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(54) ANTENNA ARRAY, ANTENNA SYSTEM AND COMMUNICATION DEVICE

(57) This application discloses an antenna array, an antenna system, and a communication device, to improve isolation between antenna units. The antenna array may include two decoupling modules and two antenna units. Two ends of each decoupling module are respectively connected to the two antenna units, and one of the two decoupling modules may be connected to the two antenna units through transmission modules. In this way, the two decoupling modules may decouple a coupling component between the two antenna units, to effectively improve the isolation between the antenna units in the communication device.

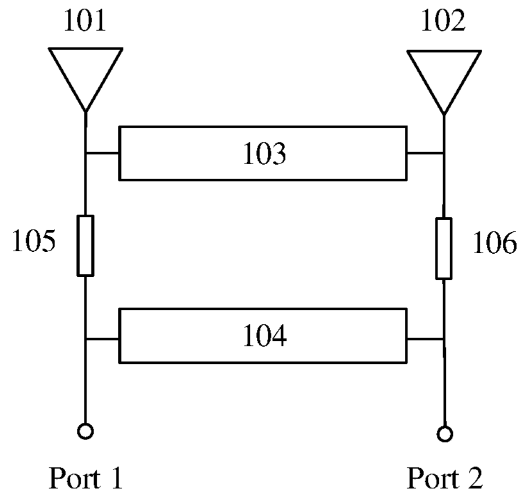


FIG. 3

EP 4 383 450 A1

Description

TECHNICAL FIELD

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

BACKGROUND

[0002] With the development of technologies, people have increasingly high requirements for a capacity of a mobile communication network. In a multiple-input multiple-output (Multiple-input multiple-output, MIMO) system, transmitting and receiving parties use a plurality of antennas for communication, and this may exponentially increase the capacity of the mobile communication network.

[0003] An important performance indicator of a MIMO antenna is isolation between antenna units. The isolation between the antenna units is related to mutual coupling between the antenna units. Poorer mutual coupling between the antenna units indicates better isolation between antennas. To reduce the mutual coupling between the antenna units, a spacing between the antenna units should generally be greater than 0.5 wavelengths (λ).

[0004] However, to further increase the capacity, a quantity of antenna units on a communication device is increasing. For example, the original quantity is increased from 4 to 8 or 16. However, a size of the communication device does not increase accordingly. For example, one of characteristics of small base stations widely used in an indoor communication scenario is a small size. Therefore, when the quantity of antenna units increases, the spacing between the antenna units may probably be less than 0.5 λ. Consequently, the mutual coupling between the antenna units is improved, and the isolation between the antenna units is reduced.

SUMMARY

[0005] This application provides an antenna array, an antenna system, and a communication device, to improve isolation between antenna units.

[0006] According to a first aspect, an embodiment of this application provides an antenna array. The antenna array may include: a plurality of antenna units including a first antenna unit and a second antenna unit, a first decoupling module, a second decoupling module, a first transmission module, and a second transmission module. Two ends of the first decoupling module may be respectively connected to the first antenna unit and the second antenna unit. Two ends of the second decoupling module may also be respectively connected to the first antenna unit and the second antenna unit. Specifically, one end of the second decoupling module is connected to the first antenna unit through the first transmission module, and the other end of the second decoupling module is connected to the second antenna unit through the second transmission module. The first decoupling module and the second decoupling module may decouple a coupling component between the first antenna unit and the second antenna unit.

[0007] In the antenna array, the two decoupling modules may decouple the coupling component between the first antenna unit and the second antenna unit, to improve isolation between the antenna units.

[0008] In a possible design, the antenna array may further include: a third transmission module and a fourth transmission module. One end of the first decoupling module may be connected to the first antenna unit through the third transmission module, and the other end of the first decoupling module may be connected to the second antenna unit through the fourth transmission module. One end of the second decoupling module may be connected to the first antenna unit through the first transmission module and the third transmission module sequentially, and the other end of the second decoupling module may be connected to the second antenna unit through the second transmission module and the fourth transmission module sequentially.

[0009] In this design, both the two decoupling modules are connected to feed lines of antennas. This improves isolation between the antenna units, and may further reduce impact on radiation performance of the antenna units.

[0010] In a possible design, a structure of the first decoupling module is different from a structure of the second decoupling module.

[0011] In a possible design, the second decoupling module may further include: a fifth transmission module, a sixth transmission module, and a seventh transmission module. The fifth transmission module and the sixth transmission module are connected in series, and two ends of the fifth transmission module and the sixth transmission module that are connected in series may be respectively connected to the first transmission module and the second transmission module. A connection point between the fifth transmission module and the sixth transmission module is grounded through the seventh transmission module.

[0012] In this design, the second decoupling module includes three interconnected transmission modules, two of the transmission modules can be respectively connected to the first antenna unit and the second antenna unit, and the 3rd transmission module is grounded. In this design, a decoupling effect of a high-impedance transmission line may be implemented through three low-impedance transmission modules, thereby effectively improving isolation between antenna units in a small-sized communication device.

[0013] In a possible design, the second decoupling module may be a first inductor. Because an inductor can be equivalent to a high-impedance transmission module, in this design, a decoupling effect of a high-impedance transmission line may be implemented through the inductor, thereby effectively improving isolation between antenna units in a small-sized communication device.

[0014] In another possible design, the second decoupling module may be a series branch including an eighth transmission module, a second inductor, and a ninth transmission module that are sequentially connected in series. In this design, two ends of the second inductor each are connected to one transmission module. Coupling caused by a small-sized inductor may be reduced through the two transmission modules, thereby further improving isolation between antenna units in a small-sized communication device.

[0015] In still another possible design, the second decoupling module may be a series branch including a first resistor, a tenth transmission module, and a second resistor that are sequentially connected in series. In this design, two ends of the transmission module each are connected to a resistor. In this way, a processing difficulty is reduced, and isolation between antenna units in a small-sized communication device may be further effectively improved.

[0016] In a possible design, any antenna unit includes at least one of the following: a planar inverted F antenna PIFA, a monopole antenna, a dipole antenna, and a microstrip patch antenna.

[0017] According to a second aspect, an embodiment of this application provides an antenna array. The antenna array may include: a plurality of antenna units including a first antenna unit and a second antenna unit, a decoupling module, a first transmission module, and a second transmission module. Two ends of the decoupling module may be respectively connected to the first antenna unit and the second antenna unit. Specifically, one end of the decoupling module is connected to the first antenna unit through the first transmission module, and the other end of the decoupling module is connected to the second antenna unit through the second transmission module. The decoupling module may decouple a coupling component between the first antenna unit and the second antenna unit. A line width of the decoupling module is greater than a line width of a transmission line that generates a same decoupling effect.

[0018] In the antenna array, the line width of the decoupling module is greater than the line width of the transmission line that generates the same decoupling effect. Therefore, isolation between the antenna units may be improved, and a difficulty in manufacturing the antenna array may be reduced. In addition, in the antenna array, the decoupling module is connected to feed lines of antennas. In this way, isolation between the antenna units is improved, and impact on radiation performance of the antenna units may be further reduced.

[0019] In a possible design, the decoupling module may include: a fifth transmission module, a sixth transmission module, and a seventh transmission module. The fifth transmission module and the sixth transmission module are connected in series, and two ends of the fifth transmission module and the sixth transmission module that are connected in series may be respectively connected to the first transmission module and the second transmission module. A connection point between the fifth transmission module and the sixth transmission module is grounded through the seventh transmission module.

[0020] In this design, the decoupling module includes three interconnected transmission modules, two of the transmission modules can be respectively connected to the first antenna unit and the second antenna unit, and the 3rd transmission module is grounded. In this design, a decoupling effect of a high-impedance transmission line may be implemented through three low-impedance transmission modules, thereby effectively improving isolation between antenna units in a small-sized communication device.

[0021] In a possible design, the decoupling module may be a first inductor.

[0022] Because an inductor can be equivalent to a high-impedance transmission module, in this design, a decoupling effect of a high-impedance transmission line may be implemented through the inductor, thereby effectively improving isolation between antenna units in a small-sized communication device.

[0023] In another possible design, the decoupling module may be a series branch including an eighth transmission module, a second inductor, and a ninth transmission module that are sequentially connected in series.

[0024] In this design, two ends of the second inductor each are connected to one transmission module. Coupling caused by a small-sized inductor may be reduced through the two transmission modules, thereby further improving isolation between antenna units in a small-sized communication device.

[0025] In still another possible design, the decoupling module may be a series branch including a first resistor, a tenth transmission module, and a second resistor that are sequentially connected in series.

[0026] In this design, two ends of the transmission module each are connected to a resistor. This may reduce a processing difficulty, and effectively improve isolation between antenna units in a small-sized communication device.

[0027] In a possible design, any antenna unit may include at least one of the following: a planar inverted F antenna PIFA, a monopole antenna, a dipole antenna, and a microstrip patch antenna.

[0028] According to a third aspect, an embodiment of this application further provides an antenna system. The antenna system includes any one of the foregoing antenna arrays.

[0029] According to a fourth aspect, an embodiment of this application further provides a communication device. The communication device includes any one of the foregoing antenna arrays or the foregoing antenna system. For technical effects that can be achieved in any one of the third aspect and the fourth aspect, refer to descriptions of technical effects that can be achieved by any possible design in the first aspect or the second aspect. Repetitions are not discussed herein.

BRIEF DESCRIPTION OF DRAWINGS

[0030]

FIG. 1 is a schematic diagram of a radio frequency channel of a communication device;
FIG. 2 is a schematic diagram of antenna units in a MIMO antenna;
FIG. 3 is a schematic diagram of a structure of an antenna array according to an embodiment of this application;
FIG. 4 is a schematic diagram of a structure of Implementation manner 1 of an antenna array according to an embodiment of this application;
FIG. 5 is a schematic diagram of a structure of Implementation manner 2 of an antenna array according to an embodiment of this application;
FIG. 6 is a schematic diagram of a structure of Implementation manner 3 of an antenna array according to an embodiment of this application;
FIG. 7 is a schematic diagram of a structure of Implementation manner 4 of an antenna array according to an embodiment of this application;
FIG. 8 is a schematic diagram of a structure of another antenna array according to an embodiment of this application;
FIG. 9 is a schematic diagram of a structure of Implementation manner 1 of another antenna array according to an embodiment of this application;
FIG. 10 is a schematic diagram of a structure of Implementation manner 2 of another antenna array according to an embodiment of this application;
FIG. 11 is a schematic diagram of a structure of Implementation manner 3 of another antenna array according to an embodiment of this application;
FIG. 12 is a schematic diagram of a structure of Implementation manner 4 of another antenna array according to an embodiment of this application;
FIG. 13 is a schematic diagram of another antenna array applied to a radio frequency channel according to an embodiment of this application;
FIG. 14 is a schematic diagram of a structure of still another antenna array according to an embodiment of this application;
FIG. 15 is a schematic diagram of a structure of Implementation manner 1 of still another antenna array according to an embodiment of this application;
FIG. 16 is a schematic diagram of a structure of Implementation manner 2 of still another antenna array according to an embodiment of this application;
FIG. 17 is a schematic diagram of a structure of Implementation manner 3 of still another antenna array according to an embodiment of this application;
FIG. 18 is a schematic diagram of a structure of Implementation manner 4 of still another antenna array according to an embodiment of this application;
FIG. 19a and FIG. 19b are respectively a top view and a side view of an antenna array according to an embodiment of this application;
FIG. 20 is a schematic simulation diagram of isolation of the antenna array shown in FIG. 9;
FIG. 21 shows a horizontal directivity pattern of a first antenna unit in the antenna array shown in FIG. 9; and
FIG. 22 shows a horizontal directivity pattern of a second antenna unit in the antenna array shown in FIG. 9.

DESCRIPTION OF EMBODIMENTS

[0031] This application provides an antenna array, an antenna system, and a communication device, to improve isolation between antenna units.

[0032] In solutions provided in embodiments of this application, the antenna array includes two decoupling modules, and two ends of each decoupling module are respectively connected to two antenna units. In this way, both the two decoupling modules may decouple a coupling component between the two antenna units, to effectively improve the isolation between the antenna units in the communication device.

[0033] The following describes some terms in embodiments of this application, to facilitate understanding of a person skilled in the art.

(1) A communication device generally refers to a device that has a communication function. For example, the communication device may be, but is not limited to, a terminal device, an access network (access network, AN) device, and an access point.
(2) The terminal device is a device that provides voice and/or data connectivity for a user. The terminal device may also be referred to as user equipment (user equipment, UE), a mobile station (mobile station, MS), a mobile terminal (mobile terminal, MT), or the like.

[0034] For example, the terminal device may be a handheld device or a vehicle-mounted device that has a wireless connection function. Currently, some examples of the terminal device are a mobile phone (mobile phone), a tablet computer, a notebook computer, a palmtop computer, a mobile internet device (mobile internet device, MID), a wearable device, a virtual reality (virtual reality, VR) device, an augmented reality (augmented reality, AR) device, a wireless terminal in industrial control (industrial control), a wireless terminal in self driving (self driving), a wireless terminal in remote medical surgery (remote medical surgery), a wireless terminal in a smart grid (smart grid), a wireless terminal in transportation safety (transportation safety), a wireless terminal in a smart city (smart city), and a wireless terminal in a smart home (smart home).

[0035] (3) The AN device is a device that connects the terminal device to a wireless network in a mobile communication system. As a node in a radio access network, the AN device may also be referred to as a base station, a radio access network (radio access network, RAN) node (or device), or an access point (access point, AP).

[0036] Currently, some examples of the AN device are a new generation NodeB (generation NodeB, gNB), a transmission reception point (transmission reception point, TRP), an evolved NodeB (evolved NodeB, eNB), a radio network controller (radio network controller, RNC), a NodeB (NodeB, NB), a base station controller (base station controller, BSC), a base transceiver station (base transceiver station, BTS), a home base station (for example, a home evolved NodeB or a home NodeB, HNB), or a baseband unit (baseband unit, BBU).

[0037] In addition, in a network structure, the AN device may include a central unit (central unit, CU) node and a distributed unit (distributed unit, DU) node. In this structure, protocol layers of the AN device are split. Functions of some protocol layers are controlled by a CU in a centralized manner. Functions of some or all of remaining protocol layers are distributed in a DU, and the CU controls the DU in a centralized manner.

[0038] (4) A transmission module may include a transmission line, for example, a microstrip or a phase-shift line. Parameters of the transmission module may include: impedance of the transmission module and a length parameter of the transmission module.

[0039] In the field of electromagnetic fields, a length of the transmission module may be represented by the length parameter of the transmission module, namely, an electrical length θ. For example, if a length of a transmission line corresponding to an electrical length 360° is 300 millimeters (mm), an electrical length θ=90° represents that a length of a transmission line is 75 mm.

[0040] (5) Isolation between antenna units refers to a ratio of power of a signal transmitted by one antenna unit to power of the signal received by another antenna unit.

[0041] (6) An S parameter may represent a transmission status between the antenna units. The S parameter may include the following.

[0042] S21 represents a ratio of a voltage of a signal transmitted by a second antenna unit to a voltage of the signal transmitted from a port of a first antenna unit to a port of the second antenna unit when the signal is transmitted through the port corresponding to the second antenna unit of the communication device. S21 may represent isolation between the antenna units.

[0043] S 11 represents a reflection coefficient of a signal transmitted to a port corresponding to a first antenna unit of the communication device (namely, a ratio of an incident voltage to a reflected voltage of the signal transmitted to the port corresponding to the first antenna unit) when the signal is transmitted through a port corresponding to a second antenna unit of the communication device.

[0044] S22 represents a reflection coefficient of a signal transmitted to a port corresponding to a second antenna unit of the communication device (namely, a ratio of an incident voltage to a reflected voltage of the signal transmitted to the port corresponding to the second antenna unit) when the signal is transmitted through a port corresponding to a first antenna unit of the communication device.

[0045] (7) A connection in embodiments of this application may be a direct connection, or may be a connection through one or more modules. For example, A and B are connected or A is connected to B may represent that A is directly connected to B, or A is connected to B through C. C may represent one or more modules.

[0046] (8) In embodiments of this application, technical indicators that the antenna array needs to meet include the following: Bandwidth (including standing wave bandwidth and isolation bandwidth) used by the communication device is greater than or equal to a bandwidth threshold (for example, 10% of antenna bandwidth); when an antenna spacing is less than or equal to a first spacing threshold (for example, 0.25 λ), the isolation between the antenna units should be greater than or equal to first isolation (for example, 18 dB); and a difference between a maximum value and a minimum value in a directivity pattern is less than or equal to a directivity pattern threshold (for example, 8 dB).

[0047] (9) In embodiments of this application, both a current and a voltage may be represented in a form of an amplitude and a phase. The amplitude may represent a maximum value of the current or the voltage, and the phase may represent a change of the current or the voltage with time.

[0048] For example, when A represents an amplitude of a current, and α represents a phase of the current, the current may be $|A| \times e^{-j\alpha}$, where |A| represents an absolute value of A. The voltage may also be represented in a similar form, and details are not described herein again.

[0049] Correspondingly, a ratio of the current to the voltage may also be represented in the form of the amplitude and the phase.

[0050] In an alternating current, the current and the voltage may be directional vectors. The vector may be represented by a real part and an imaginary part. Therefore, in embodiments of this application, the current and the voltage may also be represented by the real part and the imaginary part.

[0051] Correspondingly, the ratio of the current to the voltage may also be represented in a form of the real part and the imaginary part.

[0052] (10) A center frequency refers to a middle point of the antenna bandwidth. Signal transmission may be performed by each antenna unit within a specific frequency range (namely, the antenna bandwidth). Within the antenna bandwidth, antenna impedance is the smallest, and transmission efficiency is the highest. At the center frequency of the antenna bandwidth, a standing wave ratio is the smallest.

[0053] (11) A size of two antenna units may be

E×F×H, which represents space occupied by the two antenna units. E, F, and H respectively represent a length, a width, and a height of the space occupied by the two antenna units.

[0054] (12) In embodiments of this application, decoupling may also be replaced with cancellation or de-coupling.

[0055] (13) A feed line refers to a transmission line connecting an antenna unit and a transceiver. Transmission of a signal received by the antenna unit can be effectively performed through the feed line of the antenna. The feed line has characteristics such as a small distortion, a small loss, and a strong anti-interference capability.

[0056] (14) In embodiments of this application, a value range may include at least one of values at two ends, or may not include the values at two ends. For example, a to b may represent any one of [a, b], (a, b), [a, b), and (a, b].

[0057] In embodiments of this application, unless otherwise specified, a quantity of nouns represents "a singular noun or a plural noun", namely, "one or more". "At least one" means one or more, and "a plurality of" means two or more. The term "and/or" describes an association relationship for describing associated objects and represents that three relationships may exist. For example, A and/or B may represent the following three cases: Only A exists, both A and B exist, and only B exists. The character "/" generally represents an "or" relationship between the associated objects. For example, A/B represents A or B. "At least one of the following items (pieces)" or a similar expression thereof refers to any combination of these items (pieces), including any combination of singular items (pieces) or plural items (pieces).

[0058] In addition, it should be understood that in descriptions of this application, terms such as "first" and "second" are merely used for distinguishing and description, but should not be understood as an indication or implication of relative importance, or should not be understood as an indication or implication of a sequence.

[0059] In addition, in this application, "less than" and "less than or equal to" may be replaced with each other, and "greater than" and "greater than or equal to" may be replaced with each other.

[0060] In addition, a parameter value in this application may fluctuate to a specific extent, for example, may fluctuate by ±20%.

[0061] Embodiments of this application may be used in a radio frequency channel of the communication device. The following uses a radio frequency channel shown in FIG. 1 as an example for description. Embodiments of this application may alternatively be used in a radio frequency channel in another form. This is not limited in this application. FIG. 1 is a schematic diagram of a radio frequency channel corresponding to one antenna unit of a communication device. The following describes the radio frequency channel with reference to FIG. 1. The radio frequency channel may include, but is not limited to: an antenna unit, a band-pass filter, a power amplifier/low-noise amplifier, an up/down converter, and a modem.

[0062] The antenna unit may receive or send a signal.

[0063] The band-pass filter may filter a signal and reserve a frequency component within a frequency range in the signal.

[0064] The power amplifier is short for a power amplifier, and the low-noise amplifier is short for a low-noise amplifier. The power amplifier may amplify power of a signal to obtain a strong output signal. The low-noise amplifier is an amplifier with a very low noise figure. Noise of an amplifier itself may cause severe interference to a signal, and the low-noise amplifier may improve quality of the output signal.

[0065] The up/down converter may adjust a frequency of a signal.

[0066] The modem may convert a baseband signal into a band-pass signal with a high frequency, or convert the band-pass signal with a high frequency into the baseband signal.

[0067] After being processed by the radio frequency channel, a radio frequency signal received by the antenna unit may be converted into a baseband signal that can be processed by the communication device. After being processed by the radio frequency channel, a baseband signal generated by the communication device is sent out through the antenna unit.

[0068] The radio frequency channel shown in FIG. 1 may be applied to a MIMO system. In other words, any one of a plurality of radio frequency channels in the MIMO system may be as shown in FIG. 1. In addition, a MIMO antenna in the MIMO system may include a plurality of antenna units in the radio frequency channel shown in FIG. 1.

[0069] The following describes distribution of the antenna units in the MIMO antenna. FIG. 2 is a schematic diagram of distribution of antenna units in a MIMO antenna. Each letter in FIG. 2 represents one antenna unit. As shown in FIG. 2, when the MIMO antenna includes four antenna units (that is, 4-transmit 4-receive (4T4R)), a spacing between adjacent antenna units may be λ. When the MIMO antenna includes eight antenna units (that is, 8-transmit 8-receive (8T8R)), a spacing between adjacent antenna units may be 0.5 λ. When the MIMO antenna includes 16 antenna units (that is, 16-transmit 16-receive (16T16R)), a spacing between adjacent antenna units may be 0.25 λ. When a spacing between adjacent antenna units is small (for example, 0.25 λ), mutual coupling between the antenna units is improved, and isolation between the antenna units is reduced.

[0070] The following describes in detail embodiments of this application with reference to the accompanying drawings.

[0071] To improve isolation between antenna units, an embodiment of this application provides an antenna array. Each antenna unit included in the antenna array may be used in the radio frequency channel shown in FIG. 1, and the antenna array may improve isolation between the antenna units shown in FIG. 2. Optionally, the antenna array may be configured to improve isolation between the 16T16R antenna units shown in FIG. 2.

[0072] The antenna array may include a plurality of antenna units. The following uses a first antenna unit 101, a second antenna unit 102, and a module between the first antenna unit 101 and the second antenna unit 102 as examples for description. It may be understood that a similar module may be included between every two antenna units included in the antenna array, and details are not described herein.

[0073] FIG. 3 shows a possible structure of an antenna array according to an embodiment of this application. As shown in FIG. 3, the antenna array may include: a first antenna unit 101, a second antenna unit 102, a first decoupling module 103, a second decoupling module 104, a first transmission module 105, and a second transmission module 106.

[0074] Two ends of the first decoupling module 103 may be respectively connected to the first antenna unit 101 and the second antenna unit 102. One end of the second decoupling module 104 may be connected to the first antenna unit 101 through the first transmission module 105, and the other end of the second decoupling module 104 may be connected to the second antenna unit 102 through the second transmission module 106.

[0075] The first decoupling module 103 and the second decoupling module 104 may be configured to decouple a coupling component between the first antenna unit and the second antenna unit. For example, when a signal of the first antenna unit is transmitted to the second antenna unit through the first decoupling module and the second decoupling module, both the first decoupling module and the second decoupling module can generate a reverse current of the signal, where the reverse current may be used to decouple the coupling component between the first antenna unit and the second antenna unit.

[0076] The following describes in detail each component of the antenna array shown in FIG. 3.

[0077] Optionally, any antenna unit may be one of a planar inverted F antenna (Planar inverted F antenna, PIFA), a monopole antenna, a dipole antenna, and a microstrip patch antenna.

[0078] Optionally, a parameter of the first transmission module 105 and a parameter of the second transmission module 106 may be the same, or may be different, or may be partially the same.

[0079] For example, both impedance of the first transmission module 105 and impedance of the second transmission module 106 may be 50 S2, and both a length parameter of the first transmission module 105 and a length parameter of the second transmission module 106 may be $\theta_2=\pi/2+1k\pi$, where k may be a non-negative integer. For example, k=0 or 1.

[0080] For another example, a difference between the parameter of the first transmission module 105 and the parameter of the second transmission module 106 is less than a predetermined threshold (where for example, the predetermined threshold may be 20% of the parameter of the first transmission module 105, or may be 10% of the parameter of the second transmission module 106).

[0081] For still another example, both impedance of the first transmission module 105 and impedance of the second transmission module 106 may be 50 Ω, and a difference between a length parameter of the first transmission module 105 and a length parameter of the second transmission module 106 is less than a predetermined threshold (where for example, the predetermined threshold may be 10% of the length parameter of the first transmission module 105, or may be 5% of the length parameter of the second transmission module 106).

[0082] For still another example, both a length parameter of the first transmission module 105 and a length parameter of the second transmission module 106 may be $\theta_2=\pi/2+1\alpha\pi$, and a difference between impedance of the first transmission module 105 and impedance of the second transmission module 106 is less than a predetermined threshold (where for example, the predetermined threshold may be 20% of the impedance of the first transmission module 105, or may be 5% of the impedance of the second transmission module 106).

[0083] The following describes the second decoupling module 104 in FIG. 3 with reference to FIG. 4 to FIG. 7. The second decoupling module 104 may include but is not limited to the following manners.

Implementation manner 1:

[0084] Refer to FIG. 4. The second decoupling module 104 may include: a fifth transmission module 201, a sixth transmission module 202, and a seventh transmission module 203.

[0085] The fifth transmission module 201 and the sixth transmission module 202 may be connected in series, and two ends of the fifth transmission module 201 and the sixth transmission module 202 that are connected in series are respectively connected to the first transmission module 105 and the second transmission module 106. A connection point between the fifth transmission module 201 and the sixth transmission module 202 may be grounded through the seventh transmission module 203.

[0086] The following describes each component of the second decoupling module 104 in Implementation manner 1.

[0087] Optionally, a parameter of the fifth transmission module 201 and a parameter of the sixth transmission module 202 may be the same, or may be different, or may be partially the same.

[0088] For example, both impedance of the fifth transmission module 201 and impedance of the sixth transmission module 202 may be a value in 90 S2 to 120 S2, and both a length parameter of the fifth transmission module 201 and a length parameter of the sixth transmission module 202 may be θ_3=67°.

[0089] For another example, a difference between the parameter of the fifth transmission module 201 and the parameter of the sixth transmission module 202 is less than a predetermined threshold (where for example, the predetermined threshold may be 10% of the parameter of the fifth transmission module 201, or may be 20% of the parameter of the sixth transmission module 202).

[0090] For still another example, both impedance of the fifth transmission module 201 and impedance of the sixth transmission module 202 may be a value in 90 S2 to 120 Ω, and a difference between a length parameter of the fifth transmission module 201 and a length parameter of the sixth transmission module 202 is less than a predetermined threshold (where for example, the predetermined threshold may be 20% of the length parameter of the fifth transmission module 201, or may be 5% of the length parameter of the sixth transmission module 202).

[0091] For still another example, both a length parameter of the fifth transmission module 201 and a length parameter of the sixth transmission module 202 may be θ_3=67°, and a difference between impedance of the fifth transmission module 201 and impedance of the sixth transmission module 202 is less than a predetermined threshold (where for example, the predetermined threshold may be 10% of the impedance of the fifth transmission module 201, or may be 20% of the impedance of the sixth transmission module 202). Specifically, the impedance of the fifth transmission module 201 may be a first value in 90 S2 to 120 Ω, the impedance of the sixth transmission module 202 may be a second value in 90 S2 to 120 Ω, and a difference between the first value and the second value is less than the predetermined threshold.

[0092] Optionally, impedance of the seventh transmission module 203 may be a value in 40 S2 to 90 Ω, and a length parameter of the seventh transmission module 203 may be θ_4=33°.

[0093] In Implementation manner 1, the second decoupling module 104 includes three interconnected transmission modules, two of the transmission modules can be respectively connected to the first antenna unit 101 and the second antenna unit 102, and the 3rd transmission module is grounded. In Implementation manner 1, a decoupling effect of a high-impedance transmission line may be implemented through three low-impedance transmission modules, thereby effectively improving isolation between antenna units in a small-sized communication device.

Implementation manner 2:

[0094] Refer to FIG. 5. The second decoupling module 104 may be a first inductor 301.

[0095] Optionally, an inductance value of the first inductor may be a value in 5 henries (nH) to 50 henries.

[0096] Because an inductor can be equivalent to a high-impedance transmission module, in Implementation manner 2, a decoupling effect of a high-impedance transmission line may be implemented through the inductor, thereby effectively improving isolation between antenna units in a small-sized communication device.

Implementation manner 3:

[0097] Refer to FIG. 6. The second decoupling module 104 may be a series branch including an eighth transmission module 401, a second inductor 402, and a ninth transmission module 403 that are sequentially connected in series.

[0098] The following describes each component of the second decoupling module 104 in Implementation manner 3.

[0099] Optionally, a parameter of the eighth transmission module 401 and a parameter of the ninth transmission module 403 may be the same, or may be different, or may be partially the same.

[0100] For example, both impedance of the eighth transmission module 401 and impedance of the ninth transmission module 403 may be 50 S2, and both a length parameter of the eighth transmission module 401 and a length parameter of the ninth transmission module 403 may be θ_5=180°.

[0101] For another example, a difference between the parameter of the eighth transmission module 401 and the parameter of the ninth transmission module 403 is less than a predetermined threshold (where for example, the predetermined threshold may be 20% of the parameter of the eighth transmission module 401, or may be 10% of the parameter of the ninth transmission module 403).

[0102] For still another example, both impedance of the eighth transmission module 401 and impedance of the ninth transmission module 403 may be 50 Ω, and a difference between a length parameter of the eighth transmission module 401 and a length parameter of the ninth transmission module 403 is less than a predetermined threshold (where for example, the predetermined threshold may be 10% of the length parameter of the eighth transmission module 401, or may be 5% of the length parameter of the ninth transmission module 403).

[0103] For still another example, both a length parameter of the eighth transmission module 401 and a length parameter of the ninth transmission module 403 may be θ_5=180°, and a difference between impedance of the eighth transmission module 401 and impedance of the ninth transmission module 403 is less than a predetermined threshold (where for example, the predetermined threshold may be 10% of the impedance of the eighth transmission module 401, or may be 10% of the impedance of the ninth transmission module 403).

[0104] Optionally, an inductance value of the second inductor 402 may be a value in 5 nH to 50 nH.

[0105] In the second decoupling module 104 in Implementation manner 3, two ends of the second inductor 402 each are connected to one transmission module. Coupling caused by a small-sized inductor may be reduced through the two transmission modules, thereby further improving isolation between antenna units in a small-sized communication device.

Implementation manner 4:

[0106] Refer to FIG. 7. The second decoupling module 104 may be a series branch including a first resistor 501, a tenth transmission module 502, and a second resistor 503 that are sequentially connected in series.

[0107] The following describes each component of the second decoupling module 104 in Implementation manner 4.

[0108] Optionally, a parameter of the first resistor 501 and a parameter of the second resistor 503 may be the same, or may be different.

[0109] For example, both impedance of the first resistor 501 and impedance of the second resistor 503 may be a value in 25 S2 to 250 S2.

[0110] For another example, a difference between impedance of the first resistor 501 and impedance of the second resistor 503 is less than a predetermined threshold (where for example, the predetermined threshold may be 20% of the impedance of the first resistor 501, or may be 10% of the impedance of the second resistor 503).

[0111] Optionally, impedance of the tenth transmission module 502 may be a value in 25 S2 to 250 Ω, and a length parameter of the tenth transmission module 502 may be θ_6=90°.

[0112] In the second decoupling module 104 in Implementation manner 4, two ends of the tenth transmission module 502 each are connected to a resistor. In this way, a processing difficulty is reduced, and isolation between antenna units in a small-sized communication device may be further effectively improved.

[0113] Optionally, a structure of the first decoupling module 103 and a structure of the second decoupling module 104 may be the same, or may be different, or may be partially the same.

[0114] For example, the second decoupling module 104 is implemented in one of the foregoing four implementation manners, and the first decoupling module 103 may be a transmission module.

[0115] Impedance of the first decoupling module 103 may be $-\frac{1}{\mathrm{Im}\,(y'_{21})}\cdot$ $\mathrm{Im}\,(y'_{21})$ is an imaginary part value of Y21 between the first antenna unit 101 and the second antenna unit 102 at a center frequency. A length parameter of the first decoupling module 103 may be θ_7=90°.

[0116] For another example, the first decoupling module 103 is implemented in one of the foregoing four implementation manners, and the second decoupling module 104 is implemented in another one of the foregoing four implementation manners.

[0117] For still another example, the first decoupling module 103 and the second decoupling module 104 each are implemented in one of the foregoing four implementation manners.

[0118] Optionally, the antenna array may further include a matching network (not shown in the figure).

[0119] In some implementations, the matching network may be located between a port and a decoupling module. For example, the matching network may be located between a port 1 and the second decoupling module 104, and/or located between a port 2 and the second decoupling module 104.

[0120] The matching network may be a conventional matching network, or may be another matching network. This is not limited in this application. The matching network may reduce a loss and a distortion in a signal transmission process.

[0121] In the foregoing embodiments of this application, an antenna array includes two decoupling modules, and two ends of each decoupling module are respectively connected to two antenna units. In this way, each decoupling module may decouple a coupling component between the two antenna units, to effectively improve isolation between the antenna units in a communication device.

[0122] FIG. 8 shows another possible structure of an antenna array according to an embodiment of this application. As shown in FIG. 8, based on the antenna array shown in FIG. 3, the antenna array may further include: a third transmission module 107 and a fourth transmission module 108.

[0123] Optionally, one end of the first decoupling module 103 may be connected to the first antenna unit 101 through the third transmission module 107, and the other end of the first decoupling module 103 may be connected to the second antenna unit 102 through the fourth transmission module 108.

[0124] One end of the second decoupling module 104 may be connected to the first antenna unit 101 through the first transmission module 105 and the third transmission module 107 sequentially, and the other end of the second decoupling module 104 may be connected to the second antenna unit 102 through the second transmission module 106 and the fourth transmission module 108 sequentially.

[0125] As shown in FIG. 9 to FIG. 12, the second decoupling module 104 may have a plurality of implementation manners.

[0126] For structures and parameters of the first antenna unit 101, the second antenna unit 102, the first decoupling module 103, the second decoupling module 104, the first transmission module 105, and the second transmission module 106, refer to the descriptions of the antenna array shown in FIG. 3 to FIG. 7. Details are not described herein again.

[0127] When the first decoupling module 103 is a transmission module, impedance of the first decoupling module 103 may be $-\frac{1}{\mathrm{Im}\,(y'_{21})}\cdot$ $\mathrm{Im}\,(y'_{21})$ is an imaginary part value of Y21, at a center frequency, obtained by performing decoupling by the third transmission module 107 and the fourth transmission module 108. A length parameter of the first decoupling module 103 may be θ_7=90°.

[0128] The following describes a parameter of the third transmission module 107 and a parameter of the fourth transmission module 108.

[0129] In some possible implementations, the parameter of the third transmission module 107 and the parameter of the fourth transmission module 108 may be the same, or may be different, or may be partially the same.

[0130] For example, both impedance of the third transmission module 107 and impedance of the fourth transmission module 108 may be 50 ohms (Ω), and both a length parameter of the third transmission module 107 and a length parameter of the fourth transmission module 108 may be $\theta_1 = \frac{k\pi}{2} - \frac{\pi}{4} + \frac{\varphi}{2}$. k is a positive integer, and φ is a phase of Y21. Y21 is located in the second row and the first column of a Y matrix. The Y matrix may represent a voltage and current relationship between a port 1 and a port 2. The port 1 corresponds to the first antenna unit 101, and the port 2 corresponds to the second antenna unit 102. Y21 represents a ratio of a current at the port 2 to a voltage at the port 1 when signal transmission is performed through the port 1.

[0131] For another example, a difference between the parameter of the third transmission module 107 and the parameter of the fourth transmission module 108 is less than a predetermined threshold (where for example, the predetermined threshold may be 10% of the parameter of the third transmission module 107, or may be 20% of the parameter of the fourth transmission module 108).

[0132] For still another example, both impedance of the third transmission module 107 and impedance of the fourth transmission module 108 may be 50 ohms (Ω), and a difference between a length parameter of the first transmission module 105 and a length parameter of the fourth transmission module 108 is less than a predetermined threshold (where for example, the predetermined threshold may be 10% of the length parameter of the third transmission module 107, or may be 20% of the length parameter of the fourth transmission module 108).

[0133] For still another example, both a length parameter of the third transmission module 107 and a length parameter of the fourth transmission module 108 may be $\theta_1 = \frac{k\pi}{2} - \frac{\pi}{4} + \frac{\varphi}{2}$, and a difference between impedance of the third transmission module 107 and impedance of the fourth transmission module 108 is less than a predetermined threshold (where for example, the predetermined threshold may be 10% of the impedance of the third transmission module 107, or may be 20% of the impedance of the fourth transmission module 108).

[0134] Optionally, the parameter of the first transmission module 105 and the parameter of the third transmission module 107 may be exchanged, and the parameter of the second transmission module 106 and the parameter of the fourth transmission module 108 may also be exchanged.

[0135] In embodiments of this application, an antenna array includes two decoupling modules, and two ends of each decoupling module are respectively connected to two antenna units through a transmission module. In other words, two ends of each decoupling module are respectively connected to feed lines of the antenna units. In this way, the two decoupling modules decouple a coupling component between the two antenna units, so that impact on radiation performance of the antenna units may be avoided, and isolation between the antenna units in a communication device may be effectively improved.

[0136] Optionally, the parameter of the first transmission module 105 in the antenna array shown in FIG. 3 to FIG. 7 may be replaced with the parameter of the third transmission module 107, and the parameter of the second transmission module 106 in the antenna array shown in FIG. 3 to FIG. 7 may be replaced with the parameter of the fourth transmission module 108.

[0137] In solutions provided in embodiments of this application, a module between every two antenna units (for example, the first antenna unit 101 and the second antenna unit 102) in a plurality of antenna units may be located between the antenna unit and a band-pass filter. For example, a module between the first antenna unit 101 and the second antenna unit 102 may be located in a dotted box shown in FIG. 13 (for example, located between an antenna unit and a port). The first transmission module 105 and the third transmission module 107 may be located between the first antenna unit 101 and the port 1, and the second transmission module 106 and the fourth transmission module 108 may be located between the second antenna unit 102 and the port 2. The first decoupling module 103 and the second decoupling module 104 may be located between two radio frequency channels, and the two radio frequency channels respectively correspond to the first antenna unit 101 and the second antenna unit 102. The port 1 is an antenna port corresponding to the first antenna unit 101, and the port 2 is an antenna port corresponding to the second antenna unit 102.

[0138] Optionally, two ends of the first decoupling module 103 and the second decoupling module 104 may be further respectively connected to the port 1 and the port 2.

[0139] In solutions provided in embodiments of this application, an antenna array may include two decoupling modules, and two ends of each decoupling module are respectively connected to two antenna units. In this way, the two decoupling modules may decouple a coupling component between the two antenna units, that is, second-level decoupling is implemented, to effectively improve isolation between the antenna units in a communication device. In addition, the second decoupling module 104 is connected to ports corresponding to the antenna units, and decouples, at the ports, a coupling component between the two antenna units, so that isolation between the antenna units is improved, and impact on radiation performance of the antenna units may be further reduced.

[0140] When initial isolation between the antenna units is poor (where for example, the initial isolation is about 7 dB), the two decoupling modules provided in embodiments of this application may effectively improve the isolation between the antenna units.

[0141] FIG. 14 shows still another possible structure of an antenna array according to an embodiment of this application. As shown in FIG. 11, the antenna array may include: a plurality of antenna units including a first antenna unit 101 and a second antenna unit 102, a second decoupling module 104, a third transmission module 107, and a fourth transmission module 108.

[0142] The second decoupling module 104 may be connected to the first antenna unit 101 through the third transmission module 107, and the second decoupling module 104 may be connected to the second antenna unit 102 through the fourth transmission module 108. A line width of the second decoupling module 104 is greater than a line width of a transmission line that generates a same decoupling effect.

[0143] Optionally, a parameter of the third transmission module 107 may be replaced with a parameter of the foregoing first transmission module 105, and a parameter of the fourth transmission module 108 may be replaced with a parameter of the foregoing second transmission module 106.

[0144] As shown in FIG. 15 to FIG. 18, the second decoupling module 104 may also have a plurality of implementation manners.

[0145] For specific content of each component of the antenna array, refer to specific descriptions of the antenna array shown in FIG. 3 to FIG. 12. Details are not described herein again.

[0146] In solutions provided in embodiments of this application, two antenna units are respectively coupled to two ends of a decoupling module through transmission modules, and the decoupling module may decouple a coupling component between the two antenna units. In this solution, a line width of the decoupling module is greater than the line width of the transmission line that generates the same decoupling effect. This effectively improves isolation between the antenna units in a small-sized communication device, and may further reduce a difficulty in manufacturing the antenna array.

[0147] When initial isolation between the antenna units is good (where for example, the initial isolation is about 15 dB), the decoupling module provided in embodiments of this application may effectively improve the isolation between the antenna units.

[0148] To facilitate understanding of performance of the antenna array provided in embodiments of this application, a possible physical structure of the antenna array shown in FIG. 8 is provided, and the antenna array shown in FIG. 9 is simulated based on the possible physical structure. A simulation result is shown in FIG. 20 to FIG. 22.

[0149] FIG. 19a and FIG. 19b are respectively a top view and a side view of the antenna array shown in FIG. 8. The figures show a possible physical structure including the antenna array shown in FIG. 8. Components and reference signs of the antenna array in FIG. 19a and FIG. 19b are the same as those in FIG. 8, and details are not described herein again. As shown in FIG. 19a and FIG. 19b, to install a plurality of antenna units in limited space, a shape of a first antenna unit 101 and a shape of a second antenna unit 102 may be different.

[0150] FIG. 20 shows a simulation result of isolation before and after decoupling is performed by using the antenna array shown in FIG. 9. During simulation, bandwidth used by a communication device is 13% of antenna bandwidth. As shown in FIG. 20, in solutions in embodiments of this application, isolation between antenna units can be improved from 10 dB to 32 dB (from S21_before_decoupling to S21_after_decoupling), and a return loss in a frequency band is less than -11 dB. In this solution, the following technical indicators can be met: Bandwidth (including standing wave bandwidth and isolation bandwidth) used by the communication device is greater than or equal to 10% of the antenna bandwidth, and the isolation between the antenna units is greater than or equal to 18 dB.

[0151] In addition, the figure further shows a simulation result (namely, S21_first-level_decoupling) of isolation after decoupling is performed by using the first decoupling structure 103. As shown in FIG. 20, when decoupling is performed by using the first decoupling structure 103, a technical indicator, of the isolation, that cannot be met is as follows: The isolation between the antenna units is greater than or equal to 18 dB.

[0152] When the shape of the first antenna unit 101 and the shape of the second antenna unit 102 are different, directivity patterns of the two antenna units may also be different. FIG. 21 and FIG. 22 respectively show horizontal directivity patterns of the first antenna unit 101 and the second antenna unit 102 after decoupling is performed by using the antenna array shown in FIG. 9. In FIG. 21, a solid line represents a horizontal directivity pattern of the first antenna unit 101 when a center frequency is 1.95 GHz, and a bold dashed line represents a horizontal directivity pattern of the first antenna unit 101 when the center frequency is 2.14 GHz. In FIG. 22, a solid line represents a horizontal directivity pattern of the second antenna unit 102 when a center frequency is 1.95 GHz, and a bold dashed line represents a horizontal directivity pattern of the second antenna unit 102 when the center frequency is 2.14 GHz. As shown in FIG. 21 and FIG. 22, both a difference between a maximum value and a minimum value in the horizontal directivity pattern of the first antenna unit 101 and a difference between a maximum value and a minimum value in the horizontal directivity pattern of the second antenna unit 102 are less than 7 dB. In this solution, the following technical indicator can be met: A difference between a maximum value and a minimum value in a directivity pattern is less than or equal to 8 dB.

[0153] In addition, when signal transmission is performed by one antenna unit, if the antenna array in embodiments of this application is used to decouple a coupling component between antenna units, a current on the other antenna unit is very weak, and has small impact on a radiation field of the antenna unit that performs signal transmission.

[0154] A conventional size of two antenna units is 0.65 $\lambda \times 0.65 \lambda \times 0.1 \lambda$. In solutions provided in embodiments of this application, when a technical indicator, for example, isolation is met, the size of the two antenna units may be reduced to 0.25 $\lambda \times 0.25 \lambda \times 0.06 \lambda$. Compared with the conventional size of the two antenna units, in the solutions provided in embodiments of this application, the size of the antenna units may be reduced by more than 70%. Therefore, the antenna array provided in embodiments of this application has advantages such as miniaturization, good isolation, easy integration, and high roundness.

[0155] An embodiment of this application further provides an antenna system. The antenna system includes any one of the foregoing antenna arrays. In the antenna system, a decoupling module may decouple a coupling component between two antenna units, to effectively improve isolation between the antenna units in a communication device.

[0156] An embodiment of this application further provides a communication device. The communication device includes any one of the foregoing antenna arrays or the foregoing antenna system. In the communication device, a decoupling module may decouple a coupling component between two antenna units, to effectively improve isolation between the antenna units in the communication device. Because the antenna array provided in embodiments of this application has a small size, the antenna array may be easily integrated into a small-sized communication device (for example, a small base station with a plurality of indoor antennas), and a size of the communication device does not significantly increase due to an increase in a quantity of antenna units.

[0157] It is clear that a person skilled in the art can make various modifications and variations to this application without departing from the protection scope of this application. In this way, this application is intended to cover these modifications and variations of this application provided that they fall within the scope of the claims of this application and their equivalent technologies.

Claims

1. An antenna array, comprising: a plurality of antenna units comprising a first antenna unit and a second antenna unit, a first decoupling module, a second decoupling module, a first transmission module, and a second transmission module, wherein

   two ends of the first decoupling module are respectively connected to the first antenna unit and the second antenna unit;
   one end of the second decoupling module is connected to the first antenna unit through the first transmission module, and the other end of the second decoupling module is connected to the second antenna unit through the second transmission module; and
   the first decoupling module and the second decoupling module are configured to decouple a coupling component between the first antenna unit and the second antenna unit.

2. The antenna array according to claim 1, further comprising: a third transmission module and a fourth transmission module, wherein

   one end of the first decoupling module is connected to the first antenna unit through the third transmission module, and the other end of the first decoupling module is connected to the second antenna unit through the fourth transmission module; and
   one end of the second decoupling module is connected to the first antenna unit through the first transmission module and the third transmission module, and the other end of the second decoupling module is connected to the second antenna unit through the second transmission module and the fourth transmission module.

3. The antenna array according to claim 1 or 2, wherein a structure of the first decoupling module is different from a structure of the second decoupling module.

4. The antenna array according to any one of claims 1 to 3, wherein the second decoupling module comprises: a fifth transmission module, a sixth transmission module, and a seventh transmission module;

   the fifth transmission module and the sixth transmission module are connected in series, and two ends of the fifth transmission module and the sixth transmission module that are connected in series are respectively connected to the first transmission module and the second transmission module; and
   a connection point between the fifth transmission module and the sixth transmission module is grounded through the seventh transmission module.

5. The antenna array according to any one of claims 1 to 3, wherein the second decoupling module is a first

inductor.

6. The antenna array according to any one of claims 1 to 3, wherein the second decoupling module is a series branch comprising an eighth transmission module, a second inductor, and a ninth transmission module that are sequentially connected in series.

7. The antenna array according to any one of claims 1 to 3, wherein the second decoupling module is a series branch comprising a first resistor, a tenth transmission module, and a second resistor that are sequentially connected in series.

8. The antenna array according to any one of claims 1 to 3, wherein any antenna unit comprises at least one of the following: a planar inverted F antenna PIFA, a monopole antenna, a dipole antenna, and a microstrip patch antenna.

9. An antenna system, comprising the antenna array according to any one of claims 1 to 8.

10. A communication device, comprising the antenna array according to any one of claims 1 to 8, or comprising the antenna system according to claim 9.

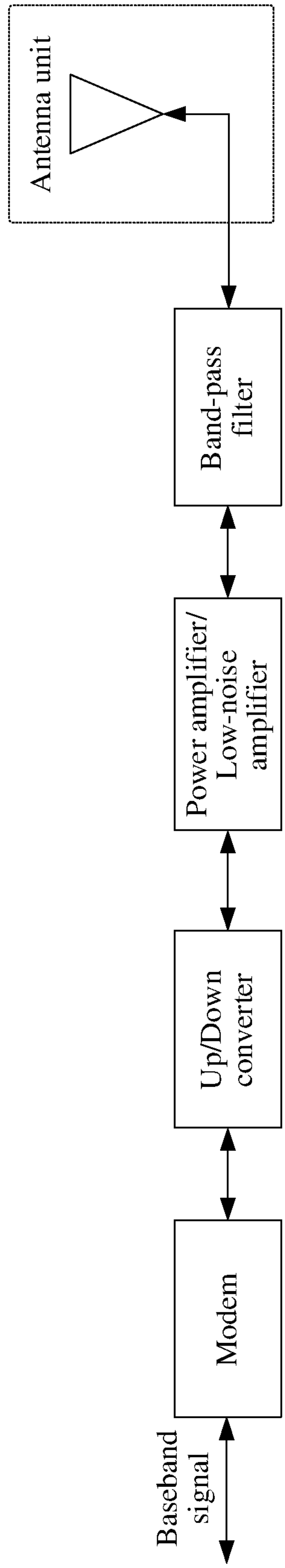

Antenna unit
Band-pass filter
Power amplifier/ Low-noise amplifier
Up/Down converter
Modem
Baseband signal

FIG. 1

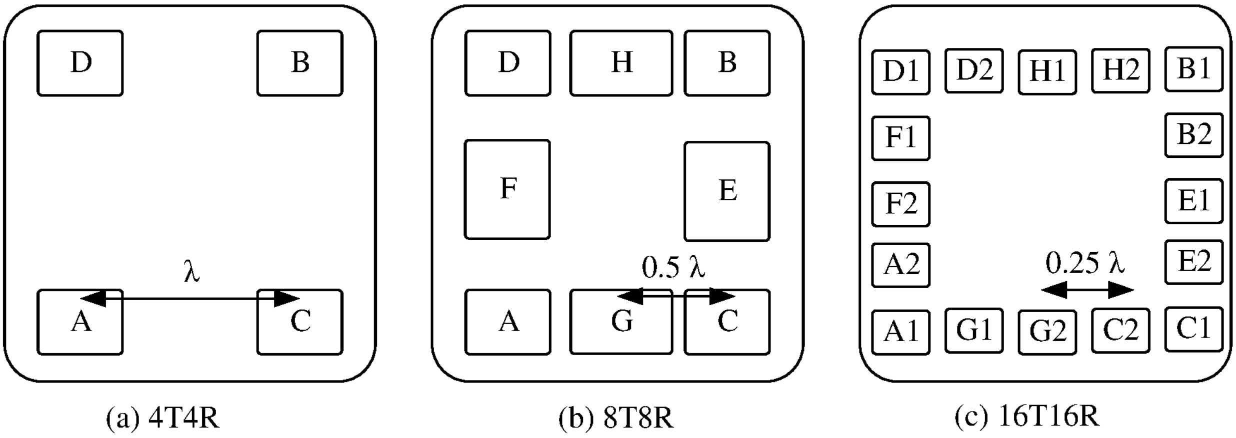

D
B
λ
A
C
(a) 4T4R
D
H
B
F
E
0.5 λ
A
G
C
(b) 8T8R
D1
D2
H1
H2
B1
F1
B2
F2
E1
A2
0.25 λ
E2
A1
G1
G2
C2
C1
(c) 16T16R

FIG. 2

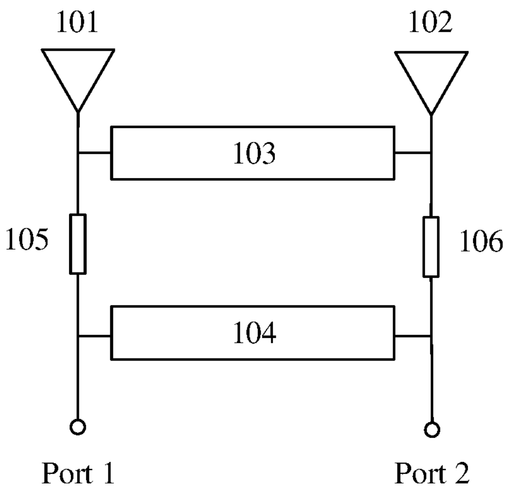
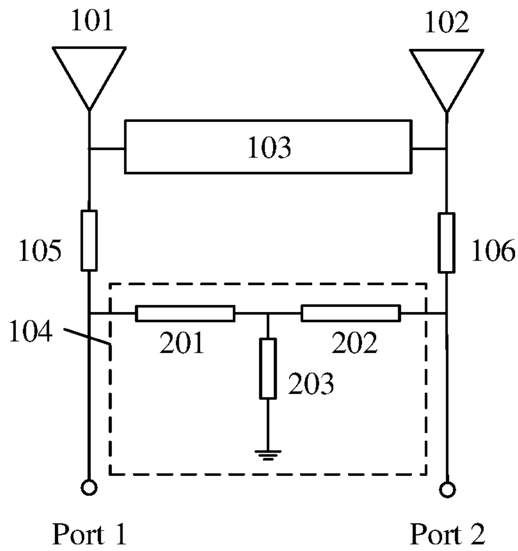

101
102
103
105
106
104
Port 1
Port 2

FIG. 3


101
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103
105
106
104
201
202
203
Port 1
Port 2

FIG. 4

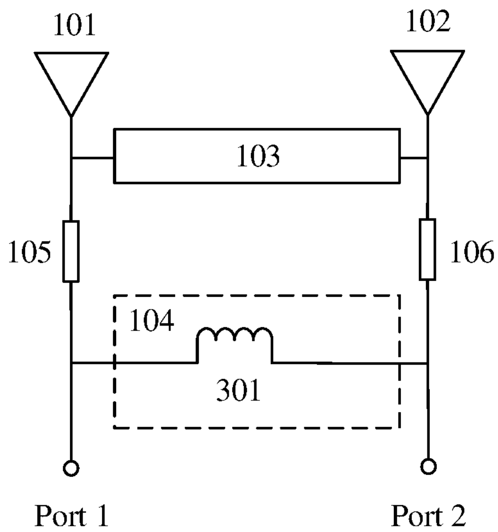
101
102
103
105
106
104
301
Port 1
Port 2

FIG. 5

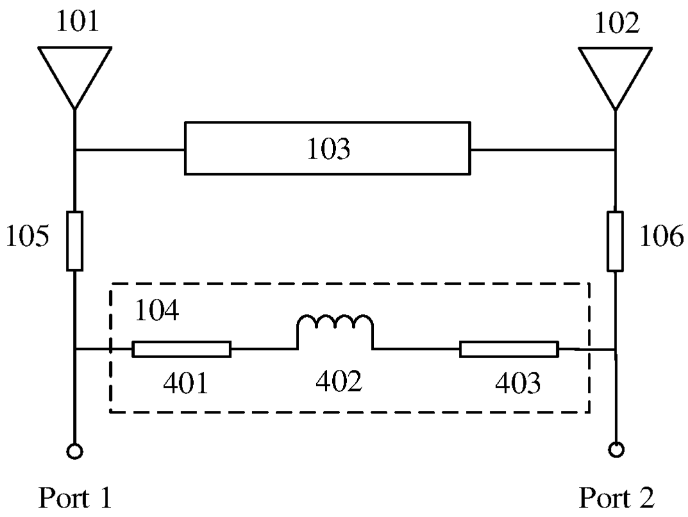
101
102
103
105
106
104
401
402
403
Port 1
Port 2

FIG. 6

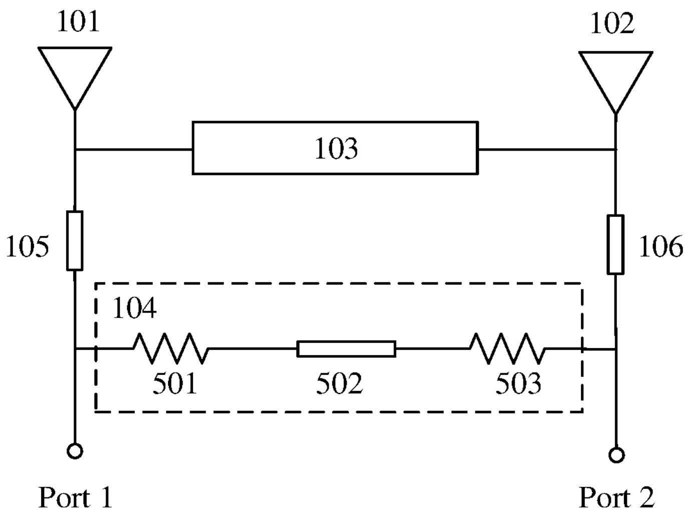
101
102
103
105
106
104
501
502
503
Port 1
Port 2

FIG. 7

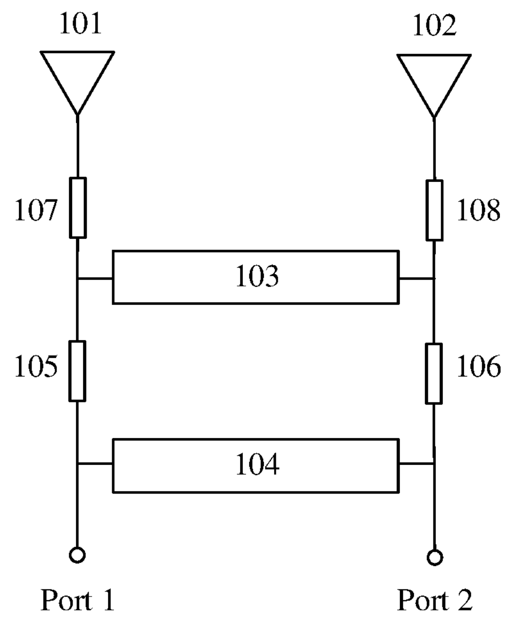
101
102
107
108
103
105
106
104
Port 1
Port 2

FIG. 8

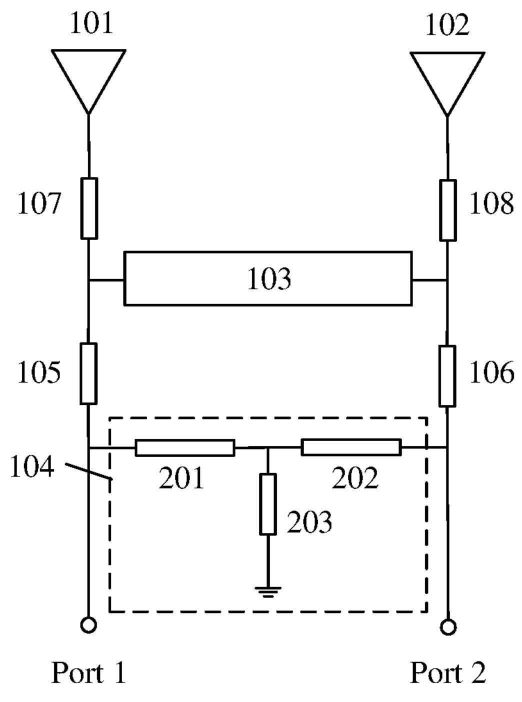
101
102
107
108
103
105
106
104
201
202
203
Port 1
Port 2

FIG. 9

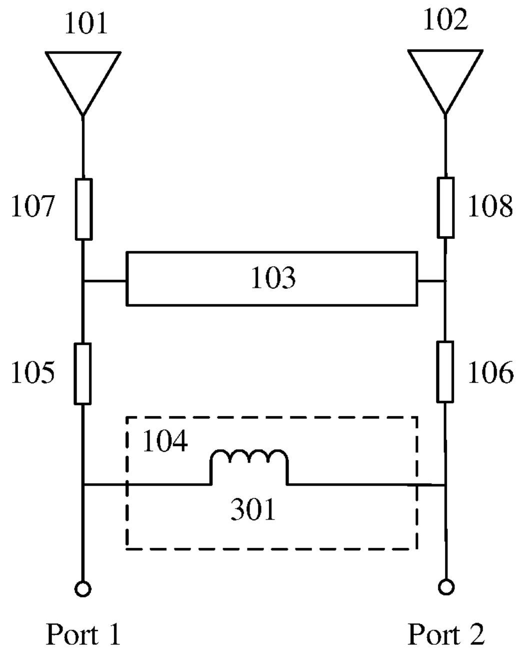
101
102
107
108
103
105
106
104
301
Port 1
Port 2

FIG. 10

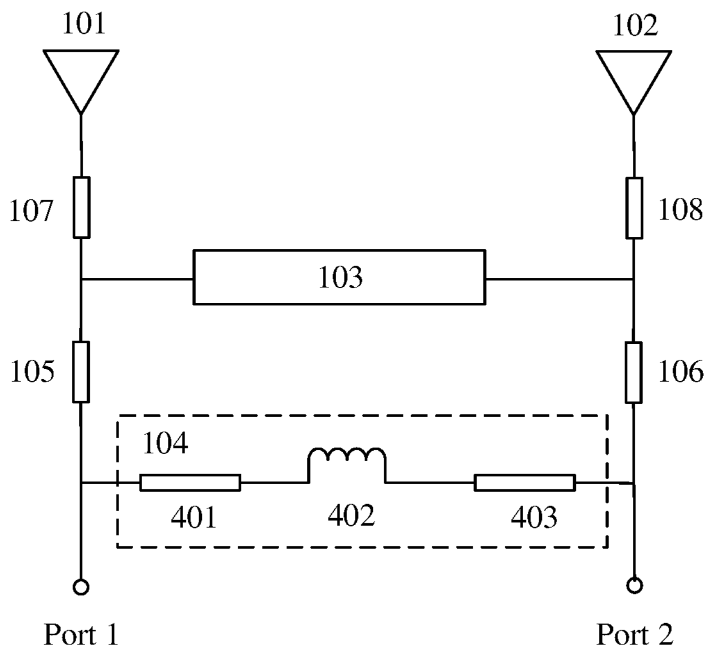
101
102
107
108
103
105
106
104
401
402
403
Port 1
Port 2

FIG. 11

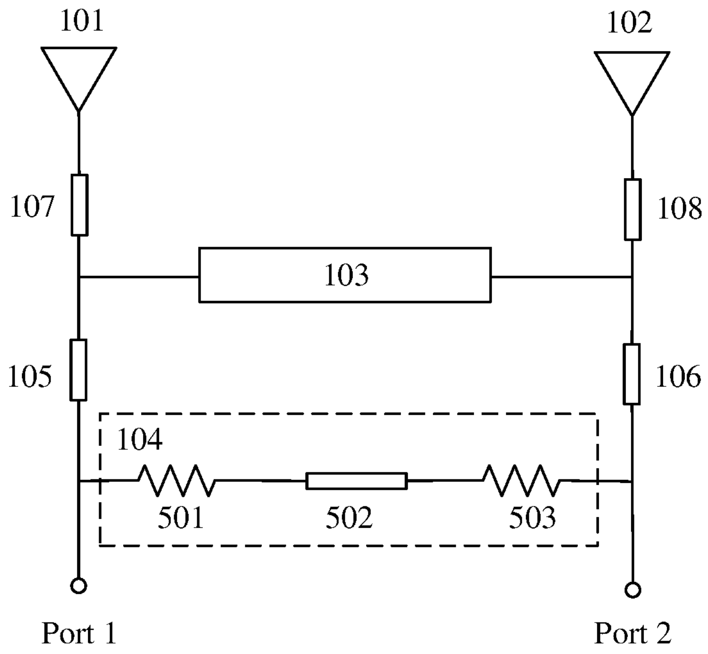

FIG. 12

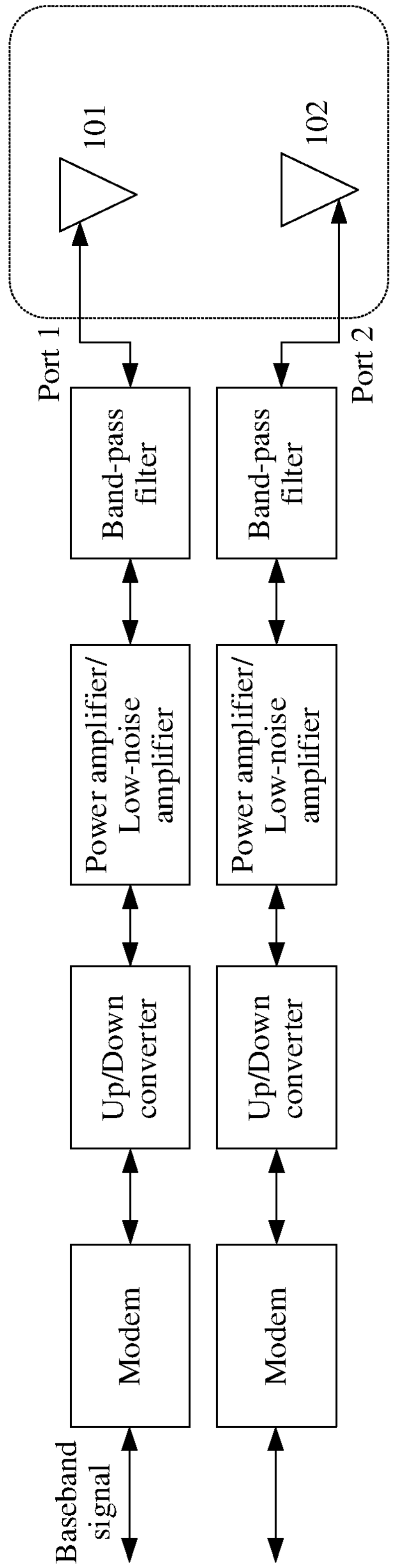
101
102
Port 1
Port 2
Band-pass filter
Band-pass filter
Power amplifier/ Low-noise amplifier
Power amplifier/ Low-noise amplifier
Up/Down converter
Up/Down converter
Modem
Modem
Baseband signal

FIG. 13

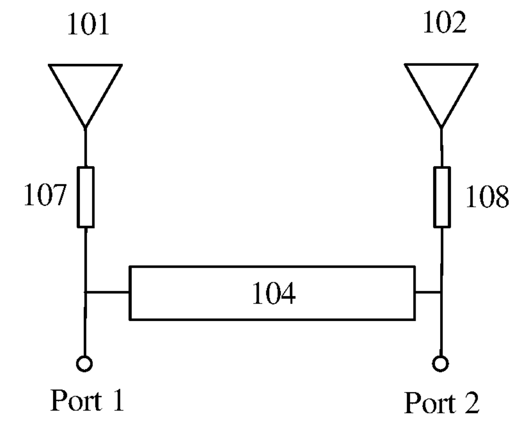

FIG. 14

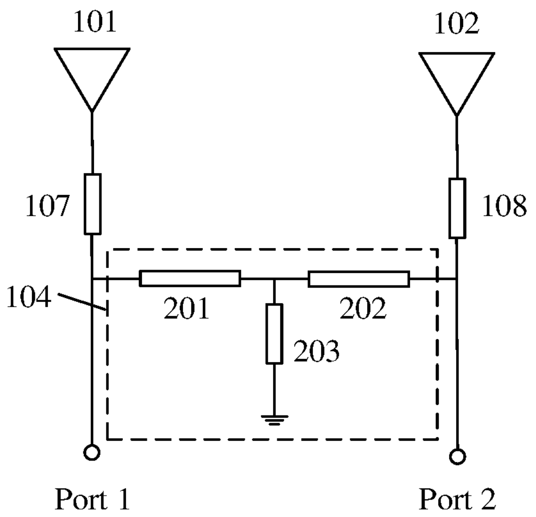

FIG. 15

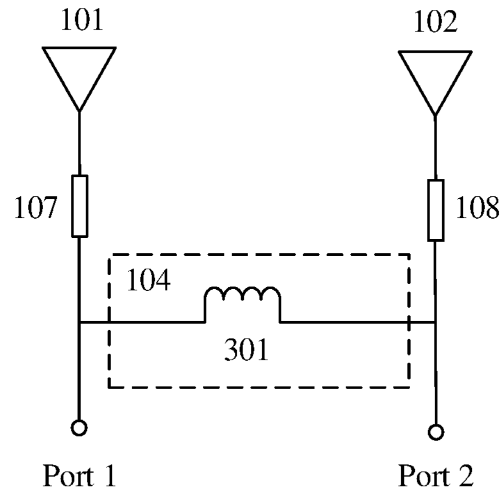

FIG. 16

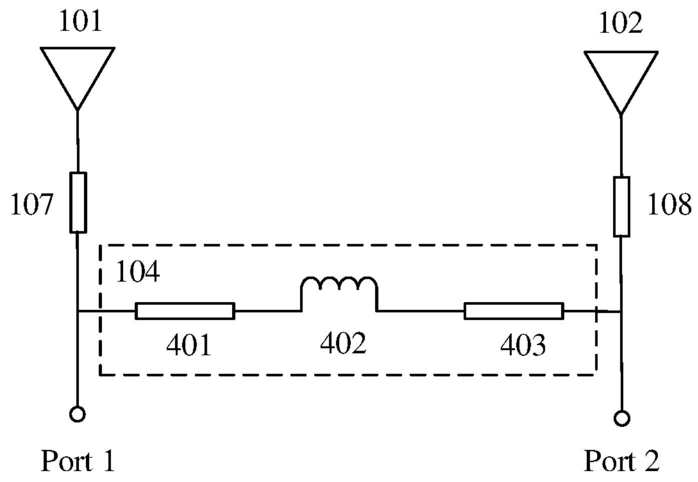
101
102
107
108
104
401
402
403
Port 1
Port 2

FIG. 17

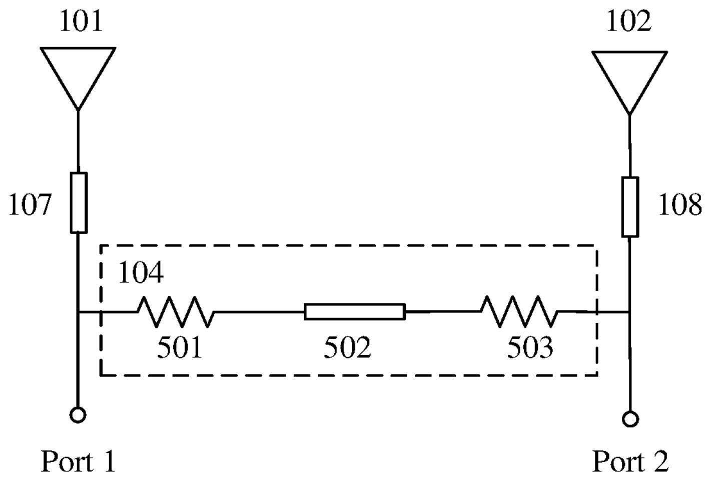
101
102
107
108
104
501
502
503
Port 1
Port 2

FIG. 18

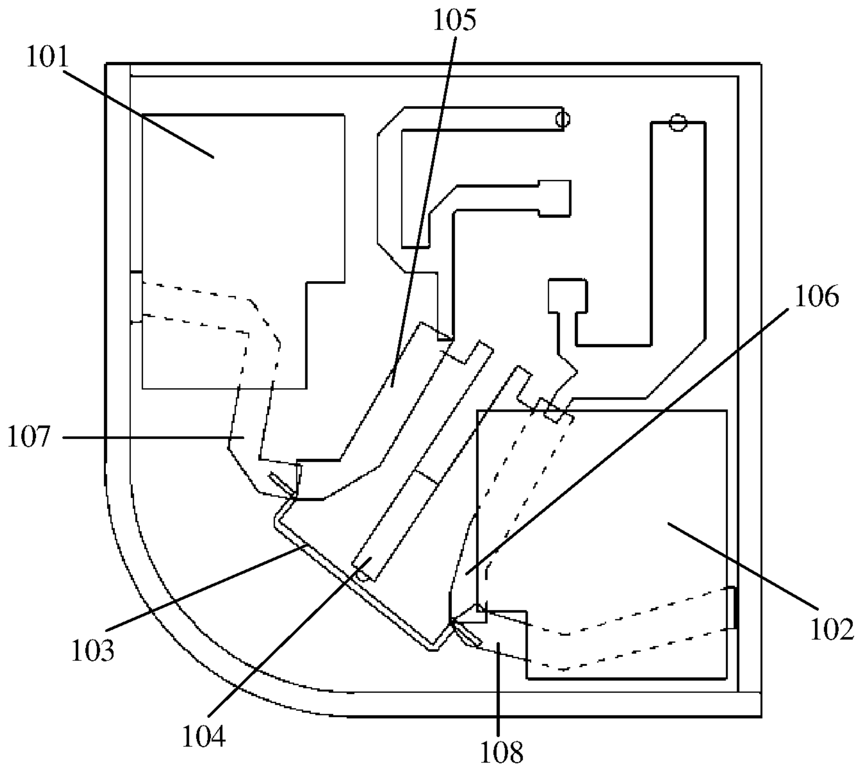

FIG. 19a

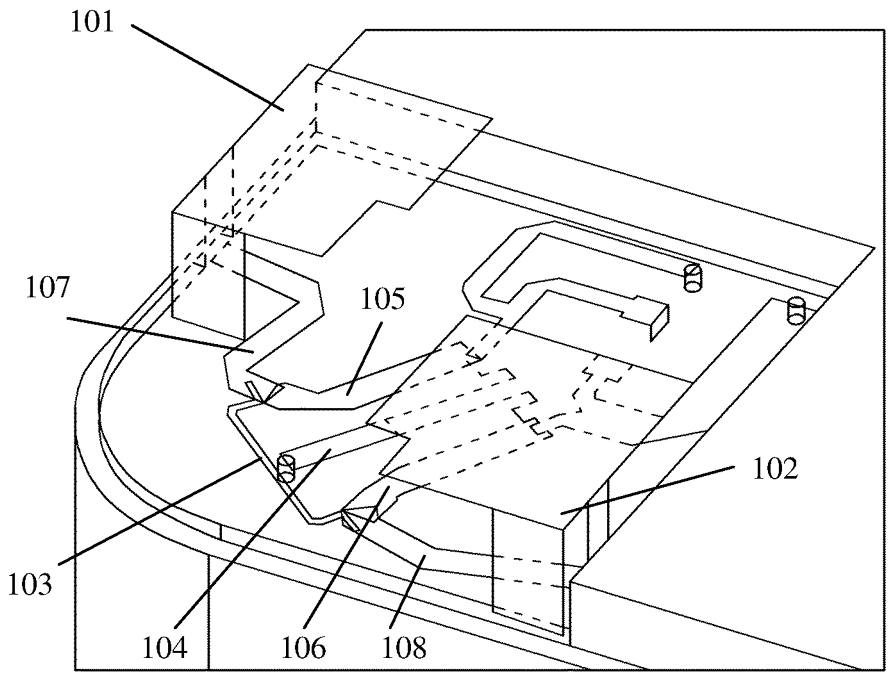

FIG. 19b

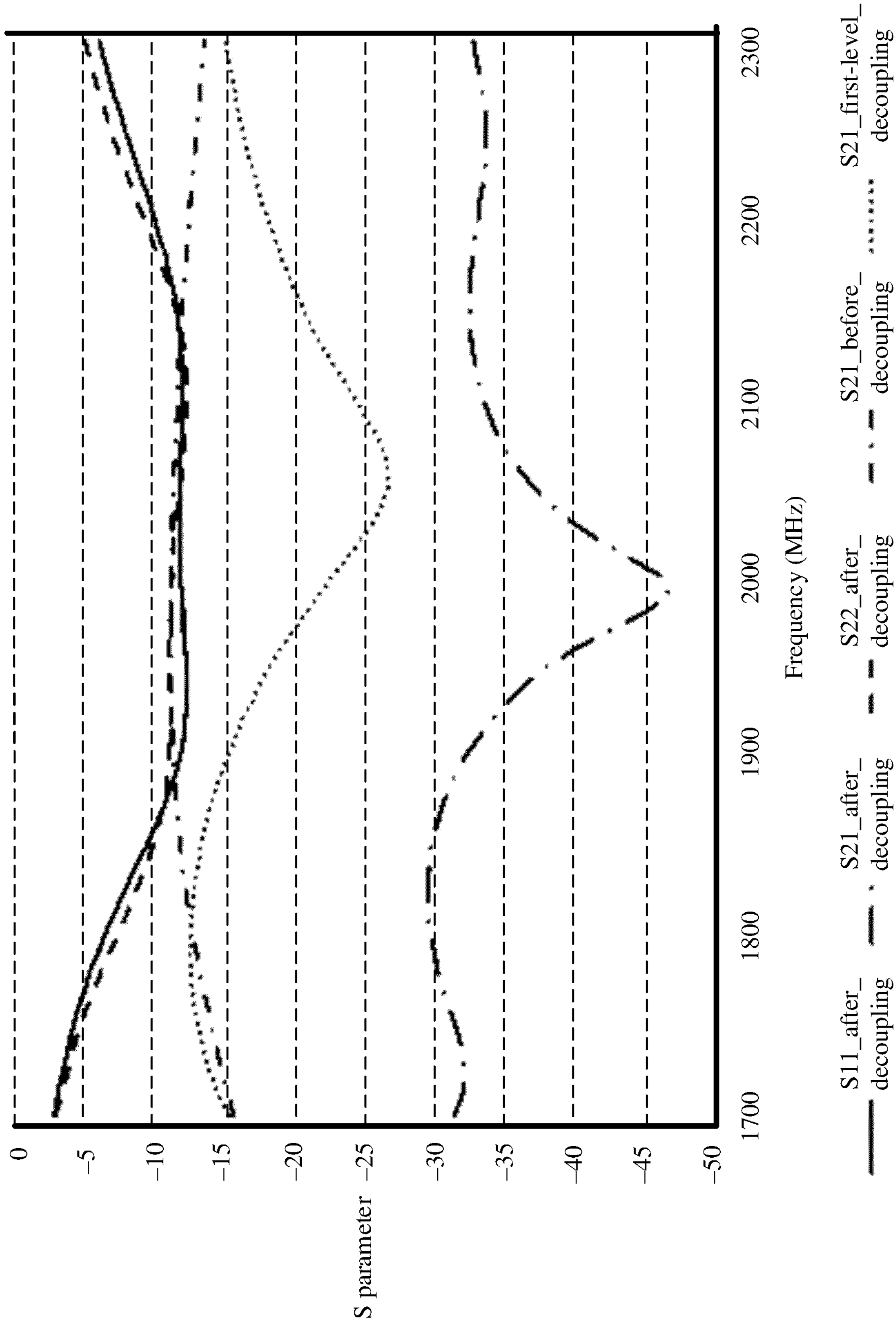
S parameter
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
−50
1700
1800
1900
2000
2100
2200
2300
Frequency (MHz)
S11_after_ decoupling
S21_after_ decoupling
S22_after_ decoupling
S21_before_ decoupling
S21_first-level_ decoupling

FIG. 20

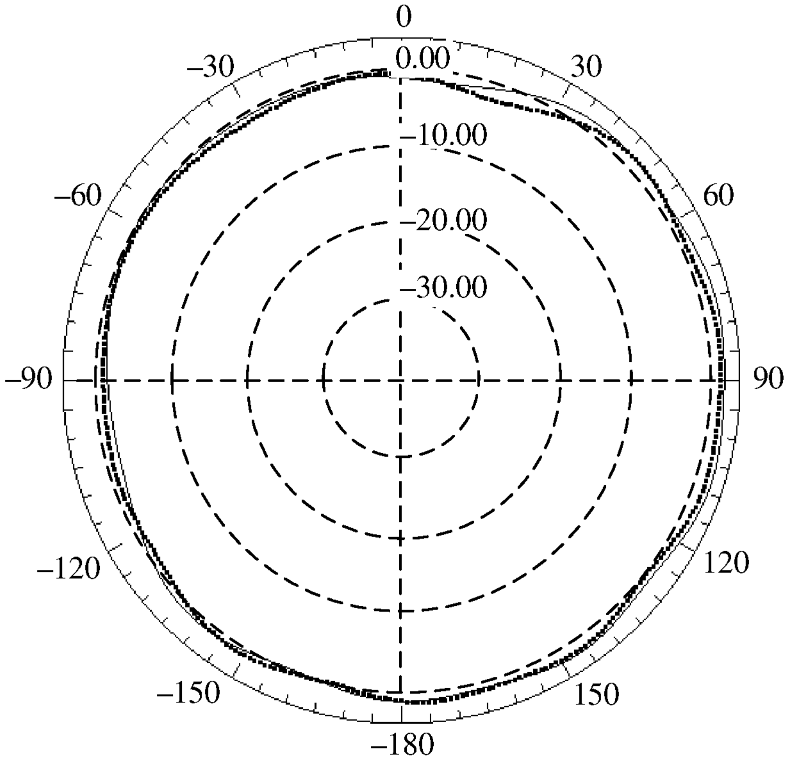
0
0.00
30
-30
-10.00
60
-60
-20.00
-30.00
-90
90
-120
120
-150
150
-180

FIG. 21

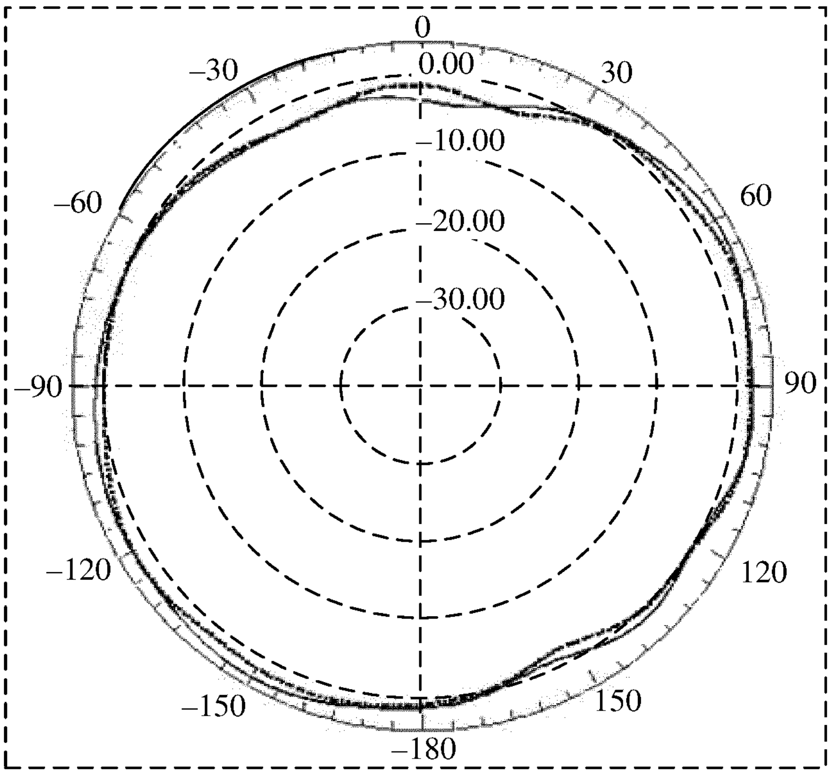
0
0.00
30
-30
-10.00
60
-60
-20.00
-30.00
-90
90
-120
120
-150
150
-180

FIG. 22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/113315

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/24(2006.01)i; H01Q 1/50(2006.01)i; H01Q 1/52(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)

CNKI, CNPAT, EPODOC, WPI: 天线, 阵列, 去耦, 解耦, 隔离, 提高, 耦合, antenna, array, decoupl+, isolat+, enhance, coupl+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 212517490 U (XIDIAN UNIVERSITY et al.) 09 February 2021 (2021-02-09) description, paragraphs [0050]-[0232], and figures 2-4	1-10
X	TW 201603391 A (THE CHINESE UNIVERSITY OF HONG KONG) 16 January 2016 (2016-01-16) description, paragraphs [0031]-[0071], and figure 5	1-10
A	CN 105103371 A (MICROSOFT TECHNOLOGY LICENSING, LLC) 25 November 2015 (2015-11-25) entire document	1-10
A	CN 105870627 A (YULONG COMPUTER TELECOMMUNICATION SCIENTIFIC (SHENZHEN) CO., LTD.) 17 August 2016 (2016-08-17) entire document	1-10
A	WO 2012071842 A1 (ZTE CORP.) 07 June 2012 (2012-06-07) entire document	1-10

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

* Special categories of cited documents:
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- "E" earlier application or patent but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "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
06 April 2022	**25 April 2022**

Name and mailing address of the ISA/CN

China National Intellectual Property Administration (ISA/CN)
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Facsimile No. **(86-10)62019451**

Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/113315

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	212517490	U	09 February 2021	CN	113659311	A	16 November 2021
TW	201603391	A	16 January 2016	US	2016006119	A1	07 January 2016
				WO	2016000531	A1	07 January 2016
CN	105103371	A	25 November 2015	EP	2929590	A1	14 October 2015
				WO	2014089530	A1	12 June 2014
				US	2014159986	A1	12 June 2014
CN	105870627	A	17 August 2016		None		
WO	2012071842	A1	07 June 2012	CN	102104185	A	22 June 2011

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