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(54) BEAM SCANNING REFLECTOR ANTENNA AND ANTENNA SYSTEM

(57) Embodiments of this application provide a beam scanning reflector antenna. The antenna includes a feed source array, a first reflector, and a second reflector, where the feed source array includes at least one feed source, the first reflector is configured to perform phase modulation on a signal, and the second reflector is configured to receive and transmit the signal. The first reflector includes a transceiver unit, configured to receive and transmit the signal; and a phase modulation unit, configured to perform phase modulation on the signal. The phase modulation unit includes a first transmission line, a second transmission line, and a liquid crystal layer, where the liquid crystal layer is deployed between the first transmission line and the second transmission line; the first transmission line and the second transmission line are used for transmission of the signal; and the liquid crystal layer is configured to control a propagation constant of the signal whose transmission is performed between the first transmission line and the second transmission line. The transceiver unit of the antenna is only configured to receive and transmit the signal, and another non-resonant element implements the phase modulation on the signal. In this way, operating bandwidth of the antenna can be increased, and a loss of the antenna can be reduced.

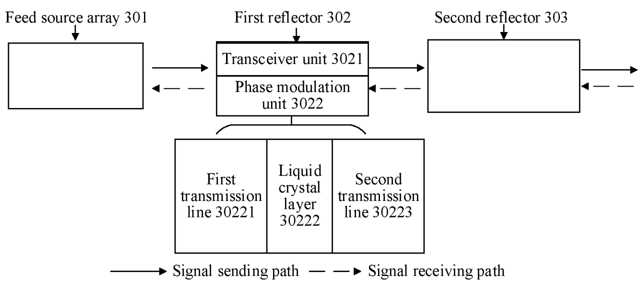

FIG. 3

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Description

[0001] This application claims priority to Chinese Patent Application No. 202210270682.2, filed with the China National Intellectual Property Administration on March 18, 2022 and entitled "BEAM SCANNING REFLECTOR ANTENNA AND ANTENNA SYSTEM", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments of this application relate to the field of antenna technologies, and more specifically, to a beam scanning reflector antenna and an antenna system.

BACKGROUND

[0003] A high-gain antenna having a beam scanning capability is usually used in millimeter-wave communication application, to overcome problems of difficulty in antenna installation and alignment and a low receive level. A phased-array high-gain antenna solution based on a conventional solid-state receive/transmit component is costly. Therefore, a beam scanning reflector antenna using a high-gain characteristic of a reflector antenna becomes a low-cost solution.

[0004] An existing high-gain reflector antenna having the beam scanning capability usually implements beam scanning in a mechanical rotation manner. However, a mechanical system solution has a slow scanning speed and low long-term reliability. In addition, the existing high-gain reflector antenna that is based on an electronic beam scanning solution and has the beam scanning capability has problems such as narrow operating bandwidth and a high loss.

[0005] Therefore, how to increase the operating bandwidth and reduce the loss of the high-gain beam scanning reflector antenna that is based on an electronic beam scanning system is a technical problem that urgently needs to be resolved currently.

SUMMARY

[0006] Embodiments of this application provide a beam scanning reflector antenna and an antenna system. A transceiver unit of the antenna is only configured to receive and transmit a signal, and another non-resonant element implements phase modulation on the signal. In this way, operating bandwidth of the antenna can be increased, and a loss of the antenna can be reduced.

[0007] According to a first aspect, a beam scanning reflector antenna is provided, including a feed source array, a first reflector, and a second reflector, where the feed source array includes at least one feed source, the first reflector is configured to perform phase modulation on a signal, and the second reflector is configured to receive and transmit the signal; the first reflector includes a transceiver unit, configured to receive and transmit the signal; and a phase modulation unit, configured to perform phase modulation on the signal; and the phase modulation unit includes a first transmission line, a second transmission line, and a liquid crystal layer, where the liquid crystal layer is deployed between the first transmission line and the second transmission line; the first transmission line and the second transmission line are used for transmission of the signal; and the liquid crystal layer is configured to control a propagation constant of the signal whose transmission is performed between the first transmission line and the second transmission line.

[0008] The transceiver unit of the antenna is only configured to receive and transmit the signal, and another non-resonant element implements the phase modulation on the signal. In this way, operating bandwidth of the antenna can be increased, and a loss of the antenna can be reduced, to ensure an air interface capacity of a communication system and a transmission distance of the signal, and further ensure communication quality of the communication system.

[0009] With reference to the first aspect, in some possible implementations of the first aspect, the first transmission line, the liquid crystal layer, and the second transmission line are arranged oppositely in a horizontal direction.

[0010] By arranging the transmission line in the horizontal direction, in this embodiment of this application, a length of the transmission line may be randomly set, and a phase modulation range may be increased by extending the length of the transmission line. In this way, phase modulation can be better performed on the signal.

[0011] With reference to the first aspect, in some possible implementations of the first aspect, the first transmission line includes at least one stub, and the second transmission line includes at least one stub.

[0012] A stub structure is arranged on the transmission line and a periodic distribution or an aperiodic distribution is formed, so that a left/right-handed metamaterial transmission line may be constructed, and an equivalent capacitance value of the transmission line may be increased. In addition, a propagation constant of the transmission line $\beta = 2\pi f\sqrt{LC}$, so that increasing the equivalent capacitance value may increase the propagation constant, and then may increase a phase shift range of the transmission line, where f is a resonant frequency, L is an inductance value of an equivalent circuit model, and C is a capacitance value of the equivalent circuit model.

[0013] With reference to the first aspect, in some possible implementations of the first aspect, when the first transmission line includes at least three stubs, the at least three stubs of the first transmission line are periodically distributed along the first transmission line.

[0014] The at least three stubs of the first transmission line are periodically distributed along the first transmission line, so that process design difficulty can be reduced in this embodiment of this application.

[0015] With reference to the first aspect, in some possible implementations of the first aspect, when the second transmission line includes at least three stubs, the at least three stubs of the second transmission line are periodically distributed along the second transmission line.

[0016] The at least three stubs of the second transmission line are periodically distributed along the second transmission line, so that process design difficulty can be reduced in this embodiment of this application.

[0017] With reference to the first aspect, in some possible implementations of the first aspect, there is a position offset between a stub of the first transmission line and a corresponding stub of the second transmission line.

[0018] The position offset is introduced; in this case, an additional adjustment parameter may be introduced, and a degree of design freedom is increased. In this embodiment of this application, an amount of the position offset between the stubs may be controlled to better perform phase modulation on the signal and impedance adjustment on the transmission line.

[0019] With reference to the first aspect, in some possible implementations of the first aspect, the transceiver unit includes an end-fire antenna.

[0020] With reference to the first aspect, in some possible implementations of the first aspect, the end-fire antenna includes at least one of the following: a dipole antenna, a V'maldi antenna, or a Yagi antenna.

[0021] With reference to the first aspect, in some possible implementations of the first aspect, the dipole antenna includes at least one of the following: two ends of the dipole antenna are connected, two ends of the dipole antenna are not connected and vertexes of the dipole antenna overlap, or two ends of the dipole antenna are not connected and vertexes of the dipole antenna do not overlap.

[0022] With reference to the first aspect, in some possible implementations of the first aspect, the phase modulation unit further includes a first substrate and a second substrate, where the first transmission line, the liquid crystal layer, and the second transmission line are deployed between the first substrate and the second substrate.

[0023] According to a second aspect, an antenna system is provided. The antenna system includes the antenna according to the first aspect and any one of the possible implementations of the first aspect, and the antenna system further includes: a phase shifter biasing module, a phase control module, an amplitude control module, and a feed source switching module, where the phase shifter biasing module is connected to the first reflector, and the phase shifter biasing module is configured to drive the first reflector to work; the feed source switching module is connected to the feed source array, and the feed source switching module is configured to switch a feed source of the feed source array; the phase shifter biasing module is connected to the phase control module, and the phase control module is configured to perform phase modulation on a signal; and the feed source switching module is connected to the amplitude control module, and the amplitude control module is configured to perform amplitude compensation on the antenna.

[0024] According to the foregoing antenna system, in this embodiment of this application, an amplitude and phase compensation mechanism is implemented by using the phase control module and the amplitude control module, so that beam scanning performance of the antenna can be enhanced. Specifically, a scanning range is increased, a scanning gain loss is reduced, a sidelobe level of a scanning pattern is reduced, and the like.

BRIEF DESCRIPTION OF DRAWINGS

[0025]

FIG. 1 is a diagram of a structure of an existing high-gain reflector antenna having an electronic beam scanning capability;

FIG. 2 is a diagram of a structure of a first reflector of the antenna shown in FIG. 1;

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

FIG. 4 is a diagram of a structure of an impedance matching unit according to an embodiment of this application;

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

FIG. 6 is a diagram of a structure of a phase modulation unit according to an embodiment of this application;

FIG. 7 is a diagram of another structure of a phase modulation unit according to an embodiment of this application;

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

FIG. 9 is a diagram of another structure of a transmission line according to an embodiment of this application;

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

FIG. 11 is a block diagram of an antenna system according to an embodiment of this application; and

FIG. 12 is a diagram of beam scanning feed source switching according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0026] The following describes technical solutions of embodiments in this application with reference to accompanying drawings. It is clear that, embodiments described in this application are merely some rather than all embodiments. All other embodiments obtained by a person of ordinary skill in the art based on content described in embodiments of this application without creative efforts fall within the protection scope of embodiments of this application.

[0027] An antenna and/or an antenna system in embodiments of this application may be used in various communication systems, for example, a global system for mobile communications (global system for mobile communications, GSM), a code division multiple access (code division multiple access, CDMA) system, a wideband code division multiple access (wideband code division multiple access, WCDMA) system, a general packet radio service (general packet radio service, GPRS), a long term evolution (long term evolution, LTE) system, an LTE frequency division duplex (frequency division duplex, FDD) system, an LTE time division duplex (time division duplex, TDD) system, a universal mobile telecommunications system (universal mobile telecommunications system, UMTS), a worldwide interoperability for microwave access (worldwide interoperability for microwave access, WiMAX) communication system, a 5th generation (5th generation, 5G) system or a new radio (new radio, NR), a future 6th generation (6th generation, 6G) system, an inter-satellite communication system, and a satellite communication system. The antenna and/or the antenna system in embodiments of this application may be further used in another communication system. Details are not described herein again.

[0028] FIG. 1 is a diagram of a structure of an existing high-gain reflector antenna having an electronic beam scanning capability. The antenna includes: a feed source 101, a first reflector 102, and a second reflector 103.

[0029] Specifically, the feed source 101 (one feed source) is configured to receive and transmit a signal. The first reflector 102 is configured to perform compensation correction on a phase of the signal that is incident or received on a surface of the first reflector 102. In other words, the first reflector 102 can be configured to perform phase modulation on the signal, and a phase modulation function of the first reflector 102 is related to a specific structure of the first reflector 102, as shown in FIG. 2. The second reflector 103 is configured to convert a spherical wave into a plane wave when working in a transmit mode, and is configured to convert a plane wave into a spherical wave when working in a receive mode. In other words, the second reflector 103 is configured to receive and transmit the signal.

[0030] A transmission path of the signal of the antenna shown in FIG. 1 is as follows:

In the receive mode, the transmission path is: the second reflector 103->the first reflector 102→the feed source 101.

[0031] In a sending mode, the transmission path is: the feed source 101→the first reflector 102→the second reflector 103.

[0032] For the specific transmission path of the signal of the antenna shown in FIG. 1, refer to directions respectively indicated by solid line arrows (receiving the signal) and dashed line arrows (sending the signal) in FIG. 1.

[0033] FIG. 2 is a diagram of a structure of the first reflector of the antenna shown in FIG. 1. The first reflector 102 includes: a resonant element 201, a first substrate 202, a liquid crystal layer 203, a second substrate 204, and a reflection layer 205.

[0034] The structure of the first reflector 102 includes the resonant element 201, the first substrate 202, the liquid crystal layer 203, the second substrate 204, and the reflection layer 205 from top to bottom sequentially.

[0035] Specifically, the resonant element 201 includes a dipole element 1, a dipole element 2, and a dipole element 3. Lengths of the dipole elements increase from left to right sequentially, and the dipole element 1, the dipole element 2, and the dipole element 3 are connected together by using a bias line. The dipole element may be understood as an antenna, for example, a dipole antenna. Materials of the first substrate 202 and the second substrate 204 are glass, the liquid crystal layer 203 is made of a liquid crystal material, and a material of the reflection layer 205 is metal, such as copper, silver, or aluminum.

[0036] The first reflector 102 can implement the phase modulation on the signal based on the resonant element 201. For example, when the resonant element 201 is enabled to be resonant at a concerned frequency point based on parameter design, in this case, an input impedance of an equivalent circuit model in which the resonant element 201 and the liquid crystal layer 203 are used as a whole is in a form of a pure resistance, where an equivalent impedance is a real number, and a reflection phase is 0°. Because a resonant frequency $f = 1/2\pi\sqrt{LC}$, (L is an inductance value of the equivalent circuit model, and C is a capacitance value of the equivalent circuit model herein), when an equivalent dielectric constant of the liquid crystal layer 203 is changed, the value C of the equivalent circuit model changes. In this case, the resonant frequency shifts, and increases or decreases. When the resonant frequency shifts, the input impedance of the equivalent circuit model at a concerned frequency position will change from the form of the pure resistance to an inductive form or a capacitive form. If the input impedance of the equivalent circuit model is capacitive, the phase of the signal varies from -180° to 0°; or if the input impedance of the equivalent circuit model is inductive, the phase of the signal varies from 0° to 180°. Therefore, the resonant element 201 can implement the phase modulation at the concerned frequency position by continuously adjusting and controlling the equivalent dielectric constant of the liquid crystal layer 203.

[0037] In addition to receiving and transmitting the signal, the resonant element 201 is further configured to perform phase modulation on the signal, so that operating bandwidth of a phase-modulated signal sent by the resonant element 201 is narrow. Consequently, operating bandwidth of the antenna is narrow, and a communication rate is affected. In addition, because a dielectric layer of the resonant element 201 is a high-loss liquid crystal material, when the resonant element 201 is resonant, most energy is lost at the liquid crystal layer, resulting in a low reflection coefficient amplitude and a large loss. Therefore, when an element of this type is used for antenna design, a loss of an entire antenna system is large. Consequently, an air interface capacity and a transmission distance of a communication system are reduced, and further, communication quality of the entire communication system is reduced.

[0038] In view of the foregoing technical problems, an embodiment of this application provides a beam scanning reflector antenna. A transceiver unit of the antenna is only configured to receive and transmit a signal, and another non-resonant element implements phase modulation on the signal. In this way, operating bandwidth of the antenna can be increased, and a loss of the antenna can be reduced, to ensure an air interface capacity of a communication system and a transmission distance of the signal, and further ensure communication quality of the communication system.

[0039] The following describes, with reference to the accompanying drawings, the beam scanning reflector antenna provided in this embodiment of this application.

[0040] FIG. 3 is a diagram of a structure of a beam scanning reflector antenna according to an embodiment of this application. The antenna includes: a feed source array 301, a first reflector 302, and a second reflector 303.

[0041] Specifically, the feed source array 301 includes at least one feed source. In other words, the feed source array 301 includes N feed sources, where N is a positive integer. The feed source of the feed source array 301 may include a horn antenna whose opening increases gradually and that is based on a metal structure, or may include a microstrip antenna based on a printing process, or may include an antenna of another type.

[0042] The first reflector 302 is configured to perform phase modulation on a signal, and the second reflector 303 is configured to receive and transmit the signal.

[0043] Specifically, a phase modulation function of the first reflector 302 is related to a structure of the first reflector 302. The first reflector 302 includes: a transceiver unit 3021 and a phase modulation unit 3022.

[0044] The transceiver unit 3021 is configured to receive and transmit the signal, and the phase modulation unit 3022 is configured to perform phase modulation on the signal. The transceiver unit 3021 is above the phase modulation unit 3022 (when the transceiver unit 3021 and the phase modulation unit 3022 are horizontally arranged, the transceiver unit 3021 is to the left or right of the phase modulation unit 3022, and a position relationship between the transceiver unit 3021 and the phase modulation unit 3022 specifically depends on an arrangement form of the first reflector 302). In other words, the phase modulation unit 3022 is configured to perform phase modulation on the signal received and transmitted by the transceiver unit 3021.

[0045] In this embodiment of this application, an example in which the transceiver unit 3021 is above the phase modulation unit 3022 is used for description. However, an implementation in which the transceiver unit 3021 is to the left or right of the phase modulation unit 3022 or another implementation is not excluded. This specifically depends on a structure form of the first reflector 302. However, regardless of whether the transceiver unit 3021 is above, to the left of, to the right of, or in another direction of the phase modulation unit 3022, the phase modulation unit 3022 is configured to perform phase modulation on the signal received and transmitted by the transceiver unit 3021.

[0046] Specifically, the phase modulation unit 3022 includes: a first transmission line 30221, a liquid crystal layer 30222, and a second transmission line 30223, where the liquid crystal layer 30222 is deployed between the first transmission line 30221 and the second transmission line 30223.

[0047] The first transmission line 30221 and the second transmission line 30223 are used for transmission of the signal, and the liquid crystal layer 30222 is configured to control a propagation constant of the signal whose transmission is performed between the first transmission line 30221 and the second transmission line 30223. Specifically, a biasing voltage of the liquid crystal layer 30222 may be controlled (this may be implemented by a liquid crystal bias network controlling a liquid crystal by using an indium tin oxide (indium tin oxide, ITO) line, and the liquid crystal bias network is usually disposed on a back of a reflection layer), to dynamically adjust a dielectric constant of the liquid crystal layer 30222, change the propagation constant of the transmission line for signal transmission, change a phase of the signal and implement phase compensation on the signal, and finally implement the phase modulation.

[0048] In a possible implementation, the transmission line includes a microstrip, a grounded coplanar waveguide, a parallel dual-wire transmission line, and the like. In this embodiment of this application, an example in which the transmission line is the parallel dual-wire transmission line is used for description, but another type of transmission line is not excluded.

[0049] In a possible implementation, the first reflector 302 further includes an impedance matching unit. The impedance matching unit may be disposed between the transceiver unit 3021 and the phase modulation unit 3022 (for example, between the transceiver unit 3021 and the first transmission line 30221, between the transceiver unit 3021 and the second transmission line 30223, or between the transceiver unit 3021, and the first transmission line 30221 and the second transmission line 30223), and is configured to implement good impedance matching between the transceiver unit 3021 and the phase modulation unit 3022. In other words, when the impedance matching between the transceiver unit 3021 and the phase modulation unit 3022 is poor, impedance matching performance between the transceiver unit 3021 and the phase modulation unit 3022 may be improved by using the impedance matching unit. A structure of the impedance matching unit may be shown in FIG. 4.

[0050] FIG. 4 is a diagram of the structure of the impedance matching unit according to an embodiment of this application. In (a) in FIG. 4, there is an impedance matching unit between the transceiver unit 3021 and the first transmission line 30221, and the impedance matching unit is a trapezoidal continuous gradient structure, and is configured to implement impedance matching between the transceiver unit 3021 and the first transmission line 30221. In (b) in FIG. 4, there is an impedance matching unit between the transceiver unit 3021 and the first transmission line 30221, and the impedance matching unit is two trapezoidal structures (a discontinuous gradient structure (which may also be understood as a discrete structure)) stacked together, and is configured to implement impedance matching between the transceiver unit 3021 and the first transmission line 30221. Impedance matching units between the transceiver unit 3021 and the second transmission line 30223, and between the transceiver unit 3021 and the first transmission line 30221 and the second transmission line 30223 are the same as the foregoing impedance matching units.

[0051] The impedance matching unit shown in FIG. 4 is merely used as an example for understanding. A specific structural style of the impedance matching unit is not limited in this embodiment of this application. The impedance matching unit shown in FIG. 4 may be integrated into the transmission line, or may be separately designed as shown in FIG. 4.

[0052] For example, the impedance matching unit may be integrated into the phase modulation unit 3022, or may be designed separately. This is not limited in this embodiment of this application. For example, the impedance matching unit includes stepped impedance matching.

[0053] The transceiver unit 3021 maintains a physical connection relationship with each of the first transmission line 30221 and the second transmission line 30223 (a non-electromagnetic space coupling relationship, where for example, electromagnetic coupling between the transceiver unit and the transmission line is implemented by using a gap).

[0054] In a possible implementation, the first reflector 302 further includes: a reflection element 3023, configured to change a transmission direction of the signal. For example, the reflection element 3023 is configured to change the transmission direction of the signal by 180°.

[0055] The reflection element 3023 is below the phase modulation unit 3022. To be specific, the structure of the first reflector 302 includes the transceiver unit 3021, the phase modulation unit 3022, and the reflection element 3023 from top to bottom sequentially. For details, refer to FIG. 5.

[0056] FIG. 5 is a diagram of another structure of a beam scanning reflector antenna according to an embodiment of this application. The first reflector 302 in the antenna further includes a reflection element 3023. For specific descriptions, refer to the foregoing descriptions. A transmission path of a signal of the antenna shown in FIG. 5 is as follows:

[0057] In a receive mode, the transmission path is: the second reflector 303→the first reflector 302->the feed source array 301.

[0058] In a sending mode, the transmission path is: the feed source array 301->the first reflector 302→the second reflector 303.

[0059] For the specific transmission path of the signal of the antenna shown in FIG. 5, refer to directions respectively indicated by solid line arrows (sending the signal) and dashed line arrows (receiving the signal) in FIG. 5.

[0060] A working principle of the antenna shown in FIG. 5 is as follows: When the signal is incident to a surface of the first reflector 302 by using the second reflector 303, the signal is first captured by the transceiver unit 3021 of the first reflector 302. Because the transceiver unit 3021 maintains the physical connection relationship with the transmission line, and can implement good impedance matching (a manner of implementing the impedance matching is the stepped impedance matching), the signal enters the transmission line (including the first transmission line 30221 and the second transmission line 30223) and arrives at the reflection element 3023 (the reflection element 3023 is configured to reflect the signal) through the transmission line. After total reflection, the signal is transmitted along the transmission line again, and then the signal is sent by the transceiver unit 3021. In a transmission process of the signal in the transmission line, the dielectric constant of the liquid crystal layer 30222 may be changed by controlling the biasing voltage of the liquid crystal layer 30222, so that the transmission line has different propagation constants, and then, a phase of the signal is changed and a phase of an incident signal is different from a phase of an emergent signal. Finally, phase modulation is implemented.

[0061] More specifically, a relationship curve between the phase of the signal and the dielectric constant of a liquid crystal may be obtained, and a needed compensation phase is matched with the dielectric constant of the liquid crystal based on the curve and the needed compensation phase, so that a needed dielectric constant distribution of the liquid crystal may be obtained. In this way, a function of performing phase modulation on the signal can be implemented based on the foregoing structure.

[0062] In a possible implementation, the first reflector 302 includes a phase-reconfigurable reflector, configured to perform compensation correction on a phase of a signal that is incident or reflected on a surface of the phase-reconfigurable reflector. In other words, the first reflector 302 is configured to perform phase modulation on the signal.

[0063] Specifically, the phase-reconfigurable reflector can implement the compensation correction on the phase of the signal that is incident or received on the surface of the phase reconfigurable reflector. The phase-reconfigurable reflector includes an electronic phase shifter, for example, a phase-shift electronic device based on a liquid crystal or a PIN diode.

[0064] For example, an aperture of the first reflector 302 may be 55 mm. For example, when the aperture of the first reflector 302 is a square, a side length of the square is 55 mm; or when the aperture of the first reflector 302 is a circle, a diameter of the circle is 55 mm.

[0065] A standard parabolic surface or a ring focus parabolic surface with a focus having a specific offset may be used for the second reflector 303. For example, the second reflector 303 may include a standard parabolic surface with an aperture of 660 mm. The second reflector 303 is made of a metal material, for example, aluminum or copper. The second reflector 303 feeds back the signal in two forms: positive feedback (which means that a focus of the second reflector is directly opposite to a focus of the first reflector) and bias feedback (which means that the focus of the second reflector is offset by a specific distance from the focus of the first reflector).

[0066] In the antenna shown in FIG. 5, the transceiver unit 3021 of the first reflector 302 is only configured to receive and transmit the signal, and is not configured to perform phase modulation on the signal. Instead, a non-resonant phase modulation unit performs compensation correction on the phase of the signal. In this way, a problem that operating bandwidth of the antenna is narrow and a loss is high in a conventional technology can be resolved.

[0067] In an implementation, the phase modulation unit 3022 is a structure of a parallel dual-wire transmission line, and the transmission line may be for transmission of a transverse electromagnetic wave (transverse electromagnetic wave, TEM). Theoretically, for a signal in this mode, there is no limitation on the operating bandwidth. Therefore, the operating bandwidth of the antenna is determined only by a size of bandwidth of the transceiver unit 3021. However, a transceiver unit and a phase modulation unit in the conventional technology are a same component, and a size of the operating bandwidth of the antenna is determined by a smaller one of bandwidth of the transceiver unit and bandwidth of the phase modulation unit. Generally, a phase modulation capability of a resonant element is effective only at a resonant position, and therefore, operating bandwidth of the resonant element is narrow. By using this solution, the operating bandwidth of the antenna can be increased, and the loss of the antenna can be reduced, to ensure an air interface capacity of a communication system and a transmission distance of the signal, and further ensure communication quality of the communication system.

[0068] FIG. 6 is a diagram of a structure of a phase modulation unit according to an embodiment of this application. In (a) in FIG. 6, the first transmission line 30221, the liquid crystal layer 30222, and the second transmission line 30223 are arranged oppositely in a vertical direction. In this way, processing is easy to implement, and processing precision is easier to control. In addition, for a structure in which opposite arrangement in the vertical direction is used, processing may be performed in a stacking manner. This can implement higher processing precision. In (b) in FIG. 6, the first transmission line 30221, the liquid crystal layer 30222, and the second transmission line 30223 are arranged in a horizontal direction. In this way, when the transmission line is arranged in the horizontal direction, a length of the transmission line may be randomly set, and a phase modulation range may be increased by extending the length of the transmission line. In this way, phase modulation can be better performed on a signal.

[0069] This embodiment of this application is described by using an example in which a direction that is the same as an incident direction (or may be an emergent direction) of the signal is the vertical direction, and a direction that is perpendicular to the incident direction (which may alternatively be the emergent direction) of the signal is the horizontal direction. However, another possible form is not limited.

[0070] In a possible implementation, the phase modulation unit 3022 further includes a first substrate 30224 and a second substrate 30225, and the first transmission line 30221, the liquid crystal layer 30222, and the second transmission line 30223 are deployed between the first substrate 30224 and the second substrate 30225. For details, refer to FIG. 7.

[0071] FIG. 7 is a diagram of another structure of a phase modulation unit according to an embodiment of this application. In (a) in FIG. 7, the first substrate 30224 is above the first transmission line 30221, and the second substrate 30225 is below the second transmission line 30223. In (b) in FIG. 7, the first substrate 30224 is to the left of the first transmission line 30221, and the second substrate 30225 is to the right of the second transmission line 30223. In other words, the liquid crystal layer 30222 and the first substrate 30224 are separated by the first transmission line 30221, and the liquid crystal layer 30222 and the second substrate 30225 are separated by the second transmission line 30223.

[0072] Materials of the first substrate 30224 and the second substrate 30225 may be glass, or may be other materials, for example, including but not limited to quartz and ceramic. The first substrate 30224 and the second substrate 30225 are mainly configured to obtain needed patterns of the transceiver unit 3021 and the transmission line (including the first transmission line 30221 and the second transmission line 30223) through processing.

[0073] In this embodiment of this application, needed metal patterns of the transceiver unit 3021, the first transmission line 30221, and the second transmission line 30223 may be obtained through processing on a lower surface of the first substrate 30224 and an upper surface of the second substrate 30225 by using an electroplating process.

[0074] In a possible implementation, the first transmission line 30221 includes at least one stub (stub), and the second transmission line 30223 includes at least one stub (stub). A stub structure is arranged on the transmission line, and a periodic distribution or an aperiodic distribution is formed (when a quantity of stubs of the transmission line is greater than three), , so that a left/right-handed metamaterial transmission line (a left-hand material is a material whose directions of electric field strength, magnetic field strength, and a wave vector comply with a left-hand rule, and a right-hand material is a material whose directions of electric field strength, magnetic field strength, and a wave vector comply with a right-hand rule) may be constructed in this embodiment of this application. In this way, an equivalent capacitance value of the transmission line is increased. In addition, a propagation constant of the transmission line $\beta = 2\pi f\sqrt{LC}$, so that increasing the equivalent capacitance value may increase the propagation constant, and then may increase a phase shift range of the transmission line, where f is a resonant frequency, L is an inductance value of an equivalent circuit model, and C is a capacitance value of the equivalent circuit model.

[0075] FIG. 8 is a diagram of a structure of a transmission line according to an embodiment of this application. In (a) in FIG. 8, the first transmission line 30221 includes at least one stub. When the first transmission line 30221 includes at least three stubs, the at least three stubs of the first transmission line 30221 may be periodically distributed or aperiodically distributed. This is not limited in this embodiment of this application. In (b) in FIG. 8, the second transmission line 30223 includes at least one stub. When the first transmission line 30221 includes at least three stubs, the at least three stubs of the second transmission line 30223 may be periodically distributed or aperiodically distributed. This is not limited in this embodiment of this application either. (c) in FIG. 8 describes a case in which there is a position offset between a stub of the first transmission line 30221 and a corresponding stub of the second transmission line 30223, and relative offset directions are y and z directions. (d) in FIG. 8 is a diagram of a transverse cross section of a position offset between the first transmission line 30221 and the second transmission line 30223. A dashed circle in (d) in FIG. 8 is for representing an overlapping region I between the first transmission line 30221 and the second transmission line 30223. The liquid crystal layer 30222 may affect the foregoing propagation constant only in the overlapping region. The position offset is introduced; in this case, an additional adjustment parameter may be introduced, and a degree of design freedom is increased. In this embodiment of this application, an amount of the position offset between the stubs may be controlled to better perform phase modulation on a signal and impedance adjustment on the transmission line.

[0076] A quantity of stubs of the first transmission line 30221 and a quantity of stubs of the second transmission line 30223 may be determined based on a needed phase shift amount φ, and the phase shift amount Φ usually needs to be greater than or equal to 360°. A specific determining procedure is as follows: First, according to a formula, the phase shift amount $\varphi = \beta L$ (β is the propagation constant of the transmission line, and a value of this physical quantity may be obtained through electromagnetic simulation; and L is a physical length of the transmission line herein), and then, the quantity of stubs may be obtained according to $L = \varphi/\beta = N * P$, where P is a stub periodicity, and N is the quantity of stubs. For example, for the specific physical length L and stub periodicity P of the transmission line, refer to (a) and (b) in FIG. 8.

[0077] For example, a width of the first transmission line 30221 and a width of the second transmission line 30223 are usually 0.01 to 0.1 wavelengths.

[0078] For example, a thickness of the first transmission line 30221 and a thickness of the second transmission line 30223 are usually 1 um to 20 um.

[0079] In a possible implementation, the stubs of the first transmission line 30221 are periodically distributed along the first transmission line 30221. That is, two adjacent stubs have a same size and a same spacing. In this way, process design difficulty can be reduced. A quantity of periodicities is determined by the needed phase shift amount. The quantity of periodicities is greater than or equal to 1. The stubs of the second transmission line 30223 may be periodically distributed or aperiodically distributed along the second transmission line 30223.

[0080] In a possible implementation, the stubs of the second transmission line 30223 are periodically distributed along the second transmission line 30223. That is, two adjacent stubs have a same size and a same spacing. In this way, process design difficulty can be reduced. A quantity of periodicities is determined by the needed phase shift amount. The quantity of periodicities is greater than or equal to 1.

[0081] In a possible implementation, the stubs of the first transmission line 30221 are aperiodically distributed along the first transmission line 30221, and the stubs of the second transmission line 30223 are aperiodically distributed along the second transmission line 30223. That is, sizes and/or spacings of the two adjacent stubs are inconsistent. In this way, a degree of design freedom can be increased, and a larger phase shift range and a lower transmission loss can be obtained.

[0082] In a possible implementation, a stub structure of the first transmission line 30221 may be the same as or different from a stub structure of the second transmission line 30223. The stub structure includes but is not limited to a square, a rectangle, a triangle, a polygon, a semicircle, a semi-ellipse, or another shape.

[0083] Optionally, there is no position offset between the stub of the first transmission line 30221 and the corresponding stub of the second transmission line 30223.

[0084] Optionally, the first transmission line 30221 and the second transmission line 30223 do not have the stub structure.

[0085] In a possible implementation, the transceiver unit 3021 in the first reflector 302 includes an end-fire antenna. The end-fire antenna includes but is not limited to a dipole antenna, a V'maldi antenna, a Yagi antenna, or the like.

[0086] An edge-fire antenna and the end-fire antenna are distinguished based on a direction of a radiation pattern. The edge-fire antenna has a maximum radiation direction perpendicular to an array straight line or an array plane, and the end-fire antenna has a maximum radiation direction along an array straight line or an array plane.

[0087] FIG. 9 is a diagram of another structure of a transmission line according to an embodiment of this application. In (a) in FIG. 9, the first transmission line 30221 includes a first transmission segment A (which may be understood as a first transmission segment), a stub A (which may be understood as a first stub), and a second transmission segment A (which may be understood as a second transmission segment). The first transmission segment A is connected to the stub A, and the second transmission segment A is not connected to the stub A. In (b) in FIG. 9, the second transmission line 30223 includes a first transmission segment B (which may be understood as a third transmission segment), a stub B (which may be understood as a second stub), and a second transmission segment B (which may be understood as a fourth transmission segment). The first transmission segment B is connected to the stub B, and the second transmission segment B is not connected to the stub B. For an arrangement relationship between the first transmission line 30221 and the second transmission line 30223, refer to (c) in FIG. 9.

[0088] Specifically, the first transmission segment A of the first transmission line 30221 and the second transmission segment B of the second transmission line 30223 are arranged opposite to each other, and the second transmission segment A of the first transmission line 30221 and the first transmission segment B of the second transmission line 30223 are arranged opposite to each other. In this structural manner, in comparison with (d) in FIG. 8, an area of an overlapping region (including an overlapping region I, an overlapping region II, and an overlapping region III) between the first transmission line 30221 and the second transmission line 30223 is increased, and therefore, phase modulation performance of the transmission line for a signal can be effectively improved. In this embodiment of this application, an effective working range of a liquid crystal can be increased, so that a range for performing phase modulation on the signal can be increased. In addition, a specific value of a width of each transmission segment is not limited in this embodiment of this application.

[0089] Dashed circles in (c) in FIG. 9 are respectively for representing the overlapping region I, the overlapping region II, and the overlapping region III between the first transmission line 30221 and the second transmission line 30223. The liquid crystal layer 30222 can affect the foregoing propagation constant only in the overlapping region between the first transmission line 30221 and the second transmission line 30223.

[0090] FIG. 8 and FIG. 9 show two structures of the transmission line. Specifically, the transmission line shown in FIG. 8 includes a first transmission segment and the stub, where the first transmission segment is connected to the stub. The transmission line shown in FIG. 9 includes the first transmission segment, the stub, and the second transmission segment, where the first transmission segment is connected to the stub, and the second transmission segment is not connected to the stub.

[0091] FIG. 10 is a diagram of a structure of a transceiver unit according to an embodiment of this application. In (a) in FIG. 10, the transceiver unit 3021 includes a dipole antenna whose two ends are connected. The two ends of the dipole antenna are connected by using a metal connection line (which may be considered as a metal short-circuit line). In this way, a bias line may be used for connecting to the metal connection line to control the dipole antenna. This simplifies design of the bias line, and increases bias efficiency. In (b) in FIG. 10, the transceiver unit 3021 includes a dipole antenna whose two ends are not connected and whose vertexes overlap each other, so that the transceiver unit has a compact structure and is easy to design and process. When the two vertexes of the dipole antenna overlap, the first transmission line 30221 and the second transmission line 30223 are physically connected to the two ends of the dipole antenna respectively. In (c) in FIG. 10, the transceiver unit 3021 includes a dipole antenna whose two ends are not connected and whose vertexes do not overlap.

[0092] The transceiver unit 3021 may be made of a high-conductivity material, for example, copper, aluminum, silver, or gold. An initial length value of the dipole antenna is usually a half wavelength of an operating frequency, a width is 0.05 to 0.1 wavelength, and a thickness is 1 um to 20 um. The two ends of the transceiver unit 3021 need to respectively maintain physical connection relationships with the first transmission line 30221 and the second transmission line 30223.

[0093] To implement impedance matching between the transceiver unit 3021, and the first transmission line 30221 and the second transmission line 30223, the foregoing impedance matching unit, for example, a stepped impedance matching unit, may be introduced between the transceiver unit 3021, and the first transmission line 30221 and the second transmission line 30223. For details, refer to the content shown in FIG. 4. Details are not described herein again.

[0094] FIG. 11 is a diagram of a structure of an antenna system according to an embodiment of this application. The antenna system includes: a feed source array 301, a first reflector 302, a second reflector 303, a feed source switching module 304, a phase shifter biasing module 305, an amplitude control module 306, and a phase control module 307.

[0095] The feed source switching module 304 is connected to the feed source array 301, and is configured to switch a feed source of the feed source array 301. The phase shifter biasing module 305 is connected to the first reflector 302, and is configured to drive the first reflector 302 to work. The phase shifter biasing module 305 is connected to the phase control module 307, and the phase control module 307 is configured to perform phase modulation on an electromagnetic wave signal. The feed source switching module 304 is connected to the amplitude control module 306, and the amplitude control module 306 is configured to perform amplitude compensation on an antenna.

[0096] As mentioned above, the feed source array 301 includes the N feed sources. When N≥2, the feed source array 301 relates to switching between a plurality of feed sources, and the switching is completed with assistance of the feed source switching module 304.

[0097] Specifically, the feed source array 301 switches a feed source working mode by using the feed source switching module 304. The feed source switching module 304 usually includes an electronic device that is based on an electronic switch, for example, an electronic switch based on a ferrite or a PIN diode. One end of the feed source switching module 304 includes a channel, and is connected to a stationary end of a single-pole multi-throw switch, and a movable end of the single-pole multi-throw switch is connected to the feed source array 301, and is configured to select a corresponding feed source. Another possible form of the feed source switching module 304 is not limited in this embodiment of this application. The phase shifter module 305 is configured to dynamically adjust a dielectric constant of a liquid crystal layer 30222 of the first reflector 302, to implement a function such as phase modulation or phase compensation on a signal.

[0098] The amplitude control module 306 and the phase control module 307 may be composition modules of a beam control module. The beam control module is a system apparatus configured to control a beam of the antenna. The beam control module 308 may be a central processing unit (central processing unit, CPU), or may be an application-specific integrated circuit (application-specific integrated circuit, ASIC), or may be configured as one or more integrated circuits, for example, one or more digital signal processors (digital signal processors, DSPs), or one or more field programmable gate arrays (field programmable gate arrays, FPGAs). The beam control module may perform, by running or executing a software program and/or a module and invoking data, a function of controlling the amplitude control module 306 and the phase control module 307.

[0099] In an antenna system shown in FIG. 11, when the antenna system works in a receive mode, a transmission path of a signal is: the second reflector 303→the first reflector 302→the feed source array 301. When the antenna system works in a transmit mode, a propagation path of an electromagnetic wave is: the feed source array 301→the first reflector 302→the second reflector 303.

[0100] The feed source array 301 is connected to a back-end radio frequency device, for example, a remote radio unit (remote radio unit, RRU) of a base station or an outdoor unit (outdoor unit, ODU) device of microwave communication. One end of the phase shifter biasing module 305 is connected to the first reflector 302, and the other end is connected to the phase control module 307. One end of the feed source switching module 304 is connected to the feed source array 301, and the other end is connected to the amplitude control module 306. The phase control module 307 and the amplitude control module 306 are submodules of the beam control module 308. The beam control module 308 may perform, by running or executing a software program and/or a module and invoking data, a function of controlling the phase control module 307 and the amplitude control module 306.

[0101] When an antenna works, it is assumed that a preset beam scanning angle of the antenna system is $[-\theta_0, \theta_0]$, and N feed sources are deployed in a plane determined by a scanning direction. Herein, it is assumed that N is an odd number and N≥1. In this case, a feed source switching rule is as follows:

- ➢ when a beam scanning range is $[-\theta_0, -\theta_0 + 2\theta_0/N]$, the system switches to a feed source numbered 1;
- ➢ when the beam scanning range is $[-\theta_0 + 2\theta_0/N, -\theta_0 + 4\theta_0/N]$, the system switches to a feed source numbered 2;
- ➢...
- ➢ when the beam scanning range is $[-4\theta_0/N, -2\theta_0/N]$, the system switches to a feed source numbered (N-1)/2;
- ➢ particularly, when the beam scanning range is $[-2\theta_0/N, 2\theta_0/N]$, the system switches to a feed source numbered (N+1)/2;
- ➢ when the beam scanning range is $[2\theta_0/N, 4\theta_0/N]$, the system switches to a feed source numbered (N+3)/2;
- ➢...
- ➢ when the beam scanning range is $[\theta_0 - 4\theta_0/N, \theta_0 - 2\theta_0/N]$, the system switches to a feed source numbered N-1; and
- ➢ when the beam scanning range is $[\theta_0 - 2\theta_0/N, \theta_0]$, the system switches to a feed source numbered N.

[0102] The foregoing feed source switching is controlled by the amplitude control module 306, and the switching rule is pre-stored in the amplitude control module 306. After the feed source switching is completed, the phase control module 307 completes the following operations:

$$\phi_1 = \phi_2 - \phi_3,$$

where

> ➢ φ_1 is a compensation phase needed by the first reflector 302;
> ➢ φ_2 is a conjugate field phase generated on the first reflector 302 by an incident plane wave at an angle corresponding to the beam scanning; and
> ➢ φ_3 is a phase distribution generated when the feed source is incident to the first reflector 302.

[0103] Values of φ_2 and φ_3 may be pre-stored in a register, and are subsequently invoked by the phase control module 307, or may be obtained by the phase control module 307 through numerical calculation. A calculation formula may be pre-stored in the phase control module 307.

[0104] FIG. 12 is a diagram of beam scanning feed source switching according to an embodiment of this application. As shown in FIG. 12, N=3, the feed sources are numbered 1, 2, and 3 from right to left, and θ_0=5°. In (a) in FIG. 10, when a scanning angle θ_1 is [-5°, -1.667°], a feed source 1 works (transmits and receives a signal). In (b) in FIG. 10, when a scanning angle θ_1 is [-1.667°, 1.667°], a feed source 2 works (transmits and receives a signal). In FIG. 10c, when a scanning angle θ_1 is [1.667°, 5°], a feed source 3 works (transmits and receives a signal).

[0105] According to the foregoing antenna system, in this embodiment of this application, an amplitude and phase compensation mechanism is implemented by using the phase control module and the amplitude control module, so that beam scanning performance of an antenna can be enhanced. Specifically, a scanning range is increased, a scanning gain loss is reduced, a sidelobe level of a scanning pattern is reduced, and the like.

[0106] A person of ordinary skill in the art may be aware that, in combination with the examples described in embodiments disclosed in this specification, units and algorithm steps may be implemented by electronic hardware or a combination of computer software and electronic hardware. Whether the functions are performed by hardware or software depends on particular applications and design constraint conditions of the technical solutions. A person skilled in the art may use different methods to implement the described functions for each particular application, but it should not be considered that the implementation goes beyond the scope of this application.

[0107] It may be clearly understood by a person skilled in the art that, for the purpose of convenient and brief description, for a detailed working process of the foregoing system, apparatus, and unit, refer to a corresponding process in the foregoing method embodiments. Details are not described herein again.

[0108] In the several embodiments provided in this application, it should be understood that the disclosed system, apparatus, and method may be implemented in other manners. For example, the described apparatus embodiment is merely an example. For example, division into the units is merely logical function division and may be other division in actual implementation. For example, a plurality of units or components may be combined or integrated into another system, or some features may be ignored or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be implemented by using some interfaces. The indirect couplings or communication connections between the apparatuses or units may be implemented in electronic, mechanical, or other forms.

[0109] The units described as separate parts may or may not be physically separate, and parts displayed as units may or may not be physical units, in other words, may be deployed in one position, or may be distributed on a plurality of network units. Some or all of the units may be selected based on actual requirements to achieve the objectives of the solutions of embodiments.

[0110] In addition, function units in embodiments of this application may be integrated into one processing unit, each of the units may exist alone physically, or two or more units are integrated into one unit.

[0111] The foregoing descriptions are merely specific implementations of this application, but are not intended to limit the protection scope of this application. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in this application shall fall within the protection scope of this application. Therefore, the protection scope of this application shall be subject to the protection scope of the claims.

Claims

1. A beam scanning reflector antenna, comprising a feed source array, a first reflector, and a second reflector, wherein:

    the feed source array comprises at least one feed source, the first reflector is configured to perform phase modulation on a signal, and the second reflector is configured to receive and transmit the signal;
    the first reflector comprises:

        a transceiver unit, configured to receive and transmit the signal; and
        a phase modulation unit, configured to perform phase modulation on the signal; and
        the phase modulation unit comprises a first transmission line, a second transmission line, and a liquid crystal layer, wherein:

the liquid crystal layer is deployed between the first transmission line and the second transmission line;

the first transmission line and the second transmission line are used for transmission of the signal; and

the liquid crystal layer is configured to control a propagation constant of the signal whose transmission is performed between the first transmission line and the second transmission line.

2. The antenna according to claim 1, wherein the first transmission line, the liquid crystal layer, and the second transmission line are arranged in a horizontal direction.

3. The antenna according to claim 2, wherein the first transmission line comprises at least one stub, and the second transmission line comprises at least one stub.

4. The antenna according to claim 3, wherein when the first transmission line comprises at least three stubs, the at least three stubs of the first transmission line are periodically distributed along the first transmission line.

5. The antenna according to claim 3 or 4, wherein when the second transmission line comprises at least three stubs, the at least three stubs of the second transmission line are periodically distributed along the second transmission line.

6. The antenna according to any one of claims 2 to 5, wherein there is a position offset between a stub of the first transmission line and a corresponding stub of the second transmission line.

7. The antenna according to any one of claims 1 to 6, wherein the transceiver unit comprises an end-fire antenna.

8. The antenna according to claim 7, wherein the end-fire antenna comprises at least one of the following: a dipole antenna, a V'maldi antenna, or a Yagi antenna.

9. The antenna according to claim 8, wherein the dipole antenna comprises at least one of the following:
two ends of the dipole antenna are connected, two ends of the dipole antenna are not connected and vertexes of the dipole antenna overlap, or two ends of the dipole antenna are not connected and vertexes of the dipole antenna do not overlap.

10. An antenna system, wherein the antenna system comprises the antenna according to any one of claims 1 to 9, and the antenna system further comprises:

a phase shifter biasing module, a phase control module, an amplitude control module, and a feed source switching module, wherein

the phase shifter biasing module is connected to the first reflector, and the phase shifter biasing module is configured to drive the first reflector to work;

the feed source switching module is connected to the feed source array, and the feed source switching module is configured to switch a feed source of the feed source array;

the phase shifter biasing module is connected to the phase control module, and the phase control module is configured to perform phase modulation on the signal; and

the feed source switching module is connected to the amplitude control module, and the amplitude control module is configured to perform amplitude compensation on the antenna.

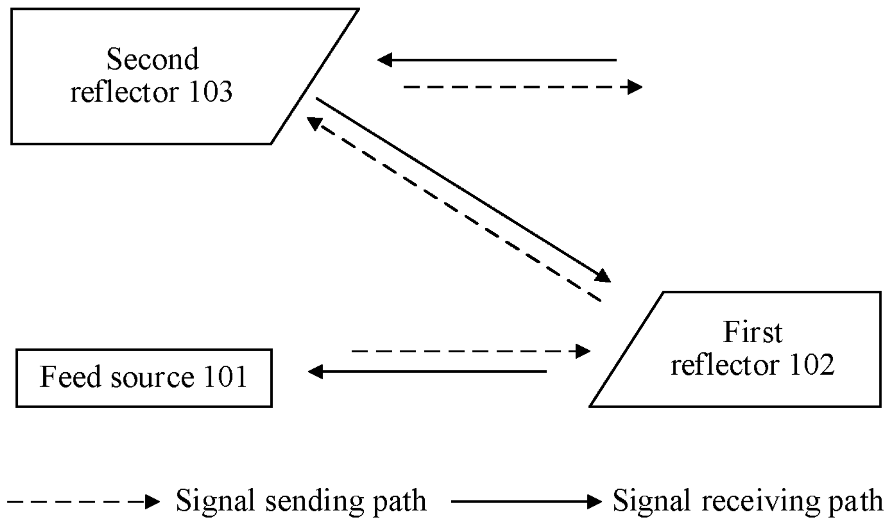

Second
reflector 103
First
reflector 102
Feed source 101
Signal sending path
Signal receiving path

FIG. 1

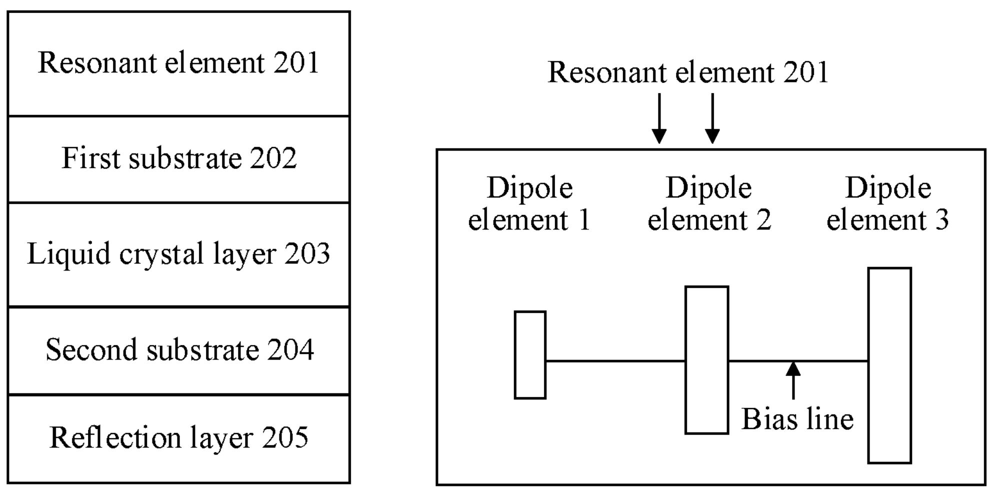

Resonant element 201
First substrate 202
Liquid crystal layer 203
Second substrate 204
Reflection layer 205
Resonant element 201
Dipole
element 1
Dipole
element 2
Dipole
element 3
Bias line

FIG. 2

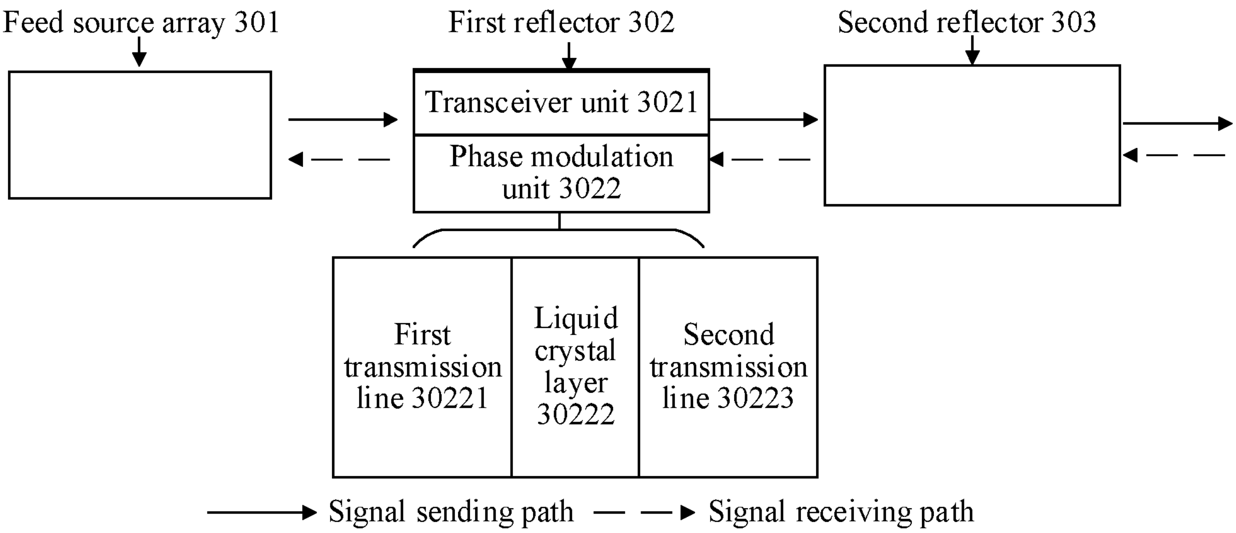


FIG. 3

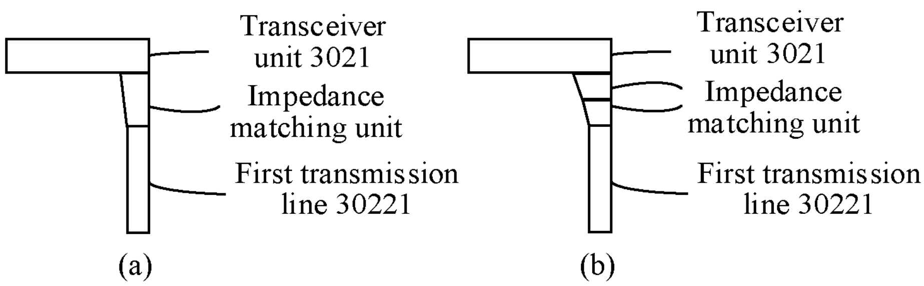


FIG. 4

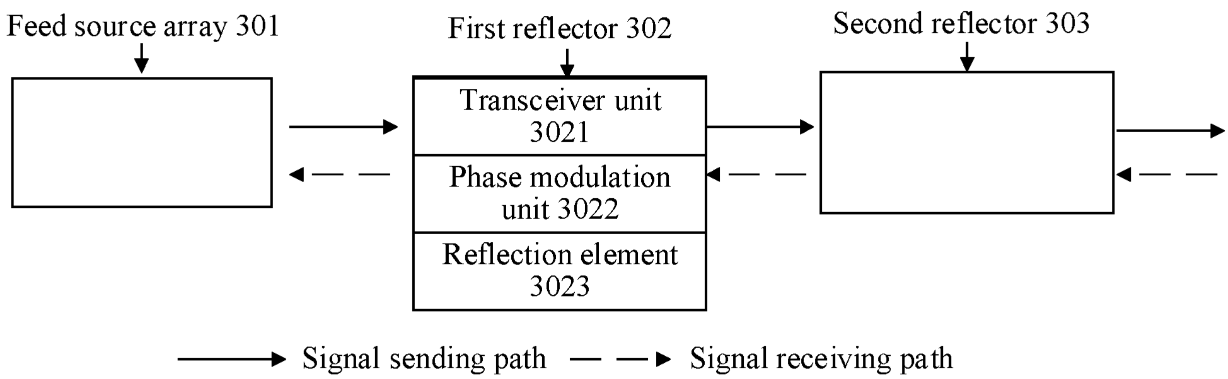
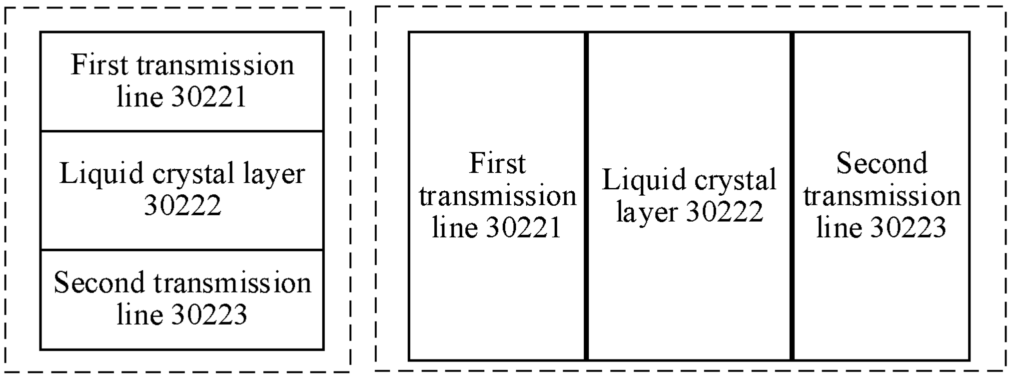
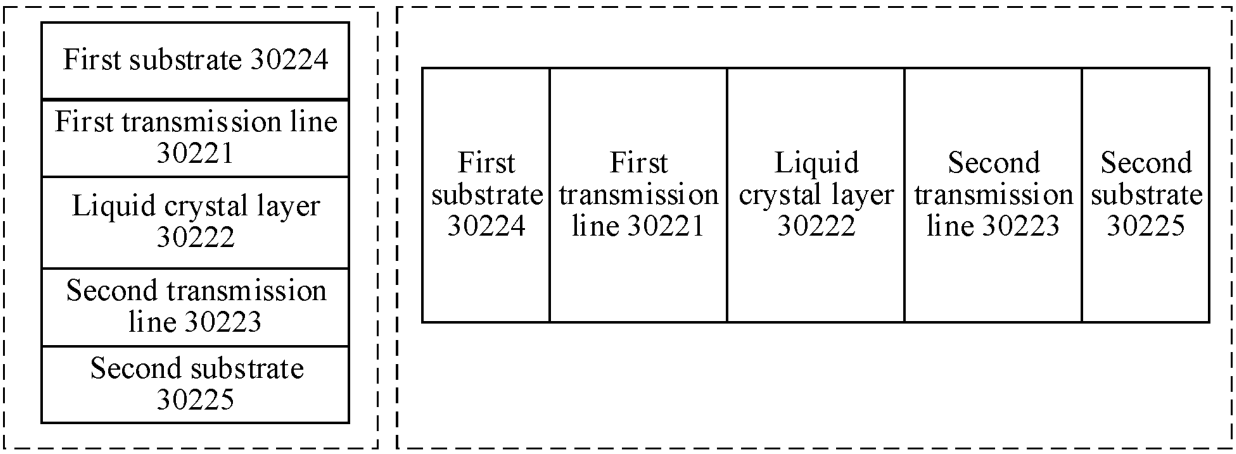


FIG. 5



(a) (b)

FIG. 6



(a) (b)

FIG. 7

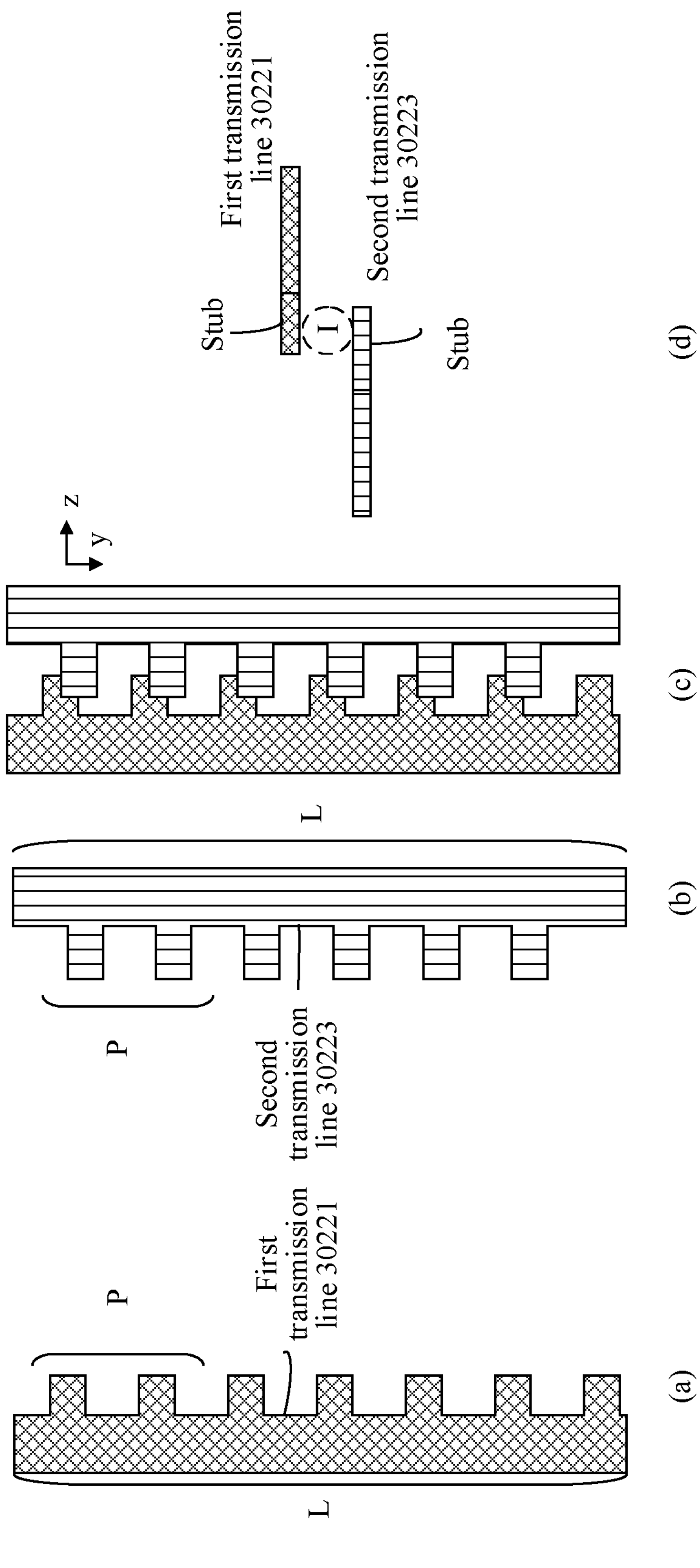

First transmission line 30221
Second transmission line 30223
Stub
I
Stub
(d)
z
y
(c)
L
(b)
P
Second transmission line 30223
First transmission line 30221
P
(a)
L

FIG. 8

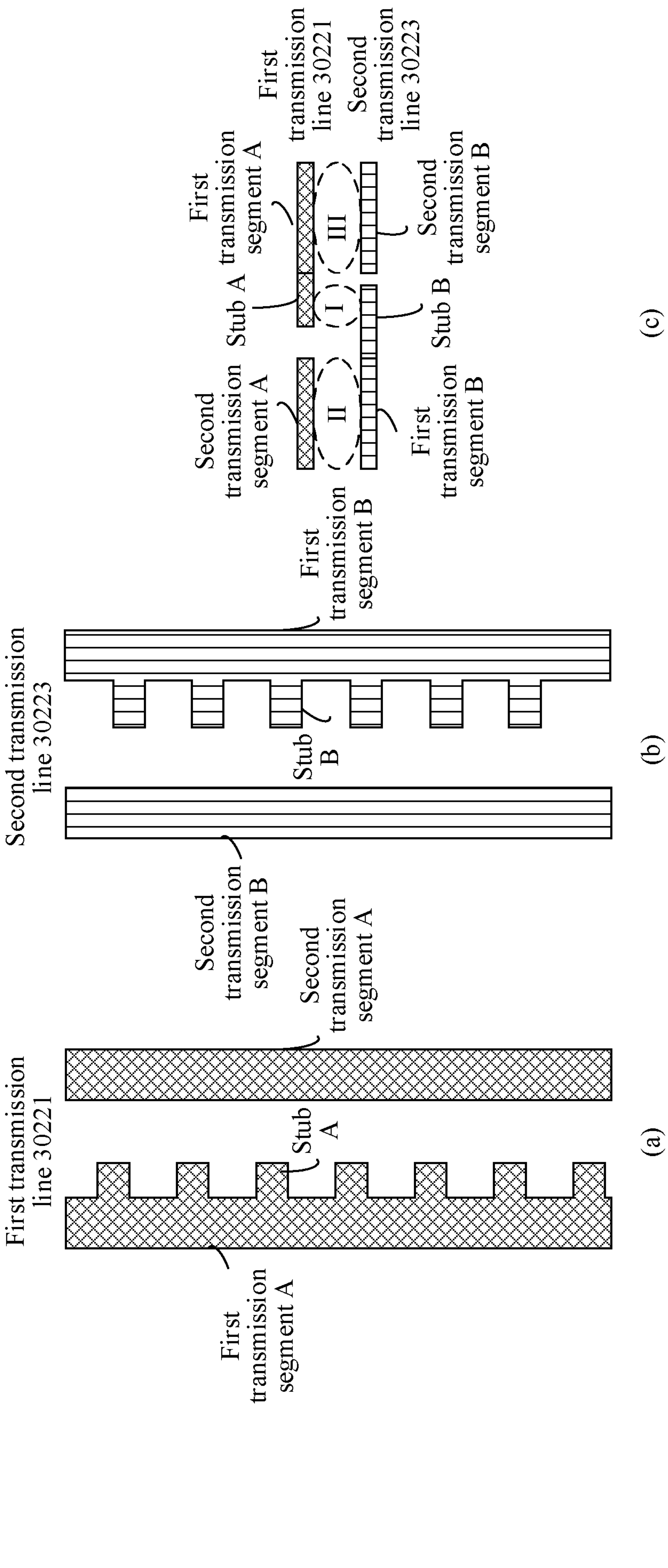

First transmission line 30221
First transmission segment A
Stub A
Second transmission segment A
(a)
Second transmission segment B
Second transmission line 30223
Stub B
First transmission segment B
(b)
Second transmission segment A
First transmission segment B
Stub A
Stub B
First transmission segment A
Second transmission segment B
First transmission line 30221
Second transmission line 30223
I
II
III
(c)

FIG. 9

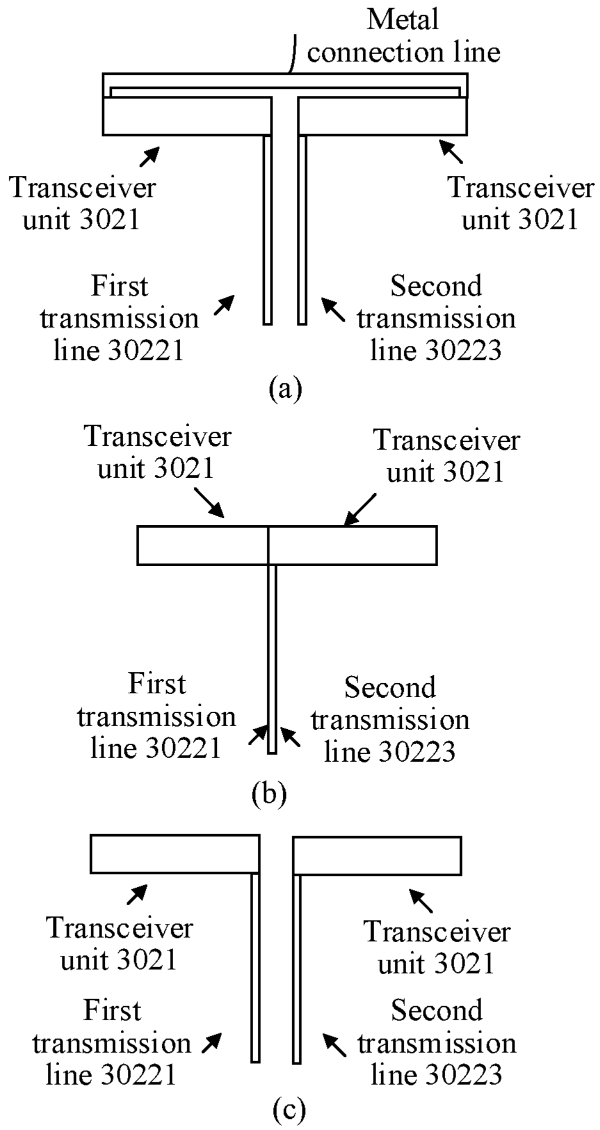

Metal
connection line
Transceiver
unit 3021
Transceiver
unit 3021
First
transmission
line 30221
Second
transmission
line 30223
(a)
Transceiver
unit 3021
Transceiver
unit 3021
First
transmission
line 30221
Second
transmission
line 30223
(b)
Transceiver
unit 3021
Transceiver
unit 3021
First
transmission
line 30221
Second
transmission
line 30223
(c)

FIG. 10

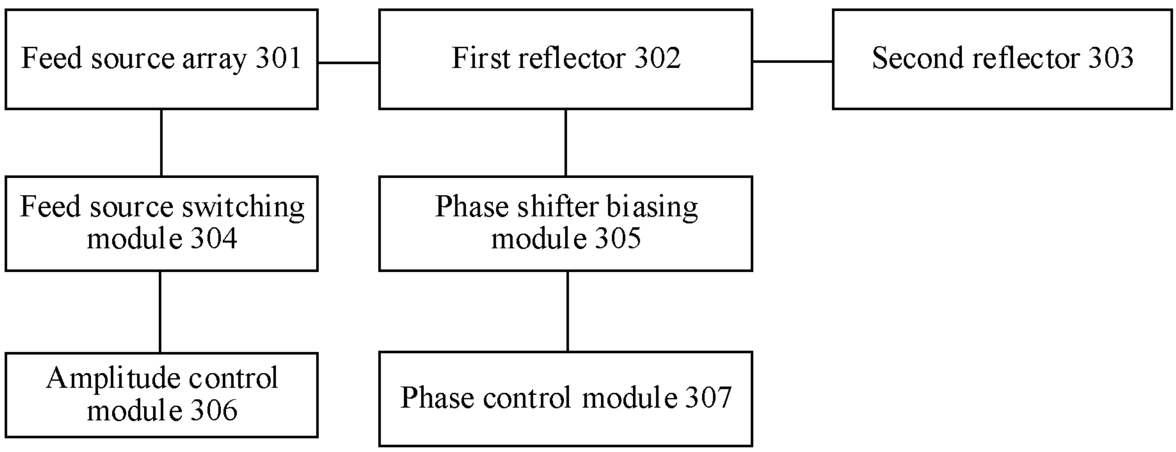

Feed source array 301
First reflector 302
Second reflector 303
Feed source switching module 304
Phase shifter biasing module 305
Amplitude control module 306
Phase control module 307

FIG. 11

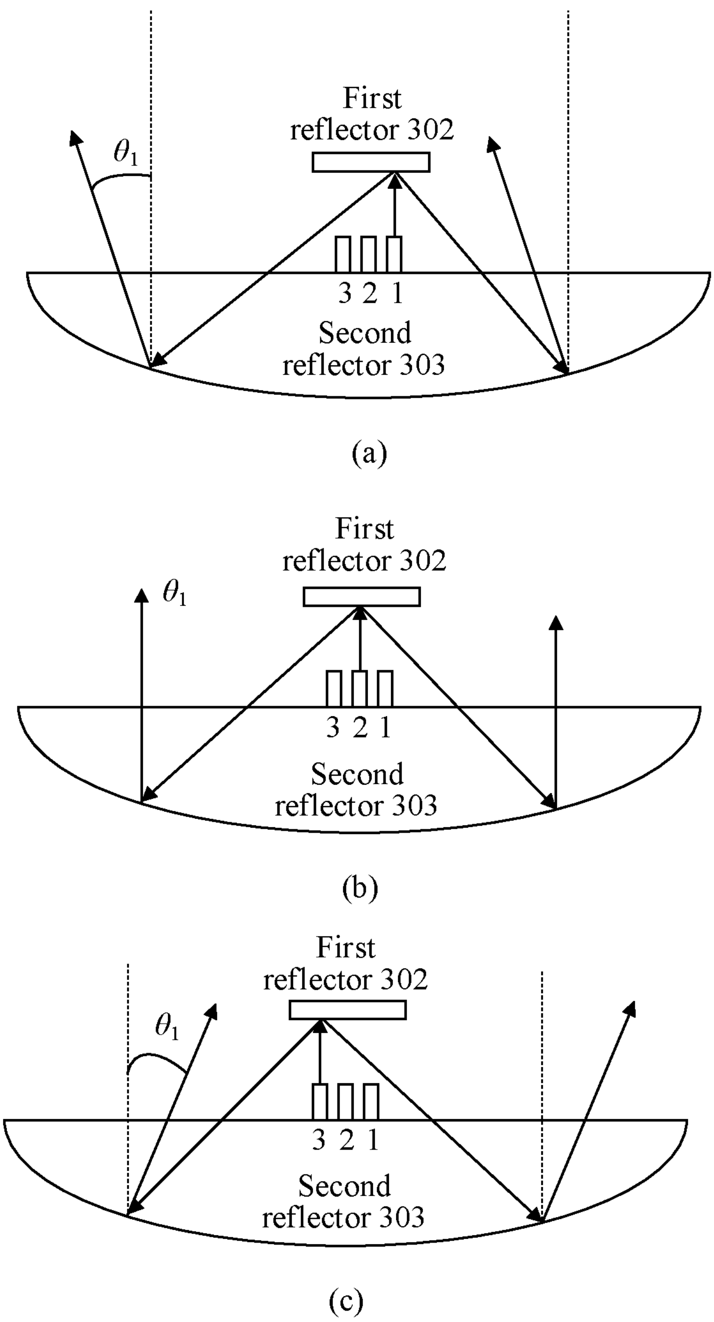

First
reflector 302
θ_1
3 2 1
Second
reflector 303
(a)
First
reflector 302
θ_1
3 2 1
Second
reflector 303
(b)
First
reflector 302
θ_1
3 2 1
Second
reflector 303
(c)

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/081891

A. CLASSIFICATION OF SUBJECT MATTER

H01Q3/26(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT, WPABSC, ENTXTC, VEN, CNKI, IEEE: 天线, 辐射, 压控, 电压, 液晶, 反射, 相位, 相移, 移相, 第二, 第2, 副, 主, 次, 微带线, 共面波导, 双线, antenna, ANT, radiate, reflect, phase, liquid crystal, voltage, second, vice, subsidiary, primary, main, microstrip, transmission line, coplanar waveguide, CPW

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 110474151 A (SHANGHAI RADIO EQUIPMENT RESEARCH INSTITUTE) 19 November 2019 (2019-11-19) description, paragraphs [0026]-[0033], and figure 1	1-10
Y	CN 112448106 A (BOE TECHNOLOGY GROUP CO., LTD. et al.) 05 March 2021 (2021-03-05) description, paragraphs [0028]-[0049], and figure 5	1-10
Y	CN 113690554 A (UNIVERSITY OF ELECTRONIC SCIENCE AND TECHNOLOGY OF CHINA) 23 November 2021 (2021-11-23) description, paragraphs [0024]-[0032], and figure 1	1-10
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Date of the actual completion of the international search	Date of mailing of the international search report
05 May 2023	**22 May 2023**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/081891

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