# Design of a Multiband Triangular DRA for C-Band Applications

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***Abstract*—In this paper, a triangular-shaped Dielectric Resonator Antenna (DRA) with microstrip line feeding is presented. In the proposed design a very low dielectric constant ($\varepsilon_d = 2.1$) material is used for obtaining multiband. The antenna demonstrates triple bands having bandwidth 0.18 GHz, 0.46 GHz, 0.57 GHz with center frequency at 3.7 GHz, 5.8 GHz, and 8.1 GHz respectively. The simulated results of the antenna show stable radiation characteristics. The proposed design can be suitable for mobile communication, ISM band, and satellite communication applications.**

***Index Terms*—Biomedical, DRA, ISM band, Microstrip antenna.**

## I. Introduction

The latest technology of wireless communication requires multiband and compact antennas, which can work for various applications and also can be fabricated easily. With the growing demand for biomedical and mobile applications, the communication systems with multiband features are becoming more prevalent. The rapid increase in the demand for mobile applications in the microwave range has led the research community to focus their attention on highly efficient antennas, which exhibit multiple bandwidths, good radiation characteristics with small size [1], [2]. DRAs meet all the above expectations with inherent features like large bandwidth, high radiation efficiency, high gain, low loss, compatibility with different excitation techniques, and less spurious feed radiation [2]. In [1], different shapes of DRA and their effect on radiation patterns are discussed elaborately. Along with the mathematical analysis the radiation characteristics of a cylindrical DRA is presented. Similarly, in [3], a triangular DRA array is demonstrated to obtain dual-band characteristics with high gain. An equilateral triangular DRA array (TDRA) is shown in [4] with a partial ground plane. Mathematical expression along with modal calculation for TDRA resonant frequency is discussed to achieve dual-band operation. An isosceles triangular shaped DRA is investigated for achieving dual-band broadside radiation is shown in [5]. In [6], an anisotropic equilateral triangular-shaped stacked dielectric resonator antenna is presented for improvement in gain. It is evident from the literature that there is no significant research has been done in the triangular slotted DRA.

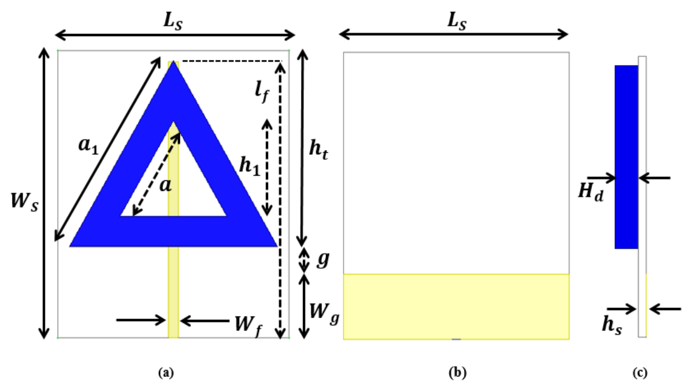


Fig. 1. Layout of the proposed antenna (a) Top view (b) Bottom view (c) Side view.

In this paper, a slotted triangular DRA is designed and fabricated which can operate in three different bands at three different resonant frequencies. This antenna can be used for mobile communication at 3.7 GHz, for biomedical application at 5.8 GHz and for fixed satellite application at 8.1 GHz.

## II. Antenna Geometry and Design

An FR4 substrate with $\varepsilon_r = 4.4$ and loss tangent (tan $\delta$)= 0.02 of dimension $L_s \times W_s \times h_s$ is used to construct the antenna as shown in Fig. 1. The metalization at the upper side of substrate (Fig. 1 (a)) has dimension $l_f \times W_f$ and it acts as the feed line for the radiating structure. Similarly the bottom side of the substrate has a ground plane of the dimension $L_s \times W_g$ (Fig. 1 (b)). A triangular shaped annular DRA ($\varepsilon_d = 2.1$) is placed above the substrate and the sides of inner triangle is varied to obtain the better results.

The expression for resonant frequency in $TM_{lmn}$ modes of an equilateral triangular DRA can be calculated by the following expression considering $(l + m + n = 0)$ [2].

$$f_{mn} = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{\left(\frac{4\pi}{3a}\right)^2 (m^2 + mn + n^2) + k_z^2} \quad (1)$$

Where, $k_z = (p\pi/2h)$, for $p = 1, 2, 3...$, and $c$ is the velocity of light in air and $a$ represents side of the equilateral triangle.

TABLE I
DIMENSIONS OF PROPOSED ANTENNA

| Parameter | Value (mm) | Parameter | Value (mm) |
|---|---|---|---|
| $L_s$ | 60 | $L_g$ | 50 |
| $W_s$ | 50 | $W_g$ | 13.5 |
| $h_s$ | 1.6 | $H_d$ | 5 |
| $W_f$ | 2 | $a$ | 44.74 |
| $l_f$ | 57.75 | $h_1$ | 20 |

Similarly, for a very thin DRA ($H_d << a$), the resonant frequency for $TM_{10}$ can be approximated by [2]:

$$f_{10\delta} = \frac{c}{2\sqrt{\varepsilon_r}}\sqrt{\left(\frac{4}{3a}\right)^2 + \left(\frac{1}{2H_d}\right)^2} \tag{2}$$

Where, $H_d$ is height of triangular DRA. The proposed design is simulated by using ANSYS HFSS vs. 15 simulator and the final design dimensions are given in Table I.

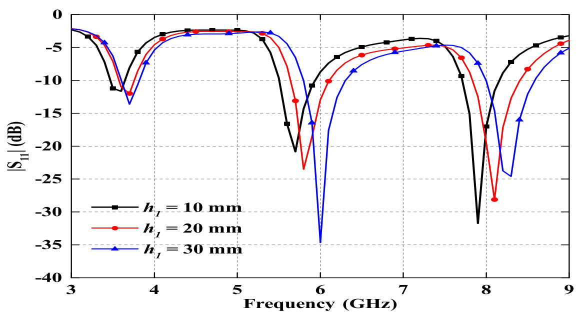


Fig. 2. Effect of $h_1$ on reflection coefficients of the proposed antenna.

Fig. 3. Fabricated prototype of the proposed antenna.

## III. PARAMETRIC ANALYSIS

In order to examine the slotted section in triangular-shaped DRA, the parameter $h_1$ was varied for three different values and their effect on reflection coefficients was observed in the simulation environment (HFSS). As shown in Fig. 2, out of the three values $h_1 = 20$ mm provides better response in all the required bands.

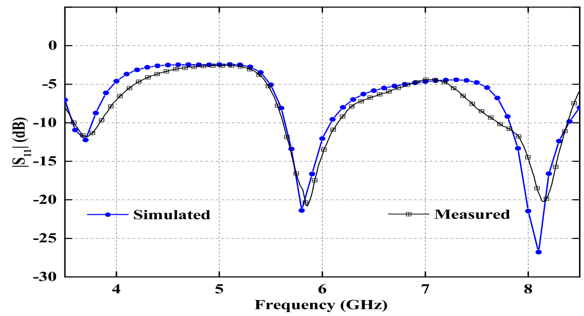


Fig. 4. Reflection coefficient versus frequency response of the proposed antenna.

## IV. RESULTS AND DISCUSSION

A prototype of the proposed antenna (shown in Fig. 1) was fabricated and the S-parameters were investigated experimentally by Keysight vector network analyzer. Fig. 3 demonstrates a fabricated prototype of the proposed antenna.

The simulated and measured reflection coefficient versus frequency plot is presented in Fig. 4. It shows the variation of the reflection coefficients in which $-10$ dB bandwidths obtained are 0.18 GHz, 0.46 GHz, and 0.57 GHz with center frequency at 3.7 GHz, 5.8 GHz, and 8.1 GHz respectively. It is evident that the measured results fairly agree with the simulation values. The small variations in the results may be caused by fabrication errors.

The variation of the simulated input impedance of the proposed design is demonstrated in Fig. 5. The plot clearly indicates proper impedance matching at the resonating frequencies 3.7 GHz, 5.8 GHz, and 8.1 GHz. Fig. 6 shows the simulated gain versus frequency plots across three different resonant frequencies i.e. 3.7 GHz, 5.8 GHz, and 8.1 GHz. It clearly indicates that the antenna shows maximum realized gain of approximately 0.4 dBi at 3.7 GHz, 0.6 dBi at 5.8 GHz and 2.6 dBi at 8.1 GHz respectively. The planar antennas have the inherent property of lower average power handling capacity (APHC). The proposed design can show an APHC up to few watts.

A table of comparison is provided (Table III) showing some reported triangular dielectric resonator antennas. From the comparison, it is evident that the proposed design is having a

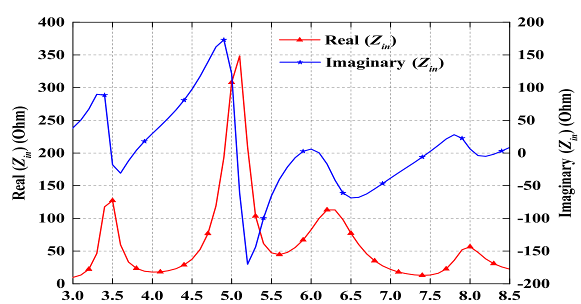


Fig. 5. Input impedance versus frequency response of the proposed antenna.

TABLE II
COMPARISON WITH RECENTLY REPORTED TRIANGULAR DIELECTRIC RESONATOR ANTENNAS

| Ref. | Dielectric constant | Resonant frequency (GHz) | Size (in $\lambda$) | Bandwidth (GHz) | Gain | Application |
|---|---|---|---|---|---|---|
| [3] | 9.2 | 3.5, 5.2 | 0.67×0.653×0.153 | 3.35-3.70,<br>4.52-5.34 | 7.02 dBi,<br>8.9 dBi | WLAN,<br>WiMAX |
| [4] | 9.8 | 2.4, 3.5 | 0.448×0.48×0.123 | 2.16-2.94,<br>3.22-3.63 | 4.18 dBi,<br>5.64 dBi | WLAN,<br>WiMAX |
| [5] | 12 | 1.68, 2.48 | 0.37×0.37×0.134 | - | 6 dB,<br>4 dB | - |
| [6] | 2.33, 10.2 | 3.5 | 1.05×1.05×0.246 | 3.025-4 | $>8$ dB | - |
| Proposed | 2.1 | 3.7, 5.8, 8.1 | 0.616×0.74×0.08 | 0.18, 0.46,<br>0.57 | 0.4 dBi,<br>0.6 dBi,<br>2.6 dBi | Mobile,<br>Satellite,<br>Biomedical |

compact size, comparable gain with tri-band applications.

## V. CONCLUSION

A compact DRA with multiband feature operating in S and C band has been investigated. The antenna is designed using a triangular DRA with 50 Ω microstrip feed line as the radiating element. The antenna demonstrates resonant frequency at 3.7 GHz, 5.8 GHz, and 8.1 GHz respectively. With a stable radiation pattern, the proposed antenna can be suitable for mobile, biomedical and fixed satellite applications.

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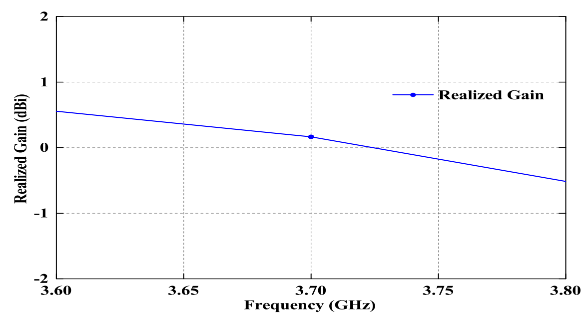
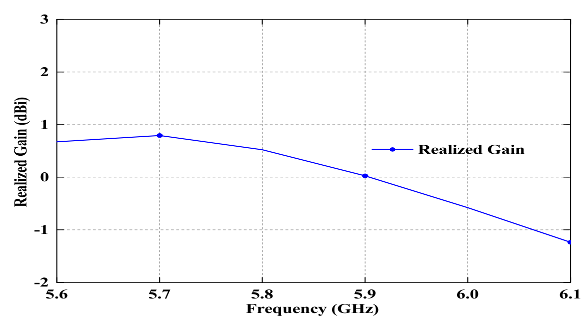



(a)

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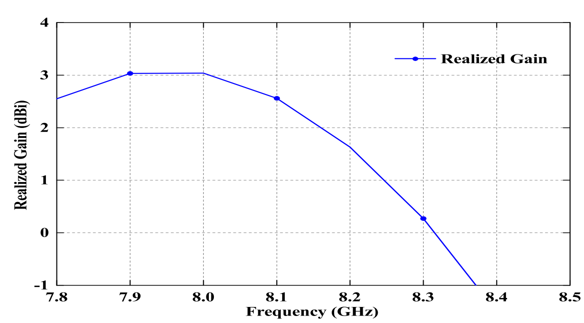


(c)

Fig. 6. Gain versus frequency plot of the proposed antenna operating across (a) 3.7 GHz (b) 5.8 GHz (c) 8.1 GHz.