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The Design of Ultra Wide Band Circular Monopole Antenna with Triple Band Notch Characteristics

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Abstract

Ultra Wide Band is the explication for the short-range wireless communication system. Electromagnetic interference with the co-existing narrow bands was the major problem in the UWB and to achieve better over, Ultra Wide Band antennas with Band Notch characteristics are designed. The FCC (Federal Communication Commission) has recommended the use of unlicensed Ultra Wide Band spectrum frequency ranging from (3.1-10.6) GHz. This paper presents a Triple Band stop Printed circular Monopole Antenna with reduced ground structure. In this paper, the co-existing wireless communication bands like Worldwide Interoperability Microwave Access band (WIMAX); INST band and X-band will be notched by using notching techniques. The proposed antenna occupies a volume of 26 X 31 X 1.6 mm^3 is falsified with FR4-epoxy substrate. Based on methodologies, various shapes are etched on the radiator to reject WIMAX (3.3-3.7) GHz; INST (4.5-4.8) GHz; X-band satellite downlink frequency (7.25-7.85) GHz. A rectangular slot is etched on the patch to create a notch at WIMAX band, a couple of inverted L shaped slots are incorporated on either side of the patch to create notch at INST band and RSRR (Rectangular split ring resonator) is placed on the feed to create notch at X-band satellite services. The results show that the antenna operates from 2.8-10.8 GHz, the RE (Radiation Efficiency) is more than 90%, the peak gain is above 2.2-5.6 dBi, and considerably good radiation properties except at the notched bands. All the simulations are performed by using Ansoft HFSS software. The results depicts that the designed proposed antenna is well fit for UWB devices and reaches the fulfillments of UWB systems applications.

Keywords: *Band-notch, interference reduction, Circular monopole antenna, UWB, Ansoft HFSS***.**

1. INTRODUCTION:

In 2002, UWB technology was authorized by FCC for civilian use, and waveband is starting from 3.1 to 10.6 GHz was classified as a usable band for UWB communication systems. It has many advantages like high-speed data of roughly 480Mbps to 1.6Gbps, less power consumption, and little interference. In consideration of the existence of narrowband wireless communication systems like IEEE 802.16 WIMAX (3.3-3.7 GHz), INST (4.5-4.8 GHz), IEEE 802.11a WLAN (5.15-5.825 GHz) and X-band satellite downlink communication services (X-band: 7.25-7.75 GHz) also working within the UWB band creating electromagnetic (frequency) interference which ends up within the signal loss. The UWB antenna with band stop characteristics is a straightforward and effective solution to restrain these interference signals for UWB communication [1]. Several Printed Monopole UWB Antennas (PMA) are utilized in various applications of wireless communication like radar, cognitive radio and indoor positioning due to their affordability, wider Band Width and design pliability [2, 3]. PMAs have various geometries but the foremost common shapes of PMAs employed by researchers for UWB applications [4-7] are rectangular, circular, square, triangular, elliptical and hexagonal. Various methods utilized in the past few years to achieve single and multiple band notch characteristics for UWB systems to suppress interference from WIMAX, WLAN and X-band systems [8-10]. Method includes locating a few of ground stubs [8]. However, the designed antenna [8] mitigates the interference from WLAN systems only. Band-notches at WLAN also as WIMAX bands are often obtained by using meandered slot and U-slot [9] and by placing modified capacitance loaded loop (MCLL) resonators near the feed line [10], and by using open loop resonator and defected microstrip structure (DMS) [11]. The designs are presented in [9-12] by providing triple band notches with good performance, but they are not compact enough and band stop resonators are hardly complicated. During this communication, an easy triple band notch UWB antenna is meant to be used in portable devices. The proposed antenna size is 26 x 31 x 1.6 mm^3 which may be a small compared to the designs of a circular monopole antenna with the reduced ground plane. The notches are often obtained by etching rectangular shaped open loop resonator on the patch to create a notch at WIMAX band, a couple of inverted L shaped open loop resonators are incorporated on either side of the patch to create a notch at INST band and embedding RSRR shaped slot on the feed line to create a notch at X-band satellite communication services.

2. ANTENNA DESIGN:

2.1. Antenna Geometry

The optimized UWB printed monopole antenna with triple notch is depicted in Fig. 1. The Proposed antenna is etched on FR4-epoxy dielectric material. The substrate is having 1.6mm height, dielectric constant of 4.4 and loss tangent of 0.02. The size of the antenna is 26 mm x 31 mm excited by a microstrip line. The designed antenna comprises a circular shaped monopole which actions as a foremost radiating part having radius ‘r’ and reduced ground.

By optimizing the patch radius and ground dimensions, good return loss is achieved. First notch at 3.5 GHz is realized by cutting rectangular slot on monopole antenna. Second notch at 4.6 GHz is realized by a couple of inverted L shaped open loop resonators are incorporated on either side of the patch. Third notch at 7.5 GHz X-band is generated by etching RSRR slot on the feed line.

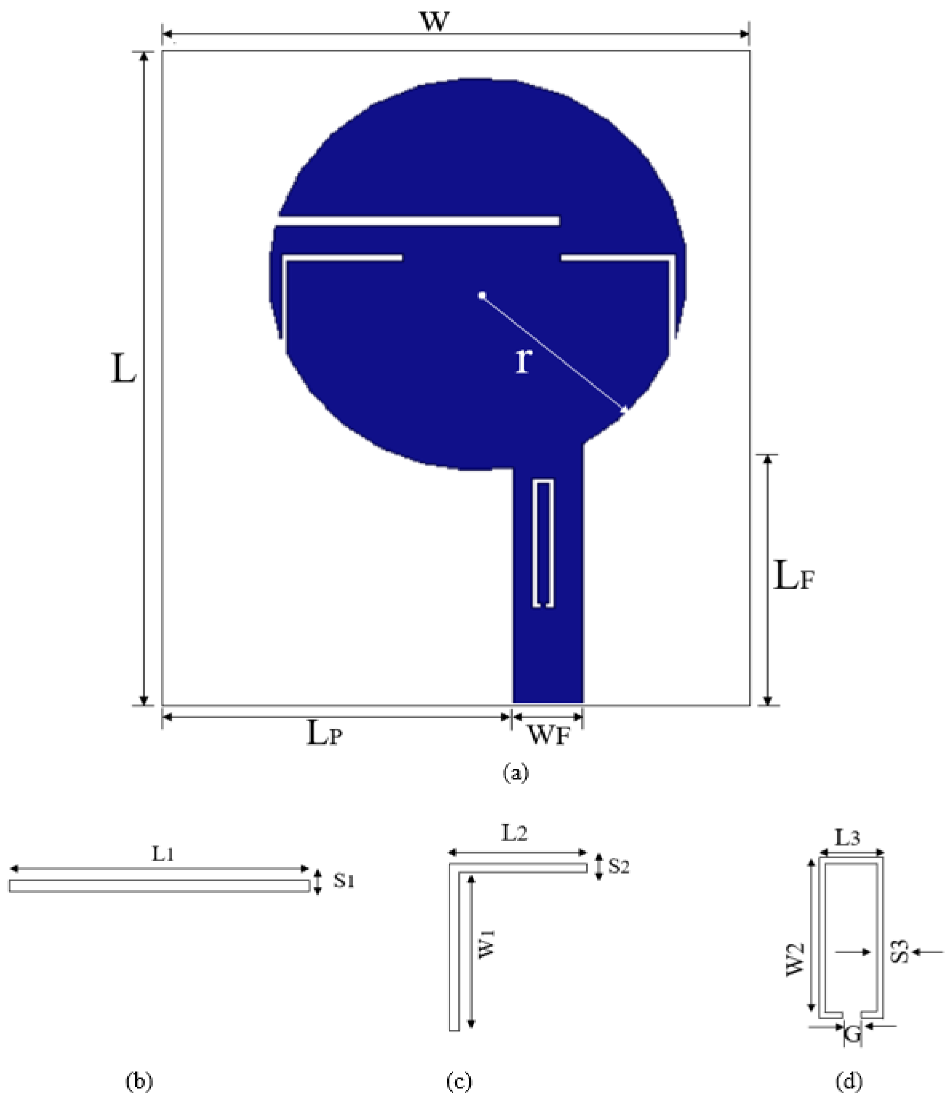


Figure 1. Configuration of the designed antenna (a) Overall model(b) rectangular slot (c) Inverted L-shaped slot (d) RSRR slot

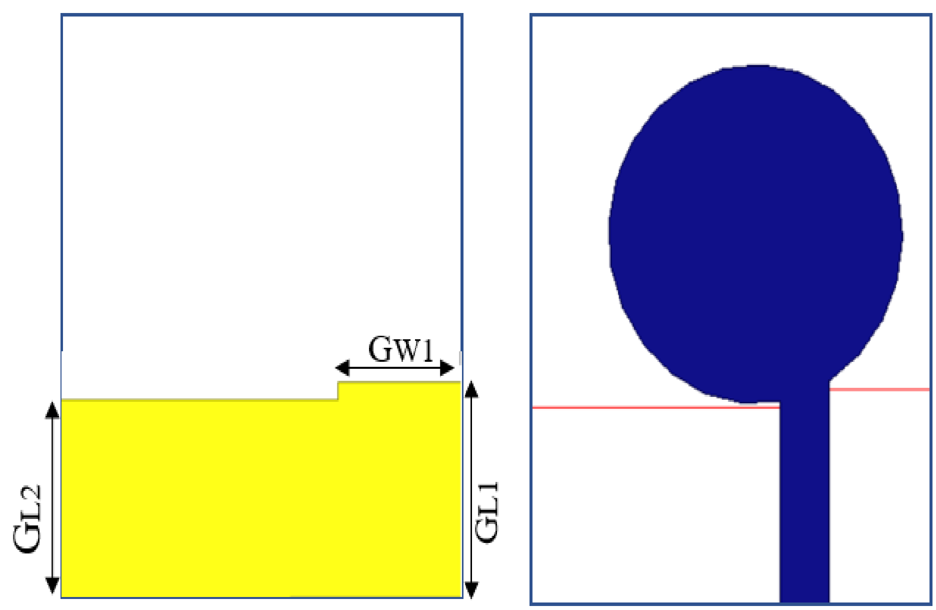
Ansoft HFSS is used for antenna design, parameters optimization and simulations. The following dimensions (in mm) are given in Table 1.

Table 1. Proposed UWB antenna dimensions

Parameter	Value (in mm)	Parameter	Value (in mm)
L	31	L_1	13.5
W	26	S_1	0.5
L_F	12.8	L_2	5
W_F	3	W_1	5.7
L_P	16	S_2	0.3
G_{L1}	11.6	L_3	1.2
G_{L2}	10.6	W_2	5.75
G_{W1}	8	S_3	0.25
r	9	G	0.8

2.2. Antenna Evaluation and Working

Antenna-1 is the basic UWB antenna comprises of microstrip line fed circular shaped radiating monopole and the reduced ground. Fig. 2 and Fig. 3 shows the evaluation of the triple band-notched antenna and the corresponding return loss at each stage. The Antenna-1 is working from 2.8-10.8 GHz as observed from Fig. 3. Antenna-2 constitutes single notch antenna is formed by cutting rectangular shaped slot on the monopole of Antenna-1 which results in a notch at 3.5 GHz ranging from 3.3-3.7 GHz. By etching couple of inverted L shaped slots is incorporated on either side of the patch of Antenna-2, dual band-notched antenna namely Antenna-3 can be formed. Antenna-3 is generating dual notches from 3.22-3.71 GHz and 4-4.74 GHz. Finally, the proposed triple notch antenna is designed by etching RSRR band stop resonator on the feed line of Antenna-3. The antenna is providing the third notch from 7-7.9 GHz in addition to 3.22-3.71 and 4-4.74 GHz bands as shown in Fig. 3.



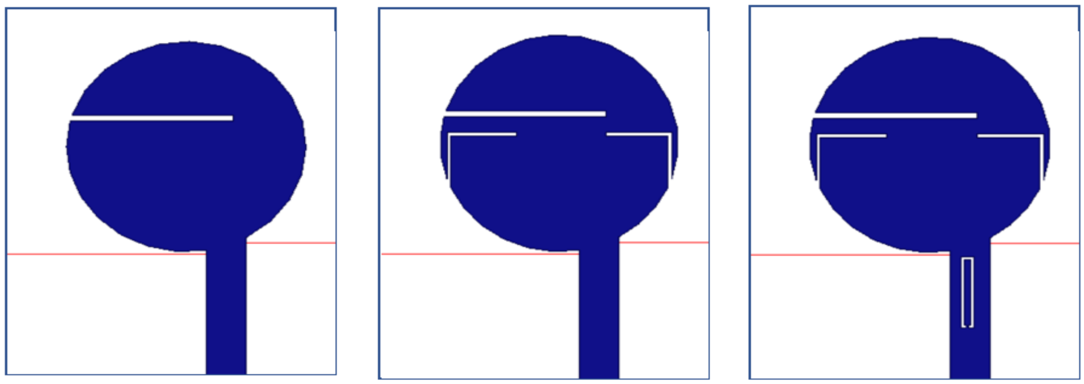


Figure. 2 The evolution of design a) reduced ground structure b) Ant-1 c) Ant-2 d) Ant-3 e) Proposed- Ant

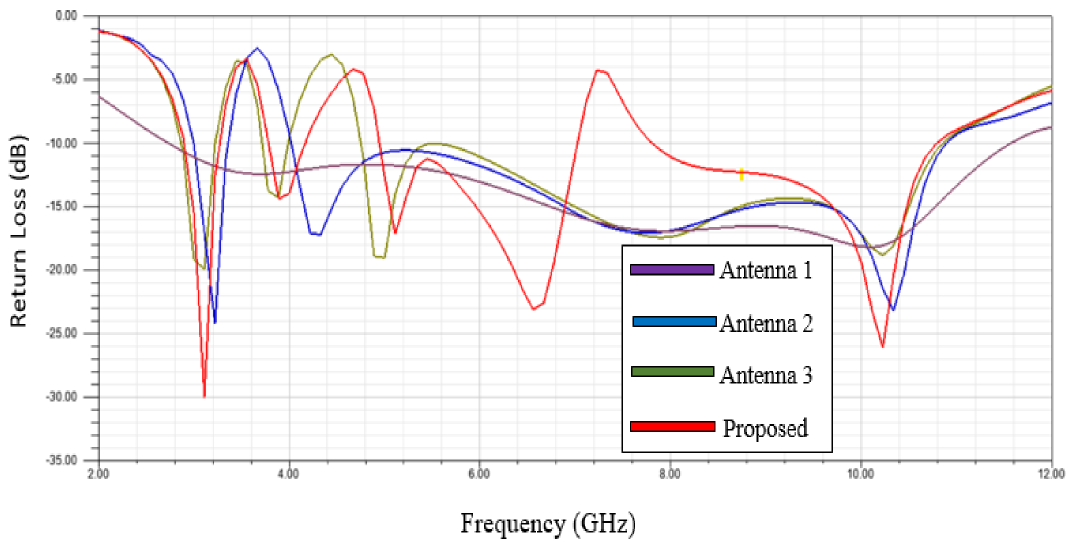


Figure 3. Simulated Return Loss Parameters of antenna at four stages

2.3. Effects of Rectangular shaped slot, a pair of inverted L shaped slots and RSRR slot

The effects of Rectangular slot, a pair of inverted L shaped slots and RSRR band-stop resonator with different lengths on the return loss of UWB antenna along with current circulation at notched bands are presented in this section. In this design, the band-stop features are attained by etching Rectangular shaped slot on the left edge of the monopole, cutting a couple of inverted L shaped slots are incorporated on either side of the monopole and inserting RSRR slot on the microstrip feed line. The lengths of the notch at center frequencies are having lengths $\lambda/4$, $\lambda/4$, and $\lambda/2$, where λ is guided wavelength, which is specified by the equation (1)

$$\lambda = \frac{c}{f_N\sqrt{(\epsilon_r + 1)/2}} \tag{1}$$

Moreover, the overall lengths of the band notch resonators can be determined using the equation (2) and equation (3) which are given by

$$L_{N1} = L_{N2} = \frac{c}{4f_N\sqrt{(\epsilon_r + 1)/2}} \tag{2}$$

$$L_{N3} = \frac{c}{2f_N\sqrt{(\epsilon_r + 1)/2}} \tag{3}$$

Where c is the velocity of light, f_N denotes notch center frequency, L_{N1}, L_{N2}, L_{N3} represents the total lengths of the resonators and ε_r indicates the dielectric constant. From equation (2) and equation (3), the desired notch positions are determined by the suitable selection of resonator lengths. With ε_r of 4.4, the calculated total lengths are 13.04mm at 3.5 GHz, 9.92mm at 4.6 GHz and 12.17mm at 7.5 GHz whereas the designed total lengths are 13.5mm at 3.5 GHz, 10.7mm at 4.6 GHz and 13.1mm at 7.25 GHz. It is clearly observed from equation (2) and equation (3) that the resonators lengths have a significant effect on the notch band positions and its center frequency. The notch center frequency decreases as the resonator lengths L_1, L_2 and L_3 increases, and vice versa. It is because of the length of the resonator is inversely proportional to its notch frequency.

3. RESULTS AND DISCUSSIONS

Figure. 4 displays the return loss parameter of the proposed antenna and the antenna is offering good impedance matching from 2.8 to 10.8 GHz with a return loss of <-10dB over whole functioning band except at notched bands.

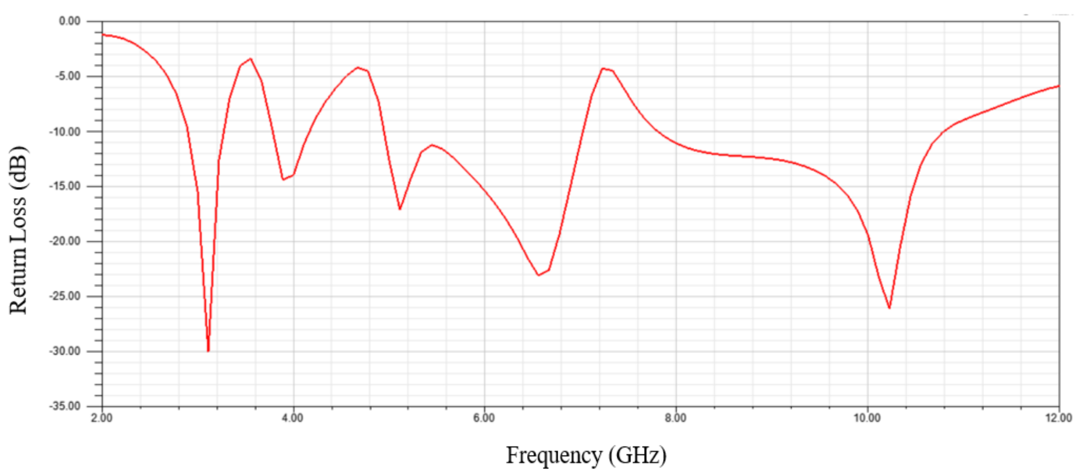
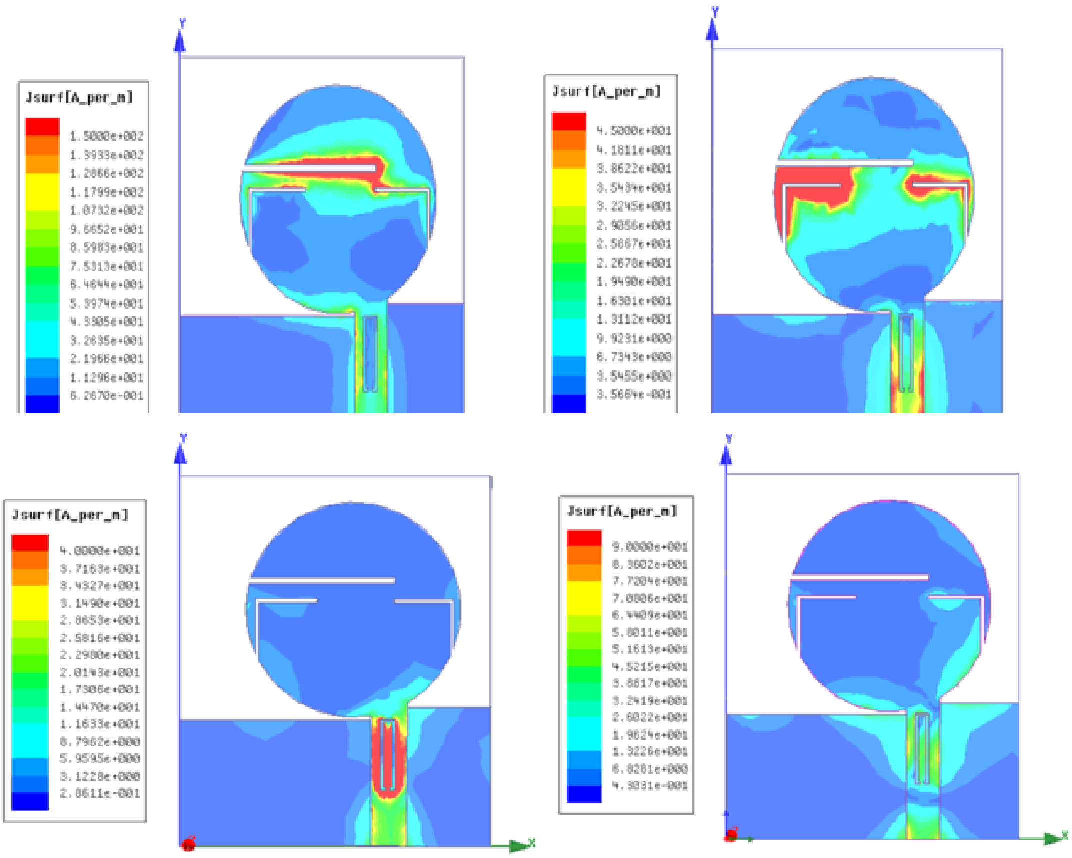


Figure.4 Return Loss Parameter of Proposed Antenna

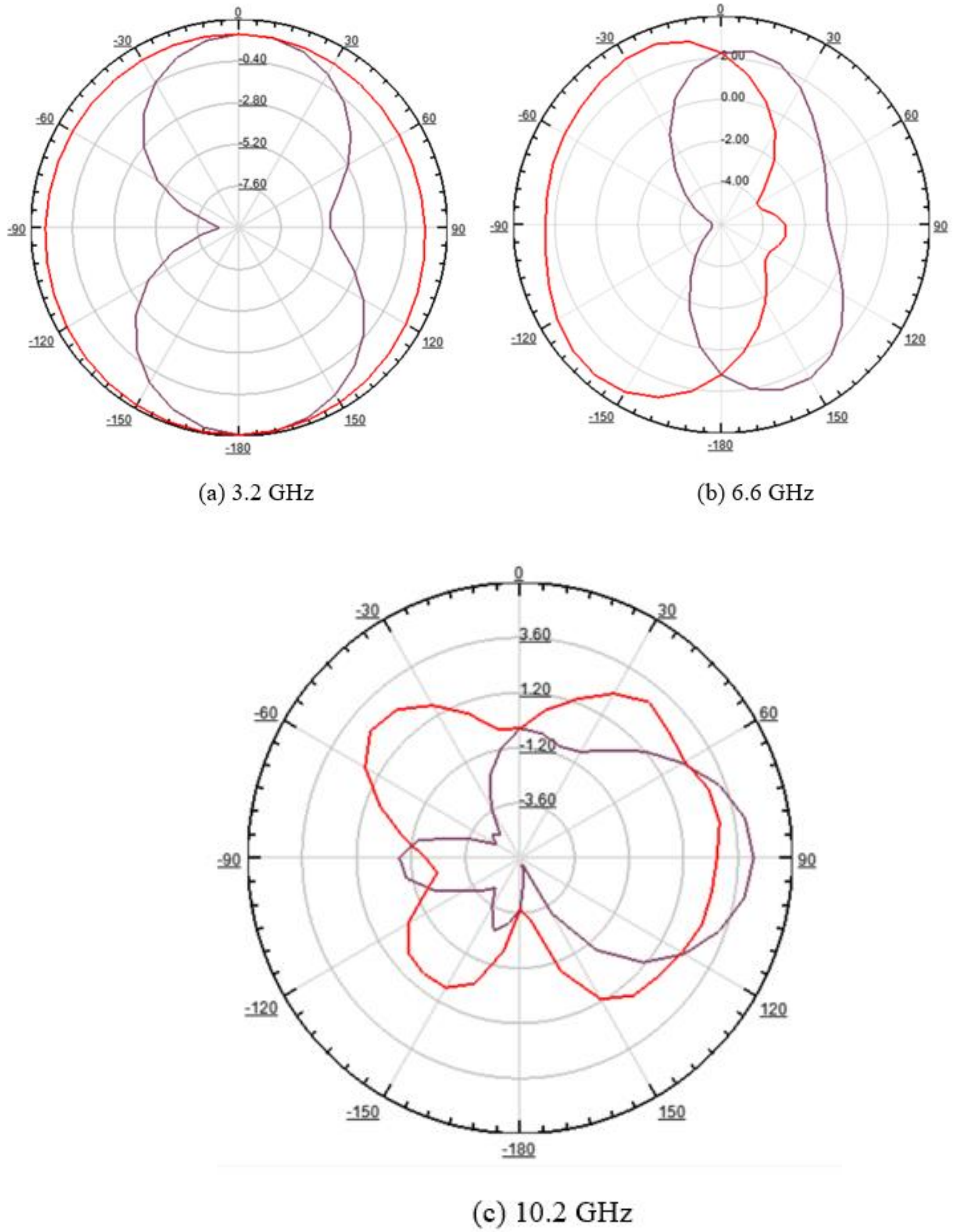
In addition to the return loss parameter, the surface current distribution is also used to illustrate the generation of band notches at 3.5, 4.6, 7.5 GHz. Fig. 5 (a)-(d) shows the current distribution at 3.5, 4.6, 7.5 GHz, respectively, and a resonant frequency (10.2 GHz). Since the current is flowing near band-notch resonators, the antenna does not radiate the energy. Therefore, the antenna efficiently suppresses the frequency interference from the existing narrowband systems. From Fig. 5(d), at 10.2 GHz, the current is flowing along the transmission line and concentrated around the edges of a radiating element; while around the band-stop resonators, the current is very small. Hence, the proposed antenna radiates more energy with a good return loss of less than -10dB.



(c) 7.5 GHz (d) 10.2 GHz

Figure 5. Surface Current Distributions

The 2-D radiation patterns of the antenna on the E- and H- planes at 3.2, 6.6 and 10.2 GHz, respectively, are given in Fig. 6 (a)-(c). The antenna achieves nearly bidirectional pattern on the E- plane and quasi-Omni directional patterns on the H- plane.

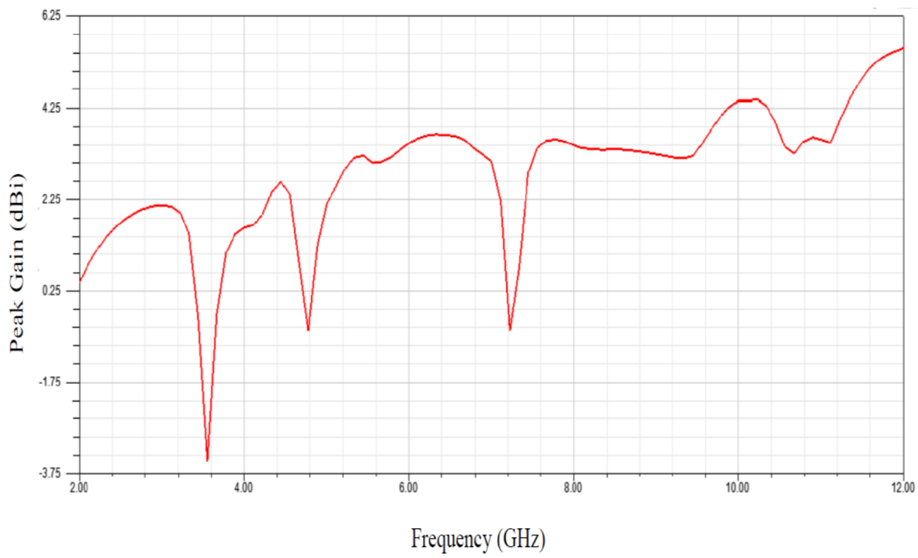


(a) 3.2 GHz (b) 6.6 GHz

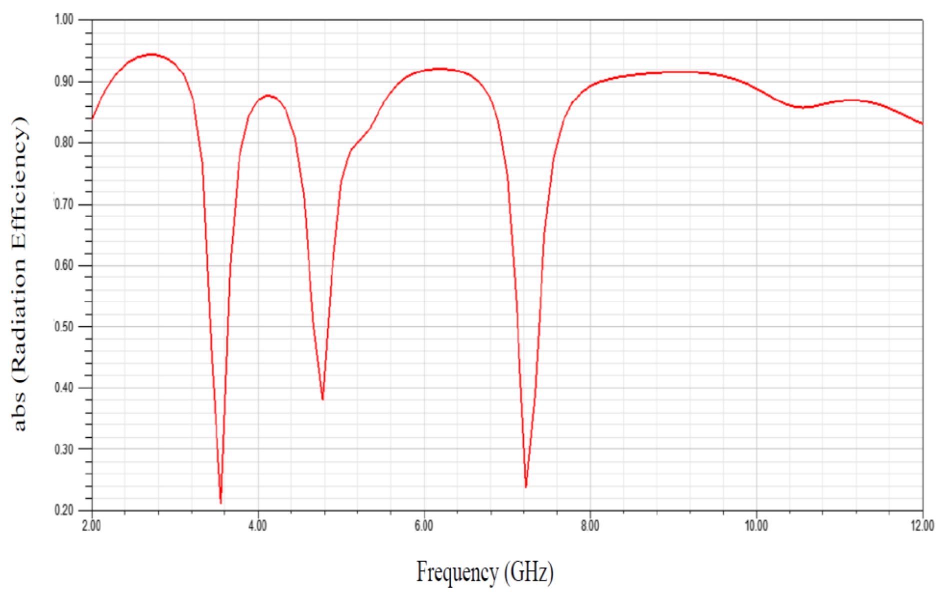
(c) 10.2 GHz

Figure 6. 2-D Radiation Patterns (violet colour represents E Plane, Red colour represents H plane)

The peak gain and radiation efficiency of the proposed antenna are shown in Fig. 7 (a) and Fig. 7 (b), respectively. The gain of more than 2.2 dBi and efficiency of above 90 % throughout the working band from 2.8 to 10.8 GHz are achieved excluding at band-notches. The reduced peak gains and radiation efficiencies at band notches confirms that the proposed antenna greatly lessens the interference from narrowband systems.



(a)



(b)

Figure 7. (a) Peak gain (b) Radiation Efficiency (abs)

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