Compact ultra-wideband monopole antenna with dual-band notched function

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Abstract: A kind of compact ultra wideband (UWB) monopole antenna with dual-band notched function is presented. The proposed antenna, using "C" and "L" apertures embedded in the annular ring patch and ground patch, gets two band-notched characteristics in WiMAX3.5 GHz and WLAN 5.5 GHz. The size of antenna is 24 mm × 36 mm × 1.6 mm. The simulation results show that waveband range of the antenna is 2.7 − 10.6 GHz for $S_{11} < -10$ dB and the band-notched wavebands are 3.2 − 3.8 GHz and 5.1 − 6 GHz. So it has miniaturization, ultra-band and band-notched characteristics. Meanwhile, the radition pattern, directivety and gain are perfect, which meets the practical need.

Key words: dual-band notched; ultra wideband; monopole antenna

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0 Introduction

With the rapid development of wireless communication technology, more and more attention is paid to ultra-waveband (UWB) technology. Especially for UWB antenna, it is the important element to decide the performance of the system., so it is of theoretical and practical value to study UWB antenna. An extremely wide spectrum of 3.1 − 10.6 GHz for UWB communication released by Federal Communications Commission in 2002 has overlaps with wireless area networks (WLAN) 5.5 GHz (5.15 − 5.83 GHz) and worldwide interoperability for microwave access (WiMAX) 3.5 GHz (3.30 − 3.70 GHz), thus it is necessary to design UWB antenna with notched function in proper frequency band to avoid interference between the systems.

Kerkhoff designed UWB monopole antenna with notched function in 2003. Later, Schantz H G and Lee W S also proposed a kind of printed antenna with notched function, explaining the relationship between notched frequency and slot size. Generally, the total length of slot is equal to a half or a quarter of waveguide wavelength that is relevant to notched center frequency. In this paper, we propose a monopole antenna program with notched function in WiMAX 3.5 GHz and WLAN 5.5 GHz.

In Ref. [1], a compact fork-shaped monopole UWB antenna with notched function was proposed, with size of 50 mm × 24 mm × 1.6 mm, and a symmetrical L-shaped slot was made on the ground in top left and top right corners. After adjusted the size of L-shaped slot and fork-shaped patch, the antenna can realize notched function at 2.4 GHz and 5.5 GHz. By analyzing notched principle in Refs. [1] and [2], we design a miniaturization, low cost and compact dual-band notched antenna by adopting annular monopole antenna model in Ref. [1] and design formulae for relative dielectric constant in Ref. [2]. After adjusted parameters about C-shaped, L-shaped slots and other parts on the ground, the antennaed realizes notched function at WiMAX 3.5 GHz and WLAN 5.5 GHz perfectly. Compared with the antenna in Ref. [1], antenna proposed in this paper has several differences: ① Different size. The size of antenna here is much smaller, 36 mm × 24 mm × 1.6 mm. ② Different notched frequency. The range here is between WiMAX 3.5 GHz and WLAN 5.5 GHz. ③ Differenct design formulae for calculating effective dielectric constant.

1 Design of antenna

The geometry of the proposed antenna is shown in Fig. 1 and Fig. 2. The substrate material is FR4, relative dielectric constant is $\varepsilon_r = 4.4$, and loss tangent is $\tan\theta = 0.02$. The antenna with geometric size of 36 mm × 24 mm × 1.6 mm is fed by microstrip line

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with characteristic impedance of 50 Ω. There are symmetrical L-shaped and step-shaped slots in top left and top right corners[3-11].

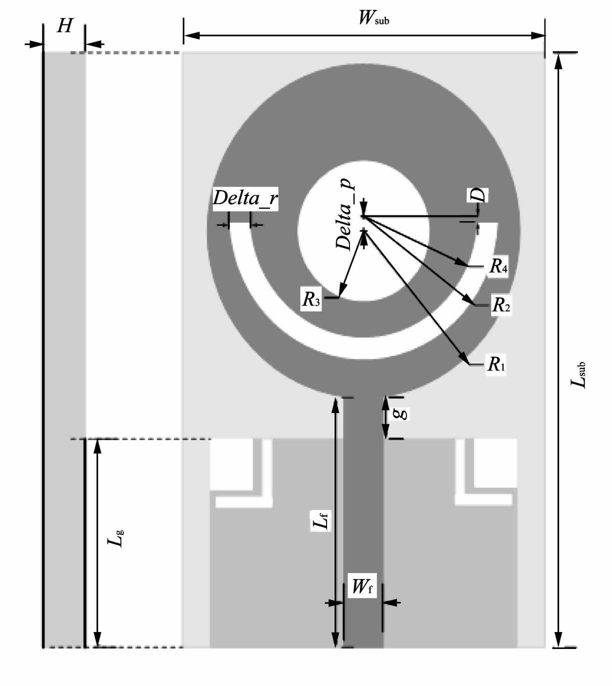

Fig. 1 Model of notched antenna

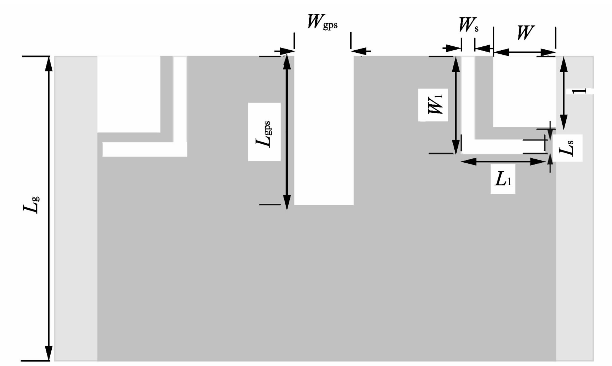

Fig. 2 Ground model of notched antenna

The length of C-shaped slot is

$$M_C = \frac{\pi}{2}(R_2 + R_4). \tag{1}$$

Notched frequency realized by C-shaped slot is

$$f_{\text{WiMAX-notch}} = \frac{c}{2M_C\sqrt{\varepsilon_{ff}}}, \tag{2}$$

where c is the speed of light, and ε_{eff} is relative dielectric constant, $\varepsilon_{ff} = \frac{\varepsilon_r + 1}{2}$[2].

The total length of L-shaped slot is

$$M_L = W_1 + L_1 - W_s/2. \tag{3}$$

Notched frequency realized by L-shaped slot is

$$f_{\text{WLAN-notch}} = \frac{c}{2M_L\sqrt{\varepsilon_{ff}}}. \tag{4}$$

By continually simulating and optimizing the antenna with commercial software ANSOFT HFS, we can get the optimum parameters shown in Table 1.

Table 1 Optimum parameters of antenna (mm)

L_{sub}	W_{sub}	H	L_g	g	W_f
36	24	1.6	12.7	2	2.4
R_1	R_2	R_3	R_4	*Delta_p*	D
10.2	8.6	3	8.4	1.1	0.5
W_1	L_1	$W_s = L_s$	L_{gps}	w	l
4.5	4.3	0.75	7	3.5	3.5

2 Performance analysis

The original annular antenna broadens bandwidth by realizing dual-frequency resonance; however, it can realize UWB by further reducing the patch and cutting slots. Therefore, the distance g between annular patch and ground, the rectangular slot and stepped slots at the top of the left and right can realize impedance matching to broaden bandwidth of the antenna. The change curve of bandwidth is shown in Fig. 3.

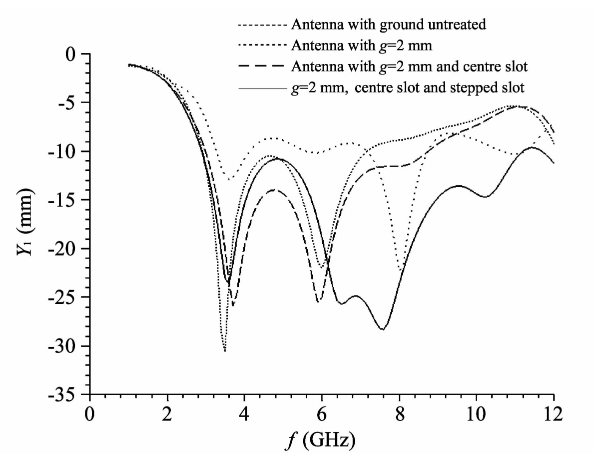

Fig. 3 Change curve of original antenna bandwidth

The length of C-shaped slot is $M_C = 25.7$ mm, which is equal to half of the waveguide wavelength of WiMAX 3.5 GHz. The slot width *Delta_r* and distance g can affect notched characteristics in WiMAX wave band.

From Fig. 4, we know that *Delta_r* can mainly affect the length of C-shaped slot. When the length of slot becomes longer, the notched centre frequency will become smaller, and the notched bandwidth becomes wider; but it has no effect on WLAN waveband.

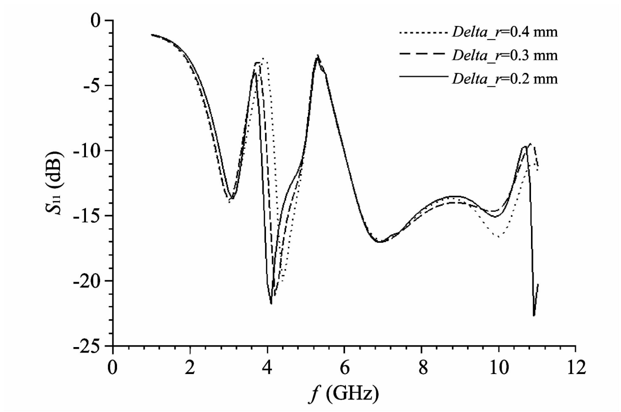

Fig. 4 Impact of *Delta_r* on S_{11}

Fig. 5 shows that when g becomes larger, the notched centre frequency of WiMAX becomes smaller, and bandwidth becomes smaller, too. Meanwhile, g will affect notched bandwidth of WLAN apparently, and the notched bandwidth will shift left as g becomes larger. The change curve of g has a function of impedance matching.

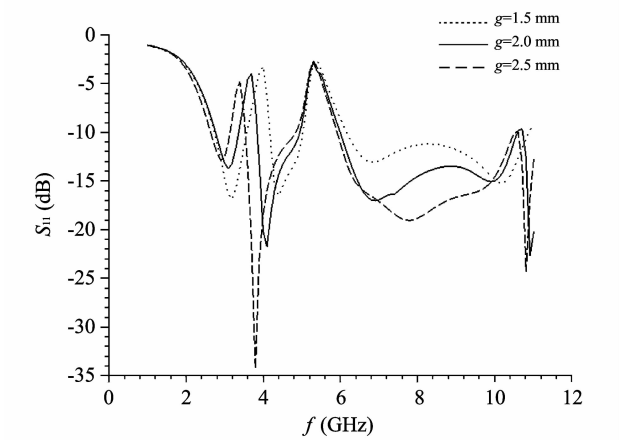

Fig. 5 Impact of g on S_{11}

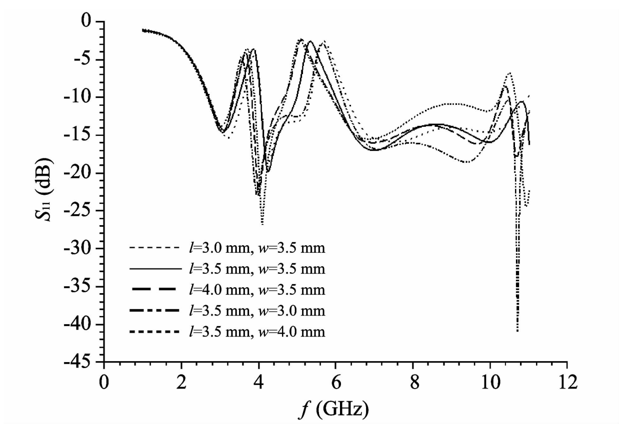

Fig. 6 Impact of l and w on S_{11}

The length of L-shaped slot is $M_L = 8.425$ mm, a quarter of wavelength of WLAN 5.5 GHz. The factors which mainly affect notched WLAN are g, L_{gps}, W_1, $L-1$, w, l, L_s and W_s.

Fig. 6 shows that l and w lead to obvious change of notched WLAN centre frequency and its bandwidth. When l remains changeless and w becomes larger, the notched WLAN centre frequency becomes smaller, but the notched WiMAX is opposite. When w remains changeless, l becomes larger, the notched WLAN and WiMAX centre frequencies become smaller.

Fig. 7 shows that the width of L-shaped slot enormously affects notched WLAN frequency. When the bandwidth becomes larger, both the notched WLAN and WiMAX frequencies become smaller.

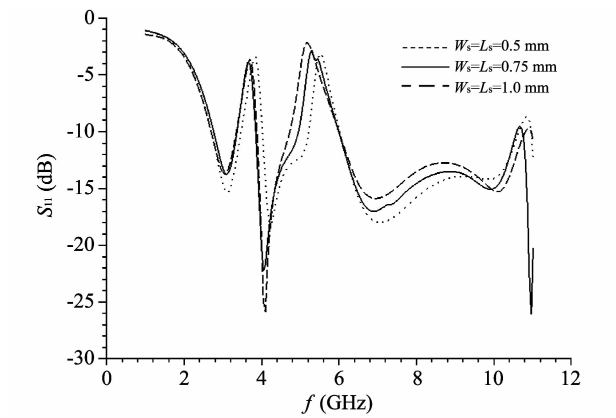

Fig. 7 Impact of width of L-shaped slot on S_{11}

From Fig. 8, we know that the change of L_{gps} affects the two notched frequency. When L_{gps} becomes larger, the notched WLAN bandwidth will become larger; when its centre frequency remains changeless, the notched WIMAX centre frequency will shift left.

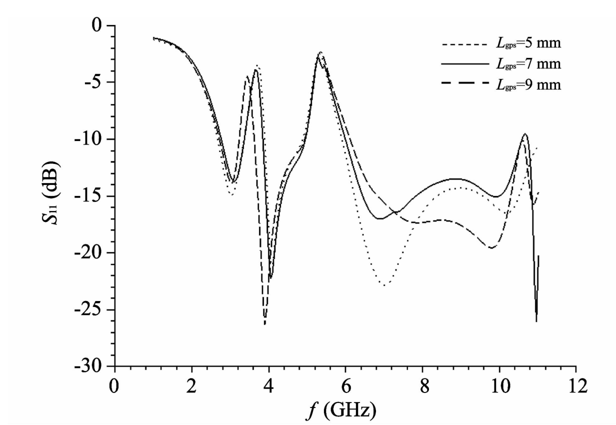

Fig. 8 Impact of L_{gps} on S_{11}

Fig. 9 shows S_{11} of the notched antenna. It can be seen that the bandwidth is 2.7−10.6 GHz while $S_{11} < -10$ dB, which meets the requirement of the frequency for UWB communication of 3.1−10.6 GHz. Between 3.2−3.8 GHz and 5.1−6 GHz, $S_{11} > -10$ dB, and the impedance restraining is apparent, so the antenna has perfect notched characteristics.

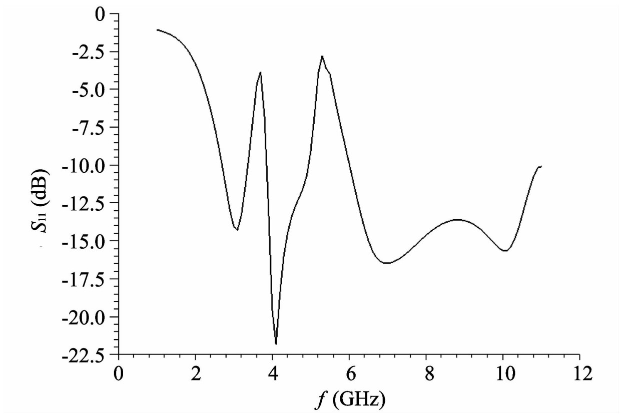

Fig. 9 S_{11} of dual-band notched antenna

The antenna directivity simulation program is carried out at 3, 5, 7 and 10 GHz to analyze its directivity characteristics. From the following Figs. 10 – 13, it can be known that the antenna has perfect directivity characteristics because it is almost omni-directional at Phi = 90 °.

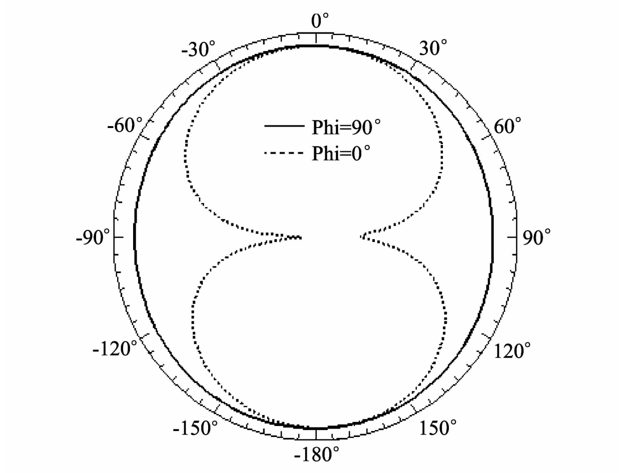

Fig. 10 Directivity at 3 GHz

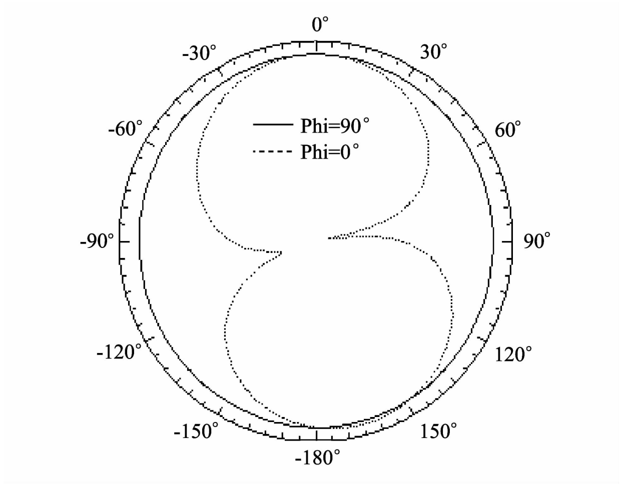

Fig. 11 Directivity at 5 GHz

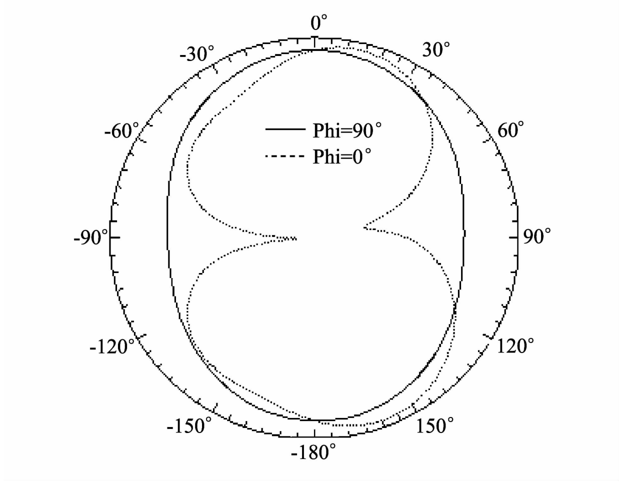

Fig. 12 Directivity at 7 GHz

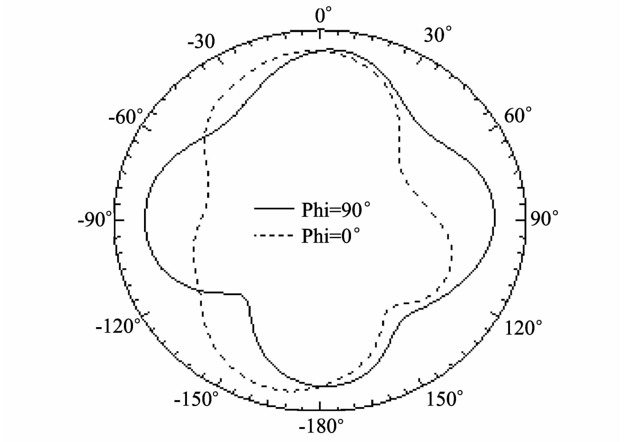

Fig. 13 Directivity at 10 GHz

From Fig. 14, it can be seen that the antenna has good gain, ranging from 1 dB to 4 dB in the whole efficient bandwidth except for two notched bandwidth, which can satisfy practical needs. Thus, it can been proved that the proposed antenna is effective and practical.

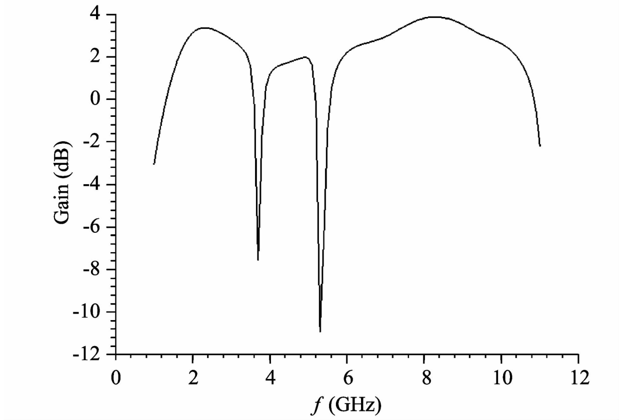

Fig. 14 Gain of the antenna

3 Conclusion

A compact annular dual-band notched UWB antenna with low-cost and small-size is proposed. It realizes notched characteristics well between WiMAX 3.5 GHz and WLAN 5.5 GHz by cutting L-shaped slot on the ground and C-shaped slot on the patch. The bandwidth of 2.7 - 10.6 GHz with $S_{11} < -10$ dB satisfies the need of UWB communications. The antenna has good directivity and radiation characteristics for it is almost omni-directional on *YOZ* plane. Except 3.2 - 3.8 GHz and 5.1 - 6 GHz, it has favorable gain on the whole bandwidth, ranging from 1 dB to 4 dB, so the propsed antenna is efficient and practical.

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一种小型双陷波超宽带单极子天线

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摘　要： 本文设计了一种小型的具有双陷波特性的环形超宽带单极子天线。通过在圆环形辐射贴片上开 C 形缝隙，在反射板上开 L 型缝隙，实现了天线在 WiMAX 3.5 GHz 和 WLAN 5.5 GHz 通信频带内的陷波特性，天线的大小为 24 mm×36 mm×1.6 mm。通过仿真可知，天线 $S_{11} < -10$ dB 时，带宽范围为 2.7－10.6 GHz，陷波范围为 3.2－3.8 GHz 和 5.1－6 GHz，实现了天线小型化、超宽带以及陷波的特性，同时，天线具有良好的辐射特性、方向性和增益，能够满足实际需要。

关键词： 双陷波；超宽带；单极子天线

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