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A NOVEL COMPACT UWB ANTENNA WITH 3.5/5.2/ 5.8 GHZ TRIPLE BAND-NOTCHED CHARACTERISTICS

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Abstract—A novel compact fork-shaped ultrawideband (UWB) antenna with triple band-notched characteristics is proposed. By embedding a spade-shaped slot on the radiating patch as well as adding a separated strip and a C-shaped resonating structure on the front side of the reference UWB antenna, the triple notched frequency bands are realized. The measured impedance bandwidth defined by VSWR < 2 of 7.8 GHz (3–10.8 GHz), with the triple notched bands of 3.3–3.7 GHz, 5.15–5.4 GHz, and 5.7–5.9 GHz, are obtained. The proposed antenna with an overall dimension of only $24 \times 30\,\mathrm{mm}^2$ is successfully simulated, designed and measured, showing broadband matched impedance and stable radiation patterns.

1. INTRODUCTION

In recent years, design of ultra-wideband (UWB) antenna has received an increasing attention after the adoption of frequency band from 3.1 to 10.6 GHz for UWB applications by the Federal Communication Commission in 2002 [1]. However, there still exist several narrow bands for other communication systems over the designated frequency band, such as: The wireless local area network (WLAN) for IEEE802.11a operating at 5.15–5.35 and 5.725–5.825 GHz, IEEE802.16 WiMAX system operating at 3.3–3.7 GHz, which may cause severe electromagnetic interference to the UWB system [2–4]. Therefore, it is desirable to design UWB antennas with band-notched performance in those frequency bands to avoid potential interference. Subsequent

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studies have shown that a wide range of etched features can be used to achieve this effect, such as embedding U-shaped, C-shaped, and H-shaped slots on the patch or on the ground plane [5–7]. However, only one or two notched bands can be achieved by the antennas mentioned above. This reveals that potential interference from other narrow bands may still exist with such antennas. Moreover, among the designs of band-notched antennas rejecting the WLAN bands up to date, the entire 5–6 GHz frequency band has been completely rejected. Hence, any useful information contained in the frequency band of 5.35–5.725 GHz will also be lost, which results in the degradation of received information and thus shorter range of coverage and lower signal quality.

In this paper, a printed UWB antenna with triple band-notched characteristics is presented. By employing a spade-shaped slot on the radiation element as well as adding a C-shaped resonating structure and a separated strip on the front side, the triple band-notched characteristics are achieved. The spade-shaped slot on the radiation element deals with the 3.3–3.7 GHz notched band while the separated strip and the C-shaped resonating structure on the front side aim at the 5.15–5.4 GHz and 5.7–5.9 GHz notched bands. Good agreement between simulated and measured results is obtained. Details of antenna design and results are given below.

2. ANTENNA DESIGN

Figure 1 shows the geometry and configuration of the proposed antenna, which is printed on a substrate with size of $24\times30\,\text{mm}^2$, thickness of 1 mm, and relative permittivity of 4.6. The antenna is fed by a 50-Ω microstrip line. By using the fork-shaped patch, broadband impedance bandwidth can be easily achieved based on the gradual change structure of the radiation patch. In order to achieve good band-notched characteristic, the spade-shaped slot, the C-shaped resonating structure, and the separated strip are adopted in the reference UWB antenna as shown in Figure 1.

The electromagnetic software Ansoft HFSS is employed to perform the design and optimization process. Finally, the dimensions of the proposed antenna are chosen to be $L_1 = 9\,\text{mm}$, $L_2 = 7.7\,\text{mm}$, $L_3 = 0.5\,\text{mm}$, $L_4 = 0.3\,\text{mm}$, $L_5 = 3.5\,\text{mm}$, $L_6 = 15\,\text{mm}$, $L_7 = 15.1\,\text{mm}$, $L_8 = 3\,\text{mm}$, $L_9 = 30\,\text{mm}$, $L_{10} = 9.45\,\text{mm}$, $L_{11} = 16\,\text{mm}$, $L_{12} = 14.3\,\text{mm}$, $L_{13} = 13.74\,\text{mm}$, $W_1 = 1.5\,\text{mm}$, $W_2 = 9.4\,\text{mm}$, $W_3 = 0.3\,\text{mm}$, $W_4 = 2\,\text{mm}$, $W_5 = 6\,\text{mm}$, $W_6 = 24\,\text{mm}$, $W_7 = 1.84\,\text{mm}$, $W_8 = 6.2\,\text{mm}$, $W_9 = 10\,\text{mm}$, $W_{10} = 0.48\,\text{mm}$, and $W_{11} = 1.5\,\text{mm}$. The photograph of manufactured triple band-notched antenna is shown in Figure 2.

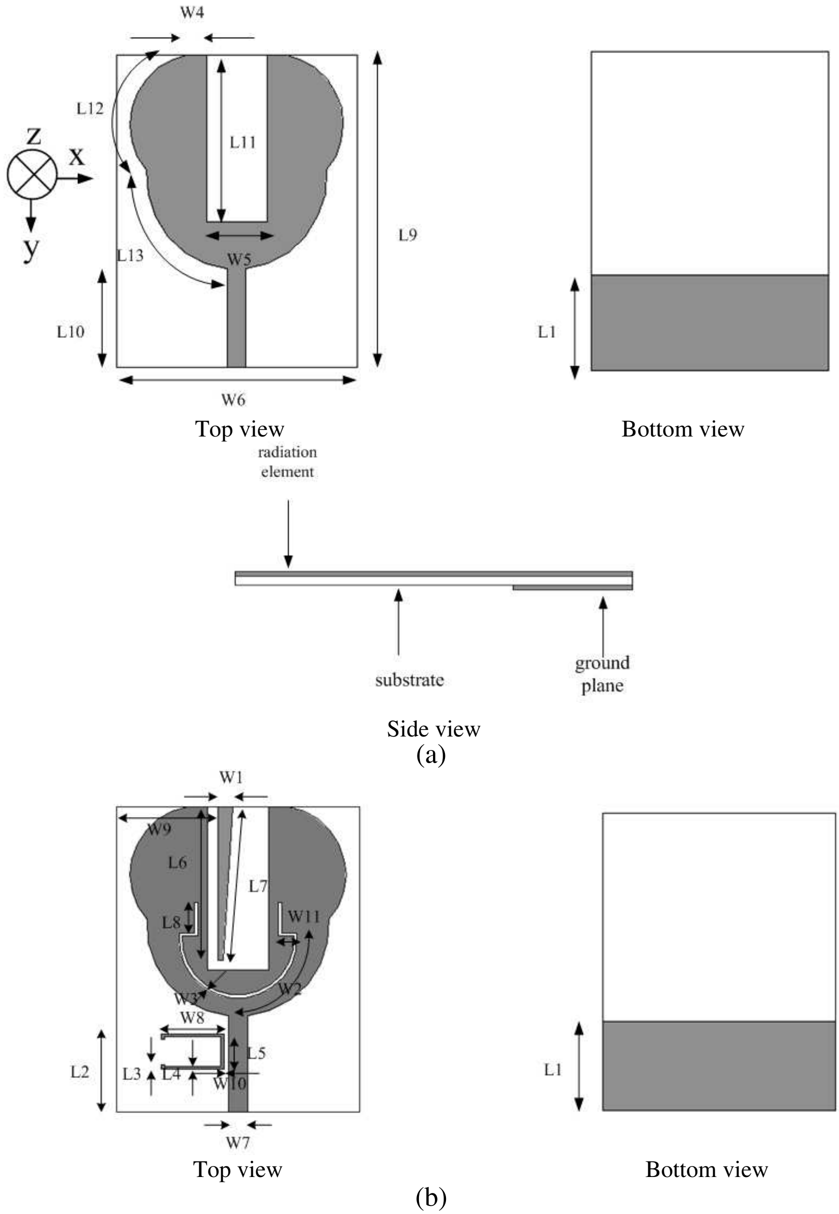


Figure 1. Configuration of the antenna. (a) UWB antenna, (b) band-notched antenna.

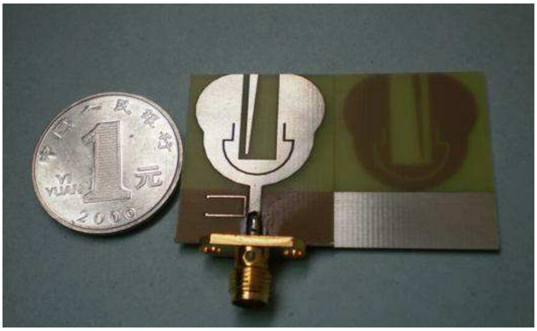


Figure 2. Photograph of the manufactured triple band-notched antenna.

3. RESULTS AND DISCUSSIONS

The measurement of VSWR was carried out with a network analyzer Agilent N5230A (10 MHz–50 GHz). Figure 3 provides an illustration for the triple band-notched characteristics of the band-notched antenna. Results of the reference antenna without notched characteristics are also shown for comparison. It is seen that the band-notched antenna exhibits three notched bands of 3.3–3.7 GHz, 5.15–5.4 GHz, and 5.7–5.9 GHz while maintaining wideband performance from 3 to 10.8 GHz for VSWR < 2, and covering the entire UWB frequency band. It also can be seen that the measured VSWR reasonably agrees with the simulated results with an acceptable frequency discrepancy, which may be due to the difference between the simulated and measured environments. Figure 4 exhibits the effect of the various lengths of the spade-shaped slot on the VSWR versus frequency. It is clearly seen from the figure that the length of the spade-shaped slot has a significant effect on the rejected frequency. That is, the frequency shift from around 3.25 GHz to 3.75 GHz corresponds to the length from 30.8 mm to 26.8 mm, since the rejected frequency can be approximately assumed as

$$f_{notch} = \frac{c}{2L \cdot \sqrt{\varepsilon_{eff}}}$$

$$\varepsilon_{eff} \approx \frac{\varepsilon_r + 1}{2}$$

where L is the length of the spade-shaped slot, f_{notch} is the first notch frequency, ε_{eff} is the effective dielectric constant, and c is the speed of light [8], it is also observed that the various lengths of the spade-shaped slot has little effect on the 5.15–5.4 GHz and 5.7–5.9 GHz notched bands. We further see that the antenna performance in the operating band is less sensitive as the stopband varies, so that good radiation performance of the antenna can be maintained.

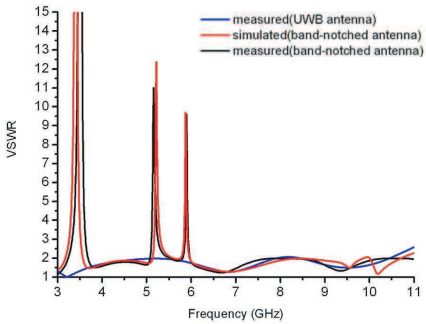


Figure 3. Simulated and measured VSWR of the triple band-notched antenna.

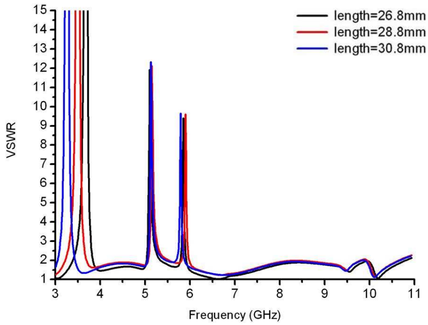
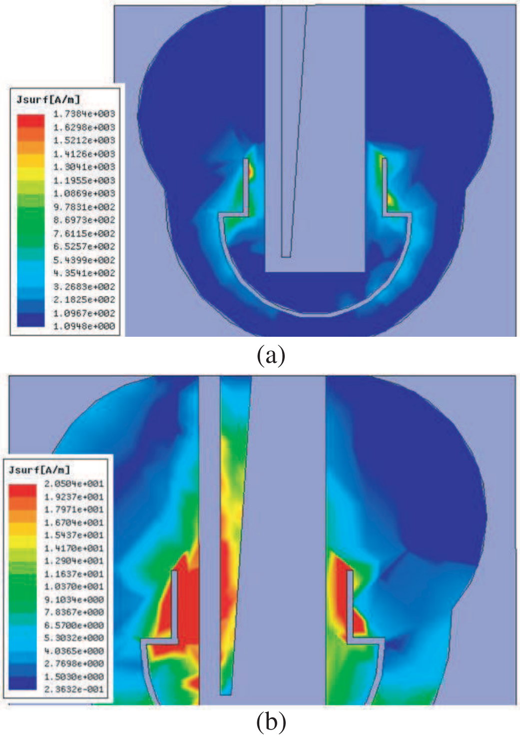
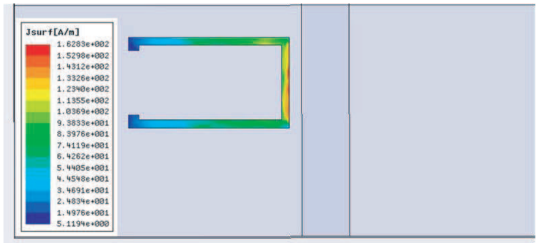


Figure 4. Simulated VSWR characteristics for the length of the spade-shaped slot.



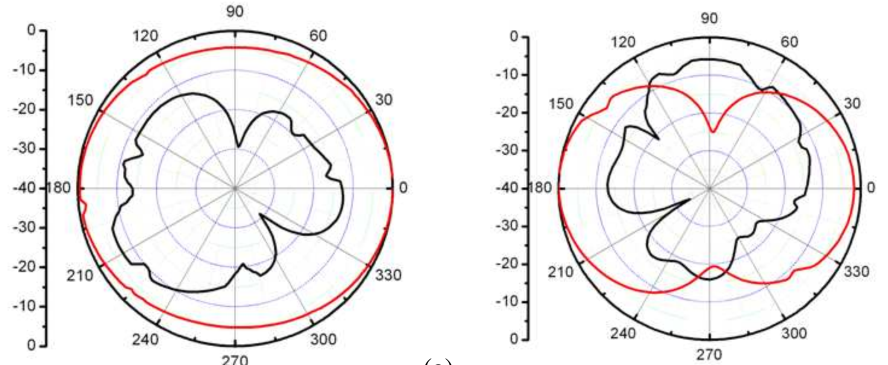


(c)

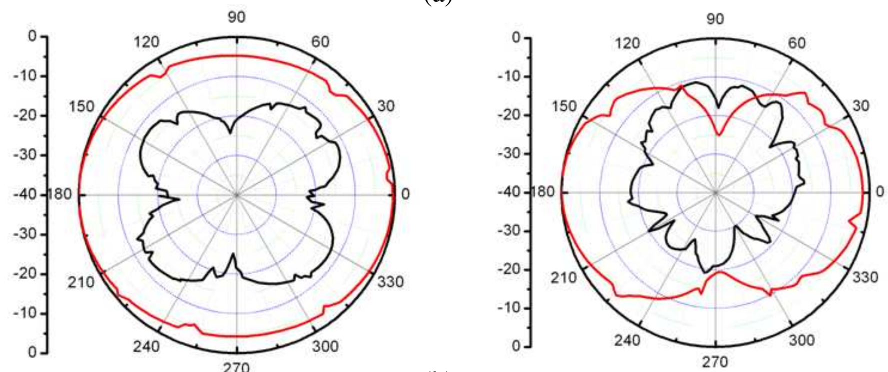
Figure 5. Surface current distributions of the three resonating structures. (a) The spade-shaped slot, (b) the separated strip, (c) the C-shaped resonating structure.

Figure 5(a) shows the surface current distribution of the spade-shaped slot on the radiation element at the first notch frequency (3.5 GHz).With the increase of the distance away from the feeding point, stronger current is found. Actually, the current is the strongest at the top of the spade-shaped slot as shown in Figure 5(a). The spade-shaped slot works as a half wavelength transformer, which transforms nearly zero impedance (short circuit) at the top of the spade-shaped slot to the high impedance (open circuit) at the feeding point. The high impedance at the feeding point leads to the desired impedance mismatching at the first notch frequency (3.5 GHz). Figure 5(b) exhibits the surface current distribution of the separated strip on the front side at the second notch frequency (5.2 GHz). Basically, the length and width of the separated strip act as the inductance, and the space between the strip and the main radiator acts as the capacitance. The couplings between the strip and the main radiator act as the stop filter at the second frequency (5.2 GHz). Figure 5(c) reveals the surface current distribution of a C-shaped resonating structure on the front side at the third notch frequency (5.8 GHz). Moreover, the current approaches zero at the both ends of the C-shaped resonating structure, whereas there is stronger current at its middle. The impedance at its middle is nearly zero, leading to the desired impedance mismatching near the notch frequency at 5.8 GHz.

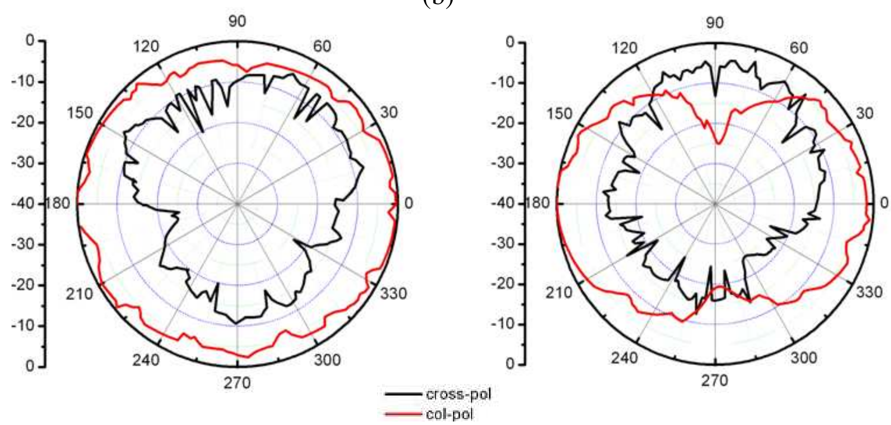
The radiation patterns for 3.1 GHz, 4.8 GHz, and 8 GHz are shown in Figure 6. It can be seen that the antenna exhibits a nearly omnidirectional radiation pattern in the H-plane and a dipole-like radiation pattern in the E-plane. As shown in Figure 7, sharp gain decreases occur in 3.3–3.7 GHz, 5.15–5.4 GHz, and 5.7 GHz–5.9 GHz bands. Figure 8 reveals the measured pass loss and group delay by using two identical fabricated prototypes for the proposed



(a)



(b)



(c)

Figure 6. Measured *E* plane (right) and *H* plane (left) radiation patterns of the proposed antenna. (a) 3.1 GHz, (b) 4.8 GHz, (c) 8 GHz.

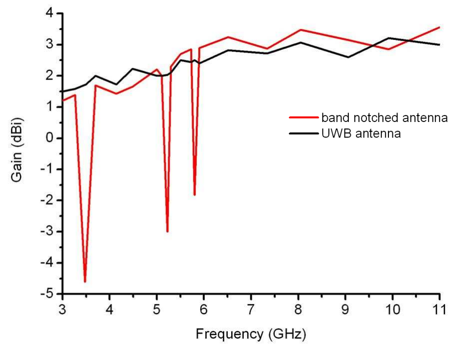


Figure 7. Measured peak gains of the antennas.

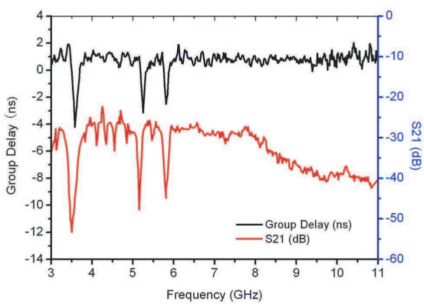


Figure 8. Measured group delay and pass loss for the proposed antenna.

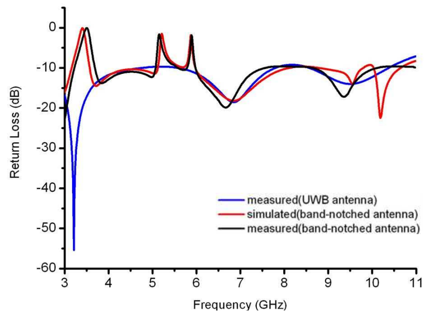


Figure 9. Simulated and measured return loss of the triple band-notched antenna.

antenna with a distance of 35 cm. As shown, significant reduction in magnitude has been obtained in the notched frequency bands. Besides, nearly constant group delay and stable magnitude variation across the operating band can be achieved as well. Figure 9 illustrates the simulated and measured return losses of the band-notched antenna and the reference antenna without notched characteristics. Fairly good agreements between the simulations and measurements have been achieved. As observed, the measured impedance bandwidth with -10 dB return loss for the proposed antenna is from 3 to 10.8 GHz, rejecting the frequency bands of 3.3–3.7 GHz, 5.15–5.4 GHz, and 5.7–5.9 GHz. All of these results indicate that the proposed antenna has good band-notched characteristics and effectively minimizes the potential interferences between UWB system and narrowband wireless systems.

4. CONCLUSION

A novel compact UWB antenna with triple band-notched characteristics at WiMAX/WLAN frequencies has been proposed and discussed. Three different resonating structures are introduced to achieve band-notched characteristics at 3.3–3.7 GHz, 5.15–5.4 GHz, and 5.7–5.9 GHz bands. The measured results of the fabricated antenna show good agreement with the simulated ones. Specially, measured results show that the intermediate frequency range between 5.4–5.7 GHz can be utilized with our proposed antenna, which is rejected by other WLAN band-notched antennas. Accordingly, the proposed antenna is well suitable for integration into UWB portable devices.

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