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# A NOVEL SELF-SIMILAR ANTENNA FOR UWB APPLICATIONS WITH BAND-NOTCHED CHARACTERISTICS

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**Abstract**—A novel self-similar antenna for band-notched ultra-wideband (UWB) applications is proposed. The UWB performance is obtained by introducing a quasi-trapezoidal radiating patch and a self-similar ground plane. By etching two similar slots on the radiating patch, band-notched characteristic can be obtained. The measured results show that the antenna covers the band of UWB from 2.6 to 12.8 GHz excluding the rejected bands from 3.3 to 3.6 GHz and from 4.8 to 6.0 GHz. In addition, the antenna exhibits nearly omni-directional radiation patterns and stable gains over the operating bands.

## 1. INTRODUCTION

The impending and widespread requirements from commercial and military domains on UWB systems have sparked great interest in the field of UWB antenna design. Various kinds of UWB antennas have been studied and proposed [1–6]. However, because of the allocation of the broad frequency range in UWB system, e.g., a portion of the spectrum between 3.1 and 10.6 GHz is allocated for UWB system by Federal Communications Commission, a UWB antenna is quite susceptible to interference by receiving several narrow band signals of neighboring RF systems, such as 3.5 GHz worldwide interoperability for the microwave access (WiMAX) and 5.2/5.8 GHz wireless local area network (WLAN) communication systems. Thus, it is desirable to design a UWB antenna with multiple band-notched characteristics to

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avoid the potential interference. In the published literatures, there have been some reports on the UWB antennas with band-notched characteristics [7–15]. However, most of these antennas are designed to generate only one notched frequency band so that just one narrow band of disturbance can be eliminated. Consequently, these antennas are still open to other potential disturbance from neighboring RF systems.

In this paper, a novel self-similar antenna for band-notched UWB applications is proposed. By adopting the self-similar design and etching two slots on the radiating patch, band-notched UWB characteristics can be obtained. The practical prototype is fabricated and tested, and the measured results show a good agreement with the simulated ones. Details of the antenna design and parameter study are presented and discussed as follows.

## 2. ANTENNA DESIGN

The configuration of the proposed antenna is shown in Figure 1. The antenna is designed and fabricated on one side of the FR4 substrate with dielectric constant of 4.4, thickness of 1.6 mm, and overall size of 28 × 33 mm$^2$. A 50-Ω coplanar waveguide (CPW) transmission line, with a width 3 mm and a gap 0.5 mm, is adopted to excite the

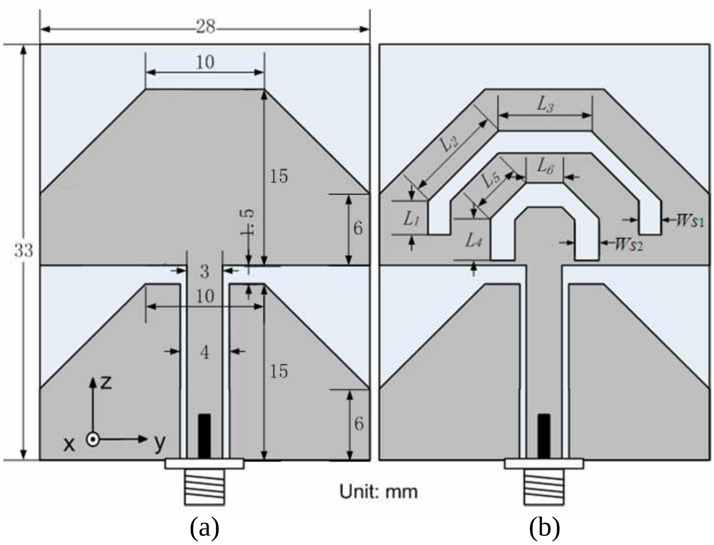


**Figure 1.** Geometry of the proposed antenna without/with slots. (a) Self-similar antenna without slots. (b) Proposed antenna.

radiating patch. To achieve optimum impedance matching at UWB frequency band, a self-similar structure has been adopted, as shown in Figure 1(a). Based on the design, the proposed antenna with two etched slots for band-notched UWB applications has been proposed, as shown in Figure 1(b). The lengths of the slots $L_{s1}$ $(2 \times L_1 + 2 \times L_2 + L_3)$ and $L_{s2}$ $(2 \times L_4 + 2 \times L_5 + L_6)$ are approximately one wavelength of the notched frequencies at 3.5 GHz and 5.5 GHz, respectively. The wavelength can be approximately calculated by the formula as follows: $\lambda_g = \lambda_0/(\frac{\varepsilon_r+1}{2})$. Where, $\lambda_g$ and $\lambda_0$ are the wavelengths in the medium and free space, $\varepsilon_r$ is the relative dielectric constant. The widths of the slots are $W_{s1}$ and $W_{s2}$, respectively. By varying the value of $L_{s1}$, $W_{s1}$, $L_{s2}$ and $W_{s2}$, the UWB applications with notched bands at 3.5 GHz and 5.5 GHz can be obtained. The required numerical analysis and proper geometrical parameters of the proposed antenna are studied with the aid of Ansoft's High Frequency Structure Simulator (HFSS) software, and the final optimum design parameters are shown in Table 1. A prototype is fabricated according to the aforementioned design results, as shown in Figure 2.

**Table 1.** Optimal parameters of the antenna prototype.

| Parameter | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $W_{s1}$ | $W_{s2}$ |
|---|---|---|---|---|---|---|---|---|
| Value/mm | 3.0 | 8.5 | 8.0 | 3.5 | 4.2 | 3.0 | 2.0 | 2.0 |

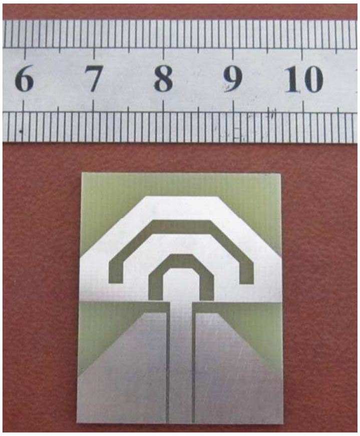


**Figure 2.** Prototype of the proposed antenna.

## 3. RESULTS AND DISCUSSION

The prototype of the proposed antenna has been constructed and experimentally studied. With the help of the Ansoft HFSS software and WILTRON37269A vector network analyzer, the simulated and measured VSWR curves are shown in Figure 3. From the measured results we can observe that the impedance band (VSWR $\leq 2$) is from 2.6 to 12.8 GHz excluding the rejected bands from 3.3 to 3.6 GHz and from 4.8 to 6.0 GHz, and the measured results show a good agreement with the simulated ones.

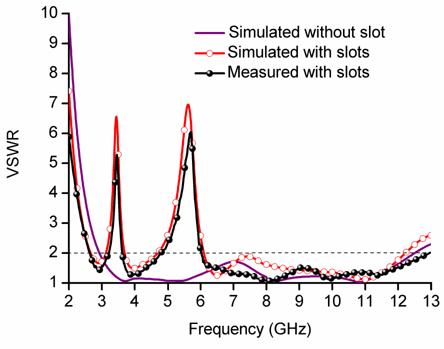


**Figure 3.** Simulated and measured VSWR curves of the proposed antenna.

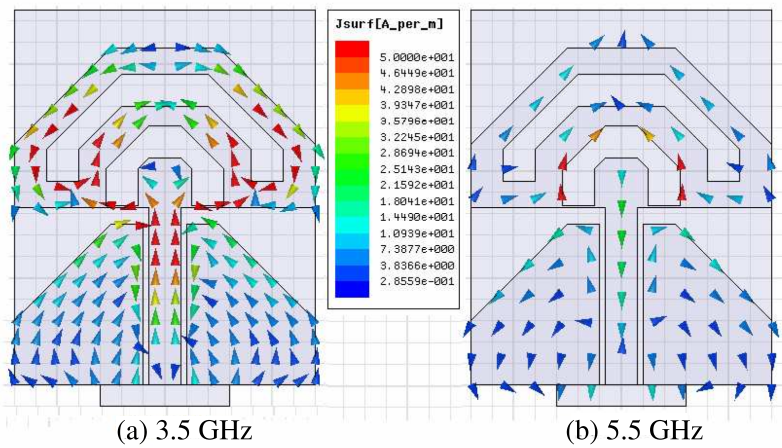


**Figure 4.** Current distributions on the proposed antenna at (a) 3.5 GHz and (b) 5.5 GHz.

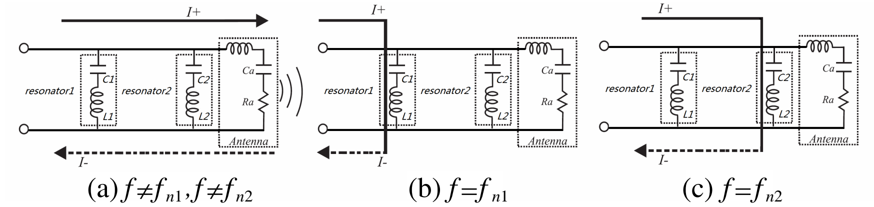


**Figure 5.** Conceptual equivalent lumped-element circuit models of the proposed antenna.

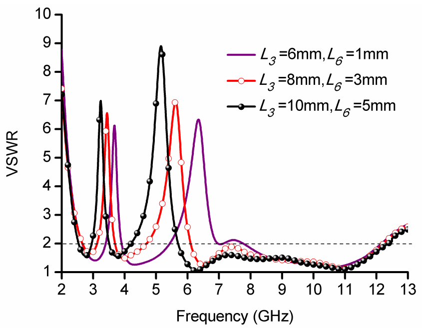


**Figure 6.** Simulated VSWR curves for different values of $L_{s1}$ and $L_{s2}$.

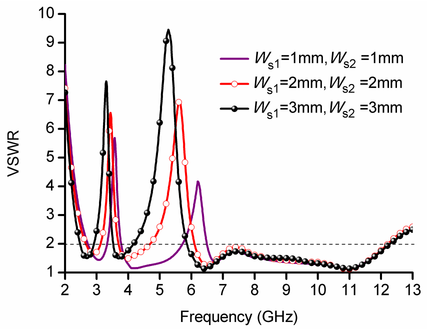


**Figure 7.** Simulated VSWR curves for different values of $W_{s1}$ and $W_{s2}$.

The mechanism of the band-notched characteristics can be investigated from the currents on the antenna. Then, the simulated current distributions at 3.5 and 5.5 GHz for the proposed antenna are presented in Figures 4(a) and (b). It can be seen that the currents at 3.5 and 5.5 GHz mainly distributed along the edges of the upper and lower slot, respectively. The behave of the current distributions at 3.5 and 5.5 GHz leads to near field radiation counteracted, which indicates high energy reflection at the port and the band-notched characteristics achieved. The conceptual equivalent lumped-element circuit models of the proposed antenna are shown in Figure 5. When the operating frequency isn't equal to the notched frequencies, the resonators don't work. Otherwise, when the operating frequency equals to the first/second notched frequency, no current flows to the antenna while excited current is induced to the first/second resonator.

Figures 6 and 7 show the simulated VSWR curves for the proposed antenna with different parameters and it can be seen that the dimensions of the etched slots have strong effects on the band-notched characteristics. Figure 6 shows that the center frequencies of the notched bands are decreasing as $L_3$ and $L_6$ increase, because $L_{s1}$ and $L_{s2}$ are approximately one wavelength of the notched-band frequencies. The optimum result can be obtained when $L_3 = 8\,\text{mm}$ and $L_6 = 3\,\text{mm}$. From Figure 7, we can see that when $W_{s1}$ and $W_{s2}$ increase, the VSWRs of the notched frequencies are increasing, the notched frequencies shift towards lower and their bandwidths correspondingly increase. In order to get higher VSWRs and proper bandwidths at notched frequencies, $W_{s1} = W_{s2} = 2\,\text{mm}$ is chosen.

The measured $E$-plane and $H$-plane radiation patterns for the proposed antenna at 3, 6 and 9 GHz are shown in Figure 8. It can be seen that the radiation patterns are bi-directional in the $E$-plane and almost omni-directional in the $H$-plane, which indicate good monopole-

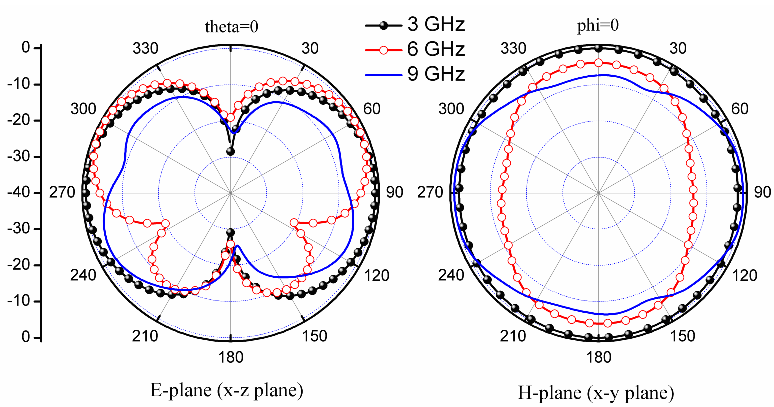


**Figure 8.** Measured far-field radiation patterns of the proposed antenna.

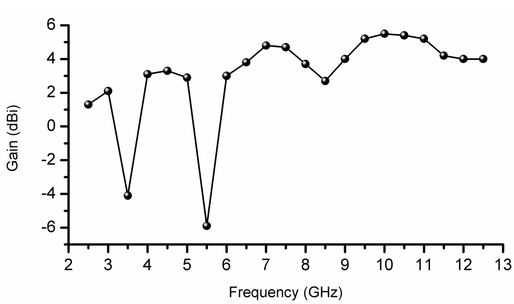


**Figure 9.** Measured peak gains of the proposed antenna.

like radiation characteristics are achieved over the operating bands.

The measured peak gains against frequency are plotted in Figure 9. The gains are from 1.3 to 5.4 dBi for the operating bands, −4.1 dBi and −5.9 dBi for the rejected bands. The result presents that the proposed antenna is successfully performed with the rejection at the 3.5 GHz WiMAX and 5.2/5.8 GHz WLAN.

## 4. CONCLUSION

A novel self-similar antenna with two etched slots for band-notched UWB applications has been designed, manufactured and measured successfully. The measured results demonstrate that the etched slots generate two excellent notched bands at 3.5 GHz WiMAX and 5.2/5.8 GHz WLAN which can be properly tuned by varying the lengths and widths of the slots. The proposed antenna also performs good monopole-like radiation characteristics over the operating bands, which makes it an excellent candidate for the band-notched UWB applications.

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