A CPW FEED UWB ANTENNA WITH QUAD BAND NOTCHES

RESHMA BABU G[1], CHITHRA THAMPI[2], SHAMEER K MOHAMMED[3]

[1]M. Tech Student, Kerala Technical University, Muslim Association College of Engineering, TVM, Kerala, India
[2]Asst. Professor, Muslim association College of Engineering, TVM, Kerala, India
[3]Head of Department, ECE, Muslim Association college of Engineering, TVM, Kerala, India

---***---

Abstract - *In this paper a coplanar waveguide (CPW)-fed printed planar circular patch antenna with four band-notches for various wireless applications is proposed. A small CPW-fed round shaped patch antenna has designed using FR4-epoxy substrate having dielectric constant of 4.4 having dimensions of 30*30*1.6 mm³. By etching out two C-shaped slots notching is achieved at 3.9 and 5.4 GHz for World Interoperability for Microwave Access (WiMAX) and Wireless Local Area Network (WLAN) respectively. A U-shaped slot etched in the feed line to create third notch band at 8.29 GHz. The complementary split ring resonators (CSRR) in the ground will produces the fourth notch at 7.27GHz. Simulated results confirm that the proposed antenna has a broad bandwidth of 2.1~10.9 GHz with VSWR < 2 and well omnidirectional radiation patterns with four notched-bands. Within the design step, individual antennas corresponding to each rejection band is designed separately, and then a finalized structure is obtained by assembling these individual antennas altogether. The final antenna achieves both the impedance matching of ultra-wideband and the respective resonances at four rejection bands.*

Key Words: CPW, CSRR, notching, WiMAX, WLAN, UWB antenna, X band satellite communication

1. INTRODUCTION

There is much interest in the use of ultra-wideband (UWB) signals (from 3.1 to 10.6 GHz) for short range, high-data rate communications. UWB radar systems have been used to improve the detection of early stage breast cancer [1], [2]. UWB ground penetrating radar is widely used to detect mines and damaged utility pipes. Many kinds of UWB planar antennas are designed to satisfy the requirements of UWB operation. However, in practical applications, some other existing narrowband services that already occupy frequencies in the UWB may cause potential interference. The narrow band services like WiMAX (3.3–3.7GHz, 3.7- 4.2 GHz), WLAN for IEEE802.11a operating at 5-6 GHz (5.15–5.35GHz and 5.725–5.825GHz), X-band satellite communication uplink and downlink services from 7.25 to 8.395GHz (downlink: 7.25–7.745GHz, uplink: 7.9–8.395GHz) also operate in the UWB [3, 4]. So, it is necessary to design UWB antennas with multiband filtering functionality to remove the effect of interference.

The conventional ground-backed UWB antennas fed by Microstrip line which have metallization on both sides are not able to integrate with active devices and other circuits. Unlike Microstrip line feed, CPW-feed has low dispersion, less spurious radiation, effective controllability over the impedance matching, and can be easily assembled it with other active devices. In [5,6] antennas presented are bigger in size, as well as have lower gain over the UWB range compared to proposed antenna of size 30*30*1.6 mm³ in this paper. Various antennas with band rejection characteristics are reported, but their gain performance is a bit lower [7, 8] By using nested C-shaped stubs on the back surface of the substrate, dual band notching of WiMAX band and WLAN band has been achieved resulting in poor gain below 2dBi in lower UWB band [7].Various notching techniques are used to reduce Electromagnetic Interference using band-notched structures such as Quarter wavelength open ended slots or slits on the radiator [9], a V-shaped slot [10], and U-shaped slots having length equals to half wavelength [11], using open resonators [12], and split ring resonators(SRR) [13.14].

In the proposed work, a compact CPW-fed microstrip patch antenna with symmetric ground plane is proposed to offer a band notching in WiMAX (3.7- 4.2 GHz) and in Wireless Local Area Network (WLAN) IEEE802.11a operating at 5-6 GHz (5.15 to 5.35 GHz and 5.725 to 5.825 GHz) by carving out two C-shaped nested slots in the circular radiating patch. Furthermore, notching at X-band satellite communication downlink (7.25–7.745GHz) and uplink (7.9–8.395GHz) is achieved by inserting co-directional CSRR at the ground plane and a U slot at the feed line respectively. The next section describes the evolution of design and analysis of different parameters to get optimized dimensions of the antenna.

2. ANTENNA CONFIGURATIONS

2.1 Conventional CPW feed UWB antenna

(Antenna 1)

Fig-1 shows the basic CPW-fed antenna configuration which is referred to as Antenna 1. Antenna 1 is a printed monopole circular CPW-fed antenna fabricated on FR4 epoxy substrate having dielectric constant of 4.4 and loss tangent equals to 0.02. Printed monopole antenna have ground plane at infinity [15]. The circular patch is fed by 50Ω coplanar waveguide (CPW) transmission line which is connected to sub-miniature A (SMA) connector. As antenna incorporates planar geometry by using single-sided copper metallization on printed circuit board (PCB) material (i.e. FR4 epoxy), so it has low manufacturing cost. The basic microstrip patch antenna comprises central conductive feed line (CPW) of width 'Wf' and gap between the central conductor and symmetrical ground planes is 'g'.

As shown in fig-1, Antenna 1 is compact in size with substrate having dimensions 'W' and 'L' equals to 30 mm each, also substrate thickness equals to 1.6 mm. The microstrip patch antenna with finite ground plane having substrate thickness equals to 'hd', has characteristic impedance 'Zo' given by

$$Z_0 = \frac{30\pi}{\sqrt{\varepsilon_r}} \frac{K(k)}{K(k')}\ \Omega \qquad (1)$$

where k and k' are parameters depends on the construction of coplanar waveguide transmission line having track width equals to '2a', sum of the track width plus gaps on either sides equals '2b' and total width (i.e. ground on either side plus '2b') equals to '2c' as shown in fig. 2. Here 'K' is the elliptical integral of first kind

$$k = \frac{c}{b}\sqrt{\frac{b^2-a^2}{c^2-a^2}} \text{ and } k' = \sqrt{1-k^2} = \frac{a}{b}\sqrt{\frac{c^2-b^2}{c^2-a^2}} \qquad (2)$$

Now, the effective dielectric constant of this CPW fed line is given by

$$\varepsilon_{re} = 1+\frac{1}{2}(\varepsilon_r-1)\frac{k(k)}{k(k')}\frac{k(k1')}{k(k1)} \qquad (3)$$

Here,

$$k1 = \frac{\sinh(\frac{\pi c}{2hd})}{\sinh(\frac{\pi b}{2hd})}\sqrt{\frac{\sin h^2(\frac{\pi b}{2hd}) - \sin h^2(\frac{\pi a}{2hd})}{\sin h^2(\frac{\pi c}{2hd}) - \sin h^2(\frac{\pi a}{2hd})}} \qquad (4)$$

$$k1' = \sqrt{1-k^2} = \frac{\sinh(\frac{\pi a}{2hd})}{\sinh(\frac{\pi b}{2hd})}\sqrt{\frac{\sin h^2(\frac{\pi c}{2hd}) - \sin h^2(\frac{\pi b}{2hd})}{\sin h^2(\frac{\pi c}{2hd}) - \sin h^2(\frac{\pi a}{2hd})}} \qquad (5)$$

Above equations are used to calculate the parameters of the conventional CPW-fed antenna design and the antenna is simulated using the High Frequency Simulation Software (HFSS 13.0). Antenna 1 shown in fig. 1 have circular patch with radius 'R'= 9.7 mm and in order to achieve 50 ohm CPW feed transmission line 'Wf'=3mm and 'g'=0.45 mm.

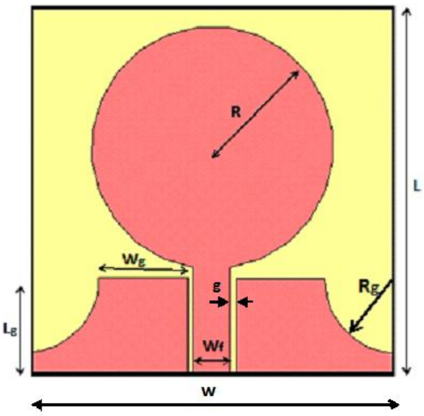

Fig-1: Conventional UWB antenna (Antenna 1)

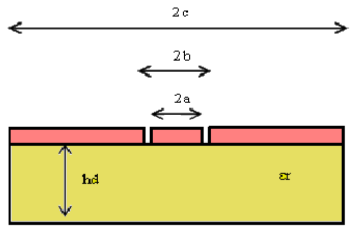

Fig-2: CPW with symmetric ground plane & finite height

The width and length of ground are optimized so as achieve better Impedance matching over the UWB range. For that the dimensions Lg, Wg and Rg are taken as 8mm, 7.05mm, 6mm respectively. The simulated reflection coefficient characteristics (i.e. S11) is shown in fig-3 which shows impedance matching over the UWB range (3.1-10.6) and S11< -10 dB. The obtained result has impedance bandwidth from 2.3 to 10.6 GHz.

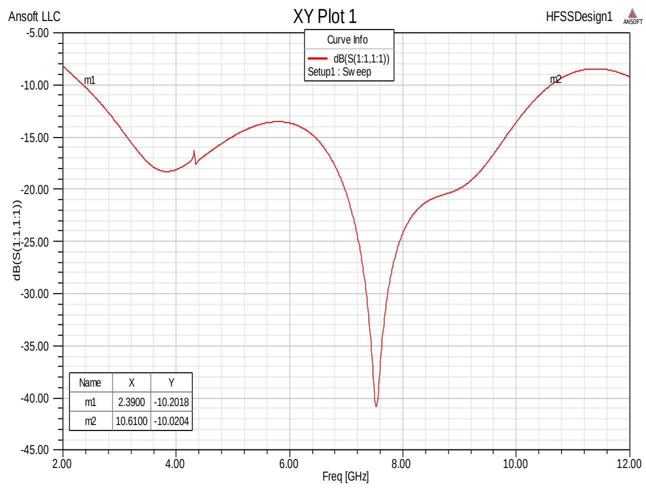

Fig-3: Simulated S11 of Antenna 1

2.2 Single band-notched UWB antenna (Antenna 2)

For avoiding interference, we need to incorporate some frequency rejection or frequency notching techniques so as to reduce interference at pre-defined bands i.e. WiMAX (3-4.2 GHz), WLAN (5-6 GHz), X-band satellite communication downlink (7.25–7.745GHz) and uplink (7.9–8.395GHz).

Initially, we have to filter out the band for WLAN applications with notching band at 5-6 GHz (5.15–5.35GHz and 5.725–5.825GHz). By etching out the C-shaped slot on the circular radiating patch, we performed the frequency band notch operation on antenna 1 so as to get antenna 2 as shown in fig-4. The length of C-shaped slot 'l_{s1}' decides notching frequency of the UWB antenna and l_{s1} almost equals to the half wavelength long of the required notching frequency. The notch frequency provide us the dimensions of the notch, so notch frequency is given by

$$f_{notch} = \frac{c}{2ls1\sqrt{\varepsilon_{reff}}} \tag{6}$$

Where c is the speed of the light, ls1 is the total length of C-shaped slot corresponding to the particular notch frequency and ε_{reff} is effective dielectric constant. By using (6) we can get the slot length which is a theoretical value of slot length. We have compared the theoretical and simulated values of slot length to get optimized value. To get notching at 5.3 GHz. the total length of the slot is chosen as ls1=20 mm

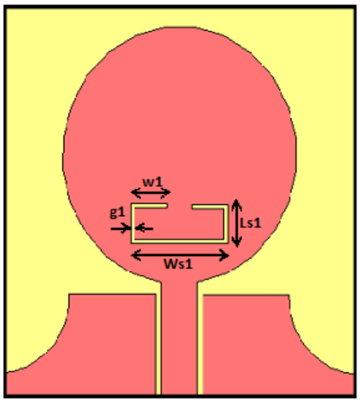

Fig-4: Single-band notched antenna (Antenna 2)

TABLE-1: Optimized dimensions of Interior C-shaped slot

Parameters	**w1**	**Ws1**	**Ls1**	**g1**	**ls1**
in mm	3	8	3	0.3	20

The simulated reflection coefficient shows an efficient notching at the desired frequency which is centered at 5.32GHz and good Impedance matching at other passband frequencies as shown in fig-5.

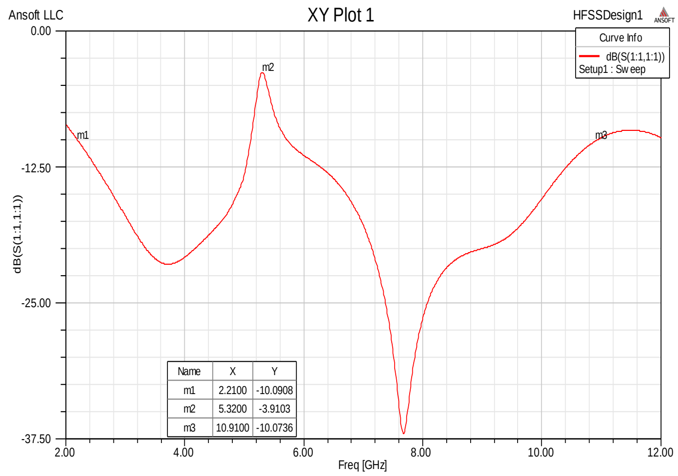

Fig-5: Simulated reflection coefficient of Antenna2

2.3 Dual band-notched UWB antenna (Antenna 3)

In order to achieve dual band notching structure, we used two C-shaped slots which are nested in one another as shown in fig-6 (denoted as Antenna 3). The proposed Antenna 3 have two C-shaped slots, interior slot for notching WLAN band (centered at 5.3 GHz) and exterior slot for notching WiMAX (centered at 3.9 GHz). The position of both the slots is adjusted to get an effective notching. The total length of C-shaped slot corresponding to the notch frequency at 3.9 GHz is ls2=22mm

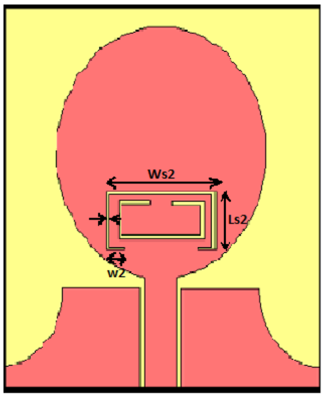

Fig-6: Dual-band notched antenna (Antenna 3)

TABLE-2: Optimized dimensions of Exterior C-shaped slot

Parameters	**W2**	**Ws2**	**Ls2**	**g2**	**ls2**
in mm	1.5	10	4.5	0.2	22

Fig-7 shows the simulated reflection coefficient. It shows an efficient notching at dual frequency bands corresponds to WiMAX and WLAN which is centered at 3.87GHz and 5.56GHz. It also provides a good Impedance matching at other passband frequencies.

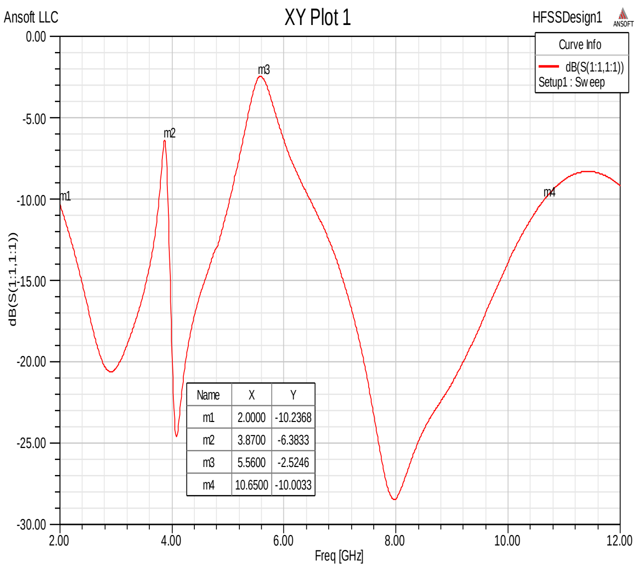

Fig-7: Simulated reflection coefficient of Antenna3

2.4 Triple band- notched UWB antenna (Antenna 4)

Rejection of the third band is obtained by inserting a U shaped slot in the feed line as shown in the fig-8 (denoted as Antenna 4). The proposed antenna has three independent rejection bands due to the two C-shaped nested slots and a U shaped slot. The U shaped slot produces a notching at X band satellite communication uplink frequency band.

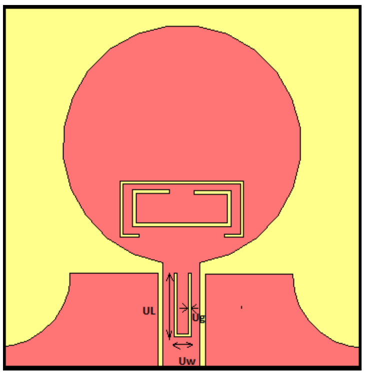

Fig-8: Triple-band notched antenna (Antenna 4)

TABLE-3: Optimized dimensions of U-shaped slot

Parameters	**UL**	**UW**	**Ug**
in mm	5	1.2	0.2

Fig-9 shows the simulated reflection coefficient. It shows an efficient notching at triple frequency bands corresponds to WiMAX, WLAN and X band satellite communication uplink frequencies which are centered at 3.8GHz, 5.4GHz and 8.4 GHz respectively. It also provides a good Impedance matching at other passband frequencies

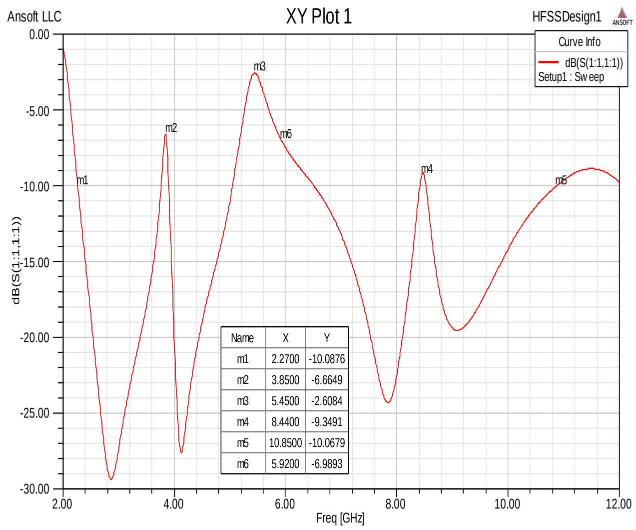

Fig-9: Simulated reflection coefficient of Antenna 4

2.5 Quad band- notched UWB antenna (Antenna 5)

Fig-10 shows the geometry of the finalized design of UWB antenna with quad band rejection characteristics. Rejection of the fourth band is obtained by inserting co-directional CSRRs on the ground plane. CSRR are electrically small LC resonant elements with a high quality factor at microwave frequency and have been used as a periodic structure of metamaterial. So, the resonance characteristics of the CSRR can be used for frequency-selective structure design. Also CSRR structure is suitable to be mounted on the planar structure. Since CSRR is usually etched on the ground plane of a substrate, it does not require additional area. Therefore, it has the benefit of size reduction. The narrow band resonance characteristics of the CSRR are affected only in the target frequency band and geometrical region on the ultra-wideband antenna.

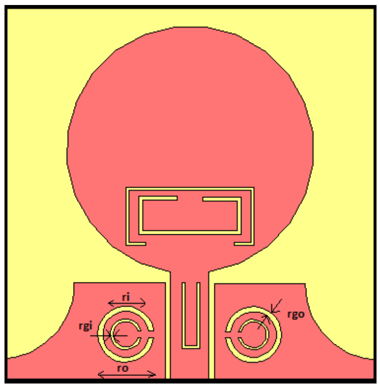

Fig-10: Quad-band notched antenna (Antenna 5)

TABLE-4: Optimized dimensions of CSRR

Parameters	**ro**	**ri**	**rgo**	**rgi**
in mm	2.2	1.2	0.4	0.2

Fig-11 shows the simulated reflection coefficient. It shows an efficient notching at quad frequency bands corresponds to WiMAX, WLAN and X band satellite communication uplink and downlink frequencies which are centered at 3.9GHz, 5.2GHz and 8.3 GHz respectively. It also provides a good Impedance matching at other passband frequencies

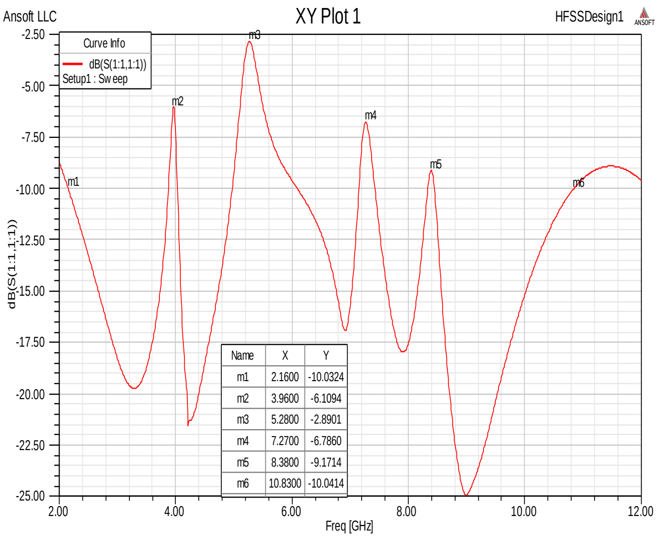

Fig-11: Simulated reflection coefficient of Antenna 5

The surface current distribution of Antenna 5 is shown in fig-12. (a), (b), (c) and (d) at 3.96 GHz, 5.28 GHz, 7.29 GHz and 8.38 GHz respectively. At the first notch frequency 3.96 GHz, surface current is concentrated around the Exterior C-shaped slot as shown in fig-12(a) and at the second notch frequency 5.28 GHz, surface current is concentrated around the Interior C-shaped slot as shown in fig-12(b). When the notch frequency is 7.29GHz surface current is concentrated around the CSRR in the ground plane as shown in fig-12(c) and at the fourth notch frequency 8.38 GHz, surface current is concentrated around the U-shaped slot as shown in fig-12(d).

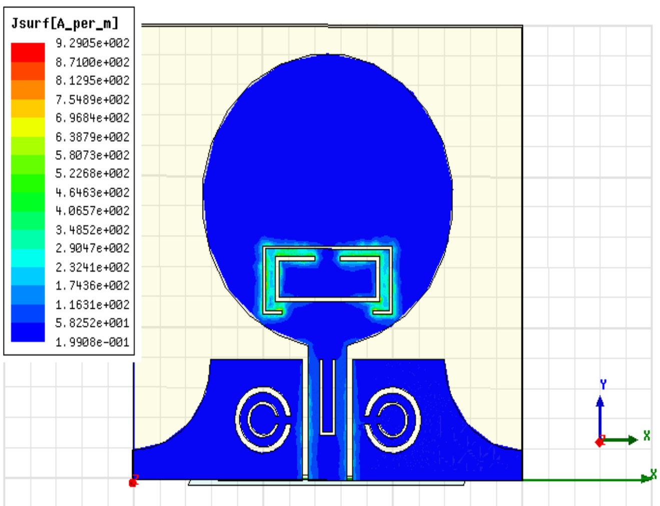

Fig-12 (a): Surface current distribution at 3.96 GHz

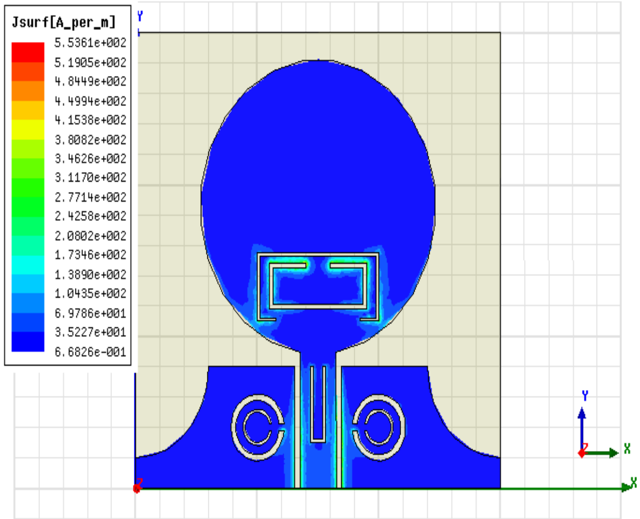

Fig-12 (b): Surface current distribution at 5.28 GHz

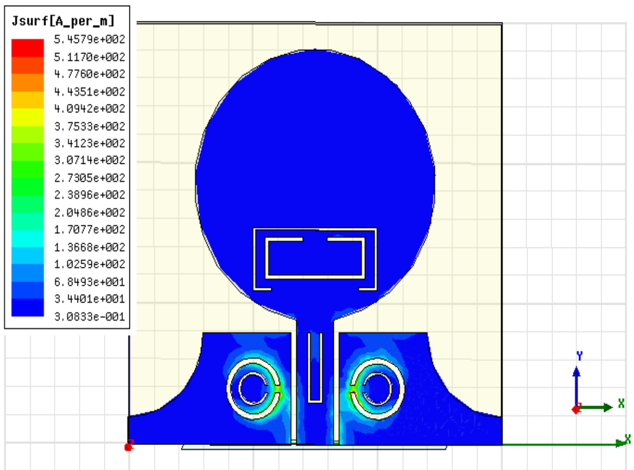

Fig-12 (c): Surface current distribution at 7.29 GHz

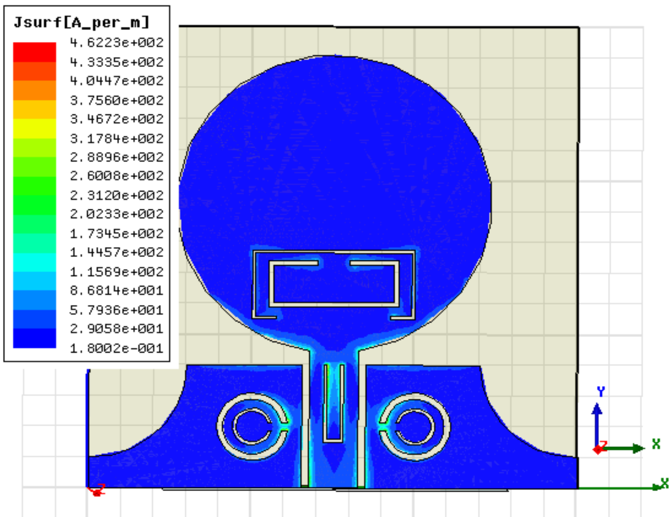

Fig-12 (d): Surface current distribution at 8.38 GHz

3. CONCLUSION

A new printed monopole antenna with a Quad band-notched function for UWB systems has been presented. The proposed antenna design was found simple, compact and easy to fabricate. This is because the etching of the antenna and feed line are realized on a single-layer of substrate and a single sided metal plane resulting in the easier fabrication and moderate prices. The suggested antenna itself is loaded with a quad bandstop filter like function to block the unwanted signal from an external wireless device and to maintain the performance of the UWB system in a hostile radio environment caused by the various radio interferences. Accordingly, the proposed quad band rejection UWB antenna might be useful for constructing the UWB communication system to mitigate the interferences from WLAN, WiMAX and X-band satellite communication systems. Antenna 5 has first notching at 3.96GHz (WiMAX) using exterior C-shaped slot, second notching at 5.28GHz (WLAN) using interior C-shaped slot, third notching at 7.29 GHz (downlink) using U shaped slot and fourth notching at 8.38 GHz (uplink) using CSRR. Impedance bandwidth of the Antenna 5 goes beyond UWB antenna (2.2 -10.8 GHz).In this paper, the proposed design covers the entire UWB band and having good reflection coefficient characteristics over the desired range. Gain of the antenna is also good. For more reliable applications in UWB range MIMO antennas can be used.

REFERENCES

[1] K. L. Wong, Planar Antennas for Wireless Communications. Hoboken, NJ: Wiley, 2003, pp. 26–53.

[2] Z. N. Chen, Antennas for Portable Devices. Chichester, U.K.:Wiley, 2007, p. 142.

[3] J. Xu, D. Y. Shen, J. F. Zheng, X. F. Zhang, and K. Wu, “A novel miniaturized UWB antenna with four band-notches,”Microwave and Optical Technology Letters, vol. 55, no. 6, pp.1202–1206, 2013.

[4] Y. Sung, “Triple band-notched UWB planar monopole antenna using a modified h-shaped resonator,” IEEE Transactions on Antennas and Propagation, vol. 61, no. 2, pp. 953–957, 2013

[5] Liu, H. and Z. Xu, “Design of UWB Monopole Antenna with Dual Notched Bands using One Modified Electromagnetic-Band-Gap Structure," The Scientific World Journal, Vol. 2013, Article ID 917965, 9 pages, 2013, http://dx.doi.org/10.1155/2013/917965.

[6] Liu, W. X. and Y. Z. Yin, “Dual Band-Notched Antenna with the Parasitic Strip for UWB," Progress In Electromagnetics Research Letters, Vol. 25, 21-30, 2011.

[7] Emadian, S. R., C. Ghobadi, J. Nourinia, M. Mirmozafari, and J. Pourahmadazar, “Bandwidth Enhancement of CPW-Fed Circle-Like Slot Antenna with Dual Band-Notched Characteristic," IEEE Antennas and Wireless Propagation Letter., Vol. 11, 543-546, 2012.

[8] Zhou, Dawei, et al. "A Simple and Compact Planar Ultra Wideband Antenna with Single or Dual Band-Notched Characteristics." Progress In Electromagnetics Research 123 (2012): 47-65.

[9] Zhou, Dawei, et al. "A Simple and Compact Planar Ultra Wideband Antenna with Single or Dual Band-Notched Characteristics." Progress In Electromagnetics Research 123 (2012): 47-65.

[10] Kim, Y. and D.-H. Kwon, “CPW-Fed Planar Ultra Wideband Antenna having a Frequency Band Notch Functions," Electron. Letter., Vol. 40, 403-405, 2004.

[11] S. M. Zhang, F. S. Zhang, W. Z. Li, T. Quan, and H. Y.Wu, “A Compact UWB Monopole Antenna with WiMAX and WLAN Band Rejections,” Progress in Electromagnetics Research Letters, vol. 31, pp. 159–168,2012.

[12] Kelly, James R., Peter S. Hall, and Peter Gardner. "Band-Notched UWB Antenna Incorporating a Microstrip Open-Loop Resonator." Antennas and Propagation, IEEE Transactions on 59.8 (2011): 3045-3048.

[13] D.-O. Kim, N.-I. Jo, H.-A. Jang and C.-Y. Kim, “Design of the Ultra Wide Band Antenna with a Quadruple-Band Rejection Characteristics using a Combination of the Complementary Split Ring Resonators,” Progress in Electromagnetics Research, vol. 112,pp. 93–107, 2011

[14] Rowdra Ghatak, R Debnath, D R Poddar, R K Mishra and S R Bhadra Chaudhuri, “A CPW Fed Planar Monopole Band Notched UWB Antenna with Embedded Split Ring Resonators”, 2009 Lough borough Antennas & Propagation Conference.

[15] K. P. Ray, P. V. Anob, R. Kapur, and G. Kumar, “Broadband Planar Rectangular Monopole Antennas,” Microwave and Optical Technology Letters, vol. 28, no. 1, pp. 55–59, 2001.