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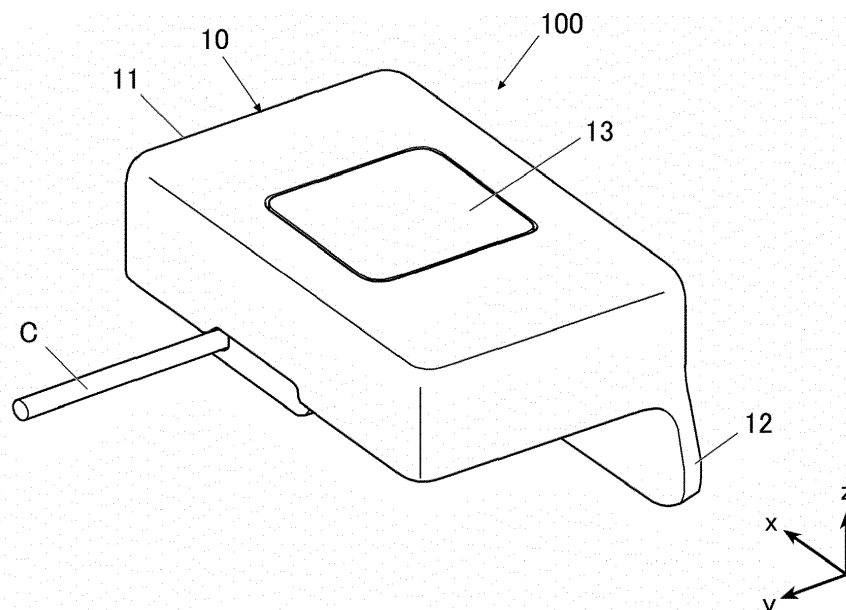
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(54) **ANTENNA DEVICE AND ANTENNA SYSTEM**

(57) An antenna device (100) includes: an antenna element (20) of a folded dipole antenna, the antenna element being a folded flat metal plate and having a folded structure; and a board (30) on which the antenna element is mounted. The antenna element includes an antenna element body (21). An unfolded shape of the antenna

element body is in mirror symmetry with respect to a line of symmetry (L1). The antenna element body includes side parts (21a, 21b) parted by the line of symmetry, each of the side parts having four or more folding lines (B1 to B5).

FIG.1



Description

TECHNICAL FIELD

[0001] The present disclosure relates to an antenna device and an antenna system.

BACKGROUND

[0002] There is known a telematics antenna to be mounted on a vehicle. Telematics is a general term for services that provide information from a cloud server to a moving object (vehicle). Specifically, an on-vehicle antenna is connected to an on-vehicle telematics control unit (TCU). Through wireless communication between the on-vehicle antenna and a base station on the cloud, the TCU receives information from the cloud server and provides the information to a person on the vehicle (e.g., the TCU displays the information on a display).

[0003] The telematics antenna conforms to communication standards (protocols), such as Long-Term Evolution (LTE), 5th Generation Mobile Communication System (5G), and Wideband Code Division Multiple Access (WCDMA; a registered trademark). The telematics antenna therefore needs to deal with a wide frequency range and requires an antenna length corresponding to the wavelengths of the frequency range. Accordingly, the antenna element tends to be large-sized.

[0004] There is also known a deformed folded dipole antenna in which an antenna element is folded once and disposed on both sides of a board in order to downsize the antenna (see Japanese Patent No. 6131816).

[0005] Herein, a known telematics antenna device 100D is described with reference to FIG.17. FIG.17 is an exploded perspective view of the known antenna device 100D.

[0006] As shown in FIG.17, the antenna device 100D includes a top cover 10D, an antenna element 20D, a board 30D, a bracket 40D, and a cable C3. The antenna element 20D is a telematics antenna element made of metal and having a three-dimensional folded structure. The left and right side parts of the antenna element 20D are folded three times. As described above, the antenna element of a telematics antenna device tends to be large-sized, in particular for an antenna device that needs to deal with lower frequencies. This is because the lower the frequency is, the longer antenna length is required with respect to the wavelength. Accordingly, the antenna element 20D becomes large-sized.

[0007] The board 30D is mounted with the antenna element 20D and circuit elements. The cable C3 is a coaxial cable covered with sponge. The cable C3 is electrically connected to conductor patterns of the board 30D (feeding point, grounding point). The bracket 40D is a metal grounding plate. The antenna element 20D and the board 30D are mounted on a flat surface of the bracket 40D and covered by the resin top cover 10D.

SUMMARY

[0008] The known antenna device 100D has the large antenna element 20D and the large bracket 40D that serves as a metal grounding surface for the antenna element 20D. Therefore, there is a demand to downsize an antenna device while retaining the antenna characteristic. Further, assembling the antenna device 100D places a burden on workers because the folding lines of the antenna element 20D are asymmetrical.

[0009] An object of the present invention is to downsize an antenna device, increase the antenna characteristic, and simplify the built-up structure of the antenna device.

[0010] To achieve the above object, according to an aspect of the present invention, there is provided an antenna device including: an antenna element of a folded dipole antenna, the antenna element being a folded flat metal plate and having a folded structure; and a board on which the antenna element is mounted, wherein the antenna element includes an antenna element body, an unfolded shape of the antenna element body is in mirror symmetry with respect to a line of symmetry, and the antenna element body includes side parts parted by the line of symmetry, each of the side parts having four or more folding lines.

BRIEF DESCRIPTION OF DRAWINGS

[0011] The accompanying drawings are not intended as a definition of the limits of the invention but illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention, wherein:

FIG.1 is a perspective external view of an antenna device in a first embodiment of the present invention; FIG.2 is a lateral view of the mounted antenna device in the first embodiment;

FIG.3 is an exploded perspective view of the antenna device in the first embodiment;

FIG.4 shows an unfolded antenna element in the first embodiment;

FIG.5 is a planar view of a board;

FIG.6 is a perspective view of the antenna element and the board of the antenna device in the first embodiment;

FIG.7A shows the frequency response of the voltage standing wave ratio (VSWR) of the antenna device in the first embodiment with respect to the frequency range of 600 MHz to 1.3 GHz;

FIG.7B shows the frequency response of the VSWR of the antenna device in the first embodiment with respect to the frequency range of 1.3 GHz to 3 GHz;

FIG.7C shows the frequency response of the VSWR of the antenna device in the first embodiment with respect to the frequency range of 3.2 GHz to 5.2 GHz;

FIG.8A shows the frequency response of the VSWR of a known antenna device with respect to the frequency range of 600 MHz to 1.3 GHz;

FIG.8B shows the frequency response of the VSWR of the known antenna device with respect to the frequency range of 1.3 GHz to 3 GHz;

FIG.8C shows the frequency response of the VSWR of the known antenna device with respect to the frequency range of 3.2 GHz to 5.2 GHz;

FIG.9 shows the unfolded antenna element in a modification;

FIG.10 is a perspective view of the antenna device consisting of the antenna element and the board in a second embodiment;

FIG.11 shows the unfolded antenna element in the second embodiment;

FIG.12A shows the frequency response of the VSWR of the antenna device in the second embodiment with respect to the frequency range of 600 MHz to 1.3 GHz;

FIG.12B shows the frequency response of the VSWR of the antenna device in the second embodiment with respect to the frequency range of 1.3 GHz to 3 GHz;

FIG.12C shows the frequency response of the VSWR of the antenna device in the second embodiment with respect to the frequency range of 3.2 GHz to 5.2 GHz;

FIG.13 is a perspective view of an antenna system that includes antenna portions and a bracket in a third embodiment;

FIG.14 shows the unfolded antenna element in the third embodiment;

FIG.15A shows the frequency response of the VSWR of a first antenna portion in the third embodiment with respect to the frequency range of 600 MHz to 1.3 GHz;

FIG.15B shows the frequency response of the VSWR of the first antenna portion in the third embodiment with respect to the frequency range of 1.3 GHz to 3 GHz;

FIG.15C shows the frequency response of the VSWR of the first antenna portion in the third embodiment with respect to the frequency range of 3.2 GHz to 5.2 GHz;

FIG.16A shows the frequency response of the VSWR of a second antenna portion in the third embodiment with respect to the frequency range of 600 MHz to 1.3 GHz;

FIG.16B shows the frequency response of the VSWR of the second antenna portion in the third embodiment with respect to the frequency range of 1.3 GHz to 3 GHz;

FIG.16C shows the frequency response of the VSWR of the second antenna portion in the third embodiment with respect to the frequency range of 3.2 GHz to 5.2 GHz; and

FIG.17 is an exploded perspective view of the known

antenna device.

DESCRIPTION OF EMBODIMENTS

[0012] Hereinafter, the first embodiment, the modification of the first embodiment, the second embodiment, and the third embodiment of the present invention are described in this order in detail with reference to the attached figures. However, the scope of the invention is not limited to the illustrated examples.

[First embodiment]

[0013] The first embodiment of the present invention is described with reference to FIG.1 to FIG.8C. Firstly, the external structure of an antenna device 100 in this embodiment is described with reference to FIG.1 and FIG.2. FIG.1 is a perspective external view of the antenna device 100 in this embodiment. FIG.2 is a lateral view of the mounted antenna device 100 in this embodiment.

[0014] The antenna device 100 is a telematics antenna device to be mounted on a vehicle (moving object). The antenna device 100 conforms to the communication standards (protocols) of LTE, 5G, and WCDMA. However, the communication standards to which the antenna device 100 conforms are not limited to them.

[0015] As shown in FIG.1, the antenna device 100 includes a top cover 10 and a cable C. FIG.1 shows the X axis, Y axis, and Z axis on the basis of the antenna device 100. The X, Y, Z axes are also shown in other figures. The antenna device 100 has a box shape (substantially cuboid) with the dimensions of 60 mm (length in the X axis direction) by 40 mm (length in the Y axis direction) by 20 mm (length in the Z axis direction), for example. The dimensions of the box-shaped antenna device 100 are not limited to these example dimensions and may be equal to or less than the example dimensions, for example.

[0016] The top cover 10 is made of resin, or more specifically, made of a combination of nonmetallic polycarbonate (PC) and acrylate styrene acrylonitrile (ASA) resin. The top cover 10 covers the antenna element 20 and the board 30, which are described later, from their top surfaces facing in the +Z direction. The material of the top cover 10 is not limited to the PC and ASA resin.

[0017] The top cover 10 includes a top cover body 11, a mount part 12, and a label 13. The top cover body 11 is the body of the box-shaped top cover 10. The mount part 12 is for mounting the antenna device 100 on a vehicle. The mount part 12 is integrally formed on the top cover body 11.

[0018] As shown in FIG.2, the antenna device 100 is mounted on an instrument panel I of the vehicle by inserting a round-head external screw 121 in a not-illustrated hole in the mount part 12 and screwing the external screw 121 into a not-illustrated internal screw formed in the instrument panel I.

[0019] The label 13 is attached to the top surface of

the top cover body 11. On the label 13, information regarding the antenna device 100 is printed (e.g., a quick response (QR) code for identifying the antenna device 100, product name).

[0020] The cable C is a coaxial cable. One end of the cable C is electrically connected to the board 30 (described later) of the antenna device 100, and the other end is connected to the TCU on the vehicle.

[0021] Next, the internal configuration of the antenna device 100 is described with reference to FIG.3 to FIG.5. FIG.3 is an exploded perspective view of the antenna device 100 in this embodiment. FIG.4 shows the unfolded antenna element 20 in this embodiment. FIG.5 is a planar view of the board 30.

[0022] As shown in FIG.3, the antenna device 100 includes the top cover 10, the antenna element 20, the board 30, and the bracket 40. The top cover body 11 of the top cover 10 includes a flat-head external screw 111, a hole 112, and a label attachment region 113.

[0023] The external screw 111 is for fixing the top cover 10 to the bracket 40 from above the label 13 (from the +Z direction side). The hole 112 is a through hole for inserting the external screw 111. The hole 112 is formed through the top cover body 11 in the Z axis direction. The label attachment region 113 is a recess part formed on the top surface of the top cover body 11 for attaching the label 13.

[0024] The antenna element 20 is for a telematics antenna. The antenna element 20 is made of metal (e.g., galvanized steel plate (iron)) and has a three-dimensional folded structure. The telematics antenna of the antenna element 20 is a folded dipole antenna.

[0025] As shown in FIG.4, the antenna element 20 has an antenna element body 21 and a protrusion 22. The antenna element body 21 is made of one flat metal plate (e.g., 0.8 mm thick). The antenna element 21 is flat when unfolded. The shape of the antenna element body 21 is in symmetry (mirror symmetry) with respect to a line of symmetry L1 as a central line. In other words, the two halves (two side parts) of the antenna element body 21 are line symmetrical with respect to the line of symmetry L1. In FIG.4, the right half (one side part) is the feeding-side antenna element part 21a, and the left half (one side part) is the grounding-side antenna element part 21b. That is, the feeding-side antenna element part 21a and the grounding-side antenna element part 21b are in line symmetry with respect to the line of symmetry L1.

[0026] The feeding-side antenna element part 21a includes a feeding point 211. The feeding point 211 is electrically connected to an inner conductor of the cable C via the conductor pattern and circuit elements on the board 30. The inner conductor of the cable C flows antenna currents of the cable C. The grounding-side antenna element part 21b includes a grounding point 212. The grounding point 212 is electrically connected to an outer conductor of the cable C via the conductor pattern and circuit elements on the board 30. The outer conductor of the cable C is grounded.

[0027] The feeding-side antenna element part 21a has five folding lines B1, B2, B3, B4, B5 in this order from the feeding point 211 in the direction in which the feeding-side antenna element part 21a extends. The feeding-side antenna element part 21a is folded at these folding lines B1 to B5. The grounding-side antenna element part 21b has five folding lines B1, B2, B3, B4, B5 in this order from the grounding point 212 in the direction in which the grounding-side antenna element part 21b extends. The grounding-side antenna element part 21b is folded at these folding lines B1 to B5. By folding the feeding-side antenna element part 21a and the grounding-side antenna element part 21b at the folding lines B1, B2, B3, B4 and B5, the three-dimensional antenna element 20 is formed, as shown in FIG.3.

[0028] In the known antenna device 100D shown in FIG.17, the antenna element 20D is asymmetrical (in mirror asymmetry) when unfolded. The respective side parts of the antenna element 20D have three folding lines. Although the antenna element 20 has more folding lines than the antenna element 20D, the feeding-side antenna element part 21a is symmetrical to the grounding-side antenna element part 21b. Therefore, in FIG.4, the folding lines B1 to B5 of the feeding-side antenna element part 21a are at the same positions in the up-down direction as the folding lines B1 to B5 of the grounding-side antenna element part 21b. That is, the folding lines of the feeding-side antenna element part 21a align with the folding lines of the grounding-side antenna element part 21b. Thus, the antenna element 20 has a simpler built-up structure than the known antenna element 20D.

[0029] Since the antenna element 20 has many folding lines, the antenna element 20 can secure a longer antenna length, which corresponds to the resonance frequency of a radio wave, as compared with an antenna element having a built-up structure of the equivalent size. In particular, with many folding lines, the antenna element 20 can easily have a long antenna element part and therefore resonate in low frequency ranges. It is preferable that each of the side parts of the antenna element 20 (each of the feeding-side antenna element part 21a and the grounding-side antenna element part 21b) have four folding lines or more.

[0030] The protrusion 22 has a rectangular loop shape and is connected to the feeding-side antenna element part 21a. The protrusion 22 as an antenna element connected to the feeding-side antenna element part 21a better contributes to the antenna characteristic because the antenna currents flow from the feeding point 211 to the grounding point 212. Alternatively, the protrusion 22 may be connected to the grounding-side antenna element part 21b.

[0031] To improve the antenna characteristic, the antenna has to resonate in a specific frequency range. The resonance of the antenna changes depending on the length of the antenna element. The protrusion 22 is therefore loop-shaped in order to secure the length of the antenna element. Since the antenna currents mainly flow

through the edge regions of the flat surface of the antenna element, the protrusion 22 without its rectangular internal region retains the antenna characteristic. The removal of the internal region of the protrusion 22 also contributes to weight reduction of the antenna device 100.

[0032] The board 30 is a printed wiring board (PWB). The body of the board 30 is made of a nonconductive material, such as glass epoxy resin. On the board body, metal conductor patterns (e.g., copper foil) are formed, the antenna element 20 is mounted, and circuit elements are mounted as needed. For example, the board 30 may be provided with (i) a lumped constant circuit as a conductor pattern and a circuit element and (ii) a filter as a circuit element, in order to reduce noise of antenna signals. The board 30 is 0.8 mm thick, for example. The board 30 has holes 33 through which an attachment boss portion 42 and a support portion 43 (described later) of the bracket 40 are inserted.

[0033] In the antenna device 100, the antenna element for the telematics antenna is mainly constituted of the antenna element 20. By adding an antenna (element) pattern(s) to the conductor pattern of the board 30, the antenna characteristic can be improved.

[0034] For example, as shown in FIG.5, a conductor pattern 32 is formed on the top surface of the nonconductive board body 31 of the board 30. FIG.5 is a schematic view and omits illustration of holes 33 and so forth. The conductor pattern 32 includes antenna patterns 321, 322. The antenna pattern 321 has an antenna length that allows resonance at 2000 MHz. The antenna pattern 322 has an antenna length that allows resonance at 1500 to 1700 MHz. For example, when a frequency range that cannot be covered by the antenna element 20 (2000 MHz, 1500 to 1700 MHz) occurs and the antenna element 20 cannot sufficiently resonate in the frequency range, the antenna patterns 321, 322 improve the antenna characteristic of the telematics antenna of the antenna device 100.

[0035] The board body 31 also includes an antenna element contact region 311 to be in contact with (mounted with) the antenna element 20. The antenna patterns 321, 322 of the board 30 are not formed on the antenna element contact region 311 to avoid interference between the antenna patterns 321, 322 and the antenna element 20.

[0036] The bracket 40 is made of resin (nonmetallic polycarbonate and ASA resin). The bracket 40 supports and covers the antenna element 20 and the board 30 from their bottom surfaces facing in the -Z direction. The bracket 40 is joined to the top cover 10. The material of the bracket 40 is not limited to the combination of polycarbonate and ASA resin and may be other nonmetallic material.

[0037] The bracket 40 includes the base 41, the attachment boss portion 42, and the support portion 43. The base 41 is the flat base of the bracket 40. The attachment boss portion 42 is integrally formed on the base 41. Inside the attachment boss portion 42, an internal

screw that engages with the external screw 111 is formed. The top cover 10 is attached to the bracket 40 by the external screw 111 screwed in the internal screw, so that the attachment boss portion 42 fixes and supports the top cover 10. The support portion 43 is integrally formed on the base 41 and supports the top cover 10 and the board 30 on which the antenna element 20 is mounted.

[0038] The process of assembling (manufacturing) the antenna device 100 is explained briefly. A worker firstly folds the antenna element 20 in the unfolded state shown in FIG.4 at the folding lines B1, B2, B3, B4, and B5 to form the three-dimensional antenna element 20, as shown in FIG.3. The worker then mounts the three-dimensional antenna element 20 on the board 30. The worker then performs soldering or the like to electrically connect the feeding side end of the conductor pattern of the board 30 to the inner conductor of the cable C and the grounding side end of the conductor pattern of the board 30 to the outer conductor of the cable C.

[0039] The worker causes the bracket 40 to support the board 30 mounted with the antenna element 20 and attaches the top cover 10 to the bracket 40. The worker screws the external screw 111 into the attachment boss portion 42 through the hole 112, the antenna element 20, and the board 30, so that the board 30 mounted with the antenna element 20 is housed inside the top cover 10 and the bracket 40. The worker attaches the label 13 to the label attachment region 113. Thus, the antenna device 100 is assembled.

[0040] Next, the antenna characteristic of the antenna device 100 is described with reference to FIG.6 to FIG.8C. FIG.6 is a perspective view of the antenna element 20 and the board 30 of the antenna device 100 in this embodiment. FIG.7A shows the frequency response of the voltage standing wave ratio (VSWR) of the antenna device 100 in this embodiment with respect to the frequency range of 600 MHz to 1.3 GHz. FIG.7B shows the frequency response of the VSWR of the antenna device 100 in this embodiment with respect to the frequency range of 1.3 GHz to 3 GHz. FIG.7C shows the frequency response of the VSWR of the antenna device 100 in this embodiment with respect to the frequency range of 3.2 GHz to 5.2 GHz. FIG.8A shows the frequency response of the VSWR of the known antenna device 100D with respect to the frequency range of 600 MHz to 1.3 GHz. FIG.8B shows the frequency response of the VSWR of the known antenna device 100D with respect to the frequency range of 1.3 GHz to 3 GHz. FIG.8C shows the frequency response of the VSWR of the known antenna device 100D with respect to the frequency range of 3.2 GHz to 5.2 GHz.

[0041] As shown in FIG.6, the frequency response of the VSWR of the antenna device 100 (the board 30 mounted with the antenna element 20) was measured as the antenna characteristic of the antenna device 100. The VSWR is a measure indicating how efficiently the radio-frequency electric power is transmitted from a pow-

er source to a load (antenna) via a transmission line. The lower the VSWR is, the better the resonance occurs.

[0042] The frequency ranges to be used in telematics communication standards (herein, LTE, 5G, and WCDMA) are: 617 MHz to 960 MHz; 1.427 GHz to 2.69 GHz; 3.3 GHz to 4.2 GHz; and 4.4 GHz to 5 GHz. To cover the above frequency ranges, the VSWR of the antenna device 100 was measured with respect to 600 MHz to 1.3 GHz; 1.3 GHz to 3 GHz; and 3.2 GHz to 5.2 GHz.

[0043] FIG. 7A shows the VSWR of the antenna device 100 with respect to the frequency range of 600 MHz to 1.3 GHz. In FIG. 7A, $\Delta 1$ indicates the VSWR at 617 MHz; $\Delta 2$ indicates the VSWR at 650 MHz; $\Delta 3$ indicates the VSWR at 698 MHz; $\Delta 4$ indicates the VSWR at 750 MHz; $\Delta 5$ indicates the VSWR at 824 MHz; $\Delta 6$ indicates the VSWR at 894 MHz; and $\Delta 7$ indicates the VSWR at 960 MHz. These frequencies indicated by $\Delta 1$ to $\Delta 7$ are the same as in FIG. 8A and so forth that show the graph of the frequency response of the VSWR of other antenna devices with respect to the same frequency range of 600 MHz to 1.3 GHz.

[0044] FIG. 7B shows the VSWR of the antenna device 100 with respect to the frequency range of 1.3 GHz to 3 GHz. In FIG. 7B, $\Delta 1$ indicates the VSWR at 1.4279 GHz; $\Delta 2$ indicates the VSWR at 1.5109 GHz; $\Delta 3$ indicates the VSWR at 1.7100 GHz; $\Delta 4$ indicates the VSWR at 1.9800 GHz; $\Delta 5$ indicates the VSWR at 2.1700 GHz; $\Delta 6$ indicates the VSWR at 2.3000 GHz; $\Delta 7$ indicates the VSWR at 2.4000 GHz; $\Delta 8$ indicates the VSWR at 2.4960 GHz; and $\Delta 9$ indicates the VSWR at 2.6900 GHz. These frequencies indicated by $\Delta 1$ to $\Delta 9$ are the same as in FIG. 8B and so forth that show the graphs of the frequency response of the VSWR of other antenna devices with respect to the same frequency range of 1.3 GHz to 3 GHz.

[0045] FIG. 7C shows the VSWR of the antenna device 100 with respect to the frequency range of 3.2 GHz to 5.2 GHz. In FIG. 7C, $\Delta 1$ indicates the VSWR at 3.41 GHz; $\Delta 2$ indicates the VSWR at 3.50 GHz; $\Delta 3$ indicates the VSWR at 3.59 GHz; $\Delta 4$ indicates the VSWR at 4.20 GHz; $\Delta 5$ indicates the VSWR at 4.50 GHz; $\Delta 6$ indicates the VSWR at 4.80 GHz; and $\Delta 7$ indicates the VSWR at 5.00 GHz. These frequencies indicated by $\Delta 1$ to $\Delta 7$ are the same as in FIG. 8C and so forth that shows the graph of the frequency response of the VSWR of other antenna devices with respect to the same frequency range of 3 GHz to 5.2 GHz.

[0046] According to FIG. 7A, the antenna device 100 resonates at the VSWR that is lower than the VSWR of the antenna device 100D shown in FIG. 8A with respect to the frequency range of 600 MHz to 1.3 GHz. The antenna characteristic of the antenna device 100 is therefore improved. Further, according to FIG. 7B, the antenna device 100 resonates at the VSWR that is lower than 5 and lower than the VSWR of the antenna device 100D shown in FIG. 8B with respect to the frequency range of 1.3 GHz to 3 GHz. The antenna characteristic of the antenna device 100 is therefore improved. Further, according to FIG. 7C, the antenna device 100 resonates at the

VSWR that is lower than 5 and lower than the VSWR of the antenna device 100D shown in FIG. 8C with respect to the frequency range of 3.2 GHz to 5.2 GHz. The antenna characteristic of the antenna device 100 is therefore improved.

[0047] As described above, according to the first embodiment, the antenna device 100 includes: the antenna element 20 of a folded dipole antenna, the antenna element 20 being a folded flat metal plate and having a folded structure; and the board 30 on which the antenna element 20 is mounted. The antenna element 20 includes the antenna element body 21. The unfolded shape of the antenna element body 21 is in mirror symmetry with respect to the line of symmetry L1. The antenna element body 21 includes side parts parted by the line of symmetry L1 (the feeding-side antenna element part 21a and the grounding-side antenna element part 21b), each of the side parts having five folding lines B1, B2, B3, B4 and B5. Thus, the antenna element 20 of the folded dipole antenna is folded at five folding lines B1 to B5. Such an antenna element 20 eliminates the need for a large metal bracket, allows downsizing of the antenna device 100, and increases the antenna characteristic of the antenna device 100 without a large metal bracket. Further, the built-up structure of the antenna device 100 can be simplified because the unfolded shape of the antenna element 20 is mirror-symmetrical.

[0048] Preferably, the antenna element 20 may have the protrusion 22 connected to the antenna element body 21. With the protrusion 22, the unfolded shape of the antenna element 20 is asymmetrical (not in mirror symmetry) with respect to the line of symmetry L1. The protrusion 22 supplements the antenna characteristic of the antenna element body 21 and thereby increases the antenna characteristic of the antenna device 100.

[0049] Preferably, the protrusion 22 may be connected to one side part among the side parts, the one side part being the feeding-side antenna element part 21a that includes the feeding point 211. According to such a configuration, the protrusion 22 can better contribute to the antenna characteristic of the antenna device 100 as compared with the protrusion 22 connected to the grounding-side antenna element part 21b.

[0050] Preferably, the protrusion 22 may be loop-shaped. Therefore, the weight reduction of the antenna device 100 is achieved without decreasing its antenna characteristic.

[0051] Preferably, the board 30 may include the conductor antenna patterns 321, 322 in a region that is not in contact with the antenna element 20 (the region different from the antenna element contact region 311). The antenna patterns 321, 322 can cover the resonance of the antenna element 20 in a specific frequency range and can avoid interference with the antenna element 20.

[0052] Preferably, the antenna device 100 may include the nonmetal bracket 40 configured to support the antenna element 20 and the board 30. The absence of a large metal bracket allows downsizing and weight reduc-

tion of the antenna device 100.

[Modification]

[0053] A modification of the first embodiment is described with reference to FIG.9. FIG.9 shows the unfolded antenna element 20A in the modification.

[0054] The antenna device in the modification includes the antenna element 20A shown in FIG.9 instead of the antenna element 20 in the antenna device 100 in the first embodiment. The parts of the antenna device in the modification that are the same as the parts of the antenna device 100 are given the same reference numerals, and the description thereof is omitted.

[0055] The antenna element 20A includes the antenna element body 21 and the protrusion 22A.

[0056] The protrusion 22A has a rectangular shape and is connected to the feeding-side antenna element part 21a. Although the protrusion 22A is smaller than the protrusion 22 in the first embodiment, this is merely an example and the size of the protrusion 22A is not limited to this. The protrusion 22A may be connected to the grounding-side antenna element part 21b.

[0057] As described above, the antenna device in the modification includes the antenna element 20A and yields the same advantageous effects as the antenna device 100 in the first embodiment.

[Second Embodiment]

[0058] The second embodiment of the present invention is described with reference to FIG.10 to FIG.12C. FIG.10 is a perspective view of the antenna element 20B and the board 30 of the antenna device 100B in the second embodiment. FIG.11 shows the unfolded antenna element 20B in the second embodiment. FIG.12A shows the frequency response of the VSWR of the antenna device 100B in this embodiment with respect to the frequency range of 600 MHz to 1.3 GHz. FIG.12B shows the frequency response of the VSWR of the antenna device 100B in this embodiment with respect to the frequency range of 1.3 GHz to 3 GHz. FIG.12C shows the frequency response of the VSWR of the antenna device 100B in this embodiment with respect to the frequency range of 3.2 GHz to 5.2 GHz.

[0059] As shown in FIG.10, the antenna device 100B in this embodiment includes the top cover 10(not illustrated in FIG.10), the bracket 40 (not illustrated in FIG.10), the antenna element 20B, and the board 30.

[0060] The antenna device 100B in this embodiment includes the antenna element 20B shown in FIG.10 instead of the antenna element 20 in the antenna device 100 in the first embodiment. The parts of the antenna device 100B in the second embodiment that are the same as the parts of the antenna device 100 are given the same reference numerals, and the description thereof is omitted.

[0061] The antenna element 20B is an antenna ele-

ment for a telematics antenna. The antenna element 20 is made of metal (e.g., galvanized steel plate (iron)) and has a three-dimensional folded structure. The telematics antenna of the antenna element 20B is a folded dipole antenna.

[0062] As shown in FIG.11, the antenna element 20B has an antenna element body 21B. The antenna element body 21B is made of one flat metal plate (e.g. 0.8 mm thick). The antenna element 20B is flat when unfolded. The shape of the antenna element body 21B is in symmetry with respect to the line of symmetry L1. The antenna element 20B does not include the protrusion 22 of the first embodiment or the protrusion 22A of the modification.

[0063] Next, the antenna characteristic of the antenna device 100B is described with reference to FIG.12A to FIG.12C.

[0064] The frequency response of the VSWR of the antenna device 100B shown in FIG.10 (the antenna element 20B mounted on the board 30) was measured as the antenna characteristic of the antenna device 100B.

[0065] FIG.12A shows the VSWR of the antenna device 100B with respect to the frequency range of 600 MHz to 1.3 GHz. FIG.12B shows the VSWR of the antenna device 100B with respect to the frequency range of 1.3 GHz to 3 GHz. FIG.12C shows the VSWR of the antenna device 100B with respect to the frequency range of 3.2 GHz to 5.2 GHz.

[0066] According to FIG.12A, the antenna device 100B resonates at the VSWR that is on the whole lower than the VSWR of the antenna device 100D shown in FIG.8A with respect to the frequency range of 600 MHz to 1.3 GHz. The antenna characteristic of the antenna device 100B is therefore improved. Further, according to FIG.12B, the antenna device 100B resonates at the VSWR that is on the whole lower than the VSWR of the antenna device 100D shown in FIG.8B with respect to the frequency range of 1.3 GHz to 3 GHz. The antenna characteristic of the antenna device 100B is therefore improved. Further, according to FIG.12C, the antenna device 100B resonates at the VSWR that is lower than 5 and lower than the VSWR of the antenna device 100D shown in FIG.8C with respect to the frequency range of 3.2 GHz to 5.2 GHz. The antenna characteristic of the antenna device 100B is therefore improved.

[0067] As described above, unlike the antenna device 100 in the first embodiment, the antenna device 100B in the second embodiment does not have a protrusion. This further simplifies the built-up structure of the antenna device 100B and reduces the weight of the antenna device 100B.

[Third embodiment]

[0068] The third embodiment of the present invention is described with reference to FIG.13 to FIG.16C. FIG.13 is a perspective view of an antenna system 100C in the third embodiment that includes antenna portions 510,

520 and a bracket 40C. FIG. 14 shows the unfolded antenna element 20C in the third embodiment. FIG. 15A shows the frequency response of the VSWR of the antenna portion 510 in this embodiment with respect to the frequency range of 600 MHz to 1.3 GHz. FIG. 15B shows the frequency response of the VSWR of the antenna portion 510 in this embodiment with respect to the frequency range of 1.3 GHz to 3 GHz. FIG. 15C shows the frequency response of the VSWR of the antenna portion 510 in this embodiment with respect to the frequency range of 3.2 GHz to 5.2 GHz. FIG. 16A shows the frequency response of the VSWR of the antenna portion 520 in this embodiment with respect to the frequency range of 600 MHz to 1.3 GHz. FIG. 16B shows the frequency response of the VSWR of the antenna portion 520 in this embodiment with respect to the frequency range of 1.3 GHz to 3 GHz. FIG. 16C shows the frequency response of the VSWR of the antenna portion 520 in this embodiment with respect to the frequency range of 3.2 GHz to 5.2 GHz.

[0069] As shown in FIG. 13, the antenna system 100C in this embodiment includes a top cover (not illustrated in FIG. 13), the antenna portions 510, 520 as the antenna device, and the bracket 40C. The antenna portion 510 includes the antenna element 20C and the board 30. The antenna portion 520 includes the antenna element 20C and the board 30.

[0070] The antenna portions 510, 520 have the same structure. The antenna portions 510, 520 function as multiple-input and multiple-output (MIMO) antennas, for example. The MIMO is a technology for improving the transmission speed and transmission quality in wireless communication by using multiple antennas for the transmitter and receiver (in the antenna system 100C, two antenna portions 510, 520).

[0071] The antenna portion 510 includes the antenna element 20C shown in FIG. 13 instead of the antenna element 20 of the antenna device 100 (the antenna element 20 and the board 30) in the first embodiment. The parts of the antenna portions 510, 520 in the third embodiment that are the same as the parts of the antenna device 100 are given the same reference numerals, and the description thereof is omitted.

[0072] The antenna element 20C is an antenna element for a telematics antenna. The antenna element 20 is made of metal (e.g., galvanized steel plate (iron)) and has a three-dimensional folded structure. The telematics antenna of the antenna element 20C is a folded dipole antenna.

[0073] As shown in FIG. 14, the antenna element 20C has an antenna element body 21C and protrusions 22, 23. The antenna element body 21C is made of one flat metal plate. The antenna element 20C is flat when unfolded. The shape of the antenna element body 21C is in symmetry with respect to the line of symmetry L1. In FIG. 14, the right half is the feeding-side antenna element part 21c, and the left half is the grounding-side antenna element part 21d, with the line of symmetry L1 as the borders.

[0074] The protrusion 22 is the same as the protrusion 22 in the first embodiment, and is connected to the feeding-side antenna element part 21c. The protrusion 23 has a rectangular shape and is connected to the grounding-side antenna element part 21d. The protrusion 23 may be connected to the feeding-side antenna element part 21c.

[0075] The bracket 40C is made of the same material as the bracket 40 in the first embodiment. The bracket 40C is shaped to support the antenna portions 510, 520 from the bottom. Thus, the size of the bracket 40C for housing the antenna device (antenna portions) is increased according to the number of antenna portions 510, 520 (herein, two antenna portions). One end of the cable C1 is electrically connected to the conductor pattern of the board 30 of the antenna portion 510, and the other end of the cable C1 is connected to the TCU. One end of the cable C2 is electrically connected to the conductor pattern of the board 30 of the antenna portion 520, and the other end of the cable C2 is connected to the TCU. The top cover (not illustrated) of the antenna system 100C is made of the same material as the top cover 10 in the first embodiment, and the shape of the top cover conforms to the shape of the bracket 40C. That is, the antenna portions 510, 520 are housed in the space inside the top cover and the bracket 40C of the antenna system 100C.

[0076] Next, the antenna characteristic of the antenna system 100C is described with reference to FIG. 15A to FIG. 16C.

[0077] For each of the antenna portions 510, 520 of the antenna system 100C shown in FIG. 13, the frequency response of the VSWR was measured as the antenna characteristic.

[0078] FIG. 15A shows the VSWR of the antenna portion 510 with respect to the frequency range of 600 MHz to 1.3 GHz. FIG. 15B shows the VSWR of the antenna portion 510 with respect to the frequency range of 1.3 GHz to 3 GHz. FIG. 15C shows the VSWR of the antenna portion 510 with respect to the frequency range of 3.2 GHz to 5.2 GHz.

[0079] According to FIG. 15A, the antenna portion 510 resonates at the VSWR that is on the whole lower than the VSWR of the antenna device 100D shown in FIG. 8A with respect to the frequency range of 600 MHz to 1.3 GHz. The antenna characteristic of the antenna portion 510 is therefore improved. Further, according to FIG. 15B, the antenna portion 510 resonates at the VSWR that is lower than 5 and lower than the VSWR of the antenna device 100D shown in FIG. 8B with respect to the frequency range of 1.3 GHz to 3 GHz. The antenna characteristic of the antenna portion 510 is therefore improved. Further, according to FIG. 15C, the antenna portion 510 resonates at the VSWR that is lower than 5 and lower than the VSWR of the antenna device 100D shown in FIG. 8C with respect to the frequency range of 3.2 GHz to 5.2 GHz. The antenna characteristic of the antenna portion 510 is therefore improved.

[0080] FIG. 16A shows the VSWR of the antenna portion 520 with respect to the frequency range of 600 MHz to 1.3 GHz. FIG. 16B shows the VSWR of the antenna portion 520 with respect to the frequency range of 1.3 GHz to 3 GHz. FIG. 16C shows the VSWR of the antenna portion 520 with respect to the frequency range of 3.2 GHz to 5.2 GHz.

[0081] According to FIG. 16A, the antenna portion 520 resonates at the VSWR that is on whole lower than the VSWR of the antenna device 100D shown in FIG. 8A with respect to the frequency range of 600 MHz to 1.3 GHz. The antenna characteristic of the antenna portion 520 is therefore improved. Further, according to FIG. 16B, the antenna portion 520 resonates at the VSWR that is on the whole lower than the VSWR of the antenna device 100D shown in FIG. 8B with respect to the frequency range of 1.3 GHz to 3 GHz. The antenna characteristic of the antenna portion 520 is therefore improved. Further, according to FIG. 16C, the antenna portion 520 resonates at the VSWR that is lower than 5 and lower than the VSWR of the antenna device 100D shown in FIG. 8C with respect to the frequency range of 3.2 GHz to 5.2 GHz. The antenna characteristic of the antenna portion 520 is therefore improved.

[0082] As described above, according to the third embodiment, the antenna system 100C includes the antenna portions 510, 520. Thus, multiple antenna devices (antenna portions 510, 520) are downsized, the antenna characteristic is improved, and the built-up structure is simplified. Therefore, the antenna system 100C is downsized, the antenna characteristic of the antenna system 100C is improved, and the built-up structure of the antenna system 100C is simplified.

[0083] Preferably, the antenna system 100C may include the nonmetal bracket 40C configured to support the multiple antenna devices (antenna portions 510, 520). The absence of a large metal bracket allows downsizing and weight reduction of the antenna system 100C.

[0084] The embodiments and the modification described above are examples of the antenna device and the antenna system according to the present invention and do not limit the present invention. For example, at least two among the embodiments and the modification may be appropriately combined.

[0085] In the above embodiments and the modification, the antenna device 100, the antenna device 100B, and the antenna system 100C include the cable C or the cables C1, C2 that is/are electrically connected to the conductor pattern of the board 30. However, the present invention is not limited to this configuration. For example, the antenna device 100, the antenna device 100B, and the antenna system 100C may include a connector that is electrically connected to the conductor pattern of the board 30.

[0086] The detailed configuration and detailed operation of the antenna device in the embodiments and the modification may be appropriately modified within the scope of the present invention.

Claims

1. An antenna device (100) comprising:
 - an antenna element (20) of a folded dipole antenna, the antenna element being a folded flat metal plate and having a folded structure; and
 - a board (30) on which the antenna element is mounted, wherein
 - the antenna element includes an antenna element body (21),
 - an unfolded shape of the antenna element body is in mirror symmetry with respect to a line of symmetry (L1), and
 - the antenna element body includes side parts (21a, 21b) parted by the line of symmetry, each of the side parts having four or more folding lines (B1 to B5).
2. The antenna device according to claim 1, wherein the antenna element includes a protrusion (22) connected to the antenna element body.
3. The antenna device according to claim 2, wherein the protrusion is connected to one side part among the side parts, the one side part being a feeding-side antenna element part (21a) that includes a feeding point (211).
4. The antenna device according to claim 2 or claim 3, wherein the protrusion is loop-shaped.
5. The antenna device according to any one of claim 1 to claim 4, wherein the board includes a conductor antenna pattern (321, 322) in a region that is not in contact with the antenna element.
6. The antenna device according to any one of claim 1 to claim 5, further comprising a nonmetal bracket (40) configured to support the antenna element and the board.
7. An antenna system (100C) comprising multiple antenna devices each of which is the antenna device according to any one of claim 1 to claim 5.
8. The antenna system according to claim 7, further comprising a nonmetal bracket (40C) configured to support the multiple antenna devices.

FIG.1

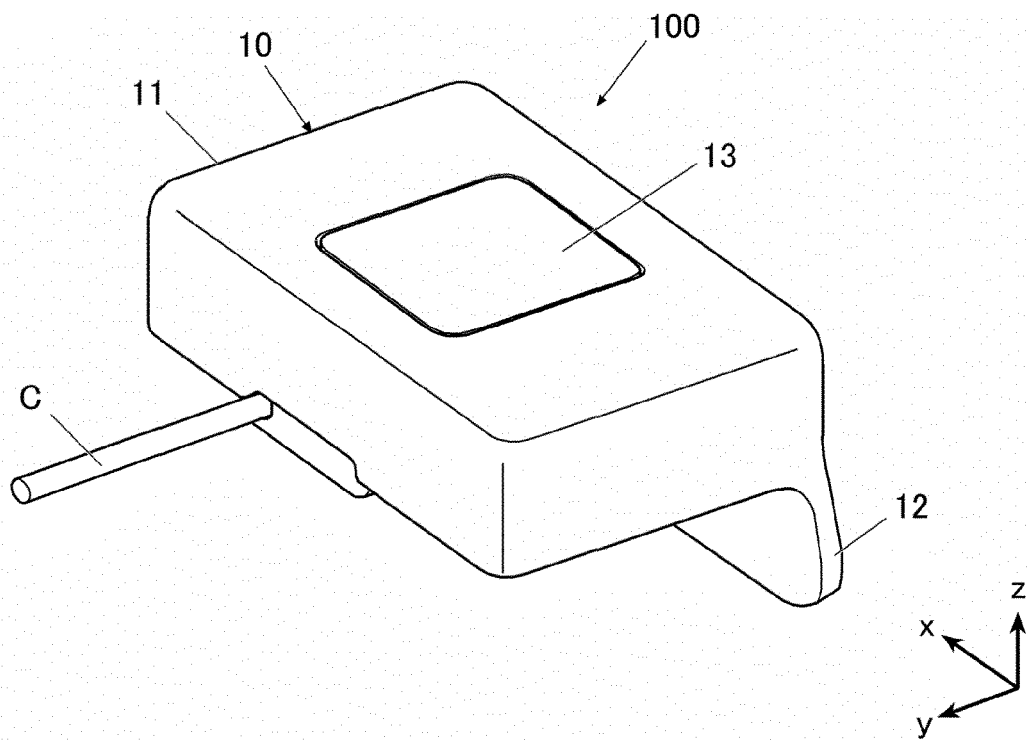


FIG.2

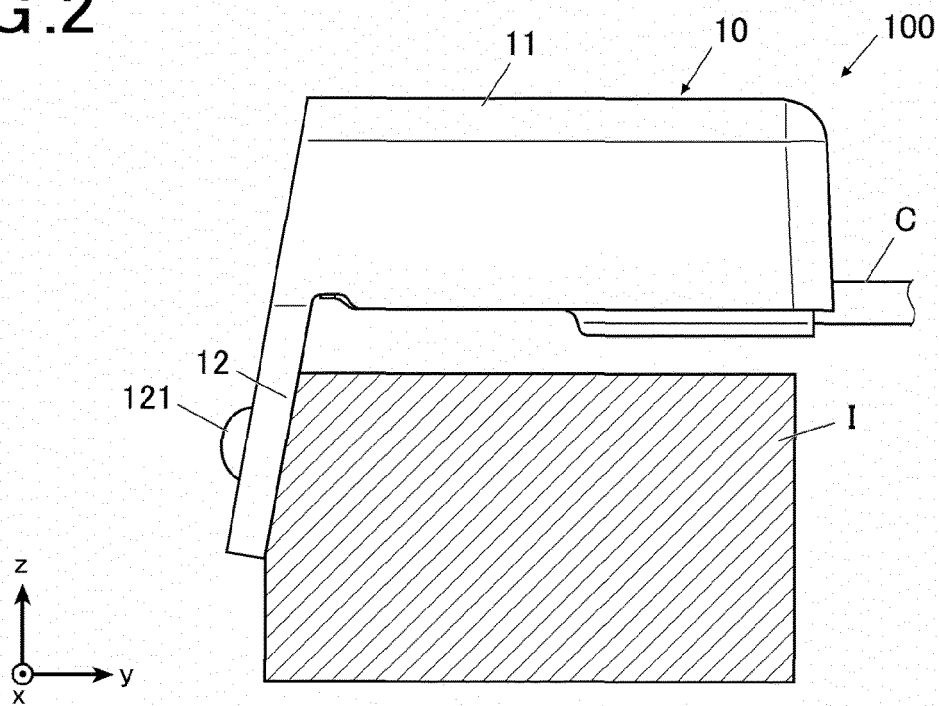


FIG.3

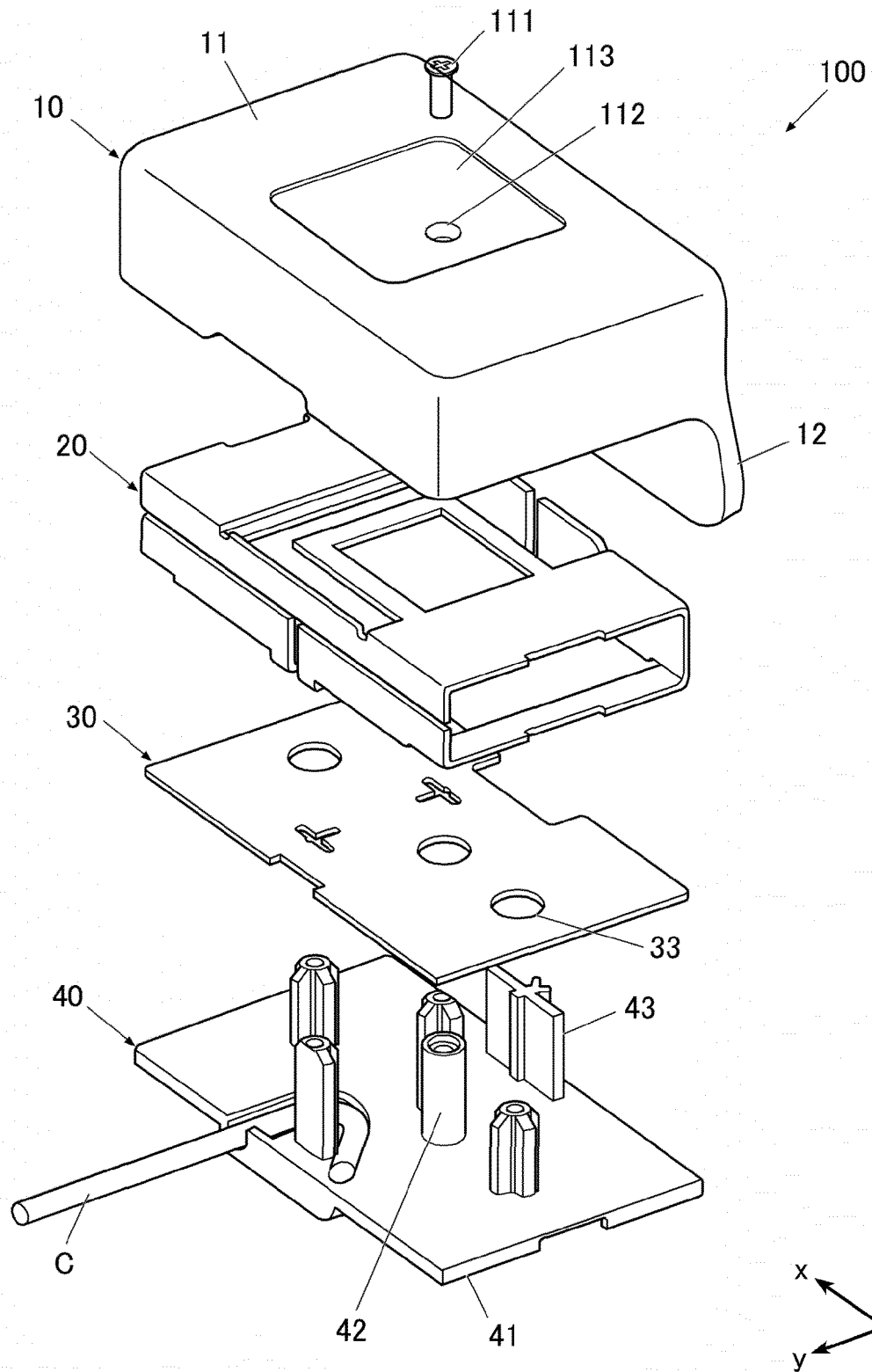


FIG.4

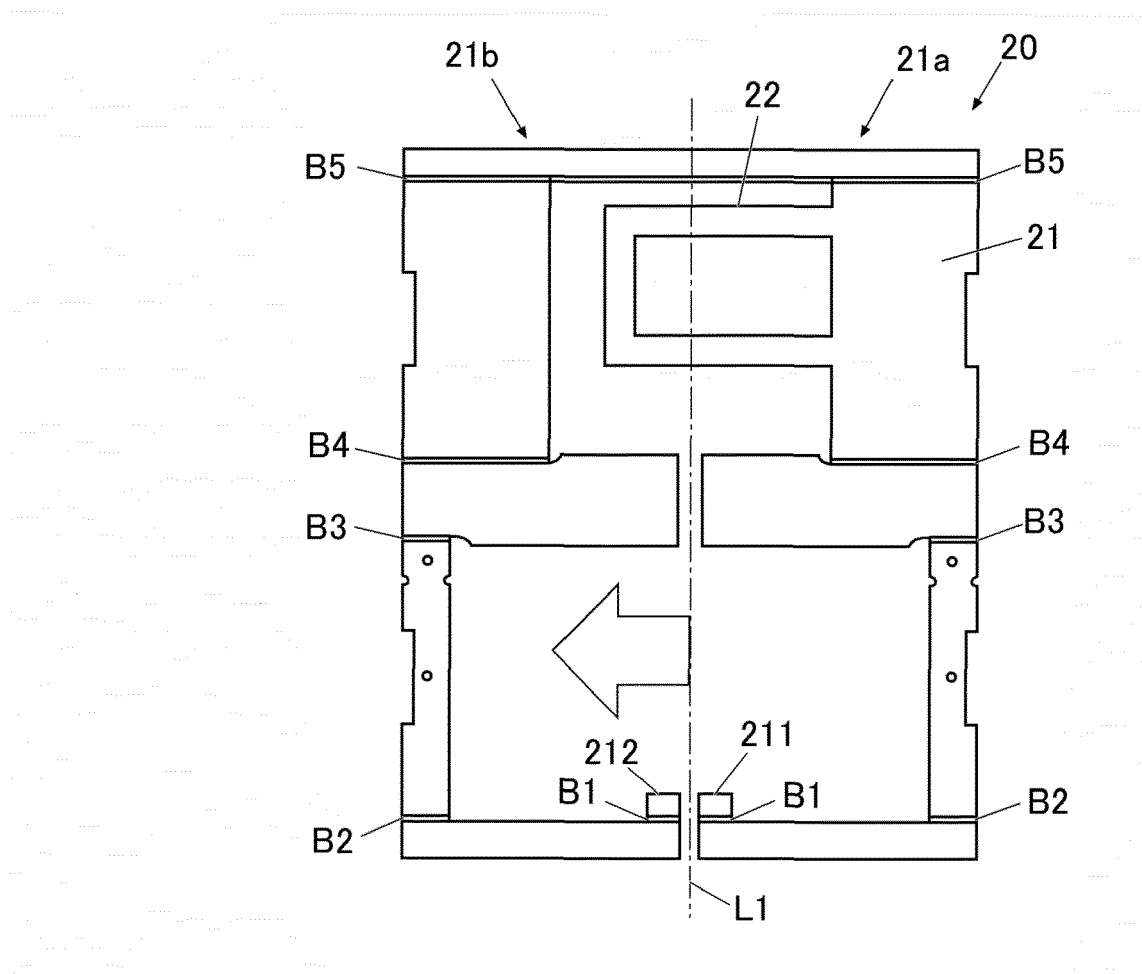


FIG.5

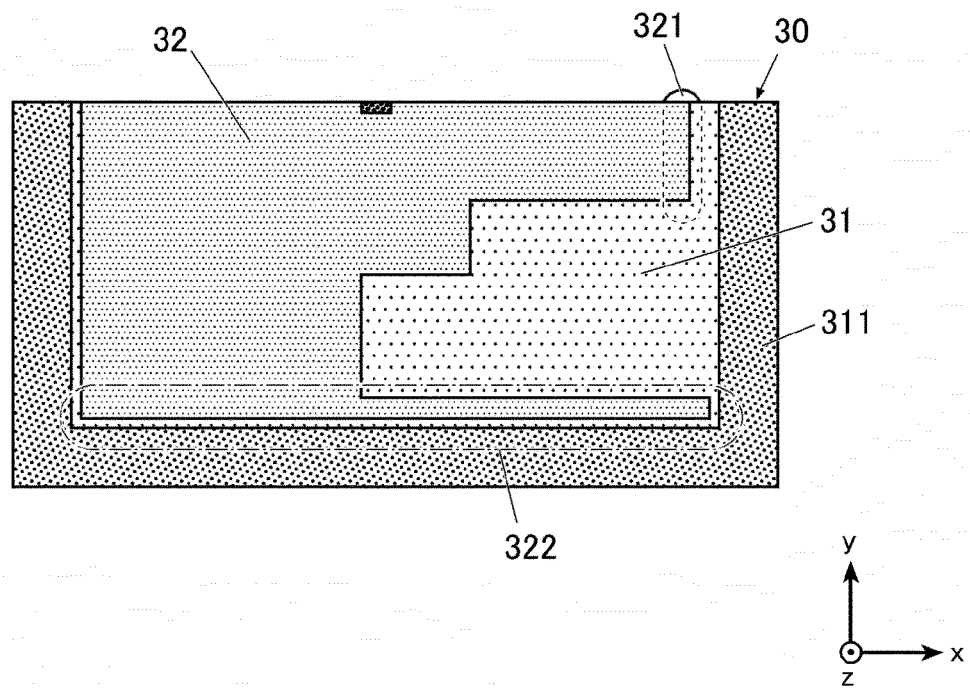


FIG.6

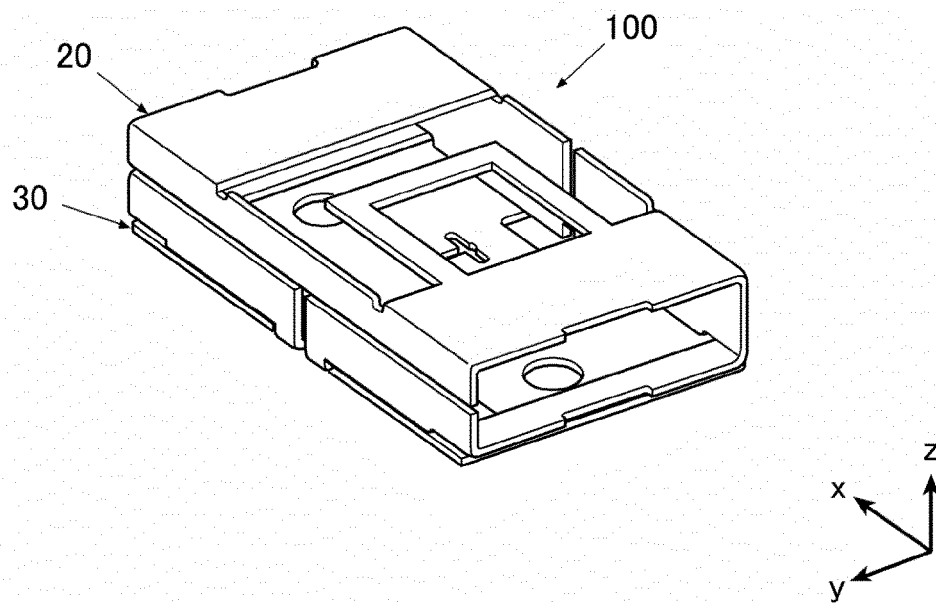


FIG. 7A

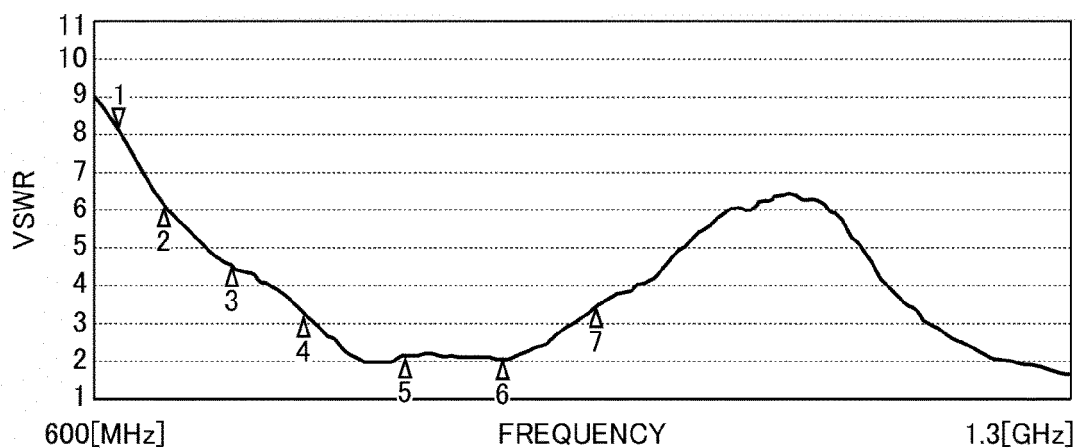


FIG. 7B

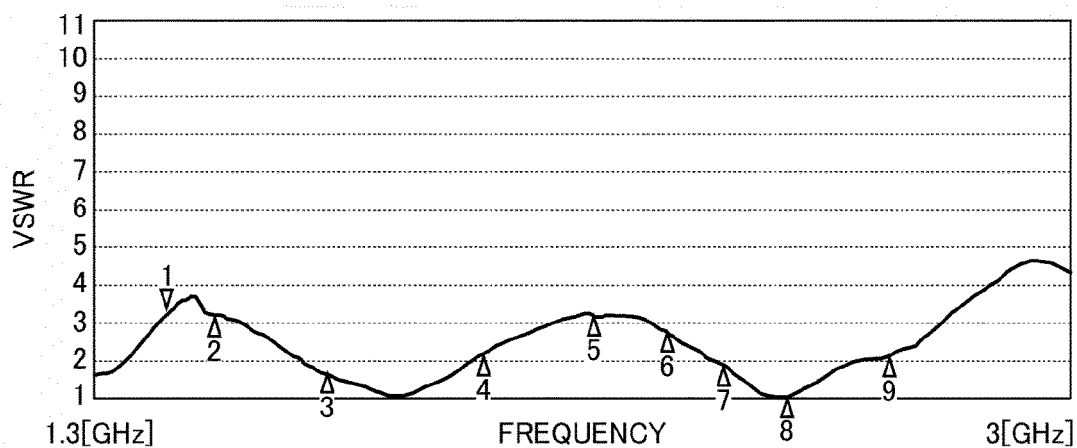


FIG. 7C

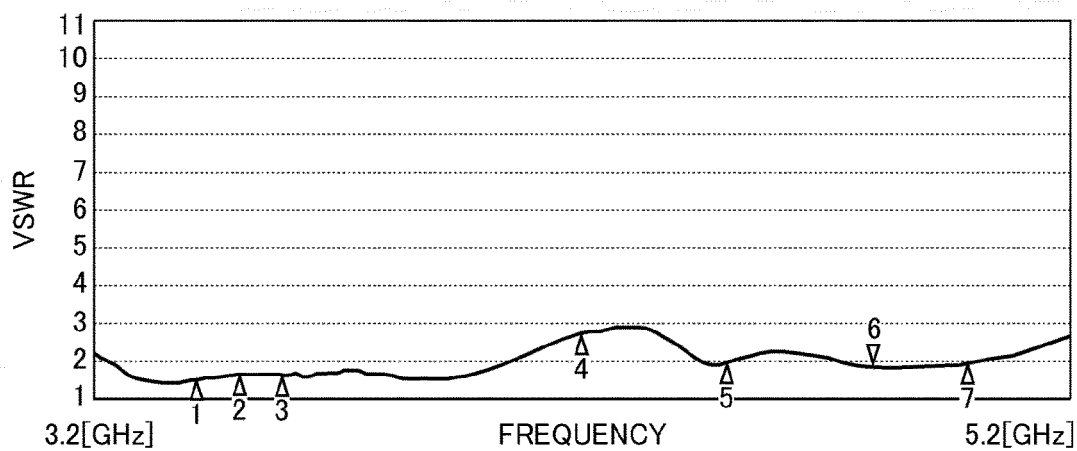


FIG. 8A

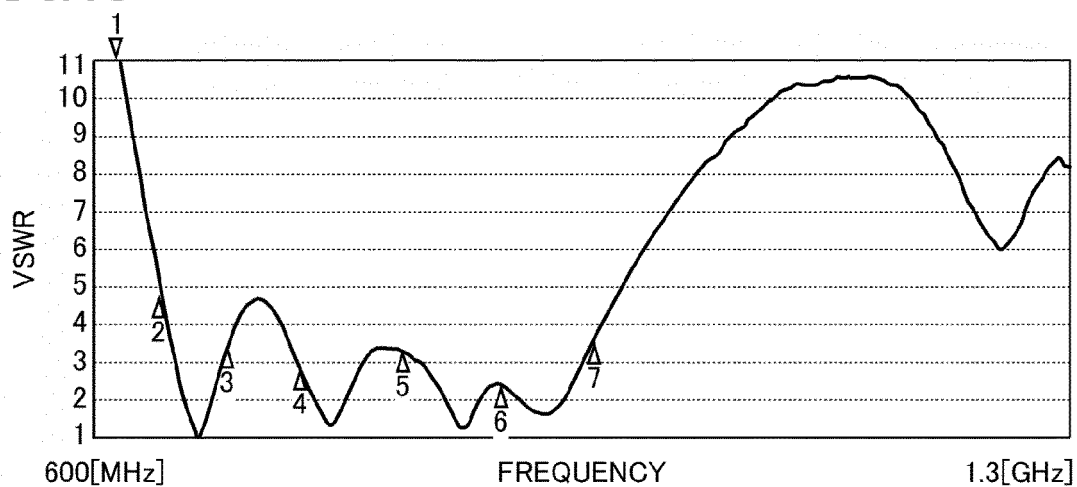


FIG. 8B

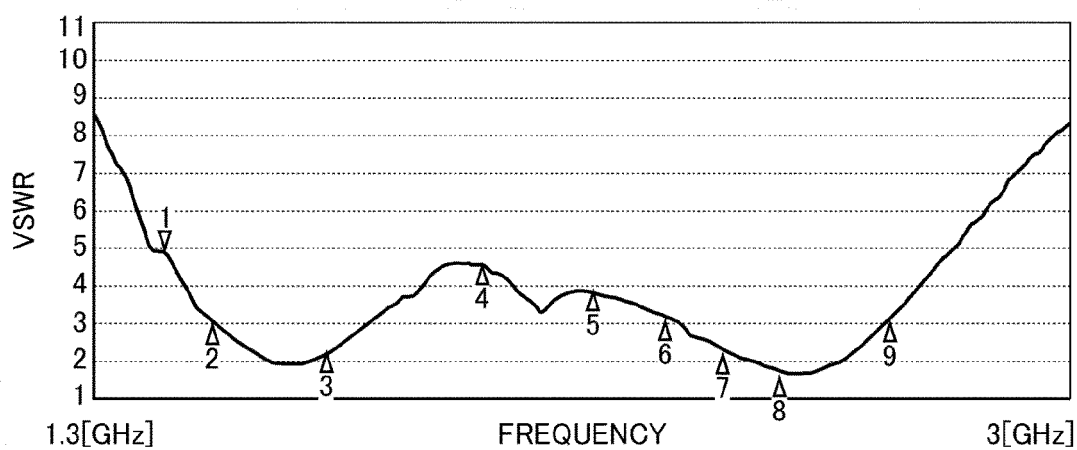


FIG. 8C

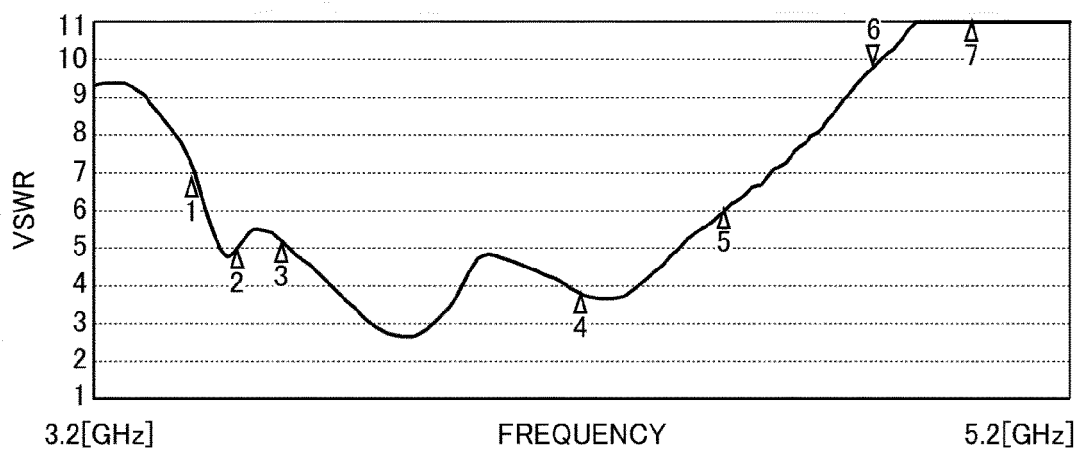


FIG. 9

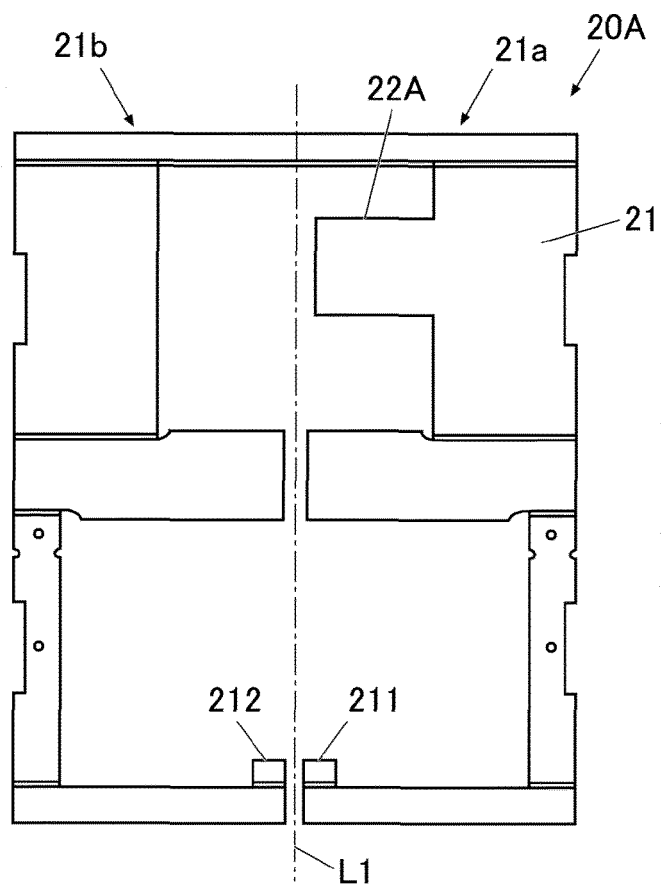


FIG. 10

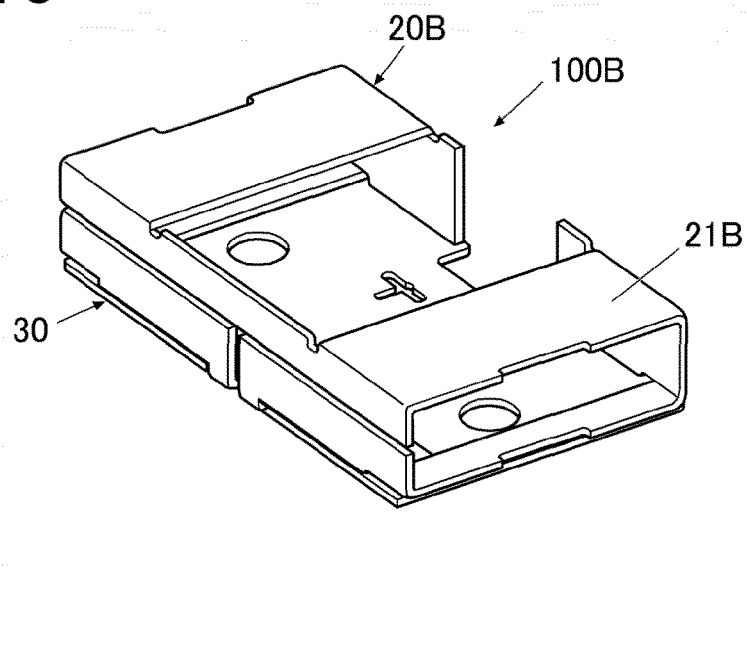


FIG.11

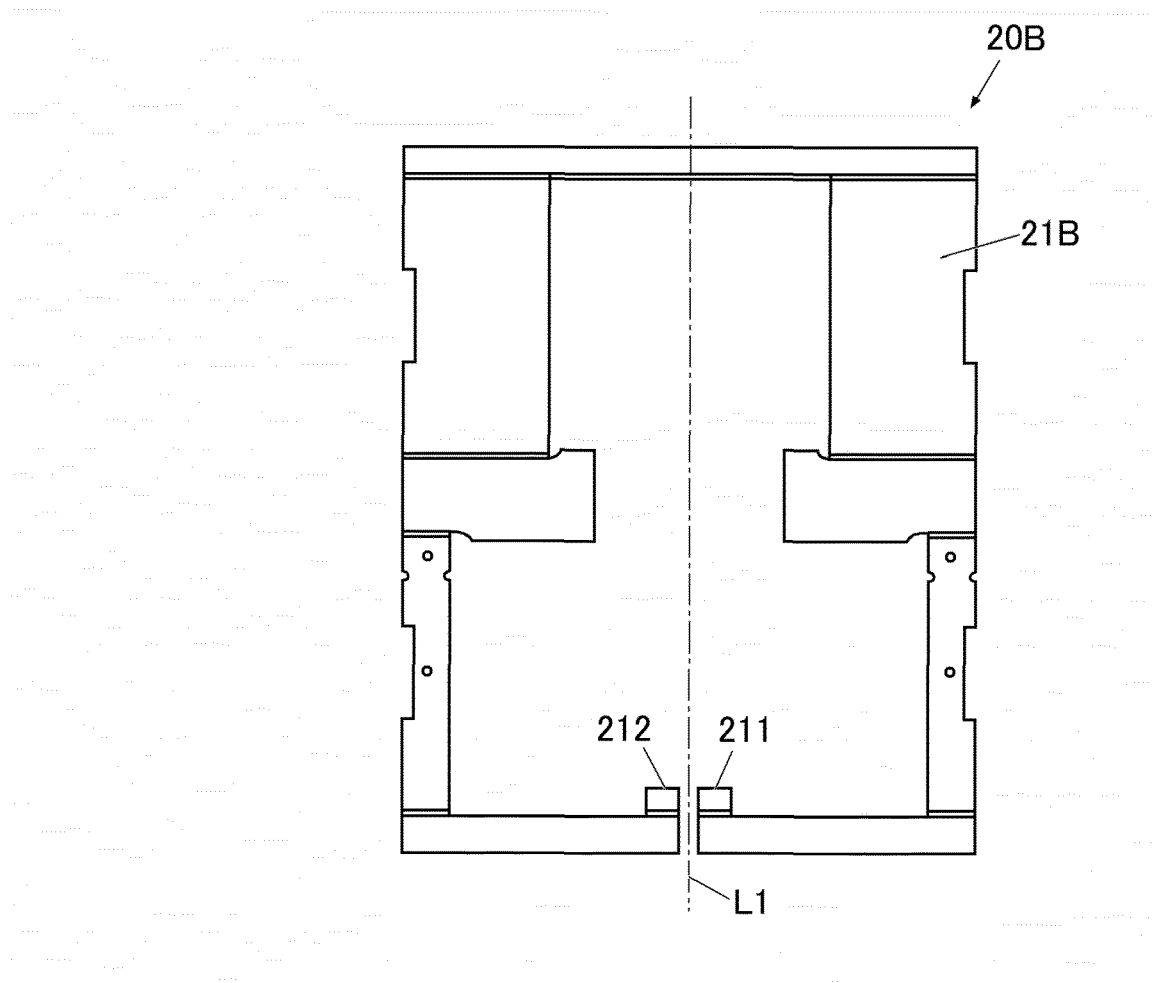


FIG.12A

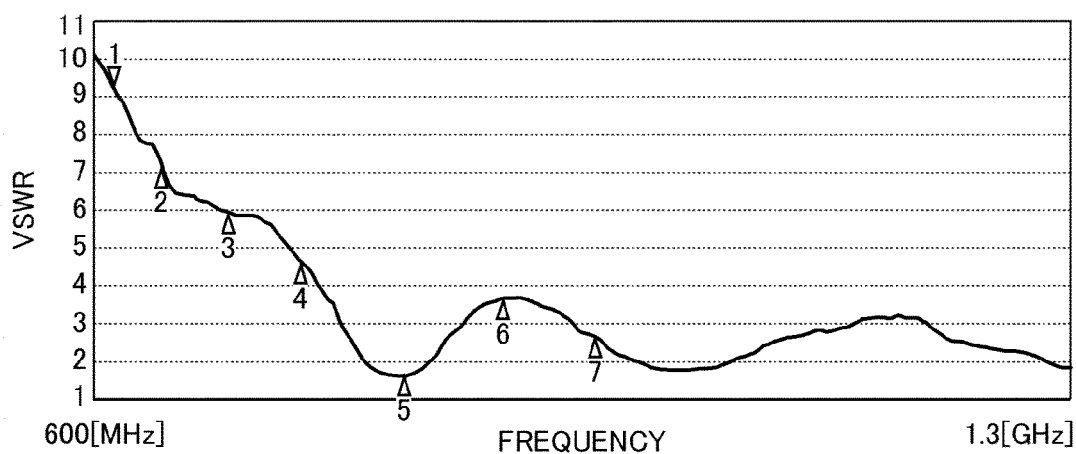


FIG.12B

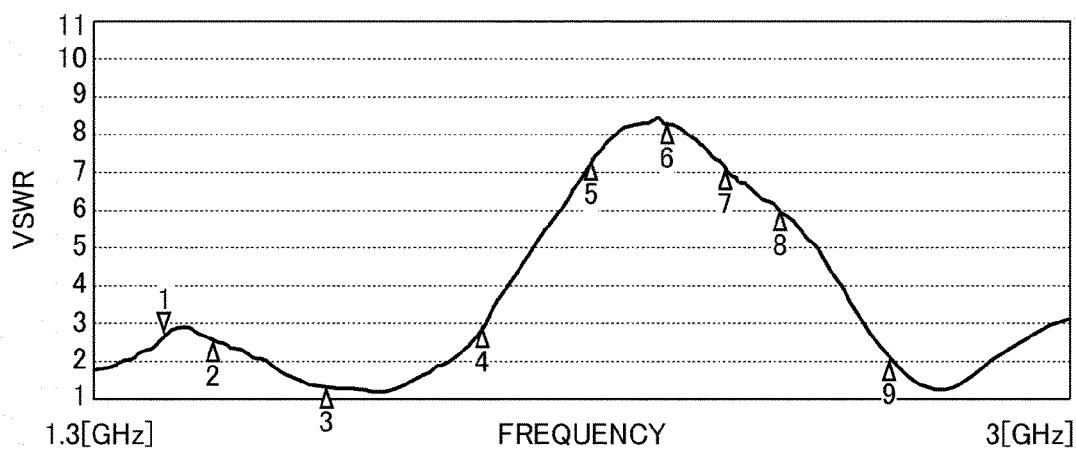


FIG.12C

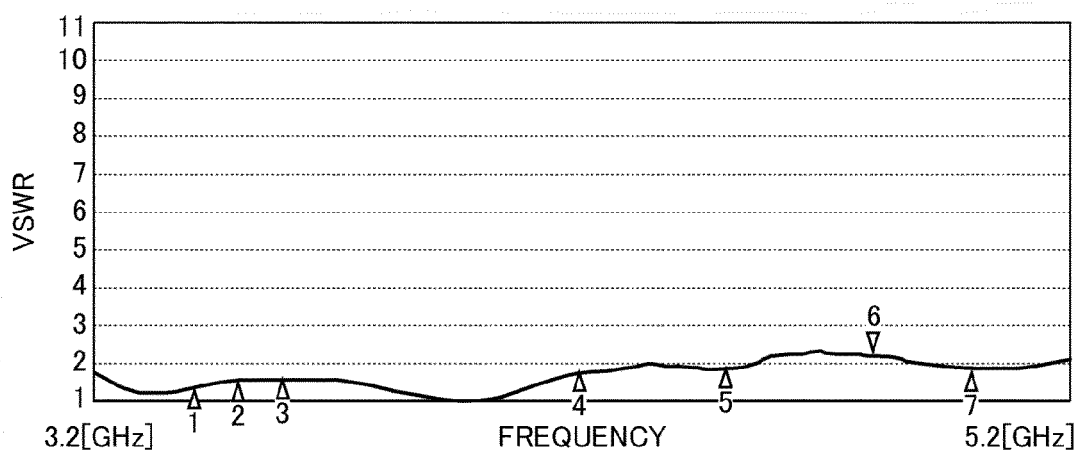


FIG.13

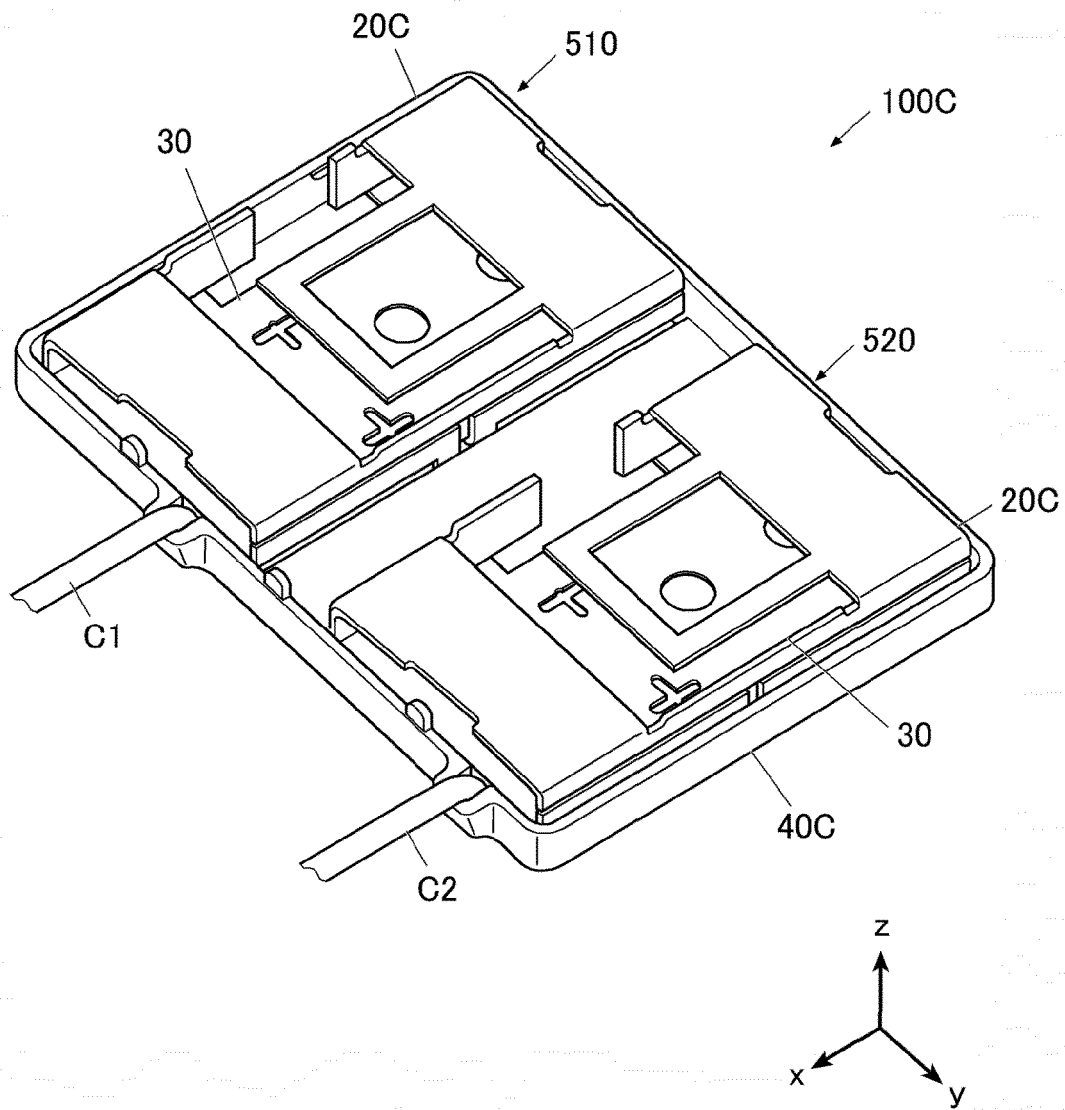


FIG.14

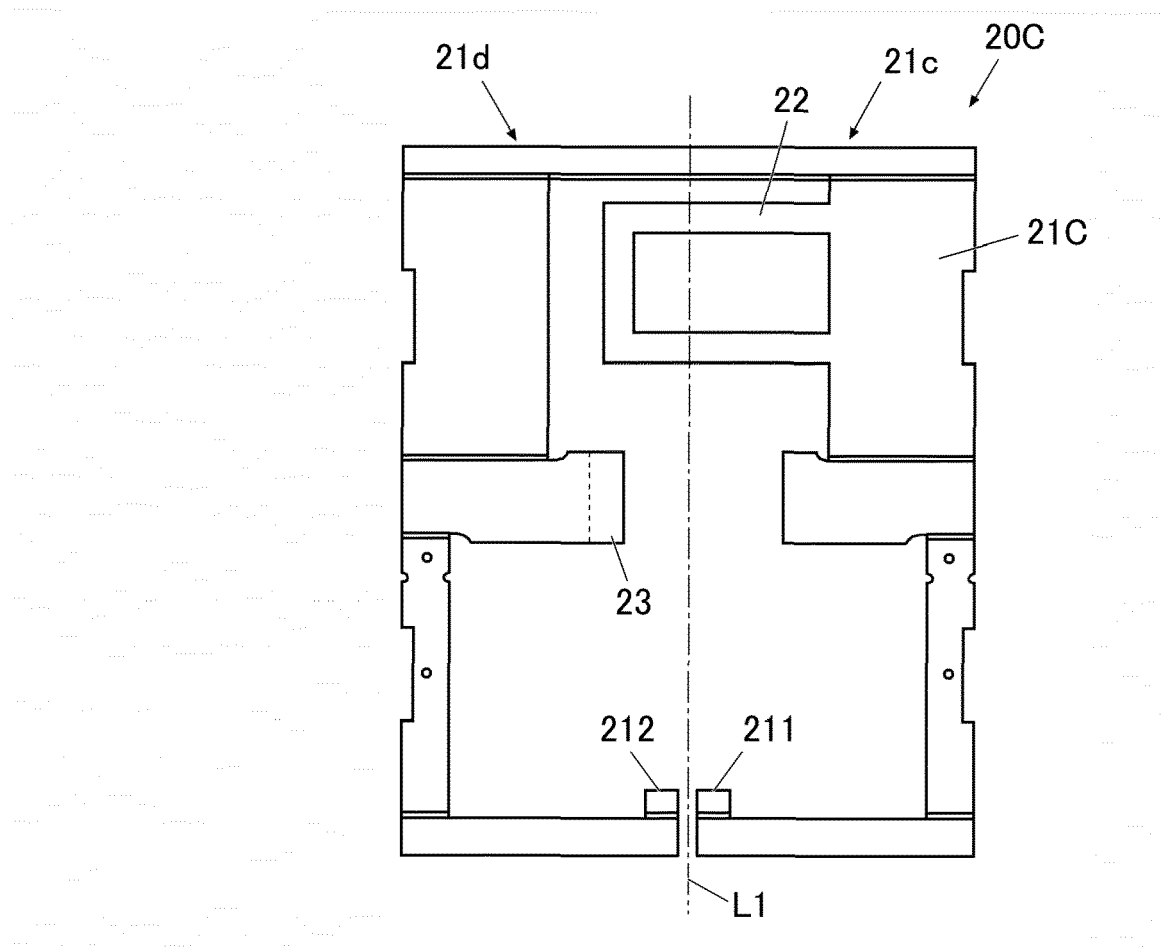


FIG.15A

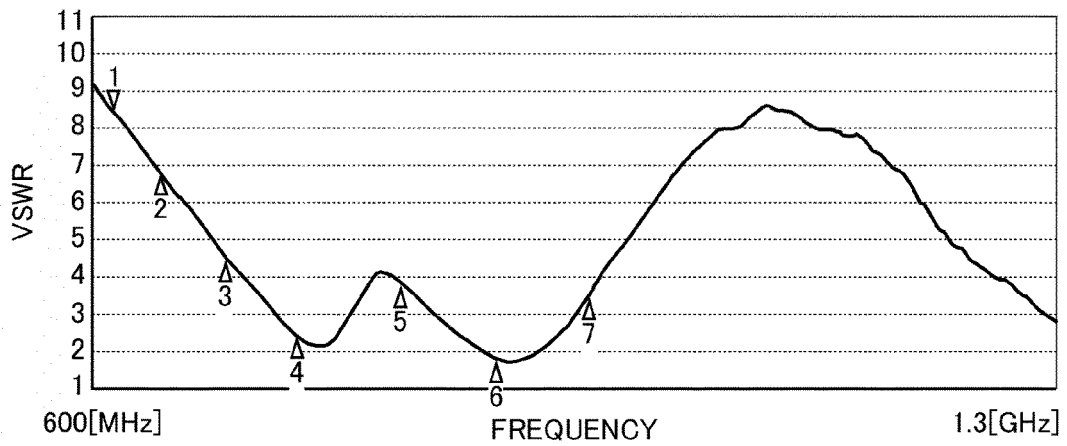


FIG.15B

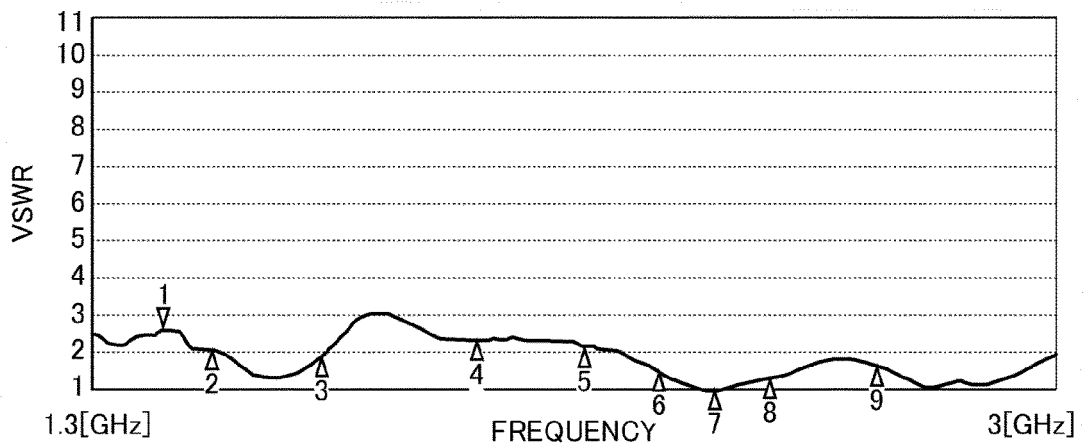


FIG.15C

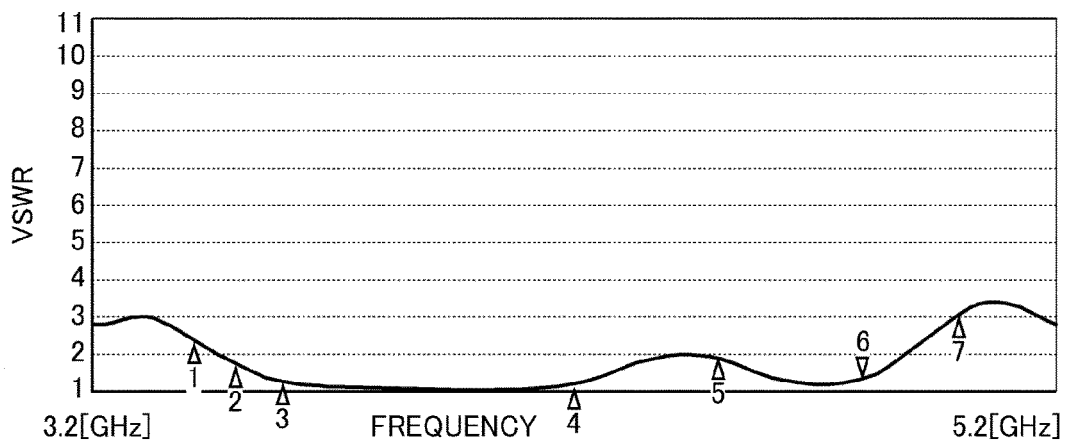


FIG.16A

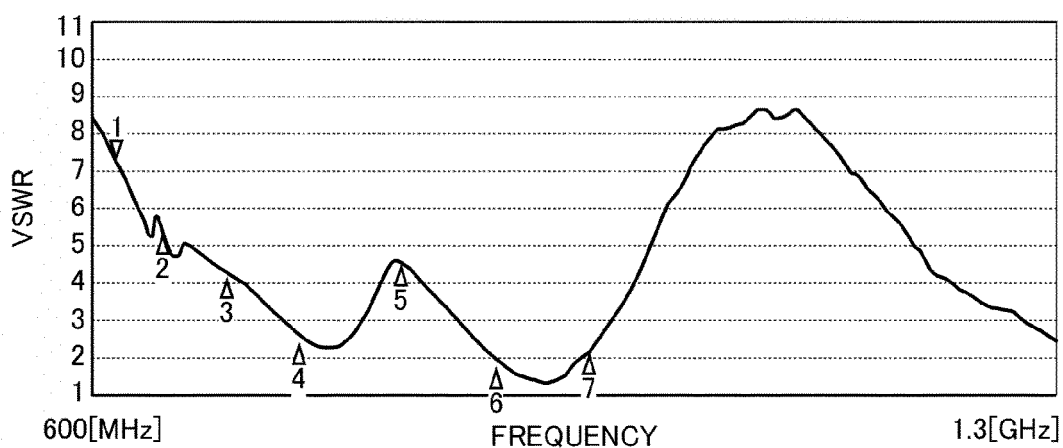


FIG.16B

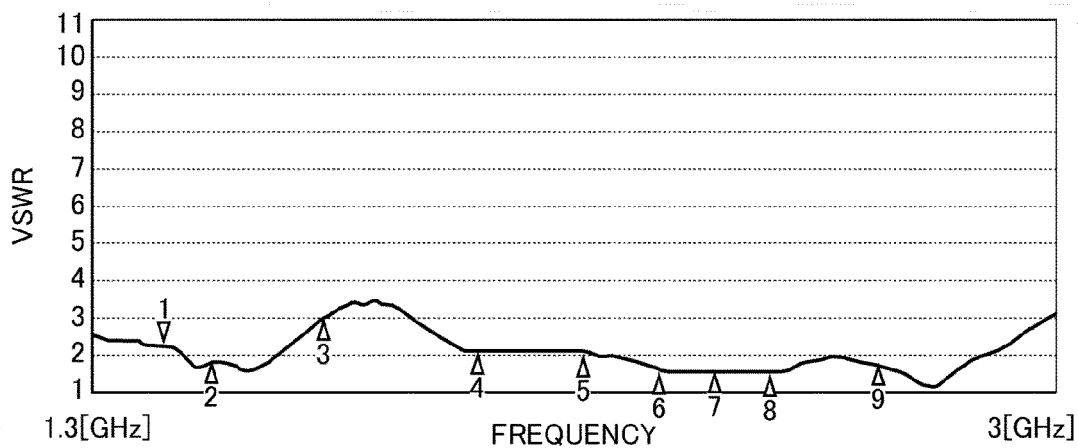


FIG.16C

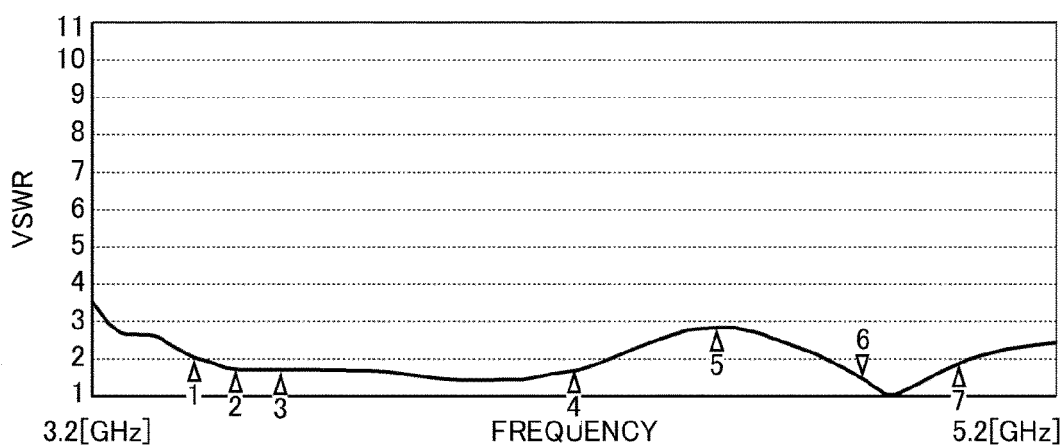
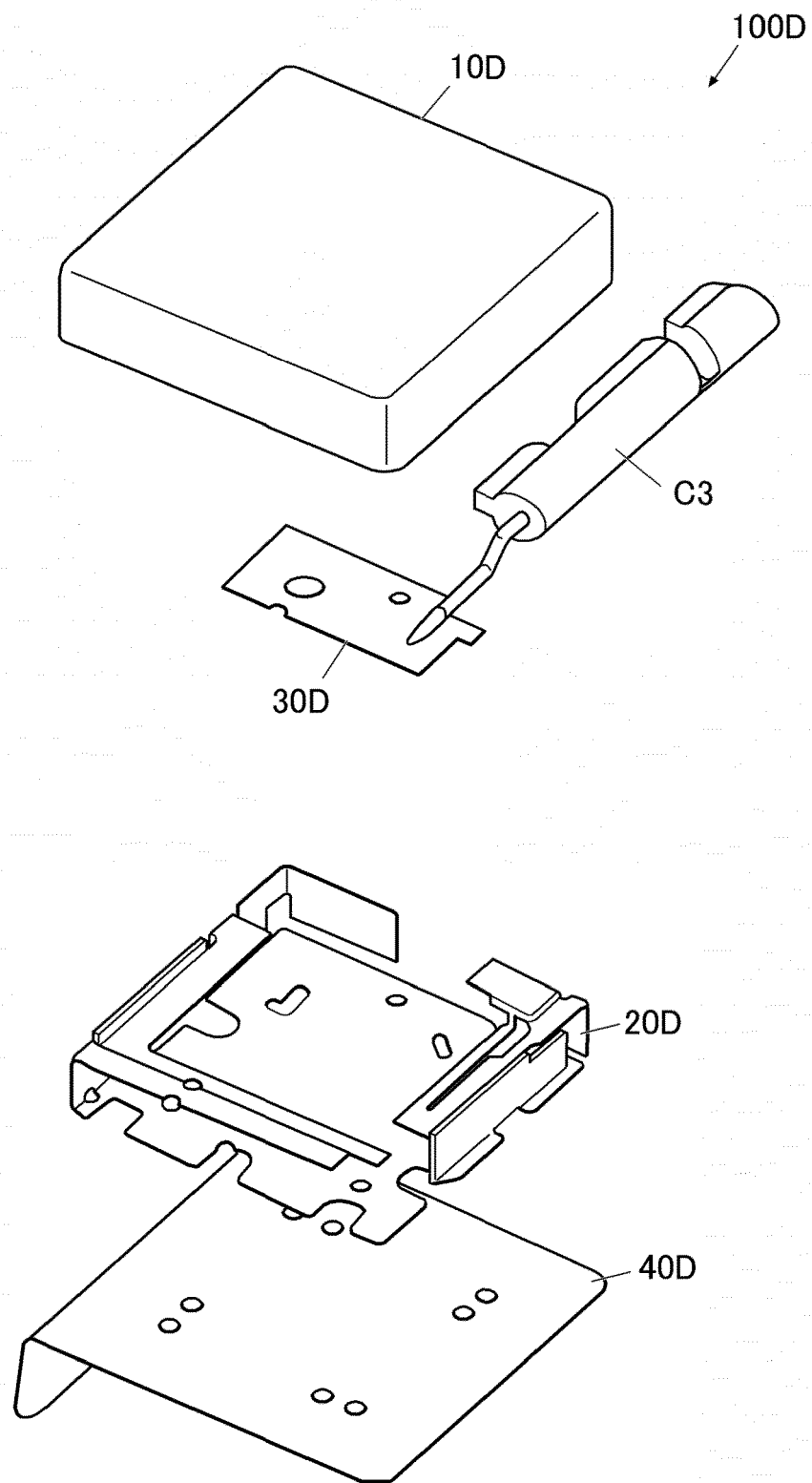


FIG.17





EUROPEAN SEARCH REPORT

Application Number

EP 22 20 1305

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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 2005 260567 A (DENSO CORP) 22 September 2005 (2005-09-22) * figure 1 * * paragraphs [0015], [0016], [0018], [0021] *	1-8	INV. H01Q9/26 H01Q1/32 ADD. H01Q21/28
A	ZHOU D ET AL: "Wideband balanced folded dipole antenna with a dual-arm monopole structure for mobile handsets", IET MICROWAVES ANTENNAS & PROPAGATION,, vol. 4, no. 2, 18 February 2010 (2010-02-18), pages 240-246, XP006034720, ISSN: 1751-8733, DOI: 10.1049/IET-MAP:20080412 * figure 1 * * 2. Antenna design concept and structure *	1-8	
A	US 10 396 442 B2 (STARKEY LABS INC [US]) 27 August 2019 (2019-08-27) * column 4, line 24 - column 5, line 31; figure 4 *	1-8	TECHNICAL FIELDS SEARCHED (IPC) H01Q
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 15 February 2023	Examiner Yvonnet, Yannick
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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15-02-2023

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