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(54) **Multi-band antenna**

Mehrbandantenne

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EP 1 276 170 B1

Description

[0001] The present invention relates to multi-band antennas, and in particular to multi-band planar antennas.

Background to the Invention

[0002] Many applications require that an antenna is able to transmit and receive signals in two or more discrete frequency bands. For example, in the field of mobile telecommunications, mobile telecommunications networks may operate in one or more different frequency bands which may vary from country to country. Hence mobile telephones (cellular telephones) are required to be able to operate in more than one frequency band if they are to be compatible with more than one mobile network using different frequency bands (this is sometimes referred to as having roaming functionality). A multi-band antenna is an antenna capable of operating in more than one frequency band.

[0003] Planar antennas, such as microstrip patch antennas, are an increasingly popular form of antenna. Planar antennas are relatively compact in structure, relatively lightweight, relatively simple to manufacture and hence relatively inexpensive. Moreover, planar antennas are suitable for internal use, i.e. they can be incorporated within a telecommunications apparatus, for example a mobile telephone handset. Not only does this improve the aesthetic appeal of the apparatus, but it also protects the antenna making it less susceptible to damage. A further advantage of planar antennas is that they may be arranged within, say, a telephone handset in such manner that the radiation emitted during use is primarily directed away from the user of the handset.

[0004] Previous attempts have been made to provide multi-band planar antennas. These attempts include combining two planar antennas one on top of the other, or side-by-side, or using a matching network. Such antennas suffer in terms of size and complexity and can therefore be relatively difficult and expensive to manufacture. Other attempts have involved the combination of slots and shorting pins, but such antennas are required to be relatively large and are unsuitable for incorporation into modern telecommunication devices, particularly telephone handsets, for this reason. The problem of size is exacerbated by the fact that many mobile telecommunications networks operate in relatively low frequency bands, low frequency operation normally requiring a large planar antenna.

[0005] Sze J-Y and Wong K-L "Broadband Rectangular Microstrip Antenna with Pair of Toothbrush Shaped Slots", Electronic Letters, vol. 34, no. 23, 12/11/1998, pp. 2186 - 2187, XP6010604, discloses an antenna having the features of the preamble of claim 1. Zurcher J-F and Gardiol, F.E., "Broadband patch antennas", 1998, section 2.5. Broadbanding, discloses, in section 2.5.2, a folded dipole antenna comprising a centrally located H-shaped slot. The antennas of each of these documents are operable in two modes of resonance that are sufficiently close in frequency as to serve as a single broadband resonant mode. United States Patent US 5,955,995 (Silverstein) discloses a planar antenna that is fed at a corner of the patch thereby causing the antenna to resonate at two adjacent frequencies. None of these antennas achieves resonance in multiple discrete frequency bands. US 5,955,995 discloses the preamble of claim 1.

[0006] There is a need therefore for improved multi-band planar antennas.

Summary of the Invention

[0007] The invention provides A patch antenna comprising a generally rectangular conductive patch defined by first and second pairs of opposing sides; a ground plane; a dielectric substrate between the patch and the ground plane; a feed mechanism for providing electromagnetic signals to a feed point on said conductive patch; and one or more slots formed in the patch, each slot being spaced-apart from the sides of the patch, wherein the feed point is located on, or in-line with, a notional line through a corner and the centre of the conductive patch, a first slot comprises an elongate body portion that is located adjacent and parallel with one of said first sides of the patch, characterised in that the antenna further includes a second slot comprising an elongate body portion that is located adjacent and parallel with the other of said first sides of the patch, said first slot including a respective foot slot portion located adjacent to and parallel with a respective second side of the patch, said second slot including a respective foot slot portion located adjacent to and parallel with the respective second sides of the patch.

[0008] The antenna is able to resonate in a plurality of discrete frequency bands. This means that the antenna is capable of multi-band operation without the need for additional resonating patches, shorting pins, matching circuits or multiple feed points.

[0009] Preferably, the feed mechanism is arranged to provide a direct feed to the conductive patch. The feed mechanism may alternatively feed the patch by indirect coupling. Preferably, the antenna is formed from microstrip.

[0010] Preferably, at least part of at least one of said slots is positioned in close proximity with an edge of the patch so that said at least one slot part radiates electromagnetic energy in a frequency band other than the natural resonant frequency bands of the patch.

[0011] Preferably, at least one slot includes a first and a second non-parallel slot portions. More preferably, said first and second slot portions are substantially perpendicular with each other. Further preferably, said at least one slot is substantially I-shaped, or H-shaped.

[0012] In a preferred embodiment, the conductive patch is generally rectangular in shape and includes a first and a second slot, one on either side of the feed point, each slot having an elongate body portion with a respective foot portion at, or adjacent, either end of the body portion, the slots being arranged so that the respective elongate body portions are substantially parallely disposed with respect to one pair of opposing edges of the patch and that the respective foot portions are located in close proximity with the other pair of opposing patch edges. Preferably, said one pair of opposing patch edges are the patch edges that radiate electromagnetic energy during resonance in a frequency band in respect of which the conductive patch is designed primarily to resonate. Preferably, said first and second slots are substantially I-shaped and said respective foot portions are arranged to be substantially parallely disposed to said other opposing patch edges.

[0013] Other preferred features are recited in the dependent claims.

[0014] Further advantageous aspects of the invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention and with reference to the accompanying drawings.

Brief Description of the Drawings

[0015] Specific embodiments of the invention are now described by way of example and with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a planar antenna in situ within a mobile telephone handset;

Figure 2 is a perspective view of a planar antenna according to the invention mounted on a Front End Module (FEM) for a radio transceiver;

Figure 3 is a side view of the antenna of Figure 2;

Figure 4 is a plan view of an unslotted planar antenna;

Figures 5a to 5c are plots of the current density across the unslotted antenna of Figure 4 at different feed frequencies;

Figure 6 is a plot of Return Loss (dB) against Frequency (GHz) for said unslotted planar antenna;

Figure 7 shows a set of equations for use in the design of a planar antenna.

Detailed Description of the Invention

[0016] Referring now to Figure 1 of the drawings, there is shown, generally indicated at 10, a perspective view of a mobile telecommunications handset. The handset 10 is shown in general outline only for reasons of clarity. The handset 10 includes a planar antenna in the preferred form of a microstrip patch antenna 12. The patch antenna 12 is mounted on a radio module, or Front End Module (FEM) 14, which in turn is mounted on a printed circuit board (PCB) 16 in conventional manner. The antenna 12 comprises a dielectric substrate 20 having a first conductive layer, or patch 18, on one face and a second conductive layer, or ground plane 22, on the opposite face. A feed mechanism (not shown in Figure 1) is provided for communication between the FEM 14 and the antenna 12. The feed mechanism may be connected directly to the patch (direct feed) or may be coupled indirectly to the patch.

[0017] In use, the FEM 14 sends and receives electromagnetic signals, including radio frequency signals, via the antenna 12 as is conventional. During transmission, the FEM 14 feeds an electrical signal to the antenna 12 via the feed mechanism. The signal excites the patch 18 to cause the radiation of electromagnetic energy, or waves, therefrom. More particularly, when the patch 18 is excited by a feed signal, a charge distribution is established on the reverse side, or underside, of the patch 18 and the ground plane. At a particular instant in time, the underside of the patch is positively charged and the ground plane is negatively charged. The attractive forces between these charges tend to hold a large percentage of the charge between the two reverse surfaces.

[0018] However, the repulsive forces between positive charges on the patch push some.of these charges towards the edges of the patch resulting in large charge density, or current density, at some of the edges (normally two opposing edges). These areas of large charge density are the source of fringing fields at the edges of the patch 18 and the corresponding radiation from the patch 18.

[0019] A planar, or patch, antenna radiates energy only in frequency bands where resonance occurs. The location of the resonant, or operational, frequency band of a patch antenna depends primarily on its dimensions and composition.

Thus, when a patch is fed with a signal in the resonant frequency band, the patch radiates energy in that frequency band.

[0020] The efficiency at which the patch radiates energy depends on, amongst other things, whether or not there is an impedance match between the patch 18 and the feed mechanism. Typically, a coaxial feeder has an impedance of 50 Ohms and it is important therefore to position the feed point such that the effective impedance presented by the patch at the feed point matches the feeder impedance. Radiation efficiency may be measured in terms of Return Loss (typically in decibels(dB)) or Voltage Standing Wave Ratio (VSWR). A Return Loss Value (RLV) of approximately -10dB or better, which corresponds to a VSWR of approximately 2 or less, is usually considered to be desirable in an operational frequency band, although poorer efficiency can be satisfactory.

[0021] Normally, a patch antenna 12 is considered as a single band structure with narrow bandwidth i.e. a structure having only one, relatively narrow, resonant frequency band. In order to design a patch antenna for operation in a desired frequency band and for a given dielectric constant and substrate thickness, equations [1] to [4] of Figure 7 may be used to determine the approximate required length and width of the patch 18. Normally some fine tuning is then required in order to finalise patch dimensions to suit the application in question.

[0022] The next step in the design of the patch antenna 12 is to determine the position of the point at which the feed mechanism feeds the antenna. Conventionally, the feed point is on a notional straight line perpendicular to the patch 18 edges and running through the centre of the patch. Such a feed position is hereinafter referred to as a central, or symmetrical, feed position. A common way to determine the best position for the feed point is to simulate the operation of the antenna 12 for various feed positions starting on a patch edge moving towards the patch centre along the notional centre line. A suitable feed point is found when there is an impedance match between the feed mechanism and the patch (it is noted that in some cases an impedance match is not found on the centre line. In such cases, the normal solution is to enlarge the size of the patch 18 or to provide an impedance matching network between the feed mechanism and the patch 18).

[0023] When fed with a signal in the resonant, or operational, frequency band, the current density on the surface of the patch 18 increases significantly along two opposing edges of the patch 18 causing electromagnetic waves to radiate from those edges. The current density also increases across the surface of the patch 18 between the two radiating edges and.this causes further electromagnetic radiation from between the two radiating edges. The resulting radiation pattern is substantially symmetrical with respect to the patch 18 and this optimises the gain of the antenna. This is the main reason why patch antennas are conventionally fed from a central position.

[0024] However, a centrally fed patch antenna provides only one resonant frequency band. Previous attempts have been made to provide multi-band planar antennas, including multi-band patch antennas. These attempts include stacking or layering two patch antennas one on top of the other, or side-by-side, or using a matching network. Other attempts have involved the combination of slots and shorting pins, or providing multiple feed points. It is considered that such earlier attempts suffer in terms of size and/or complexity. As a result they can be relatively difficult and expensive to manufacture. Moreover, it is considered that the size of such antennas makes them unsuitable for incorporation into modern telecommunication devices, particularly telephone handsets. The problem of size is exacerbated by the fact that many mobile telecommunications networks operate in relatively low frequency bands, low frequency operation normally requiring a large antenna.

[0025] As is now described, one aspect of the invention provides a single layer planar, or patch, antenna capable of multi-band operation without the use of shorting pins, matching networks or multiple feed points.

[0026] Figures 2 and 3 illustrate a patch antenna 112, arranged in accordance with a preferred embodiment of the invention, mounted on an FEM 114. The antenna 112 comprises a multi-sided patch 118 in the form of a layer of conductive material, particularly conductive metal such as copper or copper alloy. The patch 118 coats one face of a substrate 120 made of a dielectric material such as duroid, ceramic or alumina. A second conductive layer 122 coats the opposite face of the dielectric substrate 120. The second conductive layer. 122, which is typically made from the same material as the patch 118, serves as a ground plane for the antenna 112.

[0027] The antenna 112 includes a feed mechanism 124 for supplying electromagnetic signals (such as radio or microwave signals) in the form of electrical signals between the antenna 112 and the FEM 14. In Figure 2, the feed mechanism 124 takes the form of a coaxial feeder although a skilled person will appreciate that other forms of conventional feed mechanisin, such as microstrips, striplines and waveguides, may alternatively be used. The feeder 124 is preferably arranged to provide a direct feed to the patch 118 and so is fixed to a feed point 126 on the patch 118 itself. A non-conductive sleeve 123, formed for example from polytetrafluoroethylene (PTFE), surrounds the body of the feeder 124.

[0028] The feed point 126 is positioned on a notional straight line 128 passing through a corner of the patch 118 and the centre of the patch 118. When the patch is a straight-sided figure, such as the generally rectangular patch 118 shown in the example of Figure 2, the feed point 126 is positioned on, a diagonal of the patch.

[0029] When the feed point 126 is positioned on a diagonal, it is found that the patch 118 resonates in a plurality of different frequency bands. This phenomenon is believed to occur because all sides of the patch are presented to the excitation signal as possible areas from which radiation may emanate. Thus, for the generally rectangular patch 118 of Figure 2, all four sides of the patch 118 are available as possible radiating elements as a result of the diagonally positioned feed point 126. Since the frequency at which radiation occurs depends on patch dimensions, and since the respective opposing sides of the patch 118 are different lengths, the respective resonant states occur in different frequency bands.

[0030] The patch 118 includes two slots 130, 132 for manipulating the performance of the antenna 112 as is described in more detail below.

[0031] Firstly, the operation of an unslotted patch is considered. Figure 4 shows a plan view of an unslotted patch 218 provided with a diagonally positioned feed point 226. The patch 218 dimensions are calculated using equations [1] to [4] of Figure 7 for a desired operational frequency, fr, of approximately 1800 MHz, where the substrate thickness, t, is approximately 1.2 mm and the dielectric constant, εr, is approximately 10. Accordingly, the length, 1, of the patch 218 is approximately 34.20 mm, and the patch width, w, is approximately 23.37 min. The optimal position of the feed point 226 was determined by simulating the operation of the patch 218 with the feed point first positioned at or near a corner 234 of the patch 218 and then subsequently positioned at points progressively nearer the patch centre along the diagonal. For the present design, an impedance match was found when the feed point 226 was positioned 5.70 mm from the longer edge 236 of the patch 218 and 7.98 mm from the shorter edge 238 of the patch 218 as shown in Figure 4. It will be understood that the feed point 226 may equally be positioned along the respective diagonal from any corner of the patch 218.

[0032] In Figures 5a to 5c, the current density on the patches 218 is shown. It will be noted that only areas of relatively high, or significant, current density are shown by the dashed lines. In general, the current density on a patch may range from 0 to 1500 A/m, or higher. In Figure 5 only areas where the current density is approximately 400 A/m and above are depicted. Current density of approximately 500 A/m and higher is considered to be particularly significant.

[0033] Figures 5a to 5c show plots of the current density across the patch 218 at different feed frequencies where resonance occurs. Figures 5a to 5c thus show the current density of patch 218 in three different resonant states in three different frequency bands. In Figure 5 current density is indicated by short dashes on the patch 218 surface, the density of the dashes corresponds to the current density. Figure 5a shows the current density when patch 218 is fed with an excitation signal of approximately 1389MHz. The main area of high current density is indicated approximately by dashed line 501. This area corresponds to the area of most significant electromagnetic radiation from the patch 218 in this resonant state, the radiation being in a frequency band centred at approximately 1389 MHz. As can be seen from Figure 5a, in this frequency band the key areas of high current density occur at and around the mid-sections of the opposing longer edges 236, 240, and across the patch 218 between the two edges 236, 240. Consequently, the main radiation of electromagnetic energy occurs at and around the mid-sections of the edges 236, 240 and from the patch surface between the edges 236, 240 in this resonant state (and therefore in the 1389 MHz frequency band).

[0034] A second resonant state occurs when the excitation signal is approximately 1971MHz, and the corresponding current density plot is shown in Figure 5b. The main area of high current density is indicated approximately by dashed line 503. In this state, the key areas of high current density are at and around the mid-sections of the remaining two opposing edges 238, 242 and across the patch 218 between the two edges 238, 242. Consequently, the main radiation of electromagnetic energy in the frequency band around 1971 MHz occurs at and around the mid-sections of the edges 238, 242 and from the patch surface between the edges 238, 242.

[0035] A third resonant state occurs when the excitation signal is approximately 2476 MHz, and the corresponding current density plot is shown in Figure 5c. The main area of high current density is indicated approximately by dashed lines 505. In this state, the key areas of high current density are at and around the mid-sections of all four edges 236, 238, 240, 242. Consequently, the main radiation of electromagnetic energy in the frequency band around 2476 MHz occurs at and around the four edges 236, 238, 240, 242. It will also be seen that there is a null point for current density at and around the centre of the patch 218 and that the level of current density increases towards the edges of the patch 318. The current density/radiation pattern shown in Figure 5c is dual linear or circularly polarised, meaning that high current density and hence radiation is occurring simultaneously at all four edges in this frequency band.

[0036] It will be noted from Figures 5a to 5c that, as a result of the diagonal feed position, the patch 218 is able to radiate energy from all four of its edges 236, 238, 240, 242 in contrast to a conventional centre feed patch which only radiates energy from two opposing edges. This enables the patch 218 to resonate in more than one frequency band.

[0037] Figure 6 shows the Return Loss (dB) for each of the resonant states illustrated in Figures 5a to 5c. The first Return Loss Peak 601 represents a resonant, or operational, frequency band centred at approximately 1389 MHz and corresponds with the resonant state shown in Figure 5a. The second Return Loss Peak 602 represents a resonant frequency band centred at approximately 1971 MHz and corresponds with the resonant state shown in Figure 5b. The third Return Loss Peak 603 represents a resonant frequency band centred at approximately 2476 MHz and corresponds with the resonant state shown in Figure 5c. The second Return Loss Peak 602 is significantly better (approximately -13dB) than the first and third Return Loss Peaks 601, 603 (approximately -4dB and -4.5dB respectively). This is expected since the patch 218 was designed particularly for resonance at around 1800 MHz and the feed point 226 was selected to provide a good impedance match in this frequency range. Nonetheless, the first and third Return Loss Peaks 601, 603 are significant and, as is described in more detail below, can be developed to provide additional operating frequency bands for an antenna into which it is incorporated.

[0038] Thus, the unslotted patch 218 with diagonal feed may be incorporated into an antenna of the general type illustrated in Figures 2 and 3 and the resulting antenna is capable of operating in a number of different frequency bands. This is achieved using only a single conductive layer for the patch 218, using only a single feed mechanism and without the need for shorting pins or a matching circuit. However, the relatively poor Return Loss Peaks 601, 603 for the first and third frequency bands, are normally considered to be unsatisfactory for commercial use. Moreover, the three illustrated Return Loss Peaks 601, 602, 603 are in frequency bands that are not currently in commercial use in the mobile telecommunication industry. In this connection, four key frequency bands that are in current use in the mobile telecommunications market are GSM (Global System for Mobile telecommunications - approx. 890 to 960 MHz), GPS (Global Positioning System - approx. 1.57 to 1.58 GHz), DCS (Digital Communication System - approx. 1.71 to 1.88 GHz) and Bluetooth (approx. 2.4 to 2.48 GHz).

[0039] It is proposed, therefore, to provide one or more slots in the patch 218 in order to manipulate the performance of the antenna. In particular, it is proposed to provide a planar antenna capable of satisfactory operation in at least two commercially used frequency bands.

[0040] The provision of slots increases the current density in the patch around at least some of the slot edges. An increase in current density has the effect of making the patch electrically larger and this makes the patch behave as if it were physically larger even though the actual length and width of the patch are unchanged. By careful arrangement of a slot (including slot shape, slot size and slot position) one or more of the frequency bands in which the patch resonates can be adjusted. In particular, by placing at least part of a slot in or adjacent an area of the patch that has a relatively high current density during resonance in a given frequency band, the frequency band can be lowered (i.e. resonance occurs at a lower frequency). This is because the increase in current density caused by the presence of the slot causes the patch to behave as if it were larger - and larger patches generally resonate at lower frequencies.

[0041] The slots also provide a further effect when arranged in accordance with the invention. The increased surface current density around the slot edges gives rise to additional Return Loss Peaks in different frequency bands. The slot edges, when appropriately placed, act as pseudo patch edges from which electromagnetic energy can radiate. A slot can therefore effectively create one or more further resonant states for the patch and so increase the versatility of the antenna. The provision of a slot on the patch can also affect the effective impedance of the patch with respect to the feed point. The slot can therefore affect the magnitude of the Return Loss Peak in one or more resonant frequency bands.

[0042] Thus, with appropriate design and arrangement of slots in accordance with the invention, the natural resonance frequency bands of a planar antenna can be adjusted, further resonance frequency bands, i.e. operational frequencies, can be created and the return loss value (i.e. patch efficiency) in resonance frequency bands can be improved. However, removal of material from a patch to form a slot can be detrimental to the efficiency of the antenna and this must be taken into account during slot design.

[0043] It will be appreciated from the foregoing that in order to design a patch for operation in a number of different frequency bands, it is necessary to carefully select an arrangement of slots so that the patch resonates in the desired frequency bands and with a satisfactory efficiency (i.e. a satisfactory return loss value).

[0044] More than one slot is preferred as it facilitates the adjustment of a larger number of frequency bands - for example, one slot can be used to adjust the frequency value and/or return loss value primarily in one resonant frequency state, while another slot can be used to adjust the frequency value and/or return loss value primarily in another resonant frequency state.

[0045] In general, for determining the arrangement of one or more slots in order to adjust one or more resonant frequencies, it is found that placing a slot (or part of a slot) in, or adjacent, an area of significant electromagnetic radiation in a particular resonant state increases the current density in said area thereby lowering the frequency of radiation in that state. Increasing the length of the slot (or part-slot) in said area also increases the current density and decreases the radiation frequency (and vice versa). Moving the slot (or part-slot) closer to a patch edge that radiates in said resonant state also increases the current density around the slot (or-part slot) thereby lowering the radiation frequency (and vice versa). Similarly, moving a slot (or part-slot) into or towards an area of higher.radiation density further increases current density and lowers frequency. Further, the slot(s) can give rise to additional resonant states that are not appreciable in an unslotted patch. This is particularly the case when the slot(s) (or part-slot(s)) are located in close proximity with, and substantially in parallel with, a patch edge.

[0046] It will be understood that for a patch of different dimensions, the resonance states of both a slotted or unslotted patch may occur in different frequency bands to those described above and so the slots may have effect in different frequency bands.

[0047] It will be understood that the slot design techniques described herein may be applied to patches that are not necessarily fed from a point on a diagonal.

[0048] Having more than one slot in the patch is preferred as this facilitates manipulation of more than one operational frequency. It will be appreciated, however, that an operable patch may also be achieved using only one slot.

[0049] It will also be understood that the or each slot does not necessarily have to be I-shaped. It is preferred, however, that at least one slot includes a first and a second non-parallel slot portions. This increases the length of slot edges in a given area (for example around the feet) which increases the effect that the slot has on the operational frequencies. More preferably, the first and second slot portions are substantially perpendicular with each other. This is particularly useful for generally rectangular patches as it allows the slot to be positioned with a respective portion substantially parallel with a respective patch edge. For a non-rectangular patch, the relative angle between the first and second slot portions can be set accordingly. A skilled person will appreciate that there are many different slot shapes that may be used to take advantage of the teaching of the invention. For example, the feet portions of the slot need not necessarily be located at the very end of the body portion.

[0050] The second non-parallel slot portion need not necessarily be integral with the first slot portion. For example, for an I-shaped slot, the feet portions may be detached from the body portion. This results in a decrease in current density particularly in the area between the feet portions and the body portion. The reduction in current density leads to an increase in operational frequency in the resonant states where the key radiation areas include the area around the feet portions. It is also found that separating the feet from the body improves the return loss value in the DCS frequency band

[0051] It is also possible to omit the second slot portion. For example; the feet portions of an I-shaped slot may be omitted. This leads to a decrease in current density in the areas where the feet would have been which in turn leads to an increase in operational frequency in the resonant states where the key radiation areas include the area around the feet portions

[0052] A further alternative is to omit at least part of the body portion of the slot. For example, for an I-shaped slot, the mid-portion of the slot body may be removed to leave two spaced apart T-shaped slots. This arrangement is suitable in cases where the patch is intended for operation in frequency bands where the mid-portions of the slots do not play a significant role.

[0053] It is generally desirable for an antenna to produce as symmetrical a radiation pattern as possible, and so it is preferred if the slots are generally symmetrical in shape and generally symmetrical in arrangement in the patch.

[0054] It will also be understood that the invention is not limited to use with antennas in which the patch is fed directly with an excitation signal. Other conventional feed arrangements, such as coupling, coplanar waveguide or microstrip feedline, can also be used. In each case, the feed point is arranged, in accordance with the invention, to be on, or in-line with, a notional line from a corner of the patch to the centre of the patch.

[0055] It will be understood that the patch 118, 218 is capable of both transmitting and receiving signals in multiple frequency bands. Preferably, the patch 218, of the invention is mounted on a front end module (FEM) that is arranged for both transmitting and receiving signals in the appropriate frequency bands. However, the patch 218, may alternatively be used with an FEM that is receive-only or transmit-only.

[0056] It is also noted that the patches 118, 218, may resonate in further frequency bands than described herein. For example, in Figure 6 a small Return Loss Peak 604 is present at approximately 2750 MHz. However, such additional Return Loss Peaks are not utilised by the preferred embodiment of the invention.

Claims

1. A patch antenna (12) comprising a generally rectangular conductive patch (118) defined by first and second pairs of opposing sides; a ground plane (122); a dielectric substrate (120) between the patch and the ground plane; a feed mechanism (124) for providing electromagnetic signals to a feed point (126, 226) on said conductive patch; and one or more slots (130, 132) formed in the patch, each slot being spaced-apart from the sides of the patch, wherein the feed point (126, 226) is located on, or in-line with, a notional line through a corner and the centre of the conductive patch, a first slot comprises an elongate body portion that is located adjacent and parallel with one of said first sides of the patch, **characterised in that** the antenna further includes a second slot (132) comprising an elongate body portion that is located adjacent and parallel with the other of said first sides of the patch, said first slot (130) including a respective foot slot portion located adjacent to and parallel with a respective second side of the patch, said second slot (132) including a respective foot slot portion located adjacent to and parallel with the respective second sides of the patch.

2. An antenna as claimed in claim 1, wherein said foot slot portions are formed integrally with the respective elongate body portions of the first or second slot respectively.

3. An antenna as claimed in any preceding claim, wherein the sides of the first pair are shorter than the sides (240, 246) of the second pair.

4. An antenna as claimed in any preceding claim, wherein the feed mechanism (124) is arranged to provide a direct feed to the conductive patch.

5. An antenna as claimed in any preceding claim, wherein the antenna is formed from microstrip.

6. An antenna as claimed in any preceding claim, wherein said first and second slots are substantially "H"- shaped.

7. An antenna as claimed in any preceding claim, wherein said first and second slots (130, 132) are located one on either side of the feed point (124), each slot having an elongate body portion with a respective foot portion at, or adjacent, either end of the body portion, the respective elongate body portions being substantially parallely disposed with respect to a respective pair of first opposing sides of the patch, the respective foot portions being located adjacent the second pair of opposing patch sides.

8. An antenna as claimed in claim 1, wherein said first pair of opposing patch sides are the patch sides that radiate electromagnetic energy during resonance in a frequency band in respect of which the conductive patch is designed primarily to resonate.

Patentansprüche

1. Flachantenne (12), die Folgendes umfasst: eine im Allgemeinen rechteckige leitfähige Platte (118), die durch ein erstes und zweites Paar gegenüberliegende Seiten abgegrenzt ist; eine Masseebene (122); ein dielektrisches Substrat (120) zwischen der Platte und der Masseebene; einen Speisemechanismus (124) zum Anlegen elektromagnetischer Signale an einen Speisepunkt (126, 226), der sich auf der leitfähigen Platte befindet; und einen oder mehrere Schlitze (130, 132), die in der Platte gebildet sind, wobei jeder Schlitz von den Seiten der Platte beabstandet ist, wobei der Speisepunkt (126, 226) auf einer gedachten Linie durch eine Ecke und die Mitte der leitfähigen Platte angeordnet ist oder mit dieser übereinstimmt, ein erster Schlitz einen länglichen Körperabschnitt umfasst, der benachbart und parallel zu einer der ersten Seiten der Platte angeordnet ist, **dadurch gekennzeichnet, dass** die Antenne des Weiteren einen zweiten Schlitz (132) umfasst, der einen länglichen Körperabschnitt umfasst, der benachbart und parallel zu der anderen der ersten Seiten der Platte angeordnet ist, der erste Schlitz (130) einen entsprechenden Fußschlitzabschnitt umfasst, der benachbart und parallel zu einer entsprechenden zweiten Seite der Platte angeordnet ist, wobei der zweite Schlitz (132) einen entsprechenden Fußschlitzabschnitt umfasst, der benachbart und parallel zu den entsprechenden zweiten Seiten der Platte angeordnet ist.

2. Antenne nach Anspruch 1, wobei die Fußschlitzabschnitte einstückig mit den entsprechenden länglichen Körperabschnitten jeweils des ersten und zweiten Schlitzes gebildet sind.

3. Antenne nach einem der vorhergehenden Ansprüche, wobei die Seifen des ersten Paars kürzer sind als die Seiten (240, 246) des zweiten Paars,

4. Antenne nach einem der vorhergehenden Ansprüche, wobei der Speisemechanismus (124) so angeordnet ist, dass er der leitfähigen Platte eine direkte Einspeisung bereitstellt.

5. Antenne nach einem der vorhergehenden Ansprüche, wobei die Antenne aus einem Mikrostreifen gebildet ist.

6. Antenne nach einem der vorhergehenden Ansprüche, wobei der erste und zweite Schlitz im Wesentlichen "H"-förmig sind.

7. Antenne nach einem der vorhergehenden Ansprüche, wobei der erste und zweite Schlitz (130, 132) jeweils auf beiden Seiten des Speisepunkts (124) angeordnet sind, jeder Schlitz einen länglichen Körperabschnitt mit einem entsprechenden Fußabschnitt an beiden Enden des Körperabschnitts oder benachbart zu diesem aufweist, wobei die entsprechenden länglichen Körperahachnitte im Wesentlichen parallel in Bezug auf einjeweiliges Paar erster gegenüberliegender Seiten der Platte angeordnet sind und die jeweiligen Fußabschnitte benachbart zu dem zweiten Paar gegenüberliegender Plattenseiten angeordnet sind.

8. Antenne nach Anspruch 1, wobei das erste Paar gegenüberliegende Plattenseiten die Plattenseiten sind, die während der Resonanz in einem Frequenzband elektromagnetische Energie abstrahlen, wobei die leitfähige Platte primär dafür konstruiert ist, in Bezug auf das Frequenzband mitzuschwingen.

Revendications

1. Antenne patch (12) comprenant un patch conducteur généralement rectangulaire (118) défini par des première et deuxième paires de côtés opposés ; un plan de masse (122) ; un substrat diélectrique (120) entre le patch et le plan de masse ; un mécanisme d'alimentation (124) pour fournir des signaux électromagnétiques à un point d'alimentation (126, 226) sur ledit patch conducteur ; et une ou plusieurs fentes (130, 132) formées dans le patch, chaque fente étant espacée des côtés du patch, dans laquelle le point d'alimentation (126, 226) est situé ou aligné sur une ligne notionnelle passant par un coin et le centre du patch conducteur, une première fente comprend une partie de corps allongée qui est située à proximité de l'un desdits premiers côtés du patch, et parallèlement à ce côté, **caractérisée en ce que** l'antenne comporte en outre une deuxième fente (132) comprenant une partie de corps allongée qui est située à proximité de l'autre desdits premiers côtés du patch, et parallèlement à ce côté, ladite première fente (130) comportant une partie de fente de pied respective située à proximité d'un deuxième côté respectif du patch, et parallèlement à ce côté, ladite deuxième fente (132) comportant une partie de fente de pied respective située à proximité des deuxièmes côtés respectifs du patch, et parallèlement à ces côtés.

2. Antenne selon la revendication 1, dans laquelle lesdites parties de fente de pied sont formées de façon intégrante avec les parties de corps allongées respectives de la première ou de la deuxième fente respectivement.

3. Antenne selon l'une quelconque des revendications précédentes, dans laquelle les côtés de la première paire sont plus courts que les côtés (240, 246) de la deuxième paire.

4. Antenne selon l'une quelconque des revendications précédentes, dans laquelle le mécanisme d'alimentation (124) est agencé pour fournir une alimentation directe au patch conducteur.

5. Antenne selon l'une quelconque des revendications précédentes, dans laquelle l'antenne est formée à partir d'un microruban.

6. Antenne selon l'une quelconque des revendications précédentes, dans laquelle lesdites première et deuxième fentes sont essentiellement en forme de H.

7. Antenne selon l'une quelconque des revendications précédentes, dans laquelle lesdites première et deuxième fentes (130, 132) sont situées l'une et l'autre de chaque côté du point d'alimentation (124), chaque fente ayant une partie de corps allongée avec une partie de pied respective située à l'une ou l'autre extrémité, ou à proximité de l'une ou l'autre extrémité, de la partie de corps, les parties de corps allongées respectives étant disposées essentiellement parallèlement relativement à une paire respective de premiers côtés opposés du patch, les parties de pied respectives étant situées à proximité de la deuxième paire de côtés de patch opposés.

8. Antenne selon la revendication 1, dans laquelle ladite première paire de côtés de patch opposés sont les côtés de patch qui rayonnent l'énergie électromagnétique durant la résonance dans une bande de fréquences relativement à laquelle le patch conducteur est conçu essentiellement pour résonner.

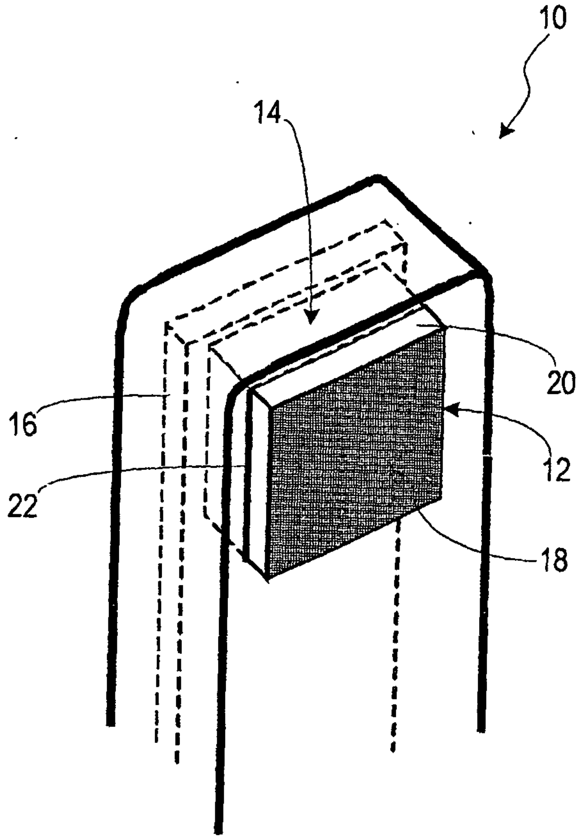

FIG. 1

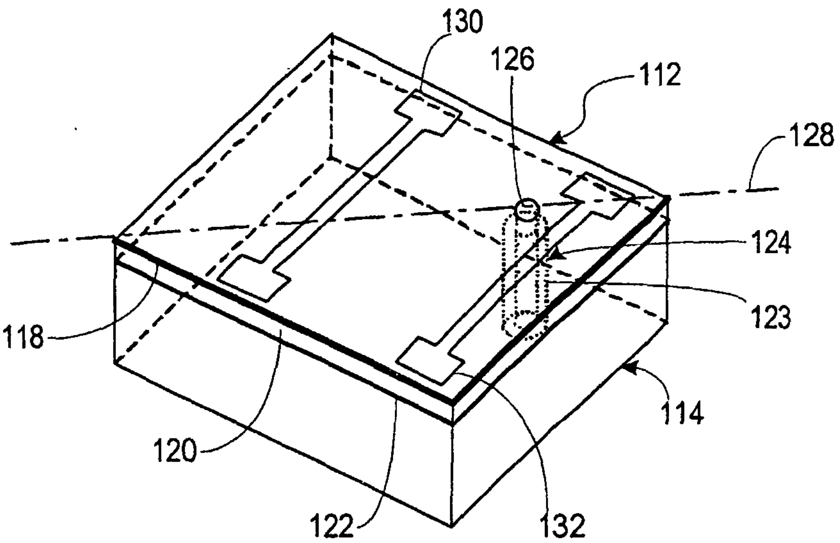
130
126
112
128
124
123
118
114
120
122
132

FIG. 2

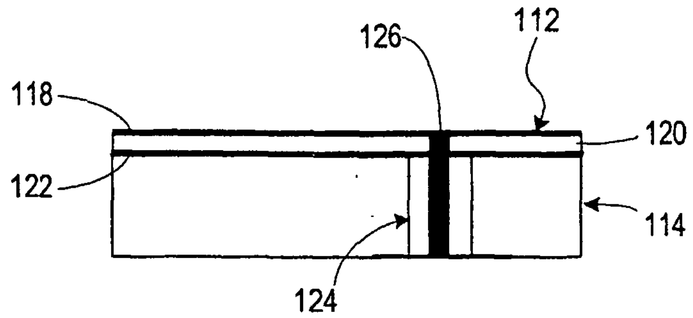
126
112
118
120
122
114
124

FIG. 3

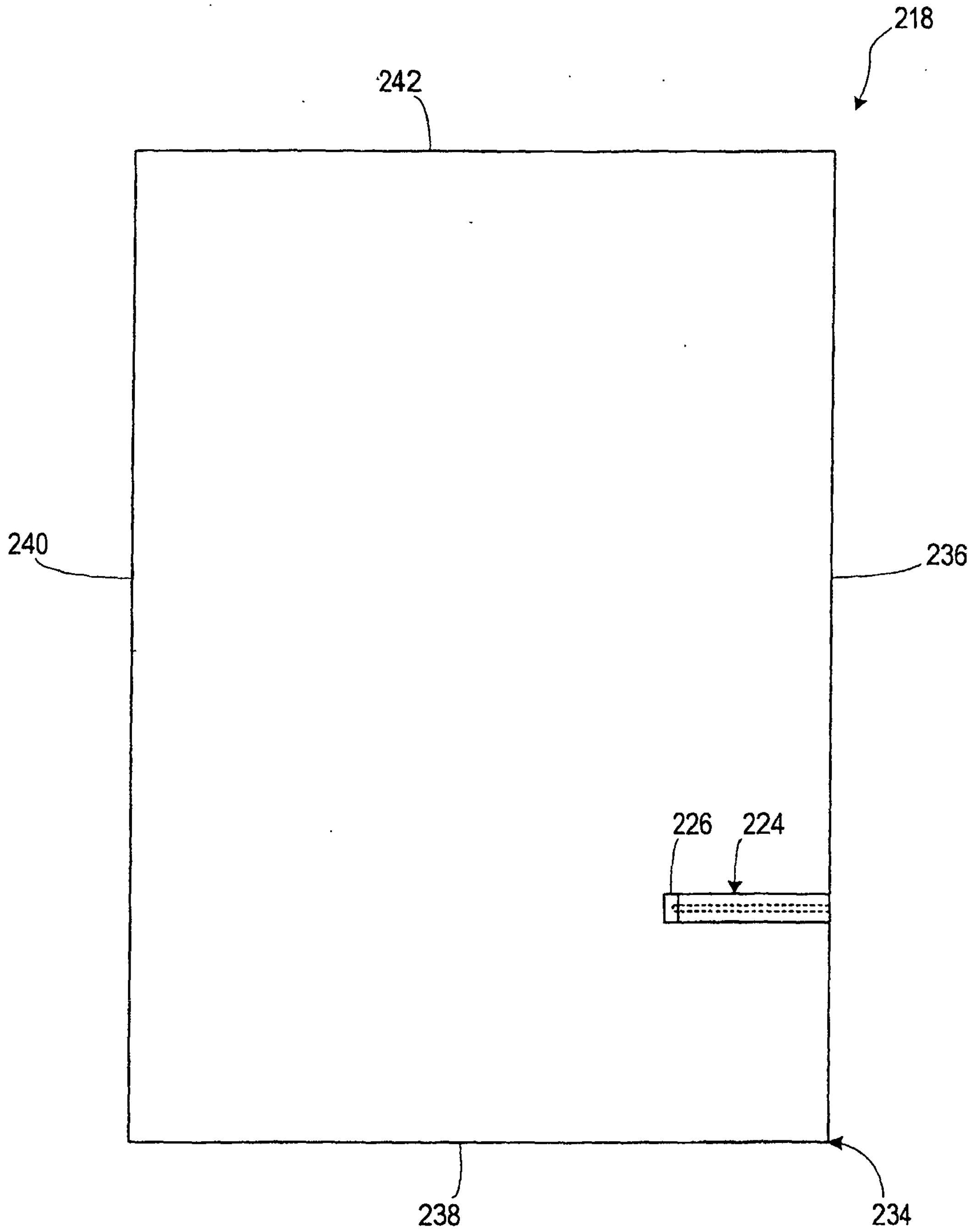

FIG. 4

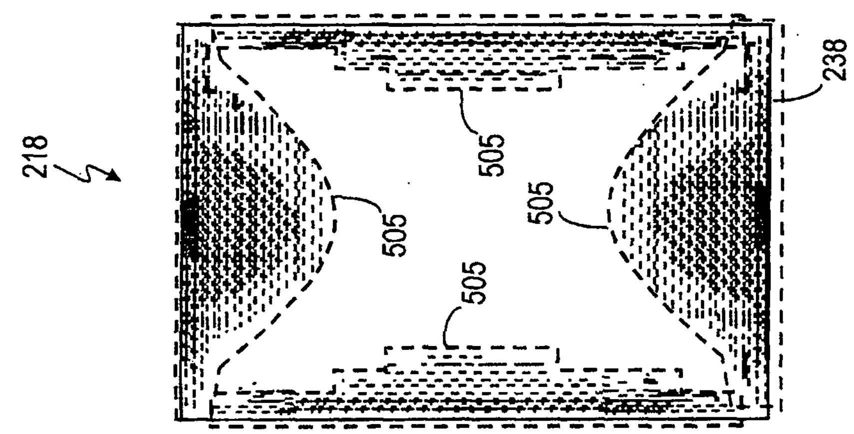

FIG. 5c

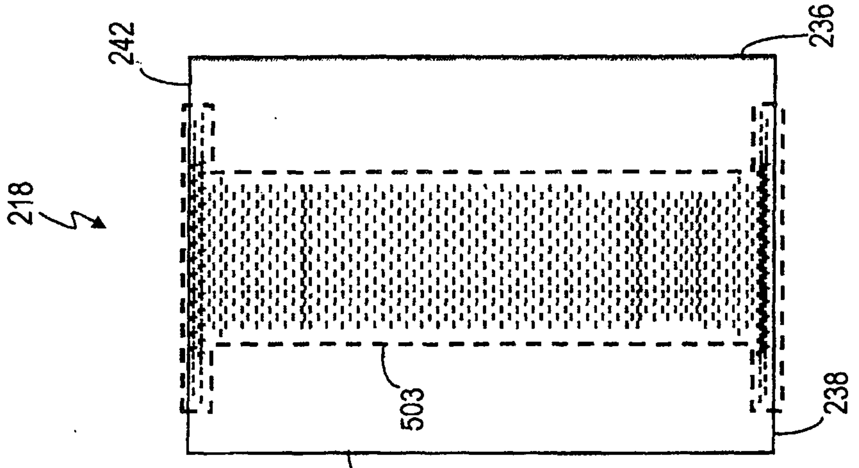

FIG. 5b

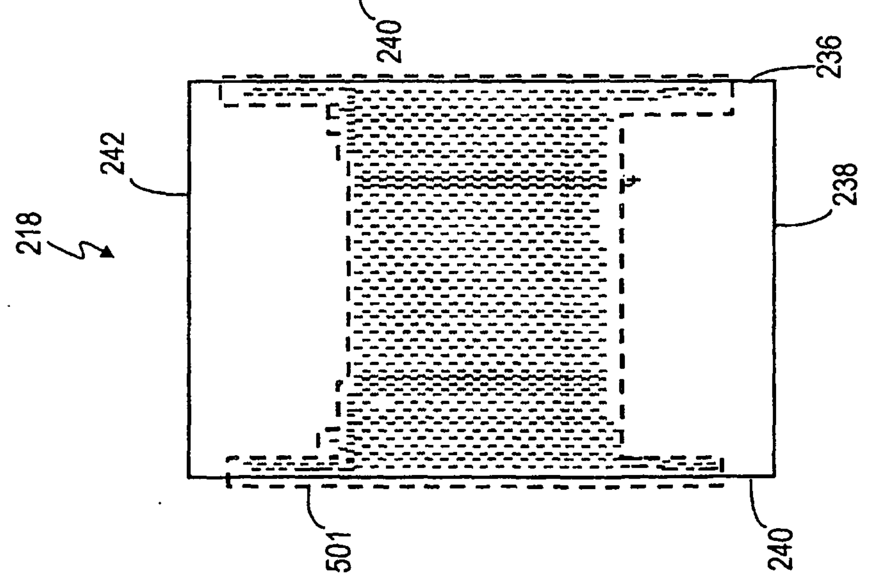

FIG. 5a

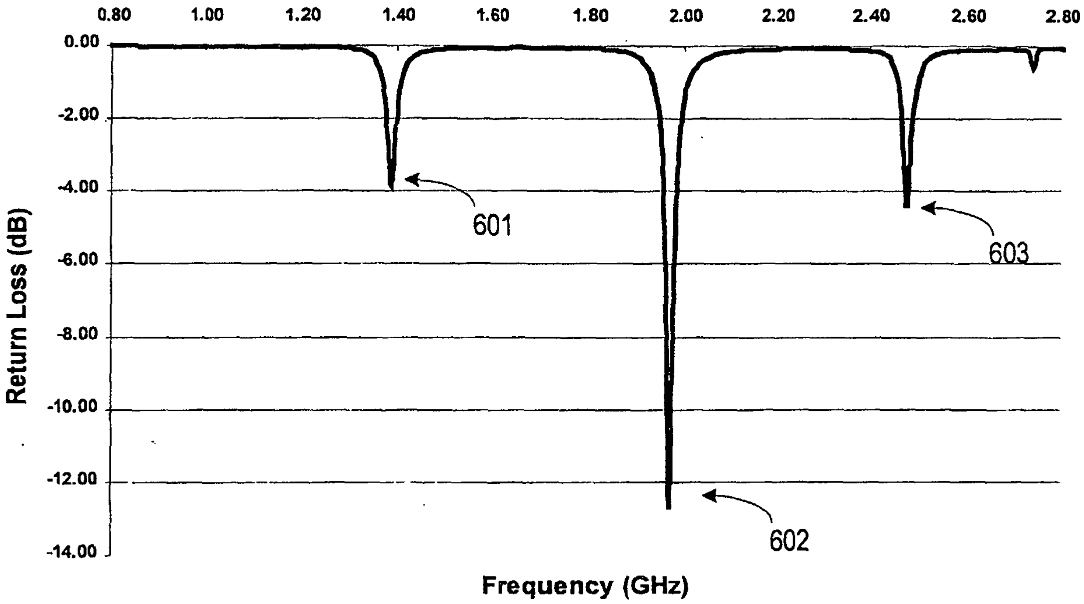
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
Return Loss (dB)
601
602
603
Frequency (GHz)

FIG. 6

Dielectric Constant	$\varepsilon r := 10$		
Substrate Thickness	$t := 1.2$		
Design Frequency	$fr := 1.8 \cdot 10^{9}$		
Speed of Light	$c := 3 \cdot 10^{11}$		
Loss Tangent	$tand := 0.0175$		
Free Space Wavelength	$\lambda 0 := \frac{c}{fr}$		
	$\lambda 0 = 166.667$		
Feed Point Impedance	$Zo := 50$		
	$pi := \frac{22}{7}$		
Patch Antenna Width	$w := \left(\frac{c}{2 \cdot fr}\right) \cdot \left(\frac{\varepsilon r + 1}{2}\right)^{-\frac{1}{2}}$	$\Longrightarrow$ $w = 35.533$	[1]
Effective Dielectric Constant	$\varepsilon eff := \left(\frac{\varepsilon r + 1}{2}\right) + \left[\frac{\varepsilon r - 1}{2 \cdot \left[1 + 10 \cdot \left(\frac{t}{w}\right)\right]^{0.5}}\right]$	$\Longrightarrow$ $\varepsilon eff = 9.391$	[2]
Patch Antenna Length uncertainty	$\Delta L := 0.412 \cdot t \cdot \left[\frac{(\varepsilon eff + 0.3) \cdot \left(\frac{w}{t} + 0.262\right)}{(\varepsilon eff - 0.258) \cdot \left(\frac{w}{t} + 0.813\right)}\right]$	$\Longrightarrow$ $\Delta L = 0.515$	[3]
Patch Antenna Length	$L := \left(\frac{c}{2 \cdot fr \cdot \sqrt{\varepsilon eff}}\right) - (2 \cdot \Delta L)$	$\Longrightarrow$ $L = 26.164$	[4]

$$\frac{w}{L} = 1.358$$

FIG. 7