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Circular Patch Antenna with Defected Ground for UWB Communication with WLAN Band Rejection

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ABSTRACT

The design and performance of coplanar waveguide fed modified circular patch antenna for possible application in ultra wideband communication systems with band rejection for upper wireless local area network band (5.15 GHz - 5.85 GHz) is reported. This antenna is designed on glass epoxy FR4 substrate having size 30 mm × 20 mm × 1.59 mm. The coplanar waveguide fed circular patch antenna is modified by introducing L shaped slits in ground plane and U shaped slot in patch and performance analysis of antenna is simulated by applying CST microwave studio simulation software. Different designed antennas were tested with available experimental facilities. The developed end product shows a nice matching with feed network at frequencies 2.62 GHz, 3.94 GHz and 8.50 GHz and provides 10.38 GHz (3.33 GHz - 13.71 GHz) impedance bandwidth with wireless local area network 5.5 GHz (4.74 GHz - 6.15 GHz) band rejection. The co and cross polar patterns in elevation and azimuth planes at two frequencies namely 2.62 GHz and 3.94 GHz are obtained which dictate that co-polar patterns are significantly better than cross polar patterns. The simulated peak gain of antenna is close to 3.86 dBi and gain variation with frequency shows a sharp gain decrease in the frequency range 4.74 GHz to 6.15 GHz.

Keywords: Ultra wideband communication systems, coplanar waveguide feed, defected ground structure, frequency band notch characteristics

1. INTRODUCTION

Present day wireless communication systems including wireless personal area network systems (WPAN) require fast data storage as well as fast data exchange rate. For ultra wideband (UWB) communication systems, antenna must have small size, wider bandwidth, easy fabrication, low power consumption and consistent radiation pattern over the desired frequency band[1]. Planar structures are very useful for these systems because they are compact in size, have light weight, low production cost and these structures can be easily put inside the systems without protruding out[2]. The conventional patch antennas having infinite ground plane have narrow bandwidth, low gain and normally operate at a single frequency corresponding to their dominant mode of excitation[3]. Looking these limitations and possible applications of these antennas in UWB systems, extensive work on UWB antennas has been reported in recent times[4-7]. Jang and Hwang[4] achieved a circular slot type UWB antenna that displays excellent band rejection characteristics in 5GHz rejection band. Xian[5], *et al.* proposed a compact printed monopole UWB antenna with the band-notch function in the frequency band 5 GHz to 6 GHz with 3 GHz to 15 GHz impedance band. Li[6], *et al*. proposed a simple dual band-notched antenna for UWB applications. This antenna has a wide impedance bandwidth with two rejection bands at 3.5 GHz and 5.5 GHz, displays moderate gains and omnidirectional patterns over the operating bands except at the undesired frequencies. A simple UWB antenna with tunable and high rejection band-notch characteristics was proposed by Li[7], *et al.* that had an inverted V-shaped stub inserted into inside of the polygon slot and a stub integrated into the radiating patch. Srivastava and Mohan[8] proposed a printed monopole antenna for UWB applications with dual band notch property. The UWB monopole had a modified circular patch with an elliptical slot to reject worldwide interoperability for microwave access (WiMAX) frequencies. The modified ground plane is introduced to attain the wide impedance UWB bandwidth with G-shaped slot below the feed line to reject WLAN frequencies. In the proposed work; a CPW fed circular patch antenna is modified in steps to improve its performance. The modification in patch geometry and defects in ground plane are introduced together to improve the overall performance of antenna. The aim of the proposed work is to avoid interference from WLAN band in UWB communication systems. Though with proposed modifications, the complexity of design is increased but this resulted into a useful antenna for UWB communication systems.

2. ANTENNA DESIGNS AND ANALYSIS

2.1 CPW Feed Circular Patch Antenna

The design of proposed antenna started with consideration of a CPW fed circular patch having patch radius 9.3 mm. This antenna is designed on glass epoxy FR4 substrate material (relative permittivity $\varepsilon_r = 4.4$, substrate height $h = 1.59$ mm and loss tangent 0.025) having size 30 mm x 20 mm x 1.59 mm.

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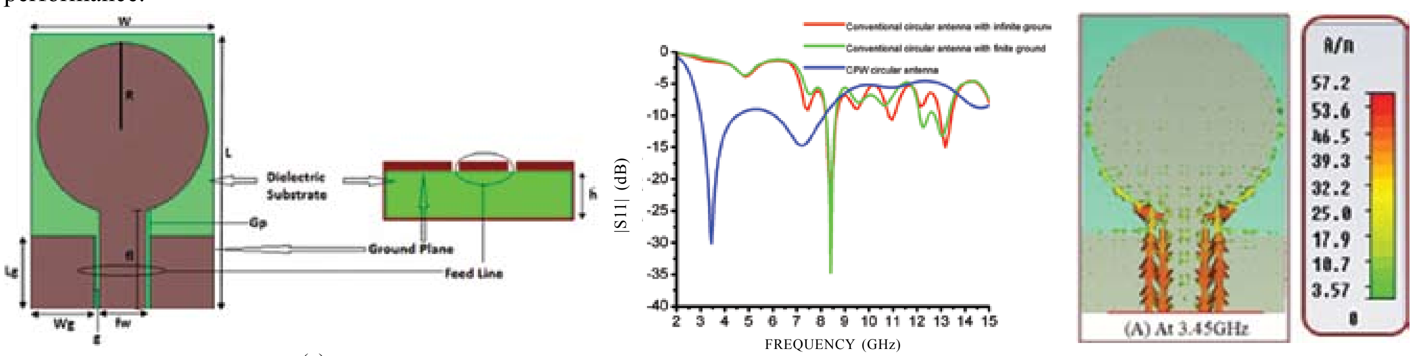
The length L_g and width W_g of the ground plane of considered geometry are 8.0 mm and 7.0 mm, respectively. The gap G_p between patch and ground is 1.8 mm whereas the gap g between the strip line and ground plane is 0.50 mm as shown in Fig. 1(a). The length f_L and width f_w of feed line are 10.8 mm and 5.0 mm, respectively. The considered feed line is electrically thick and contributes in the overall performance of antenna. These design parameters are obtained after extensive optimizations. A comparison of S_{11} variation of this geometry with the geometry having same radiating element on an infinite and finite ground planes is shown in Fig. 1(b). It clearly indicates that antenna with infinite ground plane efficiently operates at frequency 8.37 GHz while considering this radiating element with CPW fed; antenna efficiently operates at two frequencies 3.45 GHz and 7.3 GHz. Figure 1(c) shows the surface current distribution of antenna having CPW feed arrangement at frequency 3.45 GHz. It can be observed that strong current distribution appears between the lower half of the patch and feed line. The simulated impedance bandwidth close to 1.54 GHz (2.99 GHz to 4.53 GHz) and gain value close to 3.50 dBi may be achieved with CPW fed circular patch antenna This CPW fed antenna provides dumb bell shape patterns with more radiations normal to patch geometry in the upper hemisphere. This antenna is then modified in two steps to improve its performance.

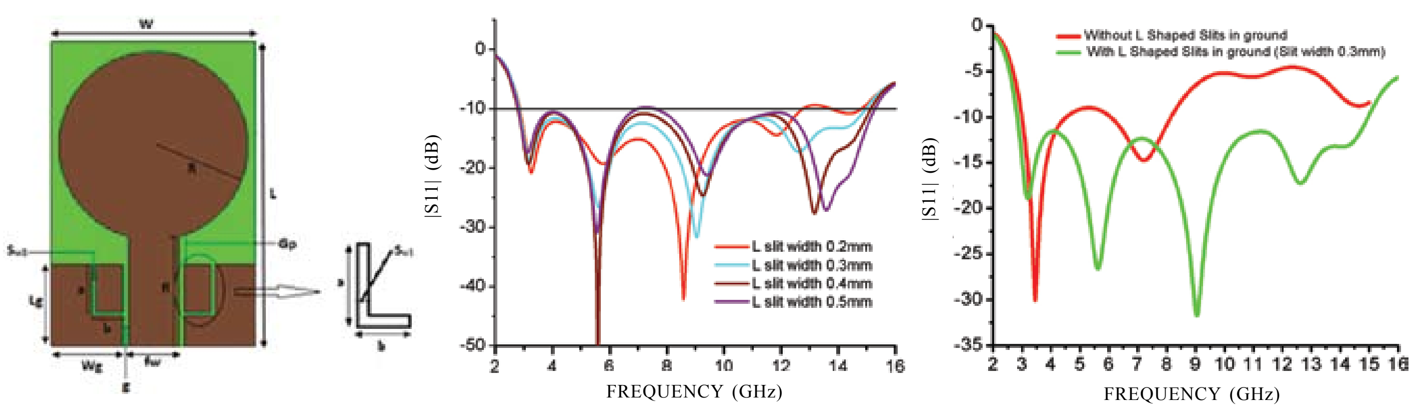
2.2 CPW Feed Circular Patch with Defected Ground Plane

In the first step of modification, two L-shaped slits are introduced one by one to make ground plane defective as shown in Fig. 2. The slit length in ground *a* and slit width in ground *b* are taken 5 mm and 3 mm, respectively. The slit width S_{w1} is optimised by simulating (S_{11}) parameter of antenna considering four different slit widths as shown in Fig. 2(b). Finally for the present work, slit width equal to 0.3 mm is selected because for this slit width, best performance from antenna is realised which is shown in Fig. 2(c). A comparison between simulated and measured reflection coefficient (S_{11}) as a function of frequency is shown in Fig. 3. The simulation results show that the considered antenna operates efficiently at frequencies 3.19 GHz, 5.62 GHz, and 9.04 GHz and presents an impedance bandwidth close to 12.14 GHz. The measured results provide an excellent matching between antenna and feed line at frequencies 3.02 GHz, 5.56 GHz, and 9.12 GHz with impedance bandwidth 9.85 GHz (from 2.68 GHz to 12.53 GHz) or 129 per cent with respect to central frequency 7.60 GHz. The simulated gain of this antenna at frequencies 3.19 GHz, 5.62 GHz, and 9.04 GHz are close to 1.23 dBi, 3.59 dBi, and 3.43 dBi, respectively.



(a) (b) (c)

Figure 1. (a) Geometry of CPW fed circular patch antenna with its parameter, (b) Comparison of variation of |S11| with frequency of circular patch antenna in different cases, and (c) Current distribution at 3.45 GHz.



(a) (b) (c)

Figure 2. (a) Geometry of CPW fed circular patch antenna with L shaped slits in ground plane, (b) Comparison of variation of |S11| with frequency of circular patch antenna for different slit thickness, and (c) Comparison of variation of |S11| with frequency of patch antenna with and without L shaped slits in ground plane.

The measured co and cross polar patterns of this antenna in elevation and azimuth planes are shown in Figs. 4(a) – 4(f) for the three frequencies namely 3.02 GHz, 5.56 GHz, and 9.12 GHz. In elevation plane, at frequencies 3.02 GHz, 5.56 GHz; the co-polar patterns are nearly 15 dB higher than cross polar patterns while at frequency 9.12 GHz; the co-polar pattern is nearly 25 dB higher than cross polar patterns. In azimuth plane; at all the three frequencies; the co-polar patterns are nearly 25 dB better than cross polar patterns. The obtained bandwidth covers the whole UWB frequency range but fails to reject the frequency band allocated for WLAN or for any other communication systems. Hence interference for WLAN and UWB communication systems cannot be avoided with present structure though proposed structure is covering entire UWB frequency range. Therefore this antenna is further modified to overcome realised limitation of structure.

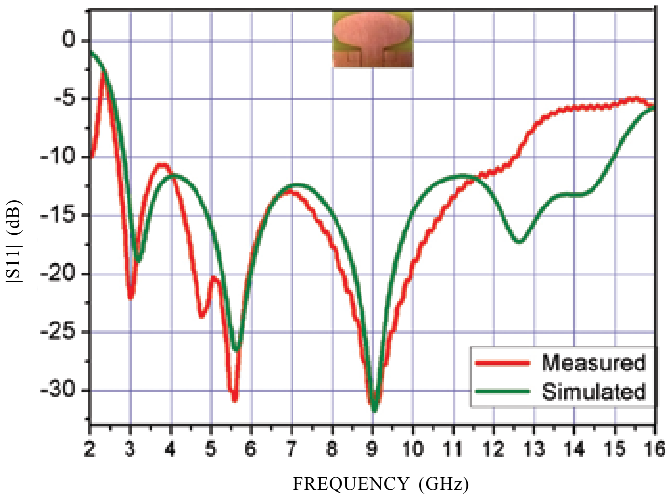


Figure 3. Simulated and measured |S11| with frequency of proposed antenna with L shaped slits in ground plane.

2.3 CPW Feed U Shaped Slot Circular Patch with Defected Ground Plane

Antenna geometry reported is previous section is further modified to make it more useful for UWB communication systems. Now a U shaped slot of appropriate dimensions is introduced in the circular patch as shown in Fig. 5(a) while developed prototype is shown in Fig. 5(b). The slot length *c* and slot width *d* are taken 5 mm and 10 mm respectively. On introducing this slot, a rejection band for WLAN system appears which was not realised in the previous case. On increasing slot line width (S_{w2}) from 1.00 mm to 1.75 mm, the rejection band shifts from lower frequency side to higher frequency side. The lower frequency side of the rejection band shifts from 4.98 GHz to 5.37 GHz while upper frequency side shifts from 5.53 GHz to 6.09 GHz. On increasing slot line width (S_{w2}), the frequency 5.62 GHz realised in previous case for nice matching between antenna and feed line starts shifting towards higher frequency side. This optimisation of slot line width is shown in Fig. 5(c) which indicates that on applying

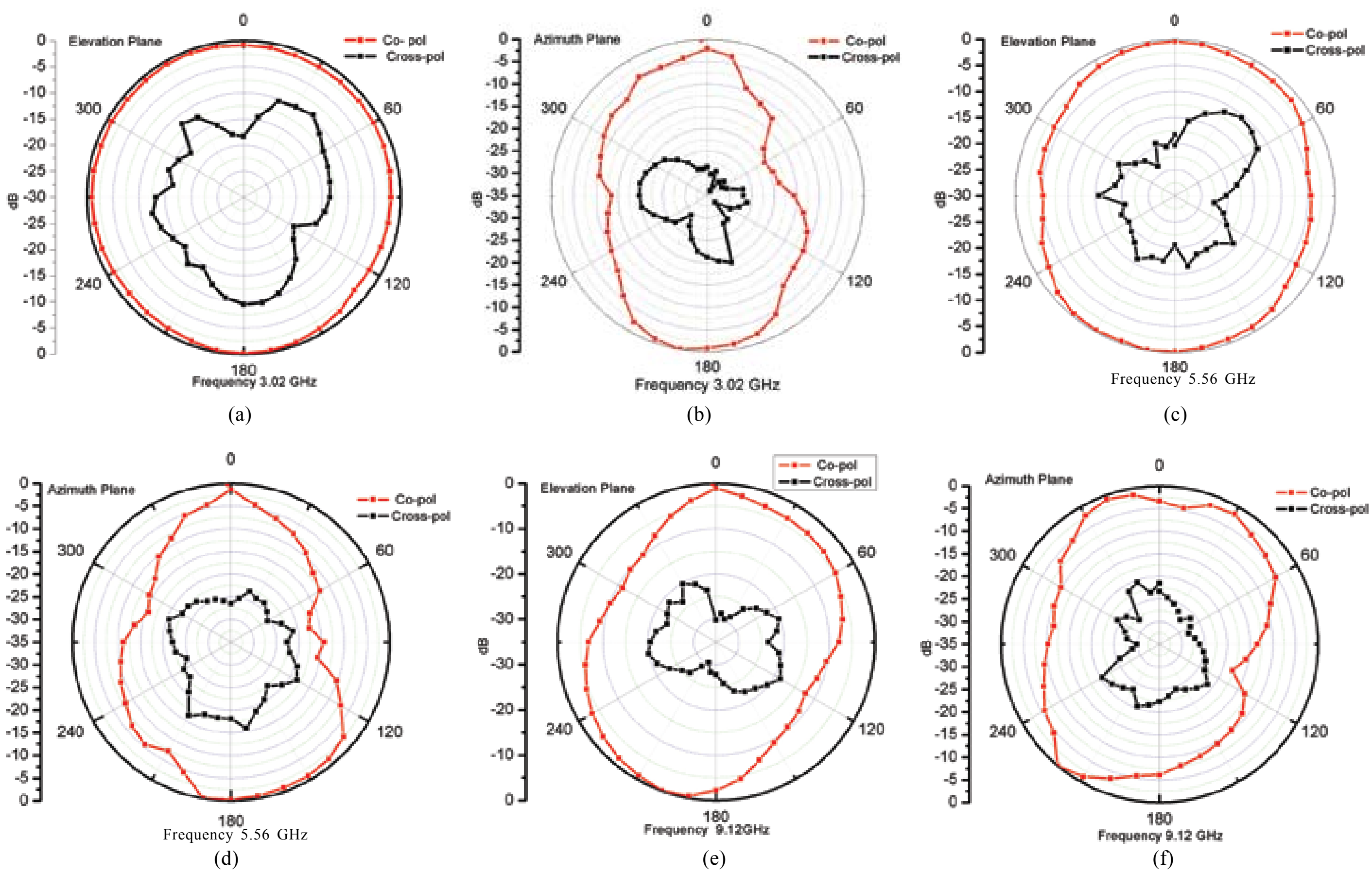


Figure 4. (a)-(f) Measured 2-D radiation pattern in elevation and azimuth planes at various resonance frequencies.

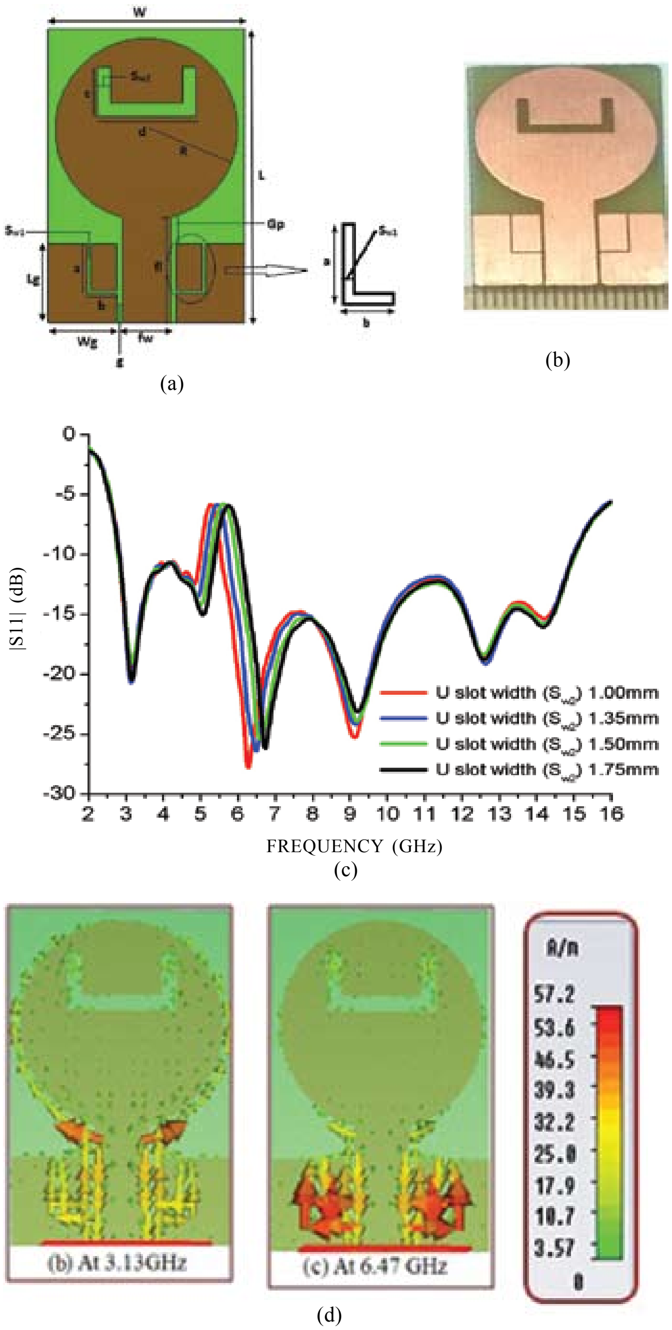


Figure 5. (a) -(b) Geometry of CPW fed circular patch antenna with U shaped slot in patch, (c) Comparison of variation of |S11| with frequency of circular patch antenna for different U slot width, and (d) Current distribution at different resonance frequencies.

slot line width S_{w2} equal to 1.35 mm; best performance with this antenna may be achieved. The simulation analysis suggests that on introducing the U slot in the circular patch; antenna efficiently operates at three frequencies namely 3.13 GHz, 6.47 GHz, and 9.05 GHz while the measured results suggest that at frequencies namely 2.62 GHz, 3.94 GHz, and 8.50 GHz; antenna operates efficiently. Figure 5(d) shows the surface current distribution of proposed antenna at frequencies 3.13 GHz and 6.47 GHz. Very strong current distribution appear on the L slits in ground planes for these frequencies. A comparison between simulated and measured variation of VSWR as a function of frequency is shown in Fig. 6. A reasonable agreement between simulated and measured VSWR results is realised. The performance of this designed antenna is compared with that of a planar UWB antenna reported by Abbosh[9], *et al.* that reports excellent band rejection for WLAN band. Similar band rejection was also realised by Jang and Hwang[4] where two parasitic patches and a parasitic slot were considered to achieve a circular-slot type UWB antenna with excellent band-rejection characteristics. The measured result showed excellent rejection band characteristics, deep rejection, very sharp skirt and sufficient rejection bandwidth, with good radiation characteristics in UWB operating band. Realised discrepancies between simulated and measured results in this communication can be attributed fabrication tolerances, SMA connectors and measured environmental effects. The feed line in present case is also thick and location of feed point during simulation and fabricated antenna may also be different. The simulated impedance bandwidth with proposed geometry is now 12.16 GHz that is extended between frequency range 2.81 GHz to 14.977 GHz. A rejection band for WLAN 5.5 GHz extended between 5.13 GHz - 5.75 GHz is also obtained. The measured data provides impedance bandwidth close to 10.38 GHz or 121 per cent with respect to central frequency 8.52 GHz and it is extended between frequency range 3.33 GHz to 13.71 GHz. This frequency band also includes a rejection band for WLAN 5.5 GHz that is extended between frequency range 4.74 GHz to 6.15 GHz.

A comparison of gain of two realised antennas as a function of frequency is shown in Fig. 7. The gain of antenna with U slot and modified ground is negligibly small in the rejection band for WLAN 5.5 GHz which is a desired feature realised with this antenna. The maximum simulated gain of the proposed geometry is close to 3.86 dBi which is obtained at frequency 7.82 GHz. The simulated gain at frequencies 3.13 GHz, 6.47 GHz, and 9.05 GHz are close to 1.98 dBi; 3.51 dBi and 3.21 dBi, respectively. The measured co and cross polar patterns of antenna in elevation and azimuth planes for the two frequencies lying in lower band allocated for UWB communication systems i.e. 2.62 GHz and 3.94 GHz are shown in Fig. 8(a) to 8(d). In elevation plane; the co-polar patterns at both frequencies are

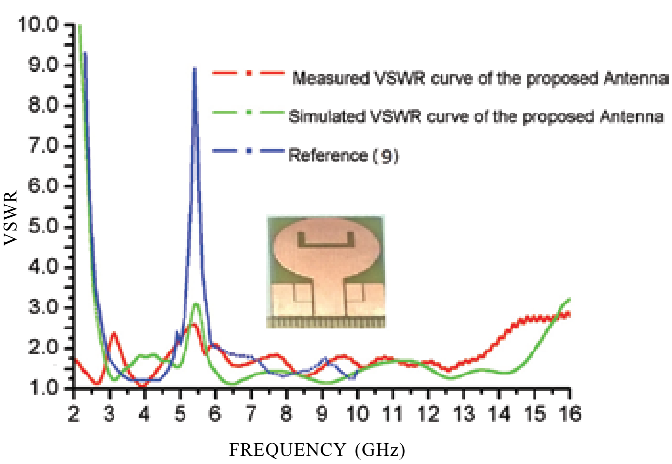


Figure 6. Comparison between VSWR curve with proposed antenna and reference antenna.

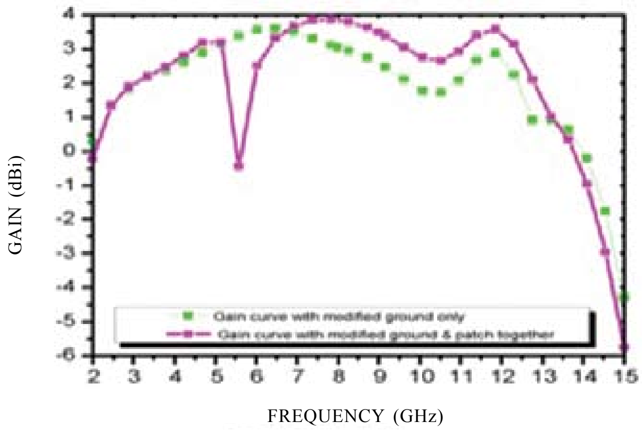
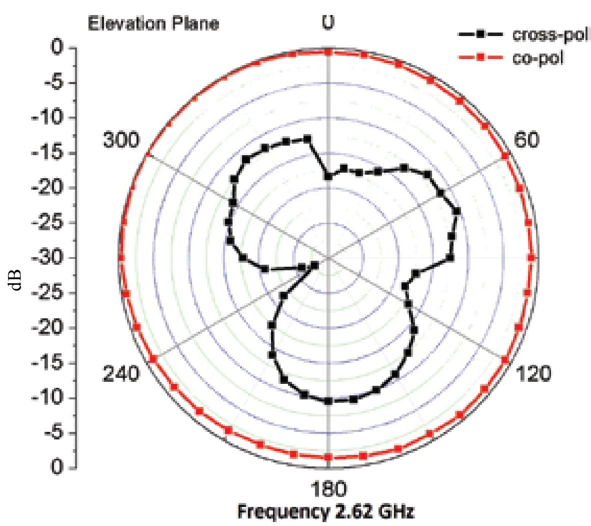


Figure 7. Simulated gain variations of proposed antenna with and without U slot in patch.

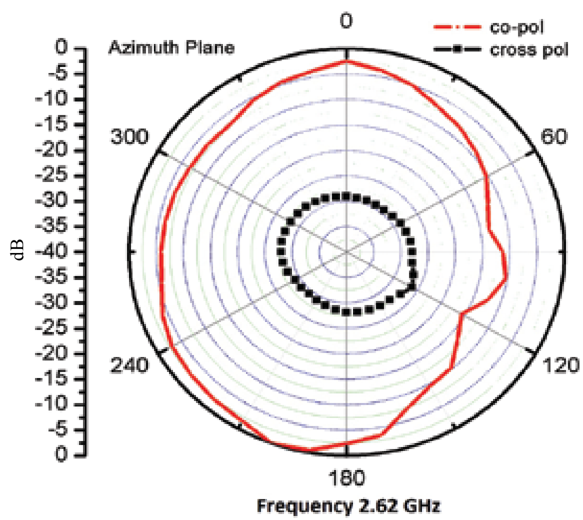
nearly 15dB higher than cross polar patterns while in azimuth plane, at both the frequencies; co-polar patterns are nearly 25 dB higher than cross polar patterns. At 2.62 GHz; the co-polar pattern in elevation plane is omni-directional while cross polar pattern is more directional in nature with 3 dB beam width close to 85°. At 3.94 GHz; the co-polar pattern in azimuth plane is more directional than elevation plane patterns with 3dB beam width close to 40°.

3. CONCLUSION

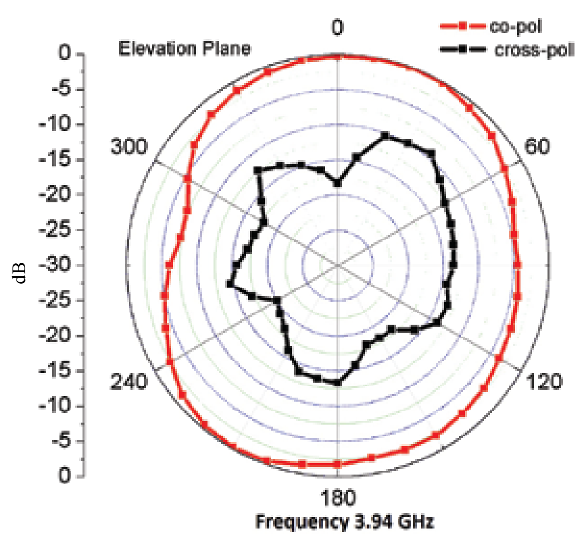
This paper reports the design and performance of a compact CPW fed modified circular microstrip patch antenna designed for ultra wideband (UWB) applications. In this structure, both ground plane and radiating patch are modified to obtain desired performance. The WLAN 5.5GHz band rejection is also realised within obtained frequency range. The experimental results show that the fabricated prototype



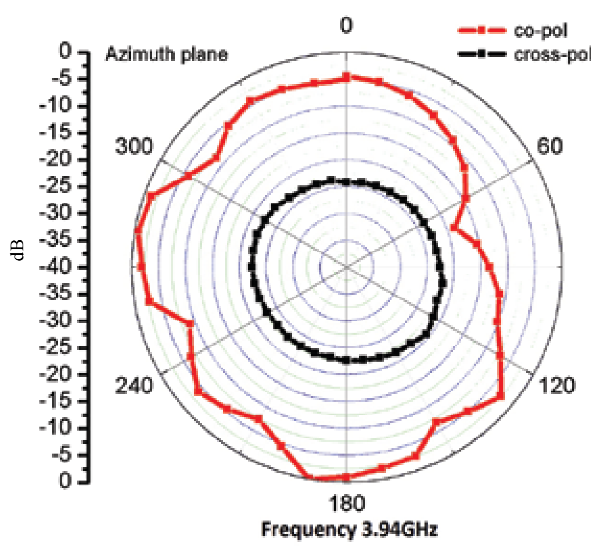
(a)



(b)



(c)



(d)

Figure 8. (a-d) Measured 2D radiation pattern in elevation and azimuth planes at various resonance frequencies.

provides wide impedance bandwidth 10.38 GHz (3.33 GHz-13.71 GHz) with rejected WLAN 5.5 GHz band (4.74 GHz to 6.15 GHz) with peak gain close to 3.86 dBi. The measured radiation patterns suggest that co-polar patterns in elevation pattern are nearly 15 dB better than cross polar patterns while in azimuth plane, co-polar patterns are nearly 25 dB higher than cross polar patterns. Proposed antenna operates well in entire UWB frequency range.

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He has designed this antenna on CST software and carried out mathematical analysis of the developed prototype.

Mr Ajay Tiwari received MTech (Comm. and Info. Tech.) from University of Rajasthan, in 2012. He is working as a Research Assistant in a DEIT, New Delhi supported project. His research interests are reconfigurable antennas, UWB antennas, wearable and flexible antennas and slot antennas. Currently he is working on reconfigurable antennas.
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