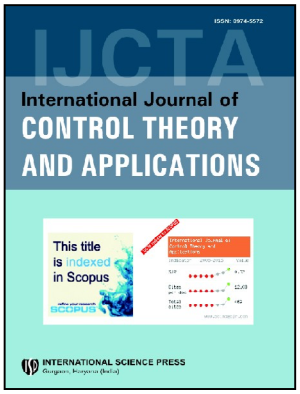

International Journal of Control Theory and Applications

ISSN : 0974-5572

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Special Issue, 2016

Reduction of Side Lobe Level for Elliptical Cylindrical Array Using Particle Swarm Optimization and Differential Evolution

R. Krishna Chaitanya[1], M Sainath[2] and K. V. Satyanarayana Raju[3]

[1] Assistant Professor, Dept. of Electronics and Communication Engineering, Sagi Rama Krishnam Raju Engineering College, Bhimavaram, Andhra Pradesh, India, E-mail: rkc639@gmail.com
[2] PG Student, Dept. of Electronics and Communication Engineering, Sagi Rama Krishnam Raju Engineering College, Bhimavaram, Andhra Pradesh, India, E-mail: sainathgnt@gmail.com
[3] Professor, Dept. of Electronics and Communication Engineering,Sagi Rama Krishnam Raju Engineering College, Bhimavaram, Andhra Pradesh, India, E-mail: kvsn45@gmail.com

Abstract: Two optimization methods including Particle Swarm Optimization and Differential Evolution are compared on cylindrical elliptical antenna array for uniform and non-uniform excited isotropic amplitudes.In evolutionary computation, differential evolution (DE) and Particle swarm optimisation (PSO) could be based on a computational technique that optimizes a problem iteratively attempt to enhance solutions. Simulation results display Differential Evolution preferred over Particle Swarm Optimization in size of optimum side lobe level for thinned cylindrical elliptical antenna array.

Keywords: Side Lobe Level, Antenna array, thinned, PSO algorithm, DE algorithm.

1. INTRODUCTION

Linear array produces excellent directivity with very narrow beam width but radiation is not uniform in all directions [3]. For a lot of purposes round array (like concentric elliptical and elliptical cylindrical) is appealing because of capability of producing directive beams and nulls on the azimuth plane, on the plane of array [2].

Before implementation of elliptical arrays circular antennas arrays are used. The main drawback of the circular arrays is increased side lobe level and it can be reduced by varying the placing between the elements. But varying the distance between elements in circular array causes mutual coupling between the elements so interference takes place in the array [3]. To avoid the above interference between the elements elliptical antenna arrays are introduced [4].

[3] In antennas total information is contained in major lobe and some amount of information in side lobes. Because of side lobe interference exists, so in order to eliminate interference we are reducing the side lobe for an antenna array using optimization techniques. Total elimination of side lobe is not possible, so need to reduce as much as possible using techniques.

[5] Thinning concentric elliptical antenna array using particle swarm optimization. In this optimization is done by maintaining constant eccentricity with different number of elements in each ring observed side lobe level variation. Not only for fully populated but also performed thinning for antenna elements in rings.

Thinning, a ring antenna elements may not obtained better radiation characteristics so some of elements are turned off and observed side lobe level obtained is of optimum value when compared to fully populated antenna array, while reduced number of elements is about 60% of total elements. An antenna array of 17 elements for fully populated antenna array minimum side lobe level is -9dB, and for optimized thinned antenna array minimum side lobe level is -18 db.

[6, 8] Using non-uniform excitation antenna amplitudes improved significant in places where weight and power are more important like radars, satellites and communication of mobile evolutionary optimizations are used. Genetic algorithm and particle swarm optimization are based on more parameters controlled. So, differential evolution is proposed with optimal weights for cylindrical elliptical antenna array with minimum side lobe level and narrow beam width. This paper gives all values of the parameter for differential evolution. Compared uniform and non-uniform excited amplitudes for 3 rings and 12 antenna elements for each ring and also obtained beam width between first nulls from radiation pattern. For uniform side lobe level is -8.50db, FNBW 38°, and for non-uniform side lobe level is -20db, FNBW.

[7, 9] Using hybrid elliptical antenna arrays compared concentric elliptical antenna array and cylindrical elliptical antenna array for uniform and non-uniform excitation antenna amplitudes. In elliptical antenna array number of antenna elements are increased side lobe level obtained is minimum but beam width increases. So, in order to increase antenna elements in one ring increasing rings in both horizontal and vertical direction and comparing them which give optimum side lobe level. Thinning is performed on both antenna arrays. For 3 rings 24 antenna elements for each ring uniform optimum side lobe level is -10db for concentric elliptical and -27db for cylindrical elliptical, non-uniform optimum side lobe level is -14db for concentric elliptical and -29db for cylindrical elliptical without thinning. With thinning uniform optimum side lobe level is -12db for concentric elliptical and -31.9db for cylindrical elliptical, non-uniform optimum side lobe level is -16db for concentric elliptical and -34db for cylindrical elliptical.

[1, 9] In this paper, cylindrical elliptical antenna array is performed on two evolutionary optimization techniques such as particle swarm optimization and differential evolution for both uniform and non-uniform excited antenna amplitudes. When comes to evolutionary techniques particle swarm optimization known as birds flocking, birds have artificial intelligence and searches for food i.e. optimum side lobe level, in differential evolution compared to particle swarm optimization for each and every particle giving some particles known as assistants in order to speed up finding optimum side lobe level. In differential evolution initial of vector, mutation, cross over, selection are performed. Thinning is performed for uniform and non-uniform amplitudes.

2. DESCRIPTION OF ANTENNA ARRAY

Array elements are placed on rings of elliptical cylindrical antenna array with eccentricity

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

With figure concentric elliptical antenna array and cylindrical elliptical antenna array as shown below,

The antenna elements are placed on the rings in both antenna arrays. While in antenna array synthesis all the antenna elements are considered as isotropic point source. Isotropic point source radiation will be uniform in all direction.

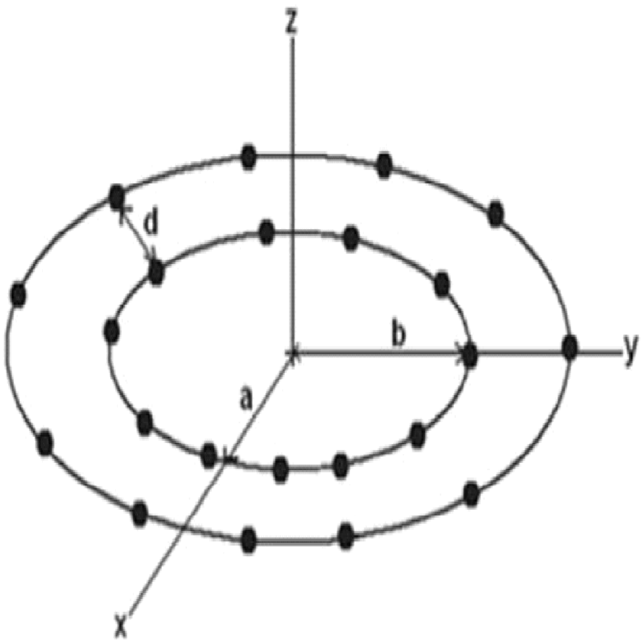


Figure 1: Concentric Elliptcial Antenna Array

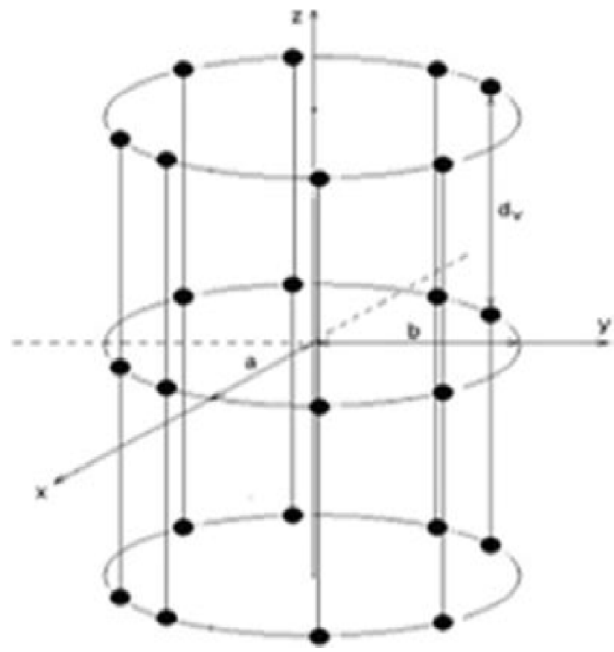


Figure 2: Elliptical Cylindrical Antenna Array

In concentric elliptical antenna array rings are increased in horizontal direction with d is the distance between them. Major and minor length is varied with respect to the m^{th} ring and d.[2]

In cylindrical elliptical antenna array rings are increased in vertical direction with d is the spacing between them. Major and minor lengths are constant.

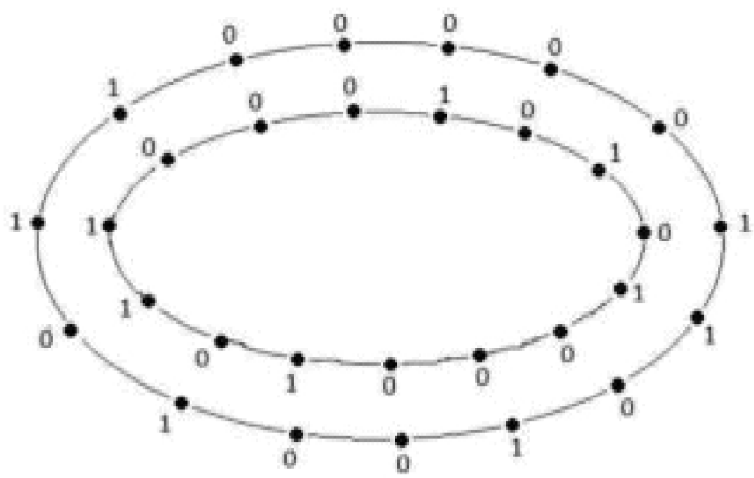


Figure 3: Thinned Concentric Elliptical Antenna Array

In an array all the antenna elements cannot give same radiation characteristics. So, by turning off some of the antenna array elements in a fully populated antenna array can obtained optimum side lobe level. Amplitude of on element is 1 and off element is 0 in uniform [5].

3. MODEL EQUATIONS

The mathematical equation of an antenna array is [2]

Array factor for elliptical antenna array is $Array\,Factor(\theta, Ø) = \sum_{n=1}^{N} A_n (\exp(jk(\alpha_n + R_n a_r)$

A_n amplitude of n^{th} Element, α_n phase of an n^{th} element,

R_n is position vector, a_r is unit vector, k is wave quantity.

R_n = acos $\varphi_n a_x$ + b sin $\varphi_n \varphi_y$

a_r = sinθcos $\varphi_n a_x$ + sinθsin φ_n a_y + cosθ a_z; φ_n = 2π (n-1)/N

Let us consider for M number of rings and each ring with N number of antenna elements then concentric elliptical antenna array is formed. All the elements are isotropic antennas.

Array factor for concentric elliptical antenna array is [4,10]

$$AF(\theta, Ø) = \sum_{m=1}^{M} \sum_{n=1}^{N} B_{mn} (\exp(jk(jk \sin\theta(am \cos\varphi n \cos\varphi + bm \sin\varphi n \sin\varphi)))$$

B_{mn} is amplitude excitation, a_m *major length and* b_m *minor length* and they are expressed as

$a_m = a + (m-1)d;\ b_m = a_m((1-e^2)^{\frac{1}{2}})$ d is distance between rings.

The Array Factor for Elliptical Cylindrical Antenna Array is

$$Array\,Factor(\theta, \varphi) = \sum_{m=1}^{M} \sum_{n=1}^{N} C_{nm}\, e^{jk \sin\theta(a\cos\varphi_n \cos\varphi + b \sin\varphi_n \sin\varphi)}$$

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

In cylindrical elliptical antenna array rings are placed one above each other in upward direction , major and minor lengths are equal for all rings.

For M elliptical rings and each ring with N number of elements array is summed as

$$AF(\theta, \varphi) = \sum_{m=1}^{M} B_m\, e^{j(m-1)(kd\cos\theta + \beta)} \times \sum_{n=1}^{N} A_n\, e^{j(\alpha_n + k\sin\theta(a\cos\varphi_n \cos\varphi + b\sin\varphi_n \sin\varphi))}$$

From figure 2 all the antenna elements in vertical line are formed as linear antenna array and horizontal antenna elements are formed as elliptical antenna array. Thus array factor of elliptical cylindrical antenna array is formed from combining linear antenna array and elliptical antenna array [10]

4. OPTIMIZATION

A Particle Swarm Optimization

PSO is known as birds searching for food in free space [5,12] Birds are initialized with a random particles and they searches for better optimum by change generations. In each iteration, for ever particle as best fitness as p_{best} and for a group of particles best fitness as g_{best}.[4-5]

$$v_{j,i+1} = (W_{i+1} * v_{i+1} + c_1 * rand1 * (pbest_j - position_{j,i}) + c_2 * rand2 * (gbest_j - position_{j,i}))$$
$$position_{j,i+1} = position_{j,i} + v_{j,i+1}$$

Vector j at new release i; C1= C2=1.5-2.05.

Inertia weight w (i+1) at $(i + 1)^{th}$ cycle is given by

$$w_{i+1} = w_{\max} - \frac{w_{\max} - w_{\min}}{i_{\max}}(i+1)$$

Where max w =1.0; min w =0.4; max i = Maxi. no. of iteration

FITNESS FUNCTION = min (SLLdB) [5]

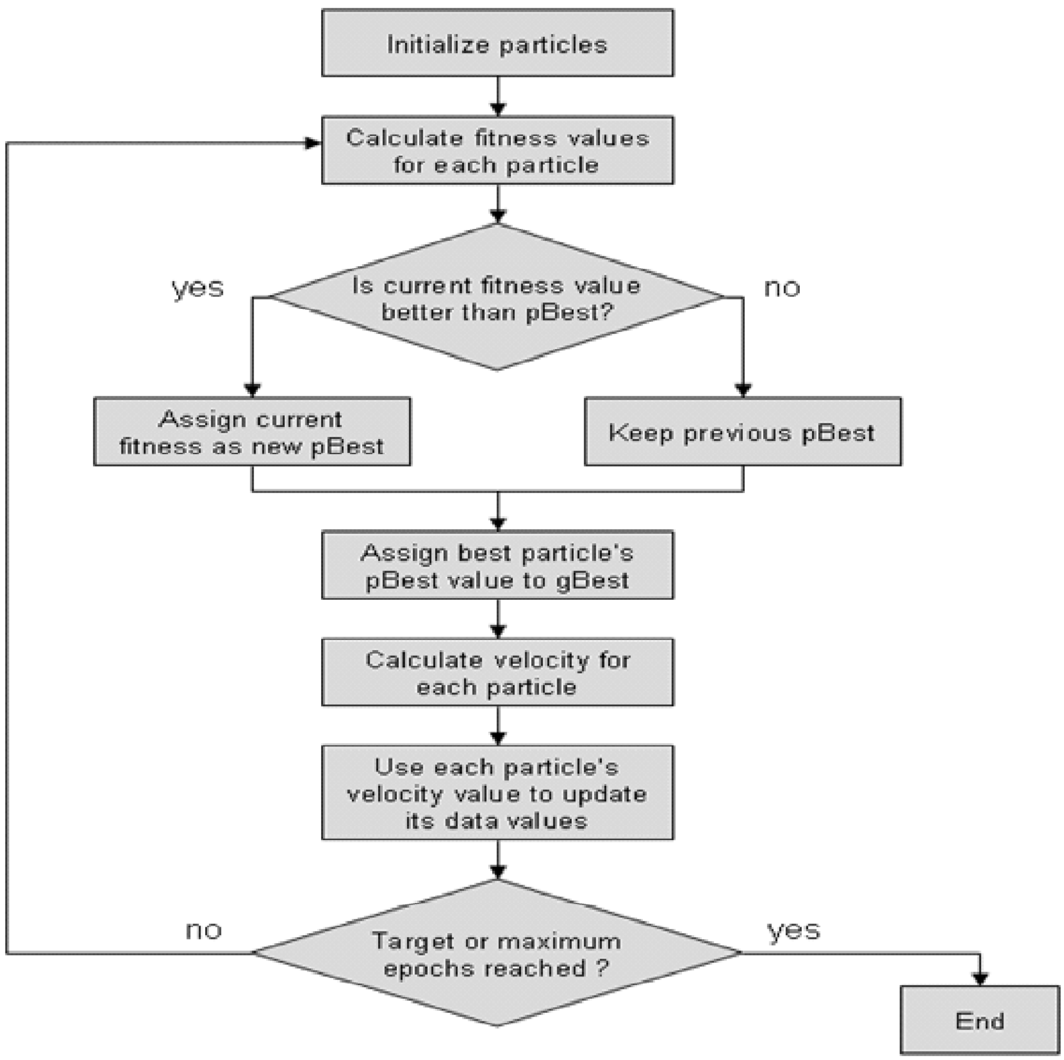


Figure 4: Particle swarm optimization algorithm flow chart

(B) Differential Evolution

It consists of vector, Mutant and combining and restoration [13,14,15]

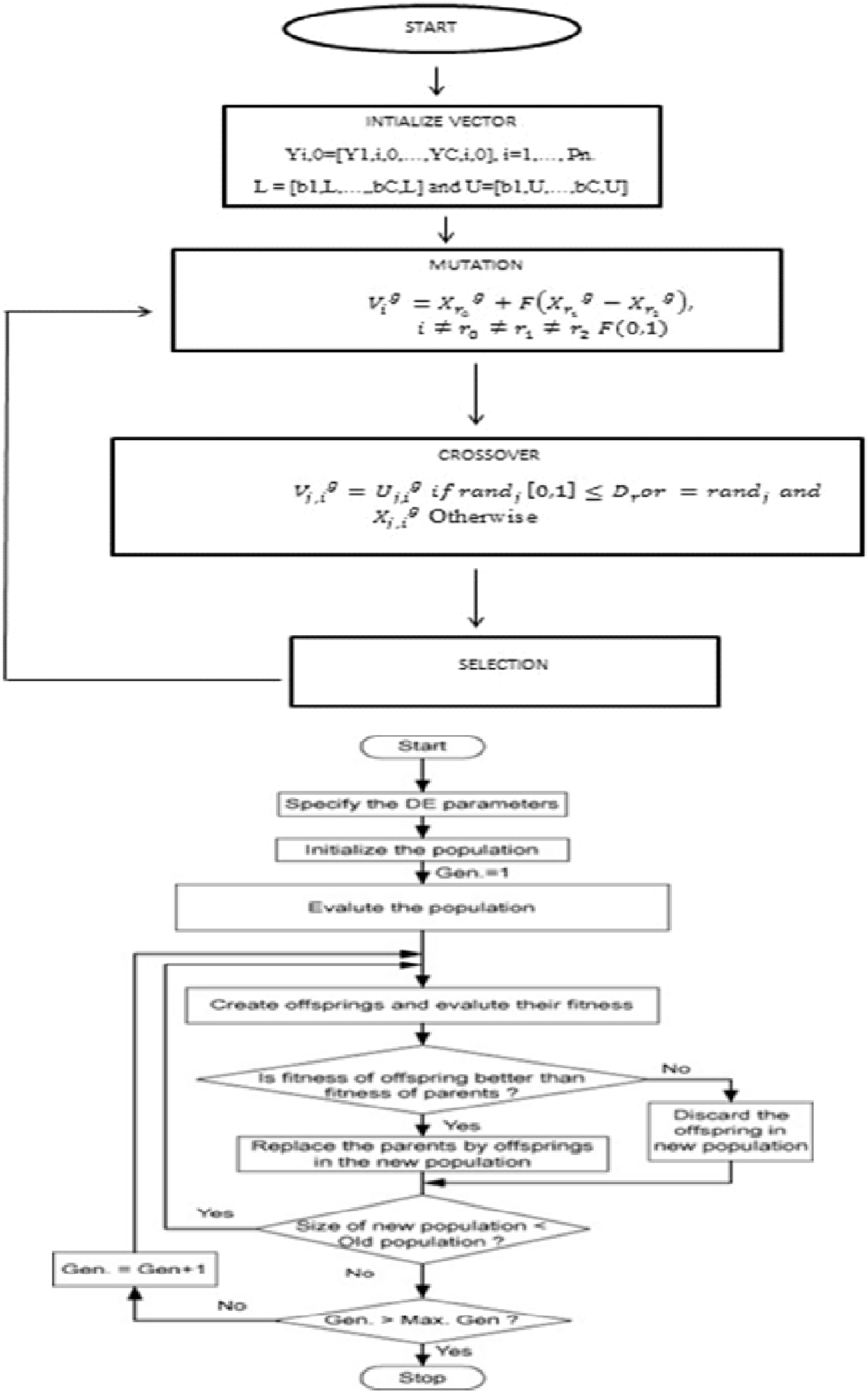
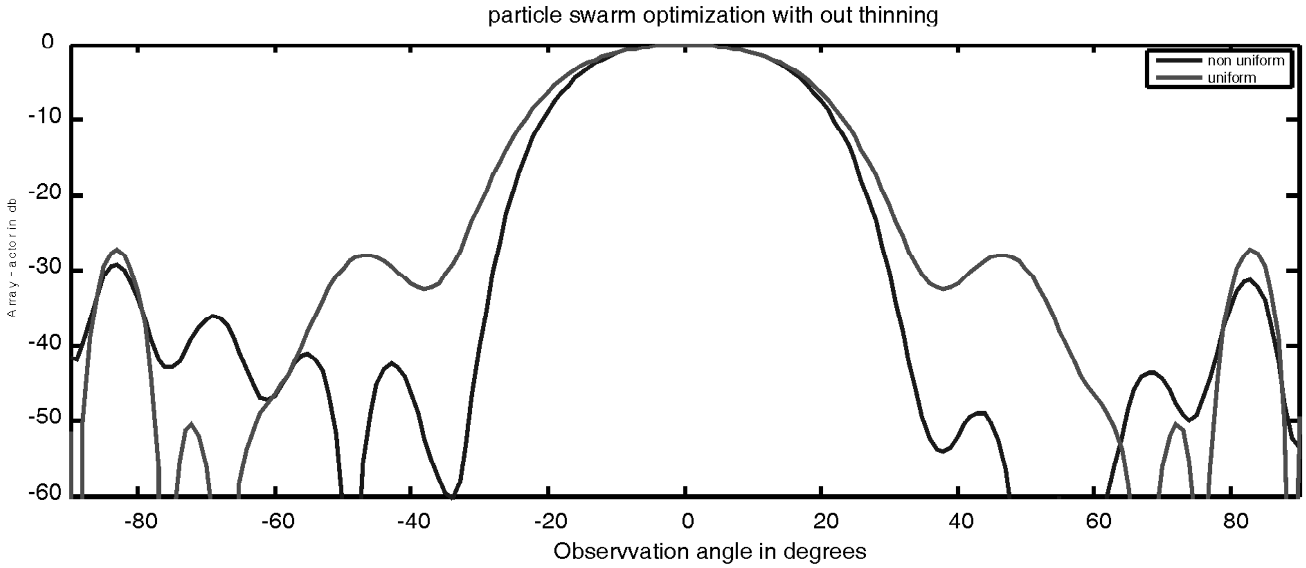


Figure 5: Differential Evolution algorithm flow chart

5. SIMULATION RESULTS

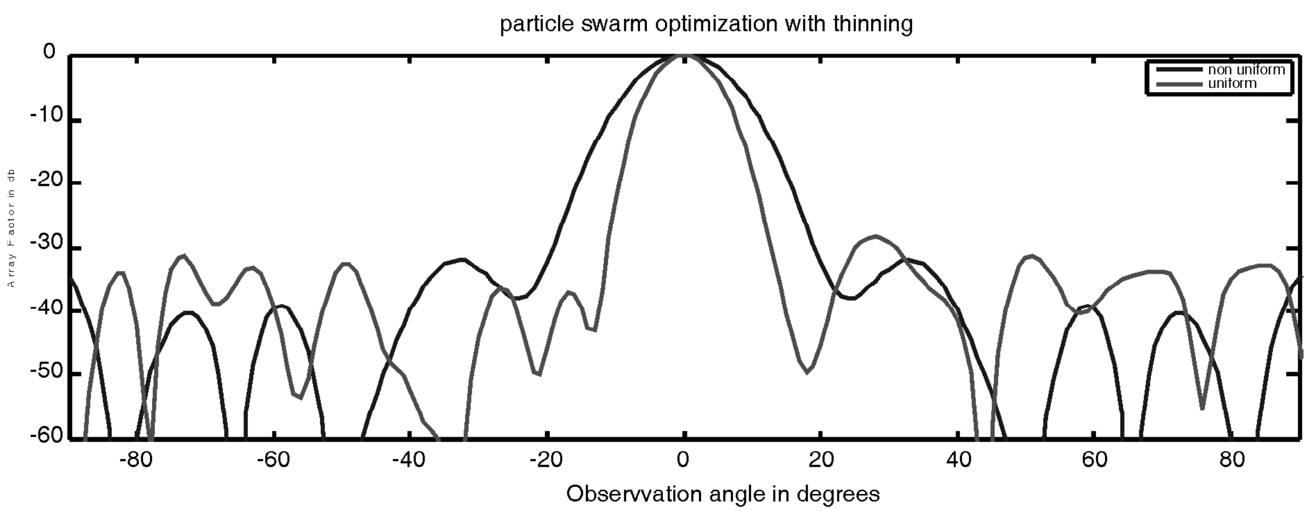
(A) Particle Swarm Optimization



(a) Without thinning: b)

Figure 6: Array factor dB vs. angle for uniform and non-uniform cylindrical elliptical using PSO without thinning

When AF is plotted for various observation angles for 3 rings and 12 antenna elements arranged for each ring along the circumference of a cylindrical elliptical antenna arrayby maintaining a constant separation distance between the elements which are uniformly excited and non-uniformly excited without thinning using PARTICLE SWARM OPTIMIZATION. Side lobe level obtained -27.5 dB for uniform and -29.2 dB for non-uniform excited elliptical cylindrical array as shown in figure 6.

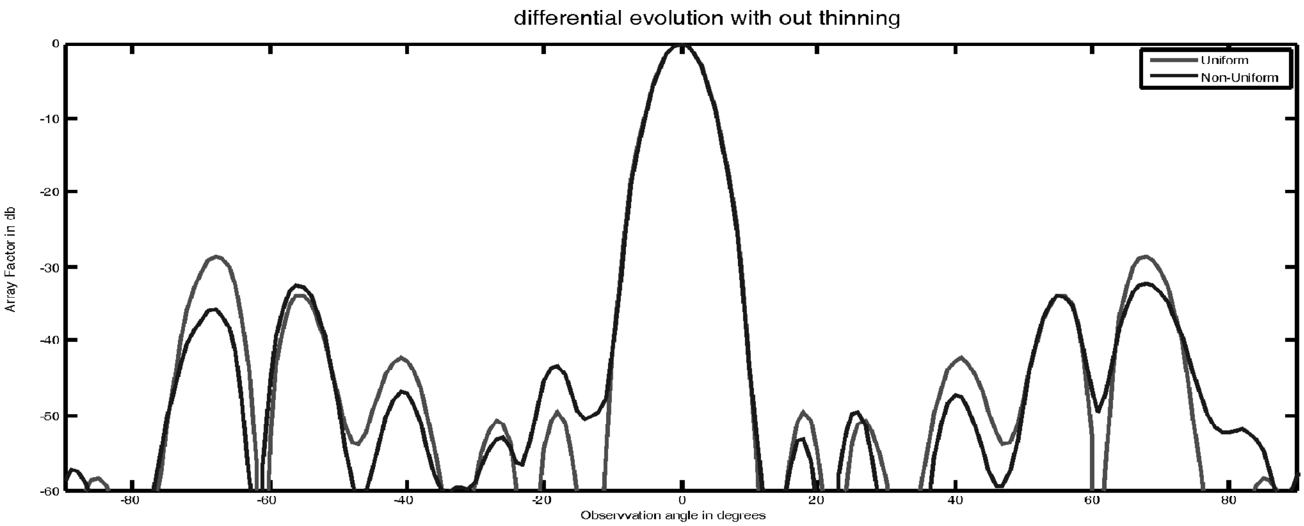


(c) With thinning: d)

Figure 7: Array factor dB vs. angle for uniform and non-uniform cylindrical elliptical using PSO with thinning

When AF is plotted for various observation angles for 3 rings and 12 antenna elements arranged for each ring along the circumference of a cylindrical elliptical antenna array by maintaining a constant separation distance between the elements which are uniformly excited and non-uniformly excited with thinning using PARTICLE SWARM OPTIMIZATION. Side lobe level obtained -28.9 dB for uniform and -32.9 dB for non-uniform excited elliptical cylindrical array as shown in figure 7.

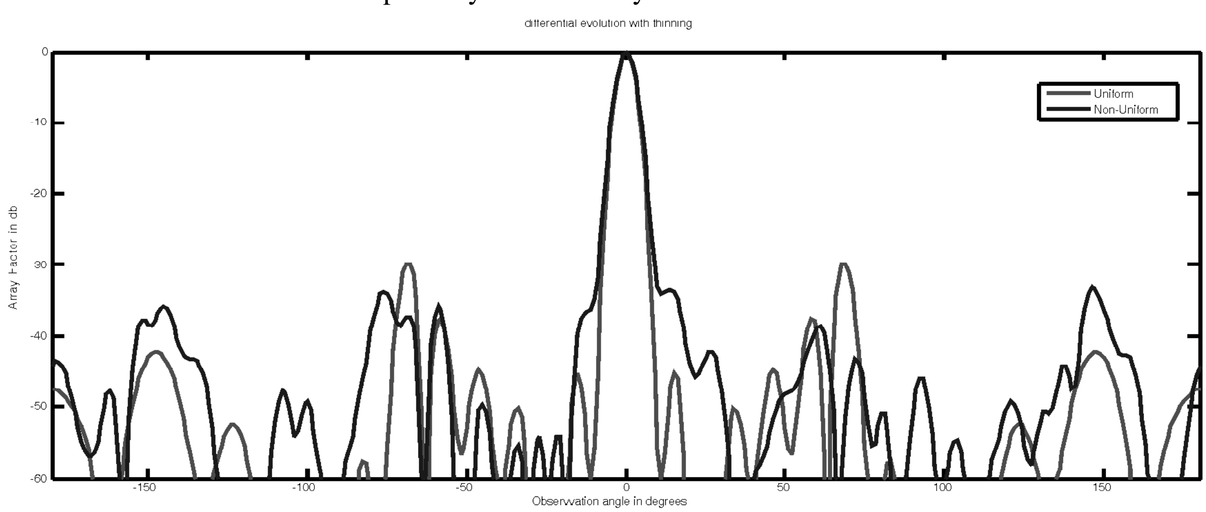
(B) Differential Evolution



(a) Without thinning

Figure 8: Array factor dB vs. angle for uniform and non-uniform cylindrical elliptical using DE without thinning

When AF is plotted for various observation for 3 rings and 12 antenna elements arranged for each ring along the circumference of a cylindrical elliptical antenna array by maintaining a constant separation distance between the elements which are uniformly excited and non-uniformly excited without thinning using DIFFERENTIAL EVOLUTION. The results thus obtained as shown in figure 8 has -28.5 dB for uniform and -32.2 dB for non-uniform excited elliptical cylindrical array.



(b) With thinning:

Figure 9: Array factor dB vs. angle for uniform and non-uniform cylindrical elliptical using DE with thinning

Thinning is a process where the number of elements in an elliptical cylindrical array excited was reduced. when AF is plotted for various observation for 3 rings and 12 antenna elements arranged for each ring along the circumference of a cylindrical elliptical antenna array by maintaining a constant separation distance between the elements which are uniformly excited and non-uniformly excited without thinning using DIFFERENTIAL EVOLUTION. In figure 9 the side lobe level was -29.8 dB for uniform and -33.8 dB for non-uniform elliptical cylindrical array.

(C) Iteration Figure

Table 1

Thinning			*Excitation amplitudes*				*PSO (slldB)*
Without thinning			**Uniform**				-27.527
	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1						
			Non uniform				
	0.776	0.3372	0.1628	0.7591	0.8175	0.6663	
	0.3531	0.4787	0.3455	0.3058	0.1295	0.5798	-29.256
	0.6194	0.1393	0.8402	0.7522	0.7747	0.5218	
	0.0102	0.2647	0.3125	0.52	0.3988	0.9295	
With thinning			**Uniform**				- 28.994
	0 1 1 1 0 0 0 1 1 0 0 1 0 0 0 0 1 1 1 1 0 0 0 0						
			Non uniform				
	0	0.3188	0.0396	0.445	0	0	
	0	0.3234	0.064	0	0	0.2115	-32.977
	0	0	0	0	0.4324	0.096	
	0.4592	0.0484	0	0	0	0.0428	

In table 1 show uniform and non-uniform excited amplitudes of a cylindrical elliptical antenna array without thinning and with thinning with respect to obtained optimum side lobe level using PARTICLE SWARM OPTIMIZATION. Non uniform amplitudes are varied between 0 to 1 randomly. Non uniform excited amplitudes elements have optimum side lobe level when compared to uniform excited amplitudes of an antenna array.

Table 2

Thinning			*Excitation amplitudes*				*DE (slldB)*
Without thinning			**Uniform**				-28.555
	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1						
			Non uniform				
	0.0302	0.932	0.6828	0.6871	0.3048	0.7043	
	0.078	0.4203	0.343	0.5037	0.3147	0.8124	- 32.251
	0.2542	0.1061	0.1432	0.1455	0.1991	0.7138	
	0.3896	0.6825	0.1352	0.0104	0.3875	0.8849	

contd. table 2

With thinning			**Uniform**				- 29.833
	1 1 1 1 1 0 1 0 1 0 1 1 0 1 1 0 1 0 0 0 1 1 1 0						
			Non uniform				
	0	0.4428	0.2886	0	0.112	0.2356	
	0.1573	0.0462	0.3958	0	0.039	0.0328	- 33.803
	0.3719	0	0.361	0	0	0	
	0.2718	0.1537	0	0.3622	0	0	

In table 2 show uniform and non-uniform excited amplitudes of a cylindrical elliptical antenna array without thinning and with thinning with respect to obtained optimum side lobe level using DIFFERENTIAL EVOLUTION. Non uniform amplitudes are varied between 0 to 1 randomly. Non uniform excited amplitudes elements have optimum side lobe level when compared to uniform excited amplitudes of an antenna array.

6. CONCLUSION

Thinning and without thinning Elliptical Cylindrical Array (ECA) is considered for uniform amplitudes and non-uniform. 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. First null beam width of uniform and non-uniform excited amplitudes are reduced with DE when compared to PSO. The side lobe level for 12 elements is -29dB and for 36 elements is -36dB for thinned non-uniform excited amplitudes using DE. The iteration figure 10 shows that with less iterations DE achieving minimum side lobe level compare to PSO [1]. The comparison shows a significant improvement for SLL using DE over PSO. [5]

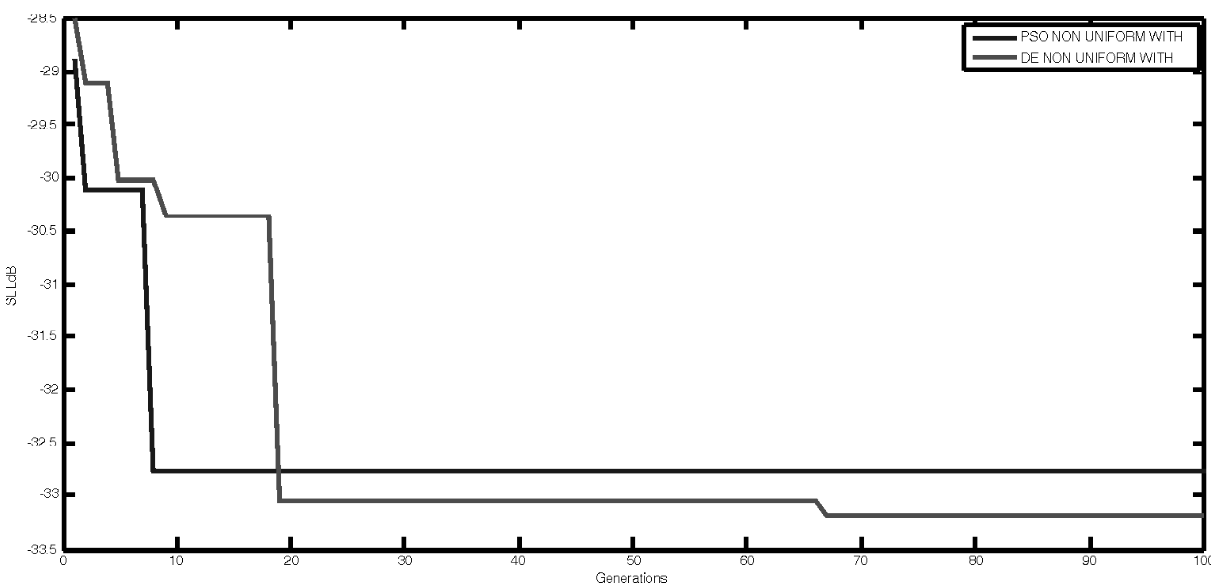


Figure 10: PSO and DE non uniform with thinning

REFERENCES

[1] R. Krishnachaitanya, M. Sainath, DR. K. V. Satyanarayanaraju "comparative analysis of reduction of side lobe level for concentric elliptical and elliptical cylindrical using DE. IEEE SCOPES 2016.

[2] A. A Lotfi neyestanak An investigation of hybrid elliptical antenna array, IET MICROW. Antenna propag. Vol.2,no.1, feb. 2008.

[3] C A Balanis theory of antenna and design, 3rd edition, john wiley & sons, 2005.

[4] Smart antennas by M. Chryssomallis, IEEE antennas and propagation magazine vol.42 no.3 pp 126-136, Jun. 2000.

[5] R Bera and J.S Roy "Optimization of thinned elliptical antenna array using PSO" , in proc. IEEE CODIS pp 527-530,Kolkata 28-29 dec. 2012.

[6] P. Rocca, G. Oliveri Differential Evolution as Applied to Electromagnetics, IEEE antenna and propagation magazine.53(1), 38-49, 2011.

[7] A.S Zare Elliptical antenna array patter synthesis with fixed side lobe level and suitable beam width by genetic algorithm" journal of telecommunication devices vol. 1,no.4 pp 113-120 dec. 2012 .

[8] Lema, gebrehiwet gebrekrstos a noval elliptical cylindrical antenna array for radar applications IEEE transactions on antenna and propagation 64.5 2016 pp 1681-1688.

[9] R Krishna chaitanya , m sainath, dr k v satyanarayanaraju "reduction of side lobe level for concentric elliptical antenna array and cylindrical elliptical antenna array using differential evolution IJRF ICKITS 2016, vol. 1 pp. No. 9-12 2016.

[10] Wang W B, Feng Q Synthesis of thinned linear and planar antenna arrays using binary PSO algorithm progress in electromagnetic research, vol.127, pp. 371-387, 2012.

[11] Rocca paolo, g oliveri, a massa Differential evolution as applied to electromagnetic, IEEE ANTENNAS AND PROPAGATION MAGAZINE 53.1 2011, pp 38-49. [21] "Pattern analysis of uniform circular array" by du K L.

[12] Najjar, mohammad shihab- yahya and nihad, design of non uniform circular antenna array using particle swarm optimization, journal of electrical engineering. 59.4 pp 216-220 2008.

[13] Shenwen wang, differential evolution without scaling factor , international journal of advancements in computing technology 4.4 2012.

[14] Shamekhi abazar an improved differential evolution optimization algorithim international jouranal of research and reviews in applied science 15.2 pp 132- 145 2013. [28] "Good parameters for differential evolution" by H Pedersen.

[15] Mohamed ali w sabry and motaz khorshid an alternative differential evolution algorithm for global optimization journal of advanced research 3.2 pp 149-165 2012.