MICROWAVE AND RADAR

(EE-326-F)

LAB MANUAL

VI SEMESTER

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EXPERIMENT NO. 1

AIM: - To study wave guide components.

APPARATUS REQUIRED :- Flanges, Twisted wave guide, wave guide tees, Directional Coupler, Attenuator, Isolators, Circulators, Matched terminator, Slide screw tuner, Slotted Section, Tunable probe, Horn antennas, Movable Short, Detector mount.

THEORY: - A pipe with any sort of cross- section that could be used as a wave guide or system of conductors for carrying electromagnetic wave is called a wave guide in which the waves are truly guided.

(1) **FLANGES: -** Flanges are used to couple sections of wave guide components. These flanges are designed to have not only mechanical strength but also desirable electric characteristics.

(2) **TWISTED WAVEGUIDE: -** If a change in polarization direction is required, twisted section may be used. It is also called rotator.

(3) **WAVE GUIDE TEE: -** Tees are junctions which are required to combine or split two signals in a wave guide. Different type of tees are :-

   (a) **H - PLANE TEE: -** All the arm of the H- plane Tee lies in the plane of the magnetic field which divides among the arm. This is thus a current or parallel junction.

   (b) **E- PLANE TEE: -** It lies in the plane of electric field. It is voltage or series junction. In this signal is divided in to two parts having same magnitude but in opposite phase.

   (c) **MAGIC TEE: -** If another arm is added to either of the T-junction. Then a hybrid T-junction or magic tee is obtained. The arm three or four is connected to arm 1&2 but not to each other.

(4) **DIRECTION COUPLER :-** The power delivered to a load or an antenna can be Measured using sampling technique in which a known fraction of the power is Measured so that the total may be calculated. A number of coupling units used for such purpose are known as directional coupler.

(5) **ATTENUATORS: -** It consists of a resistive wane inside the wave guide to absorb microwave power according to its position w.r.t side wall of the wave guide. Attenuation will be maximum if the wane is placed at center.

(a) **Fixed Attenuators:** In this the position of resistive wane is fixed, it absorbs constant amount of power.

(b) **Variable Attenuators:** - In this the position of resistive wane can be changed with the help of micrometer.

(6) **ISOLATORS: -** Ferrite is used as the main material in isolator. Isolator is a microwave device which allows RF energy to pass through in one direction with very little loss, while RF power in the reverse direction is absorbed.

(7) **CIRCULATORS: -** A microwave circulator is a multi port junction device where the power may flow in the direction from 1 to 2, 2 to 3, & so on...

(8) **MATCHED TERMINATION: -** A termination producing no reflected wave at any transverse section of the wave guide. It absorbs all the incident wave. This is also equivalent to connecting the line with its characteristic impedance.

(9) **SLOTTED SECTION: -** A length of wave guide in which a non radiating slot is cut on the broader side. This is used to measure the VSWR.

(10) **SLIDE SCREW TUNER:-** A screw or probe inserted at the top of wave guide (parallel to E) to develop susceptance the magnitude & sign of which is controlled by depth of penetration of screw and it can be moved along the length of wave guide.

(11) **H – PLANE BEND: -** An H-plane bend is a piece of wave guide smoothly bends in a plane parallel to magnetic field for the dominant mode (Hard bend).

(12) **E – PLANE BEND: -** An E-plane bend is a piece of wave guide smoothly bends in a plane of electric field (Easy bend).

(13) **HORN ANTENNAS: -** The components which radiates & intercept EM energy is of course the antenna. The open-ended wave guide, in which the open end is flared so that it looks like a horn, is called horn antenna. There are several types of horns – Sectional E-plane horn, Sectional H- plane horn and Pyramidal horn.

(14) **MOVABLE SHORT: -** It is adjustable load which moves along the length of wave guide and adjusted to get SWR.

RESULT: - Students have been able to appreciate the purpose and usage of various Components.

PRECAUTIONS:-

1. Handle all components with care and do not allow any damage to take place.
2. Do not rub/scratch the inner polished surfaces of the components with any sharp edged body.
3. If demonstrating any assembly of components, ensure that there is no cross threading and proper tightening.

QUIZ:-

Q.1 What is the purpose of wave guide flange?
Q.2 What is a wave guide?
Q.3 Why the wave guide is air filled?
Q.4 What is a wave guide bend?
Q.5 What is isolator?
Q.6 What is circulator?
Q.7 What is Attenuator?
Q.8 What are Tees. How many types of Tees are there?
Q.9 What is slotted line?
Q.10 What is tunable detector?

ANSWERS:-

Ans.1 It is used to connect two similar types of wave guides or wave guide components.
Ans.2 It is a metallic structure of any cross-section highly polished & silver plated from inside. It is used for flow of electromagnetic energy.
Ans.3 The wave guide is filled with dry air under pressure to remove any moisture from the wave guide that might cause corrosion. It also increases the power handling capacity of the wave guide.
Ans.4 It is a bend, which is used to change the path of flow of EM energy in the wave guide.
Ans.5 It is a device, which allows the flow of EM energy in one direction but does not permit energy to travel in the opposite direction.
Ans.6 It is a multi port device. It has a property that energy entering in one port is permitted to come out from the next port only and not from any other port.
Ans.7 It is a device that is used to reduce the strength of signal.
Ans.8 Junction of wave guide in different configurations is called Tee. Following type of Tees are there: - E plane Tee, H plane Tee, Magic Tee, Rat Race.
Ans.9 It is a wave guide in which a slot is made on the broader side, in the center of the side along the axis of the wave guide. It is used to facilitate movement of traveling probe along the wave guide to detect & measure the standing wave ratio.
Ans.10 It is a device that is used to detect microwave signal. Detector diode can be Point Contact Diode or Schottky Barrier Diode

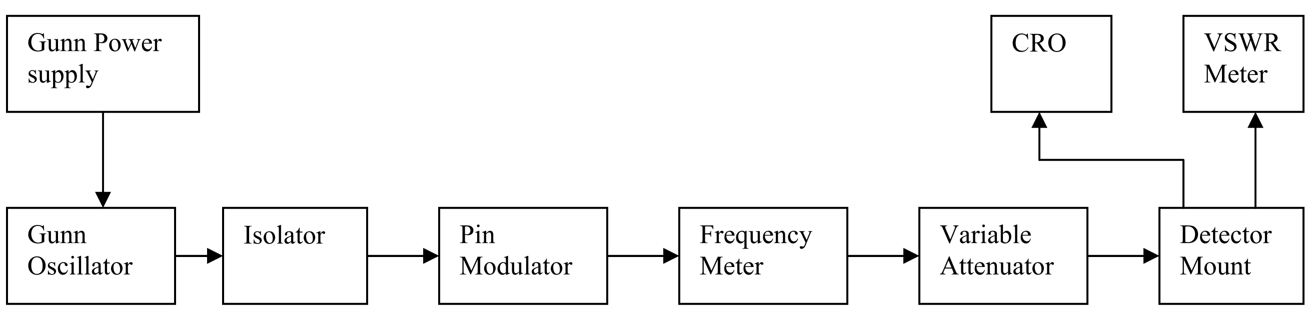
EXPERIMENT NO.2

AIM: - To study the characteristics of Gunn oscillator Gun diode as modulated source

APPARATUS REQUIRED :- Gunn Diode, Gunn power supply, PIN Modulator, Isolator, Frequency meter, Variable Attenuator, Detector mount, Wave guide stand, VSWR meter, Cables and accessories.

THEORY: - The Gunn Oscillator is based on negative differential conductivity effect in bulk semiconductor which has two conduction bands, minima separated by an energy gap. A disturbance at the cathode gives rise to high field region which travel towards the anode. When this high field domain reaches the anode, it disappears and another domain is formed at the cathode and starts moving towards anode and so on. The time required for domain to travel from cathode to anode gives oscillation frequency. In a Gunn Oscillator, the Gunn diode is placed in a resonant cavity, the Oscillation frequency is determined by cavity dimension than by diode itself.

BLOCK DIAGRAM:-



PROCEDURE: -

(1) Set the components and equipments as shown in block diagram.
(2) Initially set the variable attenuator for minimum attenuation.
(3) Keep the control knob of Gunn Power Supply as below:

Meter Switch	-	'OFF'
Gunn bias knob	-	Fully anti-clockwise
Pin bias knob	-	Fully anti-clockwise
Pin Mod frequency	-	Any position

(4) Keep the control knob of VSWR meter as below:

Meter Switch	-	Normal

Input Switch - Low Impedance
Range db Switch - 40 db
Gain Control knob - Fully clockwise

(5) Set the micrometer of Gunn oscillator for required frequency of operation.
(6) Switch 'ON' the Gunn Power Supply, VSWR meter and Cooling Fan

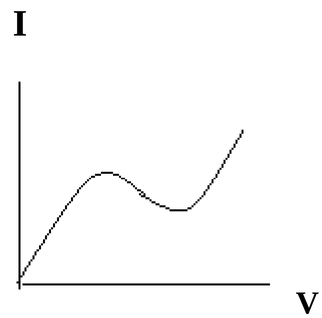
VOLTAGE – CURRENT CHARACTERISTIC

(1) Turn the meter switch of Gunn power supply to voltage position.
(2) Measure the Gunn diode current Corresponding to the various voltages
(3) Plot the voltage and current reading on the graph
(4) Measure the threshold voltage, which corresponds to the graph.

OBSERVATIONS:-

S.NO	Voltage	Current

GRAPH: -



RESULTS: - The values of voltage and current is measured and the graph is drawn.

PRECAUTIONS:-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ:-

Q.1 What are the basis of classification of microwave devices?
Q.2 What is Gunn Effect?
Q.3 What are the applications of Gunn diode?
Q.4 What is negative resistance?
Q.5 What are the advantages of Gunn diode.
Q.6 What are the disadvantages of Gunn diode
Q.7 What is threshold voltage?
Q.8 What is the role of PIN diode in the test setup?
Q.9 What is the role of Isolator in the test setup?
Q.10 In a Gunn oscillator, Gunn diode is placed in a resonant cavity. In your opinion what shall be the effect of this.

ANSWERS:-

Ans.1 - Based on electrical behavior.
- Based on conduction.

Ans.2 There are periodic fluctuations of current passing through N type Ga As when applied voltage exceeded certain critical voltage.
Ans.3 Used as amplifier and oscillators.
Ans.4 In negative resistance devices, voltage and current phases are 180° out of phase. Voltage drop across it is negative and ($-I^2 R$) power is generated.
Ans.5 It has very less noise.
Ans.6 It is very temperature dependent. Frequency of oscillations changes with change in temperature.
Ans.7 It is that voltage on curve, which corresponds to maximum current.
Ans.8 PIN diode is used to square modulate the output of Gunn oscillator.
Ans.9 To avoid the flow of reflected energy back to Gunn oscillator. This reflected energy shall destabilize the frequency, phase & amplitude of output wave from oscillator.
Ans.10 The frequency of oscillations shall be determined by the dimensions of the cavity, rather than by the diode itself.

EXPERIMENT NO. 3

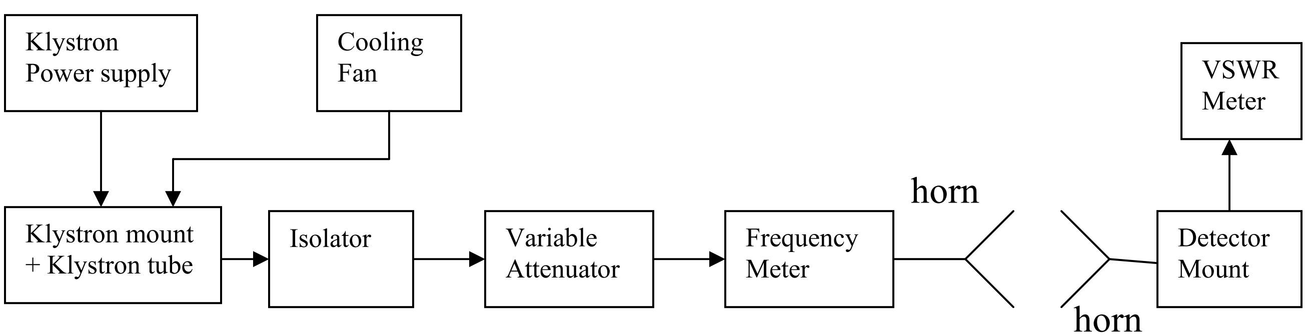
AIM: - Study of wave guide horn and its radiation pattern and determination of the Beam width

APPARATUS REQUIRED: - Klystron tube, Klystron power supply, Klystron mount, Isolator, Frequency Meter, Two horn antennas, Detector mount, Radiation pattern table, Cooling fan, VSWR meter, Cables and accessories.

THEORY: - If a transmission line propagating energy is left open at one end, there will be radiation from this end. In case of a rectangular wave guide this antenna presents a mismatch of about 2:1 and it radiates in many directions. The match will improve if the open wave guide is a horn shape.

The radiation pattern of an antenna is a diagram of field strength or more often the power intensity as a junction of the aspect angle at constant distance from the radiating antenna. An antenna pattern consist of several lobes, the main lobe, side lobe, and back lobe. The major power is concentrated in the main lobe and it is normally to keep the power in the side lobes and back lobe as low as possible.

BLOCK DIAGRAM: -



PROCEDURE: -

(1) Set the equipment as shown in fig. Keeping the axis of both antennas in same line.
(2) Initially set the variable attenuator for maximum position.
(3) Keep the control knobs of Klystron Power Supply as below:

Meter Switch	-	'OFF'
Mod Switch	-	AM

Beam voltage knob	-	Fully anti-clockwise
Reflector voltage	-	Fully clockwise
AM- amplitude knob and frequency knob	-	Around mid position.

(4) Keep the control knob of VSWR meter as below:

Meter Switch	-	Normal
Input Switch	-	Low Impedance
Range db Switch	-	40 db
Gain Control knob	-	Mid position

(5) 'ON' the Klystron Power Supply, VSWR meter and Cooling Fan

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

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

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

(9) Turn the receiving horn to the left in 5° steps up to 40°- 50° and note the corresponding VSWR db reading in normal db range.

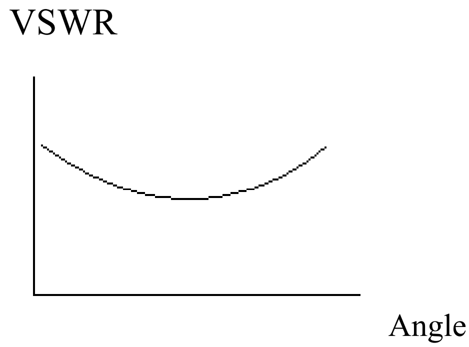
(10) Repeat the above step but this time turn the receiving horn to the right and note down the readings.

(11) Draw a relative power pattern, i.e., output vs. angle.

OBESERVATIONS AND CALCULATIONS:-

S.NO	Angle	VSWR

GRAPH: -



RESULT: - The radiation pattern is drawn using the values of angle and VSWR.

PRECAUTIONS:-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ:-

Q.1 What is Horn antenna?
Q.2 What is radiation pattern?
Q.3 What are various types of lobes.
Q.4 Where in the lobe the intensity is maximum.
Q.5 Are side lobes / back lobes desirable. Discuss?
Q.6 What are the disadvantages of side lobes / back lobes?
Q.7 What is beam width?
Q.8 What is antenna gain?
Q.9 What are the advantages of flaring?
Q.10 What are the various type of microwave antennas?

ANSWERS:-

Ans.1 This is an open ended wave guide, in which open end is flared so that it looks like horn. It can be H plane, E plane, Pyramid horn or Conical horn.
Ans.2 It is a diagram of field strength or power intensity.
Ans.3 These are main lobe, side lobe, back lobe.
Ans.4 At the center of the lobe.
Ans.5 These are not desirable but at the same time it is not possible to design an antenna without side lobes / back lobes. Through proper design, these can be reduced.
Ans.6 Loss of energy and susceptible to interference & jamming.
Ans.7 The angle between two points on a main lobe where power intensity is half of the maximum power intensity.
Ans.8 It is a measure of increased power radiated in the direction of target as compared with the power that would have been radiated from an isotropic antenna.
Ans.9 Flaring improves directivity, increases efficiency and reduces VSWR.
Ans.10 Horn antenna, Lens antenna, Slot antenna and Micro strip antenna.

EXPERIMENT NO. 4 (a)

AIM: - To study isolation and coupling coefficient of a magic Tee

APPRATUS REQUIRED: - Klystron tube, Klystron power supply, Klystron mount, Isolator, Frequency Meter, Variable Attenuator, Detector mounts, Magic Tee, Wave guide stand, Cooling fan, VSWR meter, Cables and accessories.

THEORY: - The Magic Tee is a four port device & it is a combination of the E & H plane Tee. If the power is fed into arm 3 (H- arm), the electric field divides equally between arm 1 and 2 with same phase, and no electric field exists in arm 4. If the power is fed in arm 4 (E- arm), it divides equally into arm 1 and 2 but out of phase with no power to arm 3. Further, if the power is fed from arm 1 and 2, it is added in arm 3 (H-arm), and it is subtracted in E-arm, i.e., arm 4.The basic parameters to be measured for magic Tee are defined below:

A. **Isolation: -** The isolation between E and H arms is defined as the ratio of the power supplied by the generator connected to the E-arm (port 4) to the power detected at H-arm (port3) when side arms 1 and 2 are terminated in matched load.

   Hence, Isolation 3-4 = $10 \log_{10} P_4 / P_3$

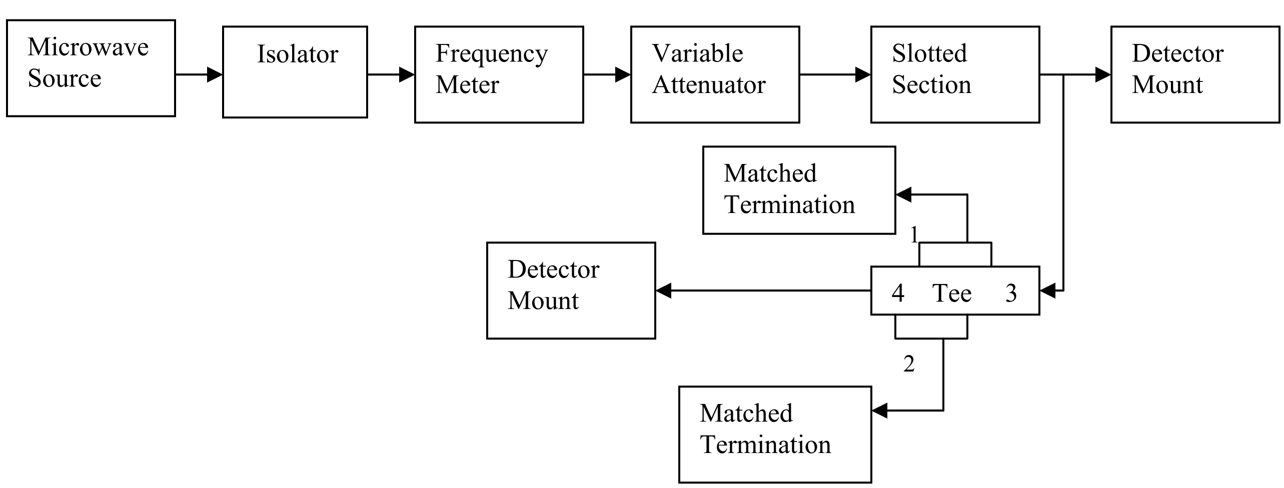
B. **Coupling Coefficient :-** It is defined as $C_{ij} = 10^{-\alpha / 20}$

   Where α is attenuation / isolation in db when i is input arm and j is output arm.

   Thus $\alpha = 10 \log Pi / Pj$

   Where Pi is the power delivered to arm i and Pj is power detected at j arm.

BLOCK DIAGRAM: -



PROCEDURE: - Measurement of Isolation and Coupling Coefficient

(1) Set the equipments as shown in fig.
(2) Remove the tunable probe and magic Tee from the slotted line and connect the detector mount to the slotted line.
(3) Energize the microwave source for particular operation of frequency and Tune the detector for max. 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 (let it be P_3).
(5) Without changing the position of variable attenuator and gain control knob of VSWR meter, carefully place the magic Tee after slotted line keeping H-arm to slotted line, detector to E-arm and matched termination to arm1 and 2. note down the reading of VSWR meter (let it be P_4).
(6) Determine the isolation between port 3 and 4 as $P_3 – P_4$ in db.
(7) Determine the coupling coefficient from equation given.
(8) The same experiment may be repeated for other ports also.
(9) Repeat the same for other frequencies.

OBSERVATIONS AND CALCULATIONS:-

$P_3 =$

$P_4 =$

Calculate Isolation and coupling coefficient using

Isolation 3-4 = $10 \log_{10} P_4 / P_3$

$\alpha = 10 \log Pi / Pj$

RESULT: - Measured values for Isolation and coupling coefficient are

I =

$\alpha =$

PRECAUTIONS:-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ:-

Q.1 What are the various type of Tees.
Q.2 What is H - plane Tee?
Q.3 What is E - plane Tee?
Q.4 What is Magic Tee?
Q.5 What is the electric property of H-plane Tee?
Q.6 What are the properties of E-plane Tee?
Q.7 What are the properties of Magic Tee?
Q.8 What are the applications of Magic Tee?
Q.9 What is the isolation between E & H arm?
Q.10 Define Coupling Coefficient?

ANSWERS:-

Ans.1 E - plane Tee, H – plane Tee, Magic Tee, and Rat Race etc.

Ans.2 An H-plane Tee is formed by cutting a rectangular slot along the width of a main wave guide and attaching another wave guide on the slot. It is3-port device.

Ans.3 A rectangular slot is cut along the broader dimension of a wave guide and a side arm is attached. This is a three-port device.

Ans.4 Rectangular slots are cut along the breadth and width of a long wave guide and side arms are attached. It is a Four-port device.

Ans.5 If equal input are given at ports 1&2 (collinear ports), the output at the port 3 shall be the sum of these two inputs.

Ans.6 If equal, in phase inputs are given at collinear ports, the output at port 3 shall be difference of the two i.e. zero. Similarly if same input is given at port 3, there shall be equal but opposite outputs at ports 1&2.

Ans.7 It has got the properties of both H & E plane Tees. However if some input is given to port 1, nothing comes out of 2.

Ans.8 - Used for measurement of impedance, Used as duplexer. Used as mixer.

Ans.9 It is defined as ratio of power supplied by generator connected to E-arm (port4) to the power detected at H-arm (port3) side arms 1&2 are terminated in matched load. Isolation 3-4 = $10 \log_{10} P_4 / P_3$

Ans.10 $C_{ij} = 10^{-\alpha / 20}$

Where α is attenuation / isolation in db when i is input arm and j is output arm

Thus $\alpha = 10 \log Pi / Pj$

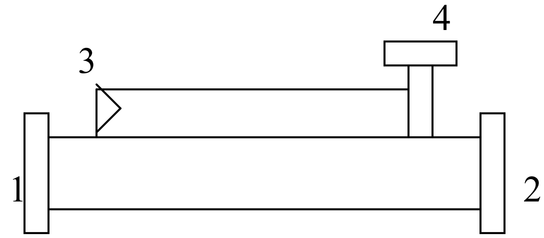
Where Pi is the power delivered to arm i and Pj is power detected at j arm.

EXPERIMENT NO. 4(b)

AIM: - To measure coupling coefficient, Insertion loss & Directivity of a Directional coupler.

APPARATUS REQUIRED: - Klystron tube, Klystron power supply, Klystron mount, Isolator, Cooling fan, Frequency Meter, Detector mount, Variable Attenuator, Wave guide stand, VSWR meter, MHD coupler, Matched Termination, Cables and accessories.

THEORY: - A directional coupler is a device with which it is possible to measure the incident and reflected wave separately. It consist of two transmission lines, main arm and auxiliary arm, electro magnetically coupled to each other. The diagram is given below. The power entering in port 1 in the main arm divides between port 2 and port 4 almost no power comes out of port 3. Power entering in port 2 is divided between port 1 and 3.



Assuming power is entering from port 1, then

The coupling factor is defined as

$$\text{Coupling (db)} = 10 \log_{10} P_1 / P_4$$

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

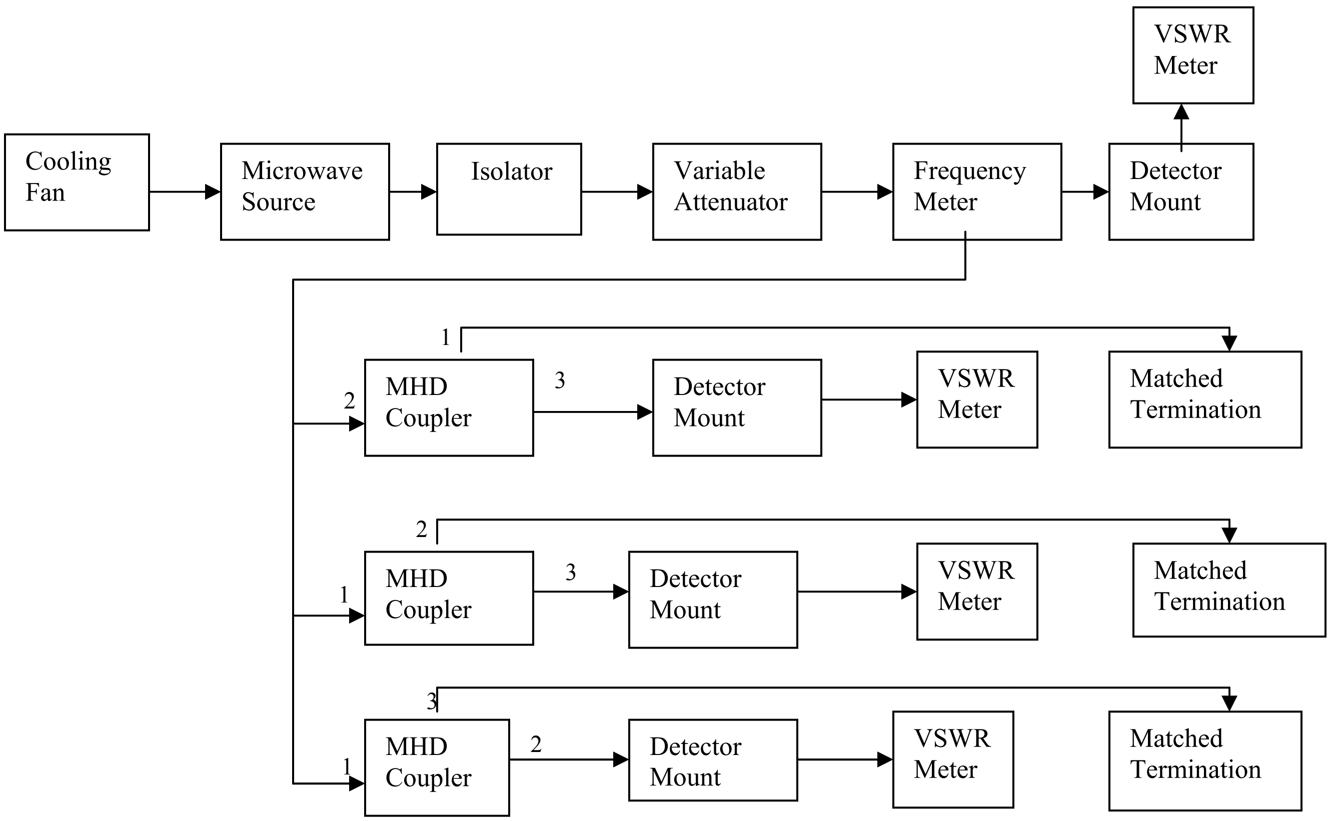
$$\text{Insertion loss} = 10 \log_{10} P_1 / P_2.$$

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

$$D \text{ (db)} = 10 \log_{10} P_{4f} / P_{4r}$$

Where P_{4f} and P_{4r} are the measured powers at port 4 with equal amount of power is fed to port 1 and 2 respectively.

BLOCK DIAGRAM:-



PROCEDURE: - Measurement of Coupling factor, Insertion loss & Directivity

(1) Set the `equipments as shown in fig.
(2) Energize the microwave source for particular operation of frequency.
(3) Remove the MHD coupler and connect the detector mount to the frequency meter. Tune the detector for max. 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 (let it be X).
(5) Insert the D.C as shown in fig. With detector mount to the auxiliary port 4 and matched termination to port 2. Without changing the position of variable attenuator and gain control knob of VSWR meter.
(6) Note down the reading on VSWR meter (let it be Y) and calculate coupling factor using X &Y, which will be in db.

(7) Now carefully disconnect the detector from the auxiliary port 4 and match termination from port2 without disturbing the setup.
(8) Connect the matched termination to the aux. Port 4 and detector to port 2 and measure the reading on VSWR meter (let it be Z).
(9) Compute insertion loss using X & Z in db.
(10) Repeat the steps from 1 to 4.
(11) Connect the D.C in the reverse direction i.e. port 2 to frequency meter side, matched termination to port1 and detector mount to port 4, without disturbing the position of the variable attenuator and gain control knob of VSWR meter.
(12) Note down the reading and let it be Y_0 .Compute the directivity as Y- Y_0.
(13) Repeat the same for other frequency.

OBSERVATION AND CALCULATIONS: -

Calculate D, C and I using the equations as given above.

RESULT: - The measured value for MHD coupler are

Coupling coefficient =
Insertion loss =
Directivity =

.

PRECAUTIONS:-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ:-

Q.1 What is directional coupler?
Q.2 What is Coupling?
Q.3 What is Directivity?
Q.4 What is Isolation?
Q.5 What is Insertion loss?
Q.6 In a two hole directional coupler, what is the distance between two holes?
Q.7 What is the material of directional coupler?
Q.8 Name a few other types of directional couplers?
Q.9 In a directional coupler, are ports matched?
Q.10 How many holes can be there in a Directional coupler?

ANSWERS:-

Ans.1 It is a combination of two wave guides electrically connected to each other through a hole or orifice. It is used to measure the power of EM wave by taking a small fraction of it.
Ans.2 Coupling, C (db) = $10 \log_{10} P_i / P_f$
Ans.3 Directivity, D (db) = $10 \log_{10} P_f / P_b$
Ans.4 Isolation, I = $10 \log_{10} P_i / P_b$.
Ans.5 Insertion loss = $10 \log_{10} Pi / Pr$.
Ans.6 The distance is $\lambda_g / 4$.
Ans.7 These are two metallic rectangular wave-guides, made of brass / copper. These are finely polished and silver plated from inside.
Ans.8
- Two hole cross guide coupler.
- Two hole branching guide coupler
- Short slot coupler
- Bifurcated coupler
- Loop directional coupler.

Ans.9 All ports are perfectly matched to the junctions
Ans.10 It can be one, two or more than two depending upon requirement. Degree of coupling shall be decided by number and location of holes.

EXPERIMENT NO. 5 (a)

AIM: - To measure attenuation and insertion loss of a fixed and variable attenuator.

APPARATUS REQUIRED: - Microwave source, Isolator, Frequency meter, Variable attenuator, Slotted line, Tunable probe, Detector mount, Matched termination, VSWR meter, test fixed and variable attenuator and Accessories.

THEORY: - The attenuator are two port bidirectional devices which attenuates some power when inserted into the transmission line.

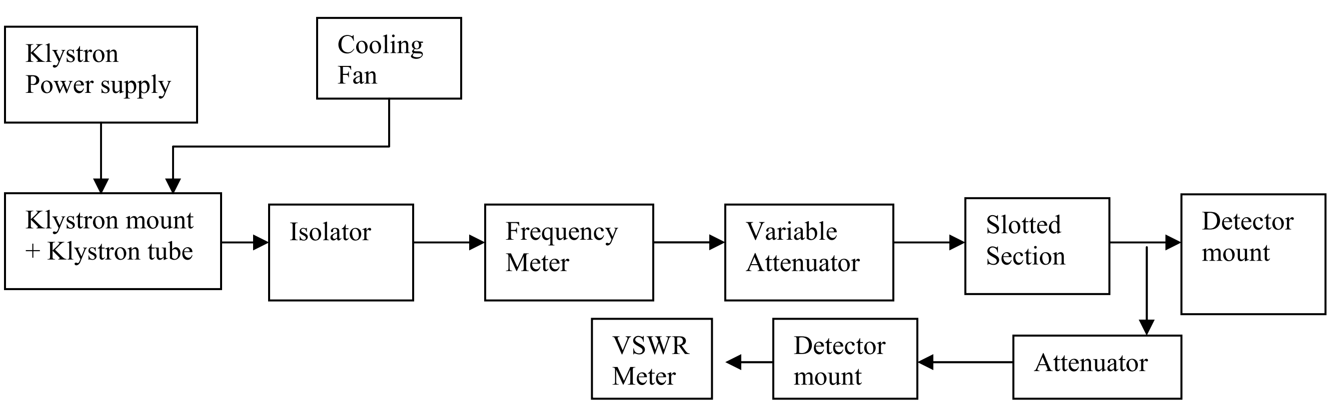
Attenuation A (db) = 10 log P1/P2

Where, P1 = Power absorbed or detected by the load without the attenuator in the line. P_2 = Power absorbed/detected by the load with attenuator in the line. The attenuators consist of a rectangular wave guide with a resistive vane inside it to absorb microwave power according to their position with respect to side wall of the waveguide. An electric field is maximum at centre in TEIO mode; the attenuation will be maximum if the vane is placed at centre of the waveguide. Moving from centre towards the side wall, attenuation decreases in the fixed attenuator, the vane position is fixed where as in variable attenuator, its position can be changed by the help of micrometer or by other methods.

Following characteristics of attenuators can be studied:

1. Input VSWR.
2. Insertion loss (in case of variable attenuator).
3. Amount of attenuation offered into the lines.
4. Frequency sensitivity, *i.e.,* variation of attenuation at any fixed position of vane and frequency is changed.

BLOCK DIAGRAM: -



PROCEDURE: -

Insertion Loss/Attenuation Measurement

1. Remove the tunable probe, attenuator and matched termination from the slotted section in the above set up.
2. Connect the detector mount to the slotted line, and tune the detector mount also for maximum deflection on VSWR meter (Detector mount's output should be connected to VSWR meter).
3. Set any reference level on the VSWR meter with the help of variable attenuator (not test attenuator) and gain control knob of VSWR meter. Let it be P1.
4. Carefully disconnect the detector mount from the slotted line, without disturbing any position on the set up. Place the test variable attenuator to the slotted line and detector mount to other port of test variable attenuator. Keep the micrometer reading of test variable attenuator to zero and record the reading of VSWR meter. Let it be P_2. Then the insertion loss of test attenuator will be $P_1 - P_2$ db.
5. For measurement of attenuation of fixed and variable attenuator, after step 4 of above measurement, carefully disconnect the detector mount from the slotted line without disturbing any position obtained up to step 3. Place the test attenuator to the slotted line and detector mount to the other port of test attenuator. Record the reading of VSWR meter. Let it be P3. Then the attenuation value of fixed attenuator or attenuation value of variable attenuator for particular position of micrometer reading will be PI - P3 db.
6. In case of variable attenuator, change the micrometer reading and record the VSWR meter reading. Find out attenuation value for different position of Micrometer reading and plot a graph.
7. Now change the operating frequency and whole step should be repeated for finding frequency sensitivity of fixed and variable attenuator.

OBSERVATION AND CALCULATIONS:-

RESULT:-

PRECAUTIONS:-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ:-

Q1. A loss-less line having characteristic impedance Zo is terminated in a pure reactance of value -jZo. The VSWR of the line will be

(a) 10 (b) 2

(c) 1 (d) infinite

Q2. A cylindrical cavity resonator has a diameter of 16 mm. What is the dominant resonant mode when the cavity length is i) 20 mm and ii) 15mm

(i) (ii)

(a)TEl11 M111 (c) TEl11 TMolO

(i) (ii)

(b) TMolO TE111

(d) TM111 TEo

Q3. In a circular waveguide with radius *'r',* the dominant mode is

(a) TMol *(b)* TEol

(c) TMl1 *(d)* TEl1

Q4. Consider the following statements:

In a magic tee,

The collinear arms are isolated from each other.

One of the collinear arms is isolated from the E-arm.

One of the collinear arms is isolated from the H-arm.

E-arm and H-arm are isolated from each other. Of these statements

(a) 1 and 2 are correct *(b)* 1 and 3 are correct

(e) 1 and 4 are correct *(d)* 2 and 3 are correct

Q5. Radiation from a helical antenna is

(a) plane-polarized *(b)* partially plane polarized

(e) Circularly polarized *(d)* elliptically polarized

ANSWERS: Q1:d

Q2: a

Q3: d

Q4: c

Q5: c

EXPERIMENT NO. 5(b)

AIM :- To measure isolation and insertion loss of a three port Circulators/Isolator.

APPARATUS REQUIRED :- Klystron tube, Klystron power supply, Klystron mount, Isolator, Circulator, Slotted Section, Tunable probe, Frequency Meter, Variable Attenuator, Detector mount, Wave guide stand, Cooling fan, VSWR meter, Cables and accessories.

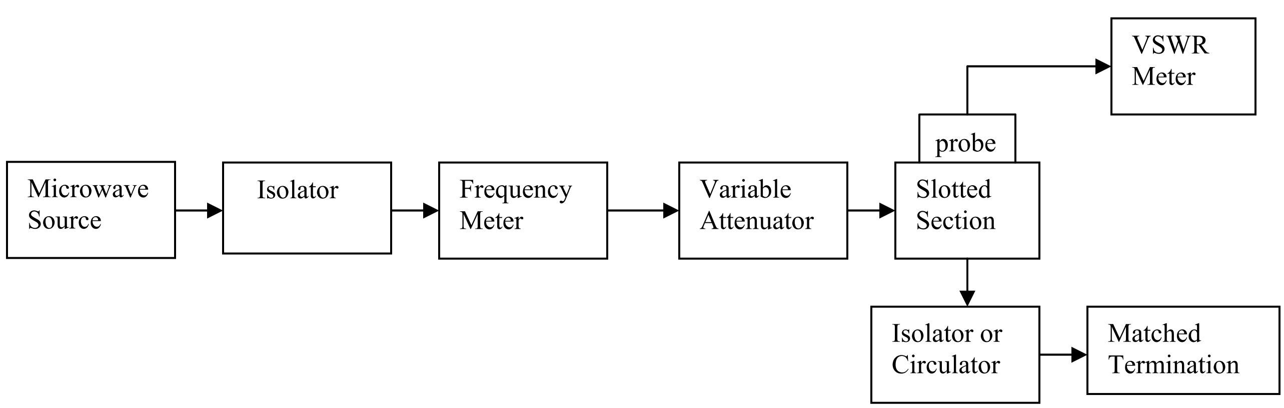
THEORY :-

ISOLATOR :- The isolator is a two-port device with small insertion loss in forward direction and a large in reverse attenuation.

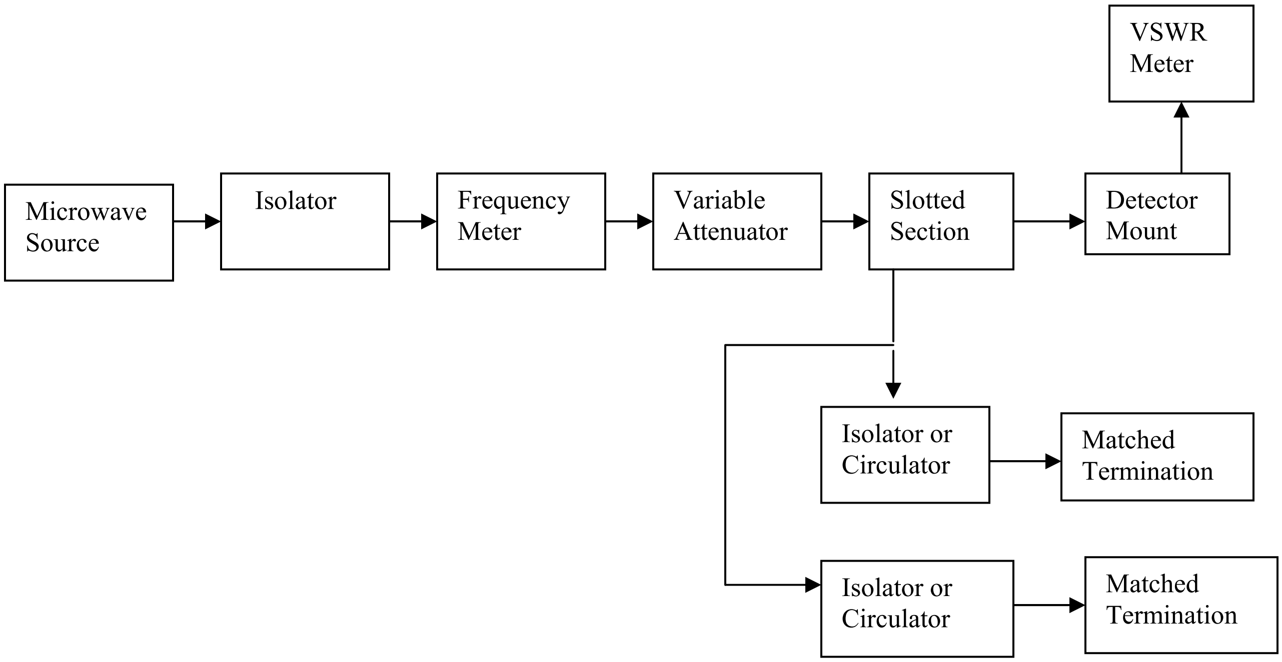
CIRCULATOR :- the circulator is a multi port junction that permits transmission in certain ways. A wave incident in port 1 is coupled to port 2 only, a wave incident at port 2 is coupled to port3 only and so on . Following is the basic parameters of isolator and circulator for study.

A. **Insertion loss :-** The ratio of power supplied by a source to the input port to the power detected by a detector in the coupling arm, i.e., output arm with other port terminated in the matched load, is defined as insertion loss or forward loss.
B. **Isolation :-** It is the ratio of power fed to input arm to the input power detected at not coupled port with other port terminated in the matched load..
C. **Input VSWR :-** The input VSWR of an isolator or circulator is the ratio of voltage maximum to voltage minimum of the standing wave existing on the line, when one port of it terminates the line and others have matched termination.

BLOCK DIAGRAM :- Measurement of VSWR



Measurement of Insertion loss and Isolation



PROCEDURE :-

(a) Input VSWR Measurement :

(1) Set up the components and equipments as shown above with input port of isolator or circulator towards slotted line and matched load on other ports of it.
(2) Energize the microwave source for particular operation of frequency.
(3) With the help of slotted line, probe and VSWR meter, find out SWR of the isolator or circulator as describe earlier for low and medium SWR measurements.
(4) The above procedure can be repeated for other ports or for other frequencies.

(b) Measurement of Insertion loss & Isolation :

(1) Remove the probe and isolator or circulator from slotted line and connect the detector mount to the slotted section. The output of the detector mount should be connected with VSWR meter.
(2) Energize the microwave source for max. output for a particular frequency of operation. Tune the detector mount for max. output in VSWR meter.

(3) Set any reference level of power in VSWR meter with the help of variable attenuator, gain control knob of VSWR meter and note down the reading (let it be P_1).
(4) Carefully remove the detector mount from slotted line without disturbing the position of set up. Insert the isolator / circulator between slotted line and detector mount. Keeping input port to slotted line and detector at its output port. A matched termination should be placed at third port in case of circulator.
(5) Record the readings in the VSWR meter. If necessary change range – db switch to high or lower position and taking 10 db changes for one set change of switch position (let it be P_2).
(6) Compute insertion loss on P_1-P_2 in db.
(7) For measurement of isolation, the isolator or circulator has to be connected reverse, i.e., output port to slotted line and detector to input port with other port terminated by matched termination. After setting a reference level without isolator or circulator in the set up as described in insertion loss measurement. Let same P_1 level is set.
(8) Record the reading of VSWR meter after inserting the isolator or circulator (let it be P_3).
(9) Compute isolation as $P_1 - P_3$ in db.
(10) The same experiment can be done for other ports of circulator.
(11) Repeat the same for other frequency.

OBSERVATIONS AND CALCULATIONS:-

Calculate VSWR, Insertion Loss and Isolation as per formulas given above.

RESULT:- Measured values are follows :

VSWR =

Insertion loss =

Isolation =

PRECAUTIONS :-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ :-

Q.1 What is an Isolator?
Q.2 What is Circulator?
Q.3 What is Insertion loss?
Q.4 What is Isolation?
Q.5 What is input VSWR of a circulator or isolator?
Q.6 What is Faraday rotation in Ferrites?
Q.7 If direction of travel of wave reverses, does the direction of polarization change?
Q.8 What is the function of resistive card in an isolator?
Q.9 How many ports a circulator can have?
Q.10 What are the applications of circulator?

ANSWERS :-

Ans.1 It is a two port device which have low insertion loss in forward direction and very high insertion loss in the opposite direction.
Ans.2 It is a multi port junction that permits transmission in certain ways. For example a wave incident at port 1 is coupled to port 2 only, wave incident at port 2 is coupled to port 3 only and so on.
Ans.3 It is the ratio power supplied by a source to the input port to the power detected at the output port.
Ans.4 It is the ratio of power fed to input arm to the power detected at the not coupled port, with other ports terminated in to matched loads.
Ans.5 It is the ratio of voltage max. to voltage min. of the standing wave existing on line and others have matched terminations.
Ans.6 When a linearly polarized wave along X-axis is made to travel through ferrite in the Z – direction, the plane of polarization of this wave will rotate with distance. This phenomenon is known as Faraday rotation.
Ans.7 No, the wave continues to rotate in the same direction even if the direction of travel of wave reverses.
Ans.8 Resistive card does not absorb any energy from the wave whose plane of polarization is perpendicular to its own plane and allows the wave to pass.
Ans.9 There is no restriction about number of ports. However, normally a circulator has four ports.
Ans.10 It can be used as a duplexer in radar antenna system

EXPERIMENT NO. 6

AIM :- To measure the standing wave ratio and reflection coefficient in a Microwave Transmission line.

APPARATUS REQUIRED: - Klystron tube, Klystron power supply, Klystron mount, Isolator, Frequency Meter, Slotted section, Tunable Probe, Variable Attenuator, Wave guide stand, VSWR meter, Movable short, Matched Termination, S-S Tuner, Cables and accessories.

THEORY :- The electromagnetic field at any point of termination line may be considered as the sum of two traveling wave, the 'incident wave' propagates from generator and reflected wave propagates towards the generator. The reflected wave is setup by reflection of incident wave from a discontinuity on the line or from load impedance. The presence of two traveling waves, gives rise to standing wave along the line. The maximum field strength is found where two waves are in phase and minimum where the two waves adds in opposite phase. The distance between two successive minimum (or maximum) is half the guide wavelength on the line. The ratio of electric field strength of reflected and incident wave is called reflection coefficient. The voltage standing wave ratio is defined as ratio between maximum or minimum field strength along the line.

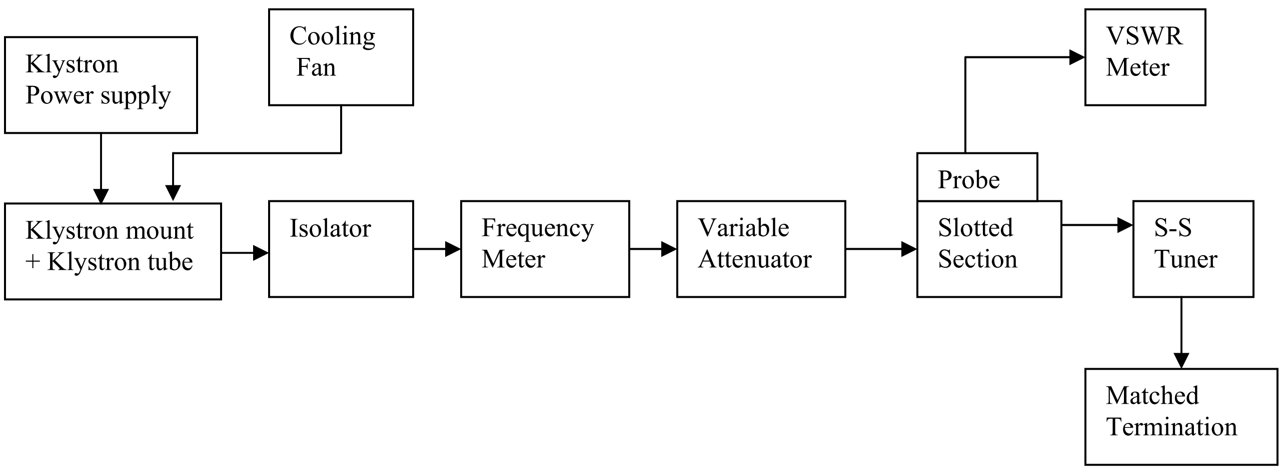
Hence, VSWR, $S = E_{max.} / E_{min}$

Reflection Coefficient, $\rho = E_r / E_i = (Z - Z_o)/(Z + Z_o)$

Where Z is the impedance at a point on line, Z_o is characteristic impedance.
The above equation gives following equation:

$$|\rho| = \frac{S-1}{S+1}$$

BLOCK DIAGRAM: -



P ROCEDURE :-

(1) Set the components and equipments as shown in block diagram.
(2) Keep variable attenuator at maximum position.
(3) Keep the control knobs of Klystron Power Supply as below:

Meter Switch	-	'OFF'
Mod Switch	-	AM
Beam voltage knob	-	Fully anti-clockwise
Reflector voltage	-	Fully clockwise
AM- amplitude and frequency knob	-	Mid position.

(4) Keep the control knob of VSWR meter as below:

Meter Switch	-	Normal
Input Switch	-	Low Impedance
Range db Switch	-	40 / 50 db
Gain Control knob	-	Mid position

(5) 'ON' the Klystron Power Supply, VSWR meter and Cooling Fan
(6) Turn the meter switch of power supply to beam voltage position and set beam voltage at 300V with the help of beam voltage knob.
(7) Adjust the reflector voltage 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, reflector voltage, and probe for maximum deflection in VSWR meter.
(10) If necessary, change the range db-switch, variable attenuator position and gain control knob to get deflection in the scale of VSWR meter.
(11) Move the probe along the slotted line, the deflection will change.

MEASUREMENT OF LOW AND MEDIUM VSWR

(1) Move the probe along with slotted line to get max. deflection in VSWR meter.
(2) Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates 1 on normal SWR scale.
(3) Keep all the control knob as it is, move probe to next minimum position and read the VSWR on scale and record it.
(4) Repeat the above step for change of S-S Tuner probe depth and record the corresponding SWR.

OBSERVATION AND CALCULATIONS :-

Calculate SWR and Reflection coefficient using

$E_{max.}=$

$E_{min.}=$

VSWR, $S = E_{max.} / E_{min}$

$$|\rho| = \frac{S-1}{S+1}$$

RESULT :- Standing wave ratio and Reflection coefficient are measured & equal to

SWR =

ρ =

PRECAUTIONS :-

5. Use fan to keep the Klystron temperature low.
6. Ensure tight connections of the apparatus
7. Avoid cross connections of the threads.
8. Use stabilized power supply.

QUIZ :-

Q.1 What is Standing Wave Ratio?
Q.2 What is reflection coefficient?
Q.3 What is VSWR meter?
Q.4 What are the important controls of a VSWR meter?
Q.5 What is Full Scale Deflection?
Q.6 The values of VSWR can vary between which two extreme values.
Q.7 What are the methods to achieve impedance matching?
Q.8 What is the role of variable attenuator in the test setup?
Q.9 How many scales are there on a VSWR?
Q.10 What is guide wavelength

ANSWER :-

Ans.1 Any mismatched load leads to reflected waves, resulting in to standing waves along the length of line. Ratio of max. to min. voltage gives VSWR.

Ans.2 Whenever EM energy enters unmatched load, full power is not transferred to load. A part of it is reflected back.

$$\text{Reflection Coefficient} = \frac{\text{Reflected power}}{\text{Incident power}}$$

Ans.3 It is a High gain, low noise voltage amplifier. It uses detected signal out of microwave detector, amplifies the same and displays it on a calibrated voltmeter.

Ans.4 Coarse and fine gain control, Scale selection switch, Input selector switch for different currents.

Ans.5 A signal which is causing certain deflection can be increased / decreased with the help of coarse / fine gain control or by increasing / decreasing attenuators, so as to give full scale deflection on the VSWR meter. This is called FSD.

Ans.6 It can vary from 1 to ∞.

Ans.7
- Resistance of load should be equal to resistance of source.
- Reactance of load should be equal and opposite to reactance of source.
- By using half wavelength & quarter wave length lines.
- Stub matching.

Ans.8 To increase / decrease the strength of the microwave signal reaching VSWR meter.

Ans.9 Three, namely Normal SWR, Expanded SWR and db scale.

Ans.10 It is the distance traveled by EM to undergo a phase difference of 2π radians. Also it is equal to twice the distance between two consecutive minimum points on VSWR.

EXPERIMENT NO. 7

AIM : - To measure the frequency of a microwave source and demonstrate relationship among guide dimensions ,free space wavelength and guide wavelength

APPARATUS REQUIRED :- Klystron tube, Klystron power supply, Klystron mount, Isolator, Frequency Meter, Slotted section, Tunable Probe, Variable Attenuator, Wave guide stand, VSWR meter, Movable Short / Matched Termination, Cables and accessories.

THEORY: - For dominant TE_{10} mode in rectangular wave guides λ_o, λ_g, and λ_c are related as below

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

Where,

λ_o = free space wavelength

λ_g = Guide wavelength

λ_c = Cut off wavelength

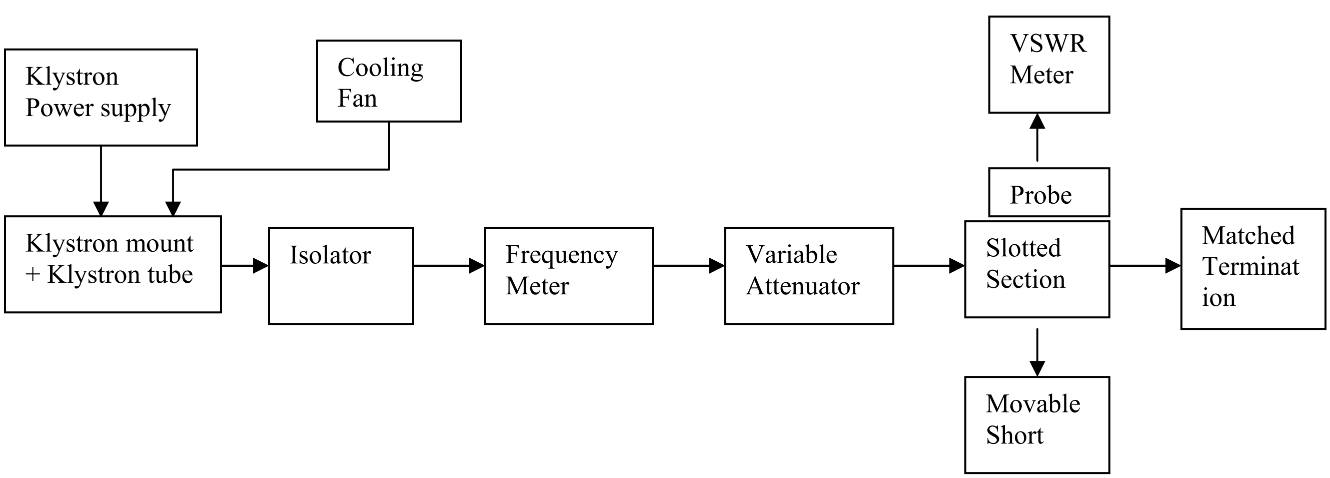
For dominant TE_{10} mode $\lambda_c = 2a$ where a is broad dimension of wave guide .

The following relationship can be proved.

$$C = f\lambda$$

Where, C is velocity of light and f is frequency.

BLOCK DIAGRAM: -



PROCEDURE: -

(1) Set the components and equipments as shown in block diagram.
(2) Initially set the variable attenuator for maximum position.
(3) Keep the control knobs of Klystron Power Supply as below:

Meter Switch	-	'OFF'
Mod Switch	-	AM
Beam voltage knob	-	Fully anti-clockwise
Reflector voltage	-	Fully clockwise
AM- amplitude knob	-	Around fully clockwise
AM- frequency knob	-	Around mid position.

(4) Keep the control knob of VSWR meter as below:

Meter Switch	-	Normal
Input Switch	-	Low Impedance
Range db Switch	-	50 db
Gain Control knob	-	Mid position

(5) 'ON' the Klystron Power Supply, VSWR meter and Cooling Fan
(6) Turn the meter switch of power supply to beam voltage position and set beam voltage at 300V with the help of beam voltage knob.
(7) Adjust the reflector voltage 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, reflector voltage, and probe for maximum deflection in VSWR meter.
(10) Tune the frequency meter knob to get the 'dip' on the VSWR scale and note down the frequency directly from frequency meter.
(11) Replace the termination with movable short, and detune the frequency meter.
(12) Move probe along with the slotted line, the deflection in VSWR meter will vary. Move the probe to a minimum deflection position, to get accurate reading, it is necessary to increase the VSWR meter range db switch to higher position. Note and record the probe position.
(13) Move the probe to next minimum position and record the probe position again.
(14) Calculate the guide length wave as twice the distance between successive minimum positions obtained as above.
(15) Measure the wave guide inner broad dimension 'a' which will be around 22.86 mm for X- band.
(16) Calculate the frequency by following equation.

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

where $C = 3 \times 10^8$ m/s i.e. velocity of light.

(17) Verify with frequency obtained by frequency meter.

(18) Above experiment can be verified at different frequencies.

OBESERVATIONS AND CALCULATIONS :-

Calculate frequency using the equation

$\lambda_g = 2d$

d = first min. – second min.

$\lambda_C = 2a$

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

RESULT :- Measured frequency f =

PRECAUTIONS :-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ :-

Q.1 What is wavelength?
Q.2 What is guide wavelength ‘λ_g’?
Q.3 What is cut off wavelength for a wave-guide?
Q.4 What is the relationship between frequency and velocity of light?
Q.5 Name various methods that can be used to measure frequency / wavelength.
Q.6 What is wave meter?
Q.7 For TE_{10} mode why $\lambda_c = 2a$
Q8 What is down frequency conversion method of measuring frequency.
Q.9 In a wave meter ‘dip’ indicates what?
Q10. In a wave meter, how resonant frequency can be changed.

ANSWERS :-

Ans.1 Amount of distance travelled by electromagnetic wave in one cycle is known as wave length .
Ans.2 Distance traveled by an EM wave to undergo a phase difference of 2π radians is called guide wave length.
Ans.3 Maximum wave length that can travel in a wave guide is called cut off wavelength.
Ans.4 $C = f \cdot \lambda$
Ans.5
- Wave meter
- Frequency down conversion method
- 2d method
- Double minimum method

Ans. 6 It is a cylindrical cavity resonator used to measure frequency.
Ans.7 $\lambda_c = 2ab / \sqrt{m^2 b^2 + n^2 a^2}$
$= 2ab / b = 2a.$
Ans. 8 With the help of local oscillator and mixer, the RF frequency is converted to low Frequency and then measured with conventional equipment.
Ans.9 It indicates that resonant frequency has been achieved and power transfer has taken place.
Ans.10 By changing the length of the cavity through movement of plunger.

EXPERIMENT NO. 8

AIM :- To measure the impedance of unknown load.

APPARATUS REQUIRED: - Klystron tube, Klystron power supply, Klystron mount, Isolator, Frequency Meter, Slotted section, Tunable Probe, Variable Attenuator, Wave guide stand, VSWR meter, Movable short, Matched Termination, unknown load, Cables and accessories.

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 SWR minimum, are characteristic properties of the load. Determining these, load can be determined.

The input impedance of a transmission line is given by

$$Zm = \frac{Vs}{Is} = \frac{Vg \cosh \gamma l + Z0\, Ig \sinh \gamma l}{Ig \cosh \gamma l + Vg/Zo \sinh \gamma l}$$

For lossless line $\gamma = \alpha + j\beta$ ($\alpha = 0$) of Λl length

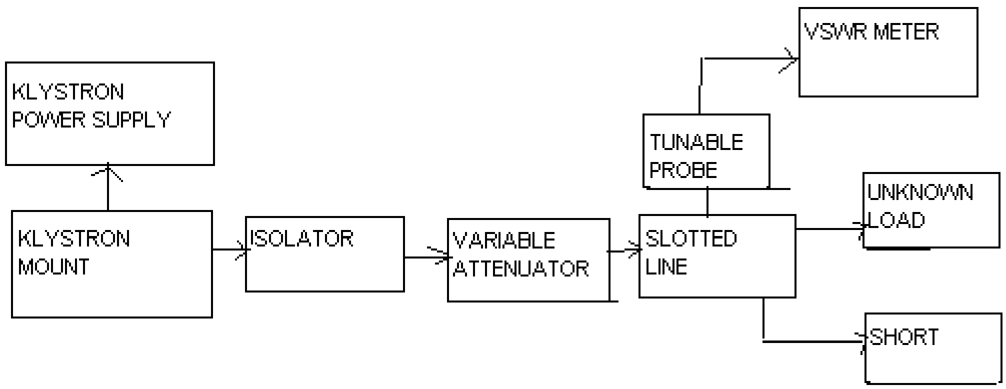
$$\text{So } Zm = \frac{Z0\,[Zg + jZ0 \tan \beta\Lambda l]}{[Z0 + jZg \tan \beta \Lambda l]}$$

where Zg is, the impedance at the receiving end, Z0 is the characteristics impedance and Zm is the impedance at the input of the transmission line. $\beta \Lambda l$, being the electrical distance , is measured between position of termination and standing wave minimum.

$$\text{So } Zg = \frac{Z0\,[Zin - jZ0 \tan \beta\Lambda l]}{[Z0 - jZin \tan \beta \Lambda l]}$$

$$= \frac{Z0\,[1 - j\rho \tan \beta\Lambda l]}{[\rho - j \tan \beta \Lambda l]}$$

Experimental setup



Procedure

1. Set the components and equipments 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
Beam voltage knob	Full anti clockwise
Reflector voltage knob	Full 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 at 300 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,(this is the position of reference minimum) and next successive minimum position as X2.
10. Replace load by short circuit termination and move the probe carriage to new standing wave minimum and 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 Xs·X.). 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 from the standing wave patterns given below.
12. Convert the shift in wavelength units, i.e., (X,X,). Wavelengths.
13. Position on minimum can be known more accurately if it is taken as midpoint of positions of equal responses on either side of minimum.

-

OBSERVATIONS AND CACULATIONS:

PRECAUTIONS :-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ:

Q1. For an open-ended rectangular waveguide antenna of size 0.9" *0.4” excited in the TE_{IO} (dominant)-mode at λ..=3 cm, the gain is nearly

(a) 1.5 *(b) 2.5*

(e) 26.5 *(d) 36.5*

Q2. Consider the following statements regarding feed which is a key component of a reflector antenna as it has a decisive bearing on the overall performance:

(a)For a horn-food antenna, the reflector focus must coincide with horn-feed's phase centre, which for a wide-flare horn lies in the plane of the horn aperture.

(b) The feed must have minimal radiation outside the angular aperture of the reflector.

(c) In prime focus of Cassegrain systems, the main or sub reflector should be in Fraunhofer zone of the feel antennas.

Of these statements

(a) 1, 2 and 3 are correct (b) 1 and 2 correct

(c) 2 and 3 correct (d) 1 and 3 correct

Q3. On a slotted line terminated in a load, the minima of the standing wave pattern measured by a square-law device, are located at (on a cm scale) 9.5, 11.0, 12.5 and 14.0. At 10.95 and 11.05 the detected levels being twice the minimum level. The VSWR on the line is

a) 10 b) 20

c) 30 d) 50

Q4. A calorimetric measurement for average power of a signal gave a value of *400* W. The value was interpreted for peak power as 0.5 MW. Then the duty cycle of the signal is

(a) 0.08 per cent (b) 8 percent

(c) 40 percent (d) 80 percent

Q5.In microwave power measurements using bolometer, the principle of working is the variation of

(a) inductance with absorption of power

(b) resistance with absorption of power

(c) capacitance with absorption of power

(d) cavity dimensions with heat generated by the power

Q6.In wave meter the pointer is

a)oscillator b)Rotary

c)Stationary d) None

Q7.Tunnable probe exist over /in

a)VSWR meter b)Slotted section

c)Attenuator d)None

Q8.The method used to measure high VSWR is

a) Slotted line method b)Double minimum Method

c)Both d)None

Q9: In low VSWR method, in VSWR meter the pattern maximum is set to

a)One b)Zero

c) Both d)None

Q10: While measuring guided wave length the termination of the bench must be

a)Short b)Match

c) Open d) None

ANSWERS:

Q1: b
Q2: d
Q3: c
Q4: d
Q5: b
Q6: b
Q7: b
Q8: b
Q9: a
Q10: a

EXPERIMENT NO. 9

AIM :-To Study working of Doppler Radar , and measure the of the velocity of the object moving in the Radar range

APPARATUS REQUIRED: A tripod stand, NV2001 trainer kit, SMPS supply, Trans-receiver P.C

THEORY:- A simple Doppler Radar sends out continuous sine waves rather than pulses. It uses the Doppler Effect to detect the frequency change caused by a moving target and displays this as a relative velocity. When the target is moving relative to Radar, an apparent shift in the carrier frequency of the received signal will result. This effect is called the Doppler Effect and it is the basis of continuous wave (CW) Radar.

The Doppler frequency is given by

$$F_d = \frac{2V_r}{\lambda} Hz$$

Or

$$F_d = \frac{2V_r\ F_t}{C} Hz$$

Where

Fd = Doppler frequency

Ft = transmission frequency.

Vr = Relative velocity of target with respect to Radar.

λ= Wavelength of transmitted wave.

C = Velocity of light.

The transmitter generates a continuous oscillation of frequency Fo that is radiated by the antenna. The target intercepts a portion of this radiated energy and the receiving antenna collects the reradiated energy. If the target is in motion with a velocity (Vr) relative to the Radar, the received signal will be shifted in frequency from the transmitted frequency Fo by an amount Fd. The plus sign for an approaching target and minus for a receding target. The received echo signal (Fo ± Fd) enters the Radar via the antenna and is mixed in a detector mixer with a portion of the transmitter signal 'Fo' to produce the Doppler frequency Fd. The purpose of using a amplifier is to eliminate the echo from stationary targets and to amplify the Doppler echo signal to a level where it can operate an indicating
device such as a frequency counter. Frequency from the transmitted frequency Fo by an amount Fd. The plus sign for an approaching target and minus for a receding target. The received echo signal

(Fo ± Fd) enters the Radar via the antenna and is mixed in a detector mixer with a portion of the transmitter signal 'Fo' to produce the Doppler frequency Fd

Experimental set up

Procedure:-

1. Fit the Trans-receiver unit on the tripod stand and adjust the suitable height for experiment.
2. Connect the SMPS supply to the trainer NV2001.
3. Connect the din connector cable from trainer board (left side of trainer) to Trans-receiver unit
4. Firstly Switch 'On' the SMPS supply and then "Power" switch on the trainer board.
5. Switch 'On' the buzzer on trainer board and set "Level" Potentiometer in fully clockwise direction.
6. Connect a CRO probe on test point of "Doppler Frequency Signal" (fd) and wave your hand or reflected in front of antenna.

7.For maximum gain detection adjust the "Detection Adjust" potentiometer in such a way that moving object in front of antenna can be detected with beep sound and also observe the signals on the Oscilloscope/DSO.

8. If any noise is observe on CRO then adjust the "Level" Potentiometer to reduce the noise.

9. Procedure for using Software

   a) Install the software and open it.

   b) Connect the audio cable from EP socket (left side of trainer) to line In/MIC in input (sound card input) of PC.

   c) Select "Start Acquisition" on the software window.

   d) If any noise is occur on software window then again adjust the "Level" potentiometer to reduce the noise.

   e) Now we can observe the waveform on PC. For measurements we have to select "Stop Acquisition" and then we can measure the frequency and time by selecting "Doppler frequency calculation".

b)Determination of the velocity of the object moving in the Radar range

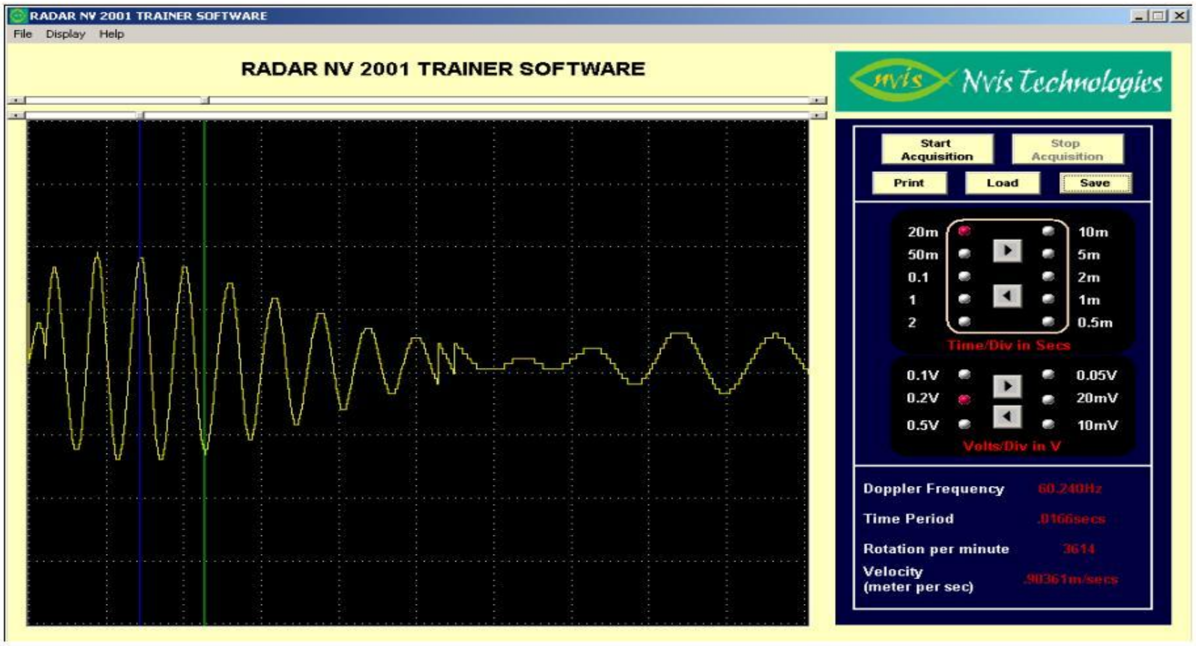
Procedure:

1. Follow the procedure as given in above from step 1 to 8
2. Connect the audio cable from EP socket (left side of trainer) to line In/MIC in input (sound card input) of PC.
3. Select "Start Acquisition" on the software window.
4. If any noise is occur on software window then again adjust the "Level" potentiometer to reduce the noise.
5. Keep the Sliding Platform for moving the object in front of Radar antenna.
6. Connect the metallic object on the sliding platform.

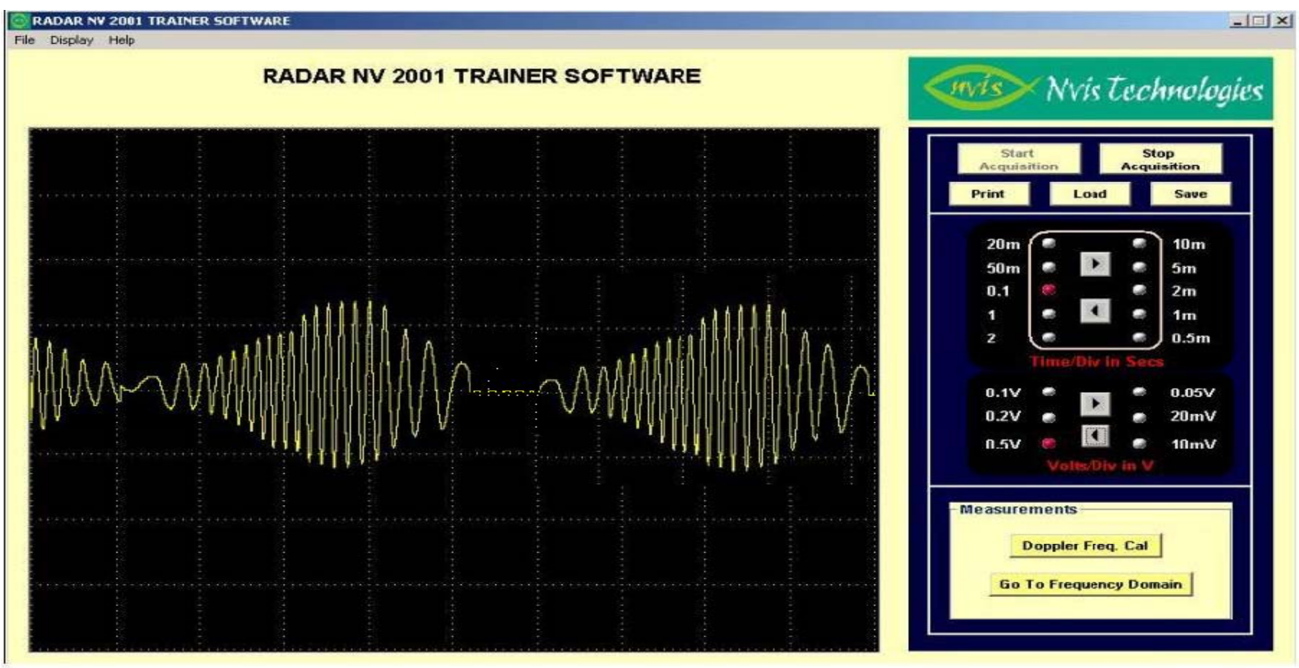
7 When object is moved slowly from right to left or left to right corresponding Doppler frequency can be observed and measured on test point '

8. Once the Doppler frequency is measured, velocity of object can be found out very easily.
9. Repeat the experiment by moving the object fast
10. Observe the change in Doppler frequency and the velocity of object.

OBSERVATIONS



waveform in frequency and time domain is observed and calculated



Observe the change in Doppler frequency and the velocity of object.

QUIZ

Q1.In a radar system ,the term rat –race is used in connection with

a)Modulator b)Pulse Characteristics

c) Receiver band width d)Duplexer

Q2.The type of radar that is used to eliminate clutter in navigational applications is

a) Pulse Radar b) Tracking Radar

c) MTI Radar d) Monopulse Radar

Q3.In microwave radar, pulse repetition frequency is used to resolve range and Doppler ambiguities using

a) CW Radar b) Pulsed Radar

c) Moving Target indicator d) Pulse –Doppler radar

Q4.A duplexer is used in a radar system to

1.protect the receiver when high power signal is transmitted

2. enable the use of a common antenna for transmission and reception

3. Allow antenna to only receive when the signal is arriving

4. Avoid noise interference in the radar system. Of these statements

a)1 and 2 are correct b) 3and 4 are correct

c)1 and 4 are correct d) 2 and 4 are correct

Q5.If the antenna diameter in a radar system is increased by factor of 9 , then the maximum range will increase by a factor of

a)$\sqrt{3}$ b) 3

c) 9 d) 81

Q6.The main component atmosphere for absorption of EM waves are

a)nitrogen oxygen b)Nitrogen and hydrogen

c) Oxygen and water vapor c) nitrogen and water vapor

Q7.If the minimum range is doubled in Radar ,the peak power has to be increased by a factor of

a) Two b)Four

c)Eight d) sixteen

Q8.Radiation for helical antenna is

a)Plane polarized b)Partially plane polarized

c)Circular polarized d)Elliptically polarized

Q9. The usable bandwidth of a microwave beacon transponder for 6/4 GHz Satellite communication is generally

a)360 MHz b)40MHz

c) 36 MHz d)1MHz

Q10.Radar where a single antenna is used for both transmitting and receiving is called

a) Monostatic Radar b)Bistatic Radar

b) Doppler Radar d)Pulsed Radar

A1.d

A2.c

A3.c

A4 .a

A5.c

A6.c

A7.d

A8.c

A9. c

A10.a

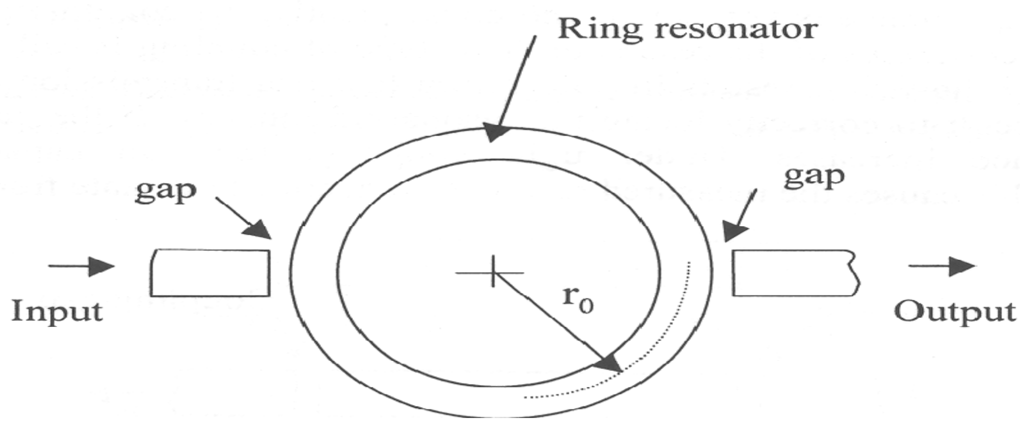
EXPERIMENT NO. 10

AIM : Measurement of the resonance characteristics of a micro strip ring resonator

APPARATUS REQUIRED:- Microwave signal source (2.2 GHz) with modulation (1 KHz) Attenuator pad, VSWR meter, Micro strip ring resonator (DUT), Directional coupler, Detector, Matched load Cables and adapters

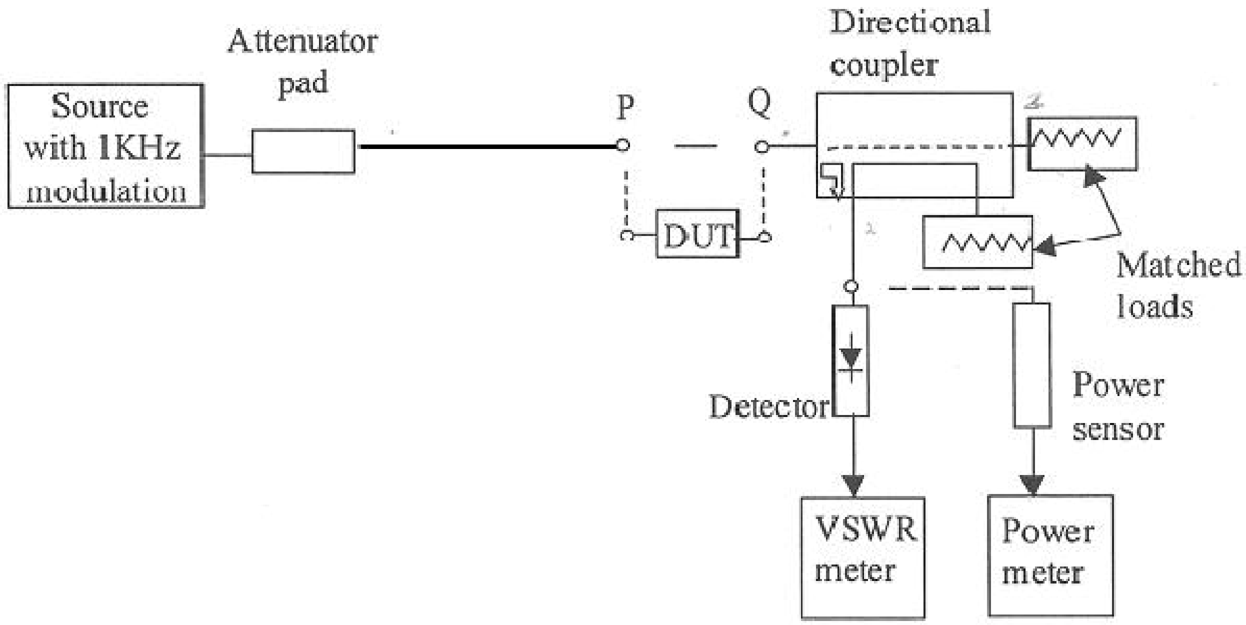
THEORY:-

The open-end effect encountered in a rectangular resonator at the feeding gaps can be minimized by forming the resonator as a closed loop. Such a resonator is called a ring resonator. The layout of a ring resonator along with the input and output feed lines. The coupling can be loose or tight depending on the gap width. Resonance is established when the mean circumference of the ring is equal to integral multiples of guide wavelength.



$$2\pi r_0 = n\lambda = \frac{n v_0}{f_0\sqrt{\varepsilon_{ef}}},\qquad \text{For } n = 1, 2, 3$$

EXPERIMENT SET UP



PROCEDURE :-

1. Assemble the set up as shown in above figure.
2. First connect P to Q directly.
3. Switch 'On' the source and the VSWR meter. (Before switching 'On' the source, ensure that there is sufficient attenuation to keep the RF output low)
4. Set the frequency of the source to 2.2 GHz. Adjust the power output of the source for a reasonable power indication on the VSWR meter. Note the reading of the VSWR meter. Increase the frequency of the source in steps of 0.1 GHz to 3 GHz and note the corresponding readings of the VSWR meter.
5. Now insert micro strip line ring resonator between P and Q.
6. Tabulate the results as per Table given below at frequencies from 2.2 to 3 GHz in steps of 0.1GHz.
7. Plot the transmission loss in dB as a function of frequency.
8. Identify a smaller frequency span of about 200 MHz around the minimum transmission loss. In this frequency range, repeat the measurements in smaller frequency steps (steps of 20 MHz) and locate the frequency at which the transmission loss reaches a minimum.

OBSERVATIONS :-

Frequency F (GHz)	VSWR meter reading without ring resonator Pin(dB)	VSWR meter reading without ring resonator Pout(dB)	Transmission Loss S21(dB)
2.2 - - 3.0			

RESULT:-

The transmission loss response of the ring resonator is measured

PRECAUTION:-

1. Before switching 'On' the source set the RF attenuation to maximum so that the detector (or the sensor) does not receive the maximum power directly.

2. When using the VSWR meter, the 1 KHz modulation on the source must be 'On' and the frequency of modulation (1 KHz) must be adjusted precisely to maximize the output on the VSWR meter.

3. Power meter with sensor can be used in place of VSWR meter with detector. Modulation of the source is not required when using the power meter. In this case, it is important to ensure that the power applied to the sensor does not exceed the maximum rated power of the sensor.

.

QUIZ

Q1.What is does MIC stand for?
Q2.Name the different transmission system utilized in MIC ?
Q3 What are the different categories of basic materials for MMICs.
Q4.Write the equation for the phase velocity of microwave strip line?
Q5.What are the ideal characteristics of substrate used for the fabrication of MMIC's?
Q6. Name the elements that can be used as conductor in MMIC's?
Q7.What are the desirable properties of Dielectric material?
Q8. What are the desirable properties of Resistive material?
Q9.Which element is used as a resistive materials for the fabrication MMIC's
Q10.What is the Disadvantage of MIC's

Ans 1: Microwave integrated circuits
Ans2: Micro strip line, lumped element circuits, thin film circuits
Ans3: Substrate material, conductor material, Dielectric films, resistive films
Ans 4: $V_0/\sqrt{\in ef}$
Ans 5: high dielectric constant, low dissipation factor ,high purity ,surface smoothness.
Ans 6:Alumima, copper ,gold silver
Ans 7: Good reproductively, ability to undergo processes without developing pin holes, low RF dielectric losses, ability to with stand voltage
Ans 8: good stability, low temperature coefficient of resistance
Ans9: Cr,Cr-Sio,NiCr ,Ta and Ti
Ans10:MIC's have lower power handling capability

EXPERIMENT NO. 11

AIM :-To study Magnetrons.

CONSTRUCTION & BASIC OPERATION :-

Basic Magnetron Structure

The nucleus of the high-voltage system is the **magnetron tube**. The magnetron is a diode-type electron tube which is used to produce the required 2450 MHz of microwave energy. A magnetic field imposed on the space between the anode (plate) and the cathode serves as the grid. While the external configurations of different magnetrons will vary, the basic internal structures are the same.

The **ANODE** is a hollow cylinder of iron from which an even number of anode vanes extends inward. The open trapezoidal shaped areas between each of the vanes are resonant cavities that serve as tuned circuits and determine the output frequency of the tube. The anode operates in such a way that alternate segments must be connected, or strapped, so that each segment is opposite in polarity to the segment on either side. In effect, the cavities are connected in parallel with regard to the output.

The **FILAMENT**, which also serves as the **cathode** of the tube, is located in the center of the magnetron, and is supported by the large and rigid filament leads.

The **ANTENNA** is a probe or loop that is connected to the anode and extends into one of the tuned cavities. The antenna is coupled to the waveguide , a hollow metal enclosure, into which the antenna transmits the RF energy.

The **MAGNETIC FIELD** is provided by strong permanent magnets, which are mounted around the magnetron so that the magnetic field is parallel with the axis of the cathode.

Basic Magnetron Operation

The theory of magnetron operation is based on the motion of electrons under the combined influence of electric and magnetic fields. For the tube to operate, electrons must flow from the cathode to the anode. There are two fundamental laws that govern their trajectory:

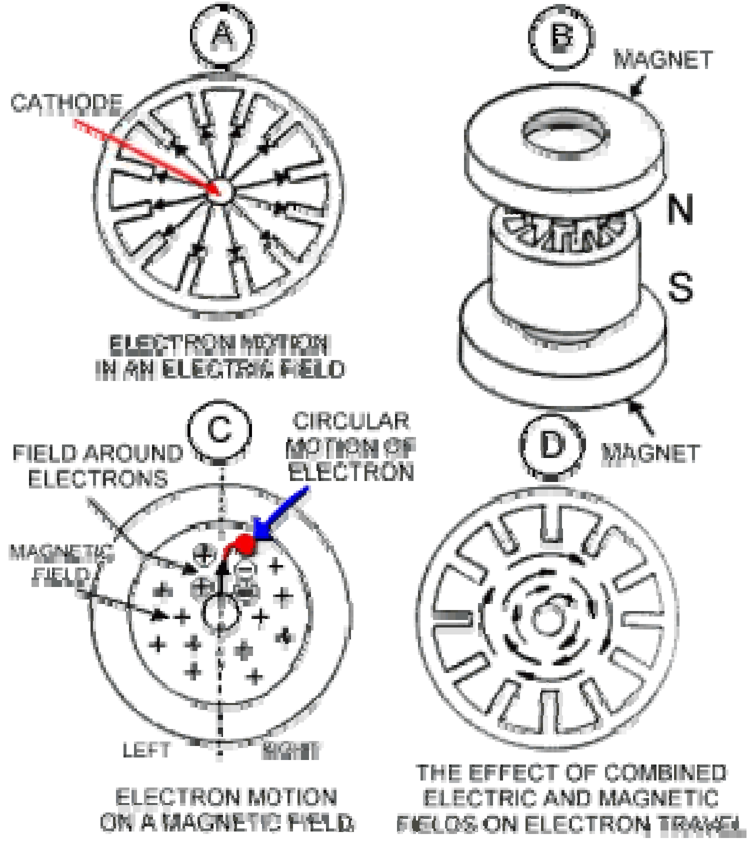


Figure 3 Electron motion in a magnetron tube
(Courtesy of Michael S. Wagner)

1. The force exerted by an electric field on an electron is proportional to the strength of the field. Electrons tend to move from a point of negative potential toward a positive potential. **Figure 3-A** shows the uniform and direct movement of the electrons in an electric field.
2. The force exerted on an electron in a magnetic field is at right angles to both the field itself, and to the path of the electron. The direction of the force is such that the electron proceeds to the anode in a curve rather than a direct path.

Effect of the Magnetic Field

In **Figure 3-B** two permanent magnets are added above and below the tube structure. In **Figure 3-C,** assume the upper magnet is a north pole and the lower is south pole, is located underneath the page, so that the magnetic field appears to be coming right through the page. Just as electrons flowing through a conductor cause a magnetic field to build up around that conductor, so an electron moving through space tends to build up a magnetic field around itself. On one side (left) of the electron's path, this self induced magnetic field adds to the permanent magnetic field surrounding it. On the other side (right) of its path, it has the opposite effect of subtracting from the permanent magnetic field. The magnetic field on the right side is therefore weakened, and the electron's trajectory bends in that direction, resulting in a circular motion of travel to the anode.

The process begins with a low voltage being applied to the filament, which causes it to heat up (filament voltage is usually 3 to 4 VAC, depending on the make and model). Remember, in a magnetron tube, the filament is also the cathode. The temperature rise causes increased molecular activity within the cathode, to the extent that it begins to "boil off" or emit electrons. Electrons leaving the surface of a heated filament wire might be compared to molecules that leave the surface of boiling water in the form of steam. Unlike steam, though, the electrons do not evaporate. They float, or hover, just off the surface of the cathode, waiting for some momentum.

QUIZ:-

Q.1 What is a magnetron?
Q.2 How many types of magnetron are there?
Q.3 What is negative resistance type magnetrons?
Q.4 What is cyclotron frequency magnetron?
Q.5 What is cavity magnetron?
Q.6 What is 'π' mode?
Q.7 What is mode jumping?
Q.8 What is strapping?
Q.9 What is frequency pushing of magnetron?
Q.10 What is pulling?

ANSWERS :-

Ans.1 It is a diode of cylindrical configuration, with a thick cylindrical cathode and co- axial cylindrical copper block as anode. The space between cathode & anode is used for interaction between electrons and electro magnetic field. It is an oscillator which gives output at RF frequencies and at high power.
Ans.2 Negative Resistance type, Cyclotron frequency type and Cavity type.
Ans.3 It makes use of negative resistance between two anode sections but have low efficiency.
Ans.4 It depend upon synchronism between an alternating component of electric and periodic oscillations of electrons in a direction parallel to this field.
Ans.5 It depends upon the interaction of electrons with a rotating electromagnetic field of constant angular velocity. This provides oscillations of very high peak power.
Ans.6 If relative phase shift of the AC electric field across adjacent cavities is 'π' radians, It called 'π'mode.
Ans.7 Resonant mode of magnetrons are very close to each other. There is always a possibility of mode jumping i.e. there shall be change in frequency. Mode jumping must be avoided.
Ans.8 Connection of alternate anode plates with two conducting rings of heavy gang, is called strapping. It helps in achieving dominant-mode.
Ans.9 Process of changing resonance frequency of magnetron, by changing the anode voltage, is called pushing.
Ans.10 Change in frequency of magnetron due to change in load impedance is called frequency pulling.

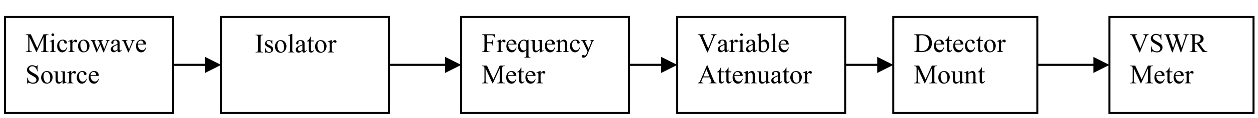
EXPERIMENT NO:12

AIM :- To study the Characteristics of Reflex Klystron tube & to determine its electronic tuning range.

APPARATUS REQUIRED :- Klystron tube, Klystron power supply, Klystron mount, Isolator, Frequency Meter, Variable Attenuator, Detector mount, Wave guide stand, Cooling fan, VSWR meter, Cables and accessories.

THEORY :- The reflex Klystron makes use of velocity modulation to transform a continuous electron beam in to microwave power. Electron Beam emitted is accelerated towards the anode cavity. After passing the gap in the cavity electron travel towards the repeller electrode which is at a high negative potential (V_r). The electron beam never reach the repeller because of the negative field and returned back towards the gap. The accelerated electrons leave the resonator at an increased velocity and the retarded electrons leave at the reduced velocity. the electrons leaving the resonator will need different time to return, due to change in velocities. as a result, returning electrons group together in bunches. As the electron bunches pass through resonator, they interact with voltage at resonator grids. If the bunches pass the grid at such time that the electrons are slowed down by the voltage, energy will be delivered to the resonator; and klystron will oscillate. The dimension of resonant cavity primarily determines the frequency. A small frequency change can be obtained by adjusting the reflector voltage. This is called Electronic Tuning Range.

BLOCK DIAGRAM:-



PROCEDURE: -MODE STUDY OF A KLYSTRON TUBE :-

(1) Set the equipment as shown in fig.
(2) Initially set the variable attenuator for maximum position.
(3) Keep the control knobs of Klystron Power Supply as below:

Meter Switch	-	'OFF'
Mod Switch	-	AM
Beam voltage knob	-	Fully anti-clockwise

Reflector voltage - Fully anti-clockwise
AM- amplitude - Around fully clockwise
AM- frequency - Around mid position.

(4) Keep the control knob of VSWR meter as below:
Meter Switch - Normal
Input Switch - Low Impedance
Range db Switch - 40 db
Gain Control knob - Mid position

(5) Switch 'ON' the Klystron Power Supply, VSWR meter and Cooling Fan.

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

(7) Adjust the reflector voltage 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 the max. Output.

(10) Rotate the knob of frequency meter slowly and stop at that position, when there is 'dip' on VSWR meter. Read directly the frequency meter between two horizontal lines and vertical marker.

(11) Change the reflector voltage and read the frequency for each reflector voltage and plot the graph .

OBSERVATIONS :-

S.NO	Repeller voltage	Frequency

RESULT:- Frequency and Repeller voltage curve is drawn and is in accordance with the stipulated curves of Klystron.

PRECAUTIONS :-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUESTIONS :-

Q.1 How many cavity Reflex Klystron does have?
Q.2 On which principle Klystron tube operates?
Q.3 What are the applications of reflex klystron.
Q.4 On what principle multi cavity klystron Amplifier Works?
Q.5 What are different modes in a reflex Klystron?
Q.6 The Secondary cavity in a two-cavity klystron is called?
Q.7 What is the efficiency of Reflex Klystron?
Q.8 The single cavity in Reflex Klystron is acts as?
Q.9 What should be the transit time?
Q.10 Why negative voltage is given to the Repeller?

ANSWERS :-

Ans.1 Only one
Ans.2 Velocity Modulation.
Ans.3 As a Oscillator, Microwave generator.
Ans.4 Velocity modulation and Current modulation.
Ans.5 They give same frequency but different transit time.
Ans.6 Catcher cavity.
Ans.7 20% - 30%.
Ans.8 Both buncher and catcher cavity.
Ans.9 $T = n + 3/4$
Ans.10 The electron beam should never reach the repeller because of the negative field and returned back towards the gap.

EXPERIMENT NO. 13

AIM : - To measure the gain of a waveguide horn antenna.

APPARATUS REQUIRED :- Microwave source, Frequency meter, Isolator, Variable attenuator, Detector mount, Two horn antenna, Turn table, VSWR meter and Accessories.

THEORY: - If a transmission line propagating energy is left open at one end, there will be radiation from this end. In case of a rectangular waveguide this antenna presents a mismatch of about 2 : 1 and it radiates in many directions. The match will improve if the open waveguide is a horn shape.

The radiation pattern of an antenna is a diagram of field strength or more often the power intensity as a function of the aspect angle at a constant distance from the radiating antenna. The power intensity at the maximum of the main lobe compared to the power intensity achieved from an imaginary Omni directional antenna (radiating equally in all direction) with the same power fed to the antenna is defined as in gain of the antenna.

3 db Beam Width

The angle between the two points on a main lobe where the power intensity is half the maximum power intensity.

When measuring an antenna pattern, it is normally most interesting to plot the pattern far from the antenna.

Far field pattern is achieved at a minimum distance of

$$\frac{2D^2}{\lambda_0} \quad \text{(for rectangular Horn Antenna)}$$

where D is size of the broad wall of horn aperture in free space wave length.

It is also very important to avoid disturbing reflection. Antenna measurement are normally made at outdoor rangers or in so called anechoic chambers made of absorbing materials. Antenna measurements are mostly made with unknown antenna as receiver. There are several methods to measure the gain of antenna. One method is to compare the unknown antenna with a standard gain antenna with known gain. An another method is to use two identical antennas, as transmitter and other as receiver from following formula the gain can be calculated.

$$P_r = \frac{P_t \lambda_0 G_1 G_2}{(4 \pi S)^2}$$

Where, P_t = transmitted power
P_r = received power
G_1 , G_2 = gain of transmitting and receiving antenna,
S = radial distance between two antenna
λ_0 = free space wave length.

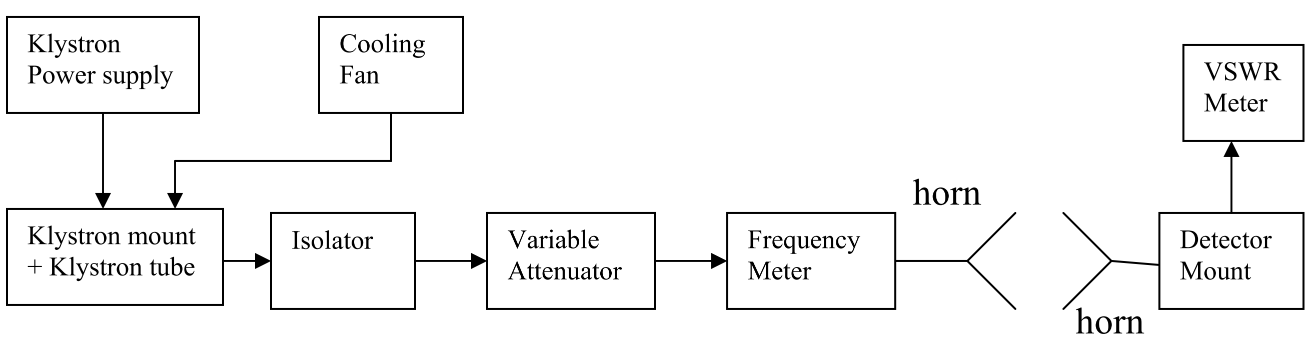
If both transmitting and receiving antenna are identical having gain G, then

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

$$G = \frac{4 \pi S}{\lambda} \sqrt{P_r / P_t}$$

In the above equation P_t , P_r , S and λ_0 can be measured and gain can be computed. As from the above equation it is not necessary to know the absolute value of P_t and P_r only ratio is required, which can be measured by VSWR meters.

BLOCK DIGRAM:



PROCEDURE: -

GAIN MEASUREMENT

1. Set up the equipments as shown in Fig. Both horns should be in line.
2. Keep the range db switch of VSWR meter at 50 db position with gain control full.
3. Energize the Gunn Oscillator for maximum output at desired frequency with modulating amplitude and frequency of Gunn Power Supply and by tuning of detector.

4. Obtain full scale deflection in VSWR meter with variable attenuator.
5. Replace the transmitting horn by detector mount and change the appropriate range db position to get the deflection on Scale (do not touch the gain control knob). Note and record the range db position and deflection of VSWR meter.
6. Calculate the difference in db between the power measured in step 4 and 5.
7. Convert G into db in above example

$$G\ db = 10 \log 318 = 15.02\ db$$

8. The same set up can be used for other frequency of operation.

OBSERVATIONS AND CALCULATIONS:

CONCLUSIONS AND RESULT:

PRECAUTIONS :-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ:

Q1. In satellite communication, highly directional antennas are used to
(a) direct the spot beam to a particular region of space on Earth
(b) strengthen the beam to overcome the cosmic noise
(c) make corrections in change of polarization of the beam
(d) select a particular channel in transmission and reception

Q2. Which one of the following is caused by reflection from stratified atmosphere from the surface or land conditions along the path?
(a) Multipath fading *(b)* Selective fading
(c) Fast fading *(d)* Reflection fading

Q3.The transit time (in cycles) for the electrons in the repeller- space of a reflex klystron oscillator for sustaining oscillations is (*n* is any integer including zero)
(a) $2(n - 1)$ *(b)* $2n - 1$

(c) $n+1/2$ *(d)* $n+3/4$

Q4. Which one of the following can be used for amplification of microwave energy ?
(a) Travelling wave tube *(b)* Magnetron
(c)· Ref1ex klystron *(d)* Gunn diode

Q5. In the case of a cubic cavity resonator, the degenerate modes would include
(a) TMlll, TEoll and TElOl
(b) TMllO, TEoll and TElll
(c) TMllO, TEo12 and TE102
(d) TMllO , TEoll and TElOl

Q6.In the bench the source is modulated by a frequency
a)1 KHz b)10KHz
c)100KHz d)None

Q7.Guide wave length does not depend upon
a)termination b)frequency
c)mode of wave d) none

Q8. Klystrons are modulated by square waves because
a) It is easy generative a square wave b) It prevents frequency modulation
c) Detector circuit is easy to design d) The termination is less complicated.

Q9.The main component atmosphere for absorption of EM waves are

a)nitrogen oxygen b)Nitrogen and hydrogen

c) Oxygen and water vapor c) nitrogen and water vapor

Q10.If the minimum range is doubled in Radar ,the peak power has to be increased by a factor of

b) Two b)Four

c)Eight d) sixteen

ANSWERS:

Q1:a
Q2: a
Q3: d
Q4: a
Q5: a
Q6 :a
Q7 :a
Q8 :a
Q9 :c
Q10:d

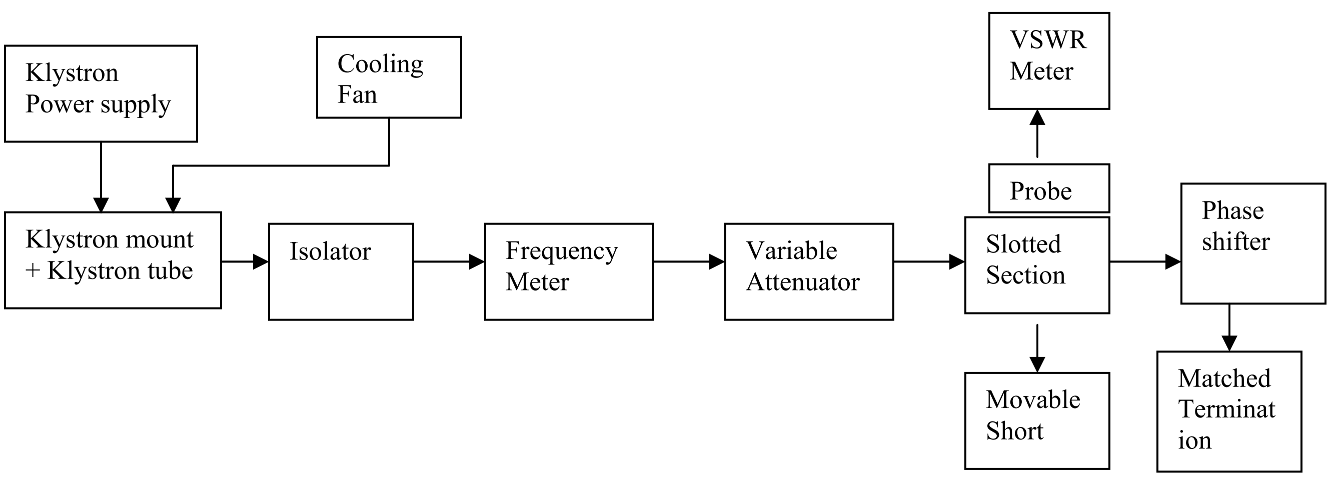
EXPERIMENT NO. 14

AIM : - To study the phase shifter.

APPARATUS REQUIRED :- Microwave source, Isolator, Variable attenuator, Frequency meter, Slotted line, Tunable probe, Phase shifter, Movable short, VSWR meter, Cables and Accessories.

THEORY: - A phase shifter consists of a piece of waveguide and a dielectric material inside the waveguide placed parallel to Electric vector of TElO mode. The phase changes, as a piece of dielectric material is moved from edge of waveguide towards the centre of the waveguide.

BLOCK DIAGRAM: -



PROCEDURE: -

1. Set up the equipment as shown in the Fig.
2. First movable short is placed at the end of slotted line.
3. Energize the microwave source for maximum output at particular frequency of operation.
4. Find out the λg with the help of tunable probe slotted line and VSWR meter. It is the twice the distance between two minima on the slotted line.
5. Find out the operating frequency for frequency meter or by relation of λg.
6. Find out λ as

$$\lambda = c/f \quad \text{or} \quad 1/\lambda^2 = 1/\lambda_g^{\,2} + 1/\lambda_c^{\,2}$$

7. Note and record a reference minima position on the slotted line. Let it is X.
8. Remove carefully the movable short from the slotted line without disturbing any position on the set up, place the phase shifter to the slotted line with its micrometer reading zero and then place the movable short to the other port of phase shifter.
9. Find out a new minima position let it is *Y*.
10. Change the position of micrometer of phase shifter and find out the corresponding position of new minima, let it is Yi.

CALCULATION :

Since new minima is multiple of half wave-length from the short, it should be possible to calculate the exact electrical length of phase shifter. For example suppose at 10 GHz a reference minima is found at X = 16.08 cm.
Now suppose that phase shifter is two wave-lengths long and placed on the line as in step 8, the new minima y = 14.90 cm is obtained.
Hence, short has apparently moved 16.08 - 14.90 = 1.18 cm. This can be written in form of as

$$\lambda\,(.393) = (1.18)\,\lambda/3$$

Since the apparent movement is in the direction the short actually moved, it is added to the approximate number of half wave length in the phase shifter. The total electrical length is 2.393 wave lengths. The phase shift in radians is found as below:
Multiply by 2π to give phase shift in radius or by 360^0 to give phase shift in degrees.
Phase shift in above example
$= 2\pi \times 2.393$ radians
$= 360 \times 2.393$ degrees
The phase shift for other micrometer reading position can be found as above.

RESULTS:

PRECAUTIONS :-

1. Use fan to keep the Klystron temperature low.
2. Ensure tight connections of the apparatus
3. Avoid cross connections of the threads.
4. Use stabilized power supply.

QUIZ:

Q1. In a hollow rectangular waveguide, the phase velocity
(a) increases with increasing frequency
(b) decreases with increasing frequency
(c) is independent of frequency
(d) will vary with frequency depending 'Upon the frequency range

Q2. A hollow cubic cavity resonator has a dominant resonant frequency of 10 GHz. The length of each side is

(a) √3 cm (b) √3/2
(c) √2 (d) 3/√2

Q3. In a rectangular waveguide, with *a* = *2b,* if the cut- off frequency for TE_{zo} mode is 16 GHz, then the cut-off frequency for the TM_{ll} mode will be
(a) 32 GHz *(b)* 8 GHz
(c) 4 √3 GHz *(d)* 8√5 GHz

Q4. Evanescent mode attenuation in a waveguide depends upon the
(a) conductivity of the dielectric filling the waveguide
(b) operating frequency
(c) conductivity of the guide walls
(d) standing waves in the guide

Q5. A transmitter in free space radiates a mean power *of 'P'* Watts uniformly in all directions. At a distance '*d'',* sufficiently far from the source, in order that the radiated field is considered as plane, the electric field *'E'* should be related to *'P'* and 'd'' as

(a) E ∞ Pd (b) E ∞ P/d
(c) E ∞ √Pd (d) E ∞ √P/d

Q6. A loss-less line having characteristic impedance Zo is terminated in a pure reactance of value -jZo. The VSWR of the line will be
(a) 10 (b) 2
(c) 1 (d) infinite

Q7. A cylindrical cavity resonator has a diameter of 16 mm. What is the dominant resonant mode when the cavity length is i) 20 mm and ii) 15mm

(i) (ii)
(a)TEll1 M111 (c) TEl1l TMolO
(i) (ii)
(b) TMolO TE111
(d) TM111 TEo

Q8. In a circular waveguide with radius *'r',* the dominant mode is
(a) TMol *(b)* TEol
(c) TMl1 *(d)* TEl1

Q9: The input impedance of a short circuited loss less line of length λ/8 is
a) Zero b)Resistive
c)Inductive d)Capacitive

Q10:Which of the following is capable giving highest data speed?
a)Coaxial cable link b)Microwave LOS link
c)Microwave satellite System d)Optical Fiber system

ANSWERS: Q1: b
Q2: a
Q3: d
Q4: a
Q5: d
Q6:d
Q7 :a
Q8:d
Q9 :c
Q10:d

EXPERIMENT NO. 15

AIM : - To determine the dielectric constant of a material.

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APPARATUS REQUIRED :- Klystron power supply, Klystron tube, Isolator, Frequency meter, Variable attenuator, Detector mount, Waveguide containing sample material.

THEORY: The most general description for electromagnetic purposes of a given homogeneous material is given by complex permittivity (Dielectric constant) together with complex magnetic permittivity.

By Maxwell's equation

$\nabla \times E = -\partial B/\partial t$, $\nabla \times H = \partial D/\partial t + \sigma E$, (1)

Since $B = \mu^* H$, $D = \varepsilon E$ (2)

where σ = conductivity of materials

$\nabla \times E = -j\omega\mu^* H$, $\nabla \times H = j\omega\varepsilon E + \sigma E$ ... (3)

where μ *= complex permeability

ε = (Real) Dielectric Constant

The equation (3) can be written

$XH = j\omega(\varepsilon - j\sigma/\omega)E$

where E" = $\varepsilon - j\sigma/\omega$ is complex dielectric constant.

The above equation can also be written as $\varepsilon = \varepsilon_o(\varepsilon' - j\varepsilon'')$

where $\varepsilon'' = \sigma/\omega\varepsilon$ and $\varepsilon' = \varepsilon/\varepsilon_0$

"

E , .

$\varepsilon_r = \varepsilon/\varepsilon_o = \varepsilon' - j\varepsilon''$

In the above terms ε " is called loss factor and ε ' associated with ability of material to store electric energy.

It is also useful to write the relative dielectric constant as

$\varepsilon_r = \varepsilon'(1 - j\tan\delta)$

where $\tan\delta = \varepsilon''/\varepsilon'$

The tan δ is referred as loss tangent.

The dielectric constant is not independent of frequency and stays constant only over small portion of frequency spectrum. In many cases E_r is effected by temperature and humidity. So that the above should be held reasonably constant during measurements.

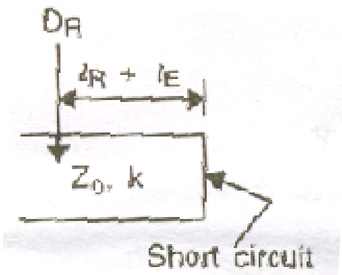
The accuracy of measurement largely depends on the smoothness of the sample, that fit of sample in waveguide and care which has been taken to insure that its surfaces are properly 'squared' w.r.t. each other. It is therefore, advisable to machine samples very carefully for smoothness, size, and squared surface.

Dielectric Measurement Method

The Fig1. shows an empty short circuited waveguide with a probe located as voltage minimum DR, Fig. 2 shows the same waveguide containing sample of length IE with a probe located at new voltage minimum D. The sample is adjacent to short circuit. We know

tan *l*K (DR - D - IE) tan *l*K *l*E kE

k/E kE /E



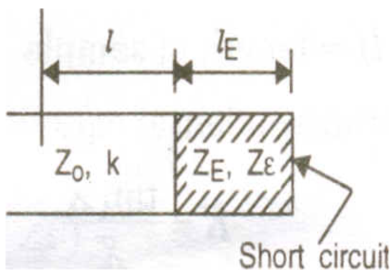
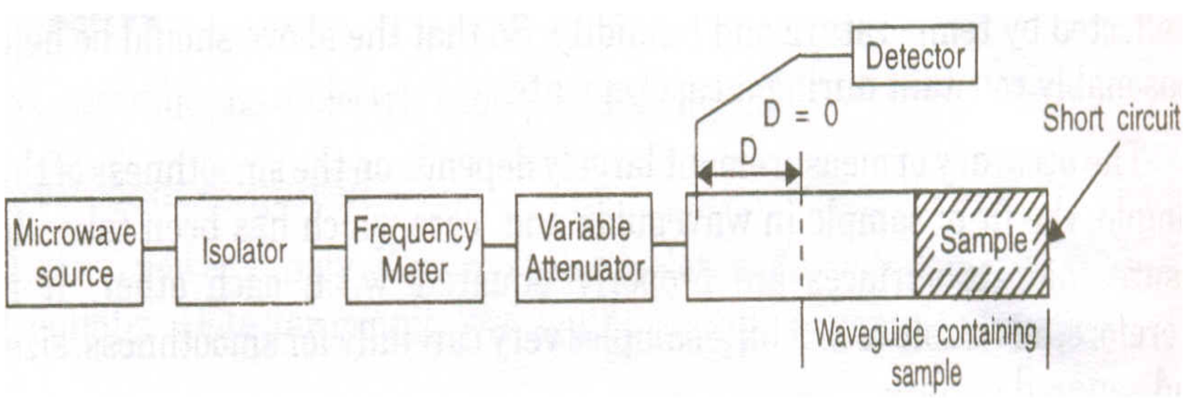


fig 1 fig 2

BLOCK DIAGRAM: -



We find that all the quantities associated with left hand are measurable. While right hand is of the form tan z/z, so that once the measurement has been performed, the complex number, Z = kE /E can be found by solution of transcendental equation and from it kE. Of-course E r follows readily from kE. In view of periodic nature of tangent function, there exist a infinite solution for εr• Hence it is necessary to know E r approximately in order to pick up write solution or to perform a second identical experiment with other sample of different length. The proper solution in the latter case are, common to the two sets of solution.

PROCEDURE: - The basic arrangement of equipment is as in Fig.

1. With no sample in short circuited line find position of voltage minima *DR* w.r.t. an arbitrarily chosen reference. With the help of slotted section and probe.
2. Measure the guide wave length λg by measuring the distance between two adjacent minima in slotted line.
3. Remove short circuit, insert a sample and replace the short circuit in such a manner that it touches the end of sample.
4. Measure *D,* the position of minima in slotted line with respect to same reference as in 2.
5. Measure VSWR *(r)* in the slotted line.

Case 1 : Analysis Case-Dielectric Sample (Loss less)

1. Compute propagation constant

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

2. Compute

K=tan[k(Ie+Dr-D)]/k/e

where le = length of sample

3. Solve transcendental equation for X

$$K-\frac{\tan X}{-\ X}$$

If dominant mode is propagating through waveguide the dielectric, constant ε' is as follows

$$\varepsilon'=\frac{(a/\pi)^2(X'/Le)^2+1}{(2a/\lambda g)^2+1}$$

where, *a* = width of waveguide

λg = guide wave length

$$X'/Le=\frac{X \text{ (determined earlier)}}{\text{length of sample}}$$

$X'/Le=X/L1e=X/L2e$

Case 2: Complex Dielectric Sample (Lossy)

If dielectric constant is complex, *i.e., V* not=∞, compute as follows:

1. determine $k=2\pi/\lambda g$
2. compute

$$\varphi=2k\,(D-DR-Le)$$

3. Compute

$$[T]=r-1/r+1$$

4. Determine the complex number $C<\psi$

$$C<-\psi=1/jkle\frac{(1-[T]e^{j\varphi})}{(1+[T]\,e^{j\varphi})}$$

5. solve the complex eq. for T and t

$$C<-\psi=\frac{\tan h(T<t)}{T<t}$$

The admittance ye is given from

$$Ye=(T/kle)^2<2(t-90^0)$$

6. Compute εr as follows

$$Ye=Ge+j\beta e$$

$$\varepsilon'=\frac{Ge+(\lambda g/2a)^2}{1+(\lambda g/2a)^2}$$

$$\varepsilon''=\frac{-\beta e}{1+(\lambda g/2a)^2}$$

OBSERVATIONS AND CALCULATION :

PRECAUTIONS :-

1. Ensure tight connections of the apparatus
2. Avoid cross connections of the threads.
3. Use stabilized power supply.

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QUIZ:

Q1. A micro strip line on alumina substrate (E *r* = 9) has a zero thickness strip of width, *W* = 3 mm. Substrate thickness *h* = 0.5 mm. Assuming TEM wave propagation and negligible fringing field, the characteristic impedance of the line will be approximately

(a) 10 Q *(b)* 21 Q
(c) 26 Q *(d)* 50 Q

Q2. If H=0.2cos(wt-bx)a_z A/m is the magnetic field of a wave in free space, then the average power passing through a circle of radius 5 cm in the *x* = 1 plane will be approximately

(a) 30 mW *(b)* 60 mW
(c) 120 mW *(d)* 150 mW

Q3. An attenuator drops a 10 V signal to 50 m V In an experiment. The loss in decibels is

(a) - 40 dB (c) -55 dB
(b) - 46 dB *(d)* - 60 dB

Q4.Which of the following pairs of types of wave propagation and associated property are correctly matched?

(a) Surface wave Vertical polarization.
(b)Duct propagation Super refraction.
(c)Sky wave Critical frequency.

Select the correct answer using the codes given below:
Codes:

(a) 1, 2 and 3 (b) 1 and 2
(c) 1and 3 (d) 2 and 3

Q5. For reliable "beyond-the-horizon" microwave communication, without using repeaters, the frequency of choice would be

(a) 1 MHz *(b)* 30 MHz
(C) 2000 MHz *(d)* 30,000 MHz

Q6. What is wavelength?

Q7. What is guide wavelength ‘λ_g’?

Q8.What is cut off wavelength for a wave-guide?

Q9. What is the relationship between frequency and velocity of light?

Q10.Name various methods that can be used to measure frequency / wavelength.

ANSWERS: Q1: b
Q2: b
Q3: b
Q4: a
Q5: b

Ans.6 .Amount of distance travelled by electromagnetic wave in one cycle is known as wave length .

Ans.7 Distance traveled by an EM wave to undergo a phase difference of 2π radians is called guide wave length.

Ans.8. Maximum wave length that can travel in a wave guide is called cut off wavelength.

Ans.9 $C = f \cdot \lambda$

Ans.10
- Wave meter
- Frequency down conversion method
- 2d method
- Double minimum method