Design and Implementation of Circularly Polarized Dielectric Resonator Antenna

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Abstract- A cross-slot-coupled wide band dual band circularly polarized rectangular dielectric resonator antenna (DRA) is investigated. It makes use of the dominant and higher order modes of a rectangular DRA. The DRA has a square cross section. It is excited by a single micro strip-feed rectangular slot feed. To generate the circularly polarized fields, two corners of the DRA are turn around for 45^0 in dominant and degenerate modes. In this paper we have to be measured the Gain, reflection coefficient, axial ratio, 3D polar plot, and radiation patterns are investigated by using ANSYS HFSS Version15.0. The simulation results are to be compared with the characterization results by using Network analyzer. Measurements were applied to verify the simulations and affordable agreement between the measured and simulated results is ascertained.

Index Terms- Dielectric Resonator Antenna, Dominant mode, cross-slot, characterization, Network analyzer

I. INTRODUCTION

The last few decades have witness that a considerable growth in wireless communication systems, with a particular attention being given to high frequency ranges such as X-band and mm-wave bands. Based on the attractive radiation characteristics such as high radiation efficiencies and gain, DRA's are more favorable for microwave frequency applications[1-5]. Along with DRA excitation at high frequencies can be achieved by a slot aperture coupling that has been demonstrated experimentally for the first time. In order to maintain the practical antenna dimensions and increasing the gain higher order mode DRA's needed to be considered at higher frequencies. The earlier mainly focus on linearly polarized radiation. The circularly polarized resonator antennas are less influenced by atmosphere conditions and insensitive to the transmitter and receiver orientations[6-7]. So the single feed circularly polarized DRA's that are operate at lower order modes with novel approaches such as employing a rotated-slot fed DRA[7].

The communication research centre is pursuing a program to investigate the capabilities of the DRA Technology as an alternative to conventional antenna. Initial work focused on characterizing the basic properties of DRA's for a variety of simple shapes and feed configurations to illustrate the potential advantages offered by DRA's. Recently the analysis has advanced with the event of the novel DRA elements. These DRAs were designed significantly enhance the certain parameters such as gain, return loss, VSWR, reflection coefficient, to develop active DRAs using ferrite materials, or to produce compact or low profile antennas. Several linear and planar arrays have been designed and fabricated, with emphasis placed on practical implementations to demonstrate the feasibility of DRAs in an array environment of novel DRA.

The research at communication research Centre on the DRA has been divided into two categories: novel DRA elements and array configurations. The research on novel DRA s includes developments in the area of bandwidth improvement .size reduction, circular polarization, high gain and active antennas[8-11]. The figure below shows that the various types of the dielectric Resonator antennas are available for us and they are to be shown below.

Various antenna technologies are currently being used for wireless communication applications, covering various frequencies from L-Band to Ka-Band. The figure below shows that the various types of Dielectric Resonator Antennas are used for Patch and the DRA materials. All these are made with different shapes and different materials[12-14]. Mostly the Substrate used here is the FR4 and Having the Dielectric constant of 4.4, and the loss tangent of less than 0.002.

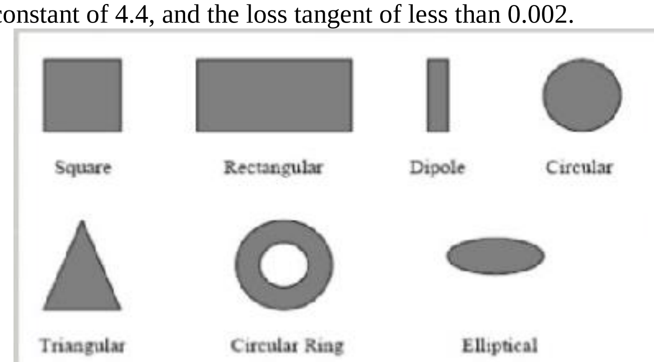

Fig.1: Different Types of DRA's

One of the attractive features of the dielectric resonator antenna is that it can assume no. of shapes. Moreover the mode of the mode of the operation and performance of a DRA can be varied by selecting a DR with desired structure. Hence a number of DRA geometries have already been tried experimentally[15-16]. The first systematic, theoretical, and experimental study was made on cylindrical disk DRA geometry. Later geometries such as split cylinder, sectored cylinder, cylindrical rings, metalized DRAs, triangular, rectangular, no touched rectangular DRA, chamfered DRA, conical, elliptical, spherical, hemispherical, spherical cap, tetrahedral, perforated DRA, stepped DRAs, and hybrid DRAs, have been reported. It was found that DRAs operating at their fundamental modes radiate like an electric or magnetic dipole, which depends on the mode of excitation and geometry of the bulk dielectric material. Geometries like conical, stair, stacked triangular etc emerged for dual band or wideband applications while those like cross, elliptical, hexagonal, cylindrical-comb etc emerged for circular polarization applications. Figure 1 shows the DR geometries, explained so far[17-20]. Though several geometries have been introduced, the most studied and common structures are still the cylindrical and rectangular DRAs because of the simplicity in their design, fabrication, and analysis. The above figure shows that the top view of the dielectric resonator antennas, all these are used for different applications. Based on the application Different types of the shapes are to be used.

II. DRA FEATURES

DRAs offer several attractive features including:

- High radiation efficiency due to absence of conductor or surface wave losses.
- Wide control over size and Bandwidth.
- Design flexibility, by using various shapes of Resonators (rectangular, cylindrical, spherical, hemi spherical).
- Ability to integrate with various existing technologies by using any one of the several feeding mechanisms (co-axial, micro strip line, slots, co-planar, aperture coupling).
- Radiation of broadside or conical shaped patterns for different coverage requirements.
- Less susceptible to tolerance errors than the antenna's operate at higher frequencies.
- Basically DRA is an electronic component that exhibits 'resonance' for a wide range of frequencies, generally in the microwave band.
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These features make the DRAs very versatile elements, adaptable to numerous wireless communication applications by appropriate choice of the design parameters.

III. ANTENNA CONFIGURATION

The figure below shows that Design configuration of the Dielectric Resonator Antenna design configuration. Here the Basic materials are used as Substrate, Ground plane, Patch, Radiation Box, Dielectric Resonators are to be used.

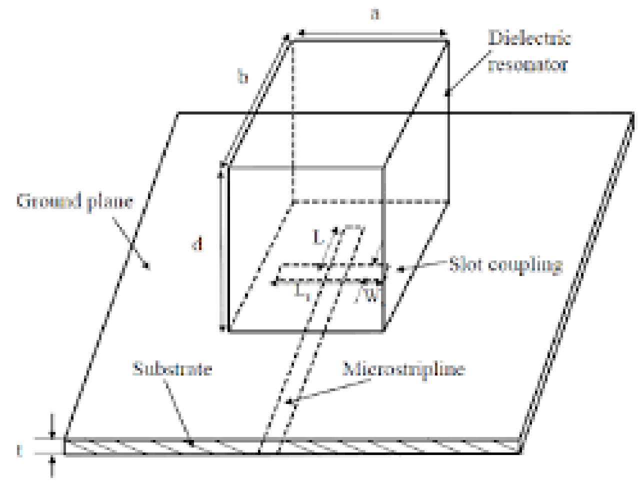

Fig.2: Configuration of the Micro strip line feed DRA

Here the Geometry of the antenna are mainly Based on the operating frequencies or length and width of the patch of the antenna.

From the above diagram L is the length of the patch and La and Wa are the Length and Width of the cross slot of the patch. 'a' is the length of the DRA, 'b' is the width of the DRA, 'd' is the Height of the DRA. This is the Basic configuration of the Dielectric Resonator Antenna.

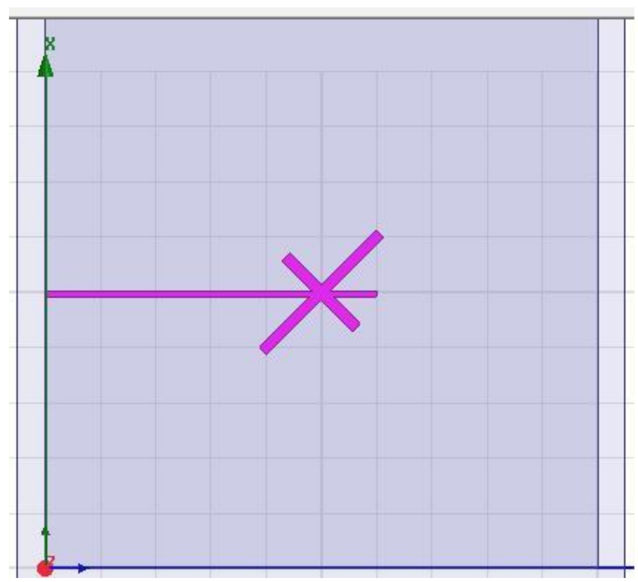

Fig.3:Top view of the feed network

The figure is shows that the proposed DRA configuration and feed network, where cross slot has been employed to excite the antenna. The DRA has been fabricated by using FR4-Epoxy with a dielectric constant of 4.4 and loss tangent of 0.02.two configurations have been considered that utilize the same DRA element with and without a dielectric coat. The DRA dimensions have been chosen as ***l1***=18mm and ***w1***=2mm.Further another one is chosen as ***l2***=30mm and ***w2***=2mm.

A 50Ω micro strip-feed line has been etched on a FR4-Epoxy substrate with a dielectric constant of 4.4. The respective length, width and thickness of the substrate are 100mm, 100mm and 5mm.Futher in order to excite the DRA two slots have been itched on the copper ground plane. Each slot is tilted by an angle of 45^0 with respect to micro strip line.

That has been printed on the backside of the substrate. Additionally unequal slot lengths have been chosen in order to excite two near-degenerate orthogonal modes of equal amplitude and 90^o phase difference that are needed to generate the circularly polarized radiation. The coupling cross slots have lengths have the same width and unequal lengths. In addition, an open stub length has been utilized for optimum matching. Furthermore, a double sided adhesive copper tape has been employed to eliminate the potential air-gaps between DRA and ground plane. These parameters are also measured by using the vector network analyzer.

IV. EVALUATION

In the study Finite Element Method (FEM) commercial software used is High Frequency Structured Simulation (HFSS) from Ansoft corporation .The Fig below shows the comparison of simulated reflection coefficient (s11) of the Dielectric Resonator Antenna, which are conventional Dielectric Resonator Antenna with a uniform feed-line one with Stub-protruded feed-line and the other with a protruded feed-line and two stubs at the slot edge. Due to the protruding element at the end of the feeding line, the coupling between the feed-line and the slot edge increases, resulting in frequency reduction of the lower resonance so that the impedance bandwidth effectively increases. To find the radiation characteristics, surfaces of the DRA are modeled as magnetic walls, either perfect or imperfect, as the case may be it should be noted here that DRA shows non-confined modes and does not satisfy the magnetic property on all surfaces. Hence the surfaces are modeled as Perfect Magnetic Conductor (PMC) planes.

V. HFSS TOOL PROCEDURE

ANSYS HFSS is 3D software tool for designing and simulating high-frequency electronic devices such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use ANSYS HFSS to style high-frequency, high-speed physics found in communications systems, microwave radar systems, advanced driver help systems (ADAS), satellites, internet-of-things (IoT) merchandise and different high-speed RF and digital devices.

High Frequency Electromagnetic Field Simulation ANSYS HFSS software is the industry standard for simulating 3-D, electromagnetic fields.The ANSYS HFSS simulation suite consists of a comprehensive set of solvers to address diverse electromagnetic problems ranging in detail and scale from passive IC components to extremely large-scale EM analyses like automotive measuring device scenes for ADAS systems. Its reliable automatic adjustive mesh refinement permits you to specialize in the planning rather than disbursement time deciding and making the most effective mesh. This automation and secure accuracy differentiates HFSS from all alternative EM simulators, that need manual user management and multiple solutions to make sure that the generated mesh is appropriate and correct. With ANSYS HFSS, the physics defines the mesh instead of the mesh process the physics. The figure below shows that Procedure for the HFSS tool.

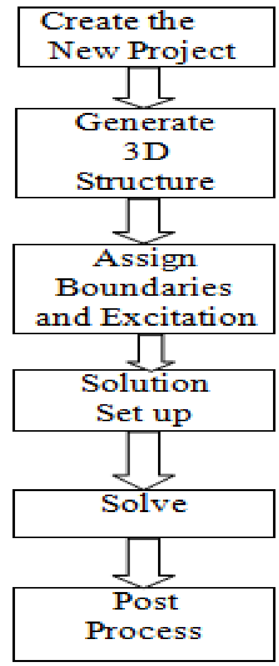

Fig..4: Flow Chart for the HFSS Procedure

VI. RESULTS AND DISCUSSIONS

The figure below shows the s-parameters of the Dielectric Resonator Antenna. Here the Centre Frequency is 5.06GHz.very good impedance match can be obtained at r=4mm, but a substantially wider bandwidth (|s11|<16.07dB) of 20% is found for r=4.5mm.This illustrates that the parasitic patch does not affect the broad-band feature of annular slot excitation which is 6% below the design frequency is still within the pass band of antenna.

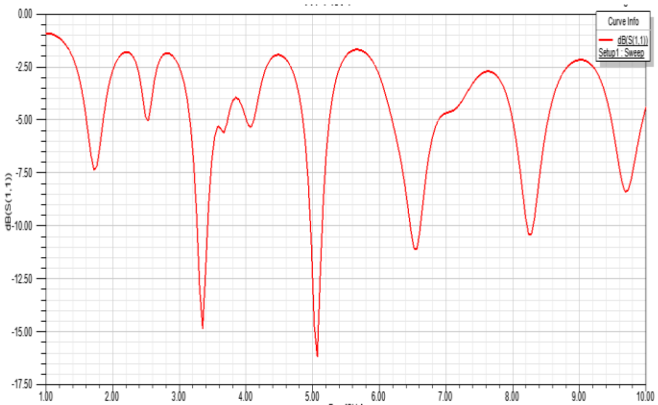

Fig.5: Reflection Co-efficient of DRA

Fig. 6 displays the radiation pattern as a function of frequency for different parasitic-patch locations, without change of the parameters. It is noted that good impedance match and radiation pattern are obtained for the $\phi=0^0$, $\phi=90^0$, $\phi=180^0$. This shows that the patch location is not critical, and thus, it is not difficult to design the Circularly Polarized Dielectric Resonator Antenna resulting that circular polarization is quite dependent on the patch length since essentially only one length around the patch produces the small axial ratio. Observe that the Circularly Polarized frequency only slightly changes with the length.

Whereas axial ratio changes with the length significantly. This is very favorable result, as one can tune the axial ratio with the Length of the patch without shifting the frequency too much. The effect of the patch width is also studied. It is found that the effect is weaker than for the patch length.

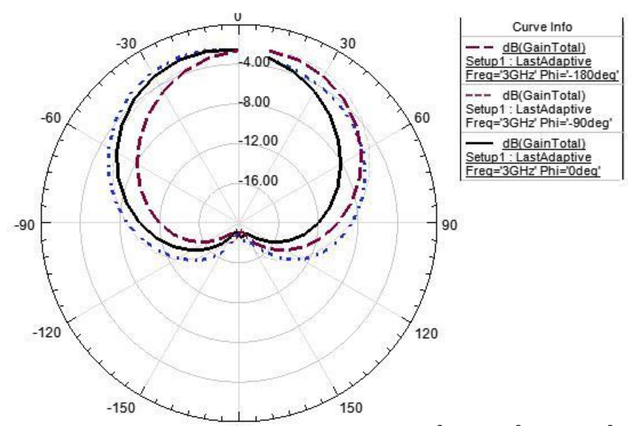

Fig.6: Radiation Pattern of DRA for $\phi=0^0$, $\phi=90^0$, $\phi=180^0$

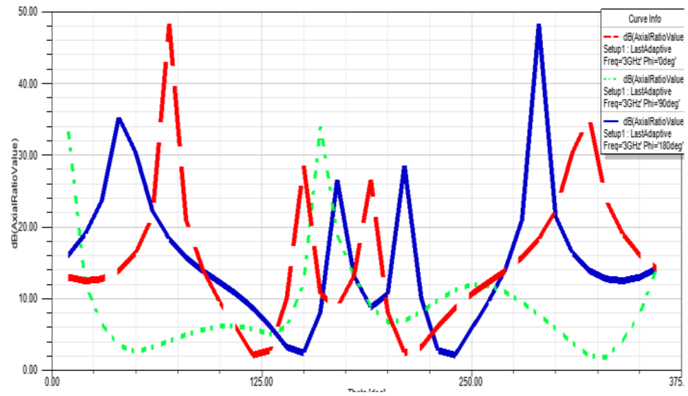

Fig.7: Radiation Pattern of DRA for $\phi=0^0$, $\phi=90^0$, $\phi=180^0$

From the above parametric study, optimized DRA feed with the given dimensions is to be fabricated and tested with the Vector Network Analyzer and all Are tested to validate the simulation results. The Simulation results and measurement reflection Coefficient results are to be compared. The measured Results are comparatively less than the simulate Results.

VII. SUMMARY AND CONCLUSION

The dominant and degenerate modes of the Rectangular Dielectric Resonator antenna were used to produce radiation patterns with enhanced gain. Based on the field configurations within the Dielectric Resonator Antenna obtained from the dielectric waveguide model, the radiation patterns were predicted using an array of short magnetic poles, whose number depends on the mode being excited within the DRA .This model predicts the Rectangular Dielectric Resonator antenna operating in higher order mode will radiate a more directive pattern. In addition by adjusting the aspect ratio of the DRA, some degree of pattern control is possible for the case of higher order modes. By comparison of the predicted patterns to the normalized patterns showed good agreement, especially in the E-Plane, where the effect on the finite ground plane are negligible. Measured patterns from the fabricated prototypes shows the gain is same as the simulated gain with the little variation is achieved for the Dielectric Resonator Antenna operating in the dominant mode. The advantage of this approach for the enhancing gain is compared to some of the other cited techniques lies in the smaller area requirements, which is an important consideration for many applications.

A 50Ω micro strip line fed cross-slot-coupled DRA with dual band Circularly Polarized Performances and that operates microwave spectrum bands is developed. The dominant modes that have been achieved the broadside radiation. A cross-slot is introduced to separate the modes into two pairs of dominant and degenerate modes of equal amplitudes and 90^0 phase difference to determine the dual- band performances.

VIII. ACKNOWLEDGMENT

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