COMPARATIVE ANALYSIS OF REDUCTION OF SIDE LOBE LEVEL FOR CONCENTRIC ELLIPTICAL ARRAY AND CYLINDRICAL ELLIPTICAL ARRAY USING DIFFERENTIAL EVOLUTION

[1]M. SAINATH, [2]R. KRISHNA CHAITANYA, [3]K.V SATYANARAYANA RAJU

[1,2,3]SRKR Engineering College, Bhimavaram, Andhra Pradesh, India
E-mail: [1]sainathgnt@email.com, [2]rkc369@email.com,[3]kvsn45@email.com

Abstract— This Paper describes optimal side lobe level of an elliptical cylindrical array for uniform excited isotropic antennas and non-uniform excited isotropic antennas when compared to concentric elliptical array using differential evolution optimization. Differential evolution (DE) is a method that optimizes a problem by iteratively trying to improve a candidate solutionwith regard to a given measure of quality. Such methods are commonly known as met heuristics as they make few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. The differential evolution optimization (DE) is used to determine optimal side lobe level (SLL), by changing the parameters like number of elements in an array, eccentricity, number of rings, and distance between rings. Simulation results show that the thinned Elliptical cylindrical antenna side lobe level is less when compare to concentric elliptical antenna and it is reduced up to -34 db.

Index Terms— Concentric Elliptical, Elliptical Cylindrical, Side Lobe Level, Thinned, Pso.

I. INTRODUCTION

Radiation pattern of a single element is relatively wide and each element provides low values of directivity. Antenna array increase the directivity without enlarging the size of single elements.

The overall array properties can also be controlled and optimized by way of adjusting number of elements, spacing between elements, amplitudes of elements, relative phase , geometrical configuration of overall array (linear, circular, elliptical and so on) [1]. Antenna arrays are widely used in sonar, radar, communication and high power transmission applications [5].

A linear array has excellent directivity and it could give the narrowest major-lobe in a given direction. Directional patterns synthesized with a circular array can also be electronically rotated within the plane of the array without a considerable change of the beam shape because circular array does not have edge elements [3]. But the circular array pattern has no nulls in azimuth plane [1]. But the array pattern should have a few nulls in the azimuth plane for intelligent antenna purposes to reject signal not-of-interest (SNOI) [2]. Concentric arrays are utilized in to decrease the side-lobe [4].

In a fully populated array, all the antenna elements are 'ON' i.e., all the elements in an array are excited so that all are in 'ON' state. Thinning of an antenna array elements means to switch 'OFF' the some of the antenna array elements, to produce narrowest beam width with lowest side lobe levels, without degrading the performance of an antenna array. In the 'OFF' state the antenna array elements are either in an open circuited or terminated by a matched load. There are so many methods to reduce the side lobe levels of an antenna array, some of which are statistically tapered thinned arrays, thinning based on empirical or analytical formula [6], and thinning using optimization techniques.

Using differential evolution optimization with and without thinning for both cylindrical elliptical and concentric elliptical side lobe level is optimizes for uniform amplitudes and non-uniform amplitudes.

II. ARRAY DESCRIPTION

An elliptical antenna array includes a number of antenna elements arranged on an ellipse [15], as proven in Fig 1(a).The geometry of concentric elliptical array shown in Fig 1(b).The geometry of cylindrical elliptical array shown in Fig1(c).In Fig. 1(a), 'a' and 'b' are semi-major and semi-minor axes respectively and eccentricity of the ellipse is

$$e = \sqrt{1 - a^2/b^2}$$

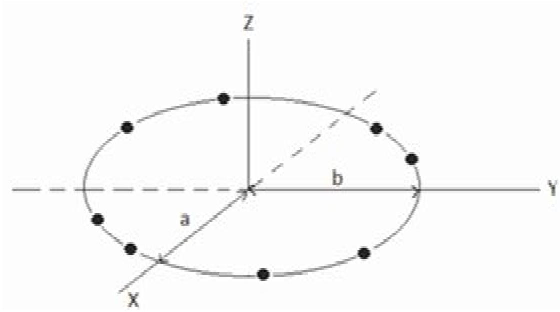

Fig.1 (a) Geometry of elliptical array

In Fig 1(b), the antenna elements alongside each ellipse form an elliptical array, and the antenna factors alongside a radial course constitute a linear array. In an absolutely populated array, all the antenna elements are 'on' that is all of the elements are

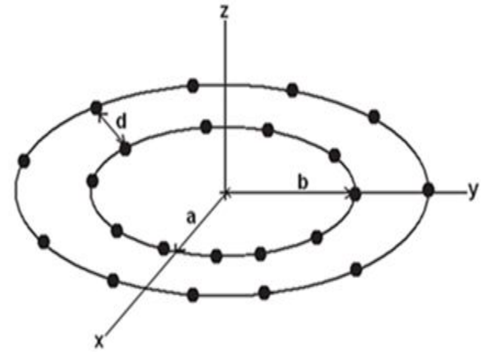

Fig.1 (b) Geometry of concentric elliptical array

Within the structure of ECA, all ellipses are of equal semi-important axis and semi-minor axis a, b, respectively, and they are placed one above the opposite, with an equal vertical spacing 'd' between them Fig.1(c).

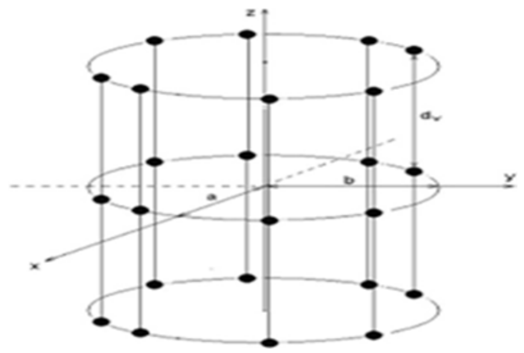

Fig.1(c) Geometry of ECA

III. DESIGN EQUATION

The array aspect of elliptical array whose elements whose lie on ellipse is bought. If the Centre of an ellipse is located at the origin on the x-y plane, then the parametric equation of ellipse within the rectangular coordinate process is given through

X=a $\quad 0\leq X \leq 2\pi$

Y=b $\quad 0\leq Y \leq 2\pi$

The place a and b are the semi-major axis and semi-minor axis, respectively, an φ is the angle between origin and a factor (x, y) of the ellipse in x-y. As a result, for an elliptical N-detail array with its Centre in originof x-y plane, the array component can also be expressed as

$$AF(\theta,\emptyset) = \sum_{n=1}^{N} A_n(\exp\,(jk(\alpha_n + R_n a_r)$$

Where A_n *and* α_n are the relative amplitude and relative phase of the n^{th} element of the array, R_n is the position vector of the n^{th} *element*, $a_r$is the unit vector of the observation factor in spherical coordinates, k is the wave quantity.

R_n = acos$\varphi_n a_x$ + bsin$\varphi_n \varphi_y$

a_r= sinθcos$\varphi_n a_x$+sinθsin$\varphi_n a_y$+cosθa_z

Where φ_n=2π (n-1)/N is the attitude in the x-y axis between the x axis and the n^{th} detail.

If N is the number of antenna elements lie on ellipses and M is the number of concentric ellipses, then the whole array component of the concentric elliptical array arrangement of isotropic elements is expressed as

$$AF(\theta,\emptyset) = \sum_{m=1}^{M}\sum_{n=1}^{N} B_{mn}(\exp\,(jk\,(jksin\theta(amcos\varphi n\;cos\varphi + bm\;sin\varphi nsin\varphi)))$$

$B_{mn}$is the amplitude of excitation current, a_m *and* b_m are semi major axis and semi-minor axis of m^{th}elliptical array respectively. If 'a' is the semi-major axis and 'd' is the spacing between ellipses then

$$a_m\text{=a + (m-1)d, } b_m\text{=}a_m((1-e^2)^{\frac{1}{2}})$$

The expression for the array factor of ECA is derived by the combination of linear and elliptical array properties.We know, the array factor of elliptical array

$$AF(\theta,\varphi) = \sum_{n=1}^{N} A_n\, e^{jksin\theta(acos\varphi_n cos\varphi+bsin\varphi_n sin\varphi)}$$

the structure of ECA, all ellipses are of equal semi-major axis and semi-minor axis a, b, respectively, and they are placed one above the other, with an equal vertical spacing d between them . Thus, the elements along a vertical line on the cylinder surface form a linear array and those in a transversal plane constitute an elliptical array. For M identical elliptical arrays of ECA, the total array factor is obtained by the summation of the M elliptical array factors given by,

$$AF(\theta,\varphi) = \sum_{m=1}^{M}\sum_{n=1}^{N} C_{nm}\, e^{jksin\theta(acos\varphi_n cos\varphi+bsin\varphi_n sin\varphi)}$$

$$C_{mn} = A_n e^{j\alpha_n}\, B_m e^{j(m-1)(kdcos\theta+\beta)}$$

The place 'd' is the spacing between factorslaid in vertical direction the term$B_m e^{j(m-1)(kdcos\theta+\beta)}$arises from the vertical aspect$m^{th}$and $A_n e^{j\alpha_n}$ is the excitation coefficient of n^{th} aspect of elliptical array.

$$AF(\theta,\varphi) = \sum_{m=1}^{M} B_m\, e^{j(m-1)(kdcos\theta+\beta)} \times \sum_{n=1}^{N} A_n\, e^{j(\alpha_n+ksin\theta(acos\varphi_n cos\varphi+bsin\varphi_n sin\varphi))}$$

$$AF\theta,\varphi) = AF(\theta,\varphi)_{linear} \times AF(\theta,\varphi)_{elliptical}$$

IV. DIFFERENTIAL EVOLUTION OPTIMIZATION

In evolutionary computation, differential evolution (DE) is a method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. Such methods are commonly known as met heuristics as they make few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, Meta heuristics such as DE do not guarantee an optimal solution is ever found. DE is used for multidimensional real valued functions but does not use the gradient of the problem being optimized, which means DE does not require for the optimization problem to be differentiable as is required by classic optimization methods such as gradient descent and quasi newton methods. DE can therefore also be used on optimization problems that are not even continuous, are noisy, change over time [12-13].

The DE is based on three basic steps .Those are initialization, Mutation and recombination (trail vector generation) and replacement [7-11].

a) Initialization:
this process is started by randomly generating the number of population (p_n) having D-dimensional parameter vectors Xi,0=[X1,i,0,…,XD,i,0], i=1,…, Pn within the given lower and upper bound LB = [b1,L,…,,bD,L] and UB=[b1,U,…,bD,U], respectively.

b) Trial vector generation:
At the g^{th} generation, due to the mutation and recombination operations applied to the current population ${p_n}^g$ a trial population ${p_u}^g$ consisting of p_n D-dimensional trial vectors is generated.

i) Differential mutation: For every target vector in the current population a new mutant vector is generated by adding a scaled, randomly sampled, vector difference to a basis vector randomly selected from the current population. At the g^{th} generation, the i^{th} mutant vector corresponding to i^{th} target vector in the current population is given by

$$V_i{}^g = X_{r_0}{}^g + F\left(X_{r_1}{}^g - X_{r_2}{}^g\right), \quad i \neq r_0 \neq r_1 \neq r_2$$

Mutation scale factor F(0,1)

ii) Discrete recombination: A new trail vector is generated for every target vector in the current population by crossing the target vector with mutant vector at a given cross over rate $C_r[0,1]$.
Let us consider for g^{th} generation, the i^{th} trial vector with respect to i^{th} target vector in the current population generates the mutant vector as

$$V_{j,i}{}^g = U_{j,i}{}^g \ if \ rand_j[0,1] \leq C_r or \ j = rand_j \ and \ X_{j,i}{}^g \text{ Otherwise}$$

c) Replacement: If the generated trail vector is better than the target vector then the next generation is replaced by trail vector otherwise the target vector remains same.

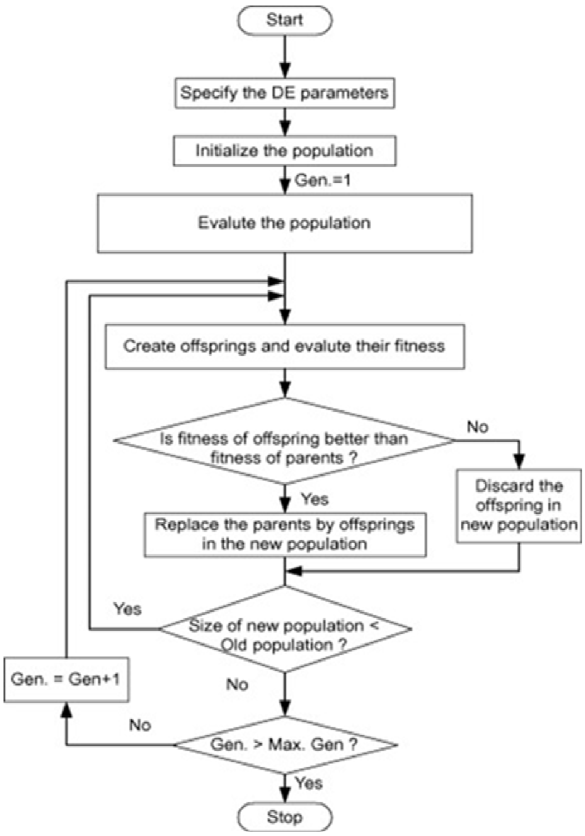

Fig.2 flow chart differential evolution

V. EXPERIMENTAL RESULTS

The differential evolution algorithm were carried out and simulated using MATLAB R2010acylindrical elliptical array antenna with separation distance of d=1 between rings. The number of elements is taken as 24, number of rings as three for uniform excitation amplitudes and non-uniform excitation amplitudes.
For differential evolution
Pop measurement = 25 (complete population measurement),
Max gen = one hundred (iteration rely limit),
Number of Variables = 5(number of genes in each and every population member)

The plot of normalized array in dB versus arrival angles in degree that is shown in figures. For optimization the optimized values varies between N=[1 20], e=[0.1 1], a=[0.5 1] , d=[1 3], M=[1 5].

Case1. Uniform excitation amplitudes

a) Without thinning:

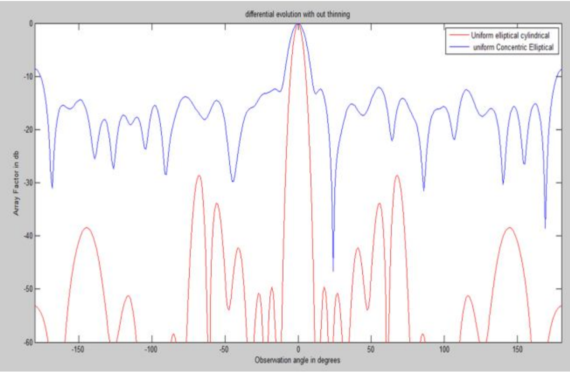

Fig.3 (a)Array factor in dB for uniform concentric elliptical and uniform elliptical cylindrical without thinning.

b) With thinning:

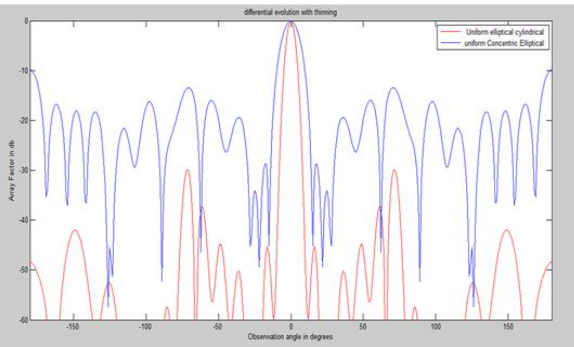

Fig.3 (b) Array factor in dB for uniform concentric elliptical and uniform elliptical cylindrical withthinning.

Case 2. Non uniform excitation amplitudes

a) Without thinning:

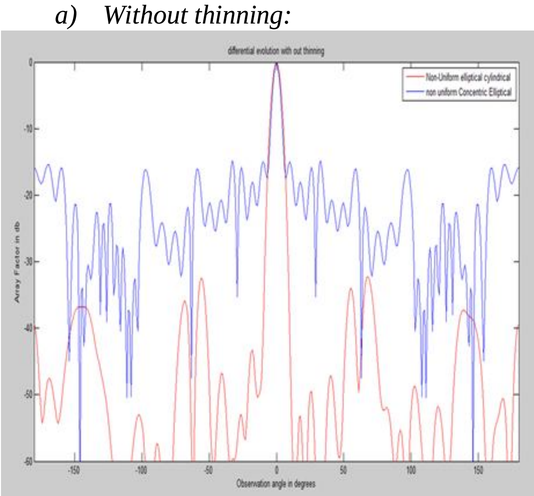

Fig.3 (c) Array factor in dB for non-uniform concentric elliptical and non-uniform elliptical cylindrical without thinning.

b) With thinning:

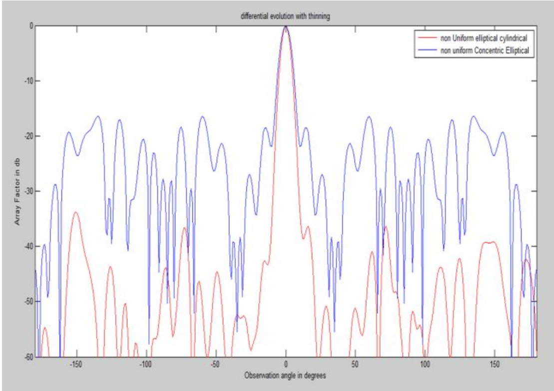

Fig.3 (d) Array factor in dB for non-uniform concentric elliptical and non-uniform elliptical cylindrical with thinning.

TABLE I

Thinning	Differential evolution		
	Excitation amplitudes	*Concentric elliptical (slldB)*	*Elliptical cylindrical (slldB)*
Without thinning	Uniform	-12.0775	-28.5553
	Non uniform	-14.8723	-32.2511
With thinning	Uniform	-13.4147	-29.8329
	Non uniform	-16.4205	-33.8025

CONCLUSION

In this paper, thinning and without thinning Concentric Elliptical antenna array and Elliptical Cylindrical Array (ECA) is considered for uniform amplitudes and non-uniform amplitudes. The DE algorithm can efficiently handle the thinning of a ECA isotropic elements with a reduction to more than 50% of the total elements as used in case of fully Populated array with a simultaneous reduction in SLL to less than -33.8dB. The comparison shows a significant improvement for SLL with significant reduction in the number of elements which will reduce the cost of designing the antenna array.

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