Design of Printed CPW-fed Monopole Antenna for WiMAX and WLAN Dual Band-Notched Characteristics for UWB Applications

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Abstract. A printed CPW-fed monopole antenna with dual band-notched characteristics for UWB applications is presented in this paper. By etching both inverted elliptical split ring slots on the radiating patch dual band-notched characteristics are obtained a narrow bandwidth at 3.3-3.8 GHz for WiMAX (3.3-3.7 GHz) and for WLAN (5.725-5.825 GHz) operating bands are achieved. The physical structure of the proposed antenna is printed on the 28 mm × 34 mm × 1.6 mm size FR-4 dielectric substrate. The presented antenna has a wide impedance bandwidth of 2.89 to more than 14 GHz expect of two notch bands. The antenna operates for the entire UWB (3.1-10.6 GHz) range and gives omnidirectional radiation patterns and stable peak gain expect at the band-notched frequencies. The proposed antenna has a planar geometry which is a good choice for any portable UWB communication system applications.

Keywords: Planar monopole antenna, dual band-notched, UWB, elliptical split ring slot, WiMAX, WLAN

1. Introduction

Since the U.S. Federal Communications Commission (FCC) is allocated the 3.1 – 10.6 GHz frequency band for commercial applications of ultra-wideband (UWB) communication system [1] in 2002. The more concentration has been paid on UWB technology due to many technological advantages such as short range high secure data transmission, low power consumption, etc.[2]. For the practical reliable use of the UWB communication technology the important device must be a planar structure with wide impedance bandwidth requirement. One of the demerits of the UWB communications is suffering from existing frequency bands such as Bluetooth (2.2-2.4GHz), WiMAX (3.3-3.7 GHz), IEE802.11a/b WLAN (5.15–5.35 GHz and 5.725–5.825 GHz) at the time of use. To overcome this serious problem, the good omnidirectional radiation characteristic UWB antenna with band-notched features is desirable.

In recent years, the many technical reports on band notched UWB antennas have been reported. The simple techniquse to implement the band-notched characteristics includes use of different geometries of radiating patch with embedding slots [3-6], inserting slits on both radiating patch and ground plane [7-9], using parasitic strips and resonators to radiating patch, etc. [10-12].

In this paper, a planar printed CPW-fed monopole antenna with dual band-notched characteristics is presented. The proposed UWB antenna consists of a truncated disk radiating patch with a pair of elliptical split-ring slots which covers the range from 2.89 to more than 14 GHz. By etching optimum dimensions of both elliptical split ring on the upper and lower side of the radiating patch the dual notch bands are achieved. The performance of the antenna design the simulated VSWR, current distributions radiation patterns and gain are presented and discussed.

2. Antenna Design

The geometry of the dual band-notched UWB antenna is illustrated in Figure 1. The antenna is fabricated on a low-cost FR-4 dielectric substrate having a relative permittivity (ε_r) of 4.4, loss tangent (tan δ) of 0.02 and a substrate thickness (h) of 1.6 mm. The proposed antenna is consists of a disk radiating patch with a pair of elliptical split-ring slots and a partial finite-size ground plane on either side of the 50Ω CPW transmission line. The disk radiating patch basically a circle with radius of 7.9 mm which is truncated the side and top edges. A truncating area with a size of T_1 and T_2 = 9.24 mm and T_3 = 11.9 mm are maintained which provides a mechanism to enhance the impedance bandwidth with VSWR ≤ 2 over the UWB range. Moreover, in order to achieve an optimum impedance matching between a ground plane and 50Ω CPW microstripline the distance g = 0.37 mm and d = 0.65 mm is maintained between radiating patch and 50 Ω CPW microstripline. The entire antenna structure is printed within a small size of 26 × 32 mm^2 substrates. A simple 50 Ω CPW microstrip line feed with a length L_f =15.15 mm and W_f =3.07 mm is selected to excite the antenna. Further, to obtain WiMAX and WLAN dual notched-band characteristics a pair of elliptical split-ring slots is loaded onto the radiating patch. With a slight change of total length of the elliptical split-ring slots, it is easy to adjust the center frequencies of the notched-bands at particular frequency range.

Finally, optimized design parameters of the antenna are depicted as follows: T_1 and T_2 = 9.24 mm, T_3 = 11.9 mm, $e1_l$=26.06 mm, $e2_l$ = 19.09 mm, $e1_w$=0.61 mm, $e2_w$=0.65 mm g=0.57 mm, d=0.65 mm, L_f=15.15 mm, W_f = 3.07 mm, L_g= 14.5 mm. The photograph of top and bottom view of dual band-notched UWB antenna is given in Figure 2. The variation of voltage standing wave ratio (VSWR) versus frequency of the proposed antenna is tested successfully

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using Rohde & Schwarz ZVK model 1127.8651 German make Vector Network Analyzer (VNA). The other results such as radiation characteristics, surface current distributions, gain and antenna efficiency and group delay variation are presented and discussed.

3. Results and Discussion

The design of the proposed dual notched-band antenna, simulation VSWR plots, current distributions, gain and the parametric study for better understanding the effect of dual notched-band characteristics are studied by the commercial electromagnetic High Frequency Structure simulator (HFSS) [13].

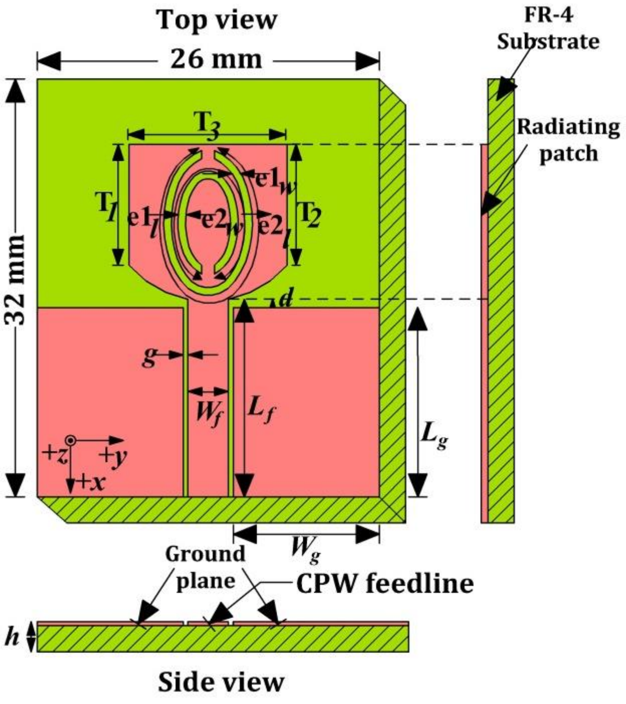


Fig.1 Geometry of the dual band-notched UWB antenna

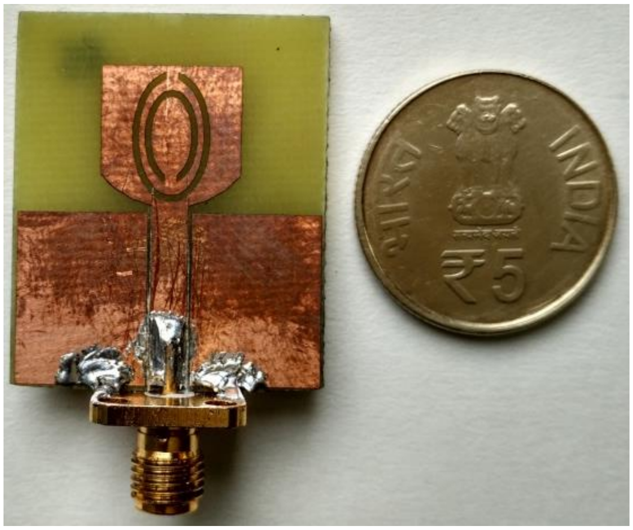


Fig. 2 Photograph of the dual band-notched UWB antenna

Figure 3 shows a comparison of measured and simulated VSWR curves of the proposed antenna. From this figure, it can observe that the measured VWSR is in good agreement with the simulated one. The antenna rejects the bandwidth of WiMAX and WLAN which covers the frequency range from 2.89 to more than 14 GHz for VSWR ≤ 2 covering the entire UWB (3.1-10.6 GHz) frequency band. Hence, this antenna rejects the interference of WiMAX (3.3-3.7 GHz) and WLAN (5.725-5.825 GHz) bands.

Figure 4 shows the simulated surface current densities (A/m) of the proposed antenna at frequencies 3.3 and 5.75 GHz and are shown in Fig. 4(a) and (b) respectively. It can be observed from the Fig.4 (a) that, the surface current densities at 3.3 GHz is mainly distributing around the edges of the bigger size elliptical split-ring slot whereas the surface currents densities at 5.75 GHz is mainly accumulating along the edges of the lower size elliptical split-ring slot which is shown in Fig.4 (b). Also, from these figures, it is well known that the proposed antenna shows a dual notched-band feature at WiMAX (3.3-3.7 GHz) and WLAN (5.725-5.825 GHz) within the UWB band. Further, the 3D radiation patterns which are measured at 3.3 GHz and 5.75 GHz also represent that, at the notched bands there is less energy is observed due to notch property.

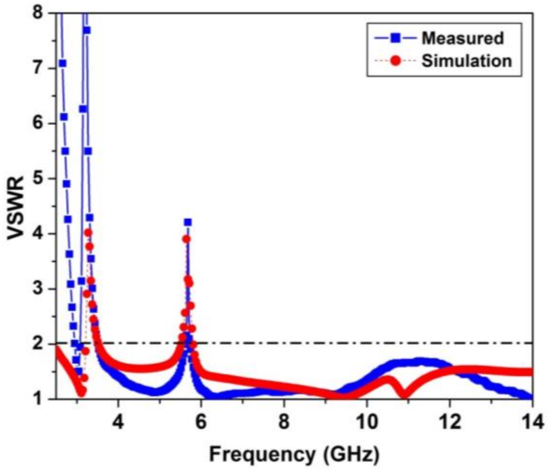
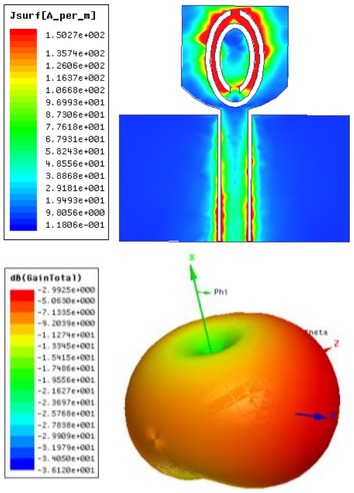


Fig. 3 Measured and simulated VSWR plots of dual band-notched UWB antenna



(a)

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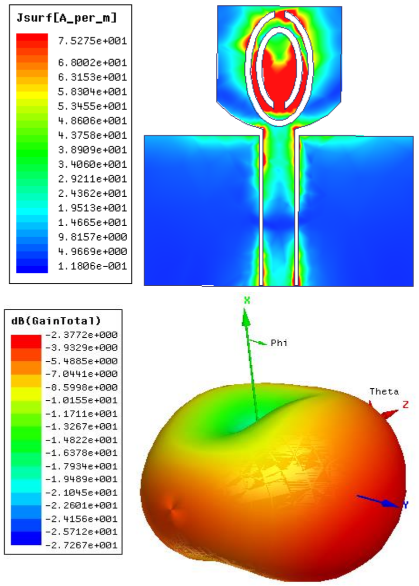

(b)

Fig. 4. Surface current distributions and 3D radiation patterns of proposed antenna at (a) 3.3 and (b) 5.75 GHz

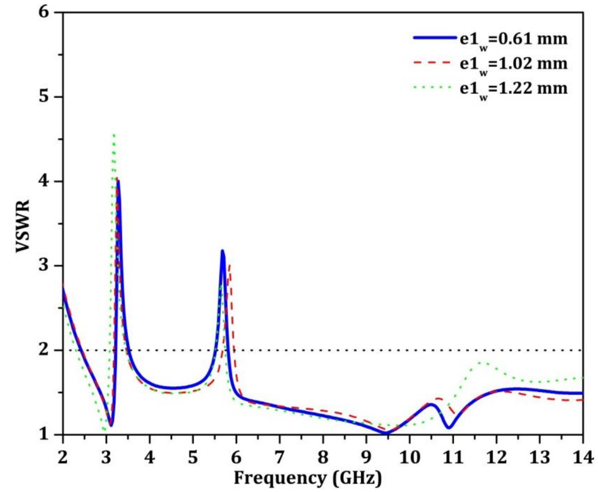

Fig. 5 Simulated VSWR curves for the different values of $e1_w$

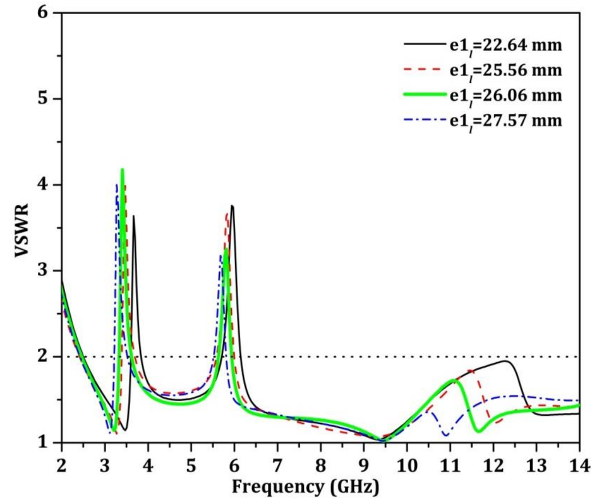

Fig. 6 Simulated VSWR curves for the different values of $e1_l$

The parametric study of the dual band-notched UWB antenna is analyzed to understand the dual notched-band characteristics by changing one parameter at a time and keeping other parameters as constant. The simulated results are obtained using the ANSYS high-frequency structure simulator (HFSS) simulation software.

Figure 5 exhibits the effect of bigger elliptical split-ring slot widths $e1_w$ on VSWR curves. A center notch frequency shift from 3.2 GHz to 3.4 GHz corresponds to the changing of the bigger elliptical split ring slot width from 0.61 mm to 1.22 mm. Figure 6 shows the VSWR curves of the proposed antenna by varying the big elliptical split-ring slot lengths e1l. From Fig. 6, it is observed that the central frequency of the notched band is controlled by the length of the elliptical split-ring slot. When the length of the elliptical split-ring slot varies from 22.64 mm to 27.57 mm the frequency shifts from around 3.2 to 3.65 GHz without disturbing the upper notched band.

Similarly, the effect of simulated VSWR plots for different values of $e2_w$ is shown in Fig. 7. It is observed from this figure that, by increasing the width of the smaller elliptical split-ring slot values $e2_w$ from 0.54 mm to 1.07 mm and by keeping the $e2_1$ value is constant, the center frequencies of the corresponding notched-band shifts towards the lower frequencies of 5.6 GHz to 5.95 GHz. Figure 8 shows the simulated VSWR plots for different values of $e2_l$. By increasing the $e2_l$ from 15.55 mm to 19.09 mm, the notch frequency is varied from 5.75 GHz to 6.8 GHz.

In addition, it is noticed from the above results that, the lengths and widths of the corresponding slots and by adjusting the one parameter keeping the other parameters constant, only the corresponding notched band changes without disturbing the other notched-band. When the total lengths of the slots are approximately equal to a half wavelength, the optimal notched-band characteristics can be achieved. The proposed antenna design the optimal values of the elliptical split-ring slots $e1_w$, $e1_l$, $e2_w$, and $e2_l$ are chosen as 0.61 mm, 26.06 mm, 0.65 mm and 19.09 respectively which approximately determines the center frequencies of the desired notched-bands of WiMAX and WLAN.

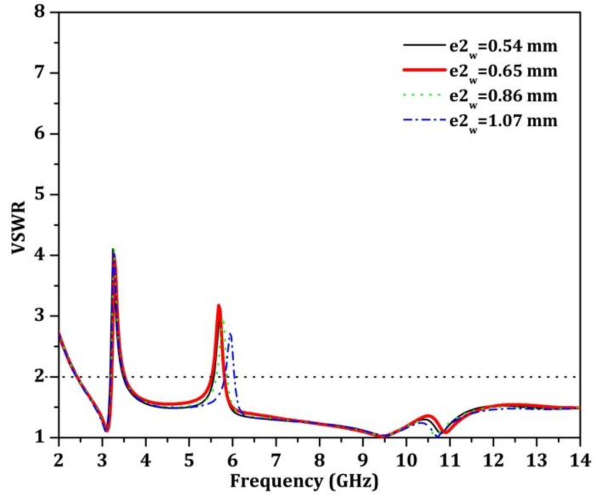

Fig. 7 Simulated VSWR curves for the different values of $e2_w$

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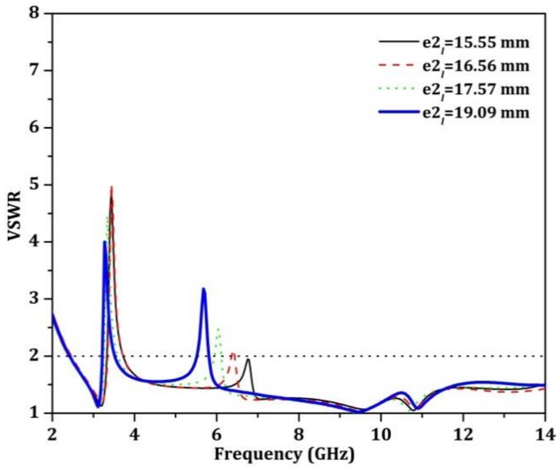
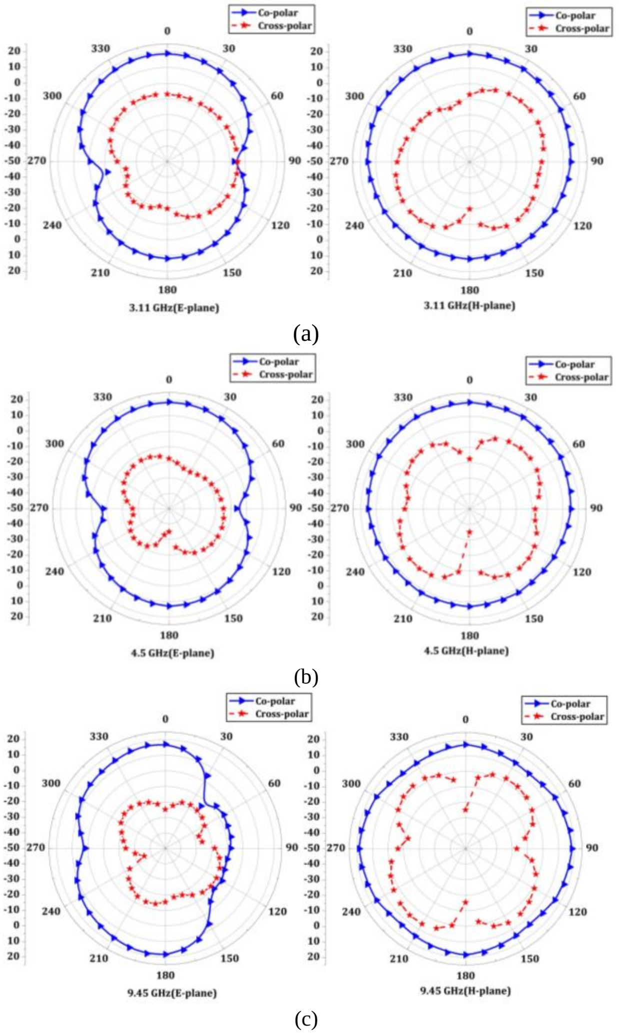


Fig. 8 Simulated VSWR curves for the different values of e1$_l$

The measured E and H-plane radiation patterns at 3.11, 4.5 and 9.45 GHz are presented in Fig. 9. From these figures, it indicates that the radiation patterns of proposed antenna are stable and omnidirectional in the H-plane and bidirectional in the E-plane.



(a)

(b)

(c)

Fig. 9 . Normalized typical E-plane and H-plane radiation patterns measured at (a) 3.11 GHz, (b) 4.5 GHz and (c) 9.54 GHz

The peak gain against the frequency of the proposed antenna is presented in Fig. 10. The gain varies from 4 dBi to 5.2 dBi for the UWB operating band, -2.8 dBi and -4 dBi for the rejected bands of WiMAX and WLAN range. Further, 97% the antenna efficiency is observed and at the notched bands. The radiation efficiencies are reduced to 50% and 45% from first to second notched bands respectively. The presented result shows that the proposed antenna is successfully performed with the rejection at 3.3 GHz WiMAX and 5.75 GHz WLAN.

Figure 11 shows the simulated group delay of the proposed antenna. The variation of group delay is within 1 ns throughout the UWB band except the dual notched bands at 3.3 GHz and 5.75 GHz in which the maximum group delay is more than 4 ns and 7 ns respectively. The group delay corresponds well to the magnitude of transmission characteristics, which indicates that the antenna has a good time-domain characteristic with small pulse distortion.

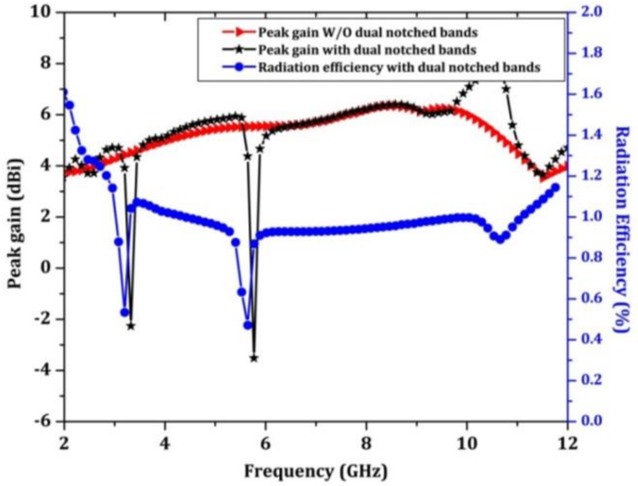


Fig.10. Peak gain and an antenna efficiency of the proposed antenna

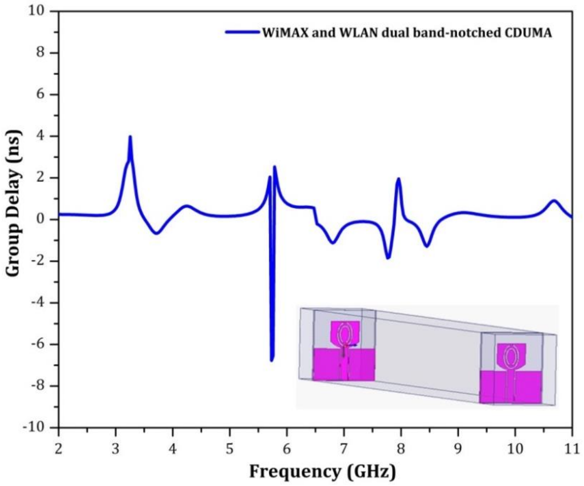


Fig. 11 Group delay variation dual band-notched UWB antenna

4. Conclusion

A planar UWB antenna with dual band-notched characteristics has been proposed and discussed in this paper. The antenna realized by etching the one elliptical split ring slot for WLAN on the radiating patch and another

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smaller elliptical ring slot for WiMAX on the radiating patch. The proposed UWB antenna covers the frequency from 2.7 GHz to more than 12 GHz with VSWR < 2 with dual notched bands at the vicinity of 3.32– 3.83 GHz and 4.96-5.43 GHz frequency range, which minimize the existing WiMAX (3.3-3.8 GHz) and WLAN (5.15-5.35 GHz) operating bands. Moreover, the proposed antenna has compact in size having a good omnidirectional radiation patterns and stable gains at the entire UWB operating band.

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B. Satyanarayana received his M. Sc., M. Phil. and Ph.D. degrees in Applied Electronics from Dept. of Applied Electronics, Gulbarga University, Gulbarga, Karnataka, India in 2011, 2013 and 2017 respectively. He is presently working as a Postdoctoral Fellow under the guidance of Dr. Manoj Kumar Meshram, Associate Professor, Indian Institute of Technology (BHU), Varanasi. His research interest includes design and development of UWB, MIMO antennas.

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