ELECTROMAGNETIC FIELDS AND MICROWAVE

LAB MANUAL
V SEMESTER B.E (ECE)
(For Private Circulation)

Name :

Reg No :

Lab : **ELECTROMAGNETIC FIELDS AND MICROWAVE LAB**

Lab Code : **BECF185P60**

SRI CHANDRASEKHARENDRA SARASWATHI VISWA MAHAVIDYALAYA UNIVERSITY
(Accredited 'B' Grade by NAAC)
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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ELECTROMAGNETIC FIELDS & MICROWAVELABORATORY

OBJECTIVES:

L	T	P	C
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- To understand the principle of Electric field and Magnetic field on variousconductors.
- To understand the working Principle of various type of Microwave Oscillators.
- To know the behaviour of microwave components and parameters.
- To practice microwave measurement procedures

LIST OF EXPERIMENTS:

1. Determination of Electric Field Pattern Between Two Circular Electrodes
2. Determination of Electric Field between Parallel Conductors
3. Measurement of Electric Field and Potential Inside the Parallel Plate Capacitor
4. Measurement of Capacitance and Inductance of Transmission Lines
5. Determination of Magnetic Field Outside A Straight Conductor
6. Determination of Magnetic Field of Coils
7. Verification of Faraday's law of Magnetic Induction.
8. Determination of Velocity of electromagnetic waves for the given Co-axial Cable.
9. Reflex klystron or Gunn diode characteristics and basic microwave parameter measurement such as VSWR, frequency, wavelength.
10. Directional Coupler Characteristics.
11. Radiation Pattern of Horn Antenna.
12. S-parameter Measurement of the following microwave components (Isolator, Circulator, E Plane Tee, H Plane Tee, Magic Tee)
13. Attenuation and Power Measurement

OUTCOMES:

At the end of the course, the students should be able to:

- Understand the working principle of microwave components
- Know about the behaviour of microwave components
- Learn about the characteristics and measurements of E and H Field

2. Experiments Offered by the Department

Microwave Engineering

1. Determine the Frequency, Guided Wavelength and Propagation Constant for a Rectangular Wave-guide operating in TE_{10} mode.

2. Determine the Standing wave ratio(S) and Reflection coefficient (K) for the given Matched load, Movable Short & Horn Antenna.

3. Determine the Unknown Impedance of the given Matched load, Movable Short & Horn Antenna using Smith Chart and Slotted Line method.

4. Draw the Radiation pattern for Horn Antenna and Find the Half Power Beam-Width, Power Gain and Directivity.

5. Determine the Insertion Loss (I), Coupling Factor(C), Directivity (D) and S-matrix for a multi-hole Directional Coupler.

6. Determine the Mode Characteristics of a Reflex Klystron and Determine its Electronic Tuning Range and Electronic Tuning Sensitivity (ETS).

7. Determine the V-I Characteristics, Threshold Voltage and Modulation Depth for the given Gun Diode.

8.Determine the Velocity of EM waves for the given Co-axial Cable.

9. Determine the Insertion Loss, Isolation Loss and VSWR for the Microwave Isolator and Circulator.

10. Determine the Isolation Loss, coupling Co-efficient and VSWR for the four different ports in Magic Tee.

Additional Experiments

11. Simulate Broadside array, End-Fired array and Dipole Antenna using MATLAB 7.0 and plot the Radiation pattern.

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ECE LABORATORY SAFETY RULES

1. No horseplay or running is allowed in the labs.

2. No bare feet or open sandals are permitted.

3. Before energizing any equipment, check whether anyone is in a position to be injured by your actions.

4. When working on equipment where more than 120 volts exist between circuit points and/or ground, get your lab instructor's approval before energizing the circuit.

5. Read the appropriate equipment instruction manual sections or consult with your instructor before applying power or connecting unfamiliar equipment or instruments into any circuits.

6. Position all equipment on benches in a safe and stable manner.

7. Do not make circuit connections by hand while circuits are energized. This is especially dangerous with high voltage and current circuits.

8. Do not work alone in the lab if equipment is energized; at least one other person is to be present. You must not work alone after normal business hours.

9. The use of 110 volts, 60 Hz. plug-in cords with open wire or alligator clip ends is hazardous; use them only with the permission and direction of your instructor.

10. For safety reasons, metal cases of instruments and appliances are usually grounded through the third wire ground. Do not consider any departure from the use of the third wire ground. e.g., "cheater plugs", without the instruction and supervision of your instructor. Failure to know whether or not an instrument case is grounded can lead to hazardous circuit conditions.

11. Tag instruments with badly frayed or broken power leads and deliver them to the shop (189E) for repair. Notify your instructor.

12. Do not bring food or beverages near the work areas in the labs.

13. Do not attempt chemical or electro-chemical experiments or activities, e.g., printed circuit board etching, without proper supervision, or in areas other than those designated for that purpose.

14. When using equipment utilizing more than 10,000 volts, e.g., color television circuits; take precautions to guard against radiation, primarily x-rays.

15. Remove metal rings and metal watchbands when working around energized, especially high voltage and current, circuits.

16. Treat high voltages with care to avoid endangering your life or the lives of your lab

LABORATORY POLICIES AND REPORT FORMAT:

1. Lab reports should be submitted on A4 paper. Your report is a professional presentation of your Work in the lab. Neatness, organization, and completeness will be rewarded. Points will be deducted for any part that is not clear.

2. The lab reports will be written individually. Please use the following format for your lab reports.
a. Cover Page: Include your name, Subject Code, Subject title, Name of the university.
b. Evaluation Sheet: Gives your internal mark split –up.
c. Index Sheet: Includes the name of all the experiments.
d. Experiment documentation: It includes experiment name, date, objective, circuit diagram, simulated circuit and verified outputs.
e. Prelab and Postlab question should be retyped in the end of every cycle.

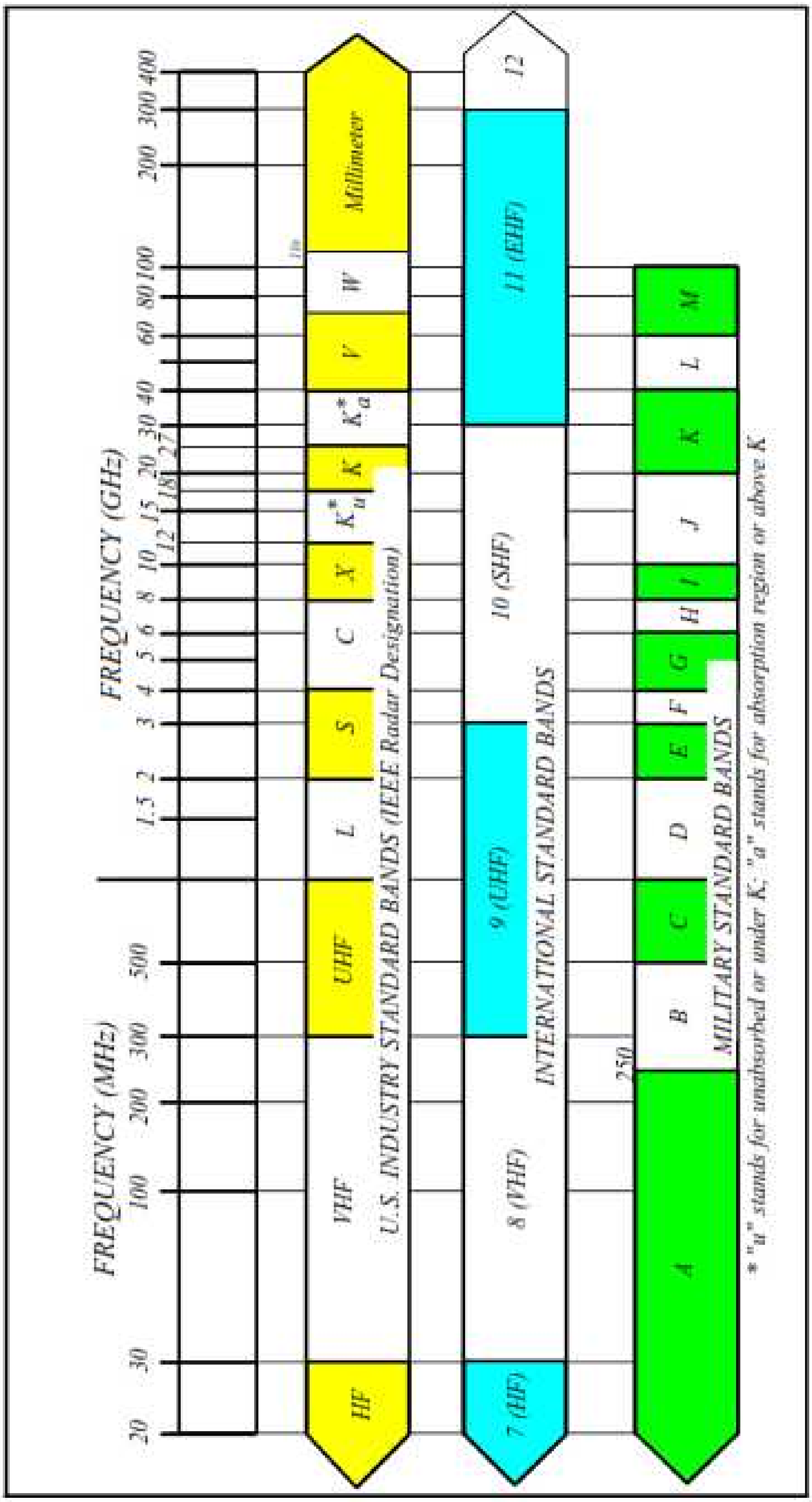
3. Your work must be original and prepared independently. However, if you need any guidance or have any questions or problems, please do not hesitate to approach your staff in charge during working hours. The students should follow the dress code in the Lab session.

4. Reports Due Dates: Reports should be submitted at the end of each cycle. A late lab report will have 20% of the points deducted for being one day late. If a report is 3 days late, a grade of 0 will be assigned.

5. Systems of Tests: Regular laboratory class work over the full semester will carry a weightage of 40%. The remaining 60% weightage will be given by conducting an end semester practical Examination for every individual student. Prelab test is conducted at the beginning of each cycle as a viva-voce and the post lab test is conducted as written test during the permission of report.

Experiments in
Microwave Engineering

The Microwave Spectrum



Frequency Band Designations

STUDY OF MICROWAVE COMPONENTS

AIM

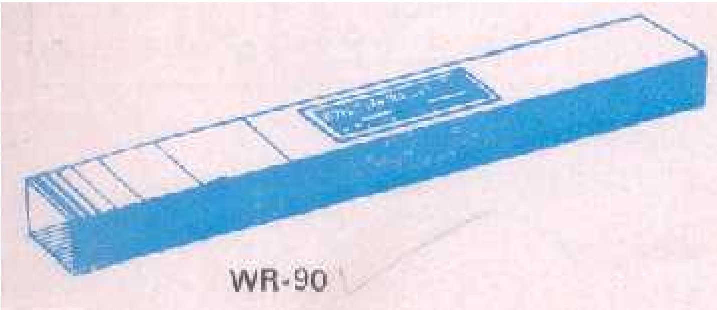
To study the microwave components in detail.

RECTANGULAR WAVE GUIDE

Wave guides are manufactured to the highest mechanical and electrical standards and mechanical tolerances.

L and S band wave guides are fabricated by precision brazing of brass-plates and all other wave guides are in extrusion quality.

W.G. sections of specified length can be supplied with flanges, painted outside and silver or gold plated in side.



SPECIFICATIONS X Band

EIA No. : WR - 90

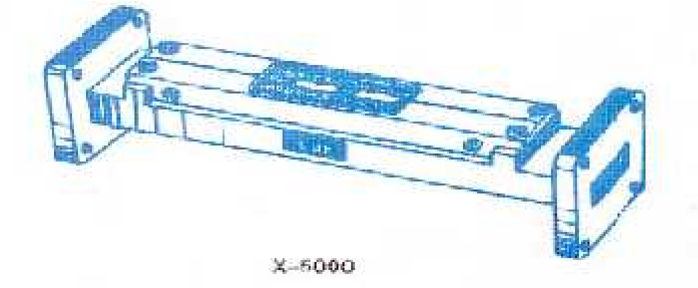
Frequency : 8.2 - 12.4 GHZ

Width : 2.286cm Height : 1.1016cm Width : 2.54 cm

Height : 1.27cm ± Tol. (μm) : 7.6 Material : Brass/Copper.

FIXED ATTENUATORS

Series 5000 fixed Attenuators are meant for inserting a known attenuation in a wave guide system. These consist of a lossy vane inserted in a section of wave guide, flanged on both ends. These are useful for isolation of wave guide circuits, padding and extending the range of measuring equipments.



Fixed Attenuators are available for 3,6 or 10 dB attenuation values, but any attenuation valve between 0 and 30dB can be provided.

SPECIFICATIONS

Model No: X-5000 /Frequency : 8.12 - 12.4 GHZ /Attenuation (dB) : 3,6,10/Callibration Accuracy : ± 0.2dB/Avg Power : 2W/Max VSWR : 1.10/Max Insertion Loss (dB) : 0.2/W.G. Type: WG – 90/Flange Type (UG/U) : 39.

A precision built probe carriage has a centimeter scale with a vernier reading of 0.1mm least count and a dial gauge can be mounted easily if precise readings are required.

Model No. : X - 6051

Freq (Ghz) : 8.2 - 12.4

Max Residual VSWR : 1.01

WG type (WR-) : 90

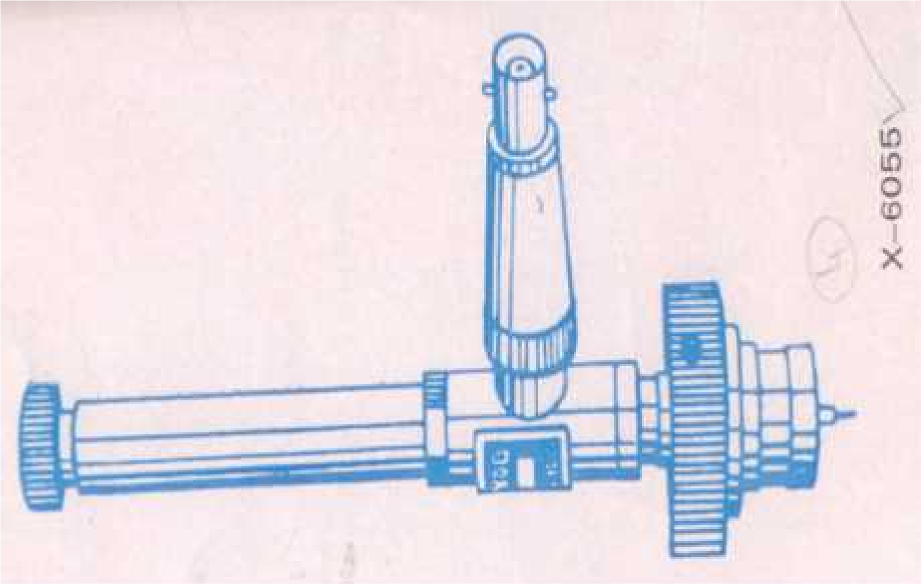
Flange Type (UG-/U) : 39

TUNABLE PROBE

Model 6055 Tunable probe is designed for use with model 6051 slotted sections. These are meant for exploring the energy of the EF in a suitably fabricated section of wave guide.

The depth of penetration into a wave guide - section is adjustable by the knob of the probe. The tip pick up the RF power from the line and this power is rectified by crystal detector, which is then fed to the VSWR meter or indicating instrument.

/Model No. : X6055 /Freq (Ghz) : 8.2 - 12.4 /output Connector : BNC(F) /Detector : IN23.



WAVE GUIDE DETECTOR MOUNT (TUNABLE)

Model 4051 Tunable Detector Mount is simple and easy to use instrument for detecting microwave power thro'a suitable detector. It consists of a detector crystal mounted in a section of a Wave guide and shorting plunger for matching purpose. The output from the crystal may be fed to an indicating instrument. In K and R bands detector mounts the plunger is driven by a micrometer.

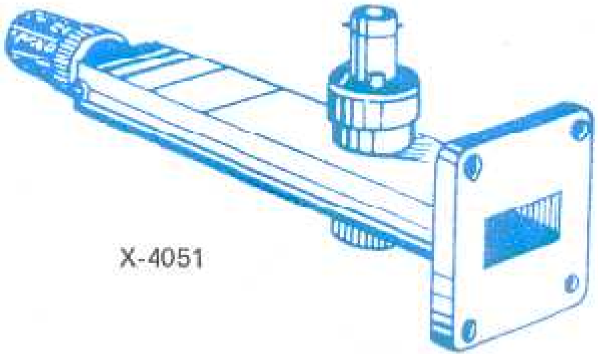
Model No. : X - 4051

Freq. Range (Ghz) : 8.2 - 12.4

O/P Connector : BNC (F)

Wave guide type (WR-) : 90

Flange Type (UG/U) : 39



Detector : IN23

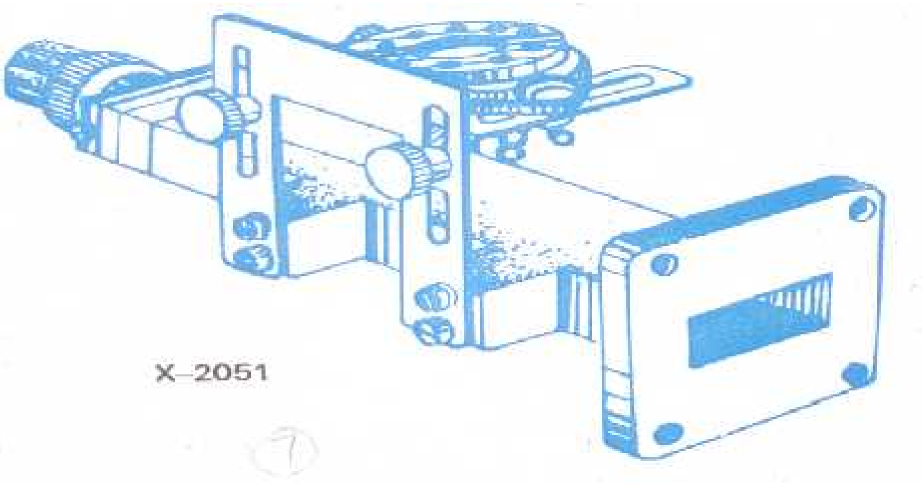
KLYSTRON MOUNT

Model 2051 Klystron mounts are meant for mounting corresponding Klystrons such as 2K25, 723A/B, 726A or RK - 5976 etc.

These consists of a section of wave guide flanged on one end and terminated with a movable short on the other end. An octal base with cable is provided for Klystron.

Model No. : X – 2051/ Freq. Range (GHz) 8.2 - 12.4/ WG Type (WR-) : 90

Flange Type (UG-/U): 39



CIRCULATORS

Model 6021 and 6022 are T and Y types of three port circulators respectively. These are precisely machined and assembled to get the desired specifications. Circulators are matched three port devices and these are meant for allowing Microwave energy to flow in clockwise direction with negligible loss but almost no transmission in the anti-clockwise direction.

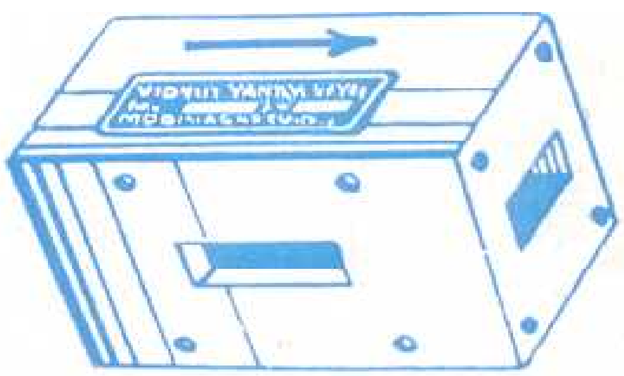
Model No. : X - 6021

Frequency Range (Ghz) : 8.6 - 10.6 or 10.2 - 12.2

Min. Isolation (dB) : 20

Max. Insertion Loss (dB) : 0.4

Max. VSWR : 1.20



X-6021

X-6022

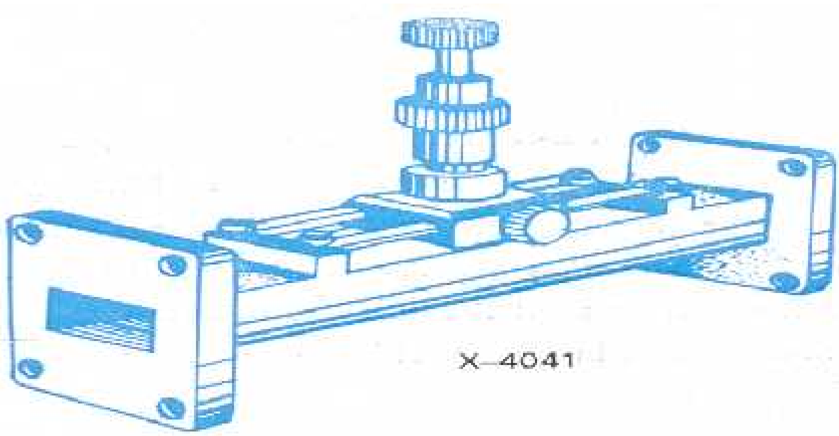
SLIDE SCREW TUNERS

Model 4041 slide screw tuners are used for matching purposes by changing the penetration and position of a screw in the slot provided in the centre of the wave guide.

These consists of a section of wave guide flanged on both ends and a thin slot is provided in the broad wall of the Wave guide. A carriage carrying the screw, is provided over the slot. A VSWR upto 20 can be tuned to a value less than 1.02 at certain frequency.

Model No. : X – 4041/ Freq. Range (Ghz) : 8.2 - 12.4/WG Type (WR-) : 90

Flange type (UG/U) : 39



X–4041

MULTIHOLE DIRECTIONAL COUPLERS

Model 6000 series Multihole directional couplers are useful for sampling a part of Microwave energy for monitoring purposes and for measuring reflections and impedance. These consists of a section of Wave guide with addition of a second parallel section of wave guide thus making it a four port network. However the fourth port is terminated with a matched load. These two parallel sections are coupled to each other through many holes, almost to give uniform coupling; minimum frequency sensitivity and high directivity. These are available in 3,6,10,20 and 40dB coupling.

Model No. : X - 6003

Frequency Range (Ghz) : 8.2 - 12.4

Coupling (dB) : 3,10,20,40

Directivity (dB) : 35

Wave guide type (WR-) : 90

Flange type (UG/U) : 39

E PLANE TEE

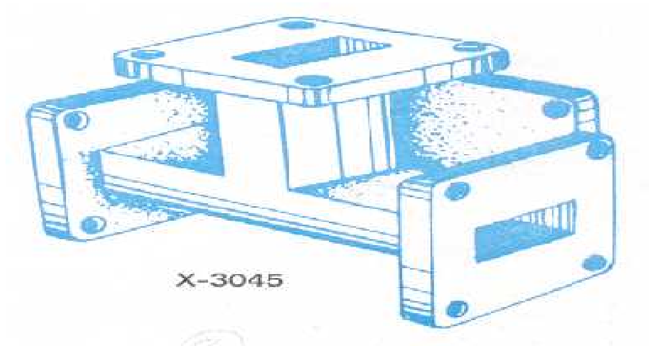
Model 3061 E - plane tee are series type T - junction and consists of three section of wave guide joined together in order to divide or compare power levels. The signal entering the first port of this T - junction will be equally dividing at second and third ports of the same magnitude but in opp. phase

Model No. : X - 3061

Frequency Range (Ghz) : 8.2 - 12.4

WG Type (WR-) : 90

Flange Type (UG/U) : 39



E PLANE TEE

H - PLANT TEE

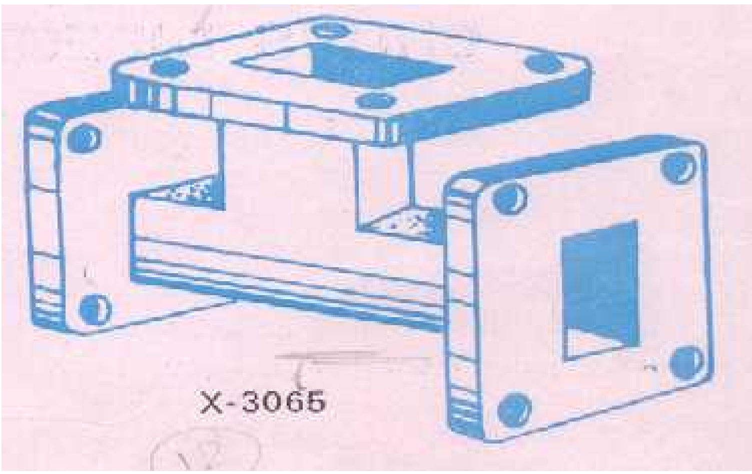
Model 3065 H - Plane Tee are shunt type T - junction for use in conjunction with VSWR meters, frequency - meters and other detector devices. Like in E-plane tee, the signal fed through first port of H - plane Tee will be equally divided in magnitude at second and third ports but in same phase.

Model No. : X - 3065

Frequency Range (GHz) : 8.2 - 12.4

WG Type (WR-) : 90

Flange Type (UG-/U) : 39



MAGIC TEE

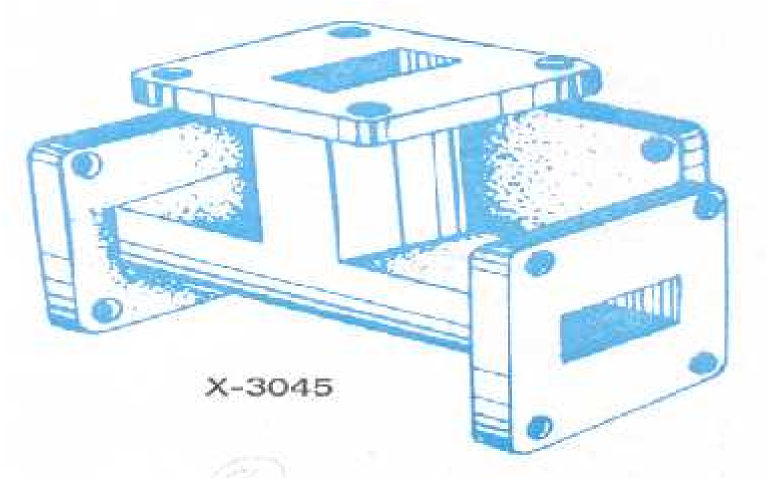
Model 3045 E - H Tee consists of a section of wave guide in both series and shunt wave guide arms, mounted at the exact midpoint of main arm. Both ends of the section of wave guide and both arms are flanged on their ends. These Tees are employed in balanced mixers, AFC circuits and impedance measurement circuits etc. This becomes a four terminal device where one terminal is isolated from the input terminal.

Model No. : X - 3045

Frequency Range (Ghz) : 8.2 - 12.4

WG Type (WR-) : 90

Flange Type (UR-/U) : 39



MOVABLE SHORT

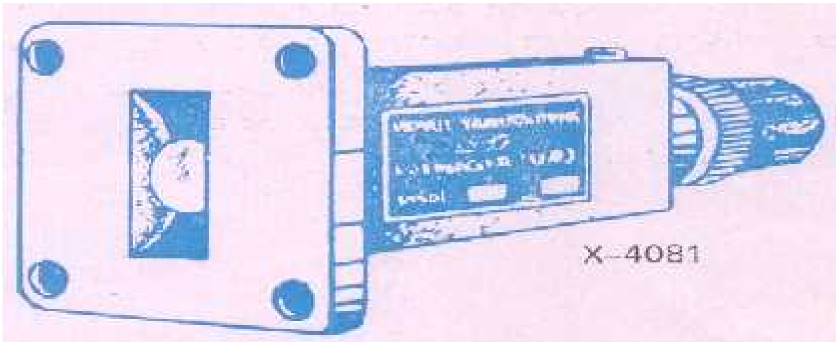
Model 4081 movable shorts consists of a section of waveguide, flanged on one end and terminated with a movable shorting plunger on the other end. By means of this noncontacting type plunger, a reflection co-efficient of almost unity may be obtained.

Model No. : X - 4081

Frequency Range (GHz) : 8.2 - 12.4

WG Type (WR-) : 90

Flange Type (UG-/U) : 39

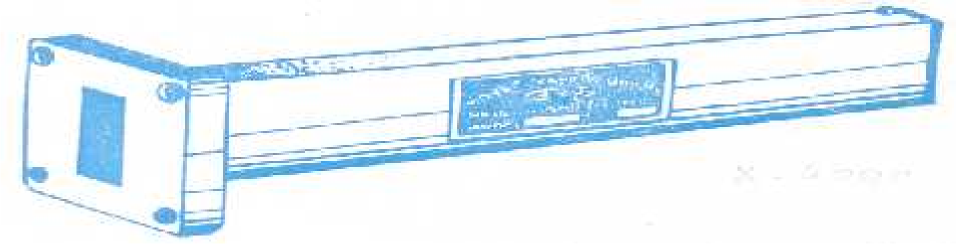


MATCHED TERMINATION

Model 4000 are low power and non-reflective type of terminations. It consists of a small and highly dissapative taper flap mounted inside the centre of a section of wave guide. Matched Terminations are useful for USWR measurement of various waveguide components. These are also employed as dummy and as a precise reference loads with Tee junctions, directional couplers and other similar dividing devices.

Model No. : X - 4000, Freq. Range (Ghz) : 8.2 - 12.4 Max VSWR : 1.04

AV Power : 2W, WG Type (WR-) 90, Flange Type (UG-/U) : 39



PYRAMIDAL WAVEGUIDE HORN ANTENNA

Model 5041 pyramidal Wave guide Horn antenna consists of waveguide joined to pyramidal section fabricated from brass sheet. The pyramidal section shapes the energy to concentrate in a specified beam. Wave guide horns are used as feed horns as radiators for reflectors and lenses and as a pickup antenna for receiving microwave power.

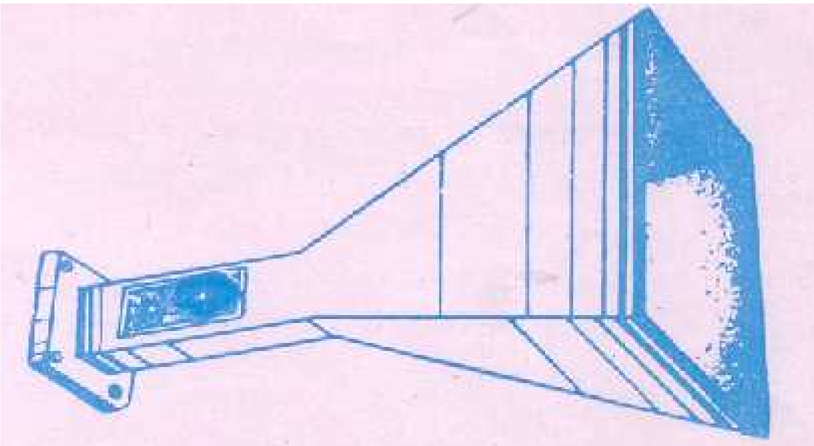
Model No. : X - 5041

Frequency Range (Ghz) : 8.2 - 12.4

Max VSWR : 1.20

WG Type (WR-) : 90

Flange Type (UG-/U) : 39

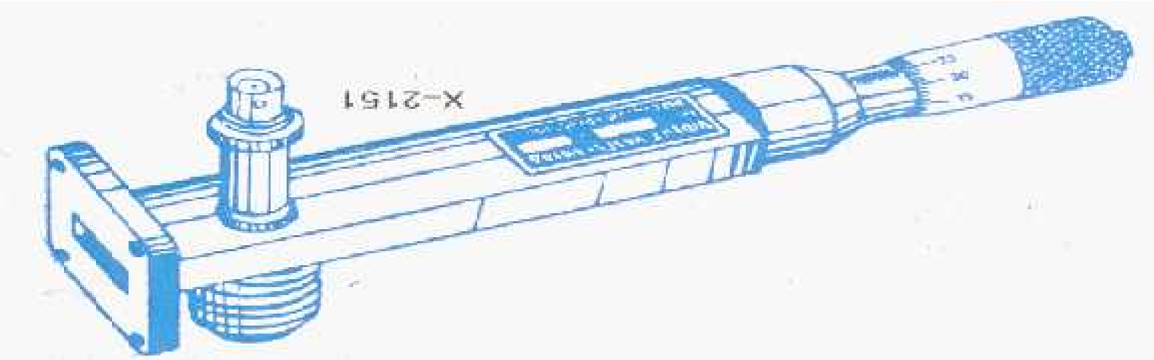


GUNN OSCILLATORS

Model 2151 Gunn Oscillators are solid state microwave energy generators. These consists of waveguide cavity flanged on one end and micrometer driven plunger fitted on the other end. A gunn-diode is mounted inside the Wave guide with BNC (F) connector for DC bias. Each Gunn osciallator is supplied with calibration certificate giving frequency vs micrometer reading.

Model No. : X - 2152, Freq : 8.2 - 12.4 Ghz, Min output power : 10 MW

WG Type (WR-) : 90 Flange Type (UG-/U) : 39



PIN MODULATORS

Model 451 pin modulators are designed to modulate the cw output of Gunn Oscillators. It is operated by the square pulses derived from the UHF(F) connector of the Gunn power supply. These consists of a pin diode mounted inside a section of Wave guide flanged on it's both end. A fixed attenuation vane is mounted inside at the input to protect the oscillator.

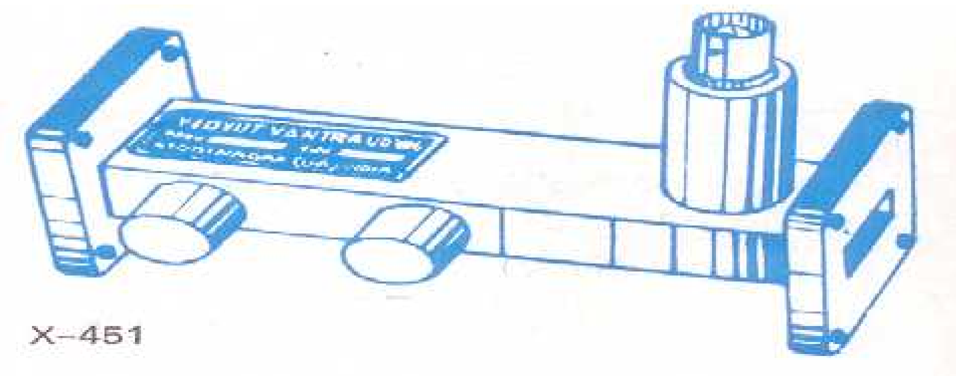
Model No. : X - 451

Frequency Range (Ghz) : 8.3 - 12.4

Max RF Power : 1W

WG Type (WR-) : 90

Flange Type (GHz) : 39



GUNN POWER SUPPLY

Model X-110 Gunn Power supply comprises of an regulated DC power supply and a square wave generator, designed to operate Gunn-Oscillator model 2151 or 2152, and pin modulators model 451 respectively. The DC voltage is variable from 0 - 10V. The front panel meter monitors the gunn voltage and the current drawn by the Gunn diode. The square wave of generator is variable from 0 - 10V. in amplitude and 900 - 1100 Hz in frequency. The power supply has been so designed to protect Gunn diode from reverse voltage application over transient and low frequency oscillations by the negative resistance of the Gunn-diode.

SPECIFICATIONS

Amplifier Type : High gain tuned at one frequency

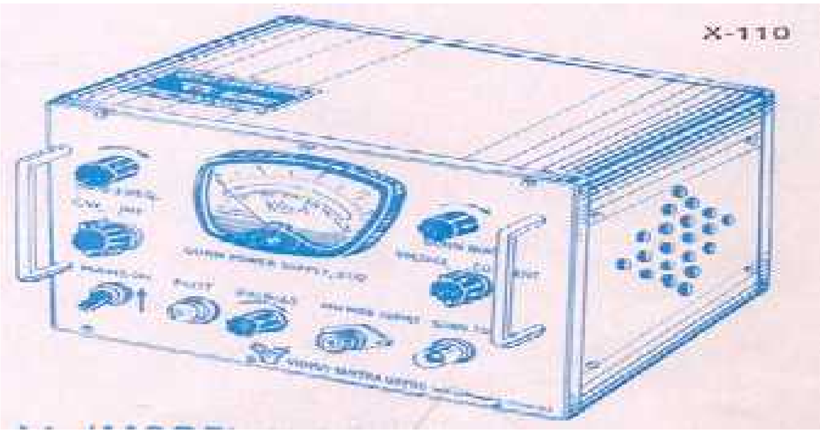
Frequency : 1000 Hz ± 2%

Sensitivity : 0.1 microvolt at 200 for full scale

Band width : 25 - 30 cps

Range : 70dB min in 10 dB steps

Scale selector : Normal Expand Mains power : 230V, 50Hz



ISOLATORS

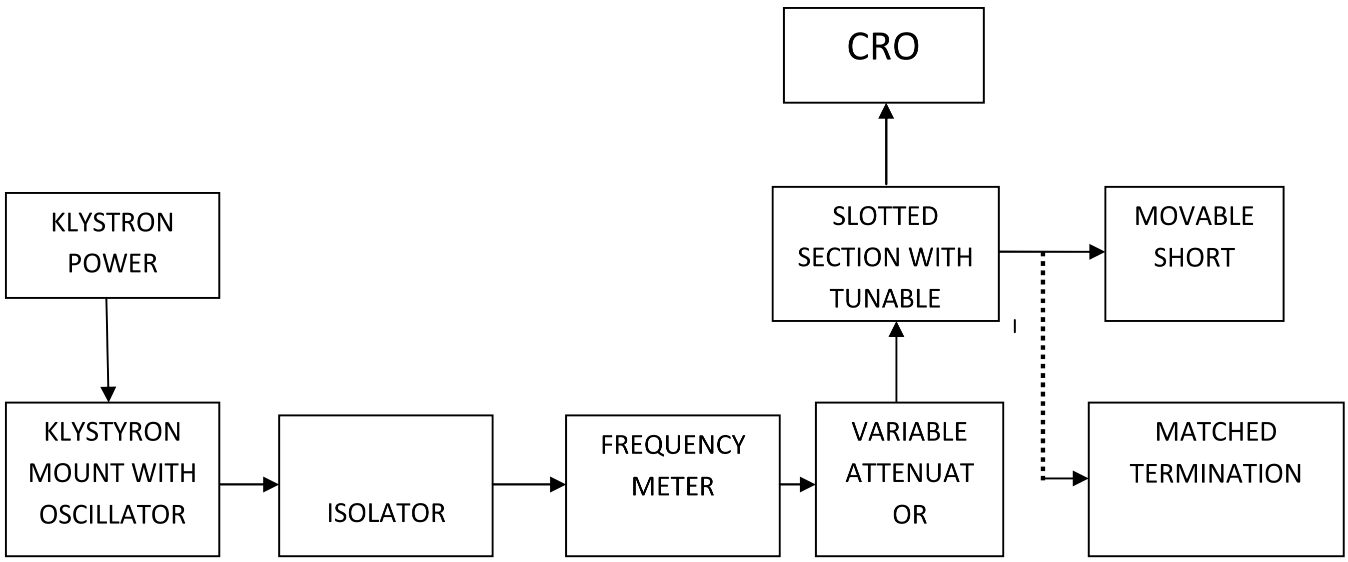
The three port circulators Model 6021 may be converted into isolators by terminating one of its port into matched load. these will work over the frequency range of circulators. These are well matched devices offering low forward insertion loss and high reverse isolation.
Model No. : X - 6022
Frequency Range (GHz) : 8.6 - 10.6 or 10.2 - 12.2
Min Isolation (dB) : 20
Max Insertion Loss (dB) : 0.4
Max VSWR : 1.20

X-6021

RESULT

Thus all the microwave components were studied in detail.

BLOCK DIAGRAM



OBSERVATION

LEAST COUNT = .01cm (Slotted line)

LEAST COUNT = .01mm (freq micrometer & attenuator)

CALCULATIONS

λ_g is calculated from slotted section line $\lambda_g/2 = (d_1 - d_2)$

a = dimension of the waveguide = 22.86mm

$\lambda_0 = 1/[(1/\lambda_g)^2 + /((1/\lambda_o)^2]^{1/2}$

$c = 3 \times 10^8$ m/s

$c = f/\lambda_0$

MESUREMENT OF FREQUENCY AND WAVELENGTH

Ex.No.1

Date:

AIM

To determine the frequency and wavelength in a rectangular waveguide working on TE_{10} model

APPARATUS REQUIRED

Klystron power supply, Reflex klystron isolator, frequency meter, variable attenuator, slotted section, VSWR meter, detector mount & CRO.

THEORY

For dominant TE_{10} mode in rectangular waveguide λ_0, λ_g, λ_C are related as below.

$$\lambda_0 = 1/[(1/\lambda_g)^2 + /((1/\lambda_o)^2]^{1/2}$$

λ_0 = Free space wavelength

λ_g = guide wavelength

λ_c = cut off wavelength

For TE_{10} mode c = 2xa where a is the broad dimension of waveguide. The following relationship can be proved.

$$c = f/\lambda_0$$

c = velocity of light f = frequency

FINAL OBSERVATION

Micrometer Reading	$\lambda_g/2$	$1/\lambda_0$	**$f = c/\lambda_0$**

PROCEDURE

1. Set up the variable components and requirements
2. Setup variable attenuation at minimum attenuation

3 Keep the control knobs of VSWR meter as shown in figure

Input switch - crystal load impedance

Meter switch – normal position

Gain – mid position

4. Keep the control knob of a klystron power supply

Beam voltage - off

Mode switch - AM

Beam voltage knob – fully anti clockwise

Reflector voltage knob – fully clock wise AM

amplitude knob – fully clock wise AM frequency knob – mid position

5. Switch on the klystron power supply, VSWR meter and cooling fan switch.
6. Switch on the beam voltage switch and set beam voltage at 300v with the help of beam voltage knob.
7. Adjust the reflector voltage to get some reflector in VSWR meter
8. Maximize the deflection with an amplitude and frequency control knobs in power supply

9. Tune the reflector voltage knob for maximum deflection
10. Tune the probe for maximum deflection in VSWR
11. Tune the frequency meter knob to get dip on the VSWR scale and down the frequency directly from the frequency meter.
12. Replace the termination with movable short and return the frequency
13. Move the probe along the slotted line the deflection in VSWR meter will vary the probe to a maximum deflection position to get accurate reading
14. Calculate the guide wavelength on twice the distance between two successive minimum position obtained as above.
15. Measure the waveguide on twice inner broadband dimensions “a” which will be around 22.86mm for x band.
16. Calculate the guide wavelength on twice the distance between two successive minimum position obtained as above
17. Verify the frequency obtained by frequency meter and above experiment can be verified at Different frequencies f is calculated and the result is verified from the given table with the Corresponding micrometer reading taken from frequency meter.

RESULT

Thus waveguide wavelength and frequency was determined for the given microwave setup and values obtained are

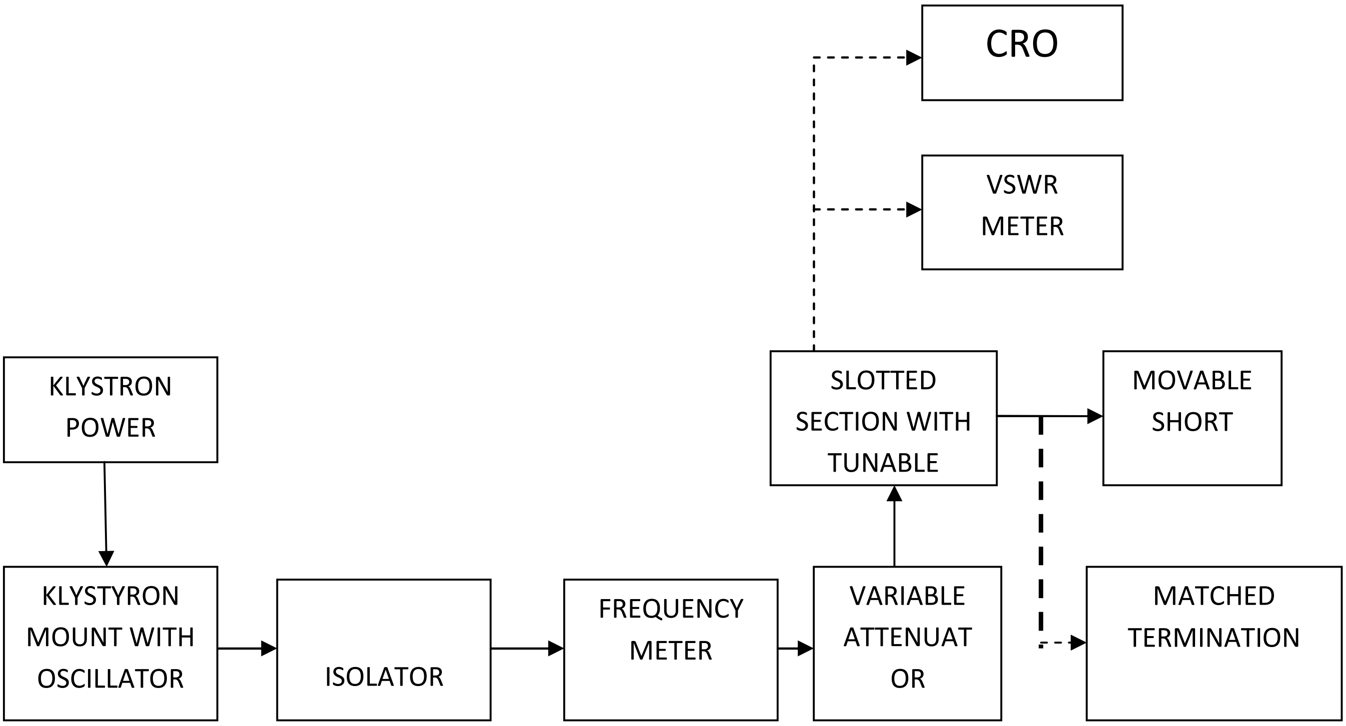
a) Frequency from the meter f_m(in GHz):

b) Observed frequency f_O(in GHz)::

c) Wavelength λ_g(in cm):

d) Wavelength λ_o(in cm):

BLOCK DIAGRAM FOR STANDING WAVE RATIO AND REFLECTION COEFFICIENT



MEASUREMENT OF STANDING WAVE RATIO AND REFLECTION COEFFICIENT

Ex.No.2

Date:

AIM:

To Determine the Standing wave ratio(S) and Reflection coefficient (K) for the given Matched load, Movable Short & Horn Antenna.

APPARATUS REQUIRED:

Klystron Power Supply, Klystron Tube , Klystron Mount, Isolator , Frequency Meter , Variable Attenuator , Slotted line , Tunable probe , Detector Mount, Wave Guide Stand , VSWR Meter , Movable short/ Termination . Slotted line with probe , Wave guide stand, Cables & Accessories.

PROCEDURE:

1. Set up the equipment as shown in the figure.
2. Keep the variable attenuator in the minimum attenuation position.
3. Keep the control knobs of VSWR as below:
Range db - 40db/50 db Input Switch - Low Impedance Meter Switch - Normal Gain (Coarse- Fine) - Mid position approx.
4. Keep the control knobs of the Klystron power supply as below:
Beam voltage - OFF Mod-switch - AM Beam voltage knob - Fully anticlockwise direction
Reflector Voltage knob - Fully clockwise direction AM-amplitude knob - Around fully clockwise
AM-frequency & amplitude knob - Mid position
5. Switch „ON‟ the Klystron Power Supply, VSWR Meter and cooling fan.
6. Switch „ON‟ the Beam voltage switch position and set beam voltage at 300V.
7. Rotate the reflector 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 the plunger of Klystron Mount and probe for maximum deflection in VSWR meter.
10. If required, change the range db-switch variable attenuator position 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

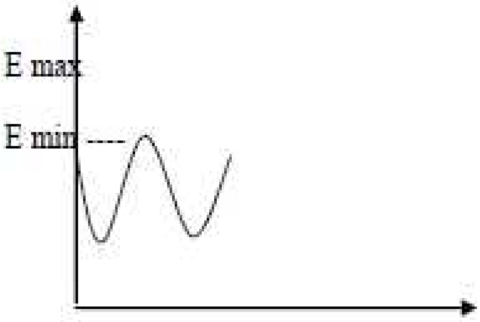


Fig.4.2(a)Standing wave

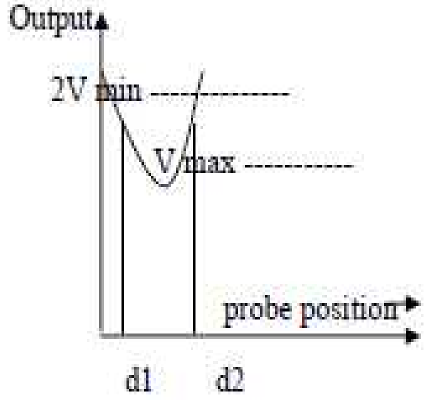


Fig.4.2(b)Double minima method

Calculations:

d 1 =_____cm

d 2 =___cm

λ g= 2(d1 – d2)

Low and medium VSWR= S =______

Reflection coefficient (for low VSWR) = S-1/S+1

High VSWR:

d 3 =_______cm

d 4 =_____cm

High VSWR= S =______

Reflection coefficient (for high VSWR) = S -1/S +1

Reflection coefficient (for low VSWR) =S-1/S+1

MEASUREMENT OF LOW AND MEDIUM VSWR:

1. Move the probe along the slotted line to get maximum deflection in VSWR Meter.
2. Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates 1.0ʻʻ on normal VSWR scale.
3. Keep all the control knobs as it is, move the probe to next minimum position. Read the VSWR on scale.
4. Repeat the above step for change of S.S. tuner probe depth and record the corresponding SWR.
5. If the VSWR is between 3.2 and 10, change the range db switch to next higher position and read the VSWR on second scale of 3 to 10.

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 and variable attenuator to obtain a reading og 3 db in the normal db scale (0 to 10 db) of VSWR Meter.
4. Move the probe to left on slotted line until full scale deflection is obtained on 0-10 db scale. Note and record the probe position on slotted line let it be d1.
5. Repeat the step 3 and then move the probe right along the slotted line until full scale deflection is obtained on 0-10 db normal db scale. Let it be d2.
6. Replace the S>S. tuner and termination by movable short.
7. Measure the distance between two successive minima positions of the probe. Twice this distance is guide wavelength λg.
8. Compute SWR from the following equation:

$$SWR=\lambda g/\pi(d_1-d_2)$$

TABULATION

S.No	Type of load	Using C.R.O		S= $(V_{max}/V_{min})^{1/2}$	S (using meter)	K = S-1/S+1
		V_{max}	V_{min}			
1.	Movable Short (High VSWR)					
2.	Matched Termination (Low VSWR)					
3.	Horn antenna (Low VSWR)					

RESULT:

Thus the Standing wave ratio(S) and Reflection coefficient (K) for the given Matched load, Movable Short & Horn Antenna was found to be as

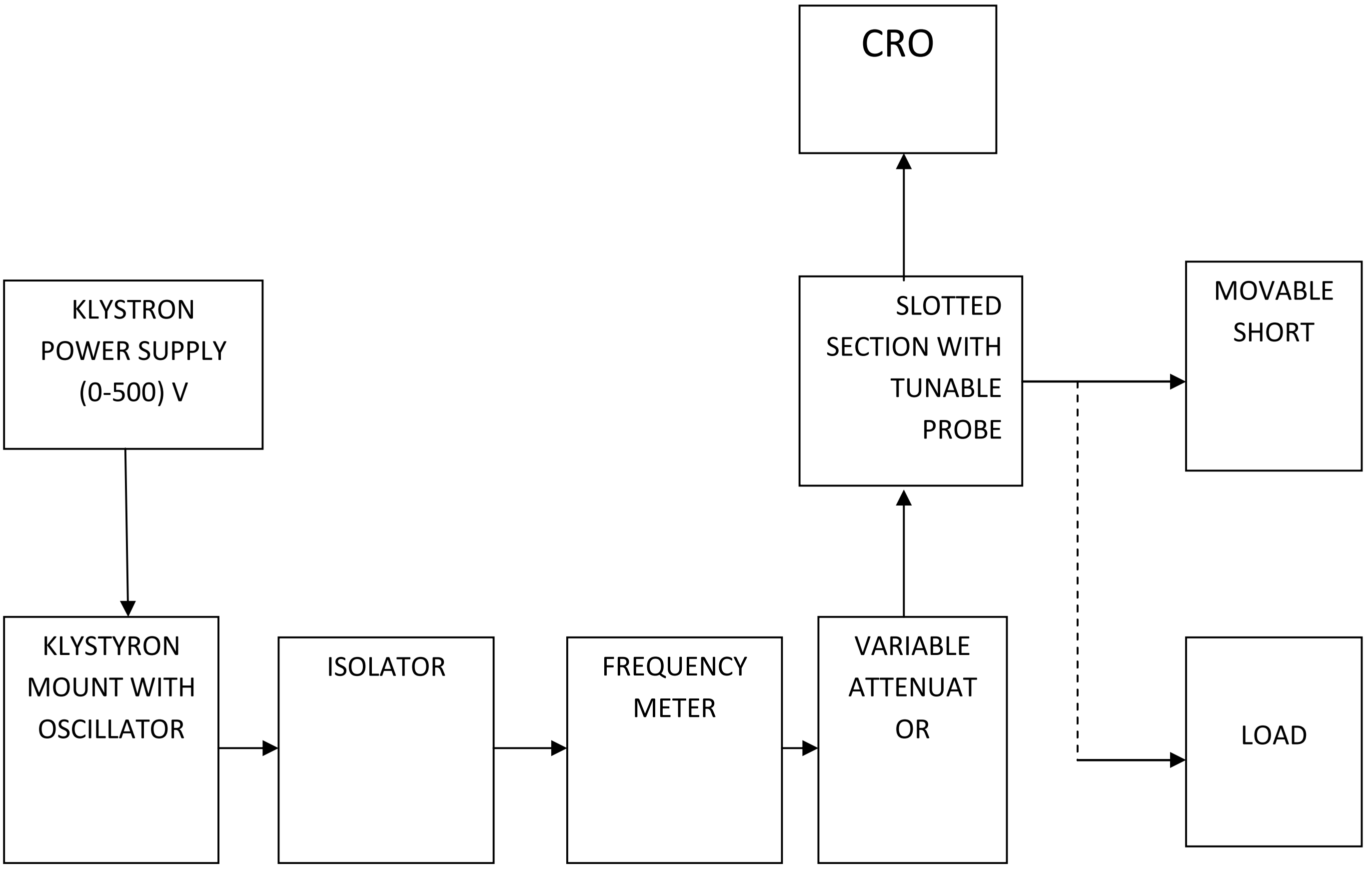
a) High VSWR:

b) Low VSWR:

c) Reflection coefficient (for High VSWR):

d) Reflection coefficient (for Low VSWR):

BLOCK DIAGRAM FOR IMPEDANCE MEASUREMENT



IMPEDANCE MEASUREMENT

Ex.No.3

Date

AIM:
Determine the Unknown Impedance of the given Matched load, Movable Short & Horn Antenna using Smith Chart and Slotted Line method.

APPARATUS REQUIRED:
Klystron Power Supply. Klystron Oscillator with mount. CRO .Frequency Meter. Isolator. Variable Attenuator. Wave guide detector with probe , Load S.S. tuner, matched load ,movable short, Hom Antenna , Slotted line with probe ,Wave guide stand, Cables & Accessories.

THEORY:
Since Impedance is a complex quantity, both amplitude and phase of the test signals are required to be measured.

Slotted line method:
The complex impedance ZL of a load can be measured by measuring the phase angle ϕ_L of the complex reflection coefficient KL from the distance of first voltage standing wave minimum d_{min} and the magnitude of the same from the VSWR(S).

Load impedance $Z_L = Z_0 \times [(1+K_L)/(1-K_L)]$

Normalized impedance $Z_L' = Z_L / Z_0 = (1- jS_L \tan(\beta\Delta l))/(S_L - j\tan(\beta\Delta l))$

Reflection co-efficient $K_L = I\ K_L\ I\ e^{(j\phi L)}$

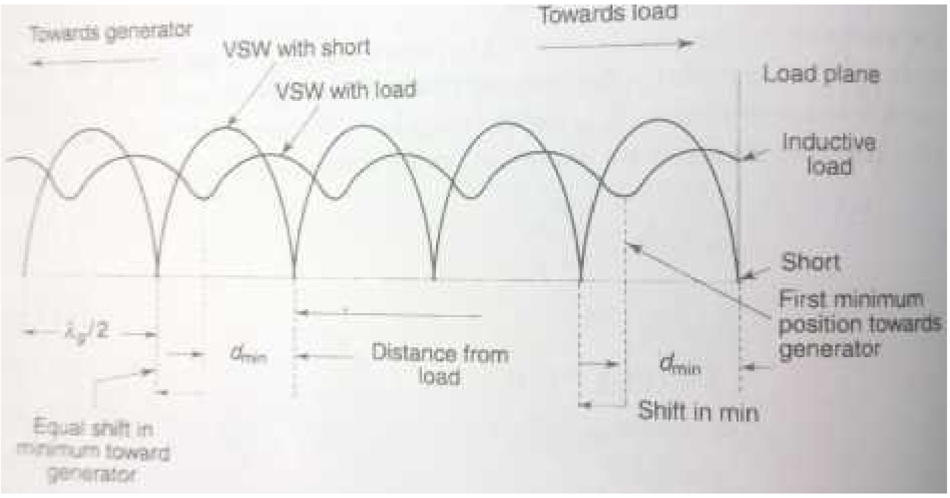
Where $I\ K_L\ I = (S_L - 1)/(S_L + 1)$

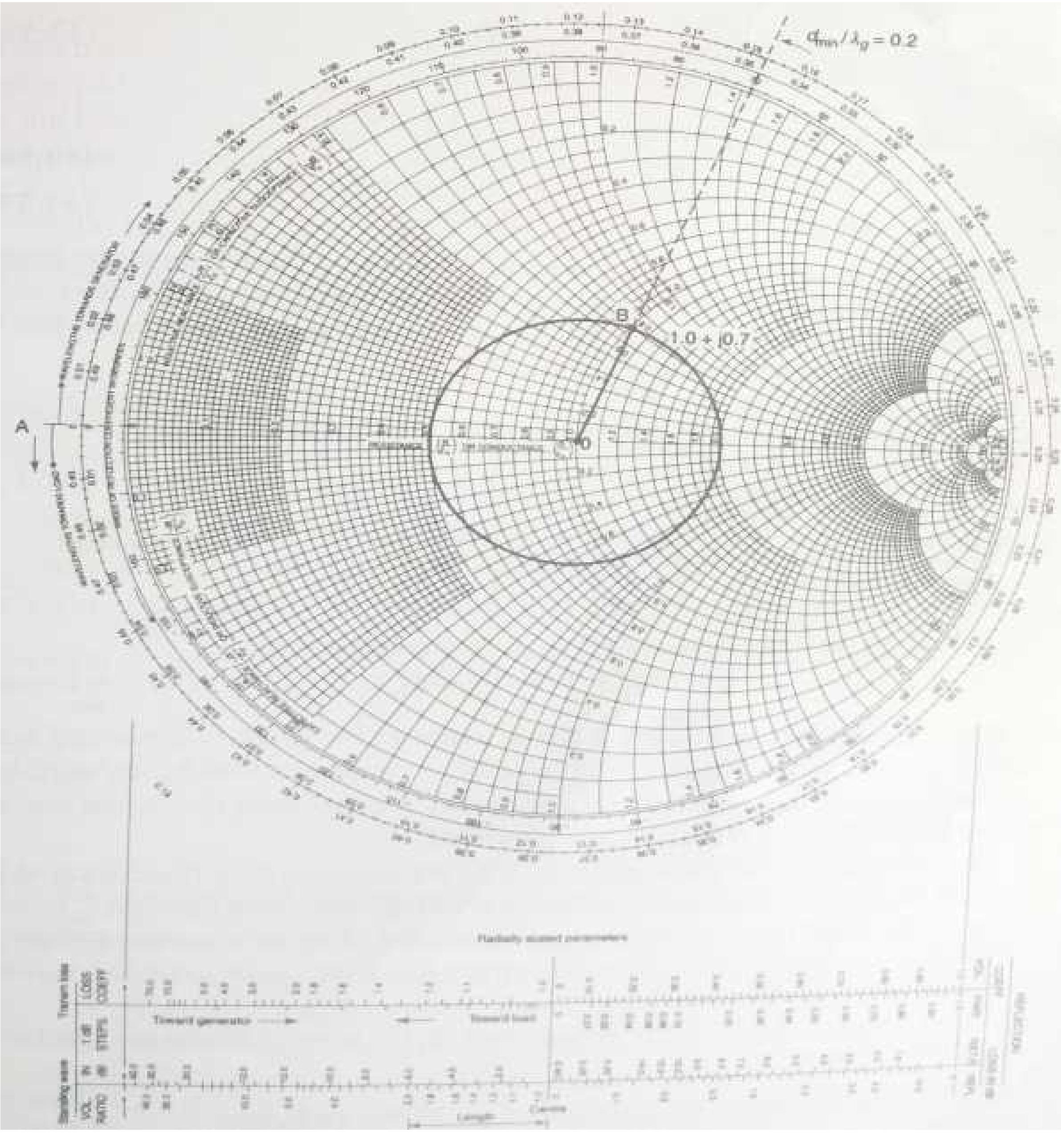
$\phi_L = 2\beta d_{minshift} - \pi$

$\beta = 2\pi/\lambda g$

$\lambda g = 2d = 2(d_{mzsc1} - d_{mzsc2})$

$\Delta l = d_{minshift} / \lambda g$


Towards generator
Towards load
VSW with short
VSW with load
Load plane
Inductive load
Short
First minimum position towards generator
$\lambda_g/2$
d_{min}
Distance from load
d_{min}
Shift in min
Equal shift in minimum toward generator


$d_{min}/\lambda_g = 0.2$
B
1.0 + j0.7
A
0
Toward generator
Toward load

The method using slotted line to determine unknown impedance is summarized below:

1. Measure the load VSWR (S_L) to find I KL I

2. Measure the distance d between the two successive voltage minimas to find $\lambda g = 2d$ and $\beta = 2\pi / \lambda g$

3. Measure the distance $d_{minshift}$ of the first voltage minimum from the load plane towards generator.

4. Phase angle ϕ_L of the load is calculated using and K_L.

5.The unknown impedance Z'_L is then calculated using slotted line method (VSWR S_L.]

NOTE:-

Since it may not be possible to reach the first $d_{minshift}$ by the probe dose to the load directly using slotted line an equivalent load reference plane on the slotted line is established by means of a short circuit at load reference plane where a voltage minimum now occurs. Since a series of minima are produced on the slotted line at intervals λg *I* 2, the load reference plane can be shifted to a convenient minimum position near the center of the slotted line. The dmin can then be measured by observing the first minimum from this shifted reference plane when the load replaces the reference short.

Smith Chart:

To ease the calculation, Smith Chart can be used to determine Z from the measurements of SI.and $d_{minshift}$ as follows, where load VSWR SL= 2 and $d_{minshift}$ $\lambda g = 0.2$ say.

I. Draw the VSWR circle centered at 0 (r =1) with radius cutting r <axis at SI.

2. Move anti clockwise from the short circuit load point A on the chart along the wavelengths towards load scale by distance ($\Delta L = d_{minshift} / \Delta g$) to Band joint points 0& B as line OB.:

3. The point of intersection between the line DB and the SL circle gives the normalized load $Z'_L = Z_L / Z_o$ and hence the complex load $Z_L = Z_o \times Z'_L$ Using Smith Chart.

Thus we can measure unknown load impedance Z_L and knowing the shift of minima with respect to short (or open) circuit identifies the nature of load.

Calculations:

WITH LOAD:
V_{max}: V_{min}: d_{mz1}:

WITH MOVABLE SHORT:
d_{mzsc1}: d_{mzsc2}:

load SWR (S_L): V_{max}/V_{min}=

λ_g =2d= 2(d_{mzsc1}-d_{mzsc2}):

$d_{minshift}$ = (d_{mz1}~ d_{mzsc1}):

Calculation of Z_o:

Z_o= Z_o (in free space)/ $((1-\lambda_0/\lambda_c)^2)^{1/2}$

where

Z_o=120Xπ=377Ω

λ_0= $1/\{((1/ \lambda g)^2+1/ \lambda c)^2)^{1/2}\}$:

Now Z_o :

USING SMITH CHART:

$\Delta l = d_{minshift} / \lambda_g$:

From Chart (Point **B** Is):

Normalized impedance $Z_L{}' = Z_L / Z_0$ = R+jX:

$I\ Z_L / Z_0\ I = (R^2+(jx)^2)^{1/2}$:

Z_L =_____X Z_o

USING SLOTTED LINE METHOD:

$\beta = 2\pi / \lambda_g$:

$\Delta l = d_{minshift} / \lambda_g$:

$Z_L{}' = Z_L / Z_0 = (1- jS_L \tan(\beta\Delta l)) / (S_L - j\tan(\beta\Delta l))$:

$I\ Z_L{}' I = I\ Z_L / Z_0\ I = (R^2+(jx)^2)^{1/2}$:

Therefore I Z_L I is

PROCEDURE:

1. Setup the equipment as shown in figure.

2. Set the variable attenuator at minimum position.

3. Keep the control knob of Klystron power supply as below.

    Meter switch - OFF

    Mod switch - AM

    Beam voltage knob - Fully Anti clockwise

    Reflector voltage knob - Fully clockwise

    AM Amplitude - Around Fully clockwise

    AM frequency knob-around mid position"

4. ON the Klystron power supply, CRO and cooling fan.

s. Turn the meter switch of power supply to beam voltage position and set beam voltage at 300V with the help of beam voltage knob.

6. Adjust the repeller voltage to get the output in CRO.

7. Maximize the output with AM amplitude and frequency control knob of power supply.

8. Tune the plunger of Klystron mount for maximum output.

9.Tune the repeller voltage knob for maximum output.

IO.Tune the probe for maximum output in CRO. connect load (s.s.tuner with matched load/horn antenna or open or short

11.Tune the frequency meter knob to get a DIP in CRO and note down the frequency directly from frequency meter.

12. Connect the load (SS tuner, matched load, movable short & Hom antenna. Or matched load) and move the probe along the slotted line to get maximum output and note V_{max}.

13. Move the probe to adjacent minima point and note down V_{min} and calculate the load VSWR (SL) Also note down the probe position, let it be d_{MZL}

14. Make d_{mzsc1} reference under load condition and replace the load by movable short to the slotted line (plunger of short should be at zero). Move the probe towards the movable short until you obtain the minima position again. Record the position dmzsc:

15. The distance between these two readings will be the value of d_{mshift}. Note these two minimas are in front of the load; therefore the distance measured is towards the load.

16. Measure the position a/two successive minima for movable short load. Let it be d_{MZSCI} and $d_{MZS2.}$ Hence λg: =2X (d_{MZSCI}~ d_{MZS2}) = 2d.

17. Calculate ΔL = $d_{MSHIFT/}\lambda_g$

18.Find out the normalized impedance Z'L using Smith Chart as described in theory section.

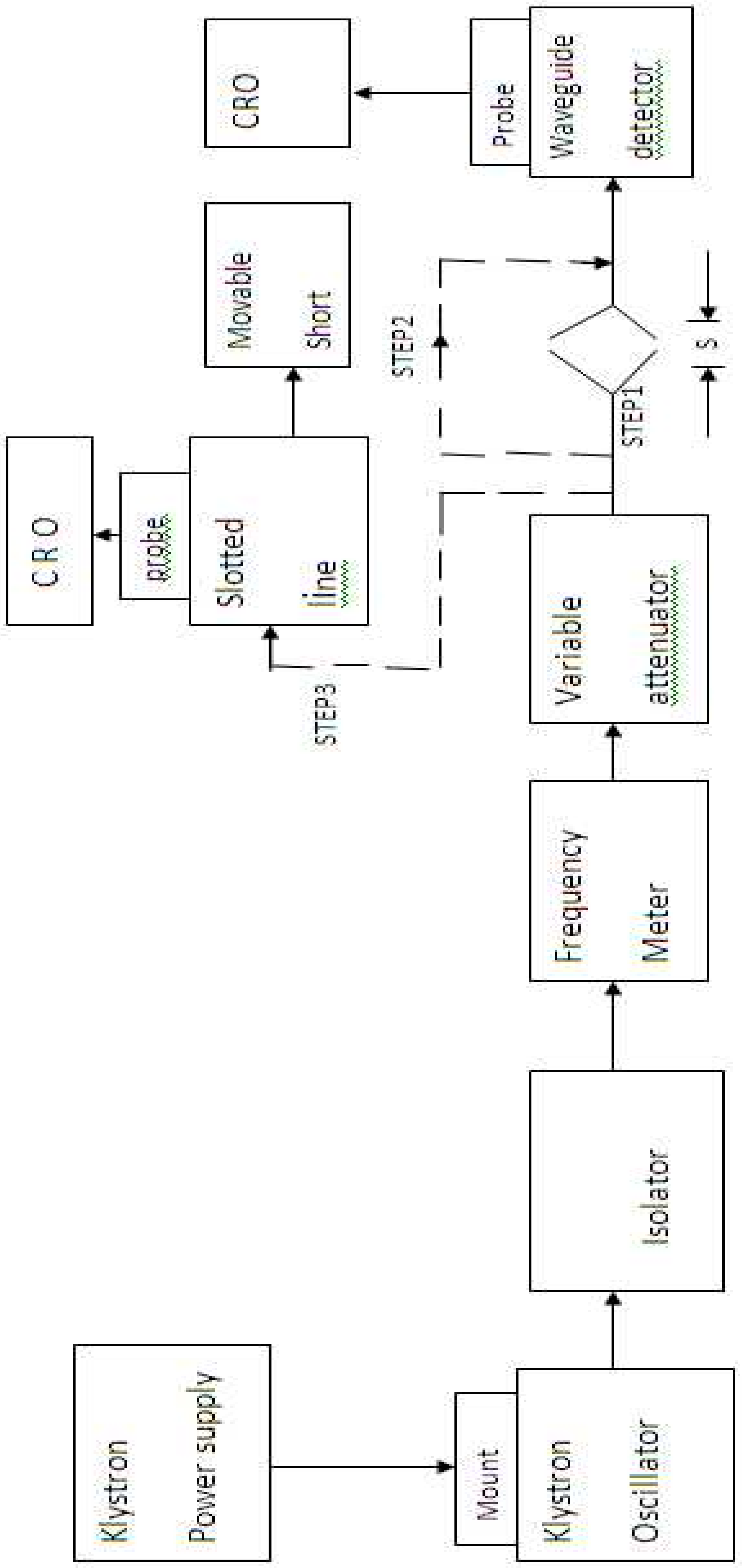
λg

RESULT:

Thus the unknown impedance was measured.

Impedance of load (ZL) using slotted line method:

Impedance of load (ZL) using Smith Chart :


Klystron Power supply
Mount
Klystron Oscillator
Isolator
Frequency Meter
Variable attenuator
STEP1
S
STEP2
STEP3
Probe
Waveguide detector
CRO
Slotted line
probe
C R O
Movable Short

HORN ANTENNA MEASUREMENT

Ex.No.4

Date

AIM:

To Draw the Radiation pattern for Horn Antenna and Find the Half Power Beam-Width, Power Gain and Directivity.

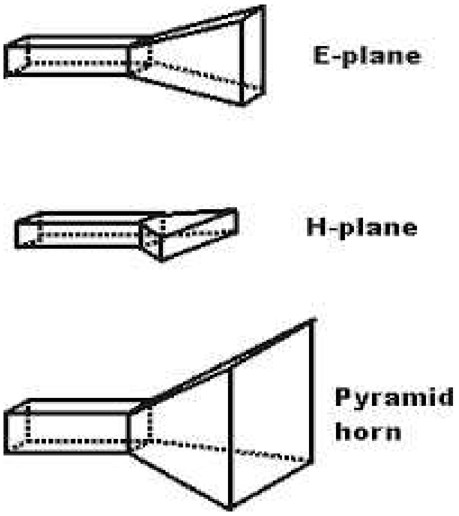
Apparatus required:

Klystron Power Supply. Klystron Oscillator with mount. CRO .Frequency Meter. Isolator.
Variable Attenuator. Wave guide detector with probe , Two Hom Antenna (Txr & Rxr) ,
Slotted line with probe ,Wave guide stand, Cables & Accessories , Tum Table.

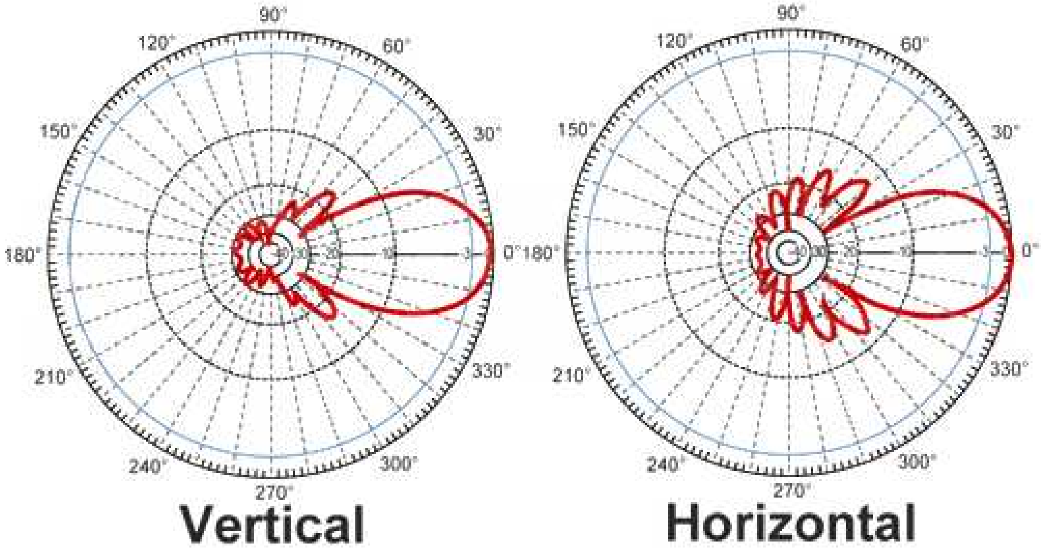
Theory:

A Horn Antenna may be regarded as flared out (or opened out) wave guide. The function of the Horn is to produce a uniform phase front with a larger aperture than that of the wave-guide and hence greater directivity. The transition region of Horn between the wave-guide at the throat and free space and the aperture could be given a gradual exponential taper to minimize reflections of the guided wave. Assuming that the rectangular wave guide is energized with a TEIO mode wave electric field (E in the y direction), the horn is flare out in a plane perpendicular to E. This is the plane of the magnetic field H. Therefore, this type of horn is called sectoral horn flared in the Hplane or simply an H plane sectoral Horn. A rectangular horn with flare in both plane, is called Pyramidal Horn .. Horn Antennas are extensively used at microwave frequencies when the power gain needed is moderate.

RADIATION PATTERN -of an antenna is a graphical representation of the radiated fields or power along different directions in space. When the radiation is expressed as field strength E *V/mj* it is called field strength pattern: lf power per unit solid angle is plotted in 3- D space, it is called power pattern. A power pattern will be the product of electric and magnetic field pattern or proportional to the square of the field strength pattern.



Radiation Pattern



HALE-POWER BEAM BANDWIDTH:

The Half power points are the points in the radiated field pattern, where the field reduces to 1/..J2 times its maximum value (i.e., power becomes *1h).* The angular separation between two half-power field point is called the Half Power Bandwidth. An Antenna pattern consists of several lobes, the main lobe, side lobes and the back lobe. The major power is concentrated in the main lobe and it is normally to keep the power in the side lobes as low as possible. The Power intensity achieved from an imaginary omni directional antenna (radiating equally in all directions) with the same power fed to the antenna is defined as a gin of the antenna.

The Directivity of the antenna: D(e,ϕ) is defined as the ratio of maximum radiation intensity along this particular direction to the average radiation intensity. The Power Gain: G(e, ϕ } is defined as the product of the Directivity and Efficiency of the antenna.

G(Φ, ϕ) = D(e, ϕ)" 11

For accuracy of the measurements care must be taken so that,

1. All Antennas meet the far-field criteria: S2: 2(02) / AO where, D- size of horn aperture; *'~O*-free space wavelength.
2. The Antennas are aligned for bore sight radiation face-to-face.
3. Impedance mismatched in the system components is minimum.
4. Polarization mismatch is minimum.

S. Reflection from various background and support structure is minimum.

A method uses two identical antennas, one as transmitter and other as receiver to calculate Power Gain.

$Pr = Pt\ [\lambda_0^2]\ GIG2\}/\ I(4\pi\ S)^2\}$ where

Pr - Received power; Pt - Transmitted Power; GI, G2- Gain of Transmitting and receiving antennas S is to the radial distance between two antennas and AO -free space wavelength; If both transmitting and receiving antenna are identical having a gain G then,

$$Pr= \{Pt[\lambda_0^2]G^2\}/\{(4\pi\ S)^2\}$$

$$G= (4\pi\ S)x((P_r/P_t)/\ \lambda_0^2)^{1/2}$$

$$= (4\pi\ S)x((V_r/V_t)^2/\ \lambda_0^2)^{1/2}$$

$$G= (4\pi\ S)x((V_r/V_t)/\ \lambda_0)$$

The Directivity of an antenna -can-be determined from the measurements of-its radiation pattern in two principal planes, E and H planes and finding the half power beam widths SE and SH degree in these planes, respectively.

Do = 41,253 *I* (SE . 9H) or 72,815/(e2E + 92H)

This method is accurate for the antennas having negligible side lobes.

Tabular column

Angle (degree)	Output Received Voltage (V_r) (mv)		Relative Power [20 log (VR/VR@()deg)]	
	Clockwise	Anti-Clockwise	Clockwise	Anti-Clockwise

Antenna Polarization pattern

H-Plane (X-direction)

Input voltage(V_t)=

PROCEDURE:

1. Set up the equipments as shown in the schematic diag.,

2. Set the variable attenuator at minimum position for the maximum output.

3. Keep the control knob of Klystron power supply as below.

Meter switch - OFF

Mod switch - AM

Beam voltage knob . - Fully Anti clockwise

Reflector voltage knob - Fully clockwise

AM Amplitude -around Fully clockwise

AM frequency knob-around mid position

4. ON the klystron power supply, CRO and cooling fan.

S. Turn the meter switch of power supply to beam voltage position and set beam voltage at 300Vwith the help of beam voltage knob.

6. Adjust the Repelier voltage to get maximum output in CRO.

7. Maximize the output with AM amplitude and frequency control knob of power

8. Tune the plunger of klystron mount for maximum output.

9. Tune the repeller voltage knob for maximum output.

GAIN MEASUREMENT:

10. Move the probe along with slotted line to minimum (output) position .Note and record the .position (d1).Similarly move the probe to next minima position. and record the probe position (d2)

11. Calculate the guide wavelength λg =2(d1-d2)

12. Measure the waveguide inner broader dimension. 'a' find λc= k-2a.

Calculate. $1/ \lambda c =((1/ \lambda g^2)+1/ \lambda c^2)\}^{1/2}$

13. Remove the slotted line and movable short and connect wave guide detector directly to variable attenuator (without horns), note the output voltage on CRO and this voltage is fixed to some reference (say 10mV) using variable attenuator .Let it be input voltage VT.

14. Now connect transmitter and receiver horns as per setup. with same axis (angle is $0^o$and note down the voltage an CRO. Let it beV_{R0} .

15. Calculate the gain G= 20 log {4715 (VR I VT) / to} in dB.

RADIATION PATTERN MEASUREMENT:-

16. The distance between the two horn antennas should be greater than (Smin=2D2/ λc } and choose

D= 8cm. [don't change any knob in the setup. Turn the receiving horn to the left in terms of 20 or 5^0steps up to 40^0- 90^0 "until output reaches zero and note the corresponding reading [V_R]on CRO.

11. Repeat the above step but this time turn the receiving horn to the right side and note down the readings.

18. Repeat the above steps for E-Plane up and down and note down the readings.

19. Calculate the relative power (P) = 2010g (V_R/V_{Ro}) for the above readings and tabulate the values.

20 Draw a radiative power (polar) pattern i.e. Relative power versus angle on polar pattern graph sheets.

DIRECTIVITY MEASUREMENT:

21. From the polar-pattern, determine 3dB-width (hal/power beam- width er_ & Ott) of the horn antenna.

22. Calculate directivity D_Θ = 41,2531 (Θ_EX Θ_H)

Tabular column

Antenna Polarization pattern

H-Plane (X-direction)

Input voltage (V_t)=

Angle (degree)	Output Received Voltage (V_r) (mv)		Relative Power [20 log (VR/VR@()deg)]	
	Clockwise	Anti-Clockwise	Clockwise	Anti-Clockwise

CALCULATIONS:

POLAR PATTERN & DIRECTIVITY:

Half power Beam bandwidth Θ_E:
Θ_H:

Directivity (D_Θ) = 41,2531 (Θ_EX Θ_H)
or
Directivity (D_Θ) = 72815 /(($\Theta_E)^2$X ($\Theta_H)^2$)

Power Gain (G):20 log (4πs)/(λ_oXV_R@0/V_T)):

Where:

d_1=

d_2=

λ_g =2X(d_2~d_1)

λ_c =2Xa

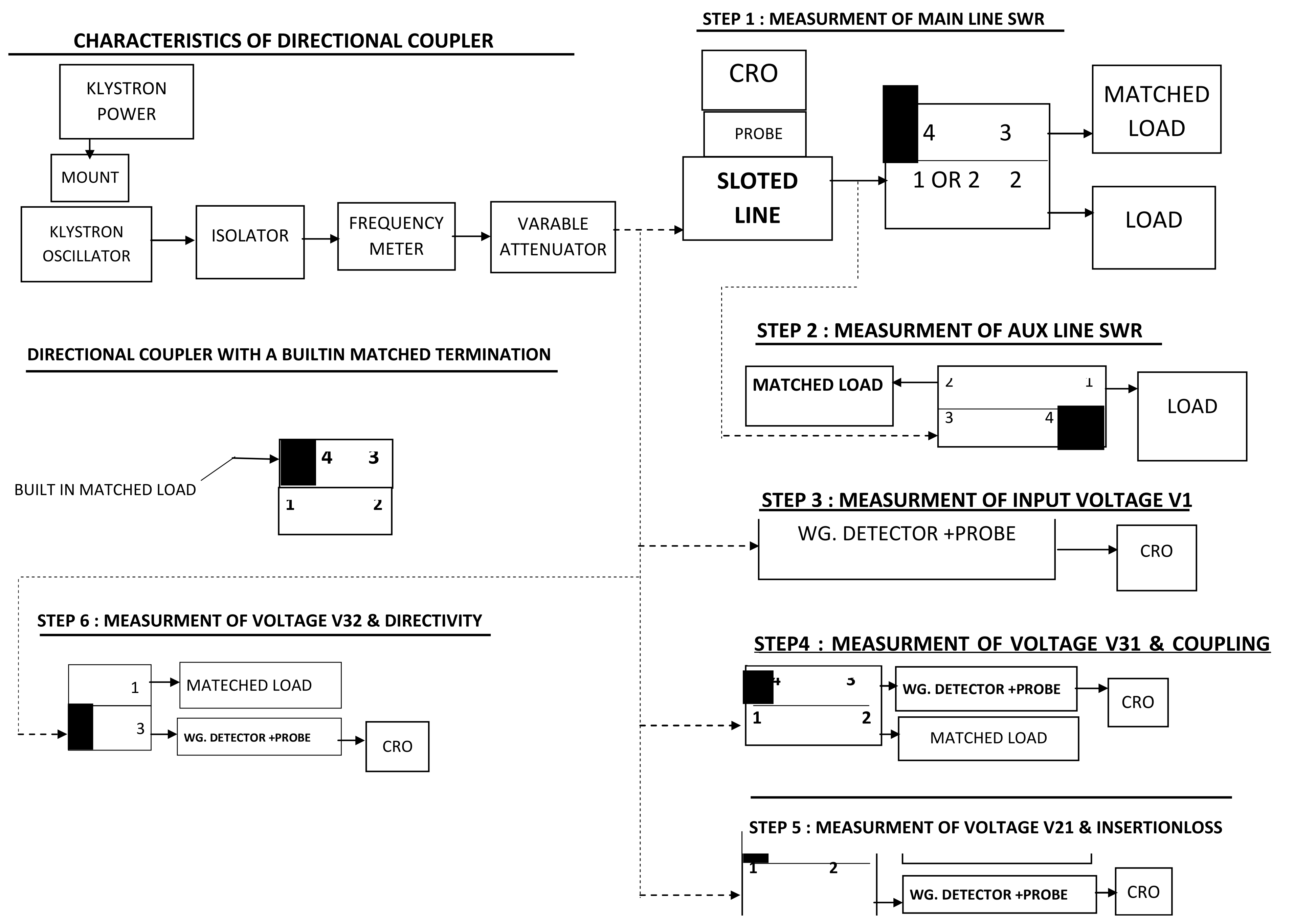
λ_0= $1/\{((1/ \lambda g)^2+1/ \lambda c)^2)^{1/2}\}$:

S_{min} = $2D^2/ \lambda_0$:

D is size of horn antenna

RESULT:
Thus the radiative power polar pattern was drawn: Also the directivity and gain of. a wave-guide horn antenna were determined.

Half power Beam bandwidth Θ_E:
Θ_H:
Power Gain (G):
Directivity (D):


CHARACTERISTICS OF DIRECTIONAL COUPLER
KLYSTRON POWER
MOUNT
KLYSTRON OSCILLATOR
ISOLATOR
FREQUENCY METER
VARABLE ATTENUATOR
STEP 1 : MEASURMENT OF MAIN LINE SWR
CRO
PROBE
SLOTED LINE
4
3
1 OR 2
2
MATCHED LOAD
LOAD
STEP 2 : MEASURMENT OF AUX LINE SWR
MATCHED LOAD
2
1
3
4
LOAD
DIRECTIONAL COUPLER WITH A BUILTIN MATCHED TERMINATION
BUILT IN MATCHED LOAD
4
3
1
2
STEP 3 : MEASURMENT OF INPUT VOLTAGE V1
WG. DETECTOR +PROBE
CRO
STEP 6 : MEASURMENT OF VOLTAGE V32 & DIRECTIVITY
1
MATECHED LOAD
3
WG. DETECTOR +PROBE
CRO
STEP4 : MEASURMENT OF VOLTAGE V31 & COUPLING
1
2
WG. DETECTOR +PROBE
CRO
MATCHED LOAD
STEP 5 : MEASURMENT OF VOLTAGE V21 & INSERTIONLOSS
1
2
WG. DETECTOR +PROBE
CRO

DIRECTIONAL COUPLER

Ex.No:5

Date

AIM:

To Determine the Insertion Loss (I), Coupling Factor(C), Directivity (D) and S-matrix for a multi-hole Directional Coupler.

APPARATUS REQUIRED:

Klystron Power Supply. Klystron Oscillator with mount. CRO .Frequency Meter. Isolator.
Variable Attenuator. Wave guide detector with probe , ,matched terminations, directional coupler , Slotted line with probe ,Wave guide stand, Cables & Accessories.

THEORY:

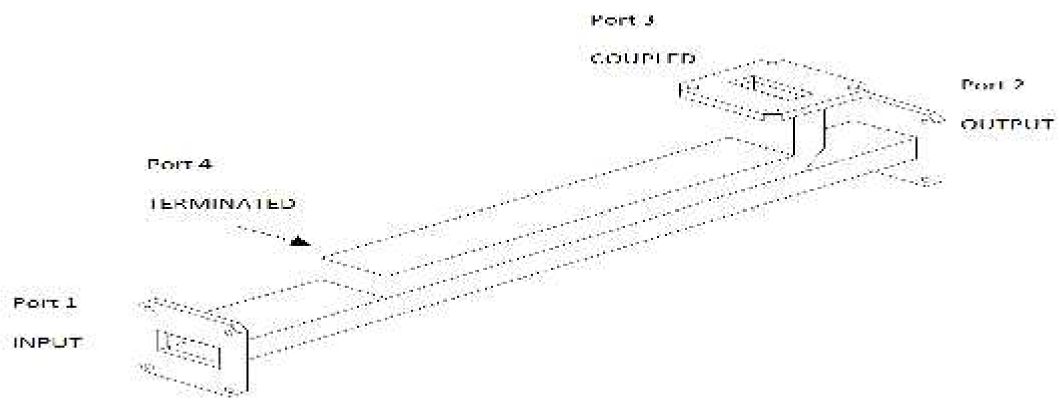
A directional coupler is a device with which it is possible to measure the incident and reflected wave separately. It consists of two transmission line, the main arm and auxiliary arm, electro magnetically coupled to each other. The directional coupler is a microwave passive device that provides a method of sampling energy from waveguide for measurement. It is constructed from an enclosed waveguide section of the same dimensions as the waveguide in which the energy is to be sampled. The broader wall of this enclosed section is mounted to be the broader wall of the waveguide from which the sample is taken. They are N (or 2) holes in the broader wall between the sections of the coupler. The n holes are λ/4 apart. The upper section of the directional coupler has wedge of energy-absorbing material at one end and a pickup probe connected t.oan output jack at the other end. The absorbent material absorbs the .energy not directed at the probe and a portion of the overall energy that enters the section .

COUPLlNG FACTOR:. .

The power entering the port 1 in the main-arm divides between port 2 and port 3
and almost no power comes out of port 4. Power entering port2 is divided between port1
and 4 with built-in termination (P4) and power is entering at port1 The coupling factor is
defined as . -

C=10IogP1/P3 =20IogV1/ V3 dB where port 4 is terminated

MULTI HOLE DIRECTIONAL COUPLER



Tabular Column

S.NO	DIRECTIONAL COUPLER CONNECTION		V_{max} (mv)	V_{min} (mv)	SWR S_i= (V_{max}/ V_{min})$^{1/2}$	REFLECTION COEFFICIENT K_i= (S_i-1)/S_i+1)
	PORT (i) AS INPUT	PORTS (j,k) TO BE MATCHED				
1	1	2,3			Main line SWR (S1) :	
2	2	1,3			Main line SWR (S2) :	
3	3	1,2			Auxiliary line SWR (S3) :	

DIRECTIVITY (D):

The directivity of the directional coupler is a measure of separation between incidents wave and reflected wave. It is measured as the ratio of the two power outputs of the auxiliary line when a given amount of power is successively applied to each terminal of the main-lines with other port terminated by matched load.

Hence, directivity (0) = 10 log P_{31}/P_{32} = 20 log V_{31}/V_{32} dB

where V31 and V32 are the voltage measured at port 3 with equal amount of voltage fed to port 1 and port 2 respectively.

MAIN LINE AND AUXILIARY LINE SWR:

Main line SWR is SWR measured, looking into the main line input terminal when the matched loads are placed at all other parts. Auxiliary line VSWR is SWR measured in the auxiliary line looking into the output terminal when the matched loads are placed on three terminals. It is the ratio of maximum voltage and minimum voltage of the standing wave existing on the line.
Main line insertion loss is the attenuation introduced in transmission line by insertion of directional coupler. It is defined as insertion loss.
I =10 log 10 P_1 / P_2=20 log V_I/ V_2 where the power is entering at port 1.

The S matrix of a directional coupler is

$$S = \begin{pmatrix} 0 & P & jq & 0 \\ P & 0 & 0 & jq \\ jq & 0 & 0 & P \\ 0 & jq & P & 0 \end{pmatrix}$$

Where $p^2+ q^2 = 1$ for conversion of energy. Here p is called transmission factor (V_I/ V21)& q is the coupling factor (V_I/V_{31})

PROCEDURE:

A. MAIN LINE SWR MEASUREMENT:

1. Set up the components and equipments as shown in figure-stepl .
2. Connect port 1 to slotted line and matched terminations to other ports.
3. Energize the microwave source for a particular frequency of operation as described in operation of klystron oscillator and tune the microwave bench for maximum output on CRO. .
4. The tunable probe carriage' is moved along the radiator slot from the load end until maximum reading is obtained on the CRO and this is called as V_{max}. Then the probe is moved to an adjacent position 6f voltage minimum and this is called' as V_{min}.
5 Calculate the standing wave ratio S =V_{max} *I* V_{min} on CRO and this is called as main line SWR
6 Repeat the above steps for the port 2 (i.e., port 2 is connected to slotted line while the other ports are connected with matched terminations and this is caned as mainline SWR S2 for port 2.-

Tabular Column 2

MEASUREMENT OF ISOLATION LOSS, COUPLING COEFFICIENT AND DIRECTIVITY

S.No:	DIRECTIONAL COUPLER CONNECTION			Input voltage (v_i) (mv)	Output voltage (v_i) (mv)
	PORT (i) AS INPUT	PORT (j) AS OUTPUT	PORTS (k) TO BE MATCHED		
1	1	2	3		V_{21}
2	1	3	2		V_{31}
3	2	3	1		V_{32}

CALCULATIONS:

S.No:	Parameter	Value
1	COUPLING FACTOR (C) = 20 log Vl/V31 dB	
2	INSERTION LOSS (I) =20 log V / V21 dB	
3	DIRECTIVITY (D)= 20 IOgV31!V32 dB	
4	ISOLATION (IS) .=20· log VI! V41 . dB	∞

AUXILARY LINE SWR MEASUREMENT:

l. Set up the components and equipments as shown in figure-step2
2. Connect port 3 to slotted line and matched terminations to other ports.
3. Energize the microwave source for a particular frequency of operation as described in Operation of klystron oscillator and get maximum-output on CRO.
4. The tunable probe carriage is moved along the radiator slot from the load end until maximum reading is obtained on the CRO and this is called as V_{max} Then the probe is moved to an Adjacent position of voltage minimum and this is called as V_{min}:
5. Calculate the standing wave ratio S== V_{max} / V_{min} and this is called as auxiliary line SWR 53 for port s.

MEASUREMENT OF COUPLING FACTOR .INSERTION LOSS AND DIRECTIVITY:

1. Remove the slotted line Matched terminations and directional coupler and connect the waveguide detector directly to the variable attenuator as shown in figure-step3. The output of waveguide detector should be connected to CRO.
2. Energize the microwave source for a particular frequency of operation as described in operation of klystron oscillator and get maximum output on CRO.
3. Set any reference level of voltage on CRO with the help of variable attenuator. Let it be VIJ
4. Carefully remove the waveguide detector from variable attenuator without disturbing the settings of the microwave bench and insert the directional coupler between variable attenuator and waveguide detector as shown in figure-steps. Keeping port 1 of directional coupler to variable attenuator, waveguide detector at its port 3 and a matched termination should be placed at port 2.
5. Note down the readings on CRO. Let it be V_{31}.
6. Calculate the coupling factor(C) as 20 log (V_1/V_{31}) dB.
7. For measurement of insertion loss, connect the port 1 of directional coupler to the variable attenuator, port 2 to waveguide detector and a matched termination should be placed at port 3 as shown-in figure step 5 after setting same reference level. without directional coupler in the setup as described in procedure step 3. Let same VI level is set.
8. Record the reading on CRO while inserting the directional coupler as given in step 7.
Let it be V21.

CALCULATIONS :

S-MA TRIX PARAMETERS TO DIRECTIONAL COUPLER:

Since port 4 is matched internally, theoretically K_4 =0.

Since there is no coupling between port 1 and 4, theoretically S_{14}= S $_{41}$= O.

The transmission loss from port 1 to 2 is S_{21}.let it be p;

From zero and unitary property of 5 matrix, We have S_{12}=S_{21}=S_{34}=S_{43}=p.

The coupling factor form port 1and 3 is S_{31}. let it be q where q is positive and real;

From zero and unitary property of S matrix, We have

S_{13}=S_{31}=S_{24}=S_{42}=q

The transmission loss from port 2 to port 3 is S_{32},let it be r;

From reciprocal property of S matrix, We have S_{23}=S_{32}=r

$$\text{S matrix} = \begin{pmatrix} k_1 & p & jq & 0 \\ P & k_2 & r & jq \\ jq & r & k_3 & p \\ 0 & jq & P & 0 \end{pmatrix}$$

Practical S matrix is $\begin{pmatrix} \quad \end{pmatrix}$

where

$p= v_1/v_{21}$:

$q= v_1/v_{31}$:

$r = v_2/v_{32}$:

9. Compute insertion loss as I=20log VI/V21 dB.

10. For measurement of directivity, connect the directional coupler in opposite direction i.e., port 2 of directional coupler to the variable attenuator, port 3 to wave guide detector and a matched termination should be placed at port 1 as shown in figure step 6 without disturbing the position of the setup.

11. Measure and note down the reading on CRO; let it be V_{32} which is equal to Vu

12. Compute the directivity as 0= 20 log V_{31}/ V_{32} dB

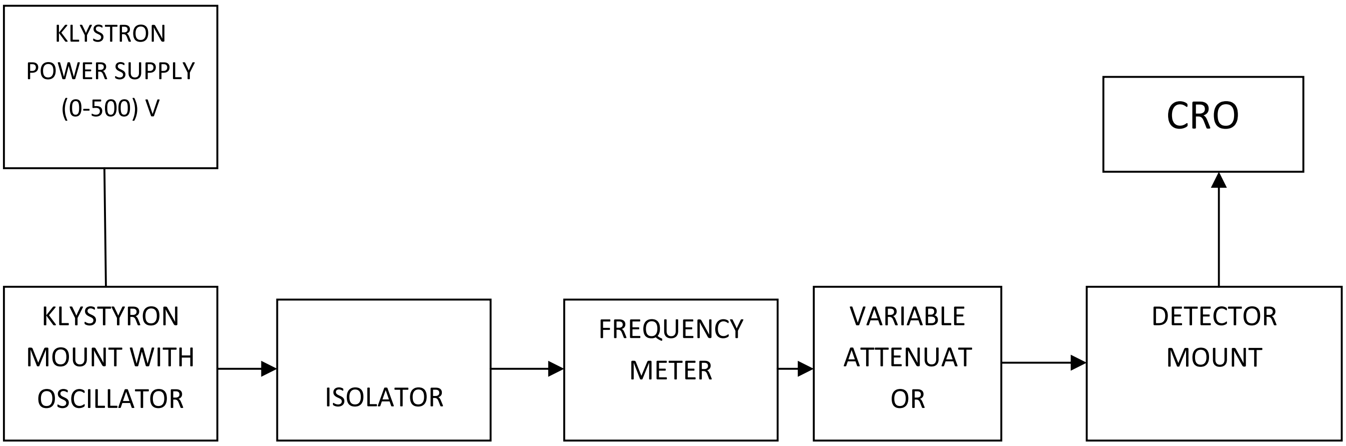
RESULT:

Thus the characteristics of multihole directional coupler was studied and the following - Parameters were measured.

Insertion loss (I) :
Coupling factor(C) :
Directivity (D) :

Therefore S = $\begin{pmatrix} \\ \\ \\ \end{pmatrix}$

BLOCK DIAGRAM FOR MODE CHARACTERISTICS OF REFLEX KLYSTRON



MODE CHARACTERISTICS OF REFLEX KLYSTRON

Ex.No.6

Date:

AIM:

To Determine the Mode Characteristics of a Reflex Klystron and Determine its Electronic Tuning Range and Electronic Tuning Sensitivity (ETS).

APPARATUS REQUIRED:

Klystron power supply, Reflex klystron isolator, frequency meter, variable attenuator, slotted section, VSWR meter, detector mount & CRO.

THEORY

Klystron is a microwave vacuum tube employing velocity modulation. These electrons move towards the repeller (ie) the electrons leaving the cavity during the positive half cycle are accelerated while those during negative half cycle are decelerated. The faster ones penetrate further while slower ones penetrate lesser in the field of repeller voltage. But, faster electrons leaving the cavity take longer time to return and hence catch up with slower ones. In the cavity the electrons bunch and intract with the voltage between the cavity grids.

It consists of an electron gun producing a collimated electron beam.

It bunches pass through grids at time the grid potentials is such that electrons are decelerated they give by energy. The electrons are then collected by positive cavity wall near cathode. To protect repeller from damage, repeller voltage is applied before accelerating voltage.

PROCEDURE

- Assemble the components as shown in fig.
- After following the necessary precautions, the Klystron Power Supply is switched ON.
- To obtain peak voltage, the attenuator is positioned at it's minimum attenuation.
- Vary the repeller voltage from it's maximum negative value and increase it in steps on N and record output power and frequency.
- The frequency is measured by tuning the basic frequency meter to have a dip in the output voltage each time.
- The frequency meter is detuned before measuring the output power each time.
- The mode characteristics of Reflex Klystron is plotted. (i.e. Output Voltage Vs Repeller voltage and Frequency Vs Repeller voltage)

CALCULATIONS

(i) Knowing mode top voltages of two adjacent modes, mode numbers of the modes is computed from the equation,

$$\frac{N_2}{N_1} = \frac{V_1}{V_2} = \frac{(n+1)+3/4}{n+3/4}$$

where

V_1 and V_2 are the values of repeller voltages required to operate the klystron in mode numbers N_1 and N_2.

(ii) Knowing mode number, transit time of each mode is calculated from

$$t_1 = \frac{n+(3/4)}{f_{01}} = \frac{N_1}{f_{01}} \quad \text{seconds}$$

f_{01} → frequency of microwave operation in one mode.

(iii) ETR – Electronic tuning range i.e, the frequency band from one end of the mode to another is calculated by

ETR = $f_{1max} - f_{1min}$ for N_1 mode (GHz)

$f_{1max} - f_{1min}$ → half power frequencies

(iv) ETS – Electronic tuning sensitivity

$$ETS = \frac{f_{1max} - f_{1min}}{V_{1max} - V_{1min}} \quad \text{(MHz/V)}$$

f_{1max}, f_{1min} → half power frequency

V_{1max}, V_{1min} → corresponding repeller voltages for a particular mode.

PRECAUTIONS

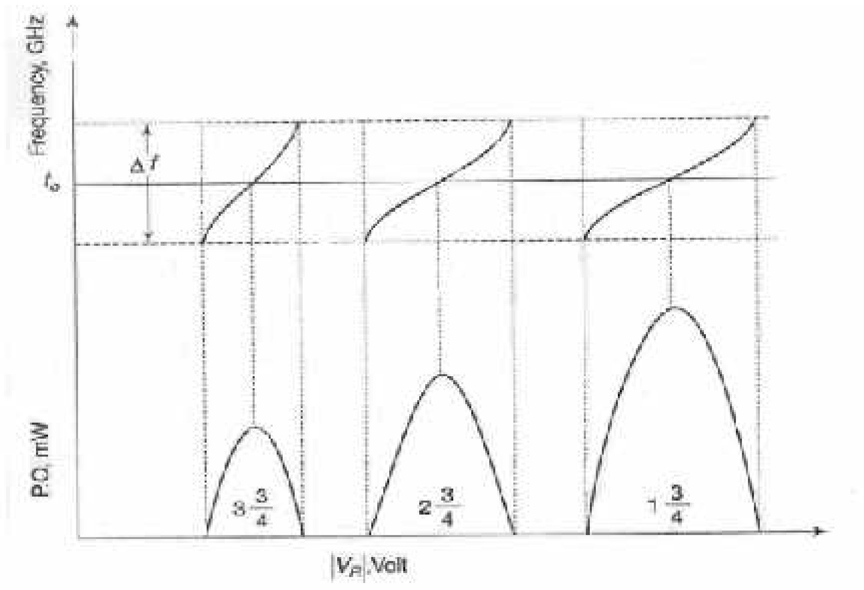
1. During operation of Klystron, repeller does not carry any current and as such it may severely be damaged by electron bombardment. To protect repeller from such damage, the repeller negative voltage is always applied before anode voltage.
2. The repeller voltage should be varied in one direction to avoid hysteric is in klystrons

3. The heater voltage should be applied first and cooling should be provided simultaneously after some time other voltages should be applied taking precaution(i).

4. While measuring power, the frequency meter should be detained each time because there is a dip in the output power when the frequency is tuned.

5. To avoid loading of the klystron an isolator/attenuation should invariably be used between klystron and the rest of the set-up.

MODEL GRAPH



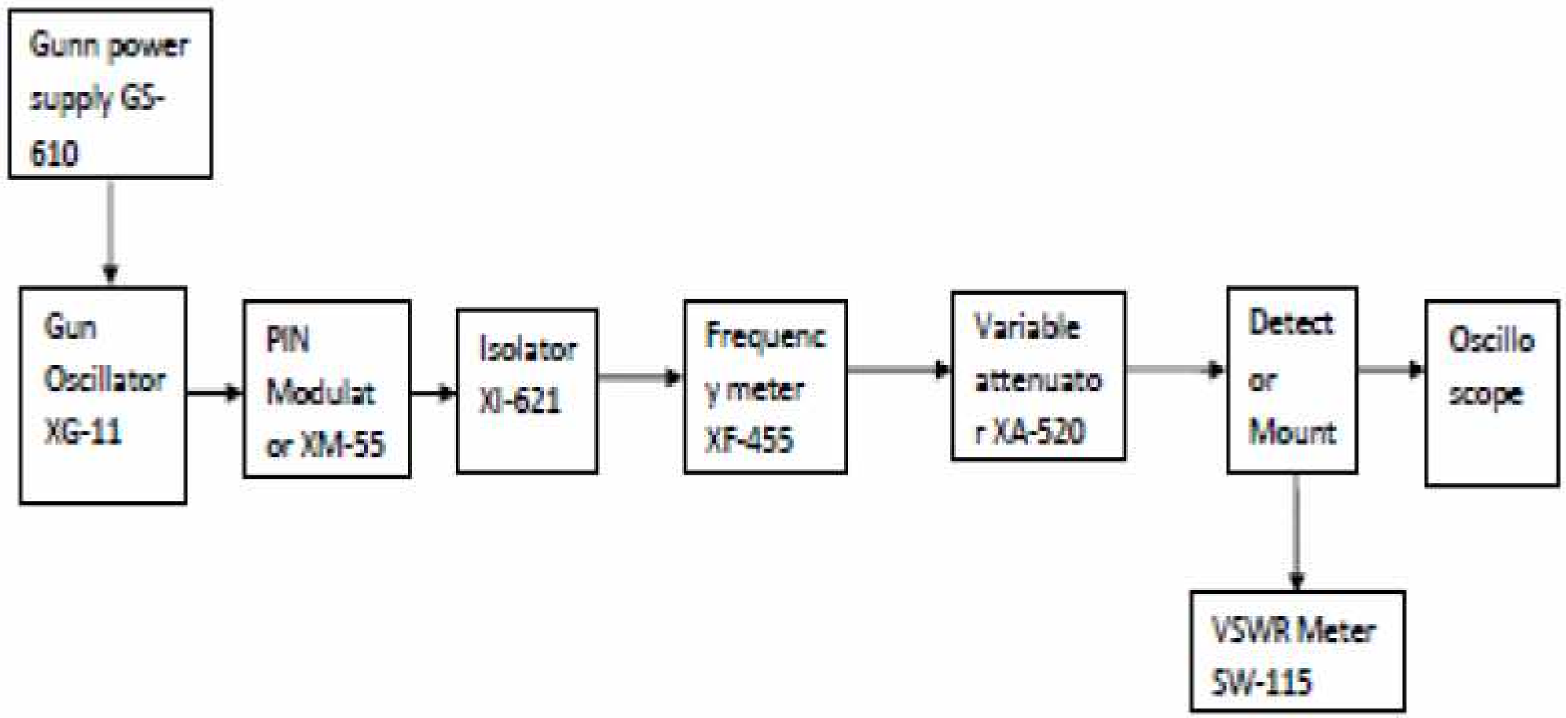
TABULAR COLUMN

Mode	Frequency GHz	Repeller voltage V	Output Voltage (mV)
1			
2			
3			

RESULT

Thus the Mode characteristics of reflex klystron were studied and the electronic tuning range and sensitivity were obtained from Mode characteristics of reflex klystron

a) Mode I ETR:
b) Mode II ETR:
c) Mode I ETS:
d) Mode II ETS:


Gunn power supply GS-610
Gun Oscillator XG-11
PIN Modulat or XM-55
Isolator XI-621
Frequenc y meter XF-455
Variable attenuato r XA-520
Detect or Mount
Oscillo scope
VSWR Meter SW-115

GUN DIODE CHARACTERISTICS

Ex.No.7

Date:

AIM:

To Determine the V-I Characteristics, Threshold Voltage and Modulation Depth for the given Gun Diode.

APPARATUS REQUIRED:

Gunn Power Supply-GS-610,Gunn Oscillator XG-11, Isolator XI -621, Frequency Meter XF- 710, PIN Modulator XM-55, BNC Cable.

THEORY:

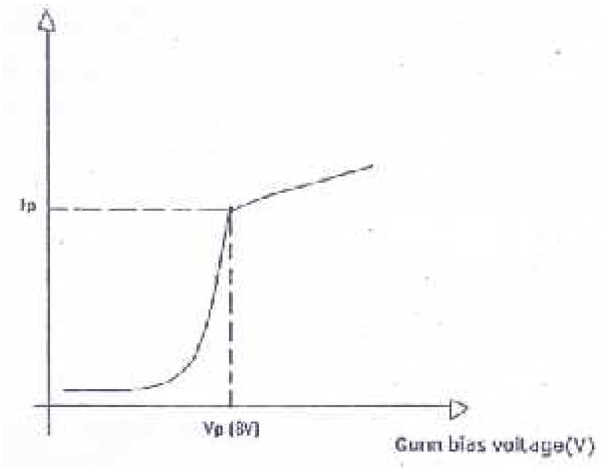
Principle:

The device, where transfer of electrons takes 'place from high mobility, low energy state to low mobility, high-energy state is known as transfer electron devices(TED). It is observed that when the field between the two end surfaces is low then the thin piece of Ga-As substance behaves like a resistor and current increases with the voltage but when the applied field exceed a certain value(E ≡ 3000 V/cm), the current decreases and this become a fluctuating function of time for the further increase of field: When the electric field is applied to this Ga-As substance the electrons from the valence band jumps to this lower conduction band valley so the current increases. But as the field becomes very high and reaches the critical field then the electron from the lower conduction band valley jumps to the low mobility, high-energy upper satellite valley of the conduction band. This device is a negative resistance device and the power will also be negative and it implies that is a source of energy. That's why Gunn diode is used for microwave oscillator. The TEDs are bulk devices having no junctions or gates and it is fabricated from compound semiconductors, such as Ga-As, Cd -Te or In- p. Thus the Gunn oscillator is based on negative differential conductivity effect' in bulk semiconductors, which has two conduction bands separated by an energy gap (greater than thermal agitation energies .The energy difference between those two satellite valleys in the conduction. Band should be less than the band gap (Eg) of the semiconductor.

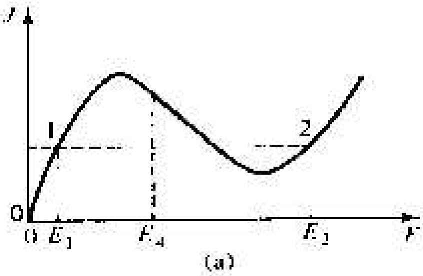
$$\Delta E < E_g \ \& \ \Delta E > .026 ev.$$

MODEL GRAPH

F-V CHARACTERISTICS



V-I CHARACTERISTICS



Tabular Column 1:

SI.No	Gunn Bias Voltage (volts)	Gunn Bias Current (mA)

A disturbance at the cathode gives rise to high field region, which travels towards the anode. When this high field domain reaches the anode, it disappears and other domain formed at the cathode and starts moving towards anode and so on. The time required for domain to travel from cathode to anode (transit time) gives oscillation frequency. The frequency of oscillation was mainly determined by the specimen. The period of oscillation is inversely proportional to the specimen length and closely equals to the transfer time of electrons between the electrodes. Although Gunn oscillator can be amplitude modulated with the bias voltage. We have used separate PIN modulator through PIN diode for square wave modulation; A measure of the square wave modulation capability is the modulation depth i.e. the output ratio between ON and OFF state. Modes:Depending on the material parameters and operating conditions various operation models of Gunn devices has been developed.

1.Transmit time or Oscillation mode: By enclosing the Gunn devices in a resonant cavity,
there are two possible variations in the gunn oscillation mode. These are quenched-domain mode and delayed domain mode. In quenched -domain do not travel fully across the width of the
domain mode, the formation of new domain is delayed, as r-f swing is not large enough to
extinguish a domain once it is formed.
2.Stable Amplification mode:
3.LSA Oscillation .mode: In this mode, a voltage swing is used in conjunction with a
frequency, whose period is short compared with a frequency and whose period is short
compound with the dielectric growth time so that it limits the amount of space charge that
can grow during the negative conductivity part of the R.F.cycle here a large pulse can be achieved from a single large chip.

Construction:

GUN diode oscillator circuits comprise of a resonant cavity, an arrangement for coupling the device to the cavity, a circuit for biasing the diode and a mechanism to couple the RF power from the cavity to external circuits or load. Since the Gunn diode consists basically of negative resistance, that is required to make it as an oscillator is an inductance to tune out the capacitance and a. shunt load resistance not greater than the negative resistance. Two commonly used circuit's are co-axial cavity and rectangular wave-guide cavity. The diode is mounted at one end of the cavity and in continuation with central conductor of co-axial line. The output can be taken out through an inductively or capacitive coupled probe the frequency of oscillation is determined mainly by length of the cavity. The location of coupling loop determines the load impedance presented to the diode. Heat sinks are included to conduct away the heat generated due to power dissipation in the device. An advantage of this coma cavity circuit is that it can be abreacted easily and coupling can be adjusted. for individual diodes. As a coaxial cavity is. also resonant· at .harmonics of fundamental frequency, the diode may oscillate harmonics of desired frequency. Its noise performance is also acceptable. The Gunn device has low noise as compared to the IMPAIT device.

TABULAR COLUMN 2:

Characteristics of Output voltage & frequency Vs Gunn Bias Voltage

S.NO	Gunn bias voltage (V)	Output Voltage (mY)	Frequency (GHz)

The Gunn devices are used for. radar local oscillator and' communication systems transmitter in the range of ·5-20 Ghz. Gunn diodes have been used successively as oscillators, amplifiers, frequency-modulated oscillators, and signal generators. A typical commercial diode uses a'10 v supply andhas a typical power dissipation of 1w Ie and a dc current of 140 rnA. Its power output is 25mWwith an efficiency of 2%and frequency oscillation is in the X-band.

PROCEDURE:

* Set the components and equipments as shown.
* Inititally set the variable attenuator for minimum position.
* Keep the control knob of Gunn power supply as below.

Meter switch - OFF
Gunn bias knob - Fully anticlockwise
PIN bias knob- Fully anticlockwise
PIN Mod frequency - Any position

•Set the micrometer of Gunn oscillator for required frequency of operation.
•ON the Gunn power supply, CRO and cooling fan.

Gunn BIAS -Voltage -Current characteristics.

1. Turn the meter switch of Gunn power supply to voltage position.
2. Measure the Gunn diode current corresponding to the various voltages controlled by Gunn bias knob through the panelmeter and meter switch.
   (Do not exceed the bias voltage above 10V)
3. Plot the voltage and current readings on the graph as shown in figure.
4. Measure the threshold voltage, which corresponds to maximum current.

Note:

❖ Do not keep the Gunn bias knob position at threshold position for more than 10 to15 Seconds. Reading should be taken as fast as possible. Otherwise due to excessive heating GUNN diode will bum.
❖ Here the ~ bias current is noted from Gunn power supply panel meter and meter switch.-Hence there is no need of separate ammeter.

TABULAR COLUMN 3:

Micrometer Reading(cm)	**Frequency (GHz)**	**Initial Attenuation**	**Final Attenuation**	**Power at A_i $P_i = 20 \log V_T$(dB)**	**Power at A_f $P_f = 20 \log V_T$(dB)**	**Modulation Depth $P_i - P_f$(dB)**

CHARACTERISTICS OF OUTPUT VOLTTAGE & FREQUENCY AS A FUNCTION OF GUNN BIAS_VOLTAGE:

1. Turn the meter switch of gunn power supply to voltage position.
2. Increase the gunn bias control knob.
3. Rotate PIN bias knob to around maximum position.
4. Tune the output on CRO through frequency control knob of modulation.
S. Any level of output voltage can be get through variable attenuator.
6. Measure the frequency by frequency meter and detune it.
7. Reduce the Gunn bias voltage in steps of O.5V or 1.0V and note down the corresponding reading of output on CRO and frequency from the frequency meter.
S. Use the reading, to draw the output voltage Vs Gunn bias voltage curve and also to draw frequency Vs gunn bias voltage curve and plot the graphs.
9. Measure the pushing factor (in MHz/volt) which is frequency sensitivity against variation in bias voltage for an oscillator. The pushing factor should be measured around S-volt bias.

CHARACTERISTICS OF SQUARE WAVE MODULATION:

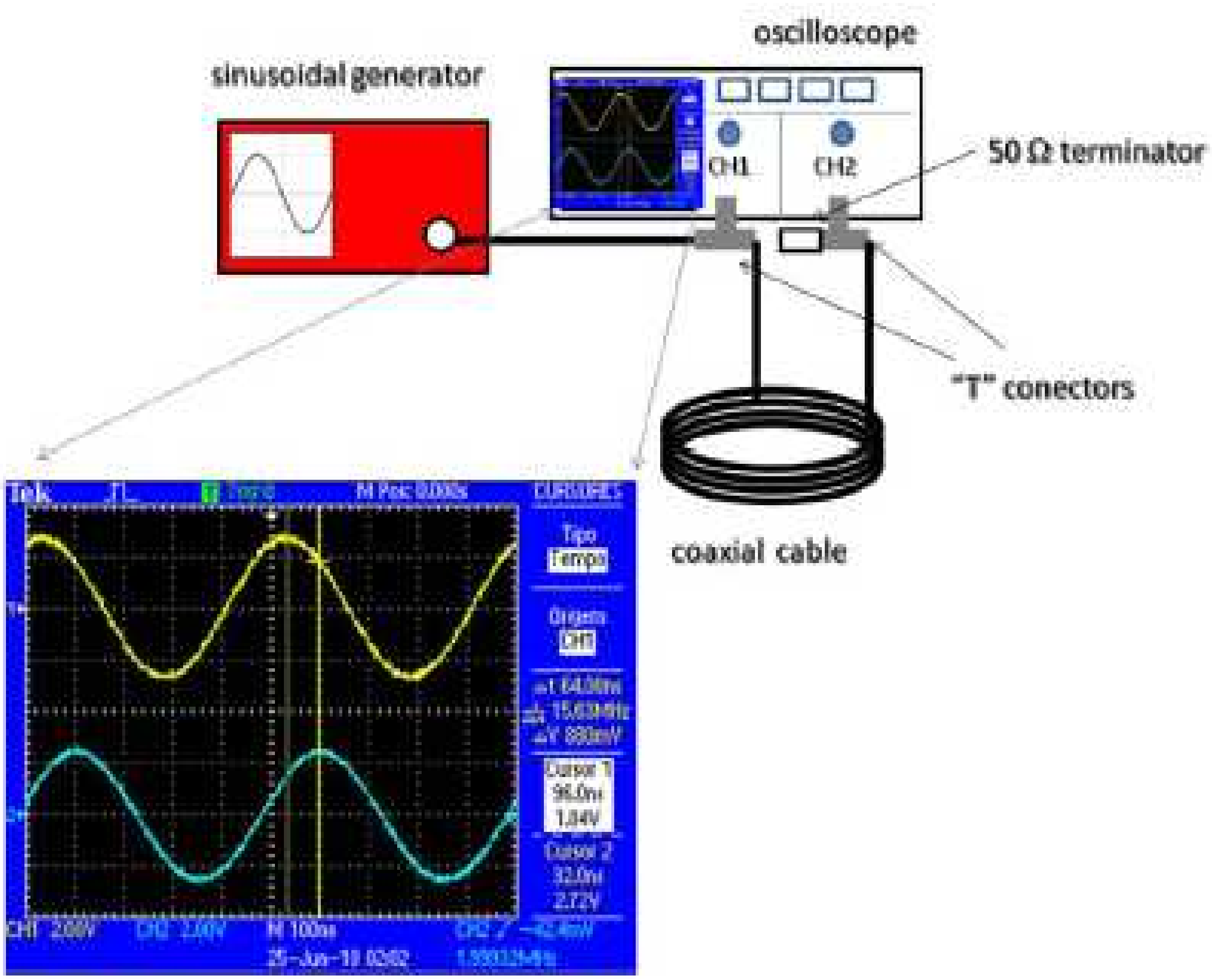
1. Keep meter switch of Cunn power supply to volt position and rotate gunn bias voltage slowly so that panel meter of gunn power supply reads lOY.
2 Tune the PIN modulator bias voltage and frequency knob for maximum output on the CRO.
3. Vary vernier micrometer of gunn diode; note down the micrometer reading and proportional frequency change by noting the DIP frequency.
4 Set the input channel of CRO in DC mode/position Coincide the bottom of square wave in CRO some reference level using Y-shift knob of CRO (or attenuaior) Note down the micrometer reading of Variable attenuator) and the corresponding output voltage (V,) ori CRO.
5. Now with the help of variable attenuator r coincide the top of square wave to same reference level .Note down the micrometer reading (AF) and the corresponding output voltage(V_F) on CRO.
6. Calculate the powers P_i & P_F for the above micrometer readings(A,) and (A_F)
ie P_I = 2010g (V_I) db ; P_F= 2010g (V_F) db
7: The difference of the powers P_i &P_F gives the modulation depth of PIN modulator.

RESULT:

The following characteristics of the Cunn diode were studied.
1. Gunn bias V·I characteristic
2. Characteristics of output voltage and frequency as a function of gunn bias voltage
3. Characteristic of square wave modulation through PIN diode and modulation depth was determined.

Threshold Voltage (V_{TH}) :
Pushing Factor (frequency sensitivity) :
Modulation depth :

4



CALCULA TIONS:-

$\Delta l = (1_2 - 1_1)$ m=

$\Delta t = (t_t - t_2)$ sec=

Velocity (c) = distance *I* time

VELOCITY OF EM WAVES

Ex.No.8

Date:

AIM:

To Determine the Velocity of EM waves for the given Co-axial Cable.

APPARATUS REQUIRED:
Pulse Generator, C.R.O, Co-axial cable

THEORY:

The pulses from the signal generators pass through the two cables (short Cable and the long cable) simultaneously. The signal takes some time to travel along the cable. So there will be time delay between the -two signals to reach the CRO inputs due to difference in Distance- traveled: Since distance traveled, per unit time is velocity, the velocity of electromagnetic wave is calculated as c == 61/ M.,J

PROCEDURE:

1. The connections are given as per the diagram.
2. Set the frequency of pulse generator (say 1 MHz) and trace the signal waveforms(pulses) from the two coaxial cable on CRO.
3. Observe the difference (tl-t2) (say 1 division on X axis) in leading edges of two pulses on CRO.
4. Determine velocity of electromagnetic wave in co-axial cable using velocity. =distance / time.

$\Delta l = (1_2 - 1_1)$ m=

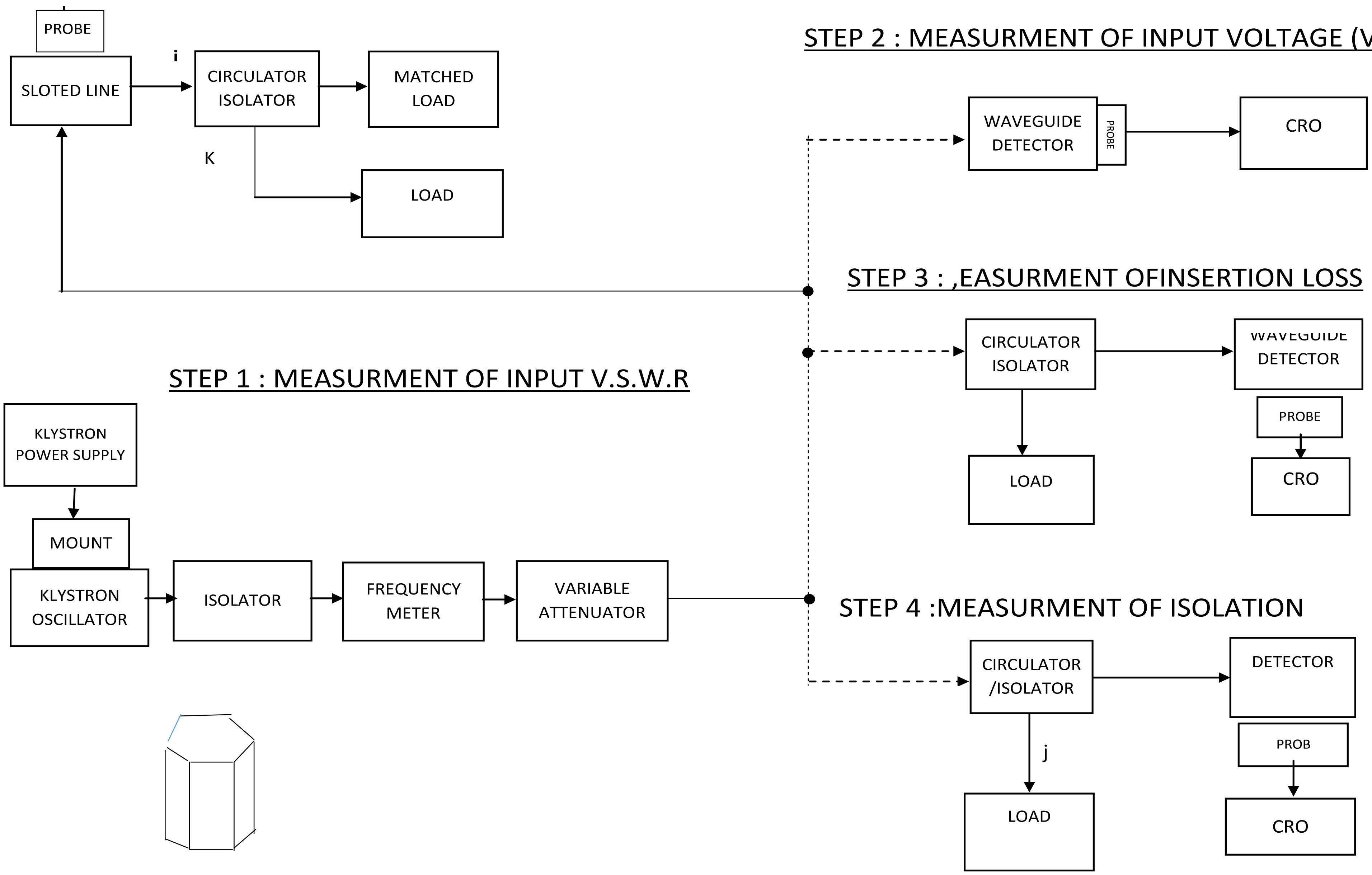
$\Delta t = (t_t - t_2)$ sec=

Velocity (c) = distance / *time*

RESULT:·
.Thus, the velocity of electromagnetic wave in coaxial cable is found:

Velocity (c) :

MEASURMENT OF INSERTION & ISOLATION LOSSES OF ISOLATOR & CIRCULATOR



MICROWAVE ISOLATOR AND CIRCULATOR.

Ex.No.9

Date:

AIM:

To Determine the Insertion Loss, Isolation Loss and VSWR for the Microwave Isolator and Circulator.

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APPARATUS REQUIRED:

Klystron Power Supply. Klystron Oscillator with mount. CRO .Frequency Meter. Isolator. Variable Attenuator. Wave guide detector with probe , ,matched terminations, Test Circulator/Isolator , Slotted line with probe ,Wave guide stand, Cables & Accessories.

THEORY:

Both microwave circulators and microwave isolators are non-reciprocal transmission devices that use the property of Faraday rotation. The ferrite exhibit Faraday rotation when a piece of ferrite is affected by a magnetic field because the ferrite is non linear material and its permeability is an asymmetric tensor. Unpaired electrons in the ferrite material tend to line up with the de magnetic field due to their magnetic dipole moment when the de magnetic field is applied to a ferrite. However, the non -reciprocal procession of unpaired electrons in the ferrite causes their relative permeability {μr)to be non. equal and the wave in the ferrite is then circularly

Polarized.This phenomenon is called the gyro magnetic resonance of the ferrite:

MICROWAVE CIRCULATORS: . . . .

A multiport waveguide junction in which the wave can flow only from the n^{th}port to $(n+1)^{th}$ port in one direction is called microwave circulator. However, there is no limitation on the number of port. A . three port circulator is formed by 120° H-plane waveguide symmetrical Y junction with a central ferrite post

TABULATION 1 :

INPUT VSWR MEASUREMENT:

S.NO	DIRECTIONAL COUPLER CONNECTION		V_{max} (mv)	V_{min} (mv)	SWR S_i= $(V_{max}/V_{min})^{1/2}$	REFLECTION COEFFICIENT $K_i= (S_i-1)/S_i+1)$
	PORT (i) AS INPUT	PORTS (j,k) TO BE MATCHED				
1	1	2,3				
2	2	1,3				
3	3	1,2				

CALCULATION OF S - MATRIX FOR ISOLATOR AND CIRCULATOR:

ISOLATOR:

The practical S· matrix is $\begin{pmatrix} K_1 & S_{12} \\ S_{21} & K_2 \end{pmatrix}$

CIRCULATOR:

The practical S matrix is $\begin{pmatrix} K_1 & S_{12} & S_{13} \\ S_{21} & K_2 & S_{23} \\ S_{31} & S_{23} & K_3 \end{pmatrix}$

From Tabulation Column1 & Tabulation Column2 we get

S· matrix (isolator) as $\begin{pmatrix} \quad \end{pmatrix}$ S· matrix(circulator) as $\begin{pmatrix} \quad \end{pmatrix}$

S.NO	CONNECTION OF PORTS	I/P VOLTAGE	FORWARD O/P VOLTAGE	REVERSE O/P VOLTAGE	Insertion loss (l_{ij}) =20 Log	Isolation Loss (l_{ik}) =20 Log v_i /	S=

MICROWAVE ISOLATORS:

A non reciprocal transmission device that is used to isolate one component from reflections of other components in the transmission line is called as isolator. An ideal isolator provides lossless transmission for propagation in one direction and completely absorbs the power in the opposite direction. Therefore the isolator is usually called uniline. To improve the frequency stability of the microwave generator such as klystrons and magnetrons in which the reflection from load affects the generating frequency, the isolators are used. In such cases, the isolators placed between the generator and load prevents the reflected power from the unmatched load from returning to the generator. Therefore, the isolator maintains the frequency stability of the generator.

INSERTION LOSS:

The ratio of power supplied by the source to the input port (i) to the power detected by a waveguide detector in the coupling arm i.e., output arm (j) with other port (k) terminated in the matched load is defined as the insertion loss or forward loss or coupling loss.

Insertion loss = 10 log P;/ P,= 20 log Vi / Vi dB. for coupled port.

ISOLATION LOSS:

It is the ratio of power fed to input arm (i) to the power detected at uncoupled port (k) with other port (j) terminated in the matched load. Isolation loss = 10 log Pi/ Pk = 20 log Vi/ Vk dB for uncoupled port.

INPUTVSWR:

The input standing wave ratio (5) of an circulator or isolator is the ratio of voltage maximum to voltage minimum of the standing wave existing on the line when one port of it terminates the line and others have matched termination.

$$\begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix}$$

Note: when a port which is. not coupled to input port is terminated by matched termination. It makes an isolator (two port device)

For an ideal loss less , matched isolator . S=

For a perfect matched, loss less, non reciprocal, three port circulator

$$S = \begin{pmatrix} 0 & 0 & 1 \\ & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \quad 1$$

	INPUT	FORWARD		REVERSE		V_i (mv)	V_j (mv)	V_k (mv)	v_i / (v_j) Db	(v_k) Db	(v_j)or (v_k)/ (v_i)
	PORT (i) AS INPUT	PORT (j) AS OUTPUT	PORT (K) TO BE MATCHED	PORT (K) AS OUTPUT	PORT (j) TO BE MATCHED						
1.	1	2	3	X	X			X		X	
2.	1	X	X	3	2		X		X		
3.	2	3	1	X	X			X		X	
4.	2	X	X	1	3		X		X		
5.	3	1	2	X	X			X		X	
6.	3	X	X	2	1		X		X		

INPUT VSWR MEASUREMENT:

1. Set up the components and equipments as shown in figure-step l.
2. Connect the port 1 to slotted line and matched terminations to other ports.
3. Energize the microwave source for a particular frequency of operation as described in operation of klystron oscillator and tune the microwave bench for maximum output on CRO.

ISOLATORS_ AND CIRCULATORS

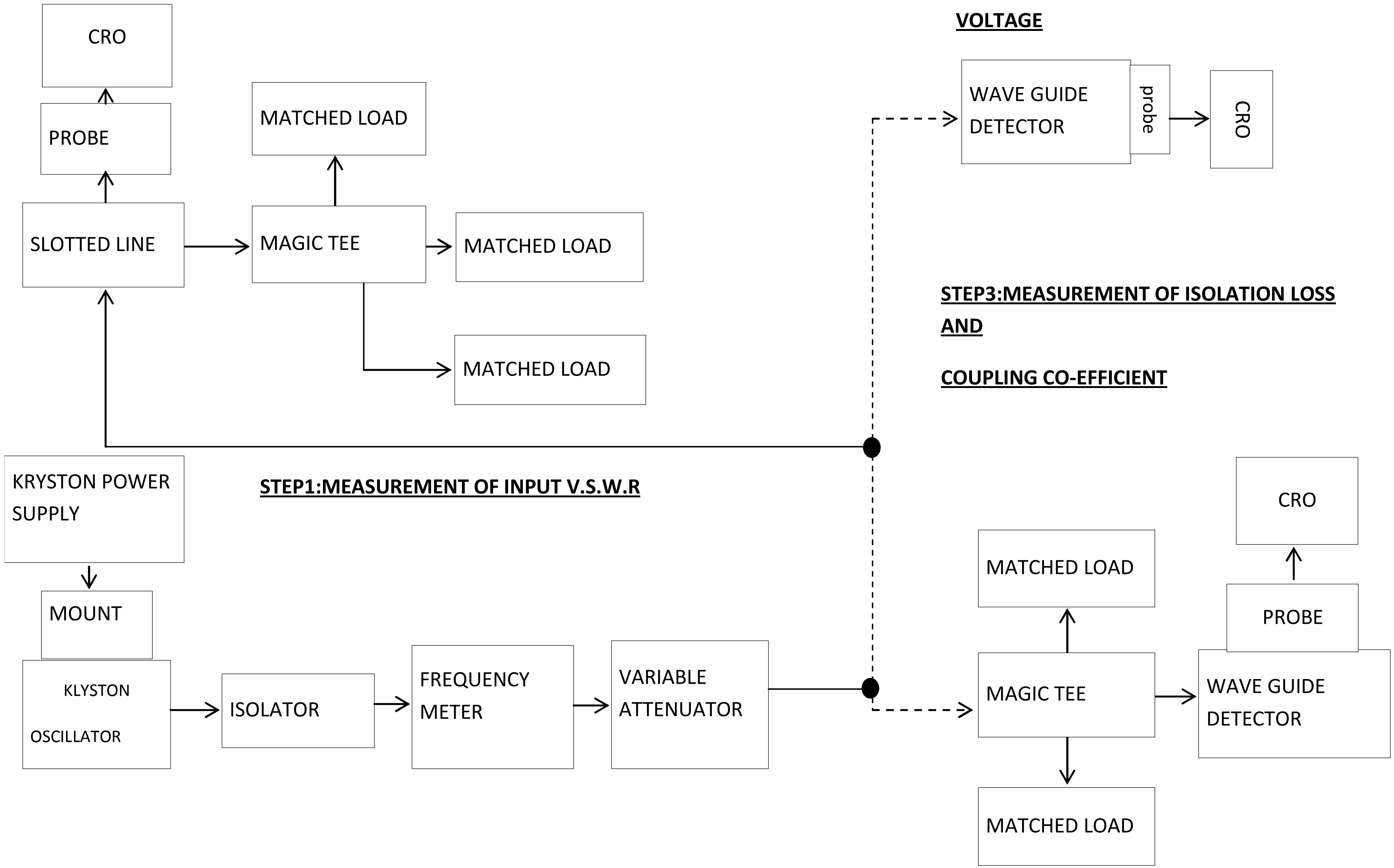
4. The tunable probe carriage is moved along the radiator slot from the load end until maximum reading is obtained on the CRO and this is called as V_{max}.Then the probe is moved to an adjacent position of voltage minimum and this is called as V_{min}. 5. Calculate the standing wave ratio (S) = V_{max} *I* V_{min} and this is called as S_1 for port I.
6. Repeat the above steps for the ports 2 and 3 one by one while the other ports are connected with matched terminations. Find S2 and S3 respectively. Also calculate the reflection coefficients kI, k2, k3 for different inputs.

B. MEASUREMENT OF INSERTION LOSS AND ISOLATION LOSS:

1.Remove the circulator or isolator, matched load and slotted line and connect the waveguide detector directly to the variable attenuator as shown in figure –step-2. The output of wave guide detector should be connected to CRO.
2. Energize the microwave source for maximum output for a particular frequency of operation. Tune the microwave bench for maximum output on the CRO.
3. Set any reference level of voltage on CRO with the help of variable attenuator. Let it be V_i. 4. Carefully remove the detector mount from variable attenuator without disturbing the settings of the microwave bench. Insert the circulator or isolator between variable attenuator and. waveguide detector and keeping input port (i) to variable attenuator and waveguide detector at its output port 0). (A matched termination should be placed at third port(k) in case of circulator.)
5. Record the readings on the CRO. Let it be V_j.
6. Compute insertion loss In= 20 log V_i/V_j dB for coupled port.
7. For measurement of isolation, the circulator or isolator has to be connected reverse i.e., connect the port (i) to the variable attenuator and port (k) to wave guide detector (A matched termination should be placed at third port G) in. case of circulator) after setting a reference level without isolator or circulator in the setup as described in the insertion loss measurement. Let -same V_i level is set.
8..Record the reading on the CRO while inserting the circulator or .isolator as given in step 7. Let it be V_k.
9. Compute isolation loss as Is= 20 log Vi /V_K dB for uncoupled port.
10. The same experiment can be done for other ports of circulator.
11. Calculate the S - parameter values (S_{oi}) from the above readings.

RESULT:
Thus the function of Circulator and isolator was studied and insertion loss,isolation loss and input SWR of circulator and .isolator were determined.

CHARACTEISTICS OF MAGIC -TEE



MAGIC TEE.

Ex.No 10

Date:

AIM:

To Determine the Isolation Loss, coupling Co-efficient and VSWR for the four different ports in Magic Tee.

APPARATUS REQUIRED:

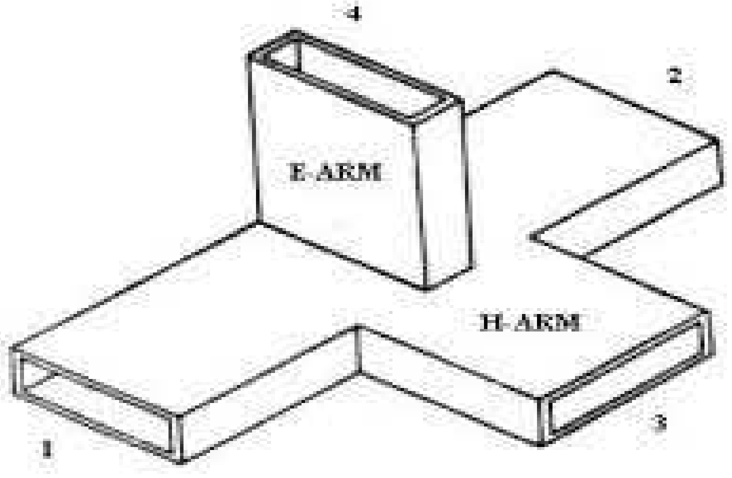
Klystron Power Supply. Klystron Oscillator with mount. CRO .Frequency Meter. Isolator.
Variable Attenuator. Wave guide detector with probe , ,matched terminations, Magic Tee, Slotted line with probe ,Wave guide stand, Cables & Accessories.

THEORY:

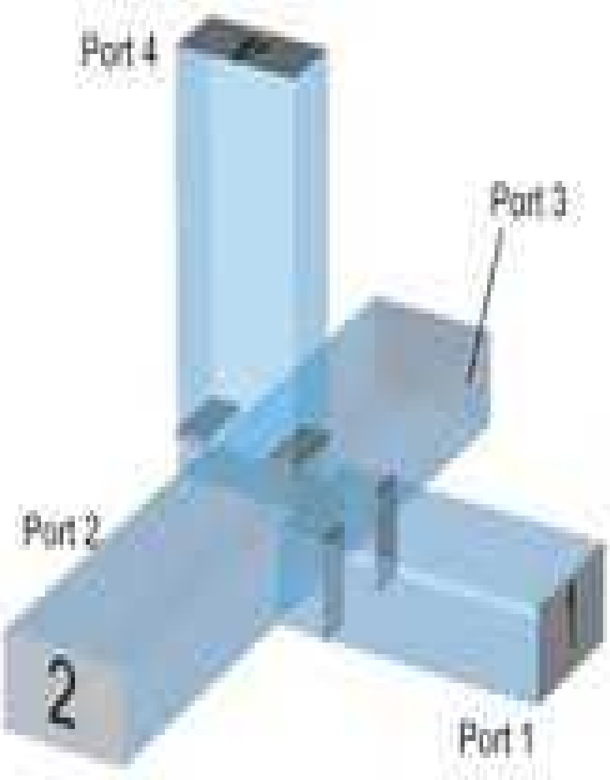
The T junction is the most simple of the commonly used wave guide junctions. The T junctions are divided into two basic types, the E type and the H-type. The hybrid junctions are more complicated developments of the basic T junctions, The Magic Tee and the Hybrid Ring are the two most commonly used hybrid junctions.

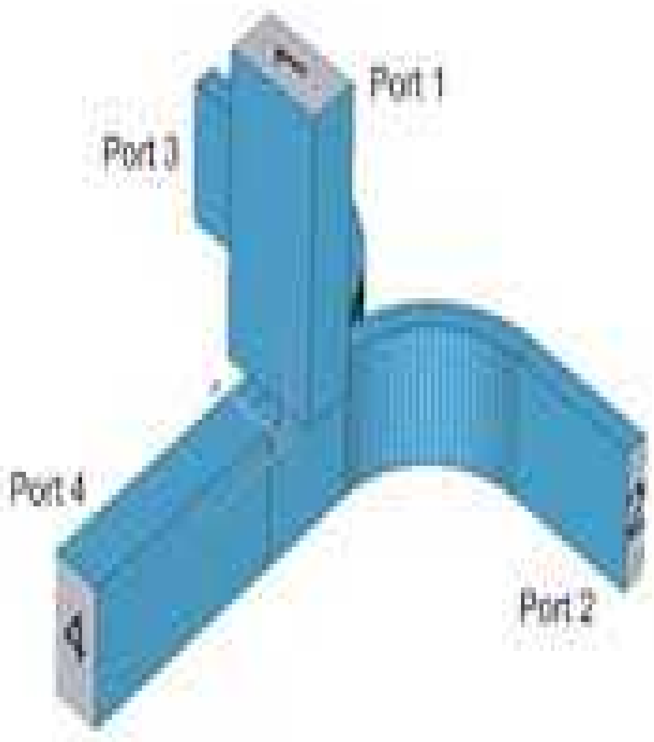
E TYPE T JUNCTION:

An E type T junction is the wave guide junction arm which extends from the main wave guide in the same direction as E field in the wave guide. In diagram (a), the input is fed into arm 3 and the output s are taken from the 1 and 2 arms: When the E field arrives between points A and B, point A becomes positive and point B becomes negative. The positive charge at paint A then induces a 'negative charge on the wall at point C. The negative charge at point B induces a positive charge at point D. These charges cause the fields to form 180 degree out of phase in the main wave guide; therefore, the outputs will be 180 degree out of phase with each other. The two in phase inputs of equal amplitude are fed into 'the 1 and 2 arms, the signals at points A and B have the same phase and amplitude. No difference of potentials exists across the entrance to the 3 arm, and no energy will be coupled out. However, when two signals fed into the 1 . and 2 arms' are. 180 degrees out of phase, points A and B haye _a difference in potential. This difference of potential induces an E field from point A to point 13in the 3rd arm and energy-is coupled out of this arm (3). Due to this, 3rd arm or port is called as differential arm. By analogy with voltage relationship in series circuit, E plane is called as voltage junction or series junction.


4
2
E-ARM
H-ARM
1
3

MAGIC –TEE


Port 4
Port 3
Port 2
2
1
Port 1


Port 1
Port 3
Port 4
4
Port 2

H-TYPE T JUNCTION:

An H- type T junction has the long axis of the 3rd arm in parallel to the plane of the magnetic lines of force in the wave guide. If two input waves are fed into port 1 and port 2 of the collinear arm, the output wave at port 3 will be in phase and additive. Also if the input is fed into port 3, the wave will split equally into port 1 and port 2in phase and in the same magnitude. Due to this 3rd port is called as sum arm. The arm delivers magnetic lines similar to current branches, so this junction is called current junction or shunt junction. If a signal is fed into the 1 arm, outputs will be obtained from the arms 3 and 2. The reverse is also true. If a signal is fed into the 2 arm, output will be obtained from the arms 1 and 3.

MAGIC T HYBRID JUNCTION:

The magic T is a combination of the H- type and E-type T junctions. In summary, when an input is applied to arm 4(E) of the magic-T hybrid junction, the output signals from arms 1 and 2 . are 180 degrees out of phase with each other and no output occurs at arm 3 (H) of the magic -T. The signal entering the arm 3 (H) divides and moves down the arms 1 and 2 outputs which are in phase with each other and with the input. Since the potentials on both sides of the arm 4 (E) are
equal, no potential difference exist at the entrance of the arm 4, resulting in no output. When an input signal is fed into the arm 1 shown in diagram(c), a portion of energy is coupled into the arm4 (E) as it would be in all E - type T junction. An equal portion of the signal is coupled through. the arm 3 (H) because of the action of the H- type T junction. The aim 2 has two fields across it that are out of phase with each other. Therefore the fields cancel, resulting in no output at the arm 2. The reverse of this action takes place if a signal is fed into the ann 2, resulting in outputs at the arms 4 and 3 and no output at the arm l.

CHARACTERISTICS OF MAGIC TEE:

1. If two waves of equal magnitude and the same phase are fed into port 1and 2, the output will be zero at port 4 and additive at port 3.
2. If a wave is fed into port 3 (arm H), it will be divided equally between port 1 and 2, of the collinear arms and will not appear at port 4 (arm E).
3. If the wave is fed into the port 4 (arm E), it will produce an output of equal magnitude and opposite phase at port 1 and 2.and the output at the port 3 is zero. i.e., S_{34}= S_{43}= O.Therefore the ports 3 and 4 are called uncoupled or isolated ports .
4. If a wave is fed into one of the collinear anus at either port I or port 2, it will not appear in the other collinear arm at port 2 or port 1 respectively because the arm E causes a phase delay while the and H causes a phase advance i.e., S_{I2} =S_{21} =0. Therefore the ports I and 2 are called uncoupled or isolated ports.

PARAMETERS OF MAGIC TEE:

A. INPUT VSWR:

It is the value of SWR corresponding to each port, which act as a load to the line while other ports are terminated in matched load. It is the ratio of maximum voltage and minimum voltage of the standing wave existing on the line

TABULAR COLUMN:

S.NO	DIRECTIONAL COUPLER CONNECTION			Input voltage (v_i) (mv)	Output voltage (v_j) (mv)	Isolation Loss (I_{ij}) =20 Log $v_i / (v_j)$ Db	COUPLING Coefficient $C_{ij}=10^{(-Iij/20)}=10^{(-a/20)}$	$S_{ji}=(v_j)/(v_i)$ for $j \neq i$
	PORT (i) AS INPUT	PORT (j) As output	PORT (k) TO BE MATCHED					
1.	**1**	**2**	**3,4**					
2.		**3**	**2,4**					
3.		**4**	**2,3**					
4.	**2**	**1**	**3,4**					
5.		**3**	**1,4**					
6.		**4**	**1,3**					
7.	**3**	**1**	**4,2**					
8.		**2**	**1,4**					
9.		**4**	**1,2**					
10.	**4**	**1**	**2,3**					
11.		**2**	**1,3**					
12.		**3**	**1,2**					

ISOLATION:

The isolation between E (4) and H (3) arms is defined as the ratio of the power supplied by the generator connected to the E arm(port 4) to the power detected at H arm(port 3) when side arms 1 and 2 are terminated in matched load. Hence, isolation (I_{43}) = 10 log P_4/P_3 = 20 log *V4/V3* .Also, isolation between the arms 1 and 2 is 112
=10 log *Pl/P2*= 20 log *VI/N2*. Similarly, isolation between other ports may also be found.

COUPLING COEFICIENT:

lt is defined as Cij = 10 (-lij/20)= 10 *(-a* /20) where *a* is 'attenuation or isolation (Iij).in dB where i is input arm and j is output arm: Thus *a* = 10 log Pi/ Pj = 20 log Vi *I* Vj dB where Vi is the voltage supplied to arm i and Vj is the voltage detected at the j arm

COMPUTATION OF $ - MATRIX:

- Because of uncoupled ports 3 and 4, $34= $43=O.Also there is no coupling between 1 & 2 even though they are collinear ports(This Is The Magic Of Waveguide Junction) _ Therefore 1&2 are also uncoupled ports and hence $12=$21=0.
- If any of the two ports 3 and 4 are matched, then the remaining two ports are automatically matched to the four port junction. Hence, $S_{11}= S_{22}= S_{33}= S_{44}=$ O.
- Because of the H plane Tee, 523=513.Becausoef the E plane Tee, $24=-S14. From the symmetric property,

1) $S_{13}= S_{31}$ and also $S_{23}= S_{32}= S_{13}$
2) $S_{14}= S_{41}$ and also $S_{24}= S_{42}=- S_{14}$

Therefore the S· matrix Magic Tee can be expressed as

	0	0	S_{13}	$-S_{14}$	
S Matrix is		0	0	S_{13}	$-S_{14}$
	S_{13}	S_{13}	0	0	
	S_{14}	$- S_{14}$	0	0	

Using the unitary property, $S=1/ (2)^{1/2}$

$$
S \text{ Matrix is } \begin{pmatrix} 0 & 0 & 1/(2)^{1/2} & 1/(2)^{1/2} \\ 0 & 0 & 1/(2)^{1/2} & -1/(2)^{1/2} \\ 1/(2)^{1/2} & 1/(2)^{1/2} & 0 & 0 \\ 1/(2)^{1/2} & -1/(2)^{1/2} & 0 & 0 \end{pmatrix}
$$

TABULAR COLUMN:

INPUT VSWR MEASUREMENT:

S.no	DIRECTIONAL COUPLER CONNECTION		V_{max} (mv)	$V_{min(mv)}$	SWR S_i= $(V_{max}/V_{min})^{1/2}$	REFLECTION COEFFICIENT $K_i = (S_i-1)/S_i+1)$
	PORT (i) AS INPUT	PORTS (j,k) TO BE MATCHED				
1	1	2,3,4				
2	2	1,3,4				
3	3	1,2,4				
4	4	1,2,3				

CALCULATION OF S - MATRIX FOR MAGIC TEE:

The practical S matrix is

$$\begin{pmatrix} K_1 & S_{12} & S_{13} & S_{14} \\ S_{21} & K_2 & S_{23} & S_{24} \\ S_{31} & S_{23} & K_3 & S_{34} \\ S_{41} & S_{42} & S_{43} & K_4 \end{pmatrix}$$

From Tabulation Column

S· matrix is

$$\begin{pmatrix} \\ \\ \\ \end{pmatrix}$$

In the-above matrix 3rd column *($S_{13}=1/(2)^{1/2}=S_{23}$)* specifies equal power division to port 1 and 2 from port.d.The *(513=1/'12=523)* specifies that equal amount of power to ports 1 and 2 and net result Sum at port 3.Similarly the 4th column*($S_{14}=1/(2)^{1/2}=S_{24}$)*) specifies that equal powerdistribution to . portl and2 from ports but with 1800 phase shift. The fourth row *(($S_{41}=1/(2)^{1/2}=S_{42}$)* specifies equal and opposite phase of power are applied to ports} and2 and net-difference at port4.

PROCEDURE:

INPUT VSWR MEASUREMENT:

1.Set up the components and equipments as shown in figure step1.
2. Connect port 1 to slotted line and matched terminations to other ports.
3. Energize the microwave source for a particular frequency of operation as described in operation of klystron oscillator and tune the microwave bench for maximum output on CRO.
4. The tunable probe carnage is moved along the radiator slot from the load end until maximum reading is obtained on the CRO and this is called as V_{max} Then the probe is moved to an adjacent position of voltage minimum and i:his is called as V_{min}.
5. Calculate the standing wave ratio S= $(V_{max}/V_{min})^{1/2}$ and this is called as S1 for port 1.
6.Repeat the above steps for the ports 2, 3 and 4 one by one while the other ports at connected with matched terminations. Find S_2, S_3, S_4 respectively. Also find the reflection coefficients K_I, K_2, K_3 and K_4 for different inputs.

ISOLATION & COUPLING MEASUREMENT:

1.Remove the magic tee, matched terminations and slotted line and connect the waveguide _detector to the variable attenuator as shown in figure-step 2. The output of waveguide detector should be connected to CRO.
2. Energize the microwave source for maximum output for a particular frequency of operation. Tune the microwave bench for maximum output on the CRO.
3. With the help of variable attenuator, set any reference voltage on the CRO. Let it be V_i
4. Without disturbing the position of variable attenuator, carefully place the magic tee after the variable attenuator keeping port (i=1) to variable attenuator, detector to port 0=2) and matched - terminations to ports 3 and 4 as shown in figure step 3. Note down the reading on the CRO. Let it be $V_{ji}=V_{2I}$.
5.Repeat the above step for port(i=1) to variable attenuator and wave guide detector to port 0= 3 and 4) one at a time while matched terminations are connected to other ports . Note down the corresponding readings V_{ji} on CRO.
6. Repeat the steps 4 and 5 for the ports (i =2, 3 and 4) one at a time and note down the reading Vii on CRO
7. Calculate the isolation l_{ij}= 10 log Pi/Pi= 20 log V_i/V_j and coupling coefficients
$C_{ij}=10^{(-lij/20)=}10^{(-a/20)}$ where a =10 log P_i/P_j= 20 Iog V_i/V_j dB
8. Calculate the S parameter values (S_{ji}) for magic tee from the above readings.

RESULT:

Thus the function of MAGIC TEE was studied and the isolation loss, coupling coefficient and input VSWR of Magic Tee junctions were determined.

Additional Experiments

INTRODUCTION TO MATLAB

INTRODUCTION

The tutorials are independent of the rest of the document. The primarily objective is to help you learn quickly the first steps. The emphasis here is \learning by doing". Therefore, the best way to learn is by trying it yourself. Working through the examples will give you a feel for the way that MATLAB operates. In this introduction we will describe how MATLAB handles simple numerical expressions and mathematical formulas. The name MATLAB stands for MATrix LABoratory. MATLAB was written originally to provide easy access to matrix software developed by the LINPACK (linear system package) and EISPACK (Eigen system package) projects. MATLAB [1] is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research.

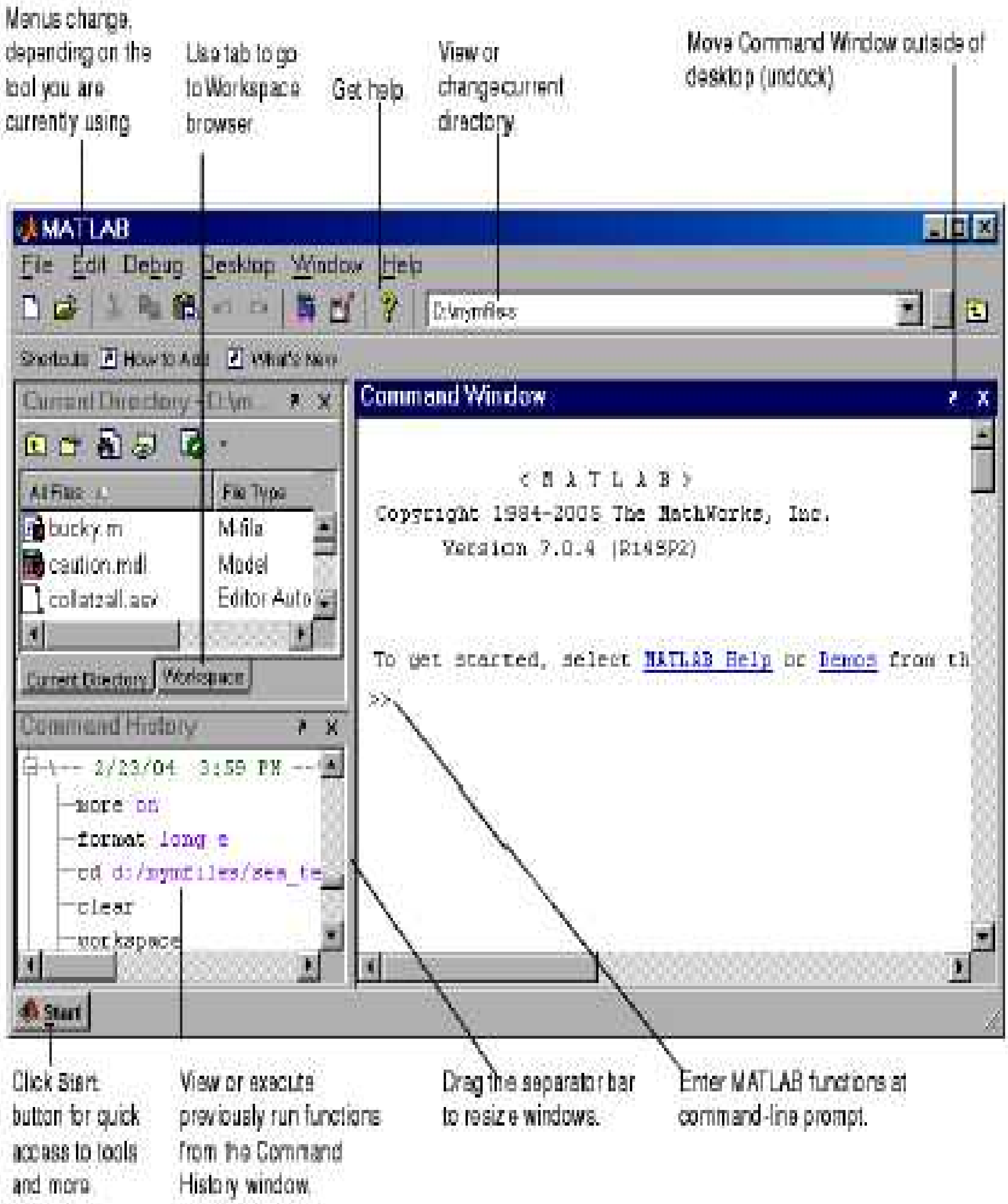
MATLAB has many advantages compared to conventional computer languages (e.g., C, FORTRAN) for solving technical problems. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide. It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphics commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as toolbox.

There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering. Later and with the addition of several toolboxes the capabilities of MATLAB were expanded and today it is a very powerful tool at the hands of an engineer.

TYPICAL USES INCLUDE:

- Math and Computation
- Algorithm development
- Modelling, simulation and prototyping
- Data analysis, exploration and visualisation
- Scientific and engineering graphics
- Application development, including graphical user interface building.

MATLAB is an interactive system whose basic data element is an ARRAY. Perhaps the easiest way to visualise MATLAB is to think it as a full-featured calculator. Like a basic calculator, it does simple math like addition, subtraction, multiplication and division. Like a scientific calculator it handles square roots, complex numbers, logarithms and trigonometric operations such as sine, cosine and tangent. Like a programmable calculator, it can be used to store and retrieve data; you can create, execute and save sequence of commands, also you can make comparisons and control the order in which the commands are executed. And finally as a powerful calculator it allows you to performmatrix algebra, to manipulate polynomials and to plot data



Menus change, depending on the tool you are currently using
Use tab to go to Workspace browser
Get help
View or change current directory
Move Command Window outside of desktop (undock)
MATLAB
File Edit Debug Desktop Window Help
Command Window
< M A T L A B >
Copyright 1984-2005 The MathWorks, Inc.
Version 7.0.4 (R14SP2)
To get started, select MATLAB Help or Demos from th
Current Directory
Workspace
Command History
more on
format long e
clear
workspace
bucky.m
caution.mdl
M-file
Model
Start
Click Start button for quick access to tools and more
View or execute previously run functions from the Command History window
Drag the separator bar to resize windows.
Enter MATLAB functions at command-line prompt.

BASIC FEATURES

The following tutorial lessons are designed to get you started quickly in MATLAB. The lessons are intended to make you familiar with the basics of MATLAB.

A minimum MATLAB session

The goal of this *minimum* session (also called *starting* and *exiting* sessions) is to learn the
rst steps:

- How to log on
- Invoke MATLAB
- Do a few simple calculations
- How to quit MATLAB

Starting MATLAB

After logging into your account, you can enter MATLAB by double-clicking on the MATLAB shortcut *icon* (MATLAB 7.0) on your Windows desktop. When you start MATLAB, a special window called the MATLAB desktop appears. The desktop is a window that contains *other* windows. The major tools within or accessible from the desktop are:

- The Command Window
- The Command History
- The Workspace
- The Current Directory
- The Help Browser
- The Start button

When MATLAB is started for the first time, the screen looks like the one .This illustration also shows the default configuration of the MATLAB desktop. You can customize the arrangement of tools and documents to suit your needs. Now, we are interested in doing some simple calculations. We will assume that you have sufficient understanding of your computer under which MATLAB is being run. You are now faced with the MATLAB desktop on your computer, which contains the prompt.

(>>) in the Command Window. Usually, there are 2 types of prompt:
>> for full version
EDU> for educational version

Note: To simplify the notation, we will use this prompt, >>, as a standard prompt sign,
though our MATLAB version is for educational purpose

cos(x)	Cosine	abs(x)	Absolute value
sin(x)	Sine	sign(x)	Signum function
tan(x)	Tangent	max(x)	Maximum value
acos(x)	Arc cosine	min(x)	Minimum value
asin(x)	Arc sine	ceil(x)	Round towards $+\infty$
atan(x)	Arc tangent	floor(x)	Round towards $-\infty$
exp(x)	Exponential	round(x)	Round to nearest integer
sqrt(x)	Square root	rem(x)	Remainder after division
log(x)	Natural logarithm	angle(x)	Phase angle
log10(x)	Common logarithm	conj(x)	Complex conjugate

pi	The π number, $\pi = 3.14159\ldots$
i,j	The imaginary unit i, $\sqrt{-1}$
Inf	The infinity, ∞
NaN	Not a number

USING MATLAB AS A CALCULATOR

As an example of a simple interactive calculation, just type the expression you want to evaluate. Let's start at the very beginning. For example, let's suppose you want to calculate the expression, 1 + 2 £ 3. You type it at the prompt command (>>) as follows,

```
>> 1+2*3
ans = 7
```

You will have noticed that if you do not specify an output variable, MATLAB uses a default variable ans, short for answer, to store the results of the current calculation. Note that the variable ans is created (or overwritten, if it is already existed). To avoid this, you may assign a value to a variable or output argument name.

For example,

```
>> x = 1+2*3
x = 7
```

will result in x being given the value 1 + 2 £ 3 = 7. This variable name can always be used to refer to the results of the previous computations. Therefore, computing 4*x* will result in

```
>> 4*x
ans = 28.0000
```

Before we conclude this minimum session, Table 1.1 gives the partial list of arithmetic operators..

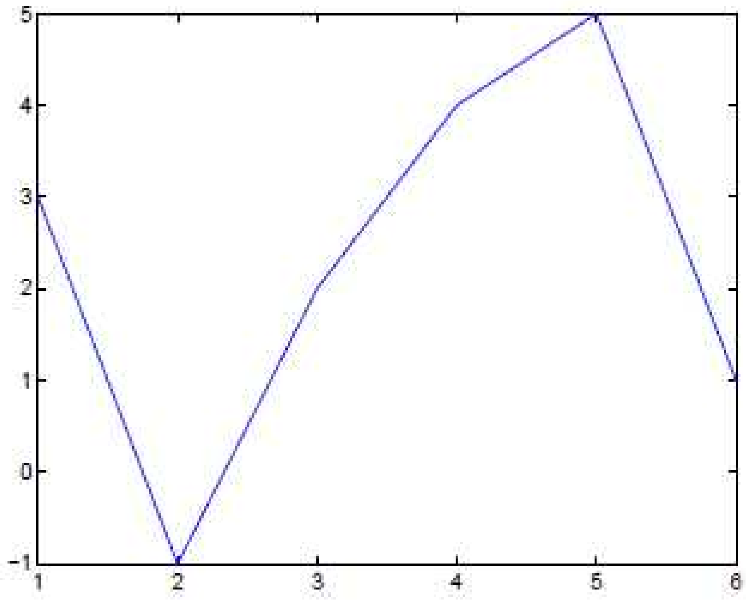
Mathematical functions

MATLAB offers many predefined mathematical functions for technical computing which contains a large set of mathematical functions. Typing help elfun and help specfun calls up full lists of *elementary* and *special* functions respectively. There is a long list of mathematical functions that are *built* into MATLAB. These functions are called *built-ins*. Many standard mathematical functions, such as sin(*x*), cos(*x*), tan(*x*), *ex*, *ln*(*x*), are evaluated by the functions sin, cos, tan, exp, and log respectively in MATLAB.

Basic plotting

Overview

MATLAB has an excellent set of graphic tools. Plotting a given data set or the results of computation is possible with very few commands. You are highly encouraged to plot mathematical functions and results of analysis as often as possible. Trying to understand mathematical equations with graphics is an enjoyable and very efficient way of learning mathematics. Being able to plot mathematical functions and data freely is the most important step, and this section is written to assist you to do just that.



Plot for the vectors x and y

```
>> x = 0:pi/100:2*pi;
>> y = sin(x);
>> plot(x,y)
```

Creating simple plots

The basic MATLAB graphing procedure, for example in 2D, is to take a vector of *x*-coordinates, x = (*x*1*; : : : ; xN*), and a vector of *y*-coordinates, y = (*y*1*; : : : ; yN*), locate the points (*xi; yi*), with *i* = 1*;* 2*; : : : ; n* and then join them by straight lines. You need to prepare *x* and *y* in an identical array form; namely, *x* and *y* are both row arrays or column arrays of the *same* length.

The MATLAB command to plot a graph is plot(x,y). The vectors x = (1*;* 2*;* 3*;* 4*;* 5*;* 6) and y = (3*;*¡1*;* 2*;* 4*;* 5*;* 1) produce the picture shown in Figure 2.1.

```
>> x = [1 2 3 4 5 6];
>> y = [3 -1 2 4 5 1];
>> plot(x,y)
```

Note: The plot functions has different forms depending on the input arguments. If y is a vector plot(y)produces a piecewise linear graph of the elements of y versus the index of the elements of y. If we specify two vectors, as mentioned above, plot(x,y) produces a graph of y versus x.

For example, to plot the function sin (*x*) on the interval [0*;* 2¼], we first create a vector of *x* values ranging from 0 to 2¼, then compute the *sine* of these values, and finally plot the result:

Notes:

0:pi/100:2*pi yields a vector that

- starts at 0,
- takes steps (or increments) of ¼=100,
- stops when 2¼ is reached.

If you omit the increment, MATLAB automatically increments by

PROGRAM:

```
clc;
clear all;
n=1:1:360;
r=n*pi/180;
figure(1);
t=sin(r);
polar(r,abs(t));
title('source pattern(broadside array)');
figure(2);
m=4;
for i=1:360;
   l(i)=1/m*(sin(m*pi/2*cos(r(i)))/sin(pi*cos(r(i))/2));
end
polar(r,abs(l));
title('(array pattern(broad side array)');
x=t.*1;
figure(3);
polar(r,abs(x));
title('radiation pattern(broadside array)');
n=1:1:360;
r=n*pi/180;
figure(4);
t=cos(r);
polar(r,abs(t));
title('sourcepattern(endfire array)');
figure(5);
m=4;
for i=1:360;
   l(i)=1/m*(sin(m*pi/2*sin(r(i)))/sin(pi*sin(r(i))/2));
end
polar(r,abs(l));
title('(array pattern(endfire array)');
x=t.*1;
figure(6);
polar(r,abs(x));
title('radiation pattern(endfire array)');
```

RADIATION PATTERN OF DIPOLE ANTENNA

Ex.No.11

Date:

AIM:

To simulate Broadside array, End-Fired array of Dipole Antenna and to plot the Radiation pattern using MATLAB7.0.

APPARATUS REQUIRED:

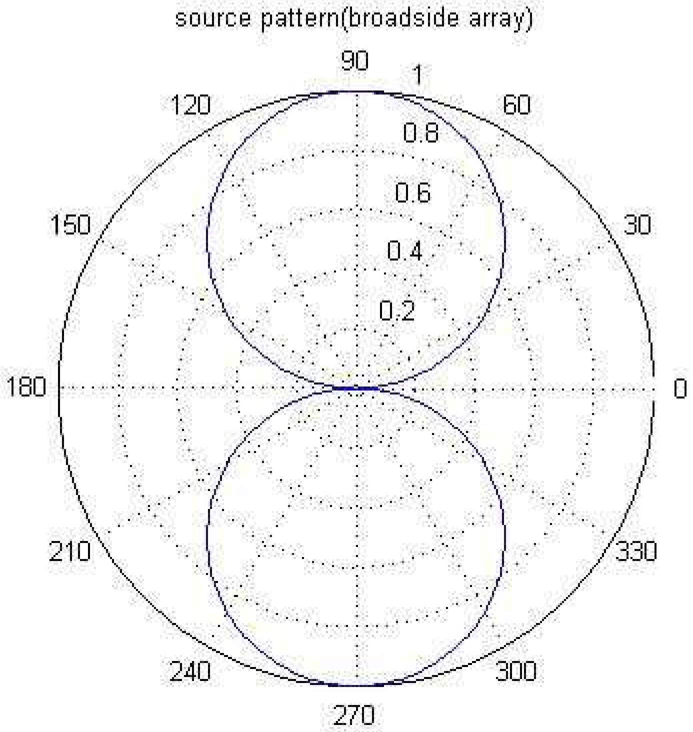
P.C with MATLAB7.0. software

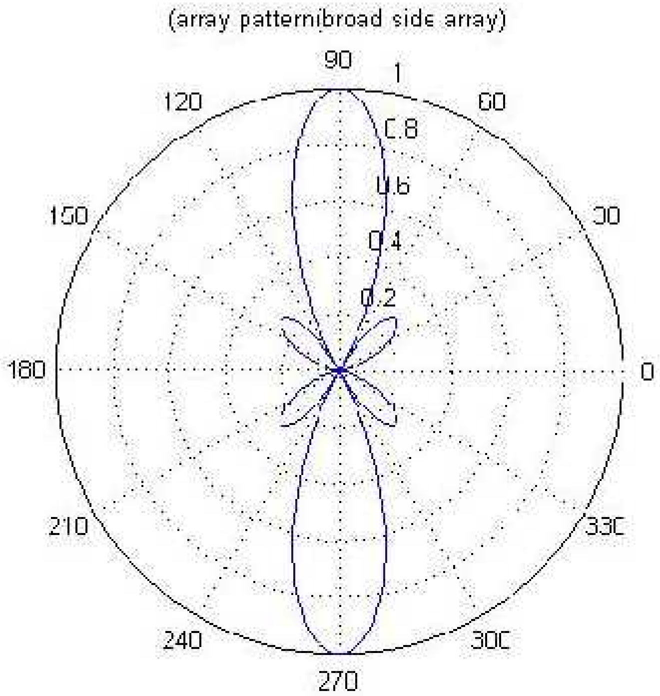
THEORY:

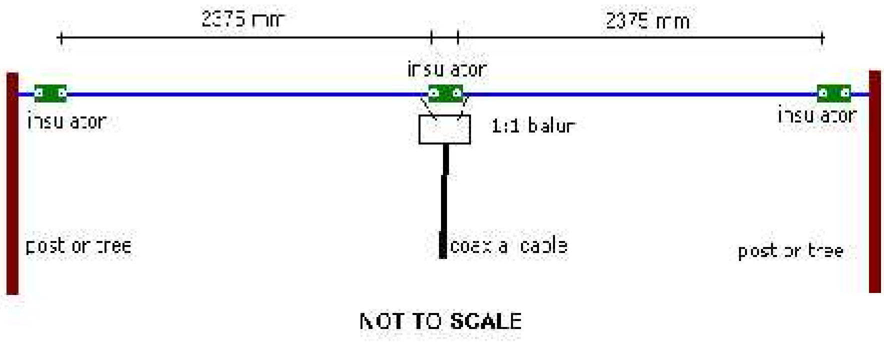
In radio and telecommunications a dipole antenna or double is the simplest and most widely used class of antenna. It consists of two identical conductive elements such as metal wires or rods, which are usually bilaterally symmetrical. The driving current from the transmitter is applied, or for receiving antennas the output signal to the receiver is taken, between the two halves of the antenna. Each side of the feed line to the transmitter or receiver is connected to one of the conductors. This contrasts with a monopole antenna, which consists of a single rod or conductor with one side of the feed line connected to it, and the other side connected to some type of ground. A common example of a dipole is the "rabbit ears" television antenna found on broadcast television sets.

The most common form of dipole is two straight rods or wires oriented end to end on the same axis, with the feed line connected to the two adjacent ends. This is the simplest type of antenna from a theoretical point of view. Dipoles are resonant antennas, meaning that the elements serve as resonators, with standing waves of radio current flowing back and forth between their ends. So the length of the dipole elements is determined by the wavelength of the radio waves used. The most common form is the half-wave dipole, in which each of the two rod elements is approximately 1/4 wavelength long, so the whole antenna is a half-wavelength long. The radiation pattern of a vertical dipole is unidirectional it radiates equal power in all azimuthal directions perpendicular to the axis of the antenna. For a half-wave dipole the radiation is maximum, 2.15 dB perpendicular to the antenna axis, falling monotonically with elevation angle to zero on the axis, off the end of the antenna.

Several different variations of the dipole are also used, such as the folded dipole, short dipole, cage dipole, bow-tie, and batwing antenna. Dipoles may be used as standalone antennas themselves, but they are also employed as feed antennas (driven elements) in many more complex antenna types, such as the Yagi antenna, parabolic antenna, reflective array, turnstile antenna, log periodic antenna, and phased array.


source pattern(broadside array)
90
1
120
60
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270

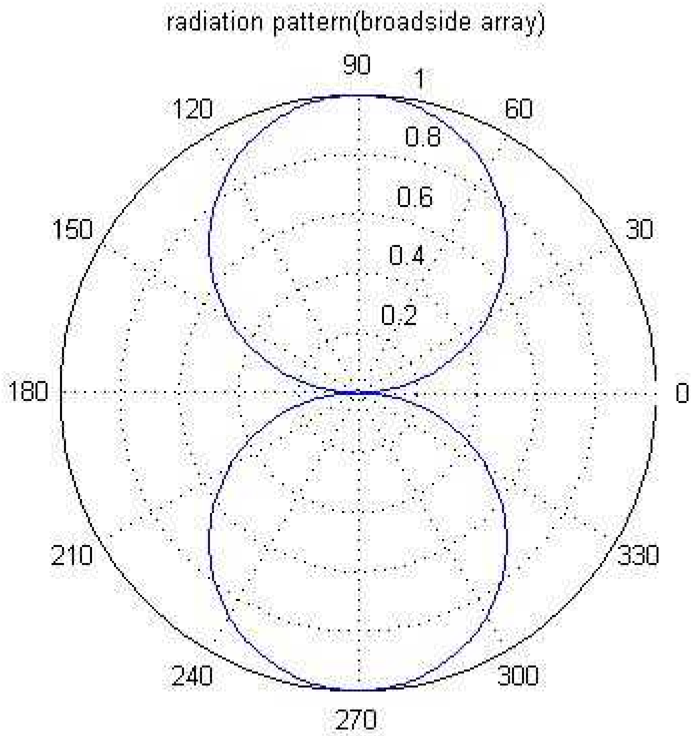

(array patternibroad side array)
90
1
120
60
180
0
210
240
270



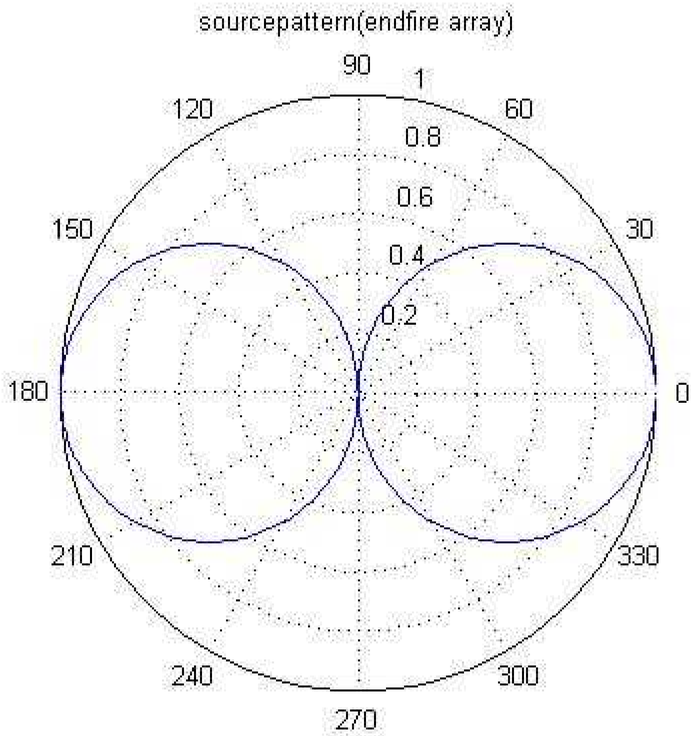
EXAMPLE OF DIPOLE ANTENNA

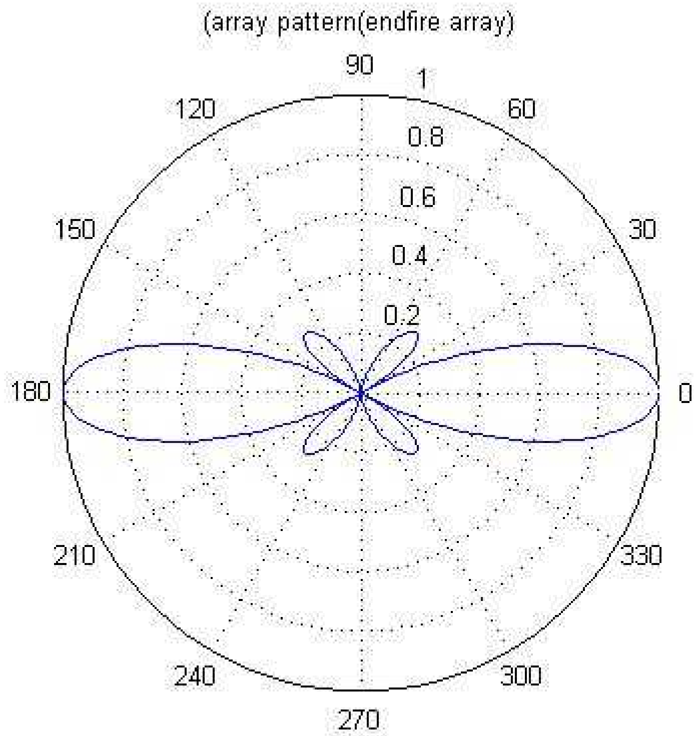
PROCEDURE:

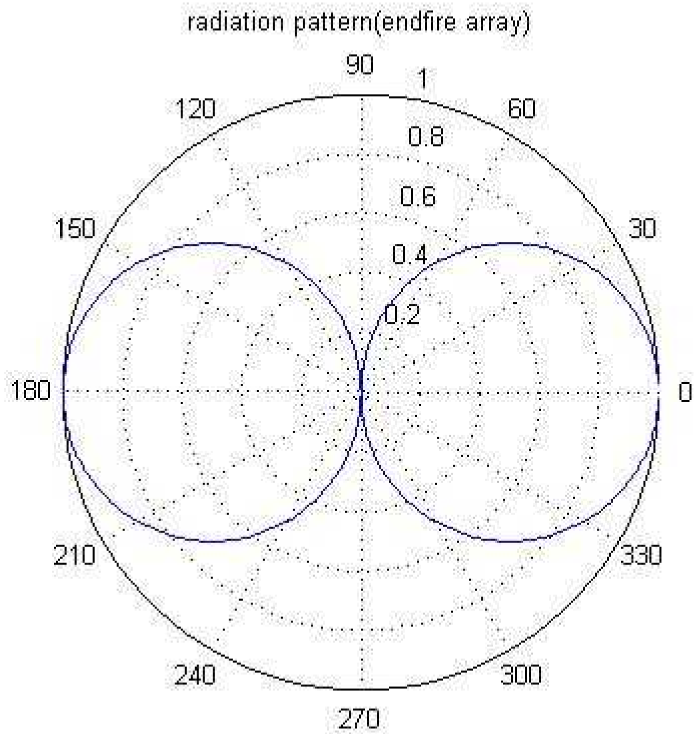
1. Open the installed Matlab 7.0 version.
2. Open a new m-file.
3. Write the program for simulation of dipole antenna
4. Save the file as m-file(.m)
5. Run the progam using command window.
6. Plot the graphs accordingly.


radiation pattern(broadside array)
90
1
120
60
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270

7.


sourcepattern(endfire array)
90
1
120
60
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270


(array pattern(endfire array)
90
1
120
60
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270


radiation pattern(endfire array)
90
1
120
60
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270

RESULT:

Thus, the simulation of Broadside array, End-Fired array and the Radiation pattern of Dipole Antenna using MATLAB7.0 was executed successfully.