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Printed Fork shaped Monopole Antenna for UWB Applications with Band Rejection Characteristics

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Abstract :*This article describes the design of a band rejection characteristics using fork shaped patch antenna for Ultra-wide-band (UWB) applications. Two bands WiMAX (3.3-3.7 GHz) and C-band satellite communications (3.7-4.2 GHz) is filtered out by inserting two asymmetrical L-shaped in each arm of the tuning fork shaped patch. The 50 ohm Microstrip feed-line is used to excite the antenna. The Ansoft's HFSS V.13.0 electromagnetic suite is used to simulate the suggested antenna using low cost glass epoxy FR-4 substrate having relative permittivity 4.4 and loss tangent 0.02. The suggested antenna shows gain at satisfactory level with omnidirectional radiation characteristics over the entire UWB band.*
Keywords -*band notch characteristics; monopole antenna; tuning fork shape; printed monopole antenna; Ultra-wide-band (UWB).*

I. Introduction

For commercial applications the first definition of the Ultra Wide Band (UWB) technology was furnished by FCC (Federal Communications Commission) in February 2002 [1]. In recent years the Ultra-Wide-Band (UWB) technology concern to the enormously large bandwidth. This large bandwidth extends several benefits such as low power consumption, high data rate, high time resolution, low-cost implementation, obstacle penetration, resistance to interference, covert transmission, co-existence with narrow-band systems and so on. Due to these benefits UWB systems used in communications, radar, imaging and positioning applications.

Basic properties and design principles of UWB antennas described in terms of both frequency-domain representation and a time-domain representation of the system [2]. Fork-Shaped Monopole Antenna presented with extra Bluetooth band [3]. In [4], Ali Foudazi et al. described planar monopole antenna for UWB applications with extra three bands GPS/GSM/WLAN, antenna has diamond-shaped patch. To increase the transmission quality of UWB systems and to avoid multi-path fading, antenna diversity technic is used [5], asymmetric coplanar strip (ACS)-fed UWB antenna presented. In [6] a pentagonal shaped patch antenna for UWB and UMTS, Bluetooth bands described, antenna is designed and built on a FR-4 substrate. In [7], Rekha P. Labade et al. investigated a novel monopole antenna for dual band Bluetooth and UWB applications; antenna structure consist of half octagonal ring shape radiating patch with modified ground plane and for achieving Bluetooth band a quarter wavelength rectangular strip is placed through via hole.

UWB performance influenced by the ground plane effects and these are suppressed by inserting a strip into a slot cut on the rectangular monopole antenna [8]. Printed slot antennas are attractive because of their wide impedance bandwidth, low cost, planar structures and easy integration with active devices or MMICs. Thus, great interest in various printed slot antennas can be seen in the literature [9]. FCC assigned the frequency bands for UWB in the range 3.1 to 10.6 GHz, the possibility of them causing interference near communications systems such as such as WLAN, Wi-MAX, and X-band was considered and researchers carried out technique to avoid such interference by adding notches [10-12]. The IEEE802.11a/n WLAN systems occupying some portion of UWB system, this cause interference to the UWB spectrum. To minimize such interference, antenna can be designed with band-notch technique [13-14]. In [15] UWB antenna designed with extra bands, antenna consists of an octagonal-shaped slot fed by a beveled and stepped rectangular patch for covering the UWB band and By attaching three inverted U-shaped strips at the upper part of the slot in the ground, Bluetooth, GSM, and GPS Bands can be obtained. A rectangular monopole antenna for UWB with dual band notch characteristics, a T-shaped stub embedded in the square slot of the radiation patch and a pair of U-shaped parasitic strips beside the feed line is used [16].

In this communication, we demonstrate the design of a band notched characteristics tuning fork shaped patch antenna for Ultra-wide-band (UWB) applications. Two bands WiMAX (3.3-3.7 GHz) C-band satellite communications (3.7-4.2 GHz) are filtered out by inserting slots in each arm of the tuning fork shaped patch. The proposed design is validated numerically, relating return loss, gain and radiation characteristics.

II. Antenna Design

The schematic of the printed fork shaped monopole antenna depicted in Fig. 1. Antenna structure consists of tuning-fork shape patch printed on a substrate (24×35 mm^2). In each arm two L-shaped slots are introduced. The ground plane is rectangular in shape with asymmetrical slots at corners and one slot in the middle. The simulation of the proposed antenna is carried out by using electromagnetic suite Ansoft's HFSS v. 13.0 [19]. The low cost FR-4 material with height 1.6 mm and dielectric constant 4.4, tan∂= 0.02 is used to design the proposed antenna. The disc monopole microstrip antenna has radius *a*, and is fed by 50 Ω microstrip line feed. The disc patch antenna of radius *a* is given by the equations described in [17],

$$a = \frac{F}{\sqrt{1 + \frac{2h}{\pi F \epsilon_r}\left[ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]}}$$

Where, $F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}}$

and remember *h* must be in *cm*.

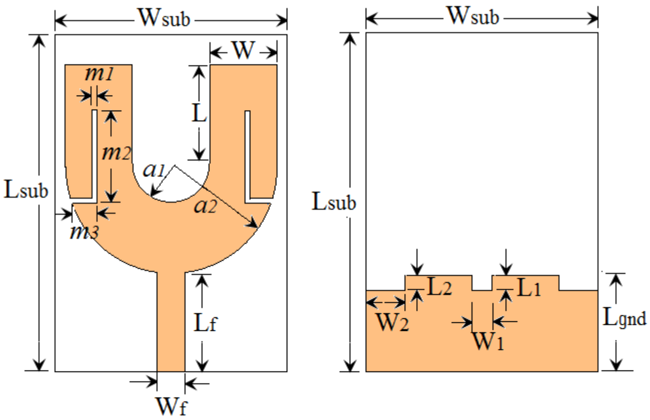

Fig. 1. Schematic of the proposed fork shaped printed monopole Antenna with L shaped slots.

a) The development of UWB Antenna

The development of UWB antenna is shown in Fig.2. Initially basic circular disc monopole antenna has been designed as shown in Fig.2 (a) Antenna #A. Beveling technique is used to increase the bandwidth by inserting asymmetric slots at corners in the ground plane shown in Fig.2 (b) Antenna #B and by this corner slots, it is noted that vertical current flow has been enhanced hence good impedance match can be observed. As shown in Fig.2 (c) Antenna #C, annular ring monopole antenna is been formed by cutting circular slot of radius a_1 with a worthless effect on the performance characteristics such as impedance bandwidth or radiation pattern. Thereafter, semi-annular-shaped monopole antenna is designed as shown in Fig.2 (d) Antenna #D. Then two rectangular strips of length L and width W has been placed to make tuning fork like structure gives final UWB antenna as designed in Fig.2 (e) Antenna #E. The optimized values that give desirable outcomes are fixed and continued on next stage.

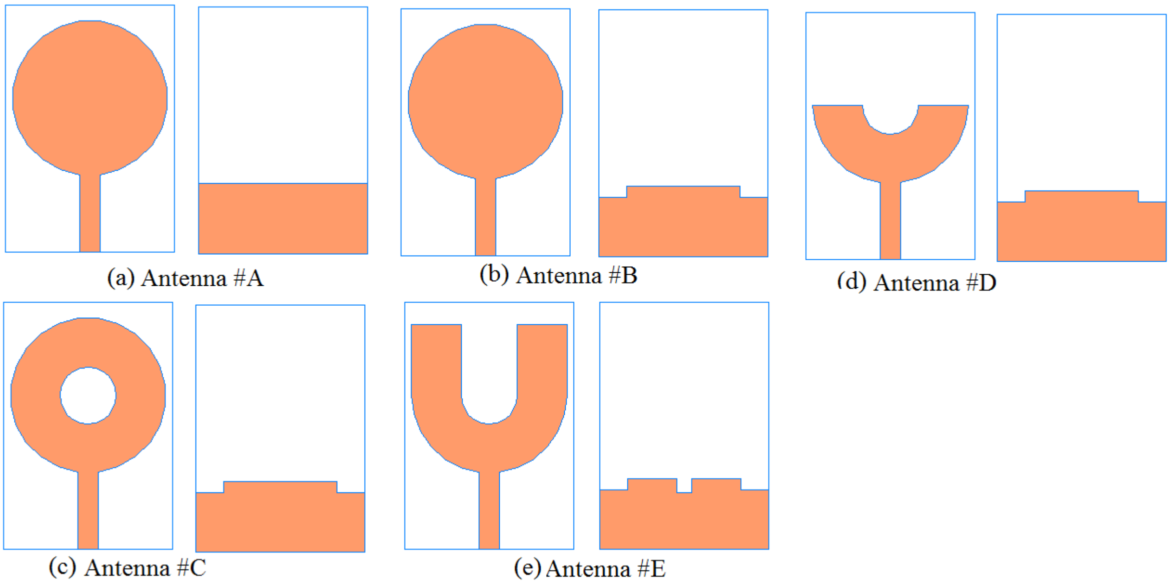

Fig. 2. The development printed fork shaped UWB monopole antenna.

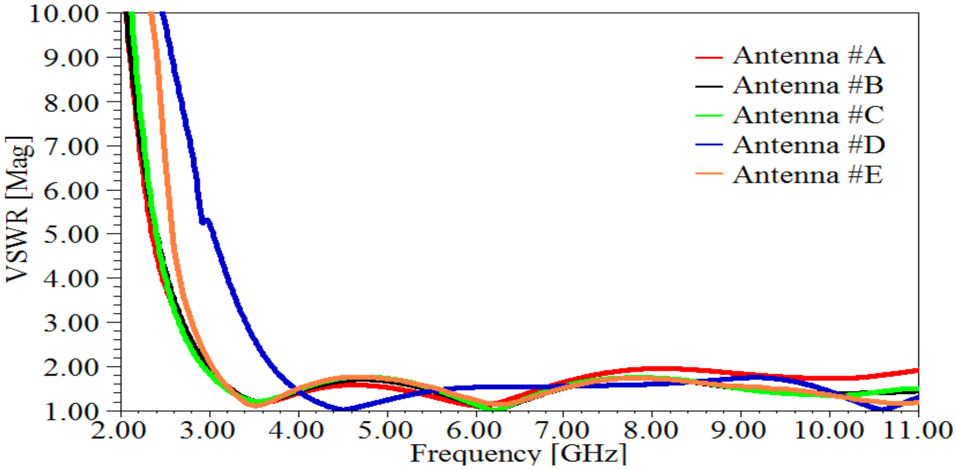

Fig. 3.VSWR polts for various antenna design.

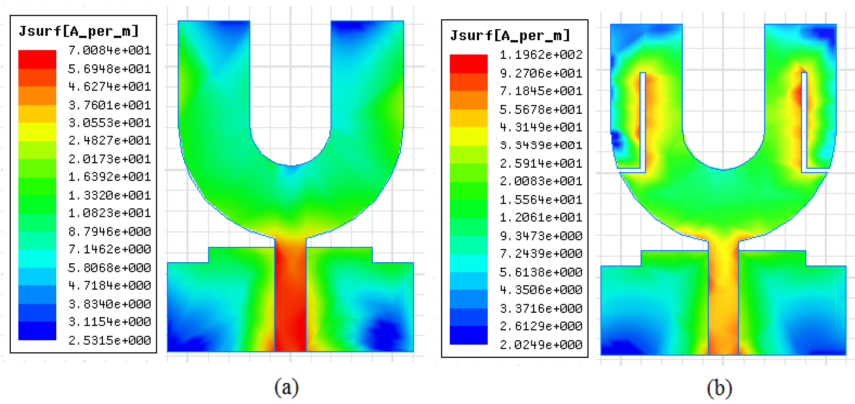

Fig. 4. Current distribution of the antenna at 3.75 GHz; (a) without slots, (b) with slots.

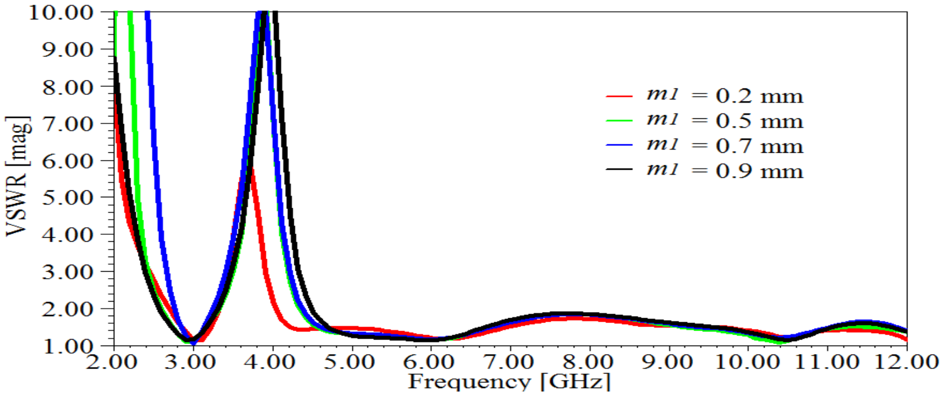

Fig. 5.VSWR plots for various width m_1.

b) Band-notched Antenna design

The schematic of the proposed band-notched fork shaped monopole antenna for UWB applications is shown in Fig. 1. For filtering out required two bands WiMAX (3.3-3.7 GHz) and C-band satellite communications (3.7-4.2 GHz),first it is necessary to observe the current distribution of fork shape patch antenna at center frequency. Two asymmetrical L-shaped slots of quarter wavelengths are inserted in each arm of the fork shaped patch to filter out WiMAX and C-band satellite communications bands. The total length of two L-shaped slots is about half wavelength of the center frequency f_c = 3.75 GHz of the band to be filtered out 3.3-4.2 GHz is given by [18],

$$f_c = f_{notch} = \frac{c}{2L_{slot}\sqrt{\frac{\epsilon_r+1}{2}}}$$

f_{notch} – notching frequency

L_{slot} – total length of two L-shaped slots

The total length of two L-shaped slots is given as,

$$L_{slot} = L_{slot\,1} + L_{slot\,2} = 2(m_1 + m_2 + m_3) = \frac{\lambda_g}{2}$$

The dimensions of the proposed antenna are optimized with the help of Ansoft's HFSS simulation software and are given as: W = 7 mm, L = 10 mm , a_1 = 4 mm, a_2 = 11 mm, L_f = 11 mm, W_f = 3 mm, L_{gnd} = 10 mm, L_1 = 2 mm, W_1 = 2 mm,L_2 = 1.5 mm, W_2 = 4 mm, m_1 = 0.7 mm, m_2 = 9.6 mm, m_3 = 2.5 mm.

III. Results and Discussions

B. Fork shaped Printed Monopole Antenna

In this part, the fork shaped printed monopole antenna with several parameters was designed, and numerical results of the VSWR, radiation characteristics are demonstrated. The electromagnetic suite Ansoft's HFSS used to carry out simulation of the proposed monopole antenna [19]. The development of Fork shaped UWB printed monopole antenna described in terms of VSWR versus frequency as shown in Fig. 3. It is observed that in each stage antenna gives impedance bandwidth at satisfactory level with VSWR in the range 2:1.

C. UWB fork shaped antenna with band rejection characteristics

After formation of fork shaped printed monopole UWB antenna it is necessary to observe current distribution at center frequency of the bands WiMAX and C- band satellite communication to reject from the UWB band. Fig. 4 (a) shows the current distribution of the fork shaped printed monopole antenna at center frequency and more current distribution observed in each arm of the fork shaped patch. The pair of L shaped slots of quarter wavelength each inserted where maximum current distribution is observed. After placing pair of L shaped slots, it is noted that more surface current is distributed near the edges of slots.

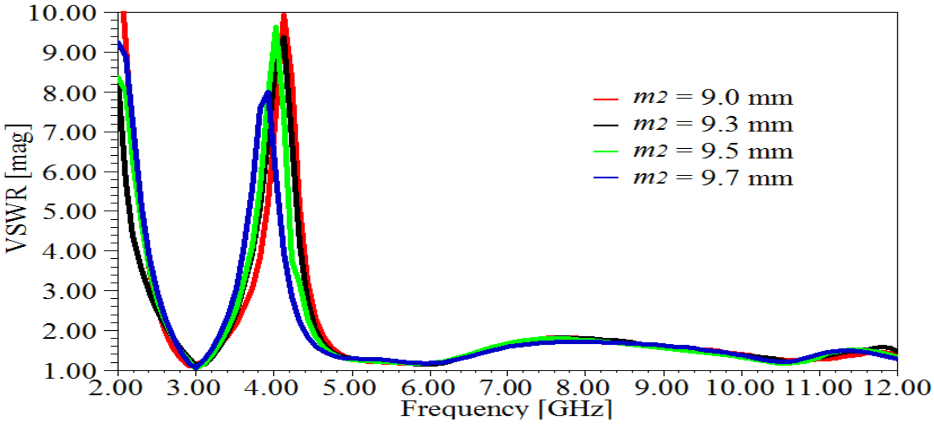

Fig. 6.VSWR plots for various length m_2.

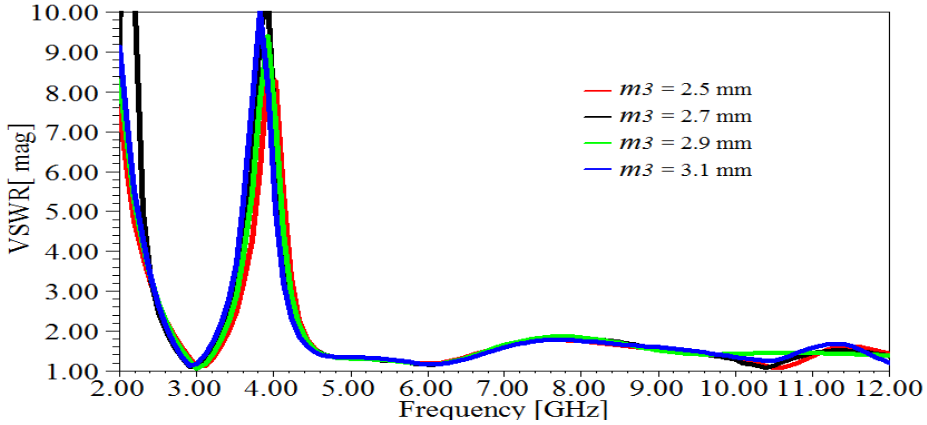

Fig. 7.VSWR plots for various length m_3.

Each L shaped slot has width m_1, and lengths m_2 and m_3, and by adjusting these lengths, desired band has been rejected. For each parameter, parametric analysis is carried to achieve desired results. Initially width m_1 of L shaped slots has been varied and other parameters are kept constant such as m_2 and m_3. Fig.5 illustrates the VSWR characteristics for four values of m_1 (0.2, 0.5, 0.7 and 0.9 mm). As width of slot m_1 increases, impedance bandwidth of rejection band increases from 74, 100, 116 and 120 MHz, and also corresponding resonant frequencies increases form 3.72, 3.83, 3.90 and 4.0 GHz respectively. In second stage length m_2 of L shaped slots have been varied and other parameters are kept constant such as m_1 and m_3. Fig.6 illustrates the VSWR characteristics for four values of m_2 (9.0, 9.3, 9.5 and 9.7 mm).

As length m_2 increases, impedance bandwidth of rejection band decreases from 118, 115, 113 and 108 MHz, and also corresponding resonant frequencies decreases form 4.41, 4.12, 4.03 and 3.92 GHz respectively.In third stage length m_3 of L shaped slots have been varied and other parameters are kept constant such as m_1 and m_2. Fig.7 illustrates the VSWR characteristics for four values of m_3 (2.5, 2.7, 2.9 and 3.1 mm). As length m_3 increases, impedance bandwidth of rejection band increases from 99, 100, 103 and 104 MHz, and corresponding resonant frequencies decrease form 4.02, 3.91, 3.90 and 3.82 GHz respectively. Fig. 8 shows the return loss plot of the proposed fork shaped printed monopole antenna with pair of L shaped slots and corresponding VSWR plot shown in Fig. 9.

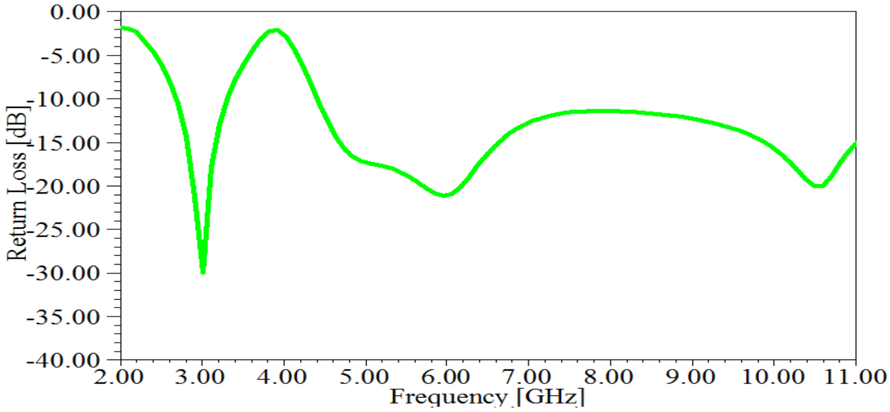

Fig. 8. Return los plot of the proposed antenna shown in Fig. 1.

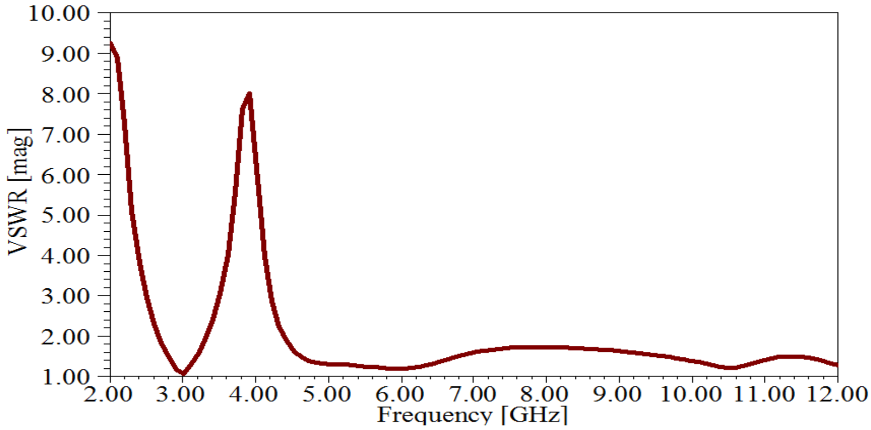

Fig. 9.VSWR plot of the proposed antenna shown in Fig. 1.

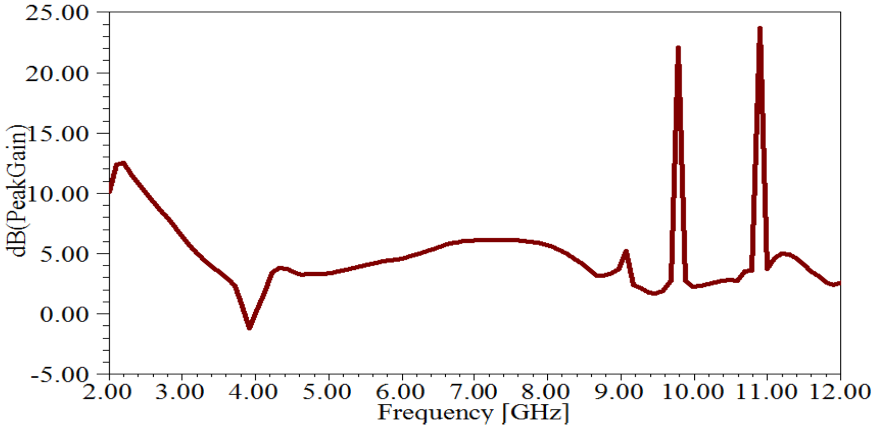

Fig. 10. Gain plot of the proposed antenna shown in Fig. 1.

It is noted that two bands WiMAX (3.3-3.7 GHz) and C-band satellite communications (3.7-4.2 GHz), is rejected causes electromagnetic interference in the existing UWB band. The gain plot of the proposed antenna shown in Fig. 10 and it is observed that a sharp decrease of maximum gain in rejection band at 3.75 GHz and outside stable gain is observed. Fig. 11 shows E – plane and H – plane radiation characteristics with co-polarization and cross-polarization at frequencies 3.5 and 5.2 GHz respectively. It is also observed that radiation characteristics in H – plane are nearly omnidirectional.

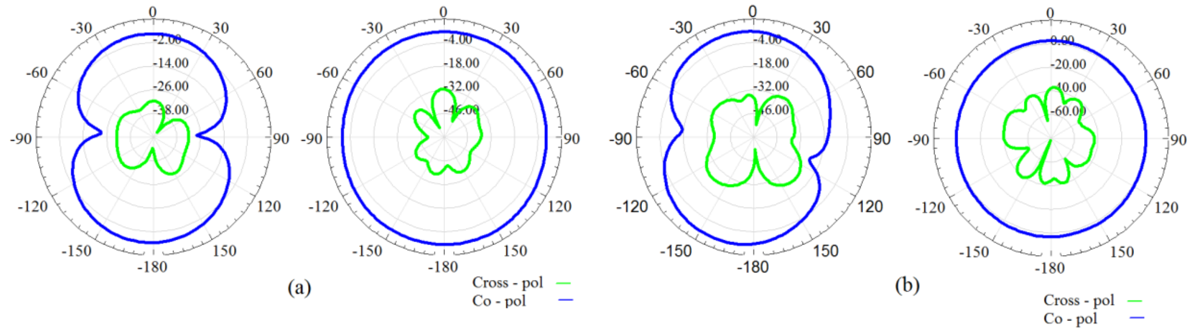

Fig. 11. E – plane and H – plane Radiation patterns at (a) 3.5 GHz ,(b) 5.2 GHz.

IV. Conclusion

In this article, compact fork shaped printed monopole antenna with a pair of L shaped slots have been designed for UWB applications with band rejection characteristics. The designed antenna has the rejection band around 3.3 - 3.6, 3.6 - 4.32 GHz in the UWB range. The narrow band wireless services create an electromagnetic interference therefore it is necessary to remove such bands by using notch technique proposed in this article. Simulation results show that proposed antenna is a good candidate for UWB applications.

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