

# A Novel UWB Antenna with Triple Band-Notches for WiMAX and WLAN

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**Abstract**—By etching a half-wavelength hook-shaped slot on the ground and adding quarter-wavelength rectangle-shaped strips in the patch, a novel triple band-notched ultra-wideband (UWB) antenna is proposed. The triple band-notches are used to prevent interferences from existing bands at 3.3–3.9 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz. Fed by coplanar waveguide, the antenna is printed on a 30\*30 mm<sup>2</sup> substrate. The parameters affecting antenna performance are simulated and analyzed. The simulated and measured results show that the proposed antenna achieves a wide bandwidth from 3 GHz to 11 GHz with triple band-notches. Radiation patterns and gain are also investigated and analyzed.

## 1. INTRODUCTION

Ultra-wideband (UWB, 3.1–10.6 GHz) antenna studies have drawn great attention in recent years for its wide bandwidth, high speed data rate, and low loss [1]. However, there are existing communication bands, including Worldwide Interoperability for Microwave Access (WiMAX, 3.3–3.7 GHz) and Wireless Local Area Network (WLAN, 5.15–5.35 GHz and 5.725–5.825 GHz), which can interfere UWB. Hence, the designs about UWB antenna with band-notched function have become a new challenge and research focus [1–5].

Single band-notched antenna has been proposed in previous works. Half or quarter wavelength strips in [6, 7] are added to realize band-notched characteristic. Slots, like Z-shaped [8] or rectangular ones [9], are also embedded in antenna patch and ground to achieve band-notched function. Based on single band-notched antennas, designs about dual or multiple band-notched UWB antennas have been reported in recent years. Inserting various slots in patch or ground, such as M-shaped [10, 11] and L-shaped [12] ones, is the most popular method to obtain dual notched bands. Split Ring Resonator (SRR) and S-shaped slot in microstrip feed line were utilized in [13], and electric ring resonator (ERR) was added in [14]. The above two approaches achieve triple notched bands at desired frequency. However, there is a great challenge to realize dual band-notched characteristic in adjacent bands like lower and upper bands of WLAN due to the strong coupling between them.

A novel triple band-notched UWB antenna over 3.3–3.7 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz is designed and proposed in this paper to prevent the interference of WiMAX and WLAN signals. The triple band-notched characteristic is obtained by adding two separated quarter-wavelength strips in patch and etching a half wavelength hook-shaped slot on the ground. The parameters affecting band-notched characteristic are studied and analyzed. The measured and simulated results are in good agreement.

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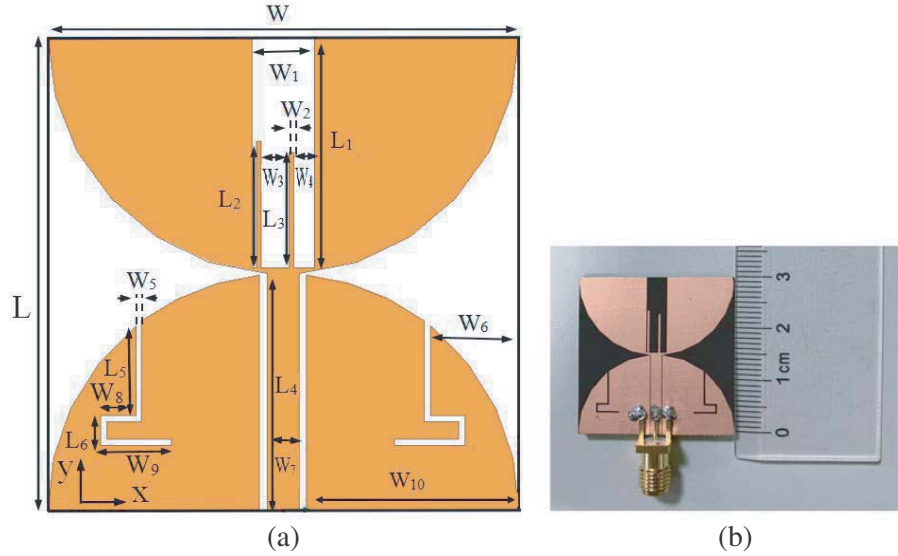
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## 2. ANTENNA STRUCTURE AND DESIGN

As shown in Fig. 1, the antenna fed by a coplanar waveguide is printed on a 1.6-mm thick RO4003 ( $\epsilon_r = 3.5$ ,  $\tan \delta = 0.0030$ ) substrate. It consists of a semicircle-shaped ( $r = 15$  mm) radiated patch, feeding line, and semicircle-shaped metal ground. A rectangular slot cut on the patch can make current distribution concentrate on a narrow region [1]. The two rectangular strips are added in the patch in order to produce notches at lower and upper WLAN bands, while the hook-shaped slot etched on the ground can realize WiMAX band-notched characteristic. The strips act as band-stop elements, and the space between them can be regarded as an electromagnetic separator. Thus, coupling between two strips does not affect dual band-notched characteristic seriously, though the two notched bands are adjacent. Optimized by HFSS software, the final values of parameters are shown in Table 1.



**Figure 1.** The geometry and photograph of the triple band-notched UWB antenna. (a) Geometry, (b) photograph.

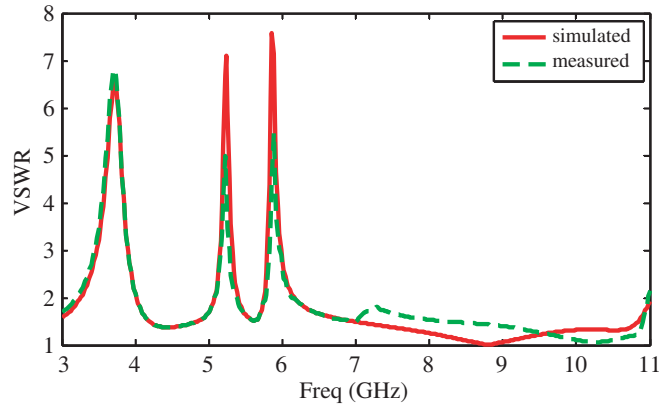
**Table 1.** The parameters of the proposed antenna.

Parameters	$L$	$L_1$	$L_2$	$L_3$	$L_4$	$L_5$	$L_6$	$W$	$W_1$
Dimensions (mm)	30	14.6	8	7.3	15	6	1.9	30	4
Parameters	$W_2$	$W_3$	$W_4$	$W_5$	$W_6$	$W_7$	$W_8$	$W_9$	$W_{10}$
Dimensions (mm)	0.3	1.8	1.3	0.4	5.6	2	2.2	4.5	13.8

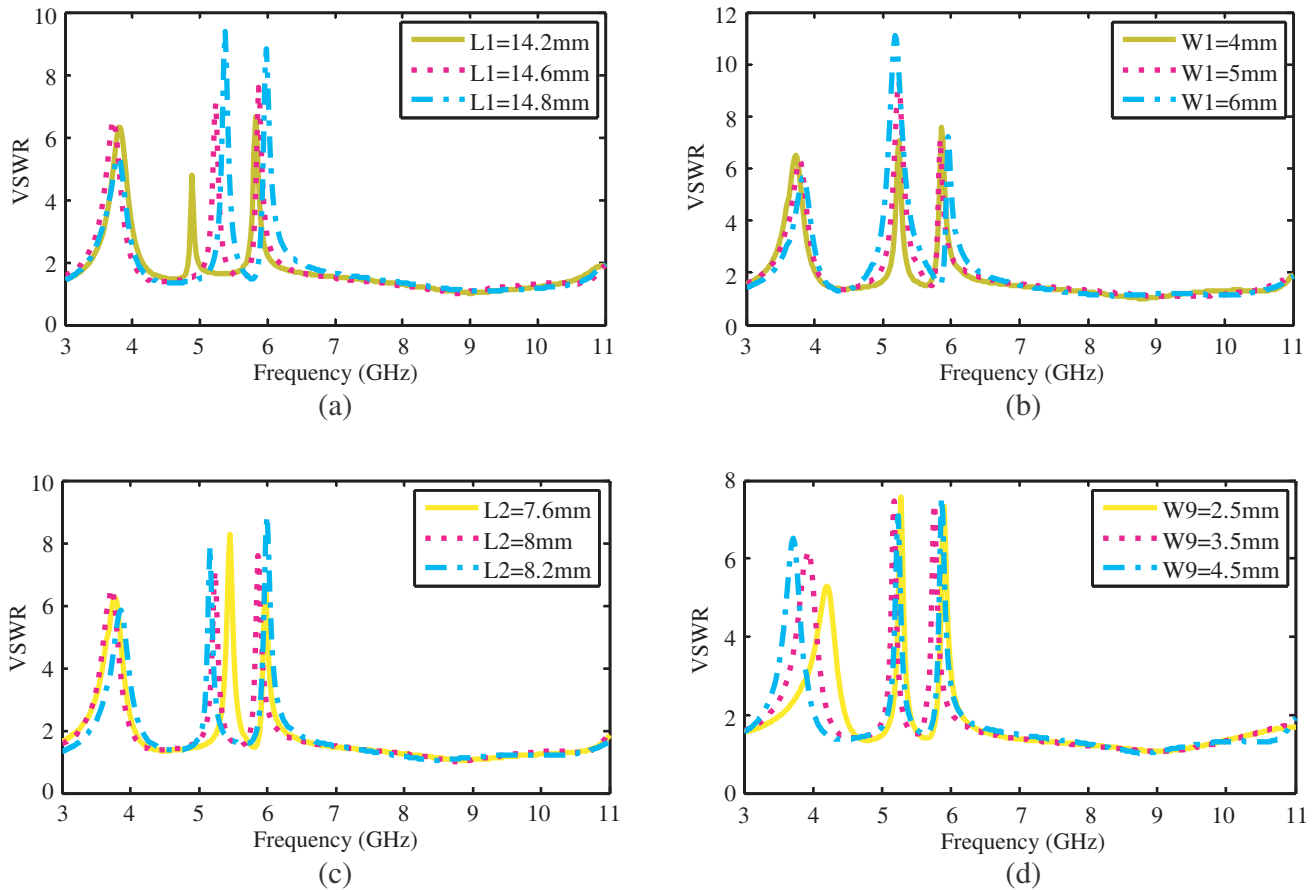
Figure 2 shows the simulated and measured VSWRs of the proposed antenna. The antenna achieves a wide bandwidth over 3–11 GHz for  $VSWR < 2$ , which can cover the entire UWB operating frequencies. The triple band-notches at 3.3–3.7 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz are obtained respectively. The measured results are in good agreement with simulated ones.

## 3. PARAMETRIC STUDIES AND PERFORMANCE ANALYSES

The parameters about strips in the patch are simulated and studied. Fig. 3(a) and Fig. 3(b) show VSWR variations with different lengths and widths of rectangle shaped slot cut in the patch. From Fig. 3(a), it is observed that two adjacent frequency differences are shifted from 0.99 GHz to 0.60 GHz corresponding to increasing  $L_1$  from 14.2 mm to 14.8 mm. Fig. 3(b) shows that with the incensement



**Figure 2.** The simulated and measured VSWR of the proposed antenna.



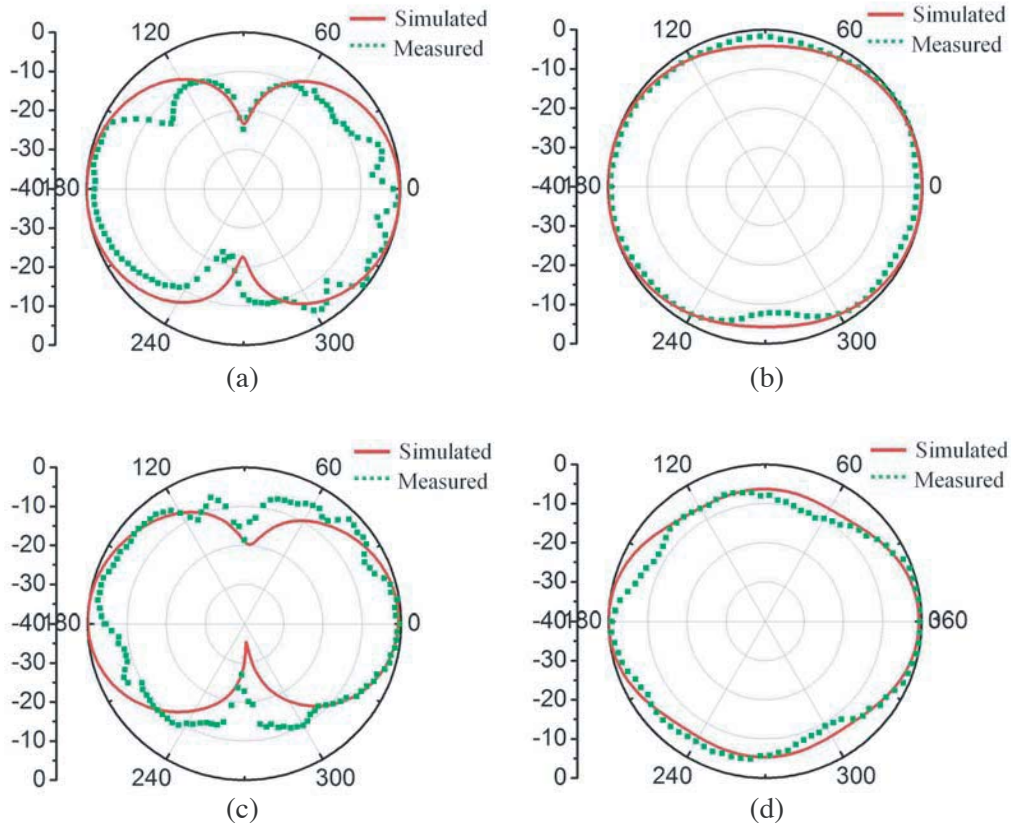
**Figure 3.** Simulated VSWR with different (a)  $L_1$ , (b)  $W_1$ , (c)  $L_2$  and (d)  $W_9$ .

of  $W_1$  from 4 mm to 6 mm, the notched bandwidth at lower WLAN frequency increases from 0.32 GHz to 0.9 GHz. It is noted that the VSWR becomes higher in notched frequencies with incensement of  $L_1$  and  $W_1$ . The current distribution concentrating on a narrower region can realize better notched characteristic.

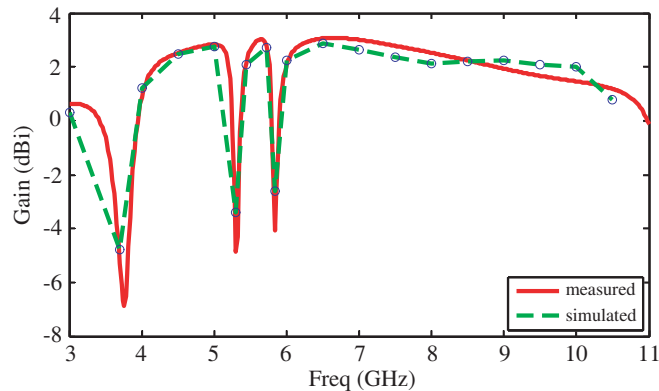
As shown in Fig. 3(c), the notched frequency decreases from 5.46 GHz to 5.16 GHz corresponding to incensement of  $L_2$  from 7.6 mm to 8.2 mm. It is observed that the length of the strip is about quarter-wavelength. The parameters about hooked-shaped slot are also simulated. Fig. 3(d) shows that the

band-notched frequency shifts from 4.20 GHz to 3.72 GHz with the incensement of  $W_9$  from 2.5 mm to 4.5 mm. Assuming  $l$  ( $l = L_5 + W_8 + L_6 + W_9 - 2W_5$ ) as the total length of the hook-shaped slot, the value of  $l$  is approximated to half-wavelength. The hook-shaped slot can be regarded as a band-stop filter, and desired notched frequency can be obtained by optimizing parameter  $l$ .

The simulated and measured radiation patterns at 4 GHz and 8 GHz are illustrated in Fig. 4. The antenna printed in  $xy$ -plane is similar to a monopole antenna. Hence,  $E$ -plane of the antenna is  $yz$ -plane, while  $H$ -plane is  $xz$ -plane. The patterns in far field are almost omnidirectional in the  $H$ -plane



**Figure 4.** The simulated and measured radiation patterns in far-field at 4 GHz and 8 GHz. (a)  $E$ -plane at 4 GHz, (b)  $H$ -plane at 4 GHz, (c)  $E$ -plane at 8 GHz, (d)  $H$ -plane at 8 GHz.



**Figure 5.** The simulated and measured peak realized gain of the proposed antenna.

**Table 2.** Comparison with other reported UWB antennas.

Antenna	Band-notched frequencies (GHz)			Notched frequency differences (GHz)		Gain (dBi)
	$f_1$	$f_2$	$f_3$	$\nabla f_A = f_2 - f_1$	$\nabla f_B = f_3 - f_2$	
[14]	3.5	5.8	7.5	2.3	1.7	4.9
[15]	3.6	5.5	7.5	1.9	2	3
[16]	5	6.8	8	1.8	1.2	3.7
[17]	4.1	5.9	8	1.8	1.1	2.8
This work	3.5	5.2	5.8	1.7	0.6	3

and bidirectional in the  $E$ -plane. The reason for discrepancy between simulated and measured results is the connection of SMA. The peak gain of the proposed antenna shown in Fig. 5 is stable over the entire operating bands, and it drops obviously at the desired notched-bands.

Table 2 shows the comparison with other reported antennas. In general, the difficulty increases with decreasing frequency difference. The frequency difference of the proposed antenna decreases obviously compared with other antennas and avoids interference at WLAN lower frequency bands and WLAN upper frequency bands.

#### 4. CONCLUSION

A novel triple band-notched UWB antenna to overcome the interference of WiMAX and WLAN signals is proposed in this paper. By adding quarter-wavelength rectangle-shaped strips in the patch, dual band-notched characteristic at lower and upper WLAN bands is achieved, which can overcome coupling between adjacent bands. A half-wavelength hook-shaped slot is etched on the ground to achieve 3.3–3.7 GHz band-notched characteristic. The parameters affecting band-notched characteristic are investigated and studied. Meanwhile, the radiation patterns are stable, and gain decreases sharply at notched bands.

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