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COMPACT CPW-FED UWB ANTENNA WITH DUAL BAND-NOTCHED CHARACTERISTICS

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Abstract—In this paper, a coplanar waveguide fed (CPW-Fed) ultra-wideband (UWB) antenna with dual band-notched characteristics is proposed. Two symmetrical slots are etched from the ground plane to achieve the notched band at 5.5 GHz. The other notched band at 3.5 GHz is obtained by etching a split ring slot in the radiator. The simulation and measurement show that the proposed antenna achieves an impedance bandwidth of 3.1–10.6 GHz with VSWR < 2, except in the bands of 3.2–3.8 GHz and 4.8–6.2 GHz. A nearly omnidirectional radiation pattern and stable gain with variation less than 3 dB are also observed except in the two notched bands. Moreover, time-domain characteristics of the antenna are analyzed and discussed as well.

1. INTRODUCTION

Since the Federal Communications Commission (FCC) released the frequency band 3.1 to 10.6 GHz for the commercial communication applications in 2002 [1], there has been considerable research effort put into ultra-wideband (UWB) radio technology worldwide. Compared with conventional narrow-band and wideband wireless communication systems, UWB systems operate over a much larger bandwidth. As a key component of the UWB systems, the antennas with ultra-wide bandwidth have been widely investigated by both academia and industry. However, over the designed bandwidth of the UWB system, there are existing narrow bands used by WiMAX operating in the 3.3–3.7 GHz band and wireless local area network (WLAN) in the frequency range of 5.15–5.825 GHz. It is desirable to design the UWB antenna with notched bands which can cover the two bands to minimize the potential interference.

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Recently, various UWB antennas with frequency band-notched function have been proposed. Many band-notched antenna designs are achieved by cutting slots in the radiator [2, 3]. To microstrip-fed UWB antennas, the band-notched characteristics can also be implemented by adding a stepped impedance resonator (SIR) or a split ring resonator (SRR) on the feed line [4, 5] or cutting slots in the ground plane [6]. When it comes to CPW-Fed UWB antennas, most of the band-notched characteristics are implemented by etching slots in the radiator [7].

In this paper, a CPW-Fed UWB antenna with dual notched bands is proposed. By etching two symmetrical slots in the ground plane nearby the feed line, a notched band at 5.5 GHz is obtained. The other one is implemented by etching a rectangle split ring slot in the radiator. The two notched bands can minimize the potential interference between the UWB system and WLAN/WiMAX narrow band communication systems. Omni-directional radiation patterns and stable gain are obtained in the desired bands. Time-domain characteristics of the antenna are discussed as well.

2. ANTENNA DESIGN

The geometry of the proposed dual band-notched UWB antenna is shown in Figure 1. The proposed antenna is printed on a low-cost FR4 substrate with the thickness of 1.6 mm and the dielectric constant of 4.4. The ground plane is modified to achieve a better matching

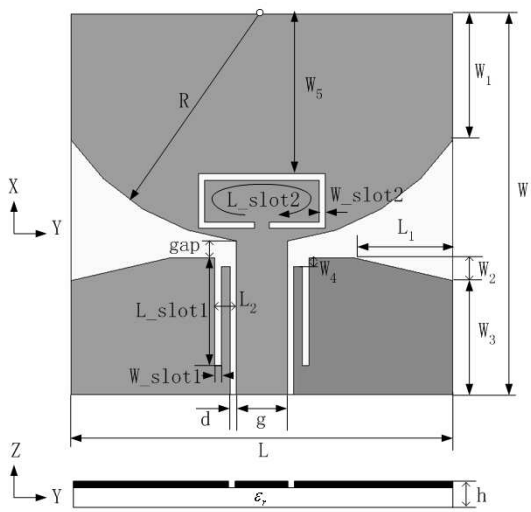


Figure 1. Geometry of proposed antenna.

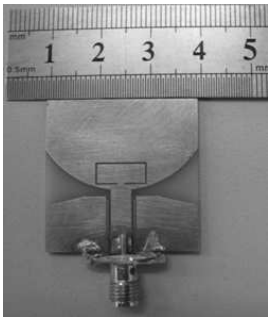


Figure 2. Photograph of proposed antenna.

impedance. Two symmetrical slots are etched from the ground plane to obtain the notched band from 4.8 to 6.2 GHz, and a rectangle split ring is etched from the radiator to notch the frequency from 3.1 to 3.7 GHz. The optimized parameters are as follows, $L \times W = 30 \times 30\,\text{mm}^2$, $g = 4\,\text{mm}$, $d = 0.5\,\text{mm}$, gap $= 1.3\,\text{mm}$, $R = 18\,\text{mm}$, $L\_\text{slot1} \times W\_\text{slot1} = 8.5 \times 0.22\,\text{mm}^2$, $L\_\text{slot2} \times W\_\text{slot2} = 26.8 \times 0.3\,\text{mm}^2$, $W_1 = 9.9\,\text{mm}$, $W_2 = 1.8\,\text{mm}$, $W_3 = 9\,\text{mm}$, $W_4 = 0.7\,\text{mm}$, $W_5 = 12.6\,\text{mm}$, $L_1 = 7.8\,\text{mm}$, $L_2 = 0.92\,\text{mm}$. The photograph of the fabricated antenna is shown in Figure 2.

The length of the slots etched from the ground plane nearby the feed line (L_slot1) can be deduced as in (1). The two slots act as two quarter-wave length shunt resonators. Based on the author's previous work [6], the length of the split ring slot in the radiator (L_slot2) can be deduced by (2). Moreover, the width and location of those slots can also adjust the notched bands.

$$L\_\text{slot1} \approx \frac{c}{4f\sqrt{\varepsilon_{eff}}} \tag{1}$$

$$L\_\text{slot2} \approx \frac{c}{2f\sqrt{\varepsilon_{eff}}} \tag{2}$$

where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} \tag{3}$$

3. RESULTS AND DISCUSSION

The prototype of the proposed antenna was fabricated and measured using Agilent N5230A vector network analyzer. Figure 3 presents the comparison of the simulated and measured voltage standing wave ratio (VSWR) of the antenna. The measured bandwidth for VSWR < 2 has

good agreement with simulations, which covers the frequency range of 3.1–10.6 GHz except in 3.2–3.8 GHz and 4.8–6.2 GHz. Besides, the measured VSWR of the antenna with only two etched slots in the ground plane and the simulated VSWR of the antenna without any slots are plotted in Fig. 3 for comparison. Obviously, the notched band at 5.5 GHz is implemented by the two etched slots in the ground plane, and the other notched band at 3.5 GHz is obtained by etching the slot in the radiator. In the desired notched bands, 3.3–3.6 GHz for WiMAX and 5.15–5.825 GHz for WLAN, the values of VSWR are all bigger than 3. Therefore, the potential interferences between UWB system and the two wireless communication systems can be suppressed effectively.

The notched bands can be affected by the length, width and location of the slots. Due to the sufficient analysis in other proposed

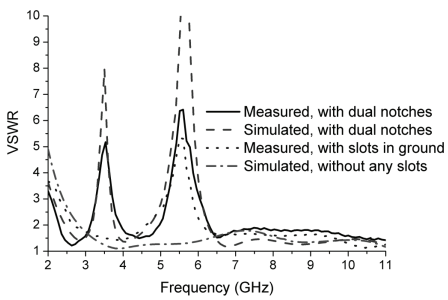


Figure 3. Measured and simulated VSWR.

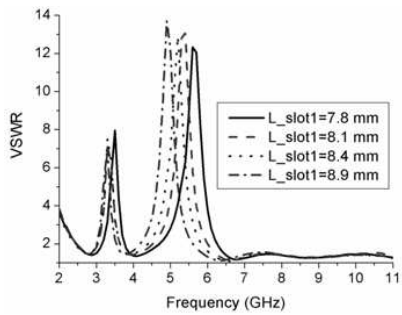


Figure 4. Effect of varying the length of the slots in the ground plane.

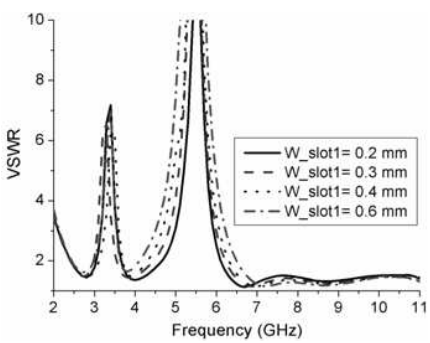


Figure 5. Effect of varying the width of the slots in the ground plane.

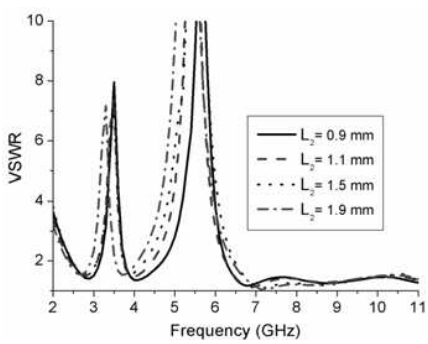
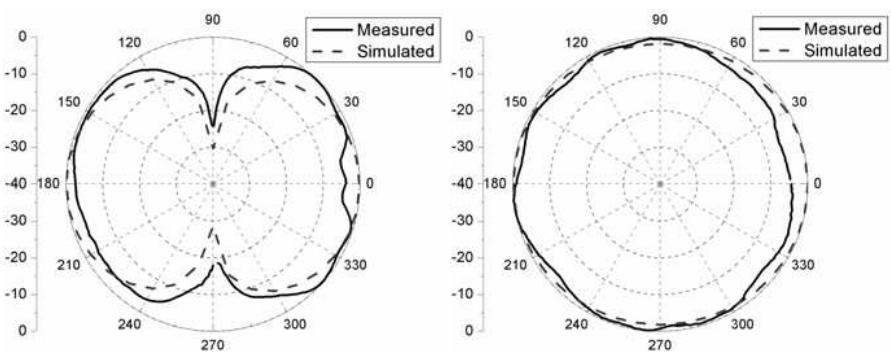


Figure 6. Effect of varying the location of the slots in the ground plane.

papers [3, 4], the effects of the slot etched from the radiator will not be discussed. Only the effects of the symmetrical slots in the ground plane will be analyzed. The variation of the simulated VSWR with different slot lengths is shown in Figure 4. It can be seen that with the length of the slots increasing, the centre frequency of the corresponding notched band will become smaller. The bandwidth of the notched band depends on the width of the slots. As can be seen in Figure 5, a wider notched band can be obtained by broadening the width of the slots, while it has little effect on the other notched band. Figure 6 shows the effect of varying the location of the slots in the ground plane. Both the bandwidth and the centre frequency of the notched band change when the location of the slots is different, and the notched band will get smaller if the slots are closer to the feed line. The results shown that the two notched bands have little effect on each other. They can be adjusted respectively.

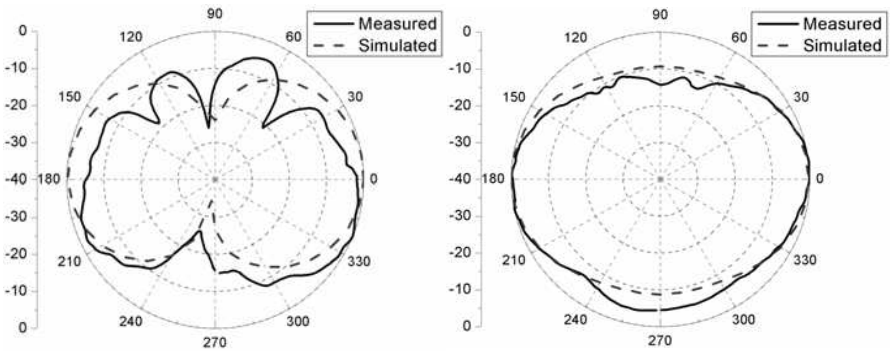
The normalized radiation patterns at 3.1, 7, 10 GHz are plotted in Figures 7–9, respectively. Figure 7 plots the E-plane (XOZ plane) and H-plane (YOZ plane) radiation patterns at 3.1 GHz. The radiation patterns are very similar to the half-wave dipole's, 8-shape in E-plane and omni-directional in H-plane. As can be seen in Figures 8 and 9, the radiation patterns deteriorate more or less with the frequency increasing, but the H-plane radiation patters are still nearly omni-directional. The measured and simulated results match well except in some orientations. It is because the antenna was measured in the outdoor antenna test system.

The maximum gains of the antenna at these frequencies are extracted from the radiation patterns and plotted in Figure 10. An



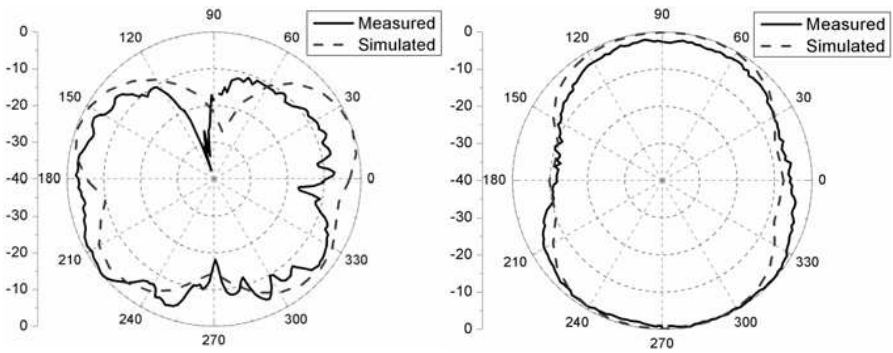
(a) E-plane (XOZ) (b) H-plane (YOZ)

Figure 7. Measured and simulated radiation patterns at 3.1 GHz.



(a) *E*-plane (*XOZ*) (b) *H*-plane (*YOZ*)

Figure 8. Measured and simulated radiation patterns at 7 GHz.



(a) *E*-plane (*XOZ*) (b) *H*-plane (*YOZ*)

Figure 9. Measured and simulated radiation patterns at 10 GHz.

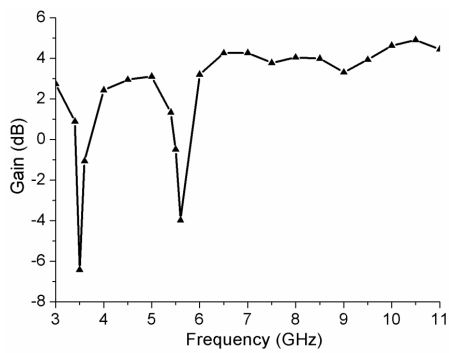


Figure 10. Gain of proposed antenna.

stable gain with the average of about 3.5 dB is obtained throughout the operating band except at the two notched frequencies. As desired, gain decreases sharply in the vicinity of 3.5 and 5.5 GHz. The gain values are about −7 dB and −4.5 dB, respectively. It just demonstrates the good band-rejected function of the antenna.

4. TIME-DOMAIN CHARACTERISTICS OF PROPOSED ANTENNA

Apart from the consideration of frequency-domain characteristics which contains the −10 dB return loss bandwidth, radiation patterns and gain, time-domain characteristics is an essential requirement for an UWB antenna [9]. Impulse response of the proposed antenna is studied in this article. The impulse response has been simulated with the CST Microwave Studio software.

In the modeling, the system is comprised of two identical antennas. The transmitter and receiver are positioned in two scenarios, i.e., face to face and side by side, with a distance of 600 mm. A 5th-derivative Gaussian pulse, as presented in (4), is used as the source signal to drive the transmitter. C is a constant that can be chosen to comply with peak power spectral density that the FCC will permit and σ is assumed to be 51 ps to ensure that the shape of the spectrum complies with the FCC spectral mask [8]. The waveform is shown in Figure 11.

$$s_1(t) = GM_5(t) = C\left(-\frac{t^5}{\sqrt{2\pi}\sigma^{11}} + \frac{10t^3}{\sqrt{2\pi}\sigma^9} - \frac{15t}{\sqrt{2\pi}\sigma^7}\right) \times \exp\left(-\frac{t^2}{2\sigma^2}\right) \quad (4)$$

Figure 12 presents the simulated impulse response for both scenarios. The time interval between the transmitting antenna input signal and the receiving antenna output signal is about 2 ns. Compared with the case of face to face, the magnitude of the received signal is

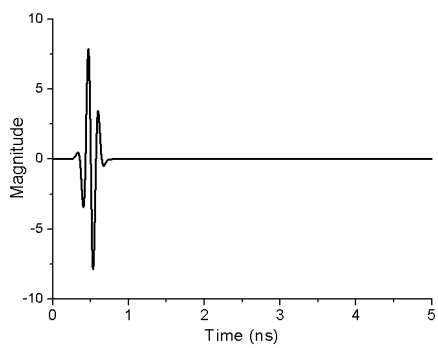


Figure 11. Transmitting antenna input signal.

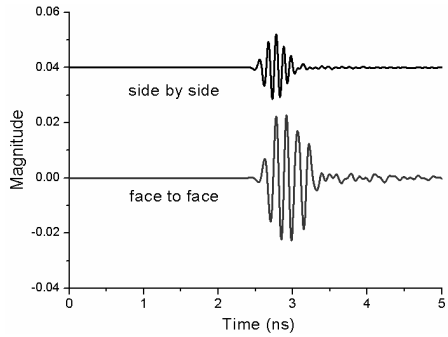


Figure 12. Receiving antenna output signals. Note that the waveforms are shifted in Y-axis for clearer distinction.

smaller when the antennas are positioned side by side. The correlation factor between the output signal and input single can be calculated with (5).

$$\rho = \max_{\tau} \left\{ \frac{\int s_1(t)\, s_2(t-\tau)\, dt}{\sqrt{\int s_1^2(t)\, dt}\sqrt{\int s_2^2(t)\, dt}} \right\} \tag{5}$$

Where τ is a delay which makes the numerator in (5) a maximum. The correlation factor is calculated to be 0.7439 when the two antennas were positioned face to face, and the value becomes 0.5908 when they are fixed side by side. The fidelity of the case of face to face is better than the case of side by side. Due to the impedance mismatching at the notched bands, ringing distortions are observed in both scenarios. Since the time interval between two contiguous input pulse is big enough, the ringing distortions have nearly no harmful effect on the next received pulse.

5. CONCLUSION

In this paper, a CPW-Fed UWB antenna with dual band-notched function has been proposed and discussed. The antenna has been successfully investigated, fabricated and measured. The band-notch characteristic is achieved by inserting two symmetrical rectangle slots in the ground plane and a split ring rectangle slot in the radiator. The notched band can be controlled by adjusting the slots. The proposed antenna has good impedance match and stable gain in the entire band except in the two notched bands. The radiation patterns are nearly omni-directional over the whole operation frequencies. Moreover, the time-domain characteristics of the proposed antenna are analyzed as

well. With little interference among WLAN and WiMAX, the antenna is suitable for UWB applications.

ACKNOWLEDGMENT

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