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Design of Compact Ultrawideband Microstrip Patch Antenna

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Abstract: A compact planar ultrawideband (UWB) antenna is designed for X-band applications. Notches and slots are introduced in the rectangular patch for bandwidth enhancement. A prototype of antenna is constructed and measured to show ultrawide operating band with 10dB return loss bandwidth of 11.2 GHz covering the WPAN range of 3.1-10.6GHz. The peak gain measured is greater than 3dB and VSWR is less than 2.5 for the proposed UWB patch antenna.

Keywords: Antenna parameters, notches, microstrip patch antenna, slots, ultra wideband (UWB).

Introduction

A patch antenna (also known as a rectangular microstrip antenna) is a type of radio antenna with compact size, which can be mounted on a flat surface. It comprises of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called as ground plane. Fabrication of patch antennas is simple and can be easily modified and customized.

Microstrip patch antenna has many advantages like compact size, simple structure, low cost and compatibility with integrated circuitry. It has tremendous applications in military, mobile communications, radar systems, global positioning system (GPS), remote sensing etc. The main disadvantage of microstrip patch antenna is its narrow bandwidth.

In the past two and a half decades, many techniques have been developed to enhance the impedance bandwidth of microstrip patch antennas. In particular, the U-slot patch enables a single layer patch microstrip antenna to attain over 30% impedance bandwidth. This wide impedance bandwidth is achieved with the use of thick and low permittivity substrates. The conventional method to increase the bandwidth is using parasitic patches [1], but, this will relatively increase the antenna size. This will make antenna unsuitable for wireless applications where small size is the main requirement.

During the past years, only a few related UWB antennas were being proposed. These include the folded metal type [2], the meandered strip type [3], the coplanar waveguide (CPW)-fed monopole types [4], [5], the microstrip-fed patch types [6]–[10], etc. However, most of these designs still have either a complex structure or a large size for being built into the compact space. Thus, techniques are required which can increase the antenna bandwidth without increasing the size of the antenna. Slots and notches are used in this paper which leads to enhancement of bandwidth and other antenna parameters. The slots cut out in microstrip patch antenna produce additional resonances thus giving continuous ultra wide bandwidth. On the other hand the notch leads to improvement in impedance matching at resonant frequencies and thus leads to impedance bandwidth extension.

This paper is thus aimed at describing the design and realization of a compact UWB antenna suitable for use in the X-band. Meanwhile, regarding that the patch monopole prototype, initially not only has a planar and simple structure to make it easy to integrate itself with the system circuit, but also has a chance to achieve a low -factor for effectively increasing bandwidth by means of simply inserting slots into the patch, a microstrip-fed slotted monopole antenna consisting of a notched rectangular patch and ground with triple embedded slots is therefore presented. By properly selecting dimensions of the notches as well as the embedded slots, good ultrawide impedance bandwidth and suitable characteristics for application in the WPAN system can be achieved. Effects of cutting notches and embedding slots to the original patch and ground on resonance were studied. [11]

Antenna Design and Discussion

The microstrip fed UWB slotted patch antenna is shown in Fig 1. This is made of a rectangular patch which acts as the radiator and etched on one side of the FR4 substrate with initial dimensions of 37(L) X 15(W) mm^2, whereas ground plane of size L_g X W was printed on the other side of the substrate.

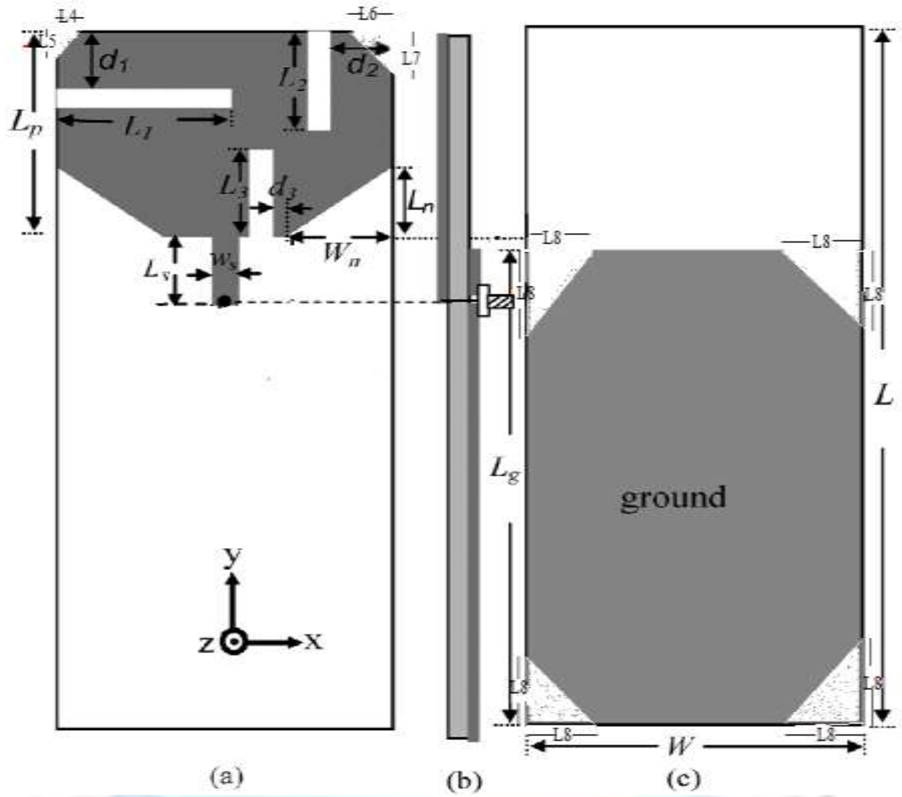


Figure 1. Proposed slotted patch antenna design configuration
(a) Top view (b) Side view (c) Bottom view

This substrate is 0.8mm in thickness with relative permittivity (ϵ_r) of 4.4. A rectangular patch with dimensions of L_p X W mm^2 is used. The patch is fed with a 50Ω microstrip line of width W_s and length L_s.

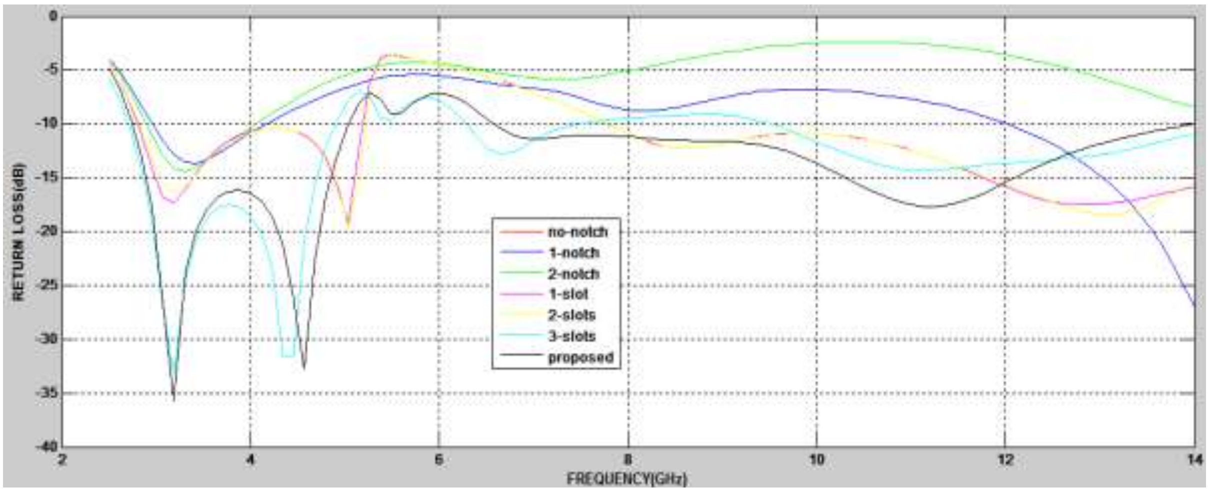
To extend impedance bandwidth and improve matching conditions triangular notches have been introduced in the patch and ground of the proposed antenna design. Two notches with dimensions of L_n X W_n are introduced on the two lower corners of the patch and notches of L5 X L4 and L6 X L7 are introduced on the top 2 corners of the patch. 4 notches of dimensions L8 X L8 are introduced on the ground plane of the antenna.

Slots are found to be effective way to excite additional resonances and get continuous ultrawide bandwidth, thus 3 straight slots of lengths L_1, L_2 and L_3 at a distance of d_1, d_2 and d_3, respectively, from the closest edge of the patch were embedded in the notched patch. All the three slots are of equal width of 1mm. The design parameters as marked in Figure 1 are shown in Table 1 with their respective units. HFSS software is used for required numerical analysis.

Table 1: Parameters of the proposed UWB patch antenna

Parameters	Unit(mm)	Parameters	Unit(mm)
L	37	W_n	5
W	15	L_s	4
L_1	8.7	W_s	1
d_1	3	L_p	11
L_2	4	L4	1.5
d_2	4	L5	1.7
L_3	5	L6	3
d_3	0.5	L7	3.2
L_n	5	L8	3

Figure 2(a) to (g) shows the evolution design of the proposed UWB antenna on simulated frequency response of the return loss. The designing starts with simple rectangular patch of 11(L) X 15(W) mm^2. This design shows resonances at 3.5, 5.5 and 9 GHz. Introduction of notches in the patch, improvement in the continuous bandwidth has been observed. Then slots are introduced in the notched patch and improvement in bandwidth with matching at excited resonance frequencies has been observed.



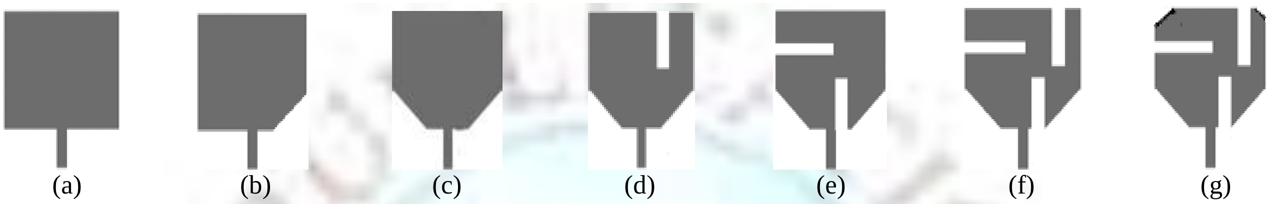


Figure 2. Return loss vs frequency curve for the proposed UWB patch antenna with different slots and notches embedded. (a) No notch (b) 1-notch (c) 2-notch (d) 1-slot (e) 2-slots (f) 3-slots (g) Proposed Design

Also to make antenna work in below 10dB range and improve the return loss notches have in introduced in the top side corners of the patch and in the ground plane of the proposed antenna design. Via iterative design process, proper geometric design parameters have been selected for these notches and slots embedded in patch and ground plane and listed in Table 1.Proposed antenna design having this configuration give the return loss value of -35.74dB and ultrawide impedance bandwidth of 11.34GHz (defined for 10-dB return loss) extending from 2.75-13.96GHz.Thus the operating band sufficiently covers the WPAN standard ranging from 3.1-10.36GHz.

Measured Results

The proposed antenna shown in Fig 1 is simulated at the operating frequency of 9 GHz in HFSS software and various results are obtained. The return loss of the proposed antenna is -35.74 dB which shows that the signal power loss in the antenna transmission is very less. This can be clearly understood by the VSWR result of the proposed antenna. Figure 3 shows the value of VSWR of the antenna lies near 2 which implies that the reflection of signal back is very less and maximum signal power is transmitted away from the antenna. The value of VSWR is near 2 for the whole bandwidth of 11.34 GHz (2.75-13.96 GHz) fully covering the requirements of UWB operation.

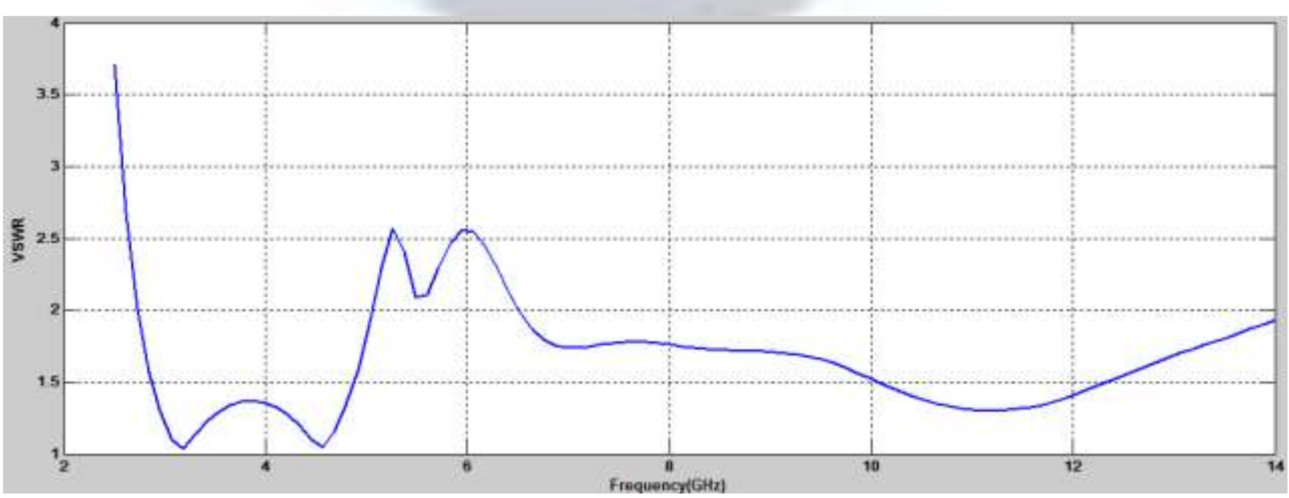


Figure 3. VSWR vs frequency curve for the proposed UWB patch antenna.

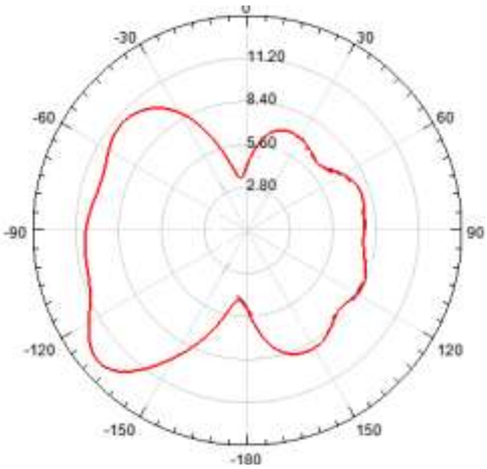


Figure 4. Far field radiation pattern in y-z plane of the proposed antenna

Radiation pattern for the proposed antenna is plotted at operating frequency of 9 GHz. Figure 4 shows the 2-D radiation pattern of the UWB patch antenna. The pattern is directional in nature. The directional pattern of the antenna in y-z plane makes it applicable for X-band applications. Fig 5 shows the radiation pattern of the proposed antenna which is omnidirectional in nature but with large back lobes. Thus this antenna should be preferred in y-z plane for coverage as well as point-to-point link applications. The peak gain of antenna is also calculated at 9 GHz operating frequency.

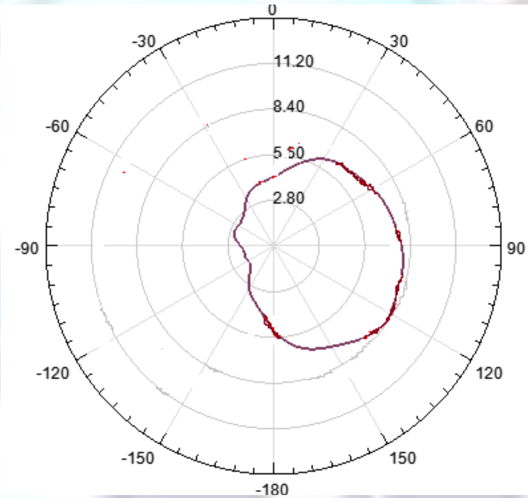


Figure 5. Far field radiation pattern in x-z plane of the proposed antenna

Fig 6 shows that peak gain is greater than 3 dB and its value varies from 4-16.5 dB in the frequency range of 2.75-13.96 GHz. The gain is stable with less than 3 dB variations in the whole frequency range. The sharp decreasing trend is observed at 3.5 GHz, which demonstrates that it is effectively notched.

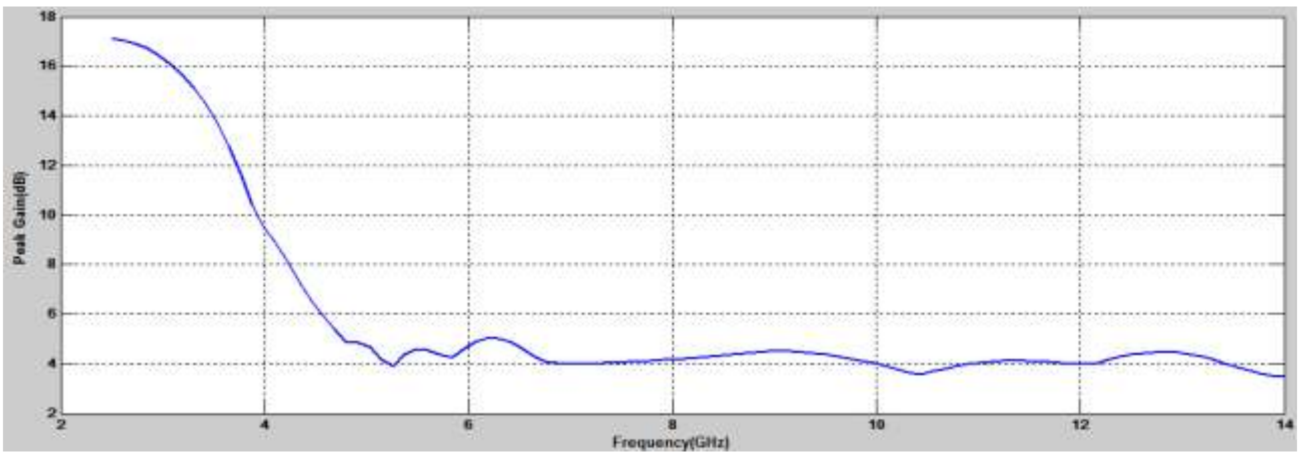


Figure 6. Peak gain vs frequency curve for the proposed UWB patch antenna

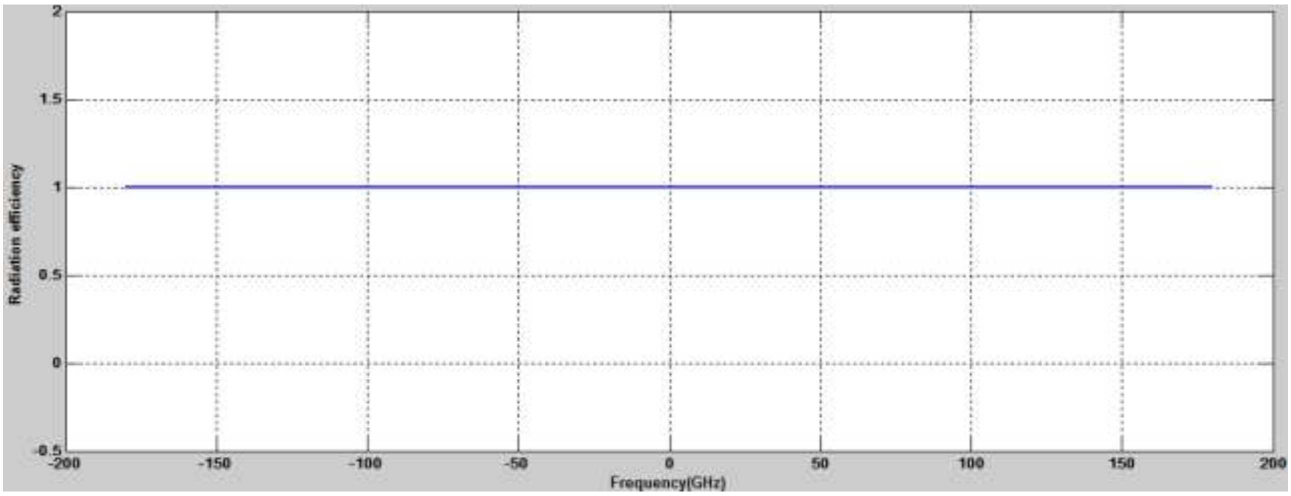


Figure 7. Radiation efficiency vs frequency curve for the proposed UWB patch antenna

Finally, the radiation efficiency of the proposed antenna is calculated. It is calculated by using the following formula-

$$e = \frac{P_{rad}}{P_{acc}} \qquad 1$$

Here, P_{rad} stands for radiated power and P_{acc} for accepted power. Figure 7 shows that the radiation efficiency at the operating frequency of 9 GHz is nearly 1 i.e. 99%, which implies that maximum power is radiated away from the antenna.

Conclusion

A novel miniaturized probe-fed planar patch antenna designed by adequately notching and slotting the patch for UWB operation has been presented. With an antenna size of only 11 X 15 mm^2, multiresonance having ultrawide bandwidth, low return loss, VSWR, high gain and radiation efficiency with suitable radiation performance to cater for the WPAN standard and X-band applications is achieved.

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