Waveguides and Antenna Laboratory Manual (UE21EC354)

Department of
Electronics and Communication Engineering
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LIST OF EXPERIMENTS

1. MATLAB implementation to obtain the E-H Field Pattern plot for rectangular waveguide for TEmn and TMmn mode
2. Analysis of Rectangular waveguide using FEKO/CST simulator

3. MATLAB implementation to obtain radiation pattern of a typical antenna systems and find the half power beam width and first null beam width.

4. MATLAB implementation to obtain radiation pattern of a typical antenna systems and compare the Exact and approximate values of maximum directivity using Kraus and Tai &Pereira for U (Θ) with N varying from 1 to 2.

5. MATLAB implementation to obtain field pattern and power pattern of a Dipole antenna.

6.Familiarization to CST software:

a) Analysis of monopole antenna using CST software.

b) Analysis of dipole antenna using CST software.

7.Matlab implementation to obtain radiation pattern of an Array.

8. To study and plot the radiation pattern of

a) End-Fire array using MATLAB

b) MATLAB implementation to obtain radiation pattern of a linear Array.

9. To study and plot the radiation pattern of

a) Broad-side array using MATLAB

b) MATLAB implementation to obtain radiation pattern of a planar Array.

10. Measurement of Gain by substitution method.

11. Explore the concept of co-polarization and cross-polarization of a sectoral antenna.

12. Measurement of Radiation pattern, beam width & of micro strip Antenna and find the half power beam width and first null beam width.

13. Analysis of Horn antenna using FEKO simulator/CST.

14. Analysis of micro strip Antenna using FEKO simulator/CST.

15.Analysis of Yagi uda antenna and helical antenna using FEKO simulator/CST

EXPERIMENT NO. 1

Aim: MATLAB implementation to obtain the E-H Field Pattern plot for Rectangular waveguide for TEmn and TMmn mode

Program:

```
clc;
close all;

% Waveguide dimensions
a = 2.286;  % Length in cm in x-direction
b = a/2;    % Length in cm in y-direction
f = 45*10.^9;   % Frequency of operation 45GHz
c = 3*10.^8;    % Velocity of light
% m = 1;    % Mode number in X-Direction
% n = 0;    % Mode number in Y-Direction
choice = input('Enter choice: 1 for TE and 2 for TM:    ');
if choice == 1
    m = input('Enter mode value m:');
    n = input('Enter mode value n:');

elseif choice == 2
    m = input('Enter mode value m:');
    n = input('Enter mode value n:');
else
   sprintf('Alert!!! Wrong choice!!!')

end

Amn = 1;    % Particular mode Constant
% A10 = 1;    % for example

% Wave propagation in Z-Direction
%**********************************%
fc = c*100/2*sqrt((m/a).^2+(n/b).^2);    % Cutoff frequency calculation in GHz
% lambda = 2*a;                %for TE10 mode
lambda = c*100/fc;              % Wavelength in cm
epsilon = 8.8540e-12;           % Permittivity constant
epsilon_r = 1;                  % Relative Permittivity constant

mu1 = 4*pi*10e-7;               % Permeability constant
mu1_r = 1;                      % Relative Permeability constant
omega = 2*pi*f;                 % Frequency of operation in rad/s
M = 40;                         % Number of points to be poltted

beta = omega*(sqrt(mu1*epsilon));  %Propagation constant
Bx = m*pi/a;    %Beta(x)
```

```
By = n*pi/b;    %Beta(y)
Bc = sqrt(Bx.^2+By.^2); %Beta(c), cutoff wavenumber
Bz = sqrt(beta.^2-Bc.^2);
if choice ==1
    if m == 0 && n == 0
        fprintf(['TE_',num2str(m),num2str(n), ' mode doesnot exist']);
    elseif fc>f
        fprintf(['TE_',num2str(m),num2str(n), ' mode cutoff frequency exceeds frequency of operation;
hence mode does not porpagate\n']);
        sprintf('The frequency of operation is up to: %0.5g',f)
        sprintf('The cutoff frequency is: %0.5g',fc)

    else
        sprintf('The frequency of operation is up to: %0.5g',f)
        sprintf('The cutoff frequency is: %0.5g',fc)
% Front View
z = 0;
x = linspace(0,a,M);
y = linspace(0,b,M);
[x,y] = meshgrid(x,y);
% z = linspace(0,2*lambda,M);

%Field Expression for TEmn
% Ex = Amn*(By/epsilon)*cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-j*Bz*z);
% Ex = Amn*(By/epsilon)*cos(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
Ex = cos(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
% Ey = -Amn*(Bx/epsilon)*sin(Bx.*x).*cos(By.*y).*exp(-1i*Bz*z);
Ey = -sin(Bx.*x).*cos(By.*y).*exp(-1i*Bz*z);
Ez = 0;

% Hx = Amn*(Bx*Bz/(omega*mu1*epsilon))*sin(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);
Hx = sin(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);
% Hy = Amn*(Bx*Bz/(omega*mu1*epsilon))*cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-j*Bz*z);
Hy = cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-j*Bz*z);
% Hz = -1i*Amn*(Bc.^2/(omega*mu1*epsilon))*cos(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);
Hz = -cos(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);


figure();
quiver(x,y,real(Ex),real(Ey));
title(['Plot of front view for TE_',num2str(m),'_',num2str(n),' E-Field']);
legend('E-Field');
xlabel('x-dimension 0 to a');
ylabel('y-dimension 0 to b=a/2');
figure();
quiver(x,y,real(Hx),real(Hy));
title(['Plot of front view for TE_',num2str(m),'_',num2str(n),' H-Field']);
legend('H-Field');
xlabel('x-dimension 0 to a');
```

```
ylabel('y-dimension 0 to b=a/2');
figure();
quiver(x,y,real(Ex),real(Ey));
hold on
quiver(x,y,real(Hx),real(Hy));
grid on
title(['Plot of front view for TE_',num2str(m),'_',num2str(n)]);
legend('E-Field','H-Field');
xlabel('x-dimension 0 to a');
ylabel('y-dimension 0 to b=a/2');


% Top View for TEmn
y = b;      % Position of x-z plane
x = linspace(0,a,M);
% y = linspace(0,b,M);
z = linspace(0,lambda,M);
[x,z] = meshgrid(x,z);      % Create Mesh grid in x-z

% Field Expression for TEmn
% Ex = Amn*(By/epsilon)*cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-j*Bz*z);
Ex = cos(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
Ey = -sin(Bx.*x).*cos(By.*y).*exp(-1i*Bz*z);
% Ez = 0;
Ez = zeros(size(real(Ey)));

Hx = sin(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-1j*Bz*z);
% Hx = A10*(Bz/(omega*mu1*epsilon))*pi/a.*sin(pi.*x./a).*exp(-j*Bz*z);
Hy = cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-1j*Bz*z);
Hz = -cos(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-1j*Bz*z);

figure();
quiver(z,x,real(Ez),real(Ex));
title(['Plot of Top view for TE_',num2str(m),'_',num2str(n),' E-Field']);
legend('E-Field');
ylabel('x-dimension 0 to a');
xlabel('z-direction');
figure();
quiver(z,x,real(Hz),real(Hx));
title(['Plot of Top view for TE_',num2str(m),'_',num2str(n),' H-Field']);
legend('H-Field');
ylabel('x-dimension 0 to a');
xlabel('z-direction');
figure();
quiver(z,x,real(Ez),real(Ex));
hold on
quiver(z,x,real(Hz),real(Hx));
grid on
title(['Plot of TOP view of E-H for TE_',num2str(m),'_',num2str(n)]);
```

```
legend('E-Field','H-Field');
ylabel('x-dimension 0 to a');
xlabel('z-direction');
% Side View for TEmn
x = a/2;
% x = linspace(0,a,M);
y = linspace(0,b,M);
z = linspace(0,2*lambda,M);
[y,z] = meshgrid(y,z);

% Field Expressions for TEmn
Ex = cos(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
Ey = -sin(Bx.*x).*cos(By.*y).*exp(-1i*Bz*z);
Ez = 0;
Ez = zeros(size(real(Ey)));

Hx = sin(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);
Hy = cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-j*Bz*z);
Hz = -cos(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);


figure();
quiver(z,y,real(Ez),real(Ey));
title(['Plot of Side view for TE_',num2str(m),'_',num2str(n),' E-Field']);
legend('E-Field');
ylabel('y-dimension 0 to b');
xlabel('z-direction');
figure();
quiver(z,y,real(Hz),real(Hy));
title(['Plot of Side view for TE_',num2str(m),'_',num2str(n),' H-Field']);
legend('E-Field');
ylabel('y-dimension 0 to b');
xlabel('z-direction');
figure();
quiver(z,y,real(Ez),real(Ey));
hold on
quiver(z,y,real(Hz),real(Hy));
grid on
title(['Plot of Side view of E-H for TE_',num2str(m),'_',num2str(n)]);
legend('E-Field','H-Field');
ylabel('y-dimension 0 to b');
xlabel('z-direction');
   end

elseif choice == 2

    if m == 0 || n == 0
      fprintf(['TM_',num2str(m),num2str(n), ' mode doesnot exist']);
   elseif fc>f
```

```
        fprintf(['TM_',num2str(m),num2str(n), ' mode cutoff frequency exceeds frequency of operation;
hence mode does not porpagate\n']);
        sprintf('The frequency of operation is up to: %0.5g',f)
        sprintf('The cutoff frequency is: %0.5g',fc)
     else
        sprintf('The frequency of operation is up to: %0.5g',f)
        sprintf('The cutoff frequency is: %0.5g',fc)
% Field Pattern plot for Rectangular wave guide for TMmn mode
%TM_mn mode field expressions

% Front View
x = linspace(0,a,M);
y = linspace(0,b,M);
% z = linspace(0,2*lambda,M);
z = 0;
[x,y] = meshgrid(x,y);

% % % Field Expressions for TMmn
% % Ex = -cos(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
% % Ey = -sin(Bx.*x).*cos(By.*y).*exp(-1i*Bz*z);
% % Ez = -sin(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
% %
% % Hx = sin(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);
% % Hy = cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-j*Bz*z);
% % % Hz = 0;
% % Hz = zeros(size(real(Hy)));
tmequation();
%Plot of TMmn E-Field view
figure();
quiver(x,y,real(Ex),real(Ey));
title(['Plot of front view for TM_',num2str(m),'_',num2str(n),' E-Field']);
legend('E-Field');
xlabel('x-dimension 0 to a');
ylabel('y-dimension 0 to b=a/2');
%Plot of TMmn H-Field view
figure();
quiver(x,y,real(Hx),real(Hy));
title(['Plot of front view for TM_',num2str(m),'_',num2str(n),' H-Field']);
legend('H-Field');
xlabel('x-dimension 0 to a');
ylabel('y-dimension 0 to b=a/2');
%Plot of TMmn E-Field and H-Field view
figure();
quiver(x,y,real(Ex),real(Ey));
hold on
quiver(x,y,real(Hx),real(Hy));
grid on
title(['Plot of front view for TM_',num2str(m),'_',num2str(n)]);
legend('E-Field','H-Field');
```

```
xlabel('x-dimension 0 to a');
ylabel('y-dimension 0 to b=a/2');

% Top View
y = b;      %Position of view
x = linspace(0,a,M);
% y = linspace(0,b,M);
z = linspace(0,lambda,M);
[x,z] = meshgrid(x,z);

% % %Field expression for TMmn
% % Ex = -cos(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
% % Ey = -sin(Bx.*x).*cos(By.*y).*exp(-1i*Bz*z);
% % Ez = -sin(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
% %
% % Hx = sin(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);
% % Hy = cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-j*Bz*z);
% % % Hz = 0;
% % Hz = zeros(size(real(Hy)));
tmequation();

figure();
quiver(z,x,real(Ez),real(Ex));
title(['Plot of Top view for TM_',num2str(m),'_',num2str(n),' E-Field']);
legend('E-Field');
ylabel('x-dimension 0 to a');
xlabel('z-direction');
figure();
quiver(z,x,real(Hz),real(Hx));
title(['Plot of Top view for TM_',num2str(m),'_',num2str(n),' H-Field']);
legend('H-Field');
ylabel('x-dimension 0 to a');
xlabel('z-direction');
figure();
quiver(z,x,real(Ez),real(Ex));
hold on
quiver(z,x,real(Hz),real(Hx));
grid on
title(['Plot of TOP view of E-H for TM_',num2str(m),'_',num2str(n)]);
legend('E-Field','H-Field');
ylabel('x-dimension 0 to a');
xlabel('z-direction');

% Side View
x = a/2;
% x = linspace(0,a,M);
y = linspace(0,b,M);
z = linspace(0,2*lambda,M);
[y,z] = meshgrid(y,z);
```

```
% % %Field Expression for TMmn
% % Ex = -cos(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
% % Ey = -sin(Bx.*x).*cos(By.*y).*exp(-1i*Bz*z);
% % Ez = -sin(Bx.*x).*sin(By.*y).*exp(-1i*Bz*z);
% %
% % Hx = sin(m*pi.*x./a).*cos(n*pi.*y./b).*exp(-j*Bz*z);
% % Hy = cos(m*pi.*x./a).*sin(n*pi.*y./b).*exp(-j*Bz*z);
% % % Hz = 0;
% % Hz = zeros(size(real(Hy)));
tmequation();

figure();
quiver(z,y,real(Ez),real(Ey));
title(['Plot of Side view for TM_',num2str(m),'_',num2str(n),' E-Field']);
legend('E-Field');
ylabel('y-dimension 0 to b');
xlabel('z-direction');
figure();
% quiver(y,z,real(Hy),real(Hz));
quiver(z,y,real(Hz),real(Hy));
title(['Plot of Side view for TM_',num2str(m),'_',num2str(n),' H-Field']);
legend('E-Field');
ylabel('y-dimension 0 to b');
xlabel('z-direction');
figure();
quiver(z,y,real(Ez),real(Ey));
hold on
quiver(z,y,real(Hz),real(Hy));
grid on
title(['Plot of Side view of E-H for TM_',num2str(m),'_',num2str(n)]);
legend('E-Field','H-Field');
ylabel('y-dimension 0 to b');
xlabel('z-direction');
    end
else

      sprintf('Alert!!! Something went wrong, try again!!!');
end
```

EXPERIMENT NO.2

Aim: Analysis of Rectangular waveguide using FEKO/CST simulator

Procedure:

Step1: new and recent -> new template -> microwave and RF/optical ->Waveguides -> time domain ->retain default settings->frequency= 8-12 GHz -> Select all tabs under monitors -> next-> finish

Step2: modelling -> brick

click on screen and escape

name: rectangular waveguide;

Xmin: -11; Xmax: 11

Ymin: -6.5; Ymax: 6.5 (orientation)

Zmin: -55; Zmax: 55

material: select from the drop down "load from material library" ->select "Alumina 99.5% (loss free)" -> load-> OK

Waveguide will be created.

Step 3: To make the waveguide hollow

Select "brick"->

name: rectangular waveguide 1; (give different name)

Xmin: -10; Xmax: 10

Ymin: -5.5; Ymax: 5.5 (orientation)

Zmin: -55; Zmax: 55

material: Alumina 99.5% (loss free)" -> OK

select "cut away highlighted shape" under shape intersection: Boolean combination

Hollow metallic waveguide is ready.

To connect the ports

Select picks-> pick face-> double click on the edges-> simulation-> waveguide port-> enter the values

Name: 1

Position:

Xmin: 11 X max: 11

Ymin: 6.5 Ymax: 6.5

Click OK

Repeat the same procedure for the other side of the waveguide to fix the port 2.

For excitation

Click on set up solver-> Start

Go to S parameter, check for the waveforms, VSWR, and radiations for 3 different frequencies.

Note down the values of VSWR, E field (V/m), H field (A/m) values for every frequency (8 – 12 GHz)

Check the radiation pattern under the far field view-> 3D view.

EXPERIMENT NO.3

THE NORMALIZED RADIATION INTENSITY OF AN ANTENNA IS REPRESENTED BY

$$U(\theta) = \cos^2(\theta).\cos^2(3\theta),\quad 0\le\theta\le 90^\circ \quad 0\le\varphi\le 360^\circ.$$

AIM: WRITE THE MAT LAB PROGRAM TO PLOT THE RADIATION PATTERN AND FIND HALF POWER BEAM WIDTH AND FIRST NULL BEAM WIDTH.

PROGRAM:

```
clc;
close all;
clear all;
X=-pi/2:.01:pi/2;
u=(cos (X).*cos(3.*X)).^2;
polar(X,u)
% to calculate the power radiated
Prad = dblquad(@(x,y)(((cos (x)).*(cos(3.*x))).^2).*sin(x), 0, pi, 0, 2*pi);
disp('Power Radiated=');
disp(Prad);
% to cal the hpbw
for angle=(-pi/2):0.00001:0
U=(cos (angle).*cos(3.*angle)).^2;
if (U>=(max(u))/2-0.01) && (U<=(max(u))/2+0.01)
theta1=angle;
end
end
theta1=theta1*180/pi;
for angle=0:0.00001:pi/2
U=(cos (angle).*cos(3.*angle)).^2;
if (U>=((max(u))/2)-0.001) && (U<=((max(u))/2)+0.001)
theta2=angle;
end
end
theta2=theta2*180/pi;
theta=abs(theta1)+abs(theta2);
disp('HPBW=');
disp(theta);
%for FNBW
for angle=0:0.00001:(pi/2)
U=(cos (angle).*cos(3.*angle)).^2;
if (U>=(min(u))/2-0.001) && (U<=(min(u))/2+0.001)
theta3=angle;
break;
end
end
theta3=theta3*180/pi;
```

```
for angle=(-pi/2):0.00001:0
U=(cos (angle).*cos(3.*angle)).^2;
if (U>=(min(u))/2-0.01) && (U<=(min(u))/2+0.01)
theta4=angle;
end
end



theta1=theta1*180/pi;
theta4=theta4*180/pi;
theta=abs(theta3)+abs(theta4);
disp('FNBW=');
disp(theta);
```

EXPERIMENT NO. 4

THE NORMALIZED RADIATION INTENSITY OF AN ANTENNA IS REPRESENTED

$U(\theta) = \cos^n(\theta), \quad 0 \le \theta \le 90^\circ, \quad 0 \le \varphi \le 360^\circ.$

Aim: WRITE THE MATLAB PROGRAM TO PLOT THE RADIATION PATTERN AND COMPARE THE EXACT AND APPROXIMATE VALUES OF MAXIMUM DIRECTIVITY FOR U (Θ) WITH N VARYING FROM 1 TO 2.

Program

```
clc;
close all;
clear all;
% to plot the waveform
N=input('Enter the value of N:');
X=-pi/2:.01:pi/2;
u=((cos (X)).^N);
polar(X,u)
% to calculate the power radiated
Prad = dblquad(@(x,y)(((cos (x)).^N).*sin(x)), 0, pi/2, 0, 2*pi);
disp('Power Radiated=');
disp(Prad);
% to cal the hpbw
for angle=(-pi/2):0.0001:0
U=(cos (angle)).^N;
if (U>=(max(u))/2-0.01) && (U<=(max(u))/2+0.01)
theta1=angle;
end
end
for angle=0:0.0001:pi/2
U=(cos (angle)).^N;
if ((U>=(max(u))/2-0.001) && (U<=(max(u))/2+0.001))
theta2=angle;
end
end
theta1=theta1*180/pi;
theta2=theta2*180/pi;
theta=abs(theta1)+abs(theta2);
D=(4*pi*max(u))/Prad;
D_K=(41253)/(theta^2);
D_T_P=(72815)/(2*theta^2);
disp(D);
disp (D_K);
disp(D_T_P);
```

EXPERIMENT NO.5

Aim: Matlab implementation to obtain field pattern and power pattern of a Dipole antenna.

Program:

```
clc;
clear all;
close all;
w=input('enter the value of wavelength=');
K=2*pi/w;
l=input('enter the value of dipole length=');
eta=120*pi;
x=0:0.01:2*pi;
I=input('enter the value of current=');
v=eta*(((K*I*l)/(4*pi)).^2)*sin(x).^2;
figure(1);
polar(x,v);
E=(cos((K*l.*cos(x))/2)-cos(K*l/2))./sin(x);
figure(2);
polar(x,abs(E));
```

```
output
enter the value of wavelength=.5
enter the value of dipole length=.4
enter the value of current=1
```

EXPERIMENT NO.6

Aim: Familiarization to CST software:

a) Analysis of monopole antenna using CST software.

b) Analysis of dipole antenna using CST software.

Procedure:

a) MONOPOLE ANTENNA

length of wire antenna = 142.5 mm

f1 = 1.4GHz, f2 = 3.4GHz, fc = 2.4GHz

l = 142.5/2400 = 60mm

length of the monopole antenna = l/2 = 30mm

Step1: new and recent -> new template -> microwave and RF/optical -> wire -> time domain -> next -> freq min: 1.4Ghz freq max: 3.4GHz -> Efield Hfield Farfield tick -> Finish

Step2: modelling -> cylinder, click on screen and escape

name: Monopole; orientation: y; outer radius: 1; ymax: 30; ymin: 0; material: PEC -> okay;

Step3: Modelling -> cylinder

name: hole; orientation: V; outer radius: 1+0.5; vmax: 0.02; material: PEC -> okay

Step4: Modelling -> brick

vmin = -0.02

click on screen and escape

name: Ground Plane; xmin: -30; xmax: 30; ymin: -0.02; ymax: 0; zmin: -30; zmax: 30 -> okay

Step5: modelling local wcs -> one click

du: 0 dv: -0.02 dw:0 -> okay

Step6: Navigation tree -> Components -> single click on monopole -> modelling -> boolean -> Subtract -> single click on hole -> enter

Step7: Modelling -> picks -> pick point -> select points on inner and outer cylinders -> simulation -> discrete port -> Impedance: 36.5 -> okay

Step8: Simulation -> setup solver -> start

Step9: After simulation check 1D and 2D results, Note down the values

1D Results: S-Parameters, VSWR

Farfields: @f=2.4 GHz

farfield plot-> Directivity, E-field and H-field

b) DIPOLE ANTENNA

FORMULA:

1.Centre frequency:2.45GHz

2.Dipole length:L=143/f(MHz)=59mm

3.Wire Diameter(W_D)=D=2(0.001λ)=0.2447

4.Feed Gap(F_G)=L/200=0.2918

STEPS:

Open new template in CST

Frequency min=2GHz Frequency max=3GHz

Monitor S:E-field,H-field,Farfield

Define at 2.45GHz

1.Go to modelling. Click on cylinder

Name: Dipole Arm1

Orientation at Z

Outer radius: W_D/2

Zmin=-L/2 Zmax=-F_G/2

Material: PEC

2.Right click on the dipole arm 1 in the navigation tree. Click on transform.

Operation: Mirror, Copy

X=0, Y=0, Z=1

3.Gap connection: Select brick in the modelling menu

Xmin=-W_D/2 Xmax=W_D/2 Ymin=0 Ymax=0 Zmin=-F_G/2 Zmax=F_G/2

Material: Vacuum

4.Port connection: Go to picks. Click pick edge. Select one edge of the dipole by selecting brick edge, then select the other edge

5.Go to simulation. Select Discrete Port.

6.Mesh->Global properties-hexahedral cells per wavelength=15.

7.Go to set up solver->start

8.After simulation check 1D and 2D results. Note down the values.

EXPERIMENT NO. 7

Aim: Matlab implementation to obtain radiation pattern of an Array

Program:

```
clc;
clear all;
N=input('enter the value of N=');
wavelength=input('enter the value of w=');
K=2*pi/wavelength;
phaseshift=input('enter the value of b=');
distance=input('enter the value of d=');
x=pi/100:pi/100:2*pi;
psi=phaseshift+(K*distance*cos(x));
af=(sin(N*psi/2))./(sin(psi/2));
polar(x,af);
```

Output

```
enter the value of N=5
enter the value of w=.5
enter the value of b=45
enter the value of d=.5
```

EXPERIMENT NO. 8a.

AIM: To study and plot the radiation pattern of an End-fire array using MATLAB.

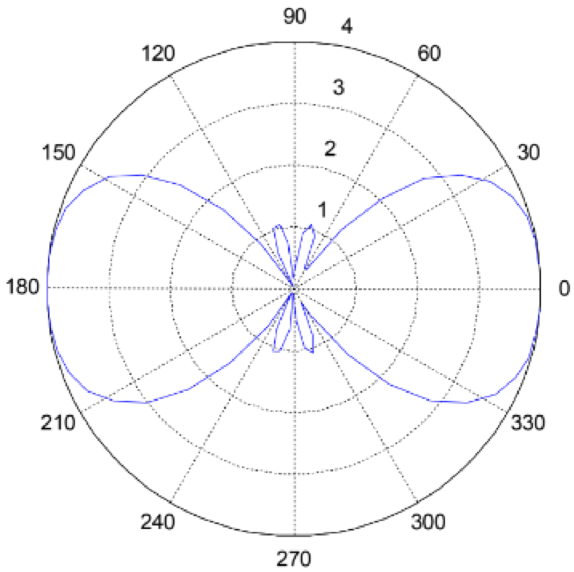
DEFINITION: An array is said to be end fire array if the phase angle is such that it makes maximum radiation in the direction of line of array i.e. 0°& 180°
.

PROGRAM:

```
clc
close all
clear all
phi=0:.1:2*pi;
c=3*(10^8);
f=input('enter frequency of signal:');
l=c/f;
D=input('enter the distance between two antennas:');
B=2*pi/l
Dr=B*D
d=input('give value of d:');
n=input('enter no. of point sources:')
si=abs(Dr*cos(phi)+d);
Eo=abs((sin(n*si/2))./sin(si/2));
polar(phi,Eo)
```

OUTPUT:
Input parameters :
enter frequency of signal:1e9
enter the distance between two antennas:l/2
B =20.9440
Dr =3.1416
give value of d:-Dr
enter no. of point sources:4
Output : n=4

Field Pattern :



EXPERIMENT NO. 8b

Aim: MATLAB implementation of the Linear Array Antenna

Program:

```
clc; clear all; close all;
d=input('Enter inter elemental spacing:  ');
lam=10;
themax=input('Enter Angle shift in degrees:  ');
N=input('Enter Number of elements:  ');
the=-90:0.2:90
n=0:N-1
pat=exp(1i*(2*pi*(d/lam)*n'*(sind(the)-sind(themax))));
figure;
plot(the,mag2db(abs(sum(pat))));
title(['Gain Spectrum plot for d=' num2str(d) ',ThethaMax=' num2str(themax)]);
set(gca,'YLim',[-50 50],'XLim',[-90 90]);
```

EXPERIMENT NO. 9a

AIM: To study and plot the radiation pattern of a Broad-side array using MATLAB

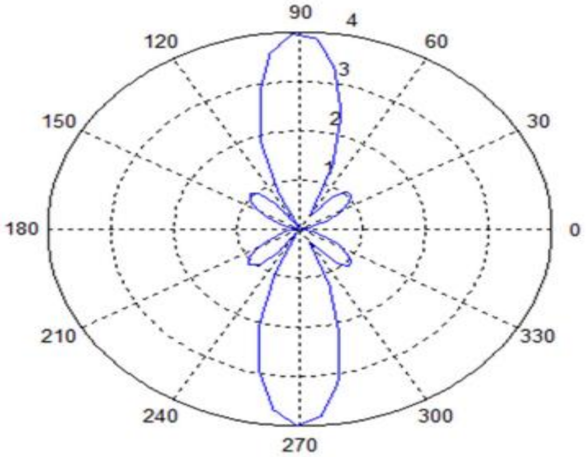
DEFINITION:
An array is said to be broad side array if phase angle is such that it makes maximum radiation perpendicular to the line of array i.e. 90˚ & 270˚.

PROGRAM:

```
clc
close all
clear all
phi=0:.1:2*pi;
c=3*(10^8);
f=input('enter frequency of signal:');
l=c/f;
D=input('enter the distance between two antennas:');
B=2*pi/l
Dr=B*D
d=input('give value of d:');
n=input('enter no. of point sources:')
si=abs(Dr*cos(phi)+d);
Eo=abs((sin(n*si/2))./sin(si/2));
polar(phi,Eo)
```

OUTPUT:
Input parameters :
enter frequency of signal:1e9
enter the distance between two antennas:l/2
B =20.9440
Dr =3.1416
give value of d:0
enter no. of point sources:4
Output parameters :
n =4

Field Pattern :



EXPERIMENT NO. 9b

Aim: MATLAB code for planar array antenna pattern.

Program:

```
clc; clear all; close all;
dx=input('Enter dx ');
dy=input('Enter dy ');
lam=10;
themax=input('Enter thetha max ');
phimax=input('Enter phi max ');
N=input('Enter N ');
M=input('Enter M ');
pat=0;
a=1;b=1;
for the=-90:0.5:90
    b=1;
    for phi=-90:0.5:90
        u(a,b)=sind(phi)*cosd(the);
        v(a,b)=sind(phi)*sind(the);
        b=b+1;
    end
    a=a+1;
end


x=1;
for m=0:M-1
    for n=0:N-1
        pat=pat+exp((u-sind(phimax)*cosd(themax))*1i*(2*pi*n*(dx/lam))+(v-
sind(phimax)*sind(themax))*1i*(2*pi*m*(dy/lam)));
    end
end
pattern=mag2db(abs(pat));
pattern=pattern-max(max(pattern));
mesh(u,v,pattern);
```

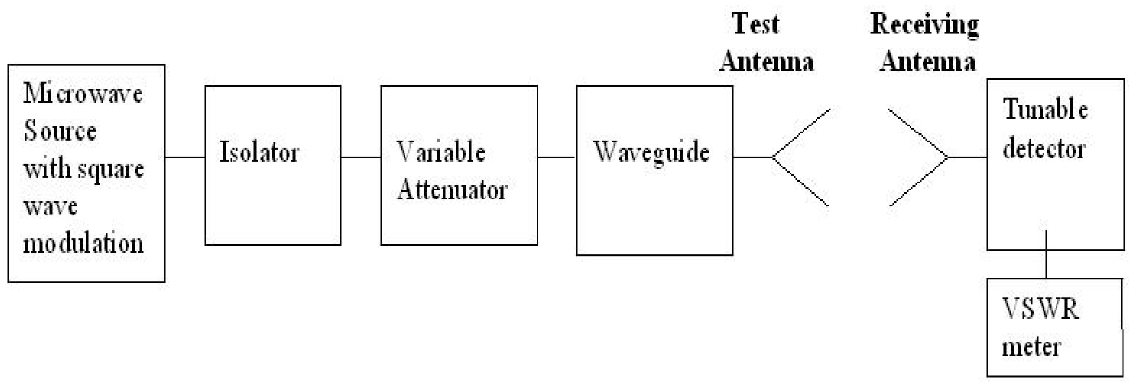
EXPERIMENT NO.10

Measurement of gain of antenna by substitution method

AIM: Measurement of gain of antenna by substitution method

COMPONENTS REQUIRED: KPS, RKO, VSWR meter, frequency meter, standard antenna and test antenna

BLOCK DIAGRAM:



THEORY: We can measure the peak gain using friss transmission equation and a gain with standard antenna. A gain standard antenna with an accurately known gain and polarization typically linear. The most popular types of gain standard antenna are the thin half wave dipole antenna(peak gain of 2.15 dB)and the pyramidal horn antenna where peak gain can be accurately calculated and is typically in the range of 15-25dB.The gain antenna is used in place of test antenna with the source antenna transmitting a fixed amount of power from the Friss transmission equation the power received is

$$\mathbf{P_R = P_T\, G_T\, G_R\, \lambda^2 / (4\Pi R)^2}$$

. Then the gain of the test antenna (*GT*) is (in linear units):

$$G_T = G_G \frac{P_{R2}}{P_R}$$

The above equation uses linear units (non-dB). If the gain is to be specified in decibels, (power received still in Watts), then the equation becomes:

$$[G_T]_{dB} = [G_G]_{dB} + 10\log_{10}\left(\frac{P_{R2}}{P_R}\right)$$

(Or)

$$[G_T]_{dB} = [G_G]_{dB} + \left(\frac{P_{R2}}{P_R}\right)_{dB}$$

And that is all that needs done to determine the gain for an antenna in a particular direction.

PROCEDURE:

1.Set up initial apparatus with both transmitting and receiving antenna as standard gain antenna whose gain is 16dB

2.TX antenna is thus transmitting standard amount of power

3.Keep the 0^0 angle such that both TX and RX are aligned.Note down the measured received power

4.Rotate the antenna to a certain angle and note down received power

5.Repeat step4 for 4 to 5 values of angle so that we can compare the peak gain of test antenna with standard antenna

6.Replace RX std antenna with a RX test antenna

7.Again repeat steps 4,5,6 and note it in tabular form

8.Calculate gain of test antenna using formula at various angles

$(G_T)db = (G_R)db + (P_T – P_S)db$

9.If calculated gain is greater than 16db or around 16db it is good performance. If it is too less it is poor performance

TABULAR COLUMN:

Degree	Standard Gain power	Gain of standard antenna	Test antenna gain power	Test antenna gain
0^0				
15^0				
30^0				

45^0				
60^0				

CONCLUSION: The gain of antenna measured at all angles as shown in tabular column and is nearly matching to gain of standard antenna but at 15^0 and 60^0 its performance is poor so that test antenna has to be calibrated for better performance.

RESULT: Gain of test antenna at various angles is calculated and performance is compared with standard antenna.

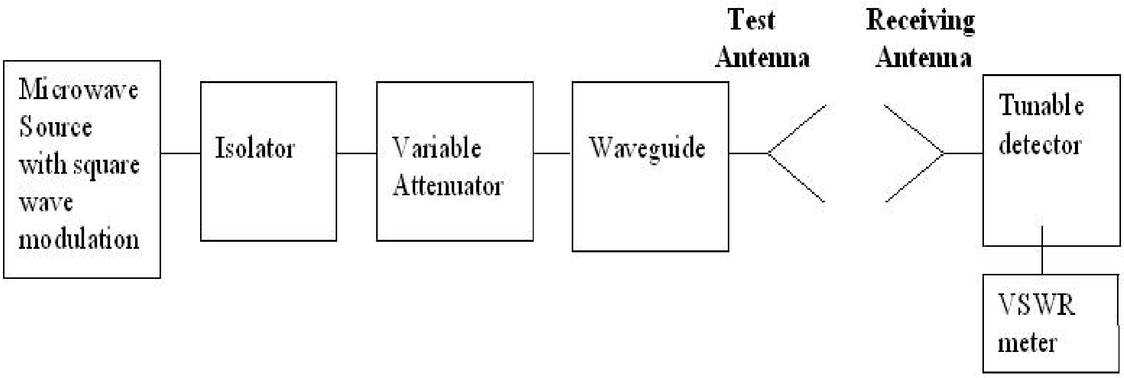
EXPERIMENT NO. 11

Determination of polarization of an antenna

AIM : To determine the polarization of an antenna

COMPONENTS REQUIRED: KPS, RKO, VSWR meter, detector and sectoral horn

BLOCK DIAGRAM:



THEORY: Polarization is one of the fundamental characteristics of any antenna. A plane electromagnetic wave is characterized by travelling in a single direction(with no field variation in two orthogonal directions).In this case the electric and magnetic fields are perpendicular to each other and to the direction of the plane wave is propagating.

A linearly polarized wave doesn't need to be along the horizontal or vertical axis. If E field has two perpendicular components that are out of phase by 90^0 but are not equal in magnitude, the field will end up elliptically polarized.

The polarization of an antenna is the polarization of radiated fields produced by antenna, evaluated in the far field.

PROCEDURE:

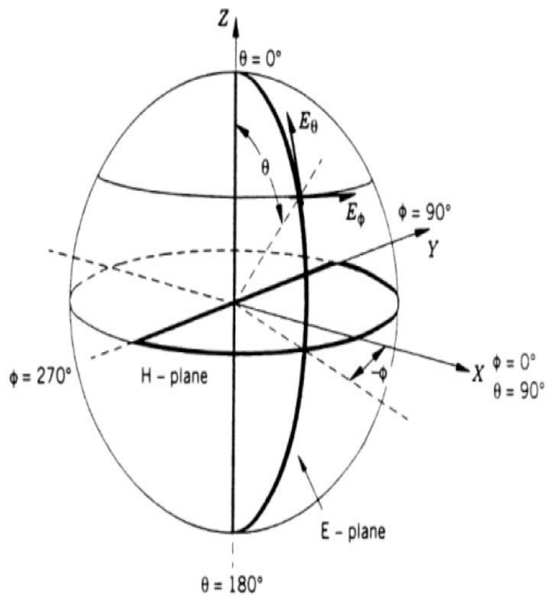
1. Make the KPS to work in $3/4^{th}$ mode such that at 0^0.we should get maximum amplitude
2. Note down amplitude in CRO or VSWR meter
3. Put the sectoral horn in E plane connect other end to diode detector and to VSWR meter
4. Rotate sectoral horn from 0^0 to 360^0 by some adjustment of screws in steps of 20^0 note down value in dB in VSWR meter

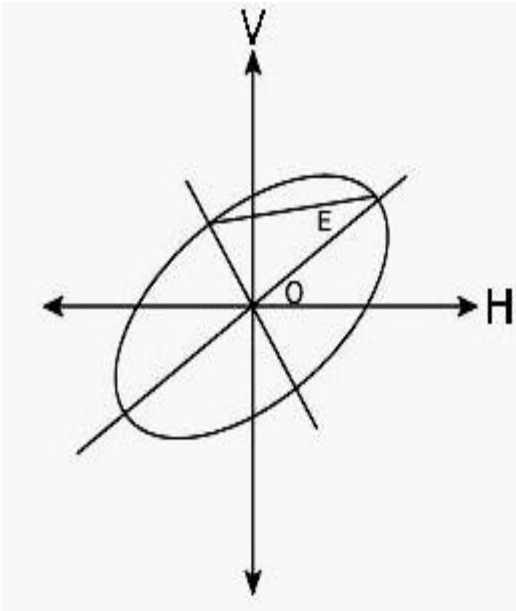
5. Change the sectoral horn to the H plane note down value in db in VSWR meter from 0^0 to 360^0
6. Plot the polarization pattern in graph

TABULAR COLUMN:

ANGLE in degree	Decibel(dB) in E plane	Decibel(dB) in H plane
0^0		
20^0		
40^0		
60^0		
80^0		
100^0		
120^0		
140^0		

PLOT OF POLARZATION ON ANTENNA IN E AND H PLANE:





RESULT: Polarization of an antenna has been found successfully

Inference : Power received when both the transmitting and receiving antenna are aligned in the same polarizing plane is maximum conversely power received is low when they are at right angles

When antennas are aligned in same plane they are in line of sight, effective aperture of the receiving antenna is large.therfore power is maximum conversely when antenna's are at right angles the effective aperture of antenna is low.therfore power received is low.

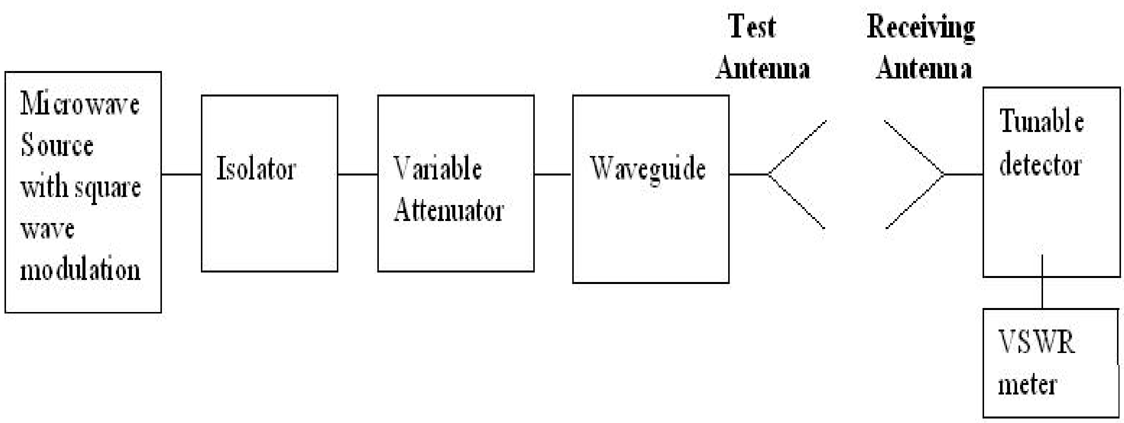
EXPERIMENT NO. 12

Measurement of radiation pattern and beam width of Microstrip antenna

AIM : Measurement of radiation pattern and beam width of Microstrip antenna

COMPONENTS REQUIRED: KPS, Microstrip antenna, VSWR meter, CRO, frequency meter and detector

BLOCK DIAGRAM:



THEORY: A microstrip antenna patch antenna is a narrowband. Wide beam antenna is fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate such as PCB with a continuous metal layer bonded to the opposite side of substrate which forms the ground plane. Common microstrip antenna shapes are squares, rectangular, circular, and elliptical but any continuous shape is possible. Some patch antenna don't uses dielectric substrate and instead made of a metal patch mounted above the ground plane using dielectric spacers single patch antenna provides a maximum directivity of the gain of around 6-9db.They have ability to polarize diversity.

PROCEDURE:

1. Inline the transmitting and receiving antenna one side such that we should get max deflection on CRO,that will be the line of sight. It should be fixed for throughout the experiment.

2. Rotate the receiving antenna clockwise and counter clockwise from 0^0 to 360^0 in steps of $5/10^0$

3.Notedown respective voltage in CRO/VSWR meter

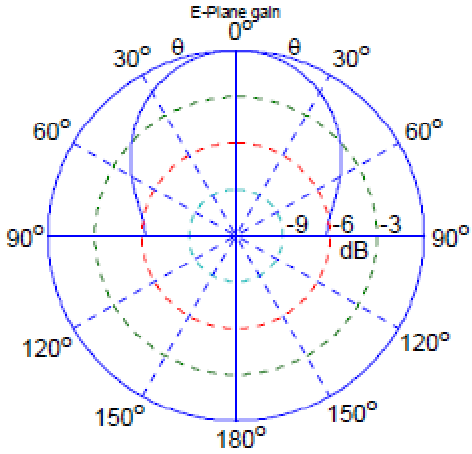
4.Plot the values in graph. Find out the beam width

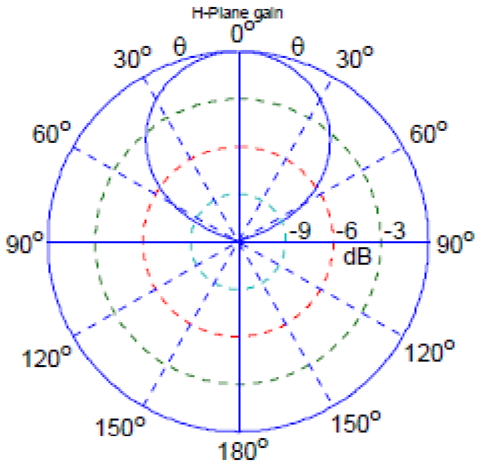
5.Observe the radiation pattern

TABULAR COLOUMN:

ANGLE in degree	Voltage in millivolt (clockwise direction)	Voltage in millivolt (anticlockwise direction)
0^0		
20^0		
40^0		
60^0		
80^0		
100^0		
120^0		
140^0		

PLOT: E AND H PLANE OF MICROSTRIP ANTENNA





RESULT: The radiation pattern and beam width of microstrip antenna has found successfully

EXPERIMENT NO. 13

Aim: Analysis of Horn antenna using FEKO simulator.

Simulation of Rectangular Horn Antenna

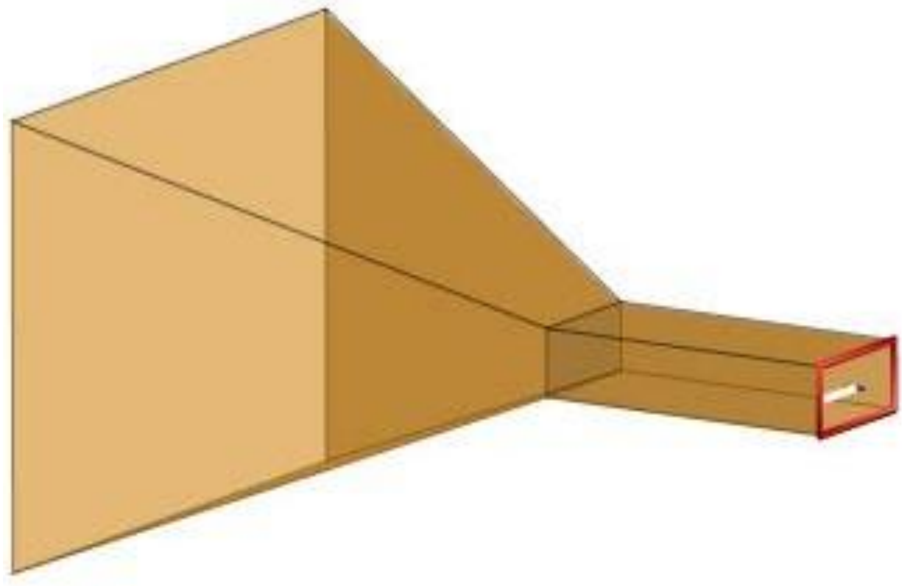
Specifications	Solution requests
Frequency :R-band (1.7GHz to 2.6GHz)	Radiation patterns
Feeding method: rectangular waveguide (WR-430) feed	Current distribution Reflection coefficient

RECTANGULAR HORN ANTENNA OVERVIEW

A horn antenna consists of a flaring metal waveguide shaped likea horn to direct the radio waves.

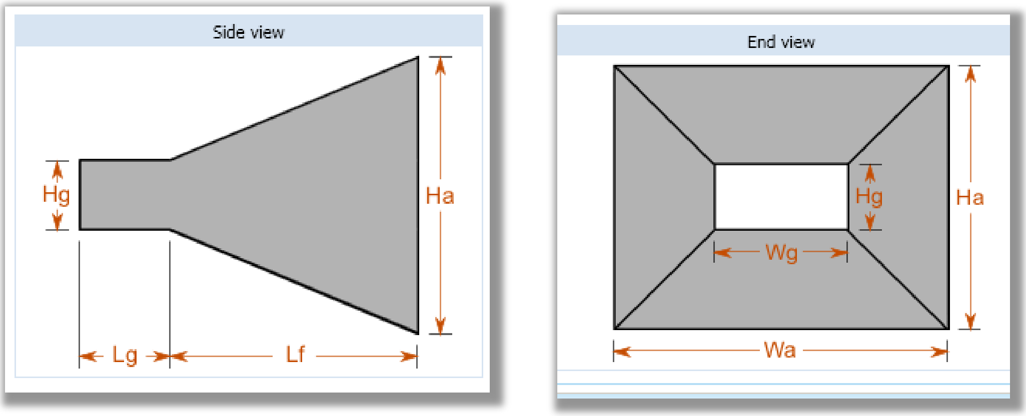
Features of horn antenna are moderate directivity (gain), lowSWR, broad bandwidth, and simple construction and adjustment.

Fig: Illustration of the horn antenna



A horn antenna is used to transmit radio waves from a waveguide (a metal pipe used to carry radio waves) out into space, or collect radio waves into a waveguide for reception. It typically consists of a short length of rectangular or cylindrical metal tube (the waveguide), closed at one end, flaring into an open-ended conical or pyramidal shaped horn on the other end.

The geometry used in this example is a rectangular horn that is excited by a waveguide feed.



QUICK STEPS TO CREATE AND RUN MODEL

Step-1: Start CADFEKO by clicking

Programs -> FEKO -> Suite 6.1 -> CADFEKO -> Create a New Model

Step-2: Set the model unit to meters.

Step-3: Add variables to model.

Step-4: Create Waveguide section using cuboids primitive.Step-5: Create Horn using flare primitive.

Step-6: Union the all above structure.

Step-7: Delete face of flare and waveguide section.

Step-8: Create Waveguide port to bottom face of waveguide section.

Step-9: Add Waveguide Excitation to waveguide port.

Step-10: Set the solution frequency in continuous frequency range and set start and end frequency.Step-11: Set solution request e.g. Far field region, S-parameter, current etc.

Step-12: Define symmetry. (It is optional).

Step-13: Mesh the model and run the FEKO solver.

Step-12: Launch POSTFEKO and view the requested results.

SIMULATION STEPS

Step-1: Start CADFEKO

To create structures in FEKO the CADFEKO must be launched by clicking on Programs -> FEKO -> Suite 6.1 -> CADFEKO -> Create a new model.

Step-2: Set the model unit

Meter unit is convenient to define lengths in this example. To change model unit Click on Construct tab -> Model unit icon in define section -> model unit dialog box will be appeared -> select unit as meter (m)
-> OK.

Step-3: Define variable

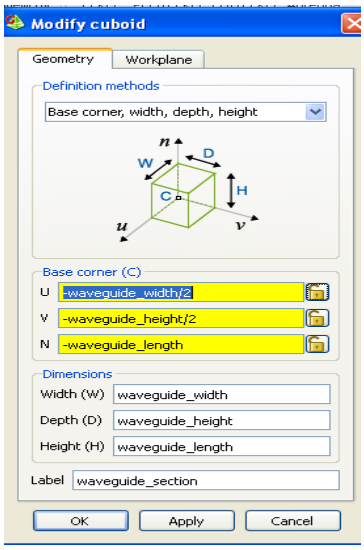
To define variable click on Construct tab -> Add variable icon in define section -> create variable dialog box will open -> enter the name of variable in name space -> enter the numeric value or the expression that evaluate the value of the variable -> click on evaluate button-> click on Add button.

Similarly add the entire variable as shown in table:

Variable Description	Variable Name	Expression
Frequency	F	2e9
Maximum frequency	Fmax	1.2*f
Minimum frequency	Fmin	0.8*f
Free space wavelength	Lambda	c0/f
Height of aperture	aperture_height	0.4117
Width of aperture	aperture_width	0.53555
Flare length	flare_length	0.45151
Waveguide length	waveguide_length	0.2248
Waveguide height	waveguide_height	0.05883
Waveguide width	waveguide_width	0.1177
Mesh size	mesh_port	lambda/20

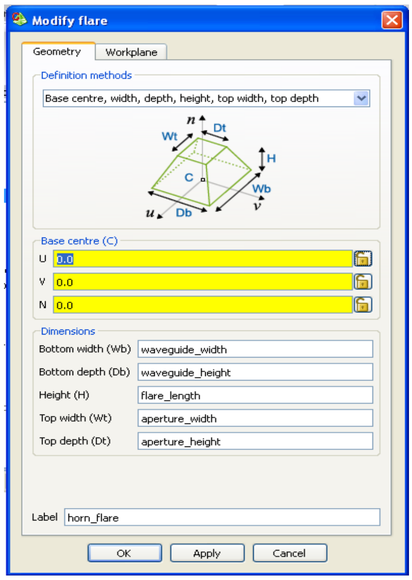
Step-4: Creation of waveguide section

Create the waveguide section using a cuboid primitive and set definition method to Base corner, width, depth, height. The Base corner coordinates are set to (-waveguide width/2, -waveguide height/2,-waveguide_length/2), and dimensions width as waveguide_width, depth as waveguide height and height as waveguide length (in the y-direction). Label it as waveguide_section.as shown in Fig.



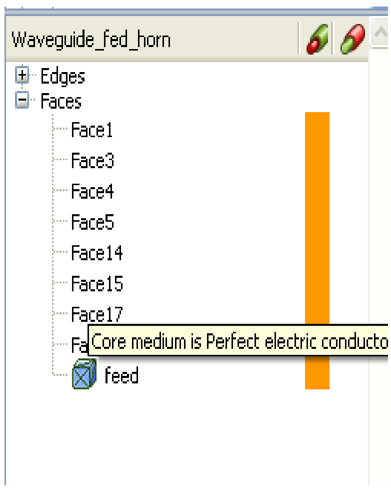
Step-5: Create Horn using flare primitive

Create the horn using the flare primitive with its base centre at the origin and using the definition method to: Base centre, width, depth, height, top width, top depth. The bottom width and bottom depth are waveguide_width , waveguide_height. The height, top width and top depth are flare_length, aperture_width, aperture_height respectively.
Label it as horn_flare. Dialog box for this is shown in Fig.



Step-6: Union

Union the two structure (Waveguide_section and horn_flare) by union button on construct tab.

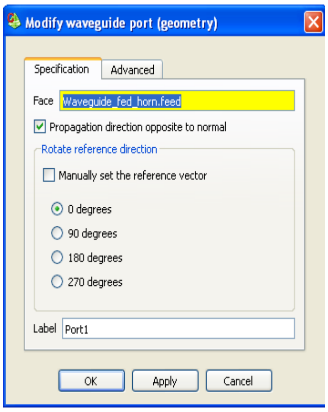


Step-7: Delete faces

Delete the face lying on the uv-plane of horn_flare. And Also delete the face opposite to the face at the origin(uvplane) of waveguide_section. This can be done by selecting individual faces from Detail tree on left- hand side

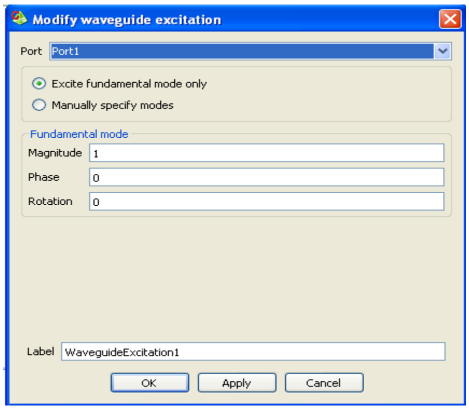
Step-8: Waveguide port

Now select the bottom face of waveguide section and create waveguide porton it, this can be done by selecting waveguide port on create ports (in construct tab). Selected face will be displayed in Face field of opened dialog box. In this dialog box set Rotate reference direction as 0 degree. And labelit as port1. Click on OK.



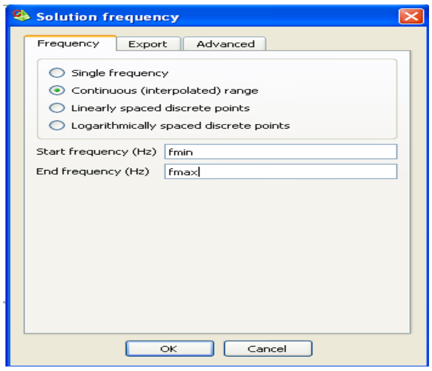
Step-9: Waveguide excitation

A waveguide excitation is applied to the selected waveguide port. For this select waveguide excitation from source/Load tab. In port field the selected port will be displayed. Select excite fundamental mode only and Label it as Waveguide Excitation1. There is also option to manually specify the mode of excitation.



Step-10: Solution frequency setup

Select continuous range and set start frequency as fmin and end frequency as fmax.



Step-11: Solution request setup

To request for Far field click on far field button on Request tab and select vertical cut (UN plane) and specify range of theta and phi as shown in Fig. and label it as E_plane_cut.

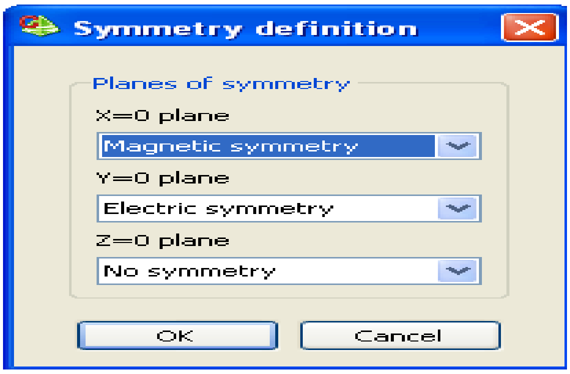
Similarly for 3D pattern select 3D pattern and specify range of theta and phi as shown in Fig. and label it as 3D_pattern.

To request for S-parameter click on S-parameter button (in Request tab) and create it.To request for current distribution in antenna, click on current button and create it.

Step-12: Symmetry

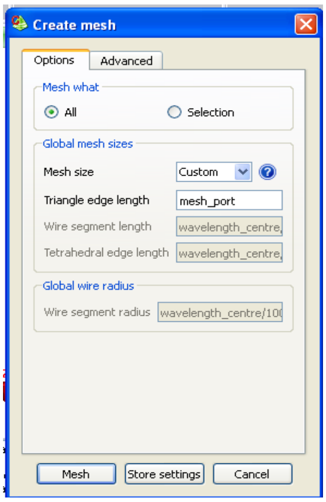
For Waveguide port we have selected the reference direction as 0 degree sothe model has magnetic symmetry at x=0 and electric symmetry at y=0.

Click on the Symmetry button (Solution settings group) onsolve/Run tab. set the symmetry.



Step-13: Meshing

The geometry is created, but before run FEKO solver it is to be for this select the Mesh tab and click on the Create mesh button. Select the custom mesh size and enter triangle edge length to be mesh_port.



Step-14: CEM Validate

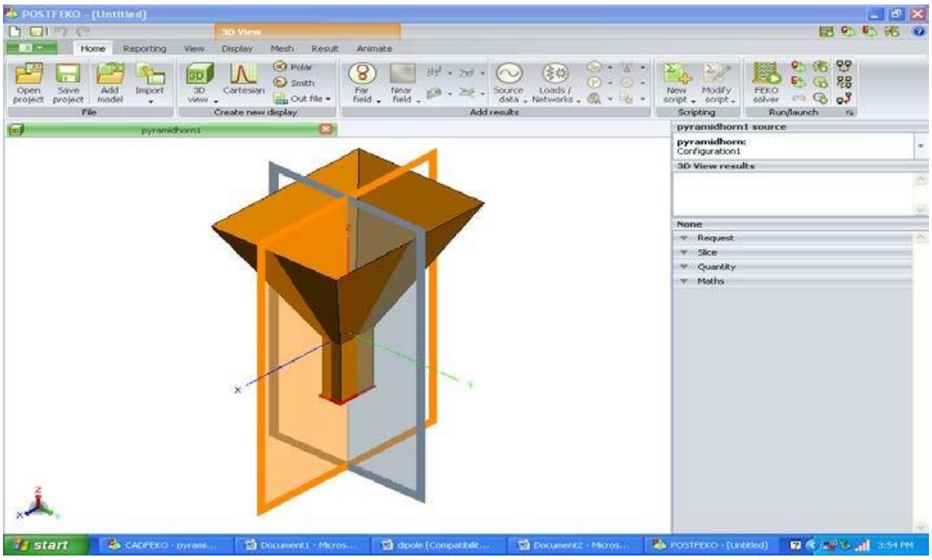
After the model has been meshed, run CEM validate. And check for any error. And save the model.

Step-15: Run FEKO solver

After executing FEKO solver, run POST FEKO to display requested result.

Step-16: Viewing Results

Click on POSTFEKO opens POSTFEKO window.



To see results like Radiation pattern(E-plane, H-plane and 3-D view) click on 3D view construct tab andselect the configuration for which you want to see the result. Select the far field and see the result.

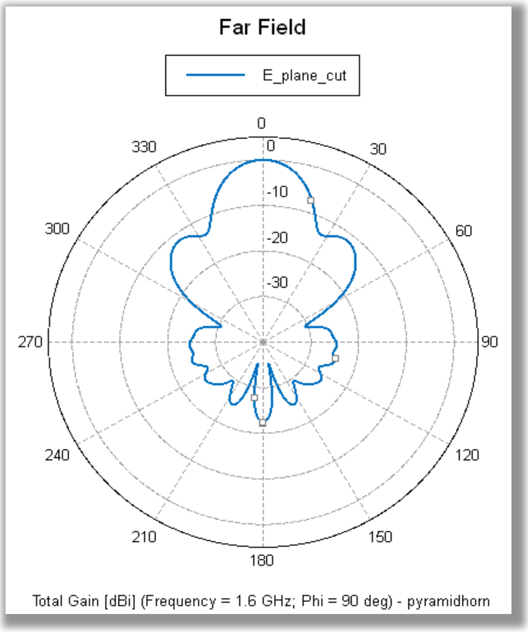


Fig: Radiation pattern (polar plot)

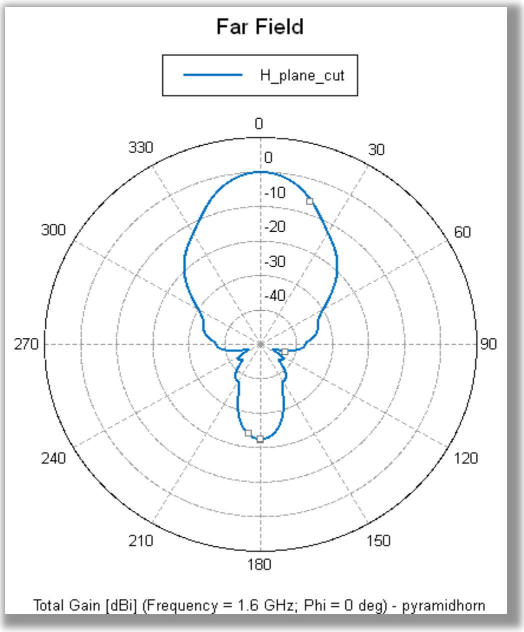
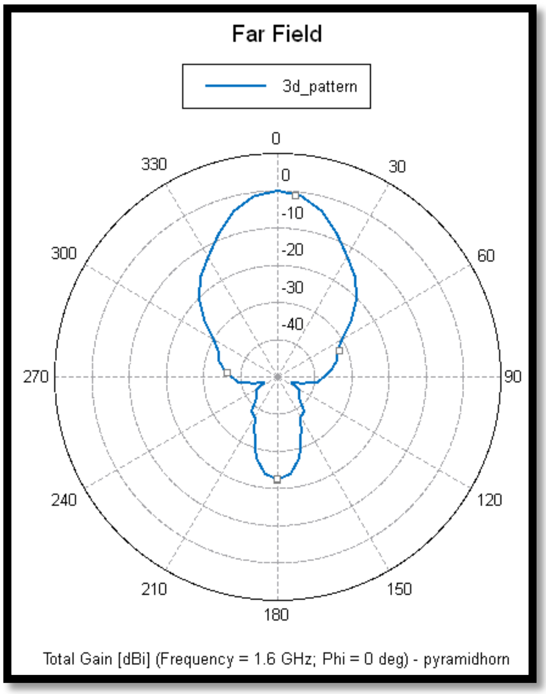
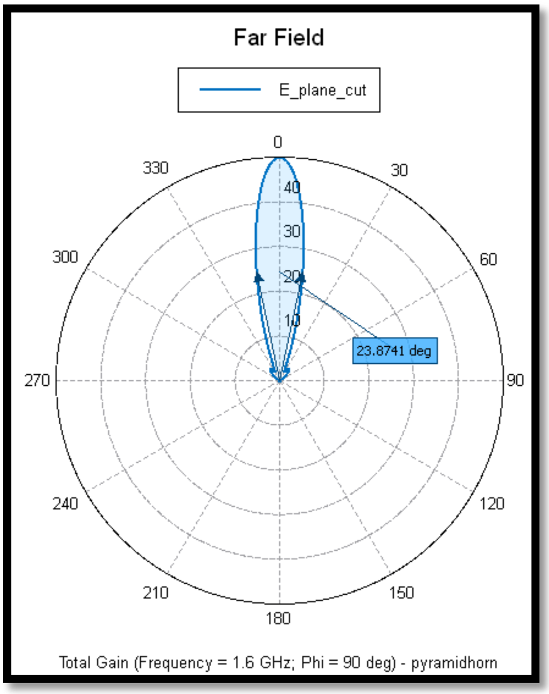


Fig: Radiation pattern (polar plot)





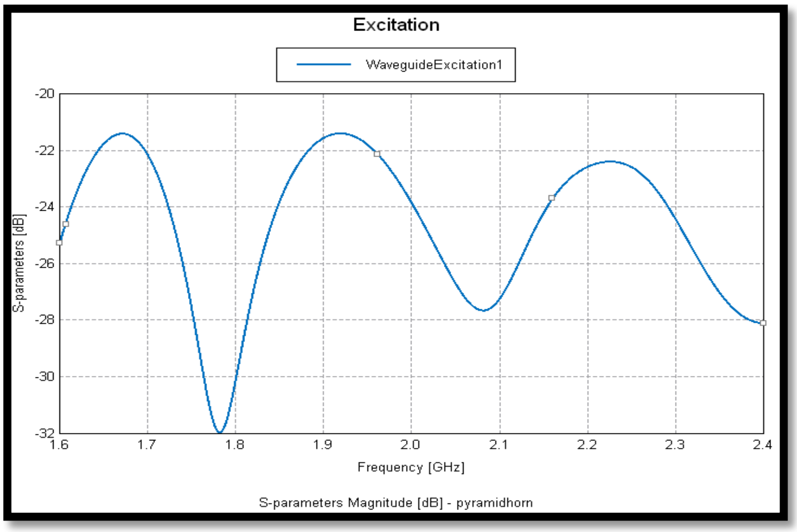


Fig: S-parameter Vs Frequency plot

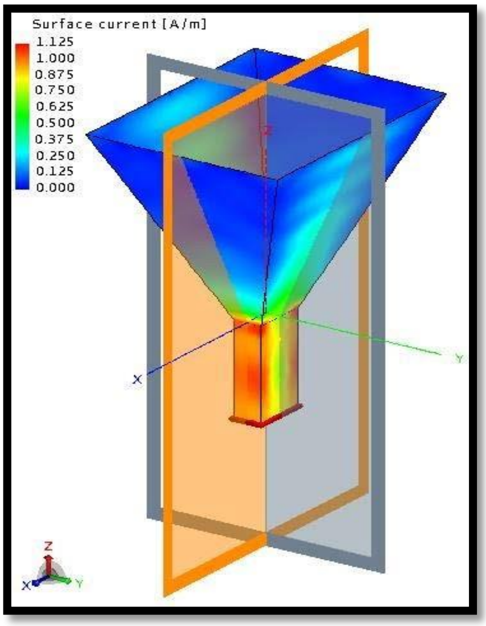


Fig: Current distribution

EXPERIMENT NO. 14

Aim: Analysis of micro strip Antenna using FEKO simulator.

Simulation of Microstrip Circular Patch Antenna

Specifications	Solution requests
Substrate height: 6.36mm	Radiation patterns
Substrate dielectric constant :2.0	Current distribution
Centre frequency: 1GHz	Reflection coefficient
Feeding method: Pin feed	

MICROSTRIP CIRCULAR PATCH ANTENNA OVERVIEW

Microstrip patch antenna consists of a flat conductive sheet i.e. patch of a particular shape like rectangle, triangle, circular etc., mounted over a larger sheet of metal called a ground plane.

In this example, patch antenna (pin feed) designed to operate close to 1.0 GHz. The model is constructed using a finite size substrate. The dielectric substrate (permittivity of 2.0 and tangent loss = 0) used is modeled with a finite substrate.

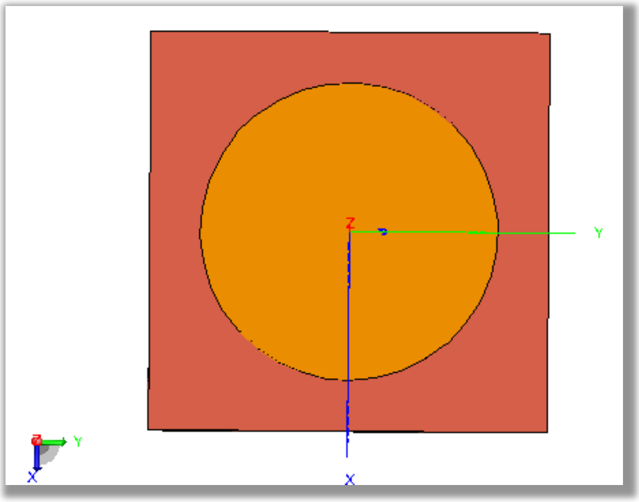


Fig: patch on a finite substrate

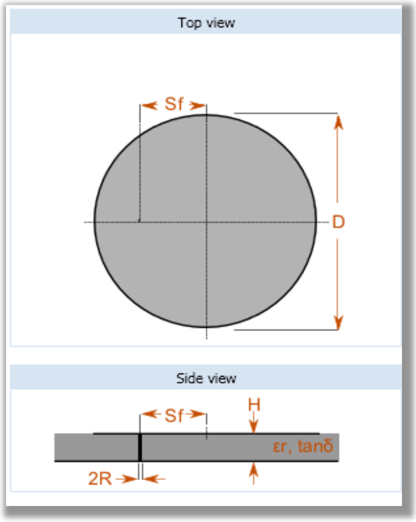


Fig :Circular patch(Top view & side view)

QUICK STEPS TO CREATE AND RUN MODEL

Step-1: Start CADFEKO by clicking

Programs -> FEKO -> Suite 6.1 -> CADFEKO -> Create a New

ModelStep-2: Set the model unit to millimeters.

Step-3: Add variables to model.

Step-4: Create finite ground plane using cuboids primitive.

Step-5: Create circular patch using ellipse primitive.

Step-6: Add new dielectric medium type.

Step-7: Specify fed position.

Step-8: Union the all above three structures.

Step-9: Set properties of substrate.

Step-10: Set patch and Ground Face as PEC (perfect electric conductor).

Step-10: Add wire port.

Step-11: Add Voltage source/Excitation.

Step-12: Set the solution frequency in continuous frequency range and set start and end frequency.

Step-13: Set solution request e.g. Far field region, S-parameter, current etc.

Step-14: Mesh the model and run the FEKO solver.

Step-15: Launch POSTFEKO and view the requested results.

SIMULATION STEPS

Step-1: Start CADFEKO

To create structures in FEKO the CADFEKO must be launched by clicking on Programs -> FEKO -> Suite 6.1 -> CADFEKO -> Create a new model

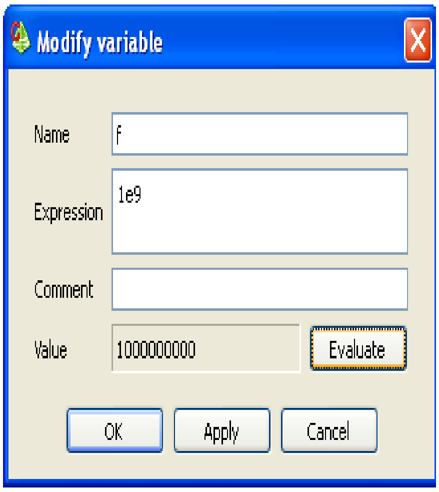
Step-2: Set the model unit

To change model unit Click on Construct tab -> Model unit icon in define section -> model unit dialog box will be appeared -> select unit as millimeter (mm) -> OK.

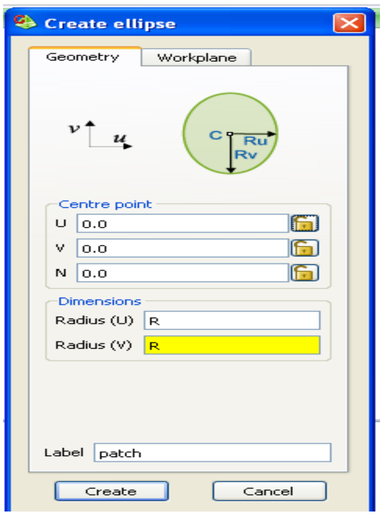
Step-3: Add variables

To define variable click on Construct tab -> Add variable icon in define section -> create variable dialog box will open -> enter the name of variable in name space -> enter the numeric value or the expression that evaluate the value of the variable -> click on evaluate button-> click on Add button.

Similarly add the following variables.

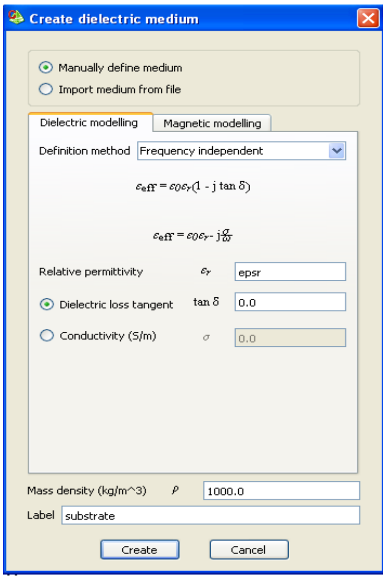


Variable Description	Variable Name	Expression
Frequency	F	1e9
		(c0/f)*1e3
Free space wavelength	lambda	160
Substrate width	sw	160
Substrate depth	sd	6.360
Substrate height	H	2.0
Dielectric constant	epsr	57.9
Radius of patch	R	0.8
Radius of wire pin	r	13.36
Feed distance		



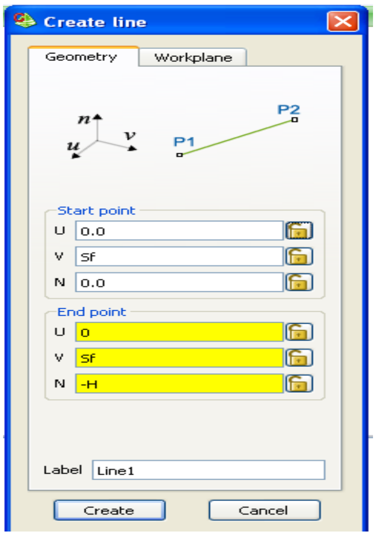
Step-4: Create finite ground plane

Create the substrate using cuboid primitive with the Base centre, width, depth, height definition method. Set the Base centre to (0, 0, 0) and dimensions as Width = Sw, Depth = Sd, Height = -H. Label it as substrate. Click on OK.



Step-6: Add a new dielectric medium type

To define properties of substrate, a new dielectric medium is to be added. This can be defined by selecting the Construct tab and clicking on the Media button (in Define group). All dielectric should be created before use in the model. In this example we select a dielectric material with zero loss tangent and having relative permittivity of 2.0. For this select the Dielectric modeling tab. Set the Definition method to Frequency independent. We have already created a variable for the relative permittivity which is epsr, so write epsr in the Relative permittivity field. Write 0.0 for the Dielectric loss tangent and label it as substrate into the Label field and click on create button.



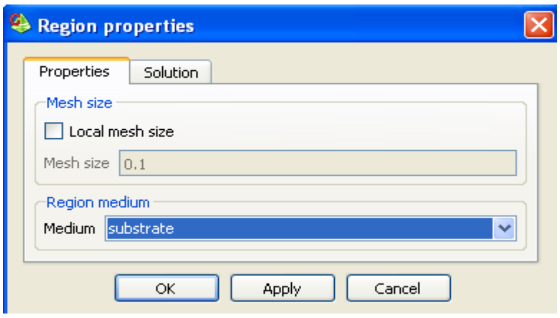
Step-7: Create wire pin (Fed position)

Now we create the wire pin that shows fed position from the centre of circular patch. Click on the Line button (in Create curve group) to create the fed pin. Since we have created variables for the distance of the fed pinfrom the centre of the patch. Simply enter the values as shown below:

Start point (U, V, N) => (0, Sf, 0) End point (U, V, N) => (0, Sf, -H)

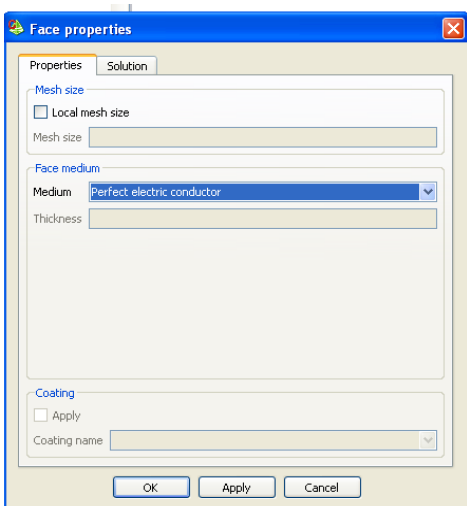
Step-8: Union

Select the three geometry parts (substrate, ground and line 1) in the model tree and click on the Unionbutton (in Modify group) of construct tab.



Step-9: Set properties of substrate

Set the properties of substrate (cuboid) as substrate (dielectric medium) by right clicking on Region (in detail tree) and in properties tab set Region medium as substrate because it is already created by us.

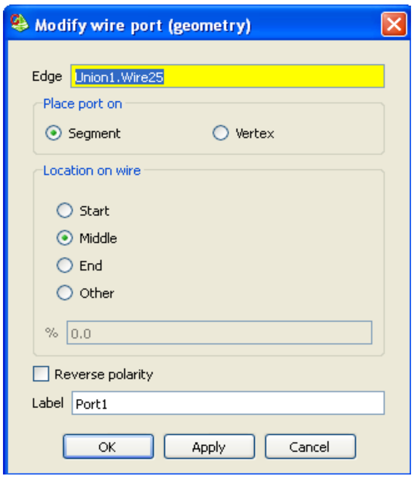


Step-10: Set patch and Ground Face as PEC

(perfect electricconductor)

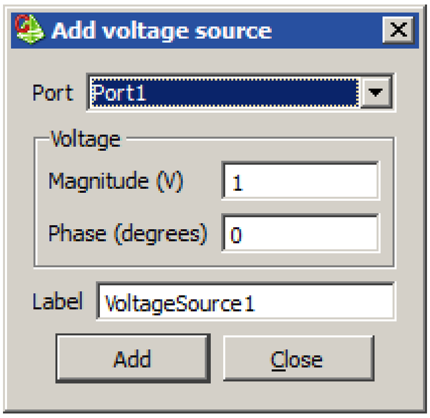
To set circular patch and Ground plane medium as PEC, these faces should be selected. From detail tree we select the required face. The selected face will be highlighted in 3-D view. Right click on selected face and select properties of it. This opens Face properties dialog box, change medium to perfect electric conductor.Click on OK.

Step-11: Add a segment wire port



To add a wire port on the middle of the wire, Select the Source/Load tab and click on the Wire port button. This opens create wire port dialog box. Set location of wire to middle and click OK.

Step-12: Add voltage source



Voltage source to the port1 is added by selecting the Source/Load tab and click on the Voltage source button (in Sources on ports group). Magnitude and phase of applied voltage source is set to 1 and 0respectively. Click on Ok.

Step-13: Setup solution frequency

Click on the Frequency button (Settings group) to set the frequency range of the simulation. Select the Continuous (interpolated) range and enter the starting and ending frequency as 0.8e9 Hz and 1.5e9 Hz respectively.

Step-14: Requesting calculations

Request S-parameter by clicking on s parameter on request tab.

Step-15: Meshing

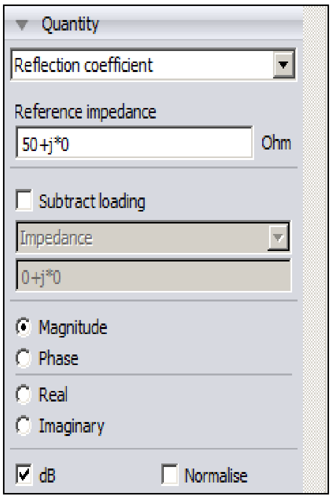
The geometry is created, but before run FEKO solver it is to be for this select the Mesh tab and click on the Create mesh button. Select the mesh size to standard setting and wire segment radius equal to r. And click on mesh.

Step-16: CEM validation

After the model has been meshed, run CEM validate. And check for any error. And save the model.

Step-17: Run FEKO solver

After executing FEKO solver, run POST FEKO to display requested result



Step-18: Viewing Result

The model creation and execution process is complete. Now run POSTFEKO toview the results. We are going to view the reflection coefficient Vs frequencyplot of the patch antenna.

In POSTFEKO window, create a Cartesian graph, Click on the Source data and select VoltageSource1. On right side of the POSTFEKO window (Traces section), set the quantity to Reflection coefficient. Display shows the reflection coefficient Vs frequency plot on Cartesian graph.

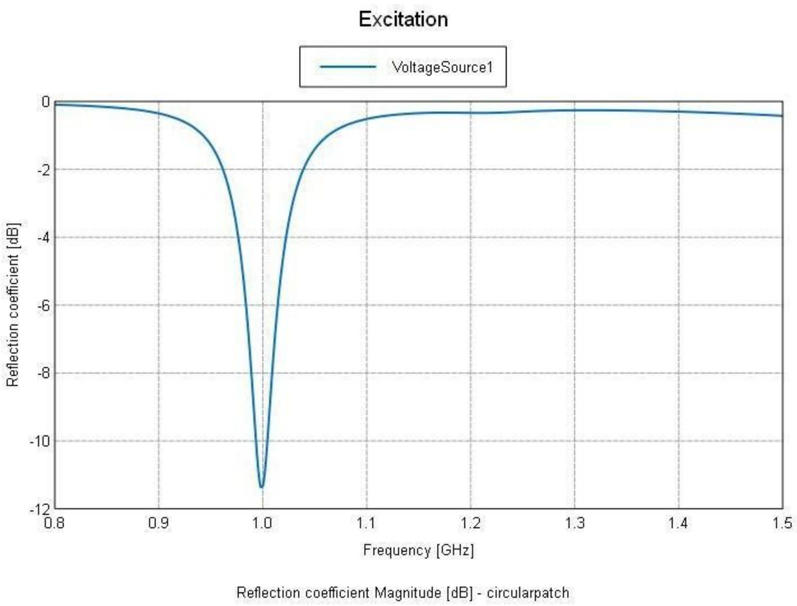


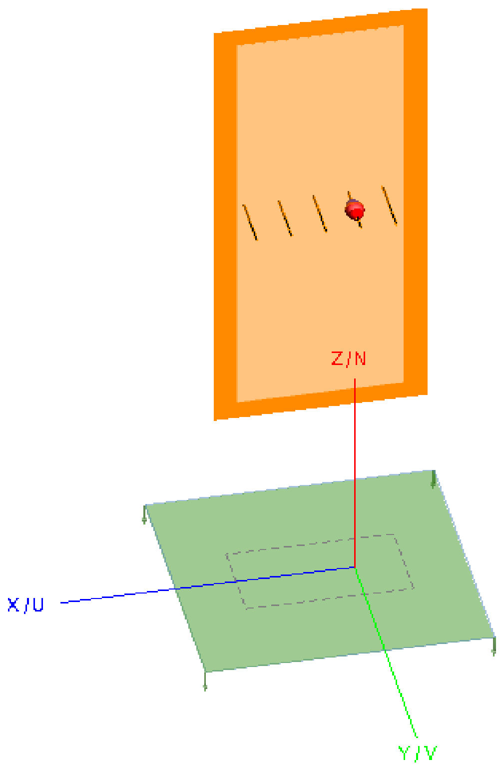
Fig: Reflection coefficient (dB) Vs frequency

EXPERIMENT NO. 15

Aim: Analysis of Yagi Uda antenna and helical antenna using FEKO simulator.

Yagi-Uda antenna above a real ground

In thisexample we consider the radiation of a horizontally polarised Yagi-Uda antenna consisting of a dipole, a reflector and three directors. The frequency is 400 MHz. The antenna is located 3 m above a real ground which is modeled with the Green's function formulation. Note that the model provided with this example includes a basic optimisation. The optimization is set up such that the optimal dimensions of the antenna may be determined to achieve a specific gain pattern (maximize the forward gain and minimize back lobes).



Antenna and ground plane

Creating the model

The steps for setting up the model are as follows:

1. Define the following variables:

   – freq = 400e6 (Operating frequency.)

   – lambda = c0/freq (The wavelength in free space at the operating frequency.)

– lr = 0.477*lambda (Length of the reflector.)

– li = 0.451*lambda (Length of the active element.)

– ld = 0.442*lambda (Length of the directors.)

– d = 0.25*lambda (Spacing between elements.)
– h = 3 (Height of the antenna above ground.)

– epsr = 10 (Relative permittivity of the ground.)

– sigma = 1e-3 (Ground conductivity.)

– wireRadius = 1e-3 (Wire radius (1 mm).)

2. Create the active element with start point as (0, -li/2, h) and the end point as (0, li/2,h). Set the labelas active Element.
3. Add a vertex port in the centre of the wire.
4. Add a voltage source on the port. (1 V, 0_, 50)

5. Create the wire for the reflector. Set the Start point as (-d, -lr/2, h) and the End point as (-d, lr/2, h). Set the label as reflector.

6. Create the three wires for the directors.

Director	**Start point**	**End point**
director1	(d, -ld/2, h)	(d, ld/2, h)
director2	(2*d, -ld/2, h)	(2*d, ld/2, h)
director3	(3*d, -ld/2, h)	(3*d, ld/2, h)

7. Create a dielectric called ground with relative permittivity of epsr and conductivity equal to sigma.

8. Set the lower half space to ground. This can be done by setting the infinite plane to use the exactSommerfeld integrals.

9. Set the frequency to freq.

Requesting calculations

A single plane of electrical symmetry on the Y=0 plane is used in the solution of this problem.The solution requests are:

Create a vertical far field request above the ground plane. (-90______90_, with _=0 and _=0.5_ increments)

Set the Workplane origin of the far field request to (0, 0, 3).Meshing information

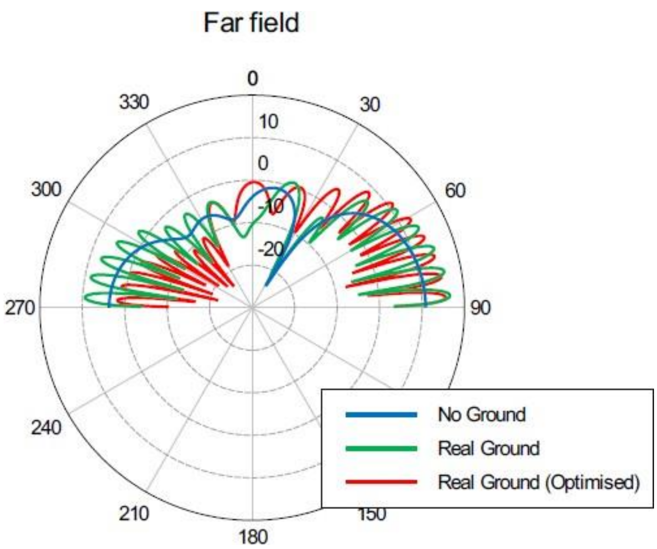
Use the standard auto-meshing option with the wire segment radius equal to wireRadius.CEM validate

After the model has been meshed, run CEM validate. Take note of any warnings and errors.Correct any errors before running the FEKO solution kernel.

Note that a warning may be encountered when running the solution. This is because losses cannot be calculated in an infinitely large medium, as is required for the extraction of antenna directivity information (gain is computed by default). This warning can be avoided by ensuring that the far field gain be calculated instead of the directivity. This is set on the Advanced tab of the far field request inthe tree.

A-5.2 Results

The radiation pattern is calculated in the H plane of the antenna. A simulation without the ground plane is compared with the results from the model provided for this example in Figure A-5-2. As expected, theground plane greatly influences the radiation pattern. (Note that the graph is a vertical polar plot of the gain in dB for the two cases.)



The directivity pattern of the Yagi-Uda antenna over a real ground and without any ground.Note that the optimised pattern is also shown.