OPTIMIZATION OF RESONANCE FREQUENCY OF CIRCULAR PATCH ANTENNA AT 5 GHZ USING PARTICLE SWARM OPTIMIZATION

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ABSTRACT

The microstrip antenna is small in size, simpler and less expensive to manufacture. They are more compatible than reflector antennas with printed-circuit technology. The microstrip patch antenna is a type of antenna that is thin, and has easy manufacturability, which provides a great advantage over traditional antennas. The Particle Swarm Optimization (PSO) has been introduced to the electromagnetic community for few years. In this paper PSO has been used for optimization of resonant frequency of circular probe-fed patch antenna. The investigation is made at a microwave frequency of 5 GHz. This Optimization problem has two variables which are height of dielectric substrate (h) and radius of the circular patch (a). The PSO algorithm is developed using 'Turbo C'.In order to verify the PSO algorithm, the Rosenbrock function is used as a performance test problem.

KEYWORDS

Particle Swarm Optimization (PSO), Rosenbrock function (RBF), Microstrip patch antenna, Circular patch

1. INTRODUCTION

In its most basic form, the microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Fig. 1.The patch is generally made up of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency.

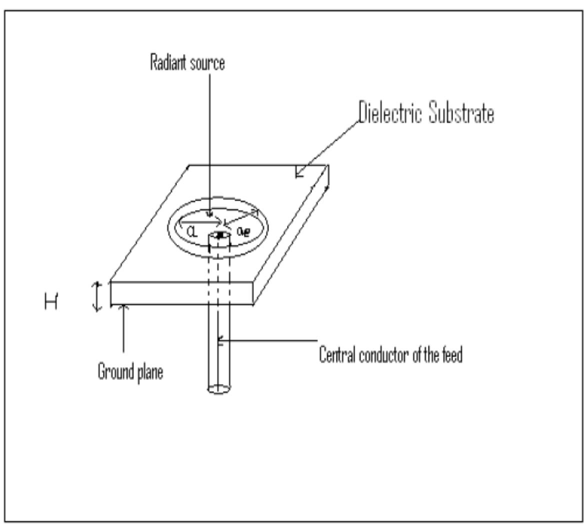

Figure 1 Circular patch antenna

The resonant frequency of operation of such antenna depends normally upon different parameters of the patch. This report presents a method for resonant frequency optimization of a circular microstrip patch antenna where the optimization parameter are patch-radius and height of substrate having dielectric constant 2.4 (normally height of substrate remain constant) fed by an SME co-axial connector with radius 0.6mm. Our aim is to design a circular microstrip antenna for operating at a desired frequency (5 GHz). PSO algorithm has been developed for obtaining the optimal values of antenna parameters (a and h) using 'Turbo c'. PSO optimizes a problem by maintaining a population called particles and moving these particles within a search-space. The movements of the particles are guided by the best found positions in the search-space, which are continually being updated as better positions are found by the particles.

2. THEORY OF MICROSTRIP PATCH ANTENNA

In telecommunication, there are several types of the microstrip antennas (also known as printed antennas) the most common of which is the microstrip patch antenna or patch antenna. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible.

The microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact microstrip patch antenna, higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance.

3. DESIGN OF CIRCULAR PATCH ANTENNA:

The resonant frequency of a circular patch antenna is approximately given without considering the effect of probe radius by [6]:

$$F = (Knm * c)/(2\pi a_e \sqrt{\varepsilon r}) \quad (1)$$

Where a_e =effective radius of the circular patch

c = velocity of light in free space

ε_r=relative permittivity of the medium

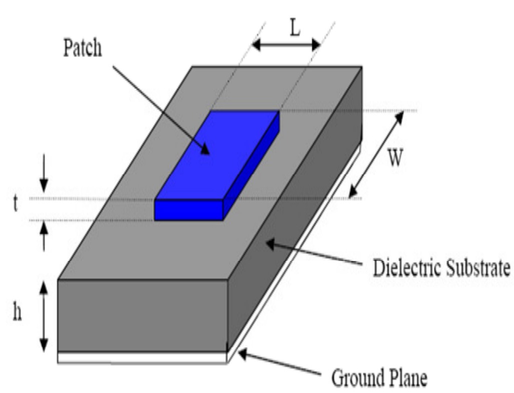

Figure 2 Microstrip patch antenna

Knm = m^{th} zero of the derivative of the Bessel function of order n. In our application we have considered the fundamental mode TM11, for which *K* value is1.84118. The expression for a_e is given by [6] as

$$a_e = a\{1+(2H/\pi a\varepsilon_r)[\ln(\pi a/2H)+1.7726]\}^{1/2} \quad (2)$$

Where H = height of the dielectric substrate
ε_r= relative permittivity of the medium
a = radius of the circular patch

4. PSO TECHNIQUE

Particle Swarm Optimization (PSO) is a robust, stochastic evolutionary computation technique based on the movement and intelligence of swarms. This technique has been applied for electromagnetic optimization recently. A swarm of bees flying in a field try to find the location with the highest density of flowers. A bee starts from a random location with a random velocity. At each step the bee changes its velocity and position. Each position is represented by an N-dimensional co-ordinate, where each dimension corresponds to a parameter to be optimized. The velocity and position of a particle can be determined from the following equations[1]:

$$VN = W*VN + C1 \text{ rand ( )}* (PBEST,N - XN) + C2 \text{ rand ( )}* (GBEST - XN) \quad (3)$$

Where *VN* is the velocity of the particle in the N^{th} dimension and *XN* is the co-ordinate of the particle in that dimension. W is known as the 'internal weight' and its value is chosen to be between 0 and 1 which determines to what extent the particle remains along its original course unaffected by the pull of PBEST and GBEST. C1 & C2 are the scaling factors which determine the relative 'pull' of PBEST and GBEST. C1 is a factor determining how much the particle is influenced by PBEST and C2 is a factor determining how the particle is influenced by the rest of the swarm. The random function 'rand' is introduced to incorporate the slight unpredictable component of natural swarm behavior[1].

$$XN = XN + \Delta T*VN \quad (4)$$

This equation updates the location of the particle for a given time step ΔT whose value is chosen to be unity.

5. PSO BASED OPTIMIZATION OF RESONANT FREQUENCY

The objective of the work is to optimize the resonant frequency of a probe-feed circular patch antenna. The range selected for optimization of parameters is as follows:

Radius of the circular patch: 0.2 cm to 2 cm

Height of the substrate: less than (1/20)th of the wavelength of operation=0.13 cm to 0.16 cm

Using equation (2), as the fitness function and values of *a* and *h* as agents the value of a_e, i.e., the effective radius, is evaluated.
The fitness function is defined as:

$$P= ((1.84118 * c)/ (2\pi a_e\sqrt{\varepsilon_r}) - f) \quad (5)$$

Where a_e is the effective radius of the patch;
ε_r is the relative permittivity of the medium,
c is the speed of light in that medium and 'f' is the theoretical frequency of resonance.
When the calculated resonant frequency matches to the desired value of the same, the value of the cost function P becomes zero.

For each particle a fitness value is calculated which is the local best for the particle. This value is compared with the global best and if any local best value is better than the global best, the global best value is replaced by that local best value as shown in Fig. 3.

6. VERIFICATION OF PSO USING ROSEN BROCK FUNCTION

In mathematical optimization, the Rosenbrock function is used as a performance test problem for optimization algorithms. In order to analyses the PSO, benchmark function of two dimensional Rosenbrock function is used in experiment, whose equation is given as follow [7].

$$f(x, y) = (1-x)^2 + 100(y-x^2)^2 \quad (6)$$

7. SOFTWARE TOOLS USED

For PSO optimization of antenna parameters we have used 'turbo c', and for plotting the surface plot of Rosen Brock function 'GNU plot' is used.

8. RESULTS AND DISCUSSIONS

The investigation is made at a microwave frequency of 5 GHz; number of particles are 20; inertia vector varies from 0.4 to 1; iteration 100; c1=c2=1.4.The table 1 shows the optimum values of a and h obtained from PSO. The fig 4 shows that after 20 iterations, the fitness function value becomes zero. The fig. 5 and 6 show that values of a and h (all the particles) converges to the same value which is 1.05 cm (a) and 0.001544 m (h). The fig. 7 shows that as inertia increase, the fitness value deteriorates. The fig. 8 shows the results of verification of the PSO algorithm using Rosenbrock function and have optimum value 0.001341 at (1.001901, 1.000148).

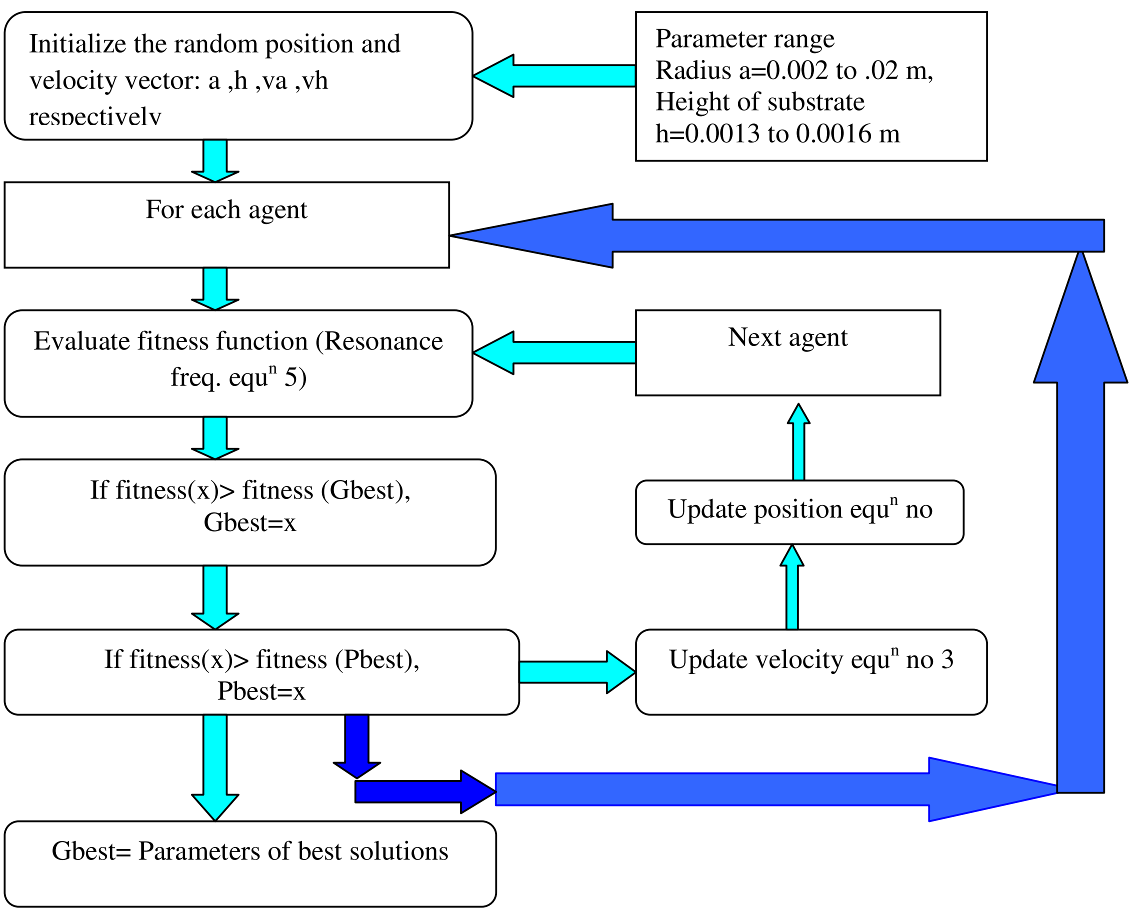

Figure 3 Flow chart of PSO of resonance freq. of circular patch antenna

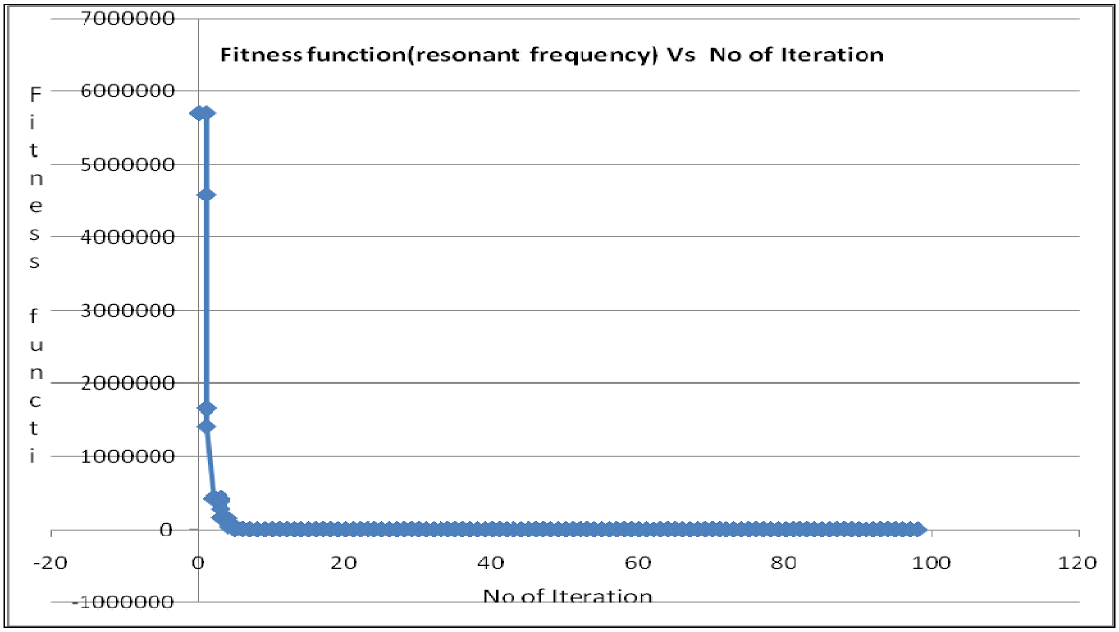

Figure 4 Fitness function (resonant frequency) vs no of iteration

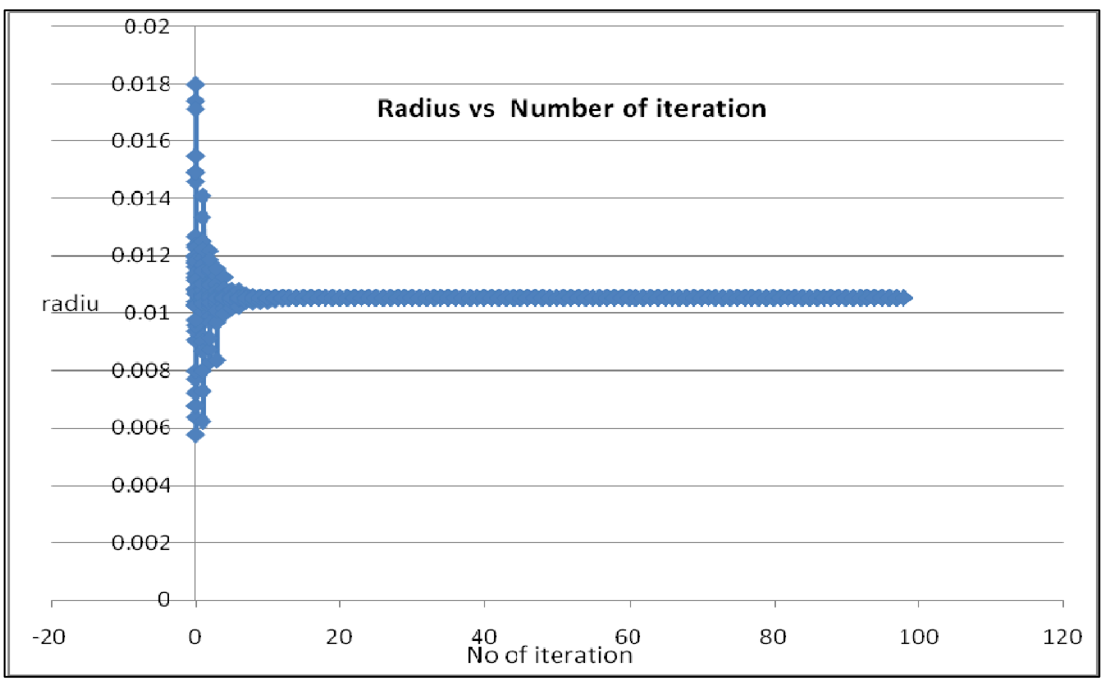

Figure 5 Radius vs number of iteration

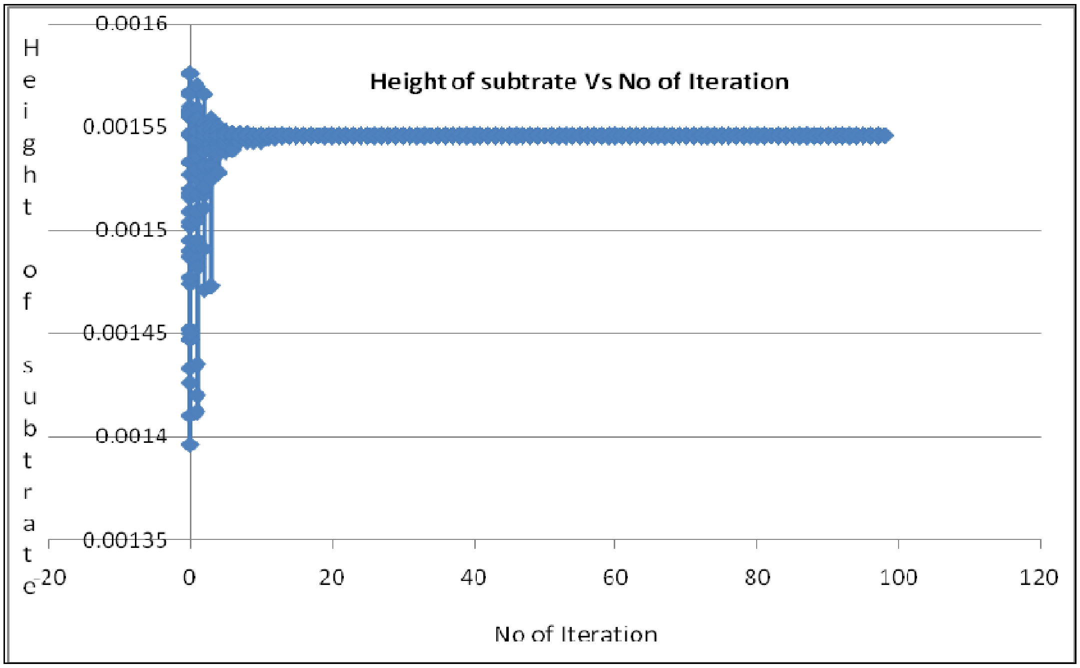

Figure 6 Height of substrate vs no of iteration

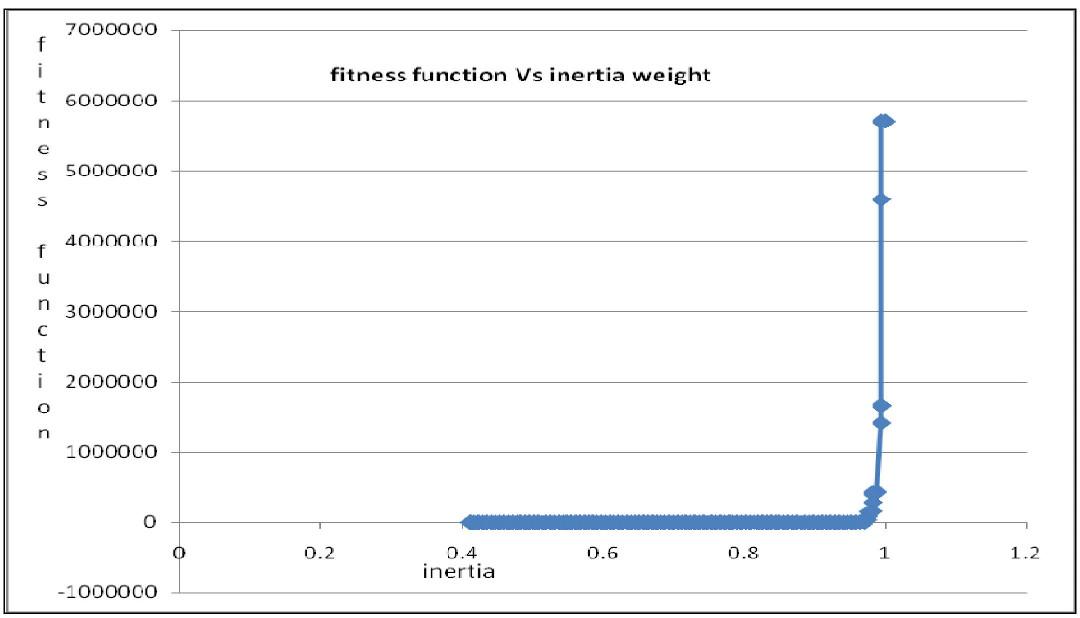

Figure 7 Fitness function vs inertia weight

Table 1 Calculated (optimum) parameters using PSO

No of particles	No of iteration	Optimum Value of a(m)	Optimum Value of h(m)	Fitness function Value
5	100	0.0106	0.001381	13077
10	100	0.010577	0.001440	0.00056517
15	100	0.010523	0.001579	0.0000
20	100	0.0106099	0.001358	0.0
25	100	0.01060966	0.001358	0.0
30	100	0.010567	0.001466	0.0
35	100	0.010591	0.0014037	0.0

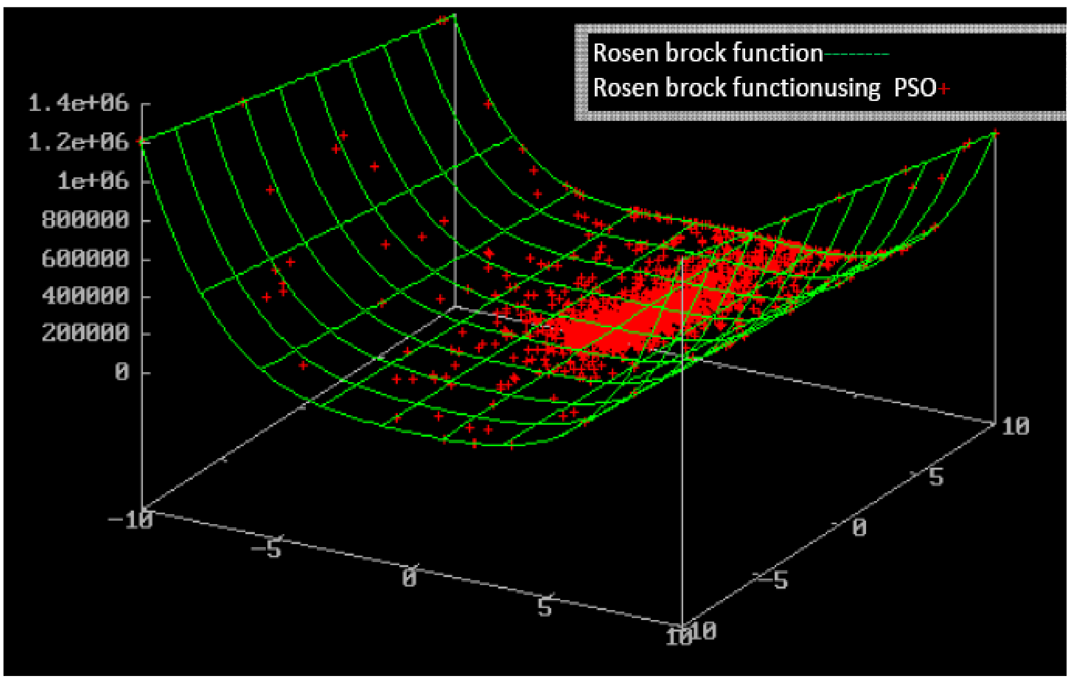

Figure 8 Surface plots of simple rosenbrock and rosenbrock using PSO

9. CONCLUSION

The particle swarm optimization procedure for optimizing resonance frequency of circular patch antenna and results of optimized parameters of it are described. From the graphical results, we can conclude that the fitness function value becomes 0 after 20 iteration, optimized radius found 0.010537 m, and height of substrate is 0.001546 m. The Rosenbrock function is used to verify the particle swarm optimization technique and at (1.001901, 1.000148) getting fitness value 0.001341. On the basis of results obtained, it can be concluded that the PSO can be efficiently used for optimization of different parameters of antenna .The advantage of PSO is its simplicity. There is an increasing demand for the use of microstrip antennas in wireless communication due to their low back radiation, ease of conformity as compared to wire antennas.

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