Communications and Information Engineering Program

CIE 338 Final Project

Electromagnetic Fields and Waves II - Spring 2024-Course Project

The simulation that validates the chosen research paper

Link of the research paper:

View of Design and Simulation of 2.4 GHz Microstrip Antenna | Journal of Millimeterwave Communication, Optimization and Modelling. (n.d.).

https://www.jomcom.org/index.php/1/article/view/25/9

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1. Introduction

The need for more performance-oriented, lightweight, and compact antennas has grown dramatically in the last several decades due to the quick development of communication systems. Because of their small size, affordability, and ease of production, microstrip antennas have become a popular choice. When integration with planar monolithic microwave integrated circuit (MMIC) components is necessary for a certain application, these antennas are particularly beneficial. Narrow bandwidth and low efficiency are typical drawbacks of microstrip antennas, though.

In this paper, a rectangular microstrip patch antenna operating at 2.4 GHz resonance frequency is designed and simulated. The IEEE 802.11b and IEEE 802.11g WLANs, among other wireless communication systems, frequently use this frequency, which is located in the ISM (Industrial, Scientific, and Medical) band. The objective is to use CST Microwave Studio for simulation and optimization in order to optimize the antenna's performance metrics, particularly return loss and bandwidth.

2. Design Considerations and Basic Theory

Design Parameters

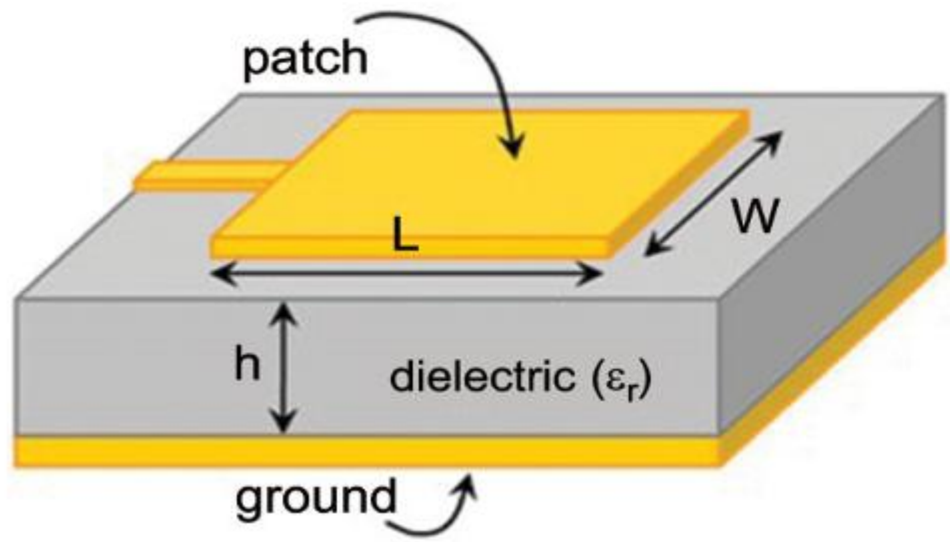
The design of the antenna needs some parameters that must be accurately calculated to not affect the simulation:

1- Resonance Frequency (Fo): frequency of the antenna at 2.4 GHz.

2- Substrate Material: FR-4: has relative dielectric constant (ε_r): 4.4 and thickness h = 1.6 mm, was selected to be suitable for high-frequency applications.

3- The Patch Dimensions: width Wp and length Lp they determine the antenna's resonant behavior and radiation characteristics.

- The antenna design is:



Calculation of Patch Dimensions:

The width of the patch Wp is calculated as:

Wp $= \frac{c}{2Fo\sqrt{\frac{\varepsilon_r+1}{2}}}$ **Where:** c **is the speed of light (3×10^8 m/s).**

The effective dielectric constant (ε_reff) is calculated as:

$$Ereff = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} + (1 + 12\,\frac{h}{Wp})^{-0.5}$$

The Feeding Method and Ground Plane

Usually, the ground plane dimensions are greater than the patch in order to guarantee appropriate radiation and reflection properties. In relation to this design:

Ground plane width is equal to 76 mm.

Ground plane length = 59 mm.

The patch antenna is supplied with power via a microstrip line feeding technique. To minimize return loss and match the impedance, the transmission line's length and width are optimized.

Slot Machine Design

In order to enhance the performance of the antenna, one slot on the ground plane and two symmetrical slots on the patch are added. By lowering the return loss and adjusting the resonance frequency, these slots assist. These measurements are adjusted during simulation to achieve the best performance.

3. Validation and Simulation Results

The designed antenna was simulated using CST Microwave Studio, focusing on various performance parameters such as return loss, gain, VSWR, and radiation pattern over a frequency range of 2 GHz to 2.8 GHz.

The parameters used in simulation are as the following:

Parameter List

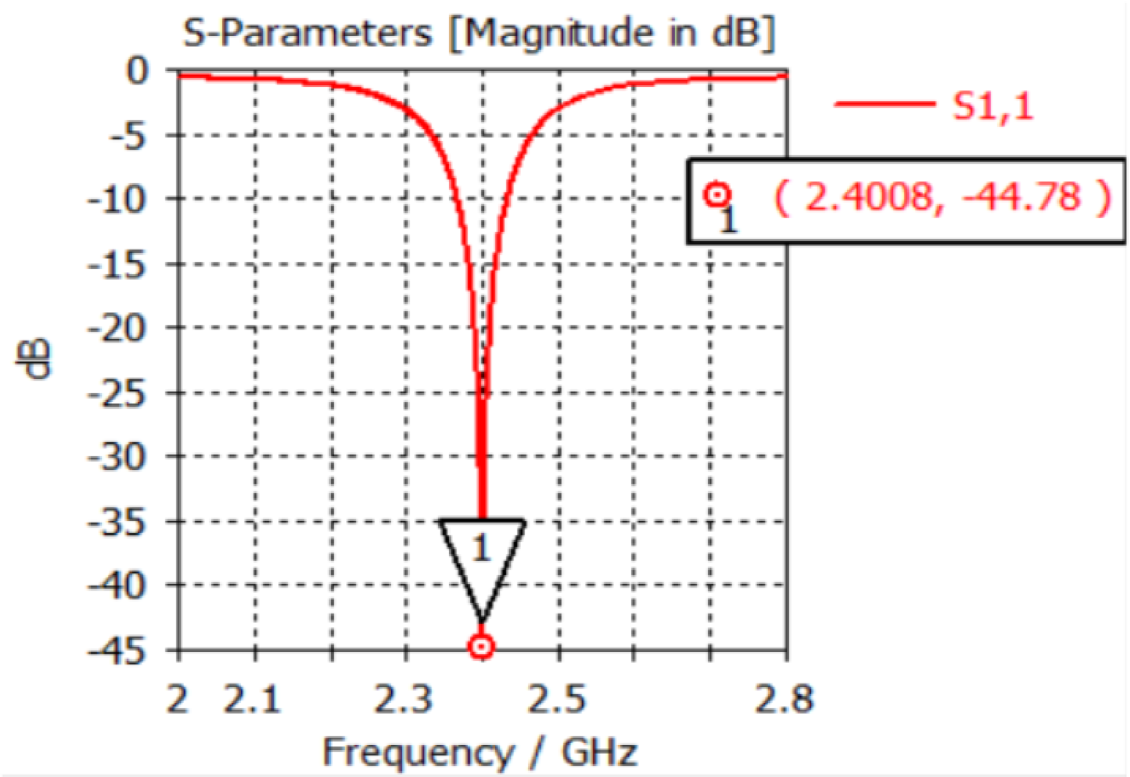
Name	Expression	Value	Description
SL	= 59	59	
SW	= 76	76	
STH	= 1.5	1.5	
Mt	= 0.035	0.035	
PL	= 29.5	29.5	
PW	= 38	38	
ML	= SL/2-PL/2	14.75	
MW	= 2.86	2.86	
InL	= 9	9	
InW	= 0.74	0.74	
K	= 5.62	5.62	
<new parameter>			

Results :

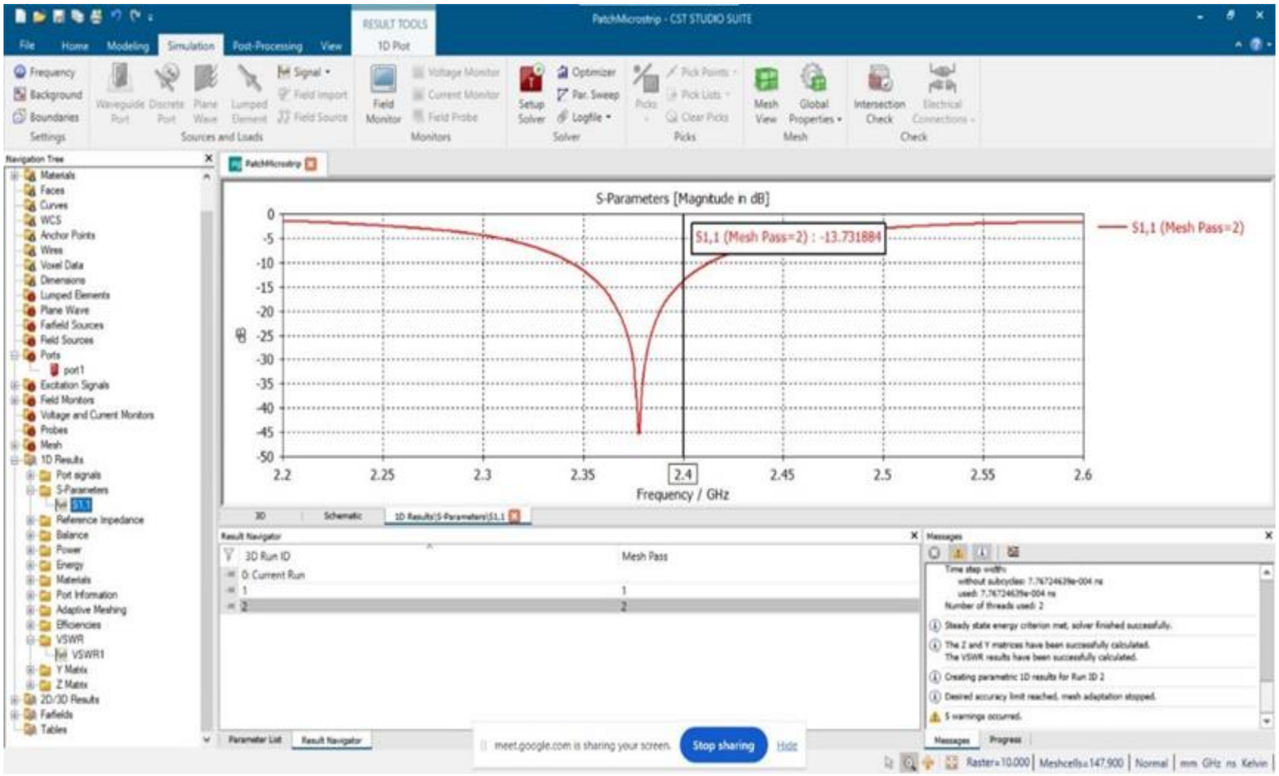
<u>(for clarification letter a) represents the graph of the research paper and letter b) represent the graphs of simulation results)</u>

1) **Simulation of S-parameters for the antenna: (indB):**

a)Exact graph from the paper:

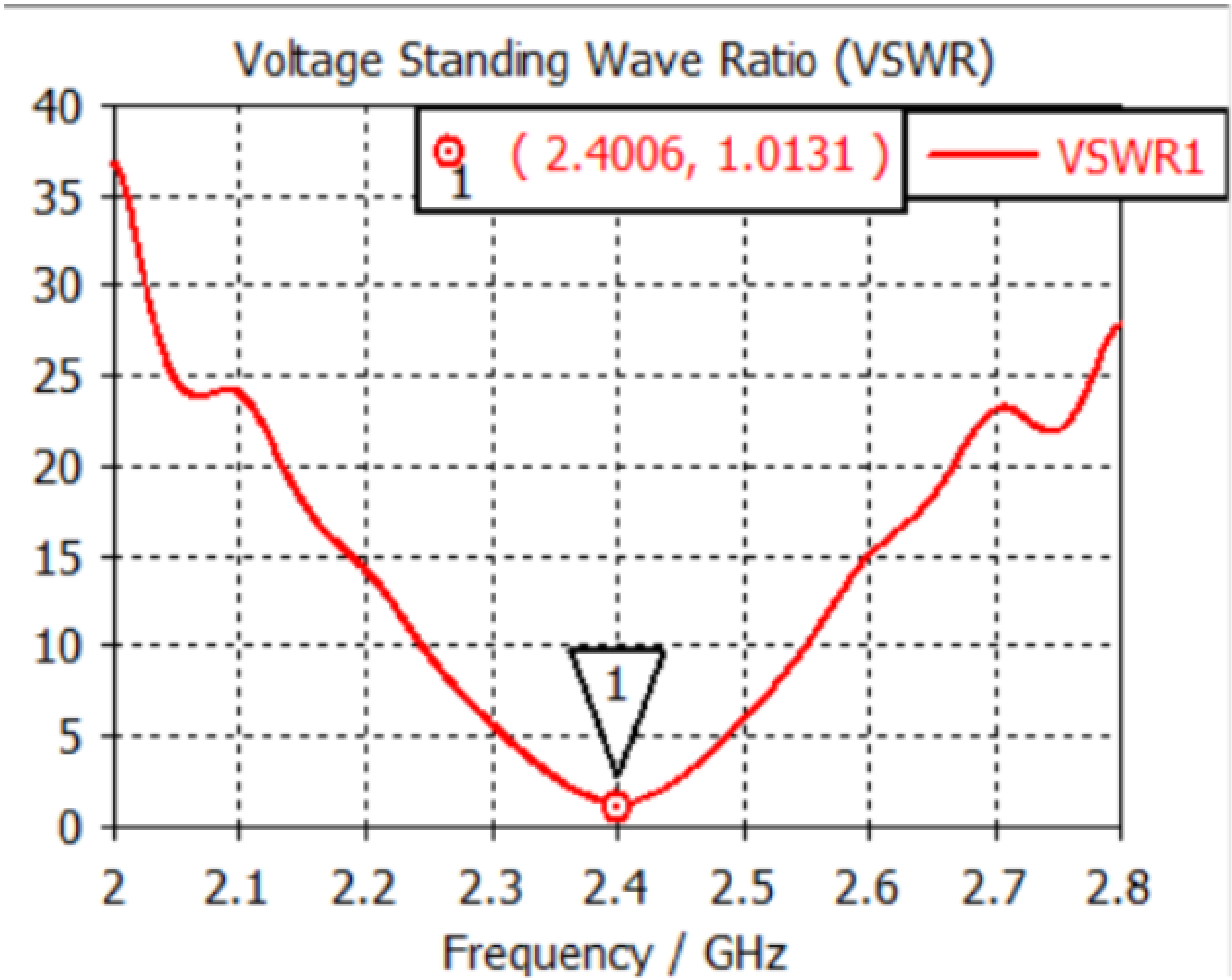


b) graph from the simulation:

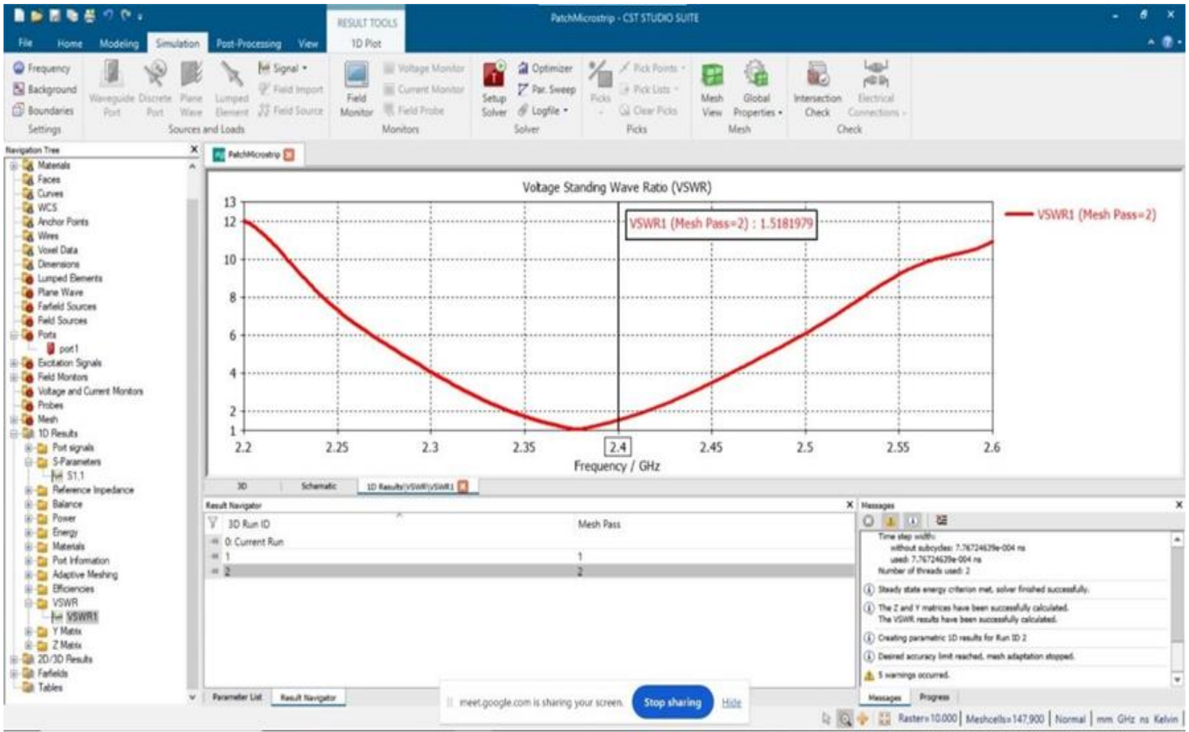


2) Graph of Voltage Standing Wave Ratio:

a)Exact graph from the paper:



b) graph from the simulation:



3) Far field of antenna :

a)

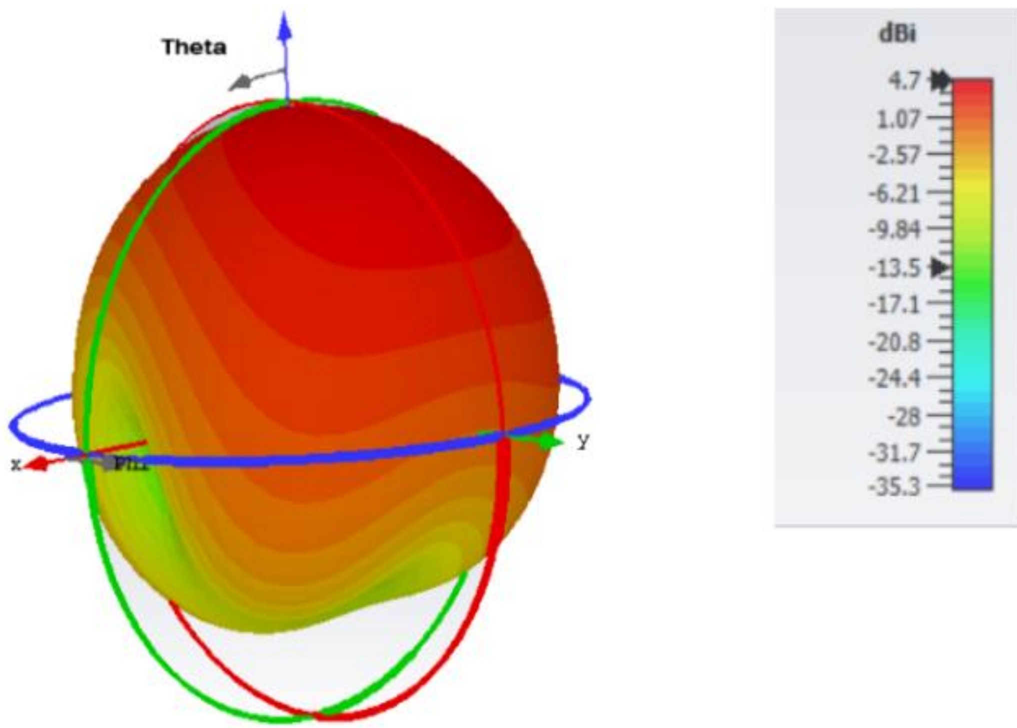
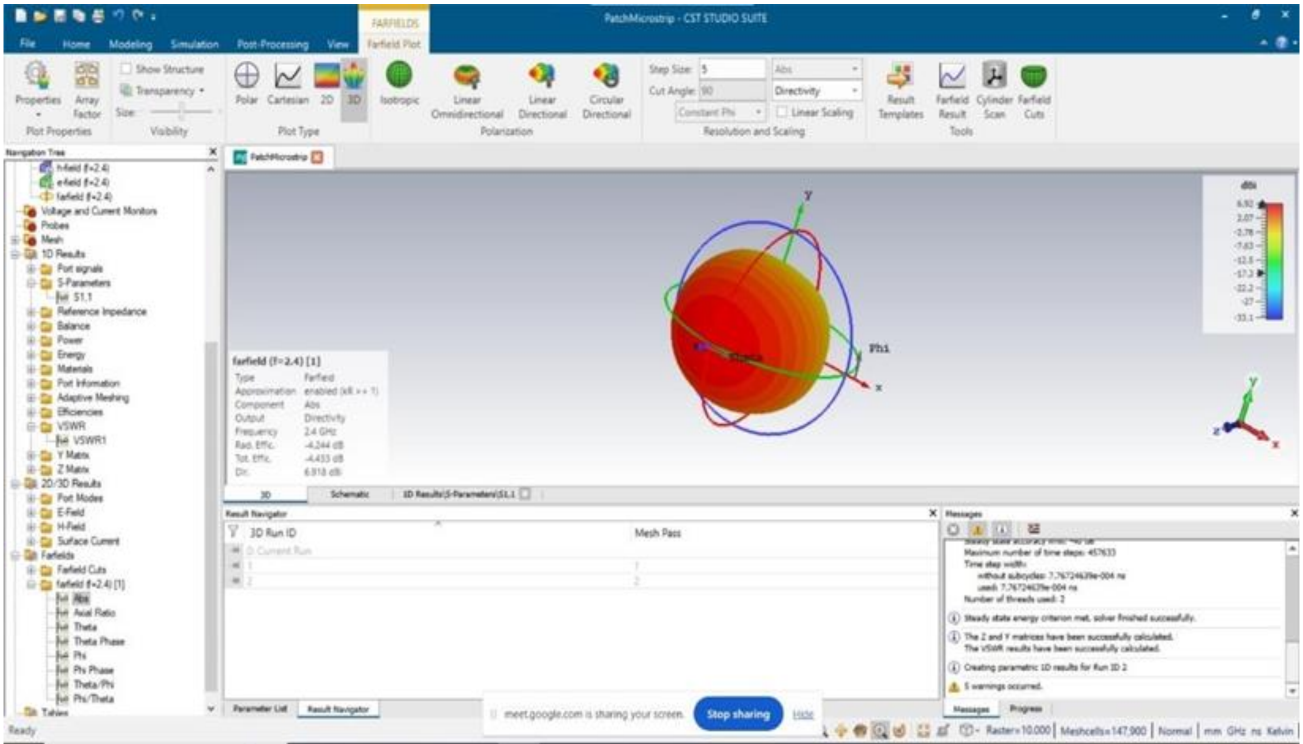


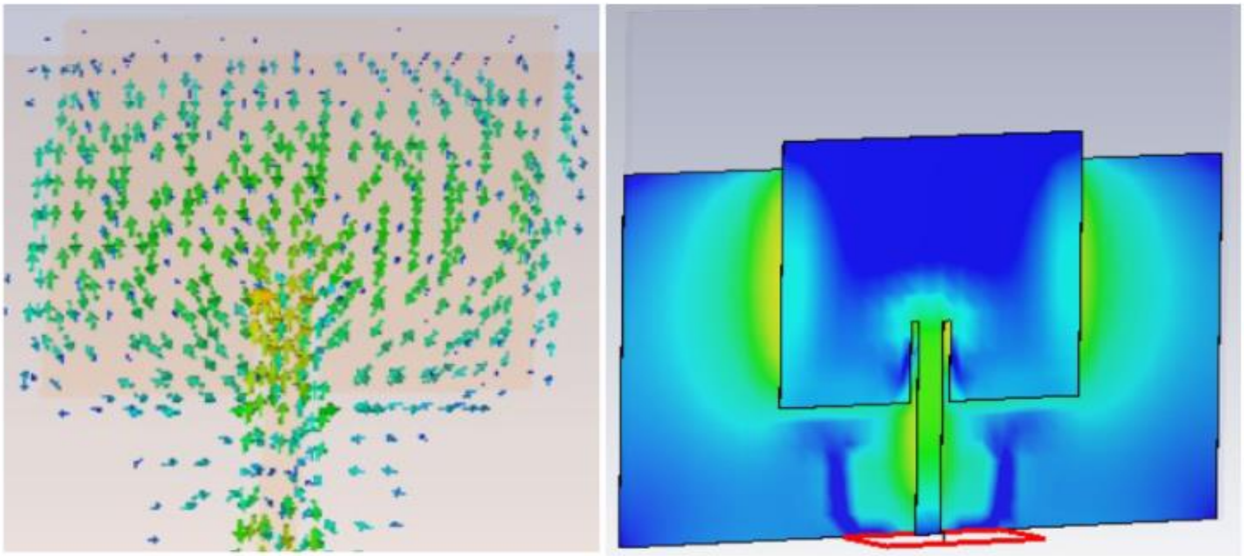
Fig. 8. Farfield of antenna

b)



4) Surface Current:

a



b)

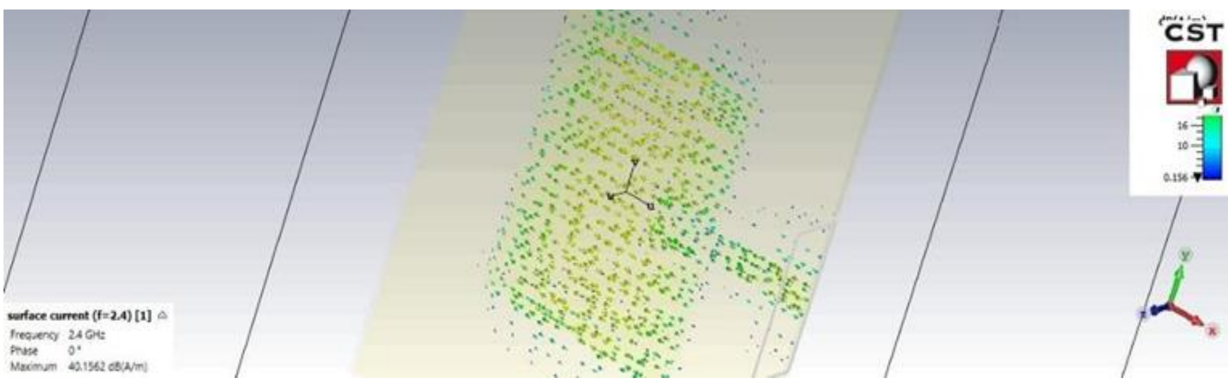
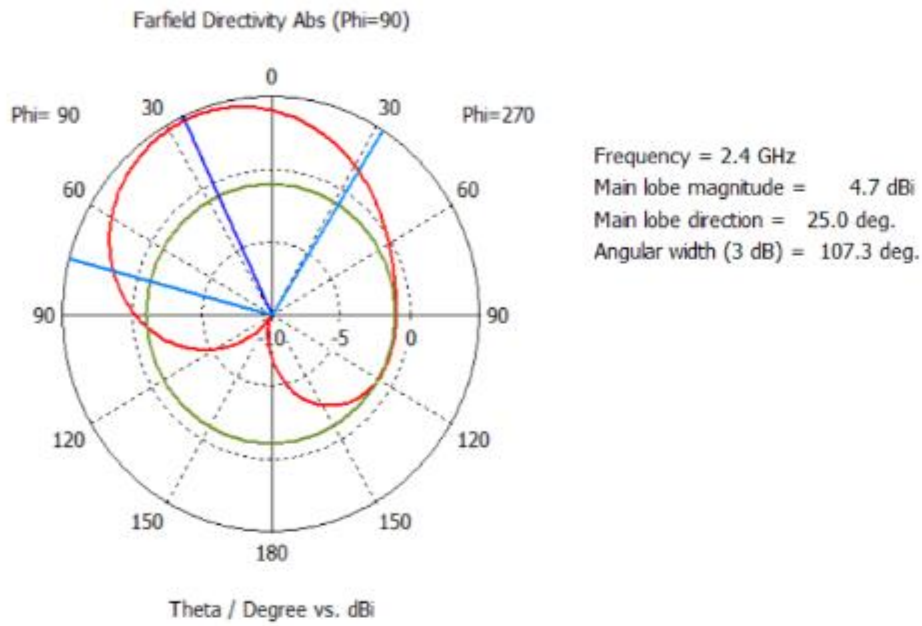


TABLE III.DIRECTIVITY

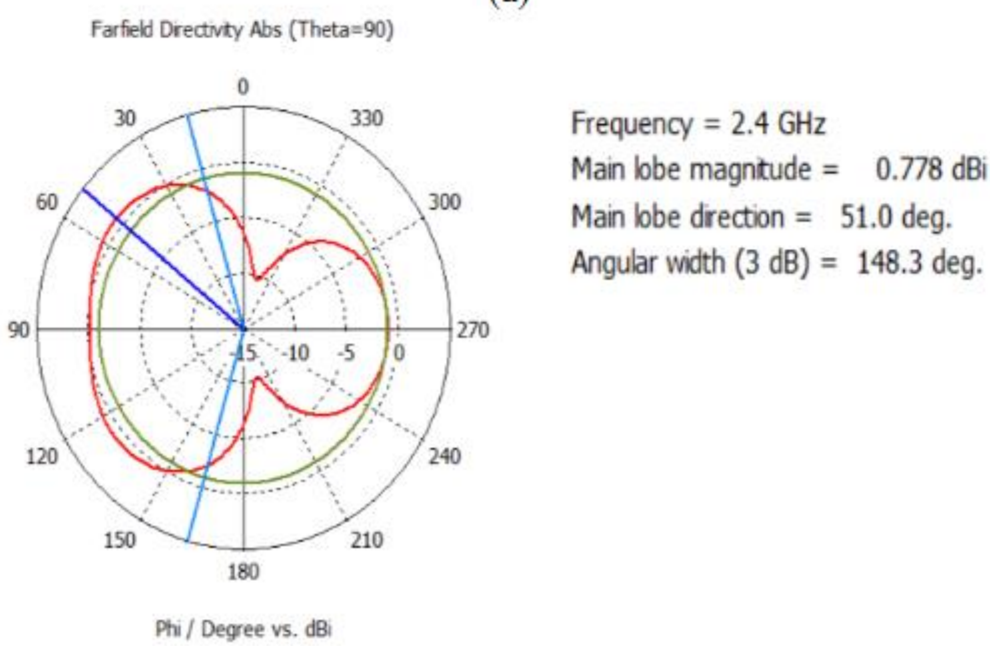
Resonant Frequency (GHz)	Directivity in Eplane(dB)	Directivity in Hplane(dB)
2.4	6.92	6.92

5) Fairfield graphs:

a)


Farfield Directivity Abs (Phi=90)
Phi= 90
Phi=270
Theta / Degree vs. dBi
Frequency = 2.4 GHz
Main lobe magnitude = 4.7 dBi
Main lobe direction = 25.0 deg.
Angular width (3 dB) = 107.3 deg.

(a)


Farfield Directivity Abs (Theta=90)
Phi / Degree vs. dBi
Frequency = 2.4 GHz
Main lobe magnitude = 0.778 dBi
Main lobe direction = 51.0 deg.
Angular width (3 dB) = 148.3 deg.

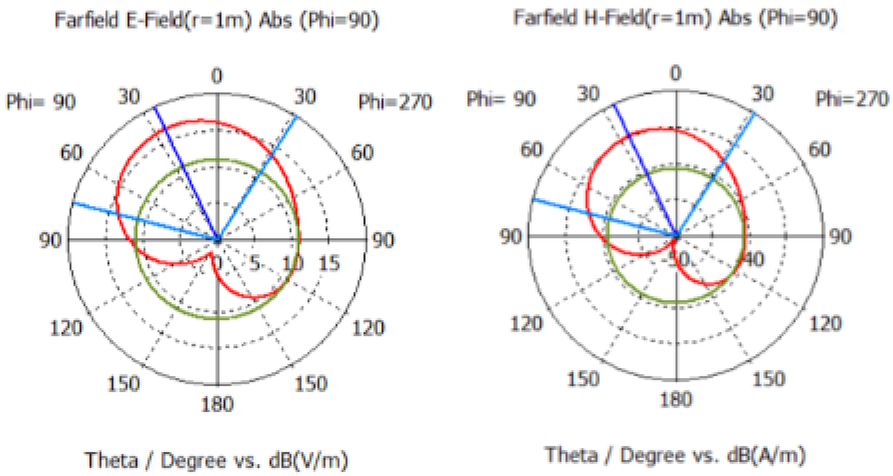
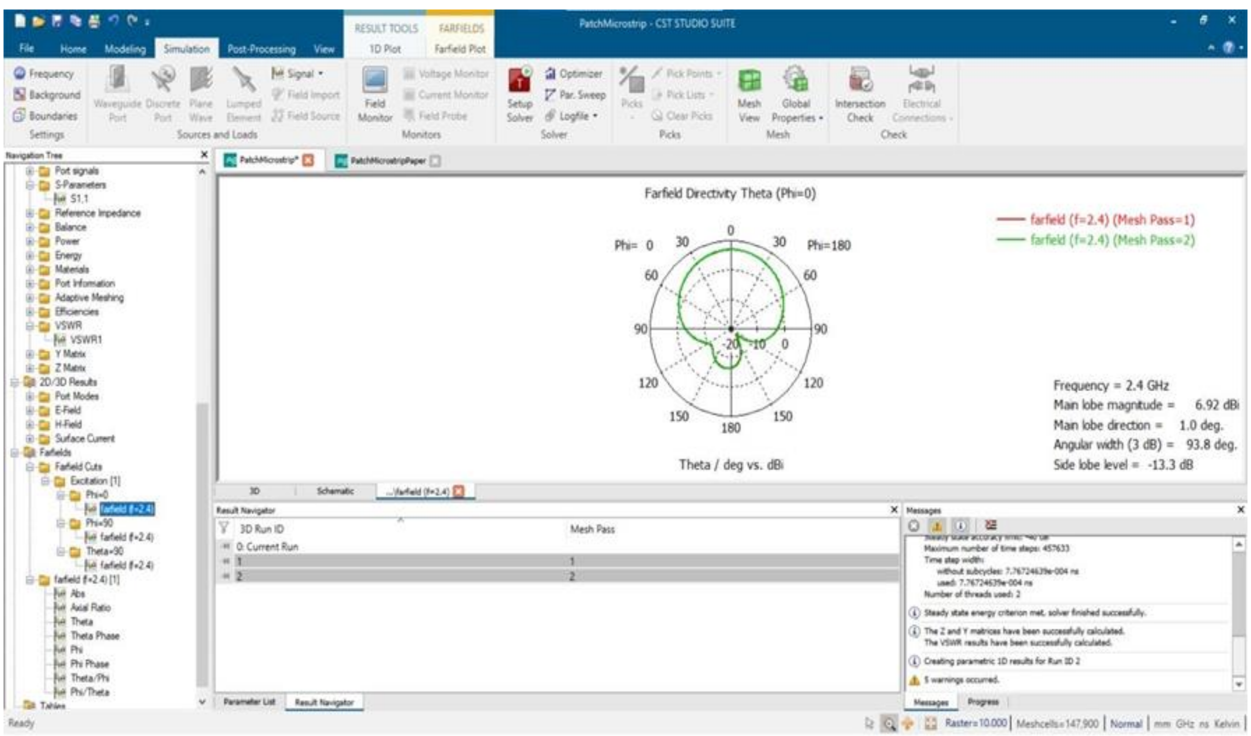
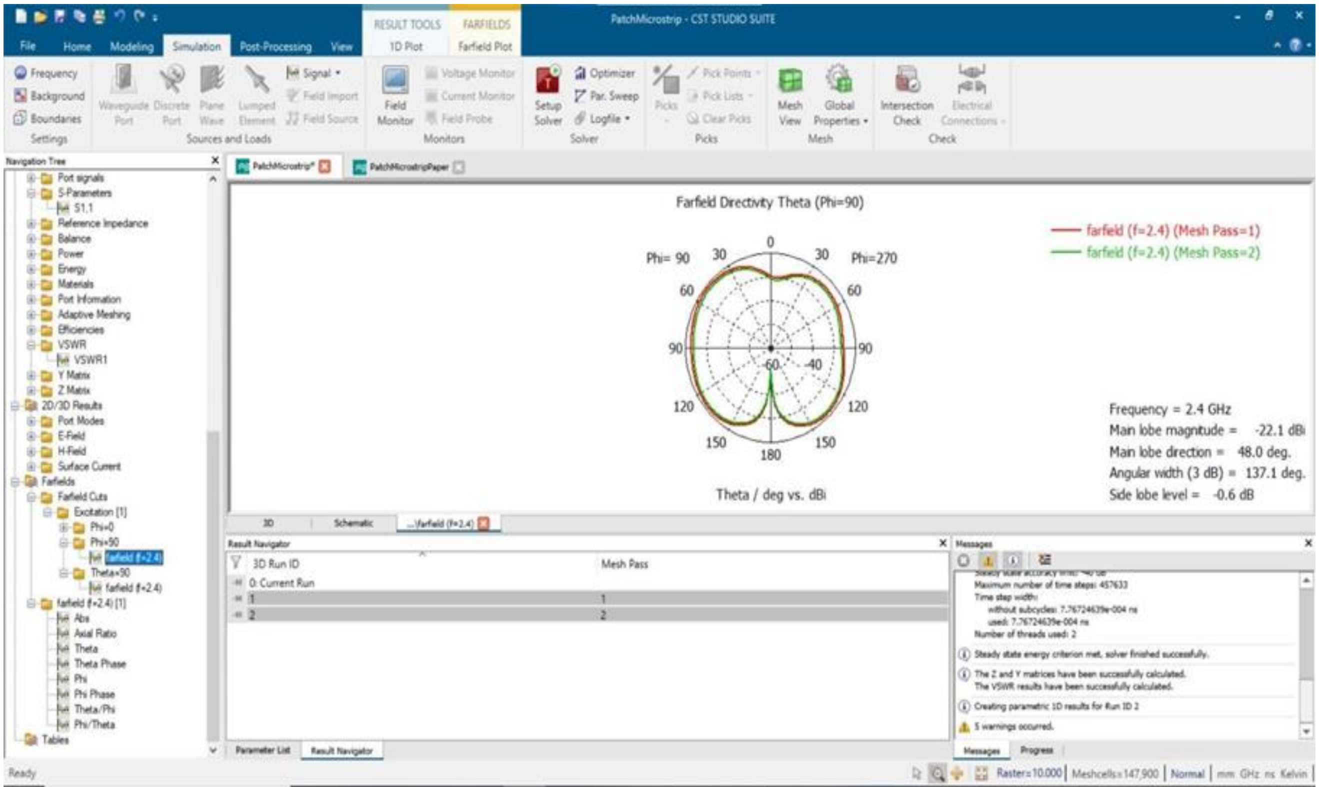
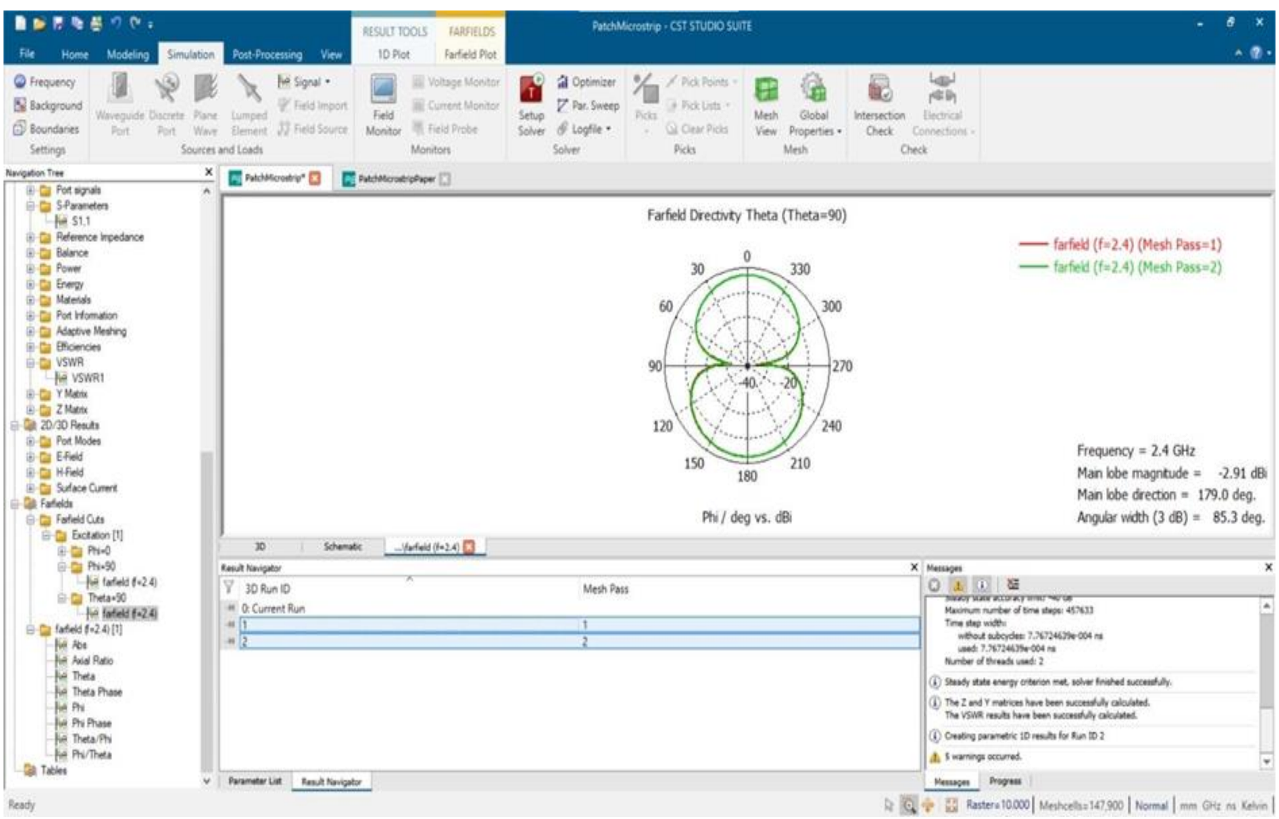


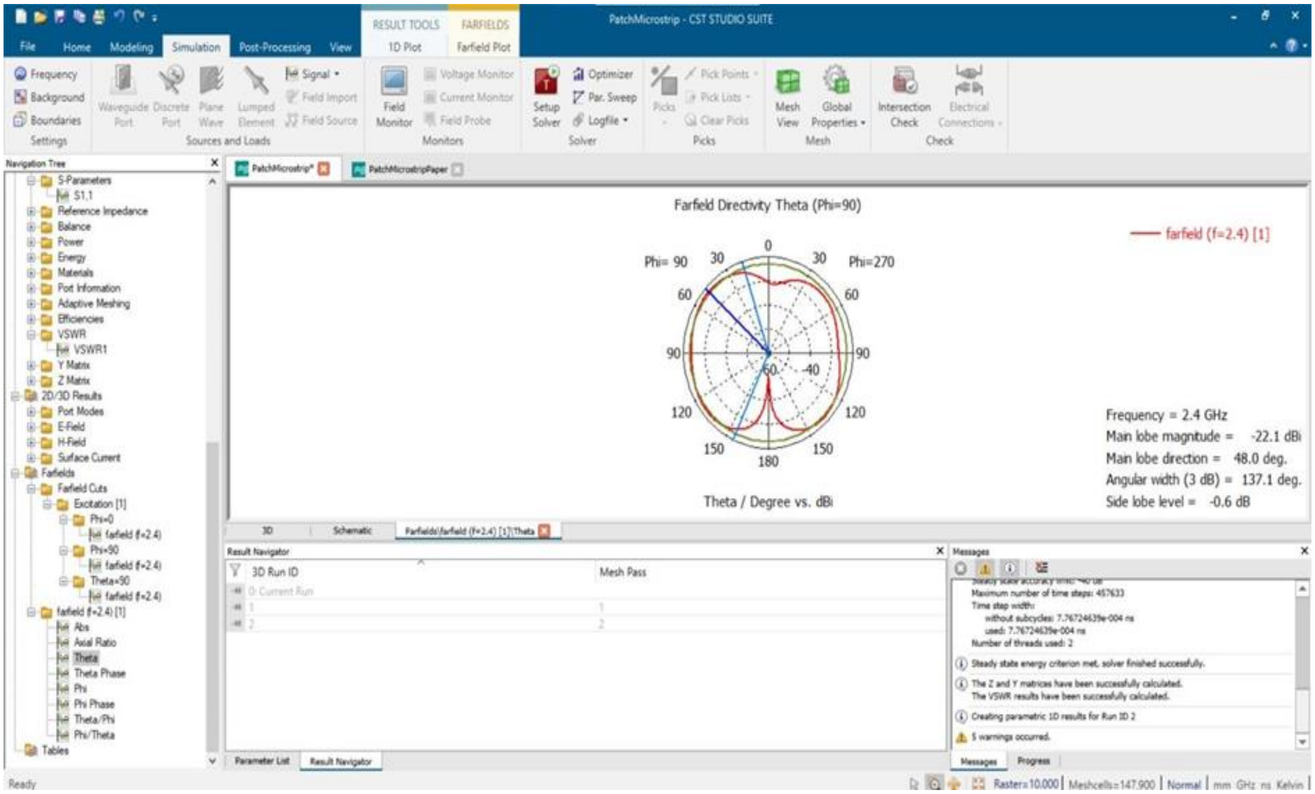
Fig. 7. Directivity at 2.4GHz E-plane and H-plane

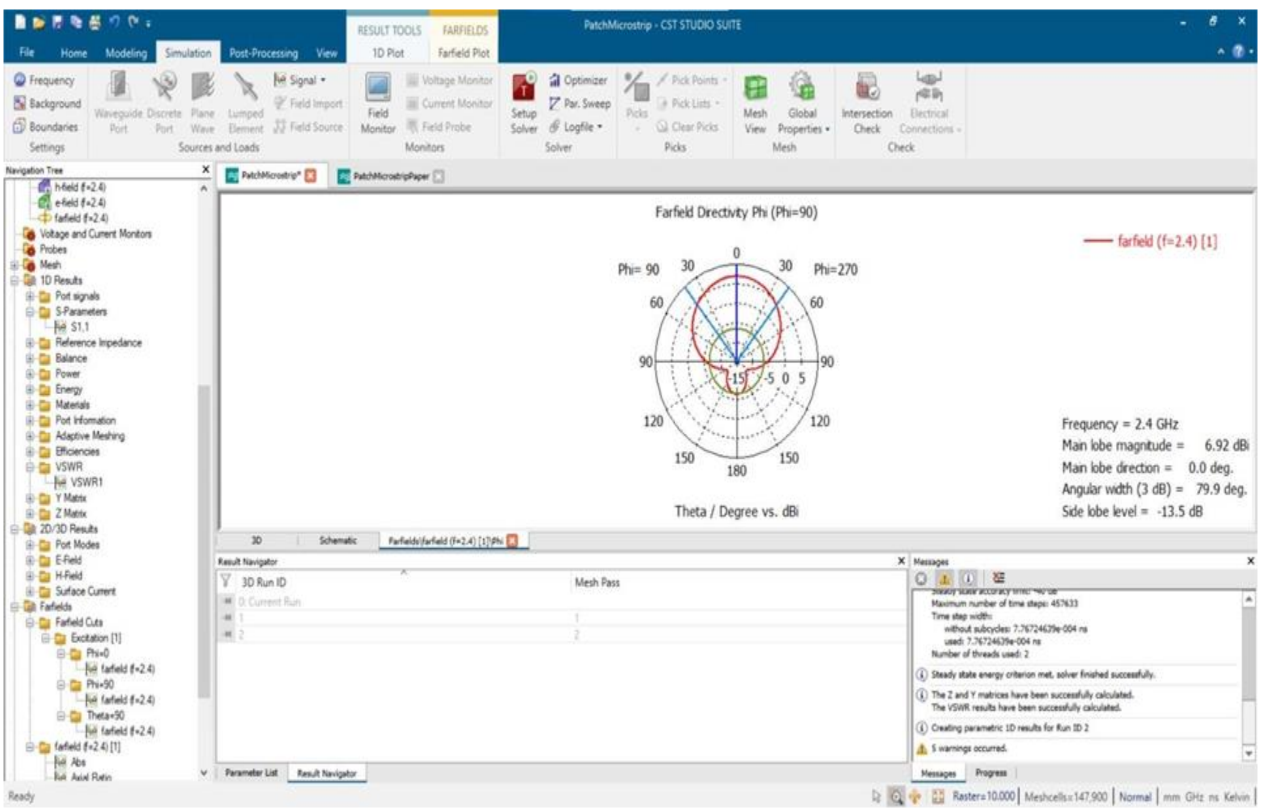
b)




PatchMicrostrip - CST STUDIO SUITE
Farfield Directivity Theta (Phi=90)
farfield (f=2.4) (Mesh Pass=1)
farfield (f=2.4) (Mesh Pass=2)
Theta / deg vs. dBi
Frequency = 2.4 GHz
Main lobe magnitude = -22.1 dBi
Main lobe direction = 48.0 deg.
Angular width (3 dB) = 137.1 deg.
Side lobe level = -0.6 dB


PatchMicrostrip - CST STUDIO SUITE
Farfield Directivity Theta (Theta=90)
farfield (f=2.4) (Mesh Pass=1)
farfield (f=2.4) (Mesh Pass=2)
Phi / deg vs. dBi
Frequency = 2.4 GHz
Main lobe magnitude = -2.91 dBi
Main lobe direction = 179.0 deg.
Angular width (3 dB) = 85.3 deg.


PatchMicrostrip - CST STUDIO SUITE
Farfield Directivity Theta (Phi=90)
farfield (f=2.4) [1]
Phi= 90
Phi=270
Theta / Degree vs. dBi
Frequency = 2.4 GHz
Main lobe magnitude = -22.1 dBi
Main lobe direction = 48.0 deg.
Angular width (3 dB) = 137.1 deg.
Side lobe level = -0.6 dB


PatchMicrostrip - CST STUDIO SUITE
Farfield Directivity Phi (Phi=90)
farfield (f=2.4) [1]
Phi= 90
Phi=270
Theta / Degree vs. dBi
Frequency = 2.4 GHz
Main lobe magnitude = 6.92 dBi
Main lobe direction = 0.0 deg.
Angular width (3 dB) = 79.9 deg.
Side lobe level = -13.5 dB

Discussion:

The variation of the two graphs is a result of the variation in the parameters used for the simulation as sums of these parameters are adjusted to give the most accurate results so they are a little bit different from each other but it is an accurate representation.

4. Team contribution to improve, tune, and optimize the operation

Firstly we try to contribute to the work of the project from the beginning to make every member specified at a certain part to complete the project without facing problems. As at the beginning two of us start to read the paper and analyze it then get the correct parameters of simulation then the other 2 start to use these parameters in simulation and follow the steps on the paper to get all the results mentioned above.

5. Challenges and problems during the work period of the project.

We have had some problem in the previous paper which is paper 3 in the drive of antenna such that the feeding position was wrong in the simulation and the parameters are not accurately correct so we tried to find another paper with valid result and we found this paper valid for results and simulate it on cst without any problems.

6. Team members' contributions to the work

Two of us works on analysis the paper and parameters (Shrourk and Sherin) 50%
and the other two works on the simulation and figures (Aya and Menna) 50%

And we all contributed on the report using google document

Conclusion:

A 2.4 GHz rectangular microstrip patch antenna with better performance was simulated successfully in this project. using substrate material caused improvements in return loss and bandwidth that was appropriate and slot dimensions that were tuned. The antenna's design has exceptional impedance matching, a robust gain, and a sufficient bandwidth, rendering it appropriate for contemporary wireless communication uses in the ISM band such as IEEE 802.11b/g WLAN systems,Bluetooth devices,Industrial, Scientific, and Medical (ISM) band communication devices

The outcomes demonstrate the design's potential for useful applications by offering a trade-off between cost, size, and performance. To validate the simulated performance, more research might look at real-world testing and other optimization strategies.