, wherein λ is a wavelength corresponding to a center frequency of a resonance frequency of 5 GHz.
 10. The antenna structure according to claim 9, wherein one end that is of the first slot and that is close to the second radiator in the first direction is open, and one end that is of the first slot and that is away from the second radiator in the first direction is closed; or one end that is of the first slot and that is close to the second radiator in the first direction is closed, and one end that is of the first slot and that is away from the second radiator in the first direction is open.
 11. The antenna structure according to any one of claims 6 to 10, wherein the second radiator further comprises a third extension segment, and the third extension segment extends from the first end of the second radiator in a direction away from the second radiator.
 12. The antenna structure according to claim 11, wherein the second radiator further comprises a fourth extension segment, and the fourth extension segment extends from the second end of the second

radiator in a direction away from the second radiator.

13. The antenna structure according to any one of claims 1 to 5, wherein the antenna structure is a planar structure, and the second radiator is located at one end of the first radiator in the first direction. 5
14. The antenna structure according to claim 13, wherein a total length of an inner border of the first slot is $\lambda/2$, and a length of the first radiator in the first direction is at least $\lambda/4$, wherein λ is a wavelength corresponding to a center frequency of a resonance frequency of 5 GHz; and one end that is of the first slot and that is close to the second radiator in the first direction is closed, and one end that is of the first slot and that is away from the second radiator in the first direction is open. 10 15
15. The antenna structure according to any one of claims 1 to 14, wherein the antenna structure is a symmetric structure. 20
16. An electronic device, comprising at least a circuit board and the antenna structure according to any one of claims 1 to 15. 25
17. The electronic device according to claim 16, wherein a partial structure of the circuit board passes through a second slot of the antenna structure. 30

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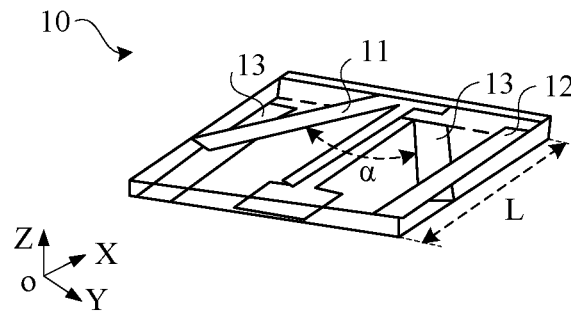


FIG. 1

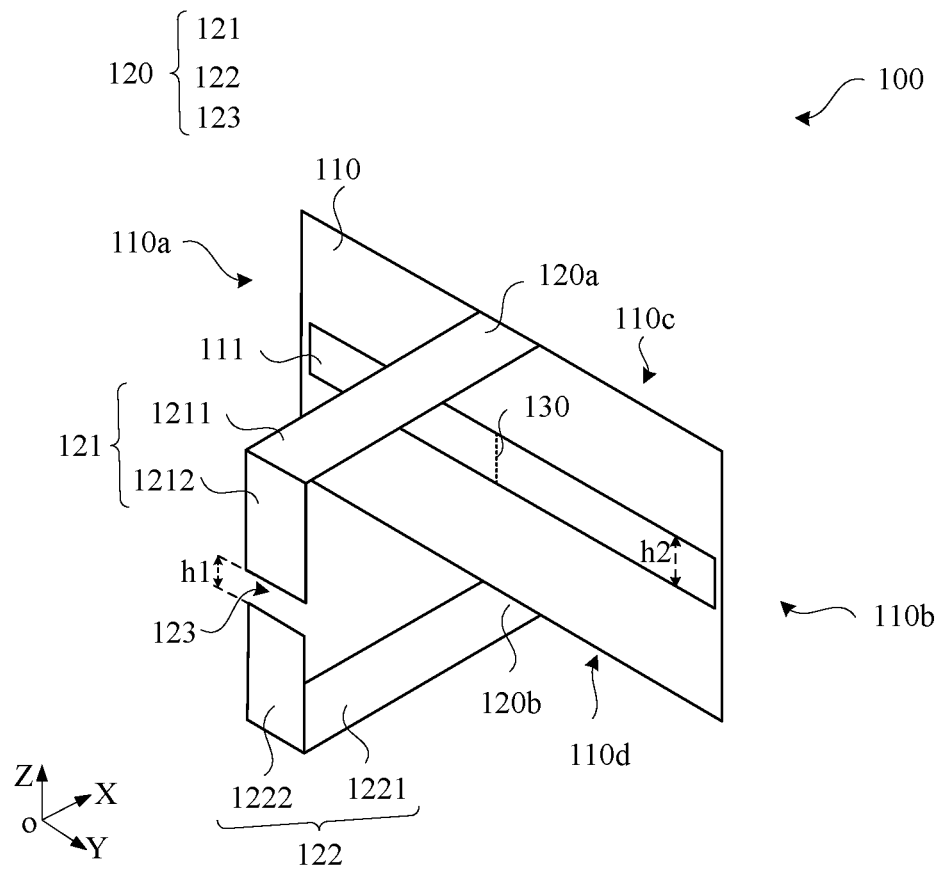


FIG. 2

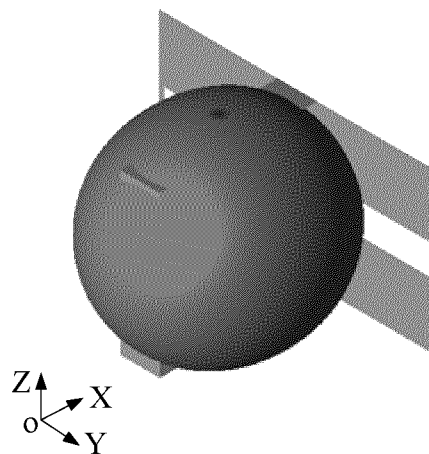


FIG. 3

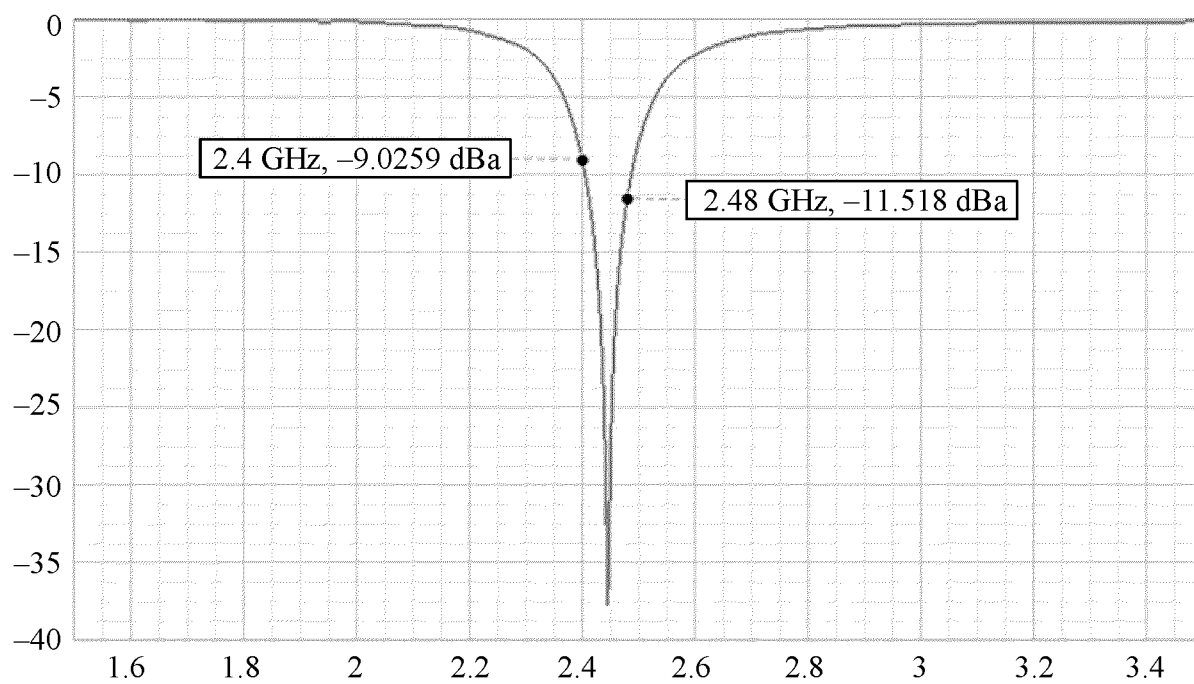


FIG. 4

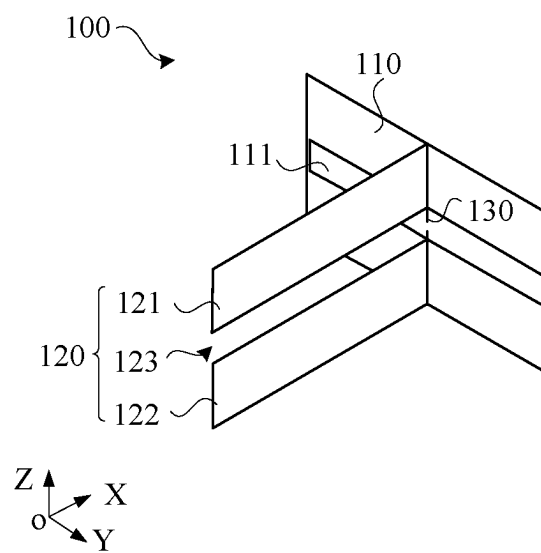


FIG. 5

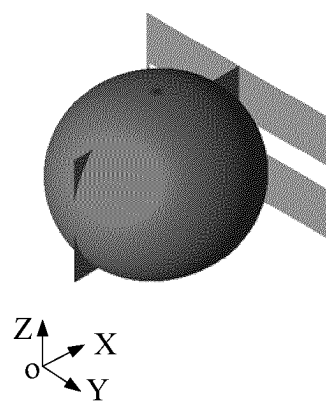


FIG. 6

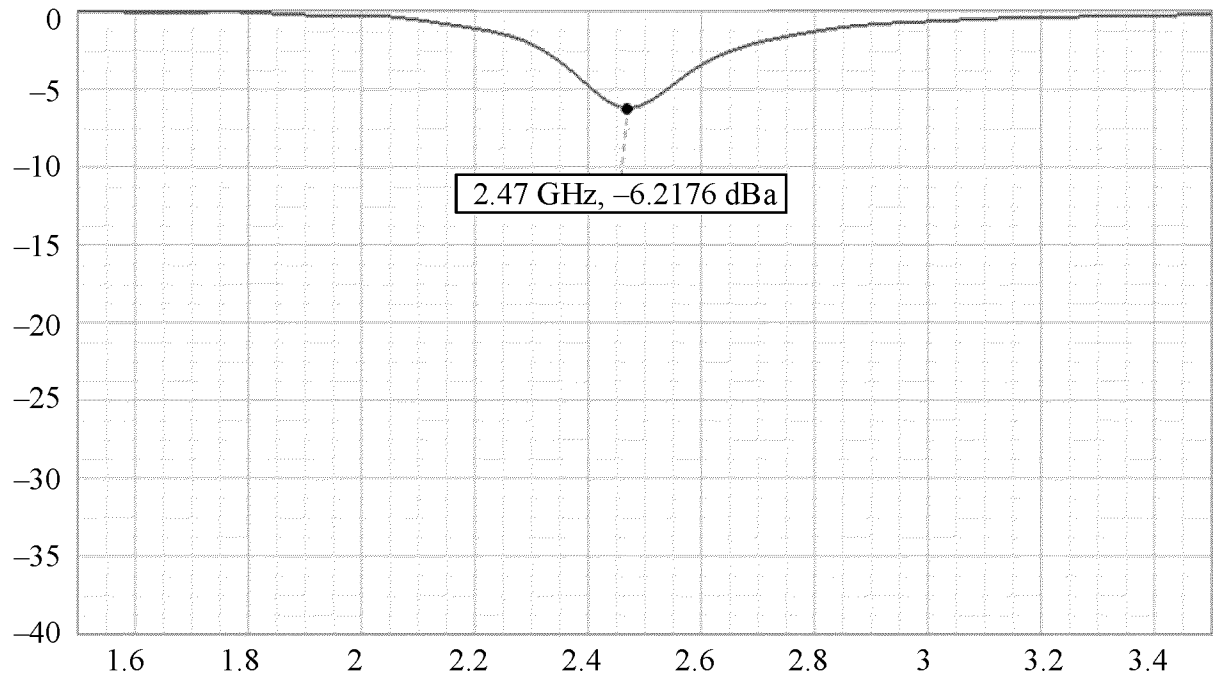


FIG. 7

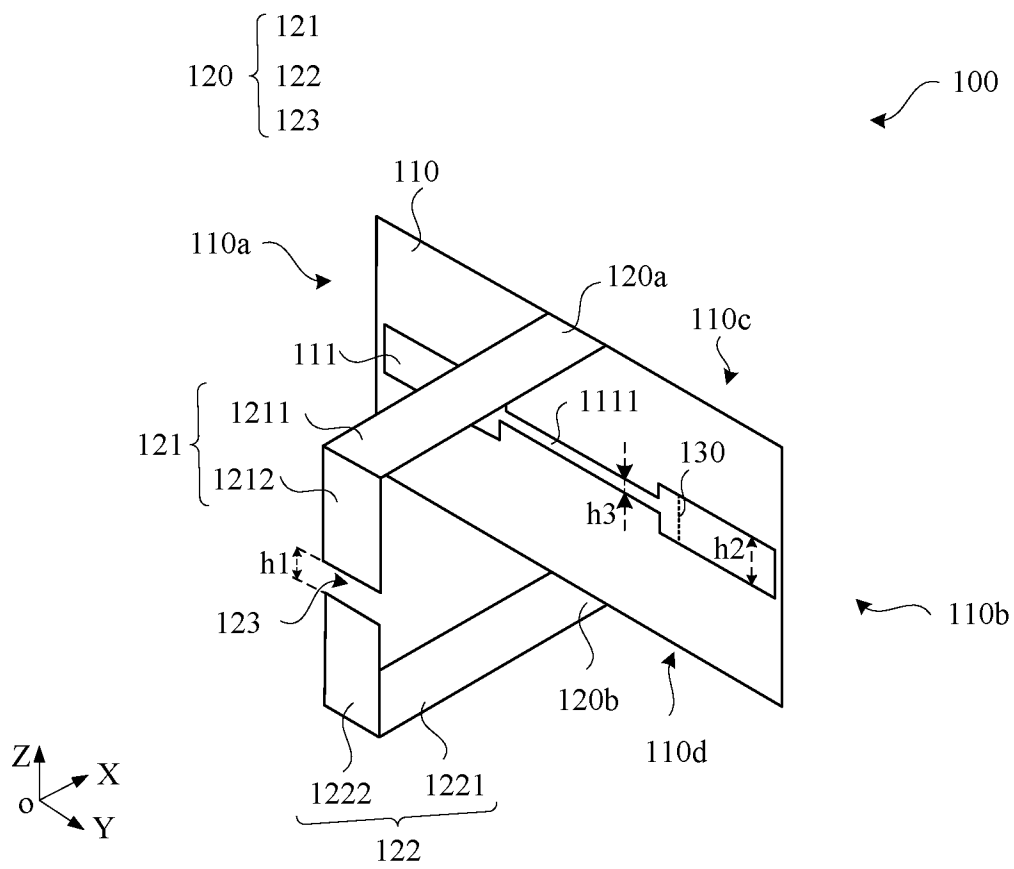


FIG. 8

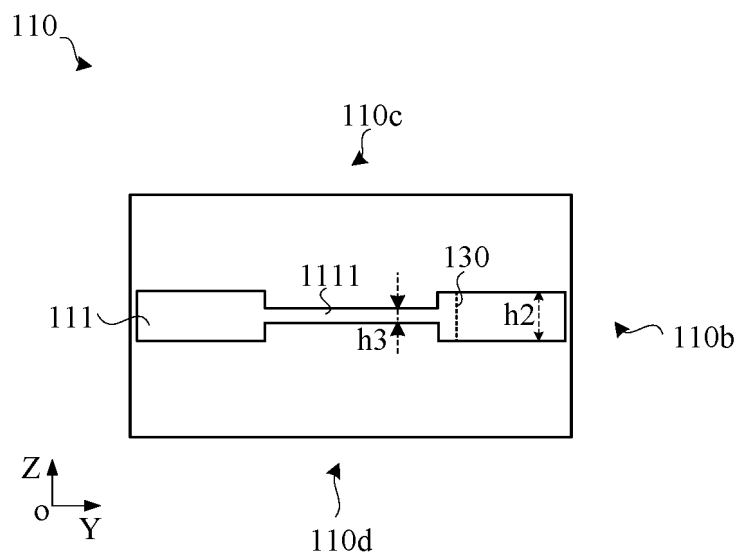


FIG. 9

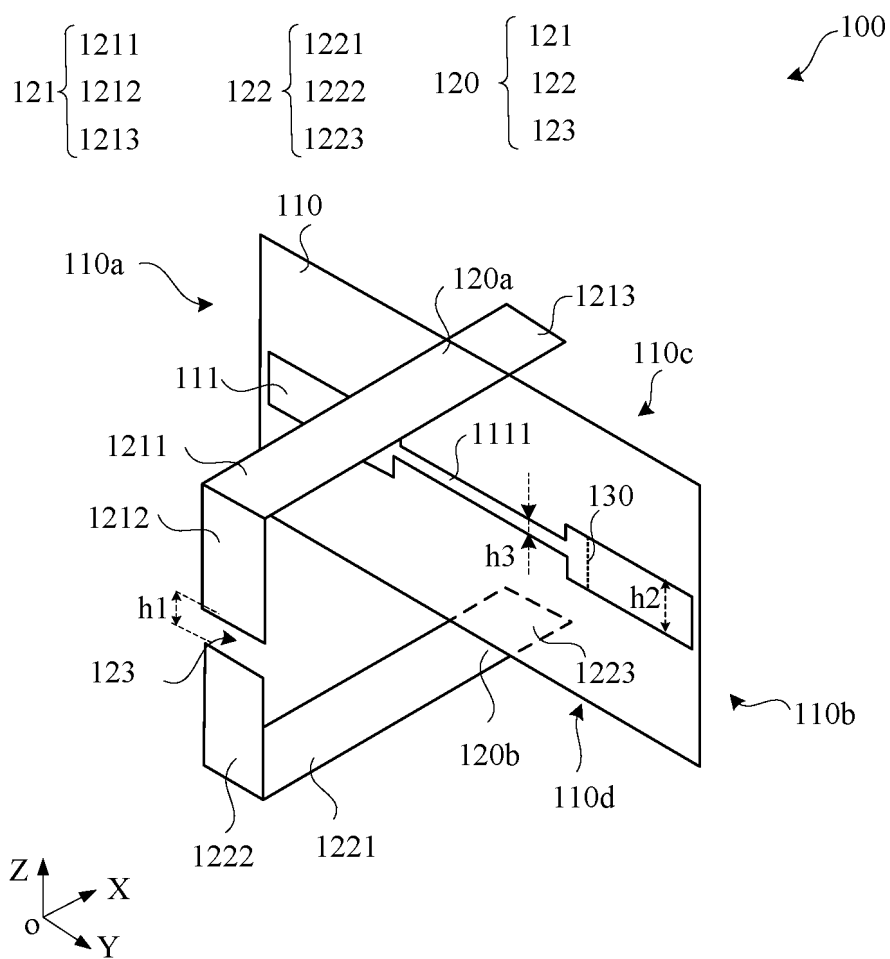


FIG. 10

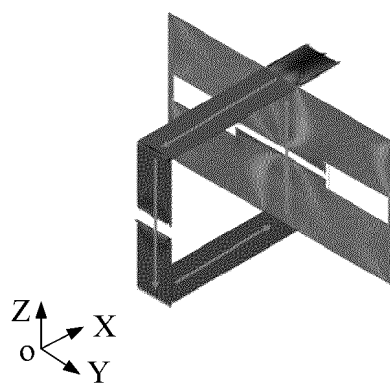


FIG. 11

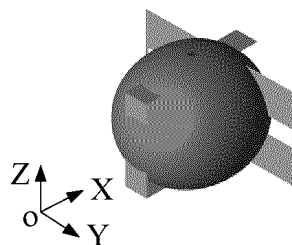


FIG. 12

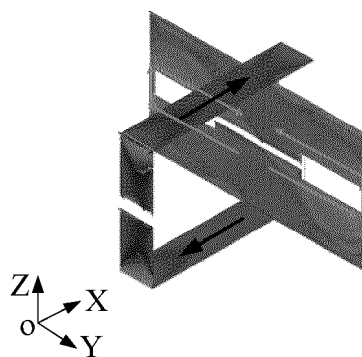


FIG. 13

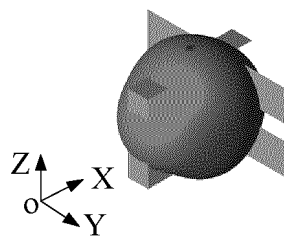


FIG. 14

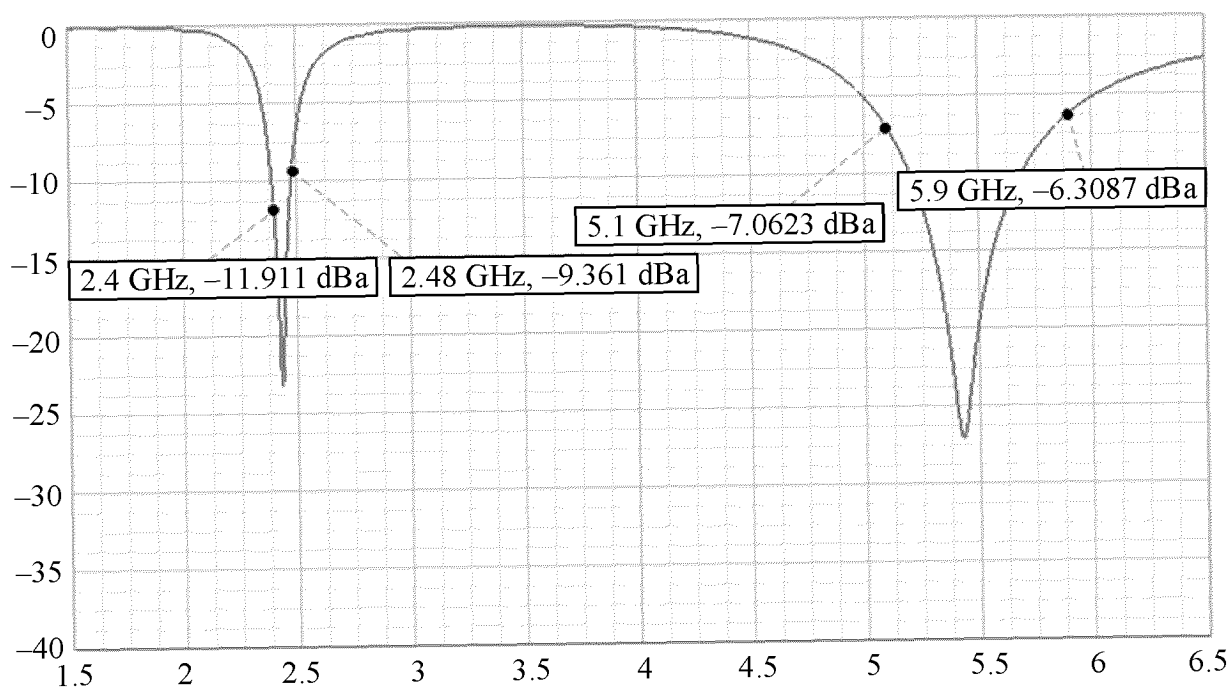


FIG. 15

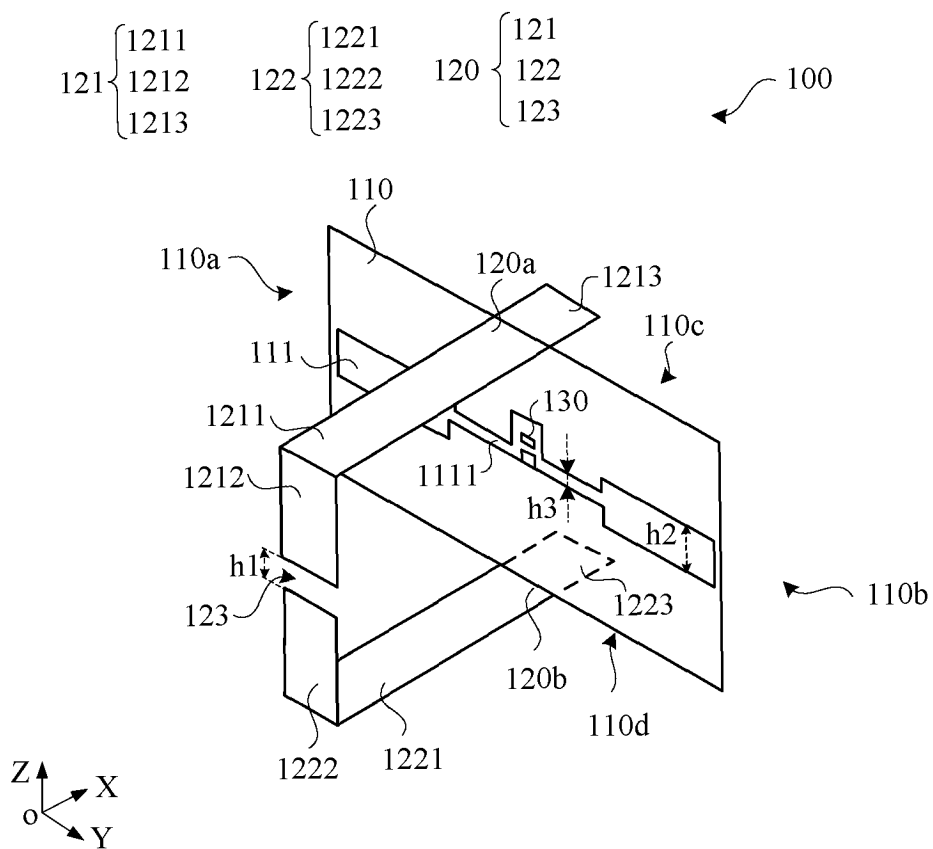


FIG. 16

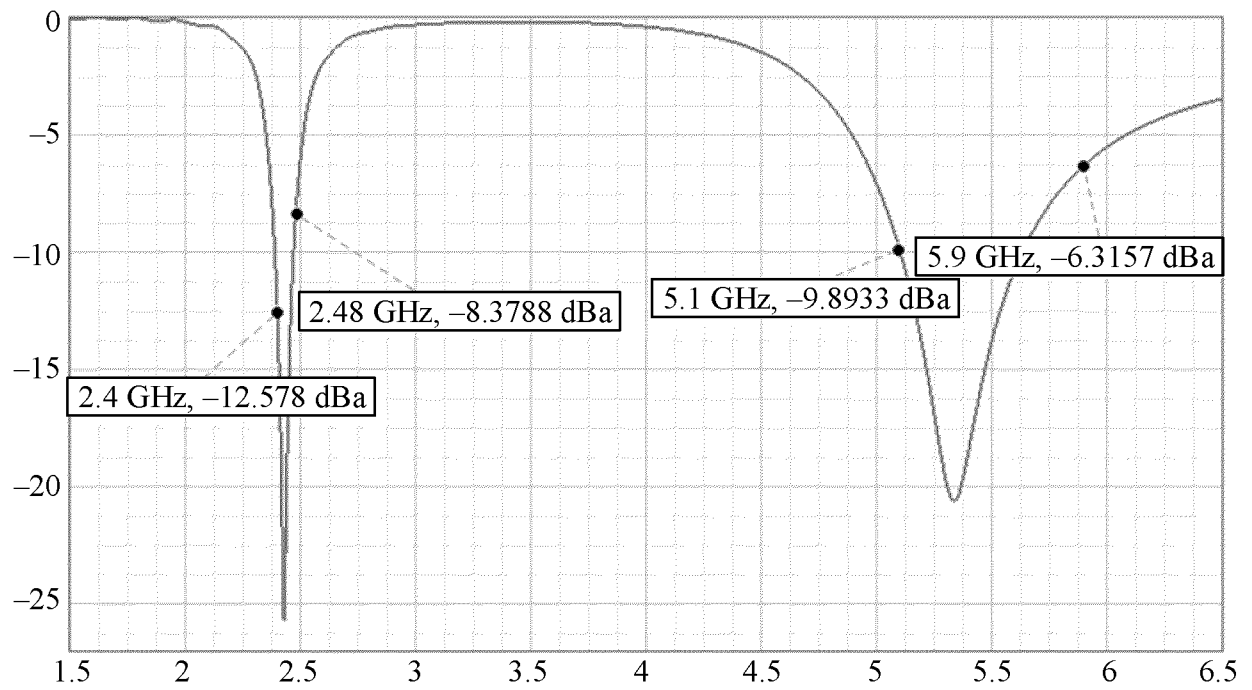


FIG. 17

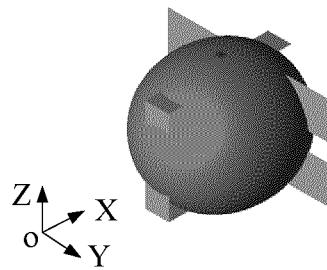


FIG. 18

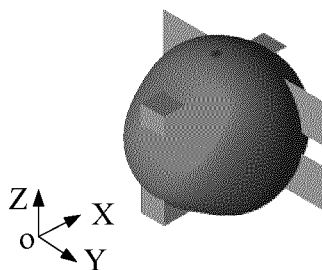


FIG. 19

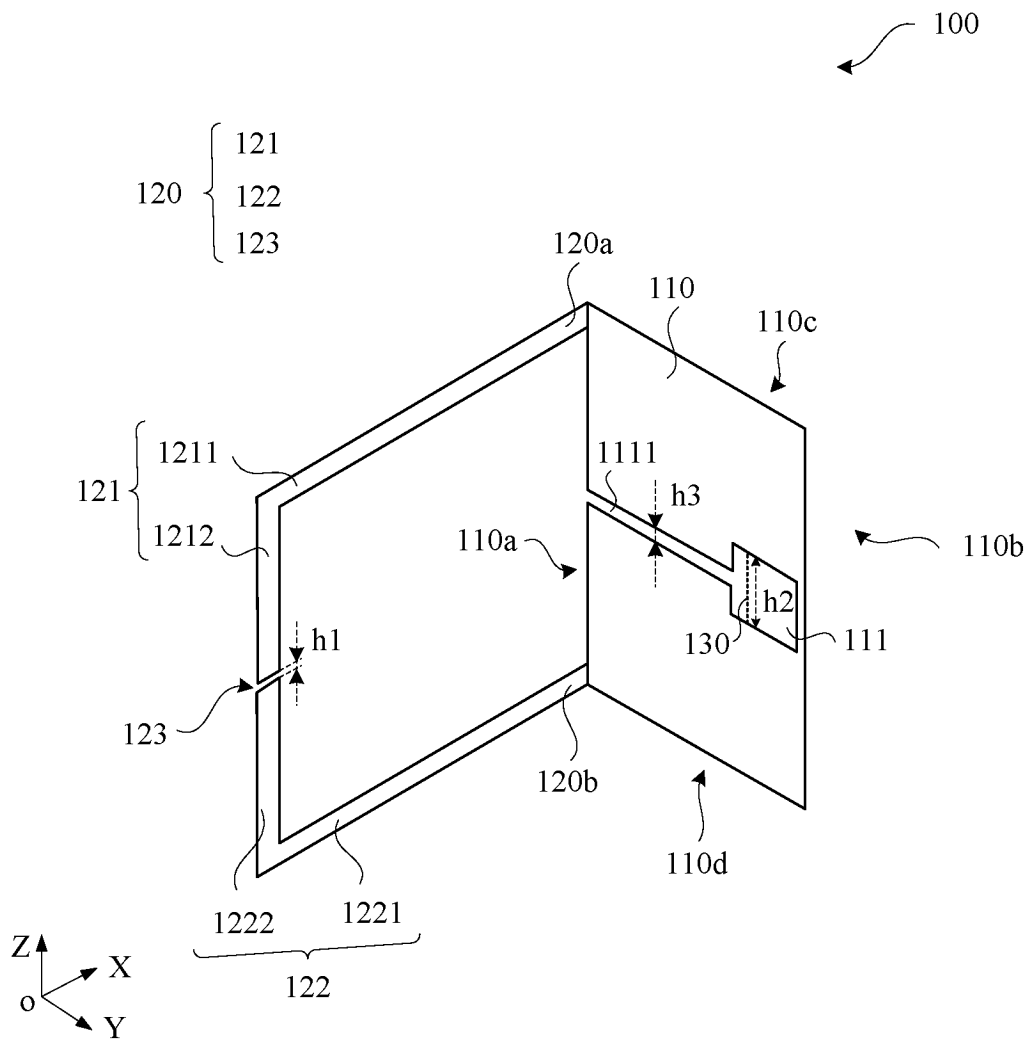


FIG. 20

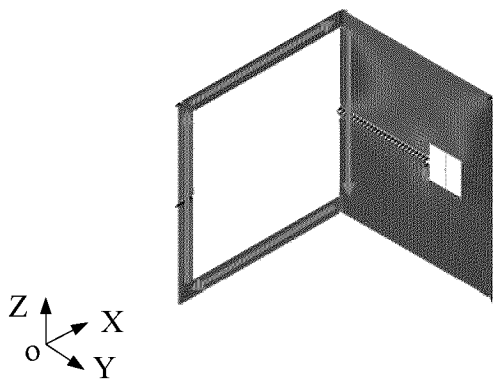


FIG. 21

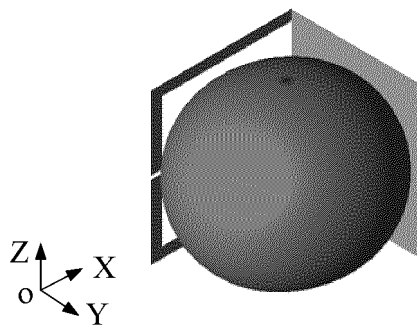


FIG. 22

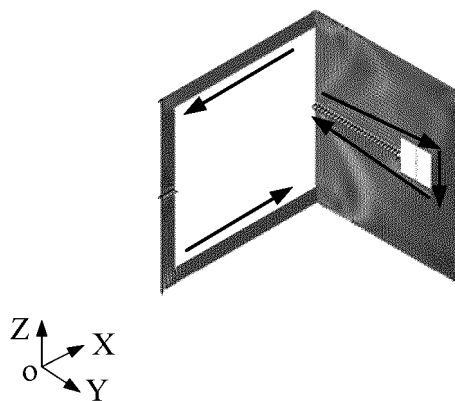


FIG. 23

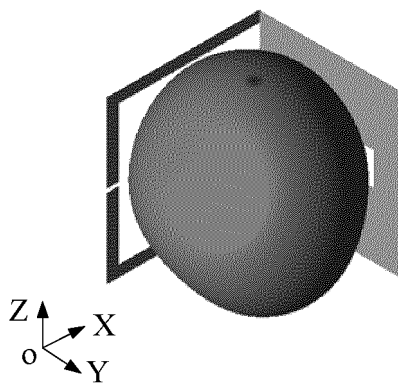


FIG. 24

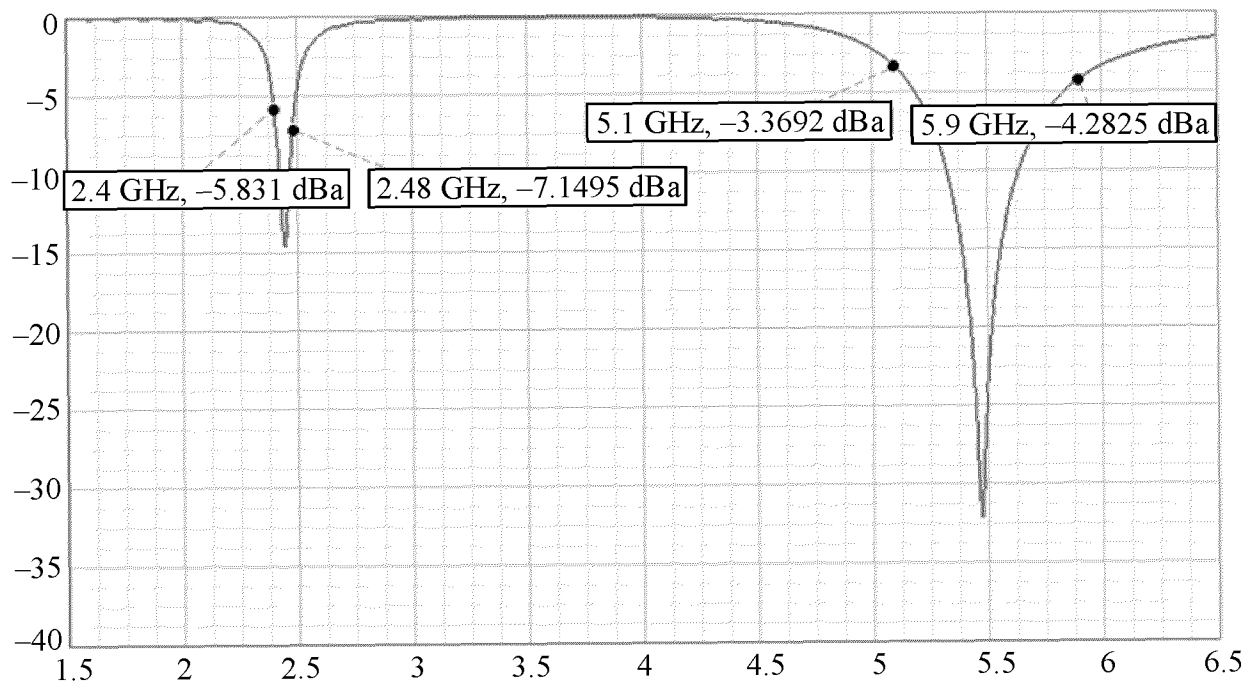


FIG. 25

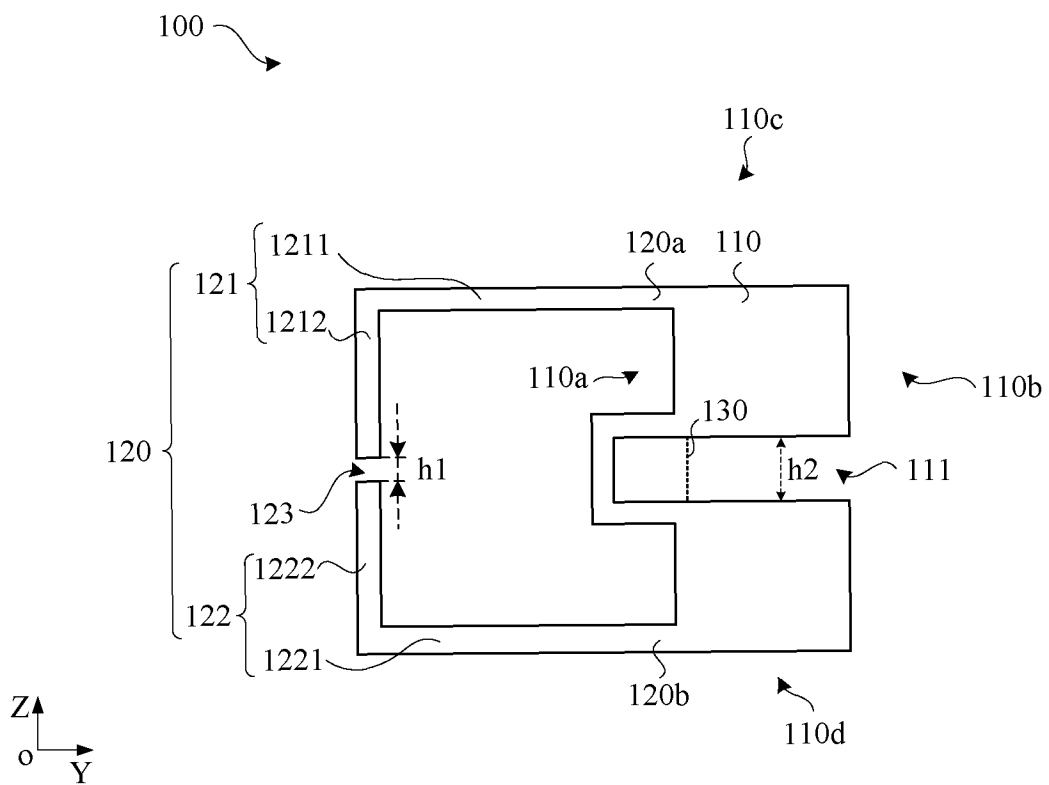


FIG. 26

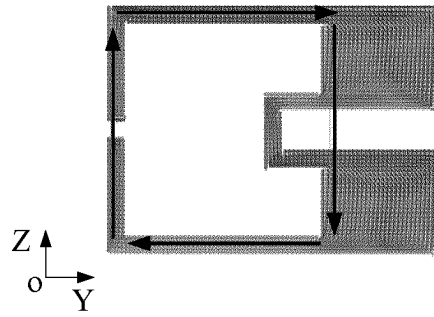


FIG. 27

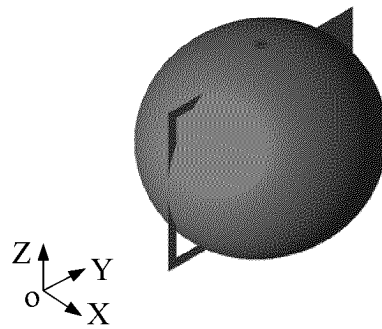


FIG. 28

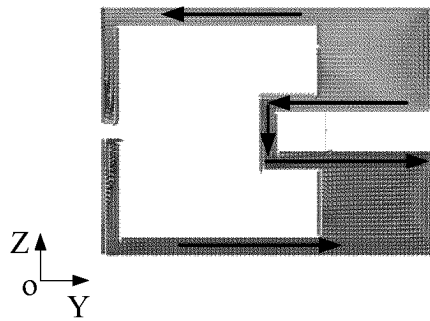


FIG. 29

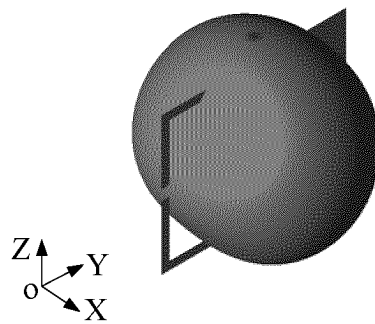


FIG. 30

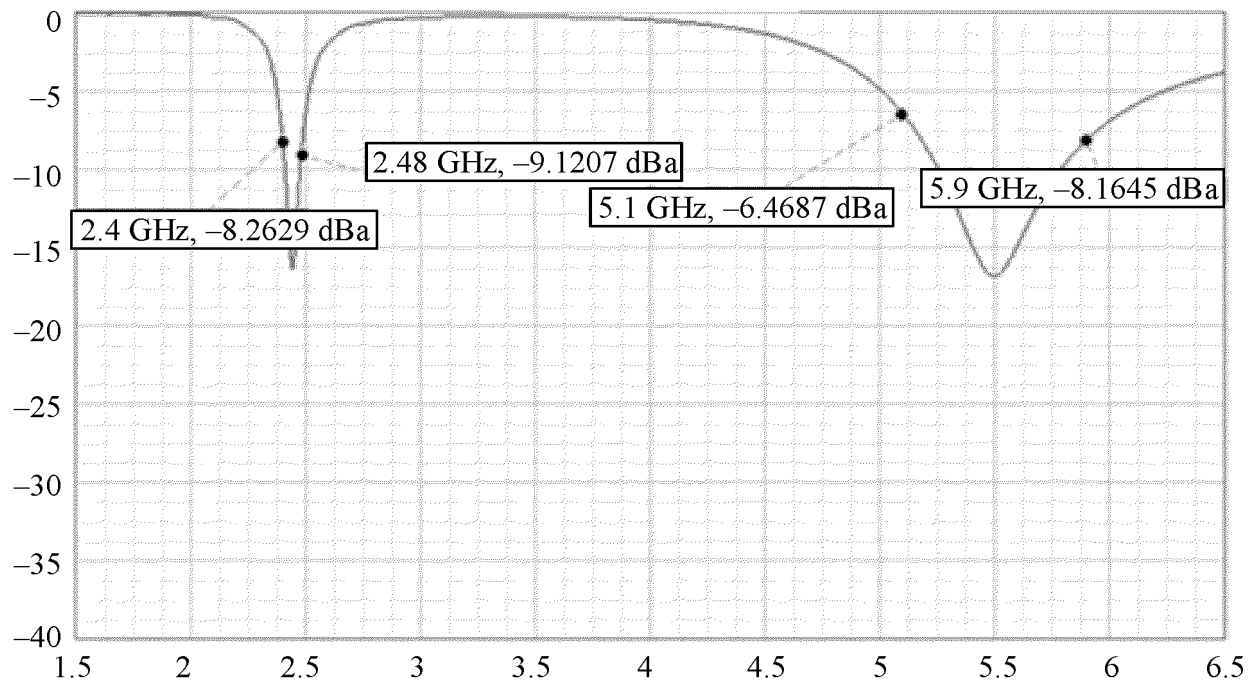


FIG. 31

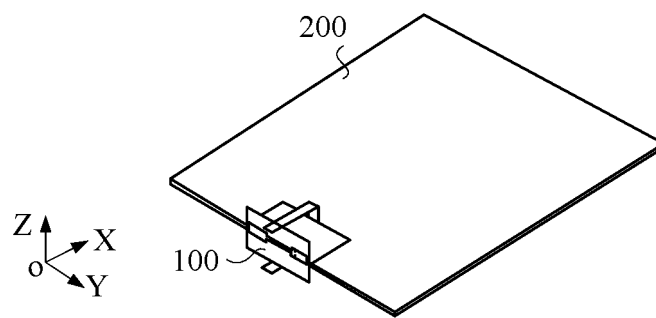


FIG. 32

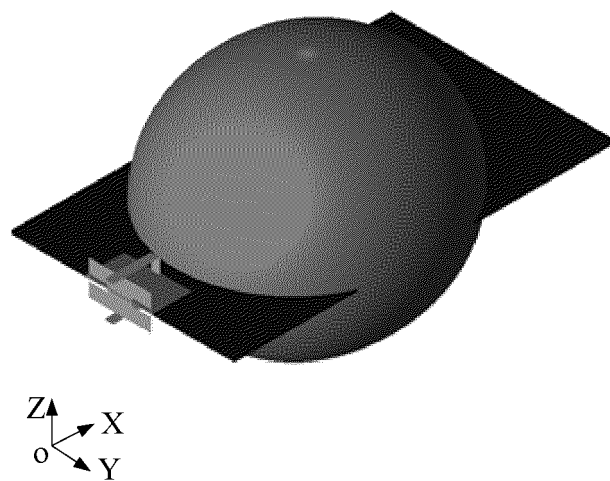


FIG. 33

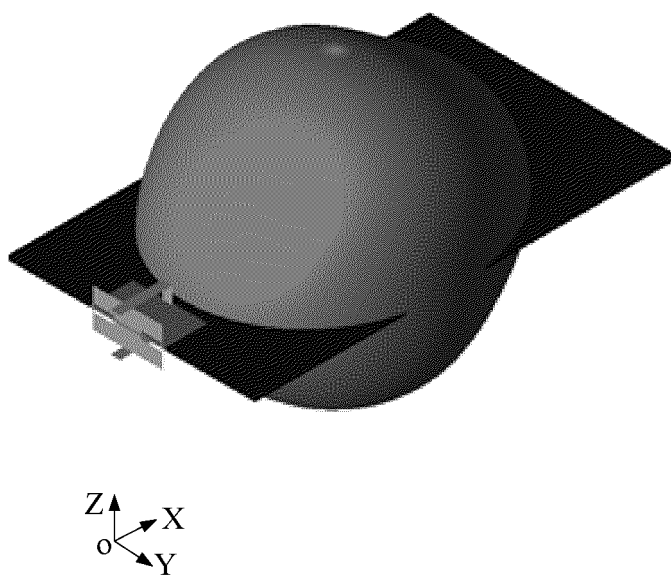


FIG. 34

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/119822

A. CLASSIFICATION OF SUBJECT MATTER H01Q1/50(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC: H01Q		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) DWPI, CNTXT, ENTXTC: 垂直, 第二, 第二方向, 第一, 第一方向, 缝, 环, 馈, 隙, 正交, vertical, second, second direction, first, first direction, slit, ring, feed, slot, orthogonal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 114976583 A (HUAWEI TECHNOLOGIES CO., LTD.) 30 August 2022 (2022-08-30) description 0069-0097, and figures 2-5	1-17
A	CN 113764885 A (HUAWEI TECHNOLOGIES CO., LTD.) 07 December 2021 (2021-12-07) entire document	1-17
A	CN 101682121 A (LAIRD TECHNOLOGIES INC.) 24 March 2010 (2010-03-24) entire document	1-17
A	US 2021305691 A1 (SONY CORP.) 30 September 2021 (2021-09-30) entire document	1-17
A	WO 2021244454 A1 (HONOR DEVICE CO., LTD.) 09 December 2021 (2021-12-09) entire document	1-17
☐ Further documents are listed in the continuation of Box C.		☒ See patent family annex.
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed		“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family
Date of the actual completion of the international search 09 November 2023	Date of mailing of the international search report 16 November 2023	
Name and mailing address of the ISA/CN China National Intellectual Property Administration (ISA/CN) China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088		Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2023/119822

Patent document cited in search report			Publication date (day/month/year)		Patent family member(s)			Publication date (day/month/year)	
CN	114976583	A	30 August 2022		WO	2022179596	A1	01 September 2022	
CN	113764885	A	07 December 2021		WO	2021244293	A1	09 December 2021	
					EP	4152519	A1	22 March 2023	
					CN	116231304	A	06 June 2023	
					US	2023283698	A1	07 September 2023	
CN	101682121	A	24 March 2010		EP	2151017	A1	10 February 2010	
					WO	2008144215	A1	27 November 2008	
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WO	2021244454	A1	09 December 2021		CN	113745804	A	03 December 2021	

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Patent documents cited in the description

- CN 202211198938X [0001]