



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication: **18.12.1996 Bulletin 1996/51** (51) Int Cl.<sup>6</sup>: **H01Q 9/04**

(21) Application number: **96304428.4**

(22) Date of filing: **13.06.1996**

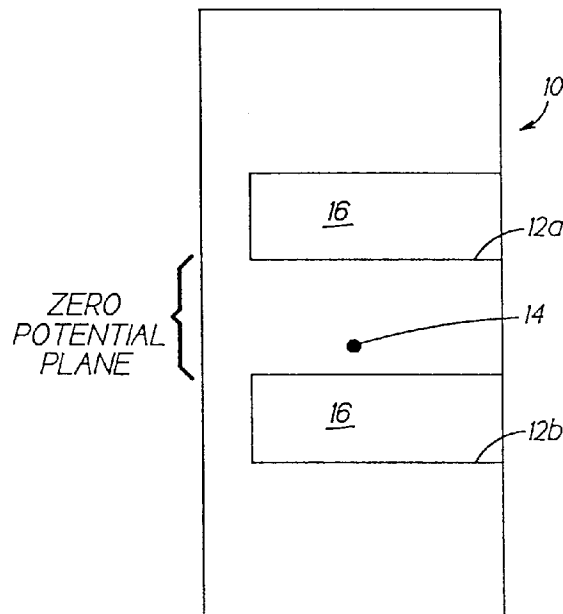
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(54) **Planar and non-planar double C-patch antennas having different aperture shapes**

(57) A shorted, dual C-patch antenna includes a truncated ground plane, a layer of dielectric material having a first surface overlying the ground plane and an opposing second surface, and an electrically conductive layer overlying the second opposing surface of the dielectric layer. The electrically conductive layer forms a radiating patch and has a non-rectangularly shaped aperture (e.g., parabolic, triangular, pentagonal) having a length that extends along a first edge of the electrically

conductive layer and a width that extends towards an oppositely disposed second edge. The length has a value that is equal to approximately 20% to approximately 35% of a length of the first edge. The antenna may further include electrically conductive vias or feedthroughs for shorting the electrically conductive layer to the ground plane at a region adjacent to a third edge of the electrically conductive layer. The antenna may be curved about one or more axes.

**FIG. 2**



## Description

This invention relates generally to antenna structures and, in particular, to a microstrip C-patch antenna structure.

In an article entitled "The C-Patch: A Small Microstrip Element", 15 December 1988, G. Kossiavas, A. Papiernik, J.P. Boisset, and M. Sauvan describe a radiating element that operates in the UHF and L-bands. The dimensions of the C-patch are smaller than those of conventional square or circular elements operating at the same frequency, which are relatively bulky. In general, the dimensions of any radiating element are inversely proportional to the resonant frequency. Referring to Figure 1, a substantially square electrically conductive radiating element or patch 5 (operating at 413 MHz) has an aperture that extends part way across the patch. The width (d) of the aperture (12.5 mm) is shown to be 20% of the total width ( $L = W = 62.5$  mm) of the patch, while for an example operating at 1.38 GHz (L-band) the width (d) of the aperture (5.5 mm) is approximately 16.7% of the width ( $L = 22$  mm,  $W = 33$  mm) of the patch. This antenna geometry is shown to exhibit a threefold to fourfold gain in area with respect to conventional square or circular antennas, although the bandwidth is somewhat narrower. Good impedance matching with a coaxial feed is shown to be a feature of the C-patch antenna, as is an omnidirectional radiation pattern with linear polarization.

In general, microstrip antennas are known for their advantages in terms of light weight, flat profiles, low manufacturing cost, and compatibility with integrated circuits. The most commonly used microstrip antennas are the conventional half-wavelength and quarter-wavelength rectangular patch antennas. Other microstrip antenna configurations have been studied and reported in the literature, such as circular patches, triangular patches, ring microstrip antennas, and the above-mentioned C-patch antennas.

In the "Handbook of Microstrip Antennas", Volume 2, Ch. 19, Ed. by J.R. James and P.S. Hall, P. Peregrinus Ltd., London, U.K. (1989), pgs. 1092-1104, a discussion is made of the use of microstrip antennas for hand-held portable equipment. A window-reactance-loaded microstrip antenna (WMSA) is described at pages 1099 and is illustrated in Figs. 19.33-19.36. A narrow reactance window or slit is placed on the patch to reduce the patch length as compared to a quarter-wavelength microstrip antenna (QMSA). The value of the reactance component is varied by varying the width (along the long axis) of the slit. Figure 19.36a shows the use of two collinear narrow slits that form a reactance component in the antenna structure, enabling the length of the radiation patch to be shortened.

The narrow slit does not function as a radiating element, and is thus not equivalent in function to the substantially larger aperture in the above-described C-patch antenna. So-called PC cards are small form-factor

adapters for personal computers, personal communicators, or other electronic devices. As is shown in Figure 7, a PC card 1 is comparable in size and shape to a conventional credit card, and can be used with a portable computer system 2 that is equipped with an interface 3 that is physically and electrically compatible with a standard promulgated by the Personal Computer Memory Card International Association (PCMCIA). Reference in this regard can be made to Greenup, J. 1992, "PCMCIA 2.0 Contains Support for I/O Cards, Peripheral Expansion", Computer Technology Review, USA, 43-48.

PC cards provide the flexibility of adding features after the base computer system has been purchased. It is possible to install and remove PCMCIA PC cards without powering off the system or opening the covers of the personal computer system unit.

The PC card 1 has standard PCMCIA dimensions of 8.56 cm x 5.4 cm. The thickness of the PCMCIA card 1 varies as a function of type. A Type II PCMCIA PC card is defined to have a thickness of 0.5 cm. The Type II PCMCIA PC card can be used for memory enhancement and/or I/O features, such as wireless modems, pagers, LANs, and host communications.

Such a PC card can also provide wireless communication capability to laptop, notebook, and palmtop personal computers, and any other computer system having a PCMCIA-compatible interface. The PC card may also work as a standalone wireless communication card when it is not connected to a computer.

For such applications it is required to provide the PC card with a small, built-in antenna having an isotropic radiation pattern. Since the PCMCIA wireless communication card may be hand-held and/or used in an operator's pocket, the antenna should be substantially immune from effects caused by the close proximity of the human body. Furthermore, the portable PCMCIA communication cards are typically randomly orientated during use and, thus, suffer from multipath reflections and rotation of polarization. Therefore, the antenna should be sensitive to both vertically and horizontally polarized waves. Moreover, the antenna should preferably exhibit the same resonant frequency, input impedance, and radiation patterns when used in free space and when used inside a PCMCIA Type II slot in a conventional portable computer.

It can be appreciated the design of an antenna that meets these various requirements presents a significant challenge.

Furthermore, there is a growing interest in developing efficient internal integrated antennas for the class of 900 MHz digital cordless telephones. A high performance built-in antenna is required to have a very small size, a compact structure, a wide bandwidth, a quasi-isotropic radiation pattern, and to exhibit a negligible susceptibility to the proximity of the human body. Furthermore, since portable cordless telephones are normally randomly orientated during use, their antennas

must be sensitive to both vertically and horizontally polarized waves. External antennas, such as the whip, sleeve dipole, and helical, are sensitive only to one polarization of the radio waves. As a result, they are not optimized for use with the portable cordless telephones in which antenna orientation is not fixed. Moreover, it has been found that when such external antennas are operated in close proximity to a user of the phone, their radiation patterns change significantly. In addition, a significant portion of the radiated power is attenuated by the user's body.

The foregoing and other problems may be overcome by an antenna structure that is constructed in accordance with this invention. More particularly, this invention provides in a first embodiment a double C-patch antenna having a plurality of non-rectangular aperture shapes on a very small (truncated) ground plane. The non-rectangular aperture shapes provide increase sensitivity to different polarizations. In further embodiments a shorted, double C-patch antenna is shown to have a non-planar construction, and is curved about one or more axes.

This invention further provides a module adapted for insertion into a data processor. The module includes an interface for electrically coupling the module to the data processor, a modem that is bidirectionally coupled to the interface, an RF energy transmitter having an input coupled to an output of the modem, an RF energy receiver having an output coupled to an input of the modem, and a shorted, double C-patch antenna having a non-rectangular aperture shape that is electrically coupled to an output of the RF energy transmitter and to an input of the RF energy receiver.

The shorted, double C-patch antenna is comprised of a ground plane, a layer of dielectric material having a first surface overlying the ground plane and an opposing second surface, and an electrically conductive layer overlying the second opposing surface of the dielectric layer. The electrically conductive layer has the shape of a parallelogram and has a non-rectangularly shaped aperture having a length that extends along a first edge of the electrically conductive layer and a width that extends towards an oppositely disposed second edge. The length has a value that is equal to approximately 20% to approximately 35% of a length of the first edge. In a presently preferred partially shorted embodiment the antenna further includes electrically conductive vias or feedthroughs for shorting the electrically conductive layer to the ground plane at a region adjacent to a third edge of the electrically conductive layer. The antenna also includes a coupler for coupling the electrically conductive layer to the output of the transmitter and to the input of the receiver.

The width of the aperture has a value that is equal to approximately 15% to approximately 40% less than a width of the electrically conductive layer, and is located from the third edge at distance that is approximately equal to the length of the aperture.

The ground plane is truncated, and has dimensions that are approximately equal to the dimensions of the electrically conductive layer.

In one embodiment of this invention the module is a wireless communications PC card having dimensions of 8.5 cm x 5.4 cm by 0.5 cm, and is thus form and fit compatible with a PCMCIA Type II PC card. In other preferred embodiments of this invention the double C-patch antenna is contained within a hand-held wireless telephone.

The aperture shapes may be, by example, triangular, parabolic, elliptical, or pentagonal. The curvature of the antenna may be generally positive or negative, and may be about one axis or about two axes.

The above set forth and other features of the invention are made more apparent in the ensuing Detailed Description of preferred embodiments of the Invention when read in conjunction with the attached Drawings, wherein:

Figure 1 is a plane view of a prior art C-patch antenna structure;

Figure 2 is a plane view of a double C-patch antenna in accordance with an aspect of this invention;

Figure 3 is an enlarged plane view of a partially shorted, double C-patch antenna having a rectangular aperture shape;

Figure 4 is a cross-sectional view, not to scale, taken along the section line 4-4 of Figure 3;

Figure 5 shows a preferred orientation for the partially shorted, double C-patch antenna of Figure 3 when contained within a wireless communications PCMCIA PC card that is installed within a host system;

Figure 6 is a simplified block diagram of the wireless communications PCMCIA PC card of Figure 5;

Figure 7 is a simplified elevational view of a portable computer and a PCMCIA PC card, in accordance with the prior art;

Figure 8a is an elevational view of a double C-patch antenna having triangularly shaped apertures in accordance with an aspect of this invention;

Figure 8b is an elevational view of a partially shorted, double C-patch antenna having a triangularly shaped aperture;

Figure 9 is an elevational view of a partially shorted, double C-patch antenna having an elliptically shaped aperture;

Figure 10 is an elevational view of a partially shorted, double C-patch antenna having a pentagonally shaped aperture;

Figure 11 is an elevational view of a first embodiment of a partially shorted, non-planar double C-patch antenna;

Figure 12 is an elevational view of a second embodiment of a partially shorted, non-planar double C-patch antenna; and

Figure 13 is an elevational view of a third embodiment of a partially shorted, non-planar double C-patch antenna.

Figure 2 illustrates, in accordance with the above-referenced commonly assigned U.S. Patent Application S.N. 08/414,573, filed 3/31/95, entitled "A Small Double C-Patch Antenna Contained in a Standard PC Card", by Mohamed Sanad, the geometry of a double C-patch antenna 10, having rectangularly shaped apertures 12a and 12b. This antenna structure differs most significantly from the above-described C-patch antenna described by Kossiavas et al. by having two radiating apertures 12a and 12b, as opposed to the single aperture described in the article. The antenna 10 is coaxially fed at the point 14 which is asymmetrically located between the two apertures 12a and 12b (i.e., the point 14 is located nearer to one of the apertures than the other). The region between the two apertures 12a and 12b is a zero potential plane of the antenna 10. A ground plane (not shown) covers a back surface of the antenna 10, and is spaced apart from the antenna metalization 18 by an intervening dielectric layer 16. The dielectric layer 16 is exposed within the regions that correspond to the apertures 12a and 12b. The various dimensional relationships between the antenna elements will be made apparent during the discussion of the partially shorted embodiment described next, it being realized that the embodiment of Figure 2 is essentially a mirror image of the embodiment of Figure 3.

In general, and for a selected resonant frequency, the antenna 10 of Figure 2 has a smaller size than a conventional half-wavelength rectangular microstrip antenna. Furthermore, for a selected resonant frequency, the antenna 10 has a smaller size than the conventional C-patch antenna 5 shown in Figure 1. However, for some applications (such as a PCMCIA application) the overall area of the double C-patch antenna 10 may still be too large.

Figures 3 and 4 illustrate a partially shorted, double C-patch antenna 20 in accordance with the invention disclosed in the above-referenced commonly assigned U.S. Patent Application S.N. 08/414,573, filed 3/31/95, entitled "A Small Double C-Patch Antenna Contained in a Standard PC Card", by Mohamed Sanad. To reduce the overall length of the double C-patch antenna 20 to

approximately one half of the length shown in Figure 2, the zero potential plane of the antenna 10, which lies between the two apertures and which is excited with the dominant mode, is short-circuited by a plurality of electrically conductive vias or posts 24. To further reduce the size of the partially shorted, double C-patch antenna 20 only a small portion of the entire length of the shorted edge 20a is shorted-circuited (hence the term 'partially shorted').

Although the partially shorted embodiment is presently preferred, it is also within the teaching of the invention to provide a continuous short along the edge 20a. By example, a length of electrically conductive material (e.g., electrically conductive tape shown as 21 in Figure 4) can be wrapped around the edge 20a to short the ground plane 22 to the radiating patch metalization 30.

The entire length of the partially shorted edge 20a is defined to be the width ( $W1$ ) of the antenna 20, while the length ( $L1$ ) of the antenna is the distance between the partially shorted edge 20a and the main radiating edge 20b which is parallel to the partially shorted edge 20a. The side of the rectangular aperture 26 which is parallel to the partially shorted edge is defined to be the width ( $W2$ ) of the aperture 26, while the side of the aperture that is perpendicular to the width  $W2$  is defined to be the aperture length  $L2$ . The length ( $L1$ ) of the partially shorted, double C-patch antenna 20 is less than one half of the length of a conventional quarter-wavelength shorted rectangular microstrip antenna resonating at the same frequency and having the same width and thickness. It should be noted that the Length and Width convention in Figure 3 has been reversed from that used when describing the conventional C-patch antenna of Figure 1.

It should be further noted that the geometry of the double C-patch antenna embodiment of Figure 2, in particular the existence of the zero potential plane between the apertures 12a and 12b, makes it possible to form the partially shorted embodiment of Figure 3. That is, the conventional C-patch antenna shown in Figure 1, because of a lack of such symmetry, is not easily (if at all) capable of having the radiating patch shorted to the ground plane.

#### Example 1

An embodiment of the partially shorted, double C-patch antenna 20 is designed to resonate at approximately 900 MHz, a frequency that is close to the ISM, cellular and paging frequency bands specified for use in the United States. The total size ( $L1 \times W1$ ) of the antenna 24 is 2.7 cm x 2.7 cm. The antenna 20 employs a dielectric layer 28 comprised of, by example, Duroid 6002 having a dielectric constant of 2.94 and a loss tangent of 0.0012. The thickness of the dielectric layer is 0.1016 cm. A density of electro-deposited copper clad that forms the ground plane 22 and the patch antenna

metalization 30 is 0.5 oz per square foot. The length (L2) of the aperture 26 is 0.7 cm, the width (W2) of the aperture 26 is 2 cm, and the edge of the aperture 26 is located 0.6 cm from the partially shorted edge 20a (shown as the distance D in Figure 4). That is, in the preferred embodiment D is approximately equal to L2. The input impedance of the antenna 20 is approximately 50 ohms, and the antenna is preferably coaxially fed from a coaxial cable 32 that has a conductor 32a that passes through an opening within the ground plane 22, through the dielectric layer 28, and which is soldered to the antenna radiating patch metalization 30 at point 34. A cable shield 36 is soldered to the ground plane 22 at point 38. The coaxial feed point 34, for a 50 ohm input impedance, is preferably located at a distance that is approximately D/2 from the partially shorted edge 20a, and approximately W1/2 from the two opposing sides that are parallel to the length dimension L1. The exact position of the feed point 34 for a given embodiment is a function of the desired input impedance. A clearance area 40 of approximately 2 mm is left between the radiating edge 20b of the antenna and the edge of the dielectric layer 28.

It has been determined that the effect of the human body on the operation of the antenna 20 is negligible. This is because such a double C-patch antenna configuration is excited mainly by a magnetic current rather than by an electric current. Furthermore, the ground plane 22 of the antenna 20 also functions as a shield against adjacent materials, such as circuit components in the PCMCIA communication card 1 and any other metallic materials that may be found in the PCMCIA slot 3.

The ground plane 22 of the antenna 20 is preferably truncated. In the disclosed embodiments the dimensions of the ground plane 20 are nearly the same as those of the radiation patch 30. Because of this, and because of the geometry of the partially shorted, double C-patch antenna 20, the generated radiation patterns are isotropic. Furthermore, the antenna 20 is sensitive to both vertically and horizontally polarized waves. Moreover, the total size of the antenna 20 is much smaller than a conventional quarter-wavelength rectangular microstrip antenna, which conventionally assumes infinitely large ground plane dimensions.

However, it should be noted that truncating the ground plane 22 of the partially shorted, double C-patch antenna 20 does not adversely effect the efficiency of the antenna. This is clearly different from a conventional rectangular microstrip antenna, where truncating the ground plane along the radiating edge(s) reduces the gain considerably.

To improve the manufacturability of the shorted, double C-patch antenna 20, the electric short circuit at the shorted edge 20a is made by a small number (preferably at least three) of the relatively thin (e.g., 0.25 mm) shorting posts 24. However, and as was stated previously, it is within the scope of the invention to use a continuous short circuit that runs along all or most of the

edge 20a.

The partially shorted, double C-patch antenna 20 does not have a regular shape and, as such, it is difficult to theoretically study the effect of the circuit components in the PCMCIA card and the metallic materials in the PCMCIA slot on the operation of the antenna. Therefore, the performance of the partially shorted, double C-patch antenna 20, both inside and outside the PCMCIA Type II slot 3, has been determined experimentally.

Referring to Figure 5, when making the measurements the antenna 20 was located close to the outer edge 1a' of a PCMCIA card 1' with the main radiating edge 20a of the antenna 20 was facing outward (i.e., towards the slot door when installed). In this case, and when the PCMCIA card 1' is completely inserted inside the PCMCIA slot 3, the main radiating edge 20a of the antenna 20 is approximately parallel with and near to the outer door of the slot 3. It should be realized when viewing Figure 5 that, in practice, the antenna 20 will be contained within the outer shell of the PCMCIA card enclosure, and would not normally be visible to a user.

Figure 6 is a simplified block diagram of the wireless communications PCMCIA card 1' that is constructed to include the shorted or partially shorted double C-patch antenna. Referring also to Figure 5, the card 1' includes a PCMCIA electrical interface 40 that bidirectionally couples the PCMCIA card 1' to the host computer 2. The PCMCIA card 1' includes a digital modulator/demodulator (MODEM) 42, an RF transmitter 44, an RF receiver 46, and the partially shorted, double C-patch antenna 20 (Figures 3 and 4). A diplexer 48 can be provided for coupling the antenna 20 to the output of the transmitter 44 and to the input of the receiver 46. Information to be transmitted, such as digital signalling information, digital paging information, or digitized speech, is input to the modem 42 for modulating an RF carrier prior to amplification and transmission from the antenna 20. Received information, such as digital signalling information, digital paging information, or digitized speech, is received at the antenna 20, is amplified by the receiver 46, and is demodulated by the modem 42 to recover the baseband digital communications and signalling information. Digital information to be transmitted is received from the host computer 2 over the interface 40, while received digital information is output to the host computer 2 over the interface 40.

It is been determined that inserting the antenna 20 inside of the PCMCIA Type II slot 3 has a negligible effect on the resonant frequency and the return loss of the antenna. The corresponding radiation patterns were measured in the horizontal plane. In these measurements, the antenna 20 was immersed in both vertically and horizontally polarized waves to determine the dependence of its performance on the polarization of the incident waves. It has been determined that the radiation patterns are nearly isometric and polarization independent. Furthermore, the performance of the antenna 20 inside the PCMCIA Type II slot 3 is excellent, and is

substantially identical to the performance outside of the slot. Similar results were obtained in the other polarization planes. However, the horizontal plane is the most important one for this application, especially if the PCMCIA card 1' is operating inside the PCMCIA slot 3 within a personal computer, because personal computers are usually operated in a horizontal position.

The measurements were repeated inside several PCMCIA slots in different portable computers and similar results were obtained. Furthermore, these measurements were repeated while a palmtop computer, containing the antenna 20 inside its PCMCIA slot 3, was hand-held and also while inside the operator's pocket. It was found that the human body has a negligible effect on the performance of the antenna 20.

In accordance with the foregoing it has been shown that the small, shorted (partial or continuous), double C-patch antenna 20, on a truncated ground plane, has been successfully integrated with a wireless communications PCMCIA card 1'. The shorted, double C-patch antenna 20 has the same performance characteristics in both free space and inside the PCMCIA slot 3 of a personal computer. The PCMCIA card 1' containing the antenna 20 has a good reception sensitivity from any direction, regardless of its orientation, because the shorted, double C-patch antenna 20 has isotropic radiation patterns and is sensitive to both vertically and horizontally polarized radio waves. Furthermore, the shorted, double C-patch antenna 20 exhibits excellent performance when closely adjacent to the human body. As a result, the wireless communications PCMCIA card 1' exhibits a high reception sensitivity when it is hand-held and also when it operated inside of an operator's pocket.

Having thus described the various embodiments of the double C-patch antenna disclosed in the above-referenced commonly assigned U.S. Patent Application S. N. 08/414,573, filed 3/31/95, entitled "A Small Double C-Patch Antenna Contained in a Standard PC Card", by Mohamed Sanad, various improvements to and further embodiments of the double C-patch antenna will now be disclosed.

Figure 8a illustrates the geometry of a double C-patch antenna 50 having two triangularly shaped apertures 52a and 52b, as opposed to the two rectangularly shaped apertures 12a and 12b illustrated in Figure 2. The antenna 50 is coaxially fed at point 14 between the two apertures 52a and 52b.

To reduce the size of the antenna 50 by approximately one half, the zero potential plane of the antenna 50 is short-circuited as shown in Figure 8b. To further reduce the size of the double C-patch antenna, the zero potential plane is short-circuited with conductive posts 24 to form a partially shorted embodiment 56. A continuously shorted embodiment is also within the scope of the teaching of this invention. The partially shorted double C-patch antenna 56 is fed at point 34 between the single triangular aperture 58 and the shorted edge 56a, the feed point 34 being located on a line of the antenna

which passes through the center of the shorted edge 56a.

In addition to the triangularly shaped apertures 52a, 52b and 58 shown in Figures 8a and 8b, and also the rectangularly shaped aperture 12a, 12b and 26 shown in Figures 2 and 3, double C-patch antennas having other aperture shapes are also within the scope of the teaching of this invention. Although described below in the context of the physically smaller, shorted or partially shorted embodiments, these other aperture shapes can also be used with the non-shortened embodiments shown in Figures 2 and 8a.

For example, Figure 9 shows a partially shorted double C-patch antenna 60 having an elliptically shaped or a parabolically shaped aperture 62, while Figure 10 shows a partially shorted double C-patch antenna 64 having a pentagonally shaped aperture 66.

Regardless of the shape of the apertures 26, 58, 62 and 64, the dimension of the aperture in the direction parallel to the shorted edge 20a, 56a, 60a and 64a, respectively, is defined as the width of the aperture. The dimension of the aperture in the direction perpendicular to the shorted edge 20a, 56a, 60a, 64a is considered to be its length (see also Figure 3). For those embodiments wherein the aperture length is not constant (e.g., Figures 8a, 8b, 9 and 10), the length is measured at its widest point (e.g., at the antenna edge that is perpendicular to the shorted edge). The length of the shorted edge is defined to be the width of the antenna, while the length of the antenna is the distance between the shorted edge 20a, 56a, 60a, 64a and the main radiating edge 20b, 56b, 60b, 64b, respectively, which is parallel to the shorted edge.

The various embodiments of the double C-patch antenna have several design parameters that can be used to optimize the performance and to control the resonant frequency and input impedance.

By example, and in addition to the length and the width of the antenna, the dimensions of the apertures have a significant effect on the characteristics of the antenna. In general, for a fixed size of the antenna, decreasing the length of the aperture reduces the resonant frequency and increases the input impedance of the antenna. However, the length of the aperture is preferably not decreased less than approximately 20% of the total length of the antenna, otherwise the efficiency of the antenna may begin to decrease. On the other hand, increasing the width of the aperture increases the input impedance and consequently reduces the resonant frequency. In general, it has been determined that the width of the aperture should not be greater than approximately 75% of the total width of the antenna to avoid a significant reduction in the efficiency of the antenna. Also, it has been found that the position of the aperture has some effect on the antenna performance. For example, moving the aperture closer to the shorted edge has been found to reduce the resonant frequency.

In general, and assuming that the surface areas of

the apertures are maintained approximately constant, the aperture shape has a small effect on the resonant frequency and the input impedance of the shorted or partially double C-patch antenna. On the other hand, the aperture shape has a significant effect on the performance of the antenna beside the human body. In the vicinity of a human body, it has been found that the double C-patch antenna 20, having the rectangularly shaped aperture 26 (Figure 3) has the best performance, while the double C-patch antenna 60, having the elliptically shaped aperture 62, experiences the greatest performance degradation.

However, it should be noted that the effect of the human body on the double C-patch antenna embodiments of this invention, having any aperture shape (e.g., rectangular, elliptical, parabolic, pentagonal, triangular, etc.), is less than the effect on the conventional rectangular microstrip antenna. To even further reduce the effect on the human body of the double C-patch antenna, the ground plane is truncated such that its size is almost equal to the size of the radiation patch. Fortunately, truncating the ground plane of the antenna also increases its sensitivity to both horizontally and vertically polarized waves, and also improves the isotropic characteristics of the radiation patterns. These features are very important in many antenna applications, such as in portable communication equipment which are usually hand-held close to the operator's body and randomly orientated. However, it should be noted that truncating the ground plane of the double C-patch antenna does not have any significant effect on the efficiency of the antenna. This is different from the conventional rectangular microstrip antenna, where truncating the ground plane beside the radiating edge(s) reduces the gain considerably.

#### Example 2

Duroid 5880 having a dielectric constant of 2.2 and a thickness of 1.27 mm was used to manufacture a 37.5 x 37.5 mm shorted (fully) double rectangular C-patch antenna. The rectangular aperture was disposed 9 mm from the shorted edge. The length of the aperture was 10 mm and its width was 26 mm. The ground plane was truncated such that its width was the same as the width of the radiation patch. The length of the ground plane was just 2 mm longer than the radiation patch. The input impedance was 50 ohms when the feed point was placed 4.5 mm from the shorted edge, and the resonant frequency was 1.024 GHz. Generally, it was found that the proximity of a human body had a negligible effect on the double C-patch antenna. The antenna was then immersed in both vertically and horizontally polarized waves and the corresponding radiation patterns in the plane of the antenna were measured. It was found that the antenna was sensitive to both polarizations, and that the radiation patterns were quasi-isotropic. Similar results were obtained in the other principal planes.

Referring now to Figures 11, 12 and 13, there are illustrated several embodiments of shorted or partially shorted double C-patch antennas that are non-planar. Although these antennas are illustrated to have rectangularly-shaped apertures, any of the various non-rectangular aperture embodiments described previously may also be used.

Figures 11 and 12 illustrate embodiments wherein the antennas 70 and 72 are curved about one major axis (e.g., the x-axis), while Figure 13 illustrates an antenna 74 that is curved about two major axes (e.g., the x and y axes). In all of these embodiments it has been found that the curvature does not adversely impact the electrical and RF characteristics of the antenna.

More particularly, Figures 11 and 12 illustrate embodiments wherein the antennas 70 and 72 can be considered to be curved about a circular cylindrical form (CCF). In Figure 11 the aperture 70a faces away from the circular cylindrical form, and this curvature can be considered as a positive curvature. In Figure 12 the aperture 72a faces towards the circular cylindrical form, and this curvature can be considered as a negative curvature.

Figure 13 illustrates a double C-patch antenna 74 embodiment wherein the antenna 74 can be considered to lie on a surface of a sphere (or any body of revolution), and to thus be curved in two axes. Similar to the embodiments of Figures 11 and 12, in Figure 13 the aperture 74a faces away from the spherical form, and this curvature can be considered as a positive curvature. If the aperture 74a instead faces towards the spherical form (not illustrated), then this curvature can be considered as a negative curvature.

The radius of curvature of the various embodiments of this invention may range from zero degrees to 360 degrees.

The ability to curve the shorted or partially shorted microstrip antenna about at least one axis, such as the shorted or partially shorted double C-patch antenna, without significantly affecting the characteristics of the antenna, enables its use in a number of applications that for one reason or another (e.g., lack of space, a hand held communicator having a curved outer surface, etc.) makes the use of a planar, non-curved antenna less desirable.

While the invention has been particularly shown and described with respect to preferred embodiments thereof, it will be understood by those skilled in the art that changes in form and details may be made therein without departing from the scope and spirit of the invention. By example, the various linear dimensions, thicknesses, resonant frequencies, and material types can be modified, and the resulting modified structure will still fall within the scope of the teaching of this invention. Further by example, other than the various illustrated aperture shapes can be employed. Also by example, and referring to Figure 3, the aperture length (L2) may have a value that is equal to approximately 20% to approxi-

mately 35% of the length (L1), and a width (W2) having a value that is equal to approximately 15% to approximately 40% less than the width (W1).

### Claims

1. An antenna structure, comprising:

a ground plane;

a layer of dielectric material having a first surface overlying said ground plane and an opposing second surface;

an electrically conductive layer overlying said second opposing surface of said dielectric layer, said electrically conductive layer being in the shape of a parallelogram and having a first non-rectangularly shaped aperture having a length that extends along a first edge of said electrically conductive layer and a width that extends towards an oppositely disposed second edge, said electrically conductive layer further having a second non-rectangularly shaped aperture having a length that extends along said first edge of said electrically conductive layer and a width that extends towards said oppositely disposed second edge, said first and second non-rectangularly shaped apertures having a zero potential plane disposed therebetween; and

means for coupling radio frequency energy into and out of said electrically conductive layer.

2. An antenna structure as set forth in claim 1 wherein said length has a value that is equal to approximately 20% to approximately 35% of a length of said first edge.

3. An antenna structure as set forth in claim 1 wherein said width of each of said first and second non-rectangularly shaped apertures has a value that is equal to approximately 15% to approximately 40% less than a width of said electrically conductive layer.

4. An antenna structure as set forth in claim 1 wherein said coupling means is comprised of means for connecting a coaxial cable to said electrically conductive layer at a point between said first and second apertures that is nearer to one of said apertures than the other.

5. An antenna structure as set forth in claim 1, wherein said structure is curved about at least one axis.

6. An antenna structure, comprising:

a ground plane;

a layer of dielectric material having a first surface overlying said ground plane and an opposing second surface;

an electrically conductive layer overlying said second opposing surface of said dielectric layer, said electrically conductive layer being in the shape of a parallelogram and having a non-rectangularly shaped aperture having a length that extends along a first edge of said electrically conductive layer and a width that extends towards an oppositely disposed second edge;

means for shorting said electrically conductive layer to said ground plane at a region adjacent to a third edge of said electrically conductive layer; and

means for coupling radio frequency energy into and out of said electrically conductive layer.

7. An antenna structure as set forth in claim 6, wherein said width of said aperture has a value that is equal to approximately 15% to approximately 40% less than a width of said electrically conductive layer, and wherein said aperture is located from said third edge at distance that is approximately equal to said length of said aperture.

8. An antenna structure as set forth in claim 6, wherein said shorting means is comprised of one of a continuous short circuit means and a plurality of electrically conductive feedthroughs that pass through said dielectric layer between said ground plane and said electrically conductive layer.

9. An antenna structure as set forth in claim 6, wherein said coupling means is comprised of means for connecting a coaxial cable to said electrically conductive layer at a point between said aperture and said third edge.

10. An antenna structure as set forth in claim 6, wherein said ground plane is truncated, and has dimensions that are approximately equal to the dimensions of said electrically conductive layer.

11. An antenna structure as set forth in claim 6, wherein said structure is curved about at least one axis.

12. A module adapted for insertion into a data processor, said module comprising:

an interface for electrically coupling said module to the data processor;



a modem that is bidirectionally coupled to said interface;

an RF energy transmitter having an input coupled to an output of said modem;

an RF energy receiver having an output coupled to an input of said modem; and

a shorted, dual C-patch antenna having a non-rectangular aperture that is electrically coupled to at least one of an output of said RF energy transmitter and to an input of said RF energy receiver.

**13.** A module as set forth in claim 12, wherein said shorted, dual C-patch antenna is comprised of:

a ground plane;

a layer of dielectric material having a first surface overlying said ground plane and an opposing second surface;

an electrically conductive layer overlying said second opposing surface of said dielectric layer, said electrically conductive layer being in the shape of a parallelogram and having said non-rectangularly shaped aperture having a length that extends along a first edge of said electrically conductive layer and a width that extends towards an oppositely disposed second edge;

means for shorting said electrically conductive layer to said ground plane at a region adjacent to a third edge of said electrically conductive layer; and

means for coupling said electrically conductive layer to at least one of said output of said transmitter and to said input of said receiver.

**14.** A module as set forth in claim 13, wherein said length of said aperture has a value that is equal to approximately 20% to approximately 35% of a length of said first edge, and wherein said width of said aperture has a value that is equal to approximately 15% to approximately 40% less than a width of said electrically conductive layer, and wherein said aperture is located from said third edge at distance that is approximately equal to said length of said aperture.

**15.** A module as set forth in claim 13, wherein said shorting means is comprised of a plurality of electrically conductive feedthroughs that pass through said dielectric layer between said ground plane and said electrically conductive layer.

**16.** A module as set forth in claim 13, wherein said shorting means is comprised of a length of electrically conductive material that extends from said ground plane to said electrically conductive layer.

**17.** A module as set forth in claim 13, wherein said coupling means is comprised of means for connecting a coaxial cable to said electrically conductive layer at a point between said aperture and said third edge.

**18.** A module as set forth in claim 13, wherein said length of said first edge is less than approximately 8.5 cm, and wherein said third edge has a length that is less than approximately 5.5 cm.

**19.** A module as set forth in claim 13, wherein said ground plane is truncated, and has dimensions that are approximately equal to the dimensions of said electrically conductive layer.

**20.** A module as set forth in claim 12, wherein said module has dimensions of approximately 8.5 cm x 5.4 cm by 0.5 cm.

**21.** A module as set forth in claim 12, wherein said shorted, dual C-patch antenna has a resonant frequency of approximately 900 MHz.

**22.** A microstrip antenna, comprising:

a substrate comprising a ground plane, a layer of dielectric material having a first surface overlying said ground plane and an opposing second surface, and an electrically conductive layer overlying said second opposing surface of said dielectric layer;

means for shorting said electrically conductive layer to said ground plane at a region adjacent to an edge of said electrically conductive layer; and

means for coupling radio frequency energy into and out of said electrically conductive layer; wherein

said substrate has a radius of curvature about at least one axis of said substrate.

**23.** A microstrip antenna as set forth in claim 22, wherein said antenna is a shorted, double C-patch antenna having a radiating aperture having a shape selected from one of rectangular and non-rectangular.

FIG. 1  
PRIOR ART

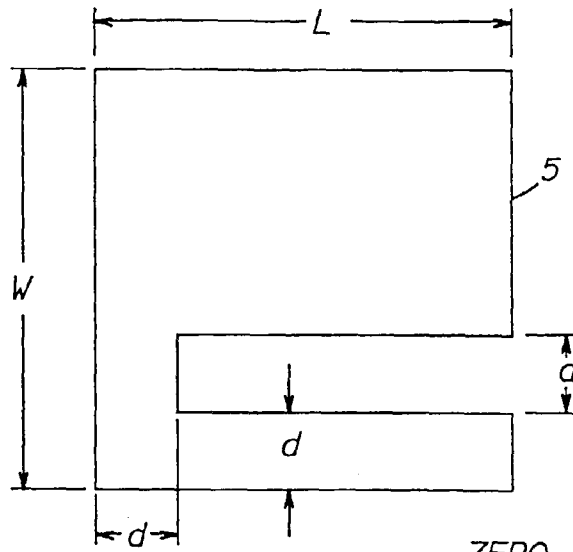


FIG. 2

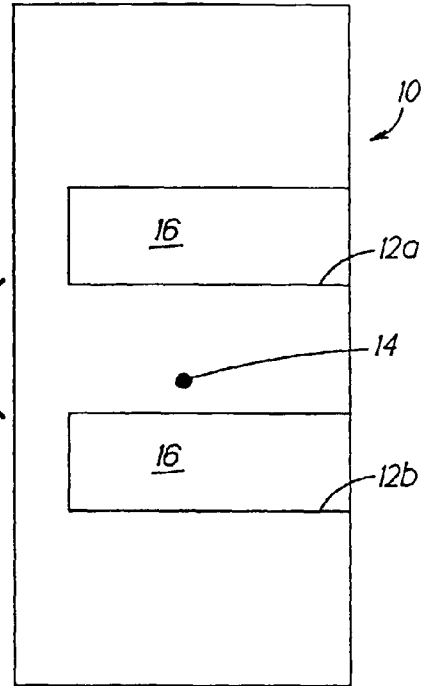


FIG. 3

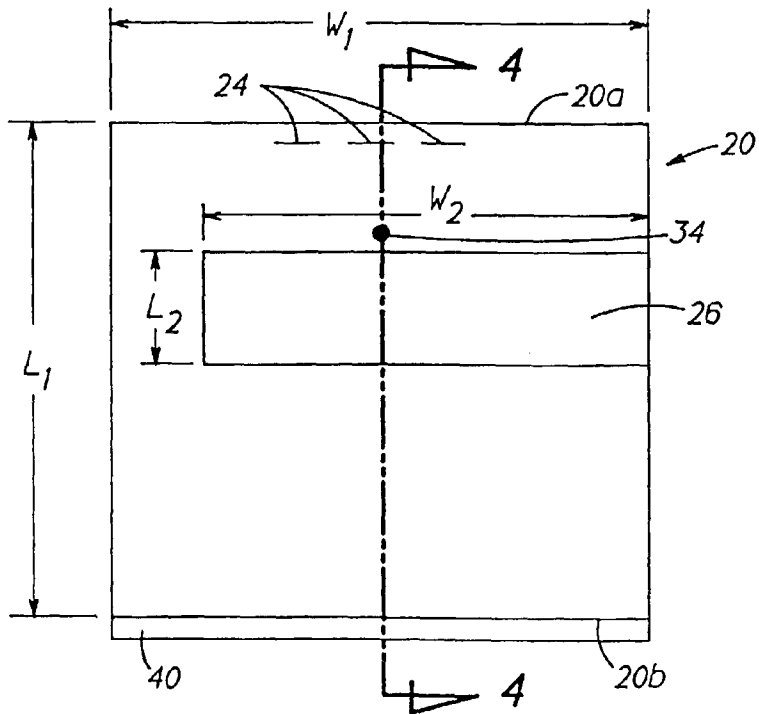


FIG. 4

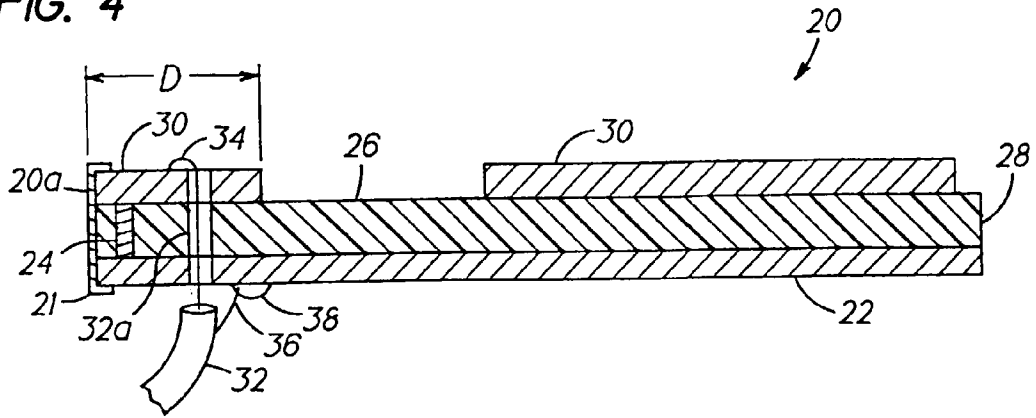


FIG. 5

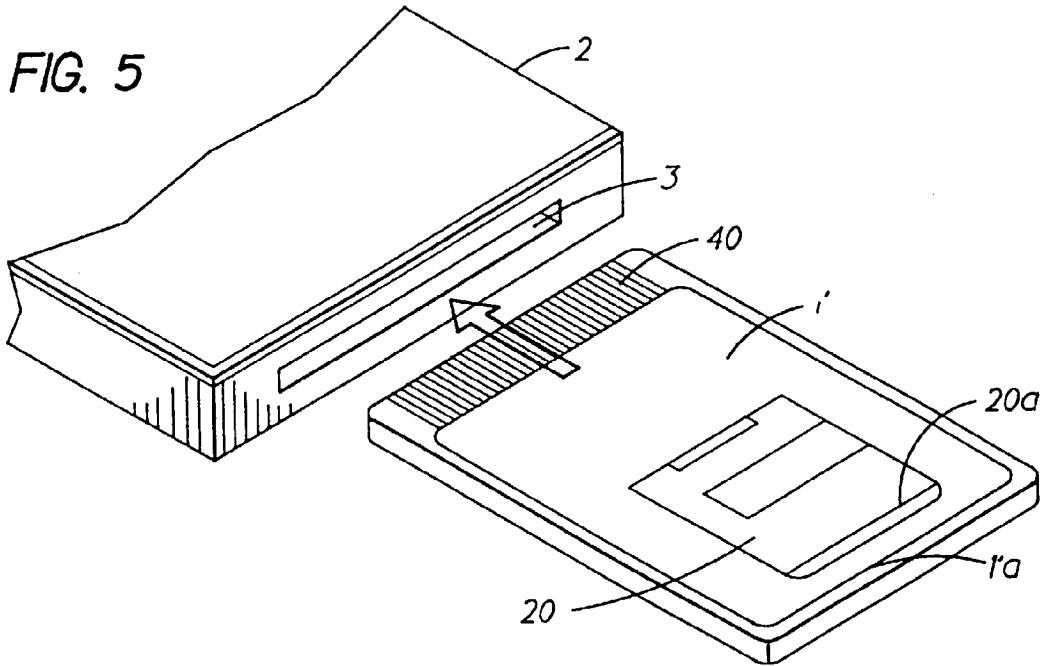


FIG. 6

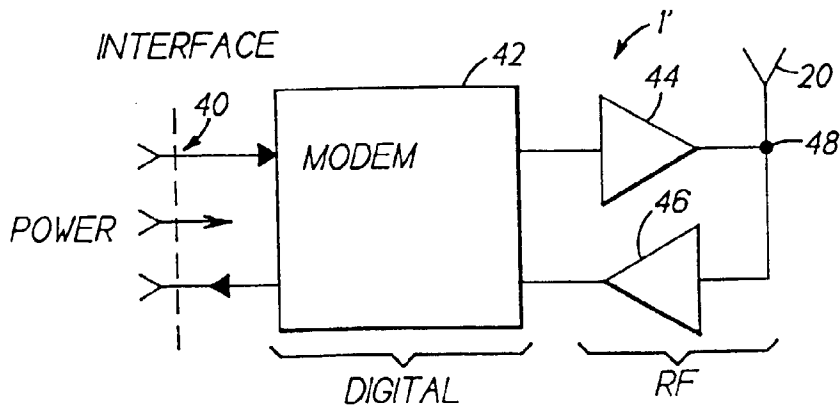


FIG. 7  
PRIOR ART

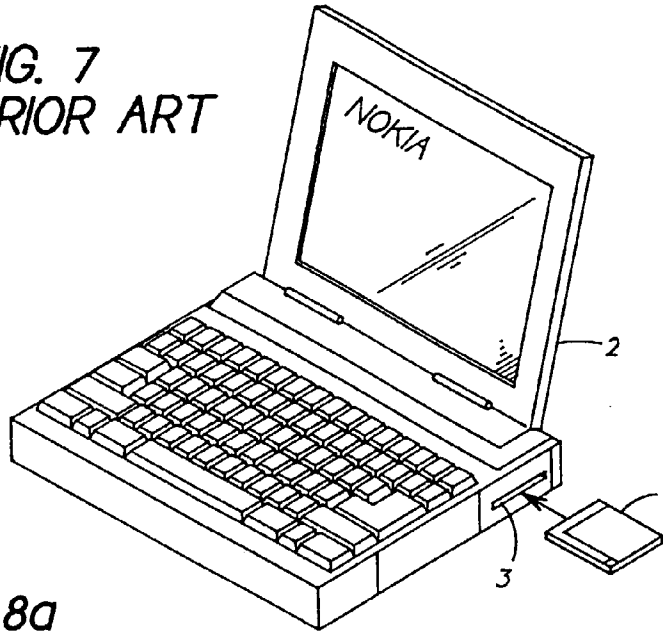


FIG. 8a

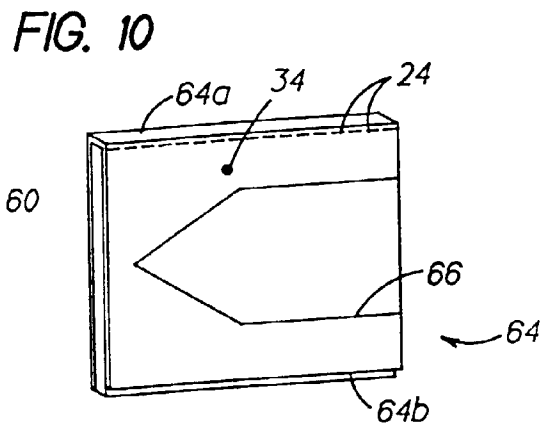
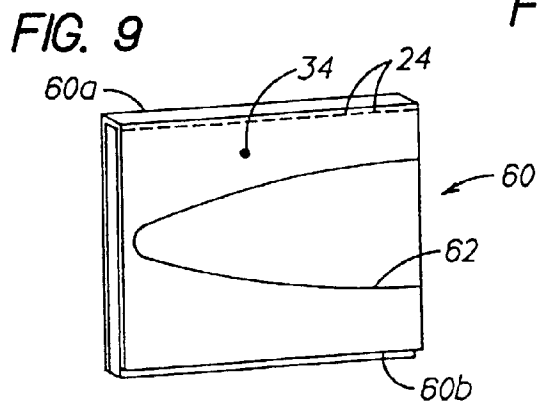
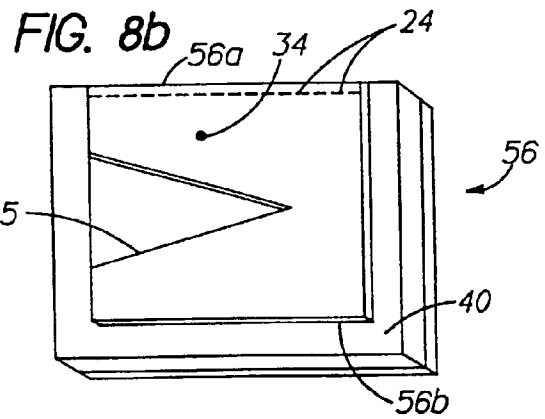
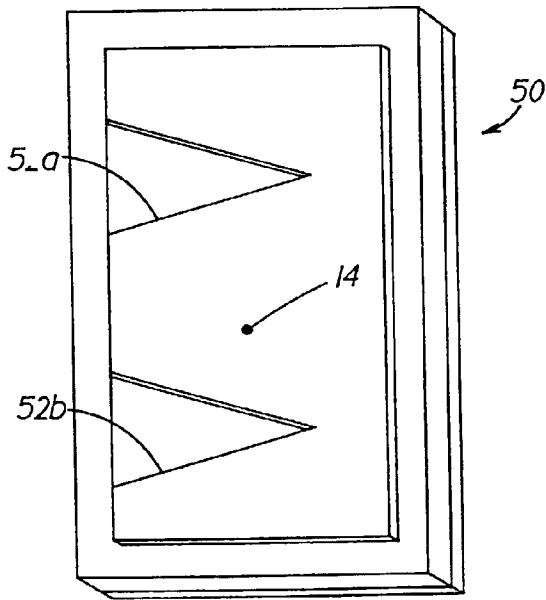


FIG. 11

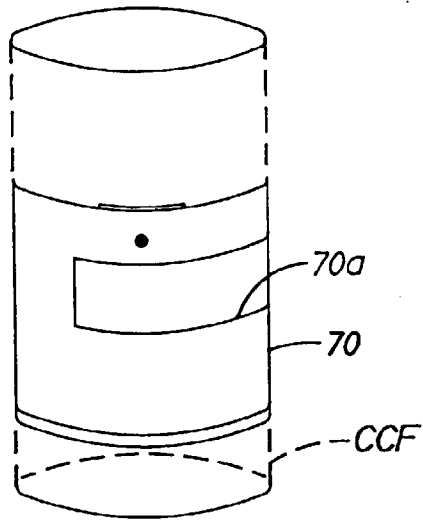


FIG. 12

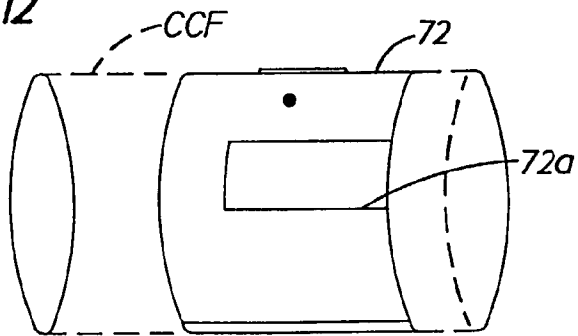
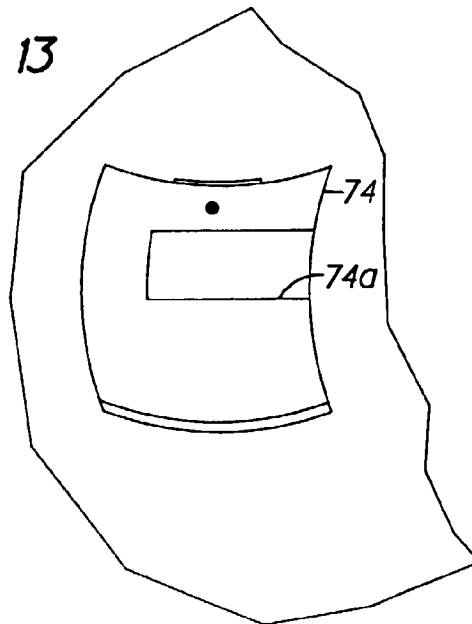


FIG. 13





European Patent  
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EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 4428

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	NINTH INTERNATIONAL CONFERENCE ON ANTENNAS & PROPAGATION, vol. 1, 4 - 7 April 1995, NETHERLANDS, pages 117-120, XP000195757 SANAD: "A very small double C-patch antenna contained in a PCMCIA standard PC card" * the whole document *	1,12	H01Q9/04
A	IEEE ANTENNAS & PROPAGATION SOCIETY INTERNATIONAL SYMPOSIUM 1994, vol. 2, 20 - 24 June 1994, USA, pages 810-813, XP000195759 SANAD: "Microstrip Antennas on very small ground planes for portable communication systems" * the whole document *	19	
D,A	ELECTRONICS LETTERS, vol. 25, no. 4, 16 February 1989, ENGLAND, pages 253-254, XP002012224 KOSSIAVAS ET AL.: "The C-patch: A small microstrip element" * the whole document *	1	
A	IEEE TRANSACTIONS ON ANTENNAS & PROPAGATION, vol. 38, no. 5, May 1990, USA, pages 722-731, XP000135619 HABASHY ET AL.: "Input impedance and radiation pattern of cylindrical-rectangular and wraparound microstrip antennas " * the whole document *	5	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01Q
-/--			
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
BERLIN		2 September 1996	Danielidis, S
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document	

EPO FORM 1503 03/82 (P/MCO1)



European Patent  
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EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 4428

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP-A-0 637 094 (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) * abstract; figures 4,11 * * page 6, line 3 - line 13 * ---	1,9,17	
A	EP-A-0 630 069 (NTT MOBILE COMMUNICATIONS NETWORK INC.) * figure 11 * * column 7, line 40 - column 8, line 3 * ---	1	
A	EP-A-0 176 311 (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) * abstract; figures 1,2,5 * -----	15,16	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
Place of search BERLIN		Date of completion of the search 2 September 1996	Examiner Danielidis, S
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons ----- & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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