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Very Compact UWB Printed Monopole Antenna with Dual Band Notched Characteristics

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Abstract

In this paper, a very compact dual band notched planar monopole antenna for ultrawideband (UWB) application is presented. By inserting a pair of symmetric rectangular-shaped slot on the ground plane (GND), additional resonances are excited, and hence the bandwidth is increased up to 148% (2.54-17 GHz). Then, by embedding a C-shaped slot on the radiation patch and inserting inverted L-shaped strips along sides of the radiation patch, dual band notched for WIMAX (3-4.1 GHz) and WLAN (5-5.9 GHz) applications is obtained. The designed antenna has a very compact size of 15×17×1 mm^3 and cover the frequency band of 2.54-17 GHz with VSWR<2. The VSWR, radiation patterns and peak gain of the proposed antenna are presented and discussed in detail.

Keywords: Dual band notched, ultrawideband (UWB) antenna, monopole antenna, WIMAX, WLAN.

INTRODUCTION

Ultra wideband (UWB) technology has experience lots of appreciable advances in recent years. Even so, there still remain many challenges in making this technology alive up to its full potential [1]. Printed monopole antennas have collect enhancing concentration in UWB application since they expose interesting advantages such as uncomplicated structure, ease fabrication, low cost, wide impedance bandwidth, and omnidirectional radiation pattern [2]. Several printed monopole antennas have been designed lately [3]-[6] to cover the frequency band that is determined by the federal communications commission (FCC) from 3.1 to 10.6 GHz for UWB applications [7]. In UWB systems, operating frequency band will cause to interference with the existing Bluetooth, WiMAX and WLAN networks operating in IEEE 802.11 wireless local-area networks (WLAN) standards and worldwide interoperability for microwave access (WiMax) in the 2.4 GHz (2.4–2.484 GHz), 3.5 GHz (3.49– 3.79 GHz), 5.2/5.5/5.8 GHz (5.15–5.35/5.25–5.85/5.725–5.825 GHz) respectively. Consequently, an appropriate antenna for UWB applications should have dual notched bands at 3.3-3.7 and 5.15-5.825 GHz and triple notched bands 2.4, 3.3-3.7 and 5.15-5.825 GHz to avoid unwanted interference. Some UWB antennas with band-notched characteristics by using various techniques have been studied in the previously published literatures [8]-[10]. Some of these techniques that are used to obtain band-notched characteristics are as follows: In [8], two different circular slots are embedded in main patch structure to obtain tri-band notched characteristic. In [9], different capacitive loaded loops (CLL) are embedded symmetrically in feed-line structure to control the band-notched frequencies. In recent paper, the band notched functions are obtained by etching a complementary split-ring resonator, and employing a defected ground plane structure [10]. Anyway, most of the antennas have common weakness of bulky size, which may lead to a challenging task in miniaturizing antenna design.

In this paper, the dual band notched characteristics in 3.5 GHz (3- 4.1 GHz), 5.5 GHz GHz (5- 5.9 GHz) is presented. The notched bands functions are generated by embedding C-shaped slot on the radiation patch and inserting a pair of L-shaped strips along sides of the radiation patch. The presented antenna simulated and designed by using commercial Ansoft company software High Frequency Structure Simulator (HFSS) ver. 11.

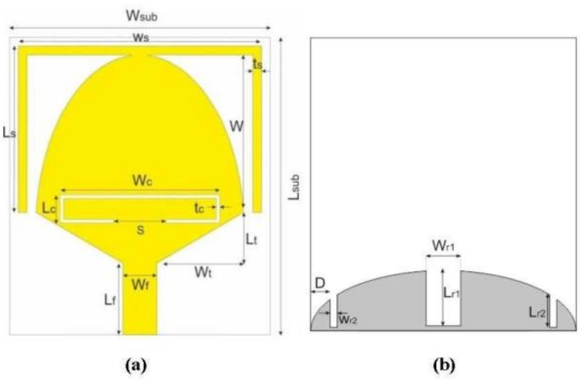


Fig. 1. Geometrical configuration of the proposed dual band notched antenna. W_{sub}=15, L_{sub}=17, W=9, W_t=5, L_t=3, W_c=9.2, L_c=1.6, t_c=0.2, S=3, W_s=14, L_s=9.5, t_s=0.5, W_{r1}=1.95, L_{r1}=3.2, W_{r2}=0.4, L_{r2}=1.9, D=1.1

Antenna Design and Configuration

The proposed dual-band notched planar monopole antenna for UWB application is shown in Fig.1. The proposed antenna is consists of a semi ellipse shaped radiation patch with two triangular-shaped slots in both sides of the patch and a semi ellipse-shaped ground plane with rectangular-shaped slots. This antenna is printed on FR4 substrate with permittivity of 4.4 and compact size of 15×17×1mm^3. The width and length of the microstrip feed line are fixed at 1.95 and 4.11 mm, respectively, to achieve 50Ω characteristic impedance [11]. To design presented antenna, the semi ellipse-shaped radiation patch and semi ellipse-shaped ground plane are used in antenna structure. Then, by inserting two triangular-shaped slots in both sides of the radiation patch, additional resonances are excited. By inserting a vertical rectangular slot under the feed line structure on the ground plane and two symmetrical rectangular-shaped slots in both sides of the ground plane, additional resonances are excited, and hence the bandwidth is increased up to 148% [12]. As shown in Fig. 3(a) and (b), lengths of $L_{r1}$and L_{r2}has very good effect at the upper band edge frequency of operating band. Fig.3 shows that inserting these slots caused to more improvement of the matching at higher frequencies and improving the coupling value between the radiation patch and ground plane. To better understand the issue, surface current distribution on the ground plane at 13GHz is presented. In the proposed design, two band notched function achieved by embedding a C-shaped slot on the radiation patch and inserting inverted L-shaped strips at the two sides of the main radiation patch. The final optimised values of the proposed antenna parameters are shown in Fig.1.

RESULT AND DISCUSSIONS

UWB Monopole Antenna

In this section, the full band antenna design with impedance bandwidth up to 17 GHz is first described. Fig. 2 shows the effect of two symmetric triangular-shaped slots of the radiation patch on the impedance bandwidth. The simulation results show that by increasing the length of L_t, both lower and upper band edge frequencies of impedance bandwidth is decreased and increased, respectively. Fig. 3 shows the effect of ground plane rectangular-shaped slots length on the impedance matching in comparison to the same antenna without notches [11]. As shown in Fig. 3(a), by increasing the length of the rectangular slots from 0.5 to 3.1 mm the lower and upper band edge frequency of the impedance bandwidth is increasing. Thus, this length can be used to extend the lower edge frequency and the upper edge frequency of the proposed antenna impedance bandwidth. Fig. 3(b) shows the effect of two rectangular-shaped slots at the both side of the ground plane on the impedance bandwidth. As shown in Fig. 3(b), it is found that by increasing size of Lr_2 from 1 up to 1.8-mm and fixed W_{r2}=0.4 mm and D=1.1 mm parameters, the impedance bandwidth of the proposed antenna has maximum width in the upper band edge frequency. Thus, these lengths can be used to extend the upper band edge frequency of the impedance bandwidth. Fig. 3(c) shows the simulated surface current distribution on the ground plane structure for the proposed antenna at 13 GHz frequency. From Fig.3 (c), It can be observed that the surface current distribution at 13 GHz concentrated on the edges of the three rectangular-shaped slots [12]. Therefore, the proposed antenna impedance bandwidth changes at this frequency

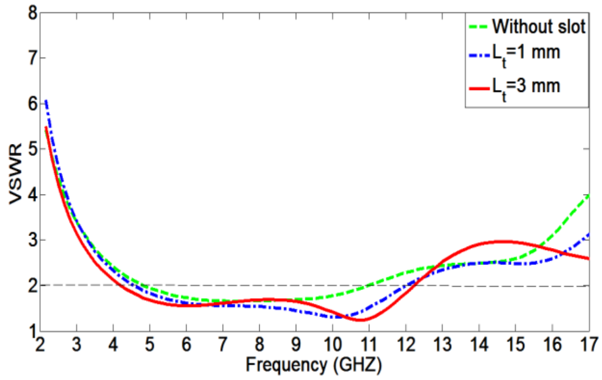
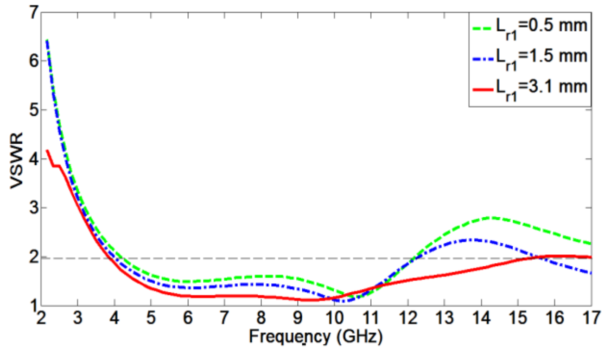
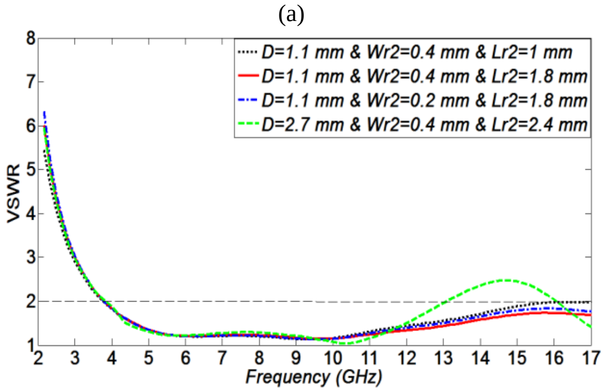


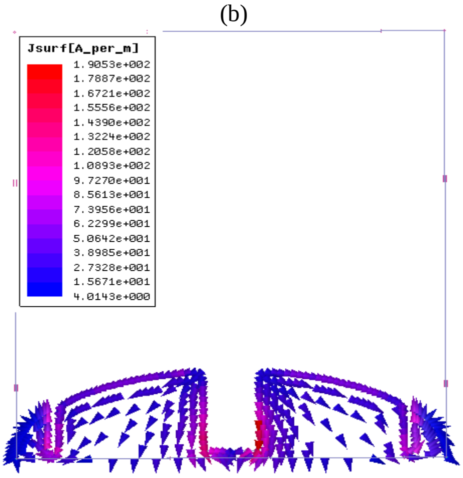
Fig. 2. Simulated VSWR curves for the proposed antenna for different values of L_t.



(a)



(b)



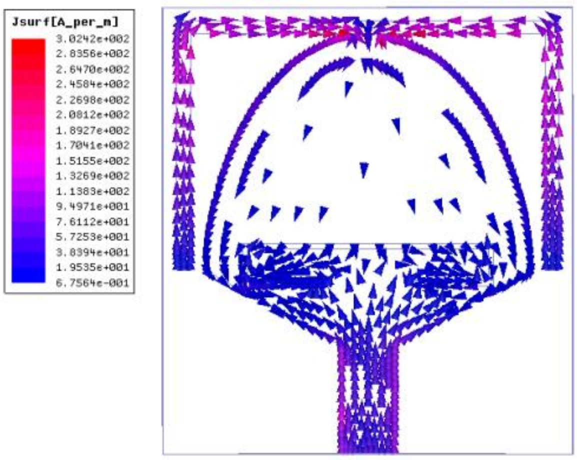
(c)

Fig. 3 (a) and (b) simulated VSWR curves for the proposed antenna without notches and effects of rectangular-shaped slot on the ground plane (a)under the feed line, (b) sides of feed line. (C) simulated surface current distributions on the ground plane for the proposed antenna at 13 GHz.

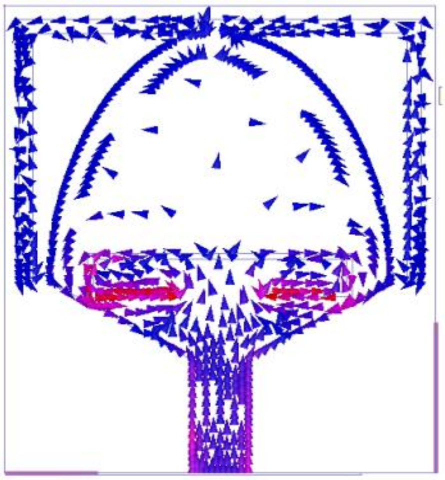
due to the resonant properties of the rectangular-shaped slots [12]. Thus, after embedding these slots, the proposed antenna has good VSWR characteristics at 13 GHz and over the 13 GHz frequency. Therefore, the antenna bandwidth is improved at the upper band edge frequency and hence the impedance bandwidth is increased up to 148% (2.54-17 GHz).

UWB Monopole Antenna With Dual Band-Notched Frequency Characteristics

The ultra wideband frequency range between 3.1-10.6 GHz is authorized by the FCC at 2002. This frequency band is one of crowded frequency spectrums over the world. For this reason, it might cause interference to the existing wireless communication systems such as the WiMAX, and WLAN systems [13]. Therefore, the novel ultrawideband antenna with a band-rejected characteristics is necessary. To solve this problem a novel compact UWB printed Omnidirectional monopole antenna with dual band notched characteristics is presented in this paper. Two notched frequency bands are achieved by inserting two inverted L-shaped strip at the two sides of the radiation patch and embedding a C-shaped slot on the radiation patch. Fig. 4 shows the simulated current distribution at centre of the notch bands. As shown in Fig. 4 (a) the current flows in opposite directions at two edges of the inverted L-shaped strips at 3.5 GHz [12]. Thus, the total effective radiation is reduced, and a notched band at desired frequency is achieved [12]. As shown in Fig. 4 (b), the surface current distribution at 5.5 GHz is concentrated around the C-shaped slot. The antenna is to be unresponsive at this frequency because the excited surface current in the antenna caused destructive interference. Various notched bands can be obtained by changing the parameters of the proposed filter structures. The first notched band depend on the length of the L_S. Fig. 5 shows the simulated VSWR curves with different values of L_S. As the length L_S increases from 2.5 to 11.5 mm, the centre of first notched band moves to the lower frequency. The parameters W_C and S mainly determine the second notched bands characteristics. Fig. 6 illustrate the simulated VSWR curves with different values of W_C and S. As shown in Fig.6, upon increasing W_C and S with other fixed parameters, the second notched band centre frequency will be move to the lower frequencies. Thus, we can conclude from these results that the notch frequency is controllable by changing the lengths of L_S, W_C, and S parameters.



(a)



(b)

Fig. 4. Simulated current distributions on the radiation patch, respectively, at (a) 3.5 GHz (b)5.5 GHz.

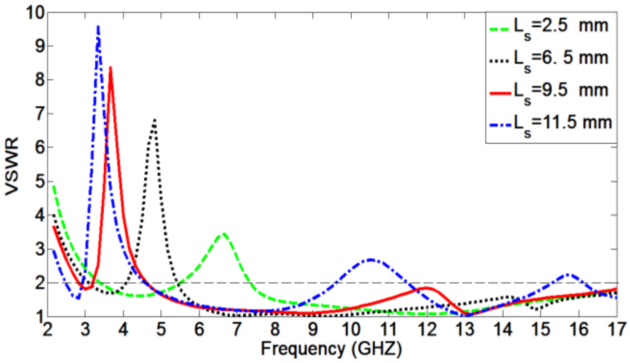


Fig. 5. Simulated VSWR curves for the proposed antenna for different values of L_S.

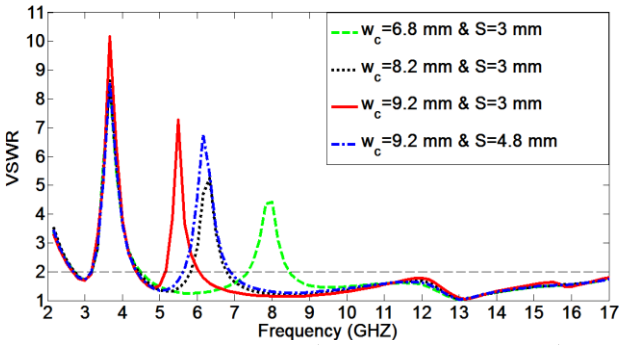


Fig. 6. Simulated VSWR curves for the proposed antenna for different values of W_C and S.

MEASURED RESULTS

The antenna structure is fabricated and tested in the Antenna Measurement Laboratory at the Iran Telecommunication Research Centre (ITRC).

The fabricated dual band-notched antenna structure is shown in Figure 7. The impedance bandwidth was measured by using Agilent 8722ES vector network analyser at ITRC anechoic chamber. The measured and simulated VSWR of the proposed antenna is shown in Fig. 8. The measured results are in close agreement with simulated results in most part of the VSWR curves. In some parts of the simulated and measured VSWR curves are not close agreement with each other because of the antenna fabricated loss and connector loss. Fig. 9 presents the simulated and measured peak antenna gain over the operating band. As shown in Fig. 9, gain decreases drastically at the notched frequency bands of (3-4.1 GHz) and (5-5.9 GHz). Outside the notched bands, the antenna peak gain is stable over the 2.5-17 GHz frequency band. The radiation patterns at 4.8-, 6.6-, and 9.7- GHz in the E-plane (xz) and H-plane (yz) are shown in Fig.10. It can be seen that the radiation patterns are nearly Omni-directional in the H-plane and nearly eight-shaped in E-plane for the three frequencies. According to the overall view of these measured radiation patterns, it is found that the proposed dual-band notched antenna behaves quite similarly to the typical printed monopole antenna [4]. For UWB antenna, the group delay needs to be constant over the entire band as well for better performance at this frequency [7]. Simulated group delay for two orientations (side by side and face to face) of the proposed dual-band notched antenna is shown in Fig. 11. It can be seen that, the side by side group delay variation is less than 0.2 ns from the frequency range 2.5-17 GHz. The face to face group delay variation is less than 0.3 ns from the frequency range of 2.5-17 GHz. However, the proposed antenna has good group delay variation at over the frequency range of 2.5-17 GHz.

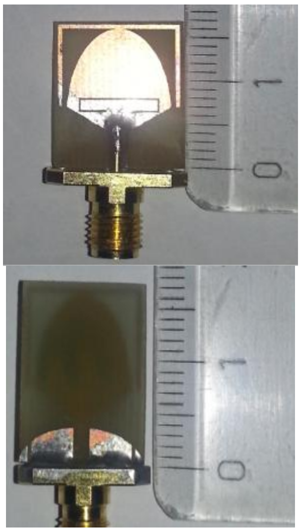


Fig. 7. Photograph of the proposed realised antenna.

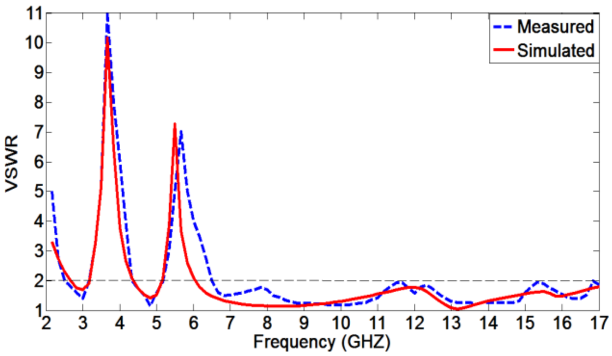


Fig. 8. Measured and simulated VSWR results of the proposed dual band-notched monopole antenna.

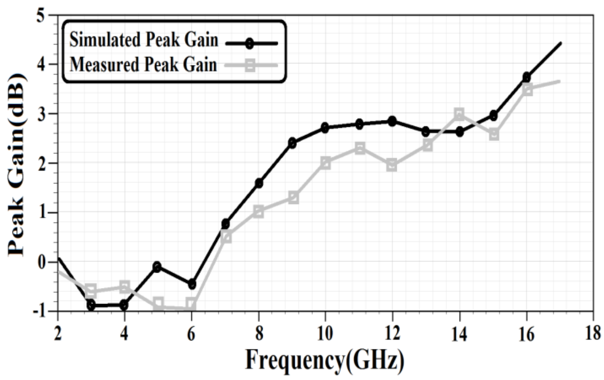


Fig. 9. Measured and simulated peak gain results of the proposed dual band-notched monopole antenna.

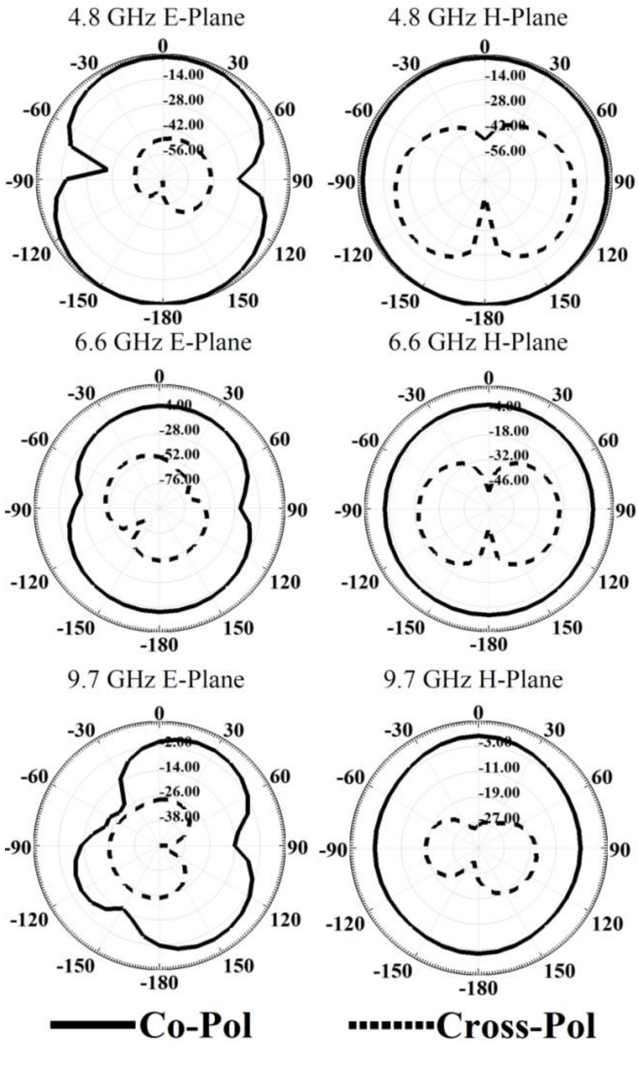


Fig. 10. Measured E-plane and H-plane radiation patterns at 4.8-, 6.6-, and 9.7- GHz.

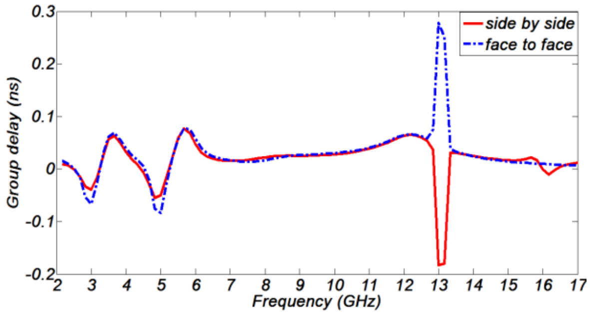


Fig.11. Simulated group delay for side by side and face to face orientations.

CONCLUSIONS

A very compact printed monopole UWB antenna with dual band notched characteristics has been presented in this paper in detail. By inserting two triangular slots on the radiation patch and three rectangular-shaped slots on the ground plane, impedance bandwidth was increased up to 148%. Then, by inserting inverted L-shaped strips at the two sides of the radiation patch and embedding a C-shaped slot on the radiation patch**,** the dual band notched characteristics at 3-4.1 GHz and 5-5.9 GHz has been obtained. The presented antenna has a very compact size of 15×17×1 mm^3 . The measured results of the dual band notched antenna show a 148% wide impedance bandwidth and Omni-directional radiation patterns over the operating band.

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