



(11) **EP 3 358 675 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
08.08.2018 Bulletin 2018/32

(51) Int Cl.:
H01Q 1/32 (2006.01) **H01Q 5/385 (2015.01)**
H01Q 5/378 (2015.01) **H01Q 9/16 (2006.01)**

(21) Application number: **17159144.9**

(22) Date of filing: **03.03.2017**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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(30) Priority: **02.02.2017 JP 2017017766**

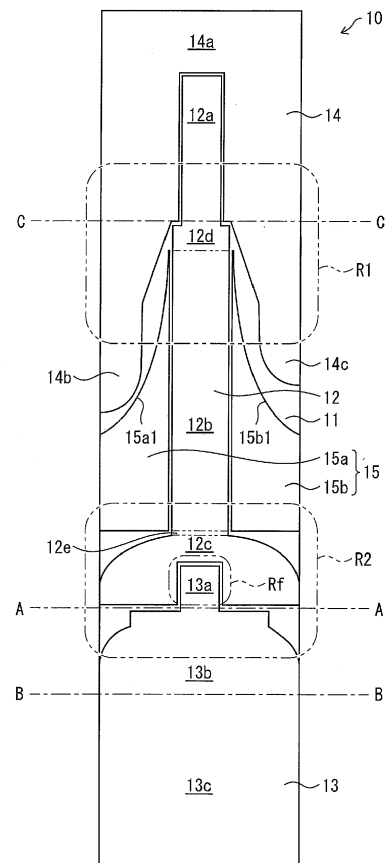
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(54) **ANTENNA**

(57) Provided is an antenna which is used in a state where the antenna is arranged so as to be adjacent to an electric conductor plate and in which dependency on an area of a region of an element which region overlaps the electric conductor plate is suppressed. The antenna includes (i) a first parasitic element (14) which surrounds a tip part (12a) on three sides and (ii) a second parasitic element (15a) and a third parasitic element (15b) between which a middle part (12b) is sandwiched and each of which is galvanically insulated from the first parasitic element (14).

FIG. 1



Description

Technical Field

[0001] The present invention relates to an antenna.

Background Art

[0002] In accordance with expansion of use application of wireless communications, automobiles have been provided with, in addition to conventionally used antennas which operate in frequency bands for FM/AM broadcasting, digital terrestrial broadcasting, and the like, antennas which operate in higher frequency bands, for example, frequency bands for 3G (3rd Generation: third generation mobile phones), LTE (Long Term Evolution), and the like.

[0003] As a method of mounting such an antenna on an automobile, there has been known a method in which an on-vehicle antenna device including therein the antenna is attached to a roof or the like of the automobile. In this case, in order to improve an appearance of the automobile, it is important to cause the on-vehicle antenna device not to be noticeable as much as possible. For example, as a technique of causing an on-vehicle antenna device not to be noticeable as much as possible so as to improve an appearance of an automobile, Patent Literature 1 discloses an on-vehicle antenna device which includes a spoiler as a housing.

[0004] As illustrated in Fig. 2 of Patent Literature 1, the on-vehicle antenna device is configured such that an antenna for LTE is provided in the spoiler which is mounted at a rear end of a roof of an automotive body.

[0005] Further, Patent Literature 1 discloses, in Fig. 4, an on-vehicle antenna device which is arranged so that an element constituting an antenna overlaps a metallic member constituting a rear end part of a roof. By causing the element to overlap the metallic member constituting the rear end part of the roof, it is possible to increase radiant gain in a direction across the roof (frontal direction of an automotive body).

Citation List

[Patent Literature]

[Patent Literature 1]

[0006] PCT International Publication, No. WO 2016/125876 (Published on August 11, 2016)

Summary of Invention

Technical Problem

[0007] However, as illustrated in Fig. 4 of Patent Literature 1, in a case where an antenna is arranged so that an element overlaps a metallic member constituting a rear end part of a roof, input impedance of the antenna

sensitively responds to a change in area of an overlapping region which is a region of the element which region overlaps the roof. This is because, by causing the roof which is constituted by an electric conductor plate to be adjacent to the element, a considerable change is caused in capacitance formed between the element and the roof.

[0008] As such, in a case where the foregoing spoiler including therein the antenna is attached to a rear end of a roof of an automotive body, an area of a region of an element which region overlaps the roof may change, and such a change may cause a change in input impedance of the antenna, depending on a type of an automobile.

[0009] The present invention has been made in view of the above problem, and an object of the present invention is to provide an antenna which is used in a state where the antenna is arranged so as to be adjacent to an electric conductor plate and which has desired input impedance independent of an area of a region of an element which region overlaps the electric conductor plate.

Solution to Problem

[0010] In order to attain the above object, an antenna in accordance with an aspect of the present invention is an antenna including: a first element; a second element; a first parasitic element which surrounds, on three sides, one of ends of the first element which one is farther from a feed region; and a second parasitic element and a third parasitic element between which a middle part of the first element is sandwiched, each of the second parasitic element and the third parasitic element being galvanically insulated from the first parasitic element.

[0011] According the antenna, a given capacitance is formed between the first parasitic element and the one of the ends of the first element, which one is farther from the feed region. Therefore, in a case where the antenna is arranged so that the one of the ends of the first element overlaps an electric conductor plate (for example, an electric conductor plate constituting a roof which is part of an automotive body of an automobile), it is possible to suppress a change in capacitance between the first element and the electric conductor plate even in a case where an area of a region of the first element which region overlaps the electric conductor plate (hereinafter, referred to as an overlapping region) changes. As a result, according to the antenna, it is possible to suppress dependency of input impedance on the area of the overlapping region.

[0012] Furthermore, according to the second parasitic element and the third parasitic element, it is possible to suppress reflection caused by mismatch between (i) impedance between the middle part and the second and third parasitic elements and (ii) impedance of a coaxial cable.

[0013] According to the above configuration, the antenna is capable of having desired input impedance, regardless of how large or small the area of the overlapping

region is. It is therefore possible to provide an antenna which is used in a state where the antenna is arranged so as to be adjacent to an electric conductor plate and which has desired input impedance independent of an area of a region of an element which region overlaps the electric conductor plate.

Advantageous Effects of Invention

[0014] According to an aspect of the present invention, it is possible to provide an antenna which is used in a state where the antenna is arranged so as to be adjacent to an electric conductor plate and which has desired input impedance independent of an area of a region of an element which region overlaps the electric conductor plate.

Brief Description of Drawings

[0015]

Fig. 1 is a plan view illustrating a configuration of an antenna in accordance with an embodiment of the present invention.

(a) of Fig. 2 is an enlarged view illustrating a region R1 of the antenna illustrated in Fig. 1. (b) of Fig. 2 is an enlarged view illustrating a region R2 of the antenna illustrated in Fig. 1.

Fig. 3 is an exploded perspective view illustrating a state where the antenna illustrated in Fig. 1 is arranged in a vicinity of an electric conductor plate.

(a) of Fig. 4 is a plan view of the antenna in the state illustrated in Fig. 3. (b) of Fig. 4 is a right side view of antenna in the state illustrated in Fig. 3.

(a) of Fig. 5 is a perspective view of an automotive body on which the antenna in accordance with an embodiment of the present invention is mounted. (b) of Fig. 5 is an enlarged plan view of the automotive body illustrated in (a) of Fig. 5.

Fig. 6 is a graph showing a VSWR characteristic of an antenna of an Example of the present invention.

Fig. 7 is a plan view illustrating a configuration of an antenna of a Comparative Example.

Fig. 8 is a graph showing a VSWR characteristic of the antenna illustrated in Fig. 7.

Description of Embodiments

[0016] The following description will discuss an antenna 10 in accordance with an embodiment of the present invention with reference to Figs. 1 through 4. The antenna 10 is an antenna which covers a frequency band for LTE (Long-Term Evolution) and which has a plurality of resonance points.

[0017] Fig. 1 is a plan view illustrating a configuration of the antenna 10. (a) of Fig. 2 is an enlarged view of a region R1 (see Fig. 1) of the antenna 10. (b) of Fig. 2 is an enlarged view of a region R2 (see Fig. 1) of the antenna 10. Fig. 3 is an exploded perspective view illustrat-

ing a state where the antenna 10 is arranged in a vicinity of an electric conductor plate 50. (a) of Fig. 4 is a plan view of the antenna 10 in the state illustrated in Fig. 3. (b) of Fig. 4 is a right side view of the antenna 10 in the state illustrated in Fig. 3.

(Configuration of antenna 10)

[0018] As illustrated in Fig. 1, the antenna 10 includes a substrate 11, an element 12, an element 13, a parasitic element 14, and a parasitic element pair 15. The parasitic element pair 15 is made up of a parasitic element 15a and a parasitic element 15b. The element 12, the element 13, the parasitic element 14, the parasitic element 15a, and the parasitic element 15b correspond to a first element, a second element, a first parasitic element, a second parasitic element, and a third parasitic element, respectively, recited in the claims.

<Substrate 11>

[0019] The substrate 11 is constituted by a flexible film dielectric material. Since the substrate 11 is flexible, it is possible to wind the antenna 10 around a support 30 as later described with reference to Figs. 3 and 4. As a material of which the substrate 11 is made, a polyimide resin is employed in the present embodiment. Note, however, that a polyimide resin is merely one of examples of a dielectric material. Therefore, the material is not limited to a polyimide resin. In the present embodiment, the substrate 11 has a rectangular shape. Note that, in the present embodiment, a direction parallel to a long side of the substrate 11 will be referred to as a longitudinal direction, and a direction parallel to a short side of the substrate 11 will be referred to as a width direction.

[0020] The elements 12 and 13 and the parasitic elements 14, 15a, and 15b are each constituted by a thin plate member made of an electrically conductive foil (copper foil in the present embodiment), and are provided on one of surfaces of the substrate 11 by patterning. Each of the elements 12 and 13 is fed with electric power through a feed cable (for example, a coaxial cable 20 illustrated in Fig. 3). The antenna 10 can be referred to as a film antenna and can be also referred to as a FPC (Flexible printed circuits) substrate.

<Element 12>

[0021] The element 12 has a tip part 12a, a middle part 12b, a root part 12c, a connection part 12d, and a connection part 12e. The element 12 extends along the longitudinal direction of the substrate 11 so as to substantially have a belt shape. When viewed along the longitudinal direction of the substrate 11, the root part 12c constitutes one of ends of the element 12 (which one is closer to a straight line A-A illustrated in Fig. 1), and the tip part 12a constitutes the other one of the ends of the element 12 (which other one is farther from the straight line A-A).

[0022] Part of the element 12 which part is surrounded by a body 14a of the parasitic element 14 (later described) is the tip part 12a, and part of the element 12 which part is sandwiched by the parasitic element pair 15 (later described) is the middle part 12b. The root part 12c has a width greater than those of the tip part 12a and the middle part 12b.

[0023] When viewed along the longitudinal direction of the substrate 11, the root part 12c is arranged on a middle part of the substrate 11. When the root part 12c is viewed along the longitudinal direction, the width of the root part 12c is (i) at one of ends of the root part 12c, substantially equal to a length of the short side of the substrate 11 and (ii) at the other one of the ends of the root part 12c, narrower than at the one of the ends of the root part 12c. The width of the root part 12c gradually becomes narrower as the root part 12c extends from the one of the ends of the root part 12c toward the other one of the ends of the root part 12c. As such, the root part 12c has a cup shape (glass shape). Note that the root part 12c has, in the middle of the one of the ends of the root part 12c, a notch having a rectangular shape.

[0024] A belt shaped member extends, from the other one of the ends of the root part 12c, along a direction which is the longitudinal direction and which is a direction away from the straight line A-A. The belt shaped member of the element 12 is made up of the connection part 12e, the middle part 12b, the connection part 12d, and the tip part 12a which are arranged in this order from the root part 12c. Note that a straight line C-C illustrated in Fig. 1 is indicative of a boundary between the connection part 12d and the tip part 12a.

[0025] The width of the root part 12c of the element 12 is, as described above, greater than that of the other part (the connection part 12e, the middle part 12b, the connection part 12d, and the tip part 12a) of the element 12. Note that a gap W3 between the root part 12c and the parasitic element 15a and a gap W4 between the root part 12c and the parasitic element 15b (see (b) of Fig. 2) will be later described in a section of the parasitic element pair 15.

[0026] Since the connection part 12d is inserted between the tip part 12a and the middle part 12b, it is possible to prevent the parasitic element 14 (later described) and the parasitic element pair 15 (later described) from being short-circuited. Furthermore, since the connection part 12e is inserted between the middle part 12b and the root part 12c, it is possible to prevent the root part 12c and the parasitic element pair 15 (later described) from being short-circuited. Note that a shape of the connection part 12d and a shape of the connection part 12e (in particular, the shape of the connection part 12d) are each not limited to a shape illustrated in Fig. 1.

<Element 13>

[0027] The element 13 has a root part 13a, a middle part 13b, and a tip part 13c. The root part 13a has a

rectangular shape, and is arranged along the notch of the root part 12c. A belt shaped electric conductor extends, from one of ends of the root part 13a (which one is closer to the straight line A-A), along a direction which is the longitudinal direction and which is, out of directions away from the straight line A-A, a direction opposite to a direction in which the belt shaped member of the element 12 extends. Therefore, the straight line A-A illustrated in Fig. 1 is indicative of a main boundary between the element 12 and the element 13.

[0028] The belt shaped electric conductor of the element 13 is made up of the middle part 13b and the tip part 13c which are arranged in this order from the root part 13a. The tip part 13c has a width which is uniform and which is substantially equal to the length of the short side of the substrate 11. Therefore, the width of the tip part 13c is greater than that of the root part 13a. A straight line B-B illustrated in Fig. 1 is indicative of a boundary between the middle part 13b and the tip part 13c.

[0029] The middle part 13b has a width which (1) is, at the boundary between the middle part 13b and the tip part 13c (at the straight line B-B), equal to that of the tip part 13c, (2) is, at a boundary between the middle part 13b and the root part 13a (at the straight line A-A), equal to that of the root part 13a, and (3) gradually becomes narrower as the middle part 13b extends from the boundary between the middle part 13b and the tip part 13c toward the boundary between the middle part 13b and the root part 13a. As such, it can be expressed that the middle part 13b has a cup shape (glass shape).

[0030] The antenna 10 is designed on the assumption that (i) one of electric conductors, of which the feed cable is made up, is connected to the root part 12c of the element 12 and (ii) the other one of the electric conductors, of which the feed cable is made up, is connected to the root part 13a of the element 13. Here, a region, including (i) a region of the root part 12c to which region the one of the electric conductors is connected and which region is in a vicinity of the notch of the root part 12c and (ii) the root part 13a to which the other one of the electric conductors is connected, will be referred to as a feed region Rf. The feed region Rf is located in a vicinity of the straight line A-A and on a side of the straight line A-A on which side the belt shaped member of the element 12 extends.

[0031] Therefore, the root part 12c constitutes one of the ends of the element 12 which one is closer to the feed region Rf, and the tip part 12a constitutes the other one of the ends of the element 12 which other one is farther from the feed region Rf. Meanwhile, the root part 13a constitutes one of ends of the element 13 which one is closer to the feed region Rf, and the tip part 13c constitutes the other one of the ends of the element 13 which other one is farther from the feed region Rf.

<Parasitic element 14>

[0032] The parasitic element 14 has a body 14a, a sub element 14b, and a sub element 14c. The sub element

14b and the sub element 14c correspond to a first extending part and a second extending part, respectively, recited in the claims.

[0033] The body 14a is arranged so as to be adjacent to the tip part 12a of the element 12 and so as to surround the tip part 12a on three sides. The body 14a substantially has a rectangular shape, and has a width substantially equal to that of the substrate 11. In the middle of one of two sides, extending along the width direction, of such a rectangle which one is closer to the straight line A-A (hereinafter, referred to as one of sides of the body 14a), a notch which has a rectangular shape and which corresponds to a shape of the tip part 12a is provided. A position of the one of the sides of the body 14a matches that of the straight line C-C. The tip part 12a is arranged in the notch thus provided of the body 14a so as to be adjacent to the body 14a.

[0034] The parasitic element 14 thus arranged is set so that a gap W1 between the body 14a and the tip part 12a (see (a) of Fig. 2) is uniform on three sides on which the body 14a surrounds the tip part 12a. Note that the width of the tip part 12a and the gap W1 are set, as appropriate, so that impedance between the tip part 12a and the body 14a has a value suitable for a virtual feed point.

[0035] Since the parasitic element 14 having the body 14a is provided, a given capacitance is formed between the tip part 12a and the body 14a of the parasitic element 14. Therefore, in a case where the antenna 10 is arranged so that the tip part 12a overlaps an electric conductor plate (for example, an electric conductor plate constituting a roof which is part of an automotive body of an automobile), it is possible to suppress a change in capacitance between the element 12 and the electric conductor plate even in a case where an area of a region of the tip part 12a of the element 12 which region overlaps the electric conductor plate (hereinafter, referred to as an overlapping region) changes. As a result, according to the antenna 10, it is possible to suppress dependency of input impedance on the area of the overlapping region.

[0036] The sub element 14b and the sub element 14c extend, from respective parts of the one of the sides of the body 14a in which parts the notch is not provided, along a direction which is the longitudinal direction and which is a direction toward the straight line A-A. The sub element 14b and the sub element 14c extend along respective outer sides of the parasitic element 15a and the parasitic element 15b (later described).

[0037] Since the body 14a is arranged so as to be adjacent to the tip part 12a, electromagnetic coupling is formed between the tip part 12a and the body 14a. As a result, a boundary region between the tip part 12a and the body 14a functions as a virtual feed point. In other words, the parasitic element 14 functions as a kind of element, although the parasitic element 14 is a parasitic element galvanically insulated from the element 12.

[0038] A length of the sub element 14b which length is measured from the straight line C-C along the longitudi-

dinal direction will be referred to as an element length of the sub element 14b. Similarly, a length of sub element 14c which length is measured from the straight line C-C along the longitudinal direction will be referred to as an element length of the sub element 14c. The element length of the sub element 14b is set so as to be longer than that of the sub element 14c. Therefore, a virtual electrical length of the sub element 14b is longer than that of the sub element 14c.

<Parasitic element pair 15>

[0039] As has been described, the parasitic element pair 15 is made up of the parasitic element 15a and the parasitic element 15b. The parasitic element 15a and the parasitic element 15b are arranged so that the middle part 12b of the element 12 is sandwiched between the parasitic element 15a and the parasitic element 15b and so that the parasitic element 15a and the parasitic element 15b are adjacent to respective both sides of the middle part 12b (which both sides faces each other in a state where the width direction is a normal direction). Note that the parasitic element 15a is galvanically insulated from each of the parasitic element 14 and the element 12. Similarly, the parasitic element 15b is galvanically insulated from each of the parasitic element 14 and the element 12.

[0040] The parasitic element 15a substantially has a trapezoidal shape, although a leg 15a1 which is one of legs of such a trapezoid is curved. That is, two sides extending along a direction in which the middle part 12b extends (two sides constituting respective lower and upper bases of the trapezoid) are parallel to each other. Note that, in the present embodiment, the lower base and the upper base are each parallel to the direction in which the middle part 12b extends.

[0041] The parasitic element 15a and the parasitic element 15b are symmetrical with respect to a center line, serving as a symmetrical axis, of the middle part 12b (a line passing through a midpoint, in the width direction, of the middle part 12b). That is, the parasitic element 15b substantially has a trapezoidal shape, although a leg 15b1 is curved, as with the case of the parasitic element 15a.

[0042] A side of the parasitic element pair 15, made up of the parasitic element 15a and the parasitic element 15b, which side is closer to the middle part 12b will be referred to as an inner side, and a side of the parasitic element pair 15 which side is farther from the middle part 12b will be referred to as an outer side. Therefore, the lower base of the parasitic element 15a constitutes an innermost part of a contour of the parasitic element 15a, and the upper base of the parasitic element 15a constitutes an outermost part of the contour of the parasitic element 15a. The leg 15a1 constitutes part of an outer part of the contour of the parasitic element 15a. In regard to the parasitic element 15b, an inner side and an outer side are similarly defined.

[0043] The parasitic element pair 15 thus arranged is set so that a gap W2 between the parasitic element 15a and the middle part 12b and a gap W2 between the parasitic element 15b and the middle part 12b (see (a) of Fig. 2) are uniform. Note that the width of the middle part 12b and the gaps W2 are set, as appropriate, so that impedance between the middle part 12b and the parasitic element pair 15 matches impedance of the feed cable. By thus causing the impedance between the middle part 12b and the parasitic element pair 15 to match the impedance of the feed cable, it is possible to suppress reflection caused by mismatch between (i) the impedance between the middle part 12b and the parasitic element pair 15 and (ii) the impedance of the feed cable.

[0044] The antenna 10 including the foregoing parasitic element 14 and the foregoing parasitic element pair 15 is capable of having desired input impedance, regardless of how large or small the area of the overlapping region is. It is therefore possible to provide an antenna which is used in a state where the antenna is arranged so as to be adjacent to an electric conductor plate and which has desired input impedance independent of an area of a region of an element which region overlaps the electric conductor plate.

[0045] Note that the antenna 10 is preferably used while (i) the element 12 is being connected to a cold side electric conductor of the feed cable and (ii) the element 13 is being connected to a hot side electric conductor of the feed cable. In this case, it is possible to further suppress the dependency of the input impedance on the area of the overlapping region, as compared with a case where (i) the element 12 is connected to the hot side electric conductor of the feed cable and (ii) the element 13 is connected to the cold side electric conductor of the feed cable.

[0046] Specifically, as illustrated in (b) of Fig. 2, part of the element 12 (the root part 12c) which part is included in the feed region Rf is set as a cold side feed point Pc, and part of the element 13 (the root part 13a) which part is included in the feed region Rf is set as a hot side feed point Ph. In a case where the feed cable is connected to the antenna 10, the cold side electric conductor of the feed cable is connected to the feed point Pc, and the hot side electric conductor of the feed cable is connected to the feed point Ph. The feed cable can be connected to the feed points Pc and Ph with use of, for example, solder.

[0047] Note that, in the present embodiment, according to comparison between the width of the tip part 12a and the width of the middle part 12b, the width of the middle part 12b is greater than that of the tip part 12a. This is merely because the element 12 is designed so that (1) the impedance between the tip part 12a and the body 14a and (2) the impedance between the middle part 12b and the parasitic element pair 15 have respective suitable values. Therefore, a relationship between the width of the tip part 12a and the width of the middle part 12b is not limited in particular.

[0048] Further, as illustrated in (b) of Fig. 2, the root

part 12c of the element 12 is part of the element 12 which part is most adjacent to the element 13. Since the width of the root part 12c, which is adjacent to the element 13, of the element 12 is greater than that of the other part (the tip part 12a, the middle part 12b, the connection part 12d, and the connection part 12e) of the element 12, the element 12 is capable of operating suitably as a cold side element.

[0049] Moreover, the fact that the element 12 has the root part 12c allows an increase in resonance frequency of the antenna 10. Therefore, it is possible to expand an operation band of the antenna 10.

[0050] Note that, in order that impedance between the element 12 and the element 13 has a desired value, gaps W5 and W6 between the element 12 and the element 13 are each arranged so as to, along a width direction of the element 13, be narrower on a center side of the element 13 and wider on an outer side of the element 13.

[0051] The gap W3 between the parasitic element 15a and the root part 12c is arranged so as to, along a width direction of the root part 12c (direction along the straight line A-A), become wider as extending from a center side of the root part 12c toward an outer side of the root part 12c (see (b) of Fig. 2). Similarly, the gap W4 between the parasitic element 15b and the root part 12c is arranged so as to, along the width direction of the root part 12c, become wider as extending from the center side of the root part 12c toward the outer side of the root part 12c.

[0052] A capacitance formed between the element 12 and the parasitic element 15a can be adjusted with use of the gap W3. Similarly, a capacitance formed between the element 12 and the parasitic element 15b can be adjusted with use of the gap W4. Therefore, according to the antenna 10, it is possible to easily cause impedance of the element 12 to match the impedance of the feed cable. Therefore, according to the antenna 10, it is possible to suppress a return loss in the element 12.

[0053] In order that the gaps W3 and W4 are arranged in such a way, the root part 12c is arranged such that a side of the root part 12c which side faces a leg 15a2 of the parasitic element 15a and a side of the root part 12c which side faces a leg 15b2 of the parasitic element 15b are each constituted by a quarter-ellipse. That is, the root part 12c has a cup shape. According to such arrangement, it is possible to cause each of the gaps W3 and W4 to be narrower on the center side of the root part 12c and wider on the outer side of the root part 12c without reducing an area of each of the parasitic elements 15a and 15b.

[0054] As has been described, the sub element 14b and the sub element 14c extend along the respective outer sides of the parasitic element 15a and the parasitic element 15b. Since each of the parasitic element 15a and the parasitic element 15b substantially has a trapezoidal shape, it is possible to arrange each of the sub element 14b and the sub element 14c on an outer side of a corresponding one of the parasitic element 15a and the parasitic element 15b without excessively reducing

an area of the corresponding one of the parasitic element 15a and the parasitic element 15b. Furthermore, since each of the leg 15a1 and the leg 15b1 is curved toward an inside of the substantial trapezoid, it is possible to set the element length of each of the sub element 14b and the sub element 14c to be longer.

[0055] The fact that the parasitic element 14 has the sub element 14b and the sub element 14c allows an increase in resonance frequency of the antenna 10. Therefore, it is possible to expand the operation band of the antenna 10. The sub element 14b and the sub element 14c are preferably different from each other in element length. This allows the sub element 14b and the sub element 14c to be different from each other in virtual electrical length. Therefore, it is possible to further increase the resonance frequency of the antenna 10.

(Arrangement of antenna 10 in vicinity of electric conductor plate)

[0056] It is assumed that the antenna 10 is used in a state where the antenna 10 is mounted on an automotive body of an automobile. For example, a case where the antenna 10 is housed in a spoiler 116 mounted at a rear end of a roof 120 of an automotive body 101 is assumed (later described with reference to Fig. 5). In this case, the antenna 10 is connected to the coaxial cable 20, which is an aspect of the feed cable, and is housed in the spoiler 116 in a state where the antenna 10 is wound around the support 30 illustrated in Fig. 3. Note that illustration of the support 30 is omitted in Fig. 4.

[0057] The electric conductor plate 50 illustrated in Figs. 3 and 4 is one that is modeled on a spoiler fixing section 121d of the roof 120 illustrated in (b) of Fig. 5. Note that a frontal direction of the automotive body 101 corresponds to a plus direction of a y-axis in coordinate systems illustrated in Figs. 3 and 4.

[0058] The support 30 substantially has a rectangular parallelepiped shape, and is surrounded by walls 31 through 36 on six sides. The wall 31 and the wall 36 face each other, and are arranged along an xy plane in the coordinate system illustrated in Fig. 3. The wall 32 and the wall 35 face each other, and are arranged along a zx plane in the coordinate system illustrated in Fig. 3. The wall 33 and the wall 34 face each other, and are arranged along a yz plane in the coordinate system illustrated in Fig. 3. The wall 31 is an upper wall, the wall 32 is a rear side wall, the wall 33 is a right side wall, the wall 34 is a left side wall, the wall 35 is a front side wall, and the wall 36 is a lower wall, in a state where the walls 31 through 36 are illustrated in Fig. 3.

[0059] The antenna 10 is wound around the support 30 so that (1) the tip part 13c is in contact with the wall 36, (2) the middle part 13b is in contact with the wall 32, and (3) the root part 13a, the root part 12c, the connection part 12e, part of the middle part 12b, and part of parasitic element pair 15 are in contact with the wall 31. Note that the antenna 10 can be fixed to the support 30 by an ex-

isting method as appropriate. For example, the antenna 10 can be adhered to the support 30 with use of fixing means such as a double-sided adhesive tape or a resin adhesive. Alternatively, the support 30 can be, for example, arranged such that the wall 31 and the wall 36 have respective protrusions, and the antenna 10 can be hooked on the protrusions.

[0060] In a case where the antenna 10 wound around the support 30 is mounted at the rear end of the roof 120, the tip part 12a of the element 12 of the antenna 10 is preferably caused to overlap the rear end of the roof 120 so as to increase radiant gain in a direction across the roof 120 from the rear end of the roof 120, that is, in the frontal direction of the automotive body 101. According to a state illustrated in each of Figs. 3 and 4, the tip part 12a is preferably caused to overlap the electric conductor plate 50. In this case, a region of the antenna 10 which region overlaps the electric conductor plate 50 will be referred to as an overlapping region R3.

[0061] A length of the tip part 12a which length is measured along a direction in which the element 12 extends (y-axis direction in the coordinate system illustrated in Fig. 4) will be referred to as a length L1. A length of part, included in the overlapping region R3, of the tip part 12a which length is measured along the direction in which the element 12 extends will be referred to as a length L2.

[0062] The antenna 10 includes the parasitic element 14 which surrounds the tip part 12a. Accordingly, even in a case where the length L2 is changed, it is possible to suppress a change in capacitance formed between the element 12 and the electric conductor plate 50, provided that $0 \text{ (zero)} < L2 \leq L1$. Therefore, according to the antenna 10, it is possible to suppress dependency of the input impedance on an area of the overlapping region R3.

[0063] It is therefore possible to increase a degree of freedom of a position at which the antenna 10 is mounted, in a case where the antenna 10 is mounted on the automobile. In other words, the antenna 10 is a highly versatile antenna, as compared with a conventional antenna, and it is possible to mount the antenna 10 on various types of automobiles without changing a design of the antenna 10. As a result, since it is not necessary to change (optimize) the design of the antenna 10 in accordance with a type of an automobile on which the antenna 10 is to be mounted, it is possible to suppress a production cost.

[Example of how antenna 10 is mounted on automobile]

[0064] Example of how the antenna 10 is mounted on an automobile will be described below with reference to Fig. 5. (a) of Fig. 5 is a perspective view of the automotive body 101 on which the antenna 10 is mounted. (b) of Fig. 5 is an enlarged plan view of the automotive body 101 illustrated in (a) of Fig. 5.

[0065] The automotive body 101 is a hatchback type automotive body. According to the automotive body 101, an outer plate (body panel) including the roof 120 is constituted by a metallic member such as a steel plate or an

aluminum plate, and the roof 120 has a substantially horizontal surface. That is, the roof 120 lies along a horizontal plane and intersects with an up-and-down direction of the automotive body 101. The roof 120 is a specific example of the electric conductor plate 50 illustrated in Fig. 3. In the following description, a direction along the roof 120 is synonymous with a direction along the horizontal plane (xy plane in a coordinate system illustrated in Fig. 5), and a direction perpendicular to the roof 120 is synonymous with a direction perpendicular to the horizontal plane.

[0066] As illustrated in Fig. 5, the antenna 10 is mounted at the rear end of the roof 120 in a state where the antenna 10 is housed in the spoiler 116 which functions as a housing. Therefore, the antenna 10 constitutes an on-vehicle antenna device 110 together with the coaxial cable 20, the support 30, and the spoiler 116.

[0067] A hatch gate 121 of the automotive body 101 is made up of a hatch gate panel 121a which constitutes a lower part of the hatch gate 121, a frame body 121c which constitutes an upper part of the hatch gate 121, and a rear glass 121b. The frame body 121c is made up of two vertical poles and two beams, and the rear glass 121b is fitted in the frame body 121c. One of the two beams of the frame body 121c which one is adjacent to the roof 120 (upper one of the two beams) is attached to the rear end of the roof 120 with use of a hinge (not illustrated). Each of the hatch gate panel 121a and the frame body 121c is constituted by a metallic member.

[0068] The spoiler fixing section 121d is provided to part of the upper one of the two beams of the frame body 121c. Part of the upper one of the two beams of the frame body 121c is caused to protrude rearward, and the part thus protruding is used as the spoiler fixing section 121d. The spoiler fixing section 121d is constituted by a metallic member, as with the case of the frame body 121c. A surface of the spoiler fixing section 121d to which surface the spoiler 116 is attached faces substantially in a zenith direction and lies along the horizontal plane, as with the case of the surface of the roof 120. As such, the spoiler fixing section 121d constitutes a rear end part of the roof 120. In the present embodiment, the spoiler fixing section 121d is constituted by a metallic member which is integrally formed with the frame body 121c. Note, however, that the spoiler fixing section 121d can be constituted by a metallic member which is formed separately from the frame body 121c and is fixed to the frame body 121c with use of a bolt or the like.

[0069] The spoiler 116 is attached to the spoiler fixing section 121d with use of fixing means (e.g., a bolt or the like, not illustrated). In a case where the spoiler 116 is fixed to the spoiler fixing section 121d, an upper surface of the spoiler 116 becomes substantially flush with an entire upper surface of the roof 120. The spoiler 116 has functions of improving an appearance of the automotive body 101, improving an aerodynamic characteristic of the automotive body 101, and the like, and also functions as a housing of the on-vehicle antenna device 110. In

the spoiler 116, the antenna 10 and a stop lamp 119 are incorporated. The spoiler 116 is made of a dielectric substance (e.g., resin), and transmits an electromagnetic wave.

[0070] The antenna 10 is arranged at a location inside the spoiler 116 at which location the antenna 10 does not interfere with the stop lamp 119. Specifically, the antenna 10 is arranged on a left side of the stop lamp 119 so as to avoid the stop lamp 119 which is arranged in the middle, in a right-and-left direction, of the spoiler 116.

[Example]

[0071] Fig. 6 is a graph showing frequency dependency of a VSWR (Voltage Standing Wave Ratio) of an antenna 10. In the following description, the frequency dependency of the VSWR will be referred to a VSWR characteristic. Note that Fig. 6 shows (i) the VSWR characteristic obtained in a case where $L2 = L1$ and (ii) the VSWR characteristic obtained in a case where $L2 = L1/2$.

[0072] The antenna 10 of the Example was designed so as to be targeted for a frequency band of not less than 698 MHz and not more than 960 MHz, that is, a lower frequency band out of a frequency band for LTE. The antenna 10 of the Example was obtained by arranging the antenna 10 illustrated in Fig. 1 such that (i) a length of the substrate 11 was 173 mm and (ii) a width of the substrate 11 was 40 mm.

[0073] According to the antenna 10 of the Example, as is clear from Fig. 6, it was possible to suppress a difference between (i) the VSWR characteristic obtained in the case where $L2 = L1$ and (ii) the VSWR characteristic obtained in the case where $L2 = L1/2$, in a frequency band of not less than 650 MHz and not more than 1,000 MHz which frequency band is broader than the frequency band for which the antenna 10 was targeted. Furthermore, it was possible to obtain desired input impedance in each of (i) the case where $L2 = L1$ and (ii) the case where $L2 = L1/2$.

[Comparative Example]

[0074] Fig. 7 is a plan view schematically illustrating a configuration of an antenna 60 in accordance with a Comparative Example for comparison with the antenna 10. The antenna 60 included a substrate 61, an element 62 provided on one of surfaces of the substrate 61, and an element 63 provided on the one of the surfaces of the substrate 61. The element 62 was connected to an outer electric conductor (cold side electric conductor) of a coaxial cable, as with the case of an element 12 of the antenna 10. The element 63 was connected to a center electric conductor (hot side electric conductor) of the coaxial cable, as with the case of an element 13 of the antenna 10. The antenna 60 had a configuration identical to that of an antenna 91B illustrated in Fig. 15 of Patent Literature 1. Therefore, the antenna 60 will not be described here in detail.

[0075] A length from a straight line C-C to an end of the element 62, which length was measured along a direction in which the element 62 extended, was referred to as a length L3. Further, in a case where the antenna 60 was arranged so that the element 62 overlapped an electric conductor plate 50, a length of a region, overlapping the electric conductor plate 50, of the element 62 which length was measured along the direction in which the element 62 extended was referred to as a length L4. The length L3 and the length L4 of the antenna 60 correspond to the length L1 and the length L2, respectively, of the antenna 10.

[0076] Fig. 8 is a graph showing a VSWR characteristic of the antenna 60. Fig. 8 shows (i) the VSWR characteristic obtained in a case where $L4 = L3$ and (ii) the VSWR characteristic obtained in a case where $L4 = L3/2$. It was found that there was a considerable difference between (i) the VSWR characteristic obtained in the case where $L4 = L3$ and (ii) the VSWR characteristic obtained in the case where $L4 = L3/2$, as compared with the VSWR characteristic of the antenna 10 illustrated in Fig. 6.

[0077] The VSWR characteristic obtained in the case where $L4 = L3/2$ indicated that the antenna 60 was sufficiently practical as an antenna for LTE. However, the VSWR characteristic obtained in the case where $L4 = L3$ did not indicate that the antenna 60 was sufficiently practical as an antenna for LTE. As such, according to the antenna 60, it was not possible to obtain desired input impedance in the case where $L4 = L3$.

(Summary)

[0078] In order to attain the above object, an antenna in accordance with an aspect of the present invention is an antenna including: a first element; a second element; a first parasitic element which surrounds, on three sides, one of ends of the first element which one is farther from a feed region; and a second parasitic element and a third parasitic element between which a middle part of the first element is sandwiched, each of the second parasitic element and the third parasitic element being galvanically insulated from the first parasitic element.

[0079] According to the antenna, a given capacitance is formed between the first parasitic element and the one of the ends of the first element, which one is farther from the feed region. Therefore, in a case where the antenna is arranged so that the one of the ends of the first element overlaps an electric conductor plate (for example, an electric conductor plate constituting a roof which is part of an automotive body of an automobile), it is possible to suppress a change in capacitance between the first element and the electric conductor plate even in a case where an area of a region of the first element which region overlaps the electric conductor plate (hereinafter, referred to as an overlapping region) changes. As a result, according to the antenna, it is possible to suppress dependency of input impedance on the area of the overlapping region.

[0080] Furthermore, according to the second parasitic element and the third parasitic element, it is possible to suppress reflection caused by mismatch between (i) impedance between the middle part and the second and third parasitic elements and (ii) impedance of a coaxial cable.

[0081] According to the above configuration, the antenna is capable of having desired input impedance, regardless of how large or small the area of the overlapping region is. It is therefore possible to provide an antenna which is used in a state where the antenna is arranged so as to be adjacent to an electric conductor plate and which has desired input impedance independent of an area of a region of an element which region overlaps the electric conductor plate.

[0082] The antenna in accordance with an aspect of the present invention is arranged so as to further including: a feed cable which is connected to the first element and the second element, the feed cable being made up of a cold side electric conductor and a hot side electric conductor, the first element being connected to the cold side electric conductor of the feed cable, the second element being connected to the hot side electric conductor of the feed cable.

[0083] According to the above configuration, it is possible to further suppress dependency of input impedance on the area of the overlapping region, as compared with a case where (i) the first element is connected to the hot side electric conductor of the feed cable and (ii) the second element is connected to the cold side electric conductor of the feed cable.

[0084] The antenna in accordance with an aspect of the present invention is arranged such that the first element has, at the other one of the ends of the first element which other one is closer to the feed region, a root part having a width greater than that of the other part of the first element.

[0085] The root part of the first element is part of the first element which part is most adjacent to the second element. Since a width of part of the first element which part is adjacent to the second element is greater than that of the other part of the first element, the first element is capable of operating suitably as a cold side element.

[0086] Furthermore, the fact that the first element has the root part allows an increase in resonance frequency of the antenna. Therefore, it is possible to expand an operation band of the antenna.

[0087] Further, the antenna in accordance with an aspect of the present invention is arranged such that a gap between the root part and the second parasitic element and a gap between the root part and the third parasitic element are each arranged so as to become wider as extending from a center side of the root part toward an outer side of the root part.

[0088] According to the above configuration, it is possible to adjust a capacitance formed between the first element and the second parasitic element with use of the gap between the root part and the second parasitic ele-

ment. Similarly, it is possible to adjust a capacitance formed between the first element and the third parasitic element with use of the gap between the root part and the third parasitic element. Therefore, it is possible to easily cause impedance of the first element to match impedance of the feed cable. Therefore, it is possible to suppress a return loss in the first element.

[0089] Further, the antenna in accordance with an aspect of the present invention is arranged such that the first parasitic element has (i) a first extending part which extends along an outer side of the second parasitic element and (ii) a second extending part which extends along an outer side of the third parasitic element.

[0090] According to the above configuration, the first extending part and the second extending part of the first parasitic element, which is virtually fed with electric power via a tip part of the first element that is adjacent to the first parasitic element, function as antenna elements. This allows an increase in resonance frequency of the antenna. Therefore, it is possible to expand the operation band of the antenna.

[0091] Further, the antenna in accordance with an aspect of the present invention is arranged such that the first extending part and the second extending part are different from each other in virtual electrical length.

[0092] According to the above configuration, it is possible to further uniform the input impedance in the operation band.

[0093] The present invention is not limited to the embodiments, but can be altered by a skilled person in the art within the scope of the claims. An embodiment derived from a proper combination of technical means each disclosed in a different embodiment is also encompassed in the technical scope of the present invention.

Reference Signs List

[0094]

- 10 Antenna
- 12 Element (first element)
- 12a Tip part (one of ends which one is farther from a feed region)
- 12b Middle part
- 12c Root part (the other one of the ends which other one is closer to the feed region)
- 13 Element (second element)
- 14 Parasitic element (first parasitic element)
- 14b Sub element (first extending part)
- 14c Sub element (second extending part)
- 15a Parasitic element (second parasitic element)
- 15b Parasitic element (third parasitic element)
- 20 Coaxial cable (feed cable)
- Pc Feed point (cold side)
- Ph Feed point (hot side)
- Rf Feed region

Claims

1. An antenna (10) comprising:

- 5 a first element (12);
- a second element (13);
- a first parasitic element (14) which surrounds, on three sides, one (12a) of ends of the first element which one is farther from a feed region; and
- 10 a second parasitic element (15a) and a third parasitic element (15b) between which a middle part (12b) of the first element is sandwiched, each of the second parasitic element and the third parasitic element being galvanically insulated from the first parasitic element.

2. The antenna as set forth in claim 1, further comprising:

- 20 a feed cable (20) which is connected to the first element and the second element, the feed cable being made up of a cold side electric conductor and a hot side electric conductor,
- 25 the first element being connected to the cold side electric conductor of the feed cable,
- the second element being connected to the hot side electric conductor of the feed cable.

3. The antenna as set forth in claim 2, wherein the first element has, at the other one of the ends of the first element which other one is closer to the feed region, a root part (12c) having a width greater than that of the other part of the first element.

4. The antenna as set forth in claim 3, wherein a gap between the root part and the second parasitic element and a gap between the root part and the third parasitic element are each arranged so as to become wider as extending from a center side of the root part toward an outer side of the root part.

5. The antenna as set forth in any one of claims 1 through 4, wherein the first parasitic element has (i) a first extending part (14b) which extends along an outer side of the second parasitic element and (ii) a second extending part (14c) which extends along an outer side of the third parasitic element.

6. The antenna as set forth in claim 5, wherein the first extending part and the second extending part are different from each other in virtual electrical length.

FIG. 1

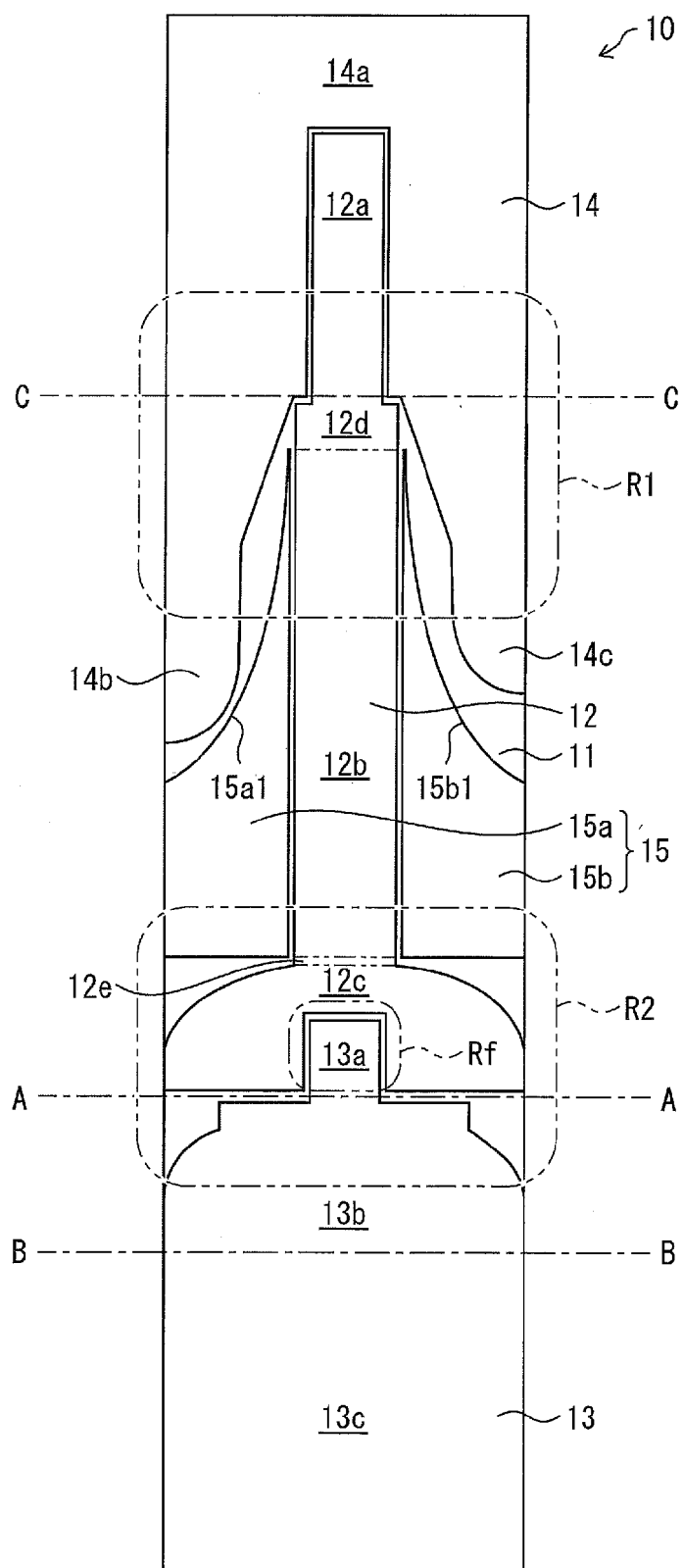


FIG. 2

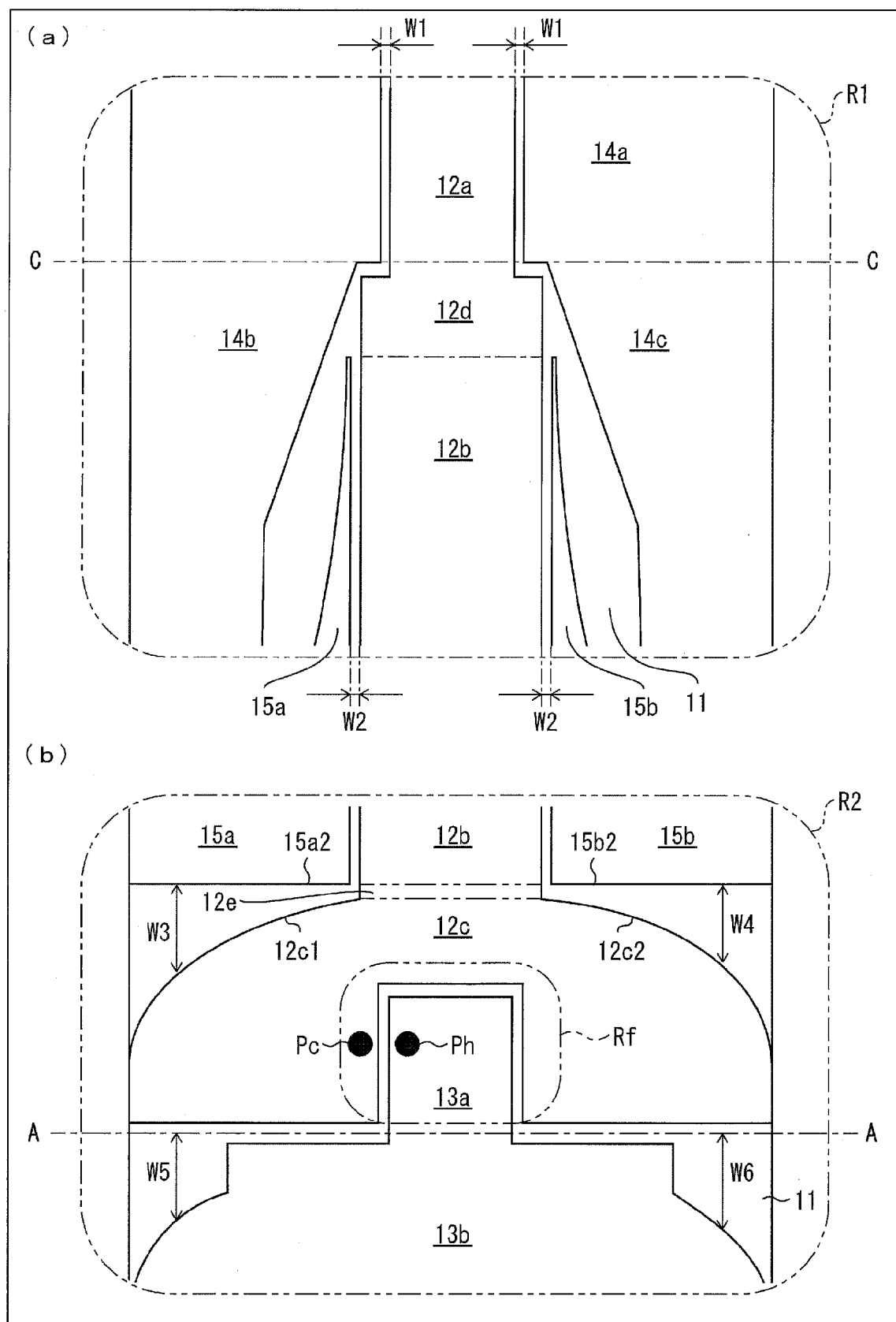


FIG. 3

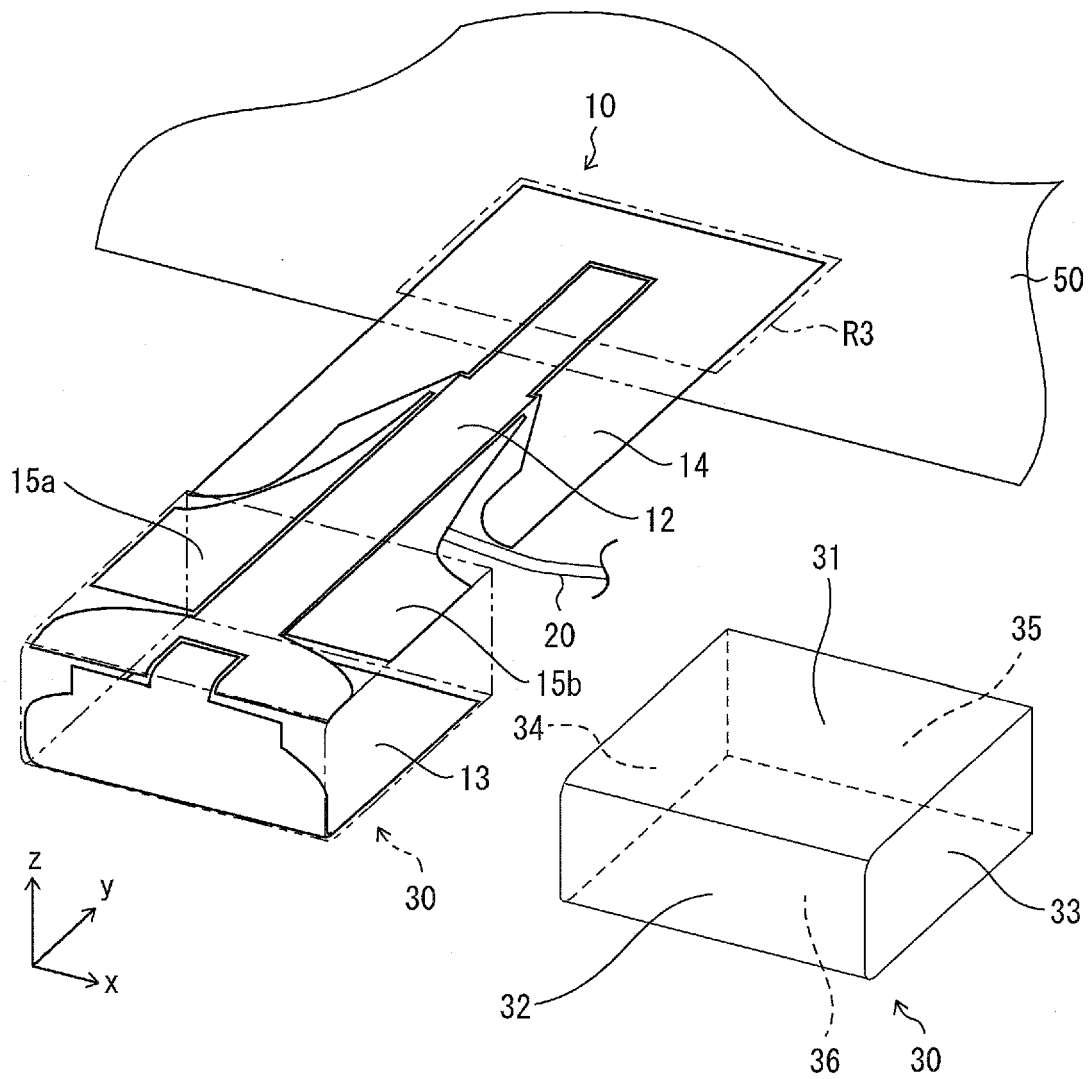


FIG. 4

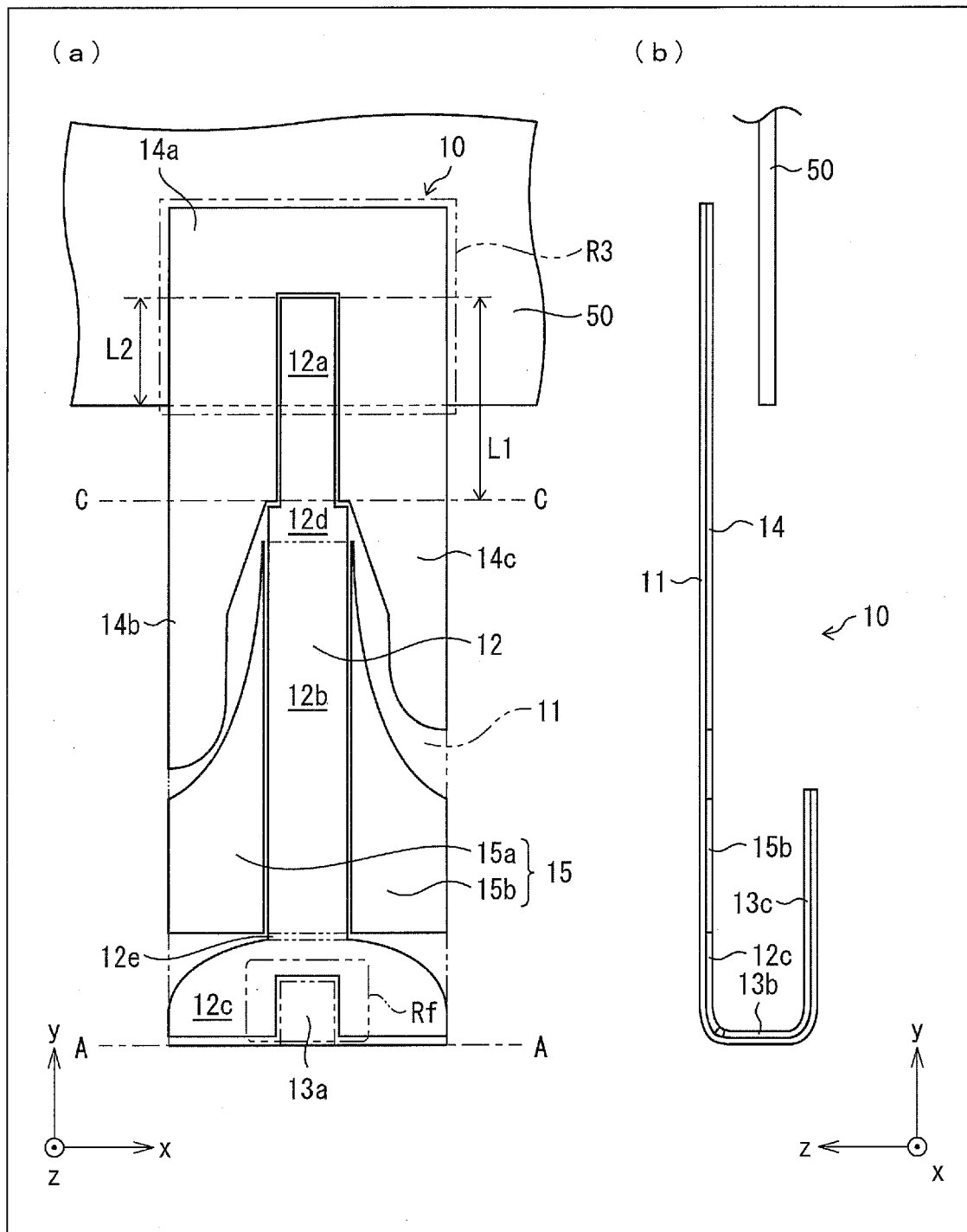


FIG. 5

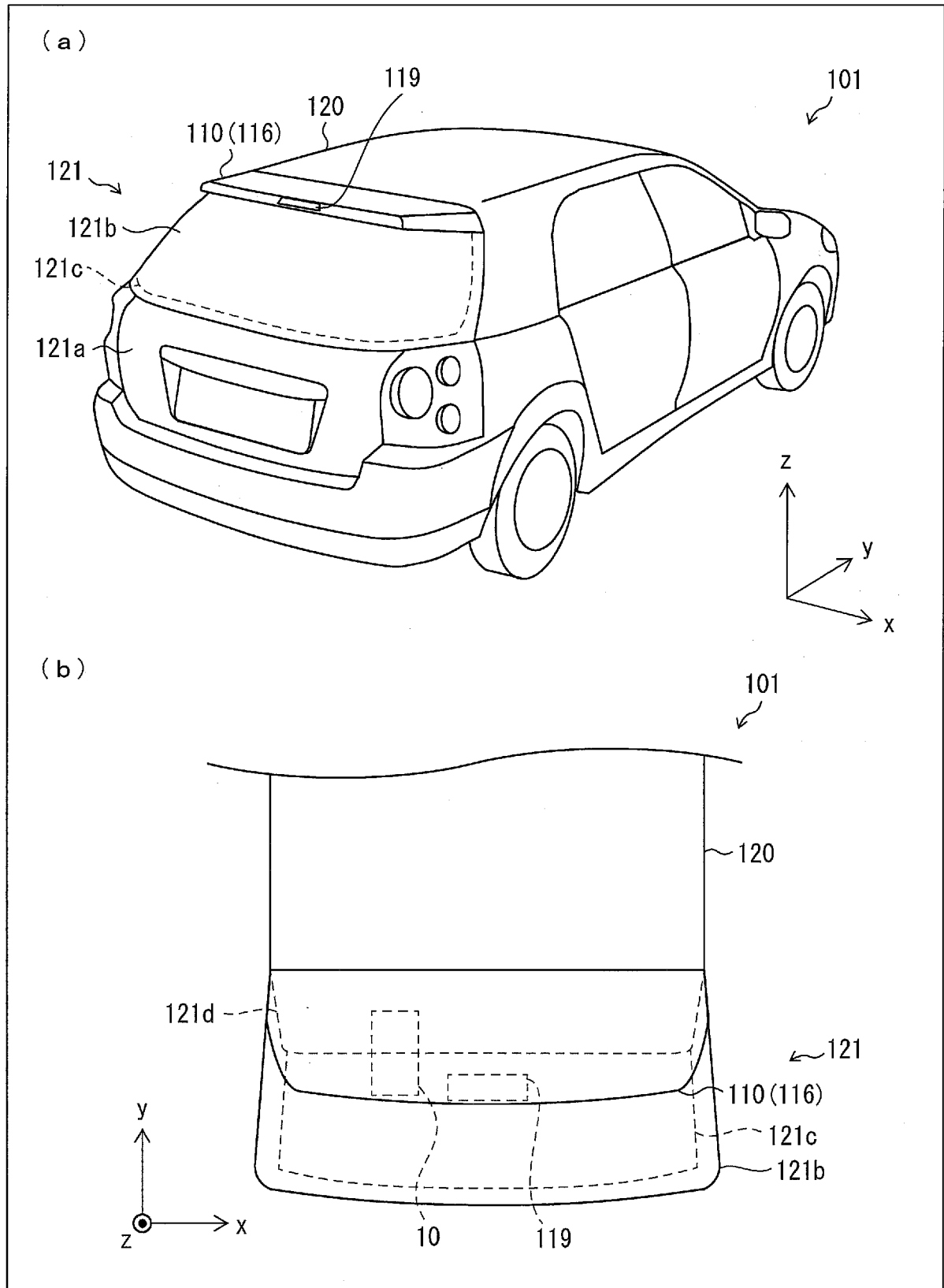


FIG. 6

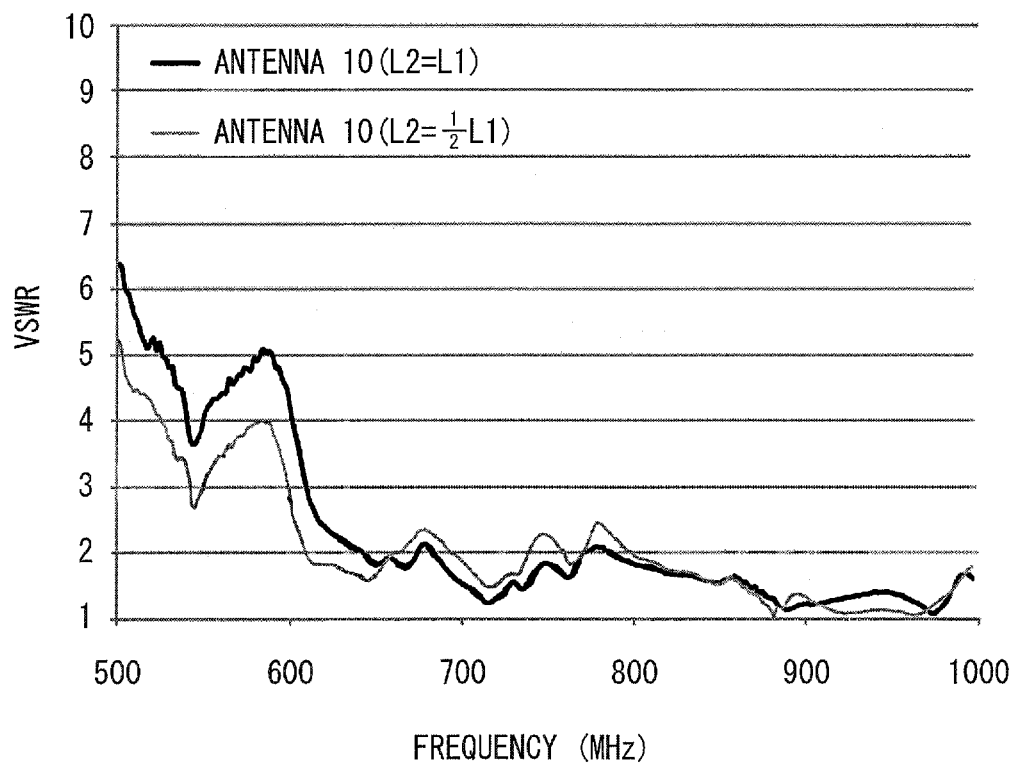


FIG. 7

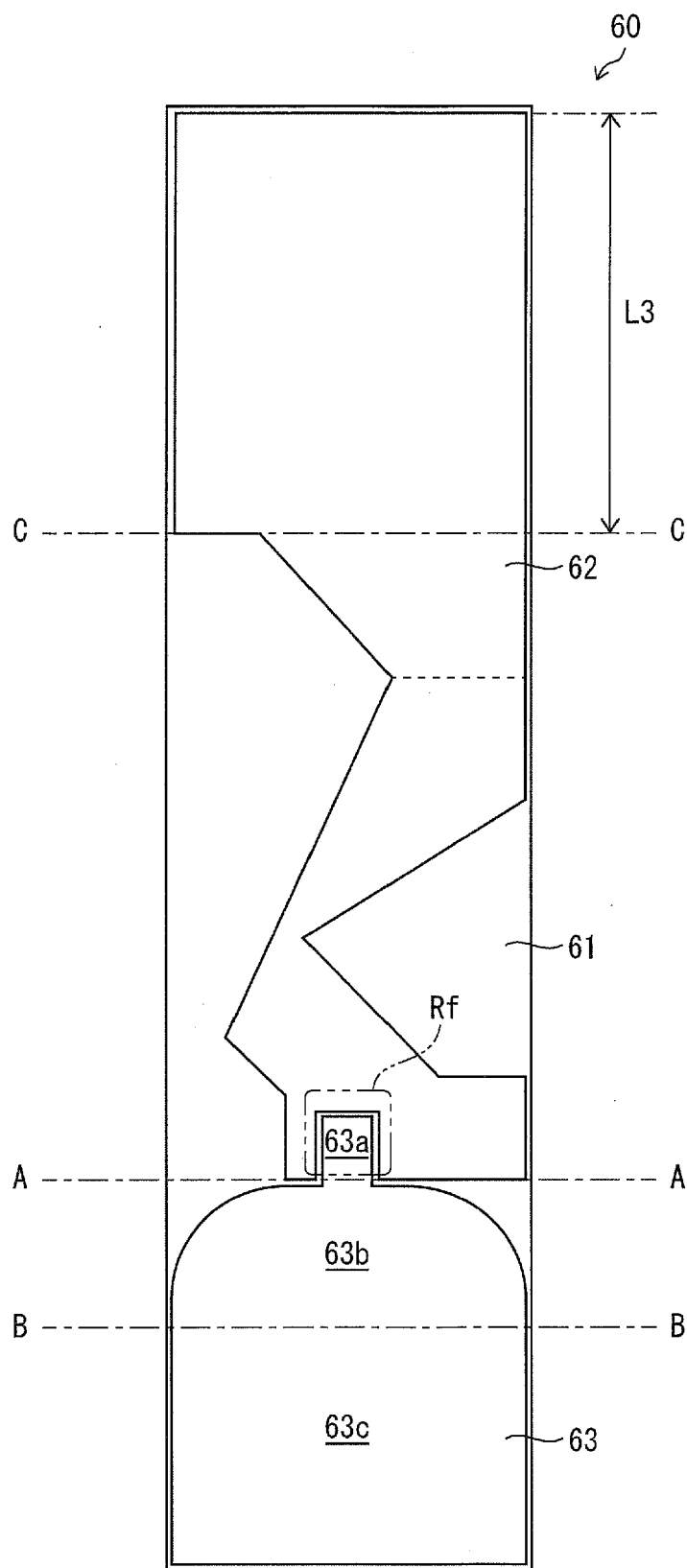
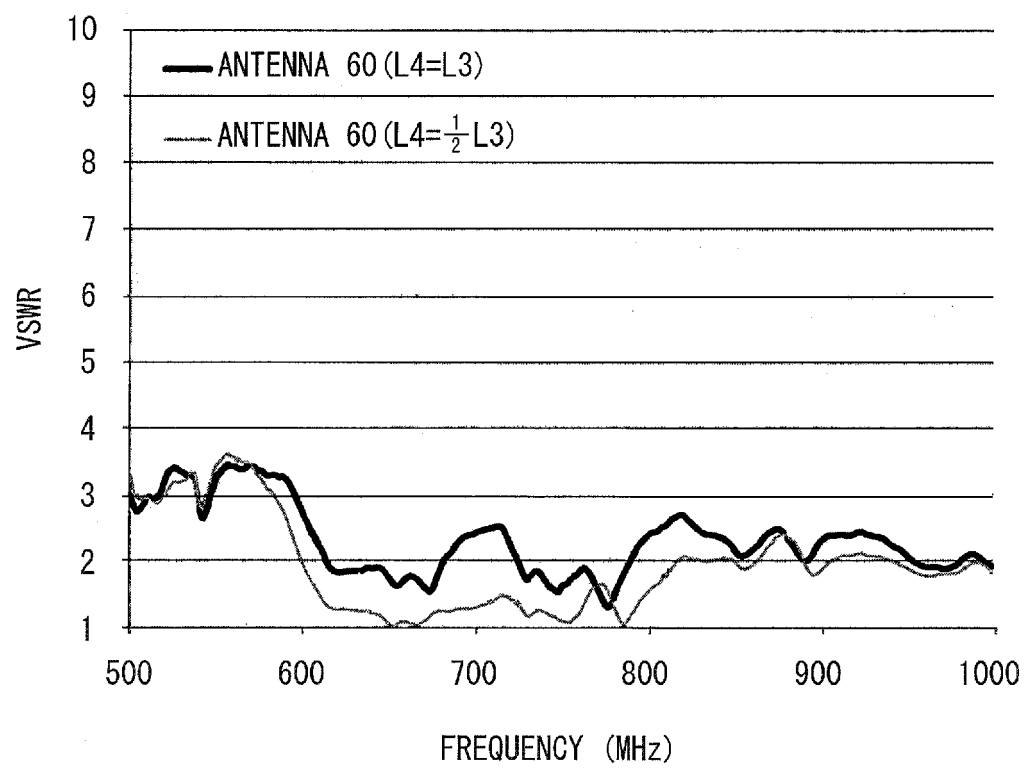


FIG. 8





EUROPEAN SEARCH REPORT

Application Number
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