A Linearly Polarized Radial Line Dielectric Resonator Antenna Array

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***Abstract* - We propose a linearly polarized dielectric resonator antenna (DRA) array, feeding by radial line waveguide, to simplify the traditional feeding structures of the DRA array. By effectively using the electromagnetic wave inside the radial line waveguide, the proposed dielectric resonator antenna array, with only one feeding port, working at 12GHz, achieves a directivity of 27.18 dB, a high aperture efficiency of 66.4%, a total efficiency of 62.95% and good linearly polarization properties.**

Keywords — dielectric resonator antenna; antenna array; linearly polarized.

I. INTRODUCTION

The dielectric resonator antenna (DRA) is known for its high radiation efficiency, low loss and small size. So, well-designed DRA arrays not only carry on the good qualities of DRA, but also get high gain characteristic.

However, traditional feeding structures of the DRA array have many disadvantages. Stripline feeding network structure [1] is the most frequently used feeding structure. But it has complex structures and the power loss on the stripline. Besides, the design difficulty increases with the number increasing of array elements. Another feeding structure is waveguide probe feeding structure [2]. By coupling the electromagnetic wave of the waveguide, the probes, with different positions, are used to excite the DRA array elements. Nevertheless, this method causes difficulty to process. So we are trying to find a way to excite DRA arrays with high efficiency and low processing difficulty.

As a kind of slotted waveguide antenna, radial line slot antenna (RLSA) [3] with high efficiency and low conductor loss has been widely used in direct broadcast from a satellite (DBS) for years. For the good performance of RLSA, many researchers devote themselves to optimizing the parameters of RLSA [4] and others use the radial line waveguide to excite helix antenna array [5], which comes with good results and can be used as high power microwave antennas.

Inspired by the radial line helix antenna array, we propose a DRA array, fed by radial line waveguide, to simplify the feeding structures of the DRA array and improve the aperture efficiency.

II. ANTENNA STRUCTURE

As shown in Fig. 1, the proposed radial line dielectric resonator antenna array (RLDRA) mainly consists of two parts, DRA array (labeled 1 on Fig. 1) and feeding radial line waveguide (labeled 2-5 on Fig. 1).

The feeding radial line waveguide includes feeding coaxial line (label 2 on Fig. 1), the top layer of the waveguide (label 4 on Fig. 1), adding part (label 5 on Fig. 1) to facilitate fixation, slow wave structure and the bottom layer of the waveguide (label 3 on Fig. 1). The top layer of the waveguide is made of a 1mm substrate layer and a copper layer, with carefully arranged slots on it to feed the DRA array. In order to suppress grating lobes, slow wave structure is used to reduce the guide wavelength, λ_g. The slow wave structure has a period of *P*, a height of *Ph* and an interval of *Pd*.

As radiators, the DRAs, which detailed show in Fig. 1 (c), have a dielectric constant of ε_r and dimensions of *a*, *b* and *h* and are mounted on the top layer of the waveguide to coupling electric field from slots.

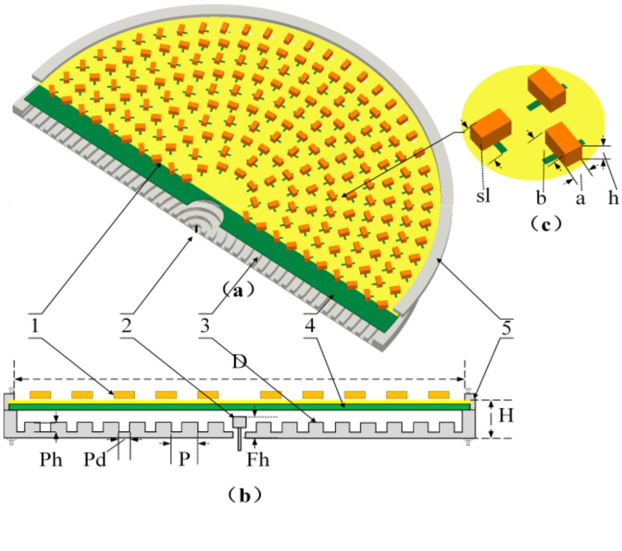

Fig. 1. The structure of radial line dielectric resonator antenna array (a) three-dimensional structure cut in half (b) cross section (c) the magnified view of the zoom region in (a).

In order to form linear polarization and increase aperture efficiency, we adopt the following arrangment priciples [6].

1) To maximum using the aperture, the array is arranged as concentric structure with all units of different circles radially spaced by one guide wavelength and units of same circles angularly spaced half guide wavelength.

2) Two DRAs, which are at a distance of half guide wavelength along the radial direction to have 180° phase difference, are used as a unit radiator. Besides, two DRAs of a unit are perpendicular to each other to suppress cross polarization.

3) The rotating angle of each unit is decided by numbers of units in the same circle.

The overall diameter of the antenna array is *D* and the height of the waveguide is *H*. The optimized results of the antenna parameters are listed in Table I.

TABLE I

FINAL OPTIMAL DIMENSION VALUES (UNIT: MILLIMETERS)

Dimension	Value
λ_0	25
λ_g	18.6
D	223.2
H	9
a	2.7
b	5
h	4
ε_r	6.15
Sl	6.5
P	5
Pd	2.5
Ph	3.5
Fh	5.6

III. Results and Discussions

A. *Aperture Distribution and DRA's working mode*

Slots on the upper layer of the waveguide are the traditional radiators of RLSA, which have length of half wavelength and suffer the influence of mutual coupling. Because of characters of high permittivity and low mutual coupling, the DRAs, as elements of an array, can reduce the size of the elements and suppress mutual coupling between elements.

Fig. 2 shows the E-field configuration of the DRA element, excited by the slot on the waveguide. The longer side of the DRA element is perpendicular to the feeding slot to couple the E-field of the slot. So E-field is stronger than H-field inside the DRA. As shown in Fig. 2, the DRA is mainly working at $TM_{11\delta}$ at 12 GHz.

Fig. 3 shows the current distribution of the upper layer of the waveguide. For processing convenience, array elements have same parameters, which causes currents attenuate along the radial direction instead of uniform distribution.

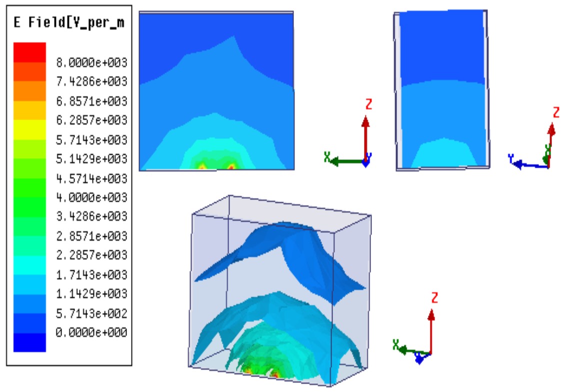

Fig. 2. E-field configuration of the DRA.

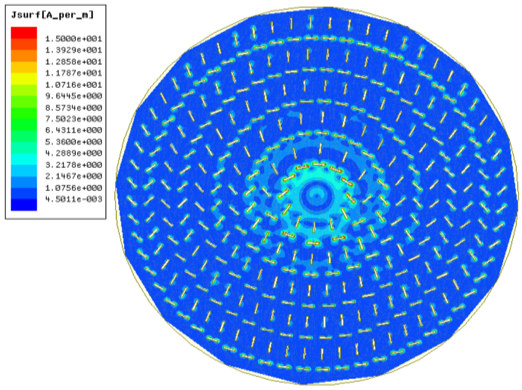

Fig. 3. The current distribution of the upper layer of the waveguide.

B. *Return Loss*

Fig. 4 shows the return loss of the proposed array. As shown in the figure, the RLDRA operates from 11.98 GHz to 12.08 GHz as with the poor performance of traditional RLSA. Because of two DRAs of a unit at a distance of half guide wavelength, reflections from two DRAs add in phase in the feeding port, which causes the poor performance of RLDRA. However, this effect can be weaken by some means but it is not the key point of this paper.

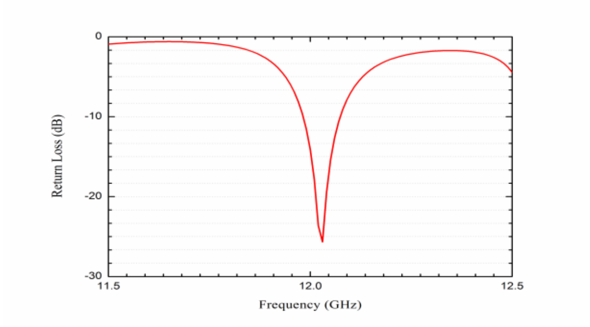

Fig. 4. The return loss of the DRA array.

C. *Radiation Patterns and Polarization*

Fig. 5 shows the simulated directivity pattern of the array at 12 GHz. The peak directivity appears at the axial direction of the antenna as we designed. This DRA array achieves a directivity of 27.18 dB with 180 elements and thus obtains an aperture efficiency of 66.4% at 12 GHz. Furthermore, with 98.77% radiation efficiency and 96% return loss efficiency, the proposed array antenna has a total efficiency of 62.95% at 12GHz.

Realized gain and directivity versus frequency of the antenna are given in Fig. 6. As shown in Fig. 6, the 3-dB realized gain bandwidth is 310 MHz.

Fig. 7-9 present the normalized radiation patterns of the co-polarization and cross-polarization components in the φ = 0°, 45° and 90° planes. The cross-polarization components are below -20dB in these planes, which confirm the polarization purity of the antenna.

D. *Comparison*

Comparisons of directivity and aperture efficiency to previously reported linearly polarized antenna arrays, fed by radial line waveguide, are illustrated in Table II. Reference [7] and reference [9] did not provide the directivity, so we roughly use gain to calculate the aperture efficiency. The proposed RLDRA array features the highest aperture efficiency in these works.

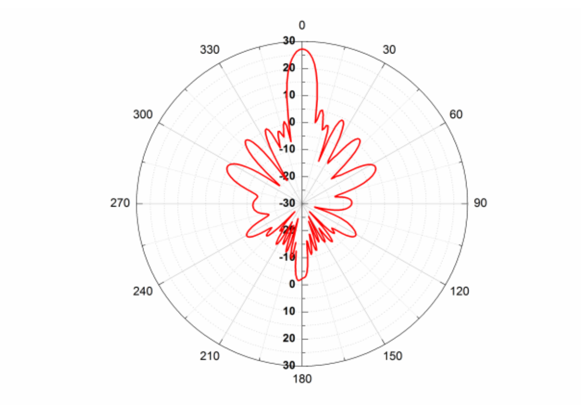

Fig. 5 The directivity pattern of the DRA array at 12 GHz.

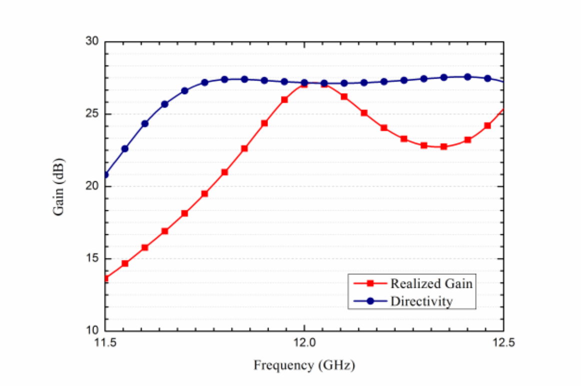

Fig. 6 The realized gain and directivity of the DRA array.

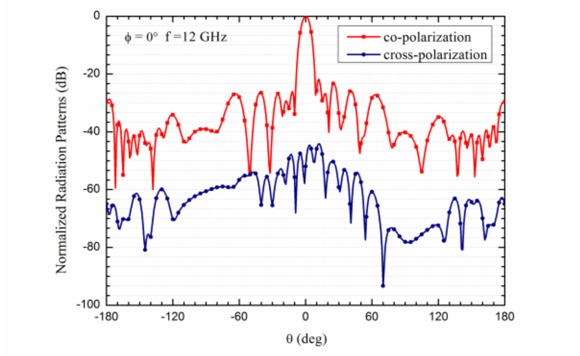

Fig. 7 The normalized co- and cross-polarization radiation patterns of the DRA array at 12 GHz (φ=0°).

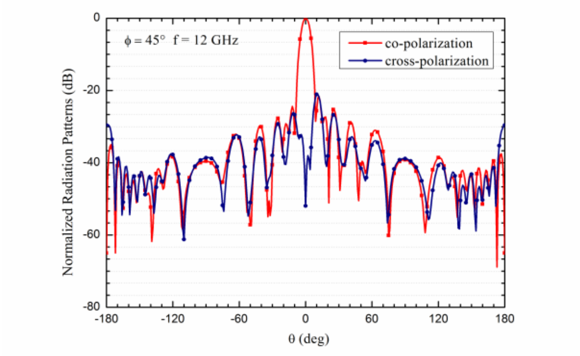

Fig. 8 The normalized co- and cross-polarization radiation patterns of the DRA array at 12 GHz (φ=45°).

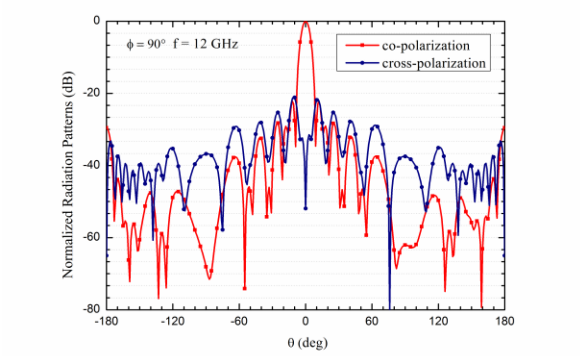

Fig. 9 The normalized co- and cross-polarization radiation patterns of the DRA array at 12 GHz (φ=90°)

TABLE II

COMPARISONS OF DIRECTIVITY AND APERTURE EFFICIENCY FOR REPORTED LP ANTENNA ARRAYS FED BY RADIAL LINE WAVEGUIDE

Author	Centre Frequency (GHz)	Directivity or Gain(dB)	Diameter	Aperture Efficiency
[7]	11.6	34.6 (Gain)	$23.2*\lambda_0$	54.29%
[8]	12.5	34.7	$22.92*\lambda_0$	57%
[9]	17.3	30.7 (Gain)	$15.57*\lambda_0$	49.1%
[10]	16.9	32.9	$20.39*\lambda_0$	49%
This Work	12	27.18	$8.928*\lambda_0$	66.4%

IV. CONCLUSION

In this paper, A DRA array, fed by radial line waveguide, is proposed to simplify the feeding structure of the DRA array. With single feeding port and integration feeding structure, this DRA array reduce the processing complexity. Besides, the RLDRA array achieves a directivity of 27.18 dB, an aperture efficiency of 66.4% and a total efficiency of 62.95%, which indicate excellent characteristics of the antenna and made this antenna array as a good candidate for high gain antenna applications.

ACKNOWLEDGMENT

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