ISSN 2320-9984 (Online)
Volume 13 Issue 1 | March 2025
International Journal of Modern Engineering & Management Research
Website: www.ijmemr.org

Optimisation of Linear Antenna Array using PSO

Pooja Sahu
M.Tech. Research Scholar
Computer Science and Engineering
Takshshila Institute of Engineering and Technology
Jabalpur (M.P.), India
Email: poojasahu7898.ps@gmail.com

Santosh Chouhan
Assistant Professor
Department of Electronics & Communication Engg.
Takshshila Institute of Engineering and Technology
Jabalpur (M.P.), India
Email: santoshchouhan@takshshila.org

Abstract**—***This paper presents the optimization performance of non-uniform linear antenna array with optimized inter-element spacing and excitation amplitude using Particle Swarm Optimization (PSO). The aim of the proposed algorithm is to obtain the optimum values for inter-element spacing and excitation amplitude for a linear antenna array in a given radiation pattern with suppressed Side Lobe Level (SLL), minimum Half Power Beamwidth (HPBW), improved directivity and placement of nulls in the desired direction. A variety of design examples are considered and the obtained results using PSO are validated by benchmarking with results obtained using other nature- inspired meta-heuristic algorithms such as the Real-coded Genetic Algorithm (RGA) and the Biogeographic Based Optimization (BBO) algorithm. The comparative results are shown that optimization of linear antenna array using the PSO provides considerable enhancement in the SLL, the HPBW, the directivity and the null control in the desired direction.*

Keywords:— *Linear Antenna Array, Improved Directivity, Null Control, Particle Swarm Optimization, Minimum Side Lobe Level, Half Power Beamwidth.*

1. INTRODUCTION

An antenna array is a combination of two or more antenna elements that can be placed in a specific geometry. In a linear antenna array, antenna elements are placed along one axis. The antenna array produces a beam, this beam can effect by changing the geometry (linear, circular, spherical etc.) and also by some other parameters i.e. inter-element spacing, excitation amplitude and excitation phase of the individual element [1]. In mostly wireless communication requires more directive antenna having high gain. Antenna array has high gain, more directive, spatial diversity. Antenna array synthesis has received importance in the near past, where various performance goals were considered. For array synthesis, different optimization algorithms e.g., the simulated annealing [2], the ant-colony optimization [3], the GA [4] and the PSO [5] have been used in the previous research studies.

optimization [3], the GA [4] and the PSO [5] have been used in the previous research studies. The optimization of linear antenna provides a pattern that has minimum the SLL and the HPBW i.e. by using the PSO and the GA [5]-[7]. The composite differential evaluation (CoDE) algorithm applied to optimize inter-element spacing, between two consecutive elements to minimize the SLL and to place nulls in the desired direction [8-9]. A multi- objective

optimization approach has been used in Ref. [10]-[11], to maximize the directivity and to minimize the SLL of an antenna array in the optimization process. In Ref. [10] the authors introduced a new technique memetic multi-objective evolutionary algorithm called memetic generalized differential evaluation (MGDE3) algorithm, which is the extension of generalized differential evaluation (GDE3) algorithm. In Ref. [12] the authors introduced a technique to realize the characteristics and performance of the non-uniform linear array. The presented technique had been utilized multi-objective functions to optimize inter-elements spacing, excitation currents, and excitation phases as well as minimized SLL and HPBW. Real-coded genetic (RCG) was employed for time modulating linear antenna array to impose nulls in the desired direction by optimizing spacing and excitation amplitude.

In this paper, two fitness function are presented. One fitness function is defined to place nulls in the desired direction by optimizing excitation amplitude, another one is provided a pattern of minimized SLL and HPBW. The paper is arranged as follow. Section II is addressed the analysis of design parameters, the number of the element, inter -element spacing, and excitation amplitude, of a linear antenna array. In section III, the PSO and optimizing the design parameters using the PSO are briefly described and studied in section IV and section V, respectively. The PSO employed to improve directivity, placing nulls in the desired direction are discussed in section in V. Finally, Section VI states the conclusions.

2. ANALYSIS OF ARRAY FACTOR

The linear antenna array parameters generally involve inter-element spacing, excitation amplitude, and number of elements, which directly influences its effect on array factor (AF). All these variables have been used to demonstrate beam forming and beam steering of a linear array. Figure 1 shows a linear antenna array in which identical antenna elements are placed on one side from the origin.

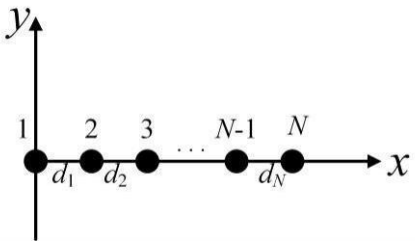

Figure 1: The geometry of N elements along the x-axis.

The AF for N elements can be considered as follows[13].

$$AF = \sum_{i=1} ai\ e^{(\,kdi\cos\theta+\phi i\,)} \quad \text{.....(1)}$$

where N is the number of antenna elements, a_i, d, ϕ_i, and k are the excitation amplitude, the inter-element spacing, the excitation phase and the propagation constant for the ith element.

To study the effects of these variables for an optimum design, a MATLAB routine has been developed using Eq. (1), and the AF has been plotted as a function of various control parameters.

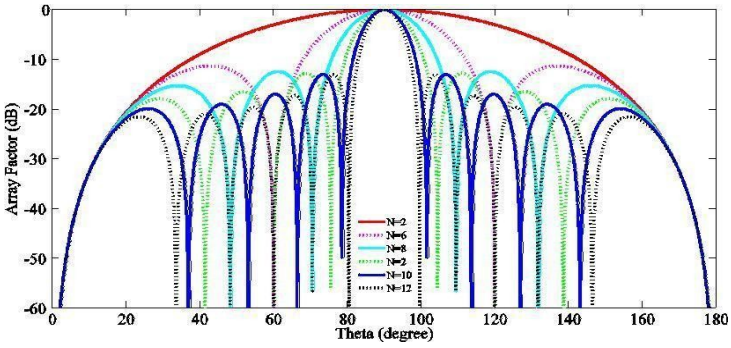

Figure 2: AF varied for element N from 2 to 12

Because the element N in an antenna array plays an important role in beam forming, beam steering, and interference reduction. Figure 2 is plotted by varying the number of elements while keeping the spacing between two consecutive elements as 0.5λ and ϕi = 90°. Results of Figure 2 are normalized with respect to the maximum value of the main lobe. From the Figure. 2, it has found that the HPBW is decreased with a minor reduction in the SLL with an increase in the number of elements.

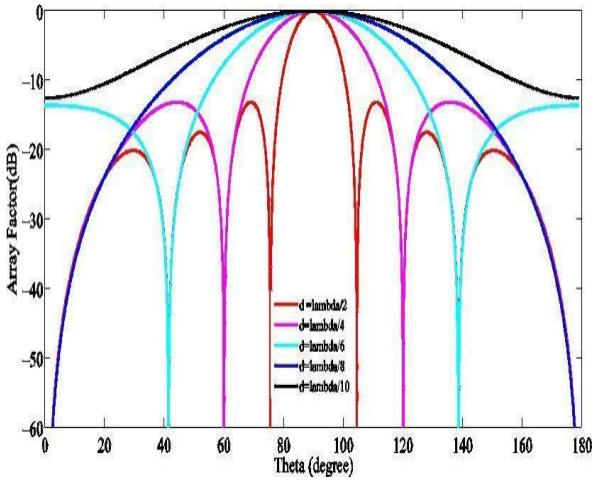

Figure 3: AF varied with distance, d decreasing from λ/2 to λ/10.

The performance of an antenna array is also dependent on the distance between two consecutive elements. The distance between the elements should be close to 0.5 λ.

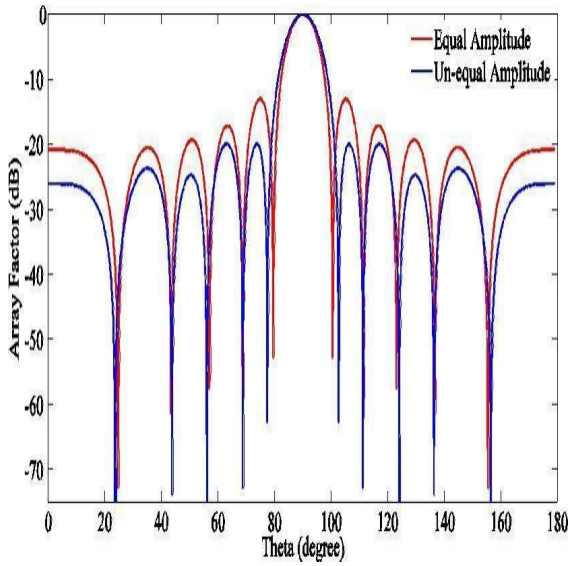

Figure 4: AF varied for equal and unequal excitation amplitude.

Excitation amplitude for each individual element, commonly known as a weight factor, also changes radiation characteristics of an array antenna. By changing its value for various elements of an array, one can change the overall array pattern. A comparative analysis of weighted and un-weighted antenna design is presented in Fig. 4. This is a primitive analysis, which is not based on the appropriately weighted amplitudes rather than the amplitudes are changed to observe its effect on AF variation. For equal and unequal amplitude excitation, the HPBW is decreased and the SLL is increased while for unequal amplitude excitation, the SLL is reduced and the HPBW is increased shown in Figure 4.

3. PARTICLE SWARM OPTIMIZATION ALGORITHM

The PSO is frequently used to solve successfully complex multidimensional optimization problems in different fields, such as antenna design and device-modeling [14]-[25] etc. In the PSO, every individual entity in the swarm is referred to as a particle and is associated with a velocity. All particles move in search of space and update their velocity according to the best position which is already found by themselves and by their neighbor which is also trying to find the best position. The PSO is a computational method which iteratively optimizes the problem based on a certain fitness function. Since we are dealing with both uniform and non-uniform linear antenna array, so each particle is a vector which contains the information for each feed antenna. This information includes the excitation amplitude $|ai|$, excitation phase $|\phi i|$ and the distance of element with respect to the previous position, d in the array. The flow chart of the PSO is given in Figure 5 and the PSO algorithm can be summarized as:

For each particle $i = 1... S$.

i. Generate random d , a and ϕ where xi= [di |ai| ϕi] and range for $|a|$, $|\phi|$ and d is [0,1], [0,3600], [$dmax$, $dmin$], respectively.

ii. Initialize individual particle velocities:

iii. Compute fitness function for each particle.

Compute the particle's best position (p_i) and the global best position (g) such that f (pi) < f (g)

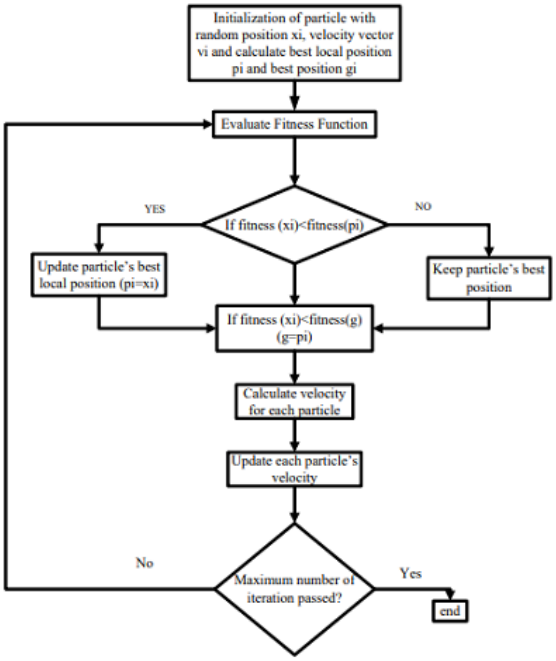

Figure 5: Flow chart of PSO

After the initialization phase, the optimization steps are as follows:

i. For each particle $i = 1, \ldots, S$ do:

ii. Pick uniformly distributed random numbers for the best local p and global position g.

iii. Update the velocity for each dimension:

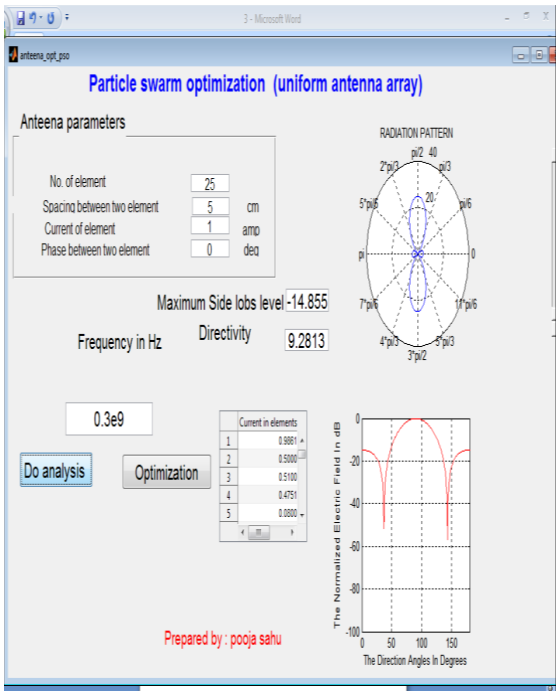

Figure 6: Optimized results for N=25element

6. CONCLUSION

In this paper, it has developed the PSO algorithm code to calculate and optimize the inter-element spacing and excitation amplitude, which the optimization objectives targeted in this work are involved the HPBW, the SLL, directivity and null steering in certain angular directions. In order to achieve these goals, the two fitness functions have been used in the PSO method. One of the fitness functions is used with different values for the number of antenna array elements to find the optimum values of excitation amplitude and inter-element spacing that give a pattern having minimum SLL and HPBW. PSO employs the second fitness function to control the nulls in a specified direction and minimize SLL and HPBW by optimizing excitation amplitude.

REFERENCES:

[1] B. Goswami and D. Mandal, "Nulls and Sidelobe Levels Control in a Time Modulated Linear Antenna Array by Optimizing Excitations and Element Locations Using RGA," *Journal of Microwaves, Optoelectronics, and Electromagnetic Applications,* Vol. 12, No. 2, December 2013.

[2] T. Girard, R. Staraj, E. Cambiaggio and F. Muller, "A simulated annealing algorithm for planar or conformal antenna array synthesis with optimized polarization," *Microwave and Optical Technology Letters,* Vol. 28, No. 2, pp. 86-89, 2001.

[3] C. M. Coleman, E. J. Rothwell and J. E. Ross, "Investigation of simulated annealing, ant -colony optimization, and genetic algorithms for self-structuring antennas," *IEEE Transactions on Antennas and Propagation*, Vol. 52, No. 4, pp. 1007 -1014, 2004.

[4] D. Marcano and F. Duran, "Synthesis

of antenna arrays using genetic algorithms," *IEEE Antennas and Propagation Magazine*, Vol. 42, No. 3, pp. 12-20, 2000.

[5] D. I. Abu-Al-Nadi, T. H. Ismail and M. J. Mismar, "Synthesis of linear array and null steering with minimized side-lobe level using particle swarm optimization," *Proceedings of the 4th European Conference on Antennas and Propagation*, pp. 1-4, 2010.

[6] M. M. Khodier and C. G. Christodoulou, "Linear array geometry synthesis with minimum sidelobe level and null control using particle swarm optimization," *IEEE Transactions on Antennas and Propagation*, Vol. 53, No. 8, pp. 2674 -2679, 2005.

[7] J. Song, H. Zheng and L. Zhang, "Application of particle swarm optimization algorithm and genetic algorithms in beam broadening of phase array antenna," *International Symposium on Signals, Systems and Electronics (ISSSE)*, pp. 17-20, 2010.

[8] M. Y. X. Lia, "Optimal synthesis of linear antenna array with composite differential evolutionary algorithm," *Scientia Iranica*, Vol. 19, No. 9, pp. 1780-1787, 2012.

[9] B. Goswami and D. Mandal, "A genetic algorithm for the level control of nulls and side lobes in linear antenna arrays," *Journal of Computer and Information Science*s, Vol. 25, No. 2, pp. 117-126, 2013.

[10] S. K. Gotsis, K. Siakavara, E. Vafiadis and J. Sahalos, "A multi-objective approach to subarrayed linear antenna arrays design based on memetic differential evolution," *IEEE Transactions on Antennas and Propagation*, Vol. 61, pp. 3042-3052, 2013.

[11] A. Bhargav and N. Gupta, "Multiobjective genetic optimization of nonuniform linear Array with low sidelobes and beamwidth," *IEEE Antennas and Wireless Propagation Letters*, Vol. 12, pp. 1547-1549, 2013.

[12] G. Ram, D. Mandal, R. Kar and S. P. Prasad, "Optimized hyper beam forming of receiving linear antenna arrays using Firefly algorithm," *International Journal of Microwave and Wireless Technologies*, Vol. 6, pp. 181-194, 2014.

[13] C. A. Balanis, "*Antenna Theory Analysis and Design*", A John Wiley and sons, 2005.

[14] G. Ram, D. Mandal, R. Kar and S. P. Ghosal, "Synthesis of time modulated linear antenna arrays using particle swarm optimization," *IEEE Region 10 Conference TENCON*, pp. 1-4, 2014.

[15] A. Banookh, and S. M. Barakati, "Optimal Design of Double Folded Stub Microstrip Filter by Neural Network Modelling and Particle Swarm Optimization," *Journal of Microwaves, Optoelectronics and Electromagnetic Applications*, Vol. 11, No. 1, June 2012.

[16] F. R. Durand, and T. Abrão, "Particle Swarm Optimization in WDM/OCDM Networks with Physical Impairments," Journal of Microwaves, *Optoelectronics and Electromagnetic Applications,* Vol. 12, No. 2, December 2013.

[17] C. J. A. Bastos-Filho and E. M. N. Figueiredo, "Design of Distributed Optical-Fiber Raman Amplifiers using Multi-objective Particle Swarm Optimization" *Journal of Microwaves, Optoelectronics and*

Electromagnetic Applications, Vol. 10, No. 2, December 2011.

[18] A. Banookh, and S. M. Barakati, "Optimal Design of Double Folded Stub Microstrip Filter by Neural Network Modelling and Particle Swarm Optimization" *Journal of Microwaves, Optoelectronics and Electromagnetic Applications*, Vol. 11, No. 1, June 2012.

[19] L. Wakrim, S. Ibnyaich, and M. M. Hassani, "The study of the ground plane effect on a Multiband PIFA Antenna by using Genetic Algorithm and Particle Swarm Optimization" *Journal of Microwaves, Optoelectronics and Electromagnetic Applications*, Vol. 15, No. 4, December 2016.

[20] S. S, Travessa, and W. P. Carpes Jr., "Use of an Artificial Neural Network-based Metamodel to Reduce the Computational Cost in a Ray-tracing Prediction Model" *Journal of Microwaves, Optoelectronics and Electromagnetic Applications,* Vol. 15, No. 4, December 2016.

[21] P. J. Bevelacqua and C. A. Balanis, "Minimum side lobe level for linear array," *IEEE Transactions on Antennas and Propagation*, Vol. 55, No. 12, pp. 3442 - 3449, 2007.

[22] A. R. Harish and M. Sachidananda, Antennas and Wave Propagation, *Oxford University Press*, 2007.

[23] K. Kennedy and R. Eberhart, "Particle swarm optimization," *Proceedings of the IEEE International Conference on Neural Networks*, pp. 1942-1948, 1995.

[24] M. A. Haq, M. T. Afzal, U. Rafique, Q. D. Memon, M. A. Khan and M. M. Ahmed, "Log periodic dipole antenna design using particle swarm optimization," *International Journal on Electromagnetics and Applications*, Vol. 2, No. 4, pp. 65-68, 2012.

[25] Q. D. Memon, M. M. Ahmed, N. M. Memon and U. Rafique, "An efficient mechanism to simulate DC characteristics of GaAs MESFETs using swarm optimization," *th IEEE International Conference on Emerging Technologies (ICET)*, pp. 1 -5, 2013.

[26] A. Sharaqa and N. Dib, "Design of linear and elliptical antenna arrays using Biogeography Based Optimization," A*rab Journal of Science and Engineering,* Vol. No. 4,pp 2929–2939, 2013.

[27] G. Al-Kubati, "Central force optimization method and its application to the design of antennas," *Master Thesis, Jordan University os science and Technology*, 2009.

[28] P. Joshi, and N. Jain, "Optimization of linear antenna array using genetic algorithm for a reduction in side lobe levels and to improve directivity," *International Journal of Latest Trends in Engineering and Technology (IJLTET)*, Vol. 2, No. 3, 2013. Vol. 28, pp 540–549, 2014.

[29] L. Pappula, and D. Ghosh, "Linear antenna array synthesis using Cat Swarm Optimization," *International*

[30] G. Ram, D. Mandal, R. Kar, S. P. Choshal, "Directivity maximization and optimal far-field pattern of time modulated linear antenna arrays using evolutionary algorithms," *International Journal of Electronics and Communication (AEU),* Vol. 69, pp 1800–1809, 2015 584