International Journal of Emerging Science and Engineering (IJESE)
ISSN: 2319–6378, Volume-1 Issue-9, July 2013

Genetic Approach in Patch Antenna Design

Shruti Vashist, M. K Soni, P. K.Singhal

Abstract—Microstrip patch antenna is one of the important elements in modern wireless communication systems and hence its design optimization is an important aspect for improving the overall performance of the system. In this paper Genetic Algorithm optimization technique has been utilized in IE3D software for optimization of the rectangular microstrip patch antenna dimensions in order to achieve better return loss, SWR and radiation properties. The patch is designed to operate in ISM band with the centre frequency at 2.4GHz and various important performance metrics of the patch antenna are analyzed for performing comparative analysis between un-optimized patch design and optimized patch design. A GUI has been designed in MATLAB for obtaining the patch dimensions based on theoretical formulas.

IndexTerms: Rotman lens Antenna, IE3D, Genetic Algorithm, MPA.

I. INTRODUCTION

The rapid advancement in the wireless communication field in the past few decades has led to the development of more efficient antenna design to be used for various cutting edge applications. Antenna is an important structure in any wireless communication system and good antenna design definitely improves the overall performance of the system. Most applications require low cost, minimal weight, low profile antennas that are capable of providing high performance over a large range of frequency. The continuous improvement in modern integrated circuit technology has made sure that the size and weight of wireless electronic system must keep on reducing. In order to work with small size electronic system, high performance antenna designs are the need of the time. All the above mentioned requirements are best met by microstrip antennas. They are easily fabricated and are also easy to integrate into arrays or into microwave printed circuits. The design of high performance microstrip antenna has always been a challenge for the antenna designers.

This is due to the fact that patch antennas have narrow impedance width and at times the requirements of a particular application can be very hard for example many applications require antennas that are capable of operating in more than one frequency band (eg. IEEE 802.11b/g in 2.4GHz band and IEEE 802.11a at 5.3GHz and 5.8GHz) [1].

Microstrip antennas have the main limitations in terms of bandwidth, poor polarization purity, limited power capacity and efficiency; all imposed by the presence of dielectric substrate. The radiating patch may be square, rectangular, triangular or any other configuration. Square microstrip antennas have a big advantage due to their polarization diversity particularly its ability to realize dual or circularly polarized radiation patterns.

Manuscript received July, 2013.

Shruti Vashist, Electronics and Commuication, Faculty of Engineering and Technology,Manav Rachna International University,Faridabad,India.

Dr.M.K.Soni, Executive Director and Dean, Faculty of Engineering and Technology,Manav Rachna International University,Faridabad,India.

Dr.Pramod Singhal, HOD,Electronics and Commuication, MITS,Gwalior, India.

In order to overcome the shortcomings of the patch antenna it is important to make an optimal antenna design for best performance. Various existing optimization algorithms can come handy in this case and genetic algorithm which is one of the global optimization algorithms has been used widely in the past by antenna designers for the optimization of the patch shape in order to achieve better overall performance of the antenna.

In this paper genetic algorithm has been used for optimization of edge fed rectangular microstrip patch antenna dimensions with inset. The paper is organized as follows: Section II presents a design approach for microstrip patch antenna, Section III gives a brief about genetic algorithm and the designed MATLAB GUI, in section IV simulation results are presented and finally in section V conclusions are drawn.

II. DESIGN APPROACH

A. Design specifications:

The rectangular microstrip antenna is made up of a rectangular patch with dimensions width (W) and length (L) over a ground plane with a substrate thickness (h) and dielectric constant (ε_r) as shown in figure1.There are numerous substrates that can be used for design of microstrip antennas and their dielectric constants are usually in the range of 2.2< ε_r <12.The steps followed in design of rectangular MSA's as given below:

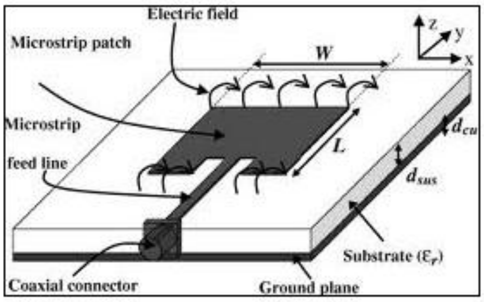

Fig 2.1 Microstrip patch antenna

The patch width (W) for efficient radiation is given as

$$W = \frac{v_o}{2\,fr}\sqrt{\frac{2}{\varepsilon_r + 1}} \text{ --------------------------------(1)}$$

Where W is patch width, v_o is speed of light, fr is the resonant frequency and ε_r is the dielectric constant of the substrate.

The effective dielectric constant (ε_{reff}): Due to the fringing and the wave propogation in the field line, an effective dielectric constant (ε_{reff}) must be obtained from equation (2).

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\sqrt{\left[1 + 12\frac{h}{W}\right]} \text{----------(2)}$$

Where ε_{reff} is the effective dielectric constant and h is the height of the substrate.

The effective length (L_{eff}) for a given resonance frequency fr is given as:

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \text{-----------------------------------(3)}$$

The length extension (ΔL) is given as-

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

The patch length (L)

$$L = L_{eff} - 2\Delta L \text{---(5)}$$

Input Impedance: Patch impedance is calculated using the formula:

$$R_{in} = \frac{1}{2\left(G_1 \pm G_{12}\right)} \text{----------------------------(7)}$$

where

$$G_{12} = \frac{1}{120\pi^2}\int_0^\pi \left[\sin\left[\frac{k_o W\cos\theta}{2}\right]\Big/\cos\theta\right]^2 J_o\left(k_o L\sin\theta\right)\sin^3\theta\, d\theta$$

$$G_1 = \frac{I_1}{120\pi^2}$$

$$I_1 = \int_0^\pi \left[\sin\left(\frac{k_o W\cos\theta}{2}\right)\Big/\cos\theta\right]^2 \sin^3\theta\, d\theta$$

$k_o = (2 * pi)/\lambda$

Inset Depth y_o: Inset depth is given by the formula-

$$Rin(y=0) = \frac{1}{2\left(G_1 \pm G_{12}\right)}\cos^2\left(\frac{\pi y_o}{L}\right) \text{----------(8)}$$

Characteristic impedance of patch: It is calculated using the formula-

$$Z_c = \frac{60}{\sqrt{\varepsilon_{reff}}}\ln\left[\frac{8h}{W_o} + \frac{W_o}{4h}\right] \quad \text{for} \quad \frac{W_o}{4h} \le 1 \text{------------(9)}$$

$$Z_c = \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{W_o}{h} + 1.393 + 0.667\ln\left(\frac{W_o}{h} + 1.44\right)\right]}$$

for $\frac{W_o}{4h} \ge 1$---------(10)

where W_O is the strip width.

Notch Width (g): It is given by the formula-

$$g = \frac{v_o}{\sqrt{2 \times \varepsilon_{reff}}} \frac{4.65 \times 10^{-12}}{f}$$

Inset Width (s): It is calculated using by the formula-
s = (2*g) + W_O

The ground plane dimensions: It has been seen that the MSA's produces good result if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around periphery

$$L_g = 6h + L \text{--(9)}$$

$$W_g = 6h + W \text{--------------------------------------(10)}$$

Where L_g and W_g are the plane ground dimensions along the patch length and width respectively.

III.GENETIC ALGORITHM

GA's are the search algorithms based on the mechanics of natural selection and natural genetics. They are stochastic search procedures modeled on the Darwinian concepts of natural selection and evolution. In GA a set or population of potential solutions is caused to evolve towards a global optimal solution. GA optimization technique is different from local optimization techniques which produce results that are highly dependent on the starting point or initial guess. GA's can handle discontinuous and non differentiable functions. They are also well suited for constrained optimization problems. Table 3.1 gives a brief about various important terms related to genetic algorithm.

Fitness function is the only connection between the physical problem being optimized and the genetic algorithm. Fitness function is used to assign a fitness value to each of the individuals in the GA population. Fitness value returned by the fitness function is in some manner proportional to the goodness of a given tried solution.

GA starts with coding the unknown variables into chromosome, randomly generating N number of solutions. The chromosomes are weighted based on their fitness function values and the inferior ones will be updated by selection, crossover and mutation operations. Optimization is terminated when stopping criteria is met.

Table 3.1

Genetic Term	Meaning
Allele	Characteristic value
Gene	It is a coded optimization parameter
Chromosome	A trial solution vector consisting of genes
Generation	Successively created populations
Child	A member of next generation
Parent	A member of next generation
Fitness	Evaluation Criteria
Reproduction	Process of producing new solution based on fitness value
Population	Set of trial solutions
Crossover	It is a process of producing new solution from crossover principle
Mutation	Change in the value within the chromosome

The block diagram of simple genetic algorithm is shown in Fig.3.1 and its use in patch antenna design is demonstrated in Fig.3.2. Fig. 3.3 shows simple diagram of Microstrip patch antenna with inset.

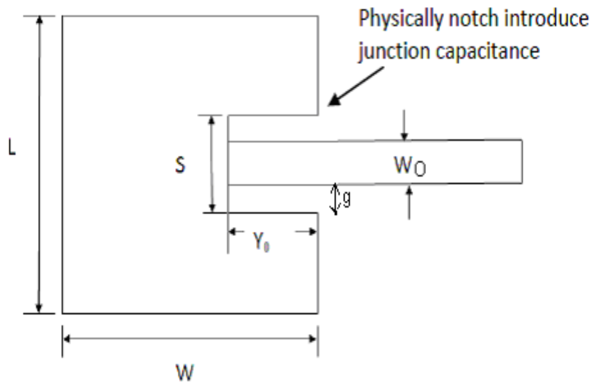

Fig. 3.3 MPA Diagram showing various design parameters

L- Patch Length
W-Patch Width
S- Inset Width
y_0- Inset Depth
g- notch width
W_0 – Strip Width

Fig. 3.4 GUI designed in MATLAB for an edge fed antenna with an inset

Fig. 3.4 shows the GUI of the patch calculator designed in MATLAB. This calculator make use of the formulas presented in section-II . The benefit of such a calculator is the reduction in time for calculating the patch dimensions for different set of inputs which otherwise has to be done manually and for large array simulations with different antenna characteristics the design time can be too long because of the huge complexity level of the calculations involved.

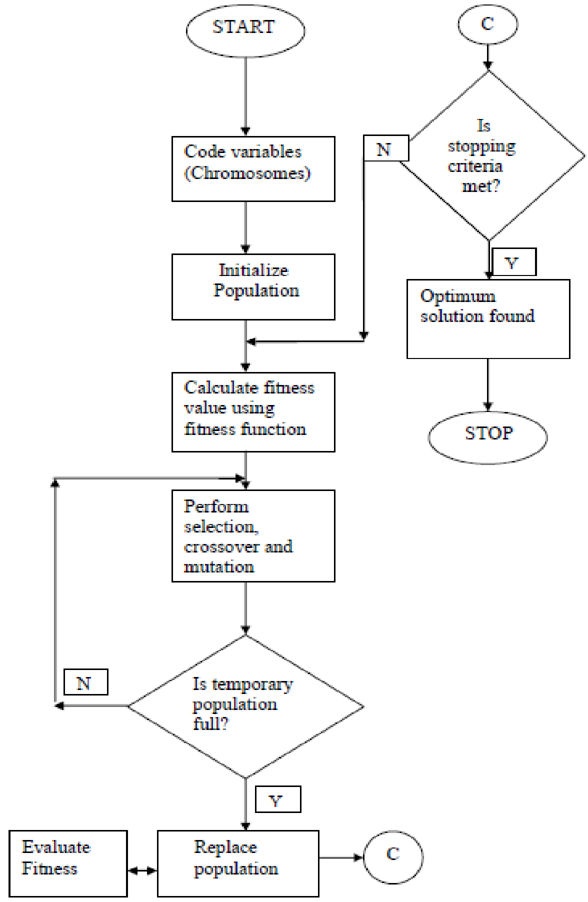

Fig. 3.1 Block diagram of simple Genetic Algorithm

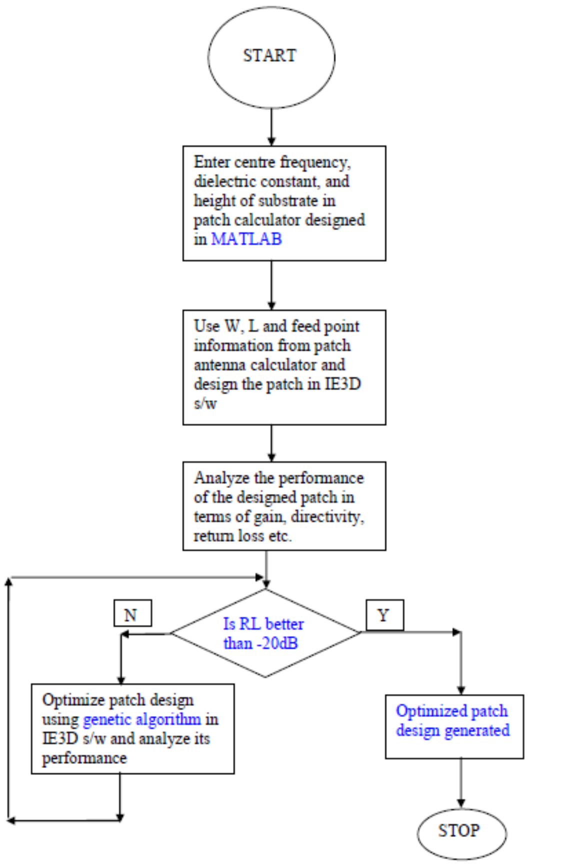

Fig.3.2 Flow chart showing use of GA in MPA design

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

IV. SIMULATION RESULTS

The specifications of the designed edge fed microstrip patch antenna with inset are as follows-
Frequency = 2.4GHz
Dielectic constant of substrate = 4.4 (FR-4)
Height of substrate = 1.6mm
Loss tangent of dielectric substrate = 0.001
Feeding = Inset feed
Polarization = Linear
Patch antenna has been designed in IE3D software and various important performance metrics are measured to analyze the performance of the designed MPA.

Fig. 4.1 shows the designed patch MPA in IE3D s/w-

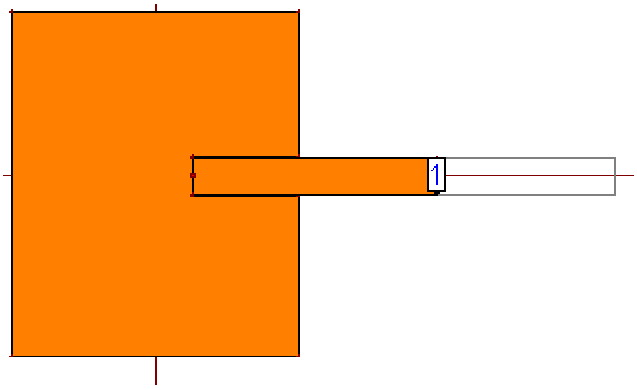

Fig.4.1 MPA in IE3D

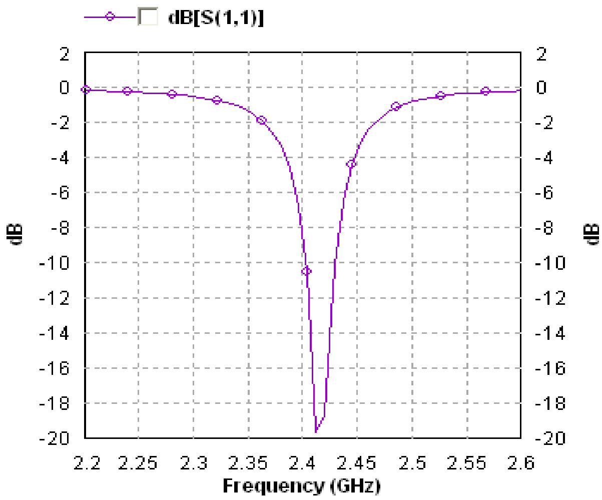

Fig.4.2 Return loss plot

Return loss: Return loss plot for the designed MPA is shown in Fig.4.2. The designed patch has centre frequency at 2.41GHz. Center frequency is the frequency at which the return loss of antenna is minimum and return loss of –19.5537 dB at 2.41GHz shows that antenna design is good but resonance frequency (center frequency) is not exactly at 2.4GHz. This in accuracy in terms of the center frequency is removed by optimizing the patch using genetic algorithm in IE3D environment. Genetic algorithm is one of the EM optimization techniques integrated with IE3D s/w. This can be utilized to reduce the efforts of manual tuning of the patch dimensions in order to achieve the desired goal. In this case the optimization goals are: Re[S(1,1)] = 0 and Im[S(1,1)] = 0 at 2.4 GHz.
Genetic Algorithm parameters are given below-

Error function limit = 0.01
Standard deviation = 0
Generations = 1000
Population size = 50
Mutation Rate = 0.15
Crossover Rate = 0.3
Random search = 0
Iterations = 50
Optimized patch exhibits return loss of -28.5206dB at exactly 2.4 GHz . Return loss plot of the optimized patch is shown in Fig. 4.3.

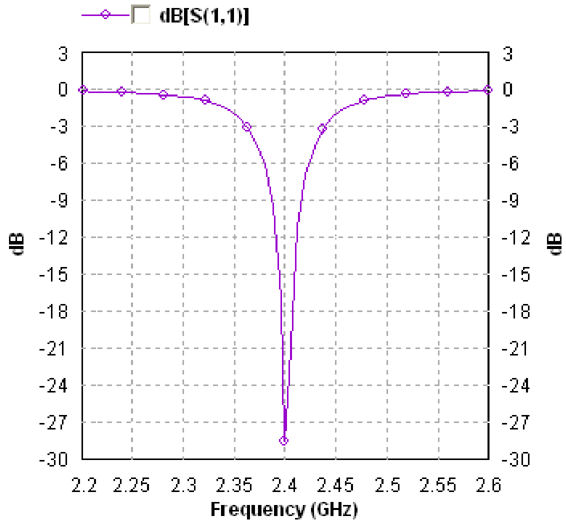

Fig.4.3 Return loss plot of the optimised MPA

VSWR: VSWR is used to describe the performance of an antenna when attached to transmission line. It is the measure of how well the antenna terminal impedance is matched to the characteristic impedance of transmission line. Ideal value of SWR is unity indicating that there is no standing wave on the line .SWR values of up to 2.0 is acceptable in patch antenna design. Bandwidth of the MPA is usually specified as the frequency range over which VSWR is less than 2. Un-optimized MPA has SWR of 2.27125 at 2.4GHz .
VSWR variation with frequency of the optimized patch antenna is shown in Fig.4.4. From this plot it is quite clear that the optimized patch has a SWR of 1.07791 at 2.4GHz.

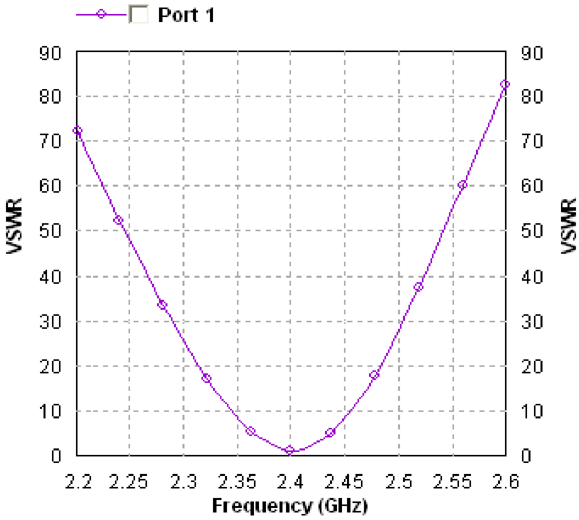

Fig.4.4 VSWR vs Freq. plot of the optimized MPA

The bandwidth of the optimised patch antenna is found to be around 25MHz which is nearly same as the bandwith of the un-optimized patch.

Input impedance plot: One of the most important requirement of a good patch design is that its input impedance should be purely real at the frequency where patch resonates. Fig.4.5 shows the input impedance variation with frequency for the optimized patch. The patch designed has the input impedance of 22.90Ω at 2.4GHz and optimized patch has input impedance of 46.54Ω at 2.4GHz, so better impedance matching is achieved in the optimized patch.

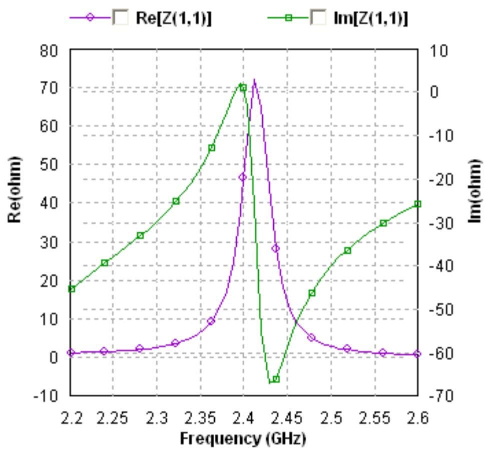

Fig.4.5 Input impedance variation with frequency

Gain: It is one of the most important parameter of a patch antenna .It is the ratio of radiation intensity in a given direction to the radiation intensity that would be obtained if the antenna radiates all the power in all the directions. Gain of an antenna is expressed in dB but when gain is referenced to the isotropic radiator the units are expressed as dBi. Fig 4.6 shows the three dimensional radiation pattern of the optimized MPA in which the maximum gain achieved is 5.65934dBi at 2.4GHz which is 7.48 % more as compared to the un-optimized MPA. 3dB beam width of the optimised patch is (79.5957,160.643) degrees.

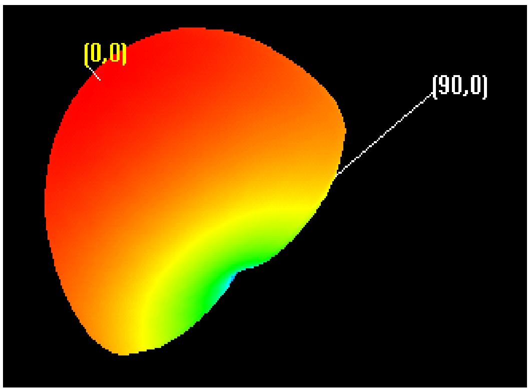

Fig.4.6 3-D radiation pattern plot

From the 3-D radiation pattern it can also be seen that no side lobes and back lobes exists.

2-D Radiation pattern plot (polar plot): Polar plot for $\Phi=0^{o}$ at 2.4GHz for the optimized patch is shown in Fig.4.7. From this plot it can be concluded that patch antenna radiates normal to the surface and maximum energy is radiated away from the users head which guarantees that an acceptable level for specific absorption rate by the users head can be maintained .

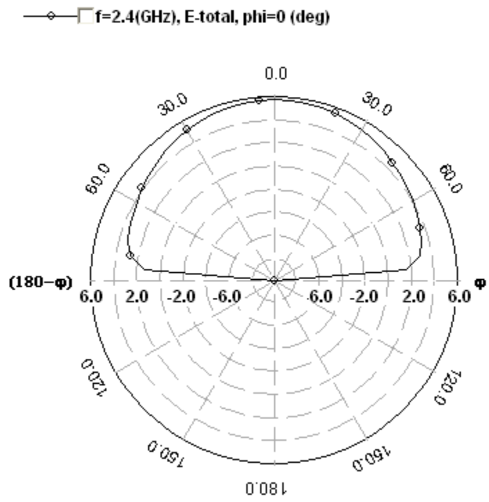

Fig.4.7 Polar plot at 2.4GHz

Smith chart Display: Fig. 4.8 shows the smith chart display for the optimized MPA. Smith chart is useful for finding the input impedance of the antenna. Impedance of around 46.54 ohm is obtained at 2.4GHz.

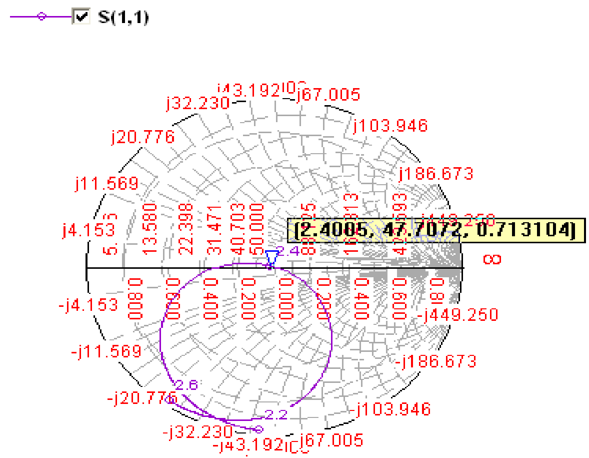

Fig.4.8 Smith chart display

The comarision between un-optimized and optimised MPA is shown in table 4.1

Table 4.1 Comparative Analysis

Parameter	Un-optimized Results	Optimized Results
Length (mm)	29.4424	29.6
Width (mm)	38.0363	39.775
Inset Depth (mm)	10.8319	10.875
Return Loss (dB)	-19.5537	-28.5206
VSWR	2.27125	1.07791
Impedance (ohm)	22.90	46.54

From the above table it can be seen that the performance of the optimized patch is better than the un-optimized patch in terms of return loss, VSWR and Input impedance.

V. CONCLUSION

From the simulation results of IE3D s/w presented in section IV it can be concluded that Microstrip patch antenna design optimization is very important aspect for achieving desired performance goals.

The optimized patch antenna using Genetic Algorithm exhibits better return loss and radiation properties as compared to the un-optimized patch designed using theoretical formulas. The optimized patch exhibits 7.48% more gain and 8.96dB better return loss as compared to unoptimized patch antenna design. A lot of research in this field has been done by employing patch of different shapes or by introducing some kind of slot in the patch for obtaining desired goals. Future research work should aim at utilizing Genetic Algorithm optimization technique to further improve the performance of the patch antenna and its array of different shapes and configurations.

ACKNOWLEDGEMENT

Authors would like to thank Mr.Umesh Dutta, Faculty FET, MRIU for his help and support.

REFERENCES

1. Balanis, C.A. (1997). "Antenna Theory: Analysis and Design." 2nd ed.New York: John Wiley and Sons, Inc.
2. Muhammad Mahfuzul Alam, Md. Musta zur Rahman Sonchoy and Md. Osman Goni," Design and Performance Analysis of Microstrip Array Antenna", Progress In Electromagnetics Research Symposium Proceedings, Moscow, Russia, August 18-21, 2009.
3. Yahya S. H. Khraisat,Al-Balqa**,"** Design of 4 Elements Rectangular Microstrip Patch Antenna with High Gain for 2.4 GHz Applications," Modern Applied Science Vol. 6, No. 1; January 2012.
4. Md. Maruf Ahamed, Kishore Bhowmik, Md. Shahidulla,Md. Shihabul Islam, Md. Abdur Rahman,"Rectangular Microstrip Patch Antenna at 2GHZ on different dielectric Constant for Pervasive Wireless Communication" International Journal of Electrical and Computer Engineering (IJECE),Vol.2, No.3, June 2012, pp. 417 ~ 424,ISSN: 2088-8708 _ 417.
5. Fouzi Harrou, Benamar Bouyeddou, Abdelwahab Tassadit and Djamal Ameziane," Design of Linear and Planar Microstrip Antennas Array", International Journal of Information Systems and Telecommunication Engineering (Vol.1-2010/ pp. 4-11).
6. Md. Tanvir Ishtaique-ul Huque1, Md. Kamal Hosain, Md. Shihabul Islam, and Md. Al-Amin Chowdhury," Design and Performance Analysis of Microstrip Array Antennas with Optimum Parameters for X-band Applications",(IJACSA) International Journal of Advanced Computer Science and Applications,Vol. 2,No. 4, 2011.
7. Marek Bugaj, Rafal Przesmycki, Leszek Nowosielski,Kazimierz Piwowarczyk, and Marian Wnuk," Multilayer Microstrip Antennas Array Operating in Dual Bands, "Progress In Electromagnetics Research Symposium Proceedings, Moscow, Russia, August 19{23, 2012 1429.
8. K.Meena and A.P.Kabilan," Modeling and simulation of Microstrip patch array for smart antennas,"International Journal of Engineering, IJE volume (3), Issue (6).
9. Anitha.V.R, Dr. S. Narayana Reddy and P.Srinivasulu," Design and Analysis of 1X16 Square microstrip linear array for wind profiling radar," Journal of Theoretical and Applied Information Technology.