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An Approach To Optimize Resonance Frequency of Rectangular Microstrip Patch Antenna using Swarm Intelligence

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ABSTRACT

Particle swarm optimization is one of the good optimization technique used in parameter calculation for Microstrip Patch Antenna. For a particular Resonance Frequency we can calculate the parameters like length , width , height of a rectangular patch antenna. But due to charge movement on the surface of antenna, generated electric field line increases the effective length of Patch. This effect changes the Resonance frequency. So we need some good optimization techniques for proper calculation of parameters- which will consider the electric field line effect and design specification (desired Resonance Frequency). In this paper only Resonance frequency is optimized and PSO has been implemented in 2 dimensional space to calculate width(w) and length(L) of patch. PSO implemented using C programming and simulation done using HFSS software.

Keywords: Microstrip , Patch Antenna, Particle Swarm Optimization ,Optimization, Resonance Frequency

1. Rectangular Microstrip Patch Antenna :

In its most fundamental form, a 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 figure. The patch is generally made 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.

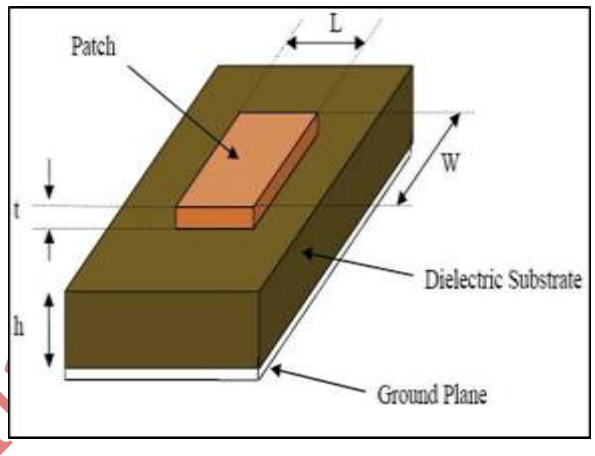

Fig 1. Structure of Microstrip Patch Antenna

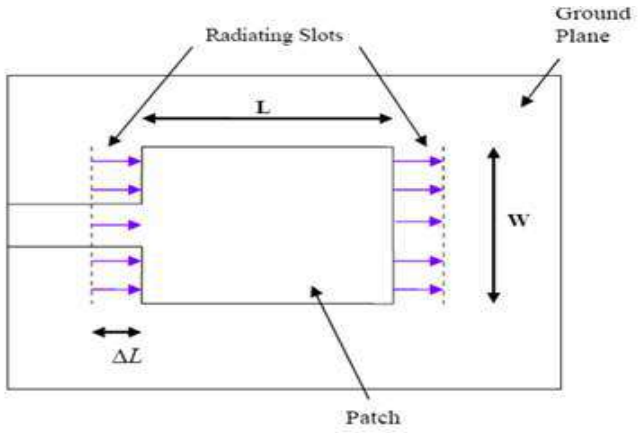

Fig 2. Radiating Slots and increase in effective length.

1.1 Calculation of Parameters :

For a rectangular patch, the length L of the patch is usually $1/3\ \lambda < L < 1/2\ \lambda$ where λ is the free-space wavelength. h is the height of dielectric substrate $h \leq \lambda$. The dielectric constant of the substrate is ε_r .

- Resonance Frequency of the Microstrip Antenna is given by—

$$f_0 = \frac{c}{2L_e\sqrt{\varepsilon_r}}$$

Where c is the speed of light in vacuum. To account for the fringing of the cavity fields at the edges of the patch, the length, the effective length L_e is chosen as

- $L_e = L + 2\Delta L$
- Width (W) = $\frac{C}{2f0\sqrt{\frac{\varepsilon+1}{2}}}$

The Hammerstad formula for the fringing extension is

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

Where

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-1/2}$$

1.2 Specification and initial calculation

Parameter	Value
Resonance Frequency to Optimize	5 GHz
Dielectric constant of substrate[5]	2.4
Thickness of substrate[5]	1.578
Width (w) before optimization	23.01mm
effective Length (L) before optimization	18.53mm

1.3 Simulation Result : Figure 3 represents active S parameter for initially designed Microstrip Antenna. It shows that the Antenna is radiating at 4.8 GHz.

Now we will use PSO algorithm to make it resonate at desired 5 GHz frequency.

Fig 3: Active S parameter for simulation using initial parameter values.

2. Particle Swarm Optimization : [1-5]

. Particle Swarm Optimization is an Artificial Intelligence approach for optimization . This algorithm was designed observing birds behavior when they search food.

The philosophy is that- When a group of birds are in random search of food in any area , they don't know where they will get maximum amount of food. The effective one is to communicate with each other (share information) and follow the bird which has more food nearby.

- In this approach , solution can be represented in an N dimensional solution space . A number of particles are randomly set into

motion in this solution space where in each iteration they calculate some **Fitness function** .

- In each iteration they share information and move to more optimum solution using a **velocity function**.
- '**Information sharing'** is done in each iteration using two best values. First One is the best solution (fitness function value) it has achieved so far , and another is the best solution found by the all particles in population . first one is called **P_Best** (Personal Best) , Second one is **G_Best** (Global Best).
- After finding the two best values, the particle updates its velocity (V[]) and positions (X[]) with following equation (a) and (b).

v[t+1]=k*(v[t]+φ1*rand[]*(pbest[]-X[t])+φ2*rand[]*(gbest[]-x[t])

…….. **(a) [**1,3]

Where $\varphi = \varphi 1 + \varphi 2;\ \varphi > 4$

K is constriction factor , k= $\frac{2}{2-\varphi-\sqrt{\varphi 2-4\varphi}}$

X[t+1] = X[t] + v[t+1] …… (b)

3. Optimization of Resonance Frequency :

- **Fitness function selection:**

Fitness = (freq- 5*10^9) { if freq> 5*10^9)
=(5*10^9- freq) {else everywhere }

Where **freq**= calculated resonance frequency for each individual solution calculated as--

$$f_0 = \frac{c}{2L_e\sqrt{\varepsilon_r}}$$

- The upper and lower limit of Width and Length was taken as bellow.
  Maximum width—24mm
  Minimum Width--- 22.5 mm
  Maximum length—19.5 mm
  Minimum Length—1.5 mm
- 15 particles were taken for optimization**Rand()** function was used to define position of this random 15 particles at beginning.
- Total 800 iteration was taken.
- PSO implemented using C programming
- K =0.798, φ1=1.3 , φ2=4.2 [3]

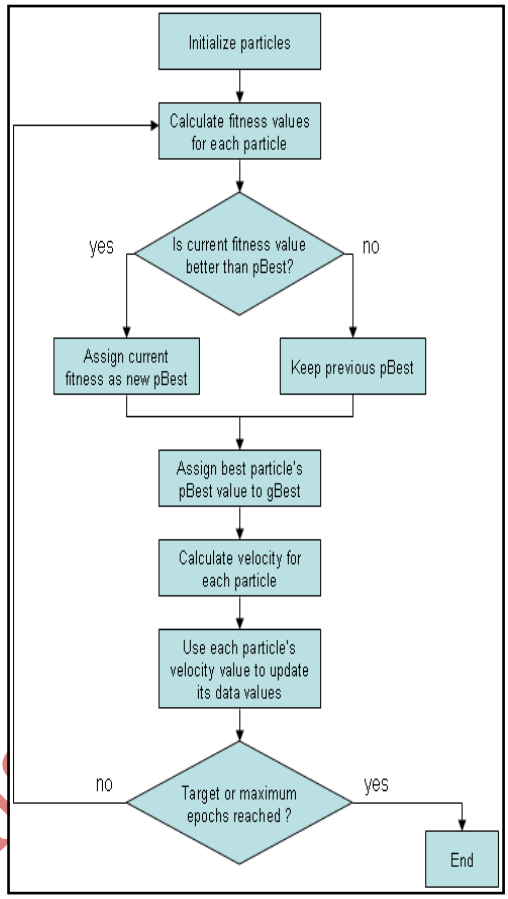

Fig 4- PSO algorithm

4. Final Simulation And Result :

The optimum result found as bellow-

Parameter	Final Value
Final Width	**23.591804mm**
Final Length	**17.781695mm**

Figure 5 shows active S parameter when simulation is done using final parameter values. It shows that **antenna now radiates at desired 5 GHz Frequency .**

Fig 5- Active S parameter for simulation using final value of Width and length.

5. Further Prospects:

This paper is focused in optimizing resonance frequency . PSO algorithm was implemented in two dimensional space where only width and length were considered . **The return loss , bandwidth ,VSWR can be improved** of this antenna .

Weights of PSO algorithm parameters(K, $\varphi 1$, etc.)
can be changed and new simulation results can be studied.

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