Design and implementation of triangular base truncated right prism dielectric resonator antenna

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In the current work, an Ultra-Wide-Band (UWB) truncated right Triangular prism Dielectric Resonator Antenna (TDRA) is presented. The objective is C-band for Wi-Fi applications. A parametric study of different dimensions of the antenna geometry namely, height of TDRA, probe length and position in order to examine the effect of altering these parameters on the bandwidth and gain. The single TDRA shows the highest BW with 44.67 % in average compared to other single and multiple elements of Cylindrical DRA (CDRA) and, Square DRA (SDRA). Consequently, it is used to design an UWB antenna for C-band applications. The antenna is fabricated on a substrate Roger 3010 with thickness 1.27mm, relative dielectric constant 10.2 and loss tangent 0.0022. It conducts bandwidth from 4.45 GHz to 7.01 GHz with good agreement between the measured and simulated results.

1. Introduction

From time to time the market demands changed according to the requirements imposed on the communication system and its applications. The most recent requests are the wide bandwidth, high efficiency and compact size of passive and active elements. Printed antennas and dielectric resonator antennas are suitable candidates for achieving these factors. Microstrip antennas suffers from high quality factor and very low efficiency, however it is compact and cheap and easy to be fabricated. On the other hand, Dielectric Resonator Antenna (DRA) is started in 1939 by Richtmayer [1] and become affected in 1983 [2]. Since that time it becomes the candidates providing good features like low loss, high bandwidth, high efficiency, high power handling capability and the flexibility of doing degrees of freedom in its dimension [3-6]. It has different applications over different frequency band especially in millimeter bands, with different shapes, cylindrical rod and tapered cylindrical rod [7]-[10], rectangular[11,12], hemispherical [13], tetrahedron [14] and triangular [15, 16].

The dielectric rod antenna is considered as a surface wave antennas which are subjected to the discontinuity-radiation concept [17] and hence its radiation parameters and performance can be demonstrated. Ando, Yamauchi, Nakano developed a numerical analysis of dielectric rod antennas using FDTD method. It has been researched and studied for many years because of its wide bandwidth, shape, ability to create a symmetric radiation pattern, low polarization cross coupling, ease of fabrication, and low cost [7]-[10],[18],[19],[20]. The choice of the optimal rod length is important because the very long rod contributes to a destructive addition of refracted and guided waves [18]. The target was increasing the band width and enhancing the antenna gain. Concerning the search for DRA with wide band performance, different DRA shapes are proposed. Some of these configurations are presented in [2], [21]-[25]. The truncated cone DRAs are considered in [26] with different configurations. It gives percentage band width from 17% to 50%, but it was found that, the onset of higher order modes can affect the radiation pattern symmetry. Recent study presents an advanced design solutions for enhancing the

realized gain of individual DRAs are investigated [27]. A design of tapered rod cylindrical DRA is optimized in [28] to achieve gain up to 17.5 dBi in millimeter wave application. Another paper presents a DRA with high gain and wide impedance band width for 5G wireless [29]. It shows a 10-dB return loss impedance bandwidth from 10.7% to 16.1% in X band.
In this paper, the attention is focused on a type of DRAs that can achieve high gain and wide band width using single element instead of using DRA array. The band width of this configuration is compared to other different configurations of single and multiple elements. A truncated right Triangular prism DRA (TDRA) with isosceles triangular base is proposed. A single element of TDRA conducts 44.67% bandwidth percentage which is higher than those four elements cylindrical, square or triangular shapes.

The organization of the paper is as follows: Section 2 presents the adopted antenna configuration. The result and analysis of the proposed DRA are summarized concerning frequency range and compared to some basics shapes of DRA geometry in Section 3. The simulated and measured radiation patterns caused by a coaxial probe excitation at the resonant frequency are also depicted in that section. Finally, Section 4 presents the conclusion of the paper.

2. ANTENNA GEOMETRY AND FABRICATION

The resonant frequency of the TDRA is calculated using basic formula [30] for cylindrical shape based on both the CDRA and TDRA have same quality factor which is proportional to the ratio of the volume to area. If the resonator has radius a, height ht and relative permittivity ε_r, then the resonant frequency of deferent modes that the DRA can support are given as:

$$f = \frac{C}{2\pi a\sqrt{\in r}}\left[1.71 + \frac{a}{ht} + 0.1578\left(\frac{a}{ht}\right)^2\right]$$

The length of the single TDRA is then optimized to get the required C-band application. The TDRA element is fabricated by adhering twelve triangles of Roger 3010 (thickness 1.27mm, relative dielectric constant 10.2 and loss tangent 0.0022) to form a TDRA with height 15.24mm as shown in Fig. 1. The dimensions of the isosceles triangle are L1=10.38 mm and L2=7.34 mm fed by a 50 Ω coaxial cable inserted in the middle of the triangle.

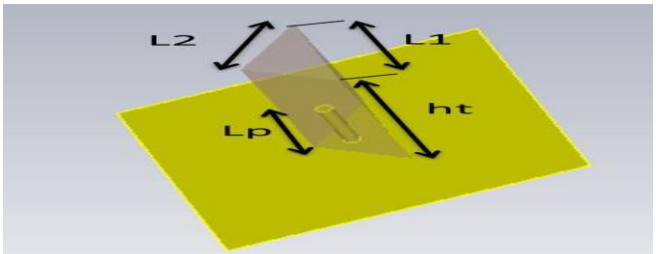


Fig. 1 . Proposed TDRA antenna.

3. SIMULATED AND MEASURED RESULTS AND DISCUSSION

Three varying parameters are used to optimize the antenna structure for better gain and bandwidth. The parameters are the height of the triangle above the ground (ht), the length of the probe above the ground (lp) and the position of the probe (Pos) ("Pos=0 means that the feeder is inserted in the middle of the triangle). Table I illustrates the optimum fractional bandwidth for the cases of ht=8.84mm, 10.16mm, 12.7mm, and 15.24mm. For each case one fixes Pos=0 and varying lp from 1mm to approximately the total length of the TDRA. The table summarizes the optimum bandwidth and its corresponding probe length for each case. The optimum fraction bandwidths are found 27.36, 33.53, 41.42 and 44.67 respectively with corresponding probe length lp 4.445mm, 5 mm, 5 mm, and 9mm. One can find that the optimum probe length is bounded from lp/ht=0.4 to lp/ht=0.5. On the other hand to study the effect of the probe position, it is changed from 0 to 5 mm.

Table I. Optimum bandwidth for the proposed antenna for different probe length; lp

Height of triangle in mm	***Bandwidth in GHz***	***Length of probe in mm***	***Center frequency***	***BW%***
ht=8.89	[8.2 -10.8]	lp=4.445	9.7 GHz	27.36
ht=10.16	[7.2 -10.1]	lp=5	8.8 GHz	33.53
ht=12.7	[6.7-10.2]	lp=5	9.1 GHz	41.42
ht=15.24	[4.45-7.01]	lp=9	5.3 GHz	44.67

Table II depicts the optimum bandwidth probe position offset from the center of the triangle for individual cases quoted in Table I when Pos is varying from 0mm to 5mm.

Table II. Optimum bandwidth for the proposed antenna for different probe position; POS

Height of triangle in mm	**Positio n in mm**	***Bandwi dth in GHz***	***Length of probe*** *in mm*	***Center frequency***	***BW %***
ht=8.89	Pos=1	[9.4 - 13.9]	lp=4.445	12.2 GHz	38.62
ht=10.16	Pos=1.5	[9.2 - 13.0]	lp=5	8.8 GHz	34.23

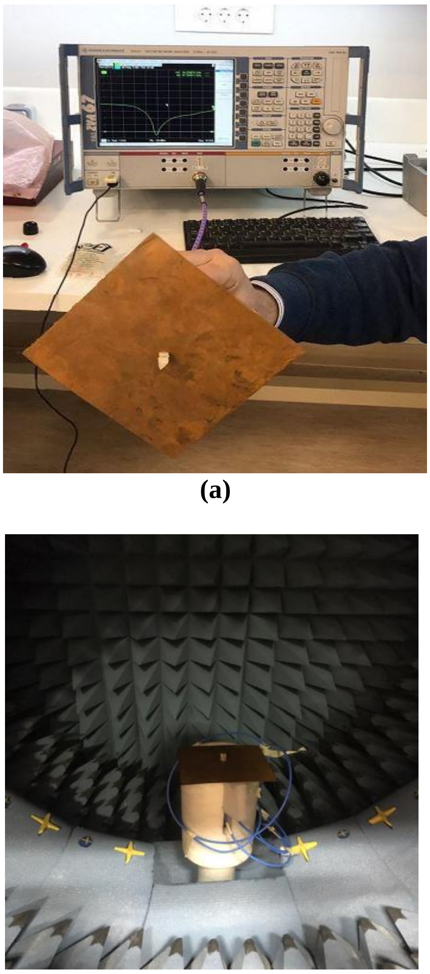
Height of triangle in mm	**Position in mm**	***Bandwidth in GHz***	***Length of probe** in mm*	***Center frequency***	***BW %***
ht=12.7	Pos=0	[6.7-10.2]	lp=5	9.1 GHz	41.42
ht=15.24	Pos=0	[4.45-7.01]	lp=9	5.3 GHZ	44.67

The optimum fractional bandwidths are 38.6, 34.23mm, 41.4 and 44.76 and its corresponding feed position offset are 1.mm, 1.5mm, 0 and 0 respectively. One can find that the best feed position is nearly at the center of the triangle, where the optimum fractional bandwidth for single TDRA adopted in this work is 44.76. The gain of this antenna is 6.2 dB. The single TDRA is compared with the equivalent single and the array multiple elements of CDRA and SDRA. Table III illustrates the band width and gain for the different DRA configurations. One can observe that the single TDRA is the best among others.

Table III. Comparison of proposed antenna with other configurations

	Cylindrical		***Square***		***Trianguler***	
	Single	**Four**	**Single**	**Four**	**Single**	**Four**
BW in GHz	[5,5 - 6.88]	[6.1 - 7.77]	[5.4 - 6.45]	[4.7 - 5.71]	[4.4 - 7.01]	[4.5 - 5.39]
BW%	21.58	23.19	16.95	18.36	44.67	16.0
Gain in dB	5.345	4.249	4.042	5.462	6.2	4.796

The optimum configuration concerning the antenna height; ht, the probe length; lp and probe position; Pos is fabricated and measured in both the network analyzer and anechoic chamber as shown in Fig. 2. The simulated and measured coefficients are depicted in Fig. 3, where the measurement is carried out in two different network analyzer. It is noticed that they are in a good agreement. The simulated and measured realized gain are shown in Fig. 4. It conducts maximum gain of 6.2 dB.



(a)

(b)

Fig. 2 . Proposed antenna fabrication and measurement.

(a) Network analyzer (b) Anechoic chamber

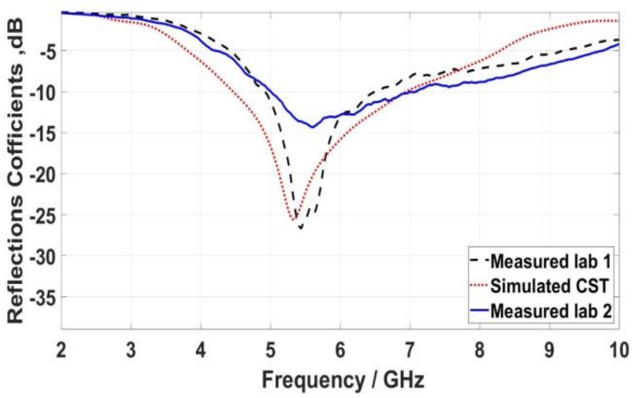


Fig. 3 . The simulated and measured reflection coefficients.

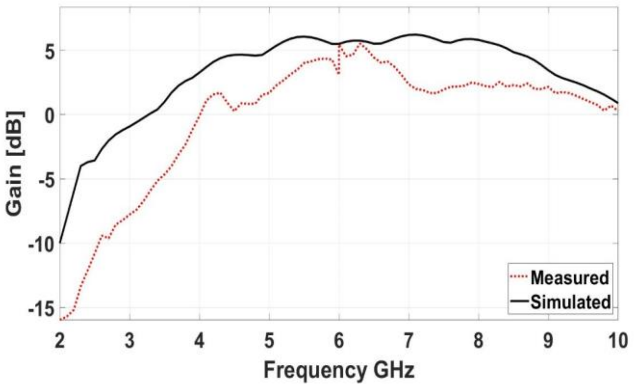


Fig. 4 . Realized gain versus frequency.

Table IV. Bandwidth comparison with papers in literatures

Reference	[7]	[8]	[15]	[18]	[25]	[26]
BW %	26.8	1.7	40	35	25	50

On the other hand the results are compared to similar work in literatures as illustrated in Table IV. It could be found that the proposed antenna has higher bandwidth except that in reference [26]

4. CONCLUSION

UWB truncated right triangular prism is developed, it is operating in the band 4.4-7.01 for c-band application. A parametric study is carried out for the antenna height and the probe position and length to achieve the highest bandwidth. It is found that the optimum performance is conducted for an antenna height of 15.24 mm. On the other hand the probe length to antenna height runs from 0.4 to 0.5 to achieve optimum bandwidth. On the same time the optimum position of the probe is at the center of the triangle (Pos=0). The antenna is fabricated on a substrate Roger 3010 with thickness 1.27mm, relative dielectric constant 10.2 and loss tangent 0.0022. The proposed antenna achieves max bandwidth of 44.67% which is higher relative to other configuration single and multiple elements.

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