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(54) **GLASS ANTENNA AND WINDOW GLASS**

(57) It is provided a glass antenna to be arranged on a window glass of a vehicle, comprising a first antenna (3) configured to receive a radio wave in a first frequency band, and a second antenna (4) configured to receive a radio wave in a second frequency band having a frequency that is approximately half of a frequency of the first frequency band. The first antenna (3) including a core-side feeding unit (36) and an earth-side feeding unit (31) to be coupled to a receiver, a core-side element (37) extended from the core-side feeding unit, and an earth-side element (32) extended from the earth-side feeding unit. The core-side element (37) having a length approximately equal to a length obtained by multiplying a wavelength at a center frequency of the first frequency band by a wavelength shortening rate of glass.

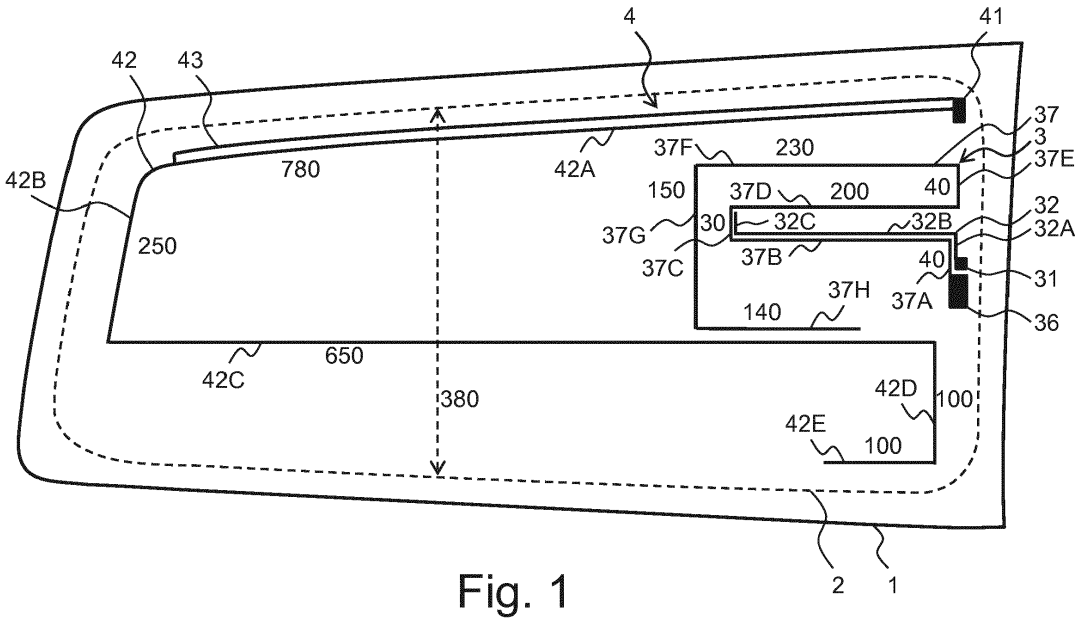

Fig. 1

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Description

BACKGROUND OF THE INVENTION

[0001] This invention relates to a glass antenna to be arranged on a surface of a glass, and more particularly, to an antenna from which a high gain can be obtained.

[0002] A plurality of antennas are arranged on a side window glass of an automobile. The side window glass has a small size. Therefore, when the plurality of antennas (e.g., an FM antenna and a DAB antenna) are arranged, the plurality of antennas interfere with each other, failing to obtain desired receiving characteristics.

[0003] As an antenna for solving the above-mentioned problem, there are antennas disclosed in JP 2012-23707 A, JP 2014-123851 A, and JP 2014-216805 A.

[0004] The following vehicle glass antenna is disclosed in JP 2012-23707 A. Specifically, the vehicle glass antenna includes a core-side feeding point and a ground-side feeding point closely arranged side by side on a glass surface of a window of an automobile in the vicinity of an opening of a metal flange of the window, a ground-side element including a line extended in a direction away from the metal flange positioned closest to the ground-side feeding point, and a core-side element including a core-side first line extended from the core-side feeding point approximately in parallel to the line of the ground-side element and a core-side second line branching from the core-side first line or extended directly from the core-side feeding point in parallel to the core-side first line. A length from the core-side feeding point to a distal end of the core-side first line and a length from the core-side feeding point to a distal end of the core-side second line are set as lengths of lines that correspond to two resonant frequencies being away from each other in a single frequency bandwidth.

[0005] The following vehicle glass antenna is disclosed in JP 2014-123851 A. Specifically, the vehicle glass antenna is arranged on a vehicle window glass including a hot-side feeding unit and an earth-side feeding unit. The hot-side feeding unit includes a hot-side feeding point, and the earth-side feeding unit includes an earth-side feeding point. The hot-side feeding unit is surrounded by the earth-side feeding unit in three directions. One end of a hot-side element is coupled to the hot-side feeding unit. The hot-side element is extended in a direction away from the hot-side feeding point. One end of an earth-side element is coupled to the earth-side feeding unit. The earth-side element is arranged so as to surround the hot-side element. The hot-side element and the earth-side element are close to each other to have a capacitively coupled portion.

[0006] The following vehicle glass antenna is disclosed in JP 2014-216805 A. Specifically, the vehicle glass antenna is arranged above a defogger on a rear window glass of an automobile, and includes an FM first antenna, an FM second antenna, and a DAB antenna. In a blank space of the FM first antenna, the FM second antenna and the DAB antenna are arranged. The FM second antenna includes an FM second antenna feeding point and an FM second antenna element arranged on a side edge portion of the rear window glass. The FM second antenna element includes an FM second antenna first line and an FM second antenna second line. The FM second antenna first line has one end coupled to the FM second antenna feeding point and is extended in a direction away from the FM second antenna feeding point. One end of the FM second antenna first line on the opposite side is coupled to a distal end or a middle portion of the FM second antenna second line.

SUMMARY OF THE INVENTION

[0007] The antenna disclosed in JP 2012-23707 A obtains a gain in vertical polarization by arranging the core-side lines and the line of the ground-side element in approximately parallel to each other so as to generate an electric field from the core-side lines to the ground-side line. However, the lines extend in a horizontal direction, and hence a large number of horizontal polarization components exist. Thus, vertical polarization components are not sufficiently obtained.

[0008] The antenna disclosed in JP 2014-123851 A has a form in which the earth-side element surrounds the hot-side element, which greatly affects an antenna in the proximity thereto.

[0009] Further, the antenna disclosed in JP 2014-216805 A includes the core-side element of the DAB antenna having a length of about 175 mm, and therefore is not configured to intensify the vertical polarization components.

[0010] This invention has a preferred object to provide a DAB antenna having reduced effects on reception performance of an FM antenna adjacent thereto. This invention has another preferred object to provide the DAB antenna having a high gain in vertical polarization.

[0011] That is, according to one embodiment of this invention, there is provided a glass antenna to be arranged on a window glass of a vehicle, comprising a first antenna (3) configured to receive a radio wave in a first frequency band, and a second antenna (4) configured to receive a radio wave in a second frequency band having a frequency that is approximately half of a frequency of the first frequency band. The first antenna (3) including a core-side feeding unit (36) and an earth-side feeding unit (31) to be coupled to a receiver, a core-side element (37) extended from the core-side feeding unit, and an earth-side element (32) extended from the earth-side feeding unit. The core-side element (37) having a length approximately equal to a length obtained by multiplying a wavelength at a center frequency of the first frequency band by a wavelength shortening rate of glass.

[0012] Further, in the glass antenna according to the one embodiment of this invention, the core-side element (37) is formed by being bent. On the core-side element (37) includes a first line (37C) containing a first position

which is at a distance $\alpha\lambda/4$ from the core-side feeding unit along the core-side element and a second line (37G) containing a second position which is at a distance $3\alpha\lambda/4$ from the core-side feeding unit along the core-side element when the wavelength at the center frequency of the first frequency band is λ and the wavelength shortening rate of the glass is α. The first line (37C) and the second line (37G) are positioned in parallel to each other.

[0013] Further, in the glass antenna according to the one embodiment of this invention, the core-side element (37) includes a first horizontal line (37B) coupled to the core-side feeding unit to be extended in a horizontal direction, a second vertical line (37C) extended upward from the first horizontal line, a second horizontal line (37D) extended from the second vertical line in the horizontal direction, a third vertical line (37E) extended upward from the second horizontal line, a third horizontal line (37F) extended from the third vertical line in the horizontal direction, and a fourth vertical line (37G) extended downward from the third horizontal line. The second vertical line (37C) contains the first position, and the fourth vertical line (37G) contains the second position. The second vertical line (37C) is positioned between the fourth vertical line and the core-side feeding unit in the horizontal direction.

[0014] Further, in the glass antenna according to the one embodiment of this invention, each of the second vertical line (37C) and the fourth vertical line (37G) has a length ranging from $\alpha\lambda/40$ to $\alpha\lambda/5$.

[0015] Further, in the glass antenna according to the one embodiment of this invention, the earth-side element (32) is arranged along the core-side element at a predetermined distance from the core-side element (37).

[0016] Further, in the glass antenna according to the one embodiment of this invention, the first frequency band is a DAB radio broadcast band, and the second frequency band is an FM radio broadcast band.

[0017] Further, in the glass antenna according to the one embodiment of this invention, the second antenna (4) includes a first transverse line (42A) extended from a feeding unit (41) in a transverse direction, a first longitudinal line (42B) extended downward from the first transverse line, a second transverse line (42C) extended from the first longitudinal line in the transverse direction, and a second longitudinal line (42D) extended from the second transverse line in a longitudinal direction.

[0018] Further, in a window glass according to the one embodiment of this invention, the window glass (1) comprising any one of the glass antenna being arranged on the window glass.

[0019] According to the representative embodiment of this invention, the DAB antenna having reduced effects on the reception performance of the FM antenna adjacent thereto can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

FIG. 1 is a drawing illustrating an antenna pattern of an example 1 of this invention.

FIG. 2 is a drawing illustrating an operation principle of the antenna pattern of an example of this invention.

FIG. 3 is a drawing illustrating an antenna pattern of an example 2 of this invention.

FIG. 4 is a drawing illustrating an antenna pattern of an example 3 of this invention.

FIG. 5 is a drawing illustrating an antenna pattern of an example 4 of this invention.

FIG. 6 is a drawing illustrating an antenna pattern of an example 5 of this invention.

FIG. 7 is a drawing illustrating other variations of example of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0021] FIG. 1 to FIG. 7 are views of a glass antenna according to an embodiment of this invention as viewed from a vehicle interior side. The antenna including a feeding unit arranged on a right side of a glass is described in the following embodiment and examples. However, the arrangement may be horizontally reversed so that the feeding unit is arranged on a left side of the glass.

[0022] As illustrated in FIG. 1, a glass antenna of the embodiment of this invention is formed on the inner side of a body flange 2 of a window glass (for example, a side window glass of an automobile) 1, and includes a DAB antenna 3 and an FM antenna 4. The DAB antenna 3 is adjusted so as to be capable of receiving DAB Band 3 (from 174 MHz to 240 MHz). The FM antenna 4 is adjusted so as to be capable of receiving an FM radio broadcast band (from 78 MHz to 95 MHz in Japan, and from 87.5 MHz to 108 MHz outside Japan).

[0023] The DAB antenna 3 includes a feeding unit including a pair of an earth-side feeding unit 31 and a core-side feeding unit 36, an earth-side element 32 extended from the earth-side feeding unit 31, and a core-side element 37 extended from the core-side feeding unit 36.

[0024] The core-side element 37 has a length approximately equal to a length obtained by multiplying a wavelength λ at a center frequency of a reception frequency band by a wavelength shortening rate α of the glass, and includes a first vertical line 37A extended upward from the core-side feeding unit 36, a first horizontal line 37B extended leftward from an upper end of the first vertical line 37A, a second vertical line 37C extended upward from a left end of the first horizontal line 37B, a second horizontal line 37D extended rightward from an upper end of the second vertical line 37C, a third vertical line 37E extended upward from a right end of the second horizontal line 37D, a third horizontal line 37F extended leftward from a right end of the third vertical line 37E, a fourth vertical line 37G extended downward from a left end of the third horizontal line 37F, and a fourth horizontal line 37H extended rightward from a lower end of the fourth

vertical line 37G.

[0025] The earth-side element 32 includes a vertical line 32A extended upward from the earth-side feeding unit 31, a horizontal line 32B extended leftward from an upper end of the vertical line 32A, and a vertical line 32C extended upward from a left end of the horizontal line 32B, thereby forming a pattern along the core-side element 37 so as to be in proximity thereto. In the DAB antenna 3 of this embodiment, the core-side element 37 has the length approximately equal to the length obtained by multiplying the wavelength at the center frequency of the reception frequency band by the wavelength shortening rate of the glass, and therefore tends to have an increased impedance. Thus, by arranging the earth-side element 32 along the core-side element 37 so as to be in proximity thereto, the impedance of the DAB antenna 3 can be reduced.

[0026] The FM antenna 4 includes a feeding unit 41, a main element 42 extended from the feeding unit 41, and an auxiliary element 43 arranged in proximity to the main element 42 so as to be approximately parallel thereto on an upper edge of the antenna. The main element 42 includes a first transverse line 42A that is extended from the feeding unit 41 in a transverse direction and is arranged along the body flange 2, a first longitudinal line 42B extended downward from a left end of the first transverse line 42A, a second transverse line 42C extended rightward from a lower end of the first longitudinal line 42B, a second longitudinal line 42D extended downward from a right end of the second transverse line 42C, and a third transverse line 42E extended leftward from a lower end of the second longitudinal line 42D.

[0027] The core-side element 37 of the DAB antenna 3 according to this embodiment has the length approximately equal to the length obtained by multiplying the wavelength λ at the center frequency of the reception frequency band by the wavelength shortening rate α of the glass. An end portion of the core-side element 37 is at a position which is at a distance $\alpha\lambda$ from the core-side feeding unit 36 along the core-side element 37 (in other words, the position is reached by tracing the core-side element 37 by a length $\alpha\lambda$ from the core-side feeding unit 36), $3\alpha\lambda/4$ is positioned on the fourth vertical line 37G, $\alpha\lambda/2$ is positioned on the third horizontal line 37F, and $\alpha\lambda/4$ is positioned on the second vertical line 37C.

[0028] In FIG. 2, a magnitude and an orientation of a current induced on the core-side element 37 are indicated by the arrows. The current induced on the element having the length corresponding to a full wavelength has peaks at the position corresponding to $\alpha\lambda/4$ and the position corresponding to $3\alpha\lambda/4$. In the core-side element 37 of the DAB antenna 3 of this embodiment, the second vertical line 37C and the fourth vertical line 37G are arranged in parallel to each other. The peak currents respectively flow through the second vertical line 37C and the fourth vertical line 37G in the same direction. The current has the peaks in the lines of the core-side element 37, which extend in the vertical direction. Therefore, a high gain is obtained in vertical polarization. Further, a radio wave is intensified by the second vertical line 37C and the fourth vertical line 37G, and hence a high gain is obtained in the vertical polarization. When the DAB antenna 3 is arranged after being rotated by 90 degrees, a radio wave in the horizontal direction can be intensified so that a high gain can be obtained in horizontal polarization.

[0029] Further, as illustrated in FIG. 3, a third longitudinal line 42F extended upward from a right end of the second transverse line 42C of the FM antenna 4 may be provided in place of the second longitudinal line 42D and the third transverse line 42E.

[0030] Further, as illustrated in FIG. 4, the horizontal line 32B of the earth-side element 32 of the DAB antenna 3 may be extended leftward from the earth-side feeding unit 31 without providing the vertical line 32A. Further, the first horizontal line 37B may be extended leftward from the core-side feeding unit 36 without providing the first vertical line 37A of the core-side element 37 of the DAB antenna 3.

[0031] Further, as illustrated in FIG. 5 and FIG. 6, the earth-side feeding unit 31 and the core-side feeding unit 36 of the DAB antenna 3 may be arranged on the inner side of the window glass 1 instead of being arranged in the vicinity of the body flange 2 of the window glass 1. Further, as illustrated in FIG. 5, a U-shaped portion formed by the first horizontal line 37B, the second vertical line 37C, and the second horizontal line 37D of the core-side element 37 of the DAB antenna 3 may be formed outside of a U-shaped portion (oriented in the opposite direction) formed by the third horizontal line 37F, the fourth vertical line 37G, and the fourth horizontal line 37H. Further, as illustrated in FIG. 6, the second horizontal line 37D and the third horizontal line 37F of the core-side element 37 of the DAB antenna 3 may be formed in a single straight line without providing the third vertical line 37E.

[0032] Further, besides the above-mentioned variations, the glass antenna of this embodiment may be configured by adjusting the lengths or the positions of the elements in the following modes as illustrated in FIG. 7.

(1) An interval between the first horizontal line 37B and the second horizontal line 37D of the core-side element 37 of the DAB antenna 3

(2) An interval between the second horizontal line 37D and the third horizontal line 37F of the core-side element 37 of the DAB antenna 3

(3) An interval between the first horizontal line 37B and the fourth horizontal line 37H of the core-side element 37 of the DAB antenna 3

(4) A position of the third vertical line 37E of the core-side element 37 of the DAB antenna 3

(5) A length of the fourth horizontal line 37H of the core-side element 37 of the DAB antenna 3

(6) A length of the earth-side element 32 of the DAB antenna 3

(7) A length of the third transverse line 42E of the main element 42 of the FM antenna 4 core-side
(8) A length of the auxiliary element 43 of the FM antenna 4

[0033] The glass antenna according to the embodiment of this invention is formed as follows. Specifically, a pattern of the glass antenna is printed at a predetermined position on an indoor surface side of the glass so that each of the lines has a width of about 0.7 mm with an electrically conductive ceramic paste. After being dried, the pattern is baked in a heating furnace. Further, the antenna may be formed in an electrically conductive pattern formed on a light-transmissive resin film and be attached onto the glass.

[0034] Functions of the glass antenna according to the embodiment of this invention are now described.

[0035] The glass antenna according to the embodiment of this invention includes the DAB antenna 3 configured to receive a radio wave in a first frequency band (DAB radio broadcast band) and the FM antenna 4 configured to receive a radio wave in a second frequency band (FM radio broadcast band) having approximately half of the frequency of the DAB radio broadcast band. The DAB antenna 3 includes the core-side feeding unit 36 and the earth-side feeding unit 31 to be coupled to a receiver, the core-side element 37 extended from the core-side feeding unit 36, and the earth-side element 32 extended from the earth-side feeding unit 31. The core-side element 37 is formed to have the length approximately equal to the length obtained by multiplying the wavelength at the center frequency in the DAB radio broadcast band by the wavelength shortening rate of the glass, specifically, the length (from 850 mm to 1,150 mm, preferably, from 900 mm to 1,100 mm, more preferably, from 950 mm to 1,100 mm) obtained by multiplying half of the wavelength at the center frequency in the FM radio broadcast band by the wavelength shortening rate of the glass. Therefore, an impedance of the DAB antenna 3 in the FM radio broadcast band is increased to reduce effects on reception performance of the FM antenna 4.

[0036] Further, on the core-side element 37, when the wavelength at the center frequency in the DAB radio broadcast band is λ and the wavelength shortening rate of the glass is α, the second vertical line 37C containing the position corresponding to $\alpha\lambda/4$ from the core-side feeding unit 36 and the fourth vertical line 37G containing the position corresponding to $3\alpha\lambda/4$ are positioned in parallel to each other. Therefore, the currents having the peaks in the same phase flow through the two vertical lines in parallel to each other. As a result, the antenna having a high gain in the vertical polarization can be provided.

[0037] Further, the core-side element 37 includes the first horizontal line 37B coupled to the core-side feeding unit 36 to be extended in the horizontal direction, the second vertical line 37C extended upward from the first horizontal line 37B, the second horizontal line 37D extended from the second vertical line 37C in the horizontal direction, the third vertical line 37E extended upward from the second horizontal line 37D, the third horizontal line 37F extended from the third vertical line 37E in the horizontal direction, and the fourth vertical line 37G extended downward from the third horizontal line 37F. The second vertical line 37C contains the position which is at a distance $\alpha\lambda/4$ from the core-side feeding unit 36 along the core-side element 37 (in other words, the position is reached by tracing the core-side element 37 by the length $\alpha\lambda/4$ from the core-side feeding unit 36), and the fourth vertical line 37G contains the position which is at a distance $3\alpha\lambda/4$ from the core-side feeding unit 36 along the core-side element 37 (in other words, the position is reached by tracing the core-side element 37 by the length $3\alpha\lambda/4$ from the core-side feeding unit 36). The second vertical line 37C is positioned between the fourth vertical line 37G and the core-side feeding unit 36 in the horizontal direction. Therefore, an outer periphery of the DAB antenna 3 formed by the third horizontal line 37F and the fourth vertical line 37G contains the first horizontal line 37B, the second vertical line 37C, and the second horizontal line 37D. Hence, the DAB antenna 3 can be downsized (λ is the wavelength at the center frequency of the DAB radio broadcast band).

[0038] Further, when the wavelength at the center frequency of the DAB radio broadcast band is λ and the wavelength shortening rate of the glass is α, each of the second vertical line 37C and the fourth vertical line 37G has a length ranging from $\alpha\lambda/40$ to $\alpha\lambda/5$ (from 25 mm to 200 mm). Therefore, a sufficient interaction can be caused between the second vertical line 37C and the fourth vertical line 37G. Further, it is preferable that a distance between the second vertical line 37C and the fourth vertical line 37G be a length ranging from $\alpha\lambda/40$ to $\alpha\lambda/5$ (from 25 mm to 200 mm).

[0039] Further, the earth-side element 32 is arranged along the core-side element 37 at a predetermined distance from the core-side element 37. Therefore, by adjusting the length of the earth-side element 32 or the position of arrangement of the earth-side element 32 (interval between the earth-side element 32 and the core-side element 37), the impedance of the DAB antenna 3 can be adjusted.

[0040] Further, even when another antenna (for example, an AM antenna) is arranged in proximity to the DAB antenna 3 on the same glass, the effects on reception performance of the another antenna is small because the earth-side element 32 is small.

[0041] Further, the FM antenna 4 includes the first transverse line 42A extended from the feeding unit in the transverse direction, the first longitudinal line 42B extended downward from the first transverse line 42A, the second transverse line 42C extended from the first longitudinal line 42B in the transverse direction, and the longitudinal line 42D or the longitudinal line 42F extended from the second transverse line 42C in the longitudinal direction. Therefore, the length of the element, which is nec-

essary to receive an FM broadcast wave, can be ensured.

[0042] Further, the main element 42 of the FM antenna 4 is arranged transversally in the middle of the window glass 1 in the vertical direction (at a position away from the body flange 2). Therefore, a high gain can be obtained even in a low frequency band (for example, a medium-wave AM radio broadcast band).

[0043] Further, the FM antenna 4 includes the auxiliary element 43 arranged along the first transverse line 42A. Through adjustment of the length of the auxiliary element 43 or the position of arrangement of the auxiliary element 43 (interval between the auxiliary element 43 and the first transverse line 42A), the impedance of the FM antenna 4 can be adjusted.

[Examples]

[0044] Various examples of this invention are now described below.

<Example 1>

[0045] FIG. 1 is a front view of a glass antenna (as viewed from the inside of the vehicle) arranged on the side window glass 1 of the automobile, for illustrating an antenna pattern of an example 1 of this invention.

[0046] The glass antenna of the example 1 includes the DAB antenna 3 and the FM antenna 4.

[0047] The DAB antenna 3 includes the feeding unit including the pair of the earth-side feeding unit 31 and the core-side feeding unit 36, the earth-side element 32 extended from the earth-side feeding unit 31, and the core-side element 37 extended from the core-side feeding unit 36.

[0048] The core-side element 37 has the length approximately equal to the length obtained by multiplying the wavelength at the center frequency of the reception frequency band by the wavelength shortening rate of the glass, and includes the first vertical line 37A extended upward from the core-side feeding unit 36, the first horizontal line 37B extended leftward from the upper end of the first vertical line 37A, the second vertical line 37C extended upward from the left end of the first horizontal line 37B, the second horizontal line 37D extended rightward from the upper end of the second vertical line 37C, the third vertical line 37E extended upward from the right end of the second horizontal line 37D, the third horizontal line 37F extended leftward from the upper end of the third vertical line 37E, the fourth vertical line 37G extended downward from the left end of the third horizontal line 37F, and the fourth horizontal line 37H extended rightward from the lower end of the fourth vertical line 37G.

[0049] The earth-side element 32 includes the vertical line 32A extended upward from the earth-side feeding unit 31, the horizontal line 32B extended leftward from the upper end of the vertical line 32A, and the vertical line 32C extended upward from the left end of the horizontal line 32B, thereby forming the pattern along the core-side element 37 in proximity thereto.

[0050] The FM antenna 4 includes the feeding unit 41, the main element 42 extended from the feeding unit 41, and the auxiliary element 43 arranged on the upper edge of the antenna so as to be approximately parallel to the main element 42 in proximity thereto. The main element 42 includes the first transverse line 42A that is extended from the feeding unit 41 in the transverse direction and is arranged along the body flange 2, the first longitudinal line 42B extended downward from the left end of the first transverse line 42A, the second transverse line 42C extended rightward from the lower end of the first longitudinal line 42B, the second longitudinal line 42D extended downward from the right end of the second transverse line 42C, and the third transverse line 42E extended leftward from the lower end of the second longitudinal line 42D.

[0051] In the example 1, the main element 42 of the FM antenna 4 is arranged transversally in the middle of the side window glass 1 in the vertical direction (at a position away from the body flange 2). Therefore, a high gain can be obtained even in the low frequency band (for example, middle-wave AM radio broadcast band).

[0052] A length of each of the lines of the core-side element 37 of the DAB antenna 3 of the example 1 is as follows. The first vertical line 37A is 40 mm, the first horizontal line 37B is 200 mm, the second vertical line 37C is 30 mm, the second horizontal line 37D is 200 mm, the third vertical line 37E is 40 mm, the third horizontal line 37F is 230 mm, the fourth vertical line 37G is 150 mm, and the fourth horizontal line 37H is 140 mm in length. A total length of the core-side element 37 is 1,030 mm.

[0053] The wavelength λ at the center frequency (207 MHz) of the DAB Band 3 is about 1,500 mm. When being multiplied by 0.7 as the wavelength shortening rate (α) of the glass, the wavelength λ is about 1,010 mm that is approximately equal to the total length of the core-side element 37. Further, the wavelength λ at the center frequency (about 98 MHz) of the FM radio broadcast band is about 3,070 mm. When being multiplied by 0.7 as the wavelength shortening rate of the glass, the wavelength λ is about 2,150 mm that is approximately equal to twice the total length of the core-side element 37.

[0054] A distance between the second vertical line 37C and the fourth vertical line 37G is 30 mm. The distance between the second vertical line 37C and the fourth vertical line 37G only needs to be determined by a phase difference between the current flowing through the second vertical line 37C and the current flowing through the fourth vertical line 37G. Further, when the length of the second vertical line 37C and the length of the fourth vertical line 37G are increased, a reception gain in the vertical polarization can be improved. It is preferable that each of the length of the second vertical line 37C and the length of the fourth vertical line 37G be from about $\alpha\lambda/40$ to about $\alpha\lambda/5$.

[0055] Further, the distance between the earth-side element 32 and the core-side element 37 is 5 mm. Through

changing of the distance between the earth-side element 32 and the core-side element 37, the impedance of the DAB antenna 3 can be adjusted.

[0056] Further, the length of each of the lines of the main element 42 of the FM antenna 4 is as follows. Specifically, the first transverse line 42A is 780 mm, the first longitudinal line 42B is 250 mm, the second transverse line 42C is 650 mm, the second longitudinal line 42D is 100 mm, and the third transverse line 42E is 100 mm in length.

[0057] The glass antenna of the example 1 can reduce the effects of the DAB antenna 3 on the reception performance of the FM antenna 4. Further, the gain in the vertical polarization of the DAB antenna 3 can be increased.

<Example 2>

[0058] FIG. 3 is a front view of a glass antenna (as viewed from the inside of the vehicle) arranged on the side window glass 1 of the automobile, for illustrating an antenna pattern of an example 2 of this invention.

[0059] The glass antenna of the example 2 differs from that of the example 1 in the shape of the main element 42 of the FM antenna 4. Configurations of the example 2 other than the above are the same as the configurations of the example 1, and therefore are denoted by the same reference symbols so as to omit the description thereof.

[0060] The glass antenna of the example 2 includes the DAB antenna 3 and the FM antenna 4. The DAB antenna 3 includes the feeding unit including the pair of the earth-side feeding unit 31 and the core-side feeding unit 36, the earth-side element 32 extended from the earth-side feeding unit 31, and the core-side element 37 extended from the core-side feeding unit 36.

[0061] The FM antenna 4 includes the feeding unit 41, the main element 42 extended from the feeding unit 41, and the auxiliary element 43 arranged on the upper edge of the antenna so as to be approximately parallel to the main element 42 in proximity thereto. The main element 42 includes the first transverse line 42A that is extended from the feeding unit 41 in the transverse direction and is arranged along the body flange 2, the first longitudinal line 42B extended downward from the left end of the first transverse line 42A, the second transverse line 42C extended rightward from the lower end of the first longitudinal line 42B, and the third longitudinal line 42F extended upward from the right end of the second transverse line 42C .

[0062] A length of each of the lines of the main element 42 of the FM antenna 4 of the example 2 is as follows. The first transverse line 42A is 780 mm, the first longitudinal line 42B is 350 mm, the second transverse line 42C is 700 mm, and the third longitudinal line 42F is 80 mm.

[0063] In the glass antenna of the example 2, the lines of the FM antenna 4 are arranged at positions close to the body flange 2. Therefore, sensitivity to the FM radio broadcast band can be improved.

<Example 3>

[0064] FIG. 4 is a front view of a glass antenna (as viewed from the inside of the vehicle) arranged on the side window glass 1 of the automobile, for illustrating an antenna pattern of an example 3 of this invention.

[0065] The glass antenna of the example 3 differs from that of the example 1 in the configuration of the DAB antenna 3. Configurations of the example 3 other than the above are the same as the configurations of the example 1, and therefore are denoted by the same reference symbols so as to omit the description thereof.

[0066] The glass antenna of the example 3 includes the DAB antenna 3 and the FM antenna 4. The DAB antenna 3 includes the feeding unit including the pair of the earth-side feeding unit 31 and the core-side feeding unit 36, the earth-side element 32 extended from the earth-side feeding unit 31, and the core-side element 37 extended from the core-side feeding unit 36.

[0067] The core-side element 37 has the length approximately equal to the length obtained by multiplying the wavelength at the center frequency of the reception frequency band by the wavelength shortening rate of the glass, and includes the first horizontal line 37B extended leftward from the core-side feeding unit 36, the second vertical line 37C extended upward from the left end of the first horizontal line 37B, the second horizontal line 37D extended rightward from the upper end of the second vertical line 37C, the third vertical line 37E extended upward from the right end of the second horizontal line 37D, the third horizontal line 37F extended leftward from the upper end of the third vertical line 37E, the fourth vertical line 37G extended downward from the left end of the third horizontal line 37F, and the fourth horizontal line 37H extended rightward from the lower end of the fourth vertical line 37G.

[0068] The earth-side element 32 includes the horizontal line 32B extended leftward from the earth-side feeding unit 31 and the vertical line 32C extended upward from the left end of the horizontal line 32B, thereby forming the pattern along the core-side element 37 in proximity thereto.

[0069] The FM antenna 4 includes the feeding unit 41, the main element 42 extended from the feeding unit 41, and the auxiliary element 43 arranged on the upper edge of the antenna so as to be approximately parallel to the main element 42 in proximity thereto. The configuration of the FM antenna 4 is the same as the configuration of the example 1.

[0070] A length of each of the lines of the core-side element 37 of the DAB antenna 3 of the example 3 is as follows. The first horizontal line 37B is 180 mm, the second vertical line 37C is 80 mm, the second horizontal line 37D is 180 mm, the third vertical line 37E is 30 mm, the third horizontal line 37F is 270 mm, the fourth vertical line 37G is 170 mm, and the fourth horizontal line 37H is 180 mm in length. A total length of the core-side element 37 is 1,090 mm.

[0071] In the glass antenna of the example 3, an area occupied by the DAB antenna 3 is increased. Therefore, the sensitivity to the DAB radio broadcast band can be improved.

<Example 4>

[0072] FIG. 5 is a front view of a glass antenna (as viewed from the inside of the vehicle) arranged on the side window glass 1 of the automobile, for illustrating an antenna pattern of an example 4 of this invention.

[0073] The glass antenna of the example 4 differs from that of the example 1 in the configuration of the DAB antenna 3. Configurations of the example 4 other than the above are the same as the configurations of the example 1, and therefore are denoted by the same reference symbols so as to omit the description thereof.

[0074] The glass antenna of the example 4 includes the DAB antenna 3 and the FM antenna 4.

[0075] The DAB antenna 3 includes the feeding unit including the pair of the earth-side feeding unit 31 and the core-side feeding unit 36, the earth-side element 32 extended from the earth-side feeding unit 31, and the core-side element 37 extended from the core-side feeding unit 36. In the example 4, the earth-side feeding unit 31 and the core-side feeding unit 36 of the DAB antenna 3 are arranged not in the vicinity of the body flange 2 of the window glass 1 but at positions on the inner side of the window glass 1, which are away from the body flange 2.

[0076] The core-side element 37 has the length approximately equal to the length obtained by multiplying the wavelength at the center frequency of the reception frequency band by the wavelength shortening rate of the glass, and includes the first vertical line 37A extended upward from the core-side feeding unit 36, the first horizontal line 37B extended rightward from the upper end of the first vertical line 37A, the second vertical line 37C extended upward from the right end of the first horizontal line 37B, the second horizontal line 37D extended leftward from the upper end of the second vertical line 37C, the third vertical line 37E extended upward from the left end of the second horizontal line 37D, the third horizontal line 37F extended leftward from the upper end of the third vertical line 37E, the fourth vertical line 37G extended downward from the left end of the third horizontal line 37F, and the fourth horizontal line 37H extended rightward from the lower end of the fourth vertical line 37G.

[0077] The earth-side element 32 includes the vertical line 32A extended upward from the earth-side feeding unit 31, the horizontal line 32B extended rightward from the upper end of the vertical line 32A, and the vertical line 32C extended upward from the right end of the horizontal line 32B, thereby forming the pattern along the core-side element 37 in proximity thereto.

[0078] The FM antenna 4 includes the feeding unit 41, the main element 42 extended from the feeding unit 41, and the auxiliary element 43 arranged on the upper edge of the antenna so as to be approximately parallel to the main element 42 in proximity thereto. The configuration of the FM antenna 4 is the same as the configuration of the example 1.

[0079] A length of each of the lines of the core-side element 37 of the DAB antenna 3 of the example 4 is as follows. The first vertical line 37A is 40 mm, the first horizontal line 37B is 200 mm, the second vertical line 37C is 30 mm, the second horizontal line 37D is 240 mm, the third vertical line 37E is 40 mm, the third horizontal line 37F is 180 mm, the fourth vertical line 37G is 150 mm, and the fourth horizontal line 37H is 130 mm in length. A total length of the core-side element 37 is 1,010 mm.

[0080] In the glass antenna of the example 4, an area occupied by the DAB antenna 3 is increased. Therefore, the sensitivity to the DAB radio broadcast band can be improved.

<Example 5>

[0081] FIG. 6 is a front view of a glass antenna (as viewed from the inside of the vehicle) arranged on the side window glass 1 of the automobile, for illustrating an antenna pattern of an example 5 of this invention.

[0082] The glass antenna of the example 5 differs from that of the example 1 in the configuration of the DAB antenna 3. Configurations of the example 5 other than the above are the same as the configurations of the example 1, and therefore are denoted by the same reference symbols so as to omit the description thereof.

[0083] The glass antenna of the example 5 includes the DAB antenna 3 and the FM antenna 4.

[0084] The DAB antenna 3 includes the feeding unit including the pair of the earth-side feeding unit 31 and the core-side feeding unit 36, the earth-side element 32 extended from the earth-side feeding unit 31, and the core-side element 37 extended from the core-side feeding unit 36. In the example 5, the earth-side feeding unit 31 and the core-side feeding unit 36 of the DAB antenna 3 are arranged not in the vicinity of the body flange 2 of the window glass 1 but at positions on the inner side of the window glass 1, which are away from the body flange 2.

[0085] The core-side element 37 has the length approximately equal to the length obtained by multiplying the wavelength at the center frequency of the reception frequency band by the wavelength shortening rate of the glass, and includes the first vertical line 37A extended upward from the core-side feeding unit 36, the first horizontal line 37B extended rightward from the upper end of the first vertical line 37A, the second vertical line 37C extended upward from the right end of the first horizontal line 37B, the second horizontal line 37D extended leftward from the upper end of the second vertical line 37C, the fourth vertical line 37G extended downward from the left end of the second horizontal line 37D, and the fourth horizontal line 37H extended rightward from the lower end of the fourth vertical line 37G.

[0086] The earth-side element 32 includes the vertical line 32A extended upward from the earth-side feeding unit 31, the horizontal line 32B extended rightward from the upper end of the vertical line 32A, and the vertical line 32C extended upward from the right end of the horizontal line 32B, thereby forming the pattern along the core-side element 37 in proximity thereto.

[0087] The FM antenna 4 includes the feeding unit 41, the main element 42 extended from the feeding unit 41, and the auxiliary element 43 arranged on the upper edge of the antenna so as to be approximately parallel to the main element 42 in proximity thereto. The configuration of the FM antenna 4 is the same as the configuration of the example 1.

[0088] A length of each of the lines of the core-side element 37 of the DAB antenna 3 of the example 5 is as follows. The first vertical line 37A is 40 mm, the first horizontal line 37B is 200 mm, the second vertical line 37C is 70 mm, the second horizontal line 37D is 420 mm, the fourth vertical line 37G is 150 mm, and the fourth horizontal line 37H is 130 mm in length. A total length of the core-side element 37 is 1,010 mm.

[0089] In the glass antenna of the example 5, an area occupied by the DAB antenna 3 is increased. Therefore, the sensitivity to the DAB radio broadcast band can be improved.

[0090] While the present invention has been described in detail and pictorially in the accompanying drawings, the present invention is not limited to such detail but covers various obvious modifications and equivalent arrangements, which fall within the purview of the appended claims.

[0091] The present application claims priority from Japanese patent application JP 2015-253527 filed on December 25, 2015, the content of which is hereby incorporated by reference into this application.

Claims

1. A glass antenna to be arranged on a window glass of a vehicle, comprising:

a first antenna (3) configured to receive a radio wave in a first frequency band; and
a second antenna (4) configured to receive a radio wave in a second frequency band having a frequency that is approximately half of a frequency of the first frequency band,
the first antenna (3) including a core-side feeding unit (36) and an earth-side feeding unit (31) to be coupled to a receiver, a core-side element (37) extended from the core-side feeding unit, and an earth-side element (32) extended from the earth-side feeding unit,
the core-side element (37) having a length approximately equal to a length obtained by multiplying a wavelength at a center frequency of the first frequency band by a wavelength shortening rate of glass.

2. The glass antenna according to claim 1,
wherein the core-side element (37) is formed by being bent,
wherein, on the core-side element (37) includes a first line (37C) containing a first position which is at a distance $\alpha\lambda/4$ from the core-side feeding unit along the core-side element and a second line (37G) containing a second position which is at a distance $3\alpha\lambda/4$ from the core-side feeding unit along the core-side element when the wavelength at the center frequency of the first frequency band is λ and the wavelength shortening rate of the glass is α, and
wherein the first line (37C) and the second line (37G) are positioned in parallel to each other.

3. The glass antenna according to claim 2,
wherein the core-side element (37) includes a first horizontal line (37B) coupled to the core-side feeding unit to be extended in a horizontal direction, a second vertical line (37C) extended upward from the first horizontal line, a second horizontal line (37D) extended from the second vertical line in the horizontal direction, a third vertical line (37E) extended upward from the second horizontal line, a third horizontal line (37F) extended from the third vertical line in the horizontal direction, and a fourth vertical line (37G) extended downward from the third horizontal line,
wherein the second vertical line (37C) contains the first position,
wherein the fourth vertical line (37G) contains the second position, and
wherein the second vertical line (37C) is positioned between the fourth vertical line and the core-side feeding unit in the horizontal direction.

4. The glass antenna according to claim 3, wherein each of the second vertical line (37C) and the fourth vertical line (37G) has a length ranging from $\alpha\lambda/40$ to $\alpha\lambda/5$.

5. The glass antenna according to any one of claims 1 to 4, wherein the earth-side element (32) is arranged along the core-side element at a predetermined distance from the core-side element (37).

6. The glass antenna according to any one of claims 1 to 5,
wherein the first frequency band is a DAB radio broadcast band, and
wherein the second frequency band is an FM radio broadcast band.

7. The glass antenna according to any one of claims 1 to 6, wherein the second antenna (4) includes a first transverse line (42A) extended from a feeding unit

(41) in a transverse direction, a first longitudinal line (42B) extended downward from the first transverse line, a second transverse line (42C) extended from the first longitudinal line in the transverse direction, and a second longitudinal line (42D) extended from the second transverse line in a longitudinal direction.

8. A window glass (1) comprising the glass antenna of any one of claims 1 to 7 being arranged on the window glass.

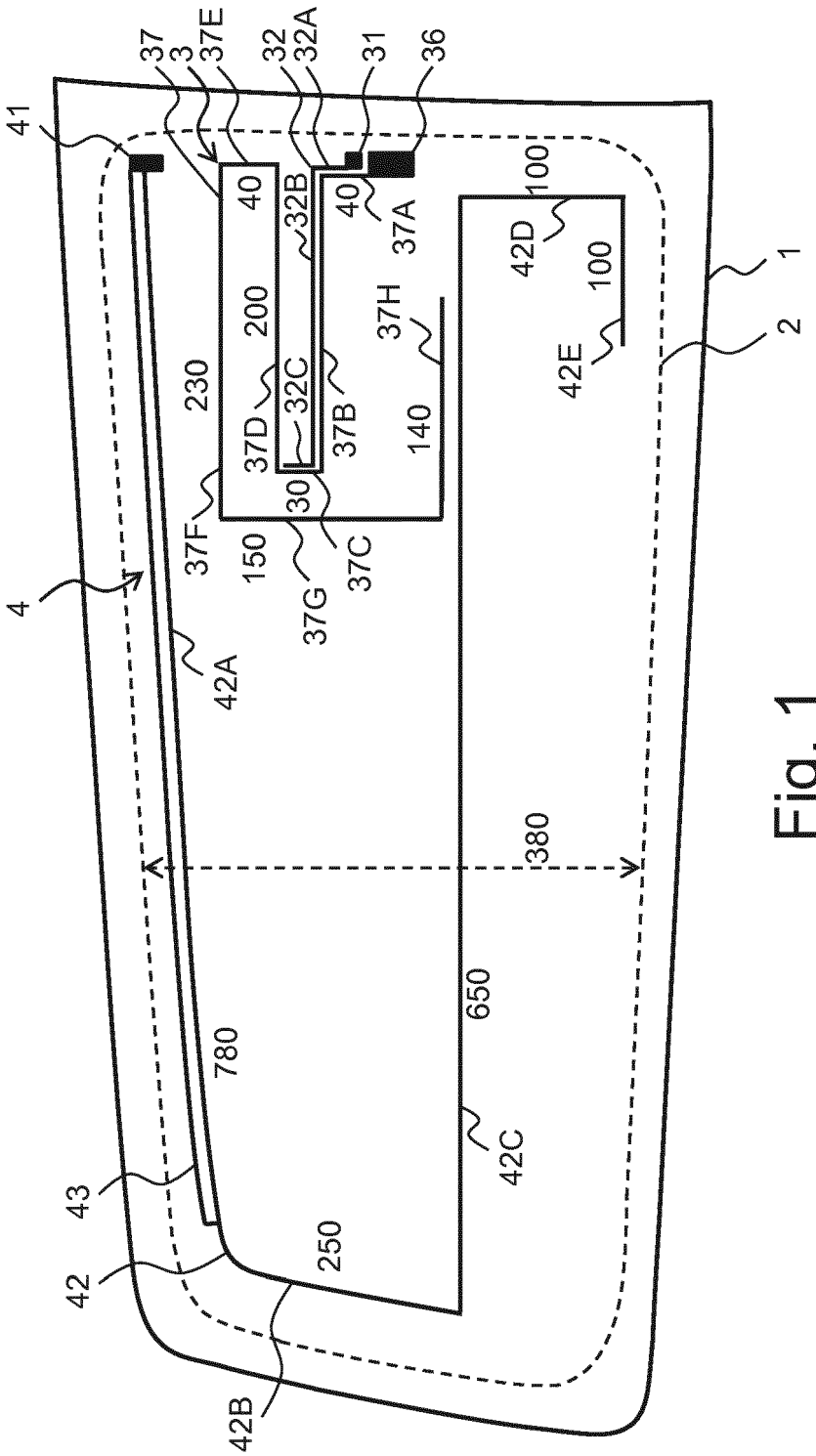
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Fig. 1

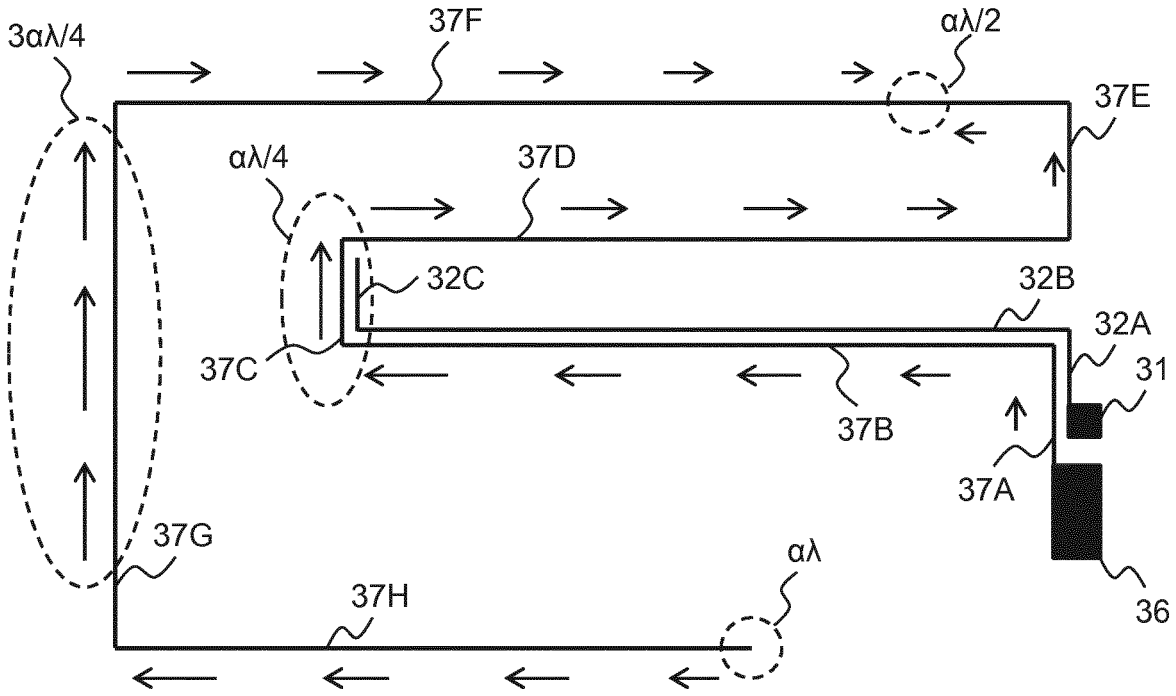

Fig. 2

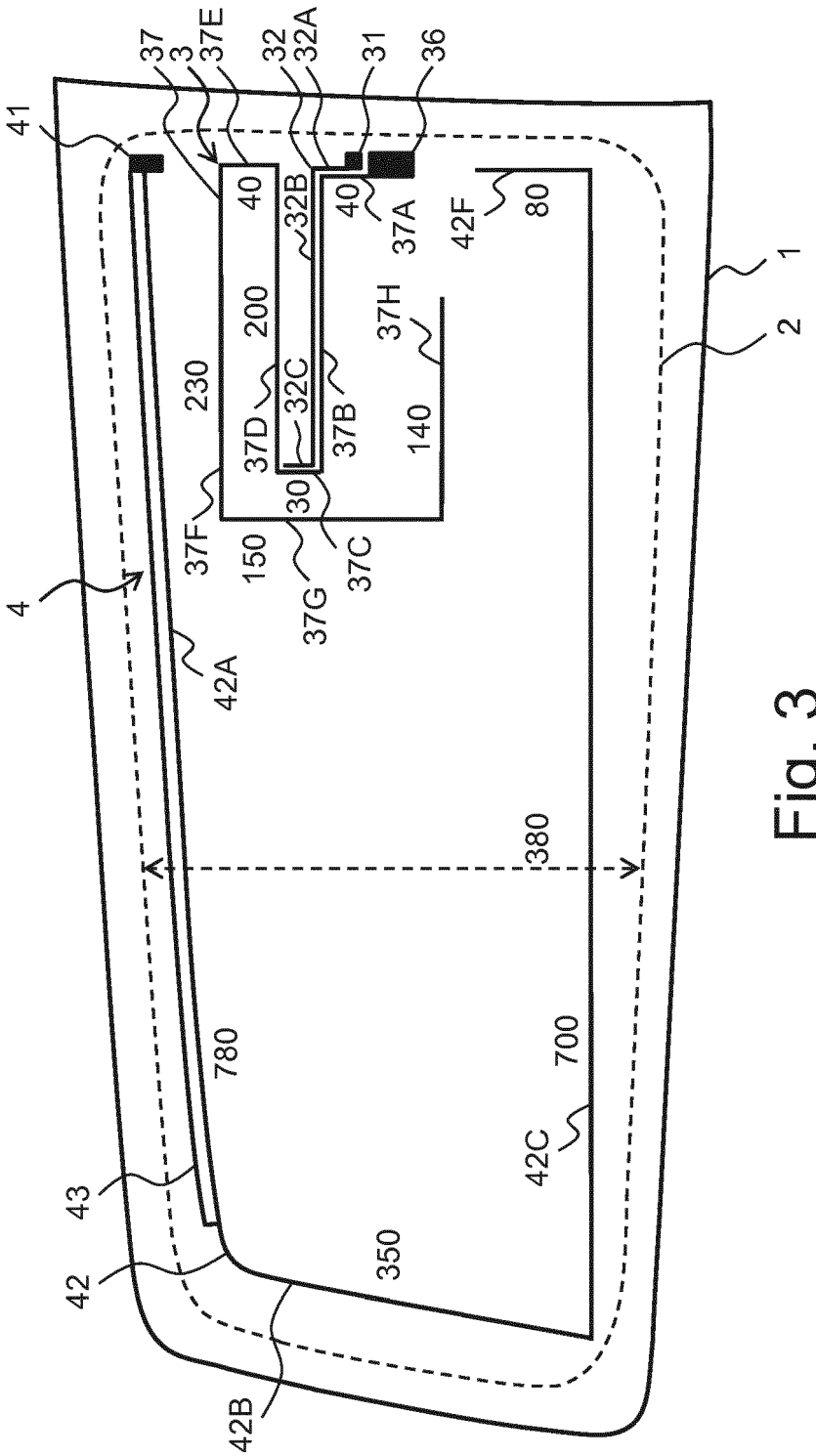
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Fig. 3

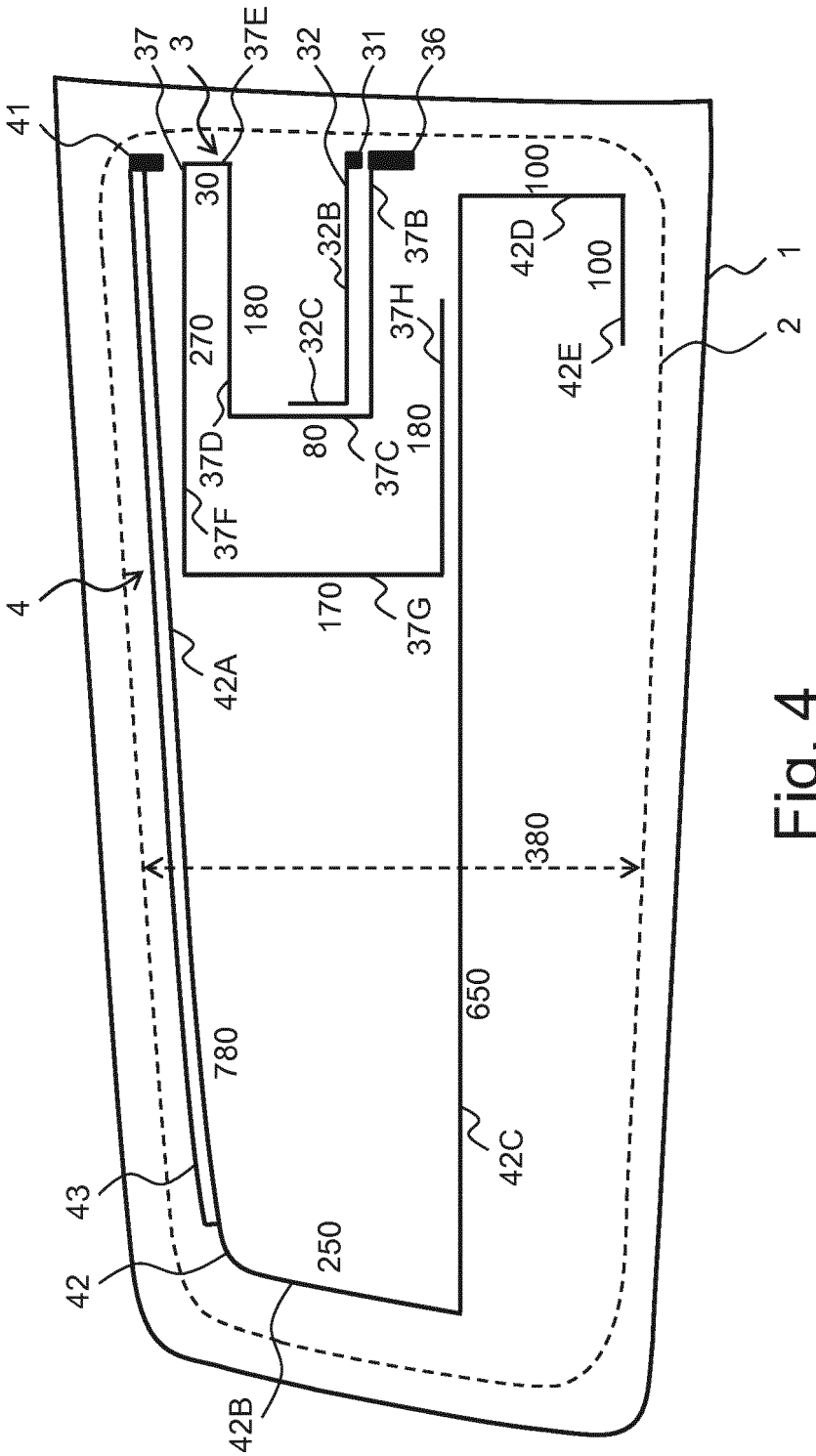
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Fig. 4

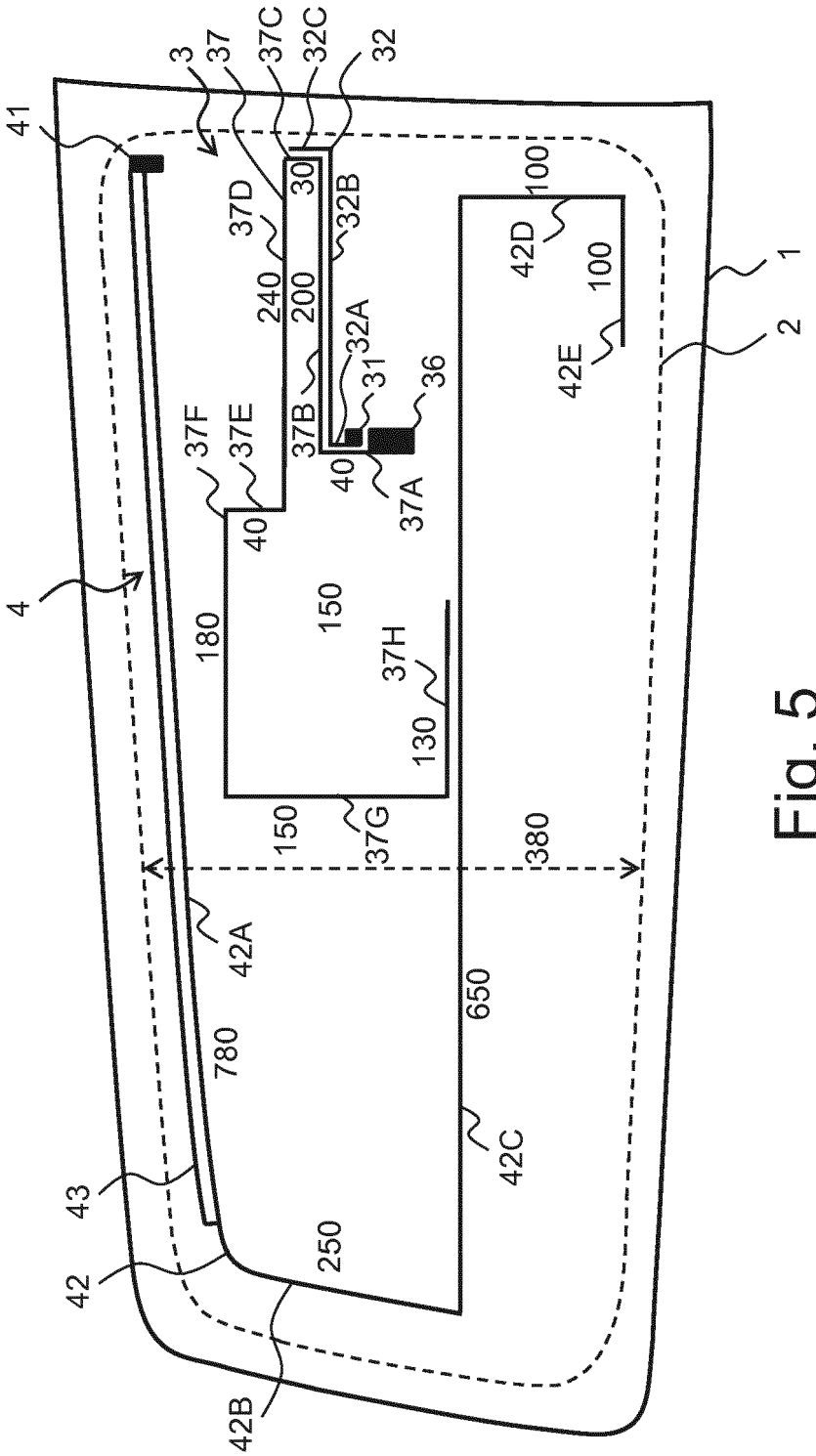
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Fig. 5

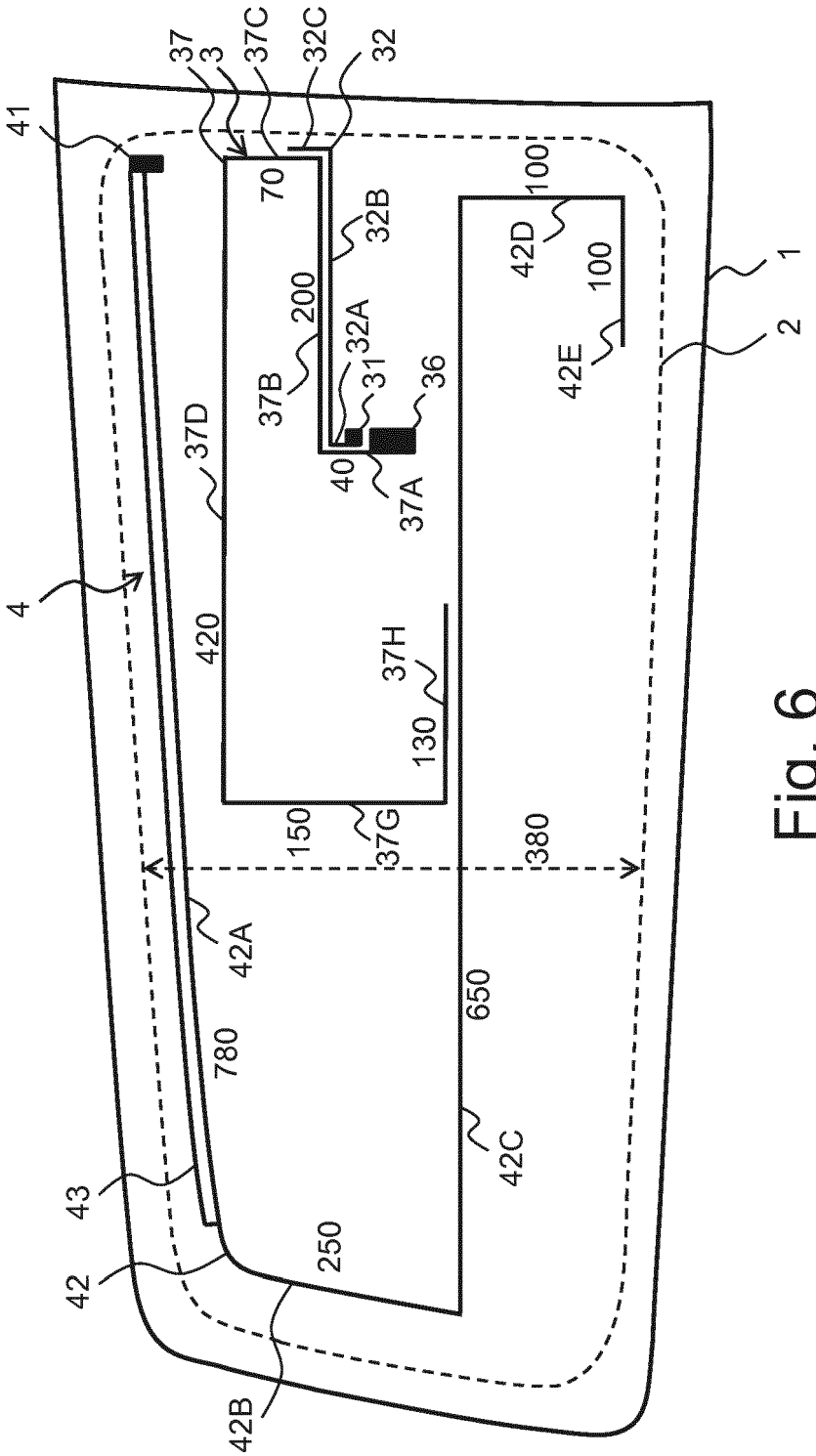
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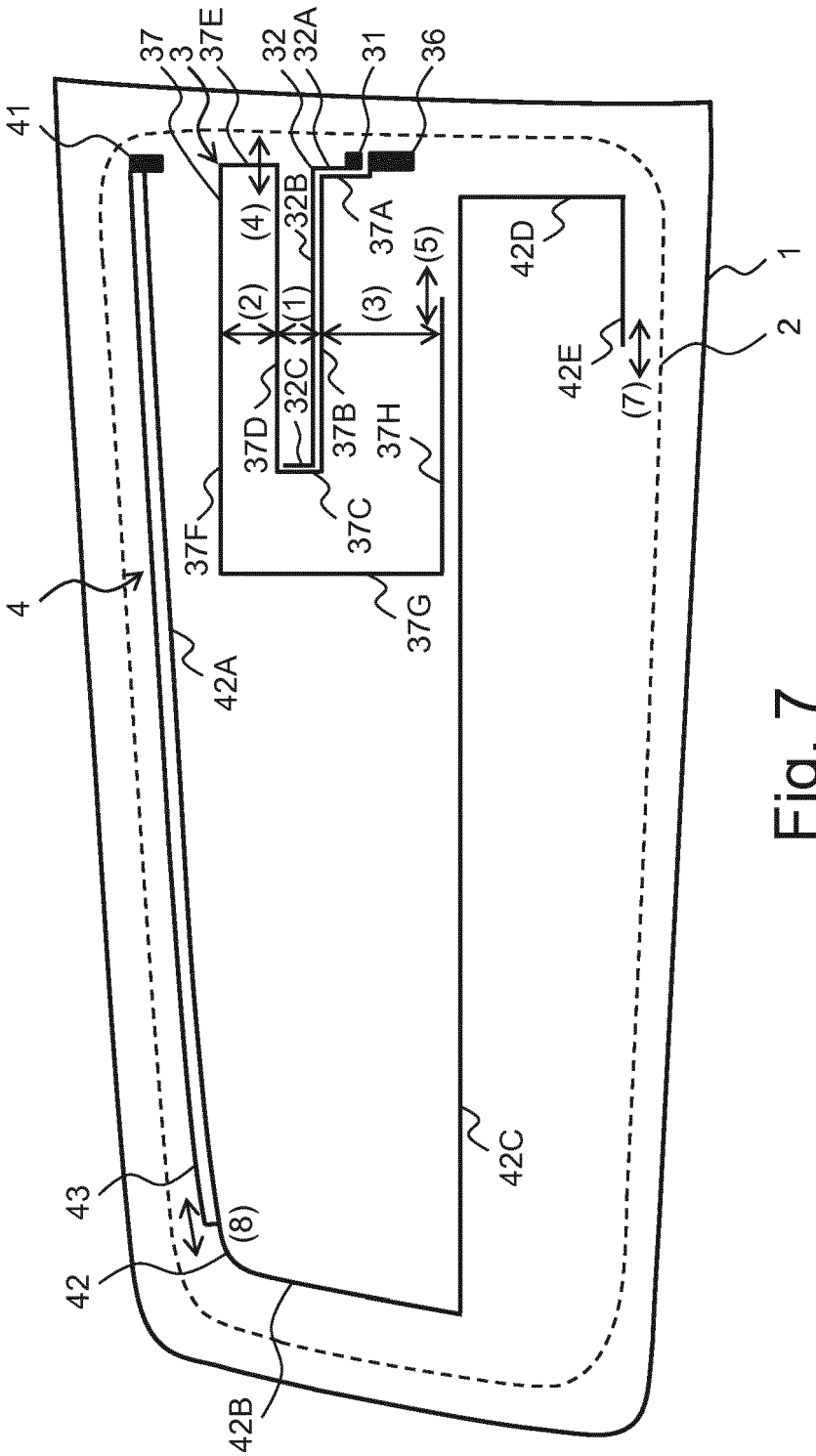
Fig. 6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42E
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32C
37D
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37G
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42C
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(8)
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42B

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 16 20 3865

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y A	EP 2 421 090 A1 (ASAHI GLASS CO LTD [JP]) 22 February 2012 (2012-02-22) * abstract * * figure 1 * * paragraph [0013] - paragraph [0014] * * paragraph [0036] * * paragraph [0079] - paragraph [0080] *	1,2,5-8 3,4	INV. H01Q1/12 H01Q21/28 H01Q9/42
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H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 May 2017	Yvonnet, Yannick

CATEGORY OF CITED DOCUMENTS

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08-05-2017

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REFERENCES CITED IN THE DESCRIPTION

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