DAYANANDA SAGAR COLLEGE OF ENGINEERING

(An Autonomous Institute affiliated to Visvesvaraya Technological University (VTU), Belagavi,
Approved by AICTE and UGC, Accredited by NAAC with 'A' grade & ISO 9001 – 2015 Certified Institution)
Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560 111, India

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Open ended experiment Report submitted for the subject

Electromagnetics and Radiating Systems – 22EC52

Submitted by

CHAITRA KRISHNA GOUDA (1DS22EC054)

Under the Guidance of
Dr. KUMAR P
Prof. RAVIKUMAR S

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DSCE, Bengaluru

Evaluation

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VISVESVARAYA TECHNOLOGICAL UNIVERSITY
JNANASANGAMA, BELAGAVI-590018, KARNATAKA, INDIA
2024-25

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CERTIFICATE

This is to certify that Open ended experiment entitled **"4-Element Inset-Fed Rectangular Microstrip Patch Antenna Array at 2.4 GHz"** as part of **Electromagnetics and Radiating Systems – 22EC52** is a bonafide work carried out by Chaitra Krishna Gouda (1DS22EC054) as 30-marks component in partial fulfillment for the 5th semester of Bachelor of Engineering in Electronics and Communication Engineering of the Visvesvaraya Technological University, Belagavi during the year 2024-2025. The Open ended experiment report has been approved as it satisfies the academic requirements prescribed for the Bachelor of Engineering degree.

Signature of Faculty
Dr. KUMAR P
Prof. RAVIKUMAR S

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DECLARATION

We declare that we abide by the ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice. The work submitted in this report of **Electromagnetics and Radiating Systems – 22EC52**, V Semester BE, ECE has been compiled by referring to the relevant online and offline resources to the best of our understanding and in partial fulfillment of the requirement for the award of the degree of Bachelor of Engineering in Electronics and Communication Engineering, at Dayananda Sagar College of Engineering, an autonomous institution affiliated to VTU, Belagavi during the academic year 2024-2025. We hereby declare that the same has not been submitted in part or full for other academic purposes.

Chaitra Krishna Gouda
1DS22EC054

Place: Bengaluru

Date: 02-12-2024

ACKNOWLEDGEMENT

It is a great pleasure for us to acknowledge the assistance and support of many individuals who have been responsible for the successful completion of this project.

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In particular, we would like to thank Dr. B G Prasad, Principal of Dayananda Sagar College of Engineering, for his constant encouragement and advice.

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Chaitra Krishna Gouda
1DS22EC054

Table of Contents

AIM:

To design a 4-element inset-fed rectangular microstrip patch antenna array at 2.4 GHz and study its design parameters and performance.

INTRODUCTION:

A microstrip patch antenna is a type of planar antenna commonly used in wireless communication systems. It consists of a metallic patch on a grounded substrate and operates efficiently at microwave frequencies, including the 2.4 GHz band, widely used for Wi-Fi, Bluetooth, and other wireless protocols.

When multiple patch elements are arranged in an array configuration, the antenna's performance is significantly enhanced in terms of gain, directivity, and radiation pattern control. The inset-fed design improves impedance matching, ensuring optimal power transfer. The 4-element array design aims to achieve higher gain while maintaining compact size and efficiency, making it suitable for modern communication systems

ANTENNA DESIGN:

The design process involves determining the physical dimensions of the patch based on the given specifications, including resonant frequency, dielectric constant of the substrate, and substrate thickness.

Design Specifications:

Resonant Frequency (f_0): 2.4 GHz

Relative Permittivity of Substrate (ε_r): 4.4

Thickness of Substrate (h): 1.6 mm

Design Equations:

1. Effective Dielectric Constant (ε_{eex}):

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-0.5}$$

2. Width of the Patch (W):

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

3. Length of the Patch (L):

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{\text{eff}}}} - 2\Delta L$$

$$\Delta L = 0.412h\frac{(\varepsilon_{\text{eff}}+0.3)(W/h+0.264)}{(\varepsilon_{\text{eff}}-0.258)(W/h+0.8)}$$

4. Inset Depth (y_0) (50 Ohm Feed) :

$$y_0 = L\sqrt{\frac{R_{in}}{Z_0}}$$

- R_{in}: Input resistance at the edge of the patch.
- Z_0: Characteristic impedance (50 Ω).

SIMULATION STEPS:

Step 1: Starting HFSS

Step 2: Creating the antenna model

Step 3: Configurations (Settings)

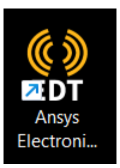
Step 4: Validation and analysis

Step 5: Results

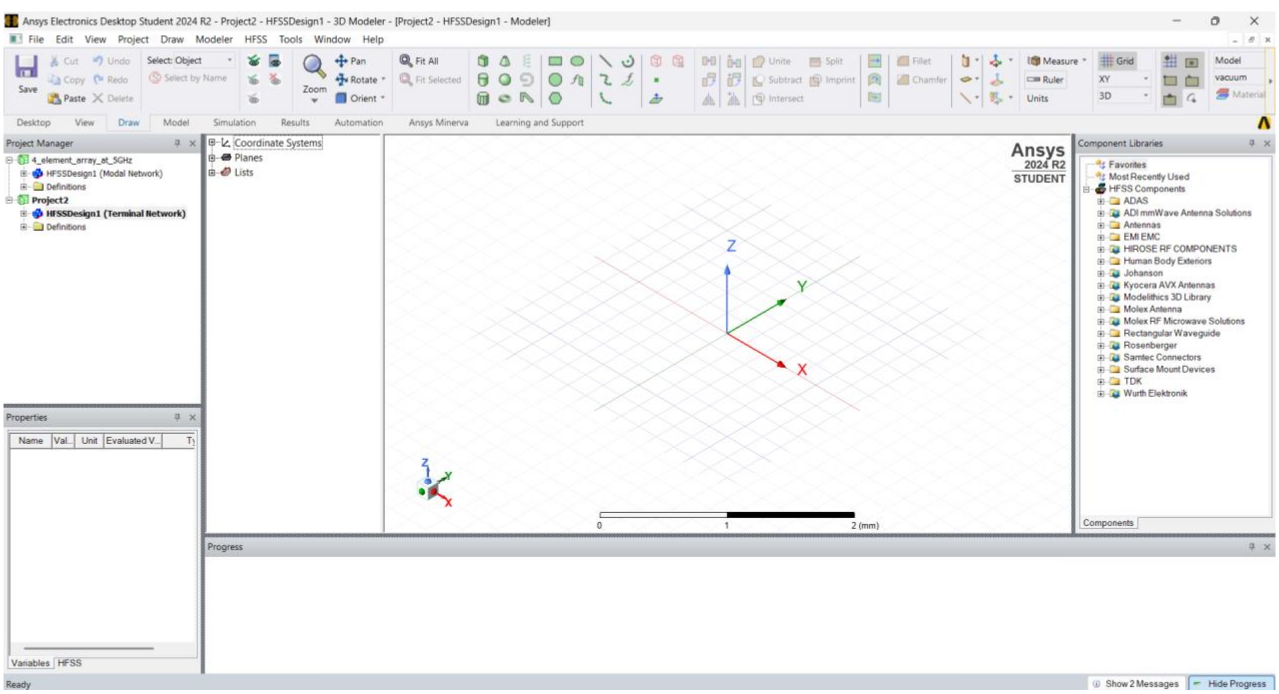
Step 1

- Starting HFSS

- Double Click on Ansys Electronics Desktop Student icon

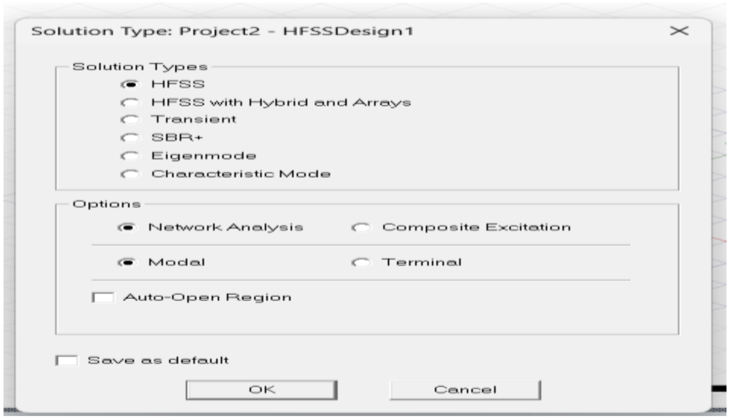


- A blank project with a blank HFSS design will be created as given below



- Creating the project
- Go to File, Save As
- Type name as inset microstrip
- Click on Save

Step 2



Creating the antenna model

- From the HFSS menu select Solution Type as given below
- Draw a rectangle(patch) with following coordinates

Command

Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate ...	Global			
Position	-Patch_X/2 ,-Patch_Y/2 ,0mm		-14mm , -14mm , 0mm	
Axis	Z			
XSize	Patch_X		28mm	
YSize	Patch_Y		28mm	

- Right click on rectangle1 in model section, Assign boundary, Perfect E
- Click ok

- Draw a box(substrate) with dimensions as given below,

Command

Name	Value	Unit	Evaluated Value	Description
Command	CreateBox			
Coordinate ...	Global			
Position	-Sub_X/2 ,-Sub_Y/2 ,0mm		-25mm , -25mm , 0mm	
XSize	Sub_X		50mm	
YSize	Sub_Y		50mm	
ZSize	-Sub_Z		-1.6mm	

- Right click on box1 in model section, assign material, type fr4 in search section, select fr4, press ok.

- Draw a rectangle (ground plane) with the following co-ordinates

Command

Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate ...	Global			
Position	-Sub_X/2 ,-Sub_Y/2 ,-Sub_Z		-25mm , -25mm , -1.6mm	
Axis	Z			
XSize	Sub_X		50mm	
YSize	Sub_Y		50mm	

- Right click on rectangle2 in model section, assign boundary, Perfect E, Click ok

- Draw one more rectangle(feedline) with the following dimensions

Command

Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate ...	Global			
Position	Sub_X/2 ,-Feed_Y/2 ,0mm		25mm , -1mm , 0mm	
Axis	Z			
XSize	-Feed_X		-2mm	
YSize	Feed_Y		2mm	

- Draw one more rectangle(cut) with the following dimensions

Command

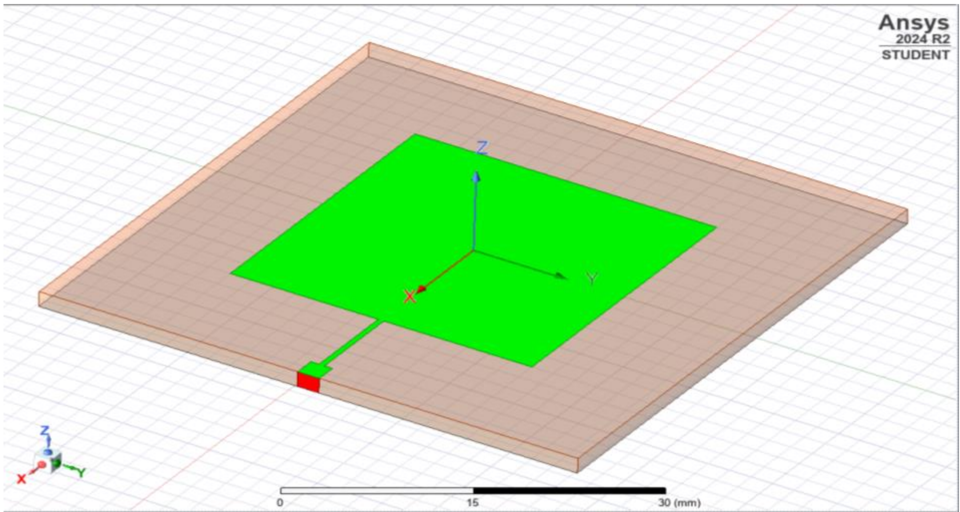
Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate ...	Global			
Position	Sub_X/2-Feed_X ,-QW_Y/2...		23mm , -0.25mm , 0mm	
Axis	Z			
XSize	-QW_X		-12mm	
YSize	QW_Y		0.5mm	

- By pressing down the control button select rectangle1 and rectangle4, click subtract
- By pressing down the control button select rectangle1 and rectangle3, click unite
- Click on visibility tab on the right corner of the window, click on XY dropdown and select YZ
- Draw rectangle with following dimensions

Command

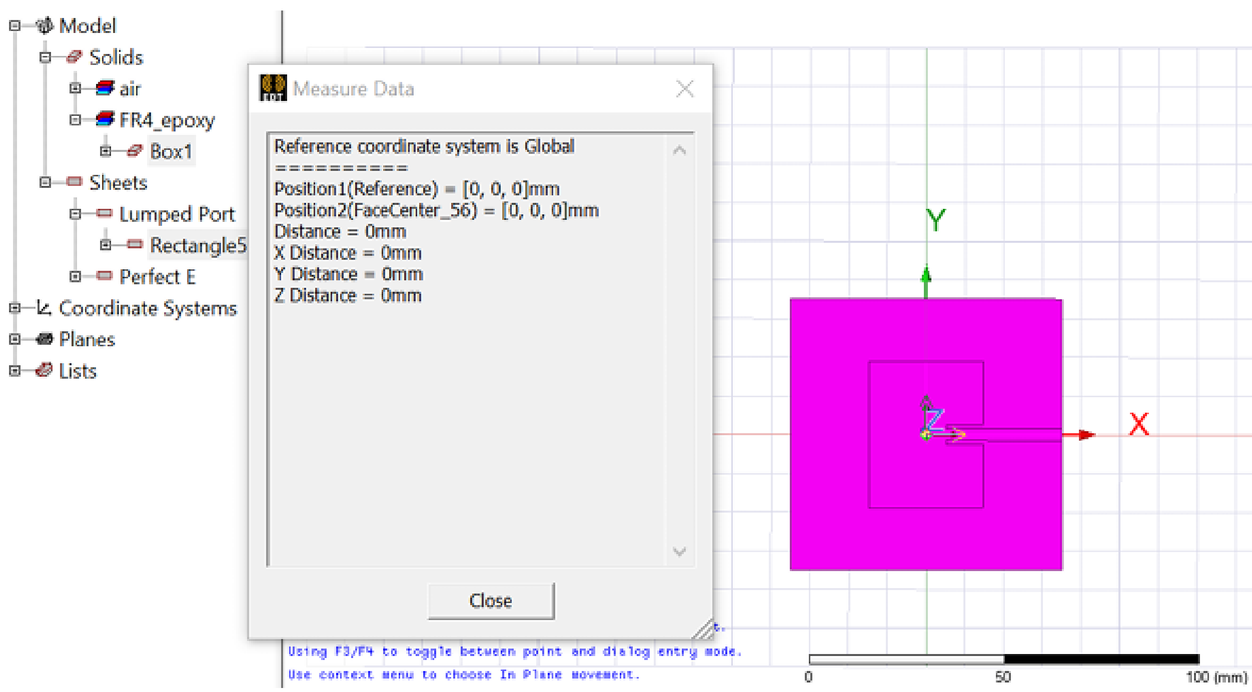
Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate ...	RelativeCS1			
Position	Sub_X ,-26mm ,-Sub_Z		50mm , -26mm , -1.6mm	
Axis	X			
YSize	Feed_Y		2mm	
ZSize	Sub_Z		1.6mm	

- Right click on rectangle5 in model section, assign excitation, port, lumped port, resistance 50 Ohms, next, click on dropdown under integration line and select choose new line.
- Draw a line from bottom center to the top center of the rectangle5, next, finish.
- Click on visibility tab on the right corner of the window, click on YZ dropdown and select XY.
- Now the model will look like as given below,



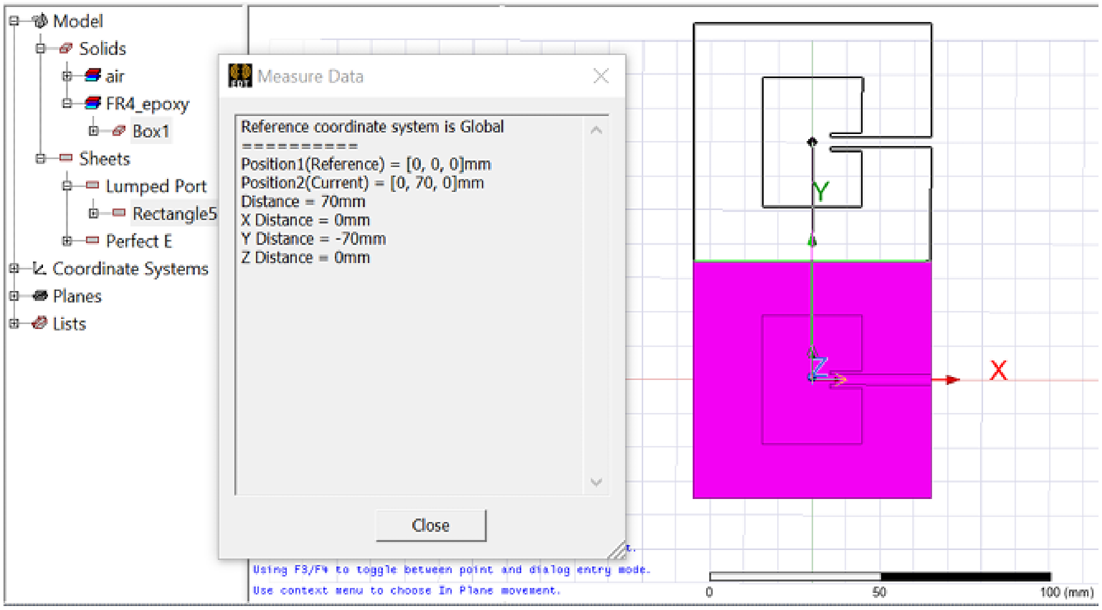
• Press control A (select all objects) in work area, right click on antenna, select edit, duplicate along line

• Press once at the origin as given below



• Note that the Position1 and Position2 are both showing [0,0,0] coordinates

• Move the cursor by 70mm to the positive side of Y-axis(you can verify by seeing Position2 which should be [0,70,0]mm, then click once again as given below

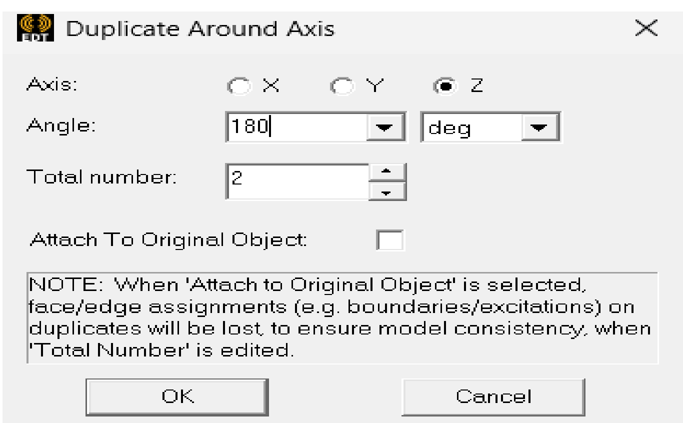


• Press ok in the next window that appears

• Now two separate antennas are created

• Press control A (select all objects) in work area, right click on antenna, select edit, duplicate around axis.

• Enter The Below Values



• Now four separate antennas are created

• Select both the substrates of two antennas and click on unite

• Select both the ground planes of two antennas and click on unite

- Create a box with dimensions as given below

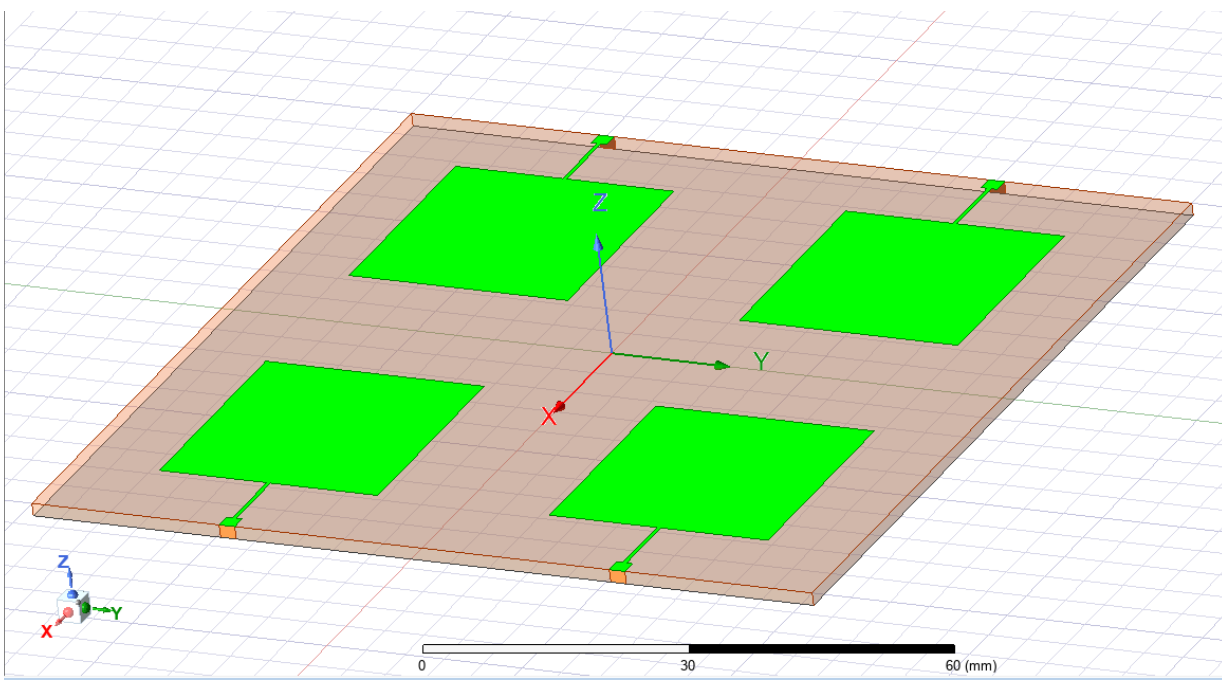
Command

Name	Value	Unit	Evaluated Value	Description
Command	CreateRegion			
Coordinate ...	Global			
+X Padding...	Absolute Offset			
+X Padding...	20	mm	20mm	
-X Padding ...	Absolute Offset			
-X Padding ...	20	mm	20mm	
+Y Padding...	Absolute Offset			
+Y Padding...	20	mm	20mm	
-Y Padding ...	Absolute Offset			
-Y Padding ...	20	mm	20mm	
+Z Padding...	Absolute Offset			
+Z Padding...	20	mm	20mm	

- Assign the material of box2 as “air”.

- Right click on Box2 in model section, assign boundary, radiation, ok.

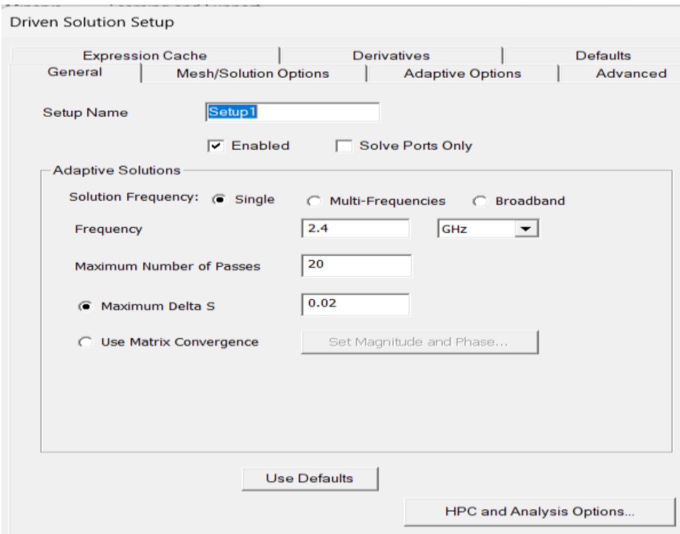
- Now your model is constructed along with radiation boundary.



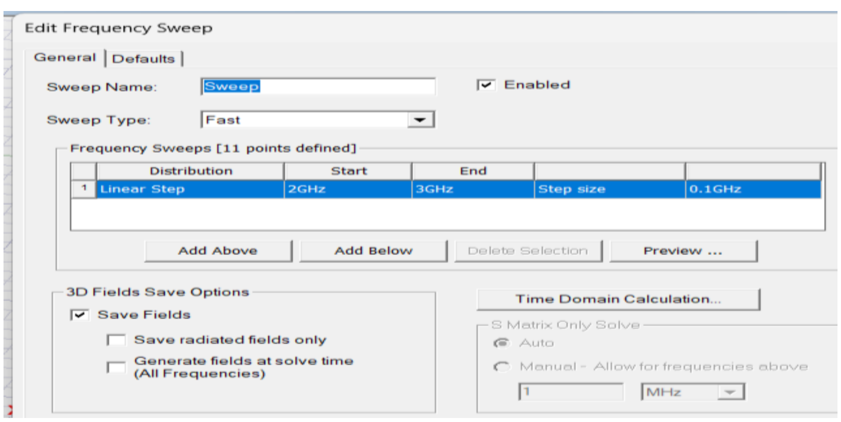
Step 3

Configurations (Settings)

- In the project manager section, Right click on analysis, add solution setup, advanced
- Enter the values as given below



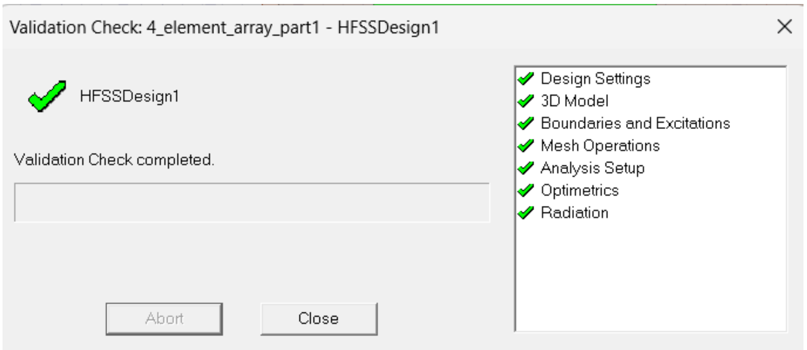
- Click on ok.
- In the next window that appears after clicking ok, enter the values as given below



Step 4 Validation and analysis

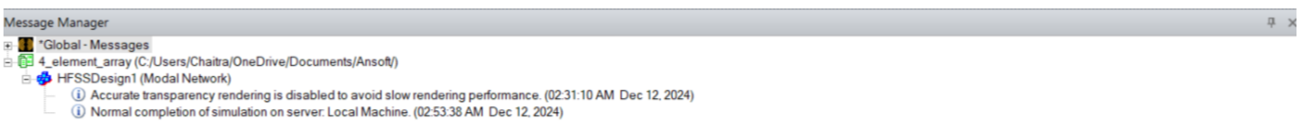
- Go to HFSS, Validation check

• The following window would appear if the model created is correct.



• Go to HFSS, Analyze all. It will take some time to calculate results based on antenna complexity and computer configuration which is running the software.

• If simulation goes well then you will receive a message in the message manager section as Normal completion of simulation on server: Local machine as given in figure below.

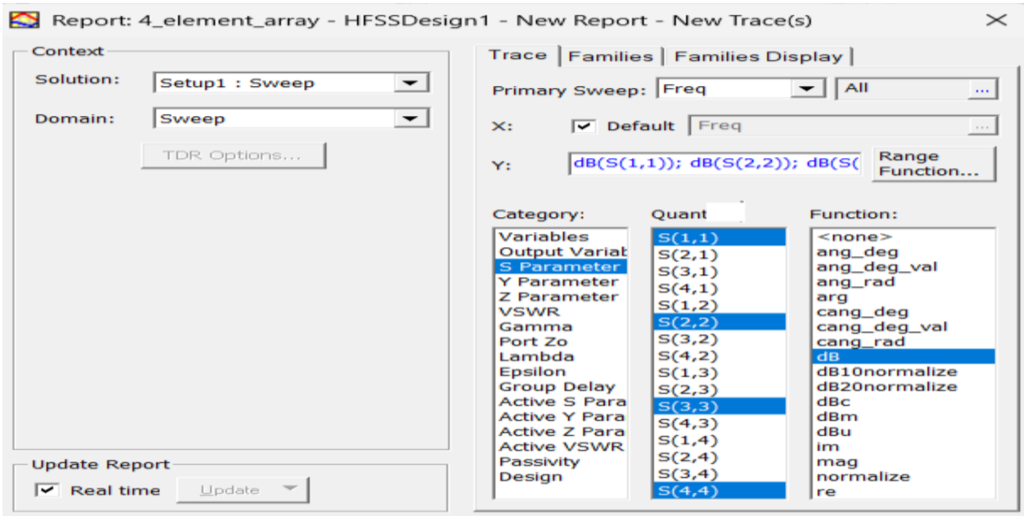


• If any errors are there then such error will be shown in message manager section. They must be resolved.

STEP 5

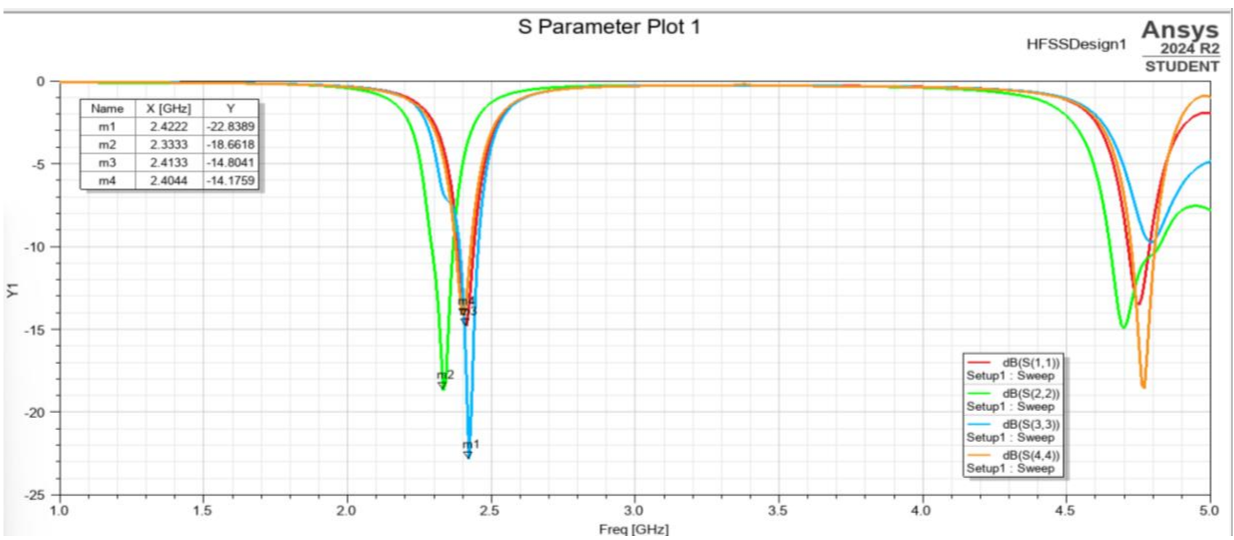
• Right click on results in project manager section, create modal solution data report, rectangular plot

• The following window should appear

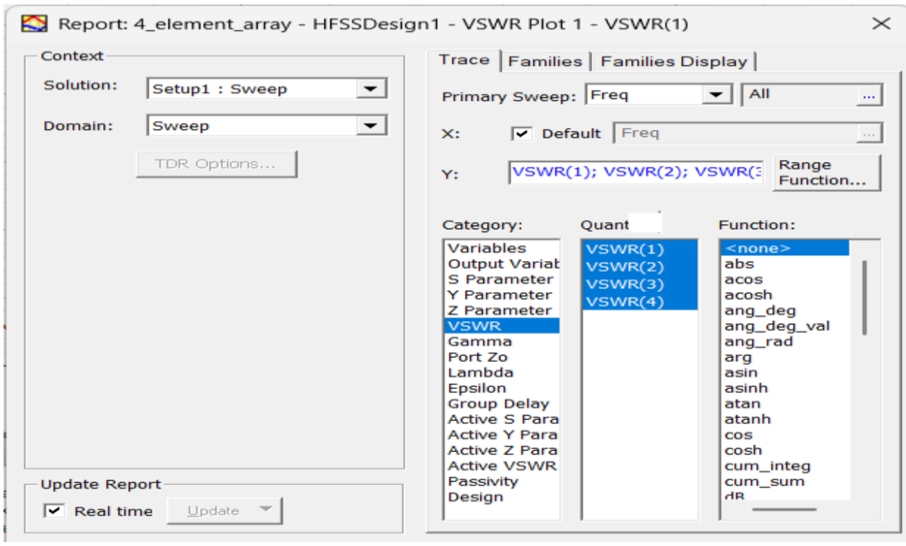


- Click on new report

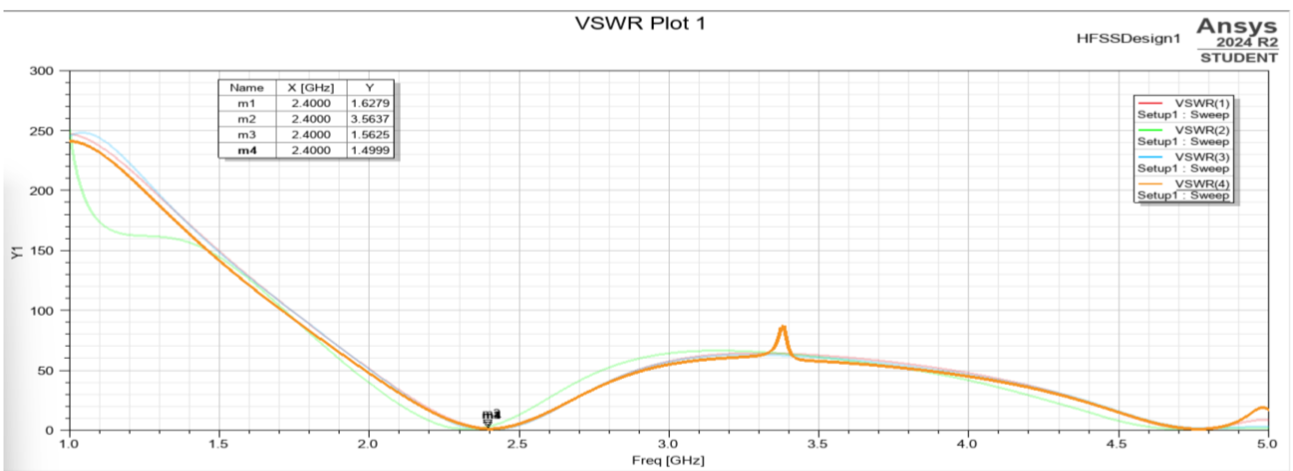
- The following window will appear showing S11 parameter (Input reflection coefficient)



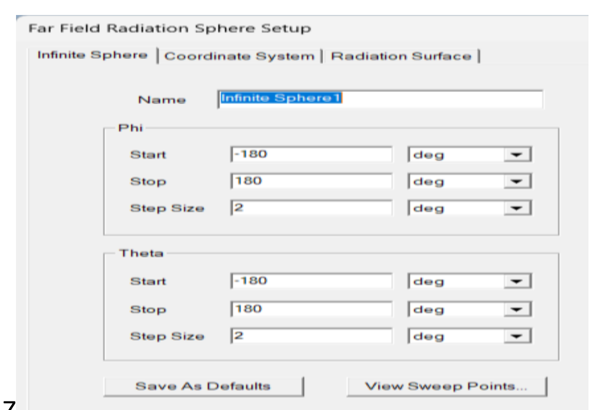
- In the same way Right click on results in project manager section, create modal solution data report, rectangular plot, select VSWR in category section, click on new report as given below



• The VSWR result will appear as given below



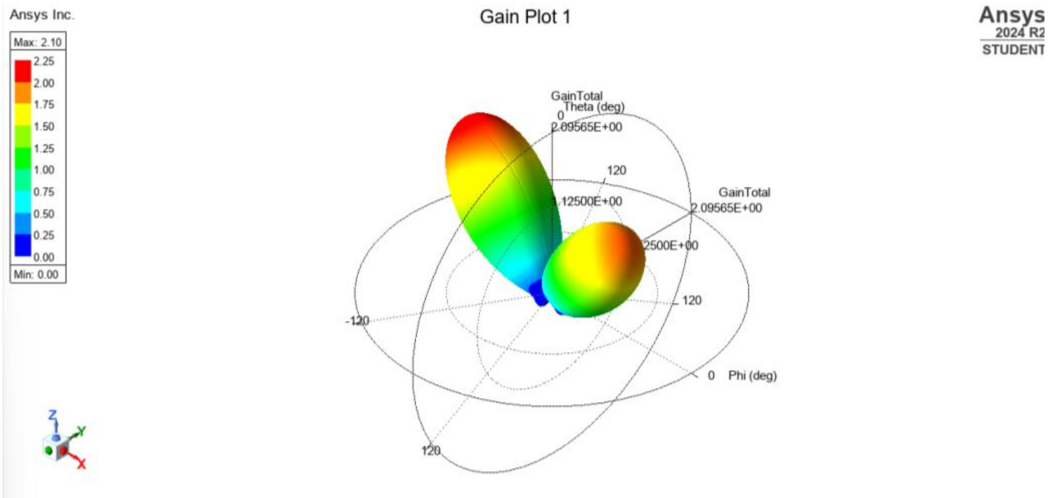
• Right click on radiation in project manager window, insert far field setup, infinite sphere • Enter the values as given below



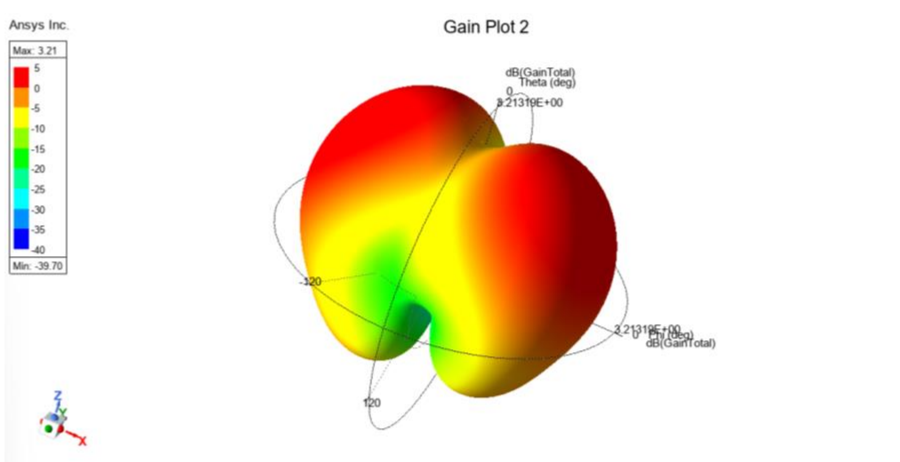
Z

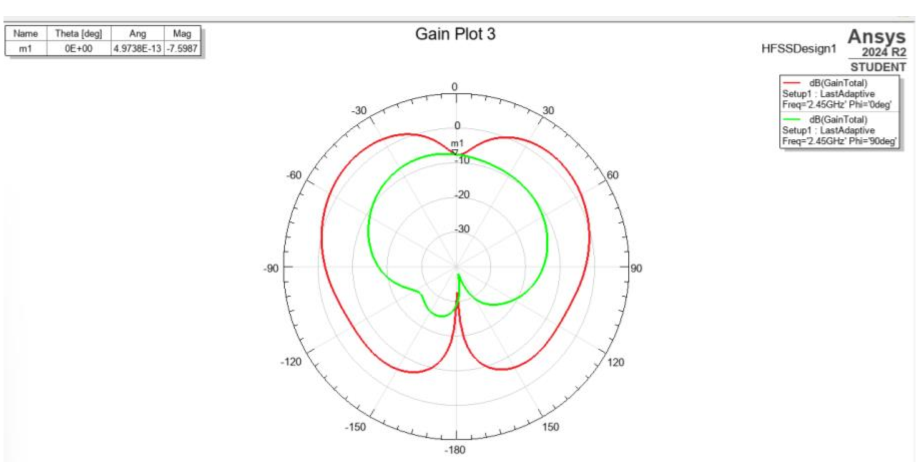
- Click on new report.

- The following 3D radiation pattern will appear

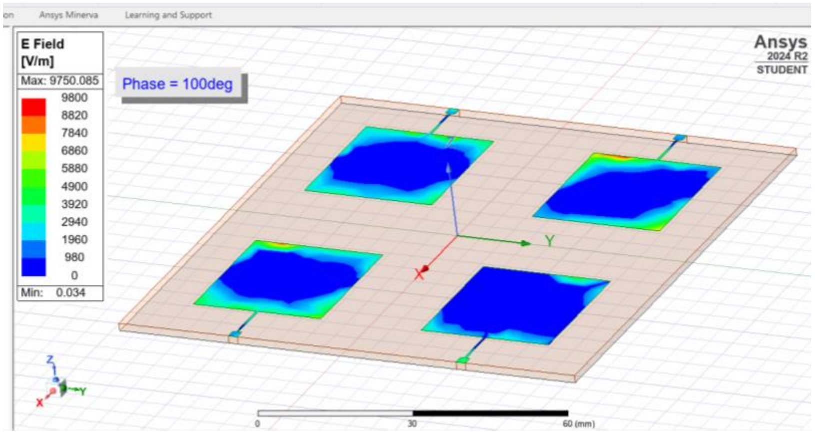


In dB,





Radition Pattern,



SL. NO.	PLOTS	VALUES			
		ELEMENT 1	ELEMENT 2	ELEMENT 3	ELEMENT 4
1.	S11 (in dB) at 2.4GHz	-22.8389	-18.6618	-14.6018	-14.1759
2.	VSWR at 2.4GHz	1.6279	3.5637	1.5625	1.4999

RESULTS AND DISCUSSION:

The inset-fed microstrip patch antenna array is a widely used design due to its simplicity and efficiency at targeted frequencies, such as 2.4 GHz. Below is a concise summary of results and discussions associated with this design:

Return Loss (S_{11}): Achieves a return loss below -10 dB, indicating excellent impedance matching and minimal signal reflection.

Bandwidth: The bandwidth achieved is suitable for wireless communication, covering the 2.4 GHz ISM band and ensuring compatibility with Wi-Fi and Bluetooth protocols.

Gain: The array demonstrates improved gain, typically ranging from 7 dBi to 10 dBi, depending on the spacing and feeding structure.

Radiation Pattern: The antenna array provides a directional radiation pattern with a low level of side lobes, enhancing signal strength and minimizing interference.

ADVANTAGES:

1. Compact Size: Ideal for modern communication systems requiring small, lightweight antenna designs.

2. Ease of Fabrication: The planar structure is cost-effective and simple to produce using standard PCB manufacturing techniques.

3. Improved Impedance Matching: The inset-fed design ensures precise control over impedance, enhancing power transfer efficiency.

4. High Gain and Directionality: Offers increased signal strength and focused radiation, making it ideal for long-range communication.

APPLICATION:

1. Wireless Communication: Used in Wi-Fi (802.11b/g/n), Bluetooth, and WLAN systems operating in the 2.4 GHz band.

2. IoT Devices: Essential for smart home and industrial IoT applications requiring reliable connectivity.

3. Satellite Communication: Suitable for small satellite systems due to its lightweight and efficient design.

4. Radar Systems: Applicable in short-range radar and sensing applications.

CONCLUSION:

The 4-element inset-fed microstrip patch antenna array at 2.4 GHz is a compact, efficient design for wireless communication. It provides improved gain, excellent impedance matching, and a directional radiation pattern, making it suitable for applications like Wi-Fi, satellite communication, and IoT. The design is cost-effective and easy to fabricate, offering a balance between performance and practicality for modern communication needs.