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A CIRCULAR WIDE-SLOT ANTENNA WITH DUAL BAND-NOTCHED CHARACTERISTICS FOR UWB APPLICATIONS

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Abstract—A circular wide-slot UWB antenna with dual band-notched characteristics is proposed in this paper. The microstrip-fed antenna consists of a calabash-shaped feeding patch and a metal ground with a circular slot etched. Dual band-notched characteristics are achieved by introducing arc-shaped parasitic strip and slot etched on the ground plane. According to the measured results, the proposed antenna can operate at the range of 2.91–11.45 GHz with VSWR < 2 for UWB applications, except the notched bands of 3.38–3.71 GHz and 5.39–6.27 GHz for the 3.5 GHz WiMAX and 5.8 GHz WLAN, respectively.

1. INTRODUCTION

Since the frequency band from 3.1 to 10.6 GHz was allocated for commercial ultra-wideband (UWB) communication systems [1], ultra-wideband antenna, as a key component in a UWB system, has received increasing attention. However, there are some other narrow band services existing over this wide band, such as the WiMAX system operating at 3.4–3.7 GHz (IEEE 802.16) and the Wireless Local Area Network (WLAN) system operating at 5.15–5.35 GHz and 5.725–5.825 GHz (IEEE 802.11a), which may cause severe electromagnetic interference to the UWB systems. Consequently, UWB antennas are necessary for the rejection of interference with existing narrow band technologies. Various antennas with band rejected characteristics have been designed and studied for UWB applications recently. Among these antennas, planar monopoles and slot antennas are two main

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types. The band-notched functions of these antennas are usually obtained by etching slots or adding parasitic strips on the patch or ground, such as C-shaped slot [2, 3], rectangular slot [4], inverted-L slots [5], inverted-T slots [6], a pair of U-shaped slots [7], folded strips [8], separated strips [9], semicircular parasitic strip [10], T-shaped parasitic strip [11] and a pair of rectangular parasitic strips [12]. Most of the antennas mentioned above have excellent band rejected characteristics. However, we can hardly find a dual-notched band antenna based on the wide-slot structure including the 3.5 GHz WiMAX rejected band.

In this paper, a circular wide-slot antenna fed by a calabash-shaped patch with dual band-notched characteristics is proposed for UWB applications. The band-notched functions for 3.4–3.7 GHz WiMAX and 5.725–5.825 GHz WLAN are achieved by adding arc-shaped slot and strip on the ground plane, respectively. By adjusting the dimensions of the slot and the strip, the desired notched bands can be obtained. Details of the design and studies of key parameters are presented below, with the simulated and measured results given also.

2. ANTENNA DESIGN

The geometry and dimensions of the proposed circular wide-slot antenna are depicted in Figure 1. The antenna is etched on a $32 \times 35\,\text{mm}^2$ substrate with thickness of $H = 1$ mm and relative permittivity of 2.65. The feeding structure is a calabash-shaped patch connected

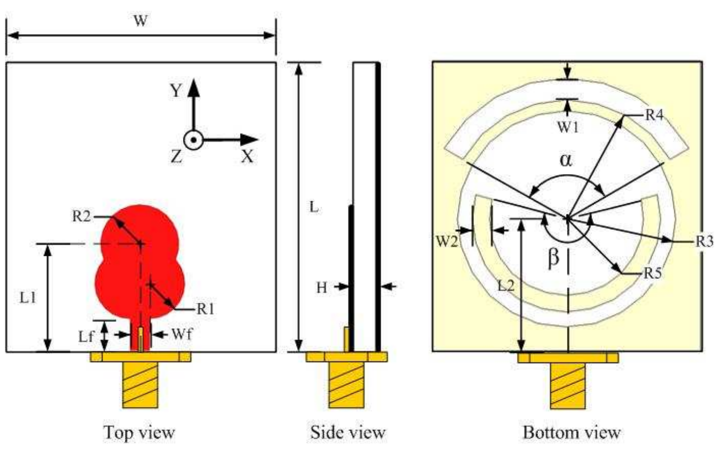


Figure 1. Geometry of the proposed antenna.

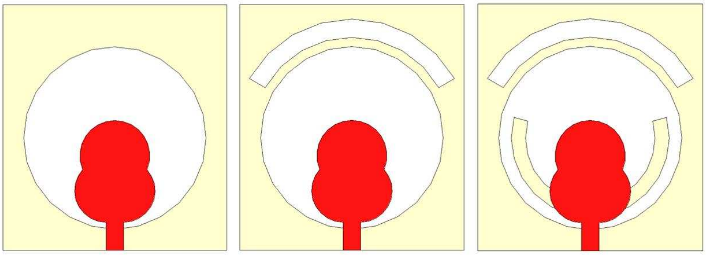
with a microstrip line, both of which are printed on one side of the substrate. The patch is composed of three circular discs with two different radius values (specified with $R1$ and $R2$). On the other side, a circular slot with radius $R3$ is etched on the ground plane to form the wide-slot radiator. By adjusting these parameters above, the ultra-wideband operating requirement can be achieved. The notched bands for 3.5 GHz WiMAX and 5.8 GHz WLAN are obtained by etching an arc-shaped slot and adding an arc-shaped parasitic strip, respectively, both of which are concentric with the circular slot. And the parameters $R4$, α, $W1$, $R5$, β, and $W2$ denote the inner radius, flare angle and width of the slot and the strip, respectively. The length of the slot is about half of the wavelength of the lower notch frequency at 3.5 GHz and the length of the parasitic strip approximately equals to the wavelength of the other notch frequency at 5.8 GHz. The wavelength can be approximately calculated by the formulas as follows:

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}}$$

$$\varepsilon_{eff} \approx \frac{\varepsilon_r + 1}{2}$$

where, λ_g and λ_0 are the wavelength in the medium and in the free space, respectively; ε_{eff} is the effective relative dielectric constant.

With the aid of the electromagnetic simulator Ansoft HFSS, the proposed antenna is analyzed. The optimized parameters of the antenna are as follows: $L = 35$ mm, $Lf = 4$ mm, $L1 = 13.5$ mm, $L2 = 16$ mm, $W = 32$ mm, $Wf = 2.5$ mm, $W1 = 2.6$ mm, $W2 = 2$ mm, $R1 = 4.5$ mm, $R2 = 5$ mm, $R3 = 13$ mm, $R4 = 14.3$ mm, $R5 = 9.2$ mm, $\alpha = 120°$, and $\beta = 210°$.



(a) Ant Ⅰ (b) Ant Ⅱ (c) Ant Ⅲ

Figure 2. Geometries of the three antennas. (a) Antenna without slot or strip. (b) Antenna with slot only. (c) Antenna with both slot and strip.

To give a better description of the design procedure, a comparison has been made among the three antennas illustrated in Figure 2, and the simulated VSWR curves are shown in Figure 3. Ant I is the original UWB antenna without any slot or strip. It operates at the band ranging from 2.65 to 13.53 GHz with VSWR < 2. Ant II with an arc-shaped slot etched on the ground shown in Figure 2(b) exhibits a single notched characteristic for 3.38–3.73 GHz band, covering the 3.5 GHz WiMAX band. Ant III is the proposed antenna. A parasitic arc-shaped metal strip is added within the circular slot just below the feeding patch on the other side to produce the 5.34–6.10 GHz notched band covering the 5.8 GHz WLAN.

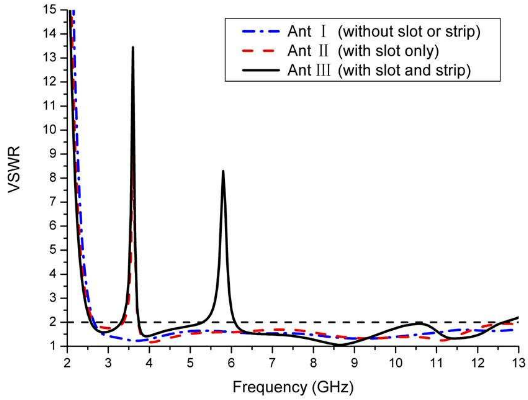


Figure 3. Comparison of the simulated VSWR curves of Ant I, Ant II and Ant III.

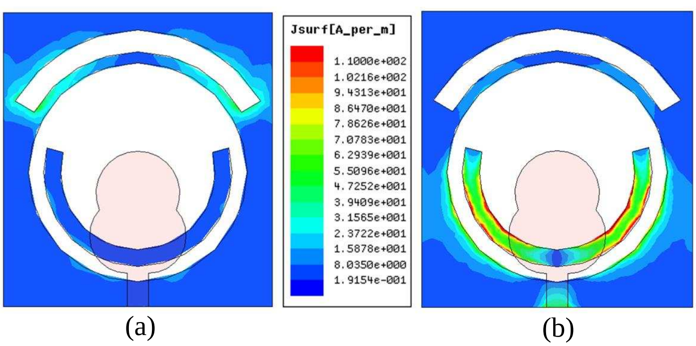


Figure 4. Surface current distributions of the propose antenna at the frequencies of (a) 3.6 GHz and (b) 5.8 GHz.

In order to investigate the electromagnetic mechanism of the band-notched operation, the surface current distributions of the proposed antenna at the center frequencies of the two notched bands are depicted in Figure 4. It can be obviously observed that the current is mainly distributed on the slot at 3.6 GHz and on the strip at 5.8 GHz, respectively. The slot and the strip act as good half-wave and full-wave resonators, respectively, which results in the dual band-notched functions.

3. RESULTS AND DISCUSSION

A prototype of the proposed antenna was fabricated and tested. The photograph of the manufactured antenna is shown in Figure 5. The measurement of VSWR was carried out by a vector network analyzer WILTRON37269A. The effects of vital parameters on the notched bands are also studied in this section.

The simulated and measured VSWR curves of the proposed antenna are shown in Figure 6. The measured result indicates that the impedance bandwidth (VSWR < 2) covers 2.91–11.45 GHz with two notched bands (VSWR > 2) covering 3.38–3.71 GHz and 5.39–6.27 GHz. Obviously, the measured VSWR reasonably agrees with the simulated one, with an acceptable frequency discrepancy, which may be caused by the errors of fabrication. However, the proposed antenna is suitable for UWB applications with dual-notched bands at 3.5 GHz WiMAX and 5.8 GHz WLAN.

Figure 7(a) shows the effect of the flare angle α of the arc-shaped

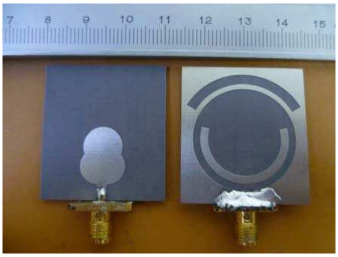


Figure 5. Photograph of the proposed antenna.

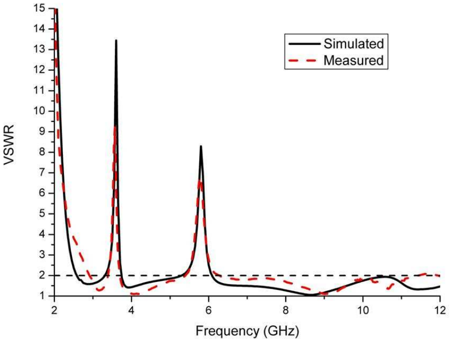
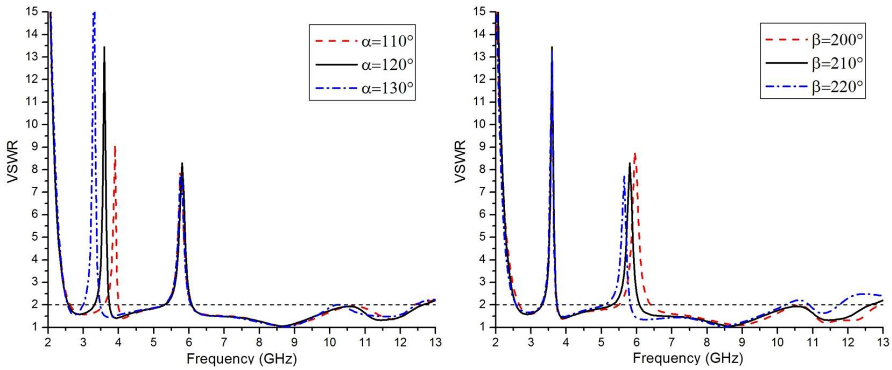
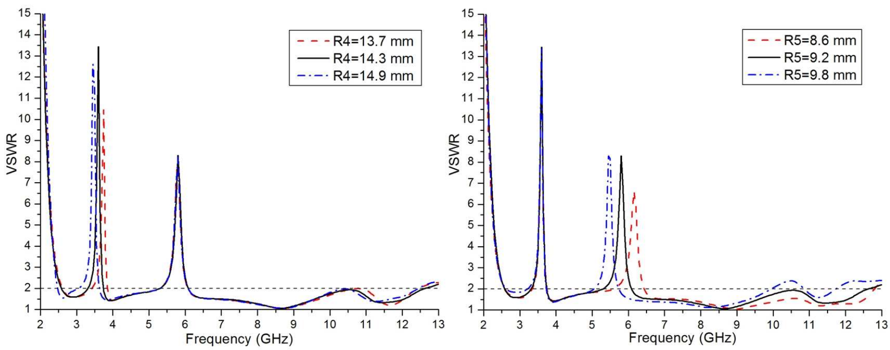


Figure 6. Simulated and measured VSWR curves of the proposed antenna.



(a) (b)

Figure 7. Simulated VSWR curves for different values of (a) α and (b) β.



(a) (b)

Figure 8. Simulated VSWR curves for different values of (a) $R4$ and (b) $R5$.

slot on the 3.5 GHz notched band. It can be observed that the notched band shifts toward lower frequency as α increases. There is also a similar relationship between the angle β and the 5.8 GHz notched band, which is illustrated in Figure 7(b). Figure 8 exhibits the effect of various radiuses of the slot/strip on the corresponding notched band. It shows that the 3.5 GHz and 5.8 GHz notch frequencies decrease with the increasing of $R4$ and $R5$, respectively. The reason is that the variation of the radius affects the length of the slot/strip and the coupling between the radiator and the slot/strip. Additionally, the interaction of the two rejected bands is slight, which makes it easy to adjust the notched bands respectively.

The simulated and measured radiation patterns of the proposed antenna at the frequencies of 3 GHz, 5 GHz, 7 GHz and 9 GHz are given in Figure 9. According to these curves, it can be seen that the antenna exhibits a nearly omni-directional radiation pattern in the H-plane (x-z plane) and a bidirectional radiation pattern in the E-plane (y-z plane), with a little degradation at the higher frequencies. The causes are probably the increase of the electrical length and the introduction of a higher cross-polarization with the increasing of the frequency.

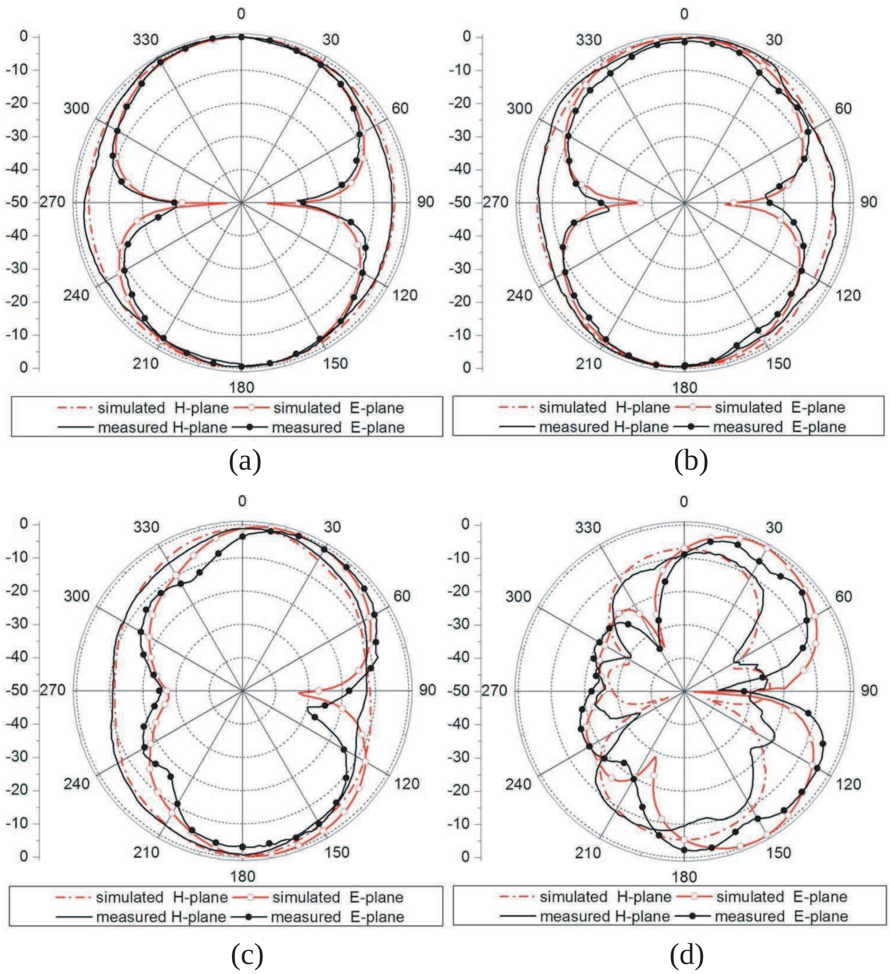


Figure 9. Simulated and measured radiation patterns of the proposed antenna at (a) 3 GHz, (b) 5 GHz, (c) 7 GHz and (d) 9 GHz.

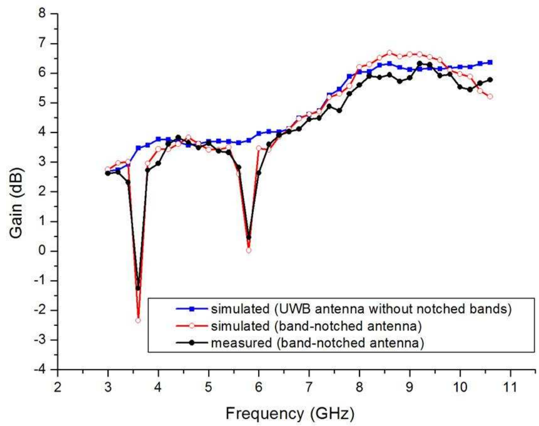


Figure 10. Peak gains of the UWB antenna and the proposed antenna.

In addition, peak gains against frequency of the UWB antenna (shown in Figure 2(a)) and the proposed antenna are plotted in Figure 10. Compared with the stable gain variation from 2.7 to 6.36 dBi of the UWB antenna, the proposed antenna exhibits sharp gain decreases at the center frequencies of the two notched bands. Therefore, the antenna has good dual band-notched characteristics.

4. CONCLUSION

A circular wide-slot UWB antenna with novel dual band-notched structures has been proposed in this paper. Arc-shaped slot and strip are introduced to achieve band-notched functions at 3.38–3.71 GHz and 5.39–6.27 GHz bands. The measured results of the fabricated antenna show that it can operate well over the UWB band with an effective rejection to the 3.5 GHz WiMAX and 5.8 GHz WLAN bands.

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