CPW-fed UWB Antenna with Tri-band Frequency Notch Functionality

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Abstract **─** In this paper, a UWB antenna exhibiting frequency suppression characteristics for WiMAX and WLAN spectra is modeled and analyzed. The proposed geometry is composed of a circular radiating element. Impedance matching at higher frequencies is achieved by incorporating steps near the feedline. Introduction of arc-shaped slots in the radiator results in significant band rejection for 3.3-3.7 GHz, 5.15-5.25 GHz and 5.725-5.825 GHz. Designed antenna has an impedance bandwidth (VSWR < 2) of 9 GHz ranging 3-12 GHz. A prototype of the proposed model is fabricated on a low loss substrate. Comparative study of measured results to the simulated results depicts that the performance parameters of the antenna, e.g., impedance bandwidth, S-parameters and radiation characteristics meet the criteria for wideband applications.

Index Terms **─** Circular patch antenna, impedance bandwidth, multiband antenna, tri-band notch, UWB antenna.

I. INTRODUCTION

The advancements in the wireless technology focus primarily on high data rate transmission with minimum interference to the existing wireless standards. In 2002, ultra wide band (UWB) spectrum from 3.1-10.6 GHz is allocated for commercial use, resulting in extensive research in UWB system designing [1]. It is observed that when multiple wireless devices are operated in a close proximity, the UWB systems experience interference as the designated spectrum is simultaneously shared by various wireless standards like WiMAX and WLAN [2]. Therefore, to improve the performance, interference mitigation has become the prime task while designing UWB antennas.

The deployment of conventional RF filters in UWB systems is not feasible as this technique results in the increased size of the circuitry and complexity. Therefore, multiple band notch characteristics can be incorporated in antennas to eliminate narrowband interferences [3].

Various band stop techniques have been proposed to combat interference challenge, e.g., etching slots in the ground plane, feedline, or in the radiating element [4-6]. Parasitic elements, defected ground structures (DGS) and use of fractal geometry is also observed to obtain band notch characteristics [7-9]. The most common technique is to etch slots in the radiating element, which affects the current distribution of the radiating patch resulting in the elimination of undesired frequency ranges overlapping the operational frequency of antenna [1]. The commonly experimented slot shapes are C shape, U and inverted U, L shaped and meander line [1, 3]. Different approaches to introduce tri-band notch characteristics are presented in [10-12]. The reported UWB antennas deploy double layered metallization. However, it is indicated in [13] that single layered metallization can further reduce the fabrication cost of monopole antennas; therefore, the presented UWB antenna is based on this concept.

This manuscript introduces a planar UWB antenna with frequency rejection functionality to minimize the interference. The proposed design displays efficient elimination of WiMAX and WLAN bands. The paper is arranged as follows, Section-II comprises of the antenna modeling and optimization process, followed by the performance analysis of proposed design in Section-III. The fabricated prototype and comparison of results is presented in Section-IV. The conclusion drawn by the presented work is given in Section-V.

II. GEOMETRY OF PROPOSED DESIGN

A modified monopole antenna, printed on Roger RT Duroid 5880 of permittivity ε_r=2.2, is proposed for band notch design. Commercially available electromagnetic simulator Ansys HFSS is used to model and investigate the simulated results of proposed antenna.

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The presented UWB antenna is compact in nature, with a size of 30 mm × 32.5 mm. The radiating structure is a circular antenna of radius **R**=9.2 mm, fed by a coplanar waveguide (CPW) transmission line of impedance 50Ω with dimensions $\mathbf{L_F}$=13 mm × $\mathbf{W_F}$=3 mm. Square shaped ground plane of dimensions $\mathbf{L_G}$=12.6 mm × $\mathbf{W_G}$=13 mm is placed on both sides of feedline, separated by a distance of 0.35mm on each side.

The criterion of VSWR less than 2 was limited to the spectrum 3-8 GHz as shown in Fig. 1. It is reported that the steps near the antenna's feedline contributes towards the reduction of impedance mismatch between the feedline and antenna [14, 15]. Therefore, three symmetrical steps were integrated within the radiating structure to enhance the bandwidth of designed antenna. It is evident from Fig. 1 that the addition of each step enhances the impedance bandwidth of the antenna.

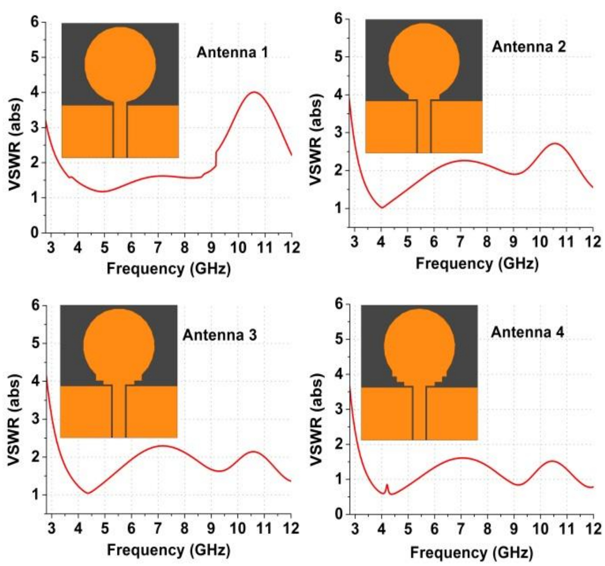


Fig. 1. Step by step optimization of simulated UWB antenna.

In Fig. 1 the simulated model Antenna 4, having three steps fused with the circular patch exhibits a VSWR < 2 for 3-12 GHz, making it operational for the ultrawide spectrum. The design is further optimized to remove electromagnetic interference caused by WLAN or WiMAX devices present in the same vicinity. For this purpose, three arcs are embedded in the radiating element to stop the reception of WiMAX and WLAN bands as shown in Fig. 2. The effective length $\boldsymbol{L_s}$ for each arc is computed using formulas [16]:

$$f_{notch} = \frac{c}{2L_s\sqrt{\epsilon_{eff}}}, \quad (1)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2}. \quad (2)$$

where, $\boldsymbol{c}$ is representing the speed of light, $\boldsymbol{f_{notch}}$ corresponds to the central frequency of the desired spectrum to be eliminated, and $\boldsymbol{\epsilon_{eff}}$ is the permittivity of the dielectric substrate, which is dependent on the dielectric contact $\boldsymbol{\epsilon_r}$ of the substrate. The calculated lengths of etched slots along with the placement position of these structures, determine the frequencies to be filtered out.

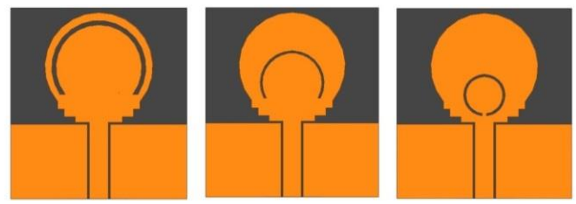


Fig. 2. Placement of resonators, S_1, S_2 and S_3 in the simulated model.

The resonating structure **'S₁'** embedded near the edge of the antenna contributes towards the suppression of WiMAX band ranging from 3.3-3.7 GHz. The slot **'S_2'** placed in the mid-section, governs the rejection of lower WLAN band from 5.15-5.25 GHz. Slot **'S_3'** present near the feedline of antenna stops the WLAN band ranging from 5.725-5.825 GHz. These slots are embedded in the radiator separately and then optimized to achieve resonance at the require frequency. The resonance produced by the slot **'S_1'** is centered at the frequency $\mathbf{fc_1}$=3.55 GHz. Similarly **'S_2'** and **'S_3'** resonate at $\mathbf{fc_2}$ and $\mathbf{fc_3}$ respectively as shown in Fig. 3.

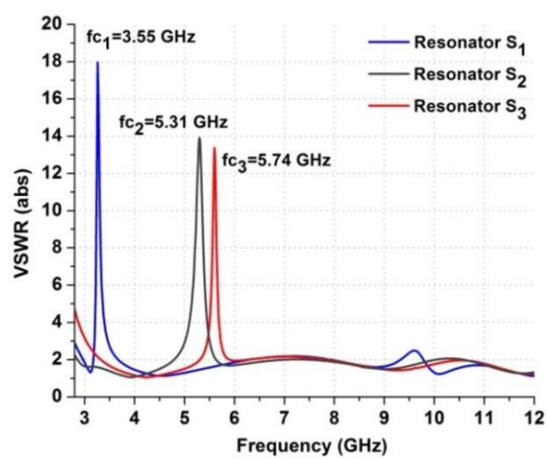


Fig. 3. Frequency response of the slots S_1, S_2 and S_3.

The three band notch structures are simultaneously deployed to suppress WiMaX and two WLAN bands. These slots are optimized to function for minimizing interference between UWB and narrowband systems. The placement distance of these slots is adjusted from the edges of antenna and the feedline [3]. The position of slots, separation between them and the arc width of each structure collectively controls the overall current distribution of the radiating element. By carefully optimizing these parameters very narrowband frequency rejections are achieved. The simulated band-notch antenna model is presented in Fig. 4. The optimized dimensions are given in Table 1.

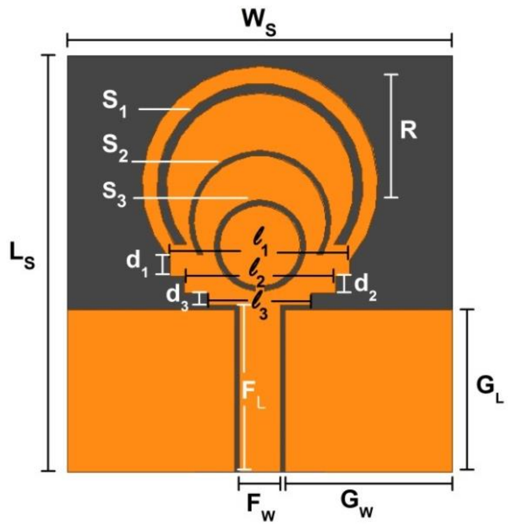


Fig. 4. Simulated UWB antenna model.

Table 1: Complete dimensions of band-notch design

Symbol	Dimension in mm	Symbol	Dimension in mm
L_S	32.5	l_1	14
W_S	30	l_2	11.8
G_L	12.6	l_3	8
G_W	13	d_1	1.28
F_L	13	d_2	1.25
F_W	3	d_3	1
S_1 Length	34.85	S_1 Width	0.93
S_2 Length	22.8	S_2 Width	0.45
S_3 Length	21.6	S_3 Width	0.4

III. PERFORMANCE EVALUATION OF THE PRESENTED DESIGN

The performance of the presented antenna is analysed on the basis of VSWR and return loss, surface current distribution and radiation characteristics.

A. VSWR and S-parameter

Figure 5 (a) shows the VSWR graph of the simulated antenna. The proposed geometry exhibits a VSWR below the value 2, except for the WiMAX and WLAN bands, where narrowband high magnitude notches are observed, as observed in Fig. 5 (a).

Similarly the return loss graph, S_{11} corresponding to the VSWR is presented in Fig. 5 (b). It is noticed that S_{11} remains below the value of -10 dB in the entire band except the band rejection frequency where it obtains a value higher than -5 dB.

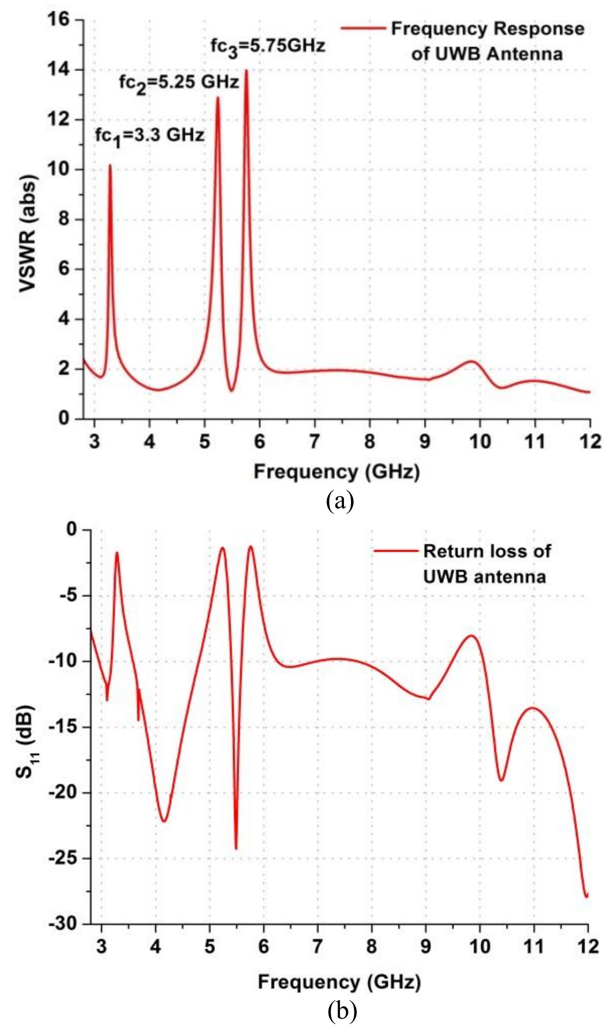


Fig. 5. Simulated results: (a) VSWR and (b) return loss.

B. Current distribution

The arc shaped slots are critically adjusted to obtain sharp rejection at the tuning frequencies. The surface current distribution plotted at the central frequency fc_1= 3.55 GHz (WiMAX), fc_2=5.25 GHz (lower WLAN) and fc_3=5.775 GHz (upper WLAN) is shown in Figs. 6 (a), (b), and (c).

It can be seen that the integration of etched slots induce band notch characteristics in the UWB antenna. The current is accumulated around the etched structure which prevents the antenna from radiating at these particular frequencies, resulting in effective band rejection. In Fig. 6 (a), the maximum current is distributed along the slot S1, which brings about the suppression of WiMAX frequencies. Similarly for the frequencies fc_2 and fc_3 the current distribution along S2 and S3 is responsible for the rejection WLAN bands.

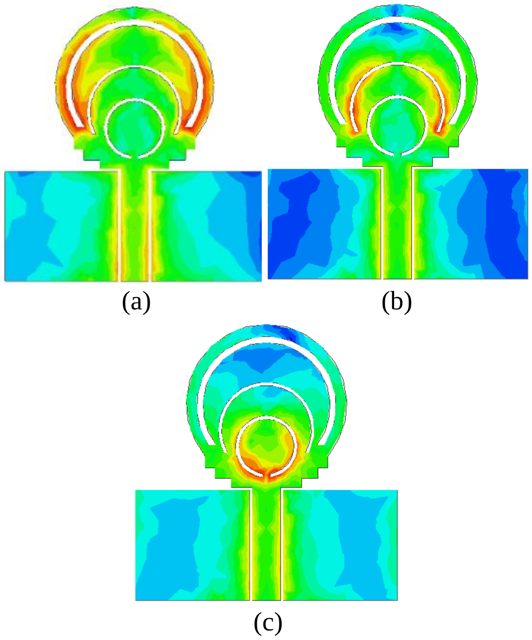


Fig. 6. Current distribution (J-surf) at frequencies (GHz): (a) 3.55, (b) 5.25, and (c) 5.77.

C. Radiation characteristics and gain

The gain of the antenna with reference to the operational frequency is presented in Fig. 7. The radiation patterns of the presented UWB antenna design are plotted in Figs. 8 (a) and (b). Due to the band notch properties, some degree of distortion is observed in the E-plane and H-plane radiation characteristics of the band-notch antenna.

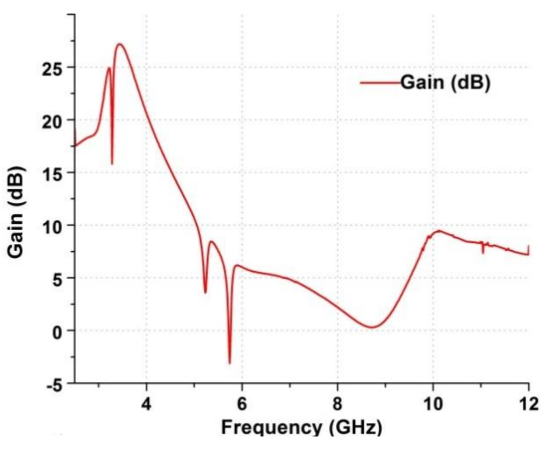


Fig. 7. Antenna gain corresponding to frequency.

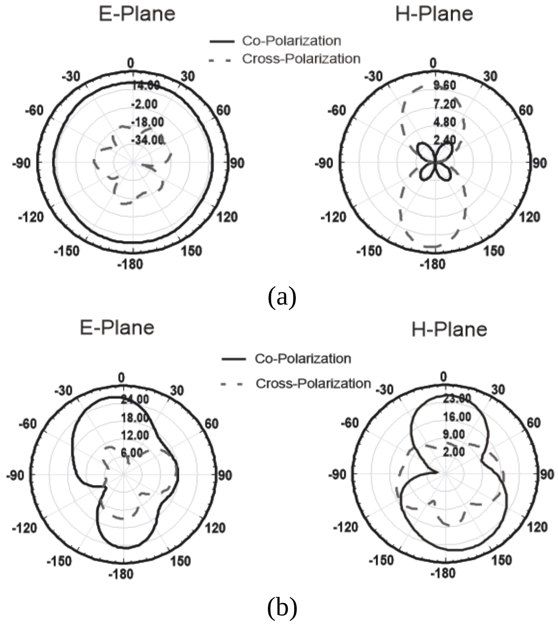
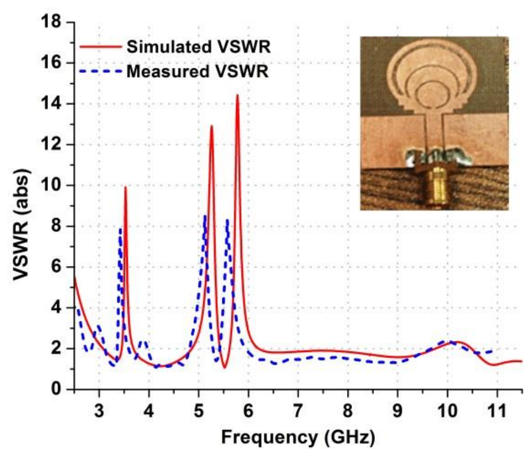


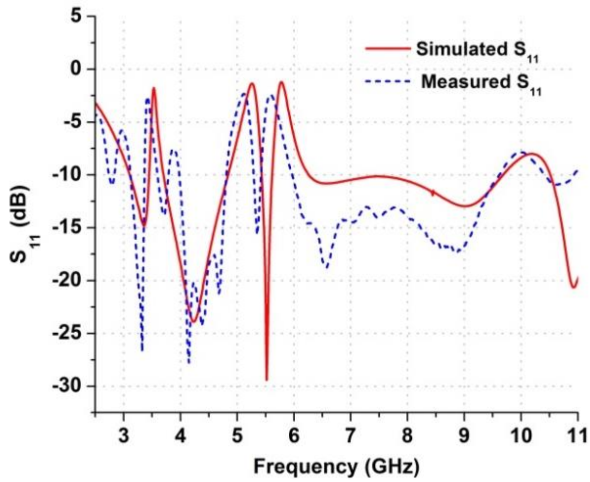
Fig. 8. E and H-field distribution: (a) 4 GHz and (b) 7 GHz.

IV. COMPARATIVE STUDY OF SIMULATED VS MEASURED PARAMETERS

A prototype of the simulated model is realized on low loss substrate Roger RT Duroid 5880 using the optimized dimensions. Single layer of substrate and one-sided metallization is deployed in the fabrication as the radiating element and ground plane is placed on the same plane. This further reduces the fabrication cost of the proposed antenna [13].



(a)



(b)

Fig. 9. Measured vs. simulated plots: (a) VSWR and (b) S_{11}.

It is evident from Figs. 9 (a) and (b) that the measured VSWR and return loss follows the same trend as observed in the simulated results. Minor deviation in central frequency of each notch is observed due to the manufacturing and calibration limitations.

V. CONCLUSION

A multiband notch antenna is modeled, realized and tested for its band rejection characteristics. The presented configuration exhibits well matched impedance characteristics, stable radiation pattern and sharp rejection capabilities in the required frequency spectrum. Investigation of the results shows that the proposed design is a feasible solution to eliminate electromagnetic interference for UWB applications.

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