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(54) **Improved vehicular radio antennas**

Fahrzeugantennen

Antennes de véhicule

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US-A- 4 794 319
US-A- 4 825 217

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Description

Field of the Invention

[0001] The invention relates to an improved radio antenna for a vehicle and in particular to a monopole antenna for a motor vehicle.

[0002] 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.

[0003] 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.

[0004] 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.

[0005] 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 inductors 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.

[0006] 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, USS 4462033 and US 4058811.

[0007] 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. An example of this is described in United States Patent No 4,825,217.

[0008] 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

[0009] According to the invention there is provided a vehicle with a radio antenna mounted upon the body of the vehicle according to claim 1, specific embodiments being set out in the dependent claims.

[0010] 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.

[0011] 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.

[0012] 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.

[0013] 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.

[0014] 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.

[0015] 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.

[0016] 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 200mm^2 and a dielectric seal 1mm thick whose relative permativity is approximately 2.3.

[0017] 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.

[0018] 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

[0019] 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

[0020] 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.

[0021] 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 cov-

ered 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.

[0022] 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.

[0023] 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.

[0024] 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.

[0025] 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 1
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 200mm^2 and a non water absorbent rubber seal 1mm thick. The relative permativity of the rubber seal is estimated to be approximately 2.3.

[0026] 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 6shows 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 invention 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 vehicle with a radio antenna (9) mounted upon an exterior surface (11) of the vehicle, the exterior surface of the vehicle being the body (11) of the vehicle functionning as ground for the antenna (9), 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, an electrically conducting base (17) mounted upon the exterior surface (11) of the vehicle and means (19) for electrically coupling the base (17) to the inner conductor of 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 (33) of the mast (15) being mounted upon and electrically connected with one end (25) of the spring member (21), the other end (27) of the spring member (21) being mounted upon and electrically connected with the 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 the electrically conductive base (17) does not touch and is not in direct electrical contact with the exterior surface (11) of the vehicle and such that there is provided a capacitive connection between the base (17) and the body (11) via the insulating base layer (31).

2. A vehicle according to claim 1, in which the insulating base layer (31) comprises a rubber grommet.

3. A vehicle according to claim 1, in which the insulating base layer (31) is a layer of substantially non compressible plastics material, which is substantially non water absorbent and a substantially stable dielectric constant.

4. A vehicle according to claim 1, in which the insulating base layer (31) comprises an inner region of plastics and an outer region of rubber, the outer region surrounding and abutting the plastics inner region.

5. A vehicle according to any one of the preceding claims, in which the coil spring member (21) is made of steel.

6. A vehicle according to claim 5, in which, the steel spring(21) is copper plated.

7. A vehicle according to any one of the preceding claims in which the antenna is mounted upon the vehicle body (11) by an electrically conductive screw (19) which passes through a cylindrical bore (49) in the vehicle body (11) and is surrounded by an insulating sleeve (47) such that the screw (19) is in contact with the base (17) but insulated from the vehicle body (11) and the insulating base layer (31), the head of the screw (19) being for connecting to the coaxial cable (13).

8. A vehicle according to claim 1, in which the spring member (21) and the capacitive connection between the base (17) and the body (11) via the insulating base (31) form the sole components of an impedance matching circuit for the antenna (9).

Patentansprüche

1. Ein Fahrzeug mit einer Radioantenne (9), welche auf einer äußeren Oberfläche (11) des Fahrzeugs angebracht ist, wobei die äußere Oberfläche des Fahrzeugs die Karosserie (11) des Fahrzeugs ist, welche als Masse für die Antenne (9) dient, und mit einem Koaxialkabel (13) elektrisch verbunden ist, welches mit dem Radiosystem des Fahrzeugs verbunden ist, wobei die Antenne (9) einen Mast (15) zum Empfangen von Radiosignalen, eine(n) elektrisch leitende(n) Fuß oder Basis (17), welcher auf der äußeren Oberfläche (11) des Fahrzeugs angebracht ist, und Mittel (19) zum elektrischen Verbinden des Fußes (17) mit dem inneren Leiter des Koaxialkabels (13) des Fahrzeugs, wobei der Mast (15) auf dem Fuß (17) mittels eines elektrisch leitenden Schraubfederelements (21) angebracht ist, umfasst, wobei ein Ende (33) des Mastes (15) auf einem Ende (25) des Federelements (21) angebracht und mit diesem elektrisch verbunden ist, das andere Ende (27) des Federelements (21) auf dem Fuß (17) angebracht ist und mit diesem elektrisch verbunden ist, und wobei der Fuß (17) eine Befestigungsfläche (29) umfasst, welche durch eine isolierende Bodenschicht (31) zum Berühren der äußeren Oberfläche (11) des Fahrzeugs bedeckt ist, so dass der elektrisch leitende Fuß (17) die äußere Oberfläche (11) des Fahrzeugs nicht berührt und nicht in direktem elektrischen Kontakt mit dieser steht und so dass eine kapazitive Verbindung zwischen dem Fuß (17) und der Karosserie (11) über die isolierende Bodenschicht (31) bereit gestellt wird.

2. Ein Fahrzeug gemäß Anspruch 1, in dem die isolierende Bodenschicht (31) eine Gummi-Durchgangstülle umfasst.

3. Ein Fahrzeug gemäß Anspruch 1, in dem die isolierende Bodenschicht (31) eine Schicht aus im We-

sentlichen nicht zusammendrückbarem Kunststoffmaterial ist, welche im Wesentlichen nicht Wasser absorbierend ist und eine im Wesentlichen stabile dielektrische Konstante aufweist.

4. Ein Fahrzeug gemäß Anspruch 1, in dem die isolierende Bodenschicht (31) einen inneren Bereich aus Kunststoff und einen äußeren Bereich aus Gummi umfasst, wobei der äußere Bereich den inneren Kunststoffbereich umgibt und an diesen stößt.

5. Ein Fahrzeug gemäß einem der vorstehenden Ansprüche, in dem das Schraubfederelement (21) aus Stahl hergestellt ist.

6. Ein Fahrzeug gemäß Anspruch 5, in dem die Stahlfeder (21) mit Kupfer plattiert ist.

7. Ein Fahrzeug gemäß einem der vorstehenden Ansprüche, in dem die Antenne auf der Fahrzeugkarosserie (11) durch eine elektrisch leitende Schraube (19) angebracht ist, welche durch eine zylindrische Bohrung (49) in der Fahrzeugkarosserie (11) hindurch geht und durch eine isolierende Hülse (47) umgeben ist, so dass die Schraube (19) in Kontakt mit dem Fuß (17) steht, aber von der Fahrzeugkarosserie (11) und der isolierenden Bodenschicht (31) isoliert ist, wobei der Kopf der Schraube (19) zum Verbinden mit dem Koaxialkabel (13) dient.

8. Ein Fahrzeug gemäß Anspruch 1, in dem das Federelement (21) und die kapazitive Verbindung zwischen dem Fuß (17) und der Karosserie (11) über den isolierenden Boden (31) die einzigen Bauteile einer Impedanz abgleichenden Schaltung für die Antenne (9) bilden.

Revendications

1. Un véhicule avec une antenne radio (9) montée sur une surface extérieure (11) du véhicule, la surface extérieure du véhicule étant la carrosserie (11) du véhicule fonctionnant comme masse pour l'antenne (9), pour couplage électrique à un câble coaxial (13) couplé au système radio du véhicule, l'antenne (9) comprenant un mât (15) pour recevoir des signaux radio, une base conductrice d'électricité (17) montée sur la surface extérieure (11) du véhicule et des moyens (19) pour coupler électriquement la base (17) au conducteur interne du câble coaxial (13) du véhicule, le mât (15) étant monté sur la base (17) au moyen d'un ressort hélicoïdal (21) conducteur d'électricité, une extrémité (33) du mât (15) étant montée sur et électriquement couplée avec une extrémité (25) du ressort (21), l'autre extrémité (27) du ressort (21) étant montée sur et électriquement couplée avec la base (17), et la base (17) comprenant une surface de montage (29) recouverte d'une couche de base isolante (31) au contact de la surface extérieure (11) du véhicule de manière à ce que la base conductrice d'électricité (17) ne touche pas la surface extérieure (11) du véhicule ni ne soit au contact électrique direct de la surface extérieure (11) du véhicule, ainsi que de manière à fournir un couplage capacitif entre la base (17) et la carrosserie (11) au moyen de la couche de base isolante (31).

2. Un véhicule selon la revendication 1, dans lequel la couche de base isolante (31) comprend un passe-fil isolant ou en caoutchouc.

3. Un véhicule selon la revendication 1, dans lequel la couche de base isolante (31) est une couche de matériau plastique substantiellement non-compressible, substantiellement imperméable et une constante diélectrique substantiellement stable.

4. Un véhicule selon la revendication 1, dans lequel la couche de base isolante (31) comprend une région interne en plastique et une région externe en caoutchouc, la région externe entourant et abutant la région interne en plastique.

5. Un véhicule selon l'une quelconque des revendications précédentes, dans lequel le ressort hélicoïdal (21) est en acier.

6. Un véhicule selon la revendication 5, dans lequel le ressort (21) en acier est plaqué de cuivre.

7. Un véhicule selon l'une quelconque des revendications précédentes, dans lequel l'antenne est montée sur la carrosserie (11) du véhicule par une vis conductrice d'électricité (19), passant au travers d'un alésage cylindrique (49) pratiqué dans la carrosserie (11) du véhicule et entourée par une manche isolante (47), de manière à ce que la vis (19) soit au contact de la base (17) mais isolée de la carrosserie (11) du véhicule ainsi que de la couche de base isolante (31), la tête de la vis (19) devant être couplée au câble coaxial (13).

8. Un véhicule selon la revendication 1, dans lequel le ressort hélicoïdal (21) et le couplage capacitif entre la base (17) et la carrosserie (11) au moyen de la couche de base isolante (31) sont les uniques composants d'un circuit à ajuster l'impédence pour l'antenne (9).

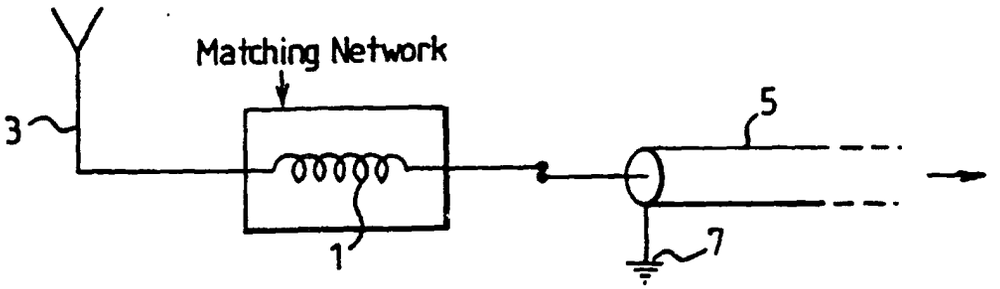


FIG.1

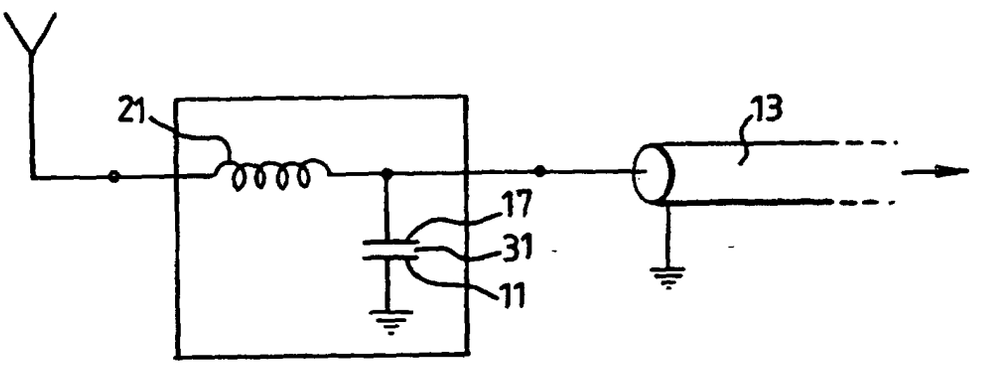


FIG.3

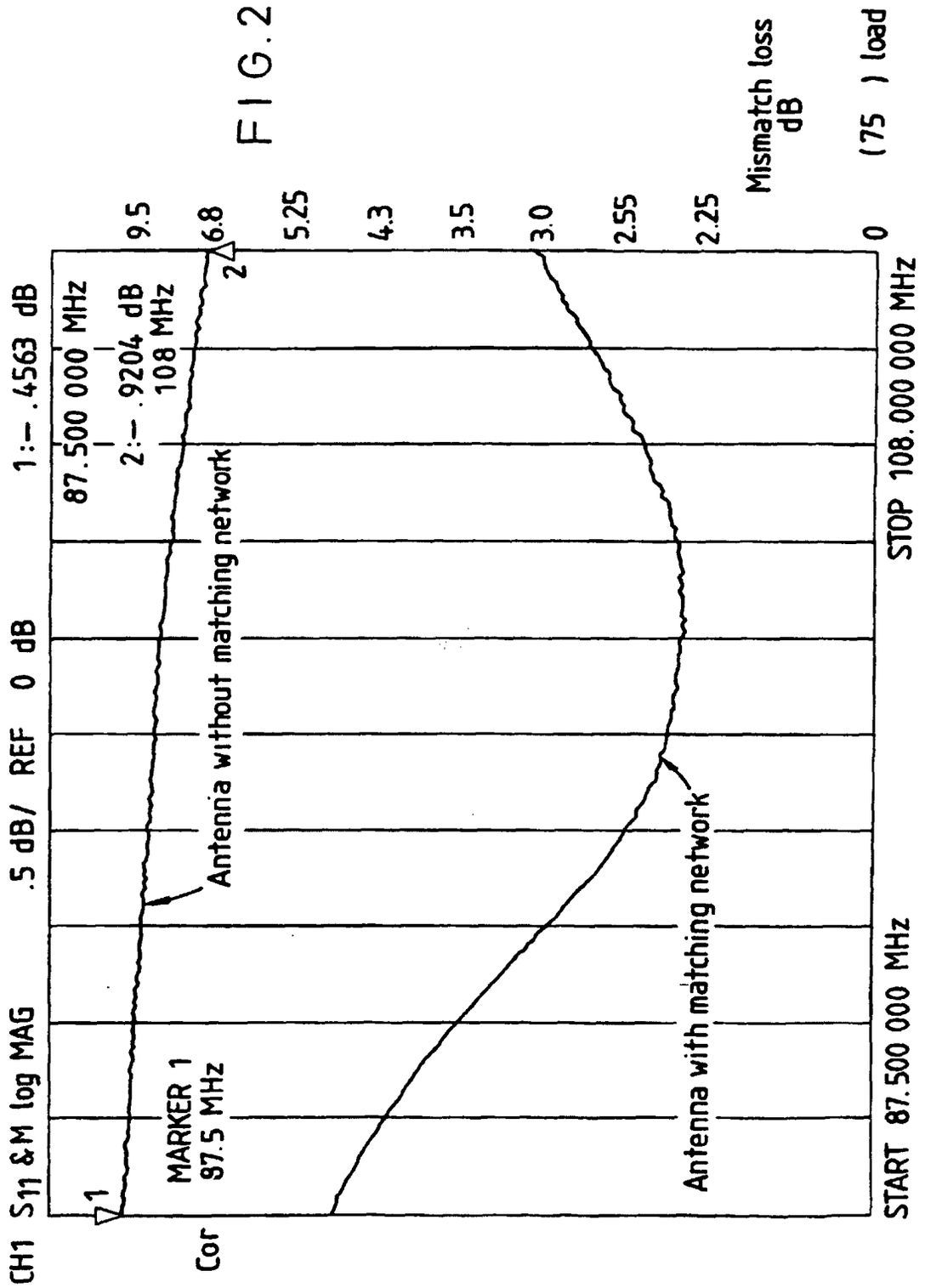

CH1 S11 &M log MAG
.5 dB/ REF 0 dB
1:- .4563 dB
87.500 000 MHz
2:- .9204 dB
108 MHz
Cor
MARKER 1
97.5 MHz
Antenna without matching network
Antenna with matching network
START 87.500 000 MHz
STOP 108.000 000 MHz
Mismatch loss
dB
(75) load
9.5
6.8
5.25
4.3
3.5
3.0
2.55
2.25
0

FIG.2

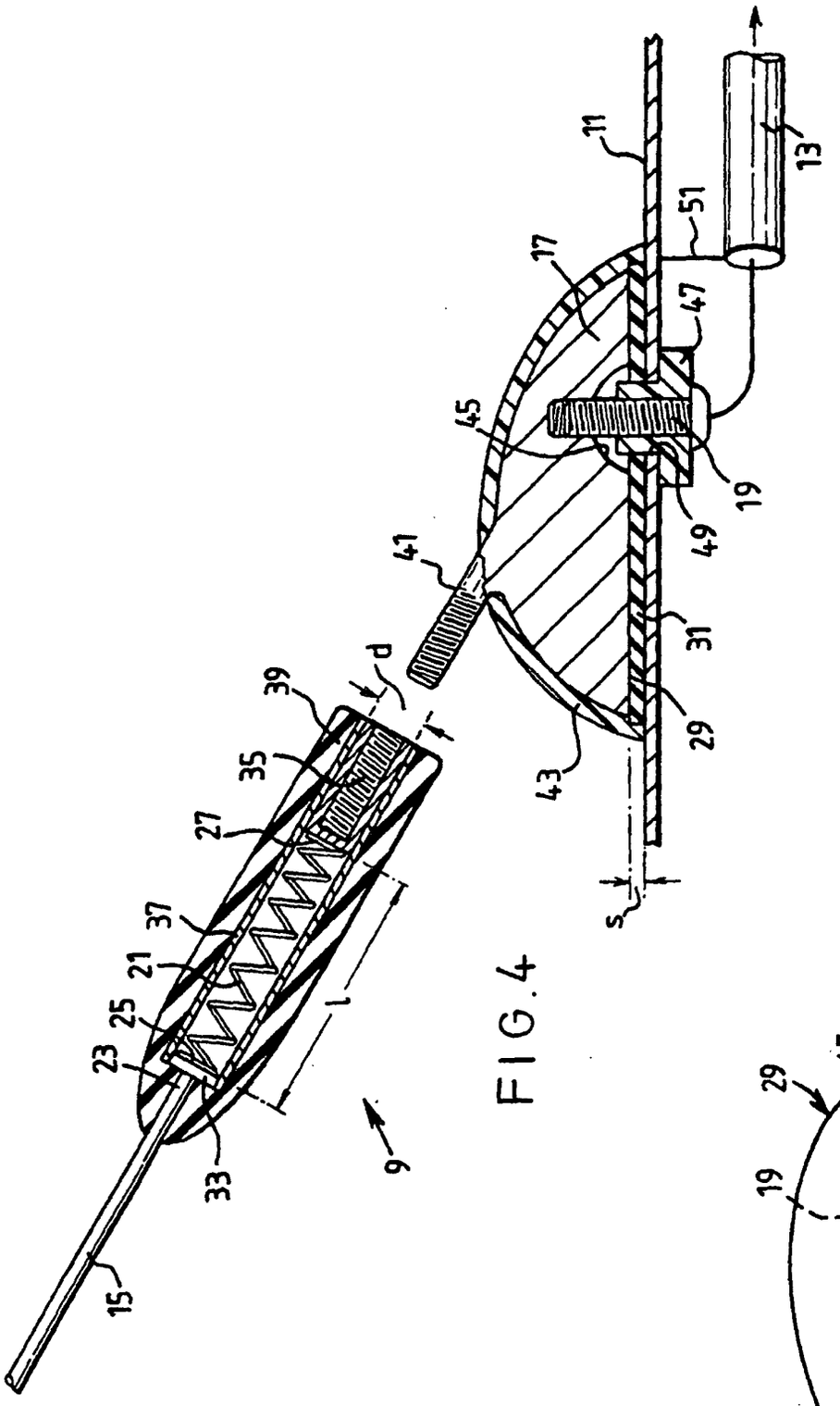

11
13
51
17
47
45
19
49
41
31
29
43
39
d
35
27
37
21
25
23
l
33
9
15
s

FIG.4

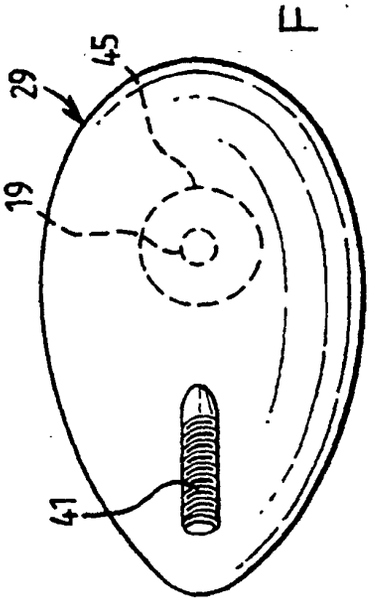

29
45
19
41

FIG.5

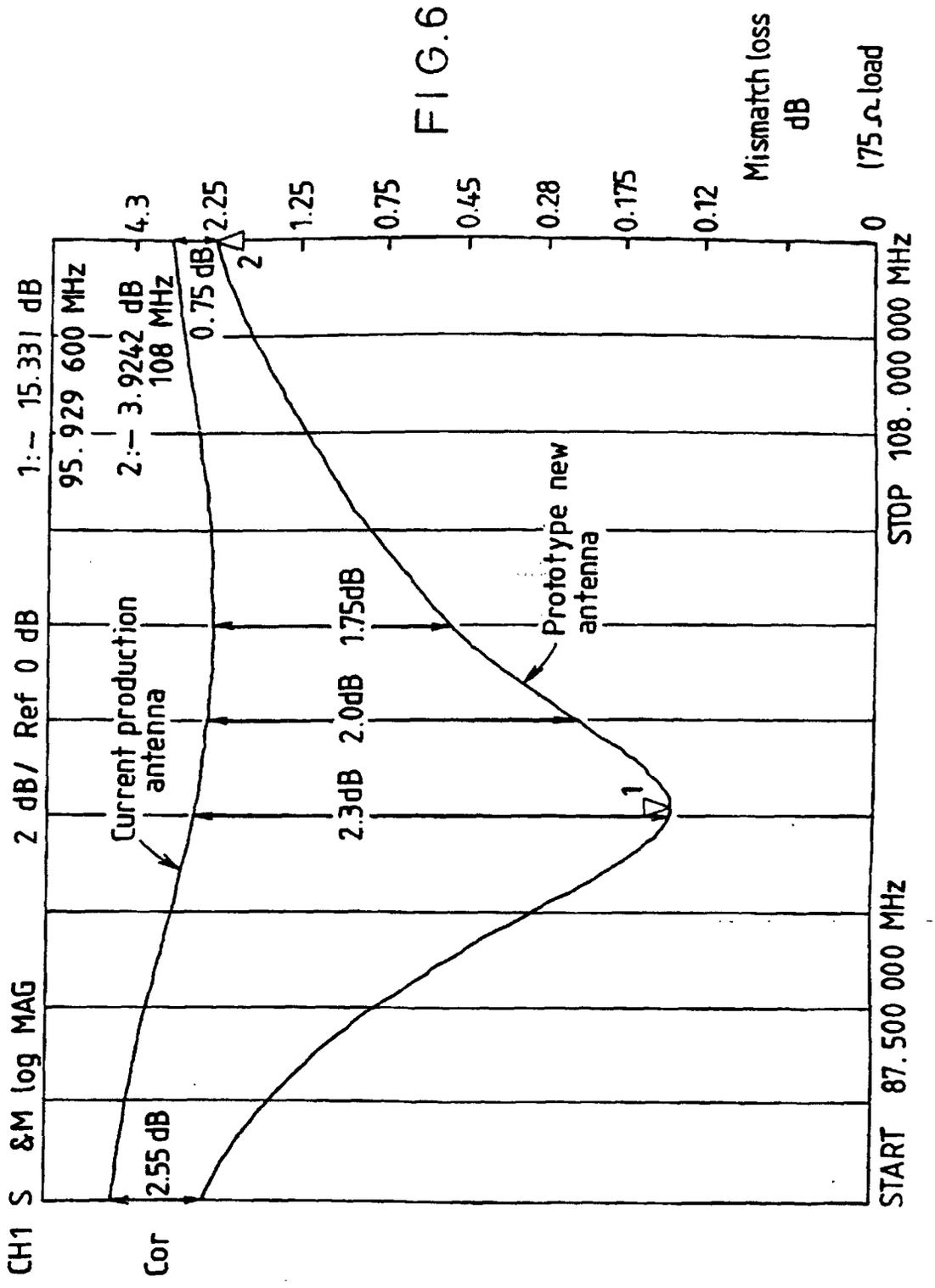

CH1 S &M log MAG
2 dB/ Ref 0 dB
1:– 15.331 dB
95.929 600 MHz
2:– 3.9242 dB
108 MHz
0.75 dB
Cor
2.55 dB
Current production antenna
2.3dB
2.0dB
1.75dB
Prototype new antenna
START 87.500 000 MHz
STOP 108.000 000 MHz
4.3
2.25
1.25
0.75
0.45
0.28
0.175
0.12
0
Mismatch loss dB
175 Ω load

FIG.6

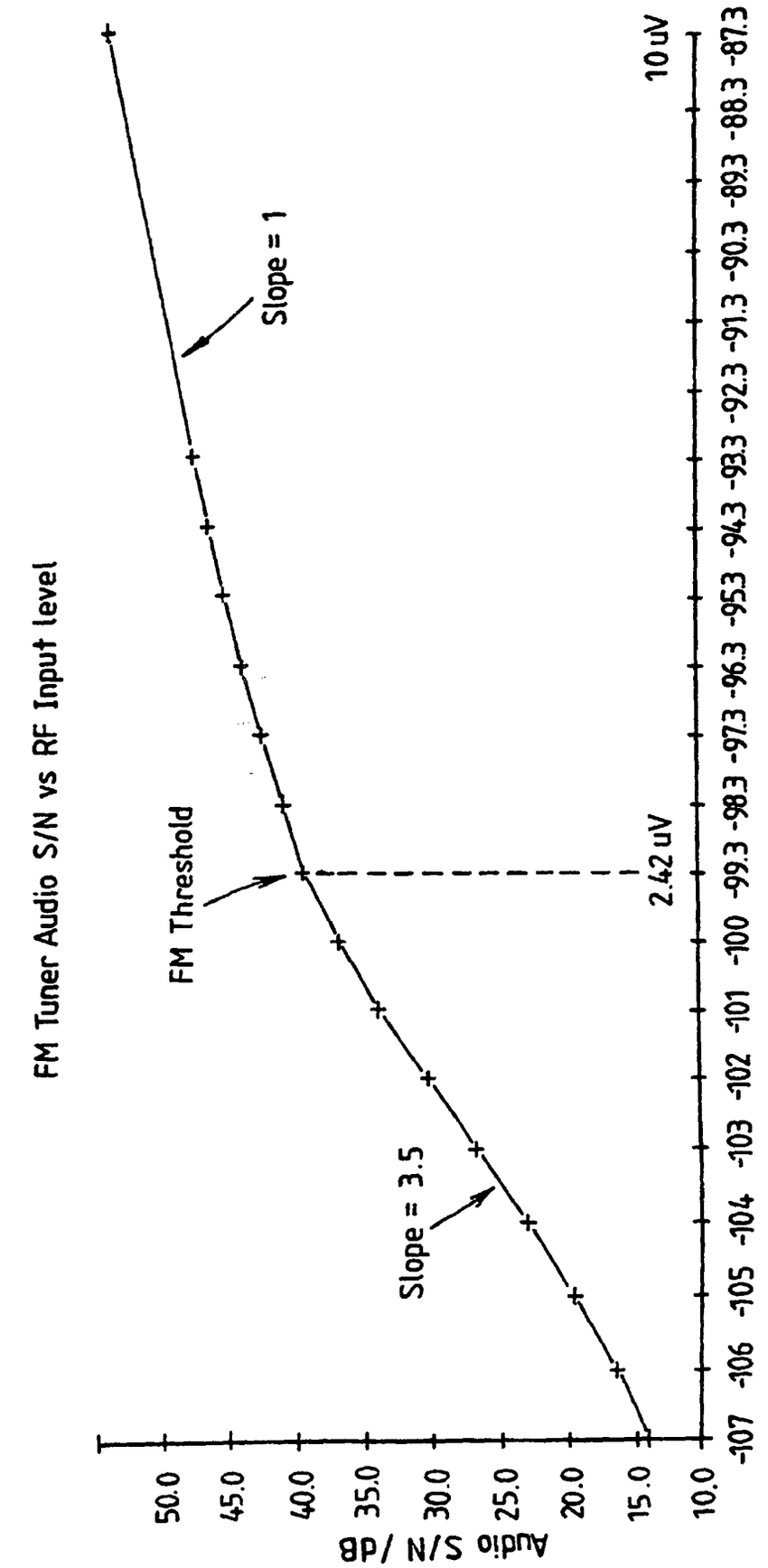

FM Tuner Audio S/N vs RF Input level
Audio S/N /dB
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
Slope = 1
Slope = 3.5
FM Threshold
2.42 uV
0.97 uV
10 uV
-107 -106 -105 -104 -103 -102 -101 -100 -99.3 -98.3 -97.3 -96.3 -95.3 -94.3 -93.3 -92.3 -91.3 -90.3 -89.3 -88.3 -87.3
RF Input / dBm

FIG.7