Characterization of a New Architecture for Antenna Array based on Phased Array and Discrete Lens Array

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Abstract*– This new architecture is proposed with the idea of taking the best of each technology (phased array and DLA). Then, a small-phased-array (few active elements) and a DLA (only passive elements) are chosen to reduce the complexity and reduce costs. The main objective of the project is to characterize 1-D small-phased-array-fed DLA.

Keywords—Phased Array, Discrete Lens Array, Optimization, Pattern Synthesis, Linear Array.

I. INTRODUCTION

Currently, some applications of antennas array include radar, sonar, satellite communication and mobile communication. An antenna array is formed by the combination of individual radiators (e.g. dipoles, patches, antennas, etc). In addition, a phased array is an array of antennas in which the relative phases of the respective signals feeding the antennas are set in such a way that the effective radiation pattern of the array is reinforced in a desired direction and suppressed in undesired directions.

Active phased arrays can achieve beam agility, diversity, reconfigurability, and adaptivity to complex signal environments [1]. However, progress in active phased array has been in stagnation due to high cost, complex array architecture, problems associated with high density device integration, and heat removal.

Therefore, an alternative for replacing the high cost of phased array is a Discrete Lens Array (DLA). A DLA is composed of two planar arrays interconnected by transmission elements. The lenses need to be fed by antennas that are located on the focal surface, proposed in McGrath's paper titled "Planar Three-Dimensional Constrained Lenses" [2].

In addition, DLA replaces large numbers of expensive phase shifters with a single spatial feed network, and it avoids the high complexity of the feed network required for conventional phased arrays [3]. Unlike phased array antenna, DLA has a constraint in its scan range due to it depends on the number of elements in the feeding (focal arc). For instance, if the feeding has six elements, then the scanning range could be ± 6 degrees (positioned each 2 degrees).

II. THEORICAL BACKGROUND

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A. Array Performance Metrics

As with all antennas, the performance of an array can be measured using several metrics. The directivity is the characteristic of an antenna that describe how much it concentrates energy in one direction in preference to radiation in other directions. The bandwidth (BW) of beam-steering array antennas if often taken as the width of the frequency band over which the gain at desired beam angle does not drop below 3 dB of the center frequency gain.

Beamwidth is usually defined as the half-power beamwidth (3 dB beamwidth) or (HPBW). This is a measure of the angular separation of points where the main beam is equal to one-half of its maximum value, or -3 dB relative to the normalized maximum gain of the beam, 0 dB.

Side lobe level (SLL) is the difference between the peak gain of the main beam and the peak gain of the highest side lobe. In this thesis they are described as a negative decibel value. For example, a side lobe which is 10 dB below the peak of the main beam has a SLL of -10 dB.

B. Discrete Lens Array

Constrained Lens Arrays (CLA) shares some similarities with the dielectric lenses and reflector antennas on one hand and with the antenna arrays on the other. Their function is to form beams in multiple directions which correspond to the location of the feed antennas at the focal surface [4]. The name constrained comes from the fact that a wave incident on one face of the array does not necessarily obey Snell's law when passing through the lens array; it is instead constrained to follow the transmission line paths. A CLA with planar front and back faces, which uses only two degrees of freedom was first proposed by McGrath [2], and is also commonly known as Discrete Lens Array (DLA), as shown in Fig. 1. He suggested arrays of microstrip patch antennas with a common ground plane, and delay lines made with microstrip transmission lines. Connection between the elements on two sides of the array can be either a feed-through pin or a slot coupler in the ground plane.

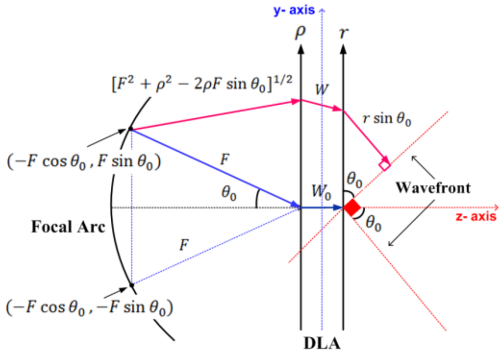

Fig. 1 Linear two degree of freedom (2DF) lens reference geometry.

III. DESCRIPTION OF THE NEW ARCHITECTURE

The Discrete Lens Array (DLA) will be designed using (1) and (2), derived by McGrath in [2], as shown in Fig. 1. In (1), the position of each element of the radiating side of the lens is r_n, and ρ_n is the position of each element on the feed side of the lens based on the known of r_n. F is the focal distance for the DLA lens. Finally, θ_0 is a parameter of the lens that specifies the direction of the path length equality to plane wave front,

$$\rho_n = r_n \sqrt{\frac{F^2 - {r_n}^2 \sin^2(\theta_0)}{F^2 - {r_n}^2}} \tag{1}$$

In (2) determines the separation W_n between the corresponding each element on the feed side and on the radiating side of the lens. W_0 is the constant assigned to the separation between the elements in the center of the DLA.

$$\begin{aligned} W_n = F + W_0 &- \frac{1}{2}\sqrt{F^2 + {\rho_n}^2 - 2\rho_n F \sin\theta_0} \\ &- \frac{1}{2}\sqrt{F^2 + {\rho_n}^2 + 2\rho_n F \sin\theta_0} \end{aligned} \tag{2}$$

The geometry of the new architecture is shown in Fig. 2. The electric field for a point of interest $E_t(\theta)$ is determined in (3); $N + 1$ is the number of element in the radiating side and the feed side of the DLA; r_n is the position of each element on the radiating side; θ is the angle at which the point of interest is with respect to the z- axis; l_0 is the distance from the element in the middle of the DLA to the point of interest; l_n is the distance from each element of the DLA to the point of interest; E_{rs_n} is the radiation pattern for the radiating side of the DLA; $l_n = l_0$; $k = 2\pi/\lambda$, and $\lambda = 1$.

$$E_t(\theta) = \frac{e^{-jk\,l_0}}{l_0} \sum_{n=-N/2}^{N/2} E_{rs_n} e^{j r_n \sin(\theta)} \tag{3}$$

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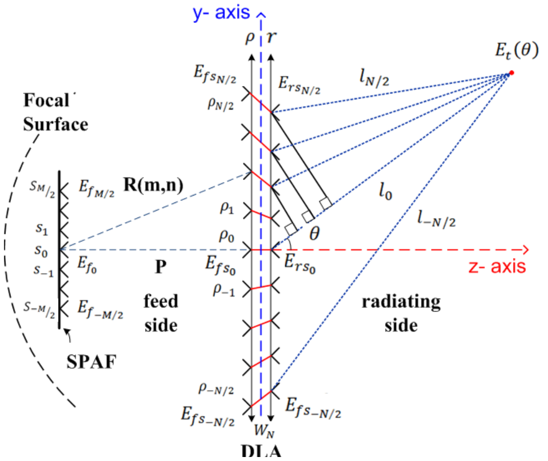

Fig. 2 Geometry of the New Architecture.

IV. PRELIMINARY RESULTS

The parameters used in the designed DLA are the following: N = 65; is number of elements in the DLA; r = 0.5λ; is distance between elements in the small-phased-array-fed; $\theta_0 = 20^\circ$; is the best focus angle; M = 7; is number of elements in the small-phased-array-fed.

In the Fig. 3 is shown several radiation patterns according to different values of θ equal $\pm 35\ degrees$.These radiation patterns have a side lobe level approximate of 11dB; a beamwidth approximate of 10°; an angle of scanning is $\pm 20\ degrees$. For s = 0.5λ and P = 15.4375λ.

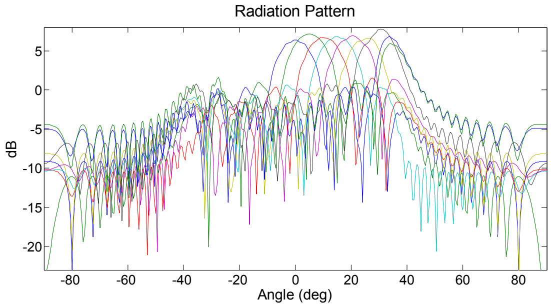

Fig. 3 Graphics radiations patterns for different values of $\theta = \pm 35\ degrees$.

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