US007161538B2

(12) **United States Patent**
Zhang et al.

(10) **Patent No.: US 7,161,538 B2**
(45) **Date of Patent: Jan. 9, 2007**

(54) **MULTIPLE BAND ANTENNA AND ANTENNA ASSEMBLY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/136,094**

(22) Filed: **May 24, 2005**

(65) **Prior Publication Data**

US 2005/0275594 A1 Dec. 15, 2005

Related U.S. Application Data

(60) Provisional application No. 60/573,875, filed on May 24, 2004.

(51) **Int. Cl.**
H01Q 1/38 (2006.01)
H01Q 9/16 (2006.01)

(52) **U.S. Cl.** .... **343/700 MS**; 343/793; 343/795; 343/895

(58) **Field of Classification Search** .... 343/700 MS, 343/702, 793, 795, 895
See application file for complete search history.

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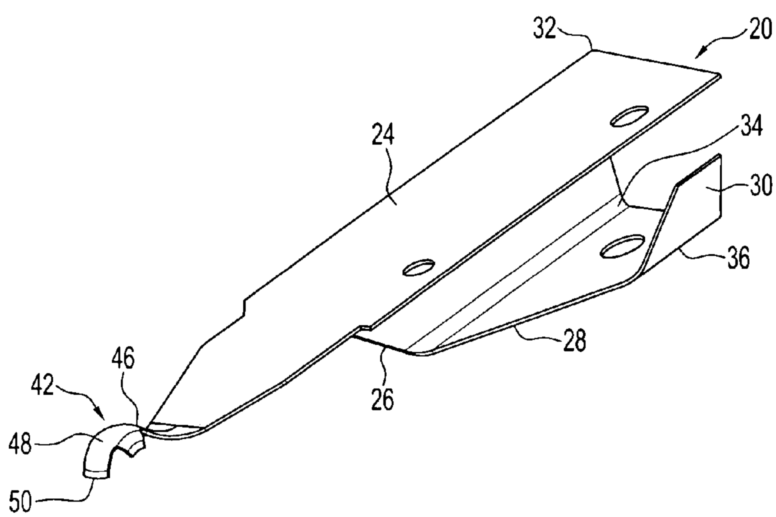
(57) **ABSTRACT**

Multiple band antenna for mounting to a portable device. The antenna comprises a piece of conductive metal including a half-bowtie portion shaped to define a monopole and folded to provide a plurality of planar surfaces together generally enclosing a volume. A flexible spring contact extends from the half-bowtie portion. The spring contact is configured for engaging a contact of the portable device.

21 Claims, 14 Drawing Sheets



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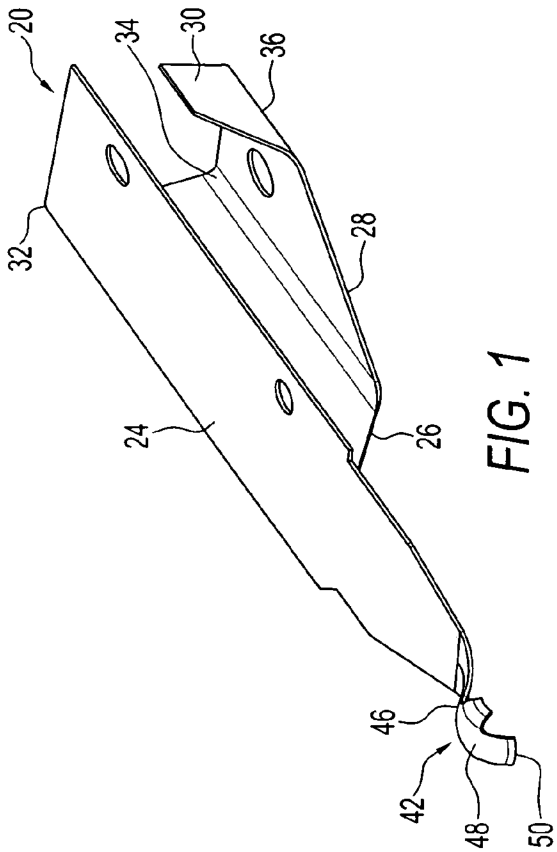

FIG. 1

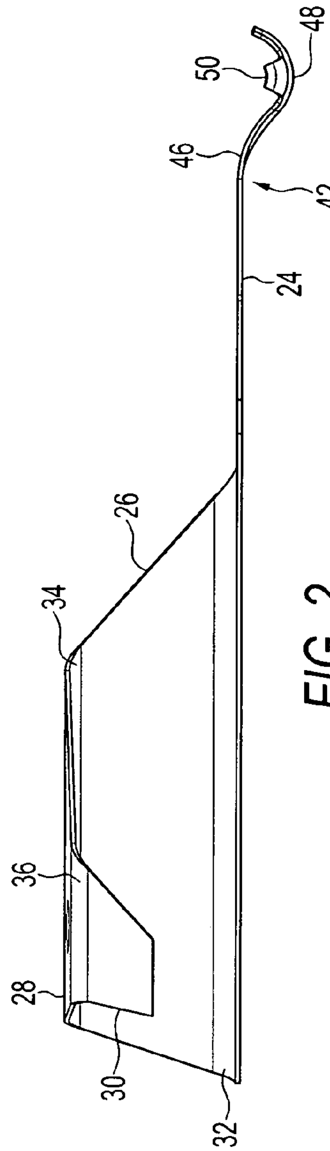

FIG. 2

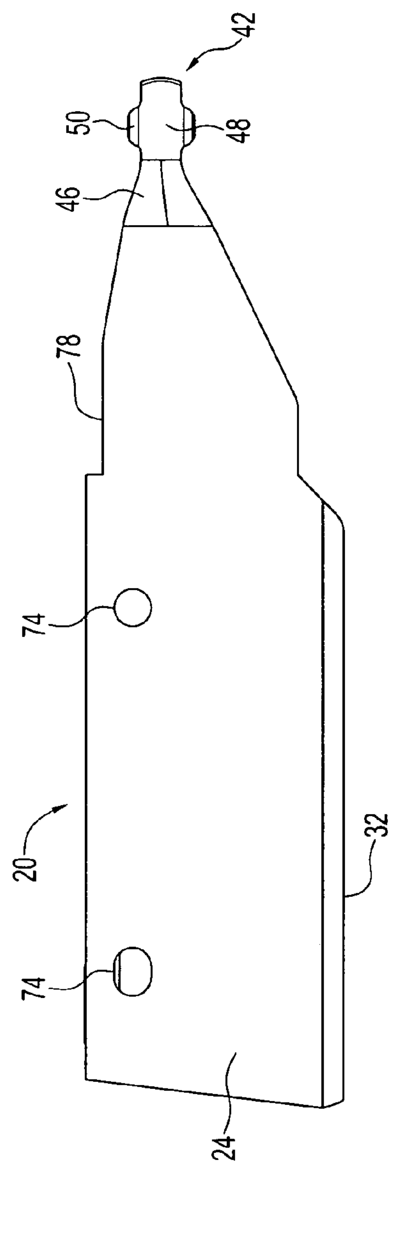

FIG. 3

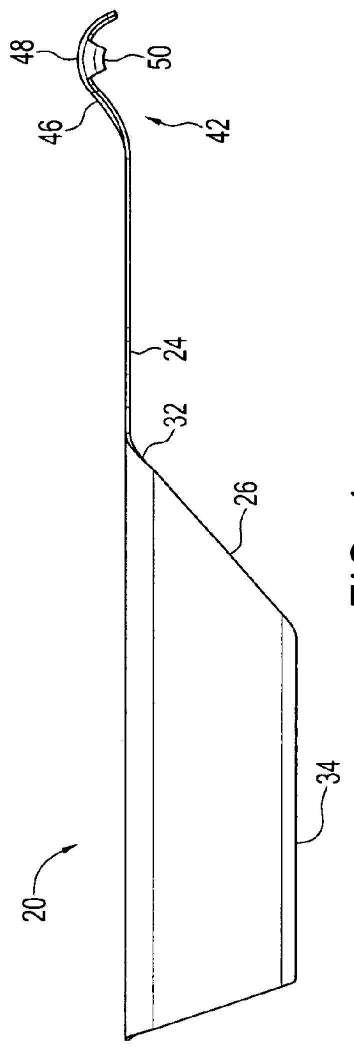

FIG. 4

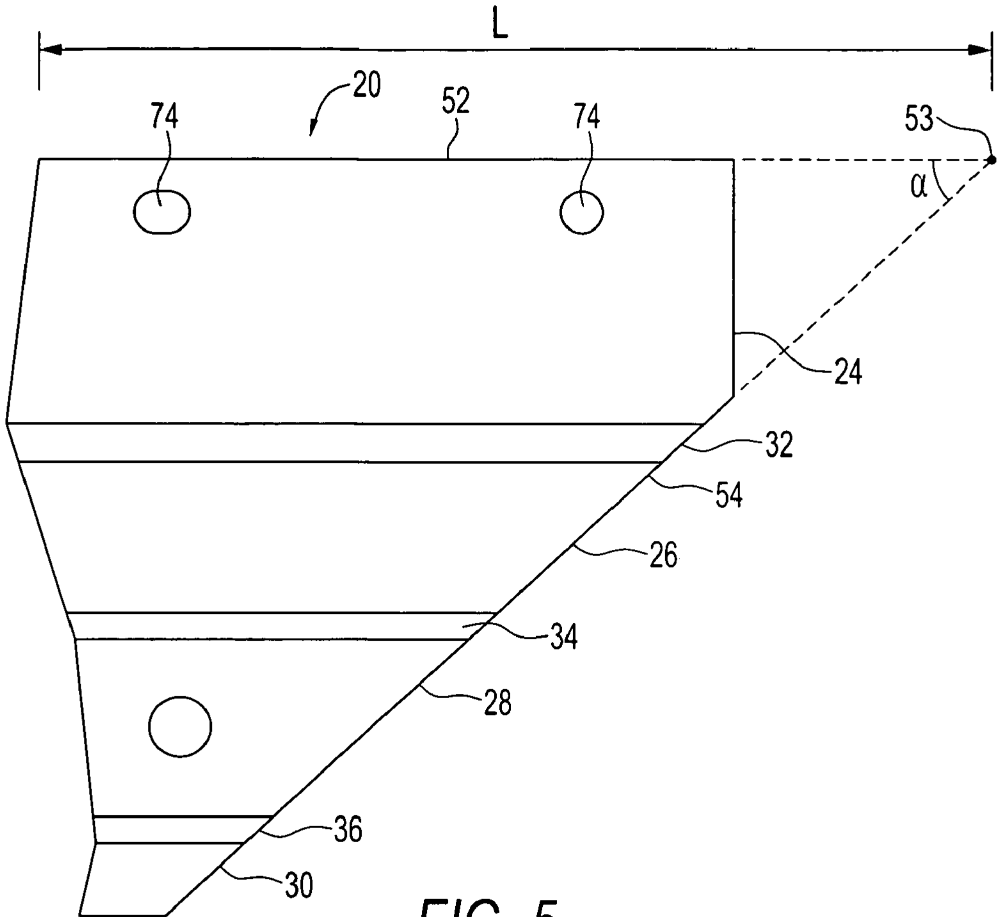
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FIG. 5

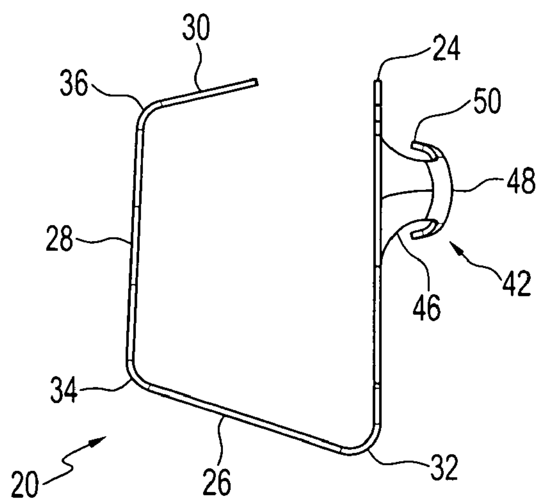
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FIG. 6

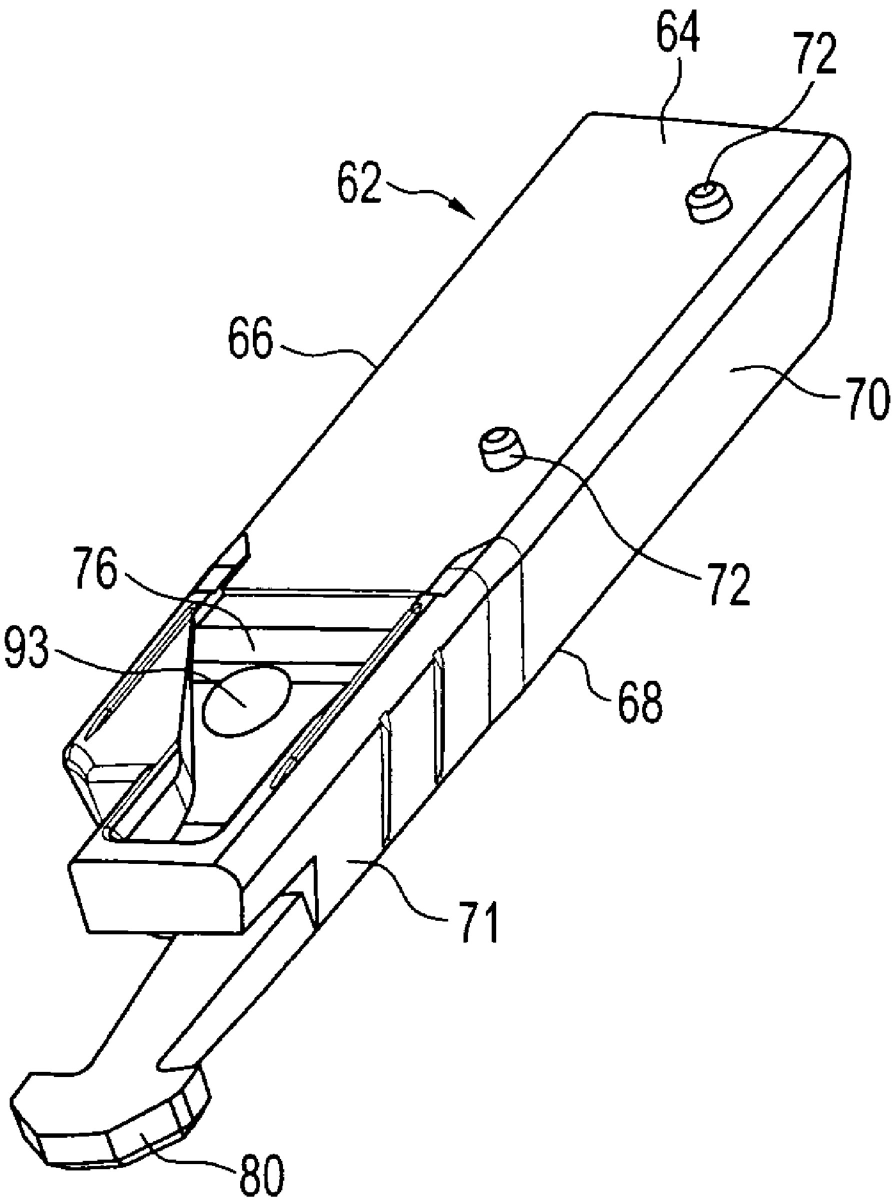

FIG. 7

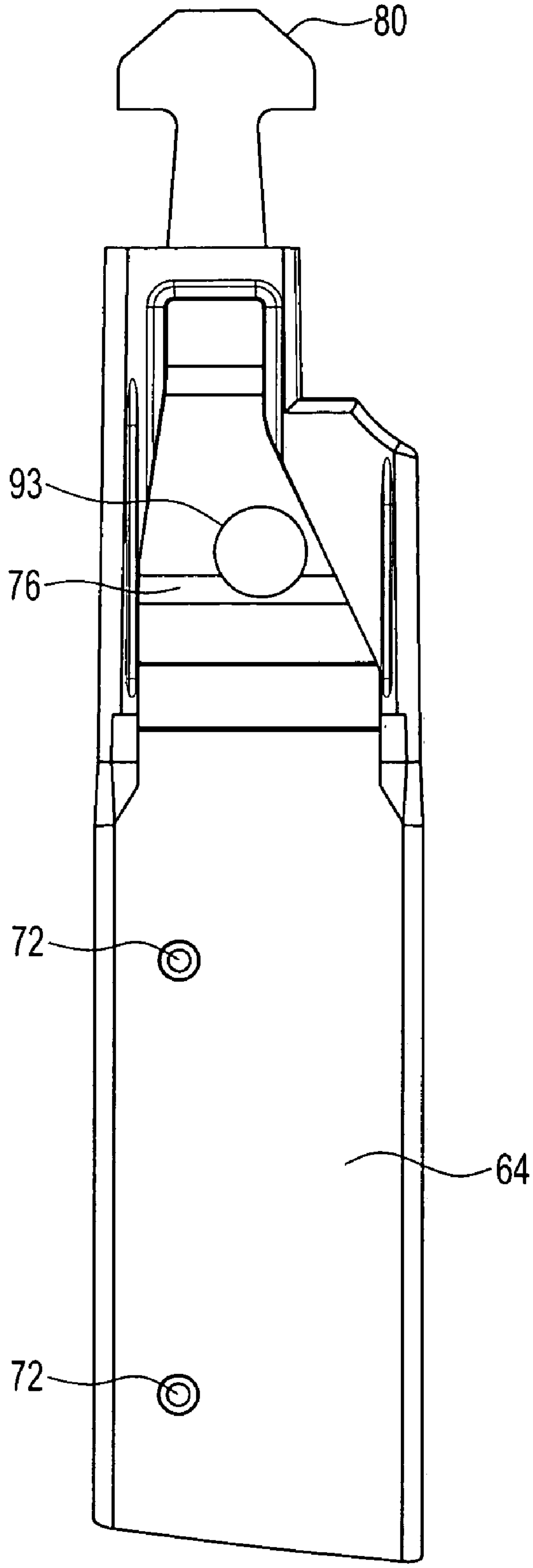

FIG. 8

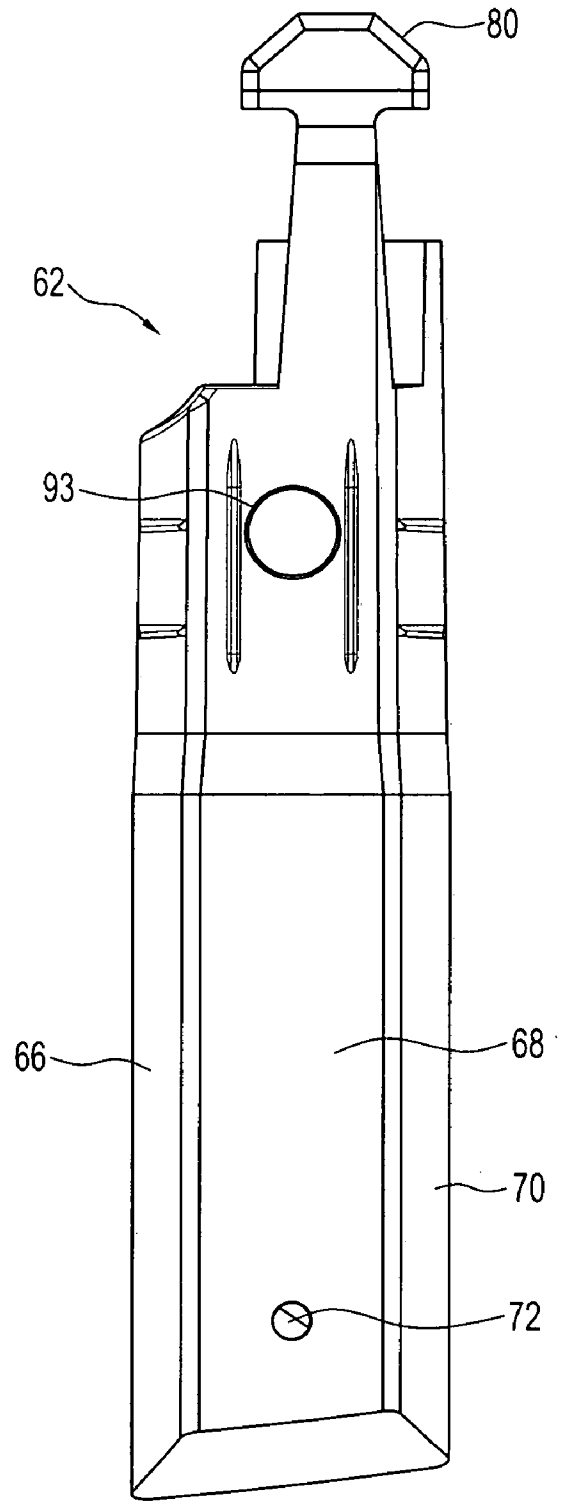

FIG. 9

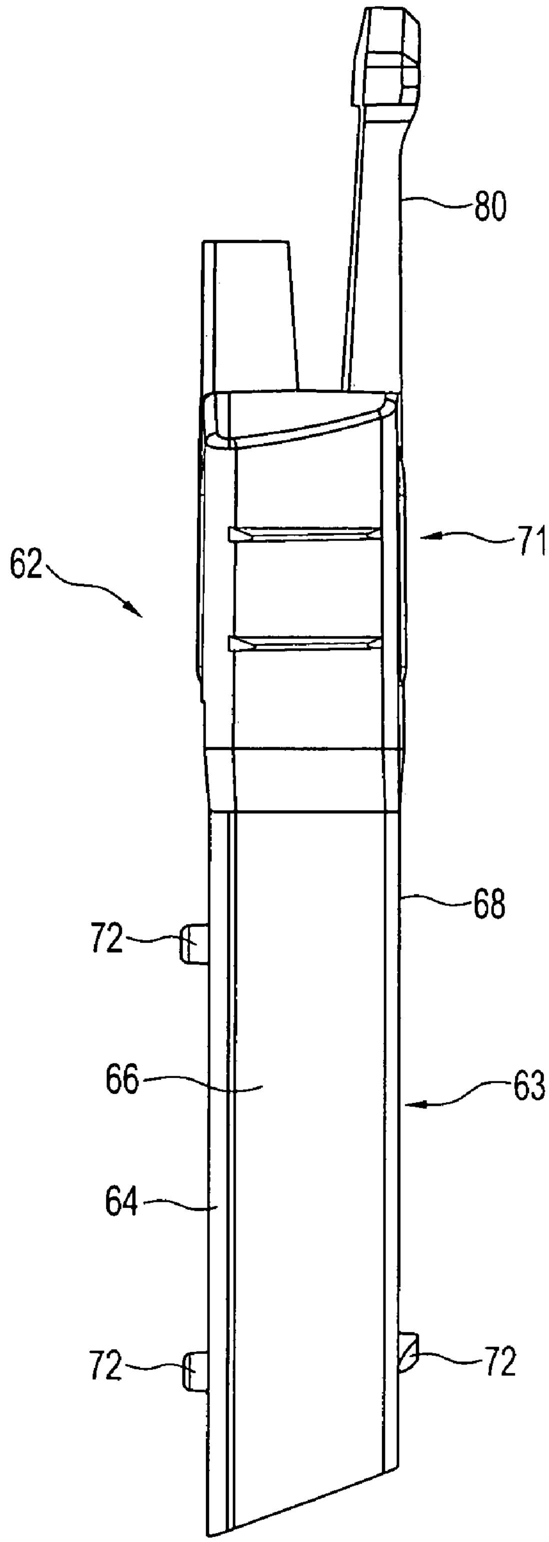

FIG. 10

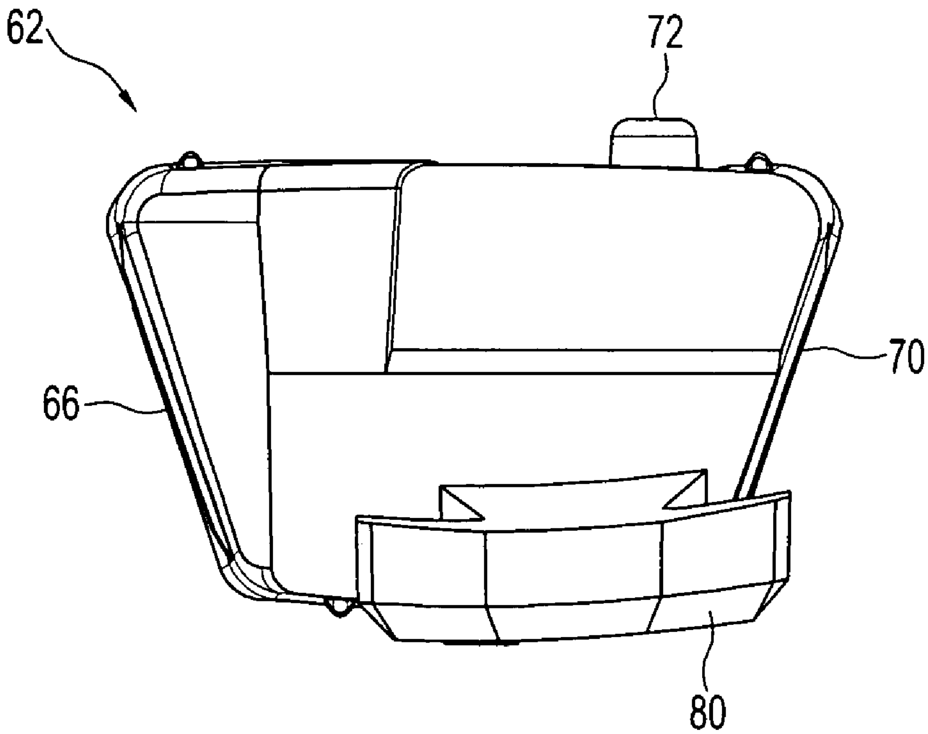

FIG. 11

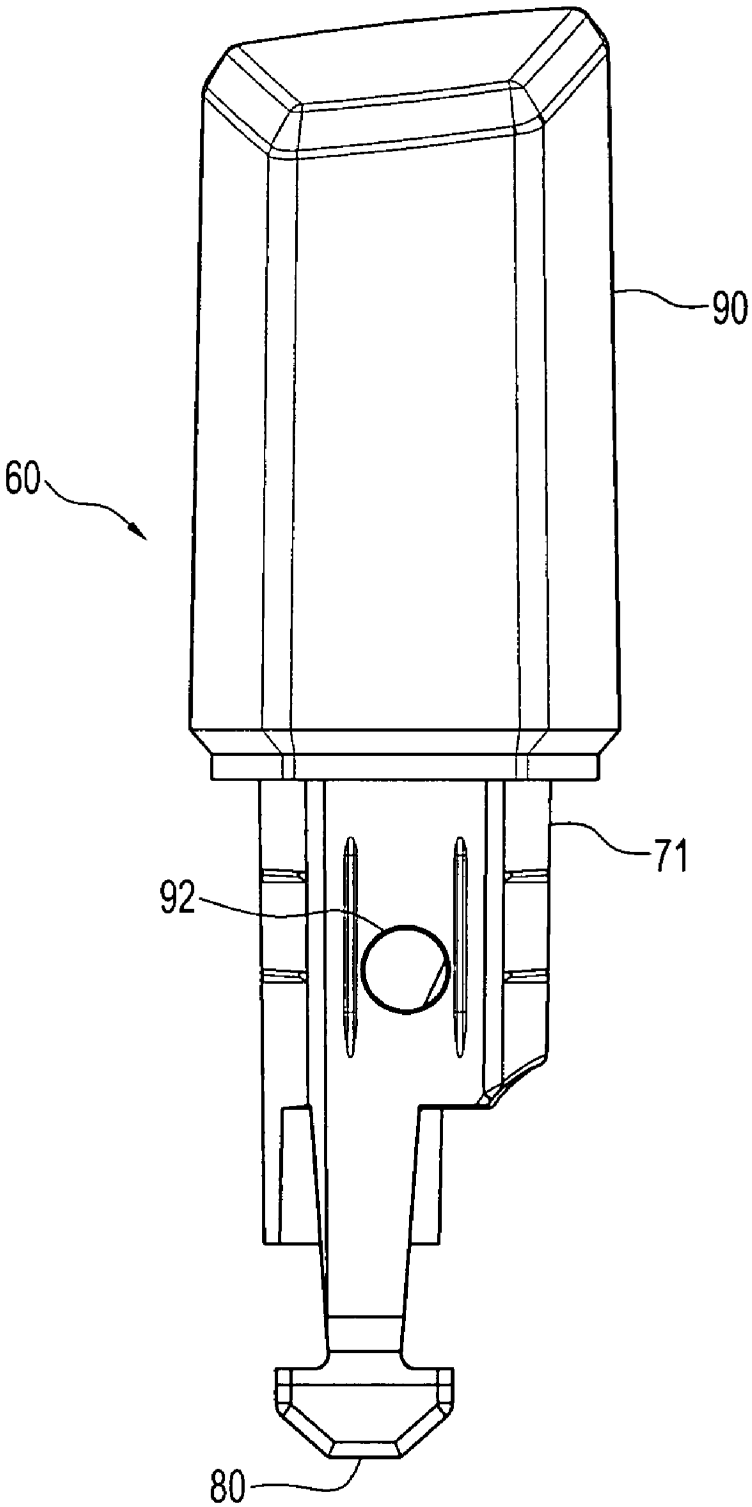

FIG. 12

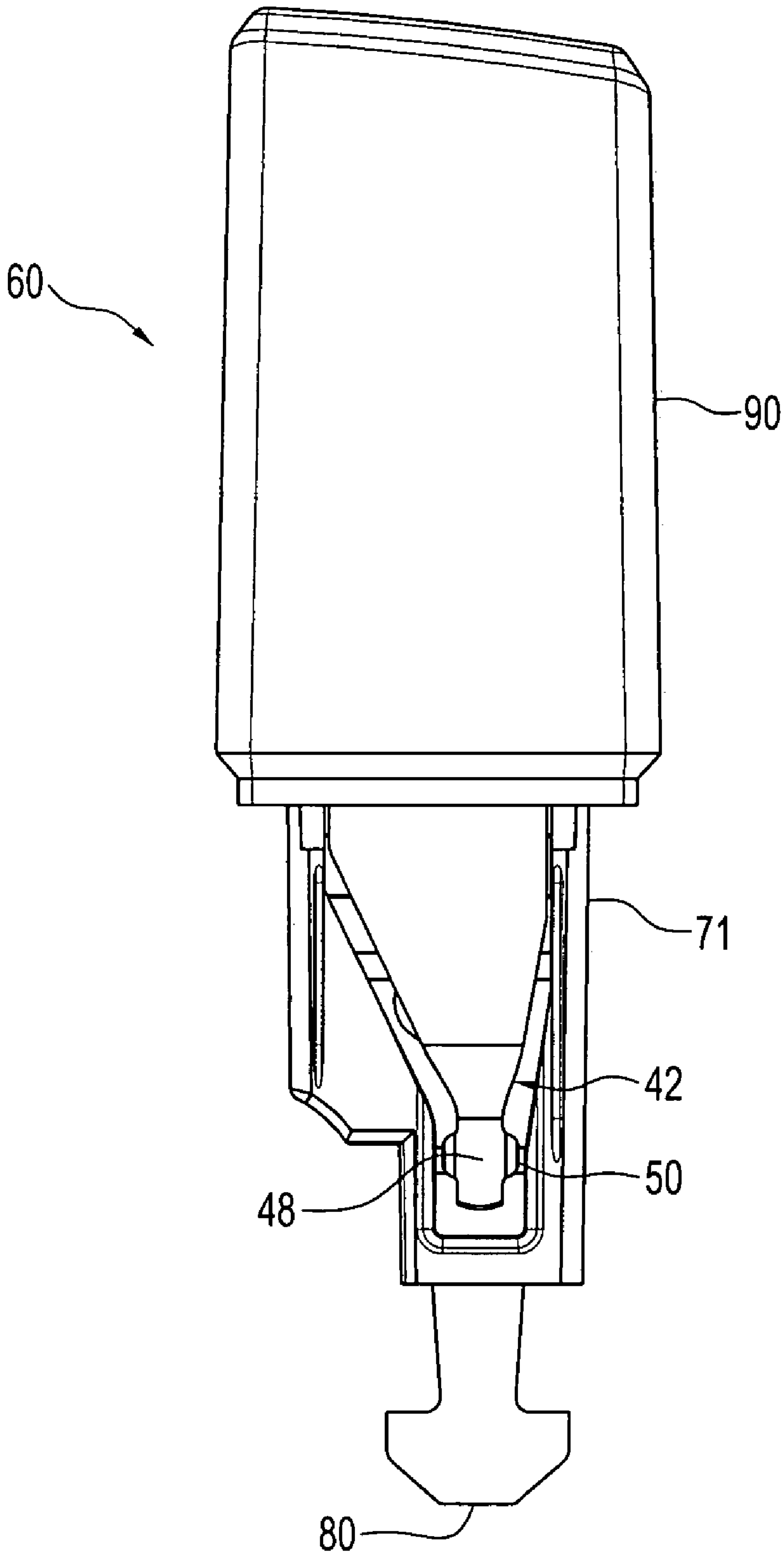

FIG. 13

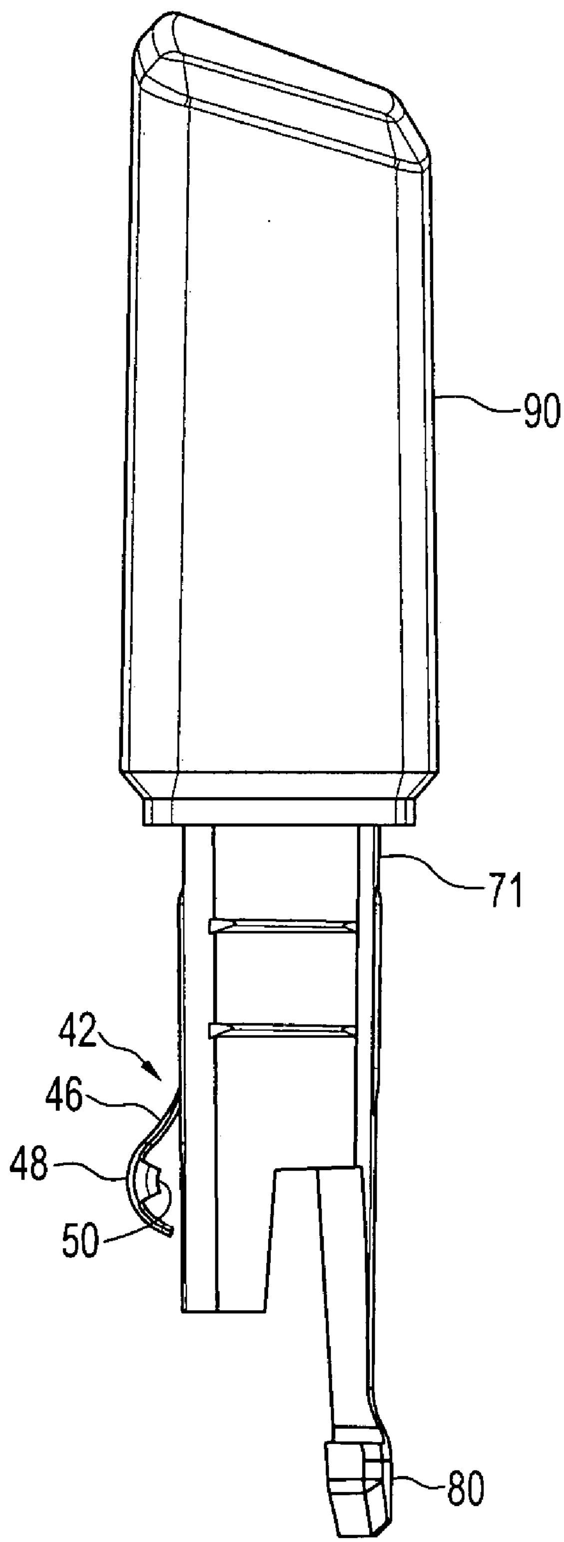

FIG. 14

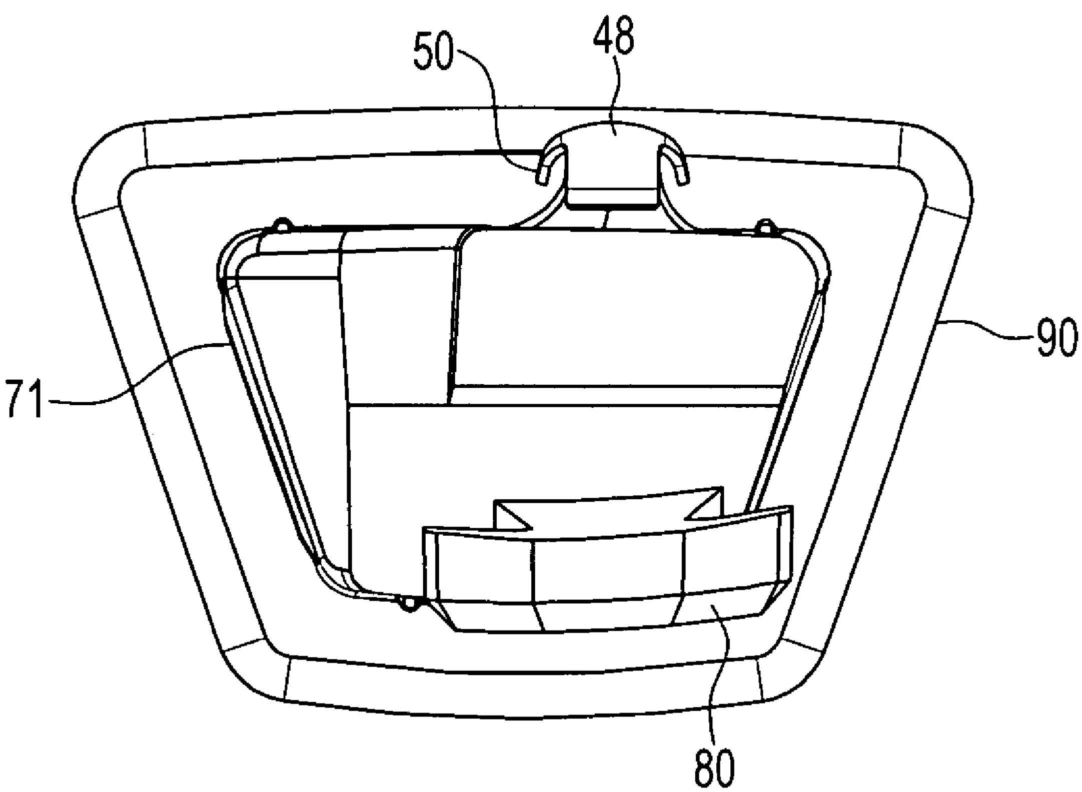

FIG. 15

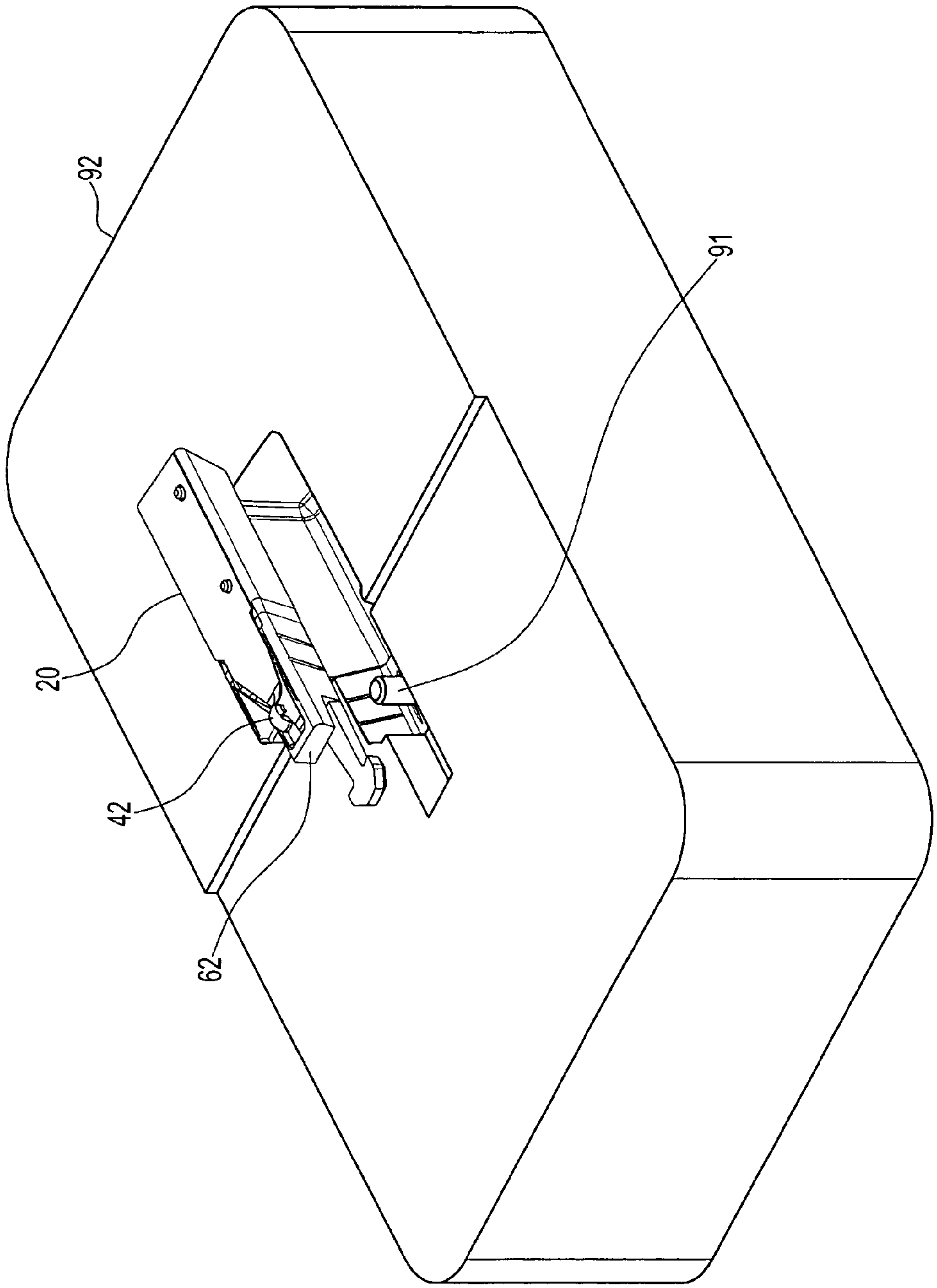

FIG. 16

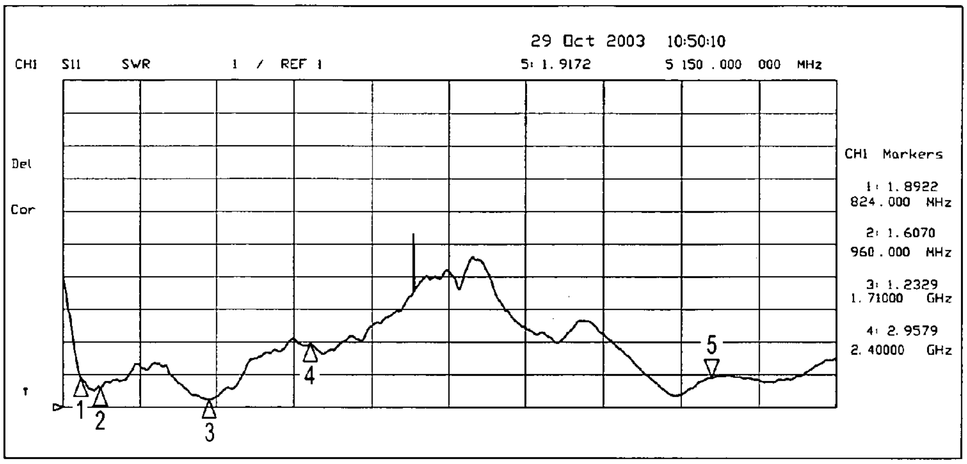

FIG. 17A

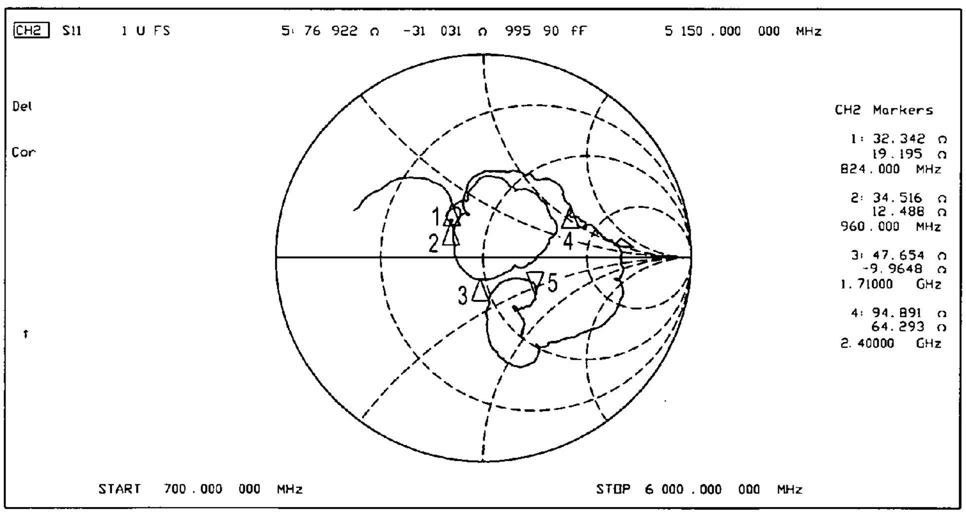

FIG. 17B

MULTIPLE BAND ANTENNA AND ANTENNA ASSEMBLY

PRIORITY CLAIM

The present application claims the benefit of U.S. Provisional Application Ser. No. 60/573,875, filed May 24, 2004, under 35 U.S.C. § 119.

BACKGROUND OF THE INVENTION

A field of the present invention is antennas for portable devices.

Antennas currently being used for portable devices such as, but not limited to, portable communication devices, portable computing devices (including hand held computers and personal digital assistants), and portable computers, are optimized by design for reception of specific radio frequency bands. For example, particular portable devices may include GSM antennas (appr. range 824–960 MHz), GPS antennas (1575 MHz), DCS antennas (1710–1880 MHz), PCS antennas (1850–1990 MHz), 802.11b antennas (2.4–2.48 GHz), and/or 802.11a/g antennas (5.15–5.85 GHz). Still others may provide antennas in 3G range, for example, or in other frequency bands.

However, because antennas for such devices are tailored to particular bands, reception in more than one or two bands typically requires multiple mounted antennas. This in turn requires valuable real estate on or in a portable device. It is desirable to make portable devices sufficiently small for practical use, while providing a sufficiently rugged design to allow extended use of the device.

SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide, among other things, a multiple band antenna for mounting to a portable device. The antenna comprises a piece of conductive metal including a half-bowtie portion shaped to define a monopole and folded to provide a plurality of planar surfaces together generally enclosing a volume. A flexible spring contact extends from the half-bowtie portion. The spring contact is configured for engaging a contact of the portable device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a multiple band antenna;

FIG. **2** is a side elevation view of the multiple band antenna of FIG. **1**;

FIG. **3** is a top plan view of the multiple band antenna of FIG. **1**;

FIG. **4** is a side elevation view of the multiple band antenna of FIG. **1**, inverted;

FIG. **5** is a top plan view of a portion of a multiple band antenna, unfolded to a flat plane, with a spring contact omitted for clarity;

FIG. **6** is an end view of the multiple band antenna of FIG. **1**;

FIG. **7** is a perspective view of an antenna base;

FIG. **8** is a top plan view of the antenna base of FIG. **7**;

FIG. **9** is a bottom plan view of the antenna base of FIG. **7**;

FIG. **10** is a side elevation view of the antenna base of FIG. **7**;

FIG. **11** is an end view of the antenna base of FIG. **7**;

FIG. **12** is a top plan view of an antenna assembly, including the multiple band antenna of FIG. **1** and the antenna base of FIG. **7**;

FIG. **13** is a bottom plan view of the antenna assembly of FIG. **12**;

FIG. **14** is a side elevation view of the antenna assembly of FIG. **12**;

FIG. **15** is an end view of the antenna assembly of FIG. **12**;

FIG. **16** is a perspective view of a mold for forming an overmold covering a portion of the base, according to a preferred embodiment of the present invention; and

FIGS. **17**A and **17**B are graphs showing voltage standing wave ratio (VSWR) for a preferred multiple band antenna.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Preferred embodiments of the present invention include a multiple band antenna capable of reception across several, e.g., six or seven, bands. A preferred multiple band antenna adds a relatively small volume to a portable device. For example, a preferred multiple band antenna can be implemented as a short stubby antenna extending from a portable device.

Antenna reception in devices prior to the present invention typically has been based on a monopole principle, where an extended antenna provides a half-dipole and a ground plane such as a printed circuit board (PCB) of the mobile electronic device serves as the other half-dipole.

Preferred embodiments of the present invention include a multiple band antenna for a portable device. The antenna includes a piece of conductive metal including a half-bowtie portion shaped to define a monopole. A PCB provides the other half-dipole. Bowtie antennas have been used for television consoles and other typically stationary products, but they usually are not used in portable devices. Further, though a bowtie typically has been employed as a dipole antenna having symmetric ends, the half-bowtie portion of present preferred embodiments operates as a monopole antenna. A flexible spring contact for engaging a contact of the portable device extends from the half-bowtie portion.

The half-bowtie portion is folded to provide a plurality of planar surfaces generally enclosing a volume, and preferably is folded about a base to conserve area and/or volume real estate of the portable device. This folded shape provides a more rigid mechanical structure for a stubby antenna, while retaining benefits of multiple band reception.

The preferred multiple band antenna and base are part of an antenna assembly coupled to other parts of the portable device, including the PCB. An overmold preferably covers part of the base and the multiple band antenna. To maintain electrical contact with the PCB, the flexible spring contact is exposed (that is, not covered by the overmold). In an exemplary embodiment, the PCB includes a rigid, C-shaped clip to provide a sufficient electrical contact area with the spring contact, while reducing or minimizing a circuit path between the spring contact and a signal splitter (diplexer) of the PCB.

It is desired in the art to provide portable devices having reception capabilities across broad portions of the electromagnetic spectrum. For example, GSM, GPS, DCS, PCS, 802.11a, and 802.11b are common frequency bands for use in current portable devices. Additional bands may become desirable in the future.

However, conventional antennas are not able to receive signals in most of these bands in a single device without the use of multiple mounted antennas. One problem with using multiple mounted antennas is that portable devices need to be truly portable; that is, portable designs naturally impose constraints on volume and area real estate. Increasing the number of mounted antennas or increasing the size of individual antennas tends to increase the overall size, including area and volume, of such portable devices. This is an undesirable result.

Another problem is that multiple antennas may introduce challenges as to integrating such antennas into the device, and additional antennas add to design and manufacturing costs for a device. Accordingly, it is desired to provide an antenna and/or antenna assembly for a portable device that enables reception across various bands, while also providing a relatively small volume and/or area in terms of device real estate.

One antenna type used in portable devices presently is a flex antenna. Such flex antennas typically include a number of traces, where individual traces allow reception of a particular band. However, traces for each individual band need to be separated from one another for increased bandwidth. A significant number of bands (for example, six) thus increases the size of such an antenna, and accordingly increases real estate for the portable device. If the traces are not sufficiently separated from one another, low bandwidth reception results.

The present inventors have discovered that the use of a single-piece antenna made of a preferably stamped, conductive material is capable of providing multiple band reception. Such an antenna has the capability of providing a greater number of bands than a conventional flex antenna used for portable devices. According to a preferred embodiment of the present invention, the individual antenna used has a substantially triangular shape, providing essentially a half bowtie antenna.

Before the present invention, bowtie antennas have been used for applications in a generally non-portable context. For example, televisions have been known to employ bowtie antennas for larger bandwidth reception. However, a preferred embodiment of the present invention implements particular capabilities of a bowtie antenna for use in a portable device, while limiting the real estate required by the portable antenna.

In such conventional bowtie antennas, the bowtie antennas have been flat. However, according to a preferred embodiment of the present invention, a half-bowtie is folded to provide a relatively small volume while providing a sturdy antenna assembly. The present inventors have found that use of a folded antenna does not detract significantly from the reception goals of many portable devices. Such an antenna, in combination with a resonating PCB, is capable of signal reception in widely varying bands, preferably including those named above, and others.

Conventional bowtie antennas are used typically for low band reception. However, the multiple band antenna according to a preferred embodiment of the present invention allows reception of both low and high band signals.

Referring now to FIGS. **1**–**6**, an exemplary multiple band antenna **20** for a portable device such as a mobile communication device, when folded, defines a first planar surface **24**, a second planar surface **26**, a third planar surface **28**, and a fourth planar surface **30** (in decreasing order of size). The multiple band antenna **20** is generally formed by, preferably, a stainless steel plated (selectively or completely) by gold and nickel sulfamate, and stamped to form a desired shape. The planar surfaces, **24**, **26**, **28**, and **30** are formed by first, second and third folds **32**, **34**, and **36**, thus generally enclosing a volume by the folded antenna **20**. As is most clearly seen in FIG. **6**, the enclosed volume in an exemplary embodiment is generally trapezoidal in shape, and is tapered from front to back. However, this particular shape is not required for a folded antenna, and other shapes are possible, for example, for space or mechanical consideration and/or for aesthetic purposes. As shown in FIGS. **1** and **3**, the first planar surface **24** extends along the full length of the multiple band antenna **20** and along most of the covered portion of a base **40**, which mechanically supports the multiple band antenna.

A flexible spring contact **42** of the multiple band antenna **20** extends from a bottom end of the antenna (in the orientation shown in FIG. **1**) for electrically connecting to a printed circuit board (PCB) of the mobile communication device. The spring contact **42** may be integrally formed with the remainder of the antenna **20**, or it may be a separate piece mechanically and electrically coupled to the remainder of the antenna. As most clearly seen in FIGS. **2**–**4**, the exemplary spring contact **42** contains a generally rounded, arced surface **46** forming a rounded portion **48** at its peak. The rounded portion **48** contains three small flaps **50** preferably formed by precisely crimping the rounded portion **48** of the spring contact **42**. This structure is preferred, not required, for the spring contact **42**, though it provides certain mechanical benefits, particularly for maintaining contact with the PCB and for rigidity. The rounded portion **48** engages the PCB for transmitting signals from the antenna **20**.

Referring now to FIG. **5**, which illustrates the multiple band antenna **20** in an unfolded position (with the spring contact **42** removed for clarity), it is shown that the unfolded antenna generally defines a triangle. To provide improved reception across low frequency bands, the multiple band antenna **20** preferably defines a length L, as shown along a top edge **52** of the antenna, and particularly of the planar surface **24**. The length L preferably is as great as is possible given the size and/or volume constraints of a particular portable device.

The top edge **52** makes an angle α with a diagonal edge **54** of the multiple band antenna **20**. Together, in a preferred embodiment, the top edge **52** and the diagonal edge **54** define two sides of a generally right triangle. This angle α, which is illustrated in FIG. **5** by extending the top edge **52** and the diagonal edge **54** to an outer point **53**, should be as large as possible to maximize the bandwidth of the antenna **20**. Thus, to increase bandwidth and low band reception, it is desirable to maximize both length L and angle α. As opposed to a flex antenna, the multiple band antenna **20** itself provides frequency reception at its different parts, without respect to individual antenna traces. In other words, the entire antenna **20** provides reception. High band reception is provided by sharpness of the contact **42** of the antenna **20** and by resonance of the PCB. Though the multiple band antenna **20** as implemented could be shaped as an unfolded half-bowtie, the total area taken up by such an antenna would be significantly larger than often permitted for portable devices. Accordingly, the folded multiple band antenna typically is a more desirable approach for portable devices. Outer edges of planar surfaces **24**, **26**, **28**, **30** are angled slightly, so that the volume enclosed by the folded antenna **20** is tapered downwardly, though this is not required.

To further increase bandwidth of the multiple band antenna **20**, it is desired to maximize distance between the ends of the antenna. Particularly, in the antenna **20** shown in FIGS. **1**–**6**, it is desired to separate the top edge **52** from the outer edge of the fourth planar surface **30**. This is accomplished by, for example, increasing angle α. By contrast, decreasing a results in decreased bandwidth. In the exemplary multiple band antenna **20**, the length L allows reception down to, e.g., the 800 MHz (GSM) frequency.

In a preferred embodiment of an antenna assembly **60** (see FIG. **12**) for the portable device, the multiple band antenna **20** is wrapped around a base **62**, which is mechanically connected to the portable device. The base **62**, when covered with an overmold, generally resembles a stub extending outwardly from the portable device. As shown in FIGS. **7**–**11**, the exemplary base **62**, preferably made of a nonconductive material such as a plastic, includes an upper portion **63** with first, second, third, and fourth planar surfaces **64**, **66**, **68**, **70** that respectively engage the first, second, third, and fourth planar surfaces **24**, **26**, **28**, **30** of the antenna **20**. For example, the first planar surface **64** of the base **62** is engaged with the first planar surface **24** of the multiple band antenna **20**, as most clearly shown in FIG. **12**. Preferably, the first planar surface **24** of the antenna **20** is dimensioned to cover as much of the first planar surface **64** of the base **62** as possible, as this allows both the length L and angle α to be maximized. Posts **72** projecting from the first planar surface **64** engage apertures **74** of the first planar surface **24** to help maintain the position of the multiple band antenna **20** about the base **62**, particularly during overmolding.

The upper portion **63** extends outwardly from the portable device. A lower portion **71** typically is fitted into the casing of the portable device. The lower portion **71** further includes a seat **76** for accepting the spring contact **42**, including a flexible, generally triangular area **78** extending from planar surface **24** (see FIG. **3**). The seat **76** preferably has a sufficient depth allowing the contact **42** when flexed downwardly to fit at least partly into the seat, to allow the antenna assembly **60** to be inserted into the casing of the portable device more easily during assembly.

When the multiple band antenna **20** is wrapped about the base **62**, it is preferred that the first, second, third, and fourth planar surfaces **24**, **26**, **28**, **30** remain as close to the planar surfaces **64**, **66**, **68**, **70** of the base **62** as is possible, with the exception of the arced surface **46** and rounded portion **48** of the spring contact **42**. When incorporated into the mobile communication device, the rounded portion **48** principally engages the PCB to make electrical contact between the multiple band antenna **20** and the PCB. Preferably, as shown in FIG. **3**, the tri angular area **78** is indented slightly inwardly on opposing sides from the first planar surface **24**. This increases flexibility of the spring contact **42** and/or permits the lower portion **71** of the base **62** to be narrower than the upper portion **63**.

The lower portion **71** of the base **62** further includes a retention device, such as a hook **80**. The hook **80** engages, for example, a casing of the portable device for retaining the multiple band antenna **20** in position with respect to the PCB.

Often, in designing antennas for portable devices, mechanical constraints, such as height and volume of the overall antenna assembly **60**, are imposed. The folded half-bowtie shape of the multiple band antenna **20** in combination with the preferably compact base **62** provides a device for relatively high bandwidth reception, while minimizing length and volume for the antenna assembly **60** and thus the overall device.

To make a connection, the spring contact **42** is electrically coupled to the PCB. The spring contact **42** deflects downwardly, particularly at the triangular area **78**, when engaging the PCB, and thus becomes biased upwardly to maintain an electrical connection. This spring force, for example, may be

50 grams or greater to securely maintain such a mechanical and electrical contact. However, this spring force can vary. In a preferred embodiment, the spring contact engages a rigid C-shaped clip (C-clip) of the PCB. The flexibility of the spring contact **42** adjusts for tolerance between the C-clip and the spring contact.

Referring now to FIGS. **12**–**15**, an overmold **90** is preferably formed about the top of the base **62**, particularly the upper end **63** of the base **40** to protect the base and the antenna **20**. Preferably, the region covered by the overmold **90** extends from the remainder of the portable device to provide what is generally known in the art as a stubby antenna. The overmold is preferably formed from a hard plastic that covers the multiple band antenna **20**. The presence of the overmold **90** in the preferred material covering the folded multiple band antenna **20** does not appear to significantly decrease performance of multiple band reception from the device.

In forming the overmold **90** on the base **62** to cover the multiple band antenna **20**, it is often difficult to maintain the position of the base **62** within a mold as the plastic material of the overmold is injected into the mold. Accordingly, the present inventors have discovered that it is useful to provide a pin extension **91** within a mold **92**, as shown in FIG. **16**, to maintain the position of the base **62** as the plastic is injected into the mold. Referring again to FIG. **12**, for example, an aperture **93** may be formed into the base **62** to mate with the pin extension **91** of the mold **92**. This helps secure the base **62**, and thus keeps the base from undesirably shifting within the mold **92** as the overmold **90** material is forced into the mold to form the overmold.

The overmold **90** does not appear to significantly affect the overall response of the multiple band antenna **20**, as opposed to a flex antenna. Furthermore, the present inventors have discovered that the half-bowtie preferred shape of the multiple band antenna **20** appears to provide much less radiation versus the ground plane. It appears that the ground plane exhibits far greater excitation in this arrangement than with a similar arrangement using a flex antenna. Thus, it appears that changing the shape of the multiple band antenna **20** to a certain degree has a relatively small effect on the overall performance of the multiple band antenna. However, as stated herein, both the angle α and the overall length L should be maximized to the extent possible to optimize reception of the multiple band antenna **20**.

FIGS. **17A**–**17B** are graphs showing a voltage standing wave ratio (VSWR) for an exemplary multiple band antenna **20**. As shown, the exemplary multiple band antenna provides better than 3:1 VSWR across CDMA, GSM, GPS, DCS, PCS, 802.11g, and 802.11a bands.

While specific embodiments of the present invention have been shown and described, it should be understood that other modifications, substitutions, and alternatives are apparent to one of ordinary skill in the art. Such modifications, substitutions, and alternatives can be made without departing from the spirit and scope of the invention, which should be determined from the appended claims.

Various features of the present invention are set forth in the appended claims.

What is claimed is:

1. A multiple band antenna for mounting to a portable device, the antenna comprising:

a piece of conductive metal including a half-bowtie portion shaped to define a monopole and folded to provide a plurality of planar surfaces together generally enclosing a volume;

a flexible spring contact extending from the half-bowtie portion, the spring contact being configured for engaging a contact of the portable device.

2. The multiple band antenna of claim **1** wherein said piece of conductive metal comprises a metal plated with a conductive material.

3. The multiple band antenna of claim **2** wherein the metal comprises stainless steel.

4. The multiple band antenna of claim **2** wherein the conductive material comprises gold.

5. The multiple band antenna of claim **1** wherein the antenna is capable of reception across at least six bands.

6. The multiple band antenna of claim **5** wherein the antenna is capable of reception across at least the GSM, GPS, DCS, PCS, 802.11g, and 802.11b bands.

7. The multiple band antenna of claim **1** wherein the half-bowtie portion when unfolded defines a generally triangular shape having an elongated top edge and an elongated diagonal edge at an acute angle to the top edge.

8. The multiple band antenna of claim **7** wherein the half-bowtie portion when unfolded defines a generally right triangle.

9. The multiple band antenna of claim **1** wherein a portion of said piece of conductive metal is indented to add flexibility to said spring contact.

10. The multiple band antenna of claim **1** wherein said spring contact comprises a generally rounded surface at a distal end.

11. The multiple band antenna of claim **10** wherein the generally rounded surface is formed by crimping, and wherein the generally rounded surface forms a rounded portion at a peak.

12. For a portable device, an antenna assembly for providing reception in multiple bands comprising:

a piece of conductive metal including a half-bowtie portion shaped to define a monopole and a flexible spring contact extending from the half-bowtie portion;

a non-conductive base for supporting said piece of conductive metal and anchoring said piece of conductive metal to the portable device;

the half-bowtie portion being folded to provide a plurality of planar surfaces disposed generally orthogonally with respect to one another, the planar surfaces being disposed on planar surfaces of an upper portion of said base so as to substantially wrap around at least part of the upper portion of said base.

13. The antenna assembly of claim **12** further comprising:

a non-conductive overmold covering at least the half-bowtie portion and the upper portion of said base.

14. The antenna assembly of claim **12** wherein said base includes a lower portion for mechanically engaging the portable device and securing the antenna assembly to the portable device.

15. The antenna assembly of claim **14** wherein the spring contact extends over at least part of a seat disposed in the lower portion of said base.

16. The antenna assembly of claim **12** wherein the antenna assembly is capable of reception across at least the GSM, GPS, DCS, PCS, 802.11g, and 802.11b bands.

17. The antenna assembly of claim **12** wherein the half-bowtie portion when unfolded is defined by a generally triangular shape having an elongated top edge and an elongated diagonal edge at an acute angle to the top edge.

18. The antenna assembly of claim **13** wherein the overmold and the upper portion of said base form a stubby antenna.

19. The antenna assembly of claim **12** wherein the spring contact is configured to engage a contact of the portable device, and wherein the spring contact is coupled to circuitry of the portable device, the circuitry of the portable device providing a half-dipole.

20. For a portable device, an antenna assembly for providing reception in multiple bands comprising:

means for reception including a half-bowtie portion shaped to define a monopole and further including means for electrically coupling to circuitry of the portable device;

means for supporting said means for reception and anchoring said means for reception to the portable device;

the half-bowtie portion being folded about a portion of said means for supporting so as to substantially wrap around at least part of said means for supporting.

21. For a portable device, an antenna assembly for providing reception in multiple bands comprising:

a piece of conductive metal including a half-bowtie portion shaped to define a monopole and a flexible spring contact extending from the half-bowtie portion;

a non-conductive base for supporting said piece of conductive metal, said base comprising an upper portion having an outer surface, and a lower portion anchoring said base to the portable device;

the half-bowtie portion being substantially wrapped around the outer surface of the upper portion of said base.

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