UNIT-VIII

MICROWAVE MEASUREMENTS

EXPERIMENT-I
VSWR MEASUREMENT

I. AIM
To measure VSWR of a given unit under lest.

II. THEORETICAL CONCEPT
VSWR means Voltage Standing Wave Ratio. Standing waves indicate the quality of transmission. The well matched loads have no reflections and VSWR is one.

$$VSWR = V_{max} / V_{min}$$

III. EQUIPMENT REQUIRED
- Klystron power supply
- Reflex klystron
- Isolator
- Frequency meter
- Variable attenuator
- Slotted line
- Klystron mount
- Detector with probe
- VSWR meter
- BWC cable
- SS tuners
- Matched terminals
- Movable short or unit under lest
- Cooling fan

IV. EXPERIMENTAL SETUP

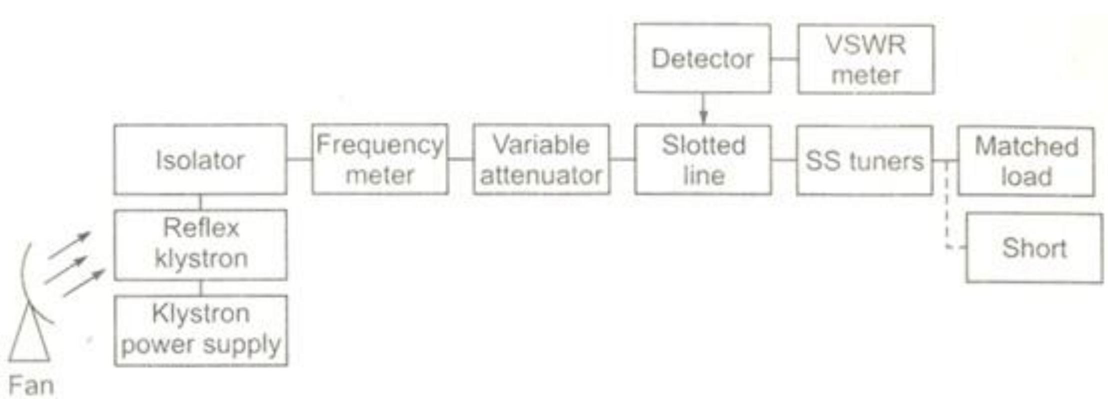

Fig 8.1: Experimental set-up for measurement of VSWR

V. PROCEDURE

For Low VSWR Values

1. Connect the components as in fig. 8.1
2. Keep variable attenuator at maximum
3. Switching ON klystron power supply. VSWR meter and cooling fan.
4. Set beam voltage to 300 V.
5. Adjust the reflector voltage to obtain deflection in VSWR meter.
6. Tune the output with the help of reflector voltage amplitude and frequency *of AM.*
7. Tune klystron to get maximum deflection in the meter
8. Adjust attenuation, gain control knob and dB switch to get deflection in the scale of VSWR meter.
9. Move the probe to get maximum deflection in VSWR meter.
10. Set the VSWR meter gain control knob or attenuator till the meter indicates 1.0 on normal scale of 0 to ∞
11. Keeping the control knobs fixed, move the probe to the next minimum position. Note the VSWR from the scale.
12. Now change SS tuner probe and repeat the steps 9 to 11. Note VSWR each position.
13. Change dB range in VSWR meter corresponding to the value of VSWR.

Measurement of High Values of VSWR (Double Minimum Method)

1. Set a convenient frequency when the matched load is in place.
2. The probe is so inserted to a depth where the minimum is read without difficulty.(3 dB)
3. The probe is moved to a point where the power is twice the minimum. Let the position be d_1 (0 dB)
4. The probe is moved to the twice power point the other side of the minimum. Let this point be d_2 (0 dB)
5. Calculate the VSWR from $VSWR = \frac{\lambda_g}{\pi(d_1 - d_2)}$

Here λ_g is guide wavelength.
Replace matched termination by short.

6. Repeat the above steps for different frequencies.
7. Tabulate the results as shown in table 7.1

Table 8.1: Measurement of VSWR by double minimum method

Frequency	Matched Load			Short		
	d_1	d_2	VSWR	d_1	d_2	VSWR
f_1						
f_2						
f_3						

VI. PRECAUTIONS

1. An isolator or attenuator should be used between the klystron and the other equipment in the setup to avoid loading of the klystron.
2. While measuring frequency, frequency meter should be detuned each time.
3. The negative repeller voltage should be applied first before anode **voltage** is applied.
4. Before switching on power supply, the control knobs of klystron power supply should be kept as below :

   Meter switch : OFF
   Mode switch : *AM*
   Beam voltage knob : Fully anti-clockwise
   Reflector voltage : Fully clockwise
   AM- Amplitude : Fully clockwise
   AM - Frequency knob : Mid position
5. The control knob of VSWR meter should kept as below
   Meter switch : Normal
   Input Switch : Low impedance position
   Range dB switch : 40/50 dB
   Gain control knob : Fully clockwise
6. Cooling fan should be used to avoid heating of klystron tube.

EXPERIMENT- II
MICROWAVE POWER MEASUREMENT

I. Aim: To measure **microwave** power

II.THEORETICAL CONCEPTS

Microwave power measurements are divided into three power ranges.

1. Low power (less than 1 mW)
2. Medium power (between 1 mW and 10 W)
3. High power (greater than 10 W)

Power at microwave frequencies is detected by

- Bolometer
- Thermo coupler
- Microwave crystal

Bolometers: These are used to detect power. Their operation depends on thermal principles. When microwave power falls over the surface, it gets converted into heat rising the temperature. The bolometer resistance varies with temperature. The impedances of bolometers are in the range 100-200 ohm. The temperature is in turn influenced by the power absorbed. The power absorbed is proportional to the resistance. The Bolometers are two types.

(a) Barretters: Whose resistance rises with temperature
(b) Thermistors: Whose resistance falls with temperature.

Thermo-Couplers: Thermo-couplers are also used as power detectors. The voltage across a thermo-couplers changes with the difference in temperature at the junctions. The voltage is proportional to the power.

Microwave Crystals: The **microwave** crystals are nothing but rectifiers which are basically nonlinear. The rectified output is proportional to the power

1. Low Power Measurement (1 to 10 mW) by Bolometer

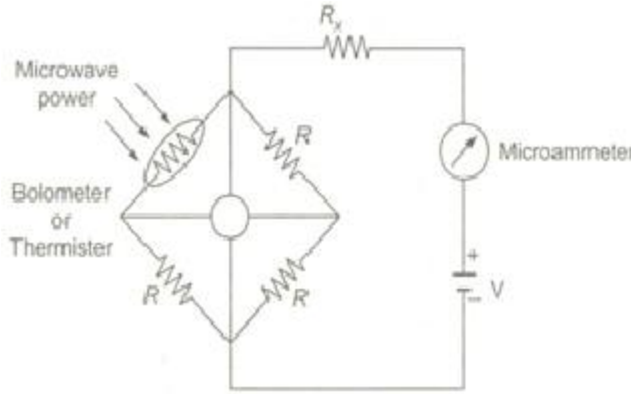

Fig 8.2: Power measurement by bridge circuit using bolometer

Bolometer is a temperature sensitive device. When microwave power is applied to bolometer, its temperature changes which in turn changes its resistance. The change of resistance is measured using a bridge circuit like Wheatstone Bridge shown in Fig 8.2.

The bolometer is connected in one of the arm of the bridge. Initially the bridge is balanced in the absence of incident of power. When microwave power is applied, imbalances of the bridge takes place due to change in resistance. This change in resistance is measured and hence the power is measured by rebalancing with R_x.

The power is measured from

$$P = \frac{1}{4}\left(I_1^2 - I_2^2\right)Rb$$

I_1 = initial current
I_2 = changed current through bolometer
R_b = Bridge Resistance

III EQUIPMENT REQUIRED

- Reflex klystron
- Klystron power supply
- Frequency meter
- Variable attenuator
- Power meter
- Thermistor and its mount
- Voltmeter
- Waveguide stands
- Waveguide to coaxial adaptors

IV. EXPERIMENTAL SETUP

The measurement setup is shown in fig. 8.3.

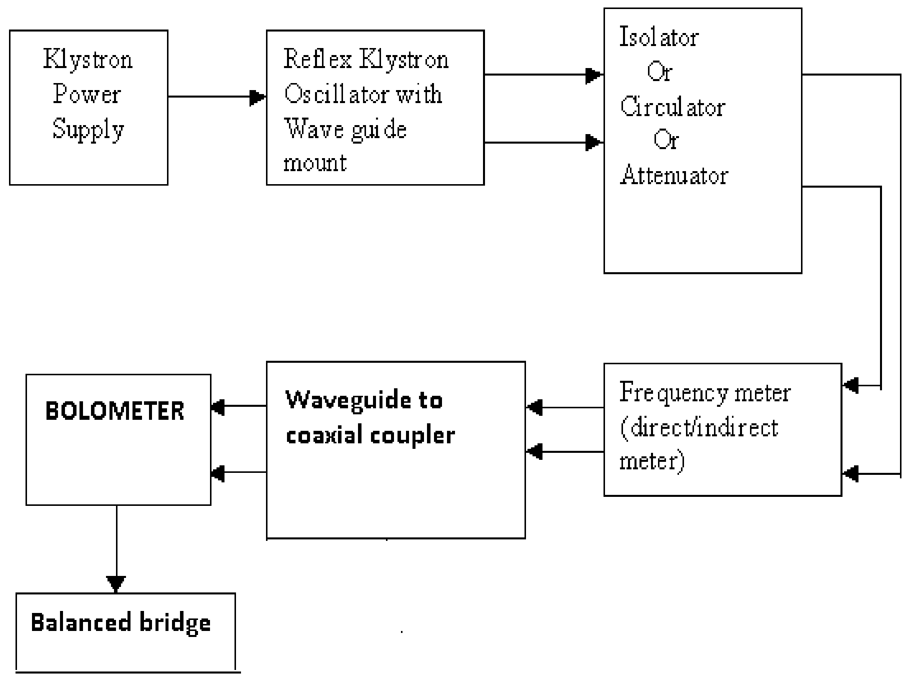

Fig 8.3: Experimental setup for power measurement

2. High Power measurement by calorimetric method

Calorimetric method is useful for high microwave powers. It involves conversion of the microwave energy into heat, absorption of heat by some liquid or dielectric and then measurement of the rise in temperature of the liquid / dielectric.

(a)Static Calorimeter

It consists of a 50 ohm coaxial cable filled with a dielectric load with a high hysteresis loss. The incident microwave power is dissipated in the load. The average input is

$$P = \frac{4.18\ m\ T\ C_p}{t}$$

Where t = Time in seconds
T = Temperature in ^oC
Cp = Specific heat in cal/gm
m = Mass of the medium in grams

(b)Circulating calorimeter

In this method the power is made to incident on the water flowing at a constant rate through a water load. The heat introduced into the fluid makes the exit temperature to be higher than the input temperature. The incident power is then measured using the relation

$$P = 4.18\ v\ d\ C_p\ T \text{ Watts}$$

Where v= Rate of the flow of the fluid in cc/s

d = the specific gravity of the fluid in gm/s

Cp = Specific heat in cal/gm.

T= outlet temp – inlet temp

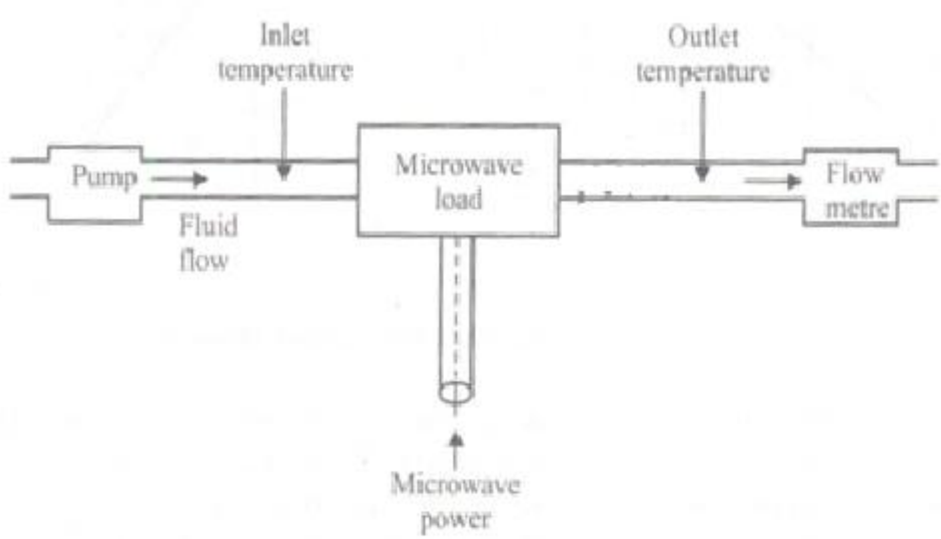

Fig 8. 4 : Measurement of microwave power with calorimeter

EXPERIMENT -III
MEASUREMENT OF INSERTION LOSS AND ATTENUATION

I. AIM
To study the attenuators (fixed and variable type)

II. THEORETICAL CONCEPTS

Definition

An attenuator is a device which reduces the power of the signal when the signal passes through it.

Attenuation is the real part of propagation constant and is the reduction of the power and is expressed in positive decibels for convenience. The attenuation of the attenuator is

$$\alpha = 10 \log_{10} \frac{p_i}{p_0}$$

Here, P_i = input power
P_O = output power

Types of Attenuators
There are
- Fixed attenuators
- Step attenuators
- Continuously variable attenuators

Fixed Attenuators
In these, the attenuation is reduced by a fixed amount. The 3 dB. 10 dB, 20 dB attenuators arc available. These attenuators are made of film resistors around a center conductor and disks. The film resistor attenuators are useful at wide range of frequencies as they exhibit constant values. In this, the material depth is less than the skin depth. The attenuators are specified by frequency and attenuation in dB.

The fixed attenuators are also called pads. For example, 6 dB pad means the output power of attenuator is one-fourth of the input.

Continuously Variable Attenuators
The attenuation is given by

$$\alpha = 2\pi \sqrt{\left(\frac{1}{\lambda_c}\right)^2 - \left(\frac{1}{\lambda}\right)^2}$$

Here, α is attenuation

λ_c. is cut-off wavelength
λ = free space wavelength

Salient Features of Attenuator

1. It reduces input power given to it.
2. It is a two-port reciprocal network.
3. Its scattering matrix is

$$S = \begin{bmatrix} 0 & s_{12} \\ s_{21} & 0 \end{bmatrix}$$

4. S_{11}=S_{12}=0
5. It has transmission coefficients.
6. Fixed attenuation uses a tapered edge of resistive vane which is made of lossy material.
7. A variable attenuator consists of a tapered resistive card. The depth of penetration into the waveguide is adjustable.
8. Accuracy of the attenuator increases if the resistive card is replaced by a piece of a metal film with glass coating.
9. The variable attenuator is frequency sensitive and some phase shift is introduced while changing the attenuation.
10. Variable attenuators arc constructed by placing lossy resistive card in the waveguide—its surface parallel to the electric field.
11. The variation of attenuation depends on the mount of card insertion. The card is tapered to
minimize the reflection.

III. EQUIPMENT 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

IV. PROCEDURE

B. Insertion Loss/Attenuation Measurement

1. Connect the setup as in fig. 8.5,

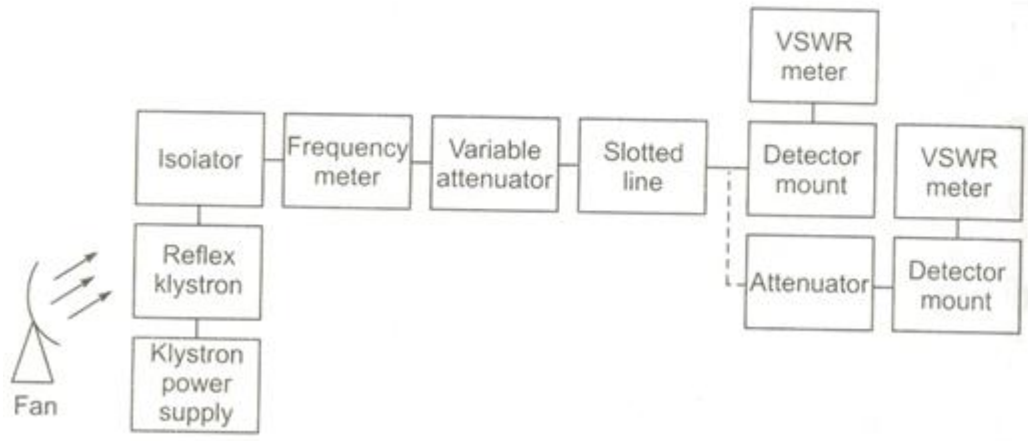

Fig 8.5: Setup for insertion loss & attenuation measurement of attenuator

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. Keep any reference level on the VSWR meter with the help of variable attenuator and gain control knob of VSWR meter. Let it be P_1
4. Disconnect the detector mount from the slotted line, without disturbing any position on the setup. 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 the 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 $P_1 – P_3$ 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. Set another operating frequency and repeat the above steps for finding frequency sensitivity of fixed and variable attenuator.

V. PRECAUTIONS

1. An isolator or attenuator should be used between the klystron and the other equipment in the setup to avoid loading of the klystron.

2. While measuring frequency, frequency meter should be detuned each time 3. The negative repeller voltage should be applied first before anode voltage is applied.
4. Before switching on power supply, the control knobs of klystron power supply should be kept as below :
   Meter switch : OFF
   Mode switch : *AM*
   Beam voltage knob ; Fully anti-clockwise
   Reflector voltage : Fully clockwise
   AM - Amplitude : Fully clockwise
   AM - Frequency knob : Mid position
5. The control knob of VSWR meter should kept as below Meter switch; Normal Input Switch : Low impedance position
   Range dB switch : 40/50 dB
   Gain control knob : Fully clockwise
6. Cooling fan should be used lo avoid heating of klystron lube.

EXPERIMENT IV
MEASUREMENT OF UNKNOWN IMPEDANCE

I. AIM
To find out unknown impedance using slotted line.

II. THEORETICAL CONCEPTS

The impedance of an antenna or a transmission line is a parameter. It is always expressed in terms of load and characteristic impedances.

If $Z_L \neq Z_0$. reflection takes place. The magnitude of the reflection coefficient, VSWR, phase, relative position of standing wave patterns with respect to short-circuit, characteristic impedance are important parameters of the load.
The input impedance of a transmission line is defined as

$$Z_{in} = \frac{V_s}{I_s}$$

And it is given by

$$Z_{in} = \frac{V_L \cosh \gamma\ell + \sin Z_0 h \gamma\ell}{I_L \cosh \gamma\ell + \frac{V_L}{Z_0} \sinh \gamma\ell}$$

here $\gamma = \alpha + j\beta,\ if\ \alpha = 0, \gamma = j\beta$

For a line of length,

$$Z_L = Z_0 \left(\frac{1 - j\rho \tan \beta\ \Delta\ell}{\rho - j \tan \beta\ \Delta\ell} \right)$$

Here. Z_L = the impedance al the receiving end
Z_0 = characteristic impedance
Z_{in} = input impedance

ρ = reflection coefficient = $\frac{VSWR - 1}{VSWR + 1}$

$\beta\ \Delta\ell$ = electrical distance in wavelength

$Z_o = \eta_o / \sqrt{1-(\lambda_o/\lambda_c)^2}$, $\eta_o = 120\pi$, $\lambda_o = c/f$ and $\lambda_c = 2a$

where a = 2.25 cm.(Specific case)

III. EQUIPMENT REQUIRED

- Gunn power supply
- Gunn oscillator
- Isolator
- Frequency meter
- Variable Attenuator
- Slotted line
- Tunable probe
- Detector
- VSWR meter
- Short
- Unknown load
- Impedance.

IV. EXPERIMENTAL SETUP

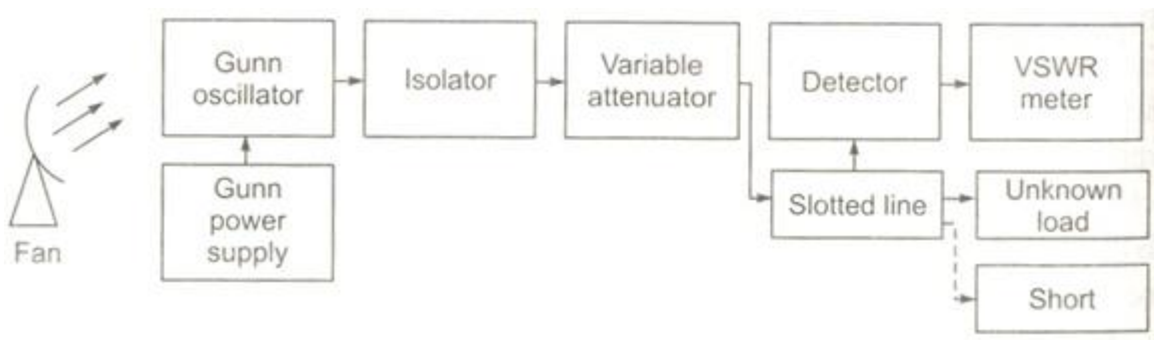

Fig 8.6: Experimental setup for the measurement of unknown impedance

V. PROCEDURE

1. Assemble the components as in fig. 8.6
2. Set variable attenuator for maximum attenuation
3. Connect the unknown load.
4. Switch on the Gunn power supply and set the micrometer of Gunn oscillator for required operating frequency.
5. Keep the mode switch power supply to square wave with modulation frequency of 1KHz
6. Move the probe along the slotted line for a minimum. Let it be a reference value at X_1
7. Obtain next successive minimum at X_2
8. Replace load by a short.
9. Move the probe to a new minimum at X_S.

10. Find out $X_s - X_2$ or $X_s – X_1$. It is positive (capacitive) if the minimum is shifted towards load. It is negative (inductive) if minimum is shifted towards generator.
11. Find out $(X_s – X_1)\lambda_g$
12. Find out the load impedance $Z_L = Z_0\left(\frac{1 - j\rho\tan\beta\Delta\ell}{\rho - j\tan\beta\Delta\ell}\right)$ from

Here, ρ = Reflection Coefficient $\beta\,\Delta\ell = 2\pi(X_2 - X_1)/\lambda_g$