



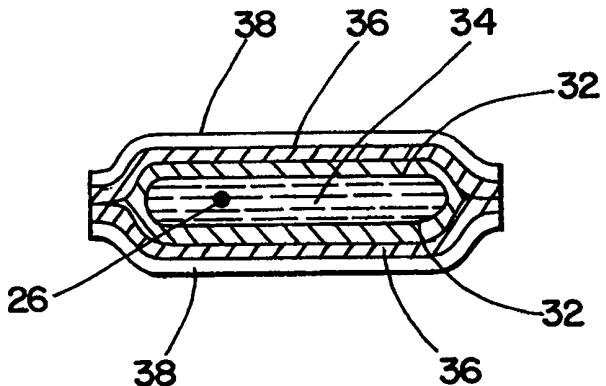
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: FLEXIBLE DIVERSITY ANTENNA

## (57) Abstract

Flexible diversity antennas having gain and bandwidth capabilities suitable for use within small communications devices such as radiotelephones are provided. A core of flexible material has an electrical conductor embedded therewithin in a meandering pattern and is surrounded by a first layer of flexible dielectric material. At one end of the antenna, the first layer of dielectric material is surrounded by flexible conductive material. The flexible conductive material is surrounded by a second layer of flexible dielectric material. The portion of the antenna surrounded by conductive material serves as a tuning element, and the portion of the antenna not surrounded by conductive material serves as a radiating element. A flexible signal feed is integral with the antenna and extends outwardly from the flexible core.



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## FLEXIBLE DIVERSITY ANTENNA

Field of the Invention

The present invention relates generally to antennas, and more particularly to antennas used within communication devices.

5

Background of the Invention

Antennas for personal communication devices, such as radiotelephones, may not function adequately when in close proximity to a user during operation, or when a user is moving during operation of a device. 10 Close proximity to objects or movement of a user during operation of a radiotelephone may result in degraded signal quality or fluctuations in signal strength, known as multipath fading. Diversity antennas have been 15 designed to work in conjunction with a radiotelephone's primary antenna to improve signal reception.

Many of the popular hand-held radiotelephones are undergoing miniaturization. Indeed, many of the contemporary models are only 11-12 centimeters in 20 length. Unfortunately, as radiotelephones decrease in size, the amount of internal space therewithin may be reduced correspondingly. A reduced amount of internal space may make it difficult for existing types of

diversity antennas to achieve the bandwidth and gain requirements necessary for radiotelephone operation because their size may be correspondingly reduced.

One type of diversity antenna is referred to  
5 as a Planar Inverted F Antenna (PIFA). A PIFA derives its name from its resemblance to the letter "F" and typically includes various layers of rigid materials formed together to provide a radiating element having a conductive path therein. The various layers and  
10 components of a PIFA are typically mounted directly on a molded plastic or sheet metal support structure. Because of their rigidity, PIFAs are somewhat difficult to bend and form into a final shape for placement within the small confines of radiotelephones. In  
15 addition, PIFAs may be susceptible to damage when devices within which they are installed are subjected to impact forces. Impact forces may cause the various layers of a PIFA to crack, which may hinder operation or even cause failure.

20 Various stamping, bending and etching steps may be required to manufacture a PIFA because of their generally non-planar configuration. Consequently, manufacturing and assembly is typically performed in a batch-type process which may be somewhat expensive. In  
25 addition, PIFAs typically utilize a shielded signal feed, such as a coaxial cable, to connect the PIFA with the RF circuitry within a radiotelephone. During assembly of a radiotelephone, the shielded signal feed between the RF circuitry and the PIFA typically involves manual installation, which may increase the  
30

cost of radiotelephone manufacturing.

Summary of the Invention

5 It is, therefore, an object of the present invention to provide PIFAs that can easily conform within the internal confines of small communications devices such as radiotelephones.

10 It is another object of the present invention to provide small PIFAs that can have sufficient gain and bandwidth capabilities for use within radiotelephones.

15 It is also an object of the present invention to provide PIFAs that can be less vulnerable to damage caused by impact forces to the devices within which they are installed.

It yet another object of the present invention to simplify radiotelephone assembly and thereby reduce radiotelephone manufacturing costs.

These and other objects of the present invention are provided by flexible diversity antennas that can have gain and bandwidth capabilities suitable for use within small communications devices such as radiotelephones. A core of flexible material, such as silicone, has an electrical conductor embedded therewithin and is surrounded by a first layer of flexible dielectric material. At one end of the antenna, the first layer of dielectric material is surrounded by conductive material, such as copper or nickel fabric. The conductive material is flexible and replaces rigid metallic elements typically utilized in

PIFAs.

The conductive material is preferably surrounded by a second layer of flexible dielectric material. The portion of the antenna surrounded by 5 conductive material serves as a tuning element, and the portion of the antenna not surrounded by conductive material serves as a radiating element. Preferably, the electrical conductor within the core extends between the radiating and tuning elements along a meandering 10 path.

A flexible signal feed is integral with the antenna and extends outwardly from the flexible core. The signal feed is electrically connected to the electrical conductor embedded within the flexible core. 15 The signal feed is surrounded by a layer of flexible material, preferably the same material as the flexible core. This flexible material is surrounded by a layer of dielectric material. Surrounding this layer of dielectric material is a layer of conductive material which serves to shield the signal feed. This layer of 20 conductive material may be surrounded by another layer of dielectric material.

Operations for fabricating a flexible diversity antenna having a predetermined impedance, 25 include: forming a planar antenna element having an electrical conductor embedded within an elastomeric core, a first layer of dielectric material surrounding the elastomeric core, portions of the first layer of dielectric material surrounded with conductive material, and a second layer of dielectric material 30

surrounding the conductive material; and then folding the planar antenna element into a shape for assembly within an electronic device, such as a radiotelephone. The elastomeric core and material utilized to laminate the various layers of material around the core are cured prior to folding the planar antenna element into a shape for assembly within an electronic device. During curing operations, texturing of the surface of the second layer of dielectric material may be performed.

Diversity antennas according to the present invention can be manufactured in a planar configuration, which is conducive to high volume automated production. Furthermore, repeatable impedance characteristics are obtainable through the selection of materials and the control of thickness of the various layers of materials. Because flexible dielectric and conductive materials are utilized, the antennas can then be formed into various shapes so as to fit into small areas during radiotelephone assembly.

In contrast with known diversity antennas, the present invention is capable of achieving sufficient gain and bandwidth for radiotelephone operation for a given size and location. Using this invention, the antenna designer has a greater degree of design flexibility than with known diversity antennas. Furthermore, conductive material can be selectively added to create a controlled impedance stripline transmission medium on sections of the antenna.

The relatively rigid antenna assemblies in

previous PIFAs generally do not lend themselves to being folded easily to conform with small spaces within communications devices. By contrast, diversity antennas according to the present invention have a flexible 5 configuration that allows the antenna to conform to the small space constraints of current radiotelephones and other communication devices. The flexible configuration of the present invention can also reduce the possibility of damage from impact forces. Furthermore, 10 the present invention incorporates an integral, flexible signal feed which eliminates the need for a separate coaxial cable to connect the antenna with signal circuitry within a device. Accordingly, assembly costs of communications devices, such as 15 radiotelephones, can be reduced:

Brief Description of the Drawings

**Fig. 1** illustrates a typical PIFA used within radiotelephones.

20 **Fig. 2** is a plan view of a flexible PIFA according to aspects of the present invention.

**Fig. 3** is a perspective view of the PIFA illustrated in **Fig. 2** with the tuning portion in a folded configuration.

25 **Fig. 4** is a sectional view of the PIFA illustrated in **Fig. 2** taken along lines 4-4.

**Fig. 5** is a sectional view of the PIFA illustrated in **Fig. 2** taken along lines 5-5.

30 **Fig. 6** is a sectional view of the PIFA illustrated in **Fig. 2** taken along lines 6-6.

Figs. 7A-7B schematically illustrate operations for fabricating flexible diversity antennas according to aspects of the present.

5

#### Detailed Description of the Invention

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, 10 however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements 15 throughout.

As is known to those skilled in the art, an antenna is a device for transmitting and/or receiving electrical signals. A transmitting antenna typically 20 includes a feed assembly that induces or illuminates an aperture or reflecting surface to radiate an electromagnetic field. A receiving antenna typically includes an aperture or surface focusing an incident radiation field to a collecting feed, producing an 25 electronic signal proportional to the incident radiation. The amount of power radiated from or received by an antenna depends on its aperture area and is described in terms of gain. Radiation patterns for antennas are often plotted using polar coordinates.

30 Voltage Standing Wave Ratio (VSWR) relates to the

5 impedance match of an antenna feed point with the feed line or transmission line. To radiate RF energy with minimum loss, or to pass along received RF energy to the receiver with minimum loss, the impedance of the antenna should be matched to the impedance of the transmission line or feeder.

10 Radiotelephones typically employ a primary antenna which is electrically connected to a transceiver operably associated with a signal processing circuit positioned on an internally disposed printed circuit board. In order to maximize power transfer between the antenna and the transceiver, the transceiver and the antenna are preferably interconnected such that the respective impedances are 15 substantially "matched," i.e., electrically tuned to filter out or compensate for undesired antenna impedance components to provide a 50 Ohm (or desired) impedance value at the circuit feed.

20 As is well known to those skilled in the art, a diversity antenna may be utilized in conjunction with a primary antenna within a radiotelephone to prevent calls from being dropped due to fluctuations in signal strength. Signal strength may vary as a result of a user moving between cells in a cellular telephone 25 network, a user walking between buildings, interference from stationary objects, and the like. Diversity antennas are designed to pick up signals that the main antenna is unable to pick up through spatial, pattern, and bandwidth or gain diversity.

30 A type of diversity antenna well known in the

art is the Planar Inverted F Antenna (PIFA) and is illustrated in **Fig. 1**. The illustrated PIFA 10 includes a radiating element 12 maintained in spaced apart relationship with a ground plane 14. The radiating element is also grounded to the ground plane 14 as indicated by 16. A hot RF connection 17 extends from underlying circuitry through the ground plane 14 to the radiating element 12 at 18. A PIFA is tuned to desired frequencies by adjusting the following parameters which can affect gain and bandwidth: varying the length **L** of the radiating element 12; varying the gap **H** between the radiating element 12 and the ground plane 14; and varying the distance **D** between the ground and hot RF connections. Other parameters known to those skilled in the art may be adjusted to tune the PIFA, and will not be discussed further.

Referring now to **Fig. 2**, a planar diversity antenna 20 in accordance with a preferred embodiment of the present invention is illustrated. The antenna 20 has an "F" shape and includes a tuning portion 22 and an adjacent radiating portion 24, as indicated. The antenna 20 is preferably manufactured in a planar configuration as illustrated in **Fig. 2**. Prior to assembly within a communications device, the flexible antenna is folded to conform with the internal space of the device.

**Fig. 3** illustrates the antenna 20 with its tuning portion 22 folded under the radiating element 24 so that the antenna has the proper configuration for assembly within a particular communications device.

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5       Fig. 3 also illustrates the shielded flexible signal feed 28 in a substantially transverse orientation with respect to the radiating element 24 so as to be in proper orientation for connection with signal circuitry within a communications device. A flexible diversity antenna according to the present invention can be formed into various shapes as required to facilitate installation within various internal spaces of devices such as radiotelephones.

10       Referring back to Fig. 2, a continuous electrical conductor 26 extends between the tuning element 22 and radiating element 24 and serves as an antenna element for sending and receiving electronic signals. In the illustrated embodiment, the electrical conductor 26 extends from a tuning element end portion 22a to an opposite radiating element end portion 24a in a meandering pattern.

15       A flexible, shielded RF or microwave signal feed 28 is integrally connected to the radiating element 24 of the antenna 20, as illustrated. The shielded signal feed 28 has a similar construction to that of the radiating element 22, which is described in detail below. An electrical conductor 30 is contained within the flexible signal feed 28 and has opposite end portions 30a and 30b. The electrical conductor 30 is electrically connected at end portion 30a with the electrical conductor 26 of the radiating element 24 at location 29, as illustrated. Opposite end portion 30b is preferably configured for assembly to a circuit board via conventional connection techniques including

soldering, displacement connectors, conductive elastomers, metal compression contacts, and the like.

The flexible signal feed 28 can be configured in various orientations to facilitate assembly within 5 radiotelephones and other electronic devices.

Conventional diversity antennas generally require a shielded signal feed from the main circuit board in a radiotelephone. Coaxial cables are often used for this purpose. However, coaxial cables are relatively costly 10 and require manual assembly. The present invention is advantageous because a shielded signal feed 28 is provided as an integral part of the antenna 20.

Referring now to **Fig. 4**, a cross-sectional view of the radiating element 24 of the antenna 20 of 15 **Fig. 2** taken along lines 4-4 is illustrated. The electrical conductor 26 is embedded within a flexible core 34. The flexible core is preferably formed from an elastomeric material such as silicone. Preferably, the flexible core is also formed from a dielectric material 20 having a dielectric constant between about 1.8 and 2.2. A first layer of flexible dielectric material 32 surrounds the elastomeric core 34 as illustrated. Preferably, the first layer of dielectric material has a dielectric constant between about 1.8 and 2.2. The 25 first layer of dielectric material may be formed from non-metalized, woven or knit fabrics. Polyester or liquid crystal polymer (LCP) cloth capable of withstanding processing temperatures up to 120°C is an exemplary dielectric material for use as the first 30 layer of dielectric material 32.

Referring now to **Fig. 5**, a cross-sectional view of the tuning element 22 of the antenna 20 of **Fig. 2** taken along lines 5-5 is illustrated. A layer of flexible conductive material 36 surrounds the first 5 layer of dielectric material 32. Preferably the conductive material 36 is metalized fabric. Preferred metalized fabrics are those with high strength and high temperature processing capability. Exemplary metalized fabrics include, but are not limited to, polyester or 10 liquid crystal polymer (LCP) woven fabric having fibers coated with copper, followed by a nickel outer layer; nickel and copper fabrics formed of metallic fibers or metallic felt structures; carbon fiber fabrics formed of fiber or felt structures. Alternatively, portions of 15 the first layer of dielectric material 32 may be metalized with conductive material on the outer surface.

Preferably, the metalized fabric 36 is laminated to the first layer of dielectric material 32 20 with an elastomeric material such as silicone. The silicone fills the voids in the metalized fabric to enhance bending characteristics. As is known to those skilled in the art, silicone provides consistent 25 flexibility with high elongation over various temperatures, particularly low temperatures. The conductive material 36 may then be surrounded as illustrated with a second layer of flexible dielectric material 38. The second layer of dielectric material 38 may be formed from non-metalized polymers formed as 30 films, or as woven or knit fabrics. Polyetherimide

(PEI) films, or cloth made of polyester or liquid crystal polymer (LCP) capable of withstanding processing temperatures up to 120°C is an exemplary dielectric material for use as the second layer of dielectric material 38.

5 The thickness of the first and second layers of dielectric material 32, 38 can be varied during manufacturing of the antenna 20 to produce a controlled characteristic impedance for the electrical conductor.

10 The characteristic impedance ( $Z_0$ ) of the RF transmission line is calculated from the geometry and the dielectric constant of the materials (conductor width and dielectric thickness) comprising the line. As the geometry changes from a stripline to microstrip

15 transmission line, the thickness of the layers is adjusted for the desired impedance. Stiffer dielectric materials may also be added to both the first and second layers of dielectric material 32, 38 to control the flexibility of the antenna 20 or to tailor the

20 dielectric constant of the antenna. Films of polyetherimide (PEI) may be used where high strength and good flexibility are required. As is known to those skilled in the art, PEI closely matches the dielectric constant of silicone elastomer and bonds well to both silicone and various outer coating materials. Bonding of the first and second dielectric layers 32, 38 may require the use of heat activated bonding films.

25 Preferably, fluorinated ethylene propylene (FEP) bonding film is utilized with TFE dielectric materials

and silicone film is utilized with PEI dielectric materials.

The antenna 20 may undergo curing operations to cure the silicone or other elastomeric material used in the core 34 and to laminate the various layers of material together surrounding the core. Curing operations are typically performed according to the recommendations of the manufacturer of the bonding system used. For example: FEP films may bond at temperatures greater than or equal to 235°C; silicone elastomer heat cured adhesives may bond at temperatures greater than or equal to 120°C; or pressure cured silicone elastomer adhesives may be given an accelerated bond at temperatures greater than or equal to 90°C. As is normal in adhesive bonding of thin sheets of materials, pressure may be applied through rigid backing plates. The interface between the backing plate and the material to be bonded may be filled with a compliant elastomer pad. The compliance of the elastomer pad aids in producing a void-free adhesive interface. Features or surface texture on the elastomer pad may be used to create fold lines or bend relief points to aid final assembly of the antenna.

The second layer of dielectric material 38 may contain surface texturing to evenly distribute bending stresses throughout the cross section of the antenna 20. Texturing may be formed via pressure pads used in the curing process. Pressure may be applied during curing to ensure that the silicone fills the voids between the fibers in the conductive material 36.

Referring now to **Fig. 6**, a cross-sectional view of the transition region between the radiating portion 24 and the tuning portion 22 of the antenna 20 of **Fig. 2** taken along lines 6-6 is illustrated. In the 5 illustrated embodiment, the second dielectric layer 38 terminates just beyond the termination point of the conductive material 36. However, the second dielectric layer 38 may extend further over the first layer of dielectric material 32. Extending the second dielectric 10 layer 38 over the first layer of dielectric material 32 may be used to produce a more even thickness transition (to aid the bonding process), or to produce a greater stiffness at the transition (to aid bending of the final assembly). A similar configuration may exist in 15 the transition region between the signal feed 28 and the radiating element 24.

A stiffer outer layer of material (not shown) may be utilized to form an environmentally suitable outer surface for the antenna 20. Various materials may 20 be utilized as an outer surface including, but not limited to, FEP. An outer layer of material may be desirable to protect against abrasion and other causes of wear.

Operations for fabricating a flexible 25 diversity antenna according to the present invention are illustrated schematically in **Figs. 7A** and **7B**. A planar antenna is formed (Block 100) and then folded for assembly within an electronic device (Block 200). Operations for forming a planar antenna include 30 embedding an electrical conductor within an elastomeric

core (Block 102), preferably in a meandering configuration. The elastomeric core is then surrounded by a first layer of dielectric material (Block 104). One or more portions of the first layer of dielectric material is surrounded with conductive material to tune the antenna to a predetermined impedance (Block 106). A shielded signal feed is integrally formed with the antenna and extends outwardly therefrom (Block 108). The elastomeric core and materials for bonding the dielectric and conductive layers to the core are cured using curing techniques known to those skilled in the art, including, but not limited to, air curing, thermal curing, infrared curing, microwave curing, and the like (Block 110). Surface texturing may be created in the second layer of dielectric material during curing operations (Block 112).

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Therefore, it is to be

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understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the appended claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

5

## THAT WHICH IS CLAIMED IS:

1. An antenna, comprising:
  - a flexible core surrounded by a first layer of flexible dielectric material and having opposite end portions;
  - a layer of flexible conductive material surrounding said first layer of flexible dielectric material at one of said end portions; and
  - an electrical conductor embedded within said flexible core and extending between said end portions.
2. An antenna according to Claim 1 wherein said layer of flexible conductive material is surrounded by a second layer of flexible dielectric material.
3. An antenna according to Claim 1 wherein said electrical conductor has a meandering configuration through said elastomeric core.
4. An antenna according to Claim 1 wherein said flexible core comprises silicone.
5. An antenna according to Claim 1 wherein said flexible conductive material comprises metalized fabric.
6. An antenna according to Claim 5 wherein

said metalized fabric is laminated to said first layer of flexible dielectric material with a silicone elastomer.

7. An antenna according to Claim 1 wherein said first and second layers of flexible dielectric material have a dielectric constant of between about 1.8 and 2.2.

8. An antenna according to Claim 1 wherein said flexible core is formed from material having a dielectric constant of between about 1.8 and 2.2.

9. An antenna according to Claim 1 wherein said first and second layers of flexible dielectric material comprise polyetherimide film.

10. An antenna according to Claim 1 further comprising an integral, flexible signal feed extending outwardly from said flexible core, said signal feed electrically connected to said electrical conductor  
5 embedded within said elastomeric core.

11. An antenna according to Claim 10 further comprising:

a layer of flexible material surrounding said signal feed;

5 a first layer of flexible dielectric material surrounding said layer of flexible material;

a layer of flexible conductive material surrounding said first layer of flexible dielectric

material; and

10 a second layer of flexible dielectric material surrounding said layer of flexible conductive material.

12. A flexible diversity antenna, comprising:

an elastomeric core surrounded by a first layer of dielectric material and having opposite end portions, said first layer of dielectric material having selected portions metalized with conductive material; and

an electrical conductor embedded within said elastomeric core and extending between said opposite end portions.

10 13. A flexible diversity antenna according to Claim 12 further comprising a second layer of dielectric material surrounding said metalized portions of said first layer of dielectric material.

14. A flexible diversity antenna according to Claim 12 wherein said electrical conductor has a meandering configuration through said elastomeric core.

15. A flexible diversity antenna according to Claim 12 wherein said elastomeric core is formed of silicone.

16. A flexible diversity antenna according to Claim 12 further comprising a signal feed extending

5 outwardly from said flexible core, said signal feed electrically connected to said electrical conductor embedded within said elastomeric core.

17. A flexible diversity antenna according to Claim 12 further comprising:

a layer of elastomeric material surrounding said signal feed;

5 a first layer of dielectric material surrounding said layer of elastomeric material;

conductive material surrounding said first layer of dielectric material; and

10 a second layer of dielectric material surrounding said conductive material.

18. A radiotelephone comprising:

a radiotelephone housing;

a circuit board disposed in said housing;

5 a flexible diversity antenna disposed in said housing, said flexible diversity antenna comprising:

an elastomeric core surrounded by a first layer of dielectric material and having opposite end portions;

10 a layer of conductive material surrounding one of said end portions; and

an electrical conductor embedded within said elastomeric core and extending between said end portions; and

15 a signal feed extending outwardly from said diversity antenna and electrically connecting said electrical conductor embedded within said elastomeric

core with said circuit board.

19. A radiotelephone according to Claim 18 wherein said layer of conductive material is surrounded by a second layer of dielectric material.

20. A radiotelephone according to Claim 18 wherein said electrical conductor has a meandering configuration through said elastomeric core.

21. A radiotelephone according to Claim 18 wherein said elastomeric core comprises silicone.

22. A radiotelephone according to Claim 18 wherein said conductive layer comprises metalized fabric.

23. A radiotelephone according to Claim 22 wherein said metalized fabric is laminated to said first layer of dielectric material with a silicone elastomer.

24. A radiotelephone according to Claim 18, further comprising:

    a layer of elastomeric material surrounding said signal feed;

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    a first layer of dielectric material surrounding said layer of elastomeric material;

    conductive material surrounding said first layer of dielectric material; and

    a second layer of dielectric material

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10 surrounding said conductive material.

25. A method of fabricating a flexible diversity antenna having a predetermined impedance, the method comprising the steps of:

5 forming a planar antenna having an electrical conductor embedded within an elastomeric core, a first layer of dielectric material surrounding the elastomeric core, portions of the first layer of dielectric material surrounded with conductive material, and a second layer of dielectric material 10 surrounding the conductive material; and

folding the planar antenna into a shape for assembly within an electronic device.

26. A method according to Claim 25 wherein said step of forming a planar antenna comprises embedding the electrical conductor in a meandering configuration through the elastomeric core.

27. A method according to Claim 25 wherein said step of forming a planar antenna comprises forming an integral shielded signal feed extending outwardly from the elastomeric core, wherein the signal feed is electrically connected to the electrical conductor embedded within the elastomeric core.

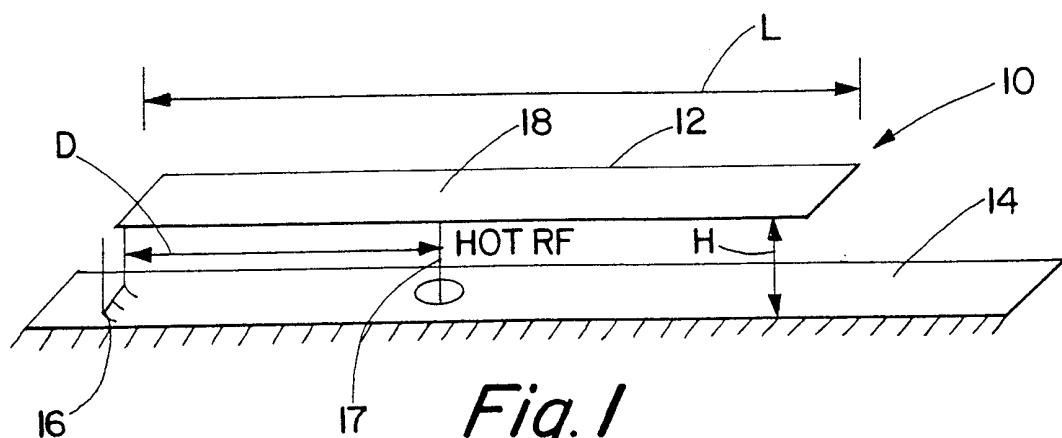
28. A method according to Claim 25 further comprising the step of curing the elastomeric core prior to said step of folding the planar antenna into a shape for assembly within an electronic device.

29. A method according to Claim 25 wherein said step of forming a planar antenna comprises forming the elastomeric core from silicone elastomer.

30. A method according to Claim 25 wherein the conductive material is metalized fabric.

31. A method according to Claim 25 wherein the metalized fabric is laminated to the first layer of dielectric material with a silicone elastomer.

32. A method according to Claim 28 wherein said step of curing the elastomeric core comprises forming surface texturing in the second layer of dielectric material.



*Fig. 1*  
(PRIOR ART)

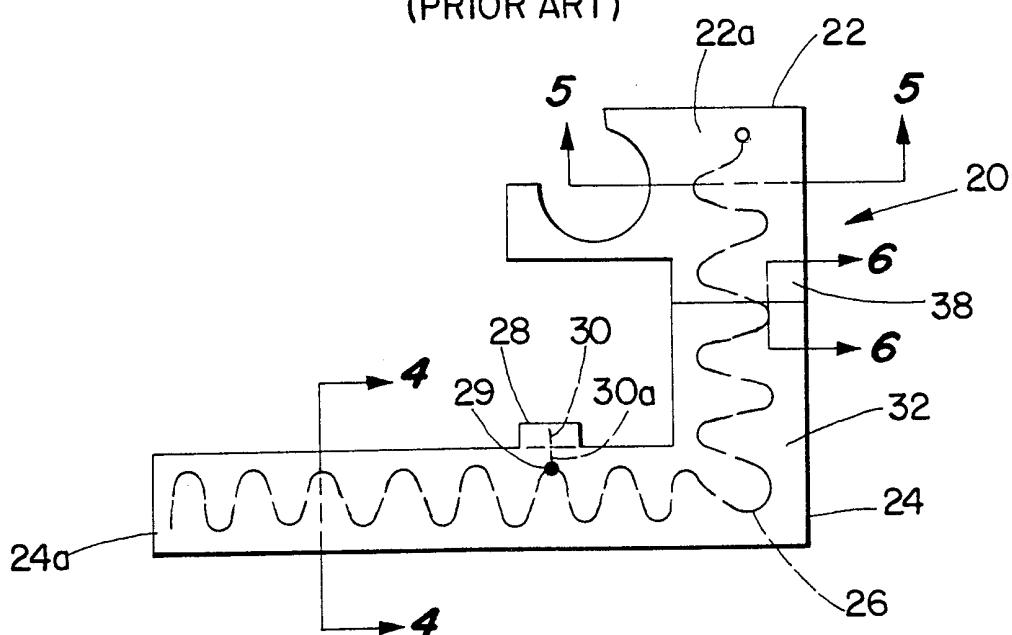


Fig. 2

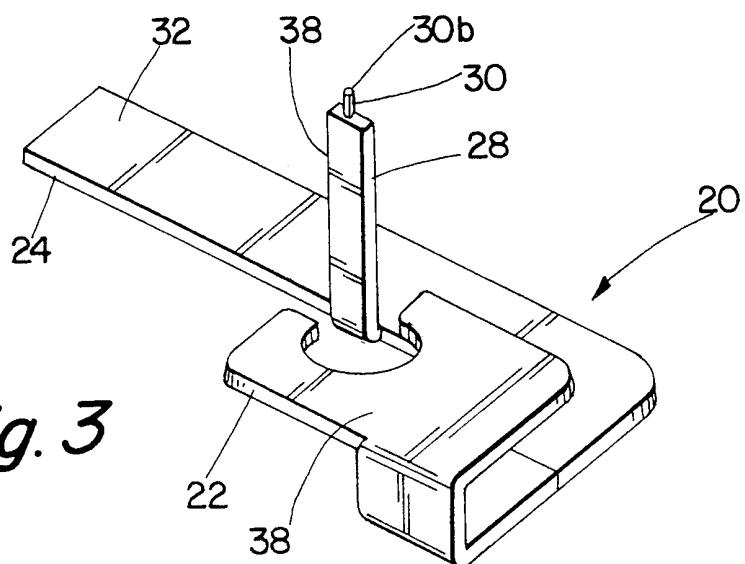
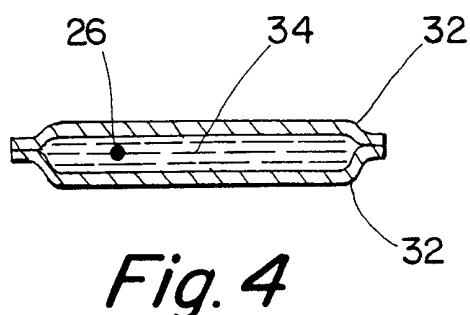
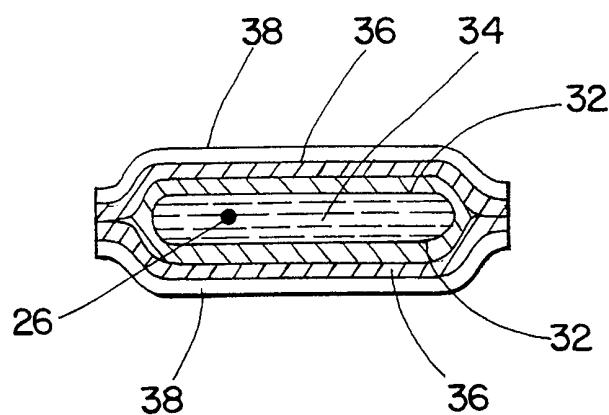


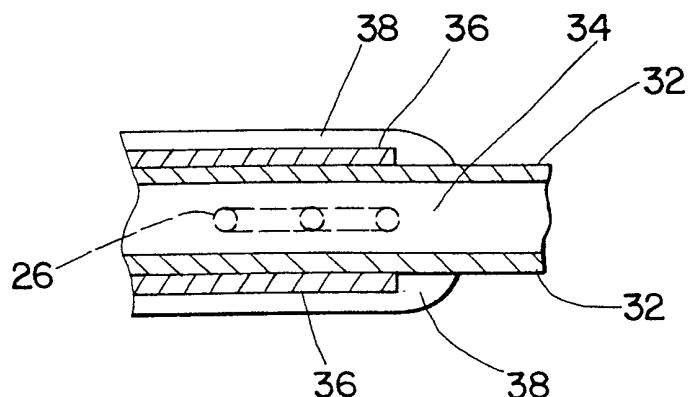
Fig. 3



*Fig. 4*



*Fig. 5*



*Fig. 6*

Fig. 7A

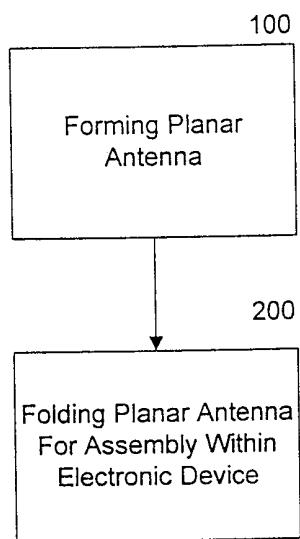
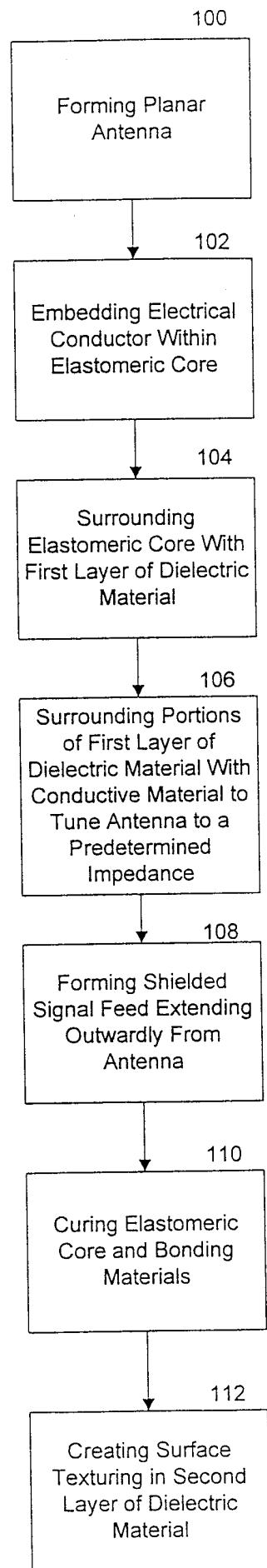


Fig. 7B



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/03949

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 H01Q1/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category <sup>°</sup>	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 223 849 A (KASEVICH RAYMOND S ET AL) 29 June 1993 see column 6, line 27 - column 6, line 52; figure 2 --- US 5 181 025 A (FERGUSON DENNIS D ET AL) 19 January 1993 see column 2, line 40 - column 2, line 58; figure 1 -----	1-32
A		1-32



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

<sup>°</sup> Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

3 May 1999

Date of mailing of the international search report

11/05/1999

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**INTERNATIONAL SEARCH REPORT****Information on patent family members****International Application No****PCT/US 99/03949**

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US 5223849	A 29-06-1993	US 5576710	A 19-11-1996	
		US 5214432	A 25-05-1993	
		US 5325094	A 28-06-1994	
US 5181025	A 19-01-1993	NONE		