Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 50 (3D) 63-66 (2018)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

A Wide band Circularly Polarized Rectangular Dielectric Resonator Antenna Excited by Novel Feed

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Received 10th June 2018 and Revised 15th September 2018

Abstract: This study presents design and analysis of a wideband circularly polarized (CP) rectangular-shaped dielectric resonator antenna (DRA) which is excited with a new roman three(ш)shaped feed, proposed feed is made-up of five metallic strips, which has been optimised to generate wideband circular polarization. The proposed antenna offers10-dB impedance bandwidth of 9.38% and 3-dB Axial-ratio (AR) bandwidth of 8.26 % in the broadside direction. The proposed DRA achieved the reasonable gain and radiation efficiency of 2-5 dB and 99.15%, respectively throughout operating band. The design is simulated in computer simulation technology (CST) and thoroughly validated through another simulator i.e. High Frequency Electromagnetic Field Simulation (ANSYS HFSS). A significant trend resemblance has been seen between results of both simulators. Furthermore, the proposed design is optimized and enhances the results by changing relative permittivity of the DRA from 9.3 to 8.0 which increase 10-dB impedance bandwidth to 16.08% and 3-dB AR bandwidth to 10.01 % in the broadside direction.

1. INTRODUCTION

Because of several qualities of a dielectric resonator antenna (DRA) like wide bandwidth, high radiation efficiency, low losses, ease of excitation, compatibility to various feeding techniques and small in size DRA has popular amongst wireless communication engineers (Petosa, *et. al,* 2007), (Mongia, *et. al,* 1994). On the other side Usual micro strip antennas have low radiation efficiency, less bandwidth and more conduction losses, to overcome these issues, DRA is most appropriate option for engineers in modern wireless communication systems (Petosa. *et. al,* 2010), (Chaudhary, *et. al,* 2013).

In today development of modern wireless communication (i.e. Radar and satellite system) great attention has been given on circular polarization (CP) because of its advantages, e.g. better mobility, reduced multipath of the signal and weather penetration (Leung, *et. al,* 2003).

The CP-DRA has been divided into two types, 1st is single feeding technique and 2nd isDoublefeeding technique. Numerous single feed CP DRA designs have been reported in the literature ,for example a rectangular DRA fed by a single-slot and an elliptical DRA exited by a single-probe obtained circular polarization bandwidth of 1.8% and 3.5% respectively (Oliver, *et. al,* 1995), (Kishak, *et. al,* 2003). In (Leung, *et. al,* 2003), a hemispherical DRA fed by a parasitic patch reported 2.4% CP Bandwidth. A rectangular DRA that is excited using an outer-fed square spiral strip attained CP bandwidth of 6.7% (Sulaiman, *et. al,* 2010). Additionally 3-dB axial ratio bandwidth of 5.71% is achieved in circularly polarised semi eccentric annular DRA which is excited through single vertical coaxial feed (Jmai, *et. al,* 2014).

In this paper, a singly-fed wideband circularly polarized rectangular DRA excited by a New roman three (ш) shaped feed has been proposed. The optimized parameters of the antenna achieved 10-dB impedance bandwidth of 8.21% and 3-dB axial ratio bandwidth of 16.08% which is comparatively better than the other single fed DRAs reported in literature. Close agreement has been seen between the simulated and theory results like Far-field patterns, axial ratio and return loss.

2. MATERIALS AND METHODS

(Fig 1). demonstrate the geometry of proposed Rectangular DRA excited with roman three (ш) shaped feeding technique. **(Fig 1).** shows the top view and 3-D view of projected antenna. In the projected design, a rectangular DRA prototype with a relative permittivity of $\varepsilon_r = 9.3$ (alumina) has been simulated. The dimensions of the DRA are H_1=25.4 mm, L_1=26.1mm and W_1=14.3mm which is similar to the one use in (Sulaiman, *et. al,* 2010). The proposed roman three type feed is made up of five(5) metallic individual strips After numerous simulations of varying the parameters of the antenna, the optimum dimension of the feed are found to be h_2=10.75mm, h_3=2.5mm, l_2=8mm and l_3=1mm.

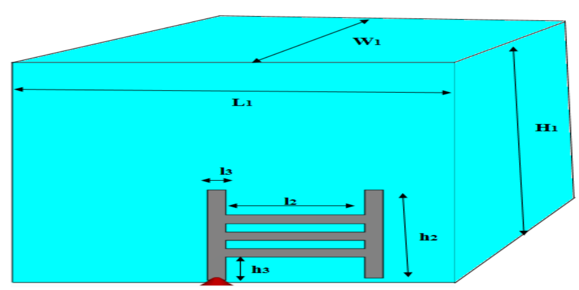

Fig.1. 3D view of proposed Antenna Design

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The current distribution throughout the metal field can be seen in **(Fig 2a).** To simulate the effect of infinite ground plane, the boundary condition of $Z_{min}$is set to be E_t=0. Discrete edge port is used to excite proposed feed. Mashed properties like lines per wavelength is 60 while lower mesh limit = 35, Mesh line ratio limit is =50 for the proposed Antenna and finally, mesh cells for the DRA is 5, 27,514. Hexahedron meshing is used to simulate the optimised design. Through parameter swipe, the feed position is shifted on the surface of the DRA along the y-axis and the optimized position of the feed is found to be at the centre of the DRA surface. Further optimization have been carried out by varying the relative permittivity of the DRA and the best results is achieved when the relative permittivity=8

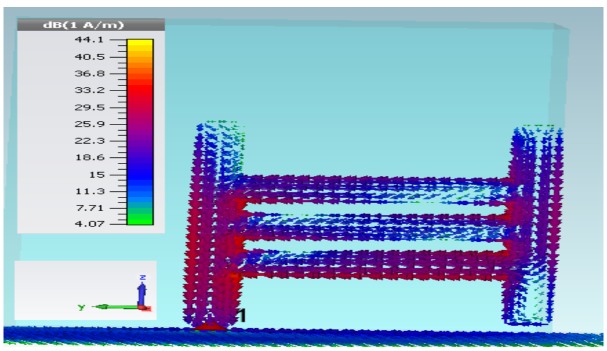

Fig.2. (a) Current Distribution

In order to validate the proposed antenna, the exact DRA design has been simulated using HFSS. Good agreement between the results has been observed and hence validated the design. Both simulators use different computational electromagnetic (CEM) method where CST uses FDTD (Finite Difference Time Domain) methods while HFSS uses FEM (Finite Element Method) (Jmai, *et. al,* 2014)

3. <u>RESULTS AND DISCUSSION</u>

A Prototype antenna was simulated and optimized with CST, Fig. 2(a)–(c) depicts the simulated results. The Validation of the proposed antenna design was performed using another simulator HFSS.

3.1 Axial Ratio Bandwidth validation

(Fig. 2b). the results show that both simulations yield similar trends with some shift in frequencies. These discrepancies can be attributed because of different simulating methods (Jmai, *et. al,* 2014).With reference to the figure the proposed antenna shows validated results for 3-dB axial-ratio bandwidths over both Simulators. Through CST proposed antenna results are from 3.88 GHz to 4.26 GHz with bandwidth of 9.38 % with minimum frequency attained at 4.02GHz .While on the other side HFSS simulator validate the CST results and over the minimum frequency 3.3GHz show 3-dB axial-ratio bandwidths of 17.66 % in the broadside direction (θ = 0, φ = 0) Overall trend shows the validation of the results as well.

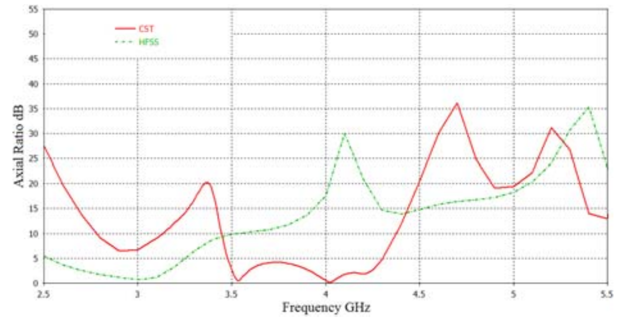

Fig.2. (b) Axial Ratio Bandwidth Validation

3.2 S_{11} Validation

It is clearly seen in **(Fig 2c).** that S_{11} has been achieved and validated over the both simulator almost at same minimum frequency i.e.3.96 GHz & 4.Ghz.CST 10-dB impedance bandwidth is 8.26% and over the same minimum frequency HFSS 10-dB impedance bandwidth achieved is 5.75%.

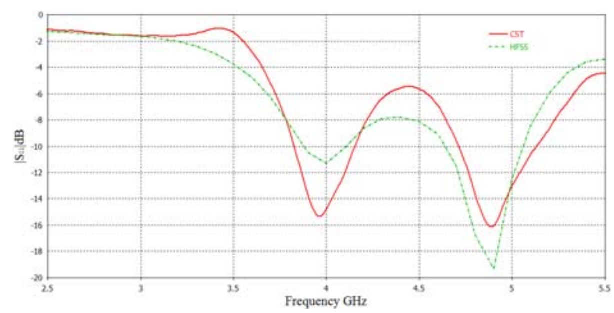

Fig.2. (c) S_{11} Validation

3.3 Optimization of the Design Through Relative Permittivity

Effect of relative permittivity on the reflection co-efficient and axial ratio is studied, it is seen that by decreasing the relative permittivity all important parameter like, reflection co-efficient, axial ratio, beam width and Gain improves significantly. **(Fig 3a-d)**. shows the simulated results by changing the relative permittivity to 8.it was observed that both 10-dB impedance bandwidthand 3-dB Axial-ratio (AR) bandwidth move slightly to the higher frequencies by decreasing the relive permittivity.

3.3.1 Effect on reflection coefficient

(Fig 3a). displays the simulated results of the 10-dB impedance bandwidth of the different value of the relatives' permittivity. Comparison graph shows clearly that reflection co-efficient improves a lot by decreasing the permittivity from 9.3 to 8.0.For permittivity 9.3, 10-dB impedance bandwidth is 8.26% (3.88 GHz-4.26) with minimum frequency 4.02 GHz. Furthermore by changing the relative permittivity to 8.0, the impedance bandwidth has improved to 10.01 % (4.04 GHz-4.40) having minimum frequency of 4.23 GHz.

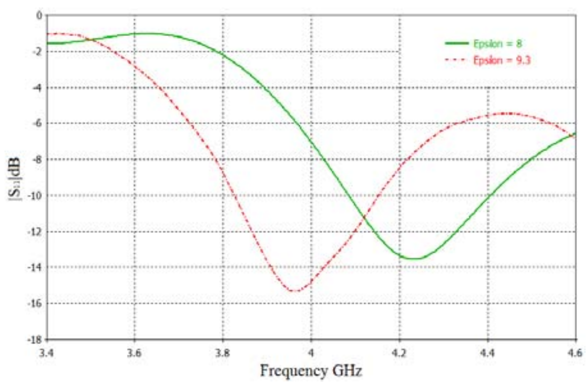

Fig.3. (a) S_{11} comparison between permittivity 9.3 & 8

3.3.2 Effect on Axial Ratio Bandwidth

The effect by varying the relative permittivity is clearly visible in Fig 3(b) that 3-dB Axial-ratio bandwidth improves significantly by changing permittivity from 9.3 to 8.0.it was found that 3-dB Axial-ratio bandwidth for relative permittivity 9.3 is 9.38%, having minimum point at 4.02Ghz, 3-dB Axial-ratio bandwidth has increase by 71% compared to those obtained using relative permittivity =9.3, i.e. 16.08 %.(3.78 GHz-4.47).

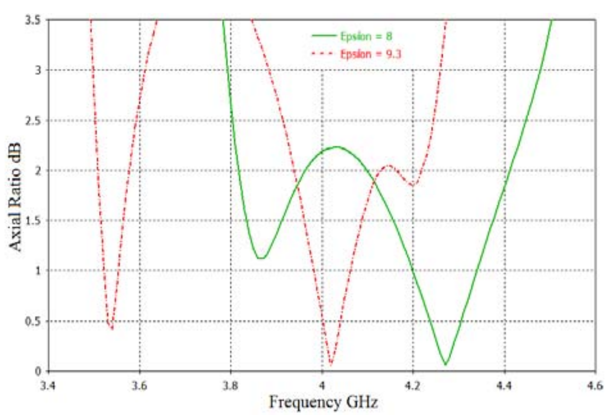

Fig.3(b). Axial Ratio bandwidth comparison between permittivity 9.3 & 8

3.3.3 Effect on gain & beam width

Changing the relativity permittivity not only effect return loss and axial ratio bandwidth but also gain and beam width of the DRA, as can be observed from Figure c-d. Fig c shows that gain rise when the relative permittivity is changed to 8.0 as antenna offers the gain of almost 4.5 dB across the whole operating bandwidth. At the minimum AR frequency (~4.05 Ghz), the gain has increased to 5 dB, compared to 3.5dB achieved when the relative permittivity is 9.3,As shown in **(Fig 3d).** useful beam width of 45° in the φ =0 plane is achieved for cross polarization DRA which is reasonable enhanced comparatively.

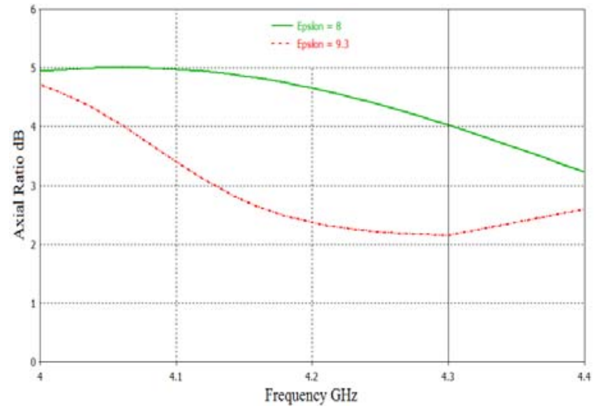

Fig.3 (c). Gain compression between permittivity 9.3 & 8

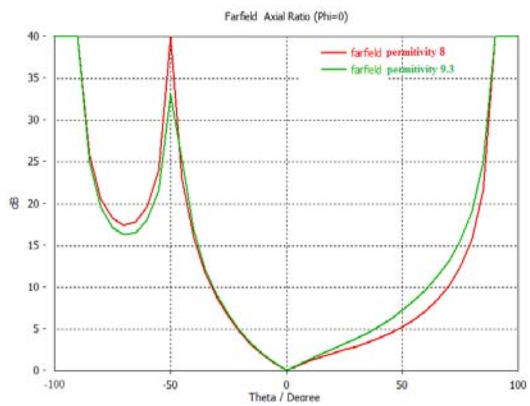

Fig.3 (d). Beam width comparison between permittivity 9.3 & 8

5. CONCLUSION

A Wideband Circularly Polarized Rectangular-Dielectric Resonator Antenna Excited by new roman (ш) feed has been investigated using CST. Based from the results obtained i.e. 10-dB impedance bandwidth of 16.08% and 3-dB AR bandwidth of 10.01 % in the broadside direction, a wideband CP DRA design has been achieved. The design has been validated through HFSS and a good agreement has been observed. Additionally the DRA has been optimised further by changing the relative permittivity to 8.0, which significantly improve the return loss, 3dB axial ratio bandwidth, Gain and beamwidth 4.5dB and 45° respectively.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Research and Innovation Department of British Malaysian Institute for providing peace full environment for research and Gomal University, Pakistan for granting oversea study leave for PhD.

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