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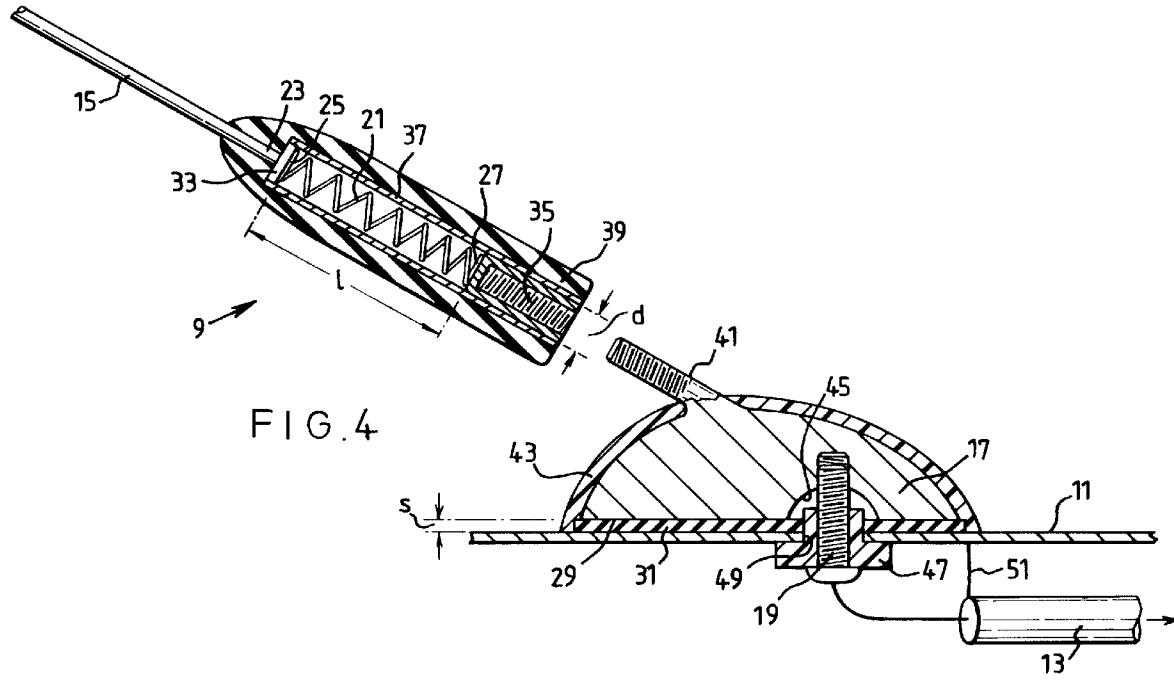
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(54) **Improved vehicular radio antennas**

(57) A radio antenna (9) for a vehicle, for mounting upon an exterior surface (11) of the vehicle and for electrical connection to a coaxial cable (13) coupled to the radio system of the vehicle, the antenna (9) comprising a mast (15) for receiving radio signals, a base (17) for mounting upon the exterior surface (11) of the vehicle and means (19) for electrically coupling the base (17) to the coaxial cable (13) of the vehicle, the mast (15) being mounted on the base (17) via an electrically conductive coil spring member (21), one end (23) of the mast (15) being mounted upon and electrically connected with one

end (25) of the spring member, the other end (27) of the spring member being mounted upon and electrically connected with the electrically conductive base (17), and the base (17) including a mounting surface (29) covered by an insulating base layer (31) for contacting the exterior surface (11) of the vehicle such that when the antenna is mounted upon the vehicle the electrically conductive base (17) does not touch and is not in direct electrical contact with the exterior surface of the vehicle (11).

EP 0 817 306 A2



Description

Field of the Invention

The invention relates to an improved radio antenna for a vehicle and in particular to a monopole antenna for a motor vehicle.

The majority of vehicles manufactured today are fitted with a radio antenna for reception of FM radio broadcasts. The most common type of antenna is the monopole antenna. This may be placed on the front or rear wing, on the A pillar or centre line of the car roof. Such antenna may consist of a fixed length rod or be telescopic.

The length and orientation of a monopole antenna relative to the vehicle bodywork play a critical part in determining the radio reception qualities in the FM band (87.5 - 108 MHz). The complex impedance of the antenna varies as a function of antenna length (at a given frequency). In order for the antenna to perform efficiently ie to transfer most of the signal power available from the antenna to the radio, the antenna impedance must be matched to the input impedance of the radio to which it is connected. For monopole antennas in general, near optimum impedance occurs when the physical length of the antenna is approximately equal to one quarter of the wavelength of the desired radio signal. This type of antenna provides good sensitivity and is referred to as a quarter wave monopole, whose length is usually chosen to be a quarter wave at the centre of the band (98 MHz) which works out to be approximately 0.75 metres.

However, in a number of modern car designs, especially where the antenna is to be roof mounted, a quarter wave monopole antenna would be too large for the vehicle. Not only would the length of the antenna itself be unwieldy, the longer an antenna is the larger its diameter needs to be for structural support and rigidity. A large diameter may detract from the appearance of the vehicle and increase the drag coefficient and wind noise. Thus it is necessary in a number of vehicles to be able to produce an efficient monopole antenna which is shorter than a quarter wave. This is known as an electrically short antenna.

Prior art systems have been developed which use an additional electronic circuit at the output of the antenna known as an impedance matching network. The purpose of such a network is to maximise the transfer of power available from the antenna to the receiver by matching the complex impedance of the antenna to the receiver input impedance. If a perfect complex conjugate impedance match between the antenna and radio can be achieved, and the matching network is loss less, then all the power available from the antenna will be transferred to the receiver. Such a system would ensure that the performance of an electrically short antenna would match that of the quarter wave monopole. The matching network typically consists of a number of passive electrical components such as capacitors and in-

ductors in a suitable circuit configuration connected to the output of the antenna. Due to the necessity to buy and then package additional electrical component, any such matching network always adds to the total cost of an electrically short antenna system.

A number of vehicle antennas have been proposed which include along the length of the mast, a coil which acts as an inductor, electrically in series with the antenna mast. Typical antennas of this type are described in DE 3931807 and US 4462033.

Glass mounted antennas for mobile telephones sometimes use the glass as a capacitive coupling between the mast and the telephone. The antenna mast is coupled to a metal plate which is mounted on the exterior surface of the glass, and a similar metal plate, mounted on the interior surface of the glass is connected to the telephone.

There has also been recognition in some prior art antennas that a capacitor can be provided by using the vehicle body as a plate of the capacitor coupled to ground. One example of such an antenna is described in CA 950978 which is a non standard antenna in the form of a horizontal rod mounted spaced from the rear of the vehicle where the air between the rod and the vehicle body acts as the dielectric. An antenna base which is capacitively mounted upon the body via a dielectric layer is also described in W092/10865. In this system the antenna base and coaxial cable are arranged such that the coaxial cable is capacitively coupled to ground via the dielectric layer.

Summary of the Invention

According to the invention there is provided a radio antenna for a vehicle, for mounting upon the body of the vehicle and for electrical connection to a coaxial cable coupled to the radio system of the vehicle, the antenna comprising a mast for receiving radio signals, a base for mounting upon the exterior surface of the vehicle and means for electrically coupling the base to the coaxial cable of the vehicle, the mast being mounted on the base via an electrically conductive coil spring member, one end of the mast being mounted upon and electrically connected with one end of the spring member, the other end of the spring member being mounted upon and electrically connected with the electrically conductive base, and the base including a mounting surface covered by an insulating base layer for contacting the body of the vehicle and sealing the gap between the base and the body such that when the antenna is mounted upon the vehicle the electrically conductive base does not touch and is not in direct electrical contact with the body of the vehicle, but there is a capacitive connection between the base and the vehicle body via the insulating base layer.

In such a system the matching network is intrinsically built into the physical structure of the antenna. No discrete electrical components are used in the design

which means that the total cost of the electrically short antenna is effectively reduced while improving the radio reception capability.

The coil spring acts as an inductor to artificially increase the electrical length of the antenna, while at the same time providing mechanical flexibility which helps with car wash robustness and avoiding the effects of vandalism. The electrically conductive base, the insulating base layer and the body of the vehicle together act as a capacitor. The capacitance is obtained through the capacitive effect between the footprint of the antenna base and the body work of the vehicle separated by non-conducting material. The capacitor thus formed couples the base of the inductor to ground. However there is still a direct connection between the inductor and the coaxial cable. Typically such non-conducting material may comprise a non-water absorbent rubber grommet which at the same time as acting as the dielectric for the capacitor also acts as a very effective water seal.

Because the antenna base does not need to include any further electrical components the base can be a substantially solid piece of conductive material. Advantageously the base is die cast.

Alternatively the insulating base material may be plastic exhibiting properties of non-compressibility and imperviousness to moisture whilst at the same time having a time invariant dielectric constant and being physically stable over the typical temperature range encountered in automotive applications.

Preferably however the insulating base layer comprises a central plastic piece and a slightly thicker non water absorbent rubber section around the circumference of the plastic thus providing a combination of non-compressibility provided by the plastic and water seal from the rubber seal which compresses to the thickness of the plastic part.

Preferably the spring coil member is of steel whose characteristics have been chosen to give the required stiffness of spring and spring inductance. More preferably the steel spring is copper plated to minimise the ohmic losses of the network.

In one example of an antenna in accordance with the invention, it has been found that an inductance of approximately 290nH and capacitance of 10pF are suitable for the matching network. It has been found that a spring having 8mm diameter and 18mm long supplies the required inductance and the capacitance may be achieved using a base footprint area of 200mm² and a dielectric seal 1mm thick whose relative permittivity is approximately 2.3.

Preferably the means for mounting the antenna to the exterior surface of the vehicle comprises an electrically conductive screw passing through a cylindrical bore in the exterior surface and being surrounded by an insulating sleeve such that the screw is in contact with the base but insulated from the exterior panel and the insulating base layer, the head of the screw being for

connecting to the coaxial cable thus supplying means to couple the base to the coaxial cable without providing a direct connection between the base and the exterior surface.

In this way the screw acts as the means for coupling the base to the coaxial cable but also acts as means for mounting the base on the vehicle.

Brief Description of the Drawings

An example of the radio antenna in accordance with the invention will now be described and contrasted with the prior art, with reference to the accompanying drawings, in which : -

Figure 1 is a schematic circuit configuration of an antenna of the prior art; Figure 2 is a graph of mismatch loss versus frequency of the antenna of the prior art with and without a matching network;

Figure 3 is a schematic circuit configuration of an example of a radio antenna in accordance with the invention;

Figure 4 is a schematic section through an antenna in accordance with the invention;

Figure 5 is a plan view of part of the antenna as shown in Figure 4;

Figure 6 is a graph of mismatch loss against frequency of the antenna shown in Figure 4 compared with an antenna of the prior art; and,

Figure 7 is a graph of FM tuner audio signal to noise ratio against radio frequency input level.

Description of the Preferred Embodiment

The antenna of the prior art is not illustrated. It comprises a roof mounted electrically short monopole antenna which is 0.48 metres long having an impedance matching network illustrated in Figure 1 packaged in the base of the antenna. The matching network consists of only one component, an inductor coil 1 which is coupled between the antenna 3 and coaxial cable 5. The coaxial cable 5 is coupled to the radio system of the vehicle and is also connected to earth 7. The graph of figure 2 illustrates the measured data of mismatch loss versus frequency of this antenna with and without the matching network. Mismatch loss is a measurable expressed in decibels (dB) which quantifies the degradation of power transfer from the antenna into a specified load impedance (75 ohms in this case) due to differences between antenna and load impedances. Maximum power transfer occurs when the antenna impedance is equal to the complex conjugate of the load impedance and this condition is represented by a mismatch loss of zero decibels. As can be seen from figure 2 the matching network employed in the antenna of the prior art significantly reduces the mismatch loss of the antenna without the matching network.

Figure 4 illustrates an example of a radio antenna

in accordance with the invention, while figure 3 illustrates the equivalent electric circuit. The antenna 9 is for mounting upon an exterior surface 11 of the vehicle for electrical connection to a coaxial cable 13 coupled to the radio system (not shown) of the vehicle. The antenna 9 comprises a mast 15 for receiving radio signals and a base 17 for mounting upon the exterior surface 11 of the vehicle. Means 19 electrically and mechanically couple the base 17 to the coaxial cable 13 of the vehicle. The mast 15 is mounted upon the base 17 via an electrically conductive coil spring 21, one end 23 of the mast being mounted upon and electrically connected with one end 25 of the spring member. The other end 27 of the coil spring member is mounted upon and electrically connected with the electrically conductive base 17. The base 17 includes a mounting surface 29 covered by an insulating base layer 31 for contacting the exterior surface 11 of the vehicle such that when the antenna is mounted upon the vehicle as shown in figure 4 the electrically conductive base 17 is not in direct electrical contact with the exterior surface 11 of the vehicle.

At the end 23 of the mast 15 is a metallic disc 33 of the same diameter as the coil spring 21. At the other end 27 of the coil spring is an internally threaded metallic member 35. The metal disc 33 spring 21 and metallic member 35 all sit within annular sleeve 37 which is flexible and plastic. Around this is non water absorbent rubber cover 39. The internally threaded member 35 mates with threaded stud 41 which extends from base 17 and is externally screw threaded. A plastic cover 43 covers the base 17. In this case the base 17 is part spherical with a semi-spherical cut-out 45. Because this is a simple solid without requiring mounting of any further electrical components the base 17 is die cast.

The antenna base 17 is secured to the panel 11 by screw 19 which is electrically conductive. The screw 19 sits within insulating nut 47 which includes a cylindrical bore for accommodating the screw 19. The screw 19 passes through bore 49 in panel 11 through the semi-spherical cut-out 45 and screws into 17. The semi-spherical cut-out 45 provides tolerance for mounting the screw into the base. The surface 29 of the base 17 can be seen clearly in figure 5.

An auxiliary connection 51 couples the panel 11 to co-axial cable 13. This provides a simple but effective antenna impedance matching network which is equivalent to that depicted in figure 3 but is built into the physical structure of the antenna avoiding the cost of using discrete electrical components. It should be noted that details of the attachment method of the antenna base to the coaxial cable are not described in detail here since they are well known and apparent to the skilled addressee of the specification.

The required values of inductance and capacitance for the correct operation of the matching network are obtained through careful design of the physical parameters of the spring 21:

Length l

Number of turns N .

Diameter d

and the physical parameters of the antenna base 17; Footprint surface area (A)

Distance to body work (S);

and the permativity or dielectric constant of the rubber insulating material (ϵ_r)

Suitable inductance and capacitance values for the matching network have been calculated which are approximately 290 nH and 10pF respectively. To achieve the required inductance the spring 21 is approximately 80mm long and 8mm diameter. The required capacitance was achieved using a base footprint area of 200mm² and a non water absorbent rubber seal 1mm thick. The relative permativity of the rubber seal is estimated to be approximately 2.3.

Figure 6 illustrates the measured mismatch loss of this prototype antenna compared to that of the prior art in which a significant improvement can be observed. The antenna described does not have its lowest point of mismatch loss exactly at mid-band position indicating that minor adjustments to the spring inductance and base capacitance may be needed. However it shows a 2.55 to 2.0dB improvement over the bottom half of the FM band (87.5-98 MHz) and 2.0 to 0.75 dB improvement over the top half of the FM band (98-108 MHz). At the point of minimum mismatch loss shows a 2.3 dB improvement over the current antenna design. Mismatch loss reduction is not the only benefit offered in terms of perceived radio reception quality. A further parameter associated with reception quality is audio signal to noise ratio (S/N) at the output of the radio and figure 6 shows a typical graph of FM tuner audio S/N versus radio frequency RF input level. The graph has two sections. The first section of the graph has a slope of 3.5 while the second section has a slope of 1. The point of inflexion is known as the FM threshold point which occurs when the carrier to noise ratio of the FM signal reaches about 10, a condition which typically occurs at about 99 dBm or 2.42 uV RF signal level. Below threshold there is a rapid rise in audio signal to noise ratio as the radio frequency level increases. The rate of signal to noise improvement is approximately 3.5 dB for every 1 dB increase in RF signal level. Beyond threshold the rate of signal to noise improvement reduces to 1 dB for every 1 dB increase in RF signal level. The graph indicates that under weak signal conditions (below threshold and typically in the signal range 1-2.5 uV) the correct impedance matching between satisfaction and can represent the difference between an antenna and radio is of critical importance to ensure higher audio signal to noise ratios and hence better reception quality. For every dB of mismatch loss improvement one can expect an increase of 3.5 dB in audio signal to noise.

Comparing the current antenna to the prior art the in-

vention enables the following audio S/N improvement to be achieved over 1-2.5 uV RF input level range:

8.7-7 dB improvement over bottom half of the FM band
7-2.6 dB improvement over top half of the FM band. Under such weak signal conditions the signal to noise improvement can contribute a significant amount to customer unlistenable and acceptable radio signal. Other benefits of improved impedance matching at stronger signal levels (above threshold) are that the effects of multipath nulls which manifest themselves as audio spits are reduced since the radio is capable of recovering more of the signal out of the nulls.

It will be appreciated by the skilled addressee of this specification that the physical characteristics of the spring and the antenna base can be chosen to give the required inductance and capacitance or the antenna impedance matching circuit and also the required mechanical properties of the antenna.

Claims

1. A radio antenna for a vehicle, for mounting upon an exterior surface of the vehicle and for electrical connection to a coaxial cable coupled to the radio system of the vehicle, the antenna comprising a mast for receiving radio signals, a base for mounting upon the exterior surface of the vehicle and means for electrically coupling the base to the coaxial cable of the vehicle, the mast being mounted on the base via an electrically conductive coil spring member, one end of the mast being mounted upon and electrically connected with one end of the spring member, the other end of the spring member being mounted upon and electrically connected with the electrically conductive base, and the base including a mounting surface covered by an insulating base layer for contacting the exterior surface of the vehicle such that when the antenna is mounted upon the vehicle the electrically conductive base does not touch and is not in direct electrical contact with the exterior surface of the vehicle.

2. A radio antenna according to claim 1, in which the insulating base layer comprises a rubber grommet.

3. A radio antenna according to claim 1, in which the insulating base layer is a layer of substantially non compressible plastics material, which is substantially non water absorbent and a substantially stable dielectric constant.

4. A radio antenna according to claim 1, in which the insulating base layer comprises an inner region of plastics and an outer region of rubber, the outer region surrounding and abutting the plastics inner region.

5. A radio antenna according to any one of the preceding claims, in which the coil spring member is made of steel.

6. A radio antenna according to claim 5, in which, the steel spring is copper plated.

7. A radio antenna according to any one of the preceding claims in which the means for mounting the antenna to the exterior surface of the vehicle comprises an electrically conductive screw for passing through a cylindrical bore in the exterior surface and being surrounded by an insulating sleeve such that the screw is in contact with the base but insulated from the exterior panel and the insulating base layer, the head of the screw being for connecting to the coaxial cable thus supplying means to couple the base to the coaxial cable without providing a direct electrical connection between the base and the exterior surface.

8. A radio antenna according to any one of the preceding claims, in which the spring member and the antenna base insulating base layer and vehicle surface together form the sole components of the impedance matching circuit of the antenna.

9. A radio antenna arranged substantially as herein described, with reference to and as illustrated in figures 3 to 6 of the accompanying drawings.

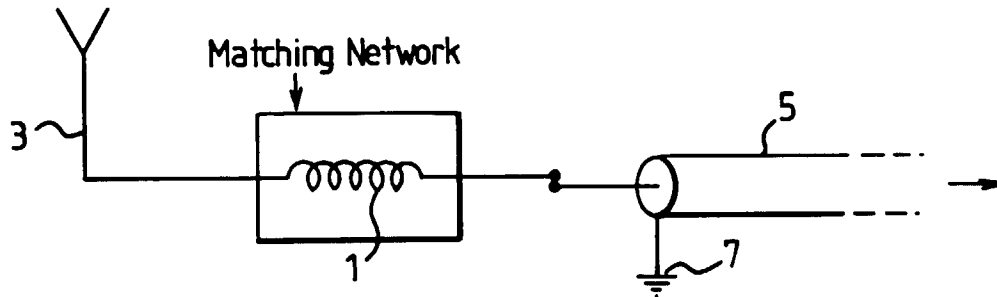


FIG. 1

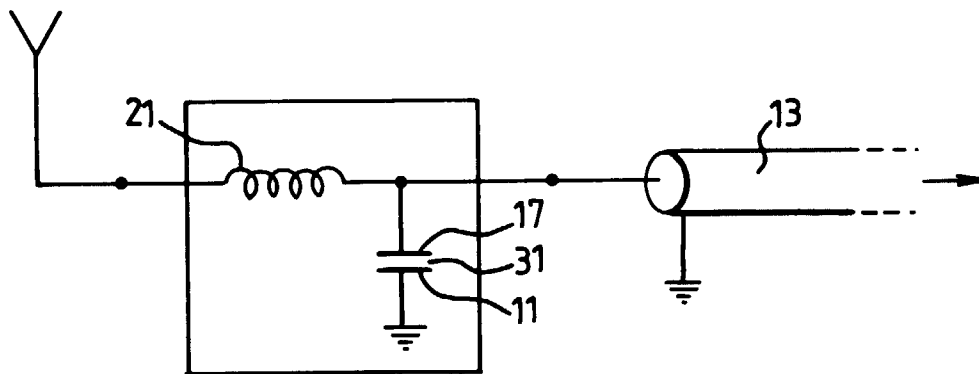
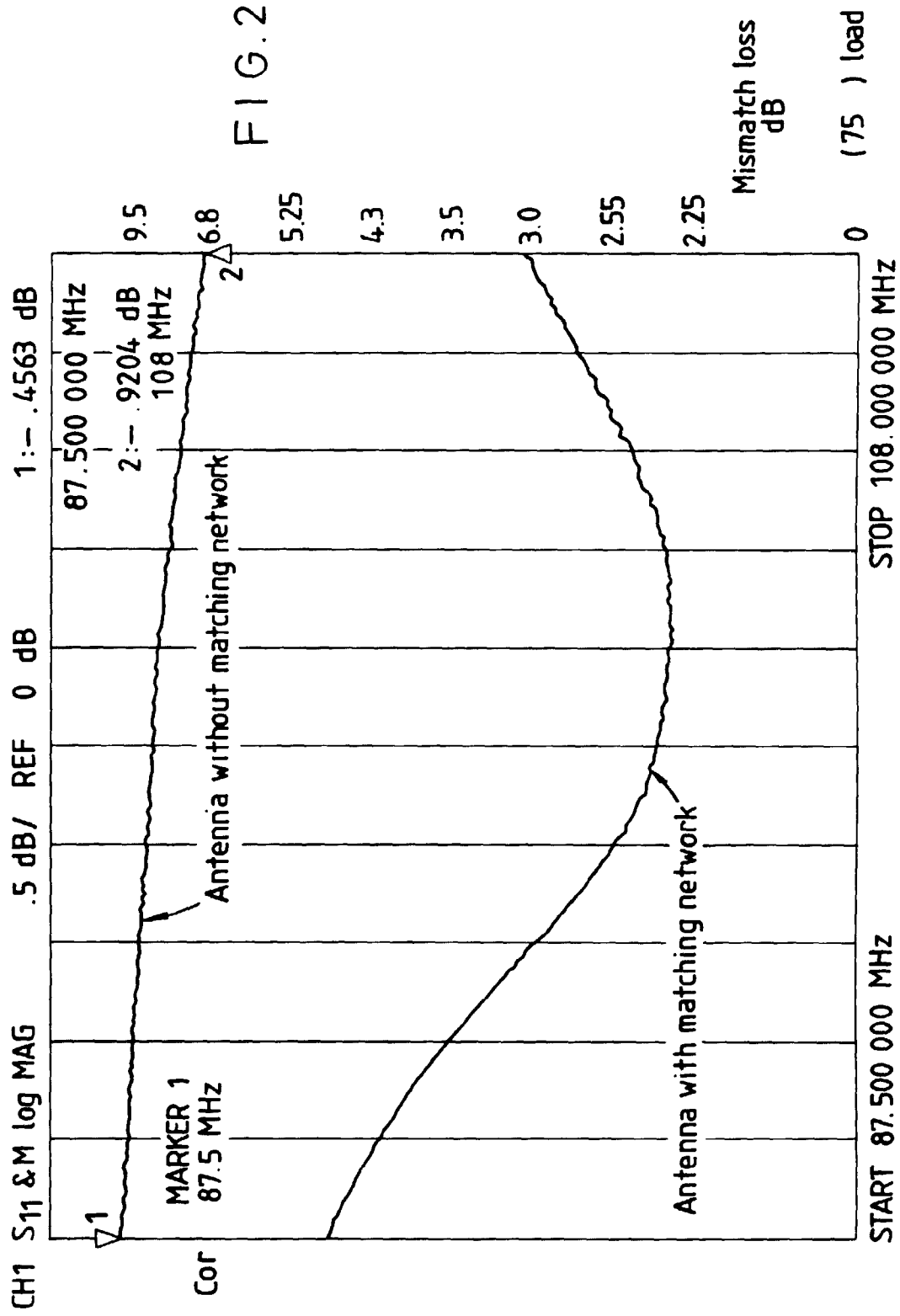


FIG. 3



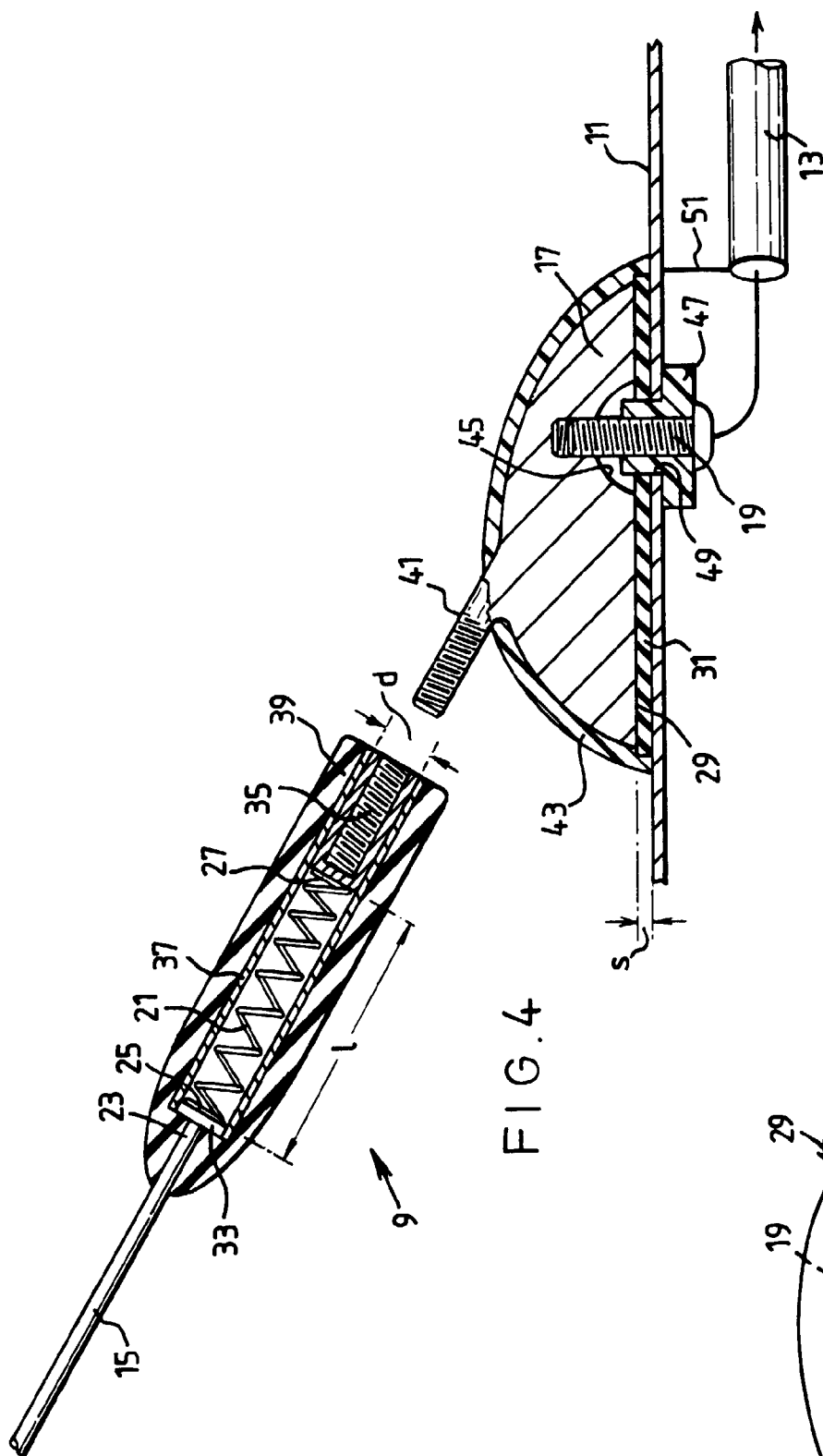


FIG. 4

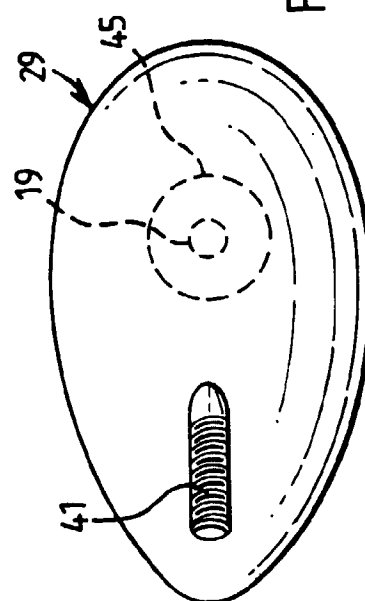
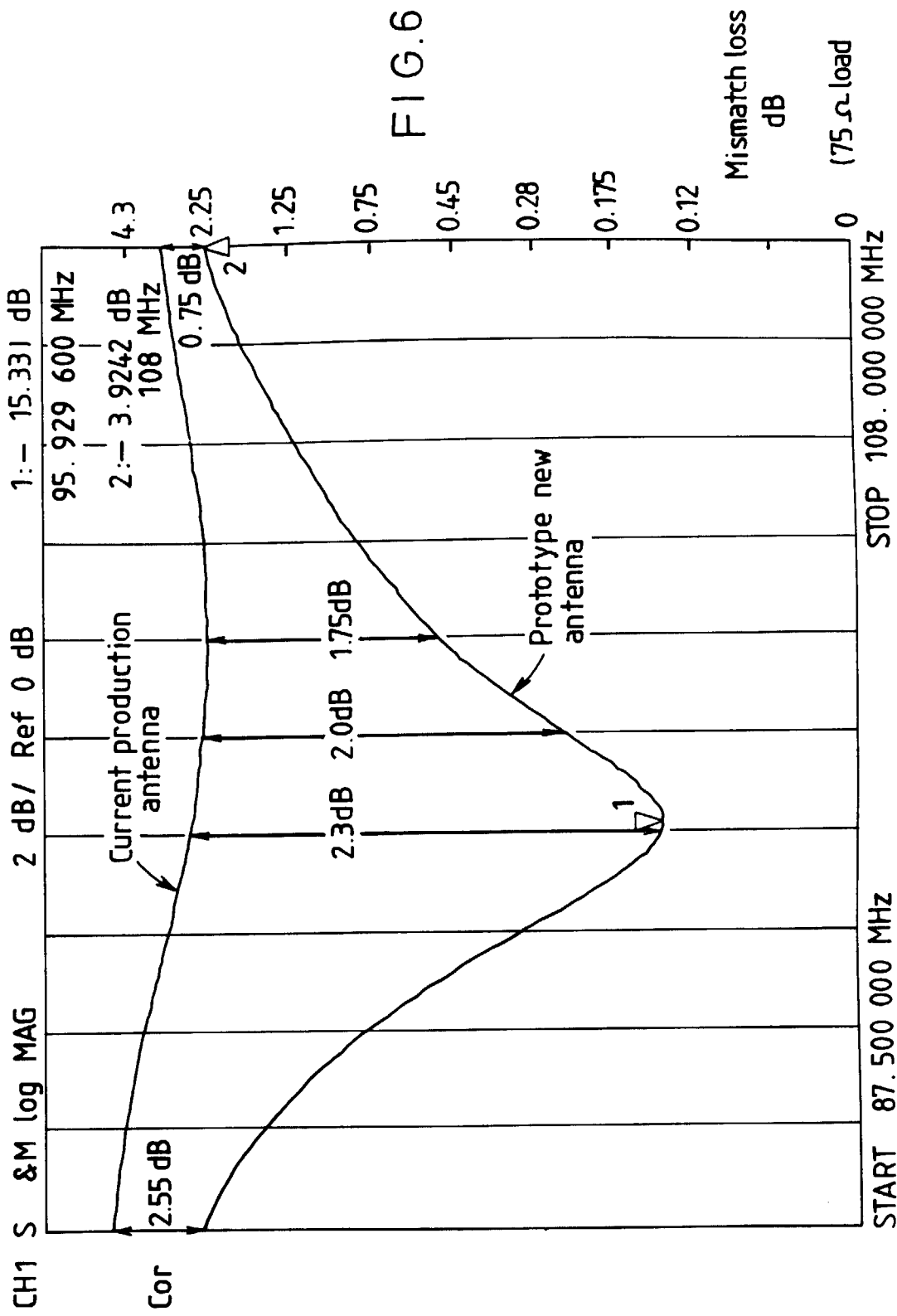


FIG. 5



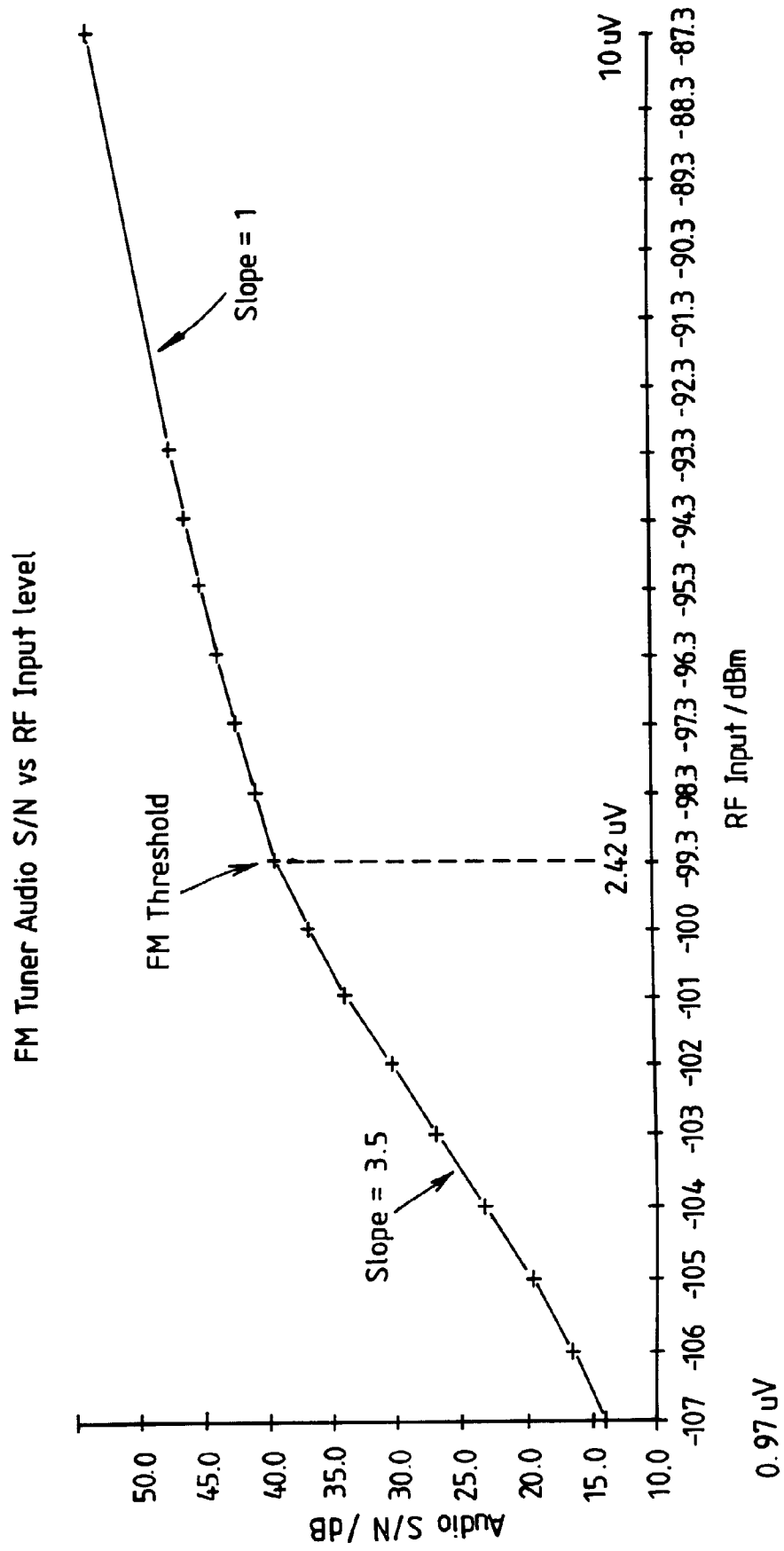


FIG.7