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Application Article

A Small UWB Antenna with Dual Band-Notched Characteristics

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A small novel ultrawideband (UWB) antenna with dual band-notched functions is proposed. The dual band rejection is achieved by etching two C-shaped slots on the radiation patch with limited area. A single band-notched antenna is firstly presented, and then an optimized dual band-notched antenna is presented and analyzed. The measured VSWR shows that the proposed antenna could operate from 3.05 to 10.7 GHz with VSWR less than 2, except two stopbands at 3.38 to 3.82 GHz and 5.3 to 5.8 GHz for filtering the WiMAX and WLAN signals. Radiation patterns are simulated by HFSS and verified by CST, and quasisymmetrical radiation patterns in the H-plane could be observed. Moreover, the proposed antenna has a very compact size and could be easily integrated into portable UWB devices.

1. Introduction

Since the Federal Communication Commission (FCC) allocated the frequency band 3.1–10.6 GHz for commercial ultrawideband (UWB) systems, considerable research efforts have been put into UWB radio technology in industry and academia. Several UWB antennas with compact size have been reported in [1–3] recently. However, UWB systems have encountered a hostile radio environment which may cause potential interferences to the UWB band. For instance, IEEE 802.16 WiMAX system operates at 3.3–3.7 GHz and IEEE 802.11a WLAN system operates at 5.15–5.825 GHz. In some cases, UWB antennas use filters to avoid interferences. However, the use of filters increases the complexity and cost of the UWB system. Thus, antenna-filtering technique may be one of the simple, effective, and inexpensive methods, and antennas with small size and band rejection functions are desirable. In order to design UWB antennas with band-notched functions, several methods have been proposed, including etching C-shaped, L-shaped, T-shaped, H-shaped, U-shaped, E-shaped, and half-circle slots on the radiation patch or on the ground plane [4–14]. Besides, by employing T-shaped, L-shaped, and spiral parasitic strips, band-rejection functions could be obtained [15–20]. By etching slots and employing parasitic strips at the same time [21, 22], dual band-notched functions could be achieved.

In this paper, a small novel ultrawideband antenna with dual band-notched characteristics is proposed and investigated in detail. The primitive UWB antenna has a compact size of 22 mm × 18 mm × 1.5 mm. By etching a C-shaped slot on the radiation patch, a single band-notched UWB antenna is first designed. By adding another C-shaped slot on the radiation patch, a small dual band-notched antenna has been successfully designed. It is observed from the simulated and measured VSWR that the proposed dual band-notched antenna could operate from 3.05 to 10.7 GHz with VSWR less than 2, except two stopbands at 3.38 to 3.82 GHz and 5.3 to 5.8 GHz for filtering the WiMAX and WLAN signals. In addition, the proposed antenna has a nearly omnidirectional radiation patterns at the H-plane across the operating frequency band, which makes it a good candidate for UWB devices.

2. Single Band-Notched UWB Antenna Design and Results

A 3.5 GHz single band-notched UWB antenna is firstly designed, and the specific geometry is shown in Figure 1. The substrate of the antenna is FR4 with a thickness of $h_{sub} = 1.5$ mm and relative dielectric constant of 4.5. An SMA connector is connected to the 50 Ω microstrip feed line to feed the antenna. The radiation patch has a

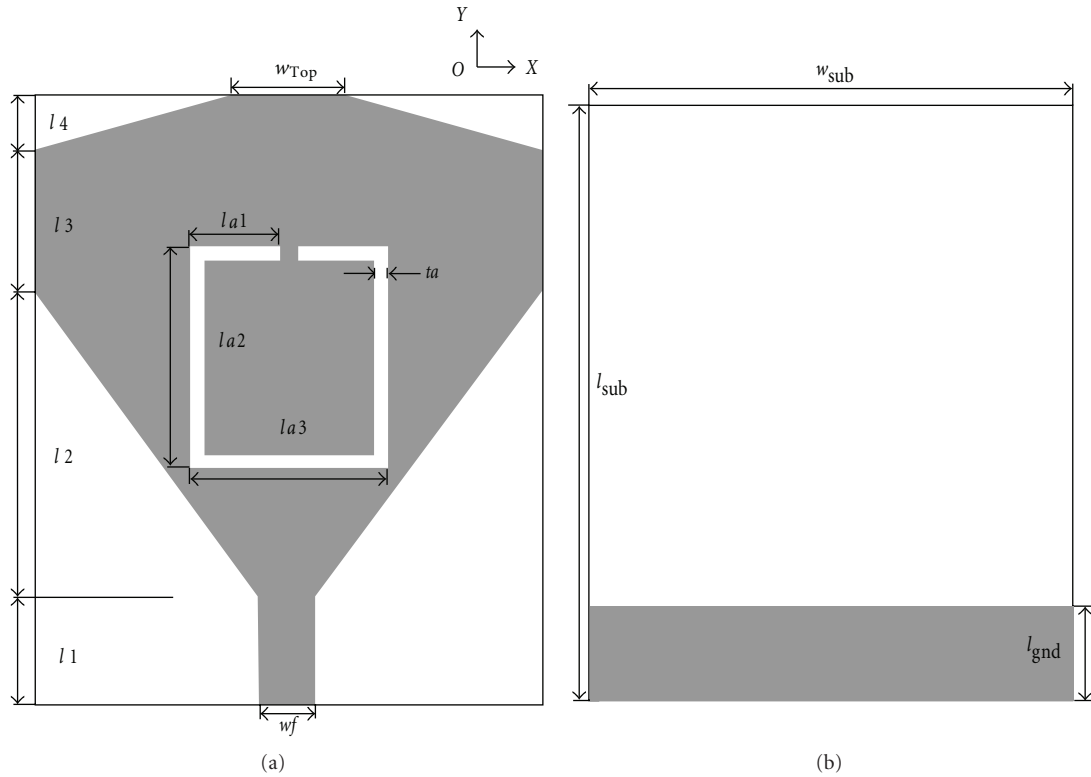


FIGURE 1: Geometry of single band-notched antenna. (a) Top view, (b) bottom view.

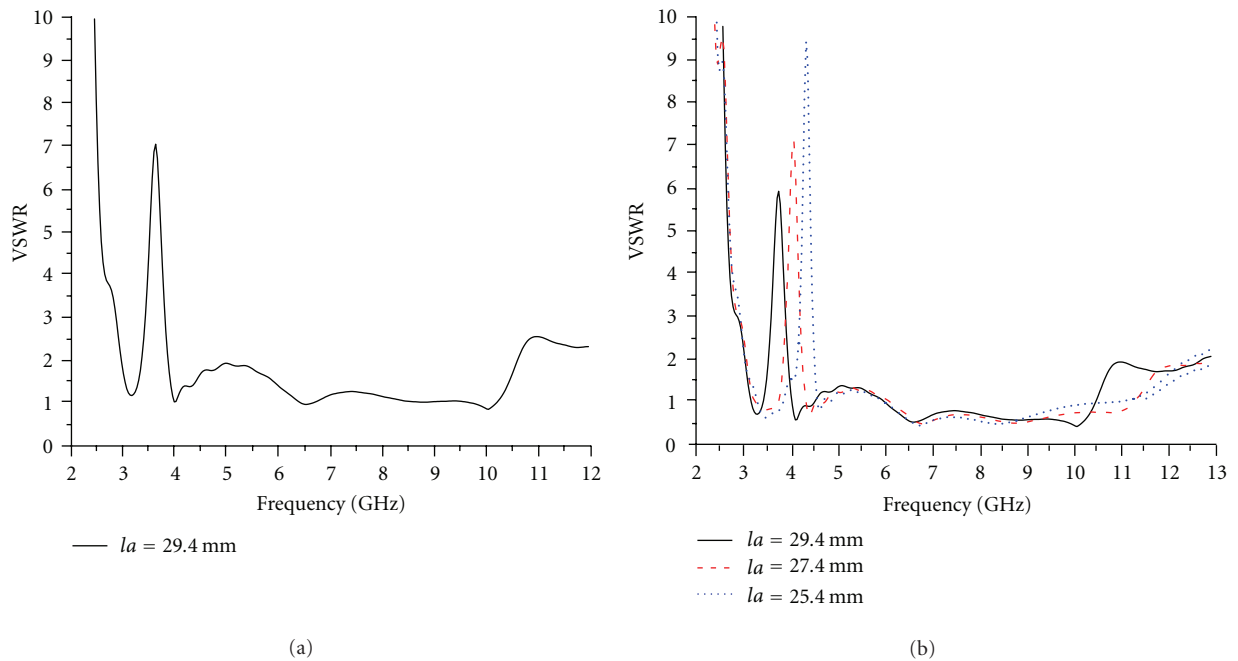


FIGURE 2: Simulated VSWR of single band-notched antenna with (a) optimized l_a , (b) different l_a .

shovel-shaped structure, and the dimensions are optimized using commercial software CST and HFSS. In order to eliminate interferences from IEEE 802.16 WiMAX system linebreak operating at 3.3–3.7 GHz, a C-shaped slot is etched on the patch to generate band rejection function. The

notched frequency generated by the C-shaped slot can be postulated as

$$f_{\text{notch}} = \frac{c}{2L \cdot \sqrt{\epsilon_{\text{eff}}}}, \quad (1)$$

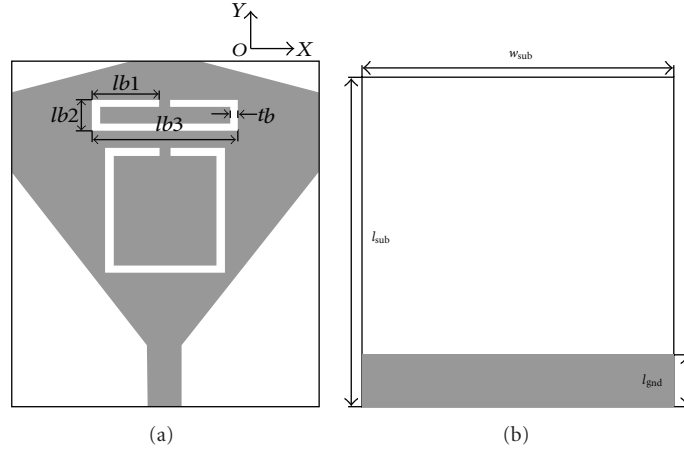


FIGURE 3: Geometry of dual band-notched antenna. (a) Top view, (b) bottom view.

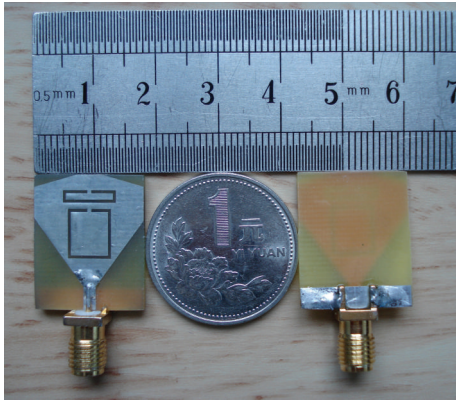


FIGURE 4: Photograph of the proposed dual band-notched antenna.

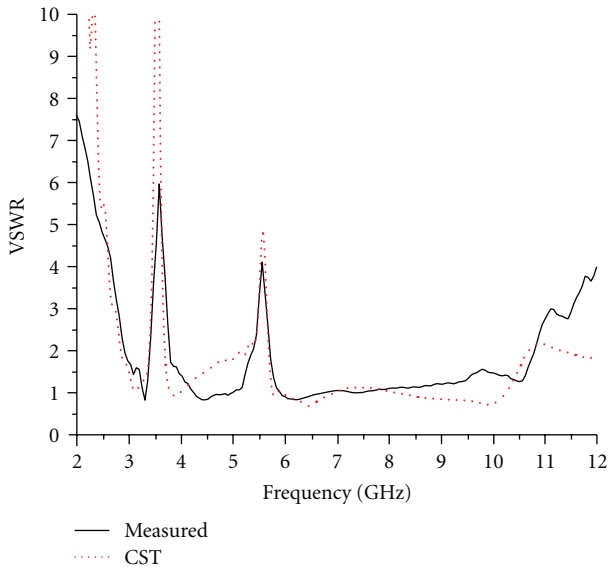


FIGURE 5: Simulated and measured VSWR of the proposed dual band-notched antenna.

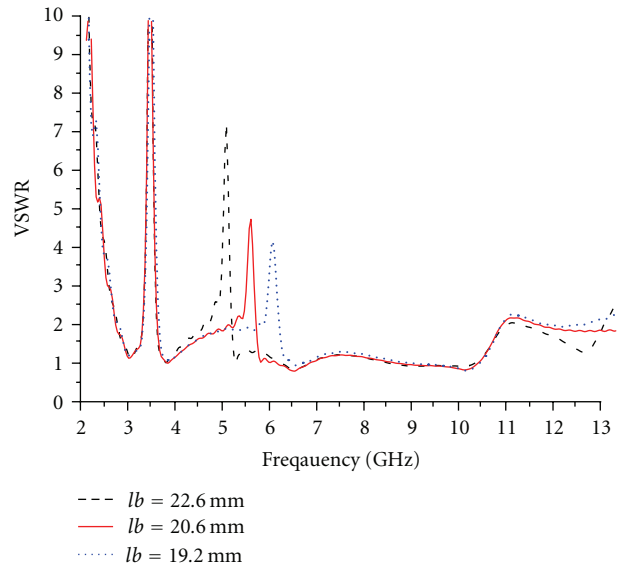


FIGURE 6: Effects of parameter lb on the 5.5 GHz band-notch function.

TABLE 1: Optimized parameters of the single band-notched antenna.

Parameters	w_{sub}	l_{sub}	l_{gnd}	h_{sub}	$l1$	$l2$	$l3$
Value (mm)	18	22	3.5	1.5	4	11	5
Parameters	$l4$	$la1$	$la2$	$la3$	ta	w_{Top}	w_f
Value (mm)	2	3.2	8	7	0.5	4	2

where L is the total length of the C-shaped slot, ϵ_{eff} is the effective dielectric constant, and c is the speed of light. The position, length, and width of the slot have great effects on the band rejection performance and should be tuned carefully. Note that when the C-shaped slot is etched on the radiation patch, there is no retuning work needed for the primitive antenna structure. The optimized parameters of the antenna geometry are listed in Table 1.

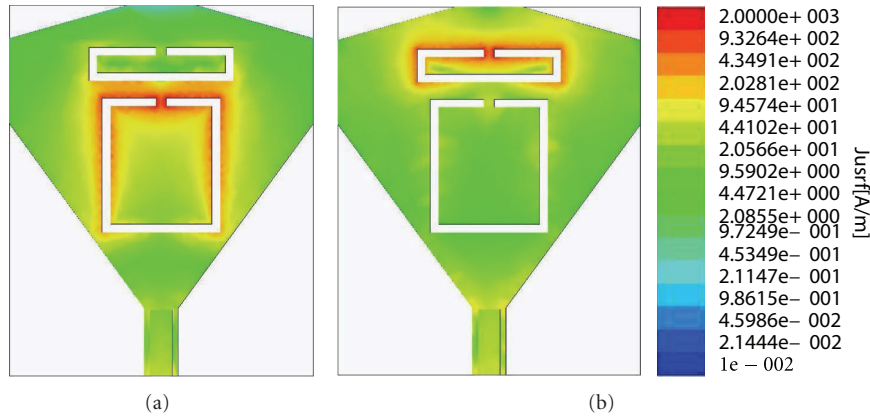


FIGURE 7: Simulated current distribution of the proposed antenna. (a) 3.5 GHz, (b) 5.5 GHz.

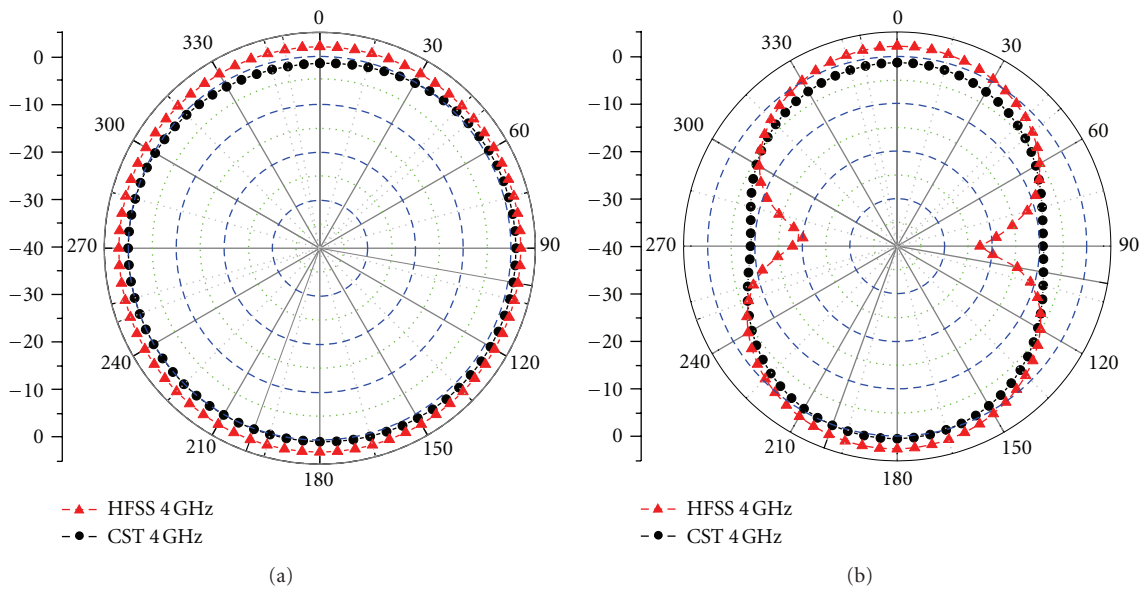


FIGURE 8: Radiation patterns of the proposed antenna at 4 GHz; (a) xoz-plane, (b) yoz-plane.

The simulated VSWR of the single band-notched antenna is shown in Figure 2. It could be observed that this antenna could operate from 2.95 to 10.68 GHz with VSWR less than 2, except one stopband from 3.35 to 3.85 GHz. Let $la = 2 \times la_1 + 2 \times la_2 + la_3$; the simulated VSWR for different la is given in Figure 2(b). By decreasing la from 29.4 to 25.4 mm, the notched frequency is shifted up from 3.6 to 4.2 GHz.

3. Dual Band-Notched UWB Antenna

3.1. Antenna Design and Configuration. Besides WiMAX systems, WLAN operating from 5.15 to 5.825 GHz may cause interferences to the UWB system too. By etching another smaller C-shaped slot on the radiation patch, 5.5 GHz band-notched function is realized. The notched frequency generated by the C-shaped slot can be postulated by (1). The specific geometry of the dual band-notched antenna is shown in Figure 3. All the dimensions are the same as that in Figure 1, except the adding of another smaller C-shaped

slot. The geometry of the smaller slot is given in Table 2. An alternative method to generate dual band-notched function is using two nested C-shaped slots [4], but the tuning process may be complicated due to mutual coupling of the slots. Thus, two independent C-shaped slots are used to generate dual band-notched functions and the tuning process could be simplified.

3.2. Simulated and Measured Results and Discussions. In order to verify the design concept, a prototype of the dual band-notched antenna is fabricated and measured. The photograph of the fabricated dual band-notched antenna is given in Figure 4. The VSWR of the dual band-notched antenna is measured by Agilent E8364B Vector Network Analyzer and is given in Figure 5. Relatively good agreement between the simulated and measured VSWR could be observed. The discrepancy is mainly due to the fabrication tolerance and hand welding inaccuracy. It could be observed that the designed antenna has a wideband performance of

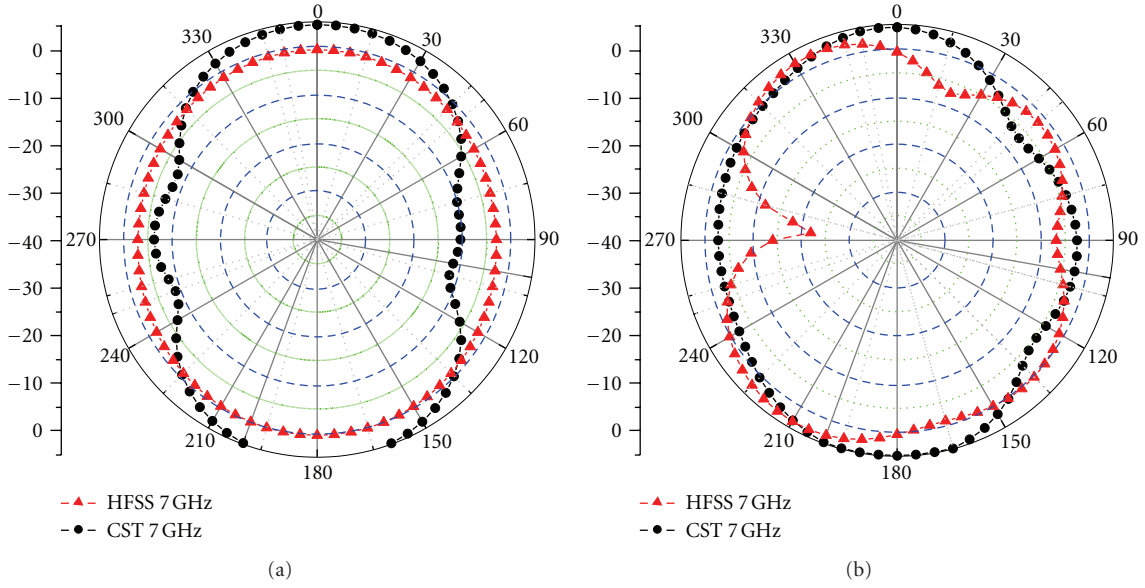


FIGURE 9: Radiation patterns of the proposed antenna at 7 GHz; (a) xoz-plane, (b) yoz-plane.

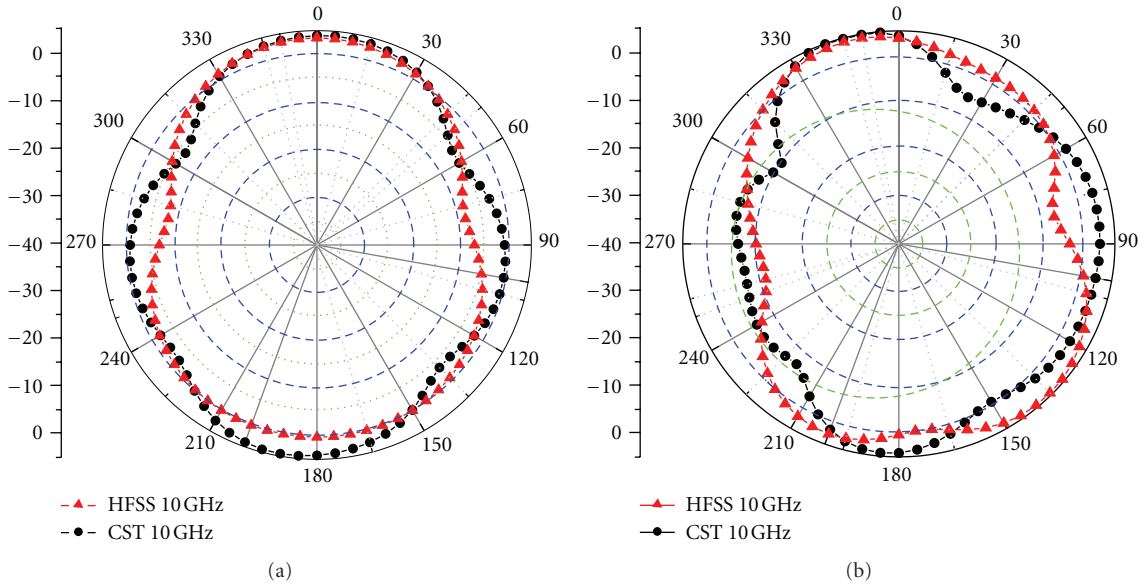


FIGURE 10: Radiation patterns of the proposed antenna at 10 GHz; (a) xoz-plane, (b) yoz-plane.

TABLE 2: Optimized geometry of the smaller C-shaped slot.

Parameters	$lb1$	$lb2$	$lb3$	tb
Value (mm)	4	2	8.6	0.5

3.05–10.7 GHz for VSWR less than 2, covering the entire UWB frequency band, with two stopbands at 3.38–3.82 GHz and 5.3–5.8 GHz for filtering the WiMAX and WLAN signals.

Let $lb = 2 \times lb1 + 2 \times lb2 + lb3$; effects of parameter lb on the 5.5 GHz band-notched function is simulated and is shown in Figure 6. Note that the tuning of parameter lb

has little affection on the VSWR of the dual band-notched antenna throughout the whole UWB frequency range, except the 5.5 GHz stopband. Thus, the 5.5 GHz band-notched characteristic could be tuned independently and no retuning work is needed for the antenna structure. It is observed that by decreasing lb from 22.6 to 19.2 mm, the notched frequency is shifted up from 5.1 to 6.0 GHz.

The simulated surface current distributions at 3.5 GHz and 5.5 GHz are given in Figure 7. The large current distribution is indicated in red, and small one is in blue. It is observed that the surface current is highly concentrated at each C-shaped slot, which means that a large portion of

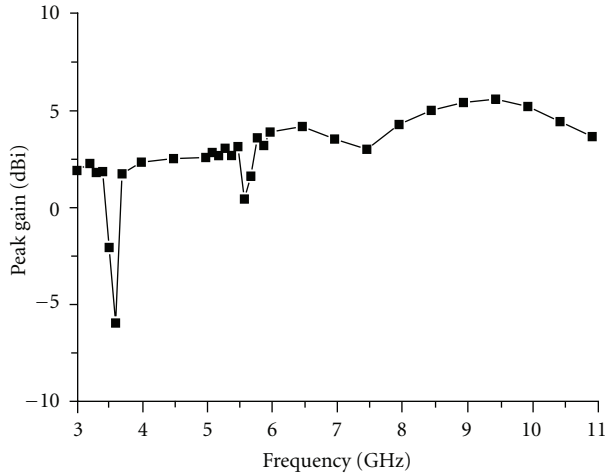


FIGURE 11: Peak gain of the proposed antenna.

electromagnetic energy has been stored around the slots and the radiation efficiency decreases at the rejected band.

The simulated radiation patterns at xoz -plane (H-plane) and yoz -plane (E-plane) of the proposed antenna at 4 GHz, 7 GHz, and 10 GHz are illustrated in Figures 8, 9, and 10, respectively. It is observed that the radiation patterns at xoz -plane are nearly omnidirectional, which makes it a good candidate for UWB devices.

Furthermore, Figure 11 shows the peak gain of the proposed dual band-notched antenna. The simulated peak gain ranges from 2 to 5.5 dBi throughout the whole UWB frequency band, except two stopbands. As discussed above, the energy at the notched frequency bands is not radiated so that the radiation efficiency drops at the notched frequency bands. Thus, the peak gain decreases sharply at 3.5 GHz and 5.5 GHz, which clearly indicates the dual band rejection functions of the proposed antenna.

4. Conclusions

In this paper, a small novel UWB antenna with dual band-notched characteristics has been proposed and analyzed. The primitive UWB antenna is fabricated on FR4 substrate and has a shovel-shaped radiation patch, which results in a compact size of 22 mm \times 18 mm \times 1.5 mm. Two C-shaped slots are etched on the small patch to achieve 3.5 GHz and 5.5 GHz dual band-notched functions. Nearly omnidirectional radiation patterns could be observed at the H-plane throughout the whole operating frequency band. Accordingly, the proposed dual band-notched UWB antenna might be useful for compact portable UWB devices to eliminate abundant electromagnetic interferences.

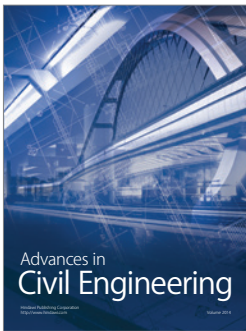
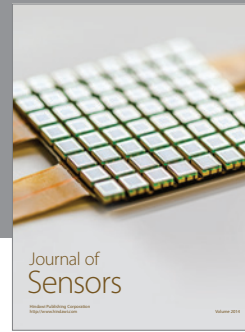
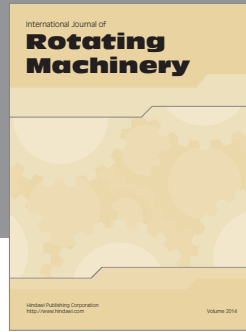
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