

A CPW-FED UWB ANTENNA WITH WIMAX/WLAN BAND-NOTCHED CHARACTERISTICS

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Abstract—A CPW-fed UWB antenna with WiMAX and WLAN band-notched characteristics is presented in this paper. The proposed antenna is fed by a CPW structure and provides the band-notched characteristics by etching an arc slot on the monopole plate and integrating the antenna with electromagnetically coupled microstrip resonator into a single module. In order to prevent interference problem due to existing nearby communication systems within the UWB operating frequency, the two band-notches are designed to reject possible interference with the existing 3.25–3.75 GHz band for IEEE802.16 WiMAX and 5.15–5.825 GHz band for IEEE802.11a WLAN and HIPERLAN/2 WLAN. The two notched bands can easily be controlled by a few geometry parameters of the arc slot and the microstrip resonator. Surface current distributions and conceptual equivalent-circuit models are used to analyze the effect of the slot and the resonator. The proposed antenna is simulated and fabricated. Moreover, the performances of the antenna are demonstrated along with simulated and measured results.

1. INTRODUCTION

Since Federal Communication Commission (FCC) released the extremely wide spectrum for commercial ultra-wideband applications in 2002, much attention has been paid for the design of UWB antennas. In order for the antenna to be considered for UWB applications, it has to have a compact profile, wideband impedance matching and omnidirectional radiation patterns.

Various techniques have been suggested to improve the impedance matching over a broad frequency spectrum. Among these designs,

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planar monopole antenna is one of the most promising candidates for UWB applications [1–3]. With CPW feed line, extra advantages are acquired, such as ease of fabrication and integration in microwave circuits [4, 5].

UWB antennas are also desired to have band-notched function to reject any interference with other existing systems such as WiMAX system operating in the band of 3.25–3.75 GHz and WLAN system operating in the band of 5.15–5.825 GHz. One way to implement a frequency notched UWB antenna is to incorporate a half wave resonant structure in an antenna. According to this principle, an effective method which is largely adopted by antenna designers is etching half wave slots on the monopole plate and there are some similar methods can also be applied, including inserting slots in the ground plane or into the feed line. Some designs based on these methods have been proposed in literature for UWB antennas with band rejection capability [6–8]. Other methods were also utilized to obtain the band-notched feature, such as attaching parasitic patches to the antenna [9, 10].

Microstrip resonators are widely used in the design of the microwave circuits due to the ease of integration and nice performance when worked as the transmission line filters, which also have the band-notched function. However, the filter usually follows the antenna as an independent passive component in most of the communication system. So the transmission line filters are not compact and thus their sizes become an issue for many applications. A novel attempt in this paper is integrating the antenna and electromagnetically coupled microstrip resonator into a single module, which can achieve the same band-notched function as other methods does.

This paper describes a realizable method to design a planar monopole UWB antenna with multiple band-notched characteristic. The method to achieve dual band-notched feature of the proposed antenna in this paper is a combination of two completely different methods, which were etching an arc slot on the monopole plate and introducing a microstrip resonator to the antenna. The two notched bands can be effectively changed by adjusting the dimension of the slot and microstrip resonator, respectively. The performance of the antenna is verified by experimental data obtained from fabrication and measurement. The design of the proposed antenna is described in the second section. The simulated and measured results of the proposed antenna are discussed in Section 3. Moreover, experiments are conducted to investigate the influences of the geometry parameters on the two notched bands in this section.

2. ANTENNA DESIGN

Figure 1 shows the configuration of the proposed band-notched UWB antenna, which consists of a planar ellipse monopole UWB antenna fed by a CPW structure, an arc slot on the monopole plate and a microstrip resonator on the other side of the antenna. Prototype antenna was mounted on an FR4 substrate with relative permittivity of 4.4, a loss tangent of 0.02 over the target frequency range, thickness of 1.6 mm

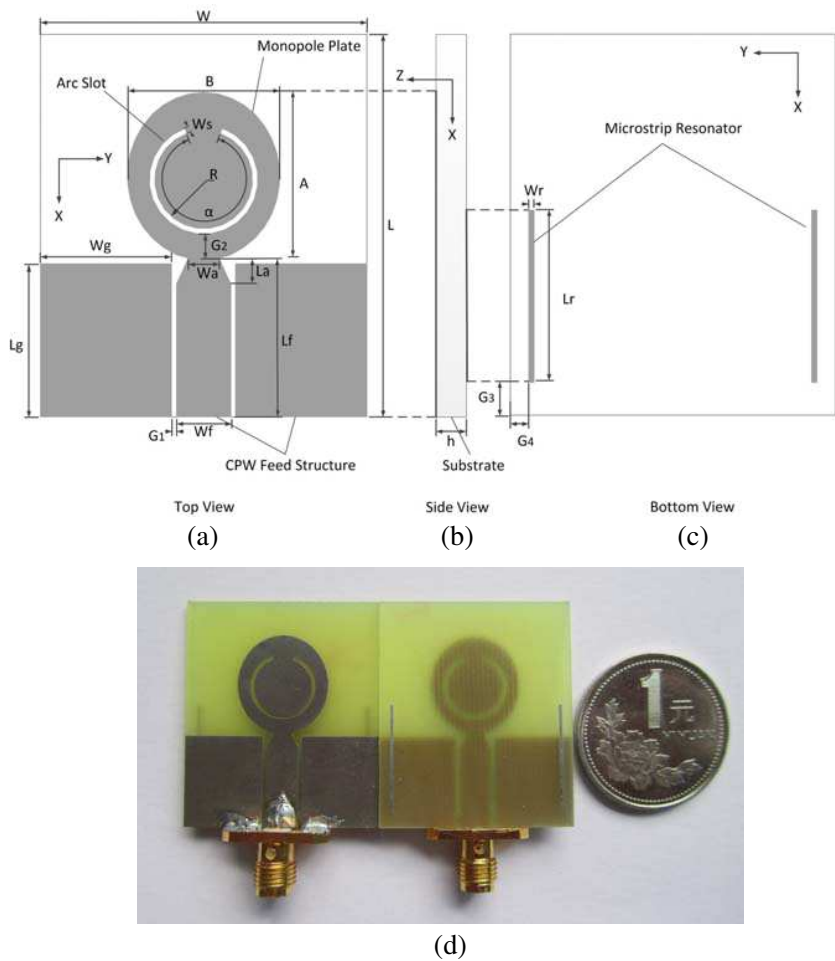


Figure 1. Configuration of the proposed printed UWB antenna with dual notched bands. (a) Top view. (b) Side view. (c) Bottom view. (d) Fabricated antenna.

and total size of $35 \times 30 \times 1.6 \text{ mm}^3$. To implement dual band-notched antenna, the arc slot is etched on the planar ellipse radiation element to achieve the lower notched band (3.25–3.75 GHz) for WiMAX and the electromagnetically coupled microstrip resonator is arranged on the opposite side to achieve the upper notched band (5.15–5.825 GHz) for WLAN.

The proposed UWB antenna has a frequency notch where the arc slot forms a half wavelength resonant structure. When the resonant length of the arc slot which is determined by the angle α of the slot and the radius R of the slot is approximately one-half wavelength at a particular frequency, a destructive interference takes place causing the antenna to be nonresponsive at that frequency. By adjusting the parameters of the slot, the lower and upper edge frequencies of the notched band within the antenna's operating bandwidth can be controlled.

Another way adopted in this paper to achieve a notched band is to introduce a microstrip resonator which has the function of filter to the antenna by integrating the antenna and electromagnetically coupled microstrip resonator into a single module. A microstrip resonator is based on the structure having at least one oscillating electromagnetic field. Among many types of resonators, microstrip resonators for filter designs may generally be classified into distributed line or patch resonators. As shown in Figure 1, a pair of conducting bars symmetrically printed on the bottom side of the substrate form the microstrip resonator, which can be named as half a wavelength resonator since they are $\lambda_g/2$ long (λ_g is the guided wavelength at the fundamental resonance frequency, f_0). They can also resonate at other frequencies, $f = nf_0$ for $n = 2, 3, \dots$. The notched band can easily be determined by adjusting the parameters of the resonator.

The mechanism of achieving the band-notched feature by etching slot and arranging microstrip resonator will be distinctly illuminated in Section 3. Moreover, the effect caused by the length of slot and conducting bar on each notched band will also be discussed in more detail in next section.

All the optimized design parameters are depicted in Table 1.

Table 1. Optimized parameters (Unit: millimeter, degree).

L	W	L_g	W_g	L_f	W_f	L_r	W_r	L_a	W_a
35	30	14	12.05	14.05	5	15.8	0.5	2.3	2.8
W_s	A	B	G_1	G_2	G_3	G_4	R	α	h
0.5	15.2	14	0.45	2.2	3	1.7	4.5	320	1.6

3. RESULTS AND ANALYSIS

Figure 2 illustrates the return loss of the proposed antenna. It is clearly seen that the bands of $|S_{11}| \geq -10$ dB are about 3.2 ~ 4.1 GHz and

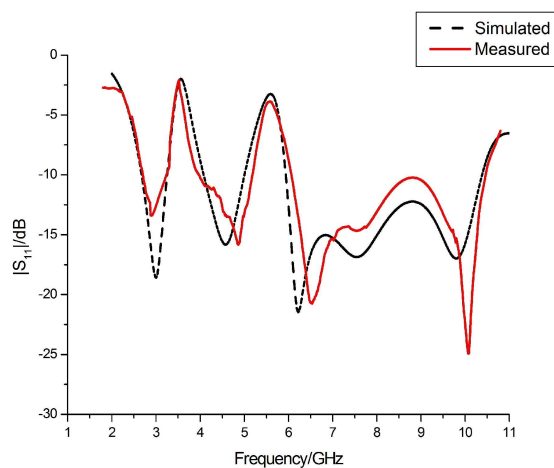


Figure 2. Measured and simulated $|S_{11}|$ of the proposed antenna.

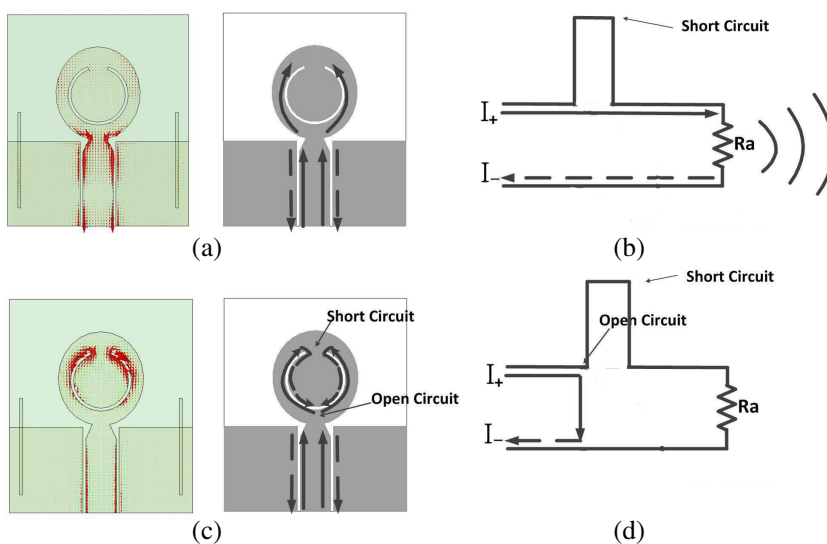


Figure 3. Surface current distribution and conceptual circuit model for antenna with arc slot at the passband in (a) and (b), at the first notch frequency 3.5 GHz in (c) and (d).

5 ~ 6 GHz, which covered the two expected notched bands. Therefore, as we designed, the proposed antenna can rejected any interference with WiMAX system operating in the band of 3.25–3.75 GHz and WLAN system operating in the band of 5.15–5.825 GHz while worked in the UWB band. As shown in Figure 2, a good agreement between the simulated and measured results is achieved. The tiny disagreement is mainly caused by the fabrication error and the environments of the measurement.

For distinctly illuminating the band-notched mechanism of the arc slot and the microstrip resonator when added to a UWB antenna, the surface current distribution obtained from Ansoft HFSS and conceptual circuit models were given and discussed in this section, which were shown in Figures 3 and 4 for antenna with arc slot and microstrip resonator, respectively.

As shown in Figure 3(c), at the notch frequency 3.5 GHz, current is concentrated around the edge of the arc slot and is oppositely directed between the interior and exterior of the slot. This causes the antenna to operate in a transmission-line-like mode, which transforms the nearly zero impedance (short circuit) at the top of the slot to nearly

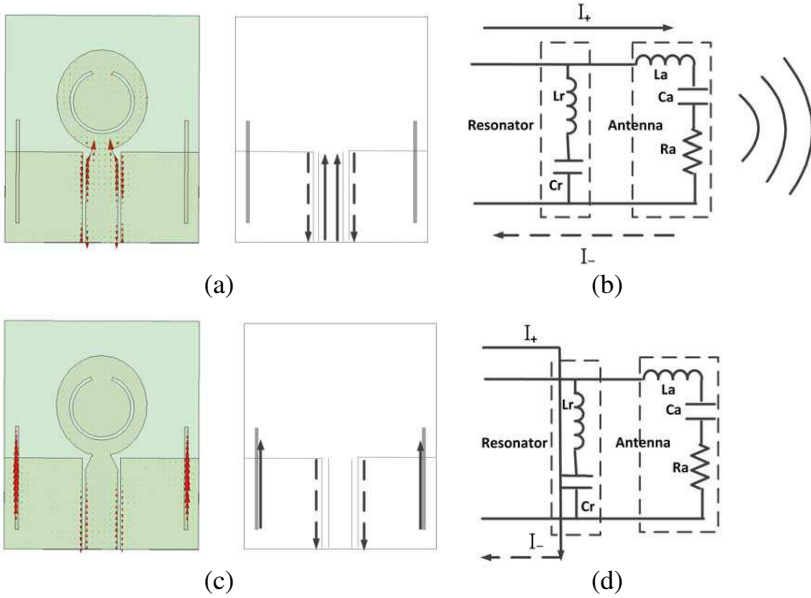


Figure 4. Surface current distribution and conceptual circuit model for antenna with microstrip resonator at the passband in (a) and (b), at the second notch frequency 5.5 GHz in (c) and (d).

infinity impedance (open circuit) at the antenna feeding point. This infinity impedance at the feeding point leads to the desired impedance mismatching near the notch frequency.

Figure 3(d) shows the conceptual circuit model for proposed antenna, which have a series stub and antenna resistance (R_a). The stub is a short-circuit stub. When the length of the stub is equal to $\lambda/4$ (λ is the wavelength of 3.5 GHz), the input impedance at the feeding point is infinity (open circuit). In this case, destructive interference for the excited surface currents in the antenna will occur, which causes the antenna to be nonresponsive at this frequency.

The surface current distribution and conceptual circuit model for the antenna with the electrically coupled microstrip resonator

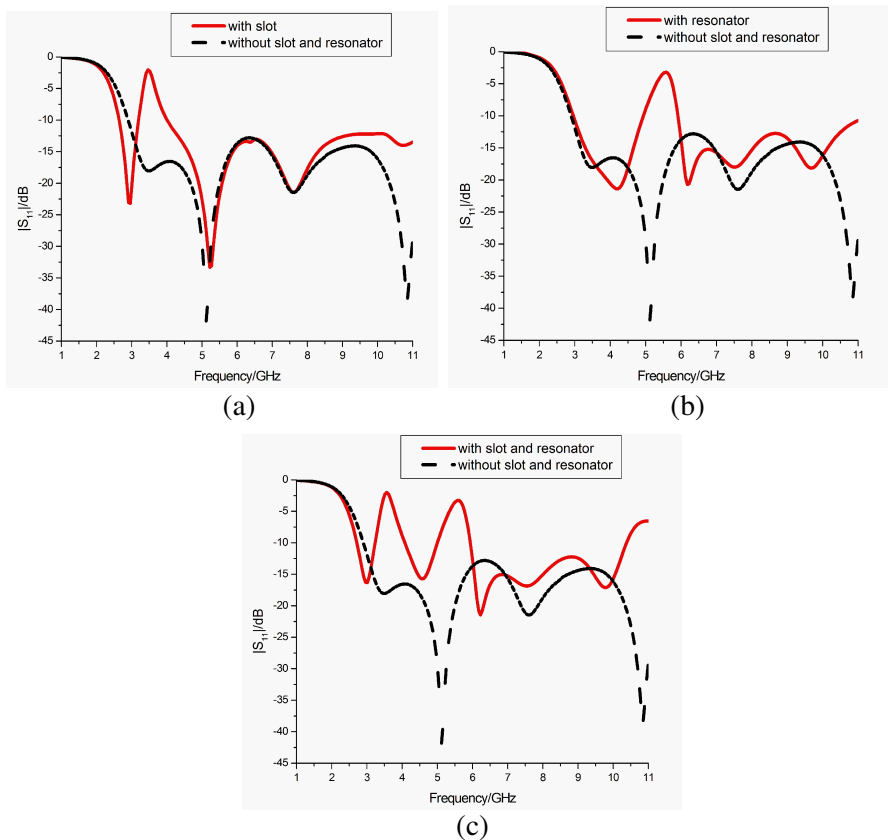


Figure 5. Simulated $|S_{11}|$ of antenna (a) only with arc slot, (b) only with microstrip resonator, (c) with arc slot and microstrip resonator.

were shown in Figure 4. The capacitively coupled open-circuited half wavelength resonator is modeled by a lumped capacitor in series with a transmission line inductor (open-circuited transmission line). When the length of the microstrip resonator is equal to $\lambda_g/2$ (λ_g is the guided wavelength at the band-notched frequency), no current flows to the antenna when current is induced in the resonator as shown in Figure 4(c). Consequently, no radiation can be made by the antenna at this frequency.

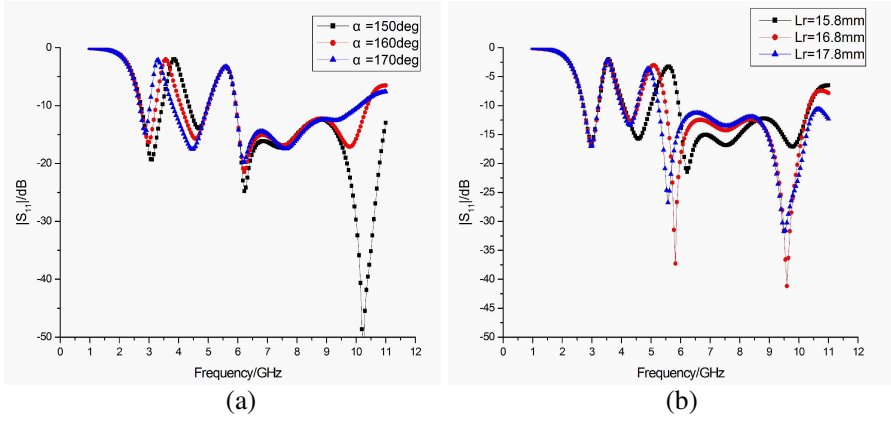
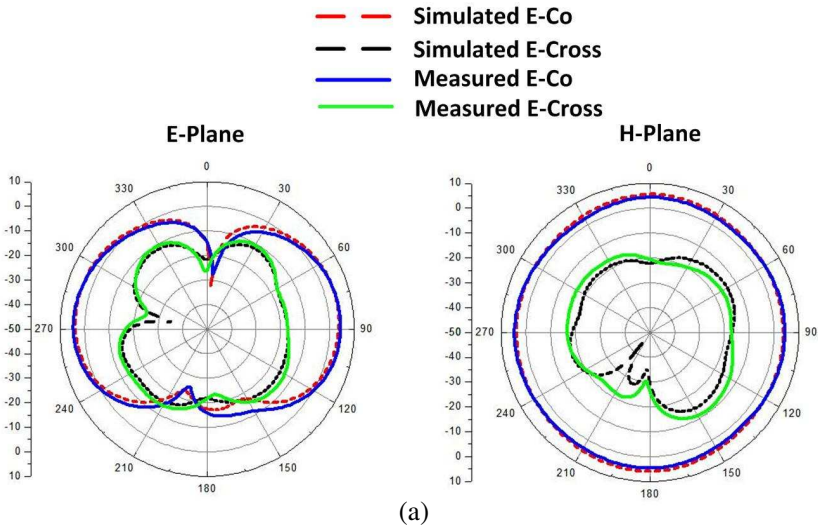


Figure 6. Simulated $|S_{11}|$ of the proposed antenna for (a) different α , (b) different L_r .



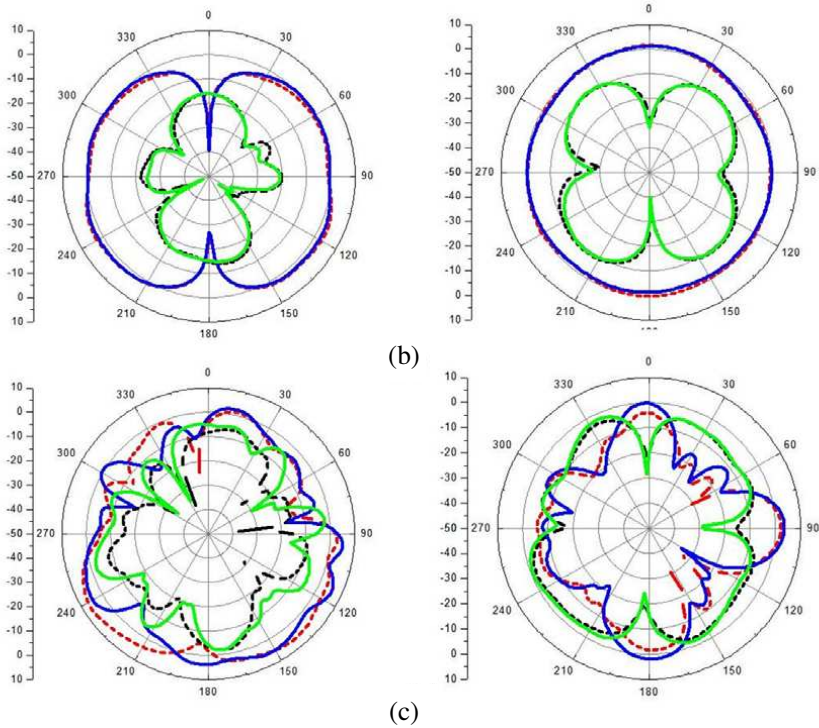


Figure 7. Radiation patterns of the proposed antenna at (a) 4 GHz, (b) 7 GHz, (c) 10 GHz.

Figure 5 shows the simulated $|S_{11}|$ for the proposed antenna. From the simulated results, we can observe that dual band-notched characteristics are created by etching arc slot and introducing microstrip resonator. As shown in this figure, the arc slot creates the first notch band of 3.25–3.75 GHz and the microstrip resonator creates the second notch band of 5.15–5.825 GHz, which meets the band-notch requirement.

It can be seen from Figure 6 that, the first notched band moves downwards as the angle of arc slot is increased, but this can hardly affect the other notched band. Similarly, it is seen that an increase in length of resonator results in moving downwards of the center frequency of the second notched band in general, and vice versa. Therefore the two notched bands of the proposed antenna can be easily controlled by the geometry parameters of the arc slot and the microstrip resonator.

The radiation characteristic of proposed antenna was also studied.

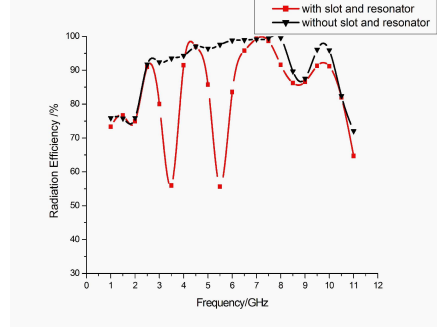
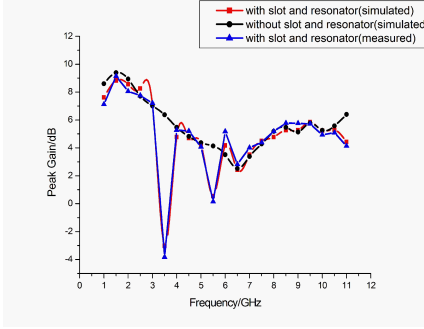


Figure 8. Peak gain of the proposed antenna. **Figure 9.** Radiation efficiency.

Figure 7 presents the simulated and measured radiation patterns of the proposed antenna at 4 GHz, 7 GHz and 10 GHz in E - and H -planes. As the figure shown, monopole-like radiation patterns are observed in E -plane while H -plane patterns exhibit good omnidirectional radiation characteristics. Further more, the insertion of the arc slot on the monopole plate and the microstrip resonator on the back of the antenna do not significantly alter the radiation patterns of the planar monopole antenna.

In the notched band, most of the power fed into the antenna is reflected back, which leads to a decrease of the radiation efficiency and hence the antenna gain. Simulated and measured gain is plotted in Figure 8. Two sharp drops occur at around 3.5 GHz and 5.5 GHz as expected. The similar variation can be seen in the radiation efficiency curve plotted in Figure 9. This characteristic can make sure the ability of the proposed antenna to reject the interference effectively.

4. CONCLUSION

In this paper, a CPW-fed planar ellipse monopole antenna with band-notch function is designed for high rate, short range wireless communication. The band rejection performance is realized by embedding an arc slot on the monopole plate and introducing the microstrip resonator. Guideline for designing antenna with band rejection characteristic is described. The proposed antenna presents nearly omnidirectional radiation patterns and wideband impedance matching over the UWB frequency spectrum excluding the WiMAX and WLAN subband, indicating the proposed antenna is a good candidate for UWB wireless communications.

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