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(71) Applicant: TOYOTA JIDOSHA KABUSHIKI KAISHA
1, Toyota-cho Toyota-shi
Aichi-ken 471(JP)

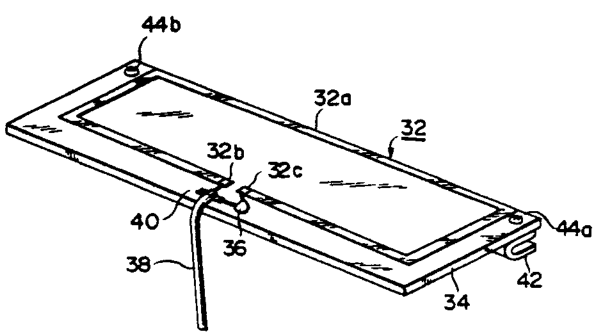
(72) Inventor: Ohe, Junzo
Daini-Ekaku Apt. 15303 2-56,
Ekakushin-machi
Toyoto-shi Aichi(JP)
Inventor: Kondo, Hiroshi
6-49, Nitamata Onishi-cho
Okazaki-shi Aichi(JP)

(74) Representative: Wood, Anthony Charles et al
c/o MICHAEL BURNSIDE & PARTNERS 2
Serjeants' Inn Fleet Street
London EC4Y 1HL(GB)

(54) **Vehicle antenna system.**

(57) The present invention provides a vehicle antenna system having no portion outwardly extending from the vehicle body, the vehicle antenna system including a loop antenna housed within the interior of the vehicle body, the loop antenna being disposed opposed to the edge of a metallic panel on the vehicle body and capable of picking up high frequency surface currents induced on the surface of the vehicle body by broadcast waves. The loop antenna is printed on a print substrate which in turn is rigidly mounted on the marginal portion of the vehicle body. The loop antenna printed on the print substrate is electrically connected in series with a capacitor to form a series resonance circuit.

FIG. 1



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VEHICLE ANTENNA SYSTEM

The present invention relates to an improved vehicle antenna system which can efficiently detect broadcast waves received by the vehicle body and deliver the detected signals to various onboard receivers.

Most of modern automobiles are provided with an antenna system for causing various onboard receivers to positively receive broadcast waves such as radio waves and TV waves and/or communication waves such as car-telephone waves. The antenna system also is used for citizen band tranceivers. Thus, the vehicle antenna system plays an essential and important role.

A pole type antenna is well-known as one of the conventional antenna systems. The pole type antenna is disadvantageous in that it is frequently damaged since it extends outwardly from the vehicle body.

A plurality of antennas are generally required to receive a plurality of waves belonging to different frequency bands. These antennas may damage the aesthetic appearance of an automobile and also create an electric interference between the antennas.

The utilization of currents induced on the vehicle body by broadcast waves has been proposed, for example, by Japanese Patent Publication Sho 53-22418 and Japanese Utility Model Publication Sho 53-34826. In the former, an electric insulator is formed on the vehicle body at a location in which currents flow concentrically. A sensor is located between the opposite ends of the insulator to directly detect the currents therebetween. Such an arrangement can detect practicable signals which are superior in S/N ratio. However, the insulator must be arranged in a notch which is formed by cutting a portion of the vehicle body. This is not applicable to mass-production of automobiles.

The latter includes an antenna system comprising a pickup coil for detecting currents on the vehicle body at its pillar. This proposal is advantageous in that the antenna system is arranged completely within the interior of the vehicle body. It is difficult, however, to arrange the pickup coil near the pillar in the direction perpendicular to the length of the pillar.

In the prior art, thus, it was not necessarily successful to provide an antenna system for detecting currents induced on the vehicle body by broadcast waves. Particularly, there could not be obtained a proper pickup structure for efficiently detecting currents induced on the vehicle body and a proper pickup arrangement for obtaining practicable S/N ratios.

In view of such problems, Japanese Patent Application Sho 60-175221, assigned to the assignee, has proposed a vehicle antenna system which comprises a loop antenna arranged near the marginal portion of the vehicle body and extending along the length of the marginal vehicle portion, the loop antenna being electrically connected in series with a capacitor to detect high frequency surface currents induced on the surface of the vehicle body by broadcast waves.

The proposed vehicle antenna system can efficiently detect high frequency surface currents flowing concentrically on the marginal portion of the vehicle body. The sensitivity thereof can very be improved by the use of the capacitor connected in series with the loop antenna. In such an arrangement, however, the loop antenna must have an increased precision in manufacturing and a stability in construction. This results in increase of the labor and cost in manufacturing. Moreover, the loop antenna should be formed of a wire having a diameter sufficient to provide a necessary strength in the loop antenna. This becomes an obstruction when it is desired to reduce the thickness of the antenna system.

It is therefore an object of the present invention to provide an improved antenna system which has an increased sensitivity and a stabilized construction and which can easily be manufactured with a reduced thickness.

To this end, the present invention provides a vehicle antenna system for detecting high frequency surface currents induced on the vehicle body by broadcast waves, the improvement comprising a loop antenna arranged in close proximity to the marginal portion of the vehicle body and extending along the length of the marginal vehicle portion, the loop antenna being electrically connected in series with a capacitor to form a series resonance circuit, the loop antenna being printed on a print substrate.

More particularly, the loop antenna is printed on a print substrate of glass-epoxy or Teflon and electrically connected in series with a capacitor to form a series resonance circuit which is adapted to create a resonance for frequencies belonging to a widened range of bands, resulting in increase of the sensitivity.

The present invention intends to utilize broadcast waves belonging to frequency bands equal to or higher than FM frequency bands, that is, 50 MHz. Thus, such an antenna construction can broadly receive high frequency surface currents induced on the surface of the vehicle body and therefore efficiently receive various broadcast waves.

In one aspect of the present invention, it is preferred that a plurality of loop antennas are concentrically printed on the print substrate, each of the loop antennas being electrically connected in series with a capacitor to form an antenna-capacitor set, each of these antenna-capacitor sets being sequentially connected in series with the adjacent antenna-capacitor set.

Figure 1 is a perspective view of a first preferred embodiment of a vehicle antenna system according to the present invention.

Figure 2 illustrates the connection of the loop antenna shown in Figure 1 with a coaxial cable.

Figure 3 is a cross-sectional view of the mounting in the first embodiment of the vehicle antenna system according to the present invention.

Figure 4 is a graph showing the reception characteristics of the first embodiment of the vehicle antenna system according to the present invention.

Figure 5 is a schematic circuit diagram of a receiver.

Figure 6 is a perspective view of a second preferred embodiment of the vehicle antenna system according to the present invention.

Figure 7 illustrates the connection of two loop antennas shown in Figure 6 with a coaxial cable.

Figure 8 is a circuit diagram showing an equivalent circuit used in the second embodiment of the vehicle antenna system according to the present invention.

Figure 9 is a cross-sectional view of the mounting of the second embodiment of the vehicle antenna system according to the present invention.

Figure 10 is a graph showing the reception characteristics of the second embodiment of the vehicle antenna system according to the present invention.

Figure 11 illustrates surface currents I induced on a vehicle body B by external waves W.

Figure 12 illustrates a probe and its processing circuit used to determine surface currents on the vehicle body, the probe being constructed in accordance with the same principle as that of the antenna system according to the present invention.

Prior to the detailed description of the present invention, a process for measuring the distribution of high frequency surface currents on the vehicle body and determining a location on the vehicle body wherein an antenna system can most efficiently detect external waves will be described with reference to Figures 11 and 12.

Figure 11 shows surface currents I induced on the vehicle body B of conductive metal at various locations depending on the intensity of external waves W such as broadcast waves when they pass through the vehicle body B. The present invention intends to utilize surface currents induced on the vehicle body by external waves belonging to relatively high frequency bands which include FM waves, TV waves and others of frequencies equal to or higher than 50 MHz.

For the particular high frequency bands, the present invention is characterized by measuring the distribution of surface currents induced on the vehicle body and locating an antenna system on the vehicle body at a location in which the density of the surface currents is higher with reduced noise.

In order to determine the distribution of surface currents, a simulation will be effected by the use of a computer and also actual measurements will be carried out to determine the intensity of currents on the vehicle body at various locations. To this end, the present invention utilizes a probe which is constructed in accordance with the same principle as that of a vehicle antenna system located on the vehicle body at the desired location, as will be described. The probe is moved along the vehicle body throughout the surface area thereof while varying its orientation at the respective locations of measurement.

Figure 12 shows the schematical construction of such a probe P. The probe P comprises a casing 10 of electrically conductive material for shielding its interior from external waves and a loop coil 12 housed within the casing 10. The casing 10 is provided with an opening 10a through which a portion of the loop coil 12 is externally exposed. The exposed portion of the loop coil 12 is located in close proximity to the surface of the vehicle body B so that a magnetic flux created by the surface currents can be detected by the loop coil 12. The loop coil 12 is electrically connected with a short-circuiting line 14 and has an output end 16 electrically connected with a core 20 in a coaxial cable 18. The loop coil 12 also includes a capacitor 22 which can cause the frequency of the loop coil 12 to resonate with a desired frequency to be measured to improve the pickup efficiency.

In Figure 12, the output of the probe P is amplified by an amplifier 24 the output voltage of which in turn in measured at a high frequency voltage meter 26. The output voltage of the amplifier 26 also is recorded by an X-Y recorder 28 as a level of surface currents at a particular location. The X-Y recorder 28 also receives a signal indicative of that location from a potentiometer 30. In such a manner, the levels of the high frequency surface currents at the respective locations will be determined to know the distribution and orientation of the surface currents.

Based on the distribution of surface currents so determined, it has been found that the surface currents flow concentrically on the marginal portions of the vehicle body such as the front window frame, rear window frame and others. Thus, the loop antenna will be disposed in close proximity to one of these marginal vehicle portions to extend along the length thereof.

Referring now to Figures 1, 2 and 3, a loop antenna 32 is printed on a print substrate 34 made of glass-epoxy, Teflon or the like in a pattern as shown.

One end 32c of the loop antenna 32 is electrically connected in series with a capacitor 36 which in turn is electrically connected with a coaxial cable 38. In the embodiment of Figure 2, the capacitor 36 and the outer conductor 38a of the coaxial cable 38 are soldered with the substrate 34 at a land 40 which is in the form of a conductive material such as copper foil left on the substrate for this purpose. The other end 32b of the loop antenna 32 is electrically connected with the inner conductor 38b of the coaxial cable 38.

In such an arrangement, the coaxial cable 38 or the capacitor 36 can simply be connected with the print substrate through the land 40. Therefore, the antenna system can inexpensively be manufactured without any connector.

The print substrate 34 also is provided with a clip 42 of U-shaped cross-section used to mount the antenna system on the vehicle body. The clip 42 is fastened to the print substrate 34 by means of screws 44a and 44b. Preferably, the clip 42 is formed of a non-conductive and resilient material such as plastics. Thus, the clip 42 may tightly be mounted on the marginal portion of the vehicle body (front window frame in the illustrated embodiment) under the influence of its resiliency.

Figure 3 shows the antenna system mounted on the roof header panel in the above-mentioned manner. The clip 42 is used such that the longest straight portion 32a of the loop antenna 32 will be disposed in close proximity to the edge portion of the roof header panel 50 which is located inside of that portion of a roof panel 46 adjacent to the front window glass and outside of a roof liner 48. More particularly, the clip 42 is fitted over the bent portion 50a in the inner edge of the roof header panel 50 such that the longest straight portion 32a of the loop antenna 32 will be disposed in close proximity to the bent portion 50a. An edge molding 52 is fastened between the roof header panel 50 and the roof liner 48.

Thus, the single winding loop antenna 32 printed on the print substrate 34 can efficiently detect high frequency surface currents flowing on the roof header panel 50 by causing the loop antenna 32 to intersect a magnetic flux created by the surface currents.

In Figure 4, a curve 100 shows the reception characteristics of the antenna system in the illustrated embodiment while a curve 200 shows the reception characteristics of a parallel resonance type antenna which is electrically connected in parallel with a capacitor. As will be apparent from Figure 4, the antenna system according to the present invention can more sensitively receive waves belonging to an increased range of bands, in comparison with the parallel resonance type antenna system.

The antenna system according to the illustrated embodiment can receive broadcast waves of frequencies within a range of FM bands to TV bands, that is, a range of bands between 76 MHz and 220 MHz if the loop antenna 32 has an inductance within a range of about 50 nH to about 100 nH and the capacitor 36 is within a range of 0.5 pF to 3 pF.

Figure 5 shows the circuit of a receiver receiving broadcast waves detected by the loop antenna 32. Such a receiver is well-known in the art and will briefly be described with respect to its operation until the voice output is produced.

The outer conductor 38a of the coaxial cable 38 is grounded. Signals detected by the loop antenna 32 are transmitted to a receiver 54 through the coaxial cable 38. The receiver 54 includes an impedance matching circuit 56, a high frequency amplifying circuit 58 and a selective output circuit section 60.

The impedance matching circuit 56 includes a band-pass filter 62 and a discharge tube 64. The detection voltage of the capacitor 36 obtained from the loop antenna 32 is applied to the input of the band-pass filter 62 with the output thereof connected with a parallel circuit consisting of the discharge tube 64 and a capacitor C_3.

The discharge tube 64 prevents the circuit from being subjected to an electrostatic breakdown due to external static electricity, lightning and others.

An impedance matching is carried out in the loop antenna by the band-pass filter 62. After being subjected to the impedance matching, the detected signals are amplified by the high frequency amplifying circuit 58. The high frequency amplifying circuit 58 includes transistors Q_1 and Q_2 which are two-step connected with each other. The outputs of these transistors are supplied to the selective output circuit section 60 wherein they are converted into voice outputs.

The circuit shown in Figure 5 further comprises peaking coils L_1 and L_2; resistors R_2 and R_3 for stabilizing the operation of the transistor Q_1; bias resistors R_5 and R_6; and bypass capacitors C_3 and C_9.

The aforementioned embodiment of the present invention can more sensitively receive broadcast waves such as FM waves or TV waves belonging to an increased range of bands by causing feeble signals detected by the loop antenna 32 to subject to the desired impedance matching and high frequency amplification.

Referring next to Figures 6 and 7, there is shown a second embodiment of the vehicle antenna system according to the present invention, which is mounted on the vehicle body as shown in Figure 9.

The second embodiment of the present invention is characterized by that two loop antennas 132 and 133 are concentrically printed on a print substrate 134 of glass-epoxy, Teflon or the like in a pattern as shown in Figure 6. Each of the loop antennas 132 and 133 is electrically connected in series with a capacitor 136 or 137. The loop antennas 132 and 133 are connected in series with each other and with a coaxial cable 138.

In the second embodiment, a land 140 is provided to solder the capacitors 136, 137 or the coaxial cable 138 onto the substrate 134. As shown in Figure 7, the outer conductor 138a of the coaxial cable 138 as well as the capacitor 136 are soldered on the land 140. The other end of the capacitor 136 is electrically connected with one end 132c of the outer loop antenna 132 while the inner conductor 138b of the coaxial cable 138 is electrically connected with one end 133b of the inner loop antenna 133 printed on the print substrate. The two loop antennas 132 and 133 are connected in series with each other by soldering the other ends 132b, 133c of the loop antennas 132, 133 with each other through the capacitor 137.

As seen from Figure 8, the outer and inner loop antennas 132 and 133 are connected in series with each other such that the capacitor 137 (C_2) will adjust the electrical balance between both the antenna-capacitor sets.

Because of such a land 140 capable of simply connecting the coaxial cable 138 or the capacitors 136, 137 with the print substrate, the antenna system can inexpensively be manufactured without any connector.

The print substrate 134 also is provided with a clip 142 of U-shaped cross-section used to mount the antenna system on the vehicle body. The clip 142 is fastened to the print substrate 134 by means of screws 144a and 144b. Preferably, the clip 142 is formed of a non-conductive and resilient material such as plastics. Thus, the clip 142 may tightly be mounted on the marginal portion of the vehicle body (front window frame in the illustrated embodiment) under the influence of its resiliency.

Figure 9 shows the antenna system mounted on the roof header panel in the above-mentioned manner. The clip 142 is used such that the loop antennas 132 and 133 will be disposed in close proximity to the edge portion of the roof header panel 150 which is located inside of that portion of a roof panel 146 adjacent to the front window glass and outside of a roof liner 148. More particularly, the clip 142 is fitted over the bent portion 150a in the inner edge of the roof header panel 150 such that the straight portions 132a and 133a of the two loop antennas 132 and 133 will be disposed in close proximity to the bent portion 150a. An edge molding 152 is fastened between the roof header panel 150 and the roof liner 148.

Thus, the two loop antennas 132 and 133 printed on the print substrate 134 can efficiently detect high frequency surface currents flowing on the roof header panel 150 by causing the loop antennas 132 and 133 to intersect a magnetic flux created by the surface currents.

Figure 10 is a graph illustrating the reception characteristics of the antenna system (the relationship between the relative sensitivity of reception and the frequency) in the above-mentioned arrangement. In Figure 10, a curve 300 indicates the reception characteristics of the antenna system according to the second embodiment; a curve 200 denotes the reception characteristics of a parallel resonance type antenna connected in parallel with a capacitor; and a curve 100 designates the reception characteristics of a series resonance type single winding loop antenna.

As seen from Figure 10, the antenna system according to the second embodiment can more sensitively receive broadcast waves belonging to an increased range of bands, in comparison with the parallel resonance type antenna system. The embodiment further provides an improved sensitivity for the broadcast waves having a frequency equal to about 100 MHz, in comparison with the single winding loop antenna as in the first embodiment. This results from increase of the self-inductance or equivalent loop area.

However, the increased number of the loop antennas causes a parasitic capacity under the influence of the adjacent loop antenna. For a particular frequency band, the parasitic capacity causes a reduction of the sensitivity. Since the parasitic capacity increases as the spacing between each adjacent loop antennas becomes smaller, it is required that the loop antennas are spaced apart from each other by a proper distance while at the same time such a distance is precisely maintained.

It is thus very difficult that the loop antennas precisely spaced apart from each other are formed of wire material as in the prior art. The present invention can provide a stable construction having an improved characteristics of reception since the loop antennas are very precisely printed on the print substrate.

The dip of the antenna system due to said parasitic capacity can be moved to an unused frequency band by adjusting the capacitors 136 -(C_1) and 137 (C_2). For example, when it is wanted to receive TV waves in Japan, it can be arranged that the dip frequency exists in a band between the third channel corresponding to 110 MHz and the fourth channel corresponding to 170 MHz, as shown in Figure 10. This prevents the antenna system from being influenced by the parasitic capacity and then provides an improved reception.

As described hereinbefore, the present invention provides a vehicle antenna system which can more simply be manufactured in a mass-production manner since the loop antenna or antennas are printed on the print substrate. Furthermore, the present invention provides a stabilized loop antenna construction for more sensitively receiving broadcast waves belonging to an increased range of bands, because the loop antenna or antennas themselves are precisely formed on the print substrate without deflection. Moreover, the thickness of the antenna system can be reduced to very small size since the loop antenna or antennas are reinforced by the thickness of the print substrate.

Claims

1. A vehicle antenna system for picking up high frequency surface currents induced on the vehicle body by broadcast waves, the improvement comprising loop antenna means disposed in close proximity to the marginal portion of the vehicle body and extending along the length of said marginal vehicle portion, said loop antenna means being electrically connected in series with capacitor means to form a series resonance circuit, said loop antenna means being printed on a print substrate.

2. A vehicle antenna system as defined in claim 1 wherein said loop antenna means includes a plurality of loop antennas concentrically printed on said print substrate, each of said loop antennas being electrically connected in series with a capacitor to form an antenna-capacitor set, the respective one of the antenna-capacitor sets being sequentially connected in series with the adjacent antenna-capacitor set.

3. A vehicle antenna system as defined in claim 1 or 2, further comprising an electrically conductive land formed on said print substrate, said land being used to solder a coaxial cable for supplying the picked high frequency surface currents to receiver means and said capacitor means onto said print substrate.

4. A vehicle antenna system as defined in claim 1 or 2 wherein said print substrate includes clip means for mounting said antenna system on the vehicle body such that the loop antenna means will be disposed in close proximity to the marginal portion of the vehicle body.

5. A vehicle antenna system as defined in claim 4 wherein said clip means is of substantially U-shaped configuration and made of a non-conductive and resilient material, said clip means being tightly fitted over the marginal portion of the vehicle body to which said loop antenna means is disposed in close proximity.

6. A vehicle antenna system as defined in claim 2 wherein each of said loop antennas is spaced apart from the adjacent loop antenna by a predetermined distance so as to reduce a parasitic capacity.

7. A vehicle antenna system as defined in claim 2 wherein the capacity between each adjacent loop antennas is set such that the dip of sensitivity due to the parasitic capacity between each adjacent loop antennas will be positioned in an unused frequency band.

8. A vehicle antenna system as defined in claim 1 or 2 wherein said loop antenna means is of a rectangular shape.

FIG. 1

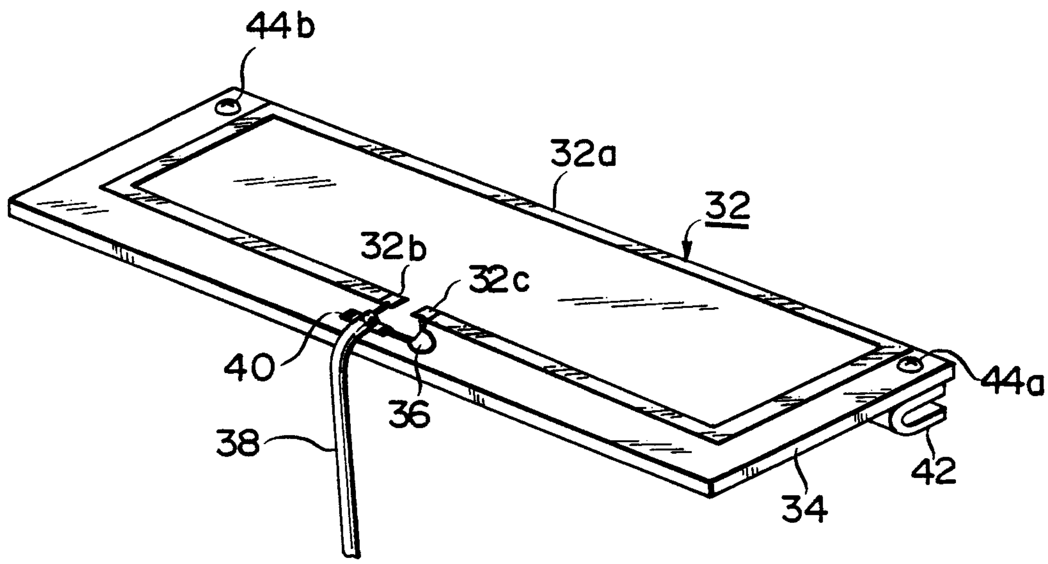


FIG. 2

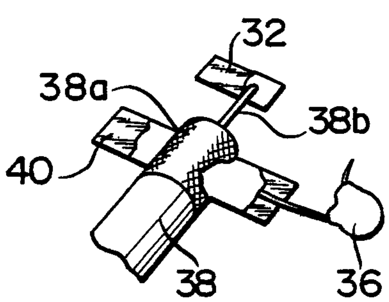


FIG. 3

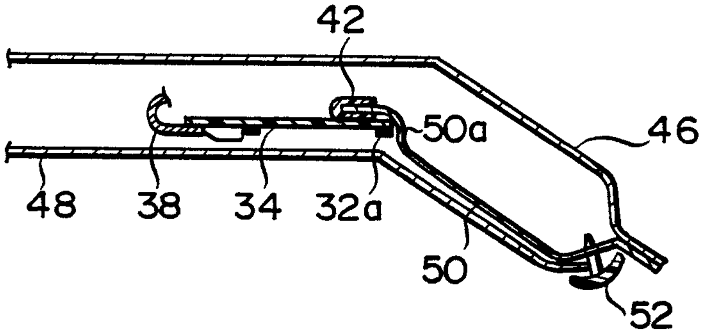

42
50a
46
48
38
34
32a
50
52

FIG. 4

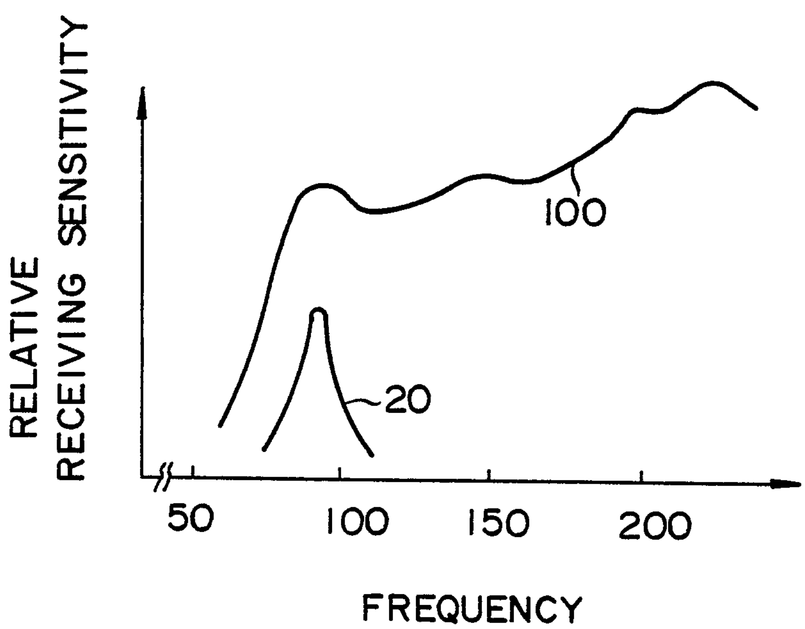
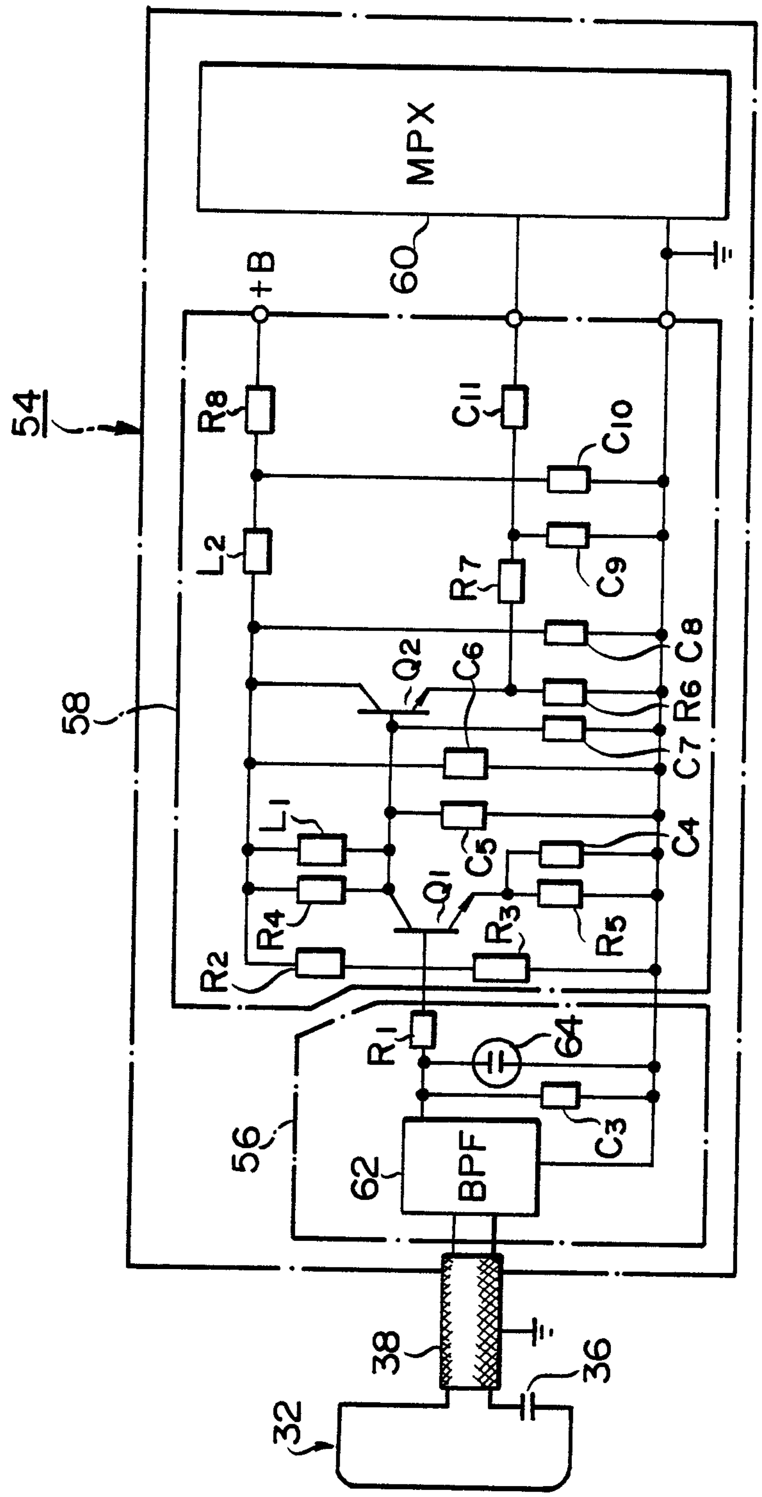

RELATIVE
RECEIVING SENSITIVITY
100
20
50
100
150
200
FREQUENCY

FIG. 5



MPX
60
+B
54
58
R8
C11
C10
L2
C9
R7
C8
Q2
R6
C6
C7
L1
C5
C4
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R3
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R2
R1
64
56
C3
62
BPF
38
36
32

FIG. 6

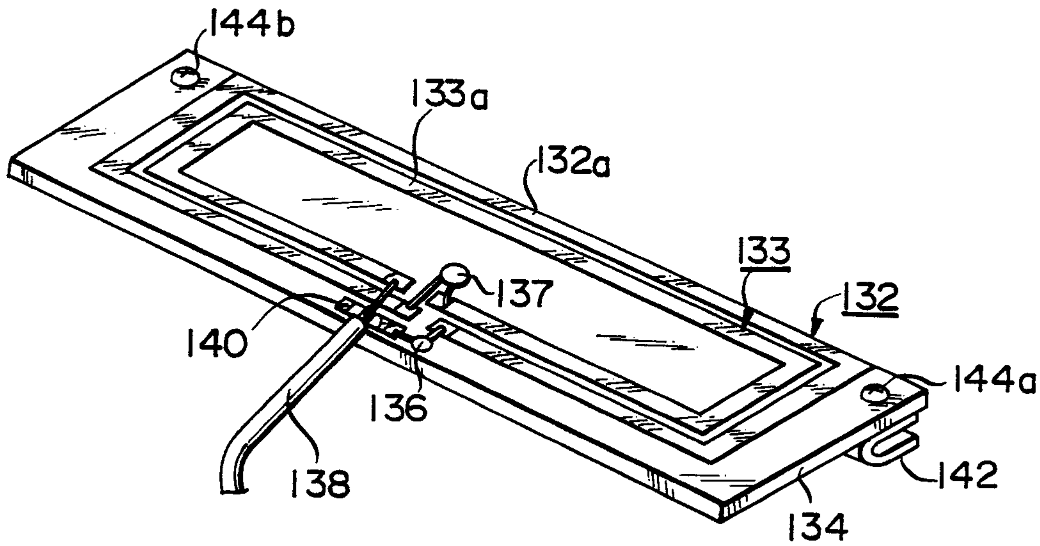


FIG. 7

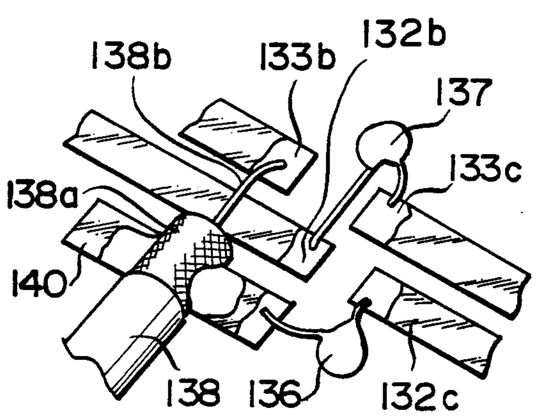


FIG. 8

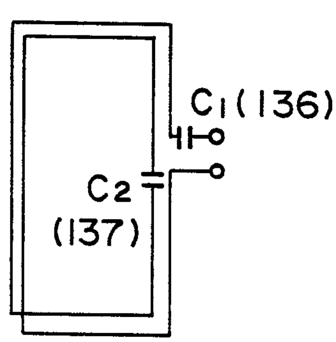
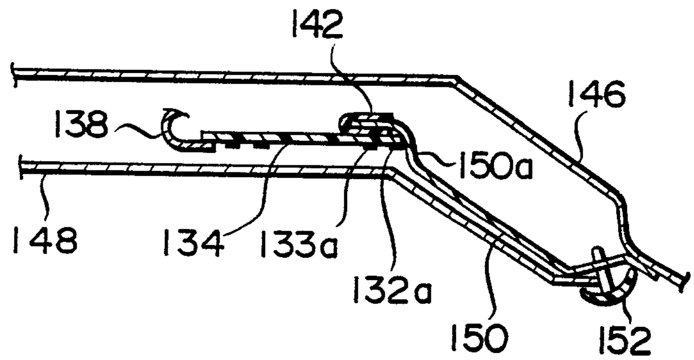
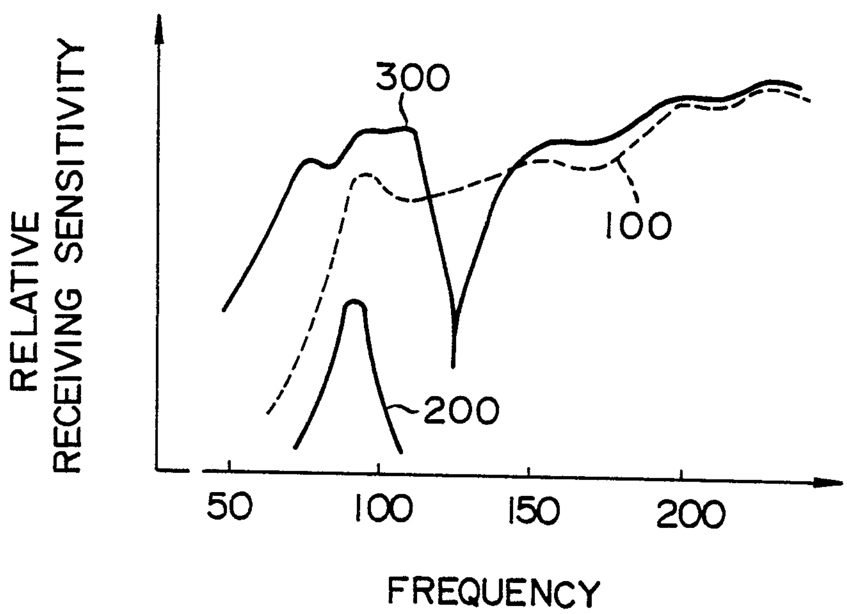


FIG. 9



142
146
138
150a
148
134
133a
132a
150
152

FIG.10



RELATIVE
RECEIVING SENSITIVITY
300
100
200
50
100
150
200
FREQUENCY

FIG.11

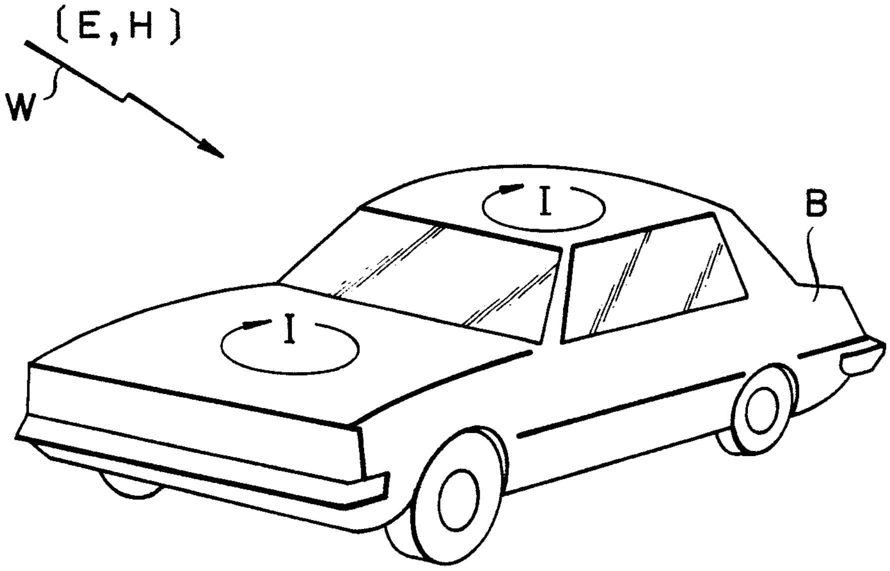
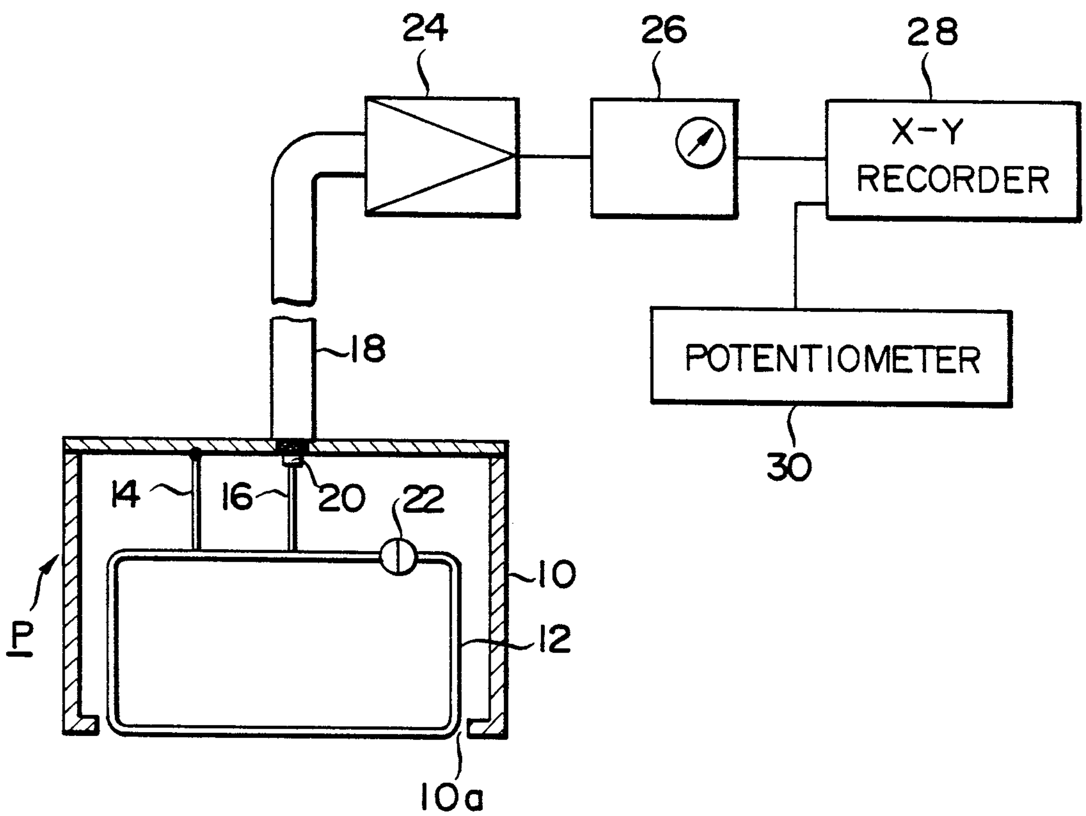

(E, H)
W
I
I
B

FIG.12


24
26
28
X-Y
RECORDER
POTENTIOMETER
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30
14
16
20
22
10
P
12
10a