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(54) **Single wire antenna mast**

(57) An antenna mast incorporates a single strand of spring wire wound into a closed coil section at a base or bending fulcrum of the antenna mast. This closed coil section acts as a straight section of wire, for purposes of RF reception characteristics, when the antenna mast is not deflected. A center strand of wire enters and exits the closed coil section from opposite sides, reducing conductive length changes attributable to flexion of the antenna mast. As a result, tuning of the antenna mast to specific frequencies remains relatively stable even when the antenna mast is deflected, for example, by wind deflection forces or by contact with objects.

EP 1 672 734 A1

Description

TECHNICAL FIELD

[0001] This disclosure relates generally to antenna systems. More particularly, this disclosure relates to antenna masts.

BACKGROUND OF THE INVENTION

[0002] The vast majority of vehicles currently in use incorporate vehicle communication systems for receiving or transmitting signals. For example, vehicle audio systems provide information and entertainment to many motorists daily. These audio systems typically include an AM/FM radio receiver that receives radio frequency (RF) signals. These RF signals are then processed and rendered as audio output. A vehicle communication system may incorporate other functions, including, but not limited to, wireless voice and data communications, global positioning system (GPS) functionality, satellite-based digital audio radio (SDAR) services, keyless entry, and remote vehicle starting.
[0003] Communication systems, including vehicle communication systems, typically employ antenna systems including one or more antennas to receive or transmit electromagnetic radiated signals. In general, such antenna systems have predetermined patterns and frequency characteristics. These predetermined characteristics are selected in view of various factors, including, for example, the ideal antenna design, physical antenna structure limitations, and mobile environment requirements.
[0004] One type of antenna, known as an antenna mast, is commonly used in high frequency communications. For example, antenna masts may be used in wireless voice and data communications systems operating at frequencies up to and even in excess of 1 GHz. An antenna mast may be implemented, for example, as a flexible fiberglass or TEFLON® rod with a helically-wound conductor for receiving radio signals.
[0005] Mobile vehicle antennas are typically designed to satisfy certain performance criteria. For example, to meet relatively stringent mechanical validation requirements set by some original equipment manufacturers (OEMs), an antenna mast must be able to withstand 1500 strikes with a 3/4 inch metal rod traveling at 10 mph. The antenna mast must also be able to withstand continuous wind deflection forces throughout its life without permanent deformation.
[0006] In addition to OEM mechanical validation requirements and other mechanical design considerations, the desired RF characteristics impose additional design constraints on the antenna mast. Specifically, desired RF reception characteristics typically add constraints relating to the geometry of the antenna mast. Some conventional high frequency exterior antenna masts incorporate multiple components or exotic materials to satisfy these design constraints. While the use of such materials provides sufficient mechanical flexibility to satisfy mechanical design considerations while staying within geometric constraints, such materials can be costly. Further, antenna masts incorporating multiple components add complexity and costs to the manufacturing process.

SUMMARY OF THE INVENTION

[0007] According to various example embodiments, an antenna mast incorporates a single strand of spring wire wound into a closed coil section at a base or bending fulcrum of the antenna mast. This closed coil section acts as a straight section of wire, for purposes of RF reception characteristics, when the antenna mast is not deflected. Because the electrical length of the antenna mast significantly affects tuning of the antenna mast to specific frequencies, the center strand, or main body, of wire enters and exits the closed coil section from opposite sides. This geometry reduces the extent to which the conductive length changes when the antenna mast bends.
[0008] One embodiment is directed to an antenna that includes an electrical conductor. The electrical conductor has a first section and a second section formed integrally with the first section. The second section comprises a closed helical structure having a central axis and first and second ends extending outwardly from the central axis in substantially opposite directions.
[0009] In another embodiment, a communication system includes an antenna comprising an electrical conductor having a first section and a second section formed integrally with the first section. The second section comprises a closed helical structure having a central axis and first and second ends extending outwardly from the central axis in substantially opposite directions.
A base is proximate the second section. An elastomeric cover extends from the base and substantially surrounds the electrical conductor. A communication device is operatively coupled to the first and second sections.
[0010] Another embodiment is directed to a method of forming an antenna. An electrical conductor is provided. The electrical conductor is formed into first and second section. The second section is formed integrally with the first section and comprises a closed helical structure having a central axis and first and second ends extending outwardly from the central axis in substantially opposite directions.
[0011] Various embodiments may provide certain advantages. For example, with the center strand of wire entering

and exiting the closed coil section from opposite sides, conductive length changes attributable to flexion of the antenna mast are reduced. As a result, tuning of the antenna mast to specific frequencies remains relatively stable even when the antenna mast is deflected, for example, by wind deflection forces or by contact with objects.

[0012] Additional objects, advantages, and features will become apparent from the following description and the claims that follow, considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Figure 1 is a system diagram illustrating an example communication system according to an embodiment.
Figure 2 is a side view illustrating an example antenna according to another embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] An antenna mast employs a single strand of spring wire wound into a closed coil section at a base or bending fulcrum of the antenna mast. This closed coil section exhibits RF reception characteristics similar to a straight section of wire when the antenna mast is not deflected. A center strand, or main body, of wire enters and exits the closed coil section from opposite sides relative to a perimeter of the closed coil section. This geometry reduces the extent to which the conductive length changes when the antenna mast bends.
As a result, tuning of the antenna mast to specific frequencies remains relatively stable even when the antenna mast is deflected, for example, by wind deflection forces or by contact with objects.

[0015] In the following description, numerous specific details are set forth in order to provide a thorough understanding of various embodiments. It will be apparent to one skilled in the art that the described embodiments may be practiced without some or all of these specific details. In other instances, for purposes of brevity, well-known components and process steps have not been described in detail.

[0016] For purposes of this description, terms such as "upper," "lower," "right," "left," "rear," "front," "vertical," "horizontal," and the like relate to the embodiment as illustrated and oriented in Figure 1. It is to be understood that various embodiments may assume alternative orientations, except where expressly specified to the contrary. It is also to be understood that specific devices and processes are described in this disclosure by way of illustration only, and are not intended to be limiting. For example, specific dimensions and other physical characteristics relating to the embodiments described in this disclosure are not to be considered as limiting, unless the claims expressly state otherwise.

[0017] Referring now to the drawings, Figure 1 illustrates an example communication system 100 according to one embodiment. An antenna mast 102 is adapted to be mounted to a surface of a motor vehicle for receiving radiated electromagnetic signals, e.g., RF signals, from one or more remote transmitters, such as a satellite or terrestrial repeater. While not required, the antenna mast 102 may be implemented as an asymmetrical mast. The antenna mast 102 incorporates an electrical conductor (not shown in Figure 1) having a number of sections. As described below in connection with Figure 2, one of the sections may have a geometry resembling an open helical structure or coil for receiving a radiated electromagnetic signal in a frequency band, such as an AMPS or PCS band. Another section is formed as a closed helical structure that acts as a straight section of wire when the antenna mast 102 is not deflected. The electrical conductor enters and exits the closed helical structure from opposite sides to minimize conductive length changes when the antenna mast 102 bends. When the antenna mast 102 is deflected, the closed helical structure remains closed at some point along its perimeter. In this way, tuning of the antenna mast 102 to the desired frequency or frequencies remains relatively stable even when the antenna mast 102 is deflected, for example, by wind deflection forces or by contact with objects.

[0018] The antenna mast 102 is installed to a base 104. The base 104 includes a cover 106, which may be formed, for example, from a polycarbonate/acrylic-styrene-acrylonitrile (PC/ASA) alloy, a polycarbonate/polybutylene terephthalate (PC/PBT) alloy, or other suitable material. The antenna mast 102 may be detachably installed to the cover 106 using a quarter-turn installation. Positive locking preferably provides tactile feedback to confirm installation of the antenna mast 102 to the cover 106 and facilitates mechanical retention of the antenna mast 102 to the cover 106.

[0019] A gasket 108 seals the interior of the cover 106 from ingress of moisture. Further, the gasket 108 provides a distributed clamp load for circuitry enclosed by the cover 106. The gasket 108 may be formed, for example, from die-cut urethane foam or another suitable material.

[0020] A circuit board module 110 contains the electronic components associated with the antenna. The circuit board module 110 may be implemented, for example, as a single two-layer FR4-type circuit board having a thickness of approximately 0.78 mm. In some implementations, the circuit board module 110 has solder locations designed to facilitate automated solder operations. Cables 112 are soldered to the solder locations. These cables 112 may be implemented, for example, as a pair of 150 mm long RG316-type military grade coaxial cables. The cables 112 are terminated at the circuit board module 110 with a surface-mount connector body (not shown) to withstand loads. The cables 112 are routed with a line-of-sight to an exit location on a cast 114 to prevent moments on the cables 112. Installation of the cables 112 does not require snaking or forming.

[0021] The cast 114 is formed, for example, from zinc and may incorporate a trivalent chromite conversion coating to promote corrosion resistance.

Internal chambering of the cast 114 provides electrical isolation between antenna systems and the cables 112. An interface between the cast 114 and the vehicle surface is achieved via a gasket 116. The gasket 116 may be implemented, for example, as a 2 mm thick open-cell NEOPRENE® foam gasket having an acrylic adhesive backing for mechanical retention to the cast 114. Such a material provides suitable long-term compression set resistance properties over a range of temperatures. A fastener 118 secures the base 104 to the vehicle surface. One example implementation of the fastener 118 is described in U.S. Patent Application Serial Number __/___,___, entitled __________, filed on__________ , 2003, and assigned to the instant assignee. The disclosure of U.S. Patent Application Serial Number __/___,___ is hereby incorporated by reference in its entirety.

[0022] The cables 112 are operatively coupled to the antenna mast 102 and provide radiated electromagnetic signals received by the antenna mast 102 to a communication device 120, such as a receiver or transmitter. The communication device 120 is tunable to a frequency within the communication band.

[0023] Figure 2 illustrates one example configuration of the antenna mast 102. The antenna mast 102 incorporates an electrical conductor 130 and a mast cover 132. The electrical conductor 130 may be formed, for example, high carbon steel. The mast cover 132 may be formed from a thermoplastic elastomer (TPE), such as SANTOPRENE®. The antenna mast 102 may be detachably installed to a nickel-plated zinc stud 134 incorporated in the cover 106 of Figure 1 using a quarter-turn installation.

[0024] A lower portion of the electrical conductor 130 is formed as a closed helix 150, that is, a helix in which adjacent turns of the electrical conductor 130 contact one another. The closed helical structure of the lower portion of the electrical conductor 130 causes the lower portion to exhibit RF characteristics similar to a straight section of wire when the electrical conductor 130 is not deflected.

[0025] As depicted in Figure 2, substantially straight portions 152 and 154 of the electrical conductor 130 enter the closed helix 150 from respective end portions 156 and 158 of the closed helix 150. The substantially straight portions 152 and 154 of the electrical conductor 130 are generally coincident with a central axis of the closed helix 150. The closed helix 150 terminates in ends 160 and 162 that extend outwardly from the central axis in substantially opposite directions. As a result, the electrical conductor 130 enters the closed helix 150 from opposite sides along a perimeter of the closed helix 150. That is, the endpoints of ends 160 and 162 along the perimeter are displaced substantially 180° from one another. With this geometry, when the antenna mast 102 is subjected to a deflection force, changes in the conductive length of one end portion of the closed helix 150 will be counteracted by changes in the other end portion. Accordingly, the overall conductive length of the closed helix 150 is substantially preserved. Tuning of the antenna mast to the desired frequency or frequencies remains relatively stable even when the antenna mast 102 is deflected.

[0026] An upper portion of the electrical conductor is formed, for example, as an open helix 164, *i.e.,* a helix in which adjacent turns of the electrical conductor 130 do not contact one another. While not required, the open helix 164 may be of similar diameter to the closed helix 150. The substantially straight portion 152 of the electrical conductor 130 enters the open helix 164 from an end portion 166 of the open helix 164. The substantially straight portion 152 of the electrical conductor 130 is generally coincident with a central axis of the open helix 164. While not required, the substantially straight portions 152 and 154 of the electrical conductor 130 may feed the open helix 164 and the closed helix 150 with 90° bends, such that, for example, portions of the electrical conductor 130 are formed substantially perpendicular to the ends of the helices.

[0027] The RF reception characteristics of the antenna mast 102 are affected by the dimensions of the open helix 164, the closed helix 150, and the substantially straight portions 152 and 154 of the electrical conductor 130. In particular, the conductive length of the electrical conductor 130 determines the RF reception characteristics. Table I below lists several example sets of dimensions, along with the corresponding total conductive length *CL* of the electrical conductor 130 in the right-most column. The dimensions disclosed in Table I are designed for dual-band reception in the AMPS (824-894 MHz) and PCS (1850-1990 MHz) communication bands. All linear dimensions are provided in millimeters, and angular dimensions are provided in degrees. The column headings in Table I refer to the corresponding dimensions in Figure 2.

Table I Tuned Spring Dimensions

version	wire diam.	L1	L2	L3	L4	θ	c-c spring diam.	c-c free length	# of turns	CL
1	0.5	2	3	5	25	7.625	4.67	1.96	12.73	35
2	0.5	2	3	6	25	7.625	4.67	1.96	12.73	36

Table continued

version	wire diam.	L1	L2	L3	L4	θ	c-c spring diam.	c-c free length	# of turns	CL
3	0.5	2	3	7	25	7.625	4.67	1.96	12.73	37
4	0.5	2	3	8	25	7.625	4.67	1.96	12.73	38
5	0.5	2	3	9	25	7.625	4.67	1.96	12.73	39
6	0.5	2	3	10	25	7.625	4.67	1.96	12.73	40
7	0.5	2	3	11	25	7.625	4.67	1.96	12.73	41
8	0.5	2	3	12	25	7.625	4.67	1.96	12.73	42
9	0.5	2	3	13	25	7.625	4.67	1.96	12.73	43
10	0.5	2	3	14	25	7.625	4.67	1.96	12.73	44
11	0.5	2	3	15	25	7.625	4.67	1.96	12.73	45

In Table I above, the dimensions in version 6, producing a total conductive length of 40 mm, are nominal. It will be appreciated that the dimensions listed in Table I are provided by way of example only and are not intended to be limiting. More generally, the upper portion of the electrical conductor 130 may be formed with a geometry other than an open helix. Such alternative configurations may be desirable for reception of radiated electromagnetic signals in other communication bands.

[0028] In some embodiments, the antenna mast 102 is configured as a dual-band antenna for receiving radiated electromagnetic signals in the AMPS and PCS communication bands. In particular, the lower frequency AMPS communication band uses the entire length of the electrical conductor 130 to achieve a quarter-wavelength resonance. The higher frequency PCS communication band uses the entire length of the electrical conductor 130 to achieve approximately a three-quarter-wavelength resonance. To allow design flexibility in cases in which the upper communication band is not a harmonic of the lower band, the pitch of the open helical structure may be varied such that the inductance of the open helical structure is low in the lower band and near a half-wavelength resonance in the upper band. The open helical structure then appears as an open circuit to the other section of the electrical conductor 130, which can in this way be resonated at a quarter-wavelength in the upper band.

[0029] As demonstrated by the foregoing discussion, various embodiments may provide certain advantages. For instance, the closed coil section provides flexibility to withstand deflection forces, while exhibiting RF reception characteristics similar to a straight section of wire when the closed antenna mast is not deflected. With the center strand of wire entering and exiting the closed coil section from opposite sides, conductive length changes attributable to flexion of the antenna mast are reduced. As a result, tuning of the antenna mast to specific frequencies remains relatively stable even when the antenna mast is deflected, for example, by wind deflection forces or by contact with objects.

[0030] It will be understood by those skilled in the art that various modifications and improvements may be made without departing from the spirit and scope of the disclosed embodiments. The scope of protection afforded is to be determined solely by the claims and by the breadth of interpretation allowed by law.

Claims

1. An antenna of the type formed from an electrical conductor, the antenna **characterised by** a first section formed from the electrical conductor and a second section formed integrally with the first section, the second section comprising a closed helical structure (150) having a central axis and first and second ends (160, 162) extending outwardly from the central axis in substantially opposite directions.

2. The antenna of claim 1, wherein the first section comprises an open helical structure (164) substantially coaxial with the second section.

3. The antenna of claim 2, wherein the open helical structure (164) and the closed helical structure (150) have substantially equal diameters.

4. The antenna of claim 2, wherein the electrical conductor (130) comprises:

   a first portion (152) substantially perpendicular to the first end (160) of the closed helical structure (150);
   a second portion (154) substantially perpendicular to the second end (162) of the closed helical structure (150); and

a third portion (152) substantially perpendicular to an end (166) of the open helical structure (164).

5. The antenna of claim 1, wherein the electrical conductor (130) comprises a tin-plated carbon steel wire.

6. The antenna of claim 1, wherein the antenna is configured and arranged to receive a radiated electromagnetic signal in at least one of an advanced mobile phone system (AMPS) frequency band and a personal communications system (PCS) frequency band.

7. The antenna of claim 1, further **characterised by** a base (104) proximate the second section.

8. The antenna of claim 1, further **characterised by** an elastomeric cover (132) substantially surrounding the electrical conductor (130).

9. A communication system of the type comprising an antenna and a communication device (120), the communication system **characterised in that**:

the antenna comprises
an electrical conductor (130) having a first section and a second section formed integrally with the first section, the second section comprising a closed helical structure (150) having a central axis and first and second ends (160, 162) extending outwardly from the central axis in substantially opposite directions,
a base (104) proximate the second section,
an elastomeric cover (132) extending from the base (104) and substantially surrounding the electrical conductor (130); and
the communication device (120) is operatively coupled to the first and second sections.

10. The communication system of claim 9, wherein the first section comprises an open helical structure (164) substantially coaxial with the second section.

11. The communication system of claim 10, wherein the open helical structure (164) and the closed helical structure (150) have substantially equal diameters.

12. The communication system of claim 10, wherein the electrical conductor comprises:

a first portion (152) substantially perpendicular to the first end (160) of the closed helical structure (150);
a second portion (154) substantially perpendicular to the second end (162) of the closed helical structure (150); and
a third portion (152) substantially perpendicular to an end (166) of the open helical structure (164).

13. The communication system of claim 9, wherein the electrical conductor (130) comprises a tin-plated carbon steel wire.

14. The communication system of claim 9, wherein the antenna is configured and arranged to receive a radiated electromagnetic signal in at least one of an advanced mobile phone system (AMPS) frequency band and a personal communications system (PCS) frequency band.

15. A method of forming an antenna, the method comprising:

providing an electrical conductor (130);
forming the electrical conductor (130) into a first section and a second section formed integrally with the first section, the second section comprising a closed helical structure (150) having a central axis and first and second ends (160, 162) extending outwardly from the central axis in substantially opposite directions

16. The method of claim 15, further comprising forming the first section of the electrical conductor (130) as an open helical structure (164) substantially coaxial with the second section.

17. The method of claim 16, wherein the open helical structure (164) and the closed helical structure (150) have substantially equal diameters.

18. The method of claim 16, further comprising:

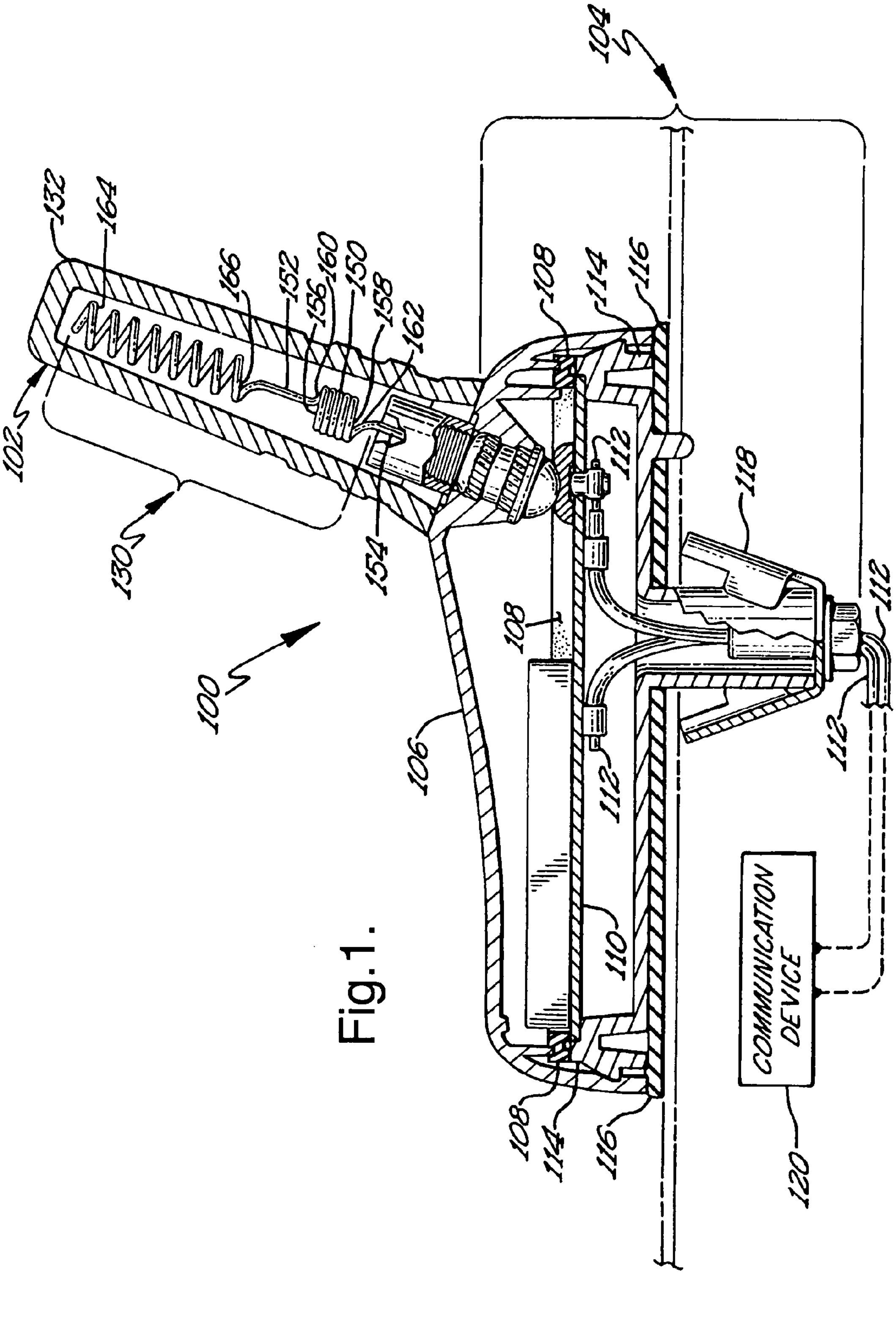
bending a first portion (152) of the electrical conductor (130) at substantially a 90° angle to the first end (160) of the closed helical structure (150);
bending a second portion (154) of the electrical conductor (130) at substantially a 90° angle to the second end (162) of the closed helical structure (150); and
bending a third portion (152) of the electrical conductor (130) at substantially a 90° angle to an end (166) of the open helical structure (164).

19. The method of claim 15, wherein the electrical conductor (130) comprises a tin-plated carbon steel wire.

20. The method of claim 15, wherein the antenna is configured and arranged to receive a radiated electromagnetic signal in at least one of an advanced mobile phone system (AMPS) frequency band and a personal communications system (PCS) frequency band.

21. The method of claim 15, further comprising providing a base (104) proximate the second section.

22. The method of claim 15, further comprising providing an elastomeric cover (132) substantially surrounding the electrical conductor (130).



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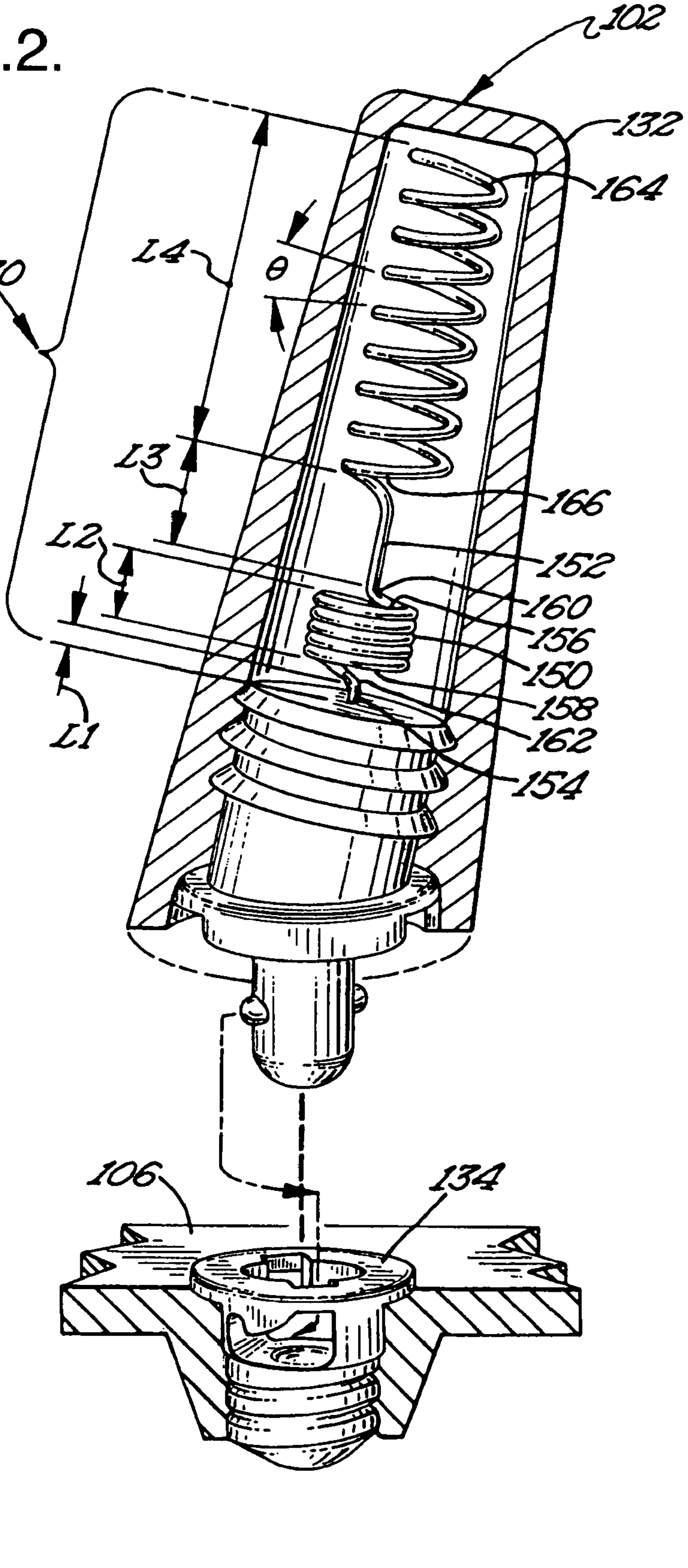
COMMUNICATION DEVICE

Fig.1.

Fig.2.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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 07 7720

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 2 400 497 A (HARADA IND [GB]; HARADA IND CO LTD [GB]) 13 October 2004 (2004-10-13) * the whole document * -----	1-22	H01Q1/32 H01Q1/00 H01Q11/08 H01Q1/36 H01Q5/00
X	DE 41 41 783 A1 (HANS KOLBE & CO, 3202 BAD SALZDETFURTH, DE; FUBA AUTOMOTIVE GMBH & CO.) 24 June 1993 (1993-06-24) * the whole document * -----	1-3, 5-11, 13-17, 19-22	
X	US 6 191 747 B1 (COSENZA JOHN M) 20 February 2001 (2001-02-20) * the whole document * -----	1,5-9, 13-15, 19-22	
A	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 03, 31 March 1999 (1999-03-31) & JP 10 322122 A (NIPPON ANTENNA CO LTD), 4 December 1998 (1998-12-04) * abstract * -----	1,9,15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01Q

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	6 March 2006	Moumen, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 07 7720

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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06-03-2006

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2400497 A	13-10-2004	NONE	
DE 4141783 A1	24-06-1993	NONE	
US 6191747 B1	20-02-2001	NONE	
JP 10322122 A	04-12-1998	JP 3667940 B2	06-07-2005

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