Compact Printed CPW-fed UWB antenna with SRR and Quarter wavelength slot with dual band-notched characteristic

Rashmi Tanwar, Ira Joshi

***Abstract*— In this article compact printed CPW-fed UWB antenna with SRR and quarter wavelength slot with dual band-notched characteristic is proposed. A beveled rectangular patch is printed on the top side of the glass epoxy FR-4 dielectric substrate, a CPW feed line along with the coplanar beveled ground plane is printed on the same side of the glass epoxy FR-4 dielectric substrate. The quarter wavelength slot of 13 mm is cut in the radiating patch with an open gap at the edge of the radiating patch. By using quarter wavelength slot, a strong band-notched characteristic in the WiMAX band is obtained. A SRR is cut in the beveled edges of the radiating patch and placed near the feed line. The Split Ring Resonator (SRR) has been introduced to provide a notch in the WLAN frequency band. The simulated impedance bandwidth of the proposed antenna is observed from 3.10 GHz to 13.62 GHz which covers the whole ultra-wideband frequency band, for VSWR is less than 2. This impedance bandwidth has two notched bands in the frequency ranges of 3.25-4.00 GHz and 5.05-5.90 GHz ,for VSWR is greater than 2.**

***Index Terms*— Notched band, quarter-wavelength slot, ultrawideband (UWB). Split Ring Resonator (SRR)**

I. Introduction

In order to support high data rates on short-ranges, new promising technologies such as the ultra wide band (UWB) transmission scheme are used. It is a radio technology used at a very low energy level for a bandwidth of 7.5 GHz, i.e. from 3.1 GHz to 10.6 GHz using a large portion of the radio spectrum. Due to the transmission of non-successive and very short pulses, UWB radio transmission will provide very high data rate, large bandwidth, short-range characteristics, low power consumption, constant gain, and a linear phase response. These antennas could be applied in radar, location tracing, sensor networks and miniature laptop applications [1]-[4]. There exist some narrow bands in UWB range, such as WiMAX operating in the 3.3 GHz to 3.7 GHz band, IEEE 802.11a (WLAN) operating in the 5.15 GHz to 5.825 GHz band, ITU8 operating at 8 GHz to 8.4 GHz and downlink of X-band satellite communication systems at 7.25 GHz to 7.75 GHz. They may cause communication interference with the UWB system and degrade the overall system performance in terms of increasing pulse distortion and bit error rate (BER). To solve this problem, one way is to use filters to notch out the interfering bands. However, the use of an additional filter will result in increasing the complexity of the UWB system and also the insertion loss, weight and size for the UWB trans-receivers. Therefore, it is desirable to design & develop single radiating element having capabilities of band notched characteristic at these bands to minimize potential interference and minimize the antenna weight and area to enhance portability. Various UWB antennas with dual band-notched characteristic have been reported to avoid interferences.

The designed antennas are generally embedded with a half-wavelength structure such as a U-shaped slot, a C-shaped slot or an arched slot. But most reported antennas were designed with only one notched band, mainly discussed on WLAN frequency band 5.15 GHz to 5.825 GHz [8]. Many UWB antennas with dual notched bands were recently reported in [9]-[12]. By etching two nested C-shaped slots in the rectangular metal radiating patch[10]. By adjusting the total length of the C-shaped slot to be approximately half-wavelength of the desired notched frequency, a destructive interference can take place, causing the antenna nonresponsive at that frequency [12]. A CPW-fed planar UWB antenna with dual band-notched characteristics at the center frequencies of 3.5 GHz and 5.5 GHz is designed by etching a half-arc-shaped and a modified π shaped slot in the semicircular and rectangular combined metal radiating patch[13]. It is found that by adjusting the total length of the slot to be approximately half wavelength of the desired notched frequency, a destructive interference can take place, causing the antenna nonresponsive at that frequency. Dang Trang et.al proposed a very compact coplanar waveguide (CPW)-fed ultrawideband (UWB) printed monopole antenna (PMA) with triple and-notched characteristics is presented[14]. Based on the background of the researches above, this paper proposes a simple and compact CPW-fed UWB antenna with dual band-notched characteristics in 3.25-4.00 GHz and 5.05-5.90 GHz band.

II. Antenna Design

The geometry of the compact printed CPW-fed UWB antenna is as shown in Fig.1. The proposed antenna is printed on the glass epoxy FR-4 dielectric substrate with

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Rashmi Tanwar, Digital Communication, R.C.E.W., Jaipur, India, 09829282707.
Ira Joshi, Electronics & Communication Department, R.C.E.W., Jaipur, India, 09829269914.

thickness of 1.6 mm, relative permittivity of 4.3 and loss tangent of 0.025. A beveled rectangular patch is printed on the top side of the glass epoxy FR-4 dielectric substrate, a CPW feed line along with the coplanar beveled ground plane is printed on the same side of the glass epoxy FR-4 dielectric substrate. Beveled edges of the radiating patch and the ground plane result in a smooth transition from one resonant mode to another, ensuring good impedance match over a broad frequency range [14]. The feed line of width 3 mm and a gap of 0.40 mm between the CPW feed line and the coplanar ground plane is provided to achieve 50 ohm characteristic impedance. The overall dimensions of this antenna are 26 mm × 20 mm. There is gap of 0.5 mm between the patch and the ground plane.

A. Basic Antenna Design

In this section, the basic antenna (without any of the slot) covering the full UWB band is first described. The effects of the geometric parameters of the radiating patch and the ground plane are discussed.

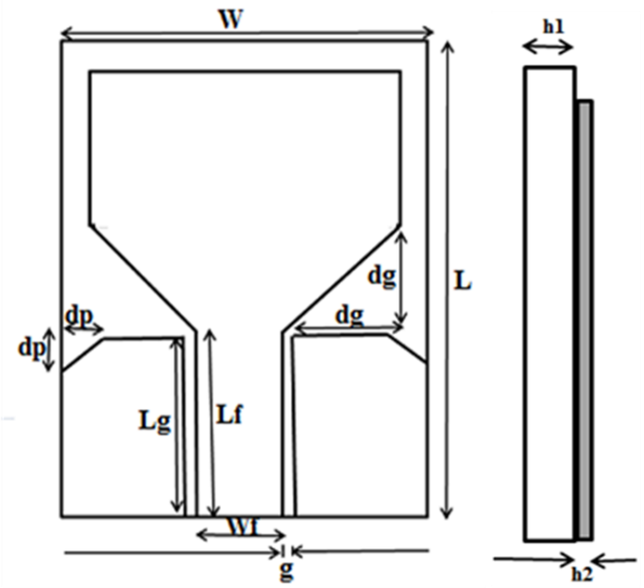

Fig.1 Geometry of the compact printed CPW-fed UWB antenna

The simulation of the proposed antenna is carried out with the CST Microwave Studio package which is based on the finite integration technique for electromagnetic computation. Fig.2 shows the simulated reflection coefficient (S11 < -10 dB) curve as the function of frequency. The simulated impedance bandwidth is observed from 3.85 GHz to 13.84 GHz which covers the almost ultra-wideband frequency band, which is defined by the FCC. Fig.2 shows the simulated voltage standing wave ratio (VSWR) curve as the function of frequency. It is observed that the VSWR is less than 2 over the operating frequency bandwidth.

Fig. 3 & 4 shows the simulated reflection coefficient (S11) and realized gain curve as the function of frequency. It is observed that the realized gain varies from 1.92 dBi to 4.53 dBi over the whole impedance bandwidth. The antenna gain variation is less than 3 dBi over the whole impedance bandwidth.

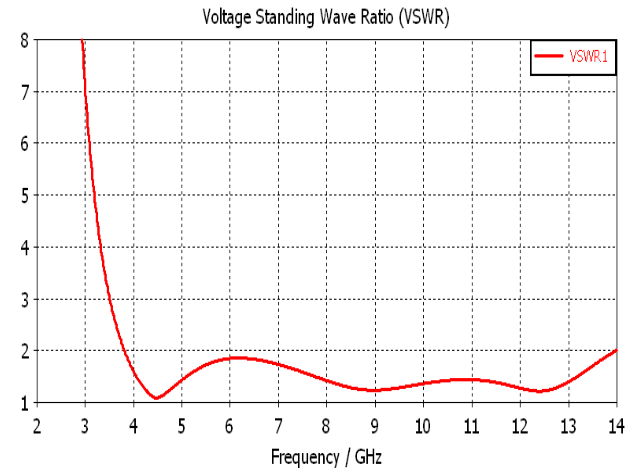

Fig.2 Simulated VSWR curve v/s frequency of compact printed CPW-fed UWB antenna

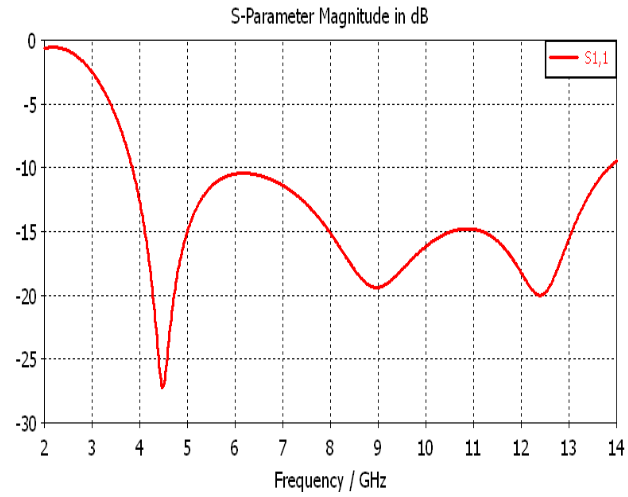

Fig.3 Simulated reflection coefficient (S11) curve v/s frequency of compact printed CPW-fed UWB antenna

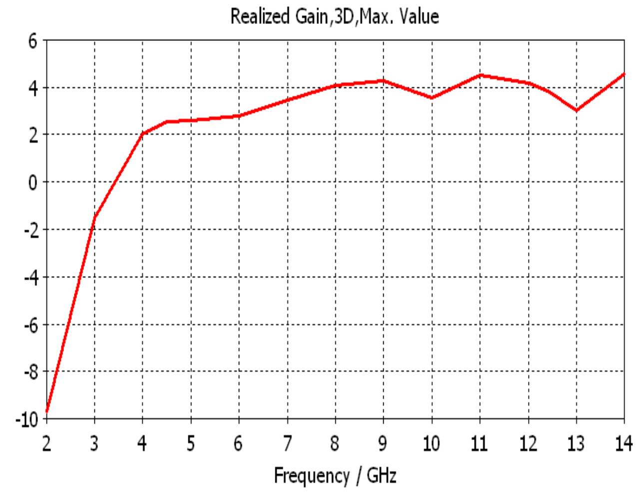

Fig.4 Simulated realized gain curve v/s frequency of compact printed CPW-fed UWB antenna

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B. Dual band-notched Antenna

To avoid the electromagnetic interference, a compact printed CPW-fed UWB antenna with dual band-notched characteristics has been proposed and discussed.

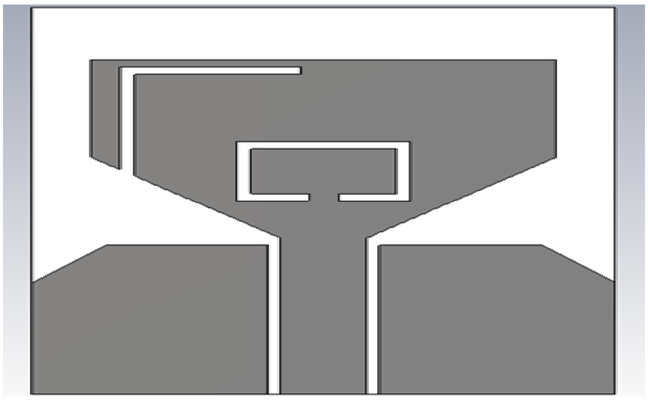


Fig.5 Compact Printed CPW-fed UWB antenna with SRR and Quarter wavelength slot with dual band-notched characteristic

The geometry of the proposed compact printed CPW-fed UWB antenna with SRR and quarter wavelength slot is as shown in Fig.5. The optimal dimensions of the antenna are given as follows L=26mm, L_f=10.5mm, L_g =10mm, W=20mm, d_g=2.5mm, d_p =6.5mm, g=0.4mm, g_1=0.25mm, h_1=1.6mm, h_2=0.05mm, sx_1=1mm, sx_2=4.8mm, sy_1=2mm, w_f =1.5mm, x_1=0 mm and y_1=0 mm.

The proposed antenna is printed on the same material as specified in the previous section. It consists of a beveled radiating patch with one split ring resonator (SRR) and one quarter wavelength slot and also CPW feed line to achieve 50 ohm characteristic impedance. There is gap of 0.4 mm between the patch and the ground plane.

Firstly, the quarter wavelength slot cut in the radiating patch with an open gap at the edge of the radiating patch.We used guided wavelength$\lambda_g=\lambda_o/\sqrt{\varepsilon_{ff}}$ and $\varepsilon_{ff}=(\varepsilon_r+1)/2$, where λ_o is the free-space wavelength [14].

The length of slot is 13 mm, which is about a quarter of the guided wavelength calculated at the center frequency of the WiMAX band, 3.5 GHz. By using quarter wavelength slot, a strong band-notched characteristic in the WiMAX band is obtained. Secondly, the SRR is cut in the beveled edges of the radiating patch and placed near the feed line. Split Ring Resonator (SRR) has been introduced to provide a notch in the WLAN frequency band. Split Ring Resonator (SRR) is a small sized high Q resonator which can be used to produce Band Notched characteristics in a planar antenna. In a SRR, two similar split rings are coupled by means of a strong distributed capacitance in the region between the rings. A SRR consisting of a pair of concentric annular rings with splits at the opposite ends is considered in this project to implement the band notch characteristics. The resonant frequency of SRR is given by [15]

$$\omega_o = [\,2/(\pi r L_e C_o)]^{1/2}$$

where r = $(r_1+r_2)/2$ is the average radius of the SRR, r_1=Outer radius, r_2=Inner radius, L_e= Equivalent Inductance,C_0= Capacitance per unit length between the two rings .

Increasing the length of the slots, which is similar to increasing
the inductor value and the capacitor value, has the effect of decreasing the center frequency and bandwidth[8]. It is observed that the key parameters that have the impact on the dual band-notched characteristics are gap in split rectangular ring 'g_1', rectangular ring length 'L_2' and rectangular ring width 'W_2'. By adjusting these parameters, the suitable dual band-notched frequency and notched impedance bandwidth may be achieved.

III. Results And Discussion

The effects of the geometrical parameter on VSWR curve of antenna performance

In the following text,five parts of the propose CPW-fed monopole antenna that will be described and discussed,respectively (1) g_1 : gap of srr in x direction, (2) sx1 : Shift left arm of slot s1 in x direction, (3) x_1 : shift width of srr in x direction, (4) sy_1 : shift upper arm of slot s1 in y direction, and (5) sx_2 : shift right the length of slot s1 in x direction.

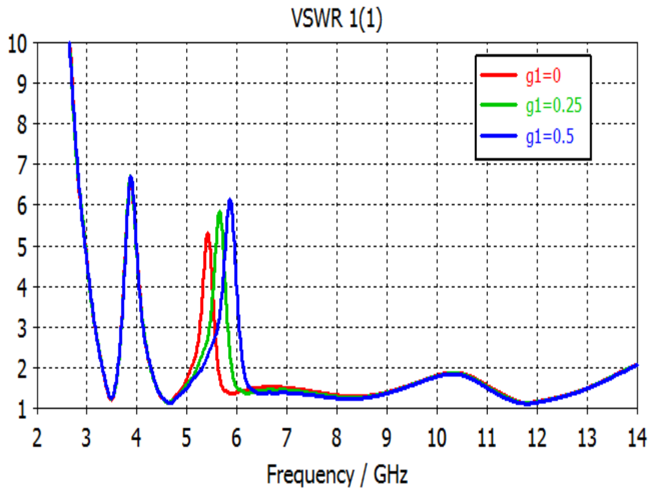


Fig.6 (a) Variation of g_1 with fixed other optimized dimensions

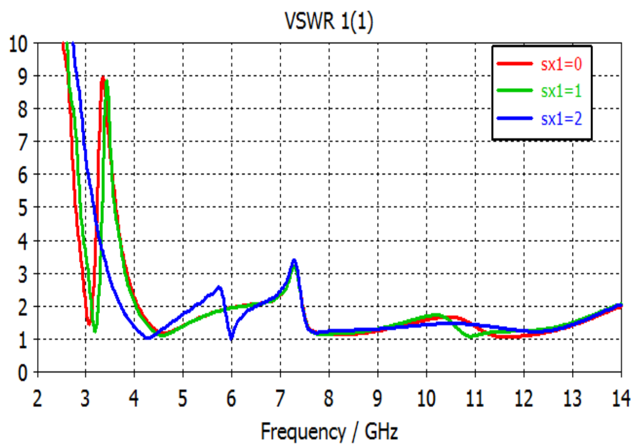


Fig.6 (b) Variation of sx_1 with fixed other optimized dimensions

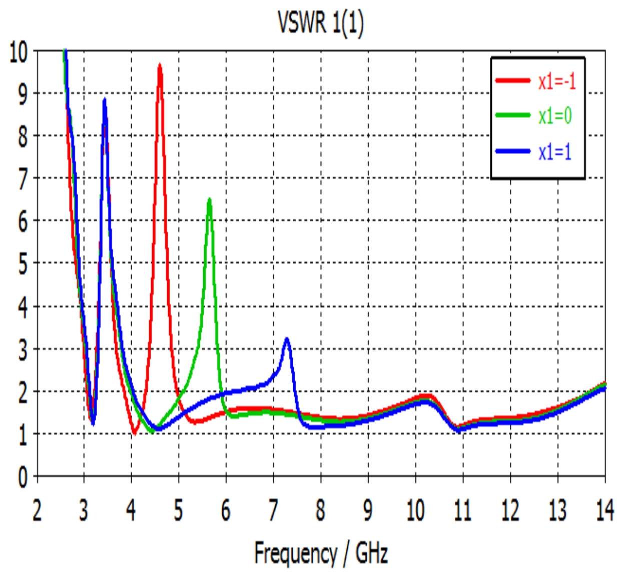


Fig.6 (c) Variation of x_1 with fixed other optimized dimensions

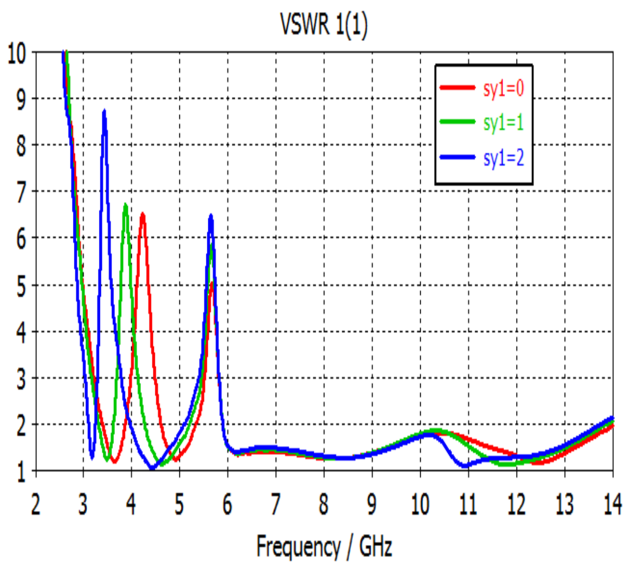


Fig.6 (d) Variation of sy_1 with fixed other optimized dimensions

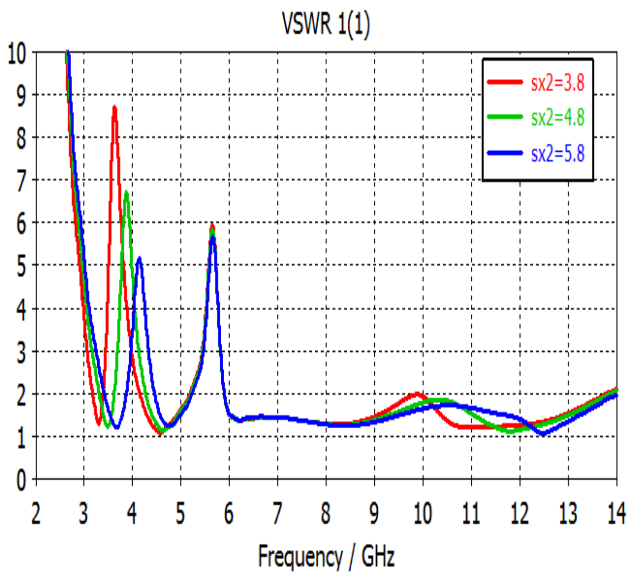


Fig.6 (e) variation of sx_2 with fixed other optimized dimensions

Fig.6 Relations between the VSWR and dimensions of the proposed antenna(in millimeter).

The effects of gap of srr in x direction (g_1)

Fig.6(a) gives the simulated VSWR curves of the antenna as a function of frequency for different values of g_1 with fixed other optimized parameter of the patch. Fig shows that as we increase the value of g_1, the centre frequency of the second notched band varied from 5.5 to 5.9 GHz. It can be seen that the VSWR of the centre frequency of the second notch band is increased in a small amount.

The effects of left arm of slot s1 in x direction (sx_1)

Fig.6(b) gives the simulated VSWR curves of the antenna as a function of frequency for different values of sx_1 with fixed other optimized parameter of the patch. It can be seen that when we increase the the arm lenth of slot s1 in left side x direction,the centre frequency of first notch band is increased.

The effects of width of srr in x direction (x_1)

Fig.6(c) shows the simulated VSWR characteristics with the optimum diemension for parameters and for different values of x_1. As we increase the width of srr in x direction from -1 to 1 mm, the centre frequency of second noth band is increased towards higher frequency and the centre frequency of first noch band remain fixed. We can conclude that the VSWR of the centre frequency of the second notch and filtering frequency is controlled by changing the width of srr in x dierection.

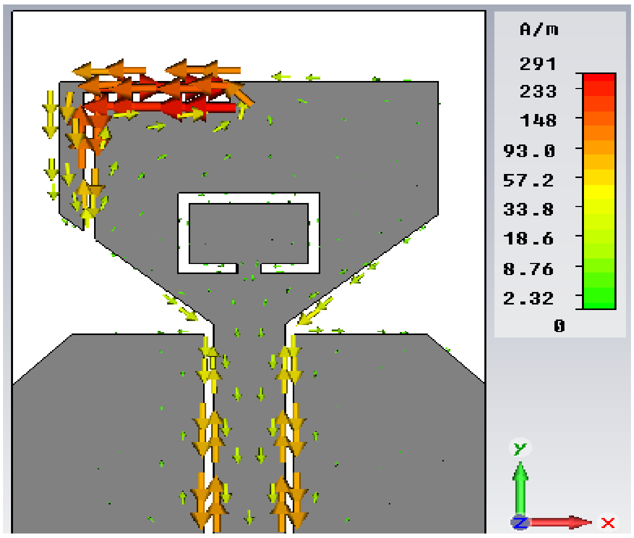
The effects of length of upper arm of slot s1 in y direction (sy_1)

Fig.6(d) indicates the simulated VSWR results for proposed antenna in terms of sy_1. For sy_1=0,1 and 2mm with other fixed diemensions, the notch frequency decrease from 4.3 to 3.5 GHz. It canbe seen that tuning the width s1 has significant effects on shifting the notch frequency.

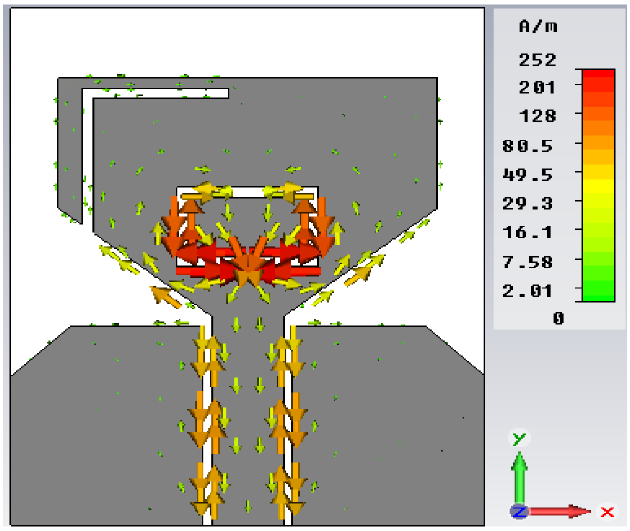
The effects of length of slot s1 in x direction (sx_2)

The effect of the length of the slot s1 on antenna performance is studied by varing sx_2, as shown in Fig.6(e) (other diemension is fixed). As we increase the value of sx_2=3.8,4.8 and 5.8 mm, the centre frequency of the first notched band varied from 3.65 GHz to 4.2 GHz.

The surface current distributions on the radiating patch of the proposed antenna are shown in Fig.7 and Fig.8. At passband (outside the notched bands) the distribution of the surface current is uniform and at the center frequency of the notched bands, stronger current distributions concentrated near the edges of slot and SRR. In this case, destructive interference for the excited surface currents in the antenna will occur, which causes the antenna to be nonresponsive at that frequency. The impedance nearby the feed-point changes acutely making large reflection at the desired notched frequency. Fig.9 shows the Simulated VSWR curve v/s frequency of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics. The notched bands are at 3.25 GHz to 4.00 GHz and 5.05 GHz to 5.90 GHz frequency band with VSWR >2.



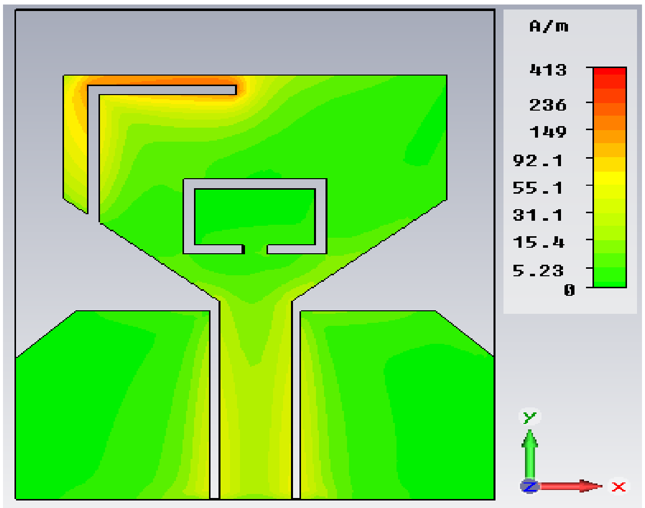
(a)



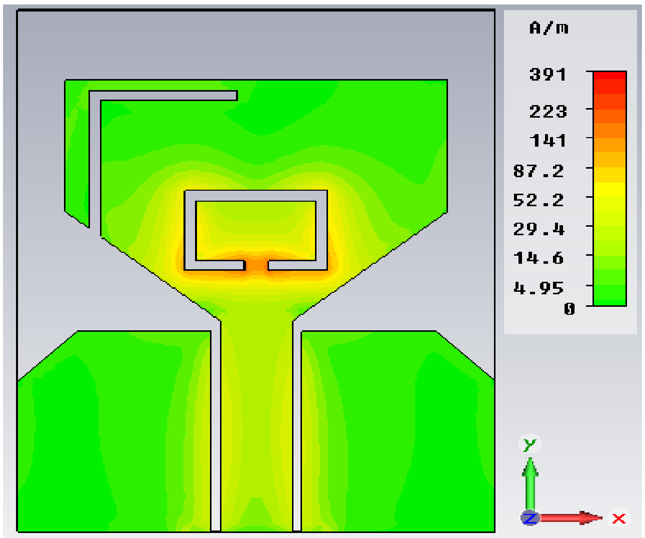
(b)

Fig.7 Simulated vector current distribution of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics (a) 3.4 GHz, and (b) 5.7 GHz

Fig.9 shows the Simulated VSWR curve v/s frequency of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics. The notched bands are at 3.25 GHz to 4.00 GHz and 5.05 GHz to 5.90 GHz frequency band with VSWR >2. Fig.10 shows the simulated reflection coefficient (S11) curve v/s frequency of the proposed antenna.Fig.11 shows the Simulated realized gain curve v/s frequency of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics. The realized gain is less than -4 in notched bands of 3.25 GHz to 4.00 GHz and 5.05 GHz to 5.90 GHz . Fig.12 shows the farfield radiation pattern of the proposed antenna.



(a)



(b)

Fig.8 Simulated magnitude current distribution of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics (a) 3.4 GHz, and (b) 5.7 GHz

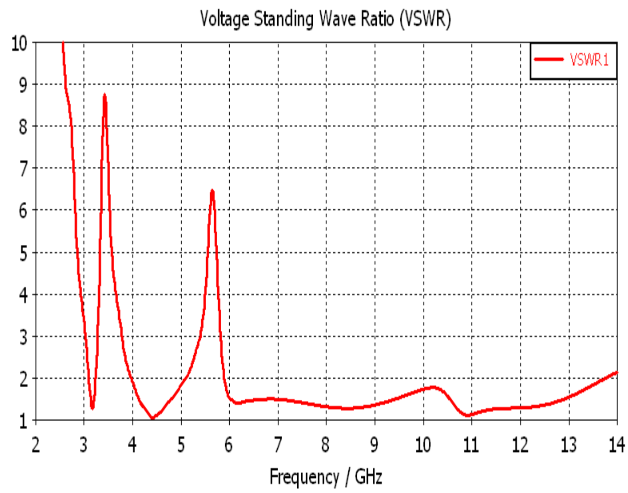


Fig.9 Simulated VSWR curve v/s frequency of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics

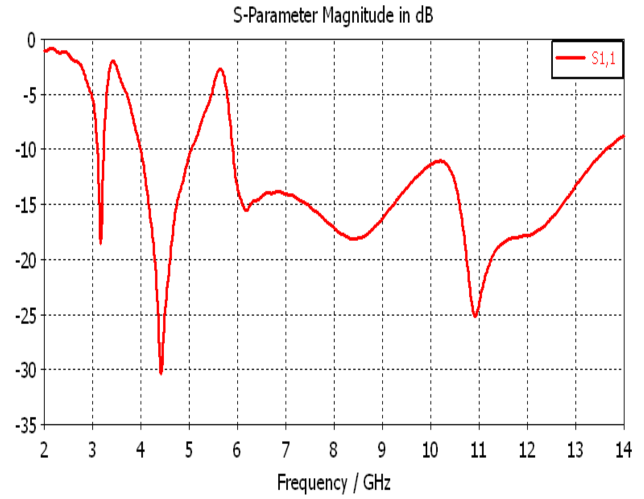


Fig.10 Simulated reflection coefficient (S11) curve v/s frequency of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics

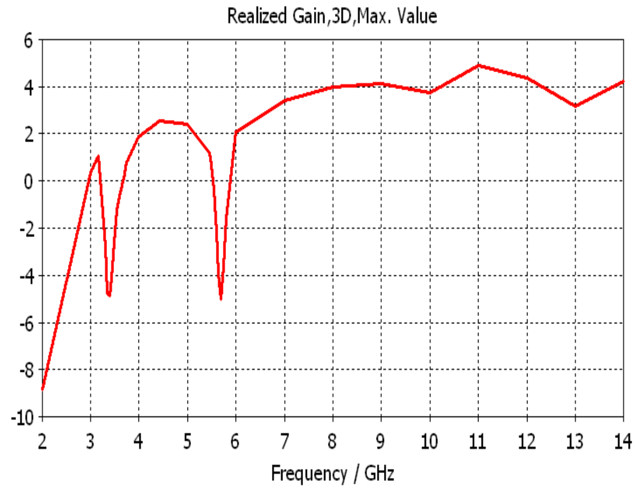


Fig.11 Simulated realized gain curve v/s frequency of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics

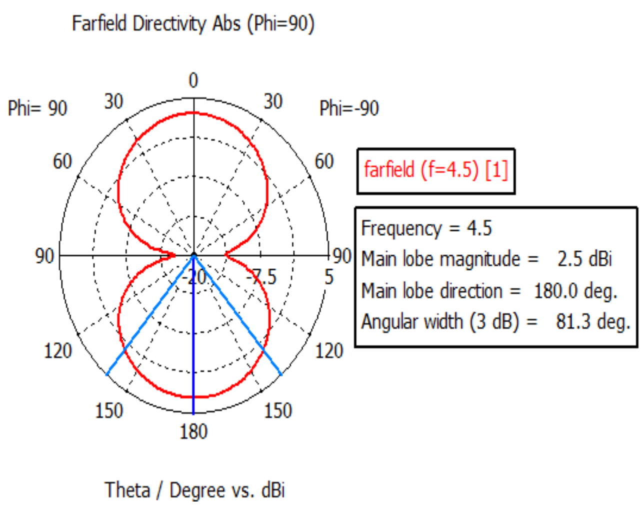


Fig.12 (a) Farfield radiation pattern at 4.5 GHz

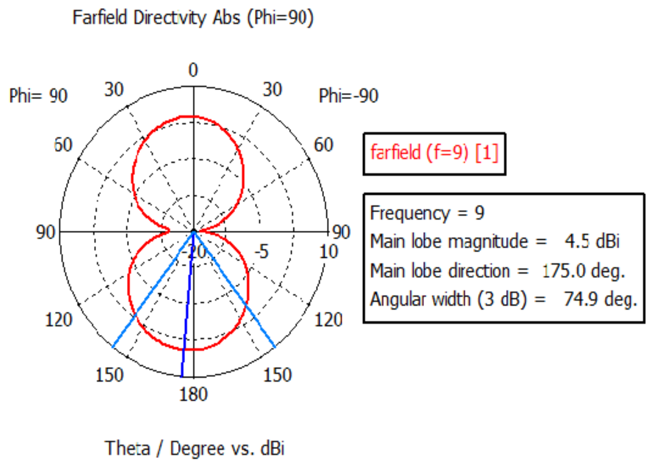


Fig.12 (b) Farfield radiation pattern at 9 GHz

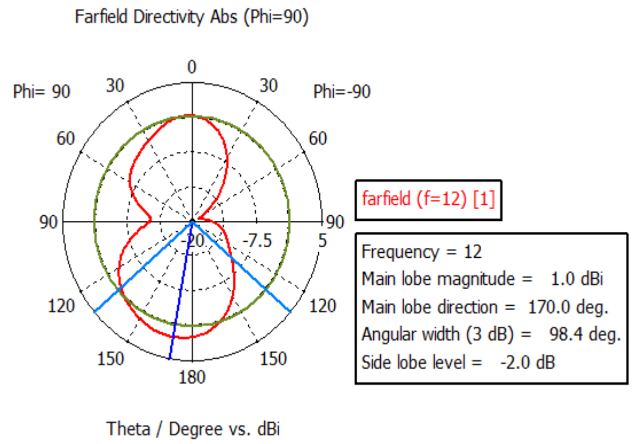


Fig.12 (c) Farfield radiation pattern at 12 GHz

IV. CONCLUSION

Simulated results of proposed antenna with dual band-notched characteristics show the simulated reflection coefficient (S11 < -10 dB) curve as the function of frequency of the proposed compact printed CPW-fed UWB antenna with dual band-notched characteristics. The simulated impedance bandwidth of the proposed antenna are observed from 3.10 GHz to 13.62 GHz which covers the whole ultra-wideband frequency band, for VSWR is less than 2. The results show that the proposed antenna has good impedance matching, nearly omni-directional radiation pattern, and flatness gain in the operating band. Thus this antenna are a good candidate for portable UWB application.

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Rashmi Tanwar D/O Mr. Ram Singh Tanwar completed her B.E(Hons.) degree from Rajasthan College of Engineering for Women, Jaipur, India in year 2006. She has Completed MBA(HRM) degree from IIIM,Jaipur, India in year 2009.Presently, she is a M.Tech student and researching in a field of "Design and Investigation of Ultra wide band antenna with Dual Band notched characteristics" in Digital Communication under the guidance of Ms. Ira Joshi, Associate Professor in E&C department from Rajasthan College of Engineering for Women, Jaipur, India. She is also working on various type of microstrip antenna like rectangular patch, circular patch, square patch with single notch and dual notch band characteristics. She had attended various national and international conferences .She has presented 4 national and 1 international paper. She has also published two paper in International Journal.


Ira Joshi D/O Mr. Gopal Joshi completed her B.E degree from Rajasthan College of Engineering for Women, Jaipur, India in year 2007. Presently she is working as Associate Professor in Electronic and Communication Department at Rajasthan College of Engg. For Women ,Jaipur. She has researched on the topic "dual frequency circularly polarized micro strip antenna" She has also researched on various type of microstrip antenna like rectangular patch, circular patch, square patch and triangular patch. She had attended various national conferences like Ethical Hacking, Renewable Energy Sources, Artificial Intelligence, Carbon footprint. She is a Member of Indian Society of Technical Education (ISTE), New Delhi . She had also presented a paper on Renewable Energy Source in National Conference.