Khulna University of Engineering & Technology, Khulna

Department of

Electronics & Communication Engineering

Report on:

Square Ring Patch Antenna with Coaxial Feed

Course No: ECE-3208
Course Title: Antenna Design Laboratory
3rd Year 2nd Term

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ABSTRACT:

In this project, A Square Ring Patch Antenna with Coaxial Feed is designed and studied for wi-fi and Bluetooth applications operated at 2.4 GHz.
FR-4 (or FR4) is used as substrate having a dielectric loss of 0.02 and a thickness of 1.6 mm. The suggested antenna design is modeled with the help of the CST studio suite.
The motive of this project was to achieve lower Return Loss, higher gain and lower VSWR. From the simulation, the Return Loss, Gain and VSWR were found to be -17.155 dB, 2.746 dB and 1.5106 respectively.

OBJECTIVES:

1. To know about the working principle of the square ring patch antenna with coaxial feed.
2. To describe the analytical (theoretical) procedure to determine the dimensions of different parts of the antenna for 2.4 GHz operating frequency region.
3. To determine S parameters, impedance bandwidth, radiation pattern, gain, and directivity of the antenna along with figures.
4. To compare the simulation results with the theoretically expected results.

INTRODUCTION:

This project presents the design and simulation of a square ring patch antenna for wireless communication applications, specifically targeting the frequency band commonly used for Wi-Fi (Wireless Fidelity) and Bluetooth communication at 2.4 GHz. The antenna is implemented using CST Microwave Studio simulation software to optimize its performance characteristics. The square ring geometry is chosen for its compactness and potential for enhanced bandwidth.

The design parameters, including the dimensions of the square ring, feed location, and substrate properties, are systematically varied to achieve optimal resonance and impedance matching. Simulation results illustrate the antenna's radiation pattern, return loss, and other key performance metrics, ensuring its suitability for wireless communication within the 2.4 GHz frequency band.

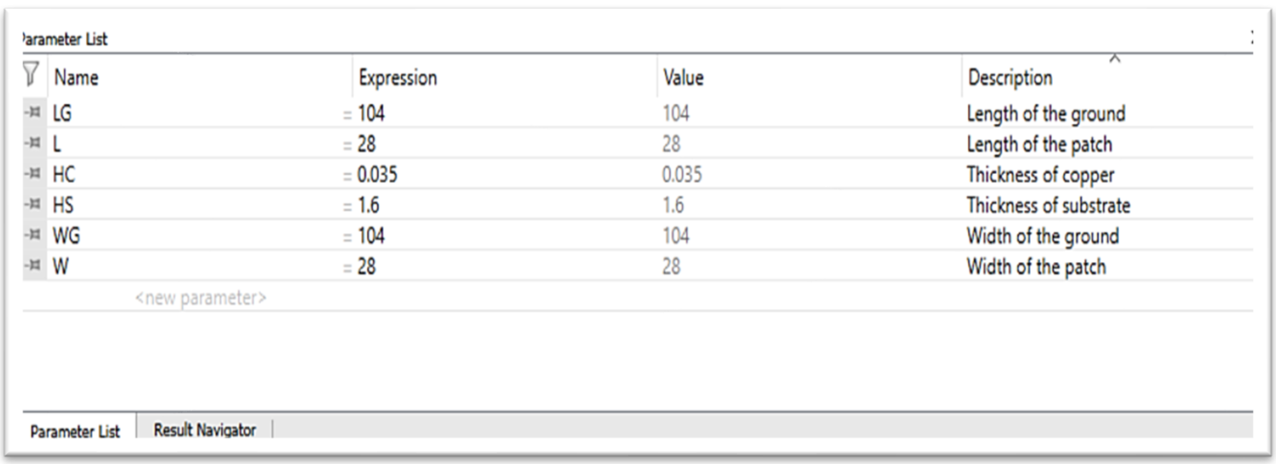
The proposed square ring patch antenna demonstrates promising characteristics, such as compact size, ease of integration, and compatibility with Wi-Fi and Bluetooth protocols.

MOTIVATION:

To design a square ring microstrip patch antenna with coaxial feed at 2.40 GHz for wi-fi and Bluetooth applications. As Wi-Fi and Bluetooth both occupy a section of the 2.4 GHz ISM band.

METHODOLOGY:

1. Firstly, we define the parameter list.
   Here,



Parameter List

Name	Expression	Value	Description
LG	= 104	104	Length of the ground
L	= 28	28	Length of the patch
HC	= 0.035	0.035	Thickness of copper
HS	= 1.6	1.6	Thickness of substrate
WG	= 104	104	Width of the ground
W	= 28	28	Width of the patch
<new parameter>			

Parameter List | Result Navigator

Figure 1: Parameter list for proposed antenna

2.Creating Ground Plane:
Material: Copper(annealed).

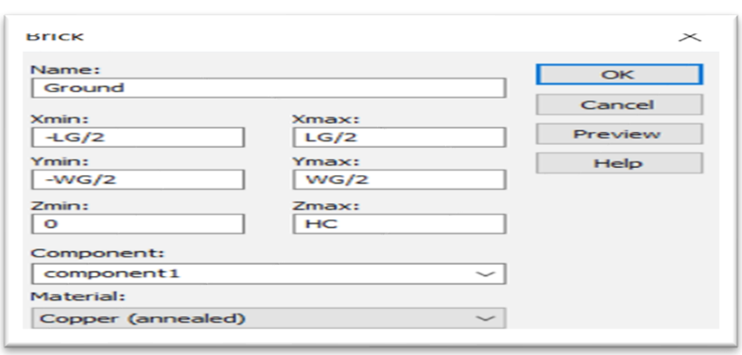


Figure 2: parameter for ground

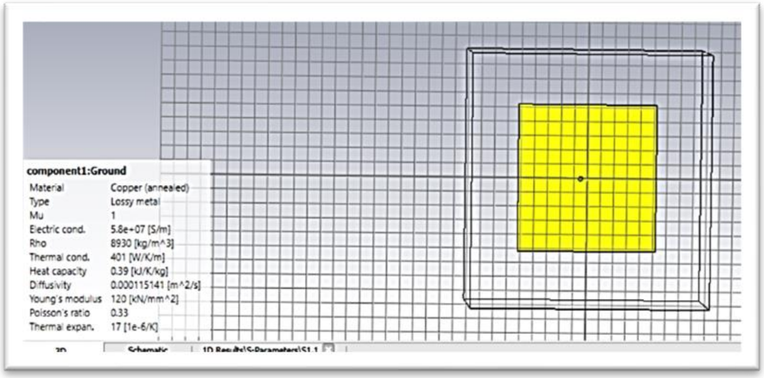
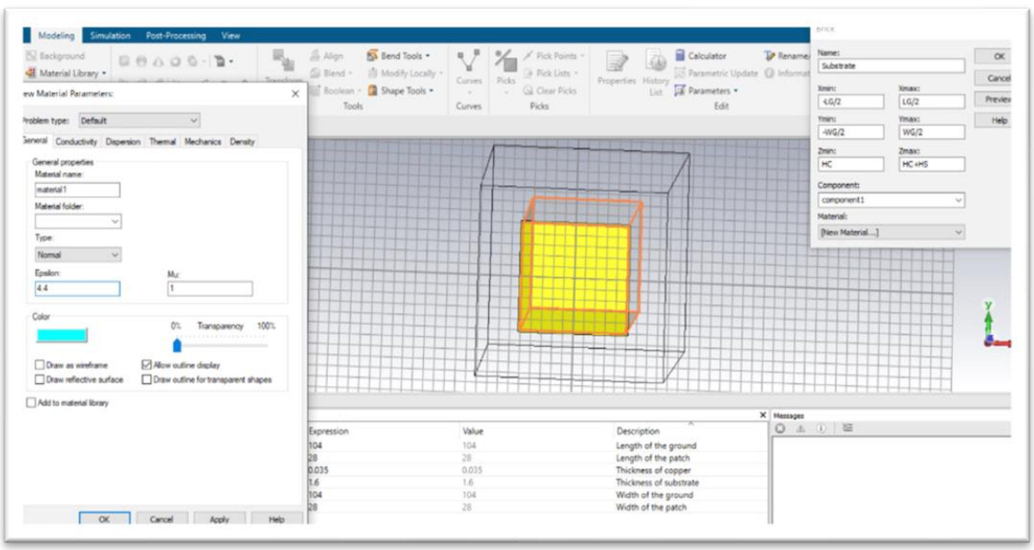


Figure 3: Ground plane

2. Creating Substrate:

Material: Low-cost FR4 substrate.



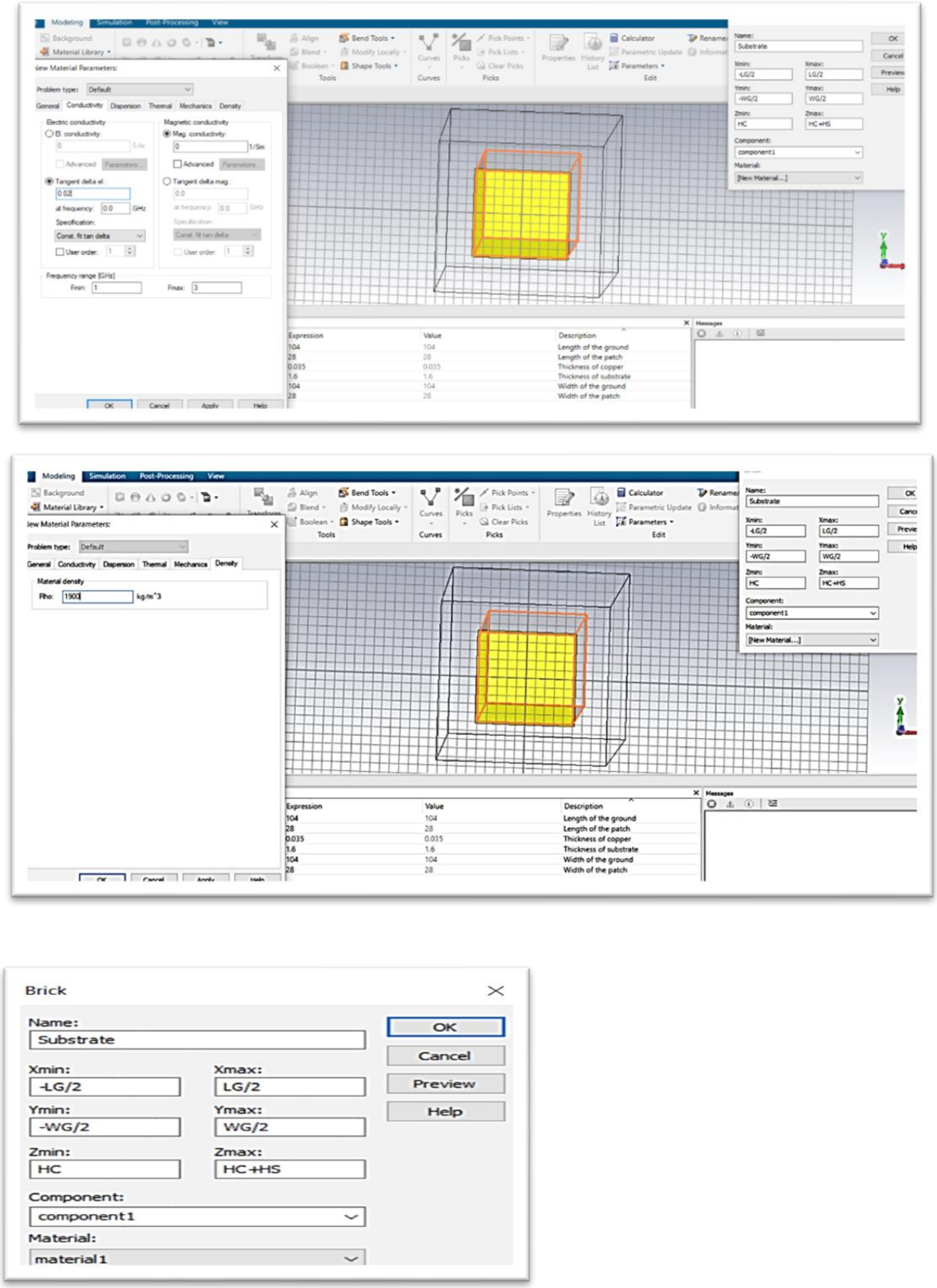


Figure 4: FR-4 Substrate.

3. Creating Patch:
   Material: Copper(annealed).

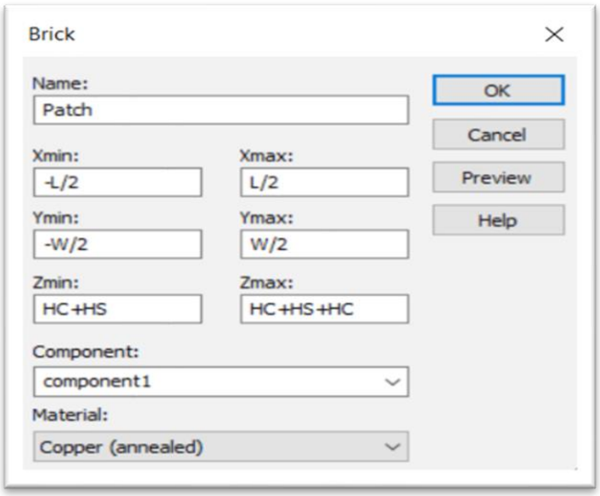
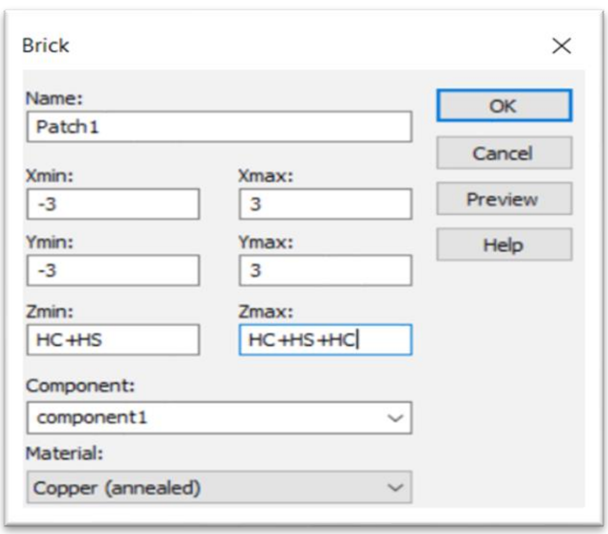


Figure 5: Parameters of patch

4. Creating Square Ring Patch:
   Take another Brick as Patch1 with the parameters below. And subtract it from the patch. We will get a square ring patch.



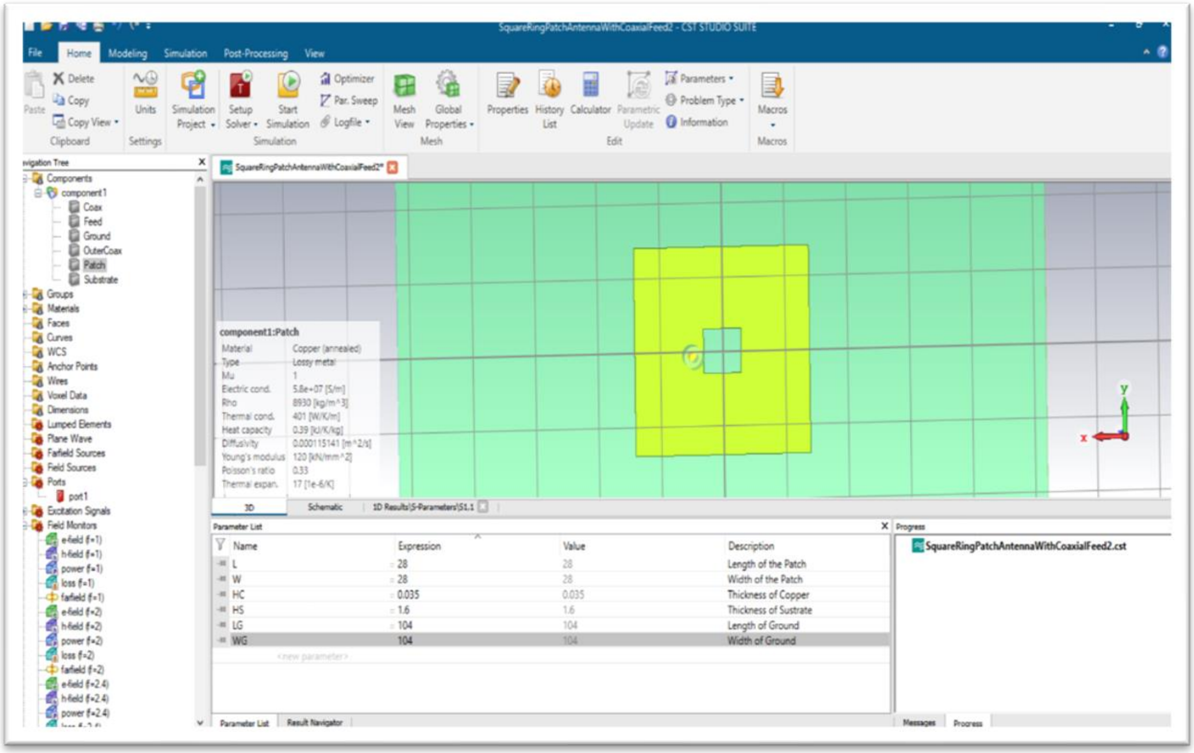
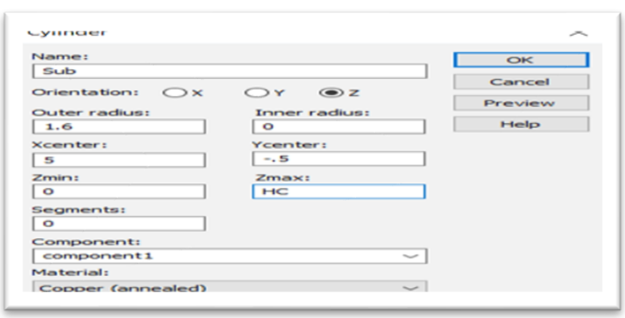


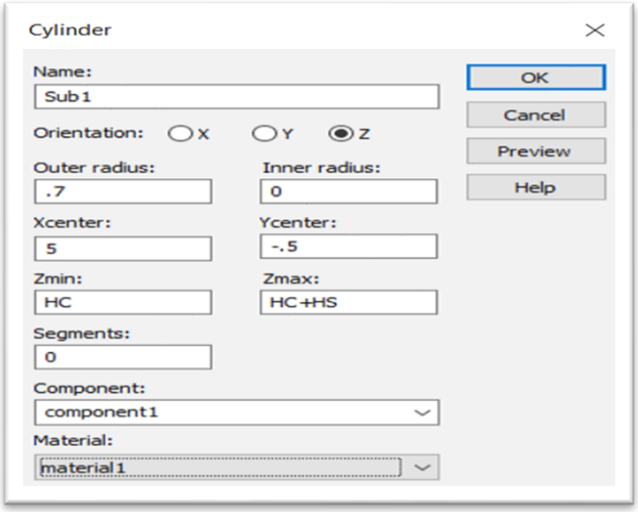
Figure 6: Square Ring Patch.

5. Creating the Feed:

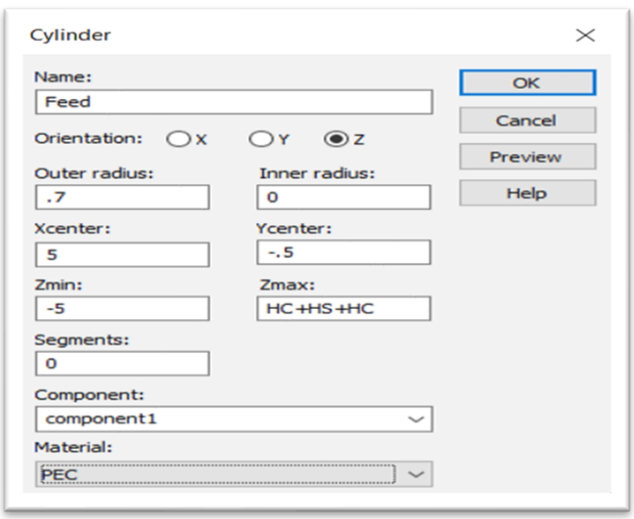
Subtract from Ground:



Subtract from Substrate:



Parameters of Feed:



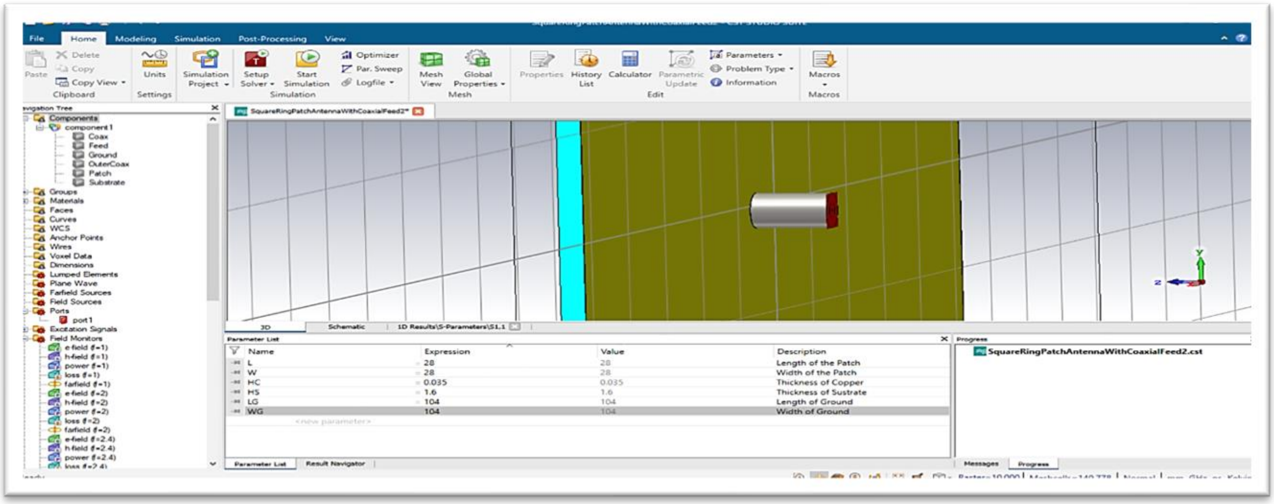
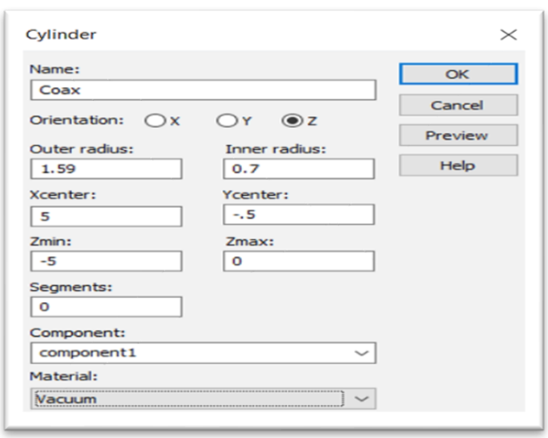


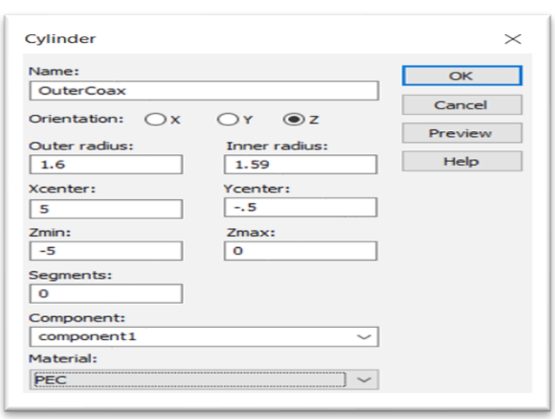
Figure 7: Feed.

6. Creating Coax:

   Dielectric path of the coaxial cable between the outer conductor and inner conductor.



Outer Covering for Coax cable:



Port:

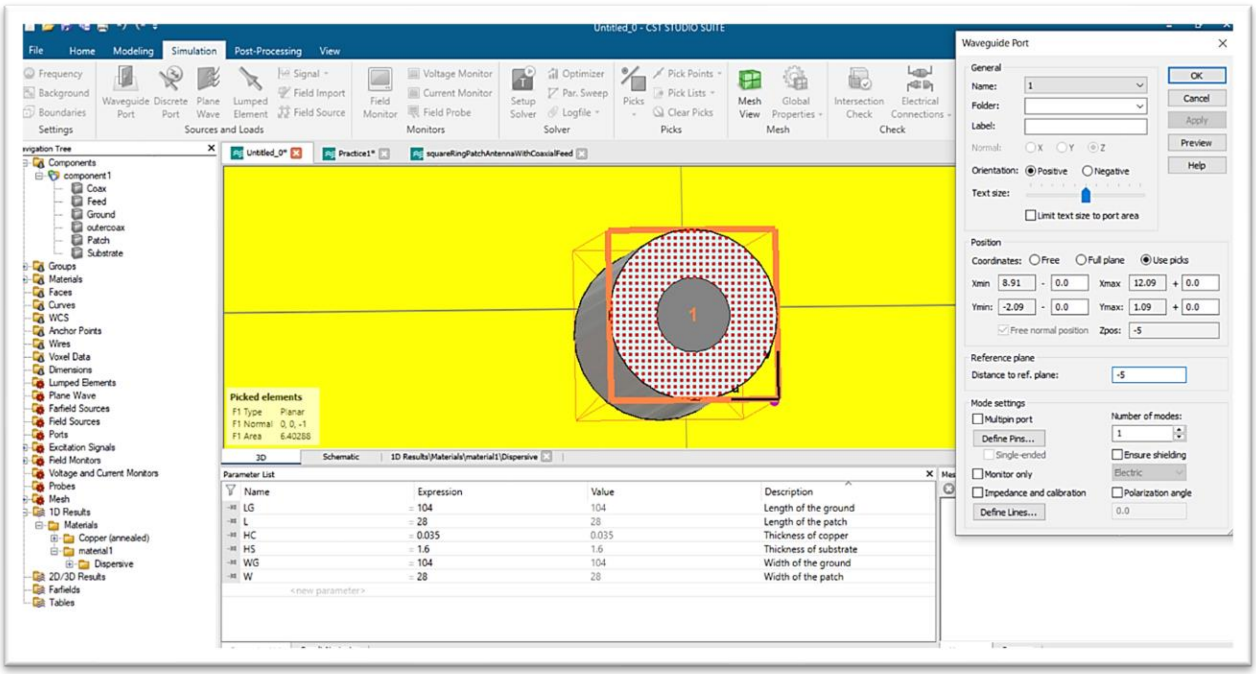


Figure 8: Creation of port

THEORY:

A square-ring patch antenna is a type of microstrip or patch antenna that has a square-ring shaped radiating element.

Microstrip Patch Antenna (MSA) is one of the most favored antenna structures because of its ease of fabrication and have many applications in wireless communication. They are very useful nowadays because they are directly printed onto the circuit boards.

The MSA (Microstrip Patch Antenna) is widely used nowadays because of its various advantage but it also has some disadvantages but due to its various advantages, it surpasses its disadvantages. These are some advantages of MSA: - a) Light Weight b) Low Profile c) Capable of dual and triple frequency operation.

It also has some drawbacks like low gain, low bandwidth.
Coaxial-fed patch antennas involve the use of a patch antenna on one side of the PCB, while the feedline is routed on the back side of the PCB. The connection between the two layers is implemented using a via.

The coaxial feed to a patch antenna involves placement of the patch antenna and its feedline element on two different layers. Normally we would put the patch on the top layer, and the feedline connection on the bottom layer.

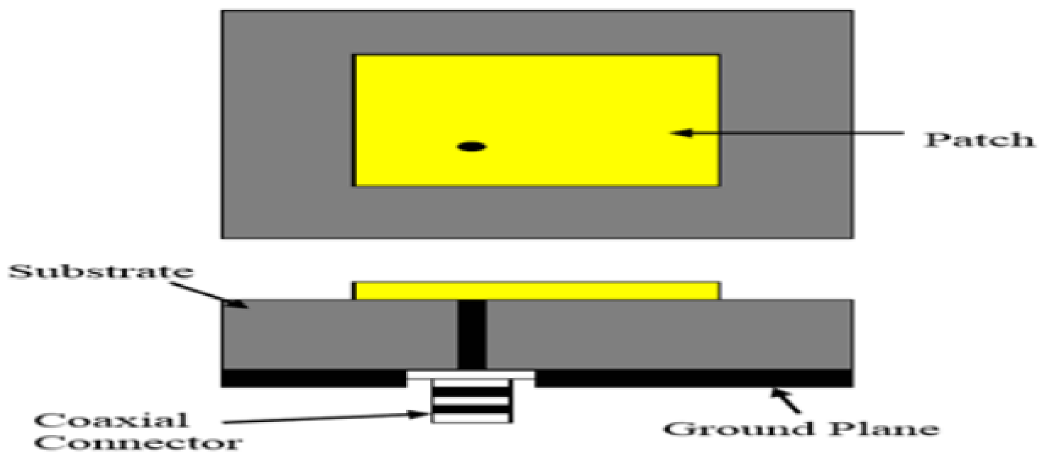


Figure 9: Coaxial Feed Patch antenna.

As we can see above, the coordinate where the patch antenna attaches to the via is not located at the center of the antenna. This is intentional because the antenna impedance varies across the surface of the patch antenna. Therefore, we want to connect the probe at a location where the input impedance into the antenna matches the coax cable/connector impedance. To do this, we first need the antenna impedance at the edge of the antenna, and we can use this to determine the feed location.

Coaxial Cable or Probe Feed

Microstrip antennas can also be fed from underneath via a probe as shown in Figure. The outer conductor of the coaxial cable is connected to the ground plane, and the center conductor is extended up to the patch antenna.

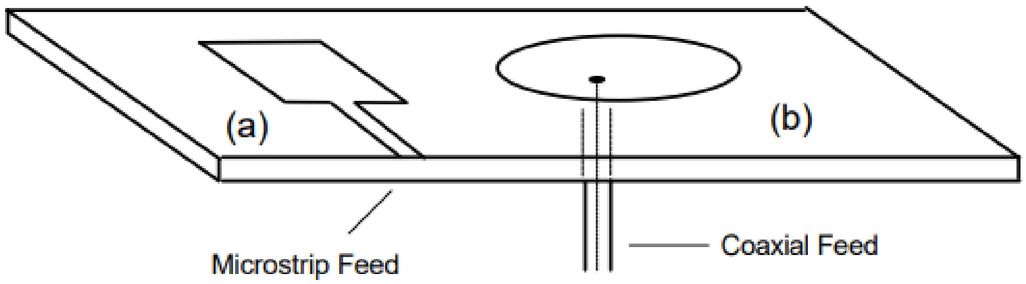


Figure 10: (a) A rectangular patch microstrip antenna fed with a microstrip edge feed. (b) A circular patch microstrip antenna fed with a coaxial probe feed.

The position of the feed can be altered to control the input impedance.
The coaxial feed introduces an inductance into the feed that may need to be taken into account if the height h gets large (an appreciable fraction of a wavelength). In addition, the probe will also radiate, which can lead to radiation in undesirable directions.

DESIGN PROCEDURE

Step 1: The width of the Square-Ring Micro strip antenna is obtained by the equation

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

Where c=3 ×108m/s, εr = 4.4, f_0=2.4 GHz

Step 2: The Effective Dielectric constant is obtained by

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \times \sqrt{\left(1+\frac{12h}{w}\right)}$$

Where εr = 4.4 and W=38 mm and h=1.6 mm

Step3: The Effective Length is given by

$$L_{ext} = \frac{c_o}{2f_r\sqrt{\varepsilon_{reff}}}$$

Substituting the ε_{reff} =4.78, c_0=3× 10^8m/s and f_0 =2.4 GHz, L_{ext}=28.5 mm

Step4: The Extension of length (ΔL) is obtained by

$$\Delta L = 0.412\,\frac{\left(\frac{w}{h} + .264\right)\left(\varepsilon_{reff} + .3\right)}{\left(\varepsilon_{reff} - .258\right)\left(\frac{w}{h} + .813\right)}$$

ΔL=0.45mm

Step5: Length of the Patch (L) is obtained by

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

Input impedance is usually 50ohm.
As it's a square ring patch antenna, so the length and the width would be the same.
So, L=38mm.

Step6: Selection of Feed Location

A coaxial probe type feed is used in this design. The feed point is selected such that it offers an impedance of 50 ohms to match the antenna. Hence, a random approach method is used for selecting the feed location. Finally, a location is selected where the return loss is most negative.

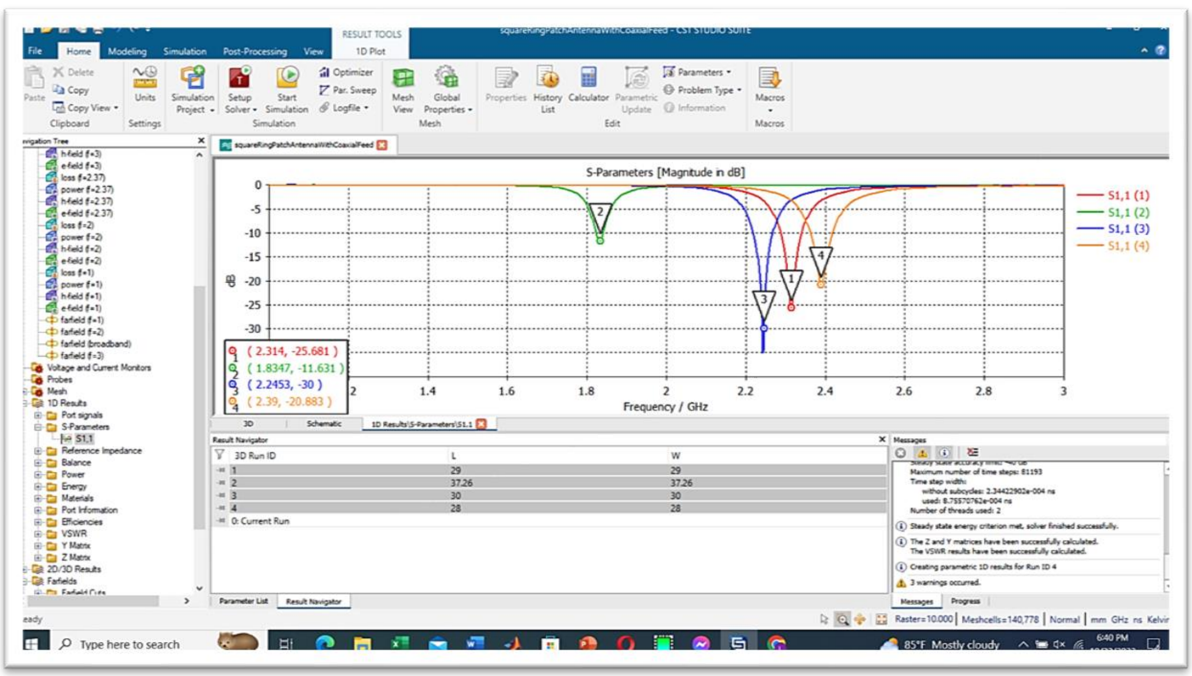
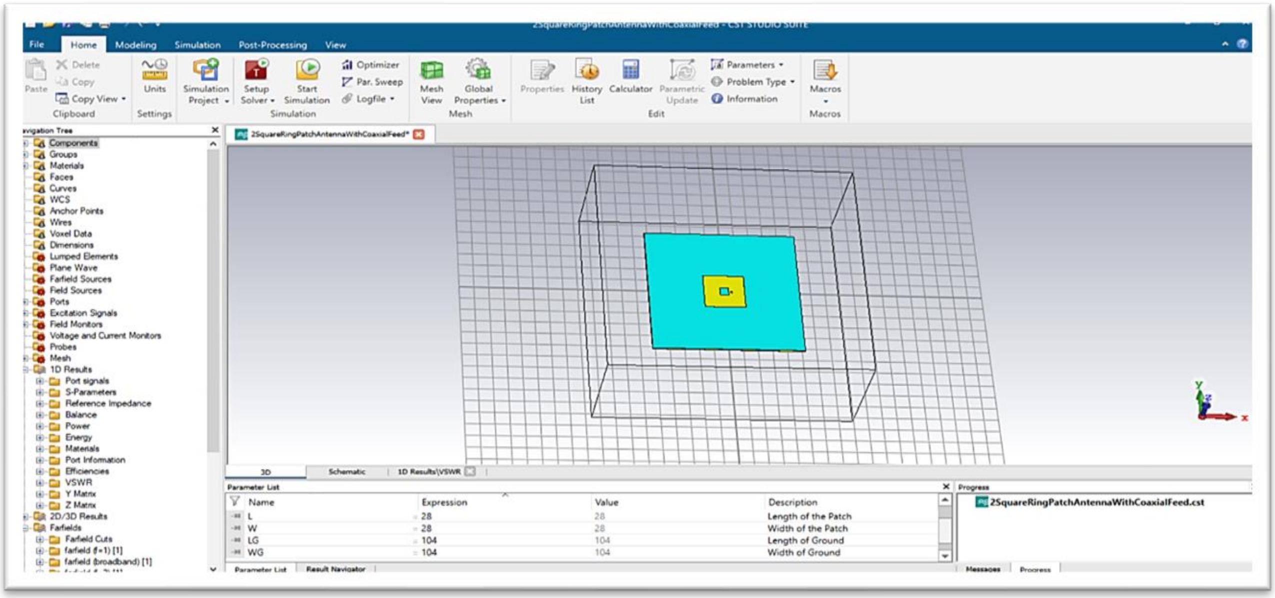


Figure 11: S-parameter for different lengths.

The required result cannot be got by using L=37.26mm.
So, we change the value of L=28mm.

DESIGN:



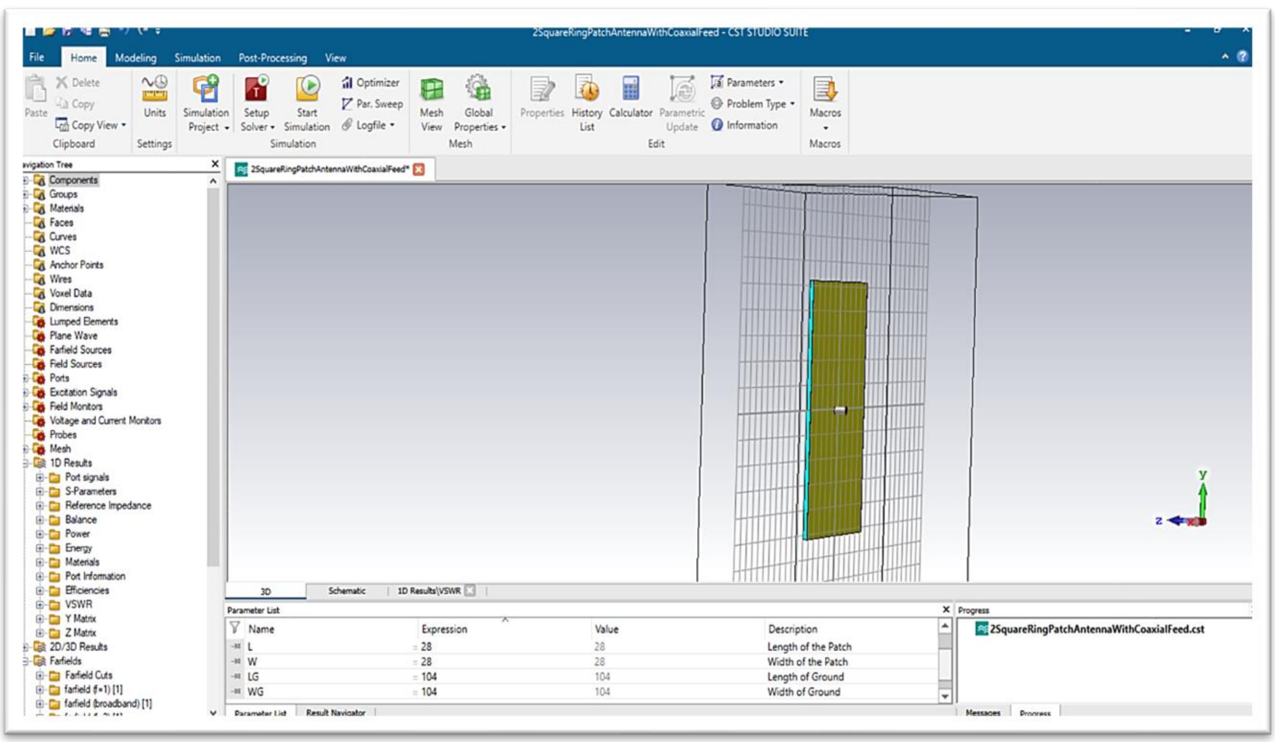
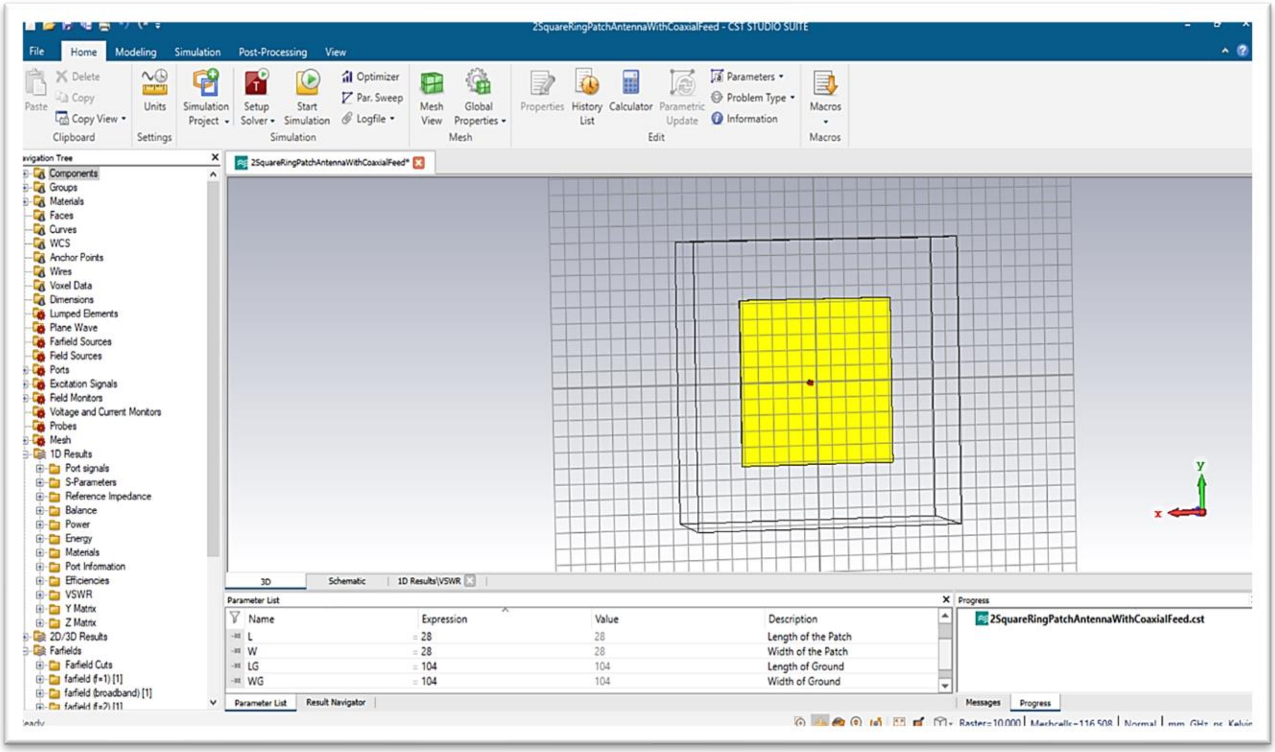


Figure 11: Views from different angles for our patch antenna.



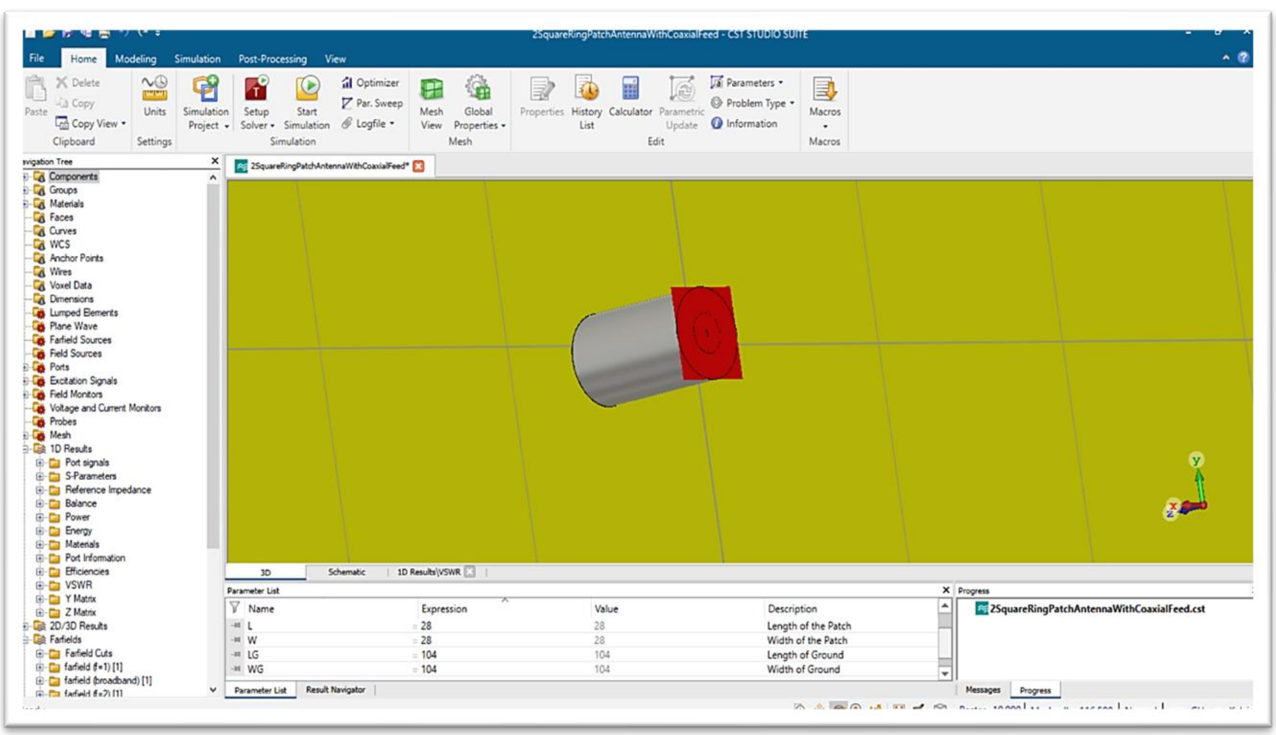


Figure 12: Ground plane and coaxial cable for our patch antenna.

RESULT ANALYSIS:

A. Return Loss

Return loss addresses the measure of the amount of signal reflected by the connector and it effects the antenna radiation efficiency. Return loss of -17.155 dB is obtained at a frequency of 2.4GHz.

The base value is taken at -10 dB which is ideal for mobile or wireless technologies. The antenna is operated at the desired frequency.
As illustrated below, it operates at 2.386 GHz. At this frequency the return loss is found to be -17.155dB.

The Bandwidth of the antenna is taken finding the distance between two intersections which are 2.3594 GHz and 2.4142 GHz. Fig. 3 shows, the antenna has a bandwidth of .0548 GHz.

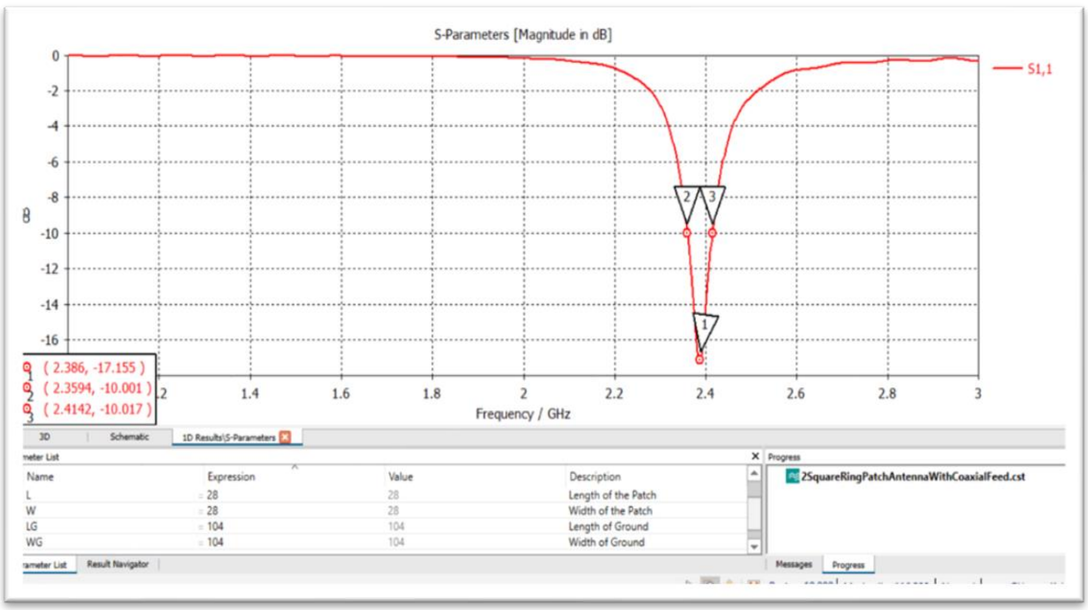


Fig. 13. Return Loss versus frequency

B. VSWR

VSWR (Voltage Standing Wave Ratio) represents the power reflection of antenna. The value of VSWR should be a positive and actual number. The Antenna's performance improves as the VSWR value decreases. It clarifies how the transmission line's impedance is matched.

Here, VSWR for 2.40 GHz is 1.5106.

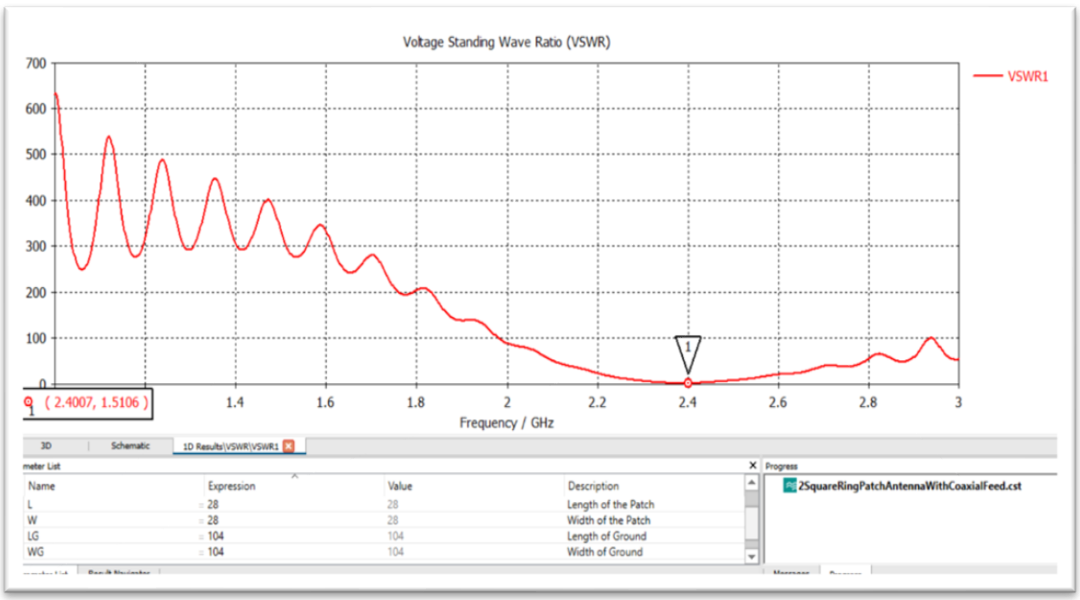


Fig. 14. VSWR vs Frequency

C. Radiation Pattern and Gain

The radiation pattern is considered to be the unique feature to identify the quality of the square-ring microstrip patch antenna with co-axial feed. It's a crucial parameter since it indicates how well the antenna is performing. Here, our designed antenna provides directional radiation pattern with minor back lobes.

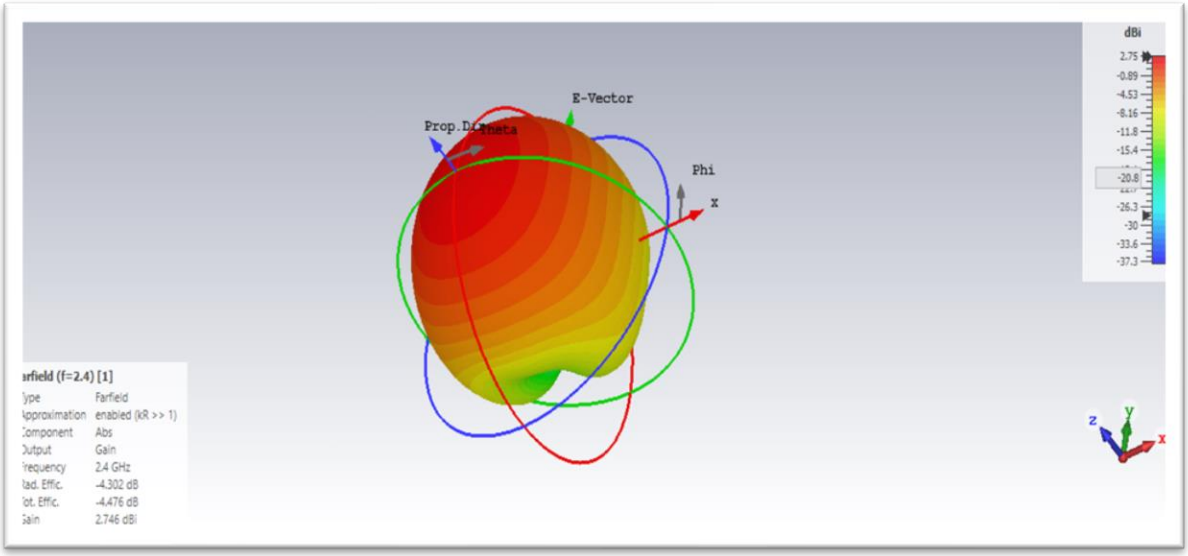


Fig. 15: 3D Radiation Pattern

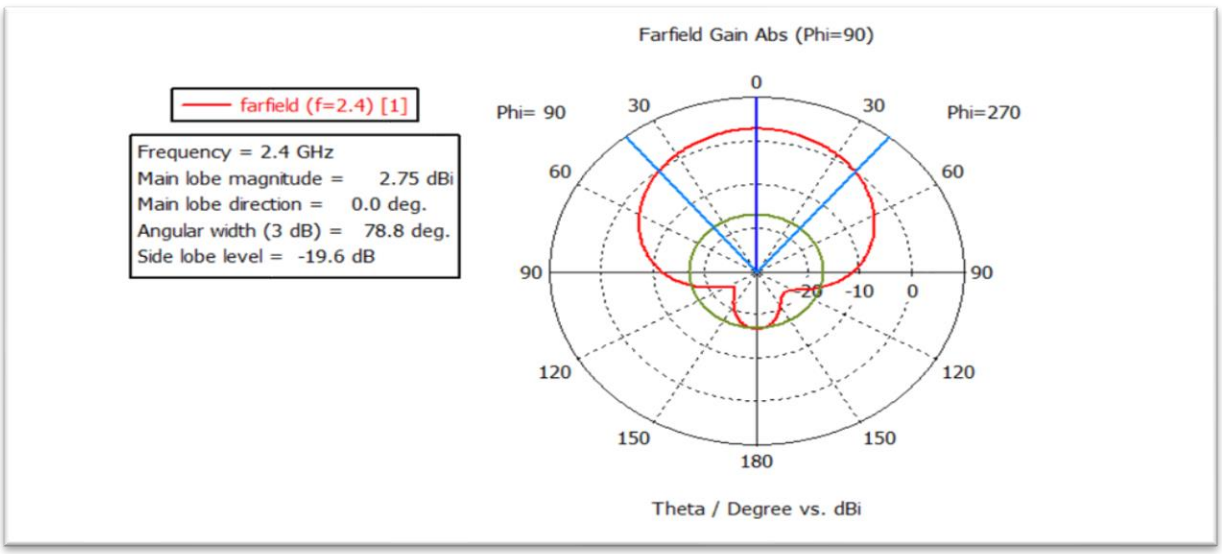


Fig. 16. 2D Radiation Pattern

D. E & H Field

For further investigation, E and H filed are shown as follow in the fig. 17 and fig.18.

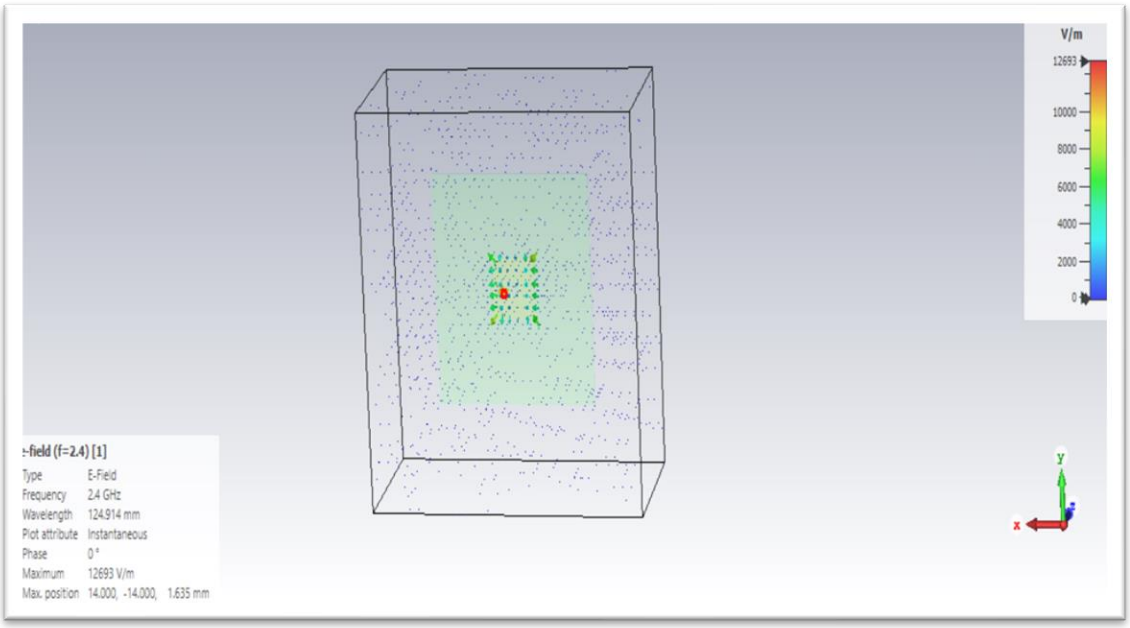


Fig. 17: E field of the Micro Strip Patch Antenna

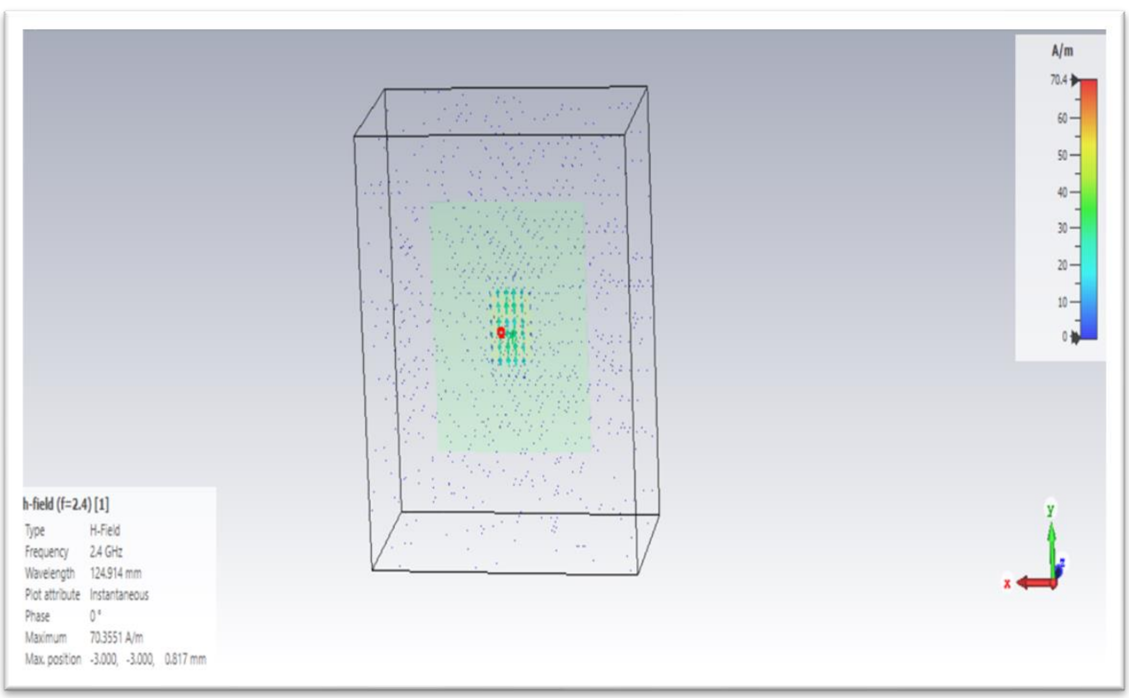


Fig. 18: H field of the Micro Strip Patch Antenna

E. Frequency vs. Gain:

Gain values should have been more than we have got here. We have got 2.7489 dB.

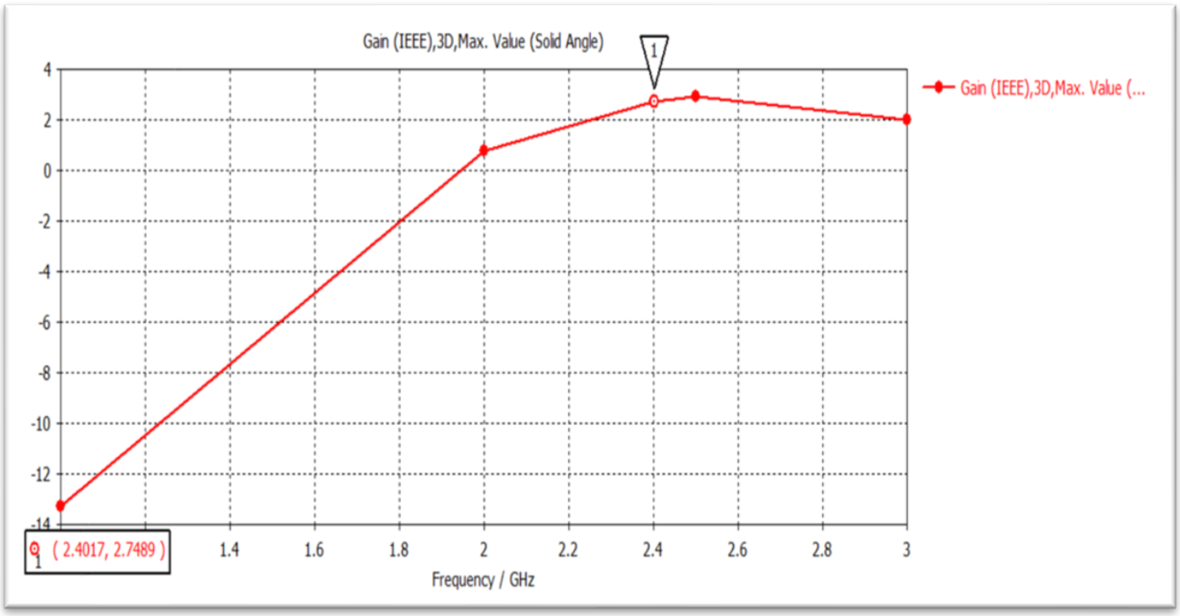


Fig. 19: Frequency vs. Gain characteristics.

CONCLUSION:

The motive of this design is to achieve lower return loss, higher gain and lower VSWR. The return loss of antenna should always be lesser than -10dB.

VSWR (Voltage Standing Wave Ratio) represents the power reflection of antenna. The value of VSWR should be a positive and actual number. The Antenna's performance improves as the VSWR value decreases. It clarifies how the transmission line's impedance is matched.

In this project, a Square-ring Patch Antenna with Coaxial Feed is designed and studied for Wi-Fi application. All the parameters are designed efficiently to decrease the power loss of the antenna. From the study, the Return Loss, VSWR and the Directivity Gain are found to be -17.155 dB, 1.5106 and 2.7489 respectively. For the future work, different methods and materials can be used in order to get effective results. The simulated results show that the proposed antenna could be a good candidate for wi-Fi systems with a little inconsistency in it.

REFERENCES:

1. https://www.ijcaonline.org/archives/volume178/number27/mohammed-2019-ijca-919010.pdf
2. https://www.antenna-theory.com/antennas/patches/patch3.php
3. https://resources.altium.com/p/how-design-coaxial-probe-feed-patch-antenna
4. https://vtechworks.lib.vt.edu/bitstream/handle/10919/36959/CH5.PDF
5. https://www.antenna-theory.com/antennas/patches/antenna.php
6. https://www.jetir.org/papers/JETIR1901717.pdf
7. https://www.kuet.ac.bd/webportal/ppmv2/uploads/165227188043_C_ICONAT2022Paper0506final.pdf?fbclid=IwAR0_XUyYDCG3jvEBa-1QdeVF05RAAOjxK7SAT2XFRdIDv0d_

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