MUFFAKHAM JAH

COLLEGE OF ENGINEERING AND TECHNOLOGY

EC - 431 MICROWAVE ENGINEERING LAB

(With effect from the academic year 2011-2012)

STUDENT'S MANUAL

DEPARTMENT OF

ELECTRONICS AND COMMUNICATION ENGINEERING

Vision and Mission of the Institution

Vision

To be part of universal human quest for development and progress by contributing high calibre, ethical and socially responsible engineers who meet the global challenge of building modern society in harmony with nature.

Mission

- To attain excellence in imparting technical education from the undergraduate through doctorate levels by adopting coherent and judiciously coordinated curricular and co-curricular programs
- To foster partnership with industry and government agencies through collaborative research and consultancy
- To nurture and strengthen auxiliary soft skills for overall development and improved employability in a multi-cultural work space
- To develop scientific temper and spirit of enquiry in order to harness the latent innovative talents
- To develop constructive attitude in students towards the task of nation building and empower them to become future leaders
- To nourish the entrepreneurial instincts of the students and hone their business acumen.
- To involve the students and the faculty in solving local community problems through economical and sustainable solutions.

Vision and Mission of ECE Department

Vision

To be recognized as a premier education center providing state of art education and facilitating research and innovation in the field of Electronics and Communication.

Mission

We are dedicated to providing high quality, holistic education in Electronics and Communication Engineering that prepares the students for successful pursuit of higher education and challenging careers in research, R& D and Academics.

Program Educational Objectives of B. E (ECE) Program:

1. Graduates will demonstrate technical competence in their chosen fields of employment by identifying, formulating, analyzing and providing engineering solutions using current techniques and tools
2. Graduates will communicate effectively as individuals or team members and demonstrate leadership skills to be successful in the local and global cross-cultural working environment
3. Graduates will demonstrate lifelong learning through continuing education and professional development
4. Graduates will be successful in providing viable and sustainable solutions within societal, professional, environmental and ethical contexts

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY

BANJARA HILLS, ROAD NO-3, TELANGANA
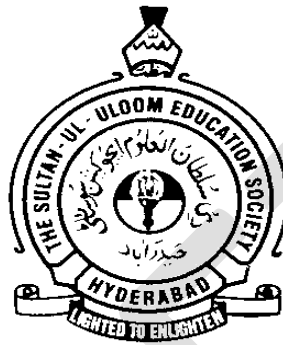
LABORATORY MANUAL

FOR

MICROWAVE ENGINEERING LAB

Prepared by: IFTEKHARUDDIN   **Checked by:**

Approved by:

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRONICS AND COMMUNICATIONS ENGINEERING

MICROWAVE ENGINEERING LAB

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                                                     4) Date   :

Approved by: (HOD) 1) Name:

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                 3) Date   :

EC 431

MICROWAVE ENGINEERING LAB

Instructions	3 Periods per week
Duration of University Examination	3 Hours
University Examination	50 Marks
Sessionals	25 Marks

List of Experiments:

1. **Characteristics of Reflex Klystron oscillator, finding the mode numbers and efficiencies of different modes.**

2. **Characteristics of Gunn diode oscillator, Power Output Vs Frequency, Power Output Vs Bias Voltage**.

3. **Measurement of frequency and Guide wavelength calculation:**
   i. **Verification of the relation between Guide wavelength, free space wavelength and cutoff wavelength of X- band rectangular waveguide.**
   ii. **Verification of the straight line relation between $(1/l_g)^2$ and $(1/l_0)^2$ and finding the dimension of the guide.**

4. **Measurement of low and high VSWRs: VSWR of different components like matched terminals, capacitive and inductive windows, slide screw tuner for different heights of the tuning posts etc.**

5. **Measurement of impedance.**

6. **To find parameters of Directional coupler.**

7. **To find Scattering matrices of Tees : E plane, H plane and Magic Tee.**

8. **To find Scattering matrices of Circulator.**

9. **Measurement of radiation patterns for basic microwave antennas like horn and parabolic reflectors in E-plane and H-plane. Also to finding the gain, bandwidth and beam width these antennas.**

10. **Study of various antennas like dipoles, loops, Yagi antenna, log periodic antenna and their radiation pattern.**

11. **Mini Project**
    i. **To design microwave components such as directional couplers, circulators and hybrid junctions using simulation software tools.**
    ii. **To design antennas arrays such as Binomial, Chebyshev using software tools.**

MICROWAVE ENGINEERING LAB

GENERAL GUIDELINES AND SAFETY INSTRUCTIONS

1. Sign in the log register as soon as you enter the lab and strictly observe your lab timings.
2. Strictly follow the written and verbal instructions given by the teacher / Lab Instructor. If you do not understand the instructions, the handouts and the procedures, ask the instructor or teacher.
3. **Never work alone!** You should be accompanied by your laboratory partner and / or the instructors / teaching assistants all the time.
4. It is mandatory to come to lab in a formal dress and wear your ID cards.
5. Do not wear loose-fitting clothing or jewellery in the lab. Rings and necklaces are usual excellent conductors of electricity.
6. Mobile phones should be switched off in the lab. Keep bags in the bag rack.
7. Keep the labs clean at all times, no food and drinks allowed inside the lab.
8. Intentional misconduct will lead to expulsion from the lab.
9. Do not handle any equipment without reading the safety instructions. Read the handout and procedures in the Lab Manual before starting the experiments.
10. Do your wiring, setup, and a careful circuit checkout before applying power. Do not make circuit changes or perform any wiring when power is on.
11. Avoid contact with energized electrical circuits.
12. Do not insert connectors forcefully into the sockets.
13. **NEVER** try to experiment with the power from the wall plug.
14. Immediately report dangerous or exceptional conditions to the Lab instructor / teacher: Equipment that is not working as expected, wires or connectors are broken, the equipment that smells or "smokes". If you are not sure what the problem is or what's going on, switch off the Emergency shutdown.
15. Never use damaged instruments, wires or connectors. Hand over these parts to the Lab instructor/Teacher.
16. Be sure of location of fire extinguishers and first aid kits in the laboratory.
17. After completion of Experiment, return the bread board, trainer kits, wires, CRO probes and other components to lab staff. Do not take any item from the lab without permission.
18. Observation book and lab record should be carried to each lab. Readings of current lab experiment are to be entered in Observation book and previous lab experiment should be written in Lab record book. Both the books should be corrected by the faculty in each lab.
19. Handling of Semiconductor Components:Sensitive electronic circuits and electronic components have to be handled with great care. The inappropriate handling of electronic component can damage or destroy the devices. The devices can be destroyed by driving to high currents through the device, by overheating the device, by mixing up the polarity, or by electrostatic discharge (ESD). Therefore, always handle the electronic devices as indicated by the handout, the specifications in the data sheet or other documentation.
20. Special Precautions during soldering practice
    a. Hold the soldering iron away from your body. Don't point the iron towards you.
    b. Don't use a spread solder on the board as it may cause short circuit.
    c. Do not overheat the components as excess heat may damage the components/board.
    d. In case of burn or injury seek first aid available in the lab or at the college dispensary

CONTENTS

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

EIA No. : WR - 90

X Band frequency: 8.2 - 12.4 GHZ

Waveguide slot width: 2.286cm	Waveguide slot Height: 1.1016cm
Total Component width: 2.54 cm	Total Component height: 1.27cm

Material: Brass/Copper.

FIXED ATTENUATORS

Series 5000 fixed Attenuators are meant for inserting a known attenuation in a wave guide system. These consists 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 : ± 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.

WAVEGUIDEDETECTORMOUNT(TUNABLE)

Model 4051 Tunable Detector Mount is simple and easy to use instrument for detecting microwave power through 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
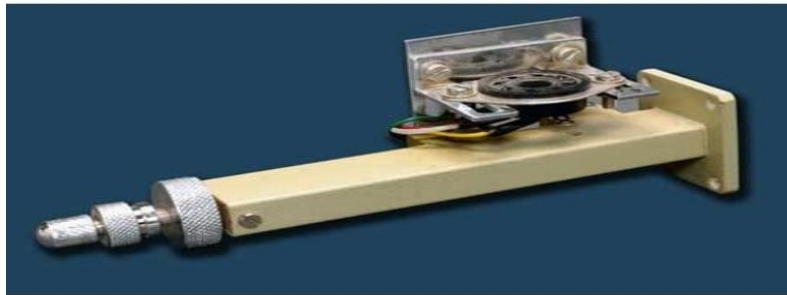
O/P Connector : BNC (F)   Wave guide type (WR-) : 90

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 terminatedwith a movable short on the other end. An octalbase with cable is provided for Klystron.

Klystron mount

Klyston tube

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.

T type and Y type Circulator

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

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.
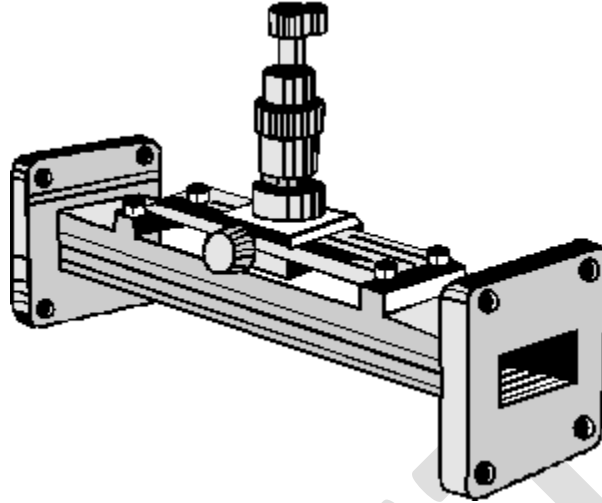
Model No. : X – 4041   Freq. Range (Ghz) : 8.2 - 12.4

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

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

H - PLANT TEE

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

Model No. : X - 3065   Frequency Range (GHz) : 8.2 - 12.4

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

MAGIC TEE

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

Model No. : X - 3045   Frequency Range (Ghz) : 8.2 - 12.4

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

MOVABLE SHORT

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

Model No. : X - 4081   Frequency Range (GHz) : 8.2 - 12.4

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

MATCHED TERMINATION

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

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

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

PYRAMIDAL WAVEGUIDE HORN ANTENNA

Model 5041 pyramidal Wave guide Horn antenna consists of waveguide joined to pyramidal section fabricated from brass sheet. The pyramidal section shapes the energy to concentrate in a specified beam. Wave guide horns are used as feed horns as radiators for reflectors and lenses and as a pickup antenna for receiving microwave power.
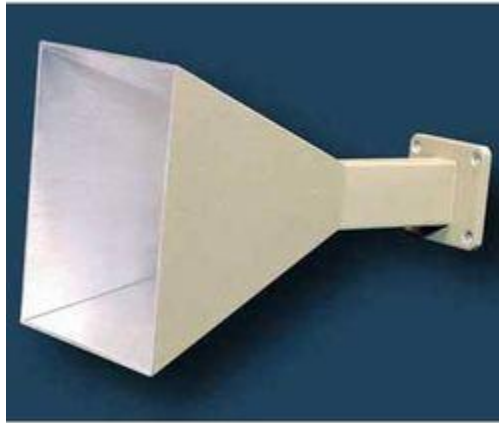
Model No. : X - 5041   Frequency Range (Ghz) : 8.2 - 12.4

Max VSWR : 1.20   WG Type (WR-) : 90

Flange Type (UG-/U) : 39

GUNN OSCILLATORS

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


Model No. : X – 2152   Freq : 8.2 - 12.4 Ghz

Min output power : 10 MW   WG Type (WR-) : 90 Flange Type (UG-/U) : 39

PIN MODULATORS

Model 451 pin modulators are designed to modulate the cw output of Gunn Oscillators. It is operated by the square pulses derived from the UHF(F) connector of the Gunn power supply. These consists of a pin diode mounted inside a section of Wave guide flanged on it's both end. A fixed attenuation vane is mounted inside at the input to protect the oscillator.
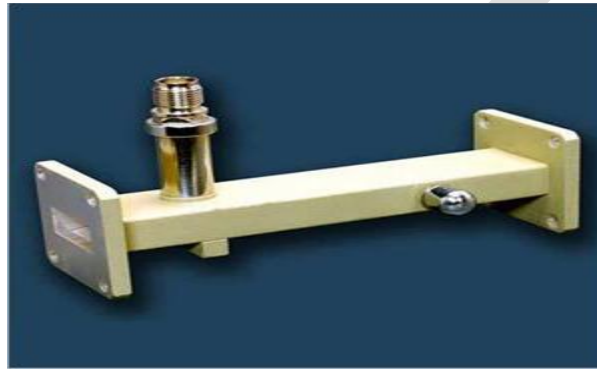
Model No. : X - 451   Frequency Range (Ghz) : 8.3 - 12.4

Max RF Power : 1W   WG Type (WR-) : 90 Flange Type (GHz) : 39

GUNN POWER SUPPLY

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

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.
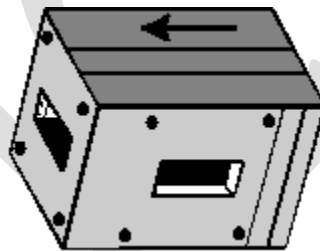
Model No. : X - 6022   Frequency Range (GHz) : 8.6 - 12.2

Min Isolation (dB) : 20   Max Insertion Loss (dB) : 0.4 Max VSWR : 1.20 .

Thus all the microwave components were studied in detail.

REVIEW QUESTIONS

1. What is microwave?

2. Mention the frequency band for a millimeter wave.

3. List some of IEEE microwave frequency bands.

4. List some of characteristic feature of microwave.

5. List some of the application of microwave technology.

6. Draw a simple microwave system.

7. What are waveguide `Tees'?

8. List the basic type of waveguide tees.

9. What is an isolator?

10. What is a circulator?

11. What is a directional coupler?

12. What is velocity modulation?

13. Mention the Principle used in Klystron?

14. When the o/p power of reflex klystron maximum?

15. What is meant by attenuator?

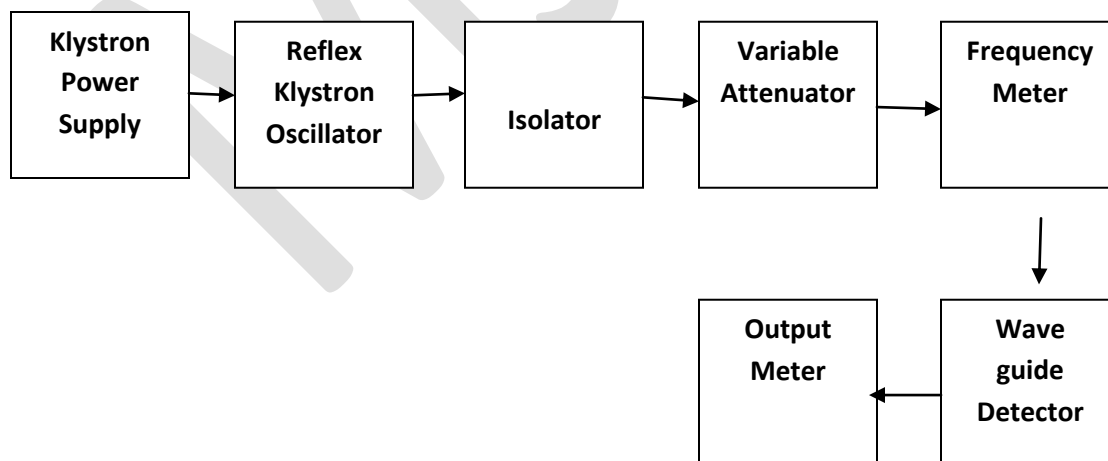## 1. CHARACTERISTICS OF REFLEX KLYSTRON OSCILLATOR

AIM

To study the Characteristics of Reflex Klystron Oscillator, find mode numbers and efficiencies of different modes.

APPARATUS REQUIRED:

Klystron Power Supply, Klystron with mount, Isolator, Frequency meter, Variable Attenuator, Slotted section with Probe carriage, CRO, Movable Short.

THEORY

Klystron is a microwave vacuum tube employing velocity modulation. These electrons move towards the repeller (ie) the electrons leaving the cavity during the positive half cycle are accelerated while those during negative half cycle are decelerated. The faster ones penetrate further while slower ones penetrate lesser in the field of repeller voltage. But, faster electrons leaving the cavity take longer time to return and hence catch up with slower ones. In the cavity the electrons bunch and intract with the voltage between the cavity grids. It consists of an electron gun producing a collimated electron beam. It bunches pass through grids at time the grid potentials is such that electrons are decelerated they give by energy. The electrons are then collected by positive cavity wall near cathode. To protect repeller from damage, repeller voltage is applied before accelerating voltage.

```
┌───────────┐     ┌───────────┐     ┌───────────┐     ┌───────────┐     ┌───────────┐
│ Klystron  │     │  Reflex   │     │           │     │ Variable  │     │ Frequency │
│  Power    │────▶│ Klystron  │────▶│  Isolator │────▶│ Attenuator│────▶│   Meter   │
│  Supply   │     │Oscillator │     │           │     │           │     │           │
└───────────┘     └───────────┘     └───────────┘     └───────────┘     └───────────┘
                                                                               │
                                                                               ▼
                  ┌───────────┐                             ┌───────────┐
                  │  Output   │                             │   Wave    │
                  │   Meter   │◀────────────────────────────│   guide   │
                  │           │                             │  Detector │
                  └───────────┘                             └───────────┘
```

Bench Set up Diagram

PROCEDURE

1) Assemble the components as shown in fig.

2) After following the necessary precautions, the Klystron Power Supply is switched ON.

3) To obtain peak voltage, the attenuator is positioned at it's minimum attenuation.

4) Vary the repeller voltage from it's maximum negative value and increase it in steps on N and record output power and frequency.

5) The frequency is measured by tuning the basic frequency meter to have a dip in the output voltage each time.

6) The frequency meter is detuned before measuring the output power each time.

7) The mode characteristics of Reflex Klystron is plotted. (i.e. Output Voltage Vs Repeller voltage and Frequency Vs Repeller voltage)

BASIC 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). Therepeller voltage should be varied in one direction to avoid hysteres is in klystrons

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

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

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

CALCULATIONS

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

$N2/N1 = V2/V1 = (n+1)+3/4/n+3/4$

where V1 and V2 are the values of repeller voltages required to operate the klystron in mode numbers N1 and N2.

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

$t1 = (n+3/4)/f01 = N1/f01$

f01 → frequency of microwave operation in one mode.

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

ETR = f1max – f1min for N1 mode (GHz)

f1max – f1min → half power frequencies

(iv) ETS – Electronic tuning sensitivity

ETS = = f1max – f1min/V1max- V1min (MHz/V)

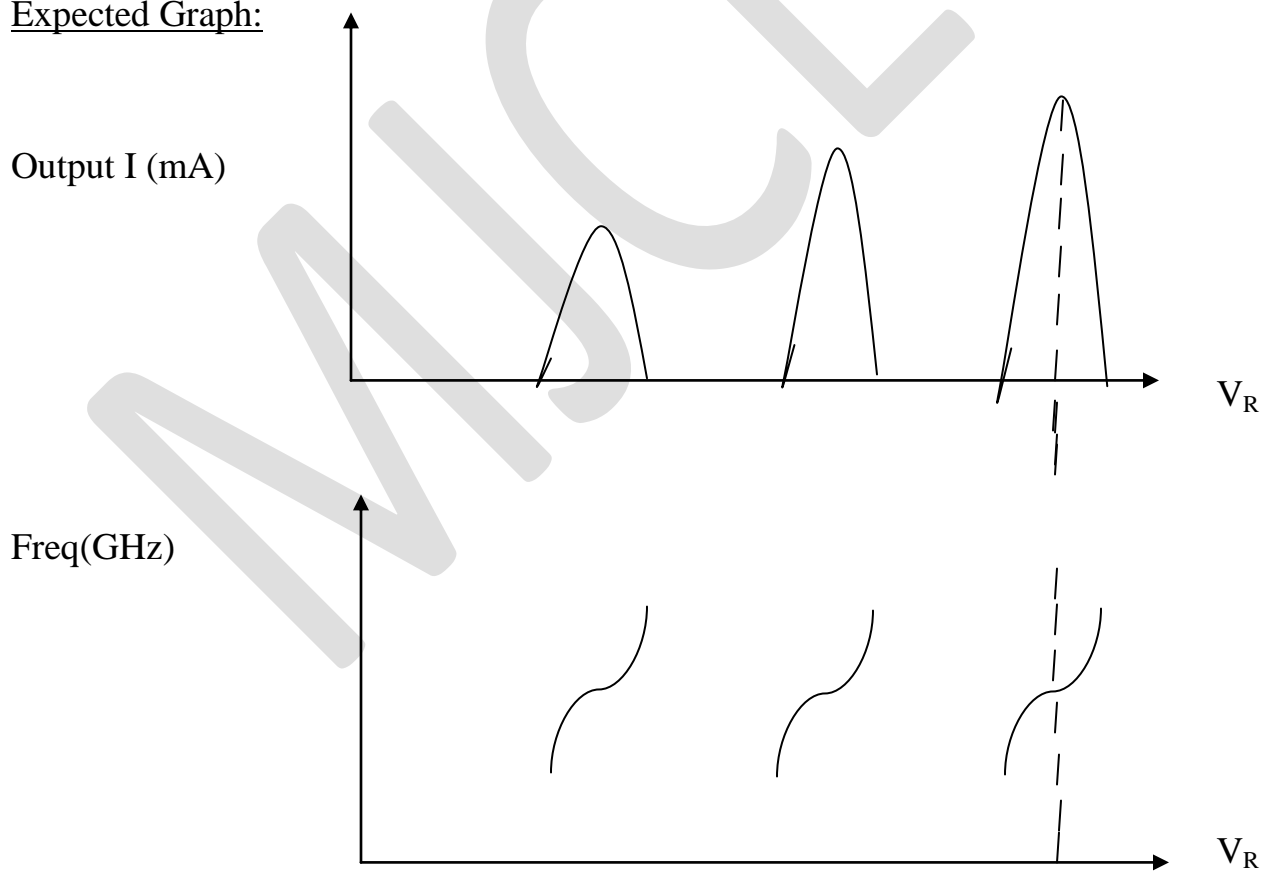f1max, f1min → half power frequency

V1max, V1min→ corresponding repeller voltages for a particular mode.

Tabular column

S.NO	Repeller Voltage(V_R)	Output I (mA)	Frequency(GHz)

Expected Graph:

Output I (mA)

Freq(GHz)

Result: The characteristics of Klystron Oscillator are verified and modes are calculated.
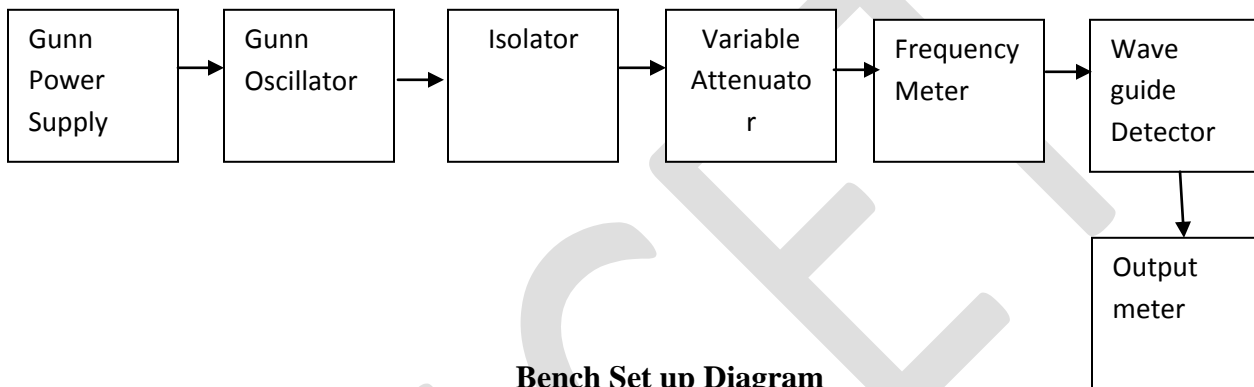
REVIEW QUESTIONS

1. List two basic configurations of Klystron tubes.

2. What is velocity modulation?

3. List the characteristic of two cavity klystron amplifier.

4. Write a note on mode of oscillations.

5. Draw the reflex klystron modes.

6. Higher order mode occurs at _____ repeller voltage.

7. When the o/p power of reflex klystron maximum?

8. List the application of reflex klystron.

9. What is transit time?

10. Which mode number is most frequently used? Why?

2. CHARACTERISTICS OF GUNN DIODE OSCILLATOR

AIM: Study of VI characteristics of Gunn diode Oscillator.

APPARATUS:

X-Band Gunn Oscillator, Microwave bench, PIN modulator, Isolator,

Frequency meter, Variable attenuator, Slotted section, Tunable probe, Detector

Mount, Matched termination, Gunn power supply, Wave guide stand, BNC cable,

Cooling fan.

```
Gunn        → Gunn        → Isolator → Variable   → Frequency → Wave
Power         Oscillator               Attenuator    Meter       guide
Supply                                                           Detector
                                                                    ↓
                                                                 Output
                                                                 meter
```

Bench Set up Diagram

THEORY:

Some bulk semiconductor materials such as Gallium arsenide (GA As), Indium phosphide (InP) and Cadmium Telluride (CdTe) have two closely spaced energy bands in the conduction band. At lower electric field strengths in the material, most of the electrons will be transmitted into higher energy band. In the higher energy band the effective electron mass is longer and hence the electron mobility is lower than what it is in the lower energy band. Since the conductivity is directly proportional to the mobility there is an immediate range of electric field strengths for which the fraction of electrons that are transferred into higher energy low mobility conduction is such that the average mobility and hence conductivity decreases with an increase in the electric field strength. Thus there is a range of voltage over which the current decreases with the increasing voltage and a negative instrumental of resistance is displayed by the device. A Gunn device is also called a transferred electronic device since the negative resistance arises from the transfer of electrons from the lower to higher energy band. The oscillations that occur in the material with energy band structure noted above was discovered by J.B.GUNN. The probability of obtaining negative differential resistance had been predicted earlier by Ridley and Watkins.

PROCEDURE;

1. Turn the two knobs of the power supply fully anticlockwise.

2. Set the micrometer on the wave guide cavity gunn oscillator to approximately 10.9mm(approximate 9.5GHz)

3. Increase the voltage in (0.5V in steps up to l0V and record the corresponding current from the meter on the gunn power supply by switching alternately to current and voltage position.

4. Simultaneously note down the output current in the ammeter.

5. At each bias voltage, tune the frequency meter to observe the dip. Note the frequency reading.

6. Draw the following graphs between

     a) Voltage-ampere characteristics as observed in the power supply panel

    (b) Output current & bias voltage

    (c) Frequency & bias voltage

   Now set the bias voltage to a value, that gives maximum outputcurrent at approximately 9.5 GHz.

7. Vary the gunn oscillator frequency by changing the position of the micrometer reading and record corresponding current till11.5GHz(approximate).
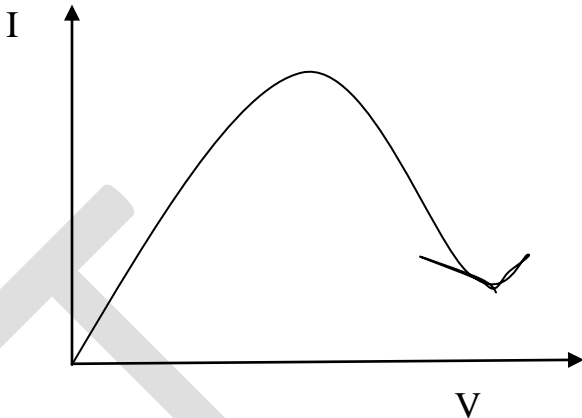
Tabular column:

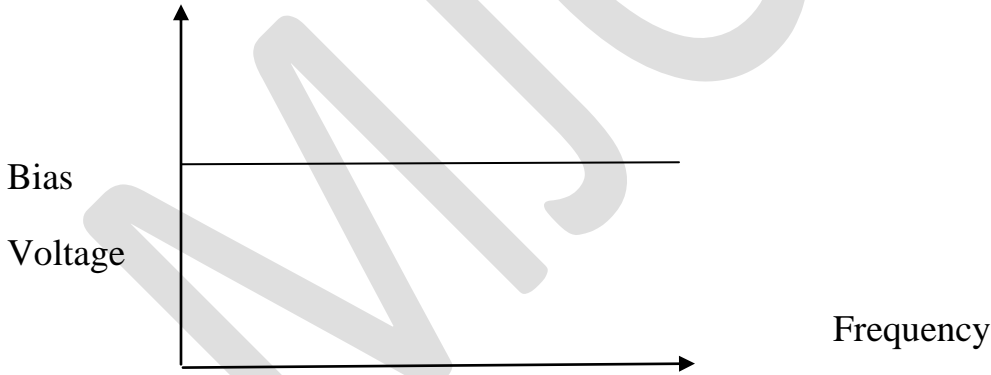| S.No	Gunn Voltage V(Volts)	Gunn Current I (mA)	Output Current I_O (mA)	Output Frequency (GHz)

Expected Graphs:
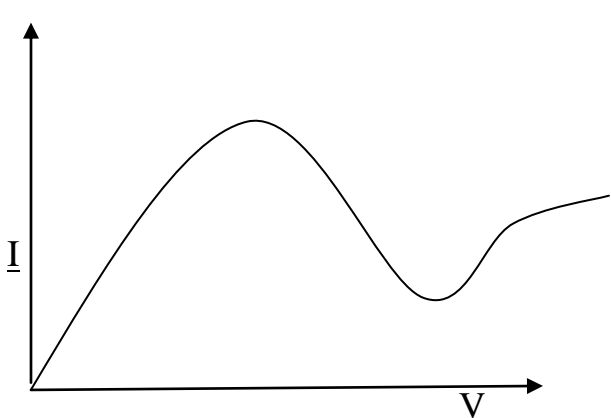

With Bench Setup

Without Bench Setup

Result: The Characteristics of Gunn diode are verified and plotted

3.MEASUREMENT OF FREQUENCY AND GUIDE WAVE LENGTH

Aim: To determine the relationship between frequency and wavelength in a rectangular wave-guide.

Apparatus: Klystron power supply or Gunn Power supply, Klystron mount with klystron tube (R.K.O) or Gunn oscillator, Variable attenuator, Frequency meter, Slotted Section with Tunable Probe, wave guidedetector, Output Meter, Matched Termination

BENCH SETUP Diagram:
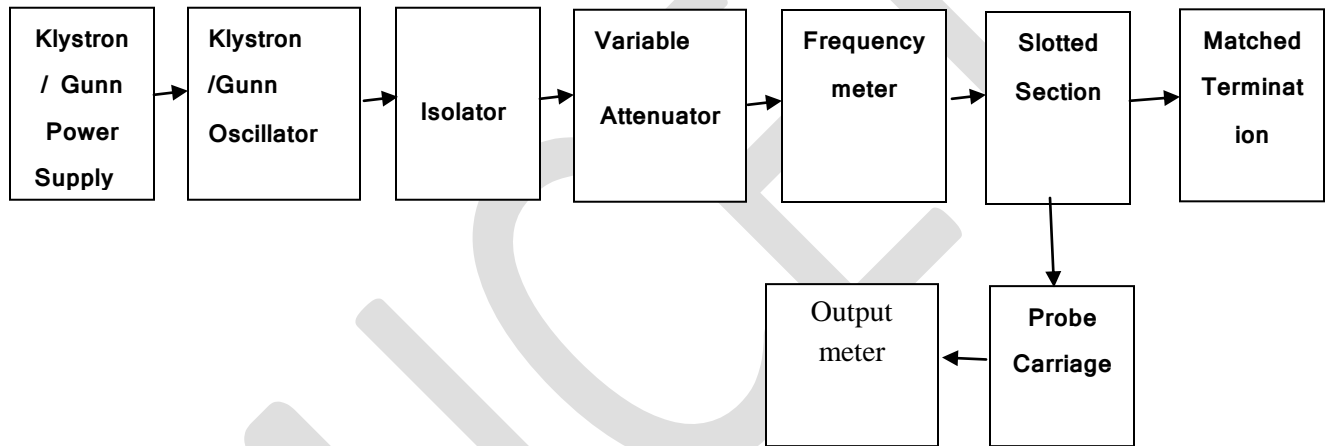
Theory:

For dominant mode TE10in the rectangular wave guide λo, λc, λg are related by this equation

$$1/\lambda o^2 = 1/\lambda g^2 + 1/\lambda c^2$$

Where   λo is free space wave length

λg is guided wave length

λc is cutoff wave length

 PROCEDURE:

1. Set up the equipment as shown in the figure

2. Set the variable attenuator at minimum.

3. Adjust the probe depth of the standing wave detector till a deflection is observed on the V.S.W.R.

4. Keep the range dB of the V.S.W.R. meter in the 40dB position.

5. Energize the klystron. Use the mode at about -160V reflector voltage module with 1khz square wave..

6. Adjust the reflector voltage to get maximum deflection on the V.S.W.R. meter.

FREQUENCY MEASUREMENT WITH THE FREQUENCY METER

1. Tune the frequency meter until a dip observed in the V.S.W.R. meter deflection. Tune the frequency meter to obtain minimum deflection.
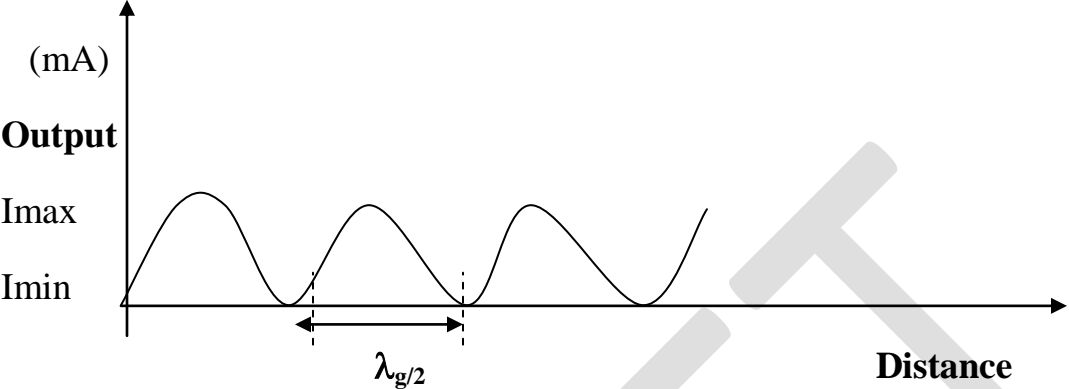2. Note the frequency meter setting.

WAVE LENGTH MEASUREMENT:

1. Replace the termination with the variable short. Detune the frequency meter.
2. Move the probe along the line and watch the V.S.W.R. meter, the deflection will vary strongly.
3. Move the probe to a minimum deflection point. To get an accurate reading, it is necessary to increase the V.S.W.R. meter gain when close to a minimum.
4. Note and record the probe position.
5. Measure the wave-guide inner dimension. a = (22.860+0.046mm)or 2.29cm.
6. Calculate the frequency.

TABULAR COLUMN:

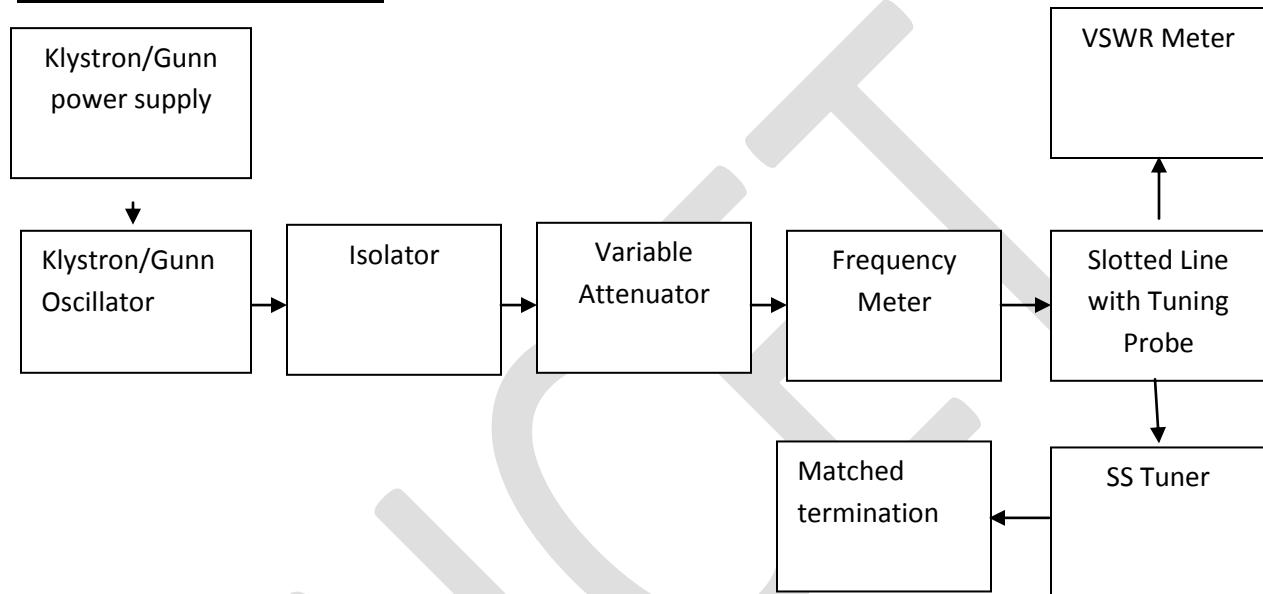| Sl. No.	$- V_R$	Output	Distance λ_g
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Expected Graph:

Result: The relation between waveguide parameters is verified

4.MEASUREMENT OF VSWR

AIM: To determine the Standing-Wave Ratio and Reflection Coefficient.

Bench Set up diagram:

```
┌─────────────────┐                                                    ┌─────────────────┐
│  Klystron/Gunn  │                                                    │   VSWR Meter    │
│  power supply   │                                                    │                 │
└─────────────────┘                                                    └─────────────────┘
         │                                                                      ▲
         ▼                                                                      │
┌─────────────────┐   ┌──────────┐   ┌──────────────┐   ┌──────────┐   ┌─────────────────┐
│  Klystron/Gunn  │──▶│ Isolator │──▶│   Variable   │──▶│Frequency │──▶│  Slotted Line   │
│   Oscillator    │   │          │   │  Attenuator  │   │  Meter   │   │  with Tuning    │
│                 │   │          │   │              │   │          │   │     Probe       │
└─────────────────┘   └──────────┘   └──────────────┘   └──────────┘   └─────────────────┘
                                                                                │
                                        ┌──────────────┐   ┌──────────┐         ▼
                                        │   Matched    │◀──│ SS Tuner │
                                        │ termination  │   │          │
                                        └──────────────┘   └──────────┘
```

APPARATUS:

Klystron tube , Klystron power supply, VSWR meter , Klystron mount,Isolator(XI-621), frequency meter, Variable attenuator, Slotted line, Tunable probe, Waveguide stand, Movable short/Termination or any unknown load and BNC cable, SS tuner.

THEORY:

The electromagnetic field at any point of a transmission line (eg a wave guide) may be considered as the sum of two travelling waves. The incident wave propagates from the generator, the reflected wave propagates towards the generator .The reflected wave is set up by the reflection of the incident wave from a discontinuity on the line or from a load impedance not equal to the characteristic impedance of the line. The magnitude and phase of the reflected wave depends upon the amplitude and phase of the reflecting impedance. The magnitude also depends

on the amplitude losses on the line. On a lossy line the reflected (and incident) wave will be attenuated. If the line is uniform and infinitely long there would be no reflected wave. The same applies for a line of finite length which is matched i.e. has a load equal to the characteristic impedance of the line. The presence of two travelling waves gives rise to standing wave along the line. The electrical (and mechanical) field varies periodically with distance. The maximum field strength is found where the two waves add in phase and the minimum where the two waves add in opposite phase. Figure above shows the voltage standing wave patterns for different load impedances. The distance between two successive minima (or maxima) is half the wavelength on the transmission line. The ratio between the electrical fields of the reflected and incident wave is called the voltage reflection coefficient, being a vector, which means that is phase varies along the transmission line. The voltage standing wave ratio VSWR on a transmission line is defined as the ratio between maximum and minimum field strengths along the line.

$\rho = E_r / E_i$,

$S = E_{max} / E_{min} = (E_i + E_r) / (E_i - E_r)$

Reflection Coefficient $= (S - 1) / (S+1)$

PROCEDURE:

1. Set up the equipment as shown in the figure.

2. Keep the variable attenuator in minimum position.

3. Keep the control knob of VSWR meter as below

Range - 40dB/50dB

I/p switch - low impedance

Meter switch - normal

Gain - mid position approximate.

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

Beam voltage - OFF

Mod switch - AM

Beam voltage knob - fully anti-clockwise

Repeller voltage knob - fully clockwise

AM amplitude knob - around fully clockwise

AM frequency - mid position

5. Switch ON the Klystron power supply, VSWR meter and cooling fan.

6. Switch ON the beam voltage and set beam voltage at 250V.

7. Rotate the reflector voltage knob to get deflection in VSWR meter.

8. Tune the output by turning the reflector voltage, amplitude and frequency of AM modulation.

9. Tune 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.

A. Measurement of Low and Medium VSWR

1. Move the probe along the slotted section to get maximum deflection in VSWR meter.

2. Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates1.0 on normal VSWR scale.

3. Keep all the control knob 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 SWR on second VSWR scale of 3 to 10.

B. Measurement of high VSWR (Double minimum method)

1. Get the depth of S.S tuner slightly more for maximum VSWR.

2. Move the probe along with slotted line until 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 the 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 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. Repeat the S.S tuner and termination by movable short.

7. Measure the distance between two successive minima positions of the probe, twice the distance is guide wavelength λg.

8. Compute SWR from the following equation

$$\text{SWR} = \lambda g/\pi(d2 - d1)$$

Vmax

√2Vmin

Vmin

d2 d1
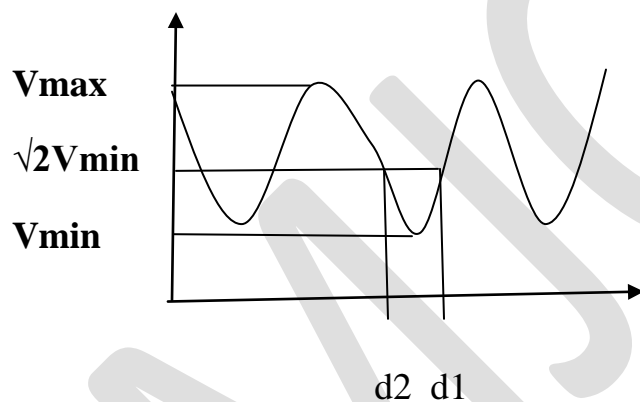
OBSERVATIONS :

1. Low VSWR =

2. High VSWR =

Reflection coefficient= S-1/S+1 =

5. MEASUREMENT OF IMPEDANCE

AIM: To measure unknown impedance using the Smith chart.

EQUIPMENT :

Klystron Tube, Klystron Power supply, Klystron Mount, Isolator, Frequency Meter, Variable Attenuator, Slotted line, VSWR Meter, Waveguide Stand, SS tuner, Movable Short/Termination

THEORY :

The impedance at any point on a transmission line can be written in the form R+jX. This SWR can be calculated $S=(1+R) / (1-R)$ Where R is reflection coefficient = Z-Zo /Z+Zo where Z0 is the characteristic impedance of the waveguide at the operating frequency. Z is the load impedance. The unknown device is connected to the slotted section and the position of one minima is determined. The unknown device is replaced by Movable short to the slotted section. Two successive minima positions are noted. Twice the difference between the minima positions will be guide wavelength. One of the minima is used as reference for impedance measurement. Find the difference of reference minima and minima position obtained from unknown load. Let it be'd'. Take a Smith chart, taking 'l' as center; draw a circle of radius equal to 'S0'. Mark a point on circumference of Smith chart towards load side at a distance equal to d/λg. Join the center with this point. Find the point where it cuts the drawn circle. The coordinates of this point will show the normalized impedance of the load.

SET UP FOR IMPEDANCE MEASUREMENT:
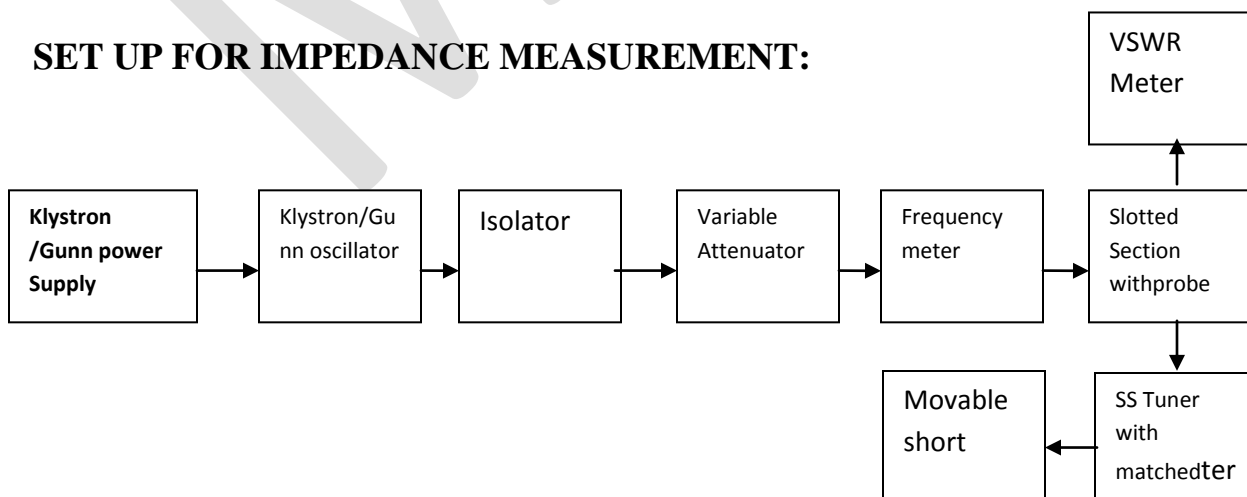
PROCEDURE :

1. Set up the equipment as shown in the figure.

2. Set the variable attenuator at minimum position.

3. Keep the control knobs of VSWR Meter as below

Range - 50 dB position

Input switch - Crystal Low Impedance

Meter switch - Normal position

Gain (Coarse – fine) - Mid position

4. Keep the control knobs of Klystron power supply as below

Beam voltage switch -'OFF'

Mod switch - AM

Beam Voltage Knob - Fully anti-clockwise

Reflector voltage - Fully clockwise

AM – amplitude - Around fully clockwise

AM- Frequency Knob - Around 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 300 V with the help of beam voltage knob.

7. Adjust the reflector voltage knob to get some deflection in VSWR meter.

8. Maximize the deflection with AM amplitude and frequency control knob of power supply.

9. Tune the plunger of Klystron Mount for maximum deflection.

10. Tune the reflector voltage knob for maximum deflection.

11. Tune the probe for maximum deflection in VSWR meter.

12. Tune the frequency meter knob to get a 'dip' on the VSWR scale, and note down the frequency directly from frequency meter.

13. Keep the depth of the pin of SS Tuner around 3-4 mm and lock it.

14. Move the probe along the slotted section to get maximum deflection.

15. Adjust VSWR meter gain control knob and variable attenuator until the meter indicates 1.0 on the normal dB SWR scale.

16. Move the probe to next minima position and note down the SWR S0 on the scale. Also note down the probe position, let it be 'dx'.

17. Remove the SS Tuner and matched termination and place movable short at slotted section. The plunger of short should be at zero.

18. Note the position of two successive minima position. Let it be d1 and d2. Hence $\lambda g = 2(d1 - d2)$.

d = dx – d1

19. Calculate $d/\lambda g$.

20. Find out the normalized impedance as described in the theory section.

21. Repeat the same experiment for other frequency if required.

OBSERVATIONS :

d1 = mm.

d2 = mm

$\lambda g = 2(d1 - d2)$ mm.

SWR = S0 =

d =

$d/\lambda g$ =

Normalized impedance =

PRECAUTIONS :

1. To protect repeller from damage the repeller negative voltage is always applied before anode voltage.

2. While modulating repeller should never become positive with respect to cavity.

3. Cooling should be provided to Reflex klystron

6. Parameters of Directional coupler.

AIM

To study the function of multi hole directional coupler by measuring the following parameters.

1. Coupling factor   4 Isolation Loss

2. Insertion loss

3. Directivity

APPARATUS

Microwave source (Klystron or Gunn diode), Isolator, Frequency meter, Variable attenuator, Slotted line, Tunable probe, Detector mount, Matched termination, MHD coupler, Waveguide Stand, Cables and Accessories, VSWR meter.
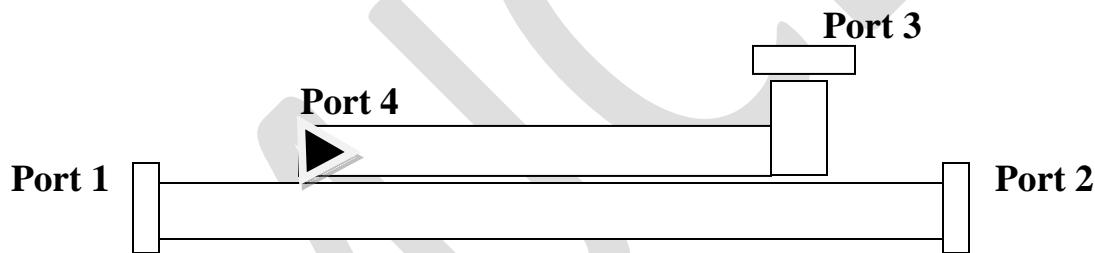

FIG.1 DIRECTIONAL COUPLER

A directional coupler is a device which is used to measure the incident and reflected wave separately. It consists of two transmission lines the main arm and the auxiliary arm. Electromagnetically coupled to each other refers to the fig. The power entering in the main arm gets divided between port 2 and 3 and almost no power comes out in port 4 power entering at port 2 is divided between port 1 and 4.

The coupling factor is defined as

Coupling (dB) = $10 \log 10 \, (P1 / P3)$ where port 2 is terminated.

Isolation (dB) = 10 log 10(P2 / P3) where P1 is matched with built in termination and power entering at port 1 the directivity of the coupler is a measure of separation between incident wave and the reflected wave directivity is measured indirectly as follows

Hence directivity D (dB) = 1-c = 10log10 (P2 / P1)

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

Insertion loss (dB) = 10log10 (P1 / P2).

Bench Setup Diagram:
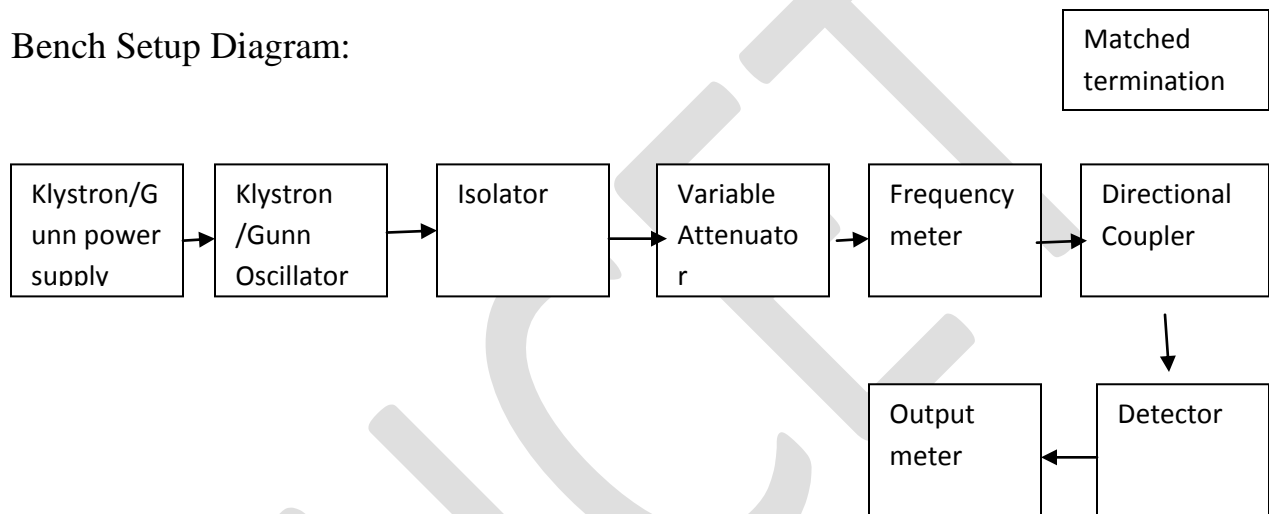
PROCEDURE

1. Set up the components and equipment as shown in the figure.

2. Energize the microwave source for particular frequency of operation.

3. Remove the multi hole directional coupler and connect the detector mount of the frequency meter. Tune the detector for maximum output.

4. Set any reference level of power on VSWR meter with the help of variable attenuator, gain control knob of VSWR meter, and note down the reading (reference level let X).

5. Insert the directional coupler as shown in second figure with detector to the auxiliary port 3 and matched termination to port 2, without changing the position of variable attenuator and gain control knob of VSWR measurement.

6. Note down the reading on VSWR meter on the scale with help of range – dB switch if required let it be Y.

7. Calculate coupling factor which will be X-Y = C (dB).

8. Now carefully disconnect the detector from the auxiliary port 3 and match termination from point 2 without disturbing the set up.

9. Connect the matched termination to the auxiliary port 3 and detector to port 2 and measure the reading on VSWR meter, suppose it is Z.

10. Compute the insertion loss X-Z in dB.

11. Repeat the steps from 1 to 4.

12. Connect the directional coupler in the reverse direction i.e. port 2 to frequency meter side matched termination to port 1 and detector mount to port 3 without disturbing the position of the variable attenuator and gain control knob of VSWR meter.

13. Measure and note down the reading on VSWR meter. Let it be Yd. X – Yd gives isolation.

14. Compute the directivity as Y – Yd.

15. Repeat the same for other frequencies.

OBSERVATIONS :

Check the condition Isolation Loss = Coupling factor + Directivity

Insertion Loss= $10 \log (Pi/Pt)$

Coupling factor = $10 \log (Pi/Pf)$

Directivity = $10 \log (Pf/Pb)$

Isolation Loss= $10 \log (Pi/Pb)$

Where Pi = input power, Pt = transmitted power Pf = forward power,
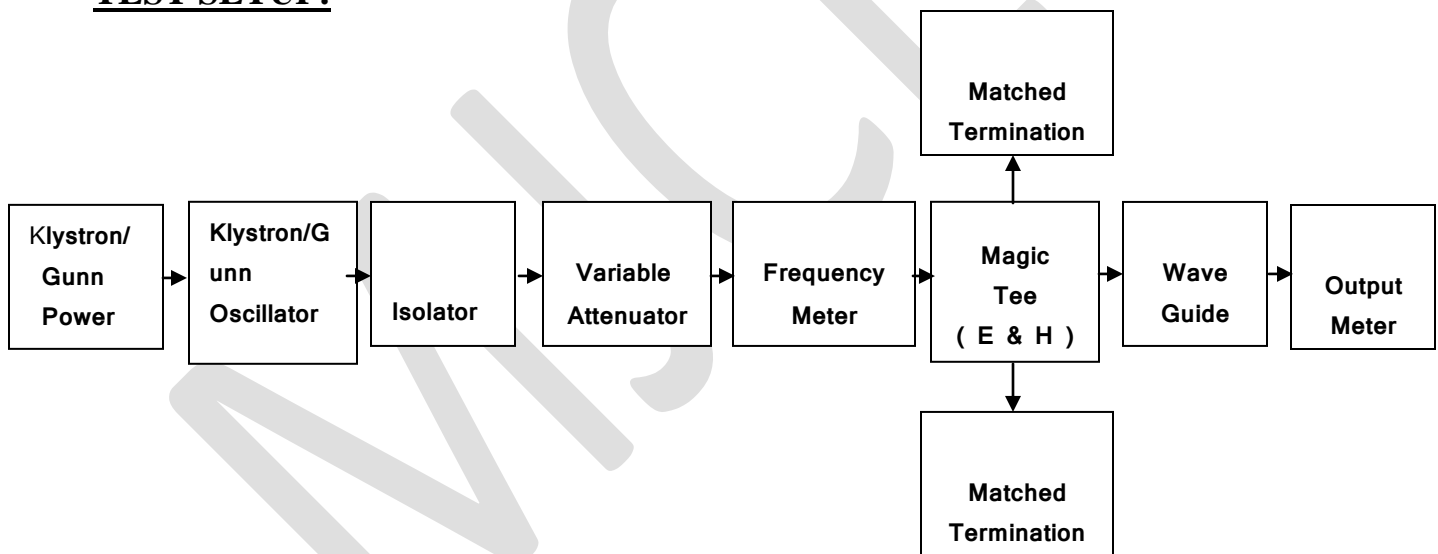
       Pb =backward power

7. SCATTERING MATRICES OF TEES.

AIM: To study the characteristics of waveguide Tees and to find its scattering matrices.

COMPONENTS:

1. Test set up(see previous experiment)
2. Ammeter
3. E-plane Tee
4. H-plane Tee
5. Magic Tee

TEST SETUP:

PROCEDURE:

Measure the output current in the test set up and note it as I1 after adjusting the reflector voltage to the maximum output.

TEE-JUNCTION:

1.   Insert the tee junction before detector mount.

2.   Measure the output current at the other ports and note it as I2&I3.

3.   Observe.

In case of E-Tee junction

I2=I3 but out of phase   i.e (I2= -I3)

In case of H-Tee junction

(I2= I3) i.e I2=I3 in phase

In case of E H-Tee junction or Magic Tee

$$[S] = \begin{pmatrix} S11 & S12 & S13 & S14 \\ S21 & S22 & S23 & S24 \\ S31 & S32 & S33 & S34 \\ S41 & S42 & S43 & S44 \end{pmatrix}$$

(I1=I4) i.e I1=I4, I2=0   input at 3 (i.e.I3)

4. Vary the frequency of oscillation and repeat step 3.

QUESTION:

1. Make out the differences between E-Tee, H-Tee & E-H Tee.

2. Change the frequency from f1 to f6 & repeat the experiment procedure at different distance (d) & plot the pattern on polar graph paper & determine 3dB beam width & directivity.
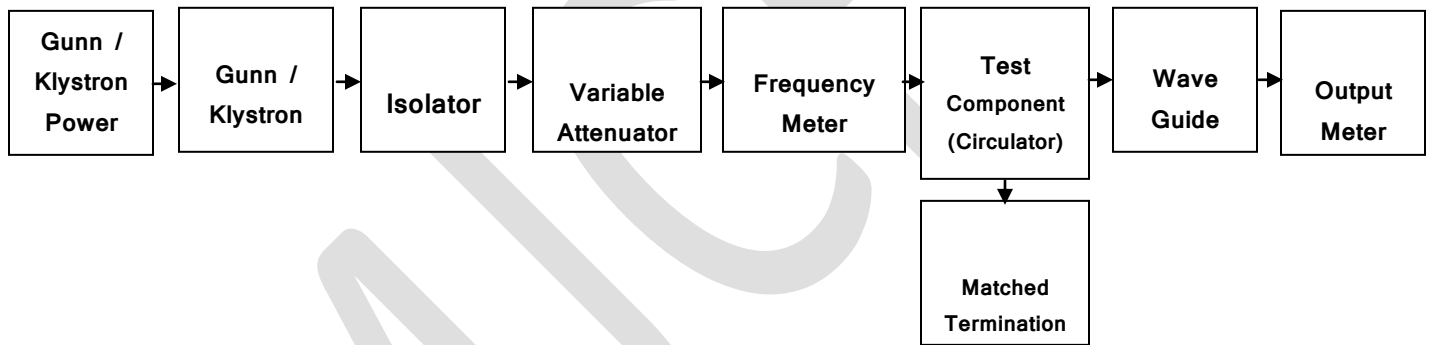
8. SCATTRING MATRIX OF CIRCULATOR

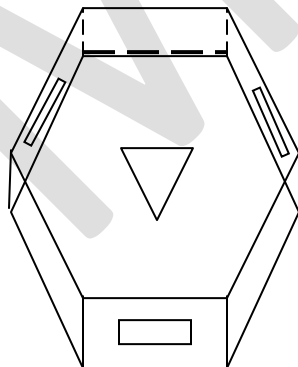**AIM**: To calculate S matrix of the circulators.

EQUIPMENT:

1. Test set up
2. Ammeter
3. Circulators

TEST SETUP:

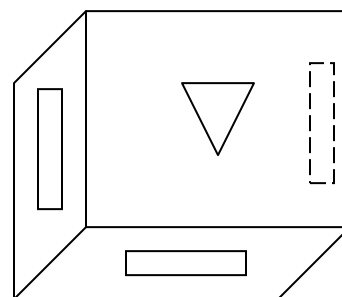| Gunn / Klystron Power | → | Gunn / Klystron | → | Isolator | → | Variable Attenuator | → | Frequency Meter | → | Test Component (Circulator) | → | Wave Guide | → | Output Meter |

Test Component (Circulator) → Matched Termination

Circulator

Y – Type   **T – Type**

$$[S] = \begin{pmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{pmatrix}$$

EXPERIMENTAL PROCEDURE ;

1.   Switch on the KPS after keeping reflection voltage knob to maximum and beam   voltage knob to minimum.   .

2.   Allow sufficient time & increase beam voltage to 290V or 300V.

3.   Decrease the reflector voltage and the maximum current at the output. Note   it as I1.

CIRCULATOR:

1.   Connect the circulator before wave guide detector.

2.   Measure currents at port B& port C by keeping matched termination
        at one port while measuring at the other port.

3.   Calculate Isolation & Insertion losses.

4.   By varying frequency repeat the steps 2 & 3 for at least four different
   values. Use calibration chart to measure frequency.

9. RADIATION PATTERN OF MICROWAVE ANTENNAS

AIM: To determine the relationship between transmitting antenna & receiving antenna and to measure radiation pattern.

EQUIPMENT:

1. Klystron power supply.
2. Klystron mount with klystron tube (R. .K.O)
3. Isolator   .
4. Frequency meter
5. Slotted section
6. Output meter
7. Crystal detector
8. Horn antennas

TEST SETUP:

Transmitter   d   Receiver
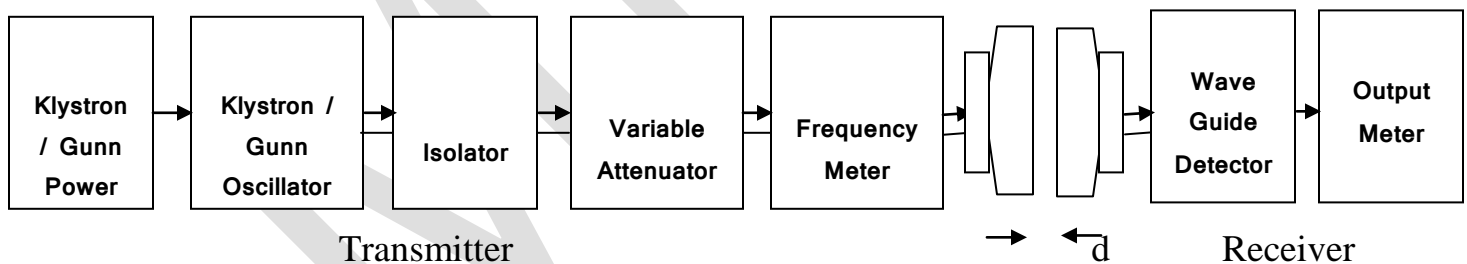
THEORY

A horn antenna may be regarded as a flared out or opened out wave guide. A wave guide is capable of radiating radiation into open space provided the same is excited at one end and opened at the other end. However, the radiation is much greater through wave guide than the 2 wire transmission line. To overcome reflection and diffraction in the wave guide, the mouth of the waveguide is opened out which assumes the shape of a electromagnetic horn. If the wave

guide is terminated by any type of horn, the abrupt discontinuity existed is replaced by a gradual transformation, then all the energy incident in forward direction in the waveguide will now be radiated, provided the impedance matching is proper. This improves directivity and reduces diffraction. If flaring is done only in one direction, then sectorial horn is produced. If flaring is done along both the walls, then pyramidal horn is obtained. By flaring the walls of the circular waveguide, a concial horn is formed. The fields inside the waveguide propagate in the same manner as in free space, but on reaching the mouth of the waveguide, these propagating fields continue to propagate in the same general direction but also starts spreading laterally and the wave front eventually becomes spherical. However this may be treated as transition region where the change over from the guided propagation to free space propagation occurs. Since the waveguide impedance & free space impedance are not equal, hence to avoid standing wave ratio, flaring of walls of waveguide is done which besides matching of impedance also provide concentrated radiation pattern(ie)greater directivity and narrower beam width. It is the flared structure that is given the name electro magnetic horn radiator. The function is to produce a uniform phase front with a larger aperture in comparison to waveguide and thus directivity is greater. If flare angle is very large, the wavefront on the mouth of the horn will be curved rather than plane. This will result in non-uniform phase distribution over the aperture, resulting in increased beam width and reduced directivity, and vice versa occurs if the flare angle is very small. The directivity of the horn antenna is given as $D = 7.5\, A/\lambda 2$ where A area of horn mouth opening. Horn antennas are extensively used at microwave frequencies under the condition that power gain needed is moderate.

PROCEDURE:

1. Measure the output current in the test set up of transmitter output a frequency(f1) & note it as I1maximum output.

2. the given attenuator as in the set up and measure the output (power) current & note it as Io, for the frequency(f1) & repeat the same experimental procedure for various frequencies upto (f6)- Place Connect the antenna, after the Frequency meter.

3. Connect similar antenna with W.G. detector to the receiving circuit.

4. Turn the receiving Antenna and note the reading for the Near field and also far field pattern.
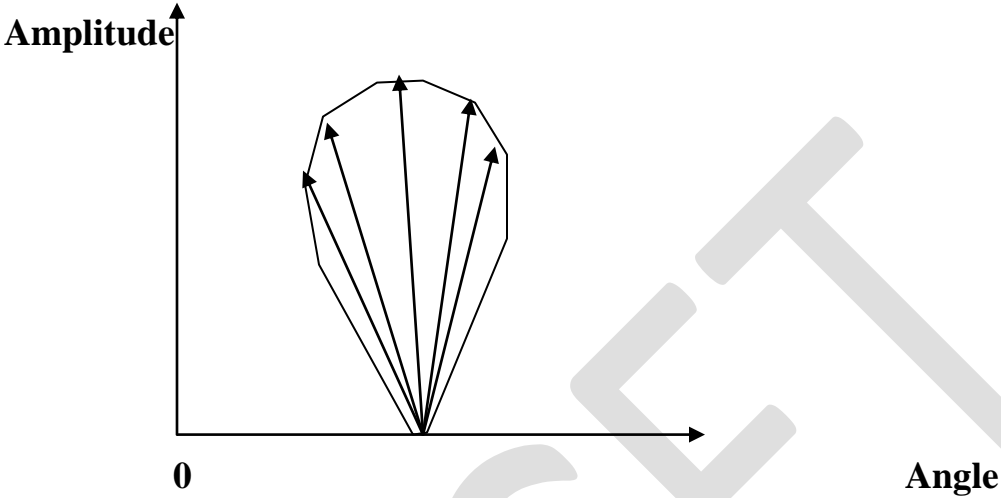
Tabular column:

Near Field $d_1 =$ **Far Field** $d_2 =$
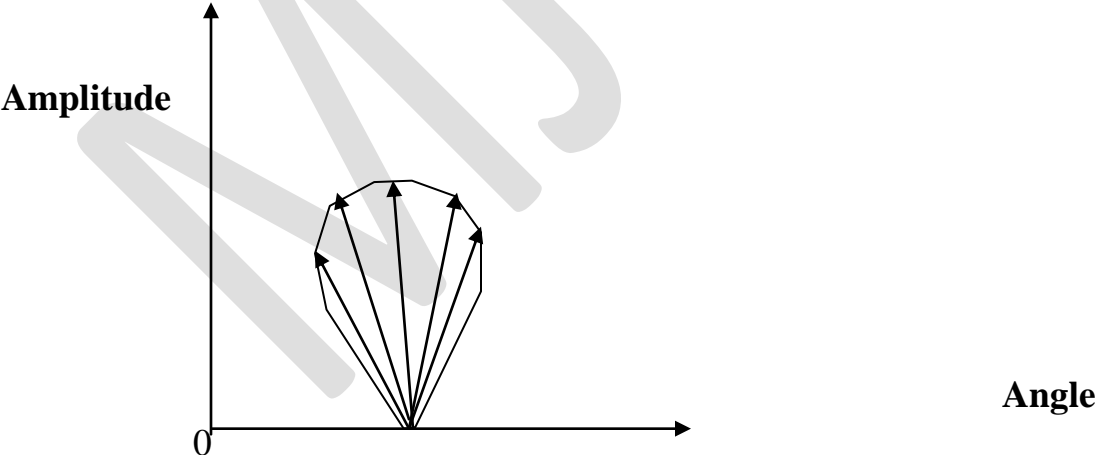
Sl No.	Angle	Output
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Sl No.	Angle	Output
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Expected Graphs:

Near field pattern

Amplitude

0   **Angle**

Far field pattern:

Amplitude

0   **Angle**

### 10. STUDY OF VARIOUS MICROWAVE ANTENNAS

Basic dipole antenna As seen the antenna consists of a radiating element that is split, normally in the centre to allow a feeder to apply power to it from a transmitter, or to take power from it to a receiver. The length of the radiating element determines many of the properties of the dipole antenna from its impedance, centre operating frequency, etc. As such this is an important feature of the antenna.Often the term dipole antenna tends to indicate a half wave dipole. This is by far the most widely used length for a dipole. It forms a resonant circuit which resonates where the electrical length is half a wavelength long - the electrical length differs from the wavelength of the signal in free space because of a number of the effects of the radiating element on the signal and it is very slightly shorter than the signal e/m wavelength in free space..

Half wave dipole antenna
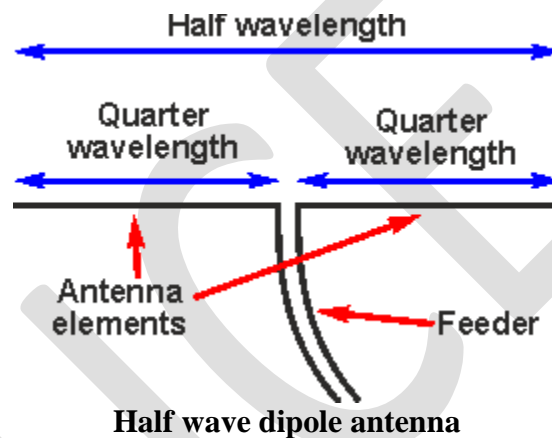
Half wave dipole radiation pattern

The radiation pattern of a half wave dipole antenna that the direction of maximum sensitivity or radiation is at right angles to the axis of the RF antenna. The radiation falls to zero along the axis of the RF antenna as   might be expected.
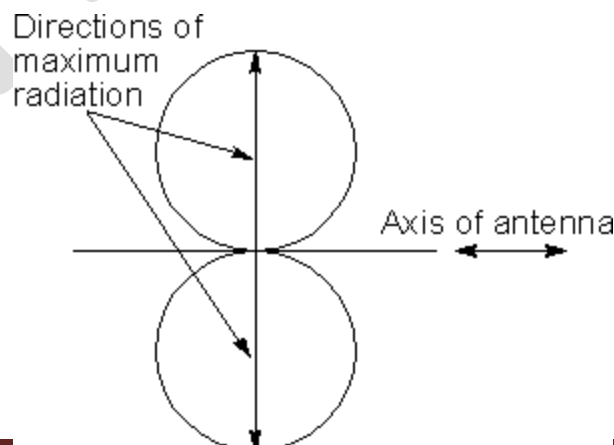
Radiation pattern of a half wave dipole antenna in free space

In a three dimensional plot, the radiation pattern envelope for points of equal radiation intensity for a doughnut type shape, with the axis of the antenna passing through the hole in the centre of the doughnut.Small Loop Antennas: The small loop antenna is a closed loop as shown in Figure 1. These antennas have low radiation resistance and high reactance, so that their impedance is difficult to match to a transmitter. As a result, these antennas are most often used as receive antennas, where impedance mismatch loss can be tolerated.The radius is a, and is assumed to be much smaller than a wavelength ($a << \lambda$). The loop lies in the x-y plane.
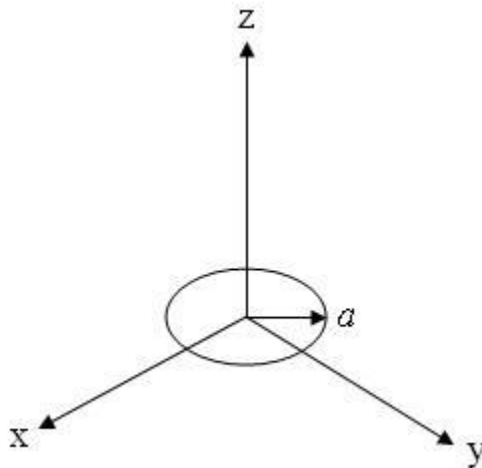
Figure 1. Small loop antenna.

Since the loop is electrically small, the current within the loop can be approximated as being constant along the loop, so that $I = I_0$.

The fields from a small circular loop are given by:

$$E_\phi = \frac{\eta k^2 a^2 I_0 e^{-jkr} \sin\theta}{4r}$$

$$H_\theta = \frac{-E_\phi}{\eta}$$

Yagi-Uda Antenna

A **Yagi-Uda antenna**, commonly known simply as a **Yagi antenna**, is a directional antenna consisting of multiple parallel dipole elements in a line, usually made of metal rods. It consists of a single driven element connected to the transmitter or receiver with a transmission line, and additional parasitic elements: a so-called *reflector* and one or more *directors*. The reflector element is slightly longer than the driven dipole, whereas the directors are a little shorter.[6] This design achieves a very substantial increase in the antenna's directionality and gain compared to a simple dipole.
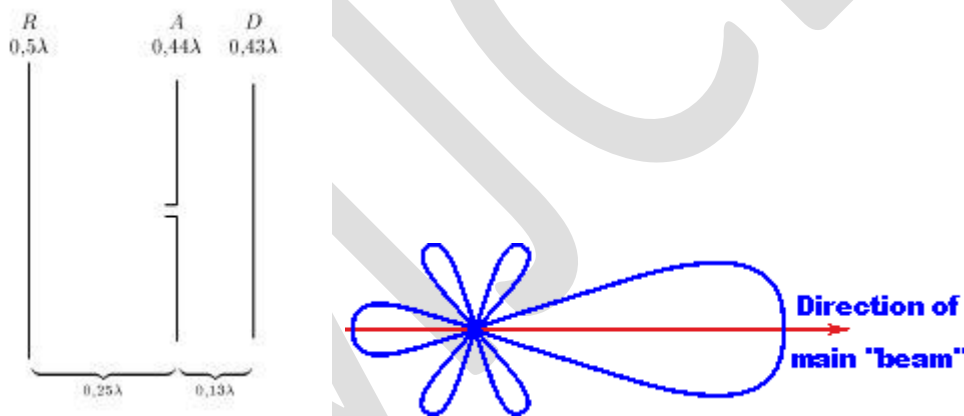
A **log-periodic antenna** (**LP**), also known as a **log-periodic array** or **aerial**, is a multi-element, directional, narrow-beam antenna that operates over a wide band of frequencies, a broad bandwidth. A particular form of the log-periodic design, the **log-periodic dipole array** or **LPDA**, is often used in television antennas that work in the VHF band. An LPDA antenna consists of a number of half-wave dipole driven elements of gradually increasing length, each consisting of a pair of metal rods. The dipoles are mounted close together in a line, connected in parallel to the feed line with alternating phase.
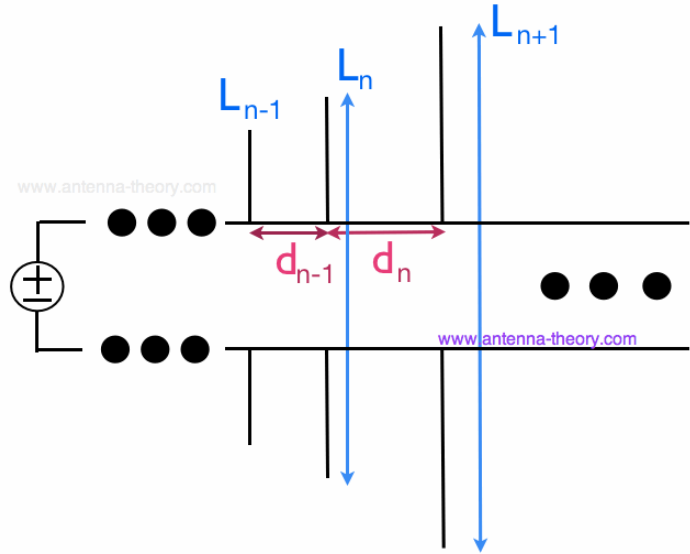
$$\frac{L_{n+1}}{L_n} = \frac{d_{n+1}}{d_n} = k$$

11.MINI PROJECT

Aim: To design microwave components such as Directional Coupler, Circulators and antenna arrays using simulation software.

Students are encouraged to design various microwave components and antenna arrays using simulation software.

APPENDIX

LABORATORY COURSE ASSESSMENT GUIDELINES

i.   The number of experiments in each laboratory course shall be as per the curriculum in the scheme of instructions provided by OU. Mostly the number of experiments is 10 in each laboratory course under semester scheme and 18 under year wise scheme.
ii.   The students will maintain a separate note book for observations in each laboratory course.
iii. In each session the students will conduct the allotted experiment and enter the data in the observation table.
iv.   The students will then complete the calculations and obtain the results. The course coordinator will certify the result in the same session.
v.   The students will submit the record in the next class. The evaluation will be continuous and not cycle-wise or at semester end.
vi.   The internal marks of 25 are awarded in the following manner:
    a. Laboratory record   -   Maximum Marks 15
    b. Test and Viva Voce   -   Maximum Marks 10
vii. Laboratory Record: Each experimental record is evaluated for a score of 50. **The rubric parameters are as follows:**
    a. Write up format   -   Maximum Score 15
    b. Experimentation Observations & Calculations -   Maximum Score 20
    c. Results and Graphs   -   Maximum Score 10
    d. Discussion of results   -   Maximum Score 5

While (a), (c) and (d) are assessed at the time of record submission, (b) is assessed during the session based on the observations and calculations. Hence if a student is absent for an experiment but completes it in another session and subsequently submits the record, it shall be evaluated for a score of 30 and not 50.
viii. The experiment evaluation rubric is therefore as follows:

Parameter	Max Score	Outstanding	Accomplished	Developing	Beginner	Points
Observations and Calculations	20					
Write up format	15					
Results and graphs	10					
Discussion of Results	5					

LABORATORY EXPERIMENT EVALUATION RUBRIC

CATEGORY	OUTSTANDING (Up to 100%)	ACCOMPLISHED (Up to 75%)	DEVELOPING (Up to 50%)	BEGINNER (Up to 25%)
Write up format	Aim, Apparatus, material requirement, theoretical basis, procedure of experiment, sketch of the experimental setup etc. is demarcated and presented in clearly labeled and neatly organized sections.	The write up follows the specified format but a couple of the specified parameters are missing.	The report follows the specified format but a few of the formats are missing and the experimental sketch is not included in the report	The write up does not follow the specified format and the presentation is shabby.
Observations and Calculations	The experimental observations and calculations are recorded in neatly prepared table with correct units and significant figures. One sample calculation is explained by substitution of values	The experimental observations and calculations are recorded in neatly prepared table with correct units and significant figures but sample calculation is not shown	The experimental observations and calculations are recorded neatly but correct units and significant figures are not used. Sample calculation is also not shown	The experimental observations and results are recorded carelessly. Correct units significant figures are not followed and sample calculations not shown
Results and Graphs	Results obtained are correct within reasonable limits. Graphs are drawn neatly with labeling of the axes. Relevant calculations are performed from the graphs. Equations are obtained by regression analysis or curve fitting if relevant	Results obtained are correct within reasonable limits. Graphs are drawn neatly with labeling of the axes. Relevant calculations from the graphs are incomplete and equations are not obtained by regression analysis or curve fitting	Results obtained are correct within reasonable limits. Graphs are not drawn neatly and or labeling is not proper. No calculations are done from the graphs and equations are not obtained by regression analysis or curve fitting	Results obtained are not correct within reasonable limits. Graphs are not drawn neatly and or labeling is not proper. No calculations are done from the graphs and equations are not obtained by regression analysis or curve fitting
Discussion of results	All relevant points of the result are discussed and justified in light of theoretical expectations. Reasons for divergent results are identified and corrective measures discussed.	Results are discussed but no theoretical reference is mentioned. Divergent results are identified but no satisfactory reasoning is given for the same.	Discussion of results is incomplete and divergent results are not identified.	Neither relevant points of the results are discussed nor divergent results identified

ix.   The first page of the record will contain the following title sheet:

SAMPLE ASSESSMENT SHEET

NAME: **ROLL NO.**

Exp. No.	Date conducted	Date Submitted	Observations &Calculations (Max 20)	Write up (Max 15)	Results and Graphs (Max 10)	Discussion of Results (Max 5)	Total Score (Max 50)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

x.   The 15 marks of laboratory record will be scaled down from the TOTAL of the assessment sheet.
xi.   The test and viva voce will be scored for 10 marks as follows:
Internal Test   -   6 marks
Viva Voce / Quiz   -   4 marks
xii.   Each laboratory course shall have 5 course outcomes.

The proposed course outcomes are as follows:

On successful completion of the course, the student will acquire the ability to:

1. Conduct experiments, take measurements and analyze the data through hands-on experience in order to demonstrate understanding of the theoretical concepts of _____, while working in small groups.

2. Demonstrate writing skills through clear laboratory reports.

3. Employ graphics packages for drawing of graphs and use computational software for statistical analysis of data.

4. Compare the experimental results with those introduced in lecture, draw relevant conclusions and substantiate them satisfactorily.

5. Transfer group experience to individual performance of experiments and demonstrate effective oral communication skills.

xiii.   The Course coordinators would prepare the assessment matrix in accordance with the guidelines provided above for the five course outcomes. The scores to be entered against each of the course outcome would be the sum of the following as obtained from the assessment sheet in the record:

   a. Course Outcome 1: Sum of the scores under 'Observations and Calculations'.
   b. Course Outcome 2: Sum of the scores under 'Write up'.
   c. Course Outcome 3: Sum of the scores under 'Results and Graphs'.
   d. Course Outcome 4: Sum of the scores under 'Discussion of Results'.
   e. Course Outcome 5: Marks for 'Internal Test and Viva voce'.

xiv.   Soft copy of the assessment matrix would be provided to the course coordinators.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY

Program Outcomes of B.E (ECE) Program:

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12: Life-long learning: Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs) of ECE Department, MJCET

PSO1: The ECE Graduates will acquire state of art analysis and design skills in the areas of digital and analog VLSI Design using modern CAD tools.

PSO2: The ECE Graduates will develop preliminary skills and capabilities necessary for embedded system design and demonstrate understanding of its societal impact.

PSO3: The ECE Graduates will obtain the knowledge of the working principles of modern communication systems and be able to develop simulation models of components of a communication system.

PSO4: The ECE Graduates will develop soft skills, aptitude and programming skills to be employable in IT sector.