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Mutual Coupling Reduction in Circularly Polarized Dielectric Resonator MIMO Antenna Arrays Using Space diversity

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Abstract

An effective technique for reducing the mutual coupling between novel feed Rectangular dielectric resonator antennas (RDRA's) using a space diversity, which is further examined and demonstrated. This is achieved by separating the two closely spaced RDRA's antennas at the optimum distance. Both RDA's are placed in E-Plane. Using the proposed techniques, a new current path is introduced which in result not only reduces the mutual coupling between the two DRAs but also produce the circular polarization. The proposed technique reduced the mutual coupling (MC) ~ 8.65 dB. Average Gain of ~ 5.9 dBi is achieved throughout. Moreover, 3-dB axial ratio bandwidth of 6.7% is achieved. The design is simulated in professional simulating tool i.e. CST, which use FET computational technique that is further validated through FEM, and significant resemblance in results is examined

Keywords; *Dielectric Resonator Antenna, circular polarization, Multi input multi output antenna, Mutual coupling, Space diversity*

I. INTRODUCTION

Over a couple of years, a substantial development in wireless application has enhanced the multiple inputs multiple outputs (MIMO) antenna technologies. For wireless activities, i.e. worldwide interoperability for microwave access (WiMAX), wireless local area network (WLAN), and long-term evolution (LTE) the best option is MIMO antennas. MIMO framework compromises on improved nature of work specially in non-line of sight as it deals fundamentally more extensive transfer speed of up to several gigabits contrasted with a single input single-output framework [1]. Also, MIMO receiving wires have the ability to enhance the channel limit over a constrained accessible transmission capacity to accomplish a high information rate. MIMO is a basic piece of existing advances on account of the upgrade of various parameters, for example, gain, information rate, limit, and proficiency, and so on.

The idea of MIMO was introduced by expending the capacity theorem [3]. In wireless system, MIMO has been used in combination with directional digital transmission and reception using beam-forming signal-processing applications [4, 5], digital transmission systems with multi-channel [6, 7], multivariate analysis with memory over the Gaussian channel [8], and pulse amplitude modulation signals [9].

Now a day's in current wireless application, mostly the devices are small in sizes. The compact and handy devices set a bound on the space between antennas in MIMO system. The adjacent locality of the radiating elements in MIMO can be a reason of deprivation of many antenna characteristics like, return loss, Axial ratio and gain and jointly such outcome is known as a MP, which thoroughly disturbs the near and far field parameters. A MC of low value is essential to be sustained between the radiating elements in order to guarantee an efficient MIMO antenna systems, [2].

Microstrip patch antennas have been used in MIMO system but such antennas have very low efficiency such as mentioned in [10], where a dual-band microstrip patch antenna is used along with capacitive loaded loops. In these techniques, the efficiency of the antenna has about 30% and 70% in lower and higher frequency band respectively. Low efficiency issue of microstrip patch antennas can be resolved by substituting the microstrip antennas with DRA for MIMO subsequently DRAs retain high radiation efficiency [11]

A lot of techniques has been used by numerous researchers to reduce MC between radiators. Almost 19.5 dB isolation has been attained by utilizing artificial magnetic conductor (AMC) ground plane [12]. On the other side, in [13] around 23 dB reduction in mutual coupling has been reported by using electromagnetic band gap structure (EBG) structure between radiating elements. Another technique through which MC drop down by approximately 28 dB using split ring resonators (SRR) in [14]. Paper [15] proposed the use of an arc which work as a defected ground structure between two cylindrical DRAs, which causes a 5.8 dB reduction in MC. In order to excite the DRA, conformal metal strip has been as that is easy to handle and additionally, offer better impedance matching with DRAs [16, 17].

II. ANTENNA GEOMETRY AND DESIGN

Space diversity is a technique through which isolation is enhanced between the closely packed radiating elements by space deviation. An optimized distance between the radiating elements certifies the proper operation of the design and produces the anticipated performance parameters along with the low mutual coupling.

Fig. 1 illustrates a rectangular DRA (RDRA) excited by roman three (III)-shaped conformal metal strip. The III shaped metal strip feed is used as it delivers better impedance matching with RDRAs. The RDRA is used in a two-element array design as shown in Fig: 2. The RDRAs with permittivity, εr = 10 are placed on a 400 mm x 400 mm PEC ground.

bandwidth and specially in resonant frequency (f0) attained can be endorsed to the dissimilar computational procedures i.e. FIT and FEM. As a whole, an acceptable trend between the results are witness.

A usable circular polarization over a broad band of ~6.7% has been attained which is clearly reflected from Fig. 5 and also validated trough FEM as well.

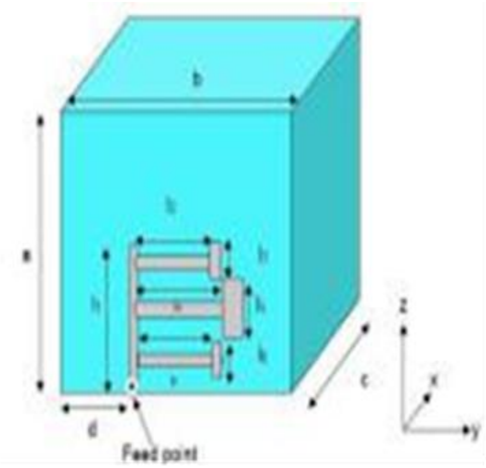

Figure. 1. Configuration of the Conformal-E-shape single RDRA.

After numerous simulations, the optimized distance between two RDRA’s based on rigorous Parametric analysis using CST tool is 3λ0/4, where λ0 denotes the wavelength with respect to resonant frequency. The dimension of the DRA and feed design is taken from the literature. [18] i.e. a=25.4 mm, b=26.1mm and c =14.3mm and optimal dimension of the feed are l1=8.75mm, l2 and l7=8.0mm, l4=9mm, l3 and l6 1.5mm and l5=2.5mm.

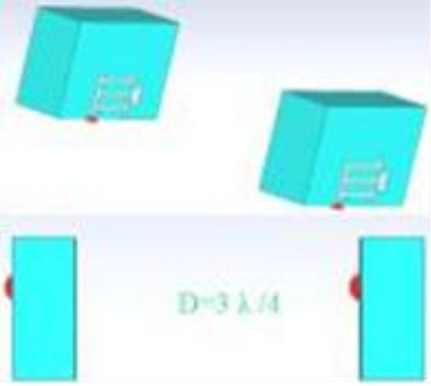

Figure. 2. Top and Side view of optimized distance RDRA array.

Configuration of the RDRAs based on the optimized distance is shown in Fig. 2-3, where both the radiating antennas are positioned side by side. Isolation between the RDRA'S is minimized by optimizing the spacing i.e. 3λ0/4 from feed to feed. This configuration reduces the mutual coupling around ~-8.65 dB throughout the entire band.

III. RESULTS AND DISCUSSIONS

One of the main cause for MC is either by means of radiation or by mean of transmitting surface waves [19]. Increasing the gap between radiating elements cover both these reasons [19]. The input impedance (S11<-10 dB) performance of proposed Antenna array shown in Fig. 4 which is further validated through another computational technique called frequency element method (FEM). A slight deviancy in the overall

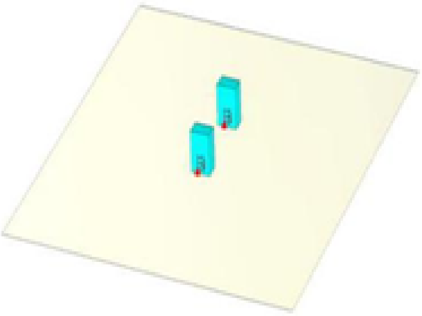

Figure. 3. Side view of RDRA array at optimized distance.

The mutual coupling performance (S21) of original design (without space diversity) and optimized design is shown in Fig. 6. It is clear that mutual coupling in original antenna is very high within the 3.65-3.85 GHz band. This has been reduced by optimizing the distance of two RDRA. As mention in [20], the direction of current flow changes when the space diversity design is used, which caused a reduction mutual coupling because of this new current path from active antenna element to passive element has been created, as can be seen in Fig 7 - 8.

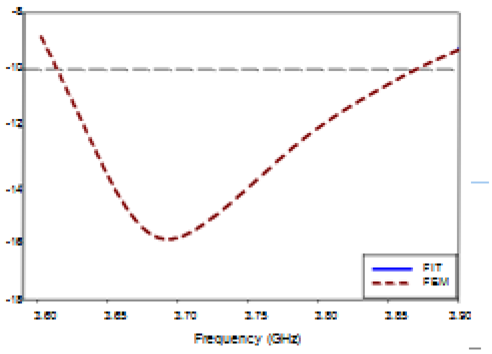

Figure. 4. Validation of return loss of optimized RDRA array.

In Fig. 8, current distribution of original antenna is co-centric while in Fig. 9, due to the optimized design, the direction of current is anti-clockwise which obviously indicate that the flow of current changes which in result lessens MC. Moreover, because of decline in MC, the RDRA array propose a reasonable simulated boresight gain of ~ 6.0 dBic as depicted in Fig. 9.

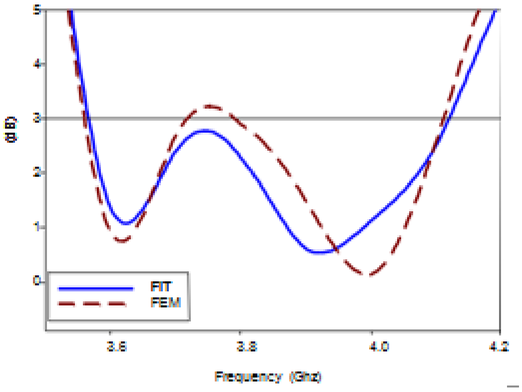

Figure. 5. Validation of Axial ratio of optimized RDRA array.

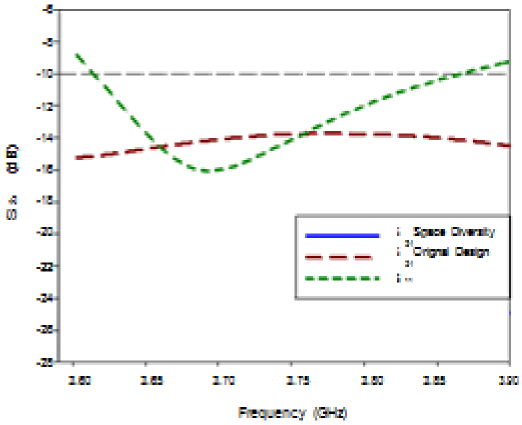

Figure. 6. Comparison of S21 between Original Designs & optimized distance RDRA array

Greater the coupling between the radiators and lesser the envelope correlation coefficient is essential in MIMO systems

The envelope correlation coefficient is interconnected to the MC, and that is proportional to the MC between arrays. The envelope correlation coefficient can be attained through far-field parameters [21] of the radiating elements.

Consider F1 (θ, φ) and F2 (θ, φ) are the Far-field patterns of two rectangular DRA array, formerly ECC will be:

$$|\rho_e(i,j,N)| = \frac{\left|\sum_{n=1}^{N} S_{i,n}^{*} S_{n,j}\right|}{\sqrt{\left|\prod_{k(=i,j)}\left[1-\sum_{n=1}^{N} S_{i,n}^{*} S_{n,k}\right]\right|}}. \quad (1)$$

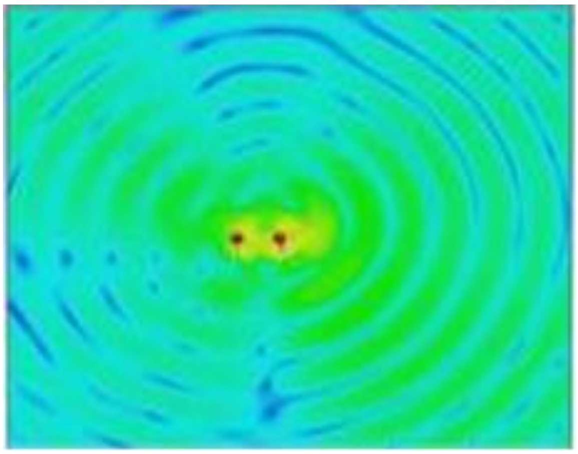

Figure. 7. Current pattern of optimized distance RDRA array.

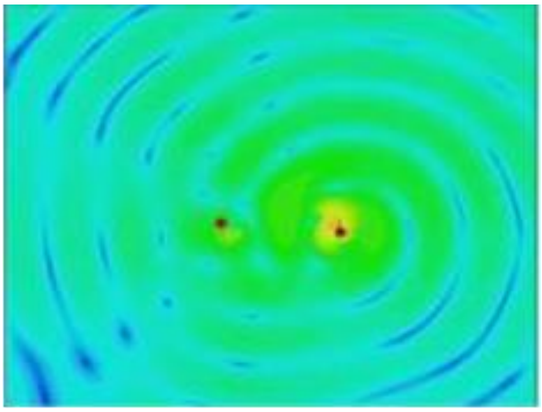

Figure. 8. Current pattern of optimized distance RDRA array.

On the other hand, the important parameter like diversity gain is dependent upon MC too [22], that is attained in the case of extreme hypothetical Diversity gain value is 10 dB while through equation 2. Diversity gain and ECC is contrariwise to one other.

$$G_{DG} = 10 \times \sqrt{1-|\rho|^2}. \quad (2)$$

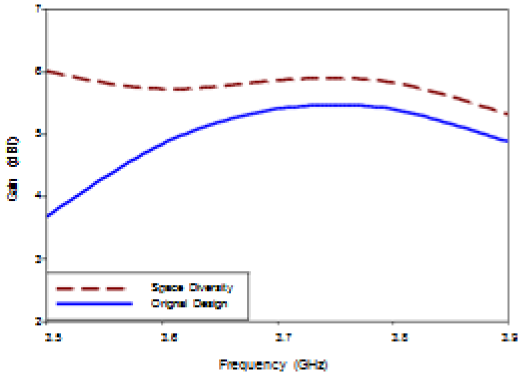

Figure. 9. Comparison of gain

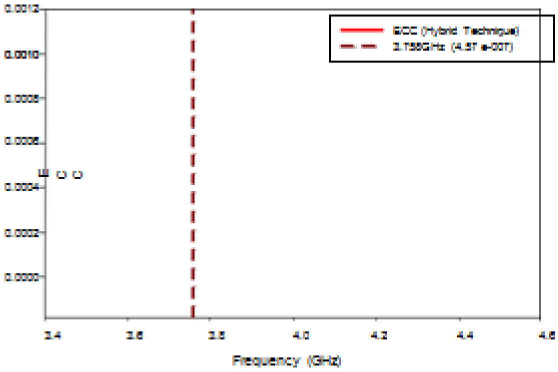

Figure. 10. ECC of optimized distance RDRA array

From Fig: 10 and 11, it is evident that anticipated rectangular DRA array offers lesser ECC value and greater Diversity gain values i.e. ~5 .68 e-008 and ~ 9.98 dBi correspondingly.

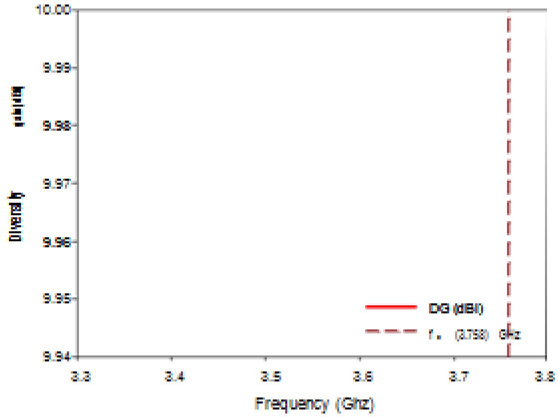

Figure. 11. DG of optimized distance RDRA array

Through finite integration computational technique at θ° and 90° the simulated radiation patterns are demonstrated in Fig. 12, 13. Since through these result it's obvious a left hand circular polarized (LHCP) wave generated by proposed MIMO design since the field component of left-hand is dominant than the component of right-hand side.

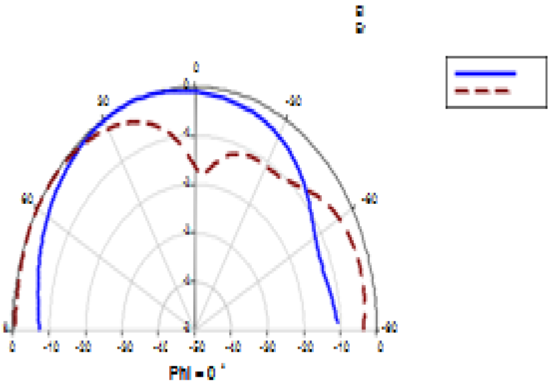

Figure. 11. Radiation pattern of optimized RDRA Array at φ=0°

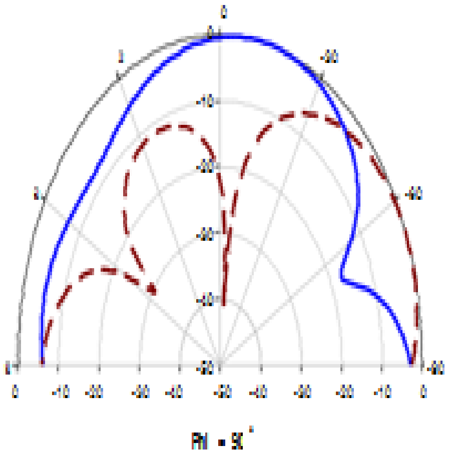

Figure. 11. Radiation pattern of optimized RDRA φ=90°

IV. CONCLUSION

In this manuscript two (2)-element RDRA array has been proposed design using space diversity technique. With optimized distance, the isolation through this technique has been reduced (< -8.65 dB) over a wideband frequency of 3.65-3.85 GHz. Moreover, return loss (S11 <-10dB) bandwidths of approximately 7% attained in conjunction with 6.7% of 3-dB axial ratio.

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