International Journal of Advance Engineering and Research Development (IJAERD)
Volume 1,Issue 3, April 2014, e-ISSN: 2348 - 4470 , print-ISSN:2348-6406

THE DEVELOPMENT OF A NOVEL ANTENNA ARRAY SYNTHESIS TECHNIQUE

Vishal M. Chudasama[1], Manish B. Dave[2], Ghariya Rutika[3],

[1]*Assistant Professor, Department of Electronics and Communication, CCET, C. U. Shah University, Wadhwan city, vishalchudasama2188@gmail.com*
[2]*Assistant Professor, Department of Electronics and Communication, CCET, C. U. Shah University, Wadhwan city, mbdave.nitrkl@gmail.com*
[3]*PG Research Scholar, Department of Electronics and Communication Engineering, Faculty of Technology, Dharmsinh Desai University, Nadiad, mehtaprarthan.ec@ddu.ac.in*

Abstract— An antenna is the back bone of the wireless communication. It is mainly used to transmit and receive signal. An antenna array is a group of radiators whose currents are of either same or different amplitudes and phases. The presence of large side lobe radiation beam levels of an antenna is undesirable as the antenna performance and efficiency will be greatly degraded. Antenna structures especially in array arrangements have the capability to provide interference reduction.

In this paper, the Particle Swarm Optimization algorithm is utilized to optimize amplitude and phase excitations of uniformly spaced Linear and Planar array antenna with isotropic Point Source as unit elements. The cost function of Particle Swarm Optimization algorithm is maximum reduction in side lobe level. The Particle Swarm Optimization algorithm finds the optimum amplitude and Phase excitations of the antenna array elements to provide the radiation pattern with maximum reduction in the side lobe level. The results show the e effectiveness of the amplitude excitations and phase excitations on the overall performance of the array and also design of antenna arrays using the Particle Swarm Optimization method provides considerable enhancements and the synthesis obtained from other optimization technique like Genetic algorithm.

Keywords-component; formatting; style; styling; insert (key words) (minimum 5 keyword require) [12pt, Times new roman, line spacing 1.0]

I. INTRODUCTION

Antenna arrays have been widely used in mobile and wireless communication systems to improve signal quality, hence to increase system coverage, capacity and link quality. The performance of these systems depends strongly on the antenna array design [5].

In many practical applications, the radiation pattern of the array is required to satisfy some basic criteria including , directivity and side lobe level[5,17]. These two criteria constitute a trade-o that has to be optimized for real world applications. Works in the literature report many strategies for designing antenna arrays. The first optimum antenna array distribution was the binomial distribution. It was proposed by Stone. The binomial distribution has large current ratio and the radiation pattern has no side lobe. One famous type of antenna arrays is the Dolph-Chebychev arrays that are uniformly spaced linear arrays fed by Dolph-Chebychev coeffi- cients. These arrays have the important property that all side lobes in their radiation pattern have equal magnitude. Furthermore, the compromise between the directivity and side lobe level for these arrays is optimal, meaning that for a specified side lobe level, the directivity is the largest, and, alternatively, for a given directivity, the side lobe level is the lowest [2,6]. Some works consider a uniform geometry with the element excitations being optimized for some desired characteristics [17]. Others assume a uniformly excited array with the physical dimensions being optimized [8]. A third approach considered by some authors consists in seeking both geometrical dimensions and element excitations [20]. In this work, varying amplitude-only and phase-only alternative is considered with the technique of Particle Swarm Optimization (PSO) exploited to synthesis of Antenna Array.

Optimization techniques can be classified into two classes: local and global optimizers [17]. The local (also called classical) methods of optimization have been successfully used in finding the optimum solution of continuous and differentiable functions. These methods are analytical and make use of the techniques of differential calculus in locating the optimum points. Since some of the practical problems involve objective functions that are not continuous and/or diff- erentiable, the classical optimization techniques have limited scope in practical applications [16]. In recent years, some optimization methods that are conceptually different from the traditional mathematical programming techniques have been developed. Most of these methods are based on certain characteristics and behaviour of biological, molecular, swarm of insects, and neurobiological systems. Most of these methods have been developed only in recent years and require only the function values (and not the derivatives) [16]. The drawbacks of existing numerical methods have forced the researchers all over the world to rely on metaheuristic algorithms founded on simulations of some natural phenomena to solve antenna problems. These algorithms use an objective function of optimization which leads to the sidelobe suppression and null control [12]. Metaheuristic algorithms, such as Genetic Algorithms [7,1,4], Simulated Annealing [11], Tabu Search [5], Memetic Algorithms [14], Particle Swarm optimizers [9,10], and Taguchi method [21] have been used in the design of antenna arrays.

The conventional methods of linear antenna array optimization use a set of linear or nonlinear design equations and solve them to get the optimal solution. Due to the complexity of the design problem, the solution lies in the use of evolutionary approaches like Genetic Al-gorithms (GA) and Particle Swarm Optimization (PSO) of optimization for electromagnetic design [19]. PSO belongs to the class of evolutionary optimization techniques together with genetic algorithms and many other tools. PSO is similar in some ways to Genetic Algorithms (GA) and other evolutionary algorithms, but requires less computational bookkeeping and generally fewer lines of code. Furthermore, the basic algorithm is very easy to understand and implement. The method is inspired by the social behavior of swarms. The individuals evolve towards the global optimum in a competitive way based on a fitness function that involves the desired parameters to be optimized. The PSO algorithm has been applied for Electromagnetics and linear antenna array design problems [18,13,3]. Minimum Side lobe level and control of null positions in case of a linear antenna array and planar antenna array has been achieved by optimizing element amplitude excitations and phase excitations using PSO [13].The reminder of the paper is organized as follows. Section 2 explains formulation of the pattern synthesis problem for linear antenna array and planar antenna array. A general overview of Particle Swarm Optimization algorithm is introduced in Section 3. The cost function that is used in the optimization process for the control of side lobe level and synthesis the pattern shape is presented. In Section 4, numerical results are discussed. Finally, the conclusion is made in Section 5.

II. PROBLEM FORMULATION

2.1. Optimization of Amplitude Excitation for side lobe level reduction

The Array factor of N element linear array antenna is given by,

$$AF(\Theta) = 2\sum_{n=1}^{N} I_n \cos\{kx_n \cos(\Theta) + \Phi_n\}$$

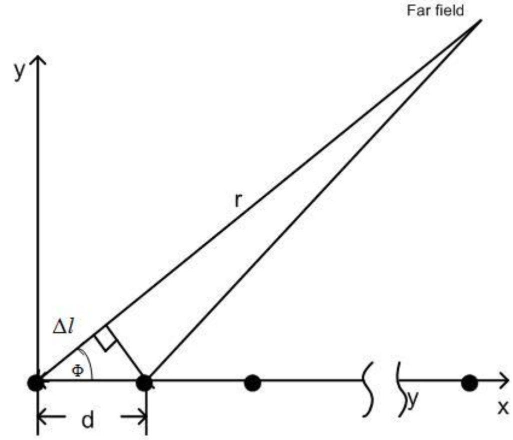

Figure 2.1: N-elements linear array geometry

In the case of a m×n uniform planar rectangular array, Im1 = I1n = I0 for all m and n, i.e., all elements have the same excitation amplitudes. Thus, The array factor of m×n Element,

$$AF = I_0 \sum_{m=1}^{M} I_{m1} e^{j(m-1)\left(kd_x \sin\Theta \cos\Phi + \Phi_x\right)} \times \sum_{n=1}^{N} e^{j(n-1)\left(kd_y \sin\Theta \sin\Phi + \Phi_y\right)}$$

Where,

K = Wavenumber

I_n = amplitude excitaton

x_n = spacing between element = $\lambda/2$

Φ_n = phase excitation = 0

Θ = observation angle

$$I_n = \left[I_1 \; I_2 \; I_3 \ldots\ldots\ldots\ldots\ldots\ldots I_n\right]$$

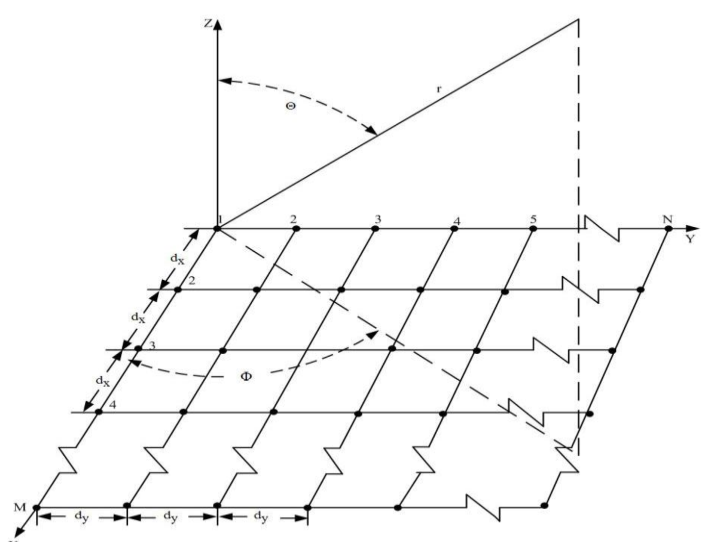

Figure 2.2: Rectangular Planar Array

Normalized Power Pattern, P(Θ) in db can be expressed as follows:

$$P(\Theta)=20\log\frac{|AF(\Theta)|}{|AF(\Theta)_{max}|}$$

To find optimum values of amplitude excitation which produces the array pattern with maximum reduction in side lobe level, the algorithm is used to minimize the following cost function,

$$\text{Maximum Side Lobe Level(MSLL)} = \min\left[\max_{\Theta\in s}\{P(\Theta)\}\right]$$

Where, s is the region of maximum side lobe.
If unit element in linear array is isotropic source, The radiation pattern is given by,

$$E(\Theta)=1$$

The resultant pattern is,

$$E_{total}(\Theta)=E(\Theta)\times AF(\Phi)$$

2.2 Optimization of phase excitation for Side lobe level Reduction

In this section, the particle swarm optimization is used to determine optimum low side lobe phase excitation for linear arrays. The optimum phase excitation is found in quantized phase space.

The Array factor of N elements linear array antenna is given by,

$$AF(\Theta)= 2\sum_{n=1}^{N} I_n\cos\{kx_n\cos(\Theta)+\Phi_n\}$$

Denoting the angular direction u=cos and matrix notation, The above equation can be formed as,

$$AF(u)=\Phi^0 S(u)$$

$$\text{Where,}\ \Phi^0=\left[e^{j\psi_1^0}\ e^{j\psi_2^0}\ e^{j\psi_3^0}\ldots\ldots e^{j\psi_N^0}\right]$$

$$S(u)=\left[a01\,e^{jk_{d1}u}\ a02\,e^{jk_{d2}u}\ a03\,e^{jk_{d3}u}\ldots\ldots\ldots a0N\,e^{jk_{dN}u}\right]$$

In the case of a m×n uniform planar rectangular array, $Im1 = I1n = I0$. for all m and n, i.e., all elements have the same excitation amplitudes. Thus the array factor of m×n Element Planar antenna array is,

$$AF=I_0\sum_{m=1}^{M} I_{m1}\,e^{j(m-1)(kd_x\sin\Theta\cos\Phi+\Phi_x)}\times\sum_{n=1}^{N} e^{j(n-1)\left(kd_y\sin\Theta\sin\Phi+\Phi_y\right)}$$

Normalized Power Pattern, P(Θ) in db can be expressed as follows:

$$P(\Theta)=20\log\frac{|AF(\Theta)|}{|AF(\Theta)_{max}|}$$

To find optimum values of amplitude excitation which produces the array pattern with maximum reduction in side lobe level, the algorithm is used to minimize the following cost function,

$$\text{Maximum Side Lobe Level (MSLL)} = \min_{\Phi_n}\left[\max_{\Theta\in s}\{P(\Theta)\}\right]$$

Where, s is the region of maximum side lobe.
If unit element in linear array is isotropic source, The radiation pattern is given by,

$$E(\Theta)=1$$

The resultant pattern is,

$$E_{total}(\Theta) = E(\Theta) \times AF(\Phi)$$

III. BASIC PARTICLE SWARM OPTIMIZATION

In the basic particle swarm optimization algorithm, particle swarm consists of n particles, and the position of each particle stands for the potential solution in D-dimensional space[9,10]. The particles change its condition according to the following three principles: (1) to keep its inertia (2) to change the condition according to its most optimist position (3) to change the condition according to the swarms most optimist position. The position of each particle in the swarm is affected both by the most optimist position during its movement (individual experience) and the position of the most optimist particle in its surrounding (near experience). When the whole particle swarm is surrounding the particle, the most optimist position of the surrounding is equal to the one of the whole most optimist particle; this algorithm is called the whole PSO. Each particle can be shown by its current speed and position, the most optimist position of each individual and the most optimist position of the surrounding. In the partial PSO, the speed and position of each particle change according the following equality,

$$v_{id}^{k+1} = v_{id}^{k} + c_1 r_1^k \left(pbest_{id}^k - x_{id}^k\right) + c_2 r_2^k \left(gbest_d^k - x_{id}^k\right)$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1}$$

In this equality, V_{id}^k and x^k_{id} stand for separately the speed of the particle i at its k times and the d-dimension quantity of its position; $pbest^k_{id}$ represents the d-dimension quantity of the individual i at its most optimist position at its k times. , $gbest^k_d$ is the d-dimension quantity of the swarm at its most optimist position. c1 and c2 represent the speeding figure, regulating the length when flying to the most particle of the whole swarm and to the most optimist individual particle. Usually, c1 is equal to c2 and they are equal to 2; r1 and r2 represent random function, and 0-1 is a random number.

Flow chart depicting the General PSO Algorithm:

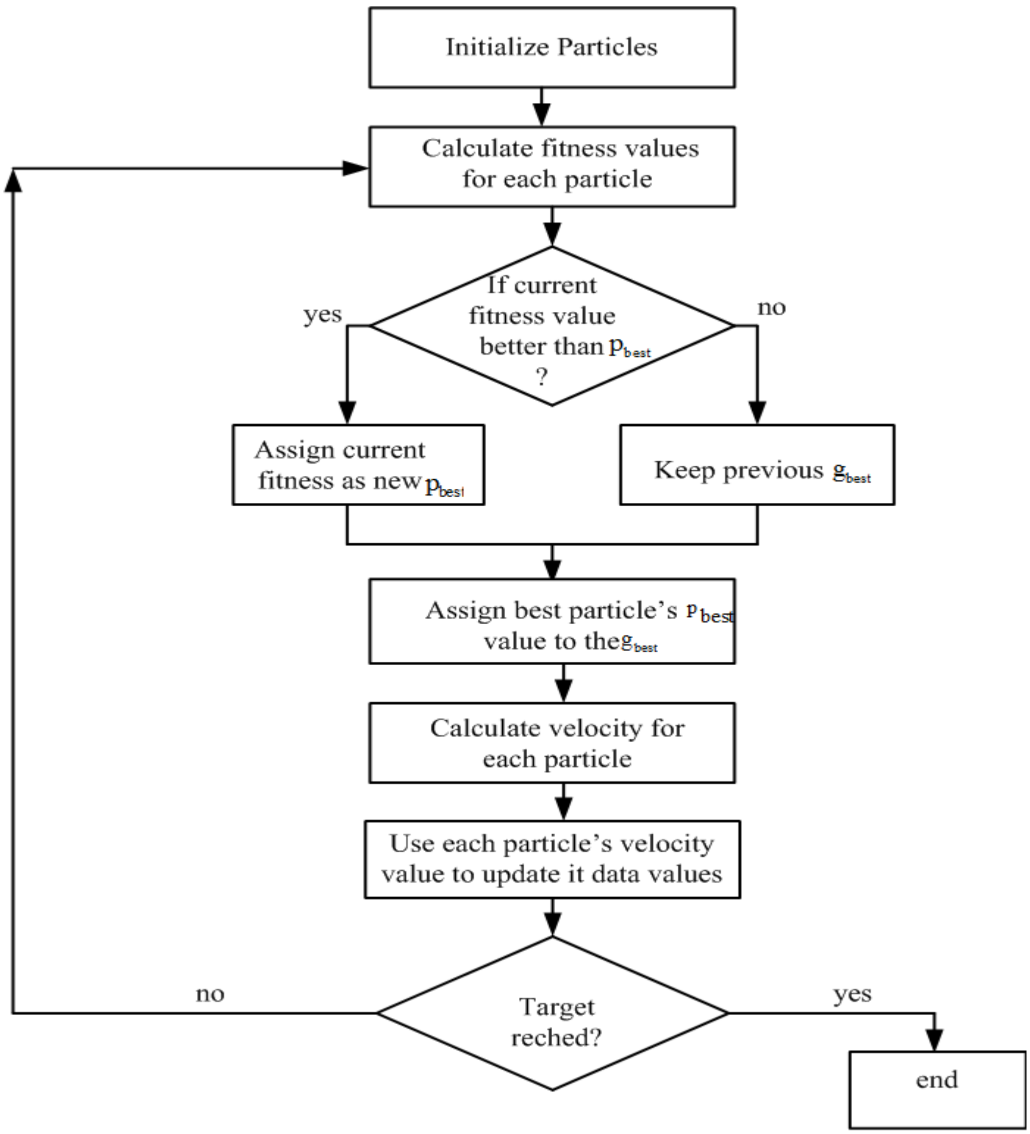

Figure 3.1 Flow chart for PSO Algorithm

The PSO algorithm has following steps

1. Create a population of particles
2. Evaluate each particles position according to the cost function
3. If a particles current position is better than its previous best position, update it
4. Determine the best particle position of swarm (gbest)
5. Update particles velocities
6. Move particles to their new position
7. Go to step 2 until criteria are satisfied

IV. SIMULATION RESULTS AND DISCUSSION

4.1 Side lobe Level Reduction Using Amplitude Excitations

The ten elements linear array of isotropic antenna with half wavelength spacing is considered in simulation. To select proper value of parameter of particle swarm optimization algorithm, the PSO algorithm is applied to optimize side lobe level for 50 iterations. Fig.4.1 shows the side lobe level of -

24dB. Fig. 4.2 shows the radiation pattern for array factor for LAA using best solution. Fig 4.3 shows that PSO gives better results than genetic algorithm by using same simulation paremeter.

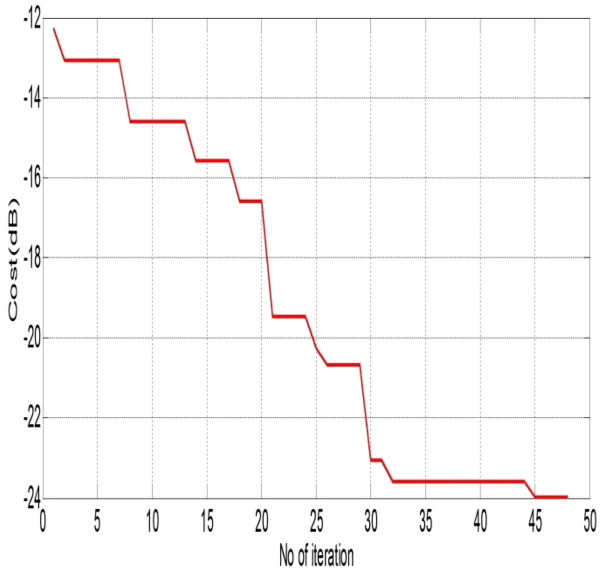

Figure 4.1: Cost v/s Number of Iteration for -24dB SLL for LAA

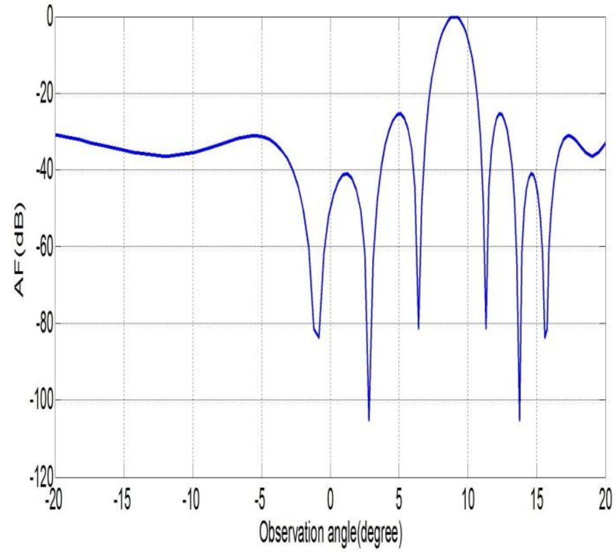

Figure 4.2: Radiation pattern for -24dB SLL for LAA

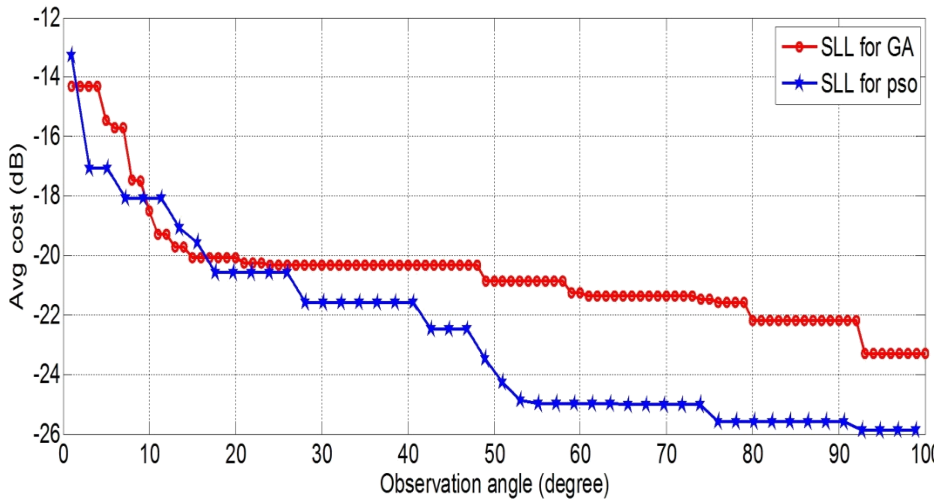

Figure. 4.3 the side lobe level of -26.21 dB

The 5×5 elements planar array of isotropic antenna with half wavelength spacing is con-sidered in simulation. To select proper value of parameter of particle swarm optimization algorithm, the PSO algorithm is applied to optimize side lobe level. Here, the results were averaged to get more optimum result. Fig.4.3 shows the side lobe level of -26.21 dB. Fig. 4.4 shows the radiation pattern for array factor for PAA using best solution.

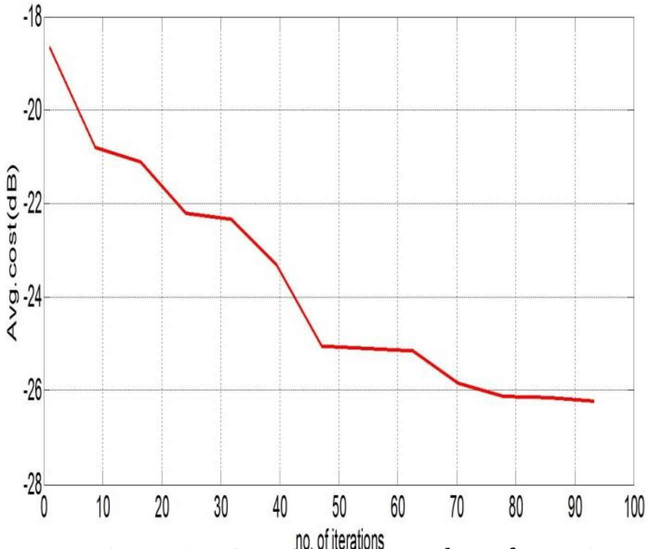

Figure 4.4: Avg.Cost v/s Number of Iteration SLL for PAA

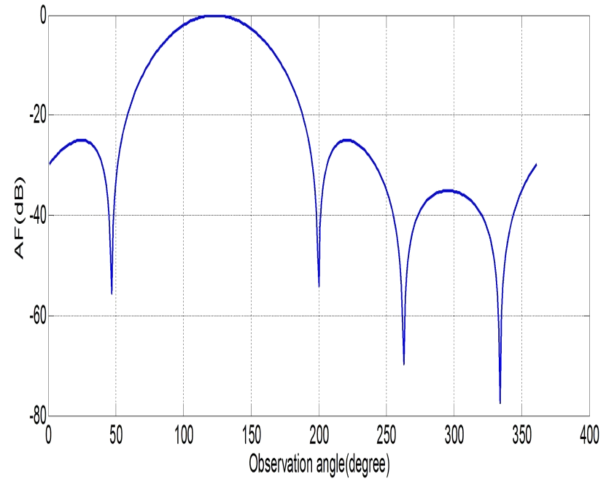

Figure 4.5: Radiation pattern for -26.21 –26.21dB dB SLL for PAA

4.2 Simulation Result for Phase Excitations

4.2.1 Side lobe Level Reduction Using Phase Excitations

The ten elements linear array of isotropic antenna with half wavelength spacing is considered in simulation. To select proper value of parameter of particle swarm optimization algorithm, the PSO algorithm is applied to optimize side lobe level. Here, The results were averaged to get more optimum result. Fig. 4.5 shows the side lobe level of -16.49dB. Fig. 4.6 shows the radiation pattern for array factor for LAA using best solution.

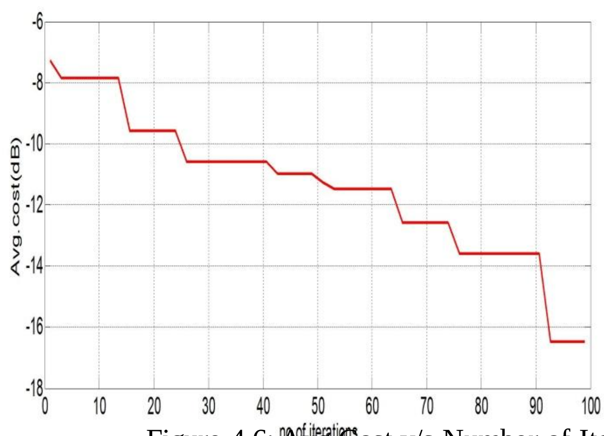

Figure 4.6: Avg.Cost v/s Number of Iteration 16.49 dB for -16.49dB

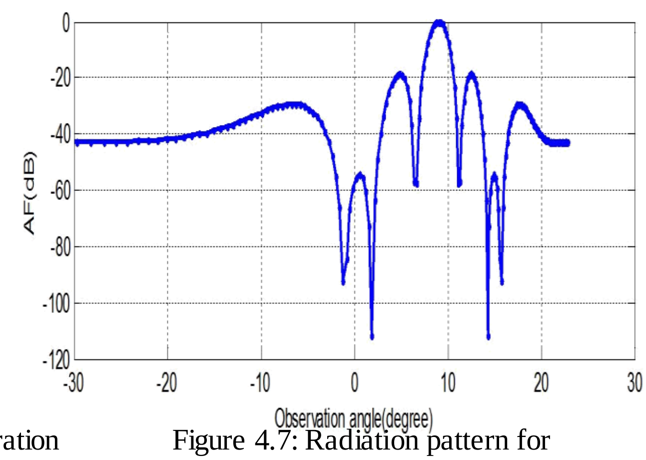

Figure 4.7: Radiation pattern for SLL for LAA

The 5×5 elements Planar array of isotropic antenna with half wavelength spacing is considered in simulation. To select proper value of parameter of particle swarm optimization algorithm, the PSO algorithm is applied to optimize side lobe level. Here, The results were averaged to get more optimum result. Fig. 4.7 shows the side lobe level of -18.98 dB.

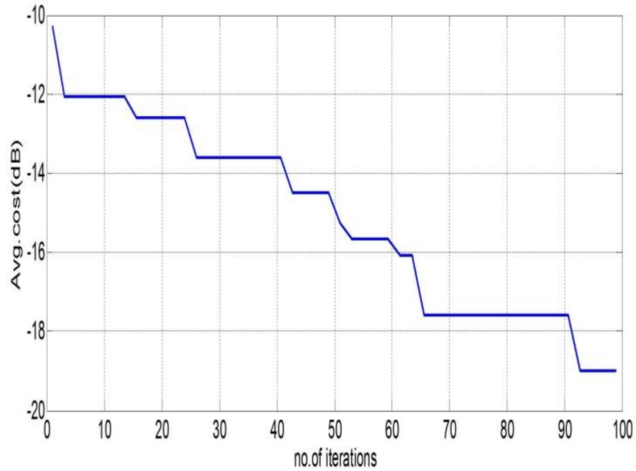

Figure 4.8: Avg.Cost v/s Number of Iteration 18.98dB SLL for PAA

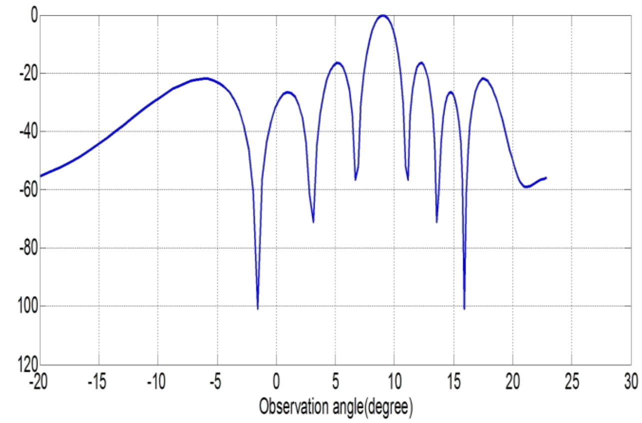

Figure 4.9: Radiation pattern for 18.98 dB for -SLL for PAA

Fig. 4.8 shows the radiation pattern for array factor for PAA using best solution. from these results, it shows that Maximum side lobe level reduction is achieved mainly due to optimization of amplitude excitation than the phase excitations. so, it is concluded that amplitude excitations gives better result in terms of side lobe level reduction.

4.3 Null steering Results

4.3.1 Placement of one Null

Null steering in phased and adaptive arrays may be achieved by controlling some of the array parameters such as the position only of the array elements, the amplitude only and the phase-only. Pattern nulling techniques are very important to cancel undesired interference. Here placement of one null at 60 is shown in below figure. It shows that interference is cancelled from the undesired user direction of 60.

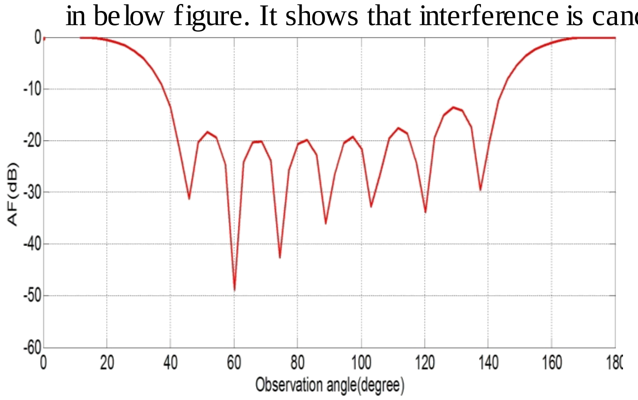

Figure 4.10: Placement of Null at 60

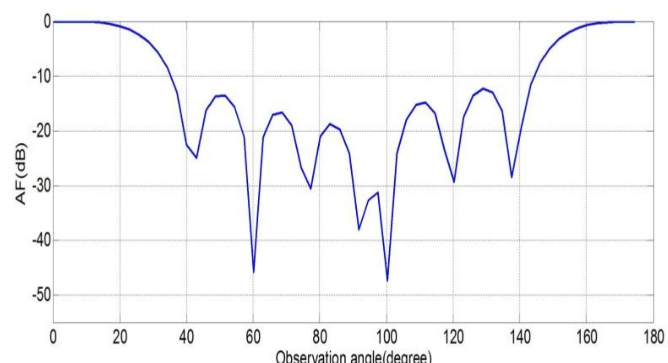

Figure 4.11: Placement of Nulls at 60 and100

4.3.2 Placement of Two Nulls

Here placement of Two nulls at 60 and 100 are shown in figure 4.11. It shows that interference is cancelled from the undesired user direction of 60 and 100.

V. CONCLUSION

A PSO based algorithm is used in order to improve the radiation pattern of linear antenna arrays and planar antenna arrays according to specific requirements. The optimization procedure is applied under the restriction of uniform amplitude excitation and under the requirements for the minimum possible side lobe level. The PSO algorithm finds the amplitude excitations of linear and planar array elements for maximum reduction in side lobe level. The results show that the proposed method is very promising and capable of optimizing any type of antenna array than any other evolutionary method like genetic.

VI. REFERENCE

1 Back, T., Fogel, D., Michalewicz, Z., "Handbook of Evolutionary Computation" Oxford University Press, Oxford (1997)
2 Balanis, C.A., "Antenna Theory: Analysis and Design", Wiley, New York (2005)
3 Baskar, S., Alphones, A., Suganthan, P.N., Liang, J.J., "Design of Yagi–Uda antennas using comprehensive learning particle swarm optimization", IEEE Transactions on Microwave and Antennas Propagation, **152**(5), 340–346 (2005)
4 Eiben, A.E., Smith, J.E., "Introduction to Evolutionary Computing, Springer", Berlin (2003)
5 Glover, F., Laguna, M., "Tabu Search", Kluwer, Norwell (1997)
6 Guney, K., Babayigit, B., Akdagli, A., "Position only pattern nulling of linear antenna array by using a clonal selection algorithm (Clonalg)", Electrical and Electronics Engineering , **90**(2), 147–153 (2007)
7 Holland, J.H., "Adaptation in Natural and Artificial Systems", University of Michigan Press, Ann Harbor (1975)
8 Jin, N., Rahmat-Samii, Y., "Advances in particle swarm optimization for antenna designs: real-number. binary, single-objective and multiobjective implementations", IEEE Transactions on Antennas and Propagation, **55**(3),556–567 (2007)
9 Kennedy, J., Eberhart, R., "Particle swarm optimization", In: IEEE International Conference on Neural Networks, pp. 1942–1948 (1995)
10 Kennedy, J., Eberhart, R.C., Shi, Y., "Swarm Intelligence", Morgan Kaufmann, San Francisco (2001)
11 Kirkpatrik, S., Gelatt, C., Vecchi, M., "Optimization by Simulated Annealing", Science **220**, 671–680 (1983)
12 Khodier, M.M., Christodoulou, C.G., "Linear array geometry synthesis with minimum side lobe level and null control using particle swarm optimization", IEEE Transactions on Antennas and Propagation, **53**(8), (2005)
13 Khodier, M.M., "Linear array geometry synthesis with minimum side lobe level and null control using particle swarm optimization", IEEE Transactions on Antennas and Propagation **53**, 2674–2679 (2005)
14 Ong, Y.-S., Keane, A.J., "Meta-lamarckian learning in memetic algorithms", IEEE Transaction on Evolutionary Computations ,**8**(2), 99–110 (2004)
15 Panduro, M.A., Covarrubias, D.H., Brizuela, C.A., Marante, F.R., "A multi-objective approach in the linear antenna array design", Int. J. Electron. Commun. **59**, 205–212 (2005)
16 Rao, S.S., "Engineering Optimization: Theory and Practice", Wiley, New York (2009)
17 Recioui, A., Azrar, A., "Use of genetic algorithms in linear and planar array synthesis based on Schelkunoff method", Microw. Opt. Technol. Lett. **49**(7), 1619–1623 (2007)
18 Robinson, J., Sammi, Y.R., "Particle swarm optimization in Electromagnetics", IEEE Transactions on Antennas and Propagation **52**(2), 397–407 (2004)
19 Sykulski, J.K., Rotaru, M., Sabene, M., Santilli, M.: "Comparison of optimization techniques for electromagnetic applications". Compel **17**(1/2/3), 171–176 (1998)
20 Vaudon, " Smart antenna array patterns synthesis: null steering and multi-user beamforming by phase control" Program on Electromagnetics Research. **60**, 95–106 (2006)
21 Weng, W.-C., Yang, F., Elsherbeni, A. "Electromagnetics and Antenna Optimization Using Taguchi's Method" Morgan and Claypool Publishers (2007)

