

ELECTROMAGNETIC FIELDS & MICROWAVE LABORATORY

COURSE MATERIAL

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**ELECTROMAGNETIC FIELDS AND MICROWAVE
LAB MANUAL**

V SEMESTER B.E (ECE)

(For Private Circulation)



Name :

Reg No :

Lab. Name : ELECTROMAGNETIC FIELDS AND MICROWAVE LAB

**SRI CHANDRASEKHARENDRASARASWATHI VISWA
MAHAVIDYALAYA UNIVERSITY
(Accredited 'A' Grade by NAAC)
Enathur, Kanchipuram – 631561**

**DEPARTMENT OF ELECTRONICS AND COMMUNICATION
ENGINEERING**

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AIM & OBJECTIVES:

- ❖ To understand the principle of Electric field and Magnetic field on various conductors.
- ❖ 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

1. SYLLABUS

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

2. EXPERIMENTS OFFERED BY THE DEPARTMENT

Microwave Engineering

1. Determine the Frequency, Guided Wavelength and Propagation Constant for a Rectangular Waveguide operating in TE_{10} mode.
2. Determine the Standing wave ratio(S) and Reflection coefficient (K) for the given Matched load, Movable Short and 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.

3. INDEX

S.No	Date of completion	Name of the experiment	Page no	Mark/Grade	Staff Sign
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4. 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

5. 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.

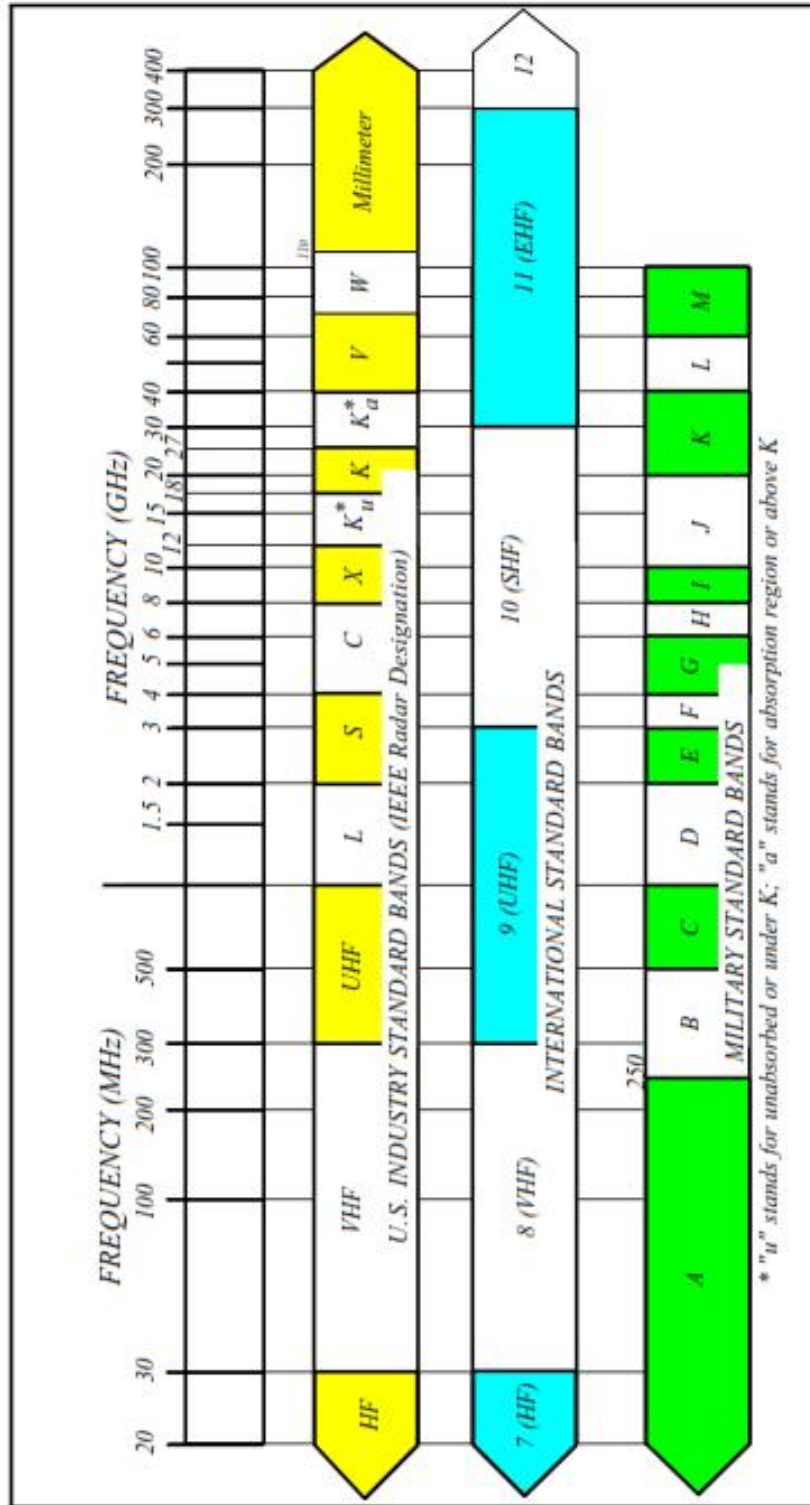
3. Your work must be original and prepared independently. However, if you need any guidance or have any questions or problems, please do not hesitate to approach your staff in charge during working hours. The students should follow the dress code in the Lab session.

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.

6. EXPERIMENTS IN MICROWAVE ENGINEERING

The Microwave Spectrum



Frequency Band Designations

STUDY OF MICROWAVE COMPONENTS

AIM

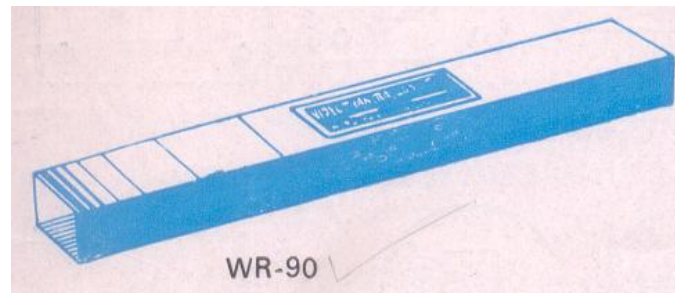
To study the microwave components in detail.

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

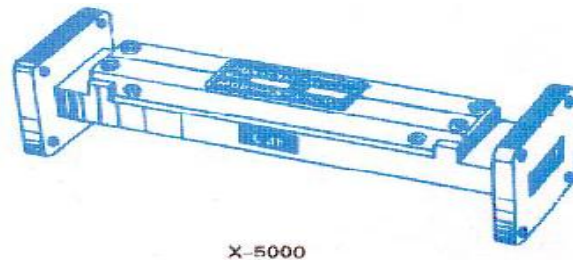
Frequency : 8.2 - 12.4 GHZ

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

Height : 1.27cm \pm Tol. (μ m) : 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/Calibration Accuracy : \pm 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

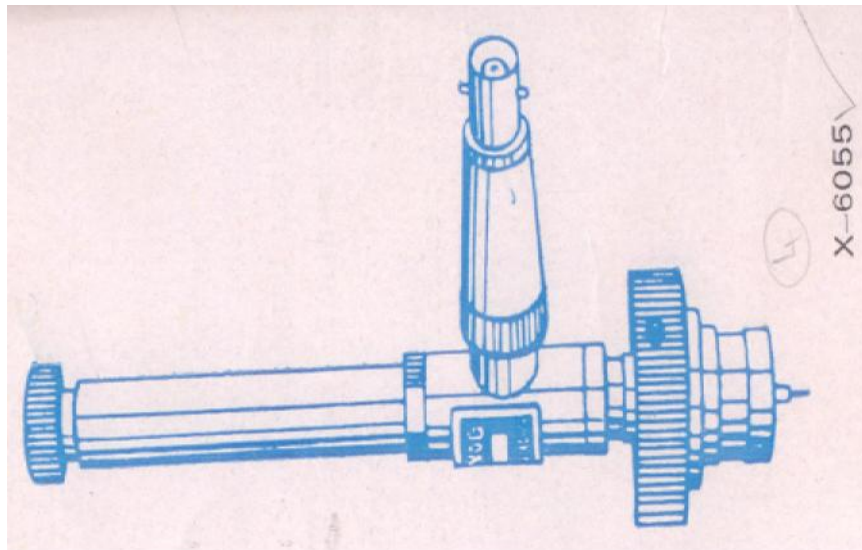
Flange Type (UG-/U) : 39

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.

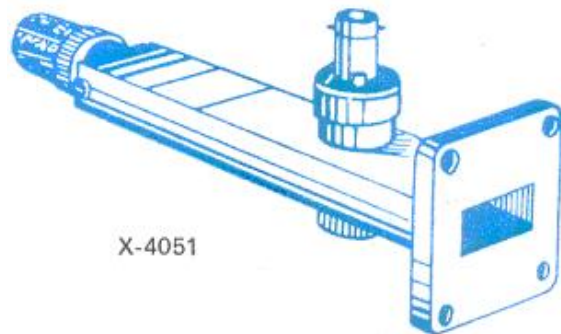
Model No. : X - 4051

Freq. Range (Ghz) : 8.2 - 12.4

O/P Connector : BNC (F)

Wave guide type (WR-) : 90

Flange Type (UG/U) : 39



Detector : IN23

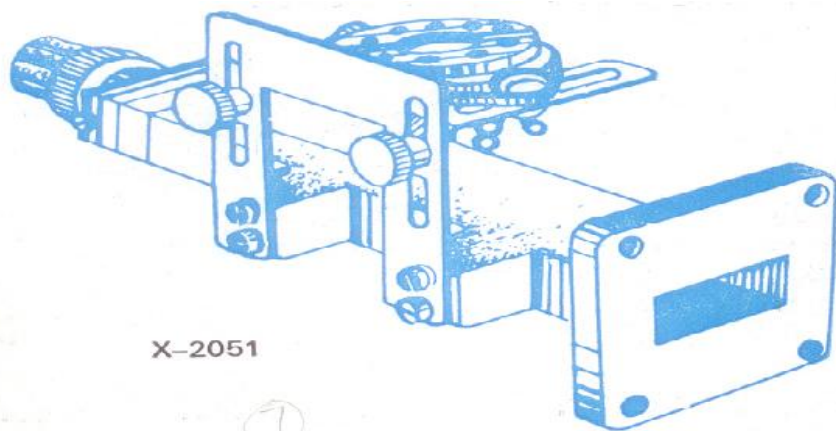
KLYSTRON MOUNT

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.

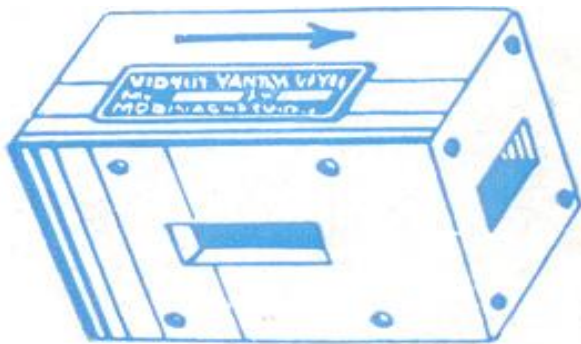
Model No. : X - 6021

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

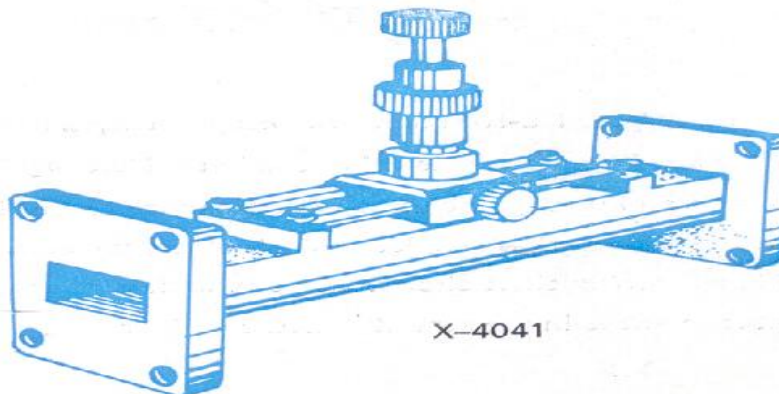
SLIDE SCREW TUNERS

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

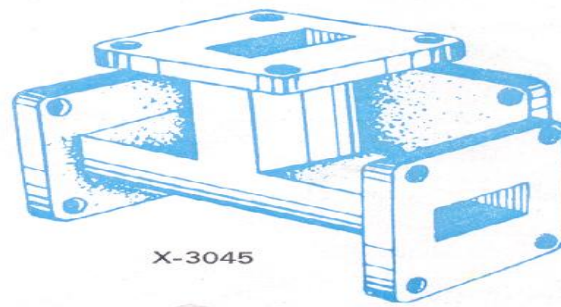
Model 3061 E - plane tee are series type T - junction and consists of three section of wave guide joined together in order to divide or compare power levels. The signal entering the first port of this T - junction will be equally dividing at second and third ports of the same magnitude but in opp. phase

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

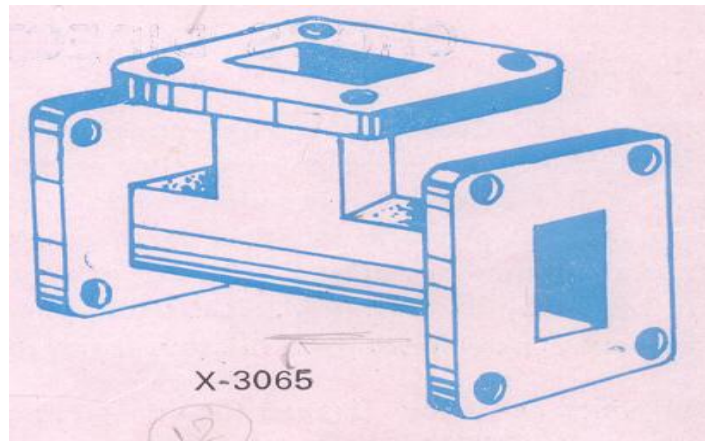
Model 3065 H - Plane Tee are shunt type T - junction for use in conjunction with VSWR meters, frequency - meters and other detector devices. Like in E-plane tee, the signal fed through first port of H - plane Tee will be equally divided in magnitude at second and third ports but in same phase.

Model No. : X - 3065

Frequency Range (GHz) : 8.2 - 12.4

WG Type (WR-) : 90

Flange Type (UG-/U) : 39



MAGIC TEE

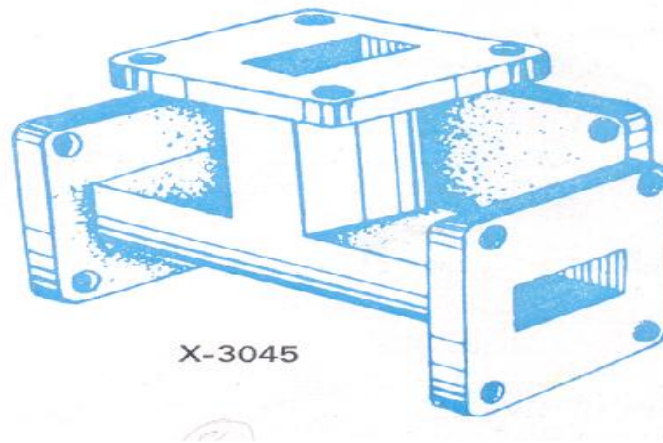
Model 3045 E - H Tee consists of a section of wave guide in both series and shunt wave guide arms, mounted at the exact midpoint of main arm. Both ends of the section of wave guide and both arms are flanged on their ends. These Tees are employed in balanced mixers, AFC circuits and impedance measurement 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

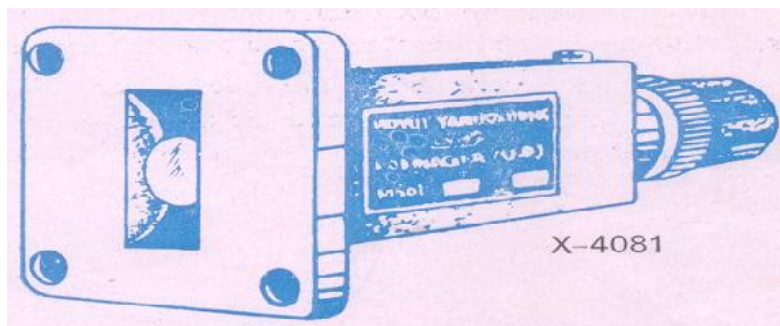
Model 4081 movable shorts consists of a section of waveguide, flanged on one end and terminated with a movable shorting plunger on the other end. By means of this noncontacting type plunger, a reflection coefficient of almost unity may be obtained.

Model No. : X - 4081

Frequency Range (GHz) : 8.2 - 12.4

WG Type (WR-) : 90

Flange Type (UG-/U) : 39

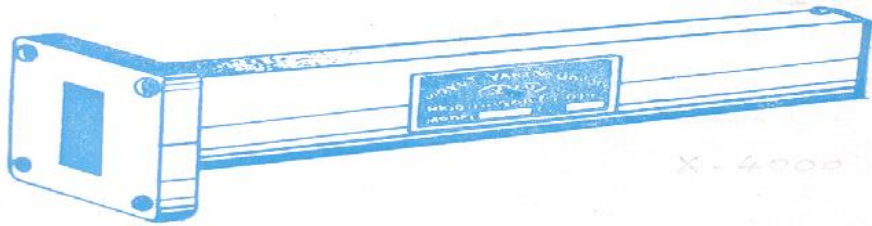


MATCHED TERMINATION

Model 4000 are low power and non-reflective type of terminations. It consists of a small and highly dissipative 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.

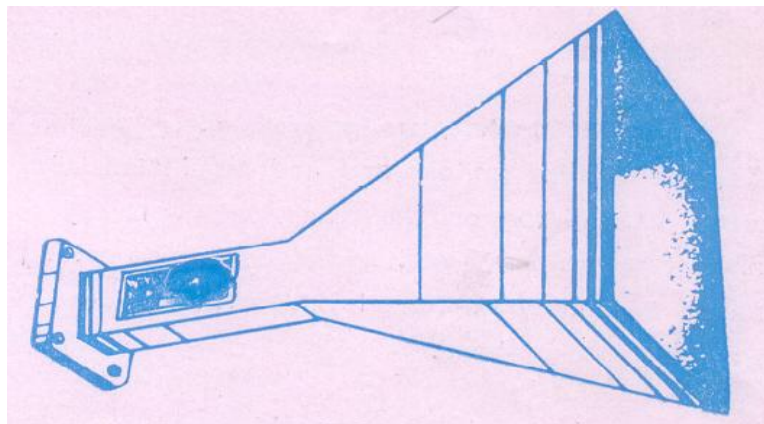
Model No. : X - 5041

Frequency Range (Ghz) : 8.2 - 12.4

Max VSWR : 1.20

WG Type (WR-) : 90

Flange Type (UG-/U) : 39

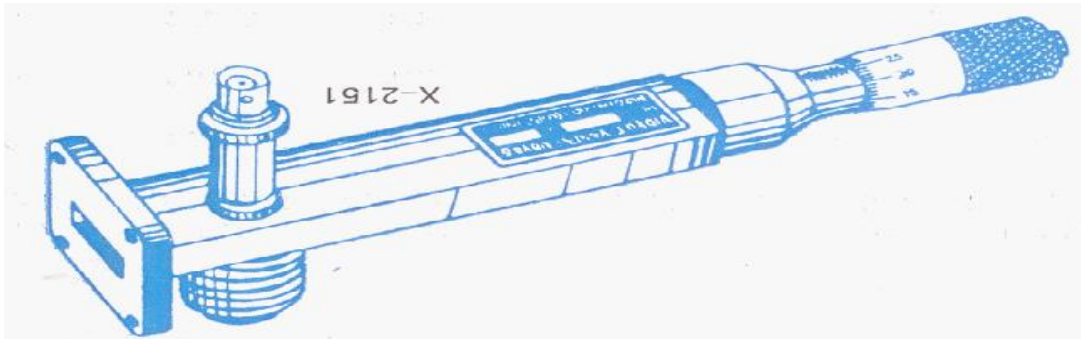


GUNN OSCILLATORS

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.

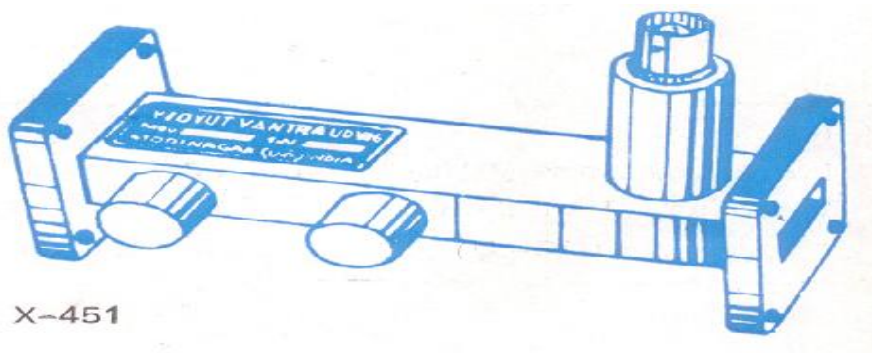
Model No. : X - 451

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

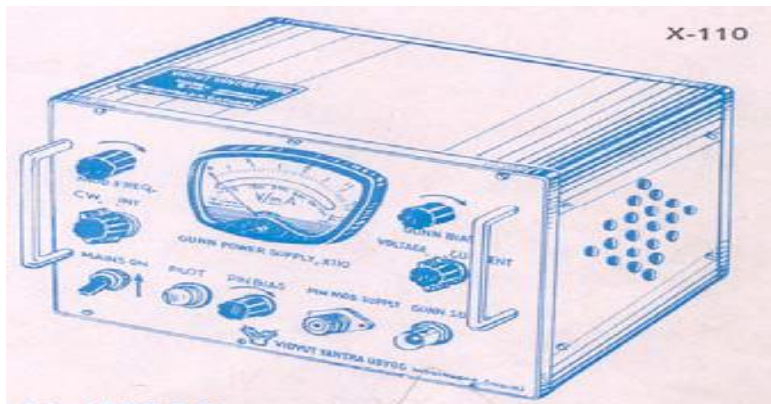
Frequency : 1000 Hz \pm 2%

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

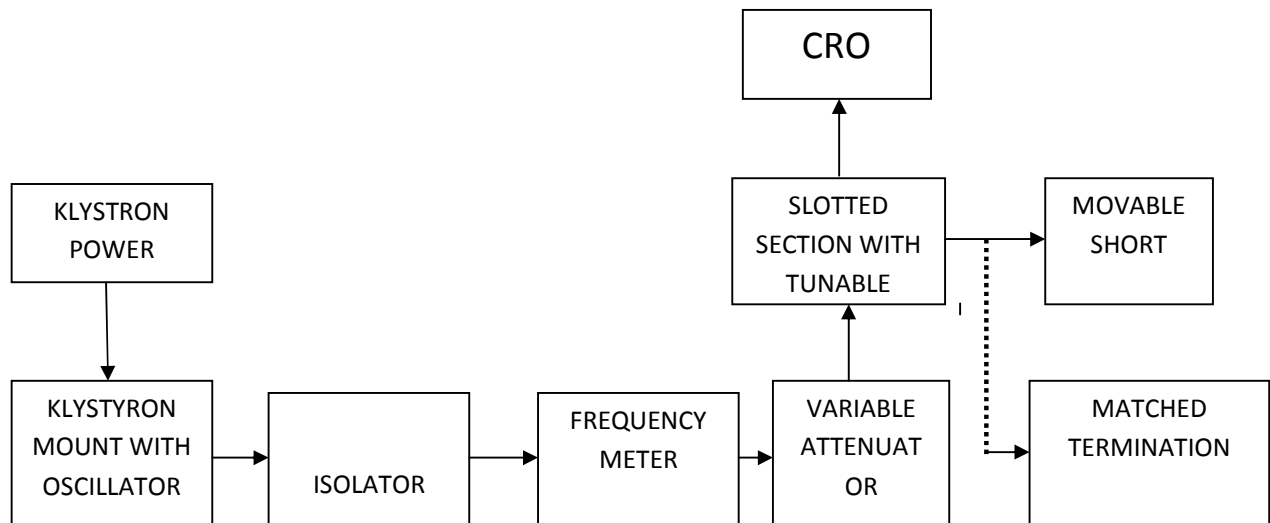


X-6021

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

g is calculated from slotted section line $g/2 = (d_1 - d_2)$

a = dimension of the waveguide = 22.86mm

$$\beta = 1/[(1/g)^2 + ((1/a)^2)^{1/2}]$$

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

$$c = f/\beta$$

MESUREMENT OF FREQUENCY AND WAVELENGTH

Ex.No.1

Date:

AIM

To determine the frequency and wavelength in a rectangular waveguide working on TE₁₀ mode

APPARATUS REQUIRED

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

THEORY

For dominant TE₁₀ mode in rectangular waveguide λ_0 , λ_g , λ_c are related as below.

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

λ_0 = Free space wavelength

λ_g = guide wavelength

λ_c = cut off wavelength

For TE₁₀ mode $\lambda_c = 2a$ 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	$g/2$	$1/\theta$	$f = c/\lambda$

PROCEDURE

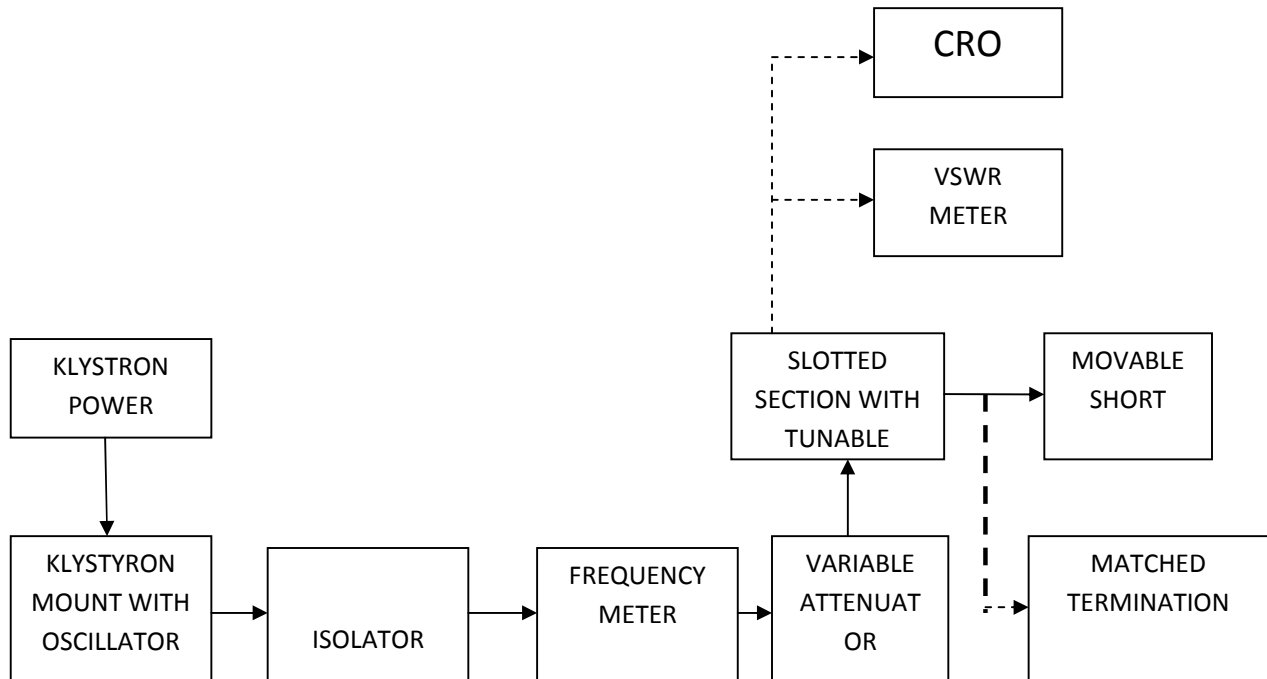
1. Set up the variable components and requirements
2. Setup variable attenuation at minimum attenuation
3. Keep the control knobs of VSWR meter as shown in figure
 - Input switch - crystal load impedance
 - Meter switch – normal position
 - Gain – mid position
4. Keep the control knob of a klystron power 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

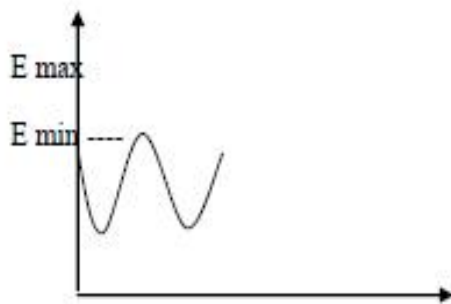


Fig.4.2(a) Standing wave

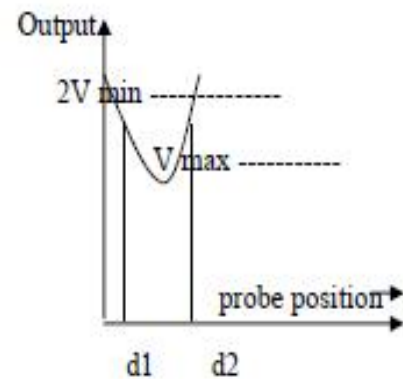


Fig.4.2(b) Double_minima method

Calculations:

$$d_1 = \text{___ cm}$$

$$d_2 = \text{___ cm}$$

$$\lambda_g = 2(d_1 - d_2)$$

Low and medium VSWR = $S = \text{___}$

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

High VSWR:

$$d_3 = \text{___ cm}$$

$$d_4 = \text{___ cm}$$

High VSWR = $S = \text{___}$

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 1.0" 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 of 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 g .
8. Compute SWR from the following equation:

$$\text{SWR} = g / (d_1 - d_2)$$

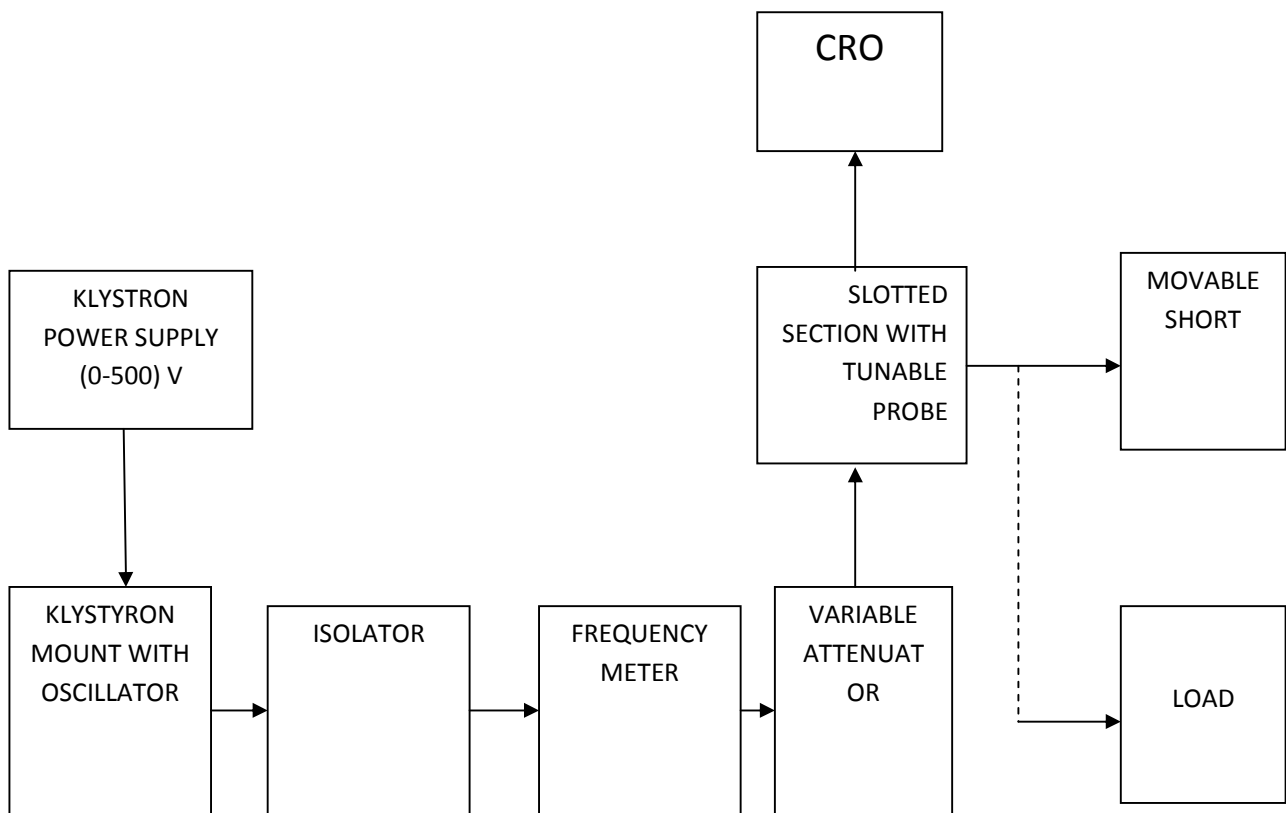
TABULATION

S.N	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, Horn 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 Z_L of a load can be measured by measuring the phase angle θ_L of the complex reflection coefficient K_L from the distance of first voltage standing wave minimum d_{min} and the magnitude of the same from the VSWR(S).

Load impedance $Z_L = Z_0 \times \frac{(1+K_L)}{(1-K_L)}$

Normalized impedance $Z_L' = Z_L / Z_0 = \frac{(1 - jSL \tan(\beta l))}{(SL - j \tan(\beta l))}$

Reflection co-efficient $K_L = \frac{I_{KL}}{I} e^{j\theta_L}$

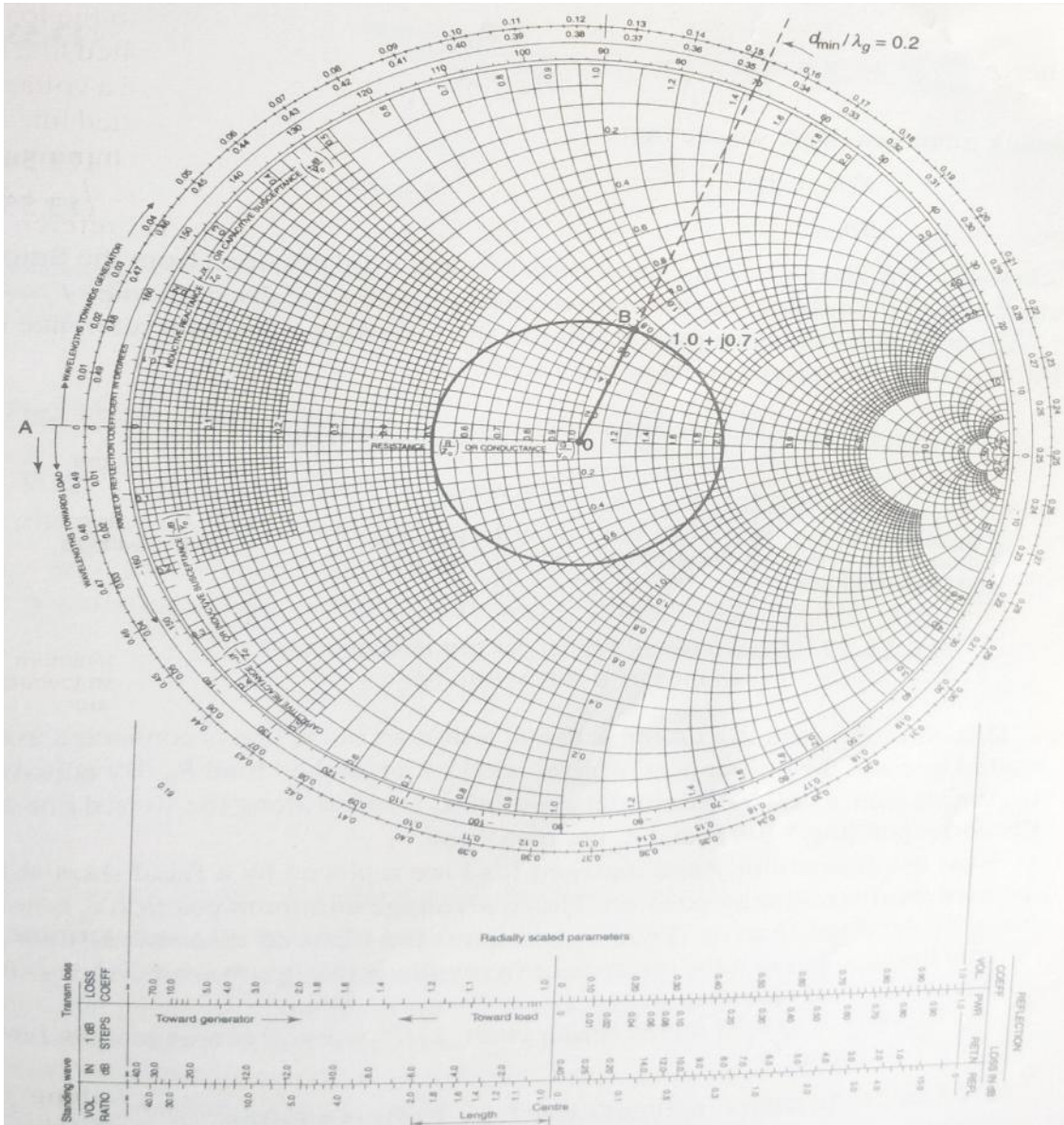
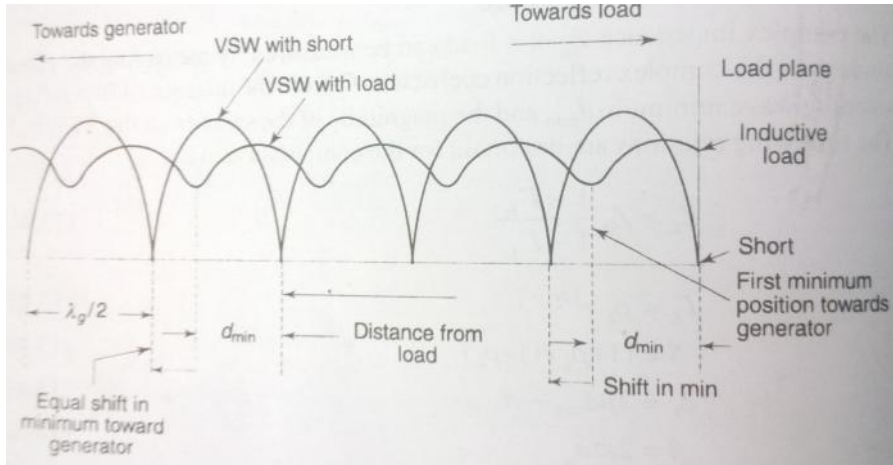
Where $\frac{I_{KL}}{I} = \frac{(SL - 1)}{(SL + 1)}$

$L = 2 d_{minshift} -$

$= 2 \lambda / g$

$g = 2d = 2(dmzsc1 - dmzsc2)$

$l = d_{minshift} / g$



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

1. Measure the load VSWR (S_L) to find Γ_L
2. Measure the distance d between the two successive voltage minima 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 $\angle \Gamma_L$ of the load is calculated using β 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 close 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 $\lambda_g / 2$, the load reference plane can be shifted to a convenient minimum position near the center of the slotted line. The d_{min} 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 S_L and d_{minshift} as follows, where load VSWR $S_L = 2$ and $d_{\text{minshift}} / \lambda_g = 0.2$ say.

1. Draw the VSWR circle centered at 0 ($r = 1$) with radius cutting $r <$ axis at S_L .
2. Move anti clockwise from the short circuit load point A on the chart along the wavelengths towards load scale by distance ($L = d_{\text{minshift}} / \lambda_g$) to Band joint points O & B as line OB .:
3. The point of intersection between the line DB and the S_L circle gives the normalized load $Z'_L = Z_L / Z_0$ and hence the complex load $Z_L = Z_0 \times Z'_L$ 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:

$$V_{\max}: \quad V_{\min}: \quad d_{mz1}:$$

WITH MOVABLE SHORT:

$$d_{mzsc1}: \quad d_{mzsc2}:$$

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

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

$$d_{\text{minshift}} = (d_{mz1} \sim d_{mzsc1}):$$

Calculation of Z_0 :

$$Z_0 = Z_0 (\text{in free space}) / ((1 - \rho/c)^2)^{1/2}$$

where

$$Z_0 = 120X = 377$$

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

Now Z_0 :**USING SMITH CHART:**

$$l = d_{\text{minshift}} / g:$$

From Chart (Point B Is):

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

$$|Z_L / Z_0| = (R^2 + (jX)^2)^{1/2}:$$

$$Z_L = \text{---} X Z_0$$

USING SLOTTED LINE METHOD:

$$= 2 / g:$$

$$l = d_{\text{minshift}} / g:$$

$$Z_L' = Z_L / Z_0 = (1 - jS_L \tan(\quad)) / (S_L - j \tan(\quad)):$$

$$|Z_L'| = |Z_L / Z_0| = (R^2 + (jX)^2)^{1/2}:$$

Therefore $|Z_L|$ 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 & Horn 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_{MZSC1} and d_{MZS2} . Hence $g = 2X (d_{MZSC1} - d_{MZS2}) = 2d$.
17. Calculate $L = d_{MSHIFT} / g$
18. Find out the normalized impedance Z/L using Smith Chart as described in theory section.

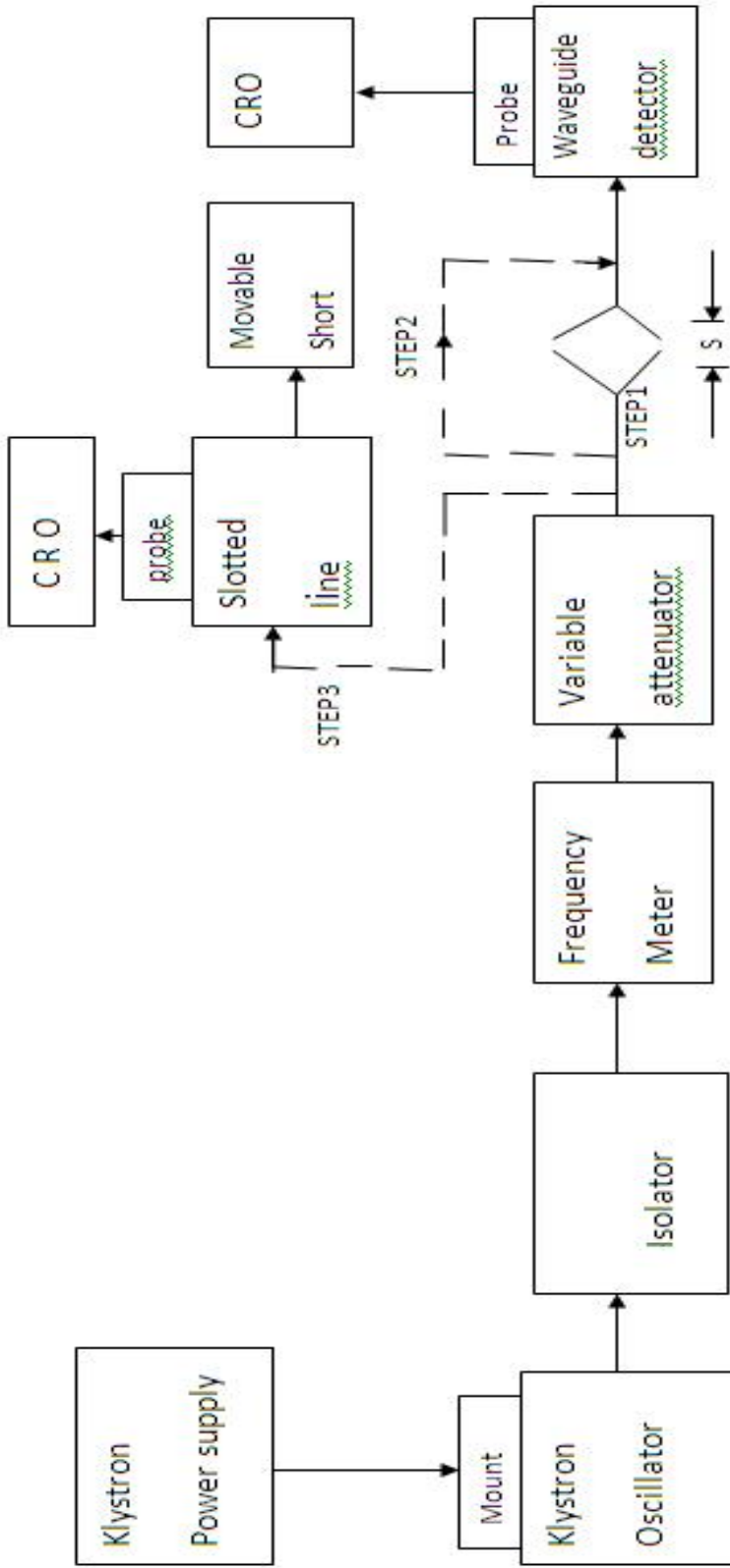
g

RESULT:

Thus the unknown impedance was measured.

Impedance of load (ZL) using slotted line method:

Impedance of load (ZL) using Smith Chart :



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.

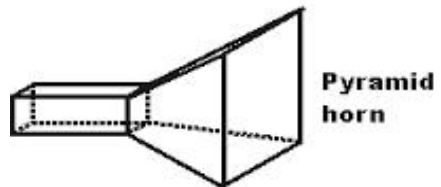
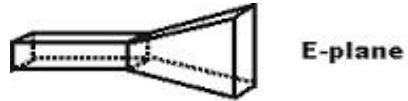
Apparatus required:

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

Theory:

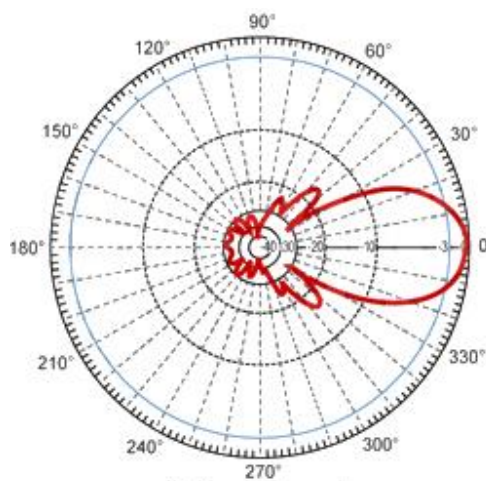
A Horn Antenna may be regarded as flared out (or opened out) wave guide. The function of the Horn is to produce a uniform phase front with a larger aperture than that of the wave-guide and hence greater directivity. The transition region of Horn between the wave-guide at the throat and free space and 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 TE₁₀ 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/m it is called field strength pattern: If 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.

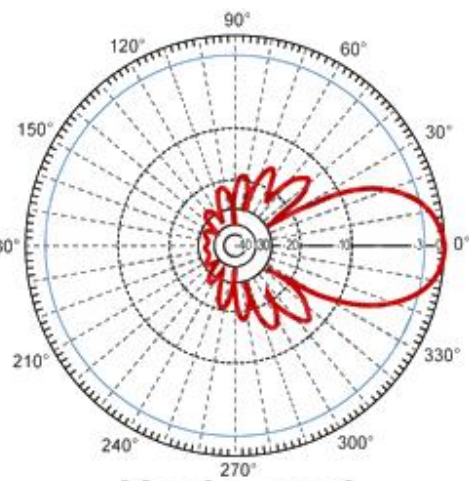


Radiation

Pattern



Vertical



Horizontal

HALE-POWER BEAM BANDWIDTH:

The Half power points are the points in the radiated field pattern, where the field reduces to $1/\sqrt{2}$ times its maximum value (i.e., power becomes $1/2$). 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 gain of the antenna.

The Directivity of the antenna: $D(\theta, \phi)$ is defined as the ratio of maximum radiation intensity along this particular direction to the average radiation intensity. The Power Gain:

$G(\theta, \phi)$ is defined as the product of the Directivity and Efficiency of the antenna.

$$G(\theta, \phi) = D(\theta, \phi) \eta$$

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

1. All Antennas meet the far-field criteria: $S \geq 2(0.2) / \lambda$ where, D - size of horn aperture; λ -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.
5. 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.

$$P_r = P_t \left[\frac{G_1 G_2}{4 \pi S^2} \right] \text{ where}$$

P_r - Received power; P_t - Transmitted Power; G_1, G_2 - Gain of Transmitting and receiving antennas S is to the radial distance between two antennas and λ -free space wavelength; If both transmitting and receiving antenna are identical having a gain G then,

$$P_r = \left\{ P_t \left[\frac{G^2}{4 \pi S^2} \right] \right\}$$

$$G = (4 \pi S) \times \left(\frac{P_r}{P_t} \right)^{1/2}$$

$$= (4 \pi S) \times \left(\frac{V_r/V_t}{\lambda} \right)^{1/2}$$

$$G = (4 \pi S) \times \left(\frac{V_r/V_t}{\lambda} \right)$$

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.

$$D_o = 41,253 I (SE \cdot 9H) \text{ or } 72,815 / (e2E + 92H)$$

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 ($V_r/V_r@(\)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.
5. 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 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 $g = 2(d1-d2)$
12. Measure the waveguide inner broader dimension. 'a' find $c = k-2a$.

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

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 V_T .
14. Now connect transmitter and receiver horns as per setup. with same axis (angle is 0° and note down the voltage an CRO. Let it be V_{R0} .
15. Calculate the gain $G = 20 \log \{ 4715 (V_{R0} / V_T) / \text{to} \}$ in dB.

RADIATION PATTERN MEASUREMENT:-

16. The distance between the two horn antennas should be greater than $(S_{min} = 2D^2 / \lambda)$ and choose

$D = 8\text{cm}$. [don't change any knob in the setup. Turn the receiving horn to the left in terms of 20° or 5° steps up to $40^\circ - 90^\circ$ 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 $(P) = 20 \log(V_R/V_{R0})$ 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 (half-power beam-width θ_{HP} & θ_{3dB}) of the horn antenna.

22. Calculate directivity $D = 4\pi A_e / \lambda^2$

CALCULATIONS:**POLAR PATTERN & DIRECTIVITY:**

Half power Beam bandwidth θ_H :

θ_H :

$$\text{Directivity (D)} = 41,2531 \left(\frac{E}{H} \right)$$

or

$$\text{Directivity (D)} = 72815 / \left(\left(\frac{E}{H} \right)^2 \times \left(\frac{H}{E} \right)^2 \right)$$

Power Gain (G): $20 \log \left(\frac{4 \pi r^2}{\lambda^2} \right) / \left(\frac{V_R}{V_T} \right)$:

Where:

$d_1 =$

$d_2 =$

$$g = 2X(d_2 - d_1)$$

$$c = 2Xa$$

$$\theta_0 = 1 / \left\{ \left(\left(\frac{1}{g} \right)^2 + \left(\frac{1}{c} \right)^2 \right)^{1/2} \right\}$$

$$S_{\min} = 2D^2 / \theta_0$$

D is size of horn antenna

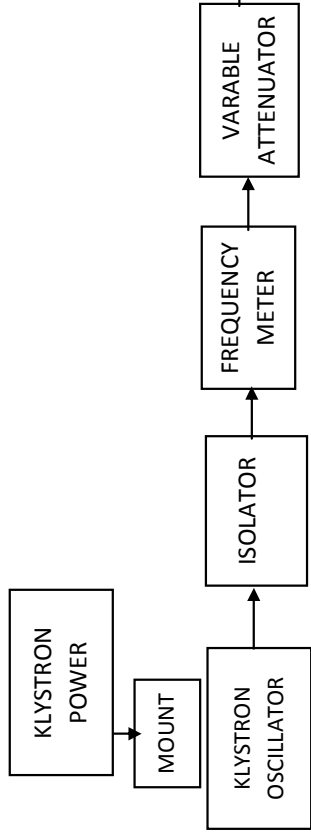
RESULT:

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

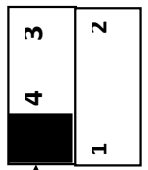
Half power Beam bandwidth θ_{HP} :

Power Gain (G):
Directivity (D):

CHARACTERISTICS OF DIRECTIONAL COUPLER

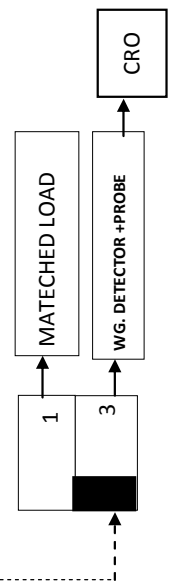


DIRECTIONAL COUPLER WITH A BUILT IN MATCHED TERMINATION

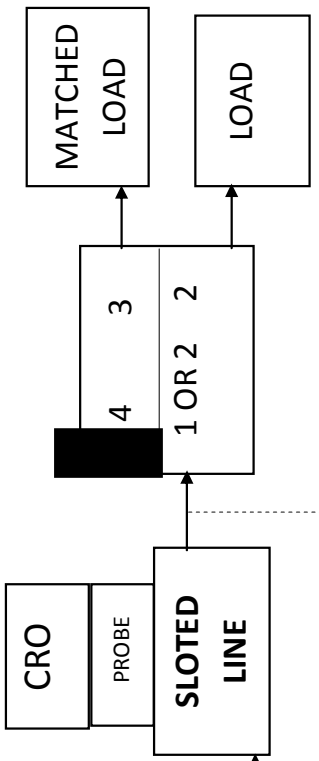


BUILT IN MATCHED LOAD

STEP 6 : MEASUREMENT OF VOLTAGE V32 & DIRECTIVITY



STEP 1 : MEASUREMENT OF MAIN LINE SWR



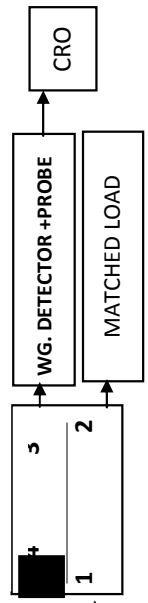
STEP 2 : MEASUREMENT OF AUX LINE SWR



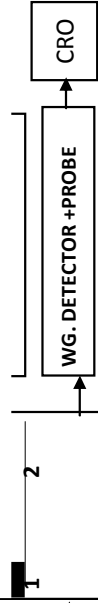
STEP 3 : MEASUREMENT OF INPUT VOLTAGE V1



STEP 4 : MEASUREMENT OF VOLTAGE V31 & COUPLING



STEP 5 : MEASUREMENT OF VOLTAGE V21 & INSERTIONLOSS



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:

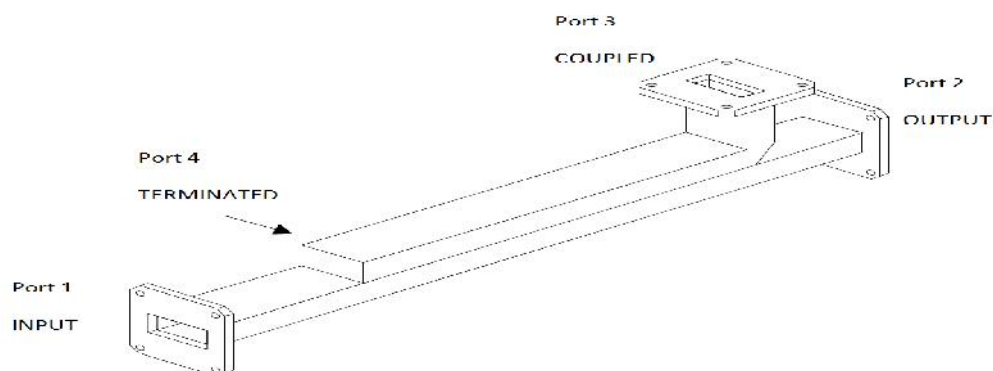
A directional coupler is a device with which it is possible to measure the incident and reflected wave separately. It consists of two transmission line, the main arm and auxiliary arm, electro magnetically coupled to each other. The directional coupler is a microwave passive device that provides a method 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 $\lambda/4$ apart. The upper section of the directional coupler has wedge of energy-absorbing material at one end and a pickup probe connected to an 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 .

COUPLING 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 . -

$$C = 10 \log_{10} P_1/P_3 = 20 \log_{10} V_1/ V_3 \text{ dB where port 4 is terminated}$$

MULTI HOLE DIRECTIONAL COUPLER



Tabular Column

S.NO	DIRECTIONAL COUPLER CONNECTION		V_{max} (mv)	V_{min} (mv)	SWR $S_i =$ $(\frac{V_{max}}{V_{min}})^{1/2}$	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 incident 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 (D) = $10 \log P_{31}/P_{32} = 20 \log V_{31}/V_{32}$ dB

where V_{31} and V_{32} 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.

$I = 10 \log 10 P_1 / P_2 = 20 \log V_1 / V_2$ 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 conservation of energy. Here p is called transmission factor (V_1/V_{21}) & q is the coupling factor (V_1/V_{31})

PROCEDURE:**A. MAIN LINE SWR MEASUREMENT:**

1. Set up the components and equipments as shown in figure-step 1.
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 of voltage minimum and this is called as V_{min} .
5. Calculate the standing wave ratio $S = V_{max} / V_{min}$ 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 called as mainline SWR S_2 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) = $20 \log V_1/V_{31}$ dB	
2	INSERTION LOSS (I) = $20 \log V / V_{21}$ dB	
3	DIRECTIVITY (D) = $20 \log V_{31}/V_{32}$ dB	
4	ISOLATION (IS) = $20 \cdot \log V_1 / V_{41}$. dB	

AUXILIARY LINE SWR MEASUREMENT:

1. 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 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 V_I
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 $20 \log (V_I/V_{31})$ 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 V_I level is set.
8. Record the reading on CRO while inserting the directional coupler as given in step 7.
Let it be V_{21} .

CALCULATIONS :**S-MATRIX 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 $S_{14} = S_{41} = 0$.

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

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

The coupling factor from port 1 and 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 $S_{23} = S_{32} = r$

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

$$\text{Practical S matrix is } \begin{pmatrix} & & & \\ & & & \\ & & & \\ & & & \end{pmatrix}$$

where

$$p = v_1/v_{21}:$$

$$q = v_1/v_{31}:$$

$$r = v_2/v_{32}:$$

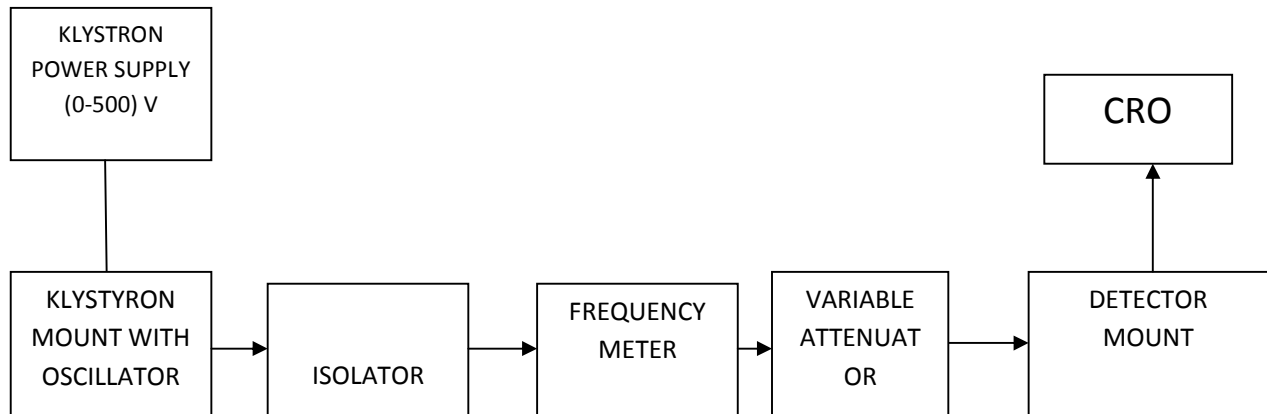
9. Compute insertion loss as $I=20\log V_1/V_2$ dB.
10. For measurement of directivity, connect the directional coupler in opposite direction i.e., port 2 of directional coupler to the variable attenuator, port 3 to wave guide detector and a matched termination should be placed at port 1 as shown in 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 V_u
12. Compute the directivity as $D= 20 \log V_{31}/ V_{32}$ 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 = $\left(\begin{array}{c} \\ \\ \end{array} \right)$

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 interact 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

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

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

(iv) ETS – Electronic tuning sensitivity

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

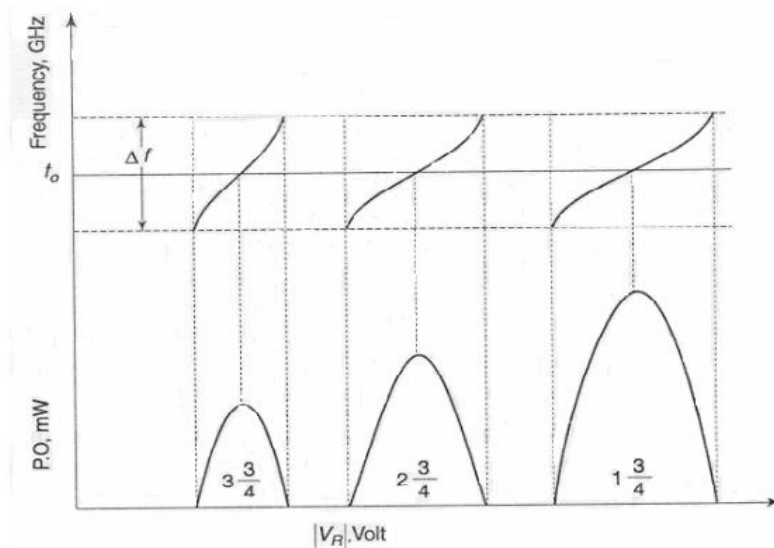
$f_{1\max}, f_{1\min} \rightarrow$ half power frequency

$V_{1\max}, V_{1\min} \rightarrow$ 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 hysteresis 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 detuned 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



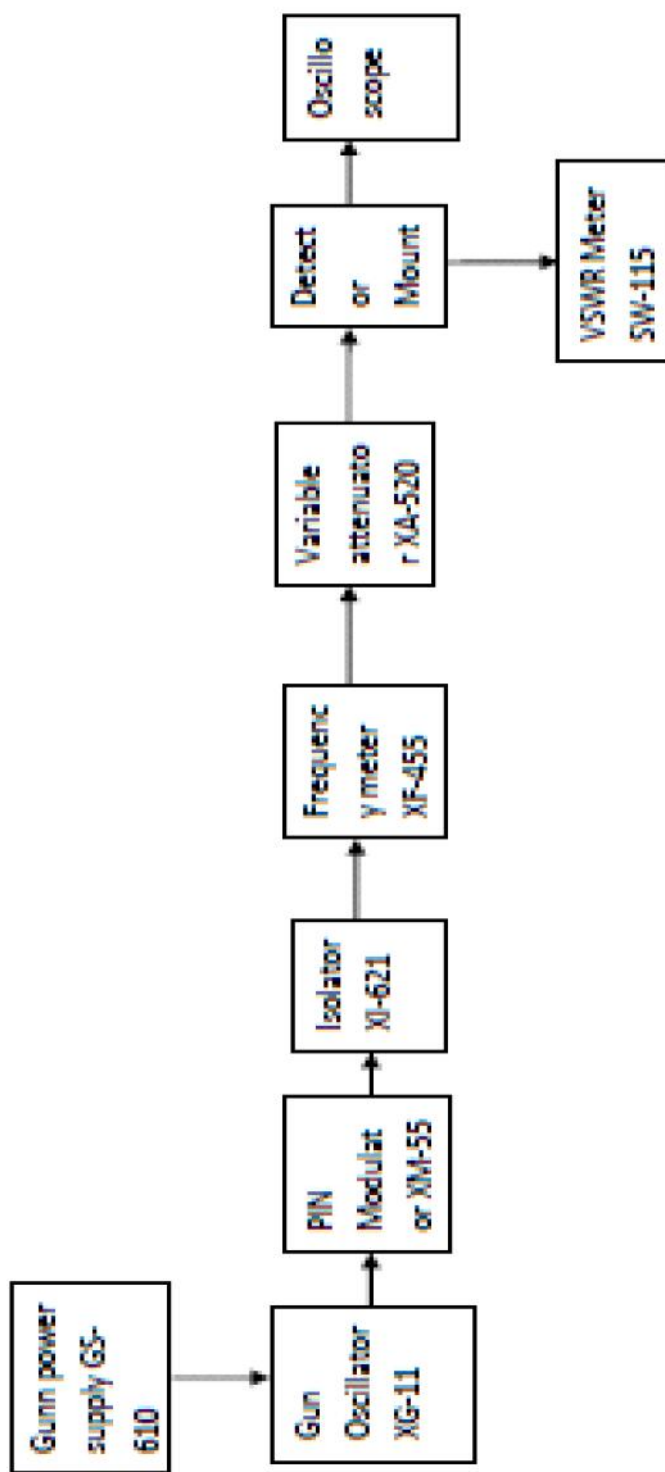
TABULAR COLUMN

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:



GUN DIODE CHARACTERISTICS

Ex.No.7

Date:

AIM:

To Determine the V-I Characteristics, Threshold Voltage and Modulation Depth for the given Gunn 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 exceeds a certain value ($E \approx 3000 \text{ V/cm}$), the current decreases and this becomes 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 jump 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 it 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 (E_g) of the semiconductor.

$$E < E_g \text{ \& } E > 0.026 \text{ eV.}$$

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.

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 and has a typical power dissipation of 1 W and a dc current of 140 mA. Its power output is 25 mW with an efficiency of 2% and frequency oscillation is in the X-band.

PROCEDURE:

- * Set the components and equipments as shown.
- * Initially 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 to 15 Seconds. Reading should be taken as fast as possible. Otherwise due to excessive heating GUNN diode will burn.
- ❖ 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 $P_i = 20 \log V_T(\text{dB})$	Power at A_f $P_f = 20 \log V_T(\text{dB})$	Modulation Depth $P_i - P_f(\text{dB})$

CHARACTERISTICS OF OUTPUT VOLTAGE & 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 0.5V 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 10Y.
- 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 attenuaioir) 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 $P_i = 20 \log (V_i) \text{ db}$; $P_F = 20 \log (V_F) \text{ db}$
- 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.

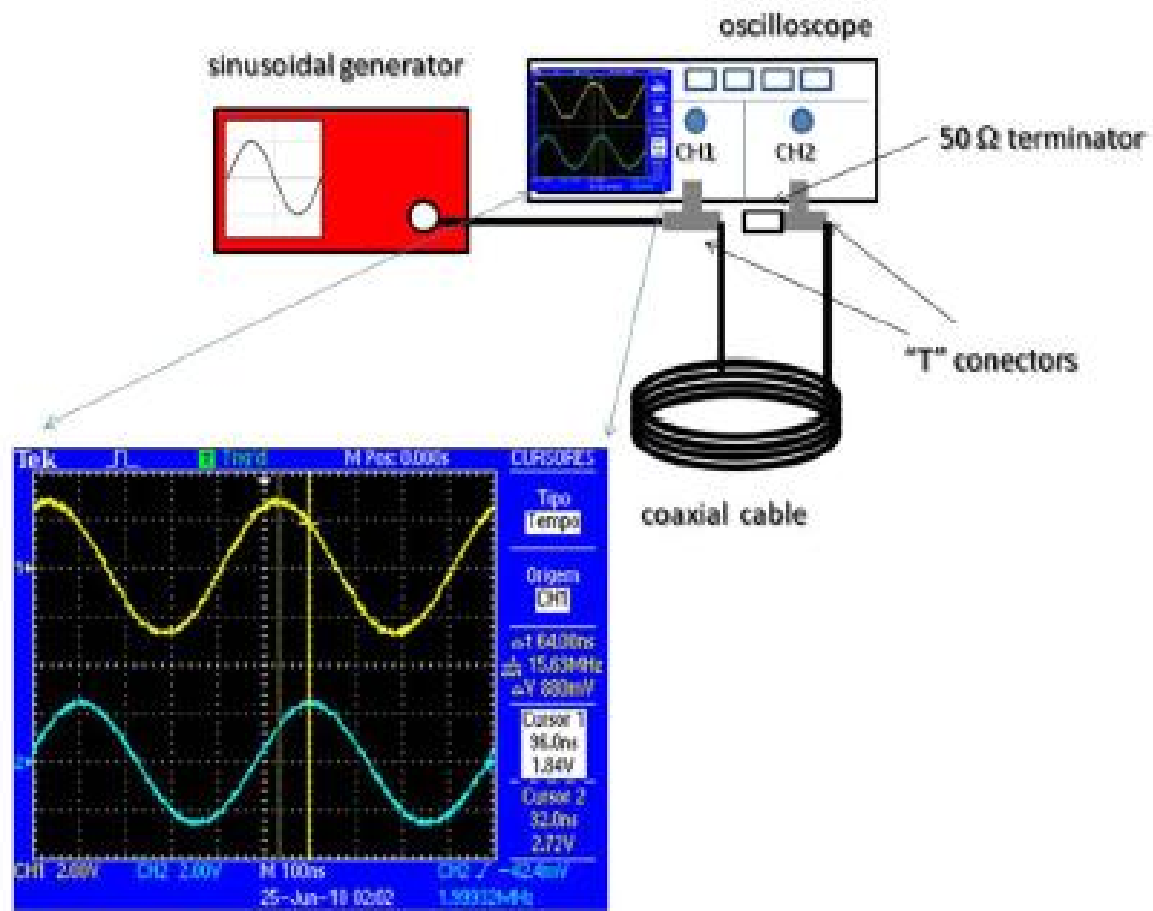
1. Gunn bias V·I characteristic
2. Characteristics of output voltage and frequency as a function of gunn bias voltage
3. Characteristic of square wave modulation through PIN diode and modulation depth was determined.

Threshold Voltage (V_{TH}) :

Pushing Factor (frequency sensitivity) :

Modulation depth :

4



CALCULATIONS:-

$$l = (t_2 - t_1) \cdot c =$$

$$t = (t_1 - t_2) \text{ sec} =$$

Velocity (c) = distance / 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 $c = \frac{d}{t}$

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 (t_1-t_2) (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.

$$l = (l_2-l_1) \text{ m=}$$

$$t = (t_1-t_2) \text{ sec=}$$

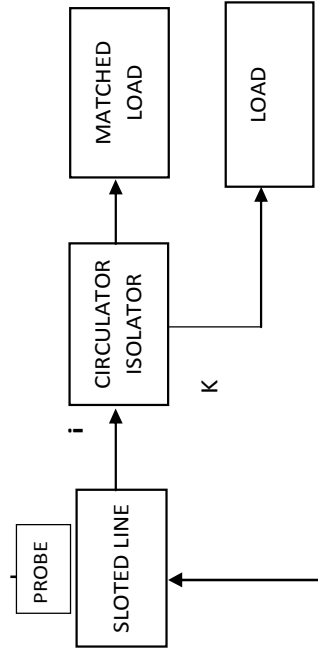
$$\text{Velocity (c) = distance / time}$$

RESULT:

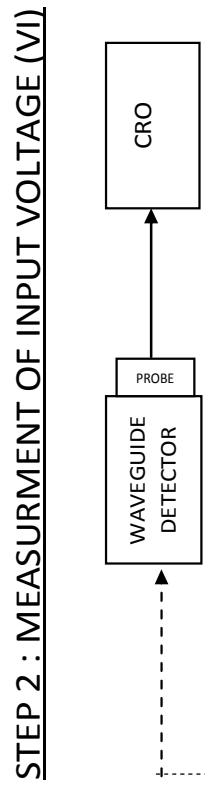
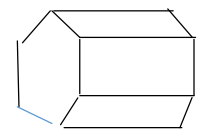
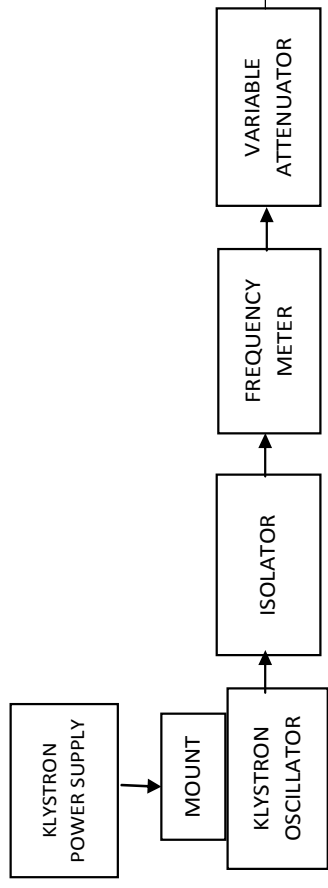
Thus, the velocity of electromagnetic wave in coaxial cable is found:

Velocity (c) :

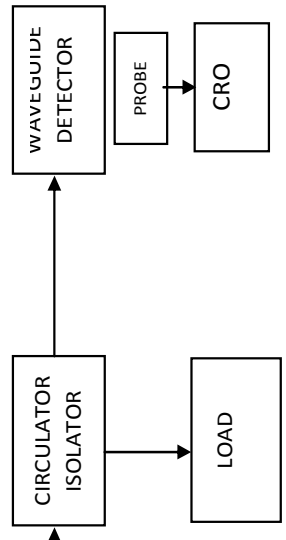
MEASUREMENT OF INSERTION & ISOLATION LOSSES OF ISOLATOR & CIRCULATOR



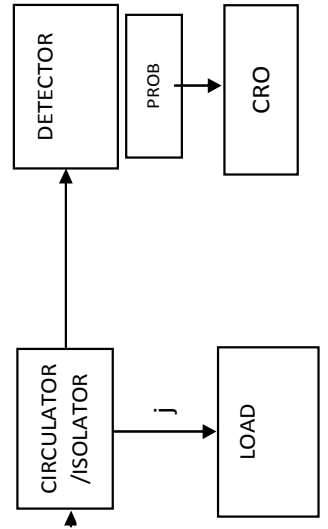
STEP 1 : MEASUREMENT OF INPUT V.S.W.R



STEP 3 : MEASUREMENT OF INSERTION LOSS



STEP 4 : MEASUREMENT OF ISOLATION



MICROWAVE ISOLATOR AND CIRCULATOR.

Ex.No.9

Date:

AIM:

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

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 $\{\mu_r\}$ 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 $(n+1)^{\text{th}}$ 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 $S_i =$ $(\frac{V_{max}}{V_{min}})^{1/2}$	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 $\begin{pmatrix} & \\ & \end{pmatrix}$ S- matrix(circulator) as $\begin{pmatrix} & & \\ & & \\ & & \end{pmatrix}$

S.NO	CONNECTION OF PORTS				I/P VOLTAGE V_i (mv)	FORWARD O/P VOLTAGE V_j (mv)		REVERSE O/P VOLTAGE V_k (mv)		Insertion loss (I_{ij}) $=20 \text{ Log } v_i / (v_j)$ Db	Isolation Loss (I_{ik}) $=20 \text{ Log } v_i / (v_k)$ Db	S= (v_j)or (v_k)/ (v_i)
	INPUT	FORWARD		REVERSE								
	PORT (i) AS INPUT	PORT (j) AS OUTPUT	PORT (K) TO BE MATCHED	PORT (K) AS OUTPUT	PORT (j) TO BE MATCHED							
0	1.	1	2	3	X	X			X		X	
0	2.	1	X	X	3	2		X		X		
1	3.	2	3	1	X	X			X		X	
S	4.	2	X	X	1	3		X		X		
	5.	3	1	2	X	X			X		X	
=	6.	3	X	X	2	1		X		X		

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.

$$\text{Insertion loss} = 10 \log P_i / P_j = 20 \log V_i / V_j \text{ dB. for coupled port.}$$

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 = $10 \log P_i / P_k = 20 \log V_i / V_k$ dB for uncoupled port.

INPUT VSWR:

The input standing wave ratio (S) 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.

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 , $\begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix}$ matched isolator .

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

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

INPUT VSWR MEASUREMENT:

1. Set up the components and equipments as shown in figure-step 1.
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} / 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 S_2 and S_3 respectively. Also calculate the reflection coefficients k_1, k_2, k_3 for different inputs.

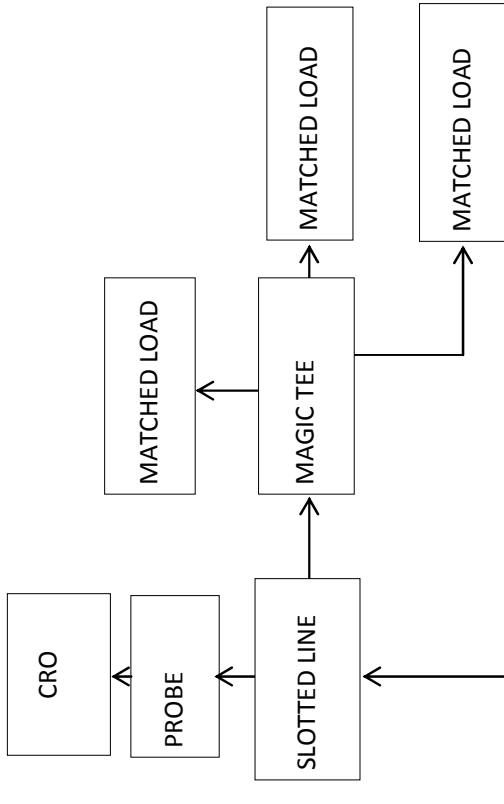
B. MEASUREMENT OF INSERTION LOSS AND ISOLATION LOSS:

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 (o). (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 $Is = 20 \log V_i / V_k$ 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:

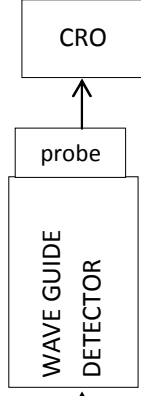
Thus the function of Circulator and isolator was studied and insertion loss, isolation loss and input SWR of circulator and isolator were determined.

CHARACTERISTICS OF MAGIC -TEE

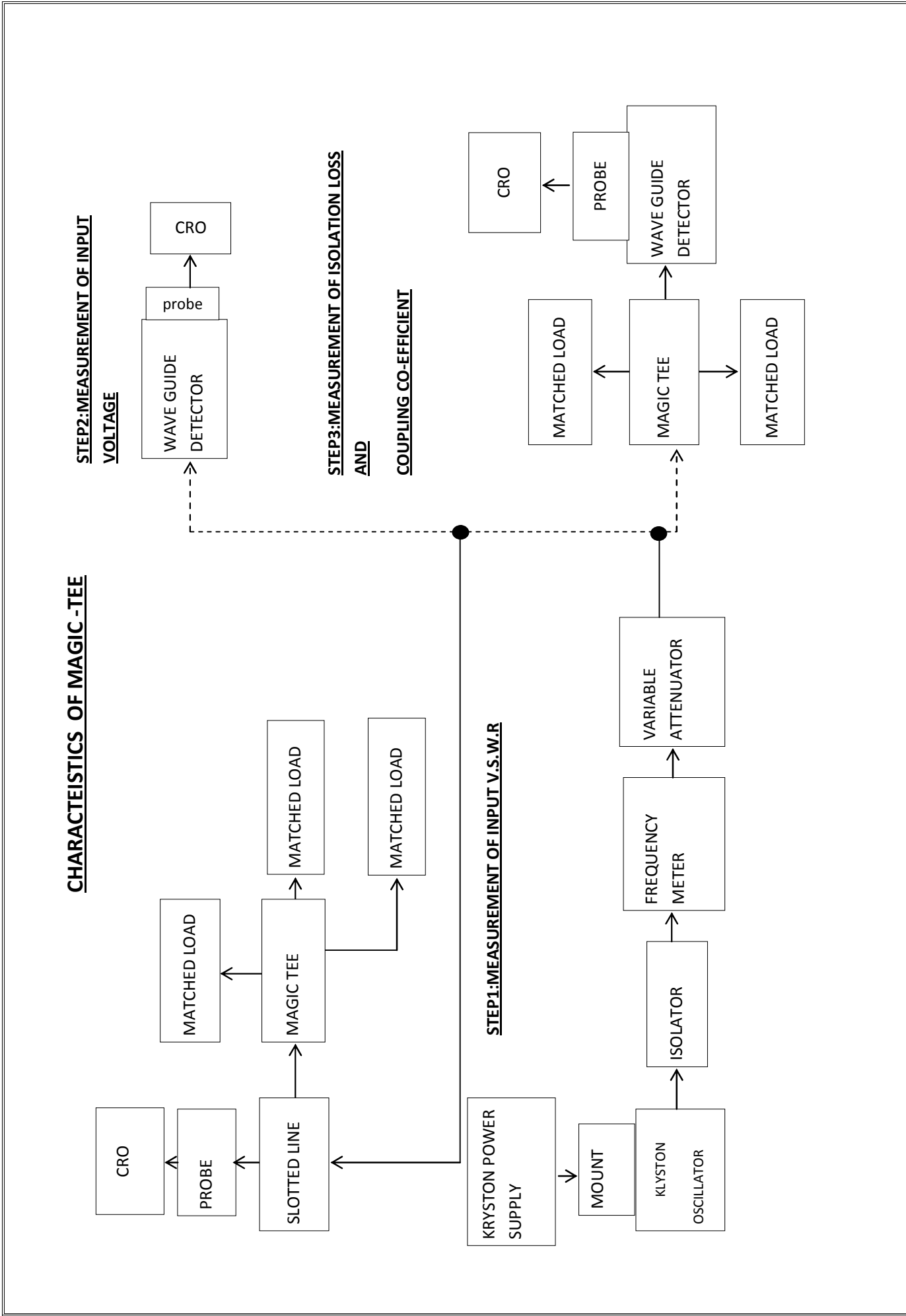
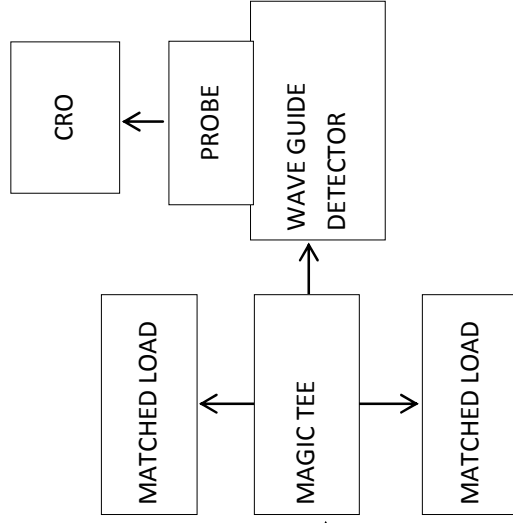


STEP1:MEASUREMENT OF INPUT V.S.W.R

STEP2:MEASUREMENT OF INPUT VOLTAGE



STEP3:MEASUREMENT OF ISOLATION LOSS AND COUPLING CO-EFFICIENT



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:

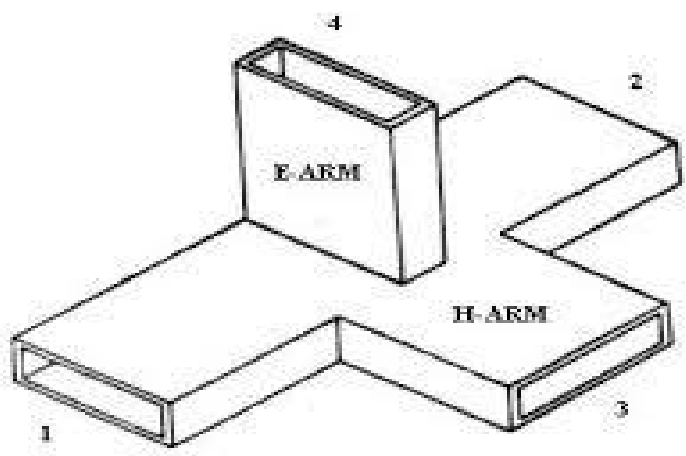
Klystron Power Supply. Klystron Oscillator with mount. CRO .Frequency Meter. Isolator. Variable Attenuator. Wave guide detector with probe , ,matched terminations, Magic Tee, Slotted line with probe ,Wave guide stand, Cables & Accessories.

THEORY:

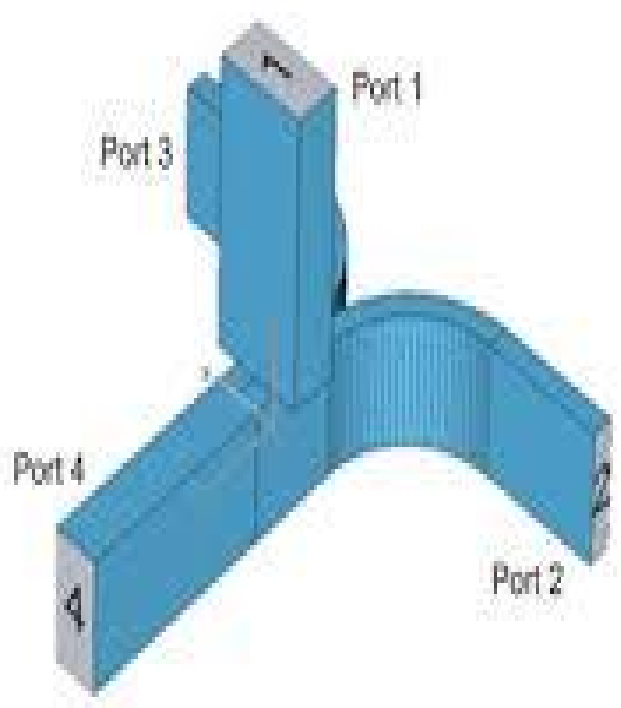
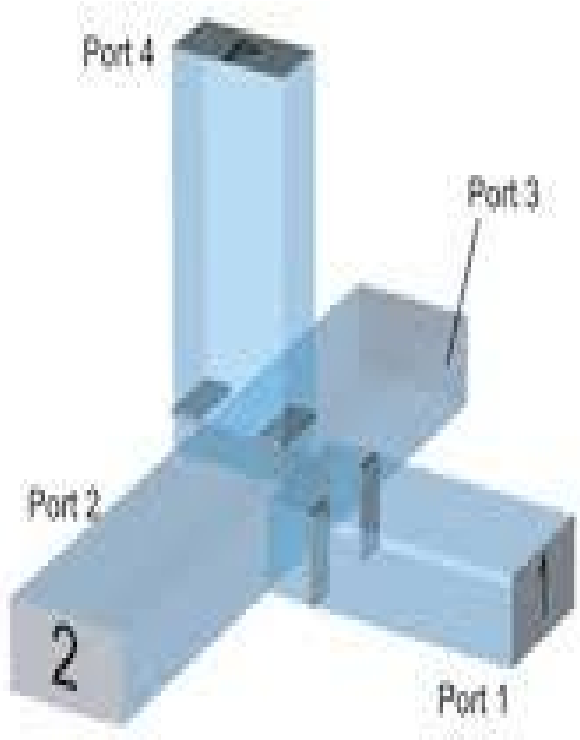
The T junction is the most simple of the commonly used wave guide junctions. The T junctions are divided into two basic types, the E type and the H-type. The hybrid junctions are more complicated developments of the basic T junctions, The Magic Tee and the Hybrid Ring are the two most commonly used hybrid 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 outputs 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 point 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 have _a difference in potential. This difference of potential induces an E field from point A to point B in 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.



MAGIC -TEE



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 2 in 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 arm 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 arm 2, resulting in outputs at the arms 4 and 3 and no output at the arm 1.

CHARACTERISTICS OF MAGIC TEE:

1. If two waves of equal magnitude and the same phase are fed into port 1 and 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., $S_{34} = S_{43} = 0$. Therefore the ports 3 and 4 are called uncoupled or isolated ports .
4. If a wave is fed into one of the collinear arms at either port 1 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 arm H causes a phase advance i.e., $S_{12} = S_{21} = 0$. Therefore the ports 1 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}) $=20 \text{ Log } v_i / (v_j)$ Db	COUPLING Coefficient $C_{ij}=10^{(-a/20)}$ $10^{(a/20)}$	$S_{ji} = (v_j) / (v_i)$ for j 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}) = $10 \log P_4/P_3 = 20 \log V_4/V_3$. Also, isolation between the arms 1 and 2 is $112 = 10 \log P_1/P_2 = 20 \log V_1/V_2$. Similarly, isolation between other ports may also be found.

COUPLING COEFFICIENT:

It is defined as $C_{ij} = 10 (-I_{ij}/20) = 10 (-a/20)$ where a is 'attenuation or isolation (I_{ij}) in dB where i is input arm and j is output arm: Thus $a = 10 \log P_i/P_j = 20 \log V_i/V_j$ dB where V_i is the voltage supplied to arm i and V_j is the voltage detected at the j arm

COMPUTATION OF S - MATRIX:

- Because of uncoupled ports 3 and 4, $S_{34} = S_{43} = 0$. 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 $S_{12} = S_{21} = 0$.
- 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, $S_{11} = S_{22} = S_{33} = S_{44} = 0$.
- Because of the H plane Tee, $S_{23} = S_{13}$. Because of the E plane Tee, $S_{24} = -S_{14}$. 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

$$S \text{ Matrix is } \begin{pmatrix} 0 & 0 & S_{13} & -S_{14} \\ 0 & 0 & S_{13} & -S_{14} \\ S_{13} & S_{13} & 0 & 0 \\ S_{14} & -S_{14} & 0 & 0 \end{pmatrix}$$

Using the unitary property, $S = 1/\sqrt{2}$

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

**TABULAR COLUMN:
INPUT VSWR MEASUREMENT:**

S.no	DIRECTIONAL COUPLER CONNECTION		V_{\max} (mv)	V_{\min} (mv)	SWR $S_i = \left(\frac{V_{\max}}{V_{\min}} \right)^{1/2}$	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

$$\left(\begin{array}{c} \\ \\ \\ \\ \end{array} \right)$$

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 ($S_{13}=1/(2)^{1/2}=S_{23}$) 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 power distribution to port 1 and 2 from ports but with 180° phase shift. The fourth row ($S_{41}=1/(2)^{1/2}=S_{42}$) specifies equal and opposite phase of power are applied to ports 1 and 2 and net-difference at port 4.

PROCEDURE:

INPUT VSWR MEASUREMENT:

1. Set up the components and equipments as shown in figure step 1.
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 of voltage minimum and this is called as V_{\min} .
5. Calculate the standing wave ratio $S = (V_{\max}/V_{\min})^{1/2}$ and this is called as S_1 for port 1.
6. Repeat the above steps for the ports 2, 3 and 4 one by one while the other ports are connected with matched terminations. Find S_2, S_3, S_4 respectively. Also find the reflection coefficients K_1, K_2, K_3 and K_4 for different inputs.

ISOLATION & COUPLING MEASUREMENT:

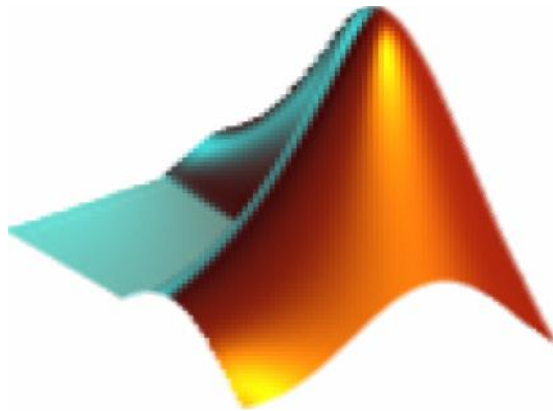
1. Remove the magic tee, matched terminations and slotted line and connect the waveguide _detector to the variable attenuator as shown in figure-step 2. The output of waveguide detector should be connected to CRO.
2. Energize the microwave source for maximum output for a particular frequency of operation. 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 V_{ii} on CRO
7. Calculate the isolation $I_{ij} = 10 \log P_i/P_j = 20 \log V_i/V_j$ and coupling coefficients $C_{ij} = 10^{(-I_{ij}/20)} = 10^{(-a/20)}$ where $a = 10 \log P_i/P_j = 20 \log V_i/V_j$ 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 primary 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.

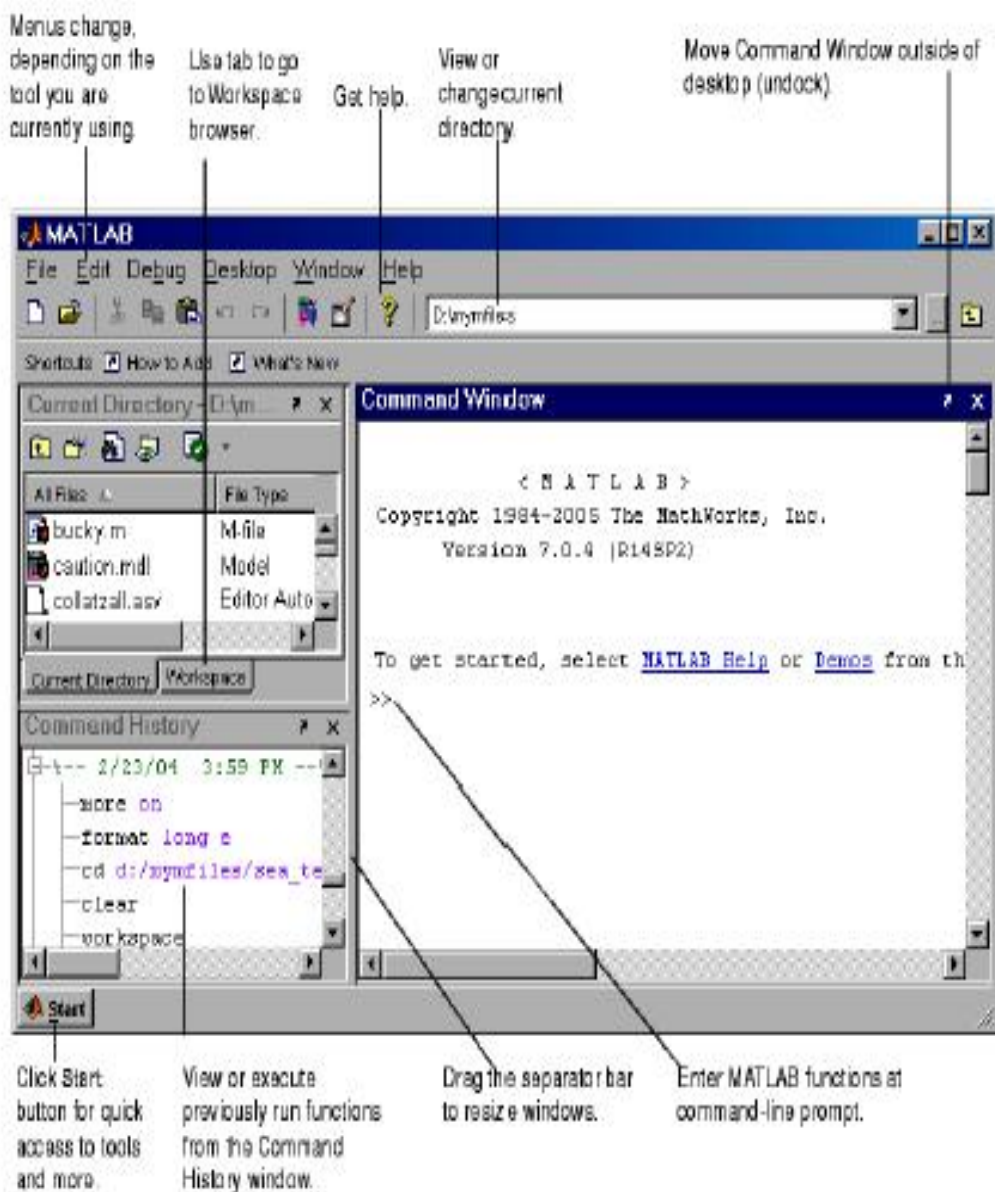
MATLAB has many advantages compared to conventional computer languages (e.g., C, FORTRAN) for solving technical problems. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now 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 perform matrix algebra, to manipulate polynomials and to plot data



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 first 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

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

<code>pi</code>	The π number, $\pi = 3.14159\dots$
<code>i, j</code>	The imaginary unit i , $\sqrt{-1}$
<code>Inf</code>	The infinity, ∞
<code>NaN</code>	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, $1 + 2 \times 3$. 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 $1 + 2 \times 3 = 7$. This variable name can always be used to refer to the results of the previous computations. Therefore, computing $4x$ will result in

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

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

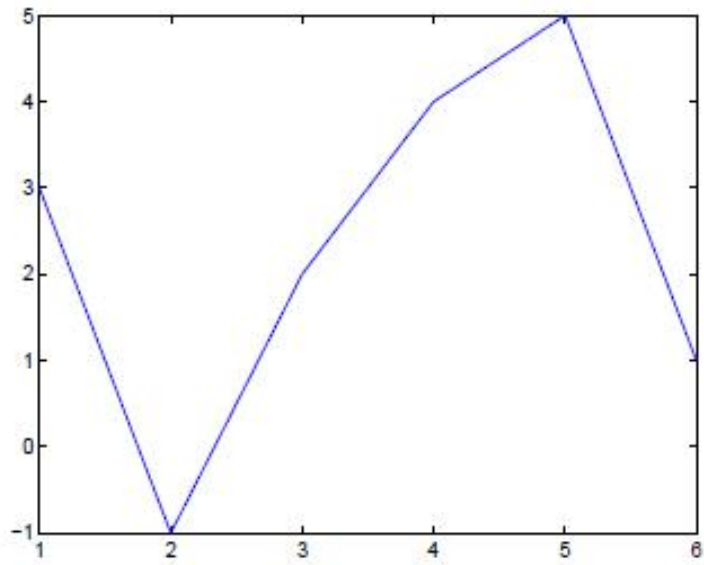
Mathematical functions

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, $x = (x_1; \dots; x_N)$, and a vector of y -coordinates, $y = (y_1; \dots; y_N)$, locate the points $(x_i; y_i)$, with $i = 1; 2; \dots; n$ 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 $[0; 2\pi]$, we first create a vector of x values ranging from 0 to 2π , 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 $\pi/100$,
- stops when 2π 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:

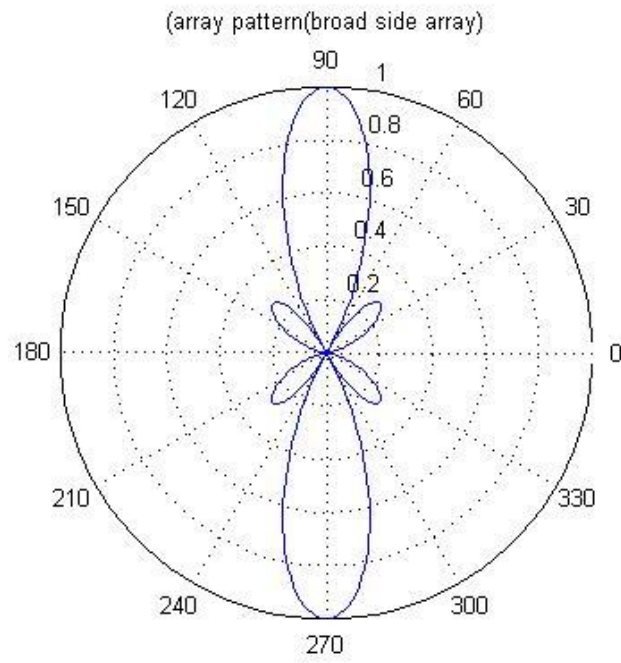
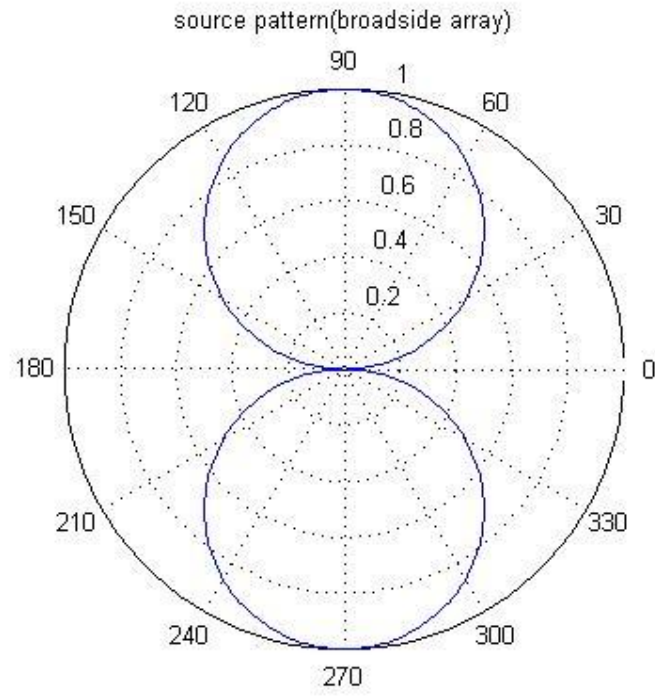
P.C with MATLAB7.0. software

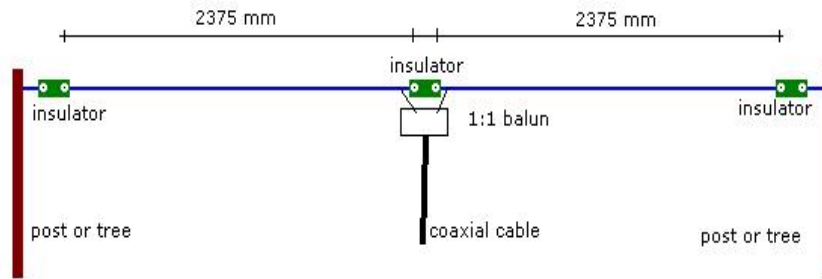
THEORY:

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.



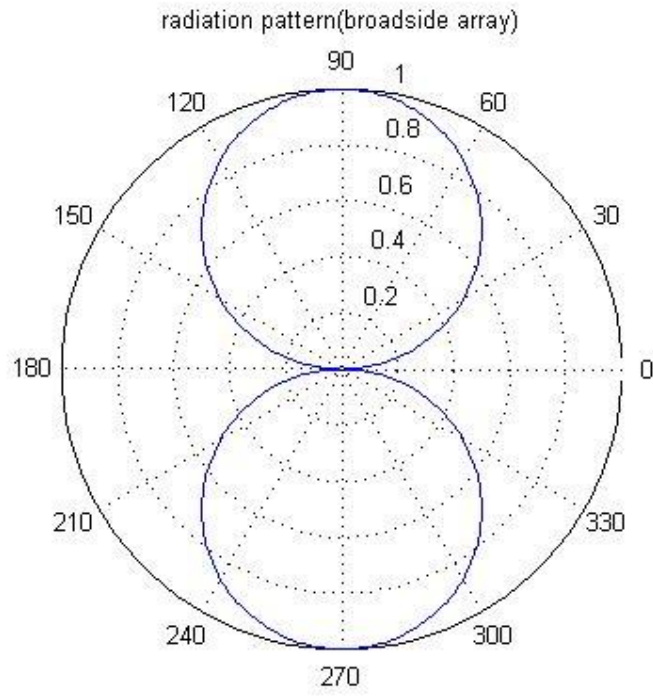


NOT TO SCALE

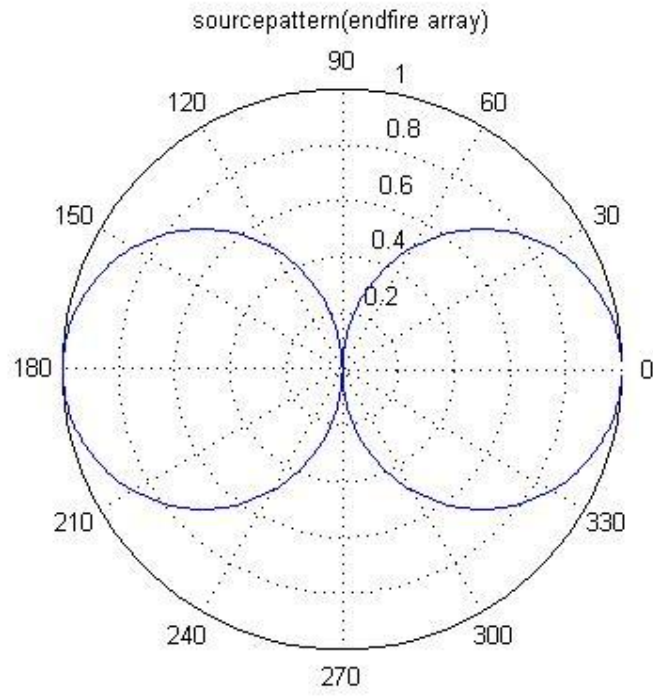
EXAMPLE OF DIPOLE ANTENNA

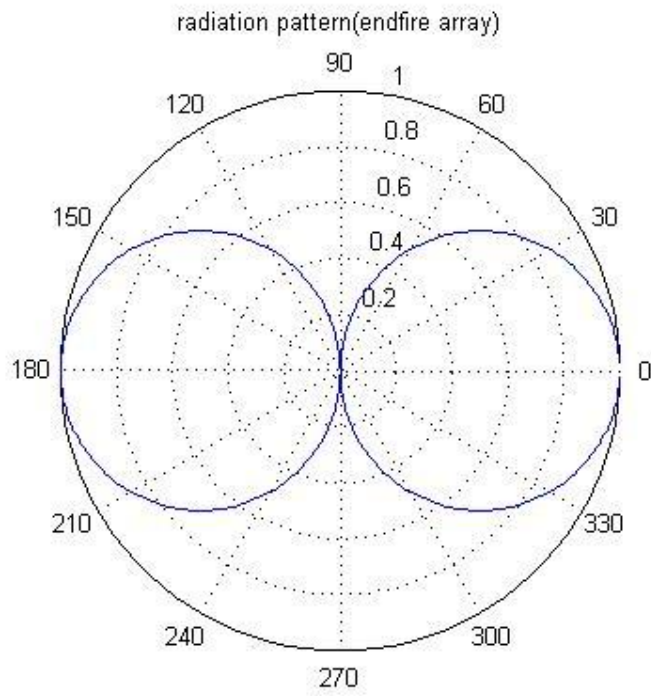
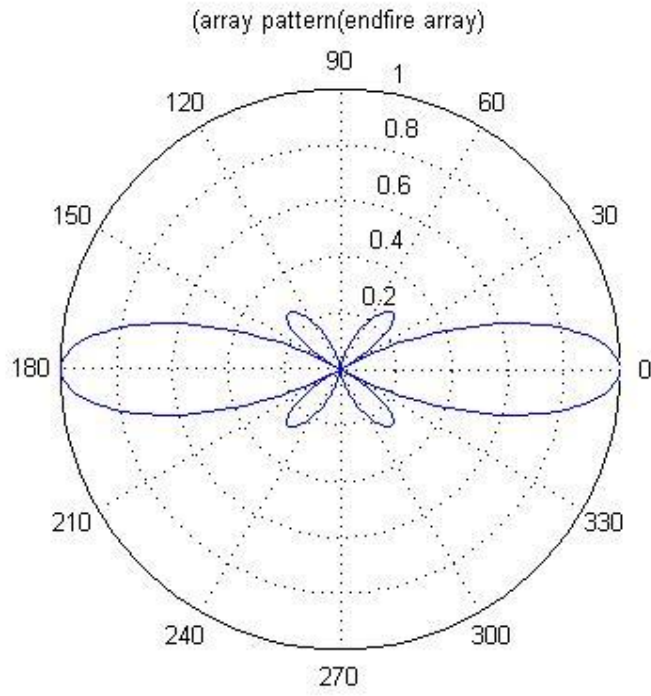
PROCEDURE:

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 program using command window.
6. Plot the graphs accordingly.



7.





RESULT:

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

7. APPLICATIONS:

• Applications of Microwaves in the field of Remote Sensing

- Radio Detecting and ranging (RADAR) uses microwave radiation to detect the range, speed, and other characteristics of remote objects. Development of radar was accelerated during World War II due to its great military utility. Now radar is widely used for applications such as air traffic control, navigation of ships, and speed limit enforcement, whether monitoring and predication, geological survey.
- A Gunn diode oscillator and waveguide are used as a motion detector for automatic door openers (although these are being replaced by ultrasonic devices).
- Radiometry, spectrometry for the study of naturally propagated EM waves.
- Radio astronomy.

❖ Applications of Microwaves in the field of Biomedical

- Microwave imaging, photo-acoustic imaging in biomedicine.
- Thermotherapy, LASER therapy for cancer sell treatment.

❖ Applications of Microwaves in the field of Navigation

- Global Navigation Satellite System (GNSS) including the American Global Positioning System (GPS) and the Russian GLONASS broadcast navigational signals in various bands between about 1.2 GHz and 1.6 GHz.

❖ Applications of Microwaves in the field of Power

- A microwave passes (non-ionizing) microwave radiation (at a frequency near 2.45 GHz) through food, causing dielectric heating by absorption of energy in the water, fats and sugar contained in the food. Microwave ovens become common kitchen appliances in Western countries in the late 1970s, following development of expensive cavity magnetrons.
- ❖ **Microwave heating is used in industrial processes for drying and curing products.**
 - Many semiconductor processing techniques use microwaves to generate plasma for such purpose as reactive ion etching and plasma-enhanced chemical vapor deposition (PECVD).
 - Microwaves can be used to transmit power over long distances, and post-World War II research was done to examine possibilities.
 - Less-than-lethal weaponry exists that uses millimeter waves to heat a thin layer of human skin to an intolerable temperature so as to make the targeted person move away. A two-second burst of the 95 GHz focused beam heats the skin to a temperature of 130 F (5⁴⁰C) at a depth of 1/6^{4th} of an inch (0.4 mm

Various molecular, atomic, and nuclear resonances occur at microwave frequencies, creating a variety of unique applications in the areas of basic science, remote sensing, medical diagnostics and treatment, and heating methods.

The majority of applications of microwaves are related to radar and communication systems. Radar systems are used for detecting and locating targets and for air traffic control systems, missile tracking radars, automobile collision avoidance systems, weather prediction, motion detectors, and a wide variety of remote sensing systems.

Microwave communication systems handle a large fraction of the world's international and other long haul telephone, data and television transmissions.

Most of the currently developing wireless telecommunications systems, such as direct broadcast satellite (DBS) television, personal communication systems (PCSs), wireless local area networks (WLANS), cellular video (CV) systems, and global positioning satellite (GPS) systems rely heavily on microwave technology.

Microwave radio is used in broadcasting and telecommunication transmissions because, due to their short wavelength, highly directive antennas are smaller and therefore more practical than they would be at longer wavelengths (lower frequencies). There is also more bandwidth in the microwave spectrum than in the rest of the radio spectrum; the usable bandwidth below 300 MHz is less than 300 MHz while many GHz can be used above 300 MHz. Typically, microwaves are used in television news to transmit a signal from a remote location to a television station from a specially equipped van.

8. POST TEST-MCQ TYPE:

1. Which of the following is a region of Electromagnetic spectrum having frequency ranging from 1GHz to 100 GHz?

- A. **Micro wave**
- B. UV
- C. IR
- D. None of these

2. Which of the following bands that comes under Microwave Band

- A. C
- B. D
- C. E
- D. **all the above**

3. Which of the following is the main advantage of microwave?

- A. **Highly directive**
- B. Moves at the speed of light
- C. Greater S/N ratio
- D. High penetration power

4. Which of the following is one of the mode in Reflex Klystron

- A. **Give same frequency but different transit time**
- B. Are caused by spurious frequency modulation
- C. Are just for theoretical consideration
- D. Result from excessive transit time across resonator gap

5. Which is the best medium for handling the large microwave power?

- A. Coaxial line
- B. **Rectangular wave guide**
- C. Strip line
- D. Circular wave guide

6. Most of the power measuring microwave devices measure

- A. **Average power**
- B. Peak power
- C. Instantaneous power
- D. None of these

7. In Microwave circuit , Wave guide section will act as a
- A. Low pass filter
 - B. Band pass filter
 - C. High pass filter**
 - D. Band reject filter
8. Which of the following is the semiconductor diode which can be used in switching circuits at microwave range?
- A. PIN diode**
 - B. Tunnel diode
 - C. Varactor diode
 - D. Gunn diode
9. A Magic – Tee is nothing but
- A. Modification of E- Plane tee
 - B. Modification of H- Plane tee
 - C. Combination of E- plane & H- plane**
 - D. Two E- plane tees connected in parallel
10. At Microwave frequencies , the size of the antenna becomes
- A. Very large
 - B. Large
 - C. Small
 - D. Very Small**
11. In Microwave communication links, The rain drop attenuation experienced is mainly due to
- A. Absorption of microwave energy by water vapour
 - B. Resonance absorption of atomic vibration in water molecules
 - C. Scattering of microwaves by collection of water drops
 - D. Refraction of microwaves through liquid drop lenses formed by rain
12. The electrodes of a Gunn diode are made of
- A. molybdenum**
 - B. GaAs
 - C. Gold
 - D. copper

13. The mode of operation in which the Gunn diode is not stable is:

- A. Gunn oscillation mode**
- B. limited space charge accumulation mode
- C. stable amplification mode
- D. bias circuit oscillation mode

14. The modes of propagation supported by a rectangular wave guide is:

- A. TM, TEM, TE modes
- B. TM, TE**
- C. TM, TEM
- D. TE, TEM

15. For any mode of propagation in a rectangular waveguide, propagation occurs

- A. Above the cut off frequency**
- B. Below the cut off frequency
- C. Only at the cut-off frequency
- D. Depends on the dimension of the waveguide

16. Dominant mode is defined as

- A. Mode with the lowest cut off frequency**
- B. Mode with the highest cut off frequency
- C. Any TEM mode is called a dominant mode
- D. None of the mentioned

17. For a lossless network, the impedance and admittance matrices are:

- A. Real
- B. Purely imaginary**
- C. Complex
- D. Rational

18. A slotted line can be used to measure _____ and the distance of _____ from the load.

- A. SWR, first voltage minimum**
- B. SWR, first voltage maximum
- C. characteristic impedance, first voltage minimum
- D. characteristic impedance, first voltage maximum

19. A modern device that replaces a slotted line is

- A. Digital CRO
- B. generators
- C. network analyzers**
- D. computers

20. If the reflection coefficient of a transmission line is 0.4, then the standing wave ratio is:

- A. 1.3333
- B. 2.3333**
- C. 0.4
- D. 0.6

21. The matrix of an ideal isolator is not _____

- A. Unitary**
- B. Symmetric
- C. Lossless
- D. None of the mentioned

22. What is a three-port microwave device that can be lossless and matched at all ports?

- A. Hybrid junction
- B. Magic Tee
- C. Circulator**
- D. Isolator

23. In the scattering matrix representation of a non-ideal circulator, the diagonal elements of the matrix are:

- A. Zero
- B. One
- C. Reflection coefficient**
- D. None of the mentioned

24. Coupled line couplers are

- A. symmetric couplers**
- B. asymmetric couplers
- C. in phase couplers
- D. type of hybrid coupler

9.CONCLUSION:

At the end of this course, the students

- ❖ Understood the working principle of microwave components.
- ❖ Known about the behaviour of microwave components.
- ❖ Learnt about the characteristics and measurements of E and H Fields.

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11. ASSIGNMENT:

1. Define s-matrix
2. What are the Properties of s-matrix?
3. Why is s-matrix used in MW analysis?
4. What are the advantages of ABCD matrix?
5. What are the properties of scattering matrix for a lossless junction?
6. Define one port circuit. Give two examples.
7. Give two examples for two port junctions.
8. What are the various reasons pertaining to the wide use of microwaves?
9. List the two types of terminations.
10. Give some examples of ferrite devices?
11. List two microwave devices using faraday rotation principles.
12. Give the differences between Isolator and Circulator.
13. Give the applications of directional coupler.
14. Define VSWR.
15. What is the principle of Microwave phase shifter?
16. What are junctions? Give some examples.
17. What is Tee junction? Give two examples.
18. What is the other name for magic TEE?
19. Give some coupling parameters of directional coupler?
20. What are the assumptions for calculation of RF power in Reflex Klystron?
21. What is the condition for oscillation in Reflex klystron?
22. Give the drawbacks of klystron amplifiers.
23. List the various applications of reflex klystron.
24. What are the elements that exhibit Gunn Effect?
25. What are the applications of Gunn Diode?
26. List some of power detecting elements?
27. What are microwave detectors?
28. What is tunable detector?
29. What is slotted section with line carriage?
30. What is the main purpose of slotted section with line carriage?
31. What is a VSWR meter?
32. Define insertion loss?
33. List the different types of Impedance measurement methods.
34. What is radiation pattern?
35. What is radiation efficiency?