Extended Bandwidth Monopole Antenna with Frequency Band-Stop Operation for Wireless Applications

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Abstract **—** This letter proposes a new monopole antenna for wireless applications, in particular ultra wideband (UWB) with 3.5/5.5 GHz dual notched bands. The antenna includes square patch, 50 Ω microstrip feed-line, and a partial ground plane using a new structure provides a broad impedance bandwidth. In order to achieve dual notched bands at 3.5 GHz and 5.5 GHz, two radiating strips and a T-shaped slot on the radiating patch are applied, respectively. The antenna is simple in geometry and has a small size of 19×14 mm^2. The measured results show a desirable agreement with the simulated results. The antenna approximately produces omnidirectional radiation patterns in H-plane, and flat gain over the whole UWB frequency excluding the two notched bands (WiMAX and WLAN bands).

Index Terms **—** Antennas, notched band, UWB (Ultra Wideband), WiMAX, WLAN.

I. INTRODUCTION

The advancement in ultra wideband (UWB) communication systems are developing at an unbelievable rate. Ultra wideband wireless systems are renowned and popular due to its advantages including high degree of reliability, robustness against jamming, low power consumption, and high data rate transmissions. Meanwhile, Federal Communications Commission (FCC) have defined UWB systems from the frequency band of 3.1 to 10.6 GHz in 2002 [1]. The design of the set of antennas in a compact dimension while providing wideband properties on all desirable frequency band is one of key issues in UWB communication. Thus, many antennas in different geometries with capabilities of super and ultra wideband have been presented [2-4]. However, there are some of the interference frequency bands into UWB such as the IEEE 802.16 standard for the Worldwide Interoperability for Microwave Access (WiMAX) system at 3.5 GHz (3.3-3.69 GHz), and the IEEE 802.11a standard for the Wireless Local Area Network (WLAN) system at 5.5 GHz (5.15-5.825 GHz). To address these drawbacks, there needs to be designed a special antenna with property of filtering interference bands. Recently, multiband stopped UWB antennas based on various techniques have been proposed [5-14]. The most common technique for a band-stopping is inserting slots. Diverse slots have been proposed by many researchers, to be inserted in the radiating element, ground plane, feeding line and vicinity of the radiating element [5-8]. The fractal structure is used to obtain both size reduction and frequency band notched characteristic in UWB antennas [12-13]. Because these structures are electronically small resonators with very high Qs, they can be considered as filters providing sharp notches or pass of certain frequency bands. Also, Electromagnetic Band Gap (EBG) structures are used to improve UWB antenna performance, such

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as increasing the antenna's gain as well as producing a frequency stop-band characteristic [14]. These aforementioned methods can obtain a good single or dual stop-band property, but some of them are with large size or complicated design procedure which makes them unsuitable for the UWB antenna candidates. In this paper, a new dual stop-band antenna with compact size of 19×14 mm^2 is suggested. To obtain two stopped bands, two strip lines as radiating patch and a T-shaped slot which is etched off the radiating patch are used. The antenna was successfully fabricated and measured, and the experimental results depict an acceptable agreement with simulations. Section II describes the antenna design, discussions on results is presented in Section III followed by conclusive comments in Section IV.

II. ANTENNA DESIGN

The proposed monopole antenna fed by a microstrip line is shown in Fig. 1, which is printed on an FR4 substrate of thickness of 1 mm, and relative permittivity of 4.4. The antenna has a compact size of 19×14 mm^2 or approximately 0.27λ×0.20λ at 4.2 GHz (the first resonant frequency). The antenna is excited using a 50 Ω microstrip line, with width 2.0 mm and length 7.0 mm. The basic antenna structure consists of a square radiating patch, a feed line, and a partial ground plane. By etching two inverted T-shaped slots on the ground plane, another resonant frequency is excited, which results in an extended impedance bandwidth of 13.7 GHz. Furthermore, by deforming square radiating patch to two radiating strip lines, a notched band at 3.5 GHz can be achieved whilst by etching a T-shaped slot off the patch and feed line, another notched band at centre frequency 5.5 GHz is obtained.

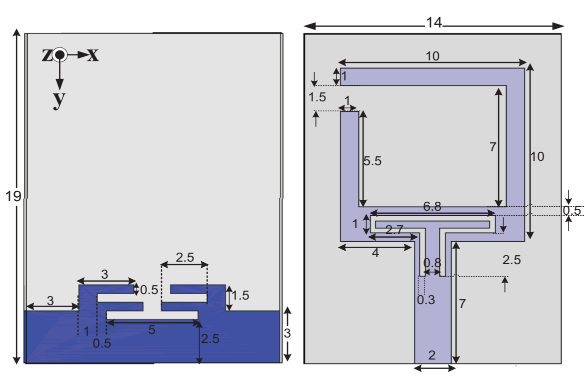

Fig. 1. Geometry of the proposed antenna.

III. ANTENNA PERFORMANCE AND DISCUSSION

In this section, the effects of the different parameters on the antenna performance are investigated. The parameters of the antenna are studied by varying one or two parameters at a time and fixing the others. The simulated results are achieved using the Ansoft simulation software High-Frequency Structure Simulator (HFSSTM) [15] and CST software [16].

As mentioned before, to earn broad impedance bandwidth, the set of slots are utilized on the ground plane. Figure 2 shows reflection coefficient for different structures of antenna indicating tangible resonant frequencies and wide impedance bandwidth. As shown in Fig. 2, by etching two inverted T-shaped slots on the ground plane, the antenna will have a good impedance matching from 3.3 GHz by 13.5 GHz.

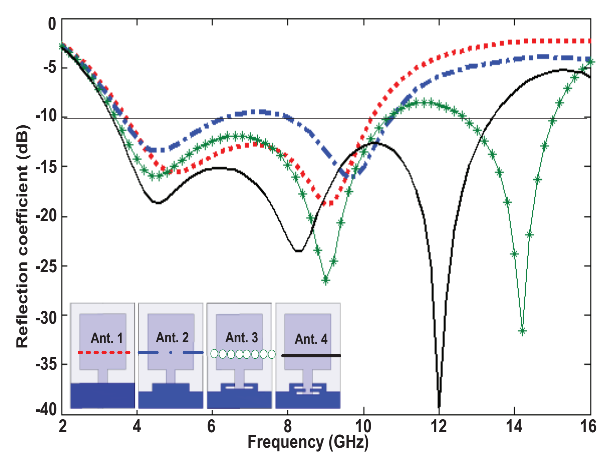

Fig. 2. Reflection coefficient characteristics for different structures of antenna indicating impedance bandwidth.

In other words, in Ant. 3, the third resonant frequency is excited by an inverted slot in 14.2 GHz, although impedance bandwidth from 10.8 GHz to 12.6 GHz is ruined, it means that it is more than -10 dB; therefore, by etching the second inverted T-shaped slot on the ground (Ant. 4), the third resonant frequency is replaced from 14.2 to 12 GHz. Consequently, the antenna will see a wide bandwidth from 3.3 to 13.5 GHz.

To study the effect of various parameters on the ground, Figs. 3 and 4 are presented. Regarding to Fig. 3, it is obvious that dx1 has important effect in producing the third resonant frequency. The best value dx1 is 3.0 mm.

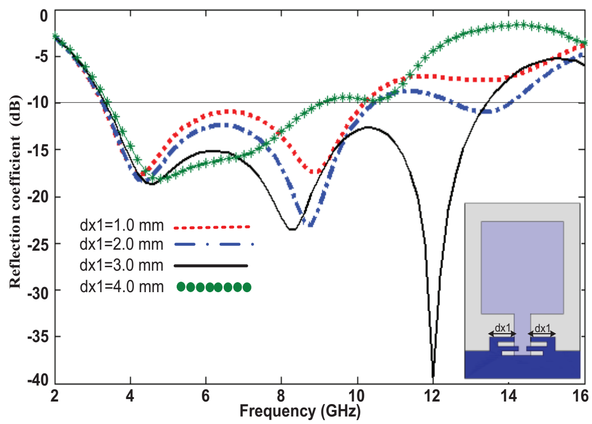

Fig. 3. Reflection coefficient characteristics for the antenna with different values dx1.

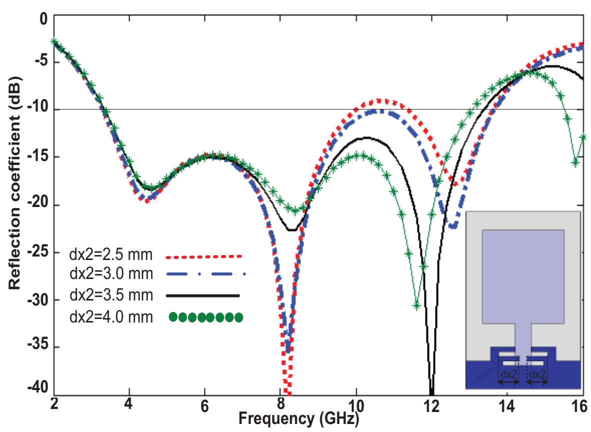

Fig. 4. Reflection coefficient characteristics for the antenna with different values dx2.

As exhibited in Fig. 4, parameters dx2 play an important role in shifting the third resonant frequency. Thus, among values of dx2 presented in Fig. 4, 3.5 mm is the best. As illustrated in Fig. 5, VSWR characteristics for different radiating patches of antenna including (1) square, (2) ring, (3) two strips, (4) two strips with T-shaped slot are compared to each other. As far as Fig. 5 is concerned, in order to generate single notched band at centre frequency 3.5 GHz, two radiating strips are utilized while by etching a T-shaped slot off the patch and feed line, another notched band at centre frequency 5.5 GHz is achieved. To exhibit being independent and controllable of both notched bands are applied Figs. 6 to 7. As depicted in Fig. 6, parameter dy1 has a markedly influence on frequency shifting for lower band stop. According to it, with increasing length dy1, the center frequency is decreased regularly in a way that by rising 1 mm in its length centre frequency of the notched band is reduced about 0.2 GHz. The best value dy1 for covering 3.3 to 3.69 corresponds to 10.0 mm. As mentioned before, in this study to generate the stop-band performance on upper band with center frequency 5.5 GHz, is used an T-shaped slot on the patch. The simulated VSWR curves with different values dy2 are plotted in Fig. 7. Related to it, when the length dy2 increases gradually, center frequency of the notched band is decreased steadily. Thus, the optimized dy2 is 2.8 mm.

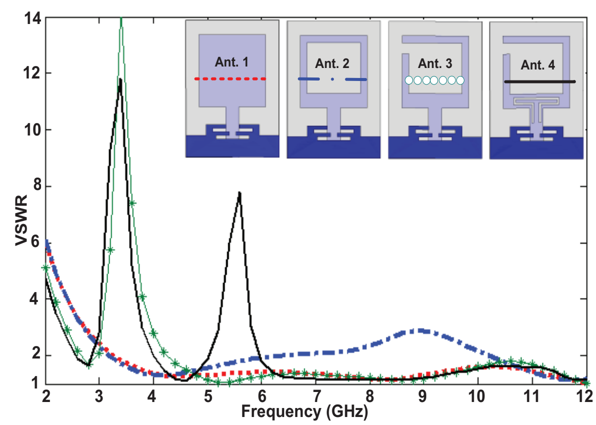

Fig. 5. VSWR characteristics for various structures of antenna indicating notched bands.

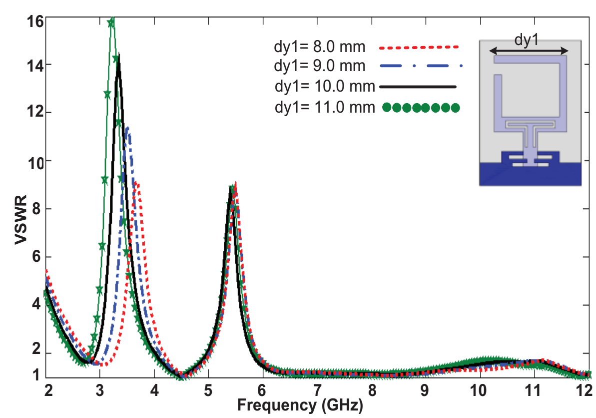

Fig. 6. VSWR characteristics for the antenna with different values dy1.

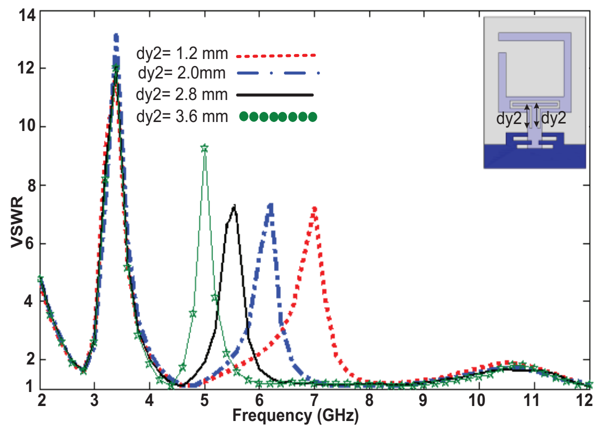

Fig. 7. VSWR characteristics for the antenna with different values dy2.

From these results, it can be found that the notched frequencies are controllable by changing the lengths dy1 and dy2. The proposed antenna with optimal design was fabricated and tested in the Antenna Measurement Laboratory at Iran Telecommunication Research Center. The numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. Figure 8 shows the measured and simulated VSWR characteristics and photo of the fabricated antenna. The fabricated antenna is able to cover the frequency band from 2.6 GHz to more than 14.0 GHz for VSWR≤2, except the notched bands around 3.0 GHz to 4.05 GHz and 4.95 GHz to 5.9 GHz. The antenna has been simulated by both HFSS [15] and CST [16].

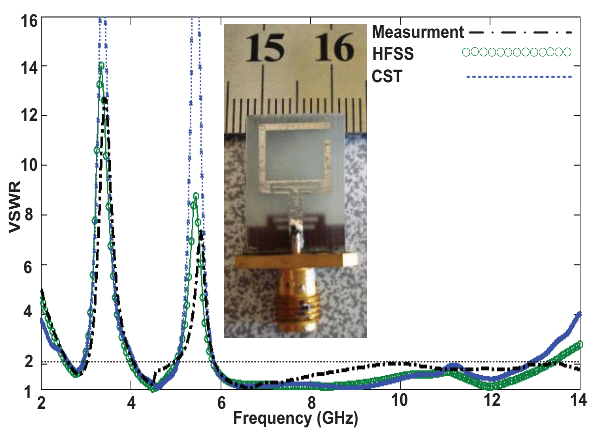

Fig. 8. Measured and simulated VSWR for the proposed antenna and photograph of the fabricated antenna.

Good agreement between simulated and measured results is observed and negligible difference between them is attributed to factors such as SMA connector effects, fabrication imperfections, and inappropriate quality of the microwave substrate. Figure 9 depicts measured gain of the antenna without and with notched bands. As shown in Fig. 9, two sharp decrease of maximum gain on notched bands at 3.5 GHz and 5.3 GHz are apparent. For other frequencies outside notched bands, the antenna nearly has a flat gain. Figure 10 exhibits the normalized far-field radiation patterns in both H-plane (x-z plane) and E-plane (y-z plane) at frequencies 6.5 and 8.5 GHz. It can be observed that the radiation patterns in x-z plane are approximately omnidirectional for the two frequencies, while radiation pattern in y-z plane are nearly bidirectional.

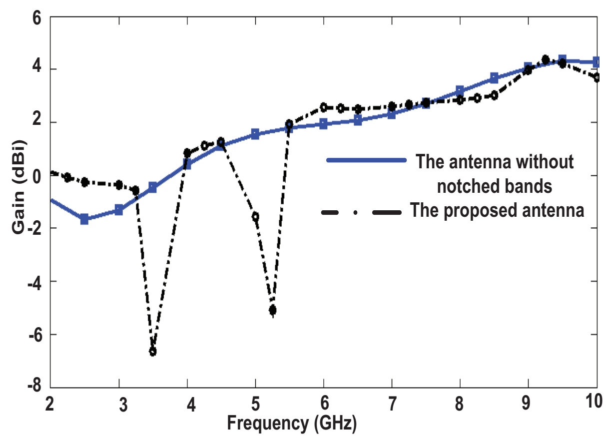

Fig. 9. Measured gain of the proposed antenna without and with notched bands.

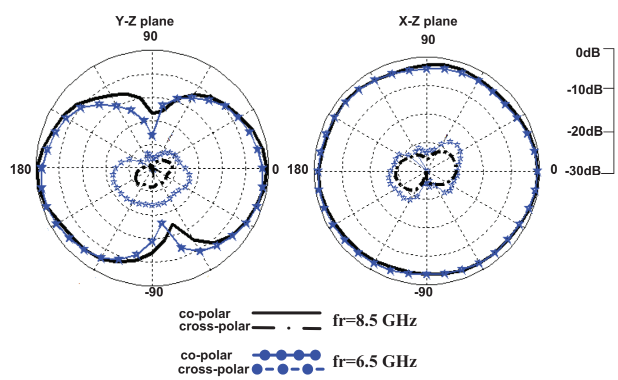

Fig. 10. Radiation patterns of the antenna at: (a) 6.5, and (b) 8.5 GHz.

IV. CONCLUSION

In this letter, a new monopole antenna with frequency band-stop operation for wireless, in particular UWB, has been suggested. The fabricated antenna can cover an extended impedance bandwidth of 2.6 GHz to 14.0 GHz with two notched bands around 3.0 GHz to 4.05 GHz and 4.95 GHz to 5.9 GHz. The antenna has a simple configuration with a small size 19×14 mm^2 which is easy to fabricate. Generally speaking, novel techniques utilized in geometry and configuration to obtain extended bandwidth, two notched bands, compact size, and inexpensive substrate for fabrication are important factors indicating the antenna could be a good candidate for UWB applications.

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