



## FINDING THE BEST FEEDING POINT LOCATION OF PATCH ANTENNA USING HFSS

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### ABSTRACT

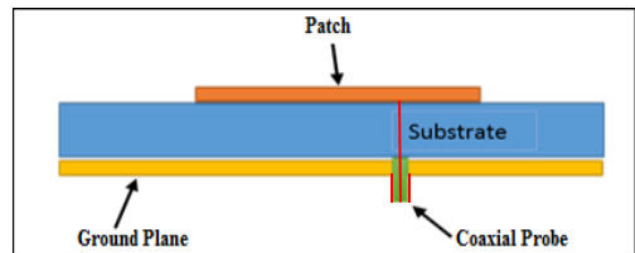
This paper describes about the finding of an optimal location of feeding location for patch antenna by using Ansoft HFSS software. The dimensions of patch antenna were calculated based on the three essential parameters. The operation frequency of patch antenna was designed at 2.4 GHz. The  $\text{LaAlO}_3$  was chosen as a substrate material for the designed patch antenna with a dielectric constant of 23.5, and a height of 1.5 mm. The materials were chosen as a perfect conductor for patch and ground plane with a cut off area from a substrate block. The centre of the patch as well as substrate is located at the origin coordinates of x-y plane, and the height of substrate at z-direction. The objective of this paper is to find the best feed point location, which achieves the highest performance for the designed antenna. The best feed point is located at  $(X_m, Y_n)$  from the origin. The simulation was done for all feed point locations. The return loss was calculated, and it has the highest value of return loss at a constant y-axis point along the length of patch antenna. The results demonstrated that the use of such a design will achieve high directivity, gain, efficiency, and performance.

**Keywords:** HFSS, feed point location, microstrip patch antenna, simulation, return loss.

### INTRODUCTION

Microstrip patch antennas are useful for wireless communication, especially in the applications for Wi-Fi. The antenna enable devices such as, personal laptop, mobile phone, multimedia player or GPS to connect or access Internet, within the range given by high performing radiating antenna. The antenna covers the large area up to square kilometers or less than [1, 2]. The antennas are commonly used in wireless communication due to their high performance, low cost, light weight, small size, suitable shape, and easy to fabricate [3, 12]. The designing of patch antennas via using different software's has become most popular in recent years. This may be due to their useful dealings with much parameter, which extremely plays an important role in designing high performance antenna. This paper highlights the designing of a rectangular microstrip patch antenna which depends on the three fundamental parameters, that is, the operation frequency, thickness of the substrate, and the dielectric constant of substrate [4]. The aim for this work is to display the best feed point location that has a high return loss. The return loss is losses in power input that is reflected back, and can be calculated from the difference in dB between the feeding and reflected power [5]. The HFSS-13.0 Software (high frequency structural simulator), which is a commercial tool is used for design and simulation [11, 6]. The methods of feeding the RF power directly to the patch antenna is to make it radiate by using a microstrip line feed and a coaxial probe feed. The feeding direct techniques were illustrated by Mandal [6]. The rectangular patch antenna radiates by utilization of a coaxial feeding probe technique, which is an extremely common [4, 7]. The coaxial probe is an inner conductor that is passed through out a substrate, and it is connected to an antenna to make it radiating. The feed probe technique is used for feeding the patch antenna as shown in Figure-1. The coaxial probe feed technique consists of

central probe conductor, which operates as directly connected with patch antenna, which provides its feeding power. The coax represents the outer connector around the probe, and it is connected with the ground plane by which the circuit become complete [8].



**Figure-1.** A schematic diagram of microstrip patch antenna.

### PATCH ANTENNA DESIGN PROCEDURE

The antenna was designed by using  $\text{LaAlO}_3$  as a substrate material with dielectric constant 23.5 [9], thickness 1.5 mm, and based on a ground plane as shown in Figure-1. The operating frequency is 2.4 GHz, which represents the aim for this design. The dimensions of the patch, substrate, and ground plane were calculated based on explanation in [1, 2]. To calculate dimensions of patch antenna, the equation (1) to (5) was calculated via MatLab software.

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

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



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$$L_{eff} = \frac{c}{2f_o \sqrt{\epsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3)(\frac{w}{h} + 0.264)}{(\epsilon_{eff} - 0.258)(\frac{w}{h} + 0.8)} \quad (4)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} [1 + 12 \frac{h}{w}]^{-\frac{1}{2}} \quad (5)$$

Where,

W = width of the patch antenna

L = length of the patch antenna

$f_o$  = resonance frequency

c = speed of light

$\epsilon_r$  = dielectric constant of the substrate

$L_{eff}$  = effective length

$\Delta L$  = length extension

h = thickness of the substrate

$\epsilon_{eff}$  = effective dielectric constant of the substrate

## GROUND DIMENSIONS

For practical considerations, all patch antenna design must have a finite ground plane, with a conducting type of material. The ground plane has similar dimension of the substrate but they are greater than the patch antenna dimensions by six times of the substrate thickness all around of the periphery as illustrated in Figure-2. As a result, the dimensions for the substrate and ground plane would be given in Equations (6) and (7) [1, 2].

$$L_g = 6h + L \quad (6)$$

$$W_g = 6h + W \quad (7)$$

Where L and W are the length and width of patch antenna respectively while  $L_g$  and  $W_g$  are length and width of ground plane respectively. The dimensions for patch and ground plane has been calculated via MatLab software. The results are listed in the following Table-1, which are used in HFSS software to design the antenna [5].

**Table-1.** Dimensions for patch antenna and ground plane.

Patch antenna	W	17.7 mm
	L	11.7 mm
Ground plane	$W_g$	26.7 mm
	$L_g$	20.7 mm

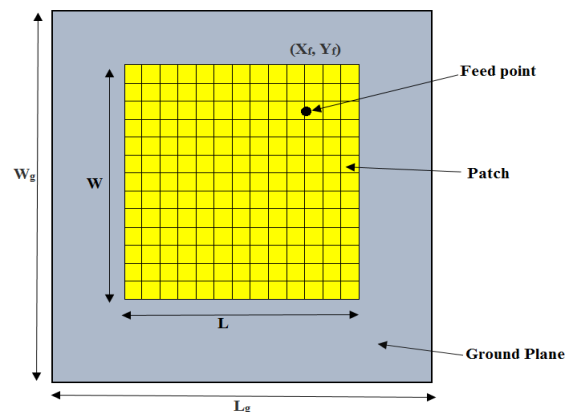
## THE FEED POINT LOCATION

The feeding probe point location can be located at the point (Xf, Yf) in the x-y coordinates, as shown in Figure-2. The location points are given by Equations (8) and (9). They had achieved low input impedance or good matches between the transmission line and the port [12].

$$X_f = \frac{L}{2\sqrt{\epsilon_{eff}}} \quad (8)$$

$$Y_f = \frac{W}{2} \quad (9)$$

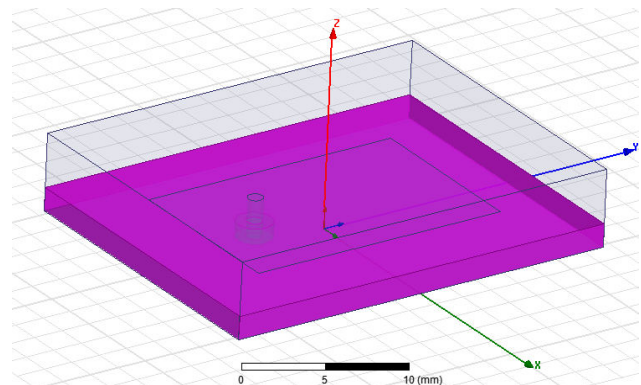
Where  $X_f$  and  $Y_f$  are the desired input feed point at x-axis and y-axis respectively. The use of MatLab software resulted as  $X_f = 2.4$  mm, and  $Y_f = 8.9$  mm, which were neglected because they represent the position at the edge of patch antenna, and it was more suitable for feeding by microstrip feed line [2].



**Figure-2.** A schematic diagram of patch antenna with 169 feed points of coaxial feeding probe.

## ANALYSIS AND SIMULATION

The HFSS software has been used to create and simulate the design of patch antenna for the desired frequency using the feeding coaxial probe technique, which has been considered as a better feeding technique in comparison with microstrip feeding line technique [6]. The patch antenna is designed to be located at origin coordinates x-y plane while the height of the substrate lies in z-direction. The analysis and simulation step has been done for all the feeding location points' x-y plane. The image of the patch antenna is taken from the software as shown in Figure-3.



**Figure-3.** The image of patch antenna from the HFSS software.



The adaptive solutions in the HFSS software solution step are selected with the parameters shown in Table-2.

**Table-2.** Adaptive solution.

maximum number of pass	15
maximum Delta	0.01
sweep type	fast

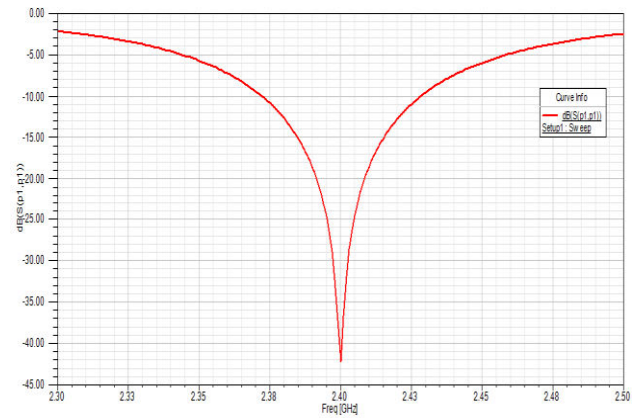
The frequency setup was set as linear which the start and stop frequency were set at 2.3 GHz and 2.5 GHz respectively with step size 0.001 GHz. The feed probe that was designed to feed the patch antenna are described in Table-3. To enhance and control all the feeding points' location, the feeding point location inside the area of patch antenna were organized. A square area of 169 points, where (13×13 mm<sup>2</sup>) has been analysed and simulated, refer to Table-4.

**Table-3.** Feed probe coaxial dimensions.

The designed part	Radius(mm)	The high(mm)
Probe	0.5	1.5
Coax	1.2	1
Coax-pin	0.5	1
Cut-out	1.2	0
port	1.2	0

**RESULTS AND DISCUSSION**

Return loss is the amount of efficiency power transferred between the feeding lines and antenna. The return loss is selected with the desired frequency which equals to 2.4 GHz. The centre of the patch was taken at the origin. The feed point location is given by the coordinates (x, y) from the origin. The feeding point must be located at that point on the patch, which includes the specific chosen area as shown in Figure-2. The return loss and frequency for all feeding point location has been analyzed and plotted with the HFSS software. Table-4 shows the results for all feeding points. The feed points were taken by choosing the constant value of y-points with variable values of x-points for the positive and negative sides. The feed point (-3,-3), shows the highest return loss. The return loss represents how much feeding power that was reflected back at the port of patch antenna as a result of the mismatches between the transmission line and the feeding points. Hence, the high return loss represents the measure of good matches that is shown in Figure-4.



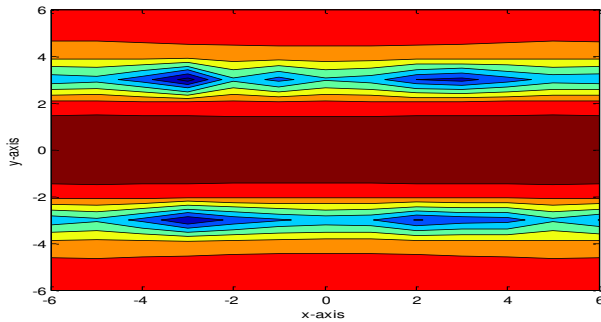
**Figure-4.** Return loss vs. frequency for the feed point (-3,-3), shows high result at 2.4 GHz frequency.

The return loss at 2.4 GHz frequency for the patch antenna has been found around from -12 dB at the line Y= ± 4 to -28 dB at the line Y= ± 3 along the X-axis, as so tabulated in Table-4, which are basically an acceptable value and a very good work antenna [13]. The return loss was plotted with (x, y) location points to get the surface plot and contour plot by using the MATLAB Software as in figure-5 and 6. The resultant high return loss are nearly between -42 dB and -35 dB for the fourth point feed location. These results are better than that obtained by Mandal *et al*[11], which had a return loss -36.2 dB at 2.35 GHz frequency.

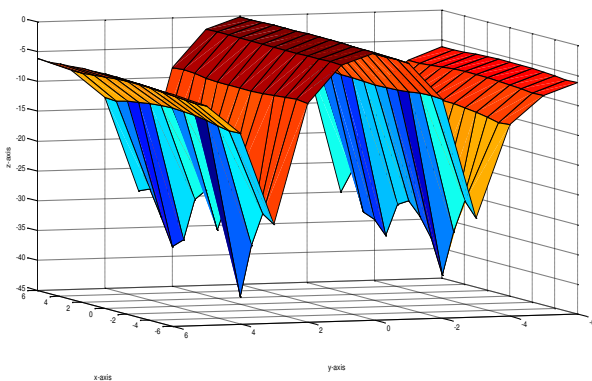
**Table-4.** Return loss (dB) of 169 feeding point locations over the patch antenna area 13×13 mm<sup>2</sup>.

		The X-axis												
		-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
The Y-axis	6	-6.175	-6.231	-6.093	-5.945	-5.831	-5.770	-5.745	-5.768	-5.840	-5.939	-6.088	-6.223	-6.174
	5	-8.218	-8.334	-8.095	-7.934	-7.767	-7.667	-7.626	-7.658	-7.753	-7.908	-8.115	-8.322	-8.244
	4	-12.960	-13.129	-12.671	-12.314	-12.075	-11.845	-11.816	-11.864	-12.025	-12.336	-12.776	-13.216	-12.884
	3	-28.370	-26.039	-31.642	-33.429	-33.753	-30.565	-28.528	-29.585	-35.335	-33.093	-32.381	-25.974	-30.022
	2	-8.312	-8.175	-8.306	-8.627	-8.763	-8.842	-8.889	-8.848	-8.740	-8.627	-8.398	-8.123	-8.344
	1	-2.150	-1.977	-2.056	-2.095	-2.064	-2.081	-2.119	-2.096	-2.071	-2.055	-2.076	-2.021	-2.141
	0	-0.222	-0.169	-0.126	-0.090	-0.061	-0.042	-0.035	-0.041	-0.060	-0.090	-0.126	-0.169	-0.223
	-1	-2.116	-2.029	-2.077	-2.013	-2.098	-2.083	-2.084	-2.119	-2.072	-2.073	-2.048	-1.978	-2.131
	-2	-8.345	-8.154	-8.374	-8.556	-8.742	-8.778	-8.754	-8.716	-8.737	-8.574	-8.322	-8.182	-8.353
	-3	-28.486	-27.180	-32.917	-32.104	-25.920	-31.901	-25.768	-27.796	-35.053	-35.628	-32.316	-28.02	-28.838
	-4	-12.999	-13.087	-12.750	-12.309	-12.058	-11.882	-11.728	-11.872	-12.049	-12.31	-12.661	-13.167	-12.976
	-5	-8.258	-8.342	-8.112	-7.899	-7.757	-7.661	-7.640	-7.666	-7.752	-7.896	-8.152	-8.336	-8.225
	-6	-6.198	-6.234	-6.095	-5.933	-5.834	-5.773	-5.751	-5.776	-5.831	-5.938	-6.094	-6.223	-6.185

Table-4 shows the location points for x and y coordinates, which are varied from -6 up to +6 which includes the origin point (0, 0). The high return loss was found at the two lines of y-axis in +3 and -3, along the x-axis. The two lines with high return loss represents the best feeding point's location for feeding the patch antenna. The best of the feed location points were indicated with yellow colour. The width of the rectangular patch antenna was taken with y-direction and the length with x-direction.



**Figure-5.** Surface plot of the return loss and the 169 feed point locations, the best feed location point appears at the fourth area plotted with blue color.



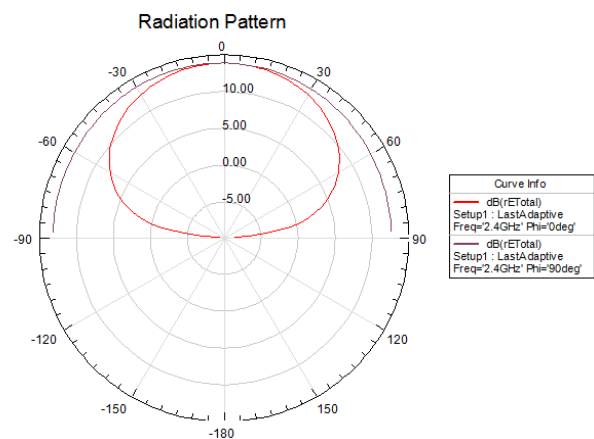
**Figure-6.** Contour plot for the return loss plotted with the 169 feed point location.

The high return loss illustrates that, there it has a low reflection feeding power, has high radiation, and it's a good antenna. In other words, the antenna has a low input impedance at the located points as well as it has all the power that could be passed to the input feeding point to the patch. The correct selection of the feeding point location decreases the input impedance for the patch antenna, as the feeding point represents the delivered point, by which the patch receives its feed power. Consequently the higher performance of the patch antenna is displayed with the better feeding located points. These results are accepted and explained by other researchers. The feed point of any patch antenna must be located at a point that achieves the input impedance of 50 ohm at the resonance frequency [10]. Therefore, the feeding points was applied for all the specific points antenna area of 169 along the X and Y coordinates including the origin point. As explained before, the best feeding point must be located at the highest return loss. Furthermore, in order to operate the patch antenna in normal case the length of patch antenna must be equal or less than  $\lambda/2$ , where  $\lambda$  is the wavelength of the dielectric medium [2, 5].

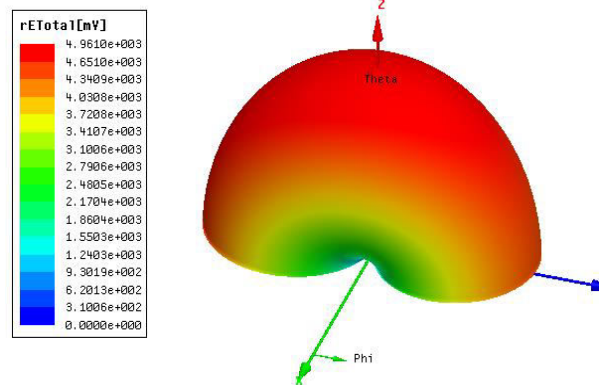
## RADIATION PATTERN

The radiation pattern of the patch antenna was plotted as shown in Figure-7 and 8. It has shown that the

distribution of power radiation around the antenna as a function of direction represented by the phi angle at 2.4 GHz. The radiation pattern of an antenna has a normal radiation distribution to its surface and it gives an image nature of the value and direction of radiation, by which the antenna emits or receives the electromagnetic waves. The best way to represent radiation pattern is by the three dimensional graph. The radiation pattern is plotted to show the visualization or provide a view of the radiation. Its magnitude depends on the patch antenna surface. Another way to represent it, is by the angular or polar coordinates. Figure-7 and 8 show the elevation pattern for designed antenna at  $\phi=0$  and  $90$  deg.



**Figure-7.** 2D radiation pattern at 2.4 GHz frequency.



**Figure-8.** 3D radiation pattern at 2.4 GHz frequency.

## THE DIRECTIVITY

The directivity is a convenient way to measure the range of power transmission in a specific direction. The directivity is considered as one of the parameters by which the antennas get a high gain [3]. Figure-9 shows the directivity for  $\phi=0$  and  $90$  deg with the highest directivity is 0.412 dB.



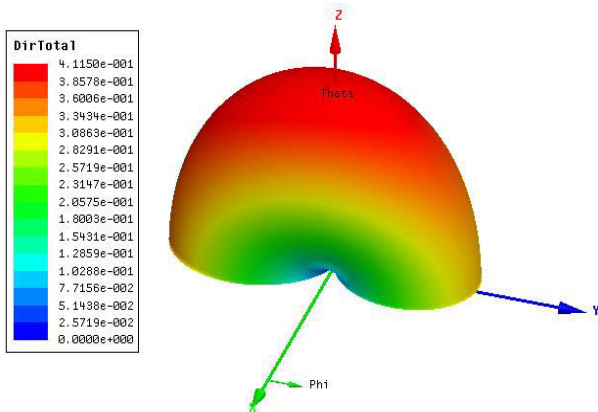


Figure-9. Directivity of antenna at 2.4 GHz frequency.

### THE GAIN

The Antennas gain is measured for its directivity and the efficiency, and therefore the gain for any antenna mathematically can be obtained as in Equation. (10):

$$G = \eta * D \quad (10)$$

Where,  $\eta$  = the efficiency,  $D$  = the directivity

Figure-10 shows the gain of antenna for  $\phi=0, 90$  deg'.

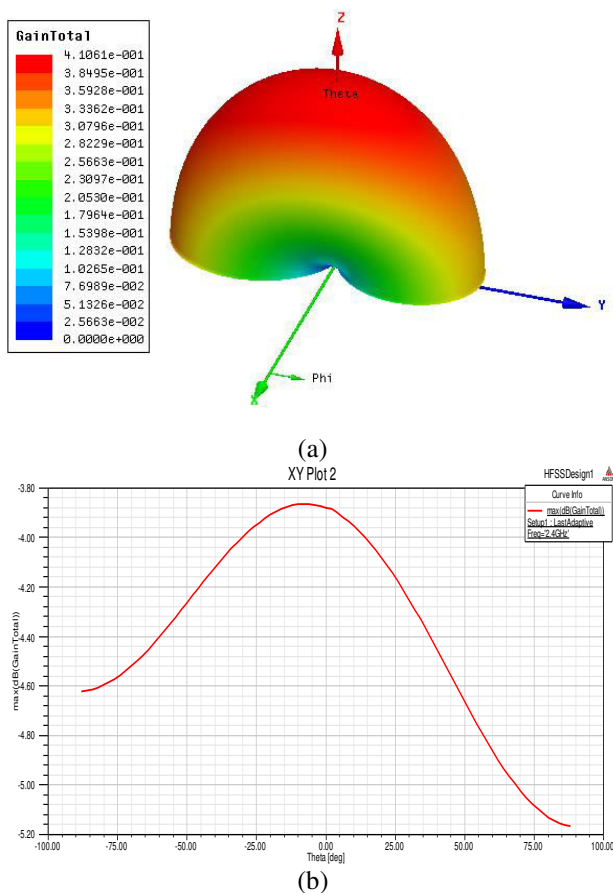


Figure-10. (a), (b) Maximum total gain of patch antenna at 2.4 GHz frequency.

### THE EFFICIENCY

The efficiency of any device represents the ratio of output power to its input, but for antenna the efficiency is calculated from the ratio between the powers radiated from it to the supplied power. The antenna is like any other devices in microwave circuit components. The power could be lost as a result of mismatches or dielectric losses. Figure-7 shows the radiation pattern for the patch antenna, which indicates high values.

### CONCLUSIONS

In this design the impedance of feeding point for microstrip patch antenna can be controlled by changing the location of feed point. The feed probe technique was used to achieve the development of patch antenna within high matching as well as lowest input impedance. The correct selection of the feeding point location decreases the input impedance for the patch antenna and raises the return loss, gain, efficiency, and directivity.

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