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# Design Microstrip Antenna Using Particle Swarm Optimization

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# تصميم الهوائيات الشريطية بأستخدام خوارزمية سرب الجسيمات الامثل

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**الخلاصة**

في هذا البحث تم بناء خوارزمية سرب الجسيمات المفضلة لتصميم الهوائيات الشريطيه الدقيقه لمختلف الاشكال ، المستطيلة و المثلث المتساوي الاضلاع. مشكلة تحليل وتصميم تلك الاشكال عرفت لحساب التردد الرنييني لسمك المادة العازلة وسماحيتها والشكل الهندسي . هنالك عده فوائد من هذا التمصميم منها وضوح وبساطة تمثيل الهوائيات باستخدام خوارزمية سرب الجسيمات المفضلة . وقد تم مقارنة النتائج التي تم الحصول عليها من سرب الجسيمات المفضلة بنتائج تم الحصول عليها من برنامج المايكرو ويف الصادر في ٢٠٠٧ نسخة ٧.١ .

## ABSTRACT

In this work, particle swarm optimization algorithm (PSO) models have been built for the design of microstrip antennas in various forms such as rectangular and equilateral triangle antenna. The analysis problem can be defined as to obtain resonant frequency for a given dielectric material and geometrical structure. This approach has a few advantages: giving a clearer and simpler representation of the problem, and totally avoiding binary encoding and decoding so as to simplify software programming. The antenna designed using PSO is implemented using Microwave Office software 7.1 produced in 2007.

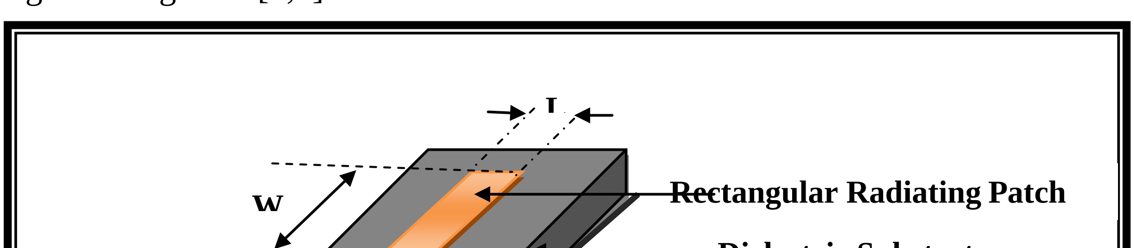
## 1- INTRODUCTION

Microstrip antennas are very popular due to their properties, such as low profile, low cost, conformability and ease of integration with active devices, since they are light weight, simple geometries, inexpensive to fabricate and can easily be made conformal to host body [1,2,3]. These attractive features have increased the applications of the microstrip antennas recently and simulated greater efforts to investigate their performance. Microstrip antenna has a very narrow bandwidth which is not exceed several of percent from the resonant frequency and the antenna operates in a vicinity of the resonant frequency. This needs very accurate calculations for various design parameters of microstrip patch antennas [4]. Patch dimensions for various microstrip patches is a vital parameter in deciding the utility of a microstrip antennas. CAD Models are generally developed using analytical, electromagnetic simulation, and measurement based methods. Accurate and efficient models for circuit components are essential for cost-effective circuit design. Jni and Rahmat-Sarnii (2005) have optimized the geometric parameters of multiband and wide band patch antenna using PSO algorithm to achieve a desired performance[5]. Papadopoulos *et al.* (2006) have used PSO algorithm to find spatial and feeding configuration of array elements of switch beam planer antenna array[6]. Pantoja et al. (2007) have optimized the design of log-periodic dipole array with aid of PSO algorithm[7]. Farzaneh et al. (2008) used Boolean particle swarm optimization for design single feed dual band microstrip antenna[8] .Li et al. (2008) used PSO to optimize the antenna array pattern[9]. Winyou Silabut , Waroth et al. (2009) have designed of a miniaturized dual-band patch antenna using particle swarm optimization with moment of methods design dual band antenna [10].Gangopadhyaya et al. (2009) have determined accurately the resonant frequency of rectangular aperture-coupled microstrip antenna using PSO algorithm[11]. Yogesh et al. (2009) presented PSO method as based design of a dual slot patch antenna[12]. Hadi and Mehri et al. (2009) used PSO for bandwidth calculation of MSA[13]. Mohammad et al. (2009) presented PSO with curve fitting for E-shaped microstrip patch antenna design[14] .Charnaani et al. (2010) have obtained using PSO, optimal tradeoff between side lobe level and beam width in time domain for ultra-wide band antenna array[15]. Choukiker et al. (2010) Planar antenna for ISM using PSO[16]. Harshvardhan et al. (2010) used PSO for U-slot microstrip patch antenna for dual band operation[17]. Mousa et al. (2011) have optimized the performance of the smart antenna system using PSO algorithm[18].

In this study, a particle swarm optimization algorithm is used to adapt of rectangular and triangular microstrip antenna parameters responding to some constraints (frequency of the fundamental mode) some more advanced techniques, which gives a global minimum, have been retained. The PSO method, which is able to optimize different natural variables, is the most versatile approach. It can optimize the physical (dimension of the patch, thickness of substrate, and electric parameters (relative permittivity). The basic theory of PSO algorithm is also presented [17,18].

## 2-Structure of Rectangular and equilateral Triangular Antenna

A microstrip antenna in its simplest configuration consists of a radiating patch on one side of dielectric substrate, which has a ground plane on the other side. The patch conductors, normally of copper and gold, can assume virtually any shape. In this paper rectangular and triangular microstrip antenna as shown in Figure (1) are designed using PSO [1,3].



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## 3- An Overview of Particle Swarm Optimization:

PSO is a population-based optimization method first proposed by Eberhart and Colleagues [19]. Some of the attractive features of PSO include the ease of implementation and the fact that no gradient information is required. It can be used to solve a wide array of different optimization problems. Like evolutionary algorithms, PSO technique conducts search using a population of particles, corresponding to individuals. Each particle represents a candidate solution to the problem at hand. In a PSO system, particles change their positions by flying around in a multidimensional search space until computational limitations are exceeded.

The PSO technique is an evolutionary computation technique, but it differs from other well-known evolutionary computation algorithms such as the genetic algorithms. Although a population is used for searching the search space there are no operators inspired by the human DNA procedures applied on the population. Instead, in PSO, the population dynamics simulates a 'bird flock's' behavior, where social sharing of information takes place and individuals can profit from the discoveries and previous experience of all the other companions during the search for food .Thus, each companion, called particle, in the population, which is called swarm, is assumed to 'fly' over the search space in order to find promising regions of the landscape. For example, in the minimization case, such regions possess lower function values than other, visited previously. In this context, each particle is treated as a point in a d-dimensional space, which adjusts its own 'flying' according to its flying experience as well as the flying experience of other particles (companions). In PSO, a particle is defined as a moving point in hyperspace. For each particle, at the current time step, a record is kept of the position, velocity, and the best position found in the search space so far. The assumption is a basic concept of PSO [18,19].

## 4-PSO Algorithm for Microstrip Antenna:

In the PSO algorithm, instead of using evolutionary operators such as mutation and crossover, to manipulate algorithms, for a d-variables optimization problem, a flock of particles are put into the d-dimensional search space with randomly chosen velocities and positions knowing their best values so far (P-best) and the position. In the d-dimensional space. The velocity of each particle, adjusted according to its own flying experience and the other particle's flying experience. For example, the i-th particle is represented as xi = (x $i_1$ ,x $i_2$ ,…, $xi_d$ ) in the dimensional space. The best previous position of the i-th particle is recorded and represented as: P-besti = (P-best $i_1$, P-best $i_2$ ,..., P-best $i_d$ ). The index of best particle among all of the particles in the group is (d) g-best . The velocity for particle (i) is represented as Vi =(v $i_1$,v $i_2$,…,v $i_d$ ).The modified velocity and position of each particle can be calculated using the current velocity and the distance from P-best $i_d$ to g-best (d) as shown in the following formulas [20]:

$$V_{i,m}^{(i+1)} = V_{i,m}^{(i+1)} = WV_{i,m}^{i} + C_1 Rand(\ )\left(Pbest_{i,m} - X_{i,m}^{i}\right) + C_2 Rand(\ )\left(gbest_{i,m} - X_{i,m}^{i}\right) \ldots(1)$$

$W$ = w Max-[(w Max - w Min* iter]/maxIter …..(2)

$$X_{i,m}^{i+1} = X_{i,m}^{i} + V_{i,m}^{i+1}, \quad i=1,2,3\ldots,n\ ;\ m=1,2,3,\ldots,d \ \ldots.(3)$$

Where

n Number of particles in the group,

d dimension,

t Pointer of iterations(generations),

w Inertia weight factor,

$c_1$,$c_2$ Acceleration constant,

P-$best_i$ Best previous position of the i-th particle.

g-$best_i$ Best particle among all the particles in the population.

Rand( ) Random number between 0 and 1.

$X_{i,m}^{(t)}$ Current position of particle i at iterations.

$V^{t}_{i,m}$ Velocity of particle (I) at iteration (t) $V_d^{min} \le V_{i,d}^{t} \le V_d^{max}$.

The evolution procedure of PSO Algorithms producing initial populations is the first step of PSO. The population is composed of the chromosomes that are real codes. The corresponding evaluation of populations called the "fitness function". It is the performance index of a population. The fitness value is bigger, and the performance is better. After the fitness function has been calculated, the fitness value and the number of the generation determine whether or not the evolution procedure is stopped (Maximum iteration number reached). In the following, calculate the P-best of each particle and g-best of population (the best movement of all particles). The updated velocity, position, g-best and p-best of particles give a new best position (best chromosome in our proposition) Figure (2) shows the PSO model for microstrip antenna and Figure (3) shows the PSO algorithm for microstrip Antenna Design, the PSO algorithm can be described as: [13,19,20].

**Comment:** PSO-based antenna designing algorithm
**Comment:** Define the solution space, fitness function, and population size
**Initialize:**

**Minimum and maximum value of particles velocity in each dimension** $\left[\mathbf{V}_{\mathbf{min}}, \mathbf{V}_{\mathbf{max}}\right]$,
Maximum iteration, number of particles,

Minimum and maximum value of particles value in each dimension $\left[X_{min}, X_{max}\right]$
Initial and final value of Inertia weighting factor **w** ,
Determine initial value for particles **x** .
**While** Iteration <Max iteration
Update inertia weighting factor **w**
**Call** evaluation function; (**Comment:** Cost function or fitness function)
Finding **p-best** and **g-best**;
**Comment: p-best** and **g-best** are best position for each and all particles respectively, Update $\mathbf{V}_{i+1}$ and $\mathbf{X}_{i+1}$. . (**Comment**: According to (1),(3))
**End While**
**Display** founded best **x**

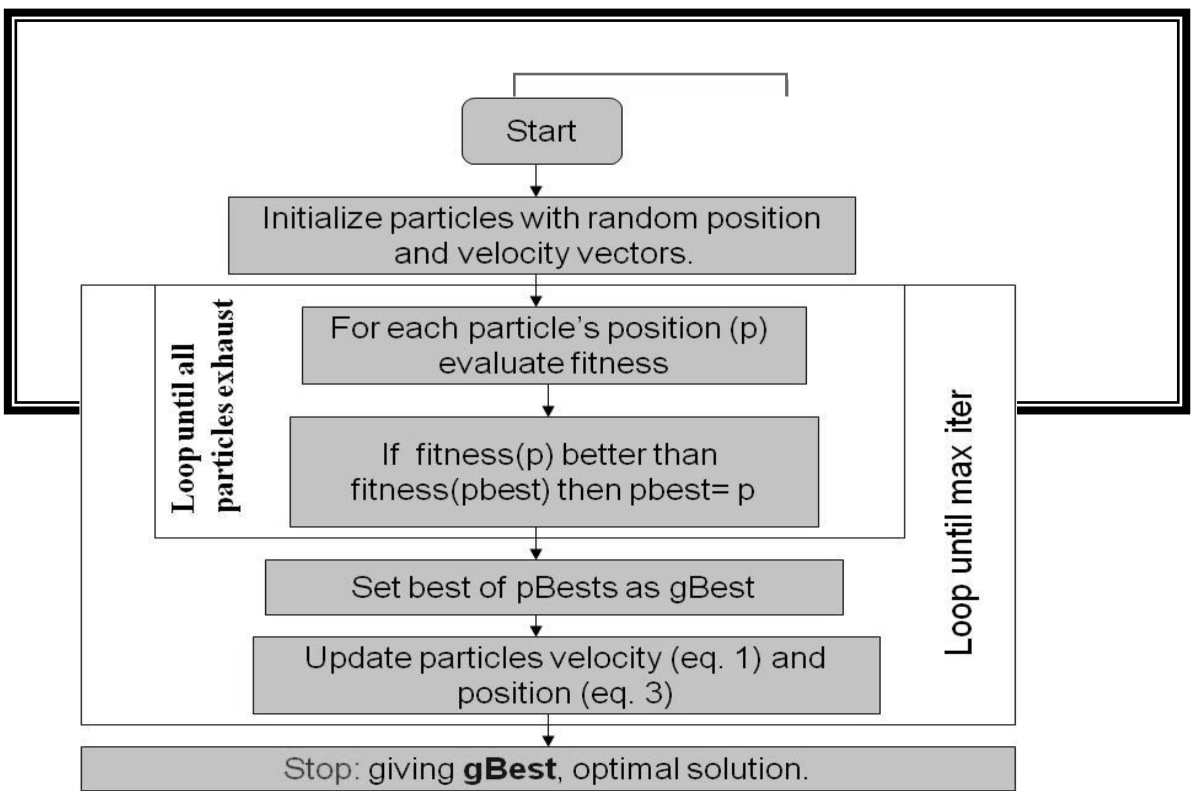


**Fig.(3) PSO Algorithm for Microstrip Antenna Design**

**4-1- Initial Particle.**

For fast convergence of PSO iteration, the initial particle can include with random position and velocity.

**4-2- Fitness Function.**

In order to show the feasibility of this paper, the case of a rectangular and triangular microstrip antenna form were studied.

**4-3-1 Rectangular Patch.**

It is about an antenna of length (L), width (W), thickness (h) posed on a substrate of permittivity ($\varepsilon_r$). The objective is to find the values of the four parameters :( L, W, h, and $\varepsilon_r$), so that the antenna satisfies the constraint the algorithm applied for resonant frequency equal to 10 GHz [3,13] to check the ability of the proposed design.

The resonant frequency of TMnm mode of the rectangular radiant element is:

$$f_{nm} = \frac{c}{2(L+2\Delta\ell)\sqrt{\varepsilon_e}} \qquad \ldots(4)$$

Where:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{a}\right)^{-1/2} \qquad \ldots(5)$$

$$\Delta\ell = 0.412h\frac{(\varepsilon_e + 0.3)\left(W/h + 0.264\right)}{(\varepsilon_e - 0.258)\left(W/h + 0.8\right)} \qquad \ldots(6)$$

**4-3-2 Equilateral Triangular Patch.**

It is about an antenna of length side (a), thickness (h) posed on a substrate of permittivity ($\varepsilon_r$). The objective is to find the values of the three parameters :( a, h, and $\varepsilon_r$), so that the antenna satisfies the constraint the algorithm applied for resonant frequency equal to 10 GHz [3] to check the ability of the proposed design.

The resonant frequency of TMnm mode of the triangular radiant element is:

$$f_{nm} = \frac{2 * c}{3a_e\sqrt{\varepsilon_e}} \qquad \ldots(7)$$

Where:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{4}\left(1 + \frac{12h}{a}\right)^{-1/2} \qquad \ldots(8)$$

$$a_e = a + \frac{h}{\sqrt{\varepsilon_r}} \qquad \ldots(9)$$

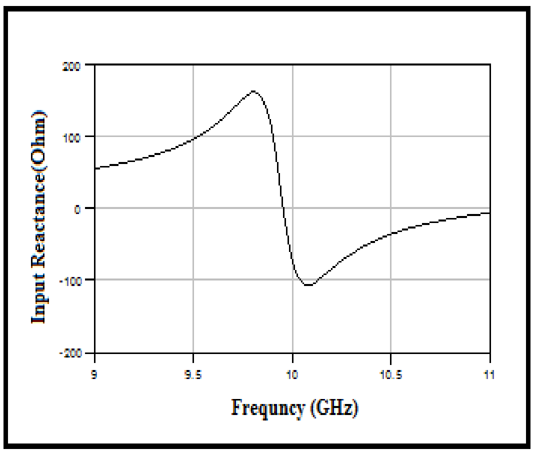
## 5-RESULTS AND DISCUSSION

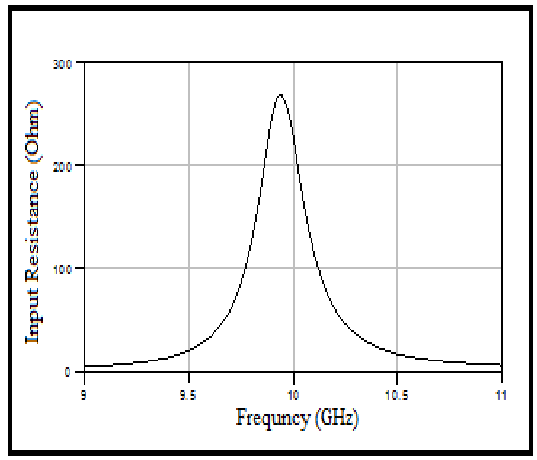
The particle swarm optimization is used here to find the optimal parameters of the microstrip antenna design using MATLAB program. A rectangular and equilateral triangular patches have been constructed and analysis in Microwave Office software 7.1.

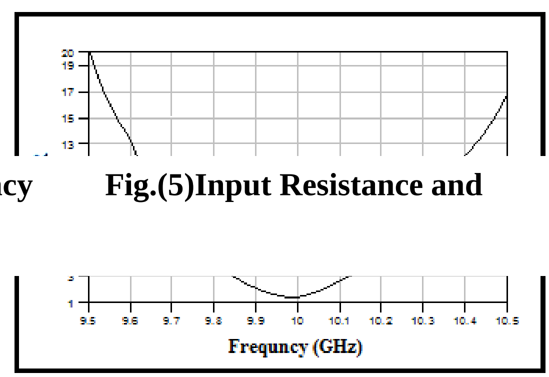
Tables (1 and 2) show the design of microstrip antenna using PSO and microwave office for different resonant frequencies. The particle swarm optimization algorithm has been proved to be useful for the design of different types of micro strip antenna (triangular and rectangular patches) that gives good accuracy in compared with MWO results. For rectangular antenna Figure (4) shows the relation between input reactance and frequency and it is found that at the center frequency 10GHz the input reactance is equal to -64 ohm. Figure (5) shows the relation between input resistance and frequency and it is found that at the center frequency 10GHz the input resistance is equal to 280 ohm. Figure (6) shows the relation between VSWR and frequency. Figure (7) shows the relation between reflection coefficient and frequency and it is found that the reflection coefficient is equal to -17 dB. Figures (8,9) show polar pattern in E and H-planes and it is found the HPBW in E-plane is equal to 61 degrees and HPBW in H-plane is equals to 62 degrees. For Triangle antenna Figure (10) shows the relation between input resistance and frequency and it is found that at the center frequency 10GHz the input resistance is equal to 330 ohm. Figure (11) shows the relation between input reactance and frequency and it is found that at the center frequency 10GHz the input reactance is equal to -100 ohm. Figure (12) shows the relation between VSWR and frequency. Figure (13) shows the relation between reflection coefficient and frequency and it is found that the reflection coefficient is equal to -17 dB. Figures (14, 15) show polar pattern in E and H-planes and it is found the HPBW in E-plane is equal to 66 degrees and HPBW in H-plane is equals to 64 degrees, from the above results which I achieved using PSO are acceptable and it's successfully implemented for designing the microstrip antenna with different shapes.

**Table (1) Design of Rectangular Microstrip Antenna Using PSO and MWO**

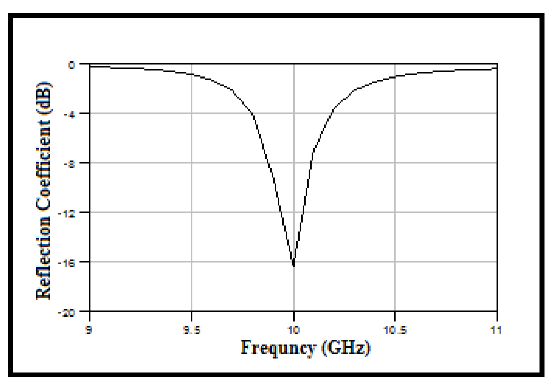
| Frequenc | Center | | | th( cm | in | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 96 | | | | |
| | | | | 16 | | | | |
| | | | | 00 | | | | |
| | | | | 64 | | | | |
| | | | | 08 | | | | |

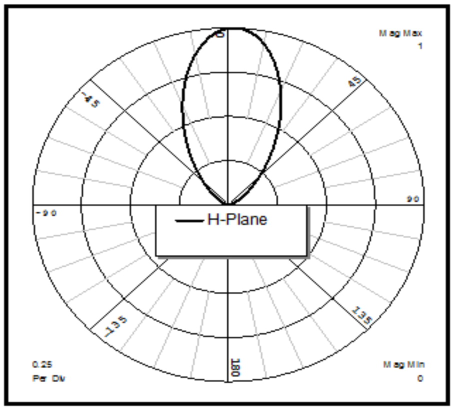



**d Resonant Frequency** **Fig.(5)Input Resistance and**





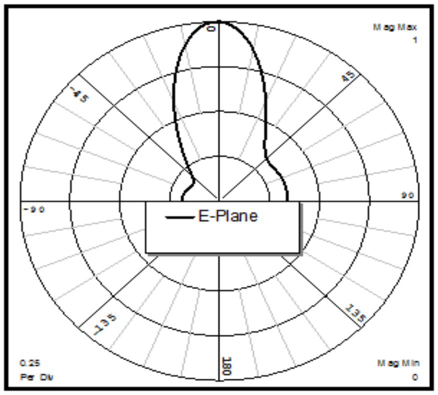




**Fig.(8) H-planes** **Fig.(9) E-planes**

**Table (2) Design of Equilateral Triangular Microstrip Antenna Using PSO and MWO**

| [illegible] | [illegible] | [illegible] | Height ( h) in cm Center | Substrate Material $\varepsilon_r$ | Accuracy% |
|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | 0.1334 | 3.2366 | 99.7% |
| 9.987 | 9.999 | [illegible] | [illegible] | [illegible] | [illegible] |
| 9.961 | 9.87 | [illegible] | [illegible] | [illegible] | [illegible] |
| 9.962 | 9.98 | 1.1386 | 0.1317 | 3.6664 | 99.8% |
| 9.997 | 9.988 | 1.2399 | 0.0585 | 3.0993 | 99.9% |

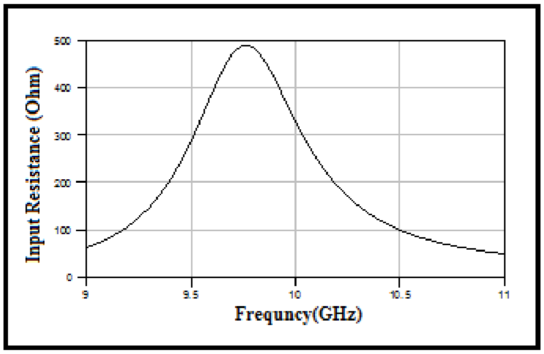



**Fig.(10)Input Resistance and Resonant Frequency**

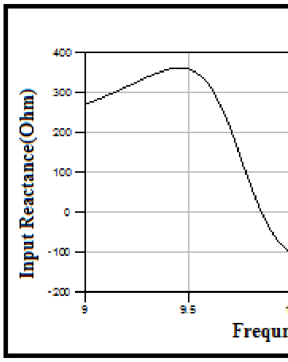



**Fig.(11)Input Reactance an**

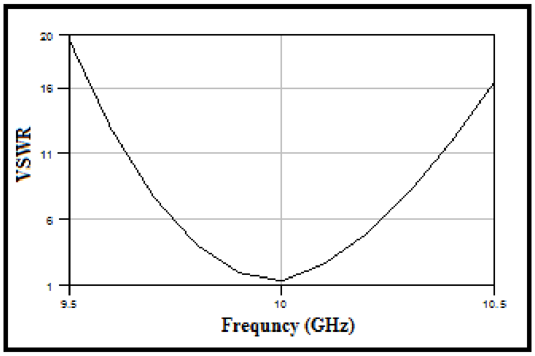



Fig.(12)VSWR and Resonant Frequency

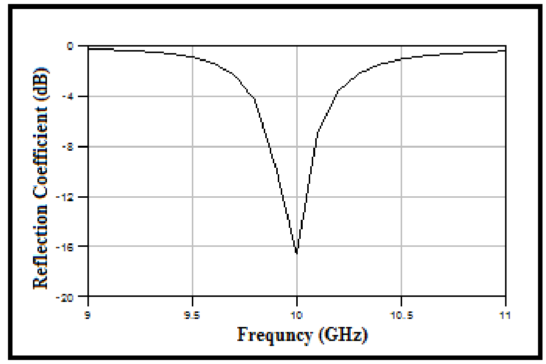



Fig.(13) Reflection Coefficient and

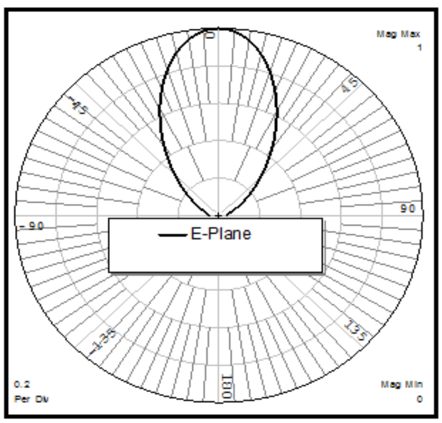



Fig.(14) E-planes

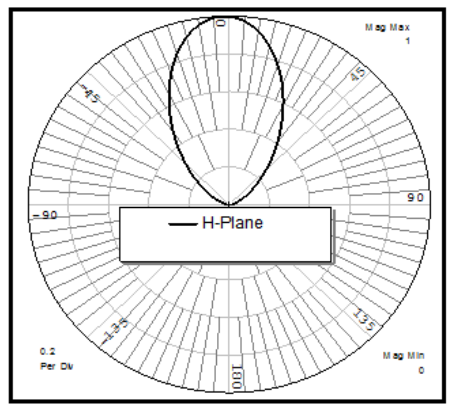



Fig.(15) H-planes

## 6- CONCLUSION

In this work, a particle swarm optimization algorithm is built for designing microstrip antennas in various forms such as rectangular and equilateral triangle patch antennas. The design procedure is to determine the resonance frequency in terms of patch dimensions, dielectric constant $\varepsilon_r$ and thickness h. The output of the particle swarm optimization algorithm is examined against the simulation which is done in MWO 2007 software depends on method of moment. This paper introduces a PSO and gives a new approach to use this technique to design the optimal parameters of a microstrip antenna which are represented. The particle swarm optimization algorithm has been proved to be useful for the design of different types of microstrip antenna.

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