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Compact band-rejection printed monopole antenna for UWB application

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Abstract: A novel compact band-notch ultra-wideband (UWB) printed monopole antenna is proposed, where the band notch characteristic is realized by inserting a pair of hook-shaped slit in the both side of radiating patch. Also, by inserting a π-shaped stub in the ground plane, additional resonance is excited and hence the bandwidth is increased up to 123%. This novel monopole antenna has ultrawide impedance bandwidth, compact size, low fabrication cost, and omni-directional H-plane radiation patterns which are suitable for various broadband applications.

Keywords: band-notch function, monopole antenna, UWB antenna

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

Ultrawideband (UWB) technology has undergone many significant developments in recent years. However, there still remain many challenges in making this technology live up to its full potential [1]. Among the newly proposed UWB antenna designs, the printed monopole antennas should be the most promising candidate for future applications due to their appealing features of simple structure, satisfactory radiation properties, ease of manufacturing, and capability for integration with printed circuit boards. Several printed monopole antennas have been proposed recently [2, 3] to cover the frequency band that is defined by the Federal Communications Commission (FCC) from 3.1 to 10.6 GHz for UWB applications.

The frequency range for UWB systems between 3.1 to 10.6 GHz will cause interference to the existing wireless communication systems, for example the wireless local area network (WLAN) for IEEE 802.11a operating in 5.15–5.35 GHz and 5.725–5.825 GHz bands and HIPERLAN/2 in Europe (5.15–5.35 GHz, 5.47–5.725 GHz), so the UWB antenna with a band-notch performance is required. Recently in literature, a number of antennas with band-notch characteristic have been presented. This includes: slot type split ring resonators (SRRs) etched on the radiating patch [4]; modified printed monopoles with T-shaped conductor-backed plane [5]; inverted U-shaped slot embedded in the uniform microstrip line [6], and so on. Nevertheless, most of these antennas have the common deficiency of large size, which may lead to a challenging task in miniaturizing antenna design.

In this paper, a novel compact band-notched UWB printed monopole antenna is presented. Bandwidth enhancement in the upper frequency band is achieved by using a π-shaped stub in the ground plane. Moreover, to realize a sharp rejection frequency band from 5 to 6 GHz a pair of hook-shaped slit embedded in the both side of radiation patch. The designed antenna has a compact size ($16 \times 20 \times 1\,\mathrm{mm}^3$) and operates over the frequency band between 3 to 12.5 GHz for VSWR < 2 with the band rejection over the 5–6 GHz. Experimental and simulated results of the impedance bandwidth behavior, radiation patterns are presented.

2 Antenna design

Fig. 1 shows the geometry of the proposed antenna. The radiating monopole and feeding mechanism are printed on the top side of the substrate, while the ground plane is printed on the bottom side. This antenna is printed on an FR4 microwave substrate with size of $20 \times 16\,\mathrm{mm}^2$, thickness of 1 mm, and dielectric constant of 4.4. The width of the microstrip feed line W_f is fixed at 1.86 mm to achieve 50-Ω characteristic impedance from 3–12.5 GHz.

The π-shaped stub is playing an important role in the broadband characteristics of this antenna, because it can adjust the electromagnetic coupling effects between the rectangular patch and the ground plane, and improves its impedance bandwidth without any cost of size or expense. This phenomenon occurs because with use of a π-shaped stub in the ground plane additional

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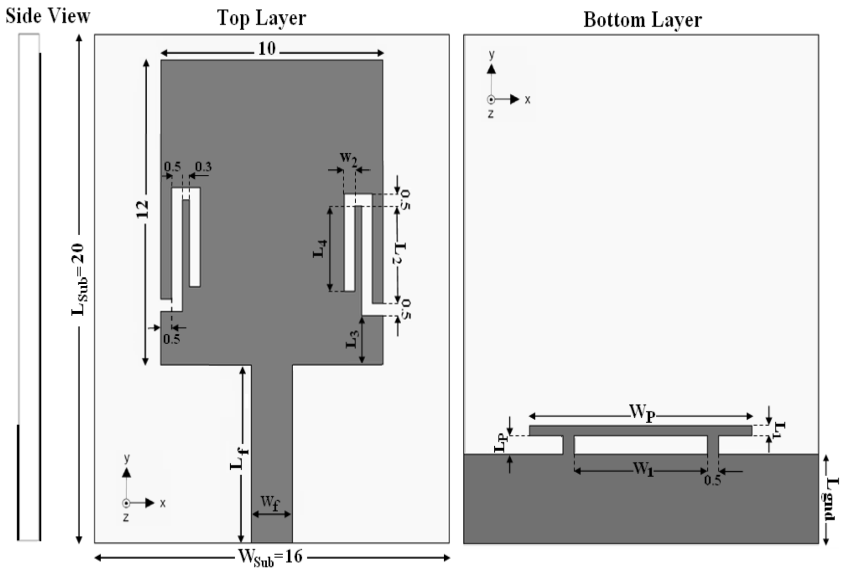

Fig. 1. Configuration and parameters of the proposed monopole antenna (unit: mm).

coupling is introduced between the bottom edge of the rectangular patch and the ground plane.

The hook-shaped slits in the radiating patch perturb the resonant response. At the notch frequency, the current concentrated on the edges of the interior and exterior of the hook-shaped slits. This leads to the desired high attenuation near the notch frequency. The band-notch characteristic can be achieved by carefully choosing the parameters (L_2 and W_2) for the hook-shaped slits.

The optimal dimensions of the designed antenna are as follows: $L_{sub} = 20\,\text{mm}$, $W_{sub} = 16\,\text{mm}$, $W_f = 1.86\,\text{mm}$, $L_2 = 4\,\text{mm}$, $L_3 = 2\,\text{mm}$, $L_4 = 3.5\,\text{mm}$, $L_f = 7\,\text{mm}$, $W_2 = 0.5\,\text{mm}$, $L_{gnd} = 3.5\,\text{mm}$, $W_p = 10\,\text{mm}$, $W_1 = 6\,\text{mm}$, $L_1 = 0.3\,\text{mm}$, and $L_p = 0.5\,\text{mm}$. Moreover, the structure of the antenna is symmetrical with respect to the longitudinal direction. The proposed printed monopole antenna with optimal design was built and tested in the Antenna Measurement Laboratory at Iran Telecommunication Research Center (ITRC).

3 Results and Discussion

The parameters of the proposed antenna are studied by changing one parameter at a time and fixing the others. To fully understand the behavior of the antenna's structure and to determine the optimum parameters, the antenna was analyzed using Ansoft HFSS. The optimized values of each physical dimension of the proposed antenna are shown in Fig. 1.

Fig. 2 (a) shows the effects of π-shaped stub and filter structure on the impedance matching in comparison to the same antenna without stub and filter structure. As shown in Fig. 2 (a), in the proposed antenna configuration, the ordinary rectangular monopole can provide the fundamental and next higher resonant radiation band at 3.7 and 8.5 GHz, respectively, in the

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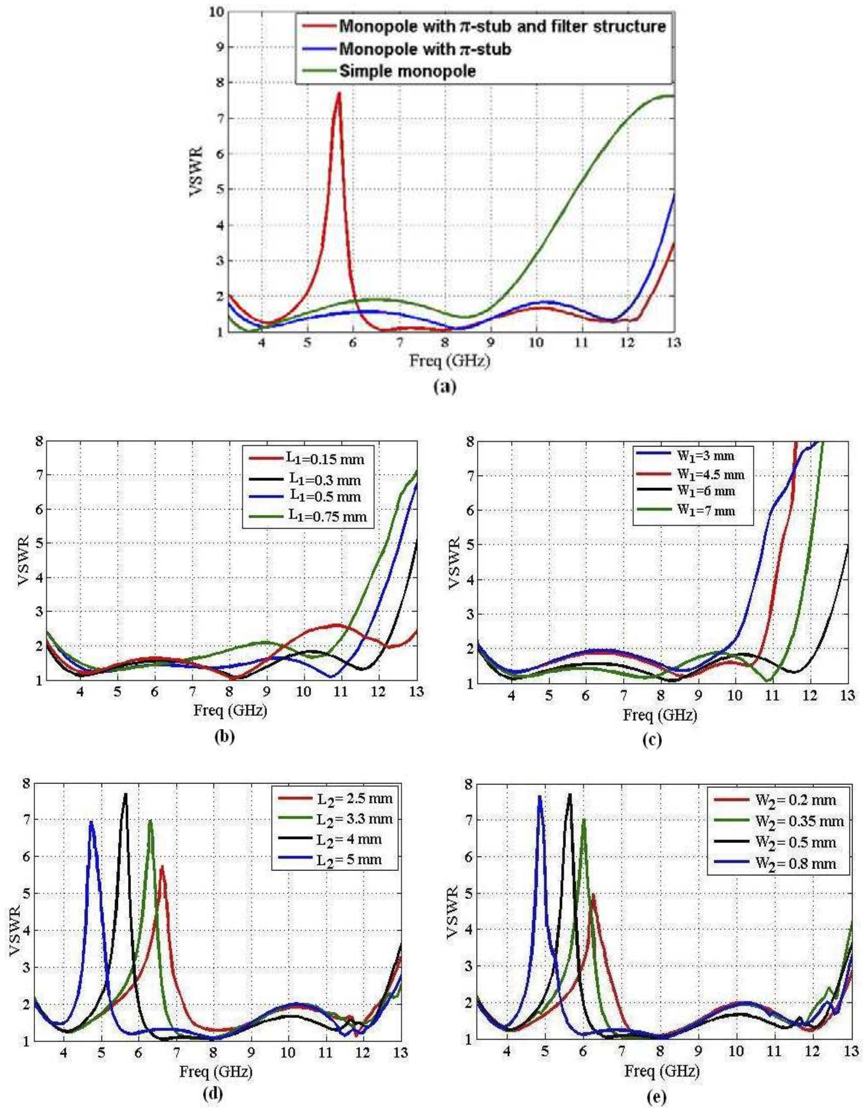

Fig. 2. (a) Simulated VSWR curves for the proposed antenna with and without stub and filter structure, (b) Simulated VSWR for proposed antenna in terms of L_1, (c) Simulated VSWR for proposed antenna in terms of W_1, (d) Simulated VSWR for proposed antenna in terms of L_2, and (e) Simulated VSWR for proposed antenna in terms of W_2.

absence of the π-shaped stub. By the use of π-shaped stub in the ground plane, the impedance bandwidth increases to the great frequency band from 3 GHz to more than 12.5 GHz, because the additional resonant mode has been generated. From the simulation results in Fig. 2 (a), it is found that by inserting the π-shaped stub, the third resonance occurs at 11.75 GHz. Therefore, the antenna impedance changes at this frequency due to the resonant properties of the π-shaped stub. Also, as shown in Fig. 2 (a), the notched band, covering the 5-GHz WLAN band, is provided by inserting a pair of hook-shaped slit in the both side of radiating patch.

The simulated VSWR curves with different values of L_1 are plotted in

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Fig. 2 (b) ($W_1 = 6$ mm). From the simulation results in Fig. 2 (b), it is observed that the upper frequency is significantly affected by the variation in length L_1. The simulated VSWR curves with the optimal length L_1 for various widths W_1 are plotted in Fig. 2 (c). It is observed that as the width W_1 increases from 3 to 6 mm, the impedance bandwidth in the upper frequency band improves and so the fractional impedance bandwidth greatly increases from 105 to 123%. Moreover, as the width W_1 increases to 7 mm, the impedance bandwidth reduces slightly. On the other hand, the lower frequency of the band is insensitive to the changes of W_1 and L_1. We conclude that the parameters W_1 and L_1, are the critical parameters to determine the upper operating frequency, impedance bandwidth and impedance matching.

Fig. 2 (d) illustrates the simulated VSWR characteristics with various lengths L_2. Fig. 2 (d) shows that the small changes in the length of the L_2, has significant effect on the position of center frequency of notched band. As the length L_2 increases from 2.5 to 5 mm, the center frequency of notched band is varied from 6.65 to 4.8 GHz. In addition, the total notched bandwidth of the antenna decreases as L_2 increased. The simulated VSWR curves with different values of W_2 are plotted in Fig. 2 (e). As shown in Fig. 2 (e) when the weight of W_2 increases from 0.2 mm to 0.8 mm, the center frequency of notched band is varied from 6.2 GHz to 4.9 GHz with higher VSWR characteristics peak. From these results, we can conclude that the notch frequency is controllable by carefully choosing the weight W_2 and length L_2 of the hook-shaped slits.

Fig. 3 (a) shows the current distribution at the notch frequency of 5.5 GHz. It can be observed on Fig. 3 (a) that the current concentrated on the edges of the interior and exterior of the hook-shaped slits at 5.5 GHz. Therefore, the resultant radiation fields cancel out and high attenuation near the notch frequency is produced. Hence, the antenna does not radiate efficiently.

To verify the proposed design, a prototype of the antenna based on optimized dimensions has been fabricated, as shown in Fig. 3 (b). The impedance bandwidth was measured by using an Agilent 8722ES vector network analyzer. As shown in Fig. 3 (b), the good agreement between the simulated and measured results is observed. The discrepancy between the simulated and measured results can be mostly attributed to the measured environment effect and the tolerance in manufacturing. It is noted that the simulated impedance bandwidth for VSWR < 2 is from 3 to 12.5 GHz with a notched band ranging from 5 to 6 GHz, whereas the measured impedance bandwidth is from 2.9 to 12 GHz with a notched band of 4.9 to 6.05 GHz, which covers the desired 3.1–10.6 GHz and avoids WLAN/HIPERLAN/2 interference.

Two principle planes are selected to present the radiation pattern of the fabricated antenna. These are referred to as y-z plane (E-plane) and x-z plane (H-plane). Fig. 3 (c) illustrates the measured and simulated radiation patterns in the H-plane and E-plane at the frequencies of 4, 7, and 10 GHz of the UWB band. It can be seen that the radiation patterns in the H-plane are nearly omnidirectional for the three frequencies. By comparing the measured and simulated patterns of Fig. 3 (c), a good agreement is observed.

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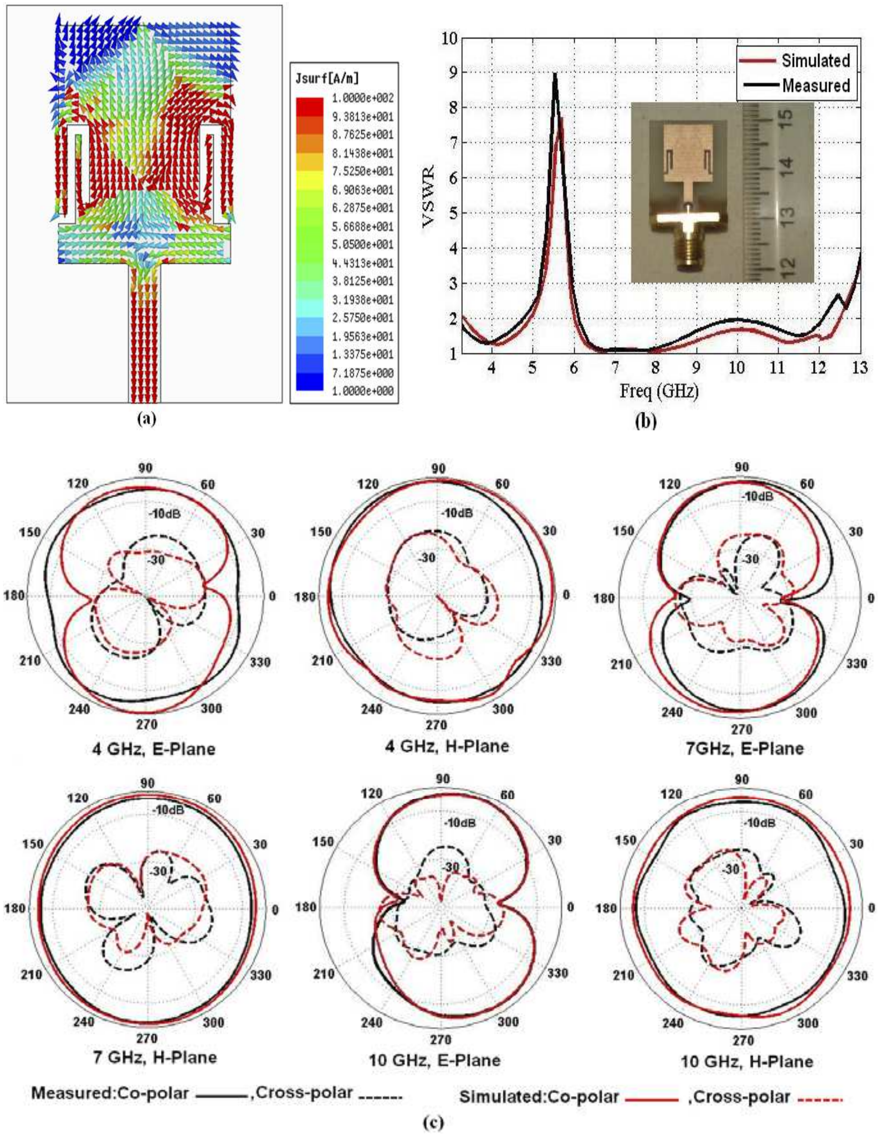

Fig. 3. (a) Simulated current distributions at 5.5 GHz (notch frequency), (b) Photograph of the fabricated prototype and comparison between measured and simulated VSWR for the proposed antenna, and (c) Measured and simulated radiation patterns of the proposed antenna at frequencies 4, 7, and 10 GHz.

4 Conclusion

A novel compact UWB printed monopole antenna with band-notch characteristic has been presented. We illustrated that by inserting a π-shaped stub with proper dimensions in the ground plane, a wide impedance bandwidth from 3 to 12.5 GHz is achieved. Frequency band-notch performance is achieved by adding hook-shaped slits in the radiating patch. The effects of the various geometrical parameters on the antenna performance are studied. The radiation pattern of this antenna shows good omni-directional pattern throughout the UWB frequency range.

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