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Design of Microstrip Patch Antenna using ANSYS HFSS

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***Abstract*-- This work presents the design and simulation of a rectangular microstrip patch antenna using ANSYS HFSS, including all major analysis steps. The antenna structure is modeled with proper substrate and ground plane selection, and excitation is applied via a suitable feed configuration. The simulation captures key excitation waveforms, observes the return loss and VSWR, and generates far-field radiation plots. E-plane and H-plane radiation patterns are plotted to examine field distribution and directivity. The project further analyzes the electric and magnetic field radiation, providing detailed insights into antenna behavior. Gain versus frequency is plotted to evaluate performance across the band, confirming the antenna's suitability for targeted wireless applications.**

***Keywords:* Antenna ,Microstrip patch antenna ,Rectangular microstrip patch, HFSS software, Gain ,Directivity ,VSWR.**

1. INTRODUCTION

The microstrip patch antenna is a widely used planar antenna in wireless communications, valued for its low profile, ease of integration, and tunable performance. Designing a microstrip patch antenna using ANSYS HFSS involves creating the patch, substrate, and ground plane, then defining excitation—typically via a wave port or lumped port—to observe input waveform and impedance matching. Simulation steps include setting up boundary conditions (such as radiation and perfect conductor boundaries), specifying the frequency sweep, and generating solution passes for accurate results. Analysis involves plotting return loss (S11), examining VSWR, and visualizing far-field radiation patterns. E-plane and H-plane field distributions are plotted by specifying relevant angles in the far-field setup, which reveals directional characteristics and directivity. Gain versus frequency plots further quantify antenna performance throughout the target band, confirming suitability for specific wireless applications.

Antenna design is done in ANSYS High Frequency Structure Simulator (HFSS) tool. It is a 3D simulation tool applicable for high frequency electronic elements as antenna and antenna arrays. This software tool has worldwide application that can be used in wireless communication, radar applications, satellite communication, Internet of things products. It solves the problems in 3D EM design. Complete analysis and provides guaranteed accuracy as result. The parameters necessary to analyse the antenna can be viewed in 2D and 3D model for accurate analysis.

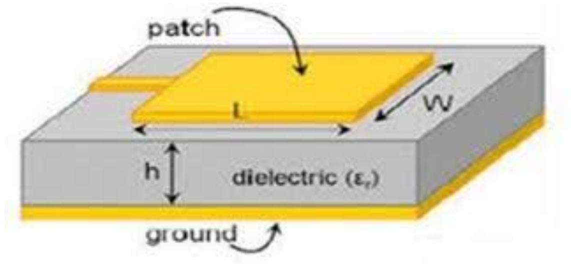

Figure 1. Rectangular antenna design

2. PROBLEM STATEMENT

Design a compact microstrip patch antenna that meets specific performance targets (resonant frequency, return loss, bandwidth, radiation pattern and gain) while satisfying practical constraints (size, substrate choice, fabrication limits)Use ANSYS HFSS to simulate, optimize, and evaluate antenna performance across parametric variations and realistic scenarios.

3.MICROSTRIP PATCH ANTENNA OF RECTANGULAR DESIGN PARAMETERS

A Rectangular Microstrip Patch Antenna is designed to operate at 2.4 GHz frequency with edge feeding technique. The proposed design is created with the substrate with FR4 epoxy under dielectric constant $\varepsilon r = 4.4$

$$W = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r + 1}{2}}}$$

W = 3×10^8 / (2 × 2.4×10^9 × sqrt((2/4.4 + 1)))

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Substrate width= 0.0625 x 0.608 = 39mm

Length = $L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}}$

= 3 x 10^8/2 x 2.4 x 10^9 r x 2.05
= 3 x 10^8/ 9.84 x 10^9
= 3.048
= 30.48mm

4. DIMENSIONS OF PROPOSED DESIGN

Parameters	Edge Feed
Resonant Frequency	2.4 GHz
Substrate	FR4 epoxy
Dielectric constant	4.4
Height of Substrate	0.8mm
Width of patch	38mm
Length of patch	29.44mm
Substrate length	60mm
Substrate width	50mm
Substrate thickness	1.6mm
Ground plane length	60mm
Ground plane width	30mm

5. FEEDING TECHNIQUES

Feeding is the basic process for establishing connection between transmitter and receiver antenna and make them connected for transfer of information. As the antenna operates in radio frequency the feeding is created in same range. The communication between the antenna happens through radio frequency signal.

5.1 Feed Technique

This feeding is provided through a feedline that connects the external edge feed on the substrate with the radiating patch. The design is made such a way that width of feed element is less than radiating patch.

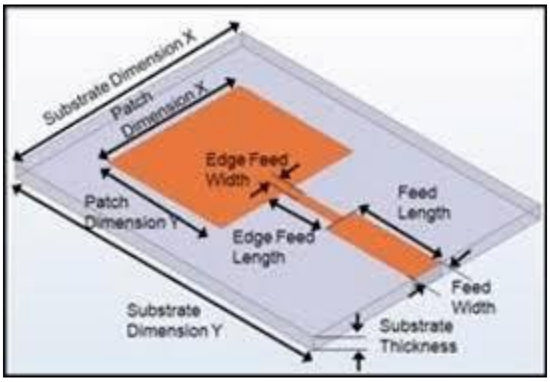

Figure 2. Rectangular antenna feeding technique

6. SIMULATION OUTCOMES

6.1 EDGE FEED:

a) Return Loss: Power loss is represented by returnloss. It is caused because of channel or transmission line discontinuities. Signals are returned due to this in transmission process.
From the above result, it is shows return loss is very narrow at the radiated 2.4 Ghz frequency. This indicates that the antenna exhibits perfect radiation.

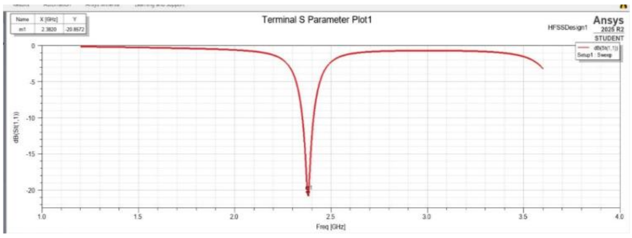

Figure 3. S Parameter / Return loss

b) GAIN: This describes how much amount of power is radiated from the antenna. The maximum radiation is obtained based in the frequency applied. If the value obtained is not optimized then the performance of antenna is low.

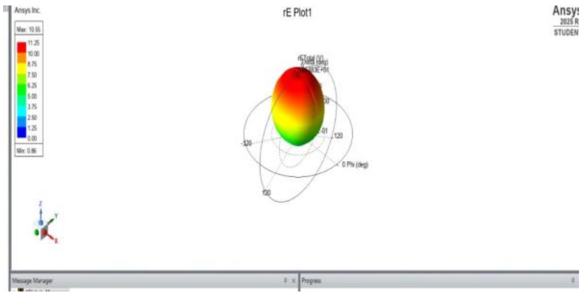

Figure 4. Gain plot

c) DESIGN: Here the design of microstrip patch antenna where observed the plot using the gain over the rectangular patch.

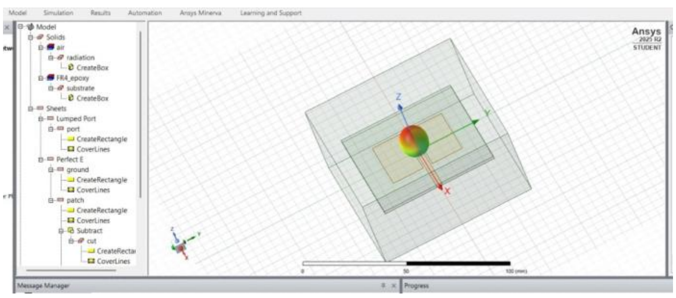

Figure 5. rectangular Antenna design / model view

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7. MICROSTRIP PATCH ANTENNA OF CIRCULAR DESIGN PARAMETERS :

A Circular Microstrip Patch Antenna is designed to operate at 2.54 GHz frequency with edge feeding technique. The proposed design is created with the substrate with FR4 epoxy under dielectric constant εr .= 4.4

$$a = F/\{1+2h/\pi\varepsilon r F[\ln(\pi F/2h)+1.7726]\}^{1/2}$$

$$F = 8.791\times10^{9}/ f_r \sqrt{\varepsilon r}$$

7.1 DIMENSIONS PROPOSED FOR DESIGN:

Ground

X=70mm

Y=70mm

Substrate:

Length=3.6mm

Center position=37,35.5,3.6

Radius=17mm

8. FEEDING TECHNIQUES FOR CIRCULAR PATCH ANTENNA:

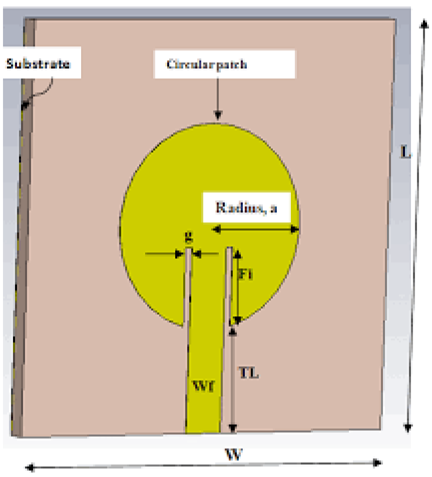

Figure 6. **Circular antenna design**

Feeding techniques for circular patch antennas determine how electromagnetic energy is transferred from the transmission line to the radiating patch. These methods are broadly classified into contacting and non-contacting types, each impacting the antenna's bandwidth, impedance matching, and ease of fabrication

Coaxial Probe Feed: A very popular method where the inner conductor of a coaxial cable extends through the substrate and is soldered directly to the patch.

Microstrip Line Feed: A conducting strip is connected directly to the edge of the circular patch.

8.1 SIMULATION OUTCOMES:

a) DESIGN: Here the design of microstrip patch antenna where observed the plot using the gain over the Circular patch.

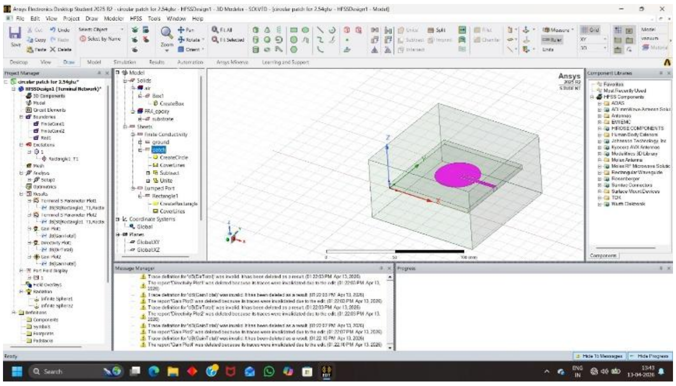

Figure 7. Circular Antenna design /model view

b) GAIN: This describes how much amount of power is radiated from the antenna. The maximum radiation is obtained based in the frequency applied. If the value obtained is not optimized then the performance of antenna is low.

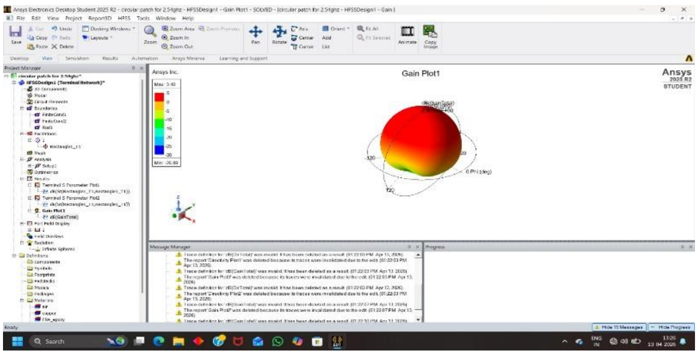

Figure 8. Gain plot

c) Return Loss: Power loss is represented by return loss. It is caused because of channel or transmission line discontinuities. Signals are returned due to this in transmission process.

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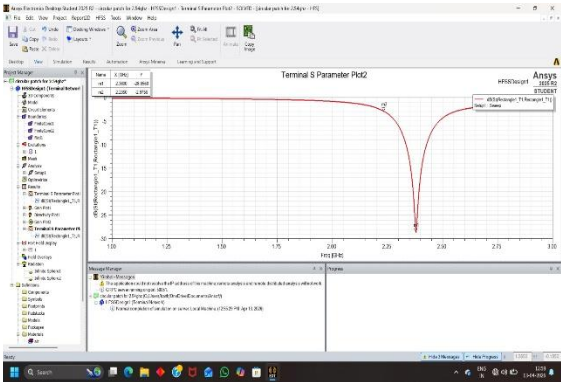

Figure 9**. S parameter / Return loss**

9. COMPARISON:

PROPERTIES	RECTANGULAR	CIRCULAR
S parameters	-20.857	-28.656
E plane(V/m)	26837.4	18.296
H plane(A/m)	213.65	13.729
VSWR	1.612dB	1.438dB
Gain	2.898dB	3.29dB
Directivity	3.329dB	6.517dB

10. CONCLUSION:

So circular patch antenna is Superior choice for design compared to rectangular patch antenna

S-Parameters (Return Loss):

At -28.656 dB, the Circular patch has a much deeper resonance compared to the -20.857 dB of the Rectangular patch. This indicates significantly better impedance matching and less reflected power.

VSWR:

The Circular patch has a lower VSWR (1.438) compared to the Rectangular patch (1.612). A lower VSWR (closer to 1.0) means the antenna is more efficient at transferring power from the feedline to the radiator.

Directivity:

This is the most significant difference. The Circular patch offers 6.517 dB, nearly double the 3.329 dB of the Rectangular patch. This means the Circular antenna is much more effective at focusing its radiation in a specific direction.

Gain:

The Circular patch provides a higher gain of 3.29 dB, which translates to better overall signal strength and transmission range compared to the 2.898 dB of the Rectangular patch.

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