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(54) **WAVE-ABSORBING STRUCTURE, ANTENNA APPARATUS, DETECTION APPARATUS, AND TERMINAL DEVICE**

(57) This application provides a wave-absorbing structure, an antenna apparatus, a detection apparatus, and a terminal device. A transparent area is disposed in the wave-absorbing structure, and an antenna radiator in the antenna apparatus is correspondingly disposed in the transparent area. The wave-absorbing structure can achieve dual effects of wave-absorbing and isolation thereby effectively suppressing impact of a surface wave and space energy on directional pattern consistency of an antenna array in the antenna apparatus, and effectively improving the directional pattern consistency of the antenna array.

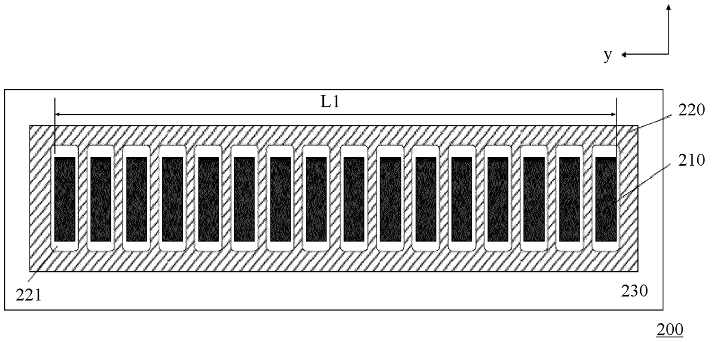


FIG. 4

Description

TECHNICAL FIELD

[0001] This application relates to the field of wireless communication, and in particular, to a wave-absorbing structure, an antenna apparatus, a detection apparatus, and a terminal device.

BACKGROUND

[0002] With continuous development of intelligent driving, demands for detection by a vehicle on a surrounding environment continue to increase. Therefore, for a vehicle-mounted radar, a requirement on performance of a millimeter-wave antenna included in the vehicle-mounted radar is increasingly high, and the performance includes directional pattern consistency of the millimeter-wave antenna. Generally, better directional pattern consistency of the millimeter-wave antenna indicates more accurate detection of the vehicle-mounted radar.

[0003] In application of a millimeter-wave vehicle radar, improvement of directional pattern consistency of a millimeter-wave antenna is of great importance. The consistency is generally improved in two aspects. On one hand, smoothness of a directional pattern of a single antenna element in the millimeter-wave antenna is improved, and jitter of the directional pattern is reduced. On the other hand, a difference between directional patterns of different antenna elements in the millimeter-wave antenna is reduced.

[0004] For a conventional printed circuit board (printed circuit board, PCB) antenna, poor directional pattern consistency is mainly caused by coupling paths such as a surface wave, space energy, and feeder spurious radiation. A key solution to improving the directional pattern consistency is to effectively suppress or guide the surface wave and reduce impact of space energy coupling and feeder radiation.

SUMMARY

[0005] This application provides a wave-absorbing structure, an antenna apparatus, a detection apparatus, and a terminal device. A transparent area is disposed in the wave-absorbing structure, and an antenna radiator in the antenna apparatus is correspondingly disposed in the transparent area. The wave-absorbing structure can achieve dual effects of wave-absorbing and isolation, thereby effectively suppressing impact of a surface wave and space energy on directional pattern consistency of an antenna array in the antenna apparatus, and effectively improving the directional pattern consistency of the antenna array.

[0006] According to a first aspect, a wave-absorbing structure is provided, and is used in an antenna apparatus, where a transparent area is disposed in the wave-absorbing structure, and an antenna radiator in the antenna apparatus is correspondingly disposed in the transparent area.

[0007] According to this embodiment of this application, the wave-absorbing structure can reduce impact of a surface wave and space energy on directional pattern consistency of an antenna array in the antenna apparatus, thereby greatly improving the directional pattern consistency of the antenna array.

[0008] With reference to the first aspect, in some possible implementations, the wave-absorbing structure includes a plurality of teeth and at least one connecting member; the plurality of teeth are connected to the at least one connecting member; and a first area is formed between two adjacent teeth in the plurality of teeth, and the first area is the transparent area.

[0009] According to this embodiment of this application, a plurality of different components in the wave-absorbing structure may be used to form the transparent area, and the transparent area is used to dispose the antenna radiator.

[0010] With reference to the first aspect, in some possible implementations, the plurality of teeth are connected to a same side of the connecting member, or the plurality of teeth are connected to different sides of the connecting member.

[0011] According to this embodiment of this application, the plurality of teeth may be connected to a same side of the connecting member, or the plurality of teeth may be connected to different sides of the connecting member. This is not limited in this application. For example, the teeth may be disposed at an edge of the connecting member, or the teeth may be disposed at any three or four edges of the connecting member.

[0012] With reference to the first aspect, in some possible implementations, the first area is a semi-closed area.

[0013] With reference to the first aspect, in some possible implementations, the wave-absorbing structure is of a comb-shaped structure.

[0014] With reference to the first aspect, in some possible implementations, the first area is a semi-closed area.

[0015] With reference to the first aspect, in some possible implementations, the wave-absorbing structure is of a fence-shaped structure. With reference to the first aspect, in some possible implementations, a second area is disposed in the at least one connecting member, and the second area is the transparent area.

[0016] With reference to the first aspect, in some possible implementations, the second area is a closed area.

[0017] With reference to the first aspect, in some possible implementations, the connecting member is of a fence-shaped structure.

[0018] According to this embodiment of this application, the wave-absorbing structure may include the transparent area formed by the semi-closed first area and the transparent area formed by the closed second area. Alternatively, the wave-absorbing structure may include only the transparent area formed by the semi-closed or closed first area. Alternatively, the wave-absorbing structure may include only the transparent area formed by the closed second area. The adjustment may be performed according to an actual design or a production requirement. This is not limited in this application.

[0019] With reference to the first aspect, in some possible implementations, distances between two adjacent teeth in the plurality of teeth are the same or different.

[0020] According to this embodiment of this application, the distances between the adjacent teeth in the wave-absorbing structure may be different, and may be determined by the antenna radiator disposed in the transparent area formed between the adjacent teeth.

[0021] With reference to the first aspect, in some possible implementations, different teeth are in a same shape or different shapes.

[0022] According to this embodiment of this application, the teeth in the wave-absorbing structure may be in any shape, may not necessarily be a rectangle in the foregoing embodiment, and may be in another shape, for example, a wave shape, a diamond shape, or a trapezoid shape. Alternatively, the teeth in different shapes may be disposed in a same wave-absorbing structure.

[0023] With reference to the first aspect, in some possible implementations, that different teeth are in a same shape or different shapes includes: different teeth have a same width, length, or thickness; or different teeth have different widths, lengths, or thicknesses.

[0024] According to this embodiment of this application, the widths, the lengths, or the thicknesses of the teeth in the wave-absorbing structure may be different, and may be determined by the antenna radiator disposed in the transparent area formed between the adjacent teeth. When the teeth of the wave-absorbing structure have different thicknesses, a thicker tooth may be used as a protruding portion to support a radome, to improve stability of the entire antenna apparatus.

[0025] According to a second aspect, an antenna apparatus is provided, including the wave-absorbing structure and the antenna radiator according to any one of the first aspects.

[0026] According to this embodiment of this application, a generated surface wave can be absorbed, to avoid radiation of the surface wave to the outside. Therefore, impact of the surface wave on directional pattern consistency of an antenna array formed by a plurality of antenna radiators can be effectively reduced. In addition, because the antenna radiator is disposed in the transparent area corresponding to the antenna radiator, the antenna radiator disposed in the corresponding transparent area can avoid space energy generated through radiation when the antenna radiator is coupled to another antenna radiator, and can reduce impact of space energy of a clutter generated when the antenna radiator is radiated in the corresponding transparent area on another antenna radiator, thereby effectively reducing the impact of the space energy on the directional pattern consistency of the antenna array.

[0027] With reference to the second aspect, in some possible implementations, the wave-absorbing structure has a plurality of transparent areas, and an antenna radiator is disposed in each of the plurality of transparent areas.

[0028] According to this embodiment of this application, the transparent area may be in a one-to-one correspondence with the antenna radiator. To be specific, a single antenna radiator is disposed in each transparent area, so that the impact of the space energy on the antenna radiator can be further reduced, and the directional pattern consistency of the antenna array can be improved.

[0029] With reference to the second aspect, in some possible implementations, the wave-absorbing structure is of a comb-shaped structure, and adjacent teeth of the comb-shaped structure form a transparent area.

[0030] With reference to the second aspect, in some possible implementations, the teeth of the wave-absorbing structure and a plane on which the antenna radiator is located are at a first angle, and the first angle is an acute angle. Descriptions of the wave-absorbing structure, descriptions of the teeth of the wave-absorbing structure, and descriptions of the transparent area are the same as those in the first aspect. Details are not described herein again.

[0031] According to this embodiment of this application, the teeth and the plane on which the antenna radiator is located are at the first angle α, where α may be an acute angle, so that a clutter can be continuously reflected in the transparent area and absorbed by the wave-absorbing structure, and impact of the clutter on another antenna radiator in the antenna array is suppressed, thereby deteriorating the directional pattern consistency of the antenna array. With reference to the second aspect, in some possible implementations, the first angle is less than or equal to a quarter of a field of view FOV of the antenna radiator corresponding to the transparent area.

[0032] According to this embodiment of this application, within the angle, a highest point of the teeth in the wave-absorbing structures on two sides of the antenna radiator may avoid the field of view of the antenna radiator, so that all electrical signals generated by the antenna radiator can be radiated within the angle.

[0033] With reference to the second aspect, in some possible implementations, an average width of the teeth of the wave-absorbing structure is a quarter of a first wavelength, and the first wavelength is a wavelength corresponding to an operating frequency band of the antenna apparatus.

[0034] According to this embodiment of this application, the average width of the teeth is a quarter of the first wavelength. This may increase reflected energy intensity of the electrical signal on the surface of the teeth, and suppress the electrical signal from escaping outside the transparent area, thereby reducing interference caused by a clutter generated by the antenna radiator disposed in the transparent area to the antenna radiator disposed in an adjacent transparent area.

[0035] With reference to the second aspect, in some possible implementations, a cross section of the teeth of the wave-absorbing structure is a trapezoid.

[0036] According to this embodiment of this application, the cross section of the teeth may be a trapezoid. Alternatively, a shape of the cross section of the teeth may be adjusted according to an actual design or a production requirement. For example, the cross section of the teeth may be in a triangle or another type.

[0037] With reference to the second aspect, in some possible implementations, the wave-absorbing structure has a plurality of transparent areas, and the plurality of transparent areas are linearly arranged.

[0038] According to this embodiment of this application, the plurality of transparent areas or the plurality of antenna radiators may be arranged in an array, for example, may be linearly arranged (in a straight line, a curve, or a broken line), or may be arranged in a 3x3 array. This is not limited in this application, and may be adjusted according to an actual design.

[0039] With reference to the second aspect, in some possible implementations, the antenna apparatus further includes a dielectric plate, and the antenna radiator is disposed on a surface of the dielectric plate.

[0040] According to this embodiment of this application, the dielectric plate may be configured to dispose the antenna radiator, and provide support for the antenna radiator.

[0041] With reference to the second aspect, in some possible implementations, a metal feeder is disposed on the dielectric plate; and a slot is disposed at a position that is of the wave-absorbing structure and that corresponds to the metal feeder. A shape of the slot may be flexibly designed according to a position of the feeder, and the shape of the slot is not limited in this application.

[0042] According to this embodiment of this application, the slot may be disposed in correspondence with the metal feeder, and is configured to shield radiation generated by the metal feeder, reduce impact on the antenna radiator, and further improve the directional pattern consistency of the antenna array. With reference to the second aspect, in some possible implementations, the antenna apparatus further includes a radome, and the wave-absorbing structure is disposed in space enclosed by the dielectric plate and the radome.

[0043] According to this embodiment of this application, the radome may be configured to protect a component disposed in the radome, to improve overall stability of the antenna apparatus.

[0044] With reference to the second aspect, in some possible implementations, a protruding portion is disposed in the wave-absorbing structure, and the protruding portion presses against the radome. According to this embodiment of this application, the protruding portion is disposed in the wave-absorbing structure, and the protruding portion may press against the radome, to support the radome.

[0045] With reference to the second aspect, in some possible implementations, the protruding portion is disposed at an edge of the wave-absorbing structure.

[0046] According to this embodiment of this application, when the antenna radiator is disposed in a central area of the dielectric plate, the protruding portion may be disposed at the edge of the wave-absorbing structure.

[0047] With reference to the second aspect, in some possible implementations, the wave-absorbing structure is fastened to the dielectric plate by using a rivet, an adhesive, or a screw.

[0048] According to this embodiment of this application, the wave-absorbing structure may be fastened to the dielectric plate by using the rivet, the adhesive, or the screw, to ensure that the wave-absorbing structure is closely connected to the dielectric plate, thereby reducing radiation of the surface wave to the outside, and effectively reducing the impact of the surface wave on the directional pattern consistency of the antenna array.

[0049] According to a third aspect, a detection apparatus is provided. The detection apparatus includes a detection device and the antenna apparatus according to any one of the second aspect.

[0050] According to a fourth aspect, a terminal device is provided, including the detection apparatus according to the third aspect. Further, the terminal device may be an intelligent transportation device (a vehicle or an unmanned aerial vehicle), a smart home device, a smart manufacturing device, surveying equipment, a robot, or the like. The intelligent transportation device may be, for example, an automated guided vehicle (autonomous guided vehicle, AGV) or an unmanned transport vehicle.

BRIEF DESCRIPTION OF DRAWINGS

[0051]

FIG. 1 is a function block diagram of a vehicle used in an embodiment of this application;
FIG. 2 shows an antenna structure for improving directional pattern consistency;
FIG. 3 is a directional pattern of the antenna structure shown in FIG. 2;
FIG. 4 is a top view of an antenna apparatus 200 according to an embodiment of this application;
FIG. 5 is a side view of an antenna apparatus 200 according to an embodiment of this application;
FIG. 6 is a schematic diagram of a wave-absorbing structure 220 according to an embodiment of this application;
FIG. 7 is a schematic diagram of another wave-absorbing structure 220 according to an embodiment of this application;
FIG. 8 is a schematic diagram of different wave-absorbing structures according to an embodiment of this application;
FIG. 9 is a schematic diagram of a cross section of the antenna structure shown in FIG. 4 and a schematic diagram of a wave-absorbing structure;
FIG. 10 is a schematic diagram of a cross section of the antenna structure shown in FIG. 4 along an x direction;
FIG. 11 is a schematic diagram of reflection of a clutter on a surface that is in a transparent area and that is close to an antenna radiator according to an embodiment of this application;
FIG. 12 is a schematic diagram of strong reflection according to an embodiment of this application;
FIG. 13 is a schematic diagram of strong transmission according to an embodiment of this application;
FIG. 14 is a schematic diagram of a cross section of teeth according to an embodiment of this application;
FIG. 15 is a schematic diagram of another antenna apparatus 200 according to an embodiment of this application;
FIG. 16 is a schematic diagram of another antenna apparatus 200 according to an embodiment of this application;
FIG. 17 is a schematic diagram of an antenna apparatus according to an embodiment of this application;
FIG. 18 is a directional pattern of an antenna apparatus according to an embodiment of this application;
FIG. 19 shows a horizontal angle measurement error of an antenna apparatus according to an embodiment of this application;
FIG. 20 is a schematic structural diagram of still another antenna apparatus 300 according to an embodiment of this application;
FIG. 21 is a schematic diagram of different wave-absorbing structures according to an embodiment of this application;
FIG. 22 is a schematic structural diagram of a semi-closed transparent area according to an embodiment of this application;
FIG. 23 is a schematic diagram of an antenna apparatus in a control group;
FIG. 24 is a schematic diagram of amplitude consistency of an antenna apparatus according to an embodiment of this application;
FIG. 25 is a schematic diagram of phase consistency of an antenna apparatus according to an embodiment of this application;
FIG. 26 is a schematic structural diagram of a closed transparent area according to an embodiment of this application;
FIG. 27 is a schematic diagram of an antenna apparatus in a control group;
FIG. 28 is a schematic diagram of energy distribution of an antenna apparatus according to an embodiment of this application; and
FIG. 29 is a directional pattern of an antenna apparatus according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0052] The following describes technical solutions of this application with reference to accompanying drawings.

[0053] FIG. 1 is a functional block diagram of a vehicle 100 according to an embodiment of this application. In an embodiment, the vehicle 100 is configured to be in a fully or partially autonomous driving mode. For example, the vehicle 100 in an autonomous driving mode may control the vehicle 100, and may determine current states of the vehicle and a surrounding environment of the vehicle through a manual operation, determine a possible behavior of at least one another vehicle in the surrounding environment, determine a confidence level corresponding to a possibility that the another vehicle performs the possible behavior, and control the vehicle 100 based on determined information. When the vehicle 100 is in the autonomous driving mode, the vehicle 100 may be set to operate without interacting with a person.

[0054] The vehicle 100 may include various subsystems, for example, a travel system 102, a sensor system 104, a control system 106, one or more interface devices 108, a power supply 110, a computer system 112, and a user interface 116. In an embodiment, the vehicle 100 may include more or fewer subsystems, and each subsystem may include a plurality of components. In addition, each subsystem and component of the vehicle 100 may be interconnected in a wired or wireless manner.

[0055] The travel system 102 may include a component that provides power for the vehicle 100 to move. In an embodiment, the travel system 102 may include an engine 118, an energy source 119, a transmission apparatus 120, and wheels/tires 121. The engine 118 may be a combination of an internal combustion engine, a motor, an air compression engine, or another type of engine, for example, a hybrid engine including a gasoline engine and a motor, or a hybrid engine including an internal combustion engine and an air compression engine. The engine 118 converts the energy source 119 into mechanical energy.

[0056] The sensor system 104 may include several sensors that can sense information about the surrounding environment of the vehicle 100. For example, the sensor system 104 may include a positioning system 122 (where the positioning system may be a GPS system, a BeiDou system, or another positioning system), an inertial measurement unit (inertial measurement unit, IMU) 124, a radar 126, a laser rangefinder 128, and a camera 130. The sensor system 104 may further include a sensor (for example, a vehicle-mounted air quality monitor, a fuel gauge, or an engine oil thermometer) of an internal system of the monitored vehicle 100. Sensor data from one or more of these sensors can be used to detect an object and corresponding features (a position, a shape, a direction, a speed, and the like) of the object. Such detection and recognition are key functions of a safe operation of the vehicle 100 in the autonomous driving mode.

[0057] The control system 106 controls operations of the vehicle 100 and components of the vehicle 100. The control system 106 may include various components, including a steering system 132, a throttle 134, a braking unit 136, a sensor fusion algorithm 138, a computer vision system 140, a route control system 142, and an obstacle avoidance system 144.

[0058] The vehicle 100 interacts with an external sensor, another vehicle, another computer system, or a user through the interface device 108. The interface device 108 may include a wireless communication system 146, a vehicle-mounted computer 148, a microphone 150, and/or a speaker 152.

[0059] In some embodiments, the interface device 108 provides a means for a user of the vehicle 100 to interact with the user interface 116. For example, the vehicle-mounted computer 148 may provide information for the user of the vehicle 100. The user interface 116 may further operate the vehicle-mounted computer 148 to receive an input from the user. The vehicle-mounted computer 148 may perform an operation through a touchscreen. In another case, the interface device 108 may provide a means for the vehicle 100 to communicate with another device located in the vehicle. For example, the microphone 150 may receive audio (for example, a voice command or another audio input) from the user of the vehicle 100. Similarly, the speaker 152 may output the audio to the user of the vehicle 100.

[0060] The wireless communication system 146 may be in wireless communication with one or more devices directly or through a communication network. For example, the wireless communication system 146 implements wireless communication through a vehicle-mounted antenna, for example, by using 3G cellular communication, a global system for mobile communications (global system for mobile communications, GSM) technology, a wideband code division multiple access (wideband code division multiple access, WCDMA) communication technology, 4G cellular communication (for example, a long term evolution (long term evolution, LTE) communication technology), or 5G cellular communication. The wireless communication system 146 may communicate with a wireless local area network (wireless local area network, WLAN) through Wi-Fi by using the vehicle-mounted antenna. In some embodiments, the wireless communication system 146 may communicate directly with a device through an infrared link or by using Bluetooth or ZigBee (ZigBee). Other wireless protocols, for example, various vehicle communication systems, such as the wireless communication system 146, may include one or more dedicated short-range communications (dedicated short-range communications, DSRC) devices, and these devices may implement public and/or private data communication between a vehicle and/or a roadside station.

[0061] Some or all of functions of the vehicle 100 are controlled by the computer system 112. The computer system 112 may include at least one processor 113. The processor 113 executes instructions 115 stored in a non-transient computer-readable medium such as a data storage apparatus 114. The computer system 112 may alternatively be a plurality of computing devices that control an individual component or a subsystem of the vehicle 100 in a distributed manner.

[0062] The user interface 116 is used to provide information for or receive information from the user of the vehicle 100. In an embodiment, the user interface 116 may include one or more input/output devices within a set of interface devices 108, such as the wireless communication system 146, the vehicle-mounted computer 148, the microphone 150, and the speaker 152.

[0063] In an embodiment, one or more of the foregoing components may be installed separately from or associated with the vehicle 100. For example, the data storage apparatus 114 may be partially or completely separated from the vehicle 1100. The foregoing components may be communicatively coupled together in a wired and/or wireless manner.

[0064] In an embodiment, the foregoing component is merely an example. In an actual application, components in the foregoing modules may be added or removed according to an actual requirement. FIG. 1 should not be construed as a limitation on embodiments of the present invention.

[0065] The vehicle 100 may be a car, a truck, a motorcycle, a bus, a boat, an airplane, a helicopter, a lawn mower, a recreational vehicle, a playground vehicle, a construction device, a trolley, a golf cart, a train, a handcart, or the like. This is not specifically limited in this embodiment of this application. With continuous development of intelligent driving, demands for detection by a vehicle on a surrounding environment continue to increase. Therefore, for a vehicle-mounted radar, a requirement on performance of a millimeter-wave antenna included in the vehicle-mounted radar is increasingly high, and the performance includes directional pattern consistency of the millimeter-wave antenna. Generally, better directional pattern consistency of the millimeter-wave antenna indicates more accurate detection of the vehicle-mounted radar. The directional pattern consistency may be understood as a deviation (a difference between a maximum value and a minimum value) between gains/phases of different antenna elements at different angles within a first angle range (for example, ±60°) in a directional pattern generated by an antenna. A smaller deviation indicates better directional pattern consistency.

[0066] In application of a millimeter-wave vehicle radar, improvement of directional pattern consistency of a millimeter-wave antenna is of great importance. The consistency is generally improved in two aspects. On one hand, smoothness of a directional pattern of a single antenna element in the millimeter-wave antenna is improved, and jitter of the directional pattern is reduced. On the other hand, a difference between directional patterns of different antenna elements in the millimeter-wave antenna is reduced.

[0067] For a conventional PCB antenna, poor directional pattern consistency is mainly caused by coupling paths such as a surface wave, space energy, and feeder spurious radiation. A key solution to improving the directional pattern consistency is to effectively suppress or guide the surface wave and reduce impact of space energy coupling and feeder radiation. The impact of the surface wave may be understood as impact of radiation generated by a surface wave effect on a dielectric layer on antenna consistency. The impact of space energy may be understood as impact of an electrical signal coupled to space by each antenna element in an antenna on antenna consistency. The impact of the feeder spurious radiation may be understood as impact of radiation generated by a metal wire in the PCB during the transmission of an electrical signal on antenna consistency.

[0068] FIG. 2 shows an antenna structure for improving directional pattern consistency.

[0069] As shown in FIG. 2, a dummy (the dummy may be understood as a grounded metal wire) is disposed between two adjacent antenna elements in an antenna array. After the dummy is added, a radiation environment of each antenna element may be close to each other, to improve directional pattern consistency.

[0070] As shown in FIG. 3, after a dummy is added, directional pattern consistency of an antenna array is improved to some extent. However, the dummy is more used to guide a surface wave, and an effect of suppressing the surface wave and space energy is limited, so that the directional pattern consistency is not good.

[0071] For another solution to improving directional pattern consistency of an antenna, for example, an artificial magnetic conductor (artificial magnetic conductor, AMC) or an electromagnetic bandgap (electromagnetic band gap, EBG) structure is disposed around an antenna element, a metal grounding structure with a sawtooth edge is laid on an antenna element, or a feeder and a chip are disposed in an electromagnetic wave shielding area, which has a limited effect of suppressing the surface wave and the space energy. In addition, there are limitations on processing and layout.

[0072] Embodiments of this application provide a wave-absorbing structure, an antenna apparatus, a detection apparatus, and a terminal device. A transparent area is disposed in the wave-absorbing structure, an antenna radiator may be correspondingly disposed in the transparent area, the wave-absorbing structure may be disposed on a dielectric plate, and the antenna radiator may be a metal layer (for example, a copper layer) on a surface of the dielectric plate. The wave-absorbing structure can achieve dual effects of wave-absorbing and isolation, thereby effectively suppressing impact of the surface wave and the space energy on directional pattern consistency of an antenna, and effectively improving the directional pattern consistency of the antenna.

[0073] FIG. 4 and FIG. 5 are schematic structural diagrams of an antenna apparatus 200 according to an embodiment of this application. FIG. 4 is a top view of the antenna apparatus 200. FIG. 5 is a side view of the antenna apparatus 200.

[0074] As shown in FIG. 4, the antenna apparatus 200 may include a plurality of antenna radiators 210 and a wave-absorbing structure 220. The wave-absorbing structure 220 may include a plurality of transparent areas 221, the transparent area 221 corresponds to the antenna radiator 210, and the antenna radiator 210 is disposed in the transparent area 221 corresponding to the antenna radiator 210.

[0075] In an embodiment, the antenna apparatus 200 may further include a dielectric plate 230. The plurality of antenna radiators 210 and the wave-absorbing structure 220 may be disposed on the dielectric plate 230. The plurality of antenna radiators 210 may form an antenna array. A metal layer 231 is disposed on a side that is of the dielectric plate 230 and that is away from the wave-absorbing structure 220. As shown in FIG. 5, the metal layer 231 may be used as a floor of the antenna apparatus 200. The antenna radiator 210, the dielectric plate 230, and the metal layer 231 form a PCB antenna. Optionally, the PCB antenna may include a plurality of layers of dielectric plates. For brevity of description, only one layer of dielectric plate is used as an example for description in this embodiment of this application. This is not limited herein.

[0076] It should be understood that, in the antenna apparatus according to this embodiment of this application, the wave-absorbing structure 220 may be disposed on the dielectric plate 230, so that a surface wave generated on the dielectric plate can be absorbed, and radiation of the surface wave to the outside can be reduced. Therefore, impact of the surface wave on directional pattern consistency of the antenna array formed by the plurality of antenna radiators 210 can be effectively reduced. In addition, because the antenna radiator 210 is disposed in the transparent area 221 corresponding to the antenna radiator 210, the antenna radiator 210 disposed in the corresponding transparent area

221 can greatly reduce space energy generated through radiation when the antenna radiator 210 is coupled to another antenna radiator 210, and can reduce impact of space energy of a clutter generated by the antenna radiator 210 disposed in the corresponding transparent area 221 on the another antenna radiator 210, thereby effectively reducing the impact of the space energy on the directional pattern consistency of the antenna array. Therefore, the wave-absorbing structure 220 can reduce the impact of the surface wave and the space energy on the directional pattern consistency of the antenna array, thereby greatly improving the directional pattern consistency of the antenna array.

[0077] In an embodiment, a material of the wave-absorbing structure 220 may be SABIC polycarbonate (SABIC PC+C), and may absorb an electromagnetic wave signal emitted into the wave-absorbing structure, thereby reducing interference caused to the antenna radiator 210.

[0078] In an embodiment, a metal layer, for example, aluminum, silver, or another metal material, may be further disposed on a surface of the wave-absorbing structure 220. A corresponding metal layer may be disposed, according to a shape of the wave-absorbing structure 220, on a surface that is of the wave-absorbing structure 220 and that is away from the dielectric plate 230, or corresponding metal layers may be disposed on surfaces of the wave-absorbing structure 220 other than a surface that is close to the dielectric plate 230, so that space energy generated through radiation when the wave-absorbing structure 220 is coupled to another antenna radiator 210 can be further reduced, and the directional pattern consistency of the antenna array can be improved.

[0079] In an embodiment, the wave-absorbing structure 220 may be fastened to the dielectric plate 230 by using a rivet, an adhesive, or a screw, to ensure that the wave-absorbing structure 220 is closely connected to the dielectric plate 230, thereby reducing radiation of the surface wave, and effectively reducing the impact of the surface wave on the directional pattern consistency of the antenna array.

[0080] In an embodiment, the transparent area 221 may be in a one-to-one correspondence with the antenna radiator 210. To be specific, a single antenna radiator 210 is disposed in each transparent area 221, so that the impact of the space energy on the antenna radiator can be further reduced, and the directional pattern consistency of the antenna array can be improved.

[0081] In an embodiment, the plurality of transparent areas 221 or the plurality of antenna radiators 210 may be arranged in an array. For example, the plurality of transparent areas 221 or the plurality of antenna radiators 210 may be linearly arranged (for example, in a straight line, a curve, or a broken line), or may be arranged in a 3x3 array. This is not limited in this application, and may be adjusted according to an actual design. In this embodiment, an example in which the plurality of antenna radiators 210 are arranged in a straight line is used for description. As shown in FIG. 4, an arrangement length L1 of the plurality of antenna radiators 210 may be adjusted according to an actual design.

[0082] In an embodiment, the wave-absorbing structure 220 may include a plurality of teeth 222 and at least one connecting member 223, and the plurality of teeth 222 may be connected to the at least one connecting member 223. As shown in FIG. 6, it may be considered that the wave-absorbing structure shown in FIG. 6 is a fence-shaped wave-absorbing structure. To be specific, all transparent areas are closed areas. A transparent area 221 is formed between two adjacent teeth 222 in the plurality of teeth 222. In this embodiment of this application, two connecting members 223 are used as an example for description. The transparent area 221 formed between the two adjacent teeth 222 may be a closed area, and the transparent area 221 encloses an antenna radiator corresponding to the transparent area 221. When only one connecting member 223 is included, the wave-absorbing structure 220 may be in a comb shape. The transparent area 221 formed between the two adjacent teeth 222 may be a semi-closed area, and the transparent area 221 encloses a part of an area of an antenna radiator corresponding to the transparent area 221, as shown in FIG. 7.

[0083] In an embodiment, the teeth in the wave-absorbing structure may be in any shape, may not necessarily be a rectangle in the foregoing embodiment, and may be in another shape, for example, a wave shape, a diamond shape, or a trapezoid shape. Alternatively, as shown in (a) in FIG. 8, the teeth in different shapes may be disposed in a same wave-absorbing structure, to better improve the directional pattern consistency of the antenna array. This is not limited in this application, and may be adjusted according to an actual design.

[0084] In an embodiment, as shown in (b) in FIG. 8, distances between the adjacent teeth in the wave-absorbing structure may be different, and may be determined by the antenna radiator disposed in the transparent area formed between the adjacent teeth, to better improve the directional pattern consistency of the antenna array. This is not limited in this application, and may be adjusted according to an actual design.

[0085] In an embodiment, as shown in (c) in FIG. 8, lengths or widths of teeth in the wave-absorbing structure may be different, and may be determined by the antenna radiator disposed in the transparent area formed between the adjacent teeth, to better improve the directional pattern consistency of the antenna array. This is not limited in this application, and may be adjusted according to an actual design.

[0086] In an embodiment, as shown in (a) in FIG. 9, (b) in FIG. 9, and (c) in FIG. 9, a metal feeder 240 may be disposed on the dielectric plate 230, and the metal feeder 240 is configured to feed the antenna radiator 210. (b) in FIG. 9 and (c) in FIG. 9 are three-dimensional diagrams of (a) in FIG. 9. This application is described by using an example in which the metal feeder 240 and the antenna radiator 210 are disposed on a same side of the dielectric plate 230. It should be understood that, the metal feeder 240 and the antenna radiator 210 may alternatively be separately disposed on two sides of the dielectric plate 230. When the antenna apparatus includes a plurality of dielectric plates, the metal feeder 240 may alternatively be disposed on another dielectric plate. This is not limited in this application.

[0087] In an embodiment, when the metal feeder 240 and the antenna radiator 210 are disposed on a same side (a same surface) of the dielectric plate 230, a slot 241 may be disposed on a side that is of the wave-absorbing structure and that is close to the dielectric plate 230. The slot 241 may be disposed in correspondence with the metal feeder 240, and is configured to shield radiation generated by the metal feeder 240, reduce impact on the antenna radiator 210, and further improve the directional pattern consistency of the antenna array. In addition, the slot 241 may be designed according to a layout of the metal feeder 240 on the dielectric plate 230. For example, the slot 241 may be disposed in the connecting member 223 of the wave-absorbing structure, and is electrically connected to the antenna radiator 210 to feed the antenna radiator 210. (a) in FIG. 9 is a schematic diagram of a cross-section that passes through the slot 214 and that is parallel to xoz. A specific position of the slot 241 is shown in (b) in FIG. 9 and (c) in FIG. 9 ((b) in FIG. 9 and (c) in FIG. 9 are schematic diagrams of a top view and a bottom view of a three-dimensional structure of the wave-absorbing structure 220). Alternatively, the slot 242 may be disposed in the teeth 222 of the wave-absorbing structure, as shown in FIG. 10. In addition, for the foregoing structure, no metal feeder may be disposed in space formed by the slot in the wave-absorbing structure, and may be adjusted according to an actual design. For example, an electronic component (a capacitor, a resistor, an inductor, or a filter component) may be disposed.

[0088] It should be understood that, the slot 241 is of a regular cube structure, and a cross section of the slot 241 is a rectangle. This is merely used as an example. In actual production or design, the slot 241 may be modified according to a layout of the metal feeder. This is not limited in this application.

[0089] It should be understood that, when the metal feeder 240 and the antenna radiator 210 may alternatively be separately disposed on two sides of the dielectric plate 230, no slot may be disposed on a side that is of the wave-absorbing structure and that is close to the dielectric plate 230, and the wave-absorbing structure is of a solid structure, so that strength and stability of the wave-absorbing structure can be effectively improved.

[0090] In an embodiment, as shown in FIG. 10, a highest point of teeth 222 in the wave-absorbing structures on two sides of the antenna radiator 210 may avoid a field of view (field of view, FOV) θ of the antenna radiator 210, so that all electrical signals generated by the antenna radiator 210 can be radiated within the angle. An electrical signal radiated within the field of view of the antenna radiator 210 may be considered as main radiation, and an electrical signal radiated beyond the angle may be considered as a clutter, which affects another antenna radiator in the antenna array, and further affects the directional pattern consistency of the antenna array. For example, in this application, the field of view may be 120°. It is understood that an electrical signal radiated at an angle with the z axis within a range of 60° is primary radiation, and an electrical signal radiated at an angle with the z axis within a range of 60° to 90° is a clutter. Therefore, the teeth 222 and the plane on which the antenna radiator 210 is located are at a first angle α, where α may be an acute angle, so that a clutter can be continuously reflected in the transparent area and absorbed by the wave-absorbing structure, thereby improving the directional pattern consistency of the antenna array. That the teeth 222 and the plane on which the antenna radiator 210 is located are at a first angle α may be understood as that side surfaces of the teeth 222 and the plane on which the antenna radiator 210 is located are at the first angle α. In some cases, the first angle α may alternatively be a right angle or an obtuse angle. This can also reduce mutual impact between antenna radiators, and therefore improve the directional pattern consistency of the antenna array.

[0091] It should be understood that, all electrical signals generated by the antenna radiator 210 can be radiated within the field of view, and clutters outside the field of view may be continuously reflected in the transparent area and absorbed by the wave-absorbing structure. Therefore, a reflected wave obtained after an electromagnetic wave signal as an incident wave at an edge of the field of view θ is reflected by a highest point of the teeth 222 needs to be perpendicular to a plane on which the antenna radiator is located, as shown in FIG. 11. In this case, an angle value of the first angle α is a critical angle. When the first angle α is less than or equal to the angle, all electrical signals generated by the antenna radiator 210 may be radiated within the field of view, and clutters outside the angle may be continuously reflected in the transparent area and absorbed by the wave-absorbing structure. It can be learned from a geometric relationship that, in this case, an angle value of the first angle α is a quarter of the field of view θ.

[0092] In an embodiment, FIG. 12 is a schematic diagram of a strong reflection principle. When a thickness of a medium is one quarter of a wavelength corresponding to an incident wave, after the incident wave is reflected on a surface of the medium for the first time, a phase of the first reflected wave is 180°, and a phase of a second reflected wave generated after reflection occurs after a part of the incident wave is emitted into the medium is 180°. The phases of the first reflected wave and the second reflected wave are the same. Therefore, the first reflected wave and the second reflected wave are mutually enhanced, and have relatively large reflected energy, so that the transmission energy through the medium is low. FIG. 13 is a schematic diagram of a strong transmission principle. When a thickness of a medium is one half of a wavelength corresponding to an incident wave, after the incident wave is reflected on a surface of the medium for the first time, a phase of the first reflected wave is 180°, and a phase of a second reflected wave generated after reflection occurs after a part of the incident waves is emitted into the medium is 360°. The phases of the first reflected wave and the second reflected wave are opposite (a difference of 180°), and the two reflected waves are mutually offset, and therefore, reflection energy is relatively small, and transmission energy through the medium is relatively large.

[0093] According to the foregoing principle, for the teeth 222, a function of the teeth 222 is to suppress, in the transparent area, a clutter generated by the antenna radiator disposed in the transparent area formed by the teeth 222, and reduce interference caused to the antenna radiator disposed in an adjacent transparent area. Therefore, an average width L2 of the teeth 222 is one quarter of the first wavelength, so that reflected energy intensity of the electrical signal on the surface of the teeth 222 can be increased, and the electrical signal is suppressed from escaping outside the transparent area, thereby reducing interference caused by a clutter generated by the antenna radiator disposed in the transparent area to the antenna radiator disposed in an adjacent transparent area, as shown in FIG. 11. The first wavelength may be a wavelength corresponding to an operating frequency band of the antenna apparatus 200, and may be understood as a wavelength corresponding to a center frequency of the operating frequency band, or may be understood as a wavelength corresponding to a resonance point of resonance generated by the antenna apparatus 200. It should be understood that, the average width L2 of the teeth 222 may alternatively be adjusted according to a design or a production requirement. This is not limited in this application.

[0094] In an embodiment, a cross section of the teeth 222 may be a trapezoid, as shown in FIG. 11. Alternatively, a shape of the cross section of the teeth 222 may be adjusted according to an actual design or a production requirement. For example, the cross section of the teeth 222 may be a triangle, or the cross section of the teeth 222 may be shown in (a) in FIG. 14 or (b) in FIG. 14. This is not limited in this application.

[0095] In an embodiment, the antenna apparatus 200 further includes a radome 250. The wave-absorbing structure 220 may be disposed in space enclosed by the dielectric plate 230 and the radome 250. The radome 250 may be configured to protect a component disposed inside the radome 250, to improve stability of the entire antenna apparatus 200, as shown in FIG. 15.

[0096] In an embodiment, a protruding portion 224 is disposed in the wave-absorbing structure 220, and the protruding portion 224 may press against the radome 250, to support the radome 250. When the antenna radiator 210 is disposed in a central area of the dielectric plate 230, the protruding portion 224 may be disposed at an edge (a side edge) of the wave-absorbing structure 220, as shown in FIG. 15. It should be understood that, the protruding portion 224 may be a tooth disposed at an edge of a plurality of teeth of the wave-absorbing structure 220 (where thickness of the plurality of teeth may be different), or may be a part of a connecting member of the wave-absorbing structure 220, and the protruding portion 224 may be integrated with the wave-absorbing structure 200, or may exist separately from the wave-absorbing structure 220. This is not limited in this application, and may be adjusted according to an actual design. When the antenna radiator 210 is disposed at the edge of the dielectric plate 230, the protruding portion may not be disposed, as shown in FIG. 16. This is not limited in this application, and may be adjusted according to an actual design.

[0097] FIG. 17 is a schematic diagram of an antenna apparatus according to an embodiment of this application.

[0098] As shown in FIG. 17, the antenna apparatus shown in FIG. 17 and the antenna apparatus shown in FIG. 4 use a same dielectric plate and antenna radiators of a same quantity and in a same layout. A plurality of antenna radiators are distributed along a straight line to form an antenna array. A difference between the antenna apparatus shown in FIG. 17 and the antenna apparatus shown in FIG. 4 lies only in that the wave-absorbing structure is disposed above the dielectric plate in FIG. 4.

[0099] FIG. 18 and FIG. 19 are simulation result diagrams of the antenna apparatus shown in FIG. 4 and FIG. 17. FIG. 18 is a directional pattern of the antenna apparatus. FIG. 19 is a horizontal angle measurement error of the antenna apparatus.

[0100] As shown in FIG. 18, a pit drop (a gain deviation) occurs in a directional pattern of an antenna array in the antenna apparatus shown in FIG. 17 around $\pm 20°$. The wave-absorbing structure is added to the antenna apparatus shown in FIG. 4, and no pit drop occurs in the directional pattern of the antenna array, and no significant deviation occurs in a range of $\pm 60°$ (an angle with a z axis is 60°). This effectively avoids the pit drop in the antenna array, thereby improving the directional pattern consistency.

[0101] As shown in FIG. 19, because the pit drop occurs in the directional pattern of the antenna array in the antenna apparatus shown in FIG. 17 around $\pm 20°$, correspondingly, an angle measurement error deviation at the position is relatively large, so that measurement precision is greatly reduced. However, because the antenna apparatus shown in FIG. 4 has relatively good directional pattern consistency of the antenna array, an angle measurement error of the antenna apparatus is basically 0°. Compared with the antenna apparatus shown in FIG. 17, angle measurement precision is improved by 0.07°, and the angle measurement precision is greatly improved.

[0102] FIG. 20 is a schematic structural diagram of still another antenna apparatus 300 according to an embodiment of this application.

[0103] As shown in FIG. 20, the antenna apparatus 300 may include a plurality of antenna radiators 310 and a wave-absorbing structure 320. The wave-absorbing structure 320 may include a connecting member 323 and a plurality of teeth 322.

[0104] A first area 3211 is formed between two adjacent teeth in the plurality of teeth 322, and the first area 3211 is a transparent area in the wave-absorbing structure 320, and is used to dispose the antenna radiator 310. A second area 3212 may be disposed in the connecting member 323, and the second area 3212 may be used as a transparent area in the wave-absorbing structure 320. The second area 3212 shown in the figure may be considered as a window-type transparent area, and is used to dispose the antenna radiator 310. It should be understood that, for the foregoing embodiment, quantities of the first areas 3211 and the second areas 3212 may be determined according to an actual design. This is not limited in this application.

[0105] In an embodiment, the plurality of teeth 322 may be separately disposed on two sides of the connecting member 323, to form a semi-closed first area 3211. It should be understood that, the plurality of teeth 322 may be connected to a same side of the connecting member 323, or the plurality of teeth 322 may be connected to on different sides of the connecting member 323. This is not limited in this application. For example, the teeth 322 may be disposed at one edge of the connecting member 323, to form a semi-closed first area 3211, or the teeth 322 may be disposed at any three or four edges of the connecting member 323, to form a semi-closed first area 3211.

[0106] It should be understood that, for the technical solution provided in this embodiment of this application, the transparent area may be set according to a layout of the plurality of antenna radiators 310 in the antenna apparatus 300, to improve directional pattern consistency of the antenna arrays in the antenna apparatus 300. For example, the wave-absorbing structure may include the transparent area formed by the semi-closed first area and the transparent area formed by the closed second area, as shown in FIG. 20. Alternatively, the wave-absorbing structure may include only the transparent area formed by the semi-closed first area, as shown in (a) in FIG. 21 and (b) in FIG. 21. Alternatively, the wave-absorbing structure may include only a transparent area formed by the closed second area, as shown in (c) in FIG. 21. It should be understood that, the foregoing embodiments show only some technical solutions, and may be adjusted according to an actual design or a production requirement. For example, any combination of a comb-shaped wave-absorbing structure, a fence-shaped wave-absorbing structure, or a window-shaped wave-absorbing structure in this application may be designed. This is not limited in this application.

[0107] In an embodiment, to suppress, in the transparent area formed in the area, a clutter generated by the antenna radiator disposed in the second area 3212, and reduce interference caused to the antenna radiator disposed in an adjacent transparent area, an average width of a tooth structure formed between two adjacent teeth in the plurality of second areas 3212 may be a quarter of a second wavelength, and the second wavelength may be a wavelength corresponding to an operating frequency band of the antenna apparatus 300.

[0108] In an embodiment, the connecting member 323 and the plurality of teeth 322 may be in a complete structure that is integrally formed, or a part of teeth in the plurality of teeth 322 may be separately prepared (for example, teeth disposed at an edge), and may be a wave-absorbing block, which is fastened on the dielectric plate 330 by using a rivet, an adhesive, or a screw, to form a complete wave-absorbing structure.

[0109] In this embodiment of this application, an example in which 10 transparent areas are disposed in the wave-absorbing structure 320 is used for description. A specific quantity may be adjusted according to a design requirement. This is not limited in this application. Antenna radiators disposed in the plurality of transparent areas may form at least one antenna array.

[0110] It should be understood that, one antenna radiator may be disposed in one transparent area, or a plurality of antenna radiators may be disposed in one transparent area. For example, a plurality of antenna radiators may alternatively be disposed in a single transparent area, and the plurality of antenna radiators in the single transparent area independently form an antenna array. In other words, one antenna array may be formed in each transparent area. Alternatively, a single antenna radiator is disposed in each of the plurality of transparent areas, and a plurality of antenna radiators in the plurality of transparent areas separately form different antenna elements of a same antenna array. In other words, the plurality of antenna radiators in the transparent areas form one antenna array together.

[0111] For example, a plurality of antenna radiators may be separately disposed in a transparent area 1 and a transparent area 2, and the antenna radiators in the transparent area 1 and the transparent area 2 may form a first antenna array and a second antenna array respectively. A single antenna radiator may be disposed in each of a transparent area 3 to a transparent area 10. The antenna radiator in the transparent area 3 and the antenna radiator in a transparent area 4 may jointly form a third antenna array. The antenna radiator in a transparent area 5 and the antenna radiator in a transparent area 6 may jointly form a fourth antenna array. The antenna radiator in a transparent area 7 and the antenna radiator in a transparent area 8 may jointly form a fifth antenna array. The antenna radiator in a transparent area 9 and the antenna radiator in the transparent area 10 may jointly form the sixth antenna array. That is, the antenna apparatus 300 may include six antenna arrays, to improve measurement precision of the antenna apparatus 300.

[0112] FIG. 22 to FIG. 25 are schematic diagrams and simulation results of still another antenna apparatus according to an embodiment of this application. FIG. 22 is a schematic structural diagram of a semi-closed transparent area according to an embodiment of this application. FIG. 23 is a schematic diagram of an antenna apparatus in a control group. FIG. 24 is a schematic diagram of amplitude consistency of an antenna apparatus according to an embodiment of this application. FIG. 25 is a schematic diagram of phase consistency of an antenna apparatus according to an embodiment of this application.

[0113] As shown in FIG. 22, the wave-absorbing structure includes two teeth and one connecting member, to form a semi-closed transparent area. A plurality of antenna radiators are disposed in the transparent area, and the plurality of antenna radiators are distributed along a straight line to form an antenna array. A difference between the antenna apparatus shown in FIG. 23 and the antenna apparatus shown in FIG. 22 lies only in that the wave-absorbing structure is disposed above the dielectric plate in FIG. 22, and the antenna radiator is disposed in the transparent area.

[0114] As shown in FIG. 23 and FIG. 24, when the antenna array is disposed in the transparent area of the wave-absorbing structure, amplitude consistency and phase consistency of the antenna array are effectively improved compared with a case in which no wave-absorbing structure is disposed, as shown in Table 1 below (an angle value range is between ±60°).

Table 1

	Amplitude consistency	Phase consistency
Without a wave-absorbing structure	≤4.3 dB	≤33°
With a wave-absorbing structure	≤2.5 dB	≤16°

[0115] It should be understood that, the antenna array is disposed in the transparent area of the wave-absorbing structure, and the wave-absorbing structures on two sides of the array can effectively absorb spatial spurious energy between the radome and an antenna board, thereby improving amplitude-phase consistency of the directional pattern.

[0116] As shown in the foregoing table, the wave-absorbing structure is disposed in the antenna apparatus, and the antenna array is disposed in the transparent area of the wave-absorbing structure, so that the antenna structure is within ±60° (an angle between the antenna apparatus and a z axis is 60°), the amplitude consistency of the antenna structure is improved by 1.8 dB, and the phase consistency is improved by 17°.

[0117] FIG. 26 to FIG. 29 are schematic diagrams and simulation results of still another antenna apparatus according to an embodiment of this application. FIG. 26 is a schematic structural diagram of a closed transparent area according to an embodiment of this application. FIG. 27 is a schematic diagram of an antenna apparatus in a control group. FIG. 28 is a schematic diagram of energy distribution of an antenna apparatus according to an embodiment of this application. FIG. 29 is a directional pattern of an antenna apparatus according to an embodiment of this application.

[0118] As shown in FIG. 26, the wave-absorbing structure includes two teeth and two connecting members, to form a closed transparent area. A single antenna radiator is disposed in the transparent area. A difference between the antenna apparatus shown in FIG. 27 and the antenna apparatus shown in FIG. 26 lies only in that the wave-absorbing structure is disposed above the dielectric plate in FIG. 26, and the antenna radiator is disposed in the transparent area.

[0119] As shown in (a) in FIG. 28, when the antenna radiator is disposed in the transparent area of the wave-absorbing structure, surface wave energy on the dielectric plate is concentrated in the closed transparent area. However, in the antenna apparatus shown in (b) in FIG. 28, because no wave-absorbing structure is disposed around the antenna radiator, the surface wave energy on the dielectric plate is escaping outward, causing spatial radiation and affecting directional pattern consistency. In FIG. 28, the energy distribution of the antenna apparatus is shown by a grid shadow in the figure.

[0120] As shown in FIG. 28, when the antenna radiator is disposed in the transparent area of the wave-absorbing structure, compared with a case in which no wave-absorbing structure is disposed, a directional pattern of the antenna radiator is obviously smooth within ±60°, and jitter of the directional pattern is effectively suppressed, thereby effectively improving the directional pattern consistency.

[0121] An embodiment of this application further provides a detection apparatus, including the antenna apparatus described above, configured to perform a detection task.

[0122] An embodiment of this application further provides a terminal device, including the foregoing detection apparatus. Further, the terminal may be an intelligent transportation device (a vehicle or an unmanned aerial vehicle), a smart home device, a smart manufacturing device, surveying equipment, a robot, or the like. The intelligent transportation device may be, for example, an automated guided vehicle (autonomous guided vehicle, AGV) or an unmanned transport vehicle.

[0123] 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 during 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 through some interfaces. The indirect couplings or communication connections between the apparatuses or units may be implemented in electronic or other forms.

[0124] The foregoing descriptions are merely specific implementations of this application, but the protection scope of this application is not limited thereto. 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 wave-absorbing structure, used in an antenna apparatus, wherein a transparent area is disposed in the wave-absorbing structure, and an antenna radiator in the antenna apparatus is correspondingly disposed in the transparent area.

2. The wave-absorbing structure according to claim 1, wherein the wave-absorbing structure comprises a plurality of teeth and at least one connecting member;

   the plurality of teeth are connected to the at least one connecting member; and
   a first area is formed between two adjacent teeth in the plurality of teeth, and the first area is the transparent area.

3. The wave-absorbing structure according to claim 2, wherein the plurality of teeth are connected to a same side of the connecting member, or the plurality of teeth are connected to different sides of the connecting member.

4. The wave-absorbing structure according to claim 2 or 3, wherein the first area is a semi-closed area.

5. The wave-absorbing structure according to claim 4, wherein the wave-absorbing structure is of a comb-shaped structure.

6. The wave-absorbing structure according to claim 2 or 3, wherein the first area is a closed area.

7. The wave-absorbing structure according to claim 6, wherein the wave-absorbing structure is of a fence-shaped structure.

8. The wave-absorbing structure according to any one of claims 1 to 7, wherein a second area is disposed in the at least one connecting member, and the second area is the transparent area.

9. The wave-absorbing structure according to claim 8, wherein the second area is a closed area.

10. The wave-absorbing structure according to claim 8 or 9, wherein the connecting member is of a fence-shaped structure.

11. The wave-absorbing structure according to any one of claims 2 to 10, wherein distances between two adjacent teeth in the plurality of teeth are the same or different.

12. The wave-absorbing structure according to any one of claims 2 to 11, wherein different teeth are in a same shape or different shapes.

13. The wave-absorbing structure according to claim 12, wherein that different teeth are in a same shape or different shapes comprises:

   different teeth have a same width, length, or thickness; or
   different teeth have different widths, lengths, or thicknesses.

14. An antenna apparatus, comprising a plurality of antenna radiators, and the wave-absorbing structure and the antenna radiator according to any one of claims 1 to 8.

15. The antenna apparatus according to claim 14, wherein the wave-absorbing structure has a plurality of transparent areas, and an antenna radiator is disposed in each of the plurality of transparent areas.

16. The antenna apparatus according to claim 14 or 15, wherein teeth of the wave-absorbing structure and a plane on which the antenna radiator is located are at a first angle, and the first angle is an acute angle.

17. The antenna apparatus according to claim 16, wherein the first angle is less than or equal to a quarter of a field of view FOV of the antenna radiator corresponding to the transparent area.

18. The antenna apparatus according to claim 16 or 17, wherein an average width of the teeth of the wave-absorbing structure is a quarter of a first wavelength, and the first wavelength is a wavelength corresponding to an operating frequency band of the antenna apparatus.

19. The antenna apparatus according to any one of claims 16 to 18, wherein a cross section of the teeth of the wave-absorbing structure is a trapezoid.

20. The antenna apparatus according to any one of claims 15 to 19, wherein the plurality of transparent areas are linearly arranged.

21. The antenna apparatus according to any one of claims 14 to 20, wherein the antenna apparatus further comprises a dielectric plate; and
the antenna radiator is disposed on a surface of the dielectric plate.

22. The antenna apparatus according to claim 21, wherein a metal feeder is disposed on the dielectric plate; and
a slot is disposed at a position that is of the wave-absorbing structure and that corresponds to the metal feeder.

23. The antenna apparatus according to claim 21 or 22, wherein the antenna apparatus further comprises a radome; and the wave-absorbing structure is disposed in space enclosed by the dielectric plate and the radome.

24. The antenna apparatus according to claim 23, wherein a protruding portion is disposed in the wave-absorbing structure, and the protruding portion presses against the radome.

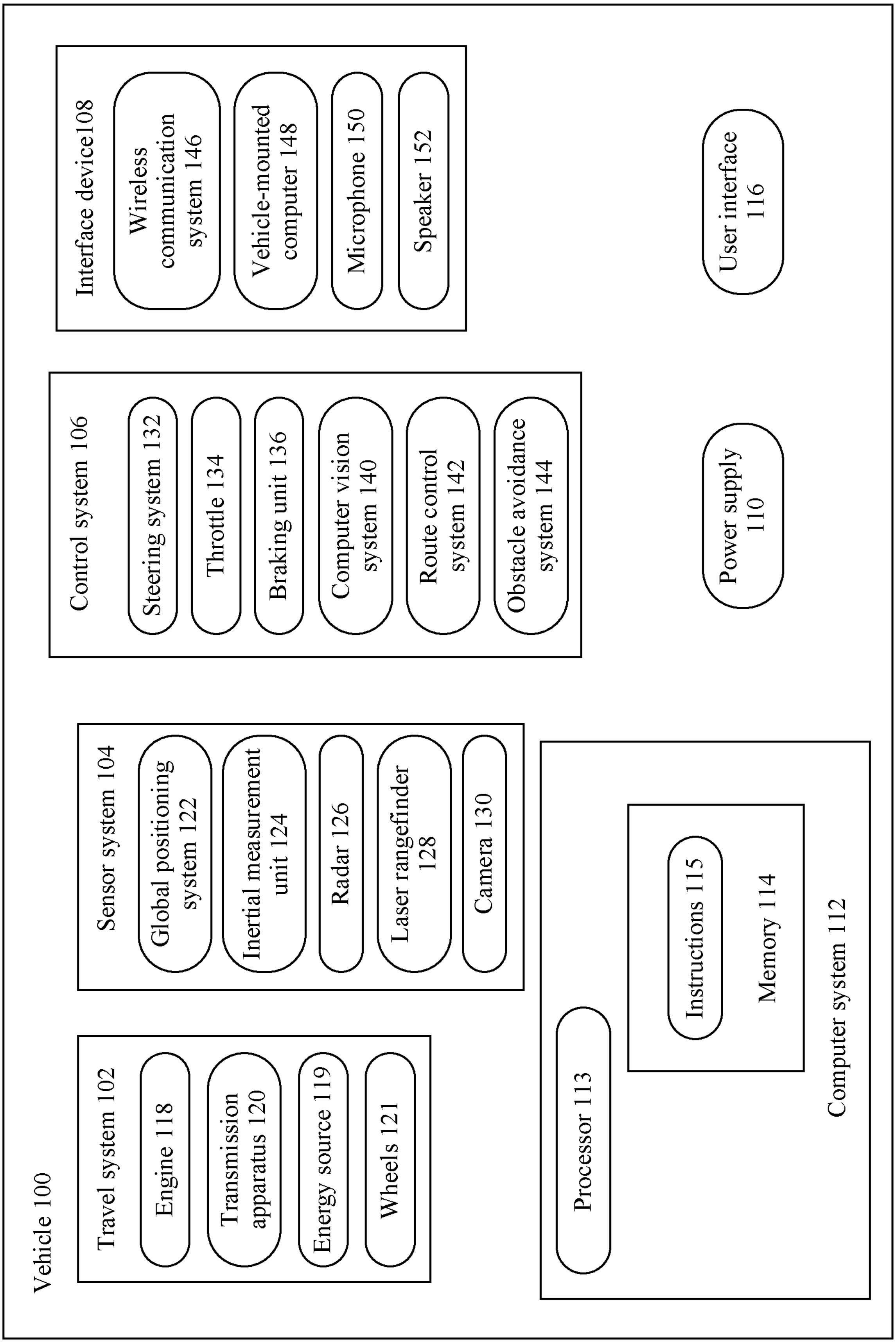
25. The antenna apparatus according to claim 24, wherein the protruding portion is disposed at an edge of the wave-absorbing structure.

26. The antenna apparatus according to any one of claims 21 to 25, wherein the wave-absorbing structure is fastened to the dielectric plate by using a rivet, an adhesive, or a screw.

27. A detection apparatus, wherein the detection apparatus comprises a detection device and the antenna apparatus according to any one of claims 14 to 26.

28. A terminal device, wherein the terminal device comprises a detection device and the detection apparatus according to claim 27.

29. The terminal device according to claim 28, wherein the terminal device is an intelligent transportation device, an intelligent manufacturing device, a smart home device, or surveying equipment.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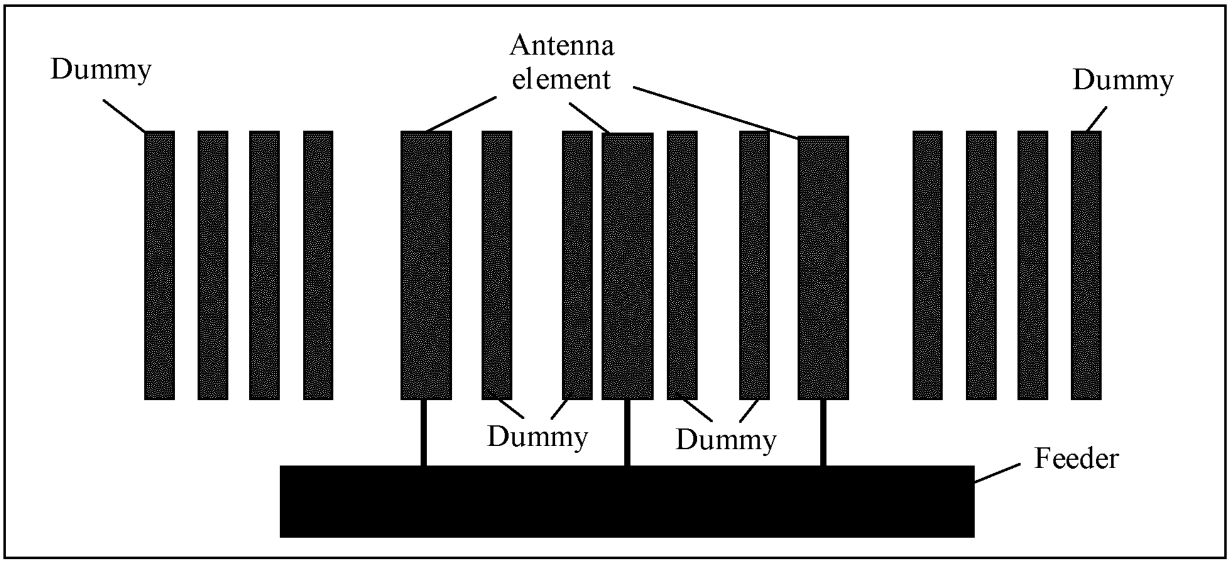
Travel system 102
Engine 118
Transmission apparatus 120
Energy source 119
Wheels 121
Sensor system 104
Global positioning system 122
Inertial measurement unit 124
Radar 126
Laser rangefinder 128
Camera 130
Control system 106
Steering system 132
Throttle 134
Braking unit 136
Computer vision system 140
Route control system 142
Obstacle avoidance system 144
Interface device108
Wireless communication system 146
Vehicle-mounted computer 148
Microphone 150
Speaker 152
Processor 113
Instructions 115
Memory 114
Computer system 112
Power supply 110
User interface 116

FIG. 1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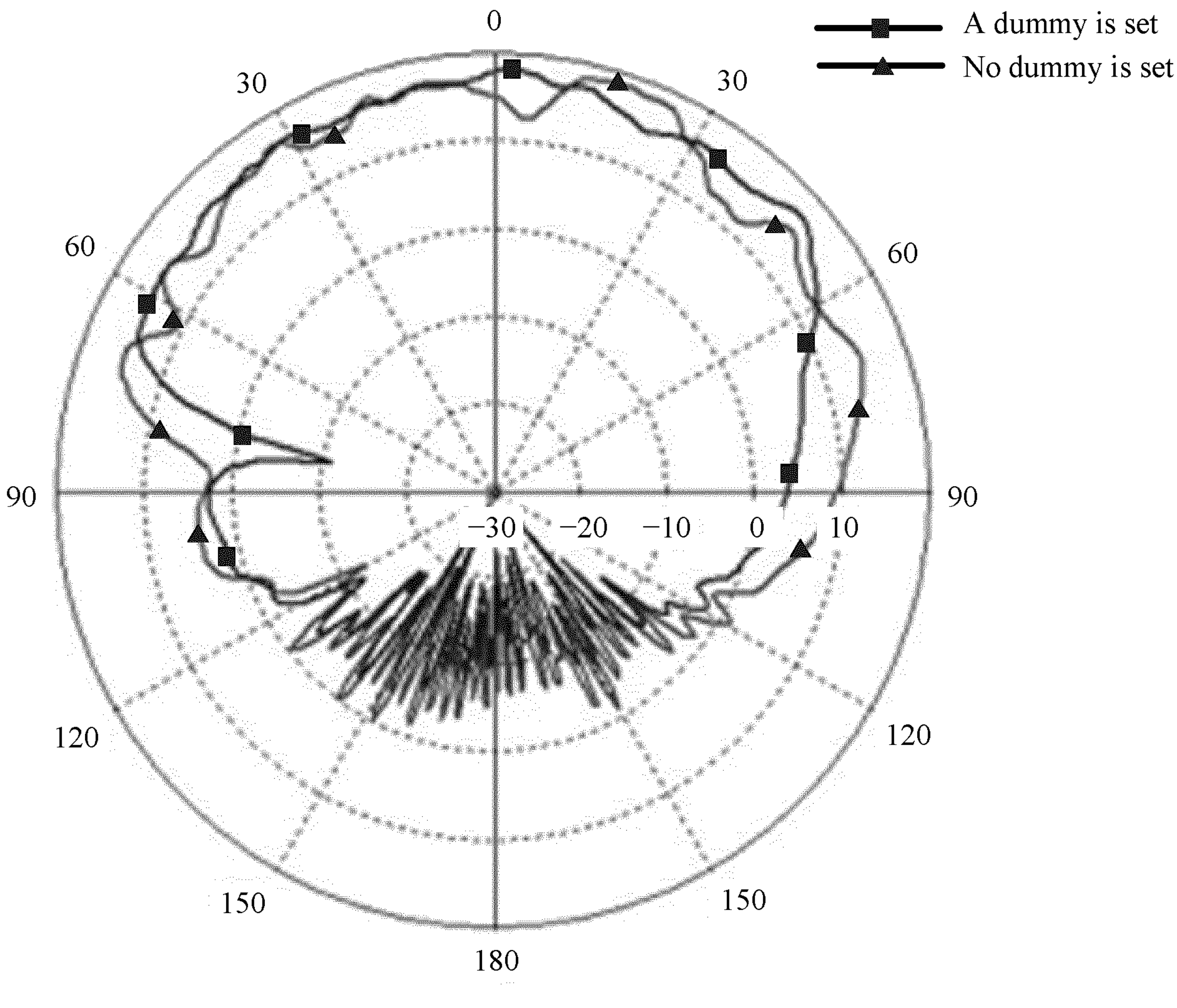
Antenna element
Dummy
Dummy
Dummy
Feeder

FIG. 2


A dummy is set
No dummy is set
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60
90
90
120
120
150
150
180
−30
−20
−10
0
10

FIG. 3

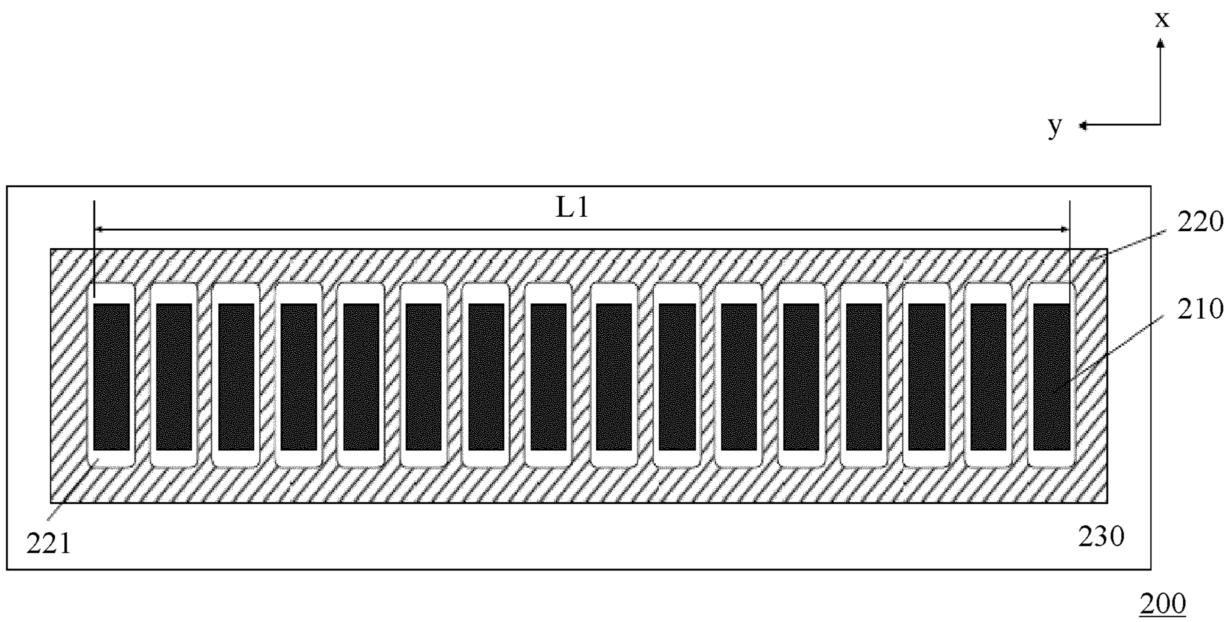


FIG. 4

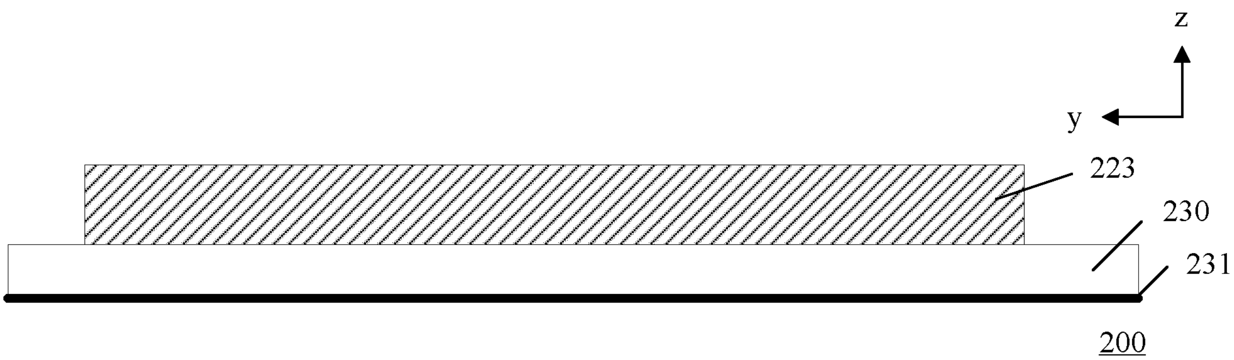


FIG. 5

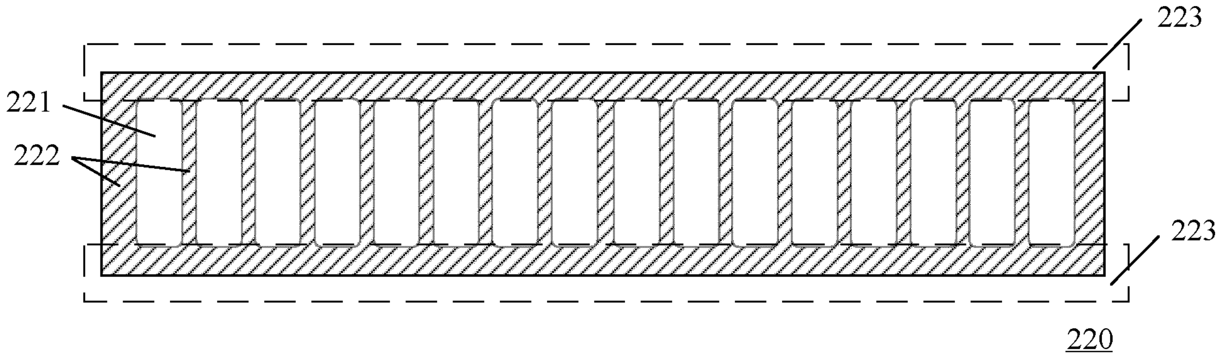


FIG. 6

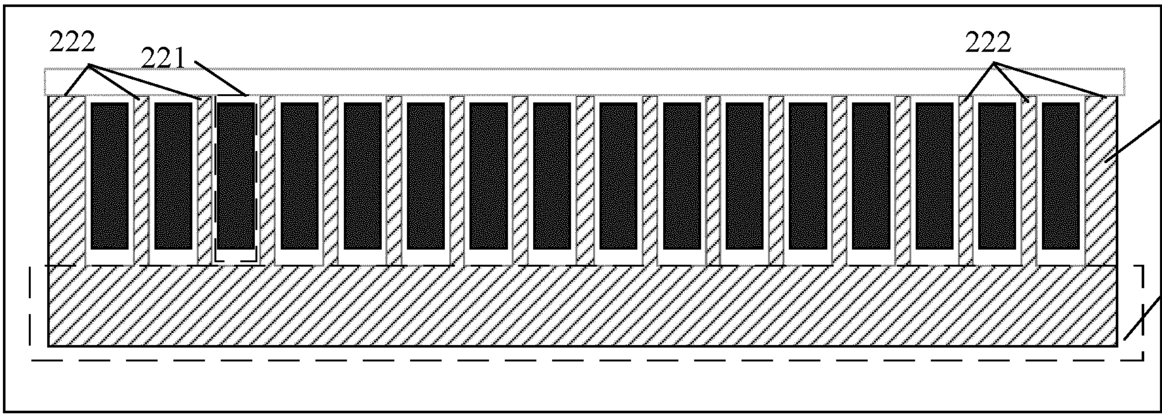
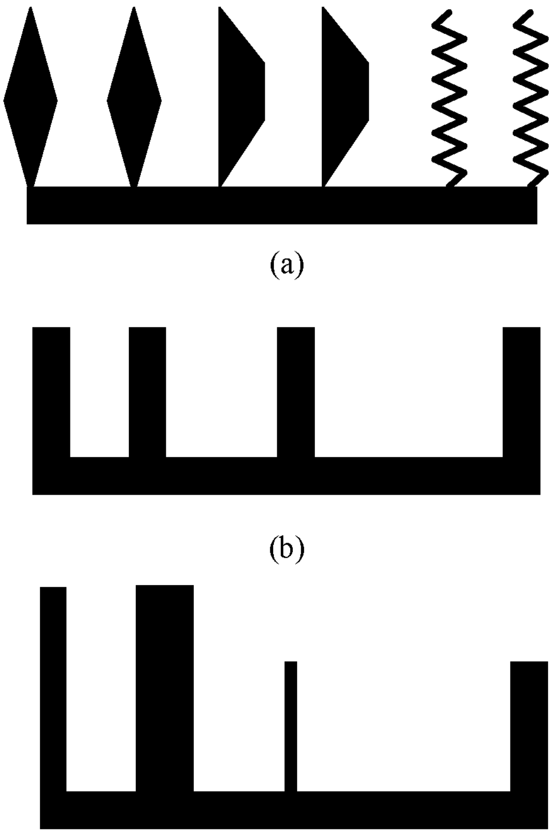


FIG. 7



(a)

(b)

(c)

FIG. 8

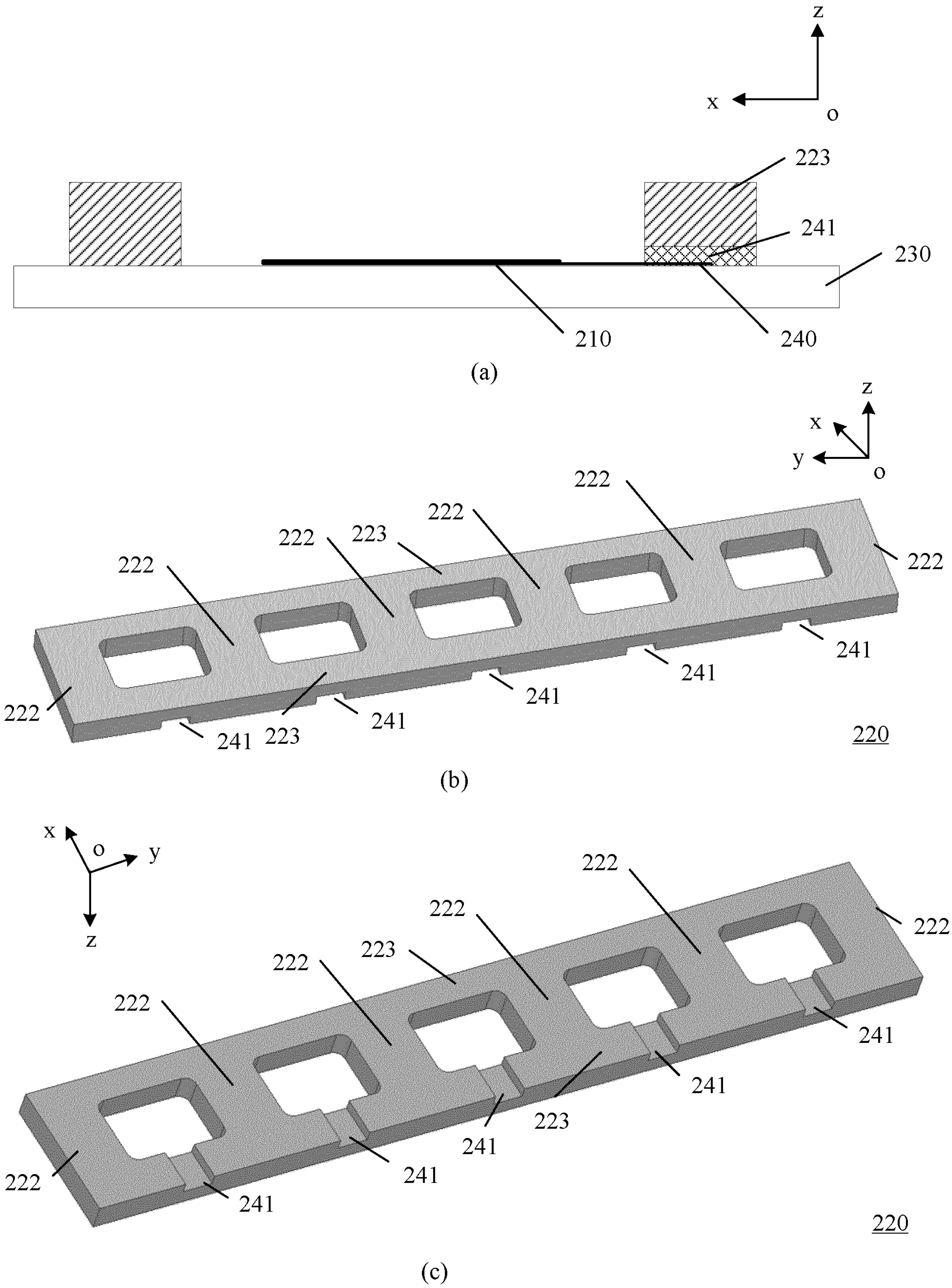

z
x
o
223
241
230
210
240
(a)
z
x
y
o
222
222
223
222
222
222
222
222
241
241
241
241
241
223
220
(b)
x
o
y
z
222
222
223
222
222
222
222
222
241
241
241
241
241
223
220
(c)

FIG. 9

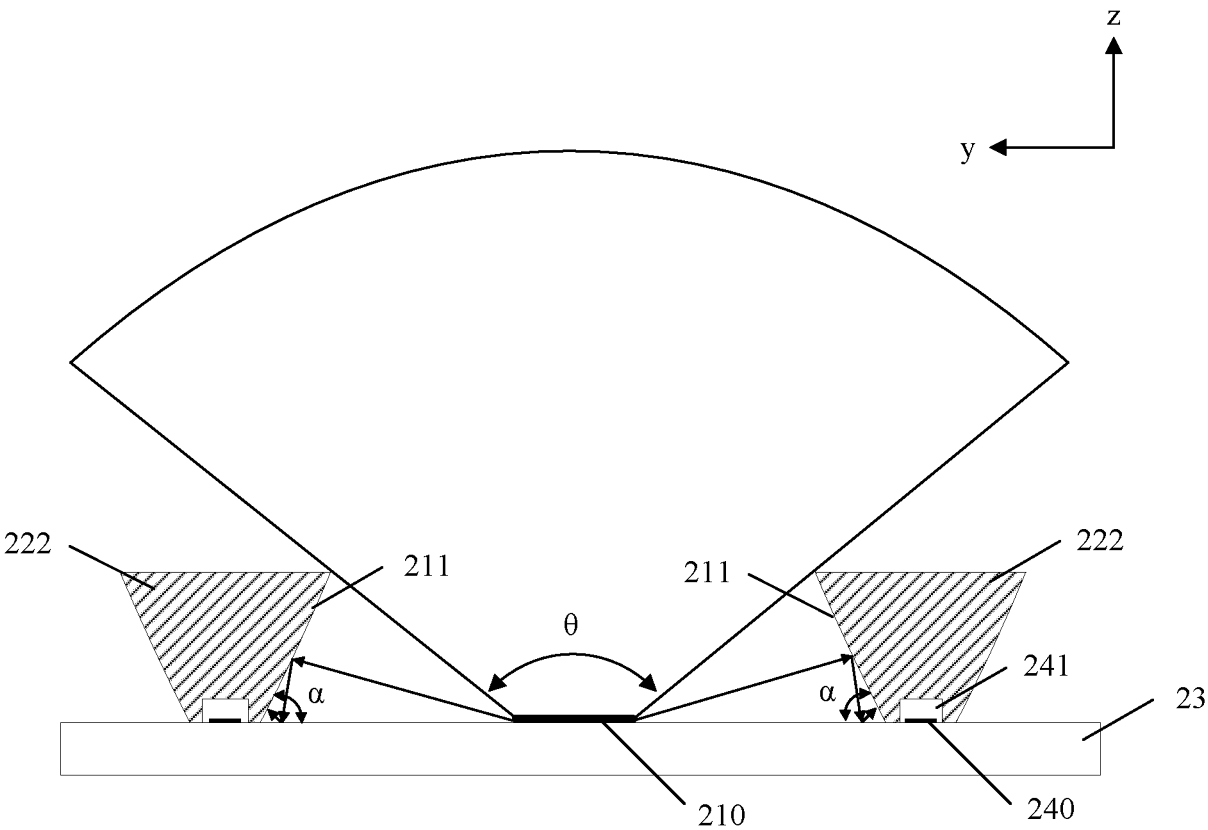

z
y
222
211
θ
211
222
241
α
α
230
210
240

FIG. 10

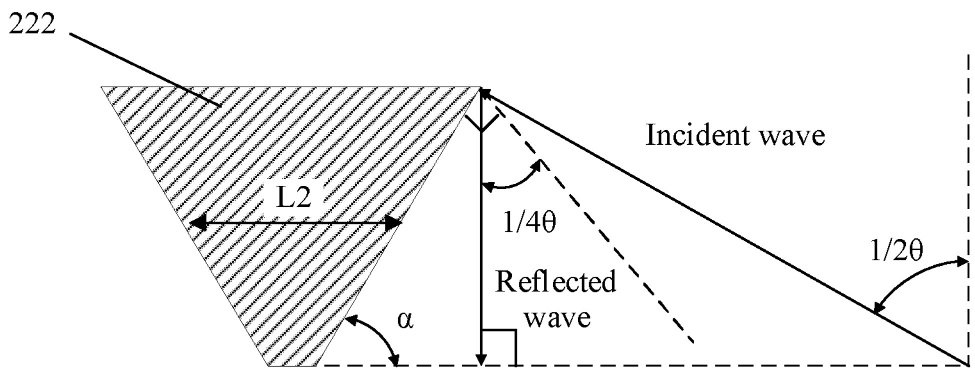

222
Incident wave
L2
1/4θ
1/2θ
Reflected
wave
α

FIG. 11

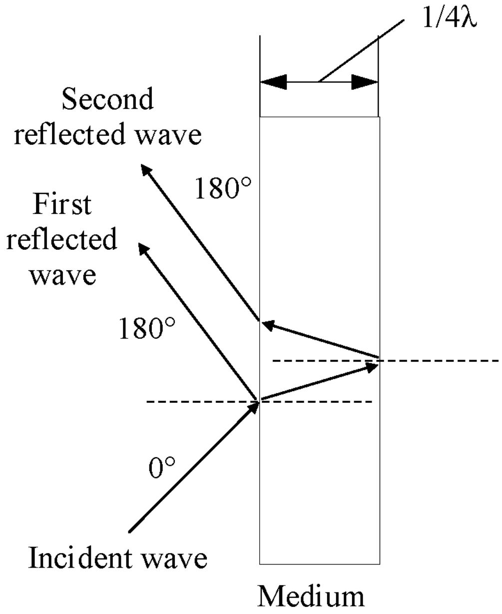

1/4λ
Second reflected wave
180°
First reflected wave
180°
0°
Incident wave
Medium

FIG. 12

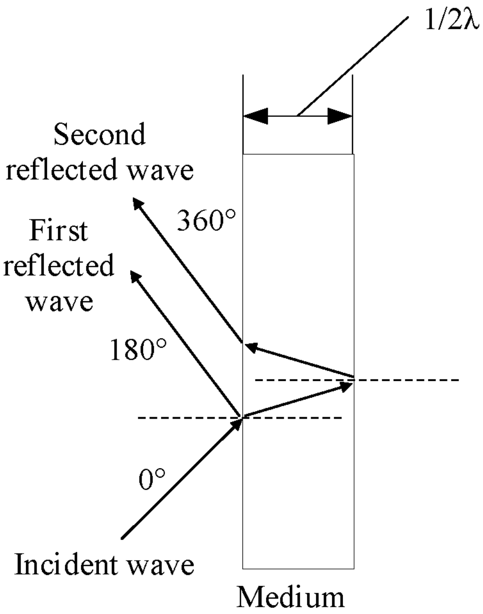

1/2λ
Second reflected wave
360°
First reflected wave
180°
0°
Incident wave
Medium

FIG. 13

(a)

(b)

FIG. 14

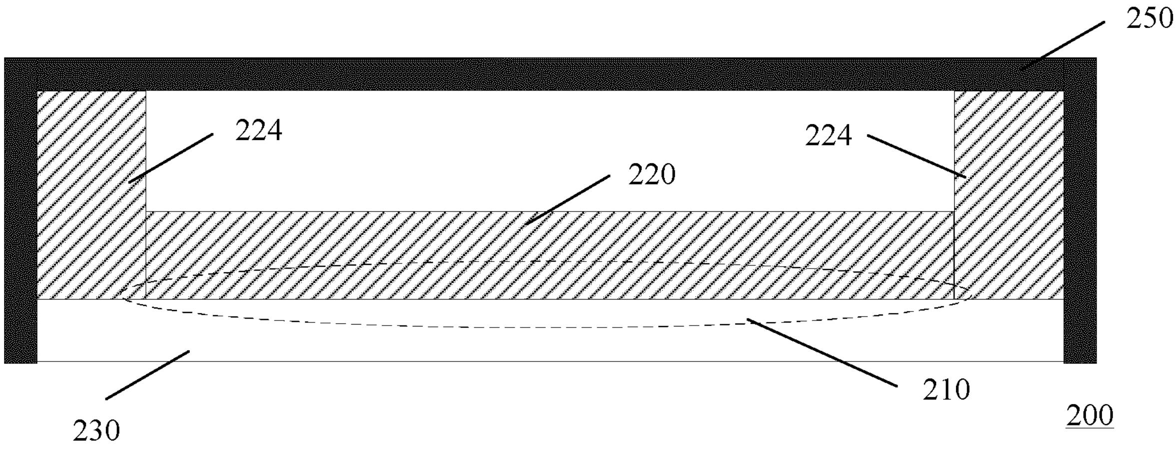


FIG. 15

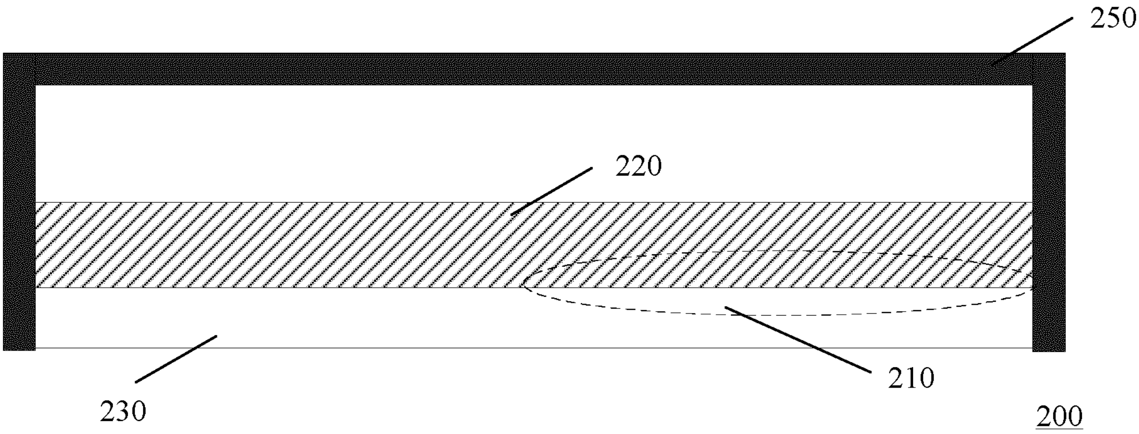


FIG. 16

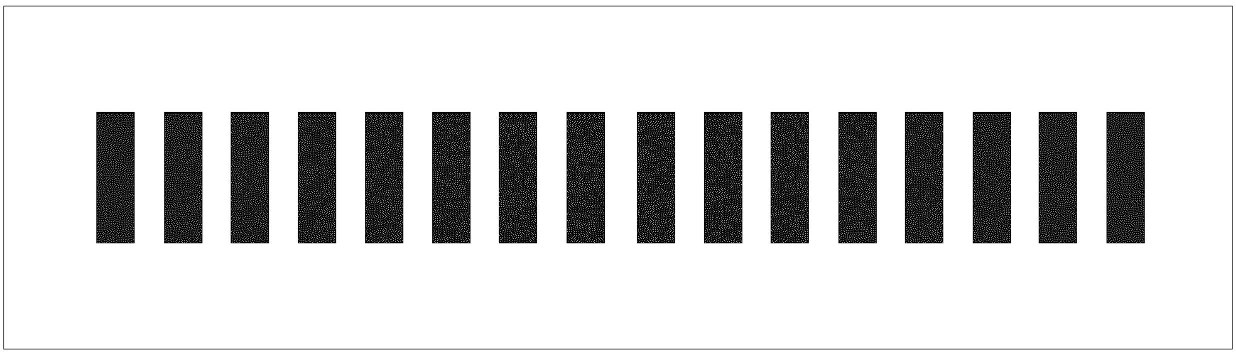


FIG. 17

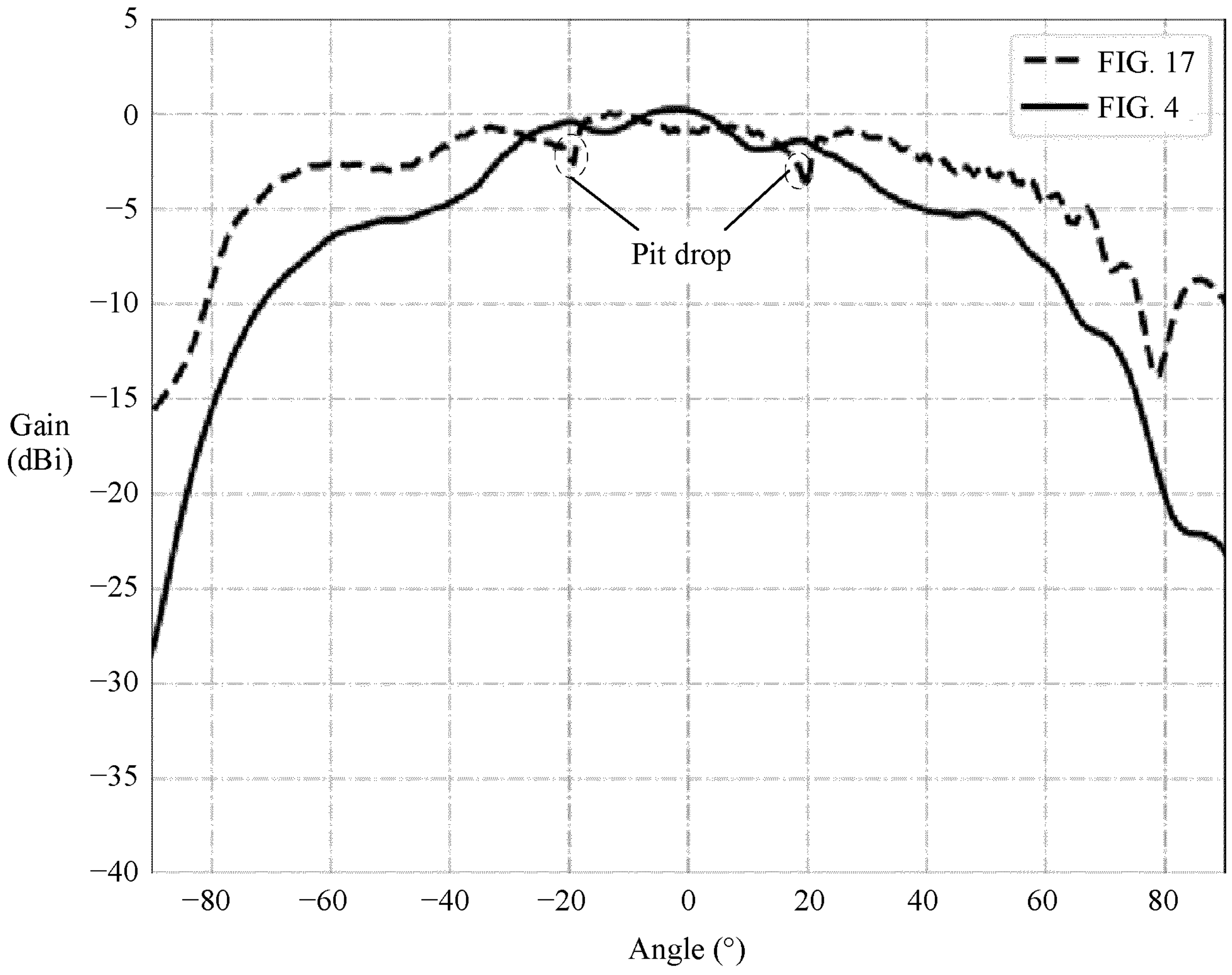


FIG. 17
FIG. 4
Pit drop
Gain (dBi)
Angle (°)
5
0
−5
−10
−15
−20
−25
−30
−35
−40
−80
−60
−40
−20
0
20
40
60
80

FIG. 18

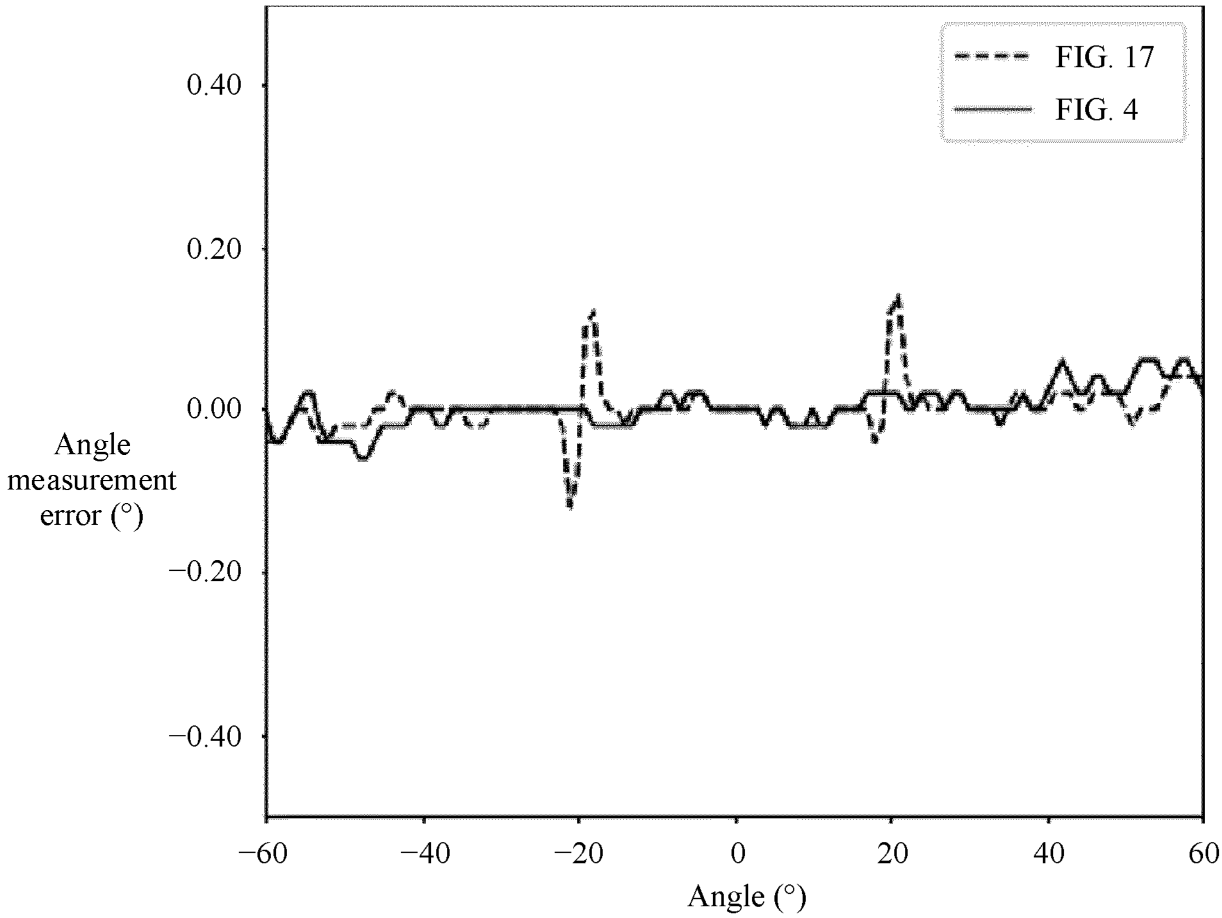
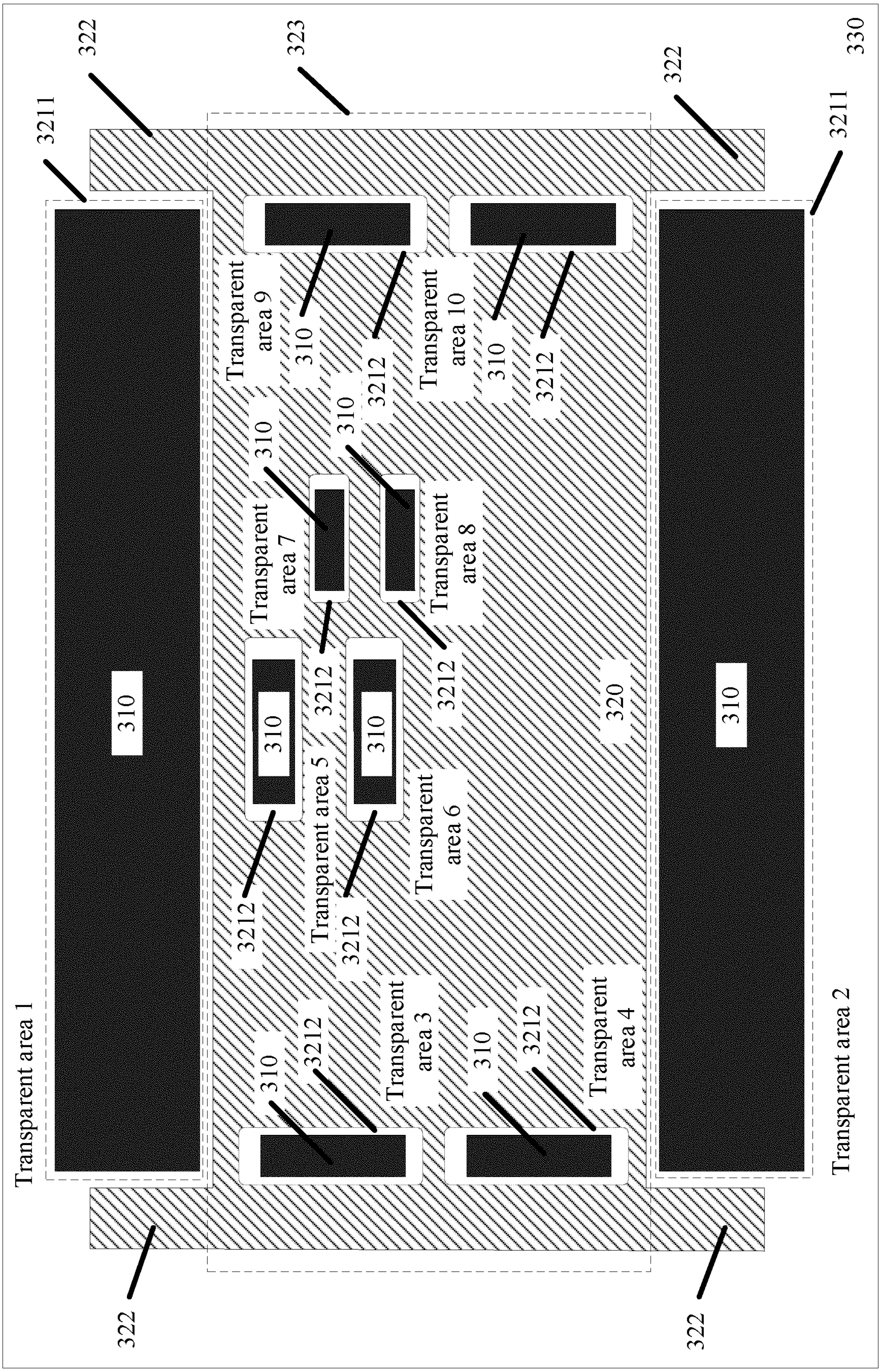


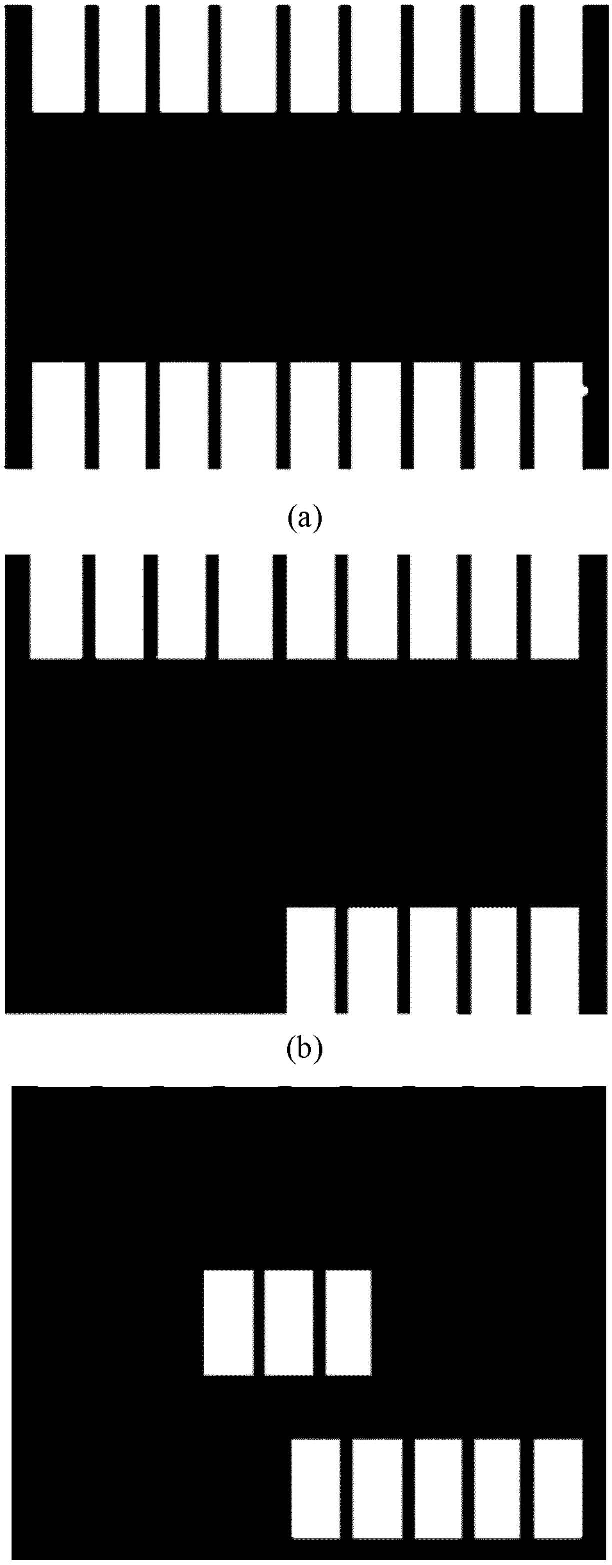
FIG. 17
FIG. 4
0.40
0.20
0.00
−0.20
−0.40
Angle
measurement
error (°)
−60
−40
−20
0
20
40
60
Angle (°)

FIG. 19


322
323
322
330
3211
3211
Transparent area 9
310
3212
Transparent area 10
310
3212
310
310
Transparent area 7
Transparent area 8
3212
3212
310
310
310
320
310
Transparent area 5
Transparent area 6
3212
3212
Transparent area 1
Transparent area 2
Transparent area 3
Transparent area 4
310
3212
310
3212
322
322

300

FIG. 20



(a) (b) (c)

FIG. 21

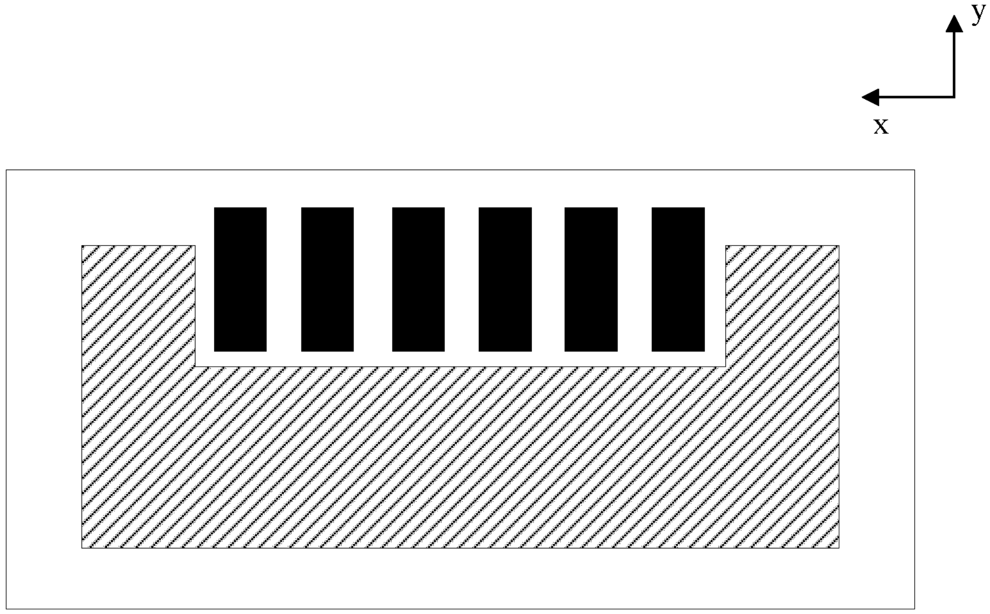


FIG. 22

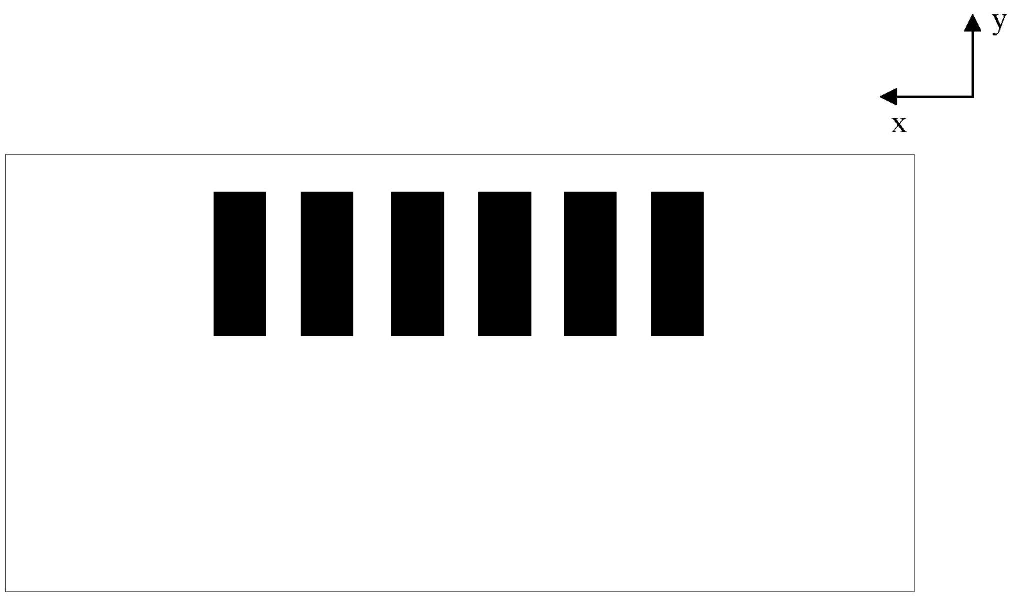


FIG. 23

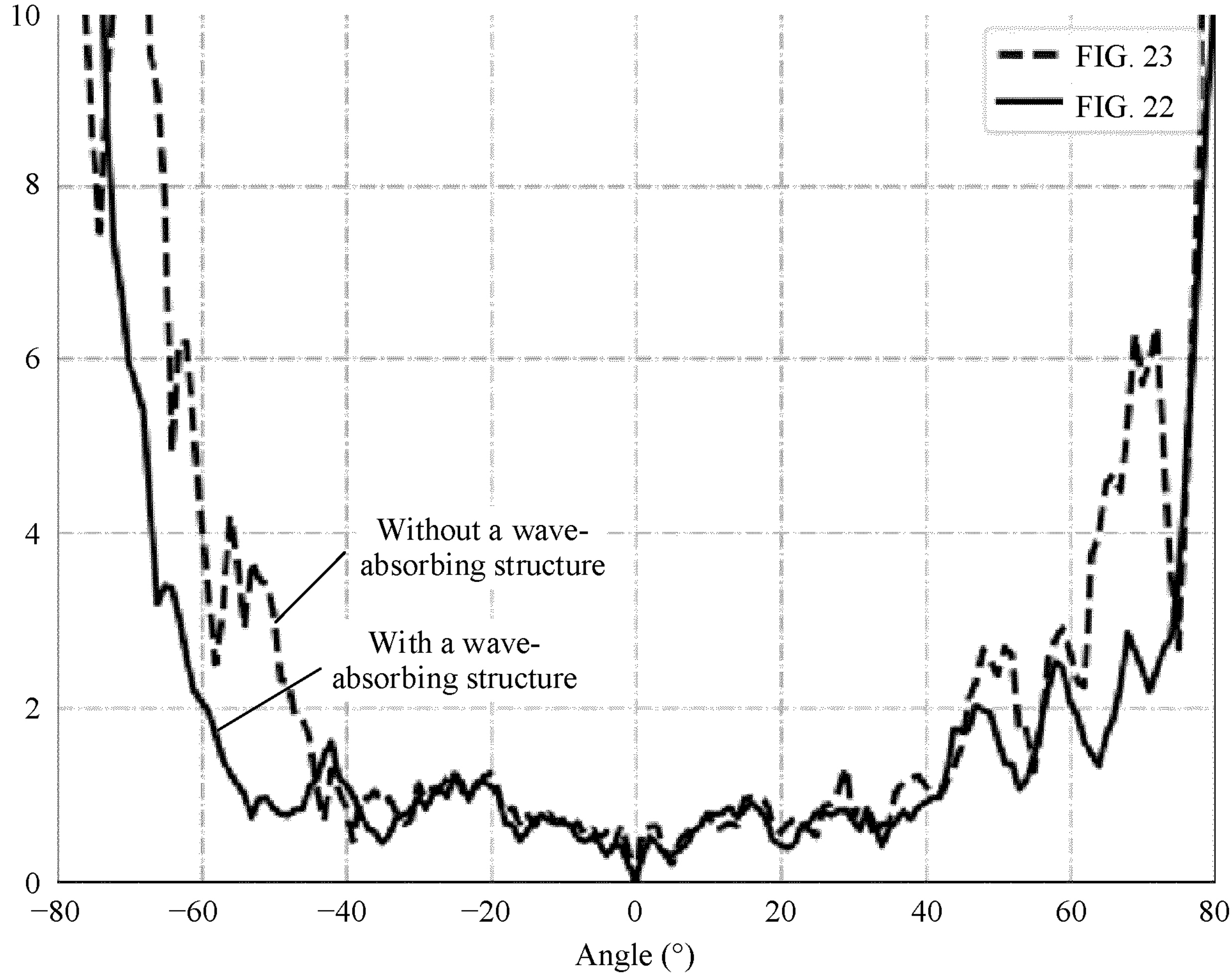
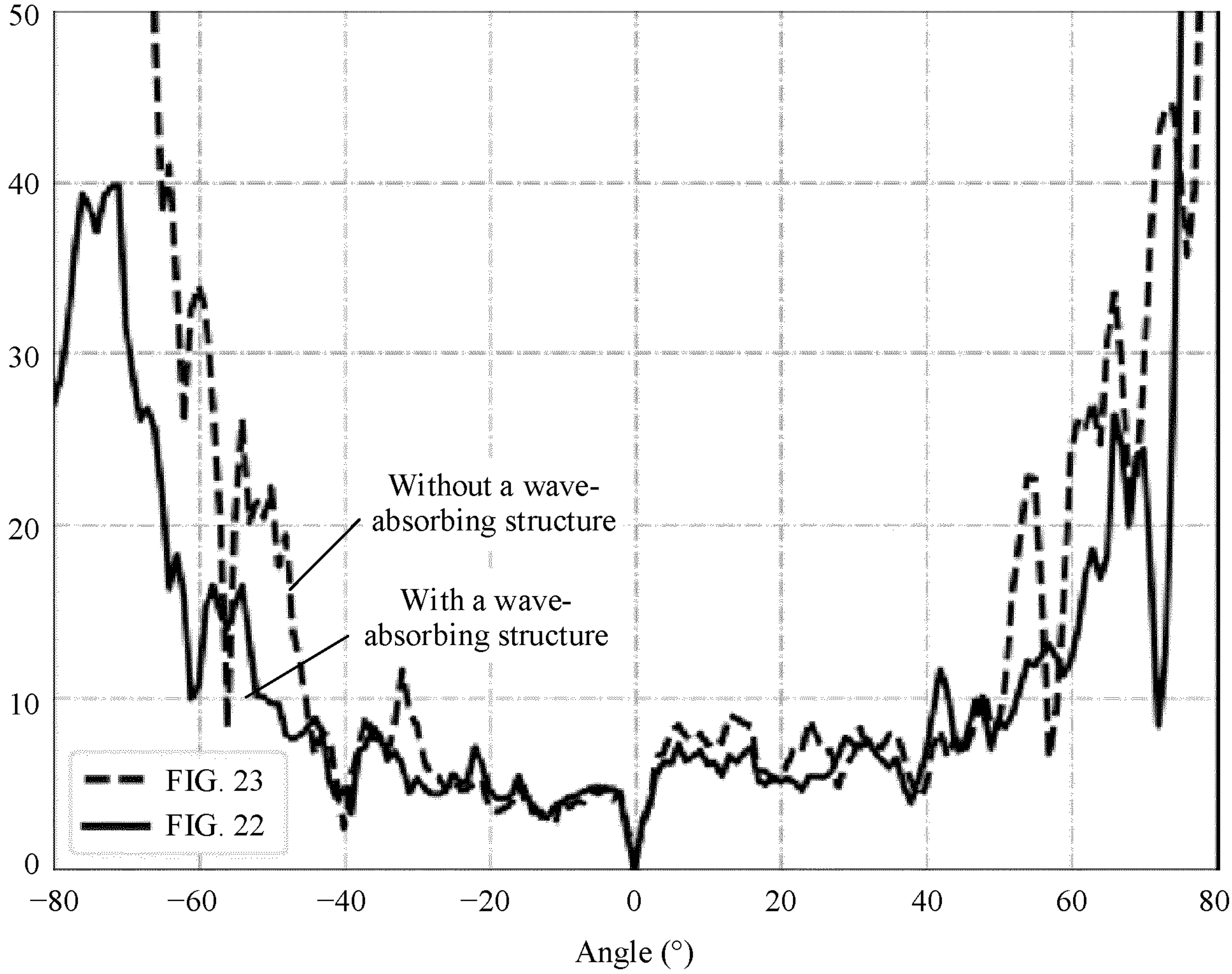

10
8
6
4
2
0
−80
−60
−40
−20
0
20
40
60
80
Angle (°)
FIG. 23
FIG. 22
Without a wave-absorbing structure
With a wave-absorbing structure

FIG. 24



50
40
30
20
10
0
−80
−60
−40
−20
0
20
40
60
80
Angle (°)
Without a wave-absorbing structure
With a wave-absorbing structure
FIG. 23
FIG. 22

FIG. 25

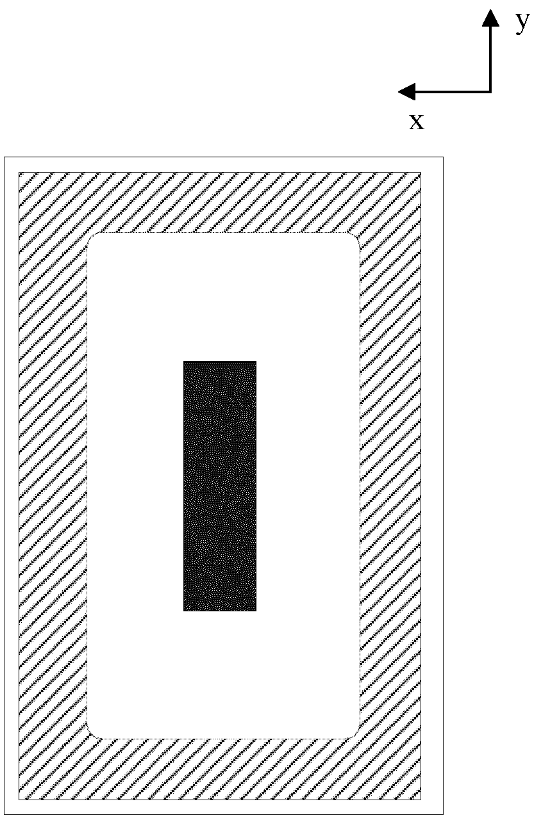


FIG. 26

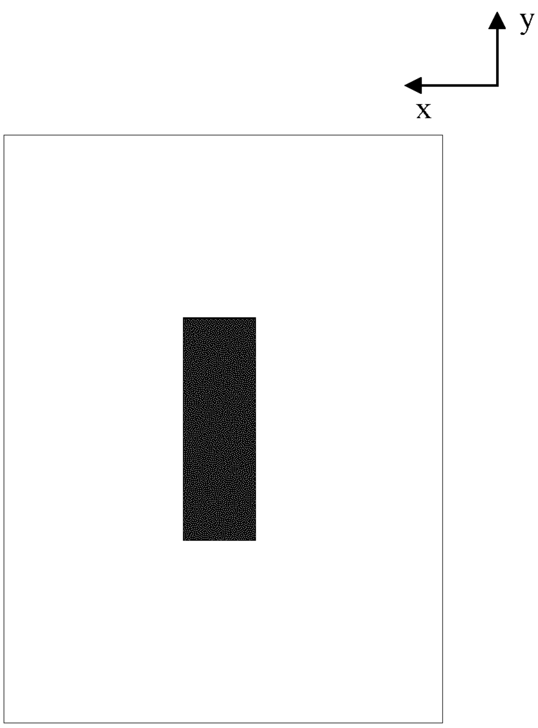
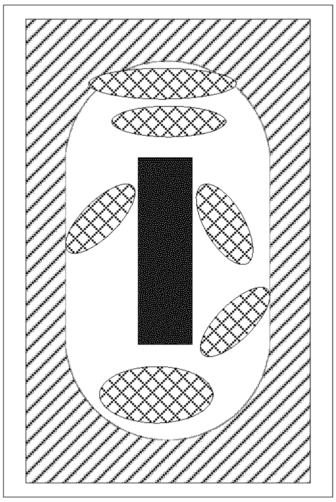
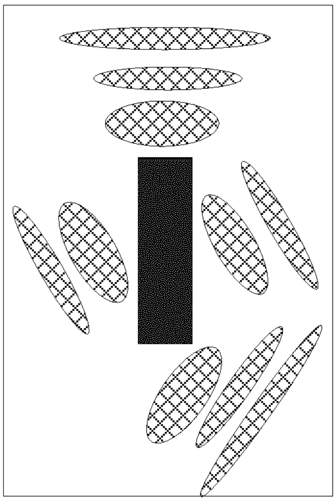


FIG. 27



Energy distribution

(a)



Energy distribution

(b)

FIG. 28

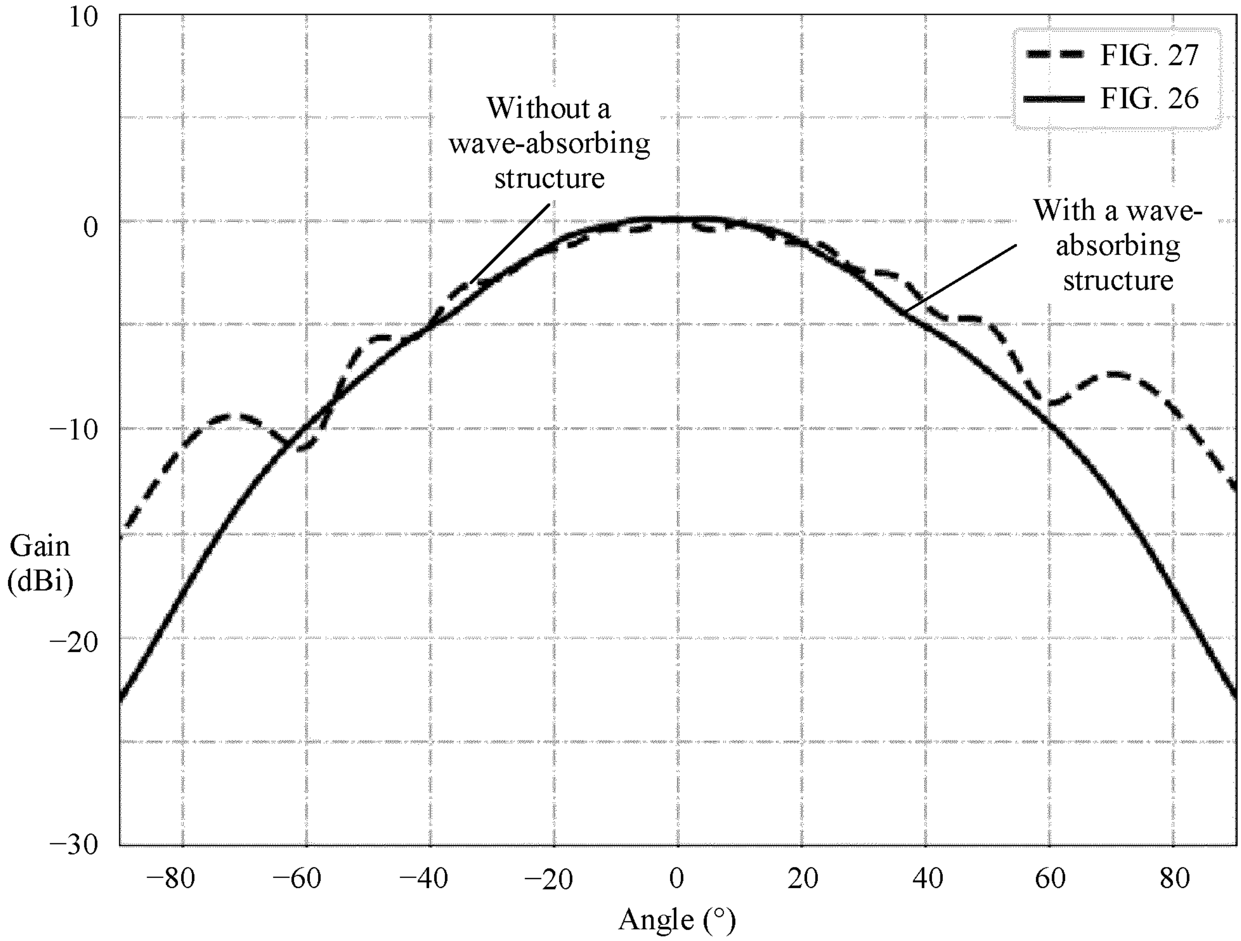

10
0
−10
−20
−30
Gain
(dBi)
−80
−60
−40
−20
0
20
40
60
80
Angle (°)
FIG. 27
FIG. 26
Without a
wave-absorbing
structure
With a wave-
absorbing
structure

FIG. 29

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/108479

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/52(2006.01)i; H01Q 17/00(2006.01)i; H01Q 1/38(2006.01)i; G01R 29/10(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; G01R

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; WPABS; ENTXT; CJFD; DWPI; ENTXTC; VEN; IEEE; CNKI: 吸波, 方向图一致性, 波吸收, 开口, 镂空, 透空, 缝, 槽, 天线, slot, around, opening, hole, aperture, gap, notch, absorb+, antenna

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005001757 A1 (HITACHI LTD.) 06 January 2005 (2005-01-06) description, paragraphs 0029-0039 and paragraph 0044; figures 1-4 and 6	1-3, 6, 7, 11-15, 20-29
X	JP 2011045036 A (SONY CORP.) 03 March 2011 (2011-03-03) description, paragraphs 0025-0038, paragraphs 0053-0058, and paragraphs 0071-0074; figures 1, 2, 5, and 11	1-3, 6-15, 20, 21, 26
X	CN 112034267 A (SHANDONG UNIVERSITY) 04 December 2020 (2020-12-04) description, paragraphs 0049-0055, and figures 2 and 3	1-3, 6-15, 20, 27-29
X	JP 2011211420 A (TOSHIBA CORP.) 20 October 2011 (2011-10-20) description, paragraphs 0010-0011, and figures 1 and 2	1
A	JP 2019041224 A (DENSO TEN LTD.) 14 March 2019 (2019-03-14) entire document	1-29

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
11 April 2022	**15 April 2022**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China** Facsimile No. **(86-10)62019451**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/108479

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2005001757 A1	06 January 2005	EP 1471598 A1	27 October 2004
		JP 2004325160 A	18 November 2004
		US 2005128134 A1	16 June 2005
JP 2011045036 A	03 March 2011	None	
CN 112034267 A	04 December 2020	None	
JP 2011211420 A	20 October 2011	US 2011234471 A1	29 September 2011
		EP 2372841 A1	05 October 2011
JP 2019041224 A	14 March 2019	None	

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