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(54) **Vehicular antenna apparatus and window glass**

(57)   A vehicular antenna apparatus includes a window glass (23) attached to a vehicle, a glass antenna (100) including a first antenna conductor, and a first feeding section (16) and a second feeding section (17) serving as a pair of feeding points of the first antenna conductor, a coaxial cable (70) including an inner conductor (71) connected to the first feeding section (16) and an outer conductor (72) is connected to the second feeding section (17), and a grounding member (73,75) configured to ground to a vehicle body a middle part (74) of the outer conductor (72) of the coaxial cable (70) extending from the pair of feeding points (16,17) to a signal processing unit (80) installed on the vehicle body. The first antenna conductor includes a first element (1A) connected to the first feeding section (16) and extending in a horizontal direction or a vertical direction. An inclination angle of the window glass (23) relative to a horizontal plane at a position of the pair of feeding points is greater than or equal to 10° and smaller than or equal to 30°. Even for such low inclination angles the vehicular antenna apparatus provides an antenna gain sufficient for receiving vertically polarized radio waves.

FIG. 1

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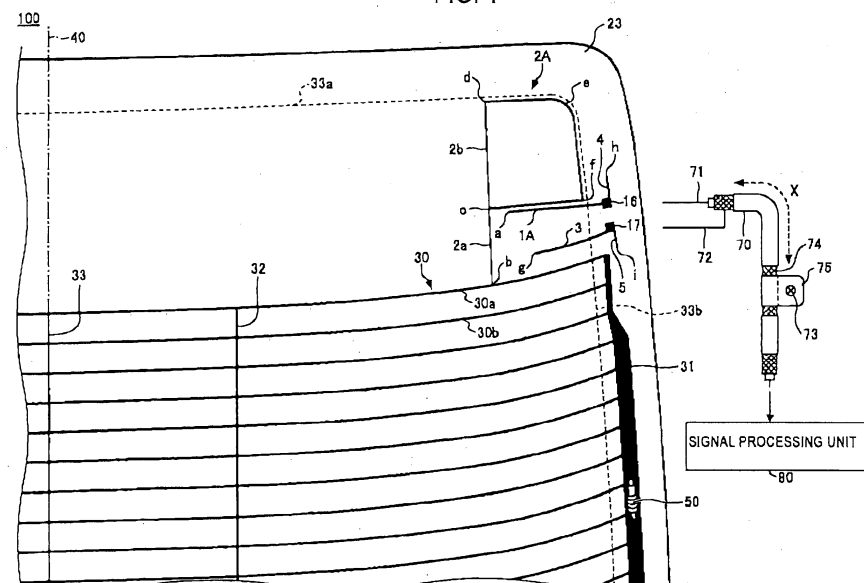
Description

TECHNICAL FIELD

[0001] The present invention relates to a vehicular antenna apparatus and a window glass including a glass antenna.

RELATED ART

[0002] In the related art, glass antennas capable of receive digital audio broadcasting (DAB) are known as described, for example, in Japanese Laid-Open Patent Publication No. H10-327009, Japanese Laid-Open Patent Publication No. 2000-307321, U.S. Patent No. 6924771 Specification, and European Laid-Open Patent Application No. 1732160 Specification. DAB has two different frequency bands, that is, band III covering 174 to 240 MHz and L band covering 1452 to 1492 MHz.

[0003] On the other hand, antenna apparatuses in which the outer conductor of a coaxial cable is grounded in the middle of the coaxial cable to the vehicle body are known as described, for example, in Japanese Laid-Open Patent Publication No. H6-276008 and Japanese Laid-Open Patent Publication No. 2006-173658.

[0004] In recent years, such vehicle types appear that the inclination angle of the window glass relative to the horizontal plane is small (that is, the surface of the window glass is substantially along the horizontal plane). In a glass antenna provided on such a window glass, the glass surface is oriented upward. Thus, when vertically polarized radio waves such as DAB are to be received, a satisfactory antenna gain is difficult to be ensured.

SUMMARY

[0005] An object of the present invention is to provide a vehicular antenna apparatus and a window glass in which even when the inclination angle of the window glass is small, an antenna gain sufficient for receiving vertically polarized radio waves is obtained.

[0006] To solve the above-mentioned problem, a vehicle antenna apparatus according to the present invention is

a vehicular antenna apparatus comprising:
a window glass attached to a vehicle;
a glass antenna including a first antenna conductor, and a first feeding section and a second feeding section serving as a pair of feeding points of the first antenna conductor;
a coaxial cable including an inner conductor connected to the first feeding section and an outer conductor is connected to the second feeding section; and
a grounding member configured to ground to a vehicle body a middle part of the outer conductor of the coaxial cable extending from the pair of feeding

points to a signal processing unit installed on the vehicle body, wherein
the first antenna conductor includes a first element connected to the first feeding section and extending in a horizontal direction or a vertical direction when viewed opposite to a surface of the window glass, and wherein
an inclination angle of the window glass relative to a horizontal plane at a position of the pair of feeding points is greater than or equal to 10° and smaller than or equal to 30°.

[0007] Further, a window glass according to the present invention is a window glass comprising the above-mentioned glass antenna.

[0008] According to the present invention, even when the inclination angle of the window glass is small, an antenna gain sufficient for receiving vertically polarized radio waves is obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 is a plan view of a glass antenna 100.
FIG. 2 is a diagram showing a state that a window glass 23 is attached to a vehicle.
FIG. 3 is a plan view of a glass antenna 200.
FIG. 4A is a plan view of a glass antenna 300A.
FIG. 4B is a plan view of a glass antenna 300B.
FIG. 5 shows the data of actual measurement of antenna gain in a case that a grounding point X was varied.
FIG. 6 shows the data of actual measurement of antenna gain in a case that a conductor length L1A of an element 1A was varied.
FIG. 7 shows the data of actual measurement of antenna gain in a case that a conductor length L3 of the element 3 was varied.
FIG. 8 shows the data of actual measurement of antenna gain of a glass antenna with or without an element 2A.
FIG. 9 shows the data of actual measurement of antenna gain in a case that a conductor length L2b of a loop element 2b was varied.

DETAILED DESCRIPTION

[0010] Embodiments of implementing the present invention are described below with reference to the drawings. Here, in the drawings describing the embodiment, mentioned directions indicate directions in the drawings until described otherwise. Further, directions such as a parallel direction and a right-angled direction permit a discrepancy at a level that does not impair the effect of the present invention. Further, each plan view is one obtained when the surface of the glass is viewed in an opposing manner. Each drawing is a diagram in which a

state that the window glass is attached to a vehicle is viewed from the inside of the vehicle. However, each drawing may be regarded as a diagram obtained when viewed from the outside of the vehicle. The vertical direction in each plan view corresponds to the vertical direction of the vehicle, and the down side of each diagram corresponds to the road surface side. Further, when the window glass is a rear window attached to the rear part of the vehicle, the horizontal direction in the drawing corresponds to the width direction of the vehicle. Here, in addition to the rear window of a vehicle, the present invention may be applied to a side window attached to a side part of a vehicle or alternatively to a windscreen attached to the front part of a vehicle.

[0011] FIG. 1 is a plan view of a glass antenna 100 of a vehicular antenna apparatus serving as a first embodiment of the present invention. The glass antenna 100 is an antenna constructed such that an antenna conductor and feeding sections are provided in a planar manner on a window glass 23.

[0012] The glass antenna 100 is an antenna of two-pole type that has an antenna conductor and a first feeding section 16 ("feeding section 16", hereinafter) and a second feeding section 17 ("feeding section 17", hereinafter) arranged in a side part region of the window glass 23 and that is provided in a planar manner on the window glass 23. The feeding section 16 and the feeding section 17 constitute a pattern of a pair of feeding points for the antenna conductor. The pair of feeding sections 16 and 17 are arranged on the window glass 23, for example, in such a manner that when the window glass 23 is attached to an opening part of a vehicle body, the feeding sections 16 and 17 are located opposite to a side edge (e.g., a pillar) of the vehicle body opening. FIG. 1 illustrates the upper feeding section 16 and the lower feeding section 17 arranged with a gap in between in a vertical direction along a side edge of the window glass 23. Instead of a vertical direction, the feeding sections 16 and 17 may be arranged with a gap in between in a horizontal direction.

[0013] As a pattern of the antenna conductor, the glass antenna 100 has at least a first antenna conductor including a first element ("element 1", hereinafter) that is connected to the feeding section 16 and extends in a horizontal direction or a vertical direction.

[0014] In FIG. 1, as the element 1, an element 1A linearly extends from the feeding section 16 as a starting point toward the left direction. The element 1A extends to a termination "a" being the end of the element 1. Here, as the element 1, FIG. 3 illustrates an element 1B extending from the feeding section 16 as a starting point toward the left direction and then bends upward and extends linearly.

[0015] As shown in FIG. 1, the vehicular antenna apparatus according to the present invention has a coaxial cable 70 for connecting the pair of feeding sections 16 and 17 to a signal processing unit 80 (e.g., an amplifier) installed on the vehicle body side. One end of the coaxial cable 70 is electrically connected to the pair of feeding

sections 16 and 17. That is, one end of an inner conductor 71 is electrically connected to the feeding section 16, and one end of an outer conductor 72 is electrically connected to the feeding section 17. The method of electrically connecting the pair of feeding sections 16 and 17 to one end of the coaxial cable 70 is not limited to a particular one. That is, the connection may be achieved by soldering or alternatively through a connector for easy connection.

[0016] The outer conductor 72 of the coaxial cable 70 is connected and grounded to the vehicle body through a grounding member in a middle part 74 between the pair of feeding sections 16 and 17 and the signal processing unit 80. In the middle part 74, the outer covering of the coaxial cable 70 is removed so that the outer conductor is exposed. As the grounding member, FIG. 1 illustrates a stopping piece 75 and a bolt 73. The outer conductor in the middle part 74 is connected and grounded to the vehicle body by the stopping piece 75 and the bolt 73.

[0017] FIG. 2 is a diagram showing a state that the window glass 23 is attached to a vehicle. When the inclination angle α of the window glass 23 at the position of the pair of feeding sections 16 and 17 relative to the horizontal plane is a relatively shelving inclination angle greater than or equal to 10° and smaller than or equal to 30° (more preferably, greater than or equal to 12° and smaller than or equal to 28°), the vehicular antenna apparatus according to the present invention having the above-mentioned configuration achieves an antenna gain sufficient for receiving vertically polarized radio waves. That is, when the window glass 23 provided with the glass antenna 100 having at least the above-mentioned configuration is attached to the vehicle body at an inclination angle α greater than or equal to 10° and smaller than or equal to 30° and then one end of the coaxial cable 70 is connected to the pair of feeding sections 16 and 17 and the outer conductor part in the middle of the coaxial cable 70 is connected and grounded to the vehicle body, an antenna gain is obtained that is sufficient for receiving vertically polarized radio waves. The other end of the coaxial cable 70 (the side opposite to the side where the pair of feeding sections 16 and 17 are connected) is connected to the signal processing unit 80.

[0018] In particular, in a configuration that the direction of arrangement of the two feeding sections is vertical and that the direction of the antenna conductor extending from the feeding sections is horizontal, decreasing inclination angle α causes increasing disadvantage in receiving of vertically polarized radio waves. However, according to the present invention, even such a configuration achieves an antenna gain sufficient for receiving vertically polarized radio waves.

[0019] The position where the inclination angle α of the window glass relative to the horizontal plane at the position of the pair of feeding sections 16 and 17 is to be defined is the middle point between the feeding section 16 and the feeding section 17.

[0020] Further, when the conductor length X of the outer conductor from the connection point between the feed-

ing section 17 and one end of the coaxial cable 70 to the connection point between the middle part 74 and the vehicle body is greater than or equal to 75 mm and smaller than or equal to 175 mm or, more preferably, greater than or equal to 100 mm and smaller than or equal to 150 mm, an antenna gain sufficient for receiving vertically polarized radio waves is obtained effectively.

[0021] Meanwhile, as shown in FIG. 1, the glass antenna 100 may be arranged on the window glass 23 provided with a defogger 30 having a plurality of heater wires running in parallel to each other. The antenna conductor and the feeding sections are arranged above the defogger 30.

[0022] The defogger 30 is a pattern of electric heating type having: a plurality of heater wires running in parallel to each other (in FIG. 1, upper heater wires 30a, 30b, and the like are illustrated and heater wires below them are omitted); and a plurality of belt-shaped bus bars for supplying electric power to the heater wires (in FIG. 1, one bus bar 31 is located in a side part on one side of the window glass 23). The plurality of heater wires are arranged on the window glass 23, for example, such as to run in parallel to the horizontal plane (the ground surface) in a state that the window glass 23 is attached to the vehicle. It is sufficient that the number of heater wires running in parallel to each other is two or greater. The plurality of heater wires running in parallel to each other may be connected to each other through a short circuit line. FIG. 1 shows a case that short circuit lines 32 and 33 are provided in the center 40 of the horizontal direction and its both sides (short circuit lines on the left side are not shown). Here, the short circuit lines may be used as adjustment of the antenna gain of the glass antenna. Further, their length may be adjusted appropriately, and one, two, or more, or none short circuit line may be employed. In FIG. 1, at least one bus bar 31 is provided respectively in the left-side region and the right-side region of the window glass 23, and extends in a vertical direction or in an approximately vertical direction of the window glass 23 (the bus bar in the left-side region is not shown).

[0023] The bus bar 31 in the right-side region is connected through a right-side coil 50 to a grounding site such as the vehicle body. The bus bar in the left-side region is connected through a left-side coil (not shown) to the positive electrode side of a DC power supply installed on the vehicle body side. This DC power supply energizes the heater wires. The right-side coil 50 and the left-side coil has a high impedance at least in a predetermined frequency band received by the glass antenna 100, for example, at frequencies of VHF band or higher, and hence suppresses passage of electric signals at the frequencies.

[0024] Further, in addition to the first antenna conductor including the element 1, the glass antenna 100 may include a second antenna conductor including a connection element 2a connected to the defogger 30. When the element 1 runs in parallel to at least one of the second antenna conductor and the defogger 30, the frequency

characteristic in the antenna gain of the element 1 can be adjusted. For example, as shown in the figure, it is preferable that the element 1 is close to at least a part of the second antenna conductor.

[0025] As the second antenna conductor, FIG. 1 illustrates a second element ("element 2A", hereinafter) having a loop shape. Since at least one of the element 2A and the defogger 30 runs in parallel to the element 1, the antenna gain on the lower frequency side within the frequency band whose receiving is achieved by the element 1 is improved. Here, as similar embodiments of the element 2A, FIG. 4A illustrates an element 2B, and FIG. 4B illustrates an element 2C. The element 2A in FIG. 1 is an example of arrangement above the element 1A. The elements 2B and 2C in FIGS. 4A and 4B are examples of arrangement below the element 1A. In the elements 2B and 2C, the element 2C has a longer loop circumference.

[0026] The element 2A has: a loop element 2b; and the connection element 2a for connecting the loop element 2b to the uppermost heater wire 30a of the defogger 30. The connection element 2a linearly extends upward from a point b as a starting point and then is connected to the loop element 2b at point c. The loop shape of the loop element 2b may be a quadrangle, a circle, an ellipse, or a polygon. Then, the antenna gain on the lower frequency side within the frequency band whose receiving is achieved by the element 1 is improved.

[0027] Further, the first antenna conductor including the element 1 may also include a third element that is connected to the feeding section 17 and extends in a horizontal direction. When the third element is employed, the frequency characteristic in the antenna gain of the element 1 can be adjusted.

[0028] In FIG. 1, as the third element, an element 3 linearly extends from the feeding section 17 as a starting point toward the left direction. The element 3 extends to the termination g being the end of the third element.

[0029] Further, the first antenna conductor including the element I may also include a fourth element that is connected to the feeding section 16 and extends in a vertical direction, and may also include a fifth element that is connected to the feeding section 17 and extends in a vertical direction.

[0030] In FIG. 1, as the fourth element, an element 4 linearly extends upward from the feeding section 16 as a starting point. Further, as the fifth element, an element 5 linearly extends downward from the feeding section 17 as a starting point. The element 4 extends to the termination h being the end of the fourth element, and the element 5 extends to the termination i being the end of the fifth element.

[0031] Even when the fourth element or the fifth element is not employed, radio waves of L band of DAB or higher are receivable. However, when the fourth element and/or the fifth element are employed, the frequency characteristic in the antenna gain for L band of DAB or higher can be adjusted.

[0032] Further, as long as the glass antenna has an

embodiment illustrated in each diagram, even when tuning is performed on the length or the like of the first antenna conductor and/or the second antenna conductor such that radio waves in the lower frequency band of the dual bands of DAB or the like are received in a state that a predetermined requirement is satisfied, the receiving characteristic for radio waves in the higher frequency band of the dual bands is hardly affected. Similarly, even when tuning is performed on the length or the like of the fourth element and/or the fifth element such that radio waves in the higher frequency band of the dual bands are received in a state that a predetermined requirement is satisfied, the receiving characteristic for radio waves in the lower frequency band of the dual bands is hardly affected. That is, tuning is achieved easily.

[0033] Further, the antenna conductor, the feeding section 16, and the feeding section 17 are fabricated by printing and baking a pattern with paste such as silver paste containing a conductive metal, for example, onto the inner surface of the vehicle window glass. However, the method of fabrication is not limited to this. That is, a linear member or a foil-shaped member composed of a conductive substance such as copper may be formed on the inner surface or the outer surface of the vehicle window glass. Alternatively, such a member may be bonded to the window glass with adhesives or the like. Further, such a member may be provided in the inside of the window glass itself.

[0034] The shapes of the feeding section 16 and the feeding section 17 and the gap between the feeding section 16 and the feeding section 17 may be determined depending on the shape of the mounting surface of the above-mentioned connector and its gap on the mounting surface. For example, a quadrangular shape such as a square, an approximate square, a rectangle, and an approximate rectangle, as well as a polygonal shape, is preferable for mounting. Alternatively, a circular shape such as a circle, an approximate circle, an ellipse, and an approximate ellipse may be employed. Further, the areas of the feeding section 16 and the area of the feeding section 17 may be identical to or different from each other.

[0035] Further, a conductor layer consisting of each antenna conductor may be provided in the inside or on the surface of a film composed of synthetic resin. Then, the synthetic resin film provided with the conductor layer may be provided on the inner surface or the outer surface of the vehicle window glass plate so that a glass antenna may be formed. Alternatively, a flexible circuit board on which each antenna conductor is formed may be provided on the inner surface or the outer surface of the vehicle window glass plate so that a glass antenna may be formed.

[0036] Further, a concealment layer may be formed on the surface of the window glass 23. Then, a part or the entirety of the feeding sections and the antenna conductor may be provided on this concealment layer. The concealment layer may be fabricated from a ceramic material such as a black ceramics layer. In this case, when the window glass is viewed from the outside of the vehicle, the part of the antenna conductor provided on the concealment layer is unseen from the outside of the vehicle by virtue of the concealment layer so that a satisfactory design property is achieved in the window glass. In the configuration illustrated in the figure, a part of the feeding sections and the antenna conductor is formed on the concealment layer (between the edges 33a and 33b of the concealment layer and the edges of the window glass 23). Thus, a thin straight line part alone of the conductor is seen from the outside of the vehicle so that a satisfactory design property is obtained.

[0037] Meanwhile, in the present invention, as the two broadcasting frequency bands to be received, a first broadcasting frequency band and a second broadcasting frequency band higher than the first broadcasting frequency band are employed. Further, the wavelength in the air at the center frequency of the first broadcasting frequency band is denoted by λ_{01}, the glass shortening coefficient of wavelength is denoted by k_1 (here, $k_1=0.54$), and $\lambda_{g1}=\lambda_{01}\cdot k_1$ is defined. Then, in the embodiment of the above-mentioned glass antenna 100 or the like, the conductor length L1A of the element 1A corresponding to the horizontal component of the element 1 is greater than or equal to $(1/12)\lambda_{g1}$ and smaller than or equal to $(1/4)\lambda_{g1}$ or, more preferably, greater than or equal to $(1/10)\lambda_{g1}$ and smaller than or equal to $(1/6)\lambda_{g1}$ within a range that the element 1A is not in contact with the conductor located on the left of the element 1A, a preferable result is obtained with respect to improvement in the antenna gain in the first broadcasting frequency band.

[0038] Here, when band III (174 to 240 MHz) is set up as the first broadcasting frequency band, the center frequency is 207 MHz. Thus, when the antenna gain for band III is desired to be improved, since the speed of radio waves is 3.0×10^8 m/s and hence λ_{g1} at the center frequency 207 MHz is 0.7826 m, it is sufficient that the conductor length L1A of the element 1A is adjusted to be greater than or equal to 70 mm and smaller than or equal to 200 mm or, more preferably, greater than or equal to 80 mm and smaller than or equal to 130 mm.

[0039] Further, in the embodiment of the glass antenna 100 or the like, when the conductor length L3 of the element 3 corresponding to the third element is smaller than or equal to $(1/12)\lambda_{g1}$ or, more preferably, smaller than or equal to $(1/14)\lambda_{g1}$ within a range that the element 3 is not in contact with the conductor located on the left of the element 3, a preferable result is obtained with respect to improvement in the antenna gain in the first broadcasting frequency band. Thus, when the antenna gain for band III is desired to be improved, it is sufficient that the conductor length L3 of the element 3 is adjusted to be smaller than or equal to 70 mm or, more preferably, smaller than or equal to 55 mm.

[0040] Further, in the present invention, as the two broadcasting frequency bands to be received, a first broadcasting frequency band and a second broadcasting

frequency band higher than the first broadcasting frequency band are employed. Further, the wavelength in the air at the center frequency of the second broadcasting frequency band is denoted by λ_{02}, the glass shortening coefficient of wavelength is denoted by k_2 (here, $k_2=0.74$), and $\lambda_{g2}=\lambda_{02} \cdot k_2$ is defined. Then, when the length (L4+E) of a conductor route that joins the termination h being the end of the element 4 to the end of the feeding section 16 with the minimum length is greater than or equal to $0.17\lambda_{g2}$ and smaller than or equal to $0.27\lambda_{g2}$ or, more preferably, greater than or equal to $0.19\lambda_{g2}$ and smaller than or equal to $0.26\lambda_{g2}$, a preferable result is obtained with respect to improvement in the antenna gain in the second broadcasting frequency band. The end of the feeding section 16 corresponds to the lower end of the feeding section 16 being opposite to the feeding section 17. Further, E of (L4+E) corresponds to the length of one vertical side of the feeding section 16.

[0041] Here, when L band (1452 to 1492 MHz) is set up as the second broadcasting frequency band, the center frequency is 1472 MHz). Thus, when the antenna gain for L band is desired to be improved, since the speed of radio waves is 3.0×10^8 m/s, it is sufficient that the length (L4+E) of the conductor route is adjusted to be greater than or equal to 26 mm and smaller than or equal to 40 mm or, more preferably, greater than or equal to 30 mm and smaller than or equal to 38 mm.

[0042] Further, when the length (L5+E) of a conductor route that joins the termination i being the end of the element 5 to the end of the feeding section 17 with the minimum length is greater than or equal to $0.07\lambda_{g2}$ and smaller than or equal to $0.2\lambda_{g2}$ or, more preferably, greater than or equal to $0.13\lambda_{g2}$ and smaller than or equal to $0.19\lambda_{g2}$, a preferable result is obtained with respect to improvement in the antenna gain in the second broadcasting frequency band. The end of the feeding section 17 corresponds to the upper end of the feeding section 17 being opposite to the feeding section 16. Further, E of (L5+E) corresponds to the length of one vertical side of the feeding section 17. Thus, when the antenna gain for L band is desired to be improved, it is sufficient that the length (L5+E) of the conductor route is adjusted to be greater than or equal to 12 mm and smaller than or equal to 30 mm or, more preferably, greater than or equal to 20 mm and smaller than or equal to 28 mm.

[Examples]

[0043] Actual measurement results such as the frequency characteristic are described below for a vehicular glass antenna constructed by attaching the glass antenna of the above-mentioned embodiment to the rear window of an actual vehicle.

[0044] The antenna gain was measured in a state that the vehicular window glass on which the glass antenna was formed was assembled to a window frame of a vehicle on a turntable at an inclination of approximately 20° relative to a horizontal plane. A connector was attached to the feeding sections and connected through a feeder wire to a network analyzer. Radio waves were projected horizontally onto the window glass. Then, by rotating the turntable, the angle of radio wave projection relative to the window glass was varied.

[0045] The measurement of antenna gain was performed in a state that the vehicle center of the vehicle provided with the glass of the glass antenna was set at the center of the turntable. Then, the vehicle was rotated by 360° with projecting radio waves at a predetermined frequency. Then, the average was calculated. The data of antenna gain was measured at every 3° of rotation angle at every 3 MHz for the frequency range of band III (170 to 240 MHz) and at every 1.7 MHz for the frequency range of L band. The elevation angle of the radio wave transmission position relative to the antenna conductor was approximately horizontal (that is, when a plane parallel to the ground surface is defined as elevation angle=0° and the zenith direction is defined as elevation angle=90°, the direction was at elevation angle=0°). The antenna gain was standardized with reference to a half-wavelength dipole antenna such that the half-wavelength dipole antenna should have 0dBd.

[Example 1]

[0046] FIG. 5 shows the data of actual measurement of antenna gain for a vehicular high-frequency glass antenna constructed by attaching the glass antenna 100 of the embodiment shown in FIG. 1 to the rear window of an actual vehicle, in a case that the conductor length X (the grounding point X) of the outer conductor from the pair of feeding sections 16 and 17 to the middle part 74 was varied. The vertical axis in FIG. 5 indicates the average of the antenna gain over the entirety of band III.

[0047] The dimensions of the individual sections of the glass antenna 100 measured in FIG. 5 with the unit of mm were as follows.

    L1A: 100
    L2a (b-c): 70
    L2b (path length of c-d-e-f-c): 380
    L3: 50
    L4: 20
    L5: 15

Conductor length of heater wire 30a between point b and bus bar 31 nearest to point b: 115

Here, L* (* indicates a symbol) denotes the conductor length of an element *. The conductor width of each element was 0.8 mm. Each of the feeding section 16 and the feeding section 17 had a square shape with a side length of 10 mm. The gap between the feeding section 16 and the feeding section 17 was 20 mm. The gap between the element 2A and the element 1A was 5 mm.

[0048] As seen from FIG. 5, in contrast to that the antenna gain for band III is -18.3dBd (not shown) when the outer conductor of the middle part 74 in the middle of the

coaxial cable 70 is not grounded to the vehicle body, the antenna gain for band III was improved when the grounding point X was greater than or equal to 75 mm and smaller than or equal to 175 mm.

[Example 2]

[0049] FIG. 6 shows the data of actual measurement of antenna gain in a case that the conductor length L1A of the element 1A was varied in a vehicular high-frequency glass antenna constructed by attaching the glass antenna 100 of the embodiment shown in FIG. 1 to the rear window of an actual vehicle. The vertical axis in FIG. 6 indicates the average of the antenna gain over the entirety of band III. The grounding point X measured in FIG. 6 was located at 150 mm. The other dimensions were similar to those of Example 1.

[0050] As shown in FIG. 6, when the conductor length L1A is greater than or equal to 70 mm, the antenna gain for band III is improved. Here, the antenna gain data in a case that the conductor length L1A was greater than or equal to 110 mm and smaller than or equal to 200 mm was converged near -6.5dBd. Thus, the data is omitted in FIG. 6.

[Example 3]

[0051] FIG. 7 shows the data of actual measurement of antenna gain in a case that the conductor length L3 of the element 3 was varied in a vehicular high-frequency glass antenna constructed by attaching the glass antenna 100 of the embodiment shown in FIG. 1 to the rear window of an actual vehicle. The vertical axis in FIG. 7 indicates the average of the antenna gain over the entirety of band III. The grounding point X measured in FIG. 7 was located at 150 mm. The other dimensions were similar to those of Example 1.

[0052] As shown in FIG. 7, when the conductor length L3 is smaller than or equal to 70 mm, the antenna gain for band III is improved.

[Example 4]

[0053] FIG. 8 shows the data of actual measurement of antenna gain for a vehicular high-frequency glass antenna constructed by attaching only the elements 1A, 3, 4, and 5 and the feeding sections 16 and 17 among the components in the glass antenna 100 of the embodiment shown in FIG. 1, to the rear window of an actual vehicle. The data shows comparison between the presence and the absence of the element 2A. The vertical axis in FIG. 8 indicates the antenna gain at each frequency measured every 3 MHz in band III. The grounding point X was located at 150 mm at the time of measurement shown in FIG. 8. The other dimensions were similar to those of Example 1.

[0054] As shown in FIG. 8, when the element 2A running in parallel to the element 1A is employed, the an-

tenna gain is improved in the lower-frequency range (174 to 210 MHz) of band III. At the higher-frequency range, a satisfactory antenna gain is obtained regardless of the presence or absence of the element 2A.

[Example 5]

[0055] The average of the antenna gain measured every 3 MHz over the entirety of band III was calculated for the cases that a notch was provided and not provided between the c-f part of the loop element 2b in a vehicular high-frequency glass antenna constructed by attaching the glass antenna 100 of the embodiment shown in FIG. 1 to the rear window of an actual vehicle. The grounding point X at the time of measurement in Example 5 was located at 150 mm. The other dimensions were similar to those of Example 1.

[0056] As a result, the average of the antenna gain over the entirety of band III was -7.2dBd when a 5-mm notch extending from point c to the right was provided, and -6.3dBd when no notch was provided. Thus, it has been found that the absence of a notch (that is, a configuration like that shown in FIG. 1 where the loop is not broken) is preferable with respect to improvement in the antenna gain.

[Example 6]

[0057] In each vehicular high-frequency glass antenna constructed by independently attaching the glass antenna 100 of the embodiment shown in FIG. 1 or alternatively the glass antenna 200 of the embodiment shown in FIG. 3 to the rear window of an actual vehicle, the average was calculated for the antenna gain measured every 3 MHz over the entirety of band III. That is, comparison was performed between a case that the element 1A extends in a horizontal direction and a case that the element 1B extends in a vertical direction. The grounding point X at the time of measurement in Example 6 was located at 150 mm. The other dimensions were similar to those of Example 1 (similarly, the conductor length of the element 1B was 100 mm).

[0058] As a result, the average of the antenna gain over the entirety of band III was -6.3dBd for the element 1A and -6.5dBd for the element 1B. That is, no substantial difference was found between the antenna gains of the elements 1A and 1B.

[Example 7]

[0059] In each vehicular high-frequency glass antenna constructed by independently attaching the glass antenna 100 of the embodiment shown in FIG. 1 or the glass antenna 300A of the embodiment shown in FIG. 4A or the glass antenna 300B of the embodiment shown in FIG. 4B to the rear window of an actual vehicle, the average was calculated for the antenna gain measured every 3 MHz over the entirety of band III. That is, the loop ele-

ments 2A, 2B, and 2C were compared with each other. The grounding point X at the time of measurement in Example 7 was located at 150 mm.

[0060] The dimensions of the individual sections of the glass antenna 300A measured in Example 7 with the unit of mm were as follows.

Conductor length between b-c: 35
Conductor length between c-d and e-f 35
Conductor length between d-e and f-c: 90
Gap between element 1A and element 2B: 5

[0061] The dimensions of the individual sections of the glass antenna 300B measured in Example 7 with the unit of mm were as follows.

Conductor length between b-g: 35
Conductor length between c-d and e-f: 35
Conductor length between d-e and f-c: 210
Gap between element 1A and element 2C: 5

[0062] The other dimensions of the individual sections of the glass antennas 100, 300A and 300B were similar to those of Example 1.

[0063] As a result, the average of the antenna gain over the entirety of band III was -6.3dBd for the element 2A, -11.1dBd for the element 2B, and -7.7dBd for the element 2C. That is, it has been found that the configuration of the element 2A in which the second element having a loop shape is arranged above the element 1A is preferable with respect to improvement in the antenna gain in comparison with the configurations of the elements 2B and 2C in which the second element having a loop shape is arranged below the element 1A.

[Example 8]

[0064] FIG. 9 shows the data of actual measurement of antenna gain for a vehicular high-frequency glass antenna constructed by attaching the glass antenna 100 of the embodiment shown in FIG. 1 to the rear window of an actual vehicle, in a case that the conductor length L2b corresponding to the circumference of the loop element 2b was varied by simultaneously changing by the same amount the conductor length between c-d and the conductor length between e-f of the loop element 2b. The vertical axis in FIG. 9 indicates the average of the antenna gain over the entirety of band III. The grounding point X at the time of measurement in FIG. 9 was located at 150 mm. The other dimensions were similar to those of Example 1.

[0065] As seen from FIG. 9, the antenna gain increases with increasing conductor length L2b corresponding to the circumference of the loop element 2b.

[Example 9]

[0066] In a vehicular high-frequency glass antenna

constructed by attaching the glass antenna 100 of the above-mentioned embodiment to the rear window of an actual vehicle, the average was calculated for the antenna gain measured every 3 MHz over the entirety of band III and for the antenna gain measured every 1.7 MHz over the entirety of L band. The grounding point X at the time of measurement in Example 9 was located at 150 mm. The other dimensions were similar to those of Example 1.

[0067] As a result, the average of the antenna gain over the entirety of band III was -6.5dBd, and the average of the antenna gain over the entirety of L band was -8.6dBd. [Industrial Applicability]

[0068] In the present invention, it is preferable that the first and the second frequency bands are assigned, for example, to VHF band of 30 MHz to 0.3 GHz. The applications of the radio waves of VHF band include an FM broadcasting band (76 MHz to 90 MHz) in Japan, an FM broadcasting band (88 MHz to 108 MHz) in the U.S., a television VHF band (90 MHz to 108 MHz, 170 MHz to 222 MHz), the band III (174 MHz to 240 MHz) of DAB, the L band (1452 MHz to 1492 MHz) of DAB, and a DMB (Digital Multimedia Broadcasting) band in South Korea. Further, in the present invention, it is preferable that, for example, the first frequency band is used as VHF band and the second frequency band is used as the lower-frequency side of UHF band of 0.3 GHz to 3 GHz. The applications of radio waves on the lower-frequency side of UHF band include a vehicle-use keyless entry system (300 MHz to 450 MHz) and an 800 MHz band (810 MHz to 960 MHz) for vehicle mobile phones.

Claims

1. A vehicular antenna apparatus comprising:

a window glass attached to a vehicle;
a glass antenna including a first antenna conductor, and a first feeding section and a second feeding section serving as a pair of feeding points of the first antenna conductor;
a coaxial cable including an inner conductor connected to the first feeding section and an outer conductor is connected to the second feeding section; and
a grounding member configured to ground to a vehicle body a middle part of the outer conductor of the coaxial cable extending from the pair of feeding points to a signal processing unit installed on the vehicle body, wherein
the first antenna conductor includes a first element connected to the first feeding section and extending in a horizontal direction or a vertical direction when viewed opposite to a surface of the window glass, and wherein
an inclination angle of the window glass relative to a horizontal plane at a position of the pair of

feeding points is greater than or equal to 10° and smaller than or equal to 30°.

2. The vehicular antenna apparatus according to claim 1, wherein
the window glass includes a defogger including a plurality of heater wires and a belt-shaped bus bar configured to supply electric power to the heater wires, wherein
the glass antenna includes a second antenna conductor including a connecting element connected to the defogger, and wherein
the first element is close to at least a part of the second antenna conductor.

3. The vehicular antenna apparatus according to claim 2, wherein the second antenna conductor includes a second element having a loop shape.

4. The vehicular antenna apparatus according to any one of claims 1 to 3, wherein a conductor length from the second feeding section to the middle part of the outer conductor is greater than or equal to 75 mm and smaller than or equal to 175 mm.

5. The vehicular antenna apparatus according to any one of claims 1 to 4, wherein the first feeding section and the second feeding section are arranged in a horizontal direction when viewed opposite to the surface of the window glass.

6. The vehicular antenna apparatus according to any one of claims 1 to 5,
wherein
a first broadcasting frequency band and a second broadcasting frequency band higher than the first broadcasting frequency band are employed, a wavelength in the air at a center frequency of the first broadcasting frequency band is denoted by λ_{01}, a glass shortening coefficient of wavelength is denoted by k_1 (here, $k_1=0.54$), and $\lambda_{g1}=\lambda_{01}\cdot k_1$ is defined, and wherein
a conductor length of the first element is greater than or equal to $(1/12)\lambda_{g1}$ and smaller than or equal to $(1/4)\lambda_{g1}$.

7. The vehicular antenna apparatus according to any one of claims 1 to 5, wherein a conductor length of the first element is greater than or equal to 70 mm and smaller than or equal to 200 mm.

8. The vehicular antenna apparatus according to any one of claims 1 to 7,
wherein
the first antenna conductor includes a third element extending in the horizontal direction when viewed opposite to the surface of the window glass, and wherein

the third element is connected to the second feeding section.

9. The vehicular antenna apparatus according to claim 8, wherein
a first broadcasting frequency band and a second broadcasting frequency band higher than the first broadcasting frequency band are employed, a wavelength in the air at a center frequency of the first broadcasting frequency band is denoted by λ_{01}, a glass shortening coefficient of wavelength is denoted by k_1 (here, $k_1=0.54$), and $\lambda_{g1}=\lambda_{01}\cdot k_1$ is defined, and wherein
a conductor length of the third element is smaller than or equal to $(1/12)\lambda_{g1}$.

10. The vehicular antenna apparatus according to claim 8, wherein a conductor length of the third element is smaller than or equal to 70 mm.

11. The vehicular antenna apparatus according to any one of claims 1 to 10, wherein
the first antenna conductor includes a fourth element extending in a vertical direction when viewed opposite to the surface of the window glass, and wherein
the fourth element is connected to the first feeding section.

12. The vehicular antenna apparatus according to claim 11, wherein
a first broadcasting frequency band and a second broadcasting frequency band higher than the first broadcasting frequency band are employed, a wavelength in the air at a center frequency of the second broadcasting frequency band is denoted by λ_{02}, a glass shortening coefficient of wavelength is denoted by k_2 (here, $k_2=0.74$), and $\lambda_{g2}=\lambda_{02}\cdot k_2$ is defined, and wherein
a length of a conductor route that joins a termination being an end of the fourth element to an end of the first feeding section with a minimum length is greater than or equal to $0.17\lambda_{g2}$ and smaller than or equal to $0.27\lambda_{g2}$.

13. The vehicular antenna apparatus according to any one of claims 1 to 12, wherein
the first antenna conductor includes a fifth element extending in a vertical direction when viewed opposite to a surface of the window glass, and wherein
the fifth element is connected to the second feeding section.

14. The vehicular antenna apparatus according to claim 13, wherein
a first broadcasting frequency band and a second broadcasting frequency band higher than the first broadcasting frequency band are employed, a wavelength in the air at a center frequency of the second

broadcasting frequency band is denoted by λ_{02}, a glass shortening coefficient of wavelength is denoted by k_2 (here, $k_2=0.74$), and $\lambda_{g2}=\lambda_{02} \cdot k_2$ is defined, and wherein

a length of a conductor route that joins a termination being an end of the fifth element to an end of the second feeding section with a minimum length is greater than or equal to $0.07\lambda_{g2}$ and smaller than or equal to $0.2\lambda_{g2}$.

15. A window glass comprising the glass antenna according to any one of claims 1 to 14.

FIG. 1

SIGNAL PROCESSING UNIT

FIG. 2

FIG. 3

FIG. 4A

300A
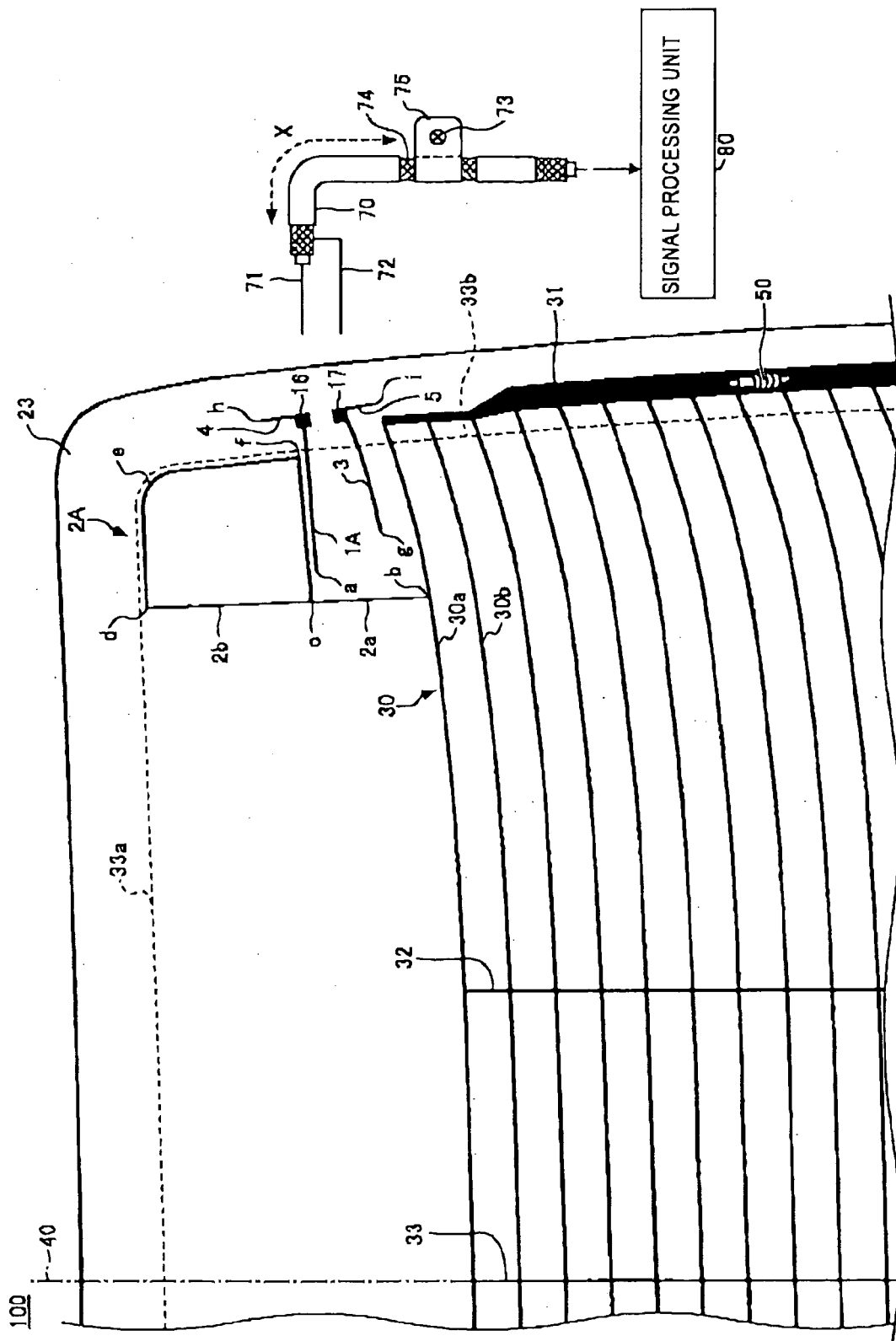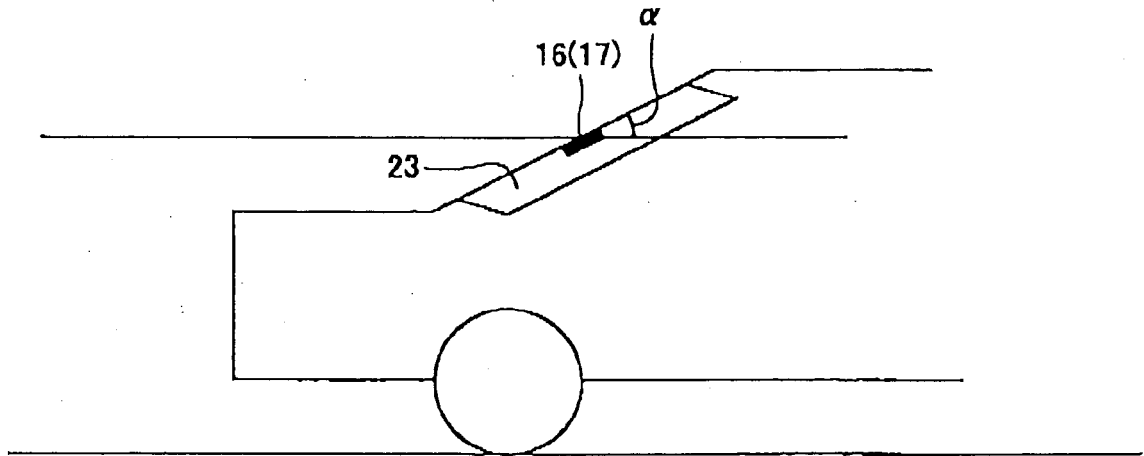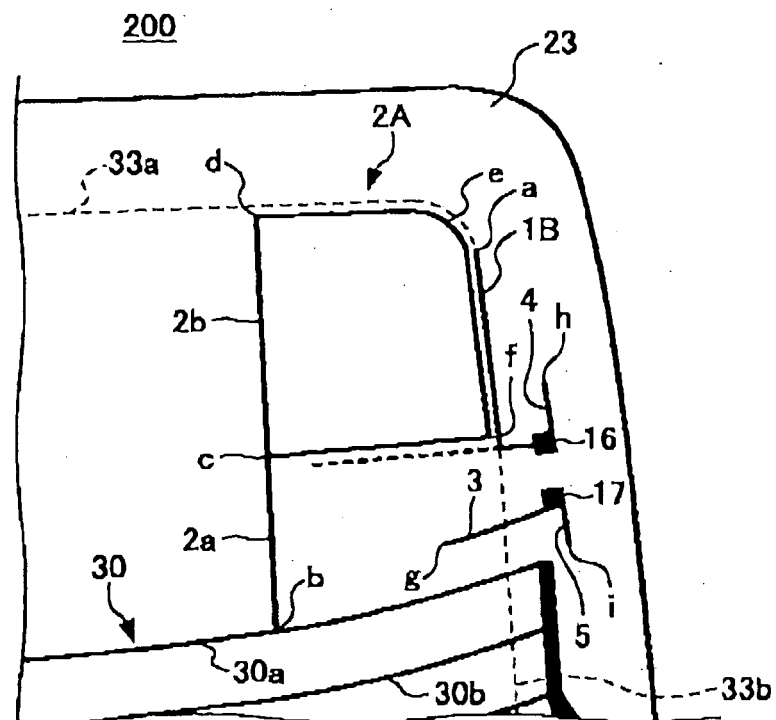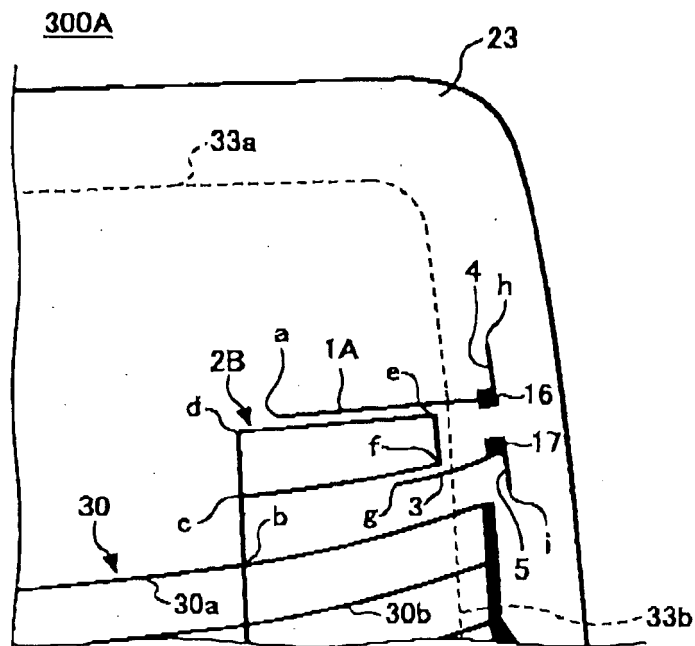
FIG. 4B

300B
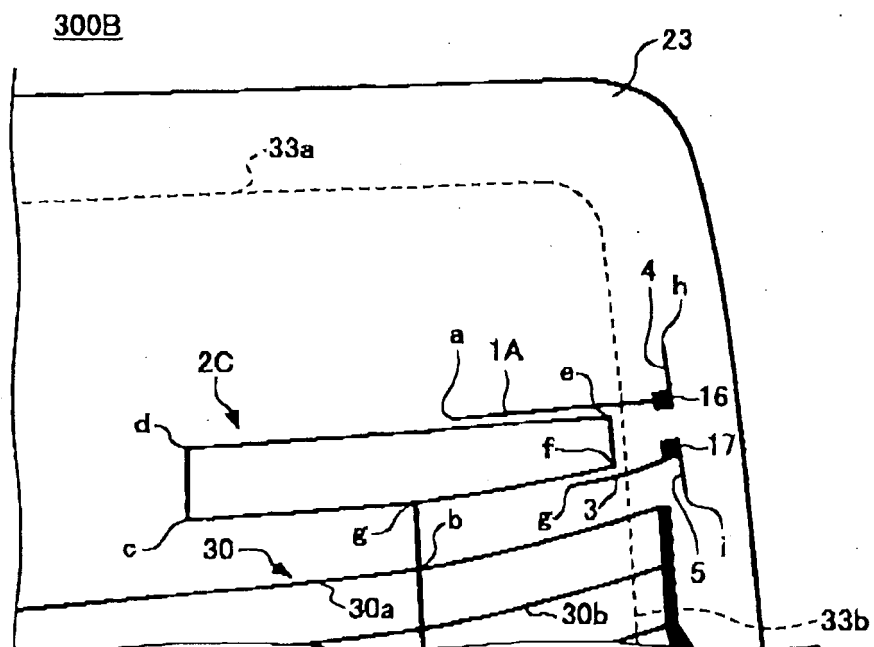
FIG. 5
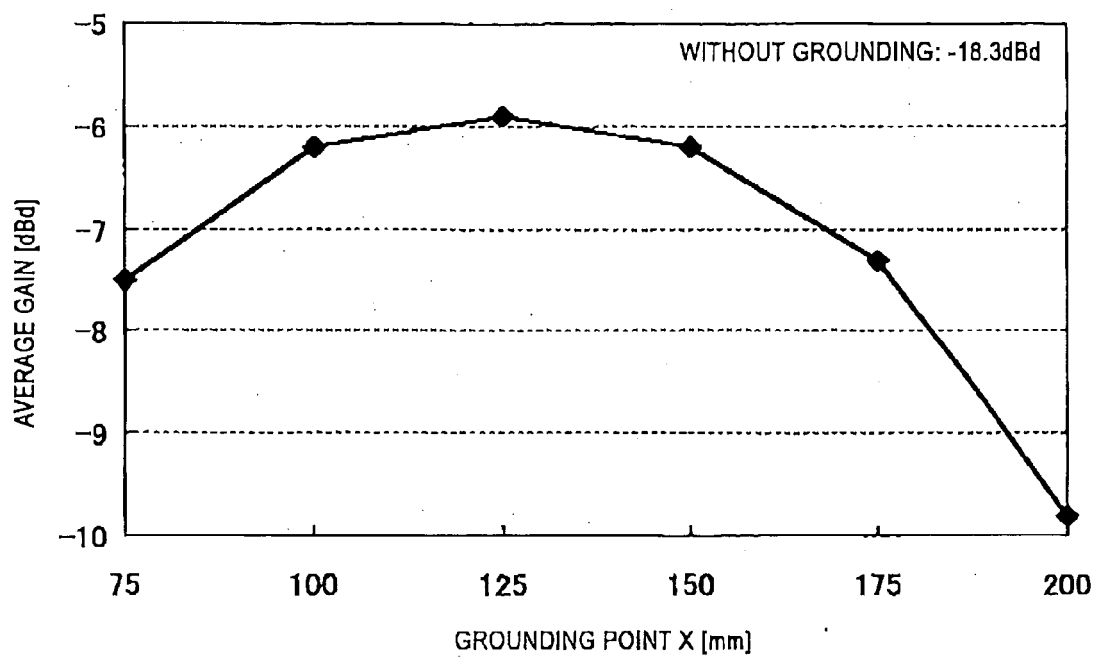
FIG. 6

FIG. 7

FIG. 8

FIG. 9

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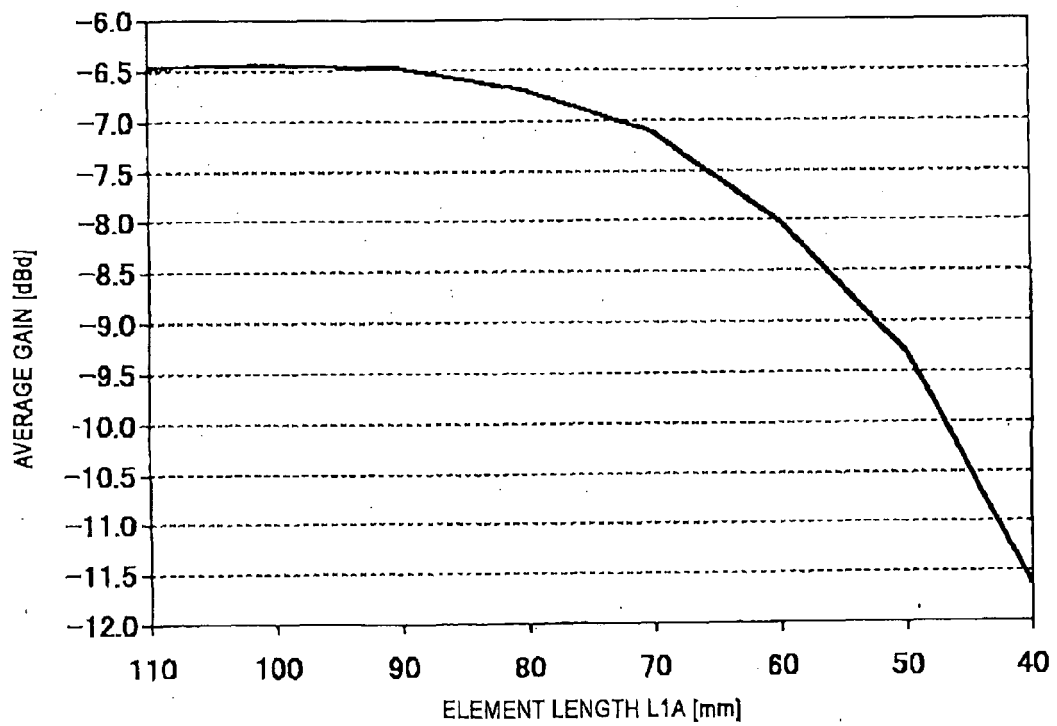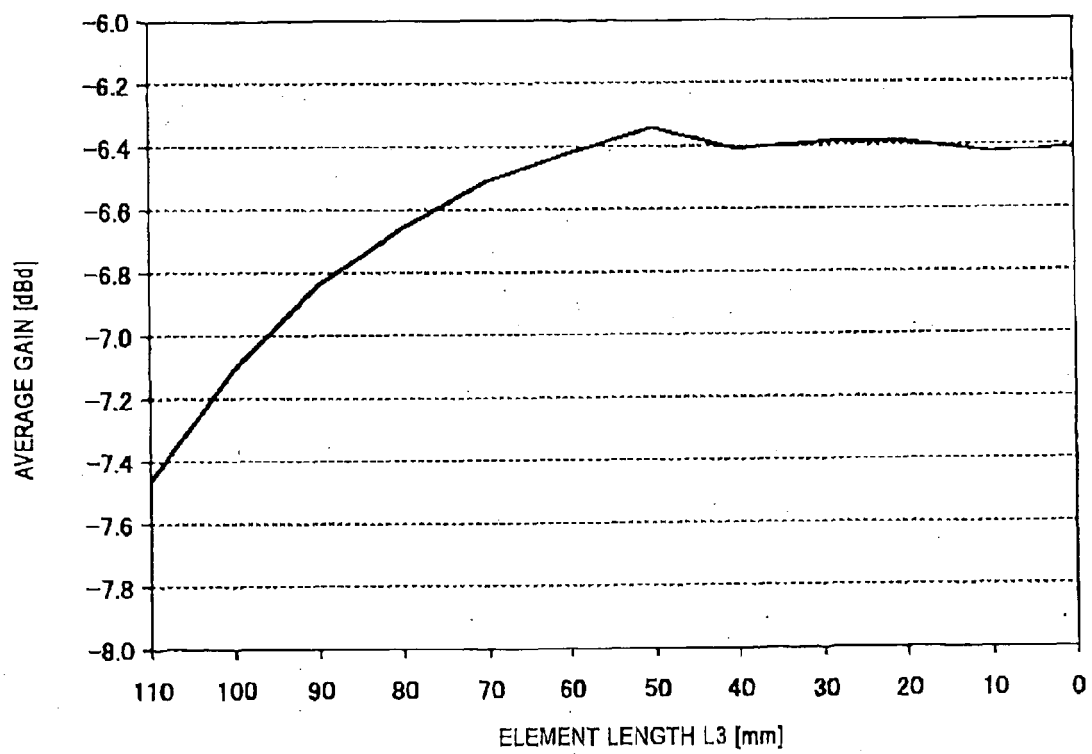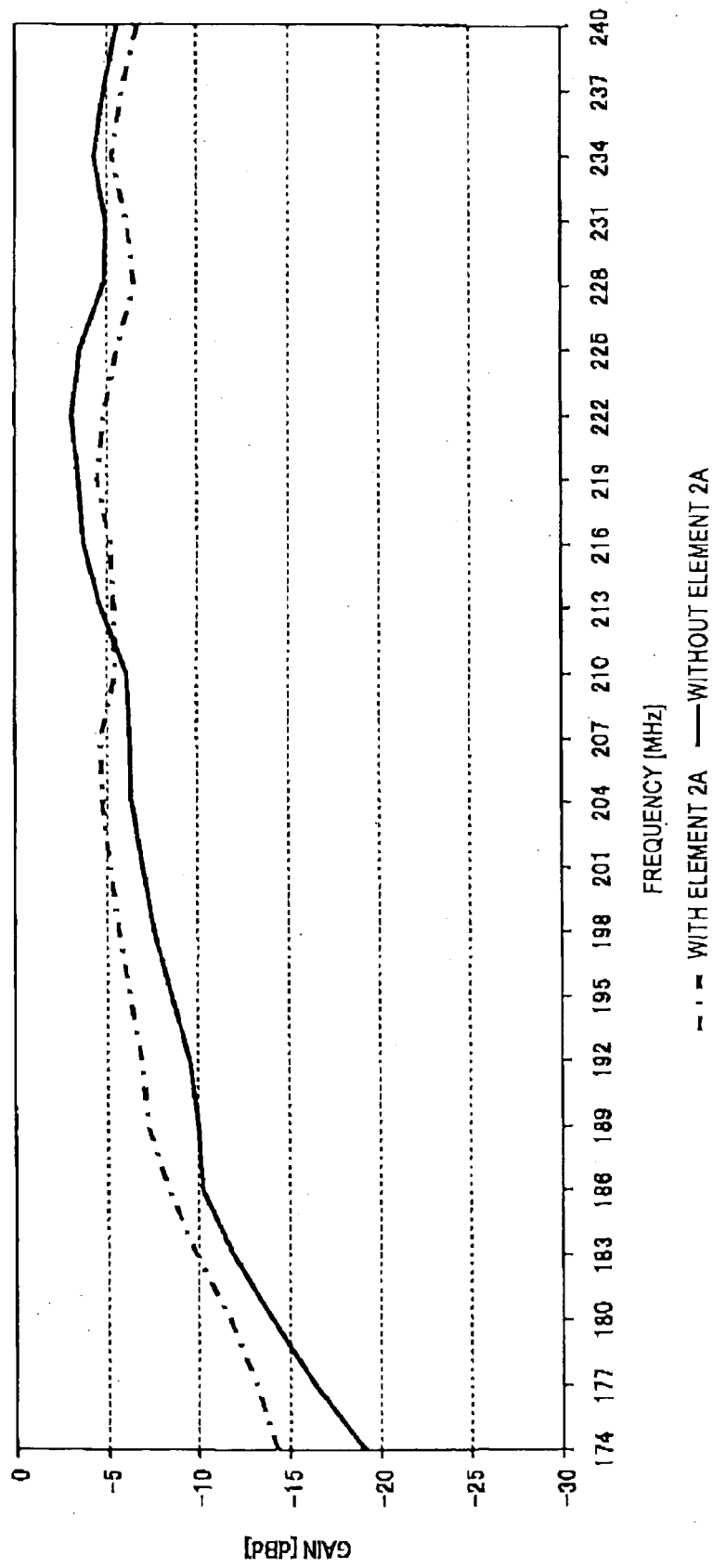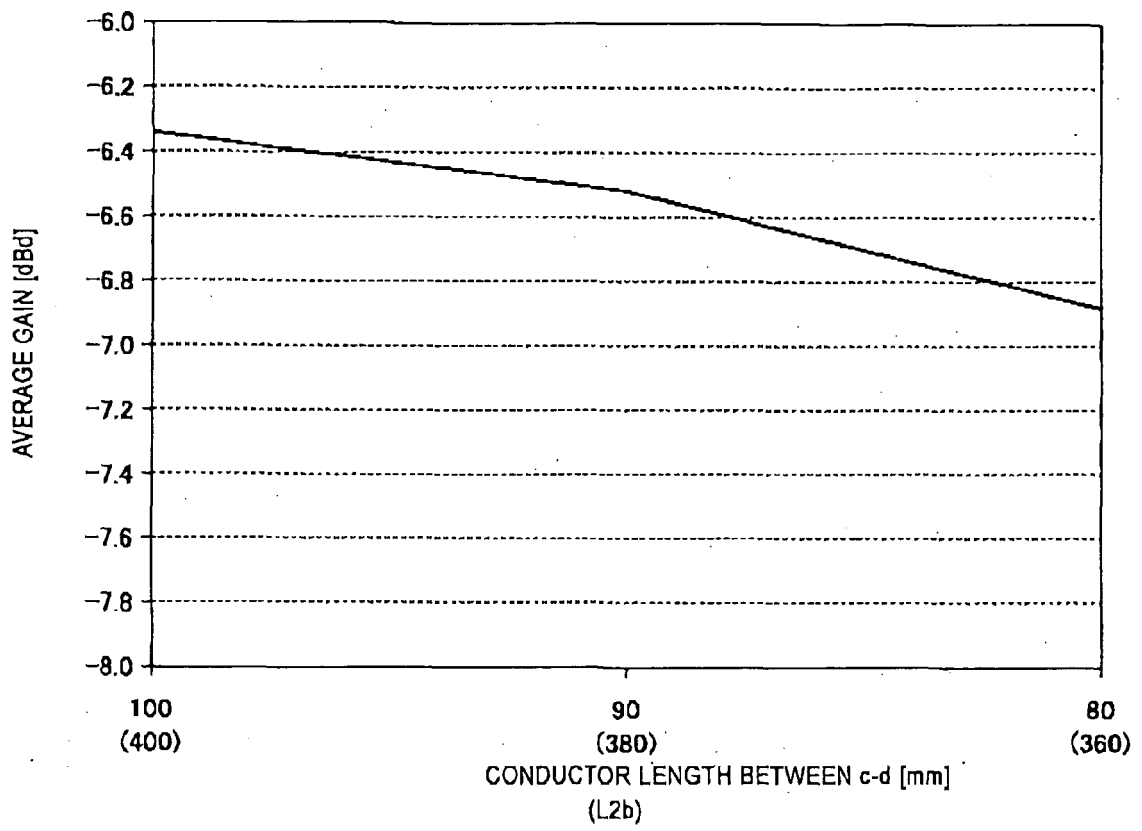
EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 2 173 008 A1 (ASAHI GLASS CO LTD [JP]) 7 April 2010 (2010-04-07) * the whole document *	1-15	INV. H01Q1/12 H01Q9/46 H01Q5/00
Y	JP 2001 326515 A (CENTRAL GLASS CO LTD) 22 November 2001 (2001-11-22) * abstract * * paragraph [0012] - paragraph [0018] * * paragraph [0024] * * paragraph [0029] * * paragraph [0038] * * paragraph [0042] * * figures 1-6 *	1-15	
Y,D	WO 02/075844 A1 (NIPPON SHEET GLASS CO LTD [JP]; OKA HIDETOSHI [JP]) 26 September 2002 (2002-09-26) * the whole document *	1-15	
Y	JP 2002 185230 A (CENTRAL GLASS CO LTD; NISSAN MOTOR) 28 June 2002 (2002-06-28) * paragraph [0028] * * paragraph [0034] * * paragraph [0039] - paragraph [0049] * * paragraph [0059] * * paragraph [0075] * * figures 1-9 *	1,2,5-8, 11,15	TECHNICAL FIELDS SEARCHED (IPC) H01Q
Y	US 5 657 029 A (IIJIMA HIROSHI [JP] ET AL) 12 August 1997 (1997-08-12) * column 4, line 40 - column 6, line 37 * * column 10, line 11 - line 62 * * figures 1, 2, 19, 20 *	1,4,5,7, 8,10,15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	10 February 2012	Köppe, Maro

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EPO FORM 1503 03.82 (P04C01)

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

EP 11 00 9323

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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10-02-2012

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 2173008	A1	07-04-2010	CN 101682108 A		24-03-2010
			EP 2173008 A1		07-04-2010
			JP 2009033735 A		12-02-2009
			KR 20100024382 A		05-03-2010
			US 2010097278 A1		22-04-2010
			WO 2009001798 A1		31-12-2008
JP 2001326515	A	22-11-2001	JP 3630616 B2		16-03-2005
			JP 2001326515 A		22-11-2001
WO 02075844	A1	26-09-2002	JP 2006173658 A		29-06-2006
			WO 02075844 A1		26-09-2002
JP 2002185230	A	28-06-2002	JP 4225373 B2		18-02-2009
			JP 2002185230 A		28-06-2002
US 5657029	A	12-08-1997	NONE		

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP H10327009 B **[0002]**
- JP 2000307321 A **[0002]**
- US 6924771 B **[0002]**
- EP 1732160 A **[0002]**