Design of a Compact UWB Band-notched Antenna with Modified Ground Plane

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***Abstract*- A compact ultra-wideband (UWB) antenna with dual band-notched characteristics is presented. The proposed antenna consists of a folded fork-shaped radiator and a modified ground plane. The modified ground plane with trapezoid shaped slots on its top edge effectively increases the bandwidth of the proposed antenna. To avoid potential interferences, the arms of the forked-shaped radiator are folded to form a pair of $\lambda_g/4$-coupled lines, and a $\lambda_g/2$ semicircular slot is embedded on the radiator. The antenna, having an entire size as small as 30 × 25 mm^2, achieves an operation frequency band from 3GHz to 17GHz with good rejection to the Worldwide Interoperability for Microwave Access (WiMAX) and the wireless local area network (WLAN) bands in both simulated and measured results.**

I. Introduction

Ultra-wideband technology has been widely used in wireless communication owing to its high data transmission rate, large bandwidth, and short-range characteristics. As a key component of UWB system, UWB antenna has gained increasing attentions. Various planar UWB antennas with wide impedance bandwidth and good radiation characteristics have been proposed and investigated. However, most of them only focus on the band of 3.1 – 10.6 GHz [1]-[4]. On the other hand, their sizes are relatively large, which cannot meet the demand of the consumer electronics applications. Although literature [5] proposed a fairly compact UWB antenna with a size of 11 × 20.5 mm^2, the -10dB impedance bandwidth is only from 3.1 to 5 GHz. An improved design of a planar elliptical dipole antenna for UWB applications has also been developed recently [6]. By using elliptical slots on the dipole arms, the antenna has achieved an operating bandwidth of 94.4%. However, the antenna does not process a physically compact size, having dimensions of 106 × 85 mm^2. Besides the above mentioned challenge, UWB antenna also needs to solve electromagnetic interference (EMI) problem since there exist several undesired radio signals within UWB bandwidth, such as WiMAX (3.3-3.6 GHz) and WLAN (5.15-5.825 GHz).

Based on these points, a novel UWB planar monopole antenna with compact size, wider bandwidth and dual notched bands is presented in this letter. The antenna has a modified ground plane which effectively increases the operation bandwidth. To achieve dual band-notched function without increasing the dimensions of the antenna, the arms of the forked-shaped radiator are folded to form a pair of $\lambda_g/4$-coupled lines, and a $\lambda_g/2$ semicircular slot is embedded on the radiator.

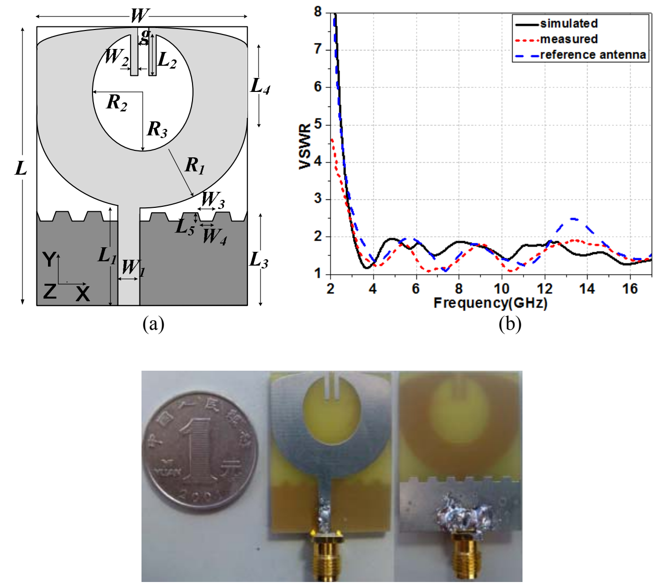
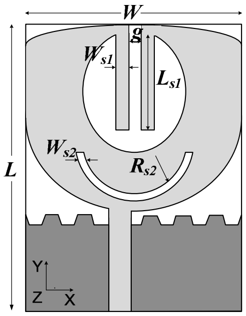


Figure 1. Proposed compact UWB antenna. (a) Configuration with the dimensions: $W = 25$, $L = 30$, $H = 1.6$, $W_1 = 2.56$, $L_1 = 10.65$, $W_2 = 1$, $g= 1$, $L_2 = 4.8$, $L_3 = 11$, $L_4 = 6.85$, $R_1 = 12.5$, $R_2 = 6$, $R_3 = 7$, $W_3 = 2.2$, $W_4 = 1.6$, $L_5 = 1$. (b) Simulated and measured VSWR. (c) Fabricated prototype.

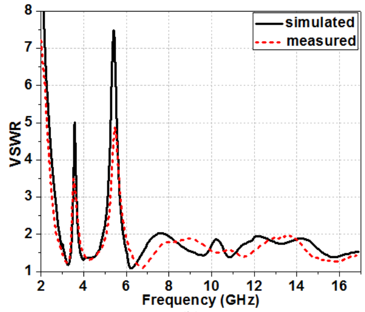
II. Antenna Configuration and Design

A. *Compact UWB Antenna Design*

Fig. 1(a) shows the geometry and dimensions of the proposed compact UWB antenna. The proposed radiator has rounded edge to broaden the bandwidth and to produce smooth transitions from one resonant mode to another. By folding the arms of the forked-shaped radiator, the current path is enlarged, thus the antenna demonstrates a fairly compact dimensions, 30×25 mm^2 in physical size. To enhance the impedance bandwidth, the ground plane is modified to a symmetrical sawtooth shape by cutting trapezoid shaped slots on its top edge. This antenna is printed on the FR4 substrate with thickness of 1.6 mm, relative dielectric constant ε_r =4.4, and loss tangent of 0.02. The antenna is fed by a 50Ω microstrip line and connected to a SMA connector, as shown in Fig. 1(c). The antenna was measured with an Agilent N5230A vector network analyzer. Both simulated and measured VSWRs of the proposed UWB antenna are shown in



(a)



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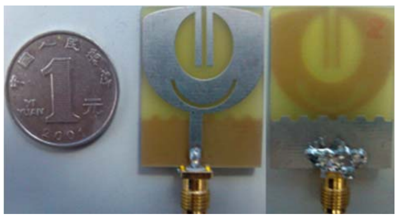


(c)

Figure 2. Proposed dual band-notched UWB antenna. (a) Configuration with the dimensions: Ws1 = 1.3, Ls1 = 11.5, g = 1, Ws2 = 0.8, Rs2 = 6. (b) Simulated and measured VSWR. (c) Fabricated prototype.

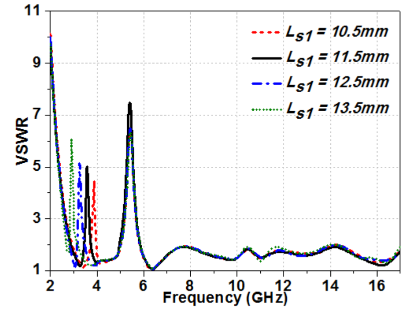
Fig. 1(b), where the primitive UWB antenna with regular ground plane is also given as a reference. The measured result clearly indicates that the proposed antenna with sawtooth shaped ground plane covers an ultra wide impendence bandwidth (VSWR < 2) of 3.1 to more than 17 GHz, providing a bandwidth of 13.9 GHz, while the reference antenna with regular ground plane only provides an impendence bandwidth of 3.1 to 12.3GHz. Compared to the reference antenna, the proposed UWB antenna can enhance the bandwidth by 51% (4.7GHz).

B. Dual Band-Notched UWB Antenna Design

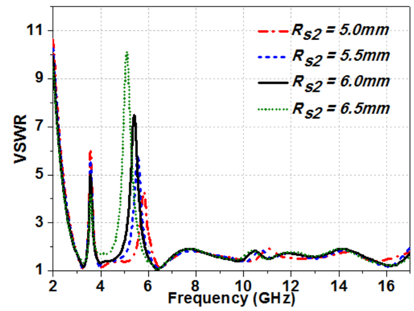
In order to mitigate EMI problems, we developed a dual band-notched UWB antenna, as shown in Fig. 2(a). The folded arms form a pair of coupled lines. When the length of the lines equal to $\lambda_g/4$, a notched band is created. By simply adjusting the length and gap width of the coupled lines, its notch frequency can be tuned to 3.5 GHz. To reject interference of WLAN band, a $\lambda_g/2$ semicircular slot is arranged in the middle of the patch close to the feeding strip. By adjusting the radius and gap width of the slot, its notch frequency can also be tuned easily.

The antenna was fabricated on FR4 substrate(Fig.2(c)). Measured and simulated VSWR values are compared in Fig. 2(b). Good agreement is observed. As can be seen, the proposed UWB antenna successfully exhibits dual notched bands of 3.3–3.63 GHz and 5.1–5.83 GHz, while it still maintains good impedance matching at the rest of the UWB band. It should be noted that the lowest operation frequency shifts to 2.7 GHz for the folded arms enlarge the current path.

To provide guidance for the design of notching structures, the effect of varying notching structures' parameters on



(a)



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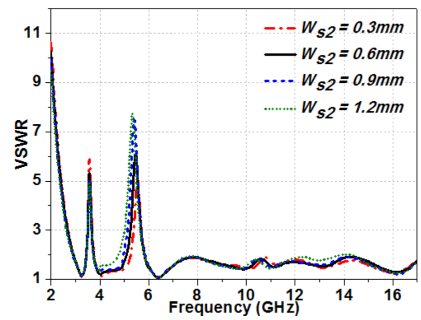
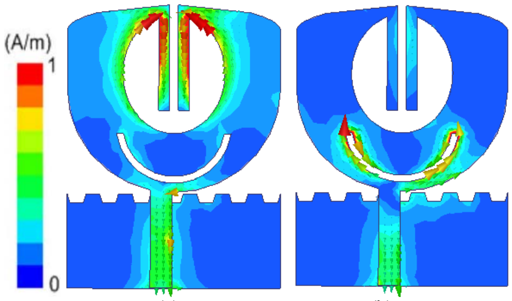


(c)

Figure 3. Effect of varying notching structures' parameters on notched bands. (a) Length L_{s1} of the coupled lines. (b) Radius R_{s2} and (c) width W_{s2} of the semicircular slot.

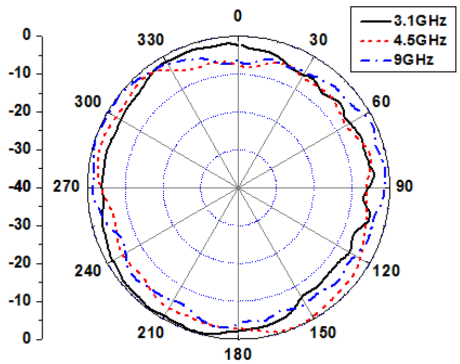
notched bands are analyzed. As shown in Fig. 3, the simulated lower notch band shifts to higher frequency with the decrease of length L_{s1} of the coupled lines, and the upper notch frequency increases as radius R_{s2} and width W_{s2} of the semicircular slot decrease. It should be noted that the variation of one notched band almost has no effect to the other, which means that these two notched bands can be controlled independently.

To explain the generation of the notched bands, surface current distributions are analyzed. As shown in Fig. 4(a), at the notch frequency of 3.5 GHz, most current concentrates along the folded arms of the radiator. While the current is maximum at one end, it is minimum at the other end, which is in agreement with the $\lambda_g/4$ dimension of arms. It can also be seen that the directions of the current vectors in the arms are opposite to that in the radiating patch, resulting in a notched

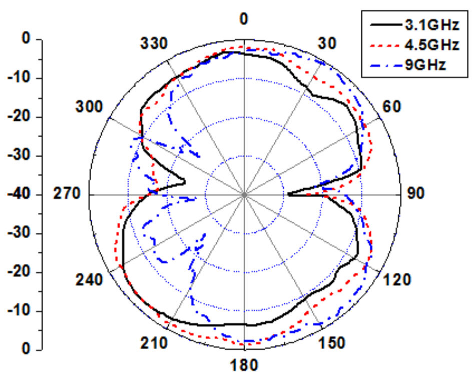


(a) (b)

Figure 4. Surface current distributions at (a) 3.5GHz and (b) 5.5 GHz.



(a)



(b)

Figure 5. Measured radiation patterns at (a) xz-plane and (b) yz-plane

band at 3.5 GHz. Similarly, as shown in Fig. 4(b), most current concentrates around the edge of the semicircular slot and flow in opposite directions (out of phase) between interior and exterior of the slot, causing a notched band at 5.5 GHz. The current distribution in Fig. 4(b) also clearly indicates that the length of the slot is about $\lambda_g/2$. It should be noted that, at the desired frequency, only the corresponding notching structure is active while the other is inactive, confirming the independence of the notched bands.

The measured radiation patterns of the proposed antenna at the passband (among dual notch bands) frequencies of 3.1, 4.5 and 9GHz in xz-plane (H-plane) and yz-plane (E-plane) are shown in Fig. 5. It can be observed that the antenna displays a good omnidirectional radiation pattern in xz-plane (H-plane), even at high frequencies.

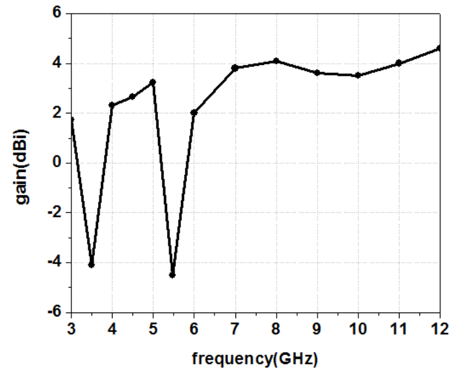
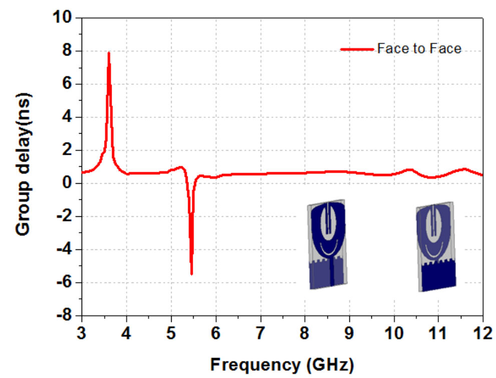
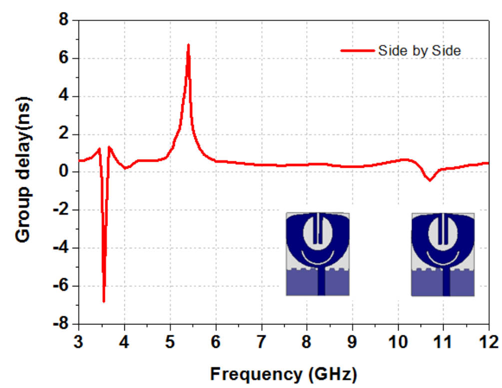


Figure 6. Measured gains of the proposed antenna



(a)



(b)

Figure 7. Simulated group delay of the proposed antenna for both (a) face-to-face and (b) side-by-side configurations.

Fig. 6 illustrates the measured maximum gain of the dual band-notched UWB antenna. Only several frequencies have been chosen for measurement. It is observed that gains are generally flat over the operating band of the antenna while significantly decrease at each notched band due to the frequency-rejected function.

Fig. 7 presents the simulated group delay of the proposed antenna for both face-to-face and side-by-side configurations. As can be seen, group delay is almost smooth in the entire UWB range except at the rejected bands, which demonstrates that the antenna is suitable for transmitting and receiving UWB pulses with minimum distortion.

III. Conclusion

In this research, a compact UWB band-notched antenna design has been proposed and fabricated. The antenna has a total size of 30 × 25 × 1.6 mm^3. The modified ground plane with trapezoid shaped slots on its top edge effectively increases the bandwidth of the proposed antenna. The measured result clearly indicates that the proposed antenna covers an ultra wide impendence bandwidth (VSWR < 2) of 13.9 GHz (3.1 to 17 GHz). By folding the arms of the forked-shaped radiator and embedding a semicircular slot on the radiator, dual effective and controllable notched bands are achieved. Good agreement is observed between the measured and simulated results, which demonstrates the proposed antenna a good candidate for multiple band-notched problem.

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