A Novel Compact Monopole Antenna with Triple High Quality Rejected Bands for UWB Applications

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Abstract **─** A novel compact ultra-wideband (UWB) monopole antenna with triple high quality notch bands is presented. By attaching a T-shaped strip to the semicircular patch on the front side and adding a rectangular ring on the back side, a notch band for WiMAX is obtained. Furthermore, by symmetrically etching a pair of curved slots and a pair of L-shaped slots in the radiation patch, band rejected filtering properties in the lower WLAN band and upper WLAN band are also achieved. Experimental results show that the designed antenna, with compact size of 24×28mm^2 has an impedance bandwidth of 2.75GHz-14.7GHz for VSWR<2, except three frequency stop bands of 3.3GHz-3.75GHz, 4.77GHz-5.4GHz,and 5.7GHz-6.23GHz. Moreover, good omnidirectional radiation patterns in the H-plane are also obtained.

Index Terms **─** Compact, monopole antenna, rejected bands, UWB applications.

I. INTRODUCTION

Ultra-wideband (UWB) technology has undergone many significant developments in recent years [1-2]. However, there still remain many challenges in making this technology alive up to its full potential [3-4]. Planar monopole antennas have been found to be excellent candidates to operate in UWB systems, owing to wide bandwidth, simple structure and omnidirectional radiation patterns [5]. However, over the UWB frequency band ranging from 3.1GHz to 10.6GHz, other frequency bands exist such as WiMAX band (3.3GHz-3.7GHz), and WLAN band (5.15GHz-5.35GHz, 5.725GHz-5.825GHz). Therefore, many band notched technologies [6-9] have been reported such as etching a pair of asymmetrical spurlines on the feedline [10], embedding a pair of Γ-shaped stubs in the patch and G-slot on the ground plane [11]. Nevertheless, all these antennas have only two notch bands and especially have only one notch band for WLAN in 5.15GHz-5.825GHz. This reveals that potential interference from other narrow bands may still exist and the frequency range between 5.35GHz-5.725GHz cannot be utilized with these antennas.

In this paper, a novel compact monopole UWB antenna with three independent notch bands is presented. By attaching a T-shaped strip to the semicircular patch on the front side and adding a rectangular ring on the back side, a notch band of 3.3GHz-3.7GHz is achieved. To realize another two narrow bands of WLAN centered at 5.2GHz and 5.8GHz, a pair of curved slots and a pair of L-shaped slots are etched in the patch symmetrically. Details of this antenna are presented and the measured results are given to demonstrate its performance.

II. ANTENNA DESIGN

Fig. 1(a) and (b) show the geometry of the proposed band notched antenna, which is fabricated on a FR4 substrate of thickness 1.6mm and permittivity 4.5. The width of the feeding line is fixed at 3.2mm to achieve 50Ω characteristic impedance (at the centre frequency). The proposed compact band notched antenna is based on a simple circular monopole antenna. The notches defected on the ground plane is designed to achieve better impedance matching over the entire UWB frequency band, because the modified truncation creates a capacitive load that neutralizes the inductive nature of the patch to produce nearly pure resistive input impedance. To realize the

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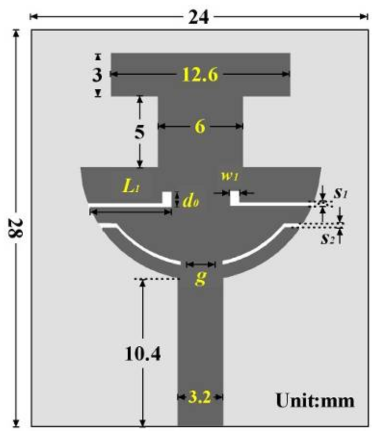
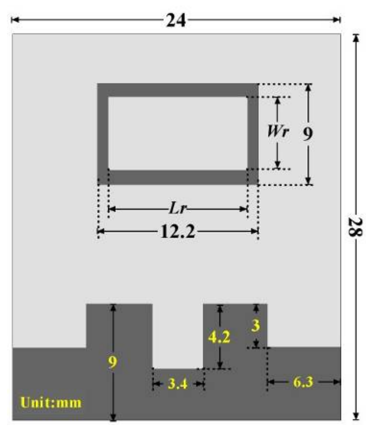
notch band for WiMAX band, a T-shaped strip was connected to the semicircular patch on the front side and a rectangular ring was added on the back side. Therefore, an extra resonator was constructed. Adjusting the related dimensions to make it resonates at the desired notch frequency (3.5GHz). Because of the symmetrical characteristics of such resonator, the fields yielded by the currents concentrated in the resonator cancel each other. As a result, a steep rejection property is achieved.



(a)Front view



(b)Back view

Fig. 1. Geometry of the proposed band notched antenna: (a) front view. (b) back view.

Similarly, the second notch band for lower WLAN band (5.15GHz-5.35GHz) comes from the pair of L-shaped slots on the patch and the third rejection band for upper WLAN band (5.725GHz-5.825GHz) is attributed to the two curved slots on the patch.

III. RESULATS AND DISCUSSION

The proposed compact monopole antenna with triple high quality rejected bands is constructed, and the numerical and experimental results are presented and discussed. The parameters of this proposed antenna are studied by changing one parameter at a time and fixing the others. To fully understand the behavior of the antenna's structure and to determine the optimum parameters, the antenna was analyzed using the commercial software CST. And a photograph of some fabricated prototypes with optimal design, i.e. d_0=1mm, L_1=5.9mm, d=0.8mm, s_1=0.1mm, s_2=0.2mm, w_1=0.7mm, L_r=10.8mm, W_r=7.4mm, is shown in Fig. 2.

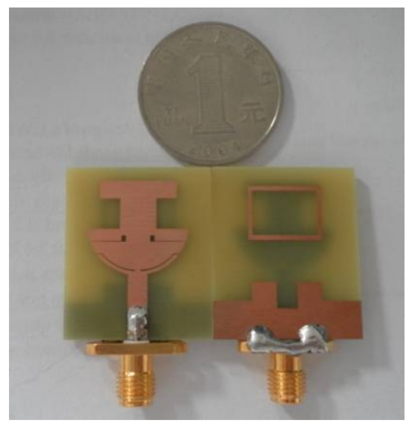


Fig. 2. Prototype of the proposed band notched antenna.

In order to minimize the physical size of the proposed antenna, the upper half circular patch was cut first and then a T shaped strip is attached to the lower half circular patch. As a result, the maximum equivalent electrical length is effectively lengthened thus compact size can be achieved. Furthermore, by adding a rectangular ring on the back, a notch band is achieved. Fig. 3 exhibits the effects of the rectangular ring to the performance of the proposed antenna. And from the results it can be observed that the inner length of the rectangular L_r have only impact on the first notch band. With the parameter L_r decreases from 11.6mm to 10.0mm gradually, the first rejected band shifts right correspondingly, while the other two rejected bands almost remain still.

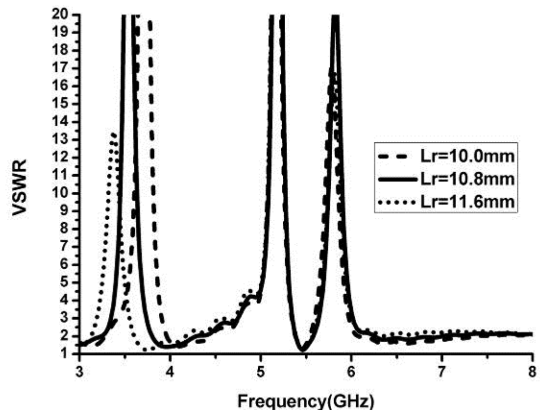


Fig. 3. Simulated VSWRs for the proposed antenna with different length of *Lr*.

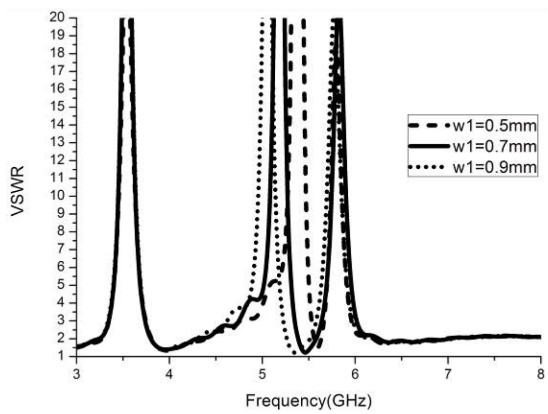


Fig. 4. Simulated VSWRs for various width w_1.

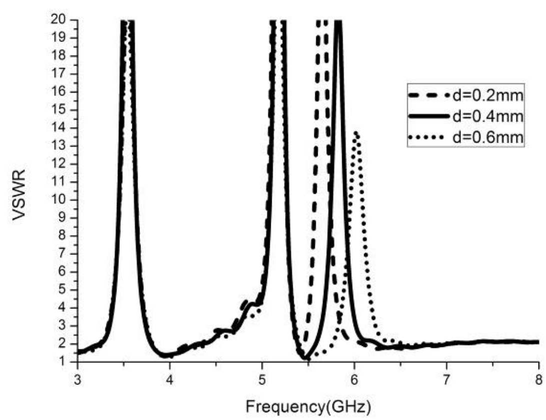
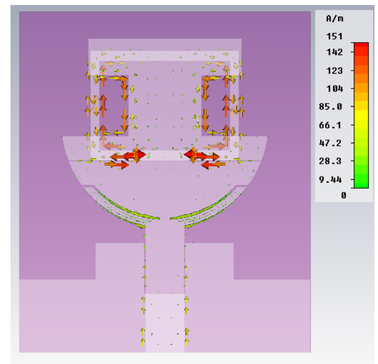
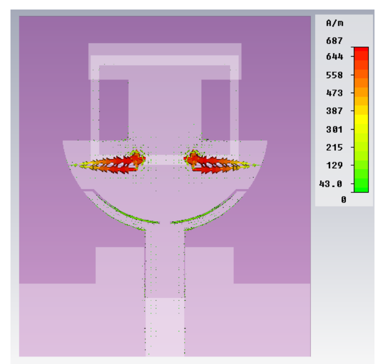


Fig. 5. Simulated VSWRs for various distances *d*.

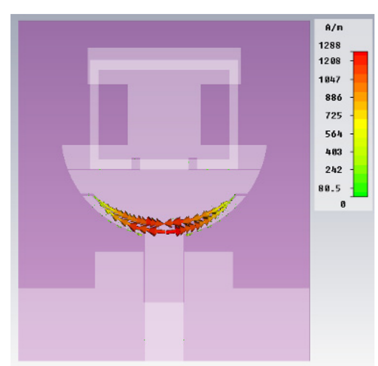
Moreover, the VSWRs for various width w_1 are plotted in Fig. 4. It can be observed that the parameter w_1 has only great impact on the second notch band. And with 'w_1' increases from 0.5mm to 0.9mm, the second notch band shift left gradually. Similarly, the parameter *d* mostly affects the third notched band alone, as shown in Fig. 5. And with d_1 increase from 0.2mm to 0.6mm, the third rejected band shifts right while the other two notch bands stand still.



(a) At 3.5GHz



(b) At 5.2GHz



(c) At 5.8GHz

Fig. 6. The current distribution at different frequencies: (a) at 3.5GHz. (b) at 5.2GHz. (c) at 5.8GHz.

The simulated current distribution of the proposed antenna at 3.5GHz, 5.2GHz, and 5.8GHz for the optimal design is presented in Fig. 6 (a), (b) and (c), respectively. It can be seen that the current at the notch frequencies are symmetrically distributed. Accordingly the radiation fields generated by the oppositely directed currents cancel each other at the notch frequencies. Thus notch bands are obtained. Furthermore, the current is mainly distributed along the T-shaped strip and the rectangular ring at 3.5GHz, and distributed along the edge of the L-shaped slots at 5.2GHz. While at 5.8GHz the current is mostly exists along the curved slots. As a result, the three notch bands are independent adjustable, which is very convenient when it comes to specific application.

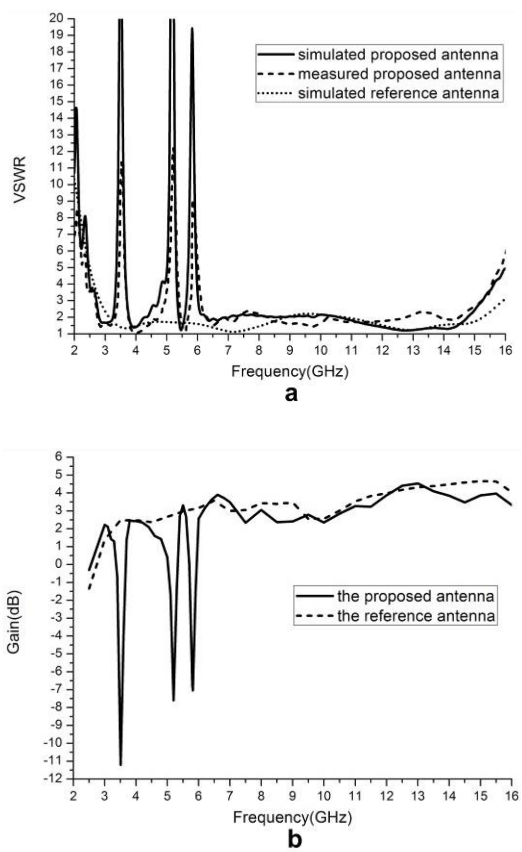


Fig. 7. (a) Simulated and measured VSWR for the proposed antenna. (b) The antenna gain of the proposed antenna and the reference antenna.

The simulated and measured VSWR of the proposed band notched UWB antenna is shown in Fig. 7 (a). Furthermore, the simulated VSWR of the UWB antenna without notched characteristics (the traditional circular monopole antenna) is also shown for comparison. It can be observed that the designed antenna has wideband performance of 3GHz-15GHz for VSWR<2, except three steep rejection bands of 3.3GHz-3.75GHz, 4.77GHz-5.4GHz, and 5.7GHz-6.23GHz. And the realized gain showed in Fig. 7 (b) exhibits three sharp gain decreases at 3.3GHz-3.75GHz, 4.77GHz-5.4GHz, and 5.7GHz-6.23GHz. Particularly, compared with other band notched antennas, the proposed antenna with VSWRs>19 at all the three notch bands demonstrates even much better rejection characteristics. Furthermore, the frequency range between 5.4GHz-5.7GHz can be utilized with the proposed antenna, which is rejected by other WLAN band notched antennas. Figure 8 shows the radiation patterns of the proposed antenna at 3.1GHz, 5.4GHz, and 7.5GHz, respectively. It can be seen that the proposed antenna exhibits a fairly good omnidirectional radiation pattern in the H-plane and a dipole-like radiation pattern in the E-plane.

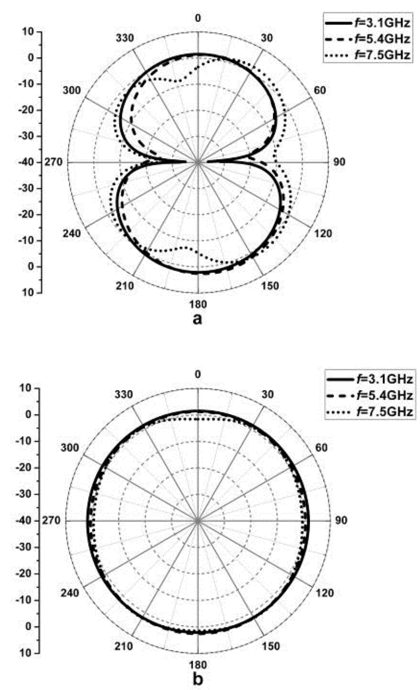


Fig. 8. The radiation patterns of the proposed antenna: (a) E plane. (b) H plane.

Furthermore, as a very important aspect of a practical antenna, the efficiency of the proposed antenna is also investigated. The simulated efficiency of the proposed band notched antenna is shown in Fig. 9. And the efficiency of the reference UWB antenna is also shown for comparison. It can be observed that the efficiency of the reference UWB antenna without notched characteristics is mostly above 80% in the operation band. However, the efficiency of the proposed band notched antenna is not more than 10% in the three notch bands, while almost remain the same in the operation band.

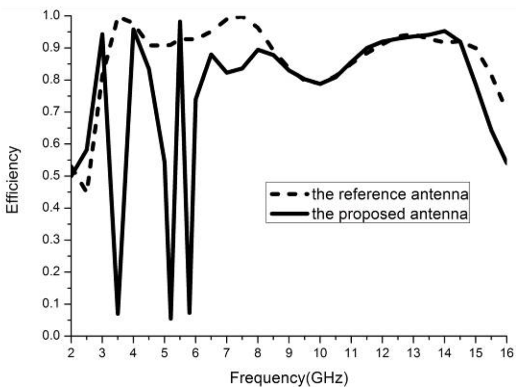


Fig. 9. The efficiency of the proposed antenna and the reference antenna.

IV. CONCLUSION

A novel compact UWB printed monopole antenna with triple high quality rejected bands has been presented. The notch bands are realized by attaching a T-shaped strip to the semicircular patch on the front side and adding a rectangular ring on the back side, etching a pair of L-shaped slots and a pair of curved slots in the radiation patch. Both wide bandwidth and good monopole-like radiation patterns are obtained. The proposed antenna's features such as sufficient and independent adjustable band notches, higher rejection peak, wide bandwidth, and omnidirectional radiation patterns, show that the proposed antenna is a very good candidate for UWB applications.

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