TEST Engineering & Management

*July – August 2020*
*ISSN: 0193-4120 Page No. 164- 172*

# A Linear Array Antenna Synthesis using PSO

**P V K Durga Prasad[1], S S Naik[2], P S R Chowdary[3]**

[1]Research Scholar, Centurion University of Technology and Management, Odisha, India
[2]Centurion University of Technology and Management, Odisha, India
[3]Dept of ECE, Raghu Institute of Technology, Visakhapatnam, India
[1]prasad2977@gmail.com, [2]ssnayak@cutm.ac.in, [3]satishchowdary@ieee.org

***Article Info***
***Volume 83***
***Page Number: 164- 172***
***Publication Issue:***
***July - August 2020***

***Article History***
***Article Received****: 06 June 2020*
***Revised****: 29 June 2020*
***Accepted****: 14 July 2020*
***Publication****: 25 July 2020*

## Abstract

The proposed paper shows that with antenna array synthesis by using particle swarm optimization (PSO). Now a day's antenna arrays has been widely utilized in segment array radar systems, satellite communications and different domain names that are related to all conversation. In satellite communications, should be required to enhance the ability of antenna array to reduce noise and interference. Hence the patterns of the antenna array need to have decrease facet lobes, minimal controllable beam width, and the sample is symmetry in azimuth angles.

In linear array antennas complex optimization problems cannot be applicable for nonlinear least square method. In present technology which is based on swarm intelligence. By using this swarm intelligence, it can use the algorithm of Partical Swarm Optimization (PSO) which reduces complex optimization problems. In this algorithm each particle represents a solution to the problem and also which gives global search ability by adding a constriction factor. For electromagnetic problems and mathematical functions will be reduced by using this algorithm. By using this PSO algorithm, it can be determined the desired resonant frequency, return loss and high gain factors.

**Keywords:**Antenna Array, Particle Swarm Optimization, Side lobes, Nonlinear least square(NLS)

## I. INTRODUCTION

Without antenna there is no wireless communication systems. The main function of antenna is to transmit and receive signal. To modification for geometric configuration and other parameters antenna gives good facility. For antenna synthesis the desired requirement is to modification of the parameter of the antenna.[1] Antennas are a very important component of communication systems. By definition, it is a device that converts guided electromagnetic waves into unguided ones and vice versa. Antenna will maintain the same characteristics for transmitting or receiving as like reciprocity property.[1] To operate efficiently on a relatively narrow frequency band, some antennas behave like resonant devices. To match transmission and reception the connection of antenna should be tuned to the same frequency band. In certain way in space the radiation was distributed.[2]

when antenna fed by the signal. Here some important parameters are defined that are basic and related to every type of antenna. Those are Input impedance, return loss, bandwidth, directivity & gain, radiation pattern, beam width, side lobes, nulls polarization.[2]

Array is a systematic arrangement of objects in a row or column. In other word it can be stated that array is a collection of similar elements arranged in a certain manner. Single-element antennas have radiation patterns that are broad and hence have a low directivity that is not suitable for long distance communications**. [2]** Thus an antenna array can be defined as a configuration of individual radiating elements (radiators) that are arranged in space and can be used to produce a directional radiation pattern. The figure 1.1 shows that different geometrical configurations of antenna arrays. For

TEST Engineering & Management

*July – August 2020*
*ISSN: 0193-4120 Page No. 164- 172*

antenna elements to different excitations the change of radiation pattern was an important characteristic of antenna array. The radiation pattern was fixed for single antenna but an antenna array's radiation pattern can be changed on its elements by various current excitations. From this it is clear that without changing physical dimensions it is easy to design desired array pattern from an array.

**Fig 1.1 Antenna Array**

General advantages of antenna array are, it can provide the capability of a steerable beam (radiation direction change) as in smart antennas, high gain (array gain) by using simple antenna elements, diversity gain in multipath signal reception, and also it enable array signal processing. In general we have different types of array antennas, those are Active and passive array, linear array, planar array, adaptive array, cylindrical array, conical array.[1-2]

## II. LINEAR ARRAY

A group of equal spacing elements placed in one dimension along a given direction is called linear array. Linear arrays may have equidistant or non equidistant element spacing which is shown in fig.2.1. They are used in the analysis of the directional properties of arrays in antenna theory, and as building blocks for forming an array of arrays.

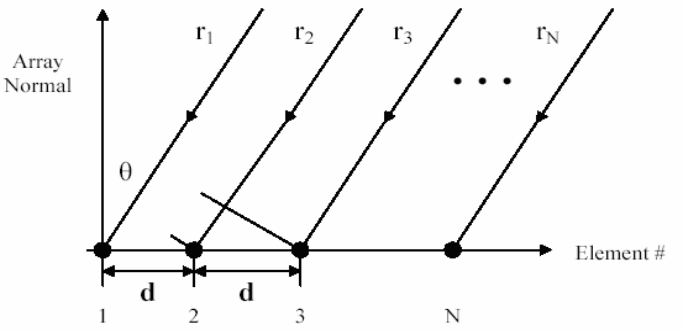



**Fig:2.1 Linear array of Nelements**

A easy directional antenna consists of a linear array of small radiating antenna factors, each fed with equal indicators (the identical amplitude and phase) from one transmitter.[2] As the entire width of the array increases, the primary beam becomes narrower. As the wide variety of factors will increase, the aspect lobes emerge as smaller.

The following figures of 2.2, 2.3 &2.4 is the radiation pattern for a linear array of 4 elements spaced half wavelength apart.

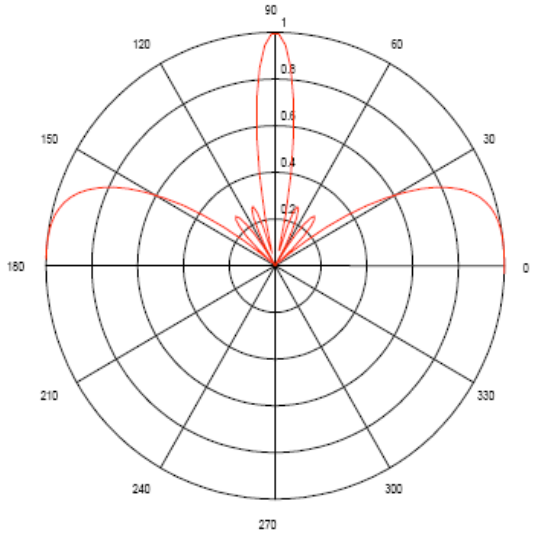



**Figure 2.2: 3- 4-Element 1.5 lambda Linear Array 4 Identical Omni directional Antennas**

If the spacing is elevated to extra than half of wavelength, big aspect lobes begin to appear inside the radiation sample. However, the imperative beam gets narrower due to the fact the overall period of the antenna has improved. The following radiation pattern, for four elements spaced 1 wavelength apart, illustrates this.

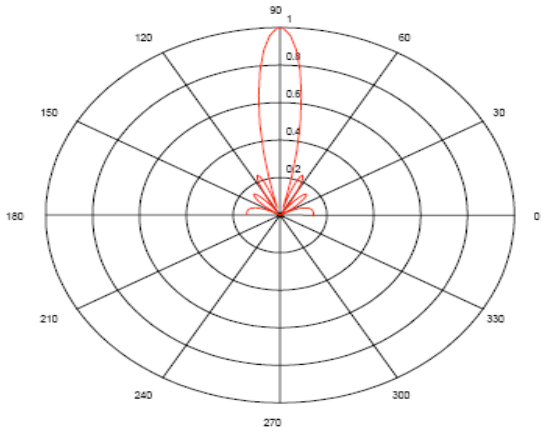



**Figure2.3: 4-Element Linear Array, Spacing lambda**

July – August 2020
ISSN: 0193-4120 Page No. 164- 172

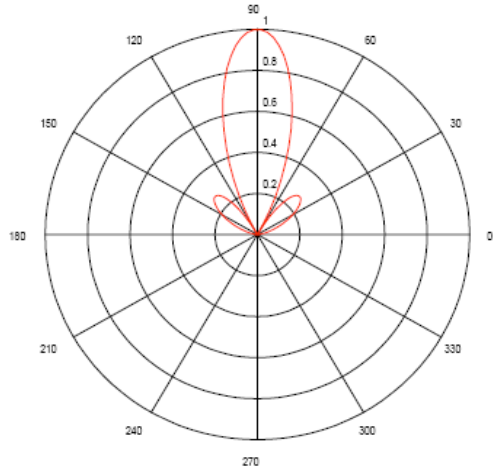



**Figure 2.4: 7-Element 3 λ Linear Array**

By retaining the general period the identical, and including factors to reduce the spacing returned to half wavelength, the aspect lobes are reduced. Following is the radiation pattern if three more elements are brought to the linear array above to reduce the element spacing.

Hence we are saying that radiation sample of antenna array is laid low with the following parameters:

1. Difference in amplitude of currents fed to different array factors
2. Difference in section of cutting-edge fed to distinct array factors
3. Distances between individual antenna factors i.e. Inter element spacing.
4. No. Of elements
5. Radiation pattern of individual elements.

## III. OPTIMIZATION TECHNIQUE

Optimization is a technique which is used to minimizing the functions in mathematical discipline and which is subjected to its constraints. Optimization technique first made in 1940s by George Dantzing which is used for military applications by making a program in mathematical approaches.[3]

By making linear array antennas with linear programming techniques which will solve a wide range of problems in antennas and making scheduling of production facility in airlines management system. Now a days this optimization technique will operates in all research applications like computer science, airlines, military, artificial intelligence and also improves in communicated oriented industries.[3]

### 3.1 Necessity of optimization:

The major problems under development in telecommunications for antenna engineers is to design simultaneously meet the radiation and integration requirements. To implementation of the feeding network and receiver front-end in the antenna system in which multiple radiators are incorporated to achieve versatile beam forming capabilities and high diversity performance.[3]

### 3.2 Optimization algorithms:

In general optimization algorithm are two types one is Traditional and other one is Non-Traditional.

**Traditional Algorithm Type:** These types of algorithms are used to finding the optimal solution of continuous & differential functions. And also, it gives a good understanding of min and max points of a function.[4] In this traditional algorithm be in two methods to minimizing the work iterative. This will reduce optimal problems in antennas. These two types are 1) Direct method 2) Gradient method. Some disadvantages of traditional methods are:

- The concurrence to an optimal solution is dependent upon the chosen optimal solution.
- Many of the algorithms leads to get stuck to a sub-optimal solution.
- An efficient algorithm is solving one optimization problem may not be efficient in solving a different optimization problem.
- Some discrete variables, algorithms are not efficient to handle different problems.
- In parallel machines also algorithms cannot be efficiently used.

**Non-Traditional Algorithm Type:** This type of algorithms are the advanced type and also most popular type algorithms. In this type we have Genetic Algorithm, Simulated Annealing, Particle swarm optimization (PSO), Ant colony algorithm.[5]

## IV. PARTICLE SWARM OPTIMIZATION (PSO)

PSO is an evolutionary algorithm based on the intelligence and co-operation of group of birds or fish schooling. It maintains a swarm of particles where each particle represents a potential solution. In PSO algorithm particles are flown through a multidimensional search space, where the position of each particle is adjusted according to its own

July – August 2020
ISSN: 0193-4120 Page No. 164- 172

experience and that of its neighbors. This will applies the concept of social interaction to problem solving.[5]
PSO means getting the best solution from the problem by taking particles and moving them around in the search space. Shown in fig. 4.1

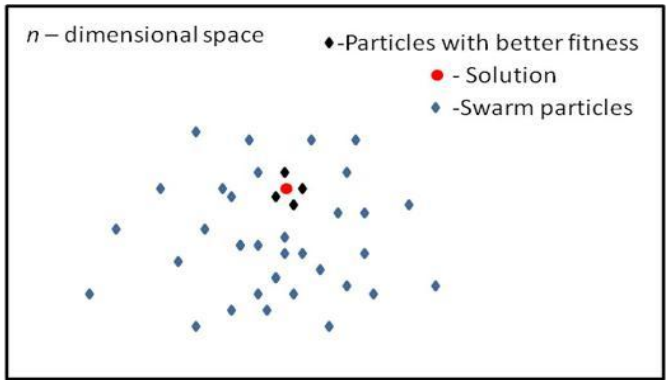



**Fig. 4.1 Paritcle in a swarm**

In the years for the reason that introduction of particle swarm optimization (PSO) as a new approach for worldwide optimization many researchers have multiplied on the original idea with alterations starting from minor parameter changes to complete remodeling of the algorithm. Others have used PSO for evaluation trying out of different international optimization algorithms, such as genetic algorithms and differential evolution. The PSO area has elevated dramatically seeing that its inception, however up to now there has been little to no consensus as to what constitutes the "popular" or "canonical" PSO algorithm.
The PSO algorithm works by way of simultaneously keeping numerous candidate answers in the search area. For every iteration of this set of rules that have each candidate solution is evaluated by means of the goal characteristic being optimized. This will figuring out the fitness of that solution. Each candidate answer may be notion of as a particle "flying". Through this fitness, the panorama locating the max or min of the objective characteristic. First this set of rules randomly chooses the answer in the search space.[6] Below determine suggests the initial condition of a four particle PSO set of rules which has a most in 1-D seek area. In this search area x-axis is includes all possible solutions. And on this curve denotes the objective function. In this algorithm it has no information of the underlying objective function, and for that reason has no manner of understanding if any of the candidate answers are near to or a ways far from a local or global most.

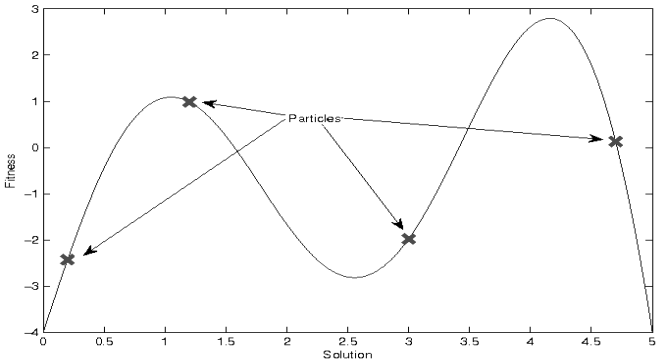



**Figure 4.2: The First state of a four-particle PSO algorithm seeking the max in a 1-D search space**

This objective function will find its candidate solution, and it will operate depends upon the fitness of resultant value.
The PSO set of rules attempts to imitate the behavior of birds or bees in obtaining a food supply. Initially, a flock of birds can also start off in random directions looking for meals. As each bird travels on its path, it could discover meals in various places. The bird recollects its very own 'non-public first-rate' place of wherein it had found food. In addition, the bird may additionally periodically fly up and survey the progress of the alternative birds within the flock. In this way, every bird may be aware about the 'international excellent' position, or place located with the most food by using any bird inside the flock. Using this widespread method, a flock of birds will descend on the region within the area that has a rather high quantity of food available. The PSO algorithm interprets this conduct into a mathematical algorithm for optimization. The PSO set of rules includes a hard and fast of debris (the 'swarm'), which are analogous to the birds. The set of rules also has a price or health feature, which evaluates the present-day role of each bird this is analogous to a chook evaluating how much food is in a sure region. [7]

### 4.1 Steps in PSO:

The PSO set of rules follows simply three steps, that are repeated till a few preventing circumstances is met
1. Evaluate the health of every particle

*July – August 2020*
*ISSN: 0193-4120 Page No. 164- 172*

2. Update individual and international fine fitness and positions
3. Update the speed and function of each and every particle

The first two steps are very fairly trivial. This Fitness evaluation technique is performed by making the candidate approach to the objective characteristic. And which is updating and evaluating the newly evaluated fitness's a few of the previous high-quality fitness, and replacing the ones pleasant fitness's and positions as important. [8-10]

### 4.2 PSO Algorithm:

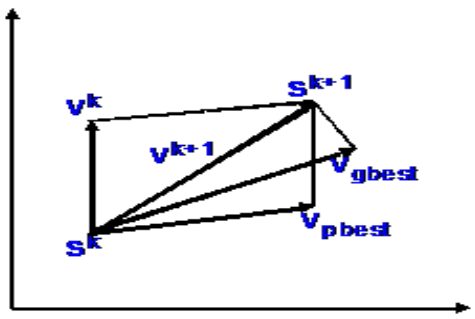
For each particle
Initialize particle
End

Do
For each particle
Calculate fitness value
If the fitness value is better than the best personal fitness value in history, set current value as a new best personal fitness value
End

Choose the particle with the best fitness value of all the particles, and if that fitness value is better than current global best, set as a global best fitness value. For each particle Calculate particle velocity according velocity change equation Update particle position according position change equation End While maximum iterations or minimum error criteria is not attained

### 4.3 Modification of searching point by PSO:

In the modification of searching point by using PSO consists of current searching point and modified searching point, current velocity and modified velocity, velocity based on Pbest,Gbest is shown in Fig.4.3




Where, $^{k}$**:** current searching point.
$\mathbf{s^{k+1}}$**:** modified searching point.
$\mathbf{v^{k}}$**:** current velocity**.**
$\mathbf{v^{k+1}}$**:** modified velocity**.**
$\mathbf{v_{pbest}}$**:** max and min velocity based on Pbest.
$\mathbf{v_{gbest}}$**:** max and minvelocity based on gbest

## V. Synthesis of Antenna Array using Particle Swarm Optimization:

In PSO algorithms, each ability solution of optimization hassle is a bird within the answer space, which referred to as "particle". Each particle has managed to its directional speed to transport tracks. This will premier by way of making looking in area. In the synthesis first role and its speed are iterated. For every iteration we have two satisfactory positions which are updated its particle. The first one is known as non-public excellent function that is an most reliable answer observed by way of particle. Another highest quality answer is the entire group is called as the first-rate role. In particle swarm optimization the 'I'th particle is in the solution space which indicates by way of the fitness function value. This PSO algorithm is a stochastic optimization method which is an populace based set of rules. This will find a option to it in the form of fitness function. A populace of people defined as random guesses of the problem answer is initialized. These individuals also are known as the particles, for this reason the name particle swarm. These people represent their positions. An iterative procedure is to enhance the positions whilst its started out. The debris iterative evaluates the positions and don't forget the vicinity where they had their first-class achievement. The particle best is the individual's best solution. Each and every particle makes this information available to their neighbor particle.[11] They also are capable of see wherein their buddies have had the fulfillment. The best solution among all of the neighbor is called worldwide nice. The fundamental utility of this PSO system is a few of the three primitive movements only one is associated to every of the particle swarm at each generation.

July – August 2020
ISSN: 0193-4120 Page No. 164- 172

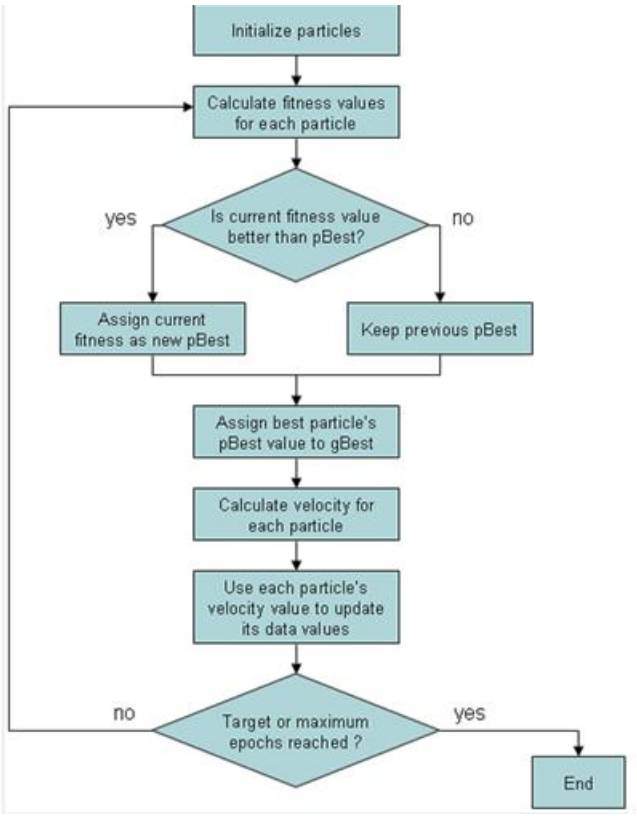



**Figure 5.1: flow chart representation of PSO**

The path-relinking implemented for the binary velocity operator's changes its adjacent elements of the origin solution. At begining, upto the first element be equal the first element of the target solution the origin solution is rotated. Then the seond one is considered.The correspondent element in the origin solution is shifted left until reaching the second position in the sequence that represents the solution. The process continues until the origin solution reaches the target solution. This procedure leads to time complexity $O(n2)$. this will apply until the traget of the solution is obtained.for this Swap-left and swap-right operations are used in this process. This sequence is the better solution to replace the position of the certain particle.[11]

### 5.1 Minimum side lobe levels for linear arrays:

One-dimensional arrays were considerably analyzed, courting again to the early part of the 20th century. Their ubiquity in textbooks and actual applications is in part because of the relative ease with which they are analyzed. However, the query of determining the minimum possible aspect lobe degree for an N-element linear array has yet to be decided.

The most important discussion is the Dolph-Chebyshev weighting method. This technique can decide minimal-side lobe weights for uniformly spaced linear arrays of omni directional antennas. The Particle Swarm Optimization (PSO) method to decide gold standard aspect lobe-minimizing positions for linear arrays assuming the weights have been regular. The weights and positions of a linear array might be optimized to decrease facet lobes. [12]

In the authors force the arrays to have symmetry about the middle to hold the array issue actual. In addition, the arrays will haven't any bounds on minimum or most detail separation, for a given linear array, a method of finding the finest weights for minimizing the aspect lobe degree is derived given:

- A beam width
- The array element's positions
- The individual antenna's radiation sample
- A favored course (d θ) for the array to be scanned

This problem will be posed in convex form; for that reason, it may be solved without searching the gap will be significantly searched via PSO a good way to locate ultimate positions in conjunction with the corresponding most efficient weights. Consequently, the effects supplied here probable constitute international bounds on the minimum-feasible aspect lobe degrees workable for a given beam width. This statistic can be used by array designers in determining how properly their arrays perform as compared to the nice design possible, to decide if changing the weights or detail positions could doubtlessly return a widespread development in performance.

## VI. RESULTS:

### 1) For generations =1000

| NO.OF ELEMENTS | Excitation coefficients | Side lobe level |
|---|---|---|
| 10 | 0.7797 0.7446<br>0.6815 0.5982<br>0.4960 0.3876<br>0.2878 0.1972<br>0.1208 0.0804 | -40.97dB |

July – August 2020
ISSN: 0193-4120 Page No. 164- 172

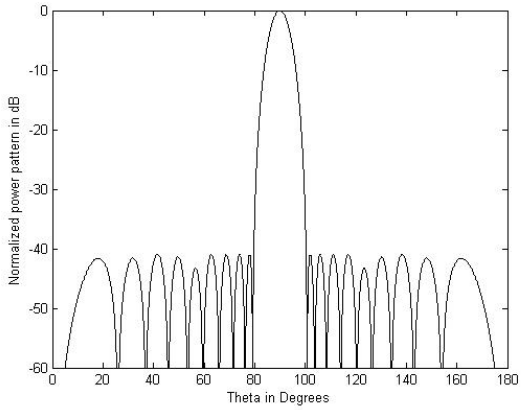



**fig 6.1:Radiation pattern of 10 element array for -40.97dB SLL**

**2) For generations =500**

| No. OF ELEMENTS | Excitation coefficients | Side lobe level |
|---|---|---|
| 10 | 0.7353 0.7018<br>0.6588 0.5741<br>0.4972 0.3974<br>0.3111 0.2139<br>0.1543 0.1110 | -36.18Db |

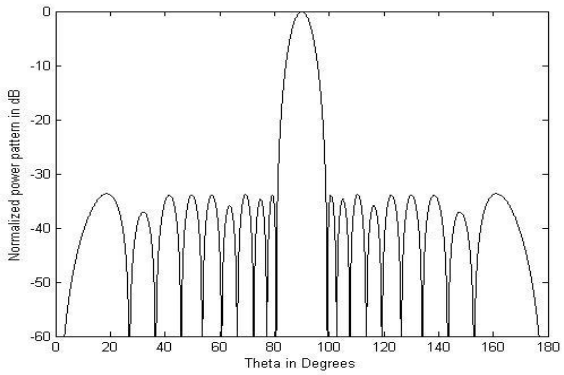



**Fig 6.2:Radiation pattern of 10 element array for -36.18dB SLL**

**3) For generations =100**

| NO.OF ELEMENTS | Excitation coefficients | Side lobe level |
|---|---|---|
| 10 | 1.0000 0.9674<br>0.9016 0.7886<br>0.6826 0.5405<br>0.4377 0.2943<br>0.2145<br>0.1569 | -35.8Db |

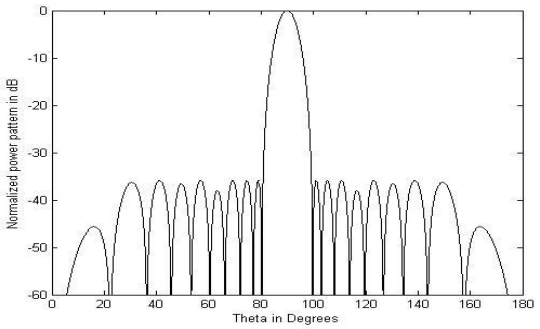



**Fig 6.3:Radiation pattern of 10 element array for -35.8dB SLL**

**4) For generations =100**

| NO.OF ELEMENTS | Excitation coefficients | Side lobe level |
|---|---|---|
| 20 | 0.9313 0.8625<br>0.8962 0.8201<br>0.8877 0.8013<br>0.7735 0.6375<br>0.6495 0.7200<br>0.4794 0.5285<br>0.4349 0.4039<br>0.2997 0.3095<br>0.2700 0.2464<br>0.1765 0.1843 | -32.28dB |

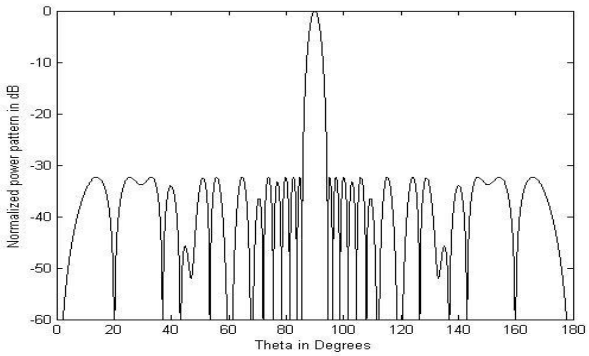



**Fig 6.4:Radiation pattern of 20 element array for -32.28dB SLL**

**5) For generations =100**

| NO.OF ELEMENTS | Excitation coefficients | Side lobe level |
|---|---|---|
| 50 | 0.8278 0.8209<br>0.9540 0.9092<br>0.8339 0.8404<br>0.7215 0.8367<br>0.5784 0.6556<br>0.8531 0.9561<br>0.8540 0.4542<br>0.6857 0.8938<br>0.6553 0.7269<br>0.4818 0.8806 | -27.23dB |

*July – August 2020*
*ISSN: 0193-4120 Page No. 164- 172*

| | | | |
|---|---|---|---|
| | **0.5125**<br>**0.4992**<br>**0.5028**<br>**0.6421**<br>**0.4870**<br>**0.3396**<br>**0.3706**<br>**0.7590**<br>**0.1622**<br>**0.1946**<br>**0.5024**<br>**0.2388**<br>**0.5094**<br>**0.2169**<br>**0.1729**<br>**0.0887** | **0.6458**<br>**0.8437**<br>**0.5454**<br>**0.5033**<br>**0.4827**<br>**0.6457**<br>**0.2927**<br>**0.4184**<br>**0.3654**<br>**0.1679**<br>**0.2665**<br>**0.1476**<br>**0.3133**<br>**0.4109** | |

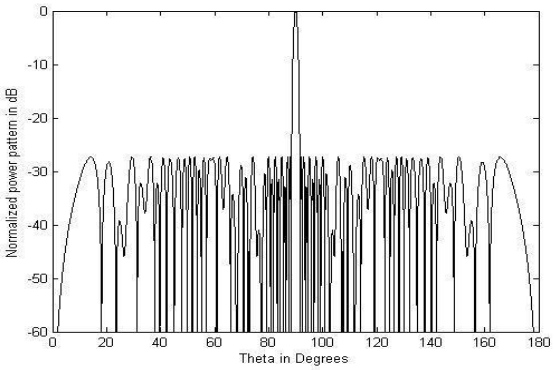



**Fig 6.5:Radiation pattern of 50 element array for -27.23dB SLL**

## VII.CONCLUSION:

The mathematical expression of PSO is very simple, and the conception is intelligible. Such set of rules is possible to resolve complex, non-linear international optimization troubles. The simulation outcomes show PSO has many blessings, and it converges fast. The method may be used to remedy specific antenna array synthesis troubles. This set of rules belongs ideologically to that philosophical college that lets in knowledge to emerge in place of seeking to impose it, that emulates nature instead of looking to manage it, and that seeks to make things simpler in place of greater complicated".

The use of progressed particle swarm optimization set of rules in the pattern synthesis of phased arrays for the motive of suppressed aspect lobe in positive areas and null placement in prescribed directions. By adopting some methods, the worldwide seek capability and the refined pinpointing seek potential of available PSO have been stronger. The numerical effects, as said in this mission propose that the proposed set of rules is successful in synthesizing linear array and planar array. By evaluating with PSO and GA, it demonstrates the superiority of IPSO in higher convergence accuracy and fewer price characteristic critiques. As for the destiny work, to expand an adaptive algorithm to use the statistics of the layout trouble received for the duration of the path of the search manner for tuning the parameters robotically and observe the set of rules to other electromagnetic hassle.

The use of PSO within the pattern synthesis of antenna arrays a hybrid set of rules is proposed by fusing the benefits of both chaotic search and PSO to keep away from the prematurity and clean trapping in local foremost. The worldwide best position in fundamental PSO is replaced by way of a complete function acquired with the aid of the brand-new studying method wherein a particle makes each measurement study from the corresponding dimension of different particles excellent position.

## REFERENCES

[1] W.Y. Wei, D.M. Gong, and B.S. Chen, "Antenna Theory", Xi'an: The publishing house of Xidian University, 1985.

[2]Y.B.Chen, Y.B.Chen, Y.C. Jiao, and F.S. Zhang, "Synthesis of Antenna Array Using Particle Swarm Optimization", 2005.

[3]Riccardo Poli, "An Analysis of Publications on Particle Swarm Optimization Applications" May 2007

[4]Daniel Bratton ,James Kennedy, "Defining a Standard for Particle Swarm Optimization, 2007.

[5]James Blondin, "Particle Swarm Optimization: A Tutorial "September 4, 2009

[6]D Nagesh Kumar, "Classical and Advanced Techniques for Optimization"

[7] Dr. T. Ghose. "Optimization Techniques and an Introduction to Genetic Algorithms and Simulated Annealing"

[8]Goldberg, D.E. "Genetic Algorithms in search, optimization, and machine learning" Addition-Wesley

[9] K. Deb, "Optimization for Engineering Design" PHI, New Delhi.

[10] T. Ghose, Dr. S. K. Goswami& Professor S. K. Basu, " Solving Capacitor PlacementProblem In Distribution Systems

*July – August 2020*
*ISSN: 0193-4120 Page No. 164- 172*

Using Genetic Algorithms "Published in Vol. 27, Number 4, 1999 of international journal of Electric Machines and Power Systems".

[11]AshishGhosh and S.K. Pal, "Biologically Inspired New Operations for Genetic Algorithms" Published in preceding of int. workshop on soft computing and Int. Systems, ISI Calcutta, January 12-13, 1998.

[12] V. V. S. S. S. Chakravarthy, P. S. R. Chowdary, Ganapati Panda, JaumeAnguera, Aurora Andújar, BabitaMajhi, "On the Linear Antenna Array Synthesis Techniques for Sum and Difference Patterns Using Flower Pollination Algorithm", Arab J SciEng (2018) Volume 43, Issue 8, pp 3965–3977/