

ELECTROMAGNETICS AND MICROWAVE LABORATORY MANUAL B.TECH (IV YEAR – I SEM) (2022-2023)

Prepared by:

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MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

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Maisammaguda, Dhulapally (Post Via. Kompally), Secunderabad – 500100, Telangana State, India

VISION

To evolve into a center of excellence in Engineering Technology through creative and innovative practices in teaching-learning, promoting academic achievement & research excellence to produce internationally accepted competitive and world class professionals.

MISSION

To provide high quality academic programmes, training activities, research facilities and opportunities supported by continuous industry institute interaction aimed at employability, entrepreneurship, leadership and research aptitude among students.

QUALITY POLICY

- ❖ Impart up-to-date knowledge to the students in Electronics & Communication area to make them quality engineers.**
- ❖ Make the students experience the applications on quality equipment and tools.**
- ❖ Provide systems, resources and training opportunities to achieve continuous improvement.**
- ❖ Maintain global standards in education, training and services.**

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: PROFESSIONALISM & CITIZENSHIP

To create and sustain a community of learning in which students acquire knowledge and learn to apply it professionally with due consideration for ethical, ecological and economic issues.

PEO2: TECHNICAL ACCOMPLISHMENTS

To provide knowledge based services to satisfy the needs of society and the industry by providing hands on experience in various technologies in core field.

PEO3: INVENTION, INNOVATION AND CREATIVITY

To make the students to design, experiment, analyze, interpret in the core field with the help of other multi disciplinary concepts wherever applicable.

PEO4: PROFESSIONAL DEVELOPMENT

To educate the students to disseminate research findings with good soft skills and become a successful entrepreneur.

PEO5: HUMAN RESOURCE DEVELOPMENT

To graduate the students in building national capabilities in technology, education and research.

CODE OF CONDUCT FOR THE LABORATORIES

1. All students must observe the Dress Code while in the laboratory.
2. Sandals or open-toed shoes are NOT allowed.
3. Foods, drinks and smoking are NOT allowed.
4. All bags must be left at the indicated place.
5. The lab timetable must be strictly followed.
6. Be PUNCTUAL for your laboratory session.
7. Program must be executed within the given time.
8. Noise must be kept to a minimum.
9. Workspace must be kept clean and tidy at all time.
10. Handle the systems and interfacing kits with care.
11. All students are liable for any damage to the accessories due to their own negligence.
12. All interfacing kits connecting cables must be RETURNED if you taken from the lab supervisor.
13. Students are strictly PROHIBITED from taking out any items from the laboratory.
14. Students are NOT allowed to work alone in the laboratory without the Lab Supervisor
15. USB Ports have been disabled if you want to use USB drive consult lab supervisor.
16. Report immediately to the Lab Supervisor if any malfunction of the accessories, is there.

Before leaving the lab

- Place the chairs properly.
- Turn off the system properly
- Turn off the monitor.
- Please check the laboratory notice board regularly for updates.



**MALLA REDDY COLLEGE OF ENGINEERING AND
TECHNOLOGY**

ECE DEPARTMENT

ELECTROMAGNETICS AND MICROWAVE LAB LABORATORY

LIST OF EXPERIMENTS

Part – A: Electromagnetics Lab (Any Five experiments using any simulation software)

- 1) Generation of EM-Wave
- 2) Propagation of wave in Rectangular Waveguide
- 3) Impedance Matching using Smith Chart
- 4) Calculation of phase and group velocity calculation at 9GHz
- 5) Plot of Radiation pattern of dipole antenna
- 6) Plot of Radiation pattern of monopole antenna
- 7) Plot of Radiation pattern of Uniform Linear Array

Part – B: Microwave Lab (Any six experiments)

1. Characteristics of Gunn diode
2. Characteristics of the reflex klystron tube
3. Attenuation measurement
4. Impedance measurement
5. Frequency measurement
- 6 .Characteristics of Multihole directional coupler
7. Determination of standing wave ratio and reflection coefficient
8. Study of magic tee



PART-A

Experiment No-1

GENERATION OF ELECTROMAGNETIC FIELD

AIM: Generate Electromagnetic Wave using MATLAB software.

Software Required: MATLAB software

Theory:

The electromagnetic radiation refers to the waves of the electromagnetic field, propagating through space, carrying electromagnetic radiant energy. It includes radio waves, microwaves, infrared, light, ultraviolet, X-rays, and gamma rays. All of these waves form part of the electromagnetic spectrum. Electromagnetic waves are typically described by any of the following three physical properties: **frequency (f), wavelength (λ), or intensity (I)**. Light quanta are typically described by frequency (f), wavelength (λ).

Program:

```
function [] = EB_field_propagation_animation()
% EB_dynamic_fields_animation : function to create
% an animation of a dynamic electromagnetic field.
%
% Author & support nicolas.douillet (at) free.fr, 2007-2021.
step = 0.05*pi; % the signal step / resolution
phase = 2*pi:-step:0; % phase vector
nperiod = 1.5; % the number of periods for the signals
time_lapse = 0.1; % the animation time lapse
title_text = 'Electromagnetic field propagation (planar waves)';
filename = 'EB_dynamic_fields_animation.gif';
title_on = true;
% Display settings
h = figure;
set(h,'Position',get(0,'ScreenSize'));
set(gcf,'Color',[0 0 0]);
axis tight manual;
az = 21; % azimuth
el = 40; % elevation
for k = 1:length(phase)

    signal = EB_field(nperiod,step,phase(k));

    pE = plot3(signal(1,:),1),signal(2,:),1),signal(3,:),1'),'Color',[1 0 1],'Linewidth',2); hold on;
    pH = plot3(signal(1,:),2),signal(2,:),2),signal(3,:),2'),'Color',[0 1 1],'Linewidth',2); hold on;

    stem3(signal(1,1:2:end,1),signal(2,1:2:end,1),signal(3,1:2:end,1),'.','Color',[1 0 1],'Linewidth',2);
    stem(signal(1,1:2:end,2),signal(2,1:2:end,2),'.','Color',[0 1 1],'Linewidth',2);
    line([signal(1,1,1),signal(1,end,1)],[0,0],[0,0],'Color',[0 1 0]), hold on;
    line([signal(1,1,1),signal(1,1,1)],[0,1],[0,0],'Color',[0 1 0]), hold on;
```

```

line([signal(1,1,1),signal(1,1,1)],[0,0],[0,1],'Color',[0 1 0]), hold on;

legend([pE, pH],{'Electric field','Magnetic field'},'Location', 'NorthEast','Color',[0 0
0],'TextColor',[1 1 1],'FontSize',14,'EdgeColor',[1 1 1]);

set(gca,'Color',[0 0 0]);
view([az,el]);
grid off, axis off;

if title_on
    title(title_text,'Color',[1 1 1],'FontSize',16);
end

drawnow;

frame = getframe(h);
im = frame2im(frame);
[imind,cm] = rgb2ind(im,256);

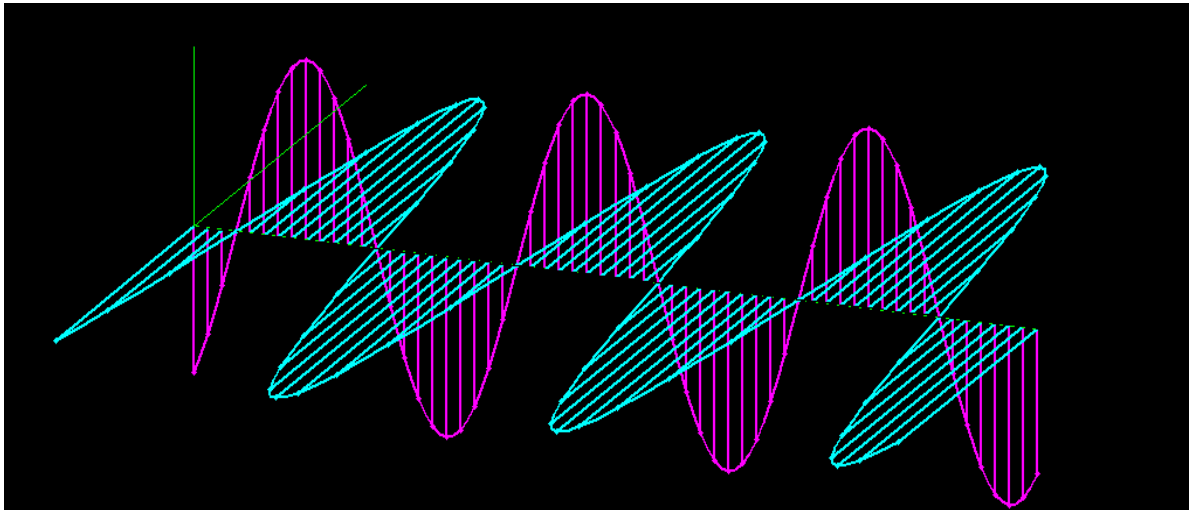
% Write to the .gif file
if k == 1
    imwrite(imind,cm,filename,'gif','Loopcount',Inf,'DelayTime',time_lapse);
else
    imwrite(imind,cm,filename,'gif','WriteMode','append','DelayTime',time_lapse);
end

clf;

end
end % EB_dynamic_fields_animation
function [signal] = EB_field(nperiod, step, phase)
%
% Author & support nicolas.douillet (at) free.fr, 2007-2021.
t = -nperiod*2*pi:step:nperiod*2*pi;
s = sin(t+phase);
signal = [t;zeros(1,length(t));s];
R = @(r)[1,0,0
        0,cos(r),-sin(r)
        0,sin(r),cos(r)];

signal(:,2) = R(-pi/2)*signal(:,1);
end

```


RESULT:**VIVA QUESTIONS:**

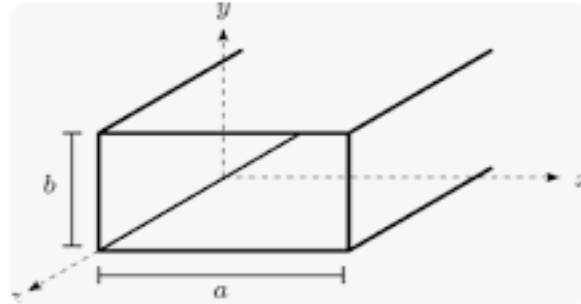
1. Define Electric field?
2. How EM wave propagates?
3. What is the speed of EM wave?
4. What is relation between frequency and wavelength?
5. What is the nature of EM wave?

Experiment No-2 RECTANGULAR WAVEGUIDE

Aim: To study propagation of wave using Rectangular Waveguide

Software Required: MATLAB software

Theory: A rectangular waveguide is a conducting cylinder of rectangular cross section used to guide the propagation of waves. Rectangular waveguide is commonly used for the transport of radio frequency signals at frequencies in the SHF band (3–30 GHz) and higher.



Programs:

% rectangular waveguide propagation modes

clear all;close all;clc

f0=5e9; % choose operating frequency [Hz]

a=1.07e-2;b=0.43e-2 % choose waveguide cross-section dimensions [m]

c=10*a; % choose waveguide length [m]

er=2.08; % Teflon choose filling material

dx=min(a,b)/50;dy=dx;dz=dx; % set space resolutions

c0=299792486;% finding all possible modes below N

N=2% 5 choose a high enough M N for given f0, or just fix M N to reasonably high values.

M_range=[0:1:N];N_range=[0:1:N];

for k=[1:1: numel(M_range)]

for s=[1:1: numel(N_range)]

fc(k,s)=c0/(2*pi*er^.5)*((M_range(k)*pi/a)^2+(N_range(s)*pi/b)^2).^-.5;

end

end

% % fc(:,1)=fc(:,1)-1

% % fc(:,2)=fc(:,2)-1

fc % cut-offs, NxM format

fMN=zeros(max(M_range)+1,max(N_range)+1,3);

fMN(:,,3)=fc;

fMN(:,,2)=meshgrid(M_range,N_range);

fMN(:,,1)=meshgrid(M_range,N_range)';

L=[0 0 0];

for k=1:1:(M_range(end)+1)

for s=1:1:(N_range(end)+1)

L=[L;fMN(k,s,1) fMN(k,s,2) fMN(k,s,3)];

end

```

end
L=uint64(L)
% TEM doesn't propagate inside rectangular waveguides, removing all null lines off L
k_all_nulls=[];
for k=1:1:size(L,1)
    if L(k,1)==0 && L(k,2)==0 && L(k,3)==0
        k_all_nulls=[k_all_nulls k]
    end
end
L(k_all_nulls,:)=[]
% sorting cut-offs in frequency ascending order
fc=L(:,3);
[n,v]=sort(fc);
L=L(v,:)
fc_sorted=L(:,3)
% modes that get through, for a given input frequency f0
% f0=f_cutoff doesn't get through, it has to be f0>f_cutoff
% safety_factor=1 % safety_factor=1 no safety band, 1.5 at least
% half carrier above cutoff ..
k=1;
while L(k,3)<=f0 && k<size(L,1)
    k=k+1;
end
k

L_through=L([k:end],:)
fc_through=fc_sorted([k:end],:)

```

RESULT:**VIVA QUESTIONS:**

1. What is TE mode?
2. What is TM mode?
3. What is TEM mode?
4. Which are the dominant modes in TE?
5. Which are dominant modes in TM?

Experiment-3

IMPEDANCE MATCHING

Aim: To study impedance match using MATLAB software.

Software Required: MATLAB software

Theory: Impedance matching is the process of designing the antenna's input impedance (Z_L) or matching it to the corresponding RF circuitry's output impedance (Z_O), which would be $50\ \Omega$ in most cases. A perfect match is obtained when $Z_L = Z_O$ in eq 2 which gives Γ a value of zero, and the SWR becomes unity in eq 1.

$$SWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

(Equation 1)

$$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o}$$

(Equation 2)

Program:

```
clc;close all;clear all;format long;
Z0=100;sm1=smithchart;hold all;
ZL=200-1j*100;
f0=5e8; % Hz
gamma_L=(ZL-Z0)/(ZL+Z0);
% show ZL on Smith chart adding text showing values
if imag(ZL)<0
    sign1='-';
else
    sign1='+';
end
hold all;plot(real(gamma_L),imag(gamma_L),'ro','LineWidth',1.5);
str1=['ZL = ' num2str(real(ZL)) sign1 'j' num2str(abs(imag(ZL))) ' \rightarrow'];
text(real(gamma_L),imag(gamma_L)+.01,str1,'Color','blue',
'FontSize',20,'HorizontalAlignment','right','VerticalAlignment','middle');
RL=real(ZL);XL=imag(ZL);
if abs(real(ZL/Z0))>=1 % ZL inside 1+jx
    disp(' ZL inside 1+jx');
    B1=1/(RL^2+XL^2)*(XL+(RL/Z0)^.5*(RL^2+XL^2-Z0*RL)^.5)
    B2=1/(RL^2+XL^2)*(XL-(RL/Z0)^.5*(RL^2+XL^2-Z0*RL)^.5)
    X1=1/B1+XL*Z0/RL-Z0/(B1*RL) ; X2=1/B2+XL*Z0/RL-Z0/(B2*RL)
elseif abs(real(ZL/Z0))<=1 % ZL outside 1+jx
    disp(' ZL outside 1+jx');
    X1=(RL*(Z0-RL))^.5-XL; X2=-(RL*(Z0-RL))^.5-XL
    B1=1/Z0*((Z0-RL)/RL)^.5; B2=-1/Z0*((Z0-RL)/RL)^.5
end
```

% the 1st match solution

[C1 ctype]=B2LC(B1,f0)

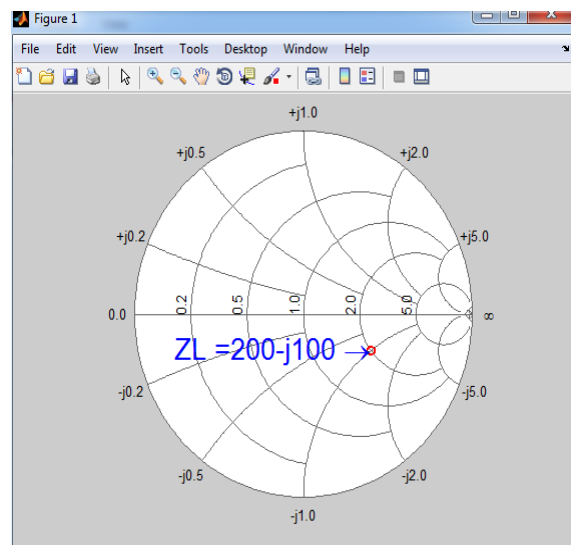
[L1 ltype]=X2LC(X1,f0)

% and the 2nd solution

[L2 ctype]=B2LC(B2,f0)

[C2 ltype]=X2LC(X2,f0)

OUTPUT:



VIVA QUESTIONS:

1. What is impedance matching?
2. What is Z_0 ?
3. What is standard characteristics impedance value ?

Experiment-4

PHASE AND GROUP VELOCITY CALCULATION AT 9GHz

Aim: To calculate phase & group velocity using MATLAB software.

Software Required: MATLAB software

Theory: Waves can be in the group and such groups are called wave packets, so the velocity with a wave packet travels is called group velocity. The velocity with which the phase of a wave travels is called phase velocity. The relation between group velocity and phase velocity are proportionate. The phase velocity of a wave is the rate at which the wave propagates in some medium. This is the velocity at which the phase of any one frequency component of the wave travels. The group velocity of a wave is the velocity with which the overall envelope shape of the wave's amplitudes—known as the modulation or envelope of the wave—propagates through space.

Program:

```
% phase velocity, group velocity X band .9inx.4in WR90 waveguide at 9GHz
clear all;close all;clc
e0=8.854e-12      % [F/m] free space permittivity
mu0=4*pi*1e-7     % [H/m] free space permeability
f0=9e9;          % choose operating frequency [Hz]
b_in=.9           % in, X band WR-90
a_in=0.4           % in
er=2.54;mur=1;     % Rexolite filler er(3GHz)=er(9GHz)=2.54
a=a_in*25.40001e-3
b=b_in*25.40001e-3
c0=299792458;     % m/s
v_propagation=c0/er^.5      % propagation velocity
k_wave=2*pi*f0*er^.5/c0     % waev number constant
N=2;M_range=[0:1:N];N_range=[0:1:N]; % finding all possible modes below N M
for k=[1:1: numel(M_range)]
    for s=[1:1: numel(N_range)]
        fc(k,s)=c0/(2*pi*er^.5)*((M_range(k)*pi/a)^2+(N_range(s)*pi/b)^2).^-.5;
    end
end
fc % cut-offs, NxM format
fMN=zeros(max(M_range)+1,max(N_range)+1,3);
fMN(:, :,3)=fc;
fMN(:, :,2)=meshgrid(M_range,N_range);
fMN(:, :,1)=meshgrid(M_range,N_range)';
L=[0 0 0];
for k=1:1:(M_range(end)+1)
    for s=1:1:(N_range(end)+1)
```

```

        L=[L;fMN(k,s,1) fMN(k,s,2) fMN(k,s,3)];
    end
end
L=uint64(L)
k_all_nulls=[];           % TEM doesn't propagate inside rectangular waveguides, removing
all null lines off L
for k=1:1:size(L,1)
    if L(k,1)==0 && L(k,2)==0 && L(k,3)==0
        k_all_nulls=[k_all_nulls k]
    end
end
L(k_all_nulls,:)=[]
fc=L(:,3); % sorting cut-offs in frequency ascending order
[n,v]=sort(fc);
L=L(v,:);
fc_sorted=L(:,3)% Since the solution manual has 2 errors, one being the actual carrier
frequency to use,
% let's calculate the propagation constants for all considered propagation modes:
kc=[];
for k=1:1: numel(fc)
    L2=double(L(k,:));
    kc=[kc; ((L2(1)*pi/a)^2+(L2(2)*pi/b)^2)^.5];
end
beta=(k_wave^2-kc.^2).^5
% modes that get through, for a given input frequency f0
% f0=f_cutoff doesn't get through, it has to be f0>f_cutoff
% safety_factor=1 % safety_factor=1 no safety band, 1.5 at least
% half carrier above cutoff ..
k=1;
while L(k,3)<=f0 && k<size(L,1)
    k=k+1;
end
k
L_through=L([k:end],:)
fc_through=fc_sorted([k:end],:)
[n3,v3]=find(imag(beta)==0)
beta=beta(n3,:) % take only the modes that propagate
% instead of
% beta=beta([1 2],:)
% let's build a beta variable for each propagating mode
for k=1:1: numel(n3)
    str1=['beta_' num2str(L(n3(k),1)) num2str(L(n3(k),2)) '=' num2str(beta(n3(k)))];
    evalin('base',str1)
end
% phase velocities or propagation velocities of each propagating mode

```

```

% vp=2*pi*f0/beta
for k=1:1:numel(n3)
    str1=['vp_' num2str(L(n3(k),1)) num2str(L(n3(k),2)) '=' num2str(2*pi*f0/beta(n3(k)))];
    evalin('base',str1)
end
% group velocities of each propagating mode
for k=1:1:numel(n3)
    str1=['vg_' num2str(L(n3(k),1)) num2str(L(n3(k),2)) '=' ...
        num2str(beta(n3(k))/(k_wave*(mu0*e0*mur*er)^.5))];
    evalin('base',str1)
end

```

Result:

Viva Questions:

1. Define Phase velocity?
2. Define group velocity?
3. Relation between phase and group velocity?
4. What is guide wavelength?

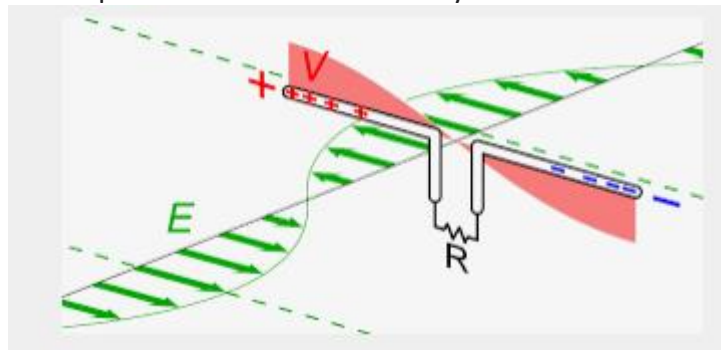
Experiment-5

DIPOLE ANTENNA

Aim: To plot radiation pattern of dipole antenna using MATLAB software

Software Used: MATLAB

Theory: A dipole antenna is an antenna with a center-fed driven element for transmitting or receiving radio frequency energy. From a physics viewpoint, this type of antenna is the simplest practical antenna. Dipole antennas (or such designs derived from them, including the monopole) are used to feed more elaborate directional antennas such as a horn antenna, parabolic reflector, or corner reflector. Engineers analyze vertical (or other monopole) antennas on the basis of dipole antennas of which they are one half.



Program:

%This program print pattern (AF) for Short and any Dipole Antenna by giving the length of your Dipole

```
lamda=input('enter the value of wave length= ');
```

```
l=input('enter your dipole length l= ');
```

```
ratio=l/lamda;
```

```
B=(2*pi/lamda);
```

```
theta= pi/100:pi/100:2*pi;
```

```
if ratio<= 0.1      %check if Short Dipole
```

```
    E=sin(theta);
```

```
    En=abs(E);
```

```
    subplot(2,3,1)
```

```
    polar(theta,En)    %This plot polar pattern in plane which dipole appear as line
```

```
else                %check if not short dipole
```

```
    f1=cos(B*l/2.*cos(theta));
```

```
    f2=cos(B*l/2);
```

```
    f3=sin(theta);
```

```
    E=(f1-f2)./f3;
```

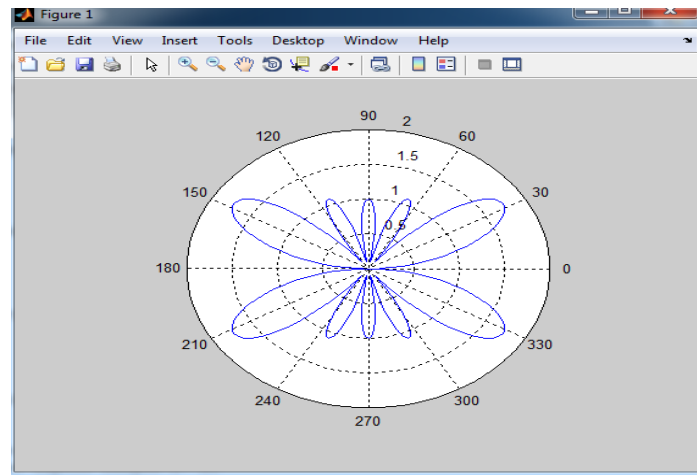
```
    En=abs(E);
```

```
    subplot(2,2,2)
```

```
    polar(theta,En)    %This plot polar pattern in plane which dipole appear as line
```

```
end
```

Result:



VIVA QUESTION:

1. What is length of dipole antenna?
2. What is monopole antenna?
3. What is radiation resistance of dipole antenna
4. What is half wave dipole?
5. What is quarter wave monopole?

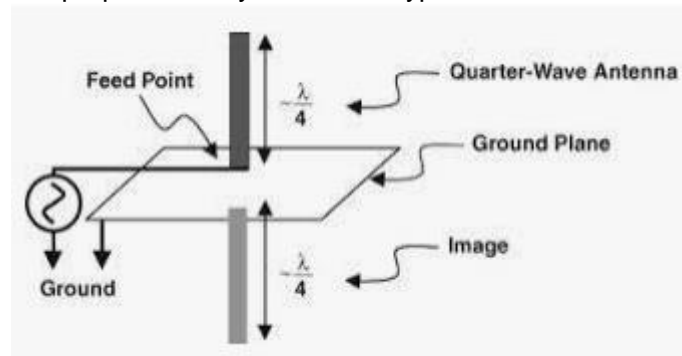
Experiment No-6

MONOPOLE ANTENNA

Aim: To plot radiation pattern of monopole antenna using MATLAB software

Software Used: MATLAB

Theory: A **monopole antenna** is a class of radio antenna consisting of a straight rod-shaped conductor, often mounted perpendicularly over some type of conductive ..

**Program:**

%This program print pattern for Short and any monopole Antenna by giving the length of your Dipole

lamda=input('enter the value of wave length= ');

l=input('enter your monopole length l= ');

ratio=l/lamda;

B=(2*pi/lamda);

theta= -pi/2:pi/100:pi/2;

if ratio<= 0.1 %check if Short Dipole

E=sin(theta);

En=abs(E);

subplot(2,3,4)

polar(theta,En) %This plot polar pattern in plane which dipole appear as line

else %check if not short dipole

f1=cos(B*l/2.*cos(theta));

f2=cos(B*l/2);

f3=sin(theta);

E=(f1-f2)./f3;

En=abs(E);

subplot(2,3,6)

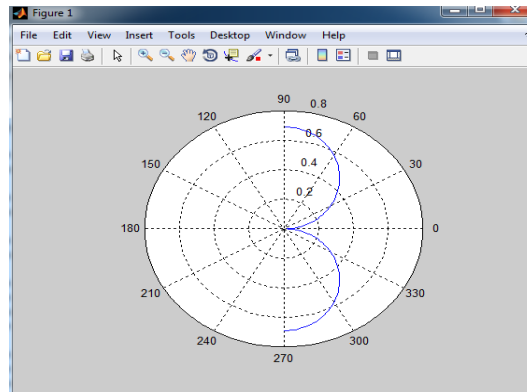
polar(theta,En) %This plot polar pattern in plane which dipole appear as line

end

OUTPUT:

LAMBDA=10

LENGTH=4

**VIVA QUESTION:**

1. What is monopole antenna?
2. What is dipole antenna?
3. What is center-fed antenna?
4. What is resistance of monopole?

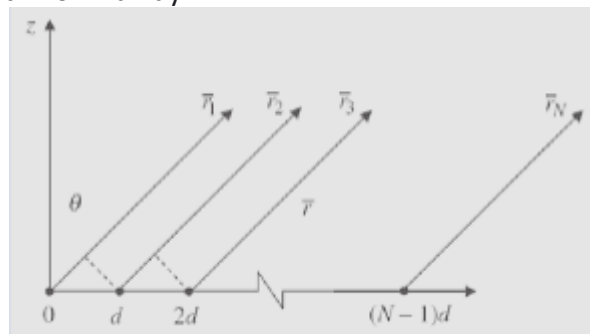
Experiment No-7

UNIFORM LINEAR ARRAY

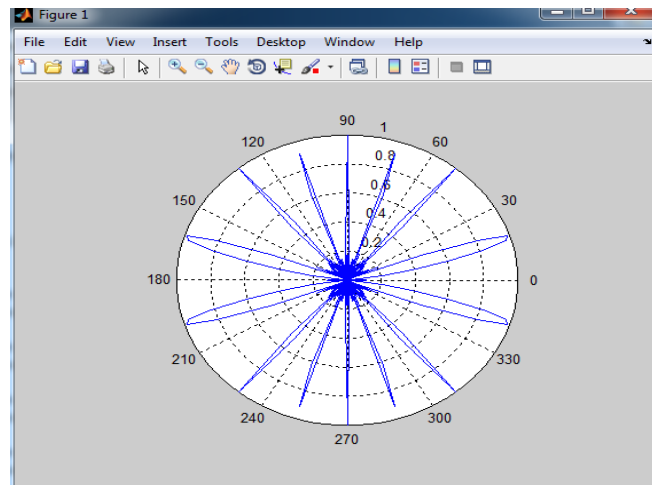
Aim: To plot radiation pattern of radiation pattern

Software Used: MATLAB

Theory: An antenna composed of a relatively large number of usually identical elements arranged in a single line or in a plane with uniform spacing and usually with a uniform feed system. An array of identical elements all of identical magnitude and each with a progressive phase is referred to as a uniform array.

**Program:**

```
%This program print pattern for linear Array (uniform) Antenna by giing
%N,alfa,d
%and the wavelength you work with
%if you want full pattern multiply this pattern by any Antenna pattern
%Have a nice Pattern "Arabia Tech"
lamda=input('enter the value of wave length= ');
N=input('enter the no. of elements= ');
alfa=input('enter your progressive phase= ');
d=input('enter the seperation distance between elements= ');
B=(2*pi/lamda);
theta= pi/100:pi/100:2*pi;
w=alfa+B*d.*cos(theta);
AF=sinc(N*(w./2))./sinc(w./2);
subplot(2,3,3)
polar(theta,AF)
```

Result:**VIVA QUESTIONS:**

1. What is BSA?
2. What is EFA?
3. What is first null?
4. What is path difference?
5. What are the conditions for EFA and BSA?

PART-B

EXPERIMENT NO-1**GUNN DIODE CHARACTERISTICS**

Aim: To study the characteristics of a Gunn diode oscillator.

Apparatus: Gunn power supply, Gunn oscillator with micrometer, Isolator, Tunable frequency meter, Detector Mount, Ammeter (0-10mA), Cable, Cooling fan.

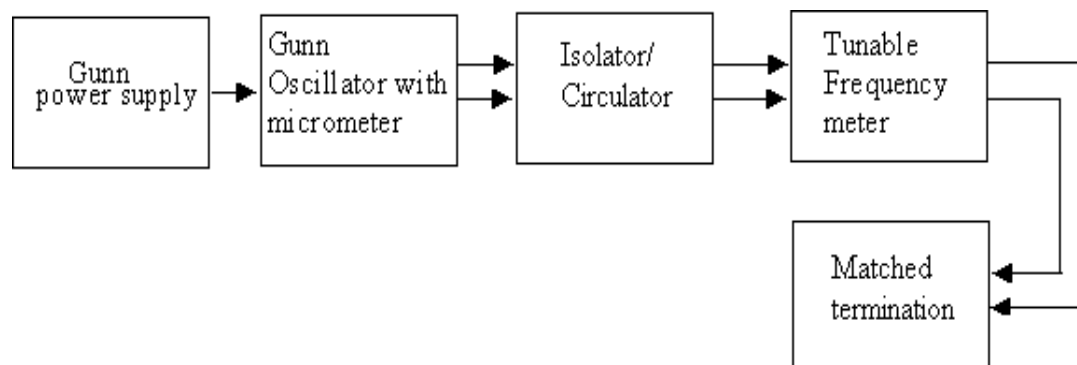
Theory:

The Gunn Diode makes use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated and passed through the positive resonator towards negative reflector, which reflects the electrons and the electrons turn back through the resonator. Suppose the RF- field exists between the resonators, the electron accelerated or retarded, as the voltage at an increased velocity and the retarded electrons leave at the reduced velocity. As a result, returning electrons group together in bunches. As the electron bunches pass through the resonator, they interact with the voltage at resonator grids.

If the bunches pass the grid at such a time that the electrons are slowed down by the voltage then energy will be delivered to the resonator, and the klystron will oscillate. The frequency is primarily determined by the dimensions of resonant cavity. Hence by changing the volume of the resonator, mechanical tuning of the klystron is possible. A small frequency change can be obtained by adjusting reflector voltage. This is called electronic tuning.

Block Diagram:

Setup for V-I Characteristics of Gunn Oscillator

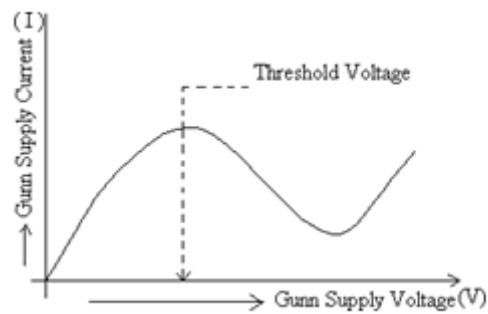


Procedure: _

1. First connect the Gunn test bench as shown in block diagram (a). Switch on the Gunn power supply.
2. The Gunn bias is adjusted to 9V (below 10V).
3. The micrometer of the Gunn oscillator is varied.
4. The tunable frequency meter is tuned until there is a dip in the ammeter.
5. The operating frequency can be taken in terms of GHz.
6. The Gunn oscillator micrometer reading and the corresponding frequency are shown in the frequency conversion charts.
7. Similar frequency conversion charts are provided for the frequency meter reading.
8. Note the frequency corresponding to Gunn oscillator micrometer reading and the frequency corresponding to frequency meter reading.
9. Both the frequency readings should be the same.
10. The above procedure is repeated for different values of the Gunn oscillator micrometer values.
11. For V-I characteristics of Gunn connect the test bench as block diagram.
12. Vary Gunn supply voltage from minimum (i.e. 0V to 6V), note down the corresponding Gunn current when it is in current (I) mode.
13. Plot graph between Gunn supply voltage Vs Gunn supply current.

Tabular Column:

S.No.	Gunn Supply Voltage(V)	Gunn Supply Current(mA)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

Expected Graphs:**Result:****Questions:**

1. What is GUNN diode ?
2. Draw the equivalent Circuit for GUNN?
3. What are the different modes in GUNN diode oscillator?
4. How many junctions are there in GUNN?
5. Explain the transferred electron effect in GUNN?
6. What are applications of GUNN?

EXPERIMENT NO-2

CHARACTERISTICS OF THE REFLEX KLYSTRON TUBE

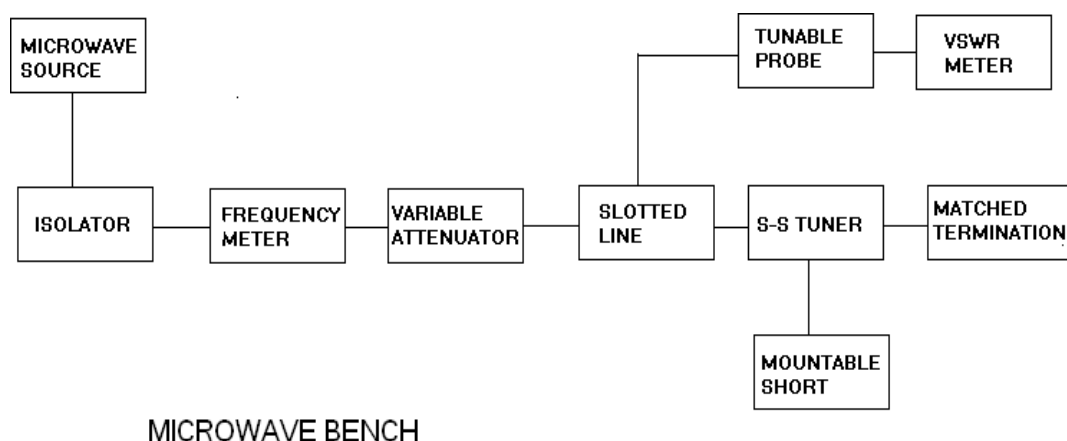
Aim: To study the characteristics of the reflex klystron tube and to determine its electronic tuning range.

Apparatus:

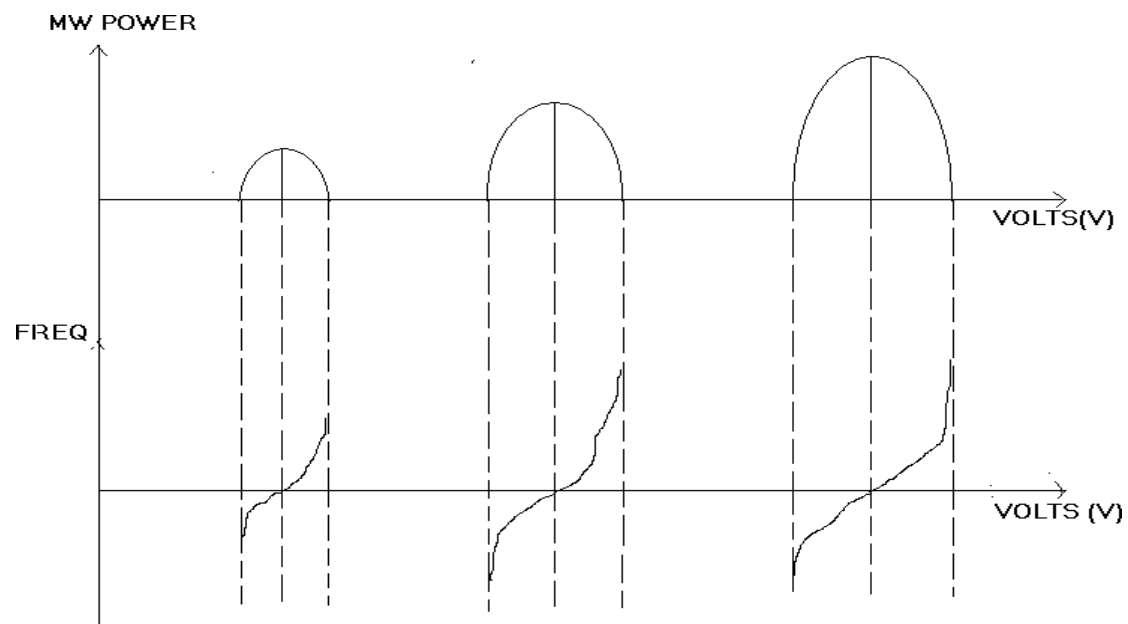
Klystron power supply, klystron mount, isolator, frequency mount, variable attenuator, detector mount, wave guide stands, oscilloscope, BNC cable, cooling fan.

Theory:

The reflex klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated and passed through the positive resonator towards negative reflector, which reflects the electrons and the electrons turn back through the resonator. Suppose the RF- field exists between the resonators, the electron accelerated or retarded, as the voltage at an increased velocity and the retarded electrons leave at the reduced velocity. As a result, returning electrons group together in bunches. As the electron bunches pass through the resonator, they interact with the voltage at resonator grids. If the bunches pass the grid at such a time that the electrons are slowed down by the voltage then energy will be delivered to the resonator, and the klystron will oscillate. The frequency is primarily determined by the dimensions of resonant cavity. Hence by changing the volume of the resonator, mechanical tuning of the klystron is possible. A small frequency change can be obtained by adjusting repeller voltage. This is called electronic tuning.

Block Diagram:

Model Graph:



Procedure:

1. Connect the components and equipments as shown in the block diagram.
2. Set the variable attenuator at the minimum attenuation position.
3. Set the mod. Switch of klystron power supply at CW position, beam voltage control knob to fully anticlockwise and repeller voltage control knob to fully clockwise.
4. Rotate the knob of the frequency meter at one side fully.
5. Connect dc milliammeter with detector.
6. Switch on the klystron power supply and cooling fan.
7. Put on the beam voltage switch (ht) and rotate the beam voltage knob slowly up to 300V and observe the beam current which does not increase more than 30mA. Do not change the beam voltage while taking the readings.
8. Change the repeller voltage slowly and watch the current meter set the maximum deflection in the ammeter.
9. Tune the plunger of klystron mount for maximum output.
10. Rotate the frequency meter slowly and stop at that position, where there is lowest output on milliammeter. Read frequency meter between two horizontal red lines and vertical marker.
11. Change the reflector voltage and read the current and frequency for each repeller voltage to get different modes of the klystron.
12. Note the readings in tabular column for every repeller voltage and draw the graph for klystron modes.

Observation:

Beam voltage (V_0) = , Beam current (I) =

Repeller Voltage (V)	Current (mA)	Power (mW)	Dip Frequency (GHz)

Result:

Questions:

- 1) What is klystron tube?
- 2) What is velocity modulation?
- 3) What is bunching?
- 4) Importance of multicavity klystron?
- 5) What is electronic tuning?

EXPERIMENT NO-3

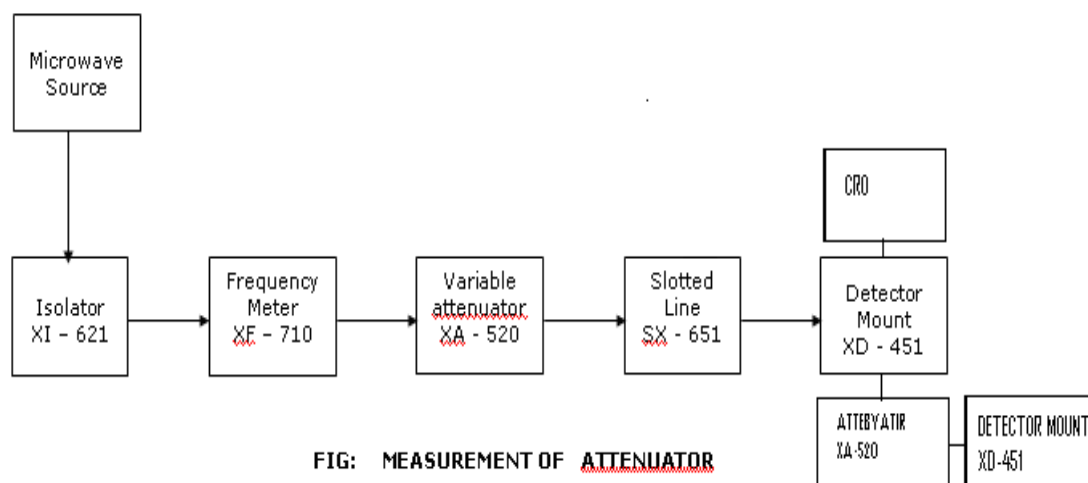
ATTENUATION MEASUREMENT

Aim: To study insertion loss and attenuation of an attenuator

Apparatus:

1. Microwave source Klystron tube (2k25)
2. Isolator (xI-621)
3. Frequency meter (xF-710)
4. Variable attenuator (XA-520)
5. Slotted line (XS-651)
6. Tunable probe (XP-655)
7. Detector mount (XD-451)
8. Matched termination (XL-400)
9. Test attenuator
 - a) Fixed
 - b) Variable
10. Klystron power supply & Klystron mount
11. Cooling fan
12. BNC-BNC cable
13. VSWR or CRO

BLOCK DIAGRAM



Theory:

The attenuator is a two port bidirectional device which attenuates some power when inserted into a transmission line.

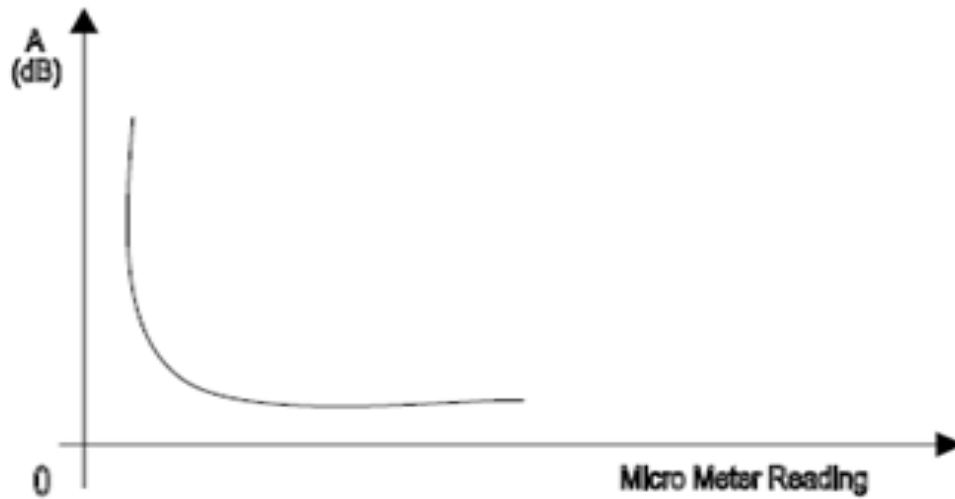
$$\text{Attenuation } A \text{ (dB)} = 10 \log (P_1/P_2)$$

Where P_1 = Power detected by the load without the attenuator in the line
 P_2 = Power detected by the load with the attenuator in the line.

Procedure:

1. Connect the equipments as shown in the above figure.
2. Energize the microwave source for maximum power at any frequency of operation.
3. Connect the detector mount to the slotted line and tune the detector mount also for max deflection on VSWR or on CRO.
4. Set any reference level on the VSWR meter or on CRO with the help of variable attenuator. Let it be P_1 .
5. Carefully disconnect the detector mount from the slotted line without disturbing any position on the setup place the test variable attenuator to the slotted line and detector mount to O/P port of test variable attenuator.
6. Keep the micrometer reading of test variable attenuator to zero and record the readings of VSWR meter or on CRO. Let it to be P_2 . Then the insertion loss of test attenuator will be P_1-P_2 db.
7. For measurement of attenuation of fixed and variable attenuator. Place the test attenuator to the slotted line and detector mount at the other port of test attenuator. Record the reading of VSWR meter or on CRO. Let it be P_3 then the attenuation value of variable attenuator for particular position of micrometer reading of will be P_1-P_3 db.
8. In case the variable attenuator change the micro meter reading and record the VSWR meter or CRO reading. Find out attenuation value for different position of micrometer reading and plot a graph.
9. Now change the operating frequency and all steps should be repeated for finding frequency sensitivity of fixed and variable attenuator.

Note:1. For measuring frequency sensitivity of variable attenuator the position of micrometer reading of the variable attenuator should be same for all frequencies of operation.

Expected Graph:**OBSERVATION TABLE:**

Micrometer reading	P1 (dB)	P2 (dB)	Attenuation = P1-P2 (dB)

Result:

Questions:

1. What is attenuation?
2. How many types of attenuators are there?
3. What is insertion loss?
4. What is the min value of insertion loss?
5. What are the methods used for measuring attenuation?
6. What are the methods used for measuring insertion loss?

EXPERIMENT NO-4**IMPEDANCE MEASUREMENT FREQUENCY MEASUREMENT**

Aim: To calculate the impedance of the given load of the Klystron.

To determine the frequency and wavelength in a rectangular waveguideworking in TE₁₀ mode.

Apparatus:

1. Reflex Klystron power supply.
2. Reflex Klystron tube with mount
3. Isolator or Circulator or Attenuator
4. VSWR meter
5. Tunable frequency meter
6. Slotted section with tunable probe and movable probe carriage
7. Shorting plate
8. Loads (Inductive window, Capacitive window, Slide screw tuner, Pyramidal Horn antenna, H-horn antenna, E-horn Antenna)

Theory:

The reflex klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated and passed through the positive resonator towards negative reflector, which reflects the electrons and the electrons turn back through the resonator. Suppose the RF- field exists between the resonators, the electron accelerated or retarded, as the voltage at an increased velocity and the retarded electrons leave at the reduced velocity. As a result, returning electrons group together in bunches. As the electron bunches pass through the resonator, they interact with the voltage at resonator grids.

If the bunches pass the grid at such a time that the electrons are slowed down by the voltage then energy will be delivered to the resonator, and the klystron will oscillate. The frequency is primarily determined by the dimensions of resonant cavity. Hence by changing the volume of the resonator, mechanical tuning of the klystron is possible. A small frequency change can be obtained by adjusting reflector voltage. This is called electronic tuning. The cut-off frequency relationship shows that the physical size of the wave guide will Determine the propagation of the particular modes of specific orders determined by values of m and n. The minimum cut-off frequency is obtained for a

rectangular waveguide having dimension $a > b$, for values of $m=1, n=0$, i.e. TE₁₀ mode is the dominant mode since for TM_{mn} modes, $n \neq 0$ or $n \neq 0$ the lowest-order mode possible is TE₁₀, called the dominant mode in a rectangular wave guide for $a > b$.

For dominant TE₁₀ mode rectangular wave guide λ_o, λ_g and λ_c are related as below.

$$1/\lambda_o^2 = 1/\lambda_g^2 + 1/\lambda_c^2$$

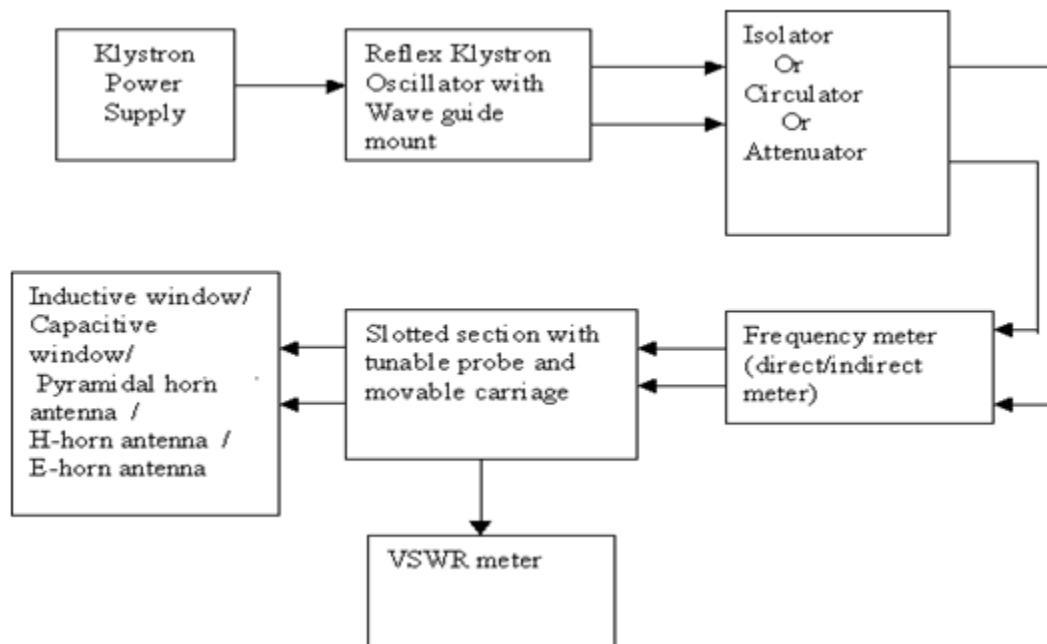
Where λ_o is free space wave length

λ_g is guide wave length

λ_c is cut off wave length

For TE₁₀ mode $\lambda_c = 2a$ where 'a' is broad dimension of wave guide.

Block Diagram:



Procedure:

1. Connect the Reflex Klystron microwave test bench as per the block diagram.
2. Keep the Modulation switch in CW mode.
3. Adjust the repeller voltage (V_r) in maximum position.
4. Switch on the power supply and HT is ON condition.
5. Adjust beam current slowly, by increasing the beam voltage (V_o) slowly till the beam current reaches 21mA to 23mA. Do not change the beam voltage, repeller voltage and beam current throughout the experiment.
6. Note the output current. Tune the frequency meter and observe the dip in

- the ammeter and note the corresponding frequency (i.e. operational frequency).
7. Detune the frequency meter.
 8. Keep the modulation switch in AM mode.
 9. Connect the tunable probe of the slotted section and VSWR meter using BNC cable.
 10. Connect the required load to the slotted section.
 11. Keep Range switch of VSWR meter in 30dB or 40 dB position.
 12. Keep meter selector in normal position and input selection in Xtal position.
 13. Keep the tunable probe at extreme right by using probe carriage of slotted section.
 14. Tune the probe so that the indicator in VSWR meter will move towards '1'.
 15. Adjust the amplitude and frequency of modulation so that the indicator in VSWR meter move towards '1' in upper scale.
 16. Now adjust the fine and coarse so that indicator is positioned on '1'
 17. Now the probe is on V_{\max} position, move the probe carriage such that indicator is deflected away from '1' and a dip is observed on meter. Now the probe is positioned in V_{\min} position. The meter reading directly gives the VSWR.
 18. If the range switch is placed on 30db the reading must be taken from 1 to 3 scale. If the range switch is 40 db position, 3 to 10 scale is considered. If the variation of probe carriage in the above two scales exceeded then change the range switch to 50db and consider the scale 1 to 3 multiplied by 10. If the reading is beyond the scale then change the range switch to 60 db and consider 3 to 10 scale multiplied by 10.
 19. Plot the smith chart for the observed values of VSWR for corresponding Loads and then calculate the normalized load impedance from the smith chart.
 20. Find the required load impedance for the corresponding load according to the given formula

Formulas:

$$\lambda_c = 2a, \quad \eta_0 = 120\pi, \quad a = 2.25\text{cm}$$

$$Z_0 = \eta_0 / \sqrt{1 - (\lambda_0 / \lambda_c)^2}, \quad \eta_0 = 120\pi, \quad \lambda_0 = c/f \text{ and } \lambda_c = 2a \text{ where } a = 2.25 \text{ cm.}$$

$$Z_l / Z_0 = \text{normalized load impedance (from the smith chart)}$$

$$\therefore \text{Load impedance } (Z_l) = Z_0 * \text{normalized load impedance}$$

16. Calculate the frequency by following equation.

$$f = \frac{c}{\lambda} = \sqrt{\left(\frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}\right)}$$

Where $C = 3 \times 10^8$ meter/sec. i.e. velocity of light.

17. Verify with frequency obtained by frequency modes

18. Above experiment can be verified at different frequencies.

$$f_0 = C/\lambda_0 \Rightarrow C \Rightarrow 3 \times 10^{10} \text{ m/s (i.e., velocity of light)}$$

$$1/\lambda_0^2 = 1/\lambda_g^2 + 1/\lambda_c^2$$

$$\lambda_0 = \frac{\lambda_g \lambda_c}{\sqrt{\lambda_g^2 + \lambda_c^2}}$$

$$\lambda_g = 2 \times \Delta_d$$

$$\text{For TE}_{10} \text{ mode} \Rightarrow \lambda_c = 2a$$

$a \rightarrow$ wave guide inner broad dimension

$a = 2.286 \text{ cm}$ (given in manual)

$$\lambda_c = 4.6 \text{ cm}$$

Result:

Questions:

1. Indicate the frequency Vs wave length for X-band?
2. Explain the principle of isolator & circulator?
3. Explain the principle of frequency meter?
4. What type of frequency meter used in microwave test bench?
5. What is the microwave frequency range?

EXPERIMENT NO-5**CHARACTERISTICS OF MULTI HOLE DIRECTIONAL COUPLER**

Aim: To study the function of multihole directional coupler by measuring the following parameters.

1. Mainline and auxiliary line VSWR.
2. The coupling factor and directivity of the coupler.

Apparatus:

Klystron power supply, klystron mount, isolator, frequency mount, variable Attenuator, detector mount, wave guide stands, oscilloscope, BNC cable, cooling fan, Slotted line tunable probe, VSWR meter.

Theory:

A directional coupler is a device with which it is possible to measure the incident and reflected wave separately. It consists of two transmission lines the main arm and auxiliary arm, electro magnetically coupled to each other. The power entering , in the main- arm gets divided between port 2 and port 3, and almost no power comes out in port 4 power entering at port 2 is divided between port 1 and port 4. The coupling factor is defined as

Coupling (C) = $20 \log p_1/p_3$ (db) where port 2 is matched.

Isolation (I) = $20 \log p_2/p_3$ (db) where port 1 is matched.

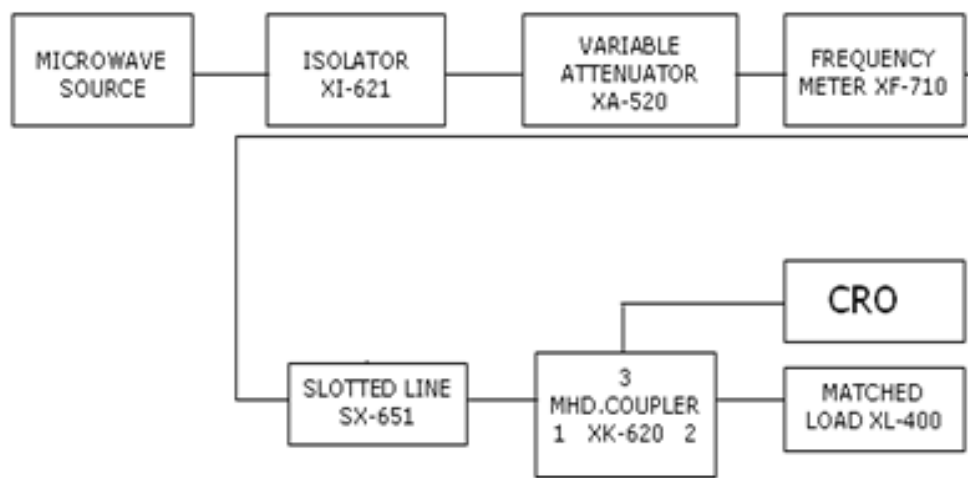
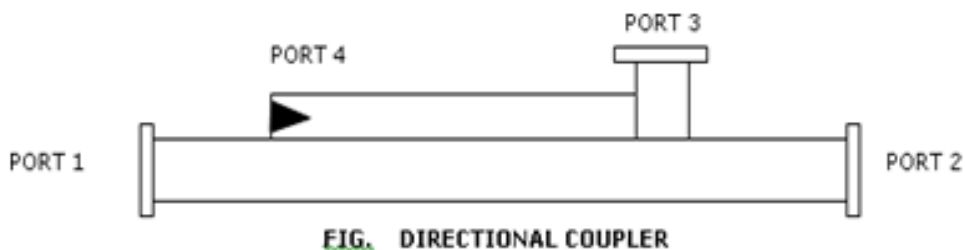
With built in termination and power entering at port 1, the directivity of the coupler is a measure of separation between incident wave and the reflected wave .directivity is measured indirectly as follows:

Hence Directivity $D = I - C = 20 \log p_2/p_1$ (db).

Main line VSWR is measured, looking into the main line input terminal when the matched loads are placed on other terminals.

Main line insertion loss is the attenuation introduced in the transmission line by insertion of coupler. It is defined as:

Insertion loss = $20 \log p_1/p_2$ (db).

Block Diagram:**Procedure:****Measurement of coupling factor, insertion loss, isolation and directivity:**

1. Set up the components and equipments as shown in block diagram.
2. Energize the microwave source for particular frequency of operation.
3. Set modulation selector switch to am position.
4. Remove the multi hole directional coupler and connect the detector mount, tune the detector for maximum output.
5. Set any reference level of power on VSWR meter with the help of variable attenuator, gain control knob of VSWR meter, and note down the reading (reference level let X).
6. Insert the directional coupler as shown in second fig with detector to the auxiliary port 3 and matched termination to port 2, without changing the position of variable attenuator and gain control knob of VSWR meter.
7. Note down the reading on VSWR meter on the scale with the help of range db switch if required. Let it be Y.
8. Calculate coupling factor which will be $X - Y = C \text{ (db)}$.

9. Now carefully disconnect the detector from the auxiliary port 3 and match termination from port 2 without disturbing the set-up.
10. Connect the matched termination to the auxiliary port 3 and detector to port 2 measures the reading on VSWR meter. Suppose it is Z.
11. Connect insertion loss X-Z in db.
12. Repeat the steps from 1 to 5.
13. Connect the directional coupler in the reverse direction, i.e. port 2 to frequency meter side, matched termination to port 1 and detector mount to port 3. Without disturbing the position of the variable attenuator and gain control knob of VSWR meter.
14. Measure and note the reading on VSWR meter let it be Y_d . $X - Y_d$ gives isolation I (db).
15. Compute the directivity as $Y - Y_d = I - C$.
16. Repeat the same for other frequencies.

Calculations:

$$\text{Coupling (C)} = 20 \log p_1/p_3 \text{ (db)}$$

$$\text{Isolation (I)} = 20 \log p_2/p_3 \text{ (db)}$$

$$\text{Directivity D} = I - C = 20 \log p_2/p_1$$
$$\text{Insertion loss} = 20 \log p_1/p_2 \text{ (db)}.$$

Result:**Questions:**

- 1) What is directional coupler?
- 2) How many ports does it have?
- 3) What is the difference between dc to magic tee?
- 4) What is Directivity?
- 5) What is Insertion Loss?

EXPERIMENT NO-6

DETERMINATION OF STANDING WAVE RATIO AND REFLECTION COEFFICIENT

Aim: To determine the standing wave ratio and reflection coefficient of X-band waveguide.

Apparatus:

Klystron power supply, klystron mount, isolator, frequency mount, variable Attenuator, detector mount, wave guide stands, oscilloscope, BNC cable, cooling fan Slotted line tunable probe, S-S tuner.

Theory:

The electromagnetic field at any point of transmission line may be considered as the sum of two travelling waves, the incident wave, which propagates from the source to the load and the reflected wave which propagates towards the generator. The reflected wave is set up by reflection of incident wave from a discontinuity in the line or from the load impedance. The superposition of the two travelling waves, gives rise to a standing wave along the line. The maximum field strength is found where the waves are in phase and minimum where the two waves add in opposite phase. The distance between two successive minimum (maximum) is half the guide wavelength on the line. The ratio of electrical field strength and incident wave is called reflection coefficient.

The voltage standing wave ratio VSWR is defined as ratio between maximum and minimum field strength along the line.

Hence VSWR denoted by s is as follows

$$S = E_{\max}/E_{\min} = [iE_i + iE_r]/[iE_i - iE_r]$$

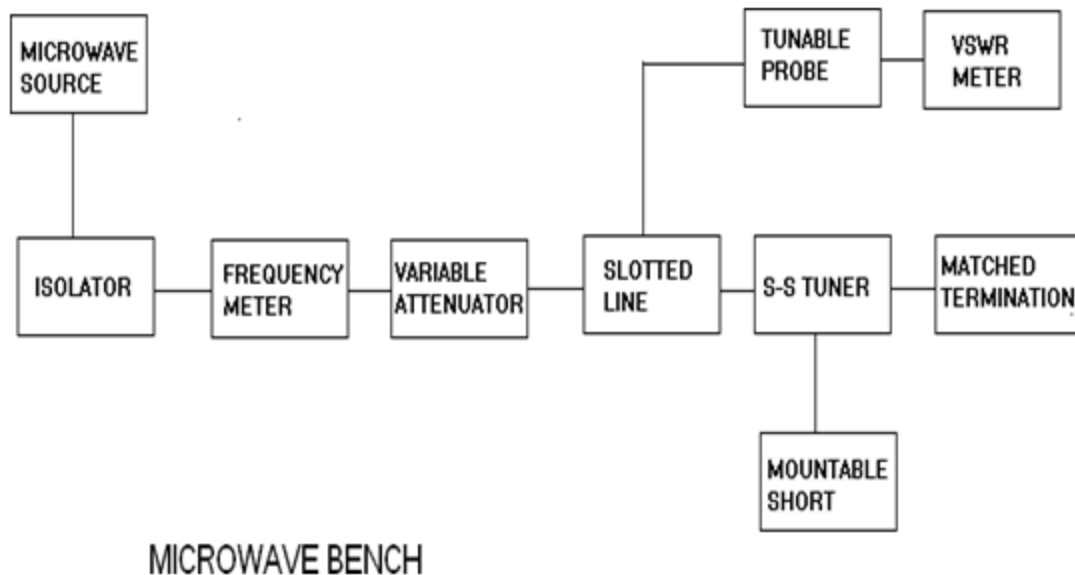
Reflection coefficient (ρ) is

$$\rho = E_r/E_i = [Z_L - Z_0]/[Z_L + Z_0]$$

Where Z_L is the load impedance, Z_0 is characteristics impedance.

The above equation gives following equation

$$\rho = S-1/S+1.$$

Block Diagram:**Procedure:**

1. Set up the equipment as shown in the block diagram.
2. Keep variable variable attenuator in the minimum attenuated position.
3. Keep the control knobs of VSWR meter as below:
 - Range db --- 30 db/ 40 db.
 - Input selector switch----- crystal 200k ohm.
 - Meter switch ----- normal.
 - Gain (coarse fine)----- mid position approx.
4. Keep the control knobs of klystron power as below:
 - Beam voltage (HT) ----- off.
 - Mod. Switch----- AM.
 - Beam voltage knob-----fully antic lock wise.
 - Reflector voltage knob----- fully clockwise.
 - Am- amplitude knob -----around fully clockwise.
 - Am- frequency-----mid position.
5. Switch on the klystron power supply. VSWR meter and cooling fan.
6. Switch on the beam voltage (ht) switch and set beam voltage at 300v.
7. Rotate the repeller voltage knob to get deflection in VSWR meter.
8. Tune the output by tuning the reflector voltage, amplitude and frequency of AM modulation.
9. Tune plunger of klystron mount and probe for maximum deflection in

VSWR meter=1.

10.If required, change the range db- switch, and gain control knob to get deflection in the scale of VSWR meter.

11. As you move probe along the slotted line, the deflection will change.

A. Measurement of low VSWR:

1. Move the probe along the slotted line to get maximum deflection in VSWR meter.
2. Adjust the VSWR meter gain control knob until the meter indicates 1.0 on normal VSWR scale.
3. Keep the entire control knob as it is, move the probe to next minimum position. Read the VSWR on scale.

B. Measurement of high VSWR:

1. Set the depth of S-S tuner slightly more for maximum VSWR.
2. Move the probe along with slotted line until a minimum is indicated.
3. Adjust the VSWR meter gain control knob to obtain a reading of 3 db in the normal db scale (0- 10 db) of VSWR.
4. Move the probe to the left on slotted line until the deflection is 6 db or 0 db obtain on 0 ---10 db scale. Note the record the probe position on slotted line let it is d1.
5. Repeat the step 3 and then move the probe right along the slotted line until deflection is 6 db or 0 db obtain on 0--- 10 db normal db scale. Let it be d2.
6. Replace the S-S tuner and termination by short.
7. Measure the distance (d) between two successive minima position of probe. Twice this distance is guide wavelength : λ_g
8. Compute SWR from the following equation :

$$\text{VSWR (s)} = \lambda_g / (\pi(d1 \sim d2)).$$

Observations:

Beam voltage: Volts.

Beam current: mA.

Operating frequency of klystron = GHz.

d1 =()mm, d2 =()mm, d11 =()mm, d12=()mm , $\lambda_g = 2(d12 \sim d11)$.

VSWR(S) = $\lambda_g / 3.14(d1 \sim d2)$.

Result:

Questions:

- 1) What is standing wave?
- 2) What is reflection coefficient?
- 3) When do standing waves form?
- 4) How they are useful in microwave engg?
- 5) What is min. value of VSWR?

EXPERIMENT NO-7**STUDY OF MAGIC TEE**

Aim: To study the scattering parameters of magic tee.

Apparatus:

Klystron power supply, klystron mount, isolator , frequency mount, variable attenuator, detector mount, wave guide stands, oscilloscope, BNC cable, cooling fan magic tee, matched termination , accessories

Theory:

Magic tee is also known as hybrid tee or E-H plane tee. It is used to obtain completely matched three part tee junction. Magic tee can be used to measure the impedance as a duplexer and as a mixer. The reflex klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated and passed through the positive resonator towards negative reflector, which reflects the electrons and the electrons turn back through the resonator. Suppose the RF- field exists between the resonators, the electron accelerated or retarded, as the voltage at an increased velocity and the retarded electrons leave at the reduced velocity. As a result, returning electrons group together in bunches. As the electron bunches pass through the resonator, they interact with the voltage at resonator grids.

If the bunches pass the grid at such a time that the electrons are slowed down by the voltage then energy will be delivered to the resonator, and the klystron will oscillate. The frequency is primarily determined by the dimensions of resonant cavity. Hence by changing the volume of the resonator, mechanical tuning of the klystron is possible. A small frequency change can be obtained by adjusting reflector voltage. This is called electronic tuning.

Procedure:

VSWR measurement of the ports:

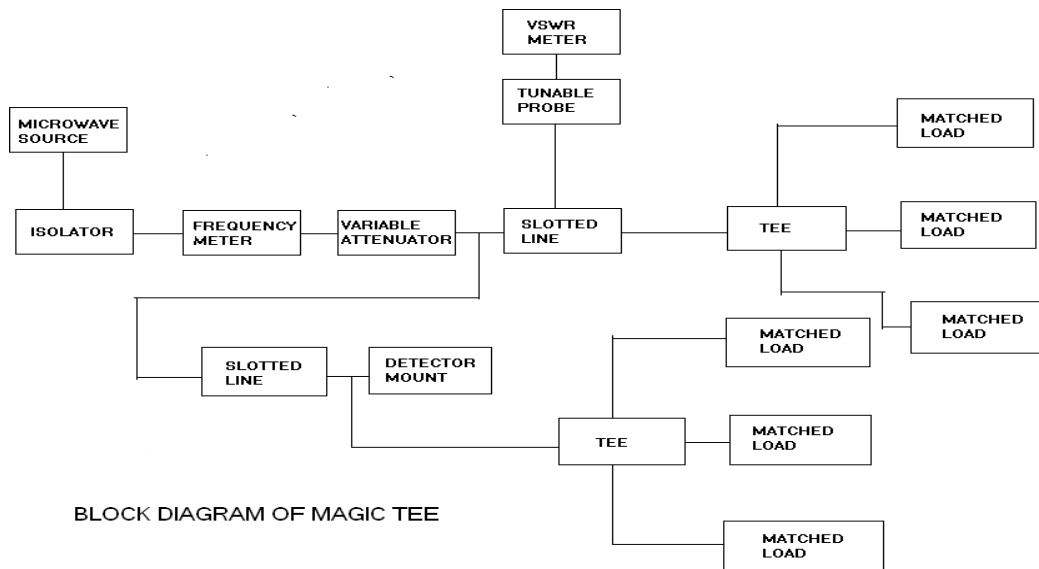
1. Set up the components and equipment as shown in block diagram keeping E- arm towards slotted line and matched termination to other parts.
2. Energize the microwave source for particular frequency of operation.
3. Measure the VSWR of E- arm as described in measurement of SWR for low and medium value.

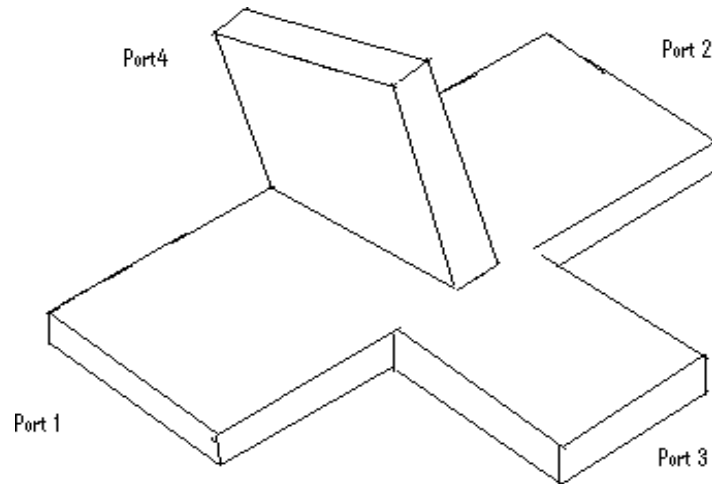
4. Connect another arm to slotted line and terminate the other port with matched termination. Measure the VSWR as above. Similarly VSWR of any port can be measured.

Measurement of Isolation and coupling factor:

1. Remove the tunable probe and magic tee from the slotted line and connect the detector mount to slotted line.
2. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.
3. With the help of variable attenuator and gain control knob of VSWR meter set any power level in the VSWR meter and note down, readings, let it be port 2.
4. Without disturbing the position of variable attenuator and gain control knob carefully place the magic tee after slotted line keeping arm connected to slotted line, detector to e- arm and matched termination to arm1 and arm 2 . Note down the reading of VSWR meter .let it be port 4.
5. Determine the coupling coefficient from equation given the theory port.
6. Determine the isolation between the port 3 and port 4 on port 3= port 4 in db.
7. Repeat the same experiment for the other ports.
8. Repeat the same experiment for other frequencies

Block Diagram:



**Observations:** $P_1 =$

$$P_3 = P_1 + P_2.$$

 $P_2 =$ $P_3 =$

$$P_4 = P_1 - P_2$$

Result:**Questions:**

- 1) What is magic tee?
- 2) How many ports does it have?
- 3) Difference between magic tee to directional coupler?
- 4) What is magic behind this?