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Synthesis Of Antenna Array Using Modified Particle Swarm Optimization Technique

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***Abstract**: In this paper the synthesis of array antennas is done using modified particles swarm optimization technique (PSO) to minimize side lobe levels. This algorithm helps in higher performance, capable to solve general N-dimensional linear and non-linear optimization problems. The Modified PSO algorithm is easily conceivable, can be implemented using simple mathematical modelling when comparing with other evolutionary algorithms such as Genetic Algorithm (GA), Invasive weed optimization (IWO). The algorithm is formulated to suppress the side lobes level (SLL). By performing multiple iterations, we yield local best position and from that local best position we yield global best position of the particle and it is applied to the Synthesis of antenna arrays. The simulation pattern shows the optimal pattern of array antenna which is able to approach the desired pattern. The results demonstrated that the modified Particles swarm optimization algorithm is superior to the conventional PSO algorithm.*

Index Terms: ***Particles swarm optimization (PSO), Genetic Algorithm (GA), sidelobe level, array antenna.***

I. INTRODUCTION

A set of multiple antennas connected together as a single antenna for the transmission and reception of radio waves is called an array antenna [1]. These antennas are generally connected to a transmitter or a receiver by feedlines. These feed lines help to feed the power to elements in a specified phase by adding together each individual antenna the radio waves are radiated to enhance power radiating in specified directions and to reduce power radiating in unspecified directions. In the same way when these are used for receiving the frequency currents from antennas combine in the receiver with correct phase to intensify the signals received from the desired direction which helps cancelling the signals from undesired direction.

The antenna arrays [2] are widely use in phase array radar and in satellite communications. In satellite communications in order to resist interface and noise the array pattern are to be made lower side lobes. The antenna array should have lower side lobes, controllable beam width, and pattern system in azimuth angles.

Modern optimization techniques made a great interest in a wide variety of fields due to the ability to solve problems depending on design parameters. Many optimization techniques have been introduced in past two decades [3-4].

Some of these algorithms are used in electromagnetism and antenna problems with different parameters. The most algorithms representing are Genetic Algorithms (GA) [14], Particle Swarm Optimization (PSO) [8] and method of Differential Evolution (DE) [13]. For antenna synthesis these optimizers are more popular. In this paper we present a comparative evaluation of GA, PSO, DE for the designing of Array antennas. For the design of array antennas, we study the behavior of array factor by optimizing amplitude and phase for better performance.

The array antenna performance has been modified with a change in particles form optimization technique which is by changing the function in PSO then the change in velocity and position happens, this makes the modified PSO better than Genetic Algorithm and Differential Evolution [13]. Since the performance has been improved the antenna designers show interest in this algorithm.

Particles swarm optimization is an evolutionary algorithm based on swarm intelligence. Kennedy and Eberhart first introduced algorithm in 1995. It is inspired by research for behavior of swarm (birds and bees) while food hunting. It has shown to be effective in solving complex global multidimensional optimization problems in various fields. The PSO intended to solve the problem of premature convergence observed in applications of PSO accomplished by using the ratio of relative fitness and the distance of other particles to find the direction in which each component particles position need to be changed. The array parameters used to determine the array pattern such as excitation coefficient and distance among the elements are chosen as the desired variables. The simulation result shows that optimal pattern with low side lobes approaches desired pattern very well. The synthesis result improves the efficiency of the antenna array [6-7].

There are many optimization techniques for antenna arrays to reduce the side lobes like GA [11], IWO [12], BEES algorithm, WDO etc. among those PSO is the best optimization technique because of it is easily updated and developed. PSO means particle swarm

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optimization technique in this swarm is nothing but group of entity.

In this we use PSO and we take particle which are of form a swarm and among them finding the least value by using this algorithm (PSO) [8-9]. We implemented the algorithm in mat-lab which helps to find the least and best value, that value is given to side lobes and reduce it.

Why do entities form swarm?

Many living things like ANTS [14], BEES, and FISHES etc. form swarm with their same kind. While forming swarm the fish's looks like a gigantic whale and even a shark can't kill these because it is scared to go their but only a whale can eat those swarmed fishes because whale releases a ultrasonic waves with that waves the swarm formed by fishes will be collapsed and their group will destroyed. Another example is ant colony all the ants together form a line like a swarm and that is said to be ant colony. for a single ant to do a job (like searching for food and building a house or nest for them) is difficult and when forming a group, it is easy to do any that why's they form swarm and do the things easily and taking upon these examples optimization algorithms are formed and with that algorithms we proving and trying to optimize an antenna.

Seeing in a fig1.1, we know that an antenna has both main lobes and side lobes, the main lobe represents that how efficiently the antenna is radiating and how much range it is covering. The side lobes are nothing but the waste to utilize that wasted side lobes correctly and accurately to the main lobe we use optimization techniques. These optimization techniques are implemented since 1995 and many techniques have come in to existence [10].

In this, we came up with one of those optimization techniques and shown how accurately it is helpful than the others.

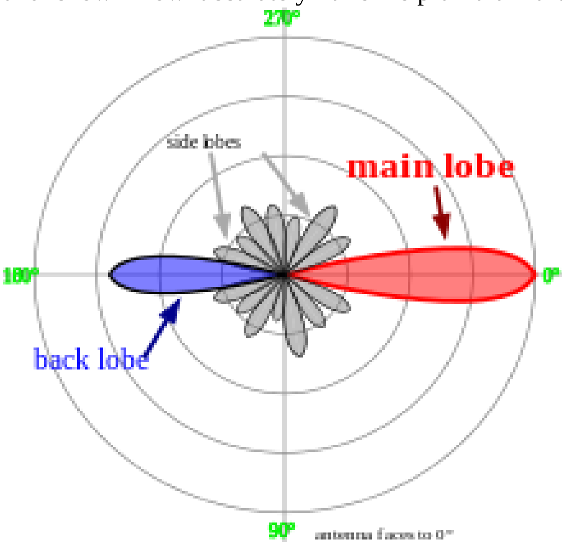

Fig 1.1. Normal radiation pattern of an antenna

The particle swarm optimization is a stochastic algorithm. In this algorithm solution of the D-dimensional optimization is a bird in a solution space which is called a particle. Every particle has fitness values which are determined by the objective function. All the particles having initial positions and velocities are iterated. At each generation one local best position is taken to update the particle. x

The velocity is calculated by how far an individual data is from target if the target is higher then larger the velocity be. From the bird's example, the birds which are farther to the food will make an extra effort to cope up with the birds flying faster similarly if the data in the pattern or a sequence then the velocity will describe how variant the pattern on the target are and how much it is necessary to change for the matching of the target. The local best value indicates how close the data has come to the target from the time algorithm has been started. When the local best value comes closer to the target then only the global best value changes. By iterations of algorithm until one of the particle reach the target global best moves closer and closer to the target. PSO [7-9] algorithm using population topologies are neighborhood are common and these are small localized subsets of global best value. Two are more particles which are determined to act together are involved by these neighborhoods which happen at the time of testing. When getting stuck in local minima the neighborhood helps the algorithm to avoid from being stuck.

With the help of random functions every variable must be created by a specified range. The i_{th} particle in the solution space is determined by a fitness function value[10].

Let denote the position of the i_{th} particle by $X_i = (X_{i1},\dots X_{id}\dots X_{iD})$ and velocity of the i_{th} particle by $V_i = (V_{i1},\dots V_{id}\dots V_{iD})$. The position and velocities of the particles updated by the personal best and global best position at each generation. Let $P_i = (P_{i1},\dots P_{id},\dots P_{iD})$ is the position vector for individual particles best fitness which is the personal best position, and $P_g = (P_{g1},\dots P_{gd},\dots P_{gD})$ be the global best position among all the generations. The position and the velocity of particle are updated according to the following equations.

In this, we used different test functions and proving that which test function is best to solve these problems.

II. MATH FUNCTIONS

There are many benchmark functions among those we take rastrigin, Ackley and griewank because when we use these test functions it gets a greater number of local best values than the other benchmark functions and by getting a greater number of local best values, we will easily able to find the best fitness value it helps us to compare many local best fitness values and can find the best fitness value (gbest).

Rastrigin function:

$$g(y) = 10*L+\sum[\, y_i^2 - 10\cos(2y_i)] \qquad (1)$$

$$f(x^*)=0, \text{ at } x^*=(0,\dots,0)$$

Ackley function:

$$f(x)=-a*\exp(-b+\sqrt{1/d\sum x(i)^2}-\exp(1/d *\sum\cos(x(i)))+a+\exp(1) \qquad (2)$$

$\sum$ ranges from i= 1 to d

a =20, b=0.2.

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Griewank function:

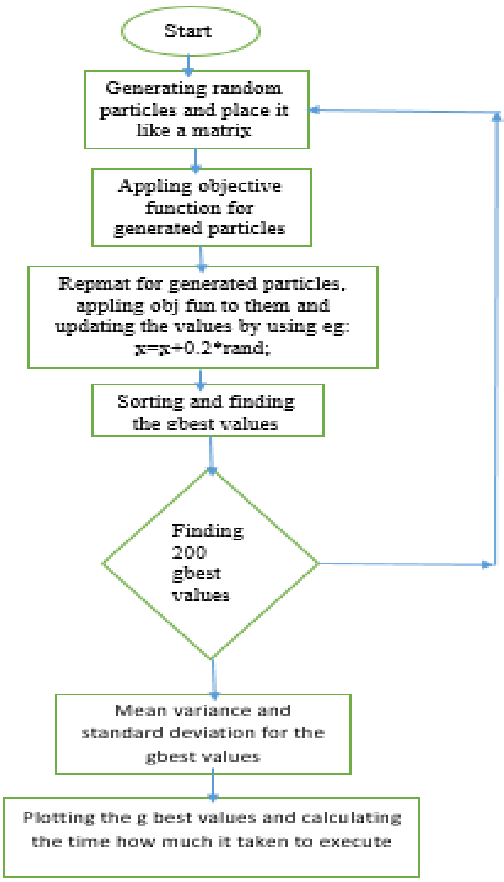
$$f(x)=1+1/4000 *\sum x_i^2-\pi \cos(x_i/\sqrt{i}) \quad (3)$$

π Ranges from i=1 to d
$\sum$ ranges from i= 1 to d

The above functions are used, among them rastrigin function gives the best output in less time comparing to the results of the Ackley function and Griewank function.

III. ALGORITHM AND FLOW CHART

1. Initialize the finite number of particles in the D dimensional solution randomly.
2. After assigning the random particles taking the test function as consideration find the position and values of the randomly generated particles.
3. Cloning for the randomly generated particles and updating the randomly generated particles for the next iteration.
4. Calculate the local best fitness value and store the position in the memory.
5. Store the local best fitness values in a memory, compare all the fitness values and store the p_{gbest} values among all the local best fitness values.
6. Repeat the experiment for more p_{gbest} values and can find the best gbest values.
7. Calculate the mean, variance and standard deviation of the p_{gbest} values for more understanding purpose.
8. If the desired output is achieved, stop the program otherwise repeat the experiment.



IV. RESULTS

A. Rastrigin output:

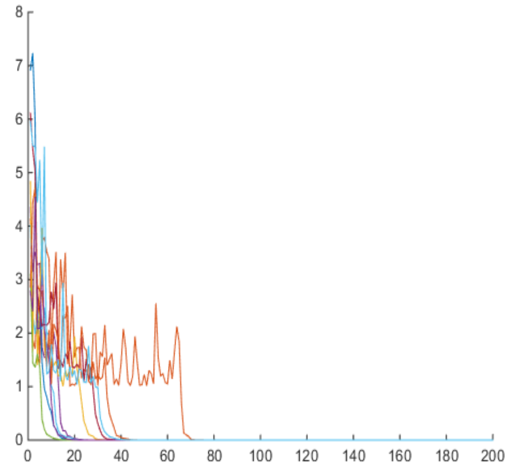


Fig 2.1 gbest values for rastring function

Fig 2.1 shows that the gbest value is gradually decreasing form one iteration to another iteration for rastrigin test function. The least value for every iteration is “0” and it takes approximately 12.011 sec to execute the entire code.

B. Ackley output

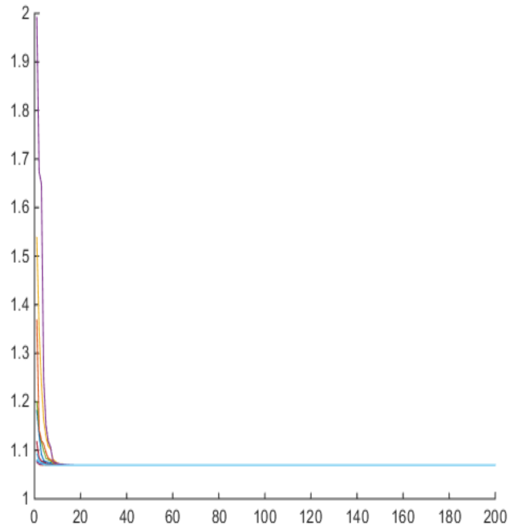


Fig 2.2 gbest values for Ackley function

Fig 2.2 shows that the least value for all the iterations of Ackley function is “1”. Each graph says that the gbest values for the iterations. In this the graph is gradually decreasing it means the last values is the finest values and least values i.e. “1”.it takes approximately 16.101 seconds to execute this code.

C. Griewank output:

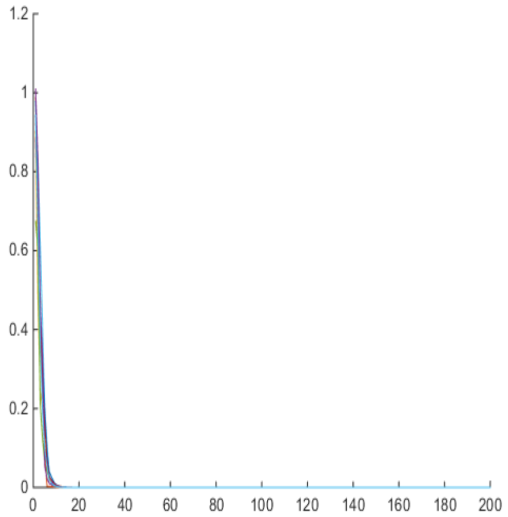


Fig2.3 gbest values of griewank test function

Fig 2.3 shows that the finest value and least value among the iterations is "0" but the time complexity is more compared to rastrigin function.

In this, we use different functions for the code and choose the best objective function based upon above results we can come to an conclusion that rastrigin function is the best function for optimization techniques because the values are more precise than the other function and time complexity is also less i.e. within less time the execution is completed and so the rastrigin function is the best function.

Table of Different values for different test function:

Table I Rastring function

Rastring function			
Mean	**Variance**	**St. Deviation**	**Time complexity**
0.7331	0.9814	0.9907	12.611049 seconds.
0.1225	0.4411	0.6642	
0.6398	0.7070	0.8408	
0.1122	0.5840	0.7642	
0.0873	0.2635	0.5133	
1.0576	0.8296	0.9108	
0.0654	0.1368	0.3698	
0.1076	0.5124	0.7158	
0.4267	0.4908	0.7006	
0.1201	0.4052	0.6366	

Table II Ackley function

Ackley function			
Mean	**Variance**	**St. Deviation**	**Time complexity**
0.0486	0.0858	0.2929	16.695934 seconds.
0.0269	0.0360	0.1897	
0.0800	0.1900	0.4358	
0.0132	0.0079	0.0888	
0.0264	0.0499	0.2234	
0.0357	0.0407	0.2018	
0.0706	0.1425	0.3774	
0.0740	0.1471	0.3836	
0.0712	0.1514	0.3890	
0.0652	0.1376	0.3709	

Table III Geiewank function

Geiewank function			
Mean	**Variance**	**St. Deviation**	**Time complexity**
0.0109	0.0065	0.0806	19.194134 seconds.
0.0135	0.0078	0.0881	
0.0145	0.0096	0.0982	
0.0103	0.0061	0.078	
0.0114	0.0068	0.0827	
0.0146	0.0106	0.1032	
0.0122	0.0077	0.0876	
0.0132	0.0086	0.0927	
0.013	0.0093	0.0966	
0.0139	0.0087	0.0934	

V. CONCLUSION

In this paper, Synthesis of antenna arrays using modified particles swarm optimization is described with detailed procedure and simulated results that reveal that modified PSO algorithm takes less time to simulate results by using Rastrigin function compared to the other objective functions such as Ackley and Griewank functions and also calculated mean, variance, standard deviation for individual functions which are tabulated on the above.

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