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DUAL BAND-NOTCHED ANTENNA WITH THE PARASITIC STRIP FOR UWB

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Abstract—A novel microstrip-fed ultra wideband (UWB) elliptical antenna with dual band-notched characteristics is proposed. Dual band-notched characteristics are achieved by employing a pair of U-shaped slots on the ground plane and a T-shaped parasitic strip on the backside of the substrate. The operation bandwidth of the designed antenna is from 2.9 to 12 GHz for voltage standing wave ratio (VSWR) less than 2, except two frequency stop-bands of 3.2–3.9 GHz for WiMAX system and 4.9–6.1 GHz for WLAN system. Moreover, the proposed antenna provides good radiation patterns across the working bands and a relatively flat gain over the entire frequency band excluding the rejected bands.

1. INTRODUCTION

Since the U.S. Federal Communication Commission (FCC) authorized the unlicensed use of the ultra wideband (UWB) in 3.1–10.6 GHz in February 2002, significant research activities and interests have been aroused in academic and industrial fields recently to explore various UWB antennas [1–6]. However, the frequency range for UWB systems approved by the FCC between 3.1 to 10.6 GHz will cause interference to the existing wireless communication systems, such as the IEEE 802.16 WiMAX system at 3.5 GHz (3.3–3.7 GHz) and the IEEE 802.11a wireless local area network (WLAN) system at 5.2/5.8 GHz (5.15–5.825 GHz). In order to avoid interference among these bands, a UWB antenna with multiple band-notched characteristics is required. Some designs have been proposed in recent literatures [7–17]. The conventional methods to achieve a notched band are used including embedded complementary split-ring resonator (CSRR) slots on the

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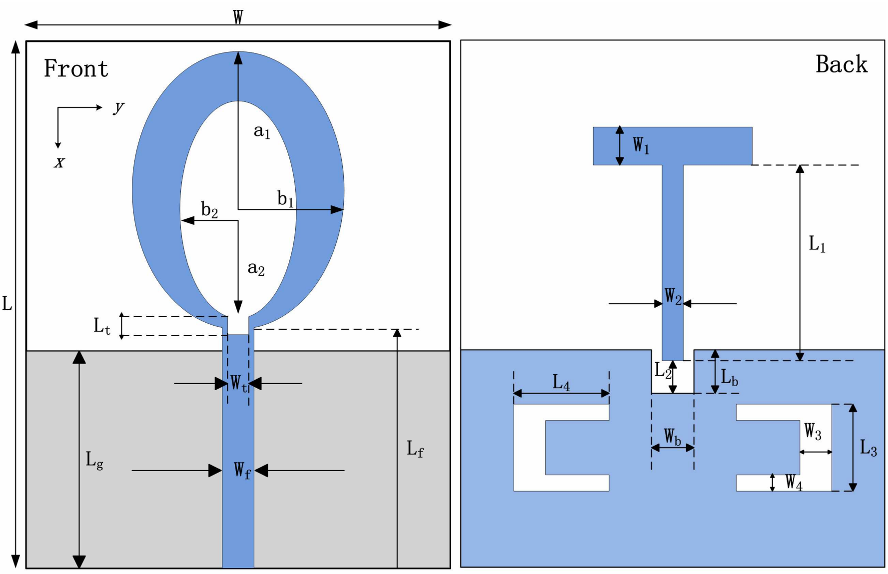
radiated patch or put parasitic elements near the printed monopole antenna. These methods aforementioned can achieve a good band-notched characteristic, but some of them are with large size or complicate the design procedure of the UWB antennas themselves.

In this letter, a microstrip-fed elliptical UWB antenna with dual band-notched characteristics is presented. The proposed antenna is designed to reject the limited band of 3.5 GHz (3.3–3.7 GHz) by attaching a T-shaped parasitic strip to the bottom layer of the antenna. To achieve the other notched band of 5.2–5.8 GHz, a pair of U-shaped slots is cut off around the microstrip line on the ground. The proposed antenna can cover the UWB frequency range (3.1–10.6 GHz) and avoid interference with the 3.5 GHz for WIMAX and the 5 GHz for WLAN wireless systems with a simple structure. Details of the antenna design with simulation and experiment results are presented and discussed.

2. ANTENNA CONFIGURATION AND DESIGN

The geometry and configuration of the proposed antenna is shown in Figure 1. The total size of this antenna including the ground plane



(a) (b)

Figure 1. Geometry of proposed UWB antenna. (a) Front view and (b) back view.

is $30 \times 35\,\mathrm{mm}^2$ ($W \times L$), which is printed on a FR4 substrate with a thickness of 1.6 mm and relative permittivity of 4.6. This antenna is composed of a partial finite-size ground with a pair of U-slots, an ellipse-shaped radiation patch with an ellipse-shaped slot and a parasitic strip. It is fed through a microstrip line with a length L_f of 11.2 mm and width W_f of 3 mm to ensure $50\,\Omega$ characteristic impedance. A square notch with a size of $L_b \times W_b = 3\,\mathrm{mm} \times 3\,\mathrm{mm}$ on the top of the ground provides the mechanism to enhance the impedance bandwidth of the proposed antenna. Moreover, in order to get better impedance matching, another rectangular notch of $L_t \times W_t = 1\,\mathrm{mm} \times 2\,\mathrm{mm}$ is symmetrically cut in the top middle of the elliptical radiator, too. The T-shaped parasitic strip is designed to provide the notched band at 3.5 GHz for WIMAX system. The length of the parasitic strip can be determined by quarter wave length at 3.5 GHz.

In fact, the strip plays a role as a filter to eliminate the identified band. Furthermore, the notched band frequency is adjustable by varying the length and location of the parasitic strip. To realize another rejected band at 5 GHz for WLAN system, a pair of U-shaped slots is embedded on the ground plane. The length of the slot $L_3 + 2 \times L_4$ is nearly equal to one-half wavelength of the resonance at 5.5 GHz. Final dimensions of the optimized antenna are as follows: $a_1 = 10.2\,\mathrm{mm}$, $a_2 = 9\,\mathrm{mm}$, $b_1 = 9.2\,\mathrm{mm}$, $b_2 = 5.5\,\mathrm{mm}$, $L_g = 10.5\,\mathrm{mm}$, $L_1 = 13.5\,\mathrm{mm}$, $L_2 = 2.2\,\mathrm{mm}$, $L_3 = 6.5\,\mathrm{mm}$, $L_4 = 8.3\,\mathrm{mm}$, $W_1 = 2.7\,\mathrm{mm}$, $W_2 = 2\,\mathrm{mm}$, $W_3 = 2\,\mathrm{mm}$, $W_4 = 1\,\mathrm{mm}$.

3. RESULTS AND DISCUSSION

All simulations of the antenna were carried out using HFSS and its VSWR is measured by using Wiltron 37269A network analyzer.

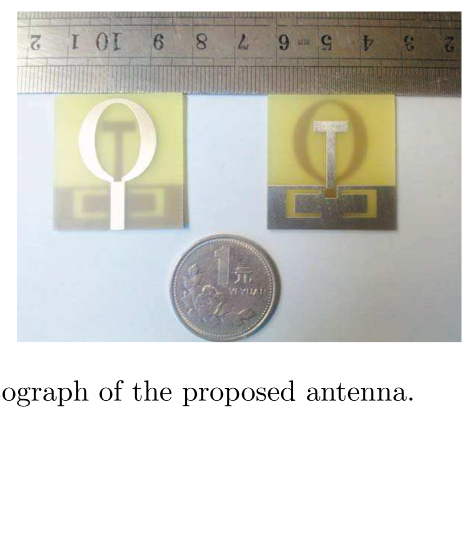


Figure 2. Photograph of the proposed antenna.

Figure 2 shows a photograph of the fabricated dual band-notched UWB antenna. The measured and simulated results for the prototype are plotted in Figure 3. The result for a reference antenna without notched bands is also compared. It is apparent that the proposed antenna can

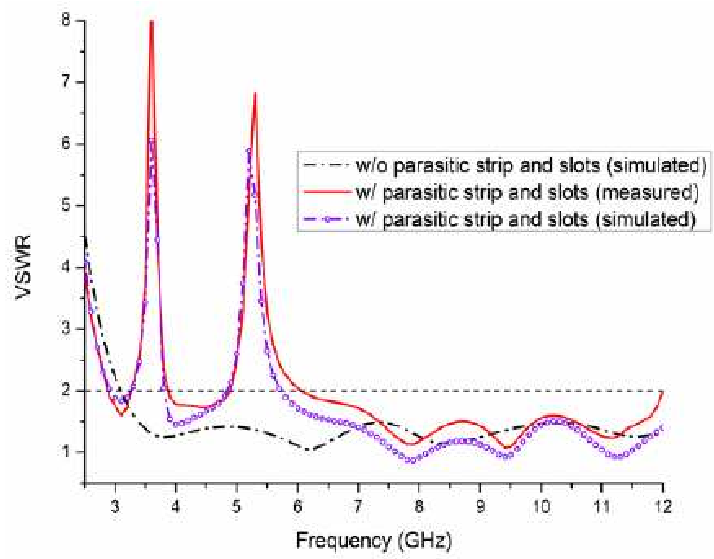


Figure 3. Simulated and measured VSWR of proposed antenna.

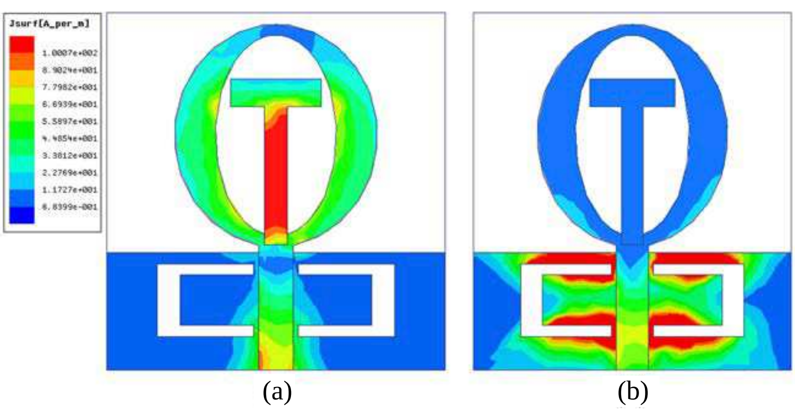


Figure 4. Surface current distribution of the proposed antenna at (a) 3.5 GHz and (b) 5.5 GHz.

cover an ultra wide frequency band of 2.9–12 GHz (defined by VSWR < 2) with dual notched bands (defined by VSWR > 2) of 3.2–3.9 GHz for WiMAX system and 4.9–6.1 GHz for WLAN system, respectively. The discrepancy in VSWR between the simulated and the measured results should be mostly attributed to the loss tangent $\tan\delta$ of the FR4 substrate and tolerance in manufacturing.

In order to better understand the mechanism of the band-notched characteristics, the simulated current distributions at 3.5 and 5.5 GHz for the proposed antenna are investigated and shown in Figure 4. It can be seen that the surface currents at 3.5 GHz mainly concentrated along the T-shaped parasitic whereas the resonant surface current at 5.5 GHz mainly distributed along the edges of the U-slots.

Figures 5 and 6 show the simulated VSWR curves of the proposed antenna with different parameters which affect the band-notched characteristics. As descriptions aforementioned, the notched band at 3.5 GHz is determined by the parasitic strip, so different lengths of the parasitic strip are investigated first. Figure 5 shows that the center frequency of the notched band at 3.5 GHz is decreasing as L_1 increases, because L_1 is approximately quarter wave length of the lower notched-band frequency. Furthermore, we can observe in Figure 5 that the length of vertical part of the T-strip (L_1) affects the impedance matching obviously. The optimum result can be obtained when $L_1 = 13.5$ mm, the center frequency of the lower notched band

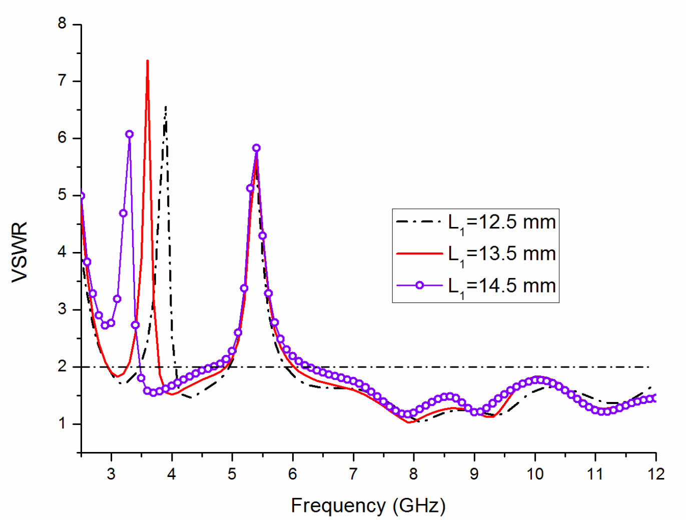


Figure 5. Simulated VSWR curves for different values of L_1.

is 3.5 GHz with a good impedance matching. From Figure 6, it can be seen that when L_4 increases, the VSWR of the higher notched frequency is increasing and its bandwidth correspondingly increases. In order to get an enough bandwidth for 5.2/5.8 GHz, $L_4 = 8.3$ mm is chosen.

Figure 7 shows the normalized radiation patterns of the proposed

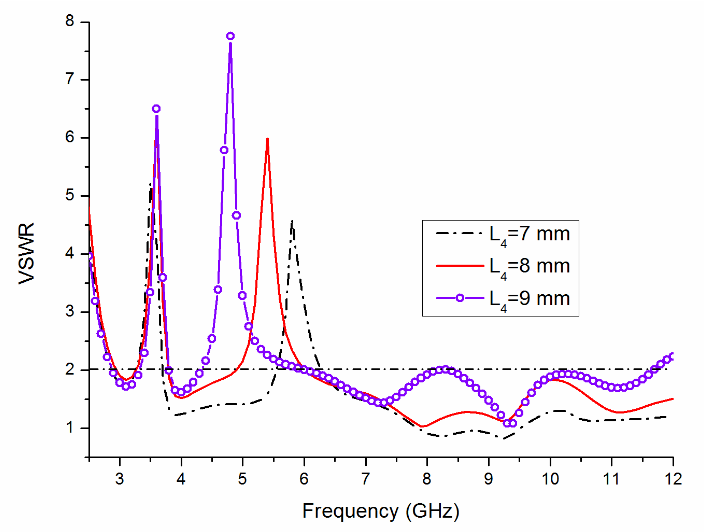
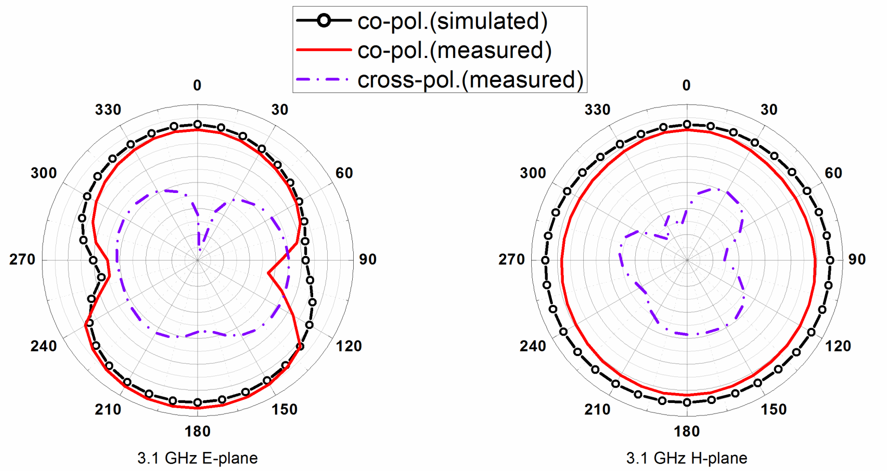


Figure 6. Simulated VSWR curves for different values of L_4.



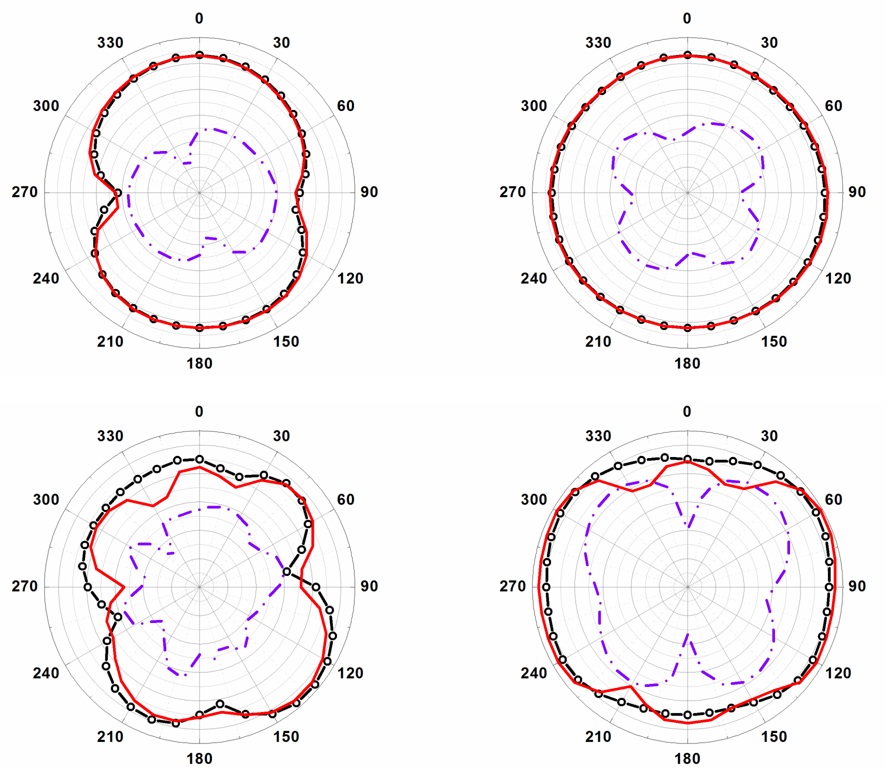


Figure 7. Radiation patterns of proposed antenna at 3.1, 4.5, and 9.5 GHz in the E-plane and H-plane.

antenna at 3.1, 4.5, 9.5 GHz, respectively. It can be seen that the proposed antenna exhibits a nearly omnidirectional radiation pattern in the H-plane (y-z plane) and a quasi-omnidirectional radiation pattern in the E-plane (x-z plane).

The measured gain of the proposed antenna is shown in Figure 8. Two sharp decrease of antenna gain can be observed in the notched frequency bands. The gains are from 1.6 to 4.1 dBi for the operating bands, −4.1 dBi and −2.5 dBi for the rejected bands. This result presents that the proposed antenna has good dual band-notched characteristics at 3.5 GHz for WiMAX and 5.2/5.8 GHz for WLAN.

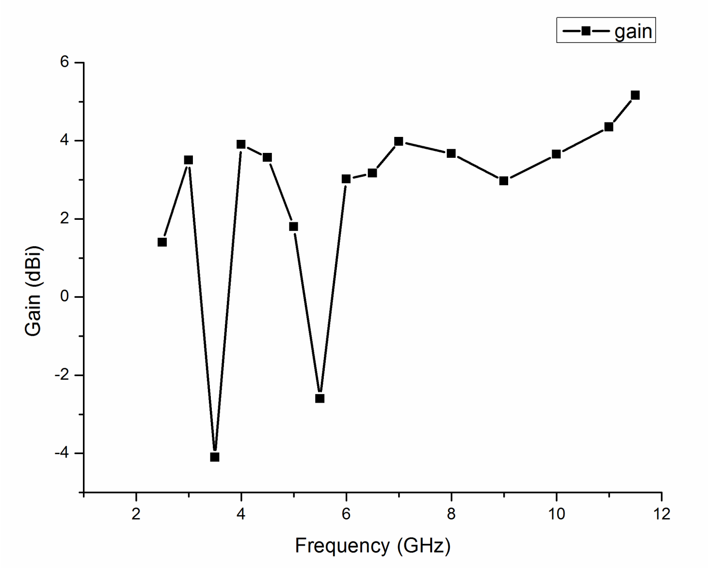


Figure 8. Peak gain of the proposed antenna.

4. CONCLUSIONS

A novel compact UWB planar elliptical antenna with dual notched bands has been proposed and discussed. Dual notched bands are achieved by using a pair of U-shaped slots on the ground while introducing a T-shaped parasitic strip on the back plane. It has a wide operating frequency band of 2.9 GHz to over 12 GHz (VSWR < 2) with 3.2–3.9 GHz and 4.9–6.1 GHz notched-bands. The proposed antenna indicates not only a broad impedance bandwidth but also a good radiation performance while retaining the small volume of $30\,\text{mm} \times 35\,\text{mm} \times 1.6\,\text{mm}^3$. These features are very attractive for portable UWB applications.

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