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

(72) Inventors:
- **LIANG, Bin**
  Shenzhen, Guangdong 518129 (CN)
- **ZHANG, Yue**
  Shenzhen, Guangdong 518129 (CN)
- **WANG, Lilin**
  Shenzhen, Guangdong 518129 (CN)
- **DING, Ning**
  Shenzhen, Guangdong 518129 (CN)
- **YAN, Chen**
  Shenzhen, Guangdong 518129 (CN)

(74) Representative: **Thun, Clemens**
Mitscherlich PartmbB
Patent- und Rechtsanwälte
Karlstraße 7
80333 München (DE)

(54) ARRAY ANTENNA AND COMMUNICATION DEVICE

(57) Embodiments of this application disclose an array antenna and a communication device. The array antenna includes a plurality of radiating antenna units, a plurality of dummy antennas, and a printed circuit board. The plurality of radiating antenna units are configured to radiate or receive electromagnetic signals. The plurality of dummy antennas are arranged in an array, and the plurality of dummy antennas do not radiate the electromagnetic signals or do not receive the electromagnetic signals. Each dummy antenna includes a carbon oil buried resistor and a feeder, the feeder is connected to the carbon oil buried resistor, and both the carbon oil buried resistor and the feeder are disposed at an inner layer of the multi-layer printed circuit board. According to embodiments of this application, a unit pattern consistency characteristic the same as or similar to that of a regular array antenna can be implemented without affecting radiating efficiency and scanning performance of the array antenna.

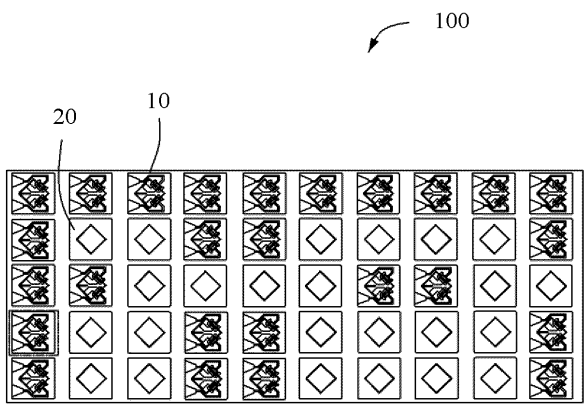

FIG. 2

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Description

TECHNICAL FIELD

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

BACKGROUND

[0002] An array antenna with an irregular arrangement is a technical means to suppress array scanning grating lobes, reduce a quantity of channels, and increase a gain. In an array antenna, consistency of element patterns is an important indicator for ensuring characteristics such as an array gain and pointing accuracy. Therefore, a manner of processing a non-radiative part and a dummy part of an irregular array is critical to array performance.

[0003] In some scenarios, to improve consistency of array units in a regular array, a plurality of dummy antennas may be disposed around the array, and loads of the dummy antennas and a chip of the array are also surface-mounted at a bottom layer of a printed circuit board (Printed Circuit Board, PCB) by using a surface mount technology (Surface Mount Technology, SMT). However, for an irregular array with a compact arrangement and a large quantity of dummy antennas which are disposed in the array, there is no sufficient space to place an SMT load. Consequently, layout space of the PCB is occupied.

SUMMARY

[0004] Embodiments of this application provide an array antenna and a communication device. The array antenna and the communication device in embodiments of this application may implement a unit pattern consistency characteristic similar to that of a regular array without affecting radiating efficiency and scanning performance of the array antenna, and may further not occupy layout space of a printed circuit board.

[0005] According to a first aspect, an embodiment of this application provides an array antenna, used in a communication device. The array antenna includes a plurality of radiating antenna units and a plurality of dummy antennas, and a processing implementation of the array antenna is a multi-layer printed circuit board (PCB). The plurality of radiating antenna units are configured to radiate or receive electromagnetic signals. The plurality of dummy antennas occupy locations in an array but do not radiate the signals. Each dummy antenna includes a carbon oil buried resistor and a feeder, the feeder is connected to the carbon oil buried resistor, and both the carbon oil buried resistor and the feeder are disposed at an inner layer of the multi-layer printed circuit board.

[0006] In this embodiment of this application, the carbon oil buried resistor is connected to a feeder end of the dummy antenna, to be used as the load of the dummy antenna. In this way, unit pattern consistency the same as that of a regular antenna array can be implemented without affecting radiating efficiency and scanning performance of the array antenna, and an appearance encryption function can be further maintained. In this embodiment of this application, the carbon oil buried resistor is disposed at the inner layer of the multi-layer printed circuit board, so that layout space of the printed circuit board is not occupied.

[0007] In an optional implementation, the carbon oil buried resistor and the feeder are disposed at a same layer of the multi-layer printed circuit board; or the carbon oil buried resistor and the feeder are disposed at different layers of the printed circuit board. In this way, unit pattern consistency the same as that of a regular antenna array can be implemented, and an appearance encryption function can be further maintained.

[0008] In an optional implementation, a shape and a size of the dummy antenna are the same as or similar to a shape and a size of the radiating antenna unit.

[0009] In an optional implementation, the carbon oil buried resistor is made of a carbon oil material with a wave-absorbing characteristic. Based on such a design, the dummy antenna may have a good wave-absorbing characteristic.

[0010] In an optional implementation, the multi-layer printed circuit board includes a first metal layer, a first dielectric layer, a second metal layer, a second dielectric layer, a third metal layer, a third dielectric layer, and a fourth dielectric layer that are sequentially stacked. Both the carbon oil buried resistor and the feeder in each dummy antenna are disposed between the third dielectric layer and the fourth dielectric layer. The carbon oil buried resistor is disposed at the inner layer of the printed circuit board, so that layout space of the printed circuit board is not affected.

[0011] In an optional implementation, the carbon oil buried resistor and a metal layer may be disposed at a same layer of the multi-layer circuit board, and a thickness of the carbon oil buried resistor is not greater than a thickness of the metal layer.

[0012] In an optional implementation, the array antenna further includes a power divider. The power divider includes an input port, a first output port, and a second output port. The input port is connected to a radio frequency chip, and the first output port is connected to the second output port through the carbon oil buried resistor.

[0013] In an optional implementation, the first output port and the second output port each are connected to one radiating antenna unit.

[0014] In an optional implementation, the power divider includes a main path feeder, a first quarter-wave transformation line, a second quarter-wave transformation line, a first branch feeder, and a second branch feeder. A first end of the main path feeder is connected to the input port, and a second end of the main path feeder is connected to a first end of the first quarter-wave transformation line and a first end of the second quarter-wave transformation line. A second end of the first quarter-wave transformation line is connected to a first end of the first branch feeder, and a second end of the second quarter-wave transformation line is connected to a first end of the second branch feeder. A second end of the first branch feeder is connected to the first output port, a second end of the second branch feeder is connected to the second output port, and one carbon oil buried resistor is connected between the first end of the first branch feeder and the first end of the second branch feeder. In this way, good matching and isolation characteristics of the ports of the power divider may be used, to ensure that unit patterns in an array are not distorted due to mutual coupling.

[0015] In an optional implementation, at least a part of the main path feeder and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board. At least a part of the first branch feeder and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board. At least a part of the second branch feeder and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board. At least a part of the first quarter-wave transformation line and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board. At least a part of the second quarter-wave transformation line and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board.

[0016] According to a second aspect, an embodiment of this application further provides a communication device. The communication device includes the array antenna described above.

[0017] In this embodiment of this application, unit pattern consistency the same as that of a regular antenna array can be implemented without affecting radiating efficiency and scanning performance of the array antenna, and an appearance encryption function can be further maintained. In this embodiment of this application, a carbon oil buried resistor is disposed at an inner layer of a multi-layer printed circuit board, so that layout space of the printed circuit board is not occupied.

BRIEF DESCRIPTION OF DRAWINGS

[0018]

FIG. 1a is a diagram of a structure of a regular array antenna according to an embodiment of this application;

FIG. 1b and FIG. 1c are diagrams of structures of irregular array antennas according to embodiments of this application;

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

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

FIG. 4 is a diagram of an S11 parameter corresponding to an array antenna according to an embodiment of this application;

FIG. 5 is a diagram of a structure of a multi-layer printed circuit board according to an embodiment of this application;

FIG. 6 is a diagram of an application scenario of a carbon oil buried resistor according to an embodiment of this application;

FIG. 7 is a diagram of another application scenario of a carbon oil buried resistor according to an embodiment of this application;

FIG. 8 is a diagram of a carbon oil buried resistor and a feeder in a multi-layer printed circuit board according to an embodiment of this application;

FIG. 9a and FIG. 9b are diagrams of effects of unit pattern consistency without using a carbon oil buried resistor as a load;

FIG. 9c and FIG. 9d are diagrams of effects of unit pattern consistency according to embodiments of this application;

FIG. 10a is a diagram of a structure of a T-type power divider;

FIG. 10b is a diagram of a structure of a Wilkinson power divider;

FIG. 11 is a diagram of a structure of a power divider according to an embodiment of this application;

FIG. 12 is a diagram of another structure of a power divider according to an embodiment of this application;

FIG. 13a to FIG. 13c respectively show patterns of a theoretical expectation, a Wilkinson power divider, and a T-type power divider;

FIG. 14 is a diagram of an application scenario of an array antenna according to an embodiment of this application; and

FIG. 15 is a diagram of a structure of a communication device according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0019] The following clearly and completely describes technical solutions in embodiments of this application with reference to the accompanying drawings in embodiments of this application. It is clear that the described embodiments are some but not all of embodiments of this application.

[0020] In embodiments of this application, words such as "first" and "second" are merely used to distinguish between different objects, but cannot be understood as indicating or implying relative importance, and cannot be understood as indicating or implying a sequence. For example, a first application, a second application, and the like are used to distinguish between different applications, but are not used to describe a specific order of applications. A feature limited by "first" or "second" may explicitly or implicitly include one or more features. In the descriptions of embodiments of this application, the word such as "example" or "for example" is used to represent giving an example, an illustration, or a description. Any embodiment or design scheme described as an "example" or "for example" in embodiments of this application should not be explained as being more preferred or having more advantages than another embodiment or design scheme. Exactly, use of the word such as "example" or "for example" is intended to present a relative concept in a specific manner.

[0021] An antenna is one of the most important front-end passive components of a communication device, and the antenna plays an extremely important role in improving performance of a communication product. With rapid development of mobile communication and large-scale application of 5G technologies, base station antennas are increasingly and widely applied. A large-scale array antenna is a development trend of a current base station antenna.

[0022] It may be understood that array antennas may include an array antenna with a regular arrangement and an array antenna with an irregular arrangement. For example, in a scenario, FIG. 1a shows the array antenna with a regular arrangement, and an array element spacing of the array antenna with a regular arrangement may be a fixed value. In another scenario, FIG. 1b shows the array antenna with an irregular arrangement, and an array element spacing of the array antenna with an irregular arrangement is not a fixed value, and array elements may be arranged in a sparse-dense manner. In another scenario, FIG. 1c shows the array antenna with an irregular arrangement, and the array antenna with an irregular arrangement may select some units from a regular array to work, and the remaining parts may be non-radiating dummies.

[0023] In an array antenna, consistency of element patterns is an important indicator for ensuring characteristics such as an array gain and pointing accuracy. Therefore, a manner of processing a non-radiative part and a dummy part of an irregular array is critical to array performance.

[0024] In a possible scenario, to improve consistency of peripheral units of a regular array, dummies are designed around the array, and loads of the dummies and a chip of the array are surface-mounted at a bottom layer of a printed circuit board (Printed circuit board, PCB) by using a surface mount technology (Surface Mount Technology, SMT). In this scenario, for an irregular array with a compact arrangement and a large quantity of dummies, there is no sufficient space to set an SMT load. Consequently, layout space of the PCB is occupied.

[0025] In another possible scenario, a dummy may be open-circuited at a terminal or shortcircuited at the terminal. However, in this scenario, electromagnetic environments in which radiating antenna units are located are different, and radiation patterns of the radiating antenna units differ greatly. Consequently, unit pattern consistency is poor.

[0026] In another possible scenario, a manner of processing a dummy may be connecting a feeder to a load at an inner layer. In this way, it can be ensured that unit patterns have good consistency. However, an implementation of a buried resistor in this scenario is resistive copper foil, to be specific, metal at the layer changes from original copper to a lossy conductor with sheet resistance. Consequently, a feeder loss of a radiating antenna at the same layer increases, and efficiency of the antenna is greatly reduced.

[0027] Embodiments of this application provide an array antenna and a communication device. In embodiments of this application, unit pattern consistency the same as that of a regular antenna array can be implemented without affecting radiating efficiency and scanning performance of the array antenna, and an appearance encryption function can be further maintained.

[0028] FIG. 2 is a diagram of a structure of an array antenna 100 according to an embodiment of this application.

[0029] The array antenna 100 may include a plurality of dummy antennas 10 and a plurality of radiating antenna units 20. It may be understood that the plurality of dummy antennas 10 and the plurality of radiating antenna units 20 may be arranged into an array. The array antenna 100 in this embodiment may be an irregular array. In other words, the plurality of dummy antennas 10 and the plurality of radiating antenna units 20 may be irregularly arranged in an antenna array. It may be understood that, in another possible implementation, the array antenna 100 may be a regular array antenna. It should be noted that, compared with a regular array, the irregular array may have an actual effect of suppressing grating lobes.

[0030] It may be understood that, in this embodiment, the dummy antennas 10 are disposed at an array edge of the array antenna 100.

[0031] In this embodiment, the radiating antenna unit 20 may be a patch. In a specific implementation process, each radiating antenna unit 20 may be connected to a radio frequency chip (not shown in the figure) or a radio frequency component (not shown in the figure) through a microstrip or a strip line. In some embodiments, the radiating antenna unit 20 may be a radiating antenna of a multi-layer structure.

[0032] It may be understood that, in this embodiment, the plurality of radiating antenna units 20 may be configured to radiate or receive electromagnetic signals. For example, every two radiating antenna units 20 may be connected to one radio frequency chip. The radio frequency chip may radiate or receive the electromagnetic signal through the radiating antenna unit 20.

[0033] In this embodiment, the plurality of dummy antennas 10 may occupy locations in the array, but the plurality of dummy antennas 10 do not radiate the signals.

[0034] In an optional implementation, the dummy antenna 10 is not connected to the radio frequency component.

[0035] As shown in FIG. 2, in this embodiment, a shape and a size of the dummy antenna 10 may be the same as or similar to those of the radiating antenna unit 20.

[0036] FIG. 3 is a diagram of a structure of a dummy antenna 10 according to an embodiment of this application. It may be understood that, in an array antenna 100, each dummy antenna 10 includes a feeder 12 and a carbon oil buried resistor 14. The feeder 12 may be a strip line feeder. In this embodiment, the carbon oil buried resistor 14 may be disposed at an inner layer of a printed circuit board (Printed Circuit Board, PCB). It may be understood that the feeder 12 of the dummy antenna 10 may not be connected to a radio frequency chip or a radio frequency component. The feeder 12 of the dummy antenna 10 may be connected to the carbon oil buried resistor 14 at the inner layer of the printed circuit board. The carbon oil buried resistor 14 may be configured to match a load for the dummy antenna 10, in other words, the carbon oil buried resistor 14 may be used as a feeder terminal load of the dummy antenna 10.

[0037] In this embodiment, the feeder 12 of the dummy antenna 10 and a feeder of a radiating antenna unit 20 are disposed at the inner layer of the multi-layer printed circuit board in a form of strip lines. In this way, an array radiation characteristic is not affected, and there is an appearance encryption function. It may be understood that, in a possible implementation, in one dummy antenna 10, a carbon oil buried resistor 14 and a feeder 12 may be at a same layer.

[0038] It may be understood that the feeder 12 may be made of a metal material. The carbon oil buried resistor 14 and a metal layer (for example, the feeder 12) may be disposed at a same layer of the multi-layer printed circuit board, and a thickness of the carbon oil buried resistor 14 is not greater than a thickness of the metal layer.

[0039] It may be understood that the carbon oil buried resistor 14 and the feeder 12 may not be located at a same layer. The carbon oil buried resistor 14 may alternatively be connected to the feeder 12 through a via (not shown in the figure).

[0040] The carbon oil buried resistor 14 may be disposed in the dummy antenna 10, or may be disposed in another area of the entire array antenna 100.

[0041] In an optional implementation, as shown in FIG. 3, the dummy antenna 10 may include two carbon oil buried resistors 14, and the two carbon oil buried resistors 14 may be correspondingly connected to feeders 12.

[0042] It may be understood that, in some embodiments, the carbon oil buried resistor 14 may be grounded. In some other embodiments, the carbon oil buried resistor 14 may alternatively not be grounded.

[0043] Based on embodiments shown in FIG. 2 and FIG. 3, the dummy antenna 10 absorbs only energy of the radiating antenna unit 20. Therefore, the dummy antenna 10 in embodiments of this application does not perform secondary reflection. In this way, a problem that secondary radiation of the dummy antenna causes distortion on a feeding antenna pattern can be avoided.

[0044] According to embodiments shown in FIG. 2 and FIG. 3, an irregular array antenna may have unit pattern consistency the same as or similar to that of a regular array antenna without increasing PCB layer stacking complexity.

[0045] FIG. 4 is a simulation diagram of a wave-absorbing characteristic of the dummy antenna 10 that uses the carbon oil buried resistor. It can be seen from FIG. 4 that, return losses of the dummy antenna 10 in an operating frequency band are all less than -20 dB. It can be learned that, using the carbon oil buried resistor 14 in the dummy antenna 10 can have a good wave-absorbing effect. It may be understood that, during actual measurement, the dummy antenna 10 may alternatively have a wave-absorbing characteristic similar to that of a simulation result.

[0046] It may be understood that, in some possible implementations, the carbon oil buried resistor 14 may be made of a carbon oil material. The carbon oil buried resistor 14 may have a wave-absorbing characteristic. In embodiments of this application, a sheet resistivity of the carbon oil buried resistor 14 may range from 1 Ω/square to 5,000 Ω/square.

[0047] It may be understood that, in some possible scenarios, carbon oil may be obtained by processing carbon powder (for example, graphite) and epoxy resin. Therefore, if the carbon oil serves as a conductor, the carbon powder in the carbon oil may be conductive, and a conductivity of the carbon powder may be related to a particle size and content of the carbon powder. For example, a larger particle size or a larger quantity of particles of the carbon powder indicates a higher conductivity and smaller resistance of the carbon powder. For example, at a normal temperature, ink of the carbon oil may be in a gel-like form, and the ink may be in a fluid gel-like form after being stirred. In other words, the ink of the carbon oil may be thermal curing ink.

[0048] The sheet resistivity mentioned above may be a resistance characteristic parameter of the carbon oil. For example, a square ink pattern is printed in a case of a specific thickness, and a resistance value measured after the square ink pattern is cured is a sheet resistivity of the carbon oil. In embodiments of this application, the sheet resistivity of the carbon oil buried resistor may be any value from 1 Ω/square to 5,000 Ω/square. It may be understood that, in another implementation, the sheet resistivity of the carbon oil buried resistor 14 may alternatively be any other value. This is not specifically limited in embodiments of this application.

[0049] A resistance value of the carbon oil buried resistor 14 may be related to a shape and the sheet resistivity of the carbon oil buried resistor.

[0050] It may be understood that the thickness of the carbon oil buried resistor 14 may be adjusted according to an actual requirement. In a possible implementation, the thickness of the carbon oil buried resistor 14 may be less than or equal to a thickness of a metal layer at which the carbon oil buried resistor is located.

[0051] In some possible scenarios, a resistor may be disposed at a surface layer of the printed circuit board. For example, as shown in FIG. 5, a first resistor 31 may be disposed at a top layer of the printed circuit board 30, and a second resistor 32 may be disposed at a bottom layer of the printed circuit board 30.

[0052] It may be understood that, compared with the scenario shown in FIG. 5, in embodiments of this application, a carbon oil silkscreen process may be used at the inner layer of the printed circuit board, in other words, in embodiments of this application, a thin carbon oil layer (namely, the carbon oil buried resistor) with a sheet resistance characteristic may be printed at the inner layer of the printed circuit board.

[0053] As shown in FIG. 6, the carbon oil buried resistor 14 may have a specific pattern and thickness. For example, a shape of the carbon oil buried resistor may be a trapezoid, a rectangle, a circle, or another irregular pattern. This is not limited in embodiments of this application.

[0054] Two sides of the carbon oil buried resistor 14 may each be connected to a metal pattern. For example, one side of the carbon oil buried resistor 14 may be connected to the feeder, and the other side of the carbon oil buried resistor 14 may be connected to a ground cable.

[0055] As shown in FIG. 7, the carbon oil buried resistor 14 is disposed at the inner layer of the printed circuit board. One side of the carbon oil buried resistor may be connected to the feeder 12, and the other side of the carbon oil buried resistor may be connected to a ground pad 16.

[0056] Compared with a conventional solution, in embodiments of this application, the carbon oil buried resistor 14 is used as a load of the dummy antenna, so that a unit pattern consistency characteristic the same as or similar to that of the regular array antenna can be implemented without affecting radiating efficiency and scanning performance of the array antenna.

[0057] FIG. 8 is a diagram of another structure of an array antenna 100 according to an embodiment of this application.

[0058] The array antenna 100 may include a first metal layer 210, a first dielectric layer 220, a second metal layer 230, a second dielectric layer 240, a third metal layer 250, and a third dielectric layer 260 that are sequentially stacked.

[0059] It may be understood that the array antenna 100 may further include a fourth dielectric layer 270. The fourth dielectric layer 270 is disposed at a location below the third dielectric layer 260.

[0060] In this embodiment, a thin carbon oil layer may be printed on a surface of the fourth dielectric layer 270 by using a carbon oil silkscreen process, in other words, a carbon oil buried resistor 14 of a dummy antenna 10 may be disposed at the fourth dielectric layer 270. It may be understood that, in this embodiment, a feeder 12 of the dummy antenna 10 may be disposed at the fourth dielectric layer 270, and the feeder 12 is connected to the carbon oil buried resistor 14. The feeder 12 may be disposed at an inner layer of a printed circuit board 40 in a form of a strip line.

[0061] The carbon oil buried resistor 14 and the feeder 12 of the dummy antenna 10 may be disposed between the third dielectric layer 160 and the fourth dielectric layer 270.

[0062] The first metal layer 210, the first dielectric layer 220, the second metal layer 230, the second dielectric layer 240, the third metal layer 250, the third dielectric layer 260, and the fourth dielectric layer 270 that are sequentially stacked may form the multi-layer printed circuit board 40.

[0063] It may be understood that, in the foregoing descriptions, a manner of disposing a carbon oil buried resistor 14 and a feeder 12 of one dummy antenna 10 is merely used as an example for description. A carbon oil buried resistor 14 of each dummy antenna 10 may be disposed at the inner layer of the multi-layer printed circuit board 40.

[0064] Based on the foregoing embodiment of this application, the dummy antenna 10 disposes the carbon oil buried resistor 14 at the inner layer of the multi-layer printed circuit board 40, instead of a surface layer of the printed circuit board. Therefore, the array antenna 100 in this embodiment of this application can implement a unit pattern consistency characteristic similar to that of a regular array when ensuring radiating efficiency and scanning performance of the array antenna, and does not occupy a layout space of the PCB.

[0065] The array antenna in this application may implement a radio frequency load function by applying a carbon oil buried resistor process at the inner layer of the multi-layer printed circuit board.

[0066] Refer to FIG. 9a to FIG. 9d as well. FIG. 9a is a diagram of an amplitude obtained when a carbon oil buried resistor is not used as a dummy load in a conventional solution. FIG. 9b is a diagram of a phase obtained when a carbon oil buried resistor is not used as a dummy load in a conventional solution. FIG. 9c is a diagram of an amplitude obtained when a carbon oil buried resistor is used as a dummy load according to an embodiment of this application. FIG. 9d is a diagram of a phase obtained when a carbon oil buried resistor is used as a dummy load according to an embodiment of this application.

[0067] It can be learned that, compared with the conventional solution, in this embodiment of this application, when the carbon oil buried resistor 14 is used as the dummy load, array pattern consistency is significantly improved.

[0068] In a possible application scenario, for example, when a feeder of an antenna is located at the surface layer of the printed circuit board, both a T-type power divider and a Wilkinson power divider may be used in the array antenna. As shown in FIG. 10a and FIG. 10b, the T-type power divider 110 may include an input port P1, an output port P2, and an output port P3. The Wilkinson power divider 120 may include an input port P4, an output port P5, and an output port P6. The input port P4 may be connected to a radio frequency component, and the output port P5 is connected to the output port P6 through a resistor R1.

[0069] In another possible application scenario, for example, when a feeder of an antenna is located at the inner layer of the printed circuit board, a Wilkinson power divider 120 in FIG. 10b is limited by a resistor with a large size and cannot be used in the array antenna.

[0070] FIG. 11 is a diagram of a structure of a power divider 130 according to an embodiment of this application.

[0071] In this embodiment, the power divider 130 may include an input port P7, an output port P8, and an output port P9.

[0072] The power divider 130 may further include a main path feeder 131, a quarter-wave transformation line 132, a quarter-wave transformation line 133, a branch feeder 134, and a branch feeder 135. A first end of the main path feeder 131 is connected to the input port P7, and a second end of the main path feeder 131 is connected to a first end of the quarter-wave transformation line 132 and a first end of the quarter-wave transformation line 133. A second end of the quarter-wave transformation line 132 is connected to a first end of the branch feeder 134, and a second end of the branch feeder 134 is connected to the output port P8. A second end of the quarter-wave transformation line 133 is connected to a first end of the branch feeder 135, and a second end of the branch feeder 135 is connected to the output port P9.

[0073] It may be understood that the input port P7 of the power divider 130 may be connected to a radio frequency chip 140. In a scenario, the radio frequency chip 140 may output a signal to the input port P7 of the power divider 130. The output port P8 may be connected to the output port P9 through a carbon oil buried resistor 15. Specifically, the carbon oil buried resistor 15 is connected between the first end of the branch feeder 134 and the first end of the branch feeder 135. The carbon oil buried resistor 15 of the power divider 130 may be disposed at an inner layer of a multi-layer printed circuit board 40. The carbon oil buried resistor 15 between the output port P8 and the output port P9 acts as an isolation resistor.

[0074] In an optional implementation, in the power divider 130, at least a part of the main path feeder 131 and the carbon oil buried resistor 15 may be located at a same layer of the multi-layer printed circuit board 40; at least a part of the branch feeder 134 and the carbon oil buried resistor 15 may be located at a same layer of the multi-layer printed circuit board 40; at least a part of the branch feeder 135 and the carbon oil buried resistor 15 may be located at a same layer of the multi-layer printed circuit board 40; at least a part of the quarter-wave transformation line 132 and the carbon oil buried resistor 15 may be located at a same layer of the multi-layer printed circuit board 40; and at least a part of the quarter-wave transformation line 133 and the carbon oil buried resistor 15 may be located at a same layer of the multi-layer printed circuit board 40.

[0075] It may be understood that a shape of the carbon oil buried resistor may be a trapezoid, a rectangle, a circle, or another irregular pattern. This is not limited in this embodiment of this application.

[0076] Based on the foregoing embodiment of this application, the carbon oil buried resistor 15 is connected between the output port P8 and the output port P9. Therefore, the input port and the output ports of the Wilkinson power divider 130 may have good matching and isolation characteristics, and it is ensured that unit patterns of an array antenna are not distorted due to mutual coupling.

[0077] Compared with a conventional solution, the power divider 130 in this embodiment of this application is not limited by a buried resistor load with a large size, and may be used in the array antenna.

[0078] In this embodiment, as shown in FIG. 11, the output port P8 of the power divider 130 may be connected to one radiating antenna unit 20, and the output port P9 of the power divider 130 may be connected to one radiating antenna unit 20. In a scenario, the radio frequency chip 140 may radiate signals through the two radiating antenna units 20 connected to the power divider 130. The power divider 130 may be a Wilkinson power divider.

[0079] It may be understood that, in some possible implementations, the array antenna 100 may include a plurality of power dividers. As shown in FIG. 12, two power dividers are used as an example for description. FIG. 12 shows only a power divider 130 and a power divider 150, but this should not be construed as a limitation. The power divider 130 may implement a one-to-many architecture, for example, a one-to-two architecture, a one-to-three architecture, or a one-to-four architecture. For example, an input port P7 of the power divider 130 may be connected to a radio frequency chip 140, an output port P9 of the power divider 130 may be connected to one radiating antenna unit 20, an output port P8 of the power divider 130 may be connected to an input port P10 of the power divider 150, the input port P10 of the power divider 150 is connected to a first end of a main path feeder 131, and a second end of the main path feeder 131 is connected to a first end of a quarter-wave transformation line 132 and a first end of a quarter-wave transformation line 133. A second end of the quarter-wave transformation line 132 is connected to a first end of a branch feeder 134, a second end of the branch feeder 134 is connected to an output port P11, a second end of the quarter-wave transformation line 133 is connected to a first end of a branch feeder 135, and a second end of the branch feeder 135 is connected to an output port P12. One carbon oil buried resistor 15 is connected between the first end of the branch feeder 134 and the second end of the branch feeder 135.

[0080] In a scenario, the output port P11 may be connected to one radiating antenna unit 20, and the output port P12 may be connected to one radiating antenna unit 20. Alternatively, in some other scenarios, the output port P11 may be connected to an input port of another power divider, and the output port P12 may be connected to one radiating antenna unit 20. Alternatively, in some other scenarios, the output port P11 and the output port P12 may each be connected to an input port of one power divider. By analogy, this embodiment of this application may implement the one-to-many architecture.

[0081] It may be understood that the carbon oil buried resistor 15 in this embodiment is made of the same material as the carbon oil buried resistor 14 in embodiments shown in FIG. 3 and FIG. 6 to FIG. 8. To be specific, both the carbon oil buried resistor 15 and the carbon oil buried resistor 14 may be made of a carbon oil material with a wave-absorbing characteristic.

[0082] Based on embodiments shown in FIG. 11 and FIG. 12, a carbon oil buried resistor process is used, so that this application can integrate a dummy antenna or the radiating antenna unit with the one-to-many Wilkinson power divider at the inner layer of the multi-layer printed circuit board, to replace a conventional T-type power divider. In this application, good matching and isolation characteristics of ports of the Wilkinson power divider may be used, to ensure that unit patterns in an array are not distorted due to mutual coupling.

[0083] It may be understood that the power divider 130 may perform equal-amplitude and in-phase power dividing, or may perform unequal-amplitude or unequal-phase power dividing.

[0084] The following describes a scattering characteristic and input and output characteristics at different conditions of the T-type power divider.

[0085] When a main port is input, $a = [1\ 0\ 0]^T$. When the rest two ports are balanced input, $a = [0\ 1\ 1]^T$. When the rest two ports are unbalanced input, $a = [0\ 1\ 0]^T$. When the rest two ports are unbalanced input, $a = [0\ 1\ e^{j50°}]^T$. When the main port is matched and the rest two ports are equal-amplitude in-phase output, $b = \begin{bmatrix} 0 & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \end{bmatrix}^T$. When the rest two ports are matched and the main port is lossless output, $b = \begin{bmatrix} \sqrt{2} & 0 & 0 \end{bmatrix}^T$. When the rest two ports are mismatched and the main port is lossy output, $b = \begin{bmatrix} \frac{\sqrt{2}}{2} & \frac{1}{2} & -\frac{1}{2} \end{bmatrix}^T$. When the rest two ports are mismatched and the main port is lossy output, $|b| = [0.91\ 0.3\ 0.3]^T$.

[0086] The following describes a scattering characteristic and input and output characteristics at different conditions of the Wilkinson power divider.

[0087] When a main port is input, $a = [1\ 0\ 0]^T$. When the rest two ports are balanced input, $a = [0\ 1\ 1]^T$. When the rest two ports are unbalanced input, $a = [0\ 1\ 0]^T$. When the rest two ports are unbalanced input, $a = [0\ 1\ e^{j50°}]^T$. When the main port is matched and the rest two ports are equal-amplitude in-phase output, $b = \begin{bmatrix} 0 & -\frac{j}{\sqrt{2}} & -\frac{j}{\sqrt{2}} \end{bmatrix}^T$. When the rest two ports are matched and the main port is lossless output, $b = \begin{bmatrix} -\sqrt{2}j & 0 & 0 \end{bmatrix}^T$. When the rest two ports are mismatched and the main port is lossy output, $b = \begin{bmatrix} -\frac{j}{\sqrt{2}} & 0 & 0 \end{bmatrix}^T$. When the rest two ports are mismatched and the main port is lossy output, $|b| = [0.91\ 0\ 0]^T$.

[0088] When the T-type power divider is used for an unequal-amplitude and in-phase operation (that is, unbalanced combining), mismatching and crosstalk occur at the rest two ports, and definite reflection exists. In addition, a dummy unit performs secondary refection on an absorbed electromagnetic wave. This further deteriorates a pattern of the radiating antenna unit.

[0089] For the Wilkinson power divider, even if the power divider is in an unbalanced state, the rest two ports may still be matched and isolated. Therefore, the power divider may have a good dummy absorbing effect.

[0090] FIG. 13a shows a pattern in a theoretical expectation. FIG. 13b shows a pattern of a Wilkinson power divider that uses an inner-layer buried resistor. FIG. 13c shows a pattern of a T-type power divider.

[0091] It can be learned from FIG. 13a and FIG. 13b that, compared with the pattern in the theoretical expectation shown in FIG. 13a, a pattern shown by a Wilkinson power divider implemented by using the carbon oil buried resistor in this embodiment of this application is very similar to the pattern in the theoretical expectation shown in FIG. 13a. However, the pattern of the T-type power divider shown in FIG. 13c is severely distorted.

[0092] Therefore, the carbon oil buried resistor can meet an engineering implementation requirement of an inner-layer power divider during cabling, and further ensure ideal radiation performance.

[0093] FIG. 14 is a diagram of an application scenario of an array antenna according to an embodiment of this application.

[0094] As shown in FIG. 14, in a possible scenario, the array antenna 100 may be used in a base station 200. For example, the array antenna 100 may be used in a communication base station in a millimeter wave band and a sub-millimeter wave band. It may be understood that a plurality of base stations 200 may communicate with an integrated receiver transcoder 300.

[0095] It may be understood that, under a constraint condition, equivalent isotropic radiated power (Equivalent Isotropic Radiated Power, EIRP) of a beam in a geosynchronous orbit satellite area<60 dBm/200 M/beam.

[0096] In a conventional array design, the EIRP is limited when the foregoing constraint is met, and a scanning range in a large-spacing array is also limited. However, in an irregular array layout, when the foregoing constraint condition is met, grating side lobe suppression of the array can be improved, and the EIRP and the scanning range of the array can be increased.

[0097] Refer to FIG. 15. An embodiment of this application further provides a communication device 400. The communication device 400 may include the array antenna 100 described in the foregoing embodiments. It may be understood that the communication device 400 may include but is not limited to a base station or a gNB in a new radio (new radio, NR) system.

[0098] A person of ordinary skill in the art should understand that the foregoing implementations are merely intended to describe this application but are not intended to limit this application, provided that proper modifications and changes made to the foregoing implementations in the essential scope of this application fall within the protection scope of this application.

Claims

1. An array antenna, used in a communication device, wherein the array antenna comprises a plurality of radiating antenna units and a plurality of dummy antennas;

   the plurality of radiating antenna units are configured to radiate or receive electromagnetic signals;
   the plurality of dummy antennas are arranged in an array, and the plurality of dummy antennas do not radiate the electromagnetic signals or do not receive the electromagnetic signals; and
   each dummy antenna comprises a carbon oil buried resistor and a feeder, the feeder is connected to the carbon oil buried resistor, and both the carbon oil buried resistor and the feeder are disposed at an inner layer of a multi-layer printed circuit board.

2. The array antenna according to claim 1, wherein both the carbon oil buried resistor and the feeder are disposed at a same layer of the multi-layer printed circuit board; or the carbon oil buried resistor and the feeder are disposed at different layers of the multi-layer printed circuit board.

3. The array antenna according to claim 1 or 2, wherein a shape and a size of the dummy antenna are the same as or similar to a shape and a size of the radiating antenna unit.

4. The array antenna according to any one of claims 1 to 3, wherein
   the carbon oil buried resistor is made of a carbon oil material with a wave-absorbing characteristic.

5. The array antenna according to any one of claims 1 to 4, wherein

   the multi-layer printed circuit board comprises a first metal layer, a first dielectric layer, a second metal layer, a second dielectric layer, a third metal layer, a third dielectric layer, and a fourth dielectric layer that are sequentially stacked; and
   both the carbon oil buried resistor and the feeder in each dummy antenna are disposed between the third dielectric layer and the fourth dielectric layer.

6. The array antenna according to claim 1, wherein

   the array antenna further comprises a power divider; and
   an input port of the power divider is connected to a radio frequency chip, and a first output port of the power divider is connected to a second output port of the power divider through the carbon oil buried resistor.

7. The array antenna according to claim 6, wherein the first output port and the second output port each are connected to one radiating antenna unit.

8. The array antenna according to claim 6, wherein the power divider comprises a main path feeder, a first quarter-wave transformation line, a second quarter-wave transformation line, a first branch feeder, and a second branch feeder; a first end of the main path feeder is connected to the input port, and a second end of the main path feeder is connected to a first end of the first quarter-wave transformation line and a first end of the second quarter-wave transformation line; a second end of the first quarter-wave transformation line is connected to a first end of the first branch feeder, and a second end of the second quarter-wave transformation line is connected to a first end of the second branch feeder; and a second end of the first branch feeder is connected to the first output port, a second end of the second branch feeder is connected to the second output port, and one carbon oil buried resistor is connected between the first end of the first branch feeder and the first end of the second branch feeder.

9. The array antenna according to claim 8, wherein

   at least a part of the main path feeder and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board;
   at least a part of the first branch feeder and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board;
   at least a part of the second branch feeder and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board;

at least a part of the first quarter-wave transformation line and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board; and

at least a part of the second quarter-wave transformation line and the carbon oil buried resistor of the power divider are located at a same layer of the multi-layer printed circuit board.

10. A communication device, wherein the communication device comprises the array antenna according to any one of claims 1 to 9.

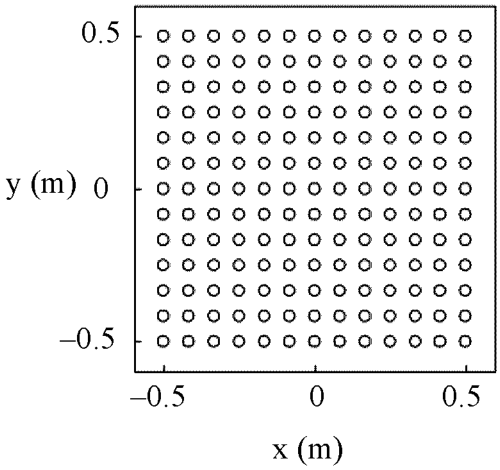


FIG. 1a

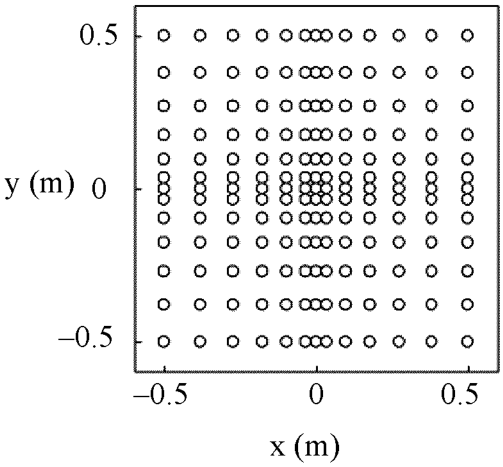


FIG. 1b

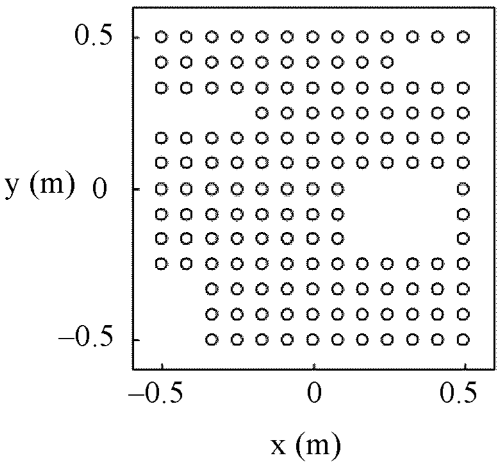


FIG. 1c

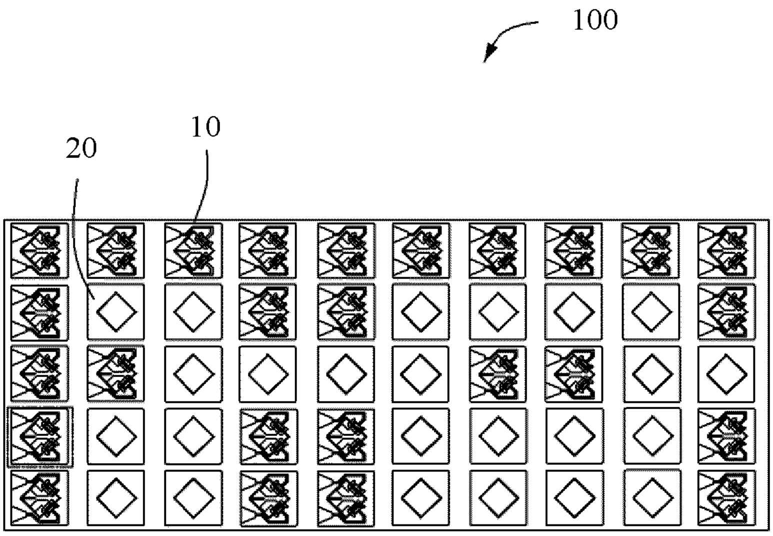


FIG. 2

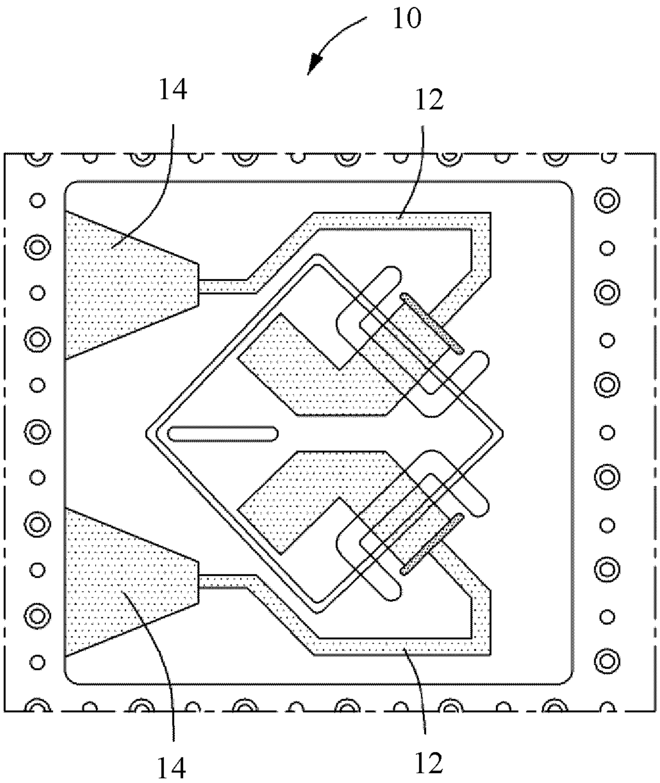
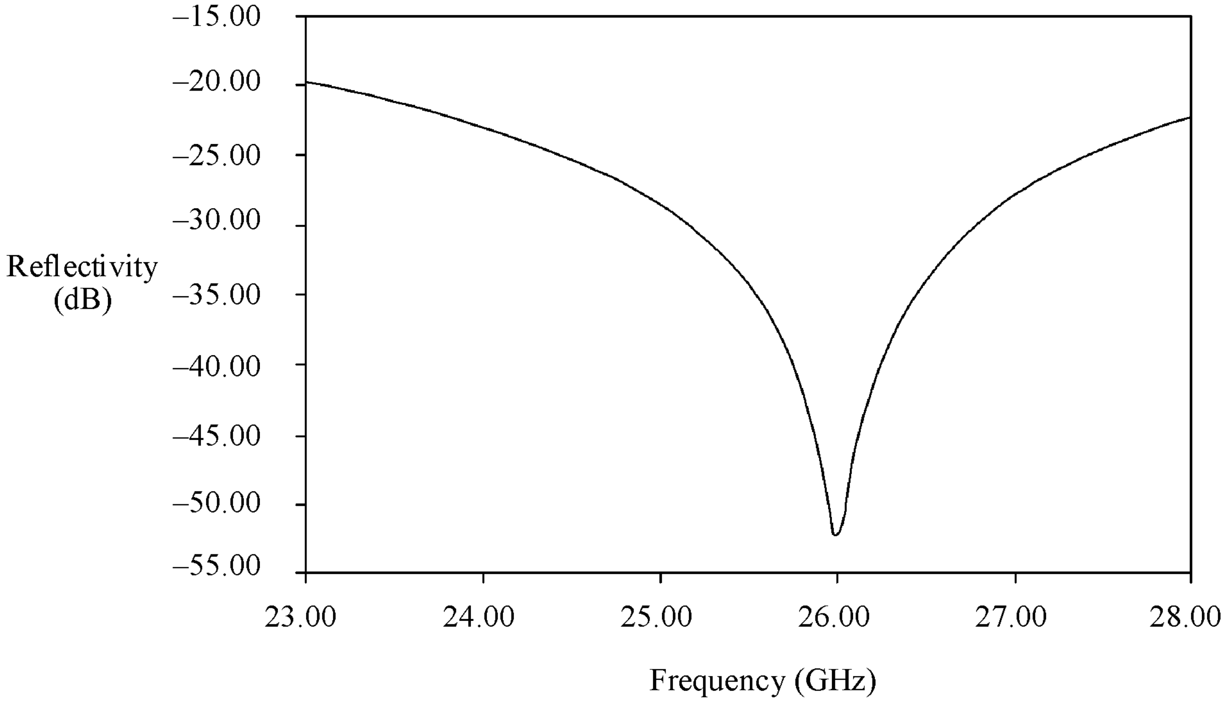
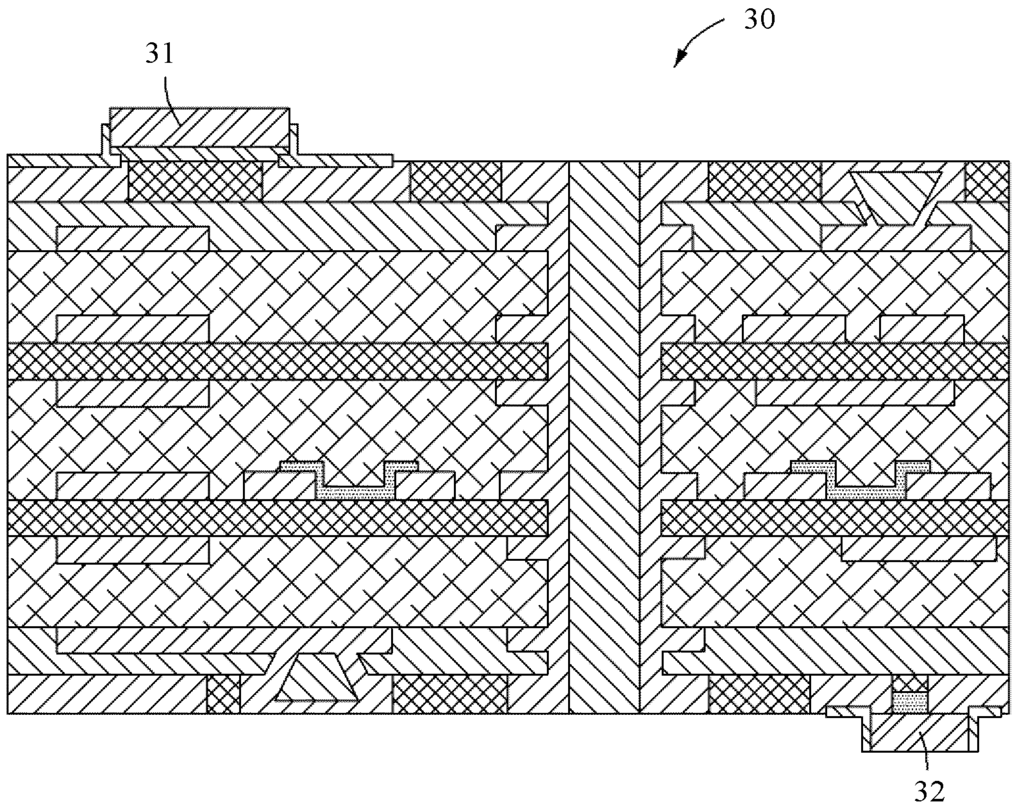


FIG. 3



−15.00
−20.00
−25.00
−30.00
Reflectivity (dB)
−35.00
−40.00
−45.00
−50.00
−55.00
23.00
24.00
25.00
26.00
27.00
28.00
Frequency (GHz)

FIG. 4



30
31
32

FIG. 5

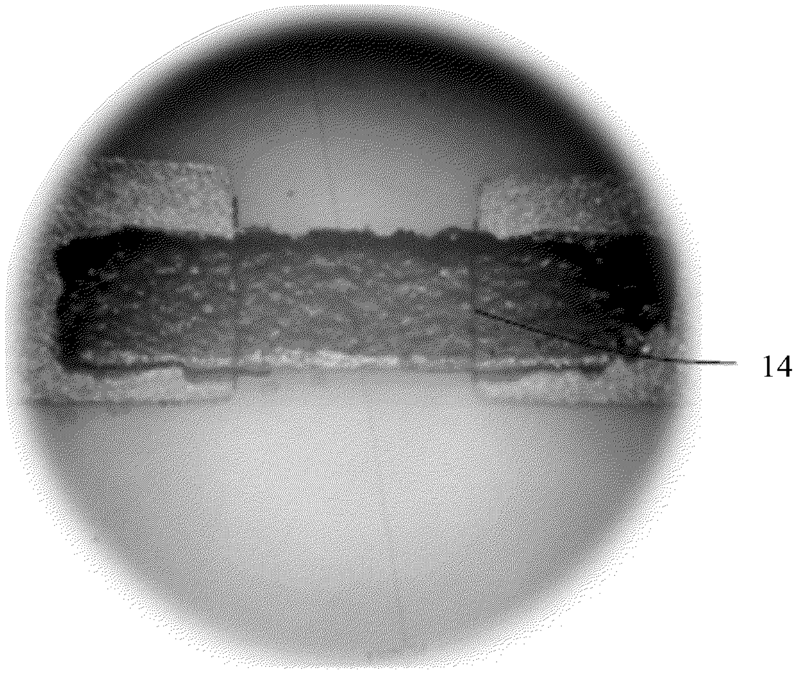


FIG. 6

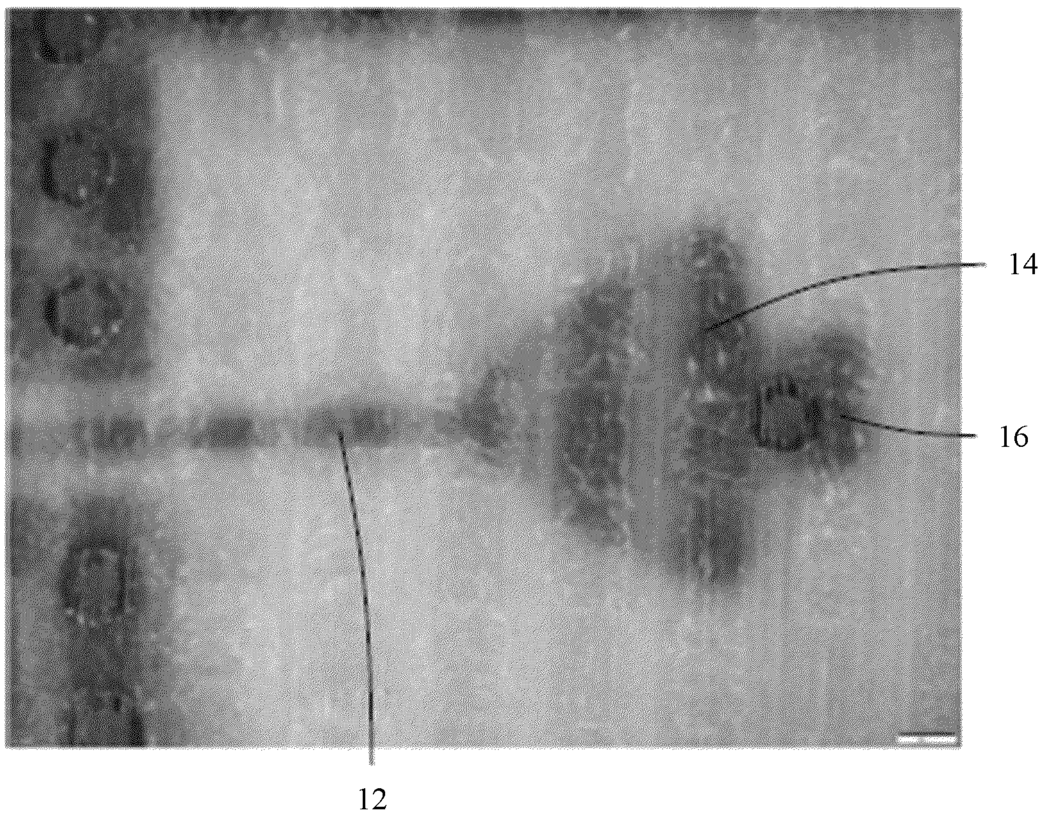


FIG. 7

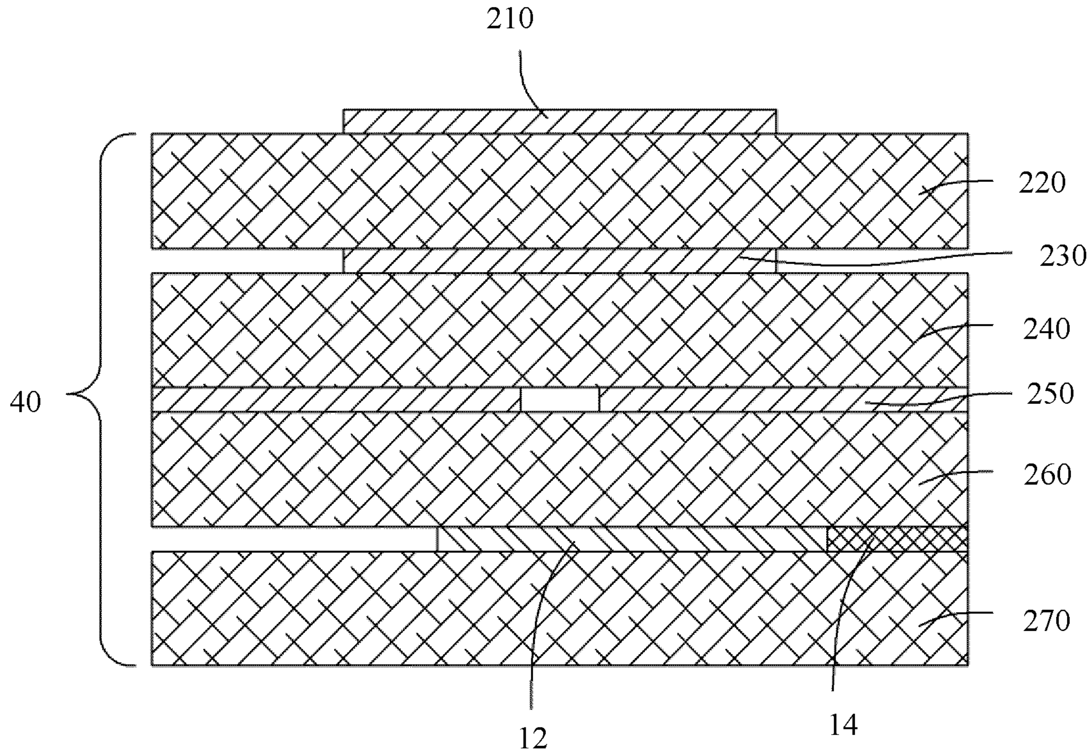

210
220
230
240
40
250
260
270
12
14

FIG. 8

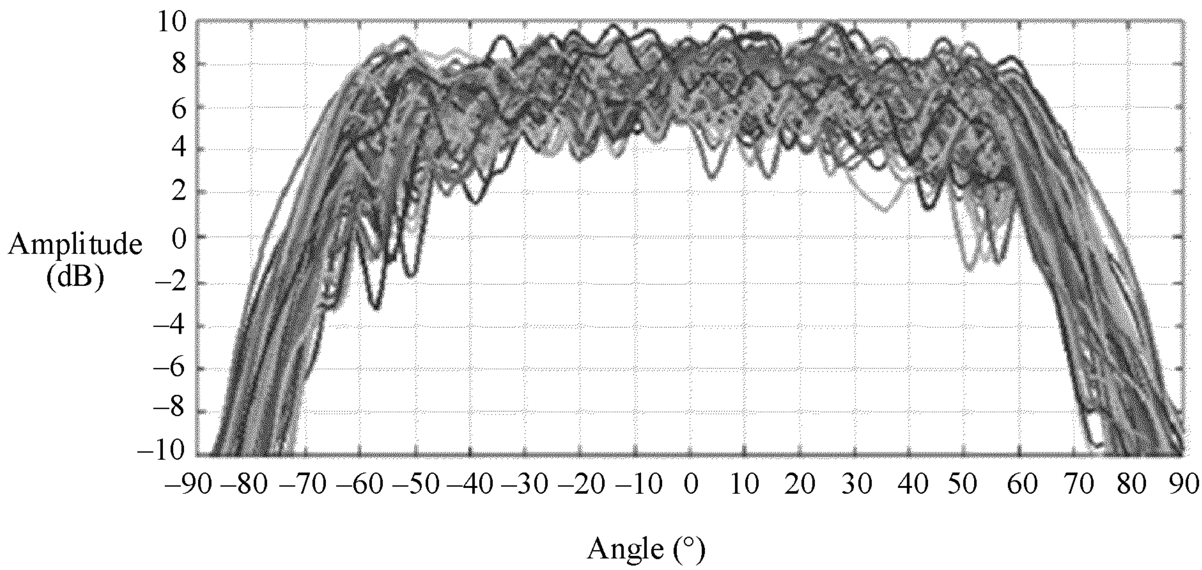

Amplitude (dB)
10
8
6
4
2
0
–2
–4
–6
–8
–10
–90 –80 –70 –60 –50 –40 –30 –20 –10 0 10 20 30 40 50 60 70 80 90
Angle (°)

FIG. 9a

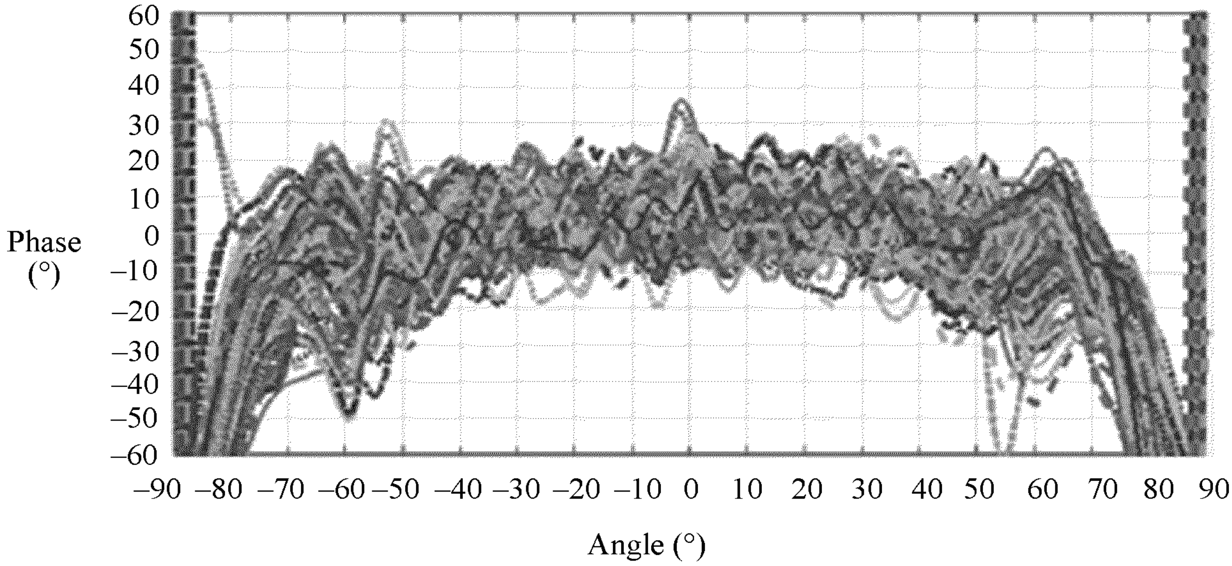

60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
Phase (°)
−90 −80 −70 −60 −50 −40 −30 −20 −10 0 10 20 30 40 50 60 70 80 90
Angle (°)

FIG. 9b

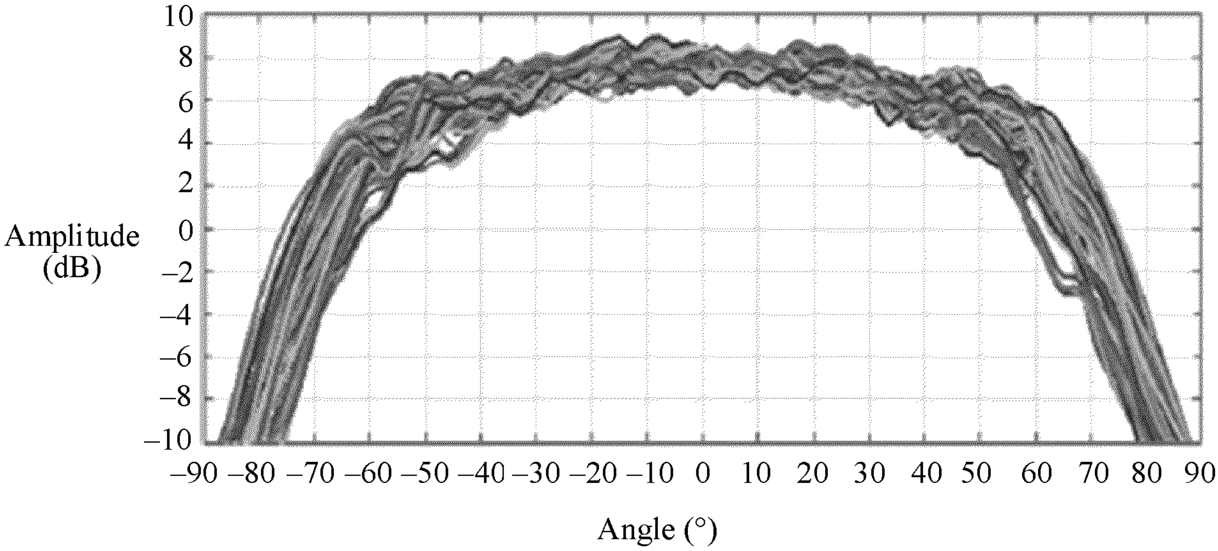

10
8
6
4
2
0
−2
−4
−6
−8
−10
Amplitude (dB)
−90 −80 −70 −60 −50 −40 −30 −20 −10 0 10 20 30 40 50 60 70 80 90
Angle (°)

FIG. 9c

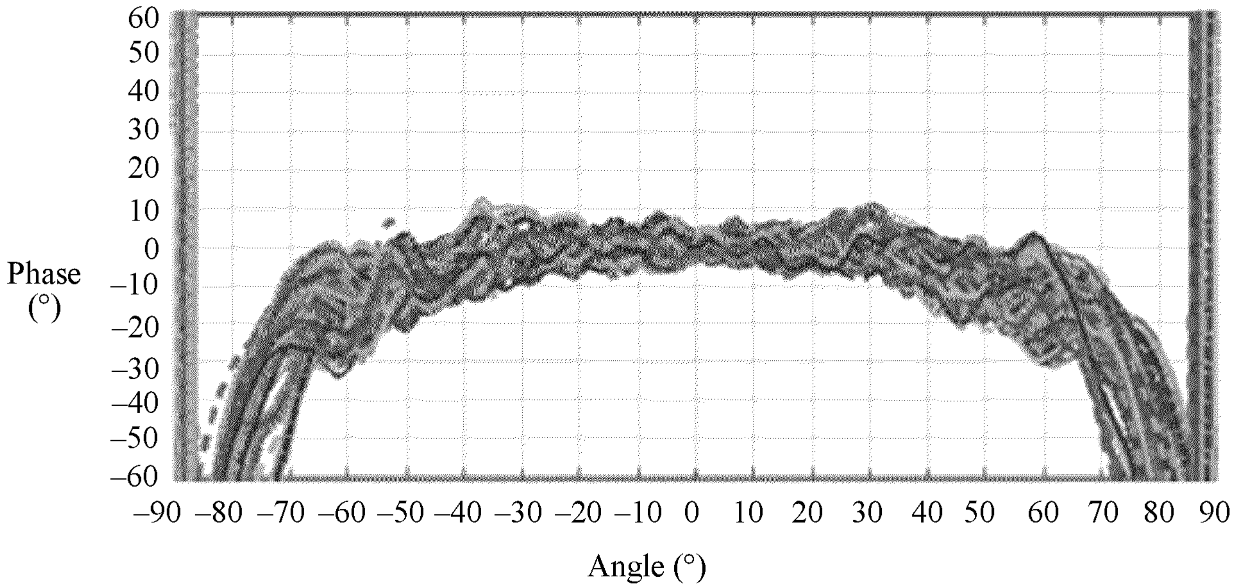


FIG. 9d

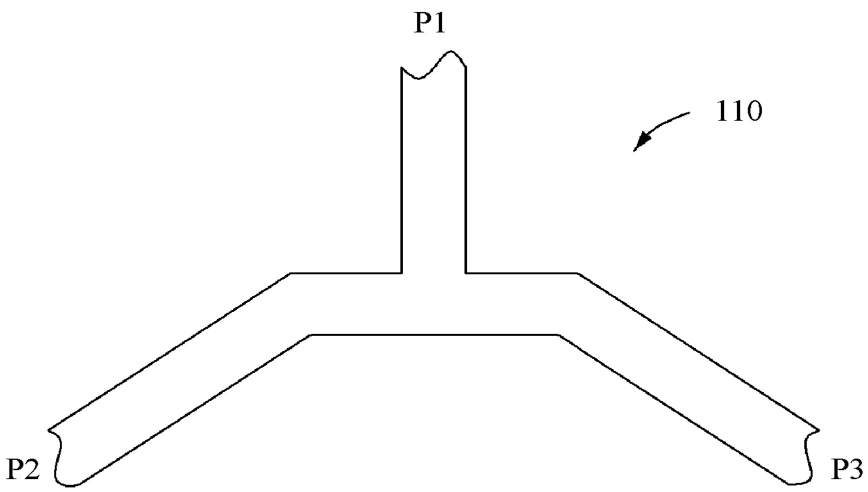


FIG. 10a

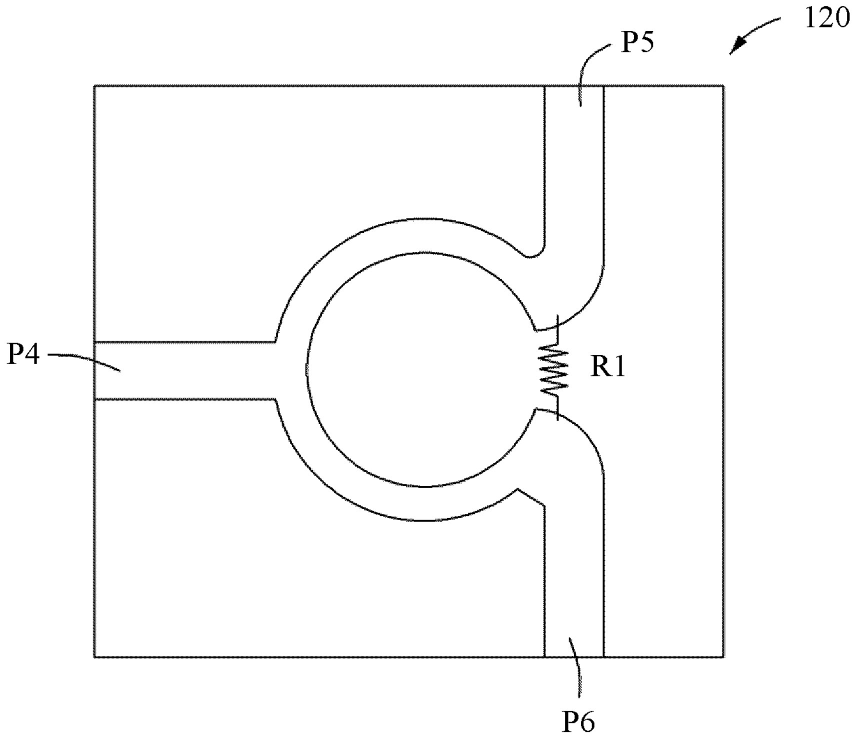


FIG. 10b

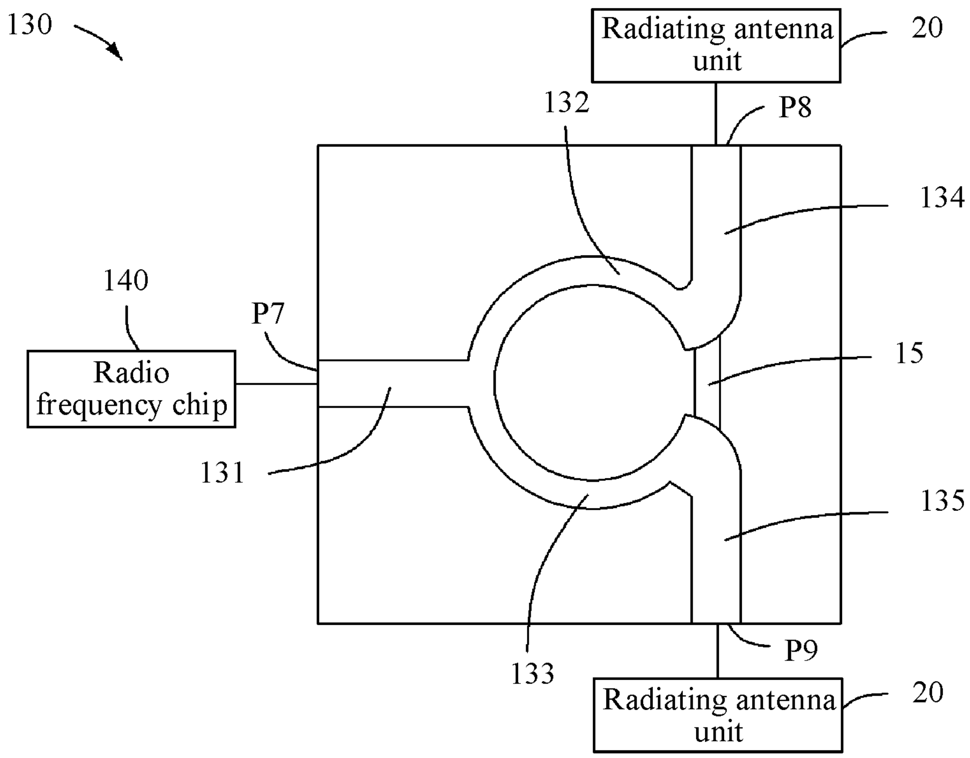


FIG. 11

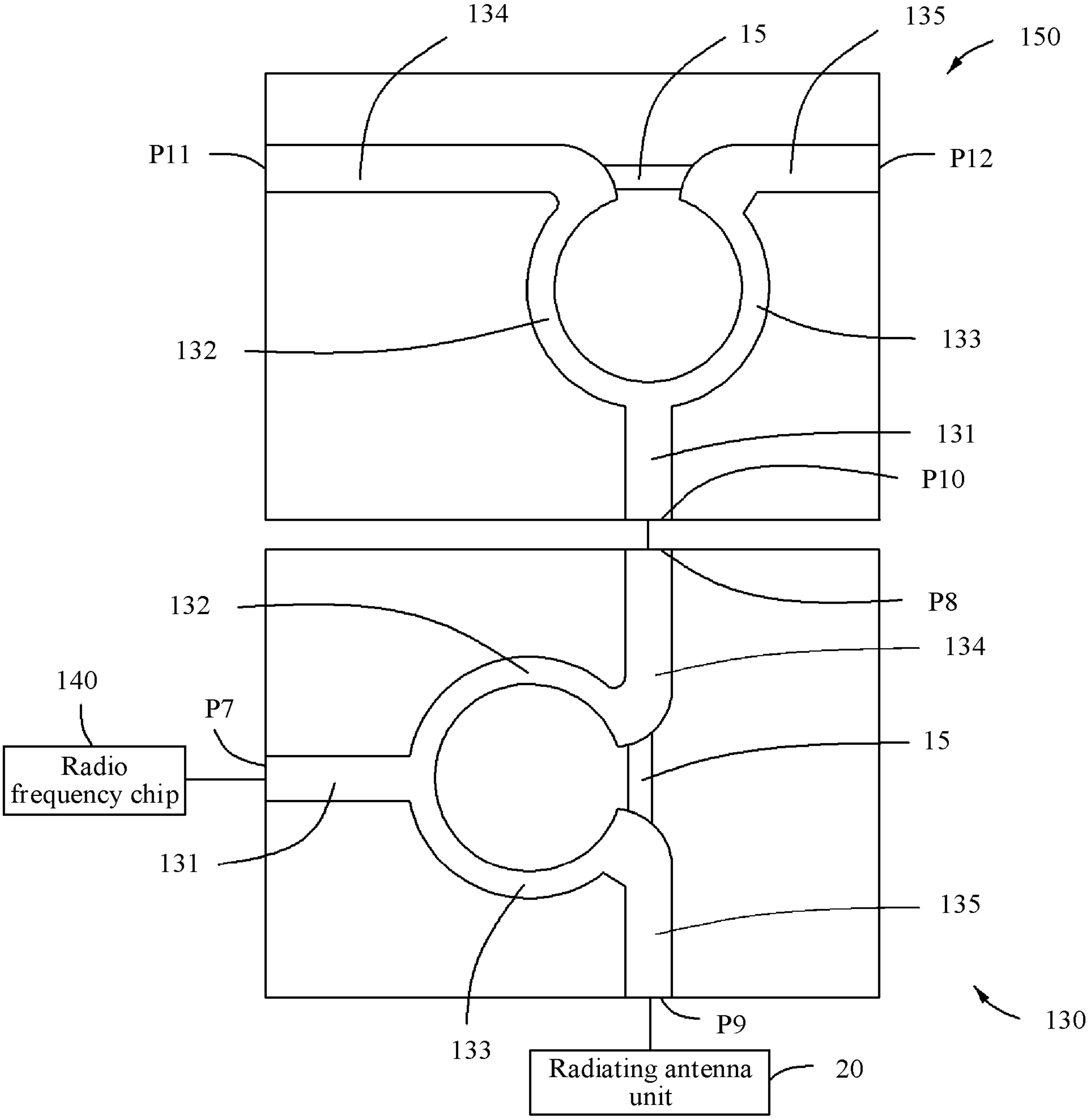
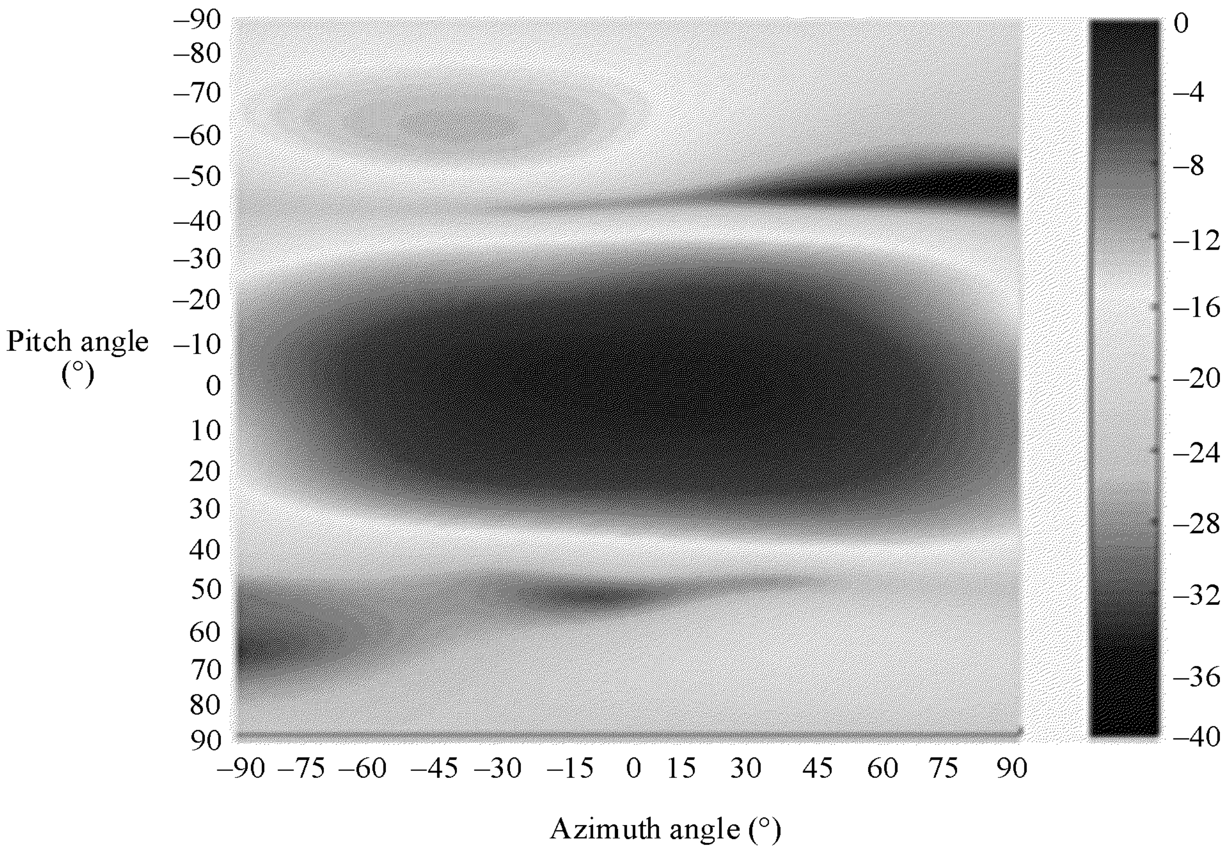
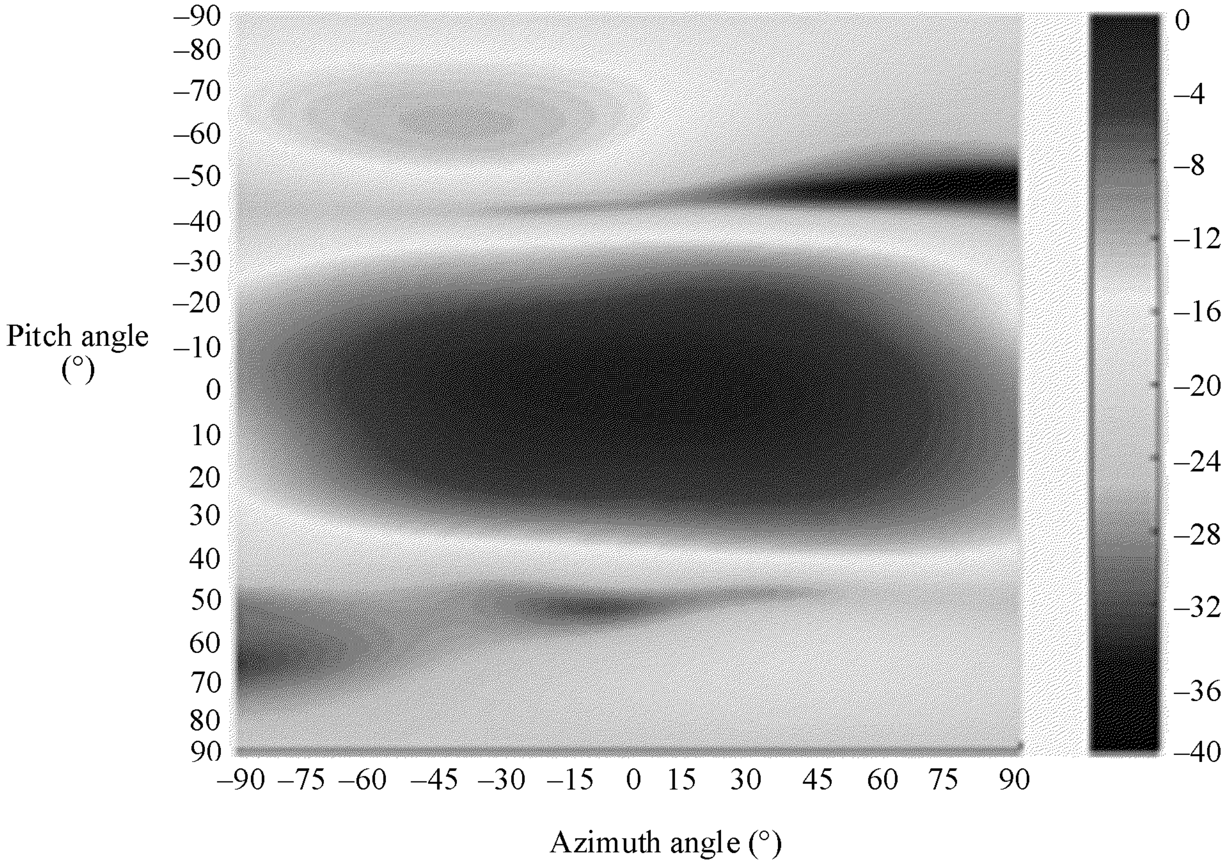

134
15
135
150
P11
P12
132
133
131
P10
P8
132
134
140
P7
Radio frequency chip
15
131
135
133
P9
130
Radiating antenna unit
20

FIG. 12



-90
-80
-70
-60
-50
-40
-30
-20
Pitch angle (°)
-10
0
10
20
30
40
50
60
70
80
90
-90 -75 -60 -45 -30 -15 0 15 30 45 60 75 90
Azimuth angle (°)
0
-4
-8
-12
-16
-20
-24
-28
-32
-36
-40

FIG. 13a



–90
–80
–70
–60
–50
–40
–30
–20
Pitch angle (°)
–10
0
10
20
30
40
50
60
70
80
90
–90 –75 –60 –45 –30 –15 0 15 30 45 60 75 90
Azimuth angle (°)
0
–4
–8
–12
–16
–20
–24
–28
–32
–36
–40

FIG. 13b

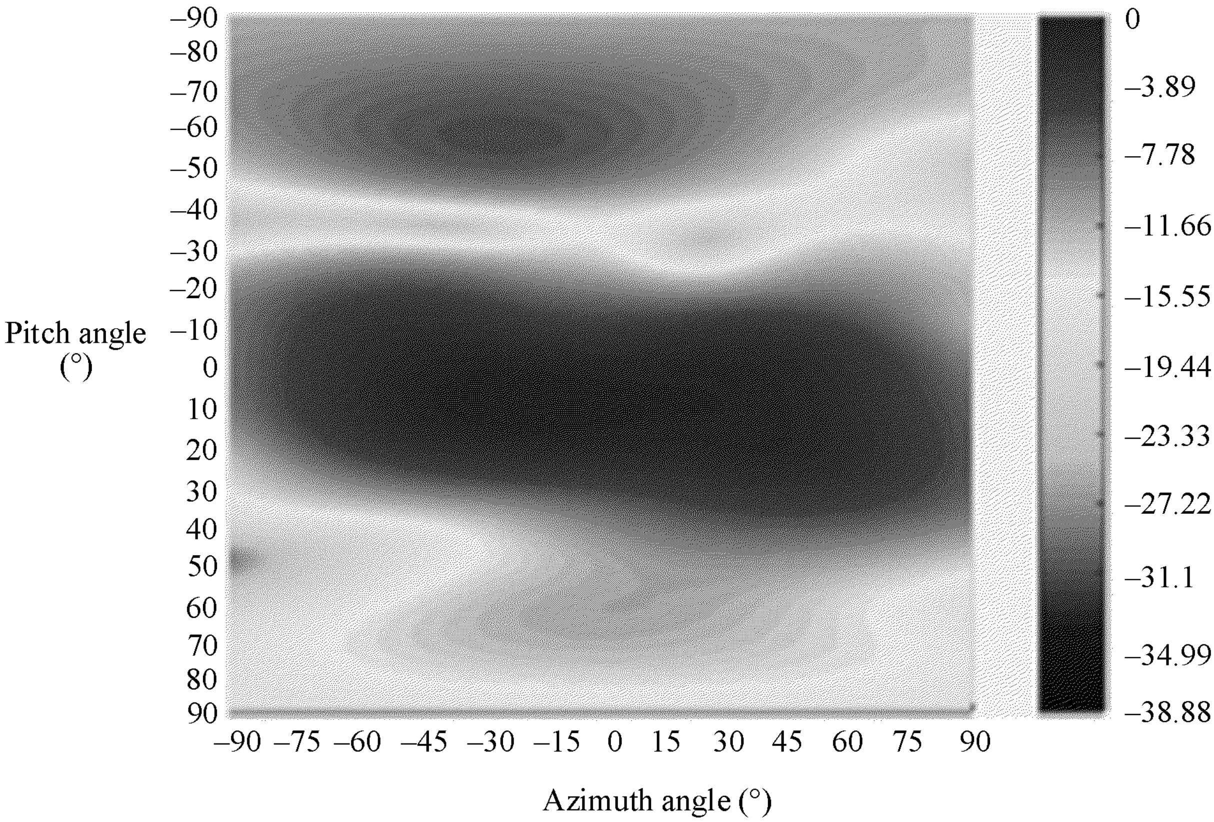


FIG. 13c

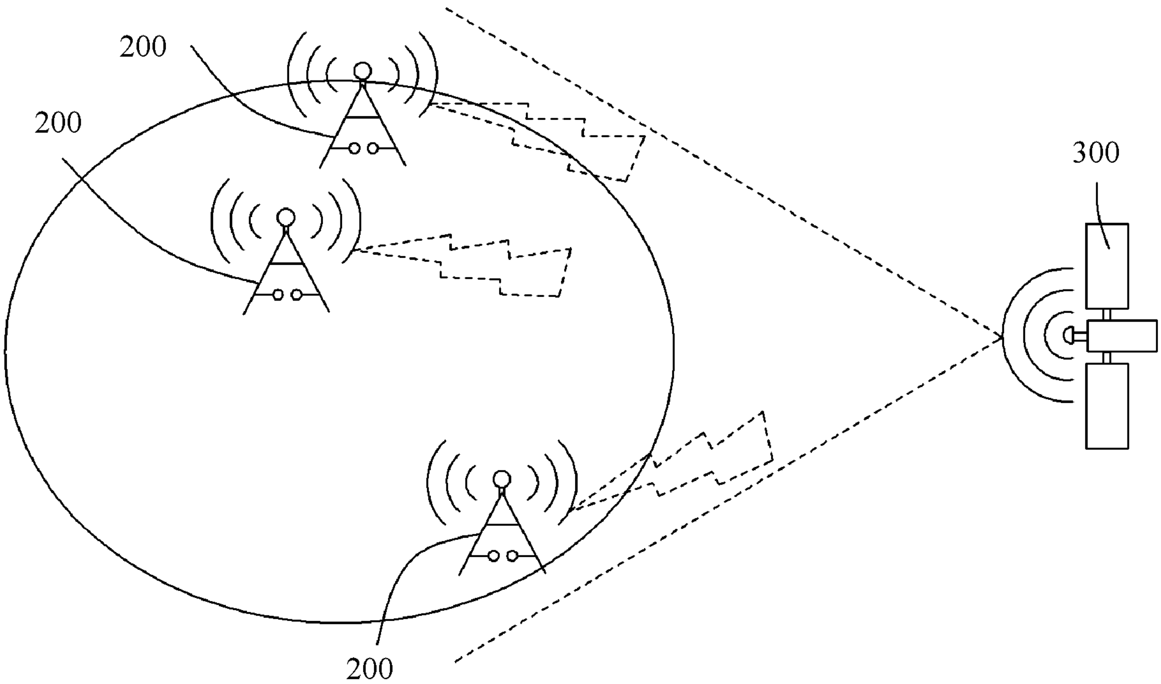


FIG. 14

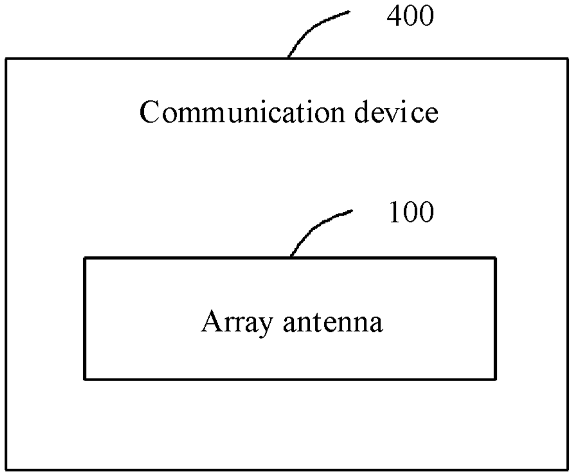


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/104696

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/38(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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)

CNPAT, CNKI, WPI, EPODOC: 哑元天线, 内层, 假天线, 虚拟导线, 辐射, 碳油埋阻, PCB, D_A, antenna, false, multi-layer, medium plate, radiating

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 111771304 A (SZ DJI TECHNOLOGY CO., LTD.) 13 October 2020 (2020-10-13) description, paragraphs 2-49	1-10
A	CN 113437535 A (HAWKEYE TECHNOLOGY CO., LTD.) 24 September 2021 (2021-09-24) entire document	1-10
A	CN 112313836 A (SZ DJI TECHNOLOGY CO., LTD.) 02 February 2021 (2021-02-02) entire document	1-10
A	US 2022158361 A1 (SAMSUNG ELECTRONICS CO., LTD. et al.) 19 May 2022 (2022-05-19) entire document	1-10
A	CN 114006165 A (NANJING UNIVERSITY OF AERONAUTICS AND ASTRONAUTICS) 01 February 2022 (2022-02-01) entire document	1-10
A	US 2018191082 A1 (FACEBOOK, INC.) 05 July 2018 (2018-07-05) entire document	1-10
A	CN 101431175 A (DELTA ELECTRONICS INC.) 13 May 2009 (2009-05-13) entire document	1-10

☑ 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
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 November 2022	**28 November 2022**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China** Facsimile No. **(86-10)62019451**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/104696

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 113036454 A (AEROSPACE INFORMATION RESEARCH INSTITUTE, CHINESE ACADEMY OF SCIENCES) 25 June 2021 (2021-06-25) entire document	1-10

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2022/104696

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	111771304	A	13 October 2020	WO	2020198992	A1	08 October 2020
CN	113437535	A	24 September 2021		None		
CN	112313836	A	02 February 2021	WO	2021097850	A1	27 May 2021
US	2022158361	A1	19 May 2022	KR	20200082417	A	08 July 2020
				WO	2020139045	A1	02 July 2020
CN	114006165	A	01 February 2022		None		
US	2018191082	A1	05 July 2018		None		
CN	101431175	A	13 May 2009		None		
CN	113036454	A	25 June 2021		None		

Form PCT/ISA/210 (patent family annex) (January 2015)