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(54) **Planar antenna for motor-vehicles**

(57) A planar microstrip antenna is adopted for motor-car systems for both cellular telephony and other applications.

In the field of cellular telephony, the antenna is utilizable in the present frequencies of 800/900 MHz (GSM, ETACS, AMPS, PCD) and the higher ones of 2.5 GHz (DCS, UMPTS, PCN, PDC 1.5); besides, it is also utilizable for applications other than telephony, such as: reception in L, DAB, GPS band and the like and at higher frequencies up to 6 GHz, also for Telepass type transponder systems and the like.

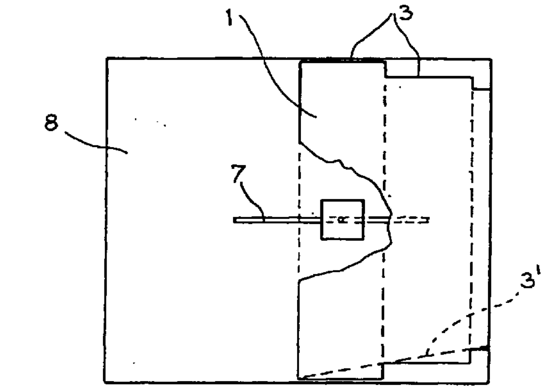

FIG. 1A

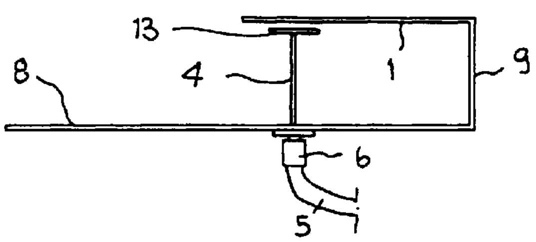

FIG. 1B

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Description

[0001] The present invention relates to a planar antenna for motor-vehicles. More particularly, the present invention relates to a microstrip (patch) planar antenna, particularly suitable for use in motor-cars both for cell-phones and for different applications.

[0002] The planar antenna of the present invention is preferably located on the windows of motor-vehicles, in particular on the rear window. It may be utilized both in the cell-phones of the present frequency field of 800/900 MHz (GSM, ETACS, AMPS, PCD) up to the higher frequencies of 2.5 GHz (DCS, UMTS, PCN, PDC, 1.5) and for applications other than telephony, such as for instance: reception in L, DAB, GPS band and the like, and at higher frequencies up to 6 GHz, as well as for Telepass type transponder systems of the, and the like.

[0003] Radiophony systems for motor-vehicles are known that utilize frequencies in the UHF band; at present systems are widespreading that use higher frequency systems, suitable to obtain an increasing number of transmission channels.

[0004] The present antennas adopted in such systems are of the stylus type; they are installed on the vehicles' metal roofs and provide acceptable performances, with an almost omnidirectional radiation and vertical polarization. The metal roof acts as a mass plane and provides a good shielding for the interior compartment from the electromagnetic radiation emitted by the antenna. In spite of this, said antennas, while having proved to have satisfactory radioactive characteristics, have some drawbacks. In fact, for their installation it is necessary to make a through-hole in the car-body, with ensuing possible problems of seal against wheathering, and their external location, besides modifying aesthetically the line of the vehicles, constitutes a precarious exposure condition, which causes them to be subject to damages, tampering and/or vandalisms.

[0005] In order to avoid such holes, there have been adopted the so-called "capacitive coupling" antennas, which are made by an element applied on the inside of the windscreen or the rear window of vehicles, connected with the transceiver apparatuses by means of a coaxial cable that transfers the electromagnetic energy through the glass to a counterpart applied on the outside of said glass. On the same external part, a stylus-like structure is applied which is responsible for the electromagnetic radiation.

[0006] However, also these antennas, while allowing the application without making holes in the body, comprise always an external protruding part subject to damages, tampering and/or vandalisms.

[0007] More recently, antennas have been realized that are directly mounted on the windscreen or the rear glass, in the inside of the passengers' compartment. They are constituted of flat leads having various shapes similar to monopoles or dipoles which however, because of their elongated shape, are mainly installed in an horizontal position, with ensuing distortion of the polarization of the magnetic field and a severe degradation of the radiation diagram, because of the electromagnetic coupling with the metal structures of the vehicle. Besides, their emission takes place indifferently both towards the inside and the outside of the passengers' compartment, exposing said passengers to high levels of electromagnetic field.

[0008] Planar antennas suitable for the frequencies of the radiotelephone systems, capable of obviating the above listed drawbacks, can be derived from the theory of the so-called patch-antennas, that consist essentially of two conductive surfaces, one of which has generally a size greater than the other one, aligned in parallel at a distance shorter than the wave length; between the two leads a dielectric material may be interposed or, more simply, the leads are maintained in the position by insulating spacers exploiting air as a dielectric. This class of antennas includes also the one called "QWSCM" (Quarter Wave Short Circuited Microstrip Antenna) wherein the resonating length of the upper lead is reduced by $\lambda/2$ to $\lambda/4$, shorting a radiant edge. This type of antenna has been proposed for use in the field of motor-cars; however, these proposals proved to be substantially specific, applicable, for instance, only to vehicles with non-metallic roofs, or so configured as not to allow the application on all the models of motor-cars or also configured with specific and limited characteristics, such as for instance a wave length <4% with VSWR = 2 (Voltage Standing Wave Ratio) and a prevailingly isotropic radiation diagram. The characteristics clash with the requirements of the present cellular communication systems which utilize a frequency band of at least 10% and with the increasingly contingent need of protecting passengers against the exposure to the electromagnetic fields emitted by the antennas.

[0009] Object of this invention is to eliminate the above drawbacks.

[0010] According to the present invention, these and other aims that will result from the following description are achieved by a planar antenna for motor-vehicles having the features of the characterizing part of claim 1.

[0011] In the whole, the antenna of the present invention has a low profile with contained dimensions, is of simple construction and low cost, and can be easily installed in the inside of vehicles' compartments.

[0012] The advantages achieved by the antenna of the present invention lie essentially in that it has a band length equal to or higher than 10%; it can irradiate uniformly throughout the horizontal plane with a prevailingly vertical polarization of the electric field, as it may be compared to a horizontal radiant slot (magnetic current) and allows an adequate containment of the radiation emitted in the inside of passengers' compartment, avoiding the exceeding of the electromagnetic field limits indicated by the norms in force. It may be installed, on a prior simple tuning, on any type of vehicle.

[0013] The invention is described in detail in the following, with reference to the figures of the attached drawings that show some embodiments reported by way of non limiting example and wherein:

Figures 1A and 1B show respectively the schematic plan and side views of an example of the antenna of the present invention;
Figure 2 shows the schematic side view of two possible arrangements of the antenna of Figure 1 on the rear window of a vehicle;
Figure 3 shows the perspective view of an embodiment of the planar antenna of the present invention, inductively charged by orthogonal metal strips;
Figure 4 shows the transmission line model of the antenna of Figure 3, which illustrates the concept of the resonant length reduction;
Figure 5 shows the perspective view of another embodiment of the planar antenna of the present invention, having a further reduced resonant length, thanks to a higher inductive charge;
Figure 6 shows the perspective view of a further embodiment of the planar antenna of the present invention;
Figure 7 shows the VSWR diagram of a planar antenna of the present invention, and
Figure 8 shows the radiation diagram on the horizontal plane.

[0014] The figures refer to a planar patch-antenna for use in motor-car applications of cellular telephony, of the known type indicated by the initials "QWSCM".

[0015] With reference to the figures, the microstrip planar antenna (patch) of the present invention comprises a radiant element 1, that adheres to glass 2 constituting the windshield or the rear window of a vehicle: a mass plane 8 parallel to said radiant element 1 and a continuous striped metal lead 9 connecting said radiant element to said mass plane 8, and constituting the mass shorting element.

[0016] Said antenna is fed by a coaxial cable 5 fixed to a capacitive coupling 4 applied to the mass plane 8 and spaced from the radiant element 1 by a portion which depends on the operating band of the antenna.

[0017] According to a first simplified and economical embodiment of the antenna of the present invention, shown in Figures 1A and 1B, the radiant element 1, the shorting lead 9 arranged orthogonally and the mass plane 8 are realized by punching and subsequent bending of one only continuos wall (9) which is oriented in a substantially orthogonal manner with respect to the radiant element 1 and the mass plane 8, parallel with each other.

[0018] The antenna is fed through a flat armor 13 capacitive coupling 4.

[0019] The lower distance of armor 13 from the upper radiant element 1 can be adjusted in order to optimize the radioactive and circuit characteristics of the antenna, in particular to optimize its band width.

[0020] In order to obtain a significant reduction in the emissions in the inside of motor-vehicles 20, the mass plane 8 may be possibly extended by means of a suitable transparent metallization of the low resistance, high optical transmittance rear window. To this purpose, transparent conductive films 2' applied on normal glasses may be utilized, or glasses already metallized by vacuum evaporation or sputtering, such as those already mounted on many models of motor-vehicles. With these solutions, the back radiation can he reduced by up to 100 times, equal to 20 dB.

[0021] The main characteristics of the antenna of the present invention, which distinguish it from the known ones, are basically the following:

a) The glass 2 of the rear window or the windshield constitute the over-layer of the quarter-wave radiant element and therefore contributes to determine the radioactive characteristics of the antenna, being the seat of surface waves.
b) The tapered geometric configuration of the radiant element 1 allows to obtain a widening of the operating band of the antenna; it may be quadrangular, or have sequential steps 3 decreasing towards the shorting extreme or may tend towards a practically trapezoid shape 3'.
c) The feeding of the antenna is obtained through a capacitive coupling 4 where cable 5 abuts, possibly associated to a connector 6. The position of the connector for the maximum impedance adaptation may be adjusted through the sliding and subsequent tie along a slot 7 obtained on the mass plane 8. The capacitive coupling determines a further widening of the operating band of the antenna, as it tunes the inductance associated to lead 9 substantially orthogonal to the radiant element 1 and the mass plane 8.
d) The radiant element 1 is associated to a mass plane (8) of reduced size. The radiant element 1 and the mass plane 8 are mutually engaged through said continuous orthogonal 9 or striped 9' lead, which constitutes the mass shorting element of the antenna.

[0022] Such characteristics cause the antenna of the present invention to be substantially universal for applications on any types of motor-cars and allow to operate in a band width equal to or higher than 10%, with a uniform irradiation on the horizontal plane, with a prevailingly vertical polarization of the electric field and boundary emissions of the electromagnetic field in the inside of the vehicle comprised within those indicated by the norms in force.

[0023] According to a second embodiment of the antenna of the present invention, illustrated in Figure 3, the mass shorting wall, instead of being constituted of a continuous lead 9, is constituted of several suitably spaced strips 9' whose number and shape or size are characterizing parameters of the project of the antenna, depending on the determination of the overall entity of the inductive charge and the entity of the reduction in the physical size of the antenna. The width determines the equivalent inductance associated to each strip.

[0024] Figure 4 schematizes the circuit configuration equivalent to a transmission line, wherefrom one understands that the inductive charging, realized by means of a plurality of strips 9' spaced by gaps, allows to shorten the resonant length of the antenna and, as a consequence, to reduce the size thereof. The broken lines represent the width of RF voltage within the antenna.

[0025] A further increase in the inductance of the antenna and therefore a greater compactness can be obtained with the embodiment shown in Figure 5, wherein strips 9', that constitute the body of mass shorting, instead of being rectilinear, are arc-shaped 9''. This solution can also be utilized to realize a simple tuning, by cutting one or more strips 9''.

[0026] A further embodiment, realizable even more easily and which is more suitable for mass industrialization, is obtained by forming the mass plane 8 of the antenna from a printed circuit board metallized on one side only, for instance by means of a surface coppering, and having a coplanar transmission line printed or etched as shown in Figure 6. In this way, the feeding line can be realized in the form of a coplanar microstrip, with the following advantages:

- structural simplicity, which makes fabrication easier.
- perfectly symmetrical configuration, with minimal overall dimensions.
- minimal electromagnetic perturbation,
- transition simplicity at the coaxial cable 5,
- possibility of side entrance of cable 5, through both the open side 10 of the board and side 11 of the mass shorting with straight 9' or arc-shaped 9'' strips,
- mechanical strength,
- possibility of tuning.

[0027] In the latter realization, the radiant element 1 that comprises arc-shaped strips 9'' is directly fastened to the conductive layer 12 of the mass plane 8 of the board by means of welding or rivets. The fastening is carried out along the lower ends of said strips 9''. In the same way, the capacitive coupling 4' is realized by means of a suspended foil 13, also provided with an arc-shaped strip 14 whose lower end is welded or tied with rivets or the like, at an end of the coplanar transmission line whose other end is connected to the connector or, more simply, to the coaxial cable 5.

[0028] Figure 7 shows the diagram of SWR or ROS (Stationary Waive Ratio) of an antenna according to the invention, measured with a 50 ohm standard instruments: as can be observed, its band with SWR < 2 is given by frequencies (700-1130) MHz and that the percent value with respect to the central frequency is > 20%.

[0029] Such percentage is much higher than that which is obtained with a traditional normal antenna of the QWSCM type.

[0030] The diagram of Figure 8 of radiation on the horizontal plane shows the measure of realization of an antenna with the gain value indicated in dB.

[0031] The planar antenna of the present invention is applied in particular in cellular telephony, from the present frequencies of 800/900 MHz (GSM, ETACS, AMPS, PCD) up to the higher ones of 2.5 GHz (DCS, UMTS, PCN, PCD 1.5); besides, it may be utilized for applications other than telephony, such as L, DAB, GPS band reception and the like and at higher frequencies up to 6 GHz, also for Telepass type transponder systems, and the like.

[0032] While the present invention has been described and illustrated according to some embodiments reported by way of non limiting examples, it is obvious that many alternatives and variants will he evident to those skilled in the art, in the light of the above description.

[0033] Therefore, the present invention intends to cover all the alternatives and variants that fall within the spirit and the protection scope of the appended claims.

Claims

1. A planar patch antenna, suitable to be applied to windscreens or rear window of vehicles, characterized in that it comprises:

    - a radiant element (1) adhering to glass (2) constituting the windscreen or the rear window;
    - a mass plane (8) parallel to said radiant element (1);
    - a mass shorting element comprising a metal lead (9, 9'') that connects said radiant element (1) to said mass plane (8), and
    - a feeding means comprising a capacitive coupling 4 fastened to a coaxial cable 5; said capacitive coupling 4 being applied to the mass plane (8) and spaced from the radiant element 1 of a portion that depends on the operating band of the antenna.

2. The planar antenna for motor-vehicles according to claim 1, characterized in that the capacitive coupling 4 is constituted of an armor (13) whose size depends on the band width of the antenna.

3. The planar antenna for motor-vehicles according to claim 1 o 2, characterized in that glass (2) of the windscreen or the rear window constitutes the overlayer of the radiant element (1).

4. The planar antenna for motor-vehicles according to any of the preceding claims, characterized in that the dimensions of the mass plane (8) are extended by means of a transparent metallization of the low resistivity, high optical transmittance rear window.

5. The planar antenna for motor-vehicles according to any of the preceding claims, characterized in that the radiant element (1) has a quandrangular shape or a profile with sequential steps (8) or a trapezoid shape (3') decreasing towards the open part.

6. The planar antenna for motor-vehicles according to any of the preceding claims, characterized in that the mass shorting body (9) is orthogonal to the radiant element (1) and the mass plane (8).

7. The planar antenna for motor-vehicles according to any of the preceding claims, characterized in that the shorting lead (9) is constituted of several spaced orthogonal straight (9') or arc-shaped (9'') strips.

8. The planar antenna for motor-vehicles according to any of the preceding claims, characterized in that the mass plane (8) of the antenna is obtained by means of a printed circuit board. metallized on one only side and provided with a printed or etched line of coplanar transmission.

9. The planar antenna for motor-vehicles according to claim 8, characterized in that the radiant element (1) comprising bent strips (9'') is directly associated to the conductive layer (12) of the printed circuit (8) along the lower ends of said strips (9'') and that the capacitive coupling (4') is realized with a foil (13) provided with a bent strip (14) whose lower end is fastened to an end of the coplanar transmission line of the mass plane (8).

10. The planar antenna for motor-vehicles according to any of the preceding claims 1-7, characterized in that the mass plane (8) is provided with a slot (7) wherein a lead (6) slides which is associated to the coaxial cable (5) for the adjustment of the capacitive coupling (4) with respect to the radiant element (1).

11. The planar antenna for motor-vehicles according to any of the preceding claims 1-7 and 10, characterized in that the radiant element (1), the shorting lead (9) and the mass plane (8) are realized by punching and subsequent bending of one only metal plate.

12. Use of the planar antenna according to any of the preceding claims 1 to 11 in cellular telephony with frequencies comprised between those of 800/900 MHz (GSM, ETACS, AMPS, PCD) and the higher ones of 2.5 GHz (DCS, UMPTS, PCN, PDC 1.5).

13. Use of the planar antenna according to any of the preceding claims 1 to 11 in the reception in L, DAB and GPS band, and at higher frequencies up to 6 GHz.

14. Use of the planar antenna according to any of the preceding claims 1 to 11 in the Telepass type transponder systems.

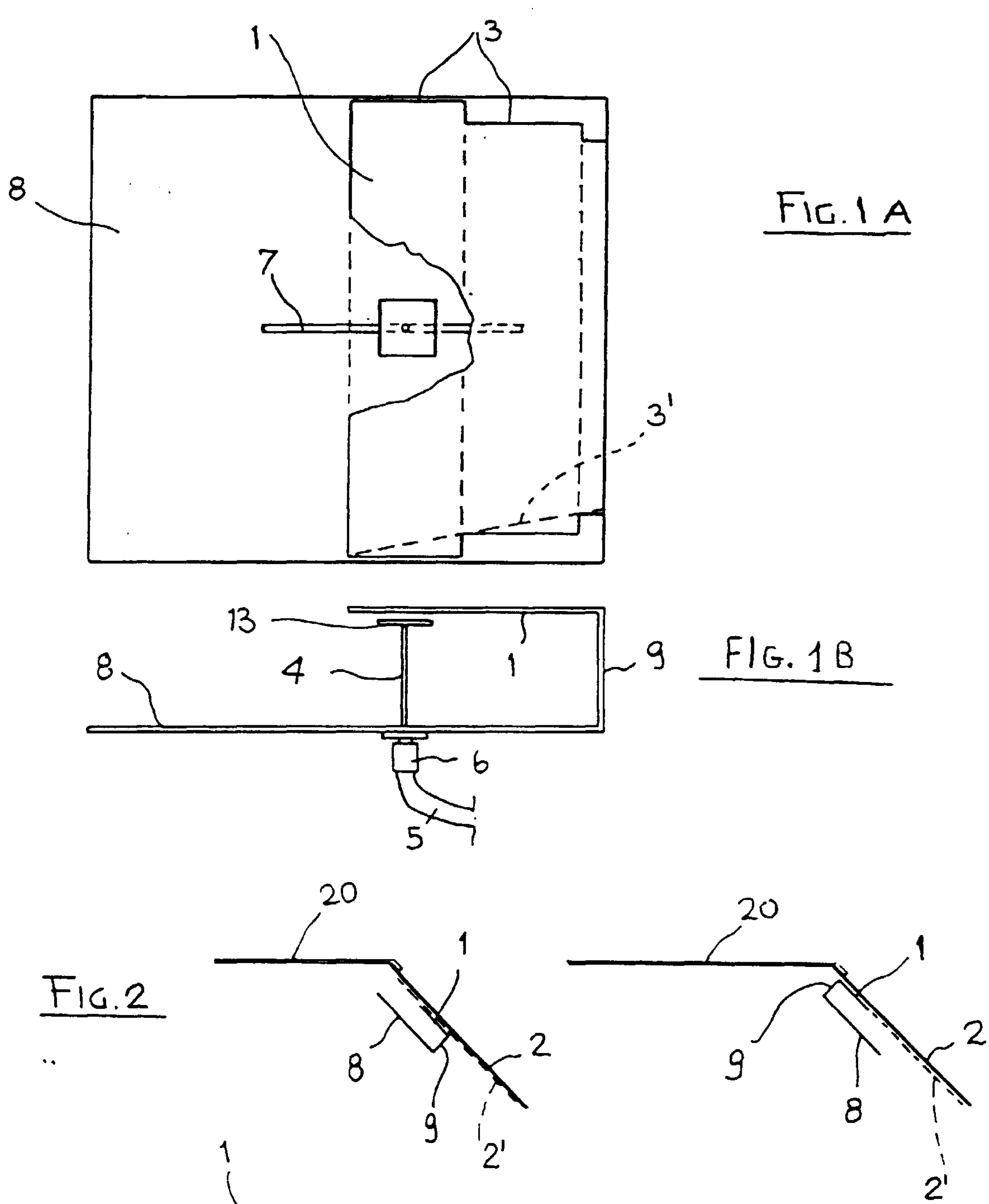


FIG. 1A

FIG. 1B

FIG. 2

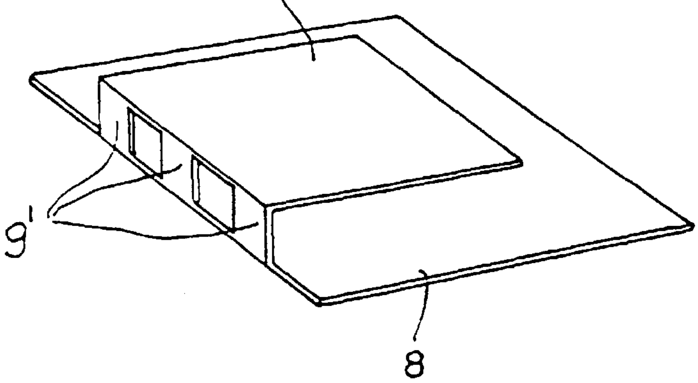


FIG. 3

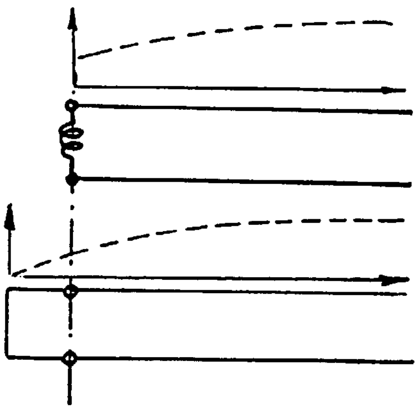


FIG.4

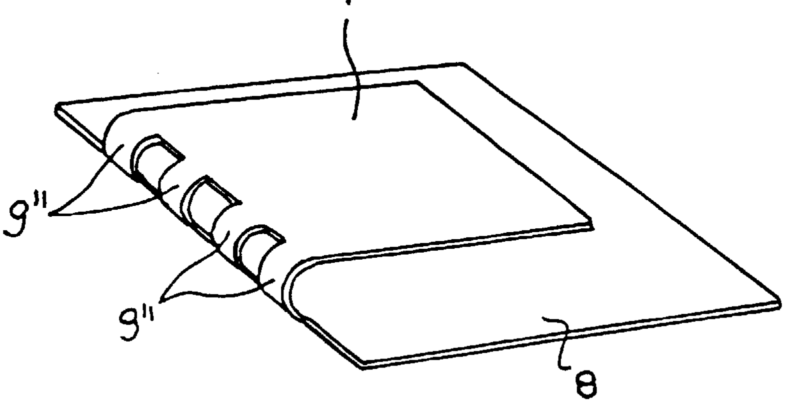


FIG.5

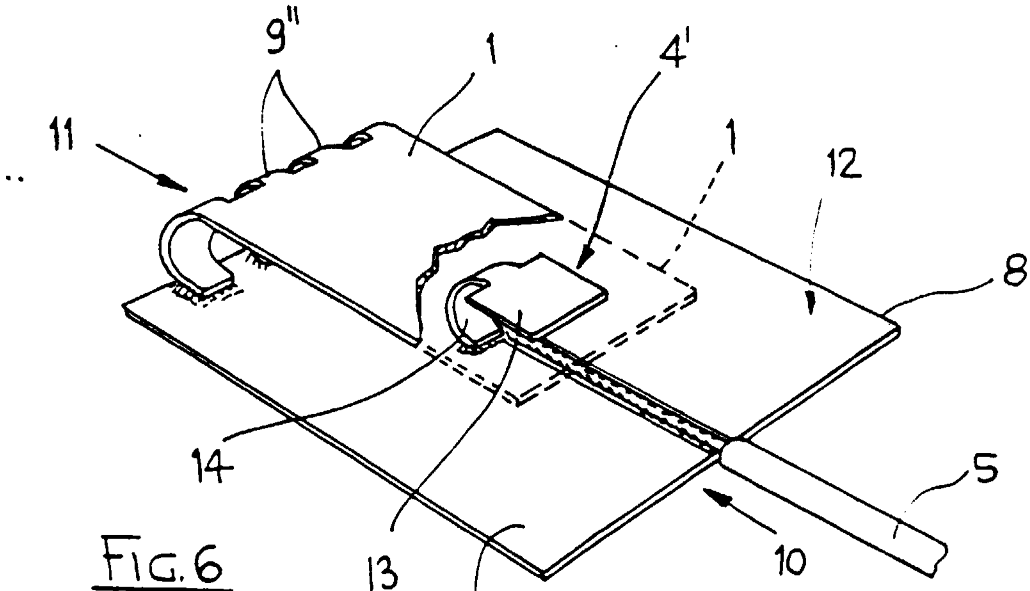
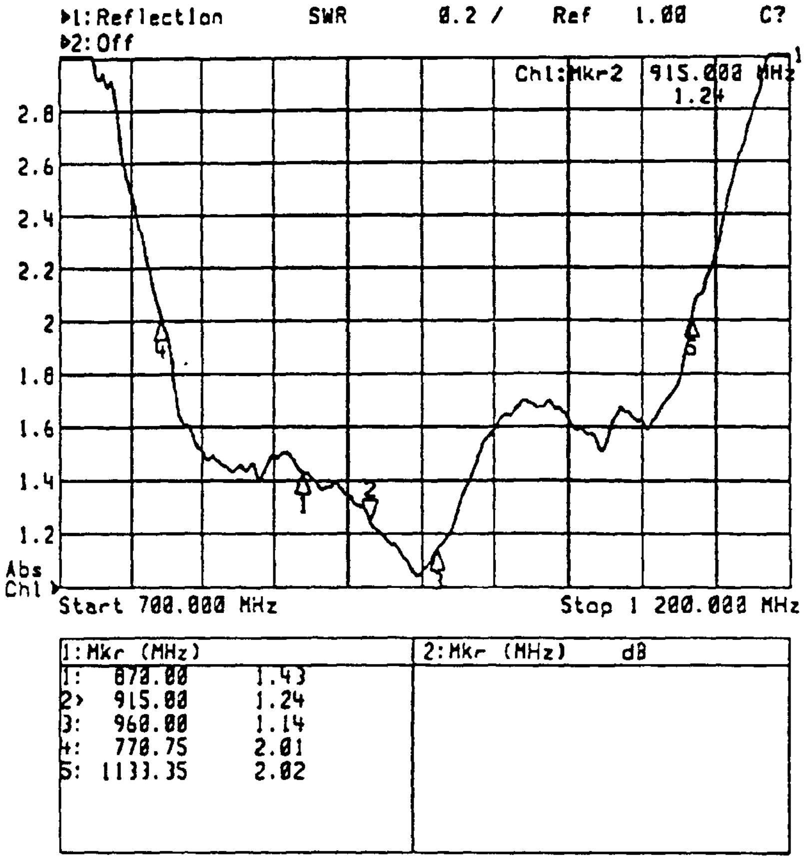


FIG.6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3: 960.00 1.14
4: 770.75 2.01
5: 1133.35 2.02
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FIG.7

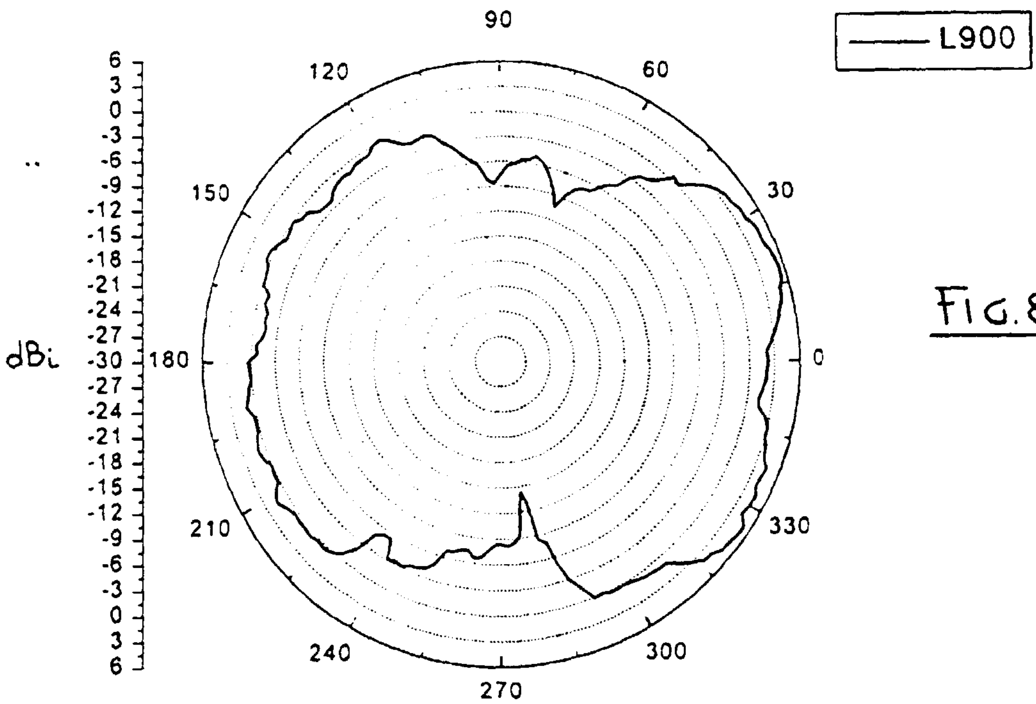
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FIG.8