International Journal of Engineering Research and Reviews ISSN 2348-697X (Online)
Vol. 3, Issue 3, pp: (102-109), Month: July - September 2015, Available at: www.researchpublish.com

Geometrical Optimization of Antenna Array Using Particle Swarm Optimization

[1]Harshanjali S, [2]Priyalakshmi S

[1]P.G Scholar, [2]Assistant Professor

[1,2]ECE Department, M.G University, SBCEW, Pathanamthitta, India

---

Abstract: **The design of antenna arrays used in the recent technologies are expected to contain large number of antenna elements operating over a broad frequency range where the signals from each antenna element are combined and processed simultaneously providing high sensitivity with multiple beams providing a wide field of view. Array geometry is the main design aspect which influences the cost and performance of the system. The optimization techniques are needed to enhance the performance of the antenna array. The large bandwidth and number of broadband antenna elements makes the optimization of antenna array system difficult to achieve with the current array geometry optimization techniques. Such array geometry optimization techniques rely mainly on genetic algorithms and pattern search techniques. Here provides a study of the array geometry effects on the performance of broadband array system. Instead of controlled randomization and space tapering, the particle swarm optimization is used as the optimization technique which is an iterative based algorithm. This algorithm can provide a global best position for the antenna elements which gives improved performance.**

Keywords: **Antenna array, Array geometry, Optimization, PSO.**

I. GEOMETRY OPTIMIZATION

An antenna array is a set of N spatially separated antennas. The number of antennas in an array can be as small as 2, or as large as several thousand. In general, the performance of an antenna array increases with the number of antennas (elements) in the array; the drawback of course is the increased cost, size, and complexity. The signals from the antennas are combined or processed in order to achieve improved performance over that of a single antenna. The main purpose of creating a fixed antenna array is an increase in the antenna's directional gain; an array consisting of N identical elements can achieve an increase in gain of up to a factor of N if optimally fed. A parasitic array does not achieve such an increase since there are more constraints on the distribution of currents attainable through passive coupling. Uses of arrays for increasing antenna gain are an alternative to attain good performance. These are called aperture antennas, in which the gain is achieved using a single geometric structure, more similar to an optical focusing device. Designs such as the horn antenna and parabolic dish antenna become more practical at higher frequencies (shorter wavelengths) whereas antenna arrays may be practical at any wavelength. At lower frequencies, where rigidly turning a large structure may be unfeasible, an array may be made steerable (or may just be tuned to optimize a particular radiation pattern) through electronic adjustment of the elements' relative phases. This principle is often used in AM broadcast, where two or more large fixed towers (vertical mono-poles) may be phased up to create a desired radiation pattern; obviously such structures cannot be moved once erected.

The optimization is the technique used to improve the performance of the antenna array. Pattern search (PS) is a family of numerical optimization methods that do not require the gradient of the problem to be optimized. Hence PS can be used on functions that are not continuous or differentiated. Such optimization methods are also known as direct-search, derivative-free, or black-box methods. A ring array is a planar array with elements lying on a circle. If several of these arrays with different radii share a common center, then the resulting planar array is a concentric ring array. Concentric ring arrays are used for direction finding and applications requiring main beam symmetry. Low side-lobes in the array factor are usually obtained through amplitude weighting the signals at each element. Optimizing the ring spacing and the number of elements in each ring produces the lowest side-lobe level and the second highest directivity while using the least number of elements.

A fractal is a recursively generated object having a fractional dimension. Many objects, including antennas, can be designed using the recursive nature of a fractal. These arrays have fractional dimensions that are found from the generating sub-array used to recursively create the fractal array. Traditional approaches to the analysis and design of antenna systems have their foundation in Euclidean geometry. There has been a considerable amount of recent interest, however, in the possibility of developing new types of antennas that employ fractal rather than Euclidean geometric concepts in their design. Fractal antenna engineering represents a relatively new field of research that combines attributes of fractal geometry with antenna theory. Research in this area has recently yielded a rich class of new designs for antenna elements as well as arrays.

The radiation pattern of an antenna array depends strongly on the weighting method and the geometry of the array. Selection of the weights has received extensive attention, primarily because the radiation pattern is a linear function of the weights. However, the array geometry has received relatively little attention even though it also strongly influences the radiation pattern. The reason for this is primarily due to the complex way in which the geometry affects the radiation pattern. the interference rejection capabilities of the antenna array depend upon its geometry. The concept of an interference environment is introduced, which enables optimization of an adaptive array based on the expected directions and power of the interference. This enables the optimization to perform superior on average, instead of for specific situations. Side-lobe level is an important metric used in antenna arrays, and depends on the weights and positions in the array. A method of determining optimal side-lobe minimizing weights is derived that holds for any linear array geometry, beam-width, antenna type and scan angle. The positions are then optimized simultaneously with the optimal weights to determine the minimum possible side-lobe level in linear arrays.

Array geometry plays a critical role in the direction-finding capabilities of antenna arrays. For linear a-periodic arrays, there exists an array that has superior spatial-spectrum estimation ability. Antenna arrays are also used for diversity reception, or comparing signal power at spatially distinct locations and processing the signals based on their relative strength. Geometry optimization process involves performing a series of simulations. The process continues until the design objective is reached and the design satisfies all specified constraints.

II. CONTROLLED RANDOMIZATION AND SPACE TAPERING

A square kilometer array with optimized performance was proposed and simulated. As the antenna temperature decreases the performance and efficiency of the antenna system increases. In order to increase efficiency the interference is reduced by suppressing the side lobes of the radiation pattern of the square kilometer array. The square kilometer array (SKA) is a radio telescope project which would have a total collecting area of approximately one square kilometer. It will operate over a wide range of frequencies and its size will make it 50 times more sensitive than any other radio instrument. It will require very high performance central computing engines and long-haul links with a capacity greater than the current global Internet traffic. It will be able to survey the sky more than ten thousand times faster than ever before.

The SKA will combine the signals received from thousands of small antennas spread over a distance of more than 3000 km to simulate a single giant radio telescope capable of extremely high sensitivity and angular resolution. The SKA will also have a very large field-of-view (FOV) with a goal at frequencies below 1 GHz of 200 square degrees and of more than 1 square degree (about 5 full Moons) at higher frequencies. One innovative development is the use of Focal Plane Arrays using phased-array technology to provide multiple FOVs. This will greatly increase the survey speed of the SKA and enable multiple users to observe different pieces of the sky simultaneously. The combination of a very large FOV with high sensitivity means that the SKA will transform the exploration of the Universe.

For effective optimization of large scale broadband arrays iterations or search techniques, this method can be used. The method starts by assuming a large number of elements are available which can be distributed over a constant aperture size. The elements are then distributed by applying controlled randomization and/or space tapering techniques which allows the designer to trade off performance of the N elements over a broadband and thus maximize their performance depending on the application requirement.

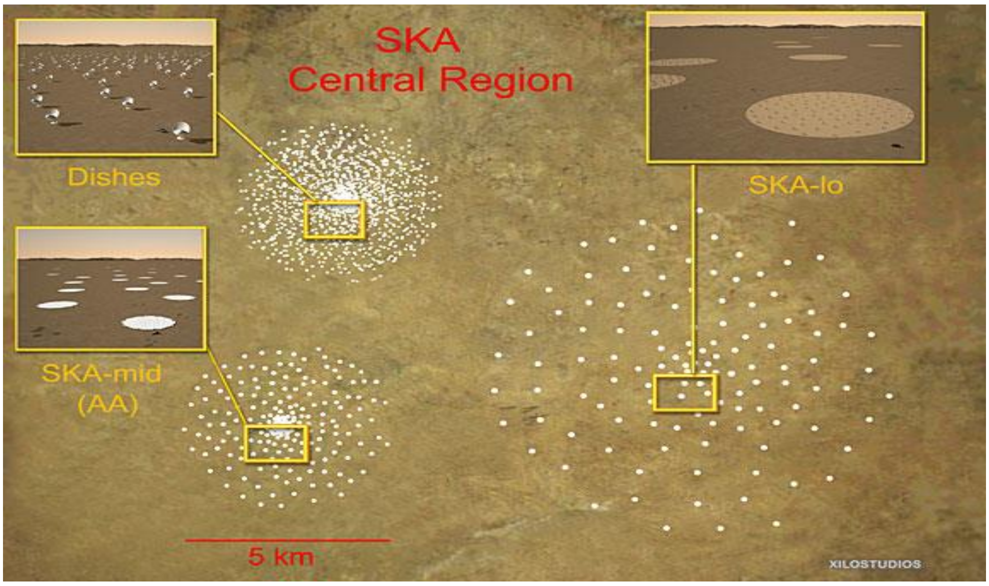


Fig. 1. Square kilometer array in central region

Here provides a study of large scale broadband array geometry and its effect on various performance aspects such as directivity, side-lobes and beam width. It presents a technique which facilitates the optimization of such large scale broadband array systems for a wide range of applications. The technique utilizes simple randomization and space tapering operations that can optimize the performance of a given number of elements over a given broad band.

A. Controlled Randomization:

The controlled randomization is a method used for optimizing the performance of an antenna array system. The randomization can be done according to some constraints. A random array of a defined number of elements N can be constructed by initially defining a certain aperture size Dap. In order to control the randomization, a minimum separation constraint can be introduced as

$dm > dmin$

$((xn)2 + (yn)2)1/2 << Rap$

Where, dm is a vector containing the distances between the nth element and all the other elements in the array. The second constraint eliminates elements outside an Rap circle and thus created a circular aperture. The distance dmin is a certain chosen minimum separation. If Rap and N are assumed constant, dmin must be bounded by a maximum value to allow the process to converge. For a given aperture size and number of elements, a larger minimum separation constraints forces more even spacing between elements avoiding too large and too close separations. This technique allows to trade off array performance over a broadband.

B. Space Tapering:

The space tapering is another technique used to improve the performance of an antenna array system. Space tapering can be applied on any arbitrary distribution by determine the physical displacement for each element in the array according to a certain tapering window such as Gaussian, Chybeshev, Taylor, etc.

The space tapering of an array of element Cartesian coordinates (xn1; yn1) , can be achieved by shifting each element position according to the chosen taper function. Let A(i) be a normalized taper function of given length larger than N, and dn be the distance of the nth element to the center of the array of radius Rap. Then the new tapered element

Cartesian coordinates (xn; yn) can be calculated from

$xn = xn1\psi (i) + xn1$

$yn = yn1\ \psi (i) + yn1$

where, $\psi (i) = A(i)Rap$. The value of ψ chosen for each element is the nearest to the distance of that element from the center of the array. This is applied on the equally spaced array.

Another space tapering technique is found which has been applied on spiral arrays based on the golden ratio. A golden ratio spiral array (GRS) can be constructed in polar coordinates from

$rn = df(n)$

$\psi\ n = 2\pi\Phi n$

Where, rn is the radial displacement of the nth element, d is a scaling factor, n is the angular displacement of the nth element, and Φ is the golden ratio = 1.618...

Since the aperture size and number of elements are kept constant in all configurations, the main constraint for the element distribution is the minimum separation. The minimum separation must be kept sufficiently large to allow for the antenna element physical size and the affect the mutual coupling. This can vary significantly depending on the required application.

III. PARTICLE SWARM OPTIMIZATION

The performance of the antenna array system gets reduced due to the effects of various factors such as atmospheric conditions etc. In order to improve the performance of the system, the optimization of the design is essential.

In Particle Swarm Optimization, the candidate solutions are considered as the particle and population is termed as swarm. These particles are moved around in the search space according to a few simple formulae. The movements of the particles are guided by their own best known position in the search-space as well as the entire swarm's best known position. When improved positions are being discovered these will then come to guide the movements of the swarm.

Particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO can be used on optimization problems that are partially irregular, noisy, change over time, etc. As the basic PSO works dimension by dimension, the solution point is easier found when it lies on an axis of the search space, on a diagonal, and even easier if it is right on the centre. The only currently existing PSO variant that is not sensitive to the rotation of the coordinates while is locally convergent has been proposed. The method has shown a very good performance on many benchmark problems while its rotation invariance and local convergence have been mathematically proven.

Particle Swarm Optimization algorithm is a biologically-inspired algorithm motivated by a social analogy. The PSO algorithm is population-based: a set of potential solutions evolves to approach a convenient solution (or set of solutions) for a problem. Being an optimization method, the aim is finding the global optimum of a real-valued function (fitness function) defined in a given space (search space). The PSO algorithm is population-based: a set of potential solutions evolves to approach a convenient solution (or set of solutions) for a problem. Being an optimization method, the aim is finding the global optimum of a real-valued function (fitness function) defined in a given space (search space).

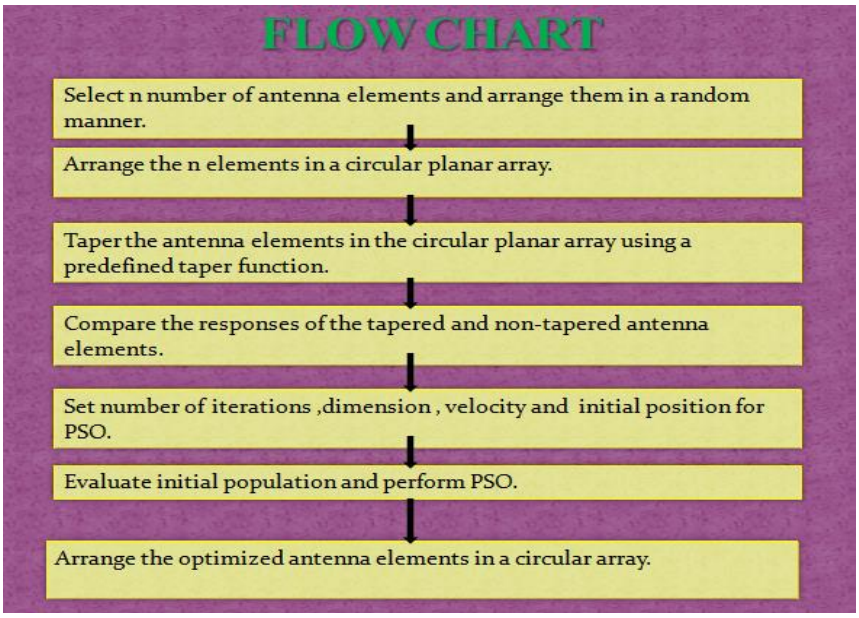
PSO simulates the behaviors of bird flocking. Suppose the following scenario: a group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food is. But they know how far the food is in each iteration. So the best strategy to find the food is to follow the bird which is nearest to the food.

PSO learned from the scenario and used it to solve the optimization problems. In PSO, each single solution is a "bird" in the search space. We call it "particle". All of particles have fitness values which are evaluated by the fitness function to be optimized, and have velocities which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles.

PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. (The fitness value is also stored.) This value is called 'pbest'. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called 'gbest'. When a particle takes part of the population as its topological neighbours, the best value is a local best and is called 'lbest'. After finding the two best values, the particle updates its velocity and positions. The development of PSO is still ongoing. And there are still many unknown areas in PSO research such as the mathematical validation of particle swarm theory.

IV. SIMULATION AND RESULTS

The simulation process can be easily described with the help of the flow chart shown below.



Select n number of antenna elements and arrange them in a random manner.

Arrange the n elements in a circular planar array.

Taper the antenna elements in the circular planar array using a predefined taper function.

Compare the responses of the tapered and non-tapered antenna elements.

Set number of iterations ,dimension , velocity and initial position for PSO.

Evaluate initial population and perform PSO.

Arrange the optimized antenna elements in a circular array.

Fig. 2. Flow chart

Select ‘n’ number of antenna elements and place those elements randomly.

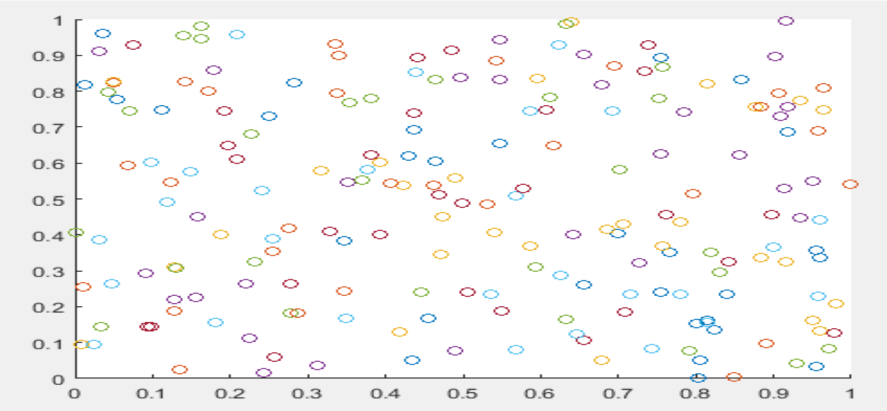


Fig. 3. Random arrangement of n elements

Select a radius value and arrange the antenna elements in a circular array which having the selected radius. The circular array provides more symmetrical patterns with lower side lobes and much higher directivity. These arrays find applications in the field of remote sensing tracking, various communication fields. Exclude the elements are outside of the selected radius.

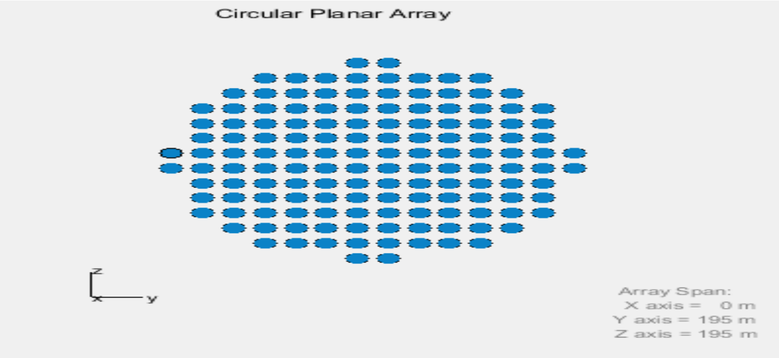


Fig. 4. Arrangement of n elements in circular array

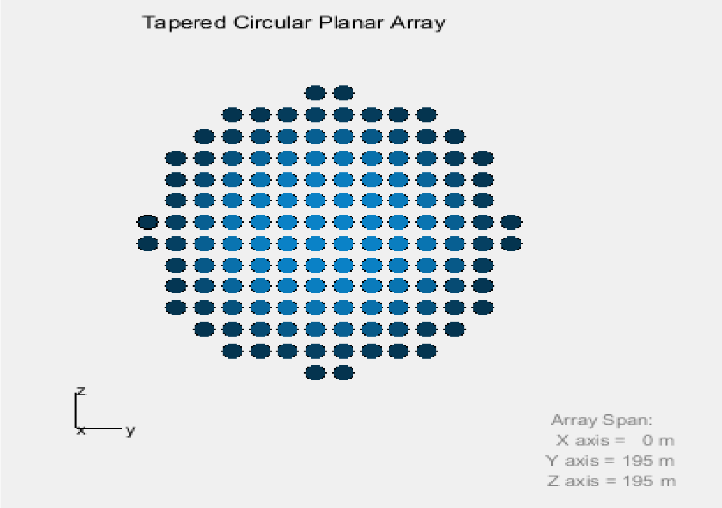


Fig. 5. Circular array showing excluded elements

Set a side-lobe level and perform the tapering according to the side lobe level.

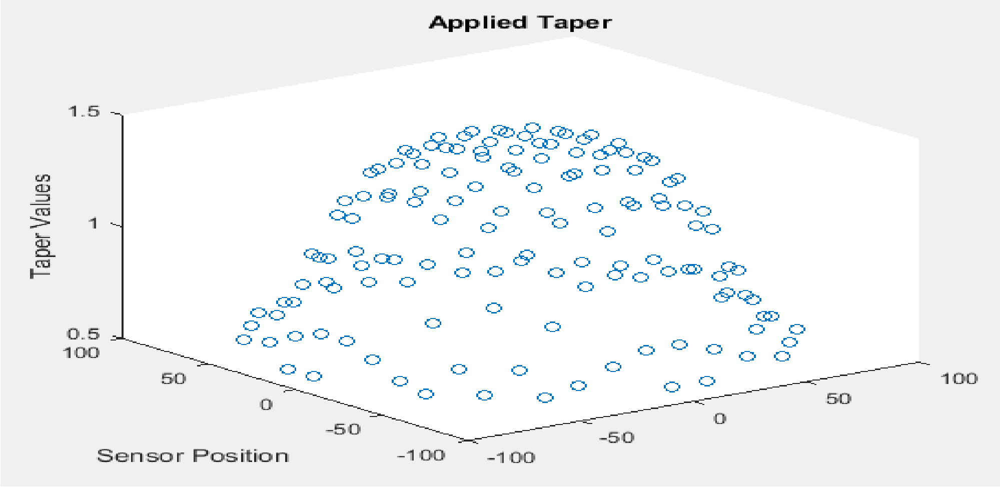


Fig. 6. Tapered array

Find out the response of tapered and non-tapered elements and make a comparison.

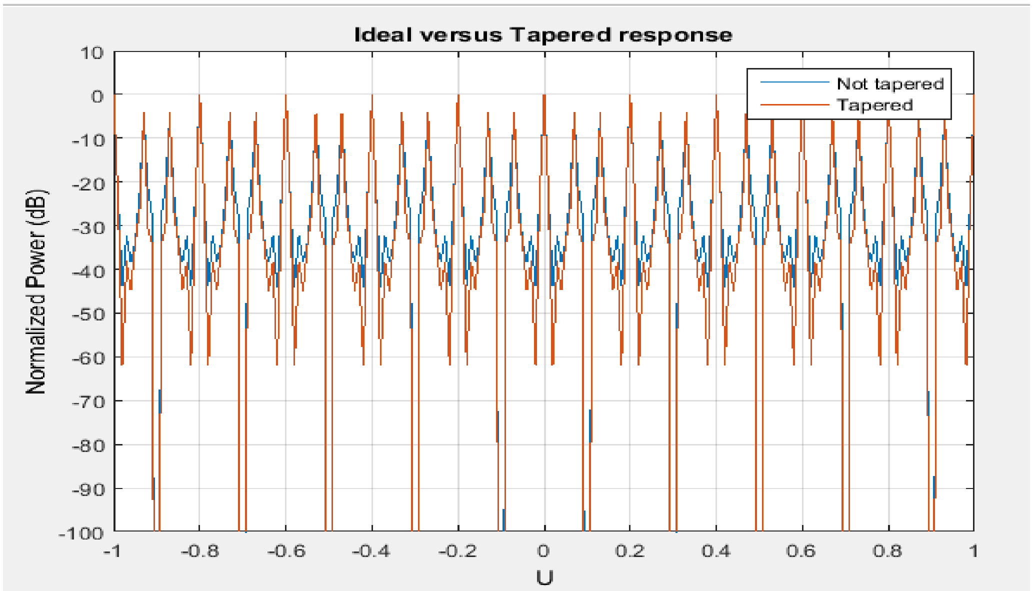


Fig. 7. Comparison of tapered and non-tapered array

Then select number of iterations for performing PSO and also set PSO parameters, dimension of the problem, velocity and assign the current position of the elements as the initial position. By performing PSO, we can find out a global best position with respect to a local best position, which is taken as the current position of antenna elements.

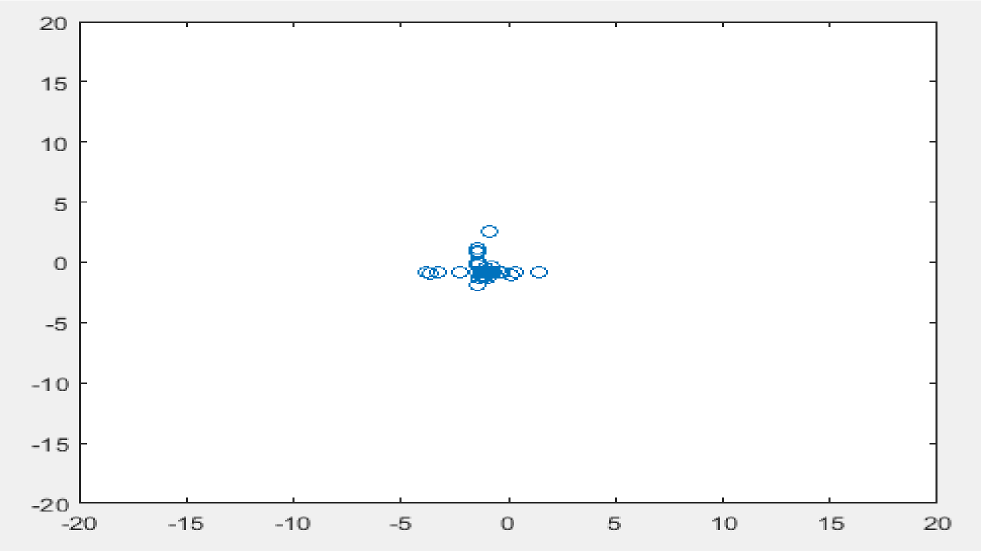


Fig. 8. Optimized elements after PSO

Then arrange the optimized antenna elements as a circular array.

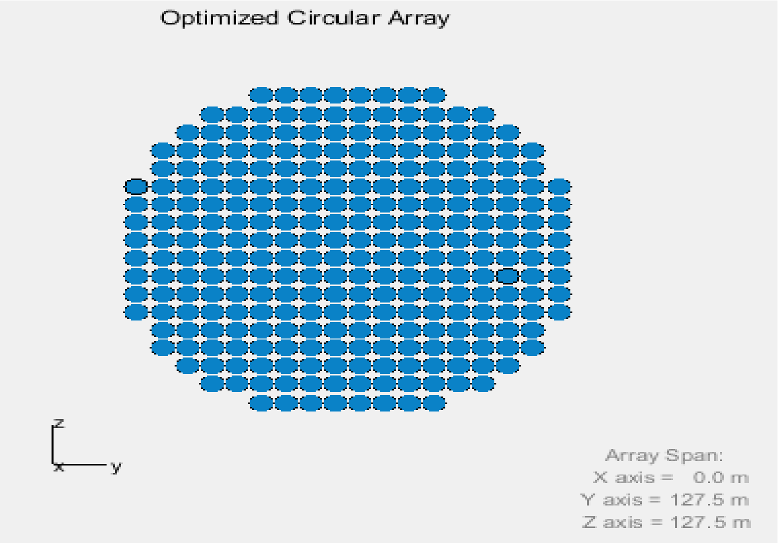


Fig: 9. Optimized elements arranged in circular array

V. CONCLUSIONS

Antenna array technique plays a very important role in modern antenna, radar, and wireless communication systems. Many optimization techniques have been developed for antenna array synthesis to satisfy various requirements. Particle Swarm Optimization is a relatively recent heuristic search method whose mechanics are inspired by the swarming or collaborative behavior of biological populations. It is an iterative based algorithm. The basic PSO algorithm consists of three steps, namely, generating particles positions and velocities, velocity update, and finally, position update. The PSO is a less expensive optimization technique. The computational savings offered by the PSO depends upon the problems and conditions. It uses less number of functions for evaluations.

The performance of the antenna array system get reduced due to the effects of inter symbol interference and other signal degradation factors. The presence of the side lobes in the radiation pattern of an antenna array system will degrades the performance. By suppressing the side lobes, we can decrease the effects of ISI, and thus increases the performance of the antenna array system.

REFERENCES

[1] Ahmed El-makadema, Laith Rashid, and Anthony K. Brown, Geometry Design Optimization of Large-Scale Broadband Antenna Array Systems, IEEE Transactions On Antennas And Propagation, Vol. 62, No. 4, April 2014.

[2] Guolong He, Yafeng Zhan, Yukui Pei, and Bin Wu, Subarrayed Antenna Array Synthesis Using Ternary Adjusting Method, Hindawi Publishing Corporation International Journal of Antennas and Propagation, January 2014.

[3] V. Rajya Lakshmi, and G. S. N. Raju, Optimization of Thinned Dipole Arrays Using Genetic Algorithm, IACSIT International Journal of Engineering and Technology, Vol. 3, No. 6, December 2011.

[4] Eloy de Lera Acedo, Nima Razavi - Ghods, Member, Luis Enrique Garcia, Peter Duffett-Smith, and P. Alexander, Ultra-Wideband Aperture Array Element Design for Low Frequency Radio Astronomy, IEEE Transactions On Antenna And Propagation, Vol. 59, NO. 6, June 2011.

[5] Iqroop Kaur, Sanjeev Kumar, Linear Antenna Array Optimization Techniques, International Journal of Engineering Trends and Technology- May to June Issue 2011.

[6] Ahmed El-Makadema, Large Scale Broadband Antenna Array Systems, Thesis for The University of Manchester for the degree of Doctorate of Philosophy in the Faculty of Engineering and Physical Sciences, January 2011.

[7] Peter Joseph Bevelacqua, Antenna Arrays: Performance Limits and Geometry Optimization, Doctor of Philosophy thesis, Arizona State University, May 2008.

[8] Thomas G. Spence, and Douglas H. Werner, Design of Broadband Planar Arrays Based on the Optimization of Aperiodic Tilings, IEEE Transactions On Antenna And Propagation, Vol. 56, NO. 1, January 2008.

[9] Randy L. Haupt, Optimized Element Spacing for Low Sidelobe Concentric Ring Arrays, IEEE Transactions On Antenna And Propagation, Vol. 56, NO. 1, January 2008.

[10] Douglas H. Werner, Randy L. Haup, and Pingjuan L. Werner Fractal Antenna Engineering: The Theory and Design of Fractal Antenna Arrays, IEEE Antennas and Propagation Magazine, Vol. 41, No. 5, October I999.