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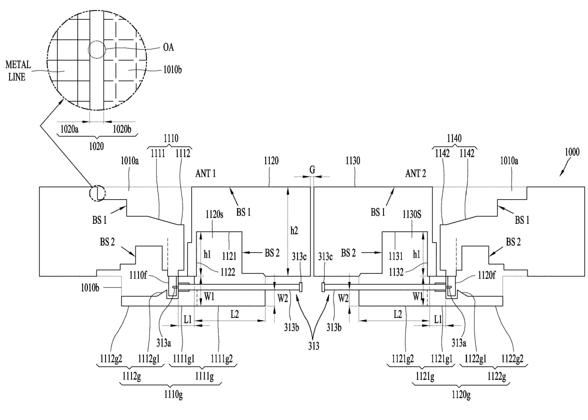
(54) ANTENNA MODULE DISPOSED IN VEHICLE

(57) An antenna assembly comprises: a first dielectric substrate that forms a transparent area and has a first conductive pattern, a second conductive pattern, and a third conductive pattern spaced apart from the second conductive pattern by a gap; and a second dielectric substrate that forms an opaque area and comprises a ground conductive pattern and a feeding pattern. The first conductive pattern may comprise a first portion and a second portion perpendicular to the first portion. The third conductive pattern may be operated by a current coupled from the second conductive pattern that has a symmetrical shape with respect to the gap in a first frequency band. A partial area of the ground conductive pattern may be disposed parallel to a coaxial cable so as to overlap same by a predetermined area.

FIG. 15B



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Description

Technical Field

[0001] The present specification relates to a transparent antenna arranged in a vehicle. One or more embodiments relate to an antenna assembly made of a transparent material to suppress an antenna region from being visible on vehicle glass.

Background Art

[0002] A vehicle may perform wireless communication services with other vehicles, nearby objects, infrastructures, or a base station. In this regard, various communication services may be provided through a wireless communication system to which an LTE communication technology or a 5G communication technology is applied. Meanwhile, some of LTE frequency bands may be allocated for 5G communication services.

[0003] Meanwhile, a vehicle body and roof are formed of metallic material, which causes a problem with blocking radio waves. Accordingly, a separate antenna structure may be arranged on top of the vehicle body or the vehicle roof. Alternatively, when the antenna structure is arranged below the vehicle body or roof, a portion of the vehicle body or roof corresponding to an antenna arrangement region may be formed of a non-metallic material.

[0004] However, in terms of design, the vehicle body or roof needs to be integrally formed. In this case, the exterior of the vehicle body or roof may be formed of a metallic material. This may cause antenna efficiency to be drastically lowered due to the vehicle body or roof.

[0005] In relation to this, to increase communication capacity without a change in the exterior design of the vehicle, a transparent antenna may be disposed on glass corresponding to a window of the vehicle. However, antenna radiation efficiency and impedance bandwidth characteristics are deteriorated due to electrical loss of the transparent antenna.

[0006] When an antenna pattern is formed with a metal mesh structure in which metal lines are interconnected on a dielectric substrate, a transparent antenna from which the metal lines are not visually distinguishable may be implemented. However, when the metal mesh structure is not formed in a dielectric region surrounding an antenna region where the antenna pattern is formed, there is a problem in that the antenna region and the dielectric region are visually distinguished, causing a difference in visibility.

[0007] To solve the problem, dummy mesh grids may be arranged even in the dielectric region, but as the dummy mesh grids are arranged, interference occurs between the dummy mesh grids and the antenna pattern, causing a problem in that antenna performance degrades.

[0008] Meanwhile, when a transparent antenna is arranged on vehicle glass, the transparent antenna for the vehicle may be electrically connected to a feeding pattern arranged on a separate dielectric substrate. In this regard, the transparent antenna for the vehicle is designed primarily for the performance of an antenna itself placed on a glass panel, which has a problem in that an actual attachment environment to the vehicle is not sufficiently reflected. This causes a problem that antenna resonance characteristics and antenna performance deteriorate depending on a location where the transparent antenna for the vehicle is attached and a direction in which a metal chassis of a vehicle body and cables for feeding are arranged.

Disclosure of Invention

Technical Problem

[0009] One aspect of the specification is to solve the aforementioned problems and other drawbacks. Another aspect of the specification is to provide a broadband transparent antenna assembly that may be arranged on vehicle glass.

[0010] Still another aspect of the specification is to improve antenna efficiency of a broadband transparent antenna assembly that may be arranged on vehicle glass.

[0011] Still another aspect of the specification is to provide a broadband antenna structure made of a transparent material that is capable of reducing feeding loss and improving antenna efficiency while operating in a wide band.

[0012] Still another aspect of the specification is to provide a method of designing a broadband antenna considering an actual attachment environment to a vehicle by analyzing the change in antenna performance according to the affection by a metal chassis as well as a glass panel of the vehicle and a cable structure.

[0013] Still another aspect of the specification is to suppress deterioration of antenna reflection coefficient characteristics and bandwidth characteristics in a transparent antenna element formed adjacent to a metal frame.

[0014] Still another aspect of the specification is to improve antenna reflection coefficient characteristics and bandwidth characteristics in a low band (LB) by arranging conductive patterns adjacent to each other with a gap interval below a threshold value between adjacent transparent antenna elements.

[0015] Still another aspect of the specification is to arrange transparent antenna elements, which are formed adjacent to a metal frame, to be adjacent to each other while maintaining isolation between the antenna elements below a certain level.

Solution to Problem

[0016] To achieve those aspects and other advantages, an antenna assembly according to one aspect of the specification includes a first dielectric substrate forming a transparent region, and including a first conductive pattern, a second conductive pattern, and a third conductive pattern spaced apart from the second conductive pattern by a gap, wherein the third conductive pattern operates by a current coupled from the second conductive pattern having a symmetrical shape on the basis of the gap in a first frequency band; and a second dielectric substrate forming an opaque region, and including a ground conductive pattern and a feeding pattern. The first conductive pattern may include a first part and a second part perpendicular to the first part. The third conductive pattern may operate by a current coupled from the second conductive pattern that has a symmetrical shape on the basis of the gap in the first frequency band. A partial region of the ground conductive pattern may be arranged to overlap in parallel a coaxial cable by a certain region.

[0017] According to an embodiment, the ground conductive pattern of the second dielectric substrate may include a first region and a second region. A first sub-region of the first region of the ground conductive pattern may be connected to a ground of the coaxial cable. A second sub-region of the first region of the ground conductive pattern may be arranged to overlap the coaxial cable by a certain region.

[0018] According to an embodiment, the second part of the first conductive pattern may be connected to the feeding pattern, and the second conductive pattern may be connected to the first region of the ground conductive pattern.

[0019] According to an embodiment, the second conductive pattern may include a third part and a fourth part perpendicular to the third part. The third conductive pattern may include a fifth part and a sixth part perpendicular to the fifth part. An end of the fifth part of the third conductive pattern may be spaced apart by the gap from an end of the third part of the second conductive pattern. A distance of the gap may be $\lambda g/20$ or less on the basis of a specific frequency of the first frequency band.

[0020] According to an embodiment, a distance of the gap formed between the end of the fifth part of the third conductive pattern and the end of the third part of the second conductive pattern may be $\lambda g/20$ or less based on a specific frequency of the first frequency band.

[0021] According to an embodiment, the first dielectric substrate may further include a fourth conductive pattern having a symmetrical shape on the basis of the gap. The second dielectric substrate may further include a second ground conductive pattern and a second feeding pattern. The fourth conductive pattern may include a seventh part and an eighth part perpendicularly connected to the seventh part and connected to the second feeding pattern.

[0022] According to an embodiment, the second ground conductive pattern of the second dielectric substrate may include a third region and a fourth region. The third region of the second ground conductive pattern may be formed in a symmetrical shape with the first region of the ground conductive pattern on the basis of the gap. The fourth region of the second ground conductive pattern may be formed in a symmetrical shape with the second region of the ground conductive pattern on the basis of the gap.

[0023] According to an embodiment, the second part of the first conductive pattern may be connected to the feeding pattern, and the second conductive pattern may be connected to the first region of the ground conductive pattern. The eighth part of the fourth conductive pattern may be connected to the second feeding pattern, and the third conductive pattern may be connected to the third region of the second ground conductive pattern. A first sub-region of the third region of the second ground conductive pattern may be connected to a ground of a second coaxial cable, and a second sub-region of the third region of the second ground conductive pattern may be arranged to overlap the second coaxial cable by a certain region.

[0024] According to an embodiment, the second conductive pattern and the third conductive pattern may be formed to have a first length in a first axial direction parallel to the coaxial cable. The coaxial cable may be formed to have a second length from a point where a signal line corresponding to one end of the coaxial cable is connected to a point corresponding to another end of the coaxial cable. The second coaxial cable may be formed to have the second length from a point where a signal line corresponding to one end of the second coaxial cable is connected to a point corresponding to another end of the second coaxial cable. The second length may be 0.5 times longer than the first length.

[0025] According to an embodiment, a second sub-region of the first region of the ground conductive pattern may be formed to have a third length in the first axial direction. A second sub-region of the third region of the second ground conductive pattern may be formed to have a third length in the first axial direction. The third length may be 0.5 times longer than the first length and shorter than the second length.

[0026] According to an embodiment, the first sub-region of the first region of the ground conductive pattern and the first sub-region of the third region of the second ground conductive pattern may be formed to have a first width in a second axial direction perpendicular to the first axial direction. The second sub-region of the first region of the ground conductive pattern and the second sub-region of the third region of the second ground conductive pattern may be formed to have a second width in the second axial direction. The first width may be larger than a sum of the second width and a diameter of the coaxial cable.

[0027] According to an embodiment, the coaxial cable may be arranged to be spaced apart in parallel from an end of the second sub-region of the first region of the ground conductive pattern. The second coaxial cable may be arranged to be spaced apart in parallel from an end of the second sub-region of the third region of the second ground conductive pattern.

[0028] According to an embodiment, the ground conductive pattern may include a second region connected to the first region and arranged on one side of the feeding pattern. The second ground conductive pattern may include a fourth region connected to the third region and arranged on another side of the second feeding pattern. The second region of the ground conductive pattern may be arranged below the first part of the first conductive pattern. The fourth region of the second ground conductive pattern may be arranged below the seventh part of the fourth conductive pattern.

[0029] According to an embodiment, the first conductive pattern, the second conductive pattern, and the second region of the ground conductive pattern may operate as a first antenna in the first frequency band through a third frequency band. The third conductive pattern, the fourth conductive pattern, and the fourth region of the second ground conductive pattern may operate as a second antenna in the first frequency band through the third frequency band.

[0030] According to an embodiment, the first conductive pattern and the second conductive pattern may operate as the first antenna of a dipole antenna mode in the first frequency band. The third conductive pattern and the fourth conductive pattern may operate as the second antenna of the dipole antenna mode in the first frequency band. The first conductive pattern and the second conductive pattern may form an asymmetrical structure. The third conductive pattern and the fourth conductive pattern may form an asymmetrical structure.

[0031] According to an embodiment, the first conductive pattern may operate as the first antenna of a monopole antenna mode in a second frequency band. The fourth conductive pattern may operate as the second antenna of the monopole antenna mode in the second frequency band. The second region of the ground conductive pattern may operate as the first antenna in the third frequency band. The fourth region of the second ground conductive pattern may operate as the second antenna in the third frequency band. The second frequency band may be higher than the first frequency band, and the third frequency band may be higher than the second frequency band.

[0032] According to an embodiment, the first conductive pattern, the second conductive pattern, the third conductive pattern, and the fourth conductive pattern may be formed in a metal mesh shape having a plurality of opening areas on the first dielectric substrate. The first conductive pattern, the second conductive pattern, the third conductive pattern, and the fourth conductive pattern may form a radiator region. The first conductive pattern, the second conductive pattern, the third conductive pattern, and the fourth conductive pattern may form a coplanar waveguide (CPW) structure on the first dielectric substrate.

[0033] According to an embodiment, the antenna assembly may include a plurality of dummy mesh grid patterns on an outer portion of the radiator region on the first dielectric substrate. The plurality of dummy mesh grid patterns may be not connected to the feeding pattern and the ground conductive pattern. The plurality of dummy mesh grid patterns may not be connected to the second feeding pattern and the second ground conductive pattern. The plurality of dummy mesh grid patterns may be separated from each other.

[0034] According to another aspect of the specification, a vehicle includes: a metal frame having an opening formed therein; a glass panel including a transparent region and an opaque region; and an antenna assembly disposed on the glass panel. The antenna assembly includes a first dielectric substrate forming a transparent region, and including a first conductive pattern, a second conductive pattern, and a third conductive pattern spaced apart from the second conductive pattern by a gap, wherein the third conductive pattern operates by a current coupled from the second conductive pattern having a symmetrical shape on the basis of the gap in a first frequency band; and a second dielectric substrate forming an opaque region, and including a ground conductive pattern and a feeding pattern. The first conductive pattern may include a first part and a second part perpendicular to the first part. The third conductive pattern may operate by a current coupled from the second conductive pattern that has a symmetrical shape on the basis of the gap in a first frequency band. A partial area of the ground conductive pattern may be arranged to overlap in parallel a coaxial cable by a certain region.

[0035] According to an embodiment, the ground conductive pattern of the second dielectric substrate may include a first region and a second region. A first sub-region of the first region of the ground conductive pattern may be connected to a ground of the coaxial cable. A second sub-region of the first region of the ground conductive pattern may be arranged to overlap the coaxial cable by a certain region.

[0036] According to an embodiment, the second part of the first conductive pattern may be connected to the feeding pattern, and the second conductive pattern may be connected to the first region of the ground conductive pattern.

[0037] According to an embodiment, the second conductive pattern may include a third part and a fourth part perpendicular to the third part. The third conductive pattern may include a fifth part and a sixth part perpendicular to the fifth part. An end of the fifth part of the third conductive pattern may be spaced apart by the gap from an end of the third part of the second conductive pattern. A distance of the gap may be $\lambda g/20$ or less based on a specific frequency of the first frequency band.

[0038] According to an embodiment, a distance of the gap formed between the end of the fifth part of the third conductive pattern and the end of the third part of the second conductive pattern may be $\lambda g/20$ or less based on a specific frequency of the first frequency band.

[0039] According to an embodiment, the first dielectric substrate may further include a fourth conductive pattern having a symmetrical shape on the basis of the gap. The second dielectric substrate may further include a second ground conductive pattern and a second feeding pattern. The fourth conductive pattern may include a seventh part and an eighth part perpendicularly connected to the seventh part and connected to the second feeding pattern.

[0040] According to an embodiment, the second ground conductive pattern of the second dielectric substrate may include a third region and a fourth region. The third region of the second ground conductive pattern may be formed in a symmetrical shape with the first region of the ground conductive pattern on the basis of the gap. The fourth region of the second ground conductive pattern may be formed in a symmetrical shape with the second region of the ground conductive pattern on the basis of the gap.

[0041] According to an embodiment, the second part of the first conductive pattern may be connected to the feeding pattern, and the second conductive pattern may be connected to the first region of the ground conductive pattern. The eighth part of the fourth conductive pattern may be connected to the second feeding pattern, and the third conductive pattern may be connected to the third region of the second ground conductive pattern. A first sub-region of the third region of the second ground conductive pattern may be connected to a ground of a second coaxial cable, and a second sub-region of the third region of the second ground conductive pattern may be arranged to overlap the second coaxial cable by a certain region.

[0042] According to an embodiment, the second conductive pattern and the third conductive pattern may be formed to have a first length in a first axial direction parallel to the coaxial cable. The coaxial cable may be formed to have a second length from a point where a signal line corresponding to one end of the coaxial cable is connected to a point corresponding to another end of the coaxial cable. The second coaxial cable may be formed to have the second length from a point where a signal line corresponding to one end of the second coaxial cable is connected to a point corresponding to another end of the second coaxial cable. The second sub-region of the first region of the ground conductive pattern may be formed to have a third length in the first axial direction. The second sub-region of the first region of the ground conductive pattern may be formed to have a third length in the first axial direction. The third length may be 0.5 times longer than the first length and shorter than the second length.

Advantageous Effects of Invention

[0043] Hereinafter, the technical effects of a broadband transparent antenna assembly that may be arranged on vehicle glass will be described.

[0044] Hereinafter, the technical effects of a broadband transparent antenna assembly that may be arranged on vehicle glass will be described.

[0045] According to the specification, 4G/5G broadband wireless communications in a vehicle may be enabled by providing a broadband transparent antenna assembly, which may be arranged on vehicle glass and include conductive patterns and an FPCB stub structure.

[0046] According to the specification, antenna efficiency may be improved by optimizing the shapes of conductive patterns and the shape of an FPCB stub and employing an asymmetrical antenna structure in a broadband transparent antenna assembly, which may be arranged on vehicle glass.

[0047] According to the specification, a broadband antenna structure made of a transparent material may be implemented, which may improve antenna efficiency by setting a different antenna operation mode for each frequency band while reducing feeding loss.

[0048] According to the specification, a broadband antenna structure considering an actual environment, in which the broadband antenna structure is attached to a vehicle, by analyzing the change in antenna performance according to the affection by a metal chassis as well as a glass panel of the vehicle and a cable structure.

[0049] According to the specification, an antenna assembly which is adjacent to a metal frame may suppress the deterioration of antenna reflection coefficient characteristics and bandwidth characteristics by utilizing conductive patterns of adjacent transparent antenna elements.

[0050] According to the specification, antenna reflection coefficient characteristics and bandwidth characteristics in a low band (LB) may be improved by arranging conductive patterns adjacent to each other with a gap below a threshold value between adjacent transparent antenna elements.

[0051] According to the specification, transparent antenna elements which are formed adjacent to a metal frame may be arranged adjacently, and a coaxial cable may be arranged parallel to an FPCB in a certain region, so that the isolation between the antenna elements may be maintained below a certain level.

[0052] According to the specification, a transparent antenna structure, which enables wireless communications in 4G and 5G frequency bands while minimizing changes in antenna performance and a difference in transparency between an antenna region and a surrounding region, may be provided.

[0053] Further scope of applicability of the disclosure will become apparent from the following detailed description. It should be understood, however, that the detailed description and specific examples, such as the preferred embodiments, are given by way of illustration only, because various changes and modifications within the technical idea and scope of the disclosure will be apparent to those skilled in the art.

Brief Description of Drawings

[0054]

FIG. 1 is a view of vehicle glass on which an antenna structure according to an embodiment of the disclosure is to be arranged.

FIG. 2A is a front view of the vehicle of FIG. 1, which has an antenna assembly arranged in different regions of front glass.

FIG. 2B is a front perspective view of the inside of the vehicle of FIG. 1, which has the antenna assembly arranged in the different regions of the front glass.

FIG. 2C is a lateral perspective view of the vehicle of FIG. 1, which has the antenna assembly arranged on upper glass.

FIG. 3 illustrates types of V2X applications.

FIG. 4 is a block diagram referenced for explaining a vehicle and an antenna system mounted on the vehicle according to an embodiment of the disclosure.

FIGS. 5A and 5C are views of a configuration that an antenna assembly according to the disclosure is arranged on vehicle glass.

FIG. 6A is a view of various embodiments of a frit pattern according to the disclosure. FIGS. 6B and 6C are views of transparent antenna patterns according to embodiments and structures in which the corresponding transparent antenna pattern is arranged on vehicle glass.

FIG. 7A is a view of a front side and a cross-section of a transparent antenna assembly according to the disclosure. FIG. 7B is a view of a grid structure of a metal mesh radiator region and a dummy metal mesh region according to embodiments.

FIG. 8A is a view of a layered structure of an antenna module and a feeding module. FIG. 8B is a view of an opaque substrate including a layered structure, in which the antenna module and the feeding structure are coupled to each other, and a coupling region.

FIG. 9A is a view of a coupling structure of a transparent antenna that is arranged in a transparent region and a frit region of vehicle glass.

FIG. 9B is an enlarged front view of a region where glass with the transparent antenna of FIG. 9A is coupled to a body structure of the vehicle. FIG. 9C is a cross-sectional view of the coupling structure between the vehicle glass and the body structure of FIG. 9B, viewed from different positions.

FIG. 10 is a view of a stacked structure of an antenna assembly and an attachment region between vehicle glass and a vehicle frame according to embodiments.

FIG. 11 is a view of a front side and a lateral side of an antenna assembly which may be attached on front glass of a vehicle.

FIGS. 12A to 12C compare cable structures and reflection coefficient characteristics of antenna assemblies according to embodiments.

FIG. 13 is a view of electric field distributions of the antenna assembly structures illustrated in FIGS. 12A to 12C.

FIG. 14A compares a first structure arranged vertically and a second structure arranged horizontally with respect to a metal frame of a vehicle according to embodiments.

FIG. 14B compares antenna efficiencies of the first and second structures of FIG. 14A.

FIGS. 15A and 15B are views of antenna assemblies including a plurality of antenna elements according to embodiments.

FIG. 15C is a view of antenna efficiency characteristics of the antenna assemblies of FIGS. 15A and 15B.

FIG. 16A is an enlarged view of a structure in which second and third conductive patterns are adjacently arranged in the antenna assembly of FIG. 15B.

FIG. 16B is an enlarged view of a structure in which the second and third conductive patterns are spaced apart from each other by at least a certain distance in the antenna assembly of FIG. 15B.

FIG. 16C is a view of reflection coefficient and isolation characteristics of the antenna assemblies of FIGS. 16A and 16B.

FIG. 17A is a view of a first structure in which an FPCB is not formed in a region where a coaxial cable is arranged.

FIG. 17B is a view of a second structure in which an FPCB is formed in a region where a coaxial cable is arranged.

FIG. 17C is a view of a structure in which a coaxial cable is coupled to a ground conductive pattern and a feeding pattern formed by the FPCB structure of FIG. 17C.

FIGS. 18A and 18B are views of reflection coefficient characteristics and efficiency characteristics of the antenna assembly structures of FIGS. 17A and 17B.

FIG. 18C is a view of a frequency band-dependent electric field distribution of an antenna assembly according to the disclosure.

FIG. 19A is a view of a structure in which the antenna assembly of FIG. 12B having a plurality of antenna elements is arranged on vehicle glass.

FIG. 19B is a view of a structure in which the antenna assembly of FIG. 12B having the plurality of antenna elements is arranged on a glass panel which is located inside a metal frame.

FIG. 19C is an exploded lateral perspective view of a coupling structure between the metal frame and the glass panel with the antenna assembly of FIG. 19B.

FIG. 20A is a view of reflection coefficient characteristics and efficiency characteristics of the antenna assembly of FIG. 19A.

FIG. 20B is a view of reflection coefficient characteristics and efficiency characteristics of the antenna assembly of FIG. 19B adjacent to the metal frame.

FIG. 21A is a view of a structure in which the antenna assembly of FIG. 12C having the plurality of antenna elements is arranged on the vehicle glass which is located inside the metal frame.

FIG. 21B is a view of reflection coefficient characteristics and efficiency characteristics of the antenna assembly of FIG. 21A.

FIGS. 22A and 22B are views of the flow of processes in which an antenna assembly according to one or more embodiments is manufactured by being coupled to a glass panel.

FIG. 23 is a view of an example of a configuration in which a plurality of antenna modules disposed at different positions of a vehicle are coupled with other components of the vehicle.

Mode for the Invention

[0055] A description will now be given in detail according to one or more embodiments disclosed herein, with reference to the accompanying drawings. For the sake of a brief description with reference to the drawings, the same or like components regardless reference numerals may be assigned the same reference numeral, and a redundant description thereof will be omitted. Suffixes "module" and "unit" used for components used in the following description are merely intended for easy description of the specification, and each suffix itself is not intended to give any special meaning or function. In describing the embodiments disclosed herein, moreover, the detailed description will be omitted when a specific description for publicly known technologies to which the disclosure pertains is judged to obscure the gist of the disclosure. The accompanying drawings are used to help easily understand various technical features, and it should be understood that the embodiments presented herein are not limited by the accompanying drawings. As such, the disclosure should be construed to extend to any alterations, equivalents, and substitutes in addition to those which are particularly set forth in the accompanying drawings.

[0056] It will be understood that although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are generally only used to distinguish one element from another.

[0057] It will be understood that when an element is referred to as being "connected with" another element, the element may be connected with the another element or intervening elements may also be present. In contrast, when an element is referred to as being "directly connected with" another element, there are no intervening elements present.

[0058] The singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0059] The term "include" or "has" as used herein should be understood that it is intended to indicate the existence of a feature, a number, a step, an element, a component, or a combination thereof disclosed in the specification, and it may also be understood that the existence or additional possibility of one or more other features, numbers, steps, elements, components, or combinations thereof are not excluded in advance.

[0060] An antenna system described herein may be mounted on a vehicle. Configurations and operations according to embodiments may also be applied to a communication system, namely, an antenna system mounted on a vehicle. In this regard, the antenna system mounted on the vehicle may include a plurality of antennas, and a transceiver circuit and a processor both configured to control the plurality of antennas.

[0061] Hereinafter, a description will be given of an antenna assembly (antenna module) that may be arranged on a window of a vehicle according to the disclosure, and an antenna system for a vehicle that includes the antenna assembly. In this regard, the antenna assembly may refer to a structure in which conductive patterns are combined on a dielectric substrate, and may also be referred to as an antenna module.

[0062] In this regard, FIG. 1 illustrates glass of a vehicle on which an antenna structure according to an embodiment may be arranged. Referring to FIG. 1, a vehicle 500 may include front glass 310, door glass 320, rear glass 330, and quarter glass 340. In some examples, the vehicle 500 may further include top glass 350 arranged on a roof in an upper region.

[0063] Therefore, the glass constituting the window of the vehicle 500 may include the front glass 310 arranged in a front region of the vehicle, the door glass 320 arranged in a door region of the vehicle, and the rear glass 330 arranged in a rear region of the vehicle. In some examples, the glass constituting the window of the vehicle 500 may further include the quarter class 340 arranged in a partial region of the door region of the vehicle. In addition, the glass constituting the window of the vehicle 500 may further include the top glass 350 spaced apart from the rear glass 330 and arranged in an upper region of the vehicle. Accordingly, each glass constituting the window of the vehicle 500 may also be referred to as a window.

[0064] The front glass 310 may be referred to as a front windshield because it suppresses wind blown from a front side from entering the inside of the vehicle. The front glass 310 may have a two-layer bonding structure having a thickness of about 5.0 to 5.5 mm. The front glass 310 may have a bonding structure of glass/shatterproof film/glass.

[0065] The door glass 320 may have a two-layer bonding structure or may be formed of single-layer compressed glass. The rear glass 330 may have a two-layer bonding structure having a thickness of about 3.5 to 5.5 mm or may be formed of single-layer compressed glass. In the rear glass 330, a spaced distance may be required between a transparent antenna and a heat line and AM/FM antenna. The quarter glass 340 may be formed of single-layer compressed glass with a thickness of about 3.5 to 4.0 mm, but is not limited thereto.

[0066] The size of the quarter glass 340 may vary depending on a type of vehicle, and may have a size smaller than the sizes of the front glass 310 and the rear glass 330.

[0067] Hereinafter, a structure in which an antenna assembly according to the disclosure is arranged in different regions of the front glass of a vehicle will be described. An antenna assembly attached to vehicle glass may be implemented as a transparent antenna. In this regard, FIG. 2A is a front view of the vehicle of FIG. 1, which has an antenna assembly arranged in different regions of the front glass. FIG. 2B is a front perspective view illustrating the inside of the vehicle of FIG. 1, which has the antenna assembly arranged in the different regions of the front glass. FIG. 2C is a lateral perspective view of the vehicle of FIG. 1, which has the antenna assembly arranged on upper glass.

[0068] Referring to FIG. 2A which is the front view of the vehicle 500, a configuration in which the transparent antenna for the vehicle according to the specification may be arranged is illustrated. A pane assembly 22 may include an antenna arranged in an upper region 310a. The pane assembly 22 may include an antenna in the upper region 310a, an antenna in a lower region 310b, and/or an antenna in a side region 310c. The pane assembly 22 may also include translucent pane glass 26 formed of a dielectric substrate. The antenna in the upper region 310a, the antenna in the lower region 310b, and/or the antenna in the side region 310c may be configured to support any one or more of various communication systems.

[0069] An antenna module 1100 may be arranged in the upper region 310a, the lower region 310b, or the side region 310c of the front glass 310. When the antenna module 1100 is arranged in the lower region 310b of the front glass 310, the antenna module 1100 may extend to a body 49 of a lower region of the translucent pane glass 26. The body 49 of the lower region of the translucent pane glass 26 may have lower transparency than other portions. A portion of a feeder and other interface lines may be arranged on the body 49 of the lower region of the translucent pane glass 26. A connector assembly 74 may be implemented on the body 49 of the lower region of the translucent pane glass 26. The body 49 of the lower region may constitute a vehicle body made of a metal material.

[0070] Referring to FIG. 2B, an antenna assembly 1000 may include a telematics control unit (TCU) 300 and an antenna module 1100. The antenna module 1100 may be located in a different region of glass of the vehicle.

[0071] Referring to FIGS. 2A and 2B, the antenna assembly may be arranged in the upper region 310a, the lower region 310b, and/or the side region 310c of the vehicle glass. Referring to FIGS. 2A to 2C, the antenna assembly may be arranged on the front glass 310, rear glass 330, quarter glass 340, and upper glass 350 of the vehicle.

[0072] Referring to FIGS. 2A to 2C, the antenna arranged in the upper region 310a of the front glass 310 of the vehicle may be configured to operate in a low band LB, a mid band (MB), a high band (HB), and a 5G Sub6 band of 4G/5G communication systems. The antenna in the lower region 310b and/or the antenna in the side region 310c may also be configured to operate in the LB, MB, HB, and 5G Sub6 band of the 4G/5G communication systems. An antenna structure 1100b on the rear glass 330 of the vehicle may also be configured to operate in the LB, MB, HB, and 5G Sub6 band of the 4G/5G communication systems. An antenna structure 1100c on the upper glass 350 of the vehicle may also be configured to operate in the LB, MB, HB, and 5G Sub6 band of the 4G/5G communication systems. An antenna structure 1100d on the quarter glass 350 of the vehicle may also be configured to operate in the LB, MB, HB, and 5G Sub6 band of the 4G/5G communication systems.

[0073] At least a portion of an outer region of the front glass 310 of the vehicle may be defined by the translucent pane glass 26. The translucent pane glass 26 may include a first part in which an antenna and a portion of a feeder are formed, and a second part in which another portion of the feeder and a dummy structure are formed. The translucent pane glass 26 may further include a dummy region in which conductive patterns are not formed. For example, a transparent region of the translucent pane glass 22 may be transparent to secure light transmission and a field of view.

[0074] Although it is exemplarily illustrated that conductive patterns may be formed in a partial region of the front glass 310, the conductive patterns may extend to the side glass 320 and the rear glass 330 of FIG. 1, and an arbitrary glass structure. In the vehicle 500, the occupants or driver may view road and surrounding environment through the pane assembly 22. In addition, the occupants or driver may view the road and surrounding environment without interference by the antenna in the upper region 310a, the antenna in the lower region 310b, and/or the antenna in the side region 310c.

[0075] The vehicle 500 may be configured to communicate with pedestrians, adjacent infrastructures, and/or servers in addition to adjacent vehicles. FIG. 3 illustrates types of V2X applications. Referring to FIG. 3, vehicle-to-everything (V2X) communication may include communication between a vehicle and each of all entities, such as vehicle-to-vehicle (V2V) communication which refers to communication between vehicles, vehicle-to-infrastructure (V2I) communication which refers to communication between a vehicle and an eNB or a road side unit

[0076] (RSU), vehicle-to-pedestrian (V2P) communication which refers to communication between a vehicle and a terminal carried by a person (a pedestrian, a cyclist, a vehicle driver, or a passenger), vehicle-to-network (V2N) communication, and the like.

[0077] Meanwhile, FIG. 4 is a block diagram illustrating a vehicle and an antenna system mounted on the vehicle according to an embodiment.

[0078] The vehicle 500 may include a communication device 400 and a processor 570. The communication device 400 may correspond to the telematics control unit (TCU) of the vehicle 500.

[0079] The communication device 400 may be a device for performing communication with an external device. Here, the external device may be another vehicle, a mobile terminal, or a server. The communication device 400 may perform the communication by including at least one of a transmitting antenna, a receiving antenna, a radio frequency (RF) circuit, and an RF device for implementing various communication protocols. In this regard, the communication device 400 may include a short-range communication unit 410, a location information unit 420, a V2X communication unit 430, an optical communication unit 440, a 4G wireless communication module 450, and a 5G wireless communication module 460. The communication device 400 may include a processor 470. According to an embodiment, the communication device 400 may further include other components in addition to the components described, or may not include some of the components described.

[0080] The 4G wireless communication module 450 and the 5G wireless communication module 460 may perform wireless communications with one or more communication systems through one or more antenna modules. The 4G wireless communication module 450 may transmit and/or receive signals to and/or from a device in a first communication system through a first antenna module. Also, the 5G wireless communication module 460 may transmit and/or receive signals to and/or from a device in a second communication system through a second antenna module. The 4G wireless communication module 450 and 5G wireless communication module 460 may also be physically implemented as one integrated communication module. For example, the first communication system and the second communication system may be an LTE communication system and a 5G communication system, respectively. However, the first communication system and the second communication system may not be limited thereto, and may expand to any different communication systems.

[0081] The processor of the device within the vehicle 500 may be implemented as a micro control unit (MCU) or a modem. The processor 470 of the communication device 400 may correspond to a modem, and the processor 470 may be implemented as an integrated modem. The processor 470 may acquire surrounding information from other adjacent vehicles, objects, or infrastructures through wireless communication. The processor 470 may perform vehicle control using the acquired surrounding information.

[0082] The processor 570 of the vehicle 500 may be a processor of a car area network (CAN) or advanced driving assistance system (ADAS), but is not limited thereto. When the vehicle 500 is implemented in a distributed control manner, the processor 570 of the vehicle 500 may be replaced with a processor of each device.

[0083] In some examples, the antenna module arranged in the vehicle 500 may include a wireless communication unit. The 4G wireless communication module 450 may perform transmission and reception of 4G signals with a 4G base station through a 4G mobile communication network. In this instance, the 4G wireless communication module 450 may transmit at least one 4G transmission signal to the 4G base station. In addition, the 4G wireless communication module 450 may receive at least one 4G reception signal from the 4G base station. In this regard, uplink (UL) multi-input/multi-output (MIMO) may be performed based on a plurality of 4G transmission signals transmitted to the 4G base station. In addition, downlink (DL) MIMO may be performed based on a plurality of 4G reception signals received from the 4G base station.

[0084] The 5G wireless communication module 460 may perform transmission and reception of 5G signals with a 5G base station through a 5G wireless communication network. Here, the 4G base station and the 5G base station may have a non-stand-alone (NSA) architecture. The 4G base station and the 5G base station may be arranged, for example, in the non-stand-alone (NSA) architecture. Alternatively, the 5G base station may be arranged in a stand-alone (SA) architecture at a separate location from the 4G base station. The 5G wireless communication module 460 may perform transmission and reception of 5G signals with a 5G base station through a 5G wireless communication network. In this instance, the 5G wireless communication module 460 may transmit at least one 5G transmission signal to the 5G base station. In addition, the 5G wireless communication module 460 may receive at least one 5G reception signal from the 5G base station. In this instance, a 5G frequency band that is the same as a 4G frequency band may be used, and this may be referred to as LTE re-farming. In some examples, a Sub6 frequency band, which is a band of 6 GHz or less, may be used as the 5G frequency band. In contrast, a millimeter-wave (mmWave) band may be used as the 5G frequency band to perform wideband high-speed communication. When the mmWave band is used, the electronic device may perform beamforming for coverage expansion of an area where communication with a base station is possible.

[0085] Regardless of the 5G frequency band, in the 5G communication system, MIMO may be supported to be performed a plurality of times, to improve a transmission rate. In this instance, UL MIMO may be performed by a plurality of 5G transmission signals that are transmitted to a 5G base station. In addition, DL MIMO may be performed by a plurality of 5G reception signals that are received from the 5G base station.

[0086] In some examples, a state of dual connectivity (DC) with both the 4G base station and the 5G base station may be attained through the 4G wireless communication module 450 and the 5G wireless communication module 460. As such, the dual connectivity with the 4G base station and the 5G base station may be referred to as EUTRAN NR DC (EN-DC). In some examples, when the 4G base station and the 5G base station are disposed in a co-located structure, throughput improvement may be achieved by inter-carrier aggregation (inter-CA). Accordingly, when the 4G base station and the 5G base station are disposed in the EN-DC state, the 4G reception signal and the 5G reception signal may be simultaneously received through the 4G wireless communication module 450 and the 5G wireless communication module 460. Short-range communication between electronic devices (e.g., vehicles) may be performed between electronic devices (e.g., vehicles) using the 4G wireless communication module 450 and the 5G wireless communication module 460. In one embodiment, after resources are allocated, vehicles may perform wireless communication in a V2V manner without a base station.

[0087] Meanwhile, for transmission rate improvement and communication system convergence, carrier aggregation (CA) may be carried out using at least one of the 4G wireless communication module 450 and the 5G wireless communication module 460 and a WiFi communication module. In this regard, 4G + WiFi carrier aggregation (CA) may be performed using the 4G wireless communication module 450 and the WiFi communication module 113. Or, 5G + WiFi CA may be performed using the 5G wireless communication module 460 and the WiFi communication module.

[0088] In some examples, the communication device 400 may implement a display device for a vehicle together with a user interface device. In this instance, the display device for the vehicle may be referred to as a telematics apparatus or an audio video navigation (AVN) apparatus.

[0089] In some examples, a broadband transparent antenna structure that may be arranged on vehicle glass may be implemented with a single dielectric substrate on the same plane as a CPW feeder. In addition, the broadband transparent antenna structure that may be arranged on the vehicle glass may be implemented with a structure in which grounds are formed on both sides of a radiator, to constitute a broadband structure.

[0090] Hereinafter, an antenna assembly associated with a broadband transparent antenna structure according to the specification will be described. In this regard, FIGS. 5A and 5B are views of configurations in which an antenna assembly according to the specification is arranged on vehicle glass. Referring to FIG. 5A, the antenna assembly 1000 may include a first dielectric substrate 1010a and a second dielectric substrate 1010b. The first dielectric substrate 1010a may be implemented as a transparent substrate and thus may be referred to as a transparent substrate 1010a. The second dielectric substrate 1010b may be implemented as an opaque substrate 1010b.

[0091] The glass panel 310 may be configured to include a transparent region 311 and an opaque region 312. The opaque region 312 of the glass panel 310 may be a frit region formed as a frit layer. The opaque region 312 may be formed to surround the transparent region 311. The opaque region 312 may be formed outside the transparent region 311. The opaque region 312 may form a boundary region of the glass panel 310.

[0092] A signal pattern formed on a dielectric substrate 1010 may be connected to the telematics control unit (TCU) 300 through a connector part 313 such as a coaxial cable. The telematics control unit (TCU) 300 may be mounted inside the vehicle, but is not limited thereto. The telematics control unit (TCU) 300 may be arranged on a dashboard inside the vehicle or a ceiling region inside the vehicle, but is not limited thereto.

[0093] FIG. 5B illustrates a configuration in which the antenna assembly 1000 is arranged in a partial region of the glass panel 310. FIG. 5C is a view of a configuration in which the antenna assembly 1000 is arranged in an entire region of the glass panel 310.

[0094] Referring to FIGS. 5B and 5C, the glass panel 310 may include the transparent region 311 and the opaque region 312. The opaque region 312 that is a non-visible area with transparency below a certain level may be referred to as a frit region, black printing (BP) region, or black matrix (BM) region. The opaque region 312 corresponding to the non-visible area may be formed to surround the transparent region 311. The opaque region 312 may be formed in a region outside the transparent region 311. The opaque region 312 may form a boundary region of the glass panel 310. A second dielectric substrate 1010b or heating pads 360a and 360b corresponding to a feeding substrate may be arranged in the opaque region 312. The second dielectric substrate 1010b arranged in the opaque region 312 may be referred to as an opaque substrate. Even when the antenna assembly 1000 is arranged in the entire region of the glass panel 310 as illustrated in FIG. 5C, the heating pads 360a and 360b may be arranged in the opaque region 312.

[0095] Referring to FIG. 5B, the antenna assembly 1000 may include a first transparent dielectric substrate 1010a and a second dielectric substrate 1010b. Referring to FIGS. 5B and 5C, the antenna assembly 1000 may include an antenna module 1100 configured with conductive patterns, and a second dielectric substrate 1010b. The antenna module 1100 may be provided with a transparent electrode part to be implemented as a transparent antenna module. The antenna module 1100 may include one or more antenna elements. The antenna module 1100 may include a MIMO antenna and/or other antenna elements for wireless communication. The other antenna elements may include at least one of GNSS/radio/broadcasting/WiFi/satellite communication/UWB, and remote keyless entry (RKE) antennas for vehicle applications.

[0096] Referring to FIGS. 5A to 5C, the antenna assembly 1000 may be interfaced with the TCU 300 through the connector part 313. The connector part 313 may include a connector 313c on an end of a cable to be electrically connected to the TCU 300. A signal pattern formed on the second dielectric substrate 1010b of the antenna assembly 1000 may be connected to the TCU 300 through the connector part 313 such as a coaxial cable. The antenna module 1100 may be electrically connected to the TCU 300 through the connector part 313. The TCU 300 may be arranged inside the vehicle, but is not limited thereto. The TCU 300 may be arranged on a dashboard inside the vehicle or a ceiling region inside the vehicle, but is not limited thereto.

[0097] In some examples, when the transparent antenna assembly according to the disclosure is attached to the inside or surface of the glass panel 310, a transparent electrode part including an antenna pattern and a dummy pattern may be arranged in the transparent region 311. On the other hand, an opaque substrate part may be arranged in the opaque region 312.

[0098] The antenna assembly formed on the vehicle glass according to the disclosure may be arranged in the transparent region and the opaque region. In this regard, FIG. 6A illustrates various embodiments of frit patterns according to the specification. FIGS. 6B and 6C are views of transparent antenna patterns according to embodiments and structures in which the respective transparent antenna patterns are arranged on vehicle glass.

[0099] Referring to (a) of FIG. 6A, a frit pattern 312a may be a metal pattern in a circular (polygonal, or elliptical) shape with a certain diameter. The frit pattern 312a may be arranged in a two-dimensional (2D) structure in both axial directions. The frit pattern 312a may be formed in an offset structure where center points between patterns forming adjacent rows are spaced apart by a certain distance.

[0100] Referring to (b) of FIG. 6A, the frit pattern 312b may be formed as a rectangular pattern in one axial direction. The frit pattern 312c may be arranged in a one-dimensional structure in one axial direction or in a 2D structure in both axial directions.

[0101] Referring to (c) of FIG. 6A, the frit pattern 312c may be formed as a slot pattern, which is formed by removing a metal pattern in a circular (polygonal or elliptical) shape with a certain diameter. The frit pattern 312b may be arranged in a 2D structure in both axial directions. The frit pattern 312c may be formed in an offset structure where center points between patterns forming adjacent rows are spaced apart by a certain distance.

[0102] Referring to FIGS. 5A to 6C, the opaque substrate 1010b and the transparent substrate 1010a may be electrically connected to each other in the opaque region 312. In this regard, a dummy pattern, which is electrically very small to have a certain size or less, may be positioned adjacent to the antenna pattern to secure the invisibility of a transparent antenna pattern. Accordingly, a pattern within a transparent electrode may be made invisible to the naked eye without deterioration of antenna performance. The dummy pattern may be designed to have similar optical transmittance to that of the antenna pattern within a certain range.

[0103] The transparent antenna assembly including the opaque substrate 1010b bonded to the transparent electrode part may be mounted on the glass panel 310. In this regard, to ensure invisibility, the opaque substrate 1010b connected to an RF connector or coaxial cable may be arranged in the opaque region 312 of the vehicle glass. Meanwhile, the transparent electrode part may be arranged in the transparent region 311 of the vehicle glass to ensure the invisibility of the antenna from outside of the vehicle glass.

[0104] A portion of the transparent electrode part may be attached to the opaque region 312 in some cases. The frit pattern of the opaque region 312 may be gradated from the opaque region 312 to the transparent region 311. The transmission efficiency of a transmission line may be improved while improving the invisibility of the antenna when the optical transmittance of the frit pattern is adjusted to match the optical transmittance of the transparent electrode part within a certain range. Meanwhile, sheet resistance may be reduced while ensuring invisibility by adopting a metal mesh shape similar to the frit pattern. In addition, the risk of disconnection of the transparent electrode layer during manufacturing and assembly may be reduced by increasing the line width of a metal mesh grid in a region connected to the opaque substrate 1010b.

[0105] Referring to (a) of FIG. 6A and FIG. 6B, a conductive pattern 1110 of the antenna module may include metal mesh grids with the same line width in the opaque region 312. The conductive pattern 1110 may include a connection pattern 1110c for connecting the transparent substrate 1010a and the opaque substrate 1010b. In the opaque region 312, the connection pattern 1110c and the frit patterns of a certain shape on both side surfaces of the connection pattern 1110c may be arranged at certain distances. The connection pattern 1110c may include a first transmittance section 1111c with a first transmittance and a second transmittance section 1112c with a second transmittance.

[0106] The frit patterns 312a formed in the opaque region 312 may include metal grids with a certain diameter arranged in one axial direction and another axial direction. The metal grids of the frit patterns 312a which correspond to the second transmittance section 1112c of the connection pattern 1110c may be arranged at intersections of the metal mesh grids.

[0107] Referring to (b) of FIG. 6A and FIG. 6B, the frit patterns 312b formed in the opaque region 312 may include slot grids, each of which has a certain diameter and is formed by removing a metal region, arranged in one axial direction and another axial direction. The slot grids of the frit patterns 312b may be arranged between the metal mesh grids in the connection pattern 1110c. Accordingly, the metal regions of the frit patterns 312b where slot grids are not formed may be arranged at the intersections of the metal mesh grids.

[0108] Referring to FIGS. 6A and 6C, the connection pattern 1110c may include metal mesh grids with a first line width W1 in the first transmittance section 1111c adjacent to the transparent region 311. The connection pattern 1110c may be formed with a second line width W2 thicker than the first line width W1 in the second transmittance section 1112c adjacent to the opaque substrate 1010b. In this regard, the first transparency of the first transmittance section 1111c may be set to be higher than the second transparency of the second transmittance section 1112c.

[0109] When the transparent antenna assembly is attached to the inside of the vehicle glass as illustrated in FIGS. 5A to 5C, the transparent electrode part may be arranged in the transparent region 311 and the opaque substrate 1010b may be arranged in the opaque region 312. In this regard, the transparent electrode part may be arranged in the opaque region 312 in some cases.

[0110] Metal patterns of a low-transmittance pattern electrode part and a high-transmittance pattern electrode part that are located in the opaque region 312 may partially be arranged in a gradation area of the opaque region 312. When the antenna pattern and a transmission line portion of the low-transmission pattern electrode part are configured as a transparent electrode, a decrease in antenna gain may be caused by the deterioration of transmission efficiency due to an increase in sheet resistance. As a way to overcome this loss of gain, the transmittance of the frit pattern 312 where an electrode is located and the transmittance of the transparent electrode may be made equal to each other within a certain range.

[0111] Low sheet resistance may be achieved by increasing the line width of the transparent electrode located in a region where the transmittance of the frit pattern 312a, 312b, 312c is low or by adding the same shape as that of the frit pattern 312a, 312b, 312c. Accordingly, invisibility may be secured while solving the problem of deteriorated transmission efficiency. The transmittance and pattern of the opaque region 312 are not limited to the structure of FIG. 6A and may differ depending on a glass manufacturer or vehicle manufacturer. Accordingly, the shape and transparency (line width and separation distance) of the transparent electrode of the transmission line may change in various ways.

[0112] FIG. 7A is a view of a front side and a cross-section of a transparent antenna assembly according to the disclosure. FIG. 7B is a view of a grid structure of a metal mesh radiator region and a dummy metal mesh region according to embodiments.

[0113] (a) of FIG. 7A is a front view of a transparent antenna assembly 1000, and (b) of FIG. 7A is a cross-sectional view of the transparent antenna assembly 1000, showing the layered structure of the transparent antenna assembly 1000. Referring to FIG. 7A, the antenna assembly 1000 may include a first transparent dielectric substrate 1010a and a second dielectric substrate 1010b. Conductive patterns 1110 that serves as a radiator may be arranged on one surface of the first transparent dielectric substrate 1010a. A feeding pattern 1120f and ground patterns 1121g and 1122g may be formed on one surface of the second dielectric substrate 1010b. The conductive patterns 1110 operating as the radiator may be configured to include one or more conductive patterns. The conductive patterns 1110 may include a first pattern 1111 connected to the feeding pattern 1120f, and a second pattern 1112 connected to the ground pattern 1121g. The conductive patterns 1110 may further include a third pattern 1113 connected to the ground pattern 1122g.

[0114] The conductive patterns 1110 constituting the antenna module may be implemented as a transparent antenna. Referring to FIG. 7B, the conductive patterns 1110 may be metal grid patterns 1020a with a certain line width or less to form a metal mesh radiator region. To maintain a certain level of transparency, dummy metal grid patterns 1020b may be formed in inner regions between adjacent patterns among the first to third patterns 1111, 1112, and 1113 of the conductive patterns 1100 or outer regions of them. The metal grid patterns 1020a and the dummy metal grid patterns 1020b may form a metal mesh layer 1020.

[0115] (a) of FIG. 7B illustrates a structure including typical metal grid patterns 1020a and dummy metal grid patterns 1020b. (b) of FIG. 7 illustrates a structure including atypical metal grid patterns 1020a and dummy metal grid patterns 1020b. As illustrated in (a) of FIG. 7B, the metal mesh layer 1020 may be formed in a transparent antenna structure by a plurality of metal mesh grids. The metal mesh layer 1020 may be formed in a typical metal mesh shape, such as a square shape, a diamond shape, or a polygonal shape. Conductive patterns may be configured such that the plurality of metal mesh grids operate as a feeding line or radiator. The metal mesh layer 1020 may constitute a transparent antenna region. As one example, the metal mesh layer 1020 may have a thickness of about 2 mm, but is not limited thereto.

[0116] The metal mesh layer 1020 may include the metal grid patterns 1020a and the dummy metal grid patterns 1020b. The metal grid patterns 1020a and the dummy metal grid patterns 1020b may have ends disconnected from each other to form opening areas OA, thereby being electrically disconnected. The dummy metal grid patterns 1020b may have slits SL formed so that ends of mesh grids CL1, CL2, ..., CLn are not connected.

[0117] Referring to (b) of FIG. 7B, the metal mesh layer 1020 may be formed by a plurality of atypical metal mesh grids. The metal mesh layer 1020 may include the metal grid patterns 1020a and the dummy metal grid patterns 1020b. The metal grid patterns 1020a and the dummy metal grid patterns 1020b may have ends disconnected from each other to form the opening areas OA, thereby being electrically disconnected. The dummy metal grid patterns 1020b may have slits SL formed so that ends of mesh grids CL1, CL2, ..., CLn are not connected.

[0118] Meanwhile, the transparent substrate on which the transparent antenna according to the specification is formed may be arranged on the vehicle glass. In this regard, FIG. 8A illustrates the layered structure of an antenna module and a feeding pattern. FIG. 8B illustrates an opaque substrate including the layered structure, in which the antenna module and the feeding structure are coupled to each other, and a coupling region.

[0119] Referring to (a) of FIG. 8A, the antenna module 1100 may include a first transparent dielectric substrate 1010a formed on a first layer, and a first conductive pattern 1110 formed on a second layer arranged on the first layer. The first conductive pattern 1110 may be implemented as the metal mesh layer 1020 including the metal grid patterns 1020a and the dummy metal grid patterns 1020b, as illustrated in FIG. 7B. The antenna module 1100 may further include a protective layer 1031 and an adhesive layer 1041a arranged on the second layer.

[0120] Referring to (b) of FIG. 8A, a feeding structure 1100f may include a second dielectric substrate 1010b, a second conductive pattern 1120, and a third conductive pattern 1130. The feeding structure 1100f may further include first and second protective layers 1033 and 1034 stacked on the second conductive pattern 1120 and the third conductive pattern 1130, respectively. The feeding structure 1100f may further include an adhesive layer 1041b formed on a partial region of the second conductive pattern 1120.

[0121] The second conductive pattern 1120 may be arranged on one surface of the second dielectric substrate 1010b implemented as an opaque substrate. The third conductive pattern 1130 may be arranged on another surface of the second dielectric substrate 1010b. The first protective layer 1033 may be formed on the third conductive pattern 1130. The second protective layer 1034 may be formed below the second conductive pattern 1120. Each of the first and second protective layers 1033 and 1034 may be configured to have a low permittivity below a certain value, enabling low-loss feeding to the transparent antenna region.

[0122] Referring to (a) of FIG. 8B, the antenna module 1100 may be coupled with the feeding structure 1100f including the second dielectric substrate 1010b, which is the opaque substrate. The first conductive pattern 1110 implemented as the metal mesh layer, which is the transparent electrode layer, may be formed on top of the first transparent dielectric substrate 1010a. The protective layer 1031 may be formed on top of the first conductive pattern 1110. The protective layer 1031 and the first adhesive layer 1041a may be formed on top of the first conductive pattern 1110. The first adhesive layer 1041a may be formed adjacent to the protective layer 1031.

[0123] The first adhesive layer 1041a formed on the first conductive pattern 1110 may be bonded to the second adhesive layer 1041b formed below the second conductive layer 1120. The first transparent dielectric substrate 1010a and the second dielectric substrate 1010b may be adhered by the bonding between the first and second adhesive layers 1041a and 1041b. Accordingly, the metal mesh grids formed on the first transparent dielectric substrate 1010a may be electrically connected to the feeding pattern formed on the second dielectric substrate 1010b.

[0124] The second conductive pattern 1120 and the third conductive pattern 1130 may be arranged on one surface and another surface of the second dielectric substrate 1010b, thereby implementing the feeding structure 1100f. The feeding structure 1100f may be implemented as a flexible printed circuit board (FPCB), but is not limited thereto. The first protective layer 1033 may be arranged on the third conductive pattern 1130, and the second protective layer 1034 may be arranged below the second conductive pattern 1120. The adhesive layer 1041b below the third conductive pattern 1130 may be bonded to the adhesive layer 1041a of the antenna module 1100. Accordingly, the feeding structure 1100f may be coupled with the antenna module 1100 and the first and second conductive patterns 1110 and 1120 may be electrically connected.

[0125] The antenna module 1100 implemented with the first transparent dielectric substrate 1010a may be formed to have a first thickness. The feeding structure 1100f implemented with the second dielectric substrate 1010b may be formed to have a second thickness. For example, the thicknesses of the dielectric substrate 1010a, the first conductive pattern 1110, and the protective layer 1031 of the antenna module 1100 may be 75 μm, 9 μm, and 25 μm, respectively. The first thickness of the antenna module 1100 may be 109 um. The thicknesses of the second dielectric substrate 1010b, the second conductive pattern 1120, and the third conductive pattern 1130 of the feeding structure 1100f may be 50 um, 18 um, and 18 um, respectively, and the thicknesses of the first and second protective layers 1033 and 1034 may be 28 um. Accordingly, the second thickness of the feeding structure 1100f may be 142 um. Since the adhesive layers 1041a and 1041b are formed on the first conductive pattern 1110 and below the second conductive pattern 1120, the entire thickness of the antenna assembly may be smaller than the sum of the first thickness and the second thickness. For example, the antenna assembly 1000 including the antenna module 1100 and the feeding structure 1100f may have a thickness of 198 um.

[0126] Referring to (b) of FIG. 8B, the conductive pattern 1120 may be formed on one surface of the second dielectric substrate 1010b forming the feeding structure 1100f. The conductive pattern 1120 may be formed in a CPW-type feeding structure that includes the feeding pattern 1120f and the ground patterns 1121g and 1122g formed on both sides of the feeding pattern 1120f. The feeding structure 1100f may be coupled with the antenna module 1100, as illustrated in (a) of FIG. 8B, through a region where the adhesive layer 1041 is formed.

[0127] The antenna module and the feeding structure constituting the antenna assembly according to the specification may be arranged on the vehicle glass and coupled through a specific coupling structure. In this regard, FIG. 9A illustrates a coupling structure of a transparent antenna that is arranged in a transparent region and a frit region of a vehicle glass.

[0128] Referring to FIG. 9A, the first transparent dielectric substrate 1010a may be adhered to the glass panel 310 through the adhesive layer 1041. The conductive pattern of the first transparent dielectric substrate 1010a may be bonded to the conductive pattern 1130 of the second dielectric substrate 1010b through ACF bonding. ACF bonding involves bonding of a tape, to which metal balls are added, to a bonding surface at high temperature/high pressure (e.g., 120 to 150 degrees, 2 to 5 Mpa) for a few seconds, and may be achieved by allowing electrodes to be in contact with each other through the metal balls therebetween. ACF bonding may electrically connect conductive patterns and simultaneously provide adhesive strength by thermally hardening the adhesive layer 1041.

[0129] The first transparent dielectric substrate 1010a, on which the transparent electrode layer is formed, and the second dielectric substrate 1010b in the form of FPCB may be attached to each other through local soldering. The connection pattern of the FPCB and the transparent antenna electrode may be connected through the local soldering using a coil in a magnetic field induction manner. During such local soldering, an increase in temperature of a soldered portion may not occur or the FPCB may be maintained flat without deformation. Accordingly, an electrical connection with high reliability may be achieved through the local soldering between the conductive patterns of the first transparent dielectric substrate 1010a and the second dielectric substrate 1010b.

[0130] The first transparent dielectric substrate 1010a, the metal mesh layer 1020 of FIG. 7A, the protective layer 1033, and the adhesive layer 1041 may form a transparent electrode. The second dielectric substrate 1010b, which is the opaque substrate, may be implemented as the FPCB, but is not limited thereto. The second dielectric substrate 1010b, which is the FPCB with the feeding pattern, may be connected to the connector part 313 and the transparent electrode.

[0131] The second dielectric substrate 1010b, which is the opaque substrate, may be attached to a partial region of the first transparent dielectric substrate 1010a. The first transparent dielectric substrate 1010a may be formed in the transparent region 311 of the glass panel 310. The second dielectric substrate 1010b may be formed in the opaque region 312 of the glass panel 310. The partial region of the first transparent dielectric substrate 1010a may be formed in the opaque region 312, and the first transparent dielectric substrate 1010a may be coupled to the second dielectric substrate 1010b in the opaque region 312.

[0132] The first transparent dielectric substrate 1010a and the second dielectric substrate 1010b may be adhered by the bonding between the adhesive layers 1041a and 1041b. A position at which the second dielectric substrate 1010b is bonded to the adhesive layer 1041 may be set to a first position P1. A position at which the connector part 313 is soldered to the opaque substrate 1010b may be set to a second position P2.

[0133] Meanwhile, the vehicle glass on which the antenna assembly according to the specification is formed may be coupled to a body structure of the vehicle. In this regard, FIG. 9B is an enlarged front view of a region where glass with the transparent antenna of FIG. 9A is coupled to a body structure of a vehicle. FIG. 9C is a cross-sectional view of the coupling structure between the vehicle glass and the body structure of FIG. 9B, viewed from different positions.

[0134] Referring to FIG. 9B, the first transparent dielectric substrate 1010a on which a transparent antenna is formed may be arranged in the transparent region 311 of the glass panel 310. The second dielectric substrate 1010b may be arranged in the opaque region 312 of the glass panel 310. Since the transmittance of the opaque region 312 is lower than that of the transparent region 311, the opaque region 312 may also be referred to as a black matrix (BM) region. A portion of the first transparent dielectric substrate 1010a on which the transparent antenna is formed may extend up to the opaque region 312 corresponding to the BM region. The first transparent dielectric substrate 1010a and the opaque region 312 may be formed to overlap each other by an overlap length OL in one axial direction.

[0135] (a) of FIG. 9C is a cross-sectional view of the antenna assembly, cut along the line AB in FIG. 9B. (a) of FIG. 9C is a cross-sectional view of the antenna assembly, cut along the line CD in FIG. 9B.

[0136] Referring to FIG. 9B and (a) of FIG. 9C, the first transparent dielectric substrate 1010a on which the transparent antenna is formed may be arranged in the transparent region 311 of the glass panel 310. The second dielectric substrate 1010b may be arranged in the opaque region 312 of the glass panel 310. The partial region of the first transparent dielectric substrate 1010a may extend up to the opaque region 312, so that the feeding pattern formed on the second dielectric substrate 1010b and the metal mesh layer of the transparent antenna are bonded and connected to each other.

[0137] An interior cover 49c may be configured to accommodate the connector part 313 connected to the second dielectric substrate 1010b. The connector part 313 may be arranged in a space between a body 49b made of a metal material and the interior cover 49c, and the connector part 313 may be coupled to an in-vehicle cable. The interior cover 49c may be arranged in an upper region of the body 49b made of the metal material. The interior cover 49c may be formed with one end bent to be coupled to the metal body 49b.

[0138] The interior cover 49c may include a metal material or dielectric material. When the interior cover 49c is made of a metal material, the interior cover 49c and the body 49b made of the metal material may constitute a metal frame 49. In this regard, the vehicle may include the metal frame 49. The opaque region 312 of the glass panel 310 may be supported by a portion of the metal frame 49. To this end, a portion of the body 49b of the metal frame 49 may be bent to be coupled to the opaque region 312 of the glass panel 310.

[0139] When the interior cover 49c is made of a metal material, at least a portion of a metal region of the interior cover 49c in the upper region of the second dielectric substrate 1010b may be cut out. A recess portion 49R from which the metal region has been cut out may be formed in the interior cover 49c. Accordingly, the metal frame 49 may include the recess portion 49R. The second dielectric substrate 1010b may be placed within the recess portion 49R of the metal frame 49.

[0140] The recess portion 49R may also be referred to as a metal cut region. One side of the recess portion 49R may be formed to be spaced apart from one side of the opaque substrate 1010b by a first length L1 which is equal to or greater than a threshold value. A lower boundary side of the recess portion 49R may be formed to be spaced apart from a lower boundary side of the opaque substrate 1010b by a second length L2 which is equal to or greater than a threshold value. As the metal is removed from the partial region of the interior cover 49c made of the metal material, signal loss and changes in antenna characteristics due to a surrounding metal structure may be suppressed.

[0141] Referring to FIG. 9B and (b) of FIG. 9C, a recess portion like a metal cut region may not be formed in the interior cover 49c in a region where the connector part and the opaque substrate are not arranged. In this regard, while protecting the internal components of the antenna module 1100 by use of the interior cover 49c, internal heat may be dissipated to the outside through the recess portion 49R of FIG. 9B and (a) of FIG. 9C. In addition, whether it is necessary to repair a connected portion may be immediately determined through the recess portion 49R of the interior cover 49c. Meanwhile, since the recess portion is not formed in the interior cover 49c in a region where the connector part and the second dielectric substrate are not arranged, the internal components of the antenna module 1100 may be protected.

[0142] Meanwhile, an antenna assembly 1000 according to the specification may be formed in various shapes on a glass panel 310, and the glass panel 310 may be attached to a vehicle frame. In this regard, FIG. 10 illustrates a stacked structure of an antenna assembly and an attachment region between vehicle glass and a vehicle frame according to embodiments.

[0143] Referring to (a) of FIG. 10, the glass panel 310 may include a transparent region 311 and an opaque region 312. The antenna assembly 1000 may include an antenna module 1100 and a feeding structure 1100f. The antenna module 1100 may include a first transparent dielectric substrate 1010a, a transparent electrode layer 1020, and an adhesive layer 1041. The feeding structure 1100f implemented as the opaque substrate and the transparent electrode layer 1020 implemented as the transparent substrate may be electrically connected to each other. The feeding structure 1100f and the transparent electrode layer 1020 may be directly connected through a first bonding region BR1. The feeding structure 1100f and the connector part 313 may be directly connected through a second bonding region BR2. Heat may be applied for bonding in the first and second bonding regions BR1 and BR2. Accordingly, the bonding regions BR1 and BR2 may be referred to as heating sections. An attachment region AR corresponding to a sealant region for attachment of the glass panel 310 to the vehicle frame may be formed on a side end area in the opaque region 312 of the glass panel 310.

[0144] Referring to (b) of FIG. 10, the glass panel 310 may include a transparent region 311 and an opaque region 312. The antenna assembly 1000 may include an antenna module 1100 and a feeding structure 1100f. The antenna module 1100 may include a protective layer 1031, the transparent electrode layer 1020, a first transparent dielectric substrate 1010a, and an adhesive layer 1041. The feeding structure 1100f implemented as an opaque substrate may overlap a partial region of the antenna module 1100 implemented as a transparent substrate. The feeding structure 1100f and the transparent electrode layer 1020 of the antenna module 1100 may be connected in a coupled-feeding manner. The feeding structure 1100f and the connector part 313 may be directly connected through a bonding region BR. Heat may be applied for bonding in the bonding region BR1. Accordingly, the bonding region BR may be referred to as a heating section. An attachment region AR corresponding to a sealant region for attachment of the glass panel 310 to the vehicle frame may be formed on a side end area in the opaque region 312 of the glass panel 310.

[0145] Referring to (a) and (b) of FIG. 10, the transparent substrate 1010a may include a (hard) coating layer to protect the transparent electrode layer 1020 from an external environment. Meanwhile, a UV-cut component may be added to the adhesive layer 1041 to suppress yellowing due to sunlight.

[0146] A broadband transparent antenna structure according to the disclosure, which may be disposed on glass of a vehicle, may be implemented with a single dielectric substrate on the same plane as a CPW feeder. In addition, a broadband transparent antenna structure according to the disclosure, which may be disposed on glass of a vehicle, may be implemented with a structure in which grounds are formed at opposite sides of a radiator so as to constitute a broadband structure. Hereinafter, an antenna assembly associated with a broadband transparent antenna structure according to the specification will be described. In this regard, FIG. 11 shows a front view and a lateral view of an antenna assembly which may be attached on front glass of a vehicle.

[0147] Referring to FIG. 11, a metal mesh layer 1020 which is a transparent pattern may be formed as an antenna pattern in a region of a glass panel 310 adjacent to a metal frame 49 of the vehicle. The interior cover 49c may include a metal material or dielectric material. When the interior cover 49c is made of a metal material, the interior cover 49c and the body 49b made of the metal material may constitute a metal frame 49.

[0148] The metal mesh layer 1020 formed as the antenna pattern may be formed in a region of front glass, for example, in an upper region of the front glass to be adjacent to the metal frame 49, but is not limited to this, and may change depending on the application. The glass panel 310 may include a transparent region 311 and an opaque region 312. The metal mesh layer 1020 as the transparent pattern may be formed in the transparent region 311, and an FPCB 1100b for feeding an antenna may be formed in the opaque region 312.

[0149] An attachment region AR corresponding to a sealant region for attachment of the glass panel 310 to the metal frame 49 may be formed in a side end region of the opaque region 312. The FPCB 1100b may be bonded to the glass panel 310 through a bonding region BR. The FPCB 1100b for feeding may be formed with a first length. An end of the FPCB 1100b and an end of the attachment region AR may form a bonding tolerance of a second length which is shorter than the first length. For example, the FPCB 1100b may be formed with a first length of about 12 mm, and the end of the FPCB 1100b and the end of the attachment region AR may be apart from each other by a second length of about 8 mm.

[0150] In some embodiments, a cable structure for feeding the antenna assembly according to the specification may be arranged vertically or horizontally to the metal frame 49 of the vehicle. In this regard, FIGS. 12A to 12C compare cable structures and reflection coefficient characteristics of antenna assemblies according to embodiments.

[0151] (a) of FIG. 12A shows a first structure of an antenna assembly 1000a which includes first to third conductive patterns 1110, 1120a, and 1130a. The first to third conductive patterns 1110a, 1120a, and 1130a may be arranged on a first dielectric substrate 1010a, and a feeding pattern 1110f and a ground conductive pattern 1110g may be formed in an FPCB structure on a second dielectric substrate 1010b. The first conductive pattern 1110a may include a first part 1111 and a second part 1112 formed perpendicular to the first part 1111. The second conductive pattern 1120a may include a third part 1121a and a fourth part 1122a formed perpendicular to the third part 1121a. The third conductive pattern 1130a may be located between the first conductive pattern 1110a and the ground conductive pattern 1110g.

[0152] (b) of FIG. 12A shows the reflection coefficient characteristics of the antenna assembly 1000a. Referring to FIG. 12A, the antenna assembly 1000a may operate in a dipole antenna mode in the LB band of 600 to 900 MHz. The first and second conductive patterns 1110 and 1120a connected to the feeding pattern 1110f and the ground conductive pattern 1110g of the CPW structure may operate in a CPW dipole antenna mode in a first frequency band, which is the LB band of 600 to 900 MHz. The antenna assembly 1000a may operate in a CPW dipole antenna mode in the first frequency band, which is the LB band, by first and second currents I1 and I2 formed in the first and second conductive patterns 1110 and 1120a. The antenna assembly 1000a configured by the third conductive pattern 1130a may exhibit a resonance characteristic of -15 dB or less in an ultrahigh band (UHB) of at least 4.5 GHz. UHB may be a frequency band higher than operating frequency bands of the first conductive pattern 1110 and the second conductive pattern 1120.

[0153] (a) of FIG. 12B shows a second structure in which an antenna assembly 1000b is arranged adjacent to the metal frame 49 of the vehicle. The metal frame 49 may be arranged adjacent to the antenna assembly 1000b, which includes first to third conductive patterns 1110, 1120a, and 1130a. The first to third conductive patterns 1110, 1120a, and 1130a may be arranged on a first dielectric substrate 1010a, and a feeding pattern 1110f and a ground conductive pattern 1110g may be formed in an FPCB structure on a second dielectric substrate 1010b. A coaxial cable 313 may be arranged parallel to the metal frame 49. A signal line 313a of the coaxial cable 313 may be connected to the feeding pattern 1110f, and a ground 313b of the coaxial cable 313 may be connected to the ground conductive pattern 1110g.

[0154] (b) of FIG. 12B shows the reflection coefficient characteristics of the antenna assembly 1000b. Referring to FIG. 12B, third and fourth currents I3 and I4 may be formed strongly above a threshold value on a ground current path by the metal frame 49, such that the antenna assembly 1000b may operate in an operation mode similar to a monopole antenna mode. Therefore, the antenna assembly 1000a may operate in an operation mode, similar to the monopole antenna mode, in the LB band of 600 to 900 MHz. A first current I1 formed in the first conductive pattern 1110 connected to the feeding pattern 1110f may be formed to be stronger than a second current I2b formed in the second conductive pattern 1120a connected to the ground conductive pattern 1110g. The antenna assembly 1000a may operate in an operation mode, similar to the monopole antenna mode, in a first frequency band, which is the LB band, by the first current I1 formed in the first conductive pattern 1110 and the third and fourth currents I3 and I4 formed in the metal frame 49. The antenna assembly 1000b having a structure in which the coaxial cable 313 is arranged parallel to the metal frame 49 may have a deteriorated reflection coefficient characteristic in the LB band, resulting in a deterioration in the LB bandwidth characteristic.

[0155] (a) of FIG. 12C shows a third structure in which an antenna assembly 1000 is arranged adjacent to the metal frame 49 of the vehicle. (a) of FIG. 12C shows a structure in which the metal frame 49 of the vehicle is arranged adjacent to the antenna assembly 1000 including first to third conductive patterns 1110, 1120, and 1130. The third conductive pattern 1130 as a coupled ground pattern may be arranged adjacent to the second conductive pattern 1120 may be arranged. A first current I1 may be formed in the first conductive pattern 1110. Second and fifth currents I2c and I5c may be formed in the second and third conductive patterns 1120 and 1130. Third and fourth currents I3c and I4c formed in the metal frame 49 may be reduced by the second and fifth currents I2c and I5c formed in the second and third conductive patterns 1120 and 1130.

[0156] Accordingly, the third conductive pattern 1130, which is the coupled ground pattern, may be arranged to reduce the influence of the metal frame 49 on the ground path. Therefore, an operation mode similar to the monopole antenna mode of (a) of FIG. 12B may change to a dipole antenna mode, as in (a) of FIG. 12C, by the third conductive pattern 1130.

[0157] The first and second conductive patterns 1110 and 1120 may be arranged on a first dielectric substrate 1010a, and a feeding pattern 1110f and a ground conductive pattern 1110g may be formed in an FPCB structure on a second dielectric substrate 1010b. A first region 1111g of the ground conductive pattern 1110g may be connected to a ground 313b of the coaxial cable 313. A portion of the first region 1111g of the ground conductive pattern 1110g may be connected to the second conductive pattern 1120. A second region 1112g of the ground conductive pattern 1110g may operate as a UHB radiator. The coaxial cable 313 may be arranged parallel to the metal frame 49. A signal line 313a of the coaxial cable 313 may be connected to the feeding pattern 1110f, and the ground 313b of the coaxial cable 313 may be connected to the ground conductive pattern 1110g.

[0158] (b) of FIG. 12C shows the reflection coefficient characteristics of the antenna assembly 1000. Referring to FIG. 12C, the antenna assembly 1000 having the structure in which the coaxial cable 313 is arranged parallel to the metal frame 49 may have improved reflection coefficient characteristics in the LB band by the third conductive pattern 1130 which is the coupled ground pattern, thereby improving LB bandwidth characteristics. In this regard, the antenna assembly 1000 may exhibit a dual resonance characteristic in the LB band by the third conductive pattern 1130, which is the coupled ground pattern.

[0159] A current distribution may be formed differently in the antenna assembly structures of FIGS. 12A to 12C, thereby implementing different operation modes. In this regard, FIG. 13 is a view of electric field distributions of the antenna assembly structures illustrated in FIGS. 12A to 12C.

[0160] Referring to (a) of FIG. 12A and (a) of FIG. 13, the antenna assembly 1000a may operate in the dipole antenna mode by forming the first and second currents I1 and I2 in the first and second conductive patterns 1100 and 1120a in the LB band. The first and second currents I1 and I2 may be formed in the first and second conductive patterns 1100 and 1120a, and thus the current distribution in end regions of the first and second conductive patterns 1100 and 1120a may be higher than the current distribution in other regions.

[0161] Referring to (a) of FIG. 12B and (b) of FIG. 13, the antenna assembly 1000b may form the first current I1 in the first conductive pattern 1100 and form the third and fourth currents I3 and I4 in the metal frame 49 in the LB band. A high current distribution may be formed in a lower region RL where the metal frame 49 and the second dielectric substrate 1010b are formed by the third and fourth currents I3 and I4 formed in the metal frame 49. Accordingly, the current distribution in the lower region RL where the metal frame 49 and the second dielectric substrate 1010b are formed may be higher than the current distribution in end regions of the first and second conductive patterns 1100 and 1120a. Accordingly, the antenna reflection coefficient and antenna efficiency characteristics may be degraded in the LB band.

[0162] Referring to (a) of FIG. 12C and (c) of FIG. 13, the antenna assembly 1000 may form the first current I1 in the first conductive pattern 1100 and form the third and fourth currents I3c and I4c in the metal frame 49 in the LB band. The second and fifth currents I2c and I5c may be formed in the second and third conductive patterns 1120 and 1130. The third and fourth currents I3c and I4c formed in the metal frame 49 may be reduced, and the second and fifth currents I2c and I5c formed in the second and third conductive patterns 1120 and 1130 may increase. Accordingly, the current distribution in a radiator region Rr where the second and third conductive patterns 1120 and 1130 are arranged may be formed high. Accordingly, the current distribution in the radiator region Rr where the second and third conductive patterns 1120 and 1130 are arranged may be formed higher than the current distribution in the lower region RL of (b) of FIG. 13. Accordingly, the antenna assembly 1000 may operate in the dipole antenna mode by the first to third conductive patterns 1110, 1120, and 1130 in the LB band, thereby improving the antenna reflection coefficient and antenna efficiency characteristics.

[0163] The antenna assembly may be arranged vertically or horizontally to the metal frame of the vehicle. In this regard, FIG. 14A compares a first structure arranged vertically and a second structure arranged horizontally with respect to the metal frame of the vehicle according to embodiments. FIG. 14B compares antenna efficiencies of the first and second structures of FIG. 14A.

[0164] Referring to FIGS. 11 and 14A, the metal mesh layer 1020 may be arranged in the transparent region 311 of the glass panel 310 on the first dielectric substrate 1010a of the antenna assembly 1000b, 1000. The first to third conductive patterns 1110, 1120a, and 1130a formed on the first dielectric substrate 1010a may be configured as a first antenna ANT1. A second antenna ANT2 may be formed in a symmetric structure with the first antenna ANT1 at a certain distance from the first antenna ANT1. Fourth to sixth conductive patterns 1110, 1120a, and 1130a formed on the first dielectric substrate 1010a may be configured as the second antenna ANT2.

[0165] (a) of FIG. 14A shows a first structure in which a coaxial cable 313-1 is arranged in a direction perpendicular to the metal frame 49 of the vehicle. In some embodiments, (b) of FIG. 13A shows a second structure in which the coaxial cable 313 is arranged in a horizontal direction with respect to the metal frame 49 of the vehicle.

[0166] Referring to FIG. 11 and (a) of FIG. 14A, the feeding pattern 1110f and the ground conductive pattern 1110g may be formed on the second dielectric substrate 1010b of the antenna assembly 1000b. The second dielectric substrate 1010b may be located in the opaque region 312 of the glass panel 310. The frame 49 of the vehicle may be arranged adjacent to the opaque region 312 of the glass panel 310. In the first structure in which the coaxial cable 313-1 connected to the feeding pattern 1110f is arranged in the direction perpendicular to the metal frame 49 of the vehicle, the opaque region 312 may be formed with a first length DL1 in a first axial direction. For example, the first length DL1 of the opaque region 312 in the first axial direction may be about 27 mm.

[0167] Referring to FIG. 11 and (b) of FIG. 14A, the feeding pattern 1110f and the ground conductive pattern 1110g may be formed on the second dielectric substrate 1010b of the antenna assembly 1000. The second dielectric substrate 1010b may be located in the opaque region 312 of the glass panel 310. The frame 49 of the vehicle may be arranged adjacent to the opaque region 312 of the glass panel 310. In the second structure in which the coaxial cable 313 connected to the feeding pattern 1110f is arranged in the horizontal direction with respect to the metal frame 49 of the vehicle, the opaque region 312 may be formed with a second length DL2 in the first axial direction. For example, the second length DL2 of the opaque region 312 in the first axial direction may be about 19 mm. In the second structure where the coaxial cable 313 is arranged in the horizontal direction with respect to the metal frame 49 of the vehicle, a TCU may be coupled between the coaxial cables 313. Accordingly, the second structure in which the coaxial cable 313 is arranged in the horizontal direction with respect to the metal frame 49 of the vehicle may be a structure which facilitates coupling with the TCU.

[0168] Referring to (a) of FIG. 14A and FIG. 14B, (i) the first structure in which the coaxial cable 313-1 is arranged in the direction perpendicular to the metal frame 49 of the vehicle may exhibit the antenna efficiency characteristics of at least -3 dB in a frequency band of 600 MHz to 0.6 GHz. Referring to (b) of FIG. 14A and FIG. 14B, (ii) the second structure in which the coaxial cable 313 is arranged in the horizontal direction with respect to the metal frame 49 of the vehicle may exhibit the antenna efficiency of -3 dB or less in a frequency band of 600 MHz to 800 MHz. For example, at a frequency of about 700 MHz, LB antenna efficiency may be reduced by about 1.5 dB.

[0169] Referring to (a) of FIG. 14A and FIG. 14B, (i) the first structure in which the coaxial cable 313-1 is arranged in the direction perpendicular to the metal frame 49 of the vehicle may exhibit the antenna efficiency characteristics of at least -3 dB in a frequency band of 4.5 GHz to 6 GHz. (ii) The second structure in which the coaxial cable 313 is arranged in the horizontal direction with respect to the metal frame 49 of the vehicle may exhibit the antenna efficiency of -3 dB or less in a frequency band of 4.5 GHz to 6 GHz. For example, at a frequency of about 5.6 GHz, UHB antenna efficiency may be reduced by about 1.5 dB.

[0170] Therefore, in the antenna assembly according to the specification, the reduction in distance between the metal frame 49 of the vehicle and the transparent antenna pattern may cause a decrease in antenna efficiency of at least 1.5 dB in the LB band. In another example, in the antenna assembly according to the specification, the reduction in antenna efficiency of at least 1.5 dB may occur in the UHB band depending on a direction in which the coaxial cable is mounted.

[0171] In some embodiments, a broadband transparent antenna structure which may be arranged on vehicle glass may assume that the coaxial cable 313 is arranged horizontally and coupled with the TCU. In this regard, FIGS. 15A and 15B are views of antenna assemblies each including a plurality of antenna elements according to embodiments. FIG. 15C is a view of antenna efficiency characteristics of the antenna assemblies of FIGS. 15A and 15B.

[0172] Referring to FIG. 12B and FIG. 15A, the antenna assembly 1000b may include the first to third conductive patterns 1110, 1120a, and 1130a formed on the first dielectric substrate 1010a. The antenna assembly 1000b may include the first antenna ANT1 and the second antenna ANT2 each including the first to third conductive patterns 1110, 1120a, and 1130a. The feeding pattern 1110f and the ground conductive pattern 1120g may be formed on the second dielectric substrate 1010b. The second conductive patterns 1120a of the first antenna ANT1 and the second antenna ANT2 may be formed in a symmetric shape with respect to one axis. The second conductive patterns 1120a of the first antenna ANT1 and the second antenna ANT2 may be arranged to be spaced apart by a gap Ga greater than or equal to a threshold value. The first antenna ANT1 and the second antenna ANT2 may operate independently, but the antenna characteristics may deteriorate in the LB band due to the arrangement of the metal frame 49.

[0173] The signal line 313a of the coaxial cable 313 may be connected to the feeding pattern 1110f, and the ground 313b of the coaxial cable 313 may be connected to the ground conductive pattern 1110g. The coaxial cable 313 may be arranged to be horizontal to the feeding pattern 1110f. The coaxial cable 313 of the first antenna ANT1 may be horizontally arranged on one side of the second dielectric substrate 1010b. The coaxial cable 313 of the second antenna ANT2 may be horizontally arranged on another side of the second dielectric substrate 1010b. Accordingly, connector portions 313c of the coaxial cables 313 of the first antenna ANT1 and the second antenna ANT2 may be arranged adjacent to each other. The connector portions 313c of the coaxial cables 313 of the first antenna ANT1 and the second antenna ANT2 may be coupled with the TCU.

[0174] Referring to FIG. 12C and FIG. 15B, the antenna assembly 1000 may include the first to third conductive patterns 1110, 1120, and 1130 formed on the first dielectric substrate 1010a. The third conductive pattern 1130 may be spaced apart from the second conductive pattern by a gap G of a threshold value or less. The third conductive pattern 1130 may operate by a current coupled from the second conductive patterns, which have a symmetric shape with respect to the gap G, in the first frequency band.

[0175] The antenna assembly 1000 may further include a fourth conductive pattern 1140 formed on the first dielectric substrate 1010a. The antenna assembly 1000 may include the first antenna ANT1 and the second antenna ANT2 each including the first to fourth conductive patterns 1110 to 1140. The feeding pattern 1110f and the ground conductive pattern 1120g may be formed on the second dielectric substrate 1010b. The third conductive pattern 1130 may be arranged at a gap G less than a threshold value from the second conductive pattern, which may increase the affection between the first antenna ANT1 and the second antenna ANT2. However, the antenna characteristics may be improved by reducing the current formed in the metal frame 49 in the LB band.

[0176] The signal line 313a of the coaxial cable 313 may be connected to the feeding pattern 1110f, and the ground 313b of the coaxial cable 313 may be connected to the ground conductive pattern 1110g. A sub-region 1112g1 of the second region 1112g of the ground conductive pattern 1110g may operate as a radiator in the UHB band. The coaxial cable 313 may be arranged to be horizontal to the feeding pattern 1110f. The coaxial cable 313 of the first antenna ANT1 may be horizontally arranged on one side of the second dielectric substrate 1010b. The coaxial cable 313 of the second antenna ANT2 may be horizontally arranged on another side of the second dielectric substrate 1010b. Accordingly, connector portions 313c of the coaxial cables 313 of the first antenna ANT1 and the second antenna ANT2 may be arranged adjacent to each other. A distance between the connector portions 313c of the first antenna ANT1 and the second antenna ANT2 may be reduced depending on the gap G of the threshold value or less. The connector portions 313c of the coaxial cables 313 of the first antenna ANT1 and the second antenna ANT2 may be coupled with the TCU.

[0177] Referring to FIGS. 15A and 15C, (i) the antenna assembly 1000b may have an antenna efficiency degraded below -3 dB, which is a reference value, in the LB band. For example, the efficiency of the antenna assembly 1000b may be -4.01 dB, which is reduced by at least -1 dB compared to the reference value, at 600 MHz in the LB band. Referring to FIGS. 15B and 15C, (ii) the antenna assembly 1000 may have an antenna efficiency improved to at least -3 dB, which is the reference value, in the LB band. For example, the efficiency of the antenna assembly 1000 may be -2.97 dB, which is more improved by at least 1 dB than the efficiency of the antenna assembly 1000b, at 600 MHz of the LB band.

[0178] Referring to FIGS. 15A and 15C, (i) the antenna assembly 1000b may have an antenna efficiency degraded below -3 dB, which is a reference value, in the UHB band. For example, the efficiency of the antenna assembly 1000b may be -3.74 dB, which is reduced below the reference value, at 5 GHz in the UHB band. Referring to FIGS. 15B and 15C, (ii) the antenna assembly 1000 may have an antenna efficiency of at least -3 dB, which is the reference value, in the UHB band. For example, the efficiency of the antenna assembly 1000 may be -1.56 dB, which is more improved by at least 2.2 dB than the efficiency of the antenna assembly 1000b, at 5 GHz of the UHB band.

[0179] A broadband transparent antenna structure according to the disclosure, which may be arranged on vehicle glass, may be implemented with a single dielectric substrate on the same plane as a CPWfeeder. In addition, a broadband transparent antenna structure according to the disclosure, which may be arranged on vehicle glass, may be implemented with a structure in which grounds are formed at opposite sides of a radiator so as to constitute a broadband structure.

[0180] Hereinafter, an antenna assembly associated with a broadband transparent antenna structure according to the specification will be described. In this regard, FIG. 16A is an enlarged view of a structure in which the second and third conductive patterns are adjacently arranged in the antenna assembly of FIG. 15B. FIG. 16B is an enlarged view of a structure in which the second and third conductive patterns are spaced apart from each other by a certain distance or more in the antenna assembly of FIG. 15B. FIG. 16C is a view of reflection coefficient and isolation characteristics of the antenna assemblies of FIGS. 16A and 16B.

[0181] Referring to FIGS. 15B and 16A, the second and third conductive patterns 1120 and 1130 of the antenna assembly 1000 may be arranged to be spaced apart from each other by a gap G of a threshold value or less. Referring to FIGS. 15B and 16B, the second and third conductive patterns 1120 and 1130 of the antenna assembly 1000 may be arranged to be spaced apart from each other by a gap Ga of at least the threshold value. Referring to FIGS. 15B to 16B, the second and third conductive patterns 1120 and 1130 may be formed in a symmetric shape in one axial direction based on a line AA'.

[0182] Referring to FIG. 16A and (a) of FIG. 16C, the first structure in which the second and third conductive patterns 1120 and 1130 are spaced apart by the gap G of the threshold value or less may have a reflection loss characteristic of -8 dB or less in the LB band of 617 to 960 MHz. Referring to FIG. 16B and (a) of FIG. 16C, the second structure in which the second and third conductive patterns 1120 and 1130 are spaced apart by the gap Ga of at least the threshold value may have a reflection loss characteristic of at least -8 dB in some frequency bands in the LB band of 617 to 960 MHz, resulting in a narrow bandwidth characteristic.

[0183] Referring to FIG. 16A and (b) of FIG. 16C, the first structure in which the second and third conductive patterns 1120 and 1130 are spaced apart by the gap G of the threshold value or less may have an isolation characteristic, which slightly deteriorates but is maintained below -8 dB, in the LB band of 617 to 960 MHz. Referring to FIG. 16B and (b) of FIG. 16B, the second structure in which the second and third conductive patterns 1120 and 1130 are spaced apart by the gap Ga of at least the threshold value may have an isolation characteristic of -12 dB or less in the LB band of 617 to 960 MHz. Therefore, the first structure, in which the second and third conductive patterns 1120 and 1130 are spaced apart by the gap G of the threshold value or less, may have excellent reflection coefficient characteristics and bandwidth characteristics while maintaining a certain level of isolation in the LB band of 617 to 960 MHz.

[0184] Hereinafter, an antenna assembly according to the disclosure will be described with reference to FIGS. 11 to 16C. The antenna assembly 1000 may include a first dielectric substrate 1010a which is a transparent substrate, and a second dielectric substrate 1010b which is an opaque substrate. The first dielectric substrate 1010a may be referred to as the transparent substrate and the second dielectric substrate 1010b may be referred to as the opaque substrate. The first dielectric substrate 1010a may form a transparent region, and include a first conductive pattern 1110, a second conductive pattern 1120, and a third conductive pattern 1130 formed on a surface of the first dielectric substrate 1010a. The third conductive pattern 1130 may be spaced apart from the second conductive pattern by a gap G. The third conductive pattern 1130 may operate by a current coupled from the second conductive patterns, which have a symmetric shape with respect to the gap G, in a first frequency band. The second dielectric substrate 1010b may form an opaque region, and include a ground conductive pattern 1110g and a feeding pattern 1110f formed on a surface of the second dielectric substrate 1010b.

[0185] The first conductive pattern 1110 may include a first part 1111 and a second part 1112 perpendicular to the first part 1111. The second conductive pattern 1120 may include a third part 1121 and a fourth part 1122 perpendicular to the third part 1121. The third conductive pattern 1130 may include a fifth part 1131 and a sixth part 1132 perpendicular to the fifth part 1131. An end of the fifth part 1121 of the third conductive pattern 1120 may be formed to be spaced apart by the gap G from an end of the third part 1121 of the second conductive pattern 1120.

[0186] A fourth conductive pattern 1140, which has a symmetrical shape with respect to the gap G may further be formed on the first dielectric substrate 1010a. The second dielectric substrate 1010b may further include a second ground conductive pattern 1120g and a second feeding pattern 1120f. The fourth conductive pattern 1140 may include a seventh part 1141 and an eighth part 1142 perpendicular to the seventh part 1141. The eighth part 1142 of the fourth conductive pattern 1140 may be connected to the second feeding pattern 1120f.

[0187] Referring to FIG. 16A, an end of the fifth part 1131 of the third conductive pattern 1130 and an end of the third part 1121 of the second conductive pattern 1120 may be spaced apart by a gap G of 1.3 mm. A distance of the gap G formed between the end of the fifth part 1131 of the third conductive pattern 1130 and the end of the third part 1121 of the second conductive pattern 1120 may be formed to be $\lambda g/20$ or less based on a specific frequency of the first frequency band. $\lambda g/20$ may be set to about 7.4 mm for the first dielectric substrate 1010a made of a glass material with a permittivity of 6.5, on the basis of 800 MHz of the first frequency band. Referring to FIG. 16B, the end of the fifth part 1131 of the third conductive pattern 1130 and the end of the third part 1121 of the second conductive pattern 1120 may be spaced apart by a second gap Ga of 13.3 mm.

[0188] As described above, when the gap G between the second conductive pattern 1120 and the third conductive pattern 1130 decreases, the isolation characteristic may be somewhat degraded, but the reflection coefficient characteristics and bandwidth characteristics may be improved in the LB band. In relation to an antenna performance evaluation, the gap G may be optimally designed to have a reflection coefficient of about -8 dB or less and an isolation of about -8 dB (or -10 dB) or less. Therefore, the distance of the gap needs to be maintained below a certain length to improve antenna performance and optimize an overall antenna size while maintaining the isolation characteristics at at least a certain level. Accordingly, the gap G between the second conductive pattern 1120 and the third conductive pattern 1130 may be set to be $\lambda g/20$ or less.

[0189] The ground conductive pattern 1110g of the second dielectric substrate 1010b may include a first region 1111g and a second region 1112g. The second part 1112 of the first conductive pattern 1110 may be connected to a feeding pattern 1110f. The fourth part 1122 of the second conductive pattern 1120 may be connected to the first region 1111g of the ground conductive pattern 1110g.

[0190] The first region 1111g of the ground conductive pattern 1110g may be connected to a ground 313b of a coaxial cable 313. The first region 1111g of the ground conductive pattern 1110g may include a first sub-region 1111g1 and a second sub-region 111g2. The first sub-region 1111g1 of the first region 1111g of the ground conductive pattern 1110g may be connected to a ground 313b of the coaxial cable 313. A portion of the first region

1111g of the ground conductive pattern 1110g may be connected to the fourth part 1122 of the second conductive pattern 1120.

[0191] The second region 1112g of the ground conductive pattern 1110g may operate as a UHB radiator. UHB may be a frequency band higher than operating frequency bands of the first conductive pattern 1110 and the second conductive pattern 1120. The second region 1112g of the ground conductive pattern 1110g may include a third sub-region 1112g1 and a fourth sub-region 1112g2. The third sub-region 1112g1 may be arranged spaced apart from an end of the feeding pattern 1110f. The third sub-region 1112g1 may be formed in a triangular shape with a certain angle of inclination. The third sub-region 1112g1 may be formed with a width which decreases in a second axial direction as the third sub-region 1112g1 is away from the feeding pattern 1110f. The fourth sub-region 1112g2 may be connected to the third sub-region 1112g1. The fourth sub-region 1112g2 may be formed in a rectangular shape. The third sub-region 1112g1 of the second region 1112g of the ground conductive pattern 1110g may operate as a UHD radiator. The second sub-region 1111g2 of the first region 1111g of the ground conductive pattern 1110g may be arranged to overlap the coaxial cable 313 by a certain area.

[0192] Referring to FIGS. 11 to 16B, the signal line 313a corresponding to one end of the coaxial cable 313 may be connected to the feeding pattern 1110f. The ground 313b of the coaxial cable 313 may be connected to a contact portion 313CP which is formed concavely to accommodate the coaxial cable 313. The contact portion 313CP may be arranged in the first sub-region 1111g1 of the first region 1111g of the ground conductive pattern 1110g.

[0193] The first region 1111g of the ground conductive pattern 1110g may include a first sub-region 1111g1 and a second sub-region 1111g2. A second length L2 of the second sub-region 1111g2 may be longer than a first length L1 of the first sub-region 1111g1 in the first axial direction. A second width W2 of the second sub-region 1111g2 may be narrower than a first width W1 of the first sub-region 1111g1 in the second axial direction. The coaxial cable 313 may be arranged spaced apart from the second sub-region 1111g2.

[0194] The second part 1112 of the first conductive pattern 1110 may be connected to the signal line 313a of the coaxial cable 313 through the feeding pattern 1110f. The fourth part 1122 of the second conductive pattern 1120 may be connected to the ground 313g of the coaxial cable 313 through the first sub-region 1111g1 of the second region 1112g of the ground conductive pattern 1110g.

[0195] The second ground conductive pattern 1120g of the second dielectric substrate 1010b may include a third region 1121g and a fourth region 1122g. The third region 1121g of the second conductive pattern 1120g may be formed in a symmetrical shape based on the gap G from the first region 1111g of the ground conductive pattern 1110g. The fourth region 1122g of the second conductive pattern 1120g may be formed in a symmetrical shape based on the gap G from the second region 1112g of the ground conductive pattern 1110g.

[0196] The second part 1112 of the first conductive pattern 1110 may be connected to the feeding pattern 1110f. The second conductive pattern 1120 may be electrically connected to the first region 1111g of the ground conductive pattern 1110g. The eighth part 1142 of the fourth conductive pattern 1140 may be connected to the second feeding pattern 1120f. The third conductive pattern 1130 may be connected to the third region 1121g of the second ground conductive pattern 1120g.

[0197] The first sub-region 1121g1 of the third region 1121g of the second conductive pattern 1120 may be connected to a ground 313b-2 of a second coaxial cable 313-2. The second sub-region 1121g2 of the third region 1121g of the second ground conductive pattern 1120g may be arranged to overlap the second coaxial cable 313-2 by a certain region.

[0198] The second conductive pattern 1120 and the third conductive pattern 1130 may each be formed to have a first length X1 in a first axial direction parallel to the coaxial cable 313. The coaxial cable 313 may be formed to have a second length X2 from a point where the signal line 313a corresponding to one end of the coaxial cable 313 is connected to a point corresponding to another end of the coaxial cable 313. The second coaxial cable 313-2 may be formed to have a second length X2 from a point where the signal line 313a corresponding to one end of the second coaxial cable 313-2 is connected to a point corresponding to another end of the second coaxial cable 313-2. The second length X2 of the coaxial cables 313 and 313-2 may be formed to be 0.5 times longer than the first length X1 of the second conductive pattern 1120 and the third conductive pattern 1130.

[0199] The second sub-region 1111g2 of the first region 1111g of the ground conductive pattern 1110g may have a third length X3 in the first axial direction. The second sub-region 1121g2 of the third region 1121g of the second ground conductive pattern 1120g may have a third length X3 in the first axial direction. The third length X3 may be formed to be 0.5 times longer than the first length X1 and shorter than the second length X2.

[0200] The first sub-region 1111g1 of the first region 1111g of the ground conductive pattern 1110g may have a first width W1 in the second axial direction perpendicular to the first axial direction. The first sub-region 1121g1 of the third region 1121g of the second ground conductive pattern 1120g may have a first width W1 in the second axial direction. The second sub-region 1111g2 of the first region 1111g of the ground conductive pattern 1110g may have a second width W2 in the second axial direction. The second sub-region 1121g2 of the third region 1121g of the second ground conductive pattern 1120g may have a second width W2 in the second axial direction. The first width W1 may be formed to be greater than the sum of the second width W2 and a diameter of the coaxial cable 313, 313-2.

[0201] The coaxial cable 313 may be arranged in parallel with being spaced apart from the end of the second sub-region 1111g2 of the first region 1111g of the ground conductive pattern 1110g. The second coaxial cable 313-2 may be arranged in parallel with being spaced apart from the end of the fourth sub-region 1121g2 of the third region 1121g of the second ground conductive pattern 1120g.

[0202] The ground conductive pattern 1110g may include the first region 1111g, and the second region 1112g connected to the first region 1111g and arranged on one side of the feeding pattern 1110f. The second ground conductive pattern 1120g may include the third region 1121g, and the fourth region 1122g connected to the third region 1121g and arranged on another side of the second feeding pattern 1120f. The second region 1112g of the ground conductive pattern 1110g may be arranged below the first part 1111 of the first conductive pattern 1110. The fourth region 1122g of the second ground conductive pattern 1120g may be arranged below the seventh part 1141 of the fourth conductive pattern 1140.

[0203] An antenna assembly according to the disclosure may operate with a plurality of antennas to perform a multi-input and multi-output (MIMO) operation. The antenna assembly 1000 may include a first antenna ANT1 and a second antenna ANT2. The first antenna ANT1 may be configured to include the first conductive pattern 1110, the second conductive pattern 1120, and the second region 1112g of the ground conductive pattern 1110g. The first conductive pattern 1110, the second conductive pattern 1120, and the second region 1112g of the ground conductive pattern 1110g may operate as the first antenna ANT1 in a first frequency band to a third frequency band. The second antenna ANT2 may be configured to include the third conductive pattern 1130, the fourth conductive pattern 1140, and the fourth region 1122g of the second ground conductive pattern 1120g. The third conductive pattern 1130, the fourth conductive pattern 1140, and the fourth region 1122g of the second ground conductive pattern 1120g may operate as the second antenna ANT2 in the first frequency band to the third frequency band.

[0204] In some embodiments, the antenna assembly 1000 according to the disclosure may improve the isolation characteristics between antennas by expanding a length of an FPCB. In this regard, FIG. 17A is a view of a first structure in which an FPCB is not formed in a region where a coaxial cable is arranged. FIG. 17B is a view of a second structure in which an FPCB is formed in a region where a coaxial cable is arranged. FIG. 17C is a view of a structure in which a coaxial cable is coupled to a ground conductive pattern and a feeding pattern formed by the FPCB structure of FIG. 17B.

[0205] Referring to (a) of FIG. 17A, coupling of the first current I1 may occur between the second conductive pattern 1120 and the first coaxial cable 313-1. Coupling of the second current I2 may occur between the first coaxial cable 313-1 and the second coaxial cable 313-2. Coupling of the third current I3 may occur by at least a threshold value between the second coaxial cable 313-2 and the third conductive pattern 1130. An interference level between the first and second antennas ANT1 and ANT2 may increase by the coupled third current I3 exceeding the threshold value.

[0206] Referring to (a) of FIG. 17A and (b) of FIG. 17A, the electric field distribution in a common region Rc, in which the second conductive pattern 1120, the first and second coaxial cables 313-1 and 313-2, and the third conductive pattern 1130 are arranged, may be formed to be higher than or equal to a threshold level. Accordingly, the antenna isolation characteristics may be degraded due to coupling between the second and third conductive patterns 1120 and 1130, which are the ground patterns, and the first and second coaxial cables 313-1 and 313-2.

[0207] Referring to (a) of FIG. 17B, the first region 1111g of the ground conductive pattern 1110g may have at least a certain length to be in parallel to the first coaxial cable 313-1. The second sub-region 1111g2 of the first region 1111g of the ground conductive pattern 1110g may be formed to have a certain length or longer. Coupling of the first current I1 may occur between the second conductive pattern 1120 and the first coaxial cable 313-1. Coupling of the second current I2b may occur by a threshold value or less between the first coaxial cable 313-1 and the second coaxial cable 313-2. The coupled first current I1 may be coupled to the fourth sub-region 1111g2 with the fourth current I4. Coupling of the third current I3b may occur by the threshold value or less between the second coaxial cable 313-2 and the third conductive pattern 1130, thereby reducing the interference level between the first and second antennas ANT1 and ANT2. The coupled second current I2b may be coupled to the second sub-region 1111g2 with the fifth current I5.

[0208] Referring to (a) and (b) of FIG. 17B, the electric field distribution in the common region Rc, in which the second conductive pattern 1120, the first and second coaxial cables 313-1 and 313-2, and the third conductive pattern 1130 are arranged, may be formed to be lower than or equal to a threshold level. Accordingly, coupling between the second and third conductive patterns 1120 and 1130, which are the ground patterns, and the first and second coaxial cables 313-1 and 313-2 may be reduced by the second sub-region 1111g2 formed parallel to the first and second coaxial cables 313-1 and 313-2. Accordingly, the second sub-region 1111g2 of the ground conductive pattern 1110g formed by the FPCB 1100b may reduce an amount of coupling leakage between adjacent antennas to be below a threshold level, thereby improving the isolation characteristics between the antennas.

[0209] Referring to FIGS. 17B and 17C, the signal line 313a corresponding to one end of the coaxial cable 313 may be connected to the feeding pattern 1110f. The ground 313b of the coaxial cable 313 may be connected to the contact portion 313CP which is formed concavely to accommodate the coaxial cable 313. The contact portion 313CP may be arranged in the first sub-region 1111g1 of the first region 1111g of the ground conductive pattern 1110g. To optimize antenna performance in the UHB band, a length Lu from the contact portion 313CP to an end of the fourth sub-region 1112g2 of the second region 1112g of the ground conductive pattern 1110g may be set in a certain range. The length Lu from the contact portion 313CP to the end of the fourth sub-region 1112g2 of the second region 1112g of the ground conductive pattern 1110g may be in a range from 0.5 to 1 time a specific wavelength corresponding to a specific frequency of the UHB band.

[0210] In some embodiments, an antenna assembly according to the disclosure may operate in a resonance mode in different regions for each frequency band, thereby improving antenna performance. In this regard, FIGS. 18A and 18B are views of reflection coefficient characteristics and efficiency characteristics of the antenna assembly structures of FIGS. 17A and 17B. FIG. 18C is a view of a frequency band-dependent electric field distribution of an antenna assembly according to the specification.

[0211] Referring to FIG. 17A and (a) of FIG. 18A, the first structure in which the FPCB is not formed in the region where the coaxial cable is arranged may satisfy the reflection loss characteristics of -8 dB or less in the LB band and the UHB band. Referring to FIG. 17B and (a) of FIG. 18A, the second structure in which the FPCB is formed in the region where the coaxial cable is arranged may satisfy the reflection loss characteristics of -8 dB or less in the LB band and the UHB band. Therefore, the reflection loss characteristics may be similar regardless of whether the FPCB is arranged parallel to the coaxial cable.

[0212] Referring to FIG. 17A and (b) of FIG. 18A, the isolation characteristic of the first structure in which the FPCB is not formed in the region where the coaxial cable is arranged may be degraded to at least -8 dB in some frequency bands of the LB band. Referring to FIG. 17B and (b) of FIG. 18A, the second structure in which the FPCB is formed in the region where the coaxial cable is arranged may satisfy the isolation loss characteristic of -8 dB or less in the LB band. Therefore, the isolation characteristic may be improved in the second structure in which the FPCB is arranged parallel to the coaxial cable.

[0213] Referring to FIG. 17A and 18B, the first structure in which the FPCB is not formed in the region where the coaxial cable is arranged may satisfy the efficiency characteristics of at least -3 dB in the LB band and the UHB band. Referring to FIGS. 17B and 18B, the second structure in which the FPCB is formed in the region where the coaxial cable is arranged may have the efficiency characteristics at least 0.2 dB higher than the efficiency characteristics of the first structure while satisfying the efficiency characteristics of at least -3 dB in the LB band and the UHB band. Therefore, the antenna efficiency characteristics may be improved in the second structure in which the FPCB is arranged parallel to the coaxial cable.

[0214] (a) and (b) of FIG. 18C show electric field distributions at frequencies of 617 MHz and 5 GHz in the antenna assembly of FIG. 16A. Referring to FIG. 16A and (a) of FIG. 18C, the second and third conductive patterns 1120 and 1130 of the antenna assembly 1000 may be arranged spaced apart by a gap G of a threshold value or less. In the LB band, the electric field distribution in a first region R1a, which includes the first and second coaxial cables 313-1 and 313-2, the bottom of the second and third conductive patterns 1120 and 1130, and the gap G, may be formed higher the electric field distributions in other regions. Therefore, the impedance matching characteristic in the low band LB may be improved through coupling of the second and third conductive patterns 1120 and 1130 corresponding to the ground patterns, thereby improving the antenna characteristic in the LB band.

[0215] Referring to FIG. 16A and (b) of FIG. 18C, the second and third conductive patterns 1120 and 1130 of the antenna assembly 1000 may be arranged spaced apart by a gap G of a threshold value or less. In the UHB band, the electric field distribution of the second region R2a, which includes the second region 1112g of the ground conductive pattern 1110g, may be higher than the electric field distributions in other regions. Therefore, an additional resonance mode may be generated in the UHB band by changing the structure of the ground conductive pattern 1110g of the FPCB on which the feeding pattern 1110f is formed. Accordingly, the antenna bandwidth and antenna efficiency in the UHB band of 5 GHz may be improved by the additional resonance mode.

[0216] In some embodiments, the antenna assembly 1000 according to the specification may operate in a plurality of frequency bands for 4G/5G wireless communications. The antenna assembly 1000 may operate in a dipole antenna mode in a first frequency band of 617 to 960 MHz. The first frequency band may correspond to the LB band of 4G/5G. The antenna assembly 1000 may operate in a monopole antenna mode in a second frequency band of 1520 to 4500 MHz. The second frequency band may correspond to an MB band and an HB band of 4G/5G. The antenna assembly 1000 may operate as a radiator through additional resonance in a third frequency band of 4500 to 6000 MHz. The third frequency band may correspond to a UHB band of 4G/5G.

[0217] Hereinafter, the radiation principle and operation of the antenna assembly 1000 for each frequency band will be described, with reference to FIGS. 11 to 18C. The first conductive pattern 1110 and the second conductive pattern 1120 may operate as the first antenna ANT1 in the dipole antenna mode in the first frequency band. The third conductive pattern 1130 and the fourth conductive pattern 1140 may operate as the second antenna ANT2 in the dipole antenna mode in the first frequency band. The first conductive pattern 1110 and the second conductive pattern 1120 may have an asymmetrical structure. The third conductive pattern 1130 and the fourth conductive pattern 1140 may be configured to have the asymmetrical structure.

[0218] The first part 1111 of the first conductive pattern 1110 may have the upper boundary BS1 and the lower boundary BS2, each of which has the step shape. The third part 1121 of the second conductive pattern 1120 may have the upper boundary BS1 formed in the straight line shape and the lower boundary BS2 formed in the step shape. The fifth part 1131 of the third conductive pattern 1130 may have an upper boundary BS1 formed in a straight line shape and a lower boundary BS2 formed in a step shape. The seventh part 1141 of the fourth conductive pattern 1140 may have an upper boundary BS1 and a lower boundary BS2, each of which has the step shape.

[0219] Therefore, the first conductive pattern 1110 may operate as the first antenna ANT1 in the monopole antenna mode in the second frequency band. The fourth conductive pattern 1140 may operate as the second antenna ANT1 in the monopole antenna mode in the second frequency band. The second region 1112g of the ground conductive pattern 1110g may operate as the first antenna ANT1 as a radiator in the third frequency band. The fourth region 1122g of the second ground conductive pattern 1120g may operate as the second antenna ANT2 as a radiator in the third frequency band. The second frequency band may be set to be wider than the first frequency band. The third frequency band may be set to be wider than the second frequency band.

[0220] In some embodiments, an antenna assembly according to the specification may be configured in a transparent antenna structure. In this regard, referring to FIGS. 7B and 15B, the first conductive pattern 1110, the second conductive pattern 1120, the third conductive pattern 1130, and the fourth conductive pattern 1140 of the antenna assembly 1100 may be formed in a metal mesh shape 1020 having a plurality of open regions OA on the first dielectric substrate 1010a. The first conductive pattern 1110, the second conductive pattern 1130, and the third conductive pattern 1140 may include metal grid patterns 1020a. The metal grid patterns 1020a and dummy metal grid patterns 1020b may form open regions OA. The first conductive pattern 1110, the second conductive pattern 1120, the third conductive pattern 1130, and the fourth conductive pattern 1140 may be formed in the CPW structure on the first dielectric substrate 1010a.

[0221] The antenna assembly 1000 may include a plurality of dummy mesh grid patterns 1020b on an outer portion of the radiator region, namely, the first region 1100a on the first dielectric substrate 1010a. In some embodiments, the plurality of dummy mesh grid patterns 1020b may also be arranged even in a dielectric region between the first to second conductive patterns 1110 to 1140. The plurality of dummy mesh grid patterns 1020b may be formed not to be connected to the feeding pattern 1110f and the ground conductive pattern 1110g. The plurality of dummy mesh grid patterns 1020b may be formed not to be connected to the second feeding pattern 1120f and the ground conductive pattern 1120g. The plurality of dummy mesh grid patterns 1020b may be separated from each other.

[0222] As described above, the antenna assembly according to the specification may be arranged on the vehicle glass and may be located adjacent to the metal frame of the vehicle. Additionally, the antenna assembly according to the specification may include a plurality of antenna elements to perform multi-input/multi-output (MIMO). In this regard, FIG. 19A is a view of a structure in which the antenna assembly of FIG. 12B having a plurality of antenna elements is arranged on vehicle glass. FIG. 19B is a view of a structure in which the antenna assembly of FIG. 12B having the plurality of antenna elements is arranged on a glass panel which is located inside a metal frame. FIG. 19C is an exploded lateral perspective view of a coupling structure between the metal frame and the glass panel with the antenna assembly of FIG. 19B.

[0223] Referring to FIGS. 12B and 19A, the antenna assembly 1000b including the first antenna ANT1 and the second antenna ANT2 may be arranged on the glass panel 310. The glass panel 310 may be formed to have certain length, width, and thickness. For example, the glass panel 310 may have a size of 600 x 400 mm and a thickness of 3.5 t. However, the size and thickness are not limited thereto and may vary depending on the application. The first antenna ANT1 and the second antenna ANT2 each including the first to third conductive patterns 1110, 1120a, and 1130a may have a symmetrical structure with respect to a line A-A'.

[0224] Referring to FIGS. 11, 12B, 19B, and 19C, the antenna assembly 1000b including the first antenna ANT1 and the second antenna ANT2 may be arranged on the glass panel 310 arranged in the metal frame 49. The metal frame 49 may include the body 49b made of the metal material and the interior cover 49c. The interior cover 49c may include a metal material or dielectric material. The interior cover 49c may be arranged below the body 49b made of the metal material to overlap the body 49b made of the metal material.

[0225] The glass panel 310 may be arranged in an empty space inside the metal frame 49. The glass panel 310 may include the transparent region 311 and the opaque region 312. A frit pattern 312f may be formed in the opaque region 312. At least a portion of the opaque region 312 may be arranged to overlap the body 49b made of the metal material.

[0226] The glass panel 310 may have certain length, width, and thickness. For example, the glass panel 310 may have a 600 x 400 mm and a thickness of 3.5 t. However, the size and thickness are not limited thereto and may vary depending on the application. The first antenna ANT1 and the second antenna ANT2 each including the first to third conductive patterns 1110, 1120a, and 1130a may have a symmetrical structure with respect to a line A-A'.

[0227] In some embodiments, FIG. 20A is a view of reflection coefficient characteristics and efficiency characteristics of the antenna assembly of FIG. 19A. FIG. 20B is a view of reflection coefficient characteristics and efficiency characteristics of the antenna assembly of FIG. 19B adjacent to the metal frame.

[0228] Referring to FIG. 19A and (a) of FIG. 20A, the antenna assembly 1000b may have reflection coefficient characteristics S11 and S22 of -8 dB or less in the full frequency band of 600 MHz to 6 GHz for 4G/5G wireless communications. Here, S11 and S22 represent the reflection coefficient characteristics of the first antenna ANT1 and the second antenna ANT2, respectively. An isolation S21 between the first antenna ANT1 and the second antenna ANT2 may have a value of -10 dB or less in the frequency band of 600 MHz to 6 GHz.

[0229] Referring to FIG. 12A, FIG. 19A, and (b) of FIG. 20A, (i) the antenna assembly 1000a may have an antenna efficiency characteristic of at least -3 dB in the full frequency band of 600 MHz to 6 GHz. Referring to FIG. 12B, FIG. 19A, and (b) of FIG. 20A, (ii) the antenna efficiencies of the first and second antennas ANT1 and ANT2 of the antenna assembly 1000b may be reduced to -3 dB or less in the UHB band of at least 4.5 GHz, in the full frequency band of 600 MHz to 6 GHz. In FIG. 12B, (ii) the antenna efficiency of the antenna assembly 1000b may be reduced in the UHB band even in a structure without a metal frame, due to the reduced length of the FPCB 1100b, the exclusion of the third conductive pattern, and the arrangement structure of the coaxial cable 313c.

[0230] Referring to FIG. 19B and (a) of FIG. 20B, the reflection coefficient characteristics S11 and S22 of the antenna assembly 1000b may be reduced by at least -8 dB in a band of about 900 MHz, in the full frequency band of 600 MHz to 6 GHz for 4G/5G wireless communications. The reflection coefficient characteristics S11 and S22 may be reduced by at least -8 dB in a band of 800 to 1100 MHz, in the full frequency band of 600 MHz to 6 GHz. Here, S11 and S22 represent the reflection coefficient characteristics of the first antenna ANT1 and the second antenna ANT2, respectively. An isolation S21 between the first antenna ANT1 and the second antenna ANT2 may have a value of -10 dB or less in the frequency band of 600 MHz to 6 GHz.

[0231] Referring to FIG. 12A, FIG. 19A, and (b) of FIG. 20B, (i) the antenna assembly 1000a may have an antenna efficiency characteristic of at least -3 dB in the band of 600 MHz to 6 GHz. Referring to FIG. 12B, FIG. 19B, and (b) of FIG. 20B, (ii) the antenna efficiencies of the first and second antennas ANT1 and ANT2 of the antenna assembly 1000b may be reduced to -3 dB or less in the UHB band of at least 4.5 GHz in the full band of 600 MHz to 6 GHz. In FIG. 12B, (ii) the antenna efficiency of the antenna assembly 1000b may be reduced in the UHB band, due to the reduced length of the FPCB 1100b, the exclusion of the third conductive pattern, and the arrangement structure of the coaxial cable 313c. In FIG. 12B, (ii) the antenna efficiencies of the first and second antennas ANT1 and ANT2 of the antenna assembly 1000b may be reduced to -3 dB or less even in the band of 600 MHz to 1 GHz.

[0232] Referring to FIG. 12B, FIG. 19B, and FIG. 20B, the reflection loss characteristic may be reduced and antenna efficiency may be lowered by about 1.2 dB in the LB band, for example, in the band of 900 MHz, due to the metal frame 49 located adjacent to the antenna assembly 1000b.

[0233] As described above, the antenna assembly according to the specification may be arranged on the vehicle glass and may be located adjacent to the metal frame of the vehicle. Additionally, the antenna assembly according to the specification may include a plurality of antenna elements to perform multi-input/multi-output (MIMO). In this regard, FIG. 21A is a view of a structure in which the antenna assembly of FIG. 12C having the plurality of antenna elements is arranged on the vehicle glass which is located within the metal frame. FIG. 21B is a view of reflection coefficient characteristics and efficiency characteristics of the antenna assembly of FIG. 21A.

[0234] Referring to FIGS. 12C, 15B, and 21A, the antenna assembly 1000 including the first antenna ANT1 and the second antenna ANT2 may be arranged on the vehicle glass 310. The vehicle glass 310 may have certain length, width, and thickness. The second antenna ANT2 may have a symmetrical structure with respect to the line A-A'. The first antenna ANT1 may include the first and second conductive patterns 1110 and 1120 and the ground conductive pattern 1110g. The second antenna ANT2 may include third and fourth conductive patterns 1130 and 1140 and a second ground conductive pattern 1120g.

[0235] Referring to FIG. 12A, FIG. 19A, and (b) of FIG. 21B, (i) the antenna assembly 1000a may have an antenna efficiency characteristic of at least -3 dB in the band of 600 MHz to 6 GHz. Referring to FIG. 21A and (a) of FIG. 21B, the antenna assembly 1000 may have reflection coefficient characteristics S11 and S22 of -8 dB or less in the full frequency band of 600 MHz to 6 GHz for 4G/5G wireless communications. Here, S11 and S22 represent the reflection coefficient characteristics of the first antenna ANT1 and the second antenna ANT2, respectively. An isolation S21 between the first antenna ANT1 and the second antenna ANT2 may have a value of -10 dB or less in the frequency band of 600 MHz to 6 GHz.

[0236] Referring to FIG. 21A and (b) of FIG. 21B, the first and second antennas ANT1 and ANT2 of the antenna assembly 1000 may have an antenna efficiency value of at least -3 dB in the LB band, in the full band of 600 MHz to 6 GHz. The first and second antennas ANT1 and ANT2 of the antenna assembly 1000 may have an antenna efficiency value of at least -3 dB in the UHB band of at least 4.5 GHz, in the full band of 600 MHz to 6 GHz. Therefore, the antenna efficiency may be improved in the LB band and the UHB band, in spite of the reduced length of the FPCB 1100b, the exclusion of the third conductive pattern, and the arrangement structure of the coaxial cable 313c.

[0237] In some embodiments, an antenna assembly according to the specification may include a first transparent dielectric substrate, on which a transparent electrode layer is formed, and a second dielectric substrate. In this regard, FIGS. 22A and 22B are views of the flow of processes in which an antenna assembly is manufactured by being coupled to a glass panel according to embodiments.

[0238] Referring to (a) of FIG. 22A, a first transparent dielectric substrate 1000a on which a transparent electrode layer is formed may be manufactured. For example, the second dielectric substrate 1000b which includes a feeding pattern 1120f and ground patterns 1121g and 1122g formed on opposite sides of the feeding pattern 1120f may be manufactured. The second dielectric substrate 1000b may be implemented as an FPCB, but is not limited thereto. Adhesion regions corresponding to adhesive layers 1041 may be formed on the first transparent dielectric substrate 1000a and the second dielectric substrate 1000b, respectively.

[0239] Referring to (b) of FIG. 22A, a glass panel 310 with a transparent region 311 and an opaque region 312 may be manufactured. In addition, an antenna assembly 1000 may be manufactured by coupling at least one second dielectric substrate 1000b to a lower region of the first transparent dielectric substrate 1000a. The first transparent dielectric substrate 1000a and the second dielectric substrate 1000b may be coupled through ACF bonding or low-temperature soldering to be implemented as a transparent antenna assembly. Through this, a first conductive pattern formed on the first transparent dielectric substrate 1000a may be electrically connected to a second conductive pattern formed on the second dielectric substrate 1000b. When a plurality of antenna elements are implemented on the glass panel 310, a feeding structure 1100f manufactured by the second dielectric substrate 1000b may also be implemented as a plurality of feeding structures.

[0240] Referring to (c) of FIG. 22A, the transparent antenna assembly 1000 may be attached to the glass panel 310. In this regard, the first transparent dielectric substrate 1000a on which the transparent electrode layer is formed may be arranged in the transparent region 311 of the glass panel 310. Meanwhile, the second dielectric substrate 1000b, which is an opaque substrate, may be arranged in the opaque region 312 of the glass panel 310.

[0241] Referring to (d) of FIG. 22A, the first transparent dielectric substrate 1000a and the second dielectric substrate 1000b may be bonded at a first position P1. A connector part 313, such as a Fakra cable, may be bonded to the second dielectric substrate 1000b at a second position P2. The transparent antenna assembly 1000 may be coupled to a TCU 300 through the connector part 313. To this end, the second conductive pattern formed on the second dielectric substrate 1010b may be electrically connected to a connector on one end of the connector part 313. A connector on another end of the connector part 313 may be electrically connected to the TCU 300.

[0242] An antenna assembly of FIG. 22B may have a structural difference, compared to the antenna assembly of FIG. 22A, in that an opaque substrate is not manufactured separately but is manufactured integrally with the glass panel 310. The antenna assembly of FIG. 22B may be implemented in such a way that a feeding structure implemented with the opaque substrate is directly printed on a glass panel 310 rather than being separately manufactured as an FPCB.

[0243] Referring to (a) of FIG. 22B, the first transparent dielectric substrate 1000a on which the transparent electrode layer is formed may be manufactured. In addition, the glass panel 310 with the transparent region 311 and the opaque region 312 may be manufactured. In the process of manufacturing of the glass panel of the vehicle, metal wires/pads for connection of the connectors may be implemented (fired). Like heat lines implemented on the vehicle glass, a transparent antenna mounting portion may be implemented in a metal form on the glass panel 310. In this regard, the second conductive pattern may be implemented in a region where an adhesive layer 1041 is formed for electrical connection to the first conductive pattern of the first transparent dielectric substrate 1000a.

[0244] In this regard, the second dielectric substrate 1000b on which the second conductive pattern is formed may be manufactured integrally with the glass panel 310. The second dielectric substrate 1000b may be formed integrally with the glass panel 310 in the opaque region 312 of the glass panel 310. A frit pattern 312 may be removed from the opaque region 312 where the second dielectric substrate 1000b is formed. The second conductive pattern may be implemented on the second dielectric substrate 1000b by forming the feeding pattern 1120f and the ground patterns 1121g and 1122g on opposite sides of the feeding pattern 1120f.

[0245] Referring to (b) of FIG. 22B, the transparent antenna assembly 1000 may be attached to the glass panel 310. In this regard, the first transparent dielectric substrate 1000a on which the transparent electrode layer is formed may be arranged in the transparent region 311 of the glass panel 310. The antenna assembly 1000 may be manufactured by coupling at least one second dielectric substrate 1000b to the lower region of the first transparent dielectric substrate 1000a. The first transparent dielectric substrate 1000a and the second dielectric substrate 1000b may be coupled through ACF bonding or low-temperature soldering to be implemented as a transparent antenna assembly. Through this, a first conductive pattern formed on the first transparent dielectric substrate 1000a may be electrically connected to the second conductive pattern formed on the second dielectric substrate 1000b. When the plurality of antenna elements are implemented on the glass panel 310, the feeding structure 1100f manufactured by the second dielectric substrate 1000b may also be implemented as a plurality of feeding structures.

[0246] Referring to (c) of FIG. 22B, the first transparent dielectric substrate 1000a and the second dielectric substrate 1000b may be bonded at a first position P1. A connector part 313, such as a Fakra cable, may be bonded to the second dielectric substrate 1000b at a second position P2. The transparent antenna assembly 1000 may be coupled to a TCU 300 through the connector part 313. To this end, the second conductive pattern formed on the second dielectric substrate 1010b may be electrically connected to a connector on one end of the connector part 313. A connector on another end of the connector part 313 may be electrically connected to the TCU 300.

[0247] Hereinafter, a vehicle having an antenna module according to one aspect of the specification will be described in detail. In this regard, FIG. 23 is a view of a configuration in which a plurality of antenna modules disposed at different positions of a vehicle are coupled with other components of the vehicle.

[0248] Referring to FIGS. 1 to 23, the vehicle 500 may include a conductive vehicle body operating as an electrical ground. The vehicle 500 may include a plurality of antennas 1100a to 1100d which may be located at different positions on a glass panel 310. The antenna assembly 1000 may include the plurality of antennas 1100a to 1100d and a communication module 300. The communication module 300 may include a transceiver circuit 1250 and a processor 1400. The communication module 300 may correspond to the TCU of the vehicle or may constitute at least a portion of the TCU.

[0249] The vehicle 500 may include an object detection device 520 and a navigation system 550. The vehicle 500 may further include a separate processor 570 in addition to the processor 1400 included in the communication module 300. The processor 1400 and the separate processor 570 may be physically or functionally separated and may be implemented on one substrate. The processor 1400 may be implemented as a TCU, and the processor 570 may be implemented as an electronic control unit (ECU).

[0250] In case where the vehicle 500 is an autonomous vehicle, the processor 570 may be an autonomous driving control unit (ADCU) integrated with an ECU. Based on information detected by a camera 531, radar 532, and/or LiDAR 533, the processor 570 may search for a path and control the vehicle 500 to be accelerated or decelerated. To this end, the processor 570 may interwork with a processor 530 corresponding to a micro control unit (MCU) arranged in the object detection device 520 and/or the communication module 300 corresponding to the TCU.

[0251] The vehicle 500 may include a first transparent dielectric substrate 1010a and a second dielectric substrate 1010b arranged on the glass panel 310. The first transparent dielectric substrate 1010a may be formed inside the glass panel 310 of the vehicle or may be attached to the surface of the glass panel 310. The first transparent dielectric substrate 1010a may be configured such that conductive patterns in the shape of metal mesh grids are formed. The vehicle 500 may include an antenna module 1100 having conductive patterns formed in a metal mesh shape on one side of the dielectric substrate 1010 to radiate radio signals.

[0252] The vehicle 500 may include a metal frame 49, a glass panel 310, and an antenna assembly 1100. The metal frame 49 may have an opening formed inside the metal frame 49, and the glass panel 310 may be arranged in the opening. The glass panel 310 may include the transparent region 311 and the opaque region 312.

[0253] The antenna assembly 1000 may include a first transparent dielectric substrate 1010a, which is arranged in the transparent region 311 of the glass panel 310 and includes a first conductive pattern 1110, a second conductive pattern 1120, and a third conductive pattern 1130 spaced apart by a gap from the second conductive pattern 1120. The antenna assembly 1100 may include a second transparent dielectric substrate 1010b, which is arranged in the opaque region 312 of the glass panel 310 and includes a ground conductive pattern 1110g and a feeding pattern 1110f. The first conductive pattern 1110 may include a first part 1111 and a second part 1112 perpendicular to the first part 1111. The second conductive pattern 1120 may include a third part 1121 and a fourth part 1122 perpendicular to the third part 1121.

[0254] The ground conductive pattern 1110g of the second dielectric substrate 1010b may include a first region 1111g and a second region 1112g. The second part 1112 of the first conductive pattern 1110 may be connected to the feeding pattern 1110f. The second conductive pattern 1120 of the second conductive pattern 1120 may be connected to the first region 1111g of the ground conductive pattern 1110g.

[0255] The first region 1111g of the ground conductive pattern 1110g may be connected to a ground 313b of a coaxial cable 313. The second sub-region 1111g2 of the first region 1111g of the ground conductive pattern 1110g may be arranged to overlap the coaxial cable 313 by a certain area.

[0256] The third conductive pattern 1130 may include a fifth part 1131 and a sixth part 1132 perpendicular to the fifth part 1131. An end of the fifth part 1121 of the third conductive pattern 1120 may be formed to be spaced apart by the gap G from an end of the third part 1121 of the second conductive pattern 1120. A distance of the gap G formed between the end of the fifth part 1131 of the third conductive pattern 1130 and the end of the third part 1121 of the second conductive pattern 1120 may be formed to be $\lambda g/20$ or less based on a specific frequency of the first frequency band.

[0257] The first dielectric substrate 1010a may further include a fourth conductive pattern 1140, which has a symmetrical shape with respect to the gap G. The second dielectric substrate 1010b may further include a second ground conductive pattern 1120g and a second feeding pattern 1120f. The fourth conductive pattern 1140 may include a seventh part 1141 and an eighth part 1142 perpendicular to the seventh part 1141. The eighth part 1142 of the fourth conductive pattern 1140 may be connected to the second feeding pattern 1120f.

[0258] The second ground conductive pattern 1120g of the second dielectric substrate 1010b may include a third region 1121g and a fourth region 1122g. The third region 1121g of the second conductive pattern 1120g may be formed in a symmetrical shape based on the gap G from the first region 1111g of the ground conductive pattern 1110g. The fourth region 1122g of the second conductive pattern 1120g may be formed in a symmetrical shape based on the gap G from the second region 1112g of the ground conductive pattern 1110g.

[0259] The second part 1112 of the first conductive pattern 1110 may be connected to the feeding pattern 1110f. The second conductive pattern 1120 may be electrically connected to the first region 1111g of the ground conductive pattern 1110g. The eighth part 1142 of the fourth conductive pattern 1140 may be connected to the second feeding pattern 1120f. The third conductive pattern 1130 may be connected to the third region 1121g of the second ground conductive pattern 1120g.

[0260] A first sub-region 1121g1 of the third region 1121g of the second conductive pattern 1120 may be connected to a ground 313b-2 of a second coaxial cable 313-2. A second sub-region 1121g2 of the third region 1121g of the second ground conductive pattern 1120g may be arranged to overlap the second coaxial cable 313-2 by a certain area.

[0261] The second conductive pattern 1120 and the third conductive pattern 1130 may each be formed to have a first length X1 in a first axial direction parallel to the coaxial cable 313. The coaxial cable 313 may be formed to have a second length X2 from a point where a signal line 313a corresponding to one end of the coaxial cable 313 is connected to a point corresponding to another end of the coaxial cable 313. The second coaxial cable 313-2 may be formed to have a second length X2 from a point where a signal line 313a corresponding to one end of the second coaxial cable 313-2 is connected to a point corresponding to another end of the second coaxial cable 313-2. The second length X2 of the coaxial cables 313 and 313-2 may be formed to be 0.5 times longer than the first length X1 of the second conductive pattern 1120 and the third conductive pattern 1130.

[0262] The second sub-region 1111g2 of the first region 1111g of the ground conductive pattern 1110g may have a third length X3 in the first axial direction. The second sub-region 1121g2 of the third region 1121g of the second ground conductive pattern 1120g may have a third length X3 in the first axial direction. The third length X3 may be formed to be 0.5 times longer than the first length X1 and smaller than the second length X2.

[0263] The antenna assembly 1000 may include a first antenna module 1100a to a fourth antenna module 1100d to perform MIMO. The first antenna module 1100a, the second antenna module 1100b, the third antenna module 1100c, and the fourth antenna module 1100d may be arranged on the upper left, lower left, upper right, and lower right sides of the glass panel 310, respectively. The first antenna module 1100a to the fourth antenna module 1100d may be referred to as a first antenna ANT1 to a fourth antenna ANT4, respectively. The first antenna ANT1 to the fourth antenna ANT4 may be referred to as a first antenna module ANT1 to a fourth antenna module ANT4, respectively. In relation to this, the first antenna ANT1 and the second antenna ANT2 of FIG. 15B may correspond to a first antenna module 1100a (ANT1) and a second antenna module 1100b (ANT2) of FIG. 23. The first antenna module 1100a (ANT1) and the second antenna module 1100b (ANT2) may be spaced apart from each other by a gap Ga of at least a threshold value as illustrated in FIG. 15A or the gap G of a threshold value or less as illustrated in FIG. 15B.

[0264] As described above, the vehicle 500 may include the telematics control unit (TCU) 300, which corresponds to the communication module. The TCU 300 may control signals to be received and transmitted through at least one of the first to fourth antenna modules 1100a to 1100d. The TCU 300 may include a transceiver circuit 1250 and a processor 1400.

[0265] Accordingly, the vehicle may further include the transceiver circuit 1250 and the processor 1400. A portion of the transceiver circuit 1250 may be arranged in units of antenna modules or in combination thereof. The transceiver circuit 1250 may control a radio signal of at least one of first to third frequency bands to be radiated through the antenna modules ANT1 to ANT4. The first to third frequency bands may be an LB band, an MB band, and an HB band for 4G/5G wireless communications, but are not limited thereto.

[0266] The processor 1400 may be operably coupled to the transceiver circuit 1250 and may be configured as a modem operating in a baseband. The processor 1400 may receive or transmit a signal through at least one of the first antenna module ANT1 and the second antenna module ANT2. The processor 1400 may perform a diversity operation or MIMO using the first antenna module ANT1 and the second antenna module ANT2 such that a signal is transmitted to the inside of the vehicle.

[0267] Antenna modules may be arranged in different regions of one side surface and another side surface of the glass panel 310. The antenna modules may perform MIMO by simultaneously receiving signals from the front of the vehicle. In this regard, to perform 4X4 MIMO, the antenna modules may further include the third antenna module ANT3 and the fourth antenna module ANT4 in addition to the first antenna module ANT1 and the second antenna module ANT2.

[0268] The processor 1400 may select an antenna module to perform communication with an entity communicating with the vehicle based on a driving path of the vehicle and a communication path with the entity. The processor 1400 may perform MIMO by using the first antenna module ANT1 and the second antenna module ANT2 based on a direction that the vehicle travels. Alternatively, the processor 1400 may perform MIMO through the third antenna module ANT2 and the fourth antenna module ANT4 based on the direction that the vehicle travels.

[0269] The processor 1400 may perform MIMO in a first band through at least two of the first antenna ANT1 to the fourth antenna ANT4. The processor 1400 may perform MIMO in at least one of a second band and a third band through at least two of the first antenna ANT1 to the fourth antenna ANT4.

[0270] Accordingly, when signal transmission/reception performance of the vehicle deteriorates in any one band, signal transmission/reception in the vehicle may be performed in other bands. For example, the vehicle may preferentially perform communication linkage in the first band, which is the low band, for wide communication coverage and linkage reliability, and then perform communication linkage in the second and third bands.

[0271] The processor 1400 may control the transceiver circuit 1250 to perform carrier aggregation (CA) or dual connectivity (DC) through at least one of the first antenna ANT1 to the fourth antenna ANT4. In this regard, a communication capacity may be expanded through the aggregation of the second band and the third band, which are wider than the first band. In addition, communication reliability can be improved through the DC with neighboring vehicles or entities by using the plurality of antenna elements arranged in the different regions of the vehicle.

[0272] The foregoing description has been given of the broadband transparent antenna assembly that may be arranged on the vehicle glass and the vehicle having the same. Hereinafter, the technical effects of a broadband transparent antenna assembly that may be arranged on vehicle glass and a vehicle having the same will be described.

[0273] Hereinafter, the technical effects of a broadband transparent antenna assembly that may be arranged on vehicle glass will be described.

[0274] According to the specification, 4G/5G broadband wireless communications in a vehicle may be enabled by providing a broadband transparent antenna assembly, which may be arranged on vehicle glass and include conductive patterns and an FPCB stub structure.

[0275] According to the specification, antenna efficiency may be improved by optimizing the shapes of conductive patterns and the shape of an FPCB stub and employing an asymmetrical antenna structure in a broadband transparent antenna assembly, which may be arranged on vehicle glass.

[0276] According to the specification, a broadband antenna structure made of a transparent material may be implemented, which may improve antenna efficiency by setting a different antenna operation mode for each frequency band while reducing feeding loss.

[0277] According to the specification, a broadband antenna structure considering an actual environment, in which the broadband antenna structure is attached to a vehicle, by analyzing the change in antenna performance according to the affection by a metal chassis as well as a glass panel of the vehicle and a cable structure.

[0278] According to the specification, an antenna assembly which is adjacent to a metal frame may suppress the deterioration of antenna reflection coefficient characteristics and bandwidth characteristics by utilizing conductive patterns of adjacent transparent antenna elements.

[0279] According to the specification, antenna reflection coefficient characteristics and bandwidth characteristics in a low band (LB) may be improved by arranging conductive patterns adjacent to each other with a gap below a threshold value between adjacent transparent antenna elements.

[0280] According to the specification, transparent antenna elements which are formed adjacent to a metal frame may be arranged adjacently, and a coaxial cable may be arranged parallel to an FPCB in a certain region, so that the isolation between the antenna elements may be maintained below a certain level.

[0281] According to the specification, a transparent antenna structure, which enables wireless communications in 4G and 5G frequency bands while minimizing changes in antenna performance and a difference in transparency between an antenna region and a surrounding region, may be provided.

[0282] Further scope of applicability of the disclosure will become apparent from the following detailed description. It should be understood, however, that the detailed description and specific examples, such as the preferred embodiments, are given by way of illustration only, because various changes and modifications within the technical idea and scope of the disclosure will be apparent to those skilled in the art.

[0283] In relation to the aforementioned disclosure, the design and operations of an antenna assembly having transparent antennas and a vehicle controlling the same may be implemented as computer-readable codes in a program-recorded medium. The computer-readable medium may include all types of recording devices each storing data readable by a computer system. Examples of such computer-readable media may include hard disk drive (HDD), solid state disk (SSD), silicon disk drive (SDD), ROM, RAM, CD-ROM, magnetic tape, floppy disk, optical data storage element and the like. Also, the computer-readable medium may also be implemented as a format of carrier wave (e.g., transmission via an Internet). The computer may include the controller of the terminal. Therefore, the detailed description should not be limitedly construed in all of the aspects, and should be understood to be illustrative. Therefore, all changes and modifications that fall within the metes and bounds of the claims, or equivalents of such metes and bounds are therefore intended to be embraced by the appended claims.

Claims

1. An antenna assembly comprising:

a first dielectric substrate forming a transparent region, and comprising a first conductive pattern, a second conductive pattern, and a third conductive pattern spaced apart from the second conductive pattern by a gap, wherein the third conductive pattern operates by a current coupled from the second conductive pattern having a symmetrical shape on the basis of the gap in a first frequency band; and
a second dielectric substrate forming an opaque region, and comprising a ground conductive pattern and a feeding pattern,
wherein the first conductive pattern comprises a first part and a second part perpendicular to the first part,
the ground conductive pattern of the second dielectric substrate comprises a first region and a second region,
the second part of the first conductive pattern is connected to the feeding pattern, and the second conductive pattern is connected to the first region of the ground conductive pattern, and
a first sub-region of the first region of the ground conductive pattern is connected to a ground of a coaxial cable, and a second sub-region of the first region of the ground conductive pattern is arranged to overlap the coaxial cable by a certain region.

2. The antenna assembly of claim 1, wherein the second conductive pattern comprises a third part and a fourth part perpendicular to the third part,

the third conductive pattern comprises a fifth part and a sixth part perpendicular to the fifth part, and
an end of the fifth part of the third conductive pattern is spaced apart by the gap from an end of the third part of the second conductive pattern.

3. The antenna assembly of claim 2, wherein a distance of the gap formed between the end of the fifth part of the third conductive pattern and the end of the third part of the second conductive pattern is $\lambda g/20$ or less based on a specific frequency of the first frequency band.

4. The antenna assembly of claim 2, wherein the first dielectric substrate further comprises a fourth conductive pattern having a symmetrical shape on the basis of the gap,

the second dielectric substrate further comprises a second ground conductive pattern and a second feeding pattern, and
the fourth conductive pattern comprises a seventh part and an eighth part perpendicularly connected to the seventh part and connected to the second feeding pattern.

5. The antenna assembly of claim 4, wherein the second ground conductive pattern of the second dielectric substrate comprises a third region and a fourth region,

the third region of the second ground conductive pattern is formed in a symmetrical shape with the first region of the ground conductive pattern on the basis of the gap,
the fourth region of the second ground conductive pattern is formed in a symmetrical shape with the second region of the ground conductive pattern on the basis of the gap,
the second part of the first conductive pattern is connected to the feeding pattern, and the second conductive pattern is connected to the first region of the ground conductive pattern, and
the eighth part of the fourth conductive pattern is connected to the second feeding pattern, and the third conductive pattern is connected to the third region of the second ground conductive pattern, and
a first sub-region of the third region of the second ground conductive pattern is connected to a ground of a second coaxial cable, and a second sub-region of the third region of the second ground conductive pattern is arranged to overlap the second coaxial cable by a certain region.

6. The antenna assembly of claim 5, wherein the second conductive pattern and the third conductive pattern are formed to have a first length in a first axial direction parallel to the coaxial cable,

the coaxial cable is formed to have a second length from a point where a signal line corresponding to one end of the coaxial cable is connected to a point corresponding to another end of the coaxial cable,
the second coaxial cable is formed to have the second length from a point where a signal line corresponding to one end of the second coaxial cable is connected to a point corresponding to another end of the second coaxial cable, and
the second length is 0.5 times longer than the first length.

7. The antenna assembly of claim 6, wherein the second sub-region of the first region of the ground conductive pattern is formed to have a third length in the first axial direction, the second sub-region of the third region of the second ground conductive pattern is formed to have the third length in the first axial direction, and

the third length is formed to be 0.5 times longer than the first length and shorter than the second length.

8. The antenna assembly of claim 7, wherein the first sub-region of the first region of the ground conductive pattern and the first sub-region of the third region of the second ground conductive pattern are formed to have a first width in a second axial direction perpendicular to the first axial direction,

the second sub-region of the first region of the ground conductive pattern and the second sub-region of the third region of the second ground conductive pattern are formed to have a second width in the second axial direction, and

the first width is larger than a sum of the second width and a diameter of the coaxial cable.

9. The antenna assembly of claim 5, wherein the coaxial cable is arranged to be spaced apart in parallel from an end of the second sub-region of the first region of the ground conductive pattern, and

the second coaxial cable is arranged to be spaced apart in parallel from an end of the second sub-region of the third region of the second ground conductive pattern.

10. The antenna assembly of claim 5, wherein the ground conductive pattern comprises a second region connected to the first region and arranged on one side of the feeding pattern,

the second ground conductive pattern comprises a fourth region connected to the third region and arranged on another side of the second feeding pattern,

the second region of the ground conductive pattern is arranged below the first part of the first conductive pattern, and

the fourth region of the second ground conductive pattern is arranged below the seventh part of the fourth conductive pattern.

11. The antenna assembly of claim 10, wherein the first conductive pattern, the second conductive pattern, and the second region of the ground conductive pattern operate as a first antenna in the first frequency band through a third frequency band, and

the third conductive pattern, the fourth conductive pattern, and the fourth region of the second ground conductive pattern operate as a second antenna in the first frequency band through the third frequency band.

12. The antenna assembly of claim 11, wherein the first conductive pattern and the second conductive pattern operate as the first antenna of a dipole antenna mode in the first frequency band,

the third conductive pattern and the fourth conductive pattern operate as the second antenna of the dipole antenna mode in the first frequency band,

the first conductive pattern and the second conductive pattern form an asymmetrical structure, and

the third conductive pattern and the fourth conductive pattern form an asymmetrical structure.

13. The antenna assembly of claim 12, wherein the first conductive pattern operates as the first antenna of a monopole antenna mode in a second frequency band,

the fourth conductive pattern operates as the second antenna of the monopole antenna mode in the second frequency band,

the second region of the ground conductive pattern operates as the first antenna in the third frequency band,

the fourth region of the second ground conductive pattern operates as the second antenna in the third frequency band, and

the second frequency band is higher than the first frequency band, and the third frequency band is higher than the second frequency band.

14. The antenna assembly of claim 5, wherein the first conductive pattern, the second conductive pattern, the third conductive pattern, and the fourth conductive pattern are formed in a metal mesh shape having a plurality of opening areas on the first dielectric substrate,

the first conductive pattern, the second conductive pattern, the third conductive pattern, and the fourth conductive pattern form a radiator region, and

the first conductive pattern, the second conductive pattern, the third conductive pattern, and the fourth conductive pattern form a coplanar waveguide (CPW) structure on the first dielectric substrate.

15. The antenna assembly of claim 14, wherein the antenna assembly comprises a plurality of dummy mesh grid patterns in an outer portion of the radiator region on the first dielectric substrate,

the plurality of dummy mesh grid patterns are not connected to the feeding pattern and the ground conductive pattern, and

the plurality of dummy mesh grid patterns are not connected to the second feeding pattern and the second ground conductive pattern, and
the plurality of dummy mesh grid patterns are separated from each other.

16. A vehicle comprising:

a metal frame in which an opening is formed;
a glass panel comprising a transparent region and an opaque region; and
an antenna assembly arranged on the glass panel,
wherein the antenna assembly comprises:

a first dielectric substrate arranged in the transparent region of the glass panel, and comprising a first conductive pattern, a second conductive pattern, and a third conductive pattern spaced apart from the second conductive pattern by a gap, wherein the third conductive pattern operates by a current coupled from the second conductive pattern having a symmetrical shape on the basis of the gap in a first frequency band; and
a second dielectric substrate arranged in the opaque region of the glass panel, and comprising a ground conductive pattern and a feeding pattern,
the first conductive pattern comprises a first part and a second part perpendicular to the first part,
the ground conductive pattern of the second dielectric substrate comprises a first region and a second region,
the second part of the first conductive pattern is connected to the feeding pattern, and the second conductive pattern is connected to the first region of the ground conductive pattern, and
a first sub-region of the first region of the ground conductive pattern is connected to a ground of a coaxial cable, and a second sub-region of the first region of the ground conductive pattern is arranged to overlap the coaxial cable by a certain region.

17. The vehicle of claim 16, wherein the second conductive pattern comprises a third part and a fourth part perpendicular to the third part,

the third conductive pattern comprises a fifth part and a sixth part perpendicular to the fifth part, and
an end of the fifth part of the third conductive pattern is spaced apart by the gap from an end of the third part of the second conductive pattern,
a distance of the gap formed between the end of the fifth part of the third conductive pattern and the end of the third part of the second conductive pattern is $\lambda g/20$ or less based on a specific frequency of the first frequency band.

18. The vehicle of claim 17, wherein the first dielectric substrate further comprises a fourth conductive pattern having a symmetrical shape on the basis of the gap,

the second dielectric substrate further comprises a second ground conductive pattern and a second feeding pattern, and
the fourth conductive pattern comprises a seventh part and an eighth part perpendicularly connected to the seventh part and connected to the second feeding pattern.

19. The vehicle of claim 18, wherein the second ground conductive pattern of the second dielectric substrate comprises a third region and a fourth region,

the third region of the second ground conductive pattern is formed in a symmetrical shape with the first region of the ground conductive pattern on the basis of the gap,
the fourth region of the second ground conductive pattern is formed in a symmetrical shape with the second region of the ground conductive pattern on the basis of the gap,
the second part of the first conductive pattern is connected to the feeding pattern, and the second conductive pattern is connected to the first region of the ground conductive pattern, and
the eighth part of the fourth conductive pattern is connected to the second feeding pattern, and the third conductive pattern is connected to the third region of the second ground conductive pattern, and
a first sub-region of the third region of the second ground conductive pattern is connected to a ground of a second coaxial cable, and a second sub-region of the third region of the second ground conductive pattern is arranged to overlap the second coaxial cable by a certain region.

20. The vehicle of claim 10, wherein the second conductive pattern and the third conductive pattern are formed to have a first length in a first axial direction parallel to the coaxial cable,

the coaxial cable is formed to have a second length from a point where a signal line corresponding to one end of the coaxial cable is connected to a point corresponding to another end of the coaxial cable,
the second coaxial cable is formed to have the

second length from a point where a signal line corresponding to one end of the second coaxial cable is connected to a point corresponding to another end of the second coaxial cable, and
the second sub-region of the first region of the ground conductive pattern is formed to have a third length in the first axial direction,
the second sub-region of the third region of the second ground conductive pattern is formed to have the third length in the first axial direction, and
the third length is formed to be 0.5 times longer than the first length and shorter than the second length.

FIG. 1

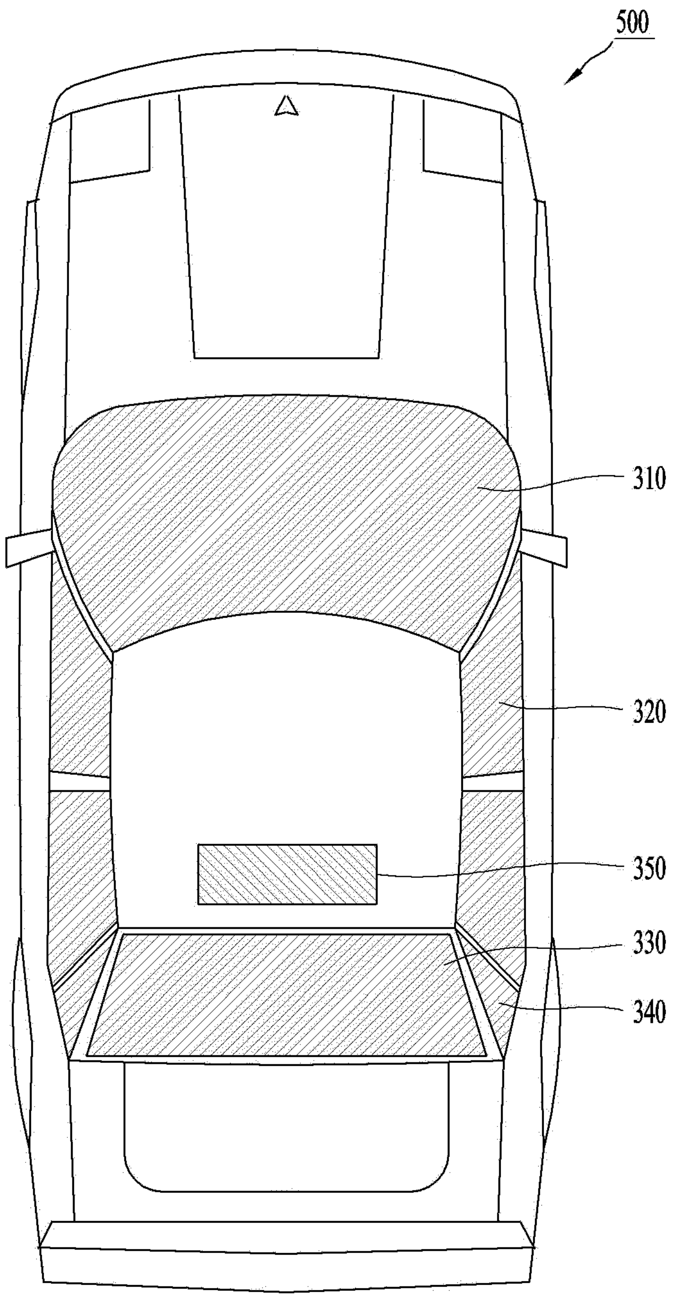


FIG. 2A

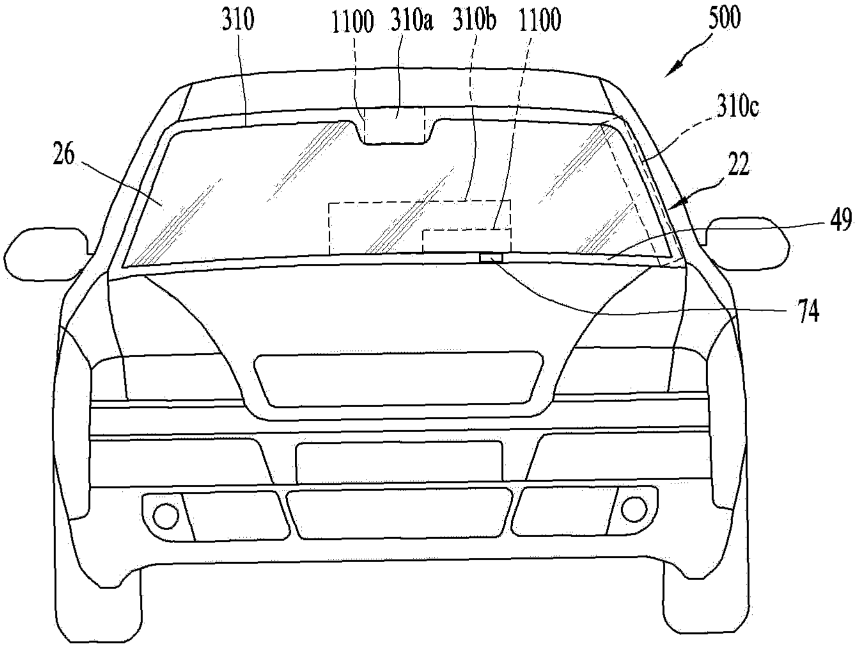


FIG. 2B

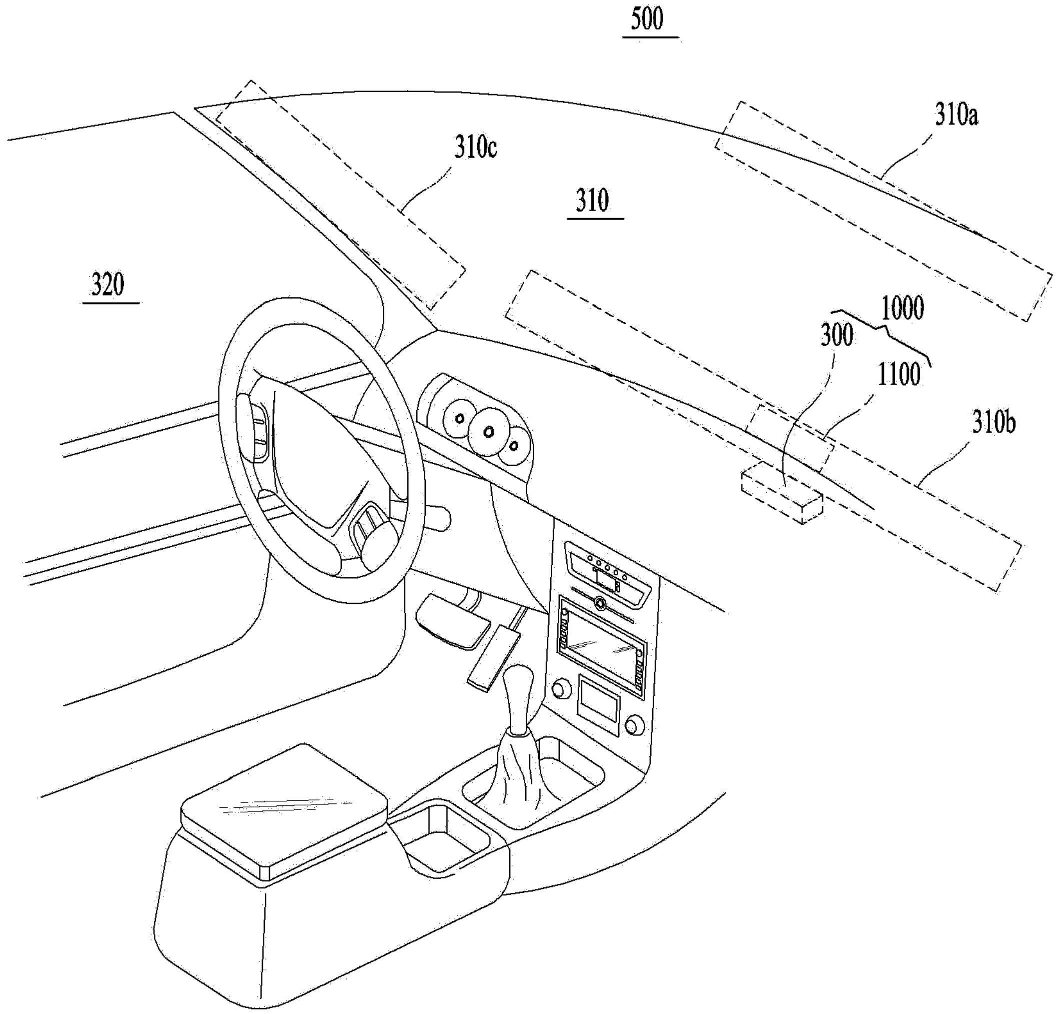


FIG. 2C

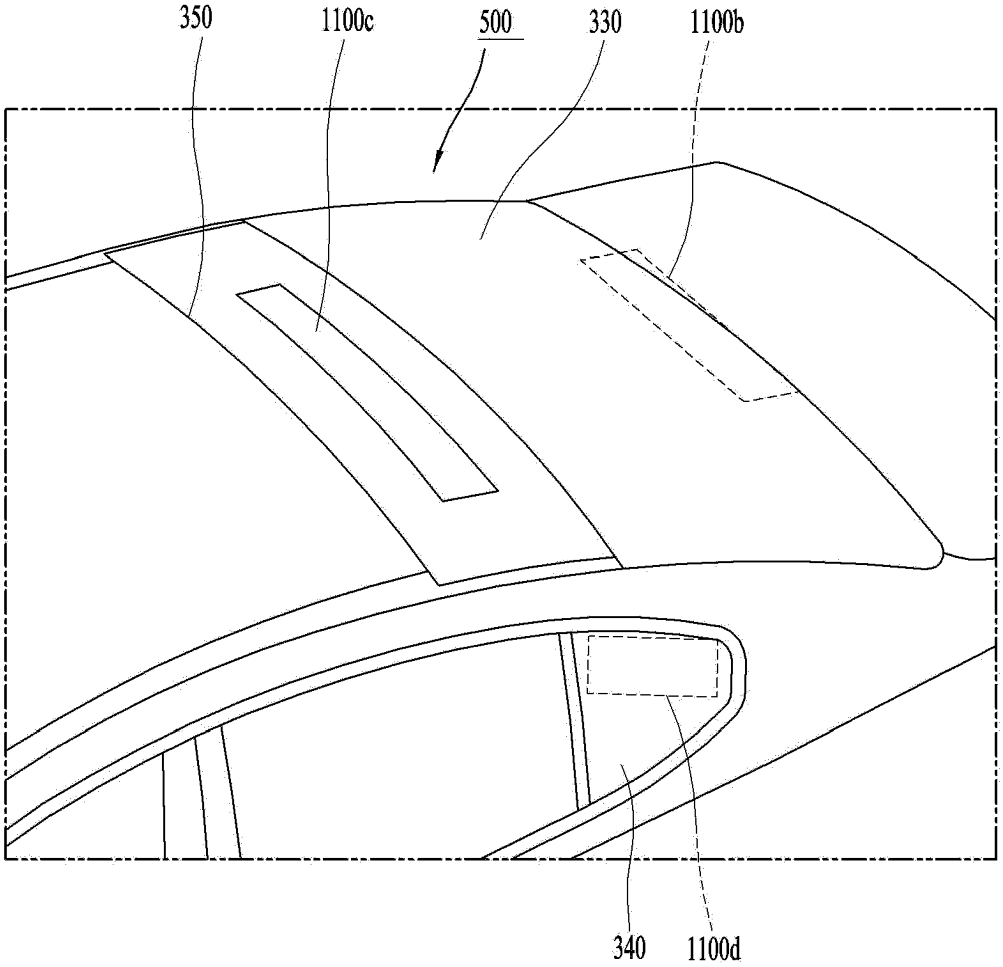


FIG. 3

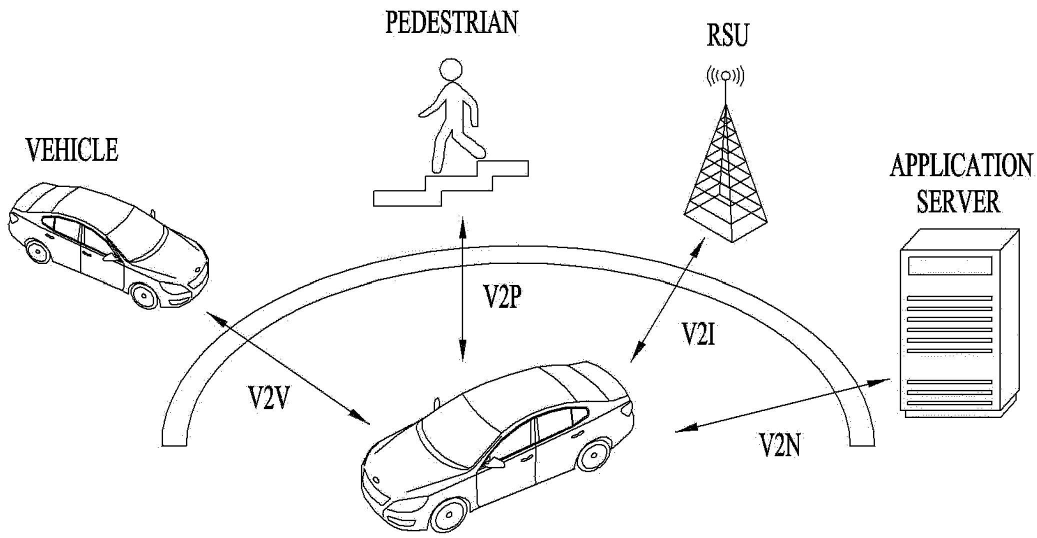

PEDESTRIAN
RSU
VEHICLE
APPLICATION SERVER
V2P
V2I
V2V
V2N

FIG. 4

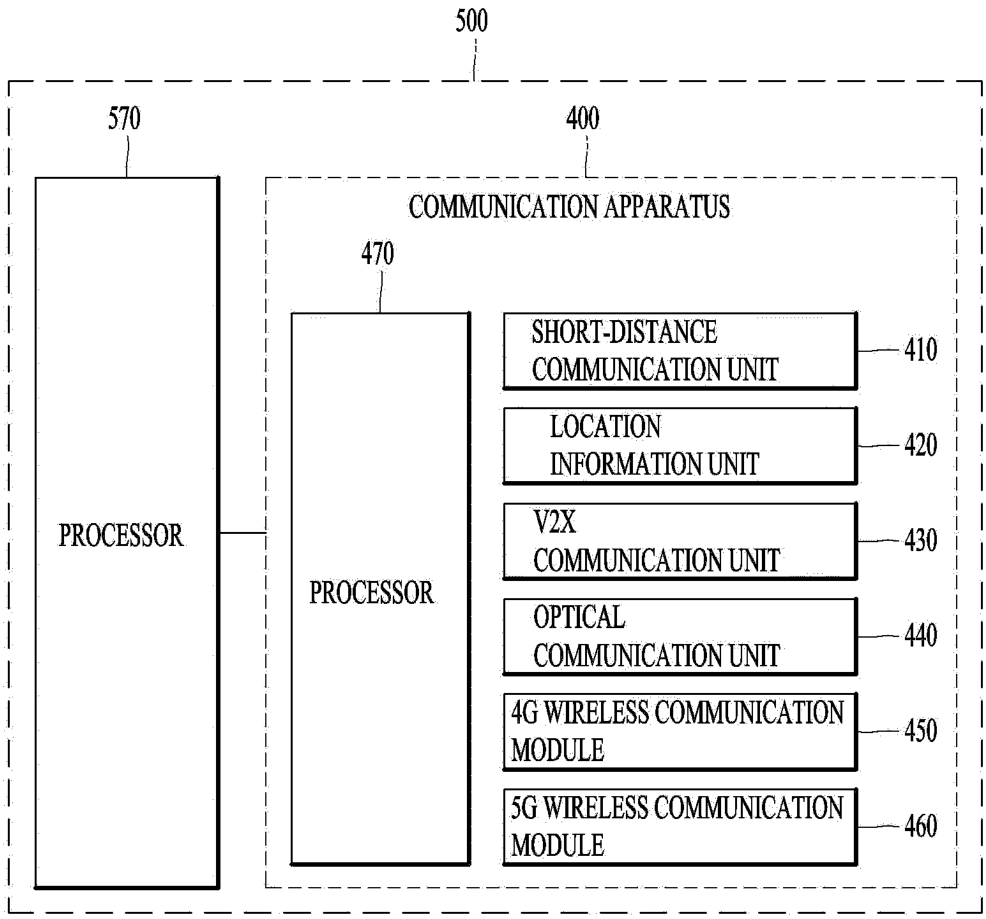

500
570
400
COMMUNICATION APPARATUS
470
PROCESSOR
PROCESSOR
SHORT-DISTANCE COMMUNICATION UNIT
410
LOCATION INFORMATION UNIT
420
V2X COMMUNICATION UNIT
430
OPTICAL COMMUNICATION UNIT
440
4G WIRELESS COMMUNICATION MODULE
450
5G WIRELESS COMMUNICATION MODULE
460

FIG. 5A

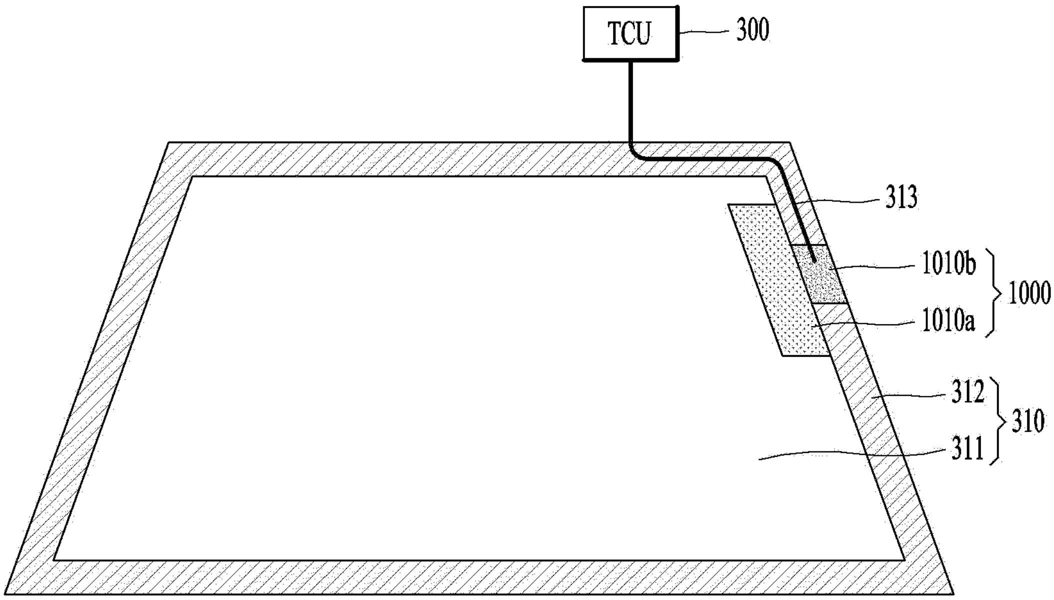

TCU
300
313
1010b
1000
1010a
312
310
311

FIG. 5B

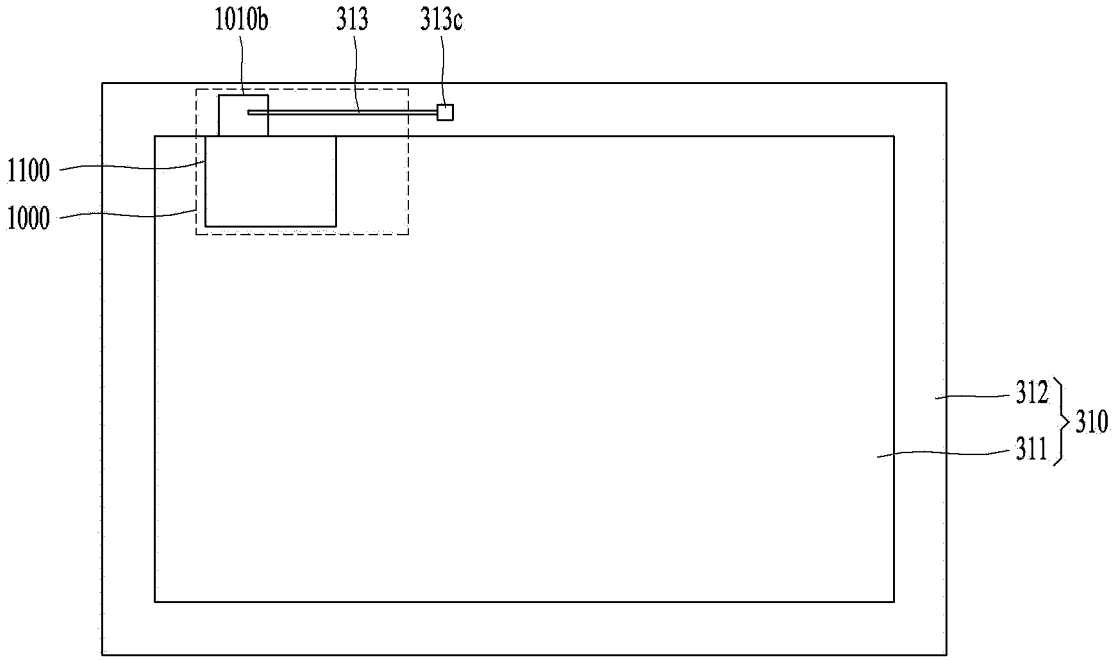

1010b
313
313c
1100
1000
312
310
311

FIG. 5C

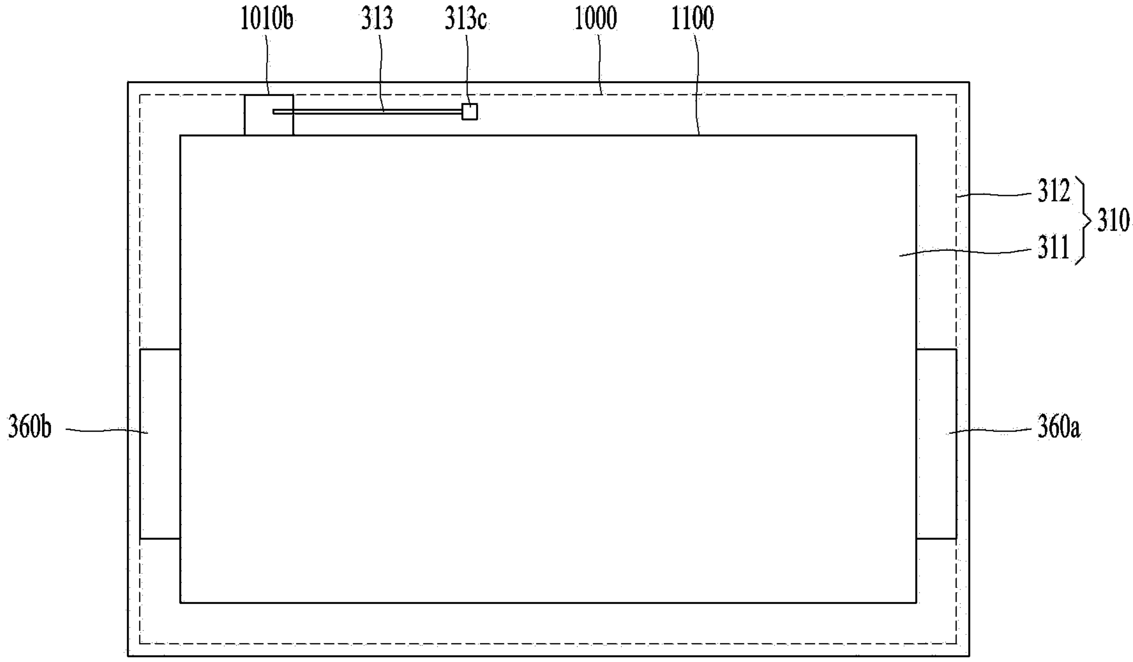


FIG. 6A

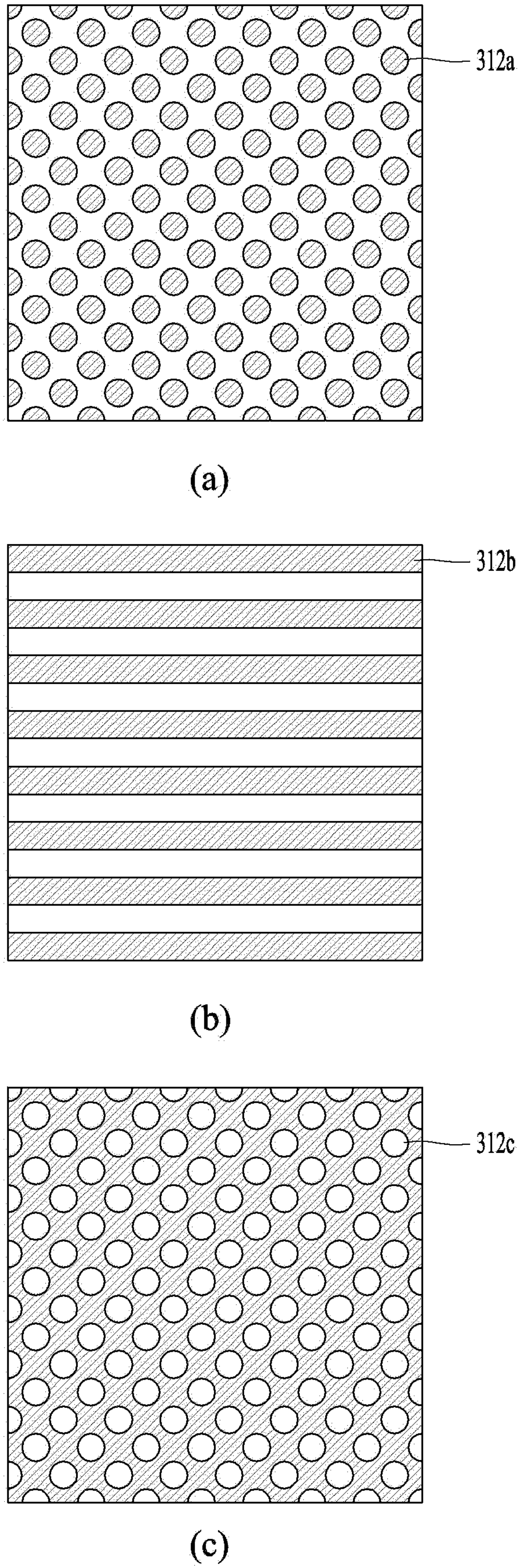
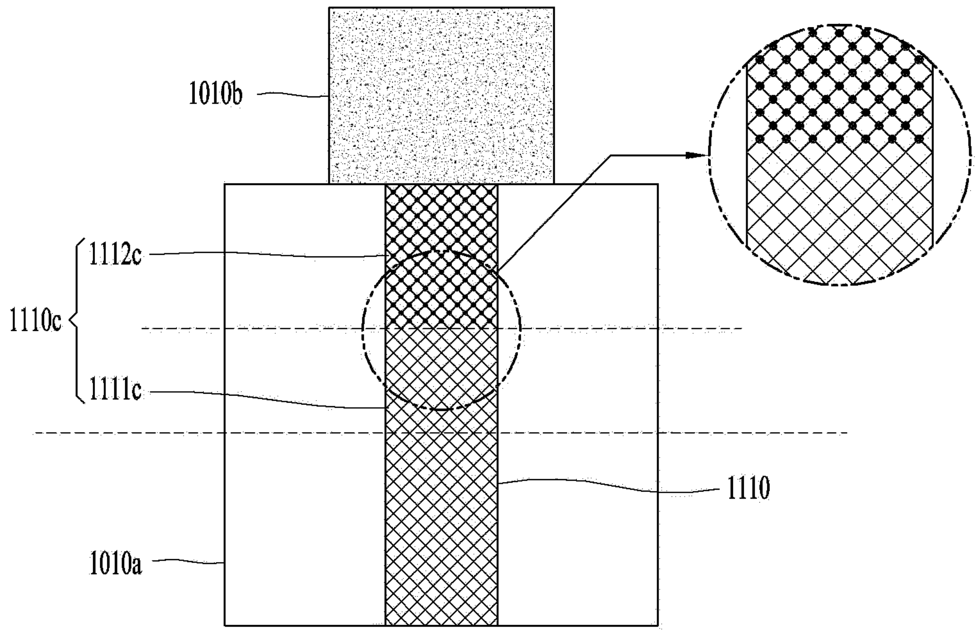
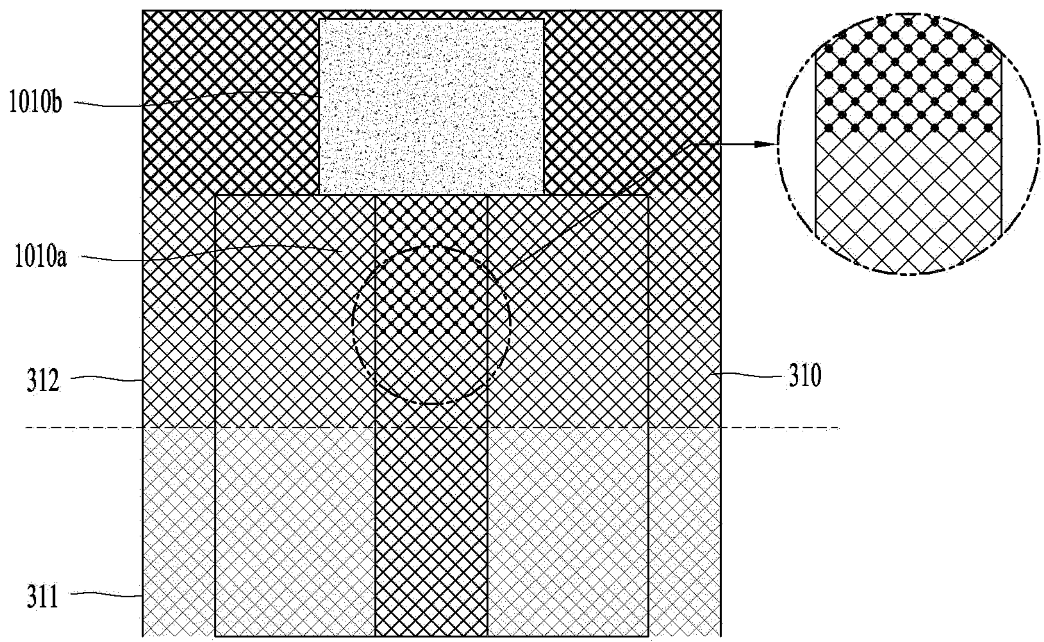


FIG. 6B



(a)



(b)

FIG. 6C

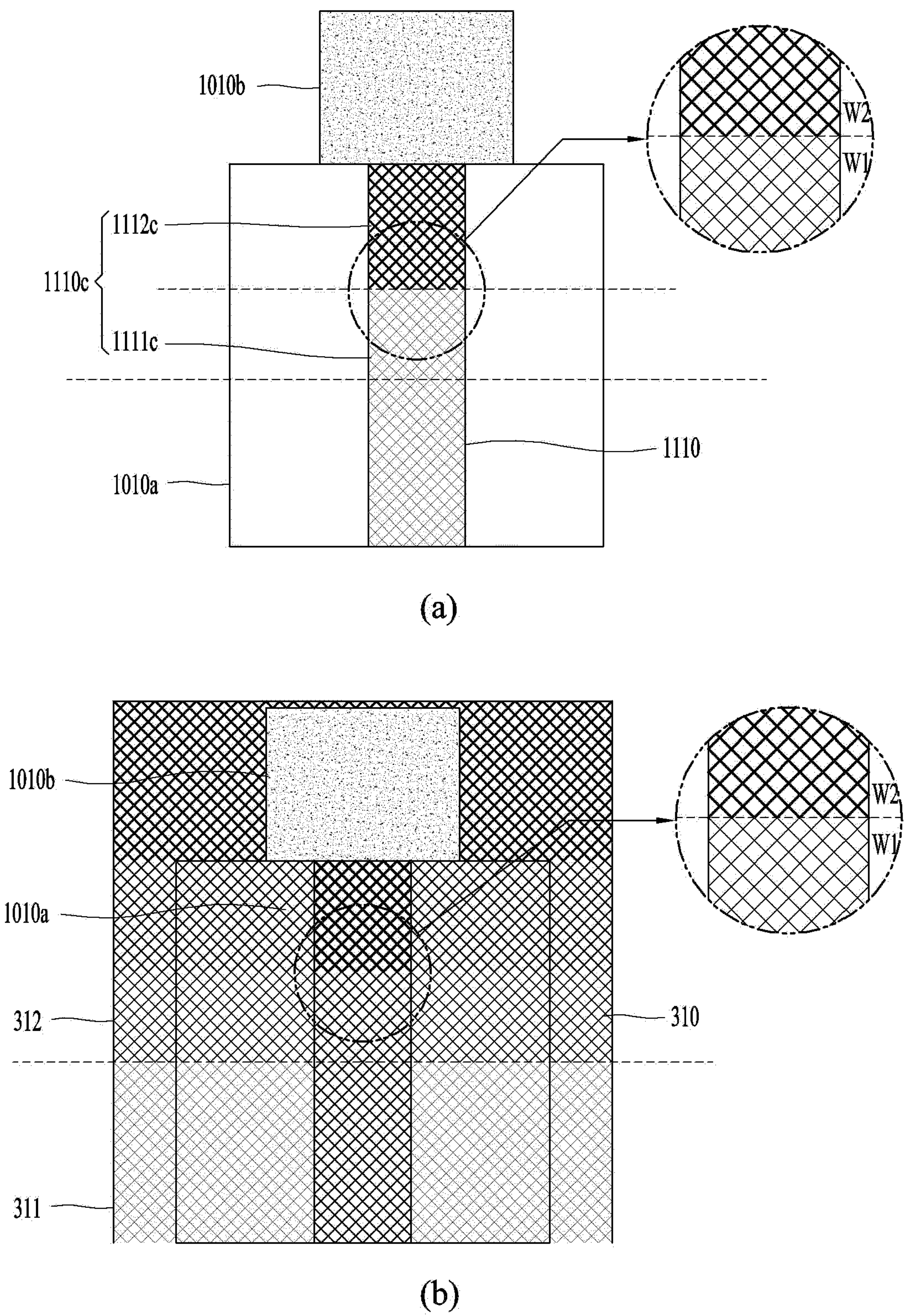
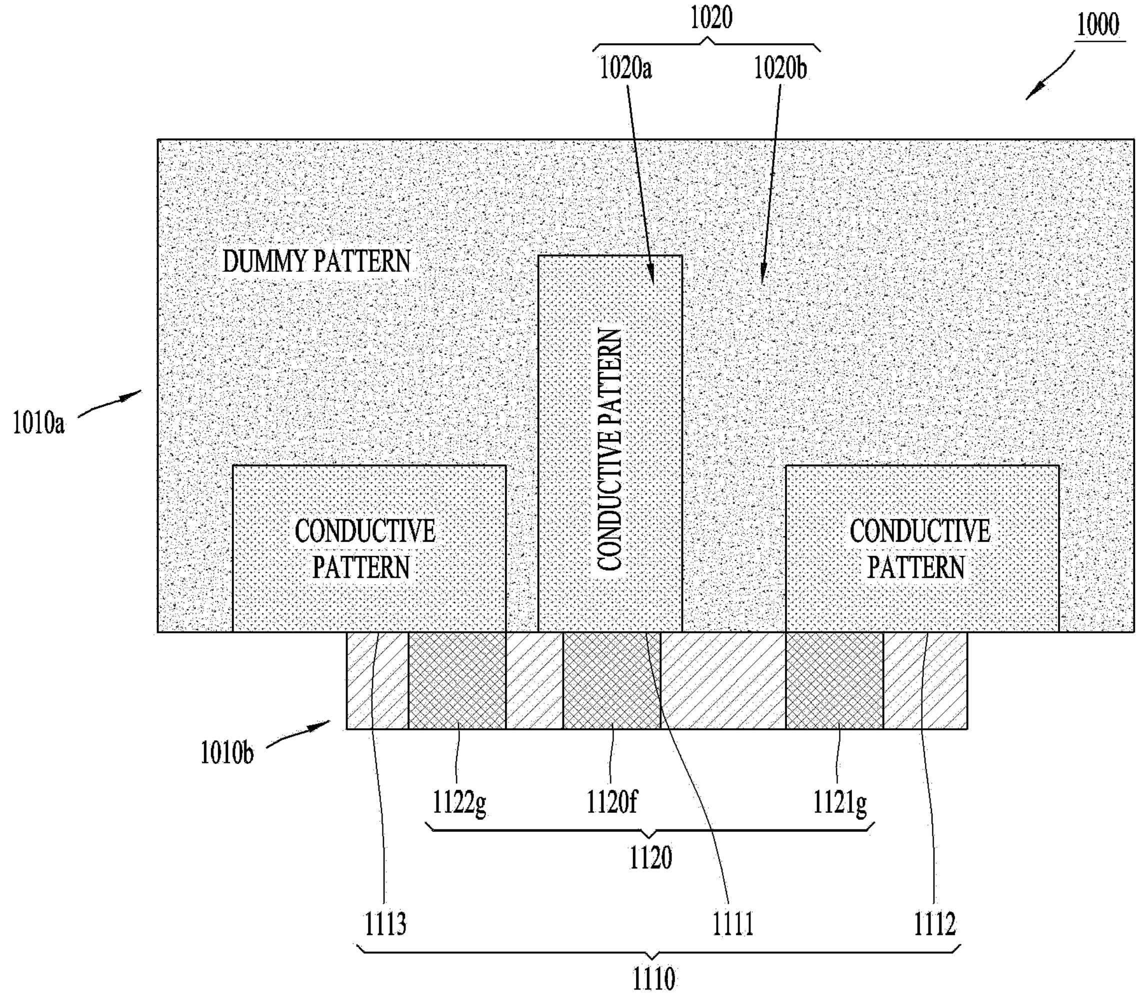
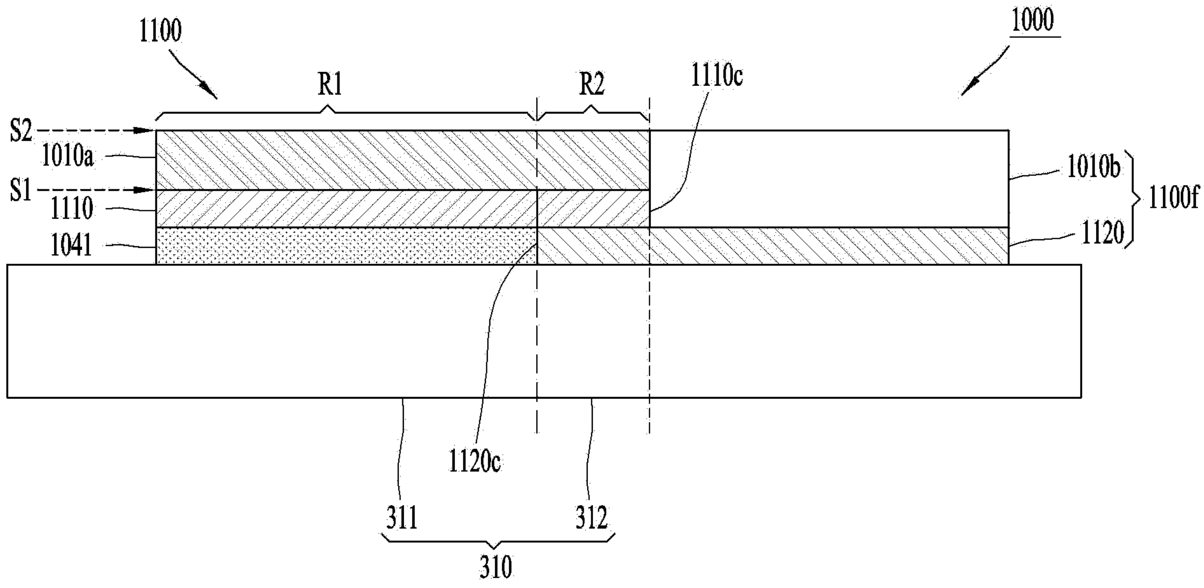

1010b
1112c
1110c
1111c
1110
1010a
W2
W1
(a)
1010b
1010a
312
310
311
W2
W1
(b)

FIG. 7A

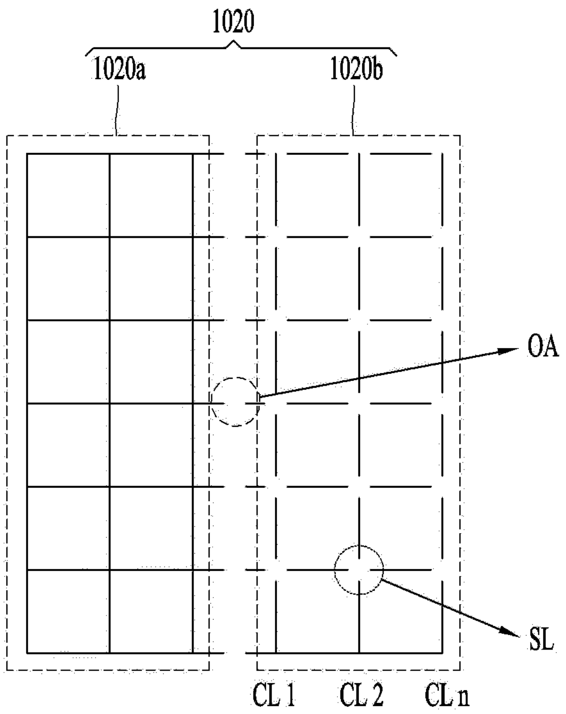

1020
1000
1020a
1020b
DUMMY PATTERN
CONDUCTIVE PATTERN
1010a
CONDUCTIVE PATTERN
CONDUCTIVE PATTERN
1010b
1122g
1120f
1121g
1120
1113
1111
1112
1110

(a)

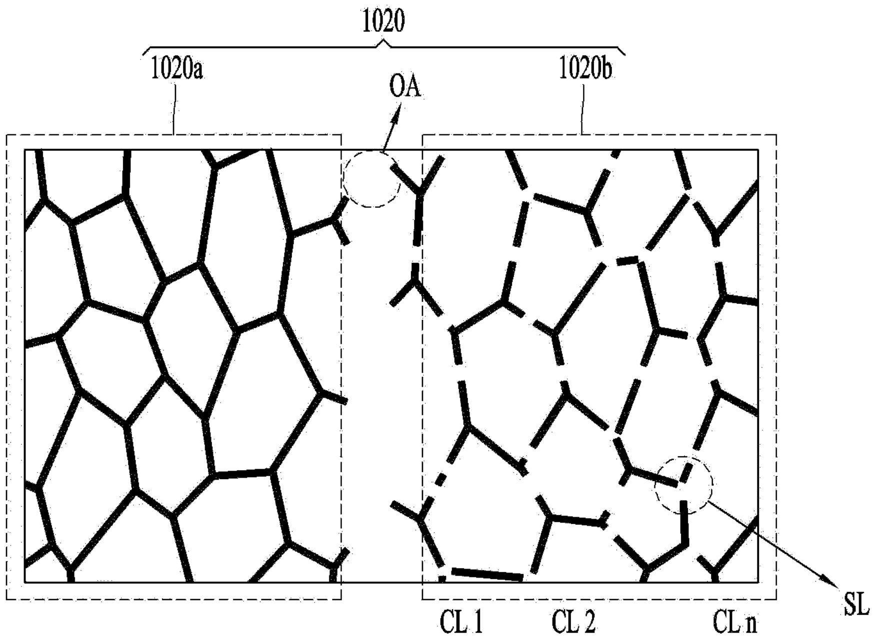

1100
1000
R1
R2
1110c
S2
1010a
S1
1110
1041
1010b
1100f
1120
1120c
311
312
310

(b)

FIG. 7B

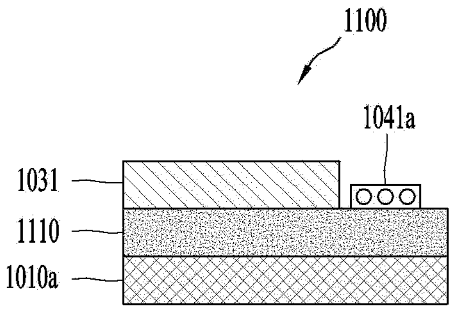

1020
1020a
1020b
OA
SL
CL 1
CL 2
CL n

(a)

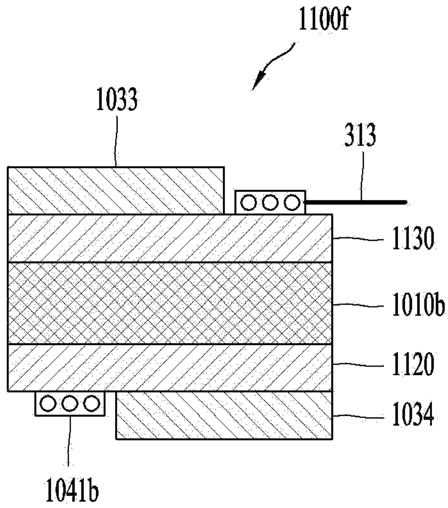

1020
1020a
OA
1020b
SL
CL 1
CL 2
CL n

(b)

FIG. 8A

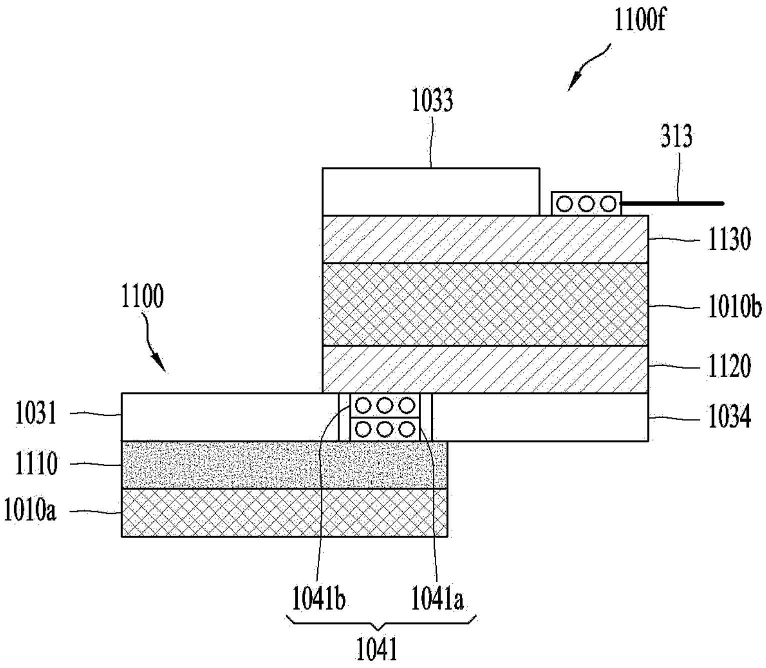

1100
1041a
1031
1110
1010a

(a)

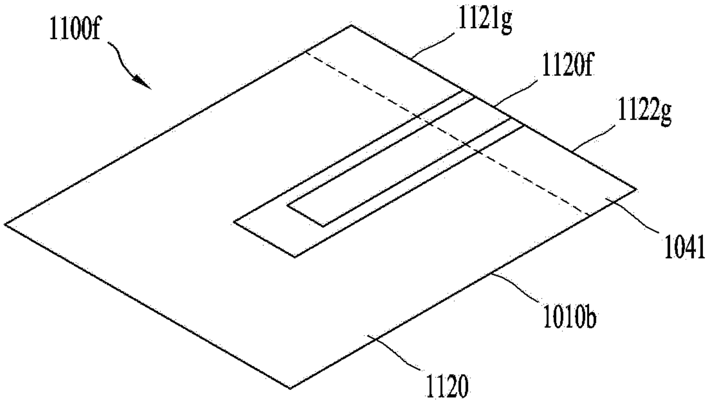

1100f
1033
313
1130
1010b
1120
1034
1041b

(b)

FIG. 8B


1100f
1033
313
1130
1100
1010b
1120
1031
1034
1110
1010a
1041b
1041a
1041

(a)


1121g
1100f
1120f
1122g
1041
1010b
1120

(b)

FIG. 9A

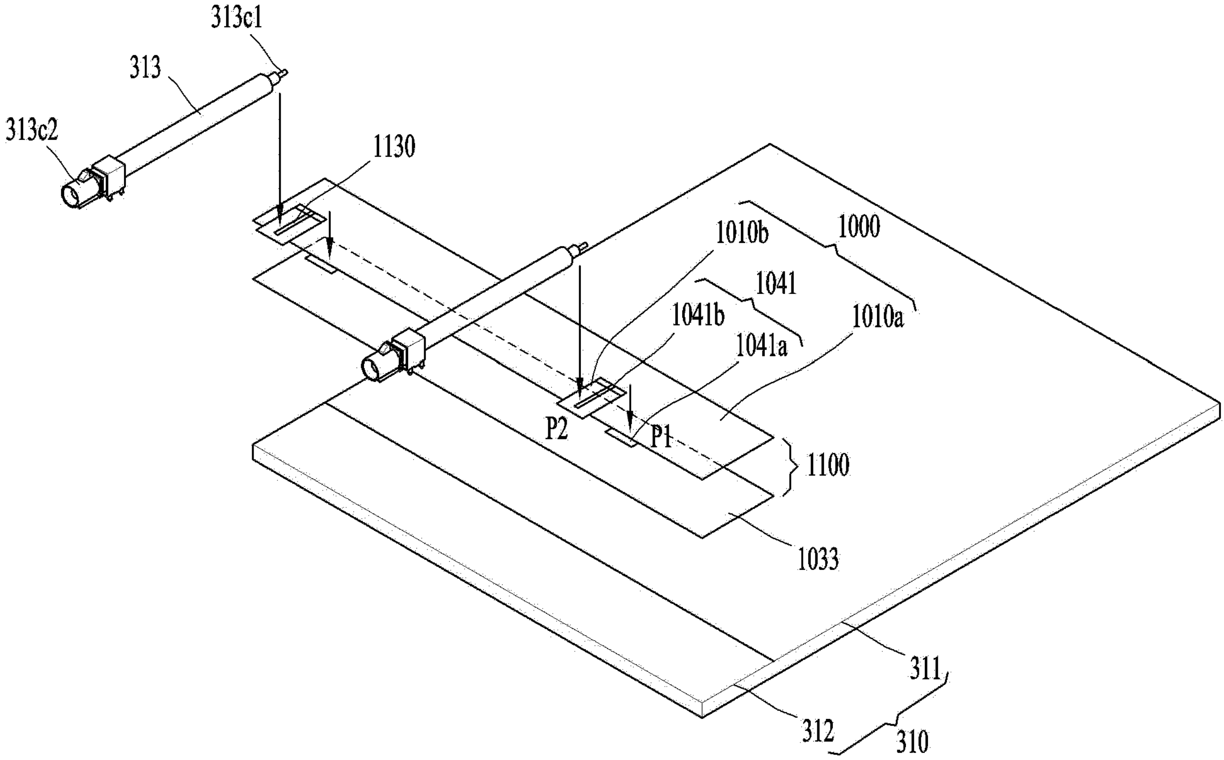

313c1
313
313c2
1130
1010b
1000
1041
1041b
1010a
1041a
P2
P1
1100
1033
311
312
310

FIG. 9B

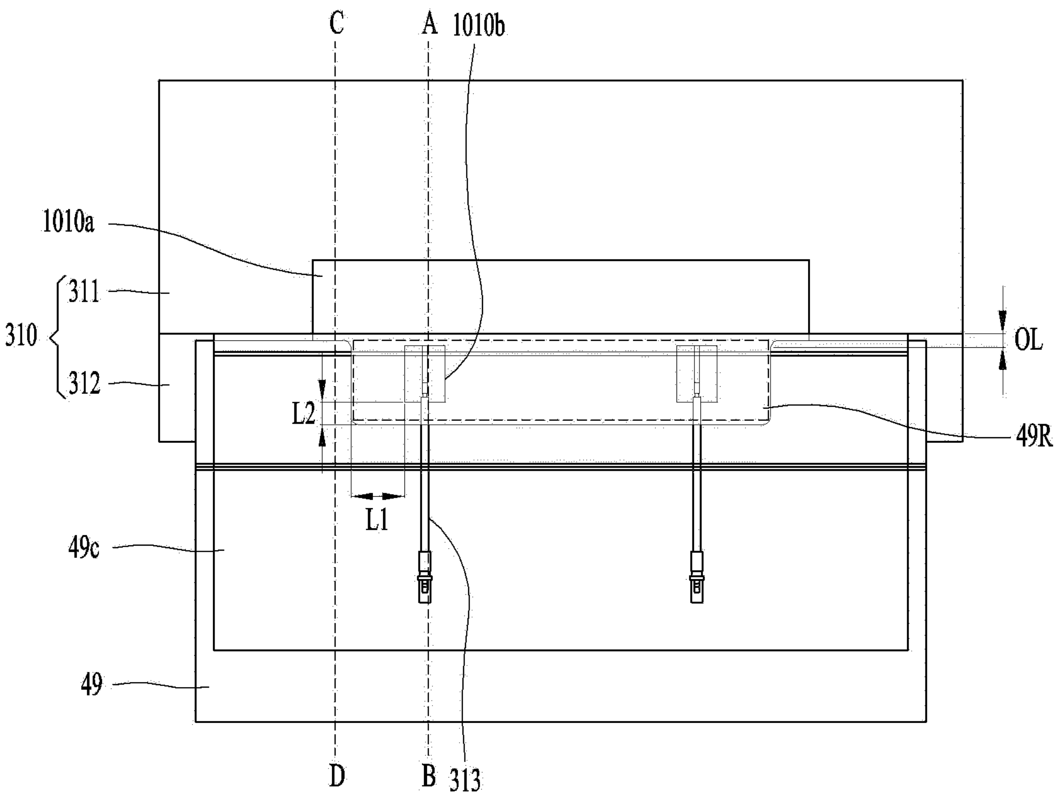
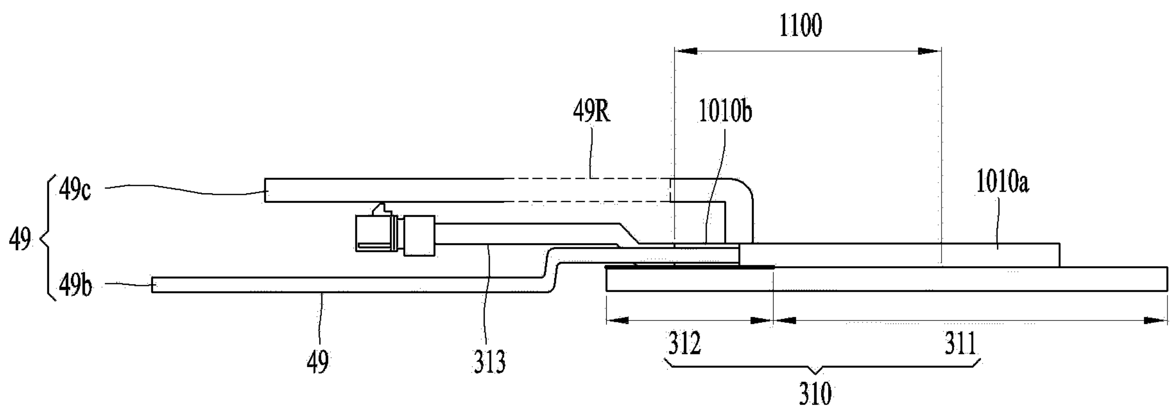
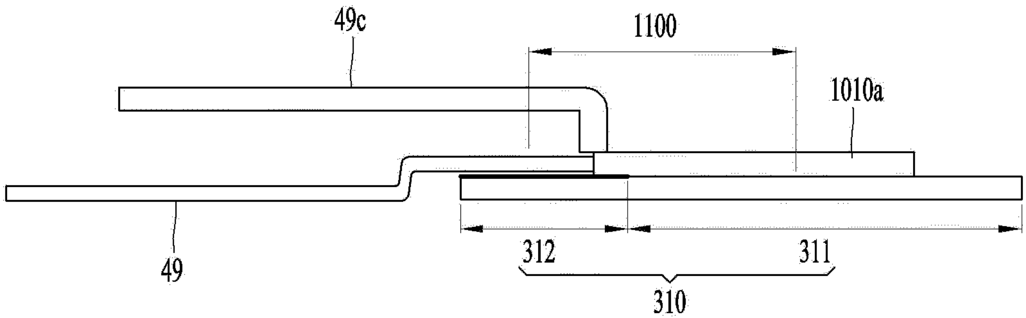

C
A
1010b
1010a
311
310
312
OL
L2
49R
L1
49c
49
D
B
313

FIG. 9C

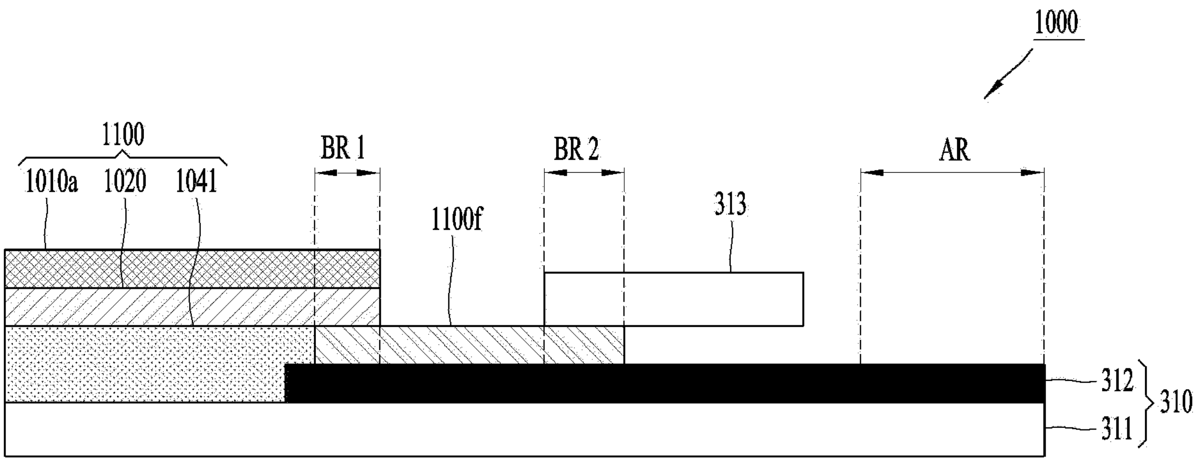

1100
49R
1010b
1010a
49c
49
49b
49
313
312
311
310

(a)

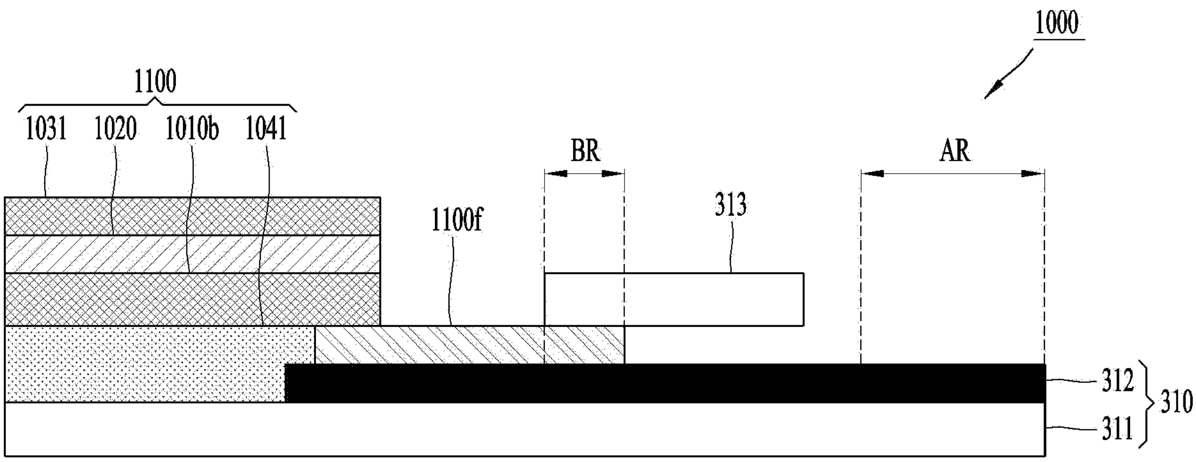

49c
1100
1010a
49
312
311
310

(b)

FIG. 10


1000
1100
1010a
1020
1041
BR 1
1100f
BR 2
313
AR
312
310
311

(a)


1000
1100
1031
1020
1010b
1041
BR
1100f
313
AR
312
310
311

(b)

FIG. 11

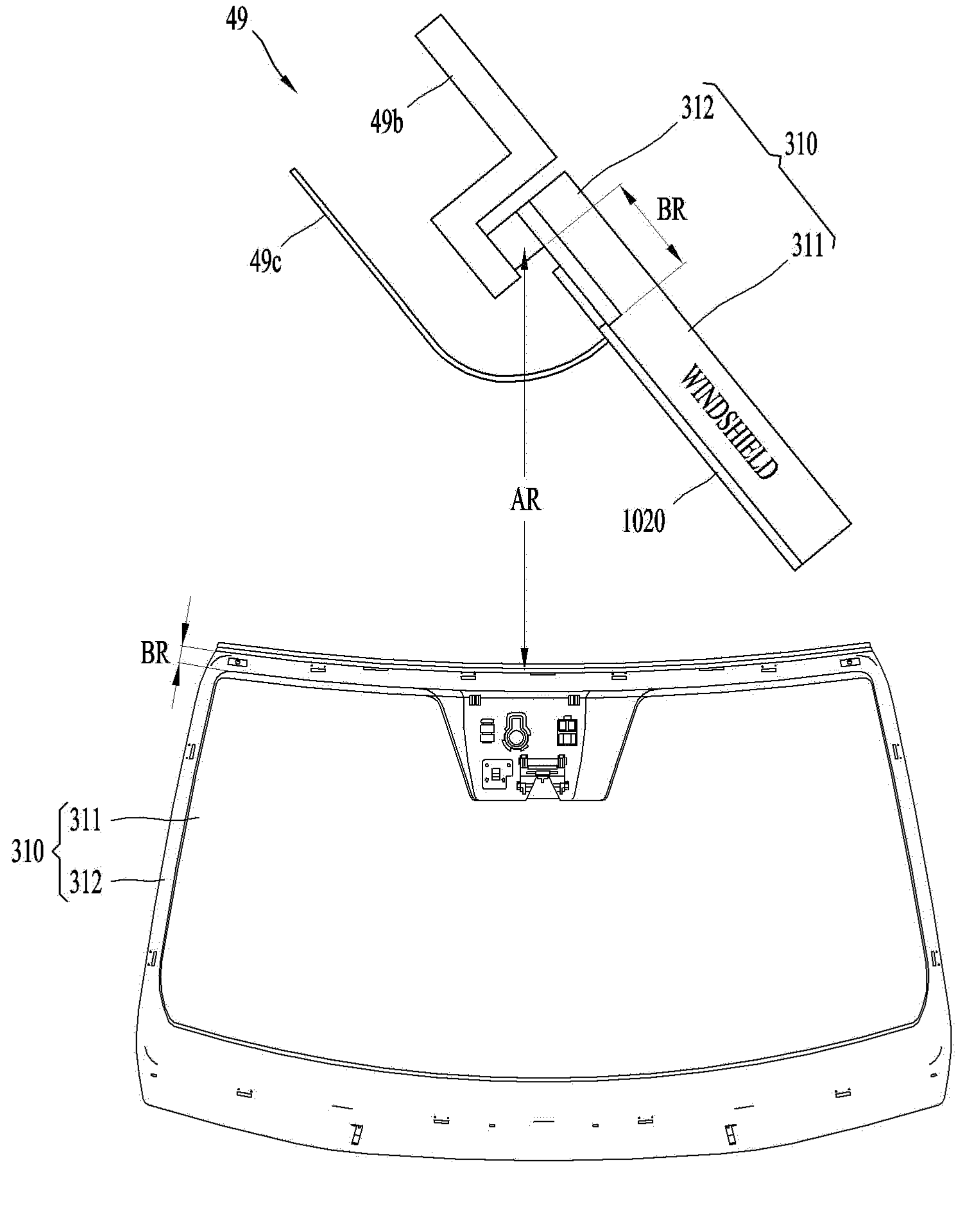
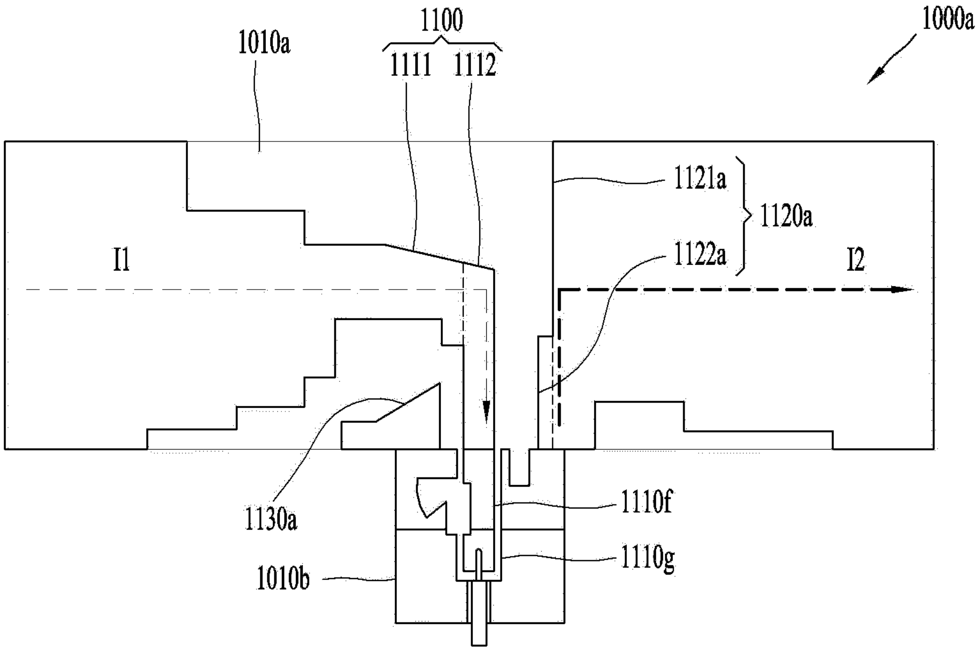
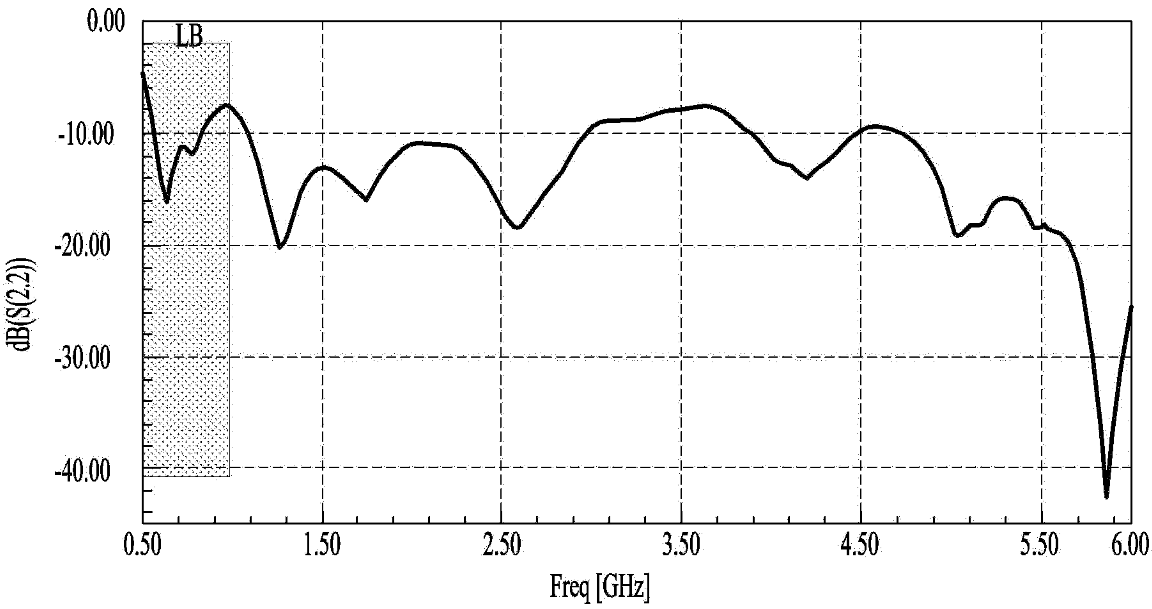


FIG. 12A

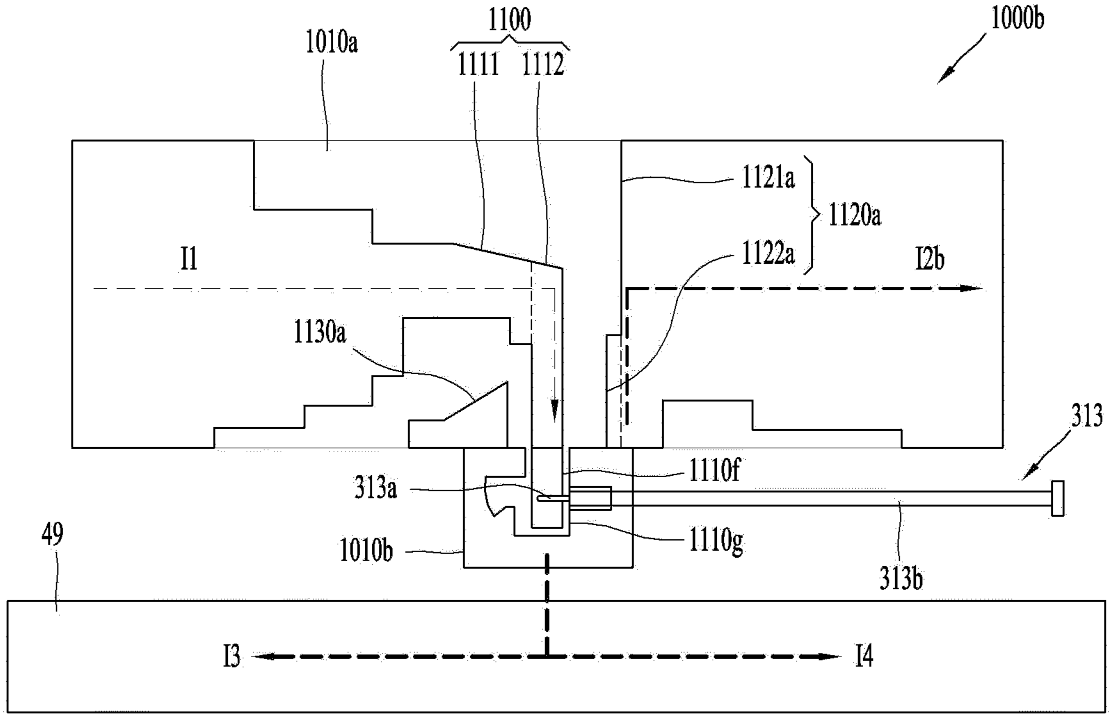

1100
1111
1112
1010a
1000a
1121a
1120a
1122a
I1
I2
1130a
1110f
1110g
1010b

(a)

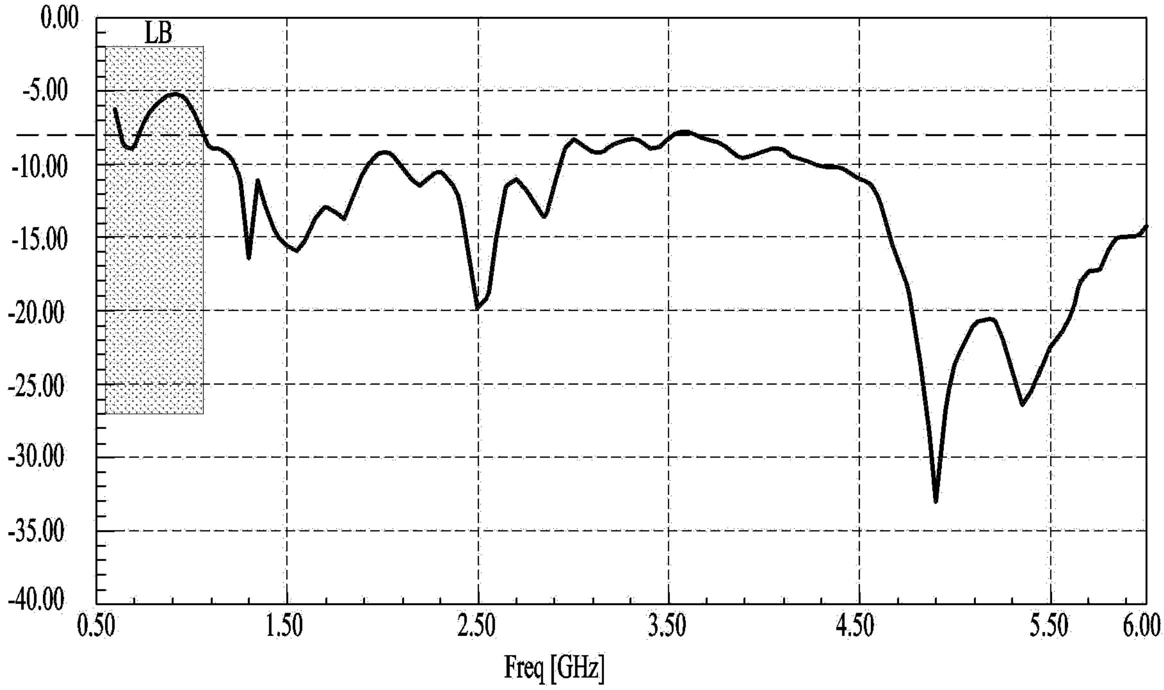

0.00
LB
-10.00
-20.00
-30.00
-40.00
dB(S(2.2))
0.50
1.50
2.50
3.50
4.50
5.50
6.00
Freq [GHz]

(b)

FIG. 12B

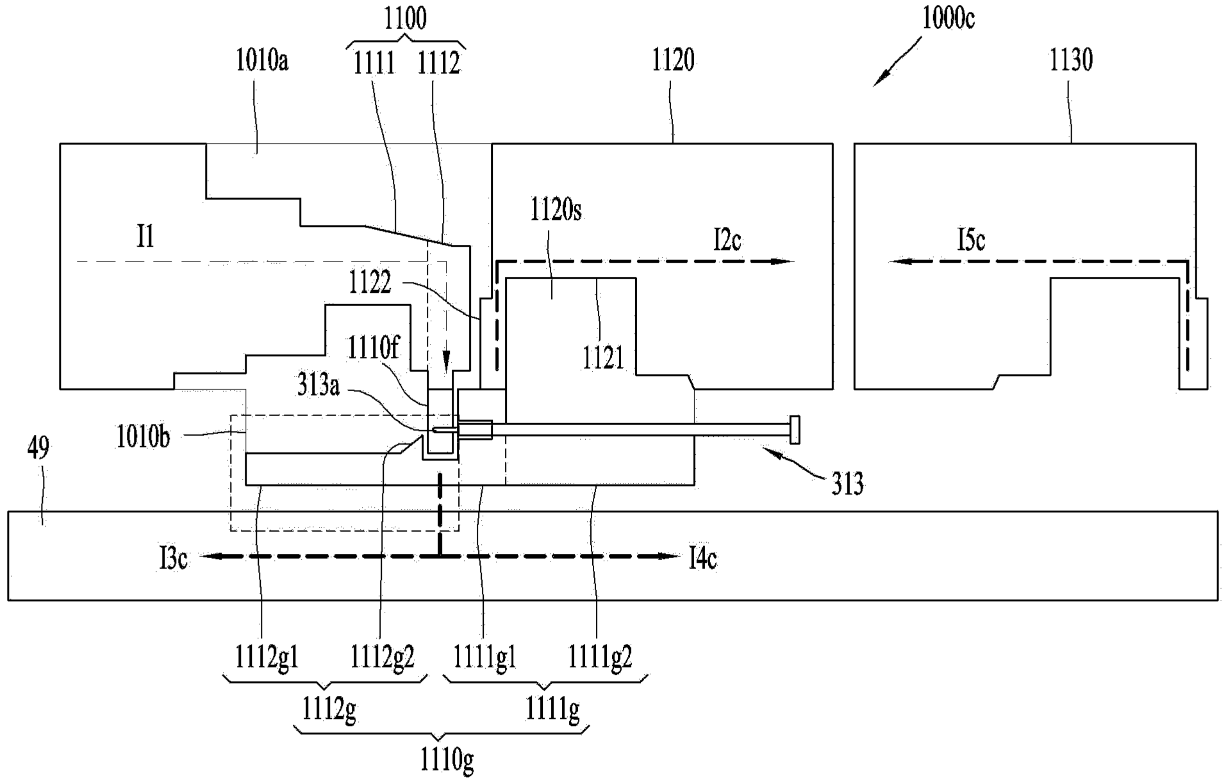

1100
1111
1112
1010a
1000b
1121a
1120a
1122a
I1
I2b
1130a
313
313a
1110f
1110g
1010b
313b
49
I3
I4

(a)

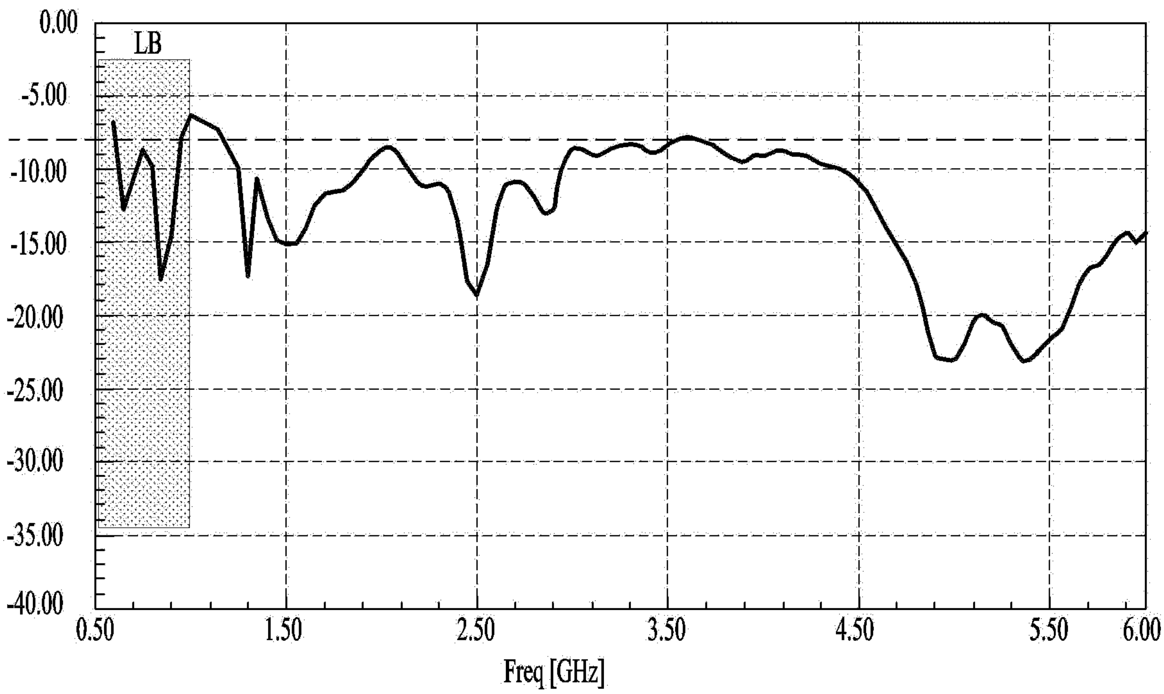

LB
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
0.50
1.50
2.50
3.50
4.50
5.50
6.00
Freq [GHz]

(b)

FIG. 12C


1100
1010a
1111
1112
1120
1000c
1130
1120s
I1
I2c
I5c
1122
1121
1110f
313a
1010b
49
313
I3c
I4c
1112g1
1112g2
1111g1
1111g2
1112g
1111g
1110g

(a)


0.00
LB
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
0.50
1.50
2.50
3.50
4.50
5.50
6.00
Freq [GHz]

(b)

FIG. 13

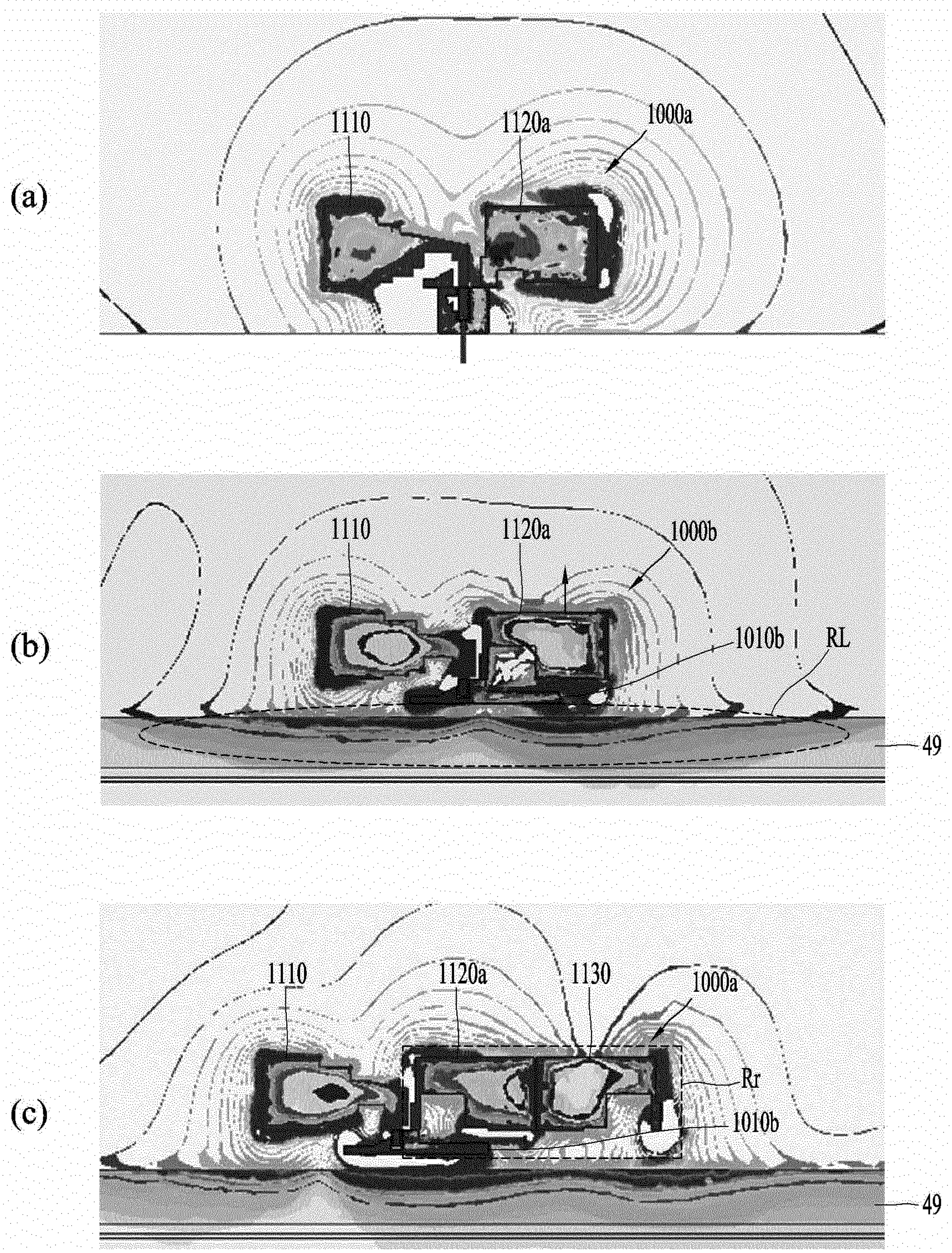
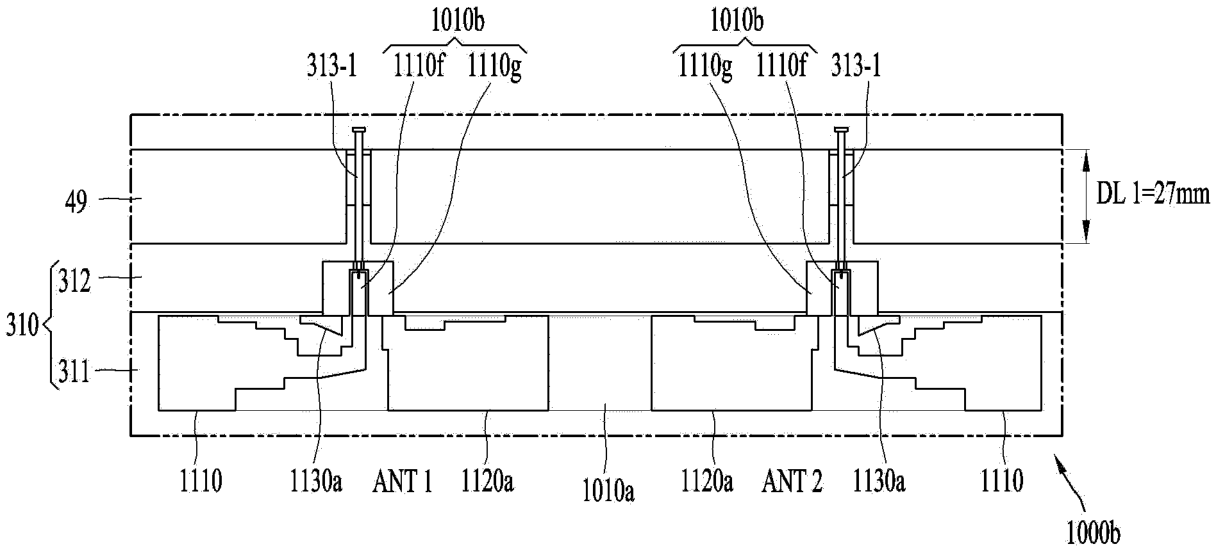
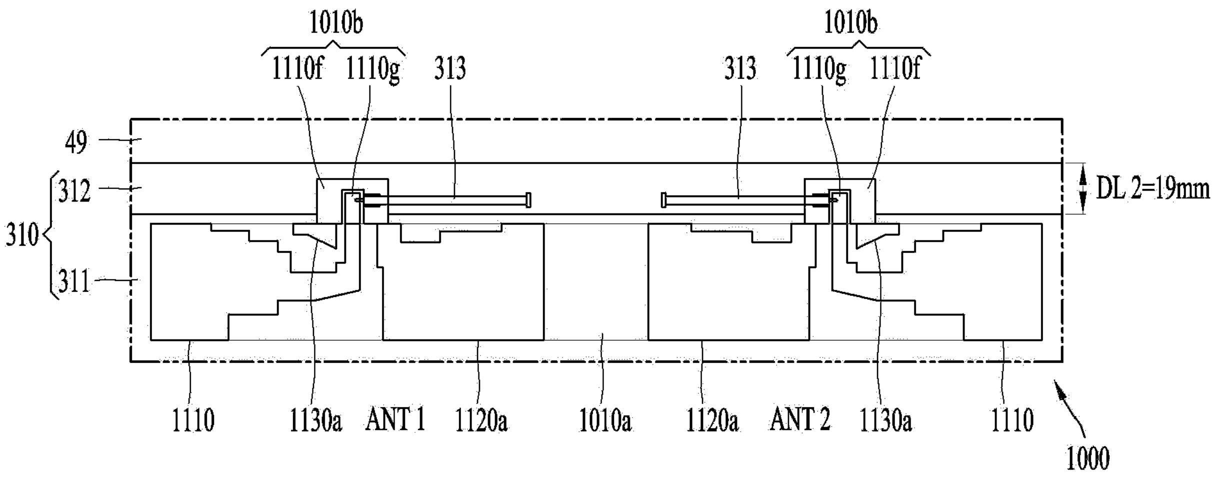

(a)
1110
1120a
1000a
(b)
1110
1120a
1000b
1010b
RL
49
(c)
1110
1120a
1130
1000a
Rr
1010b
49

FIG. 14A


1010b
313-1
1110f
1110g
1010b
1110g
1110f
313-1
49
DL 1=27mm
312
310
311
1110
1130a
ANT 1
1120a
1010a
1120a
ANT 2
1130a
1110
1000b

(a)


1010b
1110f
1110g
313
313
1010b
1110g
1110f
49
312
DL 2=19mm
310
311
1110
1130a
ANT 1
1120a
1010a
1120a
ANT 2
1130a
1110
1000

(b)

FIG. 14B

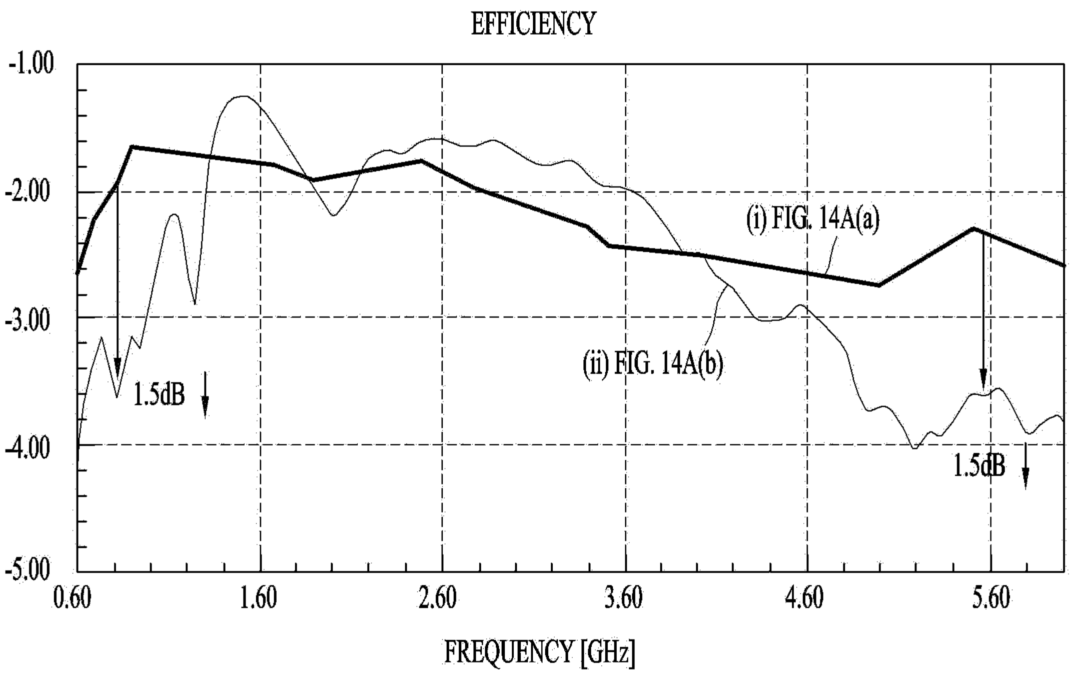

EFFICIENCY
-1.00
-2.00
-3.00
-4.00
-5.00
0.60
1.60
2.60
3.60
4.60
5.60
FREQUENCY [GHz]
(i) FIG. 14A(a)
(ii) FIG. 14A(b)
1.5dB
1.5dB

FIG. 15A

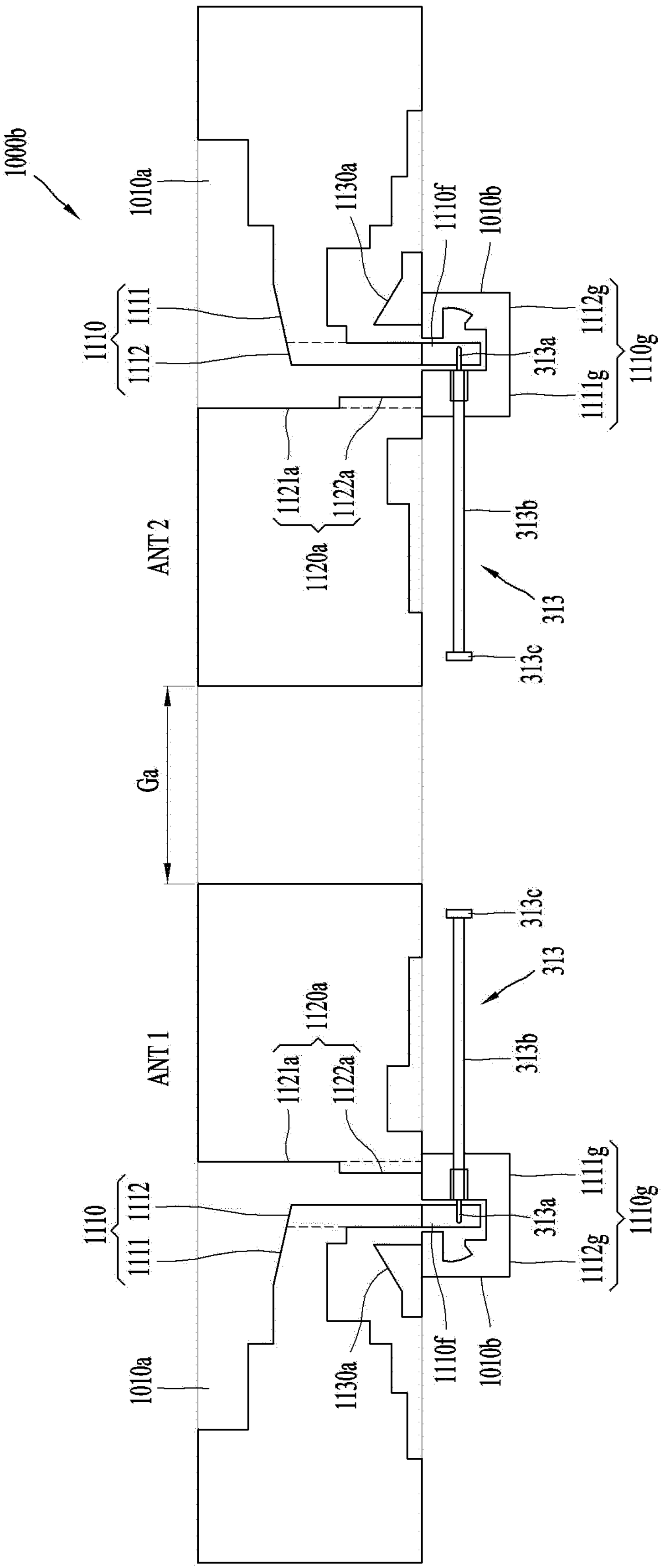

1000b
1010a
1130a
1110f
1010b
1110
1111
1112
1112g
313a
1111g
1110g
1121a
1122a
1120a
ANT 2
313b
313
313c
Ga
ANT 1
1010a
1130a
1110f
1010b
1110
1111
1112
1112g
313a
1111g
1110g
1121a
1122a
1120a
313b
313
313c

FIG. 15B

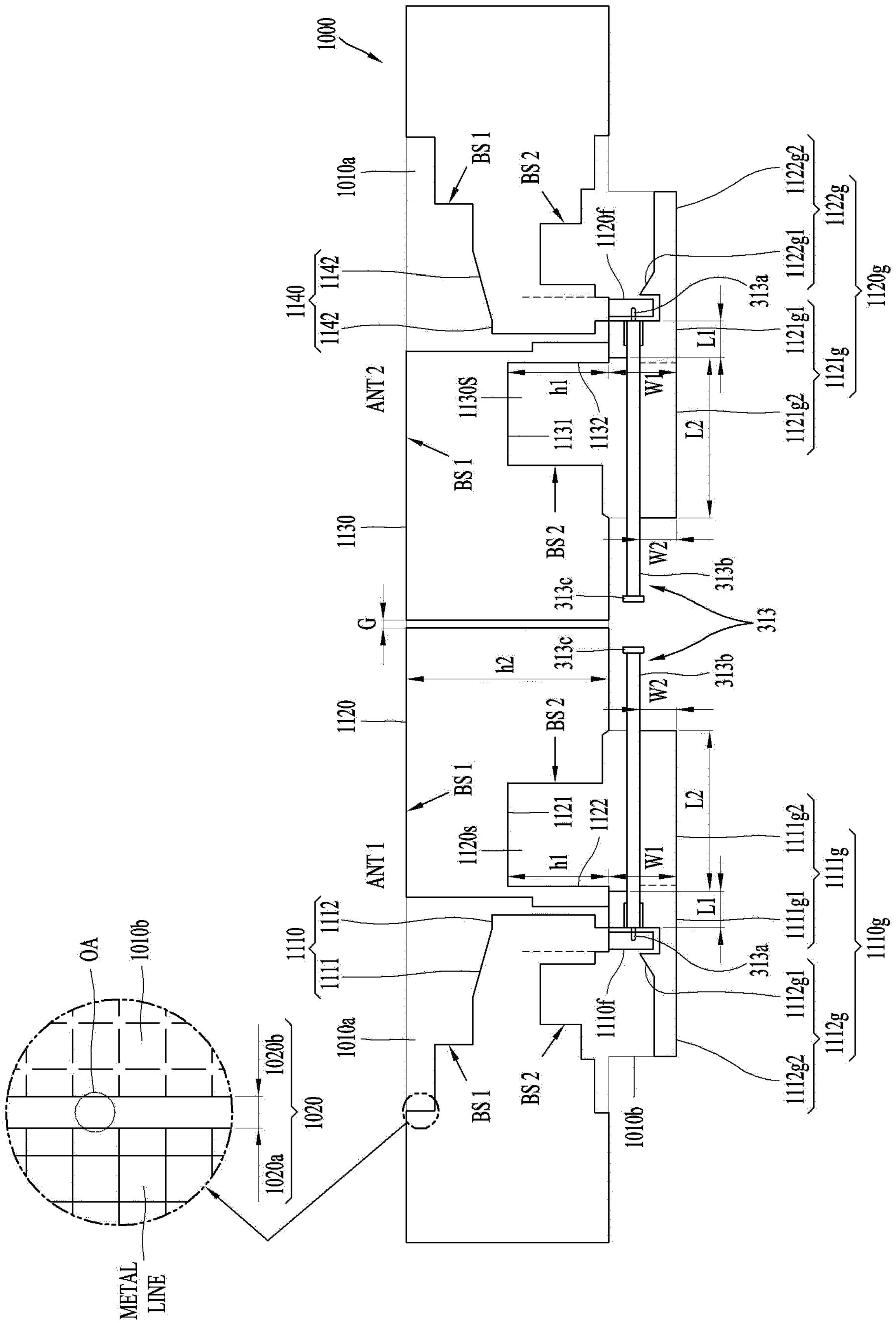
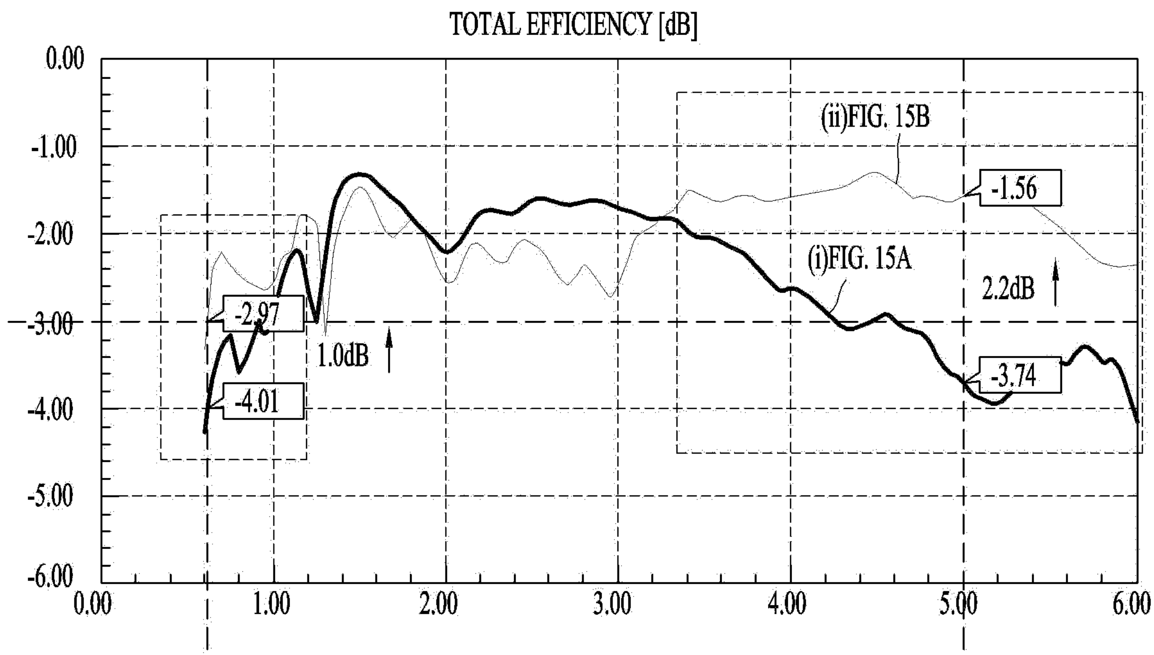

1000
1010a
BS 1
BS 2
1120f
1122g2
1122g
1122g1
1142
1140
313a
1120g
1121g1
1121g
L1
ANT 2
1130S
h1
W1
1121g2
1131
1132
L2
BS 1
1130
BS 2
W2
313c
313b
G
313
h2
313c
313b
1120
W2
BS 2
L2
BS 1
1121
1122
1111g2
ANT 1
1120s
h1
W1
1111g
1112
1110
L1
1111g1
1111
313a
1110g
1110f
1112g1
OA
1010b
1010a
1112g
1020b
BS 2
1112g2
1020
BS 1
1010b
1020a
METAL
LINE

FIG. 15C


TOTAL EFFICIENCY [dB]
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
(ii)FIG. 15B
(i)FIG. 15A
-1.56
-2.97
-4.01
-3.74
1.0dB
2.2dB

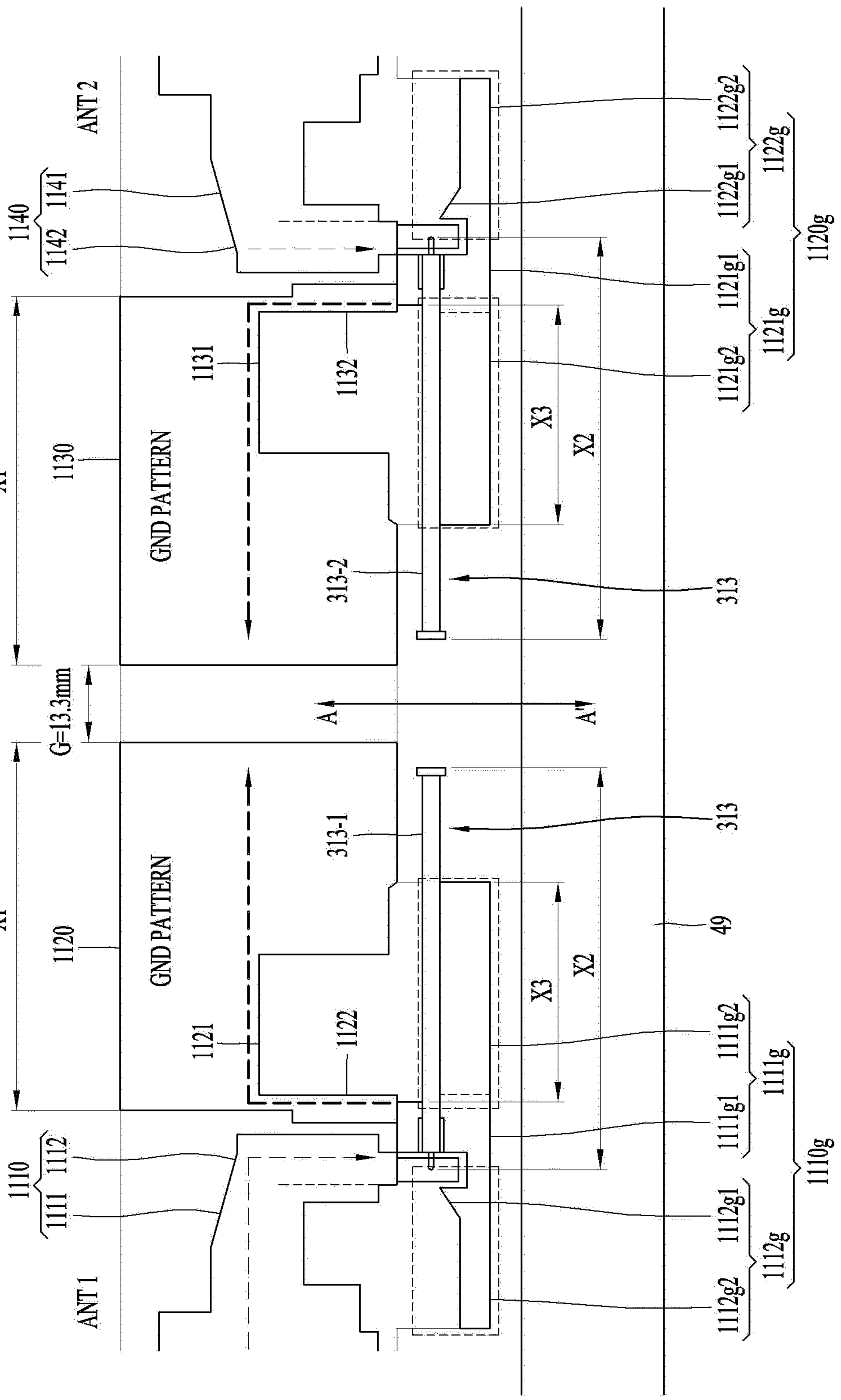

ANT 2
1140
1141
1142
1122g2
1122g1
1122g
1120g
1121g1
1121g
1121g2
X1
1130
1131
1132
GND PATTERN
X3
X2
313-2
313
G=13.3mm
A
A'
X1
1120
GND PATTERN
313-1
313
49
X3
X2
1121
1122
1111g2
1111g
1111g1
1110g
1110
1112
1111
1112g1
1112g
1112g2
ANT 1

FIG. 16A

FIG. 16B

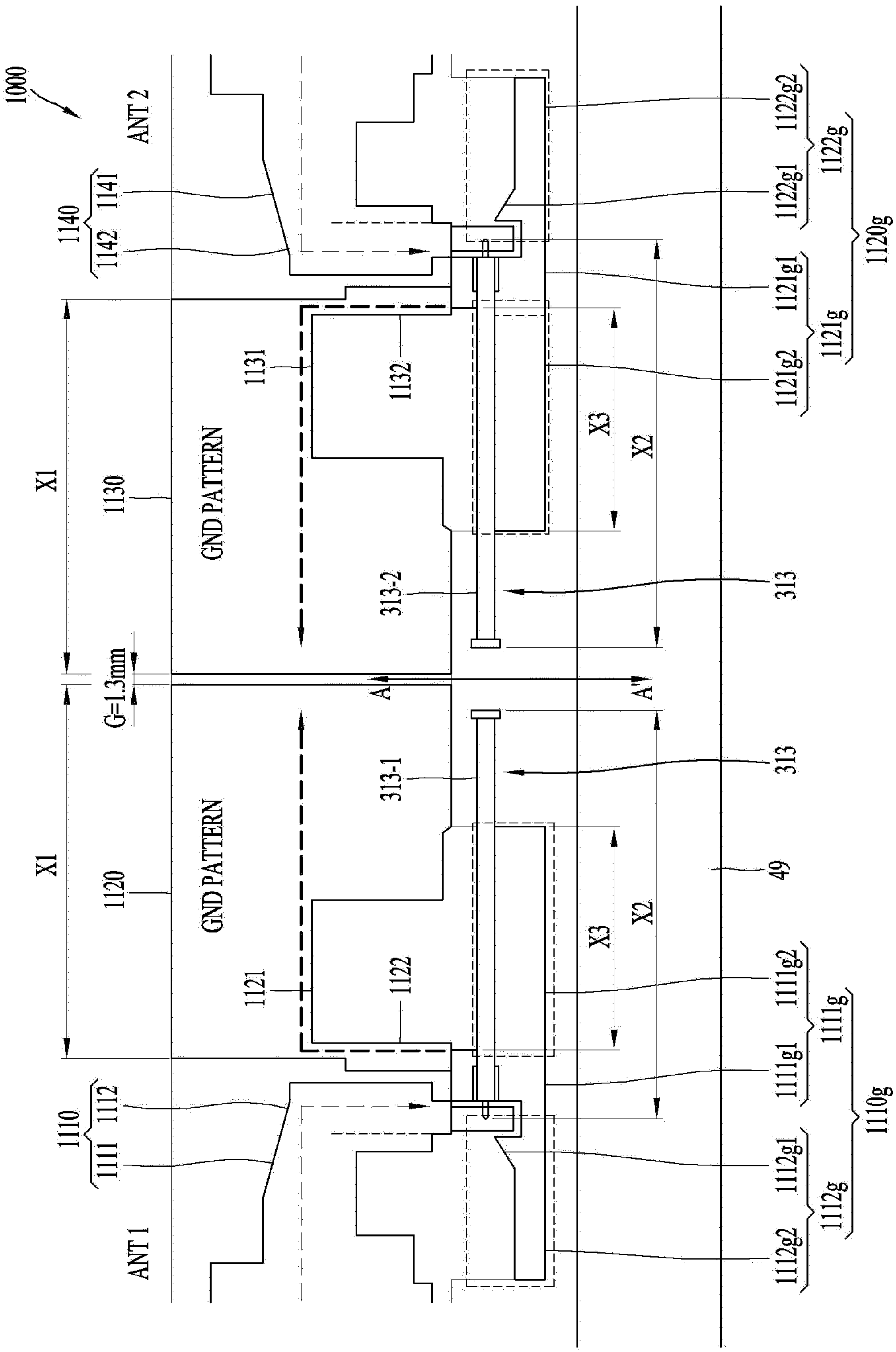
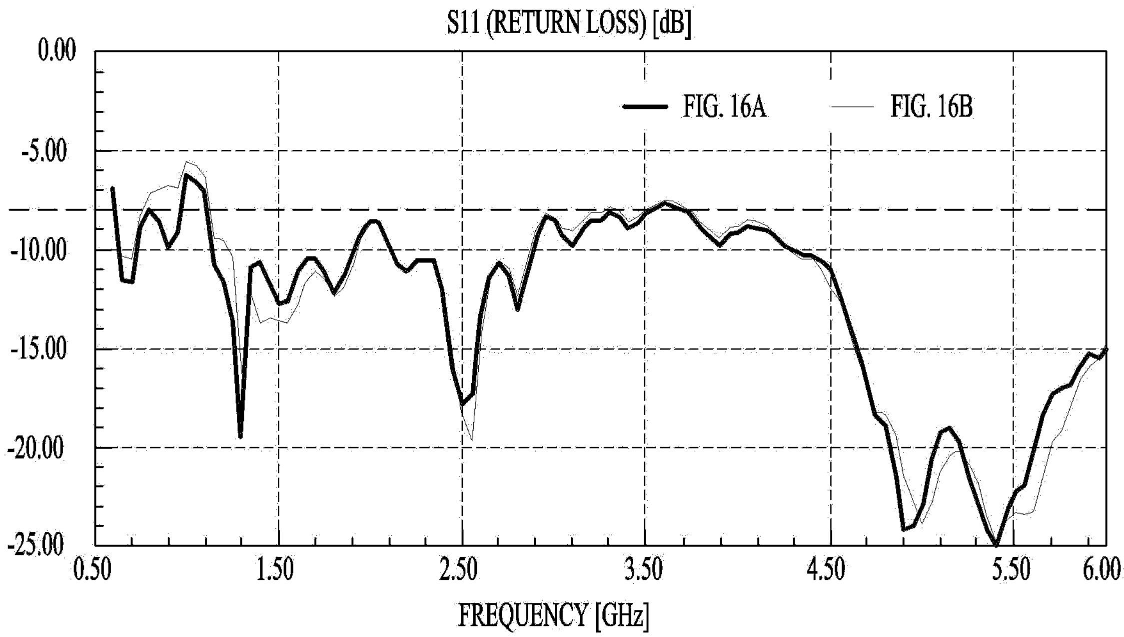
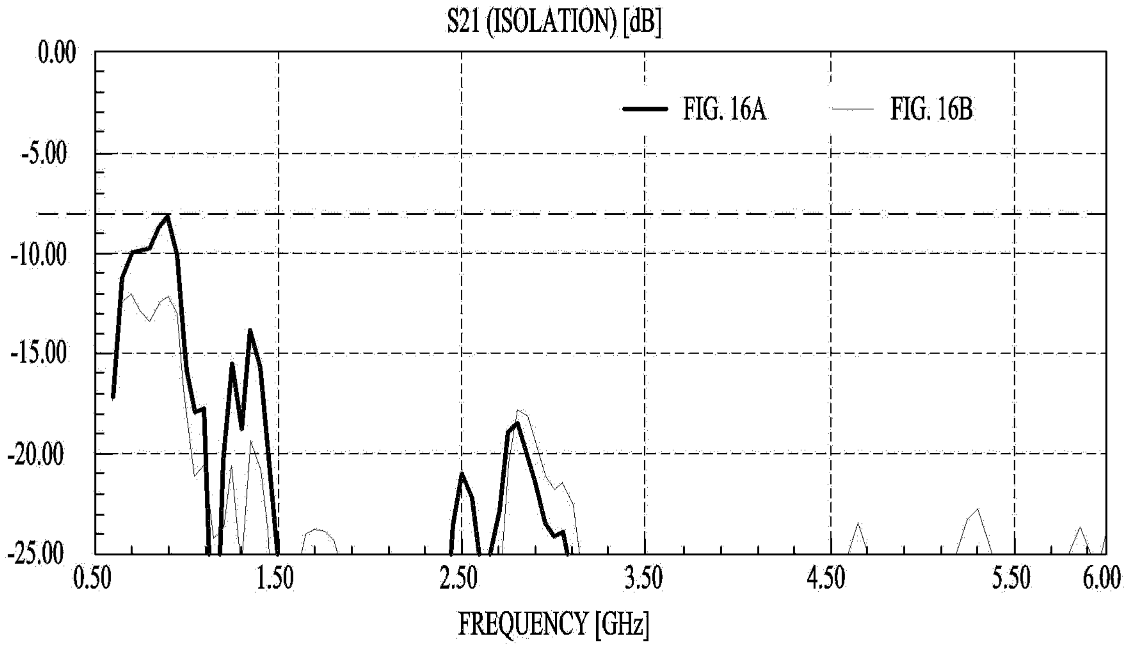

1000
ANT 2
1140
1141
1142
X1
1130
GND PATTERN
1131
1132
X3
X2
313-2
313
G=1.3mm
A
A'
313-1
313
X1
1120
GND PATTERN
1121
1122
X3
X2
49
1110
1111
1112
ANT 1
1122g2
1122g1
1122g
1120g
1121g1
1121g2
1121g
1111g2
1111g
1111g1
1110g
1112g1
1112g
1112g2

FIG. 16C

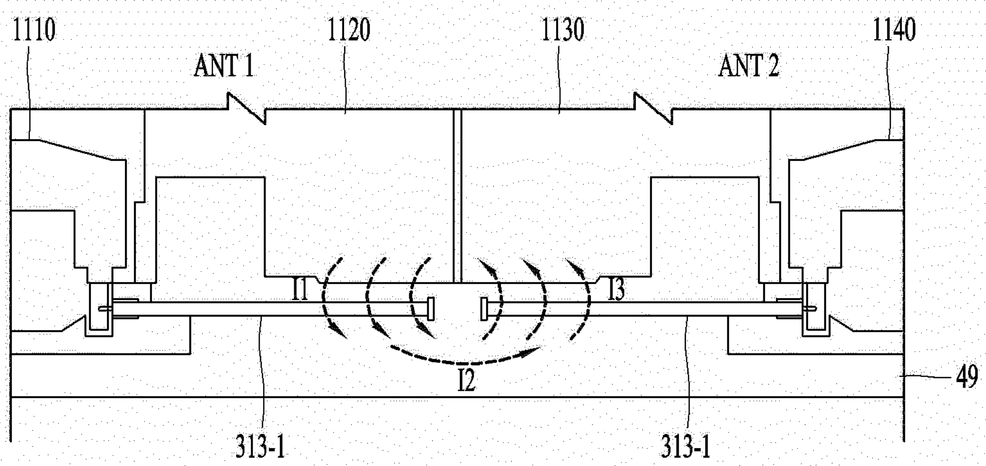

S11 (RETURN LOSS) [dB]
FIG. 16A
FIG. 16B
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
0.50
1.50
2.50
3.50
4.50
5.50
6.00
FREQUENCY [GHz]

(a)

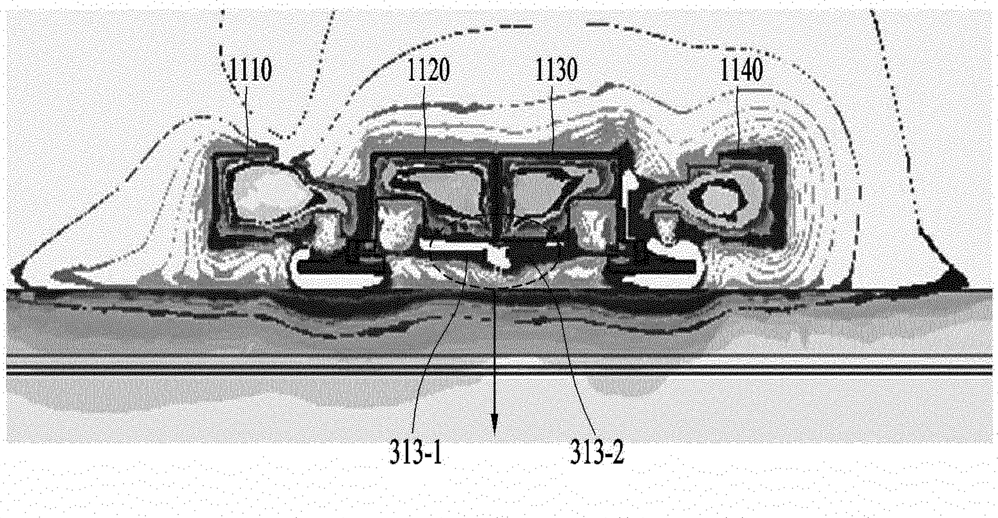

S21 (ISOLATION) [dB]
FIG. 16A
FIG. 16B
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
0.50
1.50
2.50
3.50
4.50
5.50
6.00
FREQUENCY [GHz]

(b)

FIG. 17A

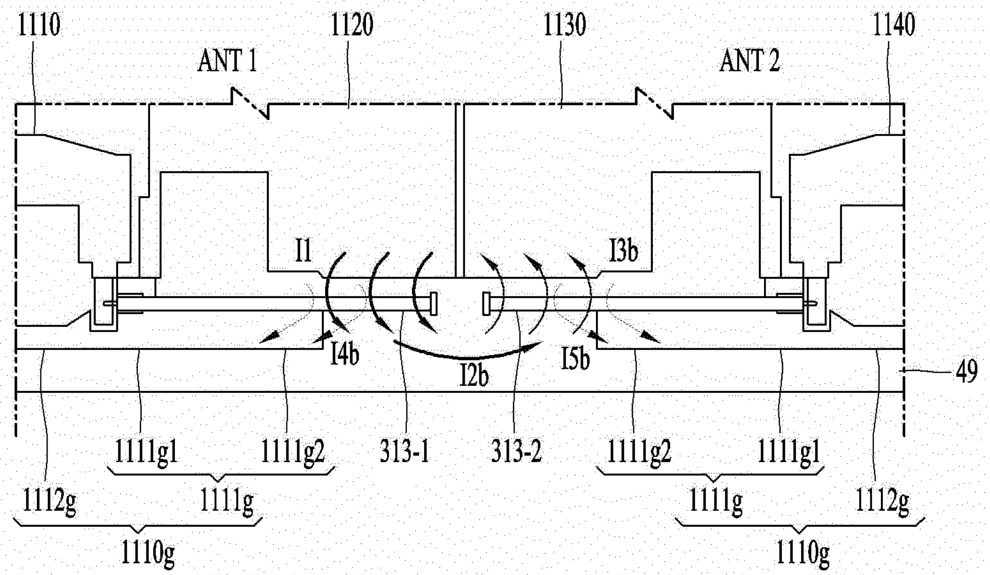

1110
1120
1130
1140
ANT 1
ANT 2
I1
I3
I2
49
313-1
313-1

(a)

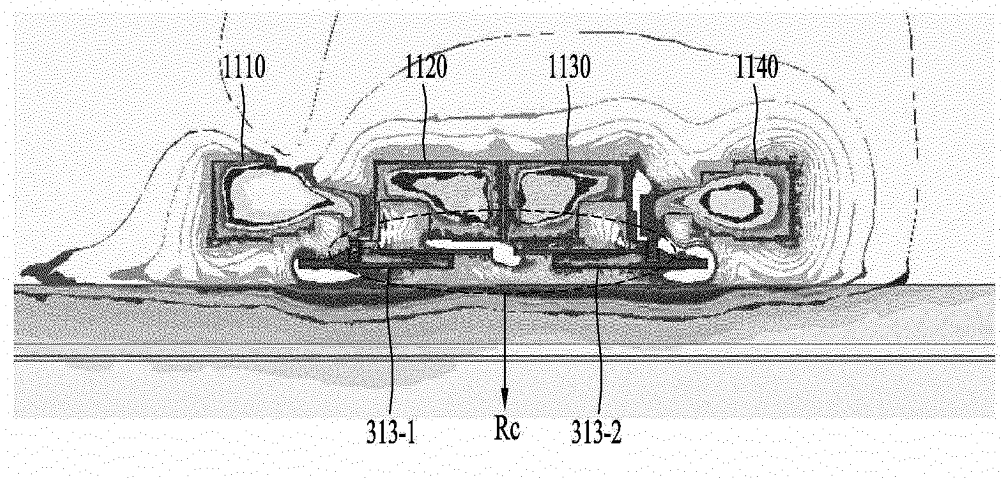

1110
1120
1130
1140
313-1
313-2

(b)

FIG. 17B

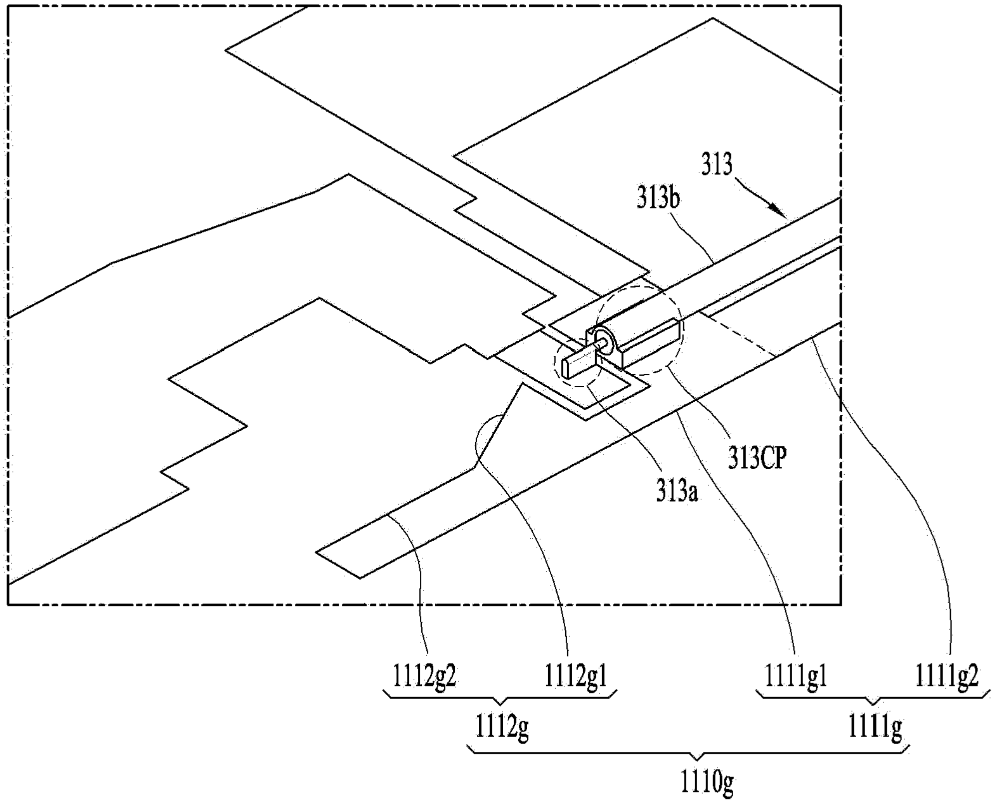

1110
1120
1130
1140
ANT 1
ANT 2
I1
I3b
I4b
I2b
I5b
49
1111g1
1111g2
313-1
313-2
1111g2
1111g1
1111g
1111g
1112g
1111g
1111g
1112g
1110g
1110g

(a)

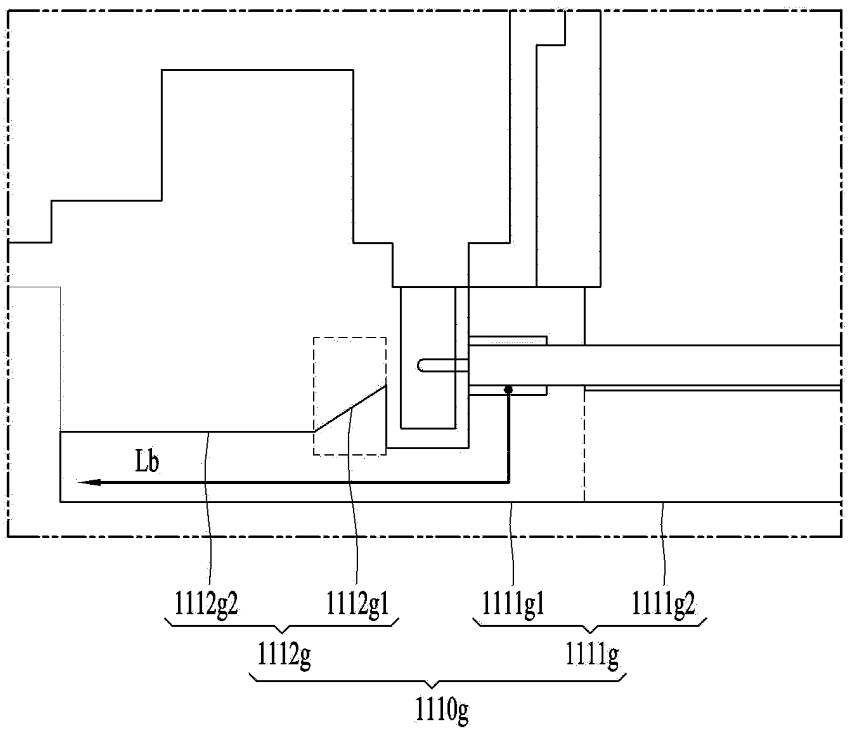

1110
1120
1130
1140
313-1
Rc
313-2

(b)

FIG. 17C

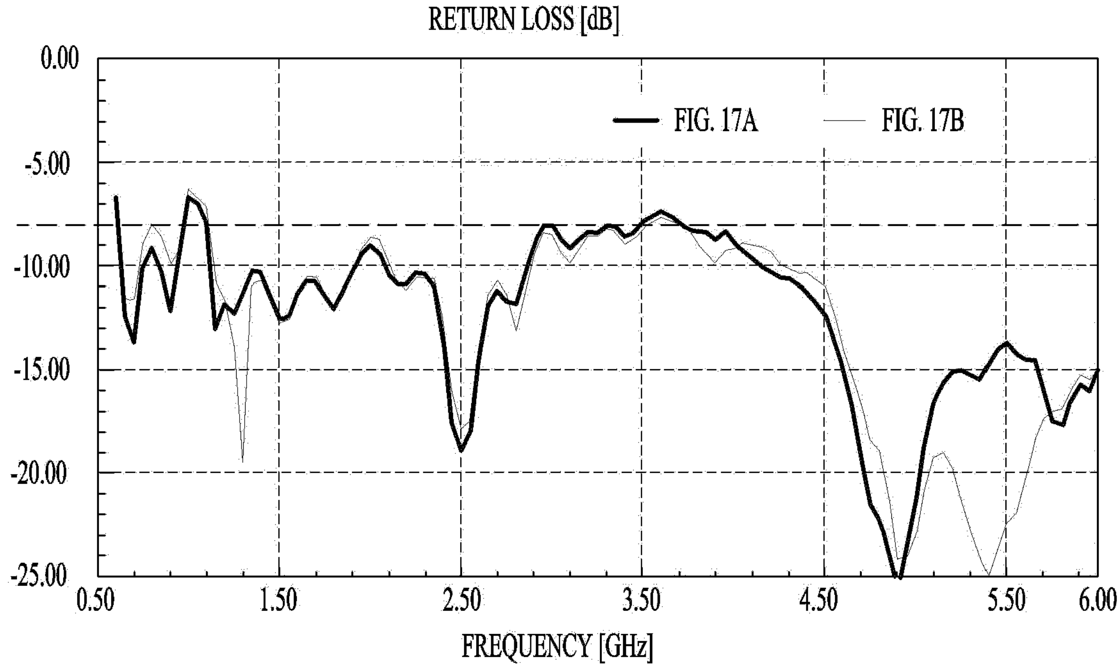

313
313b
313CP
313a
1112g2
1112g1
1111g1
1111g2
1112g
1111g
1110g

(a)

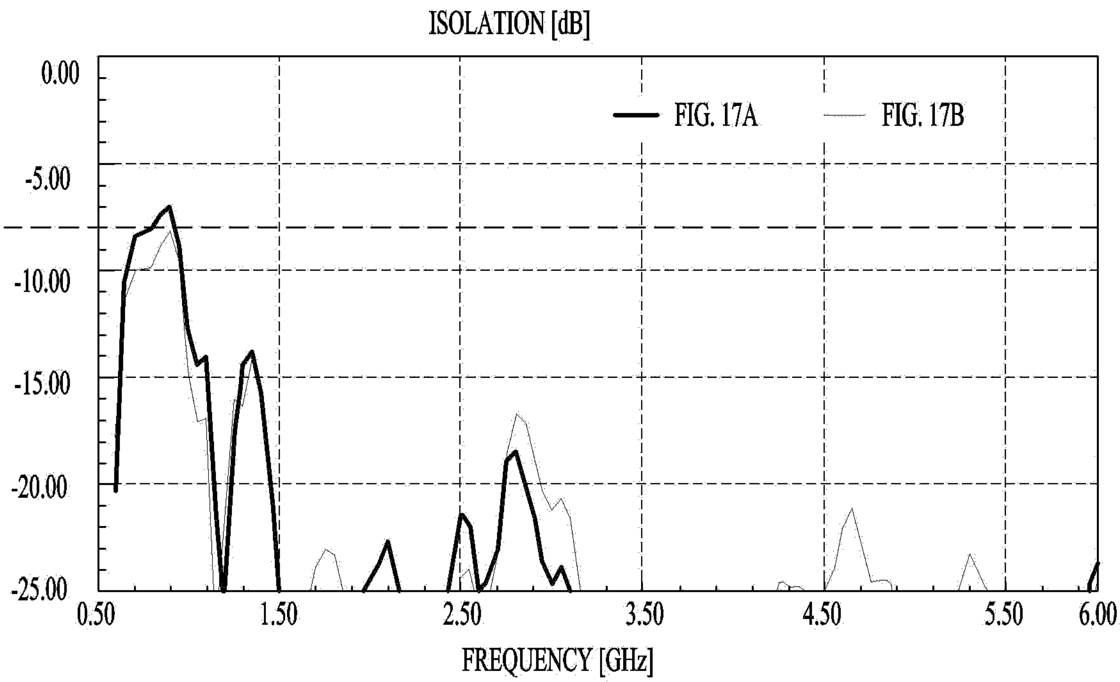

Lb
1112g2
1112g1
1111g1
1111g2
1112g
1111g
1110g

(b)

FIG. 18A


RETURN LOSS [dB]
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
FIG. 17A
FIG. 17B
0.50
1.50
2.50
3.50
4.50
5.50
6.00
FREQUENCY [GHz]

(a)


ISOLATION [dB]
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
FIG. 17A
FIG. 17B
0.50
1.50
2.50
3.50
4.50
5.50
6.00
FREQUENCY [GHz]

(b)

FIG. 18B

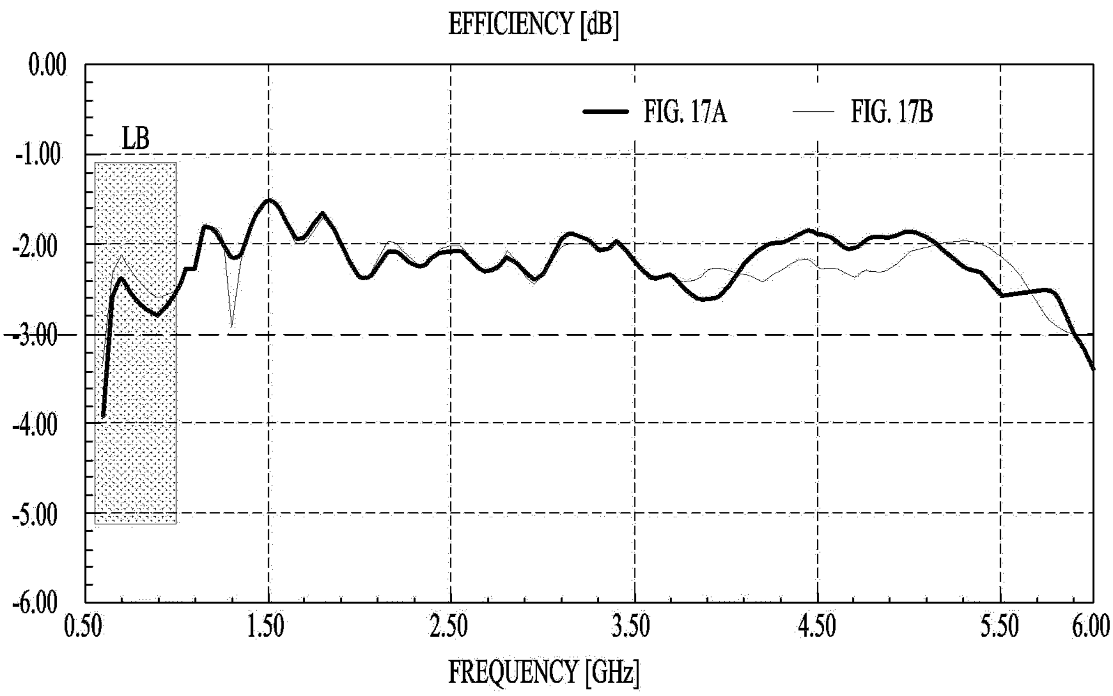
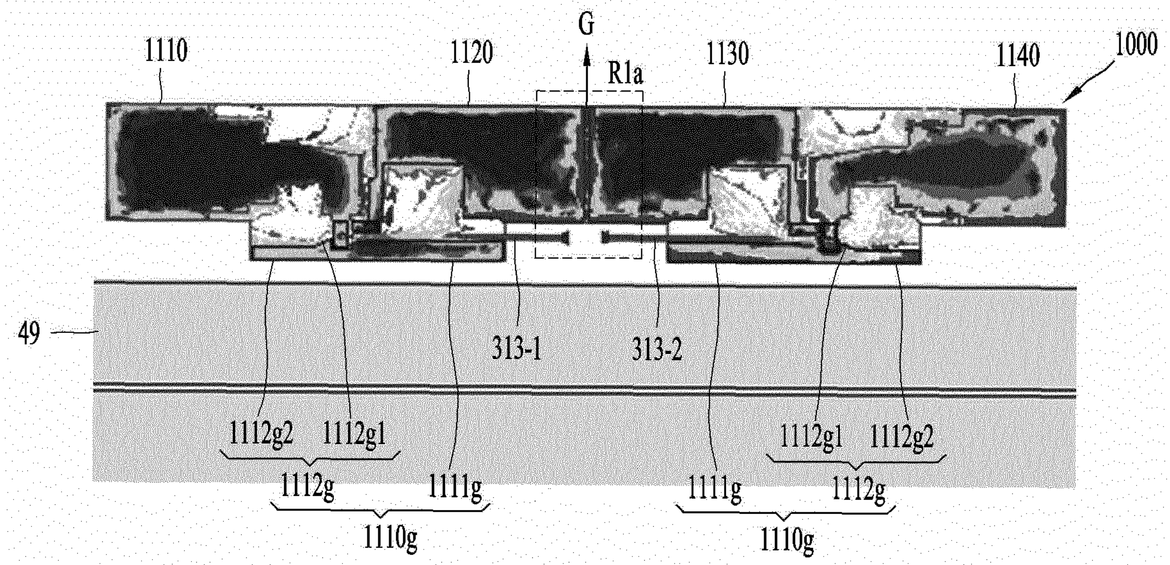
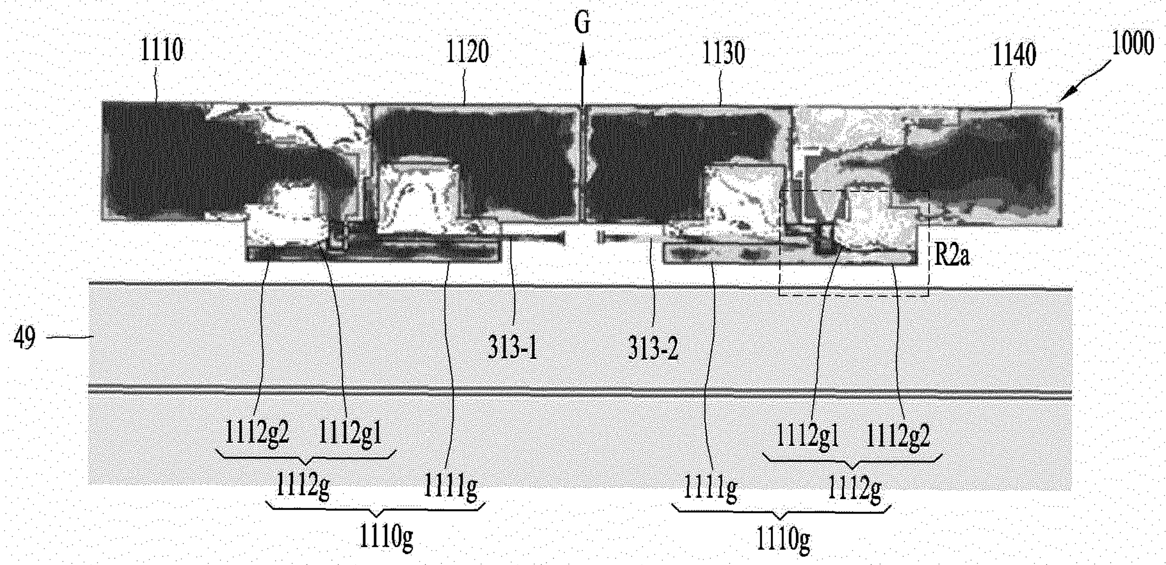

EFFICIENCY [dB]
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
LB
FIG. 17A
FIG. 17B
0.50
1.50
2.50
3.50
4.50
5.50
6.00
FREQUENCY [GHz]

FIG. 18C



(a) ELECTRIC FIELD DISTRIBUTION @ 617MHz



(b) ELECTRIC FIELD DISTRIBUTION @ 5000MHz

FIG. 19A

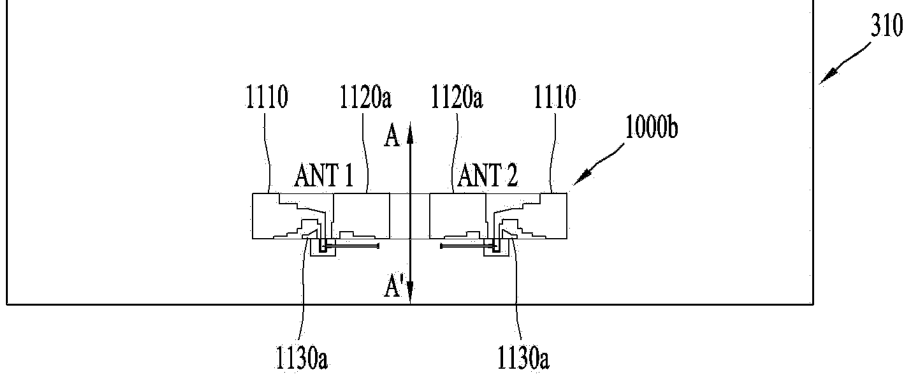


FIG. 19B

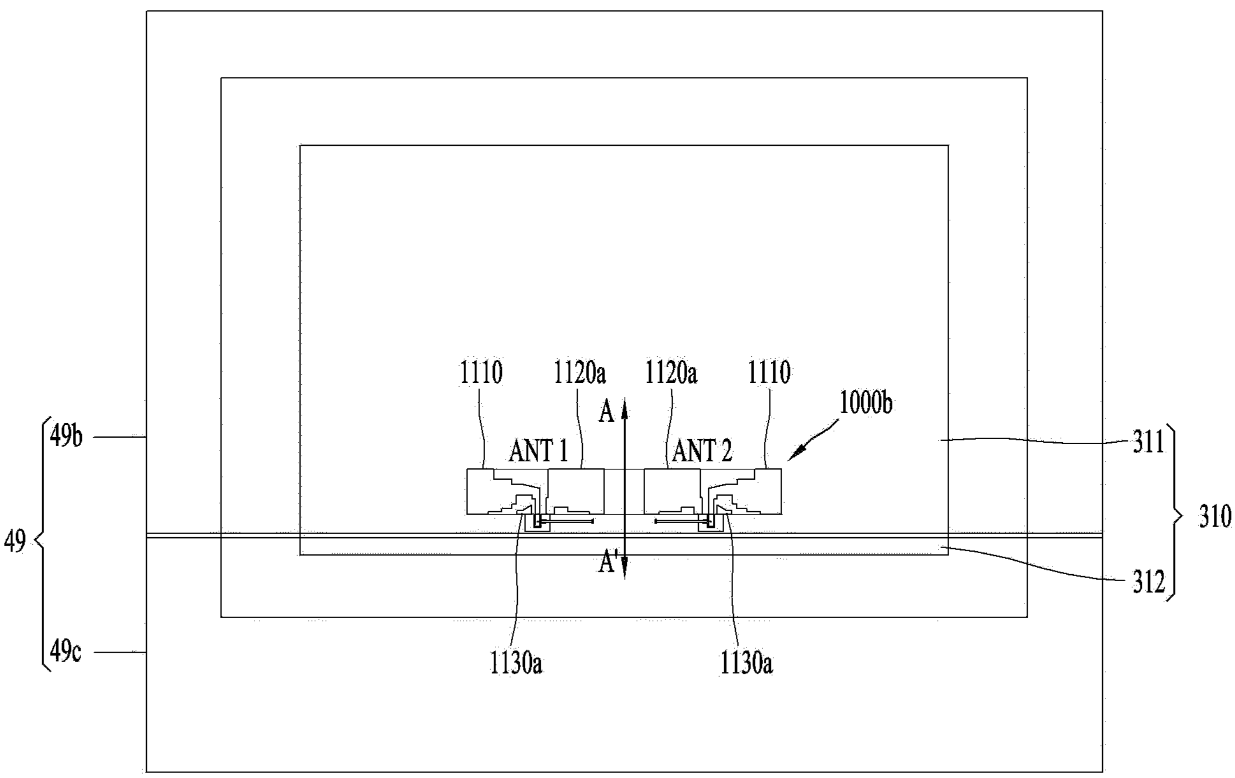


FIG. 19C

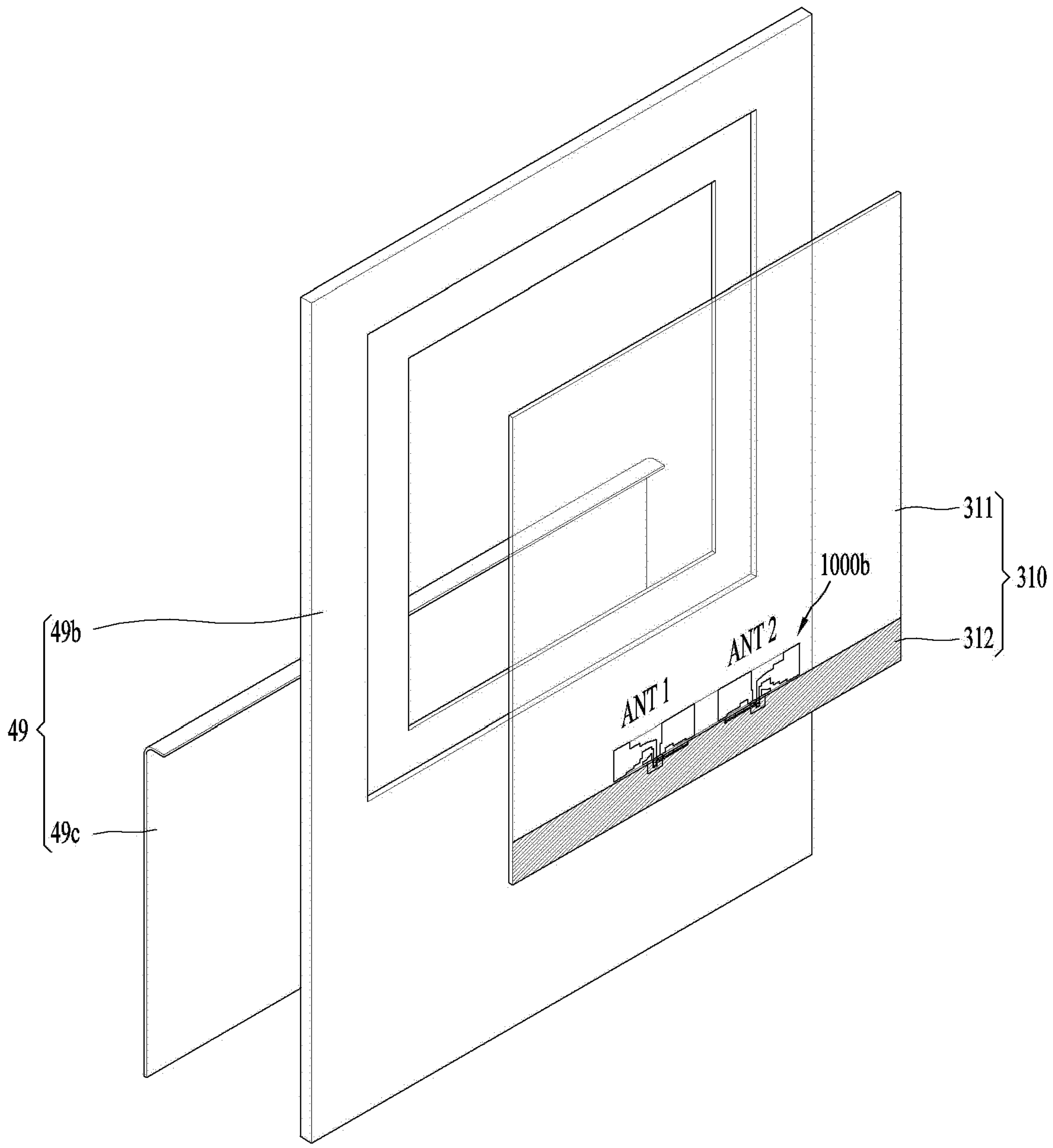
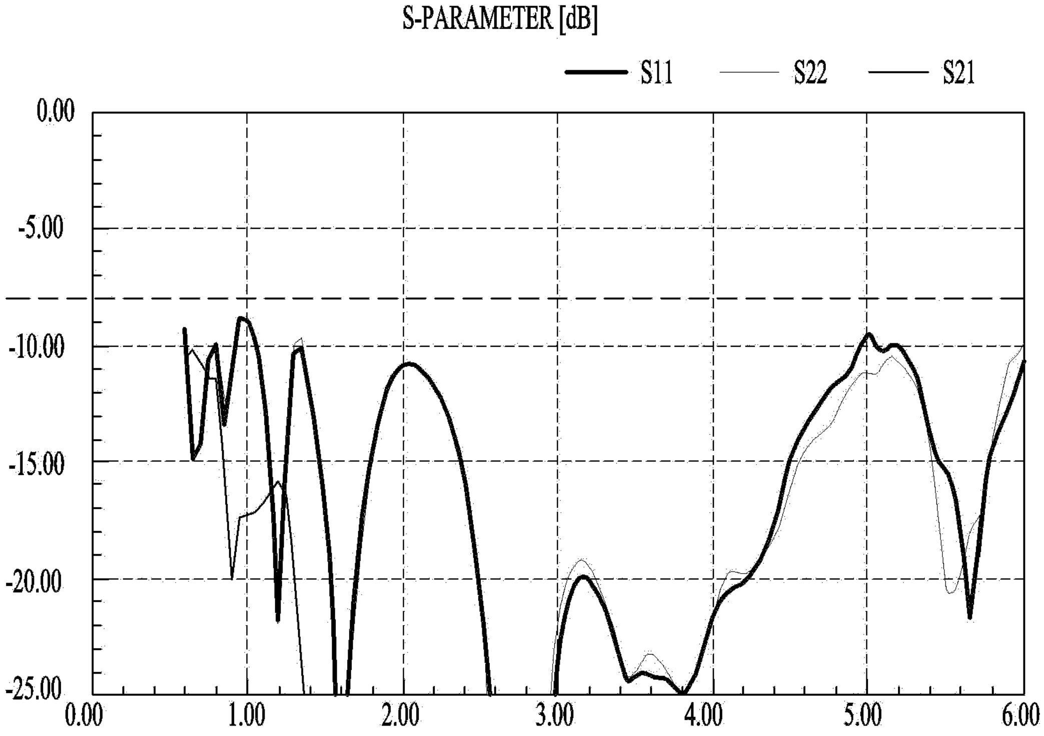
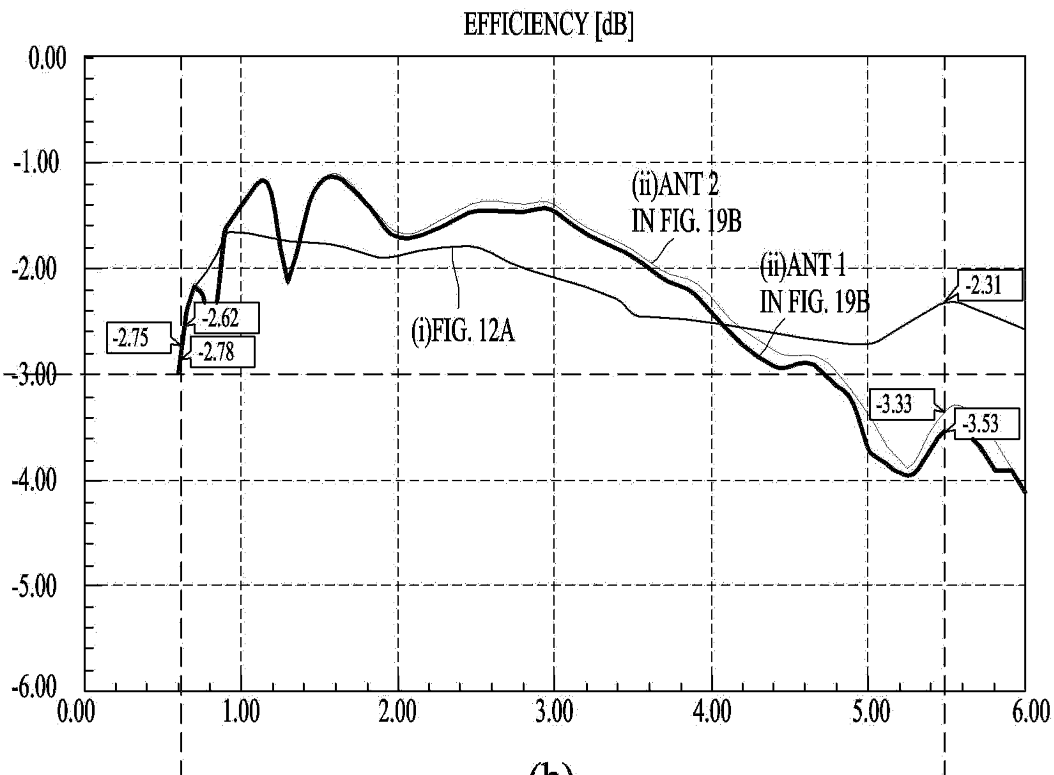


FIG. 20A

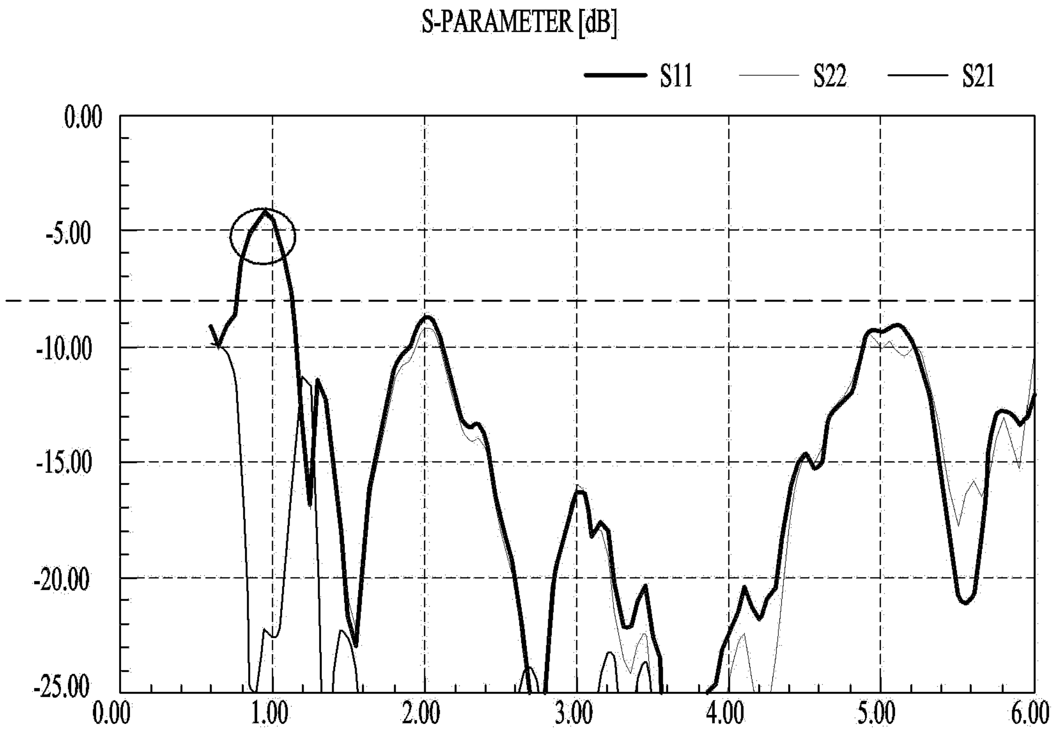

S-PARAMETER [dB]
S11
S22
S21
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00

(a)

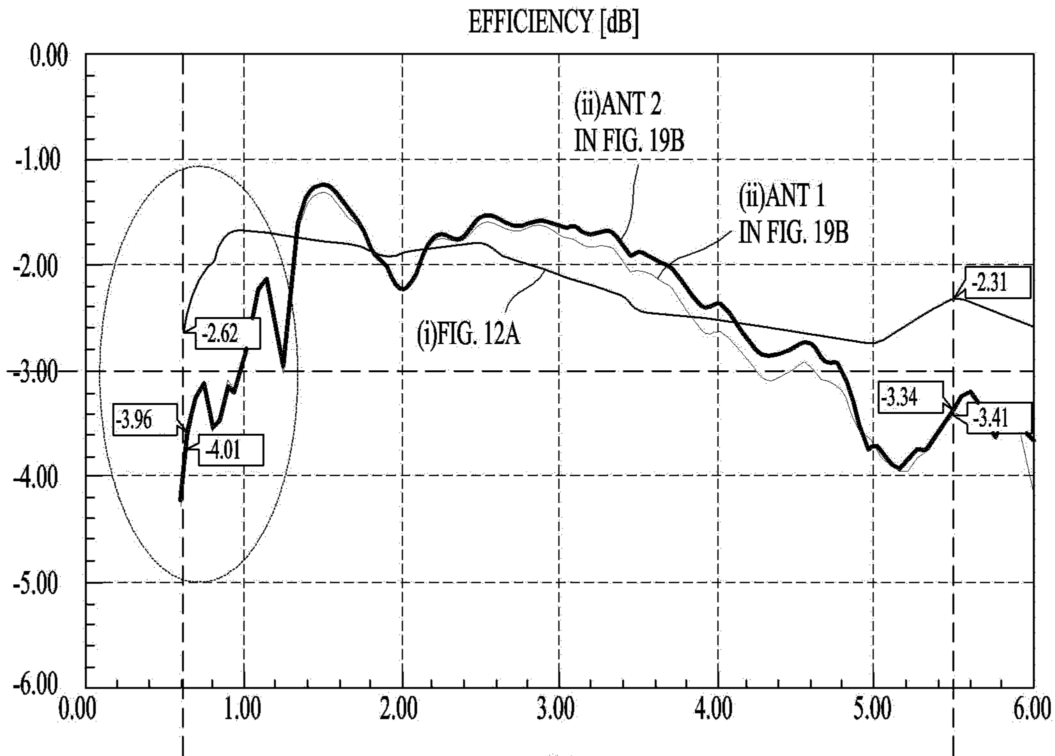

EFFICIENCY [dB]
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
(ii)ANT 2
IN FIG. 19B
(ii)ANT 1
IN FIG. 19B
(i)FIG. 12A
-2.75
-2.62
-2.78
-2.31
-3.33
-3.53

(b)

FIG. 20B

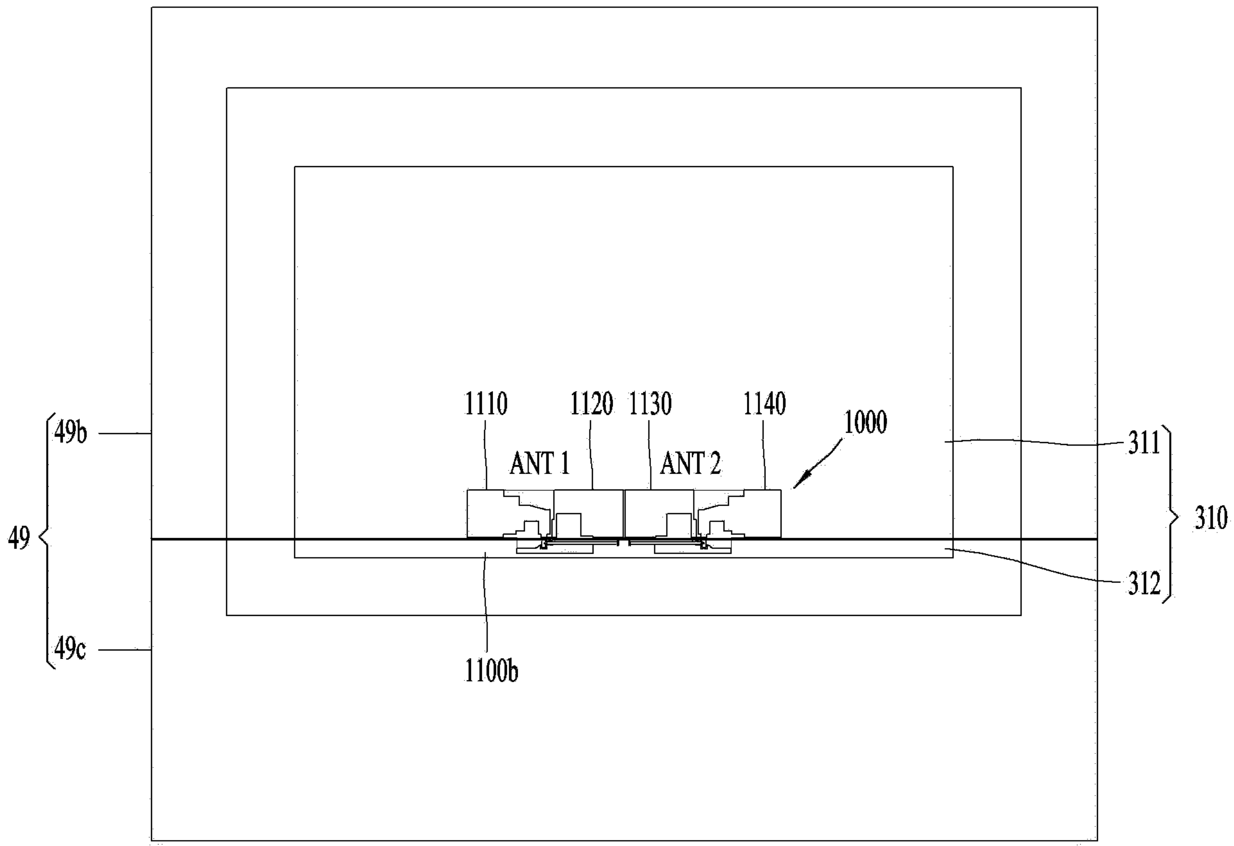

S-PARAMETER [dB]
S11
S22
S21
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00

(a)

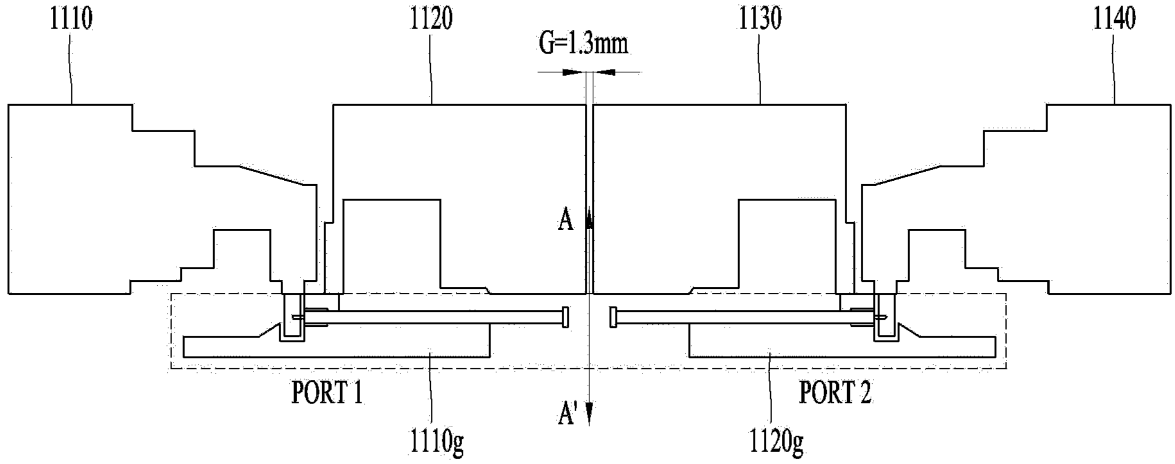

EFFICIENCY [dB]
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
(ii)ANT 2
IN FIG. 19B
(ii)ANT 1
IN FIG. 19B
(i)FIG. 12A
-2.62
-3.96
-4.01
-2.31
-3.34
-3.41

(b)

FIG. 21A

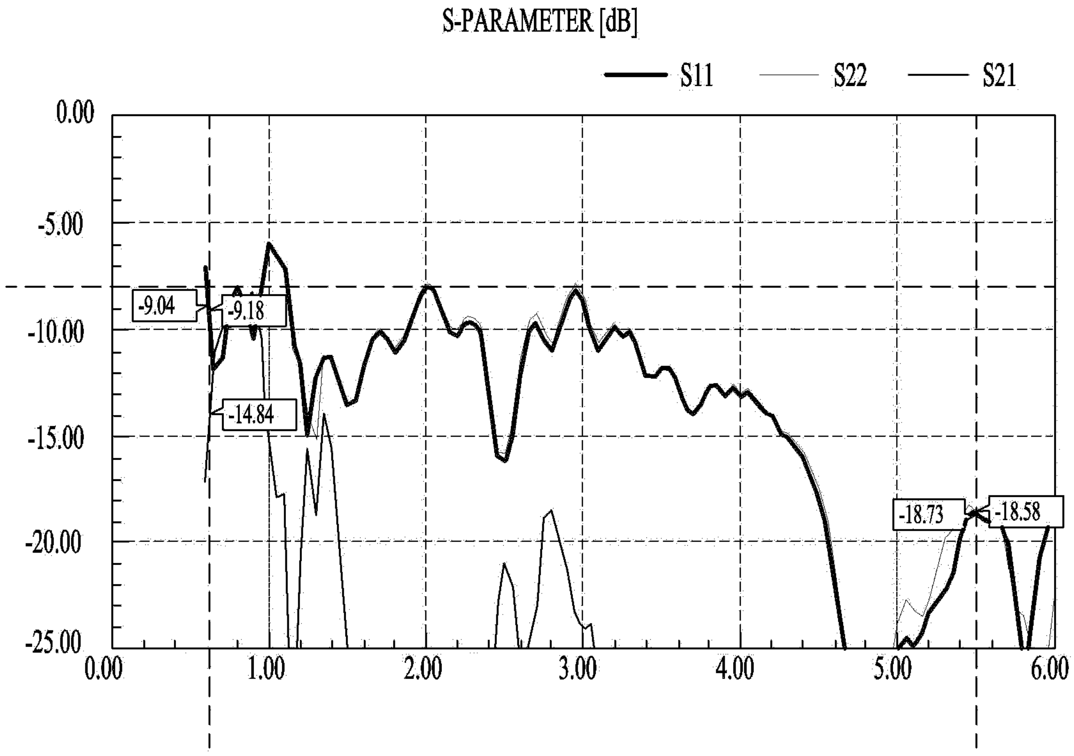

1110
1120
1130
1140
ANT 1
ANT 2
1000
311
310
312
49b
49
49c
1100b

(a)

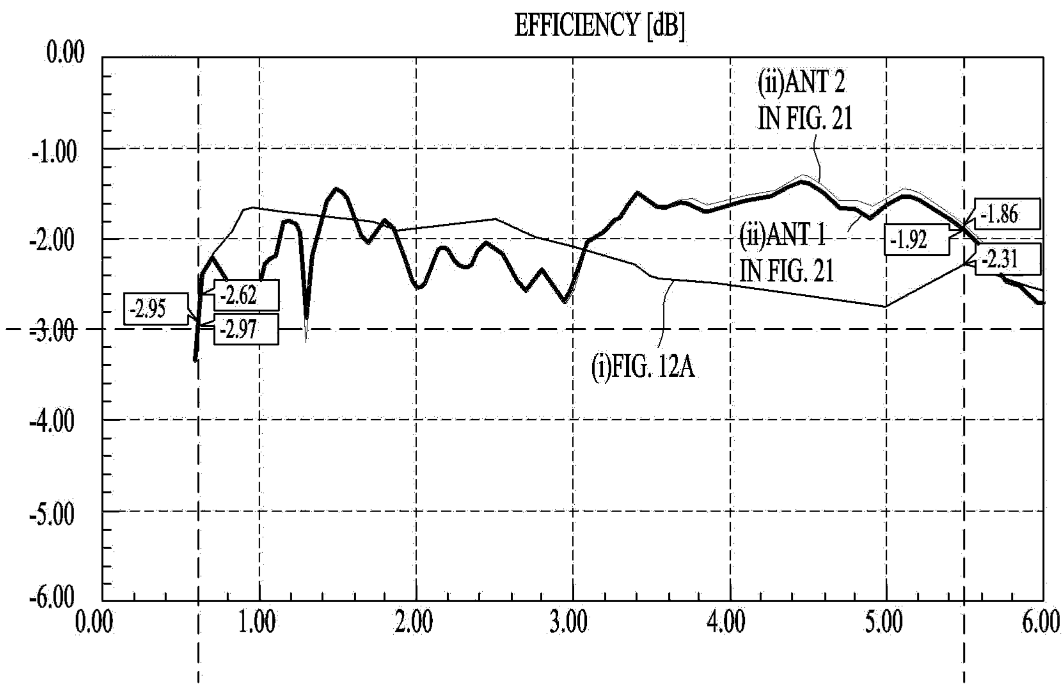

1110
1120
G=1.3mm
1130
1140
A
A'
PORT 1
PORT 2
1110g
1120g

(b)

FIG. 21B


S-PARAMETER [dB]
S11
S22
S21
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
-9.04
-9.18
-14.84
-18.73
-18.58

(a)


EFFICIENCY [dB]
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
(ii)ANT 2
IN FIG. 21
(ii)ANT 1
IN FIG. 21
(i)FIG. 12A
-2.95
-2.62
-2.97
-1.86
-1.92
-2.31

(b)

FIG. 22A

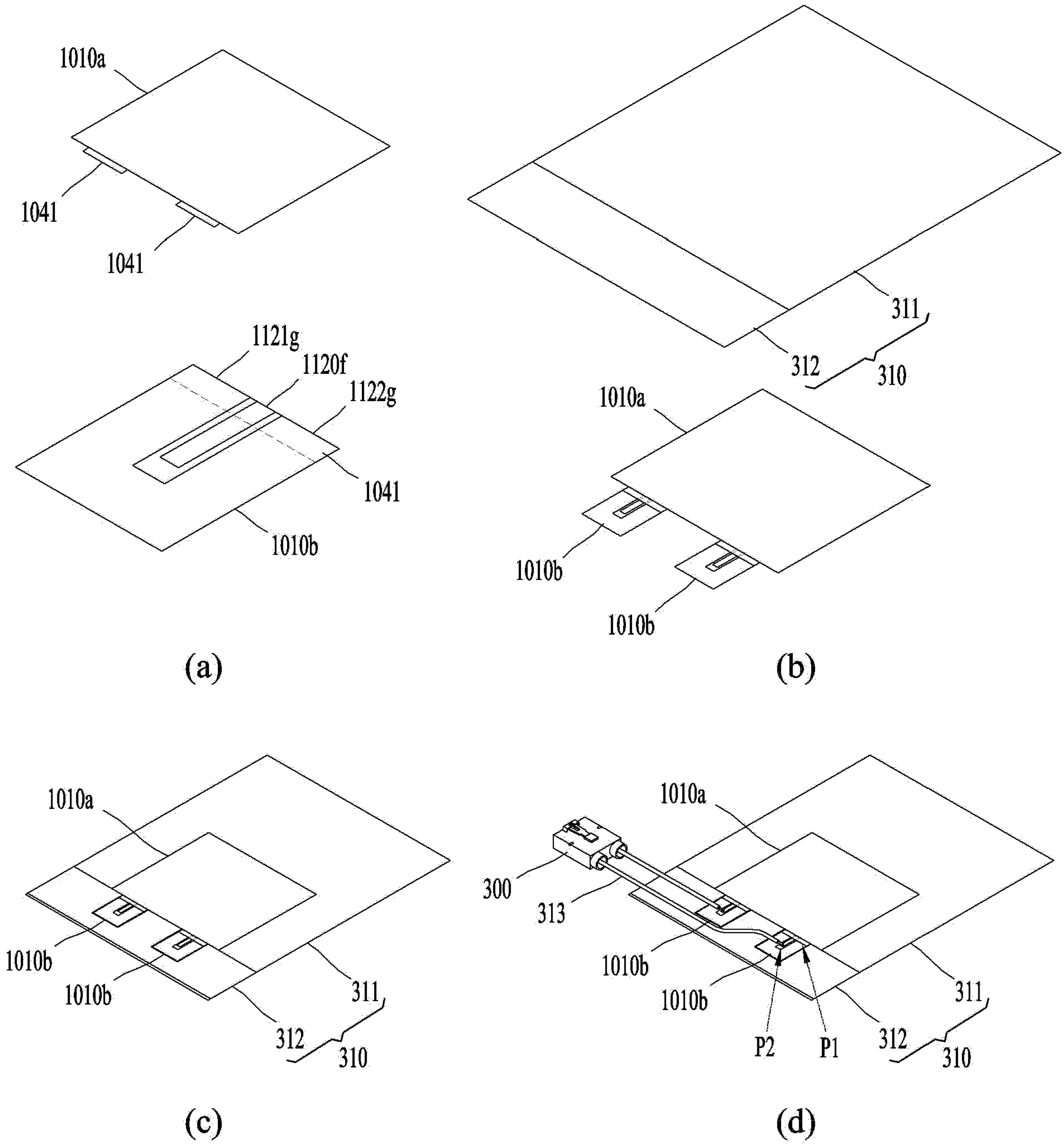
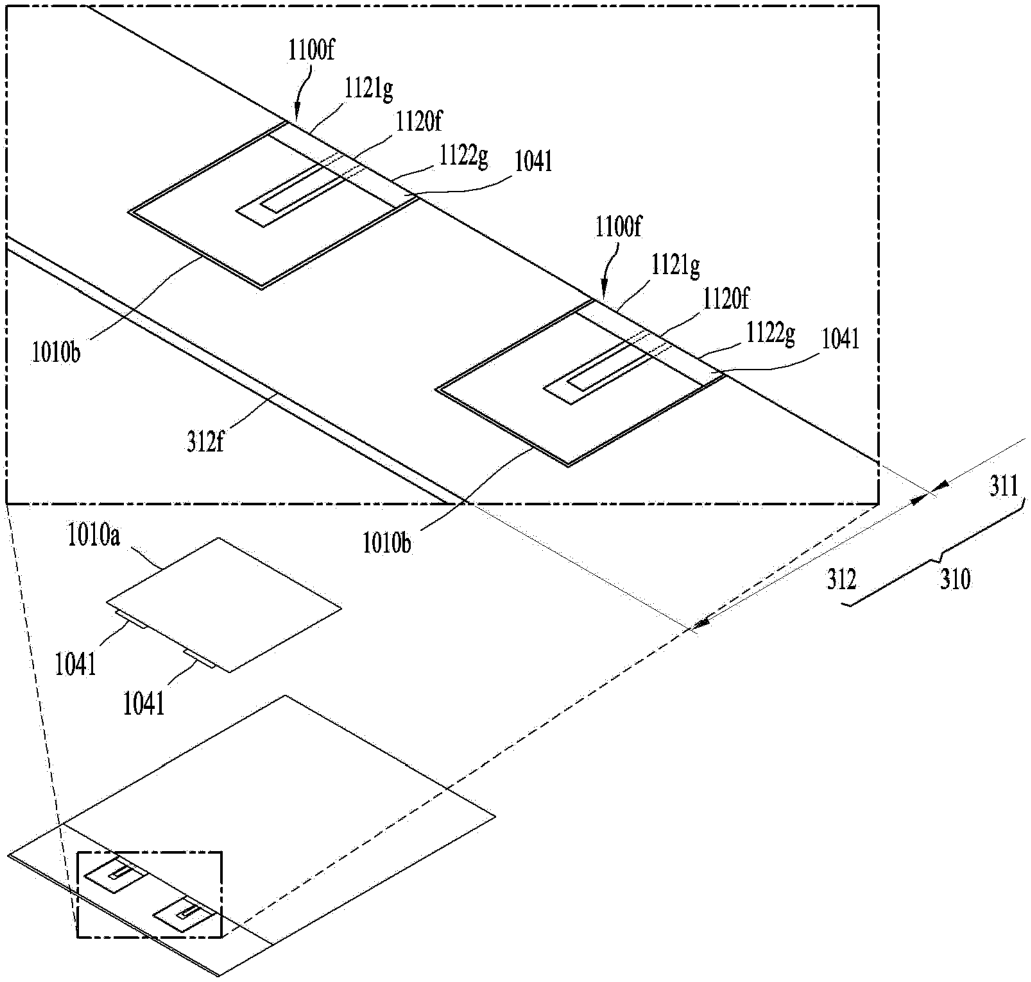
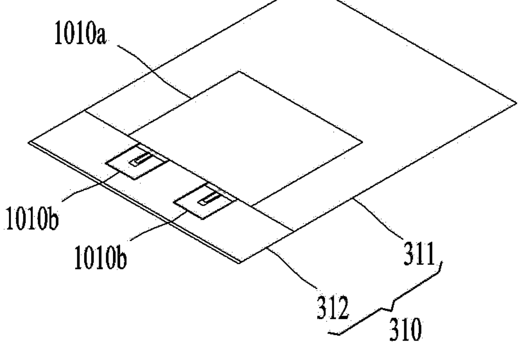

1010a
1041
1041
1121g
1120f
1122g
1041
1010b
(a)
311
312
310
1010a
1010b
1010b
(b)
1010a
1010b
1010b
311
312
310
(c)
1010a
300
313
1010b
1010b
P2
P1
312
311
310
(d)

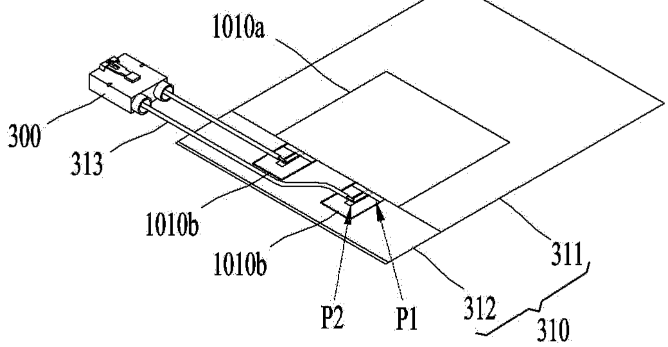
FIG. 22B


1100f
1121g
1120f
1122g
1041
1100f
1121g
1120f
1122g
1041
1010b
312f
1010b
1010a
1041
1041
311
312
310

(a)

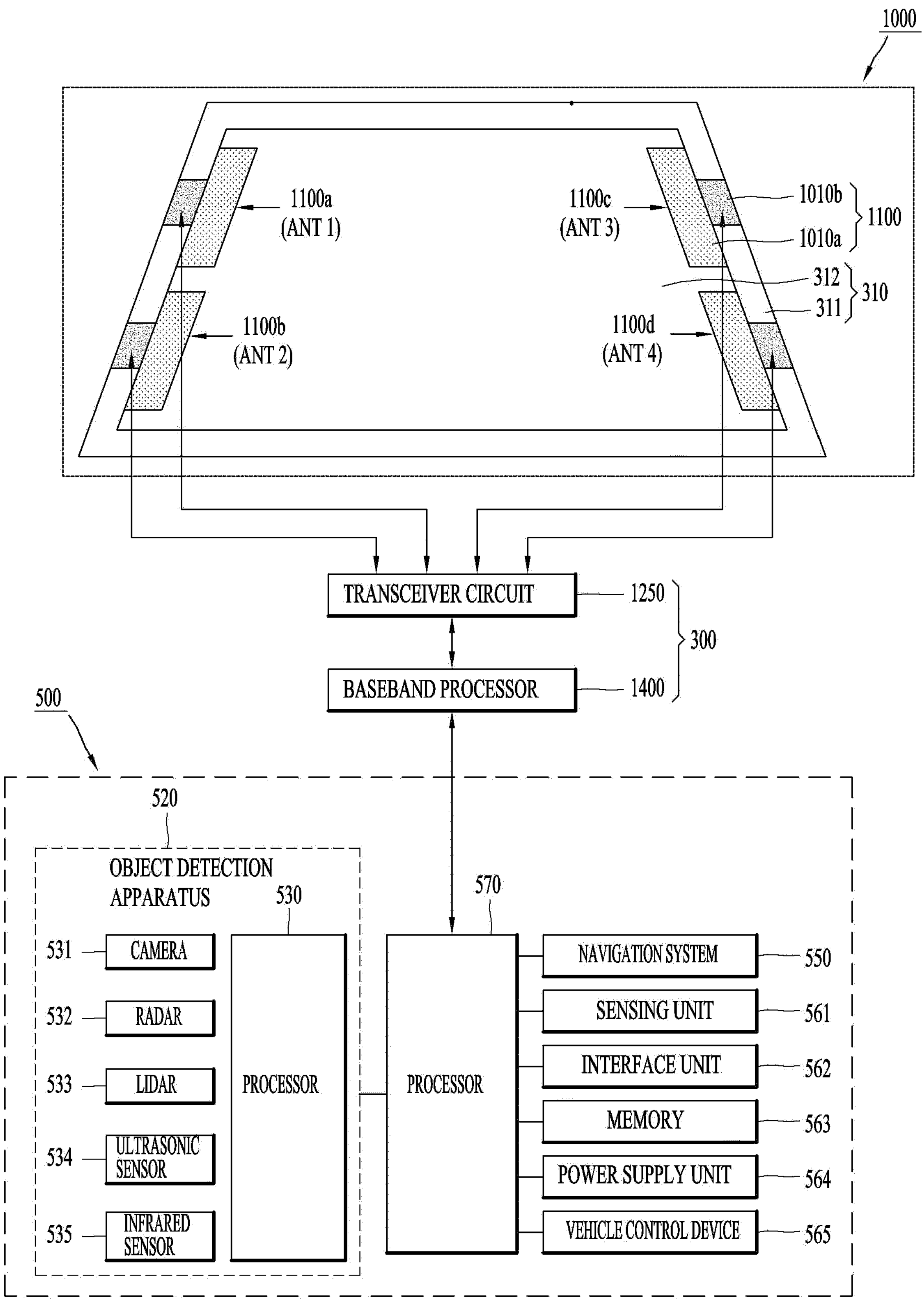

1010a
1010b
1010b
311
312
310

(b)


1010a
300
313
1010b
1010b
P2
P1
311
312
310

(c)

FIG. 23


1000
1100a
(ANT 1)
1100c
(ANT 3)
1010b
1100
1010a
312
310
311
1100b
(ANT 2)
1100d
(ANT 4)
TRANSCEIVER CIRCUIT
1250
300
BASEBAND PROCESSOR
1400
500
520
OBJECT DETECTION
APPARATUS
530
570
531
CAMERA
532
RADAR
533
LIDAR
534
ULTRASONIC
SENSOR
535
INFRARED
SENSOR
PROCESSOR
PROCESSOR
NAVIGATION SYSTEM
550
SENSING UNIT
561
INTERFACE UNIT
562
MEMORY
563
POWER SUPPLY UNIT
564
VEHICLE CONTROL DEVICE
565

INTERNATIONAL SEARCH REPORT

International application No. **PCT/KR2022/017985**

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/32(2006.01)i; **H01Q 1/38**(2006.01)i; **H01Q 1/46**(2006.01)i; **H01Q 9/40**(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 1/32(2006.01); H01Q 1/36(2006.01); H01Q 1/38(2006.01); H01Q 1/48(2006.01); H01Q 1/50(2006.01); H01Q 21/00(2006.01); H01Q 5/01(2006.01); H01Q 9/16(2006.01)

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

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

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

eKOMPASS (KIPO internal) & keywords: 차량(vehicle), 안테나(antenna), 케이블(cable), 도전 패턴(conductive pattern), 기판 (PCB)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	KR 10-2022-0131335 A (LG ELECTRONICS INC.) 27 September 2022 (2022-09-27) See paragraphs [0189]-[0209], claim 11 and figures 6-15.	1-5,9-10,14-19 6-8,11-13,20
Y	US 2013-0033411 A1 (TSAI, Tiao-Hsing et al.) 07 February 2013 (2013-02-07) See paragraphs [0006]-[0007] and figure 1.	1-5,9-10,14-19
Y	US 2008-0246680 A1 (RAWNICK, James J. et al.) 09 October 2008 (2008-10-09) See paragraph [0033], claim 1 and figures 2-4.	1-5,9-10,14-19
Y	US 2008-0180332 A1 (NORO, Junichi et al.) 31 July 2008 (2008-07-31) See paragraphs [0030] and [0041]-[0043] and figures 1-5.	16-19
A	CN 102468531 A (QUANTA COMPUTER INC.) 23 May 2012 (2012-05-23) See claims 1 and 5-6 and figures 1-4.	1-20

☐ 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
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"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
09 August 2023	**09 August 2023**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208**	
Facsimile No. **+82-42-481-8578**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2022/017985

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2022-0131335 A	27 September 2022	WO 2021-256589 A1	23 December 2021
US 2013-0033411 A1	07 February 2013	CN 102916261 A	06 February 2013
		CN 102916261 B	04 February 2015
		TW 201308754 A	16 February 2013
		TW I459638 B	01 November 2014
		US 8659488 B2	25 February 2014
US 2008-0246680 A1	09 October 2008	CA 2628069 A1	05 October 2008
		CA 2628069 C	13 March 2012
		EP 1978597 A1	08 October 2008
		EP 1978597 B1	07 July 2010
		JP 2008-259213 A	23 October 2008
		JP 4685894 B2	18 May 2011
		US 7463210 B2	09 December 2008
US 2008-0180332 A1	31 July 2008	JP 2008-182523 A	07 August 2008
		JP 4952269 B2	13 June 2012
		US 7609217 B2	27 October 2009
CN 102468531 A	23 May 2012	CN 102468531 B	06 May 2015

Form PCT/ISA/210 (patent family annex) (July 2022)