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

(57) This application provides an antenna system and an electronic device. The antenna system includes a first antenna and a metal part. The metal part surrounds the first antenna, and a medium is filled between the metal part and the first antenna. A distance between the metal part and a central line of the first antenna is r , $0.2 \times n \times \lambda_1 < r < 0.8 \times n \times \lambda_1$, λ_1 is a wavelength of an electromagnetic wave propagated in the medium, n is a natural number, $1 \leq n \leq 5$, a height of the metal part is h , $0.25\lambda_2 < h < \lambda_2$, and λ_2 is a wavelength of an electromagnetic wave propagated in the metal part. In this application, the distance between the metal part and the central line of the first antenna satisfies the foregoing distance relationship, and the height of the metal part satisfies the foregoing height range, so that the first antenna itself can excite a first resonance mode, and the first antenna can further excite a second resonance mode on the metal part. The metal part does not block an electromagnetic wave radiated by the first antenna, and a new resonance mode can be excited on the metal part, thereby significantly broadening both impedance band-

width and efficiency bandwidth.

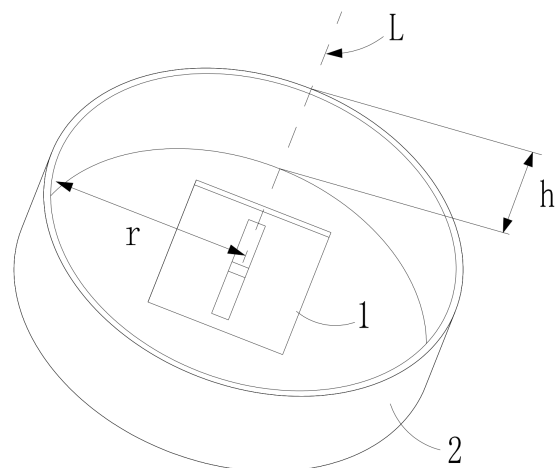


FIG. 2

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Description

[0001] The present invention claims priority to Chinese Patent Application No. 202310473546.8, filed with the China National Intellectual Property Administration on April 26, 2023 and entitled "ANTENNA SYSTEM AND ELECTRONIC DEVICE", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

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

BACKGROUND

[0003] With development of wireless communication technologies and continuous enrichment of application scenarios, consumers have increasingly high requirements on specifications of terminal antennas. For a product having a metal housing, the metal housing blocks an antenna disposed in the metal housing, causing degradation of radiation performance of the antenna. Therefore, in a scenario in which an antenna is disposed with a surrounding metal structure, a great challenge is how to improve radiation performance of the antenna.

SUMMARY

[0004] An objective of this application is to provide an antenna system and an electronic device, to improve radiation performance of an antenna in a scenario in which the antenna is disposed with a surrounding metal structure.

[0005] According to a first aspect of this application, an antenna system is provided, including:

a first antenna; and
a metal part, where the metal part surrounds the first antenna, and a medium is filled between the metal part and the first antenna;
a distance between the metal part and a central line of the first antenna is r , $0.2 \times n \times \lambda_1 < r < 0.8 \times n \times \lambda_1$, λ_1 is a wavelength of an electromagnetic wave propagated in the medium, n is a natural number, and $1 \leq n \leq 5$;
a height of the metal part is h , $0.25\lambda_2 < h < \lambda_2$, and λ_2 is a wavelength of an electromagnetic wave propagated in the metal part; and
the first antenna excites a first resonance mode, and the first antenna excites a second resonance mode on the metal part.

[0006] In this application, the distance between the metal part and the central line of the first antenna satisfies the foregoing distance relationship, and the height of the metal part satisfies the foregoing height range, so that the

first antenna itself can excite the first resonance mode, and the first antenna can further excite the second resonance mode on the metal part. In other words, the metal part does not block an electromagnetic wave radiated by the first antenna, and a new resonance mode can be excited on the metal part, thereby significantly broadening both impedance bandwidth and efficiency bandwidth.

[0007] In a possible design, the metal part is arranged centrally symmetric about the central line of the first antenna, so that the overall antenna system including the metal part and the first antenna can radiate electromagnetic waves uniformly in various directions of a horizontal plane, that is, a horizontal directivity pattern can be closer to a circle.

[0008] In a possible design, the metal part is a closed ring. The closed ring may be a circular ring, or a regular polygon such as a regular quadrilateral ring or a regular octagonal ring, or may be a shape such as a regular triangle. The metal part is a closed structure in a circumferential direction, and can encircle a periphery of the first antenna, thereby improving consistency of coupling between various positions of the metal part and the first antenna, and facilitating assembly and manufacturing of the metal part.

[0009] In a possible design, one or more metal parts are disposed. When one metal part is disposed, the metal part surrounds the first antenna, and the distance r between the metal part and the first antenna satisfies the foregoing range. When a plurality of metal parts are disposed, one of any two neighboring metal parts surrounds the other one and a spacing is maintained between the any two neighboring metal parts, so that a new resonance mode can be excited on each metal part, thereby helping further broaden the bandwidth.

[0010] In a possible design, a plurality of metal parts are disposed, and the plurality of metal parts are evenly distributed on a circumference surrounding the first antenna. The metal parts evenly distributed around the first antenna enable the first antenna to be substantially omnidirectional, and also help reduce an overall weight of the antenna system, thereby facilitating lightweight design of an electronic device.

[0011] In a possible design, a hole or a slot is disposed on the metal part. The hole means that the metal part is penetrated only in a direction perpendicular to the central line of the first antenna, and a closed structure surrounds the hole, that is, the metal part is not penetrated in a direction perpendicular to a penetration direction of the hole, thereby implementing a tuning function through the hole and helping excite a new resonance mode. The slot means that the metal part may be divided into two parts that are not connected to each other, that is, a distance between the two parts forms the slot. When the slot exists, the overall weight of the antenna system can be reduced, thereby facilitating lightweight implementation.

[0012] In a possible design, the antenna system further includes a second antenna, the second antenna includes

a radiator and a ground plane, the ground plane is the metal part, the radiator is disposed on a side that is of the metal part and that is away from the first antenna, and the second antenna forms a directional antenna by using a function of directionally reflecting an electromagnetic wave by the metal part.

[0013] The first antenna may be an omnidirectional antenna, and the first antenna is coupled to the metal part, so that a new resonance mode can be excited on the metal part. In addition, the metal part can further function as a reflection panel, and can reflect an electromagnetic wave that is radiated by the second antenna to a side of the metal part. In this way, the electromagnetic wave radiated by the second antenna to the side that is away from the metal part can be strengthened, thereby implementing directional radiation of the electromagnetic wave and achieving a high gain.

[0014] In a possible design, a plurality of metal parts and a plurality of second antennas are disposed; and the plurality of metal parts are in a one-to-one correspondence with the plurality of second antennas, and are evenly distributed on a circumference surrounding the first antenna.

[0015] In a possible design, the second antenna is one of a vertically polarized directional antenna, a horizontally polarized directional antenna, or a dual-polarized directional antenna.

[0016] In a possible design, the antenna system further includes a third antenna, the third antenna is disposed on the top of the first antenna, the third antenna is a horizontally polarized omnidirectional antenna covering a Wi-Fi 2.4 GHz frequency band, the first antenna is a vertically polarized omnidirectional antenna covering the Wi-Fi 2.4 GHz frequency band and a Wi-Fi 5 GHz frequency band, and the second antenna is a dual-polarized directional antenna covering the Wi-Fi 5 GHz frequency band.

[0017] Both the first antenna and the third antenna can generate resonance in the 2.4 GHz frequency band, so that both the horizontally polarized antenna and the vertically polarized antenna can cover the 2.4 GHz frequency band. In addition, both the first antenna and the second antenna can generate resonance in the 5 GHz frequency band, so that both the horizontally polarized antenna and the vertically polarized antenna can cover the 5 GHz frequency band. Therefore, in this embodiment, the antenna system integrating the first antenna, the second antenna, and the third antenna can cover the 2.4 GHz frequency band and the 5 GHz frequency band, and can obtain high bandwidth.

[0018] In a possible design, the third antenna protrudes from the top of the second antenna. That the third antenna protrudes from the top of the second antenna can prevent the metal part from blocking the third antenna, thereby helping to bring excellent radiation performance of the third antenna into play.

[0019] In a possible design, the first antenna is one of a dual-polarized omnidirectional antenna, a vertically po-

larized omnidirectional antenna, or a horizontally polarized omnidirectional antenna.

[0020] In a possible design, the antenna system further includes a transfer switch, and the transfer switch is connected to the first antenna, the second antenna, and the third antenna separately, to implement switching between an omnidirectional antenna and a directional antenna.

[0021] According to a second aspect of this application, an electronic device is further provided, including the antenna system provided in the first aspect of this application.

[0022] The electronic device has the same technical effects as the foregoing antenna system, and details are not described herein again.

[0023] In a possible design, the electronic device includes a housing, and the antenna system is disposed inside the housing. The housing may be a metal housing or a non-metal housing, and the antenna system may be disposed as a whole in the housing.

[0024] In a possible design, the electronic device includes a metal housing, the antenna system is disposed inside the metal housing, and the metal part of the antenna system is the metal housing. The metal housing of the electronic device is reused as the metal part of the antenna system, to reduce space occupied by the antenna system in the electronic device, thereby facilitating implementation of miniaturization design of the electronic device.

[0025] It should be understood that the foregoing general descriptions and the following detailed descriptions are merely used as examples, and should not limit this application.

BRIEF DESCRIPTION OF DRAWINGS

[0026]

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

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

FIG. 3 is a curve diagram of a return loss (S11) of an antenna system according to an embodiment of this application;

FIG. 4 is a directivity pattern of an antenna system according to an embodiment of this application;

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

FIG. 6 is a curve diagram of a return loss (S11) of an antenna system according to another embodiment of this application;

FIG. 7 is a directivity pattern of an antenna system according to another embodiment of this application;

FIG. 8 is a diagram of a structure of an antenna

system according to still another embodiment of this application;

FIG. 9 is a curve diagram of a return loss (S11) of an antenna system according to still another embodiment of this application;

FIG. 10 is a directivity pattern of an antenna system according to still another embodiment of this application;

FIG. 11 is a diagram of a structure of an antenna system according to yet another embodiment of this application;

FIG. 12 is a diagram of a structure of an antenna system according to still yet another embodiment of this application;

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

FIG. 14 is a diagram of a structure of an antenna system according to a still further embodiment of this application;

FIG. 15 is a diagram of a structure of an antenna system according to a yet further embodiment of this application;

FIG. 16 is a curve diagram of a return loss (S11) of a first antenna in an antenna system according to an embodiment of this application;

FIG. 17 is a directivity pattern of a first antenna in an antenna system according to an embodiment of this application;

FIG. 18 is a curve diagram of a return loss (S11) of a second antenna in an antenna system according to an embodiment of this application;

FIG. 19 is a directivity pattern of a second antenna in an antenna system according to an embodiment of this application;

FIG. 20 is a gain curve of a second antenna in an antenna system according to an embodiment of this application;

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

FIG. 22 is a curve diagram of an omnidirectional return loss (S11) in an antenna system according to another embodiment of this application;

FIG. 23 is a directivity pattern of a vertically polarized omnidirectional antenna in an antenna system according to another embodiment of this application;

FIG. 24 is a directivity pattern of a horizontally polarized omnidirectional antenna in an antenna system according to another embodiment of this application;

FIG. 25 is a curve diagram of a return loss (S11) of a second antenna in an antenna system according to another embodiment of this application;

FIG. 26 is a directivity pattern of a vertically polarized directional antenna in an antenna system according to another embodiment of this application;

FIG. 27 is a directivity pattern of a horizontally polarized directional antenna in an antenna system ac-

cording to another embodiment of this application; FIG. 28 is a gain curve of a second antenna in an antenna system according to another embodiment of this application; and

FIG. 29 is a diagram of a system architecture of an antenna system according to an embodiment of this application.

Reference numerals:

[0027]

- 1: first antenna;
- 2: metal part;
- 3: second antenna;
- 4: third antenna;
- 5: hole;
- 6: slot.

[0028] The accompanying drawings herein are incorporated into this specification and constitute a part of this specification, to show embodiments in accordance with this application, and are used together with this specification to explain the principle of this application.

DESCRIPTION OF EMBODIMENTS

[0029] To better understand technical solutions of this application, the following describes embodiments of this application in detail with reference to the accompanying drawings. It should be understood that the specific embodiments described herein are merely used to explain this application but are not intended to limit this application.

[0030] In descriptions of this application, unless otherwise specified and limited, the terms "first" and "second" are merely intended for a purpose of description, and cannot be understood as an indication or implication of relative importance. Unless otherwise specified or stated, the term "a plurality of" means two or more than two. The terms "connection", "fastening", and the like all should be understood in a broad sense. For example, "connection" may be a fastened connection, or may be a detachable connection, an integrated connection, or an electrical connection; or may be a direct connection, or may be an indirect connection through an intermediate medium. A person of ordinary skill in the art may understand specific meanings of the foregoing terms in this application based on a specific case.

[0031] For a purpose of implementing a wireless communication function, an antenna is usually disposed in an electronic device. However, forms of electronic devices are diversified. For an electronic device having a metal housing, when an antenna is disposed in the metal housing, the metal housing blocks radiation of an electromagnetic wave of the antenna, weakens signal strength, and causes degradation of radiation performance of the antenna.

[0032] This embodiment provides an antenna system. The antenna system may be used in an electronic device. FIG. 1 is a diagram of a structure of an electronic device according to an embodiment of this application. FIG. 1 shows an example in which the electronic device is customer-premises equipment (customer-premises equipment, CPE). Specifically, the electronic device may be a router or an electronic device having a wireless communication function, such as the CPE shown in FIG. 1 or a sound box. A specific type of the electronic device is not limited in this embodiment.

[0033] Specifically, FIG. 2 is a diagram of a structure of an antenna system according to an embodiment of this application. As shown in FIG. 2, the antenna system includes a first antenna 1 and a metal part 2. The first antenna 1 may be an omnidirectional antenna, and may be presented as being capable of 360° uniform radiation on a horizontal directivity pattern, to provide wide coverage. The metal part 2 is a mechanical part made of a metal material. For example, the metal part 2 may be a housing manufactured through separate processing and configured to protect the antenna, and can be independently installed in a housing of an electronic product, to facilitate overall installation of the antenna. For example, for the electronic product having the metal housing, the metal housing of the electronic product may be used as the metal part 2 of the antenna system, so that the metal housing of the electronic device is reused, to reduce internal space occupied by the antenna system in the electronic device, thereby facilitating miniaturization of the electronic device.

[0034] The metal part 2 surrounds the first antenna 1, and a medium is filled between the metal part 2 and the first antenna 1. In other words, there is a specific distance between the metal part 2 and the first antenna 1, and the medium may be filled within a range of the distance. The medium may be air, a flammable material (FR-4) dielectric board, a Rogers (Rogers) dielectric board, or the like, or may be a hybrid dielectric board of Rogers and FR-4, or the like. Herein, FR-4 is a grade designation of a flame-resistant material, and the Rogers dielectric board is a high-frequency board.

[0035] In this embodiment, for ease of description, as shown in FIG. 2, it is defined in this embodiment so that the first antenna 1 has a central line, where the central line is perpendicular to a horizontal radiation direction of the first antenna 1, and the metal part 2 can be disposed around the first antenna 1 in a direction perpendicular to the central line.

[0036] As shown in FIG. 2, a distance between the metal part 2 and the central line of the first antenna 1 is r , $0.2 \times n \times \lambda_1 < r < 0.8 \times n \times \lambda_1$, λ_1 is a wavelength of an electromagnetic wave propagated in the medium, n is a natural number, $1 \leq n \leq 5$, and the natural number n may be determined based on an actual application scenario of the antenna system and radiation performance of the antenna. For example, when the antenna system is used inside a router having small space, a value of the natural

number n may be small. When the antenna system is used inside a sound box having large space, the value of the natural number n may be large. The value of the natural number n within a range of [1, 5] enables the antenna system to be applicable to most electronic devices. If the value of n is too large or small, the antenna system cannot bring its good radiation performance into play in the electronic device. In addition, a height of the metal part 2 is h , $0.25\lambda_2 < h < \lambda_2$, λ_2 is a wavelength of an electromagnetic wave propagated in the metal part 2, and the height of the metal part 2 is a size of the metal part 2 in a direction parallel to the central line of the first antenna 1.

[0037] The distance between the metal part 2 and the central line of the first antenna 1 satisfies the foregoing distance relationship, and the height of the metal part 2 satisfies the foregoing height range, so that the first antenna 1 itself can excite a first resonance mode, and the first antenna 1 can further excite a second resonance mode on the metal part 2. In other words, the metal part 2 does not block an electromagnetic wave radiated by the first antenna 1, and a new resonance mode can be excited on the metal part 2, thereby significantly broadening both impedance bandwidth and efficiency bandwidth.

[0038] For example, the value of the natural number n is 1. If the distance r between the metal part 2 and the central line of the first antenna 1 is too large, for example, the distance r is greater than $0.8\lambda_1$, the metal part 2 is far away from the first antenna 1, a new resonance mode cannot be excited on the metal part 2, and the bandwidth cannot be broadened. If the distance r is too small, for example, the distance r is less than $0.2\lambda_1$, the metal part 2 is too close to the first antenna 1 and the metal part 2 blocks and shields the electromagnetic wave radiated by the first antenna 1, causing degradation of radiation performance of the antenna. In addition, a new resonance mode cannot be excited on the metal part 2, and the bandwidth cannot be broadened.

[0039] In addition, for the height of the metal part 2, if the height of the metal part 2 is too large, for example, h is greater than λ_2 , the metal part 2 has a negative effect of blocking and shielding the electromagnetic wave radiated by the first antenna 1, causing degradation of radiation performance of the first antenna 1. If the height of the metal part 2 is too small, for example, less than $0.25\lambda_2$, the metal part 2 is close to the line. As result, a new resonance mode cannot be excited on the metal part 2, and the bandwidth cannot be broadened.

[0040] Therefore, in this embodiment, both the distance r between the metal part 2 and the central line of the first antenna 1 and the height h of the metal part 2 satisfy the foregoing corresponding numerical range, to prevent the metal part 2 from blocking and shielding the electromagnetic wave radiated by the first antenna 1. In addition, a new resonance mode can be excited on the metal part 2 to broaden the bandwidth.

[0041] The first antenna 1 may be one of a dual-polar-

ized omnidirectional antenna, a vertically polarized omnidirectional antenna, or a horizontally polarized omnidirectional antenna, so that a selection range of the first antenna 1 can be expanded. In addition, when any one of the types of the first antenna 1 and the metal part 2 satisfy the distance relationship and the height range of the metal part 2 is satisfied, the metal part 2 can be prevented from blocking the electromagnetic wave of the first antenna 1, and a new resonance mode can be excited on the metal part 2, thereby expanding the bandwidth.

[0042] For example, the first antenna 1 may be a vertically polarized omnidirectional antenna. FIG. 3 is a curve diagram of a return loss (S11) of an antenna system according to an embodiment of this application. Refer to FIG. 2 and FIG. 3. The first antenna 1 shown in FIG. 2 is a vertically polarized omnidirectional antenna. In FIG. 3, a horizontal coordinate represents a frequency in GHz, a vertical coordinate represents a return loss in dB, a curve a represents an S11 curve of the antenna system according to this embodiment of this application, and a curve b represents an S11 curve of a conventional dipole antenna. The conventional dipole antenna is an antenna that is surrounded and blocked by a metal part and cannot excite a resonance mode on the metal part, or is an antenna that is not surrounded and not blocked by a metal part. It can be learned from FIG. 3 that the conventional dipole antenna can excite only one resonance mode, while the antenna system provided in this embodiment of this application can excite two resonance modes, where one resonance mode is excited by the first antenna 1 itself, and the other resonance mode is excited on the metal part 2, thereby significantly broadening both the impedance bandwidth and the efficiency bandwidth. FIG. 4 is a directivity pattern of an antenna system according to an embodiment of this application. As shown in FIG. 4, frequencies corresponding to three directivity patterns in FIG. 4 are 4.5 GHz, 5.5 GHz, and 5.9 GHz respectively. It can be learned from FIG. 4 that the antenna system has a good omnidirectional characteristic in all of the in-band directivity patterns.

[0043] For example, the first antenna 1 may alternatively be a horizontally polarized omnidirectional antenna. FIG. 5 is a diagram of a structure of an antenna system according to another embodiment of this application. Refer to FIG. 5. The first antenna 1 shown in FIG. 5 is a horizontally polarized omnidirectional antenna. FIG. 6 is a curve diagram of a return loss (S11) of an antenna system according to another embodiment of this application. Refer to FIG. 6. A horizontal coordinate in FIG. 6 represents a frequency in GHz, a vertical coordinate represents a return loss in dB, a curve c represents an S11 curve of the antenna system provided in this embodiment of this application, and a curve d represents an S11 curve of a conventional horizontally polarized omnidirectional antenna. The conventional horizontally polarized omnidirectional antenna is an antenna that is surrounded and blocked by a metal part and cannot excite a resonance mode on the metal part, or is an antenna that is

not surrounded and not blocked by a metal part. It can be learned from FIG. 6 that the conventional horizontally polarized omnidirectional antenna can excite only one resonance mode, while the antenna system provided in this embodiment of this application can excite two resonance modes, where one resonance mode is excited by the first antenna 1 itself, and the other resonance mode is excited on the metal part 2, thereby significantly broadening both the impedance bandwidth and the efficiency bandwidth. FIG. 7 is a directivity pattern of an antenna system according to another embodiment of this application. Refer to FIG. 7. Frequencies corresponding to three directivity patterns in FIG. 7 are 4.8 GHz, 5.2 GHz, and 5.6 GHz respectively. It can be learned from FIG. 7 that the antenna system has a good omnidirectional characteristic in all of the in-band directivity patterns.

[0044] For example, the first antenna 1 may alternatively be a dual-polarized omnidirectional antenna. FIG. 8 is a diagram of a structure of an antenna system according to still another embodiment of this application. Refer to FIG. 8. The first antenna 1 shown in FIG. 8 is a dual-polarized omnidirectional antenna. FIG. 9 is a curve diagram of a return loss (S11) of an antenna system according to still another embodiment of this application. Refer to FIG. 9. A horizontal coordinate in FIG. 9 represents a frequency in GHz, a vertical coordinate represents a return loss in dB, a curve e represents an S11 curve of a horizontally polarized antenna in the first antenna 1, a curve f represents an S11 curve of a vertically polarized antenna in the first antenna 1, and a curve g represents an isolation curve. It can be seen from FIG. 9 that, both the horizontally polarized antenna and the vertically polarized antenna in the dual-polarized omnidirectional antenna can generate dual resonance, and there is high isolation between the horizontally polarized and the vertically polarized at a resonance frequency band, where the isolation is greater than 60 dB. FIG. 10 is a directivity pattern of an antenna system according to still another embodiment of this application. Refer to FIG. 10. Frequencies corresponding to three directivity patterns in FIG. 10 are 5.2 GHz, 5.4 GHz, and 5.8 GHz respectively. It can be learned from FIG. 10 that the antenna system has a good omnidirectional characteristic in all of the in-band directivity patterns.

[0045] In a specific implementation, the metal part 2 is arranged centrally symmetric about the central line of the first antenna 1. For example, when the metal part 2 is a circular mechanical part, the central line of the first antenna 1 is an axis of the circular mechanical part. For another example, when the metal part 2 is a plurality of planar plates, in a direction perpendicular to the central line, distances from centers of the planar plates to the central line of the first antenna 1 are equal, and the planar plates can be arranged centrally symmetric about the central line.

[0046] The first antenna 1 is an omnidirectional antenna, and the omnidirectional antenna may evenly radiate electromagnetic waves in various directions of a horizon-

tal plane. In this way, the metal part 2 is arranged centrally symmetric about the central line of the first antenna 1, so that the overall antenna system including the metal part 2 and the first antenna 1 can uniformly radiate electromagnetic waves in various directions of the horizontal plane, that is, a horizontal directivity pattern can be closer to a circle.

[0047] In a specific implementation, the metal part 2 is a closed ring, and the closed ring may be a circular ring, or a regular polygon such as a regular quadrilateral ring or a regular octagonal ring, or may be a shape such as a regular triangle. The metal part 2 is a closed structure in a circumferential direction, and can encircle a periphery of the first antenna 1, thereby improving consistency of coupling between various positions of the metal part 2 and the first antenna 1, and facilitating assembly and manufacturing of the metal part 2.

[0048] In a specific implementation, one or more metal parts 2 are disposed. When one metal part 2 is disposed, as shown in FIG. 2, the metal part 2 surrounds the first antenna 1, and the distance r between the metal part 2 and the first antenna 1 satisfies the foregoing range. When a plurality of metal parts 2 are disposed, one of any two neighboring metal parts 2 surrounds the other one and a spacing is maintained between the any two neighboring metal parts 2, so that a new resonance mode can be excited on each metal part 2, thereby helping further broaden the bandwidth.

[0049] In a specific implementation, a plurality of metal parts 2 may be disposed, and the plurality of metal parts 2 are evenly distributed on a circumference surrounding the first antenna 1. FIG. 11 is a diagram of a structure of an antenna system according to yet another embodiment of this application. Refer to FIG. 11. FIG. 11 shows an example in which there are four metal parts 2, and the four metal parts 2 are distributed centrally symmetric about the first antenna 1. Certainly, there may alternatively be more metal parts 2, and the metal parts 2 evenly distributed around the first antenna 1 enable the first antenna 1 to be substantially omnidirectional, and also help reduce an overall weight of the antenna system, thereby facilitating lightweight design of the electronic device.

[0050] In a specific implementation, a plurality of metal parts 2 may be disposed, and a hole 5 or a slot 6 is disposed on the metal part 2. FIG. 12 is a diagram of a structure of an antenna system according to still yet another embodiment of this application. As shown in FIG. 12, the hole 5 means that the metal part 2 is penetrated only in a direction perpendicular to the central line of the first antenna 1, and a closed structure surrounds the hole 5, that is, the metal part 2 is not penetrated in a direction perpendicular to a penetration direction of the hole 5, thereby implementing a tuning function through the hole 5 and helping excite a new resonance mode. FIG. 13 is a diagram of a structure of an antenna system according to a further embodiment of this application. As shown in FIG. 13, the slot 6 means that the metal part 2

may be divided into two parts that are not connected to each other, that is, a distance between the two parts forms the slot 6. When a width of the slot 6 is large, a structure of the metal part 2 shown in FIG. 11 may be formed.

[0051] In addition, the antenna disposed in the electronic device may be an omnidirectional antenna or may be a directional antenna, or both an omnidirectional antenna and a directional antenna may be disposed. When users are close to devices and are distributed in a wide area, the antenna needs to implement omnidirectional wide coverage. When the users are far away from the devices, the antenna needs to be directional to implement a high gain to satisfy a communication requirement. However, for an existing terminal antenna, it is usually difficult to implement both wide coverage and a high gain of the antenna. Antenna arrangement space is greatly increased if an omnidirectional antenna and a directional antenna are separately arranged, but that is not conducive to miniaturization of the electronic device.

[0052] Therefore, in this embodiment, the antenna system further includes a second antenna 3. The second antenna 3 includes a radiator and a ground plane. The radiator is connected to the ground plane to implement grounding. The ground plane is the metal part 2. The radiator is disposed on a side that is of the metal part 2 and that is away from the first antenna 1. The second antenna 3 forms a directional antenna by using a function of directionally reflecting an electromagnetic wave by the metal part 2. The first antenna 1 may be an omnidirectional antenna. The first antenna 1 is coupled to the metal part 2, so that a new resonance mode can be excited on the metal part 2. In addition, the metal part 2 can further function as a reflection panel, and can reflect an electromagnetic wave that is radiated by the second antenna 3 to a side of the metal part 2. In this way, the electromagnetic wave radiated by the second antenna 3 to the side that is away from the metal part 2 can be strengthened, thereby implementing directional radiation of the electromagnetic wave and achieving a high gain.

[0053] Therefore, the metal part 2 can be coupled to the first antenna 1 to generate a new resonance mode to expand bandwidth, and can be used as the ground plane of the second antenna 3, and can reflect the second electromagnetic wave in a directional manner, thereby improving a gain. In this way, the metal part 2 is reused to help reduce a volume of the antenna system, thereby facilitating miniaturization design of the electronic device.

[0054] FIG. 14 is a diagram of a structure of an antenna system according to a still further embodiment of this application. As shown in FIG. 14, the metal part 2 is of a planar plate structure, and there are four metal parts 2. The four metal parts 2 are distributed centrally symmetric about the first antenna 1. A second antenna 3 is disposed on a side that is of each metal part 2 and that is away from the first antenna 1. The second antenna 3 may be a directional antenna having a ground plane. In this embodiment, the second antenna 3 can use the metal part 2 as

the ground plane. For example, the second antenna 3 may be specifically a patch antenna shown in FIG. 14. For example, FIG. 15 is a diagram of a structure of an antenna system according to a yet further embodiment of this application. As shown in FIG. 15, the second antenna 3 may alternatively be a magnetic/electric dipole antenna shown in FIG. 15.

[0055] The second antenna 3 may be one of a vertically polarized directional antenna, a horizontally polarized directional antenna, or a dual-polarized directional antenna, so that a selection range of the second antenna 3 can be expanded. When the second antenna 3 is any one of the foregoing polarized antennas, the metal part 2 can be reused to implement directional radiation of an electromagnetic wave, thereby improving an antenna gain.

[0056] For example, the first antenna 1 is a vertically polarized omnidirectional antenna, and the second antenna 3 is a vertically polarized directional antenna. FIG. 16 is a curve diagram of a return loss (S11) of a first antenna 1 in an antenna system according to an embodiment of this application. Refer to FIG. 14 and FIG. 16. In FIG. 16, a horizontal coordinate represents a frequency in GHz; a vertical coordinate represents a return loss in dB; a curve h represents an S11 curve when there is only a vertically polarized omnidirectional antenna but no metal part 2 and no second antenna 3; a curve i represents an S11 curve of the first antenna 1 in this embodiment; a curve j represents an efficiency curve when there is only a vertically polarized omnidirectional antenna but no metal part 2 and no second antenna 3; and a curve k represents an efficiency curve of the first antenna 1 in this embodiment. It can be learned from FIG. 16 that, for the curve h, only one resonance mode can be generated in a Wi-Fi 5 GHz frequency band (referred to as a 5 GHz frequency band in the following description); for the curve i, two resonance modes can be generated in the 5 GHz frequency band; and antenna efficiency represented by the curve k is significantly higher than that of the antenna represented by the curve j. In other words, after the metal part 2 and the vertically polarized directional antenna are disposed around the vertically polarized omnidirectional antenna, a plurality of resonance modes can be generated in the 5 GHz frequency band, thereby significantly broadening both the impedance bandwidth and the efficiency bandwidth. In addition, FIG. 17 is a directivity pattern of a first antenna 1 in an antenna system according to an embodiment of this application. As shown in FIG. 17, frequencies corresponding to three directivity patterns in FIG. 17 are 5 GHz, 5.4 GHz, and 5.8 GHz respectively. It can be learned from FIG. 17 that the first antenna 1 has a good omnidirectional characteristic in the 5 GHz frequency band.

[0057] FIG. 18 is a curve diagram of a return loss (S11) of a second antenna 3 in an antenna system according to an embodiment of this application. As shown in FIG. 18, a horizontal coordinate represents a frequency in GHz, and a vertical coordinate represents a return loss in dB. When the return loss is less than -10 dB, the second antenna 3

has good radiation performance. It can be learned from FIG. 18 that a part of the curve located below -10 dB can cover the 5 GHz frequency band, so that the second antenna 3 has a good radiation characteristic in the 5 GHz frequency band.

[0058] FIG. 19 is a directivity pattern of a second antenna 3 in an antenna system according to an embodiment of this application. As shown in FIG. 19, four second antennas 3 have uniform directivity patterns in respective directions.

[0059] FIG. 20 is a gain curve of a second antenna 3 in an antenna system according to an embodiment of this application. As shown in FIG. 20, when a gain reaches more than 6 dB, a high gain may be obtained. Therefore, it can be learned from FIG. 20 that a part of the curve located above 6 dB can cover the 5 GHz frequency band. In other words, in this embodiment, a high gain can be obtained by reusing the second antenna 3 of the metal part 2.

[0060] The first antenna 1 is not limited to a vertically polarized omnidirectional antenna, and the second antenna 3 is not limited to a vertically polarized directional antenna. In some other embodiments, the first antenna 1 may alternatively be a horizontally polarized omnidirectional antenna or a dual-polarized omnidirectional antenna, and the second antenna 3 may alternatively be a horizontally polarized directional antenna or a dual-polarized directional antenna, so that there are a plurality of combinations of the first antenna 1 and the second antenna 3 to adapt to different application scenarios.

[0061] In a specific implementation, the antenna system further includes a transfer switch, and the transfer switch is connected to the first antenna 1 and the second antenna 3 separately. For example, there are two transfer switches. One transfer switch is configured to control the first antenna 1 to be connected or disconnected, and the other transfer switch is configured to control the second antenna 3 to be connected or disconnected, so that switching between an omnidirectional antenna and a directional antenna can be implemented. Therefore, in this embodiment, both the first antenna 1 used as an omnidirectional antenna and the second antenna 3 used as a directional antenna reuse the same metal part 2, to improve integration of the antenna system, implement miniaturization design, and implement switching between the omnidirectional antenna and the directional antenna, thereby achieving excellent antenna radiation performance in different scenarios.

[0062] In a specific implementation, a plurality of metal parts 2 and a plurality of second antennas 3 are disposed; and the plurality of metal parts 2 are in a one-to-one correspondence with the plurality of second antennas 3, and are evenly distributed on a circumference surrounding the first antenna 1. Refer to FIG. 14. FIG. 14 shows an example in which the first antenna 1 is surrounded by four metal parts 2 and four second antennas 3, and each second antenna 3 corresponds to one of the metal parts 2, so that the first antenna 1 may have uniform

radiation performance in all of the four directions. Certainly, in some other embodiments, there may be more metal parts 2 and more second antennas 3, and their specific quantities may be designed based on an actual application scenario and a radiation characteristic of the antenna.

[0063] In a specific implementation, FIG. 21 is a diagram of a structure of an antenna system according to a still yet further embodiment of this application. As shown in FIG. 21, the antenna system further includes a third antenna 4. The third antenna 4 is disposed on the top of the first antenna 1. The third antenna 4 is a horizontally polarized omnidirectional antenna covering a Wi-Fi 2.4 GHz frequency band (referred to as a 2.4 GHz frequency band in the following description). For example, the horizontally polarized omnidirectional antenna may be a loop antenna; the first antenna 1 is a vertically polarized omnidirectional antenna covering the 2.4 GHz frequency band and a 5 GHz frequency band; and the second antenna 3 is a dual-polarized directional antenna covering the 5 GHz frequency band. For example, the dual-polarized directional antenna may be a dual-polarized patch antenna, a magnetic/electric dipole antenna, or the like.

[0064] FIG. 22 is a curve diagram of a return loss (S11) of an omnidirectional antenna in an antenna system according to another embodiment of this application. As shown in FIG. 22, a horizontal coordinate represents a frequency in GHz, a vertical coordinate represents a return loss in dB, a curve m is an S11 curve of the first antenna 1, a curve n is an S11 curve of the third antenna 4, and a curve p is an S11 curve of a horizontally polarized omnidirectional antenna covering the 5 GHz frequency band. It can be learned from FIG. 22 that both the first antenna 1 and the third antenna 4 can generate resonance in the 2.4 GHz frequency band, so that both the horizontally polarized antenna and the vertically polarized antenna can cover the 2.4 GHz frequency band. In addition, both the first antenna 1 and the second antenna 3 can generate resonance in the 5 GHz frequency band, so that both the horizontally polarized antenna and the vertically polarized antenna can cover the 5 GHz frequency band. Therefore, in this embodiment, the antenna system integrating the first antenna 1, the second antenna 3, and the third antenna 4 can cover the 2.4 GHz frequency band and the 5 GHz frequency band, and can obtain high bandwidth.

[0065] FIG. 23 is a directivity pattern of a vertically polarized omnidirectional antenna in an antenna system according to another embodiment of this application. As shown in FIG. 23, the vertically polarized omnidirectional antenna has a good omnidirectional characteristic. FIG. 24 is a directivity pattern of a horizontally polarized omnidirectional antenna in an antenna system according to another embodiment of this application. As shown in FIG. 24, the horizontally polarized omnidirectional antenna also has a good omnidirectional characteristic.

[0066] The first antenna 1 and the third antenna 4 are

not horizontally polarized omnidirectional antennas capable of covering the 5 GHz frequency band. In this embodiment, the second antenna 3 used as a directional antenna is a dual-polarized directional antenna that covers the 5 GHz frequency band, and there are a plurality of second antennas 3 around the first antenna 1. The second antennas 3 can radiate electromagnetic waves in different directions, so that horizontally polarized directional antennas covering the 5 GHz frequency band in the second antennas 3 can operate simultaneously, to form, in a manner of combining beams, a horizontally polarized omnidirectional antenna capable of covering the 5 GHz frequency band.

[0067] FIG. 25 is a curve diagram of a return loss (S11) of a second antenna 3 in an antenna system according to another embodiment of this application. As shown in FIG. 25, a horizontal coordinate represents a frequency in GHz, and a vertical coordinate represents a return loss in dB. In FIG. 25, a bundle of curves q marked by an elliptic box are curves of vertically polarized portions of second antennas 3, and a bundle of curves r marked by an elliptic box are curves of horizontally polarized portions of the second antennas 3. It can be learned from FIG. 25 that the second antenna 3 used as the dual-polarized directional antenna can cover the complete 5 GHz frequency band.

[0068] FIG. 26 is a directivity pattern of a vertically polarized directional antenna in an antenna system according to another embodiment of this application. FIG. 27 is a directivity pattern of a horizontally polarized directional antenna in an antenna system according to another embodiment of this application. As shown in FIG. 26 and FIG. 27, both the vertically polarized directional antenna and the horizontally polarized directional antenna have a good radiation characteristic.

[0069] FIG. 28 is a gain curve of a second antenna 3 in an antenna system according to another embodiment of this application. As shown in FIG. 28, a curve s is a curve of a vertically polarized portion of the second antenna 3, and a curve t is a curve of a horizontally polarized portion of the second antenna 3. When a gain reaches more than 6 dB, a high gain may be obtained. Therefore, it can be learned from FIG. 28 that parts of the curves above 6 dB can cover the 5 GHz frequency band. In other words, in this embodiment, the second antenna 3 used as the dual-polarized directional antenna can obtain a high gain.

[0070] In this embodiment, a transfer switch may also be connected to the third antenna 4, so that the third antenna 4 can be connected or disconnected. For example, FIG. 29 is a diagram of a system architecture of an antenna system according to an embodiment of this application. As shown in FIG. 29, the first antenna 1 is a vertically polarized omnidirectional antenna covering the 2.4 GHz frequency band and the 5 GHz frequency band, the second antenna 3 is a dual-polarized directional antenna covering the 5 GHz frequency band, and the third antenna 4 is a horizontally polarized omnidirectional antenna covering the 2.4 GHz frequency band.

There may be four transfer switches, connected to the first antenna 1, the third antenna 4, a horizontally polarized antenna in the second antenna 3, and a vertically polarized antenna in the second antenna 3 respectively, so that switching between an omnidirectional antenna and a directional antenna can be implemented.

[0071] In a specific implementation, as shown in FIG. 21, the third antenna 4 protrudes from the top of the second antenna 3. If the third antenna 4 is disposed in a space surrounded by the metal part 2, radiation of the third antenna 4 is blocked. In this embodiment, the third antenna 4 protrudes from the top of the second antenna 3, to prevent the metal part 2 from blocking the third antenna 4, thereby helping to bring excellent radiation performance of the third antenna 4 into play.

[0072] The foregoing descriptions are merely preferred embodiments of this application, and are not intended to limit this application. For a person skilled in the art, various modifications and variations may be made to this application. Any modification, equivalent replacement, improvement, or the like made without departing from the spirit and principle of this application shall fall within the protection scope of this application.

Claims

1. An antenna system, comprising:

a first antenna; and
a metal part, wherein the metal part surrounds the first antenna, and a medium is filled between the metal part and the first antenna;
a distance between the metal part and a central line of the first antenna is r , $0.2 \times n \times \lambda_1 < r < 0.8 \times n \times \lambda_1$, λ_1 is a wavelength of an electromagnetic wave propagated in the medium, n is a natural number, and $1 \leq n \leq 5$;
a height of the metal part is h , $0.25\lambda_2 < h < \lambda_2$, and λ_2 is a wavelength of an electromagnetic wave propagated in the metal part; and
the first antenna excites a first resonance mode, and the first antenna excites a second resonance mode on the metal part.

2. The antenna system according to claim 1, wherein the metal part is arranged centrally symmetric about a central line of the first antenna.

3. The antenna system according to claim 1 or 2, wherein the metal part is a closed ring.

4. The antenna system according to claim 3, wherein one or more metal parts are disposed, and when a plurality of metal parts are disposed, one of any two neighboring metal parts surrounds the other one and a spacing is maintained between the any two neighboring metal parts.

5. The antenna system according to claim 1 or 2, wherein a plurality of metal parts are disposed, and the plurality of metal parts are evenly distributed on a circumference surrounding the first antenna.

6. The antenna system according to any one of claims 1 to 5, wherein a hole or a slot is disposed on the metal part.

7. The antenna system according to claim 1, wherein the antenna system further comprises a second antenna, the second antenna comprises a radiator and a ground plane, the ground plane is the metal part, the radiator is disposed on a side that is of the metal part and that is away from the first antenna, and the second antenna forms a directional antenna by using a function of directionally reflecting an electromagnetic wave by the metal part.

8. The antenna system according to claim 7, wherein a plurality of metal parts and a plurality of second antennas are disposed; and the plurality of metal parts are in a one-to-one correspondence with the plurality of second antennas, and are evenly distributed on a circumference surrounding the first antenna.

9. The antenna system according to claim 7 or 8, wherein the second antenna is one of a vertically polarized directional antenna, or a horizontally polarized directional antenna, or a dual-polarized directional antenna.

10. The antenna system according to claim 7, wherein the antenna system further comprises a third antenna, the third antenna is disposed on the top of the first antenna, the third antenna is a horizontally polarized omnidirectional antenna covering a Wi-Fi 2.4 GHz frequency band, the first antenna is a vertically polarized omnidirectional antenna covering the Wi-Fi 2.4 GHz frequency band and a Wi-Fi 5 GHz frequency band, and the second antenna is a dual-polarized directional antenna covering the Wi-Fi 5 GHz frequency band.

11. The antenna system according to claim 10, wherein the third antenna protrudes from the top of the second antenna.

12. The antenna system according to any one of claims 1 to 11, wherein the first antenna is one of a dual-polarized omnidirectional antenna, a vertically polarized omnidirectional antenna, or a horizontally polarized omnidirectional antenna.

13. The antenna system according to any one of claims 7 to 12, wherein the antenna system further comprises a transfer switch, and the transfer switch is con-

nected to the first antenna, the second antenna, and the third antenna separately.

- 14.** An electronic device, comprising the antenna system according to any one of claims 1 to 13. 5
- 15.** The electronic device according to claim 14, wherein the electronic device comprises a housing, and the antenna system is disposed inside the housing. 10
- 16.** The electronic device according to claim 14, wherein the electronic device comprises a metal housing, the antenna system is disposed inside the metal housing, and the metal part of the antenna system is the metal housing. 15

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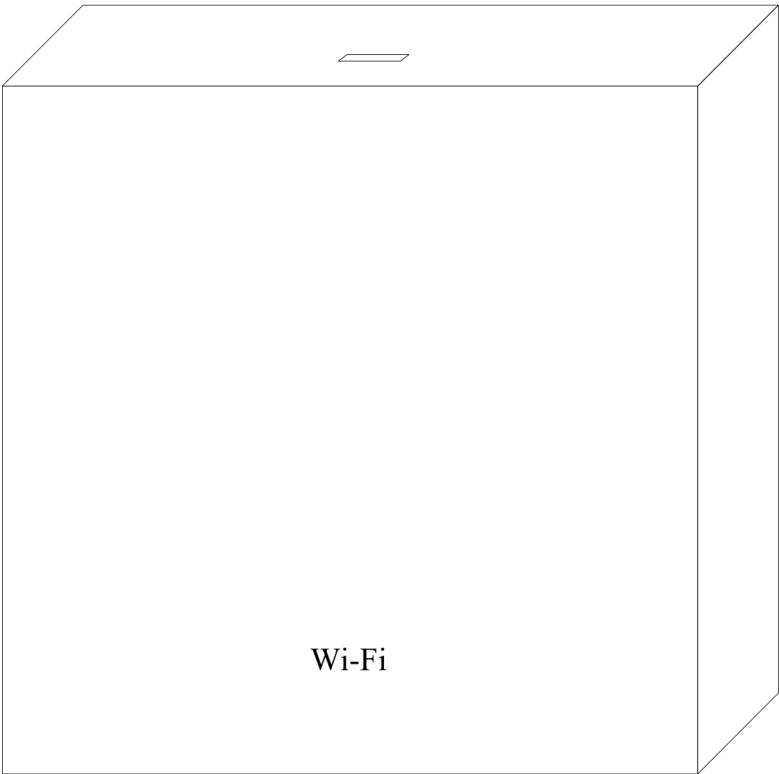


FIG. 1

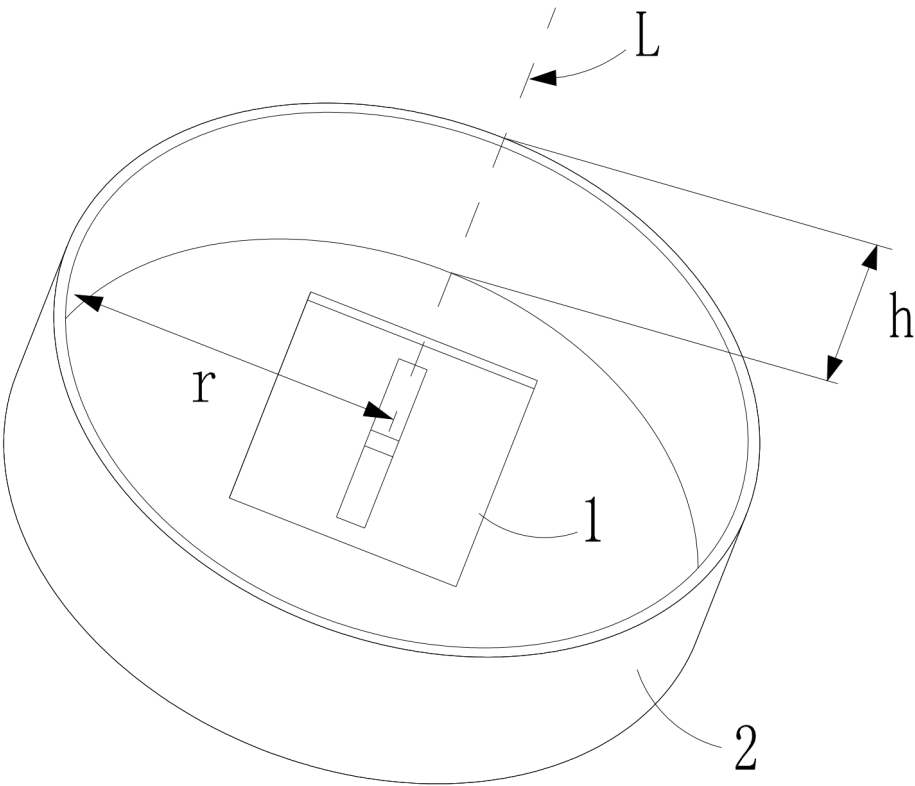


FIG. 2

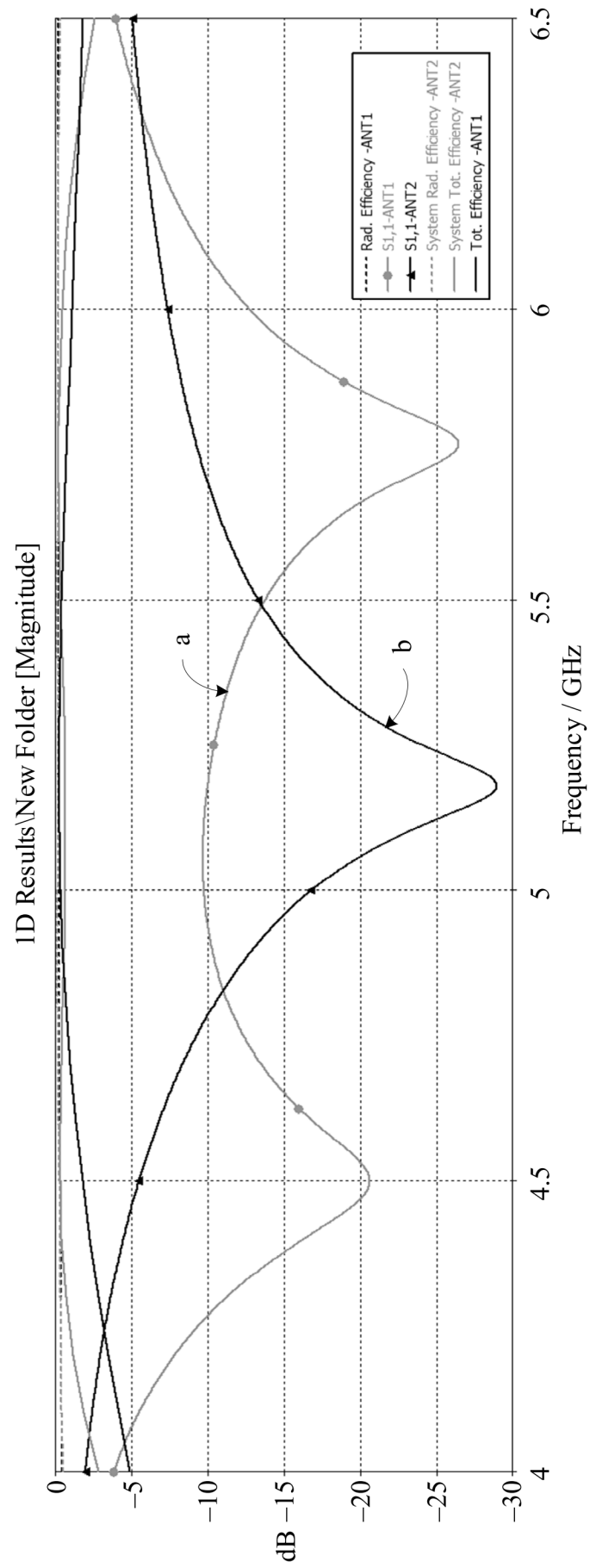
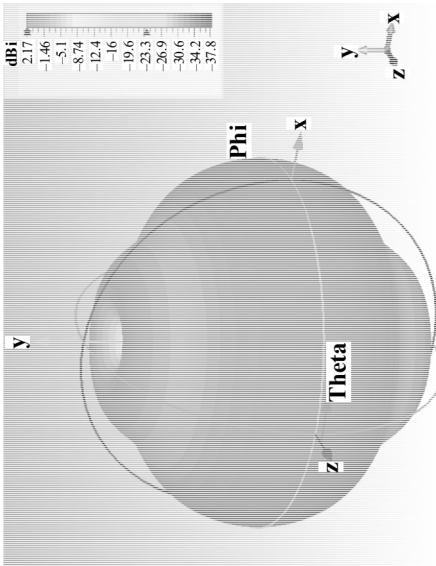
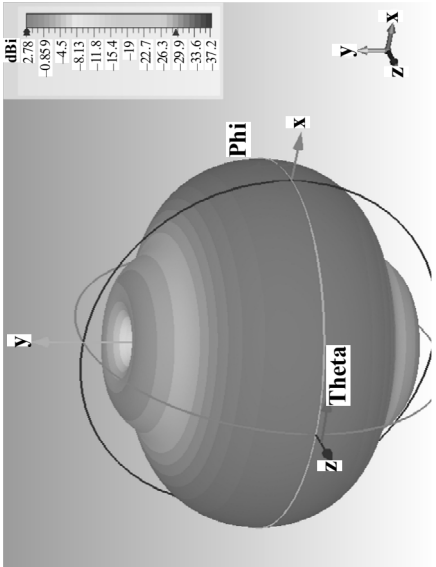


FIG. 3

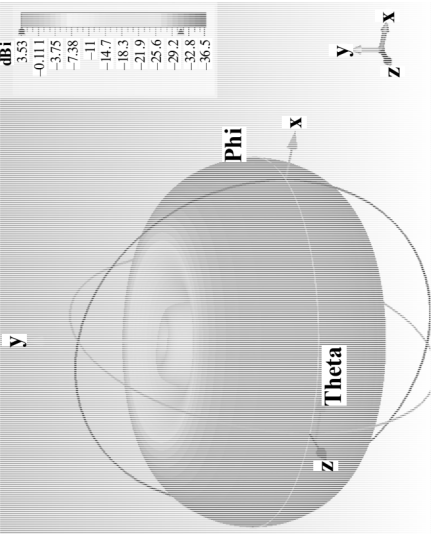


5.9 GHz



5.5 GHz

FIG. 4



4.5 GHz

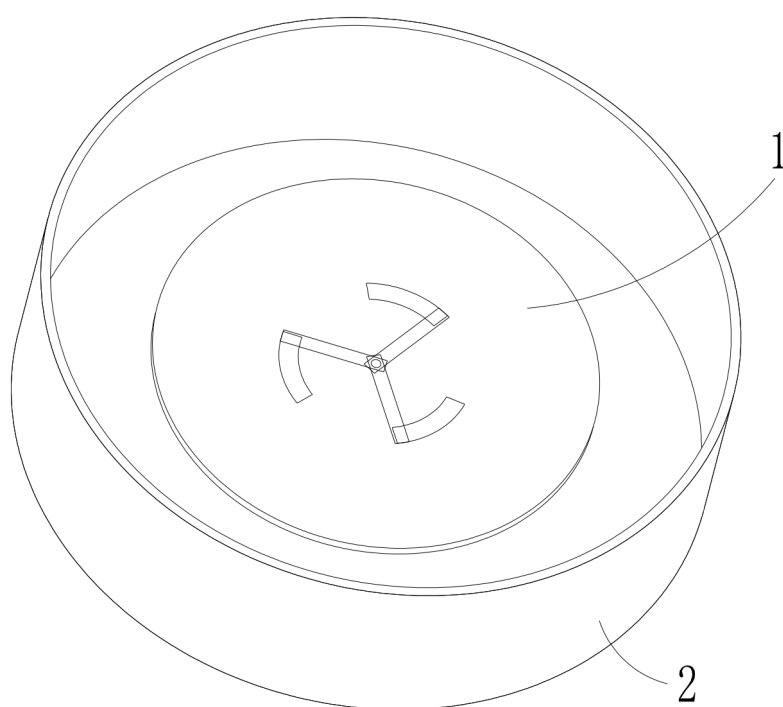


FIG. 5

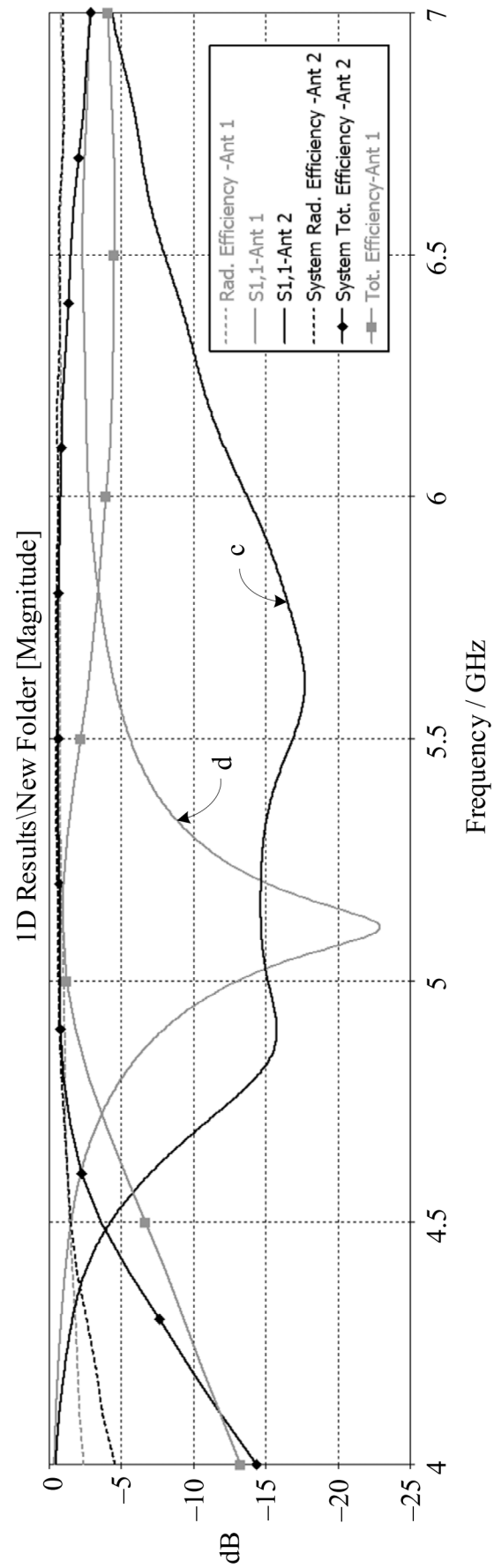
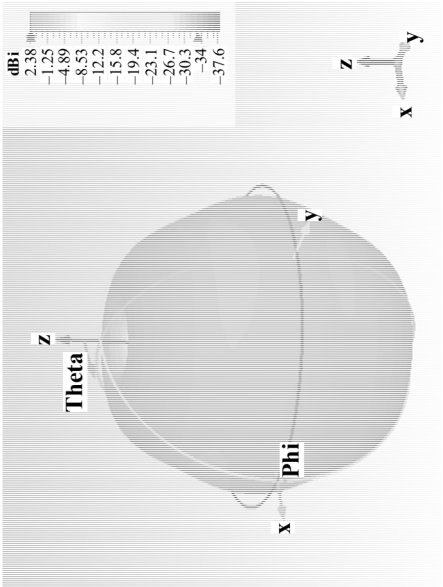
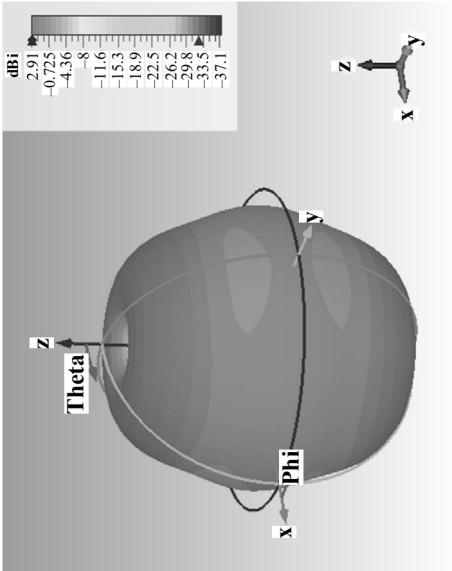


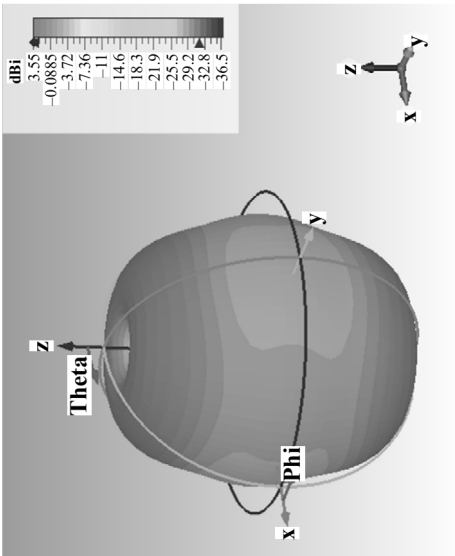
FIG. 6



5.6 GHz



5.2 GHz



4.8 GHz

FIG. 7

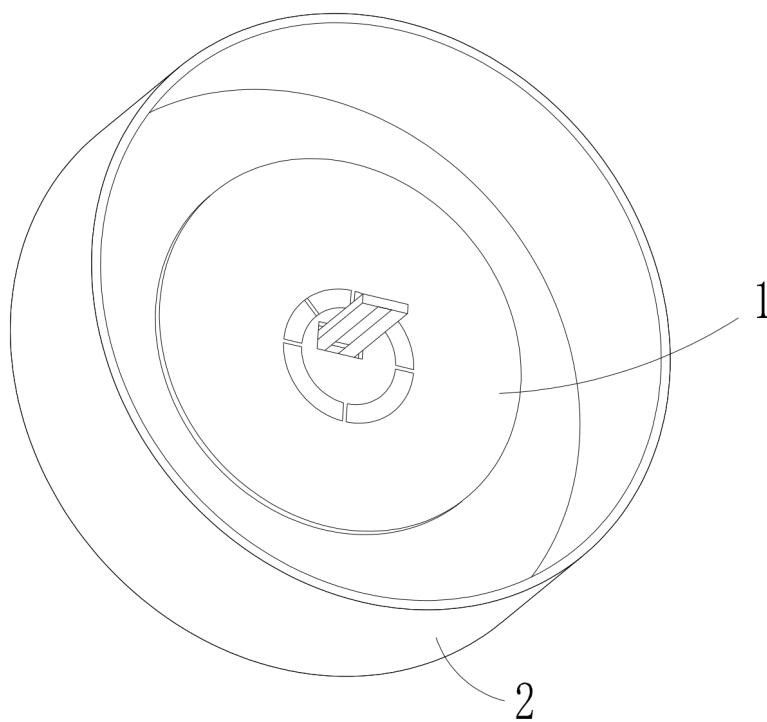


FIG. 8

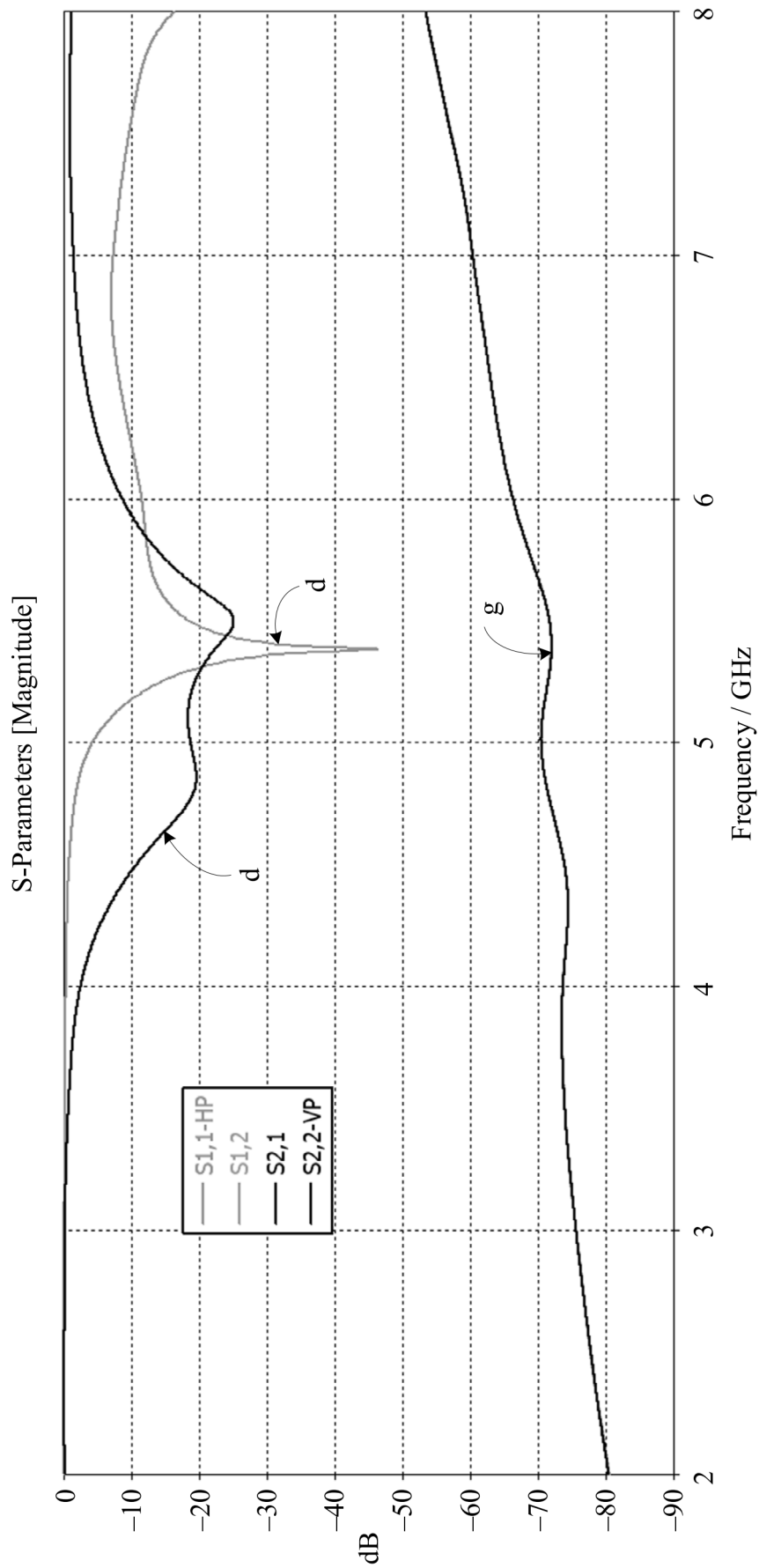
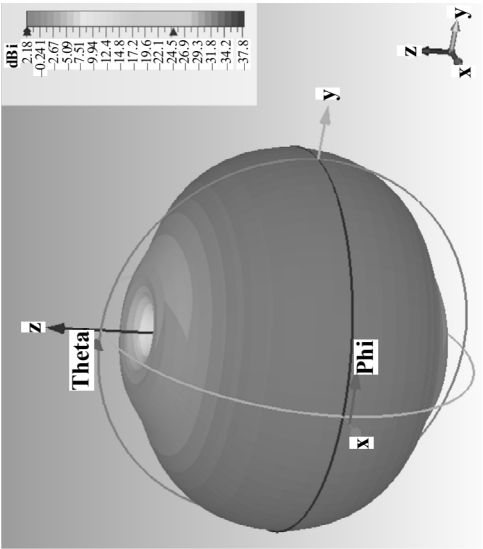
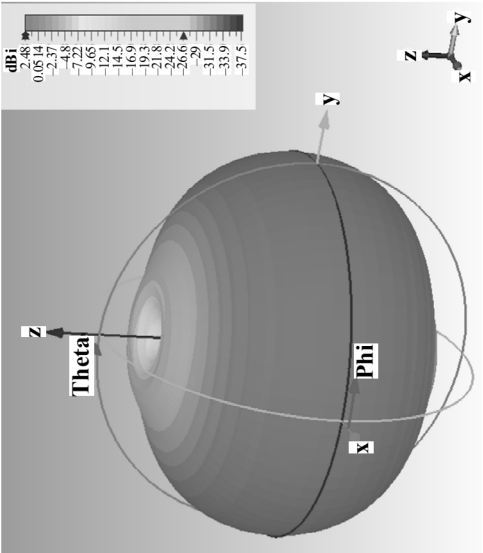


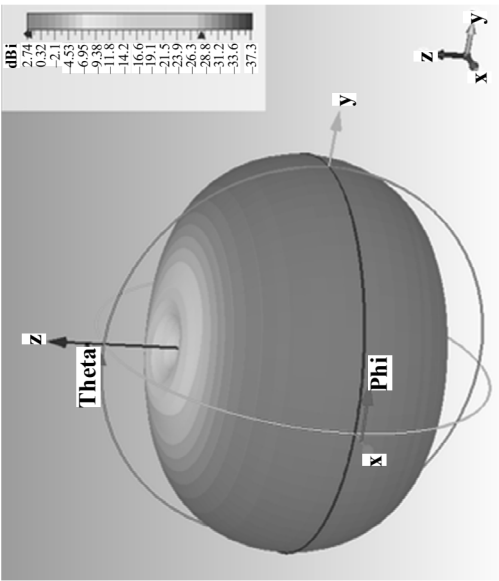
FIG. 9



5.6 GHz



5.2 GHz



4.8 GHz

FIG. 10

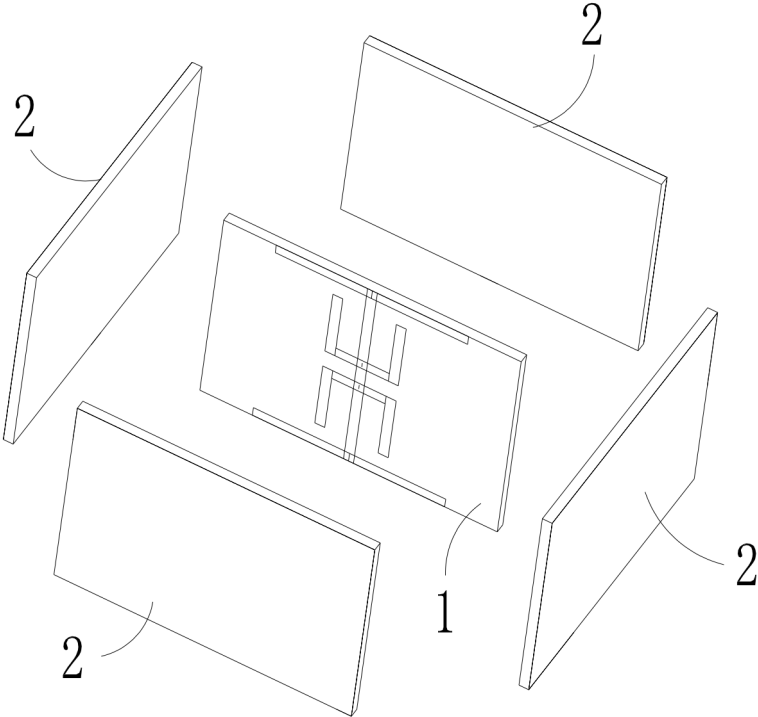


FIG. 11

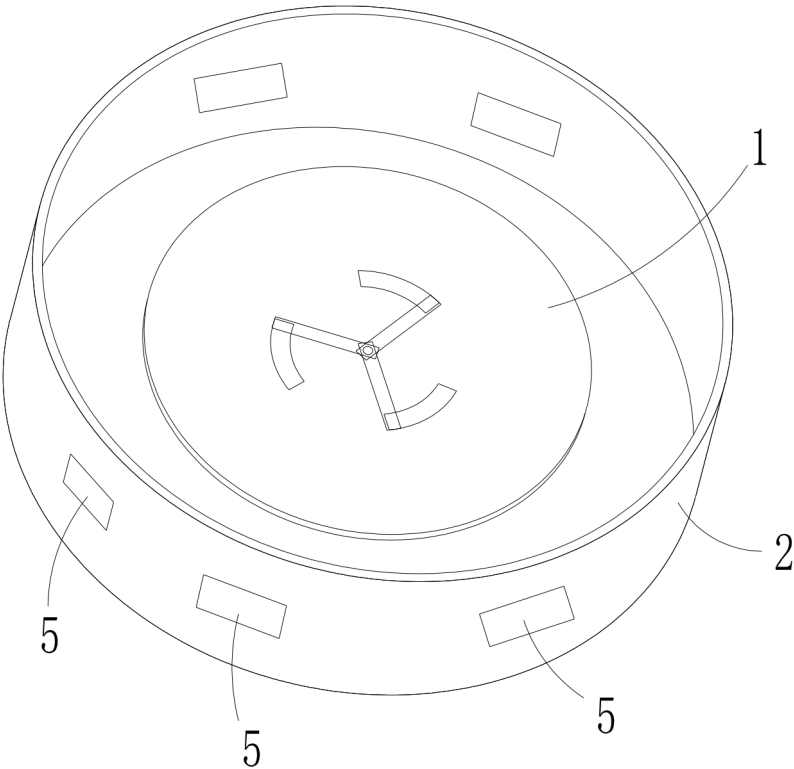


FIG. 12

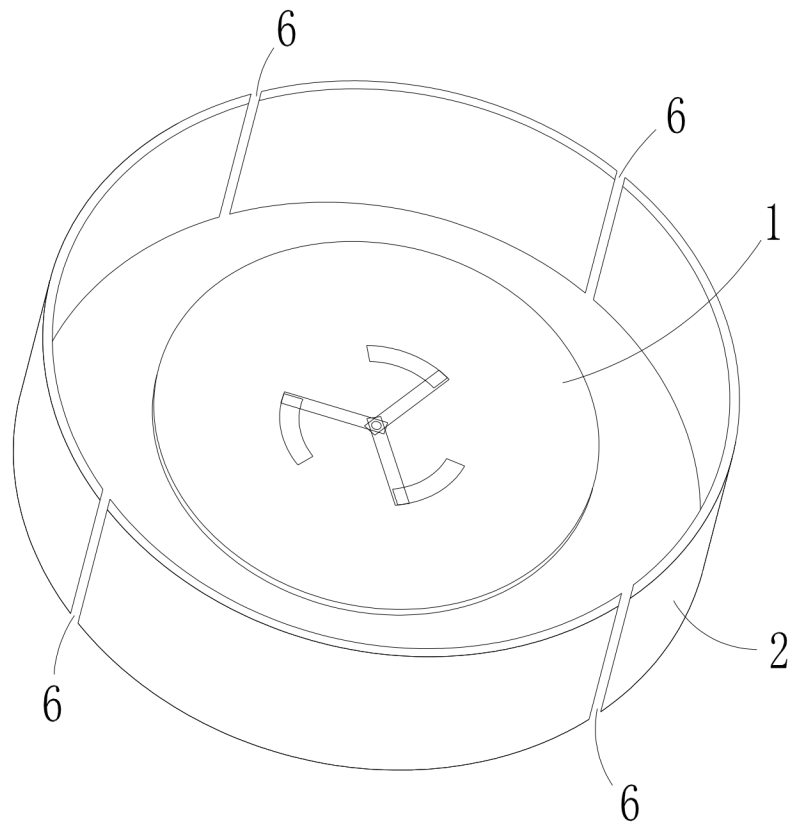


FIG. 13

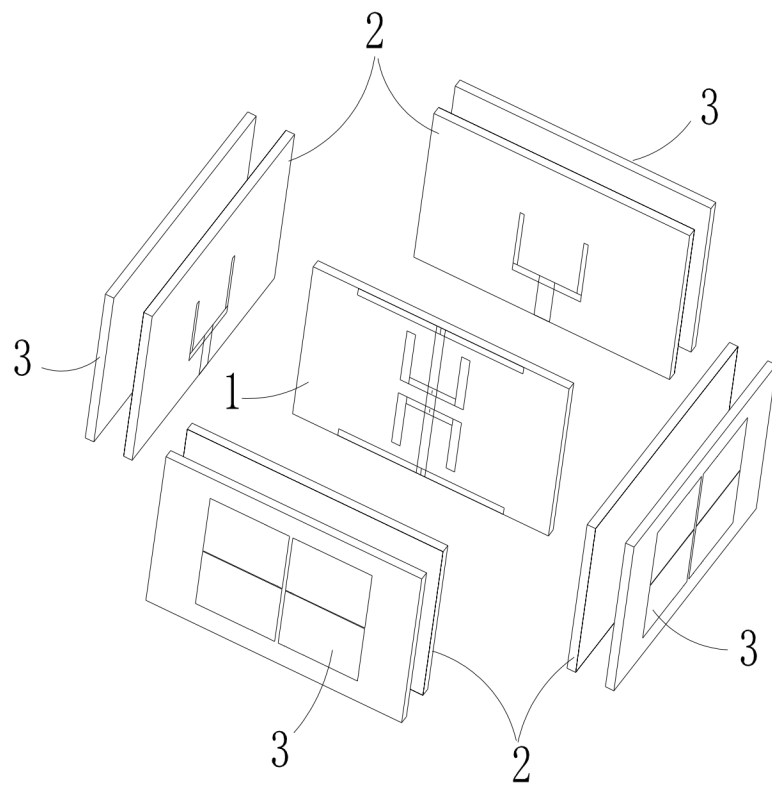


FIG. 14

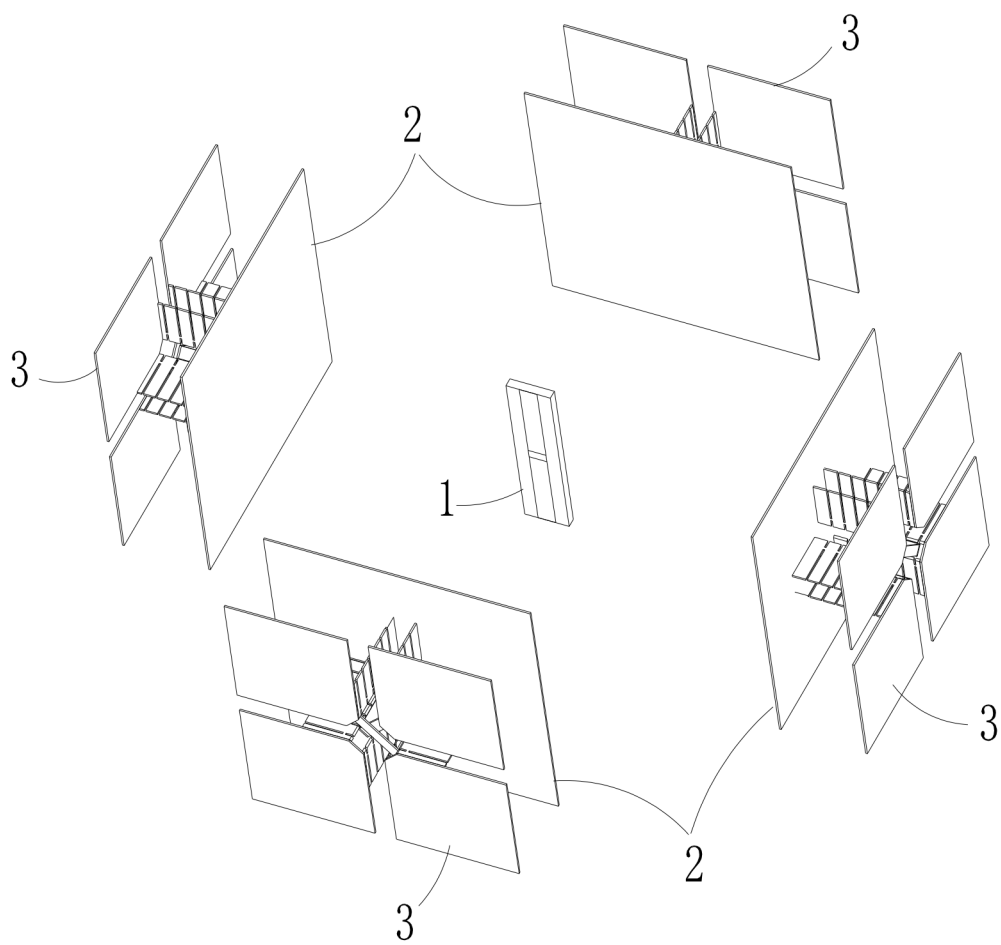


FIG. 15

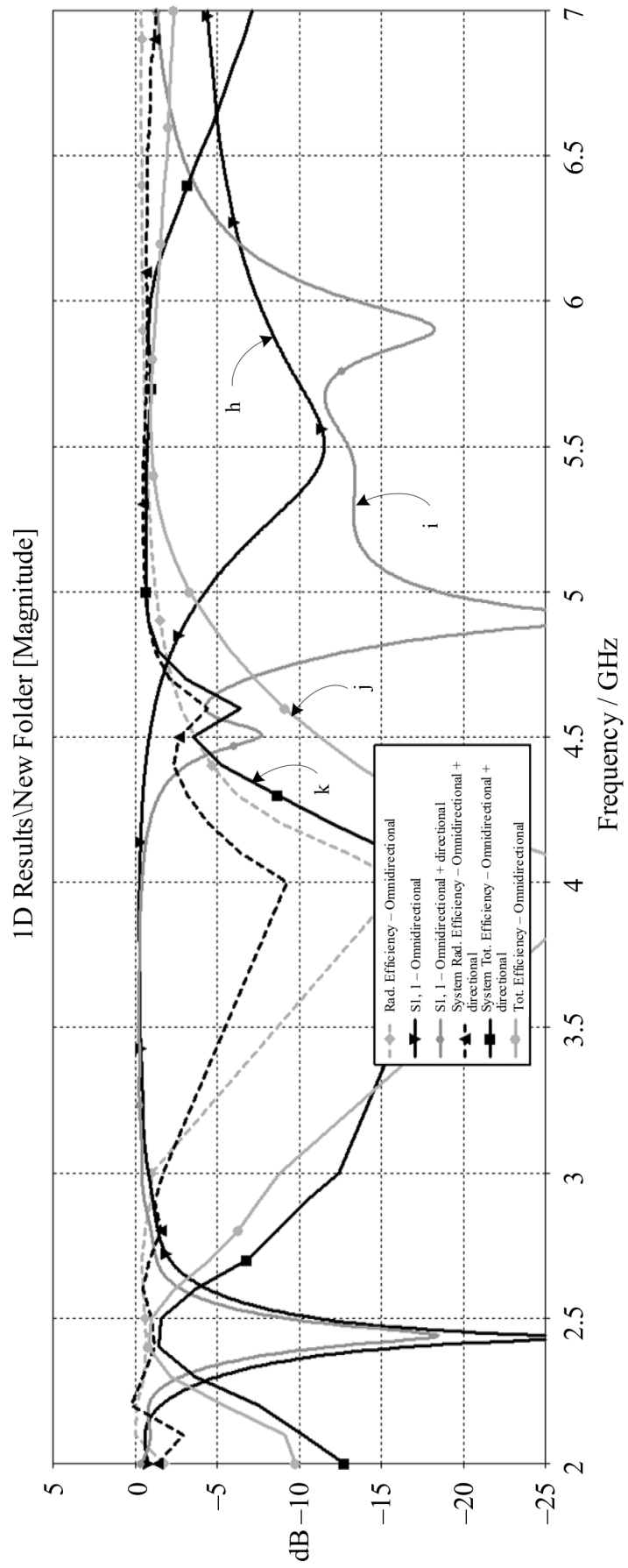
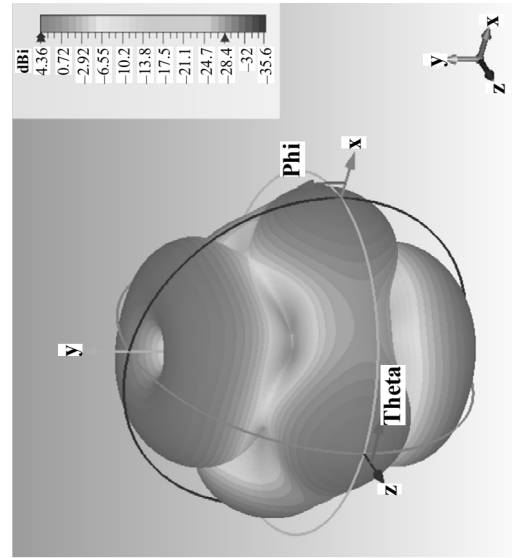
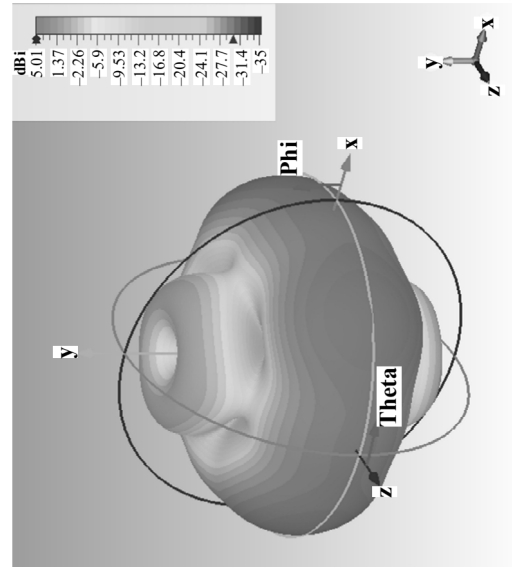


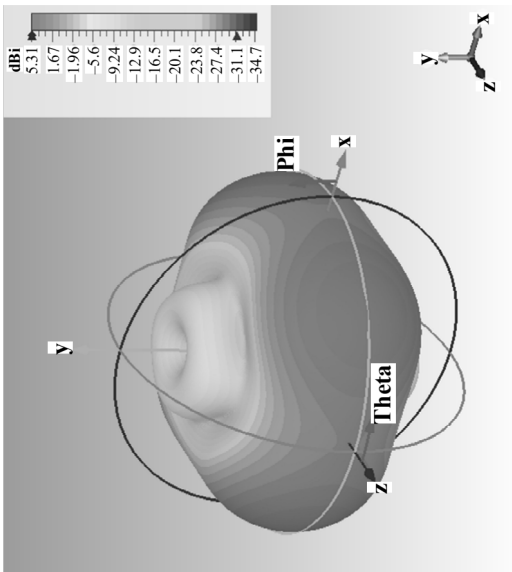
FIG. 16



5.8 GHz



5.4 GHz



5 GHz

FIG. 17

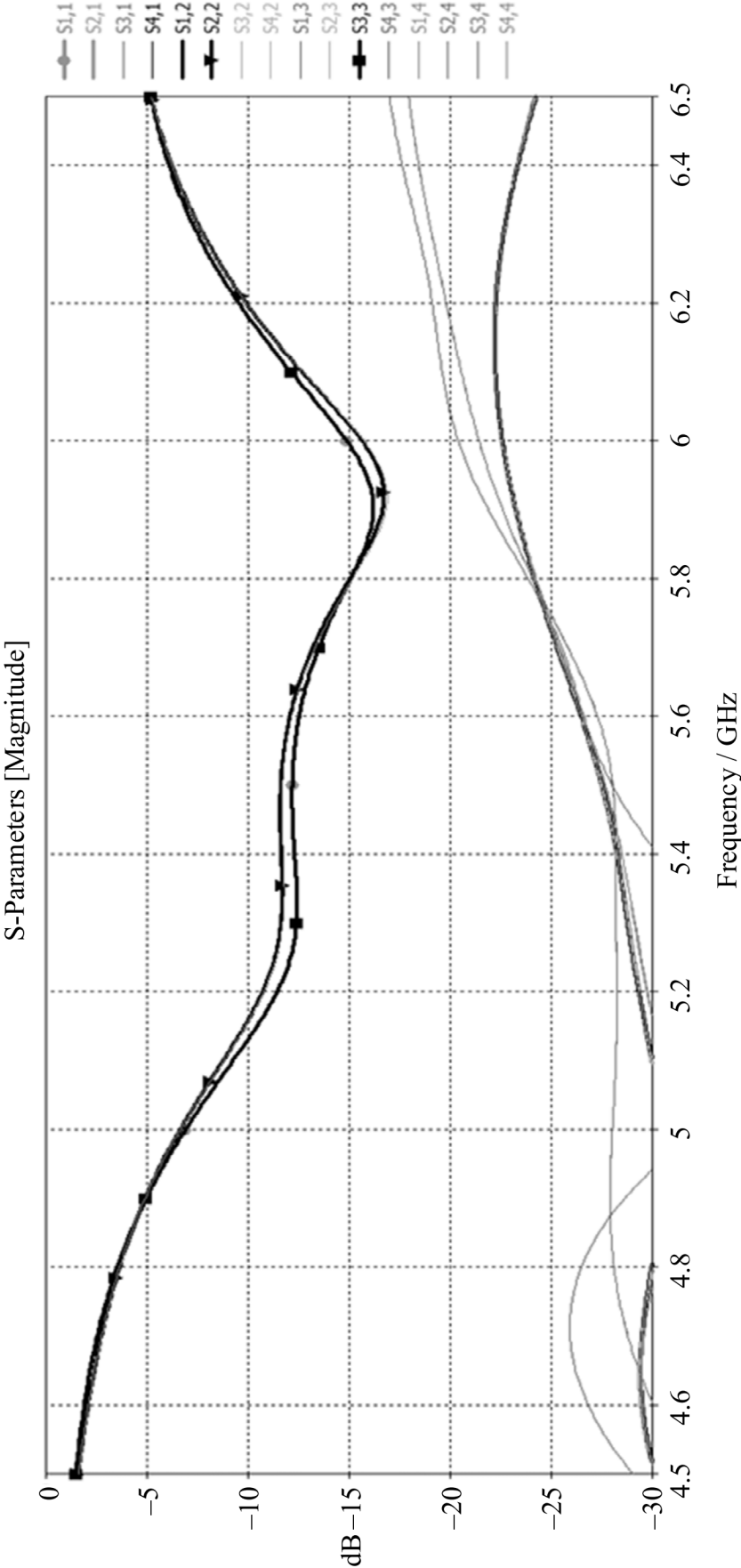


FIG. 18

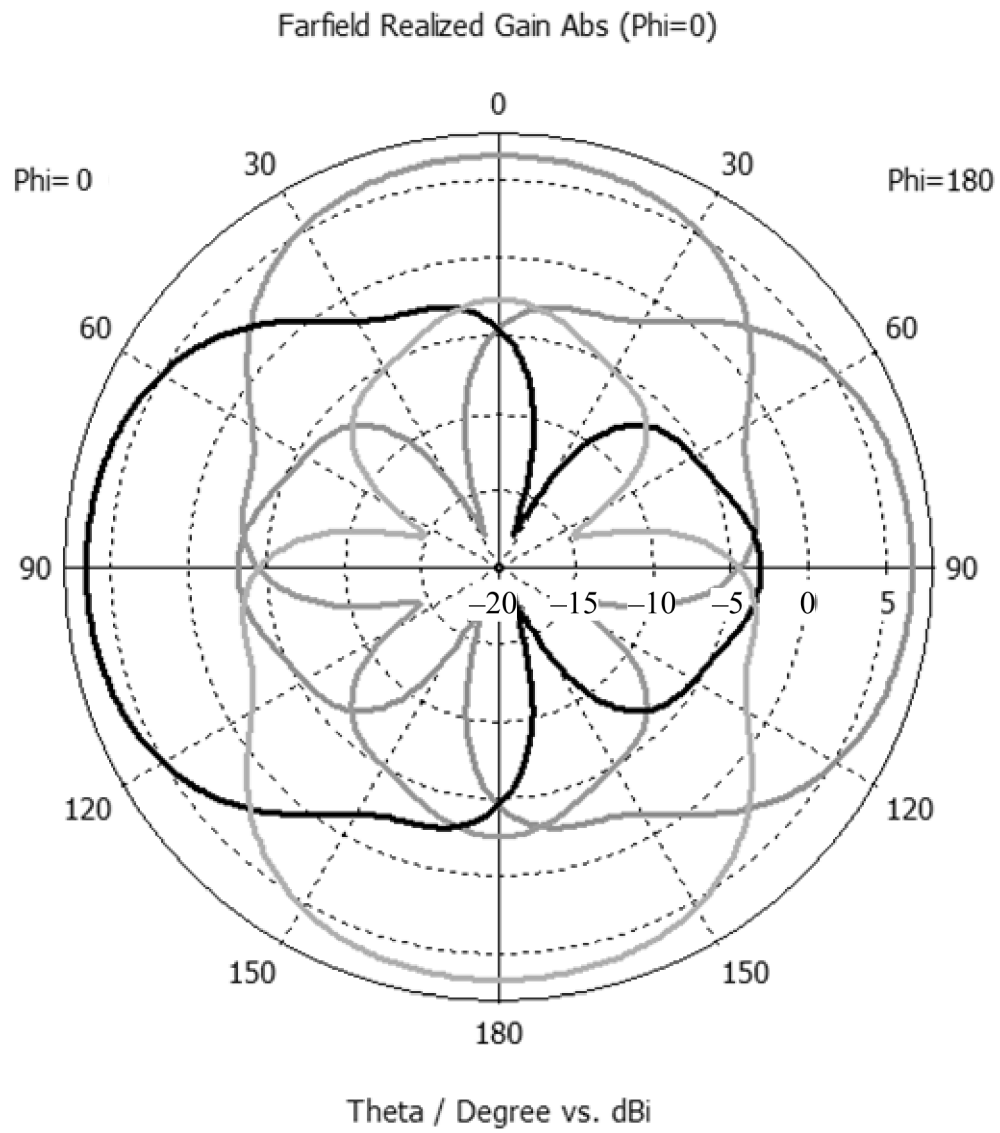
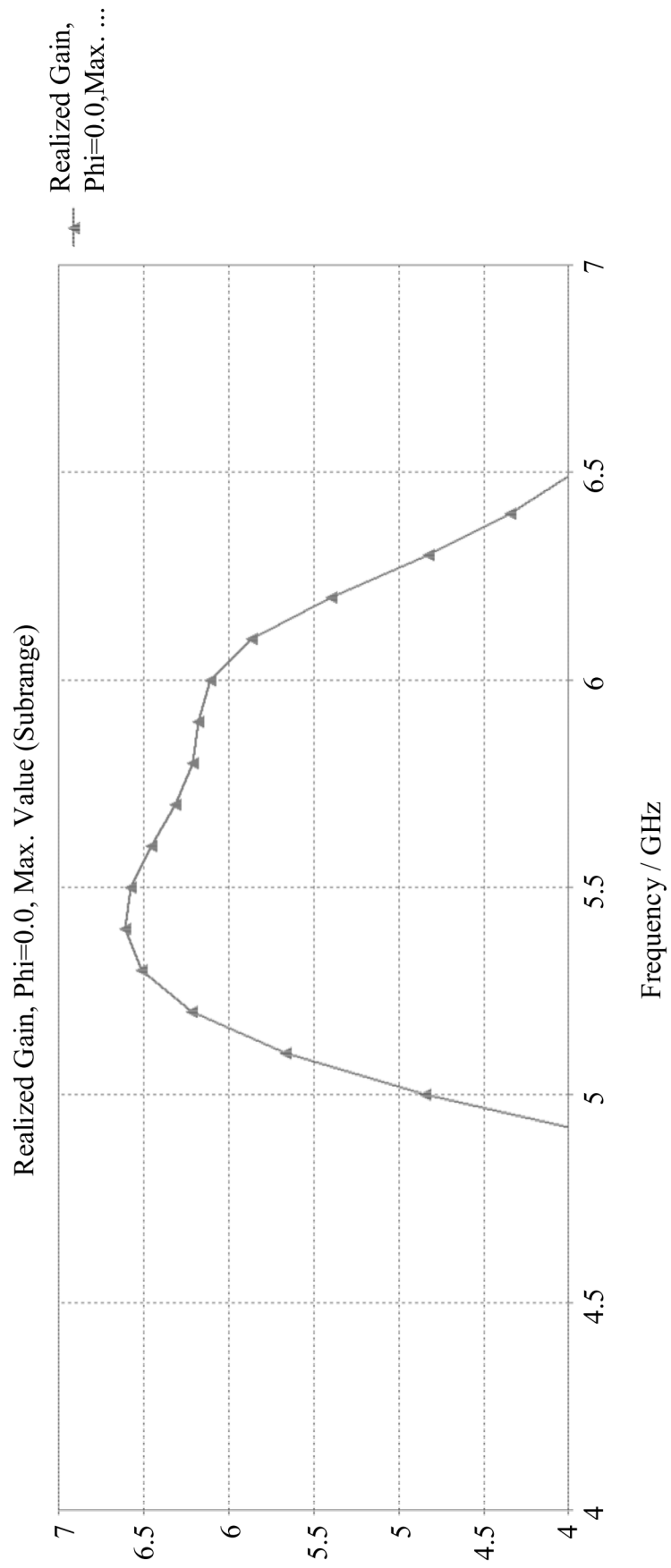


FIG. 19



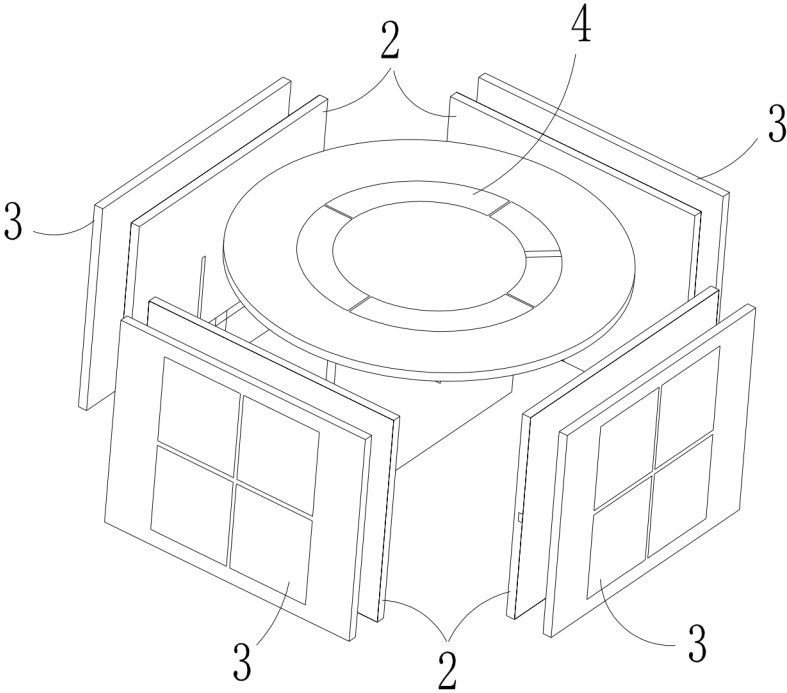


FIG. 21

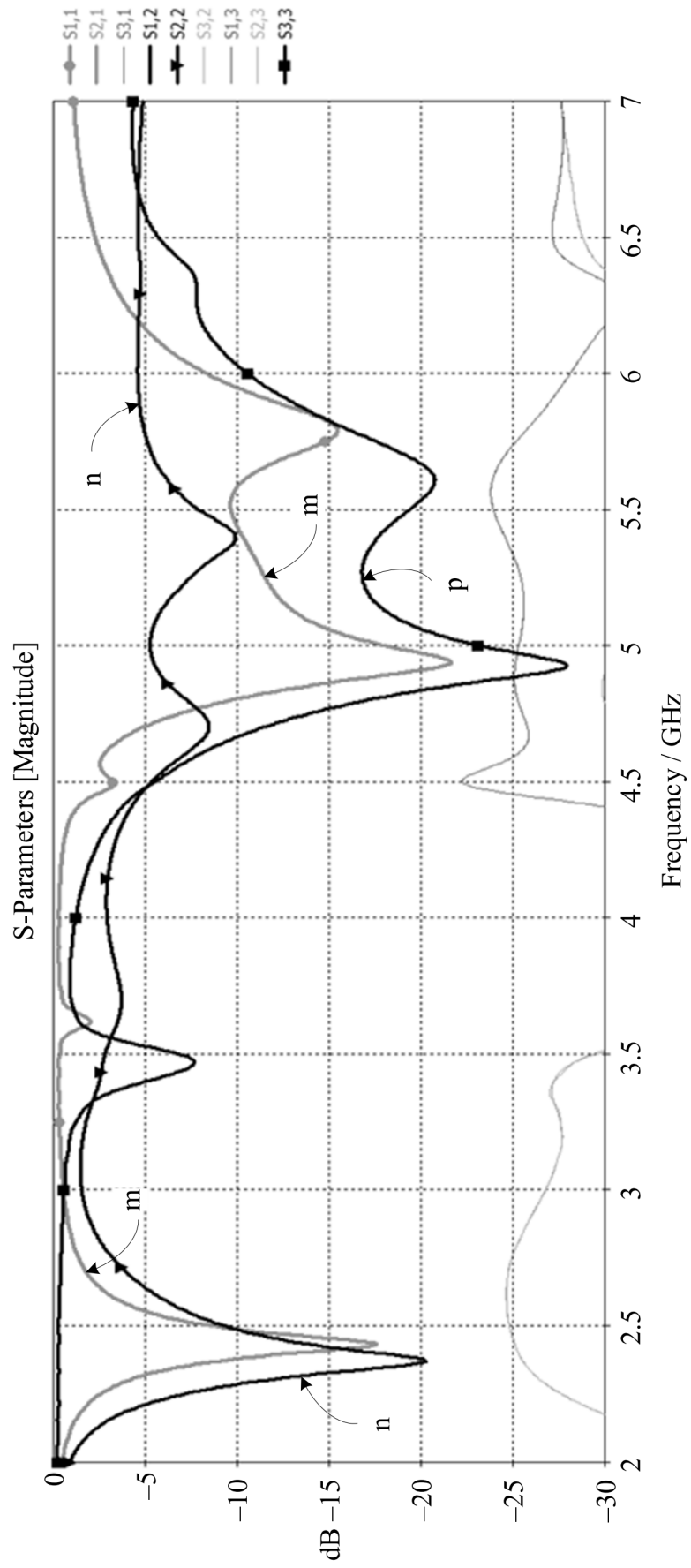


FIG. 22

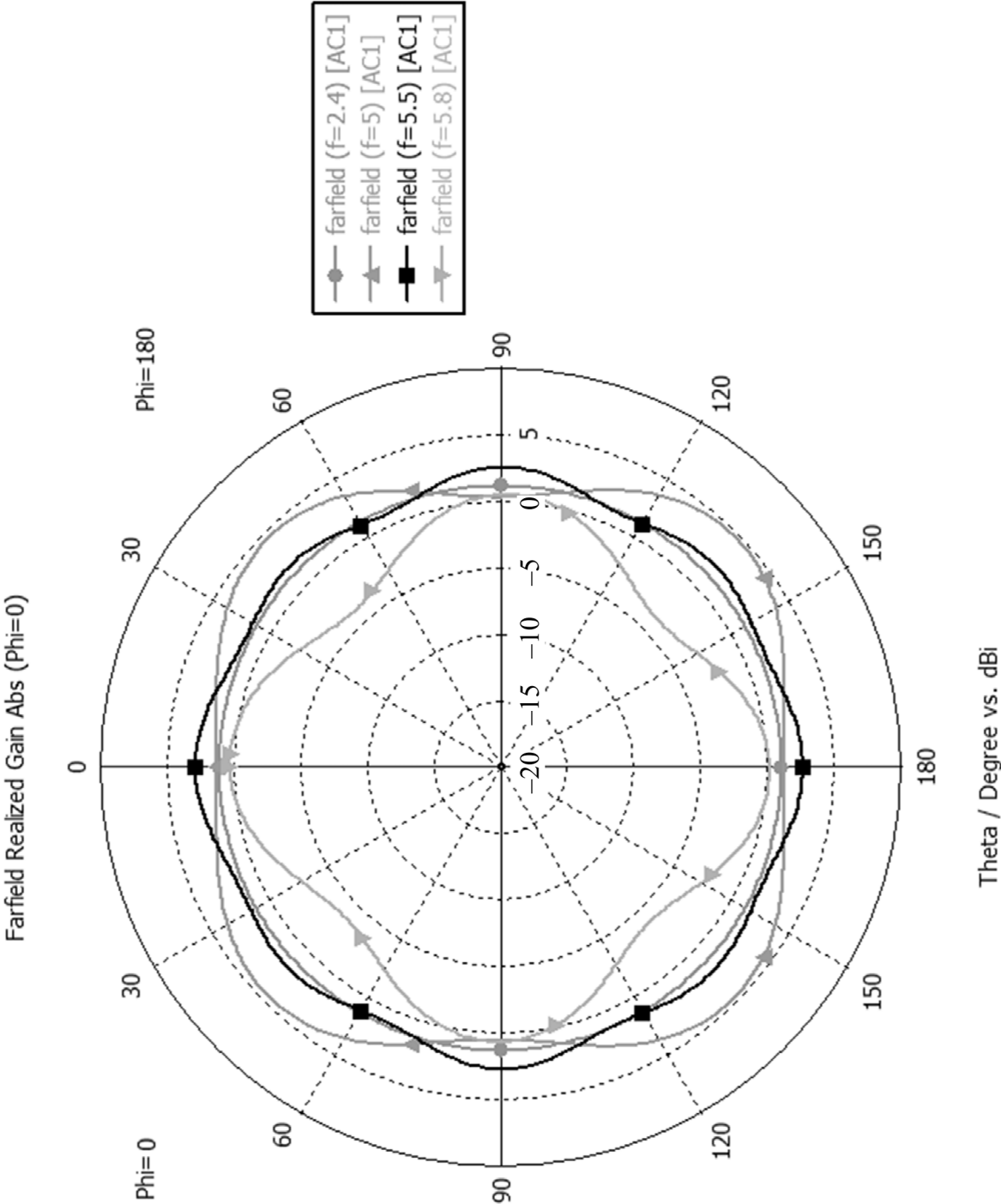


FIG. 23

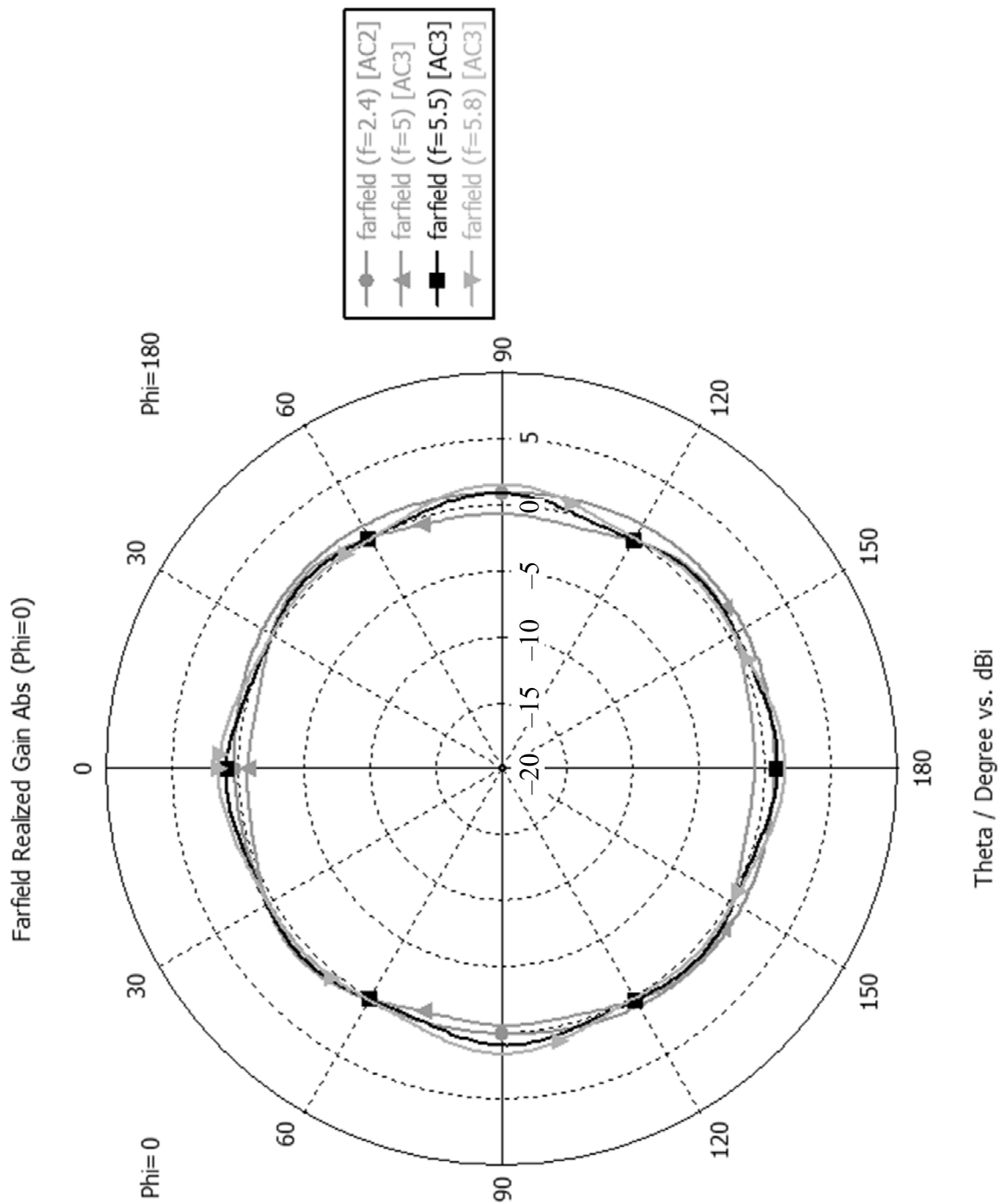


FIG. 24

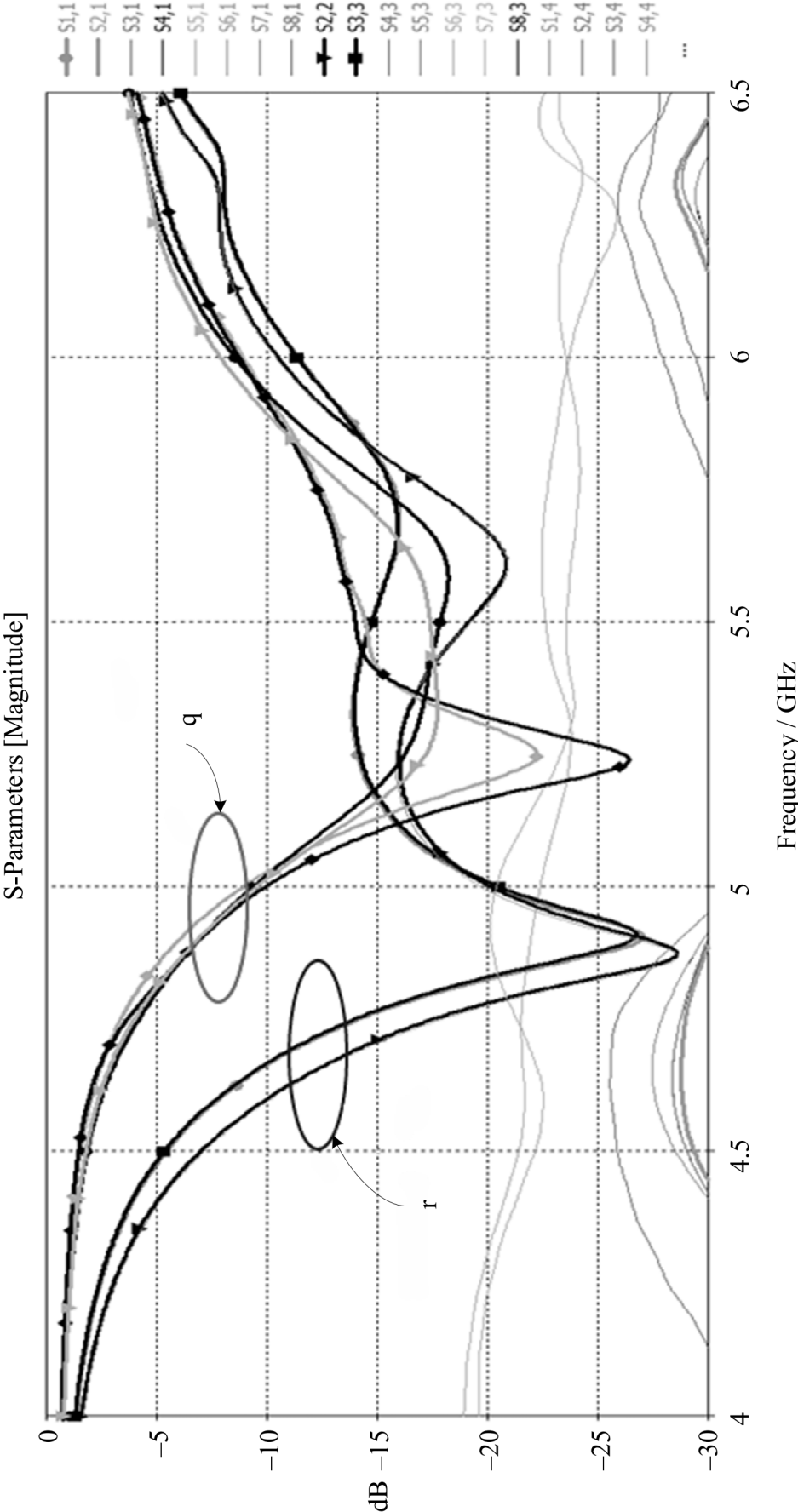


FIG. 25

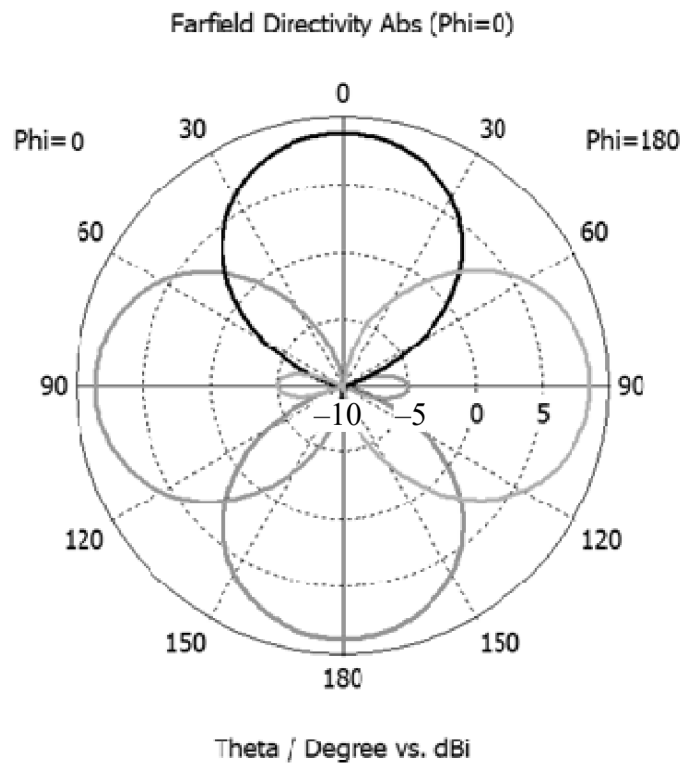


FIG. 26

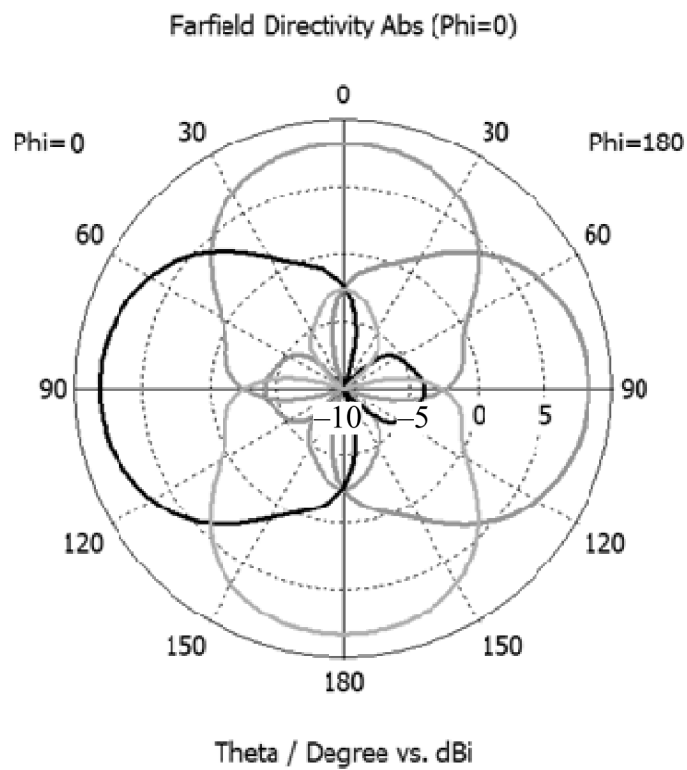


FIG. 27

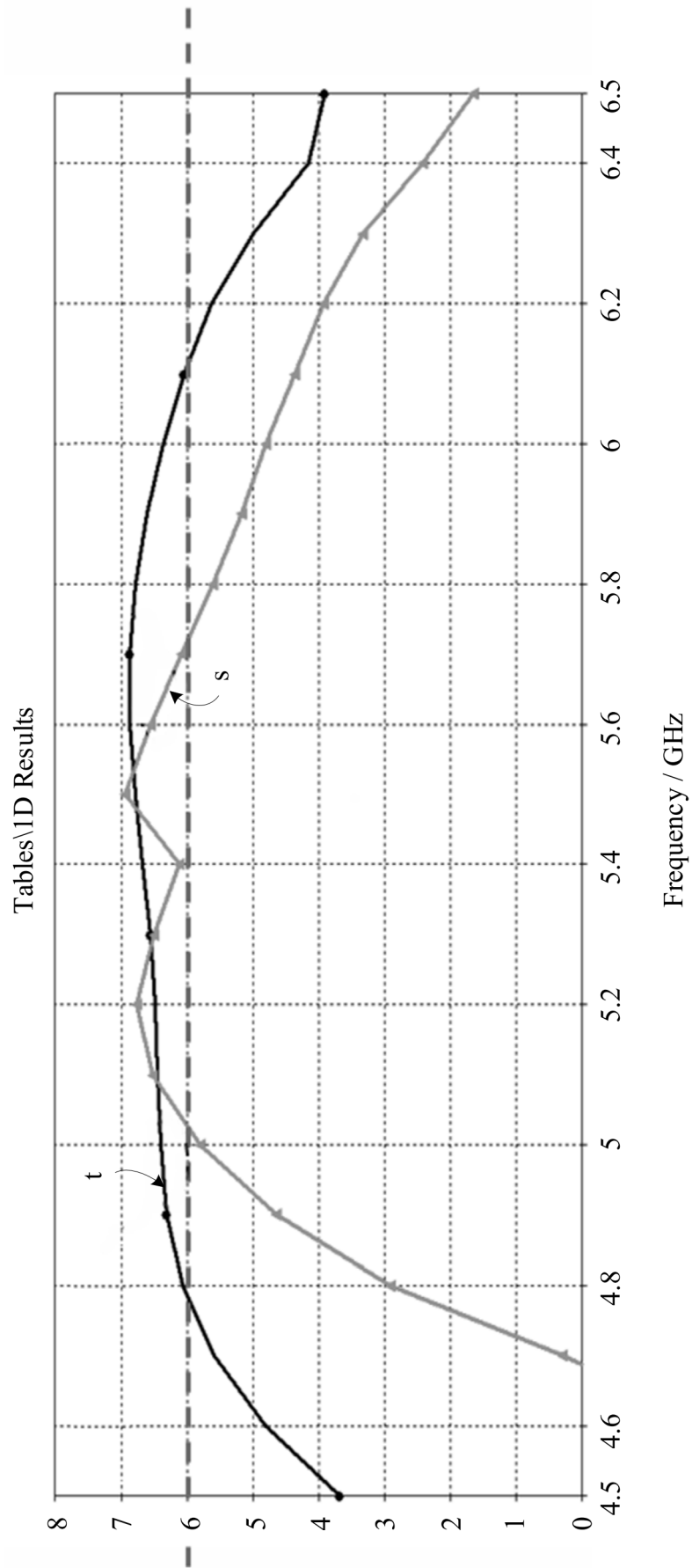


FIG. 28

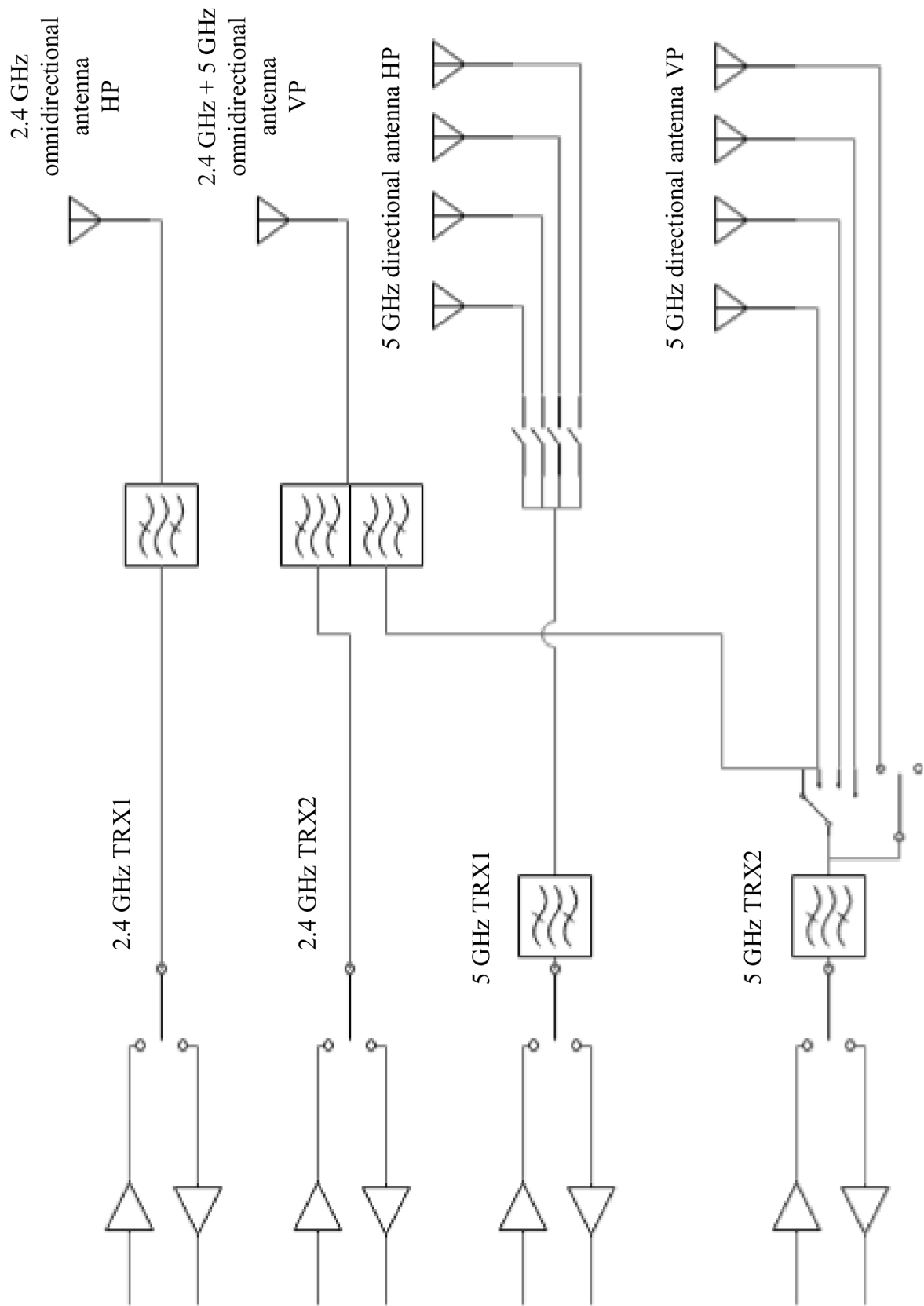


FIG. 29

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/072282

A. CLASSIFICATION OF SUBJECT MATTER

H01Q1/00(2006.01)i; H01Q5/00(2015.01)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)

CNABS: CNTXT; WOTXT; EPTXT; USTXT; VEN; 3GPP; IEEE: 天线, 金属, 罩, 壳, 框, 谐振, 距离, 间隔, 高度, 波长, 带宽, antenna, metal, cover+, shell, casing, distance, space, height, wavelength, bandwidth, BW

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 113437487 A (SHENZHEN SUNWAY COMMUNICATION CO., LTD.) 24 September 2021 (2021-09-24) description, paragraphs 23-66	1-6, 12-16
A	CN 114389006 A (HONOR TERMINAL CO., LTD.) 22 April 2022 (2022-04-22) entire document	1-16
A	KR 101692745 B1 (INCHEON UNIVERSITY INDUSTRY ACADEMIC COOPERATION FOUNDATION) 04 January 2017 (2017-01-04) entire document	1-16
A	WO 2022042239 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 03 March 2022 (2022-03-03) entire document	1-16

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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/CN2024/072282

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