Design Investigation of Circularly Polarized Dielectric Resonator Antenna Array Excited by Dielectric Image Line

E. Mousavi Kejani
Electrical Dept., Ferdowsi University of Mashhad
Mashhad, Iran
emranmousavi@gmail.com

Mohammad. H. Neshati
Electrical Dept., Ferdowsi University of Mashhad
Mashhad, Iran
neshat@ieee.org

***Abstract*— In this paper a linear circular polarized (CP) Dielectric Resonator Antenna (DRA) array, consist of 3 elements DRA using elliptical resonators, positioned on top of a metallic ground plane exciting through narrow slots is numerically investigated. A Dielectric Image Line (DIL) placed at the back side of the plane is used to excite slots. Antenna characteristics for a single element and linear array including return loss, radiation patterns and antenna gain are presented. To reduce the backward radiation a reflector is placed at the back side of structures. Results show that 5.3% bandwidth is obtained for 3-dB Axial Ratio (*AR*) at 10 GHz.**

Keywords- Dielectric Resonator Antenna (DRA); Dielectric Image Line (DIL), Linear Array

I. INTRODUCTION *(HEADING 1)*

Dielectric Resonator antennas (DRA) is one of the several promising efficient radiating structures [1] which have been proposed for applications at microwave and millimeter-wave frequencies. First DRA was proposed in 1983 [2] and after that in past 2 decades DRAs has been the topic of many researchers due to attractive properties of these type of antennas compare to the conventional antennas such as low loss, low profile and high radiation efficiency.

Different shapes of the DRs such as cylindrical, hemispherical, elliptical, pyramidal, rectangular, and triangular have been presented in literature. Feeding methods that are generally used to excite the DRA include: coaxial probe, microstrip line coupled to a narrow slot [3], or narrow slot excited by coplanar waveguide. Microstrip-slot coupled excitation of DRs is one of the most common methods for antenna application due to the printed technology which is easy to fabricate and present a good method of impedance matching [3, 5]. But the radiation efficiency of this type is reduced at high frequencies due to the excitation of the surface waves and conductor losses of the feed lines.

Dielectric transmission lines such as Dielectric Image Line (DIL) have lower losses at microwave frequencies compare to the conventional transmission lines [4, 6]. In [7] the aperture-coupled microstrip patch antenna fed by a DIL was analyzed. Good gain, suitable impedance match and low back radiation were observed.

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II. ANTENNA STRUCTURE

A. Single Element Antenna

The geometry of the elliptical CP-DRA fed by the DIL is shown in Fig. 1-b. A narrow slot, with length of 4 mm and width of 0.15 mm is etched at the centre of the ground is used to excite the DR. The DR dimensions are designed to obtain the resonance frequency of 10 GHz. The elliptical DR is rotated by 45° with respect to *x*-axis to excite two orthogonal modes for CP. The PC board RT/duroid 6010 with ε_r =10.2 is used for the DIL and DR. The antenna dimensions are listed in the TABLE I.

TABLE I. TANTENNA DIMENSIONS

DR		DIL		WR90 Transition	
r_{max}	4.5 mm	a_d	4.25 mm	A	22.86 mm
r_{min}	3 mm	b_d	4.03 mm	B	10.16 mm
h	5.08 mm	ε_{rd}	10.2	B_1	4.8 mm
ε_{rd}	10.2	slot length	4 mm	l	28.6 mm
φ	45°	slot width	0.15 mm	thickness	1.27 mm

B. Antenna Array

DRA array structure is shown in Fig. 1-c. It consists of 3 elements of DR with the same size as the single DRA excited by three slots. The distance between slots is designated by *d*. The antenna array is designed to operate at 10 GHz. The separation between elements is *d*=13 mm, that is designed to provide broadside radiation pattern perpendicular to the ground plane. The feed slots are chosen for best return loss with length=2.75 mm and width=0.35 mm and placed at the centre of the DRs.

Proceedings of ICEE 2010, May 11-13, 2010
978-1-4244-6760-0/10/$26.00 ©2010 IEEE

C. *Antenna Array with back reflector*

In order to reduce the backward radiation, a reflector is inserted from the DIL side (11 mm under the ground plane). The reflector size is 134 mm×140 mm with thickness of 35 µm.

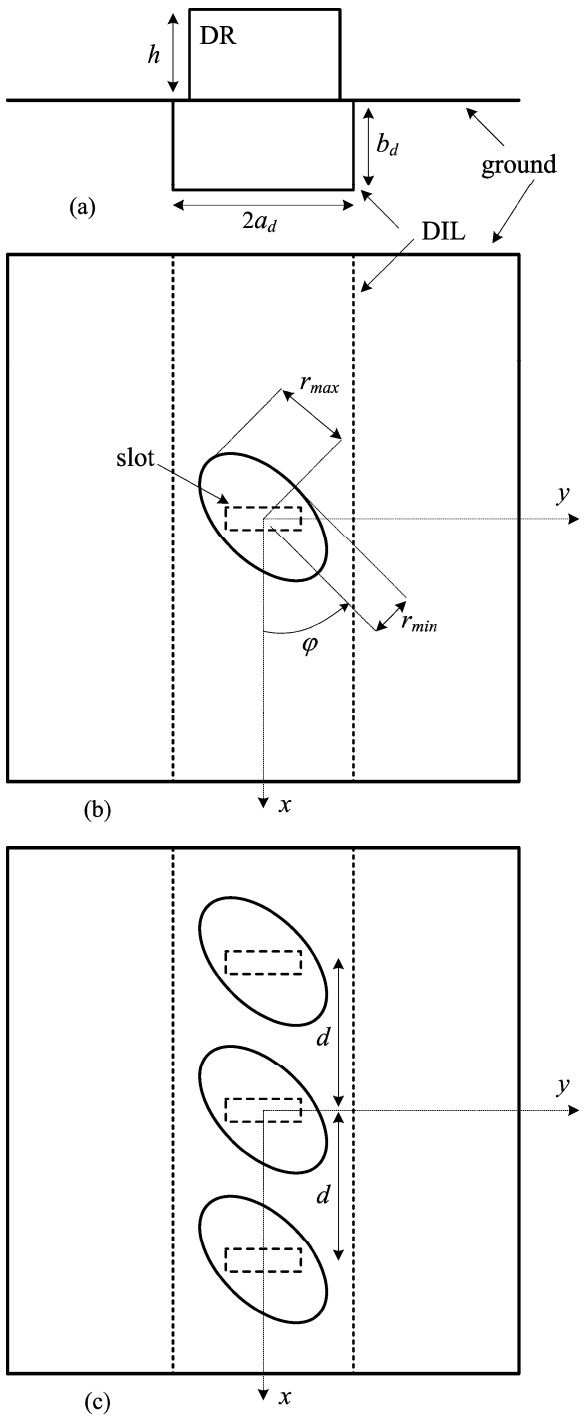

Figure 1. The geometry of elleptical DRA fed by DIL: a) side view, b) top view of single antenna, c) top viw of antenna array

III. PANTENNA SIMULATION

Antenna structures are simulated using Ansoft HFSS based on FEM [9]. The DIL is connected to an X-band rectangular waveguide through a matching transition. Both ends of the DIL are tapered to achieve an smooth transition between the waveguide and the DIL as shown in Fig. 2. Two ports are defined for antenna structures. Port one, as input port, is designated to excite TE_{10} mode of metal waveguide. The second port, at the output, is terminated to a 50 Ω matched load. Therefore, a travelling wave propagates in DIL and feed slots are excited.

The detailed structure of the single element antenna defined in HFSS for simulation process is shown in Fig. 1-b. Three sections of standard WR90 standard waveguide, operating at X-band, using a proper tapering provide transition from TE_{10} mode of the metal rectangular waveguide to dominant mode of the DIL. Narrow slot is made on ground plane to couple between DIL and DRA.

Fig. 1-c shows the detailed structure of the antenna array. A linear array with 3- elements elliptical DRA placed on the ground plane in x-direction. Three slots located at the centre of the resonators. The distance between of slots is *d*=13 mm.

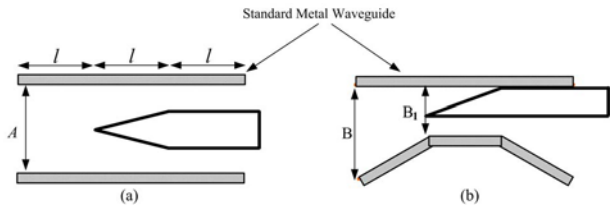

Figure 2. Rectangular waveguide to DIL transition: a) top view, b) side view

IV. RESULTS

A. *Single Element Antenna*

The simulated return loss of the single element antenna is shown in Fig. 3-a, which shows that, over the entire band, it is below -10 dB.

Axial Ratio (*AR*) versus frequency is shown in Fig. 3-b. The minimum axial ratio is 0.185 dB at 10.025 GHz, while 3dB *AR* bandwidth is 4.5% (9.78 GHz to 10.23 GHz).

Radiation patterns at 10 GHz for Right Hand Circular Polarization (RHCP) and Left Hand CP (LHCP) are shown in Fig. 4. It can be seen that patterns are broadside perpendicular to the ground. Also there is a ripple in patterns, which is said this is due to diffraction from the edge of the ground plane. Fig.5 shows the variation of *AR* versus azimuth angle. It can be concluded that minimum axial ratio occurs at about θ=0°. Moreover, *AR* beamwidth is nearly 50° for $AR \leq 3.5$ dB.

Fig. 6 shows that the obtained antenna gain for the single element resonator is around 6.5 dB, while *AR* is less than 3 dB.

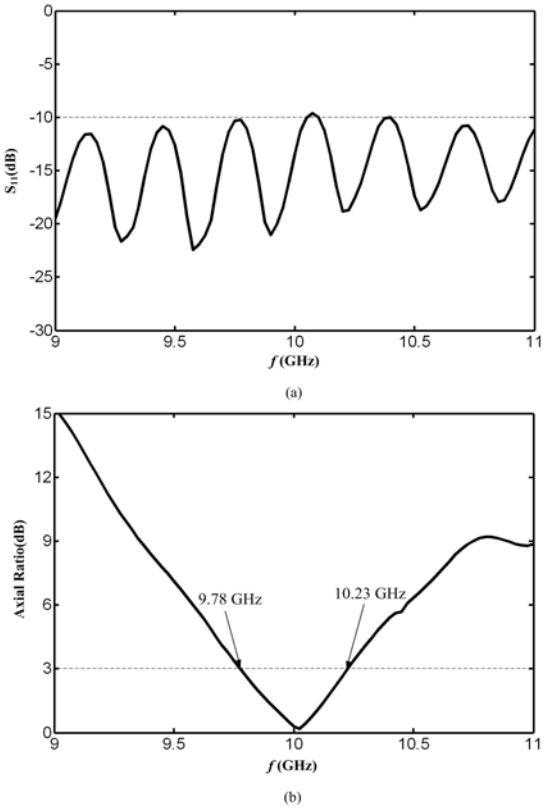

Figure 3. Simulated results of single antenna: a) return loss, b) axial ratio

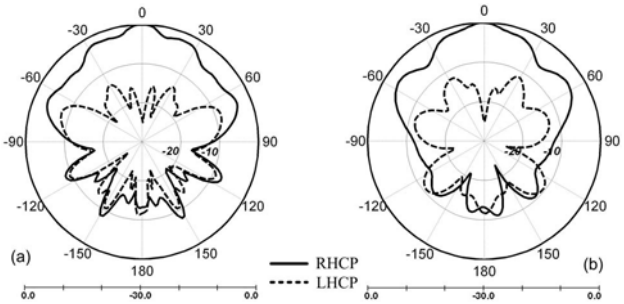

Figure 4. Radiatin patterns of single antenna at 10 GHz: a) X-Y plane, b) Y-Z plane

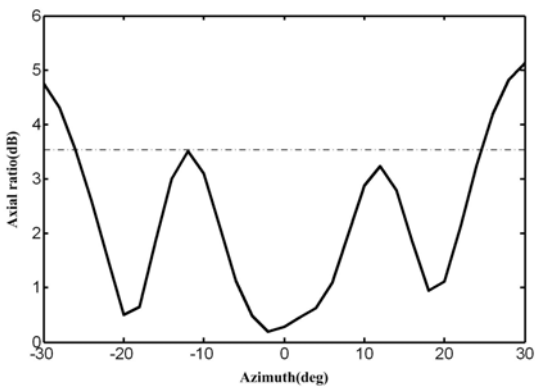

Figure 5. Axial ratio of single antenna at 10 GHz versus azimuth angle

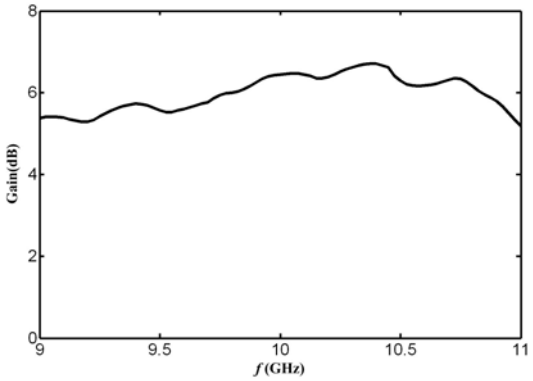

Figure 6. Antenna gain versus frequency for single element

B. Antenna Array

Fig. 7-a shows the simulated return loss of the antenna array. It can be seen that return loss is below -10 dB over the entire band. Also axial ratio of the antenna array is shown ib Fig 7-b. It can be seen that, the *AR* of the array is increased in compare to the *AR* of the single element antenna. However, minimum *AR* is 2.15 dB at 9.8 GHz. Moreover, variation of *AR* versus frequency is shown in Fig. 7-b. Although the minimum *AR* is increased, but 3 dB *AR* bandwidth is 4.5% (9.66 GHz to 10.1 GHz) which is same as the *AR* bandwidth of single element *AR* bandwidth.

Radiation patterns of the array for RHCP and LHCP at 10 GHz are shown in Fig. 8. It can be seen that radiation patterns are broadside perpendicular to the ground. Fig. 9 shows the obtained antenna gain for array antenna. The obtained gain for the array is 3 dB more than the gain for the single element at 10 GHz. The backward radiation is nearly -9.2 dB and -12.6 dB for antenna array and single element structure respectively.

C. Antenna Array with reflector

From previous analysis, Fig 4 and Fig 8, it can be seen that backward radiation for both structure is too high. This is due to radiation from the DIL and feed slots. To decrease the backward radiation and to obtain more gain a reflector, a metal ground, is placed at the back side of the structures. The reflector dimensions are set same as the dimensions of the main ground plane.

The return loss of the antenna are shown in Fig. 10-a. Generally, variation of return loss is nearly same as the return loss for the array without reflector. However, as shown in Fig. 10-b, *AR* is enhanced and it is decreased to 0.2 dB at 10 GHz and its bandwidth is increased to 5.3% (9.56 GHz to 10.09 GHz).

V. CONCLUSIONS

In this paper two new structures, including a single element and a three elements antenna array producing circular polarization have been numerically investigated.

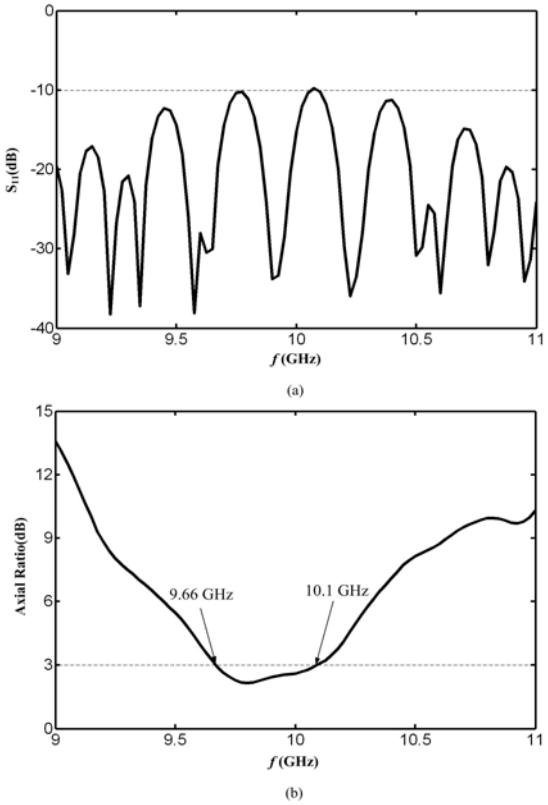

Figure 7. Simulated results of array: a) return loss, b) axial ratio

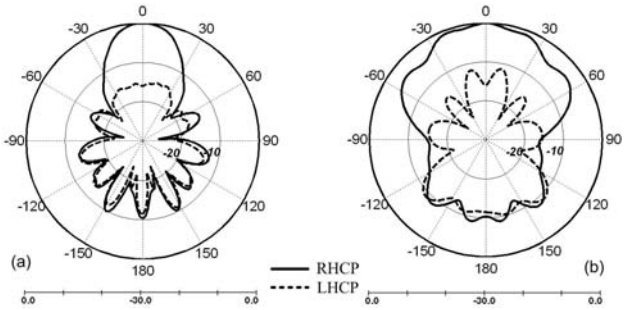

Figure 8. Radiatin patterns of single antenna at 10 GHz: a) X-Y plane, b) Y-Z plane

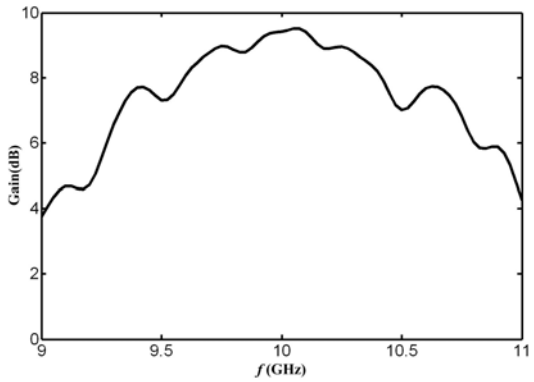

Figure 9. Antenna gain versus frequency for array

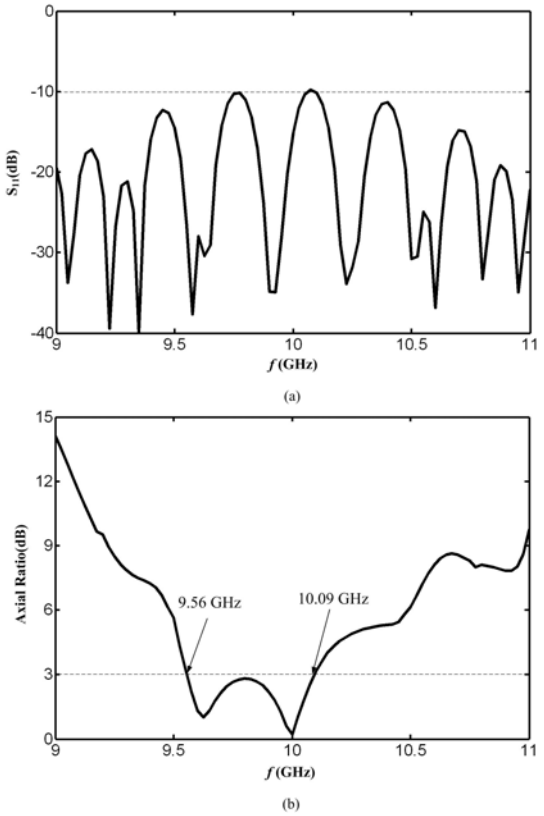

Figure 10. Results of antenna array with reflector: a) return loss, b) axial ratio

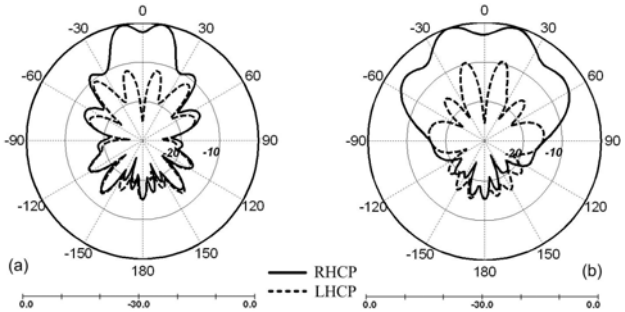

Figure 11. Radiatin patterns of antenna array with relectod at 10 GHz: a) X-Y plane, b) Y-Z plane

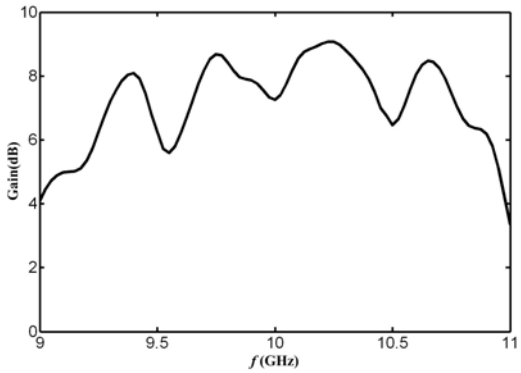

Figure 12. Antenna gain versus frequency for array with relector

An elliptical dielectric resonator antenna coupled to a Dielectric Image Line (DIL) through a narrow slot was analyzed using HFSS. An array of three elements elliptical DRA was also simulated. For two structures a circularly polarized wave is produced at 10 GHz.

Return loss, Axial Ratio, radiation patterns and antenna gain are presented. *AR* Bandwidth is 4.5% for both structures. The obtained gain of the array is 3 dB more than the gain of the single element at 10 GHz. The 3-elements DRA array with the reflector was also simulated. The backward radiation of antenna array is decreased nearly 6 dB for the structure of array with reflector compare to the back lobe of array without it.

The results show that *AR* ratio is significantly enhanced. The obtained bandwidth of *AR* is 5.3% at 10 GHz, which is 1.2% more than the *AR* bandwidth of the structure without reflector.

ACKNOWLEDGMENT

The authors would like to thank Iran Telecommunication Research Center (ITRC) for its financial supports.

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