

## ULTRA-WIDEBAND ANTENNA USING MEANDERED SLOTS FOR DUAL BAND-NOTCHED CHARACTERISTIC

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**Abstract**—This paper presents the design and results of a compact Ultrawideband (UWB) monopole antenna with a dual band-notched characteristic. The antenna consists of a semi-elliptical radiator with two meandered slots on it to produce a deep notch at 3.5 GHz (the center of WiMax band) and another notch at 5.25 GHz (the center of the lower WLAN band). The antenna is fabricated and measured, and the measured impedance bandwidth defined by  $VSWR < 2$  is 8.5 GHz (2.5–11 GHz), with the dual notched bands of 3.3–3.7 GHz and 5.12–5.37 GHz are obtained. The computer simulation results of the radiation pattern and peak gain of the antenna also agree well with measurements.

### 1. INTRODUCTION

Since the Federal Communication Commission (FCC) allowed the 3.1–10.6 GHz unlicensed band for UWB communication [1], UWB communication systems have attracted great attention in the wireless world because of their advantages, including high speed data rate, extremely low spectral power density, high precision, low cost and low complexity.

However, over the designed bandwidth of the UWB system, there exist narrow bands used by WiMAX operating in the 3.3–3.7 GHz band, lower WLAN in the 5.15–5.35 GHz band and upper WLAN in the 5.725–5.825 GHz band. These systems may potentially interfere with the UWB systems. Thus UWB antennas with band-notched

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characteristic are necessary to solve this problem. Different antenna design methods have been proposed to produce the band notched characteristic in the UWB band [2–8]. The conventional methods are cutting a slot (U-shaped, arc-shaped and pi-shaped slots) on the patch or ground plane and embedding a quarter wavelength tuning stub within a large slot on the patch. Alternative ways are etching a U-shaped slot on the feed line as a filter or adding a small patch through a via-hole on the bottom side of the substrate.

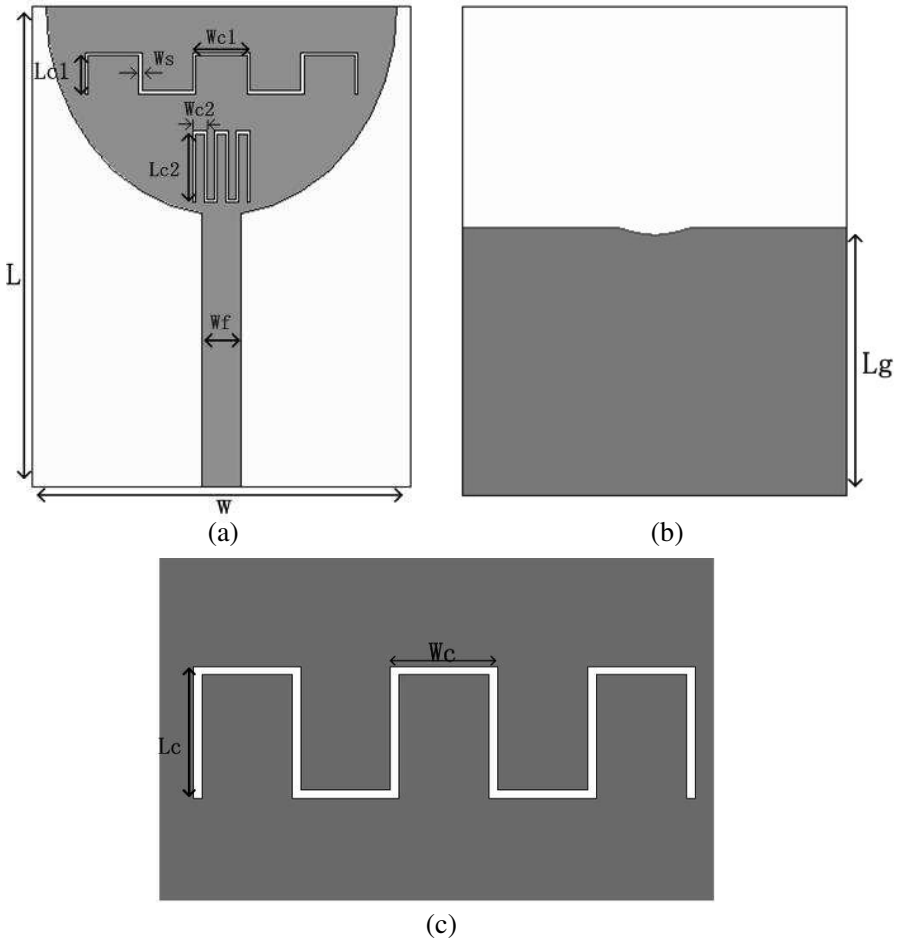
In this paper, a novel microstrip feed band-notched UWB antenna is proposed. The antenna consists of a semi-elliptical patch and a rectangular ground plane with a small segment of arc at the middle of the upper edge of it. The notched band is achieved by two meandered slots on the patch. This approach provides more degrees of freedom in design and is capable of producing a steeper rise in VSWR curve at the notch frequency. The designed antenna has a compact size of  $28\text{ mm} \times 36\text{ mm} \times 1.6\text{ mm}$ . The measured and simulated results show that the proposed antenna achieves a bandwidth ranging from 2.5 GHz to 11 GHz with two notched bands covering 3.3–3.7 GHz and 5.12–5.37 GHz. The two notched bands can avoid the potential interference between the UWB systems and lower WLAN/WiMAX narrow band communication systems without wasting much frequency resource. And the radiation pattern in the  $H$ -plane is omni-directional across the whole operating band.

## 2. ANTENNA DESIGN AND PARAMETRIC STUDY

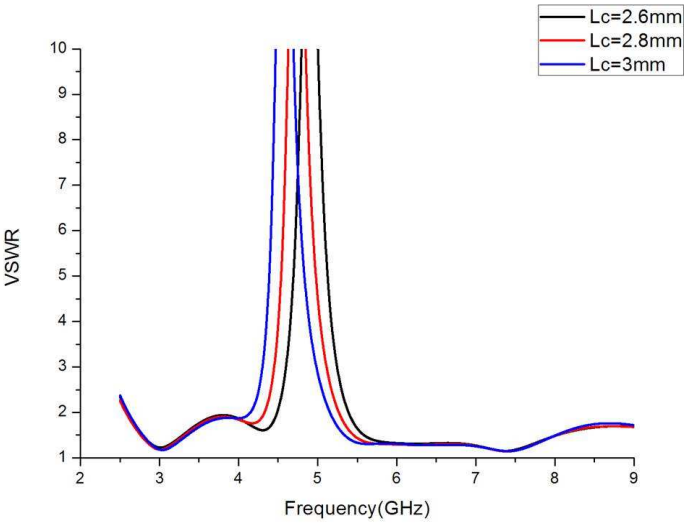
The geometry of the proposed dual band-notched UWB antenna is shown in Figure 1. The proposed antenna is printed on a low-cost FR4 substrate with the thickness of 1.6 mm and the dielectric constant of 4.4. The radiator is a semielliptical patch of the radius  $R = 18\text{ mm}$ , and  $XR = 1.3$ .  $XR$  is the axial ratio of the elliptical which forms the semi-elliptical patch. The rectangular ground plane is modified by a small segment of arc to achieve a better impedance match. Two meandered slots are etched from the radiator to obtain the notched bands. The upper one can notch the frequency from 3.3–3.7 GHz, and the lower one corresponds to the 5.12–5.37 GHz band.

To fully understand the characteristics of the meandered slot structure, a parametric study is carried out using the Ansoft HFSS. Simulation results on the VSWR with different values of  $L_c$  and  $W_c$  are shown in Figure 2 and Figure 3, respectively. From the figures we can see that the resonant frequency varies with  $L_c$  and  $W_c$ , but the VSWR values in the rest of the UWB band remain almost the same. This property provides a great freedom to the designers to select the

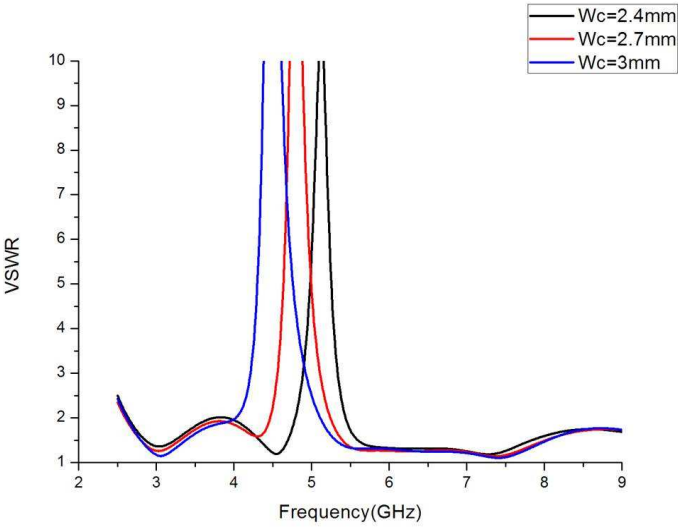
notched band for the antennas. Figure 3 shows that the bandwidth of the notched band can be adjusted easily by varying  $W_c$  with other parameters remaining constant. Smaller  $W_c$  means a narrower notched band and a higher resonant frequency. With this property another attractive merit of this structure is that it can obtain a much narrower notched band at the WLAN frequency with a bigger VSWR peak value than other structures reported.



**Figure 1.** The geometry of the UWB antenna and the slot (Unit: mm). (a) Top view. (b) Bottom view. (c) The meandered slot.



**Figure 2.** Simulated VSWR for different values of  $L_c$  with  $W_c = 2.7$  mm.



**Figure 3.** Simulated VSWR for different values of  $W_c$  with  $L_c = 2.8$  mm.

3. RESULT AND DISCUSSIONS

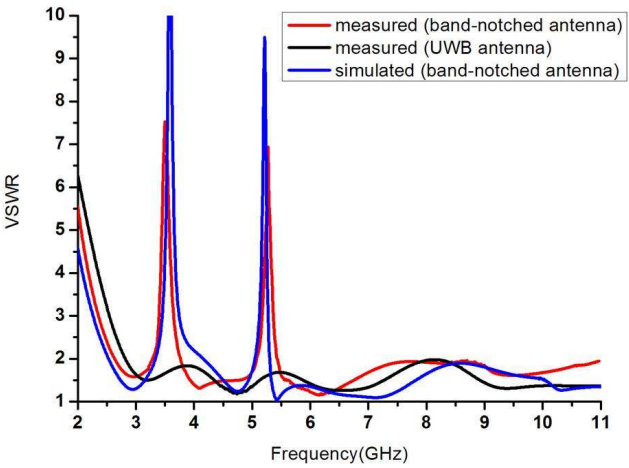
The antenna shape and its dimensions were optimized by using the Ansoft HFSS. The optimized parameters are shown in Table 1.

Based on the optimized parameters of the proposed dual band-notched UWB antenna, an example antenna was fabricated on a FR4-based substrate with a size of  $28\text{ mm} \times 36\text{ mm} \times 1.6\text{ mm}$ . The photograph of the fabricated antenna is shown in Figure 8. The impedance bandwidth was measured using an Agilent N5230A (10 MHz–50 GHz) Vector Network Analyzer, as shown in Figure 4, where a very good agreement between the simulated and measured results is observed.

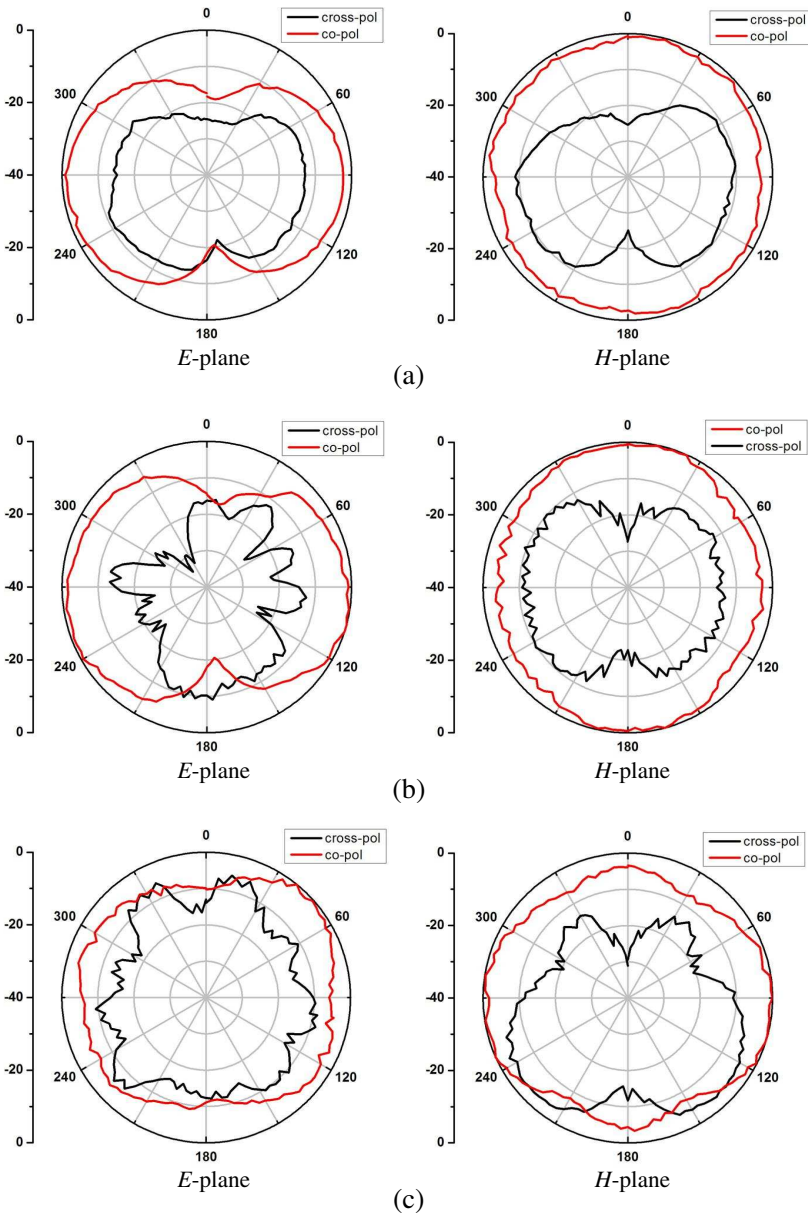
The measured radiation patterns of the designed antenna at the frequencies of 3 GHz, 6 GHz and 9 GHz are shown in Figure 5. It can be seen that the antenna exhibits a nearly omni-directional radiation pattern in the  $H$ -plane and a dipole-like radiation pattern in the  $E$ -plane. For UWB applications, omni-directional radiation

**Table 1.** Parameters of the proposed antenna (Unit: mm).

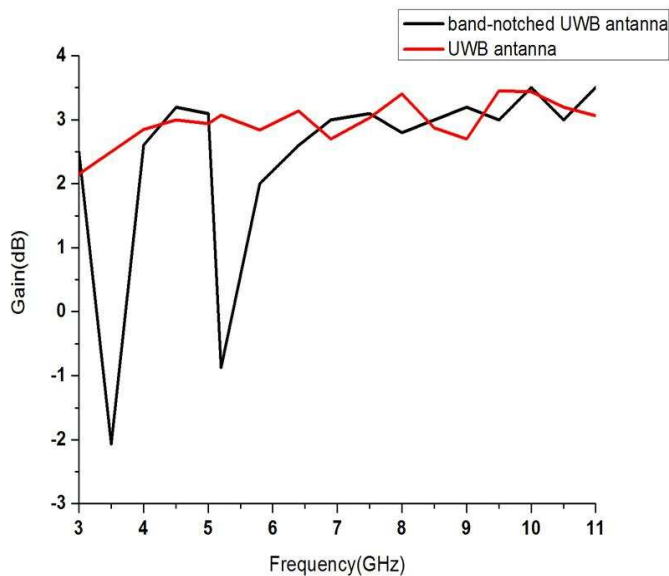
$W$	$L$	$W_s$	$W_f$	$Lc_1$	$Lc_2$	$Wc_1$	$Wc_2$	$Lg$
28	36	0.2	3	2.8	4.4	4	1	19.7



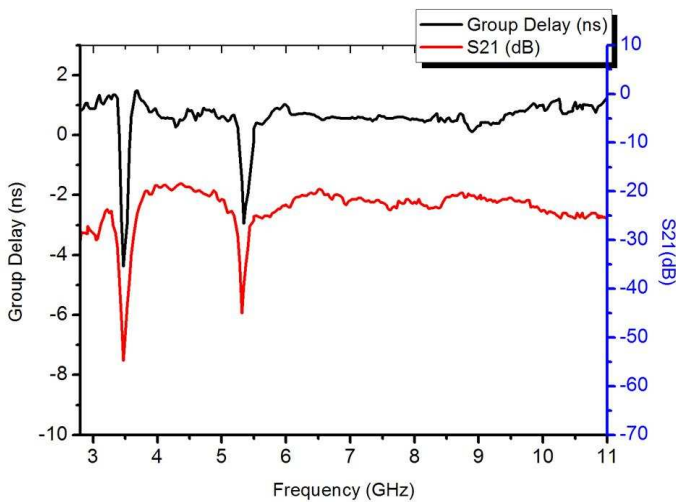
**Figure 4.** Simulated and measured VSWR of the band-notched antenna.



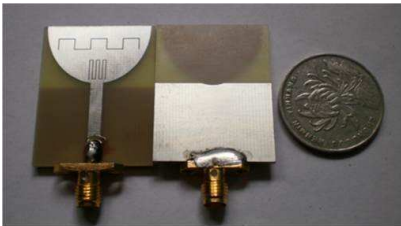
**Figure 5.** Measured radiation patterns. (a) 3 GHz, (b) 6 GHz, (c) 9 GHz.



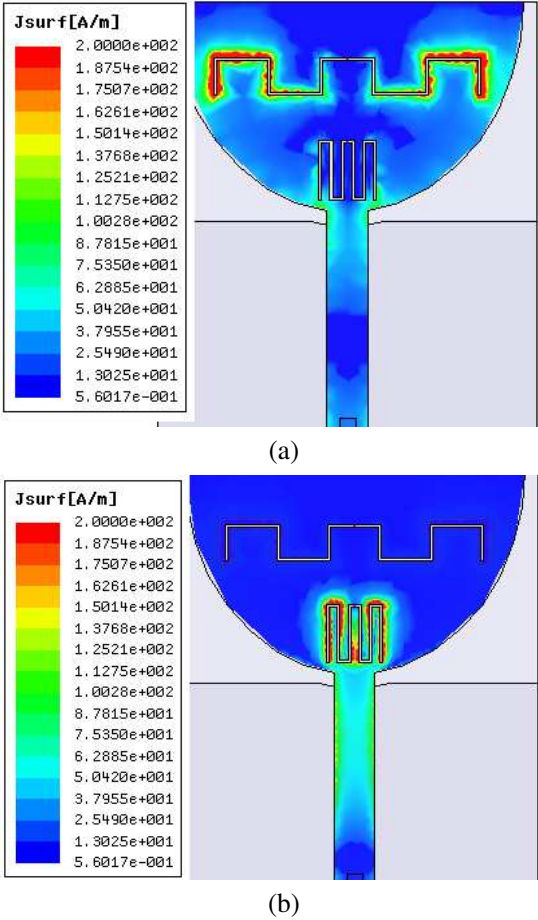
**Figure 6.** Measured peak antenna gains.



**Figure 7.** Measured pass loss and group delay of the proposed antenna.



**Figure 8.** The photograph of the fabricated antenna.



**Figure 9.** Surface current distributions at two resonant frequencies. (a) 3.5 GHz, (b) 5.25 GHz.



pattern is normally preferred. The results of measurement show that the radiation patterns at all of the three frequencies satisfy this requirement well. As shown in Figure 6 the antenna also has a sharp gain decrease at the notched band, so the antenna can avoid the potential interference with the existing WiMAX lower WLAN communication system well. Figure 7 displays the measured pass loss and group delay by using two identical fabricated antennas with a distance of 15 cm. 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.

Figures 9(a) and (b) show the surface current distribution of the dual band-notched antenna at 3.5 GHz and 5.25 GHz, respectively. At the notched bands the current is confined around the slot and it does not get radiated. We can see from the figure that the current mainly distributes around the ends of the slot and the length of the slot is about  $\lambda/2$  of the two notched frequencies respectively. So at the two notched frequencies the slots can be seen as a series-wound  $\lambda/4$  impedance convertor on the equivalent main transmission line. And the end of it is short circuit, so it is an open circuit when we look in from the main transmission line. As a result, we get a band-notched characteristic.

#### 4. CONCLUSIONS

In this paper, a meandered slot is proposed to implement the band-notched characteristics of planar monopole antennas for UWB applications. Through a parametric study we find that this structure can obtain a narrow notched band that is about 250 MHz at the WLAN band. Finally, a novel dual band-notched monopole antenna with two meandered slots on the patch has been designed and fabricated. Simulated and measured results show that the antenna has two notched bands covering 3.3–3.7 GHz and 5.12–5.37 GHz. In addition, the simulated and measured radiation patterns in the  $H$ -plane are nearly omni-directional at the operating frequencies. Therefore, this antenna is a good candidate for ultra-wideband communication applications.

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