



Circularly Polarized Spiral Fed Equilateral Triangular Dielectric Resonator Antenna

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Abstract

This paper presents a single band, circularly polarized triangular dielectric resonator antenna (DRA). Here, a thin copper plate is used for ground plane, triangular DRA for resonator, and a probe coupled patch for excitation purpose. The feeding patch is modified successively to a spiral-loop, which enables 90^0 out of phase excitation and ensures circular polarization by bringing down the axial ratio < 3 dB near 9.2 GHz. In addition to this the antenna maintains an impedance band over (9.1-9.29) GHz with 3.65 dBi peak gain. A prototype has been fabricated and characterized, and the results are found to be well matched with their simulated counter parts. This antenna can be used for X-band wireless applications.

1. Introduction

Dielectric resonator antenna (DRA) has been widely appreciated in the field of microwave engineering as an advanced electromagnetic radiator [1]. The reason(s) behind its popularity can be attributed to wideband, low loss, and high efficiency characteristics. By default the DRAs deal with linear polarization, which sometime restrains its applications [2], because of antenna misalignment, multi path fading, and polarization loss. And these issues can be easily avoided by ensuring circular polarization which guarantee matching between transmitter and receiver [3].

In general circular polarization can be confirmed by creating 90^0 out of phase excitation between two exciting modes. This kind of excitation is possible by means of either coupling mechanism [4-9] or resonator orientation [10], [11]. Coupling mechanism are mainly two types, single feed type [4-7], dual/multi feed [8], [9]. In case of single feed parasitic feed [4], off-centered feed [5], modified microstrip feed [6], and helical exciter [7] are being used. This single approach is quite simple and convenient, however the gives narrow axial ratio (AR) bandwidth. On the other hand the dual/multi feed techniques like, dual conformal feed [8], quadrature coupler [9] which gives comparatively wider AR bandwidth are quite complex and need an extra power divider circuit. The second approach i.e. modification of DR shape includes rotated stair [10], comb shaped DR [11] have also been reported in open literature.

Here, the authors propose an equilateral triangular dielectric resonator antenna and novelty of the model can be summarized as, (i) ensuring circular polarization in a triangular DRA probably for the first time, (ii) incorporation of spiral loop feed for circular polarization, (iii) antenna operates over (9.1-9.29) GHz with 3.65 dBi peak gain, (iv) antenna shows circular polarization near 9.2 GHz. This paper is organized as follows: Section 2 describes proposed antenna configuration followed by simulation results in Section 3. Section 4 describes the characterization and validation. The conclusion and references are shown in Section 5.

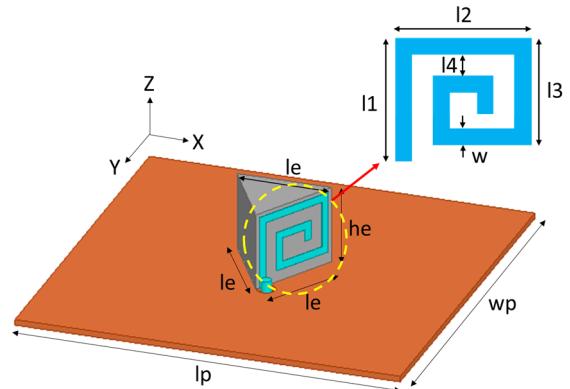


Figure 1. Schematic diagram of the proposed spiral fed triangular dielectric resonator antenna.

2. Proposed Antenna Configuration

Figure 1 depicts the proposed triangular dielectric resonator antenna (TDRA). An equilateral triangular resonator of side edge length (l_e) = 12 mm, height (h_e) = 10 mm of permittivity (ϵ_r) = 10 is placed centrally on a PEC square ground plane of (l) = 50 mm. For feeding purpose a rectangular spiral loop patch arrangement is made using adhesive backed copper tape and fixed on one side wall of the TDRA, whose outer end is coupled to a 50Ω co-axial feed probe. The necessary dimension of the loop is l_1 = 9.5 mm, l_2 = 11 mm, l_3 = 8 mm, l_4 = 1.5 mm, and w = 1 mm. The geometry is first modelled using finite element solver Ansys HFSS v13.0 [12] followed by fabrication and characterization.

3. Simulation Results

The design of the antenna starts with an equilateral triangular dielectric resonator antenna (TDRA) placed on a copper ground plane. Initially the probe fed rectangular patch coupling approach has been applied to excite the antenna properly. In the first phase a small rectangular patch of dimension $l_1 = 9.5$ mm, $w = 1$ mm [Figure 1] is stuck on one side wall of the TDRA as shown in Figure 2. This enables the antenna to operate over (8.33-9.4) GHz centered at 9.1 GHz [Figure 3]. The peak gain is observed to be 3.86 dBi [Figure 4] while the > 3 dB axial ratio shown in Figure 5 indicates linear polarization.

Further in the next phase (Phase-2) the patch is extended by adding another L-shape patch [Figure 2] of dimension $l_2 = 11$ mm, $l_3 = 8$ mm, $w = 1$ mm, and $l_4 = 1.5$ mm as shown in Figure 1. This extended patch moves the resonance deep up to -13 dB while operating over (8.15-9.15) GHz [Figure 3] with 3.92 dBi peak gain [Figure 4]. In this stage the axial ratio comes below 3 dB [Figure 5], however the axial ratio range doesn't fall in the operating range of the antenna.

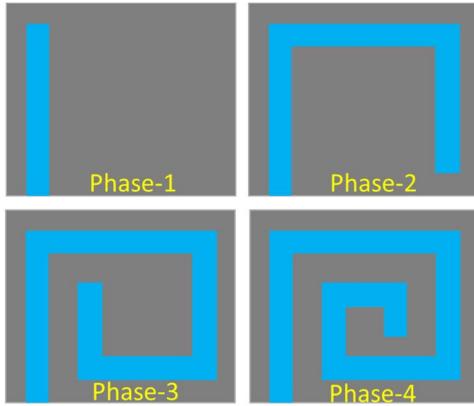


Figure 2. Development stages of the single facet spiral loop.

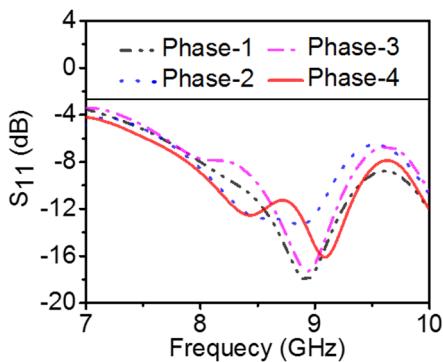


Figure 3. Variation of S_{11} in different phases.

Hence in view of improved axial ratio, in the third phase (Phase-3) the similar procedure is repeated as shown in Figure 2. This arrangement led the antenna to operate $S_{11} < -10$ dB over (8.52-9.28) GHz [Figure 3] with 3.52 dBi peak gain [Figure 4]. Here the axial ratio (~ 1.5

dB) [Figure 5] is quite improved than previous cases, however further optimization is needed. In the final phase (Phase-4) the same procedure is followed to form the final inner end of the loop, which seems like a spiral loop. This optimum phase enables the antenna to operate over (8.12-9.4) GHz [Figure 3] while the peak gain reached to 3.65 dBi [Figure 4]. Interestingly this design made the antenna to bring down the axial ratio below 3 dB over (9.1-9.29) GHz [Figure 5]. This optimized geometry is finally fabricated and characterized in the next section.

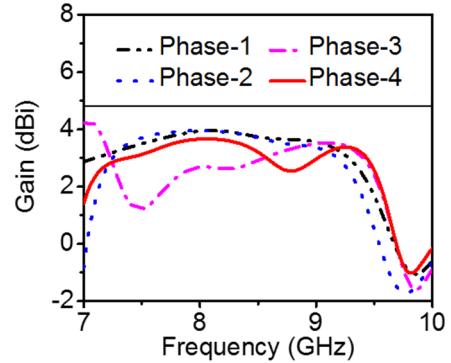


Figure 4. Variation of gain in different phases.

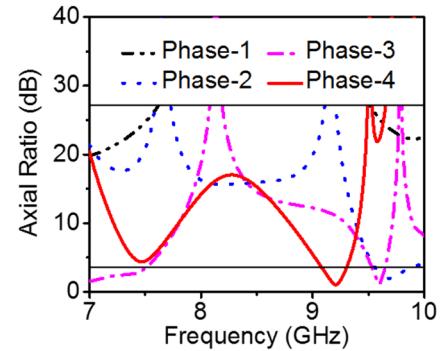


Figure 5. Variation of axial ratio in different phases.

Table 1. Comparison of Results of Different Stages of Step 1

Stages	Bandwidth (GHz)	Gain (dBi)	< 3 dB AR Bandwidth (GHz)
Stage-1	(8.33-9.4)	3.86	NA
Stage-2	(8.15-9.15)	3.92	NA
Stage-3	(8.52-9.28)	3.52	NA
Stage-4	Sim. (8.12-9.4) Mea. (8.16-9.66)	3.65 3.0	(9.1-9.29) (8.95-9.2)

4. Prototype Characterization

Figure 6 shows the fabricated prototype inside echo free anechoic chamber. Eccostock HiK dielectric bar of $\epsilon_r=10$ is machined through automatic lathe to form the optimized equilateral TDRA. An adhesive copper tape is shaped appropriately to form the optimized spiral loop and stuck on the side wall as shown in Figure 6. Then the TDRA is placed above the ground plane and necessary soldering is done at the outer end of the loop to fix the feed probe. The antenna is characterized using Vector Network Analyzer. The comparison of measured and

simulated S_{11} is shown in Figure 7. This shows slight shifting of resonance to the upper frequency, however the trend is very similar. The measured gain shown in Figure 8 shows peak value 3.4 dBi. Similarly the simulated and measured axial ratio are compared in Figure 8. Like S_{11} here also the measured axial ratio curve shifts to right. The simulated radiation efficiency is also incorporated in Figure 7, which shows ~90% efficiency over operating range. The measured and simulated LHCP and RHCP are compared in Figure 10. The mismatch of the measured results with the simulated results might be caused by soldering deposits, slight disorientation of the spiral loops, and the invisible air gap between the TDRA and the ground plane. Post characterization the simulated and measured values are compared in Table 1. Moreover, the proposed antenna is compared with some earlier versions in Table 2, which is self-explanatory. The E-field magnitude on different stages of the patch spiral loop at 9.2 GHz is shown in Figure 11, which defines field strength in each phases.

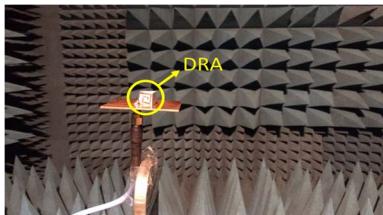


Figure 6. Fabricated prototype inside anechoic chamber with measurement setup.

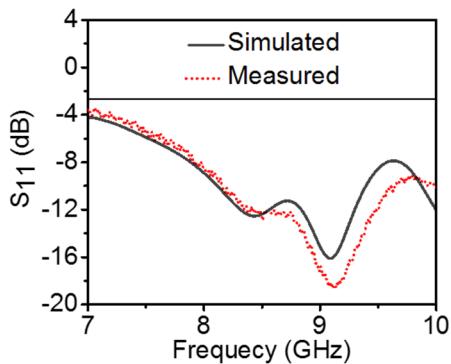


Figure 7. Comparison of simulated and measured S_{11} .

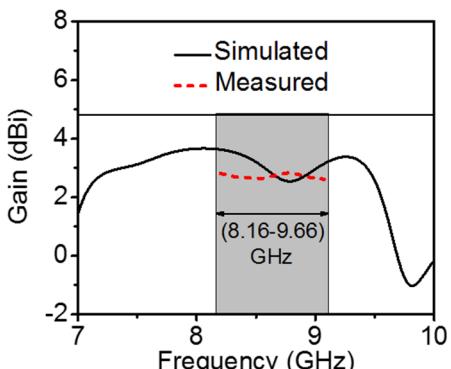


Figure 8. Comparison of simulated and measured gain.

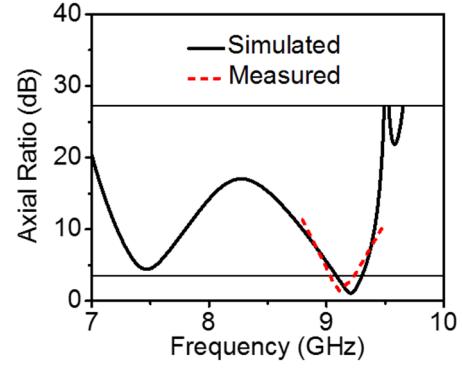


Figure 9. Comparison of simulated and measured axial ratio.

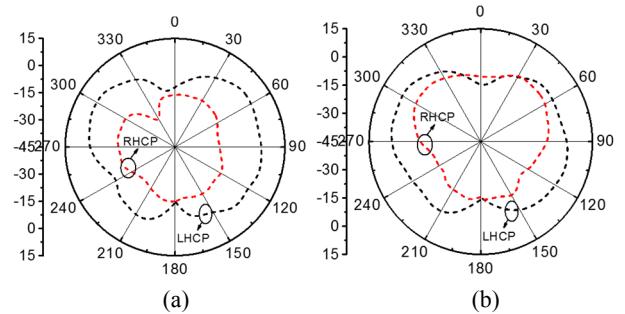


Figure 10. Measured radiation pattern at Comparison of radiation pattern at 9.2 GHz, (a) $\phi=0^\circ$, (b) $\phi 90^\circ$.

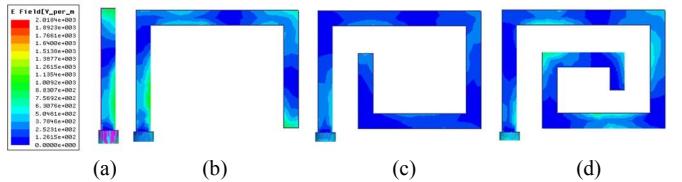


Figure 11. E-field magnitude in different phases, (a) phase-1, (b) phase-2, (c) phase-3, and (d) phase-4.

Table 2. Comparison of Proposed Model with Some Published Models

Ref.	DRA Shape	DRA Volume (mm^3)	ϵ_r	< 3dB AR at (GHz)	Technique
[5]	Cylindrical	3180.86	79	2.4	Off-centered feed
[6]	Cylindrical	9852.03	10	3.5	Helical exciter
[7]	Rectangular	5832	9.8	3.29	Modified microstrip feed
[8]	Cylindrical	69672.28	10	1.375	Multiple microstrip feed
[9]	Cylindrical	1662.53	9.5	5.47	Dual conformal strips
Present	Triangular	623.54	10	9.2	Dual facet rectangular spiral loop

5. Conclusion

Here, a circularly polarized triangular DRA is proposed and validated. Patch coupling technique is applied to resonate the TDRA near 9 GHz, while patch is modified to a spiral loop to ensure ($\text{AR} < 3 \text{ dB}$) circular

polarization between 9.1 GHz-to-9.29 GHz without much disturbing the impedance bandwidth. The optimized antenna operates between 8.12 GHz - 9.4 GHz with 3.65 dBi peak gain. This antenna can be used in X-band applications such as satellite communication. However, proper scope need to be created for its optimum utilization.

6. References

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