2nd International Conference on Current Research Trends in Engineering and Technology
© 2018 IJSRSET | Volume 4 | Issue 5 | Print ISSN: 2395-1990 | Online ISSN: 2394-4099
Themed Section: Engineering and Technology

Null Steering In Phased Antenna Array System Using Amplitude Only GA and PSO

Palak N. Patel[1], Rizwan Alad[2], Ashish Pandya[3], Prarthan Mehta[4]
[1,2,3,4]Department of E & C Engg., Faculty of Technology, Dharmsinh Desai University, Nadiad, Gujarat, India

ABSTRACT

Null steering in phased array antenna is used for synthesizing the array pattern with enforcing nulls in the direction of interference while simultaneously preserving the main beam in the direction of the desired signal with controlling sidelobe level. The prospective techniques are a GA and Particle Swarm Optimization to synthesize the amplitude excitation. In this paper, the GA and PSO both are applied to the Phased array antenna with half-wavelength dipole antennas at an equally spaced distance. The cost function is same for both the algorithm and analysis is taken in the form of sidelobe level (SLL), Signal-to-Interference Ratio (SIR) and simulation time are taken to optimize the amplitude excitation. Both algorithms are modified in terms of initial first excitation which is taken as Taylor amplitude excitation with SLL of -20dB.

Keyword: GA, PSO, Phased Array Antenna, Sidelobe level, Signal-to-interference ratio, Null Steering

I. INTRODUCTION

Practically, Array antenna has higher gain and directivity than an individual radiating element. The Radiation pattern of array elements consists of the main beam and sidelobe level where main beam power is provided to the desired user while Side lobes in the radiation pattern causes degradation of actual signal. The SLL also experience the interference from another user which ultimately create noise to the desired user. So the paper proposed the work on the null steering by which we can place the nulls in the direction of interference and it results in the improvement of SIR value and simultaneously control the sidelobe level to reduce wastage of power.

The radiation pattern synthesis to steer nulls in the direction of interference while maintaining the main beam directed towards the desired user has received much attention. Null steering in phased and adaptive arrays may be achieved by controlling some array parameters such as the complex element weights, element phases, amplitudes, and element positions [1–5]. It plays an important role in a communication system, sonar, and radar applications to improve the performance (maximizing signal to interference ratio) and to cancel the jammer signal [6]. Interference suppression in antenna arrays can be achieved by steering nulls in the directions of undesired signals while keeping the main lobe in the direction of user activity by adjusting the excitation amplitude and phase. Recently, evolutionary algorithms such as particle swarm optimization (PSO) [7], and GAs (GA) [3] have been studied for array synthesis including null constraints.

This optimization technique is promising, and researchers are still exploring its capabilities for solving electromagnetic problems. Emerging like an effective alternative to the older and well-known method of GAs (GA) [8], [9], PSO has been applied in the electromagnetic field [10], [11] including antenna design [12], [13]. PSO is a bio-inspired algorithm similar in some ways to evolutionary algorithms, such as GA and is commonly compared with them [14], [15]. Good performance can generally be obtained with both methods.

The evaluation of the cost function tends to dominate the overall computation budget for electromagnetic optimization, but the computational overhead requirements of both optimization algorithms are not always negligible [16].

Because antenna array synthesis often has a significant computational burden, finding ways to reduce the number of iterations and function evaluations required for stochastic algorithms represents an open line of research in the antenna field.

For the specific case of linear antenna arrays optimized by PSO, we can find different approaches that are used to design the desired radiation pattern, some recent research is found in [16]-[18].

In this paper, an approach based on PSO and GA for the synthesis of phased antenna arrays is presented. The objective of this paper is to present a comparative analysis between GA and PSO for null steering of half wavelength dipole array antenna. GA and PSO, for this useful design problem, are evaluated in terms of simplicity and computational time.

II. PROBLEM FORMULATION

The radiation pattern of antenna array is obtained by array factor and electric field of individual antenna element. We consider N linear half wavelength dipole array antenna with equally spaced distance (d) along the z-axis. The array will be formed as shown in Fig 1. The array factor of entire linear half wavelength dipole array can be given by

$$AF = \sum_{n=1}^{N} W_n e^{jk(n-1)d(cos\emptyset - cos\,\theta)} \tag{1}$$

In this equation the W_n is Excitation of n^th Element and θ is Direction of the main beam

The Array factor is the factor by which the directivity function of an individual antenna must be multiplied to get the directivity of the entire array. The radiation pattern of the individual dipole antenna is given by

$$E_0 = \frac{\cos(\frac{\pi}{2}\cos\theta)}{\sin\theta} \tag{2}$$

The total power pattern (E_{total}) is the pattern multiplication of the array factor and electric field of individual dipole antenna. Normalized power pattern, $P(\theta)$ in dB, can be expressed as follows:

$$P(\theta) = 20\log\frac{|E_{total}(\theta)|}{|E_{total}(\theta)_{max}|} \tag{3}$$

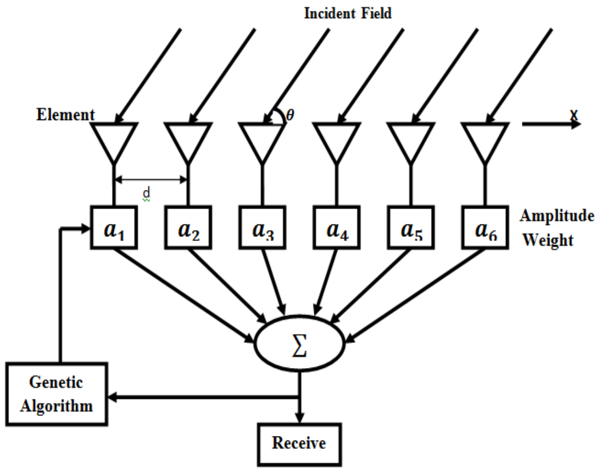


Figure 1. Linear half Dipole Array Antenna geometry

The radiation pattern of half wavelength dipole antenna array can be synthesized by the GA and particle swarm optimization to optimize the amplitude excitation.

III. PROPOSED ALGORITHM

Each chromosome in population is representing the amplitude excitation of the antenna array. The initial amplitude excitation is taken randomly from MATLAB in normal genetic algorithm where the initial SLL level is high which results in more number of iteration required for optimization. So to reduce the initial SLL, the first chromosome of initial population is taken as Taylor Excitation and other chromosomes are randomly generated in MATLAB. The Taylor Excitation is generating from PCAAD software at initial SLL of -20dB.

A. Genetic Algorithm (GA)

A GA is an optimization algorithm inspired by the well-known biological processes of genetics and evolution. Genetics is the take a look at of the inheritance and variant of biological trends. There is no single firm definition for a GA, and the computational system is highly simplified compared to the actual situation in nature. The GA provides optimal solutions by successively creating populations that improve over many generations. This process maintains until the population converges to a single optimal solution. GA may be represented as shown below in fig 2.

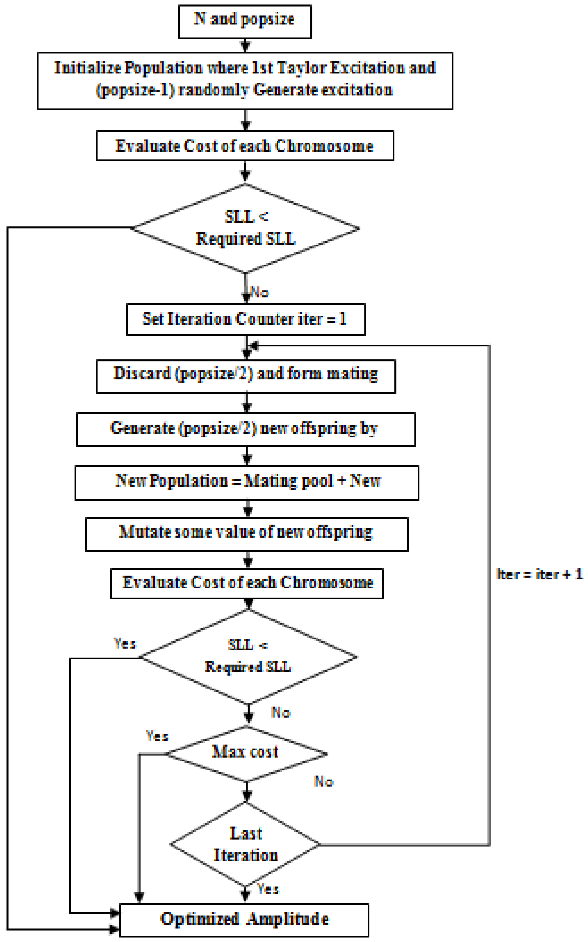


Figure 2. GA for Optimization of Null

Each Chromosome in GA population represents an amplitude excitation at each element in the array. Adjusting these settings has a small effect on the main beam but can place nulls in side lobes. The goal of the GA is to place nulls in the direction of interference by adjusting these array excitation. Since the algorithm must be fast and a global minimum is not necessary, the GA uses a small population size.

Amplitude excitations are sent to the antenna array and output is measured. This way, each chromosome has an associated cost. Members of the population with high costs are discarded because high cost indicates low fitness chromosome. The surviving members form a mating pool. The parents are combined in some manner by crossover process to generate offspring. The offspring replace the discarded chromosome.

The next step randomly mutates a certain percentage of the population by random number to provide diversity from one generation to next generation. Normally best chromosome is not mutated. After mutation, the repeats by measuring the output associated with the new population.

The Cost function is taken in the form of the value of Radiation pattern at Null, SLL and main beam. The cost function is given by,

$$\text{costfunction} = \frac{|\text{AF}_{\text{main}}|}{\prod_{m=1}^{N} |\text{AF}_{\text{Null}}|^2 + \text{SLL}} \tag{4}$$

B. Particle Swarm Optimization

The PSO algorithm is based on a population of individuals (swarm), where each individual, called agent or particle represents a possible solution within the multidimensional solution space. The swarm movement within the solution search space is given by the velocity of adaptation and position equations for each particle, considering the inertia weight model

$$V_i^{k+1} = wV_i^k + c_1 r_1 (pbest - X_i^k) + c_2 r_2 (gbest - X_i^k) \tag{5}$$

$$X_i^{k+1} = X_i^k + V_i^k \tag{6}$$

where, V_i^k represents the particle velocity iin dimension k, is the inertia weight that regulates the impact of the previous velocities in the new particle velocity, $c_1$is the cognitive parameter that indicates the maximum influence of the personal best experience of the particle and $c_2$is the social parameter that indicates the maximum influence of the social information. The terms r_1 and r_2 are two random numbers uniformly distributed between [0 1]. The personal best and global best are represented by pbest and gbest respectively. Finally, X_i^krepresents particle position.

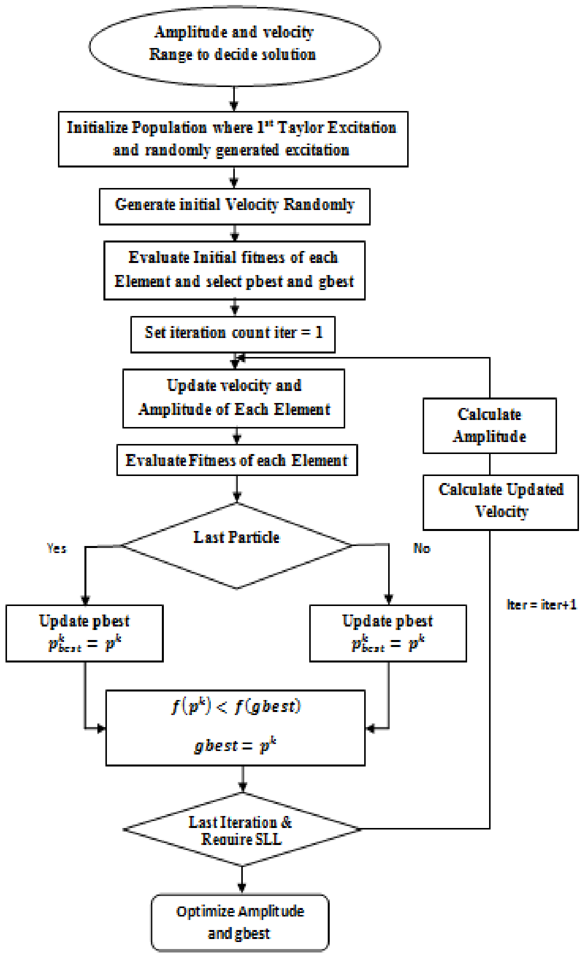


Figure 3. PSO for Optimization of Null

In the definition of a particle's vicinity, two main topologies can be discerned: global and local topologies. In a global topology, all the particles are interrelated and have immediate access to the findings of their fellows. In a local topology, each particle finds its trajectory influenced by its adjacent neighbors only, remaining isolated from distant particles of the swarm. In Fig. 3 a flowchart of the proposed PSO applying a global asynchronous scheme to antenna array synthesis is shown.

IV. RESULT AND DISCUSSION

The Null steering optimization is applied to linear half-wavelength dipole antenna with the frequency of 900MHz.The number of the element has been taken 20 with $\lambda/2$ spacing between two adjacent elements. Here the analysis is done by the comparing the GA and Particle Swarm Optimization as mention above. The Taylor amplitude excitation is generated at -20 dB SLL and $\bar{n} = 2$ which result in the radiation pattern of -25dB maximum SLL. Here the analysis is dividing into two parts where first analysis is the individual performance of GA and PSO for different number of nulls and the second analysis is the comparison of SIR and number of iteration for different value of SLL.

Table 1 and Table 2 show the effect of a number of nulls on the Number of Iteration, SLL and SIR values using GA and Particle Swarm Optimization. The nulls are placed in direction of interference and main beam direction is taken 90. The computation time is also mentioned to get a better analysis.

C. A. Genetic Algorithm (GA)

GA is simulated for 100 iterations and the required SLL value is set at -40dB. From the table, the effect of a number of nulls is shown in terms of the SLL, SIR, and a number of iteration required optimizing the required SLL.

Table 1. Analysis of GA for a different number of nulls

No of Nulls	No of Iteration	SLL (dB)	SIR (dB)	Simulation Time (s)
30, 135	15	-34	-69	83.901
30, 45, 135	35	-35	-66	89.772
30, 45, 135, 160	59	-35	-66	86.120
30, 45, 60, 135, 160	25	-37	-57	86.154

The analysis is taken for 3 nulls in the direction of 30°, 45°, 135° and their optimize Excitation plot is shown in the figure.

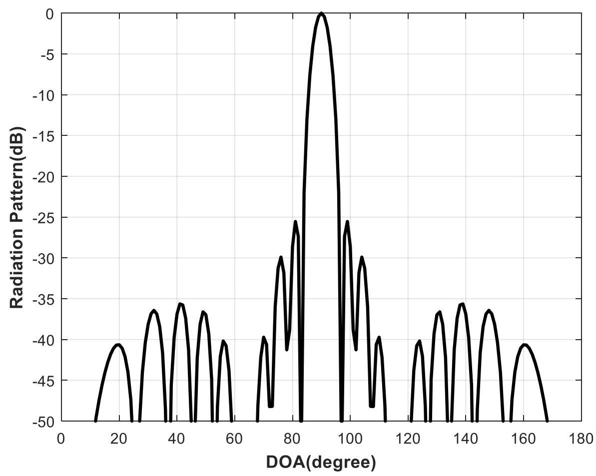


Figure 4. Initial Radiation Pattern(GA)

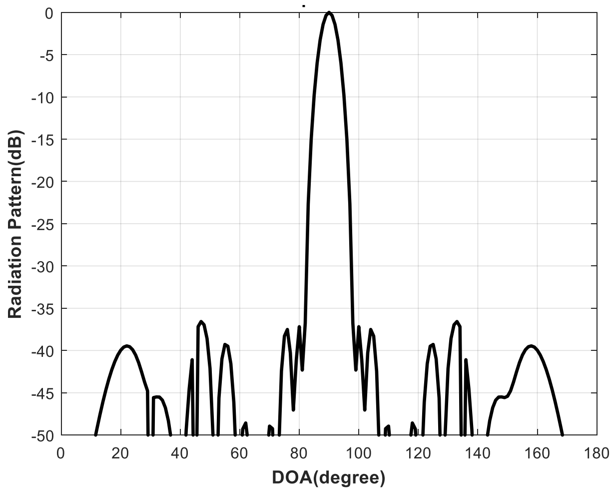


Figure 5. Optimized Radiation Pattern(GA)

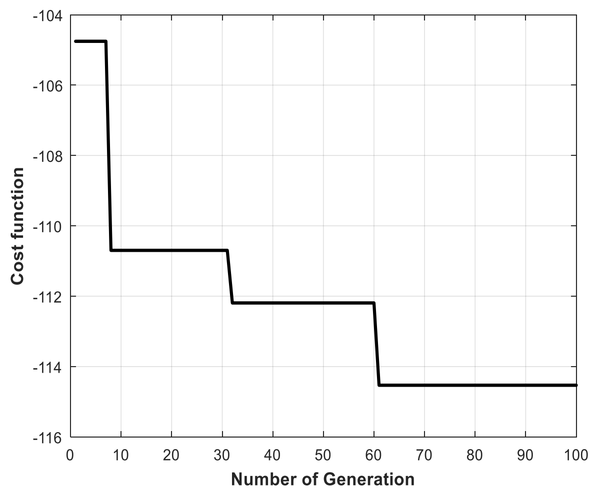


Figure 6. Convergence curve over Iteration(GA)

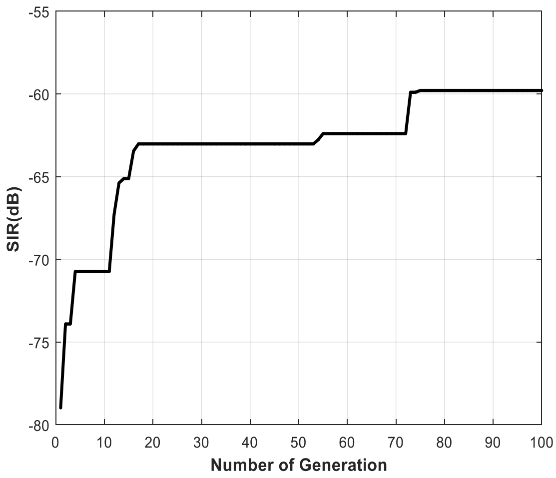


Figure 7. SIR value over Iteration(GA)

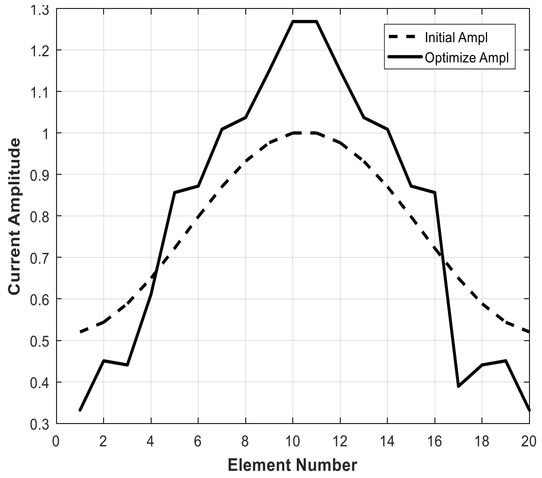


Figure 8. Amplitude Excitation(GA)

B. Particle Swarm Optimization

PSO is simulated for 100 iterations and the required SLL value is set at -40dB. From the table, the effect of a number of nulls is shown in terms of the SLL, SIR, and a number of iteration required optimizing the required SLL.

Table 2. Analysis of PSO for a different number of nulls

No of Nulls	No of Iteration	SLL (dB)	SIR(dB)	Simulation Time
30, 135	4	-37	-49	79.124
30, 45, 135	4	-35	-47	79.254
30, 45, 135, 160	14	-34	-42	78.325
30, 45, 60, 135, 160	100	-32	-68	78.658

The analysis is taken for 3 nulls in the direction of 30°, 45°, 135° and their optimize Excitation plot is shown in the figure.

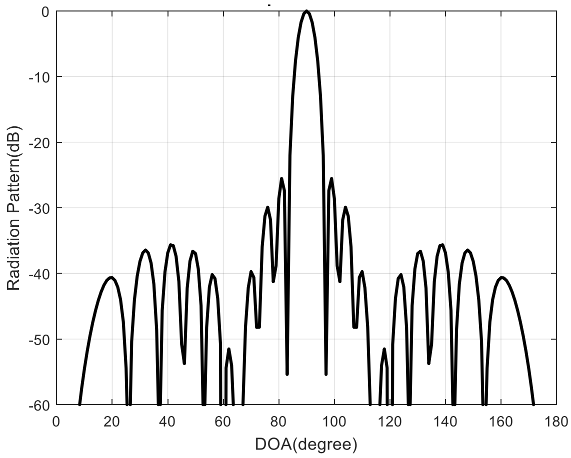


Figure 9. Initial Radiation pattern (PSO)

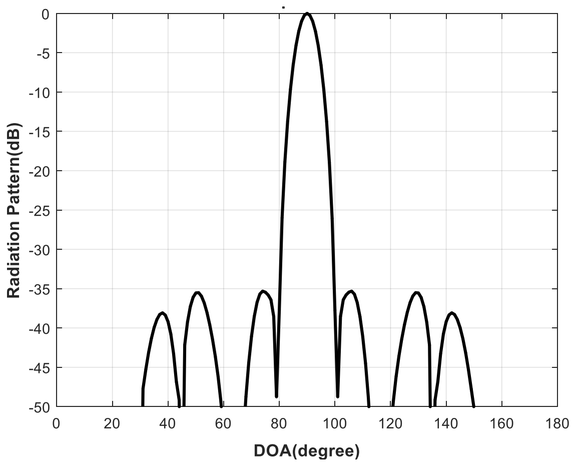


Figure 10. Optimized radiation pattern

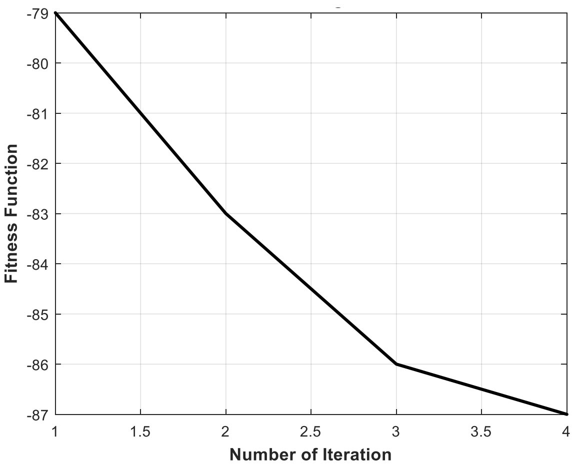


Figure 11. Convergence curve over Iteration

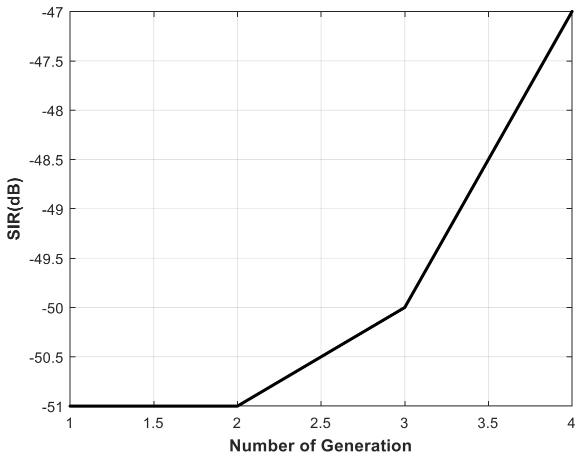
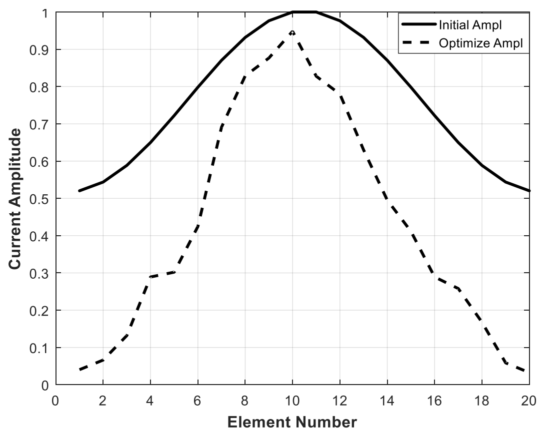


Figure 12. SIR value over Iteration



C. Comparison of GA and PSO

In the analysis, the desired SLL value is varied to check the number of iteration required to optimize the Excitation required for desired SLL value and at the same time the SIR values are also checked.

Table 3. Comparison for PSO and GA

Desired SLL value (dB)	Number of Iteration		SIR (dB)	
	GA	PSO	GA	PSO
-26	3	2	-72	-69
-28	3	2	-67	-68
-30	4	3	-66.5	-68
-32	11	3	-64.5	-68
-34	15	4	-60	-67
-36	25	15	-59	-67
-38	70	17	-56	-67
-40	100	69	-56	-66
-42	Not optimized	100	Not optimized	-66

V. CONCLUSION

We conclude that the PSO performs better compare than the GA in terms of SLL and simulation time. In 100 iterations, the GA optimizes -40dB SLL while PSO optimizes -42dB SLL. The GA also takes more time around 10 seconds to optimize the required SLL due to the different operation (Crossover, Mutation and selection) performs at each iteration. While PSO only run based on the gbest and pbest values so run time is reduced to 70 seconds over 89 seconds. PSO takes 4 iterations to optimize the three nulls and SLL of -42dB and GA requires 35 iterations to optimize three nulls and -40dB SLL.

VI. REFERENCE

[1]. N. Karaboga, K. Gunney and A. Akdagli, Null Steering of Linear Antenna Arrays with use of Modified Touring ant Colony Optimization Algorithm, Wiley Periodicals; Int J RF Microwave Computer-Aided Eng, 12, pp.375–383. 2002.

[2]. R.L. Haupt, Phase-only Adaptive Nulling with a GA, IEEE Trans Antennas Propag, 45, pp.1009–1015. 1997.

[3]. R. Vescovo, Null Synthesis by Phase Control for Antenna Array, Electronic Letters, 36, pp.198–199. 2000.

[4]. W.P. Liao and F.L.Chu, Array Pattern Nulling by Phase and Position Perturbations with the use of the GA, Microwave Opt Technol Lett, 15, pp. 251–256, 1997.

[5]. K. Gunney and A. Akdagli, Null Steering of Linear Antenna Arrays using a Modified Tabu Search Algorithm, Prog Electromagnet Res, 33, pp. 167–182, 2001.

[6]. N. Karaboga, K. Gunney and A. Akdagli, Null Steering of Linear Antenna Arrays with use of Modified Touring ant Colony Optimization Algorithm, Wiley Periodicals; Int J RF Microwave Computer-Aided Eng, 12, pp.375–383. 2002.

[7]. M.M. Khodier and C.G. Christodoulou, Linear Array Geometry Synthesis with Minimum Sidelobe Level and Null Control using Particle Swarm Optimization, IEEE Trans Antennas Propag. 53, pp.2674–2679, 2005.

[8]. J. H. Holland, GAs, Scientific American, July 1992, pp. 66-72.

[9]. A. E. Eiben and J. Smith, Introduction to Evolutionary Computing, 1st Ed. New York, NY: Springer, 2003.

[10]. J. Robinson and Y. Rahmat-Samii, “Particle swarm optimization in electromagnetic,” IEEE Transactions on Antennas and Propagation, vol. 52, no. 2, 2004, pp. 397-407.

[11]. Y. Rahmat-Sami and Nanbo Jin, “Particle Swarm Optimization (PSO) in Engineering Electromagnetics: A Nature-Inspired Evolutionary Algorithm,” presented at 2007 Int. Conf. Electromagnetics in Advanced Applications, ICEAA 2007, 2007, pp. 177-182.

[12]. Y. Rahmat-Samii, D. Gies, and J. Robinson, Particle swarm optimization (PSO): a novel paradigm for antenna designs, The Radio Science Bulletin, no.305, Sep. 2003, pp. 14-22.

[13]. N. Jin and Y. Rahmat-Samii, “Advances in Particle Swarm Optimization for Antenna Designs: Real-Number, Binary, Single-Objective and Multi-objective Implementations,” IEEE Transactions on Antennas and Propagation, vol. 55, no. 3, 2007, pp. 556-567.

[14]. Y. Rahmat-Samii, the GA (GA) and particle swarm optimization (PSO) in engineering electromagnetic, Proc. of the 17 Int. Conf. on Appl. Electromag. And Commun. 2003, pp. 1-5.

[15]. Jinghai Song, Huili Zheng, and Lin Zhang, “Application of particle swarm optimization algorithm and GAs in beam broadening of the phased array antenna,” presented at 2010 Int. Symp. On Signals Systems and Electronics (ISSSE), 2010, vol. 1, pp. 1-4.

[16]. D.W. Boeringer and D.H. Werner, Particle swarm optimization versus GAs for phased array synthesis, IEEE Transactions on Antennas and Propagation, vol.52, no.3, March 2004, pp. 771-779.

[17]. 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, 2005 pp. 2674-2679

[18]. Chao-Hsing Hsu, Chun-Hua Chen, Wen-Jye Shyr, Kun-Huang Kuo, Yi-Nung Chung, and Tsung-Chih Lin, “Optimizing Beam Pattern of Linear Adaptive Phase Array Antenna Based on Particle Swarm Optimization,” presented at 2010 Fourth Intl. Conf. in Genetic and Evolutionary Computing (ICGEC), 2010, pp. 586-589.