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UWB antenna with triple notched bands based on folded multiple-mode resonators

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Abstract: A novel ultra-wideband (UWB) monopole antenna with triple band-notched functions is presented. A pair of folded multiple-mode resonators (MMR) symmetrically coupled to the feed line are utilized to generate triple notched bands for WiMAX, WLAN and downlinks of X-band satellite communication, respectively. The centre frequencies and band gaps between them can be tuned by varying the length and width of the MMR. Simulated and measured results of the proposed antenna have been displayed and good agreement between them has been achieved.

Keywords: UWB antenna, band-notched function, multiple-mode resonator

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

Ultra-wideband (UWB) technology has attracted increasing attentions in recent years, since the Federal Communications Commission (FCC) allocated the frequency band of 3.1-10.6 GHz for commercial applications. Due to its merits, such as high data rate, low power consumption and good immunity to multipath interference, UWB system has been considered as the most promising candidate for short-range high-speed indoor communication. The UWB antenna is one of the critical components of the UWB communication system. Printed UWB antennas have advantages over some others, owing to their light weight, low profile, conformability and easy fabrication properties [1, 2].

As a result of its wideband feature, the UWB system has to co-exist with some interfering narrow band systems, such as WiMAX (3.3-3.7 GHz), WLAN (5.15-5.825 GHz) and the downlink of X-band satellite communication systems (7.25-7.75 GHz). Therefore, narrow band interference mitigation must be considered in UWB system design. This problem can be conquered by using UWB antennas with band-notched functions. A usual method to realize these functions is inserting slits into the radiating patch or ground plane [3, 4]. Multiple band-notched functions can be obtained by employing various resonant structures in one antenna. Triple band-notched functions based on three notching elements have been realized in [5]. However, this approach increases the complication of the antenna. Multiple notched bands can also be achieved by using single resonant structure. In [6], a half mode substrate integrated waveguide cavity is utilized to create multiple notch bands. Antennas with multiple notched bands based on half-wavelength stepped impedance resonators (SIR) are proposed in [7]. However, these antennas occupy too much area ($50 \times 108\,\text{mm}^2$ in [6], $46 \times 77.5\,\text{mm}^2$ in [7]), which doesn't satisfy the requirement in miniaturization of UWB system.

Recently, the multiple-mode resonator (MMR) has been introduced in [8] to design a UWB bandpass filter with four transmission poles. In this paper, a printed UWB antenna with triple band-notched functions based on this structure is proposed. A pair of MMR structures acting as resonators with multiple resonant frequencies are placed symmetrically in the vicinity of the feed line to create triple notched bands for WiMAX, WLAN and the downlink of X-band satellite communication. The MMR structures employed in this design are folded to obtain a compact dimension. The paper is organized as

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follows: In Section 2, the geometry of the proposed antenna is presented. In Section 3, simulated and measured results are shown and a parameter study is performed. In Section 4, a conclusion is drawn.

2 Antenna design

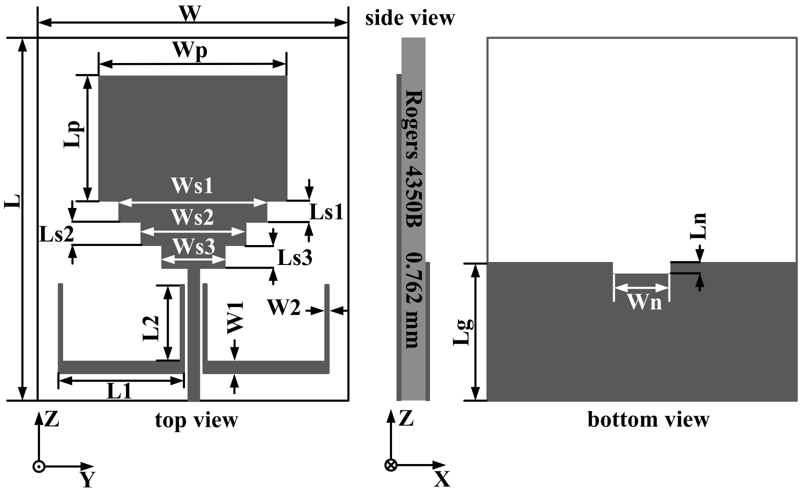

Fig. 1. Geometry of the proposed antenna.

As shown in Fig. 1, the proposed antenna is composed of a radiating patch with three staircases on the front side and a ground plane with a rectangular notch on the back side for optimum impedance matching. The patch is fed by a 50-Ω microstrip line of 1.67 mm width. The antenna is fabricated on a Rogers 4350B substrate with dielectric constant of 3.66 and thickness of 0.762 mm. To create triple notched bands, double identical folded MMR structures are placed symmetrically at different sides of the feed line with a gap of 0.2 mm. The whole antenna occupies an area of $35 \times 40\,\text{mm}^2$, which is much more compact than antennas proposed in [6, 7].

The final optimized physical parameters of the proposed antenna are as follows: $W = 35\,\text{mm}$, $L = 40\,\text{mm}$, $Wp = 20\,\text{mm}$, $Lp = 14\,\text{mm}$, $Ws1 = 16\,\text{mm}$, $Ws2 = 12\,\text{mm}$, $Ws3 = 9\,\text{mm}$, $Ls1 = 2\,\text{mm}$, $Ls2 = 2\,\text{mm}$, $Ls3 = 2\,\text{mm}$, $W1 = 2\,\text{mm}$, $W2 = 0.2\,\text{mm}$, $L1 = 15.6\,\text{mm}$, $L2 = 8.5\,\text{mm}$, $Wn = 7.3\,\text{mm}$, $Ln = 1.2\,\text{mm}$, $Lg = 15\,\text{mm}$.

3 Results and discussion

The proposed antenna was designed and optimized using CST Microwave Studio and measured using an Agilent Vector Network Analyzer E5071C. A photograph of the fabricated antenna is presented in Fig. 2 (a). The simulated and measured return loss of the antenna with folded MMR structures are also shown in Fig. 2 (a), compared with simulation of a reference antenna without band-notched functions. It can be seen that the bandwidth of the proposed antenna is from 2.8 to 10.7 GHz with S11 < -10 dB, hence good wideband impedance matching performance is obtained. In addition,

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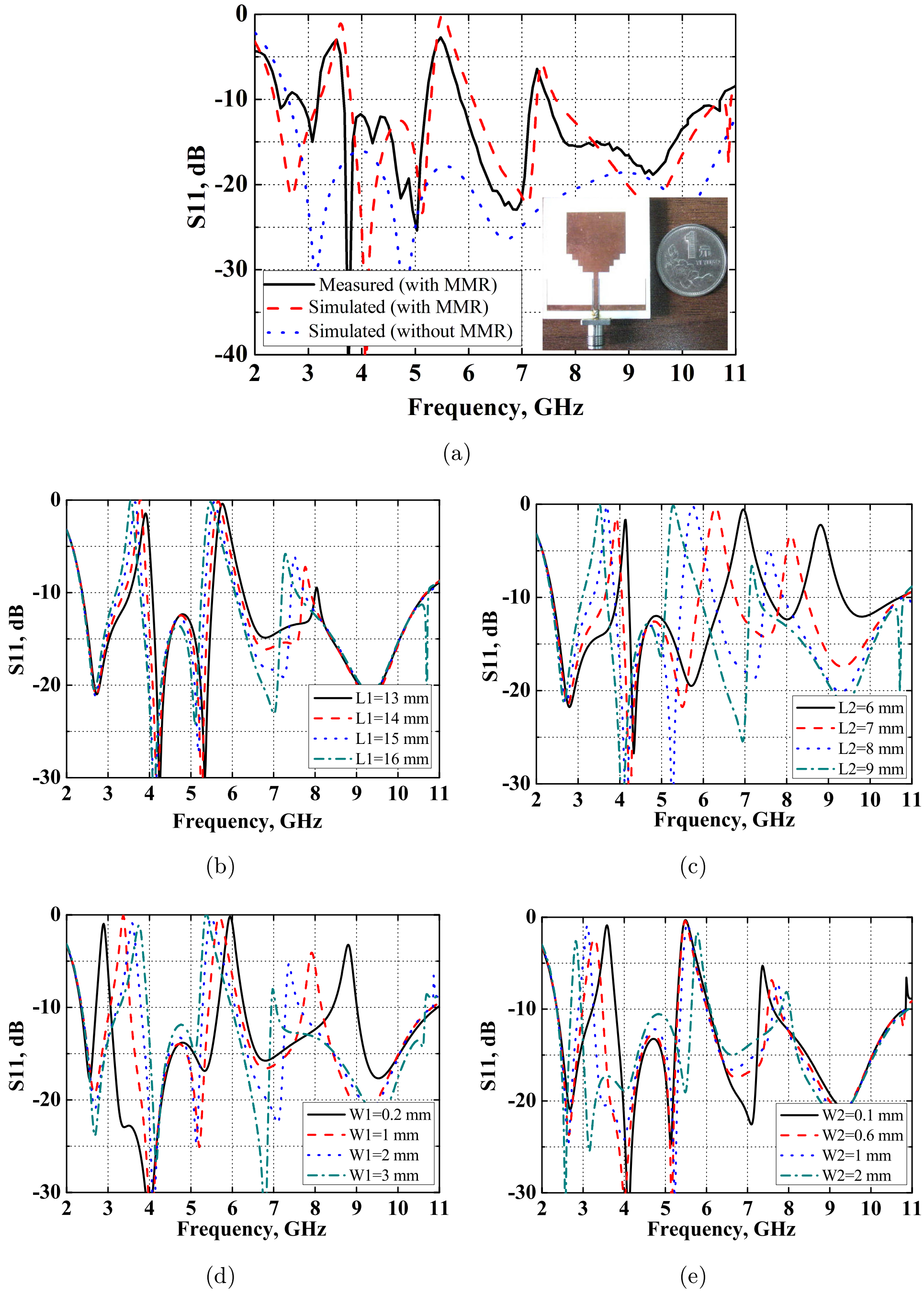

Fig. 2. (a) Simulated and measured return loss of the proposed antenna. Simulated return loss curves for different values of (b) L_1, (c) L_2, (d) W_1 and (e) W_2.

the proposed antenna has three notched bands of 3.2-3.7 GHz, 5.2-5.85 GHz and 7.15-7.5 GHz for WiMAX, WLAN and X-band satellite communication respectively. The discrepancy between the measurement and simulation is acceptable, which is mainly attributed to the measurement environment and error of fabrication. Therefore, the proposed antenna can operate over the entire UWB band from 3.1 to 10.6 GHz and avoid interferences from WiMAX, WLAN and X-band satellite communication systems effectively.

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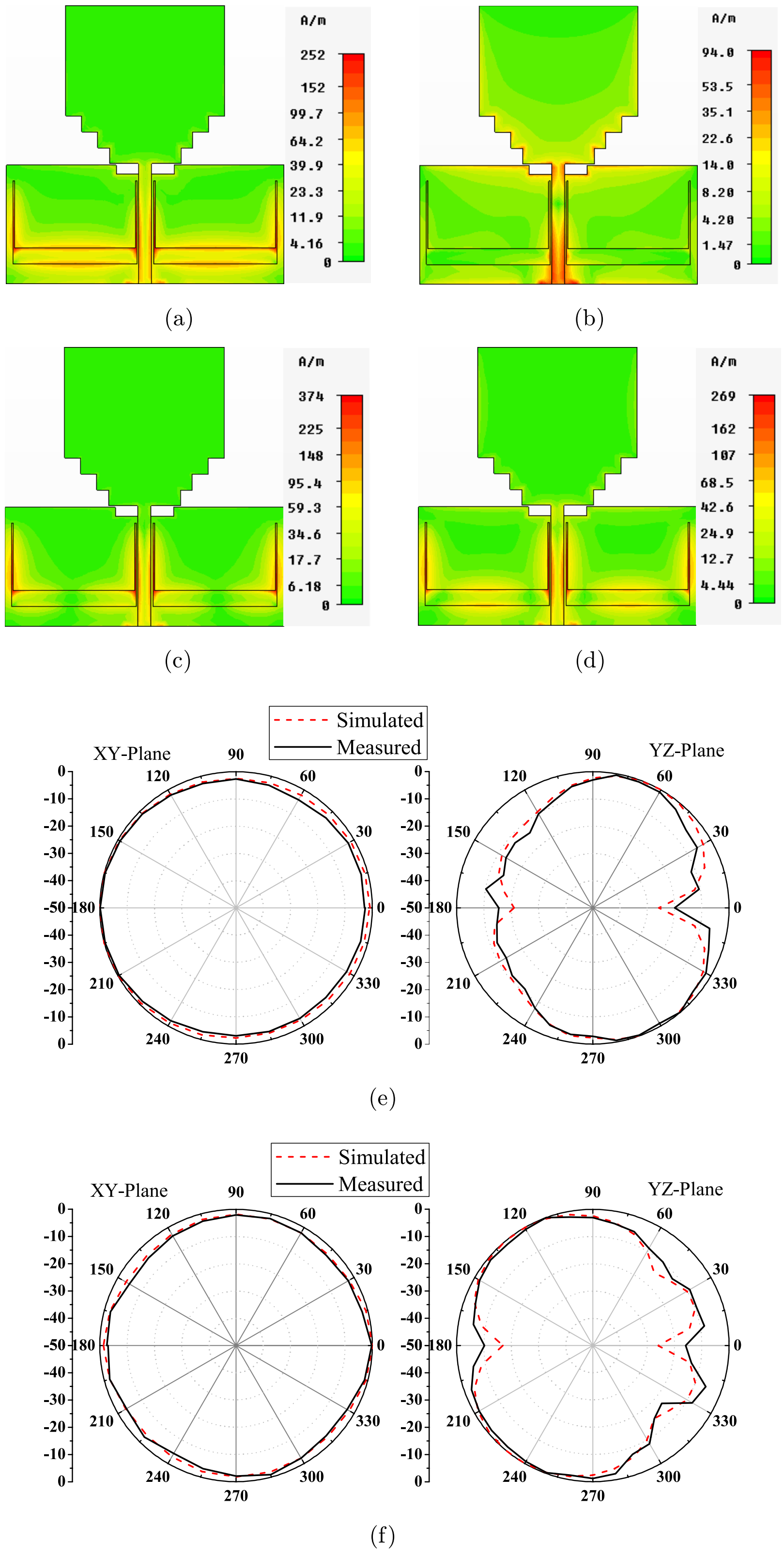

Fig. 3. Simulated surface current distributions at (a) 3.6 GHz, (b) 4.6 GHz, (c) 5.5 GHz and (d) 7.25 GHz. Simulated and measured radiation pattern at (e) 4 GHz and (f) 8 GHz.

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A parametric analysis is made for further investigation. Simulated return loss curves for the proposed antenna in terms of $L1$ and $L2$ are shown in Fig. 2 (b) and (c), respectively. It is observed from Fig. 2 (b) that as the length $L1$ increases from 13 to 16 mm, the centre frequency of the first notched band decreases from 3.9 to 3.55 GHz, the one of the second notched band decreases from 5.75 to 5.45 GHz and the one of the third notched band decreases from 8 to 7.25 GHz. It can be seen from Fig. 2 (c) that the length $L2$ also have a strong effect on the centre frequencies of the triple notched bands. The effects of various $W1$ and $W2$ on the band gaps between the three notched bands are shown in Fig. 2 (d) and (e), respectively. As shown in Fig. 2 (d), with the increasing of $W1$ from 0.2 to 3 mm, the band gap between the first and second notched bands decreases from 3.1 to 1.6 GHz and the one between the second and third notched bands declines from 2.8 to 1.6 GHz. As indicated in Fig. 2 (e), the band gaps between the three notched bands are also influenced by the width $W2$ significantly. Therefore, the centre frequencies and band gaps between them are controllable by carefully adjusting the MMRs physical parameters $L1$, $L2$, $W1$ and $W2$.

In order to understand the behavior of the folded multiple-mode resonators, especially in the notched bands, surface current distributions at 3.5, 4.6, 5.5 and 7.25 GHz are simulated and exhibited in Fig. 3 (a), (b), (c) and (d) respectively. It is clear from Fig. 3 (a), (c) and (d) that the surface current distribution is mainly concentrated on the MMR structures at the triple notched bands, and is small on the radiating patch. While it can be seen from Fig. 3 (b) that the surface current distribution is strong on the radiating patch and feed line, and is week on the MMRs at 4.6 GHz. Furthermore, it can be observed that the surface current distribution has one node at the center point of MMR structure at 5.5 GHz (Fig. 3 (c)), and two nodes near the turnings of the folded MMR structure at 7.25 GHz (Fig. 3 (d)). Therefore, the resonant frequencies at 5.5 and 7.25 GHz are the second and third order resonances of the MMR structure.

Simulated and measured radiation patterns at two frequencies 4 and 8 GHz for the two principal planes XY- and YZ-plane are presented in Fig. 3 (e) and (f). It can be seen from Fig. 3 that the proposed antenna shows an omnidirectional performance in the XY-plane, while a dipole-like radiation pattern is observed in the YZ-plane.

4 Conclusion

A printed UWB antenna with triple notched-band functions was introduced. A pair of folded MMR structures were employed to obtain three notched bands for WiMAX, WLAN and X-band satellite communication. The central frequencies and band gaps between them can be adjusted by changing the physical parameters of the MMR structures. Therefore, the mean of folded MMR is effective to generate multiple notch bands and reduce the dimension of UWB antenna.

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