QUEST FOR EXCELLENCE	**Maharashtra Institute of Technology, Aurangabad** **Practical Experiment Instruction Sheet**			
Class: : TY (ETC)	DEPARTMENT: Electronics & Telecommunication Engineering			
LABORATORY : CS- I (411)		Location: 411	Part: II	Date:

MASTER LIST OF EXPERIMENT

SUB-: Microwave Theory and Techniques. Class: T.Y. **(ETC)**

EXPT. NO.	EXPERIMENT NAME	PAGE NO.	Performed date	Checked Date	SIGN
01	To study Microwave components at X band frequencies.				
02	Study of the characteristics of the Reflex klystron tube.				
03	Study of Gunn Oscillator Characteristics				
04	Measurement of frequency of microwave source and demonstrate relationship among frequency, free space wavelength and guided wavelength.				
05	Measurement of coupling factor and directivity of directional coupler.				
06	Measurement of insertion loss and isolation loss of three port circulator.				
07	Measurement of insertion loss and isolation loss of an isolator				
08	Measurement of S-parameters of Magic Tee.				
09	Measurement of Standing wave ratio and reflection coefficient.				
10	Measurement of attenuation or insertion loss of attenuator.				

Sign of Subject Teacher

Electronics & Telecommunication Engineering Department

Vision:

To develop the department into a full-fledged centre of learning in the various fields of Electronics and Telecommunication keeping in views the latest development and making student technologically superior and ethically strong.

Mission:

To impart education and training in the field of electronics and telecommunication engineering and its ailed areas by developing competencies of the students to meet social and industrial need

Program Educational Objectives

PEO1	Graduates will demonstrate professional engineering competencies.
PEO2	Graduates will apply engineering and science knowledge to solve technical problems with high ethical standards.
PEO3	Graduates will have effective communication skills.
PEO4	Graduates will demonstrate leadership, teamwork in their profession and adapt to current trends by engaging lifelong learning.

Program Outcomes:

Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
Problem analysis: Identify, formulate, review and analyze engineering problems reaching substantiated conclusions.
Design/development of solutions: Design system components or processes as per need and specification.
Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data in the field of electronics and telecommunication.
Modern tool usage: Select, and apply appropriate techniques, modern engineering tools, skills and equipment necessary for engineering practices.
The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal and safety issues.
Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
Ethics: Apply ethical principles and commit to professional ethics, responsibilities and norms of the engineering practice.
Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
Communication: Communicate effectively in both verbal and written form.
Project management and finance: Demonstrate knowledge and understanding of the engineering principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

Engineering Graduates will be able to:

1. Design and analyze electronics systems and implement them in the development of specialized areas such as telecommunications, signal processing, VLSI and embedded systems etc.
2. Participate in qualifying and competitive examinations such as GATE, GRE, TOEFL, MPSC and UPSC.
3. Handle latest hardware and software tools and develop real time applications related to specialized areas of electronics engineering

Course Name: ETC372 - Microwave Theory and Techniques (LAB)
Course Outcomes (CO):

After completing the course Student will be able to,

ETC352.1	
ETC352.2	
ETC352.3	
ETC352.4	
ETC372.5	
ETC372.6	

Maharashtra Institute of Technology, Aurangabad			
Practical Experiment Instruction Sheet			
EXPERIMENT TITLE: To study Microwave components at X band frequencies.			
EXPERIMENT NO. : MIT(T)/ETC/CS-I/MWTT/01			
Class: : TY (ETC)	DEPARTMENT: Electronics & Telecommunication Engineering		
LABORATORY :CS- 1 (411)	Location: 411	Part: II	Date:

Experiment No. 1

Aim: To study Microwave components at X band frequencies.

Apparatus: -Different Types of Microwave components.

Theory:-

1. WAVEGUIDE TEE JUNCTION:

In microwave circuit a waveguide junction with three independent ports is commonly referred to as a tee junction.

a.) E-plane tee (Series tee): An E-plane tee is a waveguide tee in which the axis of its side arm is parallel to the E field of the main guide. If the collinear arms are symmetry about the side arm there are two different transmission characteristics (figure 1.2).It can be seen from figure1.1 that if the E-plane tee is perfectly matched with the aid of screw tuners or inductive or capacitive windows at the junction, the diagonal elements of s-matrix (s_{11}, s_{22}, s_{33}) are zero because there will be no reflection. When the waves are fed into the side arm (port 3) the waves appearing at port1 and port2 of the collinear arm will be of the same magnitude and opposite phase.

Fig1.1 E-plane Tee

b.) H-Plane Tee (Shunt Tee): A H-Plane tee is a waveguide tee in which the axis of its side arm is shunting the E-field or parallel to the H-field of the main guide as shown in figure1.3. It can be seen that if the two input waves are fed into port 1 and port 2 of the collinear arm the output at port 3 will be in phase and additive on the other hand, if the input is fed into port 3 the wave will split equally into port 1 and port2 with same magnitude and same phase.

Figure 1.2 H-plane Tee

2. MAGIC TEE (Hybrid Tee):

A magic tee is a combination of E-plane tee and H-plane tee.(see fig 1.5).It has several characteristics.

If two waves of equal magnitude and the same phase are fed into port1 and port2, the output will be zero at port3 and additive at port 4.

If a wave is fed into port 4, it will be divided equally between port 1 and port 2 and will not appear at port 3.

If a wave is fed into port 3 it will produce an output of equal magnitude and opposite phase at port 1 and port 2.The output at port 4 is zero. i.e.$S_{43}=S_{34}=0$

If a wave fed into one of the collinear arms at port 1 or port 2, it will not appear in the other collinear arm at port 2 or port 1. Because the E-arm causes a phase delay while the H arm causes the phase advance. i.e. $S_{12}=S_{21}=0$

The magic tee is commonly used for mixing duplexing and impedance measurement suppose for example there are two identical radar transmitters, in equipment. A particular application requires twice more input power to an antenna than either transmitter can deliver. A magic tee may be used to couple the two transmitters to the antenna in such a way that the transmitters do not load each other. The two transmitters should be connected to port 3 and port4 respectively.

Figure 1.3 Magic Tee

Transmitter 1 causes a wave to antenna from port 1 and another to enable from port 2, these waves are equal in magnitude but opposite in phase. Similarly transmitter 2 connected to port 4, gives rise to a wave at port 1 and port2,both equal in magnitude & in phase at port1 the two opposite waves cancel each other. At port 2 the two in phase waves add together. So double output power at port 2 is obtained for the antenna shown in figure.

3. WAVEGUIDE CORNERS BENDS, AND TWISTS:

The waveguide components are normally used to change the direction of the guide through an arbitrary angle.

In order to minimize reflection from discontinuities it is desirable to have the mean length L between continuities equal to an odd numbers of quarter wavelengths.

i.e $L= (2n+1)\ \lambda g/4$

Where n= 0, 1, 2........&λg is the wavelength in waveguide

For waveguide bend the minimum radius of curvature for small reflection is given by south worth as

R= 1.5 b for E bend.

R= 1.5 a for H bend

Where a & b are the dimensions of the waveguide bend.

4. DIRECTIONAL COUPLERS:

A directional coupler is four port waveguide junction as shown in fig 1.8. It consists of primary waveguide port1 & port 2 and a secondary waveguide port3 & port 4.

When all ports are terminated in their characteristics impedances, there is free transmission of power without reflection between port 1 and port 2 and there is no transmission of power between port 1and port 3 or between port 2& port 4, because no coupling exists between these two pairs of ports.

Figure shows the constructional diagram of a directional coupler. It consists of main arm (Primary wave guide) and auxiliary arm (Secondary wave guide). Both are connected by means of small holes between adjoining waveguide section. A number of holes & the size of the openings determine the amount of power going into the auxiliary. A pyramid shaped dummy load is located in the left side of the auxiliary arm to absorbs any energy travelling away from the auxiliary arm .Output eliminating reflection back down the line. The characteristics of a directional coupler can be expressed in terms of its coupling factor & its directivity.

5. MICROWAVE ISOLATOR:
There are two types of isolators,
A) Faraday rotation Isolator -used up to few 100W
B) Resonance absorption Isolator- for high power.

The isolator is commonly used to couple microwave source to load. Because of change in load its frequency and power can be changed due to reflection from the load. Such type of undesirable effects can be avoided with the aid of isolator in between source and load as shown in fig.

A) Faraday rotation Isolator: A ferrite device which allows unattenuated transmission in forward direction but very high attenuation in reverse direction. Its construction is similar to that of gyrator.

When TE 10 wave allow to pass through R.W.G. its plane gets rotated due to 45^0 twist. Then it converted into circularly polarized TE 11 wave further wave rotate through 45^0 because of ferrite in reverse direction, so output signal is in phase with input signal. When waves enter through port 2 it converts into TE_{11} and comes into rotation of 45^0clockwise due to ferrite rod. Further addition 45^0 clockwise rotation is produced due to twist. Now the way at port1 is parallel to the plane of resistive card. So all the waves are absorbs by it and no signals are available at port 1. Performance factors are insertion loss of less than 1db and isolation of 20 db to 30 db.

6. MICROWAVE CIRCULATOR: It is multiport ferrite devices that have the property that a wave incident in port1 is coupled in port 2 and coupled in port 3 only and so an.
A four port circulator utilizing 290^0 non-reciprocal phase shifter. In general the sequence 1
2→3→4→1 is followed.

7. FREQUNCY METER: A typical cavity wave meter is shown in fig. The axis of cavity is made perpendicular to the main wave guide and the coupling from the cavity to the wave guide is achieved to a small circular hole or iris. A block polyron (absorbing material) on the back of plunger prevents false resonance. By proper design of cavity the instrument made by dumping out any oscillations that might exists. It should be notice that as the resonance is made smaller by proper design of cavity the instrument may be made to indicate wavelength directly on a micrometer head attached to a plunger. Calibration of this wave meter is done by determining the resonant frequency for different micrometer settings. The calibration chart drawn from these readings and the wave meter calibrated accordingly. A signal is fed to cavity through input and detector is connected through output.

The size of cavity is adjusted with the plunger until the detector indicates the pronounced oscillations are taking place, whereupon frequency is read from the micrometer.

Figure 1.5 Frequency Meter

8. Microwave Attenuators: Attenuators are component that reduce the amount of power from the input to the output of the device. For high powers provision must be made to remove excess heat. It is important that attenuators reduce the power through the device without reflecting energy or affecting the mode of transmission.

Types of attenuator:

1. Fixed attenuator
2. Variable attenuator
    a. Slide vane attenuator
    b. Flap attenuator
    c. Rotary vane attenuator

A] Slide vane Attenuator: Slide vane and flap attenuators operates on the principle that a resistive material placed in parallel with the E lines of a field current will induce a current in the material that would reduce in an I^2 R power loss. The slide vane attenuator is a thin dielectric material such as glass that is coated with lossy resistive material. It can be placed in the waveguide at the location of maximum E field for maximum attenuation as shown in figure. The location of the vane will depend on the mode of propagation in the waveguide. For a TE_{10} mode the location of maximum attenuation would be in the center of waveguide.

B] Flap attenuator: A flap attenuator has a vane that is dropped into the waveguide through a slot in the top of the guide as shown in figure. The further the vane is inserted into the waveguide the greater the attenuation. The position of the slot for the vane must be located with reference to the maximum E field of the operating mode. The resistive vane of the flap attenuator is curved to reduce reflections as the vane is inserted and removed from the waveguide.

C] Rotary Vane Attenuator: It is a precision attenuator in which attenuator follows a mathematical law. It has three sections each with a resistive card in the center as shown in fig with all the cards lined up the E field is perpendicular to the card and there is zero attenuation. The center section can rotate independently of the ends. When the center section is rotated the E field is split into two components. $E\sin\theta$ component is observed by the card. $E\cos\theta$ splits into components $E\cos\theta\sin\theta$ which is observed and $E\cos^2\theta$which is not observed.$E\cos2\theta$ exist the attenuator with the sane attenuation as E field. The resulting attenuation is then equal to

Attenuation = $20 \log_{10}\cos^2\theta$
= $40 \log_{10}\cos\theta$[db]

Figure 1.6 variable attenuator

9. Detector Mount: Detection of an electromagnetic wave is accomplished through the use of special diodes that operate throughout the microwave range. These are non-linear devices designed for signal detection, frequency conversion, and frequency harmonic generation. Microwave diodes are point contact silicon, gallium or schottkybazzier diodes. They are mounted in a case that can be inserted into detector mount.

These devices cannot be mounted across the end of waveguide or located in the top of waveguide this is due to mismatch of diode with the waveguide and the requirement for areturn dc current path. Detectors are in the interfaced with the waveguides through the use of detector mount if the diode is located a quarter wavelength from the end of guide. The end ofthe guide can be a tuning plunger to tune out any slight mismatch. Diodes are square law devices only at low powers.

Figure1.7 Detector Mount

10. Slotted Waveguide Section: In slotted Waveguide Section a longitudinal slot is cut intothe top of a section of waveguide as shown in figure. These sections are used as tuners tomatch the waveguide to mismatched load for two maxima or minimum field points to belocated at the same point. The slot must be greater than half wavelength for the lowest groupwavelength. Field strength is determined through the use of a detector probe that slides alongthe top of the

waveguides. The slot is located along the plane of maximum electric field forTE 10 mode. A scale is located on the top of the guide with a vernier scale located on thecarriage.

Figure 1.8.Slotted waveguide section

Fig 1.9 Directional Coupler

Conclusion:-

Questions:-

1. What is Circulator?

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2. What is an isolation loss?

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3. What is use of slotted section?

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4. How to measure frequency using frequency meter?

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Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

Sign of Faculty with Date

Experiment No. 2

Aim: -To Study the Characteristics of the Reflex Klystron Tube.

Apparatus:-

- Klystron power supply
- klystron tube with mount
- frequency meter
- variable attenuator
- detector mount with probe connection
- Oscilloscope.

Theory:-

The reflex klystron makes the use of velocity modulation to transform a continuous electron beam into microwave power. Electrons emitted from the cathode are accelerated and passed through the positive resonator towards negative reflector, which retards and finally reflects the electrons and the electron turn back through resonator. Suppose an RF field exists between the resonators, the electrons travelling forward will be accelerated or retarded as the voltage at the resonator changes in amplitude.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 a time that the electrons are slowed down by the voltage then energy will be delivered to the resonator and klystron will oscillate.

The frequency is primarily determined by the dimensions of resonant cavity. Hence, by changing the volume of resonator, mechanical tuning of klystron is possible. Also a small frequency change can be obtained by adjusting the reflector voltage. This is called Electronic tuning.

Block Diagram:-

Fig. Experimental Setup Block Diagram

Procedure:

Mode study on oscilloscope:

1. Set up the components and equipments as shown in figure.
2. Keep position of variable attenuator at minimum attenuation position.
3. Set mode selector switch to FM-MOD position.FM amplitude and FM position Knob at mid position, keep beam voltage knob fully anticlockwise and reflector voltage knob to fully clockwise and beam switch to 'OFF' position.
4. Keep the time/division scale of oscilloscope around 100 MHz frequency measurement and volt/div to lower scale.
5. Switch 'ON' the klystron power supply and oscilloscope.
6. Switch 'ON' beam voltage switch and set beam voltage to 250 V by beam voltage control knob.
7. Keep amplitude knob of FM modulator to maximum position and rotate the reflector voltage anticlockwise to get modes as shown in figure on the oscilloscope. The horizontal axis represents reflector voltage and vertical axis represents output power.
8. By changing the reflector voltage and amplitude of FM modulation, any mode of klystron tube can be seen on oscilloscope.

Observations:-

1. Beam Voltage =

2. Beam Current =

Observation Table:-

Sr. No.	Reflector Voltage	Output Power

Conclusion:-

Questions:-

1. On which band does reflex klystron operate?

2. How mechanical tunning is done in klystron?

3. Describe VSWR meter.

4. Define velocity modulation.

Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

Sign of Faculty with Date

QUEST FOR EXCELLENCE	**Maharashtra Institute of Technology, Aurangabad**		
	Practical Experiment Instruction Sheet		
	EXPERIMENT TITLE: To Study Gunn Oscillator Characteristics		
EXPERIMENT NO. : MIT(T)/ETC/CS-I/MWTT/03			
Class: TY. (ETC)	DEPARTMENT: Electronics & Telecommunication Engineering		
LABORATORY :CS- 1 (411)	Location: 411	Part: II	Date:

Experiment No. 3

Aim: -To Study Gunn Oscillator Characteristics

Apparatus:-

- Gunn Power Supply
- Isolator
- Gunn oscillator
- PIN modulator
- Frequency Meter
- Matched termination
- Cooling Fan
- BNC-BNC cable and TNC-TNC cable.

Theory:-

Gunn diodes are based on negative differential conductivity effect in bulk semiconductor which has two conduction bands separated by an energy gap (greater than thermal energies) they are normally used as low power oscillator at microwave frequencies in transmitter and also as local oscillator in receiver front ends. J.B. Gun discovered microwave oscillation in gallium arsenide (GaAs), Indium Phosphide (InP) and Cadmium telluride (CdTe).These are semiconductors having a closely spaced energy valley the conduction bonds as shown in fig. for GaAs.When a dc voltage is applied across the material, an electric field is established across it. At low E-field in the material, most of the electrons will be located in the lower energy central valley P.

At higher E-field most of the electrons, will be transferred into high energy state of L and X valleys where the effective electron mass is larger and hence electron mobility is lower than that in the low energy P valley. Since the conductivity is directly proportional to mobility, the conductivity and hence the current decreases with increase in E-field or voltage in an intermediate range, beyond a threshold value v_{th} as shown in fig. this is called transferred electron effect and the device is also called TransferElectron Device(TED) or Gunn diode. Thus the material behaves as negative resistance device over a range of applied voltage and can be used in microwave oscillator.

Block Diagram:-

Fig. Experimental Setup Block Diagram

Procedure:

- Set the components as shown in figure.
- Keep the control knobs of Gunn power supply as below

Meter switch-----------------OFF
Gunn bias knob--------------Fully anticlockwise
Pin bias knob----------------- Fully anticlockwise
Pin mode frequency----------Any position.

- Set the micrometer of Gunn oscillator for required frequency of operation.
- Switch 'ON' the Gunn power supply.
- Measure the Gunn diode current corresponding to the various Gunn bias
- Voltages through the digital panel meter switch. Do not exceed the bias voltage above 10 v.
- Plot the voltage and current readings on the graph as shown in figure.
- Measure the threshold voltage which corresponds to maximum current

Observation Table:-

Sr No	GUNN voltage(V)	Current(A)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Conclusion:-

Questions:-

1. State different materials used for fabricating gunn diode.

2. Mention different modes of gunn diode.

3. List out advantages and disadvantages of gunn diode.

4. Why gunn diode is called TED?

Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

Sign of Faculty with Date

QUEST FOR EXCELLENCE	**Maharashtra Institute of Technology, Aurangabad**
	Practical Experiment Instruction Sheet
	EXPERIMENT TITLE: Frequency measurement of Microwave source and demonstrate relationship among frequency (f), free space wavelength (λ_0) and guide wavelength (λ_c).
EXPERIMENT NO. : MIT(T)/ETC/CS-I/MWTT/04	
Class: TY. (ETC)	DEPARTMENT: Electronics & Telecommunication Engineering
LABORATORY :CS- 1 (411)	Location: 411 · Part: II · Date:

Experiment No. 4

Aim:- Frequency measurement of Microwave source and demonstrate relationship among frequency (f), free space wavelength (λ_0) and guide wavelength(λ_c).

Apparatus:-

Klystron power supply, klystron tube with mount, variable attenuator, frequency meter, fixed attenuator, short CRO as VSWR meter

Theory:-

For dominant TE10 mode in waveguide λ_c, λ_0 and $\lambda_g$are related by following equation

$1/\lambda_0^2 = 1/\lambda_g^2 + 1/\lambda_c^2$

λ_c = cut off frequency

λ_0 = free space wavelength

λ_g = guide wavelength

For TE_{10} mode, $\lambda c = 2a/m$ where,

a= broad dimension of waveguide (2.286cm of x band)

Block Diagram:-

Fig. Experimental Setup Block Diagram

Procedure:

1. Set up the components and equipments as shown in figure.
2. Set up variable attenuator at minimum attenuation position.
3. Keep the control knobs of VSWR meter as below

Range	50 db
Input switch	Crystal low impedance
Meter switch	Normal Position
Gain	Mid Position.

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

Beam voltage	OFF
Mod switch	AM
Beam voltage knob	Fully anticlockwise
Reflector voltage	Fully clockwise
AM- amplitude knob	Around fully clockwise

AM-frequency knob Around mid-position.

5. Switch 'ON' the klystron power supply, VSWR meter and cooling fan switch.
6. Switch 'ON' the beam voltage switch and set beam voltage at 250 V 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.
   Tune the plunger of klystron Mount for maximum deflection.
   Tune the reflector voltage knob for maximum deflection.
   Tune the probe for maximum deflection in VSWR meter.

9. Tune the frequency meter knob to get a 'dip' on the VSWR scale and note down the frequency directly from frequency meter.
10. Replace the termination with movable short, and detune the frequency meter.
11. Move the probe along the slotted line. The deflection in VSWR meter will vary. Move the probe to a minimum deflection position, to get accurate reading. If necessary increase the VSWR meter range db switch to higher position. Note and record the probe position.
12. Move the probe to next maximum position and record the probe position again.
13. Calculate the guide wavelength as twice the distance two successive minimum positions obtained as above.

14. Measure the waveguide inner broad dimension 'a' which will be around 22.86mm for x-band.
15. Calculate the frequency by following equation.
    $f = c/\lambda_0$
    Where $c= 3*10^8$ meter/sec. ie velocity of light.
16. Verify with frequency obtained by frequency meter.

Observations:
Beam Voltage = 250 V
Beam current = 22mA
Repellar voltage = -250 V

Observation Table:-

Position	Voltage(p-p)	Distance(cm)
D_0		
D_0’		
D_0’’		
D_0’’’		
D_1		
D_1’		
D_1’’		
D_1’’’		
D2		

Calculations:-

Conclusion:-

Questions:-

1. Define cutoff wavelength.

2. What is free space wavelength?

3. How does TE_{10} mode propagate in rectangular waveguide?

4. How does guide wavelength measured?

Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

Sign of Faculty with Date

<table>
<tr><td rowspan="3"></td><td colspan="4">Maharashtra Institute of Technology, Aurangabad</td></tr>
<tr><td colspan="4">Practical Experiment Instruction Sheet</td></tr>
<tr><td colspan="4">EXPERIMENT TITLE: Measurement of coupling factor and directivity of directional coupler.</td></tr>
<tr><td colspan="5">EXPERIMENT NO. : MIT(T)/ETC/CS-I/MWTT/05</td></tr>
<tr><td>Class: TY. (ETC)</td><td colspan="4">DEPARTMENT: Electronics & Telecommunication Engineering</td></tr>
<tr><td colspan="2">LABORATORY :CS- 1 (411)</td><td>Location: 411</td><td>Part: II</td><td>Date:</td></tr>
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Experiment No.5

Aim: -. Measurement of coupling factor and directivity of directional coupler.

Apparatus:-

- Klystron power supply.
- Klystron tube with mount.
- Fixed attenuator frequency meter.
- Multi-hole directional coupler.
- Matched termination.
- Variable attenuator.
- Detector mount VSWR meter.

Theory:-

A directional coupler is a device with which it is possible to measure the incident and reflected wave separately. It consists of two transmission lines the main arm and auxiliary arm, electromagnetically coupled to each other. The power entering in the main arm gets divided between port 2 and 3 and almost no power comes out in port4 power entering at port2 is divided between port 1 and 4.

The coupling factor is defined as

Coupling Factor(c) $=10\log_{10} P_{in}/P_{aux}$ dB$=P_1/P_3$

$20\log V_{in}/V_{aux}$ dB

Where (dB) =coupling factor, dB.

P_{in}=Input power to the coupler.

P_{aux}=power o/p of auxiliary arm.

With built in termination and power entering at port 1 the directivity of the coupler is a measure of separation between incident wave and the reflected wave. Directivity is measured as

$$D\,(db) = 10\log_{10} (P_{aux}(Forward)/P_{aux}(reverse)) = P_2/P_1$$

$$= 20\log (V_{aux}\,(f)/V_{aux}(r))$$

Where D=Directivity of the coupler, db

P_{aux} (forward) = Power in the auxiliary arm due to power in the forward direction

P_{aux} (reverse) = Power in the auxiliary arm due to power in the reverse direction

Block Diagram:-

Fig. Experimental Setup Block Diagram

Procedure:

- Arrange the setup as shown in fig. Obtain the oscillation as described earlier. Since the output main arm is terminated their will be no reflection.
- The power going through auxiliary arm can be measured by VSWR meter. Take the reading as P_4.
- Disconnect the directional coupler and matched load.
- Connect the mount after frequency meter.
- Measured the detected output. Take this reading as P_1.
- Calculate the coupling factor in dB.
- For directivity measurement reverse the direction of directional coupler and find out the output power at auxiliary port calculate the directivity.

Calculations:-

Beam voltage = 250v
Beam current = 22mA
Repeller voltage e= -250v

Measurement in forward direction
Output at port 4=P_{4f}
Input power to port1 = P_1
C (dB) =20 $\log_{10}$ (P_1/P_{4f}) =20$\log_{10}$ (V_i/V_{4f})
C (dB) =
Measurement in reverse direction:
Output at port 4= P_{4r} in reverse direction
D (dB) =20 $\log_{10}$ (P_{4f} /P_{4r}) =20$\log_{10}$ (V_{4f}/V_{4r})

V4r=

D (dB) =

Result:-

Coupling (dB) =

Directivity D (dB) =

Conclusion:-

Questions:-

1. What is meant by insertion loss, directivity and coupling factor of a directional coupler?

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2. What is the coupling factor in dB for a coupler if the power input in 250 mW at the output of auxillary arm is 2.5 mW?

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3. The input power to a 6 dB coupler is 6.4 mW, what is the power output at auxillary arm and output of main waveguide line? Mention types of directional coupler.

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Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

Sign of Faculty with Date

Experiment No. 6

Aim:-To measure insertion loss and isolation loss of three port circulator

Apparatus:-

- Klystron power supply
- Klystron tube with mount
- Fixed attenuator
- Variable attenuate
- Frequency meter
- Circulator
- Detector mount
- Matched load
- CRO
- VSWR meter.

Theory:-

Circulator is defined as device with ports arrangement such that energy entering at port is coupled to an adjacent port but not coupled to the other ports. It is depicted in Fig. Circulator can have any no. of ports.

An isolator is a two port device that transfers energy from input to output with little attenuation & from output to input with very high attenuation. The isolator, shown in Fig. can be derived from a three port circulator by simply placing a matched load (reflection less termination) on one port.

CIRCULATOR: Insertion loss is the ratio of power supplied by at the output port to power supplied by source to the input port, measured with other ports terminated in the matched load. It is expressed in dB.

INPUT VSWR: The input VSWR of an isolator or circulator is the ratio of voltage maximum to voltage minimum of the standing wave existing in the line with all ports except the test port are matched

Block Diagram:-

Fig. Experimental Setup Block Diagram

Procedure:

- Arrange the set up as shown in Fig.
- Put frequency meter and variable attenuator at minimum position.
- Adjust the beam voltage = 250 V dc. Obtain the rectangular oscillation on the C. R. O. screen.
- Measurement of insertion loss, Arrange the set up as shown in Fig.
- Put frequency meter and variable attenuator at minimum position.
- Adjust the beam voltage = 250 V dc.
- Obtain the rectangular oscillation on the C. R. O. screen.
- Measurement of insertion loss.
- Measure the voltage present at port 2 (V_2). Now disconnect circulator connect detector mount to variable attenuator and measure (V_1).
- Calculate Insertion loss = $20 \log_{10} (V_1/V_2)$ db.
- Measurement of Isolation loss

- Now connect circulator in reverse fashion port 2 with variable attenuator, port 1 detector mount, port 3 matched load. Measure the voltage present at port 1 (V1) from the previous measurement.
- Calculate Isolation loss

Isolation = = 20 $\log_{10}$ (I_{nput} /O_{utput}) dB

Calculations:-

1. Measurement of insertion loss for circulator in forward direction

V_1=

V_2=

Insertion Loss=

2. Measurement of isolation loss for circulator in reverse direction

V_1=

V_2=

Isolation Loss =

Results:-

1. Insertion loss of circulator =

2. Isolation loss of circulator =

Conclusion:-

Questions:-

1. Define Circulator

2. What is Faraday's rotation?

3. List applications of Circulator

4. List advantages of circulator in a microwave circuit.

Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

Sign of Faculty with Date

Experiment No. 7

Aim:-Measurement of insertion loss and isolation loss of an isolator

Apparatus:-

- Klystron power supply
- Klystron tube with mount
- Fixed attenuator
- Variable attenuate
- Frequency meter
- Circulator
- Detector mount
- Matched load
- CRO
- VSWR meter.

Theory:-

Circulator is defined as device with ports arrangement such that energy entering at port is coupled to an adjacent port but not coupled to the other ports. It is depicted in Circulator can have any no. of ports.

An isolator is a two port device that transfers energy from input to output with little attenuation & from output to input with very high attenuation. The isolator, shown in Fig. can be derived from a three port circulator by simply placing a matched load (reflection less termination) on one port.

ISOLATOR: Isolation is the ratio of power applied to the output to that measured at the input. This ratio is expressed in dB. The isolation of a circulator is measured with the third port terminated in a matched load.

INPUT VSWR: The input VSWR of an isolator or circulator is the ratio of voltage maximum to voltage minimum of the standing wave existing in the line with all ports except the test port are matched.

Block Diagram:-

Fig. Experimental Setup Block Diagram

Procedure:

- Arrange the set up as shown in Fig.
- Put frequency meter and variable attenuator at minimum position.
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- Measurement of insertion loss, Arrange the set up as shown in Fig.
- Put frequency meter and variable attenuator at minimum position.
- Adjust the beam voltage = 250 V dc.
- Obtain the rectangular oscillation on the C. R. O. screen.
- Measurement of insertion loss.
- Measure the voltage present at port 2 (V_2). Now disconnect isolator and connect detector mount to variable attenuator and measure (V_1).
- Calculate Insertion loss = 20 $\log_{10}(V_1/V_2)$ db.
- Measurement of Isolation loss
- Now connect isolator in reverse fashion port 2 with variable attenuator, port 1 detector mount, port 3 matched load. Measure the voltage present at port 1 (V1) from the previous measurement.
- Calculate Isolation loss
  Isolation = = 20 $\log_{10}(I_{nput}/O_{utput})$ dB

Calculations:-

1. Measurement of insertion loss for isolator in forward direction

V_1=

V_2=

Insertion Loss=

4. Measurement of isolation loss for isolator in reverse direction

V_1=

V_2=

Isolation Loss=

Results:-

1. Insertion loss of Isolator =
2. Isolation loss of Isolator =

Conclusion:-

Questions:-

1. Define Isolator.

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____

2. List applications of isolator?

3.List the advantages of connecting isolator in a microwave circuit.

Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

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<table>
<tr><td rowspan="3">QUEST FOR EXCELLENCE</td><td colspan="4">Maharashtra Institute of Technology, Aurangabad</td></tr>
<tr><td colspan="4">Practical Experiment Instruction Sheet</td></tr>
<tr><td colspan="4">EXPERIMENT TITLE: Measurement of S-parameters of Magic Tee.</td></tr>
<tr><td colspan="5">EXPERIMENT NO. : MIT(T)/ETC/CS-I/MWTT/08</td></tr>
<tr><td>Class: :TY. (ETC)</td><td colspan="4">DEPARTMENT: Electronics & Telecommunication Engineering</td></tr>
<tr><td colspan="2">LABORATORY :CS- 1 (411)</td><td>Location: 411</td><td>Part: II</td><td>Date:</td></tr>
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Experiment No. 8

Aim: -Measurement of S-parameters of Magic Tee.

Apparatus:-

- Klystron power supply
- klystron tube with mount
- frequency meter variable attenuator
- detector mount with probe connection
- Magic Tee.

Theory:-

A **magic tee** (or **magic T** or **hybrid tee**) is a hybrid or 3 dB coupler used in microwave systems. It is an alternative to the rat-race coupler. In contrast to the rat-race, the three-dimensional structure of the magic tee makes it less readily constructed in planar technologies such as microstrip or stripline. The magic tee is a combination of E and H plane tees. Arm 3 forms an H-plane tee with arms 1 and 2. Arm 4 forms an E-plane tee with arms 1 and 2. Arms 1 and 2 are sometimes called the side or collinear arms. Port 3 is called the H-plane port, and is also called the Σ port, sum port or the P-port (for "parallel"). Port 4 is the E-plane port, and is also called the Δ port, difference port, or S-port (for "series"). There is no one single established convention regarding the numbering of the ports.

Figure: Magic Tee

To function correctly, the magic tee must incorporate an internal matching structure. This structure typically consists of a post inside the H-plane tee and an inductive iris inside the E-plane limb, though many alternative structures have been proposed. Dependence on the matching structure means that the magic tee will only work over a limited frequency band.

Where,

$S_{13} = \sqrt{V_1/V_3}$

$S_{14} = \sqrt{V_1/V_4}$

$S_{23} = \sqrt{V_2/V_3}$

$S_{24} = \sqrt{V_2/V_4}$

Block Diagram:-

Procedure:-

1. Arrange the bench setup without connecting magic – tee and
measure the input power.
2. Now connect the magic – tee and note down the output power at port 2, port 3 & port 4.
3. Substitute the value of the port currents to obtain the scattering parameters of given magic – tee.
4. For various values of input power find the scattering matrix.

Calculations:-

$S_{13} = \sqrt{V_1/V_3} =$

$S_{14} = \sqrt{V_1/V_4} =$

$S_{23} = \sqrt{V_2/V_3} =$

$S_{24} = \sqrt{V_2/V_4} =$

Conclusion:-

Questions:-

1. What is Magic Tee?

2. What is the advantage of Magic Tee over E and H plane Tee?

3. List the applications of Magic Tee.

Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

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Experiment No. 9

Aim: - Measurement of Standing Wave Ratio and Reflection Coefficient

Apparatus:-

- Klystron tube
- Klystron power supply
- VSWR meter
- Klystron mount
- Frequency meter
- Isolator
- Variable attenuator
- Slotted line

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 add 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,

$$S = Emax. /Emin = \{|E_i| + |E_r| / |E_i| - |E_r|\}$$

E_i- Incident Voltage

E_r- Reflected Voltage

Reflection Coefficient,

$$\rho = E_r / E_i$$

Block Diagram:-

Procedure:-

(1) Set the components and equipments as shown in blockdiagram.
(2) Keep variable attenuator at maximumposition.
(3) Keep the control knobs of Klystron Power Supply asbelow: 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 asbelow:
Meter Switch -Normal
Input Switch -LowImpedance
Range db Switch - 40 / 50db

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

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

(6) Adjust the reflector voltage to get some deflection in VSWRmeter.

(7) Maximize the deflection with AM amplitude and frequency control knob of powersupply.

(8) Tune the plunger, reflector voltage, and probe for maximum deflection in VSWRmeter.

(9) Move the probe along the slotted line, the deflection willchange.

MEASUREMENT OF LOW AND MEDIUM VSWR

(1) Move the probe along with slotted line to get maximum deflection in VSWRmeter.

(2) Adjust the VSWR meter gain control knob or variable attenuator until the meter indicates 1 on normal SWRscale.

(3) Keep all the control knob as it is, move probe to next minimum position and read the VSWR on scale and recordit.

(4) Repeat the above step for change of S-S Tuner probe depth and record the corresponding SWR.

Calculations:-

VSWR, S = Emax. /Emin = $\{|E_i| + |E_r| / |E_i| - |E_r|\}$

E_i- Incident Voltage

E_r- Reflected Voltage

Reflection Coefficient,

$$\rho = E_r / E_i$$

Conclusion:

Questions:-

1. What is VSWR?

2. What is the need of calculation of VSWR values?

3. Why standing waves get produce along the microwave circuit?

Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

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Experiment No. 10

Aim:- Measurement of Attenuation/Insertion loss of Attenuator.

Apparatus:-

- Klystron Tube
- Isolator
- Frequency Meter
- Variable Attenuator
- Slotted Line
- Tunable Probe
- Detector Mount
- Matched Termination

Theory:-

The attenuators are two port bidirectional devices which attenuates some power when inserted into the transmission line.

$$\text{Attenuation } A \text{ (db)} == 10 \log P_1/P_2$$

Where,
P1 = Power absorbed or detected by the load without the attenuator in the line.
P2 = 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 center in TE_{10} mode; the attenuation will be maximum if the vane is placed at center of the waveguide. Moving from center 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. InputVSWR.
2. Insertion loss (in case of variable attenuator).
3. Amount of attenuation offered into thelines.
4. Frequency sensitivity, *i.e.,* variation of attenuation at any fixed position of vane and frequency ischanged.

Block Diagram:-

Procedure:-

Insertion Loss/Attenuation Measurement

1. Remove the tunable probe, attenuator and matched termination from the slotted section in the above setup.

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 VSWRmeter).

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 beP_1.

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 P_3. Then the attenuation value of fixed attenuator or attenuation value of variable attenuator for particular position of micrometer reading will be P_1 - P_3db.

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 agraph.

7. Now change the operating frequency and whole step should be repeated for finding frequency sensitivity of fixed and variableattenuator.

<u>Calculations:-</u>

<u>Conclusion:-</u>

Questions:-

1. What is the difference between fixed and variable attenuator?

2. Why calculation of insertion loss of attenuator is necessary?

3. Why to use attenuator in a microwave circuit?

Rubrics for Practical Assessment:

Cognitive (3)	Affective (3)	Psychomotor (3)	Total (9)

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