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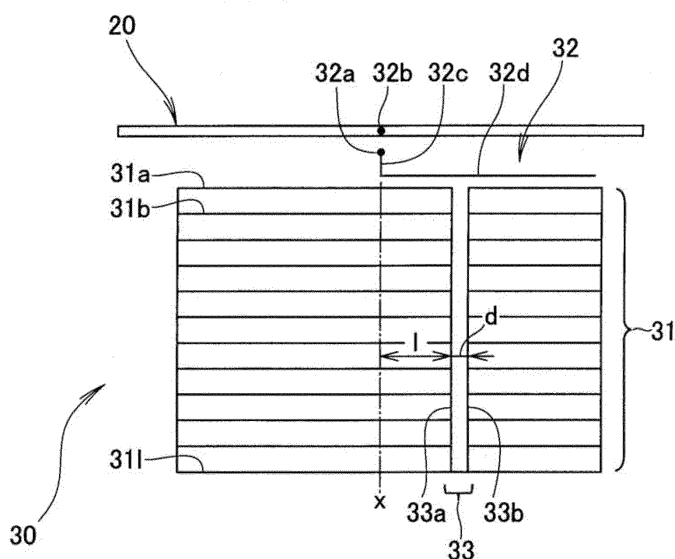
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(54) **Vehicular glass antenna**

(57) A vehicular glass antenna that allows disposition of a DAB antenna having an AM antenna is disclosed. The glass antenna (30) includes a first antenna (31) having a plurality of horizontal elements (31 a to 31 l) and vertical elements (33a, 33b), and a second antenna (32) capacitatively coupled with a topmost one (31 a) of the horizontal elements of the first antenna and arranged in an upper part of a region in which the first antenna is mounted. The first antenna includes the topmost horizontal element (31 a), a first vertical element (33a) held

in contact with the topmost horizontal element (31 a), and a second vertical element (33b). The first vertical element (33a) and the second vertical element (33b) are disposed so as to be substantially in parallel across a gap (d) for which the reception sensitivity of each of the first antenna (31) and the second antenna (32) is set to be in an optimal range, and a slit (33) having a predetermined height is formed by the gap (d). An electrical connection is established at a bottommost end of each of the first vertical element (33a) and the second vertical element (33b).

FIG.2



Description

[0001] The present invention relates to a vehicular glass antenna in which a digital audio broadcasting (DAB) antenna having good reception characteristics is installed.

[0002] Glass antennas in which a DAB antenna is installed are known from, e.g., Japanese Patent Application Laid-Open Publication Nos. 2010-081567 (JP 2010-081567 A), 2010-124444 (JP 2010-124444 A) and 2010-154504 (JP 2010-154504 A).

[0003] In JP 2010-081567 A, an L-shaped DAB antenna is positioned alongside an AM antenna in a side-by-side arrangement with the AM antenna.

[0004] JP 2010-124444 A and JP 2010-154504 A disclose a glass antenna in which a DAB antenna is incorporated within an AM antenna.

[0005] However, according to the antennas disclosed in JP 2010-081567 A, JP 2010-124444 A and JP 2010-154504 A, the area on which the AM antenna is arranged is limited by the presence of the DAB antenna, and the reception sensitivity of the AM antenna is therefore reduced. In other words, the reception sensitivity of the AM antenna increases in commensurate fashion with the increased arrangement surface area of the antenna, but arranging a DAB antenna causes reception sensitivity to be reduced by an amount commensurate with the reduced arrangement surface area of the AM antenna.

[0006] An object of the present invention is to provide a vehicular glass antenna in which a DAB antenna or the like provided with good receiving characteristics has been arranged without a reduction in the reception sensitivity of the AM antenna.

[0007] According to an aspect of the present invention, there is provided a vehicular glass antenna, which comprises: a first antenna having a plurality of horizontal elements and vertical elements, and a second antenna capacitatively coupled with a topmost one of the horizontal elements of the first antenna, the second antenna being arranged in an upper part of a region in which the first antenna is mounted, wherein the first antenna includes the topmost horizontal element, a first vertical element in held contact with the horizontal element, and a second vertical element, the first vertical element and the second vertical element are disposed so as to be substantially in parallel across a gap for which a reception sensitivity of each of the first antenna and the second antenna is set to be in an optimal range, and a slit having a predetermined height is formed by the gap, and an electrical connection is established at a bottommost end of each of the first vertical element and the second vertical element.

[0008] Consequently, the slit thus formed in the first antenna capacitatively couples with the second antenna, whereby a portion of the first antenna can be made to operate as the second antenna. Accordingly, the presence of the second antenna does not limit the arrangement surface area of the first antenna, and the second antenna can be arranged without a reduction in the sensitivity of the first antenna.

[0009] Preferably, the gap is selected to lie within a range of 2 to 20 mm. A predetermined gap is prescribed by a range in which the receiving sensitivities of the first antenna and the second antenna are both optimal. It was found by evaluation carried out by the inventor that optimal reception sensitivity can be obtained in a range of 2 to 20 (mm) for the first antenna and the second antenna, and that adjustments can be made in this range.

[0010] Desirably, the predetermined height is a size adjusted so as to be substantially $1/4\lambda$ or less. The inventor has evaluated this to be, e.g., 254 (mm).

[0011] In a preferred form, the first vertical element for forming the slit is arranged at an interval of 0 to 100 mm with reference to a virtual line extending vertically from a power feed terminal of the second antenna arranged on the upper side of the region in which the first antenna is mounted. In an evaluation carried out by the inventor, it was found that arranging the first vertical element at an interval of 0 to 100 (mm) allows the reception sensitivity of the second antenna to be the same as if the first antenna were not present.

[0012] In another preferred form, the first vertical element for forming the slit is arranged at an interval of 0 to 60 mm with reference to a virtual line extending vertically from a power feed terminal of the second antenna. In an evaluation carried out by the inventor, it was found that arranging the first vertical element at an interval of 0 to 60 (mm) allows the reception sensitivity of the second antenna to be at least the same as if the first antenna were not present.

[0013] A preferred embodiment of the present invention will be described in detail below with reference to the accompanying drawings, in which:

Fig. 1 is a top plan view illustrating a vehicle in which a vehicular glass antenna according to the present embodiment is mounted;

Fig. 2 illustrates the vehicular glass antenna arrangement according to the embodiment shown in Fig. 1;

Fig. 3 is a view illustrating the conditions for simulating the glass antenna of Fig. 2;

Figs. 4A and 4B are views showing the antenna pattern of a comparative example used for performance evaluation by simulation of the vehicular glass antenna according to the present embodiment;

Fig. 5 is a graph showing a comparison with the performance evaluation of the first comparative example shown in Fig. 4A;

Figs. 6A and 6B are graphs showing the reception sensitivity of the vehicular glass antenna according to the present embodiment in comparison with comparative examples 1 and 2;

Fig. 7 is a graph showing the results of the performance evaluation by simulation of the vehicular glass antenna according to the present embodiment; and

Fig. 8 is a view showing an example of the dimensions of each element constituting the vehicular glass antenna according to the present embodiment.

[0014] As shown in Fig. 1, the vehicular glass antenna 30 according to the present embodiment is mounted on the rear glass 15 of a vehicle 10, and includes an AM antenna 31 (first antenna) and a DAB antenna 32 (second antenna). Reference numeral 34 is a defogger.

[0015] The vehicle 10 comprises a front glass 13 provided between left and right front pillars 12L, 12R of a vehicle body 11, a rear glass 15 provided between left and right rear pillars 14L, 14R, left and right front door glass 17L, 17R elevatably mounted in left and right front doors 16L, 16R, and left and right rear door glass 19L, 19R elevatably mounted in left and right rear doors 18L, 18R. Reference numeral 20 is a roof.

[0016] The glass antenna 30 for a vehicle shown in the present embodiment is an antenna designed for receiving: band III, which is 174 to 240 MHz in DAB; two different frequency bands in the L-band of 1452 to 1492 MHz; and AM band radio waves.

[0017] With reference to Fig. 2, the glass antenna 30 for a vehicle according to the present embodiment includes an AM antenna 31 (first antenna) and a DAB antenna 32 (second antenna).

[0018] The DAB antenna 32 is composed of a power feed terminal 32a (hot terminal) arranged above the region in which the AM antenna 31 is mounted, a single vertical element 32c extending from the power feed terminal 32a as a starting end toward the AM antenna 31, and a single horizontal element 32d extending substantially parallel to twelve horizontal elements 31 a to 31i constituting the AM antenna 31 from the other end of the vertical element 32c. As described later, the DAB antenna 32 is configured so as to be capacitatively coupled to the horizontal element 31 a positioned in the topmost part of the AM antenna 31.

[0019] The AM antenna 31 has, among the plurality of horizontal elements 31 a to 31i constituting the AM antenna 31, a horizontal element 31 a positioned in the topmost part, a first vertical element 33a in contact with the horizontal element 31 a, and a second vertical element 33b. The first vertical element 33a and the second vertical element 33b are disposed substantially in parallel having a gap "d" for which the receiving sensitivities of the AM antenna 31 and the DAB antenna 32 are both prescribed to be in an optimal range, and a slit 33 having a fixed length is formed by this gap "d." The lowermost ends of the first vertical element 33a and the second vertical element 33b are electrically connected. The power feed terminal 32b (ground terminal) of the DAB antenna 32 is connected to the roof 20.

[0020] In accordance with the configuration described above, the slit 33 formed in the AM antenna 31 capacitatively couples with the DAB antenna 32, and can be made to operate as a DAB antenna 32 including the slit 33. The DAB antenna 32 can thus be designed without a reduction in the sensitivity of the AM antenna 31 because the mounting surface area of the AM antenna 31 is not required to be reduced for the DAB antenna 32.

[0021] The basis for the above is described below. The inventor carried out a simulation using a frequency of 174 to 240 MHz, which is the receiving range of the DAB antenna 32. The slope angle θ of the rear glass 15 was set to 30 degrees as a simulation condition, as shown in Fig. 3 with a portion of the vehicle as the right-side surface. The ground terminal of the antenna is connected to the roof 20, and the "y" direction of the roof 20 is infinite.

[0022] A glass antenna in which only a DAB antenna 32 without an AM antenna is mounted, as shown in Fig. 4A; and a glass antenna in which a DAB antenna 32 that includes an AM antenna 31 is mounted, as shown in Fig. 4B, were installed on the glass surface of the vehicle 10 as comparative example 1 and comparative example 2, respectively. The directivity and sensitivity of vertically polarized waves of an xy plane (Fig. 3) were obtained for each frequency at intervals of 3 MHz, and the average sensitivity at all frequencies was calculated. The roof 20 is infinite (∞), but is depicted as being finite in Figs. 4A and 4B in order to show the antenna structure.

[0023] The results of the simulation carried out under the conditions described above are summarized in Table 1 below.

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Table 1

Average sensitivity (dBd) ^c	
Without AM	With AM
-13.7	-21.1

[0024] According to Table 1, the average sensitivity was -13.7 (dBd) for the case of comparative example 1 in which the AM antenna 31 was not present; and the average sensitivity was -21.1 (dBd) for the case of comparative example 2 in which the AM antenna 31 was present.

[0025] In comparative example 1, the antenna length is adjusted so that the average sensitivity of the DAB antenna 32 is maximum without the presence of an AM antenna. Therefore, the ideal sensitivity is obtained because an AM antenna is not present.

[0026] In comparative example 2, the DAB antenna 32 is bent in an L-shape in order to avoid penetrating the mounting region of the AM antenna 31, and the average sensitivity is less than the comparative example 1. This is due to the fact that an antenna element ideal for vertically polarized waves cannot be formed in the vertical direction.

[0027] Next, in the glass antenna 30 for a vehicle of the embodiment shown in Fig. 2, the relationship between the position of the slit 33 and the average sensitivity was simulated, and the results are summarized in Table 2 below and in the sensitivity characteristics graph of Fig. 5 in which the slit position "l" is plotted on the horizontal axis and the dipole ratio (average sensitivity) is plotted on the vertical axis. As used herein, the term "slit position" refers to the distance from the power feed point (hot terminal 32a) of the DAB antenna 32 to the first vertical element 33a of the AM antenna 31 with reference to a vertically extending virtual line "x."

Table 2

Average sensitivity (dBd)		
Position (mm)	Embodiment	Comparative example1
0	-11.6	-13.7
20	-11.6	-13.7
40	-11.6	-13.7
60	-11.7	-13.7
80	-11.9	-13.7
100	-12.3	-13.7
120	-12.9	-13.7
140	-14.4	-13.7
160	-15.4	-13.7

[0028] According to the average sensitivity shown in Fig. 5 or in Table 2, the range that can be used as the slit position "l" where the average sensitivity is equal to or greater than that of comparative example 1 is 0 to 130 (mm) in the present embodiment, but the range is more preferably 0 to 100 (mm), and is most preferably 0 to 60 (mm). For example, when the slit position "l" is 40 (mm), the average sensitivity is -11.6 (dBd) in the embodiment in comparison with -13.7 (dBd) in comparative example 1. Thus, providing the slit 33 to a suitable position makes it possible to achieve, despite the presence of the AM antenna 31, a sensitivity that is equal to or greater than that of comparative example 1 shown in Fig. 4A in which an AM antenna is not present. This is because the slit 33 capacitively couples with the DAB antenna 32 to thereby operate in the same manner as an ideal element in the vertical direction for the DAB antenna 32 overall.

[0029] The same effect can be obtained by providing, in place of the slit 33, a vertical element that traverses from the horizontal element 31 a positioned in the topmost part of the AM antenna 31 to the horizontal element 31l positioned in the bottommost part. However, in the case of such a vertical element, it is known from experience that FM sensitivity may be reduced when, e.g., the AM antenna 31 is used in a shared fashion as an FM antenna, or even when separate elements are used and the two are capacitively coupled, and such configurations are not preferred due to the difficulty in designing the FM antenna and the DAB antenna 32.

[0030] Next, the glass antenna 30 of comparative examples 1 and 2, and the embodiment described above were mounted in the rear glass 15 of a vehicle, and the results of measuring actual performance in an anechoic chamber is

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shown together with the simulation results in Figs. 6A and 6B, and Tables 3 and 4.

Table 3

(dBd)			
Frequency (MHz)	Comp. Example 1	Comp. Example 2	Present Embodiment
174	-14.4	-13.8	-13.4
177	-14.1	-13.8	-13.1
180	-13.7	-13.1	-12.8
183	-13.4	-12.6	-12.5
186	-13.2	-11.9	-12.3
189	-13.1	-12.5	-12.1
192	-12.9	-15.8	-12.0
195	-12.9	-18.6	-11.9
198	-12.9	-20.0	-11.8
201	-12.9	-25.1	-11.8
204	-13.0	-23.2	-11.7
207	-13.1	-24.4	-11.6
210	-13.2	-27.8	-11.5
213	-13.4	-27.4	-11.4
216	-13.5	-28.1	-11.3
219	-13.7	-29.1	-11.2
222	-13.9	-26.1	-11.0
225	-14.0	-25.5	-10.9
228	-14.2	-24.4	-10.7
231	-14.4	-23.9	-10.6
234	-14.6	-23.3	-10.5
237	-14.7	-22.9	-10.5
240	-14.9	-22.8	-10.7
Average sensitivity	-13.7	-21.1	-11.6

Table 4

(dBd)			
Frequency (MHz)	Comp. Example 1	Comp. Example 2	Present Embodiment
174	-14.7	-15.2	-12.5
177	-14.5	-14.9	-10.9
180	-14.7	-15.5	-12.4
183	-13.5	-15.3	-13.6
186	-13.2	-14.0	-12.1
189	-12.8	-12.0	-11.5
192	-12.5	-12.7	-10.9

(continued)

(dBd)			
Frequency (MHz)	Comp. Example 1	Comp. Example 2	Present Embodiment
195	-12.5	-16.8	-11.4
198	-14.3	-18.4	-13.0
201	-11.5	-21.3	-10.1
204	-11.0	-18.6	-10.6
207	-11.1	-18.1	-11.1
210	-11.2	-18.0	-12.5
213	-11.0	-17.6	-13.5
216	-10.5	-16.6	-13.7
219	-10.2	-16.7	-12.9
222	-11.6	-17.5	-12.4
225	-12.2	-17.9	-12.7
228	-11.7	-17.5	-12.4
231	-10.8	-16.1	-11.9
234	-9.9	-14.8	-10.3
237	-11.1	-16.2	-10.2
240	-11.2	-15.9	-9.8
Average sensitivity	-12.1	-16.4	-11.8

[0031] Fig. 6A is a graph showing the simulation results, and Fig. 6B is a graph showing the reception sensitivity on the basis of actual measurement results. It is apparent from Figs. 6A and 6B, or Tables 3 and 4, that actual measurement results and simulation results are roughly similar. Therefore, it was confirmed that the same or better sensitivity than that of comparative example 1 shown in Fig. 4A in which an AM antenna is not present is obtained even with the presence of the AM antenna 31.

[0032] Next, the results of simulating the relationship between a slit width "d" and the average sensitivity for the glass antenna 30 for a vehicle of the embodiment are shown in Fig. 7 and in Table 5 below.

Table 5

Average Sensitivity		
Slit width (mm)	DAB (dBd)	AM (dBuV)
2	-11.7	43.3
5	-11.6	43.3
10	-11.5	43.2
20	-11.5	43.1
50	-12.0	42.8

[0033] Fig. 7 is a graph showing the sensitivity characteristics, in which the slit width "d" (mm) is plotted on the horizontal axis and the sensitivities (dBd, dBuV) of the DAB antenna 32 and the AM antenna 31, respectively, are plotted on the vertical axis. As used herein, the term "slit width" refers to an interval "d" between the first vertical element 33a and the second vertical element 33b constituting the slit 33 in the AM antenna 31 shown in Fig. 2. As a result of the simulation, the slit width "d" in which the optimal sensitivity is obtained for both the DAB antenna 32 and the AM antenna 31 is in a range of 2 to 20 mm.

[0034] Here, the height of the slit 33 will be further described. As used herein, the height (antenna length) of the slit

33 refers to the distance from the power feed terminal 32a (hot terminal) of the DAB antenna 32 to the horizontal element 31I positioned in the bottommost area of the AM antenna 31. The antenna length used in the simulation described above is 260 (mm) as indicated by the dimensions shown in Fig. 8. Assuming the theoretically required antenna length to be $\lambda/4$, then $\lambda/4 = 300/207/4 \times 0.7 = 254$ (mm), where the center frequency of the DAB frequency range is 297 (MHz) and the shortening ratio is 0.7. Therefore, the height of the slit 33 must be adjusted so that the antenna length is $\lambda/4$.

[0035] The above-described antenna length can be adjusted by selecting the horizontal element on the bottom side (positioned in the bottommost step) among the twelve horizontal elements 31 a to 31I constituting the AM antenna 31. There may be cases in which the antenna length is $\lambda/4$ or less when a sufficient antenna length cannot be used in terms of designing the AM antenna 31.

[0036] As described above, the glass antenna 30 for a vehicle of the present embodiment includes an AM antenna 31 composed of a plurality of horizontal elements 31 a to 31I and first and second vertical elements 33a, 33b, and a DAB antenna 32 for capacitatively coupling with the horizontal element 31 a positioned in the topmost part of the AM antenna 31, the DAB antenna being arranged in an upper part of a region in which the AM antenna 31 is mounted. The AM antenna 31 has, among the plurality of horizontal elements 31 a to 31I, a horizontal element 31 a positioned in the upper part, a first vertical element 33a in contact with the horizontal element 31 a, and a second vertical element 33b; the first vertical element 33a and the second vertical element 33b are disposed so as to be substantially in parallel across a gap "d" for which the reception sensitivity of each of the AM antenna 31 and the DAB antenna 32 is prescribed to be in an optimal range, and a slit 33 having a fixed height is formed by the gap "d"; and an electrical connection is established at a bottommost end of each of the first vertical element 33a and the second vertical element 33b. The slit 33 thus formed in the AM antenna 31 capacitatively couples with the DAB antenna 32, whereby the slit 33 can operate as the DAB antenna 32. Accordingly, the presence of the DAB antenna 32 does not limit the arrangement surface area of the AM antenna 31, and the DAB antenna 32 can therefore be designed without a reduction in the sensitivity of the AM antenna 31.

[0037] According to the glass antenna 30 for a vehicle of the present embodiment, the slit width (an interval "d" between the first vertical element 33a and the second vertical element 33b of the AM antenna 31) is prescribed so that the receiving sensitivities of the AM antenna 31 and the DAB antenna 32 are both in an optimal range. It was found by evaluation carried out by the inventor that optimal reception sensitivity can be obtained in a range of 2 to 20 mm, and that adjustments can be made in this range. Also, in evaluations carried out by the inventor, it was found that the same sensitivity can be obtained as if the AM antenna 31 were not present when the position of the slit 33, which is indicated by the distance from the power feed terminal (hot terminal 32a) of the DAB antenna 32 to the first vertical element 33a of the AM antenna 31 with reference to a vertically extending virtual line "x", is in a range of 0 to 100 mm (more preferably 0 to 60 mm). In this manner, according to the present invention, it is possible to provide a glass antenna 30 for a vehicle in which a DAB antenna or the like provided with good receiving characteristics is arranged without a reduction in the reception sensitivity of the AM antenna.

Claims

1. A vehicular glass antenna comprising: a first antenna (31) having a plurality of horizontal elements (31 a to 31I) and vertical elements (33a, 33b), and a second antenna (32) capacitatively coupled with a topmost one (31 a) of the horizontal elements (31a-31I) of the first antenna, the second antenna being arranged in an upper part of a region in which the first antenna (31) is mounted, wherein the first antenna (31) includes the topmost horizontal element (31 a), a first vertical element (33a) in held contact with the horizontal element (31 a), and a second vertical element (33b), the first vertical element (33a) and the second vertical element (33b) are disposed so as to be substantially in parallel across a gap (d) for which a reception sensitivity of each of the first antenna (31) and the second antenna (32) is set to be in an optimal range, and a slit (33) having a predetermined height is formed by the gap (d), and an electrical connection is established at a bottommost end of each of the first vertical element (33a) and the second vertical element (33b).
2. The glass antenna of claim 1, wherein the gap (d) is selected to fall within a range of 2 to 20 mm.
3. The glass antenna of claim 1, wherein the predetermined height is a size adjusted so as to be substantially $1/4\lambda$ or less.
4. The glass antenna of claim 1, wherein the first vertical element (33a) for forming the slit (33) is arranged at an interval of 0 to 100 mm with reference to a virtual line extending vertically from a power feed terminal (32a) of the second antenna (32) arranged on the upper side of the region in which the first antenna (31) is mounted.
5. The glass antenna of claim 1, wherein the first vertical element (33a) for forming the slit (33) is arranged at an interval

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of 0 to 60 mm with reference to a virtual line extending vertically from a power feed terminal (32a) of the second antenna (32).

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FIG.1

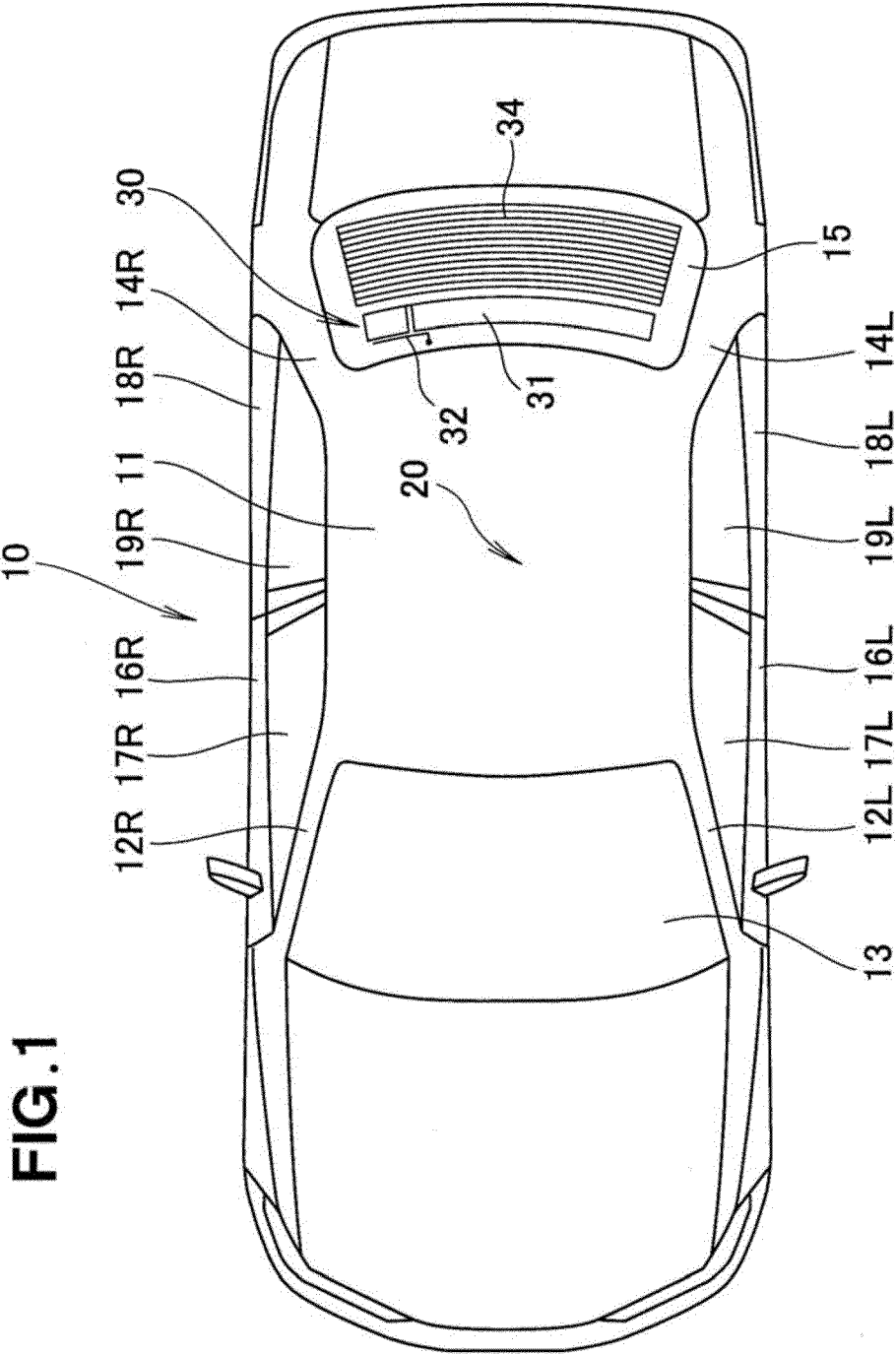


FIG.2

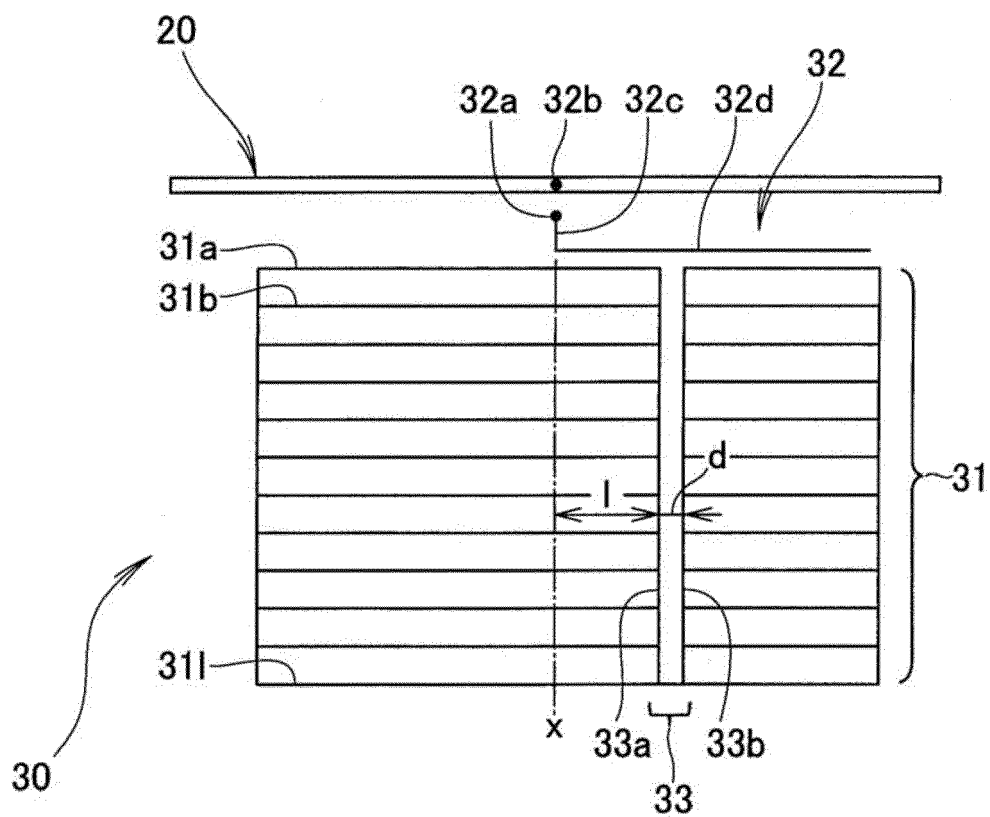


FIG.3

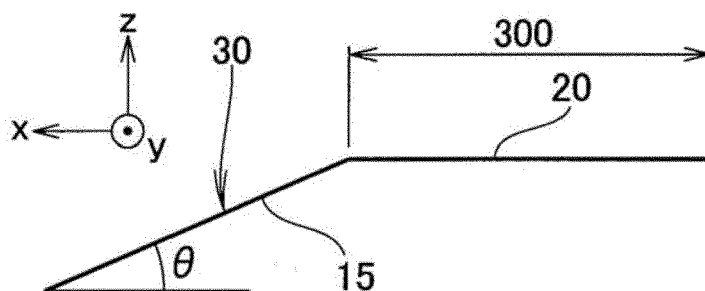


FIG. 4A

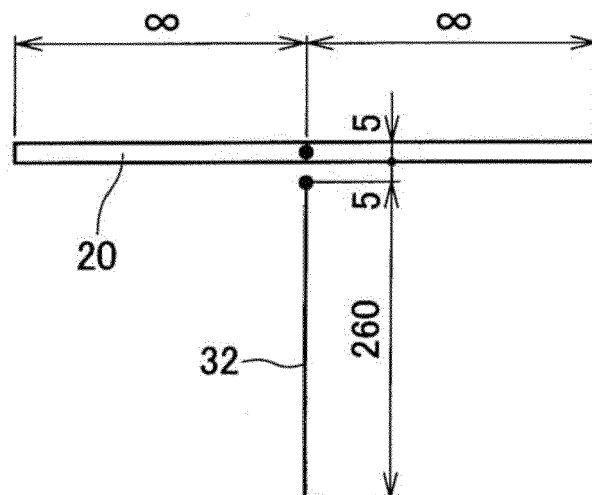


FIG. 4B

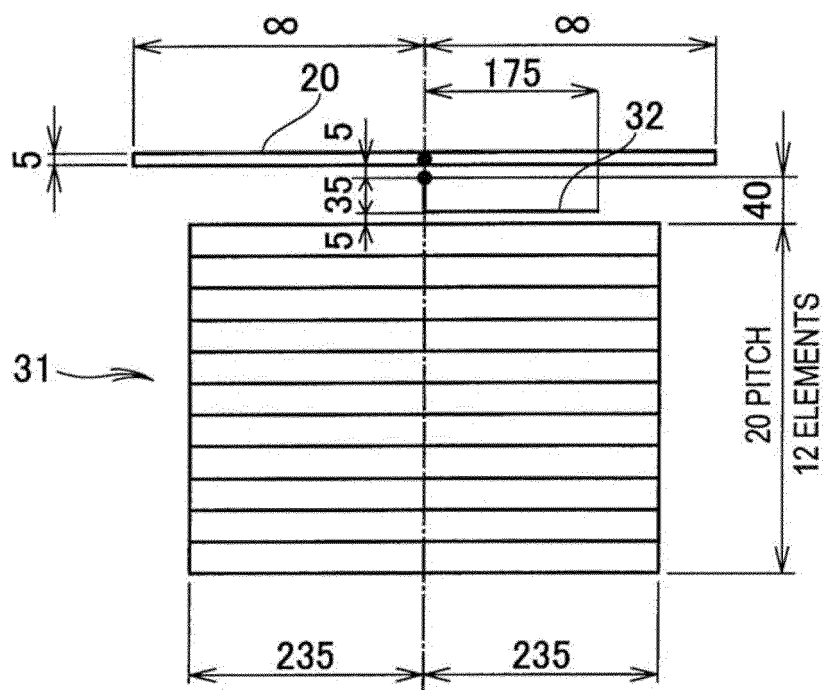


FIG.5

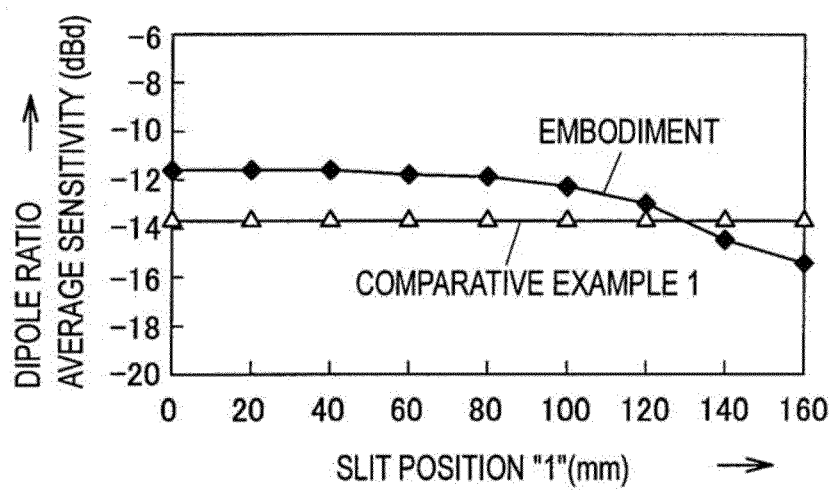


FIG.6A

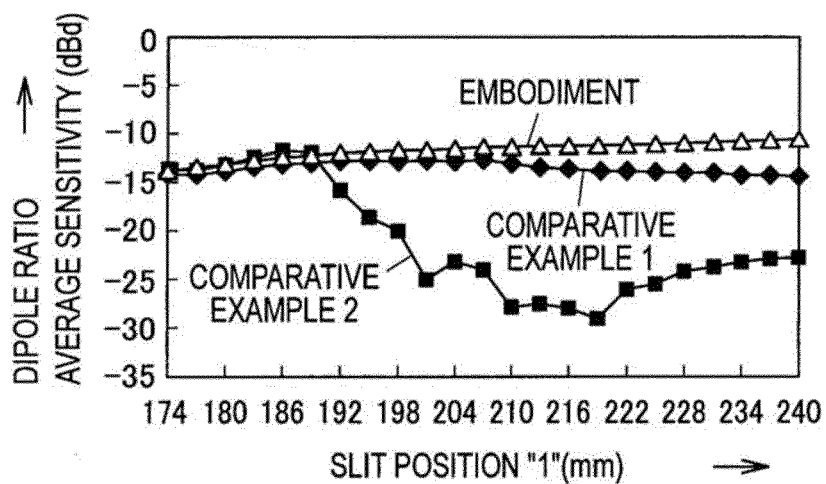


FIG.6B

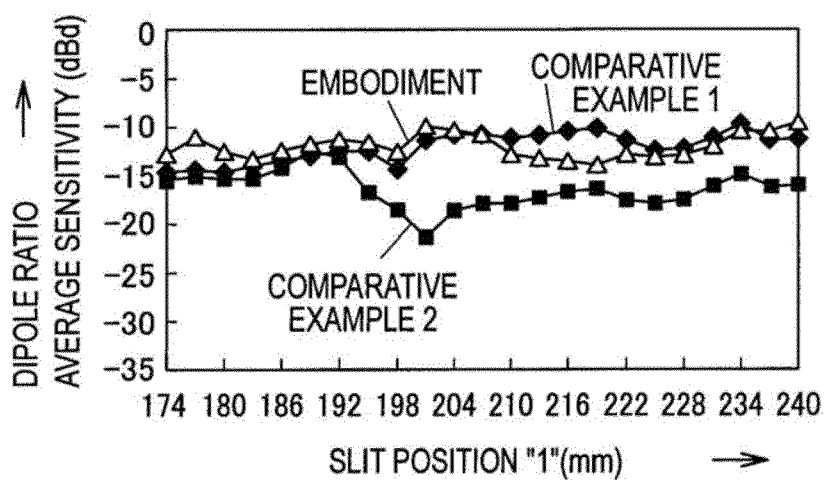


FIG.7

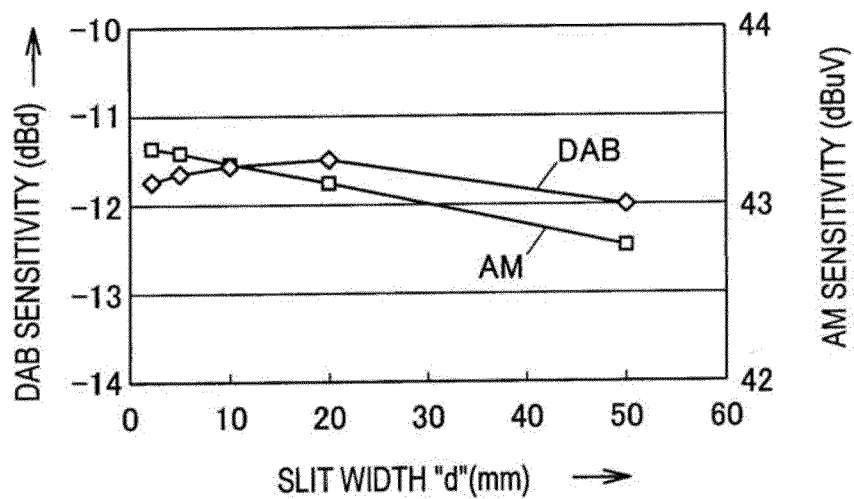
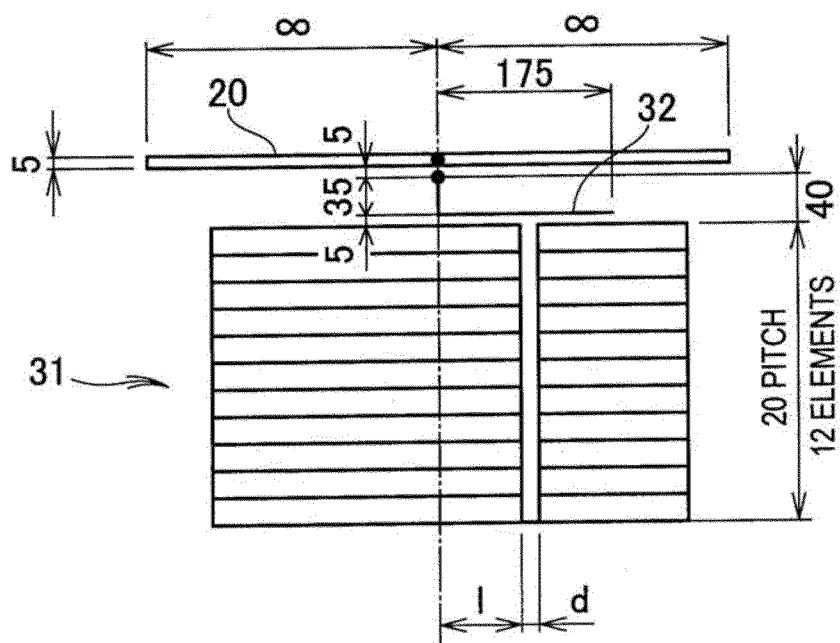


FIG. 8



REFERENCES CITED IN THE DESCRIPTION

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