Dual Triangular-shaped DRA Excited with Asymmetric Slot Coupled for Wideband Circular Polarization Applications

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***Abstract*— This paper investigates dual right-angled triangular-shaped dielectric resonator antenna (DRA) excited with asymmetric slot coupled. Here, the asymmetric slot coupled ground plane is responsible for generating orthogonal modes to realize circular polarization (CP) in the proposed antenna. The designed antenna shows $TE_{11\delta}$ mode and is confirmed by the rotation of the electric field inside the triangular DRA. This proposed antenna is realized by using dual right-angled triangular dielectric resonators (DRs), which are separated by an optimal gap to be responsible for the generation of wideband CP bandwidth. Proposed antenna shows -10 dB input impedance bandwidth of 20.22% (3.25-3.98 GHz) and 3-dB axial ratio bandwidth in broadside direction of 16.11% (3.31-3.89 GHz). In addition, this antenna offers an average gain and radiation efficiency of 5.64 dBi and 89.00% in the broadside direction respectively. The designed antenna shows right-hand circular polarization and is suitable for Wi-MAX applications (3.3-3.7 GHz).**

***Keywords*— circularly polarized, wideband, dielectric resonator antenna, cross slot**

I. INTRODUCTION

Circularly polarized (CP) antennas are used for modern wireless communication systems such as satellite, radar and Wi-MAX applications [1-19]. It immunes signal from multipath reflection and polarization mismatch [1]. Over the past decade researchers are more concentrated on dielectric resonator antennas (DRAs). It offers high radiation efficiency, wide bandwidth, low loss, flexible feeding mechanism and temperature stability [2-3]. To generate CP in DRA, mainly two mechanisms are employed, first is single and second one is dual/complex feeding mechanism. Compared with single feeding technique, dual feeding mechanism shows more axial ration (AR) bandwidth [4-5]. In recent years, more concentration on single feeding mechanism to generate wideband AR bandwidth by using modified shape of DRA has been reported [6-15]. In this paper, a wideband circularly polarized dual right-angled triangular DRA has been proposed for Wi-MAX applications. A pair of asymmetrical slot is used in the ground plane to generate CP fields in the proposed antenna. The wideband AR bandwidth can be achieved due to dual right-angled triangular shape of DRA having optimal gap between them. $TE_{11\delta}$ mode is excited and confirmed by

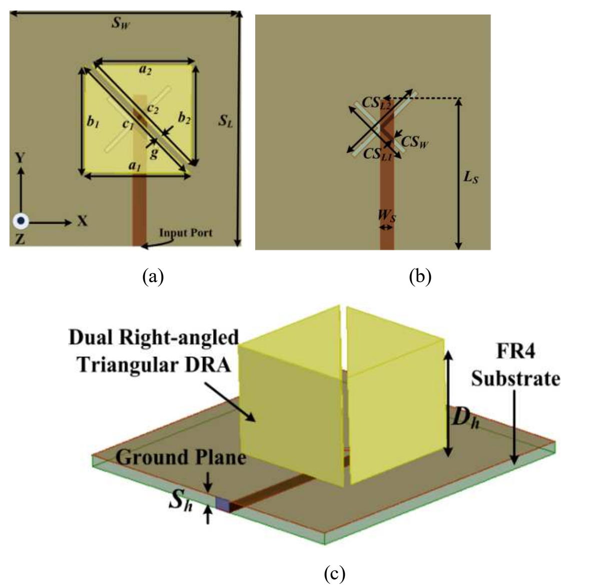


Fig. 1. Geometry of proposed antenna (a) top view with right-angled triangular DRA (b) without DRA (c) 3D view. [All dimensions in mm: a_1 = 19.79, a_2 = 18.79, b_1 = 19.79, b_2 = 18.79, c_1 = 19.79, c_2 = 18.79, D_h = 15, S_W = S_L = 45, S_h = 1.6, L_S = 28.5 , W_S = 2.5 , CS_{L1} = 13.2, CS_{L2} = 17, CS_W = 0.85].

rotation of E-field inside the triangular DRA (assuming dual set of two closely spaced triangular DRA as a special case of rectangular DRA). As a result, the proposed antenna shows wide range of impedance and AR bandwidth of 20.22% and 16.11% with 5.64 dBi gain in the broadside direction. Simulation work has been done by using HFSS and verified by CST-MS Software.

II. ANTENNA GEOMETRY

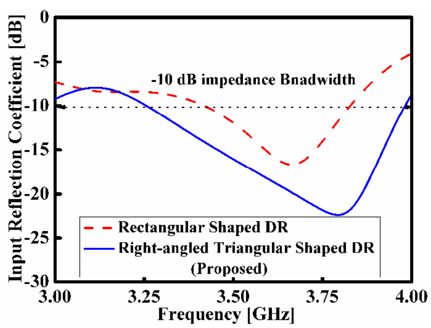
Fig. 1 depicts the geometry of proposed dual right-angled triangular DRA. The designed antenna mainly consists of FR4 glass epoxy substrate with asymmetrical slot coupled ground plane and loaded with dual right-angled triangular dielectric resonators (DRs). DR is made of Al_2O_3 having dielectric constant 9.8 and loss tangent 0.002. Designed antenna is placed on FR4 substrate and having dielectric constant 4.4 and loss tangent 0.025. Fig. 1 consists of (a) top view with right-angled triangular DRA, (b) top view without DRA and (c) 3D view of proposed designed.

III. Parametric Studies

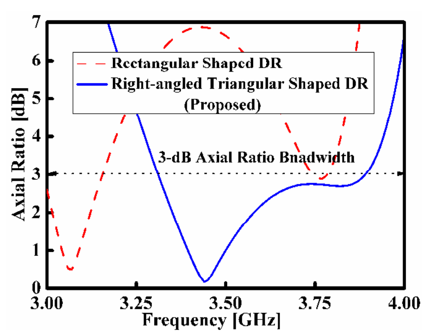
Parametric studies have been done for important parameters i.e. shape and height of DRA and width of slots of the proposed antenna.

A. Effect of Shape of DR

The effects of shape of DR on the input reflection coefficient and AR bandwidth have been studies in this connection. For the better coupling and formation of orthogonal mode to realized wideband AR bandwidth has been done by changing the shape of DR from rectangular to dual right-angled triangular. This shaped of DR shows better coupling between the asymmetrical slot coupled ground plane and shown better performance in terms of input reflection coefficient and AR bandwidth as shown in Fig. 2(a) and 2(b). The axis ratio characteristic of the proposed design antenna is completely different from that of the rectangular shaped DR because of the E-field distribution in the air cavity, which affects the E-field. Therefore, the dominant *E*-field in the proposed design has strengthened the component along the *y*-axis and *x*-axis in the air cavity. Because of this, the proposed geometry has shown a wider CP bandwidth.



(a) Input reflection coefficient

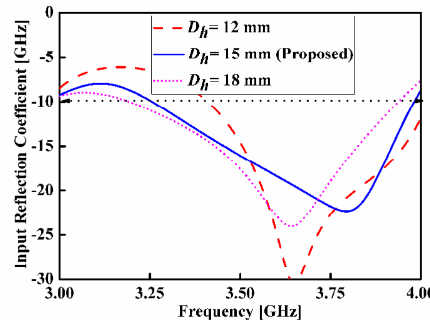


(b) Axial ratio bandwidth in broadside direction

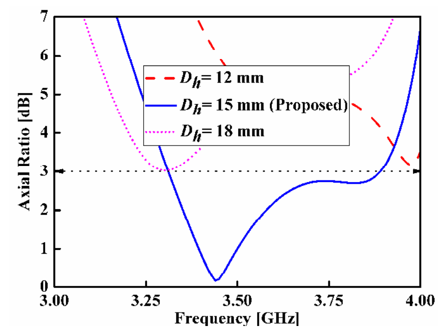
Fig. 2. Effect of shaped of DR on proposed dual right-angled triangular DRA.

B. Effect of height of DR (D_h)

Fig. 3 shows the change in input reflection coefficient and AR bandwidth while varying the height of DR. With reference to Fig. 3(a), the input reflection coefficient is shifted from higher to lower frequency band due to coupling between the DRA and slots. AR bandwidth also shifted lower frequency band and it shows better 3-dB AR bandwidth at height of 15 mm as shown in Fig 3(b). So, to satisfy the orthogonal mode conditions of designed antenna height should be optimal.



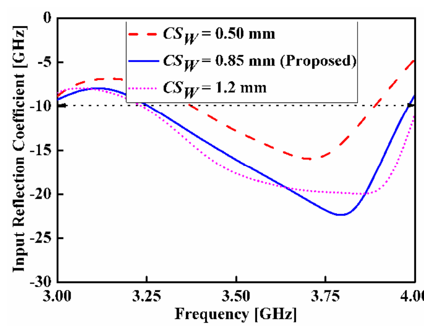
(a) Input reflection coefficient



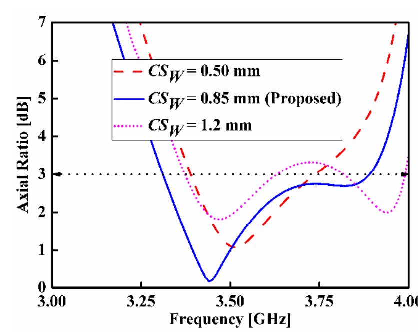
(b)) Axial ratio bandwidth in broadside direction

Fig. 3. Effect of height of DRA on proposed dual right-angled triangular DRA.

C. Effect of Width of Slots (CS_W)



(a) Input reflection coefficient



(b) Axial ratio bandwidth in broadside direction

Fig. 4. Effect of width of slot on proposed dual right-angled triangular DRA.

With reference to Figure 4, it shows the width of slots affects in input reflection coefficient and AR bandwidth. Proposed antenna has been excited by the slot coupled to show better coupling and supports the formation of orthogonal modes. Here widths of slots play an important part to couple EM fields and obtained coupling between the proposed shapes of DRA. It can be observed in Fig. 4(a), if slot width is increases from 0.50 mm to 1.2 mm the input reflection coefficient is increases. AR bandwidth is increases but converted single band to dual band as shown in Fig. 4(b). The possible reason is that the second band occurred due deformation of orthogonal mode.

IV. RESULTS AND DISCUSSION

The designed antenna having input reflection coefficient is shown in Fig. 5. With reference to Fig. 5, it has been observed that -10 dB input impedance bandwidth of 20.22% (3.25-3.98 GHz) and shows good agreement between HFSS 14.0 and CST-MS 13.0 software data. Fig. 6 shows the AR bandwidth where both the HFSS and CST shown good agreement between them. It is found that 3-dB AR bandwidth in broadside direction of 16.11% (3.31-3.89 GHz).

The CP radiation pattern in broadside direction confirmed that the proposed antenna offers right-handed circular polarization (RHCP). Fig. 7 shows the CP radiation fields in *xz*- and *yz*-plane at 3.45 GHz and 3.70 GHz respectively. In broadside direction, the difference between RHCP and left hand circular polarization (LHCP) is -38.27 dB and -16.21 dB at 3.45 GHz and 3.70 GHz respectively.

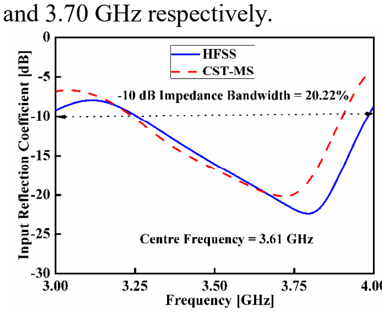


Fig. 5. Simulated input reflection coefficient of proposed dual right-angled triangular DRA.

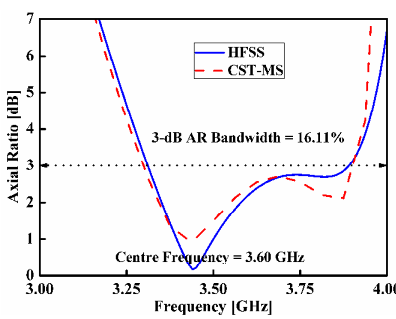


Fig. 6. Simulated AR bandwidth of proposed dual right-angled triangular DRA in broadside direction.

Fig. 8 shows the distributions of E-field at different phases inside the DRA to verify the CP conditions of proposed designed antenna at 3.60 GHz. It can be observed that if phase shifted from 0º to 90º or 180º to 270º, the distribution of electric field changes to confirm the formation of orthogonal mode. $TE_{11\delta}$ mode is also confirmed by rotation of E-field inside the triangular DRA. CP radiation pattern in broadside direction confirmed that the proposed antenna works as a RHCP conditions. The motivation of the proposed antenna geometry was to get wider 3 dB AR bandwidth along with the overlapping -10 dB impedance bandwidth. Hence, it is covering the entire Wi-MAX band frequency (3.3-3.7 GHz).

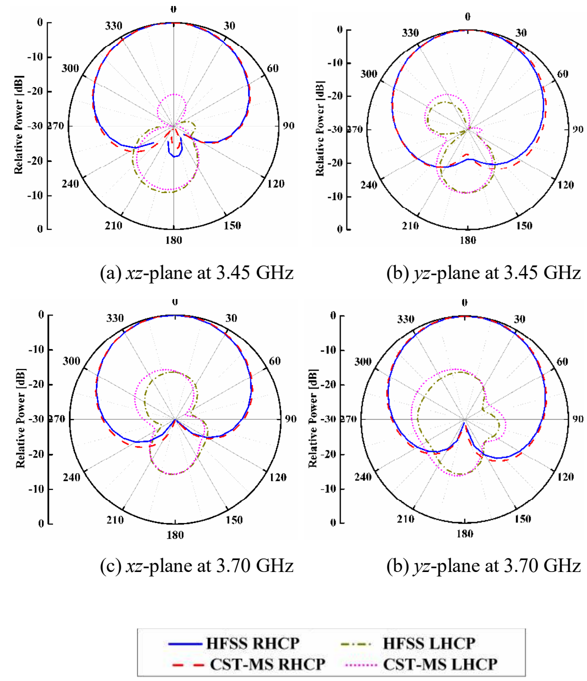


Fig. 7. CP radiation fields of proposed dual right-angled triangular DRA at 3.45 GHz and 3.70 GHz.

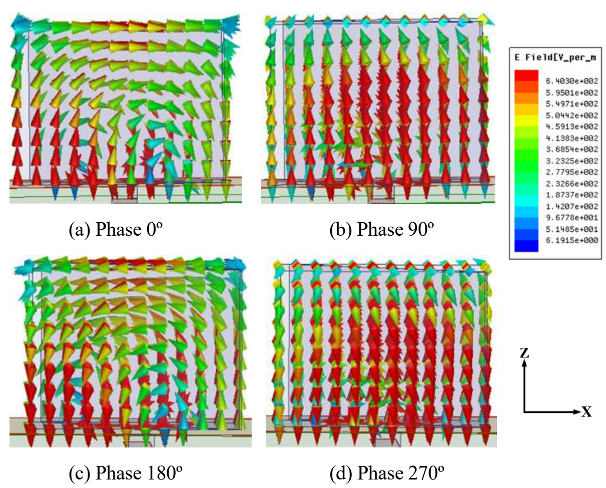


Fig. 8. Simulated E-field distribution, to confirm the orthogonal mode of proposed dual right-angled triangular DRA at 3.60 GHz.

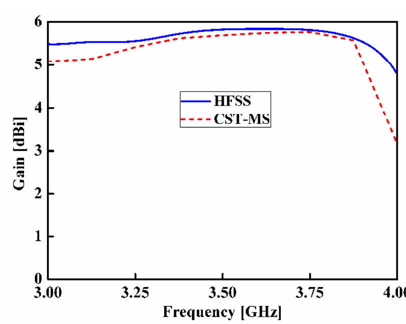


Fig. 9. Gain of proposed dual right-angled triangular DRA in broadside direction.

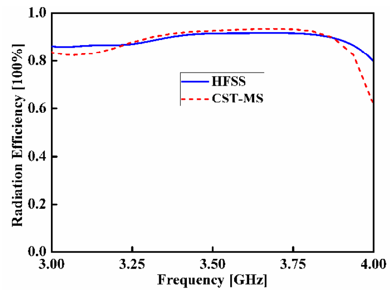


Fig. 10. Radiation efficiency of proposed dual right-angled triangular DRA in broadside direction.

Fig. 9 depicts the simulated gain in broadside direction. It can be observed that average gain is 5.64 dBi in the working band. Fig. 10 shows the average radiation efficiency in broadside direction of 89.00%. Table I depicts the comparisons of proposed antenna with recently published work. It can observe that proposed designed antenna shows better improvement in terms of AR bandwidth as compared to existing antennas.

TABLE I: COMPARISON OF AR BANDWIDTH OF PROPOSED ANTENNA WITH REFERENCE ANTENNAS.

S. No	AR Bandwidth in CPDRA					
	DR Shape	ε_r	**Feeding Technique**	f_o **GHz**	**3-dB ARBW %**	**Ref.**
1.	Rectangular	9.2	Single (Probe)	3.2	13	[6]
2.	Cylindrical	10	Single (Coaxial Line)	3.35	6.4	[7]
3.	Rectangular	10.2	Single (Aperture Coupled)	10	6	[8]
4.	Semi-eccentric annular	10	Single (Probe)	10	5.71	[9]
5.	Cylindrical	10	Single (Aperture Coupled)	2.45	6.1	[10]
6	Rectangular	9.8	Single (Probe)	3.51	14.81	[11]
7.	Cylindrical	6.85	Single (Slots)	5.85	8	[12]
8.	Rectangular	9.5	Double (Slots)	3.51	2.45	[13]
9.	**Dual Right-angled Triangular**	**9.8**	**Single (Slot Coupled)**	**3.5**	**16.16**	**This work**

V. CONCLUSION

In this paper, an asymmetrical slot coupled dual right-angled triangular DRA for wideband circular polarization has been proposed. Orthogonal mode is excited by using asymmetrical slot in the ground plane. The dual right-angled triangular shape of DRA with optimal gap is responsible for the generation of wideband input impedance bandwidth and AR bandwidth. Proposed designed antenna show -10 dB input impedance bandwidth of 20.22% and in broadside direction 3-AR bandwidth of 16.11%. From the CP radiation pattern in broadside direction confirm that the proposed antenna showing RHCP. Here the difference between RHCP and LHCP is better in broadside direction so proposed antenna can be used for wireless applications.

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