A Triple Band-notched UWB Antenna by Using an Arc-shaped Slot and a U-shaped Resonator Techniques

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Abstract— In this paper, an ultra-wideband (UWB) antenna with triple notch bands is proposed and well designed by etching an arc-shaped slot (ASS) on the fan-shaped radiating patch and integrating a U-shaped resonator (USR) alongside the microstrip feed signal line. The proposed antenna consists of a microstrip feed structure, a trapezoidal ground plane, a fan-shaped radiating patch, an ASS and a USR, which are printed on a thin substrate with dielectric constant of 2.65. The three band-notched characteristics are realized by the use of the ASS and USR, while the center frequencies of these notch bands are tunable by adjusting the dimensions of the proposed ASS and USR. By using these techniques, the proposed antenna can filter out unwanted narrowband signals from WiMAX, WLAN and RFID bands. The proposed antenna is well designed and extensively investigated. The experimental results are given to verify that the proposed antenna with a wide bandwidth, three designated band-notched functions and good omnidirectional radiation patterns, which is suitable for modern high data rate UWB communication applications.

1. INTRODUCTION

Ultra-wideband technology has been rapidly developed in recent years because of its advantages, such as large communication capacity, high data rate and low cost. UWB antenna is a key component to realize a UWB system. A planar half-sized unbalance dipole antenna has been presented to reduce the size of UWB antenna [1, 2]. However, many narrow band system overlap with the UWB system and have been widely used for a long time. Thus, these narrowband signals might interfere with the UWB system. To deal with this problem, a great number of UWB antennas with notch bands have been designed and investigated. By grooving various slots into different radiating patches or ground planes, which have been widely used in microstrip-fed and CPW-fed UWB antennas, notch bands can be obtained to suppress the potential inferences from the designated narrow band systems [3–8]. Unfortunately, it is difficult to design a UWB antenna with multi-notch-band and may destroy the ground plane. After that, several UWB antennas have been designed by using T-shaped stub and U-shaped parasitic strips, which can reduce the electromagnetic leaky caused by the slots [9]. By combing the slot and stub techniques, a fractal-shaped stub and an L-shaped slot have been employed to design a dual band-notched UWB antenna [10, 11]. However, the antenna is still large in size and cannot give resistant to triple interference signals.

For these reasons, a triple band-notched UWB antenna is proposed by grooving an arc-shaped slot (ASS) into the fan-shaped radiating patch and settling a U-shaped resonator (USR) alongside the microstrip feed signal line. The triple notch band characteristics are realized by using the ASS and USR and their center frequencies can be tuned by adjusting the size of ASS and USR. The performance of the proposed triple band-notched UWB antenna has been investigated by the use of the HFSS.

2. ANTENNA CONFIGURATION

The configuration of the proposed triple band-notched UWB antenna is depicted in Fig. 1, which is modified on the basis of the original model reported in [1, 2]. The proposed antenna consists of a fan-shaped radiation patch, a trapezoid ground plane, an arc-shaped slot with an open slit, an USR and a 50-Ohm microstrip feed structure. The proposed antenna is printed on a thin substrate with dielectric constant of 2.65 and loss tangent of 0.001. To realize the band-notched characteristics, an arc-shaped slot is etched in the fan-shaped radiation patch and the arc-shaped slot is riven into two segments by an open slit. In addition, a USR is adopted and settled alongside the microstrip feed signal line. By using the arc-shaped slot and the USR, three notch bands are produced. Also, the center frequencies of these three notch bands are tunable by adjusting the dimensions of the arc-shaped slot and the USR to render the proposed antenna to filter out unwanted signals from WiMAX, WLAN and RFID systems. The proposed antenna is optimized with a small size

of $L_1 \times L_2 = 35.6\,\text{mm} \times 20\,\text{mm}$, which is slightly smaller than the reference antenna [1, 2]. The optimized parameters are $ud = 0.5$, $cd = 0.3$, $ul = 5.1$, $uw = 4$, $hu = 8$, $w1 = 1.05$, $h = 20$, $g = 0.4$, $rf = 15$, $a = 16$, $b = 20$, $wc = 3$, $hc = 1.2$, $t = 0.4$, $w2 = 6$, $hs = 1$, $d = 4$, $dw = 3$, $ug = 0.45$ (unit: mm). The angle of the arc-shaped slot is 74° and it is riven into two segments at an angle of 38.7°.

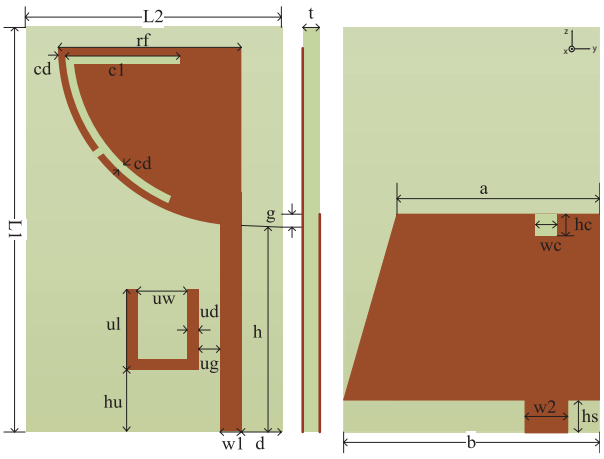


Figure 1: Physical structure of the proposed antenna.

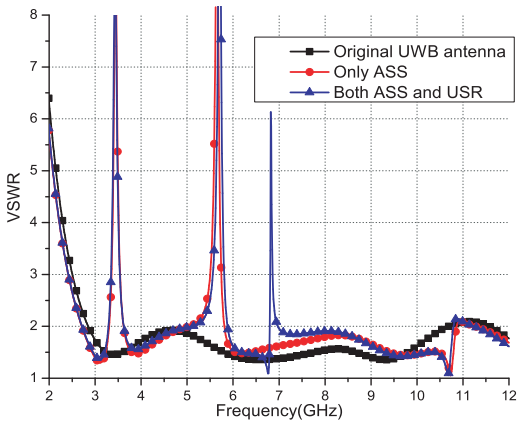


Figure 2: Notch characteristics of the antennas.

3. ANTENNA PERFORMANCE ANLYSIS

In this section, the performance of the proposed tri-band-notched UWB antenna is investigated by using the electromagnetic simulation software HFSS to verify the effectiveness of the design, including impedance characteristics, radiation patterns and the current distribution. Firstly, the band-notched characteristic is investigated by taking the ASS and USR into consideration to discuss their effects on impedance bandwidth. The effects of the ASS and USR are shown in Fig. 2. It can be seen that the proposed antenna without the ASS and USR is a UWB antenna, which has a bandwidth ranging from 2.71 GHz to 10.79 GHz with the VSWR less than 2. In this case, the proposed antenna can cover the entire UWB band released by FCC in 2002. When the proposed antenna has only ASS etched in the fan-shaped patch, it can give two notch bands at 3.4 GHz and 5.7 GHz to filter out the potential interferences from WiMAX and WLAN communication systems. When the proposed antenna integrates both the ASS and USR, it is a triple band notched UWB antenna to reject the undesired narrowband signals from WiMAX, WLAN and RFID systems.

Secondly, the key parameters are selected to discuss the effects on the band-notched characteristics. The effect of cl on the impedance bandwidth of the proposed antenna is shown in Fig. 3(a). It can be seen that the notch band at 3.4 GHz moves to the low frequency when the parameter cl increases from 5.2 mm to 7.8 mm. Also, the parameters of ul and uw have the similar effects on the corresponding notch band, which is mainly designed for the highest notch band and their performance are shown in Figs. 3(b) and (c). It is found that the center frequencies of the highest notch band moves from high frequency to low frequency, which is caused by the increased resonance length. Since the v determines the length of the two arc-shaped slots, it has been investigated and the effect of v is demonstrated in Fig. 3(d). We can see that the middle notch shifts to low frequency first and then moves to high frequency because parameter v can affect both the length of the slots. From the above discussions, we can say that the proposed antenna can give resistant to suppress the potential interferences from WiMAX, WLAN and RFID systems.

Next, the radiation patterns of proposed triple band-notched UWB antenna are studied at frequencies of 3.5 GHz, 4.5 GHz and 6.5 GHz and the results are demonstrated in Fig. 4. An omnidirectional radiation patterns are obtained in the xy-plane, while a standard eight-like radiation patterns are achieved in the xz-plane. When the frequency increases from 3.5 GHz to 6.5 GHz gradually, radiation patterns are deteriorated, which is caused by the asymmetric structure and the etched slot in the radiating patch which leaks electromagnetic waves.

Finally, surface current distribution is investigated and depicted in Fig. 5. It is observed that the current at 3.4 GHz is mainly focus on the upper segment of the etched slot, while the current at

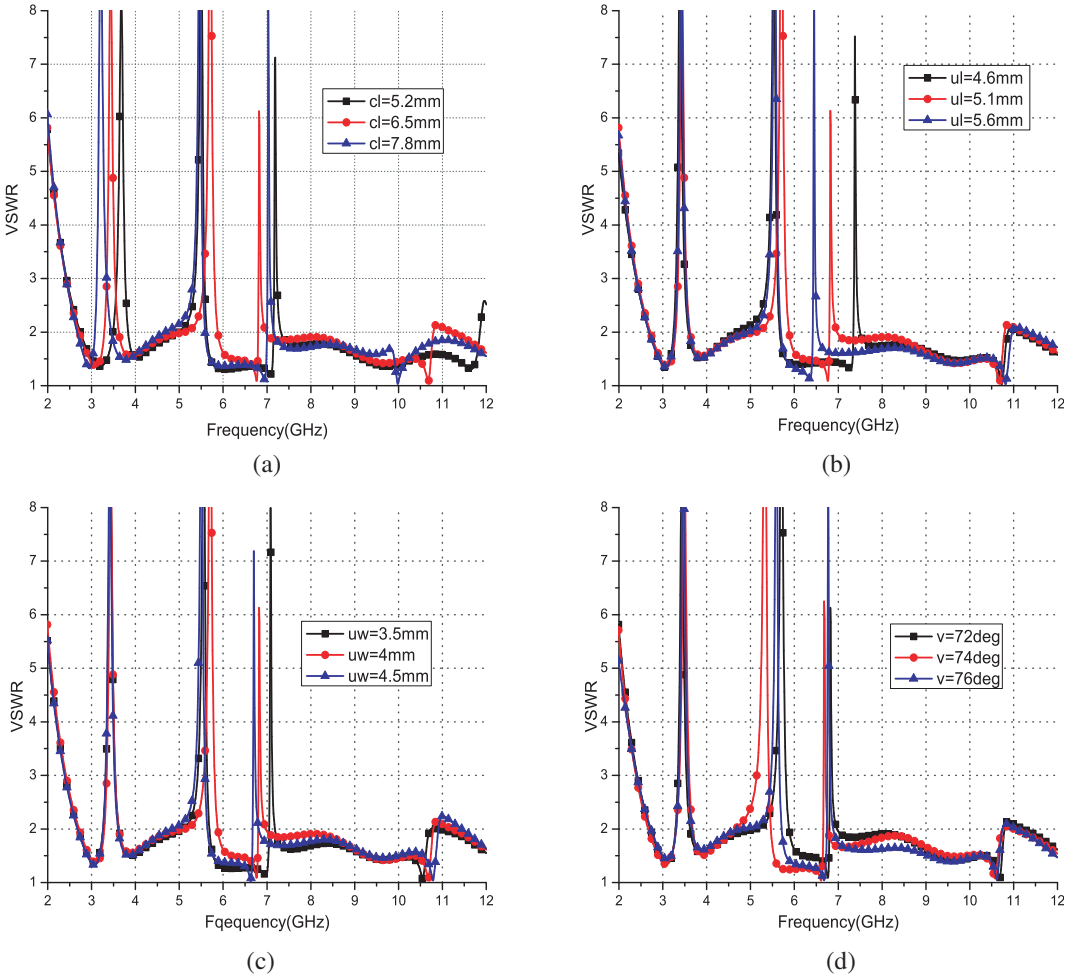


Figure 3: Effects of parameters on the proposed antenna. (a) Effects of cl. (b) Effects of ul. (c) Effects of uw. (d) Effects of v.

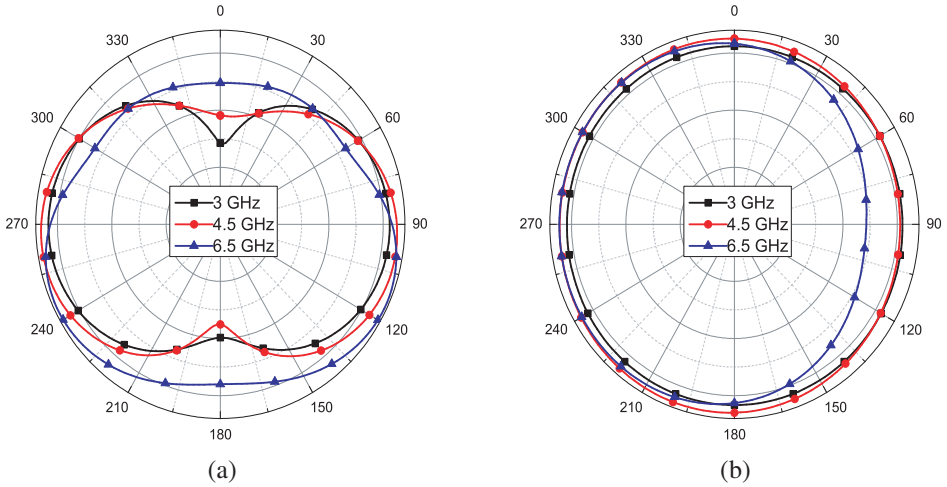
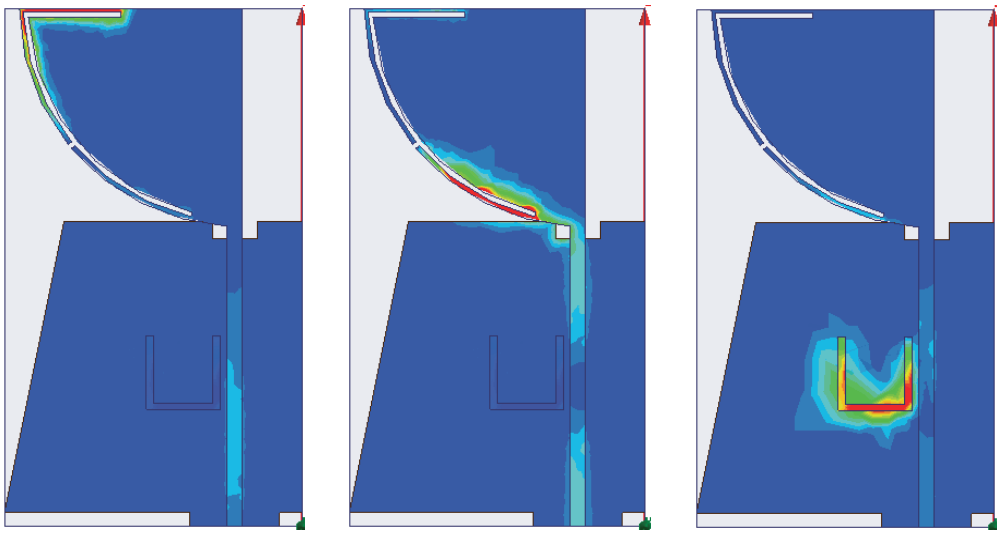


Figure 4: Radiation patterns of the proposed antenna. (a) xz-plane. (b) xy-plane.

5.7 GHz is mainly concentrate on the lower segment of the arc-shaped slot. At 6.8 GHz, the current is focused on the U-shaped resonator, while the current at the slots and the radiating patch are small. Thus, we can say that the antenna at these bands is non-resonance because the slots and the USR act as desired filters.



(a) (b) (c)

Figure 5: Surface current distributions of the proposed antenna. (a) 3.4 GHz. (b) 5.7 GHz. (c) 6.8 GHz.

4. CONCLUSION

A triple band-notched UWB antenna has been presented and well designed by the use of the HFSS. The notch bands are achieved by the slot which is split into two segments to generate two designated notch bands, while the other notch is obtained by the USR. From the simulation, we found that the proposed antenna can prevent the potential interferences from WiMAX, WLAN and RFID systems. The results showed that the proposed antenna has a wide bandwidth ranging from 2.71 GHz to 10.79 GHz, desired triple notch bands and good omnidirectional radiation patterns, which render it promising for UWB communication applications.

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