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A SURVEY OF ANTENNA ARRAY OPTIMIZATION USING META-HEURISTIC ALGORITHM

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Abstract: Antennas are termed as eyes of the world. They are used in wireless systems. There are various factors that influence the antenna design. In order to overcome the design problems, recently many algorithms have been developed to optimize the antenna with respect to general constraints, different criteria and performance characteristics. In the present era, nature inspired Meta-heuristic algorithms plays a vital role in optimizing the design issues related to an antenna. The Meta-heuristic algorithms include Genetic algorithm (GA), Ant Colony Optimization (ACO), backtracking search optimization algorithm (BSA), cuckoo search–chicken swarm optimization (CSCSO) and flower pollination algorithm (FPA). In this paper, the antenna array optimization is discussed which includes population-based meta-heuristic algorithms. This paper reviews antenna array design optimization for different antennas configurations.

Index Terms **-** *Optimization, Meta-heuristic algorithm.*

I. Introduction

Antenna is a transducer which converts electrical energy into electromagnetic energy. It is also termed as radiator which radiates electromagnetic waves into the free space. There are various types of antennas such as UWB antennas, planar antennas, Omni antennas, Reconfigurable antennas, Reflector antennas and Patch antennas. Single antenna is not capable of providing better performance in terms of directivity. So there is a need of group of Antennas which are capable of meeting the performance criteria. The solution is “Antenna arrays”. Antenna arrays are needed to provide better directivity and gain. Several antenna parameters like radiation pattern, Characteristic impedance, effective length, resonant frequency, polarization, efficiency and bandwidth are affecting antenna’s performance. Antenna design is usually a time consuming tedious task. The designer will face huge difficulty to design the structure of an antenna in order. In the recent times, the researchers are interested in developing the optimization algorithms to solve these problems. Optimization is the minimization or maximization of a function. Antenna array optimization methods have been presented using cost function (fitness function) or objective function. In this paper, the antenna optimization methods for reducing side lobe levels and introducing nulls in certain directions is mentioned.

In optimization process, there are various steps like selecting the fitness function and designing the variables. In these optimization problems, several objectives must be satisfied simultaneously to obtain the best and optimal solution. In most of the scan and non scan Radar and Communications, Pencil beams and sector beams with specific angular regions are required. To enhance scan area by avoiding multiple scans of narrow beam and once the target is detected, and then these pencil beams can be used to scan in that specified sectional region. Further, it is also necessary to increase the resolution of the Radar Systems by introducing Nulls in the desired angular Regions.

Therefore, to meet the above requirements, it is of interest to investigate thoroughly into the beam forming techniques with the objective of synthesizing sector beams, Pencil Beams and Nulls.

II. NATURE INSPIRED META-HEURISTIC ALGORITHM

1. Genetic Algorithm(GA)

A genetic algorithm (GA) [1] is a meta-heuristic algorithm which is inspired by Charles Darwin's theory of natural evolution. In GA, the production of offspring of the next generation is done by the process of selection where the fittest individuals are selected for reproduction. This can be done in five steps. They are Initial population to initialize the population, followed by fitness function. The selection of chromosomes is done. The crossover is performed among the selected chromosomes. The next step is mutation.

The flowchart is shown below.

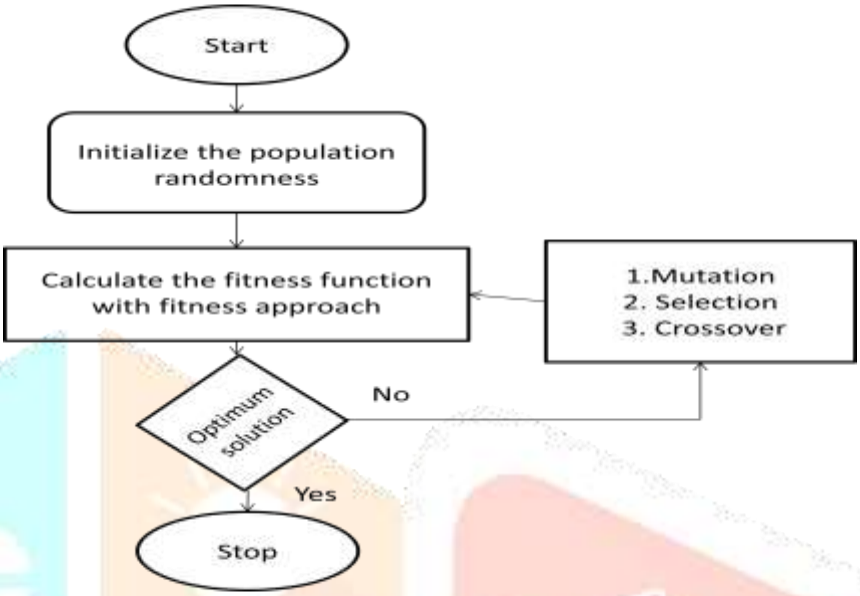

Fig. 2.1 Flowchart of GA

2. Particle Swarm Optimization(PSO)

The PSO algorithm works by having a population of particle solutions. The motion of the particles is followed by their own best known position in the global space as well as the entire particle's best known position[2].

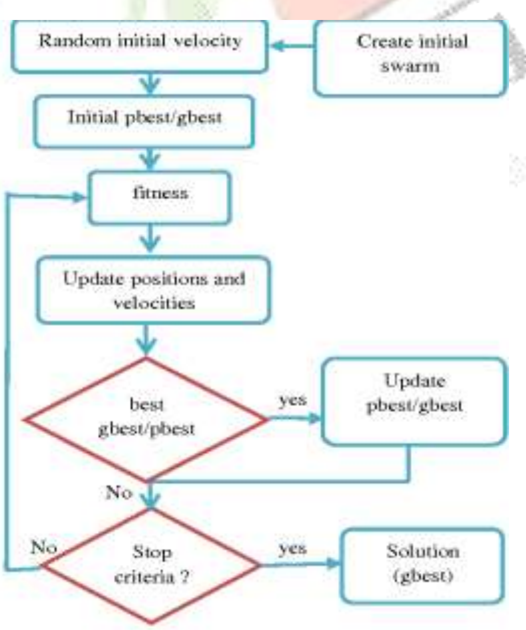

Fig.2.2. PSO Flowchart

3. Backtracking search optimization algorithm(BSA)

Backtracking search algorithm is an innovative algorithm to solve different nonlinear and complex optimization problems. It is based on an iterative process which finds global minimum in the solution space [3].

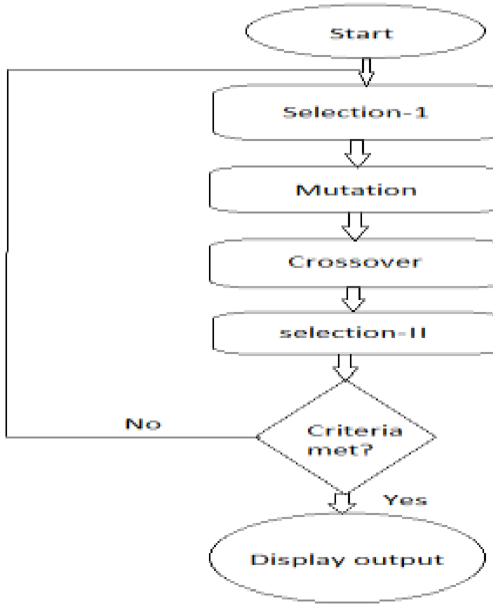

Fig.2.3. BSA Flowchart

4. Flower Pollination algorithm(FPA)

Flower pollination algorithm is a computational metaheuristic algorithm which is taken from role of flowers proliferation in plants [4].

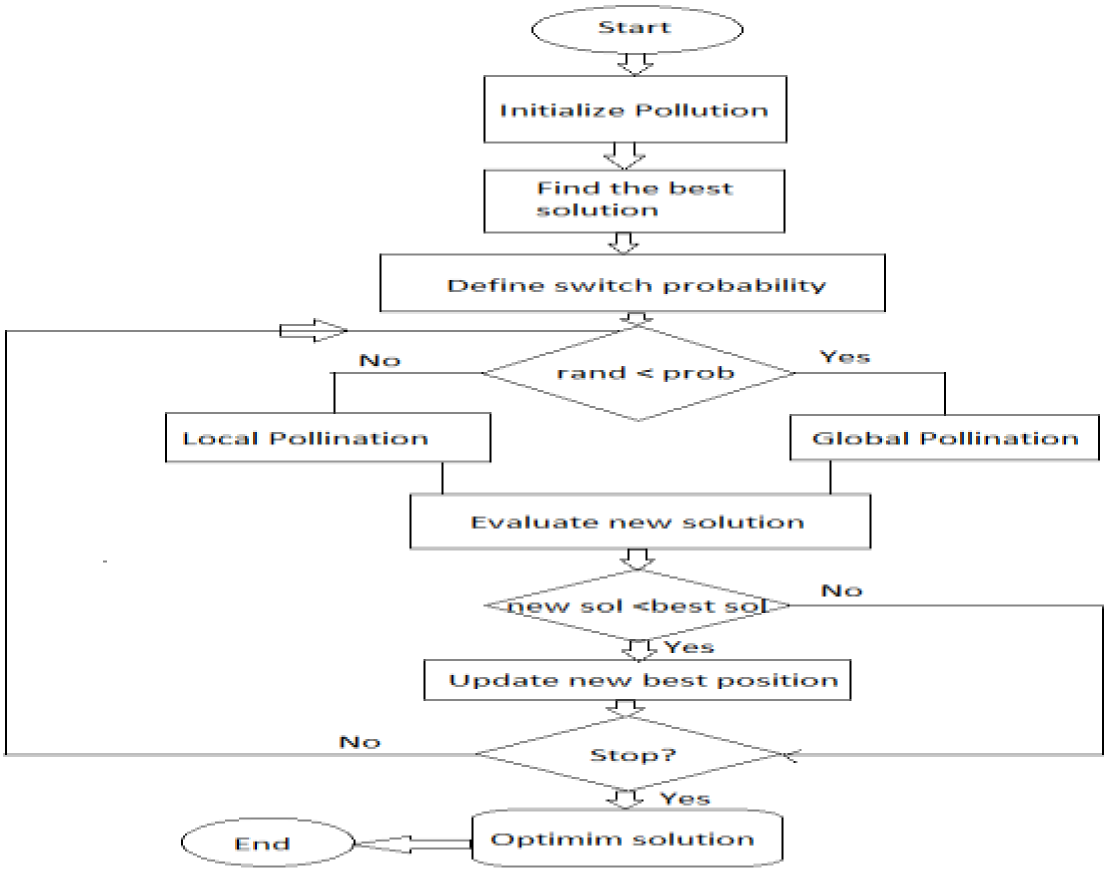

Fig.2.4. FPA Flow chart

III. LITERATURE SURVEY

1. Sidelobe Reduction in Array-Pattern Synthesis Using Genetic Algorithm

The main theme in the synthesis of antenna array geometry is to determine the layout of the array which is able to produce the pattern of radiation that is closest to the desired pattern. The shape of the pattern which is desired can vary depending on the application. Many methods are dealing with suppressing the sidelobes while maintaining the gain of the main beam, while other methods deal with the null control to reduce the effects of jamming and interference. In this paper, the linear array geometry is discussed by designing the spacing's between the elements. The uniform excitation is provided for this array aperture. In this approach, the representation of the array excitation weighting vectors is done with the help of complex number chromosomes. This can be done by

$$W = [w_1 w_2 w_3 w_4 w_5 \dots \dots . w_N] \text{..................................Eq.1}$$

Where, N is the length of the weighting factor. The MMSE defines the initial population. This method is useful for reducing the errors.

The reproduction is done with mutation and crossover. The crossover can be explained with the following equations.

$$CV1 = \frac{X + Y}{2}$$

$$CV2 = \frac{3X - Y}{2}$$

$$CV3 = \frac{3X + Y}{2}$$

Where, X and Y are the parent chromosomes. In this approach, there is no coding and it will directly works with real/complex numbers in order to simplify programming and to fast up the computation.

2. Linear Array Geometry Synthesis With Minimum Sidelobe Level and Null Control Using Particle Swarm Optimization

In this paper, the particle swarm optimization (PSO) method is considered for designing the non-uniformly spaced linear array antennas. The purpose of this approach is to improve the performance of the antenna arrays by reducing the sidelobe level and to get desired radiation pattern. For this to happen, the two approaches are considered. In the first approach, the element placement design with the constraint of length of antenna array being imposed is performed. In the second approach, perturbation of element position from a element distribution. The success of the approach is viewed by investigating the reduction of the sidelobe level along with the angle steering capability. In this paper, the PSO approach is compared with the Dolph–Chebychev array. From the results it is shown that both PSO and Dolph–Chebychev array exhibit same results with the tradeoff between the reduction of sidelobe level and directivity. Both exhibit similar performance. From the observations it is clear that PSO pattern with uniform excitation and equally spaced linear array pattern with Dolph–Chebychev excitation are similar.

Coming to the second approach, perturbation of element position from a element distribution, the results show that PSO is better when compared to Dolph–Chebychev array. But, the array size of PSO is larger than that of the Dolph–Chebychev array. It is a penalty paid for improving the sidelobe level/ directivity trade-off.

3. Optimal synthesis of linear antenna arrays with multi-objective differential evolution

In this paper, Multi-objective Optimization (MO) approach is used to solve the electromagnetic optimization. In this approach there are two design objectives. The first one is minimum Side Lobe Level and the second one is null control in specific directions. To achieve the optimal between the elements, these two objectives are to be minimized simultaneously. This algorithm employs differential evolution as the search method. The Multi-objective optimization approach provides greater flexibility in the design.

4. Pattern Nulling of Linear Antenna Arrays Using Backtracking Search Optimization Algorithm

In this paper, BSA is presented for nulling the pattern by controlling only the amplitude, position and phase of the antenna. BSA has five steps. They are initialization, selection-I, mutation, crossover and selection-II.

The initialization is performed by initial population which is given by

$$P_{ij} \sim D(low_j, up_j) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Eq(2)$$

J=1,2,3...N

I=1,2,3...D

Where N is Dimension and D is population size

The selection-I is done by using the historical population which is given by

$$old\ P_{ij} \sim D(low_j, up_j) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq(3)$$

The redefining of the historical population is done at each iteration if

$$a < b\ then\ old\ P := P | a, b \sim D(0,1)$$

In this paper, the performance and efficiency of the BSA is measured by eleven examples. In the first eight examples, a Chebyshev pattern is considered. In this, 20 elements are equally spaced with 0.5λ spacing between them. In the remaining examples, uniform array pattern is considered. In this, 22, 28, and 32 elements are equally spaced with 0.5λ spacing between them. In this paper, the null control is done by amplitude only, position only and phase only. The results show that BSA gives better performance characteristics when compared with the remaining state-of-art techniques.

5. Sidelobe level suppression using CSCSO

In this paper, a novel technique is considered to optimize the excitation amplitude and spacing between the elements of CAA (Circular antenna array) and LAA (Linear antenna array). To determine the initial solution, Chaos theory is utilized. To improve the convergence rate, levy weight coefficients are used. In this method, CS and CSO techniques are combined. In CS (Cuckoo search) algorithm, cuckoo lays an egg and hatches in nest which is randomly selected. The best nest is taken to next generation. The nest count is fixed. In CSO(Chicken swarm optimization) algorithm, groups are divided in which each group is having chicks, several hens, and rooster. The identification of chicks, hens, and rooster depends on the cost or fitness values. Rooster is having best fitness value followed by hen and chicks.

In CS and CSO, there are certain drawbacks. In CSCSO, the problem of population is solved using ergodicity of chaos theory. The search capability is increased by using weight coefficients. In this paper, the CSCSO is performed in following method. The parameter selection is done by population size and weighted levy flight. The Initial solution is based on chaos theory and weighted levy flight mechanism. The next step is beam pattern optimization. From the results it is clear that it will have low sidelobes when main lobe is fixed.

6. Synthesis of linear antenna array using flower pollination algorithm

A relatively new optimization technique, namely flower pollination algorithm (FPA) for the design of LAA for reducing the maximum side lobe level (SLL) and null control is presented. The desired antenna is achieved by controlling only amplitudes or positions of the array elements. FPA is a novel meta-heuristic optimization method based on the process of pollination of flowers. The effectiveness and capability of FPA have been proved by taking difficult instances of antenna array design with single and multiple objectives. It is found that FPA is able to provide SLL reduction and steering the nulls in the undesired interference directions

IV. CONCLUSION

In this paper, the survey of antenna arrays is done by comparing different optimization techniques. Each technique is having its own approach in solving the problem. The desired radiation pattern of an antenna is obtained by optimizing different parameters like spacing between the elements, array length and position of an antenna array.

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