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COMPACT UWB ANTENNA WITH DUAL BAND-NOTCHED CHARACTERISTICS

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Abstract—A compact ultrawideband (UWB) antenna with 3.5/5.2 GHz band-notched characteristics is proposed. The proposed antenna is composed of a half elliptic annulus radiation element fed by microstrip line and a step-shaped ground plane with truncated corners. By inserting closed-looped resonating structure onto the radiation patch and connecting open-looped resonator on the back side with patch via metallic hole, the dual notched frequency bands are achieved. The numerical and experimental results exhibit a wide impedance bandwidth ranging from 3.08 to 11 GHz with the dual notched bands around 3.5 and 5.2 GHz. Additionally, nearly omni-directional radiation patterns, moderate gain, and small group delay variation are also obtained.

1. INTRODUCTION

Wireless personal area network (WPAN) is one of the most popular applications of modern wireless technology. UWB technology is developed to reach requirements of the WPAN network using 3.1–10.6 GHz frequency band, approved by FCC [1]. In such a way, UWB antennas have received increasing attentions. Planar monopole antennas have been found as good candidates for UWB applications owing to their attractive advantages, such as wide impedance bandwidth, ease of fabrication, and acceptable radiation properties. Recently, several shaped monopole configurations, such as square, circular, elliptical, annular ring and spline shape, have been proposed for UWB applications [2–6]. However, the UWB may cause potential interference with the existing operating bands, such as: the wireless local area network (WLAN) for IEEE802.11a operating at 5.15–5.35

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and 5.725–5.825 GHz, worldwide interoperability for microwave access (WiMAX) system covering 3.4–3.690 GHz. Therefore, band-notched performance is appreciable and necessary for avoiding potential interference in those frequency bands [7, 8]. Some studies have shown that embedding U-shaped, Y-shaped, and L-shaped slots on the patch or ground plane can be used to achieve this effect [9–13]. Some others suggest that adding parasitical structure or folded strips on the radiator could realize band rejection properties [14, 15]. Additionally, by adding either a resonator load or a split-ring resonator (SRR) in the antenna structure, the undesired frequencies can also be rejected [16, 17].

In this paper, a compact half elliptic annulus monopole antenna with dual band-notched characteristics is presented for UWB application. In the proposed structure, closed-looped resonating structure is inserted onto the radiator to achieve the band-notched characteristic at around 3.5 GHz. Meanwhile, the open-looped resonator on the back side of antenna substrate rejects at around 5.2 GHz. Both numerical and experimental results are presented and discussed as follows, such as band-notched characteristic, radiation pattern, antenna gain, and group delay.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed antenna, which is printed on FR4 substrate with relative permittivity of 4.4 and thickness of 1.5 mm. The proposed antenna with total size of $24 \times 27\,\text{mm}^2$ is composed of a half elliptic annulus radiation element and a modified ground plane. The width of the microstrip feed line is $W_2 = 3.1$ mm to

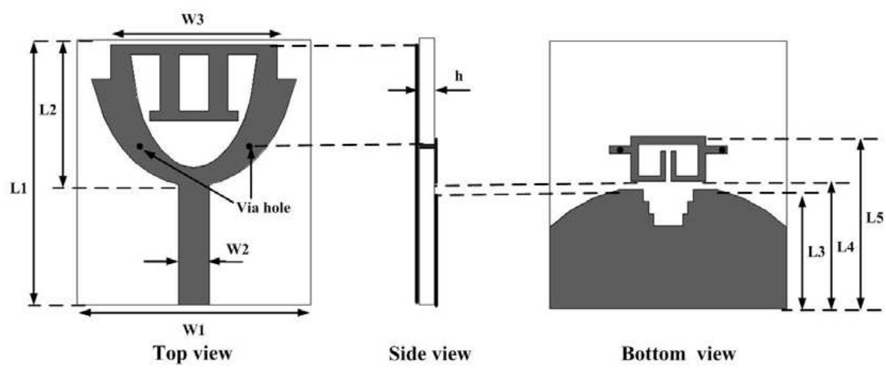


Figure 1. Geometry of the proposed antenna with notched bands.

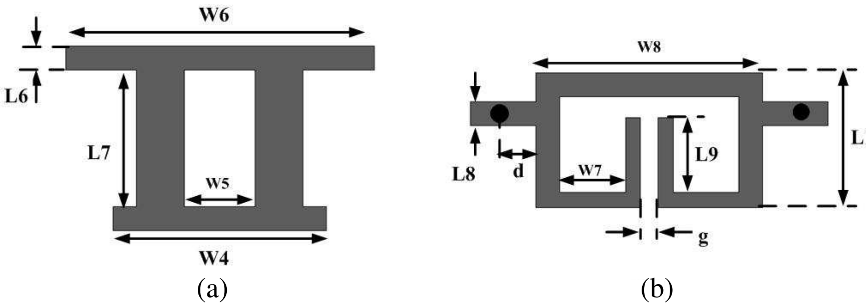


Figure 2. Resonating structure. (a) Closed-looped structure. (b) Open-looped structure.

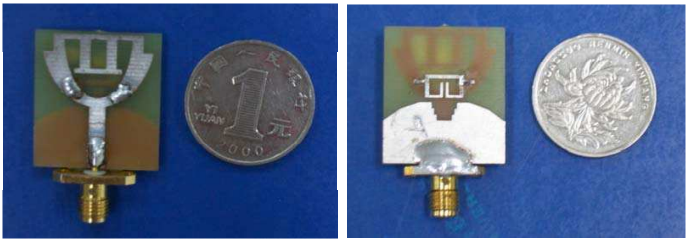
implement 50 Ohm characteristic impedance. In the proposed design, the half elliptic ring patch and the step-shaped ground plane make a joint effect to enhance the impendence matching over a wide frequency band. In order to implement band-notched characteristic at WIMAX, a closed-looped resonating structure is inserted to the radiated patch, as shown in Figure 2(a). Figure 2(b) demonstrates the open-looped resonator on the back side of antenna substrate, which is connected to the radiated patch via metallic hole, aiming to achieve band-rejected property at WLAN.

3. RESULTS AND DISCUSSIONS

An electromagnetic software package, Ansoft HFSS v11 is utilized to analyze and optimize the parameters of proposed antenna. Detailed dimensions of the proposed antenna are listed in Table 1. As a practical example, a prototype of the proposed antenna is manufactured for validating the feasibility of design. Figure 3 presents the photograph of fabricated antenna, and a 50 Ω-SMA connector is used to feed the antenna, which is measured using WILTRON37269A vector network analyzer.

Table 1. The optimal antenna parameters (Unit: mm).

W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	g	d
24	3.1	17	9.0	3.0	13	2.2	7.6	0.6	1.3
L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}
27	14.7	12	12.9	17.4	1.0	5.8	0.8	2.5	4.5



(a) (b)

Figure 3. Photograph of manufactured proposed antenna. (a) Top view. (b) Bottom view.

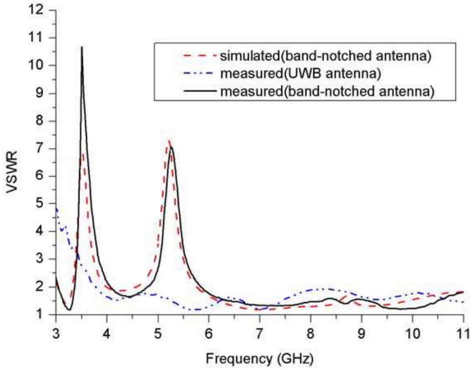


Figure 4. Simulated and measured VSWRs of proposed antenna.

The simulated and measured voltage standing wave ratios (VSWRs) of the proposed antenna are shown in Figure 4. Good agreements can be observed between the simulation and measurement results. Moreover, it can be seen that the proposed antenna achieves notched frequency bands at around 3.5 GHz and 5.2 GHz, covering the WiMAX and WLAN working bands. Meanwhile, the band-notched antenna still performs good impedance-matching at other frequencies in the UWB band. As a comparison, the VSWR characteristic of the reference UWB antenna without notched band is also plotted in the figure. It is worth noticing that the proposed band-notched antenna has better VSWR compared with that of reference UWB antenna at lower end of the frequency band, maybe it is the result of closed-looped resonating structure inserted onto the radiator. The closed loop not only rejects the band at 3.5 GHz but also increases the overall effective electrical length of the antenna in the limited patch area, which plays

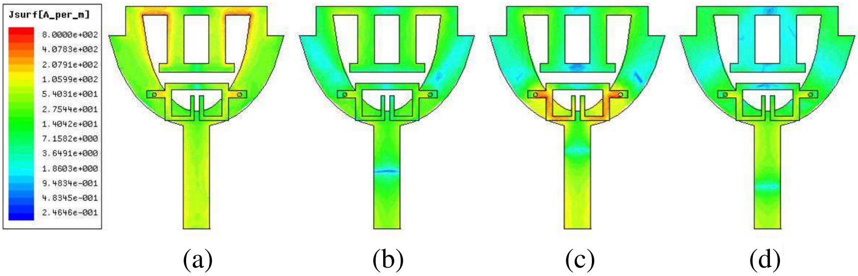


Figure 5. Surface current distribution at four different frequencies: (a) 3.5 GHz, (b) 4 GHz, (c) 5.2 GHz, (d) 7 GHz.

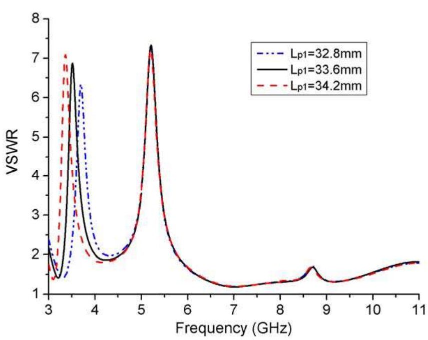


Figure 6. Simulated VSWR characteristics for the length of closed-looped structure.

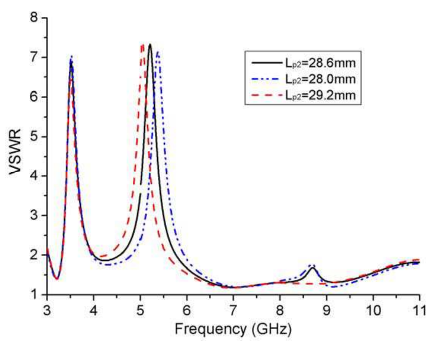


Figure 7. Simulated VSWR characteristics for the length of open-looped structure.

a significant role to extend the bandwidth at lower band.

In order to further understand the behavior of the resonating structure, especially in the rejected bands, surface current distribution at four different frequencies, 3.5, 4, 5.2, and 7 GHz, are simulated and displayed in Figures 5(a)–(d), respectively. It is seen that the current distribution around closed-looped resonating structure is relatively constant at 4, 5.2, and 7 GHz, while that increases drastically at 3.5 GHz, which implies that the closed loop resonates near 3.5 GHz. On the other hand, the obviously increased current distribution around open loop emerges at 5.2 GHz, indicating that the open loop resonates near 5.2 GHz. Thus, both from the VSWR characteristic and the simulated surface current distribution, it can be concluded that the closed-looped and open-looped resonator introduce the frequency notched function.

Parametric analysis is made for further study. The geometries of closed-looped and open-looped resonating structure have been illustrated in detail. As illustrated in Figure 2, the total length of the closed loop and open loop can be described as $L_{p1} = W_4 + W_6 + 2 \times L_7$

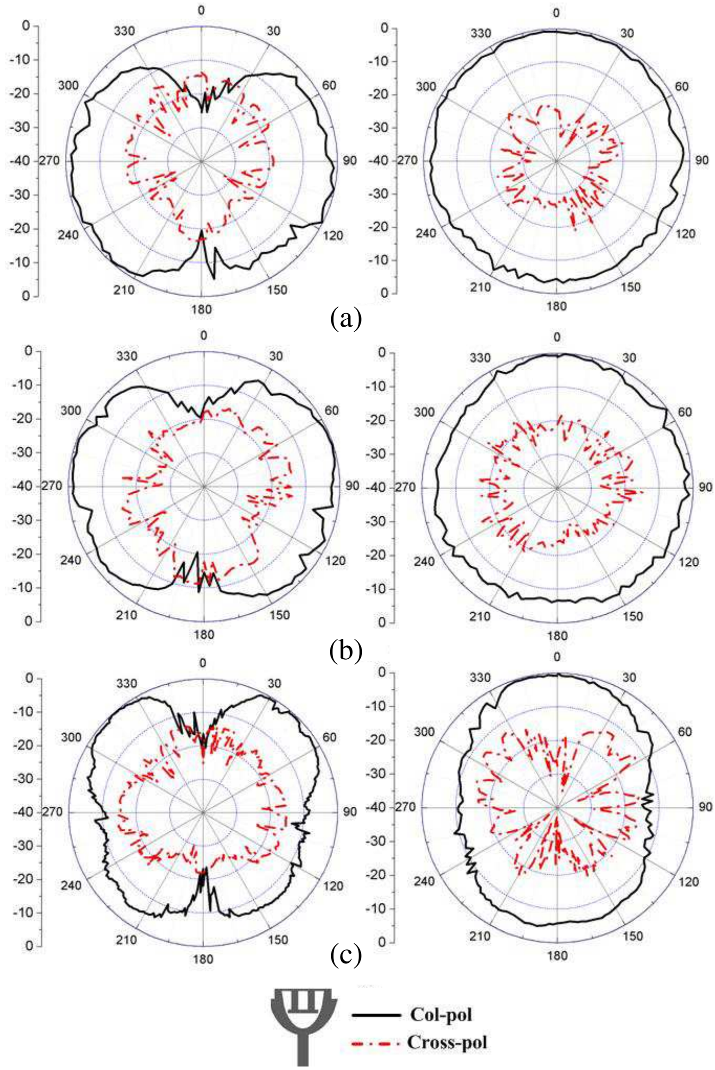


Figure 8. Measured E-plane (left) and H-plane (right) radiation patterns (a) 4 GHz, (b) 6 GHz, (c) 9 GHz.

and $L_{p2} = W_8 + 2 \times (L_{10} + L_9 + W_7 + d)$, respectively. All the other antenna descriptors have been kept fixed to the optimized values. By varying L_7 and d the overall length of closed loop and open loop are severally modified. Figure 6 shows the effect of the various total length of closed-looped resonating structure on the VSWR versus frequency, suggesting that the length of the closed loop can be used to adjust the rejected frequency band. And the centre frequency of the rejected band moves toward the lower frequency as the increase of L_{p1}. On the other hand, the behavior of VSWR for different values of L_{p2} is also shown in Figure 7. As observed and expected, increasing the resonator length leads to the shift towards the lower frequencies of the rejection band.

The radiation patterns of the fabricated antenna are measured at 4 GHz, 6 GHz and 9 GHz, as shown in Figure 8. From an overall view, nearly omni-directional radiation patterns in the H plane and dipole-like radiation patterns in the E plane are obtained. The measured gains of the proposed antenna and the reference antenna indicate that the sharp gain decreasing occur at the frequency bands around 3.5 GHz and 5.2 GHz, as illustrated in Figure 9. Another critical parameter for UWB antenna, the group delay, which measures the time signal distortion introduced by the antenna, is also measured in this design. Group delay and transfer function are depicted in Figure 10, which are measured by using two identical fabricated prototypes placed with a distance of 300 mm. As observed, small group delay variation and transfer function fluctuation across the operating band are achieved, and greater varying ranges are also obtained in the notched frequency bands.

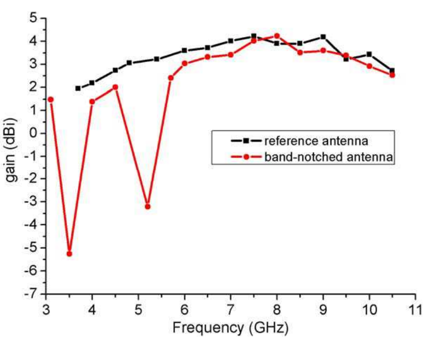


Figure 9. Measured gains of the proposed antenna.

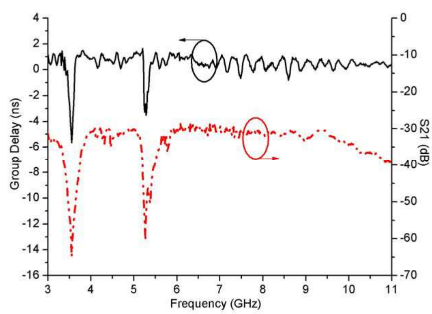


Figure 10. Measured transfer function and group delay of the transfer system.

4. CONCLUSION

A compact UWB planar monopole antenna with dual band-notched characteristics has been proposed and investigated. The proposed antenna exhibits UWB performance on impedance bandwidth ranged from 3.08 to 11 GHz, while providing band-notched properties at WIMAX and WLAN bands. The realized methodologies are simple by inserting the closed-looped resonating structure onto half elliptic annulus radiation element and connecting open-looped resonator to patch via metallic hole. Additionally, nearly omni-directional radiation patterns, stable gain, and small group delay variation are also obtained. Thus the proposed antenna may be promising for UWB applications.

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