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Comparative Analysis of Optimizing Techniques Used In Linear Antenna Array Designing

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ABSTRACT
In wireless, microwave, long distance applications there is a need for low side lobes with narrow beams. The optimization techniques which are inspired from nature are used to reduce the trade-off between side lobe reduction and beamwidth greatly. In this paper, the optimization of SLL is done for 16-element symmetrical linear antenna array using four different optimization techniques GA, BBO, FPA and Jaya Algorithm. The results describe that Jaya Algorithm showed better results compared to other optimization techniques. The convergence rate of Jaya Algorithm is good. It works only on common algorithm parameters like population size, number of iterations unlike other algorithms. It is easy to implement and more effective in providing better results in same number of iterations when compared with other algorithms.
Keywords: Antenna array, Beamwidth, Optimization Algorithms, Sidelobe level.

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I. INTRODUCTION

In many fields like military, mobile, biomedical, point-to-point, wireless there is a necessity of narrow beam with low side lobe levels. The modification in parameters of the antenna array (like the current excitations of the antenna elements, the phase between the antenna elements and distance between the antenna elements) results in variation of radiation pattern without change in physical structure of antenna. In radiation characteristics of the antenna array there is an inverse relation between beamwidth and SLL. The reduction in side lobes results in large beamwidth and vice versa. The conventional methods like Fourier method etc. cannot reduce this trade-off between SLL and beamwidth. The random stochastic techniques are used as optimization algorithms to reduce this trade-off. The dipole antennas are generally used in radio frequency antenna designing.

The aim of this paper is to analyze different optimizing techniques used for linear dipole antenna array designing. The current excitations of antenna elements are optimized using optimization techniques. The phase excitations and distance between the elements are kept constant. In this paper, four algorithms: GA, BBO, FPA and Jaya Algorithm are used for optimization of SLL of array of dipole elements and the results for 16-element array of dipole elements are compared and the radiation characteristics are plotted. Out of all the four algorithms Jaya Algorithm achieved better results. Jaya Algorithm converges to best solution faster than other algorithms. It is inspired from teaching learning based optimization technique approach. It has no algorithm specific parameters like mutation and crossover probabilities in genetic algorithm, mutation probability in BBO etc. So it is easy to implement and powerful compared to others.

II. ANTENNA ARRAY

2.1. Symmetrical Linear Antenna Array:

The group of antenna elements arranged along one axis is called linear antenna array. It is one dimensional array.

Dipole antenna is constructed with two thin dipole elements that are symmetrically fed at the centre by a balanced two wire transmission line.

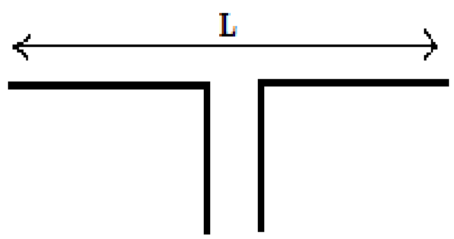

Fig.1. Half wave Dipole antenna element

The far field radiation pattern of the half wave dipole antenna is given by

$$EP(\theta) = \frac{\cos\left(\frac{\pi}{2} cos\theta\right)}{sin\theta}$$

Where θ represents the angle measured from the axis of the dipole to the line of sight. The array factor of 2N dipole antenna elements arranged in symmetrical LAA is given by

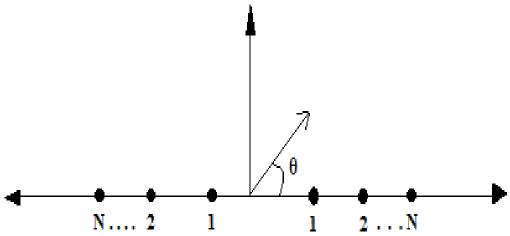

Fig.2. Symmetrical Linear Antenna Array

$$AF = 2EP(\theta) \sum_{n=1}^{N} I_n \, cos\left(\left[\frac{2n-1}{2}\right] \Phi\right)$$

Where, AF = Array factor, I_n = Current excitation of n^{th} element, Total phase of antenna array, Φ = βdcosθ + α, Phase constant, $\beta = \frac{2\Pi}{\lambda}$, d = distance between the antenna elements, θ = Observation angle, α = Phase of antenna element.

III. OPTIMIZATION ALGORITHMS

3.1. Genetic Algorithm (GA)

GA is a stochastic search algorithm. GA is inspired from Charles Darwin's theory of evolution. This process starts with the selection of fittest from the population. The only reason for choosing fittest is the new generation must be better than the old generation. The produced offspring's will have the characteristics of the parents. There are five phases in the algorithm: 1. Initialization, 2. Selection, 3. Crossover, 4. Mutation and 5. Termination. The two main operators in GA for producing the new generation are: 1. Crossover, 2. Mutation. In crossover operation the produced offspring will have characteristics of both the parents. In mutation, there will be sudden and abrupt change in offspring which make them different from old generation. It is done at very low probability. Mutation occurs to maintain diversity in population and prevent early convergence. The process is continued until the termination criterion is met. The number of iterations is considered as termination condition.

3.2. Biogeography Based Optimization (BBO)

BBO is a population based evolutionary algorithm inspired from distribution of species in the nature. The species migrate between different islands for survival. Each habitant will have sustainability index (SI) which defines measure of efficiency for living in that habitant. SI depends on several conditions like rainfall, temperature, diversity of species etc. The habitants with high SI have high emigration rate and low immigration rate whereas low SI habitants have these rates in vice-versa. The habitants with high SI have large population as they are fit for living. These habitants are more suitable to live but the competition for survival between the species increase with population. Some species migrate to low SI habitants for survival as they cannot sustain in competition. The increase in population in low SI habitants increases its living conditions. In this way, immigration and emigration rates depend on the population of species in habitants. The population is initialized and updated iteratively using both migration and mutation operation until the optimal solution is attained.

3.3 Flower Pollination Algorithm (FPA)

FPA is population based algorithm which is inspired from plant reproduction strategy through pollination. There are two types of pollination: 1. Global pollination, 2. Local pollination. Global pollination involves biotic and cross pollination whereas local pollination includes abiotic and self pollination. It is a swarm based optimization technique. This algorithm has many impressive characteristics like robustness, flexible. It need only less algorithm specific parameters. FPA is initiated with random solutions. The two main operators in FPA are: Local pollination operator and global pollination operator. All the solutions are modified using these operators iteratively in order to attain best solution. Flower constancy is considered as reproduction probability that is proportional to the similarity between any two flowers. In local pollination operator, two randomly selected members from the population are used update the current solution. The current solution is updated best solution in population along with Lévys flights in global pollination operation. The switching probability p ϵ (0, 1) is used for selection between global and local pollination operations. The process is continued until the termination criterion is met.

3.4 Jaya Algorithm:

Jaya Algorithm is a novel algorithm. Jaya means "Victory" in Sanskrit. It is a good and powerful algorithm when compared with other algorithms in providing best optimum solution.

Any population based heuristic algorithms can be broadly classified into two types: 1. Evolutionary algorithms (EAs) and 2. Swarm intelligence (SI) algorithms. The exploration and exploitation abilities of these algorithms mainly depend on algorithm specific parameters. For example in GA, the crossover operator works as exploration operator, whilst the mutation operator works as exploitation operator. The improper tuning of crossover and mutation probabilities will result in premature convergence. The controlling and tuning of these parameters is crucial in these algorithms and have great impact in finding global optimum. The process of balancing both the exploration and exploitation operators is undoubtedly a tedious and time consuming process. After examining complexity in controlling algorithm specific parameters a new concept TLBO is introduced which depends on only common controlling parameters like population size, number of iterations etc. Jaya algorithm is somewhere similar to TLBO. It belongs to the category of algorithm specific parameter less algorithms. In TLBO there are two phases: Teacher and Learners phase. Jaya algorithm works on only teacher phase in TLBO. It does not require learner's phase in TLBO. The main concept of this algorithm is to move towards the best solution avoiding the worst solutions obtained in the iteration. The tendency to move closer to the success avoiding the failure will results in victory. This mechanism makes the algorithm victorious.

The process includes five steps: 1. Initialization, 2. Evaluation, 3. Updation, 4. Selection and 5. Termination. The population is initialized and fitness function is calculated. The best and worst solutions are identified and the solutions are updated iteratively using the function:

$$S'_{j,k,i} = S_{j,k,i} + r_{1,j,i}(S_{j,best,i} - S_{j,k,i}) + r_{2,j,i}(S_{j,worst,i} - S_{j,k,i}) \quad (3)$$

Where 'j' represents design variable (1,2,...m), 'k' denotes the candidate solution (1,2,...,n) and 'i' represents the iteration number. m is the length of design variable which is equal to length of antenna array. n is the size of the population. $S'_{j,k,i}$ is updated solution of $S_{j,k,i}$ using (3). $S_{j,best,i}$ is the best solution in that particular iteration. $S_{j,worst,i}$ is the worst solution in that particular iteration. $r_{1,j,i}$ and $r_{2,j,i}$ are random numbers and must be between (0,1). If the updated solution is better than previous one it is updated else it remains same. The process is continued until the termination criterion is met.

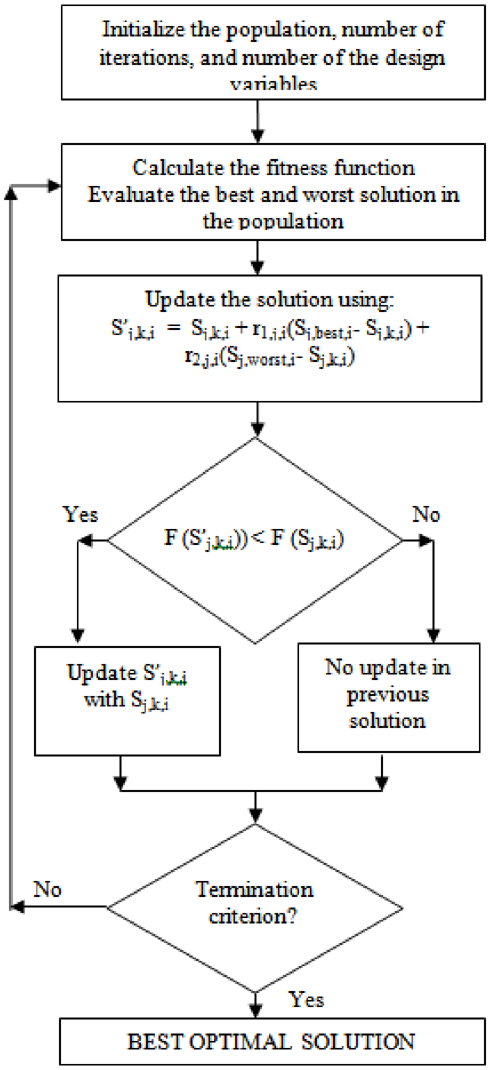

Fig.3. Flowchart of Jaya Algorithm

IV. RESULTS AND DISCUSSIONS

In this paper, the 16-element linear array of dipole elements is optimized using four algorithms: GA, BBO, FPA and Jaya Algorithm. The MATLAB 2016 is used for simulation. The optimized radiation patterns using four algorithms of 16-element antenna array is shown in Fig.3. The current excitations of the antenna array are optimized using the optimization technique. The phase between the antenna elements is kept constant, $\alpha = 0^0$. The distance between the antenna elements is kept constant, d = 0.5. The fitness function used to reduce the SLL is,

$F = \max(20\log_{10}(AF(\theta)/AF\_max))$,
where θ: [0, 90)

Common Algorithm parameters:
Number of iterations=100
Number of population = 100
Length of antenna array = 16

Algorithm Specific Parameters in GA:
Crossover Probability: 0.85
Mutation Probability: 0.01
Algorithm Specific Parameters in BBO:
Maximum Migration rates:
Maximum immigration rate, $I_b = 1$
Maximum emigration rate, $E_b = 1$
Mutation probability = 0.04
Elitism parameter: 2
Algorithm Specific Parameters in FPA:
Switching probability: p ϵ (0, 1),
Lévy's distribution:
d = step size in Lévy's distribution = $\frac{u}{|v|^{\frac{1}{\beta}}}$
u and v are normally distributed random variables.
Parameter, β =1.5.
$u \sim N(0, \sigma_u^{\ 2})$
$v \sim N(0, \sigma_v^{\ 2})$ where

$$\sigma_u = \left\{\frac{\Gamma(1+\beta)\sin(\Pi\beta/2)}{\Gamma((1+\beta)/2)\beta 2^{\frac{(1-\beta)}{2}}}\right\}^{\frac{1}{\beta}}, \ \sigma_v = 1$$

Jaya algorithm requires only common algorithm parameters.

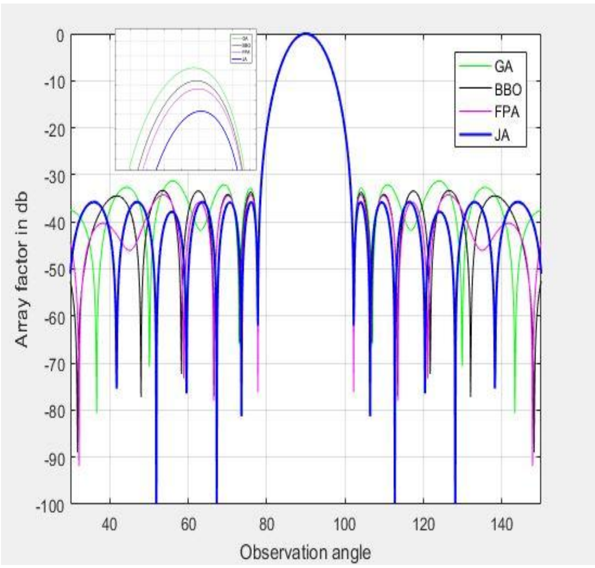

Fig.4. Radiation pattern of 16-element dipole antenna linear array

Table.1. SLL of 16-element linear array of dipole elements

Algorithm	SLL(dB)
Linear	-13.14706
GA	-31.3235
BBO	-33.3507
FPA	-34.2557
Jaya Algorithm	-35.7641

Table.2. Current Excitations of 16-element linear array of dipole elements

Algorithm	Current Excitation
Linear	1,1,1,1,1,1,1,1
GA	1.0000,0.8990,0.7753,0.6793, 0.5586, 0.3277,0.2422,0.1113
BBO	1.0000 ,0.9502,0.8264,0.7029 0.5221,0.3559,0.2785,0.1039
FPA	1.0000,0.9135,0.8280,0.6997, 0.4962,0.3908,0.2386,0.1297
JA	1.0000,0.9482,0.8386,0.6903, 0.5355, 0.3813,0.2368,0.1622

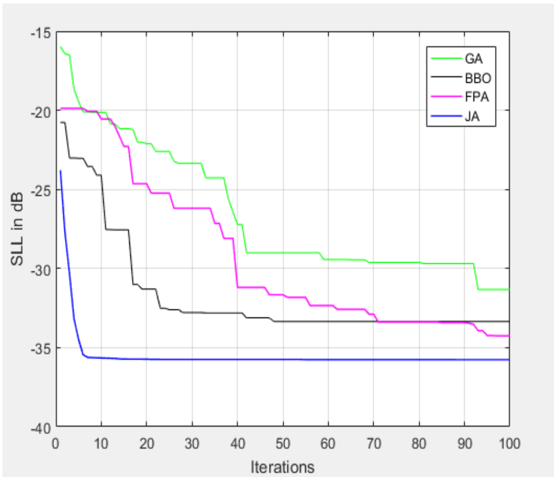

Fig.5. Convergence rate of four optimization algorithms

V. CONCLUSION

In this paper, comparative analysis on optimization of SLL for 16-element linear array of dipole elements using four different optimization algorithms GA, BBO, FPA and Jaya Algorithm is done and results are compared. The current excitations of the antenna array are modified and optimized results are tabulated in Table-2.From table-1 it is clear that out of all the techniques, Jaya algorithm provided the best SLL of -35.7641dB with 24.4^0 beamwidth. Jaya algorithm converges faster towards the optimal solution compared to other algorithms and it is shown in Fig.5. Jaya algorithm is easy to implement and more powerful algorithm among four algorithms. The tuning of the algorithm specific parameters is not required in Jaya algorithm. The order of best performance of the algorithm in attaining optimal solution is given by: JA, FPA, BBO and GA.

For further extension comparison of the optimization can also be done by using other optimization techniques like ACO, TLBO etc.

REFERENCES:

[1]. Constantine A. Balanis, *Antenna Theory: Analysis and Design*, (WILEY, Fourth Edition).

[2]. G.S.N.RAJU, *Antennas and Wave Propagation*, (Pearson Education India, 2006).

[3]. T.S.JeyaliLaseetha, Dr.R.Sukanesh, Synthesis of Linear Antenna Array using Genetic Algorithm to Maximize Sidelobe Level Reduction, *International Journal of Computer Applications* (0975 – 8887), *Volume 20– No.7*, April 2011.

[4]. Haiping Ma, Dan Simon, Patrick Siarry, Zhile Yang, and Minrui Fei, Biogeography-Based Optimization: A 10-Year Review, *IEEE TRANSACTIONS ON EMERGING TOPICS IN COMPUTATIONAL INTELLIGENCE, VOL. 1, NO. 5,* OCTOBER 2017.

[5]. U. Singh, LINEAR ARRAY SYNTHESIS USING BIOGEOGRAPHY BASED OPTIMIZATION,*Progress In Electromagnetics Research M, Vol. 11*, 2010, 25-36.

[6]. Gopi Ram, Rajib Kar, Durbadal Mandal & Sakti Prasad Ghoshal ,Optimal Design of Linear Antenna Arrays of Dipole Elements Using Flower Pollination Algorithm, *IETE Journal of Research*, 2018.

[7]. Zaid Abdi Alkareem Alyasseri, Ahamad Tajudin Khader, Mohammed Azmi Al-Betar, Mohammed A. Awadallah and Xin-She Yang, Variants of the Flower Pollination Algorithm: A Review, *Springer International Publishing AG*, 2018, *Studies in Computational Intelligence 744*, *Nature-Inspired Algorithms and Applied Optimization*.

[8]. Hari Mohan Pandey, Jaya a Novel Optimization Algorithm: What, How and Why?, *IEEE 2016 6th International Conference - Cloud System and Big Data Engineering (Confluence).*

[9]. R. Venkata Rao, Jaya: A simple and new optimization algorithm for solving constrained and unconstrained optimization problems, *International Journal of Industrial Engineering Computations* 7 (2016) 19–34.

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