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A Compact Differential-Fed Half-Elliptic Monopole Antenna with Triple Band-Notched function

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Abstract—A compact half-elliptic monopole antenna with triple notched-bands for UWB application, which is driven with differential feeding systems, is proposed. The basic antenna consists of two symmetrical half-elliptic patches and a modified ground plane. To reject the 5.5-GHz WLAN band effectively, two pairs of Ω-shaped strips are placed as parasitic elements close to the feedline. By introducing rectangular SRRs and an Ω-shaped slot on the radiators, the operating bands of 3.5-GHz WiMAX and 8-GHz ITU can be notched, respectively. Compared with conventional single-ended feed antennas, the proposed differential-fed antenna can achieve better polarization purity, especially in the high-frequency band.

1. INTRODUCTION

Since the Federal Communications Commission (FCC) released the spectrum from 3.1 to 10.6 GHz in 2002, ultra-wideband (UWB) technology which can support high-data-rate wireless transmission with low power consumption has been rapidly developed [1]. As a key component in UWB communication systems, UWB antennas have drawn great attention from antenna engineers. Until recently, various types of UWB antennas have been proposed, such as UWB planar inverted-F antenna (PIFA) [2], magneto-electric dipole antenna [3], etc. However, in order to make it better used in UWB systems, one of the major challenges is to avoid electromagnetic interference (EMI) occurring due to existing narrowband communication systems such as IEEE 802.16 WiMAX band, IEEE 802.11a WLAN bands, and ITU 8-GHz band. Therefore, to mitigate the potential interference, different methods in designing the UWB antenna with band-notched characteristics have been proposed. In [4], a pair of L-shaped slits and an E-shaped slot are embedded on the square radiation patch to create dual notched bands. Two elliptic single complementary split-ring resonators (ESCSRRs) of different dimensions are etched from the radiation patch to obtain WiMAX and WLAN notched bands, and two rectangular split-ring resonators are placed near the feedline-patch to reject the third band in [5]. By inserting a π-shaped slot with lumped varactor, a tunable notched band can be obtained [6]. Nevertheless, even though these antennas can be matched easily over the entire UWB bandwidth, the radiation pattern will be deteriorated at high frequencies (above 9 GHz) because of the structure with single-ended feed.

To enhance the radiation performance, in the design of [7], when the antenna is symmetrically driven using a differential-fed system, the cross-polarization can be suppressed greatly. Compared to a single-ended UWB antenna, the differential feeding structure has lower cross polarization [8, 9]. However, in [8], the differential-fed antenna only improves the performance of the radiation patterns without notch the narrow communication band. In [9], the size of the antenna is $30 * 35\,\mathrm{mm}^2$ and only one notched band is obtained from 5.08 to 5.95 GHz. In this paper, a compact differential-fed half-elliptic monopole antenna with triple notched-bands is presented for UWB applications. Compared to

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the circular, rectangular or elliptic monopole antenna, the structure of half-ellipse is more compact. A rectangular slot and an Ω-shaped slot are etched into the radiation patch to produce the band-notched characteristic of WiMAX and ITU. Furthermore, Ω-shaped strips are placed near the feedline to generate the WLAN notched band. The proposed antenna has lower cross polarization than single-ended UWB antenna, and good radiation pattern characteristics are obtained in the interested frequency band. The simulation and analysis for the proposed antenna are performed using the electromagnetic simulator ANSYS HFSS 15.

2. ANTENNA CONFIGURATION

The topology of the proposed antenna is depicted in Fig. 1. The proposed antenna is fabricated on a low-cost FR4 substrate with permittivity of 4.4, loss tangent of 0.024, and compact size of $26 \times 30 \times 1\,\text{mm}^3$. Fig. 2 illustrates the evolution of the antenna design principle adopted in this letter and shows the variations of corresponding simulated reflection coefficients with frequency for different stages. The basic Ant 1 etches differential microstrip feeding lines on the top side of the substrate, loading with two half-elliptic patches and a modified ground plane on the other side of the substrate. For good impedance matching, the width of the feeding line tapers from 1.9 to 1.06 mm. And the antenna can obtain an impedance bandwidth from 2.58 to 10.74 GHz with a VSWR lower than 2, which covers the FCC specified frequency range for UWB application. Next, for improving the performance of the antenna, the band-notched characteristic in the specific frequency is obtained. In Ant 2, to cut off the 4.95–6.01 GHz band limited by WLAN, Ω-shaped strips were symmetrically placed beside the feedline and the radiation patch. To notch the 7.94–8.68 GHz band, an Ω-shaped slot was embedded into the radiation patch, shown in Ant 3. To obtain the antenna with triple notched-bands, a rectangular slot was embedded into the radiation patch to notch the 3.22–4.00 GHz band, shown in Ant 4.

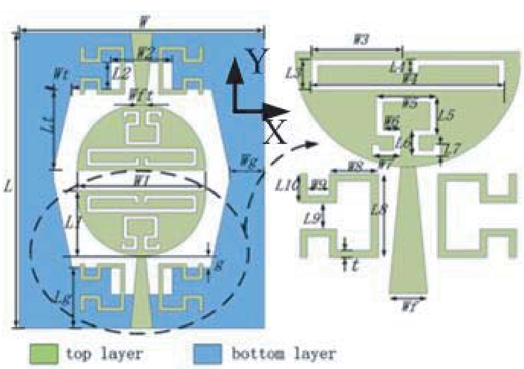


Figure 1. Topology of the proposed antenna.

The length of the slots and strips appears to be half of the guided wavelength at the notch frequency. The dimensions of the band-notched feature at the notch frequency can be assumed as

$$L_{notch} = c/2f_{notch}\sqrt{\varepsilon_r} \tag{1}$$

where L_{notch}, c, and ε_r are the total length of the strip or slot, the speed of light in free space, the effective dielectric constant, respectively. The band-notched characteristics can be controlled by adjusting the parameters of the slots or strips. By optimization dimensions of the slots and strip, the triple band-notched antenna can be obtained as presented in the Ant 4. To understand the phenomenon behind the notch performance, the simulated current distributions of the proposed antenna at the notched frequencies are shown in Fig. 3. It is clear that the surface current is mainly concentrated along the rectangular slot, Ω-shaped strips and Ω-shaped slots at the notch frequencies of 3.5, 5.45, 8.15 GHz, respectively. In fact, the antenna can hardly radiate at the desired notched band because the rectangular slot, Ω-shaped strips and Ω-shaped slots acting as resonators cause serious antenna impedance mismatching. The optimized parameter values are listed in Table 1.

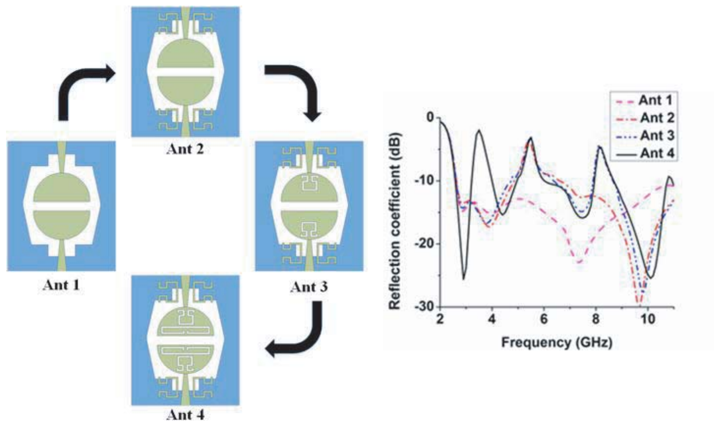


Figure 2. Design evolution and the simulated reflection coefficients against frequency.

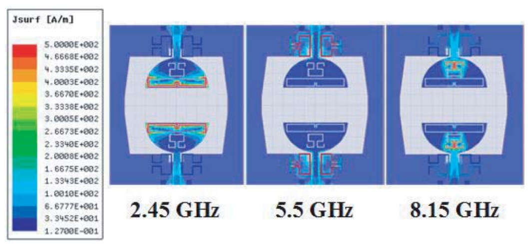


Figure 3. Simulated surface current distribution.

Table 1. Optimized antenna parameters.

Parameter	W	L	Wg	Lg	Wt	Lt	Wf
Value (mm)	26	30	3	5.8	1	7.5	1.9
Parameter	Wft	$W1$	$L1$	$W2$	$L2$	$W3$	$L3$
Value (mm)	1.06	12.1	11.1	2.8	1.5	5	1.6
Parameter	$W4$	$L4$	$W5$	$L5$	$W6$	$L6$	$W7$
Value (mm)	10.6	0.8	2.5	1.5	0.8	1.3	1.2
Parameter	$L7$	$W8$	$L8$	$W9$	$L9$	$L10$	t
Value (mm)	0.5	2.2	4	1.5	0.5	0.5	0.2

3. MEASUREMENT RESULTS AND DISCUSSION

Based on the parameter values given in Table 1, the proposed antenna was fabricated and tested. A photograph and the simulated and measured reflection coefficients of the proposed antenna are shown in Fig. 4. It is observed that the fabricated antenna achieves a wideband performance from 2.58 to 10.74 GHz for a reflection coefficient ≤ -10 dB, except for three rejection bands notched in the frequency ranges of 3.25–4.00, 4.95–6.01 and 7.98–8.78 GHz. The measured results are in good agreement with the simulation. Therefore, the proposed antenna covers the entire UWB band from 3.1–10.6 GHz designed by FCC. Moreover, triple notched-bands are obtained to suppress the potential interference from the 2.4/5.2/5.8-GHz WLAN, 3.5/5.5-GHz WiMAX and 8-GHz ITU applications.

Figure 5 shows the simulated and measured radiation patterns in E-plane and H-plane at 3.1, 4.5, 7.1, and 9.5 GHz. It is obvious that the proposed antenna displays omnidirectional radiation patterns in the H-plane and dipole-like radiation patterns in the E-plane within the entire operating band.

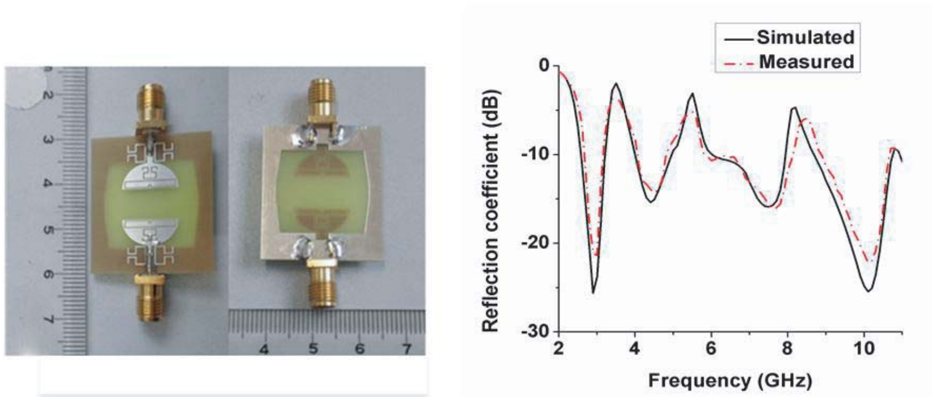
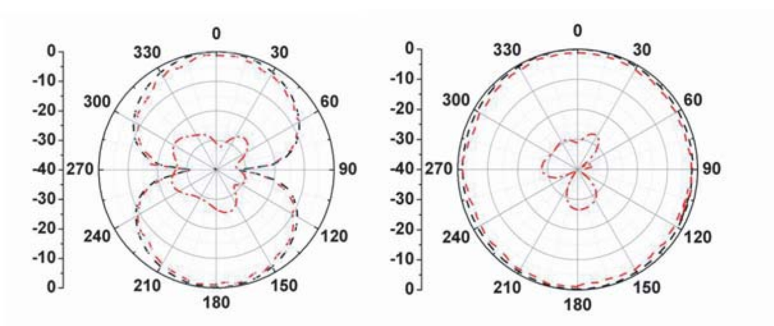
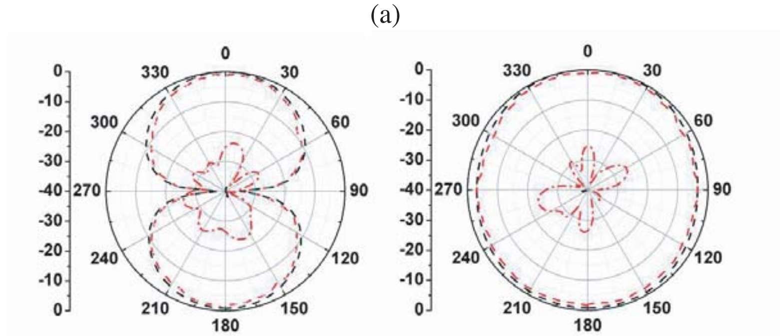


Figure 4. Photograph of the fabricated antenna and the simulated and measured reflection coefficients of the proposed antenna.



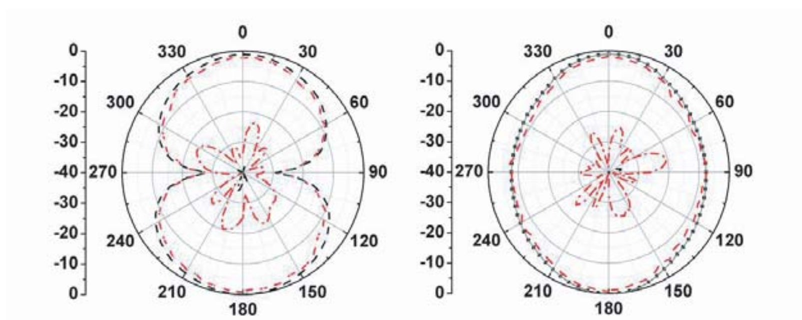
E-plane H-plane

(a)



E-plane H-plane

(b)



E-plane H-plane

(c)

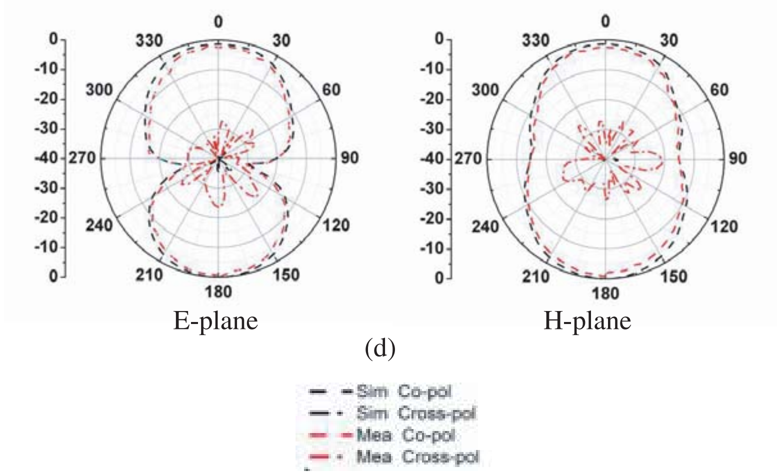


Figure 5. 2-D radiation pattern of the proposed antenna: (a) 3.1 GHz; (b) 4.5 GHz; (c) 7.1 GHz; and (d) 9.5 GHz.

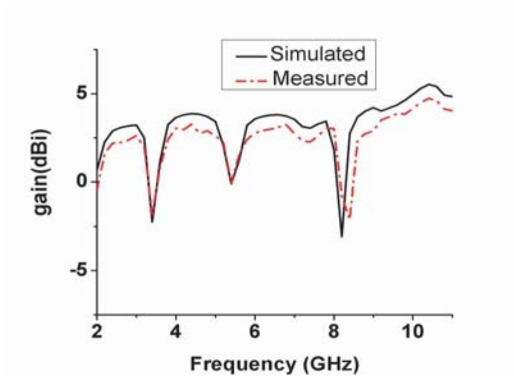


Figure 6. Simulated and measured gains of the proposed antenna.

Moreover, the measured cross-polarisation level of the radiation patterns is lower than −20 dB. It can be observed in Fig. 6 that the proposed antenna shows three sharp decreases at the frequency bands of 3.45, 5.5 and 8.15 GHz and good performance in the radiating band. The difference between the simulated and measured results may be caused by the SMA connector and the error in measurement. And the measured gain results in three operating bands can satisfy the application for wireless community.

4. CONCLUSION

In this letter, a differential-fed compact UWB antenna with triple band-notched characteristics is fabricated and measured. By embedding a rectangular slot and an Ω-shaped slot or strip in the antenna structure, triple notched-bands covering the WiMAX, WLAN, and ITU band are obtained, and the potential interferences between these systems can be reduced to the minimum. More importantly, the cross-polarisation maintains a low level even in high frequency. The measurements of the fabricated antenna exhibit good match with the simulation, which means that the proposed antenna can be a good candidate for UWB application.

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