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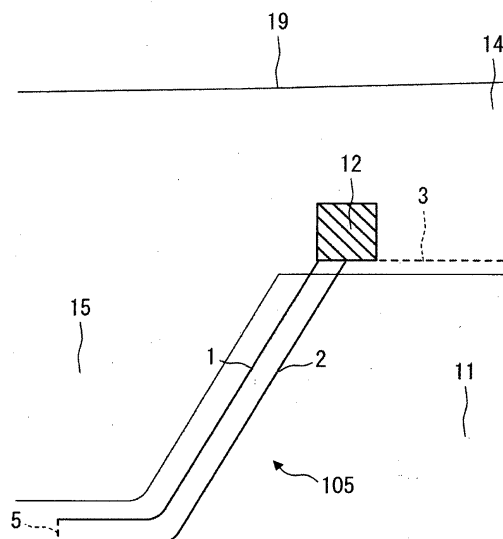
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(54) **GLASS ANTENNA-EQUIPPED VEHICLE FRONT GLASS**

(57) It is to provide a vehicle windshield provided with a glass antenna configured to be capable of dealing with dual bandwidths such as DAB, to have high receiver sensitivity, and not to disturb visibility from a driver's seat. The vehicle windshield provided with a glass antenna includes a glass antenna having an antenna conductor and a power feeder unit 12, and a light shield black film 14 being formed in a circumferential edge region of the vehicle windshield, and having a convex portion 15 which protrudes inwards in an in-plane direction from a region along an upper side of the vehicle windshield in the circumferential edge region and which is formed in a trapezoidal shape. The power feeder unit 12 is provided in the circumferential edge region close to the convex portion 15, and the antenna conductor has a first antenna element 1 connected to the power feeder unit 12 and configured to extend diagonally along a lateral side of the convex portion 15, and a second antenna element 2 connected to the first antenna element 1 and configured to extend in parallel with the first antenna element 1 while a predetermined gap is present therebetween.

FIG. 3



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Description

Technical Field

[0001] The present invention relates to a vehicle windshield provided with a glass antenna.

Background Art

[0002] Digital audio broadcasting (DAB) consists of two different frequency bandwidths, that is, Band III ranging from 174 MHz to 240 MHz and L Band ranging from 1452 MHz to 1492 MHz.

[0003] It is very difficult to design a glass antenna to be capable of dealing with a broadcast wave consisting of two separated frequency bandwidths as in the DAB, and to have high receiver sensitivity, and a glass antenna is desirably designed to be capable of dealing with dual bandwidths, and to have high receiver sensitivity. Patent Citation 1 discloses a glass antenna configured to be capable of dealing with dual bandwidths, and to have high receiver sensitivity.

Prior Art Document

Patent Citation

[0004] [Patent Citation 1] JP-A-2012-23707

Summary of Invention

Technical Problem

[0005] It is difficult to design a glass antenna to be capable of dealing with a broadcast wave consisting of two separated frequency bandwidths as in the DAB, and to have high receiver sensitivity. Since much consideration is required in order for visibility from a driver's seat not to be disturbed when a glass antenna is mounted on the windshield compared to when the glass antenna is mounted on a rear window or a side window, the glass antenna is required to have an inconspicuous shape. For this reason, a mounting region of the glass antenna is limited, and thereby it becomes difficult to design a glass antenna having high receiver sensitivity.

[0006] In the example of Patent Citation 1 illustrated in Fig. 1, since an antenna pattern is designed to occupy a small area, but a glass antenna section 55 is mounted to protrude from a light shield black film 14 applied to a circumferential edge of the windshield, the glass antenna is not inconspicuous, and does not satisfy the above-mentioned requirements.

[0007] The present invention provides a vehicle windshield provided with a glass antenna configured to be capable of dealing with dual bandwidths such as DAB, to have high receiver sensitivity and aesthetic appearance, and not to disturb visibility from a driver's seat.

[0008] In order to achieve the object, a vehicle wind-

shield provided with a glass antenna comprises:

a glass antenna having an antenna conductor and a power feeder unit; and

a light shield black film being formed in a circumferential edge region of the vehicle windshield, and having a convex portion which protrudes inwards in an in-plane direction from a region along an upper side of the vehicle windshield in the circumferential edge region and which is formed in a trapezoidal shape, wherein the power feeder unit is provided in the circumferential edge region close to the convex portion, and

wherein the antenna conductor has a first antenna element connected to the power feeder unit directly or via a first connection element, and configured to extend diagonally along a lateral side of the convex portion, and a second antenna element connected to the first antenna element via at least one of the power feeder unit and a second connection element, and configured to extend in parallel with the first antenna element while a predetermined gap is present therebetween.

25 Effect of Invention

[0009] According to the present invention it is possible to provide a vehicle windshield provided with a glass antenna configured to be capable of dealing with dual bandwidths such as DAB, to have high receiver sensitivity and aesthetic appearance, and not to disturb visibility from a driver's seat.

Brief Description of Drawings

[0010]

Fig. 1 illustrates a plan view of a conventional vehicle windshield 50 provided with a glass antenna.

Fig. 2 illustrates a plan view of a vehicle windshield 100 provided with a glass antenna 105.

Fig. 3 illustrates an enlarged plan view of the glass antenna 105 of the vehicle windshield provided with the glass antenna.

Fig. 4 illustrates an enlarged plan view of the glass antenna 205 of the vehicle windshield provided with the glass antenna.

Fig. 5 illustrates an enlarged plan view of the glass antenna 305 of the vehicle windshield provided with the glass antenna.

Fig. 6 illustrates an enlarged plan view of the glass antenna 405 of the vehicle windshield provided with the glass antenna.

Fig. 7 illustrates an enlarged plan view of the glass antenna 505 of the vehicle windshield provided with the glass antenna.

Fig. 8 illustrates an enlarged plan view of the glass antenna 605 of the vehicle windshield provided with

the glass antenna.

Fig. 9 illustrates actual measurement data regarding an impact of a change in the length of a diagonally extending portion of an antenna element on the gain of Band III.

Figs. 10(A) and 10(B) illustrate actual measurement data regarding an impact of the number of antenna elements and a loop formation on the gain of Band III and L band when a unipolar glass antenna is adopted.

Fig. 11 illustrates actual measurement data regarding an impact of the length of a first antenna element 1 and a second antenna element 2 on the gain of Band III when the unipolar glass antenna is adopted.

Figs. 12(A) and 12(B) illustrate actual measurement data regarding an impact of the angle of an antenna element on the gain of Band III and L band.

Fig. 13(A) and 13(B) illustrate actual measurement data regarding an impact of the number of antenna elements and a loop formation on the gain of Band III and L band when a bipolar glass antenna is adopted.

Fig. 14 illustrates actual measurement data regarding an impact of the length of the first antenna element 1 and the second antenna element 2 on the gain of Band III when the bipolar glass antenna is adopted.

Mode for Carrying Out the Invention

[0011] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings. In the drawings to illustrate the embodiments, a deviation in parallelism between lines, perpendicularity between lines, the curvature of a corner, or the like is allowed to the extent that the effects of the present invention is not degraded. The drawings are views when seen from the inside of a vehicle in a state where a windshield is attached to the vehicle, and may be referenced as views when seen from the outside of the vehicle. A rightward and leftward direction in the drawings is equivalent to a lateral direction of the vehicle.

(First Embodiment)

[0012] Fig. 2 is a plan view of a vehicle windshield 100 provided with a glass antenna 105, and Fig. 3 is an enlarged plan view illustrating the glass antenna 105.

[0013] As illustrated in Fig. 2, a light shield black film 14 is provided in a region with a predetermined width from an outer edge 19 of the vehicle windshield 100 provided with a glass antenna in the viewpoint of preventing the degradation of an adhesive, and in the viewpoint of aesthetic appearance so as to hide a connection portion of the windshield connected to a metal portion of a vehicle body. The light shield black film 14 has a convex portion 15 which protrudes inwards in the in-plane direction from a region along an upper side of the windshield, and which

is formed in a trapezoidal shape. Opposite lateral sides of the convex portion 15 are diagonally formed in such a manner that the distance between the opposite lateral sides decreases inwards in the plane of the windshield, and in this specification, an angle formed between a vertical center line 20 passing through the center of gravity of the windshield, and an extension line of the lateral side of the convex portion 15 is set to 5° or greater to 85° or less.

[0014] In the light shield black film and an edge portion at the in-plane side of the convex portion 15, the light shield black film may be formed uniformly or may be formed by a plurality of dots.

[0015] As illustrated in Fig. 3, the glass antenna 105 consists of a power feeder unit 12 and an antenna conductor, which are formed as planar patterns on a windshield 11.

[0016] The power feeder unit 12 is configured to electrically connect the antenna conductor and a signal processing circuit (not illustrated) such as an amplifier via a predetermined conductive member. A power feeder line such as an AV line or a coaxial cable is used as the conductive member. When the coaxial cable is used as the conductive member, preferably, an inner conductor of the coaxial cable is electrically connected to the power feeder unit 12, and an outer conductor of the coaxial cable is grounded to the vehicle body. A connector for electrically connecting the signal processing circuit (for example, an amplifier) and the power feeder unit 12 may be mounted on the power feeder unit 12. Owing to such a connector, the AV line or the inner conductor of the coaxial cable is easily attached to the power feeder unit 12. The following configuration may be adopted: a protruding conductive member is mounted on the power feeder unit 12, and the protruding conductive member is brought into contact with and is fitted into a connection portion of a vehicle body flange to which the windshield 11 is attached.

[0017] A part of the power feeder unit 12 may be provided in a circumferential edge region of the light shield black film 14, and particularly, the entirety of the power feeder unit 12 is preferably provided in the circumferential edge region. The power feeder unit 12 may be provided in the circumferential edge region close to the convex portion 15. The "vicinity of the convex portion 15" implies a range in which the power feeder unit 12 is allowed to be provided such that the effects of the present invention are not degraded, and specifically, a part of the power feeder unit 12 may be provided in a region having a radius of 35 mm around a root of the lateral side of the convex portion 15.

[0018] The glass antenna 105 includes a first antenna element 1 and a second antenna element 2 as the antenna conductors.

[0019] The first antenna element 1 is connected to the power feeder unit 12, and extends diagonally and downwards along the lateral side of the convex portion 15 which protrudes inwards in the in-plane direction from

the region of the light shield black film 14 along the upper side of the windshield, and which is formed in a trapezoidal shape. Fig. 3 illustrates the first antenna element 1 that extends diagonally along the circumference of the convex portion 15, and then is horizontally bent.

[0020] The term "along the lateral side of the convex portion 15" implies a range in which first antenna element 1 is allowed to be separate from the lateral side of the convex portion 15 such that the spirit of the present invention is not degraded in the viewpoint of aesthetic appearance and visual appearance. The first antenna element 1 is preferably within a distance of 15 mm from the edge of a light shield black film portion of the convex portion 15, and, more preferably, within a distance of 10 mm.

[0021] The bending of the first antenna element 1 is not necessarily required, and when the diagonally extending lateral side of the convex portion 15 is considerably long, the first antenna element 1 may consist of only a diagonal linear portion along the lateral side of the convex portion 15. The diagonal linear portion of the first antenna element along the lateral side of the convex portion 15 preferably has a length of 10 mm or greater to 300 mm or less, and, more preferably, a length of 30 mm or greater to 300 mm or less so as to obtain an improvement in antenna gain, and aesthetic appearance.

[0022] The second antenna element 2 is connected to the first antenna element 1 via the power feeder unit 12, and extends in parallel with the first antenna element 1 while a predetermined gap is present therebetween. Fig. 3 illustrates the second antenna element 2 along the first antenna element 1. When the number of elements diagonally extending is two as illustrated in Fig. 3, a preferable improvement in antenna gain is obtained. Due to aesthetic appearance, an improvement in antenna gain, and manufacturing limitation, the gap between the two antenna elements, that is, the first antenna element 1 and the second antenna element 2, is preferably 1 mm or greater to 15 mm or less, and, more preferably, 3 mm or greater to 10 mm or less.

[0023] In Fig. 3, the first antenna element 1 is connected to a corner of the power feeder unit 12; however, the first antenna element 1 may not be connected to the corner, and may be connected to any location on an outer circumference of the power feeder unit 12. Similarly, the second antenna element 2 may be connected to any location on the outer circumference of the power feeder unit 12.

[0024] Figs. 4 and 5 illustrate examples in which the configuration of the first embodiment is changed. In Fig. 4, the first antenna element 1 is connected to the power feeder unit 12 via a first connection element 6 that extends horizontally from the power feeder unit 12. The second antenna element 2 is connected to the first antenna element 1 via the power feeder unit 12 and a second connection element 7 configured to extend horizontally from the power feeder unit 12. In addition, as illustrated in Fig. 5, the second connection element 7 may

be configured to directly connect the second antenna element 2 and the first antenna element 1. As such, the first antenna element 1 may be connected to the power feeder unit directly or via the first connection element 6, and the second antenna element 2 may be connected to the first antenna element 1 via the power feeder unit 12 or the second connection element 7, or both the power feeder unit 12 and the second connection element 7.

[0025] When there are two predetermined separated frequency bandwidths to be received by the glass antenna 105, and it is assumed that a center frequency of a first frequency bandwidth, that is, a low bandwidth, has a wavelength λ_{01} in the air, the wavelength shortening coefficient of the windshield is k , and a wavelength λ_{g1} in the windshield is equal to $\lambda_{01} \times k$, the length of the first antenna element 1 (when the first connection element 6 is provided as illustrated in Fig. 4, the length of the first antenna element 1 also includes the length of the first connection element 6, and the same applies hereinafter) and the length of the second antenna element 2 (when the second connection element 7 is provided so as to extend directly from the power feeder unit 12 as illustrated in Fig. 4, the length of the second antenna element 2 also includes the length of the second connection element 7, and when the second antenna element 2 is directly connected to the first antenna element 1 via the second connection element 7 as illustrated in Fig. 5, the length of the second antenna element 2 also includes the length of the shortest path from a connection point between the second connection element 7 and the first antenna element 1 to the power feeder unit 12, and the same applies hereinafter) are preferably set to $(5/32) \times \lambda_{g1}$ or greater to $(5/16) \times \lambda_{g1}$ or less so as to obtain an improvement in the antenna gain of the first frequency bandwidth.

[0026] For example, when the first frequency bandwidth is set to Band III (174 MHz to 240 MHz), the center frequency is 207 MHz. Accordingly, in a case where it is desired to improve the antenna gain of Band III, and when it is assumed that the speed of a radio wave is 3.0×10^8 m/s and the wavelength shortening coefficient k is 0.64, the length of each of the first antenna element 1 and the second antenna element 2 is preferably adjusted to 145 mm or greater to 289 mm or less.

[0027] An angle α formed between an extension line of each of the first antenna element 1 and the second antenna element 2 illustrated in Fig. 2, and the vertical center line 20 passing through the center of gravity of the windshield is preferably set to 5° or greater to 50° or less, more preferably, 20° or greater to 45° or less. When at least the angle is set to 50° or less, it is possible to considerably increase obtainable gain. The shape of the convex portion 15 is preferably designed in such a manner that the angle formed between the extension line of the lateral side of the convex portion 15 of the light shield black film, and the vertical center line 20 passing through the center of gravity of the windshield is equal to the angle α formed between the extension line of each of the first antenna element 1 and the second antenna element 2,

and the vertical center line 20 passing through the center of gravity of the windshield. The reason for this is that both good antenna performance and aesthetic appearance are obtained.

[0028] That is, when the windshield is seen from the outside of the vehicle, components provided on a place where the light shield film is provided cannot be seen from the outside of the vehicle due to the light shield black film 14, and only the thin linear portions of the antenna conductors are seen; however the linear portions are formed along the light shield black film 14, and thereby the antenna conductors are inconspicuous.

[0029] As such, since the antenna elements are configured along the convex portion 15 which protrudes inwards in the in-plane direction from the region of the light shield black film 14 along the upper side of the windshield, and which is formed in a trapezoidal shape, even though the antenna configured to receive a dual-bandwidth broadcast wave is mounted, it is possible to obtain the vehicle windshield provided with the glass antenna which has the low-visibility antenna conductors, does not disturb a visual field of a driver, and has the beautiful appearance while ensuring antenna performance.

[0030] A loop may be formed by at least the first antenna element 1, the second antenna element 2, and a loop formation element 5 by connecting end portions being opposite to the power feeder unit 12 of the first antenna element 1 and the second antenna element 2 via a loop formation element 5. In the example illustrated in Fig. 3, a loop is formed by including the power feeder unit 12. Since the loop formation element 5 is an arbitrary configuration, for illustrative purposes, the loop formation element 5 is illustrated by a dotted line in Fig. 3; however, actually, the loop formation element 5 is a continuous line-like conductor similar to the first antenna element 1 and the like. Since a continuous loop is formed using the first antenna element 1 and the second antenna element 2, it is possible to considerably improve an obtainable antenna gain.

[0031] As illustrated in Figs. 4 and 5, the length of the loop formation element 5 may be longer than the gap between the first antenna element 1 and the second antenna element 2. In a configuration illustrated in Figs. 4 and 5, a foldback element 8 extends from a tip end of the loop formation element 5 in parallel with the first antenna element 1, while a predetermined gap present is present between the first antenna element 1 and the foldback element 8. Since the foldback element 8 is formed, it is possible to improve an obtainable antenna gain. In addition, it is possible to decrease the length of each of the first antenna element 1 and the second antenna element 2. The foldback element 8 may extend in the middle of the loop formation element 5. In Figs. 4 and 5, only a single foldback element is provided in one of the first antenna element 1 and the second antenna element 2; however, the present invention is not limited to that configuration in the embodiment. The foldback element 8 may be provided in either one of the first antenna element

1 and the second antenna element 2, and two or more foldback elements 8 may be provided.

[0032] Fig. 5 illustrates an example in which a tip end of the foldback element 8 is further bent. The bending of the tip end of the foldback element 8 is mainly effective in adjusting the gain of L band. Since the foldback element 8 is an arbitrary configuration requirement, for illustrative purposes, the foldback element 8 is illustrated by a dotted line in Figs. 4 and 5; however, actually, the foldback element 8 is a continuous line-like conductor similar to the first antenna element and the like.

[0033] As illustrated in Fig. 3, a third antenna element 3 may be added in such a manner as to extend horizontally from the power feeder unit 12. The third antenna element 3 is mainly used to adjust the gain of L band. Fig. 3 illustrates an example in which the third antenna element 3 extends horizontally in an opposite side of an incline direction of the first antenna element 1 and the second antenna element 2, and in contrast, as illustrated in Figs. 4 and 5, the third antenna element 3 may extend horizontally in the same side as the incline direction. Since the third antenna element 3 is an arbitrary configuration requirement, for illustrative purposes, the third antenna element 3 is illustrated by a dotted line in Figs. 3 to 5; however, actually, the third antenna element 3 is a continuous line-like conductor similar to the first antenna element and the like.

[0034] The third antenna element 3 is connected to a corner of the power feeder unit 12; however, the third antenna element 3 may not be connected to the corner, and may be connected to any location on the outer circumference of the power feeder unit 12.

[0035] When it is assumed that a center frequency of a second frequency bandwidth higher than the first frequency bandwidth has a wavelength λ_{02} in the air, the wavelength shortening coefficient of the windshield is k , and a wavelength λ_{g2} in the windshield is equal to $\lambda_{02} \times k$, the length of the third antenna element 3 is preferably set to $(1/8) \times \lambda_{g2}$ or greater to $(7/8) \times \lambda_{g2}$ or less so as to improve the antenna gain of the second frequency bandwidth.

[0036] For example, when the second frequency bandwidth is set to L band (1452 MHz to 1492 MHz), the center frequency of the second frequency bandwidth is 1472 MHz. Accordingly, in a case where it is desired to improve the antenna gain of L band, and when it is assumed that the speed of a radio wave is 3.0×10^8 m/s and the wavelength shortening coefficient k is 0.64, the length of the third antenna element 3 is preferably adjusted to 16 mm or greater to 114 mm or less.

(Second Embodiment)

[0037] Fig. 6 is an enlarged plan view illustrating a glass antenna 405 of a vehicle windshield provided with a glass antenna.

[0038] As illustrated in Fig. 6, the same reference signs as those in Fig. 3 will be assigned to members of the

vehicle windshield provided with a glass antenna, and the glass antenna 405, which have the same configurations as in the vehicle windshield provided with a glass antenna, and the glass antenna 105 illustrated in Fig. 3.

[0039] The glass antenna 405 consists of the power feeder unit 12, a ground-side power feeder unit 16, and an antenna conductor, which formed as planar patterns on the windshield 11.

[0040] The power feeder unit 12 is a power feed point electrically connected to a signal path of a signal processing circuit (not illustrated) such as an amplifier via a predetermined conductive member, and the ground-side power feeder unit 16 is a power feed point electrically connected to an external ground path (for example, a ground of the signal processing circuit or the vehicle body) via a predetermined conductive member. The ground-side power feeder unit 16 may be electrically connected to the signal path of the signal processing circuit (not illustrated) such as an amplifier via the predetermined conductive member, and the power feeder unit 12 may be electrically connected to the external ground path (for example, the ground of the signal processing circuit or the vehicle body) via the predetermined conductive member. That is, the glass antenna 405 is a bipolar antenna configured to include the power feeder unit 12 and the ground-side power feeder unit 16 as a pair of power feed points.

[0041] A power feeder line such as an AV line or a coaxial cable is used as the conductive member. When the coaxial cable is used as the conductive member, preferably, an inner conductor of the coaxial cable is electrically connected to the power feeder unit 12, and an outer conductor of the coaxial cable is connected to the ground-side power feeder unit 16. Connectors for electrically connecting the signal processing circuit (for example, an amplifier) to the power feeder unit 12 and the ground-side power feeder unit 16 may be respectively mounted on the power feeder unit 12 and the ground-side power feeder unit 16. Owing to such connectors, the inner conductor and the outer conductor of the coaxial cable are easily attached to the power feeder unit 12 and the ground-side power feeder unit 16, respectively. The following configuration may be adopted: a protruding conductive member is mounted on each of the power feeder unit 12 and the ground-side power feeder unit 16, and the protruding conductive member is brought into contact with and is fitted into the connection portion of the vehicle body flange to which the windshield 11 is attached.

[0042] A fourth antenna element 4 may be added in such a manner as to extend horizontally from the ground-side power feeder unit 16.

[0043] In the second embodiment in which the ground-side power feeder unit 16 or both the ground-side power feeder unit 16 and the fourth antenna element 4 are added, it is possible to decrease the length of each of the first antenna element 1 and the second antenna element 2 to approximately 0.75 times that of the first embodiment, and to make the glass antenna less invisible than

that of the first embodiment, and the glass antenna is good in the viewpoint of aesthetic appearance.

[0044] The fourth antenna element 4 is connected to a corner of the power feeder unit 12; however, the fourth antenna element 4 may not be connected to the corner, and may be connected to any location on the outer circumference of the power feeder unit 12.

[0045] The ground-side power feeder unit 16 is preferably grounded to the vehicle body positioned close to the glass antenna. For example, the power feeder unit 12 and the outer conductor of the coaxial cable connected to the ground-side power feeder unit 16 are preferably connected to the vehicle body positioned within a distance of 180 mm or less from the power feeder unit 12 and the ground-side power feeder unit 16.

[0046] As described in the first embodiment, arbitrary configurations are illustrated by dotted lines in Fig. 6. That is, a loop may be formed by at least the first antenna element 1, the second antenna element, and the loop formation element by connecting the end portions being opposite to the power feeder unit of the first antenna element 1 and the second antenna element 2 via the loop formation element 5, and the third antenna element 3 extending horizontally from the power feeder unit 12 may also be added. It is possible to considerably improve an obtainable antenna gain by forming the loop, and the addition of the third antenna element 3 is mainly effective in adjusting the gain of L band.

[0047] When there are two predetermined separated frequency bandwidths to be received by the glass antenna 105, and it is assumed that the center frequency of the first frequency bandwidth, that is, a low bandwidth, has the wavelength λ_{01} in the air, the wavelength shortening coefficient of the windshield is k , and the wavelength λ_{g1} in the windshield is equal to $\lambda_{01} \times k$, the length of the first antenna element 1 and the length of the second antenna element 2 are preferably set to $(9/64) \times \lambda_{g1}$ or greater to $(15/64) \times \lambda_{g1}$ or less so as to obtain an improvement in the antenna gain of the first frequency bandwidth.

[0048] For example, when the first frequency bandwidth is set to Band III (174 MHz to 240 MHz), the center frequency is 207 MHz. Accordingly, in a case where it is desired to improve the antenna gain of Band III, and when it is assumed that the speed of a radio wave is 3.0×10^8 m/s and the wavelength shortening coefficient k is 0.64, the length of each of the first antenna element 1 and the second antenna element 2 is preferably adjusted to 130 mm or greater to 217 mm or less.

[0049] Figs. 7 and 8 illustrate examples in which the configuration of the second embodiment is changed. In the example illustrated in Fig. 7, the second antenna element 2 extends diagonally along the first antenna element 1, and is connected to the first antenna element 1 via the second connection element 7 configured to extend horizontally from the power feeder unit 12. In the example illustrated in Fig. 8, the second antenna element 2 is connected to an end portion being opposite to the

power feed point of the first antenna element 1 via the second connection element 7. In addition, a cutout portion 9 is provided in the middle of the second antenna element 2. As such, the second antenna element 2 may be joined to any location on the first antenna element 1 via the second connection element 7, and the second antenna element 2 may have the cutout portion 9 in the middle thereof. The providing of the cutout portion 9 improves an obtainable antenna gain.

[0050] As illustrated in Fig. 7, the end portions being opposite to the power feeder unit 12 of the first antenna element 1 and the second antenna element 2 may be in the middle of bent portions. In addition, the third antenna element 3 and the fourth antenna element 4 may extend horizontally from a right upper corner of the power feeder unit 12 and a left upper corner of the ground-side power feeder unit 16, respectively. The application of this configuration is not limited to the second embodiment, and this configuration can also be applied to the first embodiment.

[0051] The respective connection portions of the elements may be curvedly connected to each other.

[0052] The antenna conductor, the power feeder unit 12, and the ground-side power feeder unit 16 are formed by printing paste containing a conductive metal (for example, silver paste) on an inner surface of the windshield and baking the paste. However, a method of forming the antenna conductor, the power feeder unit 12, and the ground-side power feeder unit 16 is not limited to the above-mentioned method. The antenna conductor, the power feeder unit 12, and the ground-side power feeder unit 16 may be formed by providing a line-like body or a foil-like body made of a conductive material such as copper on the inner surface of the windshield, by bonding the line-like body or the foil-like body to the windshield by using an adhesive, or by embedding the line-like body or the foil-like body in the windshield.

[0053] The shape of the power feeder unit 12 and the ground-side power feeder unit 16 may be determined corresponding to the shape of the conductive member or a mounting surface of the connector. For example, a quadrate shape such as a square shape, a substantially square shape, a rectangular shape, or a substantially rectangular shape, or a polygonal shape is preferably used in the viewpoint of mounting. A circular shape, a substantially circular shape, an elliptical shape, a substantially elliptical shape, or the like may be used.

[0054] A conductor layer made up of the antenna conductors may be embedded in a composite resin film or is provided on the surface of the composite resin film, and the composite resin film provided with the conductor layer may be formed on the inner surface or an outer surface of the windshield as the glass antenna. A flexible circuit substrate having the antenna conductors formed thereon may be formed on the inner surface of the windshield as the glass antenna.

Examples

[0055] The antenna gain of the vehicle windshield provided with a glass antenna is measured in a state where the vehicle windshield provided the glass antenna as illustrated in Fig. 2 is actually attached to a vehicle. Hereinafter, a measurement result will be described.

[0056] The antenna gain was measured in a state where the vehicle windshield provided with a glass antenna was assembled to a window frame of the vehicle on a turntable while being inclined by approximately 25° relative to a horizontal plane. The power feeder unit had a connector attached thereto, and was connected to a network analyzer via a feeder line. The turntable was rotated in such a manner that radio waves were horizontally radiated on the windshield in all directions.

[0057] The antenna gain was measured while rotating the vehicle by 360° in a state where the center of the turntable was aligned with the center of the vehicle to which the vehicle windshield provided with a glass antenna is assembled. The data obtained by measuring the antenna gain while rotating the vehicle by 360° at every rotation angle of 5° at each frequency are averaged. The measurement was performed at every 3 MHz in the frequency range of Band III, and at every 1.7 MHz in the frequency range of L band. The antenna gain was measured in a state where an elevation angle between a position of the transmission of radio waves and the antenna conductor was set to be substantially horizontal (when an elevation angle was 0° in a plane parallel with the ground, and an elevation angle was 90° in a vertical direction, the term "being substantially horizontal" indicated a direction at an elevation angle of 0°). The antenna gain was normalized on the basis of a half-wavelength dipole antenna in such a manner that the antenna gain of the half-wavelength dipole antenna became 0 dB.

<Example 1>

[0058] In a state where the second connection element 7, the second antenna element 2, and the loop formation element 5 were omitted from a glass antenna 505 illustrated in Fig. 7, and the third antenna element 3 and the fourth antenna element 4 were provided, the antenna gain of the glass antenna 505 was measured while changing only a ratio of the diagonally extending portion of the first antenna element 1 to the horizontally extending portion of the first antenna element 1. Fig. 9 illustrates a result of measuring an impact of the length of a diagonally extending portion of the first antenna element on the gain of Band III while fixing the entire length of the first antenna element 1 at 170 mm, and changing the length of the diagonally extending portion and the length of the horizontally extending portion of the first antenna element 1. The antenna gains averaged for the entire frequencies of Band III were plotted.

[0059] In Fig. 9, when the length of each portion of the glass antenna 505 was measured in a unit of mm,

First antenna element 1 (the entire length) : 170

Third antenna element 3: 45

Fourth antenna element 4: 70

[0060] In addition, the conductive width of each of the elements was 0.4 mm. Each of the power feeder unit 12 and the ground-side power feeder unit 16 had a rectangular shape having a vertical length of 14 mm by a horizontal length of 20 mm. The gap between the power feeder unit 12 and the ground-side power feeder unit 16 was 21 mm. The conductive width of the element, the size of the power feeder unit, and the gap between the power feeder unit 12 and the ground-side power feeder unit 16 were the same in all of Examples hereinbelow.

[0061] As seen from Fig. 9, it was possible to obtain a larger gain as the length of the diagonally extending portion of the first antenna element 1 was increased.

<Example 2>

[0062] The antenna gains were measured to obtain an impact on the gain of Band III and L band when the second antenna element 2 was provided, or when a loop was formed by the second antenna element 2 and the loop formation element 5 compared to when only the first antenna element 1 was provided in the unipolar glass antenna 105 including the third antenna element 3 illustrated in Fig. 3. Figs. 10(A) and 10(B) illustrate the results. Antenna gains averaged for the entire frequencies of each of Band III and L band were plotted.

[0063] In Figs. 10(A) and 10(B), when the length of each portion of the glass antenna 105 was measured in a unit of mm,

First antenna element 1: 240

Second antenna element 2: 240

Third antenna element 3: 100

Loop formation element 5: 10

[0064] In Figs. 10(A) and 10(B), a "first example" referred to the case in which only the first antenna element 1 was provided, a "second example" referred to the case in which the second antenna element 2 was provided, and a "third example" referred to the case in which the loop formation element 5 was provided, and a loop was formed by the first antenna element 1 and the second antenna element 2.

[0065] As seen from Figs. 10(A) and 10(B), when the number of antenna elements diagonally extending was two, it was possible to considerably improve the gain of a high bandwidth of Band III and L band. When the loop was formed by connecting the end portions being opposite to the power feeder unit 12 of the first antenna element 1 and the second antenna element 2 via the loop formation element 5, it was possible to considerably improve the gain of a low bandwidth of Band III and to increase the entire gain of L band.

<Example 3>

[0066] The antenna gains were measured to obtain an

impact of the length of the first antenna element 1 on the gain of Band III while changing the length of the first antenna element 1 in a state where the second antenna element 2 and the loop formation element 5 are omitted from the glass antenna 105 including the third antenna element 3 illustrated in Fig. 3. Fig. 11 illustrates the results. The antenna gains averaged for the entire frequencies of Band III were plotted.

[0067] In Fig. 11, when the length of each portion of the glass antenna 105 was measured in a unit of mm, First antenna element 1: 160 to 280

Third antenna element 3: 100

[0068] A high gain was obtained by setting the length of the first antenna element 1 to 145 mm to 289 mm.

<Example 4>

[0069] In a state where the third antenna element 3 and the fourth antenna element 4 were provided, and the second connection element 7, the second antenna element 2, and the loop formation element 5 were omitted from the glass antenna 505 illustrated in Fig. 7, the antenna gain of the glass antenna 505 was measured to obtain an impact of the angle α formed between the extension line of the first antenna element 1, and the center line 20 in the vertical direction of the windshield on the gain of Band III and L band. Figs. 12(A) and 12(B) illustrate the results. Antenna gains averaged for the entire frequencies of each of Band III and L band were plotted.

[0070] In Figs. 12(A) and 12(B), when the length of each portion of the glass antenna 505 was measured in a unit of mm,

First antenna element 1: 170

Third antenna element 3: 45

Fourth antenna element 4: 70

[0071] The test was performed in a state where parameters other than the angle of the first antenna element 1 were fixed.

[0072] As illustrated in Fig. 12(B), it was possible to considerably improve the gain when the angle α is 50° or greater, particularly in L band.

<Example 5>

[0073] The antenna gain was measured to obtain an impact on the gain of Band III and L band when the second connection element 7 and the second antenna element 2 were provided, or when a loop was formed by the second connection element 7, the second antenna element 2, and the loop formation element 5 compared to when the third antenna element 3 and the fourth antenna element 4 are provided and only the first antenna element 1 is provided in the bipolar glass antenna 505 illustrated in Fig. 7. Figs. 13(A) and 13(B) illustrate the results.

[0074] In Figs. 13(A) and 13(B), when the length of each portion of the glass antenna 505 was measured in a unit of mm,

First antenna element 1: 170

Second connection element 7: 10

Second antenna element 2: 170

Third antenna element 3: 45

Fourth antenna element 4: 70

Loop formation element 5: 10

[0075] In Figs. 13(A) and 13(B), a "fourth example" referred to the case in which only the first antenna element 1 was provided, a "fifth example" referred to the case in which the second connection element 7 and the second antenna element 2 were provided, and a "sixth example" referred to the case in which the loop formation element 5 was provided, and a loop was formed by the first antenna element 1 and the second antenna element 2.

[0076] As seen from Figs. 13(A) and 13(B), when the number of elements diagonally extending was two, it was possible to considerably improve the gain of L band while maintaining the gain of Band III. When the loop was formed by connecting the end portions of the first antenna element 1 and the second antenna element 2 via the loop formation element 5, it was possible to increase the entire gain of L band while maintaining the gain of Band III.

<Example 6>

[0077] The antenna gain was measured to obtain an impact of the length of the first antenna element 1 on the gain of Band III while changing the length of the first antenna element 1 in a state where the second connection element 7, the second antenna element 2, and the loop formation element 5 are omitted from the bipolar glass antenna 505 illustrated in Fig. 7. Fig. 14 illustrates the results.

[0078] In Fig. 14, when the length of each portion of the glass antenna 505 was measured in a unit of mm,

First antenna element 1: 110 to 300

Third antenna element 3: 45

Fourth antenna element 4: 70

[0079] As illustrated in Fig. 14, it was possible to obtain a high gain by setting the length of the first antenna element 1 to 130 mm to 217 mm.

[0080] This application has been described in detail or with reference to specific embodiments, and it is apparent to persons skilled in the related art that various modifications or addition can be made insofar as the modifications or the addition do not depart from the spirit and the scope of the present invention.

[0081] This application is based on Japanese Patent Application No. 2012-285247 filed on December 27, 2012, the content of which is incorporated herein by reference.

Explanation of Reference

[0082]

1: first antenna element

2: second antenna element

3: third antenna element

4: fourth antenna element

5: loop formation element

6: first connection element

7: second connection element

8: foldback element

9: cutout portion

11: windshield

12: power feeder unit

14: light shield black film

15: convex portion

16: ground-side power feeder unit

19: outer edge of windshield

20: center line in vertical direction of windshield

50: vehicle windshield provided with glass antenna in related art

55: glass antenna in related art

100: vehicle windshield provided with glass antenna

105, 205, 305, 405, 505, and 605: glass antenna

α : angle formed between antenna element and center line in vertical direction of windshield

Claims

1. A vehicle windshield provided with a glass antenna comprising:

a glass antenna having an antenna conductor and a power feeder unit; and

a light shield black film being formed in a circumferential edge region of the vehicle windshield, and having a convex portion which protrudes inwards in an in-plane direction from a region along an upper side of the vehicle windshield in the circumferential edge region and which is formed in a trapezoidal shape, wherein the power feeder unit is provided in the circumferential edge region close to the convex portion, and

wherein the antenna conductor has a first antenna element connected to the power feeder unit directly or via a first connection element, and configured to extend diagonally along a lateral side of the convex portion, and a second antenna element connected to the first antenna element via at least one of the power feeder unit and a second connection element, and configured to extend in parallel with the first antenna element while a predetermined gap is present therebetween.

2. The vehicle windshield provided with a glass antenna according to claim 1,

wherein an angle, formed between an extension line of a linear portion of each of the first antenna element and the second antenna element along the lateral side of the convex portion, and a vertical center line passing through the center of gravity of the vehicle

- windshield, is 5° or greater to 50° or less.
3. The vehicle windshield provided with a glass antenna according to claim 1 or 2, wherein the antenna conductor has a loop formation element configured to connect end portions being opposite to the power feeder unit of the first antenna element and the second antenna element. 5
 4. The vehicle windshield provided with a glass antenna according to claim 3, wherein the antenna conductor has a foldback element connected to the loop formation element, and configured to extend in parallel with the first antenna element while a predetermined gap is present therebetween. 10
 5. The vehicle windshield provided with a glass antenna according to any one of claims 1 to 4, wherein the antenna conductor has a third antenna element connected to the power feeder unit, and configured to extend horizontally. 15
 6. The vehicle windshield provided with a glass antenna according to claim 5, wherein the glass antenna receives a predetermined first frequency bandwidth, and a predetermined second frequency bandwidth higher than the first frequency bandwidth, and when it is assumed that a center frequency of the second frequency bandwidth has a wavelength λ_{02} in the air, the wavelength shortening coefficient of the windshield is k , and a wavelength λ_{g2} in the windshield is equal to $\lambda_{02} \times k$, the distance between the power feeder unit and an end portion being opposite to the power feeder unit of the third antenna element is $(1/8) \times \lambda_{g2}$ or greater to $(7/8) \times \lambda_{g2}$ or less. 20
 7. The vehicle windshield provided with a glass antenna according to claim 5, wherein the third antenna element has a length of 16 mm or greater to 114 mm or less. 25
 8. The vehicle windshield provided with a glass antenna according to any one of claims 1 to 7, wherein the glass antenna receives a predetermined first frequency bandwidth, and a predetermined second frequency bandwidth higher than the first frequency bandwidth, and when it is assumed that a center frequency of the first frequency bandwidth has a wavelength λ_{01} in the air, the wavelength shortening coefficient of the windshield is k , and a wavelength λ_{g1} in the windshield is equal to $\lambda_{01} \times k$, the distance between the power feeder unit and end portions being opposite to the power feeder unit of the first antenna element and the second antenna element is $(5/32) \times \lambda_{g1}$ or greater to $(5/16) \times \lambda_{g1}$ or less. 30
 9. The vehicle windshield provided with a glass antenna according to any one of claims 1 to 7, wherein the first antenna element and the second antenna element have a length of 145 mm or greater to 289 mm or less. 35
 10. The vehicle windshield provided with a glass antenna according to any one of claims 1 to 9, wherein the glass antenna has a ground-side power feeder unit in the vicinity of the power feeder unit. 40
 11. The vehicle windshield provided with a glass antenna according to claim 10, wherein the glass antenna has a fourth antenna element configured to extend horizontally from the ground-side power feeder unit in a side opposite to the power feeder unit. 45
 12. The vehicle windshield provided with a glass antenna according to claim 10 or 11, wherein the glass antenna receives a predetermined first frequency bandwidth, and a predetermined second frequency bandwidth higher than the first frequency bandwidth, and when it is assumed that a center frequency of the first frequency bandwidth has a wavelength λ_{01} in the air, the wavelength shortening coefficient of the windshield is k , and a wavelength λ_{g1} in the windshield is equal to $\lambda_{01} \times k$, the distance between the power feeder unit and end portions being opposite to the power feeder unit of the first antenna element and the second antenna element is $(9/64) \times \lambda_{g1}$ or greater to $(15/64) \times \lambda_{g1}$ or less. 50
 13. The vehicle windshield provided with a glass antenna according to claim 10 or 11, wherein the first antenna element and the second antenna element have a length of 130 mm or greater to 217 mm or less. 55
 14. The vehicle windshield provided with a glass antenna according to any one of claims 1 to 13, wherein the first antenna element and the second antenna element have a diagonally extending portion whose length is 10 mm or greater.

FIG. 1

50

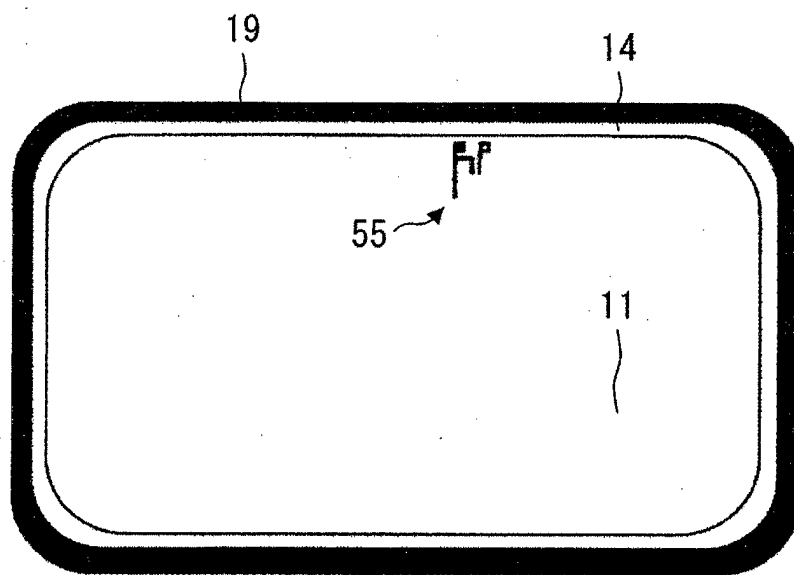


FIG. 2

100

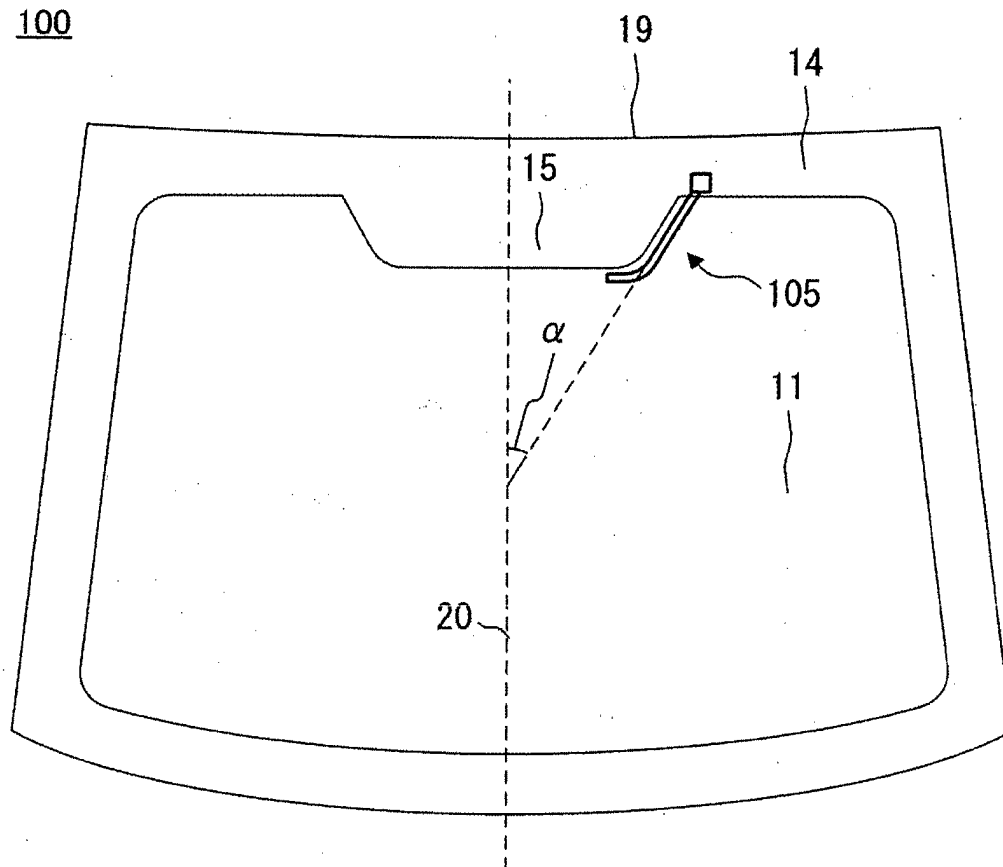


FIG. 3

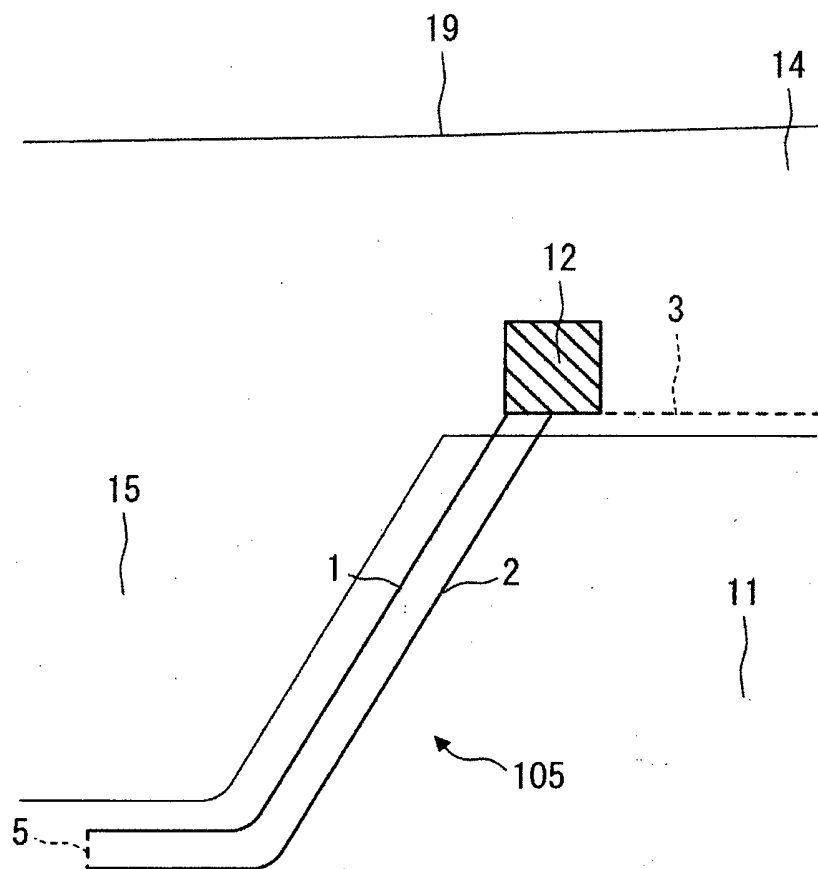


FIG. 4

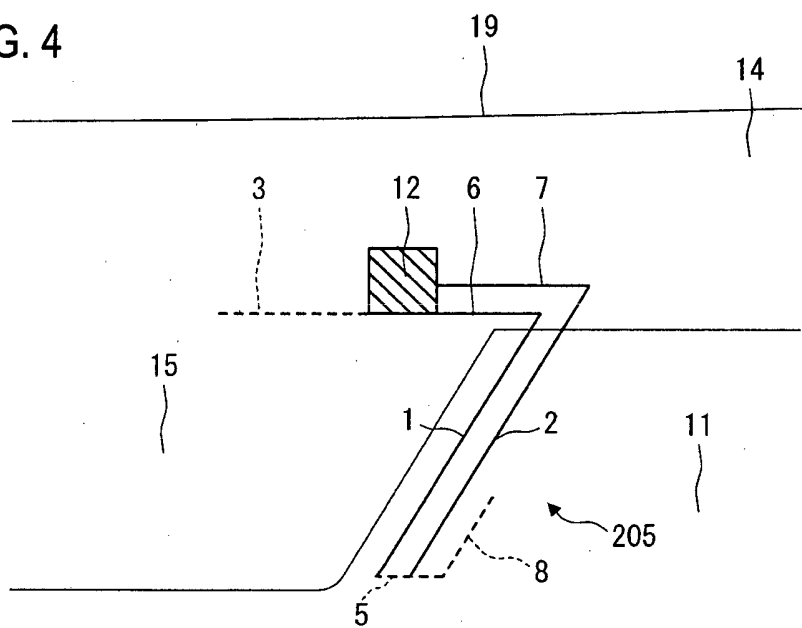


FIG. 5

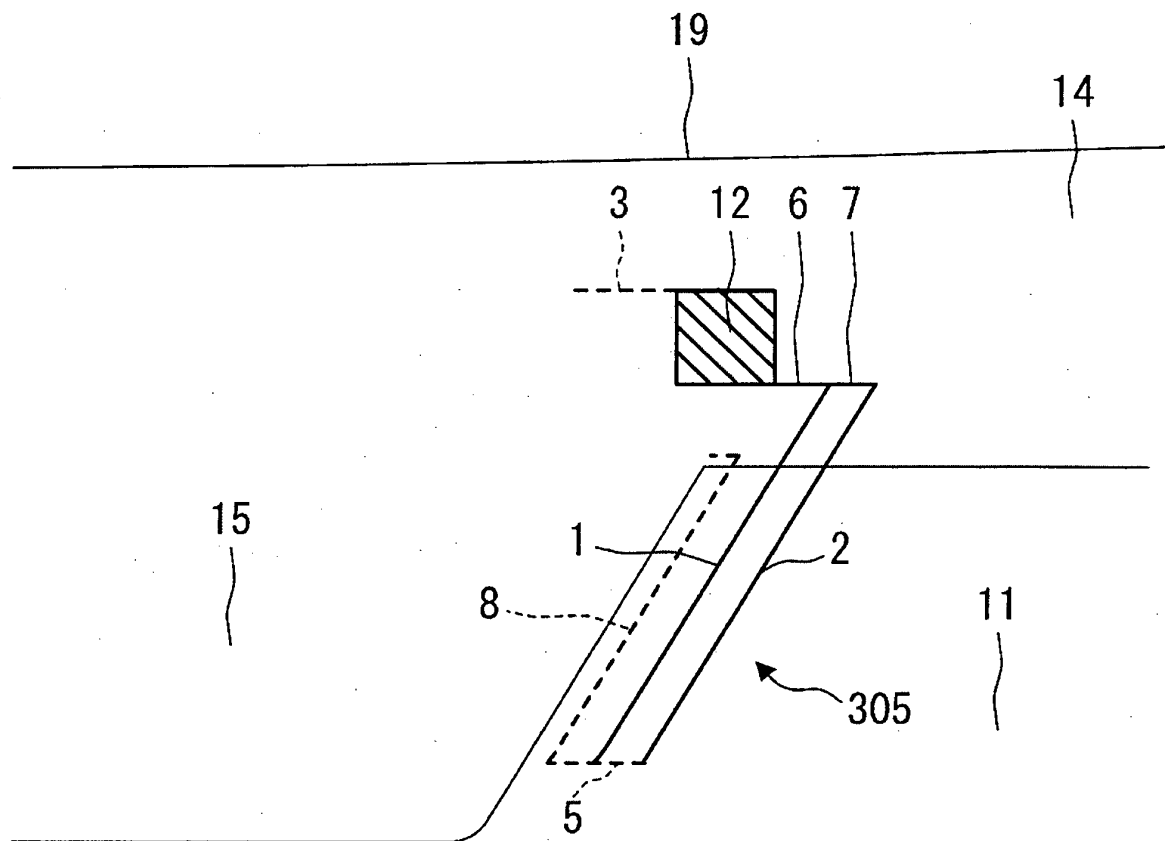


FIG. 6

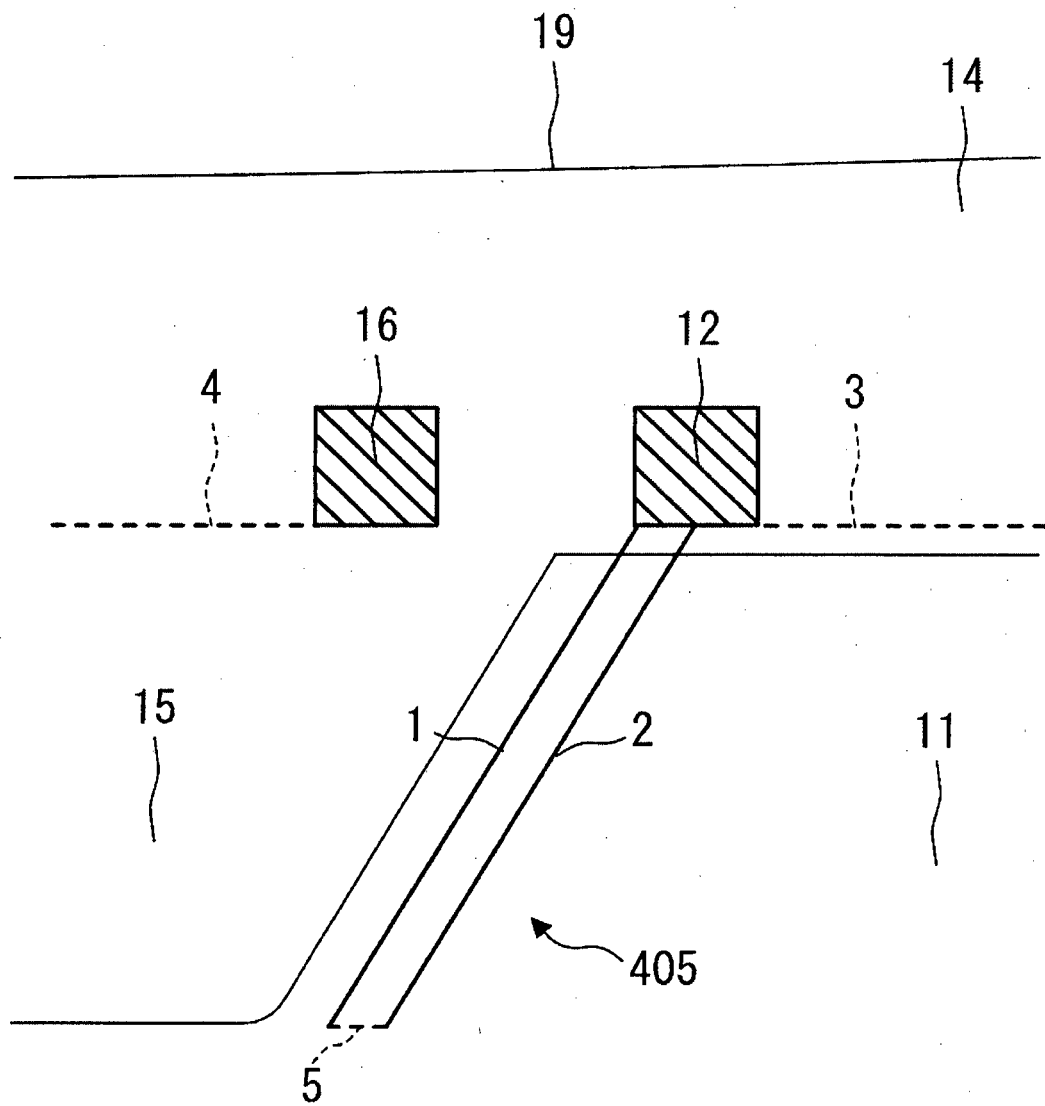


FIG. 7

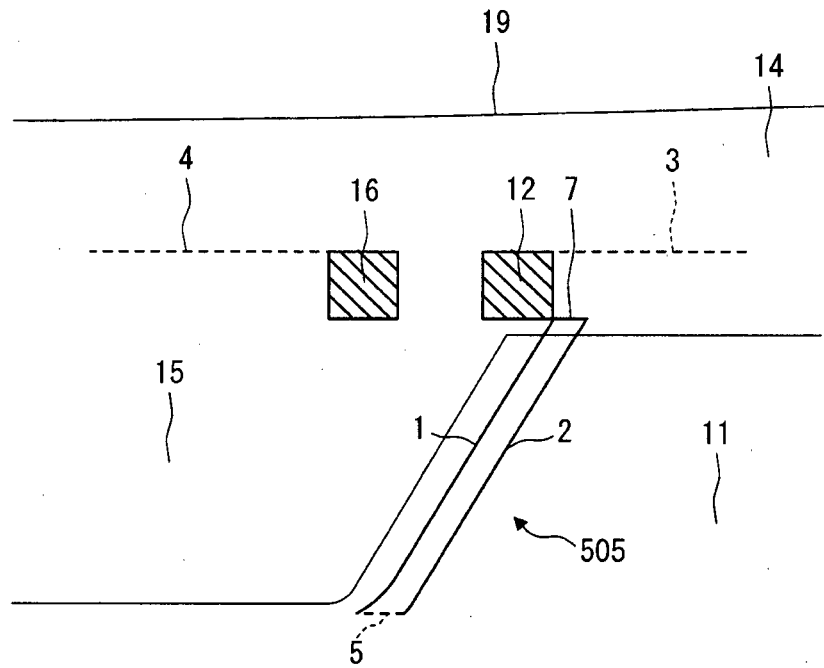


FIG. 8

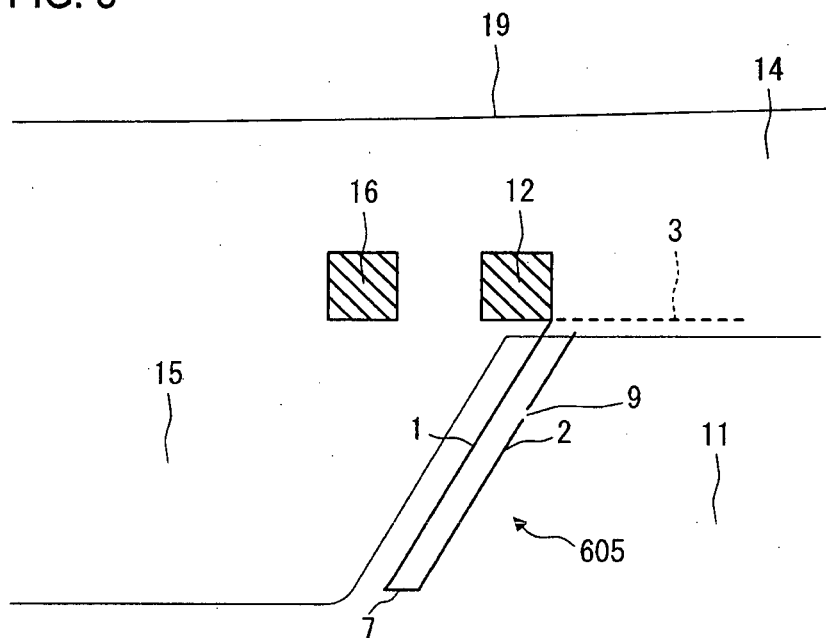


FIG. 9

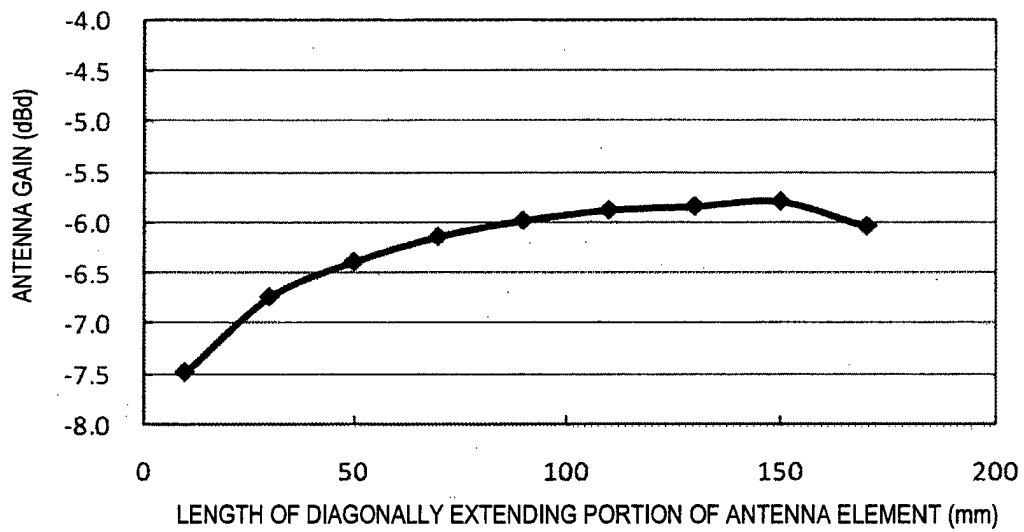


FIG. 10

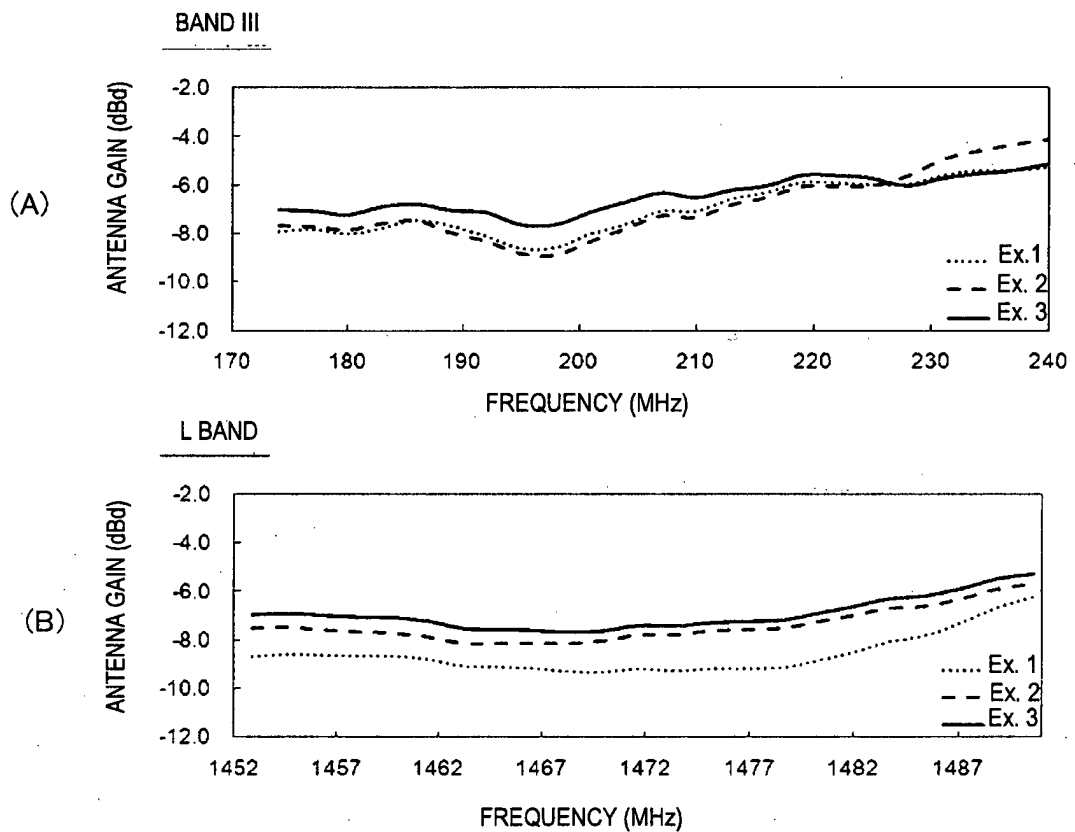


FIG. 11

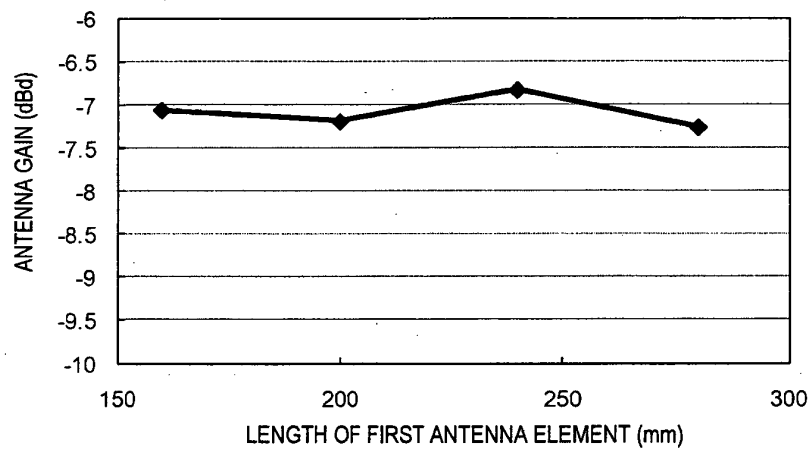


FIG. 12

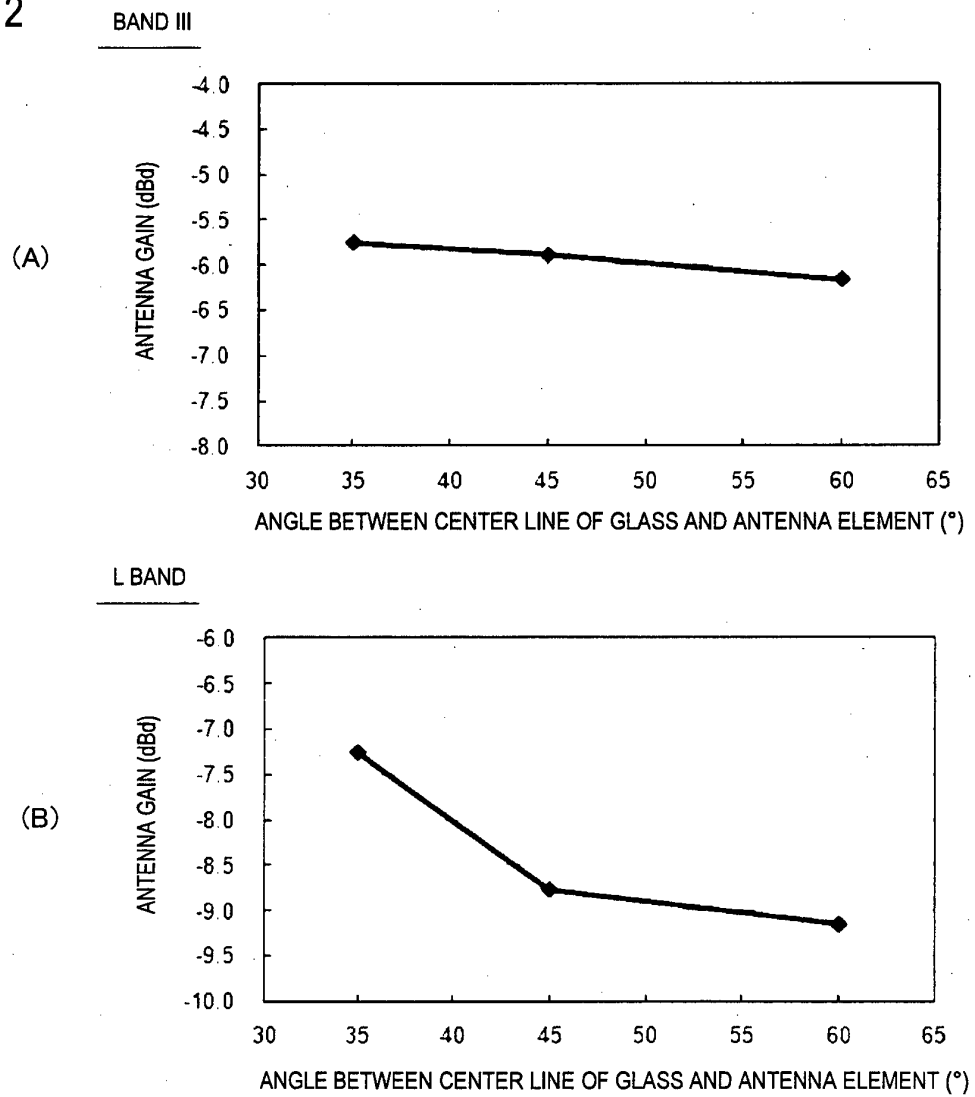


FIG. 13

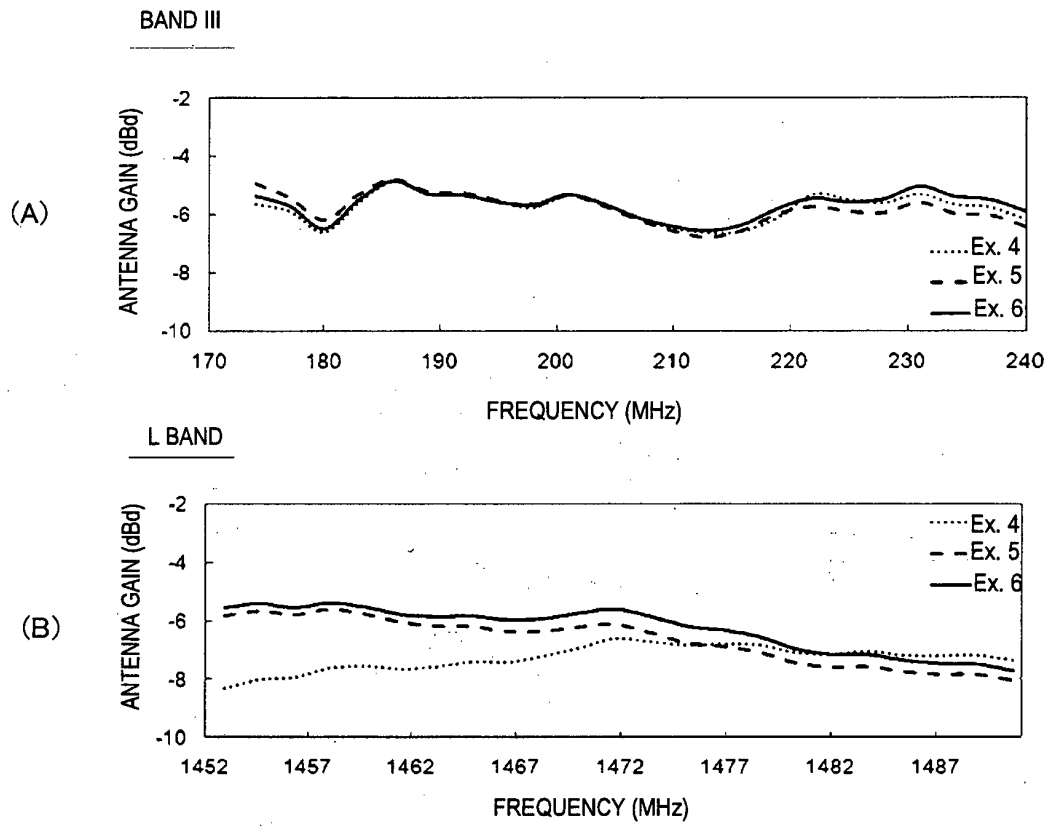
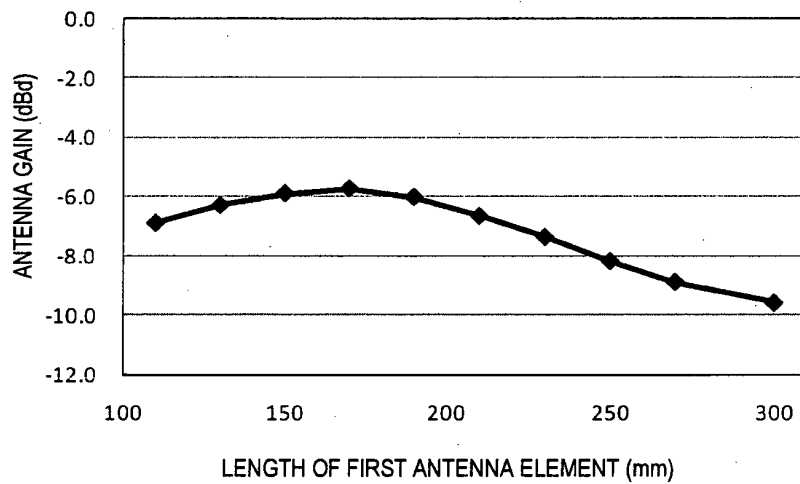


FIG. 14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/085261

A. CLASSIFICATION OF SUBJECT MATTER

H01Q1/32(2006.01)i, B60J1/00(2006.01)i, B60R11/02(2006.01)i, H01Q1/22(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01Q1/32, B60J1/00, B60R11/02, H01Q1/22

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2014

Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/029815 A1 (Central Glass Co., Ltd.), 18 March 2010 (18.03.2010), fig. 11, 12 & JP 2010-93781 A & US 2011/0037668 A1 & EP 2323221 A1 & CN 102067378 A & TW 201014037 A	1-14
A	JP 1-146614 U (Nippon Sheet Glass Co., Ltd.), 09 October 1989 (09.10.1989), fig. 1 & US 5079560 A & EP 335708 A2 & DE 68917967 C & DE 68917967 D	1-14

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search
18 March, 2014 (18.03.14)

Date of mailing of the international search report
25 March, 2014 (25.03.14)

Name and mailing address of the ISA/
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Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/085261

C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2009-253677 A (Nippon Sheet Glass Co., Ltd.), 29 October 2009 (29.10.2009), fig. 1 & DE 102009016251 A & DE 102009016251 A1 & FR 2929763 A	1-14
A	JP 2008-263537 A (Honda Motor Co., Ltd.), 30 October 2008 (30.10.2008), fig. 4 (Family: none)	1-14
A	JP 2010-268358 A (Central Glass Co., Ltd.), 25 November 2010 (25.11.2010), fig. 1 to 6 (Family: none)	1-14
A	JP 2011-146963 A (Central Glass Co., Ltd.), 28 July 2011 (28.07.2011), fig. 5 (Family: none)	1-14

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2012023707 A [0004]
- JP 2012285247 A [0081]