A Compact Microstrip Fed Notched and Slotted UWB Microstrip Patch Antenna

Aparna Saxena[1], Richa Sharma[2]

[1]Uttar Pradesh Technical University, Ajay Kumar Garg Engineering College, Ghaziabad, India

[2]Uttar Pradesh Technical University, Ajay Kumar Garg Engineering College, Ghaziabad, India

Abstract: ***A compact planar microstrip patch antenna is designed for ultrawideband(UWB) applications. Introduction of notches and slots in the rectangular patch leads to 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, ultrawideband (UWB).

1. Introduction

There are several types of microstrip antennas (also known as printed antennas) the most common of which is the microstrip patch antenna or patch antenna. A patch antenna is wide-beam , narrowband antenna. It is fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Microstrip antenna radiator can have any continuous shape shapes like circular, square, rectangular.

These antennas being conformable, mechanically rugged and having a very low profile are often mounted on the exterior of aircraft and spacecraft and are also incorporated into mobile radio communications devices. It has tremendous applications in space, global positioning system (GPS), radar systems, military, mobile communications, remote sensing etc. The 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. 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 [1-11], but, this method relatively increases 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 [8], the meandered strip type [1], the coplanar waveguide (CPW)-fed monopole types [3], [9], the microstrip-fed patch types [4]–[10], etc. However, most of these designs still have either a complex structure or a large size for being built into the compact space.

Therefore such designing of the patch antenna is required in which bandwidth is increased and the size of the antenna is reduced. Hence slots and notches are introduced in this paper which leads to enhancement of bandwidth and other antenna parameters. The slots introduced 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. [2]

This paper is thus aimed at describing the design and realization of a microstrip patch antenna for the UWB applications. The patch monopole prototype has a planar and simple structure to make it easy to integrate itself with the system circuit and is also capable to achieve a low -factor for effectively increasing bandwidth by means of simply inserting slots into the patch. Hence 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 enhanced antenna parameters for UWB application can be achieved. Effects of cutting notches and embedding slots to the original patch and ground on resonance were studied. [2]

2. Antenna Design And Discussion

The microstrip fed UWB slotted patch antenna shown in figure 1 consists 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.

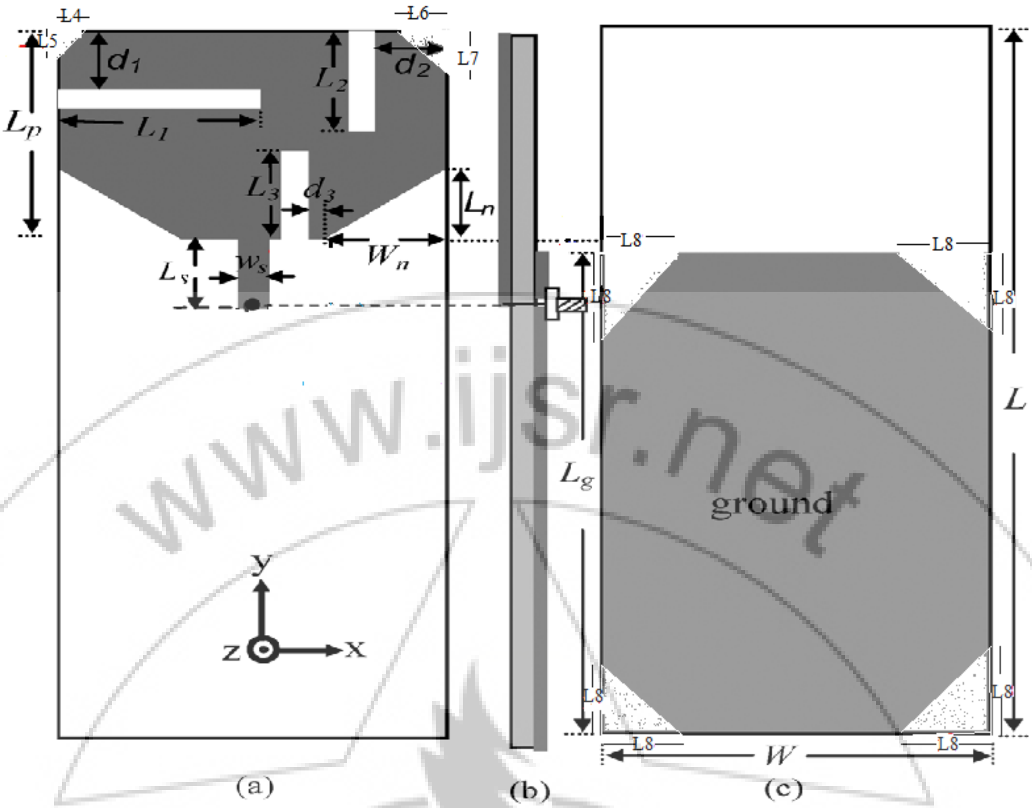


Figure 1: Slotted patch antenna design configuration (a) Top view (b) Side view (c) Bottom view

The substrate has a thickness of 0.8mm with relative permittivity (ϵ_r) of 4.4. And the rectangular patch used has the dimensions of L_p X W mm^2. Feeding provided to the patch is by 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.

Notches have been introduced in the top side corners of the patch and in the ground plane of the proposed antenna design to to make antenna work in below 10dB range and improve the return loss.
Proper geometric design parameters have been selected for these notches and slots embedded in patch and ground plane by using iterative design process and listed in Table 1.

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

Proposed antenna design having this configuration give the return loss value of less than -28dB 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.

3. Results

The proposed antenna shown in figure 1 is simulated at 5 different frequencies of-4.62, 5.36, 7.34, 9 and 13.5 GHz in HFSS software and various results are obtained. The return loss of the proposed antenna at these 5 different frequencies is shown in figure 2.

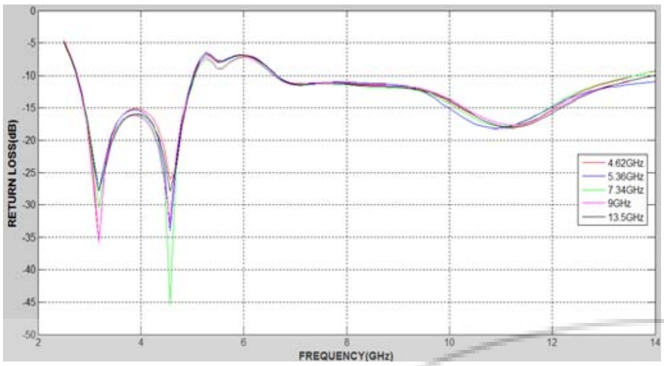


Figure 2: Return Loss vs frequency curve at 5 different frequencies of the proposed antenna

The peak return loss values at these 5 different frequencies are listed in table 2.Peak value of return loss was obtained at 7.34GHz. All the remaining frequencies have the return loss value less than -34dB except at 13.5GHz which has return loss of -29dB.

Table 2: Peak Return Loss Value at Different Frequencies

Frequency(GHz	4.62	5.36	7.34	9	13.5
Return Loss(dB)	35.73	34.05	45.44	35.74	-29

This low value of return loss signifies that the signal power loss in the antenna transmission is very less. This can be clearly explained by the Voltage standing wave ratio (VSWR). It informs about the amount of a wave which is reflected back to the antenna. Figure 3 shows the value of VSWR of the antenna lies less than 2 for all the 5 different frequencies.

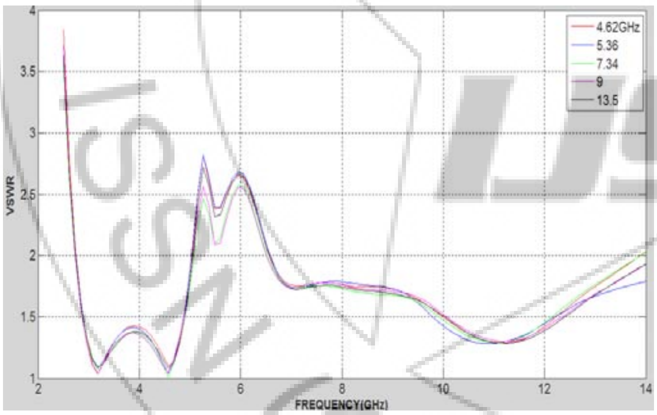
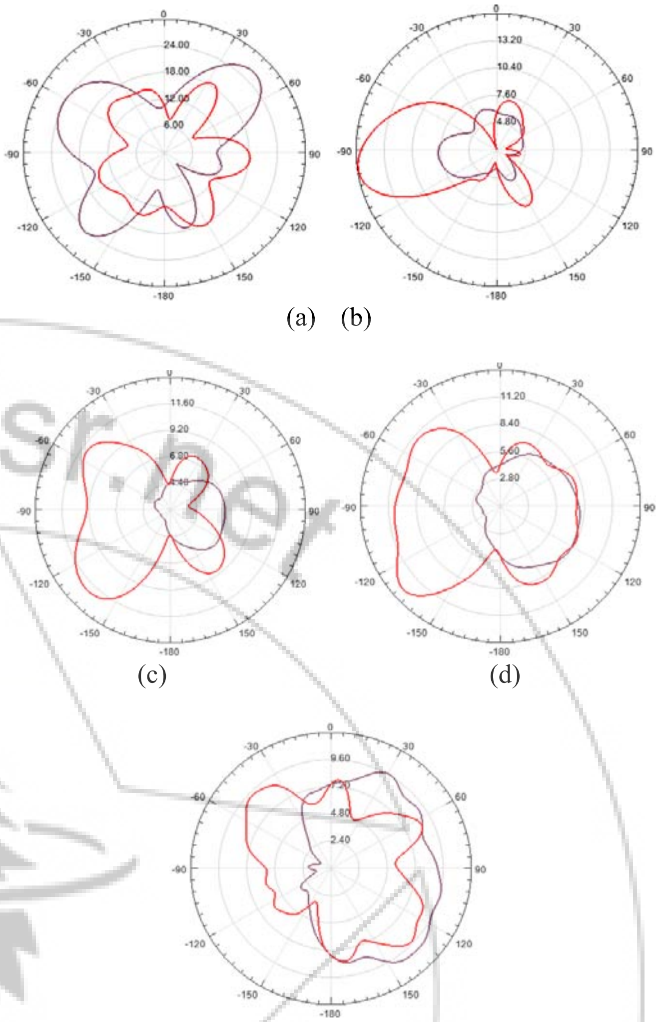


Figure 3: VSWR vs frequency curve at 5 different frequencies of the proposed antenna

At 4.62GHz the VSWR value falls below 1.5 which shows 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) which covers the requirements of UWB operation.

Radiation pattern for the proposed antenna is plotted at these 5 different frequencies. figure 4 shows the 2-D radiation pattern of the UWB patch antenna.



(a) (b)

(c) (d)

(e)

Figure 4: Radiation Pattern at different operating frequencies
(a) For frequency 4.5 GHz
(b) For frequency 5.36 GHz
(c) For frequency 7.34 GHz
(d) For frequency 9 GHz
(e) For frequency 13.5 GHz

The radiation pattern is plotted in two planes,y-z plane shown by the red colour and x-z plane represented by the brown colour. The pattern is obtained by the antenna at all these 5 frequencies is omnidirectional, hence making the antenna applicable for WPAN applications. Directional pattern is also obtained by the proposed design of the antenna by considering the y-z plane for all frequencies except at 13.5GHz. This makes the antenna applicable for point-to-point link applications. Therefore, this antenna can be used for various applications by just changing the plane of the antenna radiations.

Gain is four pi times the ratio of an antenna's radiation intensity in a given direction to the total power accepted by the antenna. Peak gain, in turn, is the maximum gain over all the user-specified directions of the far-field infinite sphere. Eqn. (1) specifies the formula used to calculate gain in HFSS

$$\text{Gain}=4\pi\frac{U}{P_{acc}} \quad (1)$$

U is the radiation intensity in watts per steradian in the direction specified.
P_{acc} is the accepted power in watts entering the antenna.

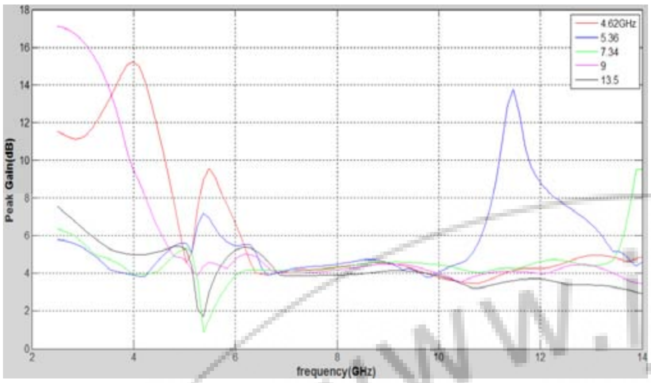


Figure 5: Peak Gain vs frequency curve at 5 different frequencies of the proposed antenna

The peak gain of antenna is calculated at these 5 different frequencies are shown in. figure 5. The 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, 5GHz and 11GHz which demonstrates that it is effectively notched.

4. Conclusion and Future Scope

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 point-to-point link applications is achieved.

This antenna due to its low profile can be easily integrated in embedded systems and is suitable for WLAN and X-band applications. The antenna works below 10dB for the whole WPAN range cover form 3.1-10.86GHz and thus applicable for WPAN and UWB applications.

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