Compact Dual Band-Reject Monopole Antenna for UWB Applications

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Abstract **—** In this letter, a compact planar ultra-wideband (UWB) monopole antenna with excellent band-rejection characteristics is proposed for UWB communications applications. To achieve band-rejection filter property at the WiFi / WiMAX bands, two different types of slots: sloped open-ended Z-shaped slot and split rectangle ring slot on radiation patch, are introduced to form two stop-bands. The measured and simulated results show that the band-notched characteristics not only bring good rejection frequency, but also improved the skirt area in the band-notched frequency, and the proposed antenna has nearly omni-directional radiation pattern, moderate gain, and low cross-polarization level, which is suitable for UWB communication applications.

Index Terms **-** Coplanar waveguide (CPW) feeding, dual notched bands, open-ended Z-shaped slot, split rectangle ring slot, and ultra-wideband (UWB) antenna.

I. INTRODUCTION

It is a well-known fact that monopole antennas have been a highly competitive topic in wireless communication systems in recent years, since they have many attractive advantages, such as simple structure, low profile, light weight, small size, easy fabrication, omni-directional radiation pattern, and so on. On the other hand, coplanar waveguide (CPW)-fed mechanism has many irreplaceable advantages over microstrip-fed manner [1], such as low dispersion, lower loss, the ability to effectively eliminate the alignment errors, and the antenna can be printed on a single side of the printed circuit board for alleviating the problem of space restrictions in a device, thus it often is introduced to design ultra-wideband (UWB) monopole antennas [1-7], which operate in the United States federal communication commission (FCC) frequency defined from 3.1 GHz to 10.6 GHz for high data rate and short range ultra-wideband communication systems [8].

However, it is generally known that UWB transmitters should not cause any electromagnetic interference on nearly communication system, such as the existing wireless local area network (WLAN) and the worldwide interoperability for microwave access (WiMAX) covering the 3.3 GHz - 3.7 GHz, 5.15 GHz - 5.35 GHz, and 5.725 GHz - 5.825 GHz. Therefore, UWB antenna with notched characteristics in these frequency bands is desired. Recently, various methods were reported to design band-notched antenna. The universal method is cutting slots on the radiation patch or ground plane, i.e., slot-type split ring resonators (SRRs), W-shaped slots, semicircular slots, L-shaped slots, U/C-shaped slots, E-shaped slot, H-shaped slot in [3, 9-16], and so on. Others main approaches are the use of parasitic elements [17-19], quarter-wavelength stub connected to radiation patch [19, 20] or ground plane [21] by metallic vias on the opposing plane, and electromagnetic-band-gap (EBG) structures [22]. However, most of the antennas mentioned above can not provide satisfactory skirt area and sufficient rejection bandwidth, which reveals that lower performance of potential interference suppression from skirt bands may still exist in such antennas.

In this work, a novel design of UWB monopole antenna is designed, which presents

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desired band-rejection features by embedding two different types of resonant slots. Experimental results demonstrate that the proposed antenna have very sharp, fully wide, and deep band-notched characteristics.

II. ANTENNA CONFIGURATION

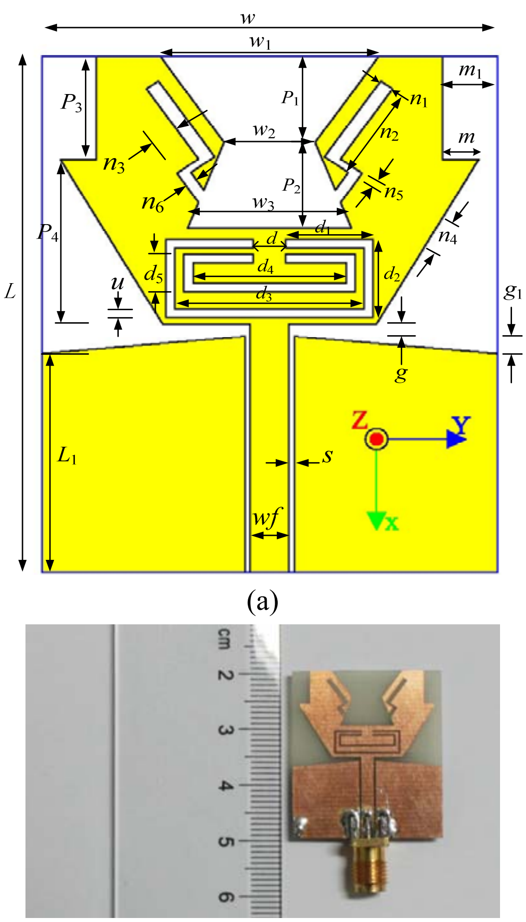
The geometrical configuration of the proposed UWB band-rejected antenna is shown in Fig. 1. The antenna has a single-layer metallic structure and is printed on an inexpensive FR-4 substrate of thickness 0.8 mm, with a dielectric constant of 4.6 and a loss tangent of 0.02. A 50 Ω CPW transmission line of strip width 2.1 mm, and gap 0.3 mm is used for feeding the antenna. The overall dimension of the antenna is only 30 mm (*L*) × 25 mm (*w*). The radiation patch is composed of a trapezoid patch and a rectangle patch, and then loaded by arbitrary hexagon-shaped slot on the edge of the radiating patch. The ground plane is modified by truncating two triangle-shaped patches in both sides of the ground plane. To achieve notched bands, a pair of sloped open-ended Z-shaped slots and two split rectangle ring slots on the radiating patch are adopted to generate two notched bands in the center frequency of 3.5 GHz and 5.5 GHz, respectively. In this design, the Z-shaped slots (ZSS) act as a quarter-guided-wavelength resonator, which the length may be empirically approximated by,

$$L_{ZSS} = n_2 + n_3 + n_4 = \lambda/4 . \quad (1)$$

The split rectangle ring slot (SRRS) is a half-guided-wavelength resonator, and can be deduced by

$$L_{SRRS} = 2(d_1 + d_2) + d_3 = \lambda/2, \quad (2)$$

where $\lambda = c \Big/ f\sqrt{\frac{\varepsilon_r + 1}{2}}$, c is the speed of light in free space, ε_r is the dielectric constant, and f is the center notched frequency. At the beginning of the design, and by using equations (1) and (2), one may estimate the notched dimensions of the sloped Z-shaped slots and split rectangle ring slot approximately. Moreover, by adjusting the width and length of the slots, the stop-band property of the antenna can be controlled desirably. The proper parameters can be obtained with the aid of the commercially available software Ansoft HFSS13 (high-frequency structure simulator), and a 50 Ω-SMA connector is connected to the end of the CPW-feed mechanism, which serves as the antenna port. Parameter values of the proposed antenna are summarized in Table I. Moreover, a photograph of the fabricated antenna with dual-band notched characteristic is shown in Fig. 1 (b).



(a)

(b)

Fig. 1. (a) Geometry of the proposed antenna and (b) photograph of the proposed antenna.

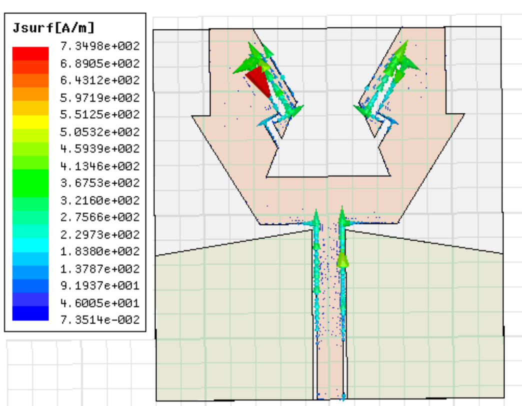
Table I: Parameter values of the fabricated antenna (dimensions are in mm).

Parameter	*u*	*L_1*	*w_1*	*w_2*	*w_3*	*wf*
Value	0.3	12.7	12	5	9	2.1
Parameter	P_1	P_2	P_3	P_4	g	g_1
Value	5	5	6	9.6	0.7	1
Parameter	d	d_1	d_2	d_3	d_4	d_5
Value	1.8	4.6	4.15	10.4	8.8	2.2
Parameter	n_1	n_2	n_3	n_4	n_5	n_6
Value	0.8	5.4	1.45	2.06	0.4	0.65
Parameter	s	m	m1			
Value	0.3	1.98	3			

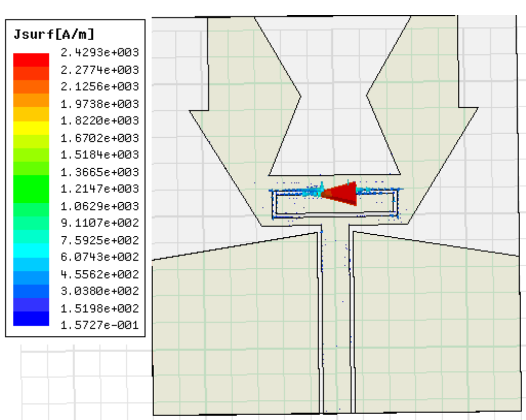
III. RESULTS AND DISCUSSIONS

A. Compact UWB Planar antenna with single notched slot

To further comprehend the band-rejection characteristic, a Z-shaped slot or rectangle split ring slot is embedded in the radiation patch as shown in Figs. 2 (a) and (b), respectively. At the notch frequency, the current flows are more dominant around the filter structures, and are concentrated on the edges of these slots with opposite direction. Therefore, the resultant radiation fields cancel out, and high attenuation near the notch frequency is produced. Namely, the antenna does not radiate efficiently in the notched frequency ranges. It is also seen that unlike Fig. 2 (b), in Fig. 2 (a) the main current not only flows around the Z-shaped slot, but also a small quantity of currents appear in CPW, which show that rectangle split ring slot have better band-rejection character than open-ended slot.



(a)



(b)

Fig. 2. Current distributions at the notched frequency.

Figure 3 shows the simulated filter characteristic with single notched slot. The figure clarifies that the maximum values of the reflection coefficient curve in the Z-shaped slot filter frequency band is closer to the high edge band-rejection frequency, which is in contrast to the low edge band-rejection frequency. Nevertheless, the split ring slot filter mechanism has opposite property. It is shown that the Z-shaped slot filter mechanism may control the high edge band-notched frequency. The spilt ring slot notched mechanism may master the low edge notched frequency, which lead to improve the skirt area in the band-notched frequency.

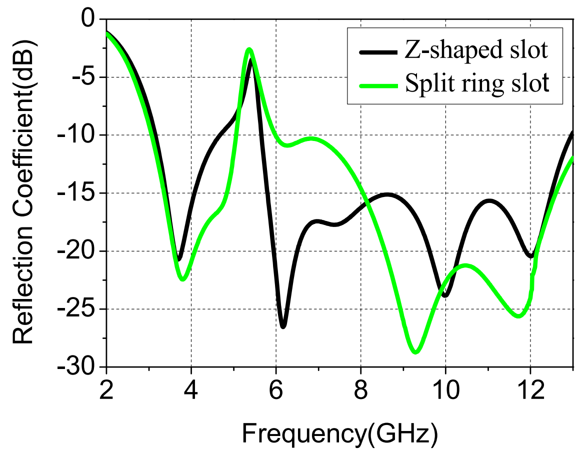


Fig. 3. Simulated reflection coefficient of a single notched slot.

B. Compact UWB planar antenna with united notched frequency characteristics

The proposed antenna was implemented and tested using an Agilent N5230A series vector network analyzer. Figure 4 shows the simulated and measured reflection coefficient against frequency for the proposed united dual band-notched antenna, which shows good agreement. There exists a discrepancy between the simulated results and the measured data owing to the error of the substrate parameters of the FR-4 substrate and the tolerance in manufacturing [22]. The simulated notched frequency bandwidth of the proposed antenna is achieved from 3.34 GHz to 3.74 GHz and 5.15 GHz to 5.9 GHz, and the measured stop-band frequency ranges are from 3.35 GHz - 3.72 GHz and 5.17 GHz - 6.14 GHz for S11 > -10dB with maximum reflection coefficient of -2.47 dB.

Obviously, the achieved notched bandwidths can suppress dispensable WLAN/WiMAX bands for UWB applications completely. Table II presents performance comparison with other works [5, 10, 15, 17], which shows that the proposed antenna not only has small size, but also good band-reject characteristics.

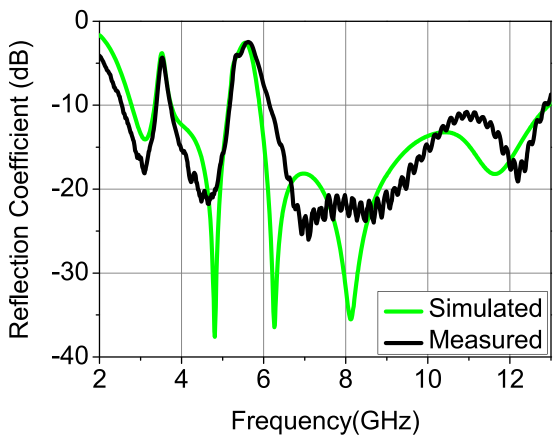


Fig. 4. Simulated and measured reflection coefficient of the proposed antenna.

Table II: Performance comparison.

Works	ε_r	Dimensions (mm^3)	Notched band ranges (GHz) (<-10dB)
Ref.[5]	4.4	21×28×1.6	3.2-3.8 and 5.1-5.9
Ref.[10]	4.4	20×30×1.5	3.4-3.8 and 4.8-6.2
Ref.[15]	2.65	14×35×0.8	3.49-4.12 and 5.66-6.43
Ref.[17]	4.4	30×35×1.6	5.12-6.08
This paper	4.4	30×25×0.8	3.35-3.72 and 5.17-6.14

Radiation characteristics are also considered. To examine the design validity, a comparison in the radiation pattern, in the *xz*- and *yz*-planes for both E_Φ and E_θ at 4 GHz, 8 GHz, and 10 GHz, by using the simulator HFSS and time-domain finite integration technique (CST Microwave Studio) is shown in Fig. 5, which shows very good agreement. From the results, it demonstrates that all the operating frequencies have the same polarization plane, similar radiation patterns, and very small cross-polarization levels throughout the UWB range of frequencies (less than -20 dB). The radiation pattern is found to be figure of eight shape along the *xz*-plane and nearly omni-directional pattern in the *yz*-plane. It is observed that at the *yz*-plane radiation pattern of the antenna shows relatively larger cross-polarization level than that at the *xz*-plane. This behavior is largely due to the strong horizontal components of the surface current and electric field. Because the vertical component of the surface current is the main contribution to the co-polarization radiation and the horizontal component contributes to the cross-polarization radiation.

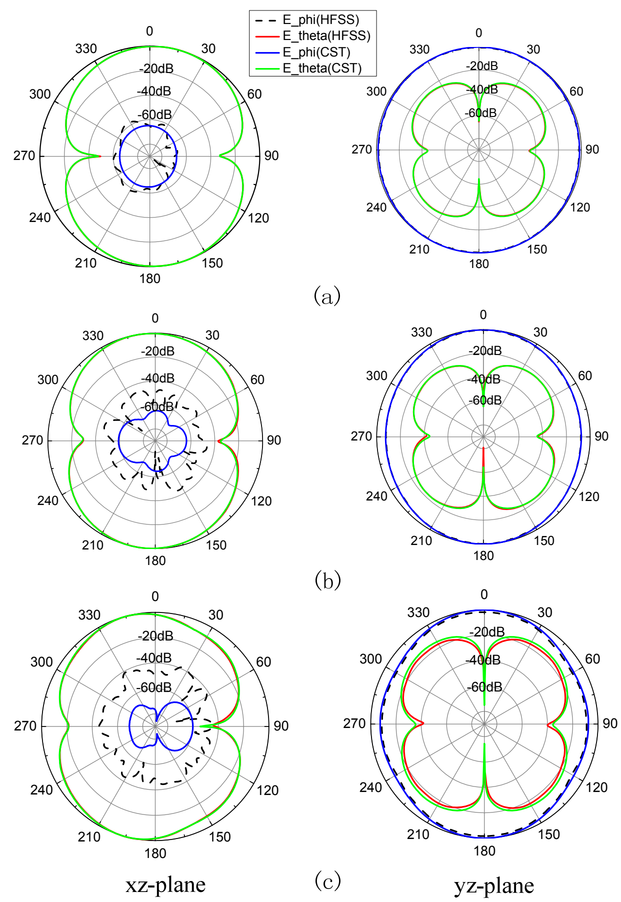


Fig. 5. Radiation patterns for the proposed antenna at (a) 4 GHz, (b) 8 GHz, and (c) 10 GHz in the *xz*- and *yz*-planes, respectively.

For the sake of further describing excellent filter performance, the simulated peak gain for the proposed antenna from 2 GHz to 13 GHz is presented in Fig. 6. As expected, the gain decreases sharply at the notched frequency bands for the antenna with band-notched filter and the band-notched characteristic is improved in the shirt area of the notched frequency. The simulated radiation efficiency is also provided in Fig. 7 and varies from 78.5 % to 94 % in the operating bands. Whereas it is low as 19.5 % and 20 %, within the band-rejection frequency (3.3 GHz - 3.7 GHz, 5.15 GHz - 5.85 GHz, respectively).

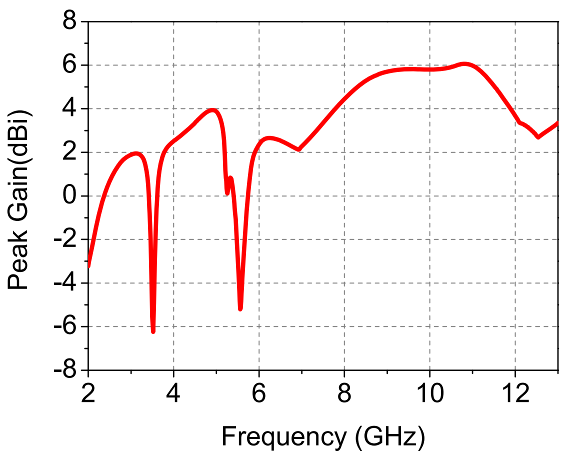


Fig. 6. Simulated gain curve of the proposed band-notched antenna.

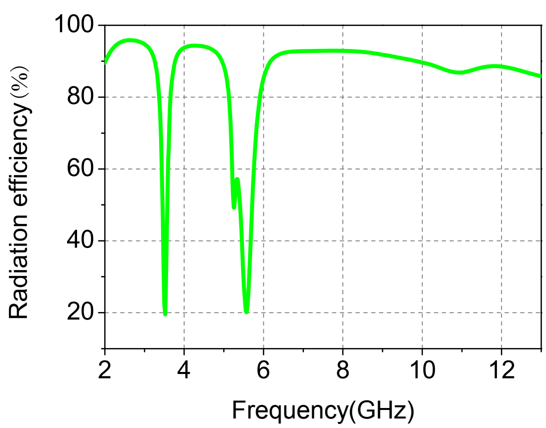


Fig. 7. Simulated radiation efficiency of the proposed band-notched antenna.

IV. CONCLUSION

In this paper, a novel planar UWB monopole antenna with excellent band-rejected characteristics is achieved by embedding two different types of slots on the radiating patch, i.e., sloped open-ended Z-shaped slot and split rectangle ring slot. The measured results show that the notched frequency of the proposed antenna has very sharp form, fully wide, and deep band-notched characteristics. This antenna also presents good omni-direction pattern in the entire UWB frequency, and keeps a stable gain and high radiation efficiency in the UWB frequency ranges expect for the notched frequency ranges. Furthermore, the proposed antenna exhibits compact and small dimensions of 30 × 25mm^2. These features make it a good candidate for ultra-wideband wireless applications.

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