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Design of Linear Antenna Array for Smart Antenna using Whale Optimization Algorithm

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ABSTRACT

The WOA is a new metaheuristic optimization algorithm and this technique is used for solving optimization problems. WOA has been designed to solve single-objective optimization problems. It mimics the hunting behavior of humpback whales. The inspiration results from the fact that a whale recognizes the location of a prey (i.e., optimal solution) by swimming around the prey within a shrinking circle and along a spiral-shaped path simultaneously. This algorithm includes three operators to simulate the search for prey, encircling prey, and bubble-net foraging behavior of humpback whales. An overview of WOA is described in this paper, rooted from the bubble-net hunting strategy, besides an overview of WOA applications that are used to solve optimization problems in various categories. The best solution has been determined to make something as functional and effective as possible through the optimization process by minimizing or maximizing the parameters involved in the problems. In this whale optimization algorithm, the parameters such as Amplitude, Position and Phase are used to determine the fitness function.

1. Introduction:

An antenna is defined as usually metallic device (as a rod or wire) for radiating or receiving radio waves. In other words, the antenna is the transitional structure between free-space and a guiding device. The guiding device or transmission line may take the form of a coaxial line or a hallow pipe(waveguide), and it is used to transport electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver. In the former case, we have a transmitting antenna and, in the latter, a receiving antenna.

An **antenna array** is a group of isotropic radiators such that the currents running through them are of different amplitudes and phases. These are radiators of electromagnetic frequency and energy. Antenna arrays are the solution to the problem defined as the limitations of operating a single antenna. An example of the problem is that although a dipole antenna allows for better control of direction than an isotropic (Omni-directional) antenna - as the length of the dipole increases, the control of direction decreases. Hence control by changing the length of a single antenna is very limited. Greater flexibility and control can be obtained for directing the beam with an arrangement of multiple radiators.

The radiation pattern of a single element is relatively wide, and each element provides low values of directivity (gain). In many applications it is necessary to design antennas with high directive characteristics (very high gains) to meet the demand of long-distance communications. This can be accomplished by increasing the electrical size of antenna.

Enlarging the dimensions of single elements often leads to more directive characteristics. Another way to enlarge the dimensions of antenna, without necessarily increasing the size of the individual elements, is to form an assembly of radiating elements in an electrical and geometrical configuration. The new antenna, formed by multi-element, referred to as an array. In most cases, the elements of an array are identical.

2. Types of antenna arrays

There are a few different general types of antenna arrays.

2.1 Linear array - antenna elements arranged along a straight line. The array consists of N elements with a spacing of *d* between the elements. The output of each element is weighted by a factor of a_k and the results summed to form the signal out of the antenna.

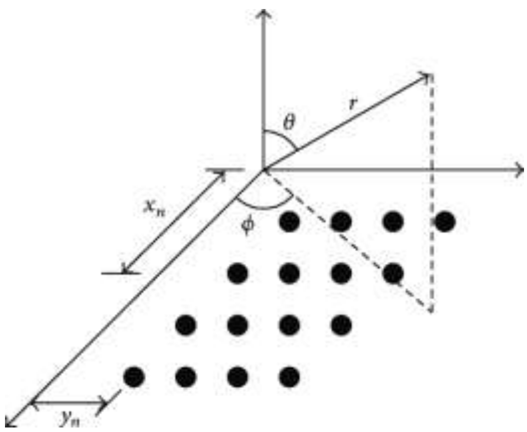
Application of Linear Array

1. Adaptive linear arrays are used extensively in wireless communication to reduce interference between desired users and interfering signals.
2. Many linear arrays spaced parallel on the common plane create a planar array antenna. These are used in mobile radar equipment.
3. The linear array is most often used to generate-a fan beam and is useful where broad coverage in one plane and narrow beam width in the orthogonal plane are desired.
4. Linear arrays can be made extremely compact and are therefore very attractive for shipboard applications.

2.2 Planar array - We now want to extend the results of linear arrays to planar arrays. In a planar array the antenna elements are located on some type of regular grid in a plane. Antenna elements arranged over some planar surface (example - rectangular array).

Applications

1. Radar
2. Smart antennas
3. Modem communication
4. Radio astronomy
5. Telemetry.



2.3 Circular array - antenna elements arranged around a circular ring. A circular array is high side-lobe geometry. If the distance of array elements is decreased to reduce the side lobes, the mutual coupling influence becomes more significant.

APPLICATION:

1. Span radio direction finding
2. Air and space navigation
3. Underground propagation
4. Radar
5. Sonar

3. Array Optimization

3.1 Linear antenna array optimization

In order to minimize the maximum SLL, the following fitness function is used:

Minimize $f_{itt} = \max\{20\ log|AF(\emptyset)|\}$

Subject to $\emptyset \epsilon [0, \emptyset_n]$ (3.1)

where [0, $\emptyset_n$] is the side lobes region which depends on the number of elements. Here, it is chosen as [0, 70^0] and [0, 80^0] for 10 and 16 elements LAAs, respectively. Three optimization cases will be considered; optimizing elements amplitudes, optimizing elements positions, optimizing elements phases.

3.2 Circular antenna array (CAA) optimization

Here, the objective is to design a CAA with deep nulls in the directions φ*nu1* and φ*nu2* which define the first null beam width (FNBW) while minimizing the side lobes levels.

Thus, the following fitness function is used:

Fitness = $(W1F1 + W2F2)/|AF_{max}|^2$

F1 = $|AF(\emptyset_{nu1})|^2 + |AF(\emptyset_{nu2})|^2$

F2 = max $\{|AF(\emptyset_{ms1})|^2, |AF(\emptyset_{ms2})|^2\}$ (3.2)

where the two angles {φ*nu1*, φ*nu2*} define the major lobe, i.e., the first null beam width (FNBW) = φ*nu2*-φ*nu1*=2φ*nu2*. φ*ms1* and φ*ms2* are the angles where the maximum side lobe level is attained during the optimization process in regions (from -180 to φ*nu1*) and (from φ*nu2* to 180), respectively. An increment of 1o is used in the optimization process

4. WHALE OPTIMIZATION ALGORITHM

4.1 Whale Optimization History

In order to solve Optimization problems in many fields swarm intelligence-based optimization algorithms have attracted much attention in recent years.

The whale Optimization algorithm (WOA) is a new type of swarm intelligence optimization algorithm proposed by Mir Jalili and Lewis in 2016 which is inspired by the unique predation behaviour of humpback whales. Whale optimization is a population-based method.

4.1 WHALE BEHAVIOUR

Whales are the biggest mammals on the earth. It is one of the larger rorqual species. One of the biggest baleen whales is humpback whales (Megaptera novaeangliae). Whales mostly live-in groups and they even can develop their own dialect.

It includes 3 operations to simulate:

(a) Search for prey, (b) Encircling prey and (c) Bubble-net feeding behaviour.
WOA is mainly used to solve the target problems of the antenna by imitating whales' predatory behaviour. bubble-net feeding is a unique behaviour that can be observed only in humpback whales.

In this work the spiral bubble-net feeding manoeuvre is mathematically modelled in order to perform optimization.

4.2 Whale Optimization Algorithm

The WOA is developed by the foraging behaviour of the humpback whales to search fishes near the surface via creating typical bubbles along a circle. In WOA the current best solution of the individual whale is the target prey. First, the best agent is defined and then the positions of other agents will be updated in the direction of the best agent. The mathematical representation of this behaviour is as follows [16]:

$$D = |C.* X'(t) - X(t)| \ (1) \qquad (4.1)$$

Where t = current iteration

A, C = coefficient vectors

X' = position vector of the best solution obtained and is updated in each iteration.

X = position vector

$.*$ = element by element multiplication

The vectors A and C are determined as follows:

$$A = 2a.* r - a \qquad (4.2)$$

$$c = 2.* r \quad (4.3)$$

Where 'a' decreases linearly from 2 to 0 throughout the iterations and 'r' is a random vector in [0, 1]. The position vector X is updated by either shrinking encircling mechanism or by the spiral mechanism depending on the value of 'p', a random number in [0, 1]. When the value of 'p' is less than 0.5, the shrinking mechanism is adopted and the mathematical equation is expressed as

$$X(t+1) = X'(t) - A.* D \quad (4.4)$$

On the other hand, when 'p' is greater than or equal to 0.5 the spiral method is adopted using the equation

$$X(t+1) = D'.* e^{bl}.*cos\ cos(2\pi l) + X'(t) \quad (4.5)$$

Where $D' = |X'(t) - X(t)|$

b= a constant defining logarithmic spiral

l= random number in [-1 ,1]

The steps adopted by the WOA algorithm are as follow:

1. Initialize X_i , i=1, 2, ……… n, as the whale population

2. Find the fitness value of an individual agent. Let X' be the best agent

3. In each iteration update a, A, C, l and p for each agent. If p is less than 0.5 and also $|A| < 1$, considering the equation (1) update the location of the present agent. Else if $|A| > 1$, get an agent randomly as X_{rand} and update the present agent's position by the equation

$$X(t+1) = X_{rand} - A.* D \quad (4.6)$$

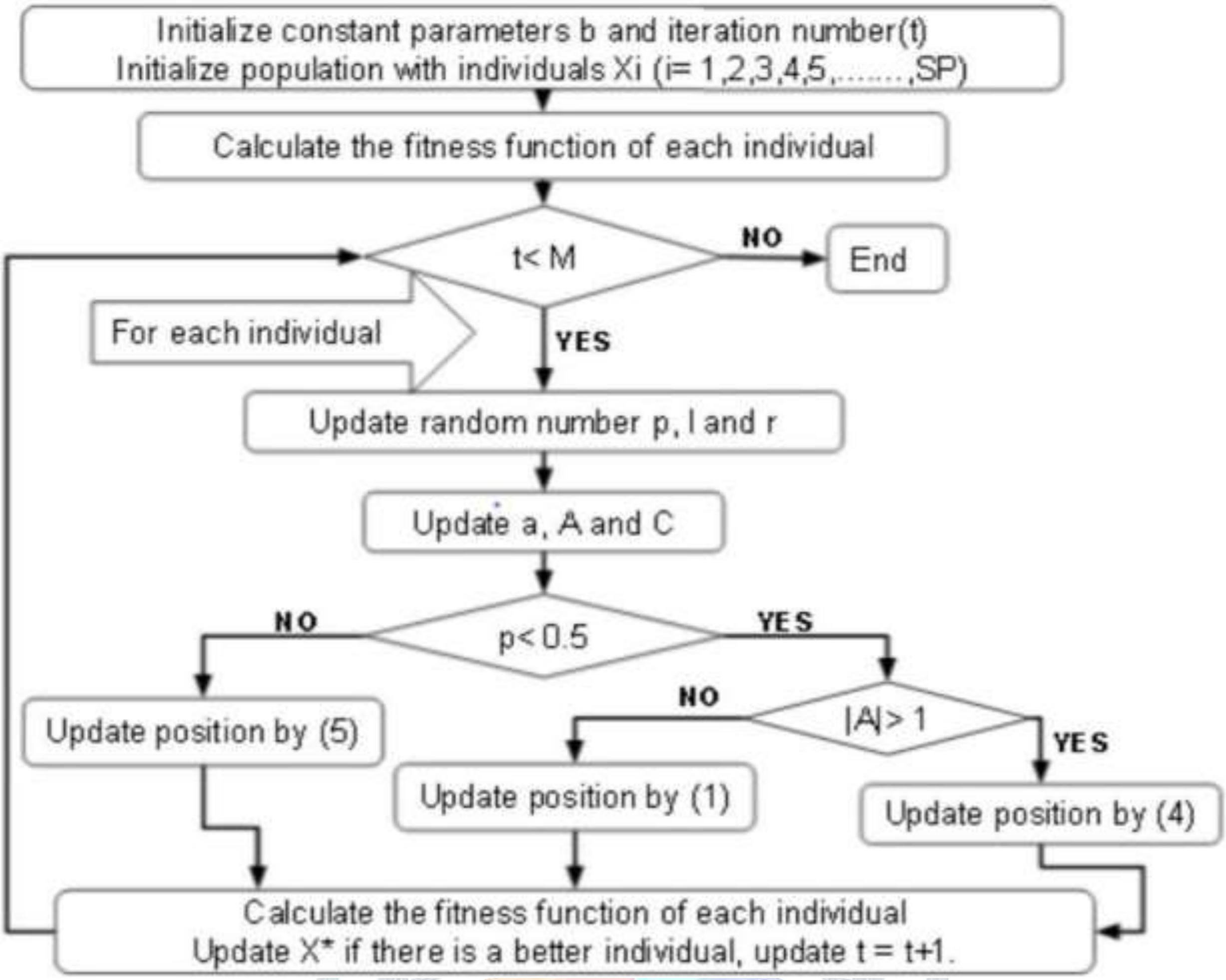
4. If p is greater than or equal to 0.5, then update the current position by equation (5)

5. Amend the agent if it goes beyond the search space. Calculate fitness of each agent.

6. If there arise a better solution, then update X'.

7. Go back to step 2.

4.3 WOA FLOW CHAT



4.4 WOA APPLICATIONS

1. It is used for getting the Radiation Pattern of an array.
2. It is used in Feature Selection.
3. It is used in Multi-objective Optimal Mobile Robot Path Planning.
4. It is used in Multi-objective Optimal Vehicle Fuel Consumption.
5. It is used in Skeletal Structures.
6. It is used in Image Segmentation.

However, since then this perspective has been expanded to include optimality.

5. RESULTS

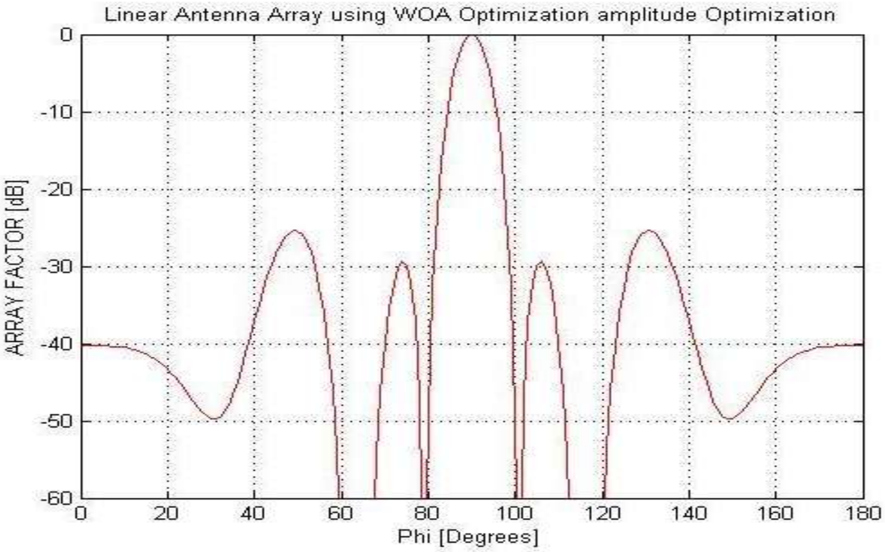
5.1.1 Optimizing elements amplitudes (I_n)

5.1.1(a) 12 elements LAA

Using the fitness function associated with the array factor for 12 elements, the linear array is optimized using the WOA method (population size=50, number of iterations=10). Table In shows the optimum amplitudes obtained using the WOA. The maximum sidelobe levels obtained using the WOA is –25.372 db. WOA results are slightly better than other methods.

N	1	2	3	4	5	6
In	0.8368	0.7268	0.4543	0.6065	0.4521	0.3953

Table 5.1. 1 (a) 12 elements LAA Optimizing elements amplitude



5.1.1 (a) 12 element LAA Optimizing elements amplitudes

5.1.1(b) 16 elements LAA

In this example, a 16-element LAA is optimized using the WOA method (population size=50, number of iterations=10). The best results are listed in Table II. Figure 4 shows the radiation pattern obtained by WOA. The maximum SLL obtained using WOA method is -29.160 db.

N	1	2	3	4	5	6	7	8
In	0.9746	0.2889	0.9936	0.2231	0.6776	0.1192	0.2071	0.2643

5.1.1(b) 16 elements LAA Optimizing elements amplitudes

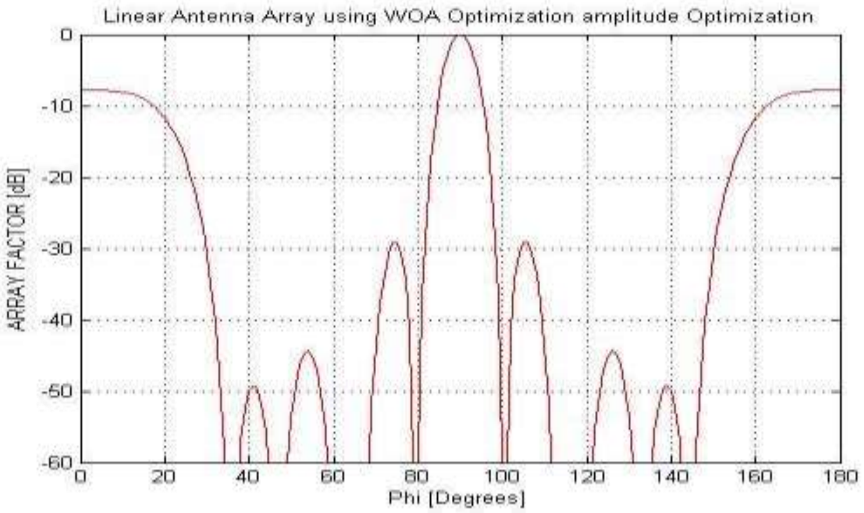


Figure 5.1.1(b) 16 elements LAA Optimizing elements amplitudes

5.1.2 Optimizing elements positions (x_n)

In order to optimize the element positions in the LAA by the WOA, the element amplitudes and the element phases are fixed as *In* =1 and φ_n=0 for *n=1…N*.

a) 18 ELEMENT LAA

The optimized positions obtained using the WOA (population size=50, number of iterations=10), while Figure 5 shows the obtained array factor. The maximum SLL obtained by WOA method is -35.746 dB.

N	1	2	3	4	5	6	7	8	9
Xn	0.0866	0.3496	0.3696	0.5075	0.8431	0.9318	1.2413	1.3580	1.5467

Table 5.1.2(a) 18 Element LAA Optimizing elements positions

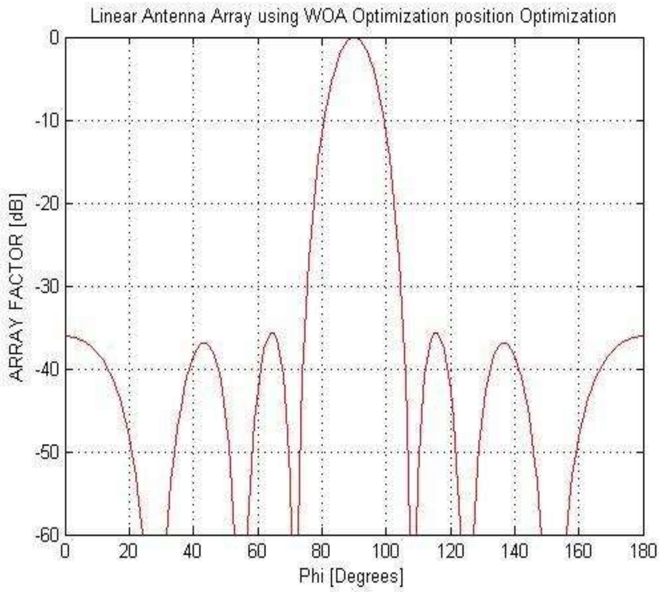


Figure 5.1.2 18 Element LAA Optimizing elements positions

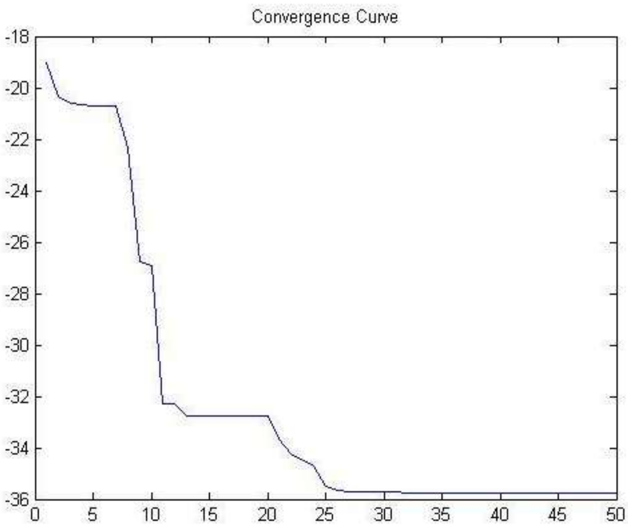


Figure 5.1.3 18 Element LAA Convergence Curve

b) 20 ELEMENT LAA

The optimized positions obtained using the WOA (population size=50, number of iterations=10),while Figure shows the obtained array factor. The maximum SLL obtained by WOA method is -36.951 dB.

N	1	2	3	4	5	6	7	8	9	10
Xn	0	0.1449	0.3085	0.4429	0.5473	0.7655	0.8133	0.9286	1.0388	1.3808

Table 5.1.2(a) 18 Element LAA Optimizing elements positions

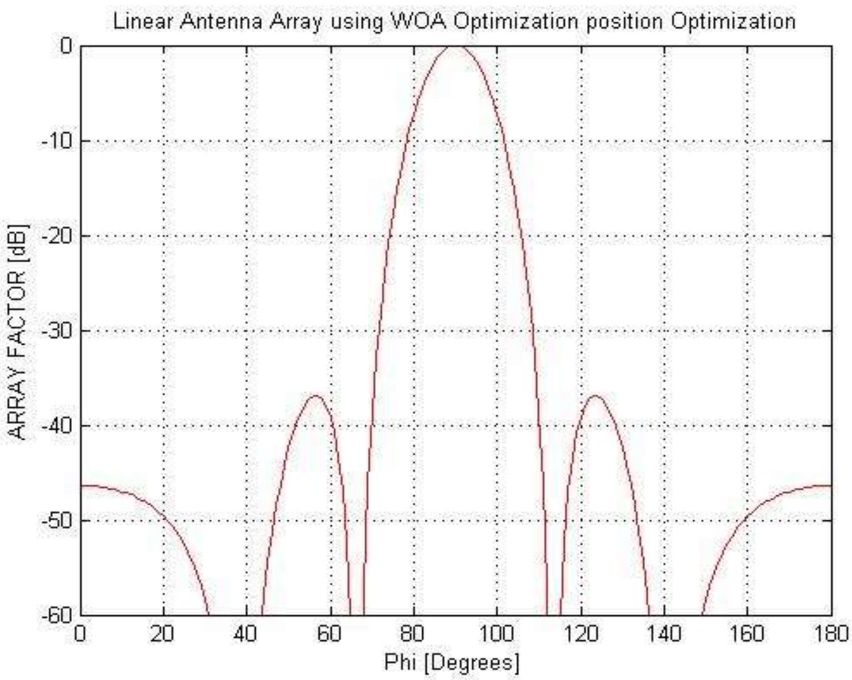


Figure 5.1.2 18 Element LAA Optimizing elements positions

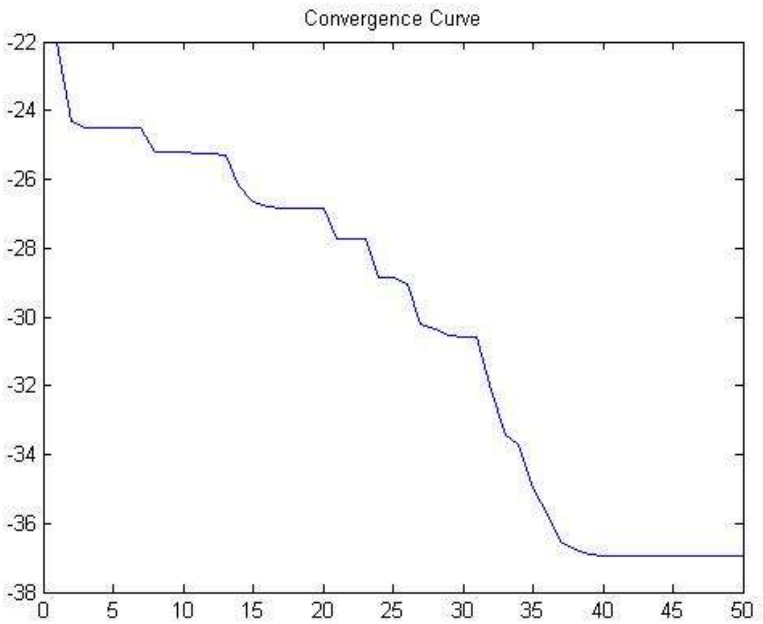


Figure 5.1.3 18 Element LAA Convergence Curve

5.1.3 Optimizing elements phases (φn)

Here, WOA method will be applied on a 26-element LAA to provide a beam-steering pattern with the main lobe in the direction of 45 degrees by optimizing the element's phases.

The phases of the element are assumed to be symmetric as φn =φ-n for *n=1, 2, …… N*, where φ_n is the phase of the *n* th element.

Table IV shows the optimum phases (in degrees) for 26 elements array using WOA method without nulls (population size=50, number of iterations=10) and beam-steering pattern with main lobe in the direction of 45 degrees by optimizing the element's phases.

5.1.3(a) 26 element LAA

The optimized positions obtained using the WOA (population size = 50, number of iterations = 10) where the number of elements is 26. The maximum SLL obtained by WOA method is -26.587 dB Figure 6 shows the radiation pattern obtained by WOA.

Method	Element wise phases
WOA	272.0521, 306.9103, 92.9872, 185.1558, 225.6845, 313.7484, 253.7998, 26.3113, 24.1070, 265.6433, 344.9554, 43.5846, 19.4335

5.1.3(a) 26 Element LAA Optimizing elements phases

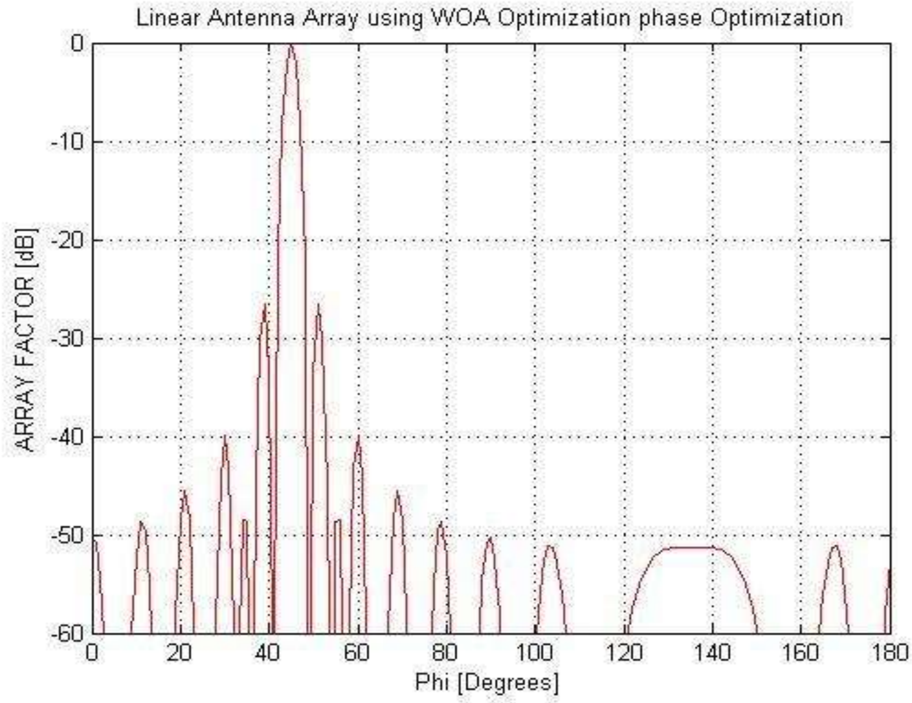


Figure 5.1.3(a) 26 Element LAA Optimizing elements phases

6. CONCLUSION

WOA is a new technique in electromagnetics optimization. It was applied on the optimization of antenna arrays. Three cases of linear array design have been considered; amplitudes optimization, positions optimization and phases optimization. WOA results have been very good algorithm and its results are as good as those obtained using other well-developed methods.

This optimization technique is very effective and put into practise for other array antenna of shapes like circular, elliptical, concentric circular etc

The Whale optimisation algorithm has given better results as compared to the other well-developed algorithms.

REFERENCES

[l] K.Rajesh Kumar, S. Aruna, K. Srinivasa Naik, Side Lobe Reduction of a Concentric Circular Antenna Array using Genetic Algorithim(GA) and Particle Swarm Optimization(PSO). IJEIT ISSN: 2277-3754 ISO 9001:2008.

[2] Vennapu. Krishna Tulasi, K. Rajesh Kumar, Dr. Vennapu. Lakshmana Rao Design of Linear and Circular Antenna Array for Side Lobe Reduction Using the Method Moth Flame Optimization Algorithm Visakkapatnam,2019 IJSEAS ISSN: 2395-3470.

[3] S. C. Swales, M. A. Beach, and D. J. Edwards, "Multi-Beam Adaptive Base- Station Antennas for Cellular Land Mobile Radio Systems," 39th IEEE Vehicular Technology Conference, Vol. 1, pp. 341-348, 1989.

[4] S. C. Swales, M. A. Beach, D. J. Edwards, and J. P. McGeehan, "The Performance enhancement of Multibeam Adaptive Base-Station Antennas for Cellular Land Mobile Radio Systems," IEEE Transactions on Vehicular Technology, Vol. 29, No. 1, pp. 56-67, February 1990.

[5] S. P. Stapleton and G. S. Quon, "A Cellular Base Station Phased Array Antenna System," 43rd IEEE Vehicular Technology Conference, pp. 93-96, 1993.

[6] G. V. Tsoulos, M. A. Beach, and S. C. Swales, "Application of Adaptive Antenna Technology to Third Generation Mixed Cell Radio Architectures," 44th IEEE Vehicular Technology Conference, Vol. 1, pp. 615-619, 1994.

[7] U. Forsse'n, J. Karlsson, B. Johannisson, M. Almgren, F. Lotse, and F. Kronestedt, "Adaptive Antenna Arrays for GSM900/DCS1800," 44th IEEE Vehicular Technology Conference, Vol. 1, pp. 605-609, 1994.

[8] T. Ohgane, "Spectral Efficiency Evaluation of Adaptive Array Base Station for Land Mobile Cellular Systems," 44th IEEE Vehicular Technology Conference, Vol. 3, pp. 1470-1474, 1994.

[9] W. C. Y. Lee, "Applying the Intelligent Cell Concept to PCS," IEEE Transactions on Vehicular Technology, Vol. 43, No. 3, pp. 672-679, August 1994.

[10] J. H. Winters, J. Salz, R. D. Gitlin, "Adaptive Antennas for Digital Mobile Radio," Proc. IEEE Long Island Section Adaptive Antenna Systems Symposium, pp. 81-86, Long Island, NY, Nov. 19, 1992.

[11] J. Kennedy and M. C. Sullivan, "Direction Finding and 'Smart Antennas' Using Software Radio Architectures," IEEE Communications Magazine, pp. 62-68, May 1995.

[12] R. Kohno, H. Imai, M. Hatori, and S. Pasupathy, "Combination of an Adaptive Array Antenna and a Canceller of Interference for Direct-Sequence Spread-Spectrum Multiple-Access System," IEEE JSAC, Vol. 8, No. 4, pp. 675-682, May 1990.

[13] S. Anderson, M. Millnert, M. Viberg, and B. Wahlberg, "An Adaptive Array for Mobile Communication Systems," IEEE Transactions on Vehicular Technology, Vol. 40, No. 1, pp. 230-236, February 1991.

[14] V. A. N. Barroso, M. J. Rendas, J. P. Gomes, "Impact of Array Processing Techniques on the Design of Mobile Communication Systems," Proc. 7th Mediterranean Electrotechnical Conf. - MELECON, Part 3/3, pp. 1291-1294, 1994.

[15] G. Xu, H. Liu, W. J. Vogel, H. P. Lin, S. S. Jeng, and G. W. Torrence, "Experimental Studies of Space-Division-Multiple-Access Schemes for Spectral Efficient Wireless Communications," IEEE International Communications Conference, Vol. 2, pp. 800-804, 1994.