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Novel Circularly Polarized MIMO Dielectric Resonator Antenna for 28 GHz Applications

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***Abstract*—A novel circularly polarized MIMO Dielectric Resonator Antenna (DRA) for 28 GHz band applications is proposed. The DRA is excited by microstrip line structure which produce circular polarization due to orthogonal feed arrangement maintaining symmetry between both the ports. Impedance bandwidth of MIMO DRA is 27-29 GHz, axial ratio bandwidth is 27.5-28.75 GHz, and maximum simulated gain is 7.53 dBi at 27.6 GHz which covers the targeted 28 GHz band (27.5-28.35 GHz) for the 5G applications. Due to wider overlaping of axial ratio bandwidth with impedance bandwidth, proposed MIMO DRA is good candidate for 5G communication at 28 GHz band. Simulated and measured results are in good agreement, making proposed DRA a good choice for mm wave applications.**

I. Introduction

"DRAs play important role in emerging wireless standards because of their inherent advantages such as no surface wave losses, high radiation efficiency, compact size, nearly constant gain, high impedance bandwidth and ease of excitation" [1]. These advantages make DRA a good choice for different applications all over the frequency spectrum, from microwave frequency bands to the optical frequency bands. Circular polarization in antennas is also desirable property as it improves reception of signal without much effect of orientation and polarization of incident wave. In [2], a detailed review of recent MIMO DRAs has been presented. In [3]–[14] different DRAs have been proposed by researchers for MIMO application with circularly polarization feature. In [15], authors proposed a circularly polarized DRA for microwave image sensing applications operating at 28 GHz band. There are scanty literature in the field of circularly polarized MIMO DRA at 28 GHz frequency. Compactness in MIMO antenna can be achieved when single dielectric resonator (DR) is excited by multiple ports instead of more than one DR fed by number of ports.

In this paper, a novel, microstrip line fed dual port circularly polarized MIMO DRA antenna is proposed for 28 GHz band applications. Moreover proposed antenna boasts single DR element excited by microstrip line feed by dual ports. Circular polarization is produced by a dual-feed circuit with a phase-delay line. Antenna demonstrates simulated impedance bandwidth of 7.14% (27-29 GHz), Axial Ratio Bandwidth (ARBW) is 4.4% (27.5-28.75 GHz) which covers the 28 GHz band allocated by FCC for the next generation 5G wireless communication standards [16]. Maximum simulated gain is 7.53 dBi at 27.6 GHz and isolation between ports is achieved

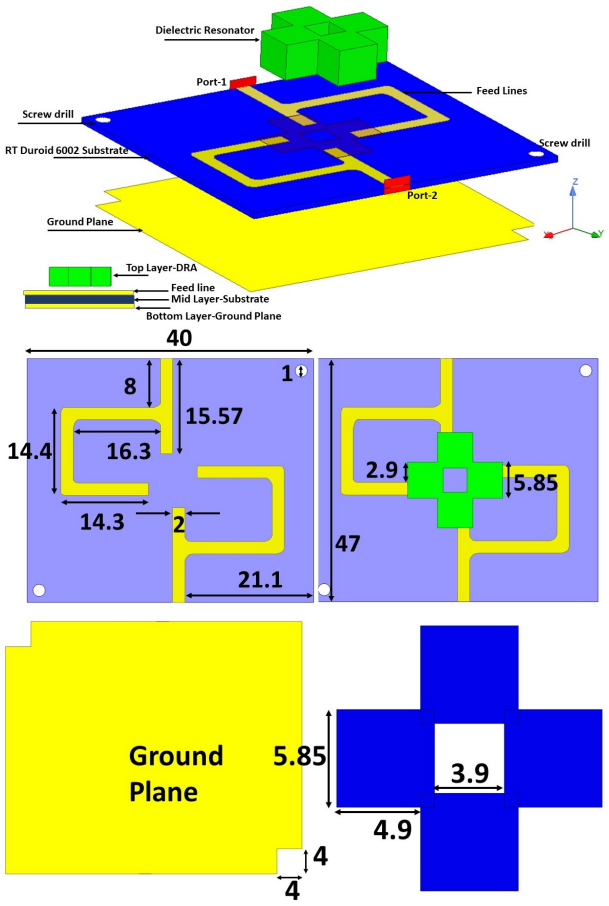

Fig. 1. Geometry of the Antenna (All dimnesions are in mm)

at least -15 dB throughout the operating bandwidth. Antenna structure is symmetric with screw drills slots which make it easy to install.

Proposed antenna geometry is shown in Fig. 1 where all dimensions are in millimeter (mm). It comprises a ceramic DRA mounted on a RT/Duroid 6002 substrate with ground plane and microstrip feedline structure to couple the electromagnetic field to DRA. Substrate has been chosen as RT/Duroid 6002 sheet with dielectric constant $\varepsilon_r = 2.94$, thickness 0.8 mm and $\tan\delta = 0.0012$ and Eccostock Hik bar with $\epsilon_r = 10$, $\tan\delta = 0.001$, height or thickness= 4.8 mm, has been used as DRA material. Symmetrical shape of overall structure has

been considered so that it can be easily adopted in various applications, because of port symmetry where in S_{xy}, x and y are interchangeable.

II. Results and Discussion

A prototype of proposed MIMO DRA is fabricated to validate simulated results. To measure far field results, proposed antenna was used as receiver antenna in an anechoic chamber with corrugated horn antenna as transmitter antenna which is illustrated in Fig. 2.

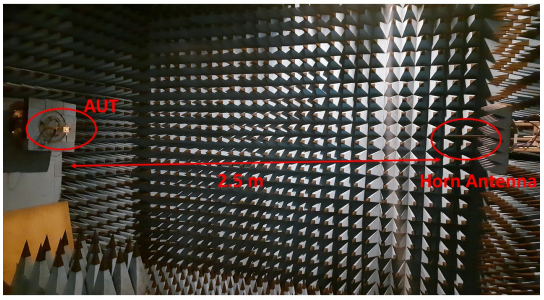

Fig. 2. Measurement of far field radiation parameters in anechoic chamber with corrugated horn as transmitter antenna

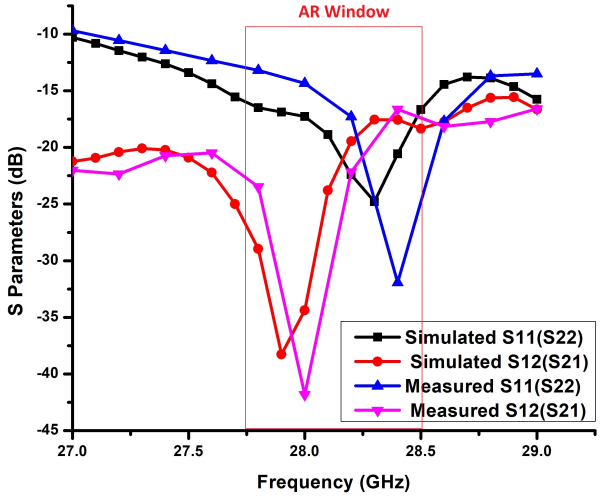

Fig. 3. Simulated and measured S_{11} and S_{12} of proposed Antenna

The antenna demonstrates simulated impedance bandwidth of 7.14% (27-29 GHz), ARBW is 4.4% (27.5-28.75 GHz) Simulated and measured impedance bandwidth of the proposed antenna is illustrated in Fig. 3 with measured axial ratio bandwidth window. Measured impedance bandwidth is 7.14% (27-29 GHz). S_{22} is same as that of S_{11} beacuse of symmetrical structure of DRA and not illustrated in Fig.3. Simulated and measured ARBW of the proposed antenna is illustrated in Fig. 4. Measured ARBW is 2.4% (27.8-28.5 GHz).

MIMO performance metrics have also been studied to justify the performance of the proposed dual feed MIMO

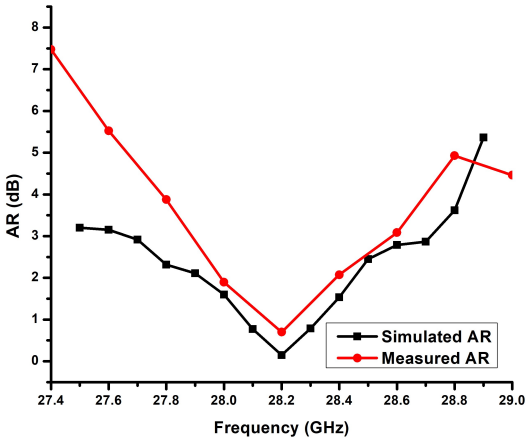

Fig. 4. Simulated and measured axial ratio bandwidth of proposed Antenna

DRA and methodology mentioned in Author's work in [12] is used to calculate MIMO parameters. ρ is one of the main performance metrics of MIMO system which describes isolation and correlation of communication channel with each other [17]. "Low values of ρ confirm the good diversity performance and channel characteristics, required for efficient MIMO operation at higher data rate" [12]. As the simulated values of ρ_{12} calculated by HFSS EM simulator uses S-parameter method of calculation which comes out well below 0.005 for all frequencies, so not shown here, but the measured value of ρ_{12} with more accurate, radiation pattern method as described in [12] is shown in Table I.

TABLE I
Measured Envelope Correction Coefficient (ρ)

Frequency(GHz)	27.4	27.6	27.8	28	28.2	28.4	28.6
ρ_{12}	0.26	0.18	0.12	0.1	0.05	0.21	0.27

It is confirmed from simulation results that for mirrored feed-line designs as shown in Fig. 5, the same DRA radiate RHCP wave (in RHCP wave electric field vector rotates in a right hand sense with respect to direction of propagation and in LHCP wave electric field vector rotates in a left hand sense with respect to direction of propagation) [18]. So, two antennas shown in Fig. 5 can be used as LHCP-RHCP antenna transmit-receive pair for mm wave application with similar radiation characteristics. For short-distance communication in Bio-Telemetry also such kind of transmitter-receiver pair may be used in near future. Figure 6 illustrates simulated field distribution at various time phases to show LHCP and RHCP in both antennas shown in Fig. 5. It is also shown in Fig. 6 that effect of circular polarization is more prominent in one part than other due to induced fields, as explained in the previous section. In the field of circularly polarized MIMO DRA scarce literature is available. The proposed antenna is an effort to fill the gap by introducing application of DRA in MIMO applications in 28 GHz band with circularly polarization feature. The cross-shaped DRA with symmetrical

feed network can produce LHCP and RHCP wave depending upon orientation of feedline.

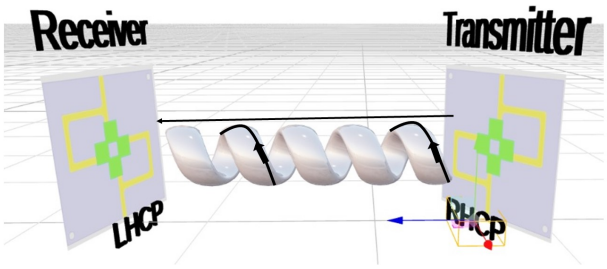

Fig. 5. Mirrored feed-line designs to achieve LHCP and RHCP field wave respectively in a transmitter-receiver pair antenna system

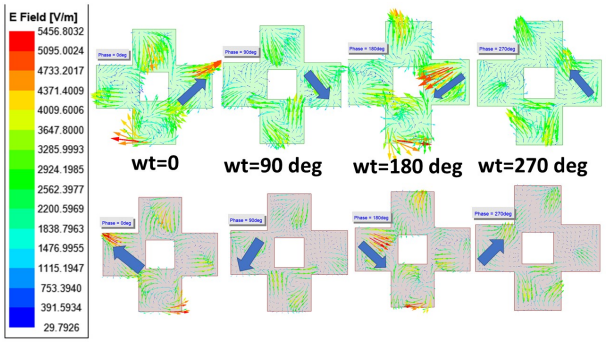

Fig. 6. Simulated field distribution at different time phases to show LHCP (top) and RHCP (bottom) circular polarization in both antennas shown in Fig. 5 at 28.2 GHz

III. Conclusion

In this paper, a novel, microstrip line fed dual port circularly polarized MIMO DRA antenna is proposed for 28 GHz band applications. The measured impedance bandwidth is 7.14% (27-29 GHz) and measured axial ratio bandwidth is 2.4% (27.8-28.5 GHz) of the antenna prototype which covers the targeted 28 GHz band (27.5-28.35 GHz) allocated by FCC for the next generation 5G wireless communication standards. The antenna structure is symmetric with screw drills which make it easy to install. For the mm wave frequency range there is need for an intensive study for reduced loss configurations. DRA antennas are intrinsically of low loss radiators. In the proposed configuration, this feature comes together with reduced dimensions, which make present structure applicable for 5G and futuristic 6G antennas in mm wave frequency bands allocated by FCC. In futuristic bio-telemetry communication system, the proposed transmitter-receiver pair can be used for short-distance communication with low loss and high efficiency.

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