PCT WORLD INTELLECTU. Intern

INTERNATIONAL APPLICATION PUBLISHED

WO 9604691A1

(51) International Patent Classification 6 : H01Q 9/04, 1/24	A1	(11) International Publication Number: WO 96/04691 (43) International Publication Date: 15 February 1996 (15.02.96)

(21) International Application Number: PCT/US95/07976

(22) International Filing Date: 22 June 1995 (22.06.95)

(30) Priority Data:
08/283,064 29 July 1994 (29.07.94) US

(71) Applicant: WIRELESS ACCESS, INC. [US/US]; 125 Nicholson Lane, San Jose, CA 95134 (US).

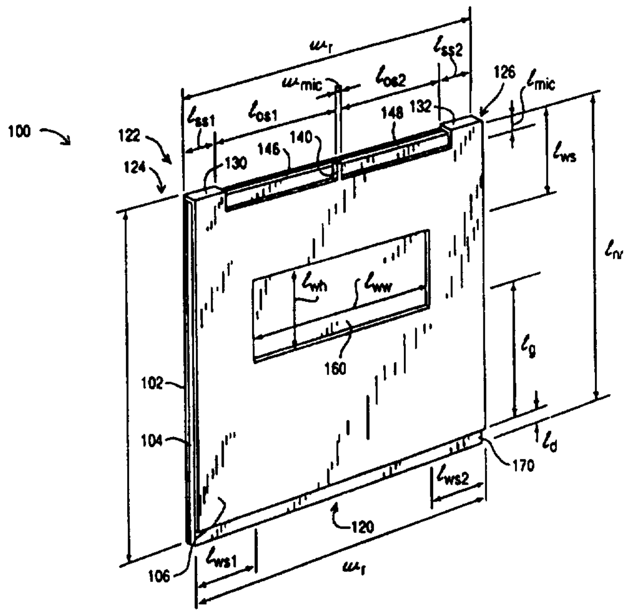
(72) Inventor: SANAD, Mohamed, S.; 3650 Buckley Street #512, Santa Clara, CA 95051 (US).

(74) Agents: HALVORSON, David, R. et al.; Blakely, Sokoloff, Taylor & Zafman, 7th floor, 12400 Wilshire Boulevard, Los Angeles, CA 90025-1026 (US).

(81) Designated States: AM, AT, AT (Utility model), AU, BB, BG, BR, BY, CA, CH, CN, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, ES, FI, FI (Utility model), GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), TJ, TM, TT, UA, UG, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ, UG).

Published
With international search report.

(54) Title: PARTIALLY SHORTED DOUBLE RING MICROSTRIP ANTENNA HAVING A MICROSTRIP FEED



(57) Abstract

An antenna for a convenient and economical installation in a small volume within a computer or other electronic equipment. The microstrip antenna includes a ground plane, a radiating patch, and a dielectric layer separating them. A partially short-circuited edge has a plurality of short-circuited sections formed thereon. A microstrip feed line is formed on the partially short-circuited edge, positioned between a first short-circuited section and a second short-circuited section. Preferably, a rectangular ring is formed in the radiating patch, offset so that it is closer to the partially short-circuited edge than to the radiating edge opposite thereto. The microstrip feed line provides an economical connection to a circuit board, and allows positioning the antenna so that the ground plane faces adjacent metal surfaces or circuits.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgystan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SI	Slovenia
CI	Côte d'Ivoire	KZ	Kazakhstan	SK	Slovakia
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CN	China	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
CZ	Czech Republic	LV	Latvia	TJ	Tajikistan
DE	Germany	MC	Monaco	TT	Trinidad and Tobago
DK	Denmark	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali	UZ	Uzbekistan
FR	France	MN	Mongolia	VN	Viet Nam
GA	Gabon				

PARTIALLY SHORTED DOUBLE RING MICROSTRIP ANTENNA HAVING A MICROSTRIP FEED

This application is a continuation-in-part of a commonly assigned, copending patent application which is incorporated by reference herein:

Serial No. 09/049,514, entitled "A Small Microstrip Antenna Having a Partial Short Circuit" by Mohamed S. Sanad, filed April 19, 1993.

This application is related to the following co-pending commonly assigned patent application:

Serial No. 08/049,560, entitled "A Small, Double Ring Microstrip Antenna", by Mohamed S. Sanad, filed on April 19, 1993.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to small microstrip antennas for electronic devices that receive and send radio frequency signals.

Description of Related Art

Small antennas are used in portable electronic devices such as pagers and portable telephones to receive and send radio frequency signals. One conventional small antenna suitable for pagers and portable telephones is a microstrip antenna. A typical two-conductor microstrip antenna includes a layered planar structure having a conductive ground plane formed in one layer, a conductive radiating patch formed in a second layer, and a dielectric layer positioned between the radiating patch and the ground plane.

The overall geometry of a microstrip antenna greatly influences its gain and frequency response. In order to provide an acceptable impedance, the feedpoint is conventionally positioned well within the perimeter of the microstrip antenna. To implement a feedpoint in such a position, a coaxial connection is often installed extending from the ground plane. However, such a coaxial connection has a number of disadvantages. The overall size and weight of the antenna are increased, thereby increasing space requirements. A coaxial connection is expensive in terms of cost-per-unit. Also, coaxial cables require additional circuit connections, thereby increasing cost and space requirements.

Optimum positioning of a microstrip antenna can be difficult due to the protruding stub of a coaxial connection. For example, positioning the ground plane adjacent to nearby metal surfaces may optimize the radiation pattern, but the stub of the coaxial connection can make such positioning difficult if not impossible. The coaxial connection could be accomplished from the radiating patch instead of the ground plane; however, gain could be disadvantageously reduced. Furthermore, if an array is formed of microstrip antennas, use of coaxial connections is disadvantageous partly due to the size and space requirements of such connections and the large number of coaxial cables that would be required.

It has been suggested to provide a narrow microstrip feed on the antenna itself. Fig. 3 illustrates a prior microstrip feedline that begins at the shorted edge and extends through the radiating patch to a feedpoint within the antenna's perimeter. Conventionally, the feedpoint must be sufficiently distanced from the shorted edge in order to obtain an acceptable impedance. A major problem inherent in such microstrip feeds is unwanted radiation and cross-polarization of emitted radiation resulting in reduced gain and a radiation pattern. This problem is related to the length of the microstrip feed and therefore a lengthy feedline can emit substantial amounts of unwanted radiation. However, microstrip feedlines are used because they reduce costs and size of the antenna over a comparable coaxial connection, and simplify its connection to a circuit board.

It would be an advantage to provide a microstrip antenna that has a low cost microstrip feed connection and yet has high gain and an acceptable input impedance.

In addition to the characteristics of impedance, gain, and frequency response, the radiation pattern can be important. Every microstrip antenna emits radiation in a particular pattern determined partly by its shape, which is often termed the "geometry" of the antenna. Many different geometries for microstrip antennas have been developed, and their resultant differences in radiation patterns and resonant frequencies characterize the antenna. For example, numerous geometries are shown in the Handbook of Microstrip Antennas, James and Hall, eds., Peter Peregrinus Ltd., London, UK, 1989, pp. 24-39.

The radiation pattern and the resonant frequency of a microstrip antenna can be degraded by adjacent physical objects such as electrical circuits, computer equipment, and people and particularly metal objects. The effect of the human body and other adjacent physical objects can disadvantageously cause the resonant frequency to shift by tens of megahertz or more. These shifts may be so severe that the microstrip antenna is rendered useless. Other operating characteristics such as the gain of the antenna can also be degraded by the body effect and the adjacent materials.

It would be an advantage to provide a compact and inexpensive microstrip antenna that can be easily connected to a circuit within electronic equipment and situated therein to optimize the radiation pattern for more efficient reception and transmission of rf signals. Such an antenna would be useful in portable electronic equipment such as pagers that must operate in the presence of people, circuits, and computer housings. Such an antenna could also be used and positioned effectively within a standard-sized PCMCIA ("Personal Computer Memory Card International Association") card that is designed to fit within a standard-sized PCMCIA slot, which are already provided in a number of computers.

SUMMARY OF THE INVENTION

The present invention provides a microstrip antenna with an economical microstrip feed connection that allows convenient installation within a computer or other electronic equipment. Advantageously, the microstrip feed connection allows positioning of the antenna so that its ground plane is positioned facing towards adjacent metal plates or circuit components to provide the optimum radiation pattern. Furthermore, the microstrip feed connection has a much lower cost and smaller profile than a comparable coaxial connection, which provides a commercial advantage as well as a space-saving advantage. The microstrip antenna is useful in portable electrical devices including pagers and telephones, as well as any other electronic device. The invention is particularly useful for installation in a PCMCIA card that can be inserted into a standard PCMCIA slot in a computer.

These advantages and others are provided in a microstrip antenna having a ground plane and a radiating patch separated by a dielectric layer, by providing a partially short-circuited edge having a short-circuited section, an open-circuited section, and a microstrip feed line coupled to the open-circuited section. The partially short-circuited edge of the microstrip antenna may include a plurality of short-circuited sections that couple the radiating patch to the ground plane, including a first short-circuited section and a second short-circuited section. The total length of the short-circuited sections electrically couple a percentage between ten percent and ninety percent of the total length of the partially short-circuited edge. Preferably, the short-circuited sections are formed on opposing ends of the partially short-circuited edge and the microstrip feed line is positioned in-between. The microstrip feed is positioned a sufficient distance from the short circuited sections to avoid cross-coupling and other disadvantageous effects.

Substantial flexibility is provided within this design to vary the input impedance without extending the microstrip feed line through the perimeter of the radiating patch. For example, the total length of the partially short-circuited edge can be varied to obtain the desired input impedance. Also, the width of the partial short-circuited sections can be varied to select the desired impedance. It is believed that the partial short circuit causes the input impedance and gain of the partially-shorted antenna to be much less sensitive to the feedpoint position than in conventional fully-shorted antennas. A ring formed within the microstrip antenna also reduces sensitivity of the impedance and gain to the feedpoint position. Therefore, the feedpoint of a microstrip feed line can be conveniently positioned directly on the partially short-circuited edge and still achieve an acceptable impedance. Preferably, the partial short-circuited sections are positioned as far away from the microstrip feed connection as possible and therefore, they are preferably positioned at opposite ends of the partially short-circuited edge with the microstrip feed centralized in-between.

In order to provide further advantages, in one embodiment the microstrip antenna includes a rectangular ring formed in the radiating patch. Preferably, the ring is offset so that it is closer to the partially short-circuited edge than to the radiating edge; however, in some embodiments the ring could be centered, or shifted closer to the radiating edge. Because a "mirror" image of the radiating patch is created in the ground plane layer, a double ring effect is created in the antenna. The input impedance is affected by the length between the edge of the ring and the short-circuited side, and the two dimensions between the edges of the rings and the two nonradiating edges. The input impedance is not highly sensitive to the position of the microstrip feed line on the partially short-circuited edge. Additional features, including cutting the edges of the nonradiating edges closely to the dielectric, enhance the isotropic radiation pattern.

The features and advantages described in the specification are not all inclusive, and particularly, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification and claims hereof. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purpose, and therefore resort to the claims is necessary to determine the inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of a partially short-circuited microstrip antenna with a microstrip feed and a rectangular ring.

Fig. 2 is a perspective view of a mounting structure for a microstrip antenna with a microstrip feed line.

Fig. 3 is a perspective view of a prior art fully short-circuited microstrip antenna with a microstrip feed coupled to the interior of its radiating patch.

Figs. 4 is a perspective view of a microstrip antenna oriented within a pager.

Fig. 5 is a perspective view of a microstrip antenna in a PCMCIA card to be inserted in a portable computer or pager.

Fig. 6 is a perspective view of a portable telephone with a cutaway section showing a microstrip antenna positioned therein.

Fig. 7 is a perspective view of a computer housing with a slot for receiving a microstrip antenna.

Fig. 8 is a block diagram of a microstrip antenna and associated circuits in a PCMCIA card.

Fig. 9 is a cross section that illustrates the position of the microstrip antenna within the PCMCIA card with respect to a slot.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figures 1 through 9 of the drawings disclose various embodiments of the present invention for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles of the invention. The following description describes a microstrip antenna that has been designed in one embodiment with dimensions suitable for application in pagers, which operate at 931.5 MHz. Therefore, the dimensions given correspond to that specific frequency of operation. It will be apparent to one skilled in the art that a microstrip antenna for other frequencies of interest can be designed by varying the antenna dimensions. For example, the frequency of operation may be 931.5 MHz for PCMCIA cards.

Reference is now made to Fig. 1 which shows a partially short-circuited microstrip antenna 100. A ground plane comprising a conductive material is formed in the ground plane layer 102. A dielectric layer 104 is affixed to the ground plane layer 102. A radiating patch 106 is formed on the side of the dielectric layer 104 opposite the ground plane layer 102. The dielectric layer 104 preferably has a very low tangent loss and a controlled dielectric constant. The dielectric layer 104 may comprise Duroid 5880 available from Rogers Corporation, Chandler, Arizona. The radiating patch 106 preferably has a thickness of 1.0 oz./m^2 of copper foil.

The microstrip antenna 100 includes four sides, including a radiating edge 120 and opposite thereto a partially short-circuited edge 122. The other two edges include a first side edge 124 and opposite thereto a second side edge 126. The radiating edge 120 is open-circuited along its entire length, as is the first side edge 124 and the second side edge 126. Even though the side edges 124 and 126 may be termed "nonradiating" edges, some amount of radiation will normally be emitted from them. However, the amount emitted is small in comparison to the radiation emitted from the radiating edge 120.

The partially short-circuited edge 122 is short-circuited along a portion of its length. Specifically, the partially short-circuited edge 122 includes a first short-circuited section 130 having a length l_{ss1} positioned adjacent to the first side edge 124 and a second short-circuited section 132 having a length l_{ss2} positioned adjacent to the second side edge 126. Each of the short-circuited sections 130 and 132 couple the radiating patch 106 with the ground plane layer 102. The first and second short-circuited sections 130 and 132 comprise any conductive material, preferably a copper foil such as the foil that comprises the radiating patch 106. The total length of the short-circuited sections is l_s (i.e., $l_s = l_{ss1} + l_{ss2}$). Alternatively, the first and second short-circuited sections can be implemented with shorting pins that connect the radiating patch 106 and the ground layer 102.

A microstrip feed line 140 comprising a conductive material having a width w_{mic} is formed along the partially short-circuited edge 122, approximately centralized between the first short-circuited section 130 and the second short-circuited section 132. The microstrip feed line 140 extends from the partially short-circuited edge 122, a length l_{mic} and connects to the perimeter of the radiating patch 106. As implemented, the width w_{mic} is approximately 4mm, and the overall antenna width w_r is 4cm. The length l_{mic} of the microstrip is minimized and may, for example, be in the range of 1-4 mm. It is not necessary that the microstrip feed line 140 extend through the perimeter of the radiating patch 106 in order to obtain a 50Ω impedance. In some implementations the microstrip feedline 140 may include features (not shown) outside the perimeter such as stubs or coplanar elements.

The width w_{mic} of the microstrip feed line 140 and its position on the partially short-circuited edge 122 are selected in order to provide the required input impedance. Because the characteristic impedance of the microstrip transmission line 150 is typically 50Ω, in the preferred embodiment the input impedance of the antenna 100 is selected to match 50Ω. A microstrip antenna having the configuration and dimensions described herein has been determined to provide an input impedance of 50Ω at 931.5 MHz. A number of other antenna characteristics apparent to one skilled in the art that affect the input impedance may also be taken into account in designing a particular antenna.

As illustrated, there are two short-circuited sections: the first short-circuited section 130 and the second short-circuited section 132. It is preferable that the first and second short-circuited sections 130 and 132 be positioned as far apart from the microstrip feed line 140 as possible. However, in some embodiments, additional short-circuited sections may be included, or their positioning varied on the partially short-circuited edge 122. The total length l_s of all short-circuited sections is preferably between 10% and 90% of the total width w_r. It has been observed that changing the length l_s as a percentage of the total width w_r affects the input impedance, and therefore varying the length l_s can be useful in tuning the antenna. However, it has been experimentally observed that if the length l_s is less than, for example 10%, then the antenna does not perform efficiently. It is believed that the minimum total length l_s of all shorted sections must be sufficient to provide a mirror image of the radiating patch in the ground plane 102. In other words, the total length l_s should not be reduced below that length which provides such an adequate mirror image. Of course, if the length l_s of the short is reduced to zero, the antenna's properties will shift to those of a half-wavelength antenna. On the other hand, if the length l_s is increased above, for example 90%, then the partially short-circuited microstrip antenna 100 will begin to assume the properties of a conventional quarter-wavelength antenna. Therefore, the length l_s should be between 10% and 90% of the value of the antenna width w_r. It is currently preferred that the length l_s of the short circuit is within the range of 20% to 50% of the antenna width w_r of the entire partially short-circuited edge 122. In order to meet the requirement of a 50Ω input impedance, the currently preferred length l_s is approximately 30%.

The partially short-circuited edge 122 includes a first open-circuited section 146 having a length l_{os1} positioned between the first short-circuited section 130 and the microstrip feed line 140. A second open-circuited section 148 having a length l_{os2} is positioned between the microstrip feed line 140 and the second short-circuited section 132. In the preferred embodiment, the length l_{os1} of the first open-circuited section 146 is made equal to the length l_{os2} of the second short-circuited section 148. In a typical quarter-wavelength antenna, such as shown in Fig. 3, the length between the fully short-circuited edge and the radiating edge is approximately equal to one quarter of the wavelength of the resonant frequency in the dielectric material. However, in the described embodiment, the length of the antenna from the partially short-circuited edge 122 to the fully radiating edge 120 (i.e., the length l_{nr}), is shorter than the quarter-wavelength for a given resonant frequency. The partial short circuit provided by the first and second short-circuited sections 130 and 132 (as well as the ring structure to be described) reduces the resonant frequency, which allows the length l_{nr} of the antenna 100 to be smaller than a quarter-wavelength for a given resonant frequency. In the preferred embodiment, for a resonant frequency of 931.5 MHz, the length l_{nr} of the antenna is 41.5 mm, which is approximately 40% shorter than many conventional microstrip antennas with an equivalent gain. The total length l_s of the short-circuited sections 130 and 132 is approximately 10.0 mm which is approximately 25% of the entire antenna width w_r. The length l_{os1} of the first open circuit section 146 is approximately 15.0 mm, and the length l_{os2} of the second open circuit section 146 is approximately 15.0 mm.

In the preferred embodiment, the antenna width w_r is made approximately equivalent to the antenna length l_{nr}, (40.0 mm) so that an approximately square structure is provided. If the antenna width w_r were to be made larger, gain would be increased somewhat. However, it was found that the antenna width w_r could be reduced to approximately that of the antenna length l_{nr} without a large reduction in gain. The square structure provides advantages including convenience in installation and a reduced size. In other embodiments, the antenna width w_r could be made wider for more gain, but this would naturally increase the overall size of the microstrip antenna 100. Also, the antenna width w_r could be made narrower to decrease the overall size of the microstrip antenna 100, but this would reduce gain.

In the preferred embodiment, the first side edge 124 and the second side edge 126 are cut closely so that the respective edges of the ground plane layer 102, the dielectric layer 104 and the radiating patch 106 are approximately flush (i.e., evenly lined up). It is believed that evenly cutting the side edges 124 and 126 provides a more isotropic radiation pattern.

A number of optimizations have been included in the microstrip antenna 100, in order to reduce area substantially with little or no corresponding reduction in gain. One advantage of area reduction is that the dielectric width w_d of the dielectric layer 104 can be made wider to further increase the gain at a small cost. In the preferred embodiment, the dielectric width w_d is between 0.015 inch and 0.090 inch, preferably approximately 0.043 inch. Of course, the area of the antenna is not changed by an increase in the dielectric width w_d.

Reference is still made to Fig. 1 which is a perspective view of the microstrip antenna 100 including a rectangular ring 160. It is believed that the ring geometry improves antenna performance in the presence of humans and computers because it is excited mainly by magnetic currents instead of electric currents. This magnetic current excitation, combined with the shape and dimensions of the antenna, enable the described antenna to be only minimally affected by adjacent circuits, and to provide relatively high gain, a uniform radiation pattern, and a minimum human body effect, even when operating in a PCMCIA slot.

The microstrip feed line 140 is positioned approximately centralized over the rectangular ring 160. The ring 160 has a rectangular shape with a ring width l_{ww} and a ring height l_{wh}. The antenna width w_r is, of course, greater than the ring width l_{ww}. Preferably, the antenna width w_r is approximately 40.0 mm, and the ring width l_{ww} is approximately 25.0 mm. The ring 160 is positioned apart from the first side edge 124 by a length l_{ws1}, and the second side edge 126 is positioned apart from the ring 160 by a length l_{ws2}. Preferably, the lengths l_{ws1} and l_{ws2} are equal. Also preferably the lengths l_{ws1} and l_{ws2} are 7.5 mm, however they can be varied to change the input impedance.

The length l_{nr} of the microstrip antenna 100 is of course greater than the height l_{wh} of the ring 160. Preferably, the antenna length l_{nr} is 41.5 mm and the ring height l_{wh} is 9.0 mm. The ring 160 is positioned apart from the radiating edge 120 by a length l_g, and the ring 160 is positioned apart from the partially short-circuited edge 122 by a distance l_{ws}, which is preferably 11.0 mm. The ring 160 may be offset towards the short-circuited edge 122 to reduce the total length of the antenna; in other words, the length l_g may be greater than the length l_{ws}. It is believed that a larger length l_g reduces the antenna length l_{nr}. It is presently preferred that the length l_g be about one-half of the total length l_{nr} of the ring antenna 100, which in the preferred embodiment is about 21.0 mm. Also preferably, the lengths l_{ws1} and l_{ws2} are 7.5 mm, however any of these lengths can be varied to change the input impedance.

In other embodiments (not shown) the ring 160 could have a shape other than rectangular, and/or it may be positioned anywhere within the radiating patch 106. The ring 160 in other embodiments could be square, for example, or it could be offset towards the radiating edge 120, the first side edge 124, or the second side edge 126. Of course, varying the shape and position of the ring 160 will also affect other antenna operating characteristics, including the input impedance, and the preferred shape is rectangular.

Preferably, an exposed dielectric section 170 having a width l_d is provided to increase gain. The radiating patch 106 does not extend over the exposed dielectric section 170, leaving the dielectric "exposed". The ground plane layer 102 continues until the edge 120. Conventional techniques teach that an exposed dielectric portion will increase gain, however in the preferred embodiment the dielectric width l_d is substantially smaller than conventional teaching would suggest. It is believed that the double ring geometry of the antenna 100 allows the dielectric width l_d to be made smaller without any reduction in gain. In the preferred embodiment, the dielectric width l_d is in the range between 0.5 and 1.0 mm.

Preferably, the microstrip feed line 140 is coupled to an external circuit as illustrated in Fig. 2 which is discussed subsequently. However, the microstrip feed line 140 can be coupled by any conventional electrical microstrip coupling (not shown) that has a first conductor that provides an electrical connection with the microstrip feed line 140, and a second conductor that provides an electrical connection with the ground layer 102.

Reference is now made to Fig. 2, which illustrates an exemplary mounting unit and circuitry shown generally at 200 suitable for installing within a PCMCIA card such as that to be discussed subsequently. The mounting unit 200 includes circuitry 210 that includes appropriate circuits such as rf and digital processing circuitry. The circuitry 210 is coupled to a plurality of electrical connectors 214 for connection with appropriate matching connectors (not shown in Fig. 2) such as those for a PCMCIA card.

The mounting unit 200 also includes a pad 218 for mounting the microstrip antenna 100 illustrated in Fig. 1 into position shown in outline form 219. The antenna is mounted with the radiating patch 106 facing downward (i.e. towards the pad 218). The mounting pad 218 includes a plurality of soldering masks for coupling the rf signal from the microstrip antenna 100 to the rf circuitry within the circuitry 210. Particularly, an active layer soldering pad 220 is positioned to be soldered to the microstrip active conductor 142. A ground soldering pad 222 is positioned to be coupled to the second short-circuited section 132, and a second soldering pad 224 is positioned to be coupled to the first short-circuited section 130. It may be noticed that the ground coupling is provided on the active side of the microstrip antenna 100; however, the short-circuited sections 130 and 132 provide a direct link with the ground layer 102 and therefore provide an adequate coupling between the ground layer 102 and the first and second ground soldering pads 222 and 224.

The microstrip antenna 100 (see Fig. 1) is positioned so that the partially short-circuited edge 122 is proximate to the circuitry 210 and the radiating edge 120 is distal from the circuitry 210. As a result, when installed, the radiating edge 120 faces outward from the slot in which it is installed (see Figs. 5 and 7, for example).

The mounting unit 200 also includes a plurality of batteries 240 coupled on an extended section 244, and a plurality of LEDs (Light Emitting Diodes) 250 that are coupled to the batteries 240 and positioned so that, when the conductors 214 are coupled to a matching connector and power is applied to the system, the LEDs will indicate as a convenience to the user that power has been supplied. The extended portion is positioned to the active layer of the antenna 219.

Preferably, the microstrip antenna 100 for the implementation shown in Fig. 2 includes a solder mask provided to insulate and protect it. Particularly, the conductors in the microstrip antenna are covered with a thin (1 mil) plastic insulator that isolates the antenna from surrounding circuit components, for example, batteries, and also protects the copper in the conductive layers of the antenna from oxidation or other corrosive actions.

Reference is now made to Fig. 4, which illustrates a preferred position in which a microstrip antenna 400 can be situated within a pager 402. Fig. 4 illustrates a microstrip antenna 400 positioned with its radiating edge 420 facing outward from the edge of the page 402. However, other configurations will be operable, and each configuration has advantages that are highly dependent upon the particular circuit configuration of the pager 402 and other factors apparent to one skilled in the art.

Reference is now made to Fig. 5 which is an illustration of a small portable computer 500 having a PCMCIA slot 510 provided therein. The PCMCIA slot 510 is constructed in accordance with a well-known PCMCIA standard presently used within the computer industry, and has been previously used for inserting additional memory and other devices, such as programs, into small portable computers. A microstrip antenna 520 is illustrated positioned within a card 530 which has dimensions of the well-known PCMCIA standard. A plurality of connectors 540 are provided to connect to matching connectors (not shown) within the slot 510. The slot 510, the connectors 540, and the matching connectors within the slot 510 are also constructed in accordance with the well-known PCMCIA standard.

The card 530 has standard PCMCIA dimensions of 85.60 mm for a length l_p illustrated at 532, and 54.0 mm for a length l_{wp} illustrated at 534. The thickness of the PCMCIA card 530 varies dependent upon type: a type I card has a width of 3.3 mm, and a type II card has a thickness of 5.0 mm. The PCMCIA standard is incorporated by reference herein. Of course, the exact dimensions of the PCMCIA standard are not essential to practicing the present invention, and other housings with other dimensions could be utilized. However, the PCMCIA size is particularly useful because it has already attained the status of a well-known standard within the computer industry.

Reference is briefly made to Fig. 8 which is a block diagram of the antenna 520 and related circuits 541 in the card 530. The antenna 520 is coupled by any suitable means to the circuits 541 including a conventional radio frequency front-end 542 to receive signals from the antenna 520 and output them to a digital processing and interface circuit 546. Conventional circuits are included within the digital processing interface circuit 546 in order to receive the rf signals and interface through the output connectors 540 with any suitable electronic equipment such as a computer circuit.

Reference is again made to Fig. 5. The PCMCIA slot 510 is usually separated from the remainder of the portable computer 500 by a metal case. Tests have indicated that an antenna 100 constructed in accordance with the present invention will radiate satisfactorily in all directions from a slot such as the PCMCIA slot 510 even if it is encased in metal. It has been observed that the preferred position within the slot is as indicated in Fig. 5, with its radiating edge 550 situated proximate to the opening from the slot 510.

Reference is now made to Fig. 9, which is a cross-section of the card 530 taken along the lines illustrated in Fig. 5. Additionally, the adjacent edges of the slot 510, including a first metal side 570 and a second metal side 572 opposite thereto are illustrated. In other words, the card 530 is positioned within the slot 510 in the illustration of Fig. 9. The card includes a first flat side 580 positioned facing the first metal side 520, and a second flat side 582 positioned facing the second metal side 572.

Within the card 530, the antenna 100 is positioned proximate to the first flat side 580, so that its ground plane 102 is positioned proximate thereto. The radiating patch 106 is positioned facing the second flat surface 582. However, as illustrated in Fig. 2, the batteries 240 and connector 220 is positioned between the radiating patch 106 and the second flat surface 582. The connector 220 is also coupled to the circuits 210 (also illustrated in Fig. 8 and described with reference thereto). The circuits 210 may include the circuits 541 illustrated in Fig. 8.

It is advantageous that the ground plane layer 102 is positioned as closely as possible to the slot side 570, which usually comprises a metal material. As a result, radiation is emitted in a direction from the ground layer 102 (i.e., in a direction toward the radiating patch 106 and away from the ground plane 102), and also from the radiating edge 550. Thus, closely positioning the ground plane layer 102 with the slot edge 570, and furthermore positioning it with the radiating edge 550 proximate to the opening of the slot 510 (see Fig. 5) provides a highly advantageous radiation pattern and substantially improves the gain over other positions of the antenna 100 within the slot 510.

Reference is now made to Fig. 6 which is a perspective view of a portable telephone 600 showing a cut-away view of a partially short-circuited, dual rectangular ring microstrip antenna 610 installed therein. The microstrip antenna 610 could be easily installed in the handset of a portable telephone, and could operate effectively therein.

The antennas, such as the microstrip antenna 400 in Figs. 4, the antenna 520 in Fig. 5, and the antenna 610 in Fig. 6 can of course be sized according to the needs of the users.

Particularly, the overall dimensions of the microstrip antenna, the dimensions of the shorting strip, and the dimensions of the rectangular ring can be adjusted to meet the desired resonant frequency and the needs of the user. For example, the antennas 520 and 610 which are used for portable computers and portable telephones respectively will have different dimensions from that described with reference to the preferred embodiment which is useful in pagers, although the overall proportions will preferably remain approximately the same.

Reference is now made to Fig. 7. A housing 700 for a computer unit 704 is illustrated. The computer unit 704 can be any of a wide variety of computer units, including large portable units, desktop computers, and work stations, among others. A slot 710 is illustrated on a side 720 of the computer housing 700. An antenna case 730 that houses a microstrip antenna 740 is provided to fit within the slot 710 in the computer housing 700. It should be apparent to one skilled in the art that, in other embodiments, the antenna 740 could be permanently installed in the computer housing 700, without the necessity of the slot 710. However, it is useful that the antenna 740 be positioned in an opening 750 in the housing 700 in order to receive and transmit efficiently.

From the above description, it will be apparent that the invention disclosed herein provides a novel and advantageous microstrip antenna. The foregoing discussion discloses and describes exemplary methods and embodiments of the present invention. As will be understood by those familiar with the art, the invention may be embodied in other specific forms without departing from its spirit or essential characteristics, and thus, the described embodiment is not restrictive of the scope of the invention.

The following claims are indicative of the scope of the invention. All variations which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

WHAT IS CLAIMED IS:

1. A microstrip antenna defining a ground plane, a radiating patch, and a dielectric layer positioned between the radiating patch and the ground plane, comprising;

a partially short-circuited edge having a short-circuited section and an open-circuited section; and

a microstrip feed line coupled to said open-circuited section.

2. The microstrip antenna of Claim 1 wherein the microstrip feedline is coupled directly to said open-circuited section.

3. The microstrip antenna of Claim 1 wherein the short-circuited section couples a length between 20% and 50% of the total length of the partially short-circuited edge.

4. The microstrip antenna of Claim 1:

wherein said microstrip antenna defines four edges including the partially short-circuited edge, a radiating edge situated positioned opposite said partially short-circuited edge, a first side edge, and a second side edge positioned opposite said first side edge; and wherein said radiating patch includes a rectangular ring formed thereon, said rectangular ring having four sides including a first side defined proximate to the radiating edge, a second side defined parallel to the partially short-circuited edge, a third side defined proximate to the first side edge, and a fourth side defined proximate to the second side edge.

5. The microstrip antenna of Claim 4 wherein said rectangular ring is offset by said second side being positioned substantially closer to the partially short-circuited edge than the first side is positioned to the radiating edge.

6. A microstrip antenna defining a ground plane, a radiating patch, and a dielectric layer positioned between the radiating patch and the ground plane, comprising:

a partially short-circuited edge having a plurality of short-circuited sections including a first short-circuited section and a second short-circuited section, and an open-circuited section positioned between said first and second short-circuited section; and

a microstrip feed line coupled to said open-circuited section.

7. The microstrip antenna of Claim 6 wherein the microstrip feedline is coupled directly to said open-circuited section.

8. The microstrip antenna of Claim 6 wherein the short-circuited section couples a length between 20% and 50% of the total length of the partially short-circuited edge.

9. The microstrip antenna of Claim 6 wherein said microstrip antenna defines a rectangular shape having four edges including the partially short-circuited edge, a radiating edge positioned opposite said partially short-circuited edge, a first side edge, and a second side edge positioned opposite said first side edge.

10. The microstrip antenna of Claim 9, wherein, on said partially short-circuited edge, the first short-circuited section is positioned proximate to the first side edge, and the second short-circuited section is positioned proximate to the second side edge.

11. The microstrip antenna of Claim 9, wherein said partially short-circuited edge, said radiating edge, said first side edge, and said second side edge have a length that is approximately equal, so that the shape of the microstrip antenna is approximately square.

12. The microstrip antenna of Claim 6:

wherein said microstrip antenna defines four edges including the partially short-circuited edge, a radiating edge situated positioned opposite said partially short-circuited edge, a first side edge, and a second side edge positioned opposite said first side edge; and

wherein said radiating patch includes a rectangular ring form thereon, said rectangular ring having four sides including a first side defined proximate to the radiating edge, a second side defined parallel to the partially short-circuited edge, a third side defined proximate to the first side edge, and a fourth side defined proximate to the second side edge.

13. The microstrip antenna of Claim 12 wherein said rectangular ring is offset by said second side being positioned substantially closer to the partially short-circuited edge than the first side is positioned to the radiating edge.

14. The microstrip antenna of Claim 6 wherein said first side edge is cut flush so that, at said first side edge, said radiating patch, said dielectric layer, and said ground plane are approximately even, and wherein said second side edge is cut flush so that, along said second side edge, said radiating patch, said dielectric layer, and said ground plane layer are approximately even.

15. Portable electronic equipment for communicating with electromagnetic signals, comprising:

a housing for enclosing said portable electronic equipment; and a microstrip antenna situated within said housing, said microstrip antenna defining a ground plane, a radiating patch, and a dielectric layer positioned between the radiating patch and the ground plane, said microstrip antenna further comprising

a partially short-circuited edge having a short-circuited section and an open-circuited section, and

a microstrip feed line coupled to said open-circuited section.

16. The microstrip antenna of Claim 15 wherein the microstrip feedline is coupled directly to said open-circuited section.

17. The microstrip antenna of Claim 15 wherein said electronic equipment includes a pager, and said microstrip antenna is positioned within said pager housing.

18. The microstrip antenna of Claim 15 wherein said portable electronic equipment includes a portable telephone.

19. The microstrip antenna of Claim 15 wherein the short-circuited section couples a length between 20% and 50% of the total length of the partially short-circuited edge.

20. The microstrip antenna of Claim 15:

wherein said microstrip antenna defines four edges including the partially short-circuited edge, a radiating edge situated positioned opposite said partially short-circuited edge, a first side edge, and a second side edge positioned opposite said first side edge; and

wherein said radiating patch includes a rectangular ring formed thereon, said rectangular ring having four sides including a first side defined proximate to the radiating edge, a second side defined parallel to the partially short-circuited edge, a third side defined proximate to the first side edge, and a fourth side defined proximate to the second side edge.

21. The microstrip antenna of Claim 20 wherein said rectangular ring is offset by said second side being positioned substantially closer to the partially short-circuited edge than the first side is positioned to the radiating edge.

22. A double ring microstrip antenna comprising:

a ground plane;

a radiating patch;

a dielectric layer positioned between the ground plane and the radiating patch;

a partially short-circuited edge having a plurality of short-circuited sections including a first short-circuited section and a second short-circuited section coupling a length between ten percent and ninety percent of the total length of the partially short-circuited edge, and an open-circuited section positioned between said first and second short-circuited section; and

a microstrip feed line coupled to said open-circuited section;

wherein said double ring microstrip antenna defines a radiating edge positioned opposite the partially short-circuited edge, a first side edge, and a second side edge; and

wherein said radiating patch includes a rectangular ring formed therein, said rectangular ring having four sides including a first side proximate to the radiating edge, a second side parallel to the partially short-circuited edge, a third side proximate to the first side edge, and a fourth side proximate to the second side edge.

23. The double ring microstrip antenna of Claim 22 wherein said rectangular ring is offset by said second side being positioned substantially closer to the partially short-circuited edge than the first side is positioned to the radiating edge.

24. The double ring microstrip antenna of Claim 22 wherein said rectangular ring defines a width of l_{ww}, between the third side and the fourth side, and also defines a height l_{wh} between the first side and the second side, and said width l_{ww} is approximately 1.5 times greater than the height l_{wh}.

25. An antenna assembly for inserting into electrical equipment, said antenna assembly comprising:

an antenna housing having a shape for insertion into said electrical equipment; and

a microstrip antenna situated within said antenna housing, said microstrip antenna defining a ground plane, a radiating patch, and a dielectric layer positioned between the radiating patch and the ground plane, said microstrip antenna further comprising

a partially short-circuited edge having a short-circuited section and an open-circuited section, and

a microstrip feed line coupled to said open-circuited section.

26. The antenna assembly of Claim 25 wherein the electrical equipment comprises a slot, and the antenna housing has a shape for insertion into said slot.

27. The antenna assembly of Claim 25 wherein the microstrip feedline is coupled directly to said open-circuited section.

28. The antenna assembly of Claim 25 wherein the short-circuited section couples a length between 20% and 50% of the total length of the partially short-circuited edge.

29. The antenna assembly of Claim 25 wherein said microstrip antenna defines a radiating edge positioned opposite the partially short-circuited edge, a first side edge, and a second side edge, wherein said radiating patch includes a rectangular ring formed therein, said rectangular ring having four sides including a first side proximate to the radiating edge, a second side parallel to the shorting conductor, a third side proximate to a first side edge, and a fourth side proximate to a second side edge.

30. The microstrip antenna assembly of Claim 25 wherein said housing includes a first flat surface and opposite thereto, a second flat surface, and said microstrip antenna is positioned within said antenna housing proximate to said first flat surface in a position in which the ground layer is positioned proximate to said first flat surface.

31. The antenna assembly of Claim 25 further comprising:

a radio frequency front end coupled to said microstrip antenna, said front end positioned within said antenna housing; and

a digital processing and interface circuit coupled to said front end to interface a radio frequency signal from said microstrip antenna with said electronic equipment, said digital processing and interface circuit positioned within said antenna housing.

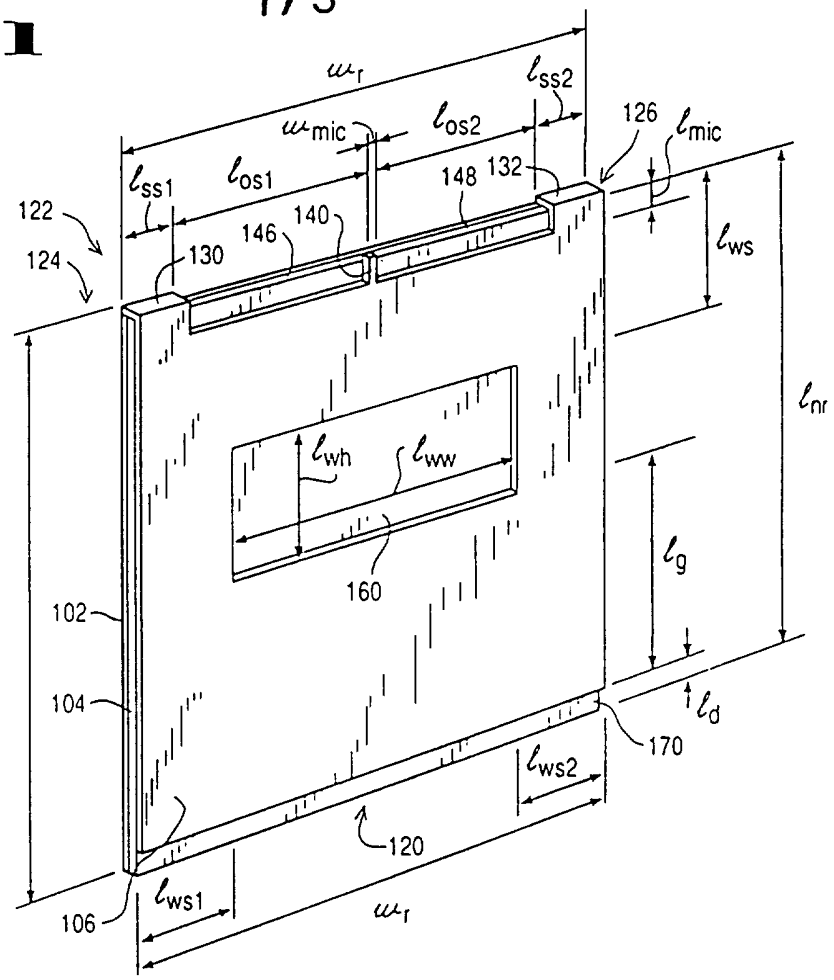
32. The antenna assembly of Claim 31:

wherein the electrical equipment includes a PCMCIA slot and first connectors disposed within said PCMCIA slot;

wherein the antenna housing has a shape for insertion into said PCMCIA slot; and

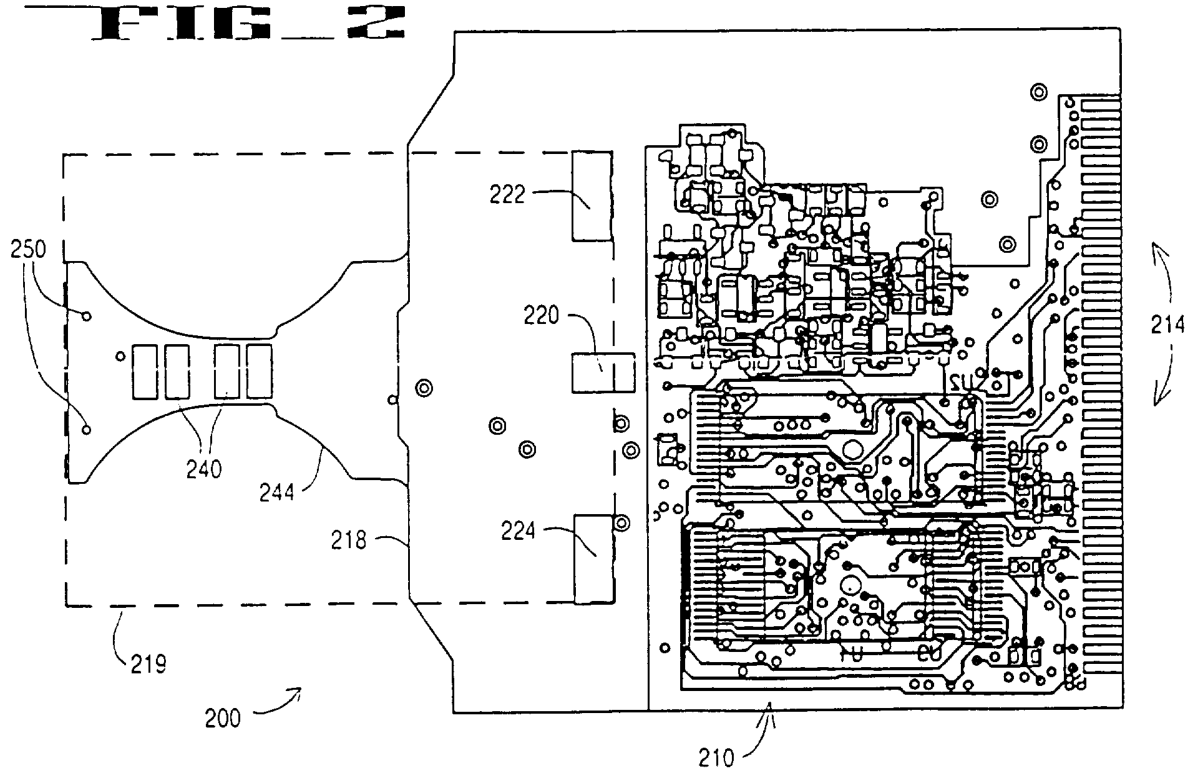
wherein said antenna housing further includes second connectors coupled to the digital processing and interface circuit, said second connectors having a shape and position for connecting with said first connectors in said PCMCIA slot.

FIG_1



100
122
124
126
130
132
140
146
148
160
102
104
106
120
170
w_r
l_{ss1}
l_{os1}
w_{mic}
l_{os2}
l_{ss2}
l_{mic}
l_{ws}
l_{nr}
l_{wh}
l_{ww}
l_g
l_d
l_{ws1}
l_{ws2}

FIG_2



250
240
244
218
219
200
222
220
224
210
214

FIG_3
(PRIOR ART)

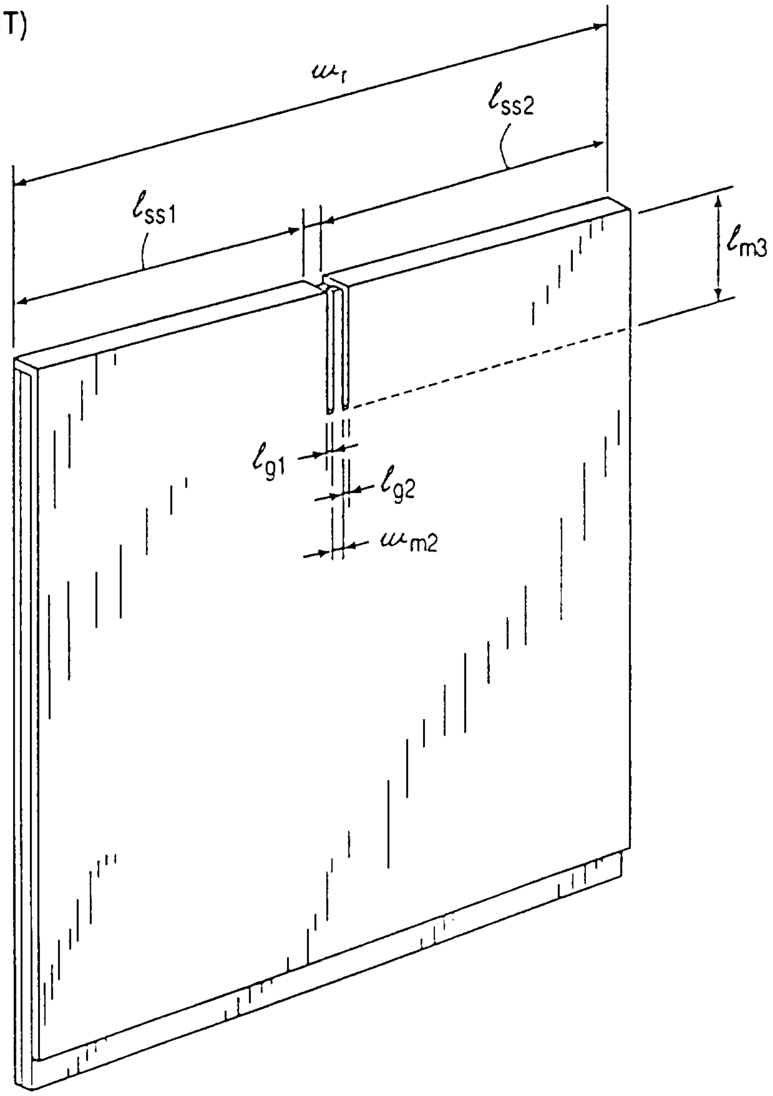


FIG_4

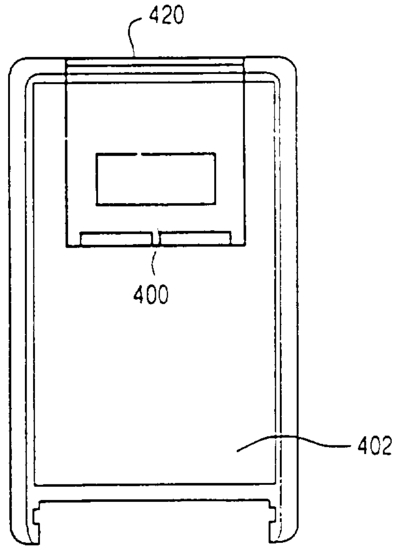


FIG_5

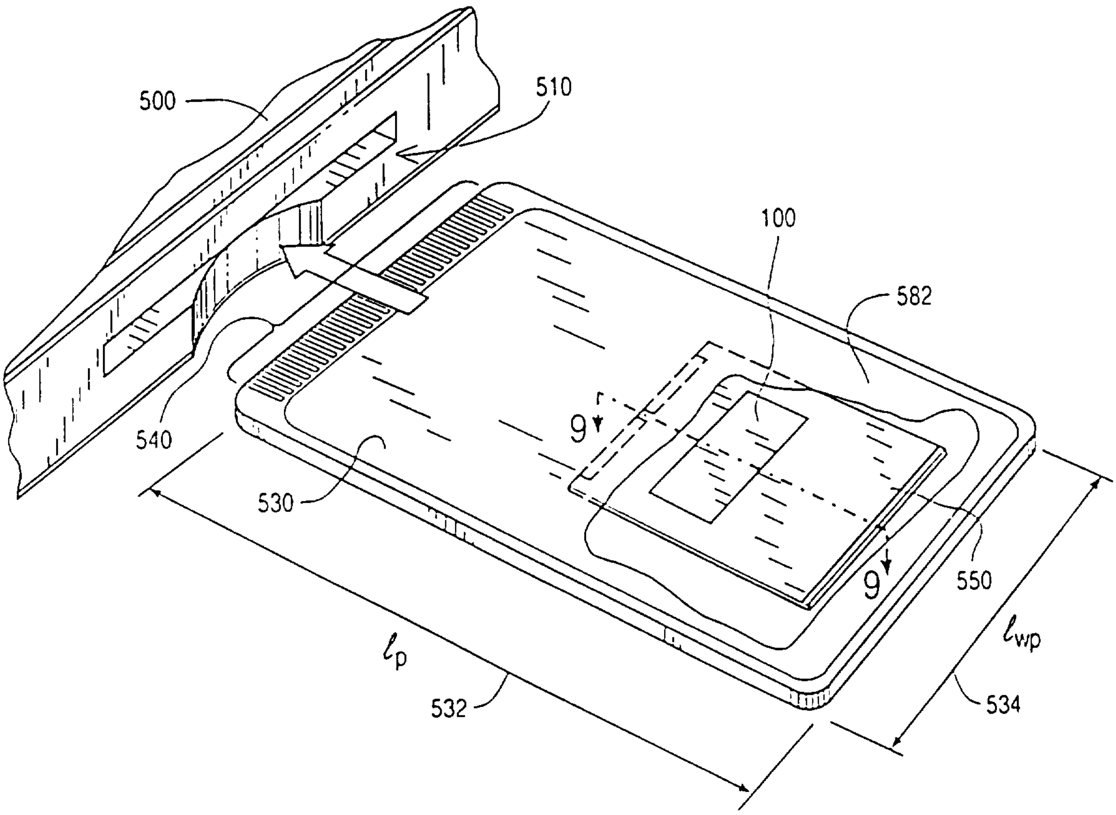


FIG_6

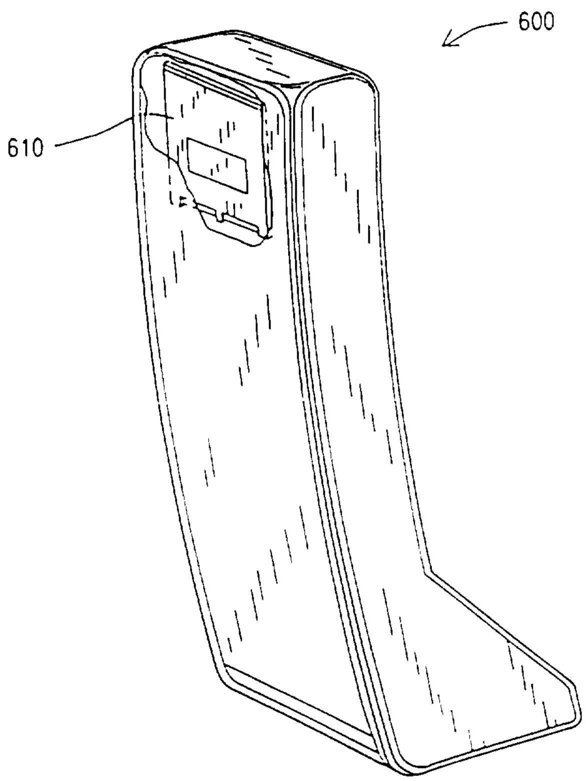


FIG_7

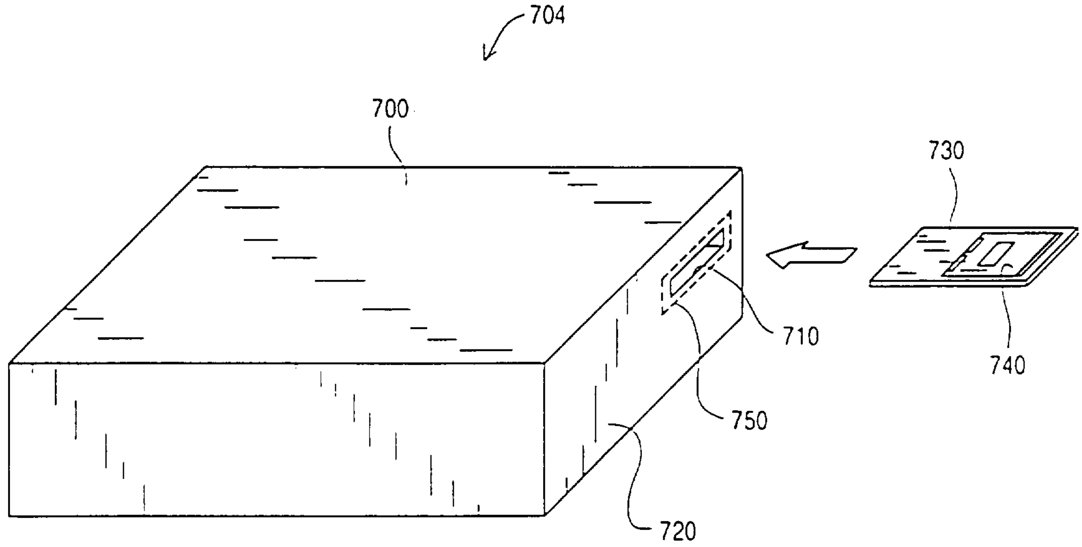

704
700
730
710
740
750
720

FIG_8

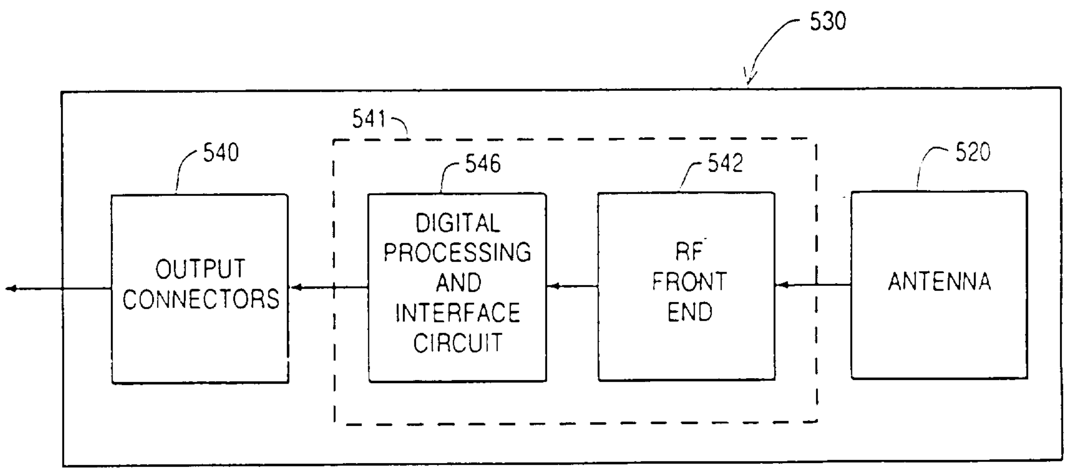
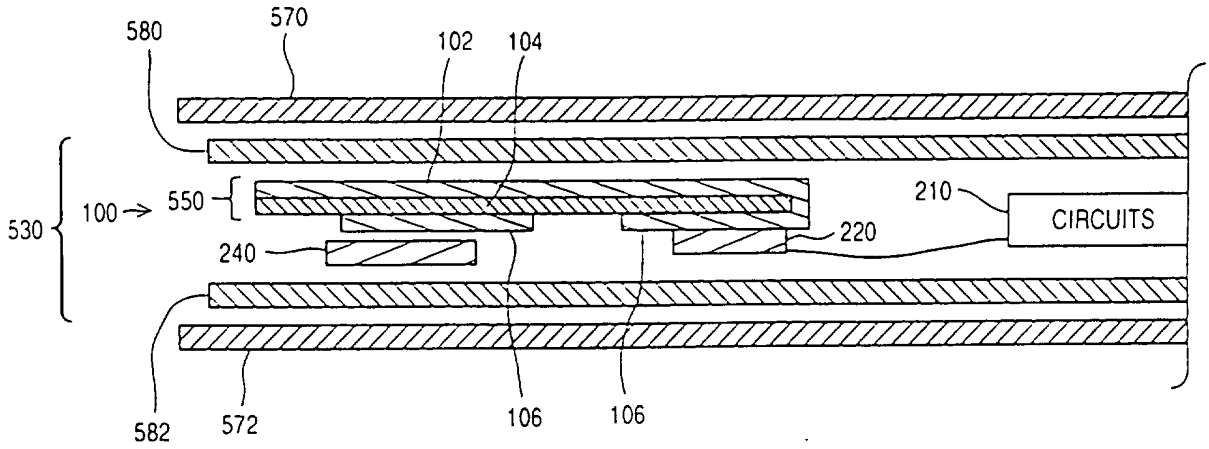

530
541
540
546
542
520
OUTPUT CONNECTORS
DIGITAL PROCESSING AND INTERFACE CIRCUIT
RF FRONT END
ANTENNA

FIG_9


580
570
102
104
530
100
550
210
CIRCUITS
220
240
582
572
106
106

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/07976

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01Q9/04 H01Q1/24

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 *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 8 no. 243 (E-277) [1680] ,8 November 1984 & JP,A,59 122204 (MITSUBISHI) 14 July 1984, see abstract ---	1,6
A	PROCEEDINGS OF THE NATIONAL ELECTRONICS CONFERENCE, vol. 35, October 1981 OAK BROOK, ILLINOIS US, pages 425-430, MEHDIZADEH ET AL. 'DESIGN AND MEASUREMENT OF SINGLE SLOT MICROSTRIP ANTENNA FOR RF SENSORS' see page 425; figures 2-B. ---	1,6
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* 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
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
19 October 1995	- 2. 11. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Angrabeit, F

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/07976

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	WO,A,94 24722 (WIRELESS ACCESS) 27 October 1994 cited in the application see claims 1-21; figures 1-8 ---	1-32
P,A	WO,A,94 24723 (WIRELESS ACCESS) 27 October 1994 cited in the application see claims 1-26; figures 1-8 -----	1-32

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 95/07976

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9424722	27-10-94	AU-B-	6637094	08-11-94
		JP-A-	6314924	08-11-94
WO-A-9424723	27-10-94	AU-B-	6637194	08-11-94
		JP-A-	6314923	08-11-94