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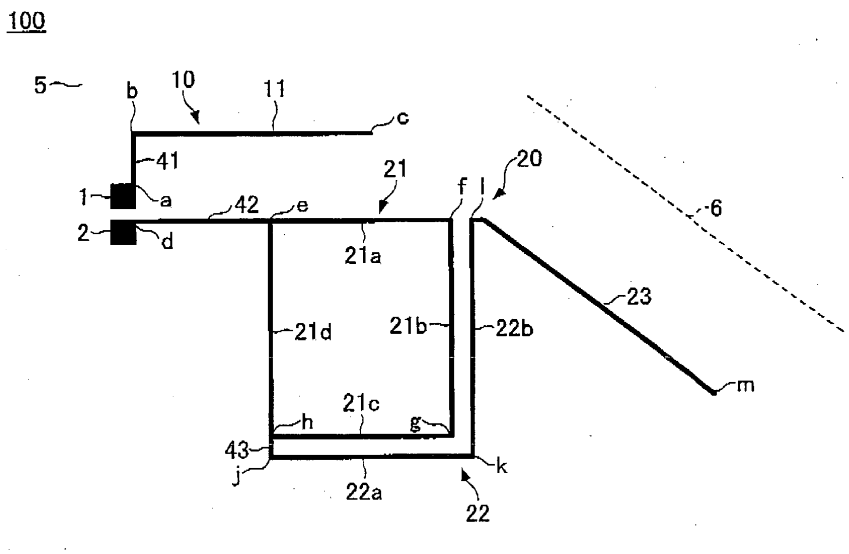
(54) Glass antenna and window glass

(57) A glass antenna that is arranged at a window glass of a vehicle includes a first feeding portion (1) and a second feeding portion (2) that are arranged one above the other, a first antenna conductor (10) that is connected to the first feeding portion, and a second antenna conductor (20) that is connected to the second feeding portion. The first antenna conductor (10) includes a first antenna element (11) that extends in a substantially horizontal direction and is connected to the first feeding portion (1) either directly or via a first connection element (41). The second antenna conductor (20) includes a second antenna element (21) that is arranged into a loop and is connected to the second feeding portion (2) either directly or via a second connection element (42), a third antenna element (22) that extends along the second antenna element (21) and is connected to the second antenna element (21) via a third connection element (43), and a fourth antenna element (23) that extends at an opposite side of the second feeding portion (2) with respect to the second antenna element (21) and is connected to the third antenna element (22).

FIG.1



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Description

[0001] The present invention relates to a glass antenna that is arranged at a window glass of a vehicle and a window glass including such a glass antenna.

[0002] For example, Japanese Laid-Open Patent Publication No. 2009-49706 (referred to as "Patent Document 1" hereinafter) and Japanese Laid-Open Patent Publication No. 2001-127519 (referred to as "Patent Document 2" hereinafter) disclose technology related to glass antennas arranged at the window glass of vehicles. Patent Document 1 discloses a glass antenna having receiving properties for receiving terrestrial digital television broadcasting waves (470 to 710 MHz). Patent Document 2 discloses a glass antenna having receiving properties for receiving FM broadcasting waves (e.g., 76 to 90 MHz in Japan; 88 to 108 MHz in the United States).

[0003] However, because terrestrial digital television broadcasting waves are horizontally-polarized waves, the glass antenna disclosed in Patent Document 1 may not easily achieve receiving properties for receiving vertically-polarized waves such as those of Band III (174 to 240 MHz) of DAB (Digital Audio Broadcasting). Also, because the bandwidth of Band III (174 to 240 MHz; 66 MHz) is wider than the bandwidth of FM broadcasting (76 to 108 MHz; 32 MHz), the glass antenna disclosed in Patent Document 2 may not easily achieve receiving properties for receiving waves of a bandwidth such as Band III that is wider than the bandwidth of FM broadcasting.

[0004] It is a general object of the present invention to provide a glass antenna that substantially obviates one or more problems caused by the limitations and disadvantages of the related art. It is one specific object of at least one embodiment of the present invention to provide a glass antenna that is capable of easily achieving receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves having a bandwidth that is wider than that of the FM broadcasting band. It is another specific object of at least one embodiment of the present invention to provide a window glass including such a glass antenna.

[0005] According to one embodiment of the present invention, a glass antenna that is arranged at a window glass of a vehicle includes a first feeding portion and a second feeding portion that are arranged one above the other, a first antenna conductor that is connected to the first feeding portion, and a second antenna conductor that is connected to the second feeding portion. The first antenna conductor includes a first antenna element that extends in a substantially horizontal direction and is connected to the first feeding portion either directly or via a first connection element. The second antenna conductor includes a second antenna element that is arranged into a loop and is connected to the second feeding portion either directly or via a second connection element, a third antenna element that extends along the second antenna element and is connected to the second antenna element via a third connection element, and a fourth antenna element that extends at an opposite side of the second feeding portion with respect to the second antenna element and is connected to the third antenna element.

[0006] Another embodiment of the present invention relates to a glass window that includes such a glass antenna.

[0007] According to an aspect of the present invention, receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves having a bandwidth that is wider than that of the FM broadcasting band may be easily achieved.

FIG. 1 is a plan view of a glass antenna according to a first embodiment of the present invention;
FIG. 2 is a plan view of a glass antenna according to a second embodiment of the present invention;
FIG. 3 is a plan view of a glass antenna according to a third embodiment of the present invention;
FIG. 4 is a plan view of a glass antenna according to a fourth embodiment of the present invention;
FIG. 5 is a plan view of a glass antenna according to a fifth embodiment of the present invention;
FIG. 6 is a plan view of a glass antenna according to a sixth embodiment of the present invention;
FIG. 7 is a plan view of a glass antenna according to a seventh embodiment of the present invention;
FIG. 8 is a graph representing measurement data of the antenna gain for Band III obtained while varying a length (L22) of a capacitively coupled portion of a third antenna element;
FIG. 9 is a graph representing measurement data of the antenna gain for Band III obtained while varying a loop length (L21) of a second antenna element;
FIG. 10 is a graph representing measurement data of the antenna gain for Band III obtained while varying a shortest path length (L10) from a first feeding portion to a farthest point on a first antenna element; and
FIG. 11 illustrates an exemplary arrangement of a glass antenna mounted to a window glass according to an embodiment of the present invention.

[0008] In the following, embodiments of the present invention will be described with reference to the accompanying drawings. It is noted that unless specified otherwise, directions in the descriptions below correspond to directions as illustrated in the drawings, and a given reference direction in a drawing corresponds to the direction represented by a corresponding reference symbol or number. Also, in the descriptions below, directional terms such as "parallel" and "perpendicular" are not used in their strict sense and are meant to allow some degree of deviation to the extent the effects of the present invention are not hindered. Also, the corners of the antenna conductors are not limited to being right-angles and may also be arched or curved, for example. Also, the plan views each illustrate a glass antenna as seen from a side facing a glass surface. It is noted that although the plan views correspond to views from inside a vehicle when a window including a glass antenna of the present invention is installed in the vehicle, the plan views may also be regarded as views from outside the vehicle. Also, vertical directions in the plan views correspond to vertical directions of the vehicle, and a downside direction in the drawings correspond to a direction toward the road surface. Also, in the case where the window corresponds to a side window arranged at a side portion of the vehicle, right-left directions in the drawings correspond to front-back directions of the vehicle. Further, it is noted that the present invention is not limited to being arranged at a side window of a vehicle and may also be arranged at a rear window mounted at the rear side of a vehicle, or a windshield mounted at the front side of a vehicle.

[0009] FIG. 1 is a plan view of a glass antenna 100 for a vehicle according to a first embodiment of the present invention. The glass antenna 100 according to the first embodiment includes a feeding portion and an antenna conductor that may be planar conductor patterns arranged on a window glass 5 of a vehicle as illustrated in FIG. 11, for example.

[0010] The glass antenna 100 includes as the conductor patterns of the feeding portion a first feeding portion and a second feeding portion that are arranged one above the other and are spaced apart in the vertical direction. In FIG. 1, feeding portion 1 is illustrated as an example of the first feeding portion and feeding portion 2 is illustrated as an example of the second feeding portion.

[0011] The feeding portion 2 may correspond to a feeding point that is electrically connected to a signal path of a signal processing circuit such as an amplifier (not shown) via a predetermined first conductive member, and the feeding portion 1 may correspond to a feeding point that is electrically connected to an external ground path (e.g., ground of the signal processing unit or the vehicle body) via a predetermined second conductive member. Alternatively, the feeding portion 1 may correspond to a feeding point that is electrically connected to the signal path of the signal processing circuit such as an amplifier (not shown) via the predetermined first conductive member, and the feeding portion 2 may correspond to a feeding point that is electrically connected to the external ground path (e.g., ground of the signal processing unit or the vehicle body) via the predetermined second conductive member. That is, the glass antenna 100 is a dipole-type antenna that includes the feeding portion 1 and the feeding portion 2 as a pair of feeding points.

[0012] The feeding portion 1 is positioned above the feeding portion 2. Note that the feeding portion 1 and the feeding portion 2 may be shifted from each other in the horizontal direction to be in a different positional relation from that illustrated in FIG. 1.

[0013] The glass antenna 100 includes as an antenna conductor pattern a first antenna conductor that is connected to the first feeding portion. In FIG. 1, antenna conductor 10 that is connected to the feeding portion 1 is illustrated as an example of the first antenna conductor.

[0014] The first antenna conductor includes a first antenna element that extends in the horizontal direction and is connected to the first feeding portion either directly or via a first connection element. In FIG. 1, connection element 41 that extends in the vertical direction is illustrated as an example of the first connection element, and antenna element 11 that extends in the horizontal direction is illustrated as an example of the first antenna element. The antenna conductor 10 includes the connection element 41 that is connected to the feeding portion 1 and the antenna element 11 that is connected to the connection element 41.

[0015] The connection element 41 extends upward in a straight line from point 'a' at the upper right side of the feeding portion 1 as a start point to point 'b' as an end point. The antenna element 11 extends in a straight line toward the right side from point 'b' as a start point to point 'c' as an end point.

[0016] The glass antenna 100 includes as another antenna conductor pattern a second antenna conductor that is connected to the second feeding portion. In FIG. 1, antenna conductor 20 is illustrated as an example of the second antenna conductor.

[0017] The second antenna conductor includes a second antenna element, a third antenna element, and a fourth antenna element. The second antenna element forms a loop and is connected to the second feeding portion either directly or via a second connection element. The third antenna element is connected to the second antenna element via a third connection element. The third antenna element extends along the second antenna element to be capacitively coupled to the second antenna element. The fourth antenna element extends at the opposite side of the second feeding portion with respect to the second antenna element and is connected to the third antenna element.

[0018] In FIG. 1, connection element 42 that extends in the horizontal direction is illustrated as an example of the second connection element, antenna element 21 is illustrated as an example of the second antenna element, connection element 43 that extends in the vertical direction is illustrated as an example of the third connection element, antenna element 22 that is connected to the connection element 43 is illustrated as an example of the third antenna element, and antenna element 23 is illustrated as an example of the fourth antenna element. The antenna conductor 20 includes the connection element 42 that is connected to the feeding portion 2, the antenna element 21 that is connected to the connection element 42, the connection element 43 that is connected to the antenna element 21, the antenna element 22 that is connected to the connection element 43, and the antenna element 23 that is connected to the antenna element

22.

[0019] The connection element 42 extends in a straight line toward the right side from point ’d’ at the upper right corner of the feeding portion 2 as a start point to point ’e’ as an end point.

[0020] The antenna element 21 corresponds to a closed loop element including partial elements 21a, 21b, 21c, and 21d that form a loop. The antenna element 21 is arranged into a rectangular shape with its four corners located at points ’e’, ’f’, ’g’, and ’h’, and having longer sides extending in the vertical direction. Note that the shape of the closed loop of the antenna element 21 is not limited to a rectangular shape, but may alternatively be a square shape or some other quadrangular shape, a circular shape, or some other polygonal shape such as a pentagon. However, a loop shape that is arranged to extend longer in the vertical direction is preferred in the case of receiving vertically-polarized waves. Thus, as one preferred embodiment, the antenna element 21 is arranged into a rectangular shape with its longer sides extending in the vertical direction so that the antenna element 21 may extend longer in the vertical direction.

[0021] The connection element 43 extends downward in a straight line from point ’h’ corresponding to the lower left side connection point of the left side partial element 21d and the lower side partial element 21c of the antenna element 21 as a start point to point ’j’ as an end point.

[0022] The antenna element 22 is an L-shaped element including partial elements 22a and 22b. The partial element 22a extends in the horizontal direction along the lower side partial element 21c of the antenna element 21 to be capacitively coupled to this lower side partial element 21c. The partial element 22b extends in the vertical direction along the right side partial element 21b of the antenna element 21 to be capacitively coupled to this right side partial element 21b. The partial element 22a extends in a straight line toward the right side from point ’j’ as a start point to point ’k’ as an end point, and the partial element 22b extends upward in a straight line from point ’k’ as a start point to point ’l’ as an end point.

[0023] The antenna element 23 is connected to the partial element 22b at point ’l’. The antenna element 23 extends in a straight line toward the right side from point ’l’ as a start point to point ’m’ as an end point. The antenna element 23 may extend diagonally toward the lower right side as illustrated in FIG. 1, for example.

[0024] Note that in a case where the antenna conductor of the present embodiment extends in a direction toward another antenna conductor or the outer rim 6 of an element mounting region of the glass antenna 100, the antenna conductor may include at least one of a straight line portion and a curved line portion that are arranged to extend without coming into contact or intersecting with the other antenna conductor or the outer rim 6. For example, in the glass antenna 100 of FIG. 1, the antenna element 23 of the antenna conductor 20 includes a straight line portion that extends in a straight line along the outer rim 6 so that it does not come into contact or intersect with the outer rim 6. The outer rim 6 may be the outer rim of the glass window 5 illustrated in FIG. 11, or the rim of a vehicle body opening to which the window glass 5 is mounted, for example. The vehicle body opening may be the rim of a vehicle body flange that forms a window opening to which the window glass 5 is mounted, for example. Also, as described below, because a vehicle body opening or an interior material is arranged along a masking film 7, in another example, the outer rim 6 may correspond to the masking film 7.

[0025] As can be appreciated, in the glass antenna 100 of the present embodiment as illustrated in FIG. 1, the feeding portion 2 is electrically connected to a signal path of a signal processing circuit such as an amplifier (not shown) via a predetermined first conductive member and the feeding portion 1 is electrically connected to an external ground path via a predetermined second conductive member; or alternatively, the feeding portion 1 is electrically connected to a signal path of a signal processing circuit such as an amplifier (not shown) via a predetermined first conductive member and the feeding portion 2 is electrically connected to an external ground path via a predetermined second conductive member. In this way, receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves of a bandwidth that is wider than that of the FM broadcasting band may be easily achieved.

[0026] Further, by arranging the glass antenna 100 at the window glass 5 in a manner such that at least one or more of the elements of the antenna conductor (e.g., partial elements 21d, 21b, and 22b; and connection elements 41 and 43) includes a vertical component that is perpendicular to the horizon plane (i.e., horizontal plane), sensitivity may be improved for receiving vertically-polarized radio waves such as Band III of DAB. The mounting angle at which the window glass 5 is mounted to the vehicle is preferably arranged to be 20 to 90 degrees, and more preferably 30 to 90 degrees with respect to the horizon plane.

[0027] Note that the positioning of the first feeding portion, the second feeding portion, the first antenna conductor connected to the first feeding portion, and the second antenna element connected to the second feeding portion may be rearranged to be line-symmetric with respect to the above-described arrangement by rotating the elements about an axis of symmetry corresponding to a virtual line extending in the horizontal direction between the first feed point and the second feed point, for example. Also, although the first feeding portion and the second feeding portion are positioned at the left side in FIG. 1, the first feeding portion and the second feeding portion may alternatively be arranged at the right side. That is, the positioning of the first feeding portion and the second feeding portion may be rearranged to be line-asymmetric with respect to the arrangement illustrated in FIG. 1 by rotating the elements about an axis of symmetry corresponding to a virtual line passing through the first feeding portion and the second feeding portion and extending in the vertical direction, for example.

[0028] As the first and second conductive members, a feeder cable such an AV cable or a coaxial cable may be used, for example. In the case of using a coaxial cable, the internal conductor of the coaxial cable may be electrically connected to the feeding portion 2, and the external conductor of the coaxial cable may be electrically connected to the feeding portion 1. Alternatively, the internal conductor of the coaxial cable may be electrically connected to the feeding portion 1, and the external conductor of the coaxial cable may be electrically connected to the feeding portion 2. Also, in one embodiment, a male connector may be attached to the front end of the coaxial cable and a female connector may be mounted to the feeding portions 1 and 2. By using such connectors, the internal conductor of the coaxial cable may be easily attached to the feeding portion 2 and the external conductor of the coaxial cable may be easily attached to the feeding portion 1 or vice versa. Further, in one embodiment, protruding conductive members may be arranged at the feeding portions 1 and 2 so that the protruding conductive members may come into engaging contact with connection parts arranged at a flange of the vehicle to which the window glass 5 is mounted.

[0029] Note that the term "point" used in the present descriptions may refer to a start point or an end point of an element extending in a given direction. The term may also be used to refer to conductor portions in the vicinity of such start point or end point. Also, connection points of conductor elements may be arranged to have some curvature.

[0030] The antenna conductors and the feeding portions may be formed by printing corresponding patterns using a paste including conductive metal such as a silver paste on the inner surface of a window glass at the interior side of the vehicle, for example. However, the present invention is not limited to such an example. In other examples, a line or a foil made of conductive material such as copper may be arranged on the inner surface or the outer surface of the window glass. The conductive material may be attached to the surface of the window using adhesive or the like, or the conductive material may alternatively be arranged within the window, for example.

[0031] The shape of the feeding portions may be determined according to the shapes of the mounting faces of the above conductive members and connectors. For example, the feeding portions may preferably be arranged into square shapes, nearly square shapes, rectangular shapes, nearly rectangular shapes, and other quadrangular or polygonal shapes. The feeding portions may also be arranged into circular shapes, nearly circular shapes, oval shapes, or nearly oval shapes, for example.

[0032] In one embodiment, a conductive layer including the antenna conductor may be arranged inside or on the surface of a synthetic resin film, and the synthetic resin film including the conductive layer may be arranged on the inner surface or outer surface of a window glass plate to fabricate a glass antenna. In a further embodiment, a flexible circuit board on which the antenna conductor is formed may be arranged on the inner surface or outer surface of the window glass to fabricate the glass antenna.

[0033] In another embodiment, a masking film may be arranged on the surface of the window glass, and a part or all of the antenna conductors and feeding portions may be arranged on the masking film. A film made of ceramic such as a black ceramic film may be used as the masking film, for example. In this way, the antenna conductor arranged on the masking film may be invisible from outside the vehicle by the masking film to thereby improve the design of the window. In FIG. 11, portions of the antenna conductors and feeding portions are arranged on the masking film 7 (between the rim of the masking film 7 and the outer rim of the window glass 5) so that only fine line portions of the antenna conductors may be visible from the outside and design aspects may be improved as a result.

[0034] FIG. 2 is a plan view of a glass antenna 200 according to a second embodiment of the present invention. Note that descriptions of features of the present embodiment that may be identical to those of the first embodiment are omitted.

[0035] According to an aspect of the present embodiment, the antenna element 22 is not limited to an L-shaped element as illustrated in FIG. 1. That is, the antenna element 22 may alternatively be an element extending in the horizontal direction as illustrated in FIG. 2, for example. The antenna element 22 of FIG. 2 extends in the horizontal direction along the lower side partial element 21c of the antenna element 21 to be capacitively coupled to this lower side element 21c. In FIG. 2, the antenna element 22 is connected to the connection element 43 at point 'j' and extends in a straight line toward the right side from point 'j' as a start point to point 'l' as an end point.

[0036] Also, the antenna element 23 is not limited to a linear element extending diagonally toward the lower right side as illustrated in FIG. 1 but may alternatively be an L-shaped element including partial elements 23a and 23b as illustrated in FIG. 2, for example. The partial element 23a extends in the horizontal direction and the partial element 23b extends along the extending direction of the outer rim 6. The partial element 23a is connected to the antenna element 22 at point 'l' and extends in a straight line toward the right side from point 'l' as a start point to point 'n' as an end point. The partial element 23b is connected to the partial element 23a at point 'n' and extends diagonally from the lower right side toward the upper left side in a straight line from point 'n' as a start point to point 'm' as an end point.

[0037] The glass antenna 200 of the present embodiment has a third antenna conductor arranged in the vicinity of at least one of the first antenna conductor and the second antenna conductor. In FIG. 2, antenna element 31 that is directly connected to the feeding portion 1 is illustrated as an example of the third antenna conductor.

[0038] The antenna element 31 corresponds to an auxiliary element that extends in the vertical direction and is connected to the feeding portion 1 at point 'o' corresponding to the upper left side corner of the feeding portion 1. The antenna element 31 extends upward in a straight line from point 'o' as a start point to point 'p' as an end point. By arranging the third antenna conductor such as the antenna element 31, the antenna gain may be improved upon receiving radio waves of a higher frequency band (e.g., L-Band of DAB at 1452 to 1492 MHz) compared to the frequency band of terrestrial digital television broadcasting (470 to 710 MHz). Note that the antenna element 31 as the third antenna conductor is not limited to being implemented in the glass antenna 200 of the second embodiment but may also be implemented in the glass antenna 100 of the first embodiment, for example.

[0039] As with the glass antenna 100 of the first embodiment, the glass antenna 200 of the second embodiment may be capable of easily achieving receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves of a bandwidth that is wider than the FM broadcasting bandwidth.

[0040] FIG. 3 is a plan view of a glass antenna 300 according to a third embodiment of the present invention. Note that descriptions of features of the present embodiment that may be identical to the above-described embodiments are omitted.

[0041] In FIG. 3, the connection element 43 is arranged to extend in the horizontal direction. Specifically, the connection element 43 of the present embodiment extends in a straight line toward the left side from intermediate point 'i' of the left side partial element 21d of the antenna element 21 as a start point to point 'j' as an end point. The intermediate point 'i' is located between points 'e' and 'h' but does not necessarily have to be the midpoint of points 'e' and 'h'.

[0042] The antenna element 22 is not limited to an L-shaped element as illustrated in FIG. 1 but may alternatively by a U-shaped element as illustrated in FIG. 3. In the example illustrated in FIG. 3, the antenna element 22 includes partial elements 22c, 22d, and 22e that form a U-shape.

[0043] The partial element 22c extends in the vertical direction along the left side partial element 21d of the antenna element 21 to be capacitively coupled to this left side partial element 21d. The partial element 22d extends in the horizontal direction along the lower side partial element 21c of the antenna element to be capacitively coupled to this lower side partial element 21c. The partial element 22e extends in the vertical direction along the right side partial element 21b of the antenna element 21 to be capacitively coupled to this right side partial element 21b.

[0044] The partial element 22c is connected to the connection element 43 at point 'j' and extends downward in a straight line from point 'j' as a start point to point 'q' as an end point. The partial element 22d is connected to the partial element 22c at point 'q' and extends in a straight line toward the right side from point 'q' as a start point to point 'r' as an end point. The partial element 22e is connected to the partial element 22d at point 'r' and extends upward in a straight line from point 'r' as a start point to point 'l' as an end point.

[0045] The glass antenna 300 of the present embodiment has a third antenna conductor arranged in the vicinity of at least one of the first feeding portion and the second feeding portion. In FIG. 3, antenna element 32 that is connected to the feeding portion 2 is illustrated as an example of the third antenna conductor.

[0046] The antenna element 32 corresponds to an auxiliary element that extends in the vertical direction and is connected to point 's' at the lower left side corner of the feeding portion 2. The antenna element 32 extends downward in a straight line from point 's' as a start point to point 't' as an end point. By arranging a third antenna conductor such as the antenna element 32, the antenna gain may be improved upon receiving radio waves of a higher frequency band (e.g., L-Band of DAB at 1452 to 1492 MHz) compared to the frequency band of terrestrial digital television broadcasting (470 to 710 MHz). Note that the antenna element 32 as the third antenna conductor is not limited to being implemented in the glass antenna 300 of the third embodiment but may also be implemented in the glass antenna 100 of the first embodiment, for example.

[0047] As with the previously-described embodiments, the glass antenna 300 of the third embodiment may be capable of easily achieving receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves of a bandwidth that is wider than the FM broadcasting bandwidth.

[0048] FIG. 4 is a plan view of a glass antenna 400 according to a fourth embodiment of the present invention. Note that descriptions of features of the present embodiment that may be identical to those of the previously-described embodiments are omitted.

[0049] According to an aspect of the present embodiment, the connection element for connecting the feeding portion 2 and the antenna element 21 may be omitted and the feeding portion 2 may be directly connected to the antenna element 21.

[0050] In FIG. 4, the connection element 43 is arranged to extend in the vertical direction. The connection element 43 extends downward in a straight line from intermediate point 'i' of the lower side partial element 21c of the antenna element 21 as a start point to point 'j' as an end point. The intermediate point 'i' is located between points 'h' and 'g' but does not necessarily have to be the midpoint of points 'h' and 'g'.

[0051] The glass antenna 400 of the present embodiment has a third antenna conductor arranged in the vicinity of at least one of the first feeding portion and the second feeding portion. In FIG. 4, antenna element 33 that is directly connected to the feeding portion 1 is illustrated as an example of the third antenna conductor.

[0052] The antenna element 33 corresponds to an auxiliary element that extends in the horizontal direction and is connected to the feeding portion 1 at point 'o' at the lower right side of the feeding portion l. The antenna element 33 extends in a straight line toward the right side from point 'o' as a start point to point 'u' as an end point. By arranging a third antenna conductor such as the antenna element 33, the antenna gain may be improved upon receiving radio waves of a higher frequency band (e.g., L-Band of DAB at 1452 to 1492 MHz) compared to the frequency band of terrestrial digital television broadcasting (470 to 710 MHz). Note that the antenna element 33 as the third antenna conductor is not limited to being implemented in the glass antenna 400 of the fourth embodiment but may also be implemented in the glass antenna 100 of the first embodiment, for example.

[0053] As with the previously-described embodiments, the glass antenna 400 of the fourth embodiment may be capable of easily achieving receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves of a bandwidth that is wider than the FM broadcasting bandwidth.

[0054] FIG. 5 is a plan view of a glass antenna 500 according to a fifth embodiment of the present invention. Note that descriptions of feature of the present embodiment that may be identical to those of the previously-described embodiments are omitted.

[0055] According to an aspect of the present embodiment, a connection element for connecting the feeding portion 1 and the antenna element 11 may be omitted and the antenna element 11 may be directly connected to the feeding portion 1.

[0056] The glass antenna 500 of the present embodiment has a third antenna conductor arranged in the vicinity of at least one of the first feeding portion and the second feeding portion. In certain embodiments, the third antenna conductor may be slightly distanced apart from the feeding portion provided the effects of the third antenna conductor may still be achieved. The above expression "in the vicinity" of the first feeding portion and/or the second feeding portion is used to encompass such embodiments. For example, the third antenna conductor may be arranged to be no more than 20 mm from the feeding portion. In FIG. 5, antenna element 34 that is indirectly connected to the feeding portion 2 via intermediate point ’v’ of the connection element 42 is illustrated as an example of the third antenna conductor. The intermediate point ’v’ is located between points ’d’ and ’e’ but does not necessarily have to be the midpoint of points ’d’ and ’e’.

[0057] The antenna element 34 corresponds to an auxiliary element that extends in the vertical direction and is connected to the connection element 42 at intermediate point ’v’. The antenna element 34 extends downward in a straight line from intermediate point ’v’ as a start point to point ’w’ as an end point. By arranging a third antenna conductor such as the antenna element 34, the antenna gain may be improved upon receiving radio waves of a higher frequency band (e.g., L-Band of DAB at 1452 to 1492 MHz) compared to the frequency band of terrestrial digital television broadcasting (470 to 710 MHz). Note that the antenna element 34 as the third antenna conductor is not limited to being implemented in the glass antenna 500 of the fifth embodiment but may also be implemented in the glass antenna 100 of the first embodiment, for example.

[0058] As with the previously-described embodiments, the glass antenna 500 of the fifth embodiment may be capable of easily achieving receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves of a bandwidth that is wider than the FM broadcasting bandwidth.

[0059] FIG. 6 is a plan view of a glass antenna 600 according to a sixth embodiment of the present invention. Note that descriptions of the present embodiment that may be identical to those of the previously-described embodiments are omitted.

[0060] The antenna conductor 10 of the glass antenna 600 of the present embodiment includes the first antenna element that extends in the horizontal direction and is connected to the first feeding portion either directly or via a first connection element. In FIG. 6, antenna element 12 that is directly connected to point ’a’ of the feeding portion 1 is illustrated as an example of the first antenna element of the present embodiment.

[0061] The antenna element 12 corresponds to a closed loop element including partial elements 12a, 12b, 12c, and 12d. The antenna element 12 is arranged into a substantially rectangular shape with its four corners located at points ’a’, ’x’, ’y’, and ‘z’ and having longer sides extending in the horizontal direction. Note that the closed loop shape of the antenna element 12 is not limited to a rectangular shape but may alternatively be a square shape or some other quadrangular shape, circular shape, or some other polygonal shape such as a pentagon, for example.

[0062] The connection element 43 extends in a straight line toward the right side from point ’g’ corresponding to the connection point of the lower side partial element 21c and the right side partial element 21b of the antenna element 21 as a start point to point ‘j’ as an end point.

[0063] The antenna element 22 may be a linear element arranged to extend along one side of the antenna element 21 as illustrated in FIG. 6. In FIG. 6, the antenna element 22 extends in the vertical direction along the right side partial element 21b of the antenna element 21 to be capacitively coupled to this right side partial element 21b.

[0064] The antenna element 23 is not limited to a linear element extending diagonally toward the lower right side as illustrated in FIG. 1 but may alternatively be an L-shaped element including partial elements 23e and 23f as illustrated in FIG. 6, for example. In FIG. 6, the partial element 23e extends in along the extending direction of the outer rim 6, and the partial element 23f extends in the horizontal direction. The partial element 23e is connected to the antenna element 22 at point ’l’ and extends diagonally in a straight line from the upper left side toward the lower right side from point ’l’ as a start point to point ‘n’ as an end point. The partial element 23f is connected to the partial element 23e at point ’n’ and extends in a straight line toward the left side from point ’n’ as a start point to point ’m’ as an end point.

[0065] Also, according to an aspect of the present embodiment, a plurality of third antenna conductors may be arranged in the vicinity of at least one of the first feeding portion and the second feeding portion. In FIG. 6, the antenna element 31 that is directly connected to the feeding portion at point 'o' and the antenna element 32 that is directly connected to the feeding portion 2 at point 's' are illustrated as examples of third antenna conductors.

[0066] As with the previously-described embodiments, the glass antenna 600 of the sixth embodiment may be capable of easily achieving receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves of a bandwidth that is wider than the FM broadcasting bandwidth.

[0067] FIG. 7 is a plan view of a glass antenna 700 according to a seventh embodiment of the present invention. Note that descriptions of features of the present embodiment that may be identical to those of the previously-described embodiments are omitted.

[0068] According to an aspect of the present embodiment, the antenna element 12 that is arranged into a loop may be connected to the feeding portion 1 via a connection element. In FIG. 7, the antenna element 12 is connected to the feeding portion 1 via connection element 41 that may be an L-shaped element, for example. The antenna element 12 is a closed loop element that is arranged into a substantially rectangular shape with its four corners located at points 'a', 'x', 'y', and 'z' and having longer sides extending in the horizontal direction. Also, the connection element 42 connecting the loop-shaped antenna element 21 to the feeding portion 2 may be arranged into an L-shaped element, for example.

[0069] As with the previously-described embodiments, the glass antenna 700 of the seventh embodiment may be capable of easily achieving receiving properties for receiving media such as Band III of DAB corresponding to vertically-polarized waves of a bandwidth that is wider than the FM broadcasting bandwidth.

[0070] Assuming λ_{01} denotes the wavelength at air of the central frequency of a frequency band (first frequency band) of vertically-polarized wave media having a bandwidth that is wider than that of the FM broadcasting frequency band, k denotes the shortening coefficient of wavelength of glass, and $\lambda_{g1}=\lambda_{01}\cdot k$ denotes the wavelength on glass, favorable results may be obtained in terms of improving the antenna gain for the first broadcasting frequency band when a target value of a longest path length La from the second feeding portion to the tip of the fourth antenna element is set to $(3/4)\cdot\lambda_{g1}$, and the actual longest path length La is greater than or equal to $(5/8)\cdot\lambda_{g1}$ and less than or equal to $(7/8)\cdot\lambda_{g1}$, and more preferably greater than or equal to $(11/16)\cdot\lambda_{g1}$ and less than or equal to $(13/16)\cdot\lambda_{g1}$.

[0071] For example, in the glass antenna of FIG. 1, the longest path length La corresponds to the longest length from point 'd' of the feeding portion 2 to point 'm' of the antenna element 23 without passing the same element twice. Specifically, the longest path length La corresponds to the conductor length of a path passing through points 'd', 'e', 'f', 'g', 'h' , 'j', 'k', 'l', and 'm' in this order. In the glass antenna of FIG. 3, the longest path length corresponds to the conductor length of a path passing through points 'd', 'e', 'f', 'g', 'h', 'i', 'j', 'q', 'r' , 'l', and 'm' in this order.

[0072] For example, in a case where the first broadcasting frequency band corresponds to Band III (174 to 240 MHz), the central frequency of the first broadcasting frequency band is 207 MHz. Thus, to improve the antenna gain for Band III, assuming the radio wave speed is 3.0×10^8 m/s and the shortening coefficient of wavelength k is equal to 0.64, the longest path length La is preferably adjusted to be greater than or equal to 579 mm and less than or equal to 812 mm, and more preferably, greater than or equal to 638 mm and less than or equal to 753 mm.

[0073] Also, favorable results may be obtained in terms of improving the antenna gain for the first frequency band when a length L22 of a capacitively coupled portion of the third antenna element extending along the second antenna element of an element portion of the third antenna element extending from the connection point of the third antenna element and the third connection element to the connection point of the third antenna element and the fourth antenna element is arranged to be greater than or equal to $(1/8)\cdot\lambda_{g1}$, and more preferably, greater than or equal to $(3/16)\cdot\lambda_{g1}$, while confining the length L22 within a range that would keep the second antenna conductor from coming into contact or intersecting with another conductor or the outer rim 6.

[0074] For example, in the glass antenna 100 of FIG. 1, the length L22 corresponds to the element length from point 'j' corresponding to the connection point of the partial element 22a and the connection element 43 to point 'l' corresponding to the connection point of the partial element 22b and the antenna element 23. That is, the length L22 corresponds to the conductor length of a path passing through points 'j', 'k', and 'l' in this order. In the glass antenna 200 of FIG. 2, the length L22 corresponds to the element length from point 'j' to point 'l' of the antenna element 22. In the glass antenna 300 of FIG. 3, the length L22 corresponds to the conductor length of a path passing through points 'j', 'q', and 'r' in this order.

[0075] Thus, to improve the antenna gain for Band III, assuming the radio wave speed is 3.0×10^8 m/s and the shortening coefficient of wavelength k is equal to 0.64, the length L22 is preferably adjusted to be greater than or equal to 115 mm, and more preferably, greater than or equal to 174 mm.

[0076] Also, favorable results may be obtained in terms of improving the antenna gain for the first frequency band when a target value of a loop length L21 of the second antenna element is set to $(1/2)\cdot\lambda_{g1}$, and the actual loop length L21 is greater than or equal to $(3/8)\cdot\lambda_{gl}$ and less than or equal to $(5/8)\cdot\lambda_{gl}$, and more preferably, greater than or equal to $(7/16)\cdot\lambda_{g1}$ and less than or equal to $(9/16)\cdot\lambda_{g1}$.

[0077] For example, in the glass antenna of FIG. 1, the loop length L21 corresponds to the element length of the closed loop of the antenna element 21. That is, the loop length L21 corresponds to the conductor length of the path passing through points 'e', 'f', 'g', 'h', and 'e' in this order.

[0078] Thus, to improve the antenna gain for Band III, assuming the radio wave speed is 3.0×10^8 m/s and the shortening coefficient of wavelength k is equal to 0.64, the loop length L21 is preferably adjusted to be greater than or equal to 347 mm and less than or equal to 580 mm, and more preferably, greater than or equal to 406 mm and less than or equal to 522 mm.

[0079] Also, favorable results may be obtained in terms of improving the antenna gain for the first frequency band when a shortest path length L10 between the first feeding portion and a farthest point on the first antenna element that is farthest from the first feeding portion by a shortest path is preferably arranged to be greater than or equal to $(1/8) \cdot \lambda_{g1}$ and less than or equal to $(1/4) \cdot \lambda_{g1}$, and more preferably, greater than or equal to $(5/32) \cdot \lambda_{g1}$ and less than or equal to $(7/32) \cdot \lambda_{g1}$.

[0080] For example, in the glass antenna of FIG. 1, the shortest path length L10 corresponds to the element length from point 'a' of the feeding portion 1 to point 'c' of the antenna element 11. In the glass antennas of FIGS. 6 and 7, the farthest point on the first antenna element that is farthest from the first feeding portion by a shortest path corresponds to a point on the looped antenna element 12 but does not necessarily have to correspond to point 'y' or 'z'.

[0081] Thus, to improve the antenna gain for Band III, assuming the radio wave speed is 3.0×10^8 m/s and the shortening coefficient of wavelength k is equal to 0.64, the shortest path length L10 is preferably adjusted to be greater than or equal to 115 mm and less than or equal to 232 mm, and more preferably, greater than or equal to 145 mm and less than or equal to 203 mm.

[0082] Also, assuming λ_{02} denotes the wavelength at air of the central frequency of a second frequency band at a higher frequency than the first frequency band, k denotes the shortening coefficient of wavelength of glass, and $\lambda_{g2}=\lambda_{02} \cdot k$ denotes the wavelength on glass, favorable results may be obtained in terms of improving the antenna gain for the second frequency band when the third antenna conductor includes at least one antenna element having an element length L30 that is greater than or equal to $(1/8) \cdot \lambda_{g2}$ and less than or equal to $(1/2) \cdot \lambda g_2$, and more preferably, greater than or equal to $(3/16) \cdot \lambda_{g2}$ and less than or equal to $(7/16) \cdot \lambda_{g2}$.

[0083] For example, in the antenna glass 200 of FIG. 2, the element length L30 corresponds to the conductor length from point 'o' to point 'p' of the antenna element 31.

[0084] For example, in a case where the second frequency band corresponds to L-Band (1452 to 1492 MHz), the central frequency of the second frequency band is 1472 MHz. Thus, to improve the antenna gain for L-Band, assuming the radio wave speed is 3.0×10^8 m/s and the shortening coefficient of wavelength k is equal to 0.64, the element length L30 is preferably adjusted to be greater than or equal to 16 mm and less than or equal to 66 mm, and more preferably, greater than or equal to 24 mm and less than or equal to 57 mm.

[0085] Also, to improve the antenna gain for the first frequency band, the distance between the second antenna element and the third antenna element that are capacitively coupled to each other is preferably greater than or equal to 3 mm and less than or equal to 17 mm. For example, in the glass antenna of FIG. 1, the distance between the second antenna element and the third antenna element corresponds to the minimum distance between the partial elements 21c and 22a and the minimum distance between the partial elements 21b and 22b.

[0086] Although certain preferred embodiments of the glass antenna and window glass have been described above, the present invention is not limited to these embodiments. That is, numerous other variations and modifications of the embodiments may be made without departing from the scope of the present invention.

[Working Examples]

[0087] In the following, working examples of the glass antenna and window glass of the present invention are described. First, measurement results of measuring the antenna gain of an automobile glass antenna fabricated by mounting the glass antenna 100 illustrated in FIG- 1 at a side window of a vehicle are described.

[0088] The automobile window having the glass antenna formed thereon was mounted to a window frame of an automobile placed on a turntable to be tilted approximately 75 degrees with respect to a horizontal plane, and the antenna gain of the automobile glass antenna was measured in this state. Connectors were attached to the feeding portion 1 and the feeding portion 2 so that an internal conductor of a coaxial cable may be connected to the feeding portion 1 and an external conductor of the coaxial cable may be connected to the feeding portion 2. In this way, the feeding portion 1 and the feeding portion 2 were connected to a network analyzer via the coaxial cable. The turntable was arranged to rotate so that radio waves may be horizontally irradiated on the window from all directions.

[0089] The antenna gain was measured by setting the vehicle center of the automobile having the window with the glass antenna to the center of the turntable and rotating the automobile 360 degrees. Specifically, at every rotational angle of 5 degrees, the antenna gain was measured at intervals of 3 MHz within the Band III frequency band. The position and elevation angle of the antenna conductor and outgoing radio was substantially horizontal (elevation angle = 0°, assuming the elevation angle of a plane parallel to the ground = 0° and the elevation angle of the zenith direction = 90°). The antenna gain was normalized based on the half-wave dipole antenna so that the antenna gain of the half-wave dipole antenna may be equal to 0 dB.

[Example 1]

[0090]

[Table 1]

L22 [mm]	255	230	210	190	160	140	120
Gain [dBd]	-8.9	-9.2	-9.1	-9.7	-10.5	-11.5	-12.2

[0091] Table 1 and FIG. 8 represent measurement data of the antenna gain of a high frequency glass antenna for an automobile that is fabricated by mounting the glass antenna 100 illustrated in FIG. 1 to a side window of an automobile, the antenna gain being measured by varying the above-described length L22 of the capacitively coupled portion while maintaining the conductor length from point 'j' to point 'm' to a fixed value. The vertical axis of FIG. 8 represents the average value of the antenna gains for Band III (174 to 240 MHz) measured at intervals of 3 MHz and at rotational angle intervals of 5 degrees.
[0092] Dimensions are represented in millimeter (mm) units, and the dimensions of parts of the glass antenna 100 subject to the measurement of Table 1 and FIG. 8 are as follows:

L11+L41: 170
L42: 50
L21 (=L21a+L21b+L21c+L21d): 410
L43: 10
Conductor Length from points 'j' to 'm': 330

[0093] It is noted that L* (where * is a numeral) represents the conductor length of the corresponding element *. The conductor width of each of the elements is 0.8 mm. The feeding portions 1 and 2 are arranged into square shapes having a side dimension of 12 mm. The distance between the feeding portion 1 and the feeding portion 2 is 13 mm.
[0094] As can be appreciated from FIG. 8, the antenna gain for Band III may be improved by adjusting the length L22 of the capacitively coupled portion to be greater than or equal to 115 mm.

[Example 2]

[0095]

[Table 2]

L21 [mm]	590	570	550	530	510	490	470
Gain [dBd]	-10.1	-9.5	-9.2	-9.1	-8.9	-9.1	-9.2

(Continued)

L21 [mm]	450	430	410	390	370	350	330	310
Gain [dBd]	-9.4	-9.8	-10.3	-10.7	-11.3	-11.9	-12.4	-13.9

[0096] Table 2 and FIG. 9 represent measurement data of the antenna gain of a high frequency glass antenna for an automobile that is fabricated by mounting the glass antenna 100 illustrated in FIG. 1 to a side window of an automobile, the antenna gain being measured by varying the loop length L21 of the antenna element 21 while maintaining the conductor lengths of the partial elements 21b and 21d at fixed values. The vertical axis of FIG. 9 represents the average value of the antenna gains for Band III (174 to 240 MHz) measured at intervals of 3 MHz and at rotational angle intervals of 5 degrees.
[0097] Dimensions are represented in millimeter (mm) units, and the dimensions of parts of the glass antenna 100

subject to the measurement of Table 2 and FIG. 9 are as follows:

L11+L41: 170
L42: 30
L21b, L21d: 155
L43: 5
Conductor Length from points 'j' to 'm': 345

Note that other dimensions are the same as those of Example 1.

[0098] As can be appreciated from FIG. 9, the antenna gain for Band III may be improved by adjusting the loop length L21 of the antenna element 21 to be greater than or equal to 347 mm and less than or equal to 580 mm.

[Example 3]

[0099]

[Table 3]

L10 [mm]	330	290	250	230	210	190	170
Gain [dBd]	-29.3	-22.3	-15.4	-13.3	-10.7	-9.3	-8.9

(Continued)

L10 [mm]	150	130	110	90	70	50
Gain [dBd]	-10	-11.5	-13.2	-15	-16.9	-18.8

[0100] Table 3 and FIG. 10 represent measurement data of the antenna gain of a high frequency glass antenna for an automobile that is fabricated by mounting the glass antenna 100 illustrated in FIG. 1 to a side window of an automobile, the antenna gain being measured while varying the above-described shortest path length L10 of the first antenna conductor. The vertical axis of FIG. 10 represents the average value of the antenna gains for Band III (174 to 240 MHz) measured at intervals of 3 MHz and at rotational angle intervals of 5 degrees.

[0101] Dimensions are represented in millimeter (mm) units, and the dimensions of parts of the glass antenna 100 subject to the measurement of Table 3 and FIG. 10 are as follows:

L42: 50
L21 (=L21a+L21b+L21c+L21d): 410
L43: 10
Conductor Length from points 'j' to 'm': 330

[0102] Note that other dimensions are the same as those of Example 1.

[0103] As can be appreciated from FIG. 10, the antenna gain for Band III may be improved by adjusting the shortest path length L10 to be greater than or equal to 115 mm and less than or equal to 232 mm.

[0104] Further, the present invention is not limited to these embodiments, but various variations and modifications may be made without departing from the scope of the present invention.

[0105] The present application is based on and claims the benefit of priority of Japanese Patent Application No. 2012-207448 filed on September 20, 2012, the entire contents of which are hereby incorporated by reference.

Claims

1. A glass antenna that is arranged at a window glass of a vehicle, the glass antenna comprising a first feeding portion (1) and a second feeding portion (2) that are arranged one above the other, a first antenna conductor (10) that is connected to the first feeding portion, and a second antenna conductor (20) that is connected to the second feeding

portion, wherein
the first antenna conductor (10) includes a first antenna element (11) that extends in a substantially horizontal direction and is connected to the first feeding portion (1) either directly or via a first connection element (41); and the second antenna conductor (20) includes a second antenna element (21) that is arranged into a loop and is connected to the second feeding portion (2) either directly or via a second connection element (42), a third antenna element (22) that extends along the second antenna element (21) and is connected to the second antenna element (21) via a third connection element (43), and a fourth antenna element (23) that extends at an opposite side of the second feeding portion (2) with respect to the second antenna element (21) and is connected to the third antenna element (22).

2. The glass antenna according to claim 1, wherein
λ_{01} denotes a wavelength at air at a central frequency of a predetermined frequency band, k denotes a shortening coefficient of wavelength of the window glass, and $\lambda_{g1}=\lambda_{01}\cdot k$ denotes a wavelength on the window glass,
a longest path length (La) from the second feeding portion to a tip of the fourth antenna element is greater than or equal to $(5/8)\cdot\lambda_{g1}$ and less than or equal to $(7/8)\cdot\lambda_{g1}$.

3. The glass antenna according to claim 2, wherein
a longest path length (La) from the second feeding portion to a tip of the fourth antenna element is greater than or equal to 579 mm and less than or equal to 812 mm.

4. The glass antenna according to any one of claims 1 to 3, wherein
λ_{01} denotes a wavelength at air at a central frequency of a predetermined frequency band, k denotes a shortening coefficient of wavelength of the window glass, and $\lambda_{g1}=\lambda_{01}\cdot k$ denotes a wavelength on the window glass,
a length (L22) of a portion of the third antenna element extending along the second antenna element of an element portion of the third antenna element extending from a connection point of the third antenna element and the third connection element to a connection point of the third antenna element and the fourth antenna element is greater than or equal to $(1/8)\cdot\lambda_{g1}$.

5. The glass antenna according to any one of claims 1 to 3, wherein
a length (L22) of a portion of the third antenna element extending along the second antenna element of an element portion of the third antenna element extending from a connection point of the third antenna element and the third connection element to a connection point of the third antenna element and the fourth antenna element is greater than or equal to 115 mm.

6. The glass antenna according to any one of claims 1 to 5, wherein
λ_{01} denotes a wavelength at air at a central frequency of a predetermined frequency band, k denotes a shortening coefficient of wavelength of the window glass, and $\lambda_{g1}=\lambda_{01}\cdot k$ denotes a wavelength on the window glass,
a loop length (L21) of the second antenna element is greater than or equal to $(3/8)\cdot\lambda_{g1}$ and less than or equal to $(5/8)\cdot\lambda_{g1}$.

7. The glass antenna according to any one of claims 1 to 5, wherein
a loop length (L21) of the second antenna element is greater than or equal to 347 mm and less than or equal to 580 mm.

8. The glass antenna according to any one of claims 1 to 7, wherein
λ_{01} denotes a wavelength at air of a central frequency of a predetermined frequency band, k denotes a shortening coefficient of wavelength of the window glass, and $\lambda_{g1}=\lambda_{01}\cdot k$ denotes a wavelength on the window glass,
a shortest path length (L10) between the first feeding portion and a farthest point on the first antenna element that is farthest from the first feeding portion by a shortest path is greater than or equal to $(1/8)\cdot\lambda_{g1}$ and less than or equal to $(1/4)\cdot\lambda_{g1}$.

9. The glass antenna according to any one of claims 1 to 7, wherein
a shortest path length (L10) between the first feeding portion and a farthest point on the first antenna element that is farthest from the first feeding portion by a shortest path is greater than or equal to 115 mm and less than or equal to 232 mm.

10. The glass antenna according to any one of claims 1 to 9, further comprising:

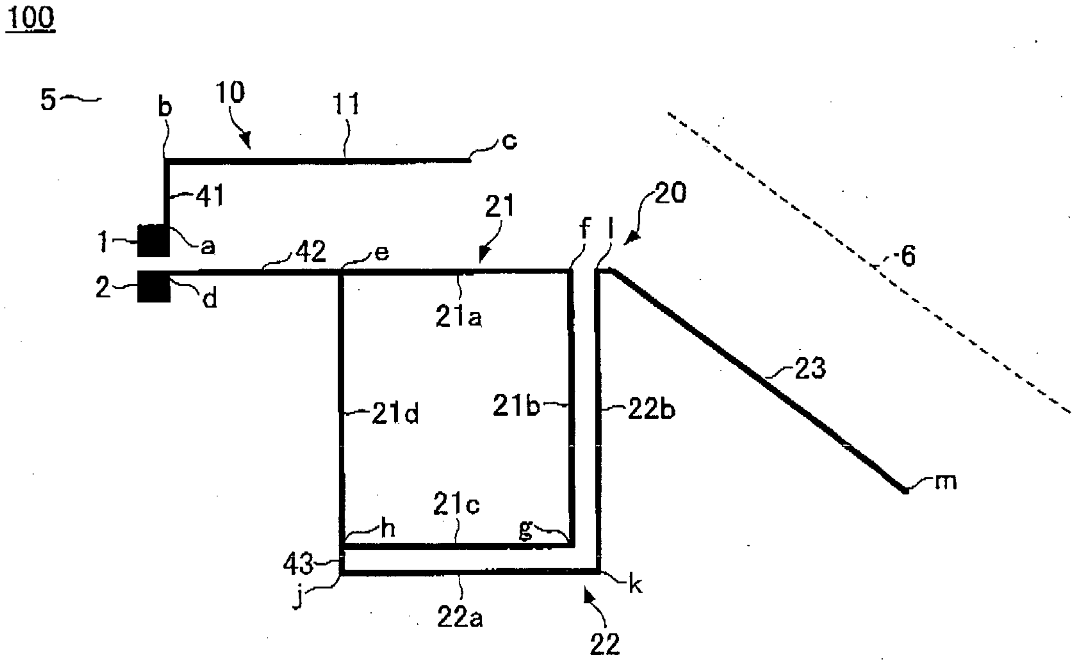
a third antenna conductor arranged in a vicinity of at least one of the first feeding portion and the second feeding portion.

11. The glass antenna according to claim 10, wherein λ_{02} denotes a wavelength at air at a central frequency of a predetermined frequency band, k denotes a shortening coefficient of wavelength of the window glass, and $\lambda_{g2}=\lambda_{02}\cdot k$ denotes a wavelength on the window glass, an element length (L30) of the third antenna conductor is greater than or equal to $(1/8)\cdot\lambda_{g2}$ and less than or equal to $(1/2)\cdot\lambda_{g2}$.

12. The glass antenna according to claim 10, wherein an element length (L30) of the third antenna conductor is greater than or equal to 16 mm and less than or equal to 66 mm.

13. A window glass comprising the glass antenna according to any one of claims 1 to 12.

FIG.1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22

FIG.2

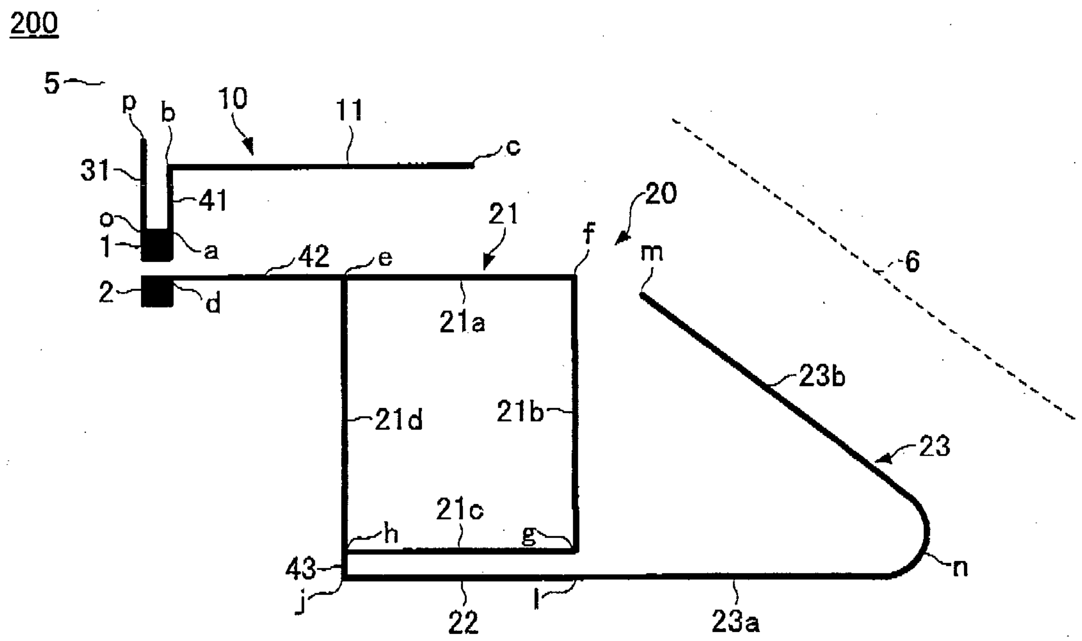
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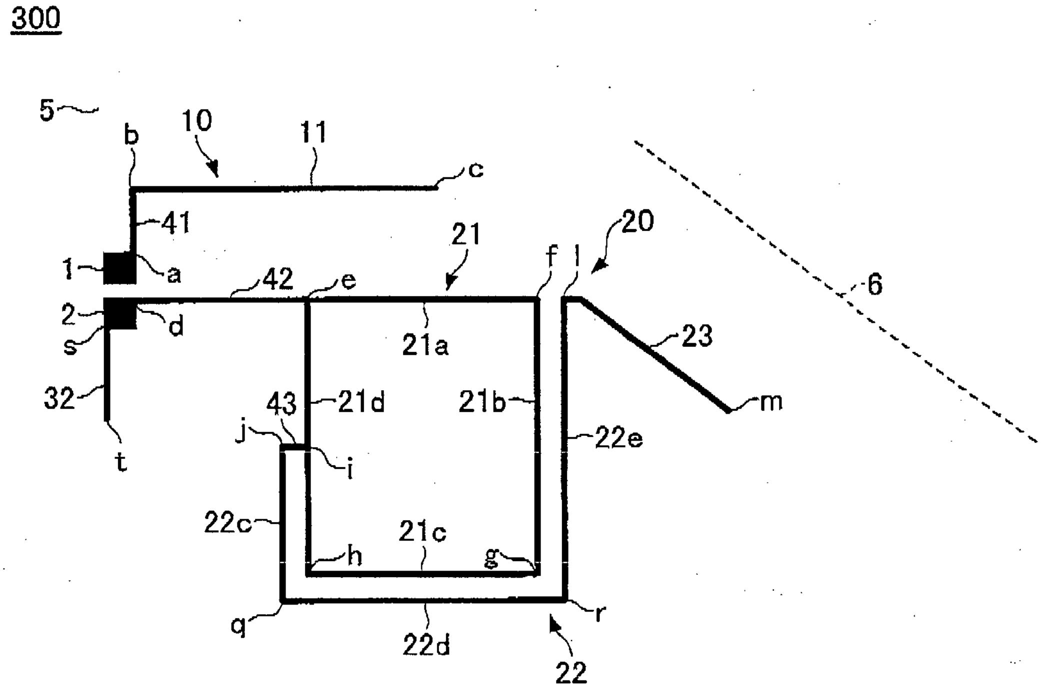
FIG.3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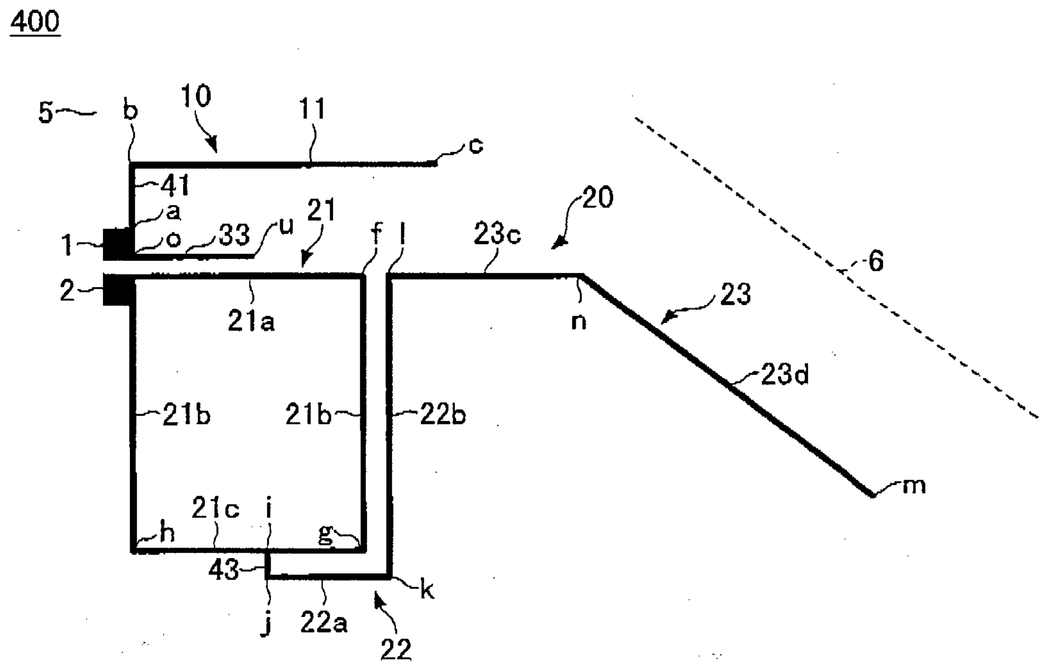
r
q
22d
22

FIG.4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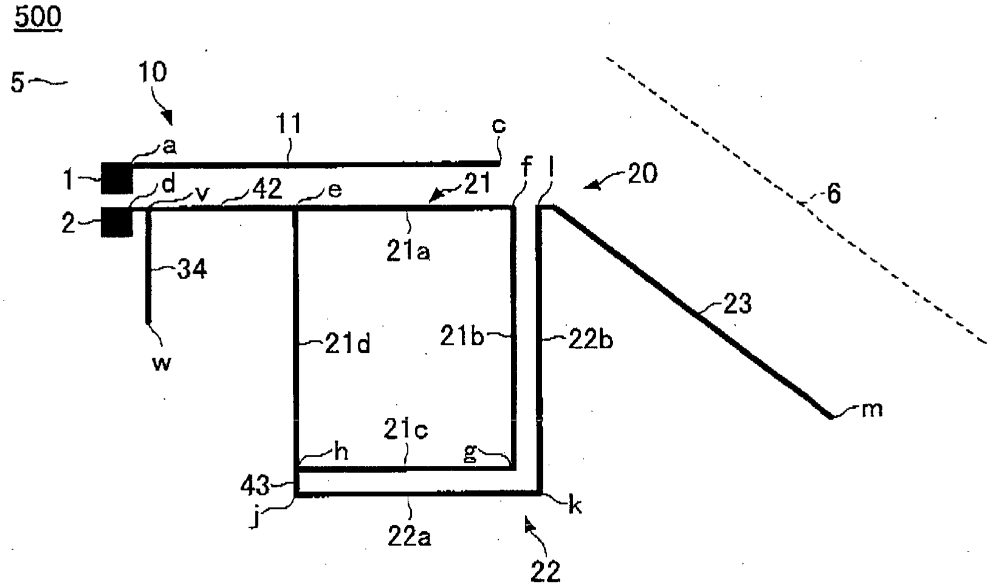
23d
21b
21b
22b
21c
i
m
h
g
43
k
j
22a
22

FIG.5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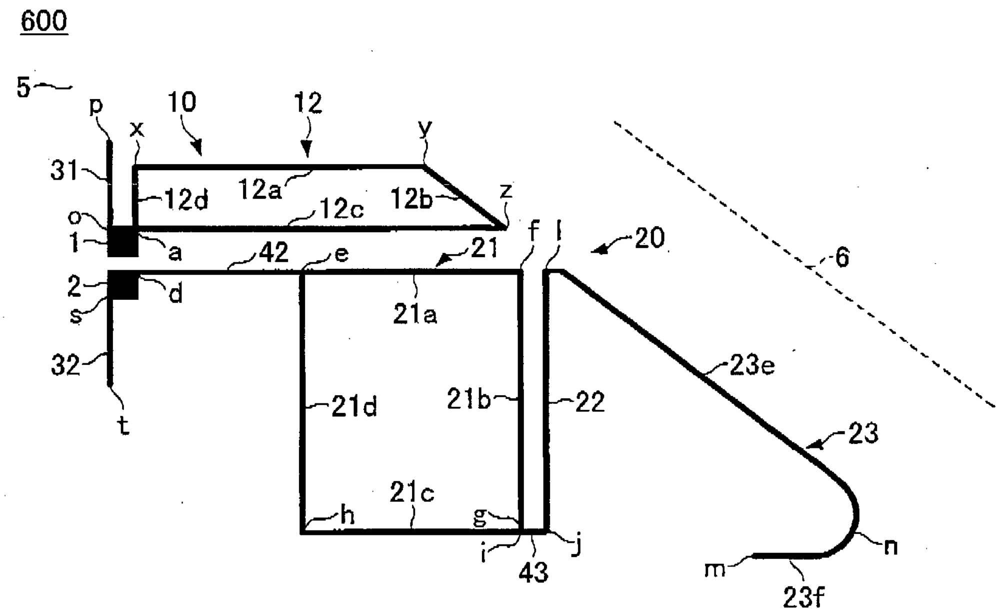
j
22a
22

FIG.6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d
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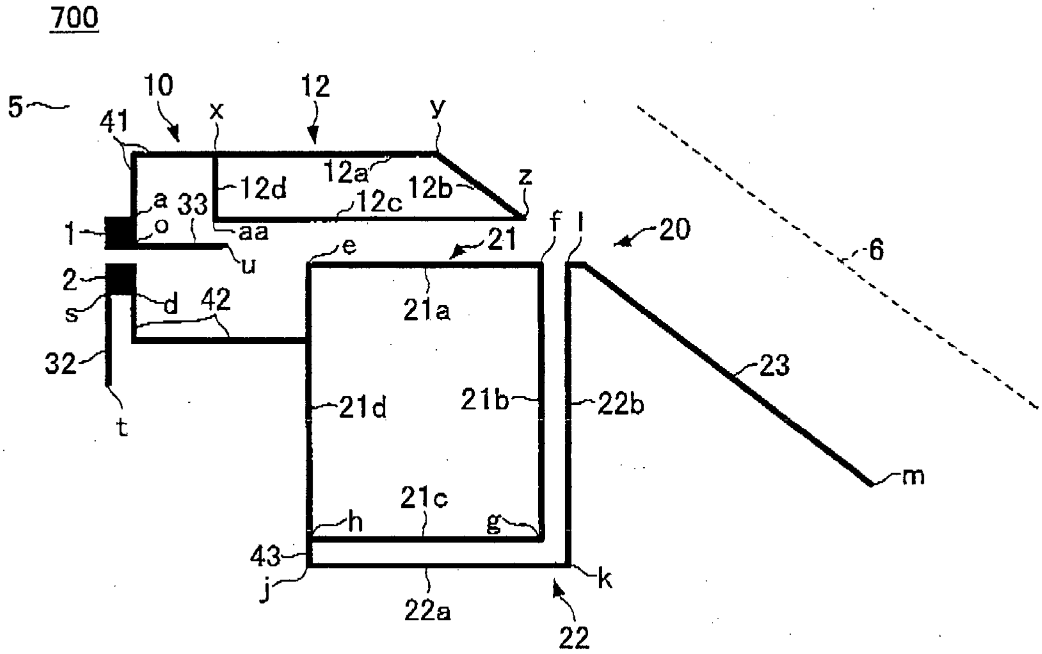
43
m
23f

FIG.7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12c
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f
l
20
6
2
s
d
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m
21c
h
g
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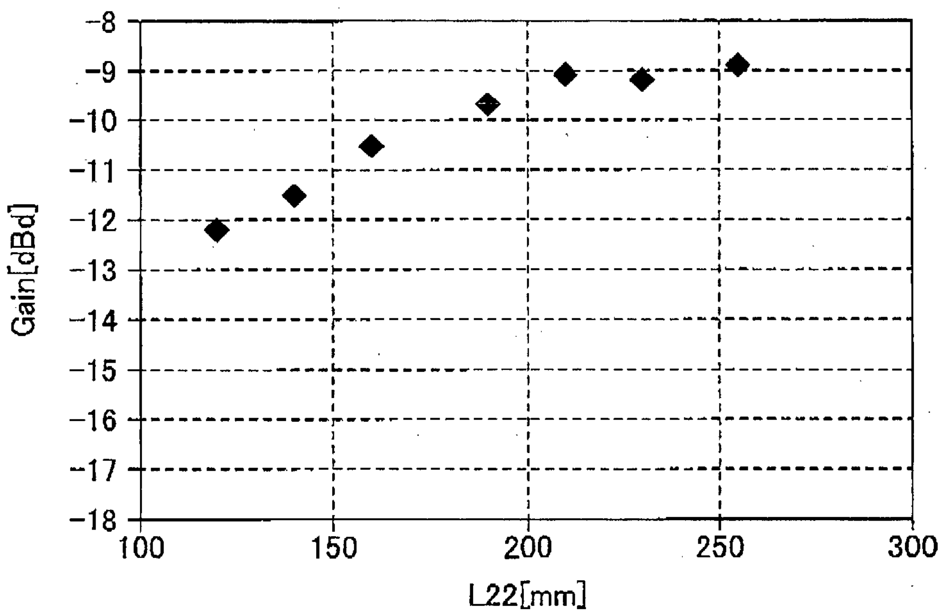
k
22a
22

FIG.8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Gain[dBd]
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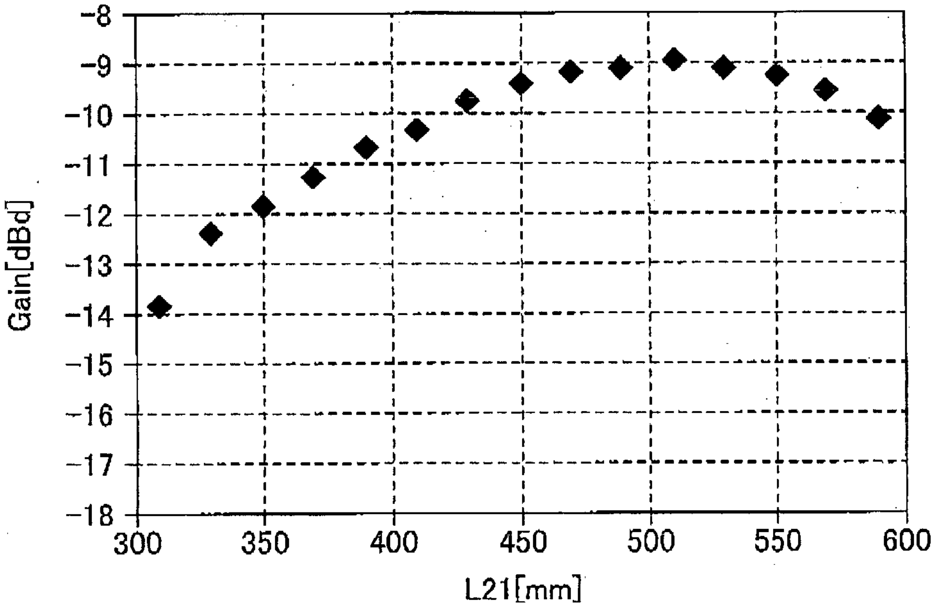
150
200
250
300
L22[mm]

FIG.9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-11
-12
-13
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-18
Gain[dBd]
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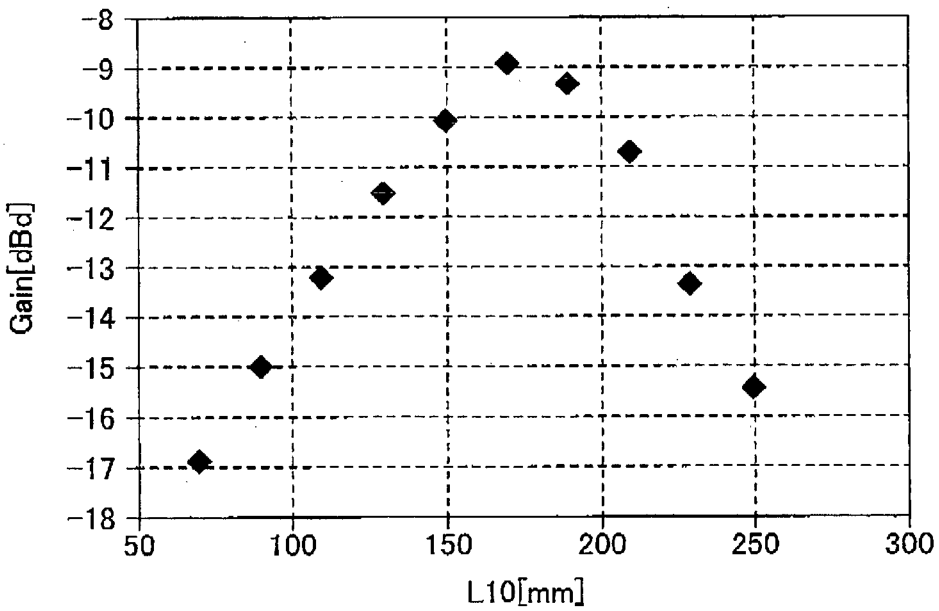
400
450
500
550
600
L21[mm]

FIG.10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-9
-10
-11
-12
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-18
Gain[dBd]
50
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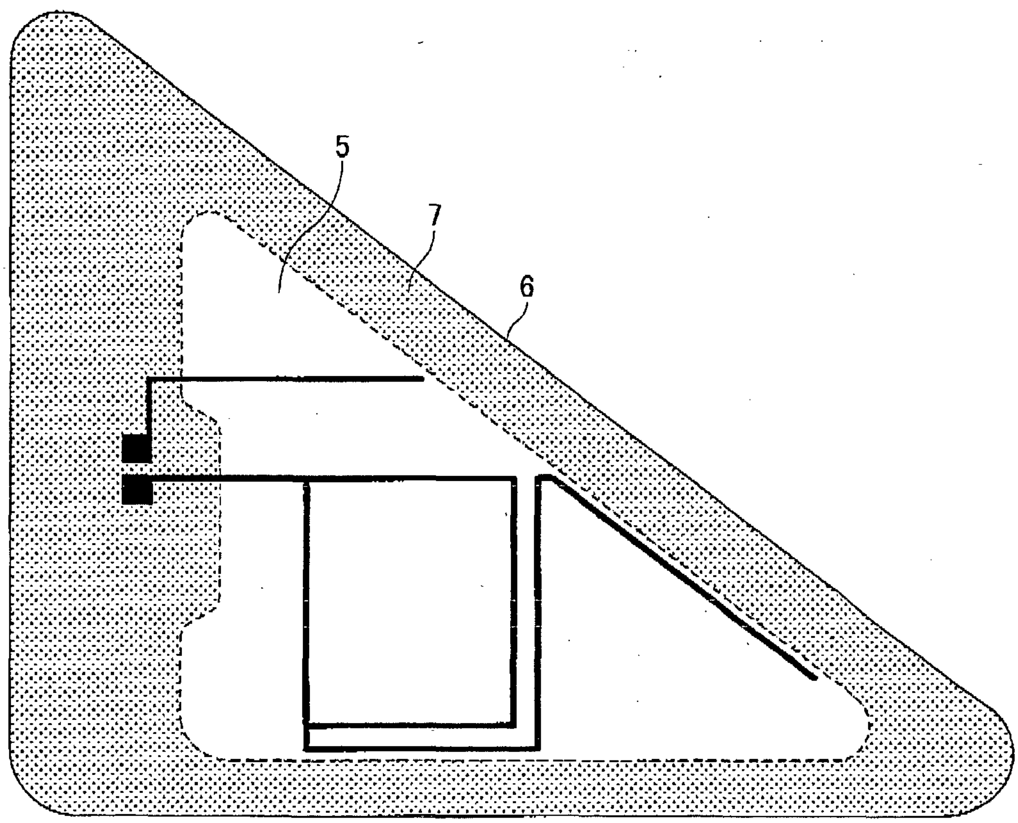
150
200
250
300
L10[mm]

FIG.11



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EUROPEAN SEARCH REPORT

Application Number
EP 13 00 4605

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2010/156730 A1 (YAMAMOTO TSUYOSHI [JP] ET AL) 24 June 2010 (2010-06-24) * abstract; figures 3,7 * * paragraphs [0088] - [0098] * * paragraphs [0112] - [0119] *	1-13	INV. H01Q1/12
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X	EP 2 485 325 A1 (CENTRAL GLASS CO LTD [JP]) 8 August 2012 (2012-08-08) * abstract; figure 5 * * paragraphs [0053] - [0055] *	1-13	
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A	WO 2011/158602 A1 (CENTRAL GLASS CO LTD [JP]; KATADA YUJI; YAMAMOTO MASAHIRO; KAIHATSU MA) 22 December 2011 (2011-12-22) * abstract; figures 6,8,10 *	1-13	TECHNICAL FIELDS SEARCHED (IPC) H01Q
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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	14 November 2013	Unterberger, Michael

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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