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)

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Open ended experiment Report submitted for the subject

Electromagnetics and Radiating Systems – 22EC52

Submitted by

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Under the Guidance of
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2024-25

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Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560 111, India

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

CERTIFICATE

This is to certify that Open ended experiment entitled **"Probe-fed microstrip patch antenna at 4GHz"** as part of **Electromagnetics and Radiating Systems – 22EC52** is a Bonafide work carried out by **Kushal S 1DS22EC113 , Manish S 1DS22EC120, Manisha S 1DS22EC121, Maurya M 1DS22EC124** 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
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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.

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Place: Bengaluru

Date: 04-12-2024

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Aim:

To design a radiation pattern of Probe-fed microstrip patch antenna at 4GHz and to plot S and VSWR parameters.

Introduction:

Probe-fed microstrip patch antennas have emerged as a popular choice for 5G applications, particularly at the 4 GHz frequency range, due to their compact size, low profile, and ease of integration with other electronic components. These antennas consist of a metallic patch on top of a dielectric substrate, with a ground plane on the bottom and a coaxial probe feed connecting directly to the patch through the substrate. The probe feeding method offers several advantages, including efficient power transfer, controllable input impedance, and reduced spurious radiation compared to edge-fed designs. When designing a probe-fed microstrip patch antenna for 4 GHz operation, key considerations include substrate selection, patch dimensions, feed point location, and bandwidth enhancement techniques. Proper design can yield antennas with return loss better than -10 dB, bandwidth of 2-5% of the center frequency, gain of 5-8 dBi, and a broadside radiation pattern with a half-power beamwidth of about 60-70 degrees. These characteristics make probe-fed microstrip patch antennas well-suited for various 5G applications, such as small cell base stations, customer premises equipment (CPE), and Internet of Things (IoT) devices, where compact and efficient antennas are crucial for optimal performance in the sub-6 GHz frequency band.

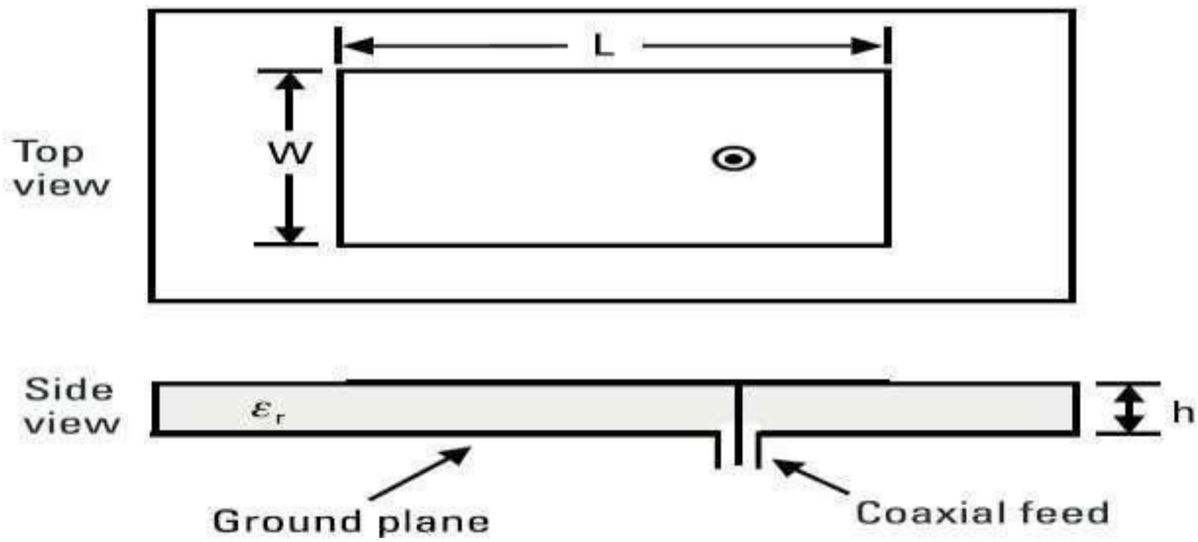
A probe-fed microstrip patch antenna for 5G applications at 4 GHz typically consists of the following components:

1. Patch: A thin metallic layer on top of the substrate that acts as the radiating element. For a rectangular patch, the width and length are calculated based on the desired frequency and substrate properties.

2. Substrate: A dielectric material that separates the patch from the ground plane. For 4 GHz applications, low-loss materials like Rogers RT/Duroid 5880 are often used.

3. Ground plane: A conductive layer on the bottom of the substrate.

4. Probe feed: A coaxial cable that connects to the patch through a via in the substrate.



Antenna Designs:

1. Design parameters:

- Frequency(fo) – 4GHz
- Relative permittivity of substrate(εr) – 4.4
- Thickness of substrate(h) – 1.6 mm

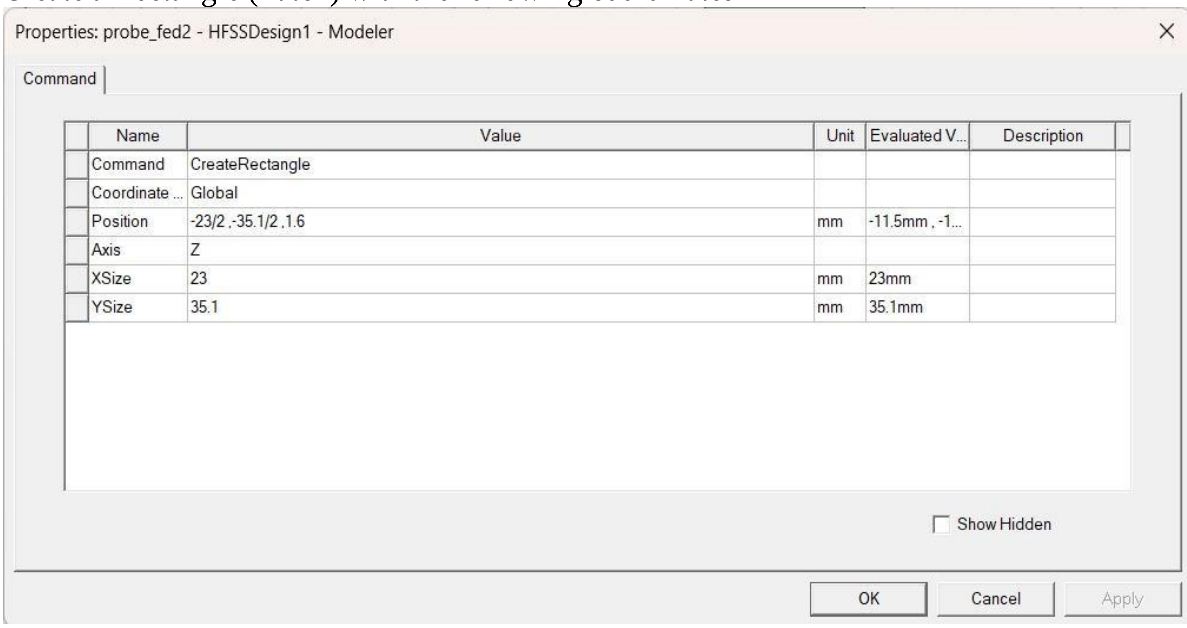
2. Design Equation:

$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_R+1}{2}}}; \quad \varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right]$$

$$Length = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right)$$

Simulation Steps:

Create a Rectangle (Patch) with the following coordinates



Properties: probe_fed2 - HFSSDesign1 - Modeler

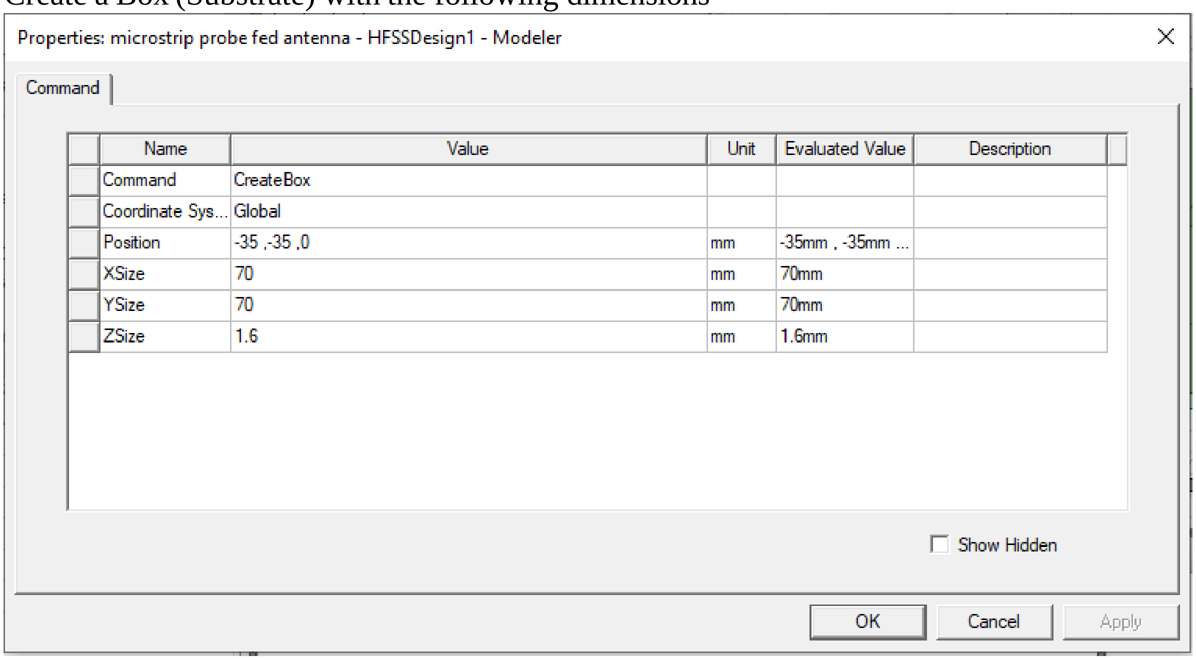
Command

Name	Value	Unit	Evaluated V...	Description
Command	CreateRectangle			
Coordinate ...	Global			
Position	-23/2 ,-35.1/2 ,1.6	mm	-11.5mm , -1...	
Axis	Z			
XSize	23	mm	23mm	
YSize	35.1	mm	35.1mm	

Show Hidden

OK Cancel Apply

Create a Box (Substrate) with the following dimensions



Properties: microstrip probe fed antenna - HFSSDesign1 - Modeler

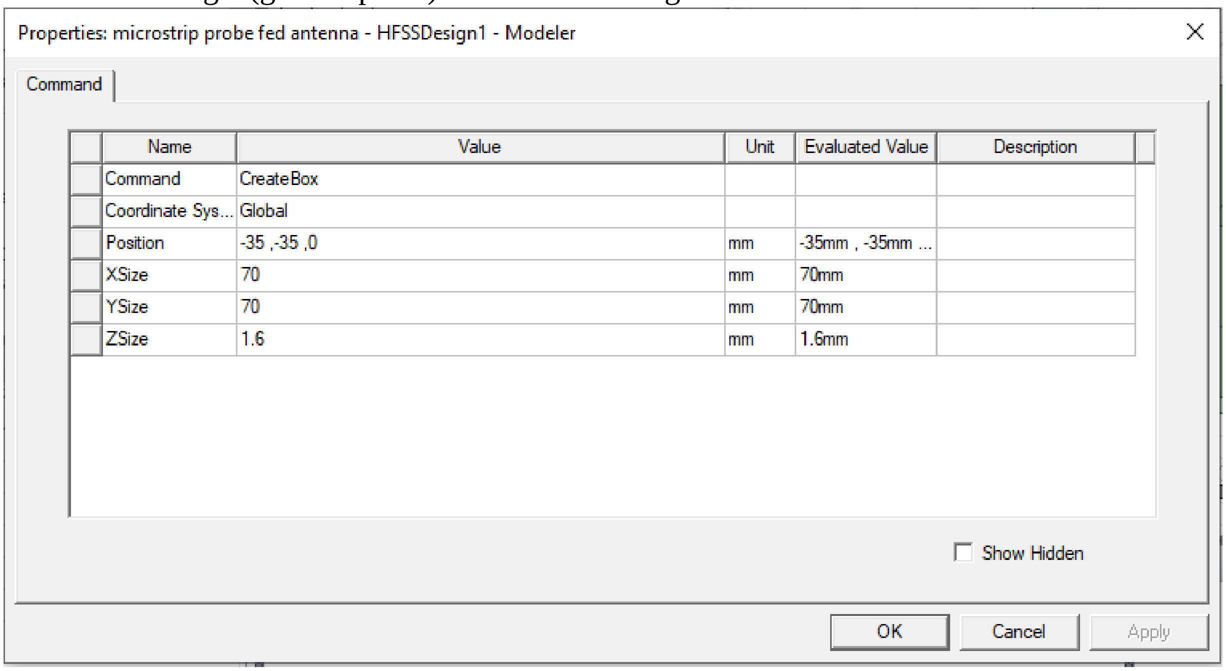
Command

Name	Value	Unit	Evaluated Value	Description
Command	CreateBox			
Coordinate Sys...	Global			
Position	-35 ,-35 ,0	mm	-35mm , -35mm ...	
XSize	70	mm	70mm	
YSize	70	mm	70mm	
ZSize	1.6	mm	1.6mm	

Show Hidden

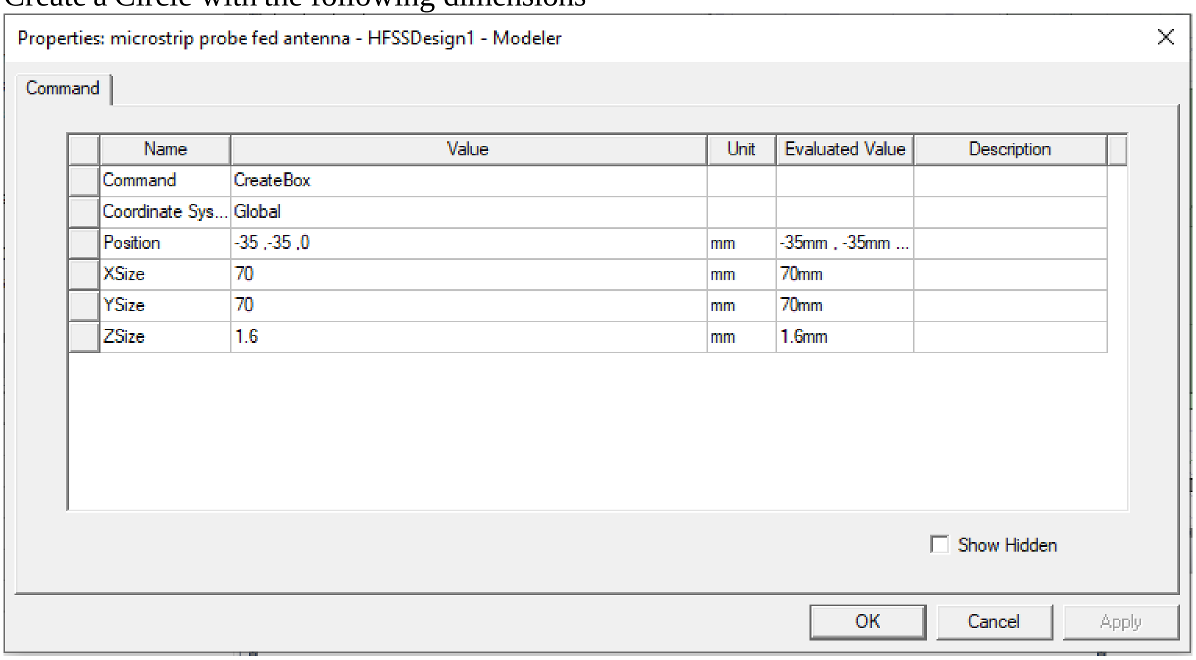
OK Cancel Apply

Create a Rectangle (ground plane) with the following dimensions



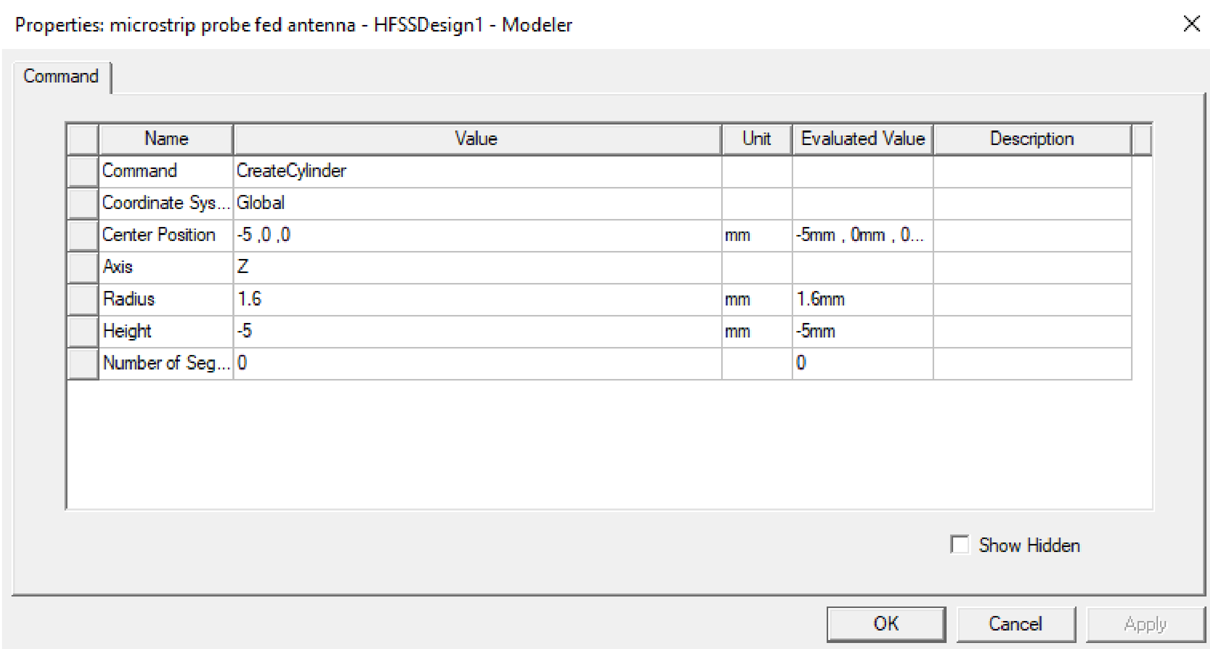
Name	Value	Unit	Evaluated Value	Description
Command	CreateBox			
Coordinate Sys...	Global			
Position	-35 ,-35 ,0	mm	-35mm , -35mm ...	
XSize	70	mm	70mm	
YSize	70	mm	70mm	
ZSize	1.6	mm	1.6mm	

Create a Circle with the following dimensions



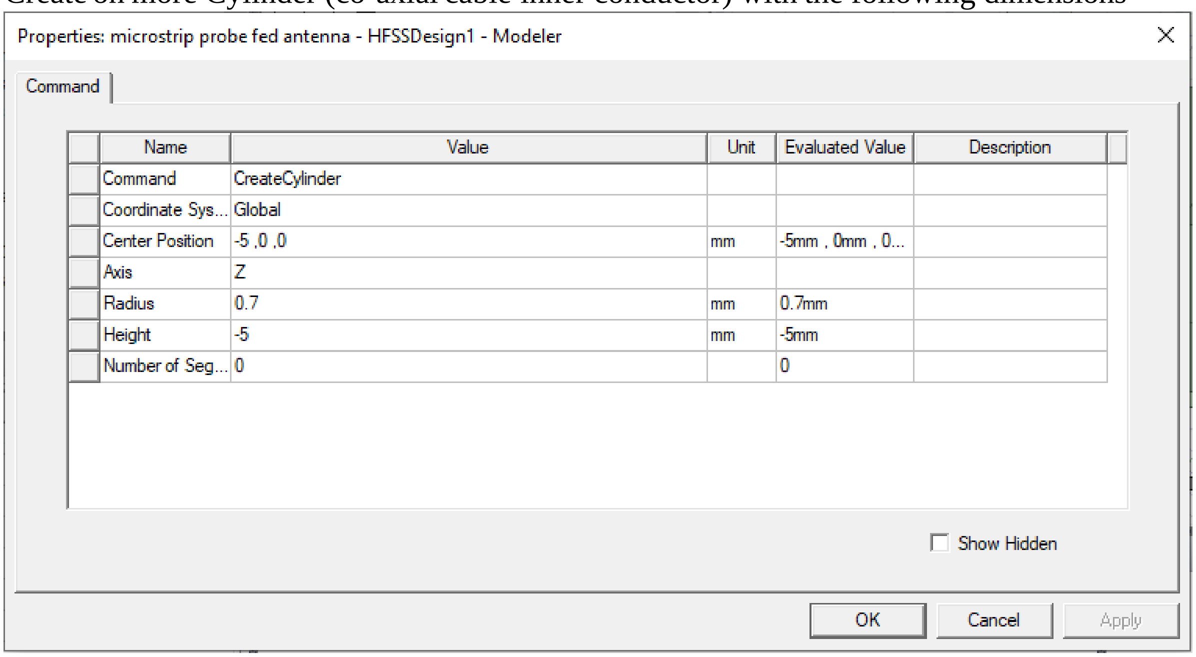
Name	Value	Unit	Evaluated Value	Description
Command	CreateBox			
Coordinate Sys...	Global			
Position	-35 ,-35 ,0	mm	-35mm , -35mm ...	
XSize	70	mm	70mm	
YSize	70	mm	70mm	
ZSize	1.6	mm	1.6mm	

Create a Cylinder (co-axial cable outer layer) with the following dimensions



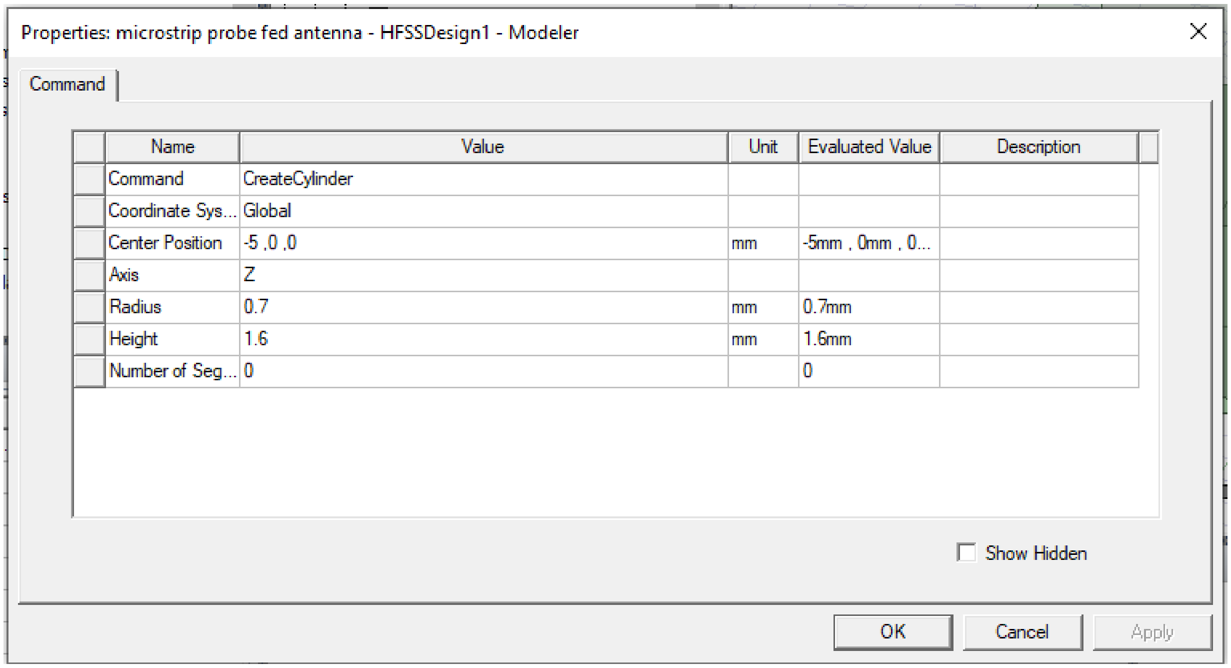
Name	Value	Unit	Evaluated Value	Description
Command	CreateCylinder			
Coordinate Sys...	Global			
Center Position	-5 ,0 ,0	mm	-5mm , 0mm , 0...	
Axis	Z			
Radius	1.6	mm	1.6mm	
Height	-5	mm	-5mm	
Number of Seg...	0		0	

Create on more Cylinder (co-axial cable inner conductor) with the following dimensions



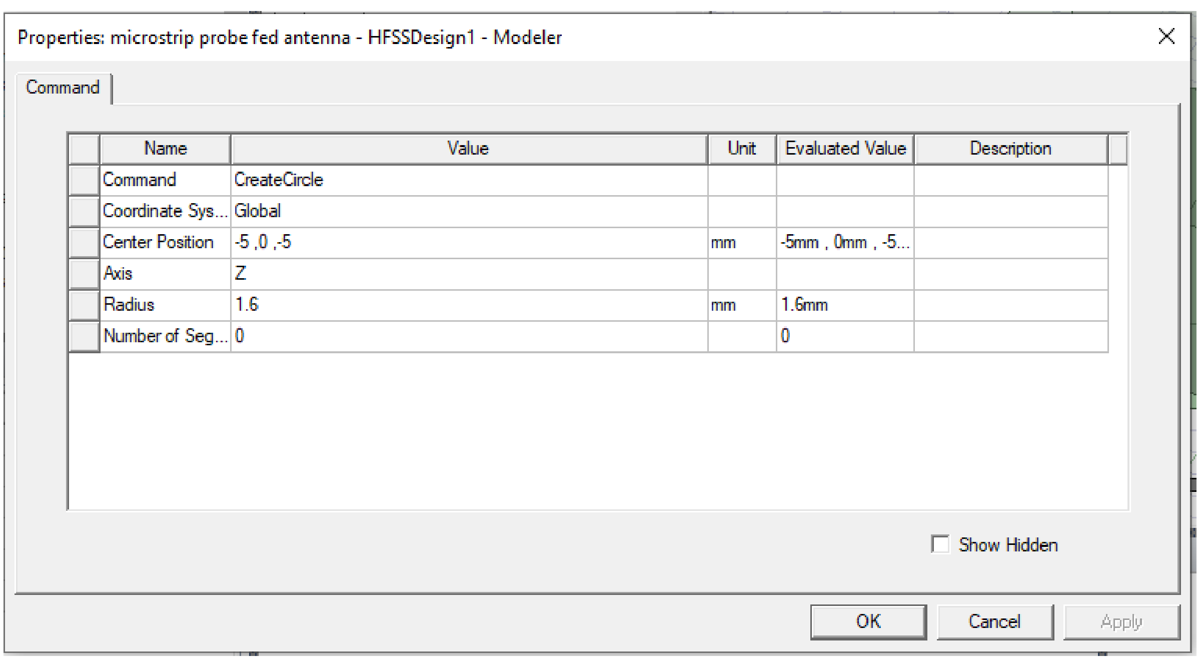
Name	Value	Unit	Evaluated Value	Description
Command	CreateCylinder			
Coordinate Sys...	Global			
Center Position	-5 ,0 ,0	mm	-5mm , 0mm , 0...	
Axis	Z			
Radius	0.7	mm	0.7mm	
Height	-5	mm	-5mm	
Number of Seg...	0		0	

Create on more Cylinder (co-axial cable inner conductor-probe) with the following dimensions



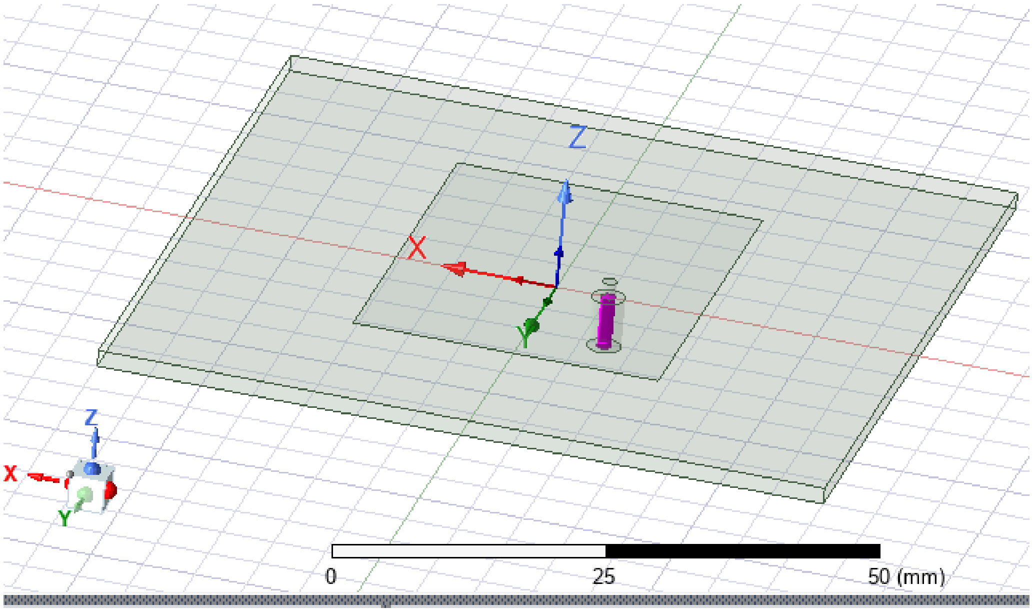
Name	Value	Unit	Evaluated Value	Description
Command	CreateCylinder			
Coordinate Sys...	Global			
Center Position	-5 ,0 ,0	mm	-5mm , 0mm , 0...	
Axis	Z			
Radius	0.7	mm	0.7mm	
Height	1.6	mm	1.6mm	
Number of Seg...	0		0	

Create circle with the following dimensions

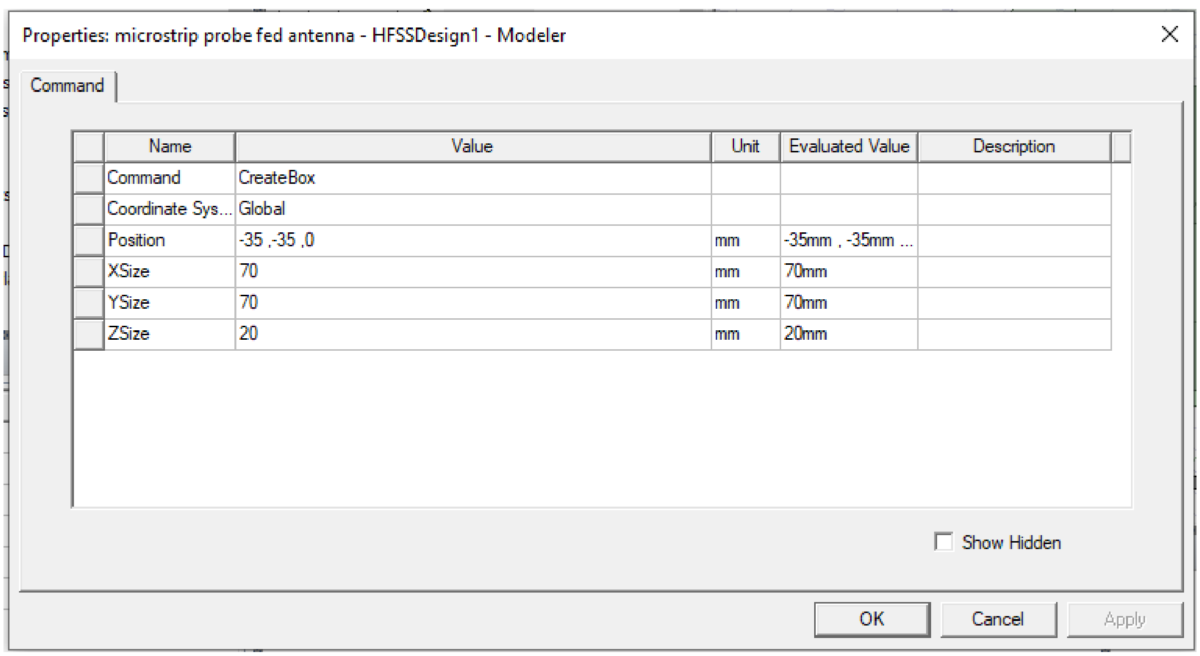


Name	Value	Unit	Evaluated Value	Description
Command	CreateCircle			
Coordinate Sys...	Global			
Center Position	-5 ,0 ,-5	mm	-5mm , 0mm , -5...	
Axis	Z			
Radius	1.6	mm	1.6mm	
Number of Seg...	0		0	

Now the model looks like this



Create box(radiation box) with the following dimensions


Properties: microstrip probe fed antenna - HFSSDesign1 - Modeler

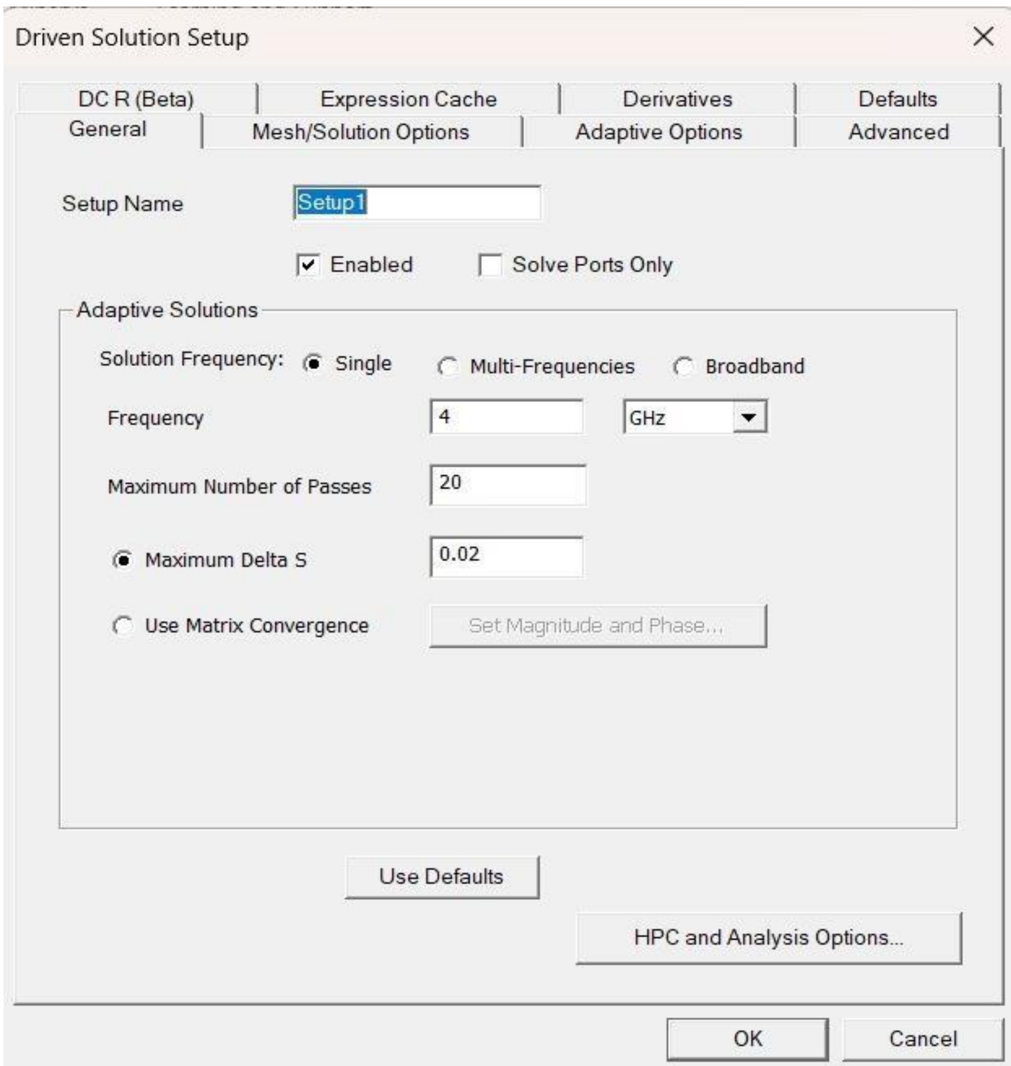
Command

Name	Value	Unit	Evaluated Value	Description
Command	CreateBox			
Coordinate Sys...	Global			
Position	-35 ,-35 ,0	mm	-35mm , -35mm ...	
XSize	70	mm	70mm	
YSize	70	mm	70mm	
ZSize	20	mm	20mm	

Show Hidden

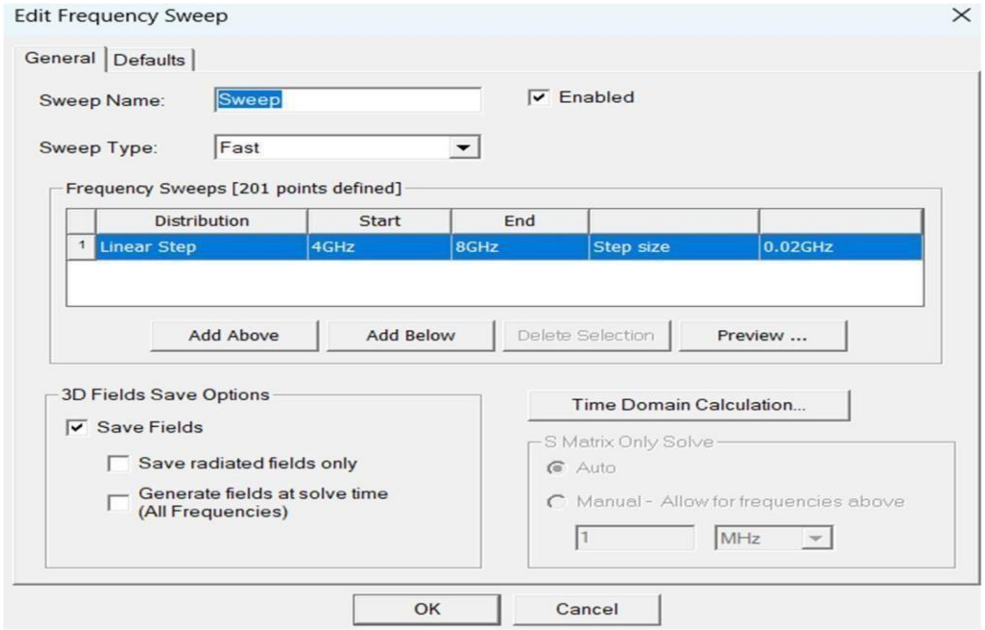
OK Cancel Apply

- Assign the material of box2 as "air"
- Right click in the work area, selection mode, faces
- Now you can select individual faces of an object instead of an entire object
- Now select 5 faces of box2 i.e. radiation box using control button except the bottom face
- Right click, assign boundary, radiation, ok
- Now your model is constructed along with radiation boundary.



Click on ok

In the next window that appears after clicking ok, enter the values as given below

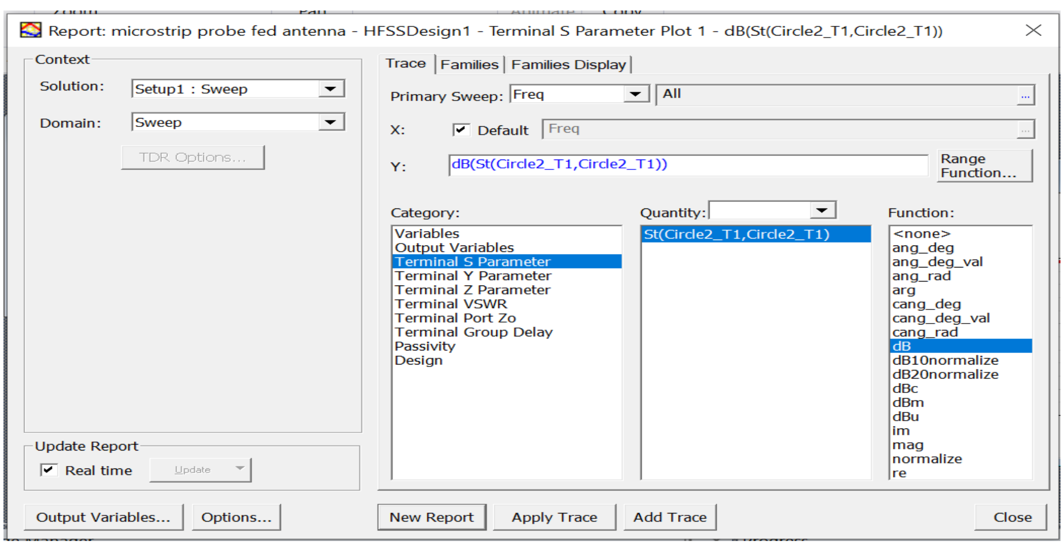


Go to HFSS, validation Check, Close the validation window.Go to HFSS, analyze all, no errors proceed.

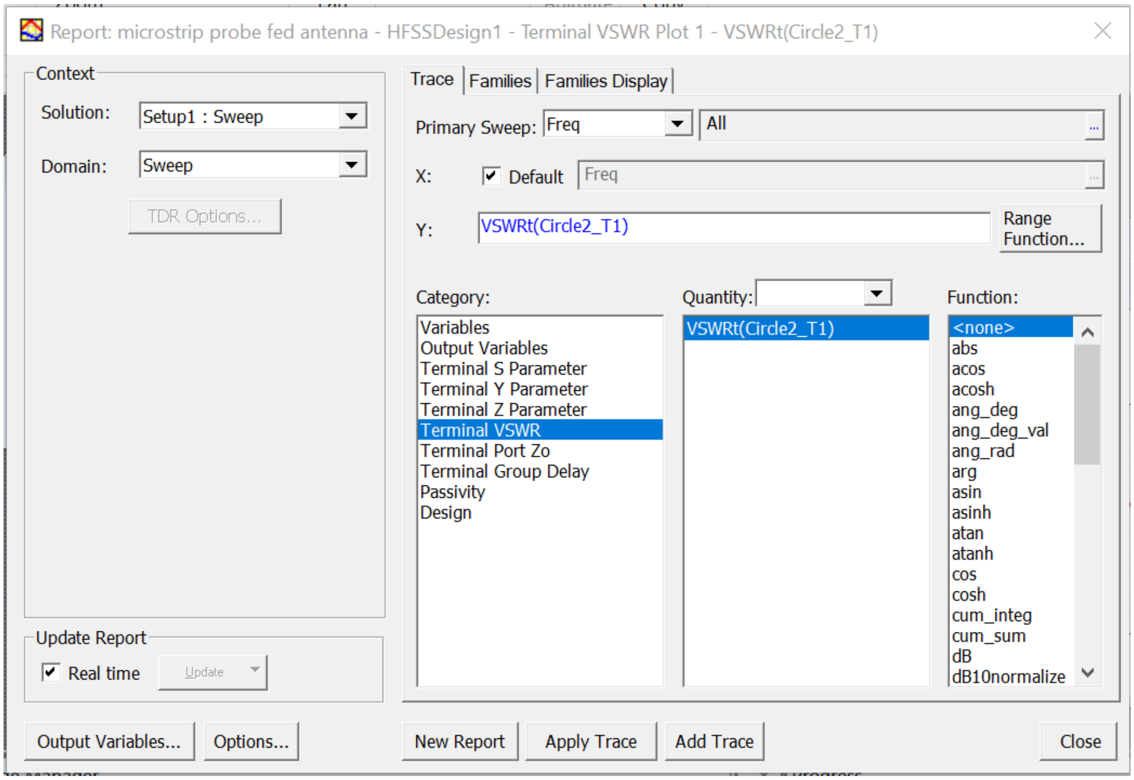
Right click on Result in Project manager section, create terminal solution data report, rectangularplot.

The following window will appear

Click on new report, close.

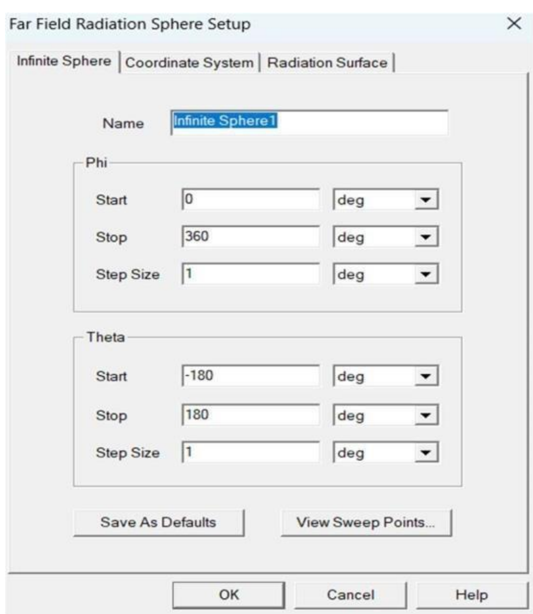


In the same way, right click on results in project manager section, create modal solution data report, rectangular plot, select VSMR in category section, click on new report as given below.



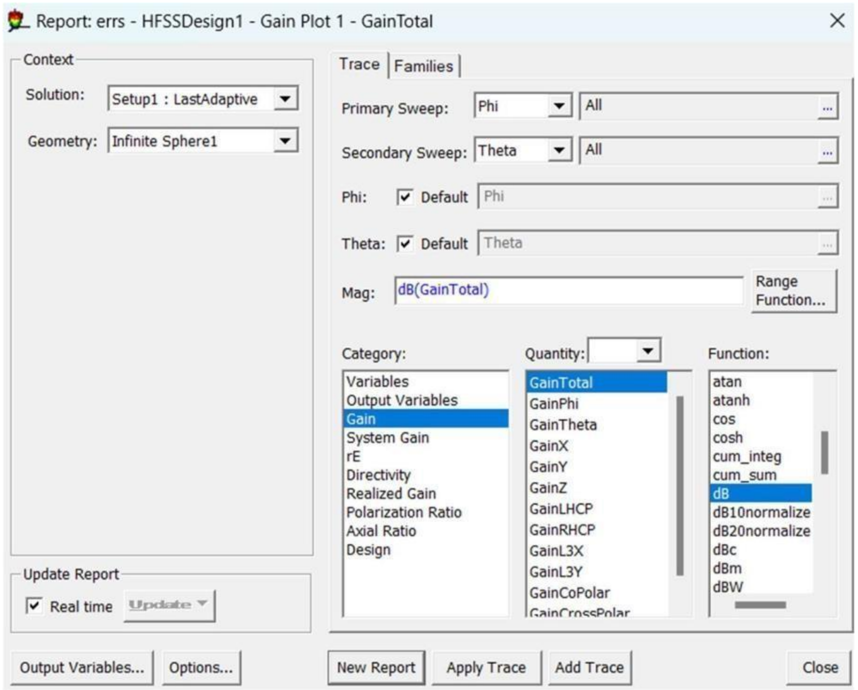
Right click on radiation in project manager window, insert far field setup, infinite sphere.

Enter the values as given below



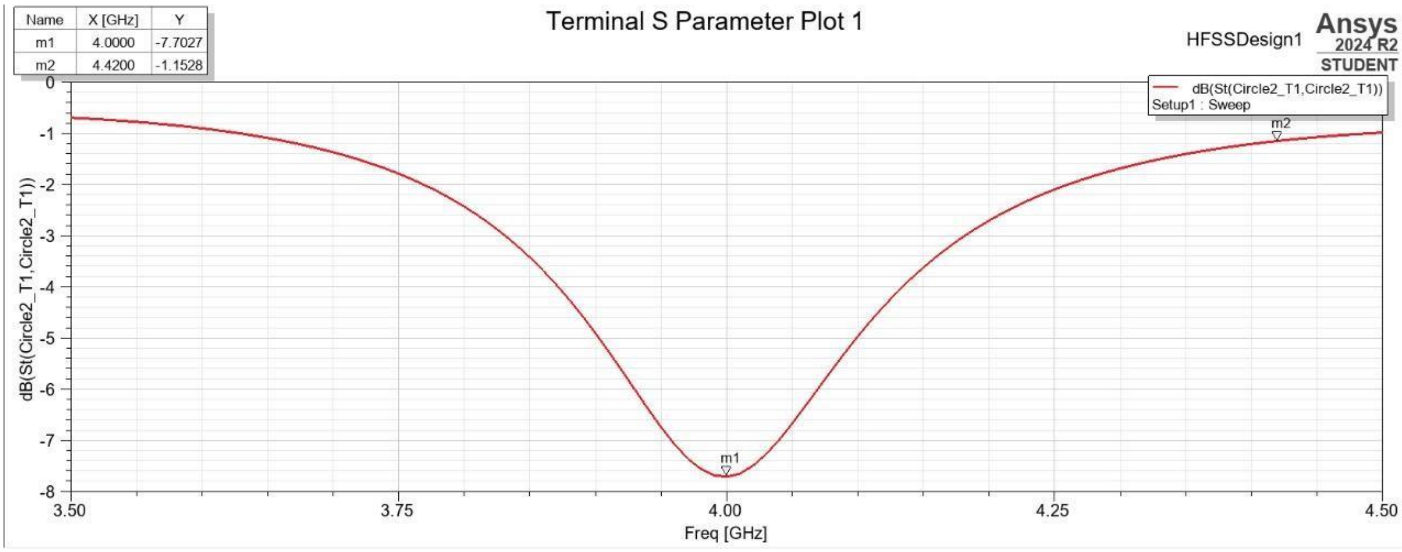
Right Click on results, create far fields report, 3D polar plot

The following window will open

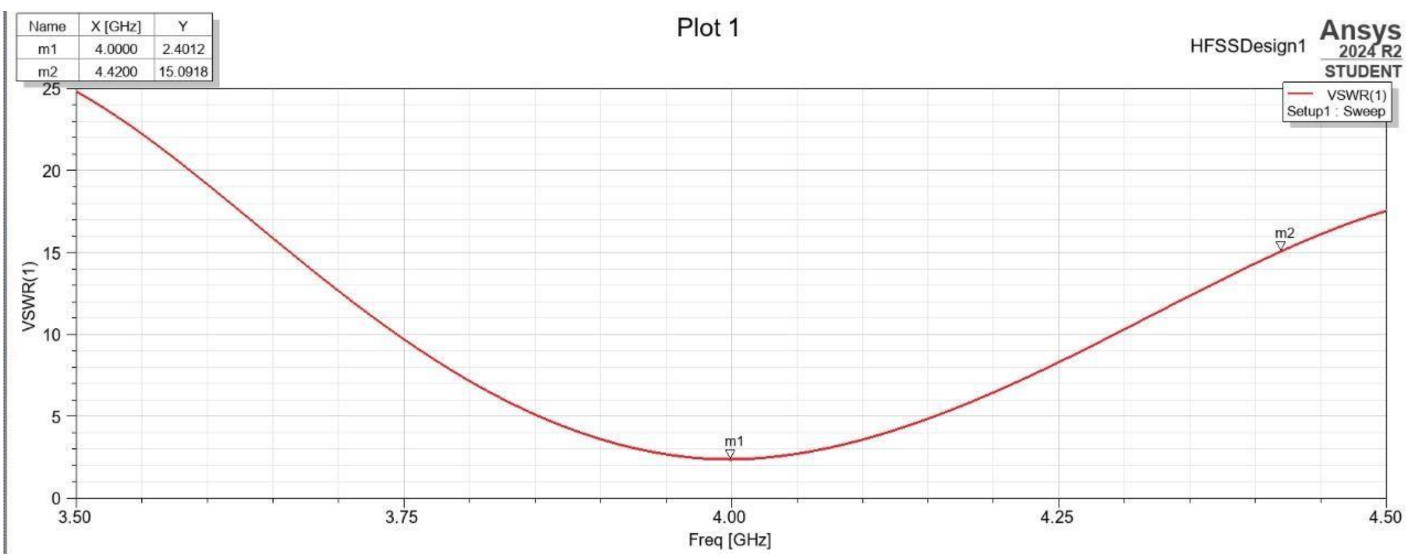


Simulation Outputs:

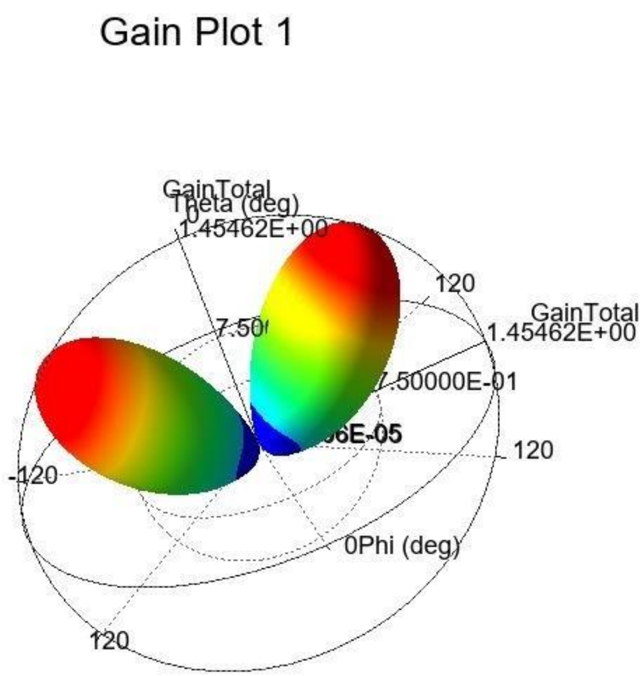
S Parameter:



VSWR Parameter:



Gain Plot:



Results and Discussion:

Sl No		Value
01	S11(in dB) at 4GHz	-7.7027
02	VSWR at 4GHz	2.4012

S parameter plot:

S-parameter plots typically display the magnitude and phase of S-parameters as a function of frequency. Common plot types include:

1. Rectangular plots: Show magnitude (in dB) or phase vs. frequency.
2. Smith charts: Display complex S-parameters on a polar plot, useful for impedance matching.
3. Polar plots: Represent magnitude and phase on a single graph.

S-parameter plots provide insights into:
- Reflection (S11, S22): Return loss and input/output matching
- Transmission (S21, S12): Insertion loss, gain, and isolation

VSWR parameter plot:

Voltage Standing Wave Ratio (VSWR) plots display the ratio of maximum to minimum voltage along a transmission line. VSWR is directly related to the reflection coefficient and S11.Key features of VSWR plots:

- Frequency is on the x-axis, VSWR on the y-axis
- Lower VSWR values indicate better impedance matching
- Ideal VSWR is 1:1, indicating perfect matching
- Commonly used in antenna design and impedance matching applications

Gain plot:

Gain plots show the amplification or attenuation of a signal through a device or system as a function of frequency. For a two-port network, gain is typically represented by S21.Characteristics of gain plots:

- Frequency on the x-axis, gain (in dB) on the y-axis
- Positive values indicate amplification, negative values indicate attenuation
- Can reveal the bandwidth and flatness of amplifiers or filters
- Often include markers to highlight specific frequency points of interest

Advantages and applications

Advantages:

1. Low profile and lightweight design, making them easy to integrate into devices
2. Simple to manufacture using printed circuit board technology
3. Relatively inexpensive to produce
4. Good conformability to different surfaces
5. Direct connection to the patch for efficient power transfer
6. Ability to control input impedance by adjusting the feed point location
7. Reduced spurious radiation compared to edge-fed designs

Applications:

1. 5G communication systems, particularly in the sub-6 GHz bands
2. Wi-Fi routers and access points
3. Satellite communications
4. Global Positioning Systems (GPS)
5. Radar systems for missiles and other applications
6. Mobile handheld radios and communication devices
7. Internet of Things (IoT) devices

Conclusion:

Probe-fed microstrip patch antennas at 4 GHz provide a versatile and efficient solution for modern wireless communication systems. Their compact size, ease of fabrication, and good performance characteristics make them ideal for various applications, especially in the rapidly growing field of 5G technology. While they may have some limitations in bandwidth, techniques such as stacked patch configurations can be employed to overcome these challenges[3]. As wireless technologies continue to evolve, these antennas are likely to play a crucial role in enabling high-speed, reliable communications across a wide range of devices and systems.