Robust Unconstrained Circular Antenna Array Synthesis using SGOA

Anivireddy Posiyya[1] | Dr. Sunil Kumar[2]

[1]Research Scholar Dept. of ECE, KALINGA UNIVERSITY, Naya Raipur, Chhattisgarh, INDIA.
[2]Professor, Dept. of ECE, KALINGA UNIVERSITY, Naya Raipur, Chhattisgarh, INDIA.

Abstract: Circular array antennas (CAA) have become more popular after the advent of wireless communication. Side lobe level is major problem in circular antenna array synthesis. Beam forming involves in accepting desired signal and rejecting any undesired signal. Many numerical techniques and methods are proposed earlier which involved pattern synthesis with non uniform excitation amplitudes, phase adjustments and non uniform spacing parameters. In this paper, the Social Group Optimization Algorithm (SGOA) is used to determines the coefficients of current excitation for a circular array in order to obtain the desired radiation features. The radiation features are analysed using the radiation pattern plots and the performance o the algorithm is analysed in terms of the simulated convergence plot. The simulations are carried out in Matlab.

Keywords: Circular antenna array, SGOA, evolutionary tools, radiation pattern, beamsteering

DOI of the Article: https://doi.org/10.46501/IJMTST0706068

Available online at: http://www.ijmtst.com/vol7issue06.html

As per UGC guidelines an electronic bar code is provided to seure your paper

To Cite this Article: Anivireddy Posiyya and Dr. Sunil Kumar[2]. Robust Unconstrained Circular Antenna Array Synthesis using SGOA. *International Journal for Modern Trends in Science and Technology* 2021, *7*, 0706225, pp. 409-414. https://doi.org/10.46501/IJMTST0706068

Article Info. Received: 19 May 2021; Accepted: 22 June 2021; Published: 27 June 2021

INTRODUCTION

Many conventional numerical approaches are introduced to gain desired side lobe level, which are time consuming and often fail to handle multi-model problems. Now-a-days, many algorithms are proposed. So, new algorithms have to be used to obtain required radiation pattern.Using algorithms for optimization is very popular, and frequently successful in real applications. The inputs or the characteristics of a device are adjusted with the help of optimization process. To find the output mathematical process is done. There are different types of variables which are given as an input such as cost function and objective or fitness function, the output is cost or fitness [1-6].

Brief description of the design problems can be stated as obtaining optimal amplitude coefficients that produce desired radiation pattern with predefined nulls and side lobe level using different algorithms. In [4] the type of antenna used is circular antenna array and the method is used to design is Genetic Algorithm. The main objective of the study is reducing the side lobe level to increase the scanning efficiency by decreasing the beam width of ring array antenna and decreasing the weight of antenna

In [7] the type of antenna used is circular antenna array and the method is used to design is Genetic Algorithm. The basic technique considers a strong non-linear relation between array antenna elements positions and also in the array factor. The computational effort can bean endured burden for optimization methods.

In [8] it is reported that the maximum of the azimuth difference pattern of the particular array synthesized for -35 dB peak side lobes using amplitude-only excitation. The reduction is done in antenna directivity due to amplitude tapering is very low and varies between 0.09 dB and 0.3 dB. The increase in 3 dB beam-width due to amplitude excitation is modest.

Formulation of Array Factor

CIRCULAR ARRAY FACTOR:

The electric field of an array is [9-12]

$$E(r,\theta,\emptyset) = \sum_{n=1}^{N} a_n \frac{e^{-jkR_n}}{R_n}$$

Where $R_n = \sqrt{r^2 + a^2 - 2ar\cos\varphi_n}$

For r>>a, it reduces to

$R_n \cong r - a\cos\varphi_n \cong r - a(a_{pn}.\check{r})$

In a rectangular coordinate system

$$\hat{a}_{pn} = \hat{x}\cos\emptyset_n + \hat{y}\cos\emptyset_n$$

$$\hat{r} = \hat{x}\sin\theta\cos\emptyset + \hat{y}\sin\theta\sin\emptyset + \hat{z}\cos\theta$$

Therefore,

$$R_n \cong r - a\sin\theta\,(\cos\emptyset_n\cos\emptyset + \sin\emptyset_n\sin\emptyset)$$

Normal way for antenna array is

$$\frac{1}{R_n} \cong \frac{1}{r}, all\ n$$

Assumptions of an antenna array is to be

E(r,$\theta,\emptyset$)=$e^{-jka\ \sin\theta\cos(\emptyset-\emptyset_n)}$,

Where a_n is the excitation coefficient (amplitude and phase):

$$\theta_N = \frac{2\pi n}{N}$$

Normal representation of a circular array is

$$a_n = I_n e^{j\alpha_n},$$

$\varphi = kd\cos\theta + \beta|_{\theta=180}$ =-kd+$\beta = 0$

$$=> \beta = kd, for\ \theta_{max} = 180^{\circ}$$

FITNESS FORMULATION

The formulation of fitness function incorporates the objective of SLL reduction and BW control. The radiation pattern is the distribution computed AF values for every interval of azimuthal angle (θ) over a range of -90⁰ to 90⁰. Hence the fitness is formulated as a function of AF values in order to obtain the desired patterns.

$$SLL_{diff} = SLL_{des} - \max[\,|\,AF(\theta)\,|_{-90}^{\theta_0 - \frac{BW_{obt}}{2}}\,] \quad -(3)$$

$$BW_{diff} = |\,BW_{Cheb} - BW_{obt}\,| \quad -(4)$$

$$f_1 = SLL_{diff} \quad if\ SLL_{diff} > 0$$
$$= 0 \quad otherwise \quad -(5)$$

$$f_2 = SLL_{diff} \quad if\ SLL_{diff} > 0$$
$$= 0 \quad otherwise \quad -(6)$$

$$f = c_1 f_1 + c_2 f_2 \quad -(7)$$

Here the term, SLL_{diff} refers to the difference between the desired SLL (SLL_{des}) and the obtained SLL (SLL_{obt}). Similarly, the term BW_{diff} is the difference between the desired Chebyshev beam width (BW_{Cheb}) and the obtained beam width (BW_{obt})

SOCIAL GROUP OPTIMIZATION ALGORITHM

The structure of the SGOA is briefly divided into two phases like [9, 17]

a) Improvement phase
b) Acquisition phase

Further, to get acquainted with the approach SGOA, let us first interact the concept of individual and population as

Individual $I_j = [I_{j1}, I_{j2}, \ldots\ldots I_{jn}]$

And population P= $[I_1, I_2, \ldots.. I_j \ldots.. I_N]$

Here n is the dimension of the problem and 'N' is refers to the number of individuals.

Constituting the population. This can be even considered as population size.

4.1 Improvement phase:

In the improvement phase, initially the best individual with the best solution in the group is chosen and every individual improve is personal traits with inspiration from the group best individual which in other words called as updating one's own capability. This is mathematically interpreted as

I_j(t+1)=C*I_j(t) +r*[$gbest_j$(t)-I_j(t)]

Here t is the iteration member and accordingly I_j(t+1) is the new j^{th} individual trait and I_j (t) is the old j^{th} individual trait. C is a selfintrospection parameter which lies between 0 and 1.

Similarly, r is a random number obtained through a uniform random variable.

4.2 Knowledge Acquisition Phase:

In this phase, the knowledge is acquired by the individual from another individual of the same group of society. Here the individual who is acquiescent should be inferior to the acquiesce. However, the *gbest* remains the more knowledgeable and also participate in transferring certain traits to every individual in the acquisition phase. Considering the above, the corresponding mathematical interpretation of the behaviour of an individual in this phase can be given as

I_j(t+1)=I_j(t)+r_1*(I_j(t)-I_k(t))+r_2(gbest(t)-I_j(t)) if f(I_j(t))<f(I_k(t))

I_j(t+1) =I_j(t)+r_1*(I_k(t)-I_j(t))+r_2(gbest(t)-I_j(t)) else where

Here I_j and I_k are two randomly selected j^{th} and k^{th} individuals. The r_1 and r_2 are two random numbers taken from U (0,1).

Also, the fitness of the k^{th} individual is represented by f(I_k(t)).

RESULTS AND DISCUSSIONS

The simulation based experimentaion is divided into two cases. The design of circular arrays is carried using amplitude only technique. As a first case, the SLL optimization is only considered in the design of non-uniform circular antenna array (NUCAA). Later in the second case the same objective of optimizing the SLL is considered while the corresponding beam is steeredand the SLL is controlled in accordnace with the uniform distribution CAA. In the subsequent sections, the case wise results are mentioned.

Case-1: Unconstrained SLL optimization

In this Section, results pertaining to the unconstrained NUCAA design are mentoned. In this case, the problem statement invovles in determining the non-uniform amplitude distribution of the current excitation of each element which produces radiation patterns with SLL less than the SLL of uniform CA. The design is carried out for NUCA with elements 15 and 30.

The determined amplitube distribution is presented in Table 1 and Table 2 for N=15 and 30 for a CAA. The amplitude distribution is capable of providing radiation patterns with the corresponding SLL as low as possible. The corresponding raidation patterns and convergence plots for this case and N=15 and 30 are presented in Fig. 1 and Fig.2 respectively.

Case-2: With Beam Steering

Like the previous case, an unconstrained NUCAA with SLL suppression as the objective is considered in this Case-2. However, the difference lies in the position of the main beam. In this case, the corresponding main beam is shifted by 15^0. The amplitudes of current excitation are determined for 15 element and 30 element CAA such that the radiation pattern observes the beam steered to 15^o. These weights are mentioned in Table 3 and Table 4 respectively for 15 and 30 element CAA. The corresponding radiation patterns and the convergence plots are also given for 15 element CAA in Fig.3(a) and Fig.3(b) while for 30 element in Fig.4(a) and Fig.4(b) respectively.

Table 1: NUCAA amplitude distribution of 15 elements (Case-1)

S.No	Element Number	Amplitude
1	1	0.8882
2	2	0.34349
3	3	0.13768
4	4	0.21476
5	5	0.15505
6	6	0.06068
7	7	0.23632
8	8	0.86751
9	9	0.88373
10	10	0.22765
11	11	0.047719
12	12	0.212
13	13	0.12045
14	14	0.21004
15	15	0.33717

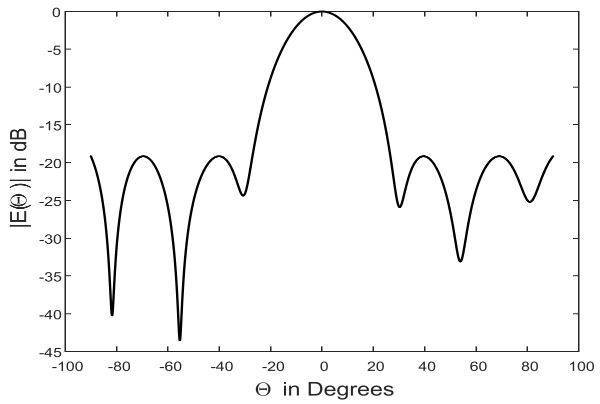

Fig.1(a): Radiation pattern of 15 element case-1 NUCA

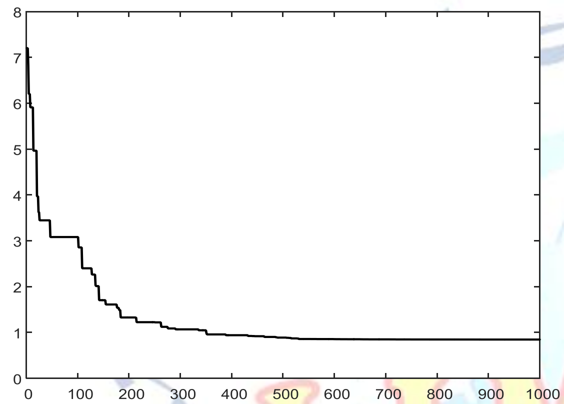

Fig.1(b): Convergence plot of simulation of 15 element case-1 NUCA

Table 2: NU amplitude distribution of 30 element NUCA of Case-1

S.No	Element Number	Amplitude
1	1	0.81566
2	2	0.9464
3	3	0.38091
4	4	0.64974
5	5	0.31393
6	6	0
7	7	0.10959
8	8	0
9	9	0.099847
10	10	0.067129
11	11	0.19603
12	12	0.14561
13	13	0.56478
14	14	0.62215
15	15	0.90986
16	16	0.67677
17	17	0.97384
18	18	0.68399
19	19	0.29426
20	20	0.18008
21	21	0.071489
22	22	0.16569
23	23	0.5158
24	24	0
25	25	0.19171
26	26	0.016426
27	27	0.19168
28	28	0.29568
29	29	0.6234
30	30	0.97754

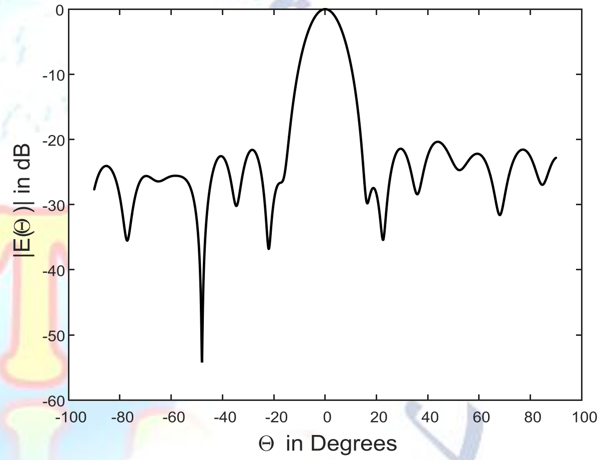

Fig.2(a): Radiation pattern of 30 element case-1 NUCA

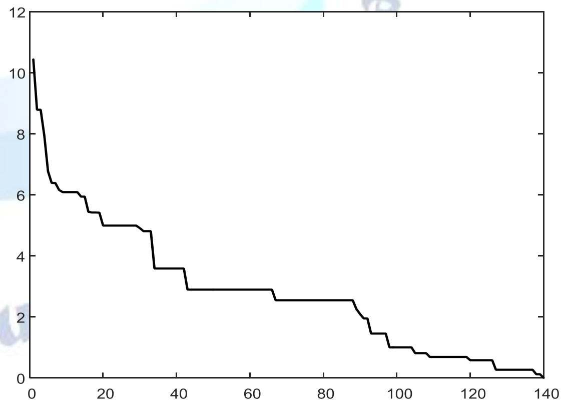

Fig.2(b): Convergence plot of simulation of 30 element case-1 NUCA

Table 3: NU amplitude distribution of 15 element NUCA of Case-1

S.No	Element Number	Amplitude
1	1	0.822298
2	2	0.7395
3	3	0.07338

4	4	0.14965
5	5	0.1745
6	6	0.14743
7	7	0.21511
8	8	0.16389
9	9	0.93912
10	10	0.69724
11	11	0.10564
12	12	0.16163
13	13	0.32275
14	14	0
15	15	0.24424

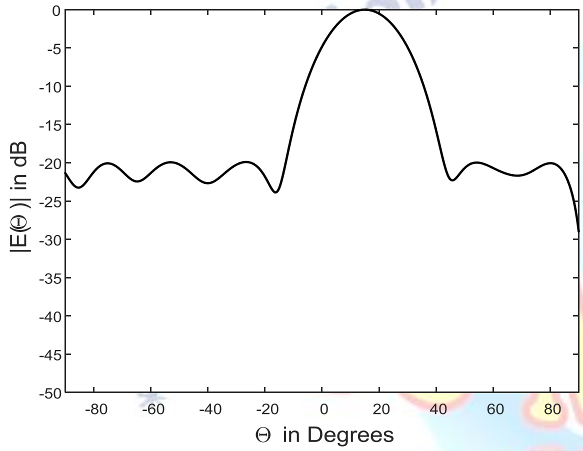

Fig.3 (a): Radiation pattern of 15 element case-2 NUCA

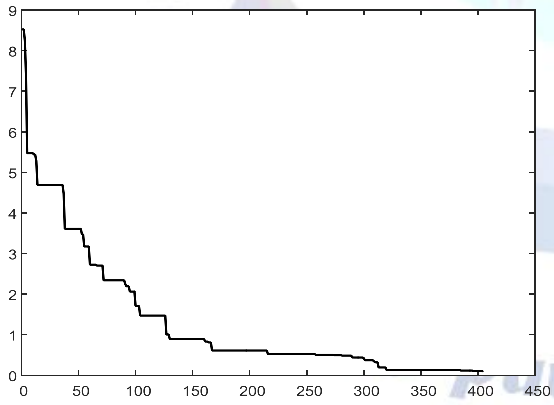

Fig.3 (b): Convergence plot of simulation of 15 element case-2 NUCAA

Table 4: NU amplitude distribution of 30 element NUCAA of Case-2

S.No	Element Number	Amplitude
1	1	0.86749
2	2	0.75409
3	3	0.95044
4	4	0.85274
5	5	0.37551
6	6	0.59533
7	7	0
8	8	0
9	9	0.13875
10	10	0.28443
11	11	0
12	12	0.25115
13	13	0.28173
14	14	0.38338
15	15	0.45773
16	16	1
17	17	0.61053
18	18	0.95692
19	19	0.70128
20	20	0.23415
21	21	0.3463
22	22	0.18247
23	23	0.1269
24	24	0.006352
25	25	0.25971
26	26	0
27	27	0.22465
28	28	0.37758
29	29	0.26143
30	30	0.17494

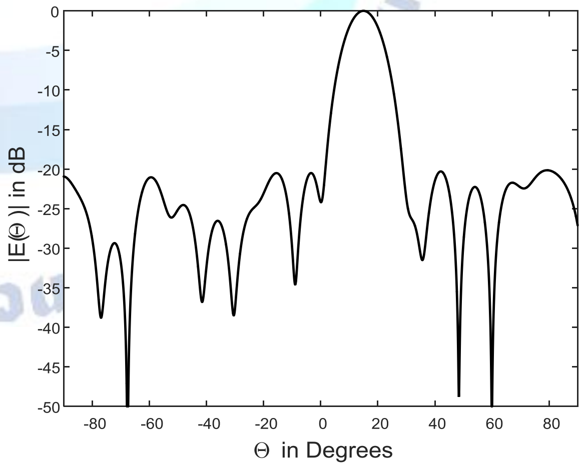

Fig.4 (a): Radiation pattern of 30 element case-2 NUCAA

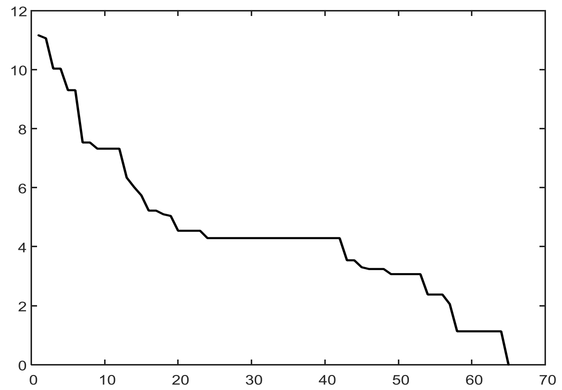

Fig.4(b): Convergence plot of simulation of 30 element case-2 NUCAA

CONCLUSIONS

The SGOA is used to synthesize NUCAA under unconstrained beam steering conditions with optimized SLL to a lower value copared to the respective uniform distribution. The robustness of the algorithm is evident with its consistent performance in designing NUCAA with SLL optimization without and with BW constraint under various beam positions. This clearly indicates the performance eof the SGOA in handling the optimization problem which are complex in nature and associated with the electromagnetic system design. Replacing the isotropic element which are theoretical radiating elements with the practical dipoles or patch antennas would be the best scope for future work.

REFERENCES

1. Bernard D. Steinberg, "Principles of Aperture and Array System Design," John Wiley and Sons, New York, 1976.
2. Chakravarthy, V. S., & Rao, P. M. (2015, March). Amplitude-only null positioning in circular arrays using genetic algorithm. In 2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT) (pp. 1-5). IEEE.
3. Chakravarthy, V. V. S. S. S., Chowdary, P. S. R., Satapathy, S. C., Anguera, J., & Andújar, A. (2019). Social group optimization algorithm for pattern optimization in antenna arrays. In Socio-cultural inspired metaheuristics (pp. 267-302). Springer, Singapore.
4. Chakravarthy, V. V. S. S. S., Sarma, S. V. R. A. N., Babu, K. N., Chowdary, P. S. R., & Kumar, S. T. (2015). Non-uniform circular array synthesis using teaching learning based optimization. Journal of Electronics and Communication Engineering, doi, 10, m9.
5. Swathi, A. V. S., Chakravarthy, V. V. S. S. S., & Krishna, M. V. (2021). Circular antenna array optimization using modified social group optimization algorithm. Soft Computing, 25(15), 10467-10475.
6. K. Guney, S. Basbug, "Null Synthesis of Time-Modulated Circular Antenna Arrays Using an Improved Differential Evolution Algorithm," Antennas and Wireless Propagation Letters, IEEE, vol.12, pp.817-820, 2013.
7. Sharaqa, N. Dib, "Circular antenna array synthesis using Firefly algorithm," Wiley Periodicals, 20721, 2013.
8. Babayigit, B., A. Akdagli, and K. Guney : A clonal selection algorithm for null synthesizing of linear antenna arrays by amplitude control, Journal of electromagnetic Waves and Applications, Vol. 20, No. 8, 1007–1020, 2006.
9. Haupt, R. L.: Phase-only adaptive nulling with a genetic algorithm, IEEE Transactions on Antennas and Propagation, Vol. 45, 1009–1015, 1997.
10. Mouhamadou, M., P. Armand, P. Vaudon, M. Rammal : Interference supression of the linear antenna arrays controlled by phase with use of SQP algorithm, Progress In Electromagnetics Research, PIER 59, 251–265, 2006.
11. Ismail, T. H. , M. M. Dawoud : Null steering in phased arrays by controlling the element positions," IEEE Transactions on Antennas and Propagation, Vol. 39, 1561–1566, 1991.
12. Akdagli, A., K. Guney, D. Karaboga: Pattern nulling of linear antenna arrays by controlling only the element positions with the use of improved touring ant colony optimization algorithm, Journal of Electromagnetic Waves and Applications, Vol. 16, No. 10, 1423–1441, 2002.