Department of Electronics & Communication Engineering

LAB MANUAL

SUBJECT: MICROWAVE LAB **[EC-IV]**

B.Tech Year – 3rd Semester -VI
(Branch: ECE)

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EXPERIMENT No. : 01

STUDY OF MICROWAVE COMPONENTS AND INSTRUMENTS

A. **Aim:**
To become familiar with microwave components and instruments available in the laboratory.

B. **Apparatus Used:**
Klystron power supply, Gunn power supply, VSWR meter, power meter, Slotted section, Frequency/wave meter, RF Generator, Vector Network Analyzer.

C. **Theory**

Components/Devices:
Attenuator, circulator, Isolator, Waveguide twist, Magic Tee, E plane, H plane Tee, Directional coupler, Matched termination, PIN modulator, Crystal detector, Reflex klystron tube, Gunn diode, different types of antennas available.

LIST OF EQUIPMENTS AND DEVICES TO BE STUDIED:

1. Klystron Power Supply
2. Klystron tube
3. Isolator
4. Circulator
5. Attenuator
6. Direct reading frequency meter
7. Slotted line section with probe carriage
8. Crystal Detector
9. VSWR Meter
10. Different types of Antennas available
11. Magic tee
12. E and H Plane Tee
13. Matched Termination
14. Waveguide to coaxial adapter

INTRODUCTION

A microwave test bench is an assembly of various microwave components, held together by Nuts & Bolts. It consists of a microwave source (Oscillator) at one end. The waves generated are led down by a wave guide through various components, so that the student can observe the propagation of waves, and their interaction and/or processing by various components.

1. Klystron Power Supply

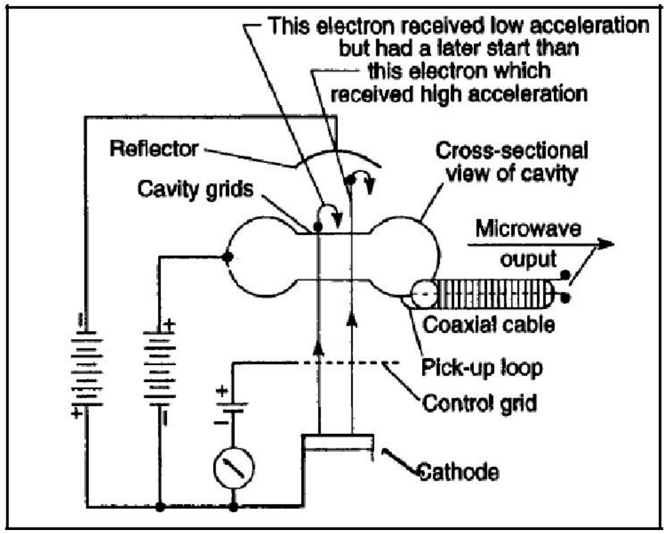
Klystron Power supply is a regulated power supply for operating low power klystron. Klystron power supply generates voltage required for driving the reflex klystron tubes like 2k25, 2k56, 2k22. It is absolutely stable, regulated and short circuit protected power supply. It has the facility to vary the Beam Voltage continuously and built in facility of square wave and saw tooth generators, for amplitude and frequency modulation.

2. Reflex Klystron (Klystron mount with tube)

A waveguide of suitable length having octal base on the broad wall of the waveguide for mounting the klystron tube. It consists of movable short at one end of the waveguide to direct the microwave energy generated by the klystron tube. A small hole located exactly at the center of the broad wall of the waveguide is used to put the coupling pin of the tube as the electric field vector of EM energy is maximum at the center only. The maximum power transfer can be achieved by tuning of the movable plunger.

The Reflex Klystron

The reflex klystron, shown in Fig., employs a somewhat different stratagem to extract energy from an electron beam in the form of microwave oscillation. The anode of the klystron is a resonant cavity that contains perforated grids to permit accelerated electrons to pass through and continue their journey. Such electrons are not, however, subsequently collected by a positive electrode. Rather, they are deflected by a negatively polarized 'reflector' and are thereby caused to fall back into the cavity grids. The operational objective of the tube is to have such electrons return to the cavity grids at just the fight time to reinforce the electric oscillatory field appearing across these grids. When this situation exists, oscillations are excited and sustained in the cavity. Microwave power is coupled out of the cavity by means of a loop if coaxial cable is used, or simply through an appropriate aperture if a waveguide is used for delivering the power to the load. After the kinetic energy of the electrons has been given up to the oscillatory field of the cavity, the spent electrons fall back to the positive biased control grid where they are collected, thereby adding to control grid current. If the tube is not oscillating, a relatively high number of electrons are deflected by the retarding field of the reflector with sufficient energy to pass through the cavity grids, thence to be collected by the control grid. However, when oscillations are sustained in the cavity, the falling electrons yield most of their



energy to the oscillating electric field appearing across the cavity grids. Such electrons are subsequently collected by the cavity grids, which in this function behave as the plate of an ordinary diode. Inasmuch as the spent electrons do not fall into the positive field of the control grid, a profound dip in control-grid current accompanies the onset of oscillation within the cavity.

3. **Isolator:**

The microwave test bench includes an attenuator, and an isolator. Both of these help to stop the reflected power from reaching the oscillator and pulling the frequency of the cavity and Gunn diode off tune when the load impedance is varied. An isolator is a two port device that transmits microwave or radio frequency power in one direction only**.** It is used to shield equipment on its input side, from the effects of conditions on its output side; for example, to prevent a microwave source being detuned by a mismatched load. An

ideal isolator transmits all the power entering port 1 to port 2, while absorbing all the power entering port 2.
An isolator in a non-reciprocal device, with a non-symmetric matrix.

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

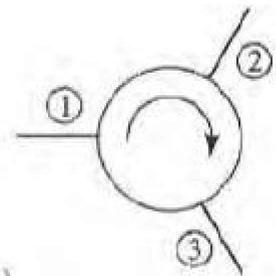
To achieve non-reciprocity, an isolator must necessarily incorporate a non-reciprocal material. At microwave frequencies this material is invariably a ferrite which is biased by a static magnetic field. The ferrite is positioned within the isolator such that the microwave signal presents it with a rotating magnetic field, with the rotation axis aligned with the direction of the static bias field. The behavior of the ferrite depends on the sense of rotation with respect to the bias field, and hence is different for microwave signals travelling in opposite directions. Depending on the exact operating conditions, the signal travelling in one direction may either be phase-shifted, displaced from the ferrite or absorbed.

4. **Circulator**

A circulator is a passive non-reciprocal three port device in which microwave or radio frequency power entering any port is transmitted to the next port in rotation only. There are two types of circulators and their [S] matrices i.e. Clockwise circulator and Counterclockwise circulator.

Clockwise Circulator

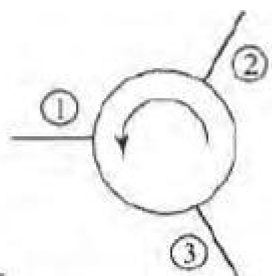
$$[S] = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$



(a)

Counterclockwise Circulator

$$[S] = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$



(b)

5. **Attenuator:**

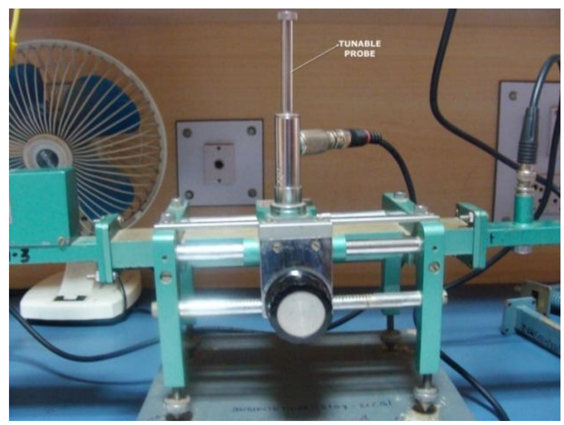
Attenuators are required to adjust the power flowing in a waveguide. Attenuators are of fixed, variable and rotary vane type, i.e.

Fixed: Any amount of fixed attenuation can be supplied between 3 to 40 dB. These attenuators are calibrated frequency band. **Variable:** Variable attenuators provide a convenient means of adjusting power level very accurately.

6. **Direct reading frequency meter**

This Frequency Meter has convenient readout with high resolution is provided by long spiral dials. These dials have all frequency calibrations visible so you can tell at a glance the specific portion of each band you are measuring. Overall accuracy of these frequency meters is 0.17% and includes such variables as dial calibration. It is constructed from a cylindrical cavity resonator with a variable short circuit termination. The shorting plunger is used to change the resonance frequency of the cavity by changing the cavity length. DRF measures the frequency directly. It is particularly useful when measuring frequency differences of small changes. The cylindrical cavity forms a resonator that produces a suck-out in the frequency response of the unit. This you would turn the knob until a dip in the response is observed.

7. **Slotted line section with probe carriage:**



The slotted line represented the basic instrument of microwave measurements. With its help it is possible to determine the VSWR, attenuation, phase and impedances. The position of carriage (probe) can be read from a scale with its vernier. The total travel of probe carriage is more than three time of half of guide wavelength.This system consists of a transmission line (waveguide), a traveling probe carriage and facility for attaching/detecting instruments. The slot made in the center of the broad face do not radiate for any power of dominant mode. The precision built probe carriage having centimeters scale with a vernier reading of 0.1 mm least count is used to note the position of the probe. Additionally slotted section can be used to measure reflection coefficient and the return loss.

8. **Crystal Detector:**

The crystal detector (Detector mount) can be used for the detection of microwave signal. RF choke is built into the crystal mounting to reduce leakage from BNC connector. Square law characteristics may be used with a high gain selective amplifier having a square law meter calibration. At low level of microwave power, the response of each detector approximate to square law characteristics and may be used with a high gain selective amplifier having a square law meter calibration.

9. VSWR Meter

The SWR meter or VSWR (voltage standing wave ratio) meter measures the standing wave ratio in a transmission line. The meter can be used to indicate the degree of mismatch between a transmission line and its load (usually a radio antenna), or evaluate the effectiveness of impedance matching efforts.

Ways to express VSWR

The reflection coefficient is what you'd read from a Smith chart. A reflection coefficient with magnitude of zero is a perfect match and a value of one is perfect reflection. The symbol for reflection coefficient is uppercase Greek letter gamma (Γ). Note that the reflection coefficient is a vector, so it includes an angle. Unlike VSWR, the reflection coefficient can distinguish between short and open circuits. A short circuit has a value of -1 (1 at an angle of 180 degrees), while an open circuit is one at an angle of 0 degrees.The **return loss** of a load is merely the magnitude of the reflection coefficient expressed in decibels. The correct equation for return loss is:

$$R.L. = -20\log\ |\Gamma|$$

Here are the equations that convert between VSWR, reflection coefficient and return loss:

$$\Gamma = \frac{VSWR - 1}{VSWR + 1} \qquad RL = -20\log\left[\frac{VSWR - 1}{VSWR + 1}\right]$$

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \qquad RL = -20\log(\Gamma)$$

$$\Gamma = 10^{\frac{-RL}{20}} \qquad VSWR = \frac{1 + 10^{\frac{-RL}{20}}}{1 - 10^{\frac{-RL}{20}}}$$

10. Different types of Antennas available

- **Conical Horn :**

It is also called as waveguide fed Conical Horn. The conical horn antenna is a practical microwave antenna, often used as a feed for communication / satellite dishes and radio telescopes. Although the axial symmetry makes it capable of handling any polarization of the exciting fundamental (TE11) mode, the pin-fed horn design provided here is for linearly polarization.

There are a number of permutations on the basic horn design which can serve to minimize the effects of diffractions, improve pattern symmetry and reduce the side lobe levels. These include corrugating the internal walls, curving the walls at the aperture, incorporating corrugations with the wall curvature at the aperture, and introducing higher order modes in the horn to reduce the field at the aperture edges. A lens is often placed across the aperture to compensate for phase error and thus narrow the beam width.

- **Parabolic Dish:**

A parabolic antenna is an antenna that uses a parabolic reflector, a surface with the cross-sectional shape of a parabola, to direct the radio waves. The most common form is shaped like a dish and is popularly called a dish antenna or parabolic dish. The main advantage of a parabolic antenna is that it is highly directive; it functions analogously to a searchlight or flashlight reflector to direct the radio waves in a narrow beam, or receive radio waves from one particular direction only. Parabolic antennas have some of the highest gains that is they can produce the narrowest beam width angles, of any antenna type. They are used as high-gain antennas for point-to-point radio, television and data communications, and also for radiolocation (radar), on the UHF and microwave (SHF) parts of the electromagnetic spectrum. The relatively short wavelength of electromagnetic radiation at these frequencies allows reasonably sized reflectors to exhibit the desired highly directional response.

With the advent of TVRO and DBS satellite television dishes, parabolic antennas have become a ubiquitous feature of the modern landscape, not only in rural locales where CATV and terrestrial signals were limited or non-existent, but also in urban and suburban regions, where the aforementioned services compete with CATV and broadcast media. Extensive terrestrial microwave links, such as those between cell phone base stations, and wireless WAN/LAN applications have also proliferated this antenna type. Earlier applications included ground-based and airborne radar and radio astronomy.

Although the term **dish antenna** is often used for a parabolic antenna, it can connote a spherical antenna as well, which has a portion of spherical surface as the reflector shape.

TYPES OF PARABOLIC DISH:

Parabolic antennas are distinguished by their shapes:

- **Cylindrical** - The reflector is curved in only one direction and flat in the other. The radio waves come to a focus not at a point but along a line. The feed is often a dipole antenna located along the focal line. It radiates a fan-shaped beam, narrow in the curved dimension, and wide in the uncurved dimension. The curved ends of the reflector are sometimes capped by flat plates, to prevent radiation out the ends, and this is called a pillbox antenna.
- **Orange peel** - Another type is very long and narrow, shaped like the letter "C". This is called an orange peel design, and radiates an even wider fan beam. It is often used for radar antennas.
- **Paraboloidal or dish** - The reflector is shaped like a paraboloid. This is the most common type. It radiates a narrow pencil-shaped beam along the axis of the dish.
- **Shrouded dish** - Sometimes a cylindrical metal shield is attached to the rim of the dish. The shroud shields the antenna from radiation from angles outside the main beam axis, reducing the side lobes. It is sometimes used to prevent interference in terrestrial microwave links, where several antennas using the same frequency are located close together. The shroud is coated inside with microwave absorbent material. Shrouds can reduce back lobe radiation by 10 dB.

They are also classified by the type of feed; how the radio waves are supplied to the antenna:

- **Axial or front feed** - This is the most common type of feed, with the feed antenna located in front of the dish at the focus, on the beam axis. A disadvantage of this type is that the feed and its supports block some of the beam, which limits the aperture efficiency to only 55 - 60%.
- **Offset or off-axis feed** - The reflector is an asymmetrical segment of a paraboloid, so the focus, and the feed antenna, is located to one side of the dish. The purpose of this design is to move the feed structure out of the beam path, so it doesn't block the beam. It is widely used in home satellite television dishes, which are small enough that the feed structure would otherwise block a significant percentage of the signal.

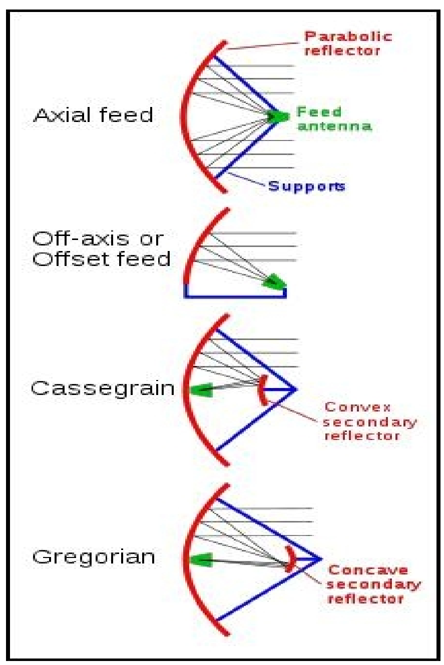


Figure (right) shows the main types of parabolic antenna feeds.

- **Cassegrain** - In a Cassegrain antenna the feed is located on or behind the dish, and radiates forward, illuminating a convex hyperboloidalsecondary reflector at the focus of the dish. The radio waves from the feed reflect back off the secondary reflector to the dish, which forms the main beam. An advantage of this configuration is that the feed, with its waveguides and "front end" electronics does not have to be suspended in front of the dish, so it is used for antennas with complicated or bulky feeds, such as large satellite communication antennas and radio telescopes. Aperture efficiency is on the order of 65 - 70%.
- **Gregorian** - Similar to the Cassegrain design except that the secondary reflector is concave, (ellipsoidal) in shape. Aperture efficiency over 70% can be achieved.

Gain:

The directive qualities of an antenna are measured by a dimensionless parameter called its gain, which is the ratio of the power received by the antenna from a source along its beam axis to the power received by a hypothetical isotropic antenna. The gain of a parabolic antenna is:

$$G = \frac{4\pi A}{\lambda^2} e_A = \frac{\pi^2 d^2}{\lambda^2} e_A$$

Where,

A is the area of the antenna aperture, that is, the mouth of the parabolic reflector

d is the diameter of the parabolic reflector

λ is the wavelength of the radio waves.

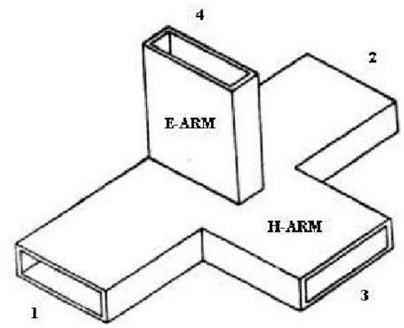
e_A is a dimensionless parameter called the aperture efficiency. The aperture efficiency of typical parabolic antennas is 0.55 to 0.60.

11. Magic Tee:

The magic tee is a combination of E and H plane tees. Arm 3 forms an H-plane tee with arms 1 and 2. Arm 4 forms an E-plane tee with arms 1 and 2. Arms 1 and 2 are sometimes called the side or collinear arms. Port 3 is called the H-plane port, and is also called the Sum port or the P-port (for Parallel). Port 4 is the E-plane port, and is also called the (delta) port, difference port, or S-port (for Series).

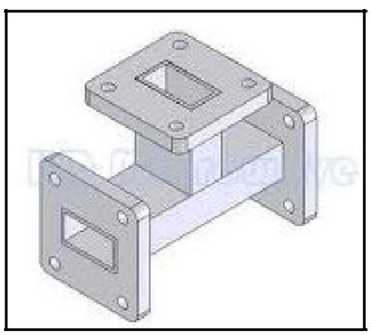
The name "magic tee" is derived from the way in which power is divided among the various ports. A signal injected into the H-plane port will be divided equally between ports 1 and 2, and will be in phase. A signal injected into the E-plane port will also be divided equally between ports 1 and 2, but will be 180 degrees out of phase. If signals are fed in through ports 1 and 2, they are added at the H-plane port and subtracted at the E-plane port. Thus, with the ports numbered as shown, and to within a phase factor, the full scattering matrix for an ideal magic tee is

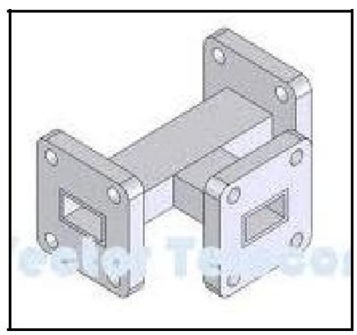
$$S = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 & 0 & 1 & -1 \\ 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 \\ -1 & 1 & 0 & 0 \end{pmatrix}$$



12. E and H Plane Tee

In E Plane Tee the junction of the auxiliary arm is made on the broad wall of the main waveguide. And in H Plane Tee the junction of auxiliary arm is made on the narrow wall of the main waveguide.





E Plane Tee **H Plane Tee**

13. Matched Termination

These are used for terminating the waveguide systems operating at low average power and are designed to absorb all the applied power assuring low SWR. Where a matched load is required as in the measurement of reflection, discontinuities of obstacle in waveguide systems, these components are used. These are also employed as a precise reference loads with tee junctions, directional couplers etc.

14. W/g Coaxial Adaptor:

These adapters consist of a short section of waveguide with a probe transition coax mounted on broad wall. It transforms waveguides impedance into coaxial impedance. Power can be transmitted in either direction. Each adaptor covers 50% of the waveguide band.

Objectives:

1. Note relevant Technical specifications of the instruments.
2. Study position and functions of the front panel controls of the equipment.
3. Know basic principle of operation and functional block diagram of the instrument.
4. Facilities provided and limitations of the equipment if any.
5. Know initial settings of controls of the equipments before switching on the supply.
6. Precautions to be taken while carrying out the measurements.

D. <u>Procedure:</u>
<u>(Separate sheet provided)</u>

E. <u>Observation: (Include your own Table relevant to the Experiment)</u>

1. Identify the components/devices.
2. Study basic principle of operation of devices and components.
3. Know typical application of each component.
4. Identify the E field and H field mode patterns in these devices.

F. Analysis of Results: (Write your own)
(Include sample calculations/Display/plot/typical graph)

G. Conclusions: (Write your Own)

Precautions:

1. Check the connections before switching on the kit.
2. Connections should be done properly.
3. Observation should be taken properly.

Approved By:

(HOD ECE) (Lab Instructor)

EC - IV: MICROWAVE LAB
EXPERIMENT No. : 02

REFLEX KLYSTRON CHARACTERISTICS

H. Aim:

To study mode characteristics of reflex klystron and hence to determine mode number, transit time electronic tuning range (ETR) and electronic tuning sensitivity (ETS)

I. Equipment and Component:

1. Klystron power supply MTI KP 503
2. Klystron tube /2k25
3. Isolator MTI/ NVIS- 204
4. Frequency Meter MTI/NVIS – 205A
5. Variable Attenuator MTI/ NVIS - 206
6. Detector mount MTI/ NVIS - 209
7. Waveguide stands MTI/NVIS
8. VSWR meter MTI VS 501/NVIS
9. Cathode Ray Oscilloscope Scientech -801C

J. Experimental Setup:

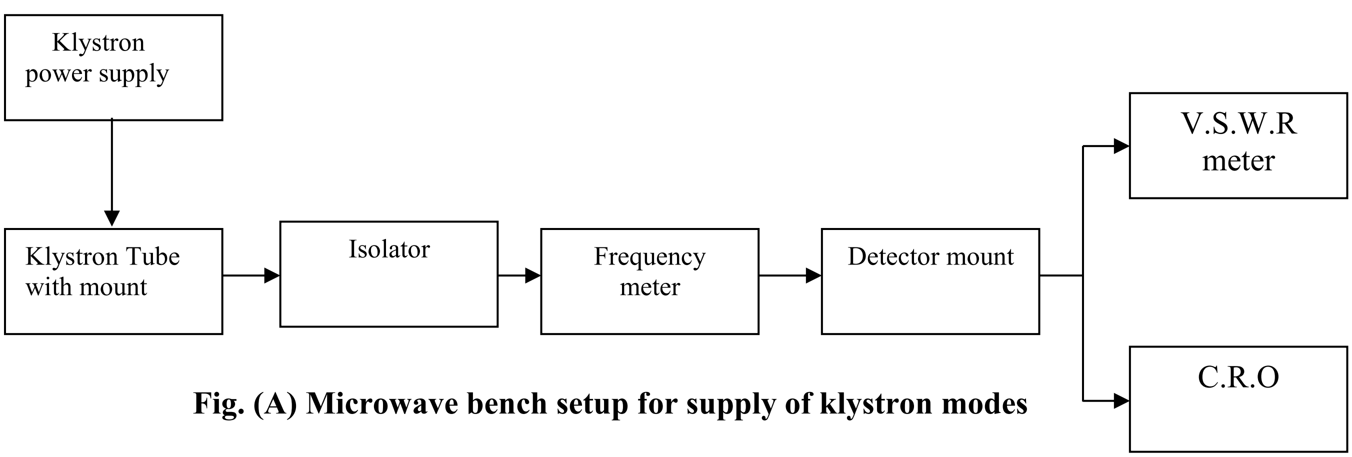
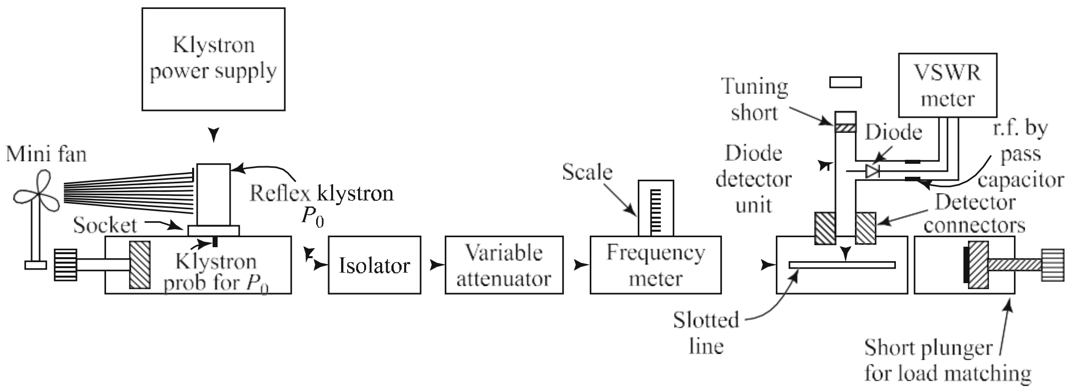


Fig. (A) Microwave bench setup for supply of klystron modes



Microwave bench set-up for reflex klystron characteristic

K. Theory

The Reflex Klystron is a microwave tube used as a microwave source in the lab. It makes use of velocity modulation to transform a continuous electron beam into microwave power. Its oscillation frequency can be varied over a wide band and it can be pulse and frequency modulated.

Electrons emitted from the cathode are accelerated by and pass through the positive resonator grid towards the reflector. The reflector is at a negative voltage with respect to cathode, and consequently it retard and finally reflects (reflex klystron) the electrons, which then turn back through the resonator grids: In case the klystron starts to oscillate, a hi-field exists between the resonator grids. The electron travelling through the grid will be either accelerated or retarded as the voltage changes in amplitude. Accelerated electrons leave the grid at an increased velocity and retarded electrons leave at a reduced velocity. Because of the difference in velocity the electrons leaving the grids will need different time to return (i.e., have different transit times).As a result of returning electron group together in bunches. This variation in velocity of the electrons is called velocity modulation.

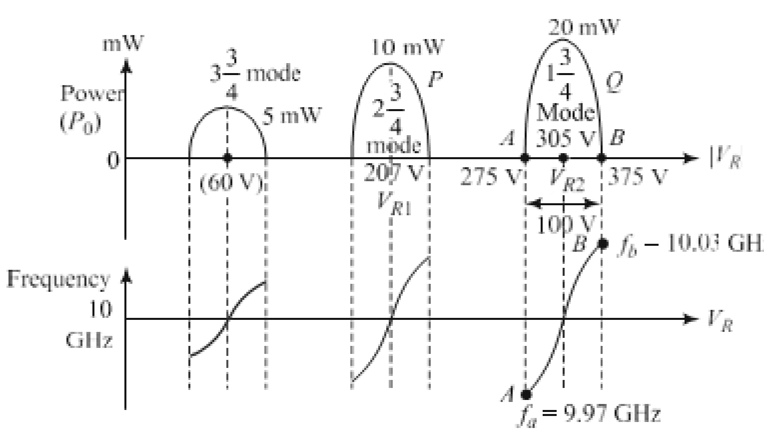


Fig.(B) Mode characteristics of reflex Klystron

As the electron bunches pass through the resonator grids, they interact with the voltage between the grids. If the bunches pass through the grids at a time such that the electrons are slowed down by the grid voltage energy will be delivered to the resonator and the klystron will oscillate. Strongest oscillation will occur when transit time in the reflector resonator region n + ¾ cycles of the resonator frequency, where ‘n’ an integer is including zero. If the bunches pass through the grids at a time such that the electrons are accelerated by the voltage, energy will be removed from the resonator and no oscillations will occur.

L. <u>Procedure:</u>

1. Connect the components and equipment as shown in fig. A
2. Keep the control knob of klystron power supply as below:
   Mode switch : AM
   Beam voltage knob : Fully anti-clockwise
   Repeller voltage knob : Fully clockwise
   Meter switch: Beam Voltage/Beam Current/ Repeller Voltage: Beam current Current
3. Rotate the frequency meter at one side (NOTE*: Rotate frequency meter very slowly*).
4. Switch on the klystron power supply, V.S.W.R/CRO and cooling fan for the klystron tube. Wait for 1-2 minutes for the klystron to respond.
5. Cathode voltage knob at minimum position gives a beam voltage about 235V to 300V. Observe beam current on the meter by changing meter switch to beam current position. “The beam current should not be more than 30mA”. (Try to set Beam current at 20 mA by increasing/Decreasing beam voltage knob)
6. Now change the meter switch to repeller/reflector voltage position.
8. Decreasing the reflector/repeller voltage, record output power and frequency.
9. To measure frequency, switch the Mode-switch of klystron to AM mode and observe output on CRO display. Use AM amplitude, frequency controls and controls on Oscilloscope front panel try to get clear display on C.R.O. By rotating the frequency meter observe for dip in the output and note the corresponding frequency.
10. Put ‘ON’ the beam voltage switch and rotate the beam voltage knob clockwise in supply slowly and watch VSWR meter set the voltage for maximum deflection on the meter.
11. Change the repeller voltage slowly & watch the VSWR meter. Set the voltage for maximum deflection on the meter.
12. Rotate the knob of frequency meter slowly and stop at that position where there is lowest O/P on VSWR meter.
13. Read directly, the frequency meter between two horizontal fine marks.

14. Change the repeller voltage and read the power and frequency for each repeller voltage.

M. Mechanical and Electronic Tuning

Mechanical tuning depends on changing the width of cavity i.e. the effective I capacitance and thus the resonant frequency of the klystron changes. The power output remains same with tuning.

Electronic tuning refers to change in repeller voltage causing a change in output frequency. However, the power output also changes. A measure of electronic tuning is given by 'Electronic tuning Sensitivity (ETS)'. This can be determined by taking the slope of the frequency characteristic of the modes.

N. Observation: (Include your own Table relevant to the Experiment)

S.No.	Repeller voltage (volts)	Power output (mW)	Wave meter reading Frequency (GHz)

O. CALCULATIONS:

1. Tuning range of 1 ¾ mode is
   $Po = 10^{(x/20)}$ watts, where x is dB reading in VSWR meter.
   (Include sample calculations/Display/plot/typical graph)
2. By taking the values of repeller voltage we can calculate the the mode number
   $N_1 = n + ¾$ with $V_2 =$
   $N_2 = (n +1) + ¾$ with $V_1 =$
   N_1 & N_2 are respective modes numbers.
3. ETS (Electronic Tuning Sensitivity) = $f_2 - f_1 / V_2 - V_1$ MHz / V

P. Precautions:

4. Check the connections before switching on the kit.
5. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.
6. Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

7. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.
8. Switch on the main supply and give some warm up time to get current / accurate reading.
9. Connections should be done properly.
10. Don't see directly inside the waveguide.
11. After the completion of experiment, before leaving the bench switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 2.
12. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.
13. Don't increase the repeller voltage more than -70V (i.e.) it should be between -70Vto 270V.

Q. <u>Conclusion:</u> (Write your own)

1…….. ?
2…….. ?

R. <u>Question:</u>

1. Explain the operation of the reflex klystron tube.
2. What is the basic principle involved in microwave tubes.
3. What is the difference between velocity modulation and current density modulation?
4. What happens to the power output as the repeller voltage increases?
5. What are the various modes of operation in the reflex klystron?
6. How electronic tuning is achievable in klystron.
7. What changes occurs in the frequency due to the repeller voltage variation.
8. What is the maximum theoretical efficiency, frequency range of the reflex klystron?
9. How bunching is achieved in reflex klystron.
10. What is the advantage of reflex klystron over two cavity klystron?

Approved By:

(HOD ECE) (Lab Instructor)

EC - IV: MICROWAVE LAB

EXPERIMENT No. : 03

STUDY OF GUNN OSCILLATOR

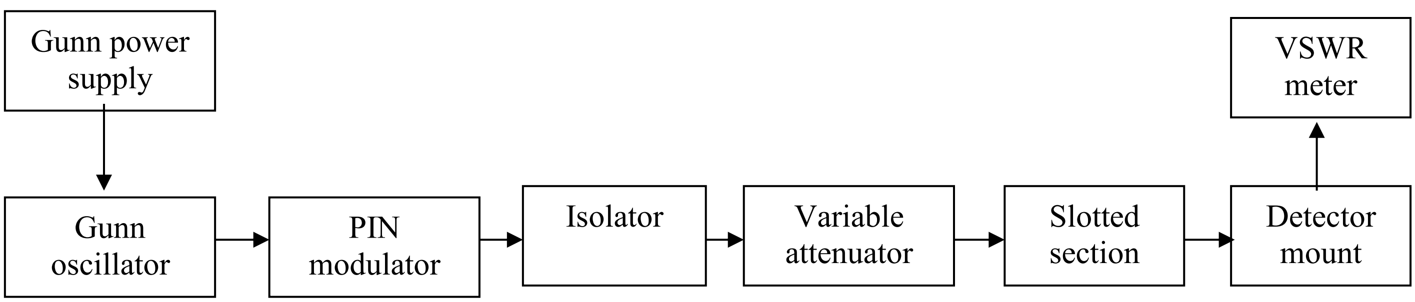
A. Aim:

To study I-V characteristics of Gunn Diode and depth of modulation of modulation of PIN diode.

B. Apparatus Used:

Gunn power supply, Gunn oscillator, PIN modulator, Isolator, Frequency Meter, Variable attenuator, Detector mount, Slotted section, VSWR meter.

C. Experimental Setup:



D. Theory

The Gunn oscillator is base on negative differential conductivity effect in bulk semi-conductors. Gunn diode has two conduction bands separated by an energy gap (greater than thermal agitation energies). When an electron is moved to the satellite energy band, it will have negative differential mobility. This produces the negative resistance required for the oscillations.

In a Gunn Oscillator, the Gunn diode is placed in a resonant cavity. In this case the oscillation frequency is determined by cavity dimension than by diode itself.

Although Gunn oscillator can be amplitude-modulated with the bias voltage, separate PIN modulator through is used in this experiment. A square wave modulating signal is applied through the modulator on to the microwave carrier signal.

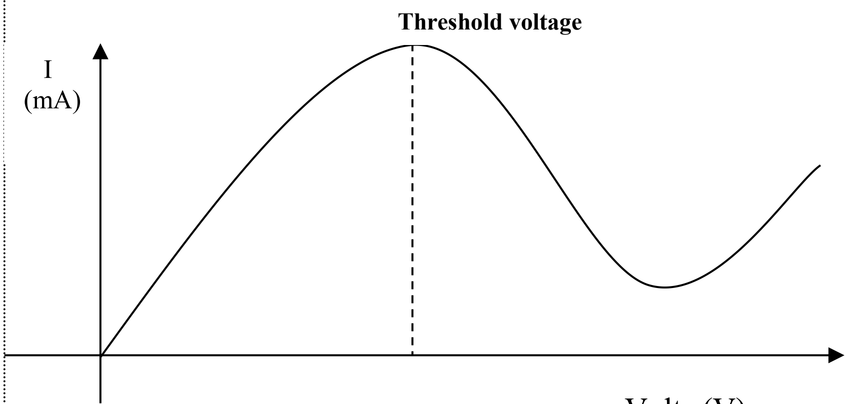


Fig: I-V CHARACTERISTICS OF GUNN OSCILLATOR

E. Procedure:

1. Set the components and equipments as shown in figure above.
2. Initially set the variable attenuator for maximum attenuation.
3. Keep the control knob of Gunn power supply as below:
   - Meter switch : 'OFF'
   - Gunn bias knob : Fully anti-clockwise
   - Pin bias knob/Mod Amplifier: Mid position
   - Pin mod frequency : Mid position
4. Keep the, control knob of VSWR meter as below:
   - Meter switch : Normal
   - Input switch : crystal low impedance/ 200K
   - Range db switch : 50db
   - Gain control knob : Fully clockwise
5. Set the micrometer of Gunn oscillator between 5-7mm for required frequency of operation.
6. 'ON' the Gunn power supply, VSWR meter and cooling fan.
7. Keep the mode switch of Gunn power supply to square wave/internal Modulation.
8. Turn the meter knob to voltage position and note that, as Gunn bias voltage is varied current starts decreasing. This indicates negative resistance characteristic of Gunn diode. Apply the voltage such that the device is in the middle of the negative resistance region.
9. Connect detector output to SWR meter.
10. Adjust the square wave modulation frequency to approximately 1KHz.
11. Change the meter range if no deflection is observed.

12. Keep the slotted line probe at position where maximum deflection in meter is observed.
13. Adjust the attenuator setting, gain control knob on VSWR meter and tune the detector plunger for pointer to indicate VSWR 1.
14. Move detector probe along the slotted line and note position of probe where pointer comes to extreme left position, which is first minimum. In order to know exact position of minimum note the positions of equal response points on either side of the minimum and then the midpoint of those positions will give position of minimum. The same way note next minimum positions.
15. Repeat the above procedure for different settings of micrometer.

Depth of Modulation of PIN Diode:

1. Apply Gunn Bias Voltage slowly so that panel meter of Gunn power supply reads 8V.
2. Tune the PIN modulator bias voltage and frequency knob for maximum output on the oscilloscope.
3. Coincide the bottom of square wave oscilloscope to some reference level and note down the micrometer reading of variable attenuator.
4. Now with help of variable attenuator coincide the top of square wave to same reference level and note down the micrometer reading.
5. Connect VSWR to detector mount and note down the dB reading in VSWR meter for both the micrometer reading the variable attenuator.
6. The difference of both dB reading of VSWR meter gives the modulation depth of PIN modulator.

Note: After tuning the Gunn source, the procedure for VSWR & Impedance measurement depth of PIN modulator.

F. <u>Observation: (Include your own Table relevant to the Experiment)</u>

S.NO.	Gunn Bias Voltage (V)	Gunn Diode Current (I)

G. Analysis of Results: (Write your own)
(Include sample calculations/Display/plot/typical graph)

H. Conclusions: (Write your Own)

Precautions:

14. Check the connections before switching on the kit.
15. Connections should be done properly.
16. Observation should be taken properly.

Approved By:

(HOD ECE) (Lab Instructor)

EC - IV: MICROWAVE LAB
EXPERIMENT No. : 04

FREQENCY MEASUREMENT

S. Aim:

To measure the frequency generated by source and wavelength in rectangular waveguide for TE_{10} mode.

Apparatus Used:

1. Klystron power supply MTI KP 503
2. Klystron tube /2k25
3. Isolator MTI/ NVIS- 204
4. Frequency Meter MTI/NVIS – 205A
5. Variable Attenuator MTI/ NVIS - 206
6. Detector mount MTI/ NVIS - 209
7. Waveguide stands MTI/NVIS
8. VSWR meter MTI VS 501/NVIS
9. Cathode Ray Oscilloscope Scientech -801C
10. Movable short XT-481
11. Matched termination XL-400
12. Slotted section
13. Tunable probe

T. Experimental Setup:

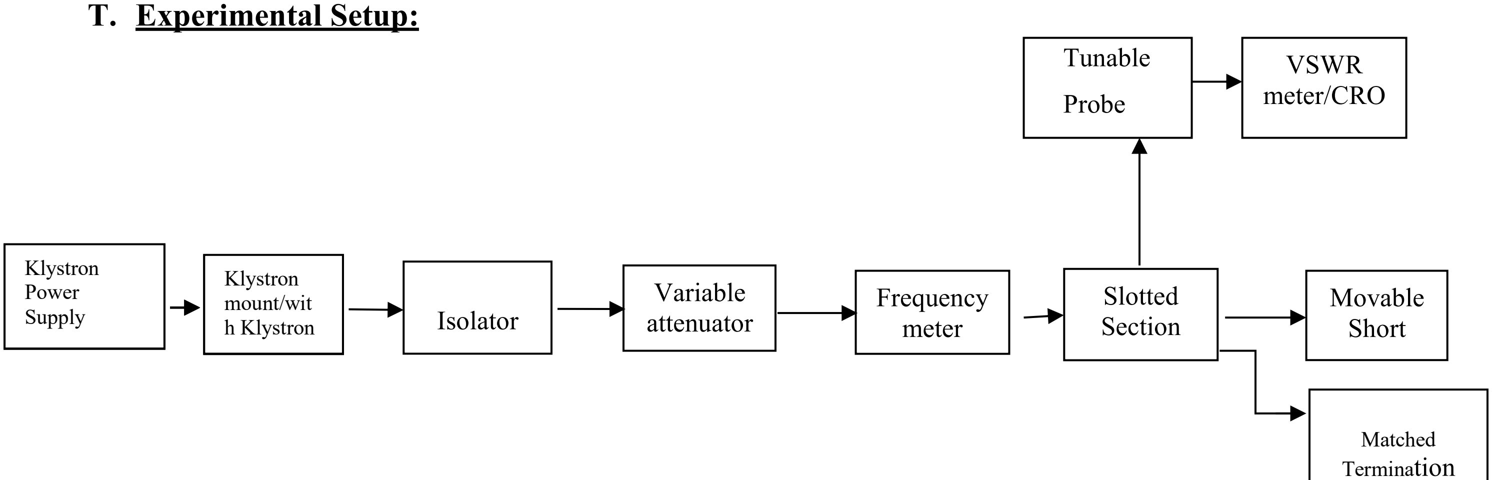


Fig (3): SETUP FOR FREQUENCY MEASUREMENT

U. Theory

The measurement of frequency or wavelength is one of the primary requirements in most microwave measurement. Frequency is the most fundamental quantity because the frequency of oscillation is the same all parts of the microwave system under steady-state conditions. Wavelength on the other hand depends on the configuration of the electric and magnetic fields as determined by the geometry of the measuring device. The relation between length of the transmission line, frequency and wavelength terminated in a short circuit reviewed briefly as shown in fig-3. An input voltage wave of the quarter – wave line at 'a' will have phase change of 90 degree in traveling form the input (open) to the shorter end, 180 degree phase change at the short, a another 90 degree in relating to the open end. The total phase change is 360 degree and the reflected wave in phase with the applied wave. The different voltage and current pattern are referred to as modes. The $\lambda_g/4$, 3 $\lambda_g/2$, $\lambda_g/2$ & λ_g.

Modes of resonance are shown in the illustration. The resonant mode excited by the possible frequency is calculated the fundamental mode or the dominant mode.

A better way to measure frequency is with a calibrated resonant cavity. A resonant cavity wave meter is analog of a tuned resonant circuit, in general there are two primary types (1) Transmission cavities, which only the signal to which they are tuned and (2) Absorption cavities, which attenuate (by absorption) only frequency to which they are tuned. A absorption type is preferred for laboratory frequency measurements. For the power level is adjusted to give a full scale reading on the output VSWR meter then the wave meter is turn slowly until there is a dip in the power level. The frequency may then the read form the dial of the meter.
For dominate mode TE10 mode rectangular wave guide the following relation is in use:

$$\frac{1}{\lambda_o^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

Where, λ_o is free space wavelength
λ_g is guide wavelength
λ_c is cut off wavelength
For TE_{10} mode λ_c =2a where 'a' is broad dimension of waveguide
Note: From the free space wavelength calculate the frequency

V. Procedure: Using (Klystron and VSWR meter)

1.Set up the component & equipments as shown in Figure above.
2.Set up variable attenuator at minimum attenuation position
3.Keep control knobs of VSWR meter as given below :-

Range	50dB
Input switch	Crystal low impedance
Meter switch	Normal position
Gain (Coarse & Fine)	Mid - position

Keep control knobs of klystron power supply as given below

Beam voltage	- Off
Mod-switch	-Am
Beam voltage switch	- Full anticlockwise
Reflector voltage	- Full clockwise
Am amplitude knob	- Full clockwise
Am frequency knob	- Mid position

4. Switch on the klystron power supply, VSWR meter and cooling fan switch
5. Switch on the beam voltage switch and set beam voltage between 250-300V with beam voltage knob**. Do not set above 300V**
6. Set the reflector voltage to get some deflection in VSWR meter.
7. Maximize the deflection with AM amplitude and frequency control knob of supply.
8. Tune the plunger of klystron mount for maximum deflection.
9. Tune the reflector voltage knob for maximum deflection.
10. Tune the probe for maximum deflection in VSWR meter.
11. Tune the frequency meter to get a 'dip' on the VSWR meter and note the frequency from frequency meter f_m.
12. Replace the termination with movable short and de tune the frequency meter.
13. Move the probe along with the slotted section. The deflection in VSWR meter will vary.
14. Move the probe position move the probe to next minimum position and note again.
15. Calculate the guide wavelength as twice the distance between two minimum positions.
16. Measure the wave guide inner broad dimension 'a' which will be around 22.85 to 22.86 mm for X band.
17. Calculate the frequency,

$$f = C\sqrt{\frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}}$$

where C = velocity of light =3x10^8 meter per second

18. Verify with frequency obtained by frequency meter

Repeat step 12 to 18 for different repeller voltage

W. <u>Procedure: Using (Klystron/Gunn and CRO)</u>

1. Switch on the Gunn Power supply. Check Gunn current is changing with Gun bias or not.
2. Obtain Square wave in the CRO.
3. Maximize the O/P by changing Gunn Bias, Micrometer of Gunn Diode, Attenuator, Tunable probe Detector Plunger, Tunable probe penetration.
4. Measure frequency by observing zero or close to zero amp output in CRO.
5. Replace the termination with movable short and de tune the frequency meter.
6. Move the probe along with the slotted section. The deflection in CRO will vary.

7. Move the probe position move the probe to next minimum position and note again.
8. Calculate the guide wavelength as twice the distance between two minimum positions.
9. Measure the wave guide inner broad dimension 'a' which will be around 22.85 to 22.86 mm for X band. ($\lambda_c = 2a$)
10. Calculate the frequency (f_{cal})

Repeat step 6 to 10 for different Gunn Bias

NOTE: In microwave communication the medium of propagation is usually the free space surrounding the single frequency these variations are periodic and sinusoidal and therefore can be considered in terms of frequency in cycle/second.

X. Observation: (Include your own Table relevant to the Experiment)

S.N	Repeller Voltage	d_1 (cm)	d_2 (cm)	$\lambda_g = 2(d_2 - d_1)$	$\beta = \frac{2\pi}{\lambda_g}$	Frequency Meter Reading f_0 (GHz)	$\omega = 2\pi f_0$	Frequency $f_{cal} = C\sqrt{\frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}}$	Error % $\frac{f_0 - f_{cal}}{f_0}$
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Y. Precautions:

17. Check the connections before switching on the kit.
18. Keep all the knobs in minimum position before going to switch 'ON' the power supply of VSWR / Klystron power supplies.
19. Note: For klystron power supply "HT" should be 'OFF' before switching 'ON'

the main supply.

20. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.
21. Switch on the main supply and give some warm up time to get current / accurate reading.
22. Connections should be done properly.
23. Don't see directly inside the waveguide.
24. After the completion of experiment, before leaving the bench switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 2.
25. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.
26. Don't increase the repeller voltage more than -70V (i.e.) it should be between -70Vto 270V.

Z. Applications:

It is used for Measurement of unknown frequency and wavelength

AA. Questions:

1. How slotted line technique is used to measure frequency and wavelength?
2. What is the purpose of slotted line in the microwave bench?
3. What type of wave is propagating in the wave guide?
4. What is meant by guide wavelength?
5. Bring out a relationship between the guide wave length and cut of wavelength?
6. How the guide wavelength can be determined by using the slotted line?
7. What is the purpose of crystal detector probe?
8. Which technique is preferable for the measurement of frequency?
9. What is the cut of wavelength of the dominant mode in the wave guide?
10. How waveguide acts as a high pass filter?
11. What is the cut-off wavelength for a rectangular waveguide?
12. What modification, if any, may be required in the relation in question 1, for a circular waveguide?

AB. Analysis of Results: (Write your own)
(Include sample calculations/Display/plot/typical graph)

AC. Conclusions: (Write your Own)

Approved By:

(HOD ECE) (Lab Instructor)

EC - IV: MICROWAVE LAB
EXPERIMENT No. : 05

MEASURING VSWR

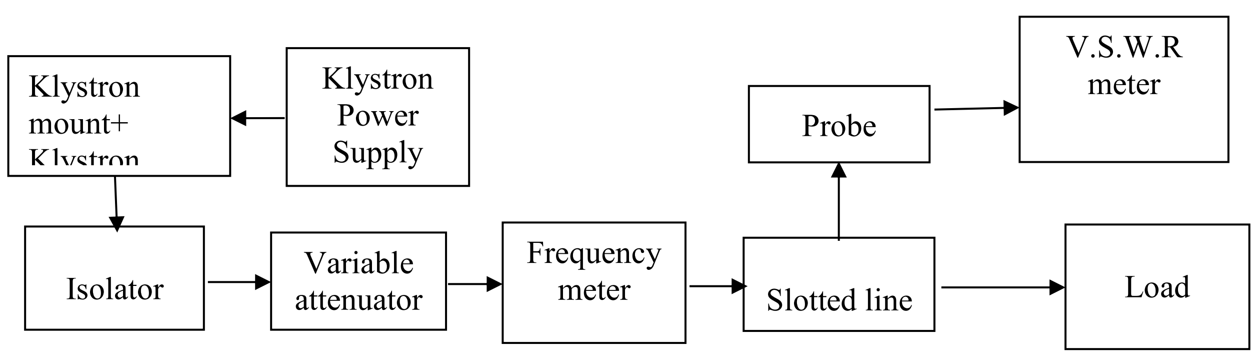
AD. Aim:

To become familiar with the basic technique for measuring voltage standing wave ratio & Reflection coefficient.

AE. Apparatus Used:

14. Klystron power supply MTI KP 503
15. Klystron tube /2k25
16. Isolator MTI/ NVIS- 204
17. Frequency Meter MTI/NVIS – 205A
18. Variable Attenuator MTI/ NVIS - 206
19. Detector mount MTI/ NVIS - 209
20. Waveguide stands MTI/NVIS
21. VSWR meter MTI VS 501/NVIS
22. Cathode Ray Oscilloscope Scientech -801C
23. Slotted section
24. Tunable probe
25. Movable short
26. S.S. Tuner

AF. Experimental Setup:



LOAD={ Horn Antenna, Parabolic Dish, Liquid Dielectric cell, Solid Dielectric cell, SS tunner + Matched Termination, Movable short, Short Circuit, Open circuit etc.}

AG. Theory

The reflex klystron makes use of velocity modulation to transform a continuous electron beam into microwave power. The electromagnetic field at any point of transmission line may be considered as the sum of two traveling waves the instant wave propagates from generator and the reflected wave propagates towards the generator. The reflected wave is set up by the reflection of instant wave from a discontinuity on the line or from the load impedance. The magnitude and face of the reflector wave depends up on amplitude and face of the reflecting impedance. The maximum field strength is found were two wave are in face and minimum were the two waves adds in opposite face. The distance between two successive minimum (or maximum) is half the guide wave length on the line.

The ratio electrical field strengths of reflected and incidents wave is called reflection coefficient. VSWR (voltage standing wave ratio) is defined as the ratio between maximum and minimum field strength along the line.

Standing waves are an indication of the quality of transmission. A well matched transmission line has no reflection and consequently the VSWR is unity. The slotted line is the basic instrument. A probe is moved align the line sample the voltage, the output of the probe is detected and read on the VSWR meter. The ratio between maximum voltage and minimum voltage is of course, the VSWR.

The output meter can be any kind of voltmeter, in practice; however, a standing wave ratio meter is used. This is a audio amplifier peaked a t a modulation frequency with a meter calibrated especially for reading VSWR. The probe set at a voltage maximum, so that the VSWR meter reads full scale. The probe is then moved to a minimum point and assuming there is a square law detector, the scale on the VSWR meter reads VSWR directly.

The standing wave ratio is decibel is expressed as

SWR (dB) = 20 log VSWR

Reflection co-efficient (R)

When a signal is sent down a transmission line, it travels smoothly until it reaches a discontinuity. Then some of energy is reflected, the size of the reflection depending on the size and nature of the discontinuity. The size of the reflection is called the reflection co-efficient: the simplest standing wave occurs when the reflection co-efficient are unity, it occurs when the load impedance is a short circuit, an open circuit. It does not occur if the load has resistive component which will absorbs some of the incident power. If the transmission line is terminated in short or open circuit, the reflected voltage (Er) is equal to the incident voltage (Ei) & the reflection co-efficient is 1. Then the reflection co-efficient is also zero, and the VSWR is 10. It should be noted that reflection co-efficient must be between zero and one. Reflection co-efficient (R)= the ratio of voltage reflected (Er) to the voltage incident. However, the same information could be presented by referring to the loss in decibels between the incident and reflected signals. This is called the return loss and is designated R L the relationship are

RL= 20 log 10 Ei/Er

$$= 20\log_{10}\frac{1}{R} = 20\ \log_{10}(VSWR\ +\ 1/VSWR - 1) = -\ 20\ \log_{10}(S - 1/S + 1)$$

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

VSWR = E_{max}/E_{min}

= $E_i + E_r/E_i - E_r$ - (1) where E_i = incident voltage and E_r = reflected voltage

= (1+ reflection co-efficient)/(1-reflection co-efficient)

Reflection co-efficient (R) the size of reflection

= $E_r/E_i = Z_i - Z_0/Z_i + Z_o$ - (2) where Z_i is load impedance, Z_o is characteristic impedance

The above equation following equations

= (VSWR-1)/(VSWR+1) - (3)

Note: The reflection co-efficient is expressed as a dimension less, the ratio of the voltage reflected to the voltage incident. It must be noted that reflection co-efficient must lie between zero and one. If reflection co-efficient is zero there is no reflection, if reflection co-efficient is one, there is total reflection. The value of VSWR is determined by the reflection co-efficient as indication in equation-1

AH. Procedure:

1. Set the equipments as figure –(5)
2. Keep variable attenuator in the minimum attenuation position
3. Keep the control knob of VSWR meter as below

Range db	-	40db to 50db
Input Switch	-	Low impedance
Meter Switch	-	Normal
Gain	-	Mid position

4. Keep the control knob of Klystron power supply

Beam voltage	-	Off
Mod-switch	-	AM
Beam voltage knob	-	Full anti clockwise
Reflector voltage knob	-	Full clockwise
Am-amplitude knob	-	Full clockwise
Am frequency & amplitude knob	-	Mid position

5. Switch on the klystron power supply, VSWR meter & cooling fan.
6. Switch on the beam voltage switch and set beam voltage at 260V.
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 we move probe along the slotted line, the deflection will change.
12. Measurement of low and medium VSWR.

(1) **Measurement of low and medium V.S.W.R**.

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 indicated 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 SS tuner probe depth and record the corresponding SWR.
5. The VSWR is between 3.2 and 10, change the range db to next higher position and read the VSWR on second VSWR scale of 3 to 10.

(2) **Measurement of high VSWR**

1. Set the depth of SS tuner slightly more for maximum VSWR.
2. Move the probe along with slotted line until a minimum is indicated.
3. Adjust the VSWR gain control knob and variable attenuator to obtain a reading of 3db in the normal db scale 10db 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 then move the probe right along the slotted line until full scale deflection is obtained by 10db normal db let it be d_2.
6. Replace the SS tuner and termination by movable short.
7. Measure the distance between two successive minima positions of the probe > twice this distance is guide wavelength.
8. Compute VSWR form the following equation.

$$\text{VSWR}=\frac{\lambda g}{\pi(d1-d2)}=\frac{\lambda_g}{\pi(\Delta x)}$$

Where, λ_g is the guide wavelength, d1 and d2 are location of double minimum points Note: This method overcomes this effect of probe loading, since the probe is loading always around a voltage minimum. However, does not overcome the effect of detector characteristic for high values of VSWR, the twice-minimum method should be used. In this method the probe is moved to a point where the power is twice the minimum. This position is denoted d-1. Probe is moved to the twice power point on the other side of the minimum. The probe designated d-2. The VSWR may be found by the relationship.

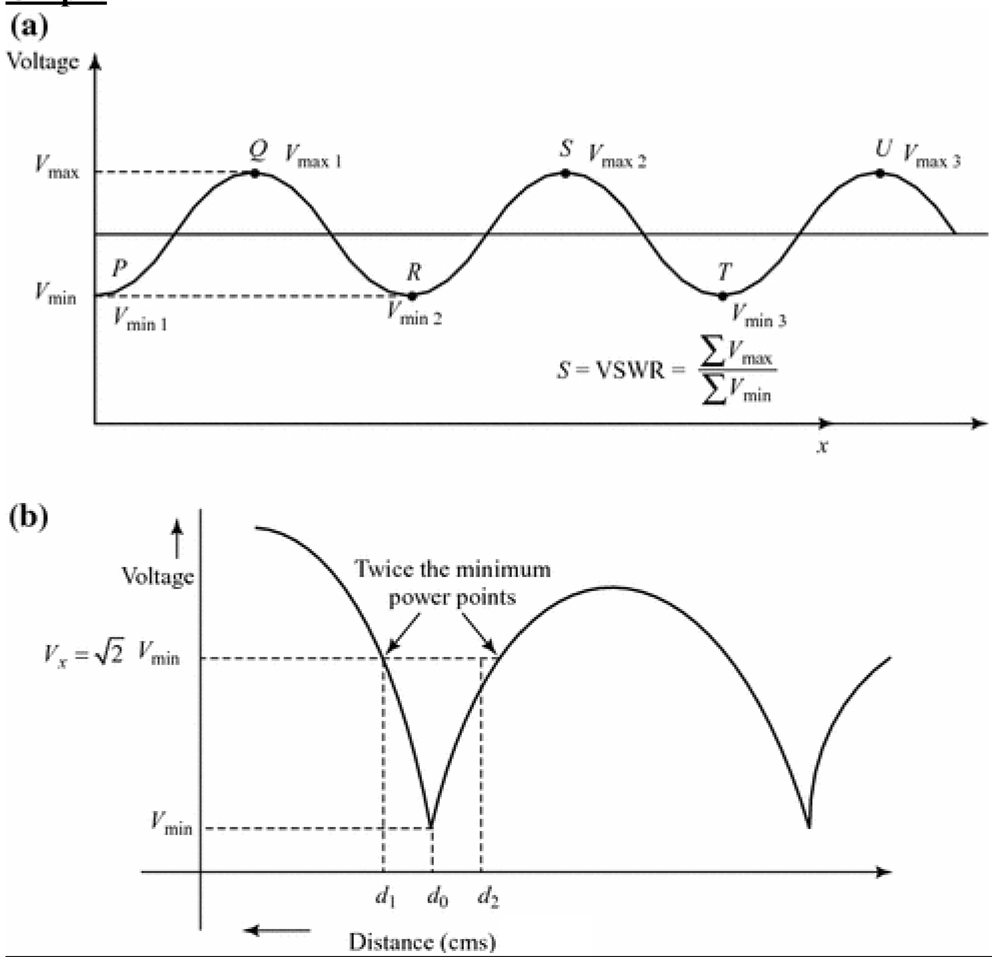
VSWR= $\frac{\lambda g}{\pi(\mathrm{d1}-\mathrm{d2})}$

The units of wavelength (λ_g) and distance are same.

9. Measure the distance between two successive minima position of probe, twice this distance is guide wave length λ_g.

$$\text{VSWR} = \frac{\lambda g}{\pi(d1-d2)}$$

AI. <u>Graph:</u>



AJ. <u>Observation: (Include your own Table relevant to the Experiment)</u>

Single Minima

Load Type	Repeller Voltage	SWR	d_{ref}	d_1
Horn				
Parabolic Dish				
Liquid Dielectric cell				

Double Minima

Load Type	d_1	d_2	d_0	$d_0^{'}$	$\lambda_g = 2(d_0 - d_0^{'})$	$S = \lambda_g/\pi(d1 - d2)$

AK. Application:

1. By knowing the VSWR we can measure the unknown impedance.
2. Standing wave ratio in transmission.
3. In selecting the load impedance.

AL. Analysis of Results: (Write your own)
(Include sample calculations/Display/plot/typical graph)

AM. Conclusions: (Write your Own)

AN. Precaution:

27. Check the connections before switching on the kit.
28. Connections should be done properly.
29. Observation should be taken properly.
30. Keep all the knobs in minimum position before going to switch ‘ON’ the power supply of VSWR / Klystron power supplies.

Note: For klystron power supply "HT" should be 'OFF' before switching 'ON' the main supply.

31. Beam knob should be completely in anticlockwise direction and repeller voltage knob should be completely clockwise direction.
32. Switch on the main supply and give some warm up time to get current / accurate reading.
33. After the completion of experiment, before going to switch off the mains keep all the knobs in minimum position (i.e.) as those are in rule 1.
34. If the main supply failed in the middle of the experiment, come to 1st condition (i.e.) keep all the knobs in minimum positions and switch off main switches.
35. Don't increase the repeller voltage more than -70 V (i.e.) it should be between -70V to –270V

AO. <u>Questions:</u>

1. Define VSWR.
2. Define reflection coefficient
3. What are the maxima and minima values of reflection coefficient?
4. What are the maxima and minima values of VSWR?
5. Mention the different techniques in measuring the VSWR.
6. Which method is used to measure VSWR>10.
7. What is the relation between VSWR and guided wavelength?
8. Explain about SS tuner.
9. Why standing waves are obtaining from transmission.
10. How to reduce standing waves?
11. Why the slot is cut in the center of the waveguide not off center?
12. What types of errors are introduced in measurement due to finite probe depth and a slot in a waveguide?
13. Why detector is required to have a square law response? If it has response proportional to the cube of the input what correction you will need to apply.

Approved By:

(HOD ECE) (Lab Instructor)

EC - IV: MICROWAVE LAB

EXPERIMENT No. : 06

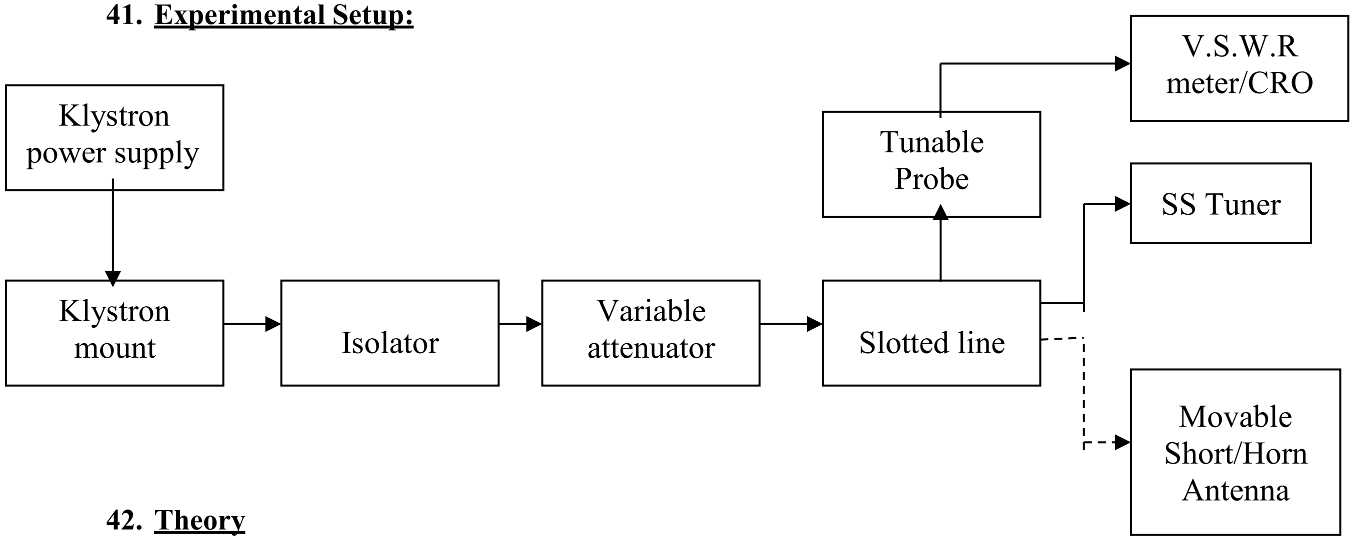
MEASUREMENT OF UNKNOWN LOAD IMPEDANCE

AP. Aim:

To determine impedance of unknown load by measuring VSWR and the position of first field minimum.

AQ. Apparatus Used:

27. Klystron power supply MTI KP 503
28. Klystron tube /2k25
29. Isolator MTI/ NVIS- 204
30. Frequency Meter MTI/NVIS – 205A
31. Variable Attenuator MTI/ NVIS - 206
32. Detector mount MTI/ NVIS - 209
33. Waveguide stands MTI/NVIS
34. VSWR meter MTI VS 501/NVIS
35. Cathode Ray Oscilloscope Scientech -801C
36. Slotted section
37. Tunable probe
38. Movable short
39. SS Tuner
40. Short.
41. **Experimental Setup:**



42. **Theory**

The waveform from generator incident on the load is reflected (if the load is not a characteristic impedance).The magnitude and hence VSWR, the phase and hence the relative position (with respect to short-circuit) of the VSWR minimum, are characteristic properties of the load. Determining these, load can be determined.

The input impedance of a transmission line is given by

$$Z_{in} = \frac{V_s}{I_s} = \frac{V_R \cosh \Upsilon l + Z_0 I_R \sinh \Upsilon l}{I_R \cosh \Upsilon l + V_R / Z_0 \sinh \Upsilon l}$$

For lossless line $\Upsilon=\alpha+j\beta$ ($\alpha=0$) of 'Δl' length

$$Z_{in} = Z_0 \frac{Z_R + jZ_0 \tan\beta\Delta l}{Z_o + jZ_R \tan\beta\Delta l}$$

Where Z_R is, the impedance at the receiving end i.e impedance of load, Z_o is the characteristic impedance and Z_{in} is the impedance at the input of the transmission line, $|D_o|$, being the electrical distance, is measured in wavelengths between position of termination and standing wave minimum, or

$$Z_R = Z_0 \frac{\rho - j\tan\beta\Delta l}{1 - j\rho\tan\beta\Delta l}$$

AR. <u>Procedure:</u>

1. Set the components and equipment's as shown in figure above.
2. Initially set the variable attenuator for maximum attenuation.
3. Termination the receiving end with unknown load.
4. Keep the control knob of klystron power supply

   Beam voltage - Off
   Mod-switch - Full anti clockwise
   Reflector Voltage Knob - Full clockwise
   Am-amplitude Knob - Full clockwise
   Am frequency and amplitude knob - Mid position
   Switch On the klystron power supply, VSWR meter & cooling fan.
   Switch On the beam voltage switch and set beam voltage at 260 V.
   Rotate the reflector voltage knob to get deflection in VSWR meter.
   Tune the output by tuning the reflector voltage, amplitude and frequency of am modulation.
   Tune plunger of klystron mount and probe for maximum deflection in VSWR meter.
5. Keep the control knob of VSWR meter as below:

   I. Switch : Normal
   II. Input switch : Low impedance
   III. Range db switch : 40db
   IV. Gain control knob : Fully clockwise
6. Connect detector output to SWR meter.
7. Adjust the square wave modulation frequency to approximately 1 KHz.
8. Tune the detector by adjusting short plunger for maximum meter deflection.
9. Move the probe along slotted line; adjust it at standing wave minimum. Record the probe position as X_1(this is the position of reference minimum) and next successive minimum position as X_2.
10. Replace load by short circuit termination and move the probe carriage to new standing wave minimum record the probe position as X_s (This is known as position of reference plane)

11. Find the shift minima (X_s- X_2 or $X_s – X_1$). It will be positive if minimum is shifted towards load (i.e., for inductive load) and negative if minimum is shifted towards generator (for capacitive load). Shift in minimum for different loads can be easily known form the standing wave patterns given below.
12. Convert the shift in wavelength units, i.e.,(X_s- X_1)/I. Wavelengths.
13. Position on minimum can be known more accurately if it is taken as midpoint of positions of equal response on either side of minimum

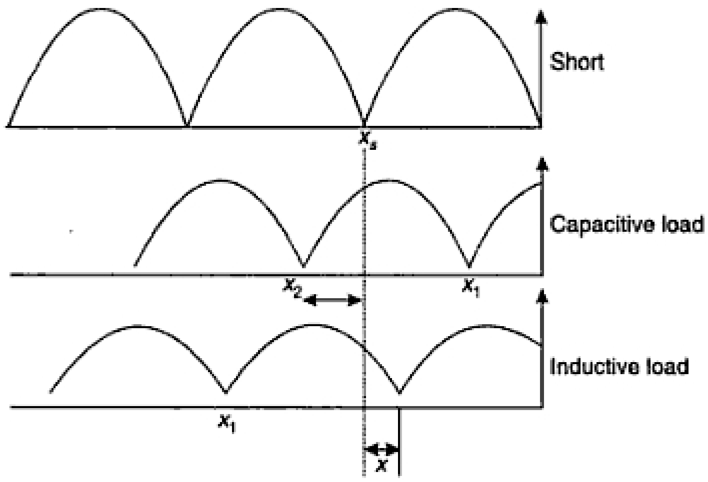


Fig.2 Standing wave patterns for different loads

AS. <u>Observation: (Include your own Table relevant to the Experiment)</u>

S.NO.	Position of minimum Load	Load VSWR	Frequency of excited wave	Shift in minima<λ/4 $\lambda_g = 2(d_2 - d_1)$	Direction of shift towards load/generator Capacitive/Inductive
1					
2					
..					
…					

AT. Conclusions: (Write your Own)

(A) Using formula:

Guide wavelength, '$\lambda_g/2$' =2*distance between two successive minima's
=2*(X_s- X_1)

Calculate free space wavelength λ_0 using relation $1/\lambda_0^2 = 1/\lambda_g^2 + 1/\lambda_c^2$

Compute load, using

$$Z_L = Z_0 \frac{\rho - j\tan\beta\Delta l}{1 - j\rho\tan\beta\Delta l}$$

$\beta\Delta l = 2\pi (X_s - X_1)/\lambda$

(B) Using smith chart:

1. Note VSWR and shift in minima 'X' in terms of wavelength.
2. Use smith chart and draw a VSWR circle with radius I/VSWR.
3. Locate a point at a distance X from 0.0 (short circuit) moving in anti-clockwise direction (shift towards load) at the circumference. Join this point to the center of smith chart.
4. Point of intersection of VSWR circle and this line gives load; reactive component on reactive circle and resistive components on real circles.
5. This normalized impedance multiplied by characteristic impedance of the guide gives load impedance. Characteristic impedance of guide is given by relation

$Z_o = \frac{I\,20\,\pi}{\sqrt{(1-(\frac{\lambda_c}{\lambda_0})^2)}}.$

AU. Analysis of Results: (Write your own)
(Include sample calculations/Display/plot/typical graph)

AV. <u>Observation: (Include your own Table relevant to the Experiment)</u>

S.NO.	Position of minimum Load	Load VSWR	Frequency of excited wave	Shift in minima<λ/4 $\lambda_g = 2(d_2 - d_1)$	Direction of shift towards load/generator Capacitive/Inductive

AW. Conclusions: (Write your Own)

(C) Using formula:

Guide wavelength, '$\lambda_g/2$' =2*distance between two successive minima's
=2*(X_s- X_1)

Calculate free space wavelength λ_0 using relation $1/\lambda_0^2 = 1/\lambda_g^2 + 1/\lambda_c^2$

Compute load, using

$= Z_0 \frac{1 - j\rho \tan\beta\Delta l}{\rho - j \tan\beta\Delta l}$

$\beta\Delta l = 2\pi\,(X_s - X_1)/\lambda$

(D) Using smith chart:

6. Note VSWR and shift in minima 'X' in terms of wavelength.
7. Use smith chart and draw a VSWR circle with radius I/VSWR.
8. Locate a point at a distance X from 0.0 (short circuit) moving in anti-clockwise direction (shift towards load) at the circumference. Join this point to the center of smith chart.
9. Point of intersection of VSWR circle and this line gives load; reactive component on reactive circle and resistive components on real circles.
10. This normalized impedance multiplied by characteristic impedance of the guide gives load impedance. Characteristic impedance of guide is given by relation

$Z_o = \frac{I\,20\,\pi}{\sqrt{(1-(\frac{\lambda_c}{\lambda_0})^2)}}.$

AX. Analysis of Results: (Write your own)
(Include sample calculations/Display/plot/typical graph)

AY. Questions:

1. What are the various methods used for the measurement of impedance?
2. How impedance can measured by using slotted line?
3. How can you determine whether the impedance is inductive or capacitive?
4. How impedance can be measured by using magic tee?
5. What is the purpose of slotted line for the measurement of impedance?
6. How impedance can be measured by using reflectometer?
7. What is the purpose of variable attenuator?
8. How impedance can be determined by using directional couplers?
9. Why standing waves are produced in the wave guide?
10. What is meant by reflection coefficient and how impedance can be determined?

Approved By:

(HOD ECE) (Lab Instructor)

EC - IV: MICROWAVE LAB
EXPERIMENT No. : 07

ATTENUATOR CHARACTERISTICS

AZ. Aim:
To study characteristics of a Variable Attenuator.

BA. Apparatus Used:

43. Klystron power supply MTI KP 503 OR Gunn Power Supply
44. Klystron tube /2k25 OR Gunn Oscillator and Pin Modulator
45. Isolator MTI/ NVIS- 204
46. Frequency Meter MTI/NVIS – 205A
47. Variable Attenuator MTI/ NVIS - 206
48. Detector mount MTI/ NVIS - 209
49. Waveguide stands MTI/NVIS
50. VSWR meter MTI VS 501/NVIS
51. Cathode Ray Oscilloscope Scientech -801C
52. Movable short XT-481
53. Matched termination xl-400
54. Slotted section
55. Tunable probe

BB. Experimental Setup:

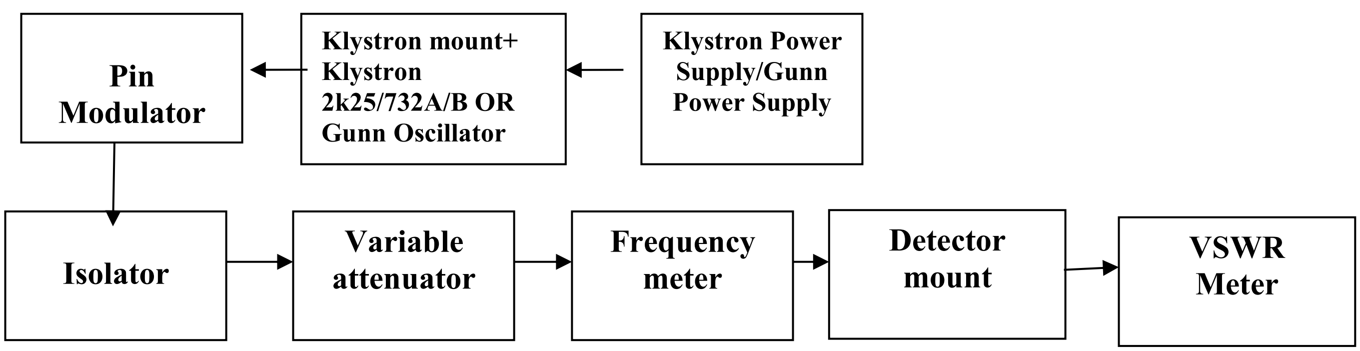


Fig: 1- SETUP FOR ATTENUATOR CHARACTERISTICS

BC. Theory
Attenuators are required to adjust the power flowing in a waveguide. Attenuators are of fixed, variable and rotary vane type i.e.
Fixed: Any amount of fixed attenuator can be supplied between 3 to 30db. These attenuators are calibrated frequency band.
Variable: Variable attenuator provides a convenient means of adjustments power level vary accurately.

Attenuators are usually passive devices made from simple voltage divider networks. Switching between different resistances forms adjustable stepped attenuators and continuously adjustable ones using potentiometers. For higher frequencies precisely matched low VSWR resistance networks are used.

Fixed attenuators in circuits are used to lower voltage, dissipate power, and to improve impedance matching. In measuring signals, attenuator pads or adapters are used to lower the amplitude of the signal a known amount to enable measurements, or to protect the measuring device from signal levels that might damage it. Attenuators are also used to 'match' impedance by lowering apparent SWR.

The attenuator is a two port bi-directional device which attenuates some power when inserted into the transmission line.

Attenuation A (dB) = 10 log [P1/P2]

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

P_2 = Power detected by the load with the attenuator in the line.

The attenuators consists of a resistive vane inside the waveguide to absorb microwave power according to its position with respect to sidewall at center in TE_{10} mode, the attenuation will be maximum if the vane is placed at center towards the sidewall, attenuation decreases. In the fixed attenuator the vane position is fixed whereas changed by the help of micrometer of by other methods.

BD. <u>Procedure:</u>

1. Set the components and equipment's as shown in figure above.
2. Initially set the variable attenuator for maximum attenuation.
3. Terminate the receiving end with unknown load.
4. Keep the control knob of Klystron power supply
   Beam voltage - Off
   Mod-switch - AM
   Reflector Voltage knob - Full anti clockwise
   Am-amplitude knob - Full clockwise
   Am frequency & amplitude knob -Mid position
   Switch On the klystron power supply, VSWR meter & cooling fan.
   Switch On the beam voltage switch and set beam voltage between 250V- 290V.
   Rotate the reflector voltage knob to get deflection in VSWR meter.
   Tune the output by tuning the reflector voltage, amplitude and frequency of am modulation.
   Tune plunger of Klystron mount and probe for maximum deflection in VSWR meter.
5. Keep the control knob of VSWR meter as below:
   I. Switch : normal
   II. Input switch : Low impedance
   III. Range db switch : 30db OR 40db
   IV. Gain control knob : Fully clockwise
6. Connect detector output to SWR meter.
7. Adjust the square wave modulation frequency to approximately 1KHz
8. Tune the detector by adjusting short plunger for maximum meter deflection.

BE. <u>Observation: (Include your own Table relevant to the Experiment)</u>

Tabular Column:
Micrometer reading: 11.79mm.
Frequency : 9.97 GHz.

S.NO.	Screw Gauge Reading (mm)	Attenuation in Decibel

BF. APPLICATIONS:

Attenuators mainly used for

1. Measuring power gain or loss in dB
2. For providing isolation between the instruments.
3. For reducing the power input to a particular stage to prevent overloading.

BG. QUESTIONS:

1. What is the purpose of attenuator in the microwave bench?
2. What is the difference between Flap Attenuator and Movable Vane Attenuator?
3. With what type of materials the attenuators are made up of?
4. Where attenuators are mainly used?
5. What is the difference between fixed attenuator and variable attenuator?
6. With what type attenuators the vane type attenuator is made up of?
7. Where the rotary vane precision attenuator is preferable?
8. What is the difference between attenuator and isolator?
9. List out the applications of the attenuator.
10. With what type of material the glass vane is being coated.

BH. Analysis of Results: (Write your own)
(Include sample calculations/Display/plot/typical graph)

BI. Conclusions: (Write your Own)

Precautions:

36. Check the connections before switching on the kit.
37. Connections should be done properly.
38. Observation should be taken properly.

Approved By:

(HOD ECE) (Lab Instructor)

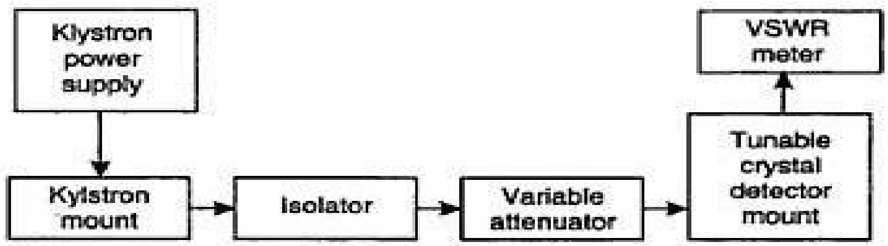
EC - IV: MICROWAVE LAB
EXPERIMENT No. : 09

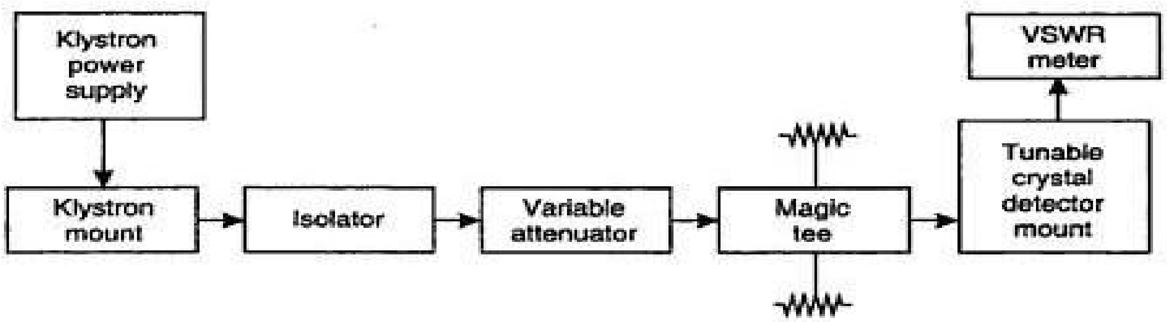
STUDY OF POWER DIVISION IN MAGIC TEE

A. Aim:
To measure isolation between E and Harms of the magic tee and Demonstrate 3 dB power division in the arm of magic tree.

B. Apparatus Used:
Klystron power supply, Klystron Mount, Isolator, Attenuator, Frequency meter, VSWR meter, magic tee and matched terminations.

C. Experimental Setup:





D. Theory

A four port junction which is a combination of an E-plane and H-plane tee is called Hybrid Tee. When matched elements are introduced to reduce the reflections, it is called a magic Tee.
It has four arms or ports which have the names indicated in figure 9.

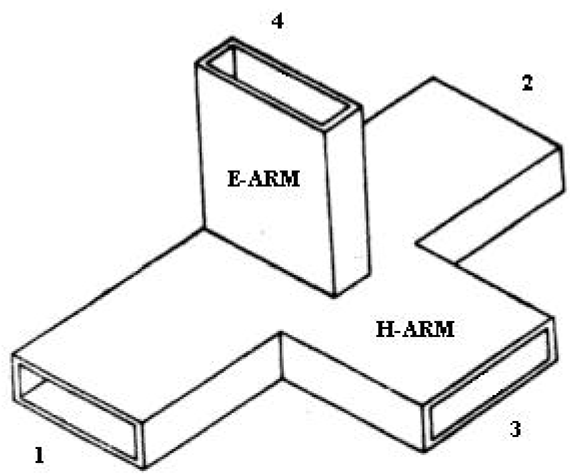


Fig.(9)- Magic Tee

The arm which makes an H-plane tee with the collinear arm is called H-arm or Shunt arm. The fourth arm which makes E-plane tee with the collinear arms is called E-arm or series arm. The shunt and series arms are polarized. i.e. the voltage vectors in these two arms are perpendicular to each other. Therefore as long as there is nothing within the junction to rotate the polarization, there can be no coupling between the two arms. The E and H arms are matched by employing posts and irises to minimize reflections from these two ports.

The magic associated with the hybrid junction is the way in which the power is divided in the various arms. The signal fed into the shunt or H-arms divides its ~ If equally and in phase in the two side arms with no coupling in E-arm. When the signal is fed into the series or E-arm it also divides itself equally in the two arms, but this time two halves are 180^o out of phase ad there is no coupling to the H-arm. If the power is fed into one of the arms, it divides equally in the shunt and series arm and there is no coupling in the other side arm. That is to finally that in a magic tee, opposite arms are isolated.

A magic tee can also be used as a signal combiner. If the signals are fed to both the side arms, they will combine in phase in H-arm and 180^o out of phase in E-arm.

A magic tee is normally characterized by two quantities

1. Isolation between E and H arms
2. Power division in collinear arms

Isolation between E and H arms

If the power flowing into E arm is taken as P_E and power flowing out of H-arm as P_H then

$$\text{Isolation(dB)} = -10 \log_{10} P_{H}/ P_E$$

This assumes that both the collinear arms are match terminated.

Power division

The power fed in either the E or H arm should divide itself equally in both the side arms, when the opposite port is match terminated. If we designate the power entering the E arm as P_E and power in side arms as P_{C1} and P_{C2} then the ratio of the power coupled in side arms to that entering in the E-arm is given by the relation.

Coupling (dB) = $10 \log_{10} P_{C1}/ P_H = -10 \log_{10} P_{C2}/ P_H$.

E. <u>Procedure:</u>

General

1. Set up the equipment as shown in fig 9a.
2. Keep the control knobs of Klystron Power Supply as below
   - Mode Switch : AM
   - Beam Voltage Knob : Fully Anti Clockwise
   - Repeller Voltage Knob : Fully Clockwise
   - Meter Switch : Cathode Voltage Position
3. Measurement or isolation between E and H arms
   - 3.1 Set the attenuator around 20dB. Let this setting be (A_1) dB
   - 3.2 Achieve a state reference reading on the SWR meter, preferably in 40dB range of the SWR meter
   - 3.3 Disconnect and setup as shown in fig 9b
   - 3.4 Reduce the attenuation till the SWR meter reads the value obtained in step 3.2 note the attenuation setting (A_2) dB. The difference in the attenuator setting (A_1-A_2) dB gives the isolation in dB.
4. Experimental setup for demonstrating the 3 dB power division in the collinear arms.
   - 4.1 Now the power input be either E or H arms.
   - 4.2 Set the attenuator to get reference reading on SWR meter without the component under test. Note the attenuator setting (A_1) dB
   - 4.3 Connect the component under test(Magic tee)
   - 4.4 Reduce the attenuation to get the reference reading obtained in step 4.2
   - 4.5 Note down the attenuator setting (A_2) dB

   The difference in the attenuator settings gives the ration of the power coupled to the collinear to that in the main arm, in dB. This value is around 3dB.

F. <u>Observation: (Include your own Table relevant to the Experiment)</u>

Isolation measurement

Attenuator setting when measuring input to E-arm A_1 dB	Attenuator setting when measuring power to H-arm A_2 dB

Measurement of power division

Attenuator setting when measuring input to E/H arm A_1 dB	Attenuator setting when measuring power at collinear to arms A_2 dB

G. Analysis of Results: (Write your own)
(Include sample calculations/Display/plot/typical graph)

H. Conclusions: (Write your Own)

Isolation between E and H arms (dB) = $(A_1 - A_2)$ dB
Coupling between collinear arms and E/H arms (dB) = $(A_1 - A_2)$ dB

Precautions:

39. Check the connections before switching on the kit.
40. Connections should be done properly.
41. Observation should be taken properly.

Approved By: **Prepared By: Kamta Sharma**

(HOD ECE) (Lab Instructor)