Compact UWB Microstrip-fed Slot Antenna with Dual-band Rejection by Using EBG and Four-arm Spiral Structures

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Abstract ─ A microstrip-fed slot antenna with dual rejection bands is designed and prototyped for ultra-wideband (UWB) applications. The rejection band for WiMAX is achieved by symmetrical etching a pair of nested four-arm spiral slots on the ground plane. Self-interdigital electromagnetic band-gap (EBG) structures are embedded to create other rejection bands for WLAN and are placed on both sides of the gradient T-shaped microstrip-fed. The simulated result and measurement data show that the antenna impedance bandwidth (Voltage Standing Wave Ratio is less than 2) covers the entire UWB bandwidth range with two eliminated bands of 3.22-3.81 GHz (0.59 GHz, 16.7%) and 5.11-5.84 GHz (0.73 GHz, 13.4%). In addition, the designed antenna achieves a stable gain and exhibits omni-directional radiation patterns except at rejection frequency bands, which makes it a suitable candidate for UWB applications that will not be interfered by WiMAX/WLAN systems.

Index Terms ─ Dual band rejection, electromagnetic band gap, UWB antenna.

I. INTRODUCTION

Ultra-wideband (UWB) technology has become one of the most promising technologies for its inherent advantages, such as low power consumption, high security, low cost, high speed transmission rate, and so on [1]. Over the past ten years, as a result of accelerating growth of UWB technology, a vast body of literature introduce novel antennas for various UWB system applications [2-7].

UWB communication devices occupy a large frequency spectrum (3.1-10.6 GHz) [8], which covers several other wireless system bands, such as WiMAX (3.3-3.7 GHz) and WLAN (5.15-5.825 GHz). The UWB devices met a hostile electromagnetic environment, which may cause potential interferences to it. Solution to avoid interference is the introduction of rejection bands within the pass band of the UWB antenna.

Various techniques for the design of UWB antennas with notch band characteristics have been reported including etching slot on the radiating patch or on the ground plane [9-11], application of parasitic element near the radiating patch or the ground plane [12-14], and so on. In [15], a compact UWB microstrip-fed slot antenna with the band-stop performance is designed by employing genetic algorithm to optimize the shape of slot. In [16], a compact band-notched UWB circular monopole antenna is introduced with dimensions of 39 mm×35 mm. The notch band for WLAN is realized by means of four mushroom-like electromagnetic band-gap (EBG) structures, which are placed on sides of the feed line. A dual notched band UWB planar antenna with smaller dimensions of 32 mm×26 mm is presented in [17], a T-shaped stub on the radiating element is used to create notch band for WiMAX, and a pair of U-shaped stubs on the side of the feed line are used to generate notch band for WLAN. In [18], the microelectro-mechanical system (MEMS) U-shaped afloat is designed and used instead of a simple slot to activate and deactivate the band notch characteristic of an UWB monopole antenna. However, the utilization of MEMS is difficult for realization and usually results in cost and fabrication error increasing. Generally, the design goal of UWB antenna with band notch characteristic is to achieve small size, low profile, high gain, light weight, low cost and simple structure.

In this paper, a compact design and new structure

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of microstrip-fed slot antenna with much smaller dimensions of 23.8 mm×22 mm is proposed for UWB applications. Two rejection bands of WiMAX and WLAN can be realised in the pass band. A stable gain and omni-directional radiation patterns except at rejection bands are obtained. Detailed controlling mechanisms, simulation results and measurement data are demonstrated.

II. ANTENNA DESIGN

Microstrip-fed wide slot antennas [5, 9-11, 14] have been extensively investigated in the past three decades due to its attractive features, such as low profile, light weight, low cost and wide band. In order to cover the UWB frequency spectrum, the shape of the microstrip-fed, the slot and the ground plane should be properly collocation. Figure 1 shows the configuration of the proposed UWB slot antenna, in which a gradient T-shaped feed line is designed for broadband matching and is printed on the front side of a double-sided FR4 dielectric substrate with a relative permittivity of 4.4, a thickness of 1.6 mm and a loss tangent of 0.02. To achieve 50Ω characteristic impedance, the parameters of the feed line are chosen to be L_1=5 mm, L_2=2.7 mm, L_3=2 mm, W_3=6 mm and W_4=2.2 mm.

Since the EBG structure has a surface wave suppression characteristics [19], various types of these structures have been implemented in different applications such as reduction of mutual coupling between two planar antennas to eliminate spurious responses of a filter [17]. In this paper, we utilize the EBG structure to create a stop band within the pass band of the UWB slot antenna. As shown in Fig. 1, a compact self-interdigital EBG structure resonated at 5.5 GHz is designed and there are two elements on each side of the feed line for filtering the WLAN frequency spectrum. The EBG patch is printed on the front side of FR4 dielectric substrate and its parameters are chosen to be W_5=1.6 mm, W_6=0.2 mm, L_6=4.4 mm and g=0.2 mm.

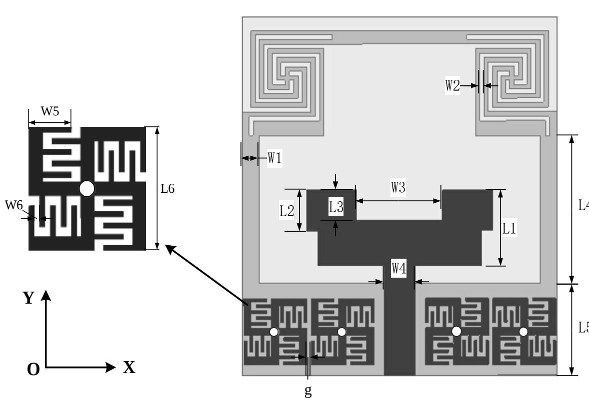
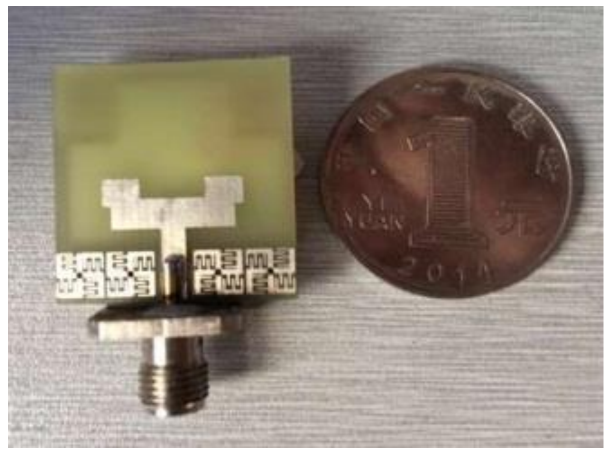
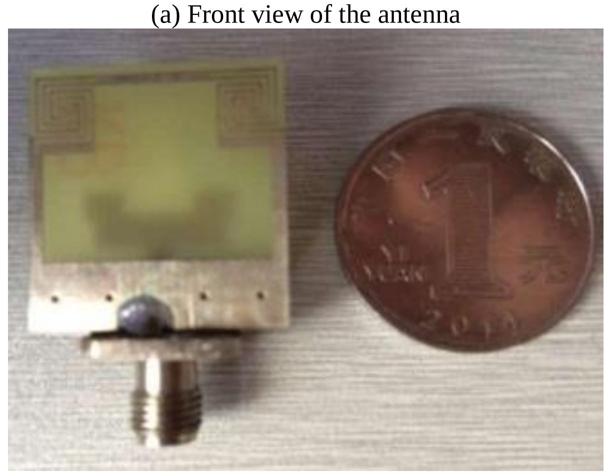


Fig. 1. Configuration of the proposed dual band-notched UWB slot antenna.

The ground plane is printed on the back side of the FR4 dielectric substrate, and we introduce a pair of four-arm spiral slots to generate another rejection band for WiMAX systems. As shown in Fig. 1, the two four-arm spiral slots are symmetrically etched in the front part of the ground plane. The width of the microstrip line and the gap between strips of the four arm spiral slot have the same dimension of 0.3 mm. Figure 2 shows the photograph of the proposed UWB slot antenna, which has a smaller size of 23.8 mm×22 mm×1.6 mm compared to the previous similar antennas [16, 17]. The other antenna parameters are as follows: L_4=9.8 mm, L_5=6.1 mm, W_1=1.5 mm and W_2=0.3 mm.



(a) Front view of the antenna



(b) Back view of the antenna

Fig. 2. Fabricated dual band-notched UWB slot antenna.

III. RESULTS AND DISCUSSION

The simulated results and measured voltage standing wave ratio (VSWR) of the proposed antenna are plotted in Fig. 3. From Fig. 3, two rejection bands of 3.22-3.81 GHz (0.59 GHz, 16.7%) and 5.11-5.84 GHz (0.73 GHz, 13.4%) are observed in the VSWR characteristics, respectively. Taking VSWR less than 2 as a reference, it can be seen that the proposed antenna achieves an ultra-wide operating band ranging from 2.74 to 12.32 GHz with two notched bands. Thus, the proposed UWB slot antenna can availably shield the interference from WiMAX and WLAN systems. It should be mentioned that the discrepancy between the simulation result and measurement data is mainly because of the fabrication error.

The simulated peak gain of the proposed antenna is shown in Fig. 4. Obviously, the gain falls sharply in the two rejection bands since the radiated power is reflected back to the antenna. At the central frequency of the WiMAX band, the simulated peak gain and the measured data are suppressed to -2.91 dB and -3.05 dB, respectively. On the other hand, the simulated gain and the measured data are -2.65 dB and -2.48 dB at the central frequency of the WLAN band, respectively. It clearly indicates the effect of the designed EBG structures and four-arm spiral slots. Other than the rejection bands, the antenna has a stable gain from 1.78 dB to 4.53 dB within the operating band.

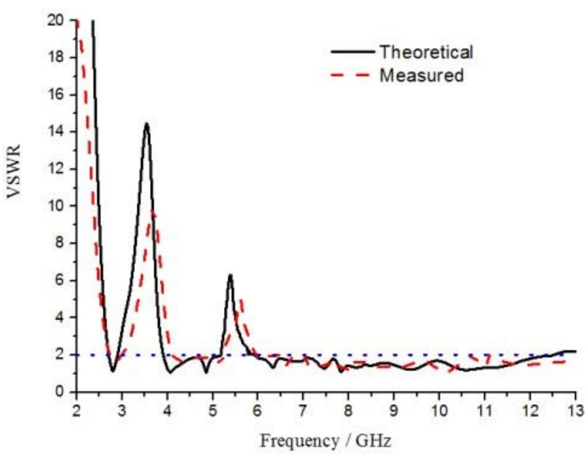


Fig. 3. VSWR variation of the proposed antenna with frequency.

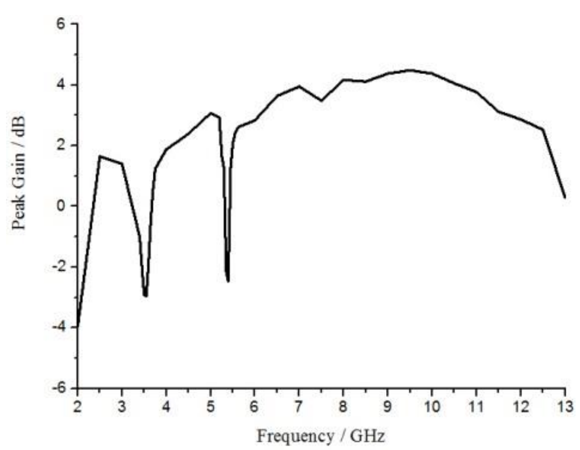
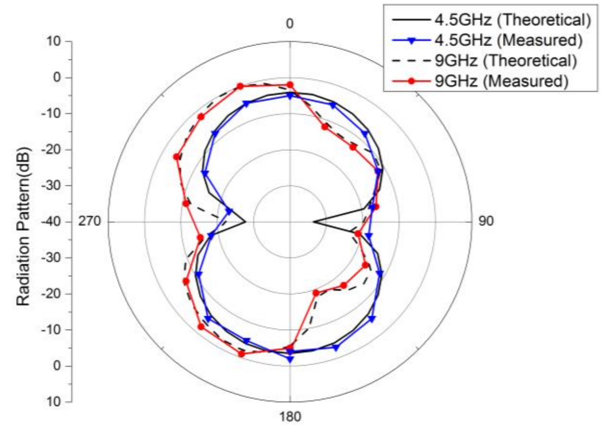
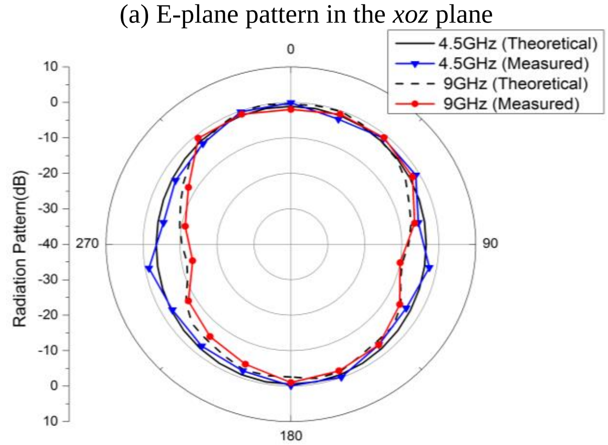


Fig. 4. Peak gain variation of the proposed antenna with frequency.

The simulated results and measured radiation patterns at 4.5 GHz and 9 GHz in the *xoz*- and *yoz*-plane are depicted in Figs. 5 (a) and (b), respectively. There is a slight difference observed between the simulation result and measurement data as a result of the fabrication error. It is found that the radiation patterns are in the omni-directional pattern in the *yoz*-plane (H-plane), whereas in the *xoz*-plane (E-plane), two nulls in the broadside directions are observed that are similar to the typical monopole antennas. Compared with the past dual notched band UWB antennas, the proposed antenna has advantages of small size, low profile, high gain, light weight, low cost and simple structure, which make the proposed antenna a suitable candidate for the UWB applications that is not interfered by WiMAX and WLAN systems.



(a) E-plane pattern in the *xoz* plane



(b) H-plane pattern in the *yoz* plane

Fig. 5. Radiation pattern of the proposed antenna at 4.5 and 9 GHz.

IV. CONCLUSION

A compact UWB slot antenna with dual rejection band characteristics is designed and prototyped. The designed basic UWB antenna consists of a gradient T-shaped feed line and ground plane with a wide rectangle slot. By etching a pair of four-arm spiral slots and embedding self interdigital EBG structures, the proposed slot antenna can achieve two rejection bands of 3.22-3.81 and 5.11-5.84 GHz, which covers the entire WiMAX and WLAN bandwidth ranges, respectively. Meanwhile, the proposed antenna exhibits good performance such as stable gain and omni-directional radiation patterns except at rejection bands are obtained.

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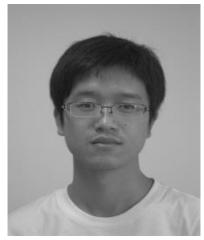

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