ELectronics EXpress

LETTER

IEICE Electronics Express, Vol.10, No.5, 1–6

A dual band-notched UWB antenna with hook-shaped slots and folded stubs

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Abstract: A novel planar antenna with WiMAX and WLAN band-notched characteristics is presented for ultra-wideband (UWB) applications. The UWB antenna consists of a staircase-shaped radiating element, a microstrip feedline and a modified ground plane. To realize WiMAX band-notched characteristic, a pair of hook-shaped slots is etched on the radiating element. Two folded stubs extending from the ground plane are used to reject the WLAN band for the first time. The antenna meets a bandwidth from 2.95 to 11.6 GHz, with two notched-bands of 3.25–3.95 GHz (WiMAX) and 5.00–6.50 GHz (WLAN), respectively. Measured and simulated results of the impedance bandwidth, gain, and radiation patterns are presented and discussed.

Keywords: band-notched, UWB antenna, hook-shaped slot, folded stub

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

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DOI: 10.1587/elex.10.20130020
Received January 10, 2013
Accepted January 31, 2013
Published March 05, 2013

ELectronics EXpress

1 Introduction

UWB antennas have attracted much attention due to their advantages of simple structure, low cost, ease of fabrication and easy integration with monolithic microwave integrated circuits (MMICs). On the other hand, there are several existing communication systems in the UWB band, such as worldwide interoperability for microwave access (WiMAX) system operating at 3.4–3.69 GHz and wireless local area network (WLAN) system covering the 5.15–5.35 GHz and 5.725–5.825 GHz, which may cause potential electromagnetic (EM) interference to the UWB system. Therefore, it is necessary to design a UWB antenna with WiMAX and WLAN band-notched characteristics.

In recent years, various antennas with notched bands have been presented [1, 2, 3, 4]. In [1], a WiMAX band-notched antenna with U-shaped slot etched on the radiator is presented. The antenna has a small size of 12 mm × 18 mm. However, it only has a single notched band. Dual notched bands antennas have been reported in [2, 3]. In these designs, by protruding T-shaped strips inside the square-ring radiating patch [2] or inserting modified split ring resonator (SRR) on the radiating element [3], two notched bands have been realized. Nevertheless the antennas have the common deficiency of large size. In [4], by inserting shorted quarter-wavelength resonator strips which are connected to the ground plane via holes, the antenna achieves two notched bands with limited size. It is a pity that the antenna has a low rejection level at the notched bands (less than −3 dB). This means that more than half of the EM energy is radiated out.

In this letter, a novel planar UWB antenna with WiMAX and WLAN band-notched characteristics is proposed. The staircase-shaped radiating element and the modified ground plane are inserted to increase the bandwidth. To achieve the WiMAX band-notched function, a pair of hook-shaped slots is etched on the radiating element. Two folded stubs which are connected to the opposite ground via rectangular patch are inserted to realize the WLAN band-notched characteristic. The surface currents through the stubs are strong enough to obtain high rejection level in the notched bands, which is more than −2.5 dB. Details of the antenna design, simulated and measured results are presented and discussed as follow.

2 Antenna configuration

Fig. 1 shows the configuration and parameters of the proposed antenna, which is printed on a 16 mm × 32 mm FR4 substrate with thickness 0.8 mm, permittivity 4.4, and loss tangent 0.02. The proposed antenna is symmetric about its centerline. The commercial simulation software High Frequency Structure Simulator (HFSS) is used to investigate the designed antenna. The optimal dimensions of the proposed antenna are as follow: h1 = 11 mm, h2 = 12 mm, h3 = 1 mm, h4 = 3 mm, h5 = 12 mm, h6 = 1.8 mm, h7 = 2 mm, w1 = 1.5 mm, w2 = 3 mm, w3 = 6.5 mm, w4 = 1.8 mm, w5 = 1.5 mm, w6 = 1.8 mm, w7 = 3 mm, g1 = 0.2 mm, g2 = 1.3 mm, g3 = 0.6 mm, g4 = 2.3 mm, g5 = 1.5 mm,

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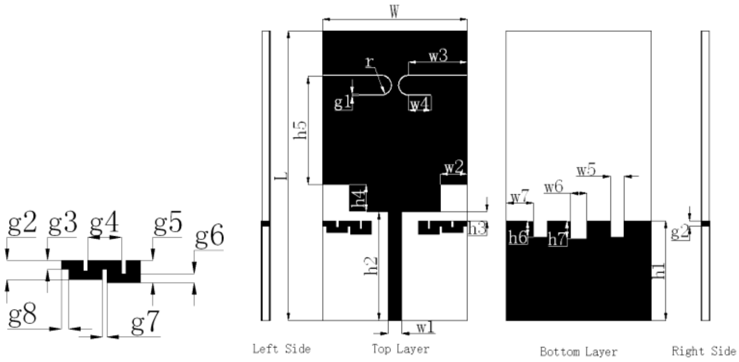

Fig. 1. Configuration and parameters of proposed antenna.

g6 = 0.6 mm, g7 = 0.3 mm, g8 = 0.5 mm and r = 1 mm.

3 Antenna design and results

3.1 Full-band antenna

The basic antenna consists of a rectangular radiating patch and a ground plane. In order to achieve 50 Ω impedance characteristic, the width of feed-line (w1) is chosen as 1.5 mm. By introducing a staircase-shaped structure and etching three rectangular slots on the ground plane, the impedance bandwidth is greatly increased. The simulated return loss of the basic antenna and modified antenna is plotted in Fig. 2. It is clearly seen that the enhancement of bandwidth is due to the additional resonance exciting at 9.1 GHz.

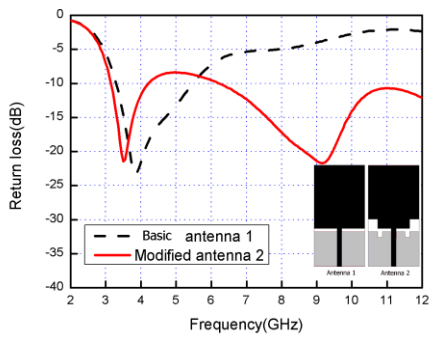

Fig. 2. Simulated return loss of the basic and modified UWB antenna.

3.2 Single band-notched antenna

According to the previous work, band-notched characteristic can be obtained if the slot is etched on the right position. The length of the slot can be calculated by:

$$l = \frac{c}{4f_{center} \cdot \sqrt{\varepsilon_{eff}}} \tag{1}$$

where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} \tag{2}$$

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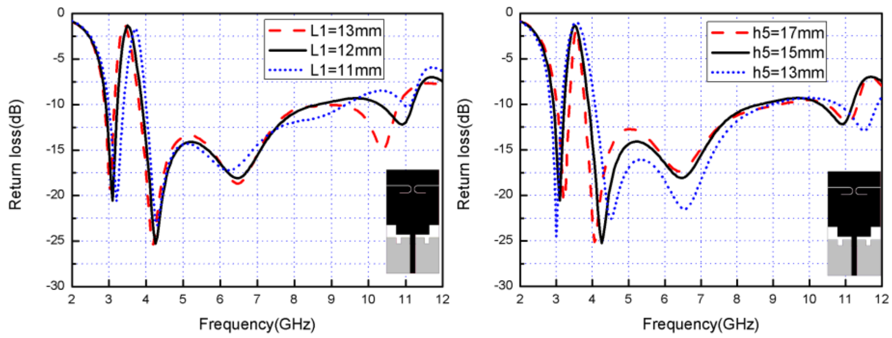
f_{center} is the center frequency of the rejected band, ε_{eff} is the effective dielectric constant, and c is speed of the light. Equation (1) can be used to predict the length of the slot.

To make the WiMAX (3.4–3.69 GHz) band notched, a pair of hook-shaped slots are etched on the radiating element. The center frequency (3.5 GHz) is determined by the total length of the slot L1 (L1 = w3 + w4 + pi * r). In this structure, at the rejected band, the surface currents concentrated on the edges of the interior and exterior of the hook-shaped slots are oppositely directed. As a result, the resultant radiation fields cancel out, and high attenuation near the rejected frequency is produced [5].

Fig. 3 (1) shows the return loss of the single-notched antenna for different value of L1. By adjusting the total length of the slot, the center frequency of the rejected band is tunable. The height of the hook-shaped slots (h5) is also an important parameter to shift the bandwidth of the notched band. As shown in Fig. 3 (2), by increasing the height of h5, the bandwidth of the notched band is decreased from 0.93 GHz to 0.42 GHz.



(1) (2)

Fig. 3. Simulated return loss of single-notched antenna with different L1 (1) and h5 (2).

3.3 Dual band-notched antenna

To achieve the second notched band, two folded stubs are connected to the opposite ground via rectangular patches which are printed on the side of the substrate. Equation (1) can predict the length of the stubs. The configuration is shown in Fig. 1. In the proposed structure, at the notched frequency, the surface currents concentrated on the folded stubs and the opposite ground plane are oppositely directed. As a result, the resultant radiation fields cancel out and high attenuation near the rejected frequency is achieved [4].

Fig. 4 (1) shows the return loss of the dual band-notched antenna for different value of L2 (L2 = 2 * g3 + 2 * g4 + 3 * g6). By adjusting the total length of the stub from 7 mm to 6 mm, the center frequency of the rejected band is shift from 5.1 GHz to 5.7 GHz. In order to better understand the antenna behavior, the simulated surface current distribution is shown in Fig. 4 (2). As it can be seen in Fig. 4 (2) (a), the current density is concen-

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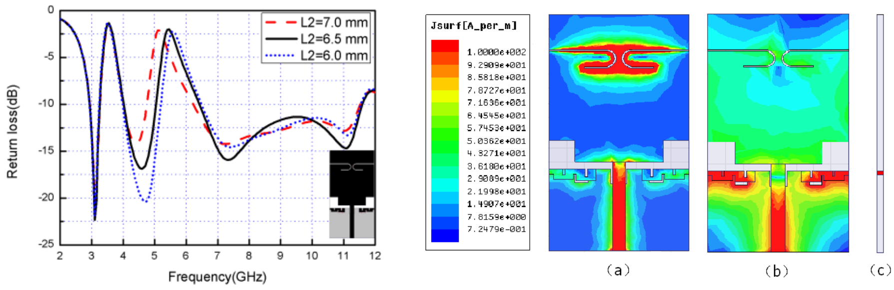


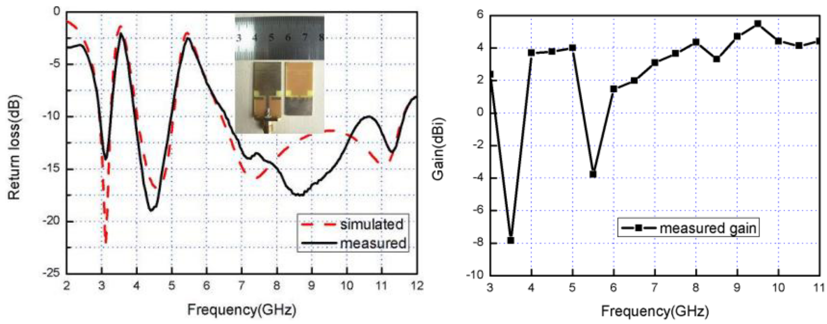
(1) (2)

Fig. 4. (1) Simulated return loss of double-notched antenna with different L2, (2) Simulated surface current distribution of the proposed antenna at (a) 3.5 GHz, (b) 5.5 GHz, (c) 5.5 GHz (side view).

trated around the pair of hook-shaped slots at 3.5 GHz while in Fig. 4 (2) (b) concentration exists over the two folded stubs at 5.5 GHz.

3.4 Experimental results

To demonstrate the above discussions, an antenna prototype is fabricated, as shown in Fig. 5 (1). An Agilent vector network analyzer (VNA) E8363B is used to measure performance of the proposed antenna. Fig. 5 (1) shows the simulated and measured return loss of the dual band-notched antenna. The result indicates that a good agreement between the simulations and the measurements is achieved though a little discrepancy in the high frequency. The probably reason is the unstable characteristics of FR4 in the high frequency. The designed antenna has a bandwidth from 2.95 to 11.6 GHz defined by return loss ≤ -10 dB with two dual notched bands of 3.25–3.95 GHz (WiMAX band) and 5.00–6.50 GHz (WLAN band), respectively. The antenna has a high rejection level in the rejected bands, which is more than -2.5 dB.



(1) (2)

Fig. 5. (1) Simulated and measured return loss of proposed antenna, (2) Measured gains of the proposed antenna.

The measured radiation patterns including the co-polarization and cross-polarization in the E-plane (xz-plane) and the H-plane (yz-plane) at 3, 6.5 and 10 GHz are shown in Fig. 6. It shows that the patterns are nearly omni-

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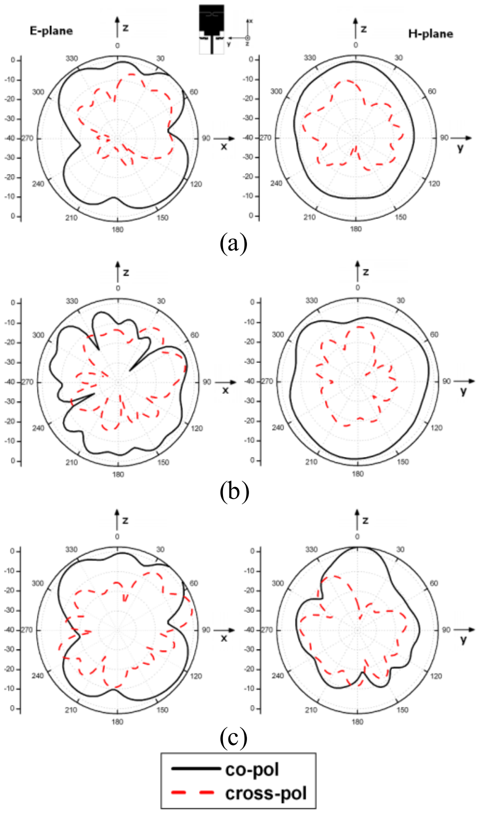

Fig. 6. Radiation patterns of the proposed antenna (a) at 3 GHz, (b) at 6.5 GHz, (c) at 10 GHz.

directional in H-plane but more directional in high frequency and monopole-like radiation pattern in the E-plane.

The measured gain of the proposed antenna is illustrated in Fig. 5 (2). The gain increases with operation frequency and decreases obviously in the notched frequency at 3.5 and 5.5 GHz. Outside the notched band, the variation of the antenna gain is less than 3 dB, indicating that the antenna has a stable gain performances across the operation band.

4 Conclusion

A novel compact printed antenna with WiMAX and WLAN band-notched for UWB application has been investigated. By introducing the staircase-shaped radiating element and the modified ground plane, a wide impedance bandwidth which is from 2.95 to 11.6 GHz is achieved. A pair of hook-shaped slots etched on the radiating element and two folded stubs extend from the ground plane are selected to reject the WiMAX (3.25–3.95 GHz) and WLAN (5.00–6.50 GHz) band, respectively. Good performance of the antenna makes it suitable for UWB application.

Acknowledgments

This work is supported by the National Natural Science Foundation of China (Grant NO. 61201001) and the Fundamental Research Funds for the Central Universities of China (NO. ZYGX2010J117).

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