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A comparative study of GA, PSO and APSO: Feed point optimization of a patch antenna

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Abstract – In this age of wireless communication, micro strip antennas have drawn maximum attention of antenna community because of its compact size, light weight and low profile configuration. In this paper the problem of locating feed point of an inset fed microstrip patch antenna designed for wireless communication is dealt with. The optimization is done using three techniques: Genetic Optimization (GA), Particle Swarm Optimization (PSO) and Accelerated Particle Swarm Optimization (APSO). Results obtained using all these techniques are in good agreement and are compared using convergence graphs. Return loss and radiation pattern for the optimized antenna was verified using IE3D software.

Index Terms – Micro strip antenna, optimization, genetic algorithm, particle swarm optimization, accelerated particle swarm optimization

I. INTRODUCTION

The explosive growth in the field of wireless communication and information transfer has created the need for advancements in the field of antenna design as a fundamental part of any wireless system. The antennas used must have to be small, light-weighted and low profile configuration. Microstrip antennas fulfill these entire criterions and hence are currently the most active field of antenna research and development. [1]

In recent years several algorithms have been developed for optimization of various kinds of problems related to antenna design.The aim of any optimization technique is to find a solution that represents a global maximum or minimum in a suitably defined solution domain, that means to find the best solution among many possible solutions for a considered problem.[2]

In this paper a study of three optimization techniques namely Genetic algorithm, Particle swarm optimization and Accelerated particle swarm optimization is dealt with. All these techniques are used for the feed point optimization of microstrip patch antenna. In the following sections a brief overview of all the algorithms are given followed by the verification of the results using IE3D software.

II.GENETIC ALGORITHM

Genetic algorithm is a robust global stochastic search methods based on the Darwinian concepts of natural selection and evolution. The parameters of each individual of the population are usually encoded as a string of bits (chromosomes). The first group of individuals (generation) is created randomly. The fitness of each individual is determined. Mating these individuals forms a new generation. The more fit individuals are selected and given greater chance of reproducing. The best individual may be passed unchanged to the next generation. This iterative process creates successive generations until a stop criterion is reached. It is expected that individuals of successive generations converge to the global maximum. [3], [4].

Once the problem is encoded in a chromosomal manner and after the fitness function is chosen we start to evolve solutions using the following steps:

1. Initialization: The initial population of candidate solutions is usually generated randomly across the search space.
2. Evaluation: The fitness functions of the candidate solutions are evaluated.
3. Selection: Solutions with higher fitness values get more copies.
4. Recombination: Parental solutions are combined to get new, possibly better solutions.
5. Mutation: Locally but randomly modifies a solution.
6. Replacement: Replaces the original parental population.
7. Repeat steps 2-6 until a terminating condition is met.

III. PARTICLE SWARM OPTIMIZATION

Inspired by natural phenomenon such as bird flock Particle swarm optimization (PSO) is an evolutionary computation technique developed by Kennedy and Eberhart in 1995. This optimizing technique has been based on mechanism similar to how a swarm of bees search for the location with highest density of flowers in a field.[5]. This method has been effectively used by antenna engineers in optimizing numerous multidimensional problems.

PSO is initialized with a group of random particles which searches for an optimum value by updating two best values in each iteration. First one is called the personal best or *pbest* which is the best value so far obtained by any particle in the population. All the particles explore the search space and the information collected by them is used to find the best particle in the swarm called as global best or *gbest.* After finding the two best values, the particle updates its velocity and positions with following equations (1) and (2):

v[ ] = v[ ] + C1.rand( ) . (pbest[ ] - present[ ]) + C2. rand( ) .(gbest[ ] - present[ ]) (1)
present[ ] = persent[ ] + v[ ] (2)

v[ ] is the particle velocity, persent[ ] is the current particle (solution). pbest[ ] and gbest[ ] are defined as stated before. rand() is a random number between (0,1). It is introduced to randomly position all particles in the swarm to enable exhaustive exploration and exploitation of each particle on the entire solution space.C1, C2 are learning factors. Usually C1 = C2 = 2

III.ACCELERATED PARTICLE SWARM OPTIMIZATION

APSO is similar to that of PSO except the fact that it is an accelerated version of PSO. It harnesses the same concept of movement of swarm to locate the optimum value. Process begins with a randomly initialized population moving in randomly chosen directions. In PSO after locating the pbest and gbest in each iteration the particles would update their position and velocity for the next move. APSO updates acceleration in addition to position and velocity thus speeding up the process of search exploration. Finally, all particles will fly towards better and better positions over the searching process until the swarm moves closer to its optimum value.[6]

Thus in APSO there are three parameters to be considered for optimization which includes position, velocity and acceleration unlike in PSO there were just two parameters. This makes APSO faster than PSO though the difference can be noticeable when the dimension of the problem becomes more unlike when it's dealt with lower order dimension.

IV.ANTENNA DESIGN

In this paper we designed a microstrip antenna for Bluetooth communication purpose i.e at a centre frequency(fr) of 2.44 GHz with dielectric constant (ε_r) 4.36 and substrate thickness (h) 1.6mm. At this frequency using the below formulae [7] we calculated the length and width of the antenna which came to be 29.061 mm and 37.526mm respectively.

Calculation of the Width (W):

$$W = \frac{C0}{(2\times fr)}\sqrt{\frac{2}{(\varepsilon_r+1)}} \quad (3)$$

Calculation of Effective dielectric constant (ε_{reff}):

$$\varepsilon_{reff} = (\varepsilon_r + 1)/2 + \frac{(\varepsilon_r - 1)/2}{\sqrt{(1+12\times\frac{h}{W})}} \quad (4)$$

Calculation of the length extension (ΔL):

$$\Delta L = .412\frac{((\varepsilon_{reff}+.3)*((W/h)+.264))}{((\varepsilon_{reff}-.258)*((W/h)+.8))} \quad (5)$$

Calculation of effective length of patch (L):

$$Leff = L + 2\,\Delta L \quad (6)$$

$$L_{eff} = \frac{c}{(2.fr.\sqrt{(\varepsilon_{reff})})} \quad (7)$$

Where co is the speed of light in free space.

Impedance matching is a very important for designing an antenna as it decides the coupling effect. Perfect impedance matching leads to maximum coupling and thus minimizing the return loss. To locate the point where the impedance is 50 ohm is difficult task and is usually done by hit and trial method. In this paper the optimization task is to locate the feed point of an inset fed microstrip antenna.

We thus use an optimization technique to locate the point where the impedance is 50 ohm. We know that the impedance of a microstrip antenna varies as shown in figure(i)

$$Rin(y = y_o) = Rin(y = 0) \times \cos^2((\pi/L).y_o) \quad (8)$$

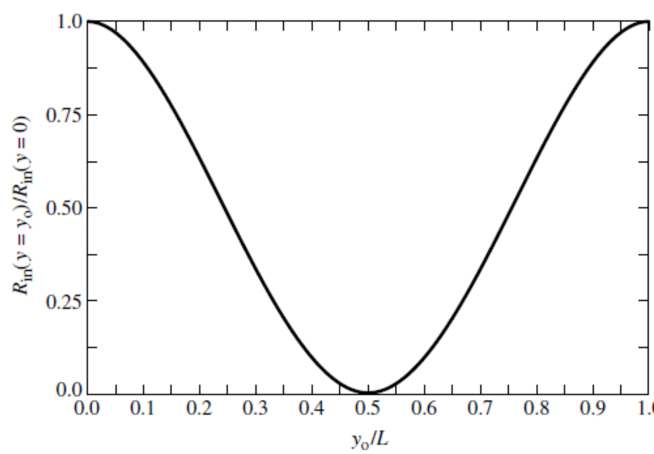

Figure (i) normalised impedance of the microstrip patch

Using GA, PSO and APSO we designed a one dimensional fitness function to locate the feed point y(cm) of the antenna which is as given below:

$$F = abs(Rin(y)-50) \quad (9)$$

V.RESULTS

In this paper we compare the three optimization techniques namely GA, PSO and APSO. Matlab was used for implementing all these algorithms. The following parameters were chosen for optimization.

Technique	GA	PSO	APSO
Particles	-	25	25
Iterations	100	1000	100
Convergence(for an accuracy up to 0.01)	30	30	18

Convergence graph for all the techniques are obtained as shown in the figures below. All the algorithms converge to the same theoretical value but in different number of iterations.

IE3D software was used to verify the results. Return loss and the radiation pattern for the optimized design are shown in the following section.

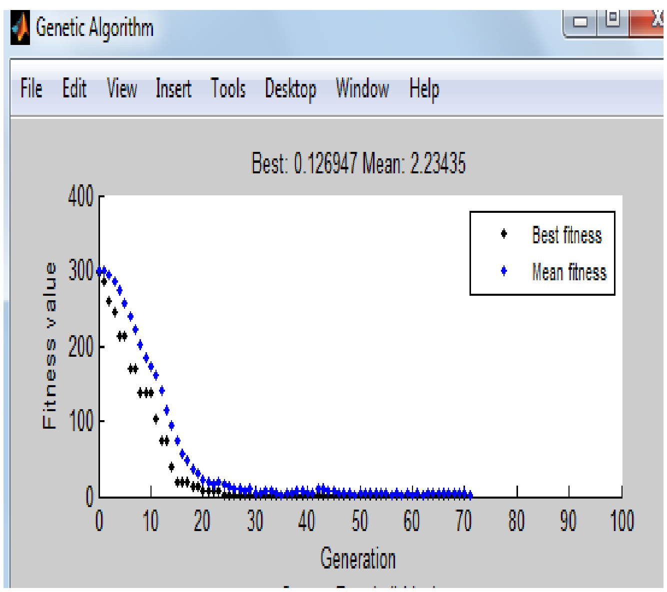

Figure (ii) Convergence graph of GA

In GA we took the help of matlab's Global optimization tool box for this purpose whose convergence graph is as shown above in figure(ii). And for PSO Brian Birge[8] optimization tool box was used for the same as shown in figure(iii). APSO was obtained using matlab code.

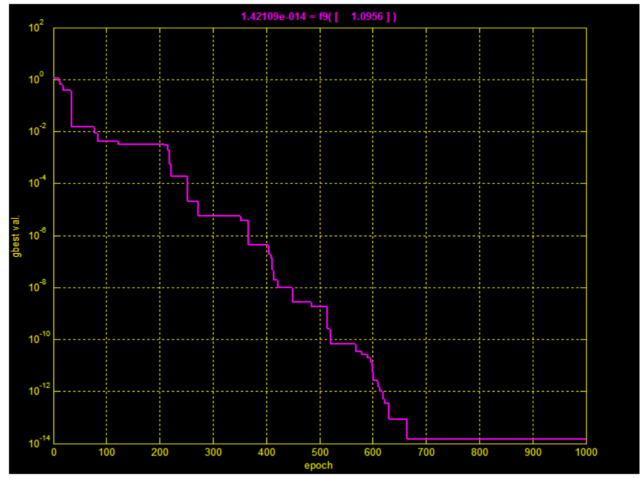

Figure (iii) Convergence graph of PSO

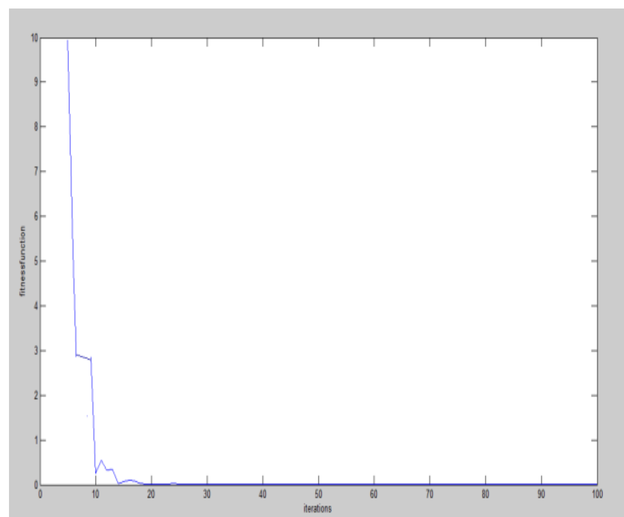

Figure (iv) Convergence graph of APSO

VI .RESULTS –VERIFICATION

Using IE3D an inset fed antenna operating for the frequency of 2.44 GHz with dielectric substrate 4.36 and thickness 1.6mm was designed as shown below.

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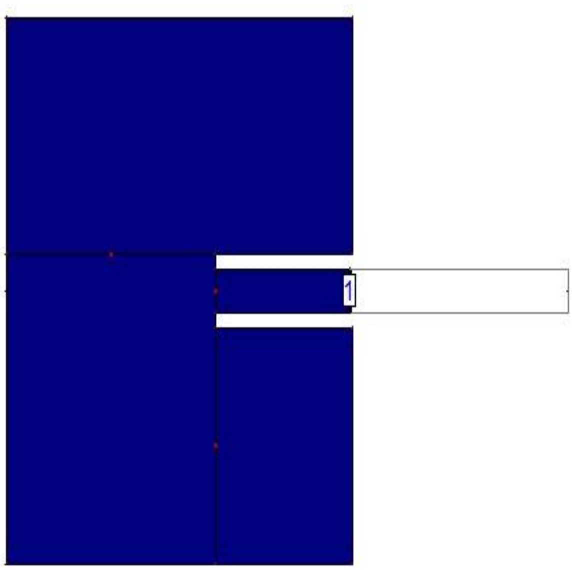

Figure (v) Inset fed microstrip antenna.

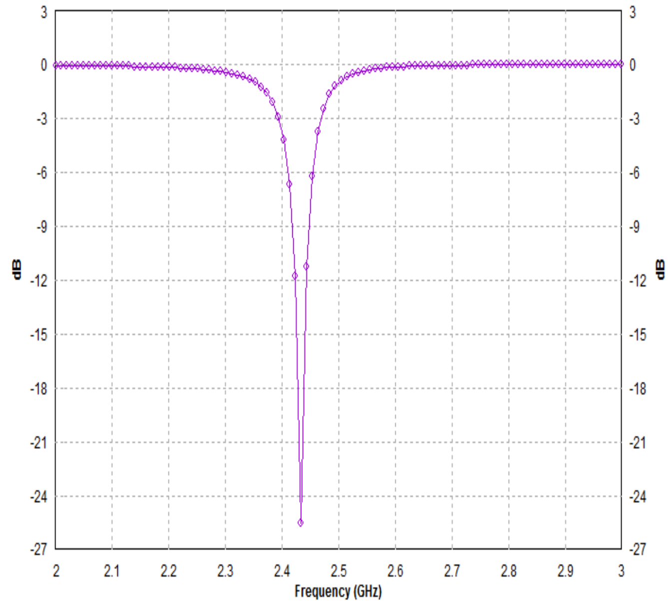

Figure (vi) Return loss

The antenna was designed for the protocol IEEE 802.11 i.e. for bluetooth communication purpose with length of the antenna as 29.061 mm and width of the antenna as 37.526 mm. Thickness of the feed point was taken to be 3 mm and the depth of the inset fed was the optimizing parameter. Using all the algorithms the optimized value was obtained as 10.956 mm.

With this design the antenna was simulated for a frequency range of 2 GHz to 3 GHz and the return loss was obtained around -26 GHz at the frequency of 2.44 GHz as shown in figure(v).

The analysis of the antenna structure was carried further to study the radiation pattern of the optimised structure which is shown in figure (vi).The radiation pattern clearly shows that there is radiation only in the forward direction but no radiation in the backward direction which gives an accuracy of the impedance matching of the designed structure. This means that the antenna is very much optimized to 50ohm.

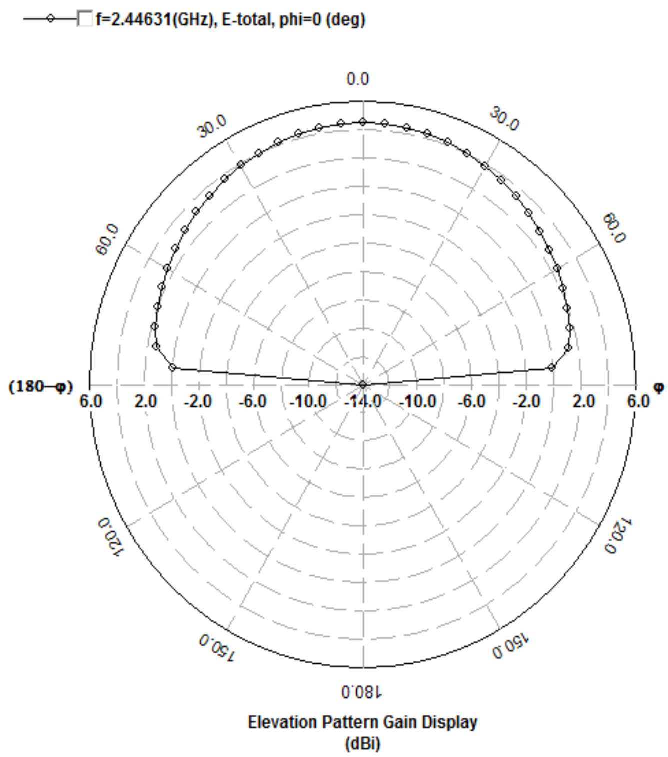

Figure (vii) Radiation pattern

VI.CONCLUSION

Optimization is a well used technique in electromagnetic community and with the advent of new techniques in this field our task becomes easier. In this paper we discussed optimization of microstrip patch antenna's physical parameters by using genetic, particle swarm and accelerated particle swarm optimization techniques. These techniques have been used to find the location of feed point of an inset fed rectangular antenna. All the techniques converge to the same theoretical value but with different number of iterations. In GA there are a large no of parameters to be adjusted compared to PSO and APSO. For accuracy up to 0.02 we compared all the optimization results and conclude that APSO is the best. The convergence graph clearly shows that APSO needs very less no of iterations to compute the same task and thus outperforms others. This is due to the fact that acceleration constants are also updated in APSO in addition to the position and velocity constants as in PSO. This reduces the time of computation and hence is faster than PSO.

The APSO algorithm selects the particles that are far away from the global solution and accelerates them towards global optima with an exploration power to avoid the premature convergence. Simulation results indicate that the proposed algorithm gives robust results with good quality solution and faster convergence. Thus results encourage the use of APSO for optimal design.

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