Substrate integrated waveguide fed circularly polarized elliptical dielectric resonator antenna array

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***Abstract*—In this paper, a circularly polarized antenna array comprising of four elliptical dielectric resonator is proposed for X-band applications. The array is excited by 1×4 substrate integrated waveguide based power divider. The proposed array offers an impedance bandwidth (for $S_{11} \leq -10$ dB) of 17.3% (10.57-12.58 GHz) and 3dB axial ratio bandwidth of 7% (11.28-12.10 GHz). The antenna array is right hand circularly polarized (RHCP) and radiating maximum in broadside direction. The isolation between right hand circularly polarized (RHCP) and left hand circularly polarized (LHCP) fields is better than 12 dB. The proposed DR antenna array exhibits a peak RHCP gain of 11.42 dBic across the CP band.**

I. Introduction

Circularly polarized (CP) antennas are more preferable over linearly polarized (LP) antennas in most of the wireless communication systems such as satellite communication, navigation systems because of their ability to minimize polarization mismatch between transmitting and receiving antennas [1]. Moreover, they also provide better mobility and reduces multipath reflections from the building and ground surface.

For the past few decades, the dielectric resonator antennas (DRAs) have received lot of attention due to their attractive features such as light weight, compact, no inherent conductor loss, wide bandwidth, high radiation efficiency etc. [2]. Recently, one major aspect of DRA research has been concentrated on designing CP antennas [3], [4]. However, the gain for the single element is typically ≈ 5-6 dBic. But for some applications high gain antennas are required and to achieve the same, the DRAs can be arrayed. A few investigations have been done to design the circularly polarized dielectric resonator antenna arrays [5]–[7]. In [5], [6], the antenna array has been excited using aperture/probe coupling. However, the feeding losses of these excitation mechanism are dominant at higher frequencies. Recently, substrate integrated waveguide (SIW) has received much more attention due to its numerous advantages such as low profile, easy integration to other planar circuits, compact, high-Q etc [8]. In [9], a mm-wave SIW-DRA has been proposed, where the DRA is fed by small aperture situated on the top wall of SIW.

In this paper, a four element elliptical dielectric resonator antenna array excited using 1×4 SIW based power divider is proposed for CP operation. The array design is optimized through simulations using Ansoft HFSS and a prototype of same is built and tested.

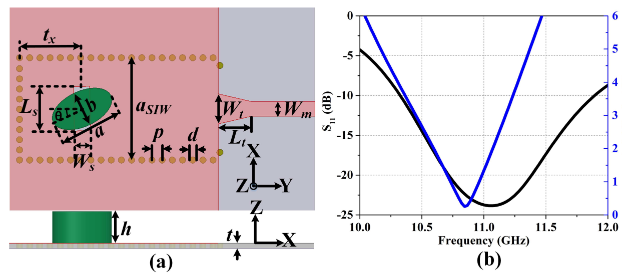

Fig. 1. (a) Schematic of SIW fed elliptical DRA (b) Response of SIW fed elliptical DRA

II. Antenna Design

A. Single Element

Fig. 1(a) shows the substrate integrated waveguide (SIW) fed elliptical DRA for CP operation. The SIW is designed on RT/Duroid 5880 substrate of relative permittivity 2.2 and thickness 0.787 mm whereas for designing DR RT/Duroid 6010 of relative permittivity 10.2 and loss tangent 0.002 is used. The DR is excited by a narrow slot of dimension $L_s \times W_s$ which is situated on top wall of SIW which is operating in TE_{10} mode. Initially, the distance t_x is chosen as $\lambda_g/2$ [9], which is subsequently optimized through simulation for maximum coupling.

Fig. 1(b) shows the reflection coefficient and axial ratio characteristics of SIW fed elliptical DRA. It is found that DRA operates around 11 GHz. The antenna exhibits an impedance bandwidth of 13.6% (10.3-11.8 GHz) and the 3dB axial ratio bandwidth of 7.4% (10.4-11.2 GHz). The peak RHCP gain of antenna is 6.32 dBic in the CP band.

Next, the electric field distribution in DR, as observed from the positive z-direction is depicted in Fig. 2. It is observed that the electric field vector at $t = 0$ is orthogonal to that at $t = T/4$ and rotates counterclockwise as the time t progresses, thereby producing right hand circularly polarized (RHCP) field.

B. Antenna Array Design

Fig. 3 shows the schematic of proposed CP antenna array. The four elliptical DR are excited by using 1×4 SIW based power divider [10]. The simulated and measured impedance

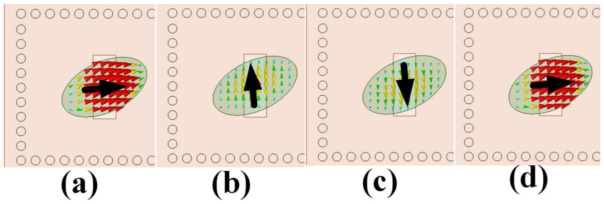

Fig. 2. Electric field distribution in DR at 10.8 GHz: (a) t=0 (b) t=T/4 (c) t=3T/4 (d) t=T

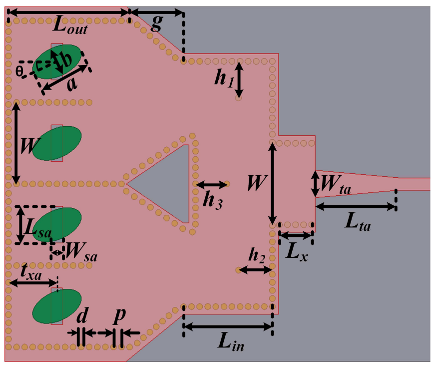

Fig. 3. Schematic of the proposed DR antenna array. Dimensions: $W = 16, p = 1.55, d = 1.15, W_{ta} = 5.25, L_{ta} = 16.2, L_x = 7.55, L_{in} = 17.05, g = 10.35, L_{out} = 23.25, h_1 = 7, h_2 = 6.5, h_3 = 6, a = 10, b = 5.5, t_{xa} = 9.3, W_{sa} = 2.2, L_{sa} = 7, \theta = 25°$ (all dimensions are in mm)

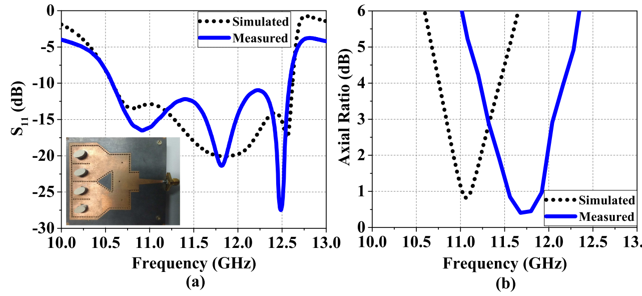

Fig. 4. Comparison between simulated and measured response of proposed array (a) reflection coefficient (b) axial ratio

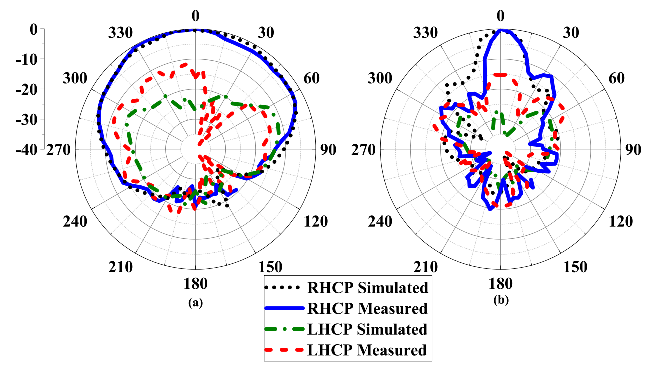

Fig. 5. Normalized radiation pattern of proposed array at 11.75 GHz (a) XZ-Plane (b) YZ-Plane

bandwidth is 17.5% (10.58-12.62 GHz) and 17.3% (10.57-12.58 GHz), respectively as shown in Fig. 4(a). The antenna array exhibits a simulated and measured 3dB axial ratio bandwidth of 4.5% (10.84-11.34 GHz) and 7% (11.28-12.10 GHz), respectively as depicted in Fig. 4(b). Some discrepancy in the DRA measurement is not unusual which is owing to fabrication tolerances and inevitable air gap that exist between the DRA and SIW. The adhesive that is used to glue the DR over SIW might effect the performance as well.

Fig. 5 shows the normalized RHCP (co-polarized) and LHCP (cross polarized) patterns corresponding to the CP center frequency. The simulated and measured isolation between the RHCP and LHCP is better than 15 dB and 12 dB, respectively. The peak RHCP gain of 11.42 dBic in the CP band is achieved by the proposed antenna array.

III. Conclusion

A circularly polarized elliptical dielectric resonator antenna array has been presented. The proposed array exhibits an impedance bandwidth of 17.3% (10.57-12.58 GHz) and the 3dB axial ratio bandwidth of 7% (11.28-12.10 GHz). The antenna is right hand circularly polarized (RHCP) and radiating maximum in broadside direction. The LHCP fields in both planes are at least 12 dB down the RHCP fields. The peak RHCP gain of 11.42 dBic has been achieved across the CP band. The proposed array could be suitable for satellite communication.

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