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(54) **RADIATION STRUCTURE, CIRCUIT BOARD, WAVEGUIDE ANTENNA AND COMMUNICATION APPARATUS**

(57) A radiation structure, a circuit board, a waveguide antenna, and a communication apparatus are provided, and are used in a millimeter-wave radar. The radiation structure includes a metal layer, and the metal layer includes a microstrip and a coupling structure. A width of the coupling structure is greater than a width of the microstrip. The coupling structure includes a coupling slot, and the coupling slot is formed by slitting the metal layer. A field pattern of radiation excited by a magnetic current source formed by the coupling structure matches a propagation mode of a waveguide port, to implement efficient conversion and transmission of electromagnetic energy between the microstrip and a waveguide.

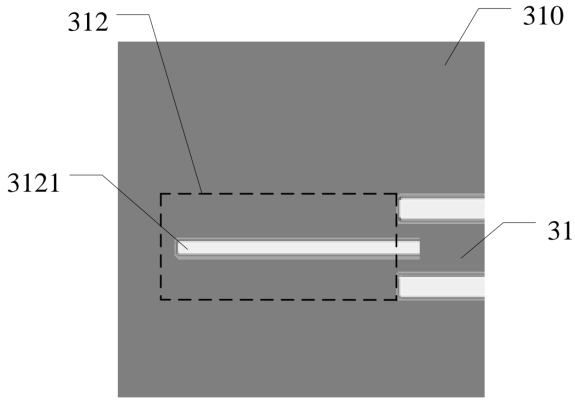

FIG. 3A

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Description

TECHNICAL FIELD

[0001] This application relates to the communication field, and specifically, to a radiation structure, a circuit board, a waveguide antenna, and a communication apparatus.

BACKGROUND

[0002] With rapid development of autonomous driving technologies, vehicle-mounted millimeter-wave radars are increasingly widely used.

[0003] In millimeter-wave radar antennas, a waveguide antenna has significant advantages over a printed antenna of a conventional printed circuit board (printed circuit board, PCB) in terms of characteristics of low loss and wide frequency band. To transfer energy into a waveguide feeder for feeding of the waveguide antenna, the waveguide antenna needs a transition structure that can convert an electromagnetic wave that is horizontally propagated on a microstrip into a vertically connected rectangular waveguide.

[0004] However, in an existing transition structure, conversion efficiency of electromagnetic energy from a microstrip to a waveguide is low, resulting in performance degradation of an entire radar system.

SUMMARY

[0005] An embodiment of this application provides a radiation structure, to implement efficient conversion and transmission of electromagnetic energy. Embodiments of this application further provide a corresponding circuit board, waveguide antenna, communication apparatus, millimeter-wave radar, transportation means, and the like.

[0006] A first aspect of this application provides a radiation structure. The radiation structure includes a metal layer, and the metal layer includes a microstrip and a coupling structure. A width of the coupling structure is greater than a width of the microstrip. The coupling structure includes a coupling slot, and the coupling slot is formed by slitting the metal layer.

[0007] In this application, the coupling slot is formed by slitting the metal layer, and a dielectric layer is below the metal layer. The metal layer is slit to expose the lower dielectric layer, to form the coupling slot. When the radiation structure is used in a waveguide antenna, the coupling structure is coupled to a waveguide port on an upper layer, and the coupling structure is a region used for coupling to the waveguide port on the upper layer.

[0008] In this application, the radiation structure is specifically configured to implement a transition function of the waveguide antenna. After the radiation structure is attached to the waveguide port of the waveguide antenna, the microstrip may excite TE_{10} (an electromagnetic transmission mode with a lowest cut-off frequency in a waveguide) field mode distribution in a resonant cavity (a cavity formed by the coupling structure), and the coupling slot on the metal layer in the resonant cavity may effectively cut off a transverse current of the metal layer in the resonant cavity. According to the Babinet's principle, the coupling slot is equivalent to a magnetic current source, and is used to convert a guided electromagnetic wave in the resonant cavity into a radiated electromagnetic wave. A field pattern radiated by the magnetic current source formed by the coupling slot matches a TE_{10} propagation mode of the waveguide port, to implement efficient conversion and transmission of electromagnetic energy between the microstrip and the waveguide, that is, implement efficient conversion from a microstrip transverse electromagnetic mode (transverse electromagnetic mode, TEM) to a waveguide TE_{10} transmission mode.

[0009] According to the first aspect, the radiation structure includes the metal layer, and the metal layer includes the microstrip and the coupling structure. The width of the coupling structure is greater than the width of the microstrip. The coupling structure includes the coupling slot, and the coupling slot is formed by slitting the metal layer. The field pattern of radiation excited by the magnetic current source formed by the coupling structure matches the propagation mode of the waveguide port, to implement efficient conversion and transmission of the electromagnetic energy between the microstrip and the waveguide.

[0010] In a possible implementation of the first aspect, the coupling slot is located in the middle of the coupling structure.

[0011] In this possible implementation, when the coupling slot is located in the middle of the coupling structure, currents on two sides of the coupling slot are mirror-symmetric. In this way, an electric field distributed in upper-layer space of the coupling structure is excited. This improves implementability of the solution.

[0012] In a possible implementation of the first aspect, the coupling slot is located at a current node of the coupling structure.

[0013] In this possible implementation, the coupling slot is specifically located at the current node of the coupling structure, so that currents on two sides of the coupling slot are mirror-symmetric. In this way, an electric field distributed in upper-layer space of the coupling structure is excited. This improves implementability of the solution.

[0014] In a possible implementation of the first aspect, currents on two sides of the coupling slot are mirror-symmetric.

[0015] In this possible implementation, the currents on the two sides of the coupling slot are mirror-symmetric. In this way, an electric field distributed in upper-layer space of the coupling structure is excited. This improves implementability of the solution.

[0016] In a possible implementation of the first aspect, a wide structure is disposed in the middle of the coupling slot, and a width of the wide structure is greater than a width of the coupling slot.

[0017] In this possible implementation, the wide structure disposed in the middle of the coupling slot can adjust radiation impedance of the coupling slot, further improving conversion efficiency.

[0018] In a possible implementation of the first aspect, a maximum width of the wide structure is at least 0.1 millimeter greater than the width of the coupling slot.

[0019] In this possible implementation, the wide structure may be a rectangular structure, or an irregular gradient structure, provided that a width of a widest position of the wide structure is 0.1 millimeter greater than the width of the coupling slot. This improves implementability of the solution.

[0020] In a possible implementation of the first aspect, the metal layer further includes a transitional structure, the transitional structure is configured to connect the microstrip and the coupling structure, and the transitional structure includes an impedance matching structure and a delay structure; a feeder width of the impedance matching structure gradually changes from a first width to a second width; and the delay structure is configured to divide the microstrip into a first signal line and a second signal line, and in the delay structure, a length of the first signal line is greater than that of the second signal line.

[0021] In this possible implementation, the impedance matching structure is configured to implement impedance transformation from the microstrip to the two differential signal lines, and the delay structure is configured to implement differential mode transmission on the two differential signal lines. This improves implementability of the solution.

[0022] In a possible implementation of the first aspect, the radiation structure is used in a waveguide antenna, a length of the impedance matching structure is 0.2 to 0.25 times a wavelength of the waveguide antenna, the length of the first signal line is greater than 0.45 to 0.55 times the wavelength of the waveguide antenna of the second signal line, and a length of the coupling slot is 0.45 to 0.55 times the wavelength of the waveguide antenna.

[0023] In this possible implementation, sizes of the impedance matching structure, the first signal line, the second signal line, and the coupling slot are related to the wavelength of the waveguide antenna. This improves implementability of the solution.

[0024] In a possible implementation of the first aspect, the coupling slot is formed by corroding, engraving, or etching the metal layer.

[0025] In this possible implementation, the coupling slot is formed by corroding, engraving, or etching the metal layer, that is, a slot is formed by corroding, engraving, or etching a middle position of the metal layer of the coupling structure, to expose the dielectric layer below the metal layer to form the coupling structure.

[0026] A second aspect of this application provides a circuit board. The circuit board includes the radiation structure according to the first aspect or any one of the possible implementations of the first aspect.

[0027] In a possible implementation of the second aspect, the circuit board further includes a short-circuit structure, and the short-circuit structure surrounds the radiation structure.

[0028] In this possible implementation, the short-circuit structure is configured to surround the radiation structure, and is specifically configured to form a shielding structure, to allow a metal layer and a dielectric layer to form a closed resonant cavity, limiting an electric field excited by a coupling structure to being mainly distributed in the resonant cavity. This avoids leakage and improves transmission efficiency.

[0029] In a possible implementation of the second aspect, the short-circuit structure is a plurality of continuously arranged metal pillars.

[0030] In this possible implementation, the short-circuit structure is the plurality of continuously arranged metal pillars, that is, the short-circuit structure is in a cylindrical shape. This improves implementability of the solution.

[0031] A third aspect of this application provides a waveguide antenna. The waveguide antenna includes a waveguide structure and the radiation structure according to the first aspect or any one of the possible implementations of the first aspect. The waveguide structure includes a waveguide port and a protrusion structure; the protrusion structure is disposed around the waveguide port, the protrusion structure is attached to the radiation structure, and the protrusion structure is located around a coupling slot; and the waveguide port is configured to couple, to the waveguide structure, energy radiated by the radiation structure.

[0032] According to the third aspect, the rectangular waveguide port formed by the protrusion structure on a lower end face of the waveguide structure is aligned and attached to the coupling slot on an upper surface layer of a PCB circuit board in the radiation structure. In other words, the protrusion structure is attached to the radiation structure, and the waveguide port is configured to couple, to the waveguide structure, the energy radiated by the radiation structure.

[0033] In a possible implementation of the third aspect, the protrusion structure is disposed on the top and/or two sides of the waveguide port.

[0034] In this possible implementation, the protrusion structure may be disposed on the top of the waveguide port, or on the two sides of the waveguide port as a discrete structure, or may be disposed on the top of the waveguide port and on the two sides of the waveguide port. This improves implementability of the solution.

[0035] In a possible implementation of the third aspect, a length of the protrusion structure along a long side of the waveguide port is 0.2 to 0.3 times a wavelength of the waveguide antenna.

[0036] In this possible implementation, length sizes and a spacing of protrusion structures along the long side of the waveguide port are designed based on an approximately 0.25 wavelength of an intermediate frequency of a 76 GHz to 81 GHz frequency band. This electrical size can ensure transmission suppression (namely, a stopband) of an electromagnetic wave in the frequency band.

[0037] In a possible implementation of the third aspect, there are a plurality of protrusion structures, and a spacing between the plurality of protrusion structures is 0.2 to 0.3 times the wavelength of the waveguide antenna.

[0038] In this possible implementation, a spacing between the plurality of protrusion structures is 0.2 to 0.3 times the wavelength of the waveguide antenna, ensuring isolation between different channels.

[0039] In a possible implementation of the third aspect, there are a plurality of radiation structures and a plurality of waveguide structures, and the plurality of waveguide structures are arranged in parallel at a preset spacing.

[0040] In this possible implementation, the plurality of waveguide structures are arranged in parallel at the preset spacing, to form multi-port transition. Adjacent transition ports maintain complete structures without sharing, further ensuring isolation between different channels.

[0041] In a possible implementation of the third aspect, the preset spacing is 3 millimeters.

[0042] In this possible implementation, the preset spacing is 3 millimeters, to ensure isolation between different channels. This improves implementability of the solution.

[0043] A fourth aspect of this application provides a communication apparatus. The communication apparatus includes the radiation structure according to the first aspect or any one of the possible implementations of the first aspect, the circuit board according to the second aspect or any one of the possible implementations of the second aspect, or the waveguide antenna according to the third aspect or any one of the possible implementations of the third aspect.

[0044] A fifth aspect of this application provides a millimeter-wave radar. The millimeter-wave radar includes the radiation structure according to the first aspect or any one of the possible implementations of the first aspect, the circuit board according to the second aspect or any one of the possible implementations of the second aspect, or the waveguide antenna according to the third aspect or any one of the possible implementations of the third aspect.

[0045] A sixth aspect of this application provides a transportation means. The transportation means includes the millimeter-wave radar according to the fifth aspect.

[0046] In embodiments of this application, the radiation structure includes the metal layer, and the metal layer includes the microstrip and the coupling structure. The width of the coupling structure is greater than the width of the microstrip. The coupling structure includes the coupling slot, and the coupling slot is formed by slitting the metal layer. The field pattern of radiation excited by the magnetic current source formed by the coupling structure matches the propagation mode of the waveguide port, to implement efficient conversion and transmission of the electromagnetic energy between the microstrip and the waveguide.

BRIEF DESCRIPTION OF DRAWINGS

[0047]

FIG. 1 is a diagram of an architecture of an autonomous driving sensor of a vehicle;
FIG. 2A to FIG. 2C are diagrams of a structure of a waveguide antenna;
FIG. 3A and FIG. 3B are diagrams of an embodiment of a radiation structure according to an embodiment of this application;
FIG. 4 is a diagram of another embodiment of a radiation structure according to an embodiment of this application;
FIG. 5 is a diagram of another embodiment of a radiation structure according to an embodiment of this application;
FIG. 6 is a diagram of a delay structure according to an embodiment of this application;
FIG. 7 is a diagram of an embodiment of a circuit board according to an embodiment of this application;
FIG. 8 is a diagram of an embodiment of a waveguide antenna according to an embodiment of this application;
FIG. 9 is a diagram of a protrusion structure according to an embodiment of this application;
FIG. 10A to FIG. 10D are diagrams of another embodiment of a waveguide antenna according to an embodiment of this application;
FIG. 11 is a diagram of electric field distribution of a waveguide antenna according to an embodiment of this application;
FIG. 12 is a diagram of stopband range analysis for a protrusion structure according to an embodiment of this application;
FIG. 13 is a diagram of z-direction tolerance analysis for an insertion loss according to an embodiment of this

application;
FIG. 14 is a diagram of z-direction tolerance analysis for wave isolation according to an embodiment of this application;
FIG. 15 is a diagram of impedance bandwidth analysis according to an embodiment of this application;
FIG. 16 is a diagram of in-band insertion loss analysis according to an embodiment of this application;
FIG. 17 and FIG. 18 are diagrams of unit z-direction tolerance analysis according to an embodiment of this application;
FIG. 19 is a diagram of a structure of a communication apparatus according to an embodiment of this application; and
FIG. 20 is a diagram of structures of a transportation means and a millimeter-wave radar according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0048] The following describes embodiments of this application with reference to the accompanying drawings. It is clear that the described embodiments are merely some rather than all of embodiments of this application. A person of ordinary skill in the art may learn that, with development of technologies and emergence of a new scenario, the technical solutions provided in embodiments of this application are also applicable to a similar technical problem.

[0049] In the specification, claims, and accompanying drawings of this application, the terms "first", "second", and so on are intended to distinguish between similar objects but do not necessarily indicate a specific order or sequence. It should be understood that the data termed in such a way are interchangeable in appropriate circumstances so that embodiments described herein can be implemented in an order other than the order illustrated or described herein. In addition, the terms "include" and "have" and any other variants are intended to cover the non-exclusive inclusion. For example, a process, method, system, product, or device that includes a list of steps or units is not necessarily limited to those expressly listed steps or units, but may include other steps or units not expressly listed or inherent to such a process, method, product, or device.

[0050] The specific term "example" herein means "used as an example, embodiment or illustration". Any embodiment described as an "example" is not necessarily explained as being superior or better than other embodiments.

[0051] In addition, to better describe this application, numerous specific details are given in the following specific implementations. A person skilled in the art should understand that this application can also be implemented without some specific details. In some instances, methods, means, elements, and circuits that are well-known to a person skilled in the art are not described in detail, so that the subject matter of this application is highlighted.

[0052] An embodiment of this application provides a radiation structure, to implement efficient conversion and transmission of electromagnetic energy. Embodiments of this application further provide a corresponding circuit board, waveguide antenna, communication apparatus, millimeter-wave radar, transportation means, and the like. Details are separately described in the following.

[0053] The following uses an example to describe an application scenario related to embodiments of this application.

[0054] With rapid development of autonomous driving technologies, vehicle-mounted millimeter-wave radars are increasingly widely used. In an in-vehicle millimeter-wave radar communication system, a multiple-in multiple-out (multiple-in multiple-out, MIMO) system radar is usually used to detect object information in a form of a virtual array. For autonomous driving, this is mainly reflected in a vehicle driving scenario, for example, autonomous vehicle following, lane change assistance, and autonomous parking.

[0055] FIG. 1 shows a conventional distributed autonomous driving sensor solution, which uses one long-range radar (LRR) installed at a front of a vehicle body, and six short-range radars (SRR). The LRR generally requires detection effect of more than 200 meters. A target function is to detect and provide a warning for a distant target directly in front of the vehicle body, mainly corresponding to a vehicle-mounted scenario like active cruise and braking assistance. For an antenna, this imposes a high requirement for a gain, while requirements for a beamwidth and angular resolution are lower. The SRR is mainly installed at four corners of a vehicle. A target function is to accurately detect and identify information about an obstacle around the vehicle. Main application scenarios are autonomous parking, lane change assistance, and blind spot detection. For an antenna, this imposes high requirements for a beamwidth and angular resolution.

[0056] Based on the foregoing analysis, the LRR requires higher antenna efficiency to implement more distant detection, and the SRR requires more channels to improve the angular resolution. However, in millimeter-wave radar antennas, in terms of characteristics of low loss and wide frequency band, a waveguide antenna has significant advantages over a printed antenna of a conventional printed circuit board (printed circuit board, PCB) in high efficiency and wide frequency band. For example, a 77 GHz (millimeter-wave frequency band) vehicle-mounted radar antenna may be used by the vehicle for object detection and communication in a self-driving scenario or an autonomous driving scenario.

[0057] With evolution and improvement of a system function, a radar antenna develops toward low loss, large bandwidth, and large panel. However, for introduction of a large panel requirement, system channels need to be added as many as possible in limited system space, to expand a virtual aperture. In a waveguide antenna, a radio frequency chip is generally a microstrip. To transfer energy into a waveguide feeder for feeding of the waveguide antenna, the waveguide antenna needs a transition structure that can convert an electromagnetic wave that is horizontally propagated on a microstrip into a vertically connected rectangular waveguide. In addition, a radiation pattern and a feeder of a PCB antenna are both located on an outer surface layer of a PCB, and there is a limitation on trace crossings in a multi-channel multi-trace scenario. The waveguide antenna is a three-dimensional structure, and waveguide feeders and antennas may be designed on different layers, implementing a higher-density trace. Therefore, more channels for feeder tracing can be flexibly implemented by adding a trace layer in a vertical dimension.

[0058] In the foregoing scenario, the transition structure needs to have a low insertion loss, and has a very good tolerance capability in horizontal and vertical directions. A tolerance capability of a device means robustness, and specifically means that performance can still meet a requirement when an actual size, a material property, and the like of the component deviate from a design requirement and are uncertain. A stronger tolerance capability indicates better robustness. In addition, considering a large quantity of channels and integrated design, a transition device needs to be designed in a small size. Therefore, to implement large-scale waveguide antenna and system integration design, a transition structure having a small size, a low insertion loss, and strong tolerance becomes an important component for ensuring high-performance and stable operation of a system.

[0059] As shown in FIG. 2A, a waveguide antenna includes a radio frequency chip 210, a horizontal microstrip 220, a microstrip-waveguide transition structure 230, a vertical rectangular waveguide feeder 240, and an antenna 250. An electromagnetic wave transmission path is: radio frequency chip 210 - horizontal microstrip 220 - microstrip-waveguide transition structure 230 - vertical rectangular waveguide feeder 240 - antenna 250. As shown in FIG. 2B and FIG. 2C, in an example of a specific structure of the waveguide antenna, the waveguide antenna includes the radio frequency chip 210, the microstrip 220, the transition structure 230, the waveguide feeder 240, and the antenna 250.

[0060] The following describes, with reference to the foregoing application scenario, a radiation structure, a circuit board, a waveguide antenna, a communication apparatus, a millimeter-wave radar, and a transportation means that are provided in embodiments of this application.

[0061] As shown in FIG. 3A, an embodiment of a radiation structure provided in an embodiment of this application includes a metal layer 310.

[0062] For example, the metal layer 310 may be a part or all of the microstrip 220 in the waveguide antenna and the transition structure 230 shown in FIG. 2A to FIG. 2C. In other words, the metal layer 310 may be used as the transition structure 230 and a part or all of the microstrip 220 to form a waveguide antenna. However, a specific structure of the radiation structure is different from that in FIG. 2A to FIG. 2C.

[0063] Specifically, the metal layer 310 includes a microstrip 311 and a coupling structure 312. A width (a longitudinal length shown in FIG. 3A) of the coupling structure 312 is greater than a width of the microstrip 311. It should be understood that the dashed box in FIG. 3A merely indicates an approximate range of the coupling structure 312, provided that the width of the coupling structure 312 is greater than the width of the microstrip 311 and a resonant cavity can be formed. A specific shape and structure of the coupling structure 312 are not limited in this embodiment of this application. When the radiation structure is used in a waveguide antenna, the coupling structure 312 is coupled to a waveguide port on an upper layer, and the coupling structure 312 is a region used for coupling to the waveguide port on the upper layer.

[0064] The coupling structure 312 includes a coupling slot 3121. The coupling slot 3121 is formed by slitting the metal layer 310. Further refer to FIG. 2B. A dielectric layer is below the microstrip 220 and the transition structure 230 in FIG. 2B. That is, after the metal layer 310 is slit, the dielectric layer below is exposed, to form the coupling structure 312.

[0065] It should be understood that, in the radiation structure provided in this embodiment of this application, the coupling structure may be understood as a radiation patch (patch). The radiation patch is a thin metal layer pattern that meets a shape requirement and that is engraved on a surface of a PCB circuit board, or a structure that has a radiation function. The PCB circuit board may be sequentially divided into an upper metal layer, a dielectric layer, and a lower metal layer from top to bottom. The lower metal layer is a metal ground layer of the microstrip and the radiation patch, and may form a dielectric cavity to implement effective radiation of the radiation patch. The dielectric layer provides a required support thickness and a corresponding dielectric constant for the microstrip 3231 and the radiation patch. The upper metal layer includes the radiation structure and a radio frequency chip.

[0066] The radiation structure is specifically configured to implement a transition function of the waveguide antenna. After the radiation structure is attached (coupled) to the waveguide port of the waveguide antenna, the microstrip 311 may excite TE_{10} (an electromagnetic transmission mode with a lowest cut-off frequency in a waveguide) field mode distribution in the resonant cavity (a cavity formed by the coupling structure 312), and the coupling slot 3121 on the metal layer 310 in the resonant cavity may effectively cut off a transverse current of the metal layer 310 in the resonant cavity. According to the Babinet's principle, the coupling slot 3121 is equivalent to a magnetic current source, and is used to convert a guided electromagnetic wave in the resonant cavity into a radiated electromagnetic wave. A field pattern radiated by the magnetic current source formed by the coupling slot 3121 matches a TE_{10} propagation mode of the waveguide port, to implement efficient conversion and transmission of electromagnetic energy between the microstrip and the waveguide, that is, implement efficient conversion from a microstrip transverse electromagnetic mode (transverse electromagnetic mode, TEM) to a waveguide TE_{10} transmission mode. In other words, the field pattern of radiation excited by the magnetic current source formed by the coupling structure 312 matches the propagation mode of the waveguide port, to implement efficient conversion and transmission of the electromagnetic energy between the microstrip and the waveguide.

[0067] Optionally, as shown in FIG. 3B, a wide structure 3122 is disposed in the middle of the coupling slot 3121. The wide structure 3122 may be located in a middle position (a horizontal direction shown in FIG. 3B) of the coupling slot 3121. A width (a vertical length shown in FIG. 3B) of the wide structure 3122 is greater than the width of the coupling slot 3121. Optionally, a maximum width of the wide structure 3122 is at least 0.1 millimeter greater than the width of the coupling slot 3121. The wide structure 3122 may be a rectangular structure, or an irregular gradient structure, provided that a width of a widest position of the wide structure 3122 is 0.1 millimeter greater than the width of the coupling slot 3121. This improves implementability of the solution. A specific shape of the wide structure 3122 is not limited in this embodiment of this application.

[0068] As shown in FIG. 4, another embodiment of a radiation structure provided in an embodiment of this application includes a metal layer 410.

[0069] For example, the radiation structure may correspond to a part or all of the microstrip in the waveguide antenna and the transition structure shown in FIG. 2A to FIG. 2C, but a specific structure of the radiation structure differs.

[0070] Specifically, the metal layer 410 includes a microstrip 411, a coupling structure 412, and a transitional structure. The transitional structure is configured to connect the microstrip 411 and the coupling structure 412.

[0071] The following separately describes the coupling structure 412 and the transitional structure in detail.

I. Coupling structure

[0072] Both the coupling structure 412 and the microstrip 411 are a part of the metal layer. A difference lies in that a width (a longitudinal length shown in FIG. 4) of the coupling structure 412 is greater than a width of the microstrip 411. It should be understood that the dashed box in FIG. 4 merely indicates an approximate range of the coupling structure 412, provided that the width of the coupling structure 412 is greater than the width of the microstrip 411 and a resonant cavity can be formed. A specific shape and structure of the coupling structure 412 are not limited in this embodiment of this application.

[0073] The coupling structure 412 further includes a coupling slot 4121. The coupling slot 4121 is located in the middle of the coupling structure 412, that is, in a longitudinal direction shown in FIG. 4, the coupling slot 4121 is located in a middle position of a longitudinal direction of the coupling structure 412. More specifically, as shown in FIG. 5, the coupling slot 4121 is located at a current node of the coupling structure 412, that is, a current at the coupling slot 4121 is zero, and currents on two sides of the coupling slot 4121 (in current directions shown by horizontal arrows in FIG. 5) are mirror-symmetric. In this way, an electric field distributed in upper-layer space of the coupling structure 412 (in electric field directions shown by longitudinal arrows in FIG. 5) is excited.

[0074] Further, the coupling slot 4121 is formed by slitting the metal layer 410. Specifically, the coupling slot 4121 is formed by corroding, engraving, or etching the metal layer 410, that is, a slot is formed by corroding, engraving, or etching a longitudinal middle position of the metal layer 410 of the coupling structure 412, to expose a dielectric layer below the metal layer 410 to form the coupling slot 4121.

[0075] Optionally, a wide structure 4122 is disposed in a middle position of the coupling slot 4121. The wide structure 4122 may be located in the middle position (for example, a horizontal direction shown in FIG. 4) of the coupling slot 4121. On the coupling slot 4121 formed by corroding, engraving, or etching the metal layer 410, the middle position of the coupling slot 4121 is additionally corroded, engraved, or etched upward and downward in the longitudinal direction shown in FIG. 4, exposing the dielectric layer to obtain the wide structure 4122. A width (a vertical length shown in FIG. 4) of the wide structure 4122 is greater than the width of the coupling slot 4121. Optionally, a maximum width of the wide structure 4122 is at least 0.1 millimeter greater than the width of the coupling slot 4121. The wide structure 4122 may be a rectangular structure, or an irregular gradient structure, provided that a width of a widest position of the wide structure 4122 is 0.1 millimeter greater than the width of the coupling slot 4121. This improves implementability of the solution. A specific shape of the wide structure 4122 is not limited in this embodiment of this application.

II. Transitional structure

[0076] The transitional structure includes an impedance matching structure 413 and a delay structure 414. The impedance matching structure 413 and the delay structure 414 are also formed by corroding, engraving, or etching the metal layer 410.

[0077] Specifically, a feeder width (a vertical length shown in FIG. 4) of the impedance matching structure 413 gradually changes from a first width to a second width, where the first width is less than the second width, that is, the width of the microstrip 411 gradually increases in the impedance matching structure 413. The impedance matching structure 413 is configured to implement impedance transformation from the microstrip 411 to two differential signal lines.

[0078] The delay structure 414 is configured to divide the microstrip 411 into a first signal line 4141 and a second signal line 4142, where the first signal line 4141 and the second signal line 4142 are differential signal lines. In the delay structure

414, a length (the horizontal direction shown in FIG. 4) of the first signal line 4141 is greater than that of the second signal line 4142. The delay structure 414 is configured to enable an electrical length difference between the first signal line 4141 and the second signal line 4142 to be half a wavelength (a phase difference is 180°), to implement differential mode transmission on the two differential signal lines.

[0079] Optionally, the delay structure 414 may be in a "Π" shape shown in FIG. 4, or may be an arc-shaped structure shown in FIG. 6 or in another fold line form, provided that the delay structure 414 can meet differential mode transmission on the two differential signal lines. A specific shape of the delay structure 414 is not limited in this embodiment of this application.

[0080] Optionally, the radiation structure is used in a waveguide antenna, a length of the impedance matching structure 413 is 0.2 to 0.25 times a wavelength of the waveguide antenna, the length of the first signal line 4141 is greater than 0.45 to 0.55 times the wavelength of the waveguide antenna of the second signal line 4142, and a length of the coupling slot 4121 is 0.45 to 0.55 times the wavelength of the waveguide antenna.

[0081] The radiation structure is specifically configured to implement a transition function of the waveguide antenna. After the radiation structure is attached to a waveguide port, with reference to the foregoing description of the radiation structure, the two differential signal lines may excite TE_{10} field mode distribution in the resonant cavity, and a coupling slot on the metal layer in the resonant cavity may effectively cut off a transverse current of the metal layer in the resonant cavity. According to the Babinet’s principle, the coupling slot is equivalent to a magnetic current source, and is used to convert a guided electromagnetic wave in the resonant cavity into a radiated electromagnetic wave. A field pattern radiated by the magnetic current source formed by the coupling slot matches a TE_{10} propagation mode of the waveguide port, to implement efficient conversion and transmission of electromagnetic energy between the microstrip and the waveguide, that is, implement efficient conversion from a TEM to a waveguide TE_{10} transmission mode. In addition, the wide structure in the middle of the coupling slot can adjust radiation impedance of the coupling slot, further improving conversion efficiency.

[0082] Refer to FIG. 7 as well as FIG. 4. An embodiment of a circuit board provided in an embodiment of this application includes the radiation structure and a short-circuit structure 430.

[0083] For example, the circuit board may correspond to the microstrip and the transition structure in the waveguide antenna shown in FIG. 2A to FIG. 2C, but specific structures of the radiation structure and the short-circuit structure 430 differ.

[0084] Specifically, the short-circuit structure 430 is a plurality of continuously arranged metal pillars, and is specifically a plurality of plated hole short-circuit pillars disposed on the metal layer 410. The short-circuit structure 430 is configured to surround the radiation structure, and is specifically configured to form a shielding structure, to allow the coupling structure 412 to form a closed resonant cavity, limiting an electric field excited by the coupling structure 412 to being mainly distributed in the resonant cavity. This avoids leakage and improves transmission efficiency.

[0085] It should be understood that the short-circuit structure 430 may be in a cylindrical shape or square shape. A specific shape of the short-circuit structure 430 is not limited in this embodiment of this application.

[0086] As shown in FIG. 8, an embodiment of a waveguide antenna provided in an embodiment of this application includes a radiation structure 810 and a waveguide structure 820.

[0087] For example, the waveguide antenna may correspond to the waveguide antennas shown in FIG. 2A to FIG. 2C, but the specific radiation structure 810 and the specific waveguide structure 820 are different.

[0088] Specifically, the waveguide structure 820 includes a waveguide port 821 and a protrusion structure 822. The rectangular waveguide port 821 formed by the protrusion structure 822 on a lower end face of the waveguide structure 820 is aligned and attached to a coupling slot on an upper surface layer of a PCB circuit board in the radiation structure 810. The protrusion structure 822 is disposed around the waveguide port 821, the protrusion structure 822 is attached to the radiation structure 810, the protrusion structure 822 is located around the coupling slot, and the waveguide port 821 is configured to couple, to the waveguide structure 820, energy radiated by the radiation structure 810.

[0089] Refer to FIG. 9 as well as FIG. 8. The protrusion structure 822 may be specifically a pin structure, and the protrusion structure 822 is disposed on the top and/or two sides of the waveguide port 821. For example, an annular protrusion structure 8221 surrounds the top of the rectangular waveguide port 821. For example, at a center of a long side of the rectangular waveguide port 821, two protrusion structures 8222 are respectively on the two sides of the waveguide port 821, and protrusion parts of the protrusion structures 8222 exceed a middle protrusion of the rectangular waveguide port 821. For another example, at a bottom end of the long side of the rectangular waveguide port 821, two protrusion structures 8223 are respectively on the two sides of the waveguide port, and protrusion sizes of the protrusion structures 8223 do not exceed a bottom protrusion of the waveguide port 821. Optionally, a length of the protrusion structure 822 along a long side of the waveguide port 821 is 0.2 to 0.3 times a wavelength of the waveguide antenna.

[0090] Optionally, there are a plurality of protrusion structures 822, and there are also a plurality of radiation structures 810 and waveguide structures 820. A spacing between the plurality of protrusion structures 822 is 0.2 to 0.3 times the wavelength of the waveguide antenna. The plurality of radiation structures 810 are arranged in parallel at a preset spacing and the plurality of waveguide structures 820 are arranged in parallel at a preset spacing. Optionally, the preset spacing is 3 millimeters.

[0091] For example, as shown in FIG. 10A to FIG. 10D, a waveguide antenna includes four radiation structures 810 and four corresponding waveguide structures 820, to form a 4-channel waveguide antenna. The waveguide antenna further includes a waveguide feeder 830 and an antenna 840. A plurality of waveguide ports 821 are placed in parallel at a spacing of 3 mm, and may form multi-port transition. Adjacent transition ports maintain complete structures without sharing. The waveguide structure 820 is fastened to the top of the radiation structure 810 through screw fastening, adhesive bonding, soldering, or the like. A protrusion structure 822 at the bottom of a waveguide structure 820 is kept in contact with a PCB circuit board of a radiation structure 810, and a tail end of the waveguide structure 820 is connected to the waveguide feeder 830 and the antenna 840, to finally implement an entire waveguide antenna system.

[0092] Further, a radio frequency chip is configured to generate a radio frequency signal, and the radio frequency signal is output to a microstrip in the radiation structure 810 by using a radio frequency port. The microstrip is configured to output the radio frequency signal to a radiation patch in the radiation structure 810. The radiation patch is configured to: radiate the transmitted radio frequency signal and couple the radio frequency signal to the waveguide structure 820. The waveguide structure 820 includes the waveguide port having a protrusion structure. The waveguide port may be specifically an electromagnetic band gap (electromagnetic band gap, EBG) structure. The EBG structure is a periodic structure that can allow or block transmission of an electromagnetic wave of a specific frequency, and is configured to receive, through coupling, an electromagnetic field radiated by the radiation patch and feed energy of the electromagnetic field into the waveguide feeder 830. The waveguide feeder 930 is configured to transmit a signal obtained through coupling to the antenna 840. The antenna 840 finally effectively radiates the transmitted signal.

[0093] It can be learned from the foregoing embodiment that the waveguide antenna provided in this embodiment of this application further has effect of tolerance and stable operating bandwidth, which are separately described in the following.

I. Tolerance

[0094] In a diagram of electric field distribution shown in FIG. 11, length sizes and a spacing of protrusion structures along the long side of the waveguide port are designed based on an approximately 0.25 wavelength of an intermediate frequency of a 76 GHz to 81 GHz frequency band. This electrical size can ensure transmission suppression (namely, a stopband) of an electromagnetic wave in the frequency band. In a diagram of stopband range analysis for a protrusion structure shown as FIG. 12, a horizontal coordinate indicates a frequency range, and a vertical coordinate indicates a propagation constant (Propagation Constant). A larger propagation constant indicates better transmission effect, and a smaller propagation constant indicates better effect of blocking transmission of an electromagnetic wave. In FIG. 12, in a frequency range of 70 GHz to 90 GHz covering a millimeter wave frequency band, propagation constants of a mode 1 are all 0 for different gap (gap) values, indicating an excellent stopband characteristic of the protrusion structure. This ensures high isolation between adjacent channels when there is an assembly gap. Therefore, the protrusion structure in the waveguide antenna provided in this embodiment of this application can meet a stopband requirement of 76 GHz to 81 GHz, and maintain a good shielding characteristic within a tolerance range (gap) of 0 millimeters to 0.2 millimeter.

[0095] In z-direction tolerance analysis for an insertion loss (the insertion loss means a loss amount after electromagnetic wave leakage caused by an assembly deviation of a transition structure in a transmission process of an electromagnetic wave) shown in FIG. 13, a horizontal coordinate indicates a frequency, a vertical coordinate dB (S(WG, MG)) indicates an insertion loss dB value in a single channel of the transition structure, where WG indicates a waveguide port, MG indicates a microstrip port, and h_error indicates different assembly gaps. In z-direction tolerance analysis for isolation (the isolation means a quantity of electromagnetic waves transmitted from a main transmission channel to another channel after leakage occurs between adjacent channels when a plurality of arranged channels are arranged) shown in FIG. 14, a horizontal coordinate indicates a frequency, a vertical coordinate dB (S(MS1, MS)) indicates an isolation dB value between two adjacent channels (dB indicates decibel), MS1 and MS indicate microstrip ports of the two adjacent channels, and h_error indicates different assembly gaps.

Table 1

Height difference (mm)	Insertion loss (dB)	Isolation (dB)
0	-0.7	-51.93
0.1	-0.76	-40.58
0.15	-0.85	-35.78
0.2	-0.94	-32.64

[0096] With reference to FIG. 13, FIG. 14, and Table 1, it can be learned that the waveguide antenna simulates 0.2 mm installation tolerance (an end face of the protrusion structure is not closely attached to the coupling slot during assembly, a 0.2 mm gap exists). When a change occurs, transition tolerance fluctuates by only 0.3 dB, and isolation is higher than -30 dB. Transition still maintains good operating characteristic under limit tolerance (the 0.2 mm gap is a maximum gap value that may occur during assembly). As shown in FIG. 13, when the z-direction height tolerance is 0.2 mm, a worst insertion loss is -0.94 dB; or when the height tolerance changes from 0 mm to 0.2 mm, an insertion loss fluctuation range is -0.7 dB to -0.94 dB at 76 GHz to 81 GHz. Isolation of nearest adjacent ports is higher than -32.64 dB.

II. Stable operating bandwidth

[0097] The delay structure and the impedance matching structure in the radiation structure can implement good impedance matching. In a diagram of impedance bandwidth analysis shown as FIG. 15, a horizontal coordinate indicates a frequency, and a vertical coordinate indicates a return loss S11 of a waveguide port of the single channel of the transition structure. In a diagram of in-band insertion loss analysis shown as FIG. 16, a horizontal coordinate indicates a frequency, and a vertical coordinate indicates an insertion loss in the single channel of the transition structure.

[0098] As shown in FIG. 15 and FIG. 16, typical values are as follows: bandwidth: 74.3 GHz to 82.6 GHz at -15 dB; and insertion loss: -0.70 at 76 GHz, -0.70 at 78.5 GHz, and -0.91 at 81 GHz.

[0099] In diagrams of unit z-direction tolerance (0 mm to 0.2 mm) analysis shown as FIG. 17 and FIG. 18, a horizontal coordinate indicates a frequency, a vertical coordinate dB (S(MS, MS)) indicates a return loss dB value of a microstrip port in the single channel of the transition structure, MS indicates the microstrip port, WG indicates the waveguide port, and h_error indicates the different assembly gaps.

[0100] With reference to FIG. 17 and FIG. 18, it can be learned that FIG. 17 shows return losses of four ports that are seamlessly installed in a z-direction when four radiation structures are arranged along a short side with a 3 mm gap. FIG. 18 shows return losses of the four ports that are installed in the z-direction when 0.2 mm limit tolerance exists. Compared with a result in FIG. 17, a result in FIG. 18 deteriorates but still meets an indicator requirement, indicating that the radiation structure has an excellent tolerance capability. Specifically, when Z-direction tolerance increases to 0.2 mm, a return loss of the microstrip port is less than -19.5 dB at 76 GHz to 81 GHz, and a return loss of the waveguide port is less than -15 dB at 76 GHz to 81 GHz. Impedance matching is mainly determined by a graphic size of the metal layer in the PCB circuit board, and is specifically implemented by a microstrip width and length on an upper layer of the PCB circuit board, stable field distribution is implemented at a junction between the PCB circuit board and the waveguide port, and energy transmission is mainly performed through radiation. Therefore, impedance matching is less affected by installation accuracy.

[0101] In embodiments of this application, the radiation structure includes the metal layer, and the metal layer includes the microstrip and the coupling structure. The width of the coupling structure is greater than the width of the microstrip. The coupling structure includes the coupling slot, and the coupling slot is formed by slitting the metal layer. The field pattern of radiation excited by the magnetic current source formed by the coupling matches the propagation mode of the waveguide port, to implement efficient conversion and transmission of the electromagnetic energy between the microstrip and the waveguide. The circuit board and the waveguide antenna that include the radiation structure also have the same beneficial effect.

[0102] As shown in FIG. 19, an embodiment of a communication apparatus provided in an embodiment of this application includes any one of the foregoing radiation structure, circuit board, or waveguide antenna.

[0103] FIG. 19 is a diagram of a possible logical structure of a communication apparatus 1900 according to an embodiment of this application. The communication apparatus 1900 includes a processor 1901, a communication interface 1902, a storage system 1903, and a bus 1904. The processor 1901, the communication interface 1902, and the storage system 1903 are connected to each other through the bus 1904. In this embodiment of this application, the processor 1901 is configured to control and manage an action of the communication apparatus 1900. The communication interface 1902 is configured to support the communication apparatus 1900 in performing communication. The storage system 1903 is configured to store program code and data of the communication apparatus 1900.

[0104] The processor 1901 may be a central processing unit, a general-purpose processor, a digital signal processor, an application-specific integrated circuit, a field programmable gate array or another programmable logic device, a transistor logic device, a hardware component, or any combination thereof. The processor may implement or execute various example logical blocks, modules, and circuits described with reference to content disclosed in this application. The processor 1901 may alternatively be a combination, for example, a combination including one or more microprocessors or a combination of a digital signal processor and a microprocessor, for implementing a computing function. The bus 1904 may be a peripheral component interconnect standard (Peripheral Component Interconnect, PCI) bus, an extended industry standard architecture (Extended Industry Standard Architecture, EISA) bus, or the like. Buses may be classified into an address bus, a data bus, a control bus, and the like. For ease of representation, the bus is represented only by one bold line in FIG. 19. However, this does not mean that there is only one bus or only one type of bus.

[0105] The communication apparatus 1900 further includes any one of the foregoing radiation structure, circuit board, or waveguide antenna.

[0106] As shown in FIG. 20, in an embodiment of a transportation means 2000 provided in an embodiment of this application, the transportation means 2000 includes a millimeter-wave radar 2001, and the millimeter-wave radar 2001 includes any one of the foregoing radiation structure, circuit board, or waveguide antenna.

[0107] The transportation means in this application may include road transportation, water transportation, air transportation, an industrial device, an agricultural device, an entertainment device, or the like. For example, the transportation means may be a vehicle. The vehicle is a vehicle in a broad sense, and may be transportation (like a commercial vehicle, a passenger vehicle, a motorcycle, a flight vehicle, or a train), an industrial vehicle (like a pallet truck, a trailer, or a tractor), an engineering vehicle (like an excavator, a bulldozer, or a crane), an agricultural device (like a lawn mower or a harvester), an entertainment device, or a toy vehicle. A type of the vehicle is not specifically limited in embodiments of this application. For another example, the transportation means may be transportation like an aircraft or a ship.

[0108] In the several embodiments provided in this application, it should be understood that the disclosed structure may be implemented in another manner. For example, the described embodiments are merely examples. For example, the structure division may be other division in actual implementation. For example, a plurality of units or components may be combined or integrated into another structure, or some features may be ignored. Some or all of the structures may be selected based on an actual need to achieve the objectives of the solutions of embodiments.

[0109] The foregoing embodiments are merely used to describe the technical solutions of this application, but not to limit the technical solutions. Although this application is described in detail with reference to the foregoing embodiments, a person of ordinary skill in the art should understand that modifications may still be made to the technical solutions described in the foregoing embodiments or equivalent replacements may still be made to some technical features thereof, without departing from the scope of the technical solutions of embodiments of this application.

Claims

1. A radiation structure, comprising a metal layer, wherein

   the metal layer comprises a microstrip and a coupling structure, and a width of the coupling structure is greater than a width of the microstrip; and
   the coupling structure comprises a coupling slot, and the coupling slot is formed by slitting the metal layer.

2. The radiation structure according to claim 1, wherein the coupling slot is located in the middle of the coupling structure.

3. The radiation structure according to claim 1 or 2, wherein the coupling slot is located at a current node of the coupling structure.

4. The radiation structure according to any one of claims 1 to 3, wherein currents on two sides of the coupling slot are mirror-symmetric.

5. The radiation structure according to any one of claims 1 to 4, wherein a wide structure is disposed in the middle of the coupling slot, and a width of the wide structure is greater than a width of the coupling slot.

6. The radiation structure according to claim 5, wherein a maximum width of the wide structure is at least 0.1 millimeter greater than the width of the coupling slot.

7. The radiation structure according to any one of claims 1 to 6, wherein the metal layer further comprises a transitional structure, the transitional structure is configured to connect the microstrip and the coupling structure, and the transitional structure comprises an impedance matching structure and a delay structure;

   a feeder width of the impedance matching structure gradually changes from a first width to a second width; and
   the delay structure is configured to divide the microstrip into a first signal line and a second signal line, and in the delay structure, a length of the first signal line is greater than that of the second signal line.

8. The radiation structure according to claim 7, wherein the radiation structure is used in a waveguide antenna, a length of the impedance matching structure is 0.2 to 0.25 times a wavelength of the waveguide antenna, the length of the first signal line is greater than 0.45 to 0.55 times the wavelength of the waveguide antenna of the second signal line, and a length of the coupling slot is 0.45 to 0.55 times the wavelength of the waveguide antenna.

9. The radiation structure according to any one of claims 1 to 8, wherein the coupling slot is formed by corroding,

engraving, or etching the metal layer.

10. A circuit board, comprising the radiation structure according to any one of claims 1 to 9.

11. The circuit board according to claim 10, wherein the circuit board further comprises a short-circuit structure, and the short-circuit structure surrounds the radiation structure.

12. The circuit board according to claim 11, wherein the short-circuit structure is a plurality of continuously arranged metal pillars.

13. A waveguide antenna, comprising a waveguide structure and the radiation structure according to any one of claims 1 to 9, wherein

the waveguide structure comprises a waveguide port and a protrusion structure;
the protrusion structure is disposed around the waveguide port, the protrusion structure is attached to the radiation structure, and the protrusion structure is located around the coupling slot; and
the waveguide port is configured to couple, to the waveguide structure, energy radiated by the radiation structure.

14. The waveguide antenna according to claim 13, wherein the protrusion structure is disposed on the top and/or two sides of the waveguide port.

15. The waveguide antenna according to claim 13 or 14, wherein a length of the protrusion structure along a long side of the waveguide port is 0.2 to 0.3 times a wavelength of the waveguide antenna.

16. The waveguide antenna according to any one of claims 13 to 15, wherein there are a plurality of protrusion structures, and a spacing between the plurality of protrusion structures is 0.2 to 0.3 times the wavelength of the waveguide antenna.

17. The waveguide antenna according to any one of claims 13 to 16, wherein there are a plurality of radiation structures and a plurality of waveguide structures, and the plurality of waveguide structures are arranged in parallel at a preset spacing.

18. The waveguide antenna according to claim 17, wherein the preset spacing is 3 millimeters.

19. A communication apparatus, comprising the radiation structure according to any one of claims 1 to 9, the circuit board according to any one of claims 10 to 12, or the waveguide antenna according to any one of claims 13 to 18.

20. A millimeter-wave radar, comprising the radiation structure according to any one of claims 1 to 9, the circuit board according to any one of claims 10 to 12, or the waveguide antenna according to any one of claims 13 to 18.

21. A transportation means, comprising the millimeter-wave radar according to claim 20.

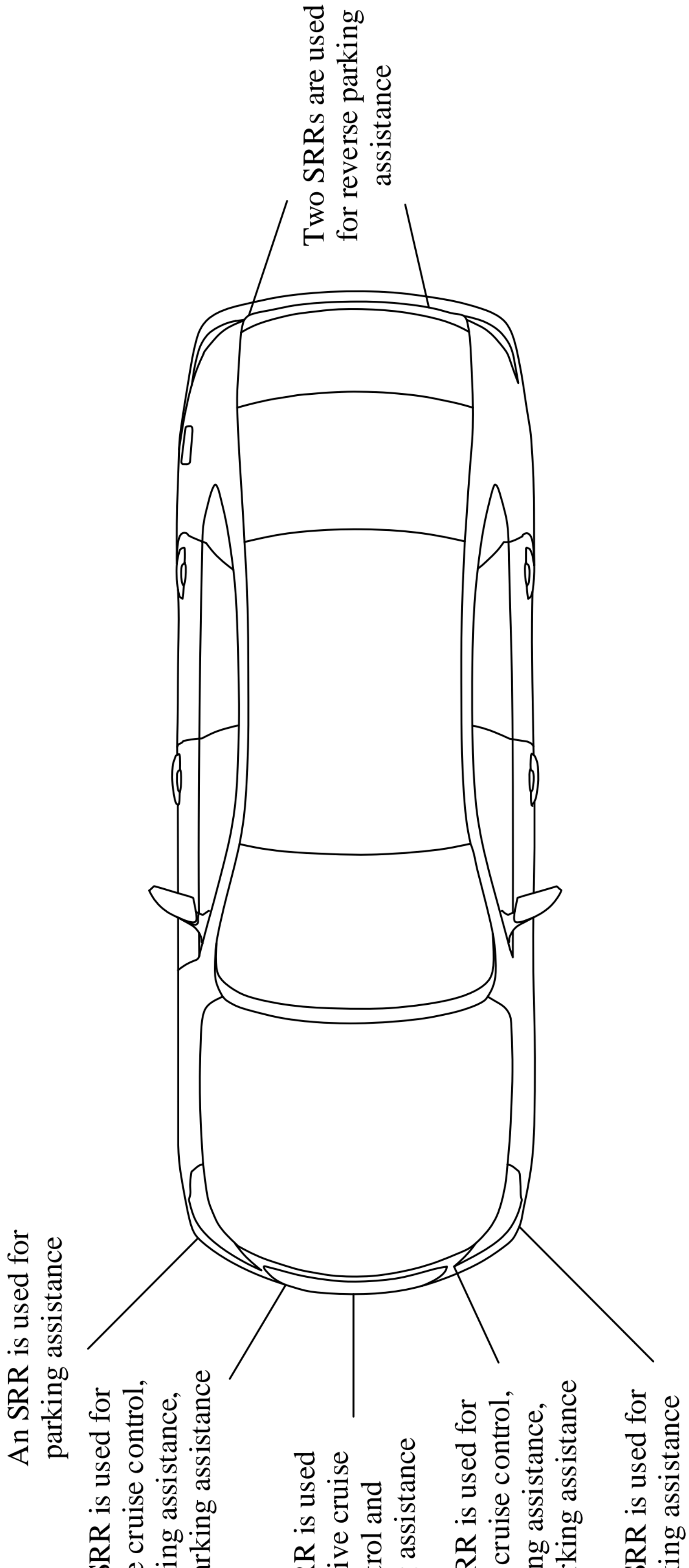

Two SRRs are used for reverse parking assistance
An SRR is used for parking assistance
An SRR is used for active cruise control, braking assistance, and parking assistance
An LRR is used for active cruise control and braking assistance
An SRR is used for active cruise control, braking assistance, and parking assistance
An SRR is used for parking assistance

FIG. 1

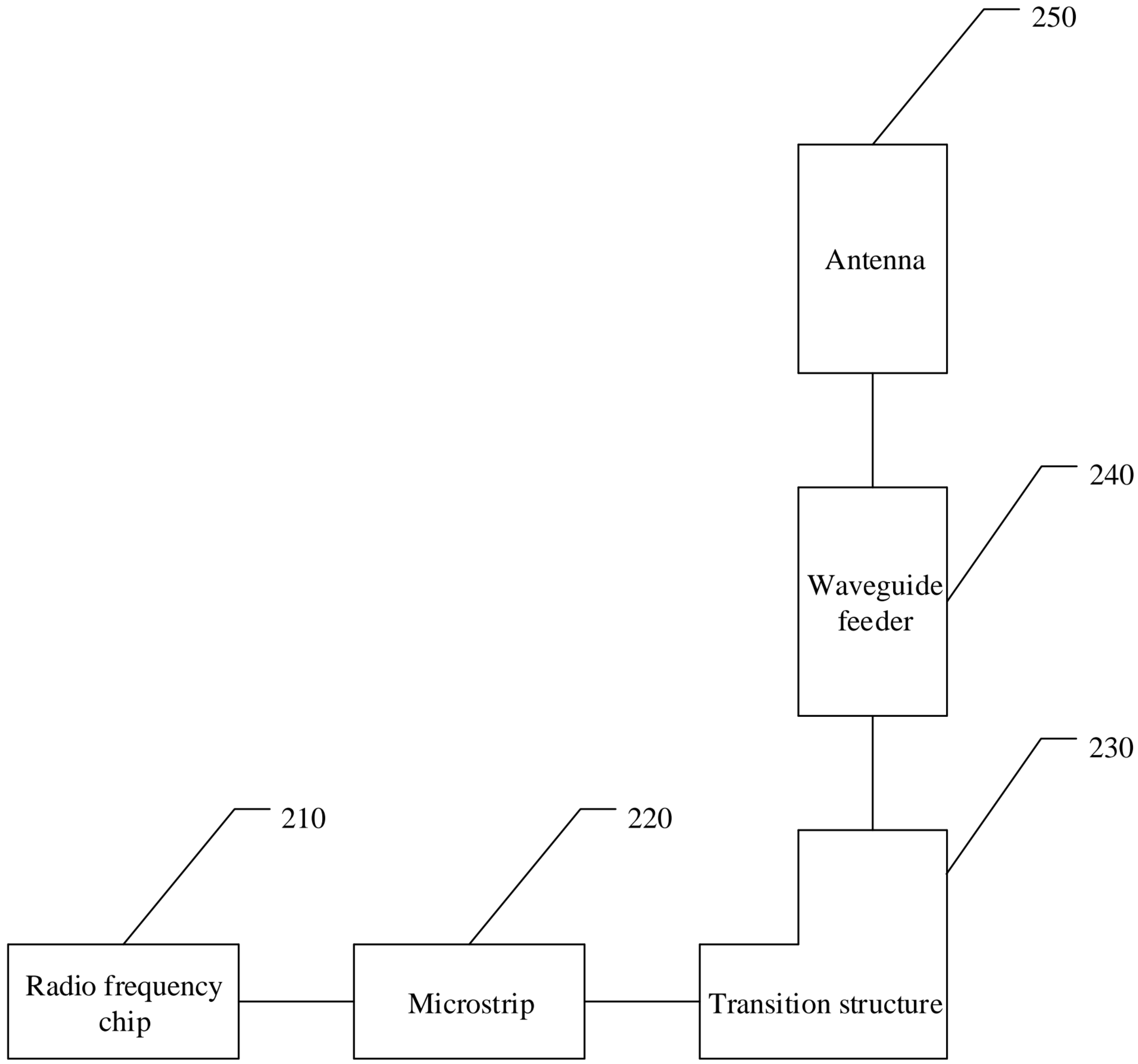

250
Antenna
240
Waveguide feeder
230
210
220
Radio frequency chip
Microstrip
Transition structure

FIG. 2A

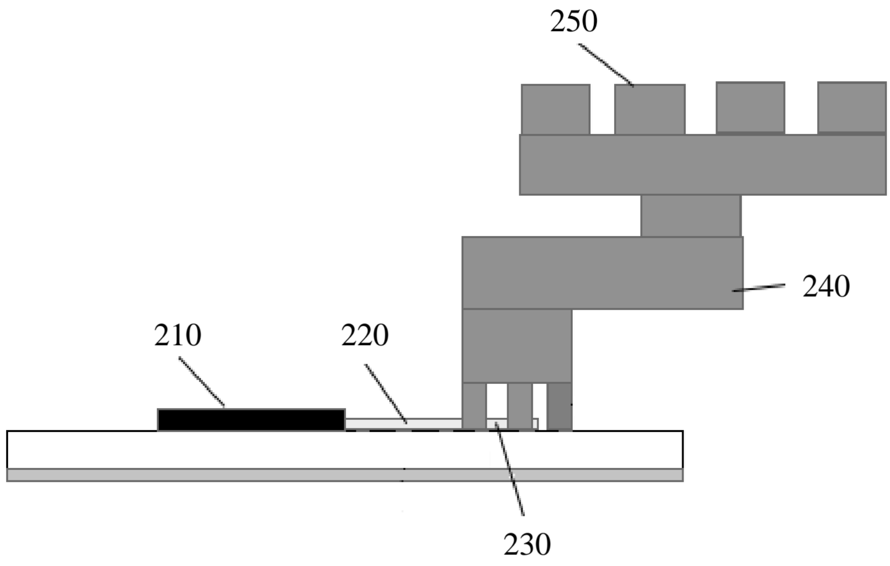


FIG. 2B

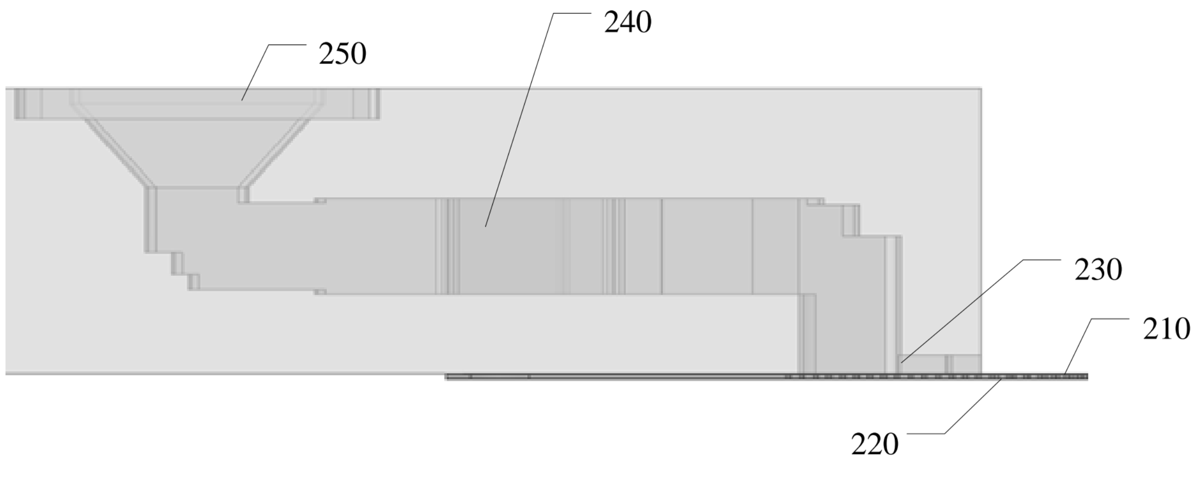


FIG. 2C

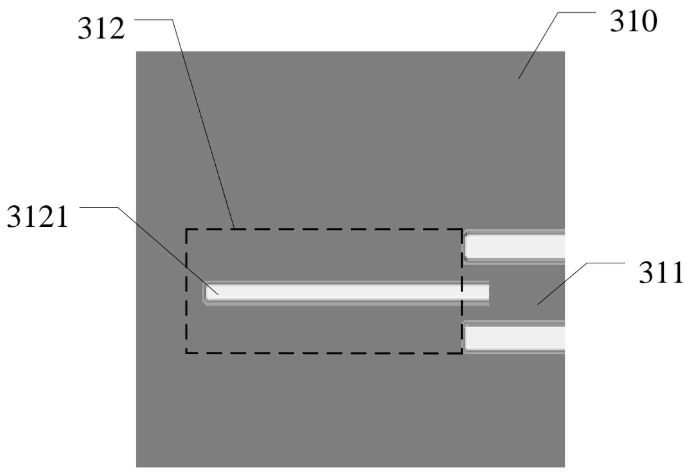


FIG. 3A

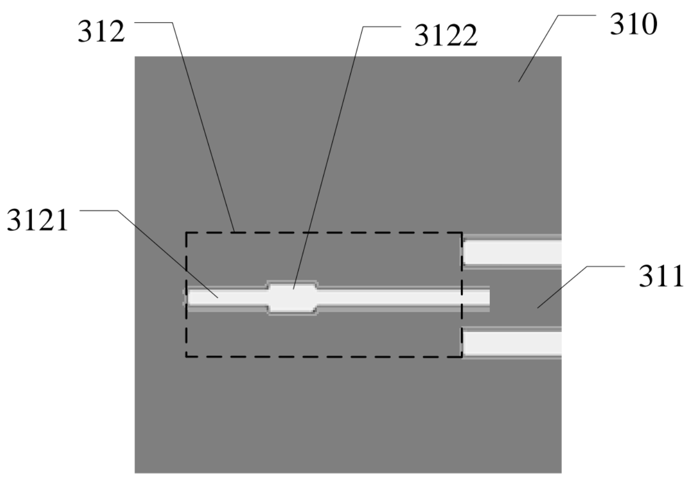


FIG. 3B

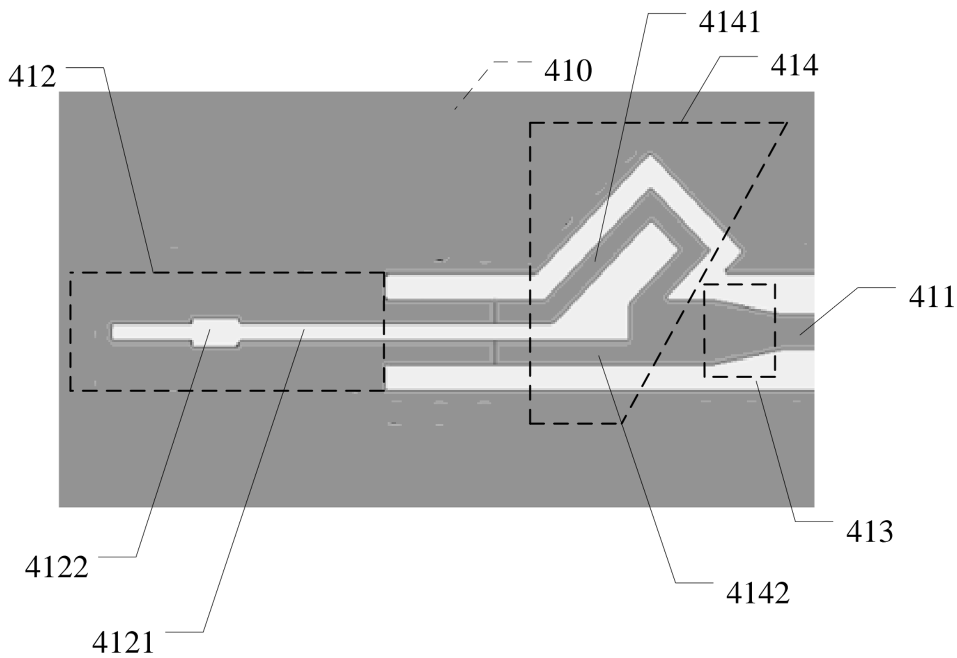

4141
412
410
414
411
413
4122
4142
4121

FIG. 4

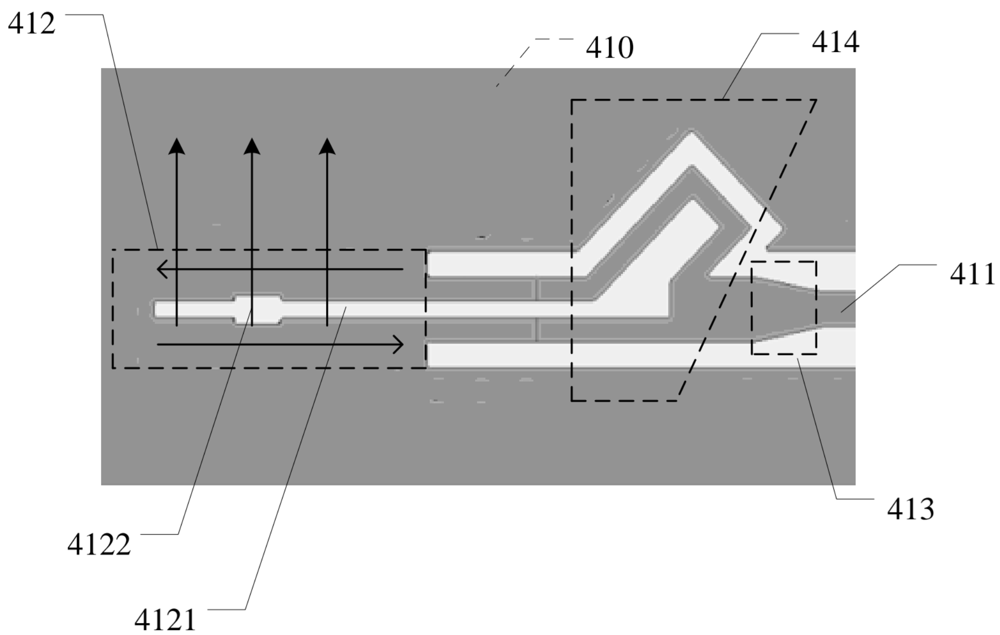

412
410
414
411
413
4122
4121

FIG. 5

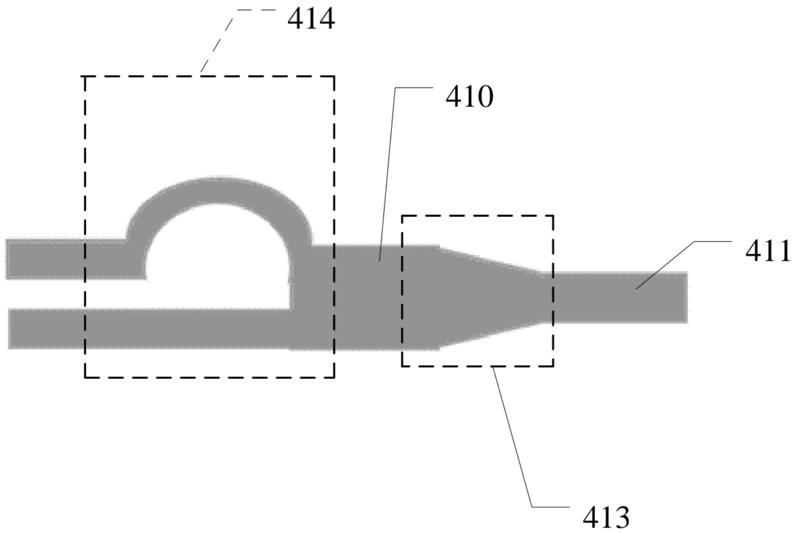


FIG. 6

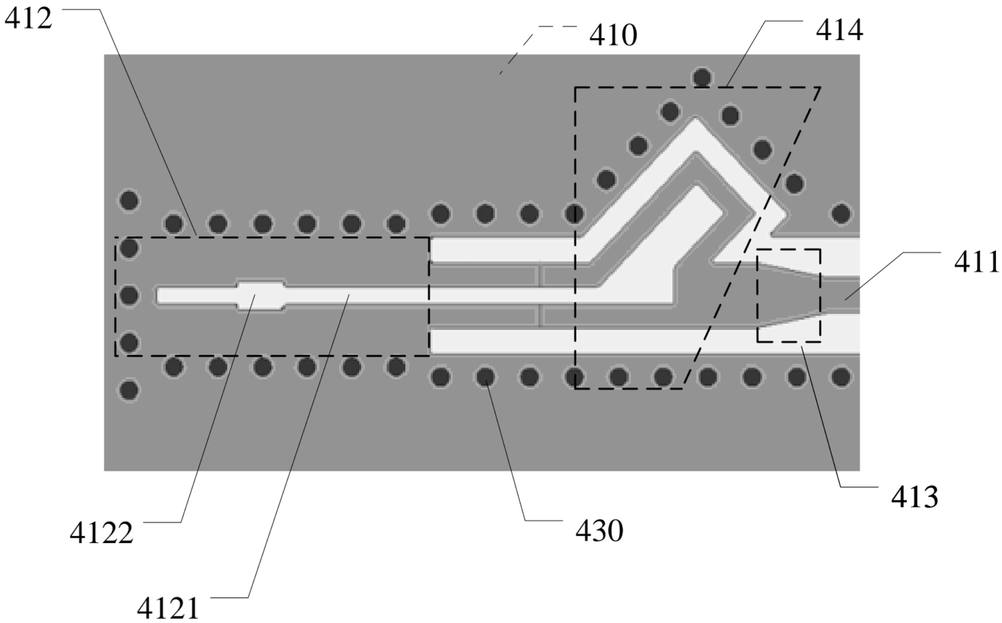


FIG. 7

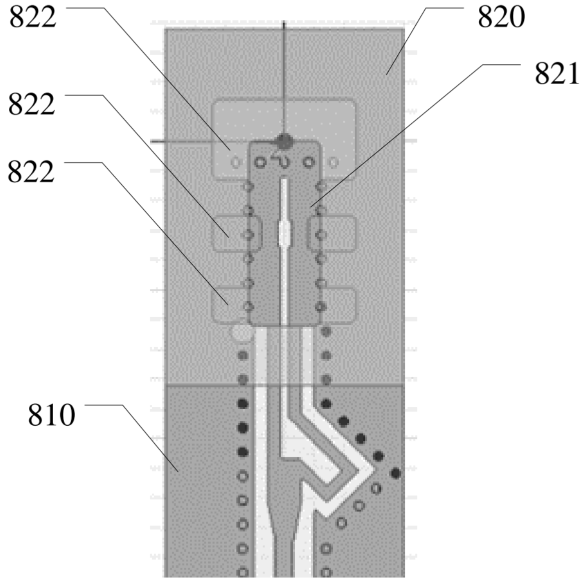


FIG. 8

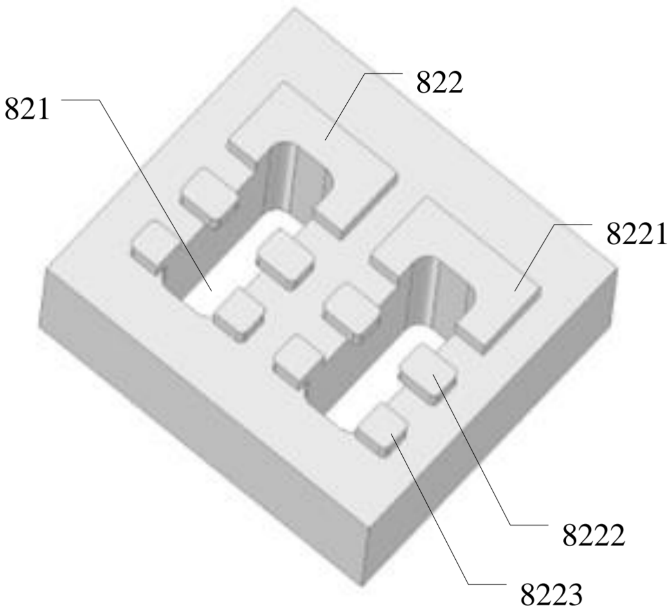


FIG. 9

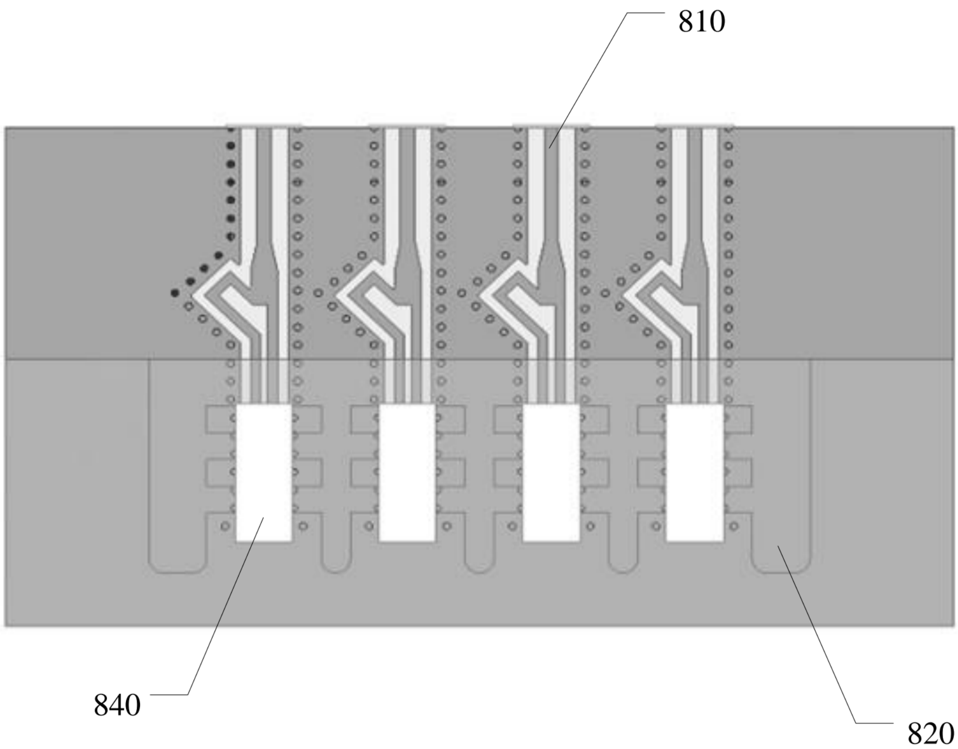


FIG. 10A

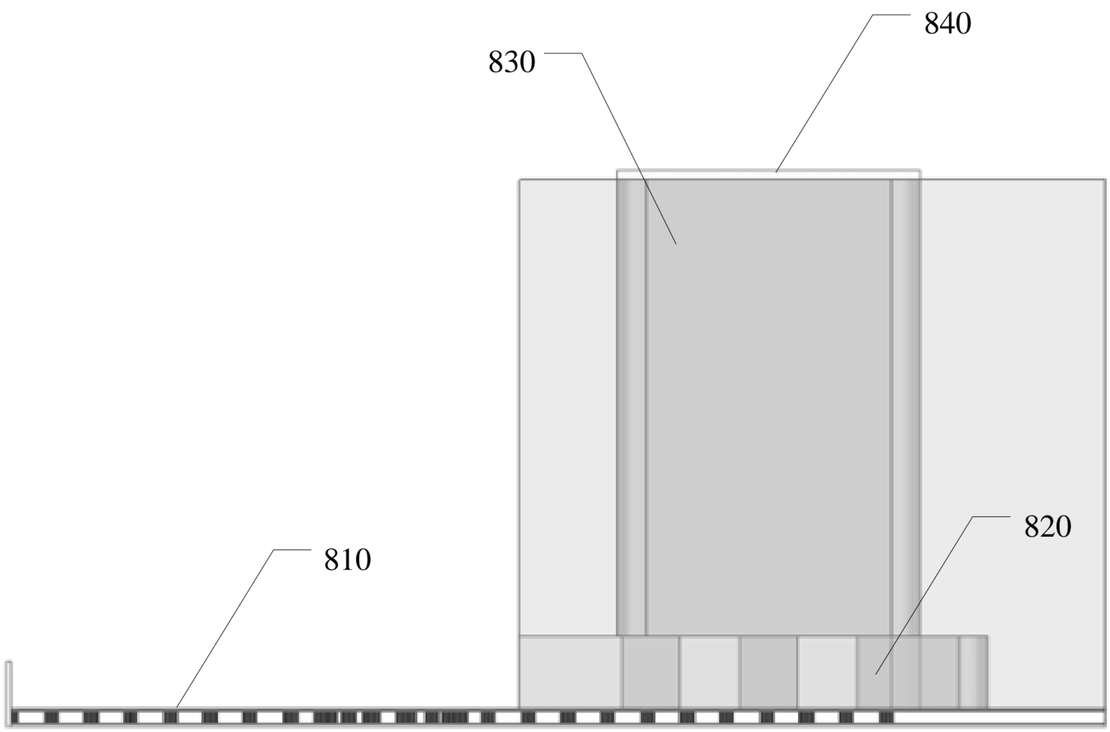


FIG. 10B

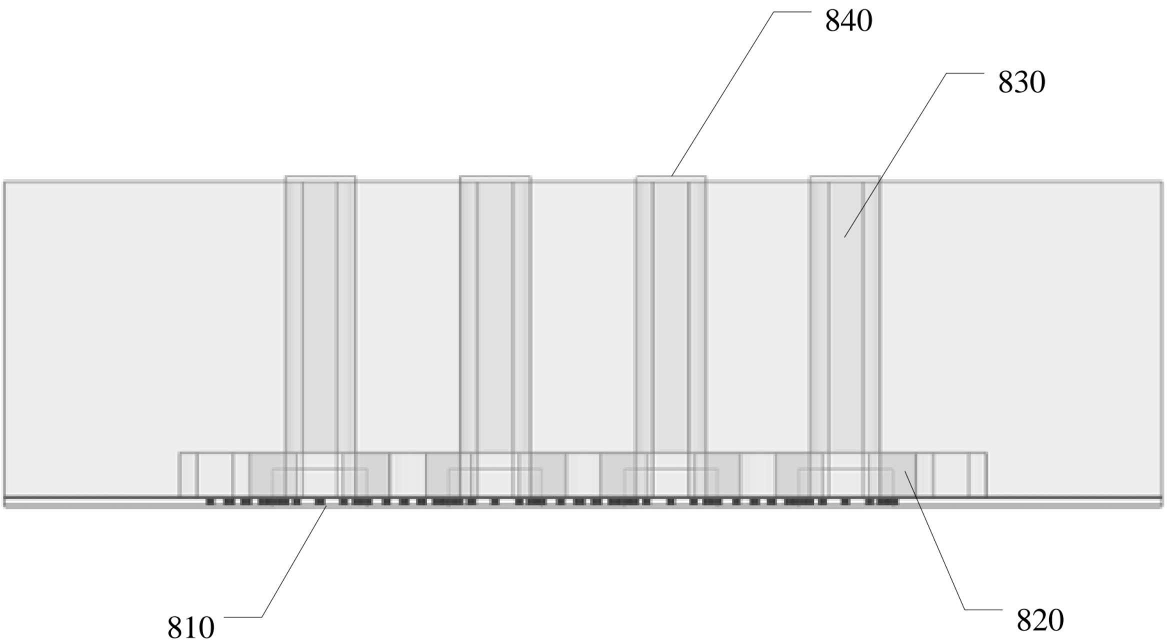


FIG. 10C

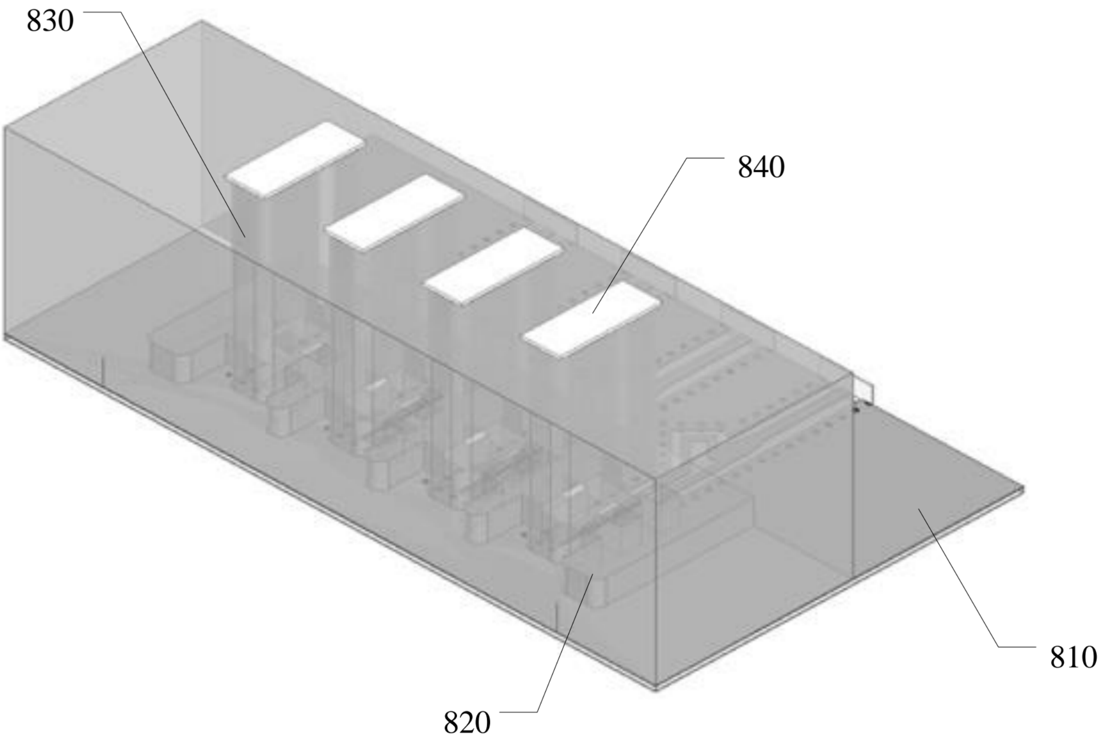


FIG. 10D

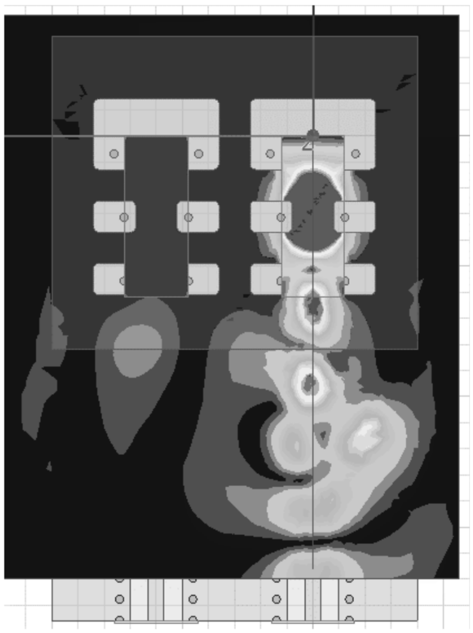


FIG. 11

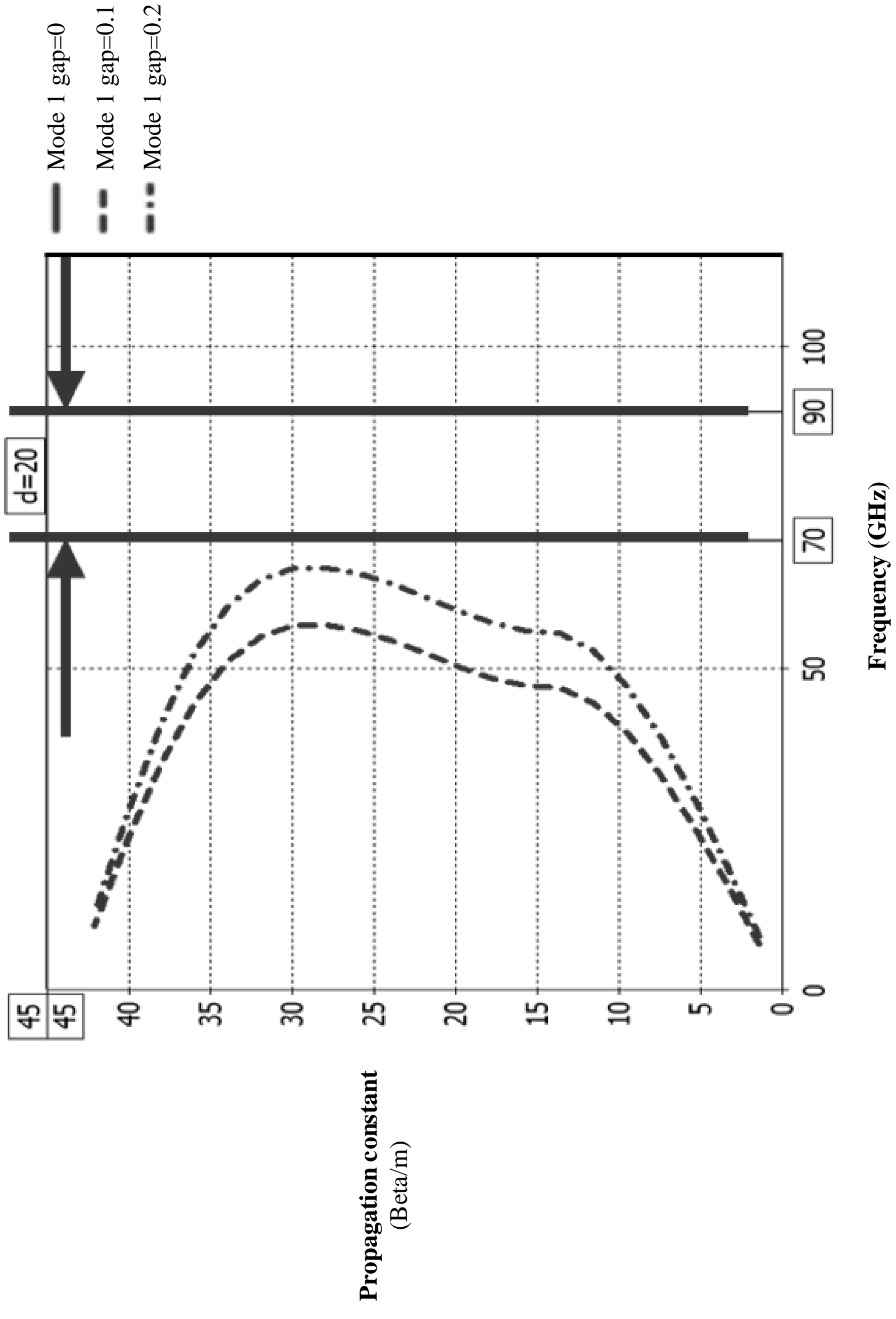

Mode 1 gap=0
Mode 1 gap=0.1
Mode 1 gap=0.2
d=20
45
45
40
35
30
25
20
15
10
5
0
0
50
70
90
100
Frequency (GHz)
Propagation constant
(Beta/m)

FIG. 12

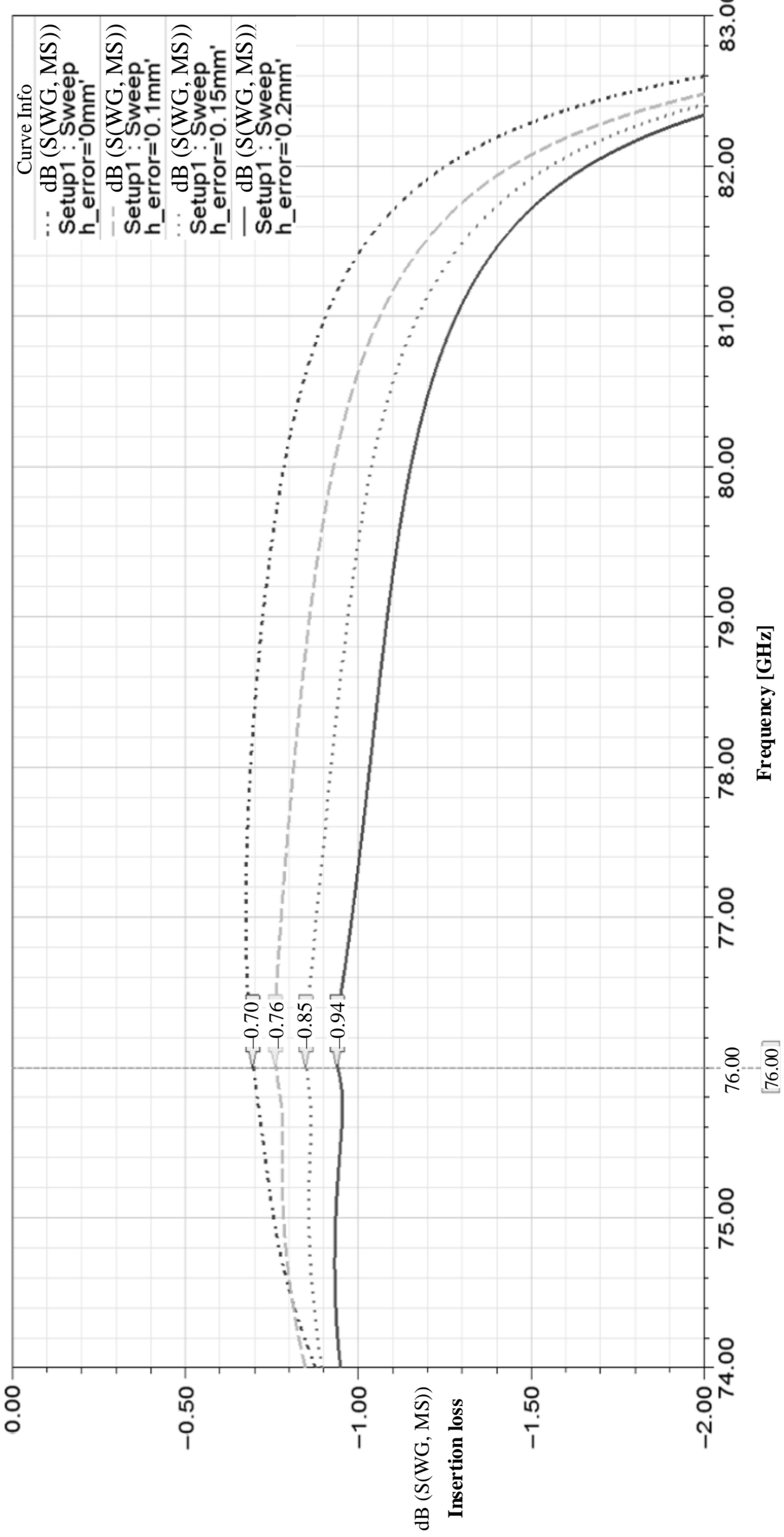

Curve Info
dB (S(WG, MS))
Setup1 : Sweep
h_error='0mm'
dB (S(WG, MS))
Setup1 : Sweep
h_error='0.1mm'
dB (S(WG, MS))
Setup1 : Sweep
h_error='0.15mm'
dB (S(WG, MS))
Setup1 : Sweep
h_error='0.2mm'
−0.70
−0.76
−0.85
−0.94
76.00
76.00
0.00
−0.50
−1.00
−1.50
−2.00
74.00
75.00
76.00
77.00
78.00
79.00
80.00
81.00
82.00
83.00
Frequency [GHz]
dB (S(WG, MS))
Insertion loss

FIG. 13

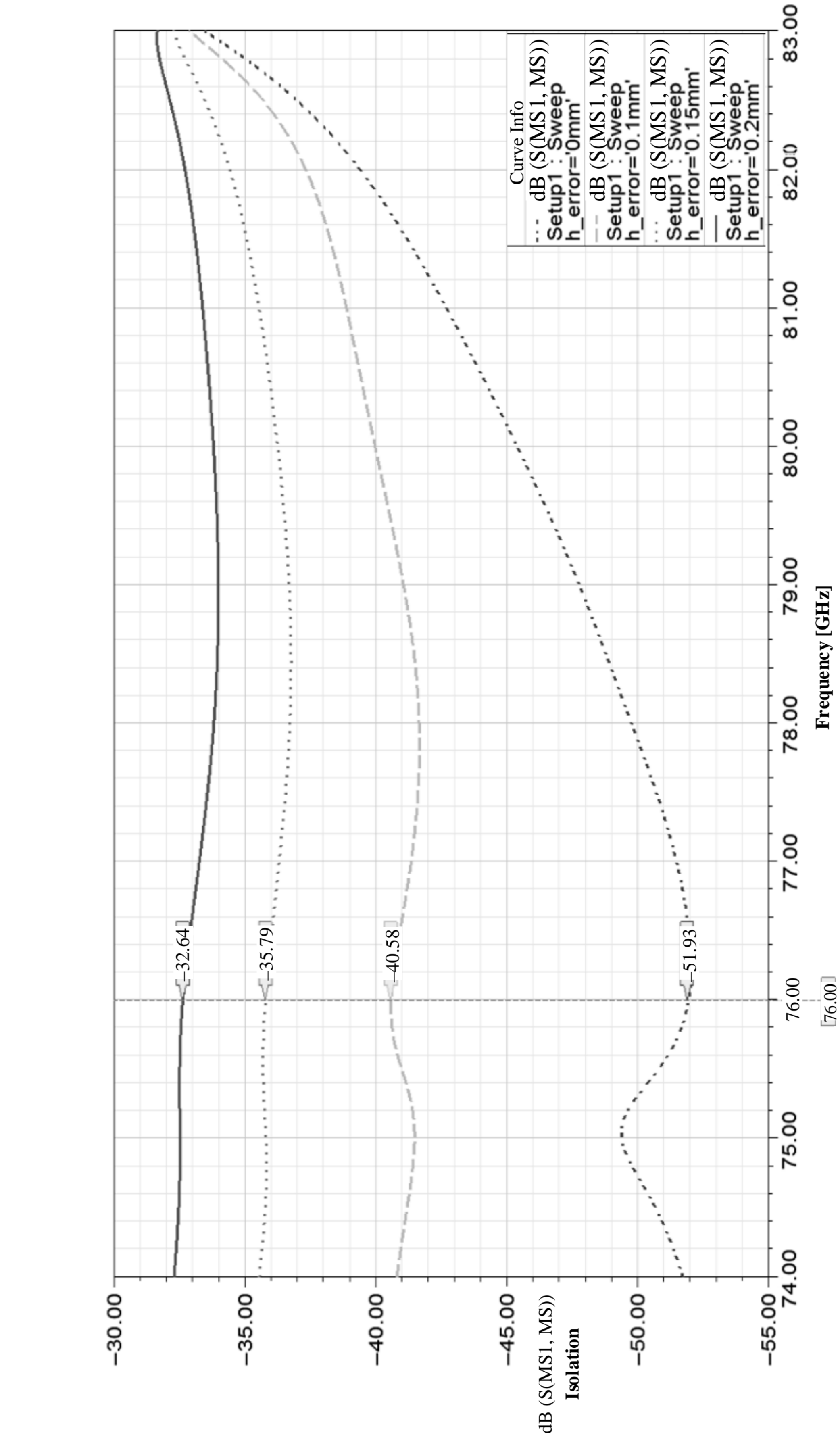
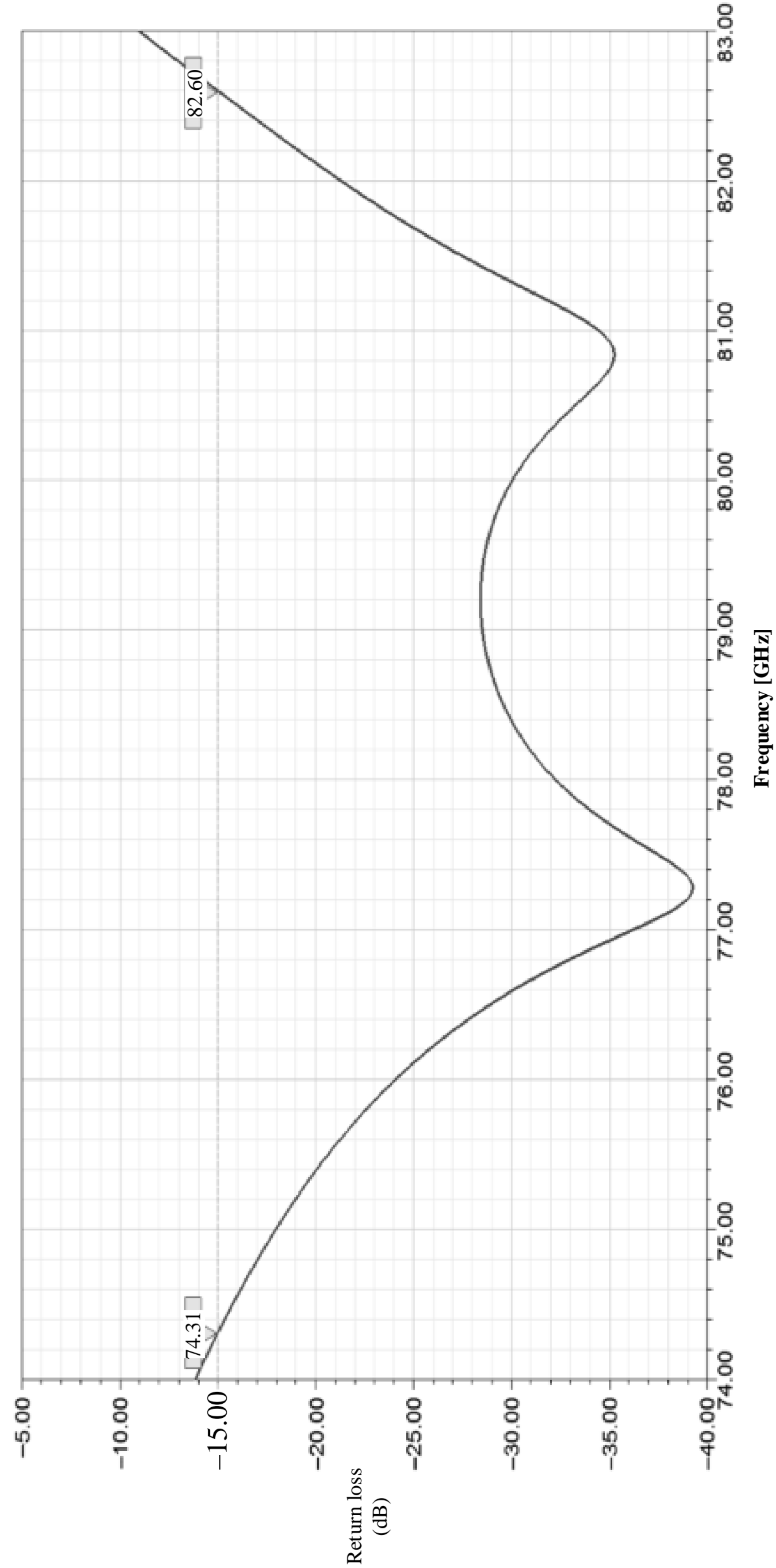

Curve Info
dB (S(MS1, MS))
Setup1 : Sweep
h_error='0mm'
dB (S(MS1, MS))
Setup1 : Sweep
h_error='0.1mm'
dB (S(MS1, MS))
Setup1 : Sweep
h_error='0.15mm'
dB (S(MS1, MS))
Setup1 : Sweep
h_error='0.2mm'
-32.64
-35.79
-40.58
-51.93
76.00
76.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
74.00
75.00
76.00
77.00
78.00
79.00
80.00
81.00
82.00
83.00
dB (S(MS1, MS))
Isolation
Frequency [GHz]

FIG. 14



Return loss
(dB)
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
74.00
75.00
76.00
77.00
78.00
79.00
80.00
81.00
82.00
83.00
74.31
82.60
Frequency [GHz]

FIG. 15

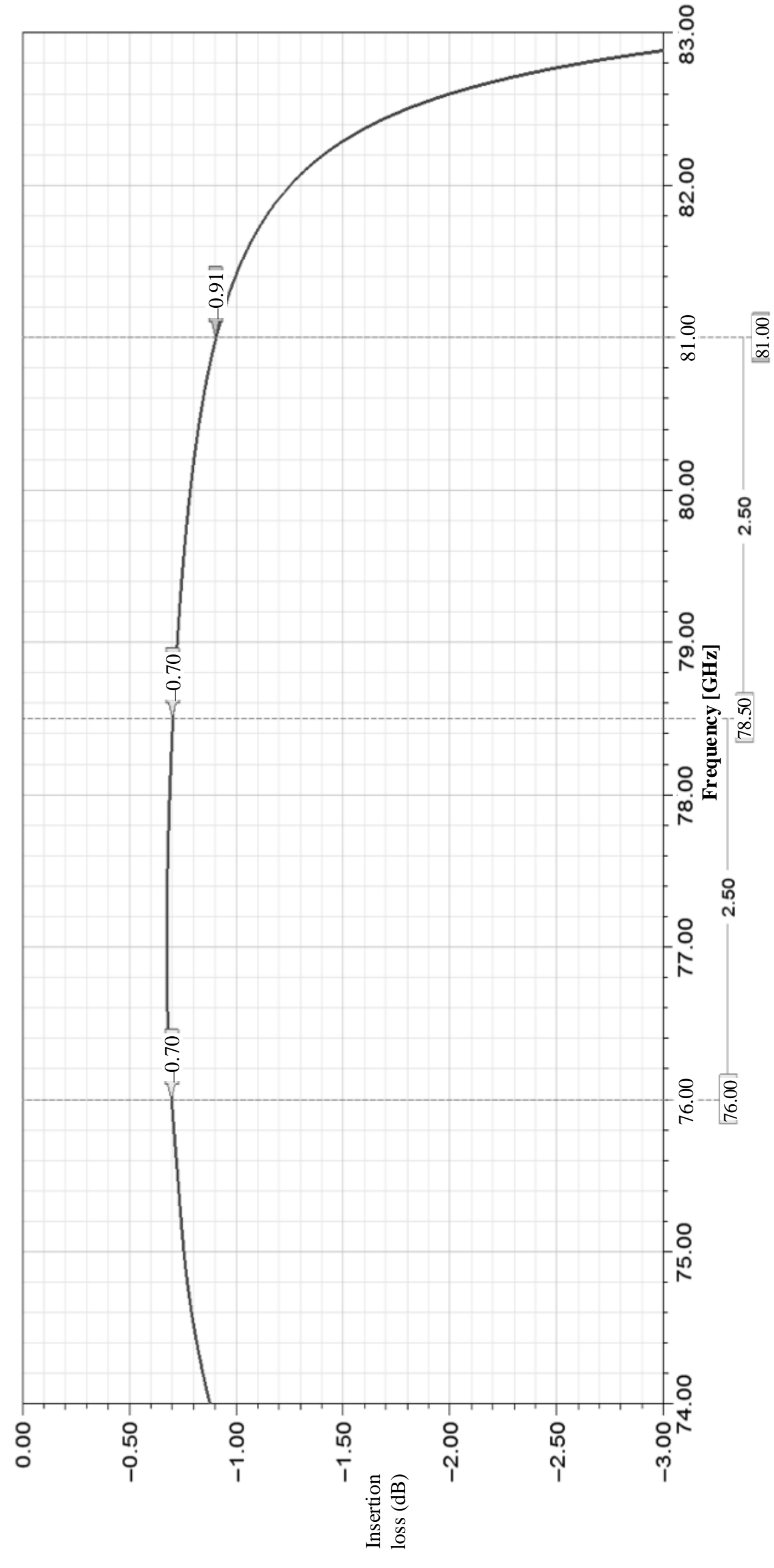

Insertion loss (dB)
0.00
−0.50
−1.00
−1.50
−2.00
−2.50
−3.00
74.00
75.00
76.00
77.00
78.00
79.00
80.00
81.00
82.00
83.00
Frequency [GHz]
−0.70
−0.70
−0.91
76.00
78.50
81.00
2.50
2.50

FIG. 16

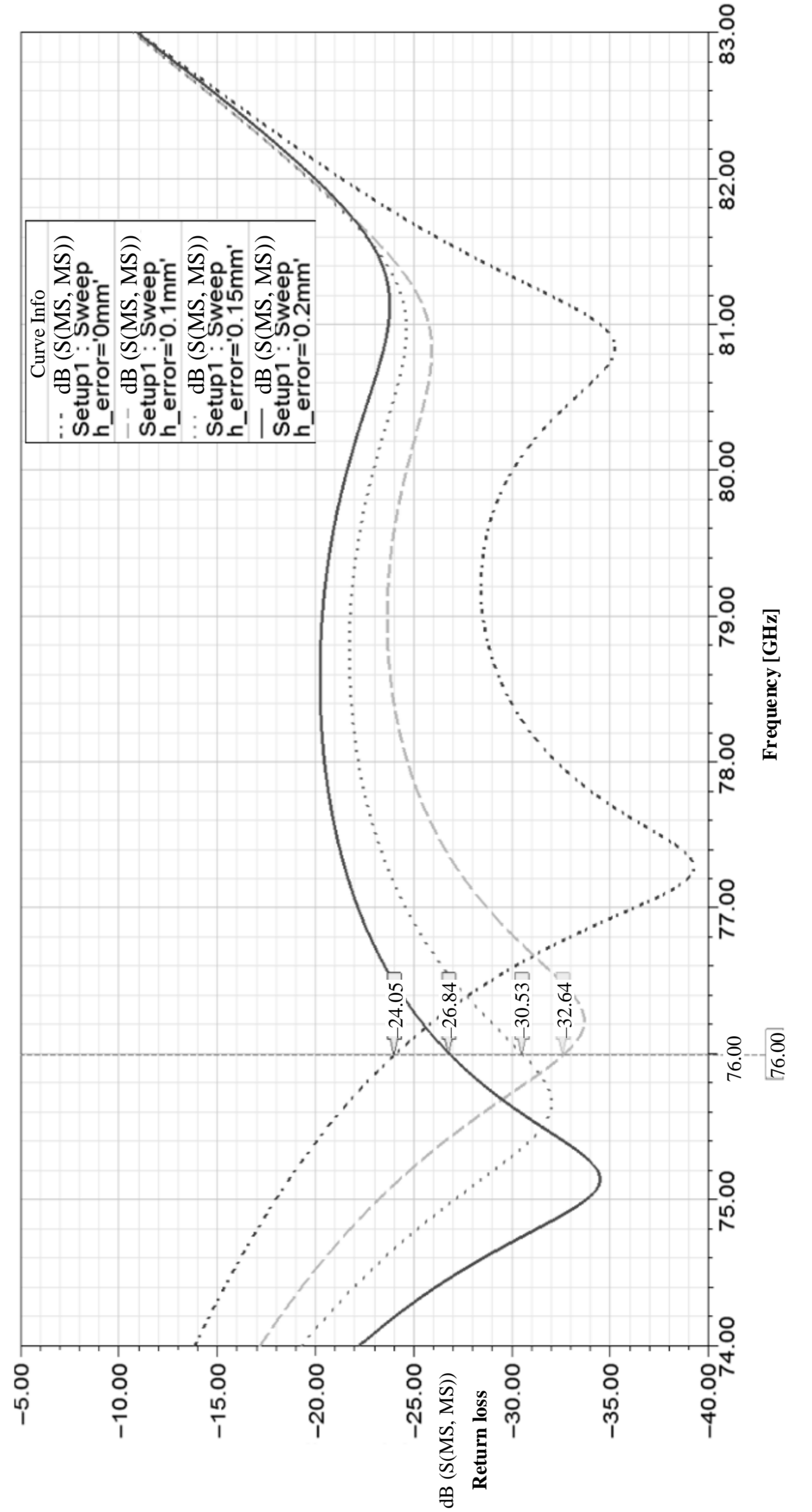

Curve Info
dB (S(MS, MS))
Setup1 : Sweep
h_error='0mm'
dB (S(MS, MS))
Setup1 : Sweep
h_error='0.1mm'
dB (S(MS, MS))
Setup1 : Sweep
h_error='0.15mm'
dB (S(MS, MS))
Setup1 : Sweep
h_error='0.2mm'
−24.05
−26.84
−30.53
−32.64
76.00
Frequency [GHz]
74.00
75.00
76.00
77.00
78.00
79.00
80.00
81.00
82.00
83.00
dB (S(MS, MS))
Return loss
−5.00
−10.00
−15.00
−20.00
−25.00
−30.00
−35.00
−40.00

FIG. 17

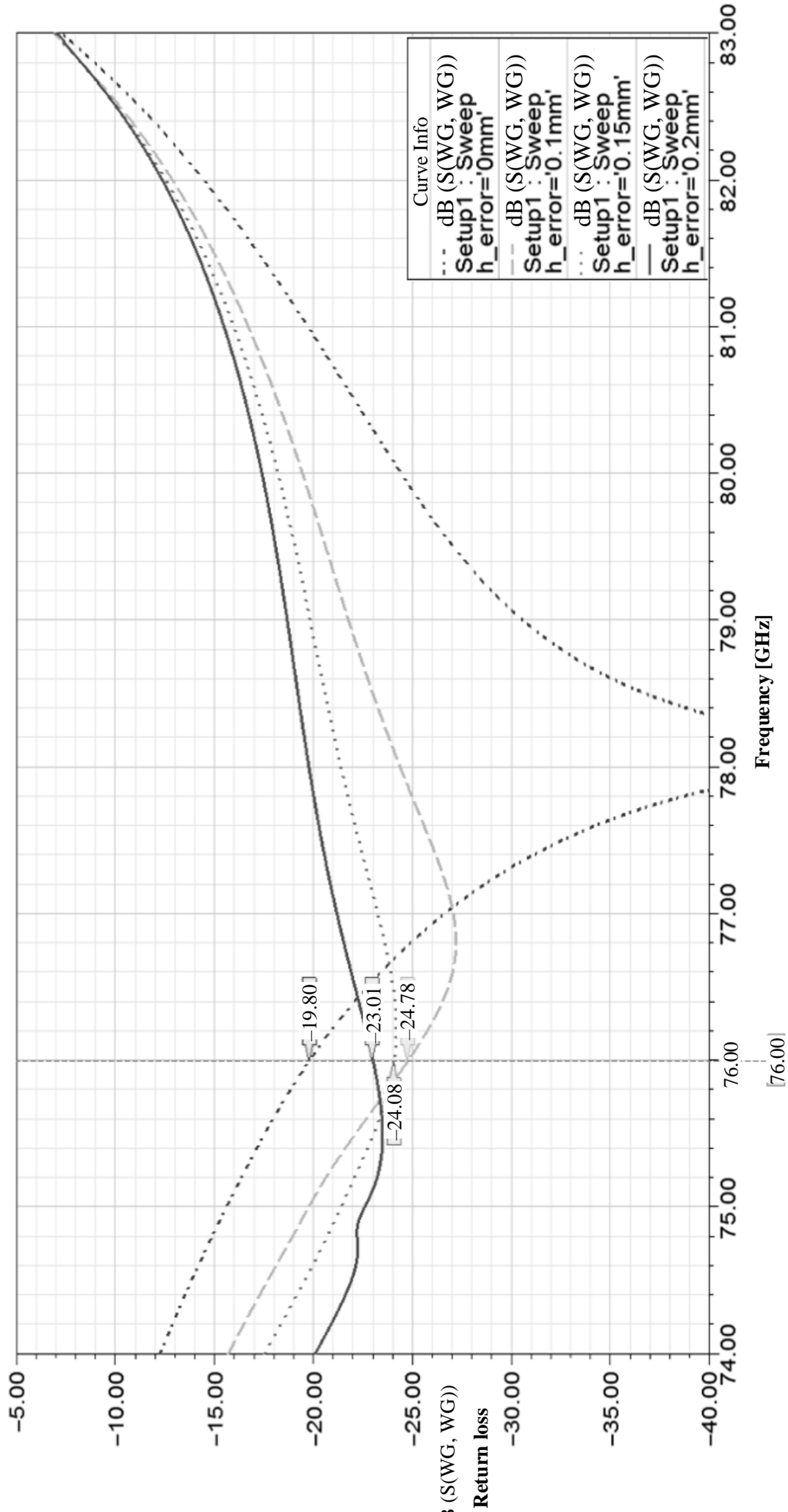

Curve Info
dB (S(WG, WG))
Setup1 : Sweep
h_error='0mm'
dB (S(WG, WG))
Setup1 : Sweep
h_error='0.1mm'
dB (S(WG, WG))
Setup1 : Sweep
h_error='0.15mm'
dB (S(WG, WG))
Setup1 : Sweep
h_error='0.2mm'
-19.80
-23.01
-24.78
-24.08
76.00
Frequency [GHz]
dB (S(WG, WG))
Return loss
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
74.00
75.00
76.00
77.00
78.00
79.00
80.00
81.00
82.00
83.00

FIG. 18

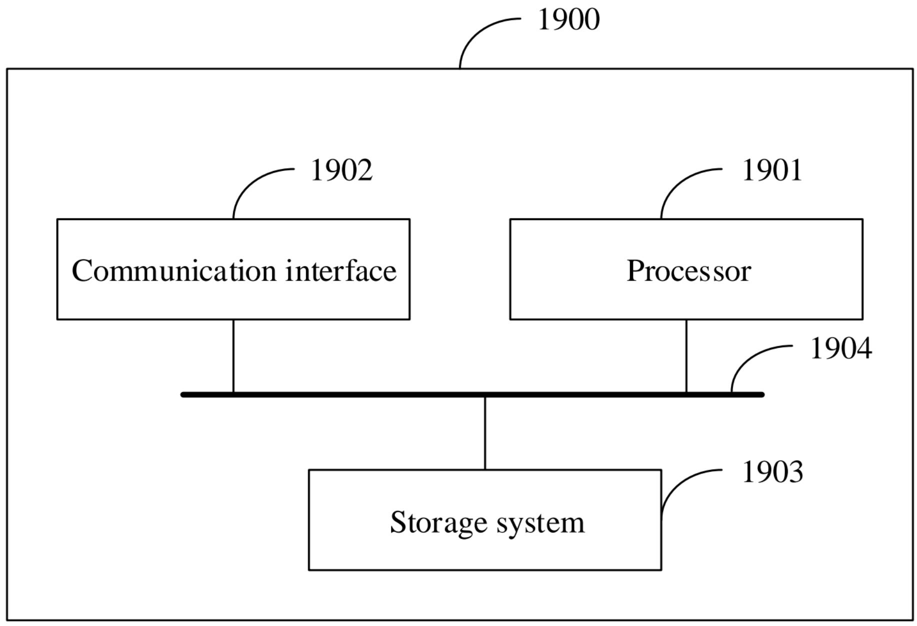

1900
1902
1901
Communication interface
Processor
1904
1903
Storage system

FIG. 19

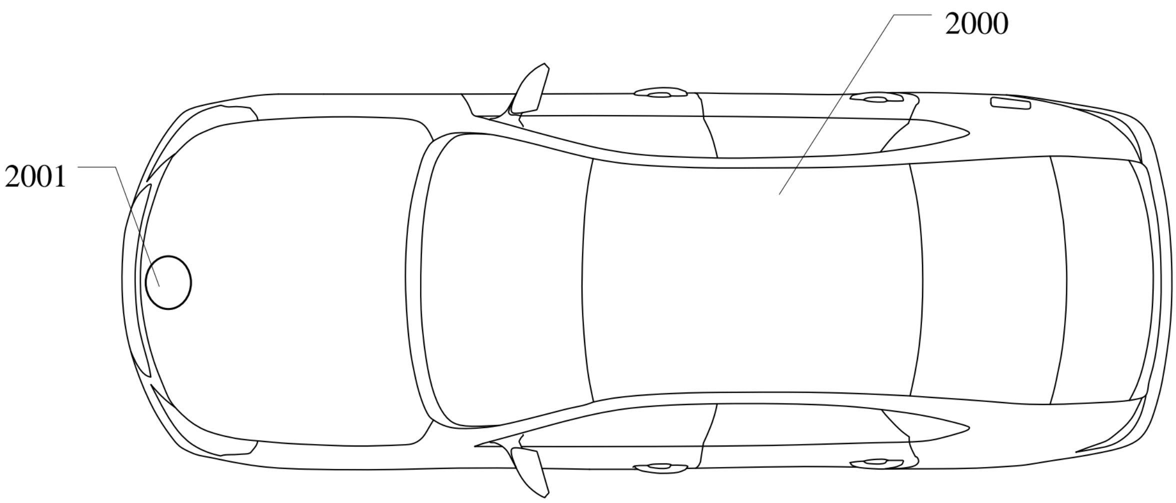

2000
2001

FIG. 20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/082166

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/32(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)

DWPI, CNTXT, ENTXTC: 波导, 车载, 宽, 雷达, 凸, 微带, 隙, 槽, 缝, 开口, 转, PCB, waveguide, vehicle, car, radar, convex, microstrip, slot, gap, slit, opening, conversion

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 115036701 A (SHANGHAI JIHE HUOBAN INTELLIGENT DRIVING CO., LTD.) 09 September 2022 (2022-09-09) description, paragraphs 0045-0050, and figures 1-3	1-12, 19-21
Y	CN 115036701 A (SHANGHAI JIHE HUOBAN INTELLIGENT DRIVING CO., LTD.) 09 September 2022 (2022-09-09) description, paragraphs 0045-0050, and figures 1-3	13-18
Y	CN 218448402 U (FUSI (HANGZHOU) INTELLIGENT TECHNOLOGY CO., LTD.) 03 February 2023 (2023-02-03) description, paragraphs 0027-0028, and figure 2	13-18
X	CN 115207589 A (HUAWEI TECHNOLOGIES CO., LTD.) 18 October 2022 (2022-10-18) description, paragraphs 0045-0059, and figures 3-5	1-12, 19-21
A	CN 115207588 A (HUAWEI TECHNOLOGIES CO., LTD.) 18 October 2022 (2022-10-18) entire document	1-21
A	WO 2022213826 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 13 October 2022 (2022-10-13) entire document	1-21

☐ 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
- "D" document cited by the applicant in the international application
- "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
16 October 2023	**19 October 2023**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/082166

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	115036701	A	09 September 2022	None			
CN	218448402	U	03 February 2023	None			
CN	115207589	A	18 October 2022	None			
CN	115207588	A	18 October 2022	WO	2022213826	A1	13 October 2022
WO	2022213826	A1	13 October 2022	CN	115207588	A	18 October 2022

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