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Design and Implementation of Dual Notch Band Characteristics in UWB Antenna for Wireless Personal Communications

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ABSTRACT

A monopole antenna with dual notch band was designed using Coplanar Waveguide (CPW) feed. The rectangular structure with staircase shaped radiating patch includes Split Ring Resonator (SRR) and Complementary Split Ring Resonator (CSRR) for WiMAX, WLAN and Ultra-Wide Band (UWB) applications are proposed in this paper. The first and second notch band frequencies were analyzed by varying the radius of SRR and CSRR. The proposed model was fabricated, and measurement is carried out in Network Analyzer. The measured reflection coefficient was under ≤ -10 dB for the frequency bands of 3.216 GHz – 3.99 GHz and 4.29 GHz – 4.78 GHz with a bandwidth (BW) of 780 MHz and 485 MHz respectively. The proposed dual notch band antenna has Omni-directional radiation patterns with a constant gain.

Key words: WLAN, WiMAX, UWB antenna, SRR, CSRR.

1. INTRODUCTION

The compact Ultra-Wide Band (UWB) antenna used to support various applications due to their high data rates, low power requirement, high bandwidth small size and low cost. The 3.1 GHz to 10.6 GHz frequency is used for UWB band. But several frequencies of in the UWB range used for wireless applications like WiMAX, WLAN, and HiperLAN, etc. The interference with the other wireless bands the UWB antennas performance is degrading. To improve the performance of UWB antenna notch band frequencies are needed to include. In this paper, the proposed dual notch band antenna for removing WiMAX and WLAN are designed, simulated and measured.

Recently, many designs of UWB antennas for WiMAX, WLAN applications are mentioned in the literature survey. In triple-band antennas of various strips and arc dimensions are reported. Three resonant modes were excited due to dual L-shaped strips in rectangular ring patch [1]. The rectangular horizontal strips are attached such that the antenna resonates in WLAN and Wi-MAX frequency Bands with an area of 38 x 30 x 0.8 mm^3. Similarly, an antenna with Hybrid strips which includes an L-shaped, a meandered strip with an area of 30 x 20 x 1 mm^3 and with a circular ring [2], for the frequencies between 3-6 GHz a Y-Shape strip with the defected ground plane technique were effectively implemented for wireless applications [3]. A microstrip-fed antenna with the size of 16 □ 18 mm was proposed, dual band operations for WLAN/Bluetooth for implementing UWB applications. In [4], monopole antennas with three arc-shaped monopole strips and dual L-shaped slots extending from the ground plane are designed respectively. Both these designs resonate in three bands suitable for Wi-MAX/WLAN applications. In [5], rhombic slot antennas with a couple of etched inverted U-shaped slots with -10 dB return loss for multi-bands was developed. A swastika shape radiating patch antenna with a slotted square as the ground structure was proposed low-frequency applications. Dual-band antennas for WLAN applications are proposed.

An E- and L-Shaped radiating elements generated two resonant modes fed by microstrip line is proposed in [6], to cover two higher bands and a lower band of a WLAN system. Patch antenna with structures like rectangular, circular, rhombic, and annular rings are modeled for dual-band operations to implement IEEE 802.11a/b/g using the self-similarity property [7]. A triple-band microstrip antenna using double T-shaped slots with L-shaped feed is reported. A modified staircase shaped monopole antenna fed by CPW with L-shaped strip for UWB band is proposed. In [8], L-shaped monopole antenna with microstrip-fed for high and low-frequency bands of WLAN is reported in the size of a smartphone. In [9], Notch band characteristics for WLAN is obtained by using a tapered step with a circular patch, while MIMO structure reduces the polarization diversity issues. By using tapered steps on a ground plane with UBG structure bandwidth was observed.

The antenna proposed is a circular fractal antenna with a notch band characteristic. By including U slot in the feed getting the notch band characteristics, the width and position variables are modified to get the UWB bandwidth. In [10], by altering the feed area, adding another fractal geometry to a wire square circle receiving wire a UWB antenna is proposed. Using a staircase and inverted staircase structures are proposed for UWB applications in [11]. Three resonant modes were characterized for ACS-fed monopole antenna using dual mirror L-shaped radiating structure. In an antenna comprising of the rectangular patch with dual U-shaped slots are fed by CPW mechanism, that can generate three distinct operating bands is proposed. Metamaterials are a class of artificial material which provides properties that are not readily available in nature. SRR and CSRR are metamaterial inspired structures, due to their unusual electromagnetic properties they are embedded in antennas for size miniaturization, multiband operation, bandwidth, and gain enhancement. SRR is used to produce desired magnetic susceptibility. The CSRR base 5G communication antenna is designed, simulated using HFSS and measured results are presented in [12]. The antenna had good isolation enhancement comparing with previous literature. The band reject filters using SRR and CSRR are designed, analyzed and carrying experimentation is presented in this article.

From the previous studies, the antennas have limited bandwidth, complex structures and only a few of them can cover multiple bands. The presented characterized antenna is a compact staircase rectangular patch with Dual notch characteristics for a compact line of site communications. The dual notch band characteristics are obtained by using SRR and CSRR on a staircase shaped rectangular patch. The antenna was designed using CST Microwave Studio suite software using FR4 substrate with 50-ohm feed and CPW ground plane.

2. ANTENNA DESIGN

A monopole antenna with dual-band notch was designed using Coplanar waveguide (CPW) feed. The structure is designed using the rectangular structure with staircase shaped radiating patch with SRR and CSRR for WiMAX, WLAN and Ultra-Wide Band applications. Figure 1 demonstrates the geometry of the proposed UWB antenna for dual notch applications.

The overall size of antenna 20 x 17 mm^2 is designed using FR4 substrate with $\varepsilon_r = 4.3$, the thickness (H) is 0.8 mm, $\tan\delta = 0.02$ and making the proposed antenna very compact and optimized. The CPW-fed line length (L_f), width (W_f) 5.1 mm and 2.6 mm respectively. The distance between ground plane and feedline is 0.2 mm was considered to match a 50-ohm impedance. The length and width of coplanar ground planes are 4 mm and 7 mm. The SRR and CSRR slots widths are 0.5 mm and 0.6 mm respectively. All the dimensions of the dual notch antenna are optimized and represented in Table 1.

Table 1: Parameters of the dual notch band antenna

S. No	Parameter	Dimensions (in mm)
1	L	20
2	W	17
3	H	0.8
4	L_f	5.1
5	W_f	2.6
6	L_g	4
7	W_g	7
8	L_p	11.5
9	W_p	12
10	T_p	0.0256
11	R1	4.7
12	R2	4.2
13	R3	3.7
14	R4	3.1
15	L1	1
16	L2	1
17	L3	1
18	W1	6
19	W2	8
20	W3	10

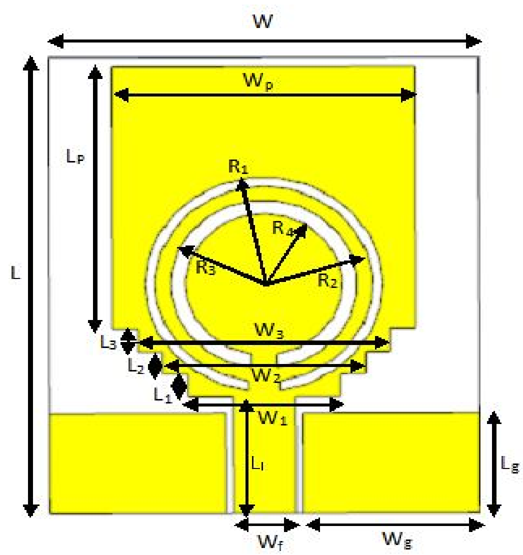
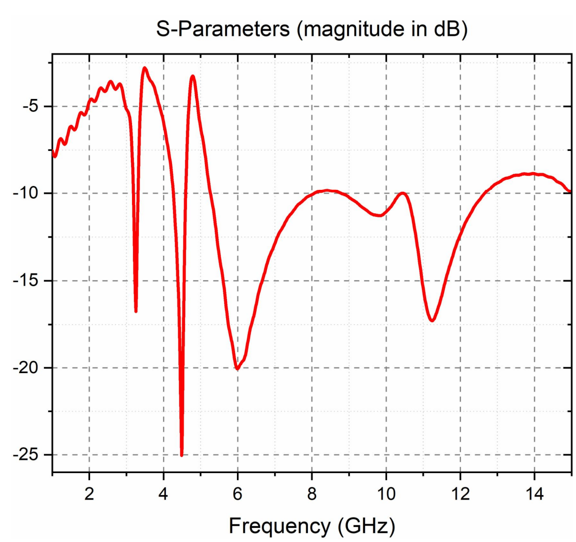
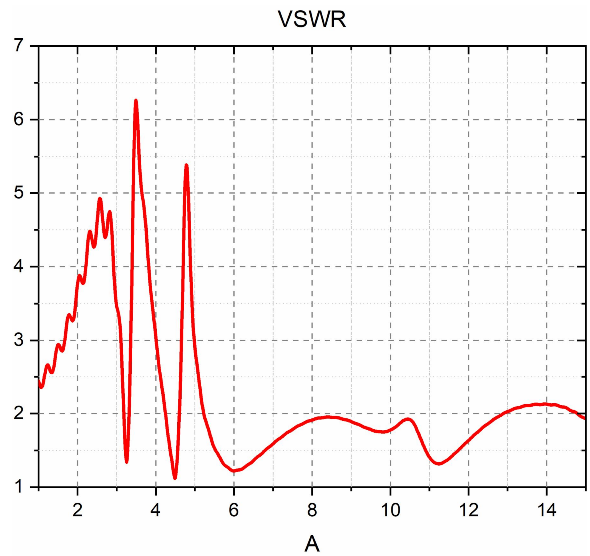


Figure 1: Geometry of the proposed dual notch band CPW antenna**.**



(a)



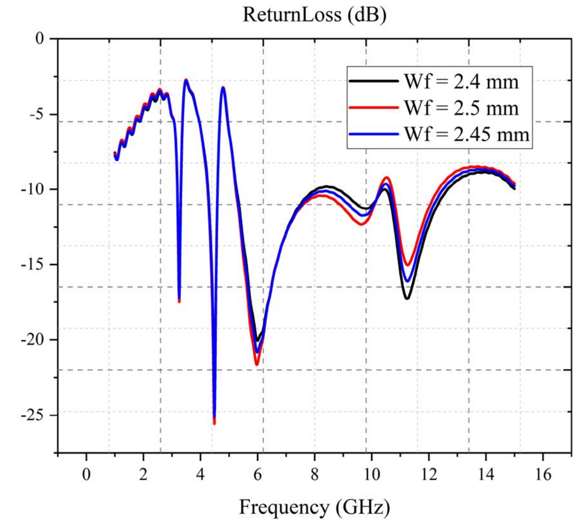
(b)

Figure 2: Simulated plots of (a) RL (b) VSWR of the dual notch band antenna

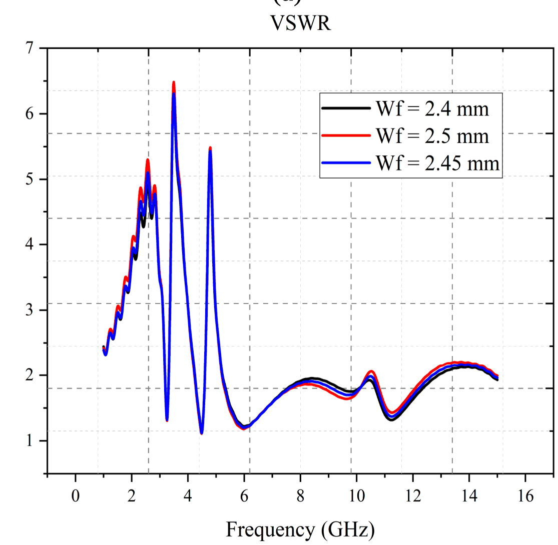
The SRR and CSRR used to get dual notch characteristics for two frequency bands. In this model, a single CSRR is implemented inside an SRR on the rectangular patch. The SRR is used to get the first stopband characteristics in the frequency range of 3.216 GHz – 3.99 GHz the operating range of WiMAX. The CSRR is used to get the second stopband characteristics in the frequency range of 4.29 GHz – 4.78 GHz the operating range of WLAN. The corresponding plots for Return Loss vs Frequency and VSWR vs frequency are plotted to depict the operational ranges of the two bands in figure 2.

3. RESULTS AND DISCUSSIONS

This dual notch band antenna has been simulated and observed the return loss and VSWR for varying feed line widths, the height of substrate, length of patch and different radii of the SRR and CSRR. The return loss (RL) and VSWR plots in figure 3 for variable widths of feed indicate the narrow change in it, causes a small variation in the RL and VSWR. Although the plots coincided for the frequencies with a RL of -25 dB at 4.5 GHz, -18 dB at 3.2 GHz. From figure 4, the optimized height of the antenna is taken as 0.8 mm. For a patch length of 11 mm and 11.5 mm, the results are almost similar with a promising return loss of -25 dB at 4.5 GHz frequency in figure 5. But even for another 0.5 mm rise in patch length i.e. at a length of 12 mm, the antenna has a RL of -45 dB at a frequency of 4.9 GHz.

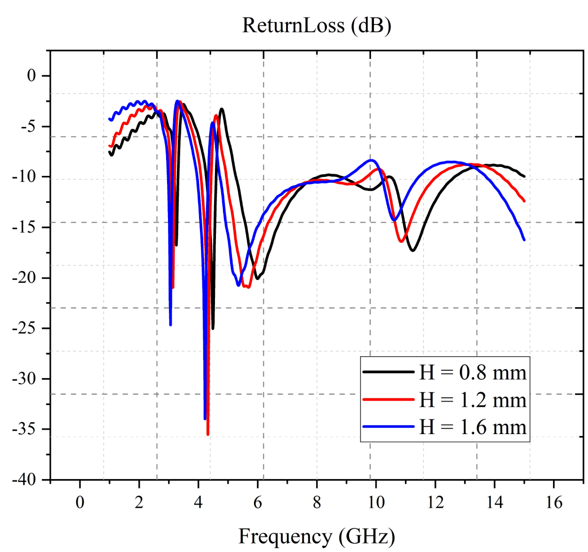


(a)

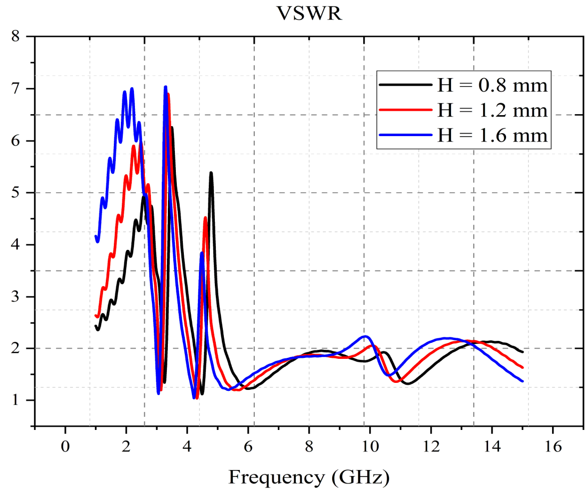


(b)

Figure 3: (a) RL (b) VSWR plot for varying W_f

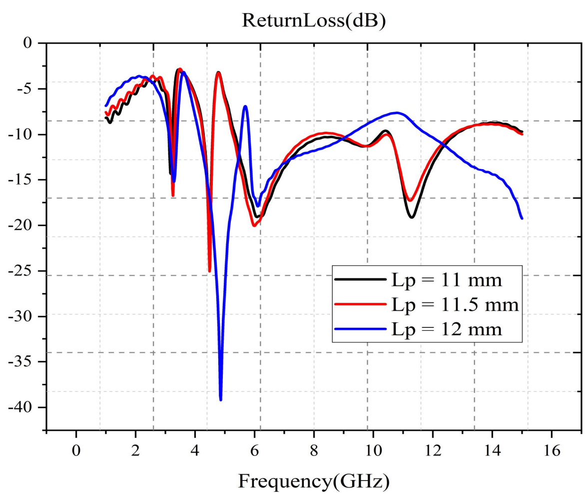


(a)

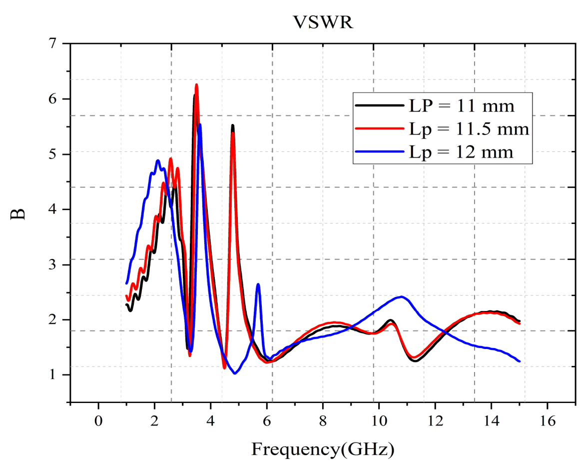


(b)

Figure 4: (a) RL (b) VSWR plot for varying H



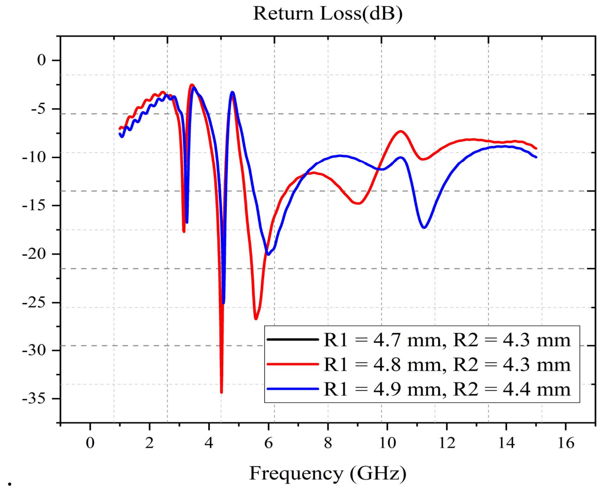
(a)



(b)

Figure 5: (a) RL (b) VSWR plot for varying L_p

From figure 6 and figure 7 shows the RL and VSWR of the change in radius of the SRR and CSRR. The change in radius also affects the RL and VSWR performance of the dual notch band antenna. The optimized radius of SRR and CSRR are R1 = 4.7 mm, R2 = 4.2 mm, R3 = 3.7 mm, R4 = 3.1 mm.



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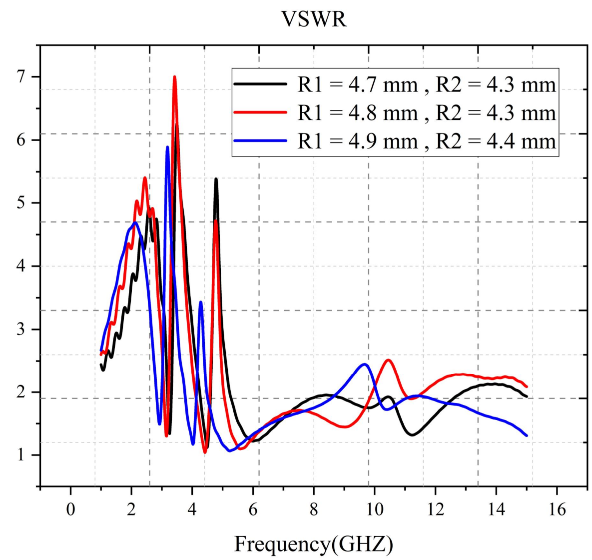
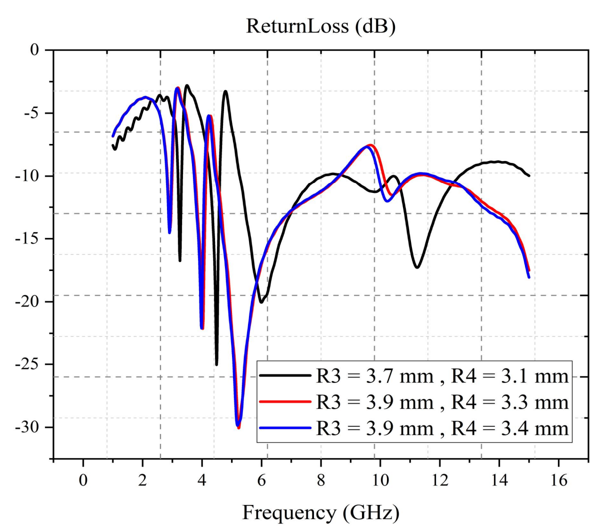
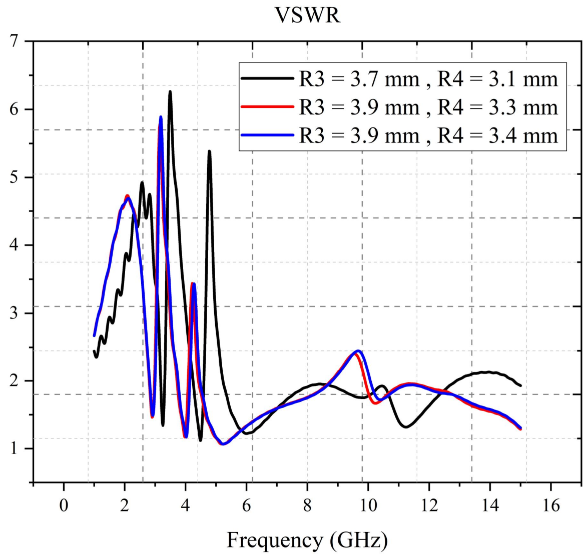


(b)

Figure 6: (a) RL (b) VSWR plot for varying R1, R2



(a)



(b)

Figure 7: (a) RL (b) VSWR plot for varying R3, R4

The optimized dual notch band UWB antenna is fabricated and carried measurements using Anritsu Model number MS2037C (VNA Master). Figures 8 and 9 show the fabricated prototype and the testing setup used to measure the antenna characteristics respectively. The measured results show that |S11| ≤ -10 dB for the operating bands from 3.216 GHz – 3.99 GHz and from 4.29 GHz – 4.78 GHz respectively. This results the proposed UWB antenna can be used for notching the WiMAX/WLAN frequencies in UWB band. The simulated and experimental result variations are due to fabrication tolerances and SMA connector losses. Figure 10 shows the measured RL and VSWR. The measured results are almost similar performance with the simulated results.

Figure 8: Prototype of the dual notch band antenna.

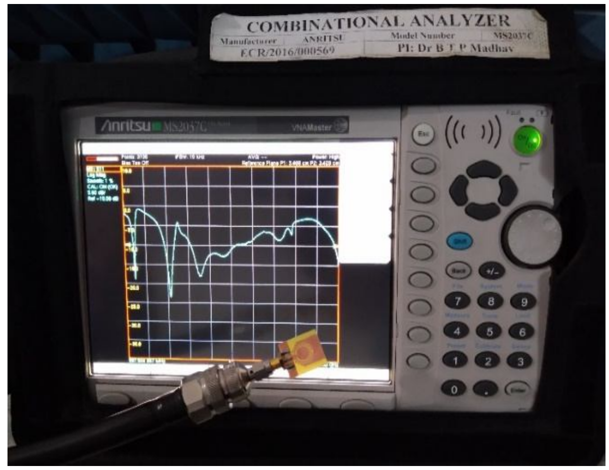
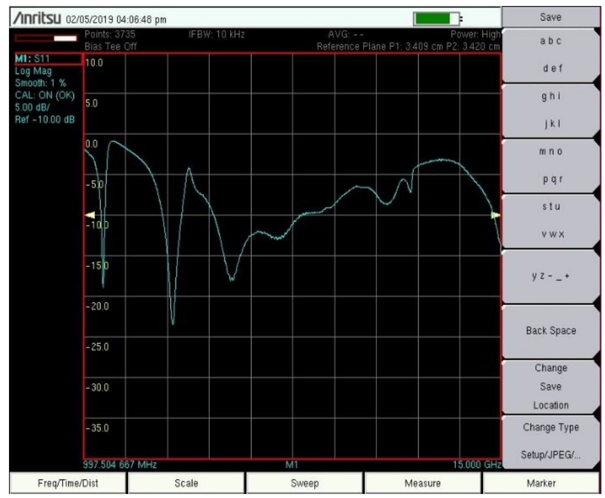
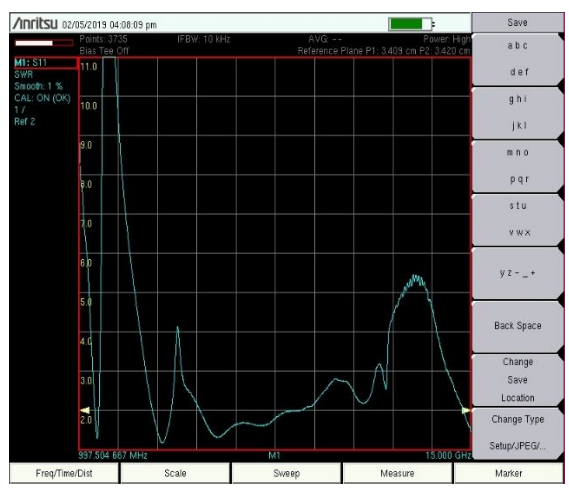


Figure 9: Testing setup for the proposed antenna



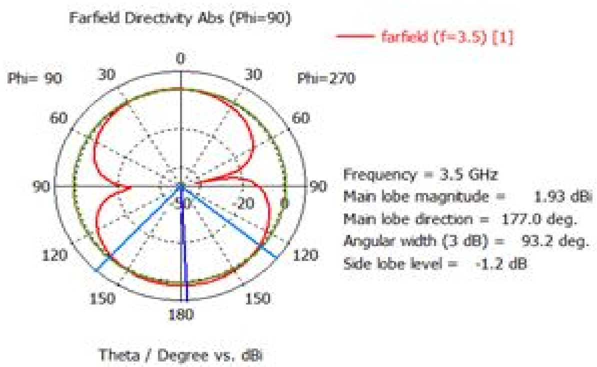
(a)



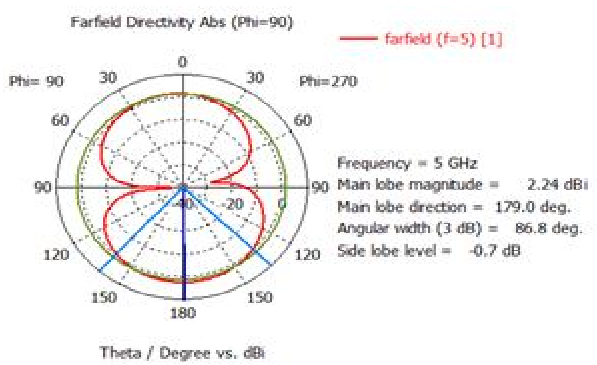
(b)

Figure 10: Measured (a) RL (b) VSWR for fabricated antenna.

The simulated 2D patterns of the proposed dual notch band antenna at frequencies of 3.5, 5, 6, 9, 10.6 GHz respectively are shown in figure 11. For a frequency of 3.5 GHz and 5 GHz frequency the directivity, main lobe directions are 2.094 dBi, 177° and 2.239 dBi, 179° respectively. The gain at the above frequencies is 2.09 dB and 2.24 dB. Similarly, at a frequency of 6 GHz the directivity, main lobe direction and gain are 2.786 dBi, 178° and 2.79 dB. At a frequency of 9 GHz frequency, there is a sudden increase in directivity to 4.703 dBi and a reduction in main lobe direction to 158° with a gain of 4.7 dB. But for a frequency of 10.6 GHz frequency, there is a slight abnormal change in directivity as it decreased to 2.411 dBi and has main lobe direction as 138° which has slight irregular radiation pattern. Even the gain has reduced to 2.4 dB. By the observation 2D, radiation patterns are almost identical for the frequencies ranging from 3.5 GHz to 9 GHz. The directivity also slightly increased along with the frequency till 9 GHz. According to the simulated radiation pattern, the antenna exhibits a constant radiation pattern from 3.5 GHz to 9 GHz with very fewer side lobes. Hence it can be used for multiple applications in different frequency ranges.



(a)



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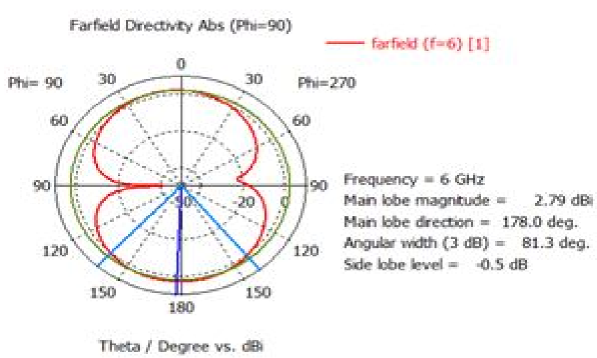
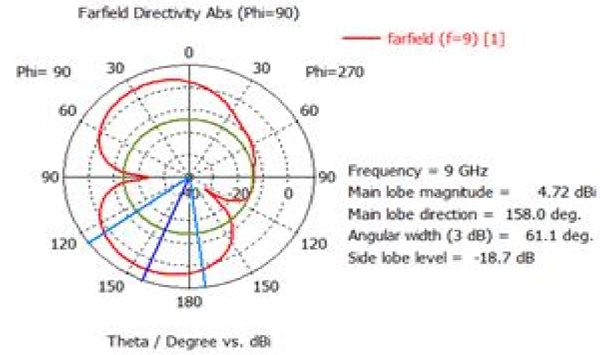
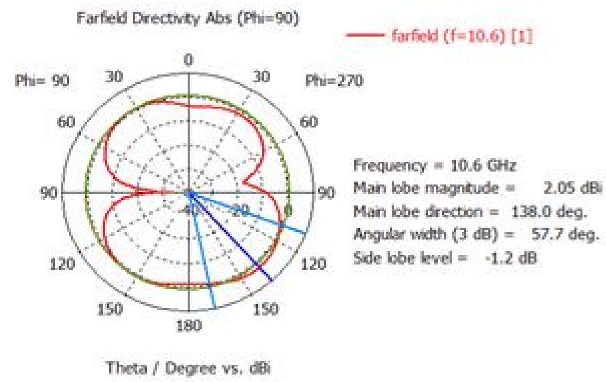


(c)



(d)



(e)

Figure 11: Radiation Pattern of proposed dual notch band UWB antenna at frequencies (a) 3.5 (b) 5 (c) 6 (d) 9 and (e) 10.6 GHz.

The proposed rectangular dual notch antenna has dimensions of 20x17 mm^2, the compactness of the dual notch antenna has used in several wireless applications. Moreover, the developed proposed antenna has several advantages like low fabrication cost due to single-side printing, compact size (only 340 mm^2), Omni-directional and bidirectional radiation patterns, low cross-polarization field component, and acceptable peak gains. 3.216 GHz − 3.99 GHz and 4.29 GHz – 4.78 GHz.

4. CONCLUSION

A compact rectangular Dual notch UWB antenna for Wireless Personal Communications is designed, simulated and measured results are presented in this paper. The proposed antenna has a simple rectangular structure of staircase-shaped radiating patch. The SRR and CSRR slots are included in the proposed antenna to get the notch band characteristics. The SRR and CSRR slots are optimized, SRR is responsible for the notch band of frequency range from 3.216 GHz to 3.99 GHz and the CSRR is responsible for 4.29 GHz to 4.78 GHz. The simulated results of return loss and VSWR of the proposed dual notch band structure are A good agreement with the measurement results. The proposed antenna has several advantages with the literature in terms of size, Omni-directional patterns, and peak gain.

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