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Research Article

Compact Fractal Ground Based UWB Band Notch Antenna

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Abstract: A compact micro-strip fed planar UWB monopole antenna with band notch features is proposed in this study. The proposed design consists of rectangular radiating patch with impedance steps and fractal slots in the partial ground plane. Wide-band matching is obtained by using the stair cased radiating patch and fractal slots in the partial ground plane. A slot is inserted in the radiating patch to reject 5.8 GHz WLAN band.The design antenna has a compact size of (30×36 mm^2).The proposed antenna is modelled on FR4 substrate and is simulated in CST Microwave studio. The results have also been verified using Ansoft (HFSS).The antenna due to its compact size and appreciable properties can be used in portable UWB systems.

Keywords: UWB antenna, bandnotch, fractal

1. INTRODUCTION

The frequency band from 3.1 GHz to 10.6 GHz has been allocated by the Federal Communications Commission (FCC) for Ultra wideband (UWB) wireless communication applications. As UWB is the most promising technology for future short range wireless communication [1]. The advantages of UWB communication are that they offer more resistance to multipath phenomenon, high data rate short range wireless communication, low complexity and low emission power. Antenna is the important part of UWB system. The antenna required must have an omnidirectional and stable radiation pattern and high radiation efficiency [2].

The problem is that the IEEE 802.11a WLAN system operates in 5.15 to 5.825 GHz band which generate potential interference with the UWB communication. This interference can be avoided by using good filtering techniques. But the filtering technique is much expensive and increases the system complexity. So by designing antenna having band notch features is the most simple and economical solution [3-5]. Various band-notched UWB antennas have been developed for UWB wireless communication. There are various techniques to design band notch antennas such as etching L-shaped, E-shaped, C-shaped, arc shaped and U-shaped slots on the radiating patch [6-10]. Also there is another technique which uses parasitic strips in the printed monopole [11-12].

In this paper, a novel compact planar UWB antenna is analyzed and simulated. The proposed rectangular patch antenna parameters are calculated based on transmission line modal analysis [13] and the detailed antenna geometry and parameters are given. The antenna with non-uniform impedance steps and fractal slots in the ground plane can cover the entire UWB frequency band without rejecting WLAN band. First the antenna results have been analyzed with and without fractal slots [14] in the partial ground plane. Then we have analyzed the antenna results with and without notch by introducing slot in the radiating patch. A slot in the radiating patch is inserted to notch the 5.8 GHz WLAN band without affecting its gain. The antenna designed has high gain, stable radiation pattern and best matching in the desired frequency band.

2. ANTENNA GEOMETRY

The configuration of the proposed UWB antenna having band notch characteristics is shown in Fig. 1.

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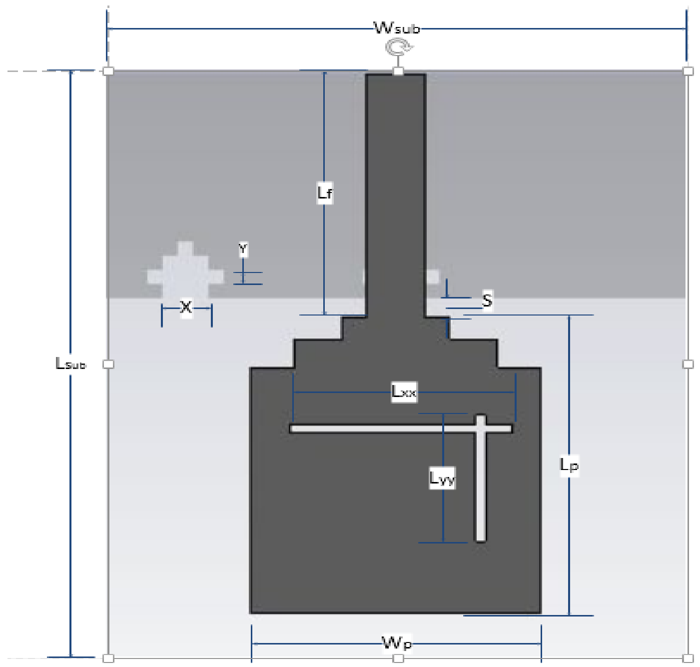


Fig. 1. Front view of proposed band notch UWB antenna.

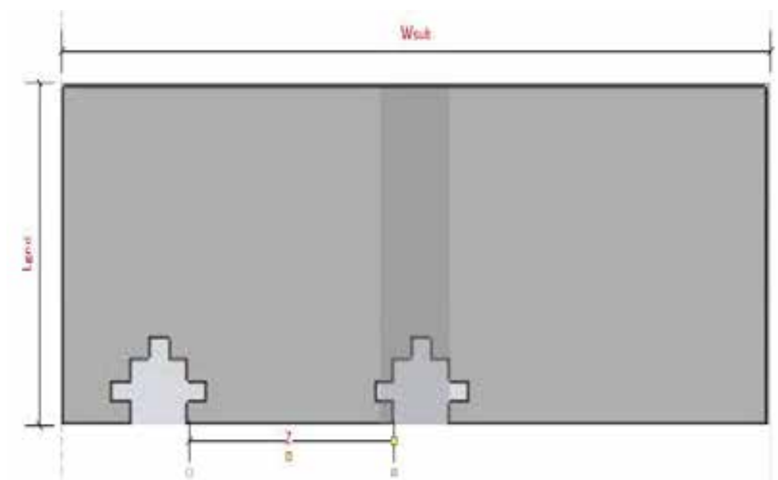


Fig. 2. Bottom view of proposed UWB antenna with fractal slots.

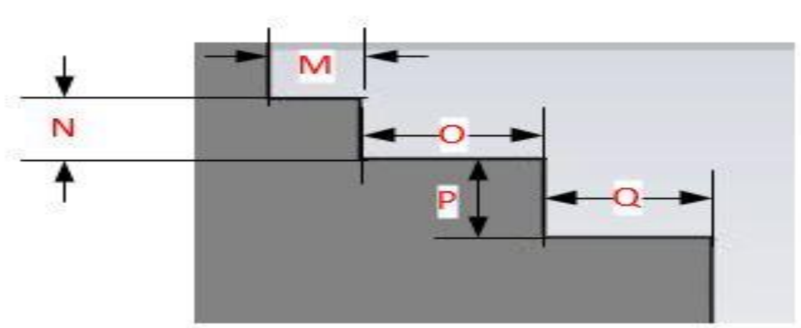


Fig. 3. Stair case steps for impedance matching.

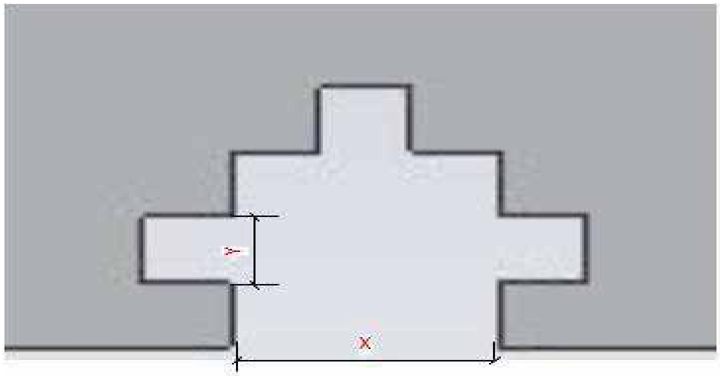


Fig. 4. Fractal slot in ground plane.

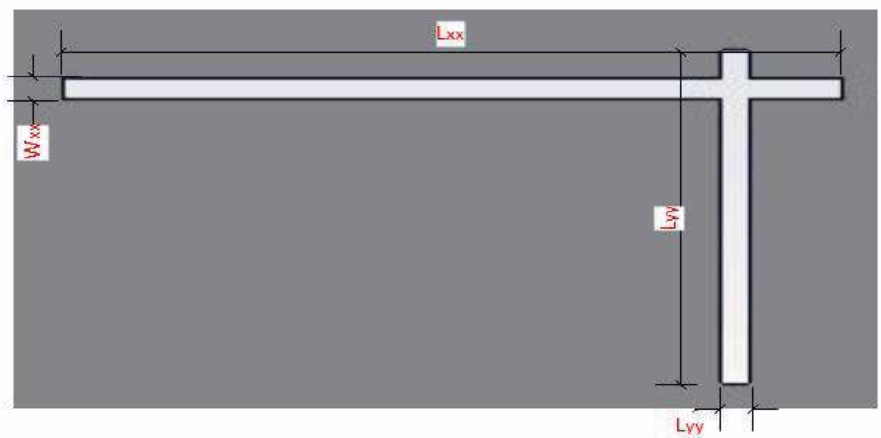


Fig. 5. L-shaped slot inserted in the patch for introducing band notch.

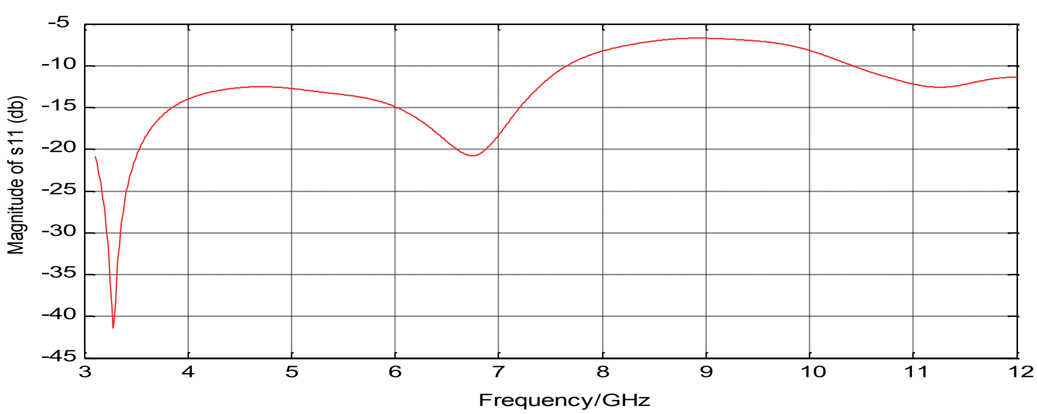


Fig. 6. S_{11} of UWB antenna without slot.

Table 1. Dimensions of substrate, patch, ground plane and feed line.

Substrate Width (Wsub)	Substrate Length (Lsub)	Patch Width (Wp)	Patch Length (Lp)	Ground Length (Lgnd)	Feed line length (Lf)	Feed line Width (Wf)	Gap between patch and gnd (S)
30 mm	36 mm	15 mm	16.5 mm	12.5 mm	13.5 mm	3 mm	1 mm

Table 2. Dimensions of stair cased impedance steps.

M	N	O	P	Q
1.25 mm	1.25 mm	2.5 mm	1.6 mm	2.5 mm

Table 3. Dimensions of inserted slot in the patch.

Horizontal length (Lxx)	Vertical length (Lyy)	Horizontal Width (Wxx)	Vertical Width (Wyy)
11.5 mm	7 mm	0.5 mm	0.5 mm

The top view of antenna consists of rectangular patch with L shaped slots as shown in Fig. 1. This antenna covers the entire UWB range while rejecting the WLAN band. The antenna is fed with a 50 Ω microstrip line modeled on FR4 substrate having thickness 1.6 mm, relative permittivity of 4.4 and tanδ = 0.0025. The bottom side of antenna consists of partial ground plane with two fractal shaped slots as shown in Fig. 2. The overall size of antenna is 30×36 mm2 (Wsub × Lsub) which is quite compact. The distance between ground plane and radiating patch is kept at S = 1mm.

The optimized dimensions of the proposed design are listed in Table 1 to Table 3. Fig. 3 shows the stair case configuration at the edge of antenna for impedance matching. Fig. 4 shows fractal slot inserted in the ground plane. There are two fractal slots in the ground plane and the distance between them is Z =11.2 mm while X = 2.4 mm and Y = 0.8 mm. Fig. 5 shows the L shaped slots inserted in the antenna for introducing the required band notch at 5.8 GHz WLAN band.

3. RESULTS AND DISCUSSION

3.1 UWB Antenna without Slot

First the antenna has been designed without fractal slots in the ground plane. The S_{11} plot shows that the antenna cannot cover the entire UWB band and is matched to the 50 Ωtransmission line only from 3.1 to 7.7 GHz.

So we must enhance the impedance bandwidth of the antenna. This is achieved by increasing electrical path length for the surface current. To increase the electrical path length for surface current distribution two similar fractal slots are etched on top edge of the ground plane. So by increasing the electrical path length for surface current the impedance bandwidth in turn enhances [15, 16]. The fractal geometry has been introduced in the ground plane as shown in Fig. 4. The distance between these two slots(Z) is optimized to achieve the required UWB frequency range. Good Impedance matching has been found at Z= 11.2 mm and S = 1 mm which is the gap between the radiating patch and the ground plane. The S_{11} curve in Fig. 7 shows that the antenna now covers the entire UWB frequency band and has a maximum value of -25db at 6.65 GHz.

3.2. UWB Antenna with Slot

By inserting slot in the radiating patch, the antenna operates in the entire UWB band while rejecting WLAN signal. The slot geometry is shown in the Fig. 5. Now there is no more potential interference of the UWB and WLAN signals. The length of the notch band is calculated from the equation below:

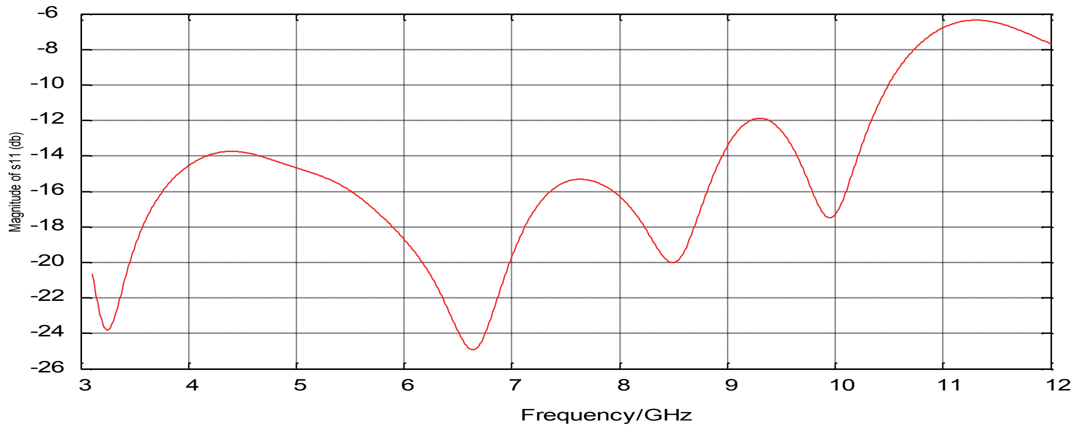


Fig. 7. S_{11} for UWB antenna with fractal slots.

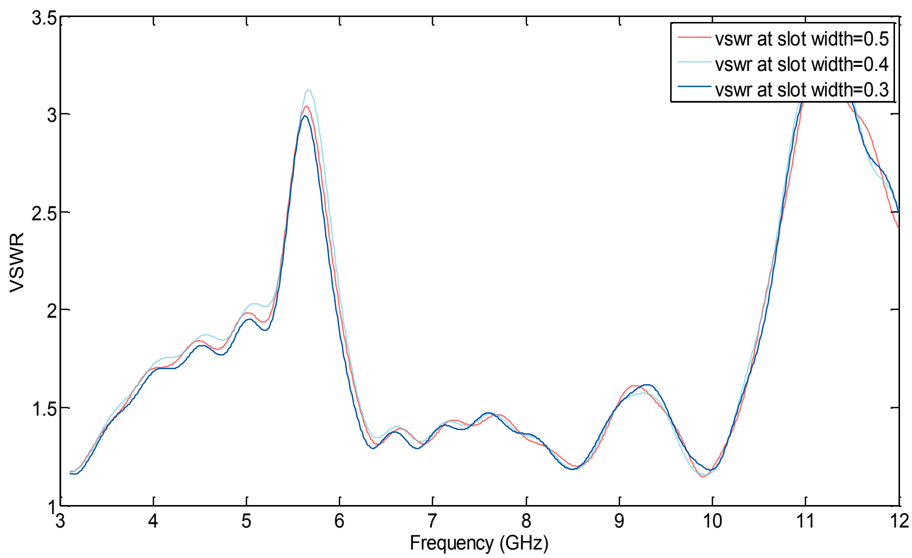


Fig. 8. Effect on VSWR due to slot width.

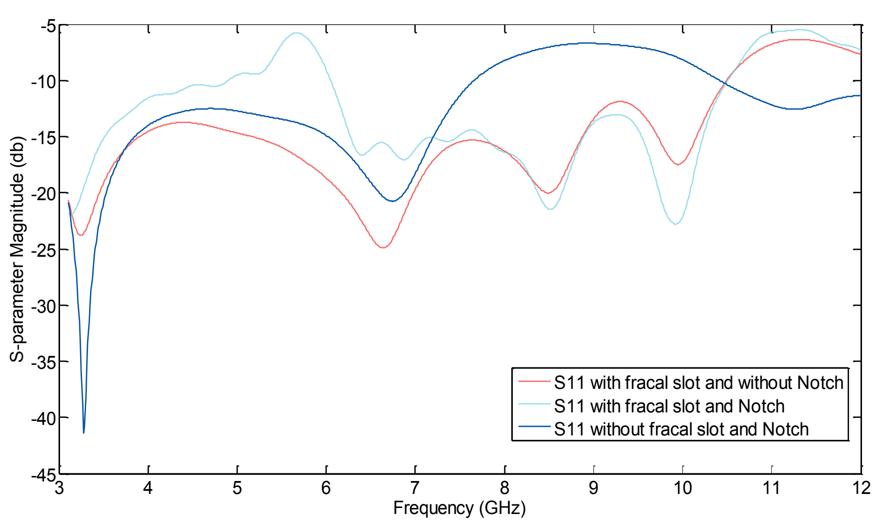


Fig. 9. S_{11} for proposed UWB antenna using Ansoft HFSS.

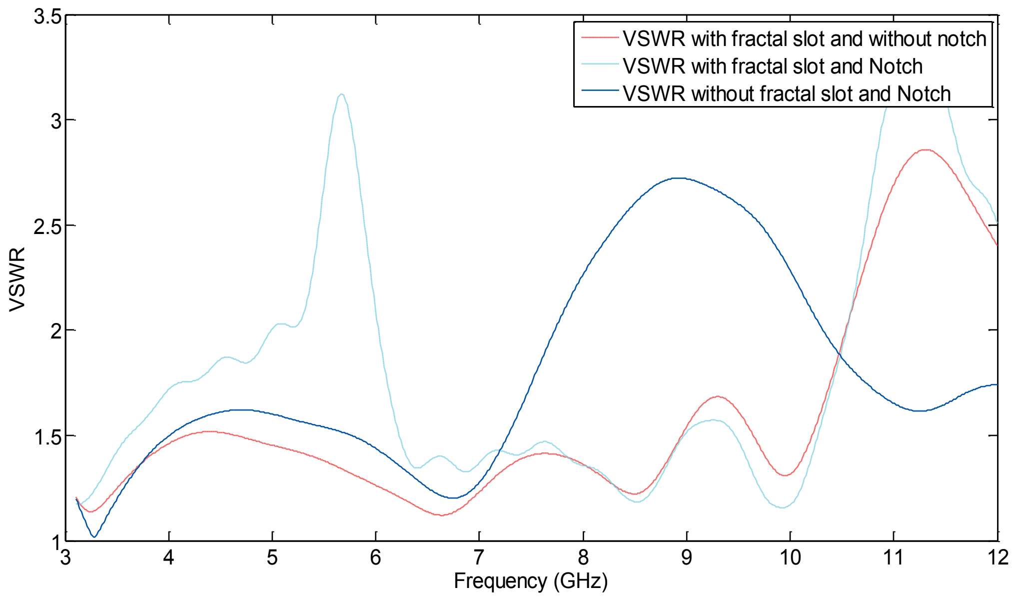


Fig. 10. VSWR for the simulated UWB antenna using Ansoft HFSS.

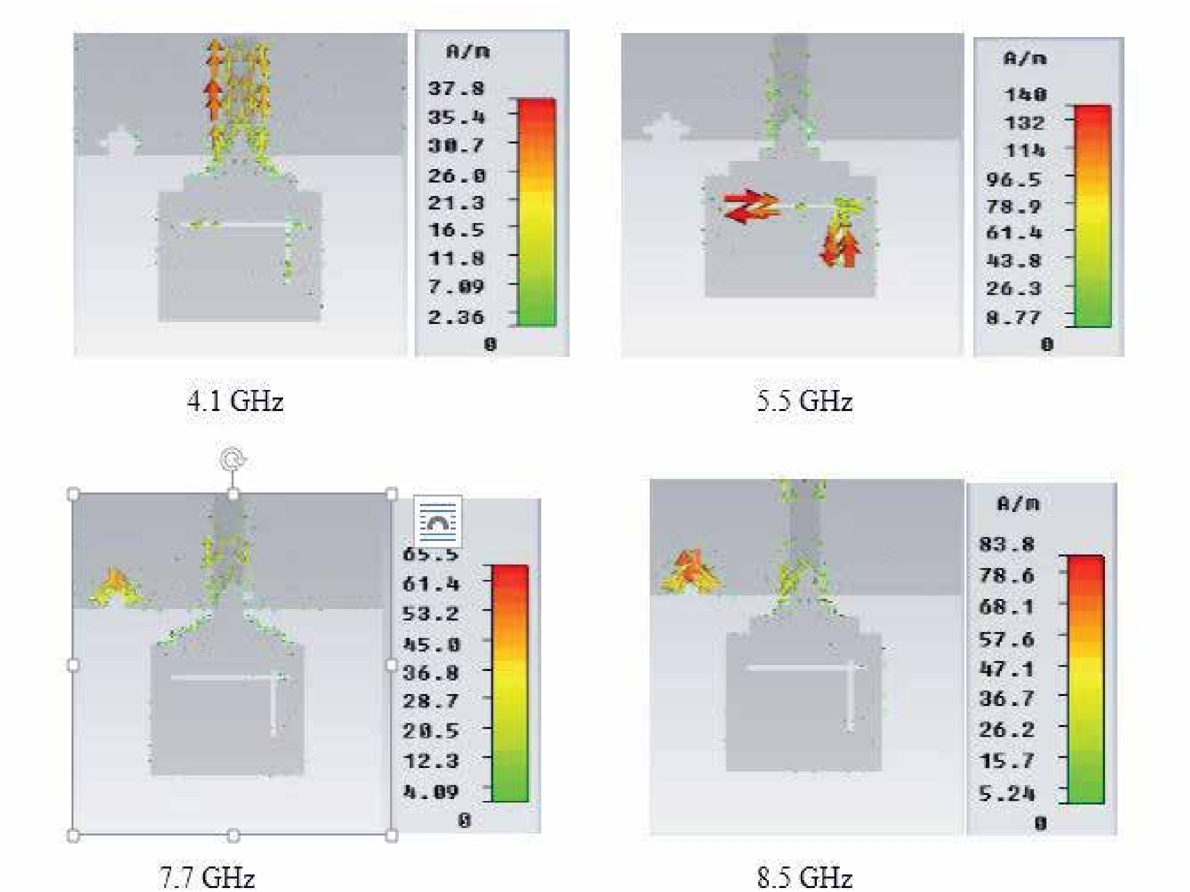


Fig. 11. Simulated current distributions on the surface of the proposed antenna at different frequencies.

$$f_{notch} = \frac{C}{2 \times L \sqrt{\frac{\varepsilon r+1}{2}}}$$

Where, L is the length of the slot, εr is the relative permittivity and C is the speed of light. The length of the slot resonator is calculated from (1) while its position is analyzed from surface current distribution as shown in Fig. 11. The width of the slot is selected by simulating at different slot widths as shown in Fig. 8. The resonator will introduce high reflection at resonance which will lead to band notching effect. The length (Lxx and Lyy) of the slot is the important parameter in notching the desired band. It is cleared from the VSWR curves that the antenna performance is slightly changed by changing the slot width, so we can choose any value of the above. We selected the width of the slot to be 0.5 mm.

So, by introducing the slot of length and width discussed above in the radiating patch, the VSWR in the 5.8 GHz WLAN band is greater than 2 as shown in Fig. 8, which shows that the antenna performance is not good in this band.

The antenna results have also been verified using Ansoft HFSS. The verified results have been plotted in Fig. 9 and Fig. 10. The S_{11} and VSWR plot has been analyzed first with and without fractal slots in the partial ground plane and then analyzed with and without notch in the radiating patch. These results show that there is one notch band at 5.8 GHz WLAN band. A very small difference is observed between the results simulated through CST and HFSS.

3.3 Surface Current Distribution

Fig. 11 shows the simulated current distributions on the surface of the proposed antenna at 4.1, 5.5, 7.7, and 8.5 GHz. At 4.1, 7.7, and 8.5 GHz, the current mostly flows along the microstrip feed line, while very small current is around the slot. On the other hand, the surface current distribution on the antenna at 5.5 GHz is concentrated around the slot.

3.4 Radiation Patterns

The simulated far field radiation pattern of the proposed antenna at different frequencies is shown in Fig.11.The radiation pattern is stable throughout the operating band and shows that no ripples are present at higher frequencies.

3.5 Far Field 3D Radiation Pattern

The simulated far field of the proposed antenna at two different frequencies is shown in Fig. 12. The antenna has a maximum gain of 5.31 dB at 8.5 GHz and an average gain of almost 4.2 dB.

3.6 Transmission Response of UWB Antenna

This section considers the communication between the two designed UWB band-notched antennas. The two antennas are designed and the distance between the transmitting and the receiving antennas is kept 60cm, which is almost 6 wavelengths of the considered band of operation at the lowest frequency. Also we consider that the antennas are at the far field of each other. Now by exciting the transmitting antenna with different input pulses such as modulated Gaussian pulse, first order Rayleigh pulse, fifth derivative of Gaussian pulse and fourth order Rayleigh pulse.

We also consider that the antennas operate in two orientations: (a) face to face and (b) side by side as shown in Fig. 13. Fig. 14 shows the transfer function, S_{21} versus the frequency in two different orientations. By analyzing the figures it is clear that the transfer function of face to face orientations is better than that of side by side.

4. CONCLUSIONS

A compact UWB rectangular radiating patch antenna along with fractal slots in the partial ground plane has been proposed. Wide band matching is achieved by introducing fractal slots in the partial ground plane and non-uniform stair cased impedance steps at the radiating patch. The potential interference between the UWB system and WLAN band has been minimized by introducing slot in the radiating patch, which rejects the WLAN band. The antenna results have been analyzed showing high Gain and good radiation pattern. The antenna exhibits low VSWR in the frequency band from 3 to 10.6 GHz with a band-notching effect at the frequency band at 5.8 GHz. The antenna has a compact size which makes it a potential candidate for UWB portable devices.

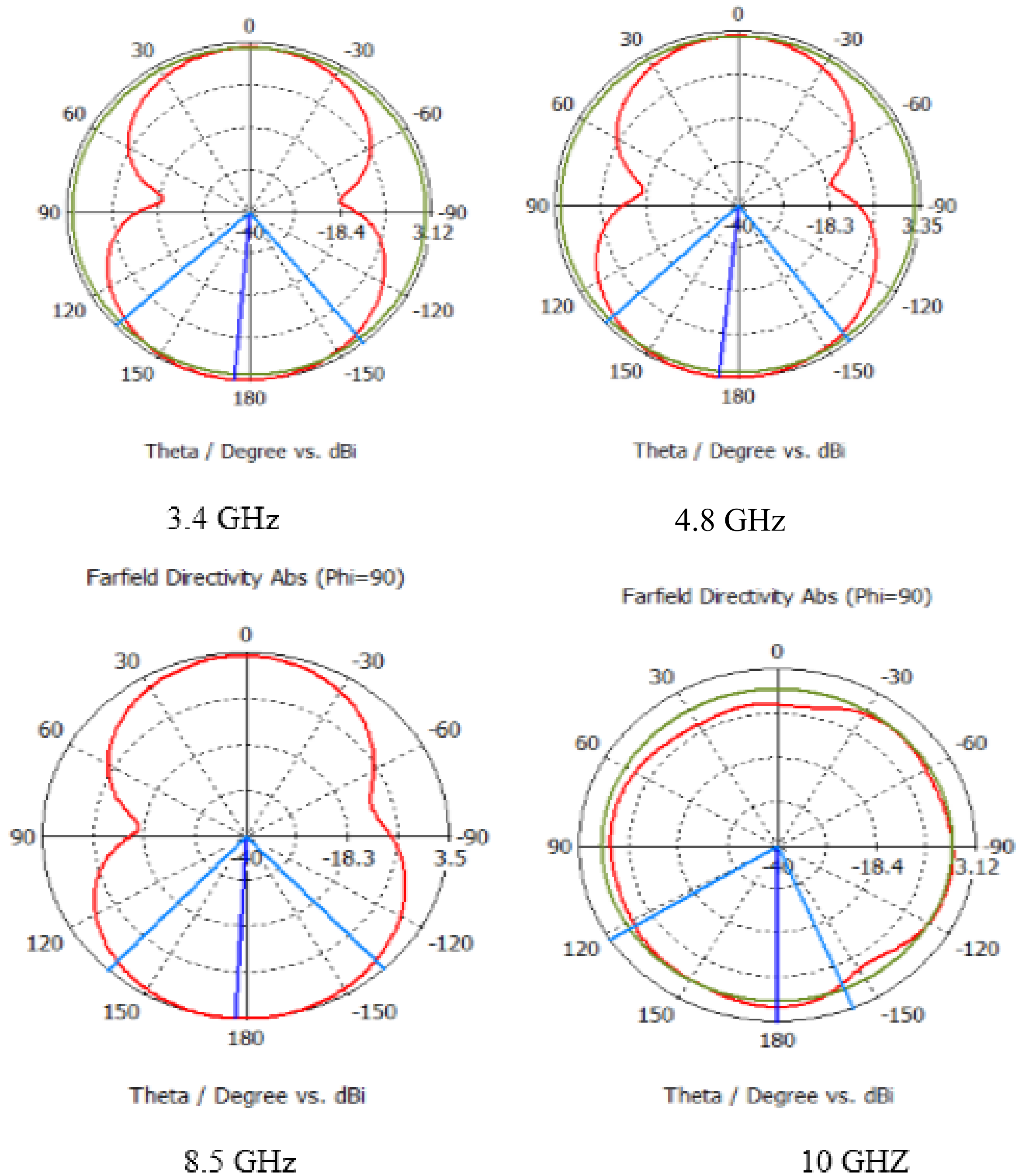
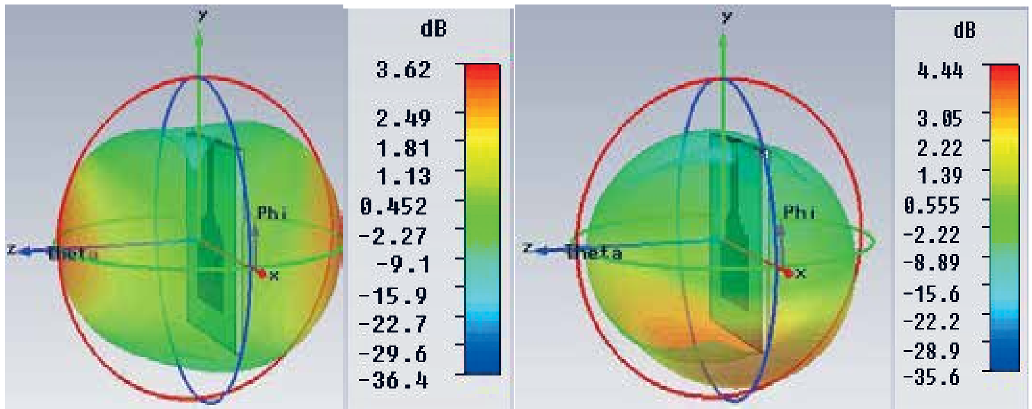


Fig. 12. Simulated far field radiation pattern of the proposed antenna at different frequencies.



5.45 GHz 7 GHz

Fig. 13. Simulated 3D far field of the proposed antenna at 5.45GHz and 7GHz.

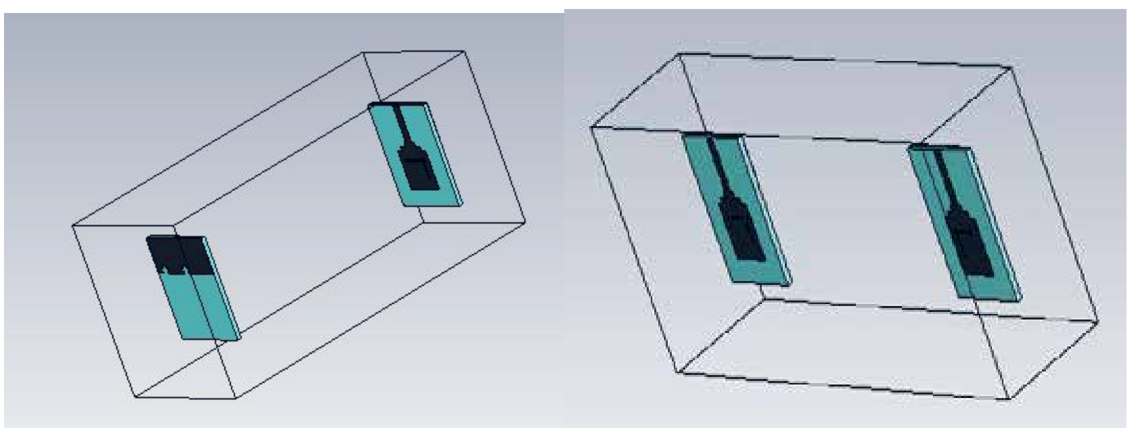


Fig. 14. Transmitting and Receiving antennas in two different orientations: (a) Face to face; (b) Side by side.

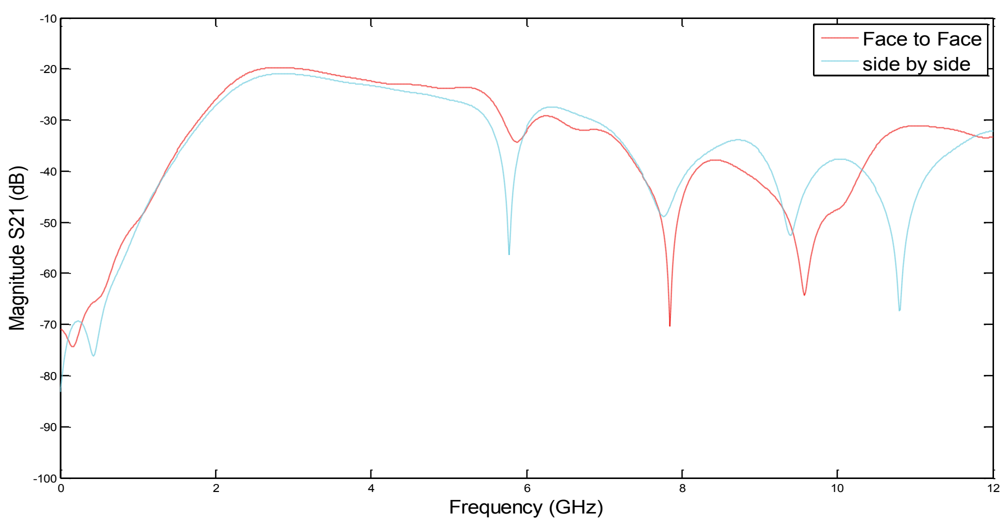


Fig. 15. Transmission Coefficient S_{21} between two UWB antennas.

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