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Optimization of Rectangular Microstrip Patch Antenna Using Particle Swarm Optimization

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Abstract: **Particle swarm optimization is a algorithm used for design of microstrip patch antenna. It update the population and search for the optimum with random techniques. This paper presents the optimization of microstrip patch antenna for frequency ranges from 3GHz to 14GHz. A substrate material RT/Duroid 5880 of dielectric constant 2.20 and height 1.30mm has been used for the design of microstrip patch antenna. Particle swarm optimization (PSO) has been used to optimize the parameters like patch length (L), width (W) and Probe offset using simulation software Sonnet 13.52**

Keywords: **Dielectric constant; Microstrip Patch antenna; Particle swarm optimization; Resonant frequency; Return loss; Smith chart; VSWR; Sonnet 13.52.**

I. INTRODUCTION

The microstrip patch antenna is the present day antenna designer's choice due to its low profile, low weight, low cost and small size. Furthermore, they can be easily designed to operate in dual-band, multi-band application, dual or circular polarization. In its most basic form, a microstrip patch antenna consists of a radiating patch generally made of conducting material such as copper on one side of a dielectric substrate which has a ground plane on the other side [1]. Patch antennas are planar antenna and suitable for use as active antennas. These are used in wireless links and are important in many commercial applications. However, microstrip patch antennas have narrow bandwidth. Most common methods to feed the patch antenna are microstrip line feed, aperture coupled feed, proximity coupled feed and coaxial probe feed. A rectangular microstrip patch antenna using coaxial probe feed is shown in figure 1 [2],[3].

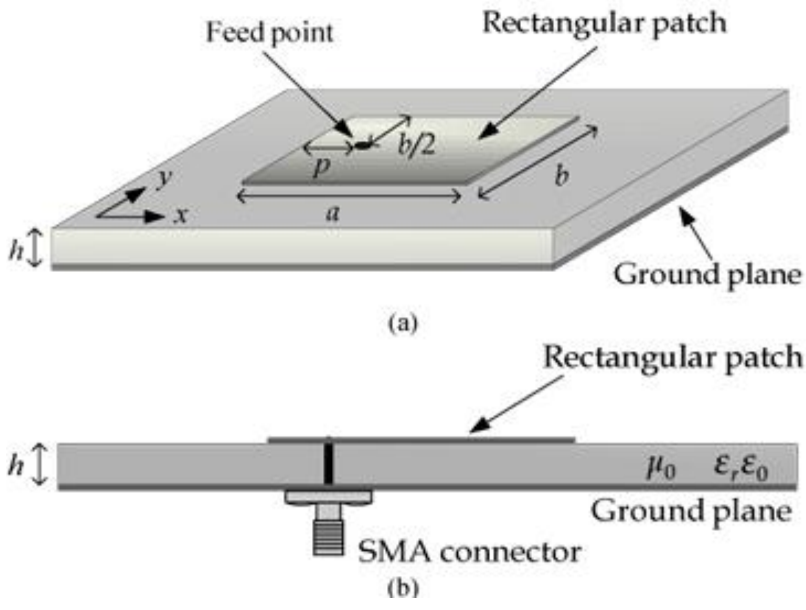

Fig.1 Microstrip patch antenna: (a) top view, (b) side view

II. PSO ALGORITHM

In 1995, James Kennedy and Russell Eberhart presented particle-swarm optimization (PSO), an optimizer that is based on movement and intelligence of a swarm of bees or flock of birds [4]. A swarm of bees starts from a random location and a random velocity to find the location with abundance of flowers. As each bee has a change of velocity and position at each step, the change of Velocity Vmn of the particle is given as:

$$v_{mn} = wv_{mn} + c_1 rand(\,)(P_{mn}^{bp} - x_{mn}) + c_2 rand\,(\,)(g_m^{bp} - x_{mn})$$

Where x_{mn} is the coordinate of the particle along the N^{th} dimension.

P_{mn}^{bp}, is the personal best position and g_m^{bp} is the global best position.

The personal position and value are related to individual particles. Where global best position and value are equal to all individuals.

c_1, c_2 are scaling factors and rand ( ) is uniformly distributed random number (0 to 1)

W is inertial weight and is used for controlling the convergence. Find out next position by using the equation given below

$$x_{mn} = x_{mn} + v_{mn} * \Delta t$$

Δt is time step whose value is chosen to be 1.

III. RESULTS AND DISCUSSIONS

In this paper to resonate rectangular microstrip patch antenna at resonant frequency ranging from 3GHz to 14GHz, the length, width and probe offset of the rectangular patch have been optimized. By using the following equations, the Resonant frequency f_r of the rectangular microstrip patch is given by [5]:

$$f_r = \frac{c}{(2L\sqrt{\varepsilon rff})} \qquad (1)$$

Where c is the velocity of light.

Equation for ε_{reff} is given as:

$$\mathcal{E}_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-0.5} \qquad (2)$$

Resonant length of the patch is not exactly equal to the physical length of patch due to the fringing fields on the sides of patch.

Effective length L_{eff} of patch is longer than its physical length and is given as:

$$L_{eff} = (L + 2\Delta L) \qquad (3)$$

Increase in patch length (ΔL) is given as:

$$\Delta L = 0.412\frac{h(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (4)$$

By considering the fringing fields on sides of the patch, the resonant frequency of patch is given as [6]:

$$f_r = \frac{c}{2L_{eff}\sqrt{\varepsilon_{reff}}} \qquad (5)$$

Using Equation no.(6) the width of rectangular patch is calculated .

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (6)$$

Parameters chosen for design of rectangular microstrip patch antenna are:

1. Center frequency ranges from 3GHz to 14GHz

2. The substrate material is RT/Duroid 5880

3. Dielectric constant of the material is 2.20

4. Loss tangent of material is 0.0009

5. Substrate thickness is 1.30mm

TABLE-1

The Optimized Patch length, Width, Probe offset and Return loss for frequency ranges from 3GHz to 14GHz.

Frequency (In GHz)	**Optimized Patch Length** (in mm)	**Optimized Patch width** (in mm)	**Probe offset** (in mm)	**Return loss** (in db)
3	32.89	20.76	13.29	-33.78
4	24.43	15.57	9.57	-28.55
5	19.35	12.47	7.54	-20.52
6	16.02	10.36	5.81	-33.22
7	13.66	8.99	5.05	-20.03
8	11.85	7.78	4.27	-30.60
9	10.58	6.92	3.43	-14.13
10	9.45	6.23	3.07	-18.36
11	8.52	5.66	2.77	-27.29
12	7.82	5.19	2.34	-23.79
13	7.02	4.79	2.34	-13.16
14	6.45	4.45	2.13	-10.73

Following are the Different parameters plotted in Sonnet software

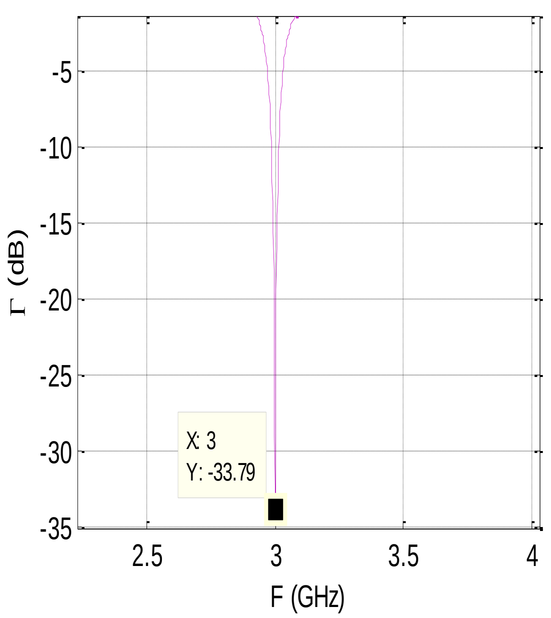

Fig.2 Return Loss at 3GHz resonant frequency

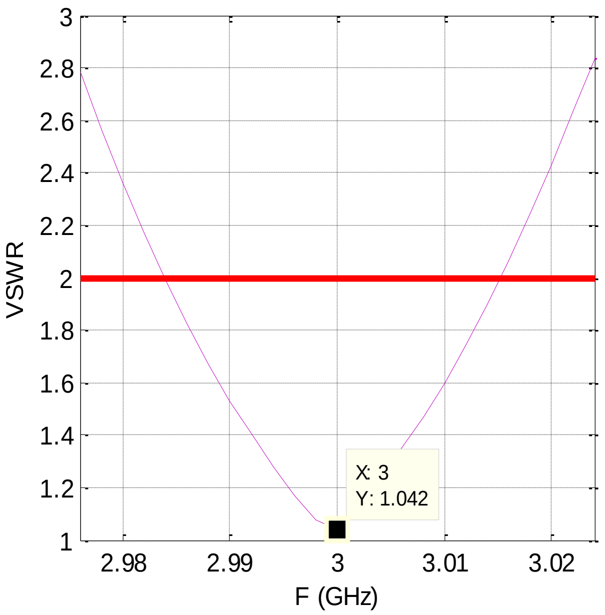

Fig.3 VSWR plot of the 3GHz patch antenna

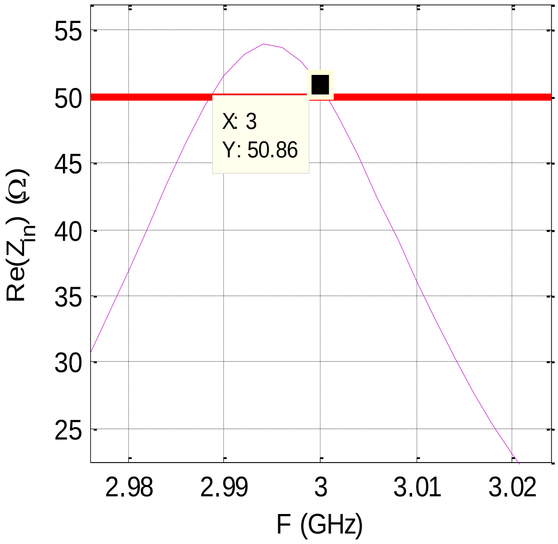

Fig.4 Input impedance plot for 3GHz

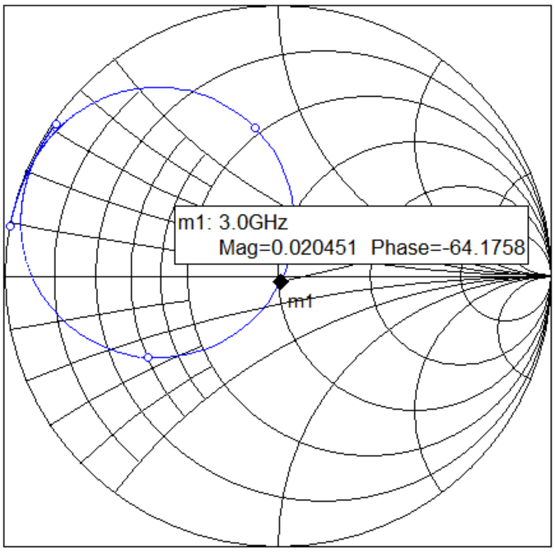

Fig.5 Smith chart of the 3GHz patch antenna

IV. CONCLUSION

It can be concluded that for designing of patch antenna, the optimization by using PSO restricts the variation from center frequency and saves time as compared to the design of patch antenna without using an optimization algorithm. It is easy to implement PSO and there are few parameters to adjust. Return loss graph plotted above showed that the micro strip patch antenna with the use of PSO resonated exactly at the center frequency.

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