LETTER

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Compact UWB antenna with dual band-notches for WLAN and WiMAX applications

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Abstract: A compact planar ultra-wideband (UWB) antenna with dual band-notches characteristics is presented. The proposed antenna utilizes a T-shaped stub on the radiating patch and U-shaped slot on ground to generate two notched bands at 3.5 and 5.5 GHz with little effect on the radiation patterns. Under this circumstance, the antenna not only exhibits a wide operational frequency band from 3 to over 12 GHz with good rejection of interference to WiMAX and WLAN bands, but also performs an effective manage function owing to two controllable notched bands by tuning the structures of the T-shaped stub and U-shaped slot independently. For verification, the proposed antenna is fabricated and measured. Good agreement between measured and simulated results is observed.

Keywords: UWB, planar antenna, band-notched, WLAN, WiMAX

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

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1 Introduction

Since the Federal Communication Commission (FCC) released the bandwidth 3.1–10.6 GHz for ultra-wideband (UWB) systems in 2002, UWB technology has attracted much interest. As an essential component of UWB communication system, UWB antenna has received increasing attentions. Planar monopole antennas have been found as good candidates for compact UWB applications due to their attractive merits, such as low cost, low profile, ease of fabrication, easy integration with other RF

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circuits, and acceptable radiation properties.

In the design of UWB antennas, there are still facing many challenges, such as stable gain, good omnidirectional radiation pattern, small size and electromagnetic interference (EMI). Among them, EMI is an important issue [1]. In the allocated UWB band, there coexist with other wireless narrowband standards, such as IEEE 802.16 (WiMAX) system in the frequency band of 3.3–3.7 GHz and the IEEE 802.11a WLAN system operating in the lower frequency band from 5.15 to 5.35 GHz and in the higher frequency band from 5.725 to 5.825 GHz. As a result, UWB antennas with band-notched performance in those frequency bands are essential to alleviate potential interference. Various techniques have been proposed to implement the band-notched characteristic for UWB antennas [2, 3, 4, 5]. An UWB antenna with U-shaped slot etched on the radiator is presented in [2]. The antenna has a small size of 15 mm × 18 mm. However, it aims at creating a single-notched band and fails to reject the WiMAX band. A simple antenna performs dual notched bands has been reported in [3]. The antenna consists of a pair of arc-shaped strips near the patch and a pair of two slots in the ground plane to obtain the dual band-notch characteristics. Although the antenna exhibits the characteristics of omnidirectional pattern and high dual-band rejection, it still has a shortage of large size. In [4], a compact antenna with two notched bands has been realized, yet it occupies too much of a wide notch-band width with notch frequency around 3.5 GHz, and then the useful frequencies are wasted. A dual band-notched antenna in [5] is achieved by etching two U-shaped slots in its patch. Nevertheless strong coupling between the two adjacent U-shaped slots makes it difficult to tune the two stopbands.

In this letter, a compact planar UWB antenna with dual notched bands is presented and investigated. The antenna consists of a T-shaped stub on the radiating patch and U-shaped slot on ground to achieve two notched bands for WLAN and WiMAX band rejection, each of which can be controlled independently and conveniently. The measured results show that the antenna has an operating frequency range from 3 to over 12 GHz with VSWR$\leq$2, and two controllable band-notches at 3.5 and 5.5 GHz, respectively. Details of antenna design, simulation, and measurement are presented to validate the performances of the proposed antenna.

2 Antenna analysis and design

The geometrical configurations of the proposed antenna are shown in Fig. 1. The antenna is designed on a FR4 substrate, with the permittivity constant of 4.4, a thickness of 1.5 mm and a loss tangent of 0.02. The antenna is fed by 50-Ω microstrip line whose width is 2.45 mm. The total size of the antenna including the ground plane is only 25 × 30 mm^2. In order to achieve good impedance matching, a square notch with a size of 4 mm by 3 mm on the ground is adopted. The distance between the patch and ground plane, namely, gap, is also critical for impedance matching and has been optimized to be 0.8 mm.

To achieve dual notched bands, a T-shaped stub on the radiating patch and a U type slot on the ground under the feed line are adopted to generate two notched bands with central frequencies of 3.5 and 5.5 GHz, respectively. To ensure the center frequency of the upper notched band, the

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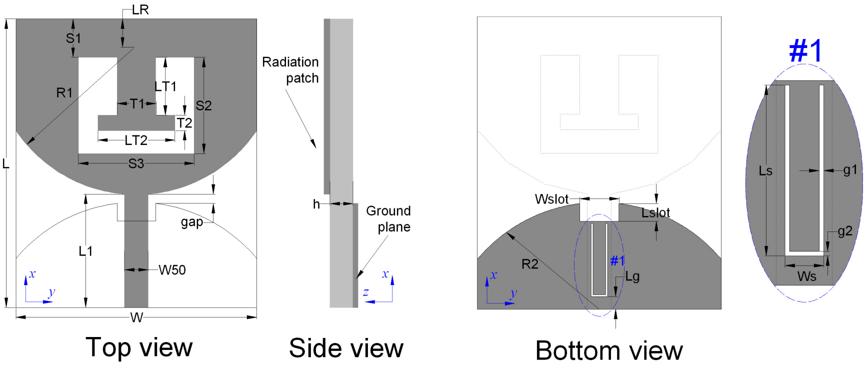

Fig. 1. Geometries of the proposed antenna: (a) top and side views and (b) bottom view.

length of the U-shaped slot can be estimated by empirical formula:

$$L = \frac{c}{f_{notch}\sqrt{\varepsilon_{eff}}} \tag{1}$$

Where

$$\varepsilon_{eff} = \frac{\varepsilon_r}{2} \tag{2}$$

L is the total length of U-shaped slot, f_{notch} is the center frequency of the notched band, c is the speed of light in the vacuum, and ε_r is the permittivity of substrate.

The optimized dimensions of the antenna with dual notched bands at WiMAX (3.5 GHz) and WLAN (5.5 GHz) as follows: W=25 mm, L=30 mm, L1=10.5 mm, R1=15.06 mm, LR=3.2 mm, S1=4 mm, S2=10 mm, S3=12 mm, W2=2.45 mm, W3=12 mm, W4=16 mm, T1=4 mm, LT1=6 mm, T2=1.6 mm, LT2=8 mm, R2=16.3 mm, Ls=7.5 mm, Ws=1.7 mm, g1=g2=0.2 mm. The comparisons of simulated VSWR between the proposed antenna and the original one are shown in Fig. 2. It can be seen that the original antenna has an impedance bandwidth (VSWR≤2) from 3 to more than 12 GHz. Compared with the original antenna, the proposed UWB antenna with two effective notched bands of WiMAX around 3.5 GHz and WLAN in the frequency band of 5.0 – 5.8 GHz.

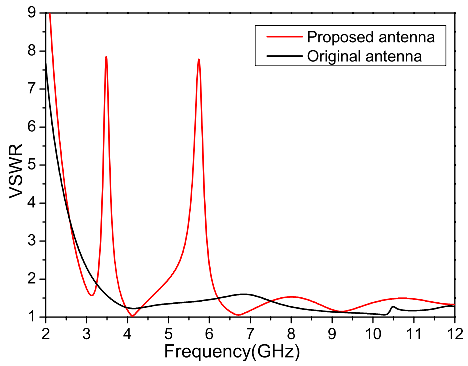

Fig. 2. Simulated VSWR of the proposed antenna and the original one without band-notched.

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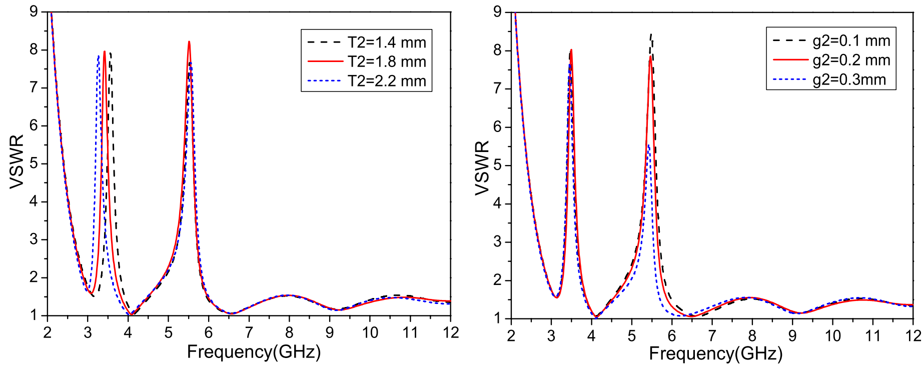
To better understand how different dimensions of the T-shaped stub and the U type slot affected the notched-bands; some parametric studies are carried out using computer simulation. Note that, when one parameter is changed, the others are fixed. For simplicity, two parameters (T2, g2) of the proposed antenna are studied as shown in Fig. 3. The first notch band is mainly decided by the dimension of T-shaped stub. It can be seen that the resonant frequency of the first notch can be tuned by T2. As can be seen in Fig. 3 (a), the center frequency of the first notched band decreases as the value of T2 increases. Fig. 3 (b) shows the bandwidth of the second notched band can be adjusted easily by varying the values of g2. The results of the parametric study indicated that the notch frequency and bandwidth of the proposed antenna could be individually set using the dimensions of the T-shaped stub and the U type slot. It is observed that the two notched bands can be controlled independently and conveniently. Therefore, we can design the notch at the desired frequency with the desired bandwidth.



(a) (b)

Fig. 3. Simulated VSWR with different values of (a) T2 and (b) g2.

3 Experimental results and discussions

To validate the simulated result shown in Fig. 2, the presented antenna has been fabricated on a FR4 substrate. The simulated and measured VSWR of the proposed dual band-notched UWB antenna are also displayed in Fig. 4. The results clearly show that the present UWB antenna with dual effective notched bands of WiMAX in the frequency band of 3.26 to 3.78 GHz and WLAN around 5.5 GHz. It can be seen that a good agreement is reached except a little deviations of second notch between the simulated and measured results. This is mainly caused by bad weld error, which makes the jaws fill in the U-shaped slot. In addition, the fabrication tolerances, and dielectric loss of the substrate, will also result in the discrepancy in the simulated and measured VSWR.

Fig. 5 illustrates the simulation surface current distributions at two center notched bands. When the antenna is working at the center of first notched band around 3.5 GHz, most of the current distributions flow along U type slot, which implies that it resonates near 3.5 GHz, thus energy cannot be radiated effectively and formed a notched band at 5.5 GHz. The situations at 5.5 GHz can be similarly analyzed, and the current distribution is shown in Fig. 5 (b). Fig. 6 exhibits the measured far-field radiation

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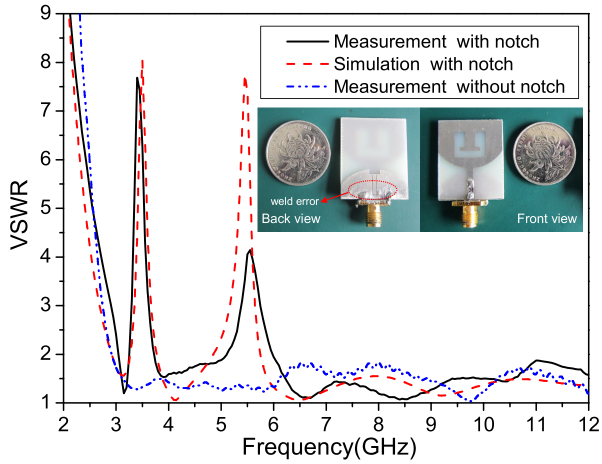

Fig. 4. Measured and simulated VSWR of the proposed antenna.

patterns of E-plane (x-z plane) and H-plane (x-y plane) at 3 GHz, 6 GHz and 9 GHz, respectively. It is noted that the radiation patterns are almost omnidirectional in H-plane and similar to monopole antenna in E-plane. The measured peak gain of the proposed antenna is shown in Fig. 7 (a). It is observed that the transfer gain remain flat on the operating band, except drastically decreases in each notched band due to the band-notched characteristics. Finally, the group delay of proposed antenna has also been measured. The result is shown in Fig. 7 (b). In the experiment, the distance between the two antennas is 30 cm (face to face). The group delay is about 1.0 ns across the frequency band except in the notched bands, due to the band-notched function. For the rest of the frequency band, the group delay characteristic is relatively flat, indicating that the antenna has good linear transmission performances.

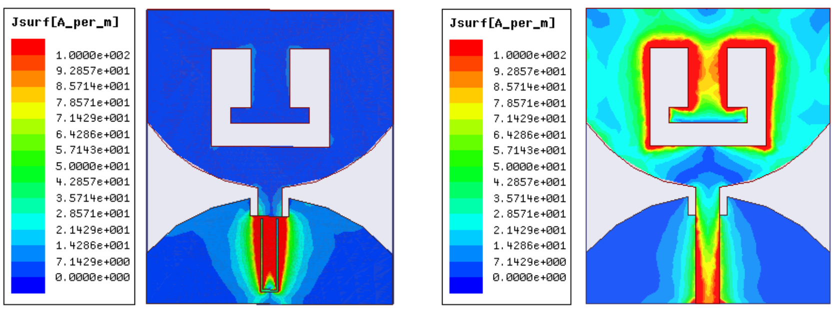

Fig. 5. Surface current distribution at (a) 3.5 GHz and (b) 5.5 GHz.

4 Conclusion

A compact UWB antenna with WiMAX and WLAN band-notched is proposed. By introducing a T-shaped stub and a U-shaped slot, the proposed antenna can obtain two notched bands at 3.5 and 5.5 GHz which can be tuned independently and conveniently. Meanwhile, the antenna exhibits a wide operational bandwidth from 3 to over 12 GHz. Further-

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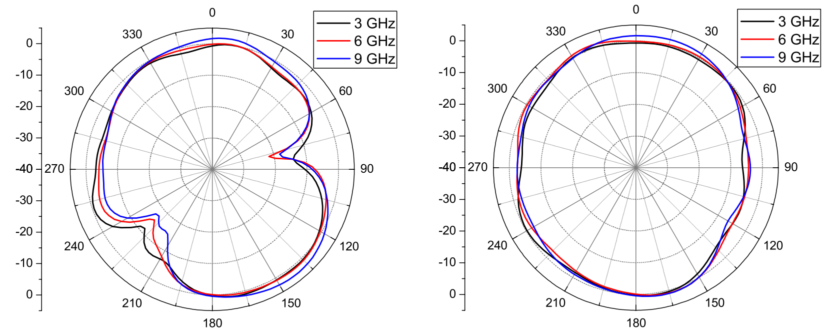
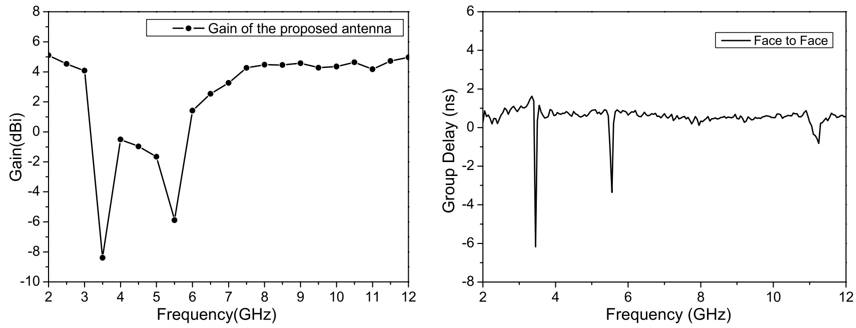


(a) (b)

Fig. 6. Measured radiation patterns of (a) E-plane and (b) H-plane.



(a) (b)

Fig. 7. (a) Measured gain and (b) group delay of the proposed antenna.

more, the radiation pattern of this antenna shows good omnidirectional performance and stable gain in the operating band, which makes it suitable for UWB application.

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