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Bandwidth and Beamwidth Enhancement of a Singly-Fed Circularly Polarized Rectangular Dielectric Resonator Antenna using Parasitic Patch

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Abstract: The circular polarization (CP) bandwidth and beamwidth of a rectangular dielectric resonator antenna (DRA) fed by an off-set conformal metal strip has been enhanced using parasitic patch. An increment of ~38% in the axial ratio (AR) bandwidth and ~37.5% in CP beamwidth has been achieved by placing the parasitic patch at optimized distance from the feeding strip on the DRA surface. A CP bandwidth of ~7.2% in conjunction with an impedance matching bandwidth of ~26.4 has been offered by the antenna. The proposed antenna offers a CP beamwidth of 112° in the $\phi = 0°$ plane and 80° in the $\phi = 90°$ plane. The DRA has been designed, simulated and optimized using the computer simulation technology (CST). Finite Integration Technique (FIT) in CST has been used to compute the results while finite element method (FEM) has been used for validation of the results. A similar trend has been observed between two set of results.

Keywords: Dielectric resonator antenna, circular polarization, conformal feeding strip, finite integration technique, finite element method, parasitic patch, wide-band antenna.

1.0 INTRODUCTION

From the previous few decades the wireless communication researchers are focusing more on DRAs because of their important features like flexible shape, wider bandwidth, no metallic losses etc. The circularly polarized systems are much more reliable as compared to linearly polarized systems in terms of efficiency and performance. Single and dual feeding mechanisms can be used to achieve the CP of DRAs. Dual feeding technique has been discussed in [1, 2]. But the singly fed DRAs are more preferable because of simple geometry and compact size. Many singly fed circularly polarized DRAs have been proposed in literature. A conformal strip excitation has been used to achieve 3-dB axial ration (AR) bandwidth of 7% of a rectangular DRA [3]. A rectangular DRA has been excited by hook-shaped feed to achieve CP bandwidth of 8.3% and a cylindrical DRA 9.8% of as reported in [4, 5]. A parasitic patch has been used to get AR bandwidth of 2.4% of a hemispherical DRA and 2.7% of a rectangular DRA [6, 7]. As reported in [8], the CP bandwidth of a singly fed rectangular DRA has been enhanced by 29% using parasitic patch. A CP bandwidth of 1.8% has been provided by a rectangular DRA using single-slot feed as claimed in [9]. An off-set metal strip has been used to excite a rectangular DRA to achieve a 3-dB axial ratio bandwidth of 5.2% as studied in [10]. In all these articles good impedance matching bandwidth has been achieved over same frequency range.

In this article the CP of rectangular DRA reported in [10] has been enhanced using parasitic patch placed at the optimized distance from the feeding metal strip. The orthogonal mode pair $TE^x_{\delta 11}$ and $TE^y_{1\delta 1}$ has been excited to generate circularly polarized wave. The patch parameters are optimized to achieve CP bandwidth of 7.2% along with wide impedance matching bandwidth of 26.4% over same frequency range.

2.0 MATERIALS AND METHODS

A rectangular DRA fed by an off-set conformal metal strip with parasitic patch has been presented in Fig. 1. The CST has been used to design the antenna prototype. The band of frequency has been set at 2 to 4 GHz. The Z_{min} is set at Electric ($E_t = 0$) in the boundary conditions to simulate the infinite ground plane. The hexahedral meshing has been used for modeling the rectangular DRA and permittivity, $\in_r = 10$ has been used. The dimensions of the dielectric block are: a = 26.1 mm, b = 25.4 mm, and c = 14.3 mm as reported in literature [5]. The mashing has been done by setting the cells per wavelength = 45, similarly the cells per max model box edge = 20 giving the number of unknowns = 692,064. The discrete edge port has been used to excite the model. The various simulations with the aid of different parameter sweeps has been used to optimize the length, and width of the parasitic metal strip. Accordingly the transform command along with parameter sweeps has been used to find the optimal patch position.

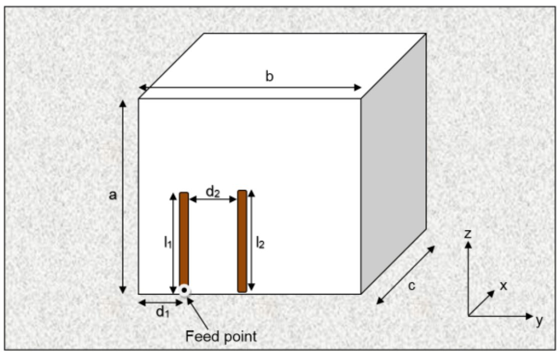

Fig. 1: Rectangular DRA excited by an off-set conformal metal strip with parasitic patch

The antenna has been optimized in time domain solver using FIT. The validation has been done in frequency domain solver using FEM.

3.0 RESULTS AND DISCUSSION

The optimized feed position and parameters are d_1= 4.0 mm, and l_1=11.0 mm [10]. The parasitic patch dimensions and position have been optimized after running numerous simulations and optimized measurements of position, and length are, d_2=7.0 mm, l_2=11.5 mm. The width of the parasitic patch is 1 mm.

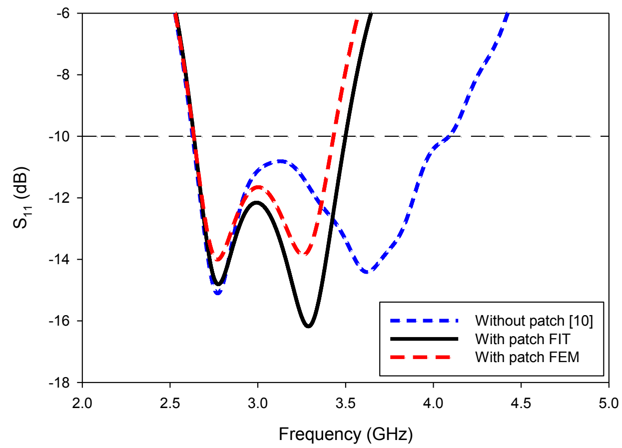

Fig. 2: Return losses of the rectangular DRA

The return losses of the antenna with/without parasitic patch has been illustrated in Fig. 2. The $TE^x_{\delta 11}$ has been computed at 2.774 GHz in FIT and 2.771 GHz in FEM while $TE^y_{1\delta 1}$ has been computed at 3.28 GHz in FIT and 3.25 GHz in FEM. A small marginal difference is due to different computational environment of the simulation techniques. As observed, $|S_{11}| \leq 10$ dB bandwidth of 26.4% has been offered by the DRA. The S_{11} bandwidth has been reduced but the focus of the reach is to improve useful CP bandwidth and beamwidth which is achieved effectively.

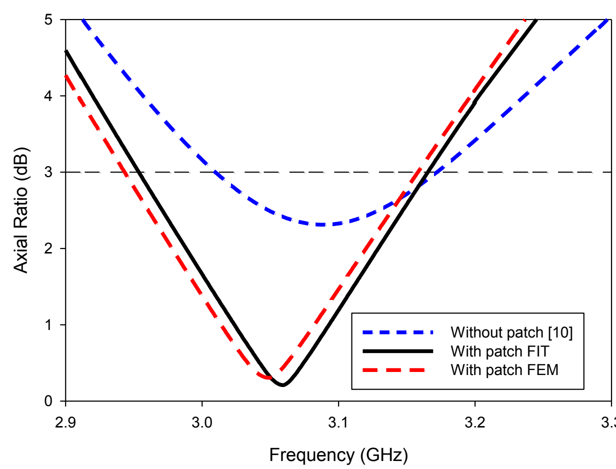

Fig. 4: Axial ratio of the rectangular DRA

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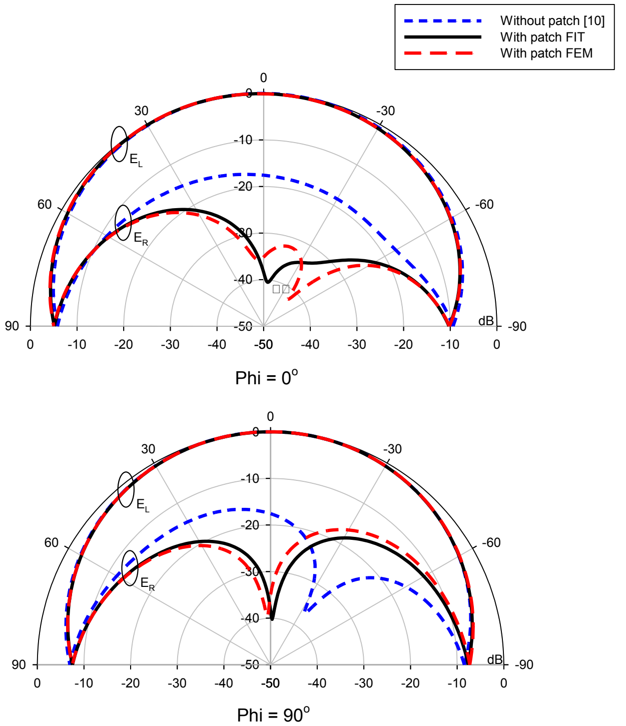

Fig. 5: Radiation patterns of the rectangular DRA at optimum AR frequency

The Fig. 4 depicts the axial ratio of the rectangular DRA with/without parasitic patch in the bore-sight direction. The AR bandwidth of 7.2% has been achieved as illustrated by the results. Moreover the optimum AR value i.e. 0.21 dB has been computed at 3.06 GHz in FIT and 0.3 dB at 3.05 GHz in FEM. A useful CP bandwidth of ~7.2% has been provided by the proposed antenna, that is, ~38% enchantment to that reported in [10], as shown in the Fig. 4.

The radiation patterns of the antenna design has been shown in Fig. 5. The left hand circular polarization has been achieved by the DRA. As observed the left hand field component is greater than right hand field component by more than 30 dB at optimum AR frequency i.e. 3.06 GHz in bore-sight direction. The Fig. 6 depicts the beamwidth of the rectangular DRA with/without. The DRA offers CP with a successful beamwidth of 112° in the ϕ = 0° plane and 80° in the ϕ = 90° plane which is clear enhancement of ~35% and 11% in ϕ = 0° and ϕ = 90° planes respectively, as discussed in [10]. Moreover, the beamwidth provided by the antenna are comparable to those reported in [11].

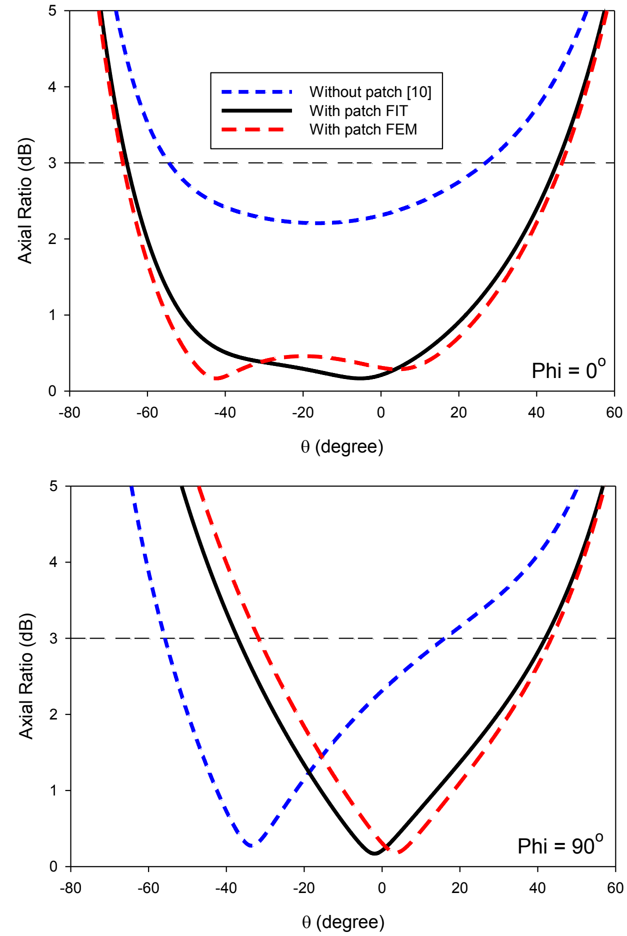

Fig. 6: AR beamwidth of the rectangular DRA

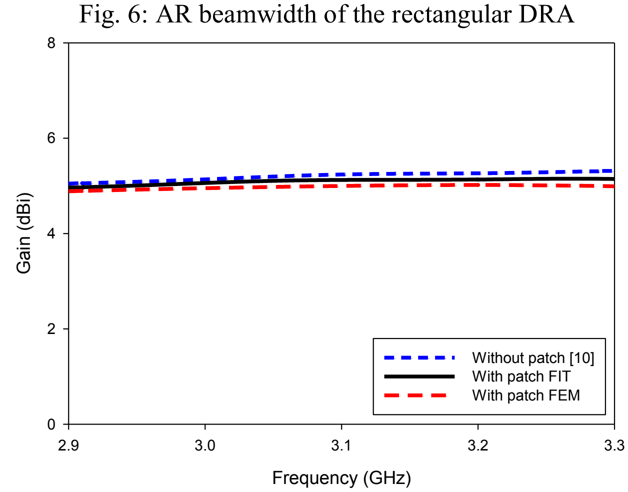

Fig. 7: Gain of the rectangular DRA

The gain of the rectangular DRA has been presented in Fig. 7. A useful gain of ~5.1 dBi has been provided by the antenna along the whole CP bandwidth. The gain of the antenna has been computed and presented in both FIT and

FEM. A similar trend has been observed in the results of both simulation techniques.

4.0 CONCLUSION

The CP bandwidth and beamwidth of a rectangular DRA has been successfully enhanced by ~38% and 37% respectively using a parasitic metal strip. An AR bandwidth of ~7.2% along with a $|S_{11}| \leq 10$ dB bandwidth of ~26.4% has been achieved over same frequency range. A wider CP beamwidth of 112^o along with a useful gain of ~5.1 dBi has been provided by the antenna. A good agreement between the results from two simulation techniques has been observed.

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