ANTENNA DESIGN & ANALYSIS LAB MANUAL

Prasad V. Potluri
SIDDHARTHA INSTITUTE OF TECHNOLOGY
VIJAYAWADA

DEPARTMENT OF

ELECTRONICS & COMMUNICATION ENGINEERING

Prasad V. Potluri Siddhartha Institute of Technology
(Autonomous)
Accredited with A+ grade by NAAC
ISO 9001:2015 Certified Institute, Permanently Affiliated to JNTUK, KAKINADA
All the UG Programmes are accredited by NBA Under Tier-1

Course Code: 20EC3652 **III Year II Semester**

ANTENNA DESIGN & ANALYSIS LAB

Course Code	20EC3652	Year	III	Semester	II
Course Category	Program Core	Branch	ECE	Course Type	Lab
Credits	3	L-T-P	0-0-3	Prerequisites	EMF &W, AA&S
Continuous Internal Evaluation:	15	Semester End Evaluation	35	Total Marks	50

Course Outcomes	
Upon successful completion of the course, the student will be able to	
CO1	Utilize simulation software tools for antenna design L3
CO2	Model and simulate various antennas for different frequency ranges. L3
CO3	Measure the radiation characteristics of the antennas L5
CO4	Analyse the radiation characteristics of antenna arrays-L4
CO5	Make an effective report of the experiments

Mapping of course outcomes with Program outcomes (CO/ PO/PSO Matrix)

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

* - Average value indicates course correlation strength with mapped PO

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO1	PSO2
CO1	3				3								3	3
CO2	3				3								3	3
CO3				1	1		1						1	1
CO4		1			1		1						1	1
CO5										3				
Average (Rounded to nearest integer)	3	1		1			1			3			3	3

Syllabus		
S.No.	**Experimental Topics**	**Mapped CO**
1	Introduction to antenna simulation software tools	CO1, CO5
2	Design and analysis of wire antennas (Dipoles, Monopoles, Loop antennas, Yagi-Uda antenna etc.)	CO1, CO2, CO4, CO5
3	Design and analysis of wideband antennas (Conical & Bow-Tie antennas)	CO1, CO2, CO4, CO5
4	Design and analysis of microstrip antennas (Rectangular, circular and other patch shapes)	CO1, CO2, CO4, CO5
5	Measurement of radiation characteristics of Antennas	CO3, CO5
6	Analysis of Linear Antenna Arrays	CO1, CO4, CO5

❖ **A Minimum of TEN experiments covering all the above topics need to be conducted**

Learning Resources
Text Books
1. Constantine A. Balanis - Antenna Theory and Applications – John Wiley & Sons, 4th Ed., 2021 2. J.D Kraus, R. J. Marhefka & A.S.Khan - Antennas and Wave Propagation –TMH, 4 th Ed., 2010.
Reference Books
1. E.C. Jordan and K.G. Balmain - Electromagnetic Waves and Radiating Systems – PHI,2nd Ed., 2009. 2. K.D. Prasad, Satya Prakashan - Antennas and Wave Propagation – Tech India Publications, New Delhi, 2001 3. E.V.D. Glazier and H.R.L. Lamont - Transmission and propagation-, vol.5 StandardPublishers Distributors- New Delhi
e- Resources & other digital material
1. http://anlage.umd.edu/HFSSv10UserGuide.pdf 2. https://www.youtube.com/watch?v=kUDlCVOPlvY

Experiment No: 01

Introduction to Simulation tools

Aim: Introduction to Simulation software tools

Requirements:
A PC loaded with HFSS Software

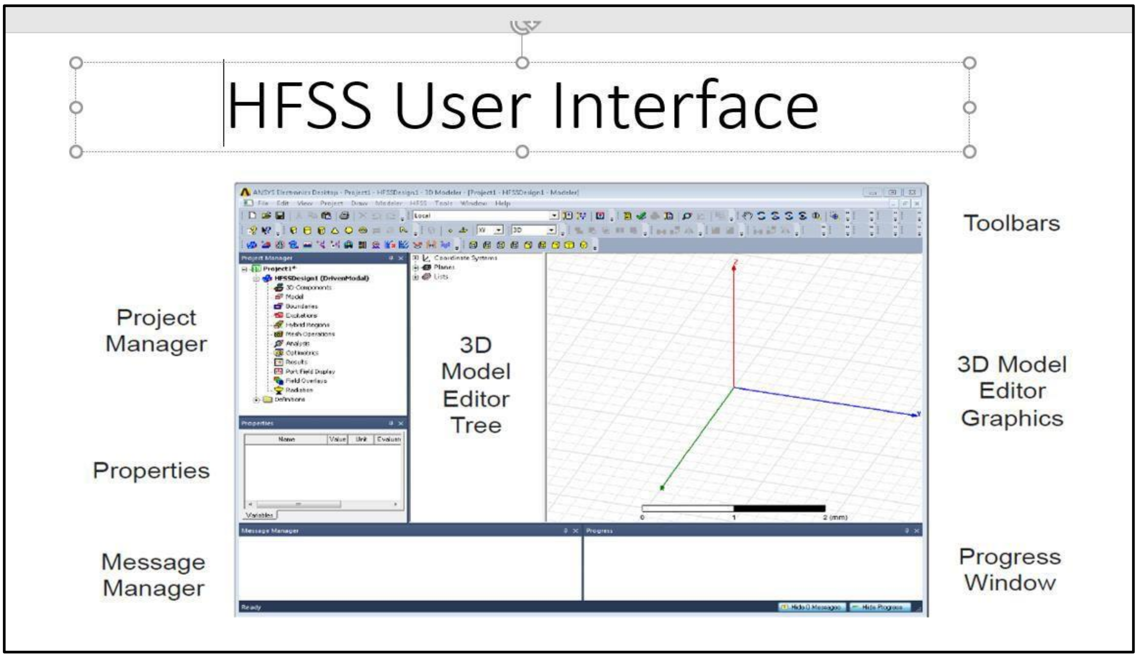


Fig.1: The ANSYS Electronics Desktop

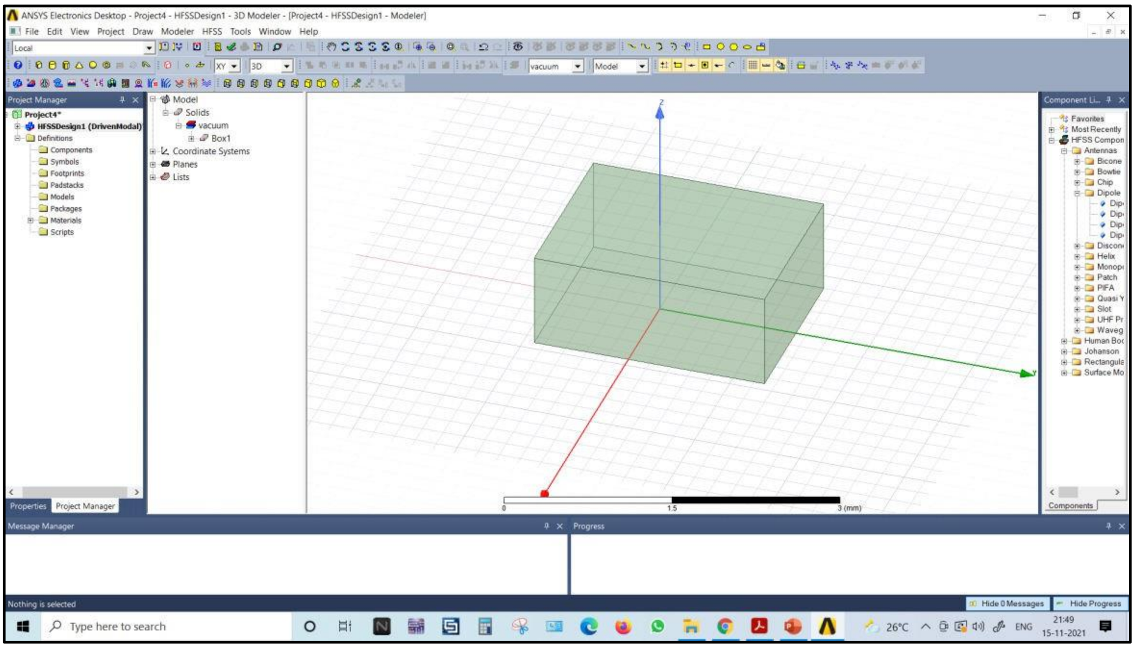


Fig.2: Creation of Box

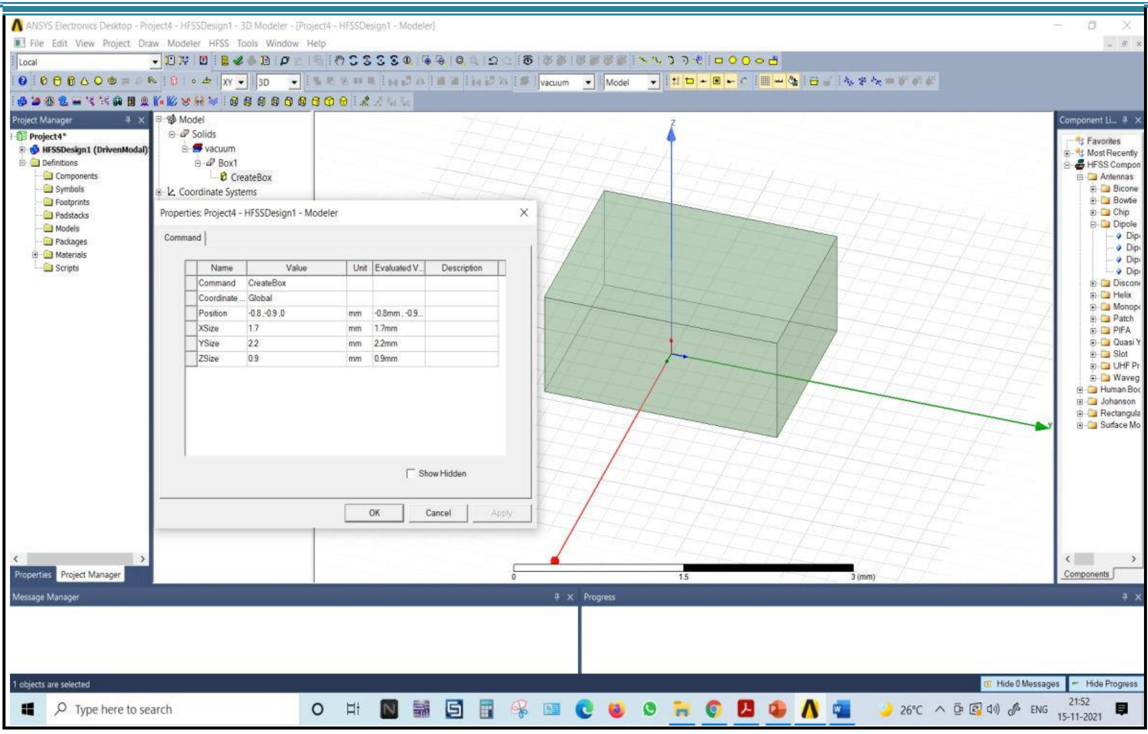


Fig.3: Assigning Dimensions to the Box

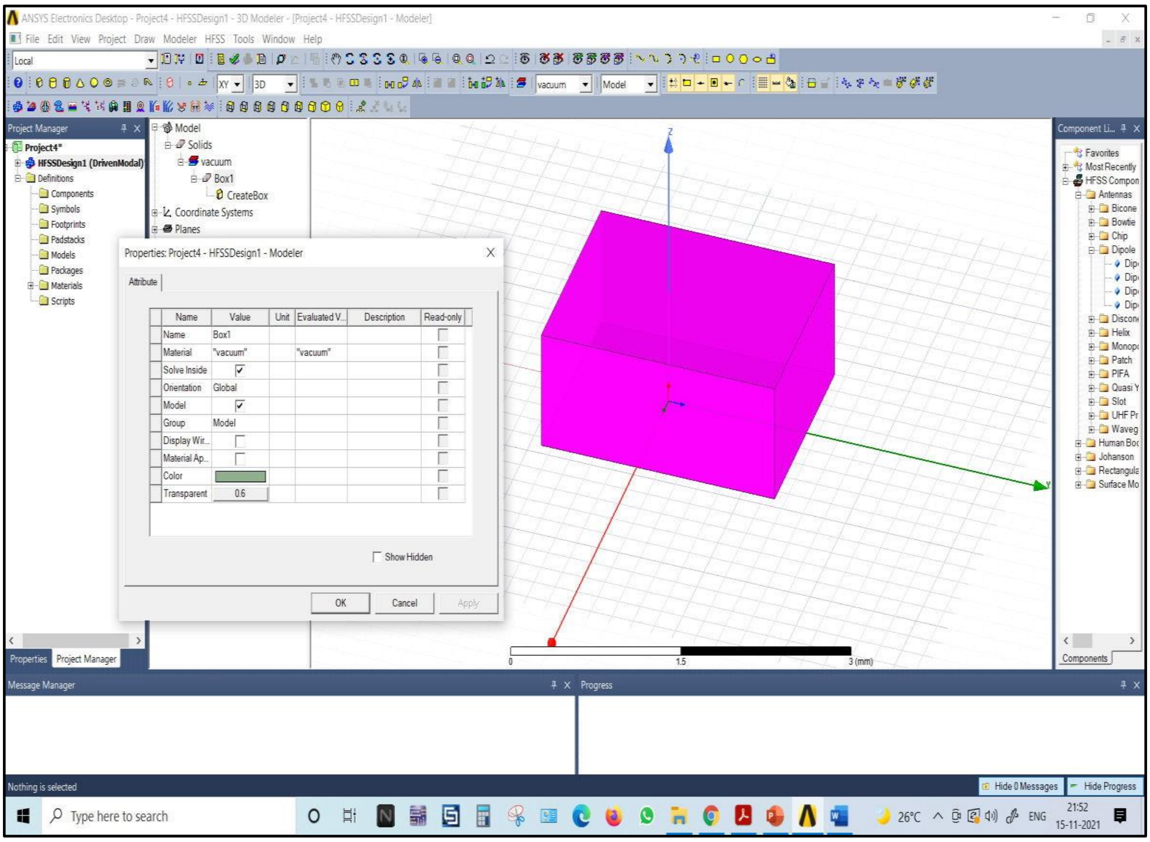


Fig.4: Assigning materials, colour & transparency to the Box

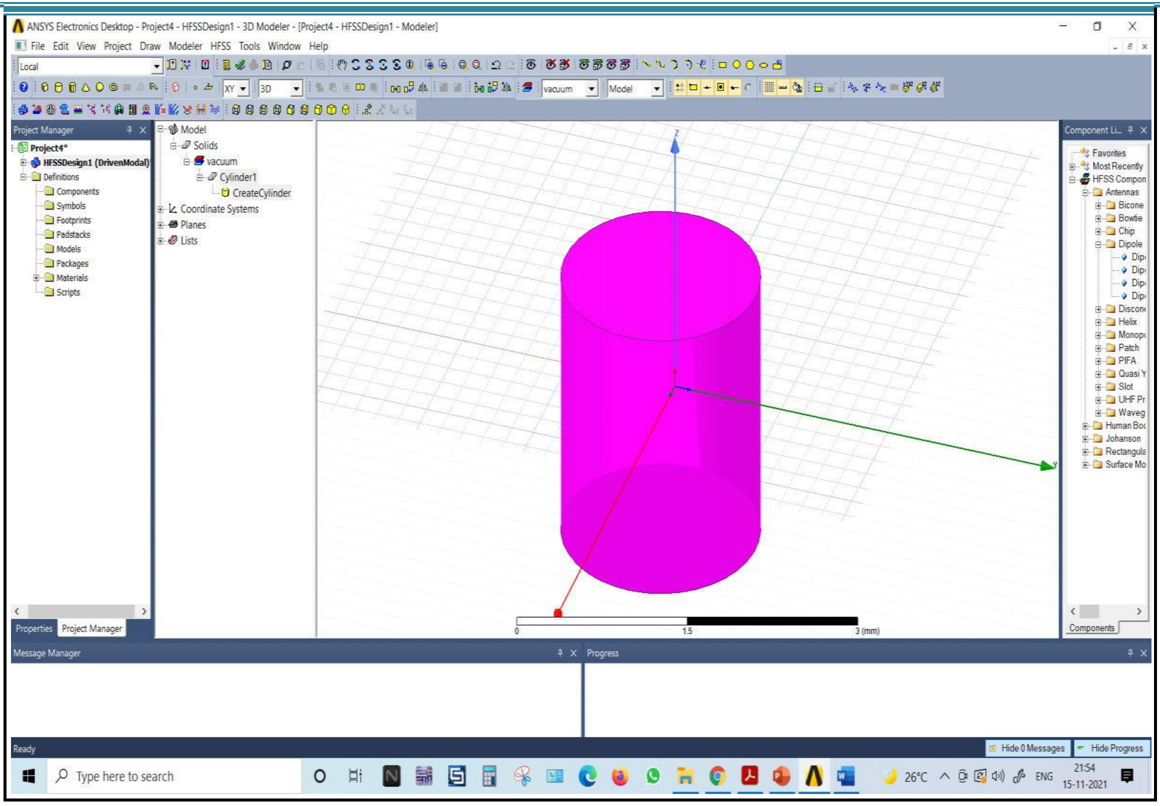


Fig.5: Creation of Cylinder

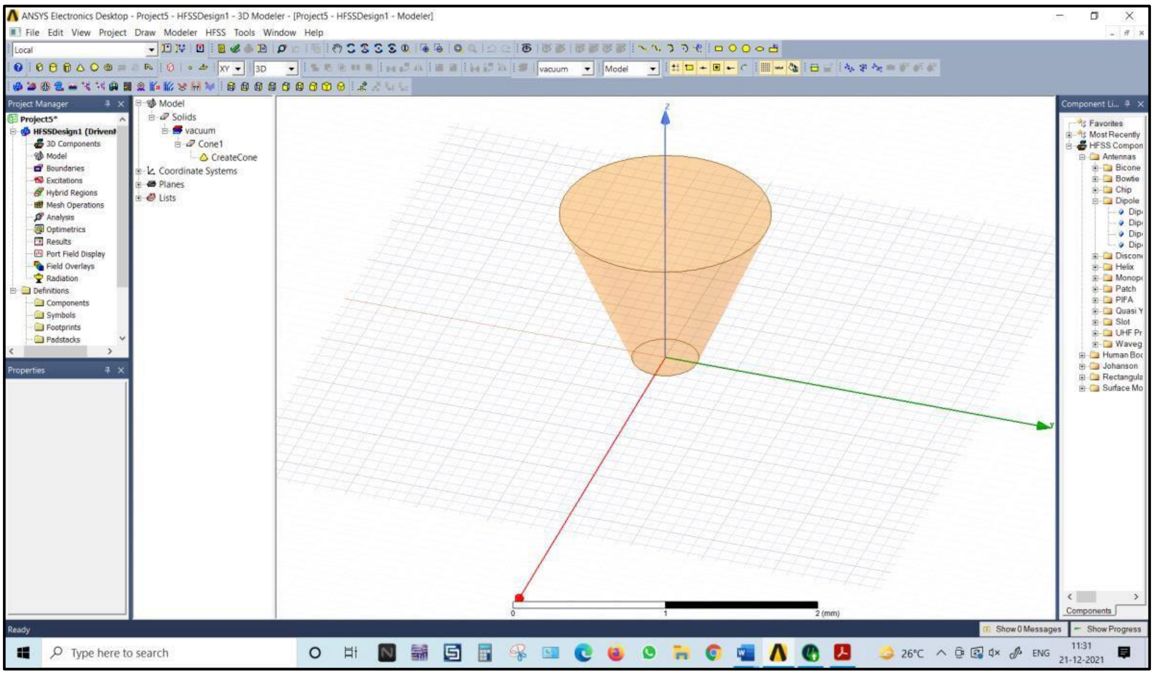


Fig.6: Creation of Cone

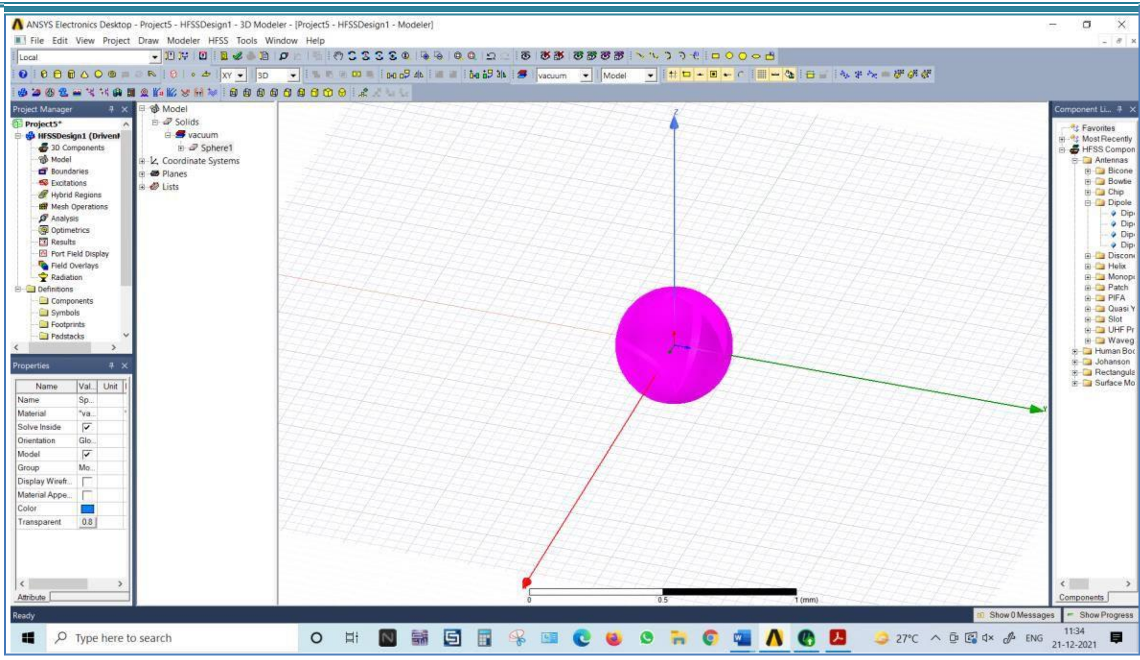


Fig.6: Creation of Sphere

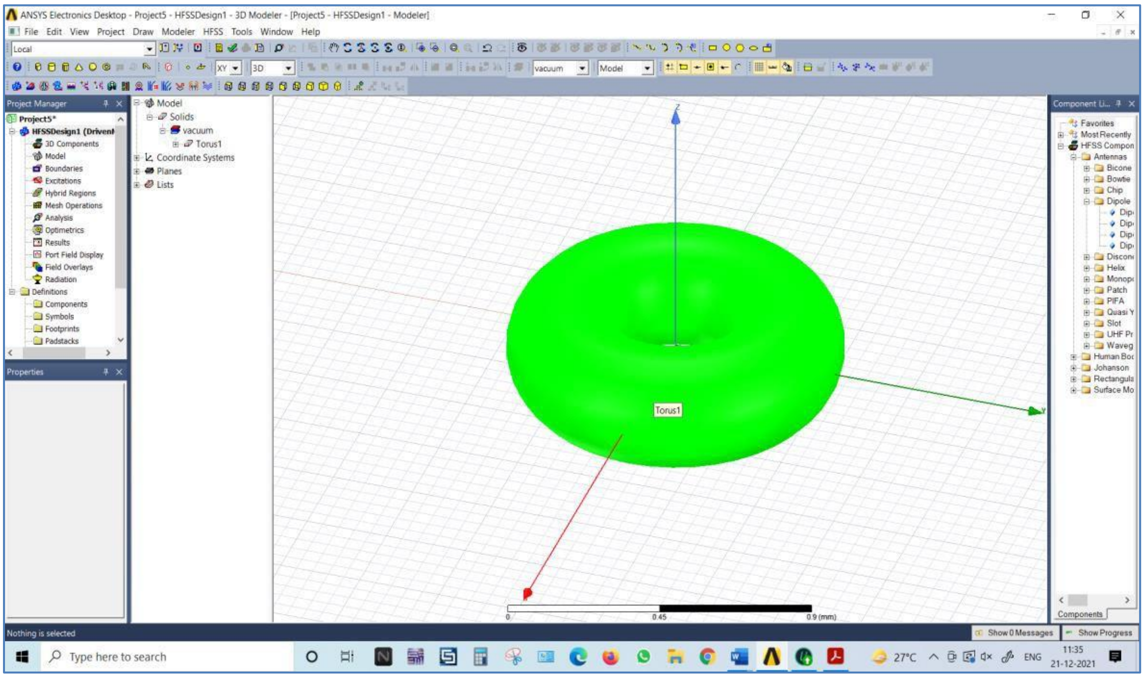


Fig. 7: Creation of Torus

Result:

Conclusion:

Experiment No: 02

Halfwave Dipole

Aim: Design a half wave dipole for a frequency of 2.4GHz and determine its radiation pattern and reflection coefficient.

Requirements:
A PC loaded with HFSS Software

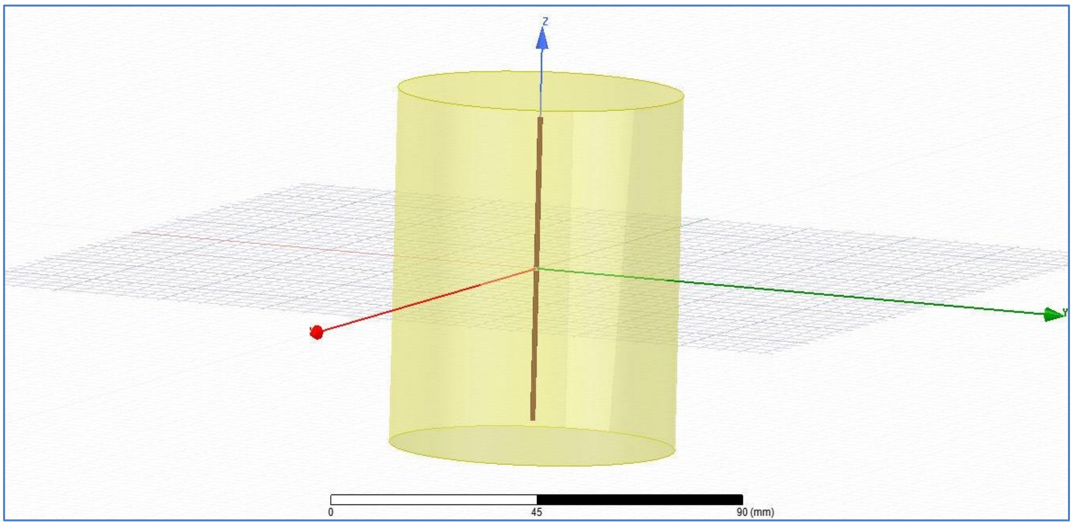


Fig.1 Halfwave Dipole

Procedure:

1. Find Wavelength λ

   $\lambda =$ c/f= 3 x 10^8 m/s & 'f' is the operating frequency

2. Calculate Length of each monopole
3. Choose radius of each monopole.
4. Apply Excitation & necessary boundaries
5. Go to Validation check & analyze all.
6. Plot the results.

Simulation Results:

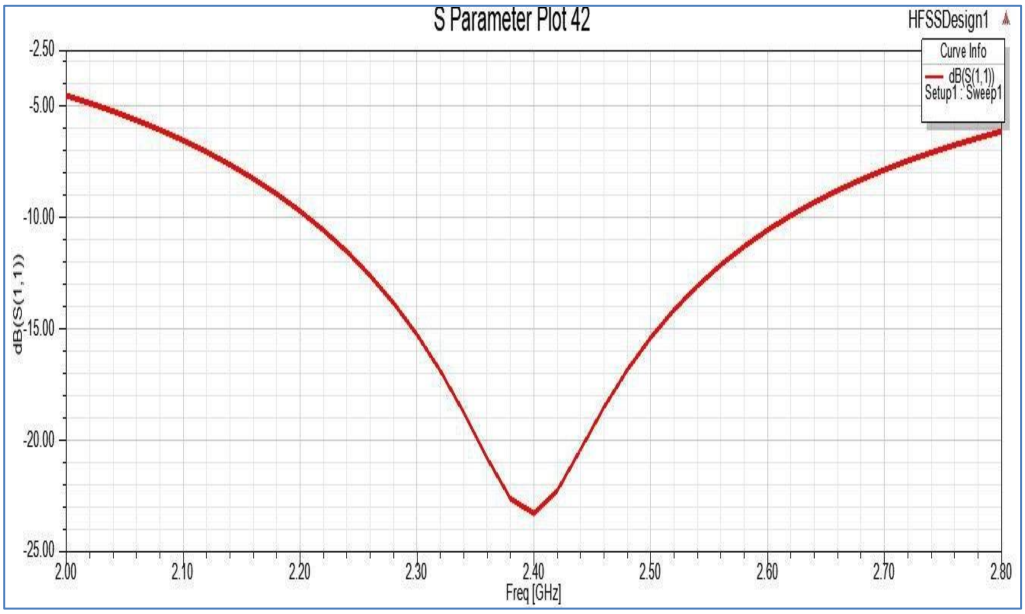


Fig. 2 S_{11} -The Reflection Coefficient in dB

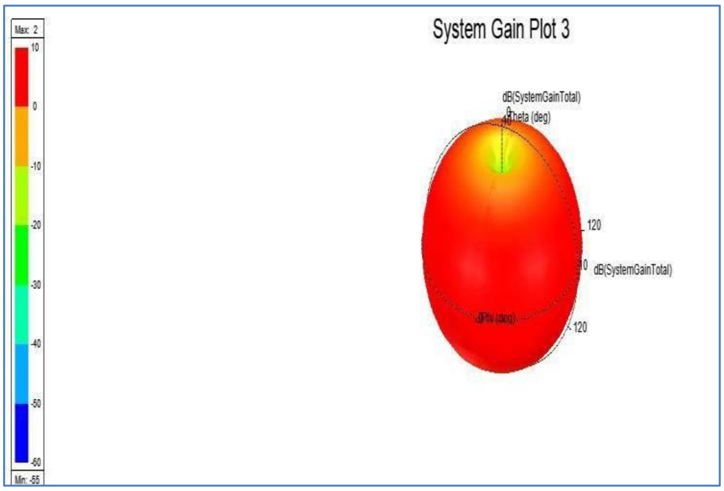


Fig.3: Radiation Pattern (3D)

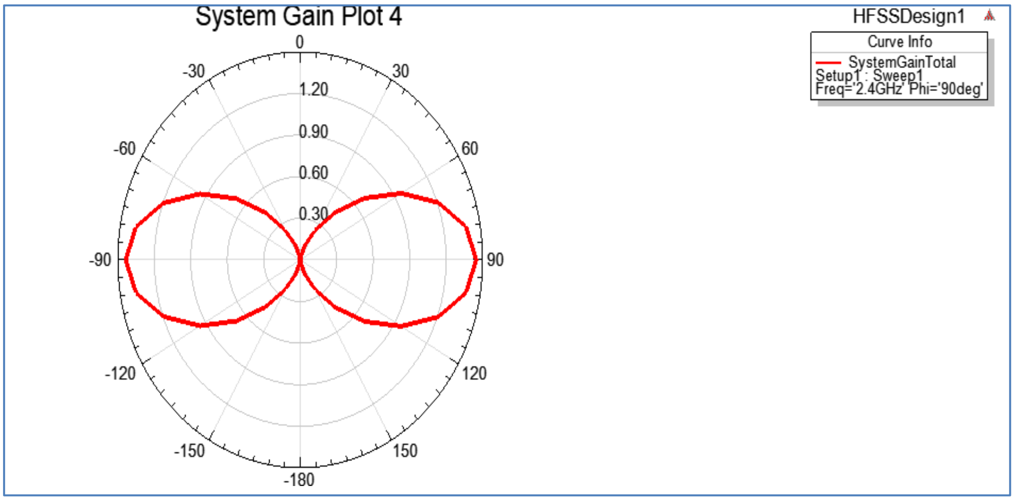


Fig. 4 E-Plane Pattern

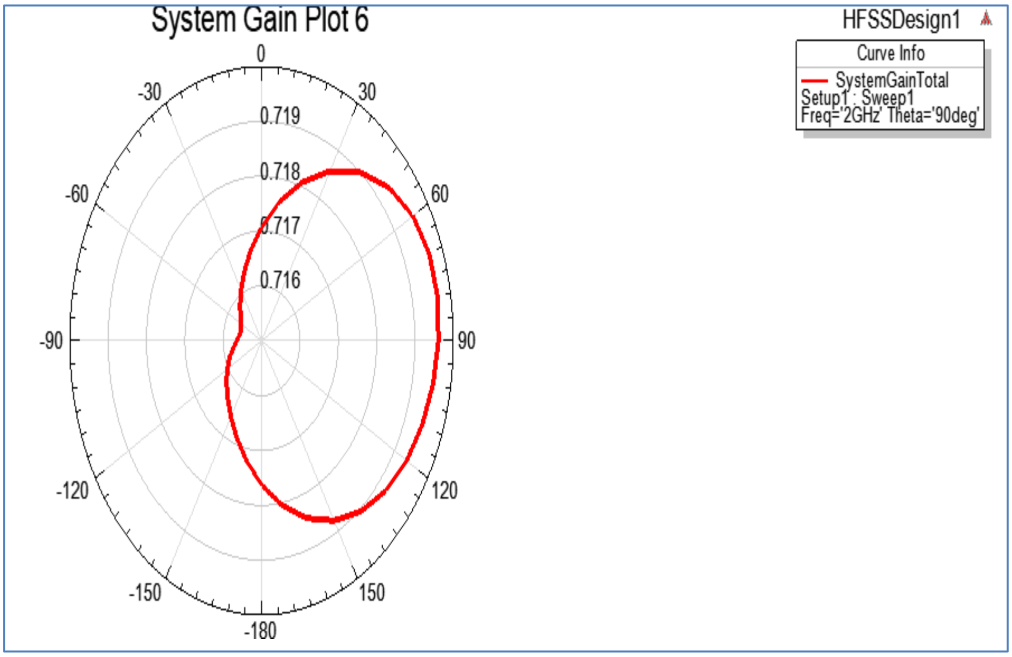


Fig. 5 H-Plane pattern

Result:

Conclusion:

Experiment No.: 03

Biconical Antenna

Aim: Design a biconical antenna for a frequency of 6GHz and determine its radiation pattern and reflection coefficient.

Requirements:
A PC loaded with HFSS Software

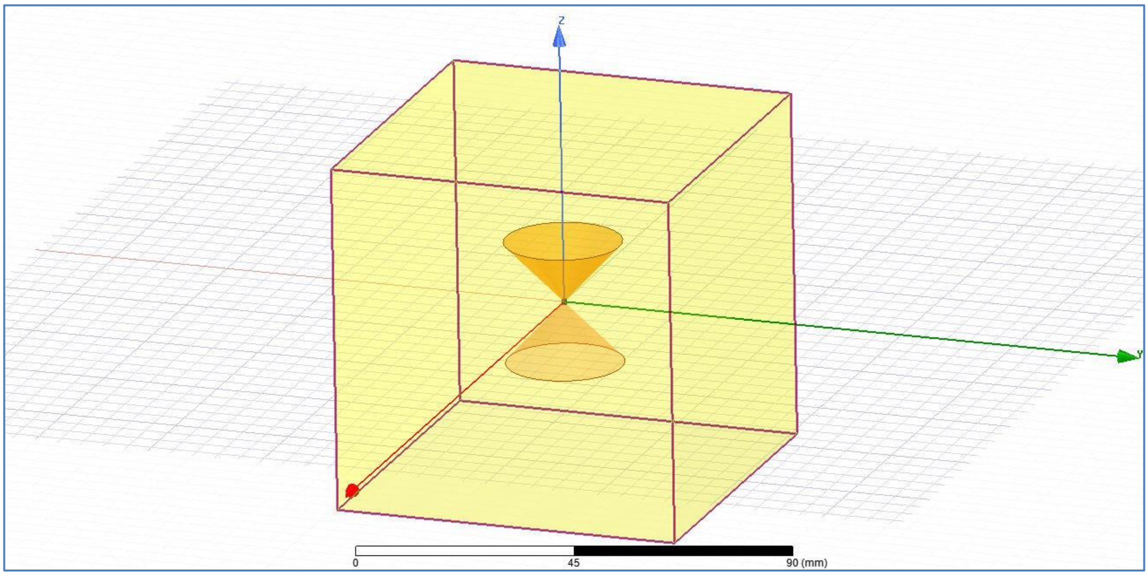


Fig.1 Biconical antenna

Procedure:

1. Find Wavelength λ

   λ = c/f= 3 x 10^8 m/s & 'f' is the operating frequency

2. Calculate Length of each cone
3. Choose inner & outer radius of each cone.
4. Apply Excitation & necessary boundaries
5. Go to Validation check & analyse all.
6. Plot the results

Simulation Results:

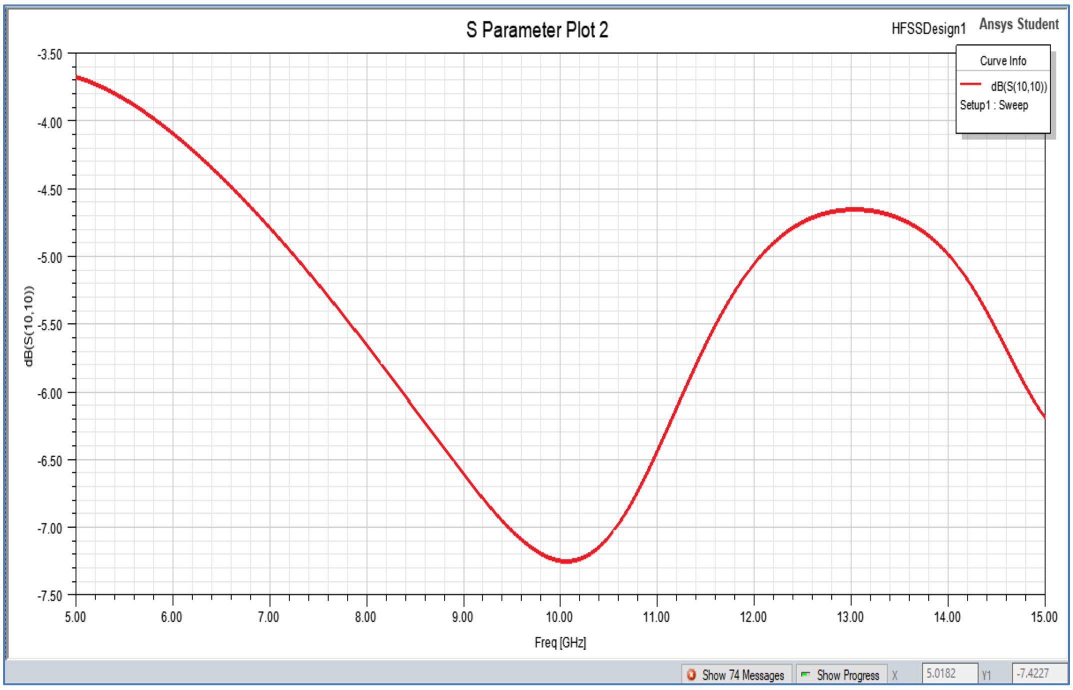


Fig. 2 S_{11} -The Reflection Coefficient in dB

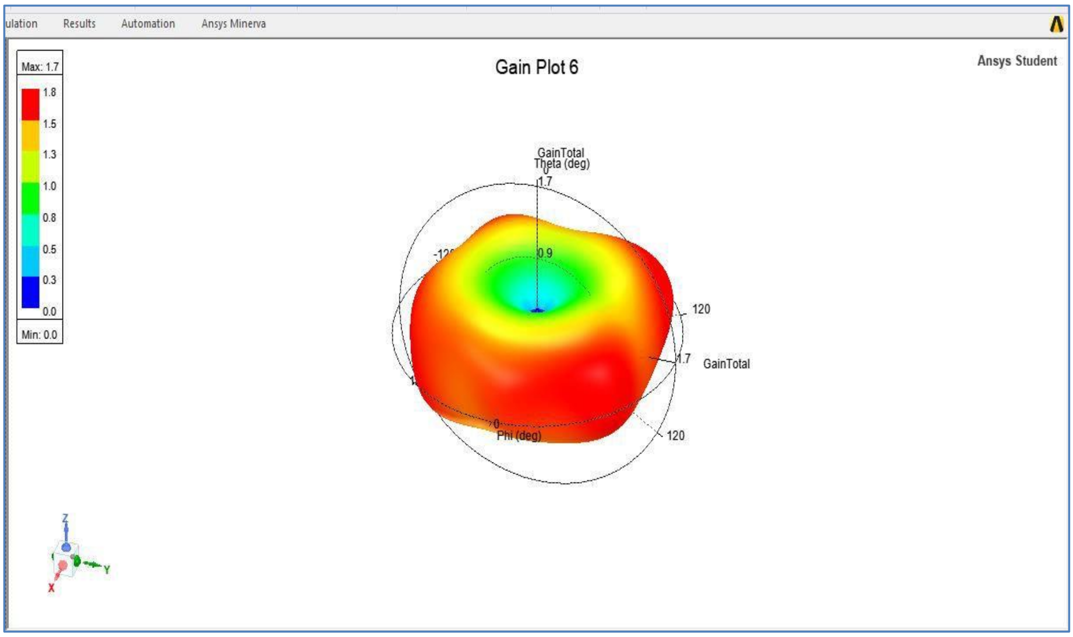


Fig.3: Radiation Pattern (3D)

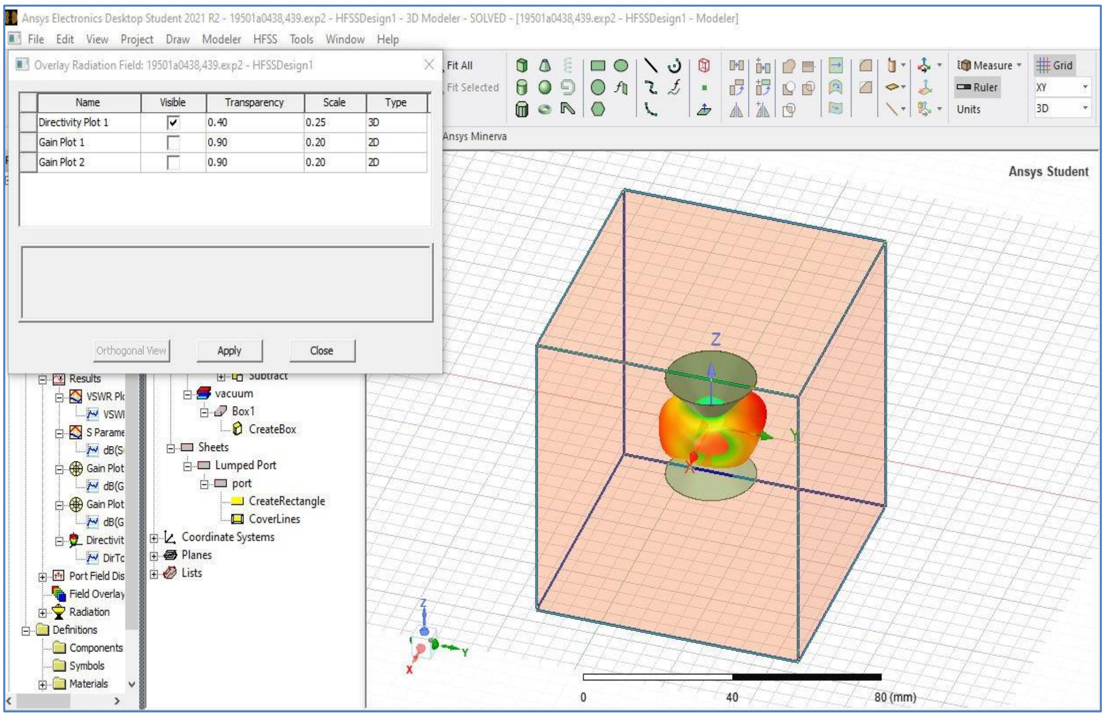


Fig.4 Radiation Pattern (3D) Along with bicone

Result:

Conclusion:

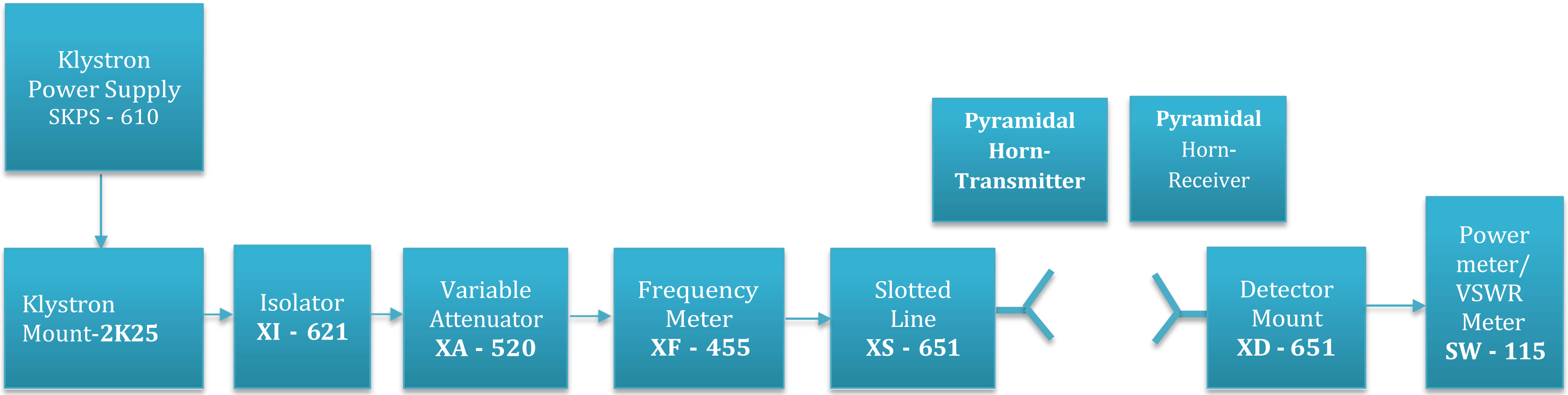
Experiment No. 4

Measurement of Radiation Pattern of a Pyramidal Horn Antenna

Aim: Conduct an Experiment to Measure the Radiation from a Horn Antenna and Plot its Power Pattern.

Apparatus: Microwave Source, Isolator, Variable Attenuator, Frequency meter, Slotted Line, Detector Mount, Pyramidal Horn Antennas, Tripod Stand, Connecting Cables.

Circuit Diagram:



Procedure

A. Antenna Radiation Pattern

1. Set up the equipments as shown in the figure 1. Keeping the axis of both antenna in same line.
2. Energize the Gunn Oscillator for maximum output at desired frequency with square wave modulation by tuning square wave amplitude and frequency of modulating signal of Gunn Power supply and by tuning the detector.
3. Also tune the S S Tunner in the line for maximum output (if S S Tunner is in the setup).
4. From diagram determine 3db-width (beam width) of the horn antenna.

Observations

S.No.	Antenna Position (Angle in Degrees)
1	
2	
3	
4	
5	
6	
7	
8	

Graph (Polar/Rectangular Plot) – Angle

Result:

Conclusion:

Experiment No.: 05

Rectangular Microstrip Antenna

Aim: Design a rectangular microstrip patch antenna and obtain its radiation characteristics using simulation.

Requirements:
A PC loaded with HFSS Software

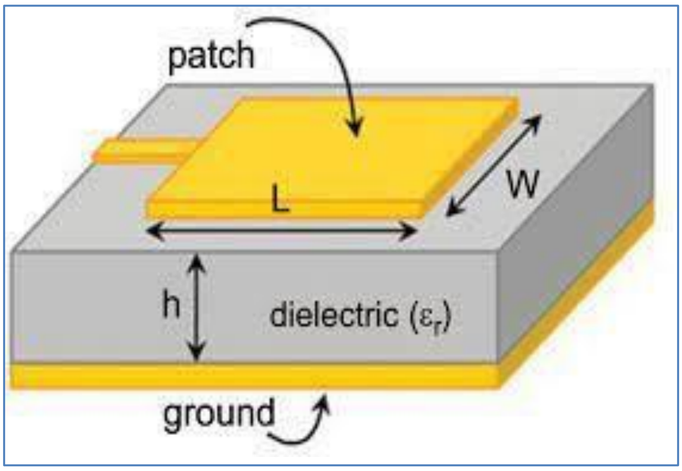


Fig.1: Rectangular Microstrip Antenna

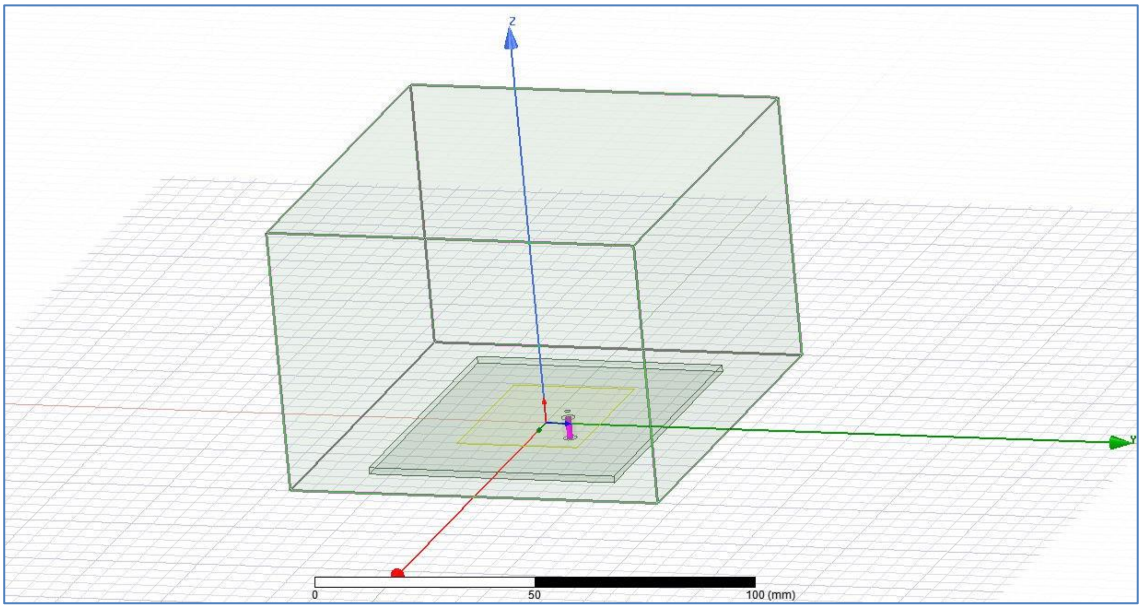


Fig.2: Rectangular Microstrip Antenna with coaxial feed in HFSS

DESIGN EQUATIONS:

i) Width of the Patch

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

ii) Effective Dielectric Constant

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2}$$

iii) Calculation of ΔL

$$\Delta L = 0.412 \times h \times \frac{(\epsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)}$$

iv) Actual Length of Patch

$$L = \frac{c}{2f_0\sqrt{\epsilon_{reff}}} - 2\Delta L$$

v) Effective Length of the Patch

$$L_{e} = L + 2\Delta L$$

vi) Length of the Substrate Ls= L_P + 6h and

Width of the Substrate Ws = W_P + 6h

vii) Ground Plane dimensions & substrate dimensions are same except thickness.

viii) Feed Point Location is given by

$$x_f = \frac{L_P}{2\sqrt{\epsilon_{reff}}}$$

$$y_f = \frac{W_P}{2}$$

Where X_f and Y_f are the desired input feed point at x-axis and y-axis respectively

Procedure:

1. Calculate Dimensions of Patch, Substrate & Ground plane using design equations
2. Select the type of feeding Technique & find the feed location
3. Draw the Structure as per dimensions & feeding technique.
4. Apply Excitation & necessary boundaries
5. Go to Validation check & analyse all.
6. Plot the results

Simulation Results:

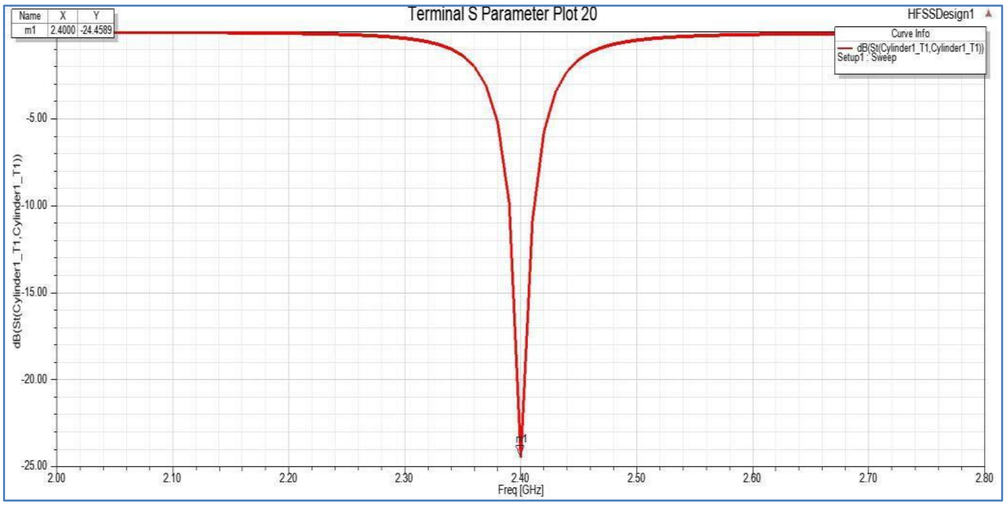


Fig. 3: S_{11} -The Reflection Coefficient in dB

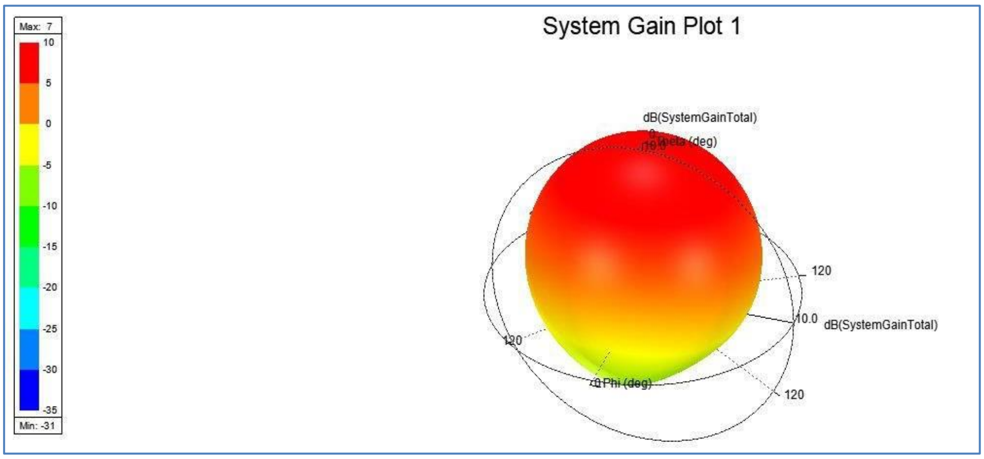


Fig.4: Radiation Pattern (3D)

Result:

Conclusion:

Experiment No.: 06

Circular Microstrip Antenna

Aim: Design a Circular microstrip patch antenna and obtain its radiation characteristics using simulation.

Requirements:
A PC loaded with HFSS Software

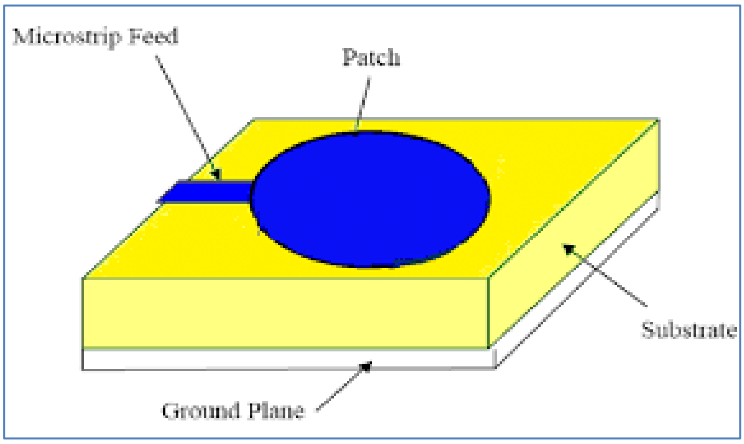


Fig.1: Circular Microstrip Antenna

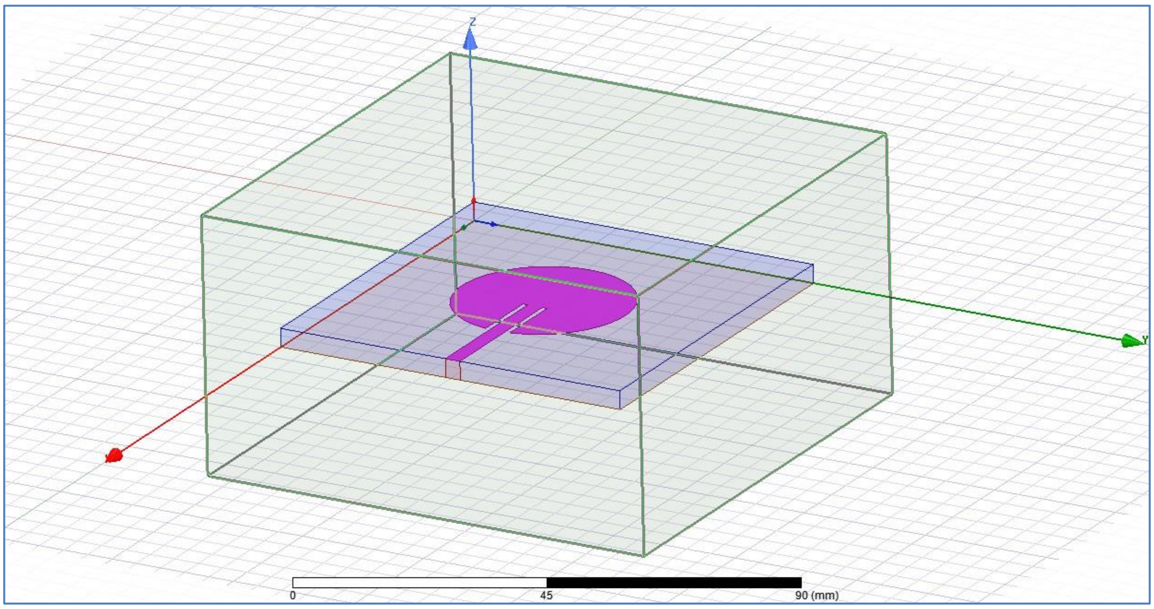


Fig.2: Circular Microstrip Antenna with inset feed in HFSS

DESIGN EQUATIONS:

i)

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.776\right]\right\}}$$

& $$F = \frac{8.791 \times 10^9}{f_r \epsilon_r}$$

Where h is in cm.

ii) Length of the Substrate Ls= L_P + 6h and

Width of the Substrate Ws = W_P + 6h

iii) Ground Plane dimensions & substrate dimensions are same except thickness.

iv) Feed Point Location is given by

$$x_f = \frac{L_p}{\sqrt[2]{\varepsilon_{reff}}}$$

$$y_f = \frac{W_p}{2}$$

Where X_f and Y_f are the desired input feed point at x-axis and y-axis respectively

Procedure:

1. Calculate Dimensions of Patch, Substrate & Ground plane using design equations
2. Select the type of feeding Technique & find the feed location
3. Draw the Structure as per dimensions & feeding technique.
4. Apply Excitation & necessary boundaries
5. Go to Validation check & analyse all.
6. Plot the results

Simulation Results:

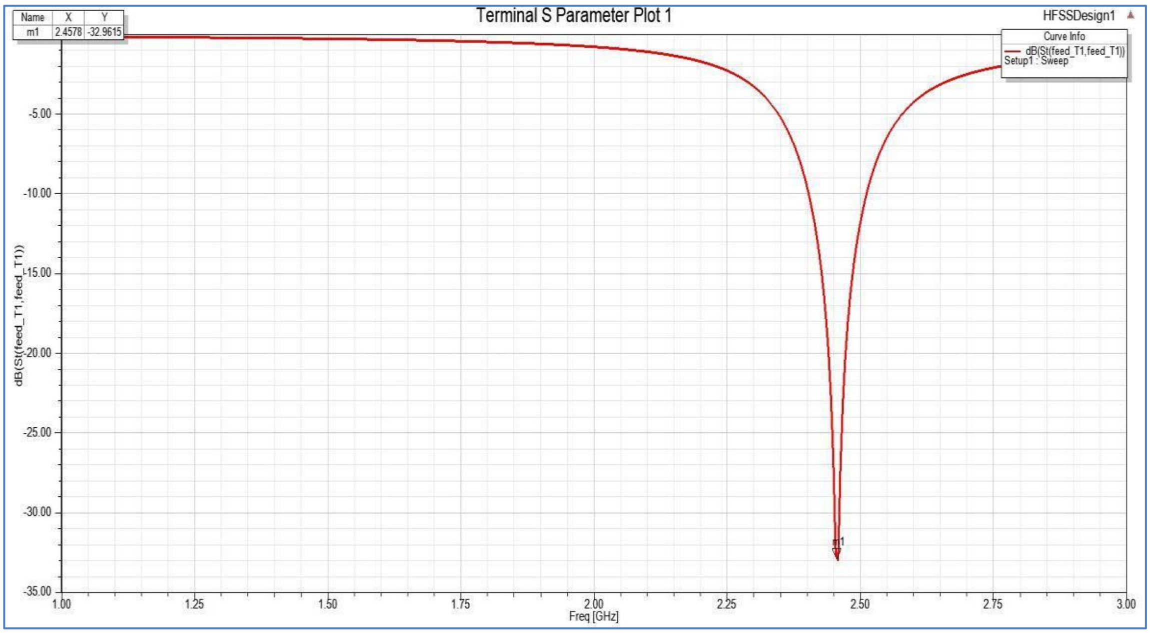


Fig. 3: S_{11} -The Reflection Coefficient in dB

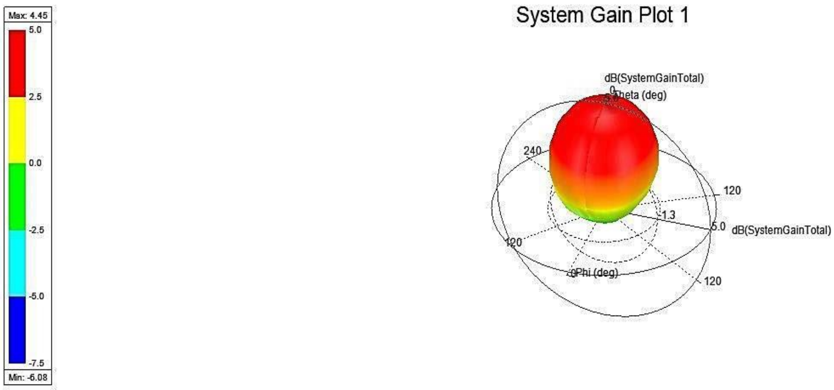


Fig.4: Radiation Pattern (3D)

Result:

Conclusion:

Experiment No.: 07

Square Loop Antenna

Aim: Design a square loop antenna for a frequency of 6GHz and obtain its radiation pattern, reflection coefficient.

Requirements:
A PC loaded with HFSS Software

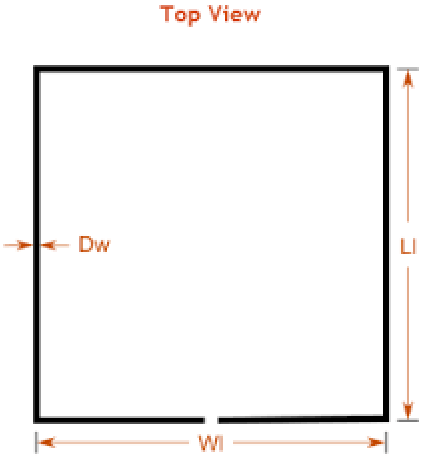


Fig.1: Square Loop Antenna

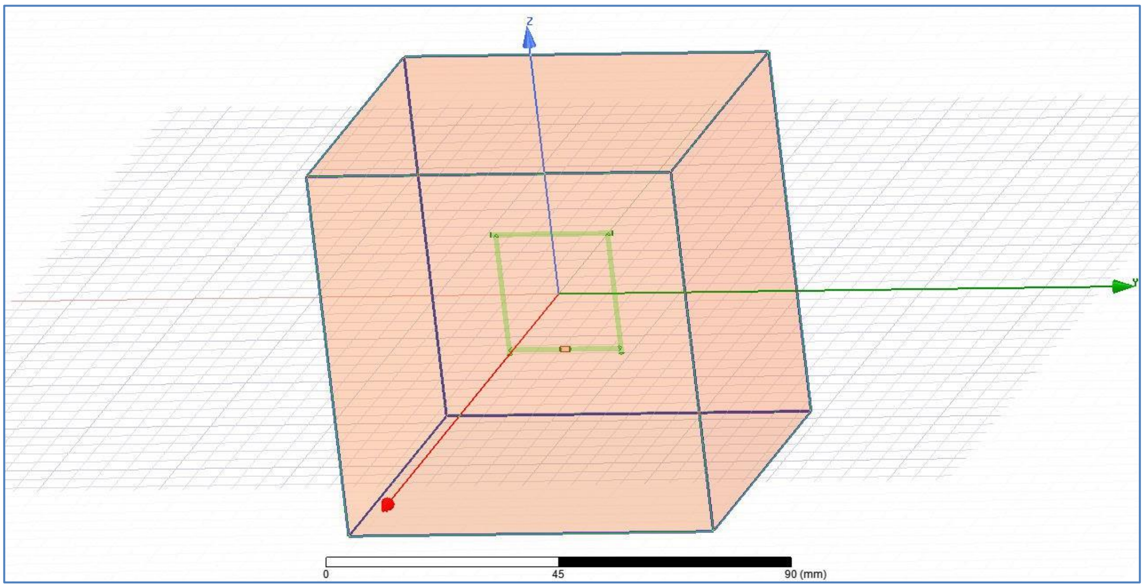


Fig.2: Structure of Square Loop Antenna in HFSS

Procedure:

1. Find Wavelength λ

   $\lambda = c/f = 3 \times 10^8$ m/s & 'f' is the operating frequency

2. Calculate Length of each monopole
3. Choose radius of each monopole.
4. Apply Excitation & necessary boundaries
5. Go to Validation check & analyse all.
6. Plot the results

Simulation Results:

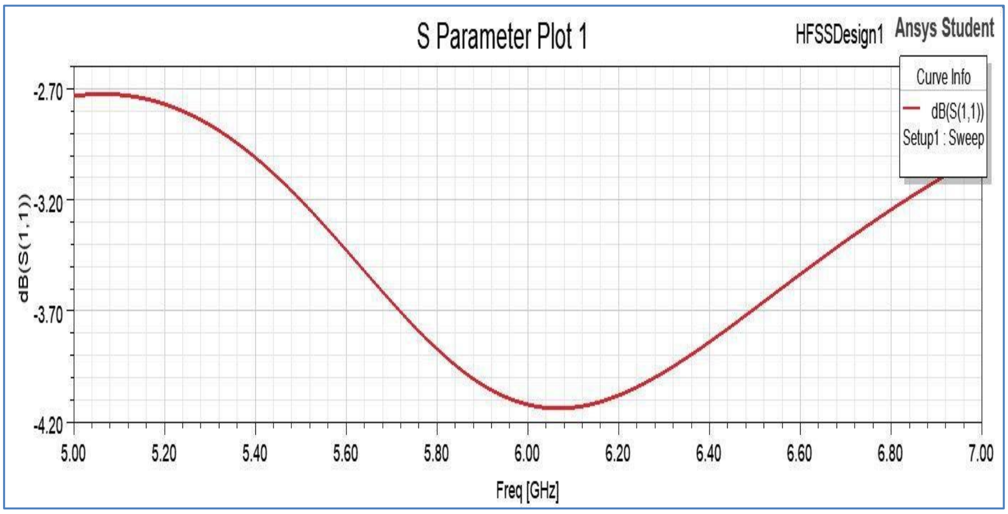


Fig. 3: S_{11} -The Reflection Coefficient in dB

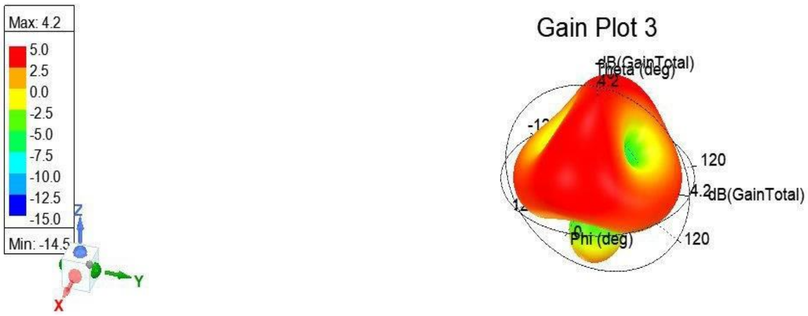


Fig.4: Radiation Pattern (3D)

Result:

Conclusion:

Experiment No.: 08

Rectangular Waveguide

Aim: Model a Rectangular Waveguide and obtain its radiation characteristics

Requirements:
A PC loaded with HFSS Software

Fig.1: Rectangular Waveguide

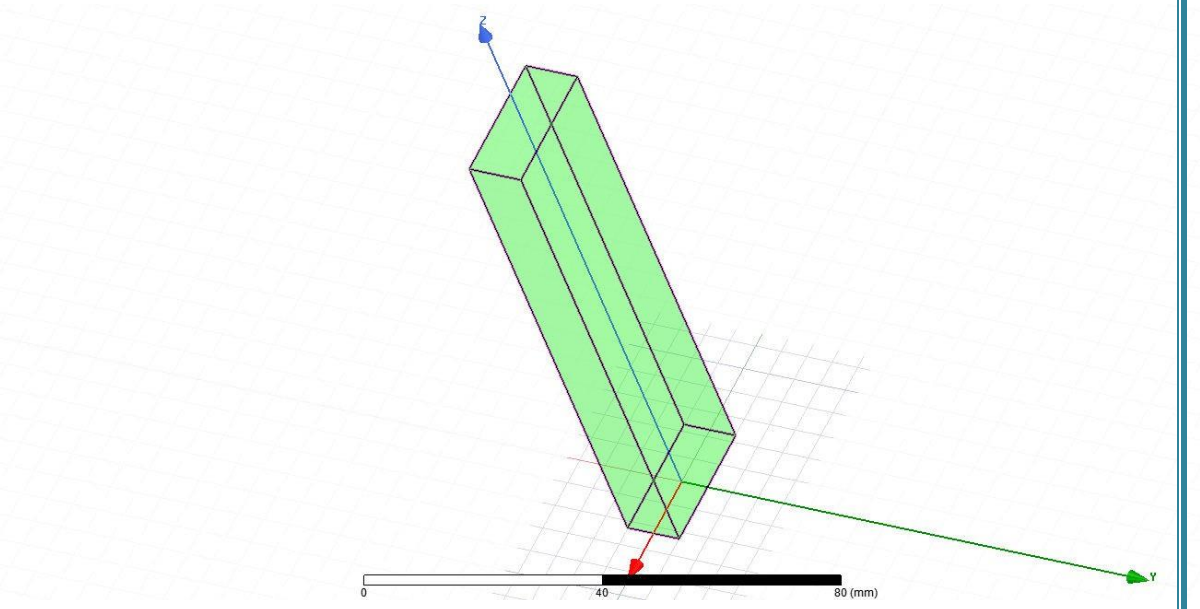


Fig.2: Circular Microstrip Antenna with inset feed in HFSS

DESIGN EQUATIONS:

i) $$f_c = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left[\frac{m\pi}{a}\right]^2 + \left[\frac{n\pi}{b}\right]^2}$$

ii) $$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}} m$$

a is inside width(m), longest dimension,

b is inside height(m), shortest dimension,

m is number of ½ - wavelength variations of fields in the “a” direction,

n is number of ½ - wavelength variations of fields in the “b” direction,

µ is the permeability &

ε is the permittivity.

Procedure:

1. Calculate Dimensions waveguide using design equations
2. Draw the Structure as per dimensions.
3. Apply Excitation & necessary boundaries
4. Go to Validation check & analyse all.
5. Plot the results

Simulation Results:

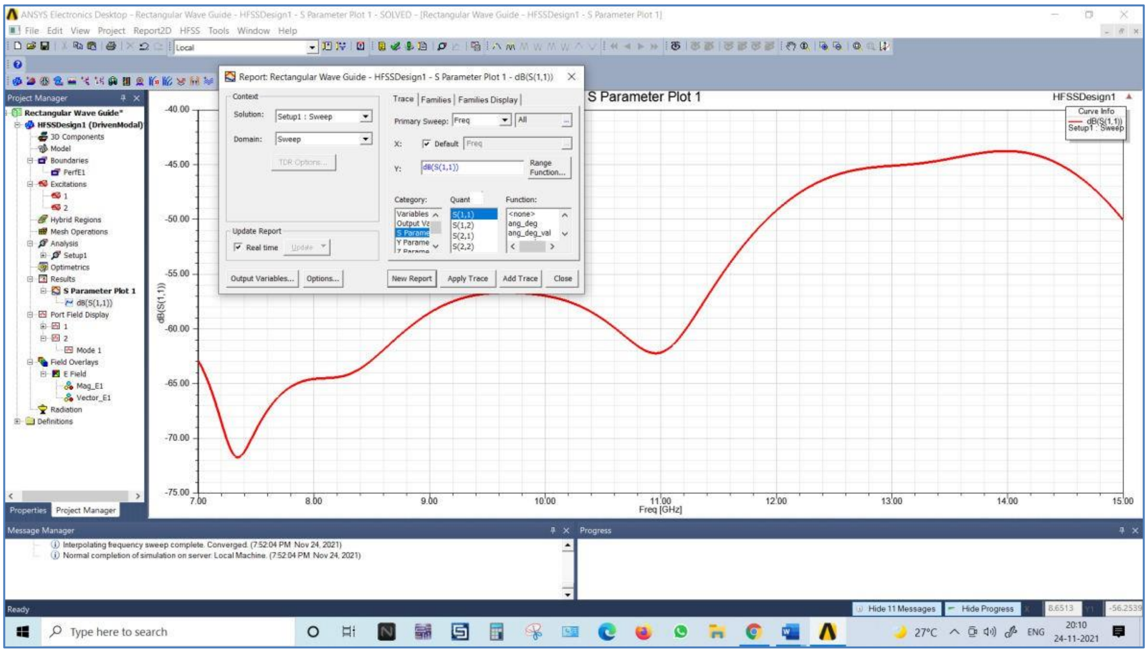


Fig. 3: S_{11} -The Reflection Coefficient in dB

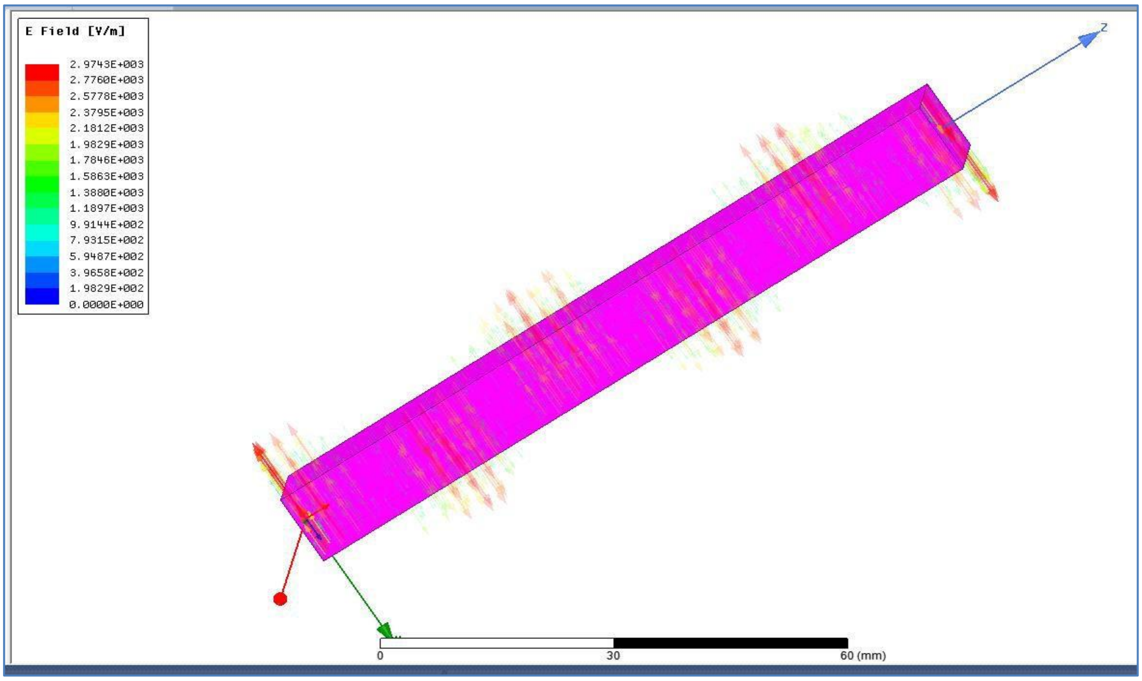


Fig. 4: Field distribution

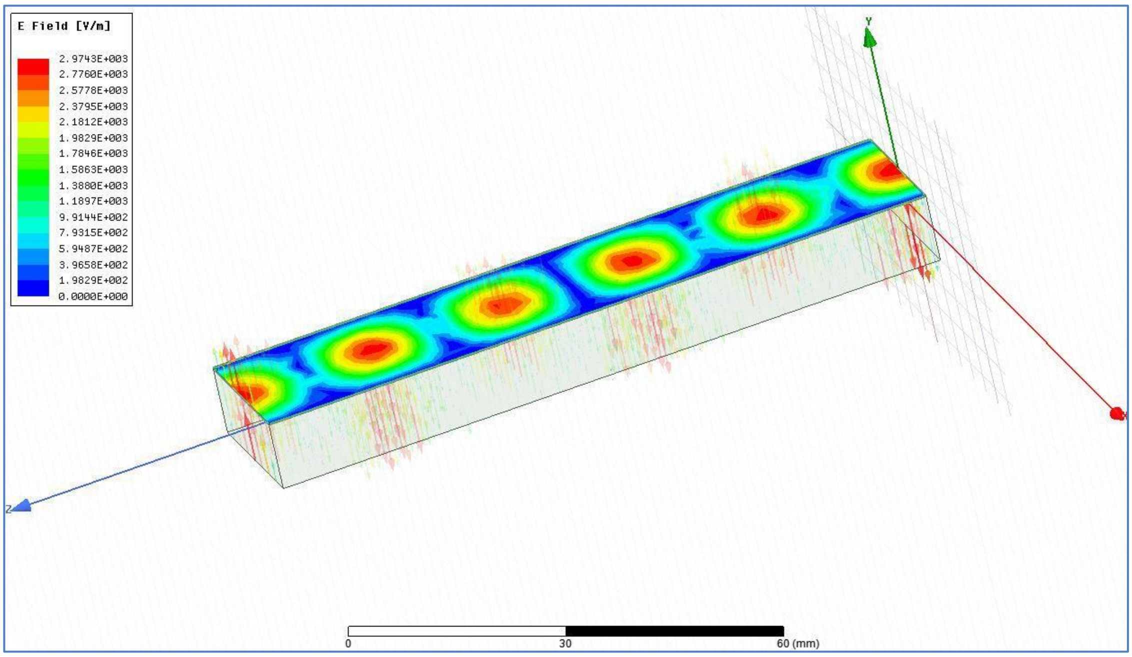


Fig. 5: Field distribution in 3D

Result:

Conclusion:

Experiment No.: 09

Linear Antenna Array Analysis

Aim: For a Linear Array of Elements Obtain the Radiation Patterns

Requirements:
A PC loaded with MATLAB Software

Procedure:

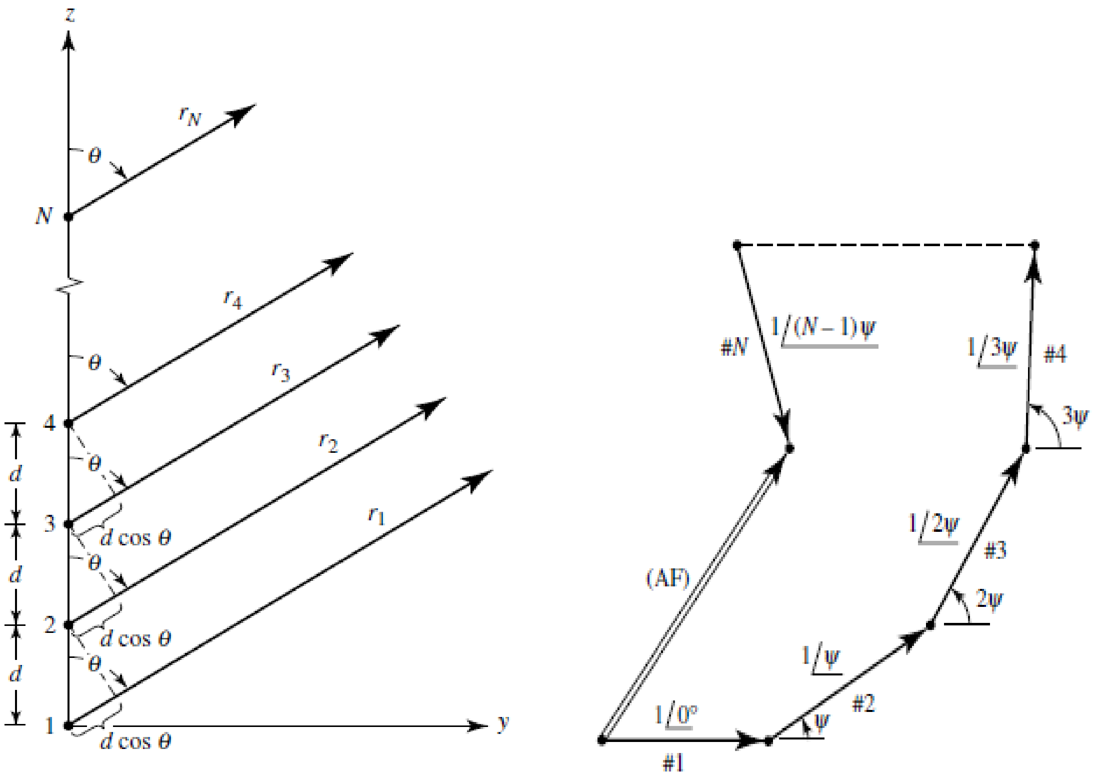


Fig.1: Geometry

1. Suppose that there are N isotropic radiators equally spaced along the z-axis and fed with equal amplitudes
2. We assign a fixed phase shift **Q** between progressive elements
3. The array factor field is

$$\mathbf{ARRAY\ FACTOR} = \mathbf{1} + \mathbf{e^{jT}} + \boldsymbol{e^{2jT}} + \cdots \dots \dots \dots . + \boldsymbol{e^{j(N-1)T}}$$

$$\mathbf{T} = \mathbf{kd\cos\theta} + \mathbf{Q}$$

Multiplying both the sides by $e^{j\Psi}$

$$\mathbf{(AF)e^{jT}} = \mathbf{e^{jT}} + \mathbf{e^{j2T}} + \mathbf{e^{j3T}} + \cdots \dots . \mathbf{e^{j(N-1)T}} + \mathbf{e^{jNT}}$$

Subtracting the above equations

$$\mathbf{AF(e^{jT}-1) = (-1+e^{jNT})}$$

$$\mathbf{AF = \left[\frac{e^{jNT}-1}{e^{jT}-1}\right] = e^{j[(N-1)/2]T}\left[\frac{e^{j(N/2)T}-e^{-j(N/2)T}}{e^{j(1/2)T}-e^{-j(1/2)T}}\right]}$$

$$\mathbf{AF = e^{j[(N-1)/2]T}\,\frac{\sin(NT/2)}{N\sin(T/2)}}$$

If the reference point is the physical centre of the array the array factor is

$$\mathbf{AF = \frac{\sin(NT/2)}{N\sin(T/2)}}$$

$$\mathbf{T = kd\cos\theta + Q}$$

where $\mathbf{k = \frac{2\pi}{\lambda}}$ = wave number

λ=Wave length= $\mathbf{c/f}$

$\mathbf{c = 3x10^8}$m/s & f - the frequency of operation

β = Phase shift between progressive elements

N=Number of elements of the array; $\mathbf{\theta = 0}$ to 2π

Broadside Array

The radiation of an array directed normal to the axis of the array and is called broadside radiator

$$\mathbf{T = kd\cos\theta + Q\,|_{\theta=90^\circ} = Q = 0}$$

End-Fire Array

Instead of having the maximum radiation broadside to the axis of the array, it may be desirable to direct it along the axis of the array (end-fire). It may be necessary to radiate toward only one direction (either $= \mathbf{0^\circ or\ 180^\circ}$)

To direct the first maximum toward $\mathbf{\theta = 0^\circ}$

$$\mathbf{T = kd\cos\theta + Q\,|_{\theta=0^\circ} = \mathit{kd} + Q = 0;\ Q = -\mathit{kd}}$$

If the maximum is desired toward $\theta = 180^\circ$then

$$\mathbf{T = kd\cos\theta + Q\,|_{\theta=180^\circ} = -\mathit{kd} + Q = 0;\ Q = \mathit{kd}}$$

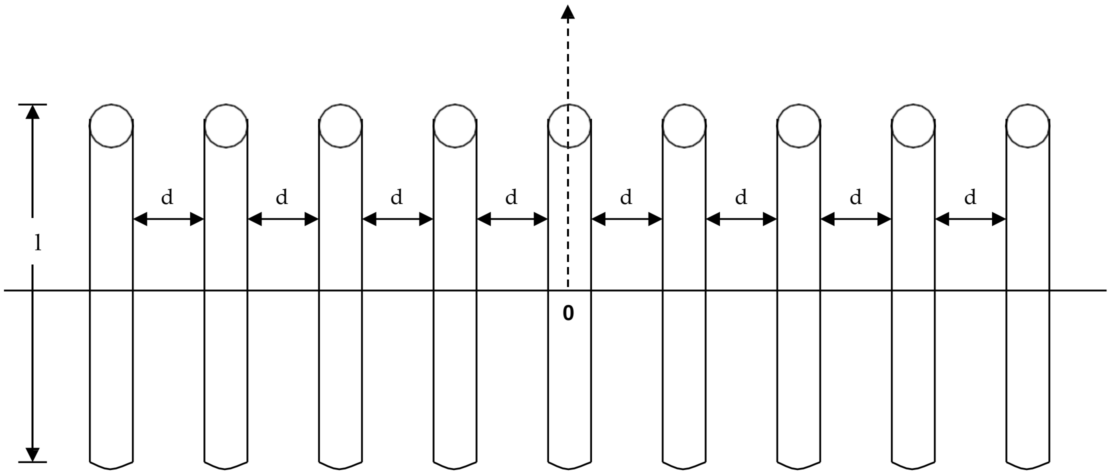


Fig.2: Linear Antenna Array of odd Number of Elements

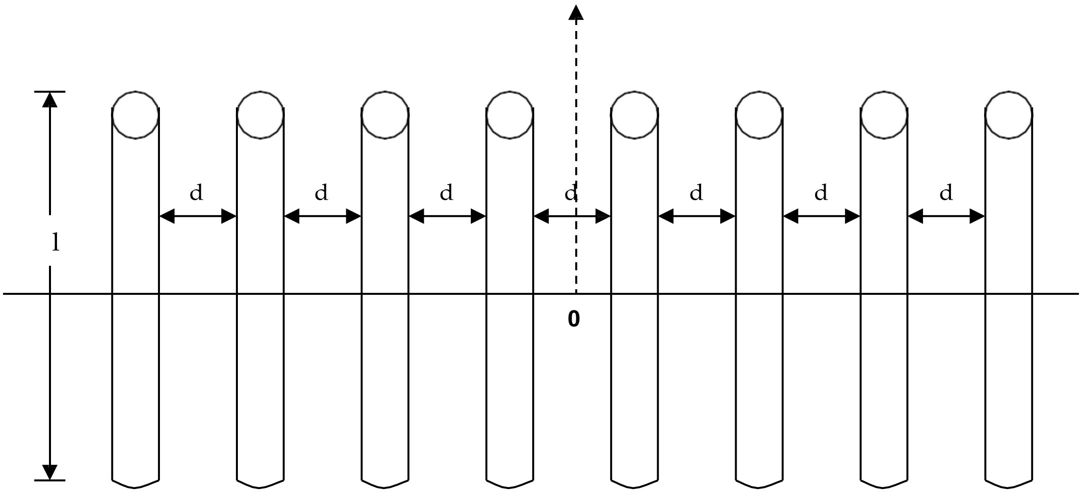


Fig.3: Linear Antenna Array of Even Number of Elements

Result:

Conclusion:

Experiment No.: 10

Linear Antenna Array Synthesis

Aim: Synthesize the Linear Antenna Array to Generate Sector Beam

Requirements:
A PC loaded with MATLAB Software

Procedure:

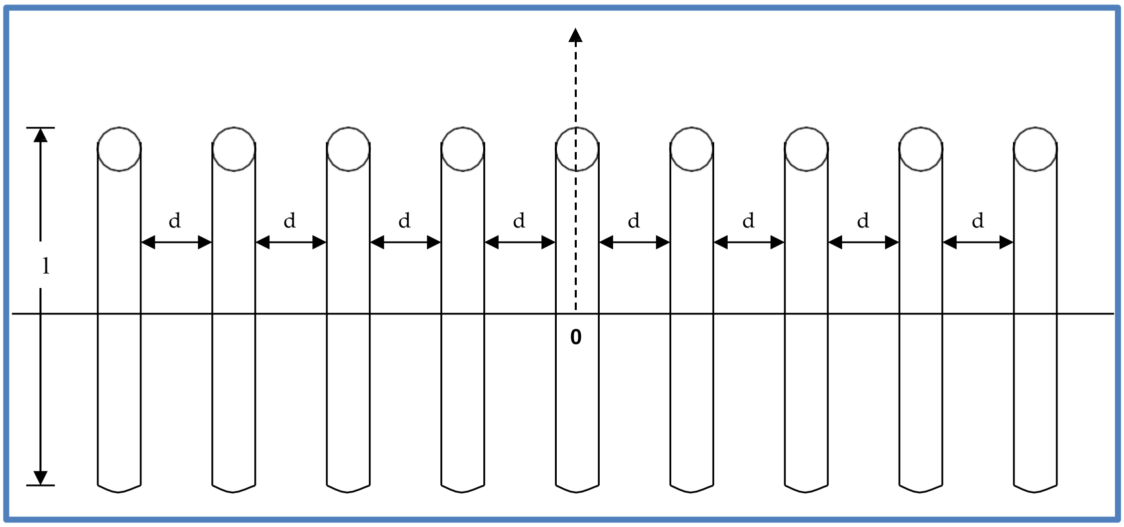


Fig.1: Geometry

4. The linear antenna arrays can be synthesized to generate desired radiation patterns(Sector Beam)
5. The array factor of the array is shown below. This is the Fourier series method of synthesis of the linear array

$$\mathbf{E(\theta) = \sum_{n=1}^{N} I_n(t) e^{jkt_n \cos\theta}}$$

$\mathbf{I_n(t)}$ **= complex excitation coefficients of the** $\mathbf{n^{th}}$**element**

t_n**=be the location of the** n^{th}**element**

Substituting $\mathbf{t_n = L x_n}$ ***and*** $\mathbf{2L}$ **– be the length of the array**

$\mathbf{x_n}$ be the position of the $\mathbf{n_{th}}$ element of the array

The above expression for the far field becomes

$$E(\theta) = \sum_{n=1}^{N} I(x_n) e^{jkLxn \cos\theta}$$

$$E(u) = \sum_{n=1}^{N} b(x) e^{j2\pi \frac{L}{\lambda} u x_n}$$

$$b(x_n) = \int_{-1}^{1} E(u) e^{j2\pi \frac{L}{\lambda} u x_n} du$$

The complex amplitude distribution can be expressed as

$$I(x_n) = b(x_n) e^{jT(x)}$$

Where **b(x_n)** is the amplitude of the current in the **n^{th}** element

$$x_n = \frac{2n - 1 - N}{N}$$

The array extends from -1 to 1 and 'x_n' is the position of the elements in the array. E (u) is the desired radiation pattern.

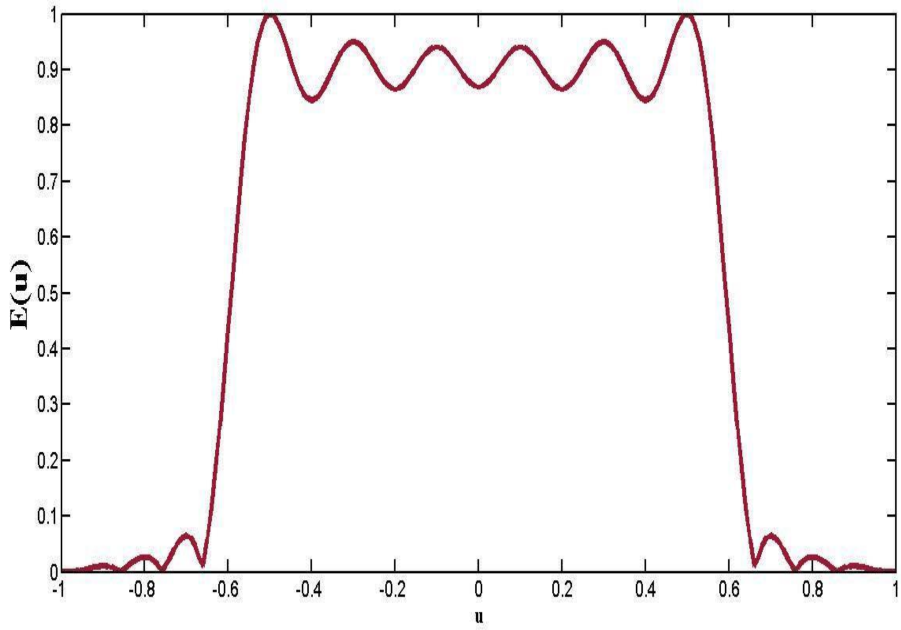
Sector Pattern

$$E(u) = 1 \qquad -u_o \leq u \leq u_o$$

=0 otherwise

```
%Sector Beam with Fourier series
clc
clc
syms m u n
u0=0.6
L=25
N=50
q=(2*n-1-N)./N
g1=int ((exp(-j*pi*L*q*u)),-u0,u0)
u=[-1:0.01:1];
E=double (symsum(g1*(exp(j*pi*L*q*u)),n,1,50))
E1=abs(E./max(E))
plot(u,E1)
```

```
xlabel('u')
ylabel('E(u)')
```



Result:

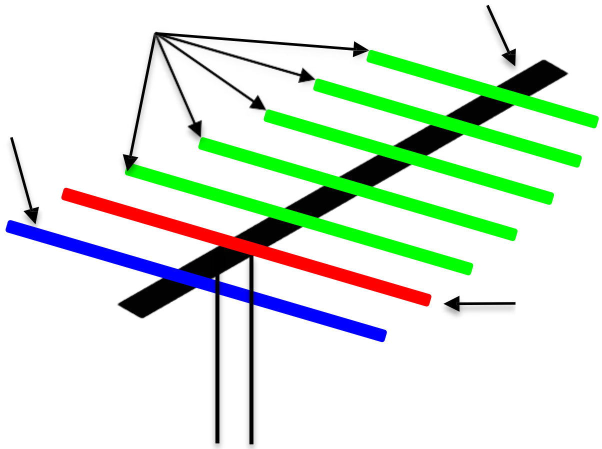
Conclusion:

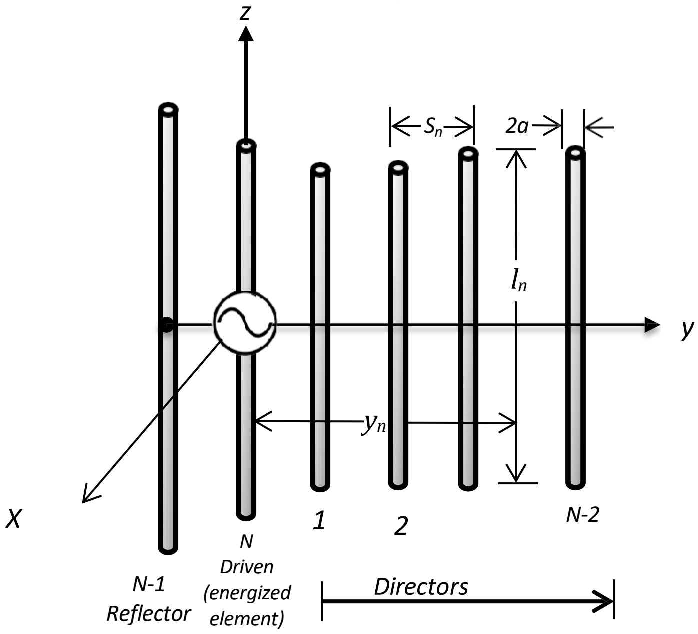
Additional Experiment

YAGI-UDA ANTENNA

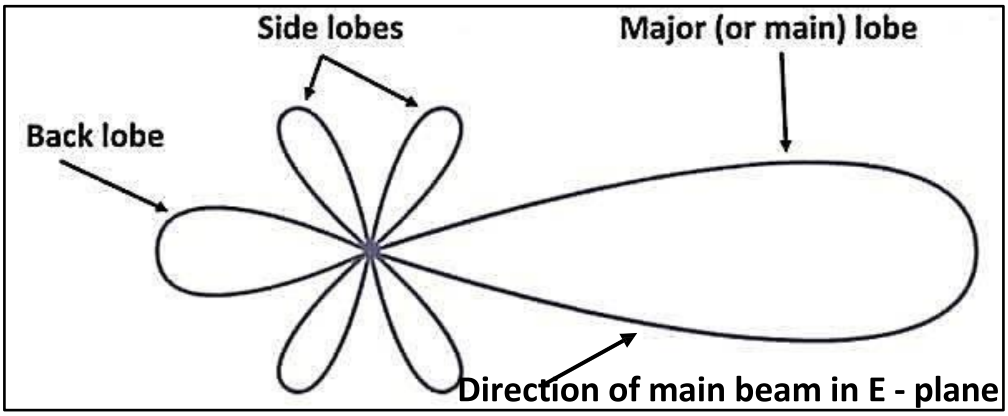
Aim: Design model and simulate the Yagi-Uda antenna for any specified frequency of operation. Analyze the radiation characteristics of the array

Requirements: Antenna Simulation Software, Computing system

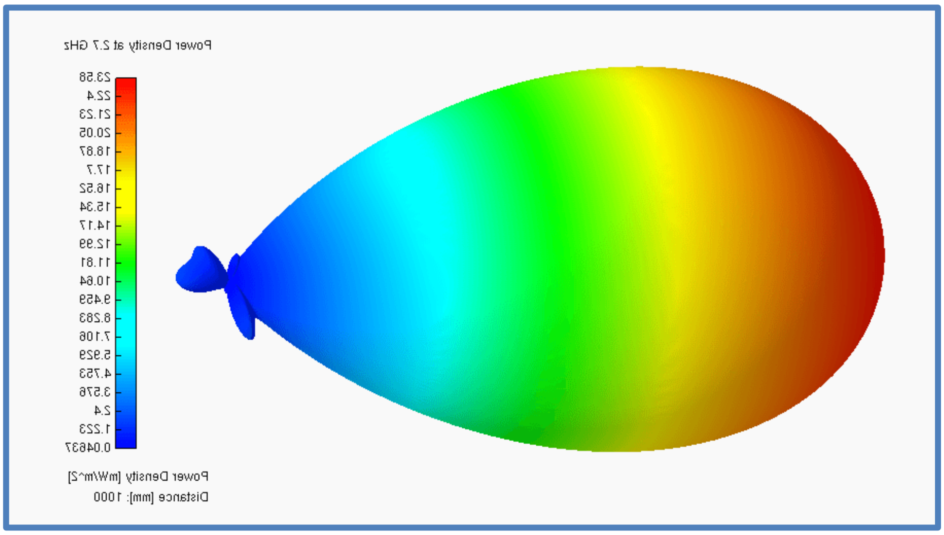




- Director Length: (0.4 – 0.45)λ
- Feeder Length: (0.47 – 0.49)λ
- Reflector Length: (0.5 – 0.525)λ
- Reflector – Feeder Spacing: (0.2 – 0.25)λ
- Director Spacing: (0.3 – 0.4)λ



Yagi Antenna Radiation Pattern



Results:

Conclusion: