International Journal of Engineering & Technology, 7 (4.38) (2018) 1451-1453

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



A Rectangular Dielectric Resonator Antenna with a Wideband Circular Polarization excited by an H-Shaped Conformal Metal Strip

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Abstract

A unique conformal H-shaped metal strip has been used to excite a rectangular dielectric resonator antenna (DRA). By using this proposed single feeding technique, a broadband circular polarization has been produced. A circular polarization bandwidth of ~17.6% and an impedance-matching bandwidth of ~21.6% with a useful overlap of ~14.4% has been achieved. The Computer simulation technology (CST), a 3D simulation tool has been used to design and simulate the antenna prototype. The design has been successfully built and simulated using Finite Integration Technique (FIT). The results of FIT has been validated by Finite Element Method (FEM) i.e. another simulation technique available in CST. A great resemblance between the results from FIT and FEM has been observed.

Keywords: *Dielectric resonator antennas (DRAs), H-shaped antennas, circular polarization (CP), finite integration technique (FIT), finite element method (FEM).*

1. Introduction

In the recent decades an extensive research has been done on the dielectric resonator antenna (DRA) due to its appealing features, such as minute size, no metallic losses, flexible excitation and broad bandwidth (Luk, K.M., et. al, 2003.), (Petosa, A., et. al, 2007). The circularly polarized networks are much more reliable compared to linearly polarized networks because of their significant features. The circularly polarized systems are much more robust against distortion due to multipath and losses due to mismatch of polarization. The circular polarization of DRA can be achieved by single and dual feeding mechanisms. The broadband circular polarization of DRA has been achieved by dual feeding mechanism is reported in (Mongia, R.K., et. al, 1994), (Leung, K.W., et. al, 2000), (Wong, W.C, et. al, 2001). The CP of DRA using single feeding technique has also been demonstrated in the literature. A single-probe feeing technique has been used to excite elliptical DRA and 3.5% CP bandwidth has been reported (Kishk, A.A., et. al, 2003). A 3 dB axial ratio (AR) bandwidth of 2.7% of a rectangular DRA excited by a parasitic patch has been achieved (Li, B., et. al, 2005). A singly outer-fed circularly polarized rectangular DRA with a 7% AR bandwidth has been demonstrated in (Sulaiman, M.I., et. al, 2010). As demonstrated in (Guo, L., et. al, 2016), a 3dB AR bandwidth of 6.1% of a DRA with compact ground plane excited by microstrip line has been achieved. A singly outer-fed rectangular DRA with 8.3% AR bandwidth has been reported in (Illahi, U., et. al, 2017). A CP bandwidth of 8.2% of a rectangular DRA excited by a conformal strip has been demonstrated in (Iqbal, J., et. al, 2017). In all these research articles the CP bandwidth and impedance matching bandwidths of antennas achieved at same frequency.

In this article the rectangular DRA has been excited by a unique H-shaped conformal metal strip to produce circular polarization. The size of the H-shaped feed has been optimized to produce circular polarization at bore-sight direction.

2. Problem Statement

Dual feeding excitation networks have some serious limitations such as complexity and comparatively large size. Whereas single feeding techniques are much more beneficial because of simplicity and overall size of antenna is small. Low permittivity of dielectric is required for wider bandwidth operations so microstrip line feeding cannot be used because coupling is reduced significantly by reducing the permittivity (Gangwar, R.K., et. al, 2010). Probe feeding of DRA have two major constrains; the need to drill hole for probe accommodation, in addition to this, high permittivity is required for good coupling. Conformal strip feeding has no such issues and it can be applicable to arbitrary shapes of DRAs as demonstrated in (Leung, K.W., et. al, 2000).

3. Aim of Research

To design a singly-fed circularly polarized rectangular dielectric resonator antenna. Conformal metal strip should be used for excitation. Antenna should provide wider useful CP bandwidth in conjunction with impedance matching bandwidth. Additionally, it should provide good useful gain and beamwidth along with stable

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radiation patterns throughout the CP bandwidth.

4. Method of Research

A rectangular DRA has been excited by a conformal H-Shaped feed as illustrated in Figure 1. Computer simulation technology (CST) has been used to model the antenna prototype. The FIT i.e. a time domain solver has been used to build and simulate the design. The results have been further verified by FEM i.e. the frequency domain solver also available in CST. To simulate the infinite
ground plane, Electric (Et = 0) has been used as the boundary conditions for Zmin. The dielectric with a relative permittivity of □r = 9.3 (Alumina) has been used for DRA prototype. The DRA dimensions are the same as those given in (Li, B., et. al, 2005): a = 26.1 mm, b = 25.4 mm and c = 14.3mm. The hexahedrons meshing has been used to simulate the design. The antenna has been mashed using Cells per wavelength = 40, Cells per max model box edge = 20 and Number of Cells = 526,419. The conformal H-shaped feed has been constructed with three individual metal strips. The metal strips parameters have been optimized after running many simulations with different parameter sweeps. The optimized feed parameters are found to be l1 = 10.75 mm, l2 = 10.5 mm, l3 = 11 mm, d1 = 7.2 mm, d2 = 1.25 mm and d3 = 4.25 mm. The width of l1 is 1 mm while l2 and l3 is 1.5 mm. The discrete edge port has been used to excite the antenna. The feed position has been varied along with transform command. The best position has been optimized at Y = 6.

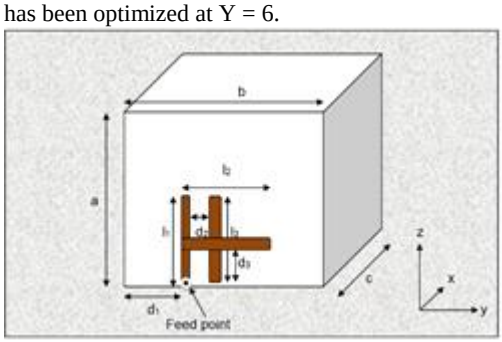


Figure 1. Rectangular DRA excited by H-shaped conformal metal strip

5. Analysis and Discussion

The input impedance and return losses of the rectangular DRA have been demonstrated in Figure 2 and Figure 3 respectively.

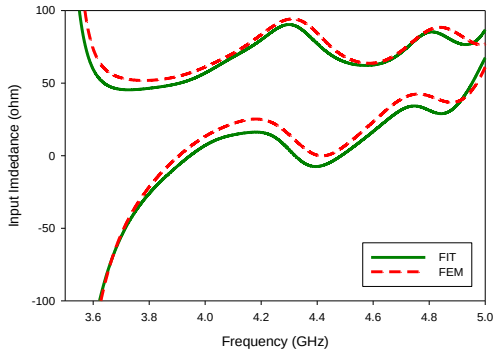


Figure 2. Input Impedance of the rectangular DRA.

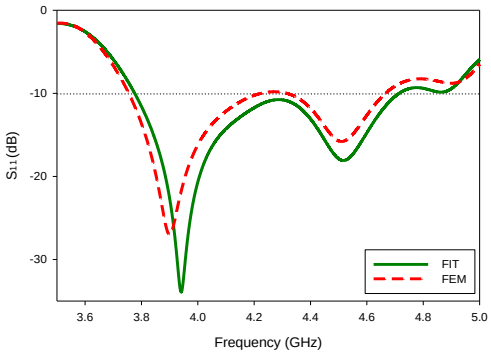


Figure 3. Return losses of the rectangular DRA.

As demonstrated at the the tuning frequency i.e. 3.94 GHz the real component of the input impedance is ~50Ω and the imaginary component is ~0Ω and the return loss has been achieved over a bandwidth of ~21.6%. The minimum value attained by |S11| ≤ 10 dB has been found at 3.94 GHz in FIT and 3.9 GHz in FEM. The slight marginal difference shows the validity of design.
In Figure 4 the axial ratio at bore-sight direction has been computed and demonstrated. The 3dB AR extends from 3.63 GHz to 4.34 GHz. Moreover the minimum point of AR has been computed at 0.168 dB at frequency of 4.08 GHz in FIT and 0.189 dB at a frequency of 4.07 GHz in FEM. As the results demonstrate that the circular polarization has been achieved over a bandwidth of ~17.6%.

Figure 4. Axial Ratio of the rectangular DRA.
The Figure 5 demonstrate the overlap between return loss and axial ratio. As observed a useful overlap of ~14.4% has been provided by the antenna at same frequency range which is a great improvement to that has been achieved in literature for singly-fed rectangular DRA.

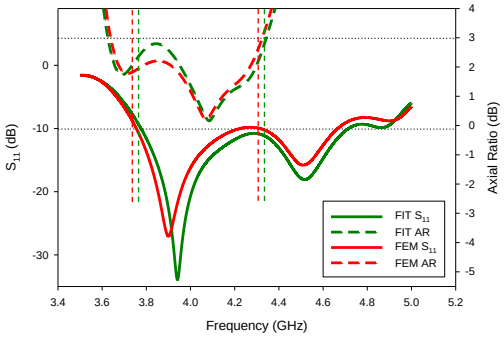


Figure 5. Overlapping bandwidths regions for S11 and AR of the rectangular DRA

The radiation patterns of the antenna has been represented in Figure 6. From radiation pattern it is clear that left-hand CP has been achieved, since the left-hand field component is greater than its right-hand counterpart by a difference greater than 20 dB in the bore-sight direction at minimum AR frequency i.e. 4.08 GHz.

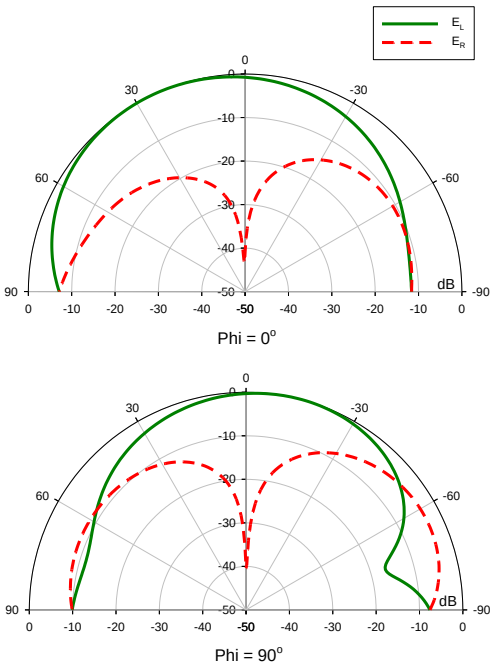


Figure 6. Radiation pattern of the rectangular DRA.

The Figure. 7 represents the beamwidth of the antenna. In the ϕ = 0o plane, a CP over a beamwidth of 69o has been provided by the DRA. The achieved beamwidth is comparable to those reported in (Tam M.T., et. al, 2000).

Figure 8 illustrates the gain of the antenna and it has been observed that a useful gain of ~4.4-6.2 dBi has been offered by the antenna along the whole CP bandwidth.

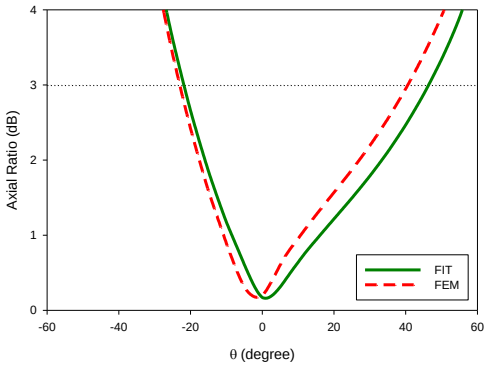


Figure 7. Beamwidth of the rectangular DRA.

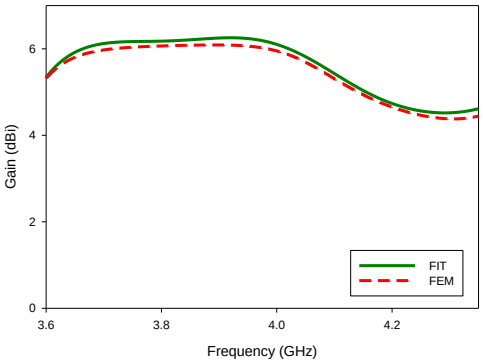


Figure 8. Gain of the rectangular DRA.

6. Conclusion

The singly-fed rectangular DRA has been excited using a unique H-shaped conformal metal strip. The antenna achieved 3dB Axial Ratio bandwidth over a wide band of ~17.6% and an impedance matching bandwidth of ~21.6% along with useful overlap of ~14.4% which is a significant improvement as compared to those reported in literature of singly outer-fed CP rectangular DRAs. The far-field pattern confirms that the circular polarization has been attained over a beamwidth of 69o. Moreover, antenna provides a satisfactory gain throughout the CP bandwidth. A good resemblance between the results from FIT and FEM has been observed.

Acknowledgements

At first the authors wish to acknowledge the research facilities provided by the Postgraduate and Research Department of UniKL BMI. The authors would also express their gratitude to Gomal University, Pakistan for granting study leave to carry out this research.

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