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(54) Slot-loaded microstrip antenna

(57) A microstrip antenna may include an electrically conductive ground plane layer, a dielectric layer adjacent the electrically conductive ground plane layer, and an electrically conductive patch layer adjacent the dielectric layer on a side thereof opposite the electrically conducive ground plane layer. The electrically conductive patch layer may be electrically floating with respect to the electrically conductive ground plane layer and may comprise a body portion and a feed strip extending outwardly from an interior medial portion of the body portion. The feed strip may have opposing first and second sides and an end electrically connected to the body portion. The body portion may have spaced apart first and second slots adjacent respective ones of the first and second opposite sides of the feed strip, and a third slot adjacent the end of the feed strip and spaced from the first and second slots.

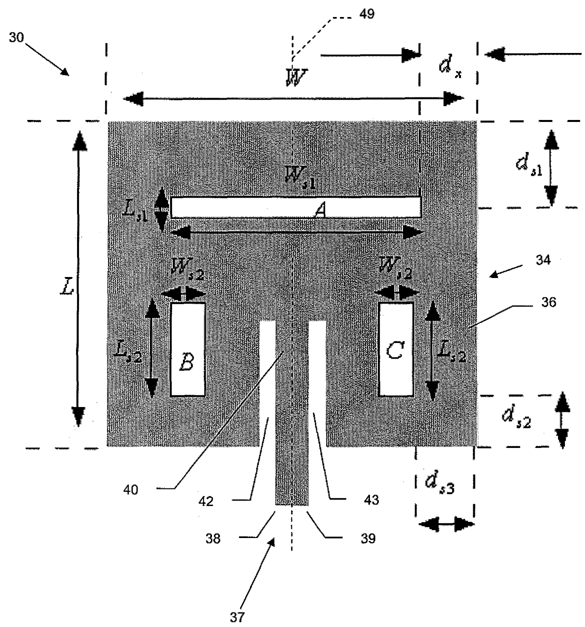

FIG. 3

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Description

Field of the Invention

[0001] The present invention relates to the field of communications devices, and, more particularly, to mobile wireless communications devices and related methods.

Background of the Invention

[0002] Cellular communications systems continue to grow in popularity and have become an integral part of both personal and business communications. Cellular telephones allow users to place and receive voice calls most anywhere they travel. Moreover, as cellular telephone technology has increased, so too has the functionality of cellular devices and the different types of devices available to users. For example, many cellular devices now incorporate personal digital assistant (PDA) features such as calendars, address books, task lists, etc. Moreover, such multi-function devices may also allow users to wirelessly send and receive electronic mail (email) messages and access the Internet via a cellular network and/or a wireless local area network (WLAN), for example.

[0003] Even so, as the functionality of cellular communications devices continues to increase, so too does the demand for smaller devices which are easier and more convenient for users to carry. One challenge this poses for cellular device manufacturers is designing antennas that provide desired operating characteristics within the relatively limited amount of space available for the antenna.

[0004] Microstrip antennas are one type of antenna that have unique features such as low profile, low weight, low cost and relatively easy fabrication, which has led to their use in mobile wireless communications devices. A typical prior art microstrip patch antenna **100** is shown in FIG. 1 which has a length L and width **W.** The length L is usually chosen to be a half-wavelength of the operating frequency of the antenna **30.** However, to obtain lower operating frequencies, the value of L typically has to be increased (i.e., the antenna **30** is made larger), which is undesirable within a mobile wireless communications device where space is at a premium.

[0005] Another prior art microstrip patch antenna **200** is shown in FIG. 2, which implements one common approach to obtain a lower resonant frequency while at the same time maintaining a relatively small antenna size. In particular, the antenna **200** has shorted ground pins **201** positioned transversely across a vertical centerline of the antenna, as shown. This approach allows the physical length of the antenna **200** to be reduced to one-quarter of the operating wavelength X. Yet, due to the reduced effective aperture, the antenna gain is also undesirably decreased.

[0006] Still another prior art approach for reducing the size of a microstrip antenna is to use a folded, multi-layer (i.e., non-planar) structure than can effectively reduce the antenna size to 1/8th λ or even more on its aperture plane. One drawback of this approach is that it necessarily results in increased thickness, which may be particularly undesirable in small handsets. Another drawback of this approach, as well as using shorting ground pins, is that these structures may be somewhat difficult, and potentially more expensive, to manufacture.

[0007] Other prior art microstrip antenna designs are set forth in U.S. Patent Nos. 7,126,544 and 7,145,510 both to Liu et al.; 6,400,322 to Fan et al.; 4,613,868 to Weiss; and U.S. patent publication no. 2006/0132373 to Yuanzhu, for example.

[0008] Accordingly, new microstrip antenna designs may be desirable that allow the above-noted advantages to be achieved without significant increases in size/thickness or manufacturing difficultly.

Brief Description of the Drawings

[0009] FIG. 1 is a top view of a prior art microstrip antenna.

[0010] FIG. 2 is a top view of another prior art microstrip antenna.

[0011] FIG. 3. is a top view of a microstrip antenna in accordance with one exemplary embodiment.

[0012] FIG. 4 is a schematic side view of a wireless communications device including a microstrip antenna, such as the one illustrated in FIG. 3.

[0013] FIGS. 5-7 are graphs of simulated return loss vs. frequency for different configurations of the antenna of FIG. 3.

[0014] FIGS. 8-9 are, respectively, graphs of simulated and measured return loss vs. frequency for a prior art microstrip antenna and two slot loaded microstrip antenna embodiments.

[0015] FIG. 10 is a top view of the prior art microstrip antenna of FIG. 1 showing simulated current distribution therefor at a frequency of 1.99 GHz.

[0016] FIG. 11 is a top view of the microstrip antenna of FIG. 3 showing simulated current distribution therefor at a frequency of 1.52 GHz.

[0017] FIG. 12 is a top view of an alternative embodiment of the microstrip antenna of FIG. 3 showing simulated current distribution therefor at a frequency of 1.49 GHz.

[0018] FIGS. 13-15 are simulated 3D far-field radiation pattern diagrams for the microstrip antennas of FIGS. 10-12, respectively.

[0019] FIGS 16 and 17 are graphs of measured 2D radiation patterns for the antenna of FIG. 3 on an E-plane and H-plane, respectively.

[0020] FIG. 18 is a schematic block diagram illustrating exemplary components of a mobile wireless communications device that may include a microstrip antenna such as the one illustrated in FIG. 3.

Detailed Description of the Preferred Embodiments

[0021] The present description is made with reference to the accompanying drawings, in which preferred embodiments are shown. However, many different embodiments may be used, and thus the description 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. Like numbers refer to like elements throughout, and prime notation is used to indicate similar elements in different embodiments.

[0022] Generally speaking, a microstrip antenna is disclosed herein which may include an electrically conductive ground plane layer, a dielectric layer adjacent the electrically conductive ground plane layer, and an electrically conductive patch layer adjacent the dielectric layer on a side thereof opposite the electrically conducive ground plane layer. The electrically conductive patch layer may be electrically floating with respect to the electrically conductive ground plane layer and may comprise a body portion and a feed strip extending outwardly from an interior medial portion of the body portion. More particularly, the feed strip may have opposing first and second sides and an end electrically connected to the body portion. Also, the body portion may have spaced apart first and second slots adjacent respective ones of the first and second opposite sides of the feed strip, and a third slot adjacent the end of the feed strip and spaced from the first and second slots.

[0023] The electrically conductive patch layer may be a planar electrically conductive layer, for example. Moreover, the planar electrically conductive patch layer may have a rectangular shape. Additionally, the first and second slots may each be elongate and extend parallel to the feed strip. The first and second slots may also have identical shapes and be symmetrically positioned with respect to the feed strip.

[0024] In addition, the third slot may have an elongate shape and extend in a direction transverse to a direction of the feed strip. More particularly, the third slot may have opposing ends symmetrically positioned with respect to the feed strip. Alternatively, the third slot may have opposing ends asymmetrically positioned with respect to the feed strip. Further, the feed strip may comprise an elongate electrically conductive strip with the opposing sides in spaced relation from adjacent portions of the body portion. The feed strip may extend along a vertical centerline of the body portion, for example.

[0025] A mobile wireless communications device is also disclosed which generally includes a housing and a microstrip antenna carried by the housing, such as the one described briefly above. Moreover, a wireless communications circuit may be carried by the housing and coupled to the microstrip antenna.

[0026] A method aspect for making a microstrip antenna is also disclosed which may include positioning a dielectric layer adjacent an electrically conductive ground plane layer, and positioning an electrically conductive patch layer, such as the one described briefly above, adjacent the dielectric layer on a side thereof opposite the electrically conducive ground plane layer.

[0027] Referring now to FIGS. 3 and 4, a microstrip antenna **30** that may advantageously be used in a mobile wireless communications device **31** (e.g., a cellular device) in accordance with one exemplary aspect is first described. The antenna **30** illustratively includes an electrically conductive ground plane layer **32,** a dielectric substrate or layer **33** adjacent the electrically conductive ground plane layer **32,** and an electrically conductive patch layer **34** adjacent the dielectric layer **33** on a side thereof opposite the electrically conducive ground plane layer **32,** as shown.

[0028] The antenna **30** is preferably carried within a housing **35** of the device **31.** The patch layer **34** may be positioned at various locations within the device **31,** such as adjacent the top (i.e., near the output speaker), or adjacent the bottom (i.e., near the input microphone), or therebetween. Moreover, the antenna **30** may be used for different types of wireless communication beside cellular, such as WLAN communications (e.g., 802.11x, Bluetooth), etc., as will be appreciated by those skilled in the art. To this end, one or more wireless communications circuits **41** (e.g., transmitter/receiver) may be carried by the dielectric layer **33,** as will be discussed further below.

[0029] The patch layer **34** is preferably electrically floating with respect to the ground plane layer **32,** although a connection or "short" to the ground plane may be used in some embodiments if desired. The patch layer **34** illustratively includes a body portion **36** and a feed strip **37** extending outwardly from an interior medial portion of the body portion along a centerline **49** thereof, as shown. More particularly, the feed strip **37** is an elongate electrically conductive strip having opposing first and second sides **38, 39** and an end **40** electrically connected to the body portion at the interior medial portion. The opposing sides of the feed strip **37** are in spaced relation from adjacent portions of the body portion (i.e., vertical slots **42, 43** separate the first and second sides **38, 39** from the body portion **36).** The feed strip **37** is also symmetrically positioned with respect to the centerline **49** in the exemplary embodiment, although this need not be the case in all embodiments, and other placements of the feed strip are also possible.

[0030] In the example embodiment illustrated in FIGS. 3 and 4, the patch layer **34** is advantageously a planar electrically conductive layer having a rectangular shape defined by length **L** and width **W.** More particularly, in the present example the length **L** and width **W** are equal to define a square patch, but other dimensions may be chosen in different embodiments to provide other rectangular shapes.

[0031] The body portion **36** also advantageously includes spaced apart first and second slots **B, C** adjacent respective ones of the first and second opposite sides

38, 39 of the feed strip **37,** and a third slot **A** adjacent the end **40** of the feed strip and spaced from the first and second slots **B, C** to advantageously define a slot-loaded patch element. The slots may be etched in the body portion **36,** for example, during manufacturing, as will be appreciated by those skilled in the art.

[0032] In the example embodiment shown in FIGS. 3 and 4, the first and second slots **B, C** are each elongate with a same vertical length L_{s2} and extend parallel to the feed strip **37.** The first and second slots **B, C** also have a same width W_{s2}. While in the example embodiment the first and second slots **B, C** are rectangular, it should be noted that in other embodiments the first and second slots **B, C** need not have a same shape (i.e., one or both of the slots may have a shape other than rectangular), nor the same dimensions.

[0033] In addition to having identical shapes in the present example, the first and second slots **B, C** are also symmetrically positioned with respect to the feed strip **37.** The third slot **A** also has an elongate rectangular shape and extends in a direction transverse to a direction of the feed strip 37. The third slot **A** has a horizontal width $\mathbf{W_{s1}}$ and a vertical length L_{s1}, as shown. As with the first and second slots **B, C,** the third slot **A** may have a shape other than rectangular, as well as different dimensions and placements on the body 36.

[0034] In the presently described embodiment, the third slot **A** is positioned a vertical distance d_{s1} from the top of the body portion **36,** and a horizontal distance $\mathbf{d_x}$ from the right side of the body portion. In this exemplary embodiment, the horizontal distance $\mathbf{d_x}$ is chosen so that the opposing ends of the third slot **A** are symmetrically positioned with respect to the feed strip **37.** In other embodiments, such as the antenna **30'** shown in FIG. 12, the third slot **A** may have opposing ends that are asymmetrically positioned with respect to the feed strip **37.**

[0035] The first and second slots **B, C** of the example embodiment depicted in FIGS. 3 and 4 are positioned a vertical distance $\mathbf{d_{s2}}$ from the bottom of the body portion **36,** and a horizontal distance d_{s3} from the sides of the body portion. While these distances are the same in the embodiment of FIG. 3, the slots **B, C** need not be symmetrically positioned in all embodiments with respect to the feed strip 37.

[0036] By way of comparison, a prior art microstrip patch antenna **100** as shown in FIG. 1 having a resonant frequency of around 2 GHz was compared with a microstrip antenna **30** in accordance with one embodiment having substantially the same dimensions (i.e., the same length **L** and width **W).** From the simulated and measured results described below it will be appreciated that with loaded slots the resonant frequency of the antenna **30** is decreased to 1.5 GHz without introducing any shorted ground pins or folded multi-layered structures, as typically required with prior art microstrip antenna configurations.

[0037] Generally speaking, the length $\mathbf{W_{s1}}$ and the distances $\mathbf{d_{s1}}$ and $\mathbf{d_x}$ of slot **A** control the main current distributions, and hence define the effective electrical length and resonant frequency of the antenna **30.** The dimensions of slots **B** and **C** are identical in the present embodiment, and they are symmetrically placed on the opposing sides **38, 39** of the feed line **37** for finely adjusting the resonant frequency and improving impedance matching. The graph of FIG. 5 illustrates the influence of the width $\mathbf{W_{s1}}$ on resonant frequency. Plots **51-53** respectively correspond to lengths L of 29mm, 23mm, and 17mm all with a same distance d_{s1} of 5mm. Moreover, plots **61-64** (FIG. 6) demonstrate the influence of d_{s1} on resonant frequency for a width $\mathbf{W_{s1}}$ of 23mm for d_{s1} values of 5mm, 9mm, 11mm, and 13mm, respectively. Referring additionally to FIG. 7, the effect of $\mathbf{d_x}$ on resonant frequency for a width W_{s1} of 23mm and distance d_{s1} of 5mm are shown by plots **71-74** corresponding respectively to $\mathbf{d_x}$ values of 2mm, 3mm, 4mm, and 5mm.

[0038] Turning now additionally to FIGS. 8 and 9, simulated and measured return losses are respectively shown for the prior art microstrip antenna **100,** the microstrip antenna **30** including a symmetrical slot **A** with respect to the feed strip **37,** and an alternative microstrip antenna **30'** with an asymmetrical slot **A** (FIG. 12). As will be appreciated by those skilled in the art, the simulated and measured results demonstrate good correlation therebetween. In FIGS. 8 and 9, the plots 81, **91** correspond to the microstrip antenna **30** including a symmetrical slot **A,** the plots **82, 92** correspond to the microstrip antenna **30'** with an asymmetrical slot **A,** and the plots **83, 93** correspond to the prior art microstrip antenna **100.**

[0039] From the above-noted graphs it can be observed that the loaded slots **A-C** provide lower resonant frequency, which will be further understood with reference to the current distributions illustrated in FIGS. 10-12 for the prior art microstrip antenna 100, the microstrip antenna **30** including a symmetrical slot **A,** and the microstrip antenna **30'** with an asymmetrical slot **A,** respectively. Compared to the current distributions in FIG. 10, the currents in FIG. 11 flow through longer paths due to the loaded slots, especially slot **A.** In addition, from FIG. 8 it can be seen that the two lower resonant frequencies occur at 1.42 and 1.49 GHz as slot **A** moves from the center toward the edge. The corresponding current distributions at 1.49 GHz are illustrated in FIG. 12 for the microstrip antenna **30'** with the asymmetrical slot **A.**

[0040] Simulated 3D far-field radiation patterns (with infinite ground planes) at 1.9 GHz, 1.52 GHz, and 1.49 GHz are respectively shown in FIGS. 13-15 for the prior art microstrip antenna 100, the microstrip antenna 30 including a symmetrical slot **A,** and the microstrip antenna **30**' with the asymmetrical slot **A.** It can be seen that the loaded slots **A-C** only slightly disturb the gain patterns. Measured 2D radiation patterns at f=1.52 GHz are shown in FIGS. 16 and 17 for the antenna **30** with a symmetrically loaded slot **A** on the body portion **36** on an E-plane and H-plane, respectively.

[0041] The above-described slot loaded microstrip antenna embodiments therefore advantageously provide a relatively easy and low cost approach to reduce the size (and potentially weight in some implementations) of a typical prior art microstrip antenna while maintaining a desired operating frequency and a relatively high gain. With suitable slot placement, the resonant frequency of such a microstrip antenna can be shifted to a lower value, or for a given resonant frequency a slot loaded microstrip antenna has a smaller aperture size than a full (i.e., non-slotted) microstrip patch. Moreover, the slot loaded patch structure may also be relatively easily implemented/manufactured, as compared to more complicated prior art approaches such as multi-layer (i.e., non-planar) patch structures. The above-noted features may also be obtained without the drawbacks associated with using ground pins as discussed in the background above.

[0042] Exemplary components of a hand-held mobile wireless communications device **1000** in which the above-described slot loaded antenna embodiments may advantageously be used are now further described with reference to FIG. 18. The device **1000** illustratively includes a housing **1200,** a keypad **1400** and an output device **1600.** The output device shown is a display **1600,** which is preferably a full graphic LCD. Other types of output devices may alternatively be utilized. A processing device **1800** is contained within the housing **1200** and is coupled between the keypad **1400** and the display **1600.** The processing device **1800** controls the operation of the display **1600,** as well as the overall operation of the mobile device **1000,** in response to actuation of keys on the keypad **1400** by the user.

[0043] The housing **1200** may be elongated vertically, or may take on other sizes and shapes (including clamshell housing structures). The keypad may include a mode selection key, or other hardware or software for switching between text entry and telephony entry.

[0044] In addition to the processing device **1800,** other parts of the mobile device **1000** are shown schematically in FIG. 18. These include a communications subsystem **1001;** a short-range communications subsystem **1020;** the keypad **1400** and the display **1600,** along with other input/output devices **1060, 1080, 1100** and **1120;** as well as memory devices **1160, 1180** and various other device subsystems **1201.** The mobile device **1000** is preferably a two-way RF communications device having voice and data communications capabilities. In addition, the mobile device **1000** preferably has the capability to communicate with other computer systems via the Internet.

[0045] Operating system software executed by the processing device **1800** is preferably stored in a persistent store, such as the flash memory **1160,** but may be stored in other types of memory devices, such as a read only memory (ROM) or similar storage element. In addition, system software, specific device applications, or parts thereof, may be temporarily loaded into a volatile store, such as the random access memory (RAM) **1180.** Communications signals received by the mobile device may also be stored in the RAM **1180.**

[0046] The processing device **1800,** in addition to its operating system functions, enables execution of software applications **1300A-1300N** on the device **1000.** A predetermined set of applications that control basic device operations, such as data and voice communications **1300A** and **1300B,** may be installed on the device **1000** during manufacture. In addition, a personal information manager (PIM) application may be installed during manufacture. The PIM is preferably capable of organizing and managing data items, such as e-mail, calendar events, voice mails, appointments, and task items. The PIM application is also preferably capable of sending and receiving data items via a wireless network **1401.** Preferably, the PIM data items are seamlessly integrated, synchronized and updated via the wireless network **1401** with the device user's corresponding data items stored or associated with a host computer system.

[0047] Communication functions, including data and voice communications, are performed through the communications subsystem **1001,** and possibly through the short-range communications subsystem. The communications subsystem **1001** includes a receiver **1500,** a transmitter **1520,** and one or more antennas **1540** and **1560.** In addition, the communications subsystem **1001** also includes a processing module, such as a digital signal processor (DSP) **1580,** and local oscillators (LOs) **1601.** The specific design and implementation of the communications subsystem **1001** is dependent upon the communications network in which the mobile device **1000** is intended to operate. For example, a mobile device **1000** may include a communications subsystem **1001** designed to operate with the Mobitex™, Data TAC™ or General Packet Radio Service (GPRS) mobile data communications networks, and also designed to operate with any of a variety of voice communications networks, such as AMPS, TDMA, CDMA, WCDMA, PCS, GSM, EDGE, etc. Other types of data and voice networks, both separate and integrated, may also be utilized with the mobile device **1000.** The mobile device 1000 may also be compliant with other communications standards such as 3GSM, 3GPP, UMTS, etc.

[0048] Network access requirements vary depending upon the type of communication system. For example, in the Mobitex and DataTAC networks, mobile devices are registered on the network using a unique personal identification number or PIN associated with each device. In GPRS networks, however, network access is associated with a subscriber or user of a device. A GPRS device therefore requires a subscriber identity module, commonly referred to as a SIM card, in order to operate on a GPRS network.

[0049] When required network registration or activation procedures have been completed, the mobile device **1000** may send and receive communications signals over the communication network **1401.** Signals received from the communications network **1401** by the antenna **1540** are routed to the receiver **1500,** which provides for signal amplification, frequency down conversion, filtering, channel selection, etc., and may also provide analog to digital conversion. Analog-to-digital conversion of the received signal allows the DSP **1580** to perform more complex communications functions, such as demodulation and decoding. In a similar manner, signals to be transmitted to the network **1401** are processed (e.g. modulated and encoded) by the DSP **1580** and are then provided to the transmitter **1520** for digital to analog conversion, frequency up conversion, filtering, amplification and transmission to the communication network **1401** (or networks) via the antenna **1560.**

[0050] In addition to processing communications signals, the DSP **1580** provides for control of the receiver **1500** and the transmitter **1520.** For example, gains applied to communications signals in the receiver **1500** and transmitter **1520** may be adaptively controlled through automatic gain control algorithms implemented in the DSP **1580.**

[0051] In a data communications mode, a received signal, such as a text message or web page download, is processed by the communications subsystem **1001** and is input to the processing device **1800.** The received signal is then further processed by the processing device **1800** for an output to the display **1600,** or alternatively to some other auxiliary I/O device **1060.** A device user may also compose data items, such as e-mail messages, using the keypad **1400** and/or some other auxiliary I/O device **1060,** such as a touchpad, a rocker switch, a thumb-wheel, or some other type of input device. The composed data items may then be transmitted over the communications network **1401** via the communications subsystem **1001.**

[0052] In a voice communications mode, overall operation of the device is substantially similar to the data communications mode, except that received signals are output to a speaker **1100,** and signals for transmission are generated by a microphone **1120.** Alternative voice or audio I/O subsystems, such as a voice message recording subsystem, may also be implemented on the device **1000.** In addition, the display 1600 may also be utilized in voice communications mode, for example to display the identity of a calling party, the duration of a voice call, or other voice call related information.

[0053] The short-range communications subsystem enables communication between the mobile device **1000** and other proximate systems or devices, which need not necessarily be similar devices. For example, the short-range communications subsystem may include an infrared device and associated circuits and components, or a Bluetooth™ communications module to provide for communication with similarly-enabled systems and devices.

[0054] In another embodiment there is provided a microstrip antenna comprising:

an electrically conductive ground plane layer;
a dielectric layer adjacent said electrically conductive ground plane layer; and
an electrically conductive patch layer adjacent said dielectric layer on a side thereof opposite said electrically conducive ground plane layer;
said electrically conductive patch layer being electrically floating with respect to said electrically conductive ground plane layer and comprising

a body portion, and
a feed strip extending outwardly from an interior medial portion of said body portion, said feed strip having opposing first and second sides and an end electrically connected to said body portion,
said body portion having spaced apart first and second slots adjacent respective ones of the first and second opposite sides of said feed strip, and a third slot adjacent the end of said feed strip and spaced from said first and second slots.

[0055] Optimally, the electrically conductive patch layer comprises a planar electrically conductive layer.

[0056] Optimally, the planar electrically conductive patch layer has a rectangular shape.

[0057] Optimally, the first and second slots are each elongate and extend parallel to said feed strip.

[0058] Optimally, the first and second slots have identical shapes and are symmetrically positioned with respect to said feed strip.

[0059] Optimally, the third slot has an elongate shape and extends in a direction transverse to a direction of said feed strip.

[0060] Optimally, the third slot has opposing ends being symmetrically positioned with respect to said feed strip.

[0061] Optimally, the third slot has opposing ends being asymmetrically positioned with respect to said feed strip.

[0062] Optimally, the feed strip comprises an elongate electrically conductive strip with the opposing sides in spaced relation from adjacent portions of said body portion.

[0063] Optimally, the feed strip extends along a vertical centerline of the body portion.

[0064] In another embodiment there is provided a mobile wireless communications device comprising:

a housing;
a microstrip antenna carried by said housing and comprising

an electrically conductive ground plane layer,
a dielectric layer adjacent said electrically conductive ground plane layer, and
an electrically conductive patch layer adjacent said dielectric layer on a side thereof opposite said electrically conducive ground plane layer,
said electrically conductive patch layer being electrically floating with respect to said electri-

cally conductive ground plane layer and comprising

a body portion, and
a feed strip extending outwardly from an interior medial portion of said body portion, said feed strip having opposing first and second sides and an end electrically connected to said body portion,
said body portion having spaced apart first and second slots adjacent respective ones of the first and second opposite sides of said feed strip, and a third slot adjacent the end of said feed strip and spaced from said first and second slots; and
a wireless communications circuit carried by said housing and coupled to said microstrip antenna.

[0065] Optimally, the electrically conductive patch layer comprises a planar electrically conductive layer having a rectangular shape.
[0066] Optimally, the first and second slots are each elongate and extend parallel to said feed strip.
[0067] Optimally, the first and second slots have identical shapes and are symmetrically positioned with respect to said feed strip.
[0068] Optimally, the third slot has an elongate shape and extends in a direction transverse to a direction of said feed strip.
[0069] Optimally, the feed strip comprises an elongate electrically conductive strip with the opposing sides in spaced relation from adjacent portions of said body portion.
[0070] In another embodiment there is provided a method for making a microstrip antenna comprising:

positioning a dielectric layer adjacent an electrically conductive ground plane layer; and
positioning an electrically conductive patch layer adjacent the dielectric layer on a side thereof opposite the electrically conducive ground plane layer;
the electrically conductive patch layer being electrically floating with respect to the electrically conductive ground plane layer and comprising

a body portion, and
a feed strip extending outwardly from an interior medial portion of the body portion, the feed strip having opposing first and second sides and an end electrically connected to the body portion,
the body portion having spaced apart first and second slots adjacent respective ones of the first and second opposite sides of the feed strip, and a third slot adjacent the end of the feed strip and spaced from the first and second slots.

[0071] Optimally, the electrically conductive patch layer comprises a planar electrically conductive layer having a rectangular shape.
[0072] Optimally, the first and second slots are each elongate and extend parallel to the feed strip.
[0073] Optimally, the first and second slots have identical shapes and are symmetrically positioned with respect to the feed strip.
[0074] Optimally, the third slot has an elongate shape and extends in a direction transverse to a direction of the feed strip.
[0075] Optimally, the feed strip comprises an elongate electrically conductive strip with the opposing sides in spaced relation from adjacent portions of the body portion.
[0076] Many modifications and other embodiments will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that various modifications and embodiments are intended to be included within the scope of the appended claims.

Claims

1. An apparatus (31) comprising:

a microstrip antenna (30), the microstrip antenna (30) comprising:

a single electrically conductive planar patch layer (34) comprising:

a body portion (36) having an unbroken, contiguous perimeter including a plurality of slots (A, B, C) etched completely within the unbroken contiguous perimeter, each slot of the plurality of slots (A, B, C) being positioned at a vertical distance (d_{s1}, d_{s2}) and a horizontal distance (d_{s3}, d_x) from an edge of the perimeter of the body portion (36); and
an elongated conductive feed strip (37) extending outwardly from an interior medial portion of the body portion (36) along a centerline (49), the elongated conductive feed strip (37) having opposing first and second sides (38, 39) in spaced relation from adjacent portions (42, 43) of the body portion (36) and an end (40) electrically connected to the body portion (36) at the interior medial portion.

2. The apparatus of claim 1, further comprising:

a housing (35) including the microstrip antenna (30) disposed therein;

an electrically conductive ground plane layer (32); and

a dielectric layer (33) adjacent the electrically conductive ground plane layer (32), wherein the single electrically conductive planar patch layer (34) is adjacent the dielectric layer (33) on a side thereof opposite the electrically conductive ground plane layer (32), the single electrically conductive planar patch layer (34) electrically floating with respect to the electrically conductive ground plane layer (32).

3. The apparatus of claim 1, wherein the body portion (36) comprises spaced apart first and second slots (B, C) adjacent respective ones of the first and second opposite sides (38, 39) of the elongated conductive feed strip (37), and a third slot (A) adjacent the end (40) of the elongated conductive feed strip (37) and spaced apart from the first and second slots (B, C).

4. The apparatus of claim 3, wherein each slot of the plurality of slots (A, B, C) has a length dimension (L_{s1}, L_{s2}) and a width dimension (W_{s1}, W_{s2}); and wherein a location of each slot of the plurality of slots (A, B, C) within the body portion (36) determines a resonant frequency (61-64, 71-74) of the microstrip antenna (30).

5. The apparatus of claim 3, wherein the spaced apart first and second slots have identical shapes and are symmetrically positioned with respect to the feed strip.

6. The apparatus of claim 3, wherein the third slot extends in a direction transverse to a direction of the feed strip.

7. The apparatus of claim 6, wherein the third slot has opposing ends that are symmetrically positioned with respect to the feed strip.

8. The apparatus of claim 6, wherein the third slot has opposing ends that are asymmetrically positioned with respect to the feed strip.

9. The apparatus of claim 1, wherein the feed strip comprises an elongate electrically conductive strip with the opposing sides in spaced relation from adjacent portions of the body portion.

10. The apparatus of claim 1, wherein the feed strip extends along a vertical centerline of the body portion.

11. The apparatus of claim 2, wherein the apparatus is a wireless transmission device (1000).

12. The apparatus of claim 2, wherein the apparatus is a mobile wireless communications device (31).

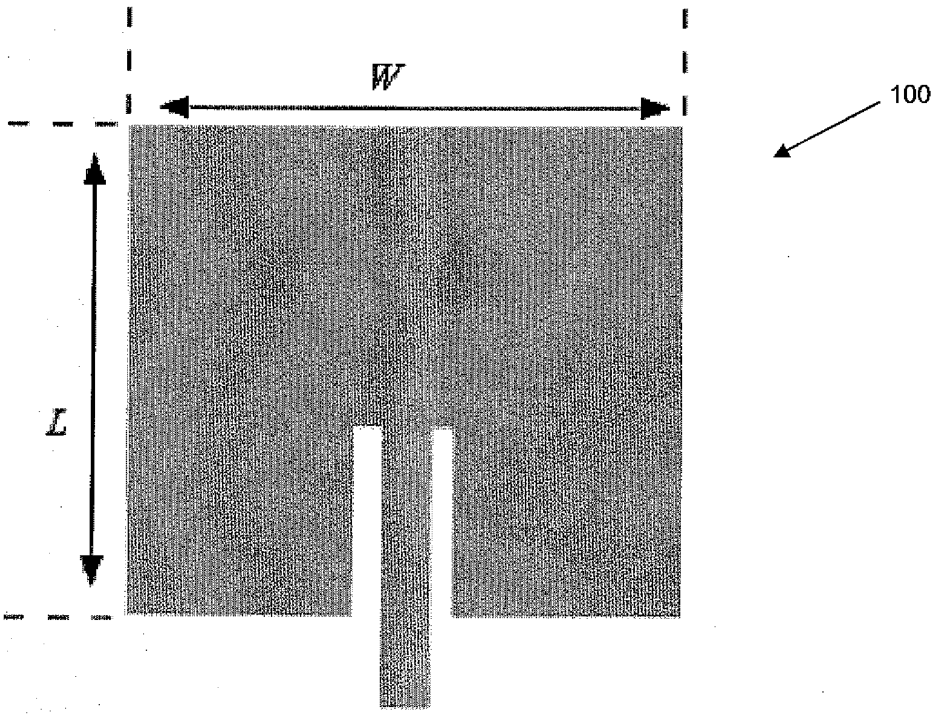

FIG. 1
(Prior Art)

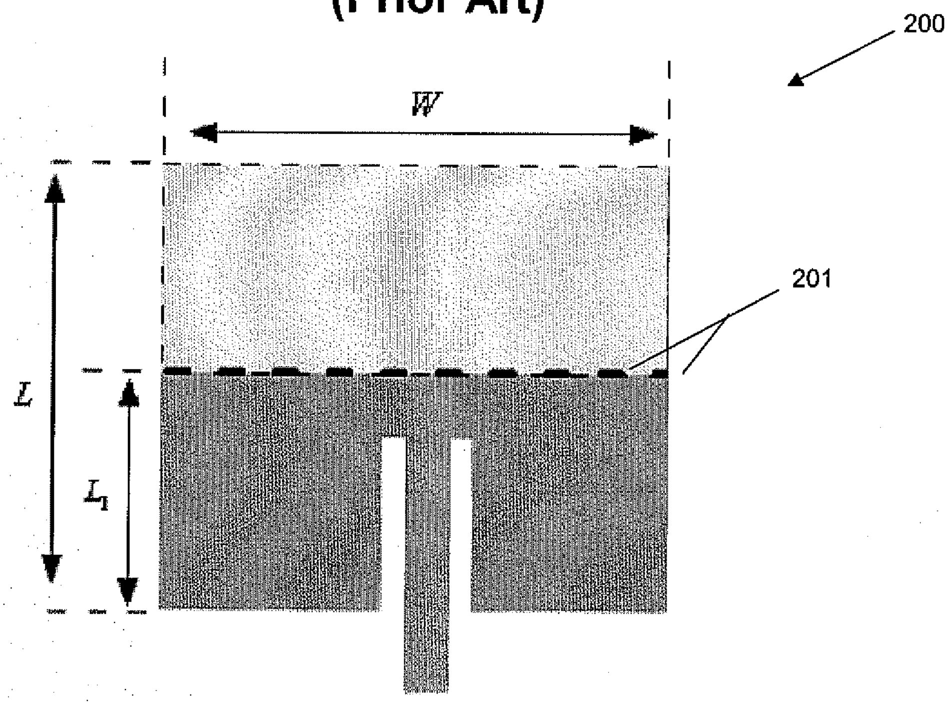

FIG. 2
(Prior Art)

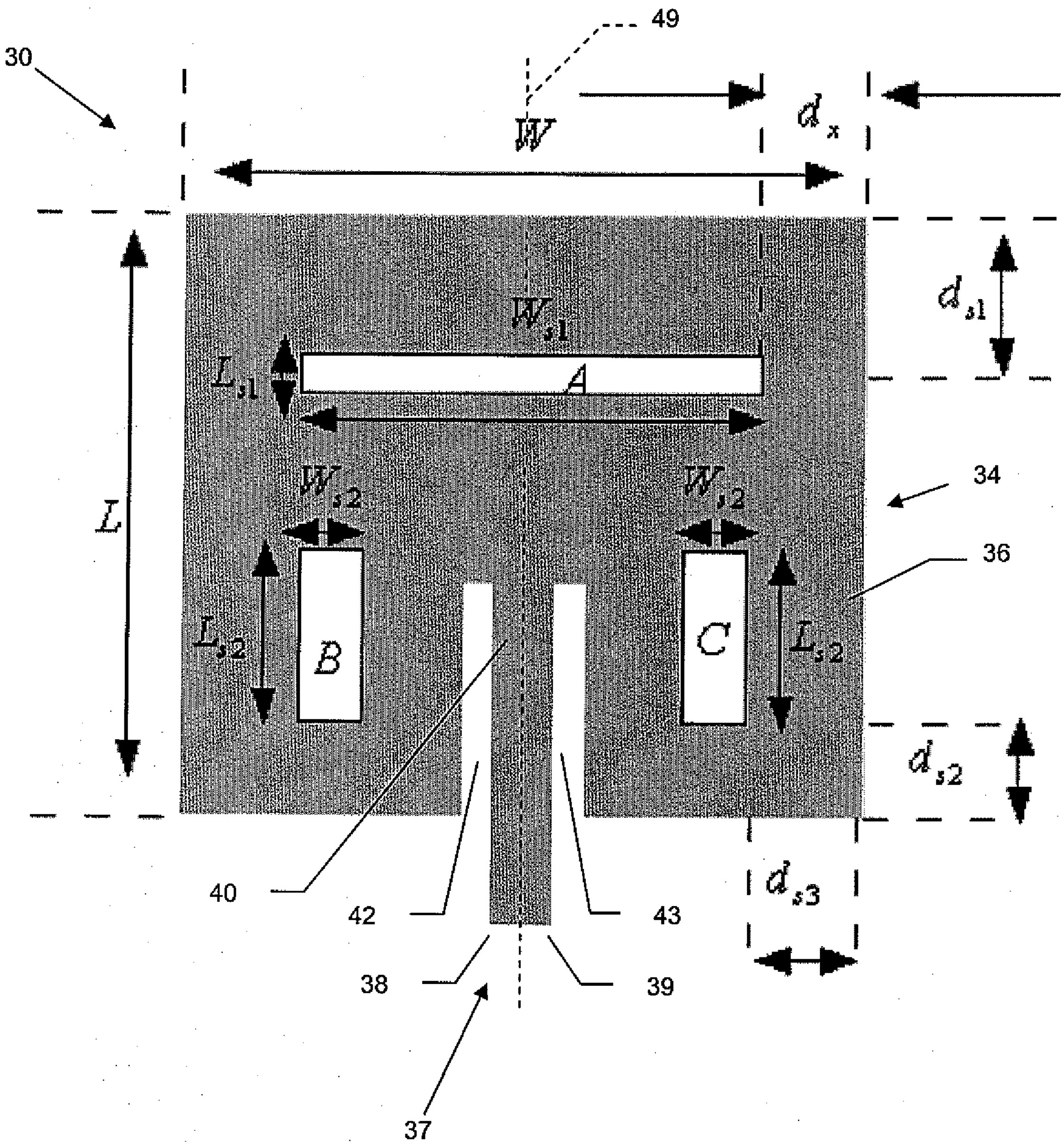
30
49
W
d_x
d_{s1}
W_{s1}
L_{s1}
A
34
W_{s2}
W_{s2}
36
L
L_{s2}
B
C
L_{s2}
d_{s2}
40
42
43
d_{s3}
38
39
37

FIG. 3

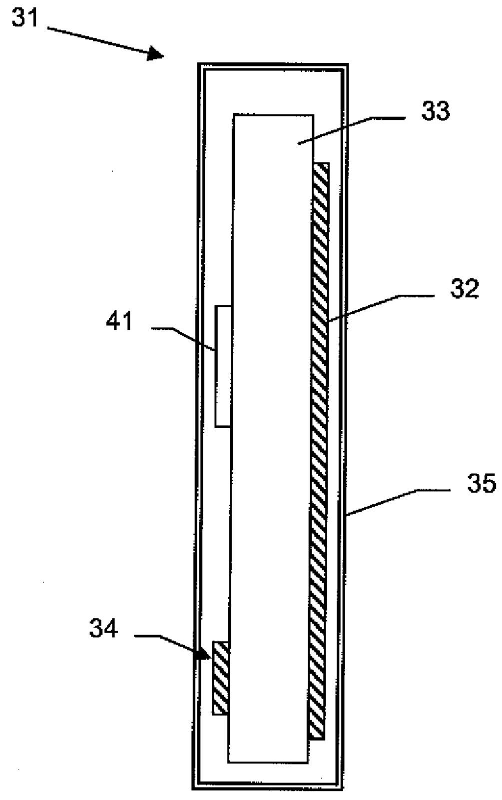

FIG. 4

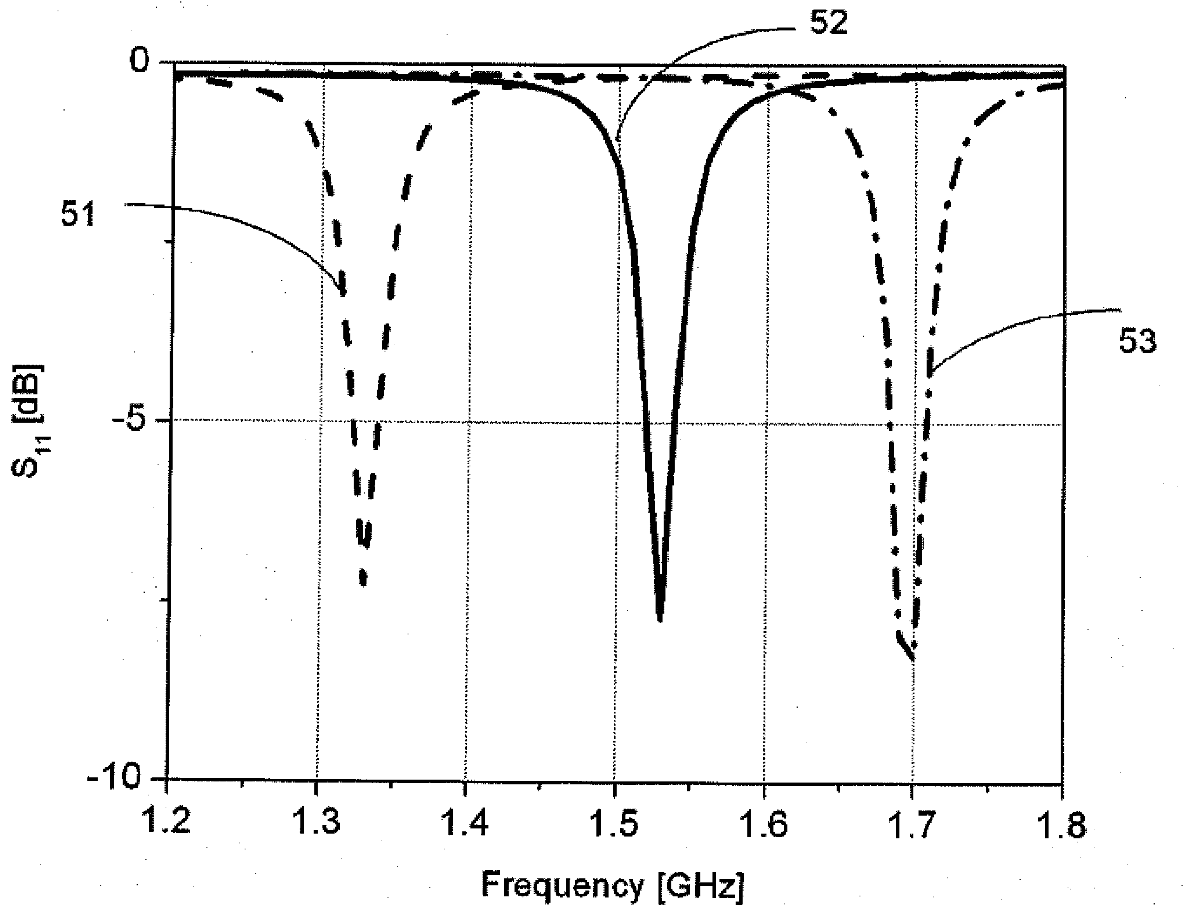

FIG. 5

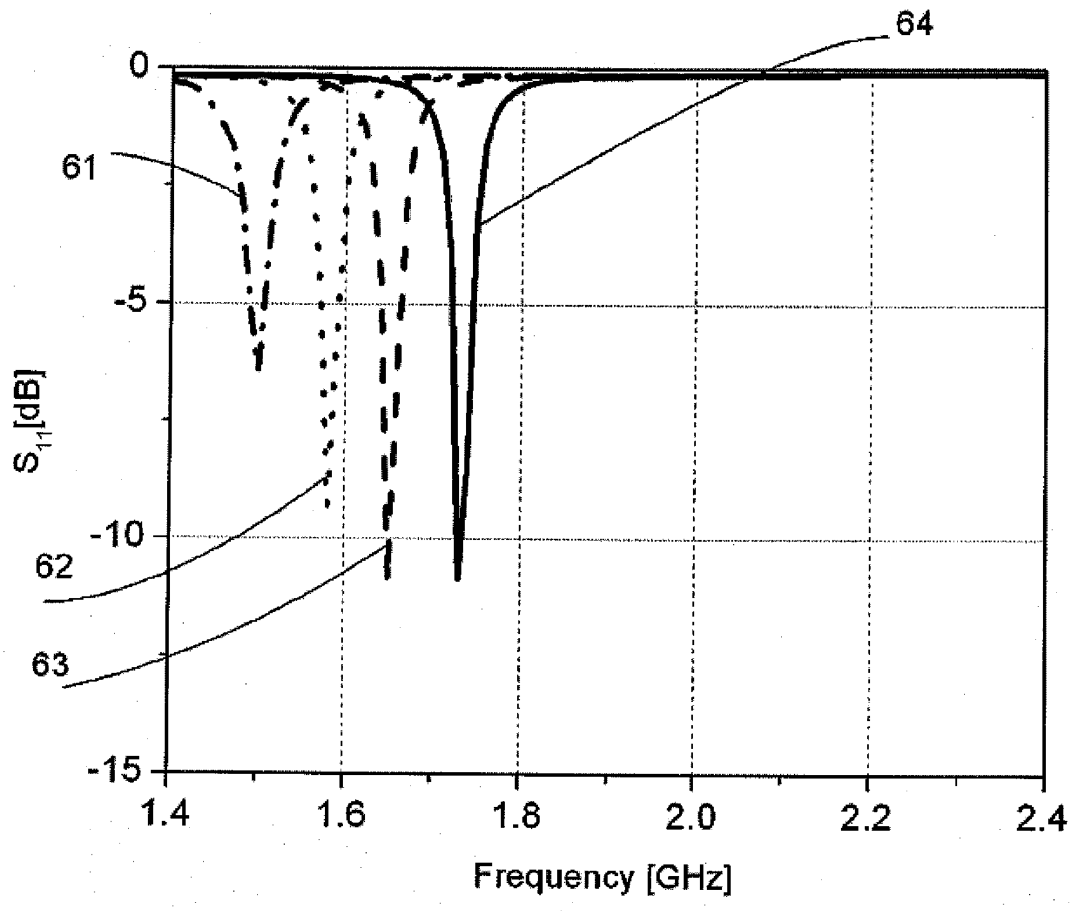

FIG. 6

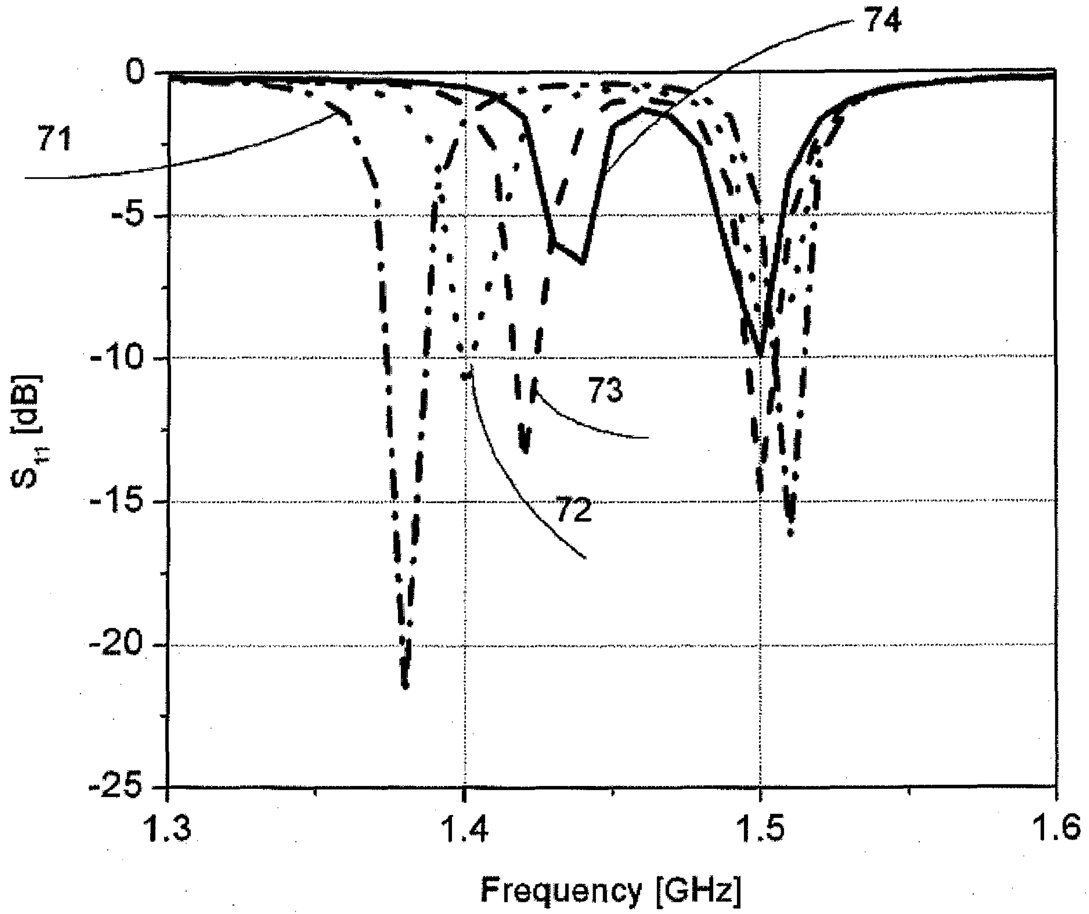

FIG. 7

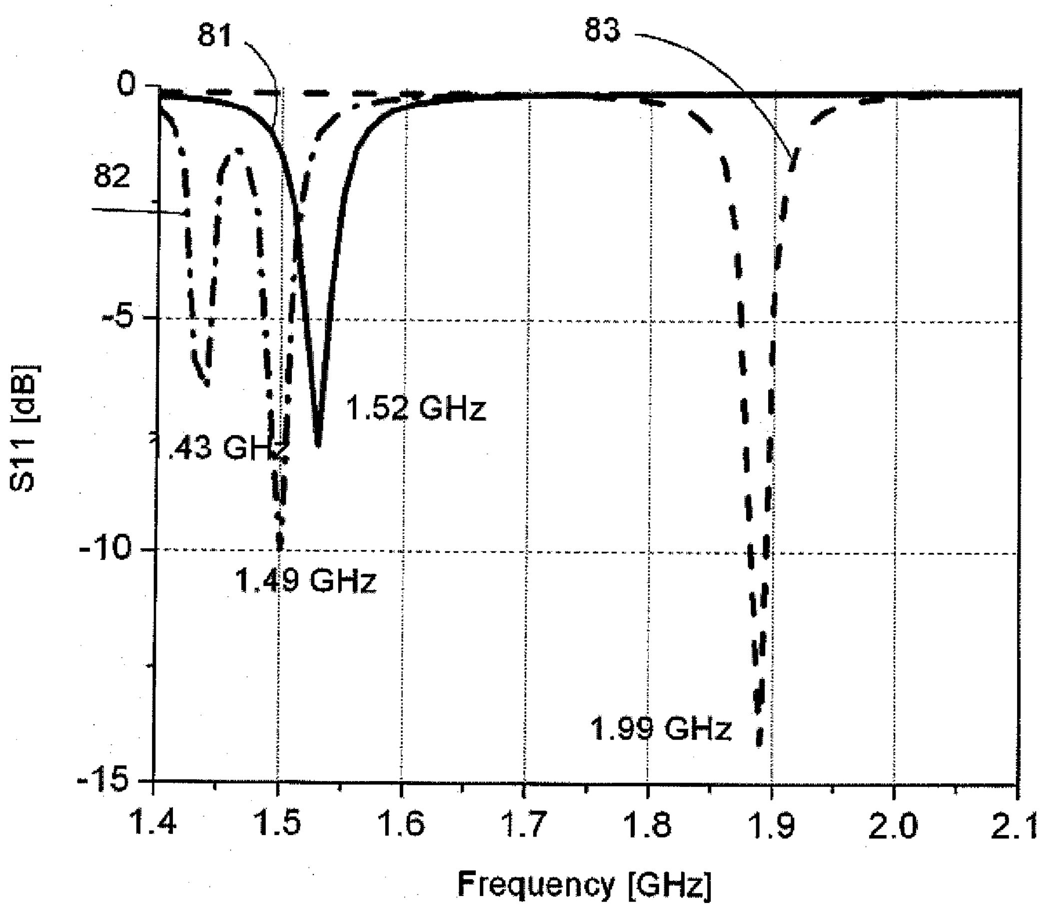
81
83
82
0
-5
-10
-15
S11 [dB]
1.52 GHz
1.43 GHz
1.49 GHz
1.99 GHz
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
Frequency [GHz]

FIG. 8

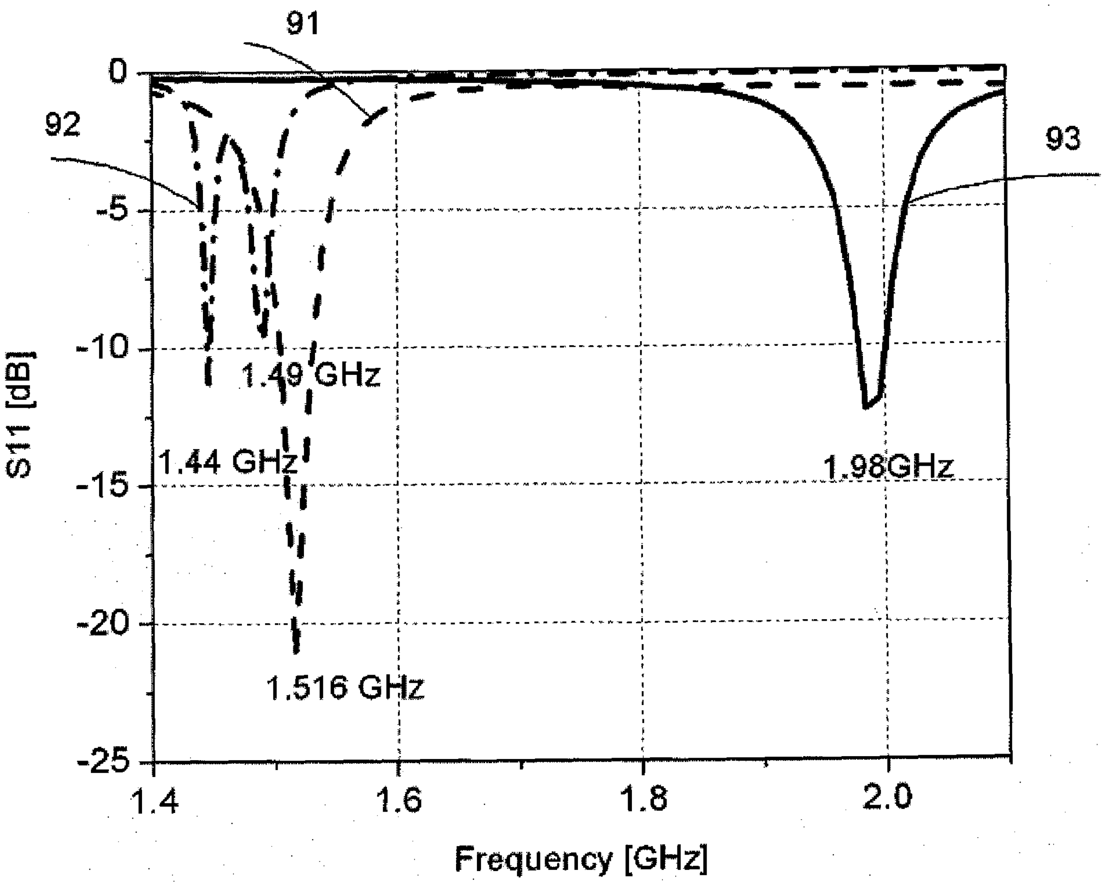
91
92
93
0
-5
-10
-15
-20
-25
S11 [dB]
1.49 GHz
1.44 GHz
1.516 GHz
1.98GHz
1.4
1.6
1.8
2.0
Frequency [GHz]

FIG. 9

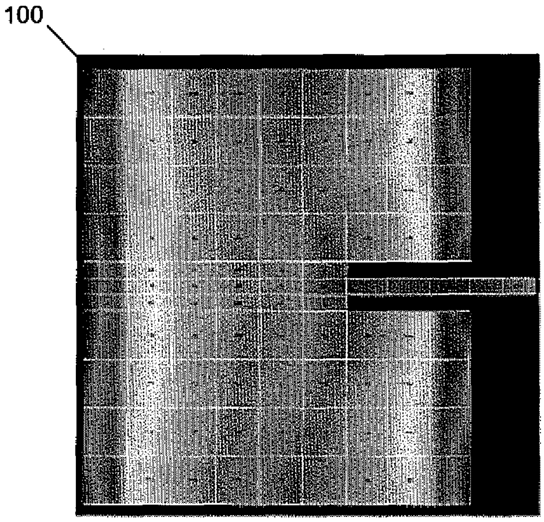

FIG. 10

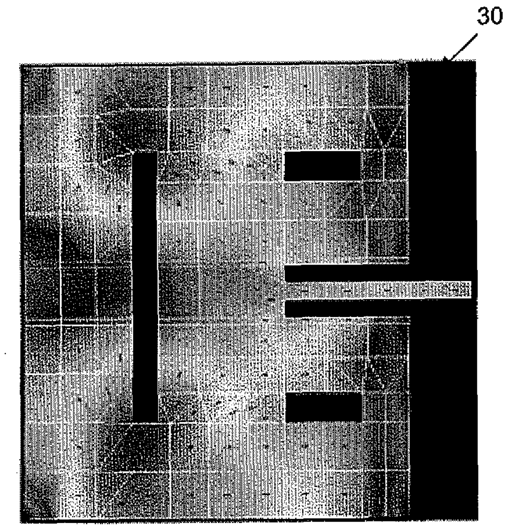

FIG. 11

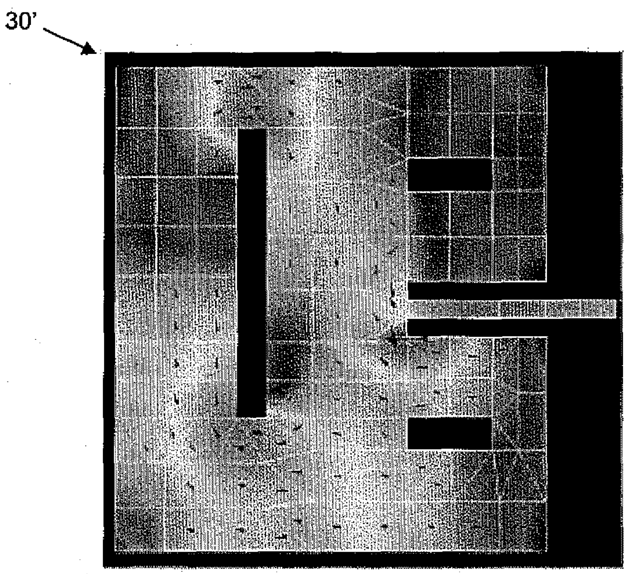

FIG. 12

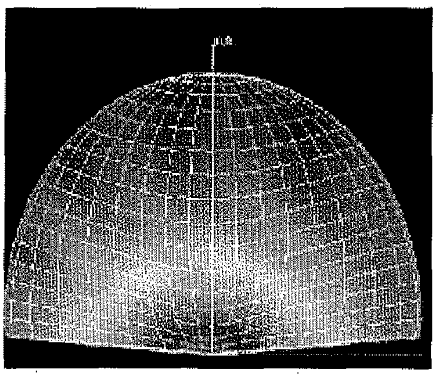

FIG. 13

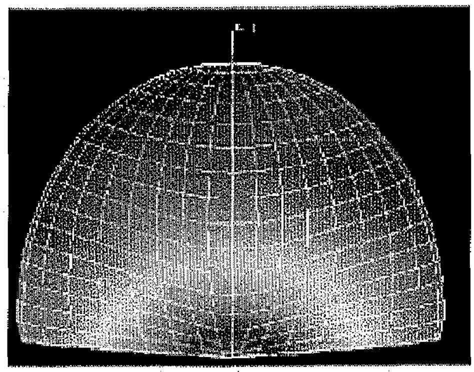

FIG. 14

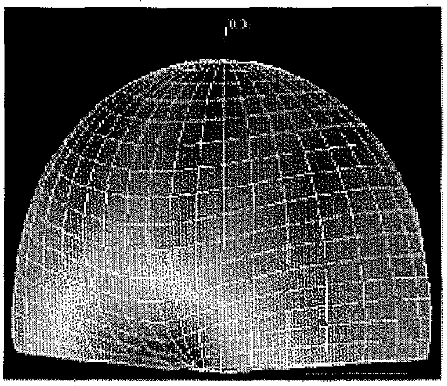

FIG. 15

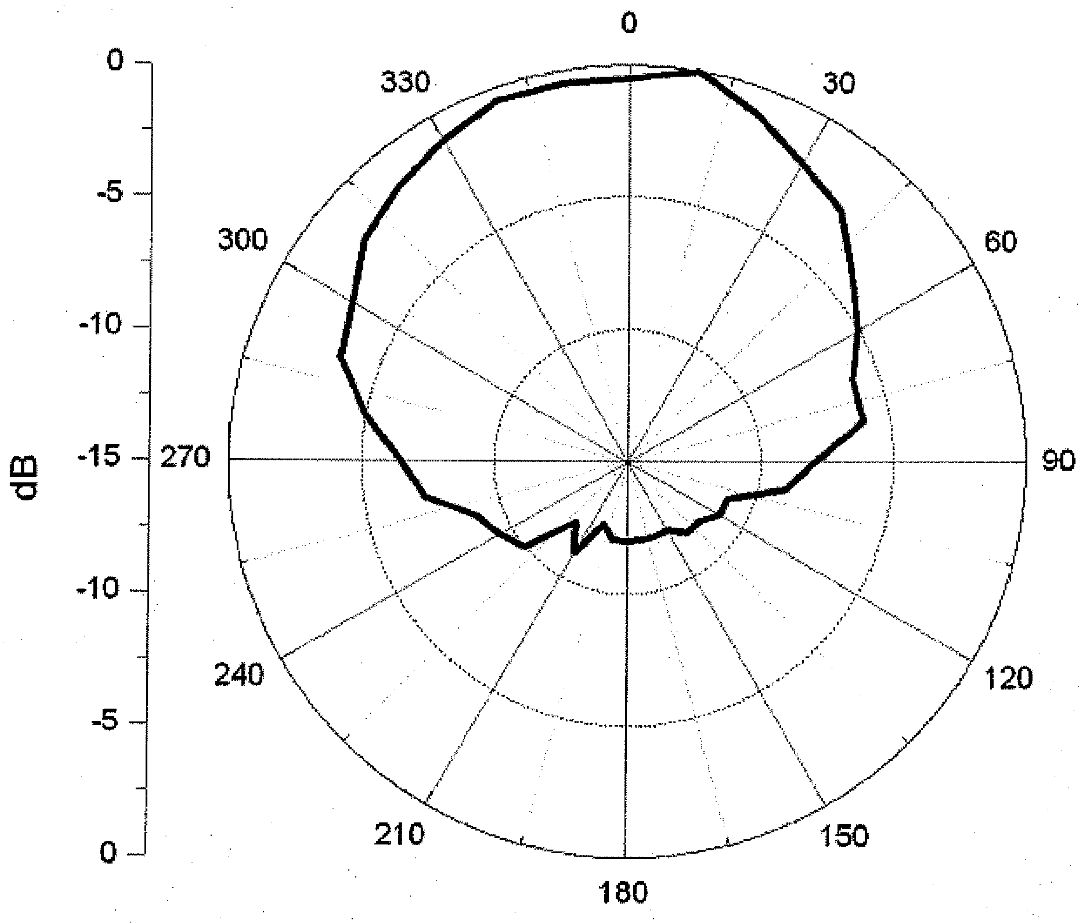

FIG. 16

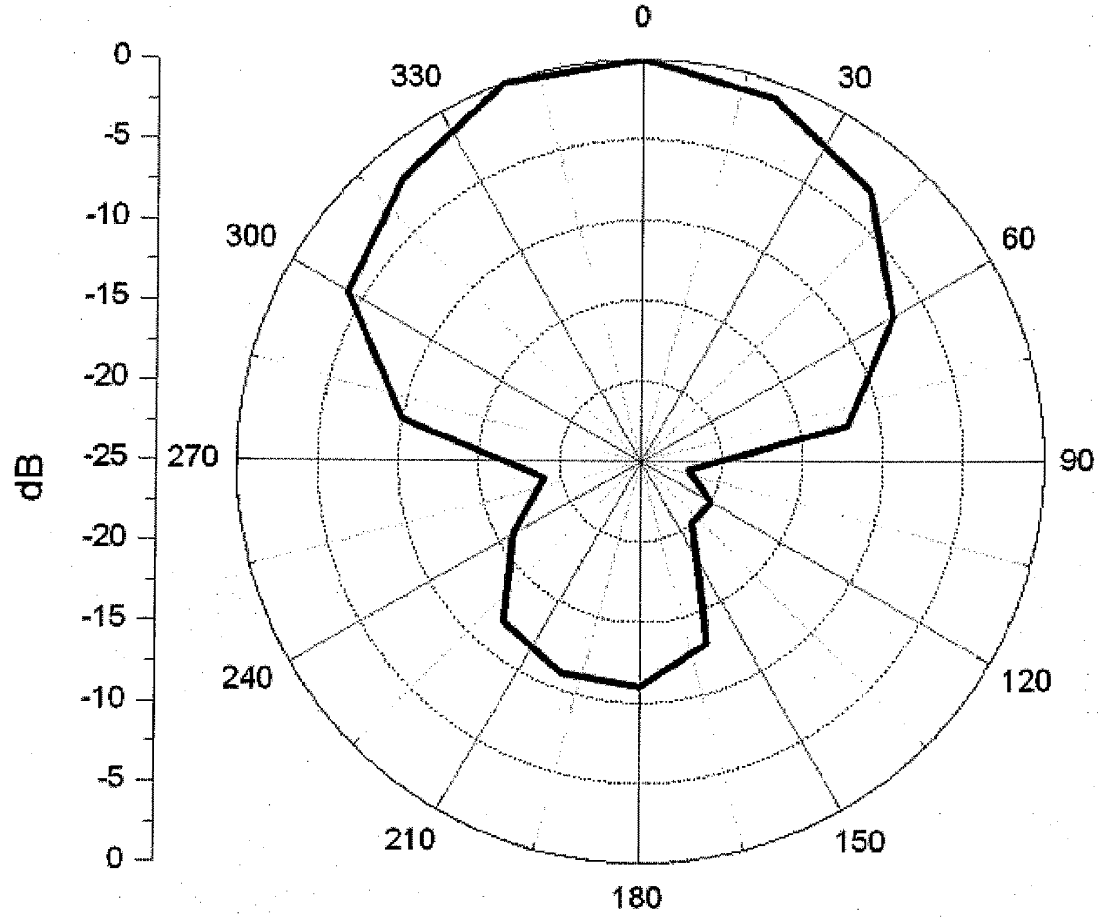
0
330
30
300
60
270
90
240
120
210
150
180
dB
0
-5
-10
-15
-20
-25
-20
-15
-10
-5
0

FIG. 17

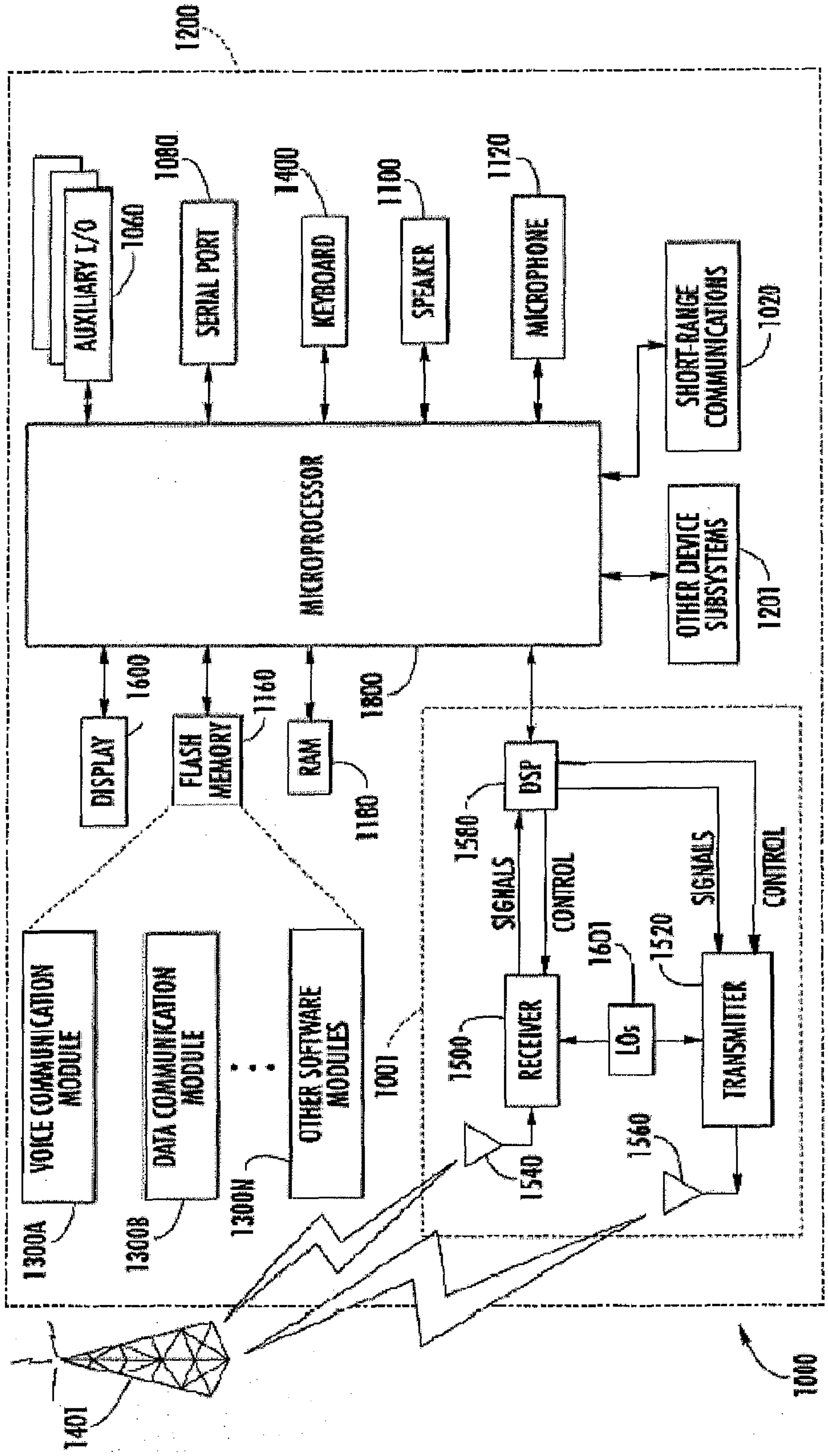
1200
AUXILIARY I/O
1060
1080
SERIAL PORT
1400
KEYBOARD
1100
SPEAKER
1120
MICROPHONE
SHORT-RANGE COMMUNICATIONS
1020
MICROPROCESSOR
OTHER DEVICE SUBSYSTEMS
1201
1600
1160
1800
DISPLAY
FLASH MEMORY
RAM
1180
VOICE COMMUNICATION MODULE
DATA COMMUNICATION MODULE
OTHER SOFTWARE MODULES
1300A
1300B
1300N
1001
DSP
1580
SIGNALS
CONTROL
SIGNALS
CONTROL
1601
1520
RECEIVER
LOs
TRANSMITTER
1500
1540
1560
1401
1000

FIG. 18

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EUROPEAN SEARCH REPORT

Application Number
EP 09 16 7890

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	SEWOONG KWON ET AL: "A Harmonic Suppression Antenna for an Active Integrated Antenna" IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 13, no. 2, 1 February 2003 (2003-02-01), XP011066958 ISSN: 1531-1309 * the whole document * -----	1,3-12	INV. H01Q1/24 H01Q9/04 H01Q13/10
X	FANG SHYH-TIRNG ET AL: "Bandwidth enhancement of inset-microstrip-line-fed equilateral-triangular microstrip antenna" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 34, no. 23, 12 November 1998 (1998-11-12), pages 2184-2186, XP006010612 ISSN: 0013-5194	1,2,9-12	
A	* the whole document * -----	1,2,11, 17	TECHNICAL FIELDS SEARCHED (IPC)
X	VANI R.M. ET AL: "A STUDY ON RECTANGULAR MICROSTRIP ANTENNA WITH GROUP OF SLOTS FORM COMPACT OPERATION" MICROWAVE AND OPTICAL TECHNOLOGY LETTERS, vol. 40, no. 5, 5 April 2004 (2004-04-05), pages 396-398, XP002448190 * the whole document * -----	1,2,9-12	H01Q
X	US 2005/156784 A1 (RYKEN MARVIN L JR [US] ET AL RYKEN JR MARVIN L [US] ET AL) 21 July 2005 (2005-07-21) * paragraphs [0002], [0007], [0008], [0014] - [0020] *	1,9-12	
A	* figures 1,2 * -----	3-5	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	25 September 2009	Kruck, Peter

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

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The members are as contained in the European Patent Office EDP file on
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25-09-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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- US 7145510 B, Liu **[0007]**
- US 6400322 B, Fan **[0007]**
- US 4613868 B, Weiss **[0007]**
- US 20060132373 A, Yuanzhu **[0007]**