Compact UWB Dielectric Resonator Antenna with WLAN Band Rejection

M. Abedian, S. K. A. Rahim, S. Danesh, and Tharek Abdul Rahman

***Abstract*—A new compact band-notched dielectric resonator antenna (DRA) for ultra-wideband (UWB) applications is presented. The antenna elements consist of a thin monopole printed antenna loaded with rectangular dielectric resonator (RDR) which is housed into a dielectric substrate, an I-shaped parasitic strip, and a slot on the ground plane. Here, to realize band-notched characteristic, an I-shaped parasitic strip is placed on the top of DRA. By cutting a slot on the ground plane, impedance matching performance is improved. The proposed antenna provides an impedance bandwidth of around 98 %, excellent omni-directional radiation patterns with low cross polarization, nearly constant gain, and high radiation efficiency across the whole desired frequency band.**

***Index Terms*— Dielectric resonator antenna (DRA), ultra-wideband (UWB) antenna, band-notched.**

I. Introduction

Ultra-wideband (UWB) communication systems which is defined by the Federal Communications Commission (FCC) from the 3.1-10.6 GHz unlicensed band achieves immense attention in the wireless communication due to several advantages, including high data rates, simple hardware configuration, high precision ranging, and low power consumption [1]. In terms of UWB antenna design, there are some challenges to achieve such as compact antenna size, constant gain, high radiation efficiency, and avoiding electromagnetic interferences from nearby narrow band systems.

The Dielectric Resonator Antennas (DRAs) are potential candidate for UWB applications because of various advantages such as high radiation efficiency, compact antenna size, low dissipation loss, and various excitation mechanisms [2-6]. In the past two decades, remarkable efforts for the DRA have been reported to enhance the bandwidth [7, 8]. For instance, in [7], an L-shaped dielectric resonator (DR) excited by a conformal inverted-trapezoidal patch connected to a microstrip line is applied to achieve a wide bandwidth of about 71.4%. In parallel, Gao et al. [8], introduced a T-shaped DR to obtain a wide bandwidth of about 75.08, the frequency range from 3.81 to 8.39 GHz.

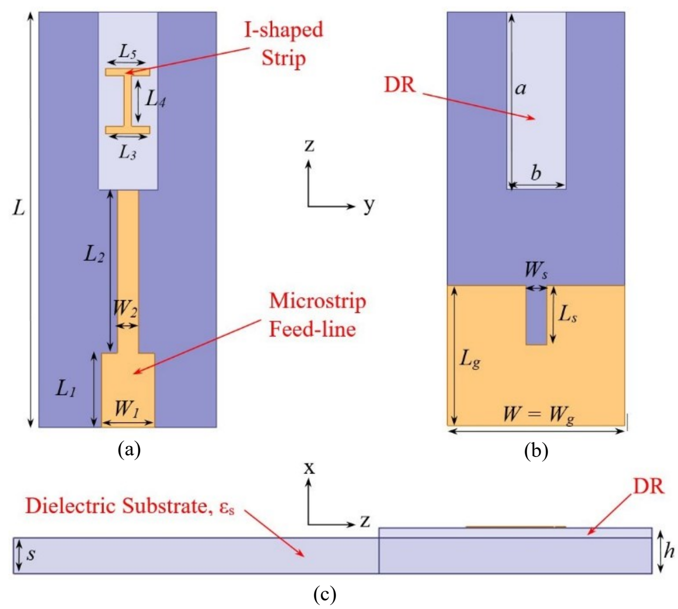


Fig. 1. Geometry of the proposed DRA; (a) top view, (b) bottom view, (c) side view.

However, these two antennas suffer from a large size and deformations radiation pattern with high cross-polarization, especially at high frequencies.

To avoid electromagnetic interference between UWB system and existing narrowband systems such as WiMAX (3.3-3.8 GHz) and WLAN (5.15-5.825 GHz), several UWB DRAs have been presented by introducing hybrid techniques to accommodate one or several rejection bands, for instance by modifying the metallic sheet underneath the DR [9], applying a combination mechanism of two short circuit strips and modified feeding patch [10], and embedded a stub located to the hollow center of a U-shaped feed-line and etching an inverted T-shaped parasitic strip at the back plane of antenna which is surrounded by RDRs [11].

In this work, a new compact band-notched UWB dielectric resonator antenna is presented and studied using the CST Microwave Studio. By implementing a combination mechanism of an inserted RDR exciting microstrip feed line, an I-shaped parasitic strip, and a slot on the ground plane, ultra wideband characteristics with excellent omni-directional

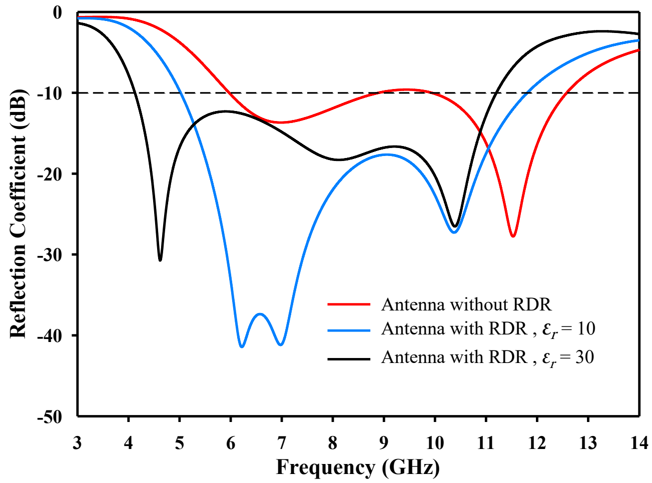


Fig. 2. Simulated reflection coefficient for the antenna with and without RDR.

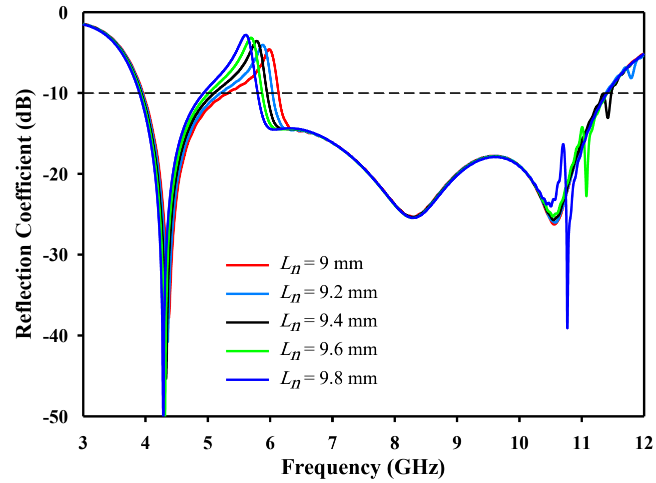


Fig. 3. Reflection coefficient for the DRA with various total lengths L_n of the I-shaped strip.

Table I. Antenna dimensions.

Parameters	Dimension (mm)	Parameters	Dimension (mm)
L	28	$W = W_g$	12
L_1	5	W_1	3.6
L_2	11	$W_2 = W_s$	1.4
$L_3 = L_5$	3	a	12
L_4	3.4	b	4
L_s	4	h	2
L_g	9.5	s	1.524

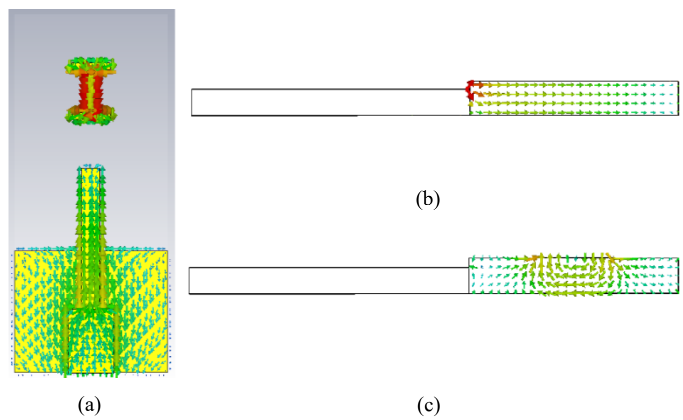


Fig. 4. Simulated (a) surface current distributions, and E-field vectors inside the RDR; (b) without and (c) with the parasitic strips at notched frequency.

radiation patterns, band-notched of about 5.11–5.94 GHz for WLAN systems, nearly constant gain, and high radiation efficiency are achieved.

II. Antenna Configuration and Design

The geometry of the proposed antenna is shown in Fig. 1. The antenna is comprised of an inserted DRA excited by microstrip feed line which is supported by a 12 (y-axis) × 28 (z-axis) mm^2 Taconic RF-35 substrate with a dielectric constant of $\varepsilon_s = 3.5$ and a substrate thickness of 1.524 *mm*. The DRA has a length a = 12 mm, a width b = 4 mm, and a thickness h = 2 mm with relative permittivity $\varepsilon_r = 30$ and loss tangent tan δ = 0.002. A partial ground plane with size of $L_g \times W_g$ = 9.5 × 12 mm^2 is applied on the bottom plane of the dielectric substrate. For the purpose of impedance matching improvement, a slot is embedded on the proper position of ground plane to reduce the ground-plane effects by changing the current distribution. The optimized parameters of the proposed antenna are listed in Table I.

III. Numerical Investigation

In UWB monopole printed antenna, one of the main problems is achieving wide impedance bandwidth and omni-directional radiation pattern with low cross-polarization in H-plane due to using the wide resonator metal patch which effects on radiation patterns, especially at higher frequencies. To overcome this problem, an inserted DR with dielectric constant of 30 is used to improve bandwidth with excellent omni directional radiation patterns. The rectangular DRA is designed using dielectric waveguide model (DWM) equations in order to predict its resonant frequencies [12]. Figure 2 shows the reflection coefficient of UWB antennas with and without RDR.

The reflection coefficient curve for a RDR with permittivity of 9.8 is also included in the figure and illustrates the importance of the choice of dielectric constant. It is clearly observed from the figure that the RDR will improves the impedance bandwidth of the antenna, especially at the lower frequencies due to the excitation of a mode $TE^x_{\delta 01}$ inside the RDR. It is noticeable that, by considering the proposed configuration, a wider bandwidth is achieved using the RDR with permittivity of 30 compared to the case with lower permittivity due to the mode resembling $TE^x_{\delta 01}$ is excited at lower frequency.

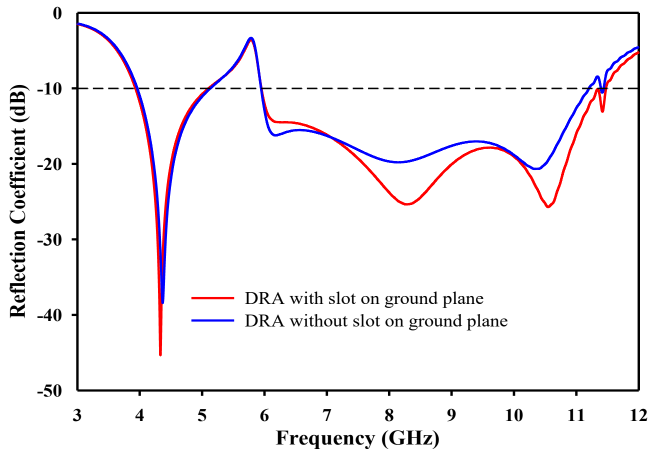


Fig. 5. Simulated reflection coefficient for the inserted DRA with and without slot on the ground plane.

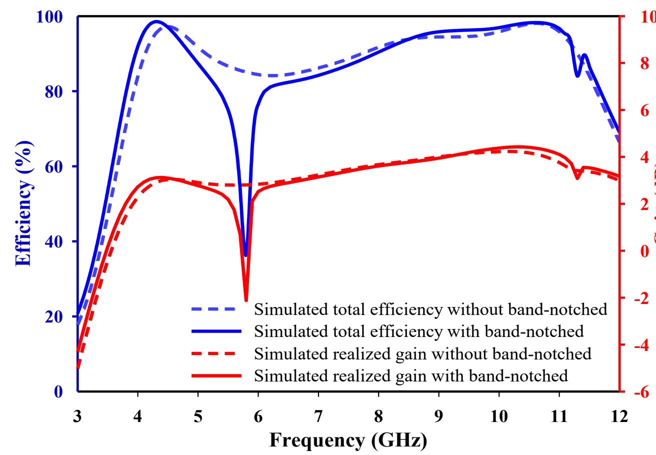


Fig. 6. Simulated total efficiency and realized gain of proposed DRA.

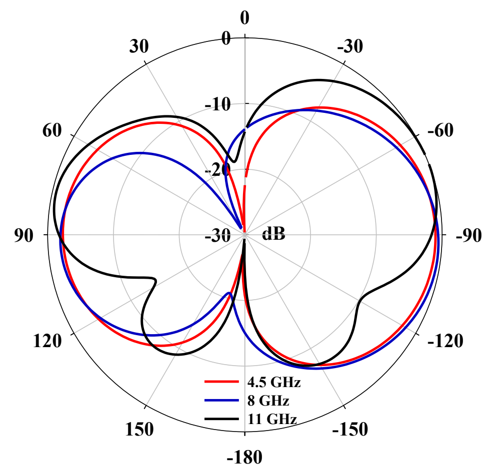
As shown in the schematic of Fig. 1 (a), I-shaped parasitic strip is located to top of inserted RDR, this I-shaped strip is designed to introduce the band rejection function for WLAN systems in the band extending from 5.15 to 5.85 GHz. Figure 3 illustrates the effect of varying the total length of the strip $L_n = L_3 + L_4 + L_5$ on the reflection coefficient versus frequency. It can be seen from the figure that by increasing the length L_n from 9 mm to 9.8 mm, the center of the frequency notch can be shifted down from 6 to 5.6 GHz. Figure 4 illustrates the simulated surface current distributions and electric field vectors inside the RDR at the center of band rejection. As can be seen in the figure, the I-shaped parasitic strip significantly alters the mode of the RDR and therefore affects the impedance matching. In addition, the currents are strongly concentrated around the I-shaped parasitic strip, and the currents flow direction on the strip are opposite to those on feed line. This significantly affects the antenna performance with a large reflection within the desired band-notched. However, a second harmonic can be noticed to be appearing on the I-shaped parasitic strip at the upper end of the impedance bandwidth.

In terms of design, the notched frequency (f_n) is approximately given by

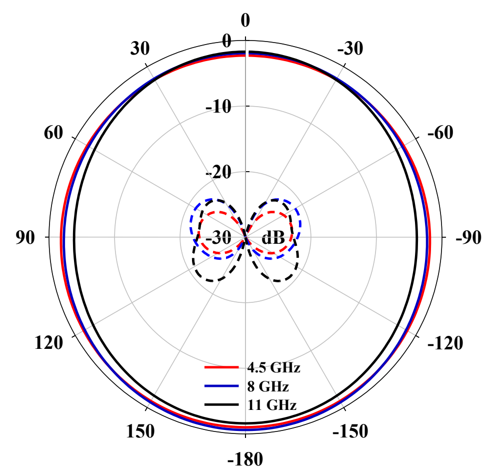
$$f_n = \frac{c}{L_n \sqrt{\varepsilon_r}} \tag{1}$$

where c is the speed of light, L_n and ε_r are the resonant length of the I-shaped parasitic strip and the relative permittivity of the dielectric resonator, respectively.

Figure 5 shows the effect of the slot on reflection coefficient, as a function of the frequency. It can be observed that by etching the slot, better impedance matching and wider impedance bandwidth of about 98%, covering range from 3.92-11.48 GHz with 0.83 GHz band rejection from 5.11-5.94 GHz is achieved due to minimizing the effect of ground plane on DRA



(a)



(b)

Fig. 7. Simulated radiation patterns; (a) E (xz)-plane and (b) H (xy)-plane; E_θ , E_φ at 4.5 GHz; E_θ , E_φ at 8 GHz; E_θ , E_φ at 11 GHz;

performance by changing the current path and confining the current distribution on the ground plane.

Figure 6 shows simulated total efficiency and realized gain of proposed DRA versus frequency. The proposed antenna provides high total efficiency and nearly constant gain across the desired frequency, with exception of the rejected band. It can be observed from the figure that the realized gain and the efficiency dramatically decrease down within the band rejection. It is noticeable that the gain variation of proposed DRA is less than 2 dB across the desired frequencies. It indicates that the proposed UWB DRA provides almost excellent circle shape of H-plane.

Figure 7 illustrates the simulated H (xy)-plane and E (xz)-plane radiation patterns of proposed DRA at three different frequencies, namely 4.5, 8, and 11 GHz. It is clearly observed from the figure that the H-plane is omnidirectional radiation pattern with low cross-polarization less than -20 dB. In the E-plane, as the frequency increases, typical eight-shaped patterns are distorted because of asymmetric structure of the proposed DRA in z-direction and unbalanced current distribution in the xz-plane.

IV. Conclusion

A new compact UWB DRA with WLAN band rejection has been proposed. The presented DRA with a small size of $12 \times 28 \times 2$ mm^3, consists of an inserted rectangular DR excited by microstrip feeds. An I-shaped parasitic strip located on the top of RDR is introduced to create a band rejection function in the 5.11-5.94 GHz band. Better impedance matching have been achieved by etching the slot on the ground plane. The proposed compact DRA provides good omnidirectional radiation patterns, a wide impedance bandwidth of more than 98%, high radiation efficiency, and nearly constant gain over the desired frequency.

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