

MICROWAVE ENGG.

EC-604

LIST OF EXPERIMENTS

1. Study of characteristics of the Reflex Klystron Tube and to determine its electronic tuning range.
2. To determine the frequency & wavelength in a rectangular waveguide workin in TE₁₀ mode.
3. To determine the Standing Wave-Ratio and Reflection Coefficient.
4. To measure an unknown Impedance with Smith chart.
5. Study of V-I characteristics of Gunn Diode.
6. Study of the following characteristic of Gunn Diode
(A) Output power and frequency as a function of Bias Voltage.
(B) Square wave modulation through PIN diode.
7. Study of Magic Tee.
8. Study of Isolator and Circulators .
9. Study of Attenuators.
10. Study the Phase Shifter

EXPERIMENT NO:1

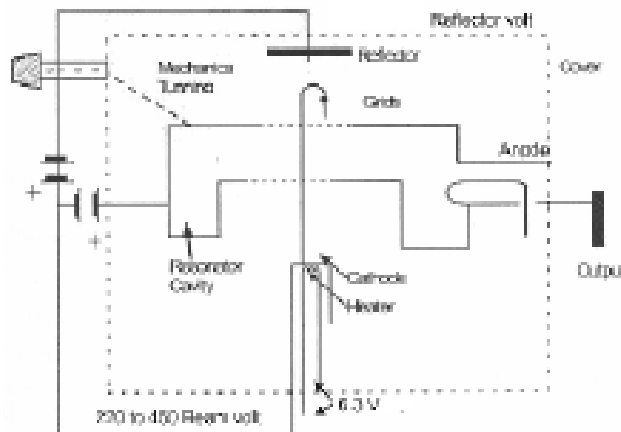
Objective Study of characteristics of the Reflex Klystron Tube and to determine its electronic tuning range

Apparatus required :

1 Klystron Power Supply, 2 Klystron tube with Klystron mount, 3 Isolator, 4 Frequency meter, 5 Variable attenuator, 6 Detector mount, 7 Wave guide stand, 8 SWR meter and Oscilloscope, 9 BNC cable

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 & passed through the positive resonator towards negative reflector, which retards and finally, reflects the electrons and the electrons turn back through the resonator. Suppose an rf-field exists between the resonators the electrons traveling forward will be accelerated or retarded, as the voltage at the resonator changes in amplitude.



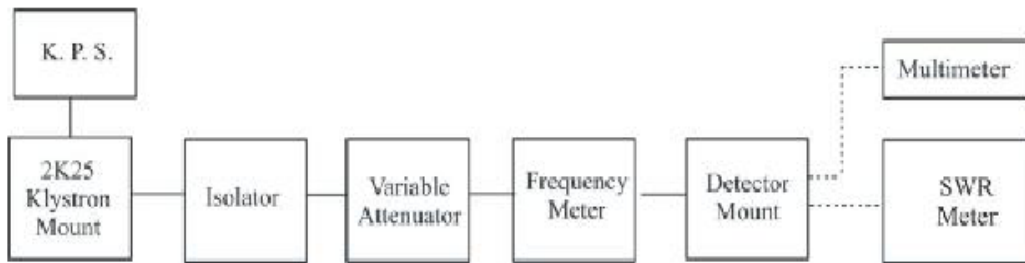
Schematics Diagram of Klystron 2K25

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. Figure 4 shows the relationship between output power, frequency and reflector voltages. Square Wave modulation of the Klystron:

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 The same result can be obtained, if the modulation voltage is applied on the reflector voltage as shown in the figure 5

Procedure :Carrier Wave Operation :

1. Connect the components and equipments as shown in

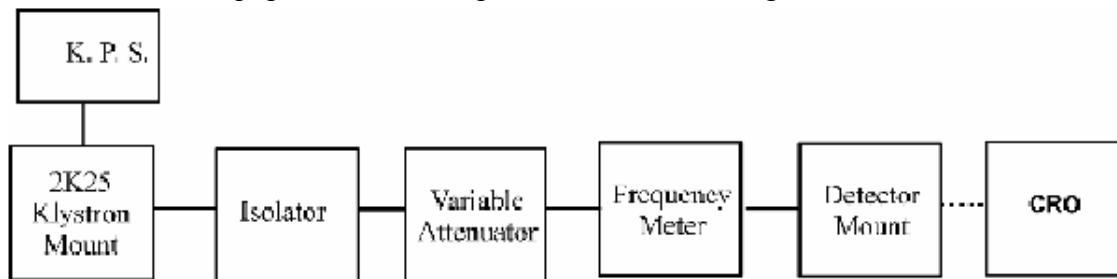


Setup for study of Klystron Tube

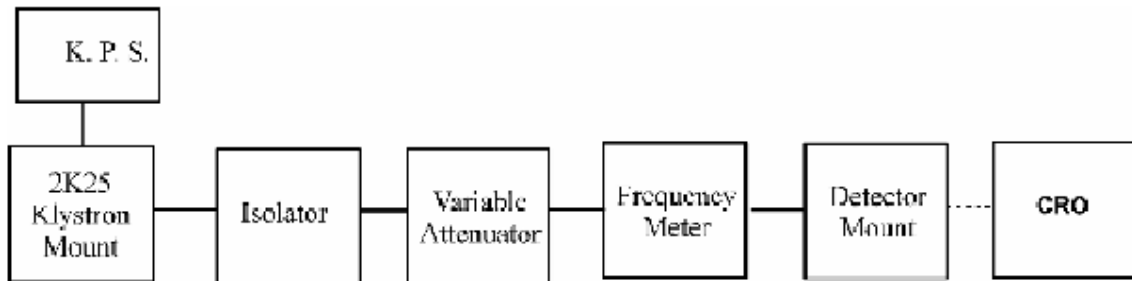
2. Set the Variable Attenuator at the maximum position (at no attenuation).
3. Set the mode switch of klystron Power Supply to CW position, beam voltage control knob to full anti-clock wise and reflector voltage control knob to fullyclock wise and the meter select to Beam position.
4. Keep SWR meter at 50dB attenuation and coarse and fine potentiometers on mid position and crystal impedance at 200ohm.
5. Keep SWR/dB switch at dB position.
6. Set the multi-meter in DC microampere range.
7. Switch 'On' the klystron Power Supply & cooling fan for klystron tube.
8. Set the meter select to beam voltage position and rotate beam voltage knob clockwise slowly. Observe beam current on the meter by changing the meter switch to beam current position. 'The beam current should not increase more than 25mA.
9. Change the reflector voltage slowly and observe the reading on the SWR meter. Set the voltage for maximum reading in the meter. If no reading is obtained, change the plunger position of klystron mount and detector mount. Select the appropriate range on SWR Meter. Now replace SWR meter to multi-meter.
10. Tune the plunger of klystron mount for the maximum output.
11. Rotate the knob of frequency meter slowly and stop at that position, when there is less output current on multi-meter. Read directly the frequency between two horizontal line and vertical line markers. If micro meter type frequency meter is used, read micrometer frequency and find the frequency from its calibration chart.

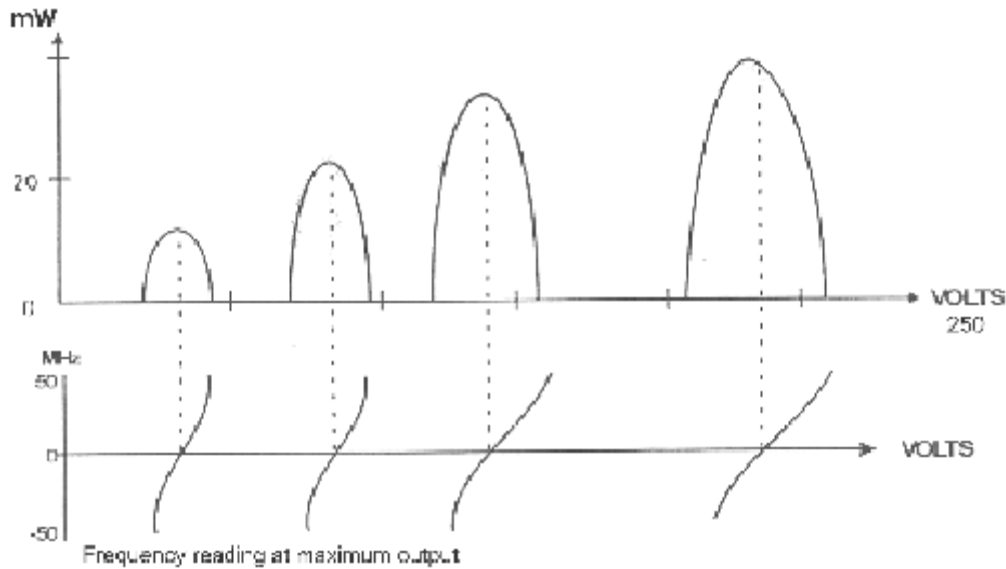
Square Wave Operation :

- 1.Connect the equipments and components as shown in fig.



2. Set Micrometer of variable attenuator for no attenuation.
 3. Set the range switch of SWR meter at appropriate position, crystal selector switch to 200ohm impedance position, mode select to normal position.
 4. Now in KPS Set Modulation selector switch to AM- Mod. Position. Beam voltage control knob to fully anticlockwise position. Reflector voltage control knob to the fully clockwise position and meter select switch to 'beam' position.
 5. Switch 'On' the Klystron Power Supply, SWR meter and cooling fan.
 6. Change the beam voltage knob clockwise up to 300V.
 7. Keep the AM amplitude knob and AM frequency knob at the mid-position.
 8. Rotate the reflector voltage knob to get reading in SWR meter.
 9. Rotate the AM amplitude knob to get the maximum output in SWR meter.
 10. Maximize the reading by adjusting the frequency control knob of AM.
 11. If necessary, change the range switch of SWR meter if the Reading in SWR meter is greater than 0.0db or less than -10dB in normal Mode respectively. Further the output can also be reduced by Variable Attenuator for setting the output for any particular position.
 12. Connect oscilloscope in place of SWR Meter and observe the square wave across detector mount.
- Mode Study on Oscilloscope : 1. Set up the components and equipments as shown in
2. Set Mode selector switch to FM-Mode position with FM amplitude and FM frequency knob at mid position. Keep beam voltage control knob fully anticlockwise and reflector voltage knob to fully clockwise.





Modes of 2K25

3. Keep the time/division scale of Oscilloscope around 100Hz frequency measurement and volt/ div to lower scale.
4. Switch 'On' the klystron Power Supply and oscilloscope.
5. Keep the meter switch of klystron Power Supply to beam voltage position and set beam voltage to 300V by beam voltage control knob.
6. Keep amplitude knob of FM modulator to maximum position and rotate the reflector voltage anti-clockwise to get modes as shown in figure 9 on the oscilloscope. The horizontal axis represents reflector voltage axis, and vertical axis represents output power.
7. By changing the reflector voltage and amplitude of FM modulation, any mode of Klystron tube can be seen on an Oscilloscope.

EXPERIMENT NO:2

Objective :

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

Apparatus required :

- 1 Klystron Power Supply
- 2 Klystron tube
- 3 Isolator
- 4 Frequency meter
- 5 Variable attenuator
- 6 Slotted section
- 7 Tunable probe
- 8 Wave guide stand
- 9 SWR meter
- 10 Matched termination.

Theory :

Mode represents in wave guides as either

$$\text{TE } m, n / \text{TM } m, n$$

Where

TE – Transverse electric,

TM – Transverse magnetic

m – Number of half wave length variation in broader direction.

n – Number of half wave length variation in shorter direction.

$$\frac{\lambda_g}{2} = (d_1 - d_2)$$

Where d_1 and d_2 are the distance between two successive minima/maxima

It is having highest cut off frequency hence dominant mode.

For dominant TE₁₀ mode in rectangular wave guide λ_0 , λ_g and λ_c are related as below.

$$\frac{1}{\lambda_0} = \sqrt{\frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}}$$

Where

λ_0 is free space wave length

λ_g is guide wave length

λ_c is cutoff wave length

For TE₁₀ mode, $\lambda_c = \frac{2a}{m}$

Where $m = 1$ in TE₁₀ mode and 'a' is broad dimension of waveguide. The following relationship can be proved

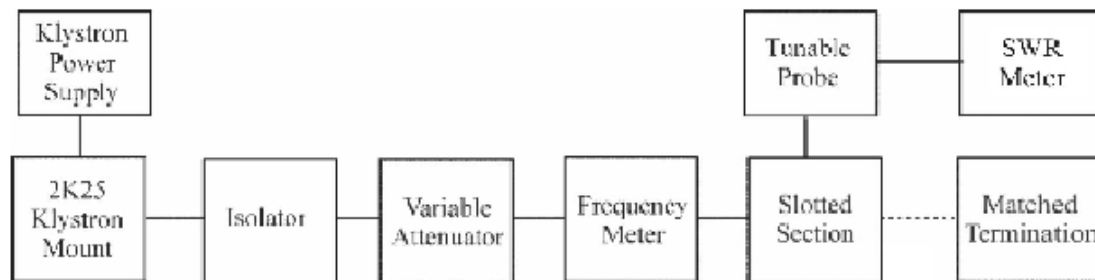
$$C = f\lambda$$

Where

$c = 3 \times 10^8$ m/s is velocity of light and f is frequency.

Procedure :

1. Set up the components and equipments as shown in figure 10
2. Set the variable attenuator at maximum position (at no attenuation).
3. Keep the control knobs of SWR Meter as below :
Range dB : 50 dB position
Crystal : At 200ohm Impedance
Mode select : Normal Position
Gain (Coarse & Fine) : Mid Position
SWR/dB : dB position
4. Keep the Control knobs of Klystron Power Supply as below.
Mod- Switch : AM
Beam Voltage Knob : Fully anticlockwise
Reflector Voltage : Fully clockwise
AM-Amplitude Knob : Fully clockwise
AM-Frequency : Mid Position



Setup for study of frequency & wave length measurement

5. Switch on the klystron Power Supply, SWR 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, current around 15-20mA.
7. Adjust the reflector voltage to get some reading in SWR Meter.
8. Maximize the reading with AM amplitude and frequency control knob of Power Supply.
9. Tune the plunger of klystron mount for maximum reading.
10. Tune the reflector voltage knob for maximum reading on SWR meter.
11. Tune the probe for maximum reading in SWR meter.
12. Tune the frequency meter to get a 'dip' on SWR meter and note down the frequency directly from frequency meter and detune the DRF.
13. Move the tunable probe along with the slotted line to get the reading in SWR meter. Move the tunable probe to a minimum reading position. To get accurate reading, it is necessary to increase the SWR meter range dB switch to high position, record the probe position i.e. d_1 .
14. Move the probe to next minimum position and record the probe position again i.e. d_2 .
15. Calculate the guide wavelength as twice the distance between two successive minimum positions obtained as above.

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

16. Measure the wave-guide inner broad dimension 'a' which will be around 22.8 mm for X band and Calculate

$$\lambda_c = 2a$$

For TE₁₀ mode

17. Calculate the frequency by following equation:

$$f = \frac{c}{\lambda_0} = c \sqrt{\frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}}$$

Where

$c = 3 \times 10^8$ meter/sec. i.e. velocity of light.

18. Verify with frequency obtained by frequency meter.
19. Above experiment can be verified at different frequencies.

EXPERIMENT NO:3

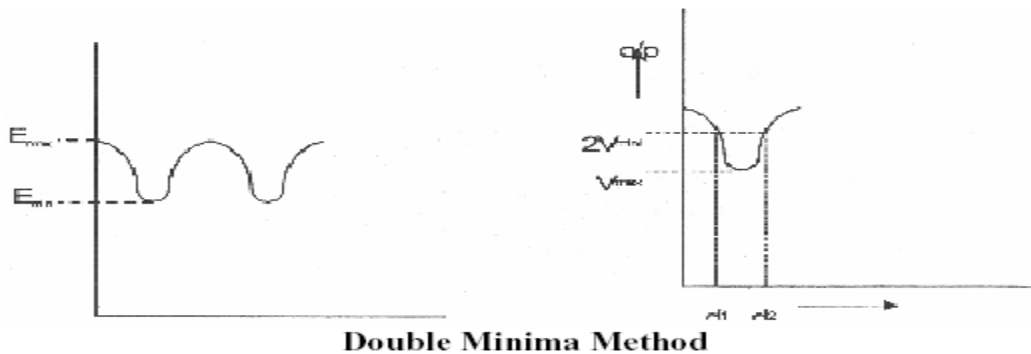
Objective :

To determine the Standing Wave-Ratio and Reflection Coefficient

Apparatus required :

- 1 Klystron Power Supply
- 2 Klystron tube
- 3 SWR meter
- 4 Isolator
- 5 Frequency meter
- 6 Variable attenuator
- 7 Slotted line
- 8 Tunable probe
- 9 Wave guide stand
- 10 Matched Termination
- 11 BNC cable
- 12 S-S tuner

Theory : It is a ratio of maximum voltage to minimum voltage along a transmission line is called SWR, as ratio of maximum to minimum current. SWR is measure of mismatch between load and line. The electromagnetic field at any point of transmission line may be considered as the sum of two traveling waves: the 'Incident Wave' propagates from generator and the reflected wave propagates towards the generator. The reflected wave is set up by reflection of incident wave from a discontinuity on the line or from the load impedance. The magnitude and phase of reflected wave depends upon amplitude and phase of the reflecting impedance. The superposition of two traveling waves, gives rise to standing wave along with the line. The maximum field strength is found where two waves are in phase and minimum where the line adds in opposite phase. The distance between two successive minimum (and maximum) is half the guide wavelength on the line. The ratio of electrical field strength of reflected and incident wave is called reflection between maximum and minimum field strength along the line.



Double Minima Method

Hence SWR denoted by S is

$$S = \frac{E_{\max}}{E_{\min}}$$
$$= \frac{|E_I| + |E_r|}{|E_I| - |E_r|}$$

Where

E_I = Incident Voltage

E_r = Reflected Voltage

Reflection Coefficient, ρ is

$$\rho = \frac{E_r}{E_I} = \frac{Z - Z_0}{Z + Z_0}$$

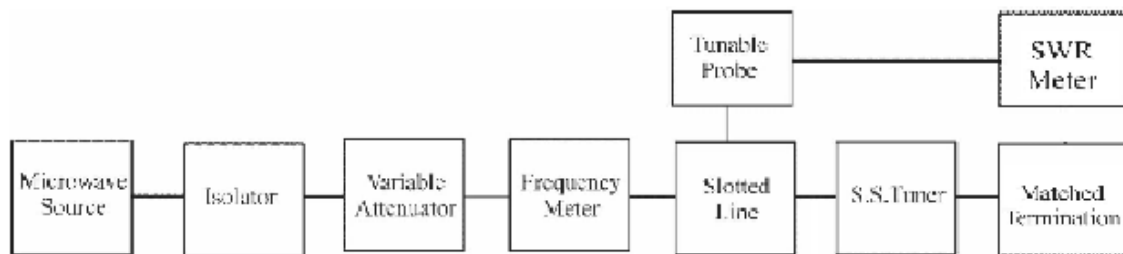
Where

Z is the impedance at a point on line,

Z_0 is characteristic Impedance.

The above equation gives following equation

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



Setup for SWR measurement

Procedure :

1. Set up the equipment as shown in the figure 12
2. Keep variable attenuator at maximum-position (at no attenuation).
3. Keep the control knobs of SWR Meter as below :

| | | |
|----------------------|---|-----------------|
| Range dB | : | 50 dB position |
| Crystal | : | 200 ohm |
| Mode Switch | : | Normal Position |
| Gain (Coarse & Fine) | : | Mid Position |
| SWR/dB switch | : | dB position |
4. Keep the control knobs of klystron Power Supply as below:

| | | |
|----------------------------------|---|---------------------|
| Mod-Switch | : | AM |
| Beam Voltage Knob | : | Fully Anticlockwise |
| Reflector Voltage Knob: | | Fully clockwise |
| AM Frequency & amplitude Knob | : | Mid Position |
5. Switch 'On' the klystron Power Supply, SWR meter and cooling fan.
6. Keep the meter switch of klystron Power Supply to beam Voltage position and set the beam voltage at 300V.
7. Rotate the reflector voltage knob to get reading in SWR Meter.
8. Tune the output by tuning the reflector voltage, amplitude and frequency of AM modulation.
9. Tune for Maximum reading by tuning the plunger of Klystron Mount. Then tune for maximum reading by tuning the probe.
10. If necessary change the range dB switch, variable attenuator position and gain control knob to get reading in the SWR meter.
11. Move the probe along with slotted line, the reading will change.

a. Measurement of low and medium SWR

- i. For low SWR set the S.S. tuner probe for no penetration position.
- ii. Move the probe along with slotted line to get maximum reading in SWR Meter in dB.
- iii. Adjust the SWR Meter gain control knob or variable attenuator until the meter indicates 0.0dB in normal modes. SWR for 0.0dB is 1.0 by keeping switch at SWR we can read it directly.

- iv. Keep all the Control knobs as it is, move the probe to next minimum gain position.
- v. Keep SWR /dB switch at SWR position.
- vi. Read the SWR from display and record it.
- vii. Repeat the above step for change of S.S. Tuner probe penetration & record the corresponding SWR.
- viii. If the SWR is grater than 10dB, then you have to use the following procedure.

b. Measurement of High SWR (Double Minimum Method)

- i.** Set the depth of S.S. Tuner slightly more for maximum SWR.
- ii.** Move the probe along with Slotted line until a minimum indicated.
- iii.** Adjust the SWR meter gain control knob and variable attenuator obtain a reading of 3 dB (or any other reference) at SWR Meter.
- iv.** Move the probe to the left on slotted line until maximum reading obtained i.e. '0' dB (or power should be increased by 3 dB). Note and record the probe position on slotted line. Let it be d_1 .
- v.** Repeat the step 3 and 4 and then move the probe right along with slotted line until maximum reading is obtained in normal dB mode i.e upto 0dB. Let it be d_2 .
- vi.** Measure the distance between two successive minima position. Twice of this distance is wave guide length λ_g .

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

- vii.** Calculate SWR by following equation.

$$SWR = \frac{\lambda_g}{\pi(d_1 - d_2)}$$

For different SWR, calculate the reflection coefficient.

EXPERIMENT NO:4

Objective :

To measure an unknown Impedance with Smith chart

Apparatus required :

- 1 Klystron Tube 2K25
- 2 Klystron Power Supply
- 3 Klystron Mount
- 4 Isolator
- 5 Frequency meter
- 6 Variable attenuator
- 7 Slotted Line
- 8 Tunable Probe
- 9 SWR meter
- 10 Wave guide stand
- 11 S.S. Tuner
- 12 Matched Termination.

Theory :

The impedance at any point of a transmission line can be written in the form $R + jX$. For comparison SWR can be calculated as

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

Reflection Coefficient

$$R = \frac{Z - Z_0}{Z + Z_0}$$

Where

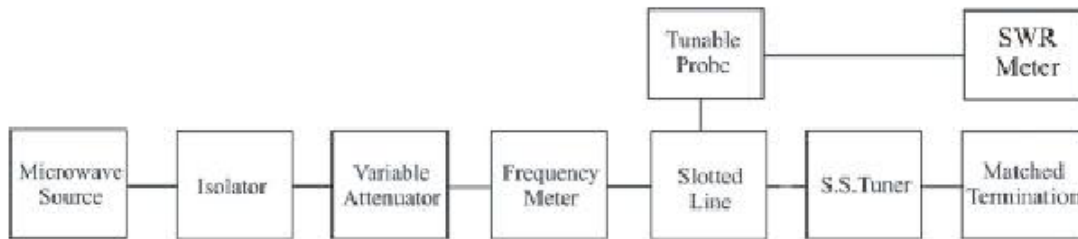
Z_0 = Characteristics impedance of w/g at operating frequency

Z = Load impedance at any point.

The measurement is performed in following way :

The unknown device is connected to the slotted line and the $SWR = S_0$ and the position of one minima is determined. Then unknown device is replaced by movable short to the slotted line. Two successive minima positions are noted. The twice of the difference between minima position will be guide-wave length. One of the minima is used as reference for Impedance measurement. Find the difference of reference minima and minima position obtained from unknown load. Let it be 'd'. Take a Smith chart taking '1' as center; draw a circle of radius equal to S_0 . Mark a point on circumference of chart towards load side at a distance equal to d/λ_g . Join the center

with this point. Find the point where it cut the drawn circle. The coordination of this point this will show the normalized impedance of load.



Setup for Impedance measurement

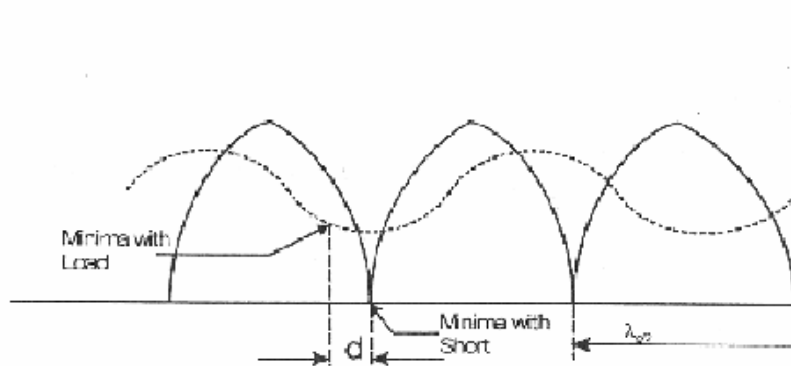
Procedure :

1. Set up the equipments as shown in the.
2. Set the variable attenuator at no attenuation position.
3. Connect S.S. tuner and matched termination after slotted line.
4. Keep the control knobs of SWR Meter as below :

| | | |
|----------------------|---|-----------------|
| Range dB | : | 50 dB position |
| Crystal | : | 200 ohm |
| Mode Switch | : | Normal Position |
| Gain (Course & Fine) | : | Mid Position |
| SWR/dB switch | : | dB position |
5. Keep the Control knobs of Klystron Power Supply as below :

| | | |
|-------------------|---|---------------------|
| Mod Switch | : | AM |
| Beam Voltage Knob | : | Fully anticlockwise |
| Reflector Voltage | : | Fully clockwise |
| AM-Amplitude | : | Fully Clockwise |
| AM-Frequency Knob | : | Mid Position |
6. Switch "On" the Klystron Power Supply, SWR meter and cooling Fan.
7. Turn the meter switch of Power Supply to beam voltage position and set beam voltage at 300V with help of beam voltage knob.
8. Adjust the reflector voltage to get some reading in SWR Meter.
9. To get the maximum reading, tune the AM amplitude and frequency control knob from Power Supply.
10. Tune the reflector voltage knob for maximum reading.
11. Tune the tunable probe for maximum reading in SWR meter.
12. Tune the frequency meter knob to get dip on the SWR meter, and note down the frequency directly from frequency meter.

13. Keep the depth of pin of S.S. Tuner to around 3-4mm and lock it.
 14. Move the probe along with slotted line to get maximum reading.
 15. Adjust SWR meter gain control knob and variable attenuator unit such that the meter indicates 0.0dB on the normal dB mode.
 16. Move the probe to next minima point.
 17. Now change SWR/dB switch to SWR position.
- Note down the SWR = S_0 from the meter. Also note down the probe position, let it be d .



Standing waves in impedance measurement

Figure 14

18. Note the position of two successive minimum positions. Let it be as d_1 and d_2 . Hence.

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

Calculate $\frac{d}{\lambda_g}$

19. Take a Smith chart taking '1' as center; draw a circle of radius equal to S_0 . Mark a point on circumference of chart towards load side at a distance equal to d/λ_g . Join the center with this point. Find the point where it cut the drawn circle. The coordination of this point this will show the normalized impedance of load.

EXPERIMENT NO 5

Objective :

Study of V-I characteristics of Gunn Diode

Apparatus required :

1. Gunn oscillator
2. Gun Power Supply
3. PIN modulator
4. Isolator
5. Frequency meter
6. Variable attenuator
7. Detector mount
8. Wave guide stands
9. SWR Meter
10. Cables and accessories.

Theory :

The Gunn Oscillator is based on negative differential conductivity effect in bulk semiconductors, which has two conduction bands minima separated by an energy gap (greater than thermal agitation energies). A disturbance at the cathode gives rise to high field region, which travels towards the anode. When this high field domain reaches the anode, it disappears and 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 (transit time) gives oscillation frequency.

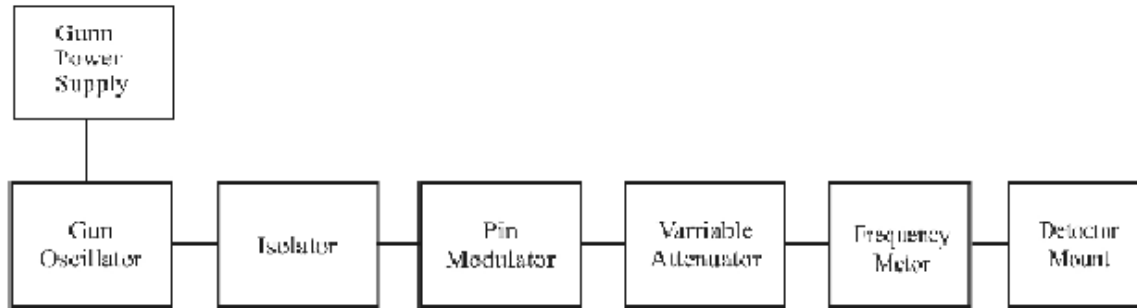
In a Gunn Oscillator, the Gunn diode is placed in a resonant cavity. In this case the Oscillation frequency is determined by cavity dimension. Although Gunn oscillator can be amplitude modulated with the bias voltage. We have used separate PIN modulator through PIN diode for square wave modulation.

A measure of the square wave modulation capability is the modulation depth i.e. the output ratio between, 'On' and 'Off' state.

Procedure :

1. Set the components and equipment as shown in the
2. Initially set the variable attenuator for maximum attenuation.
3. Keep the control knob of Gunn Power Supply as below:

| | | |
|-------------------|---|----------------------|
| Gunn Bias Knob | : | Fully anticlockwise |
| Pin bias Knob | : | Fully anti-clockwise |
| Pin Mod frequency | : | Mid position |
| Mode switch | : | CW Mode |



Setup for Study of V-I characteristics of Gunn Diode

4. Keep the control knob of SWR meter as below:

| | | |
|----------------------|---|-----------------|
| Range dB | : | 50 dB position |
| Crystal | : | 200 ohm |
| Mode Switch | : | Normal Position |
| Gain (Course & Fine) | : | Mid Position |
| SWR/dB switch | : | dB position |

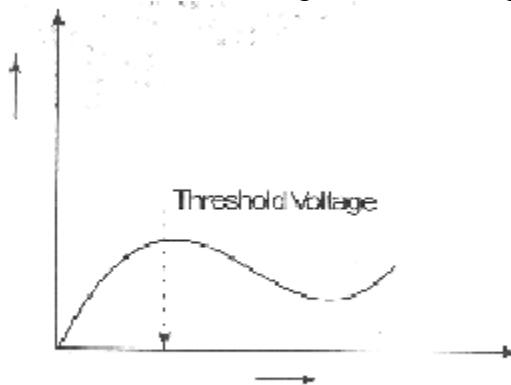
5. Set the micrometer of Gunn Oscillator for required frequency of operation.

6. Switch 'On' the Gunn Power Supply SWR Meter and cooling fan.

7. Measure the Gunn diode current corresponding to the various voltage controlled by Gunn bias knob through the panel, do not exceed the bias voltage above 10 volts.

8. Plot the voltage and current reading on the graph as shown in

9. Measure the threshold voltage which, corresponds to maximum current.



I-V Characteristics of Gunn Oscillator

Note : Do not keep Gunn bias knob position at threshold position for more than 10-15 seconds. Otherwise due to excessive heating, Gunn Diode may burn.

| Sr. No. | V (Volt) | I (mA) |
|---------|----------|--------|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |

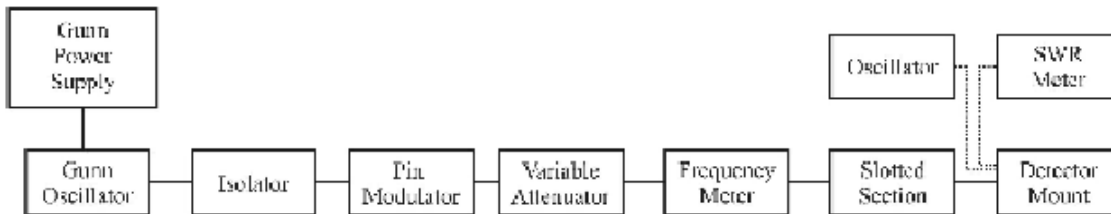
EXPERIMENT NO 6

Objective :

- Study of the following characteristic of Gunn Diode
1. Output power and frequency as a function of Bias Voltage.
 2. Square wave modulation through PIN diode.

Apparatus required :

1. Gunn oscillator
2. Gun Power Supply
3. PIN modulator
4. Isolator
5. Frequency meter
6. Variable attenuator
7. Detector Mount
8. Wave guide stands
9. SWR meter
10. Cables and accessories.



Setup for the study of the Gunn Oscillator

Procedure :

1. Set the components and equipment as shown in the
2. Initially set the variable attenuator for maximum attenuation (for no attenuation).
3. Keep the control knob of Gunn Power Supply as below:

| | | |
|-------------------|---|------------------------|
| Gunn Bias Knob | : | Fully anticlockwise |
| Pin bias Knob | : | Fully anti-clockwise |
| Pin Mod frequency | : | Mid position |
| Mode switch | : | Internal mod. Position |
4. Keep the control knob of SWR meter as below :

| | | |
|----------------------|---|-----------------|
| Range dB | : | 50 dB position |
| Crystal | : | 200 ohm |
| Mode Switch | : | Normal Position |
| Gain (Course & Fine) | : | Mid Position |
| SWR/dB switch | : | dB position |
5. Set the micrometer of Gunn oscillator for required frequency of operation

6. Switch on the Gunn Power Supply, SWR Meter.
 - a. Out Put Power and Frequency as a Function of Bias Voltage.
 - i. Increase the Gunn bias control knob upto 10V.
 - ii. Rotate PIN bias knob to around maximum position.
 - iii. Tune the output in the SWR meter through frequency control knob of modulation.
 - iv. If necessary change the range dB switch of SWR meter to higher or lower dB position to get reading on SWR meter display. Any level canbe set through variable attenuator and gain control knob of SWR meter.
 - v. Measure the frequency using frequency meter and detune it.
 - vi. Reduce the Gunn bias voltage from 10V in the interval of 0.5V or 1.0V and note down corresponding reading of output at SWR meter in dBand corresponding frequency by frequency meter. (Do not keep Gunn bias knob position at threshold position for more than 10-15 seconds. Otherwise due to excessive heating, Gunn Diode may burn).
 - vii. Draw the power vs. Voltage curve and Frequency vs. Voltage curve and plot the graph.
 - viii. Measure the pushing factor (MHz /Volt) which is frequency sensitivity against variation in bias voltage for an oscillator. The pushing factor should be measured around 8 volt bias. For example

| Volt (V) | Power (dB) | Frequency (GHz) |
|-----------------|-------------------|------------------------|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

b. Square Wave Modulation

- i. Move the Gunn bias voltage Knob slowly so that panel meter of Gunn Power Supply reads 10V
- ii. Keep the Gunn Power Supply in Internal modulation mode.
- iii. Tune the PIN modulator bias voltage and frequency knob for maximum detected output on the oscilloscope.
- iv. Coincide the bottom of square wave in oscilloscope to some reference level and note down the micrometer reading of variable attenuator.
- v. Now with the help of variable attenuator coincide the top of square wave to same reference level and note down the micrometer reading.
- vi. Now Connect detector mount to SWR Meter and note down the Db reading in SWR Meter for both t attenuator.
- vii. The difference of both dB reading of SWR meter gives the modulation depth of PIN modulator.

EXPERIMENT NO 7

Objective :

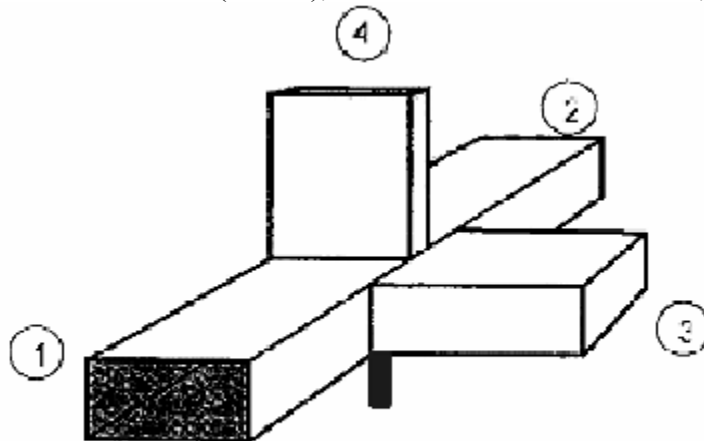
Study of Magic Tee

Apparatus required :

1. Microwave source
2. Isolator
3. Variable attenuator
4. Frequency meter
5. Slotted line
6. Tunable probe
7. Magic Tee
8. Matched termination
9. Wave guide stand
10. Detector mount
11. SWR meter and accessories.

Theory :

The device magic Tee is a combination of the E and H plane Tee. Arm 3, the H-arm forms an H plane Tee and arm 4, the E-arm forms an E plane Tee in combination with arm 1 and 2 a side or collinear arms. If power is fed into arm 3 (H-arm) the electric field divides equally between arm 1 and 2 in the same phase, and no electrical field exists in arm 4. Reciprocity demands no coupling in port 3 (H-arm). If 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.



Magic Tee

The basic parameters to be measured for magic Tee are defined below.

1. Input SWR

Value of SWR corresponding to each port, as a load to the line while other ports are terminated in matched load

2. 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 (port 3) when side arms 1 and 2 are terminated in matched load.

Hence,

$$\text{Isolation (dB)} = 10 \log_{10} \left[\frac{P_4}{P_3} \right]$$

Similarly, isolation between other parts may also be defined

3. Coupling coefficient.

It is defined as $C_{ij} = 10^{-\alpha/20}$

Where

α = attenuation / isolation in dB

'i' is input arm

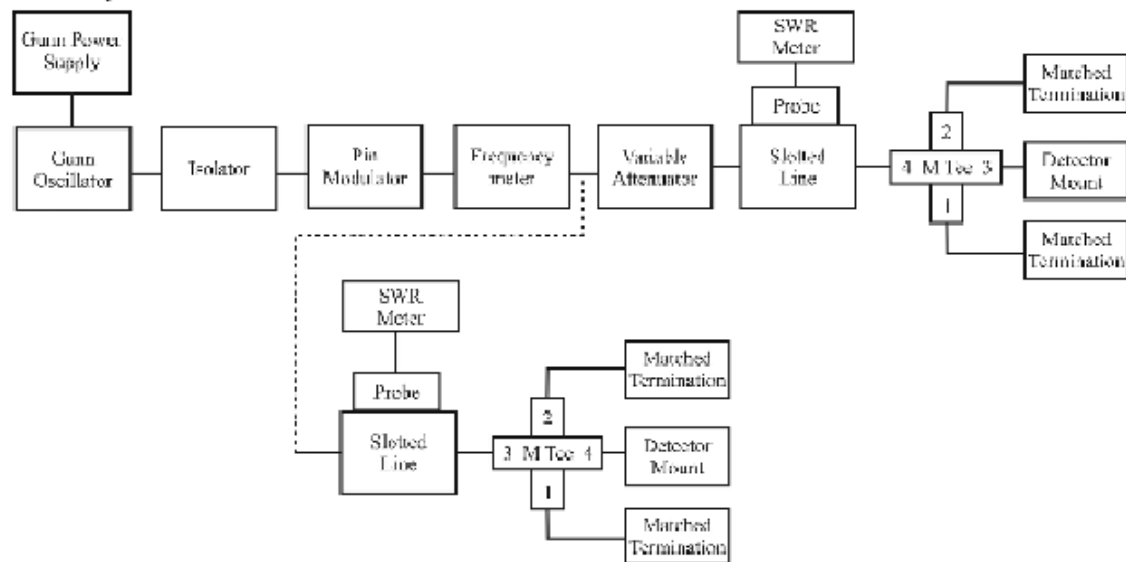
'j' is output arm.

Thus
$$\alpha = 10 \log_{10} \left[\frac{P_i}{P_j} \right]$$

Where

P_i is the power delivered to arm i

P_j is power detected at j arm.



Setup for the study of Magic Tee

Procedure :

1. SWR Measurement of the Ports

- a. Set up the components and equipments as shown in figure keeping E arm towards slotted line and matched termination to other ports.
- b. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.
- c. Measure the SWR of E-arm as described in measurement of SWR for low and medium value.
- d. Connect another arm to slotted line and terminate the other port with matched termination. Measure the SWR as above. Similarly, SWR of any port can be measured.

2. Measurement of Isolation and Coupling Coefficient

- a. Remove the tunable probe and Magic Tee from the slotted line and connect the detector mount to slotted line.
- b. Energize the microwave source for particular frequency of operation and tune the detector mount for maximum output.
- c. With the help of variable attenuator and gain control knob of SWR meter, set any power level in the SWR meter and note down. Let it be P3.
- d. Without disturbing the position of variable attenuator and gain control knob, carefully place the Magic Tee after slotted line keeping H-arm connected to slotted line, detector to E arm and matched termination to arm 1 and 2. Note down the reading of SWR meter. Let it be P4.
- e. Determine the isolation between port 3 and 4 as $P3-P4$ in dB.
- f. Determine the coupling coefficient from equation given in the theory part.
- g. The same experiment can be repeated for other ports also.
- h. Repeat the above experiment for other frequencies.

EXPERIMENT NO 8

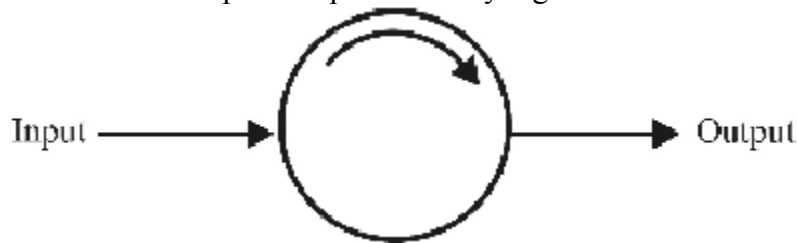
Objective : Study of Isolator and Circulators

Apparatus required :

1. Microwave source
2. Power Supply for source
3. Isolators
4. Circulators
5. Frequency meter
6. Variable attenuator
7. Slotted line
8. Tunable probe
9. Detector mount
10. SWR meter
11. Test isolation and
12. Circulation and accessories

Theory :

Isolator : An isolator is a two-port device that transfers energy from input to output with little attenuation and from output to input with very high attenuation.



Circulator : The circulator is defined as a device with ports arranged such that energy entering a port is coupled to an adjacent port but not coupled to other ports. Refer to the figure. A wave incident on port 1 is coupled to port 2 only, a wave incident at port 2 is coupled to port 3 only and so on.



Following are the basic parameters of isolator and circulator for study.

1. 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.

2. Isolation

It is the ratio of power fed to input arm to the power detected at not coupled port with other port terminated in the matched load

3. Input VSWR

The input VSWR of an isolator or circulator is the ratio of voltage maximum to

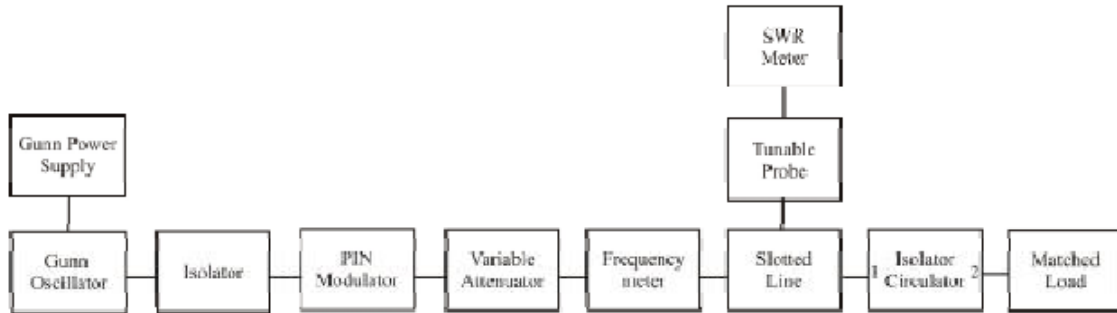
voltage minimum of the standing wave existing on the line when one port of it terminates the line and other have matched termination.

Note : When port which is not coupled to input port is terminated by matched termination it marks as Isolator. (Two port device).

Procedure :

1. Input VSWR Measurement

a. Set up the components and equipments as shown in the with input port of isolator or circulator towards slotted line and matched load on other ports of it

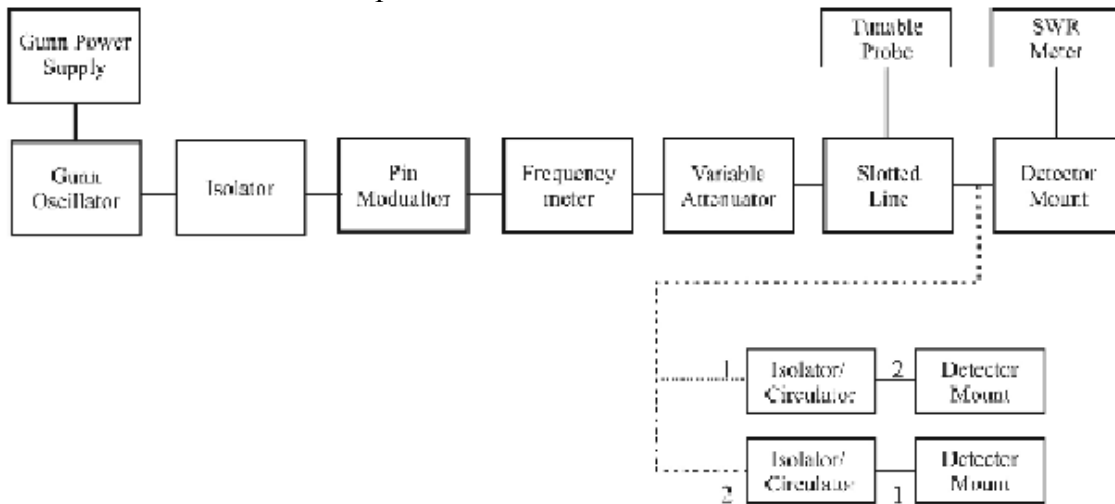


Measurement of VSWR of Isolator or Circulator

- b. Energize the microwave source for particular operation of frequency.
- c. With the help of slotted line, probe and SWR meter. Find SWR, of the isolator or circulator as described for low and medium SWR measurements.
- d. The above procedure can be repeated for other ports or for other frequencies.

2. Measurement of Insertion Loss and Isolation.

a. 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 SWR meter.



Setup for Measurement Loss & Isolation of Isolator & Circulator

- b. Energize the microwave source for maximum output particular frequency of operation. Tune the detector mount for maximum output in the SWR Meter.
- c. Set any reference level of power in SWR meter with the help of variable attenuator and gain control knob of SWR meter. Let it be P1.
- d. 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 a third port in case of circulator.
- e. Record the reading in the SWR meter. If necessary change range –dB switch to high or lower position and 10dB change for one step change of switch position. Let it be P2.
- f. Compute insertion loss on P1 – P2 in dB.
- g. For measurement of isolation, the isolator or circulator has to be connected in reverse i.e. output port to slotted line and detector to input port with another port terminated by matched termination (in case circulator) after setting a reference level without isolator or circulator in the set up as described in insertion loss measurement. Let same P1 level is set.
- h. Record the reading of SWR meter inserting the isolator or circulator as given in step 7. Let it be P3.
- i. Compute isolation as P1 - P3 in dB.
- j. The same experiment can be done for other ports of circulator.
- k. Repeat the above experiment for other frequencies if required.

EXPERIMENT NO 9

Objective :

Study of Attenuators

Apparatus required :

- 1 Microwave source
- 2 Isolator
- 3 Frequency meter
- 4 Variable attenuator
- 5 Slotted line
- 6 Tunable probe
- 7 Detector mount
- 8 Matched termination
- 9 SWR meter.

Theory :

The attenuators are two port bi-directional devices which attenuate power when inserted into the transmission line

Where

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

P_2 = Power absorbed/detected by the load with attenuator in 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 wave-guide. As electric field is maximum, at center in TE₁₀ mode, the attenuation will be maximum if the vane is placed at center of the wave-guide. Moving from center toward the side wall, attenuation decreases in the fixed attenuator, the vane position is fixed whereas in a variable attenuator, its position can be changed by help of micrometer or by other methods.

Following characteristics of attenuators can be studied

1. Input SWR.
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.

Procedure :

1. Input SWR Measurement

- a. Connect the equipments as shown in the figure 39
- b. Energize the microwave source for maximum power at any frequency of operation.
- c. Measure the SWR with the help of tunable probe, Slotted line and SWR meter as described in the experiment of measurement of low and medium SWR.
- d. Repeat the above step for other frequencies if required.

EXPERIMENT NO 10

Objective :

Study the Phase Shifter

Apparatus required :

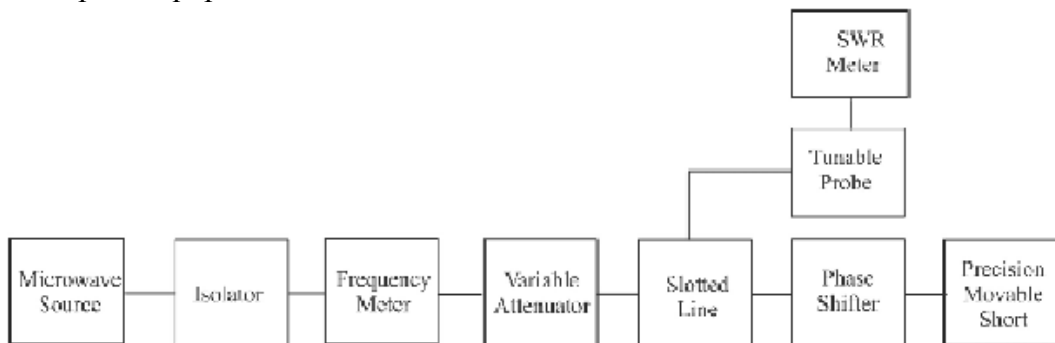
1. Microwave source
2. Isolator
3. Variable attenuator
4. Frequency meter
5. Slotted section
6. Tunable probe
7. Phase shifter
8. Precision Movable short
9. SWR Meter
10. Cables and accessories

Theory :

A phase shifter consists of a piece of Wave-guide and a dielectric material inside the wave-guide placed parallel to Electric vector of TE₁₀ mode. The phase changes as piece of dielectric material is moved from edge of wave-guide towards the center of the wave-guide.

Procedure :

1. Set up the equipment as shown in the



Setup for Study of Phase Shifter

2. First connect the Matched termination at the end of slotted line.
3. Energize the microwave source for maximum output at particular frequency of operation.
4. Find out the λ_g (guide wavelength) with help of tunable probe Slotted line and SWR meter. It is the twice the distance between two minimas on the slotted line.
5. Now connect the precision movable short at the place of matched termination & find out the minima for this setup.
6. Note and record the reference minima position of precision movable short from its micrometer. Let it be X
7. Remove carefully the movable short from the slotted line without disturbing its current position. Place the phase shifter to the slotted line with its micrometer reading at zero and then

place the movable short to the other port.

8. The reference minima will shift from its previous position, rotate the micrometer of movable precision short to get the reference minima again and note the micrometer reading of movable short.

9. Now Open the phase shifter in suitable steps & record the corresponding micrometer reading of movable short. Measure the phase shift as per the given example.

| Micro meter reading of Phase shifter | Micro meter reading of Precision movable short |
|--------------------------------------|--|
| 2 mm | |
| 4 mm | |
| 6 mm | |
| 8 mm | |
| 10 mm | |

Calculation :

We can calculate phase shift in terms of degree by

$$\lambda g = 360^\circ \text{ (One cycle)}$$

For example : If $\lambda g = 4.32 \text{ cm}$

Phase shifter position is moved to 2mm. Now the reference minima gets changed. Vary the precision movable short to get the reference minima position say 0.5 cm now the shift in phase is

Since, $4.32 \text{ cm} = 360^\circ$

So phase shift for 0.5cm will be

$$= \frac{360 \times 0.5}{4.32} = 56^\circ$$