UWB Rectangular Slot Antenna with Band-notched Characteristics

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ABSTRACT

This paper presents a band-notched rectangular slot antenna for Ultra Wide-Band (UWB) communication which is designed on a dielectric substrate with relative permittivity (ε_r) of 4.4, thickness of 1.6 mm and loss tangent (tan δ) = 0.002. This antenna is designed to be used in frequency band of 2.44-10.44 GHz. Band notched characteristics of antenna to reject the frequency band of 5.15–5.825GHz, which is limited by IEEE 802.11a, is realized by rectangular slot etched on the radiator. Parametric study of rectangular slot of proposed antenna also has been investigated. The antenna with optimal parameters obtained from parametric study is simulated.

Keywords

Ultra-wide band (UWB) antenna, Circular Monopole, band-notch, Rectangular slot, WLAN.

1. INTRODUCTION

UWB technology has been rapidly advancing as a promising high data rate wireless communication technology for various applications. The emergence and acceptance of the ultra wide-band (UWB) impulse radio technology in the USA [1], there has been considerable research progress put into UWB radio technology worldwide. Recently, the Federal Communication Commission (FCC)'s allocation of the frequency band 3.1–10.6 GHz for commercial use has sparked attention on ultra-wideband (UWB) antenna technology in the industry and academia.

Several antenna designs have been studied for UWB applications [2–5]. Planar monopole antennas are good candidate for UWB communication because of its ease of fabrication, simple structure, low profile and lightweight. Due to wide frequency bandwidth, printed circular disc monopole antenna is considered as promising candidates for applications in UWB communications [11]. However, the frequency band of UWB communication systems includes the IEEE 802.11a frequency band; i.e., 5.15–5.875GHz. Therefore, UWB communication systems may generate interference with wireless local-area networks (WLANs) based on IEEE 802.11a standard. The interference between ultra-wideband (UWB) antennas and other narrow band systems have spurred growth in designing UWB antennas with notch characteristics. To overcome problems caused by electromagnetic interference (EMI) between UWB and WLAN systems, various UWB antennas with a notch function have been developed for UWB communication systems [6–10]. Notch characteristics with triple notch frequencies, dual notch frequencies and single notch frequency were achieved in this literature using various design configurations employed with planar monopole printed antennas.

The proposed antenna in this paper covers the commercial UWB frequency range (i.e., 2.44–10.44 GHz), while rejecting the limiting band (i.e., 5.15–5.825GHz) to avoid possible interferences with existing communication systems running over it. The band rejection of the antenna is provided by etching the rectangular slot on the radiator. Effect of the parameters of this rectangular slot like slot length and slot width on performance of antenna have also been studied. Performance simulations of the antenna were performed with IE3D software, which is based on the method of moment. The remaining of this paper organized as follows. Section II presents the design of the antenna. Parametric study of our proposed antenna is presented in Section III. Simulation results accompanied with some discussions are presented in this section. Finally, Section IV concludes the paper.

2. ANTENNA DESIGN

The geometry of proposed UWB band-notched antenna is as shown in Fig. 1. The antenna permittivity is 4.4, thickness is 1.6 mm and loss tangent (tan δ) = 0.002. The antenna structure is simulated using method of moment based IE3D 14.1 software. Designed antenna system consists of circular monopole with rectangular slot on radiator for UWB band-notch function. Overall antenna dimensions are 30 mm x 35 mm. Optimized dimensions are listed in Table 1.

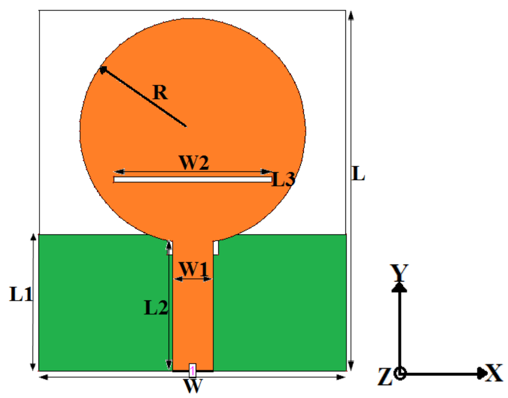


Fig.1. Antenna Geometry

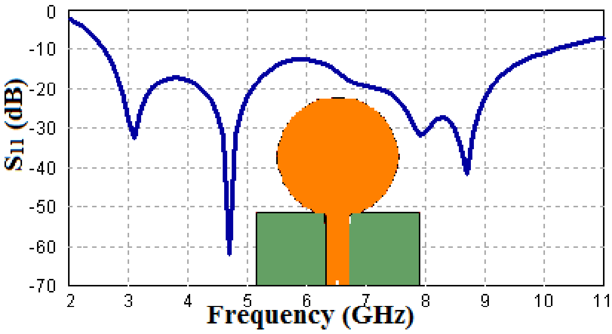
Table 1. Optimum dimensions of proposed antenna

Parameters	Value(mm)	Parameters	Value(mm)
W	30	L1	13.4
L	35	L3	0.5
R	11	W1	4
L2	12.7	W2	15.4

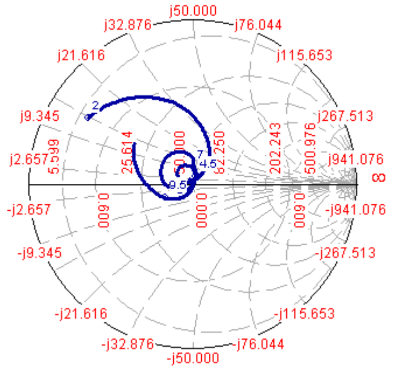
3. RESULTS AND DISCUSSIONS

3.1 Simulated S-parameters

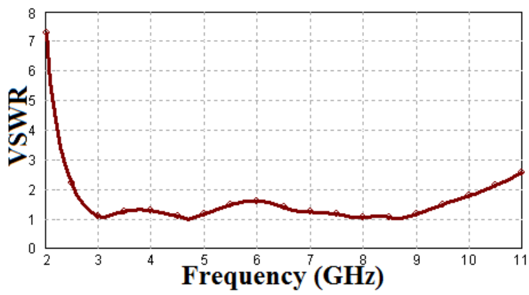
The S_{11} vs frequency plot of the only UWB antenna, its impedance variation and VSWR plot is shown in Fig 2(a), (b) and (c) respectively. Circular monopole of radius (R) =11 mm gives the UWB operation (2.44-10.44 GHz) VSWR is 2 in whole UWB band.



(a)



(b)



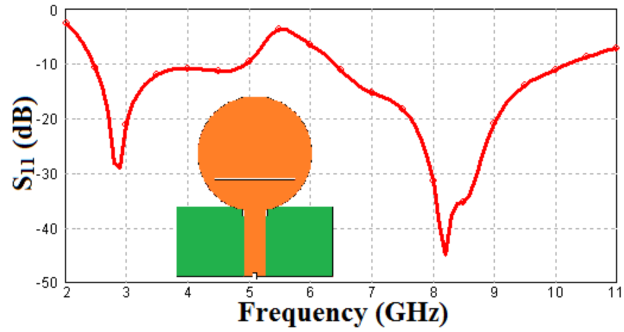
(c)

Fig.2. UWB Antenna (a) Simulated S_{11}, (b) Impedance variation, (c) VSWR Plot.

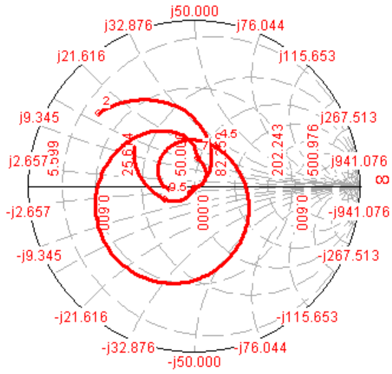
The notch frequencies for 5.5 GHz band is calculated using the relation given in Eq.1 [11], where c is the speed of the light, L is the length of the notch element and $\varepsilon_{eff}$is the effective dielectric constant of the substrate.

$$f = \frac{c}{2\sqrt{\varepsilon_{eff} f_r}} \qquad (1)$$

Rectangular slot (15.4 mm x 0.5 mm) is introduced on the radiator. It acts as an LC band-stop filter that blocks the current at notch frequency of 5-6.2 GHz. The S_{11} of UWB rectangular slot band notch antenna with respect to frequency plot, its impedance variation and VSWR plot is shown in Fig 3(a), (b) and (c) respectively. At notch frequency of 5.5 GHz, VSWR is above 4 and in operating band, it is below 2.



(a)



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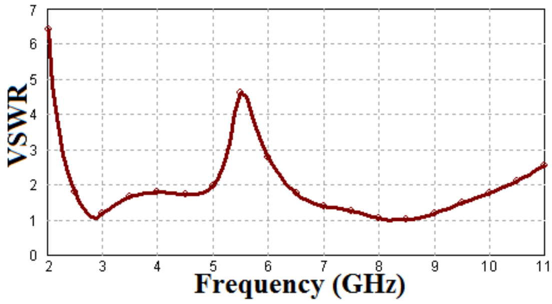


(c)

Fig.3. UWB Rectangular slot band notch Antenna, (a) Simulated S_{11}, (b) Impedance variation, (c) VSWR Plot.

Parametric Study

Fig 4 shows the variations in S_{11} with rectangular slot length (W2). As W2 decreases from 15.4 mm to 13.4 mm, band-notch frequency shifts towards higher frequency. The optimum value of W2 is 15.4 mm for required band notch frequency and bandwidth

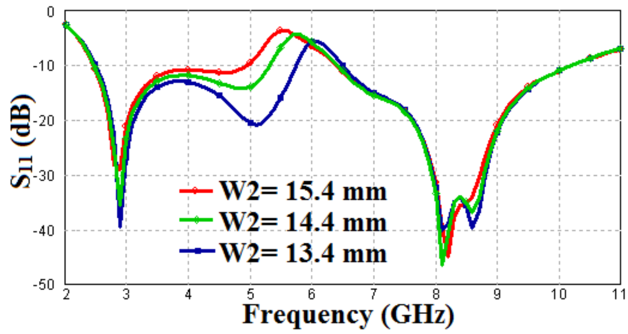


Fig.4. Variation of S_{11} with W2

Fig 5 shows the variations in S_{11} with rectangular slot width (L3). It does not show the major effect on the band-notch function. The optimum value of SW is 0.5 mm for required band notch frequency and bandwidth

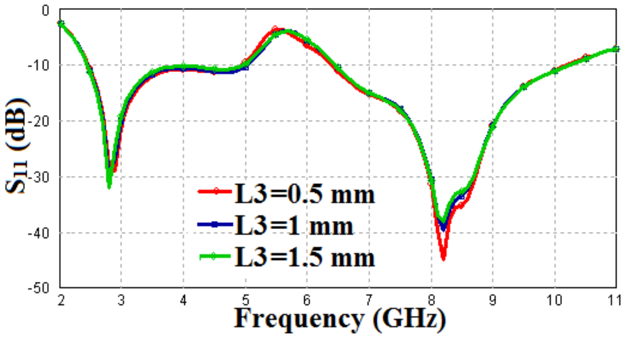
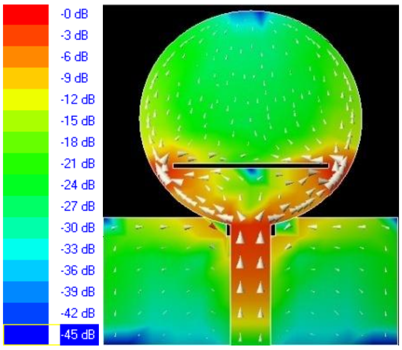
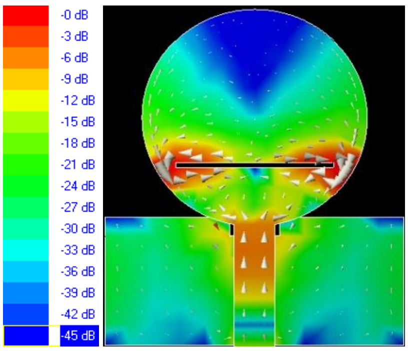


Fig.5. Variation of S_{11} with W2

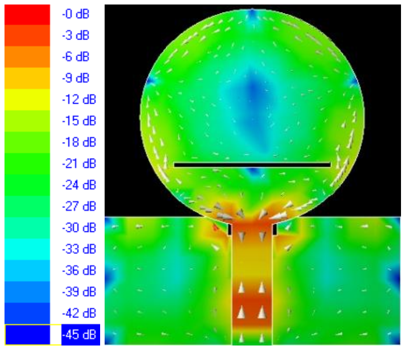
Fig 6 (a), (b) and (c) shows the surface current distribution at frequency 2.8 GHz, 5.5 GHz and 8.2 GHz respectively. Rectangular slot on the radiator blocks the current at notch frequency (5.5 GHz) and return loss degrades below the -4 dB.



(a) at 2.8 GHz



(b) at 5.5 GHz

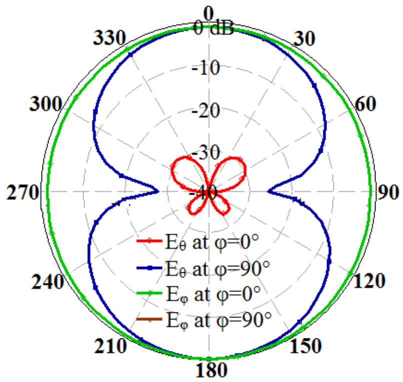


(c) at 8.2 GHz

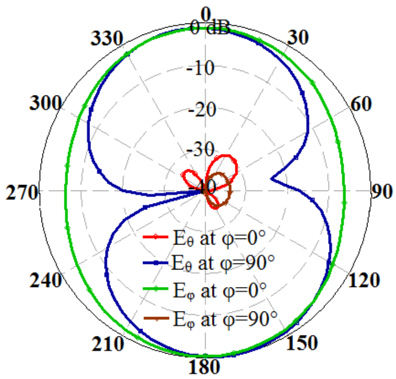
Fig.6. Surface Current Distribution

Simulated Radiation Patterns

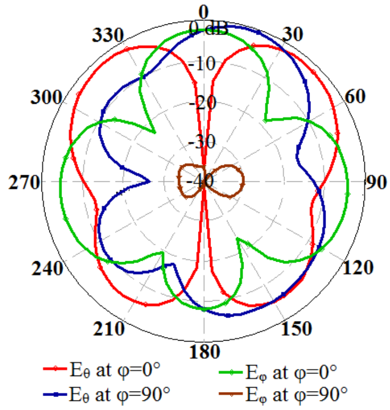
The normalized radiation patterns at 3.1, 4.4 and 8 GHz at φ =0˚ (X-Z plane) and φ=90° (Y-Z plane) are shown in Fig 7. Radiation patterns shows cross polarization increases with increase in frequency. Cross polarization also causes due to J_x current at the edge of ground plane and due to the excitation of higher order modes. Since in these antennas, monopole radiator and ground plane both contribute to radiation field. Therefore, impedance bandwidth and radiation pattern can be improved by optimizing ground plane dimensions and shape of ground plane. Impedance bandwidth and radiation pattern is more sensitive to length of the ground plane than ground plane width.



(a) at 2.8 GHz



(b) at 5 GHz



(c) at 8.2 GHz

Fig.7. Simulated Radiation Pattern

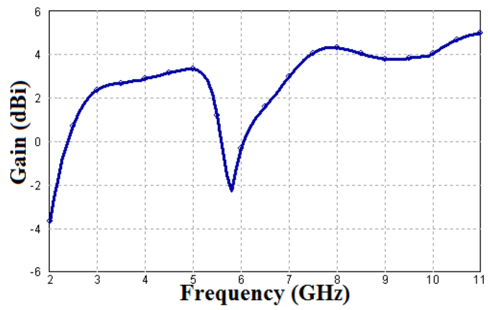


Fig.8. Antenna Gain

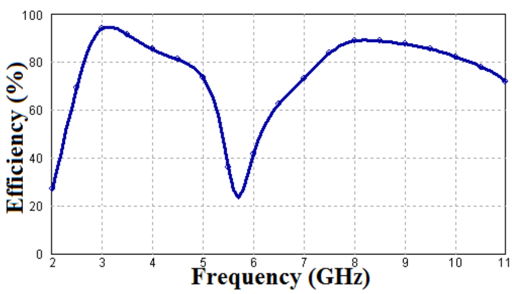


Fig.9. Antenna Efficiency

The simulated gain of proposed antenna is illustrated in Fig 8. It shows the antenna gain ranges from 2 to 6 dBi within 2.44–10.44 GHz frequency band, except for the notched band (5–6.5 GHz) where the gain decreases even to −2 dBi. Fig 9 shows the antenna efficiency curve which reveals that in notch band of 5- 6.2 GHz, efficiency goes on decreasing. Efficiency at notch frequency of 5.5 GHz is significantly decreases below the 40%.

4. CONCLUSION

A band-notched ultra wide-band rectangular slot antenna is proposed in this paper. In order to obtain band notch characteristic, rectangular slot is etched on the radiator. Band-notched characteristics can be controlled by adjusting rectangular slot length and width parameters. Parametric studies of antenna are presented. The proposed antenna design with optimal dimensions is simulated. The simulation shows that VSWR is below 2 within the desired frequency bandwidth from 2.44 GHz to upper 10.44 GHz, whereas a notched bandwidth of 5-6.15 GHz is obtained. Current distributions, radiation patterns, and gain of the antenna are also studied in this paper.

5. REFERENCES

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