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Design and Analysis of Rectangular Micro stripAntenna with Defective Ground for UWB Applications

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Abstract: Two different ideas for a flawed ground plane in a rectangular microstrip patch antenna are shown here. The impedance bandwidth of 53.6% is provided by the geometry in the first suggested design, and the pattern properties remain unchanged over the whole frequency range of 4.57 GHz to 7.91 GHz. The second layout is achieved by altering the slot shapes in the ground structure to create a bandwidth notch. Three different resonance frequencies (4.45 GHz, 7.32 GHz, and 10.31 GHz) allow the antenna to function. Ansoft HFSS 11 simulation software is utilized for both antenna designs, and the substrates are both 1.59-mm-thick, 4.4-relative-permittivity FR4 epoxy.

Keywords: Slotted Microstrip Patch Antenna, Impedance Bandwidth, Radiation Pattern, Return Loss.

I. Introduction

Ultra-wideband (UWB) systems have been used in a wide variety of contexts in recent years thanks to their many advantageous characteristics, including their compact size, high data transmission rate with short range, greater bandwidth, simple hardware configuration, low power consumption, and omni-directional radiation pattern. Using the FCC's unlicensed spectrum from 3.1 GHz to 10.6 GHz [1-8], ultra-wideband is a short-range wireless technology with a high data rate. Potential interference from UWB systems is experienced by a variety of licensed narrowband systems operating in this frequency range. Narrow band technologies include HYPERLAN/2 at 5.45 GHz to 5.725 GHz and IEEE 802.11a Wireless Local Area Network at 5.15 GHz to 5.35 GHz and 5.725 GHz to 5.825 GHz. As a precaution against

These interferences need a filter circuit, which increases both the complexity and expense of the system. A better option would be to use an antenna that can filter out these frequencies. Many different methods for designing specialized antennas have been published recently. Cutting slots on the patch or on the ground plane, such a U-shaped slot, cutting a fractal slot, etc., is the most common way to achieve a band-notched characteristic in a printed monopole antenna[9-14]. Parasitic components surrounding the printed monopole patch is another option. Recently, it has been shown that cutting the Split Ring Resonator (SRR) and Complementary Split Ring Resonators in the patch may achieve a band-notch for microstrip-fed Ultra-wideband antennas [15–19]. There is a lot of focus on developing and implementing Ultra-wideband systems in the business and academic sectors right now. The original idea for ultra-wideband (UWB) radio was created in the late 1960s, thus it has been around for quite some time. The United States Department of Defense coined the phrase "Ultra Wideband" in 1989. Since its inception, ultra-wideband (UWB) technology has primarily served military needs, particularly radar applications that necessitate wideband signals in the frequency domain or very short duration pulses in the time domain to obtain extremely precise, reliable, and swift data on fast-moving targets such as missiles. UWB signals have a fractional bandwidth of around 20% of the core frequency, and as of late the FCC has defined them as signals with a minimum absolute bandwidth of 500 MHz. UWB systems use very brief pulses to transfer data across a wide absolute bandwidth of up to 7.5 GHz. The FCC approved the use of the 3.1–10.6 GHz unlicensed frequency spectrum for commercial wireless purposes in 2002. Affirmed by.This means its transmit power can only be -41.3 dBm/MHz. It has recently attracted the attention of academics, scientists, and engineers, particularly in the areas of commercial and individual wireless communications [20, 22]. Recent ground penetrating radar, medical imaging systems, surveillance systems, and wall-imaging systems are just a few examples of the many fields that might benefit from the new coming UWB technology. Compared to the more traditional Narrowband (NB) systems already in use, UWB systems provide a number of benefits. Its simplicity is a benefit since it allows it to replace more sophisticated traditional NB systems. Its inexpensive price is one of the reasons it is often used in commercial communication applications. Since the available power level for UWB systems is limited (to ensure compliance with FCC regulations), they may operate extremely near to the noise floor. The resulting noise-like signal spectrum is effective in reducing the detrimental impacts of factors like interference, multipath fading, and jamming. UWB systems may be used in place of traditional narrowband systems for a variety of radar applications requiring great time-domain resolution and extremely high precision, such as tracking the objects, geo-location, localization, positioning, etc. [23, 24]. When it comes to wireless LANs, UWB technology is a great option for providing ultra-high-speed data services of up to 500 Mbps. An antenna array might be used to boost speed even more, as opposed to a single antenna element using a variety of beam shaping methods.

UWB antennas have been the focus of much study and development in recent years. With the rise in popularity of UWB systems, there has been a significant improvement in the engineering of UWB antennas. It is not easy to put in place a UWB system. Creating an antenna that does all you need it to is a challenge. This is due to the fact that it plays a pivotal role in the UWB system and its efficiency directly impacts the system as a whole. Vivaldi antennas, spiral antennas, log periodic antennas, and bi-conical antennas are only few of the current antenna designs that may provide high bandwidth for Ultra-Wideband systems. One of the antennas that may be used for ultra-wideband (UWB) operation is a Vivaldi antenna. Because of its highly directional radiation pattern, the Vivaldi antenna is unsuitable for use in indoor wireless communication or portable/mobile devices. This is because omni-directional radiation patterns allow for efficient and easy communication between transmitters and receivers in all directions. Mono-conical and bi-conical antennas are physically limited in their usefulness due to their size and mass. Log periodic and spiral antennas are two types of Ultra-Wideband antennas that can work over the 3.1 GHz to 10.6 GHz frequency range, but they are not ideal for use in portable/mobile devices or indoor wireless applications for communication due to their dispersive characteristics with frequency, severe ringing effects, and large physical dimensions. Given these drawbacks, we seek for such a potential antenna for UWB applications [25-38].

The ideal antennas for this task are printed monopoles or planar antennas. Many types of polygonal (trapezoidal, rectangular, etc.) and elliptical (circle) planar monopole antennas have been proposed for various applications.

Uses for very wide bands [39-45]. This study proposes a Rectangular microstrip Patch Antenna that uses a U-slot and a W-slot on the ground.

II.ANTENNA DESIGN-I (Rectangular Microstrip Patch Antenna for with U-SlottedGround)

Figures 1 and 2 illustrate the dimensions of a U-slotted ground, rectangular microstrip patch antenna used for ultra-wideband (UWB) applications. Glass epoxy FR-4 dielectric substrate with thickness 'H' = 1.59mm, relative permittivity r= 4.4, and loss tangent tan = 0.02. The top surface of the glass epoxy FR-4 dielectric substrate is printed with a rectangular patch measuring 10 mm x 11 mm. On the same side of the substrate, a rectangular feed line (1.9 mm x 8 mm) is printed. By milling two identical U-shaped slots into the ground plane, bandwidth is increased. This allows us a bandwidth of 3.4 GHz. This antenna is 22 mm x 24 mm. The antenna's functionality may be modified by altering the size of the ground-plane slots and the rectangular patch.

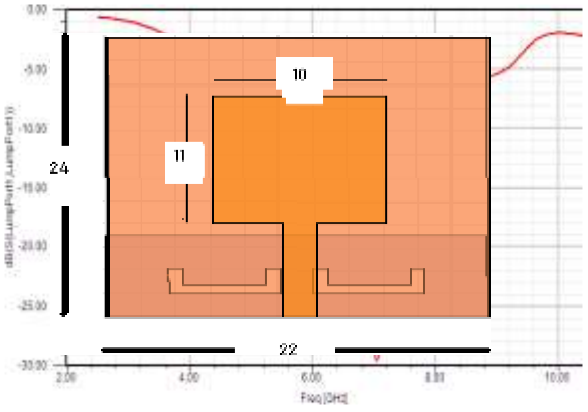
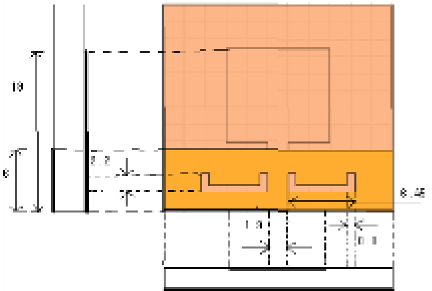


Figure 1 : Top view Rectangular patch antenna

Figure 2: Back view of U-slotted ground with back and sideview.



It's also worth noting that the substrate's height may be increased to enhance bandwidth, but that this introduces surface waves, which are often undesirable since they drain power intended for direct radiation (space waves). Propagation of surface waves

antenna pattern and polarization properties are degraded when electromagnetic waves travel through the substrate and become dispersed at corners and surface discontinuities like the truncation of the dielectric and ground plane. Cavities may be used to dampen down surface waves while yet allowing for wide bandwidths. Slotted microstrip patch antennas were developed for this same reason. The proposed antenna has a number of drawbacks, the most significant of which is its interference with other licensed bands. These bands include the ones used by the IEEE 802.11a Wireless Local Area Network (WLAN), which uses the frequencies 5.15–5.35 GHz and 5.725–5.825 GHz, and by HYPERLAN/2, which uses the frequencies 5.45–5.725 GHz.

III.RESULTS AND DISCUSSION (DESIGN-I)

Simulated results of the rectangular microstrip patch antenna with broad bandwidth are presented in this section,. Figure 3 shows the variation of return loss with frequency, curve for the proposed design. The range of frequency falling below
-10db is from 4.57 GHz to 7.91 GHz. Due to this a Bandwidth of 3.34 GHz is achieved. The central frequency of 6.24 GHz is obtained. Therefore, a bandwidth as high as 53.57% is achieved.

Figure 3: Variation of return loss (S_{11}) withfrequency for proposed design-I

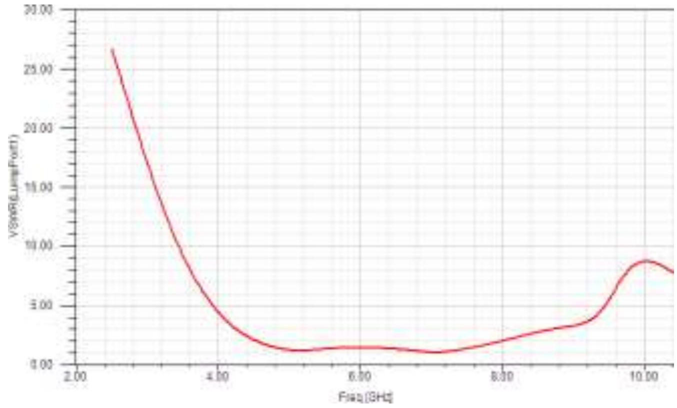


Figure 4: Variation of VSWR with frequencyfor proposed design-I

Figure 4 shows the variation of VSWR with frequency for proposed design-I. The VSWR falls below 2 for the proposedantenna under the preferred band.

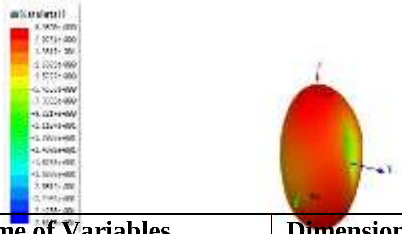


Figure 5: 3D Radiation Pattern of Proposed Antenna

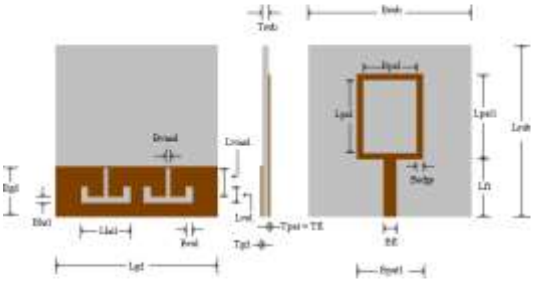
Figure 5 shows the 3D radiation pattern for proposed antenna. We can see that a gain of as high as 3.96 dB is achieved which is shown by red colour whereas a gain of as low as -2.43 dB isachieved.

IV. ANTENNA DESIGN-II

The primary goal of this redesign was to address a serious shortcoming in previous antenna designs. To prevent unwanted interaction with already licensed bands, band notching features have been included in this design.

In Fig. 6, we see a plan for a rectangular U-slotted patch antenna with a W-slotted ground, ideal for ultra wideband use.The antenna's overall geometry is the same with the exception of a few minor tweaks. Printed onto a dielectric substrate made of glass FR4-epoxy, which has a loss tangent of tan = 0.02, is the antenna that was created. Lsub mm x Bsub mm are used to describe the dimensions of the rectangular substrate. Tsub mm is defined as the substrate thickness. A 1 mm x 1 mm rectangular patch is then manufactured on top of the patch. The patch is made out of pec, which stands for "Perfect Electric Conductor." This square or rectangular area will remain Tpat mm thick. Now, the center of the patch has a rectangular slot cut into it measuring Lpsl mm by Bpsl mm; this leaves a border measuring B edge. A Lfl mm x Bfl mm rectangular feed line is also placed on the same side of the substrate to provide power to the patch. Tfl mm is assumed to be the feed line thickness. The rectangular microstrip patch antenna is now fully visible from the front.

A Lgd mm x Bgd mm rectangular ground plane is created on the substrate's reverse side. The base material is assumed to be pec. Tgd mm is used to represent the thickness of this ground plane. Now the ground plane is slotted in a U shape twice. Each U-shaped slot has the same width all the way through, therefore Bhsl mm = Bvsl mm. Finally, in the middle of two parallel horizontal holes of length Lhsl mm, two vertical rectangular slots are cut into the ground plane. This results in a W-shaped opening, the central arm of which is much longer than the other two.



(b) (b) (c)

Fig. 6. Design-II Antenna Geometry: (a) Back View (b) SideView (c) Front View

The dimensions of the antenna are shown in the tabular formatwhich is as follows:-

Name of Variables	**Dimensions (in mm)**
Substrate Length, L_{sub}	24 mm
Substrate Breadth,Bsub	22 mm
Substrate Thickness, Tsub	1.59 mm
Patch1 Length, Lpat1	12 mm
Patch1 Breadth, Bpat1	9 mm
Patch thickness, Tpat	0.03 mm
Feed Line Length, Lfl	8 mm
Feed Line Breadth, Bfl	1.9 mm
Feed Line Thickness, Tfl	0.03 mm
Ground Plane Length, Lgd	22 mm
Ground Plane Breadth, Bgd	7 mm
Ground Plane thickness, Tgd	0.03 mm
Patch Slot Length, Lpsl	10 mm
Patch Slot Breadth, Bpsl	7 mm
Edge Breadth, Bedge	1 mm
Horizontal Slot Length, Lhsl	6.45 mm
Horizontal Slot Breadth, Bhsl	0.8 mm
Vertical Slot Length, Lvsl	2.2 mm
Vertical Slot Breadth, Bvsl	0.8 mm
Vertical Middle Slot Length, Lvmsl	4 mm
Vertical Middle Slot Breadth, Bvmsl	0.4 mm

Here, we get a bandwidth of 2.2 GHz by varying the dimensions of the patch and cutting additional symmetrical vertical slots on the ground plane. Apart from this, a rectangular slot of *Lpsl* mm x *Bpsl* mm dimension is cut on the patch in order to generate band notching characteristics. The optimum values of the dimensions of the complete antenna are mentioned in the table.

V. RESULTS AND DISCUSSION (DESIGN-II)

A unique compact rectangular slotted microstrip patch tri-band antenna with band-notched features is given here. The antenna consists of a pair of symmetrical W-shaped (with center arm extending longer than other two side arms) slotted ground. Return loss versus frequency curve for the proposed antenna is shown in Fig. 7. The antenna's return loss graph reveals its usable frequency range at the expense of some signal strength. Below -10 dB of return loss is regarded to be within acceptable ranges. Here, the frequencies between 4.09 and 4.80 GHz, 6.96 and 7.68 GHz, and 9.92 and 10.69 GHz all drop below -10 dB. This tri-band utilizes three distinct frequencies—4.45 GHz, 7.32 GHz, and 10.31 GHz—to provide a total bandwidth of 2.2 GHz.

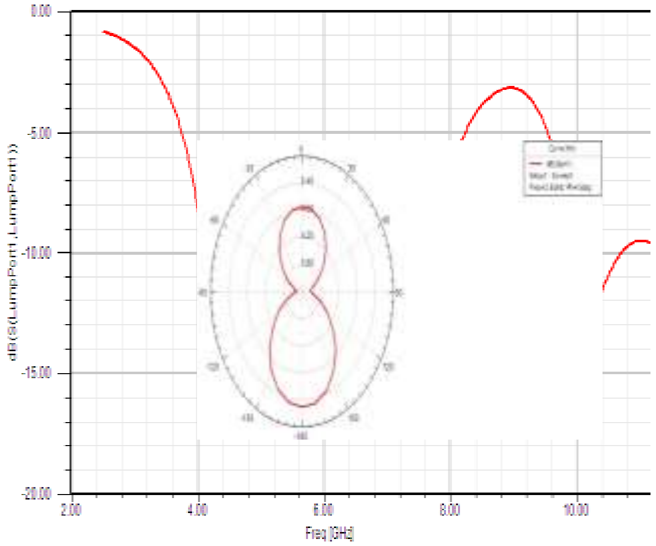


Fig. 7 Variation of return loss (S_{11}) with frequency forproposed design-II

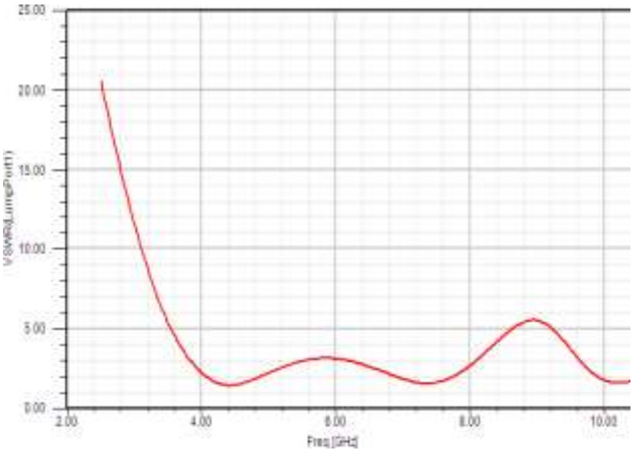
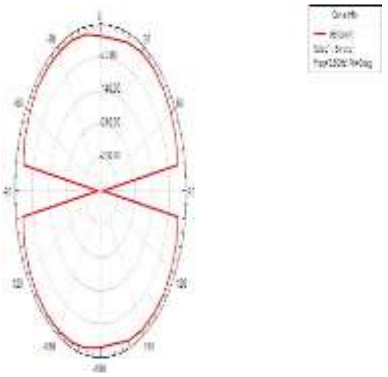


Fig. 8 Variation of VSWR with frequency for proposeddesign-I

The VSWR is calculated by dividing the greatest signal voltage by the lowest signal voltage achieved during the standing wave. Impedance mismatch grows in proportion to the standing wave's amplitude. If the impedance is perfectly matched, no standing waves will be produced, and the highest voltage will be equal to the lowest voltage. If the VSWR (Voltage Standing Wave Ratio) is less than 2, the voltage is within safe operating parameters. The suggested antenna's VSWR is shown to change with frequency in Fig. 8. Figure 8 shows that the proposed antenna's VSWR is below 2, well within the allowable range, for the intended frequency ranges.



(a)

(c)

Fig. 9 Radiation Pattern of the proposed Design-II (a) E-Plane

(b) H-Plane.

The radiation pattern of an antenna describes the change in radiated power as a function of direction away from the antenna. The suggested antenna's radiation pattern is shown in Fig.9 as a 2D (Two-Dimensional) diagram in the E-Plane and H-Plane. The antenna's observable omnidirectional radiation pattern indicates that the planned Ultra-Wideband microstrip antenna meets its design requirements.

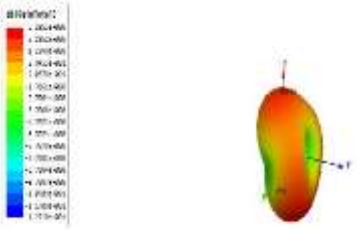


Fig. 10 3D Polar Plot of Design-2 Antenna

3D polar plot of an antenna is nothing but the 3D (Three-Dimensional) radiation pattern of an antenna. Fig.10 shows the 3D polar plot of the proposed antenna. We can seethat a gain of as high as 3.3 dB (shown by red colour) and as low as -1.28 dB (shown by blue colour) is achieved by the proposed antenna.

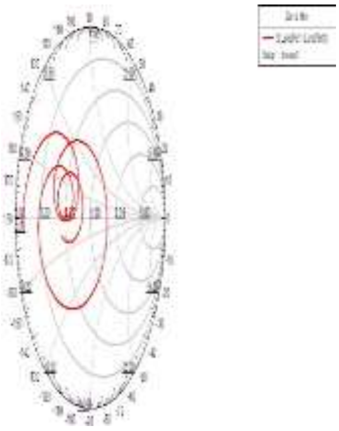


Fig. 11 Variation of input impedance for design-II

The Smith chart is one of the most helpful graphical aids for high frequency circuits. Smith charts are useful for visualizing complicated functions of any kind. Mathematically speaking, the Smith chart is a visualization of all conceivable complex impedances with regard to the coordinates indicated by the reflection coefficient. The scope of definition of the reflection coefficient is the 1-radius circle in the complex plane. As far as the intended antenna goes, this is a successful outcome. At resonant frequencies, the input impedance is near to 50 with very little imaginary portion, as illustrated in Figure 11.

VII. CONCLUSIONS

By incorporating two symmetric U-shaped slots into the ground with a rectangular patch, design-I has shown that a wide bandwidth microstrip patch antenna may be created. The bandwidth is around 3.34 GHz at the major 6,24 GHz frequency center. As a result, we may increase our bandwidth to as much as 53.57 percent. The design-II has shown that antennas with band notching properties may be constructed by altering the form of the holes in the ground. Here, we do this by concurrently cutting slots in the patch and the ground plane of varied widths and lengths. This design's broad operating bandwidth implies it won't conflict with already licensed frequencies. This means that the problem with design-I has been fixed. Below -10 dB is a frequency band from 4.09 GHz to 4.80 GHz. between 6.96 and 7.68 and 9.92 and 10.69 gigahertz. This tri-band enables operation throughout a frequency range from 4.45 GHz to 10.31 GHz, with a total bandwidth of 2.12 GHz. Modern communication systems need antennas capable of operating on several frequencies. With the intention of keeping the overall design as simple as feasible and keeping the realization cost as cheap as possible, these objectives have been met by adopting slotted ground for the radiating element.

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