

# A Review on Optimization of Micro strip Patch Antenna

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**ABSTRACT:** Patch antenna is widely used antenna type in many applications. These are cheap, low profile, light weight, small size, compatible with monolithic microwave integrated circuit (MMIC) designs. In this study the bandwidth and gain of the antenna are optimized by making change in the parameters like inset cut length, inset cut width, substrate thickness, dielectric constant, strip width, feed line length, z Top surface, meshing frequency.

**KEYWORDS:** Micro strip patch antenna, bandwidth, gain, optimization, z-parameter, s-parameter

## I. INTRODUCTION

Wireless communication system has acquired a leading place in the industry due to its tremendous growth of wireless technologies such as 3G, 4G, 5G, voice and internet services, in last couple of years [1], [2]. However, it is a challenging task to provide enough capacity and high data rate wireless services with a limited spectrum resource while maintaining the quality of services. Due to recent advancement in the industries, it is possible to design compact, low cost and compatible antennas. Micro strip patch antenna is one of key solutions due to its attractive features like inexpensiveness, light weight, planar structure and ease of fabrication which allows to combat the current requirements [1], [2]. A micro strip antenna includes a radiating patch placed on a dielectric substrate with a ground plane on other side of the substrate. This radiating patch can be of different shapes such as circular, square, rectangular and annular. Though, patch antennas provide several advantages such as ease of fabrication, low profile, planar structure, integrable with microwave circuits and high frequency operability, these antennas suffer from some disadvantages such as low gain and efficiency, huge loss, surface wave excitation, narrow bandwidth [1], [2]. Different design parameters play an important role in determining gain, directivity and the bandwidth of the antennas. Therefore, adjusting and optimizing design parameters such as substrate thickness, substrate type, stacking patches, matching networks, topology and material of substrates, meshing patches, slots and shorting pins, different shapes and structures, can provide improved performance and structure [10]. In this paper, some of existing techniques based on optimization of different design parameters of micro strip antenna are reviewed.

## II. LITERATURE REVIEW

M. J. Rathod [3] and G. Breed [4] proposed the increased thickness of the parallel plate transmission line using high dielectric constant substrate, high inductance of transmission line by cutting holes or slots for increasing the bandwidth of the antenna. Different slots shapes such as S, L, E, U, C, have been tested for evaluating the increment in the bandwidth of the antenna. In [5], multiple slots are utilized for the enhancement of patch antenna apart from the substrate thickness, dielectric constant and the type of feeding. In [6], K. Song et al. proposed a corner-truncated scheme for bandwidth increment over a wide frequency range. In this scheme, two corners of the rectangular patch are truncated to enhance the impedance bandwidth. In [7], N. Ripin et al. developed a rectangular microstrip patch antenna with Electromagnetic Band Gap structure which avoids the propagation of surface wave excited by the rectangular patch antenna. In [8], J. S. Kuo et al. proposed to use of three triangular slots in the ground below the equilateral-triangular radiating patch for enhancing the antenna gain. In [9], a rectangular and fractal U shape is proposed for the improvement

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of gain and bandwidth of the antenna. In addition, gain and bandwidth of the antenna are optimized based on genetic algorithm. In [11], an optimization technique based on particle swarm optimization and curve fitting was introduced for an inverted E-shaped microstrip patch antenna. The relationship among various parameters of a microstrip antenna is shown based on curve fitting data obtained from Zeeland IE3D software. The method demonstrated a significant improvement of 15% in the bandwidth as compared to conventional microstrip antenna. In [12], a comparative study was performed based on different optimization techniques including differential evolution (DE), particle swarm optimization (PSO) and bacterial foraging optimization (BFO) for optimization of rectangular microstrip patch antenna with inset feed parameter. A minimization objective problem based on impedance function was solved using aforementioned three optimization algorithms. It was shown that DE optimization algorithm outperforms in terms of number of iteration and performance as compared to that of PSO and BFO based optimization algorithms. In [13], a detailed discussion was performed conventional antennas and various type of micro strip antennas including, micro strip patch antennas, printed slot antennas, micro strip dipoles and micro strip travelling wave antennas. Furthermore, different applications such as mobile and satellite communication, radio frequency identification, interoperability, global positioning system, radar, body area network were discussed based on different characteristics such as profile, fabrication, dual-frequency operation, shape flexibility, spurious radiation and bandwidth of micro strip patch antenna, polarization, micro strip slot antenna and printed dipole antenna. In [14], a micro-strip patch antenna for the frequency of 2.4 GHz was developed based on edge feeding technique. The antenna achieved the gain of 12 dB and broader beam width of 400 and 260 in the E- and H-plane respectively. In [15], an U-shaped planer antenna was proposed by varying the substrate material and thickness. Results demonstrated improvement in the bandwidth, the number of bands and efficiency. In [16], a micro strip antenna was designed for the enhancement of antenna gain using a hybrid substrate. A constructive interference was introduced inside the substrate due to ferrite rings. The method showed an improvement of 4 dB gain and 1% bandwidth. In [17], different parameters such as directivity, gain are analyzed of single patch, 2 × 1 patch, 4 × 1 patch array antenna. Authors suggested that the array antennas can play an important role in satellite communication and RADAR due to their high gain and directivity. In [18], the use of U slot metallic rings was demonstrated for the enhancement of gain of micro strip antenna. These rings were kept at  $l=4$  of free space wavelength from the patch edges with the patch width as 3 times of  $l=16$  of the free space wavelength. Results demonstrated an improvement of gain by 4.3 dB and bandwidth by 2%. In [19], a patch antenna with enhanced gain, bandwidth and directivity has been developed by using micromachining technique for RFID applications. For compacting the antenna, dielectric constant of 11.9 is taken. Performance of the antenna has been collated while using single dielectric layers, after that they used two dielectric layers of substrate (silicon/air) and then expanded the substrate layers to three (silicon/air/silicon). Finally, it was concluded that better results in terms of bandwidth, gain and directivity can be achieved using multilayer substrate. In [20], a micro-strip patch antenna was designed and analyzed with different feeding methods that are series, corporate and series-corporate feeding. HFSS tool was used to perform simulations and compared with 2, 4, 16 and 8 element patch arrays. It was concluded that micro strip antenna is best for long distance communication. It is analyzed that to get the desired performance, 16 × 1 patch antenna with corporate feed method is good. At 10.6 GHz, return loss of -15.28 dB and directivity of 15.3 dB were attained. Antenna with directivity of 11 degrees is suitable for directive patch antenna. This antenna can be used for Wi-Max, WLAN applications by changing the dimensions. In [21], authors collated different shaped micro-strip antennas on the basis of efficiency, gain, directivity and other parameters having defected ground structure. Fifteen different shaped micro-strip patch antennas (i.e., E shaped, F shaped, inverted F shaped, G shaped, H shaped, I shaped, L shaped, inverted L shaped, S shaped, T shaped, inverted T shaped, U shaped, inverted U shaped, W shaped, inverted W shaped) were used for building a total efficiency comparison of antennas on the basis of surface wave concept. It was concluded that antennas having total efficiency of -2.546 dB is most efficient H shaped micro-strip patch antenna. In [22], an E-shaped micro strip patch antenna was designed. Gain and bandwidth of the proposed antenna were compared with rectangular micro strip patch antennas. Using HFSS, simulation was performed and concluded that for E-shaped patch antenna the gain is enhanced to 5.52 dB and bandwidth is enhanced to 440 MHz while in rectangular antenna the bandwidth and gain were observed as 50 MHz and 2.65 dB respectively. It was deduced that E-shaped antenna models a good return loss of -34.28 dB in contrast to the rectangular patch antenna. In [23], an enhancement of bandwidth from 12% to 182% was achieved through various techniques; 24% increase can be achieved by Impedance matching techniques; 58% increase is attained by the modification of patch geometry; DGS technique allocates 84% and 182% bandwidth furnished by metamaterial

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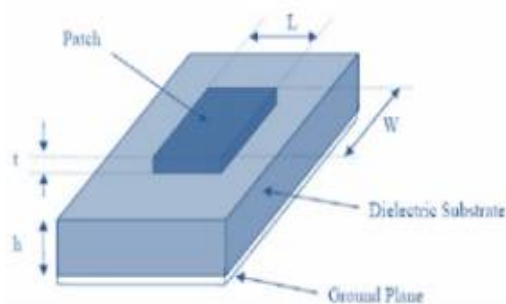
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resonators. Reconfigurable antennas have also been discussed. Antennas with two patches were designed which has C type cuts with operating modes like two dual bands and one wideband. Bandwidth of dual-band was kept 2-5% while bandwidth of wideband was kept 33%. Another design proposed in the paper represents compact UWB micro strip antenna with built-in capability of discarding tri-band frequency notches. In Srisuji, an analysis of different types of micro-strip antennas such as dual frequency micro-strip patch antenna, star shaped antenna, E shaped antenna, Octagonal shaped patch antenna, was presented for different band off frequencies which can be used in different applications such as, Wireless Local Area Network, Military, Radar, Wi-Fi, Wimax, GPS etc. Results demonstrated that octagonal antennas outperform in wider bandwidth over the range of 2.5-18GHz and in radiation pattern as compared to different shaped antennas. In, [25], authors proposed a U-slot patch structure to obtain a structure with wideband behavior.

### III. MICROSTRIP PATCH ANTENNA

A **micro strip antenna** is a type of antenna made by using micro strip techniques on a PCB (printed circuit board). A simple micro strip patch antenna consists of a metallic patch and ground in between of them is dielectric medium called the substrate. This substrate has a particular value of dielectric constant. The dimensions of a patch are smaller as compared to the substrate and ground. Dimensions of a micro strip patch antenna depend on the resonant frequency and value of dielectric constant [26]. The idea of MPA (micro strip patch antenna) arose from applications of printed circuits technology where it was not only used for circuitry component connections, transmission lines but also for radiating elements in electronics. Micro strip patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. They are very widely used in mobile phone markets and are low cost, and can be easily fabricated.

Micro strip patch antennas are used for communication purposes especially in military and civil applications.



The figure mentioned above is an example of a rectangular patch antenna. MPA are generally available in many shapes including circular, square, etc. We will now study the designing equations of these micro strip patch antennas.

### IV. DESIGNING EQUATION

For designing a patch antenna we derive the equations for all the dimensions of the patch and select the values for resonant frequency and a dielectric medium for that particular antenna type.

Here, essential parameters for design are generally considered as:

- $f_0 = 2.4 \text{ GHz}$
- $\epsilon_r = 2.45$
- $h = 1.58 \text{ mm}$

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Following equations are considered for designing a patch antenna

1. **Width (W):**

$$W = \frac{c}{2f_0 \sqrt{\frac{(\epsilon_r + 1)}{2}}}$$

where,

**W= Width of the patch**

**C= Speed of light**

**$\epsilon_r$ = value of the dielectric substrate**

2. **Effective Length ( $L_{eff}$ ):**

$$L_{eff} = \frac{c}{2f_0 \sqrt{\epsilon_{reff}}}$$

3. **Extended length (L):**

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

4. **Actual length (L):**

$$L = L_{eff} - 2\Delta L$$

## V. EM OPTIMIZATION

### OPTIMIZATION OF MICROSTRIP PATCH ANTENNA:

Optimization technique is generally used in designing antennas. Optimization is widely used in almost all the antennas as it gives effective output of simulated output, it generates specific range or precise values for the parameters and graphs obtained are sharp and more precise. It can help designers to achieve their goal with much less effort. Some goals may even be impossible by manual tuning. But EM optimization may yield excellent results for you.

For simulation and optimization process of patch antennas we use IE3D software which is a full wave EM simulator and optimizer in which integral equations are solved using the frequency-domain method. IE3D has several built-in optimization methods that include Powell optimizer, genetic optimizer, random optimizer, and an adaptive optimizer. The variables for optimization defined by IE3D are controlled by their directions and bounds.[27]

Assume we want to optimize the antenna to a perfect match at 1.88 GHz. EM optimization is one of the most important features of IE3D. One of the most important applications of the IE3D is for antenna design. In this part we will study how we can use IE3D for simulation and optimization of MPA.

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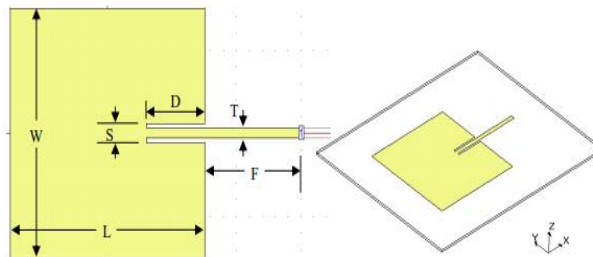
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## SIMULATION:

Before initiating the simulation process, we design a simple patch antenna by setting standard values of all the parameters.



Parameter	Value
Substrate Thickness	31Mils
Patch Length	1512 mils
In set width, S	112 mils
Strip Width, T	60 Mils
Di electric constant	4.4
Patch Width, W	1500 Mils
In set depth, D	452 Mils
Feed line length, F	750 Mils

Table :1 Simulation parameters

The whole process is executed in MGRID in IE3D and values are entered for the respective parameters. After designing a patch, an inset and a feed line is created. The values for the following are shown in the above table. Next we define a port, by selecting Port for Edge Group in the advanced Extension and save the structure for further simulation process. Further we modify some parameters to reduce the width and set AEC Layers = 1 by changing the AEC ratio to 0.05. Now as we have set all the parameters correctly the structure is ready for simulation. Here the standard resonant frequency entered is 1.88 GHz But we simulate the structure from 1.7 to 2 GHz with 151 frequency points. Thus our simulation process is progressed

## VI.OPTIMIZATION

After obtaining desired simulated results next step is to optimize those results. Before we start optimization, we should first consider the following. For the antenna we are discussing, we can adjust the length L to change the resonant frequency. We can adjust the inset depth D to tune matching. Hence we set our starting resonating frequency as 1.88 GHz now we can optimize one dimension at a time and it would make optimization much easier.

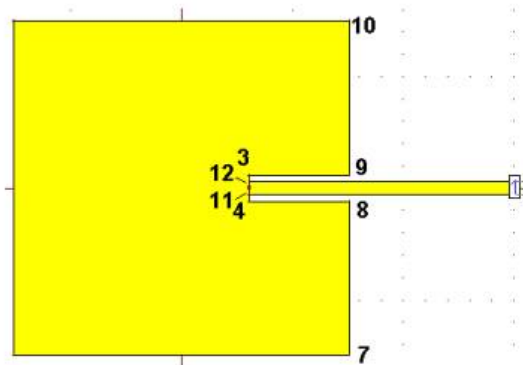
Previously we changed values of certain parameters hence it changes our structure. To change the shape of a structure, we need to change the locations of vertices. We need to identify which vertices we should adjust to change the L and D values. Therefore to change the patch length L, we can change the X-coordinate of Vertex Group 1. To change the inset depth D, we can change the X-coordinate of Vertex Group 2. As shown in the fig below

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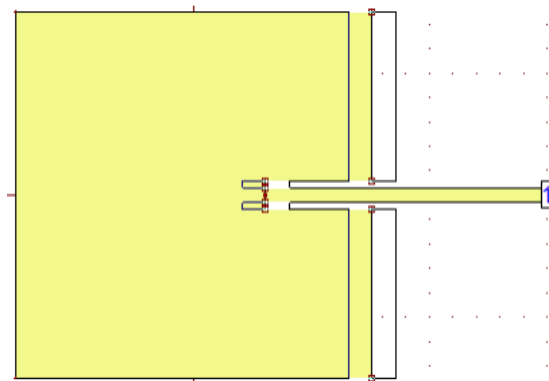
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We select vertices of the structure and enter some standard for further analysis by setting the tuning Angle = 0. Low Bound = -100, high bound=100



This process is repeated but the parameter's values are changed to Low Bound as -200 and High Bound as 200. The structure is saved. Now the structure is ready for optimization. For optimization we select the optimize command in MGRID. The Optimization Setup dialog comes up same as the Simulation dialog box except some minor change. The frequency is changed to 1.88 GHz by defining Re(S), 1st Parameter = (1, 1); and 2nd parameter Im[S(1,1)];

The saved structure is opened again by setting the frequencies in Frequency Parameters dialog where the Start Freq = 1.7, End Freq = 2.0, Number of Freq = 151. The optimization process is done. Now we define graphs for following parameters and display S-Parameter, Z-parameters, VSWR(dB)

These graphs will display all the optimized results for the required parameters and you can differentiate on observing the simulated and optimized graphs.



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## VII. RESULTS

### S-Parameters

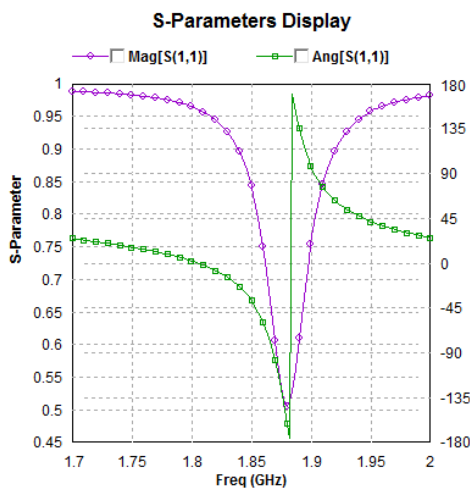


Figure 1. S -Parameter before optimization

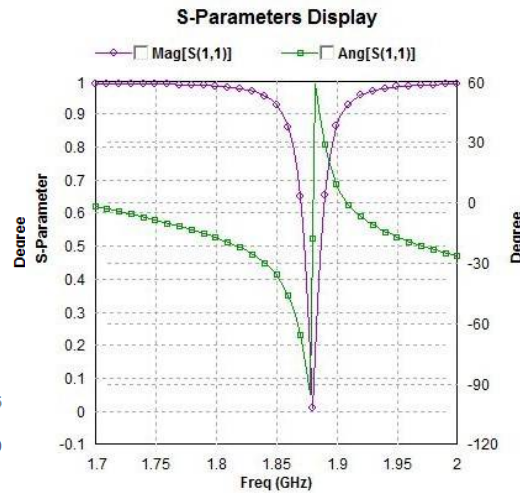


Figure 1.1 S-Parameter after optimization

### Z- Parameters

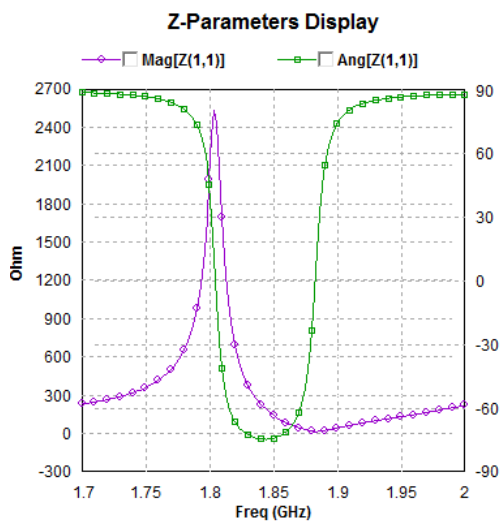


Figure 2. Z-parameter before optimization

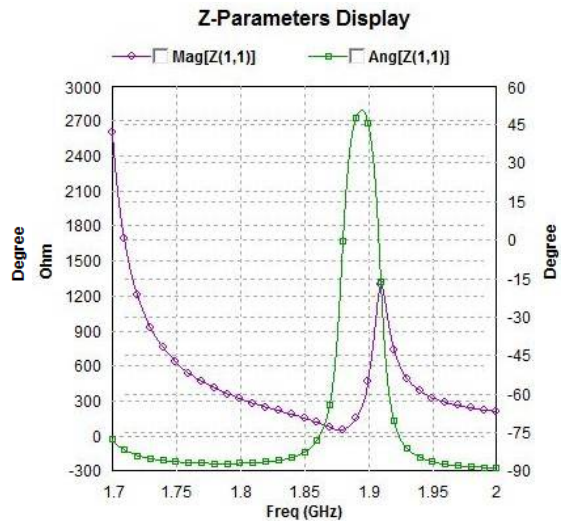


Figure 2.1 Z-parameter after optimization

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## VSWR Graph

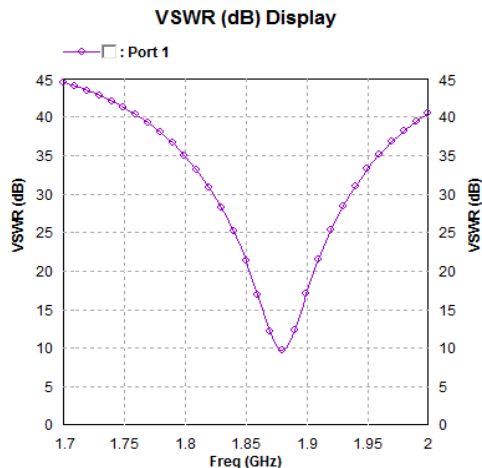


Figure 3. VSWR (dB) before optimization

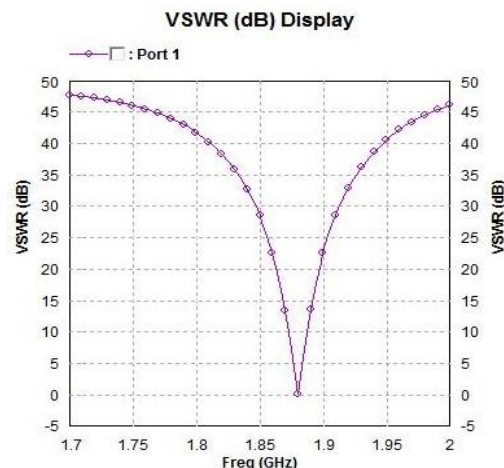


Figure 3.1 VSWR (dB) after optimization

## VIII. CONCLUSION

From this work various curves of S, Z, and VSWR are obtained. From the curve of S-parameters,  $S_{11}$  represents how much power is reflected from the antenna, and hence is known as the reflection coefficient. For a frequency greater than 1.85 GHz the magnitude of  $S_{11}$  is 0.5 and at a frequency less than 1.8 GHz, the antenna will radiate nothing.

From the impedance curve shown in fig. 2.1 it is observed that at a frequency greater than 1.9 GHz, the impedance offered by the antenna is 1.2 Kilo Ohms and the return loss is zero at the resonance frequency as shown in fig 3.1

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