# Synthesis of Linear Antenna Array with Optimal SLL and Beam Width

Grandhi Challa Ram, D. Girish Kumar, G. R. L. V. N. S. Raju

***Abstract***: ***In many areas of wireless communications, there is a need for high directive radiating beams. To generate such a high directive beams, a linear array of antennas is preferred to that of using a single antenna. Generally a narrow beam width tends to have high directivity but specific to the applications there is also a need for wider beam widths. In case of a radar application it requires a narrow beam width when it is operating in target mode and on the other hand it requires wider beam width when it works under search mode. These optimal beam width variations can be obtained by using Optimization techniques. In this paper Biogeography based Optimization algorithm is used to generate narrow and wide beam widths for a Linear array antenna. While we try to optimize the beam widths of a linear array it will lead to an increase in the side lobe level which make it unavailable for practical applications. As a sensible antenna should always posses a very low side lobe levels a tradeoff should be made for both side lobe level and beam width. This tradeoff which has an optimal side lobe level along with directivity can be achieved by proposed fitness function optimization. The results obtained by using Genetic algorithm and Biogeography based optimization algorithm are compared.***

***Keywords***: ***Biogeography Based Optimization (BBO), First Null Beam width (FNBW), Genetic Algorithm (GA), Side Lobe Level (SLL).***

## I. INTRODUCTION

Antenna is the most important framework in any of the wireless communication systems. The performance of the communication system will relay on the type of antenna used. For such an application where the directivity plays a vital role should go for a linear array antenna as these array antennas will give up good directivity as when compared with not one of several. The directive beam radiations from these antennas are available in variable ranges but on the obligation of the application the antennas array must be synthesized.

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A linear antenna array can be sculpted by allocating a number of antennas over a straight path with a defined spacing among them. As it is been evident that an array antenna comes up with good directivity than the independent antenna radiation we go for use of array antenna to generate a good directive beam.

To synthesize a linear antenna is perplexing as its radiation depends on its physical variable parameters such as the number of antennas in array, the distance with which they are deployed and their respective phases. By varying any of these parameters the radiation of the array can be modified. Side lobe levels in the radiation pattern indicates the inefficiency of the antenna as an increase of side lobe level will leads to unwanted radiations and interference. An effective antenna radiation pattern must possess a very low side lobe levels in radiation pattern.

The desired side lobe level can be obtained by optimization algorithms like genetic algorithm and biogeography based optimization algorithm. In general optimization algorithms are iterative structure which gives the optimal output for a given set of inputs. In order to achieve low side lobe level the array factor is used as fitness function in optimization algorithm. In a similar way to increase the directivity the beam width has to be decreased this can also be achieved by using FNBW as the fitness function in optimization algorithm. When we try decrease the beam width of the array antenna there will be a raise in the side lobe levels and vice versa, which makes it ineffective. A narrow main beam width with low side lobe levels can be obtained by considering both these parameters in the fitness function of the optimization algorithm. In this paper a narrow main beam is obtained without significantly increasing side lobe level by using optimization algorithms like GA and BBO. These algorithms are implemented in MATLAB 2019 software.

This paper is briefed as follows. The section II gives details about the preliminaries; section III briefs the operation of GA algorithm, section IV and V gives the brief of BBO algorithm and Results respectively.

## II. PRILIMINARIES

### A. Linear Antenna Array

A linear antenna array (LAA) can be sculpted by allocating a number of antennas over a straight path with a defined spacing among them. As it is been evident that an array antenna comes up with good directivity which is be given by its array factor [1].

The equation for array factor is given below by considering N elements in a linear array

$$AF = I_0 e^{j\beta z_0 \cos\theta} + I_1 e^{j\beta z_1 \cos\theta} + ....... + I_{N-1} e^{j\beta z_{N-1} \cos\theta} \quad (1)$$

$$I = 1 + e^{jz} + e^{j2z} + ........ + e^{j(n-1)} \quad (2)$$

$$Z = 2\pi(\frac{s}{\lambda})\cos\phi + \alpha \quad (3)$$

Where I represent the excitation of each element in the array and s denotes the spacing between the elements and $\phi$ represents the phase value. From these equations it is evident that array factor can be varied by all these parameters.

### B. Cost function

Cost function (cf) or the fitness function is important part of optimization algorithms [2]. The fitness functions are defined on the objective of which parameter is to be optimized. If the objective of optimization is to reduce the side lobe levels then the cost function (cf) is given by equation

$$cf = [abs(SLL(obtained) - abs(SLL(required)] \quad (4)$$

When the objective is to reduce the first null beam width then the cost function is given by the following equation

$$cf = [abs(FNBW(obtained) - abs(FNBW(required)] \quad (5)$$

The cost function to optimize both SLL and FNBW simultaneously to obtain narrow beam with low side lobes is given by

$$cf = [D1 * \{FNBW(req) - FNBW(obt)\} + D2 * \{abs(SLL(obt) - abs(SLL(req)\}] \quad (6)$$

In the above equation the constants D1 and D2 are varied on the preference between the SLL and FNBW. D1 value is to taken high when priority is given for the reduction of FNBW and similarly the value of D2 is taken high when the SLL is to reduced.

## III. GENETIC ALGORITHM

This algorithm is used to search for the best combination of inputs until the outcome will satisfy the termination criteria. As from the name genetic this algorithm uses the DNA genetics process of obtaining good quality genes of children by fusing the parent genes [3]. This algorithm works with two stages first one is cross over where parent genes are crossed to obtain the second generation with improved qualities and then these second generation genes are mutated so get the required quality. By using these principles to the fitness function the optimized output can be obtained [4]. The brief of the algorithm is shown in “Fig. 1”, the initial population are the given set of excitation with fixed number of elements in the array. In this paper optimization of SLL and FNBW is done by using genetic algorithm by keeping both phase and distance between the elements constant and varying the element excitation and number of elements.

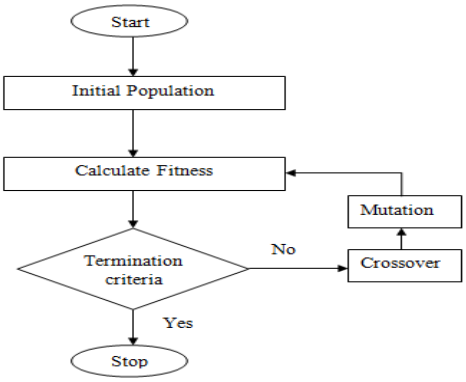


**Fig. 1. Genetic Algorithm**

## IV. BIOGEOGRAPHY BASED OPTIMIZATION

This algorithm is superior to genetic algorithm even though it is much similar to genetic algorithm. By the name of the algorithm it is clear that this algorithm uses the principle of nature habitation [5]. It is an iterative algorithm in which it checks whether the conditions are suitable for habitation or not. The parameter which can judge the existence of habitant in an island is known as Habitat Suitability Index (HSI). Those islands with high value of HSI will have good emigration rate and very low immigration rate.

BBO works on the principle that the species will always tends to stay in places which have high HIS and they always move from the locations with very low HIS [6]. The brief stages in BBO are calculation of immigration and migration rates, migration and mutation operations. The structure of BBO is shown in “Fig. 2”, optimization of SLL and FNBW is done by using BBO algorithm by keeping both phase and distance between the elements constant and varying the element excitation and number of elements.

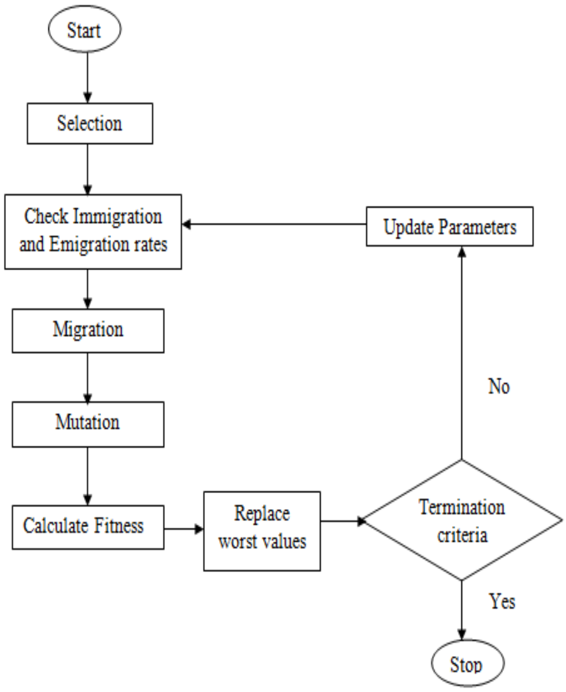


**Fig. 2.Biogeography Base Optimization**

## V. RESULTS

These results are obtained by using MATLAB2019 software. Results are obtained for the optimization of both First null beam width and side lobe level.

### A. Results for Uniform Linear Antenna Array

In Uniform LAA the radiating elements are arranged linearly with uniform spacing (s) between each antenna in the array which is taken as half of the wavelength. The amplitude of all the elements is constant. For uniform linear array results are obtained for SLL and FNBW. The results are tabulated below.

**Table- I: Results of Uniform Linear Array Antenna**

| No.of elements (N) | Spacing between elements (s) | SLL (dB) | FNBW (degrees) |
|---|---|---|---|
| 30 | 0.5 $\lambda$ | -13.21 | 9.20 |
| 20 | 0.5 $\lambda$ | -13.19 | 12.40 |
| 16 | 0.5 $\lambda$ | -13.14 | 16.00 |
| 10 | 0.5 $\lambda$ | -12.97 | 22.91 |

Radiation patterns for Array factor of uniform linear array antenna are given in the following figures.

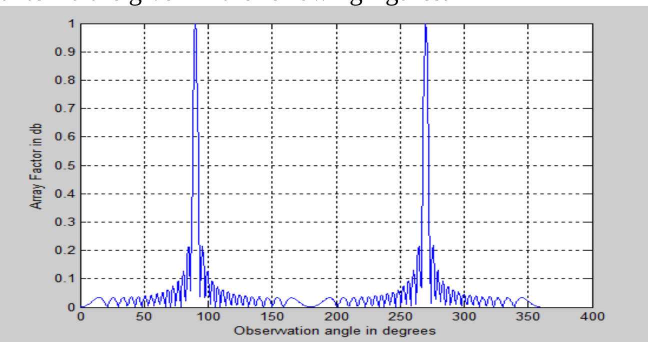


**Fig. 3. Radiation plot for uniform linear array with N=30**

### B. Results using Genetic Algorithm

Genetic algorithm is used to optimize the SLL and FNBW for non uniform linear array antenna by varying the amplitudes of the radiating antenna elements in the array.

The cost functions as mentioned above are used to optimize SLL and FNBW individually and the tradeoff is obtained by optimizing them simultaneously at once.

**Table- II: Results of SLL using GA optimization**

| No.of elements (N) | Spacing between elements (s) | SLL (dB) |
|---|---|---|
| 30 | 0.5 $\lambda$ | -20.02 |
| 20 | 0.5 $\lambda$ | -19.87 |
| 16 | 0.5 $\lambda$ | -18.91 |
| 10 | 0.5 $\lambda$ | -18.52 |

Radiation patterns for Array factor of non uniform linear array antenna using GA are given in the following figures.

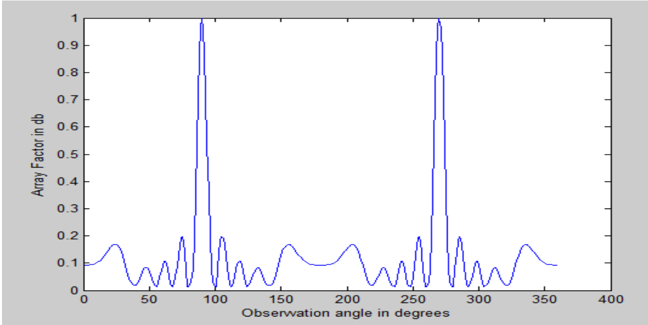


**Fig. 4.Radiation plot for SLL using GA with N=10**

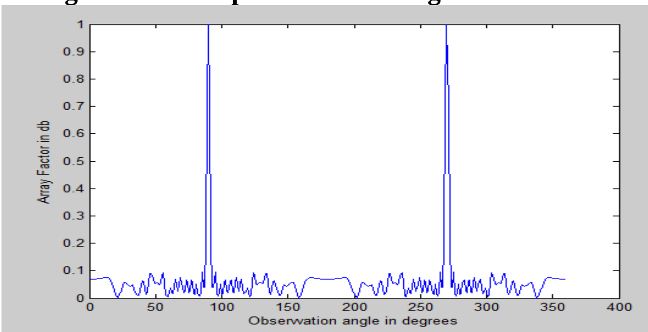


**Fig. 5.Radiation plot for SLL using GA with N=10**

**Table- III: Results of FNBW using GA optimization**

| No.of elements (N) | Spacing between elements (s) | FNBW (degrees) |
|---|---|---|
| 30 | 0.5 $\lambda$ | 6.84 |
| 20 | 0.5 $\lambda$ | 9.38 |
| 16 | 0.5 $\lambda$ | 12.35 |
| 10 | 0.5 $\lambda$ | 17.91 |

Radiation patterns for Array factor of non uniform linear array antenna using GA are given in the following figures.

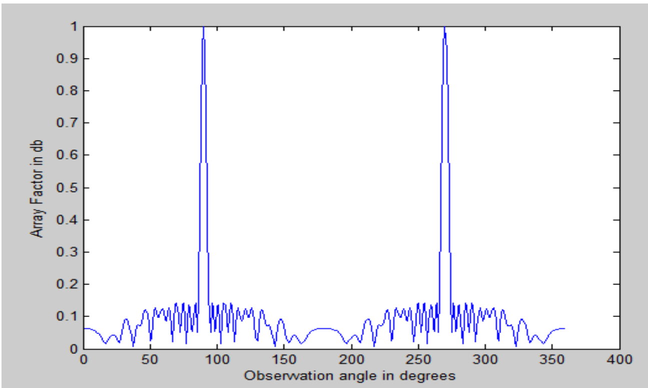


**Fig. 6. Radiation plot for FNBW using GA with N=30**

**Table- IV: Results of SLL & FNBW using GA optimization**

| No.of elements (N) | Spacing between elements (s) | SLL(dB) and FNBW(degrees) |
|---|---|---|
| 30 | 0.5 $\lambda$ | 8.0 -13.81 |
| 20 | 0.5 $\lambda$ | 11.4 -13.36 |
| 16 | 0.5 $\lambda$ | 14.8 -13.14 |
| 10 | 0.5 $\lambda$ | 21.4 -13.04 |

### C. Results using Biogeography Based Optimization

BBO is used to optimize the SLL and FNBW for non uniform linear array antenna by varying the amplitudes of the radiating antenna elements in the array.

The cost functions as mentioned above are used to optimize SLL and FNBW individually and the tradeoff is obtained by optimizing them simultaneously at once.

**Table- V: Results of SLL using BBO optimization**

| No.of elements (N) | Spacing between elements (s) | SLL (dB) |
|---|---|---|
| 30 | 0.5 $\lambda$ | -27.69 |
| 20 | 0.5 $\lambda$ | -26.11 |
| 16 | 0.5 $\lambda$ | -24.55 |
| 10 | 0.5 $\lambda$ | -22.32 |

Radiation patterns for Array factor of non uniform linear array antenna using BBO are given in the following figures.

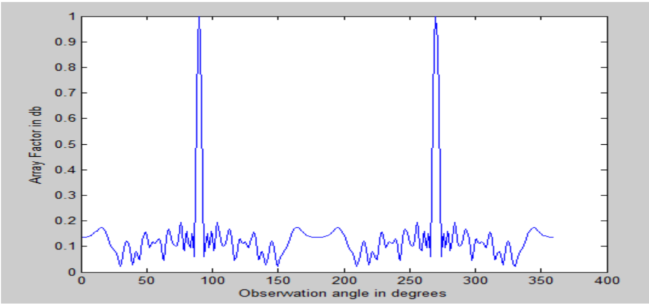


**Fig. 7.Radiation plot for SLL using BBO with N=30**

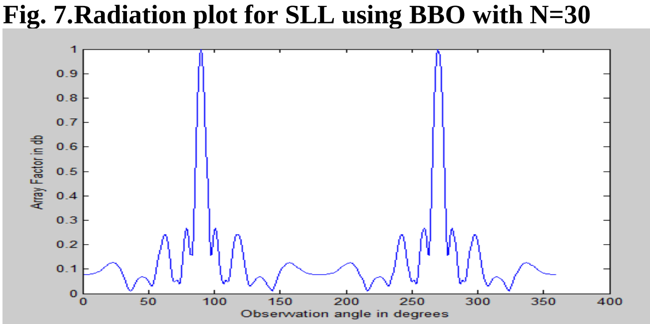


**Fig. 8.Radiation plot for SLL using BBO with N=16**

**Fig. 9.**

**Table- VI: Results of FNBW using GA optimization**

| No.of elements (N) | Spacing between elements (s) | FNBW (degrees) |
|---|---|---|
| 30 | 0.5 $\lambda$ | 5.22 |
| 20 | 0.5 $\lambda$ | 7.39 |
| 16 | 0.5 $\lambda$ | 8.77 |
| 10 | 0.5 $\lambda$ | 12.82 |

Radiation patterns for Array factor of non uniform linear array antenna using GA are given in the following figures.

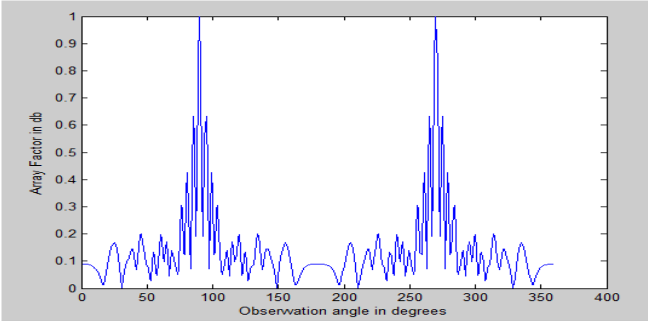


**Fig. 10. Radiation plot for FNBW using BBO with N=30.**

**Table- VII: Results of SLL & FNBW using BBO optimization**

| No.of elements (N) | Spacing between elements (s) | SLL(dB) and FNBW(degrees) |
|---|---|---|
| 30 | 0.5 $\lambda$ | 6.5 -21.31 |
| 20 | 0.5 $\lambda$ | 9.3 -19.56 |
| 16 | 0.5 $\lambda$ | 12.3 -18.74 |
| 10 | 0.5 $\lambda$ | 16.7 -17.14 |

## VI. CONCLUSION

In this paper the optimal values of SLL and FNBW are obtained by using GA and BBO optimization algorithms. Optimal values are obtained by considering spacing between elements and phases to be constants. By using BBO algorithm for linear array antenna SLL is reduced to -27.69dB and FNBW reduced to 5.22 degrees. On the other hand by sing GA for LAA the SLL and FNBW are reduced to -20.02dB and 6.84 degrees respectively.

The results obtained for simultaneous optimization of SLL and FNBW using BBO are -21.31dB and 6.5 degrees respectively. The above result states that even with the decrease in FNBW it has a low SLL value which makes it available for practical applications. By comparing the results of BBO algorithm yields better results to that of GA optimization.

## REFERENCES


1. S. Liang, T. Feng, and G. Sun, “Sidelobe-level suppression for linear and circular antenna arrays via the cuckoo search–chicken swarm optimisation algorithm,” *IET Microwaves, Antennas & Propagation*, vol. 11, no. 2, pp. 209–218, 2016
2. D. Z. Zhu, P. L. Werner, and D. H. Werner, “Design and optimization of 3-D frequency-selective surfaces based on a multiobjective lazy ant colony optimization algorithm,” *IEEE Transactions on Antennas & Propagation*, vol. 65, no. 12, pp. 7137–7149, 2017.
3. B. Smith, “An approach to graphs of linear forms (Unpublished work style),” unpublished.
4. H. Li, Y. Liu, G. Sun, A. Wang, and S. Liang, “Beam pattern synthesis based on improved biogeography-based optimization for reducing sidelobe level,” *Computers & Electrical Engineering*, vol. 60, pp. 161–174, 2017.
5. Er, M. H., “Linear antenna array pattern synthesis with prescribed broad nulls," *IEEE Trans. Antennas Propagat*., Vol. 38, 1496-1498, 1990.
6. K. K. and Y. L. Lu, \Sidelobe reduction in array pattern synthesis using genetic algorithm," *IEEE Trans. Antennas Propagat*., Vol. 45, 1117-1122, 1997.

7. A. Balanis, Antenna Theory Analysis and Design, 2nd Edition, John Willy & sons Inc, New York, 1997.
8. G.challa ram and N.venkateswara rao, "Optimization of SLL and FNBW in linear arrays using PSO optimization", *International conference on Communication, computing and Internet of things IC3IoT 2018*.
9. Stephen J.Blank, "Antenna Array Synthesis Using Derivative, Non-Derivative and Random Search Optimization", *IEEE Sarnoff Symposium*, DOI 10.1109/SARNOF. 2008.4520115, pp 1-4, May 2008.
10. G.Challa ram and N.Venkateswara rao, "Synthesis of Linear array antenna with wide range of beamwidths using DE algorithms". *International Journal of Engineering & Technology*, 7 (4.5) (2018) 273-276.
11. G.Challa ram and N.Venkateswara rao, "Synthesis of Linear array antenna for required range of beamwidth using optimization algorithms". *International Journal of Engineering & Technology*, 7 (3.31) (2018) 16-20.

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