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A NOVEL DUAL BAND-NOTCHED MONOPOLE ANTENNA FOR ULTRA-WIDEBAND APPLICATION

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Abstract—In this article, a printed ultra-wideband (UWB) monopole antenna with dual band-notched characteristics of size 26 mm × 35 mm is presented. The prototype consists of pincers-shaped radiation element and corner rounded ground plane. By inserting a pair of flexuous slots on the radiation element and a C-shaped slot on the ground plane, the 3.5/5.5 GHz dual band-notched characteristics are achieved, respectively. Moreover, good radiation patterns and gains within the operating band have been obtained. The detailed design and experimental results are discussed in this article.

1. INTRODUCTION

Ultra-wideband technology has gained a lot of popularity among researchers and the wireless industry after the FCC permitted its marketing within the frequency band of 3.1 GHz to 10.6 GHz [1]. In UWB systems, high performance UWB antennas play a key role. Therefore, many researchers have been devoted to this field in the last decade [2–4]. However, the frequency range for UWB system from 3.1 to 10.6 GHz will cause interference to the existing wireless communication systems, e.g., the wireless local network (WLAN) operating in 5.15 $\sim$ 5.23 GHz and 5.725 $\sim$ 5.825 GHz bands. To avoid the interference between the UWB and WLAN systems, many frequency-notched UWB antennas have been developed by inserting a V-shaped [5], U-shaped [6], a pair of inverted-T-shaped slot [7] or adding symmetrical parasitic patches around the radiation patch [8]. In addition, to increase the impedance bandwidth of antennas, techniques such as adding steps to the lower edge of the patch are adopted [9].

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In this article, a compact printed monopole antenna with 3.5/5.5 GHz dual band-notched characteristics is designed for UWB application. By embedding a pair of flexuous slots on the radiation element and a C-shaped slot on the ground plane across the microstrip feed line, the 3.5/5.5 GHz dual band-notched characteristics are obtained, respectively. The proposed antenna can be easily adjusted to achieve the dual band-notched characteristics by changing the dimensions of these slots. Moreover, the designed antenna can operate and present stable radiation patterns over the UWB band, except the unwanted bands for WiMAX and WLAN. To verify the proposed design, an experimental prototype was designed, fabricated and measured. Both the simulated and measured results such as voltage standing wave ratio (VSWR), radiation pattern, and gain are presented and discussed in detail as follows.

2. ANTENNA DESIGN

Figure 1 depicts the geometry of the proposed antenna. As shown in this figure, the antenna is composed of a corner round ground and a pincers-shaped radiation element, which is fed by a 50 Ω microstrip line with width W_2. In this design, we use the low-cost FR-4 substrate with thickness of 1.6 mm, relative dielectric constant of 4.4, and total size of 26 mm × 35 mm. Between the microstrip line and pincers-shaped

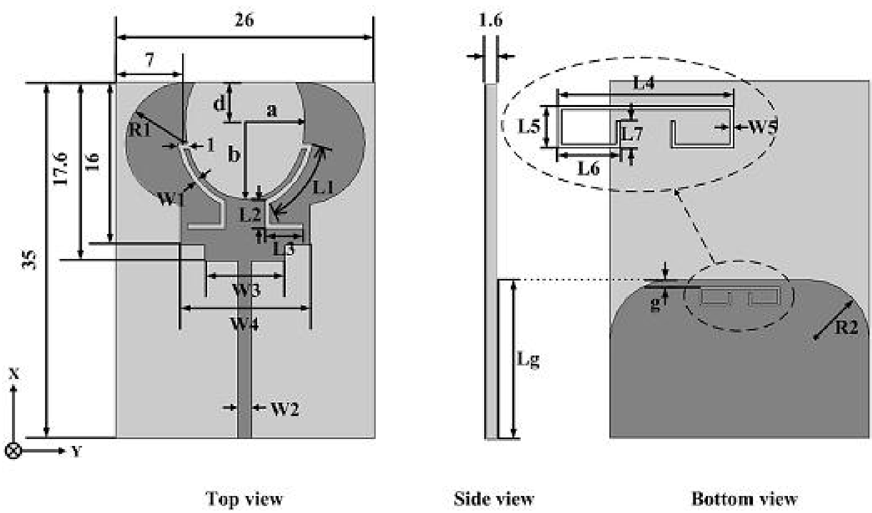


Figure 1. Geometry of the proposed UWB antenna. (unit: mm).

radiating patch, a rectangular step is used to adjust the impedance bandwidth over the UWB frequency band. Besides, the round-corner of the ground is also used for bandwidth enhancement. By analyzing the current distribution, it is found that the edge of the ground also contributes to the radiation. Thus the pincers-shaped radiation element and the ground plane form an equivalent dipole antenna. As depricted in Figure 1, a pair of flexuous slots is inserted on the radiation element, which produces a band-notched characteristic at 3.5 GHz. To generate another band-notched characteristic at 5.5 GHz, a C-shaped slot is embedded on the ground. The band-notched structure on the pincers-shaped radiating patch is: $L_1 = 7.6$ mm, $L_2 = 2.8$ mm, $L_3 = 3.8$ mm, and the width of the slots is 0.5 mm. Another band-notched structure on the ground is: $L_4 = 8$ mm, $L_5 = 1.8$ mm, $L_6 = 3.1$ mm, $L_7 = 1.2$ mm, and the width of the slots is 0.2 mm. $L_1 + L_2 + L_3$ and $L_4/2 + L_5 + L_6 + L_7$ are a quarter of the wavelength of the corresponding band-notching frequency. By adjusting the length of slots, dual band-notched characteristics at 3.5/5.5 GHz are achieved.

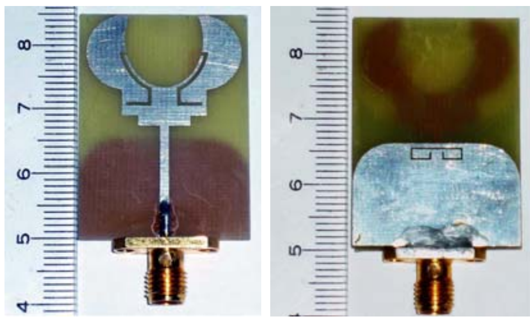
To verify the design, the proposed antenna is modeled, simulated and optimized by using a three-dimensional (3-D) EM-simulator, HFSS 11. The key structural parameters are discussed and optimized. By adjusting these structural parameters, good dual band-notched characteristics are obtained. The optimized dimensions for the proposed dual band-notched antenna are as follows: $L_1 = 7.6$ mm, $L_2 = 2.8$ mm, $L_3 = 3.8$ mm, $L_4 = 8$ mm, $L_5 = 1.8$ mm, $L_6 = 3.1$ mm, $L_7 = 1.2$ mm, $W_1 = 0.5$ mm, $W_2 = 1.4$ mm, $W_3 = 8$ mm, $W_4 = 13$ mm, $W_5 = 0.2$ mm, $a = 6$ mm, $b = 7.5$ mm, $d = 4$ mm, $R_1 = 6$ mm, $R_2 = 6$ mm, $L_g = 15.5$ mm, $g = 0.7$ mm, as shown in Figure 1.

3. RESULTS AND DISCUSSION

The proposed dual band-notched UWB antenna has been fabricated and measured. The photograph of fabricated antenna is shown in Figure 2.

Variations of VSWR with frequency for the proposed antennas are plotted in Figure 3. Owing to the configuration of the dual band-notched antenna, two new resonant modes are excited. As seen from the measured results, the proposed antenna meets VSWR (≤ 2) requirement through the UWB band with dual band rejection characteristics from 3.3 to 3.7 GHz and from 5.0 to 6.1 GHz, covering the bands WiMAX and WLAN. It is clearly seen that the simulated and measured results for the dual band-notched antenna are in good agreement. In Figure 4 and Figure 5, the central frequencies of 3.5 and 5.5 GHz stop-bands can be changed by the lengths of L_2 and L_6

respectively, while other parameters are fixed at the above optimized values. When $L_2 = 2.8\,\text{mm}$ and $L_6 = 3.1\,\text{mm}$, the central frequencies of the stop-bands are about 3.5 and 5.5 GHz. These changes indicate that the band-notched characteristics of the proposed antenna are easy to tune. To understand how these rejection bands are excited with the appearance of a C-shaped slot and a pair of flexuous slots, the current distribution at 3.5/5.5 GHz is simulated and depicted in Figure 6. In this figure, a half-wavelength current distribution along the perimeter of the slots was observed. Obviously, the current distributions at 3.5/5.5 GHz along the corresponding slots edge are on the x-axis



(a) Top view (b) Bottom view

Figure 2. Photograph of the fabricated dual band-notched antenna.

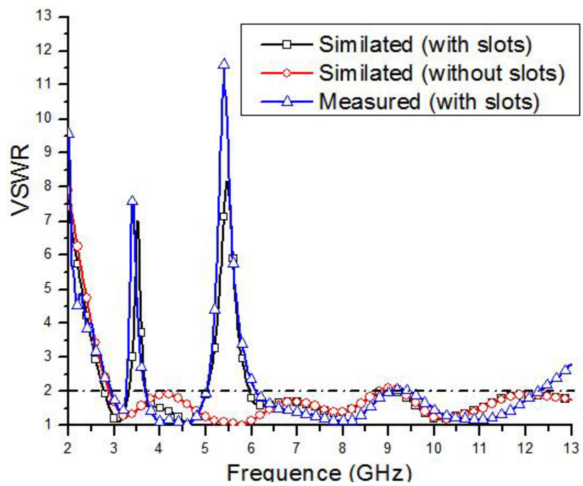


Figure 3. Variation of VSWR with frequency for the proposed antennas.

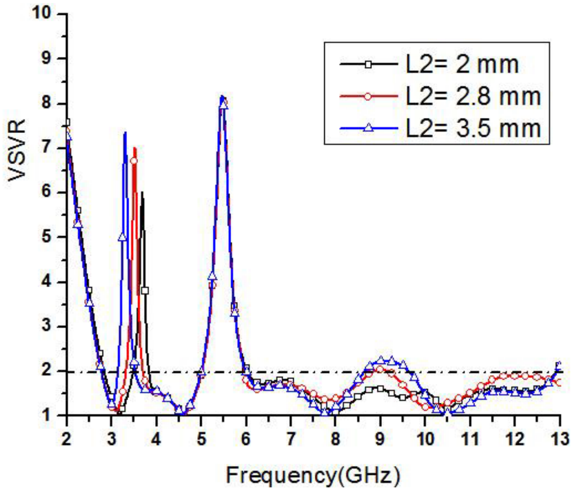


Figure 4. Simulated VSWR for antennas with various L_2.

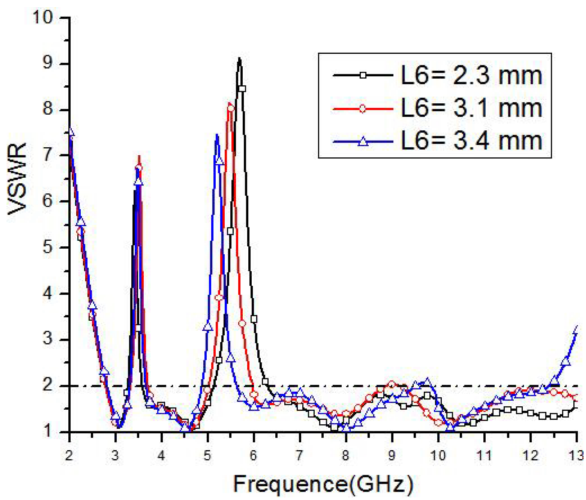


Figure 5. Simulated VSWR for antennas with various L_6.

symmetry and in opposite direction, which causes the band-rejection characteristics.

Antenna group delay is measured from 3 GHz to 11 GHz using a WILTRON37269A vector network analyzer. A pair of identical antennas with dual band-notched characteristics served as the

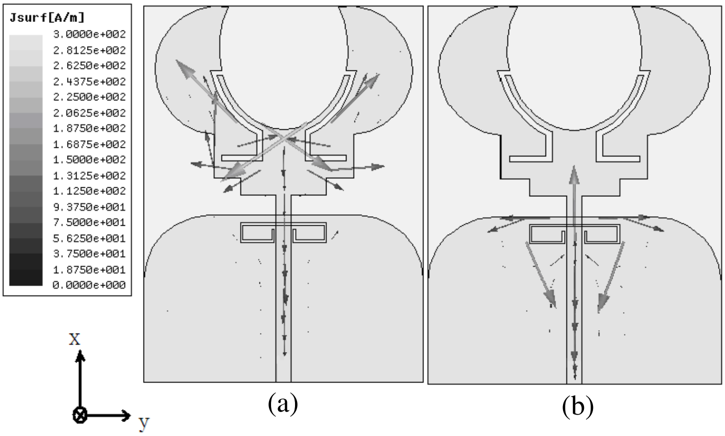


Figure 6. Calculated currents distribution: at (a) 3.5 GHz and (b) 5.5 GHz.

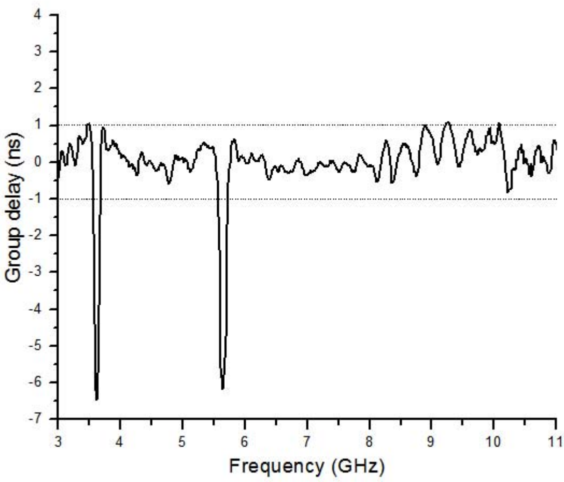


Figure 7. Measured results in the time domain for the proposed antenna.

transmitting and receiving antennas in the communication system. The antenna pair was mounted on the two ports of the analyzer and aligned face-to-face at a distance of 30 cm. As observed in Figure 7, the group delay fluctuates between −1 ns and 1 ns over a wide frequency range except for the notched bands. Dramatic variations in the notched

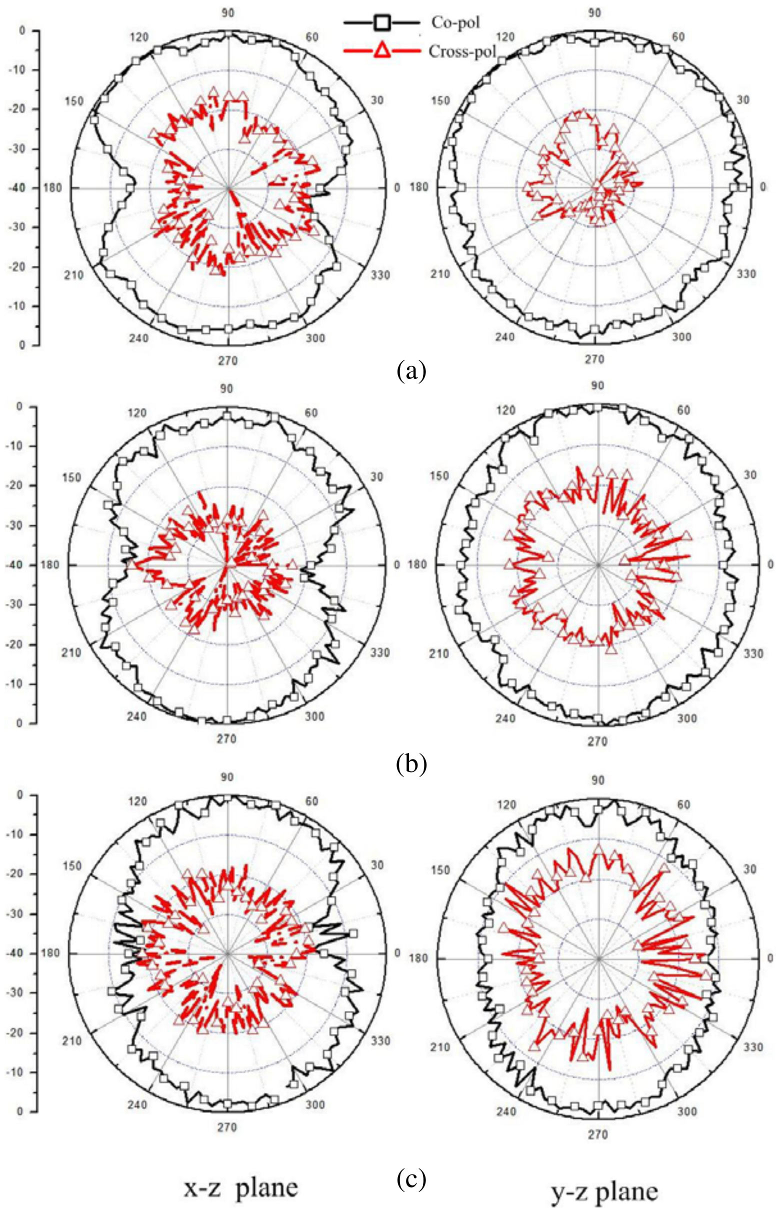


Figure 8. Measured radiation patterns of the dual band-notched antenna (a) At 3 GHz; (b) At 5 GHz; (c) At 7 GHz.

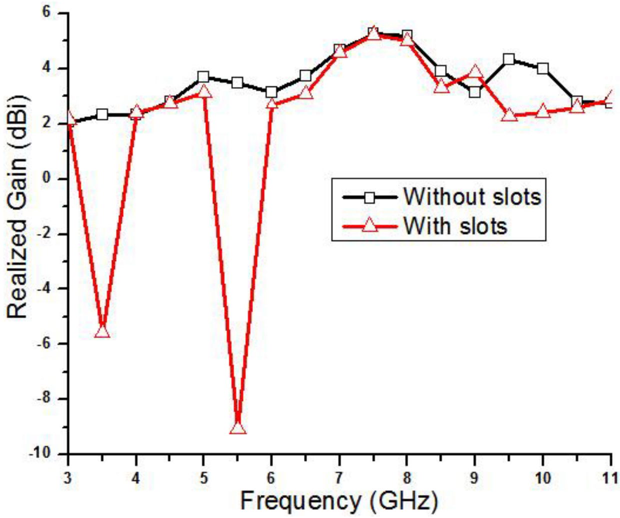


Figure 9. Measured gain against frequency of the proposed antennas.

bands are observed obviously. This can be attributed to the resonant behaviors of slots.

The radiation patterns of the dual band-notched antenna at 3 GHz, 5 GHz and 7 GHz are shown in Figure 8. From these curves, we can see that the antenna with dual band-notched characteristics gives quasi-omnidirectional radiation in the H-plane (y-z plane). Furthermore, Figure 9 shows the measured gain against frequency of the proposed antenna. The measured gain of the referenced antenna without slots ranges from 2 dBi to 5.2 dBi over UWB band. As depicted in the figure, gain decreases drastically to $-5.6/-9.1$ dBi at 3.5/5.5 GHz the central frequencies of notched bands, which demonstrates that band-notched function is good.

4. CONCLUSION

A printed monopole antenna with 3.5/5.5 GHz dual band-notched characteristics has been designed, fabricated and measured. The measured results confirm that the impedance bandwidth (VSWR ≤ 2) of the proposed antenna ranges from 2.9 to 12.3 GHz with dual notched bands at the central frequency of 3.5 GHz and 5.5 GHz, respectively, which covers the desired band $3.1 \sim 10.6$ GHz and eliminates the WiMAX and WLAN bands. In addition, the designed antenna has good omnidirectional radiation characteristics with stable gain. Therefore, the proposed antenna can be used for UWB application.

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