NULL PATTERNS IN CIRCULAR ARRAYS FOR BEAMFORMING APPLICATIONS

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Abstract- In this paper, the circular array null pattern synthesis for beamforming applications is presented using the novel social group optimization algorithm. As a part of the simulation, the circular array of 24 element length is considered with inter-element spacing of 0.5 λ is considered. The patterns are synthesized for null steering and sidelobe level (SLL) optimization.

I. INTRODUCTION AND LITERATURE SURVEY

Multiple antennas can be arranged in various geometrical configurations to form antenna array with high directive radiation pattern. Linear antennas are limited in their steering capability. This limitation can overcome by the use of planar antenna arrays. The circular arrays have become popular in recent years over other array geometries because they have the capability to perform the scan in all the directions without a considerable change in the beam pattern and provide 360^0 azimuth coverage.

Circular arrays are less sensitive to mutual coupling as compared to linear and rectangular arrays since they do not have edge elements. They can be used for beam forming in the azimuth plane for example at the base stations of the mobile radio communication systems as the components for signal processing [1-5].

A design method of circular apertures for narrow beam width and low sidelobes has been reported by Taylor [1]. It includes the development of continuous circular aperture distributions, which contain only two independent parameters, A and $\bar{n}$, where A is related to the design of sidelobe level and $\bar{n}$ is a number controlling the degree of uniformity of the sidelobes. A realized radiation pattern is expressed in the integral form. They are compared with a line source and circular aperture.

Panduro et al. made an attempt to apply evolutionary approach towards the design of circular arrays. Real-coded Genetic algorithm (GA) has been employed to determine an optimum set of amplitude excitations and antenna element separations, which provide a radiation pattern with maximum sidelobe level reduction coupled with the constraint of a fixed beam width and [2].

A non-uniform circular antenna array with optimum side lobe level reduction is designed in [5]. The Particle Swarm Optimization (PSO) method is used in the optimization process. The method of PSO is used to determine an optimum set of weights and antenna element separations that provide a radiation pattern with maximum side lobe level reduction with the constraint of a fixed major lobe beamwidth.

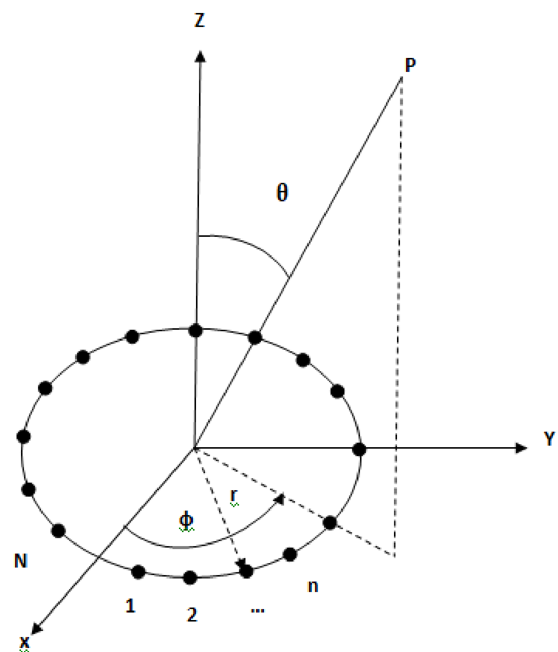

Fig.1: Geometry of Circular array

II. FORMULATION

The elements are nonuniformly spaced on a circle of radius r in the Y-Z plane. The elements are assumed to be isotropic sources so that the radiation pattern of the array can be described by its array factor. The geometry of an N element circular antenna has been shown in Fig.1.

The array factor in the Y-Zplane can be written as [191]

$$A_F(\theta) = \sum_{n=1}^{N} A_n \exp[jka\cos(\theta - \phi_n + \alpha_n)]$$

Where,

$$ka = \sum_{i=1}^{N} d_i$$

$$\phi_n = \frac{\left(2\pi \sum_{i=1}^{n} d_i\right)}{\left(\sum_{i=1}^{N} d_i\right)}$$

$$\alpha_n = -ka\cos(\theta_o - \phi_n)$$

A= [A_1, A_2…A_n…. A_N], A_n represents the excitation amplitude of the n-th element of the array, d= [d_1, d_2…d_n….d_{N-1}], $d_n$represents the distance from element n to (n+1). Excitation current phases are fixed at zero degree.

Here θ_0 be the angle where global maximum is attained in θ= $[-\pi, \pi]$.

Normalized power pattern can be expressed as

$$P(\theta) = 20\log_{10}\left[\frac{|A_F(\theta)|}{\left||A_F(\theta)|_{max}\right|}\right]$$

The Amplitude-Dynamic Ratio (ADR) is defined as the ratio between the maximum and minimum excitation amplitudes. It can reduce the mutual coupling problem.

The directivity of a circular array with isotropic elements can be expressed as

$$D = \frac{4\pi |A_F(\theta_s, \phi_s)|^2}{\int_0^{2\pi}\int_0^{\pi} |A_F(\theta,\phi)|^2 \sin\theta \, d\theta \, d\phi}$$

Here, (θ_s, ϕ_s) = Steering angle.

III. FITNESS FUNCTION

The uniform circular array is of high sidelobe geometry (approximately 8 dB below the main lobe). The first and most important parameter in pattern synthesis of antenna array is the sidelobe level (SLL) that is desired to be as low as possible. So, the objective of the work in this chapter is to minimize the maximum sidelobe level of the array pattern by adjusting the amplitudes and positions of the elements while first null beam width (FNBW) is kept within some specified constraints. Thus the following fitness function is used.

$$\text{Fitness} = \text{Max}_{\theta \in S}\left|\frac{P(\theta)}{P(\theta_o)}\right| \quad \text{subject to } F \le F_u$$

IV. RESULTS

From the review on it should be understood that the array antenna working for the wireless applications should have the capability to accept as well reject the signals in multiple direction along with the several constrains imposed in terms of SLL and beam width. Considering this, an experimental frame work has been designed that fosters the study of circular array capability in beamforming with constraints using evolutionary algorithm like FFA. The following table describes the simulation based experimentation frame work employed for this purpose. However, the local search methods like RLS method is also employed and compared with the proposed method in terms of convergence. Several inferences like computational time, complexity of the study can be studied using the convergence plots. The same has been performed here in this work in each case mentioned in the following plots.

The null patterns with desired null in the desired direction like (45^0, 30^0) and (45^0, 15^0) are presented in Fig.2 & Fig.3. The patterns are obtained using the SGOA.

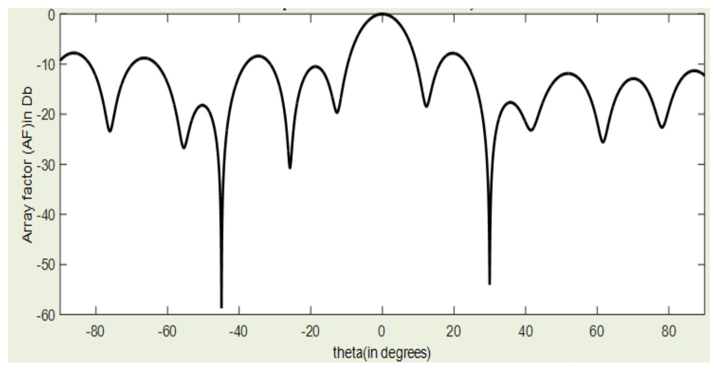

Fig.2: Patterns with null with at -45^0& 30^0

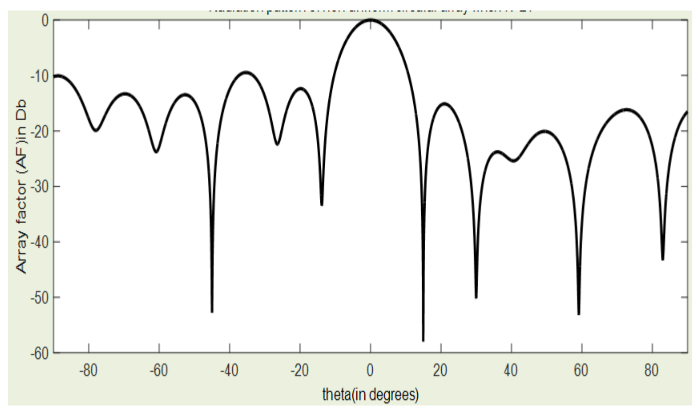

Fig.3: Patterns with null with at -45^0& 15^0

Similarly, the SLL optimized patterns with desired nulls in the desired direction like (45^0, 30^0) and (45^0, 15^0) are presented in Fig.4 & Fig.5. The produced patterns have the advantage of both the nulls as well as the desired SLL.

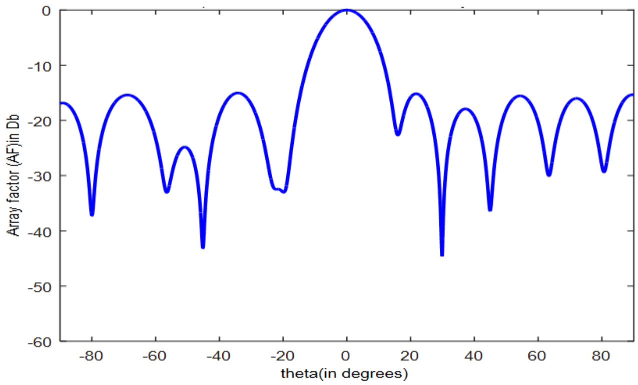

Fig.4: SLL optimized Patterns with nulls with at -45^0& 30^0

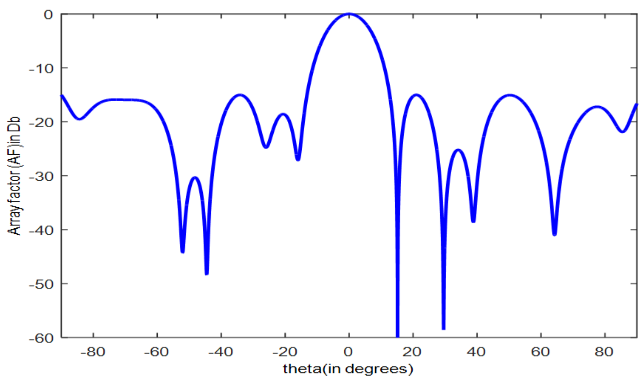

Fig.5: SLL optimized Patterns with nulls with at -45^0& 15^0

V. CONCLUSIONS

The patterns, subject to SLL constraint for null steering and optimization are successfully simulated using the SGOA and analysed. The effect of inclusion of the SLL constraint has impact on the simulation environment in terms of computation time and convergence slope. Further, the constraint on beamwidth shall be included for future scope of work.

VI. REFERENCES

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