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A Novel Compact Size Dual Notched Bands UWB Elliptical Monopole Antenna

Emad S. Ahmed, Maalim Qasim Mohammed

Abstract— In this paper, a new compact ultra-wideband printed elliptical monopole antenna is presented. The proposed antenna operates over a wideband from 2.85 to 15.4 GHz for voltage standing wave ratio (VSWR) less than two. Two modifications are introduced to enhance the frequency-impedance characteristic of the presented elliptical monopole antenna. The first one is to chamfer the edges of the ground plane with 45°angle. The second modification is to use asymmetrical in length finite ground planes. By utilizing a symmetrical L-shaped slot and an inverted U-shaped slot embedded in the radiating patch and feed line respectively, a dual band notched characteristic were achieved. These bands are 3-4 GHz and 5-6 GHz used for WiMAX and WLAN operations. The center frequency and the width of the notch bands are adjusted by varying the length and the width of the slots. The antenna shows omnidirectional radiation pattern characteristics with acceptable gain. Compared with other recently proposed dual band notch antennas, the proposed antenna exhibits advantages of a compact size, simple structure, wide bandwidth and good band-notch characteristic. The simulation results are obtained and optimized using a commercial electromagnetic simulator CST Microwave Studio.

Index Terms— Ultra wideband, CPW-fed UWB antenna, band-notched characteristics.

I. INTRODUCTION

Wireless communication systems become more and more popular. However, the technologies for wireless communication still need to be improved further to satisfy the higher resolution and data rate requirements. The UWB technology brings the convenience and mobility of wireless communications with higher data rates, freeing people from wires, enabling wireless connection of multiple devices for transmission of video, audio and other high bandwidth data [1]. It provides full wireless connectivity delivering more than 110 Mbps data transfer rate supporting applications transfer at very low levels of power consumption, In Ultra-Wideband (UWB) communication systems one of the key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band, It is used within an ultra-wide spectrum and with an extremely low emission power level, The high radiation efficiency is also required especially for UWB applications to ensure the transmit power spectral density requirement achieved. Conductor and dielectric losses should be minimized in order to maximize radiation efficiency [2].

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Ultra-Wideband (UWB) was approved by the Federal Communications Commission (FCC) in Mar. 2002 for unlicensed operation in the (3.1-10.6 GHz) band.

The maximum allowable power spectral density (P.S.D) -41.3 dBm /MHz of the UWB radiation in order to limit the interference with other communication systems corresponds to approximately 0.5 MW of average transmit power [3].

Many different types of antenna are being considered for UWB applications, Among these antenna configurations, circular monopole features simple structure, easy fabrication, wide frequency bandwidth and satisfactory radiation patterns [4]. Challenges of the feasible UWB antenna design include the UWB performances of the impedance matching and radiation stability, the compact appearance of the antenna size, and the low manufacturing cost of consumer electronics applications [5,6]. The main problem of the frequency band rejection design is the difficulty of controlling the bandwidth of the notch band in a limited space. The UWB communication systems use the (3.1-10.6 GHz) frequency band, Therefore the UWB antenna must achieve almost a decade of impedance bandwidth, spanning 7.5 GHz, unfortunately there are some other existing narrowband services that already occupy frequencies in the UWB band, such as the C-band (3.7-4.2 GHz) satellite communication systems , WiMAX band (3.3-3.7 GHz), Therefore, UWB communication systems may cause unwanted interference with other co-existing communication systems.

To overcome problems caused by this electromagnetic interference, various UWB antennas with single or multiple wireless local-area network (WLAN) IEEE802.11a and HIPERLAN/2 WLAN is operating in the (5.15-5.825 GHz) band notch functions have been developed for UWB communication systems [7,8]. Printed antennas have proved to be a good choice for these systems due to their low profile, small size, light weight, low cost, and ease of fabrication and integration in microwave circuits [9].

With co-planar waveguide (CPW) feeds, extra advantages are acquired, such as wider bandwidth, better impedance matching, lower radiation loss, and less dispersion [10], it is desired to design the UWB antenna with dual-notched bands in (3-4 GHz) and (5-6 GHz) to minimize the potential interference.

Recently, a number of UWB antennas with band-notched characteristics have been discussed and various methods have been used to achieve band notched function [11,12] .There is a growing need for broadband antennas which can satisfy the entire frequency range of future ultra wideband (UWB) systems with a reasonable performance, It has been reported that a circular disc monopole antenna has a very large impedance bandwidth , However it also seems that the circular disc monopole antenna is not particularly easy to integrate into handsets or mobile terminal cases [13-15].

In this paper a new design for printed CPW fed elliptical monopole antenna for dual band rejection characteristics with notched slots were presented. The notched frequency bands are adjusted by varying the length and width of the slots. It is needed that the proposed antenna can cover an ultra wide frequency band of (3.1-10.6 GHz) with the reflection coefficient S11≤ -10 dB, and rejects the bands (5-6 GHz) and (3-4 GHz) with S11≥-10 dB. The characteristics of the antenna are evaluated by using computer simulations based on the transient time solver method on the CST Microwave Studio™ package.

II. ANTENNA DESIGN

A CPW fed elliptical monopole antenna for UWB application with a band-notch characteristic is presented in Fig. 1, and the optimal parameters are given in Table I. The proposed antenna can be tuned to operate within the UWB band. The total size of this antenna including the ground plane is 22 mm×25.5 mm printed on FR-4 substrate, with thickness 1.6 mm, t =0.035mm and relative permittivity of 4.4. The radiating element is an ellipse-shaped patch fed by 50 Ω CPW line of width Wf =3 mm. The gap between the radiating element and the ground plane is 0.37 mm to obtain 50-Ω port impedance. For this proposed model, the optimization was carried out to achieve the best impedance bandwidth.

The impedance matching of the proposed antenna is enhanced by correctly adjusting the dimension of the feeding structure, substrate, patch and ground plane size. To achieve dual-band notched characteristics of the frequency band of WiMAX and WLAN, symmetrical L-shaped slots are inserted in the patch, and an inverted U-shaped slot is embedded in the CPW feed line, therefore the (3.5/5.5 GHz) dual band-notched characteristics are obtained. Accordingly, two modifications are introduced on the proposed antenna to improve its operating bandwidth. The first one is to chamfer the two upper ground plane edges with 45° angle and distance equal to 4 mm. The second modification is to use a partial modified ground plane with a two different width wg1 and wg2.

The rejected frequency can be calculated as:

$$(1)\ f_{notch} = c \,/\, L_{slot}\sqrt{\varepsilon_{eff}}\ )$$

$$(2)\varepsilon_{eff} = (\varepsilon_r + 1)/2$$

Where *Lslot* is the length of the slot; *Ɛeff* is the effective dielectric constant; ***c*** is the speed of light. We can use (1) and (2) to predict the length of the slot resonator, then, optimize the parameter *Lslot* with full wave simulation .

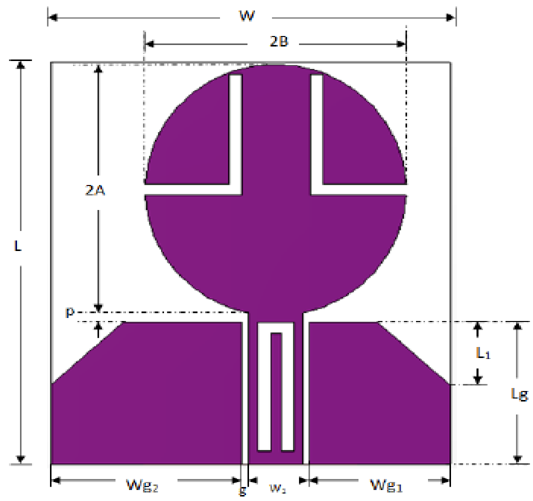

Fig. 1 Geometry of proposed dual-band notched UWB antenna.

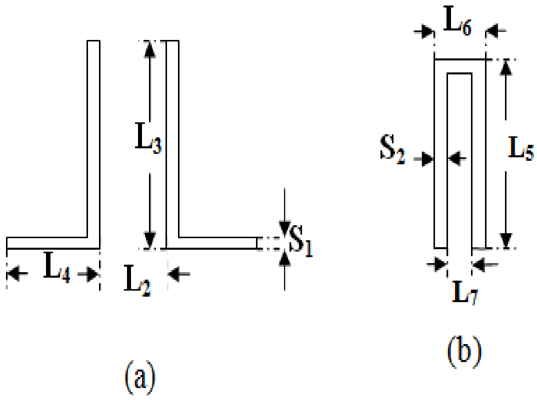

Fig. 2 Configuration of proposed cutting slot (a)symmetrical L-shape (b) inverted U-shape.

Table I : Antenna parameters, mm

W	L	Wg1	Wg2	Lg	W1	L1	2A	2B
22	25.5	7.76	10.5	9	3	4	16	14.4
L2	L3	L4	L5	L6	p	g	h	S1= S2
3.8	7.7	5.3	8.2	2	0.4	0.37	1.6	0.7

We can take (1) into account in obtaining the total length of the slot at the beginning of the design and then adjust the geometry of the final design. The total length of the symmetrical L-shaped slot embedded in the patch of the proposed antenna is:

$$\lambda/2_{notched} = [2(L_3 + L_4 + S_1)] \qquad (3)$$

And the total length of the inverted U-shaped slot embedded in the CPW feeder line is:

$$\lambda/2_{notched} = [2 \times L_5 + L_7] \qquad (4)$$

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The total length of the slot must be approximately the half wavelength at the desired notched frequency, By changing the total lengths of the slot, the desired rejected band frequencies can be easily obtained. It is requisite to control the notched bandwidth to obtain an effective band-notched UWB antenna.

The Effect of varying the parameters of the notch functions on the performance of the proposed antenna has been studied. Moreover, the designed antenna has a wideband impedance bandwidth, operate and present appropriate gain and stable radiation patterns over the UWB band, except the unwanted bands for WiMAX and WLAN, the proposed antenna has the advantages of simple design, compact size. Furthermore; the proposed antenna is cheap due to the use of low cost FR4 substrate with simple structure. The simulated results including the return losses, voltage standing wave ratio (VSWR), current distributions, radiation patterns, and gain are presented and discussed in detail.

III. ANTENNA SIMULATION RESULTS

Fig. 3 shows the reflection coefficient of the proposed antenna shown in Fig. 1. Simulation was done by using CST Microwave Studio™ package. As shown in Fig. 3 ,it is demonstrated that the chamfered and modified ground plane of the proposed antenna have a considerable effect on the performance of the return loss of the antenna by achieving a wider bandwidth and meet the bandwidth requirement for UWB antenna. It is apparent that the proposed antenna satisfies the -10 dB return loss for VSWR < 2 requirements for (2.85-15.4 GHz) and by selecting the optimal parameters mentioned in table. I, the proposed antenna can be tuned to operate within the UWB band and cover the frequency band (3.1 to 10.6 GHz) released by the FCC for a UWB system. Variations of VSWR within the frequency of the proposed antenna are plotted in Fig. 4.

The return loss responses of the proposed antenna, shown in Fig. 5 have been carried out for different width of the ground plane Wg_1, Wg_2. It is clearly shown that the variation of the ground plane has little effect on the lower frequency *(fL)* position, while the effect becomes clearer on the higher frequencies. On the other hand, the best bandwidth has been achieved with Wg1=7.76 mm and Wg2=10.5.

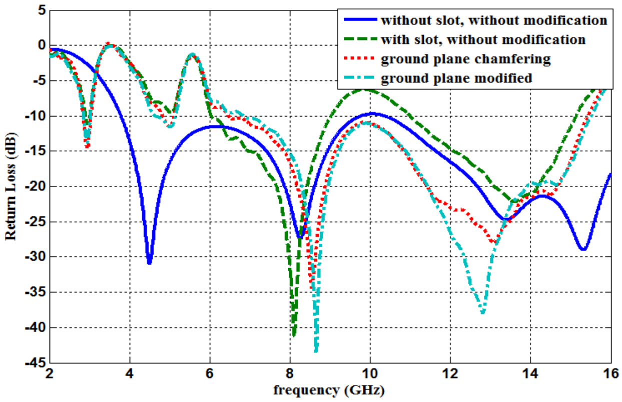

Fig.3. Return loss of the proposed antenna.

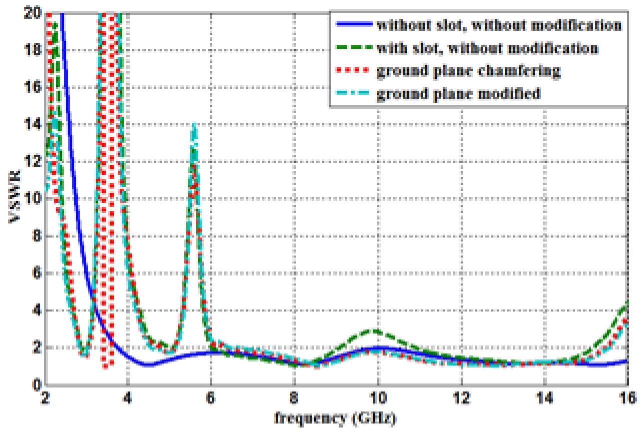

Fig.4. Simulated VSWR of the proposed antenna.

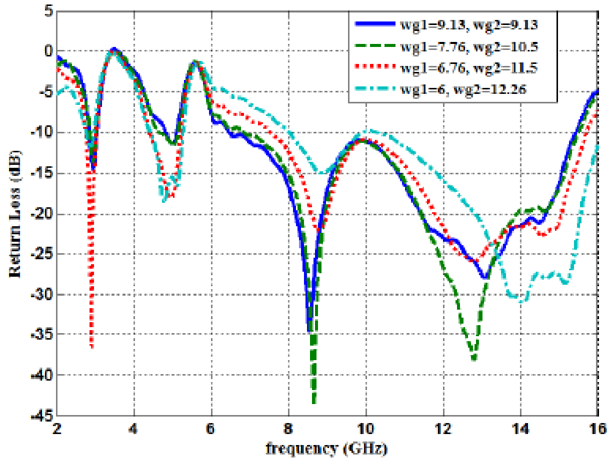

Fig.5 The return loss responses of modeled printed elliptical monopole antenna with different width wg_1, wg_2.

The trenchant frequency band notch is acquired much closed to the desired frequency of 5.5 and 3.5 GHz. The band-notched (5-6 GHz) characteristics are based on the length and width of the inverted U-shaped slot. Fig.6 illustrates the variation of the notched bandwidth with the width L_6 of the inverted U-shaped slot in the CPW transmission line, when the slot has a narrow width , a narrow band notched occurred , increasing the width of L_6 increase the band-notched width, This indicate that the width of L_6 has a clear effect on the notched bandwidth (5-6) GHZ, the center frequency of the lower notched band is 5.5 GHz with a good impedance matching to obtain an effective band-notched UWB antenna.

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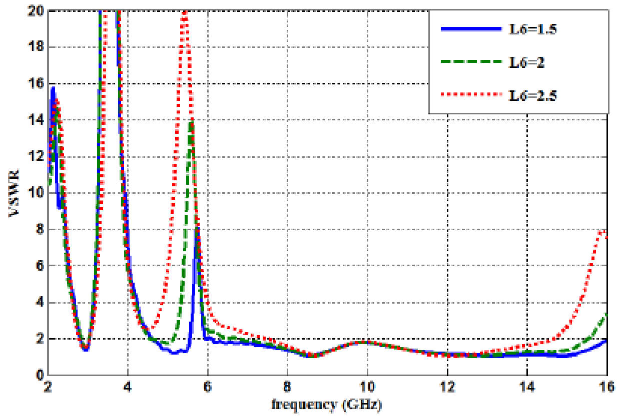

Fig.6. Effects of the varying the length L_6 of the inverted U-slot on the notched bandwidth 5-6 GHz.

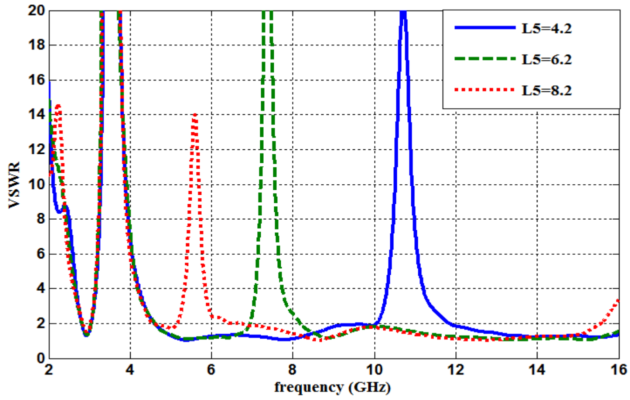

Fig.7. Effects of varying the length L_5 of the inverted U-slot on the notched bandwidth 5-6 GHz.

Fig. 7 shows the effect of varying the length (L_5) of th inverted U-shaped slot. In the case of decreasing the length c L_5 from 8.2 mm to 4.2 mm the notched center frequenc shifting from 5.5 GHz to 10.5 GHz, Furthermore, in Fig. 7 can be observed that the length of L_5 affects the notc location. The optimum result can be obtained when L_5 = 8. mm.

The first adjustment of the second band-notched (3-4 GHz frequency can be done by tuning the length L_3 and L_4 of th symmetrical L-shaped slot as observed in Fig. 8 and Fig. By decreasing L_3 from 7.7 to 5.7, the band notched shifte forward , to get better impedance matching, adjustment c notched bandwidth, the length L_3 optimized at 7.7 mn Shifting the band notched backward occurred when th length of L_4 increased from 5.3 to 6.6 as shown in Fig. 8 It is necessary to control the notch bandwidths in order to obtain an effective band-notched UWB antenna.

To better understand the mechanism of the band-notched characteristics, the simulated current distributions at 3.5 and 5.5 GHz for the proposed antenna are demonstrated. In this case, destructive interference for the excited surface currents in the antenna will occur, which cause the antenna to be nonresponsive at those frequencies.

Fig. 10 shows the current distributions at 3.5, 5.5, 8.5 and 10.5 GHz. The current is distributed mainly along the transmission line at all selected frequencies but the current density is low on the surface of the elliptical patch. It can be seen that the surface currents at 3.5 GHz mainly focus along the symmetrical L-shaped slot and near the feed point and has a small effect on the lower band notch 5 GHz, whereas at the notched band center frequency 5.5 GHz, the current mainly stronger over the area of the inverted U-shaped slot and has no effect on the upper slot which indicates that the changed dimensions of the inverted U-shaped slot has very small virtue on the band notch 3.5 GHz.

For f=8.5, the current distributed around the CPW feed and on the U-slot. For f=10.5 the current concentrates around the feed ,U-slot, and has a little distribution on the lower edge of the patch and at the edge of ground plane. This explains the importance of an optimized dimension of the feed line.

Fig. 11 Shows the simulated Omnidirectional radiation at 2.85 GHz, 5,5 GHz, and 15.4 GHz frequencies for the proposed antenna required to receive signal from all directions.

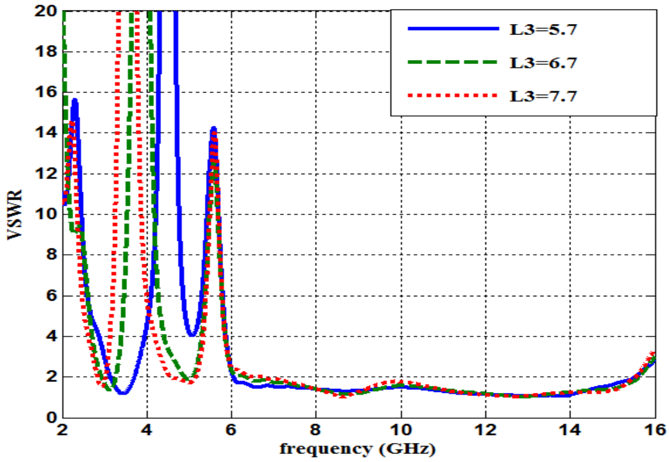

Fig.8. Effects of varying the length L_3 of L-slot on the

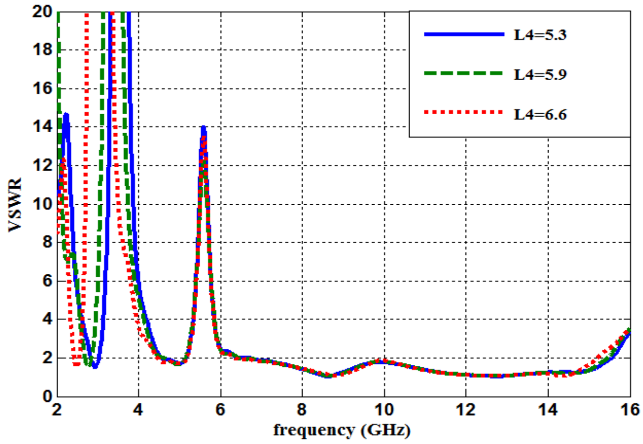

Fig. 9 Effects of the varying the length L_4 of the symmetrical L-slot on the notched bandwidth 3-4 GHz.

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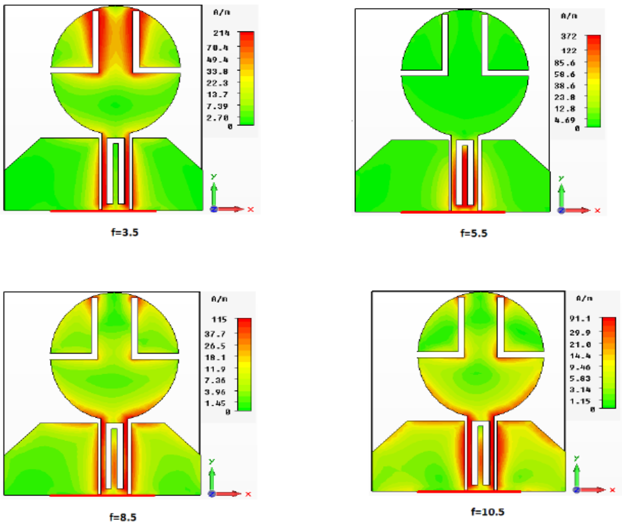

Fig.10. Current distribution at 3.5 GHz, 5.5 GHz, 8.5 GHz and 10.5 GHz.

The antenna gain is found to vary from 1.83 to 5.86 dBi. Fig. 12 shows the 3D plot of the field pattern of the proposed antenna at 2.85, 5.5, and 15.4GHz and the gain at these frequencies. The shape and color of the pattern represent the strength of the fields of the antenna in a particular direction, measured in dBi or decibels with respect to an isotropic radiator (*i.e.* the ratio of the gain of the antenna in a particular direction to the gain of an ideal isotropic antenna, which uniformly distributes energy in all directions.) The antenna gain is found to vary from 1.83 to 5.86 dBi.

In Table II, a comparison between the performance of the proposed antenna and some recently dual band notched UWB antennas [14, 16, and 17] that cover the UWB band from 3.1-10.6 GHz is presented.

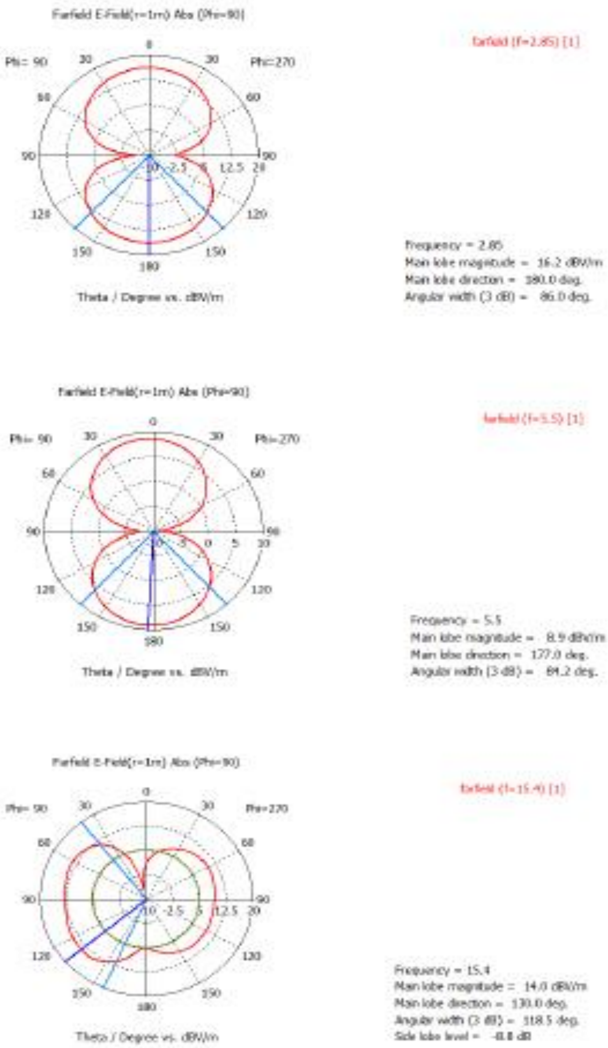

Fig.11. Polar plot of far-field antenna pattern at selected frequencies in the y-z plane

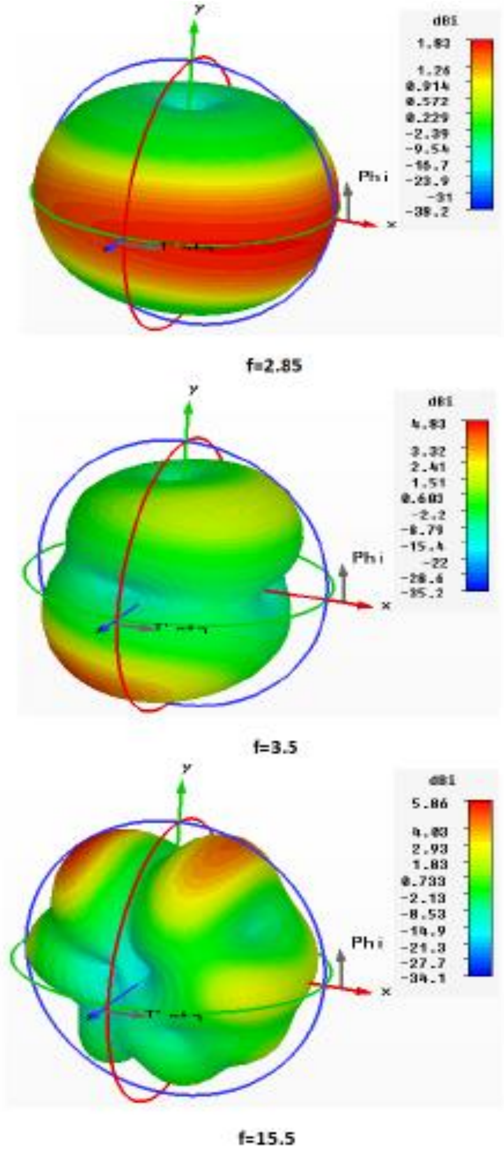

Fig.12. 3D plot of field pattern shows the gain at selected frequency.

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Antenna	*This work*	*[14]*	*[16]*	*[17]*
Simulated Bandwidth (GHz)	2.85-15.4	3.1-11.8	3-11	2.9-12
Simulated Notch Bandwidth (GHz)	5-6 3-4	5-6 3-4	5-6 3.3-3.6	3.2-3.7 5.2-5.8
Notch Slot Type	Inverted-U L-shaped slot	Inverted-U U-shaped slot	L-shaped, Hook shaped slot	T-shaped, U-shaped slot
Antenna size (mm^2)	22 × 25.5	30×30	39.2 ×43.5	30×35
Gain (dBi)	1.83-5.86	<13	1.9-7	1.6-4.1

Table II : Comparison between recently proposed antennas and this antenna.

IV. CONCLUSION

In this paper, A novel CPW-fed printed monopole antenna for UWB operation with band notch characteristics for rejecting WiMAX (3-4 GHz) and WLAN (5-6 GHz) frequencies has been presented. In order to eliminate the potential interference between the UWB and narrowband systems such as WiMAX and WLAN, symmetrical L-shaped slot and an inverted U-shaped slot are embeded on the radiating patch and on the CPW feeding Line respectively that achieve dual band notch. The proposed antenna with an overall size 22 mm×25.5 mm consist of an elliptical radiating patch fed by 50 CPW with the modified and tapered ground plane. The adjustment of dual band-notched is achieved by controlling the length, Width of the slot. The simulation results of the proposed antenna shows many advantages needed for UWB operation. These advantages include compact size with simple shape, wide bandwidth, good impedance matching, acceptable return losses, Omni-directional radiation patterns and stable gain. The proposed antenna is appropriate for applications in the UWB communications.

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