5.5 MICROWAVE POWER MEASUREMENT, BOLOMETERS

Q30. Explain the measurement of power using bolometer method.

Ans: Model Paper-I, Q11(a)

Measurement of Microwave Power using Bolometer: Bolometer is a simple temperature sensitive device, whose resistance varies with temperature. It is also called as square law device, since it produces a current which is proportional to the applied power i.e., square of the applied voltage.

Figure shows the circuit arrangement of balanced bolometer bridge technique in which bolometer itself is used in one of the arms of the bridge.

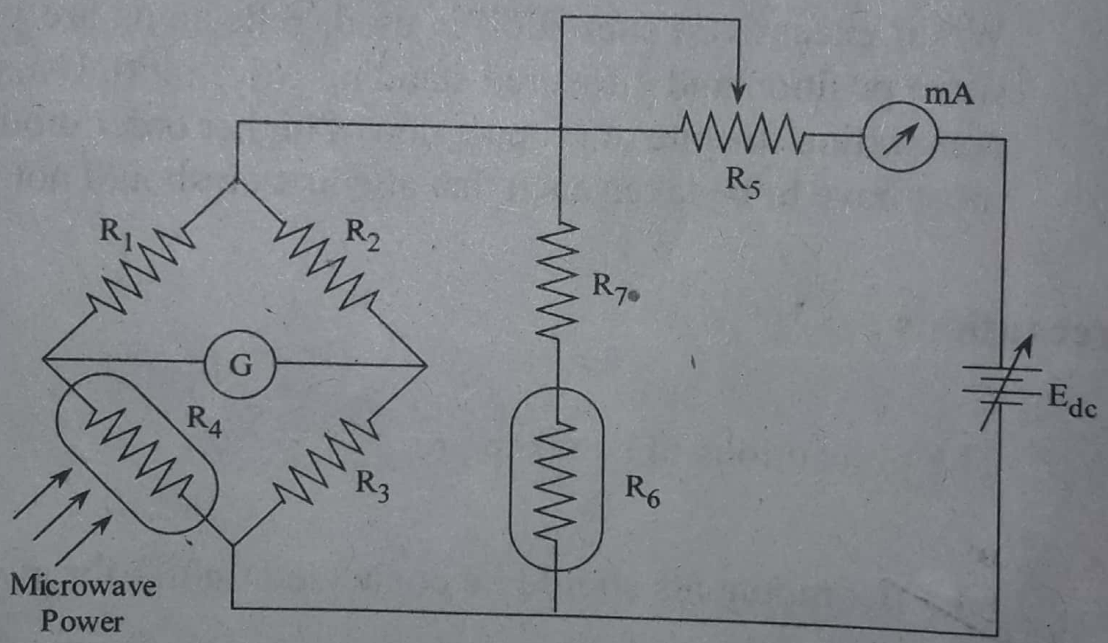


Figure: Balanced Bolometer Bridge

Initially, the value of R_5 is adjusted in such a way that, it not only varies the D.C power applied to the bridge but also balances the bridge. Before the application of microwave power, the bolometer element is brought to a predetermined operating resistance. At the balanced bridge condition, E_1 be the voltage of the battery. The applied microwave power gets dissipated in the bolometer. Thus, the resistance of bolometer is changed due to heating, which leads to the unbalancing of the bridge.

Now, E_2 be the applied D.C power to bring back the bridge to balancing condition. Hence, this change in D.C battery voltage, $(E_1 - E_2)$ will be proportional to the microwave power. When the bridge is unbalanced, the detector reads the microwave power directly as the detector G can be directly calibrated in terms of microwave power.

The errors in the above method must be avoided by providing some type of temperature compensation, because the bolometers are temperature sensitive. The resistors R_6 and R_7 in the circuit arrangement shown in figure provide the required temperature compensation.

Q31. Write short notes on the measurement of medium microwave power.

Ans:

Measuring Medium Microwave Power: The power in the range of 10 mW to 10 W is considered as medium power.

This range of powers are best measured using calorimetric techniques. In calorimetric technique, the rise in temperature of a load is observed and the corresponding power applied is measured. The load selected must have high specific heat (e.g, water). In this method the power is measured based on mass, specific heat, temperature rise values at a constant fluid flow rate.

The method normally used for medium power measurements is the self balancing bridge technique, whose setup is shown in figure.

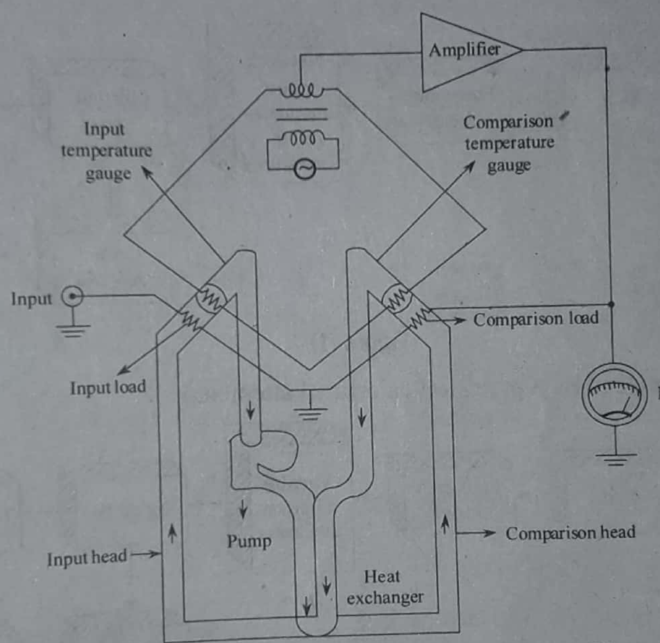


Figure: Self Balancing Bridge Setup for Medium Power Measurement

The setup consists of,

1. Two identical temperature gauges (temperature sensitive resistors)
2. An indicating meter
3. Two load resistors.

The two identical gauges along with the two load resistors are placed in the two arms [input and output arms]. The output arm is referred to as comparison head, the resistor load as comparison load and the gauge as comparison temperature gauge. Similarly the input side arm, resistor load and gauge are called as input head, input load and input temperature gauge respectively.

Operation: When an unknown input power is applied by a microwave source, heat is generated in the input load resistor which raises the temperature of the gauge. This unbalances the bridge. The resulting signal is amplified and applied to the comparison load resistor which heats up the comparison temperature gauge and the bridge is rebalanced. The meter on the comparison side measures this power which is directly equal to the unknown input power.

In this way, the medium power is measured using calorimetric techniques.

5.6 MEASUREMENT OF ATTENUATION, FREQUENCY, STANDING WAVE MEASUREMENTS - MEASUREMENT OF LOW AND HIGH VSWR, CAVITY Q

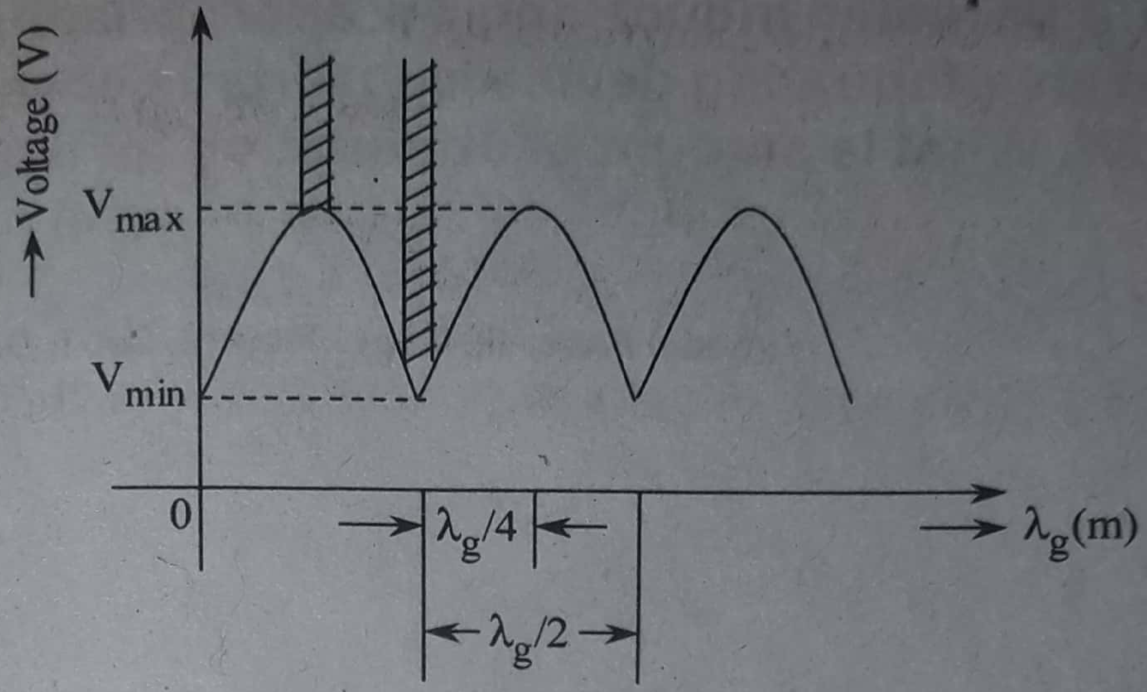
...titution method of measurement of attenuation. Model Paper-II, Q11(a)

Q7. Define VSWR. Model Paper-III, Q

Ans: Voltage standing wave ratio is defined as the ratio of maximum to minimum voltage on a line having standing waves i.e.,

$$\text{VSWR}, S = \frac{|V_{max}|}{|V_{min}|}$$

Figure shows the standing waves along the length of the line, which are due to the mismatch of load at the termi



Figure

And, the expression for VSWR is given by,

$$S = \left|\frac{V_{max}}{V_{min}}\right| = \frac{1+|K|}{1-|K|}$$

Where,

$$K = \text{Reflection coefficient} = \frac{V_r}{V_i}$$

When $K = 0$, $S = 1$

When $K = 1$, $S = \infty$

When $K = \infty$, $S = 1$

Q37. Define VSWR. Describe the methods for measuring high and low VSWRs.

Model Paper-III, Q11(a)

(or)

Discuss methods for measurement of low and high VSWR.

Nov.-15, (R09), Q8(a) M[8]

(or)

What is VSWR? Explain the method measurement for low and high VSWR?

Ans:

Nov.-13, (R09), Q8(b) M[8]

Voltage Standing Wave Ratio (VSWR)

For answer refer Unit-V, Q17.

1. Low VSWR Measurement (S < 10)

Figure (2) shows the setup which is used to measure low VSWRs i.e., less than 10 and the readings are directly taken from the VSWR meter.

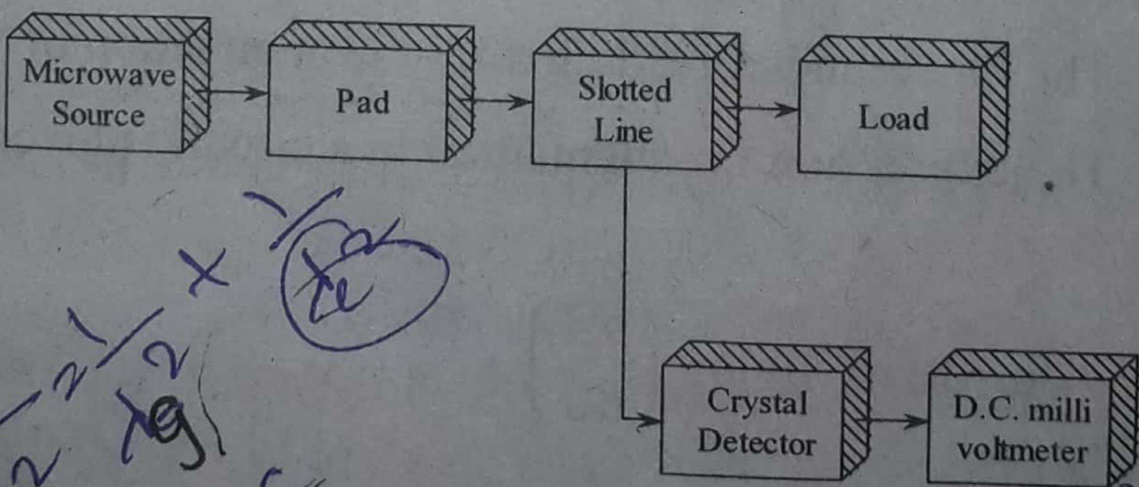


Figure (2)

In this method of measurement, an adequate reading on D.C. milli voltmeter is taken by simply adjusting the attenuator. The maximum reading on the meter can be obtained by moving the probe on slotted waveguide i.e., V_{max}. Now, the full scale reading is noted down by adjusting the value of attenuator. Next, the minimum reading on the meter i.e., V_{min} is obtained by adjusting the probe on the slotted line. Then, the ratio of first reading i.e., V_{max} to the second reading i.e., V_{min} gives VSWR.

When the meter is calibrated in terms of VSWR, the maximum deflection on the VSWR can be obtained by adjusting the pad.

When VSWR > 10, the meter will be congested and accurate measurement is not possible. So, the above method is not suitable for VSWR > 10.

2. High VSWR Measurement (S > 10)

The method which is used to measure high VSWRs i.e., greater than 10 is called as double minimum method. In this method, the minimum deflection on the VSWR meter can be read by inserting the probe to the required depth. Let d_1 be the position where the power is twice the minimum, which is obtained by moving the probe. Now, the probe is moved to twice the power point on the other side of the minimum and is denoted by d_2 shown in figure (3).

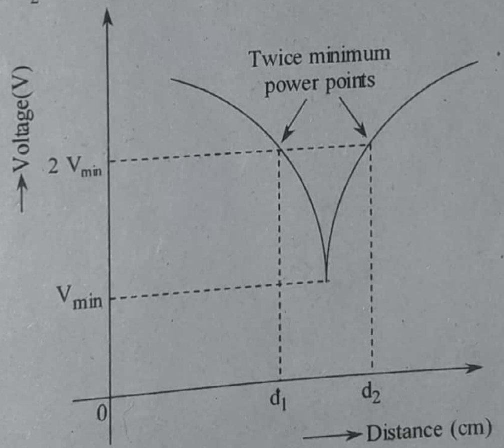


Figure (3)

Then, VSWR can be calculated using the formula,

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

Where,

$$\lambda_g = \text{Guided wavelength} = \frac{\lambda_o}{\sqrt{1-\left(\frac{\lambda_o}{\lambda_c}\right)^2}}$$

λ_c = Cutoff wavelength = $2a$ (for TE_{10} mode)

λ_o = Operating wavelength = $\frac{c}{f}$

...determine the SWR

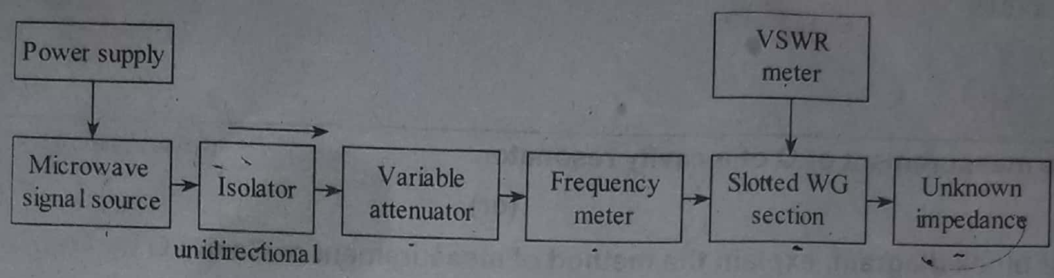
5.7 IMPEDANCE MEASUREMENTS

Q42. Describe the measurement of impedance using slotted line and Smith chart.

Ans:

Model Paper-II, Q11(

Measurement of Impedance using Slotted Line: Microwave test bench holds good for measurement for almost any microwa parameter is as shown in figure below.



Figure

An unknown impedance is connected to the load, to measure VSWR, wavelength and position of voltage at first minim (x_1). The unknown impedance and load at terminated output are then replaced by short circuit. The position of voltage at fir minima (x_2) is now measured. The shift in minimum is measured as, $\frac{(x_2 - x_1)}{\lambda}$. On Smith chart a circle is plotted with cente VSWR and the load as radius. The shift in minima on the circumference of the Smith chart is marked. The shift in minima poir on the Smith chart is then corrected to the centre of the VSWR circle (i.e., one) by drawing the line. The point at which this lin cuts the circle gives the value of unknown impedance as $R + jX$ or $R - jX$.

Procedure for Calculating Impedance using Smith Chart

1. Obtain the normalized impedance for the given load impedance Z_R using the relation,

   $Z_r = \frac{Z_R}{Z_o}$; Where $Z_o \rightarrow$ Characteristic impedance.

2. Plot the normalized impedance Z_r in the Smith chart say point p.
3. Now rotate point p in the clockwise direction through a distance equal to length of line.
4. By rotating the point p through a distance equal to the length of the line, to obtain a point Q.
5. The coordinates of Q will give the desired normalized impedance.
6. Finally, the input impedance of a given transmission line is obtained by multiplying normalized impedance with the characteristic impedance.

How to measure an attenuation of a given microwave signal?

Nov.-13, (R09), Q8(a) M[7]

Ans:

Measurement of Attenuation: The ratio of input power to the output power is known as attenuation. Generally, it is expressed in decibels (dB).

i.e., $\boxed{\text{Attenuation (dB)} = 10\log\dfrac{P_i}{P_o}}$

Where,

P_i = Input power

P_o = Output power

The commonly used method for the measurement of attenuation is RF substitution method. This method is particularly suitable for the networks with large attenuation and low input powers because the attenuation is measured at a single power position. Thus, the results obtained are accurate compared to the power ratio method. Figure (1) shows an arrangement used for the measurement of output power, P by including a network whose attenuation has to be measured.

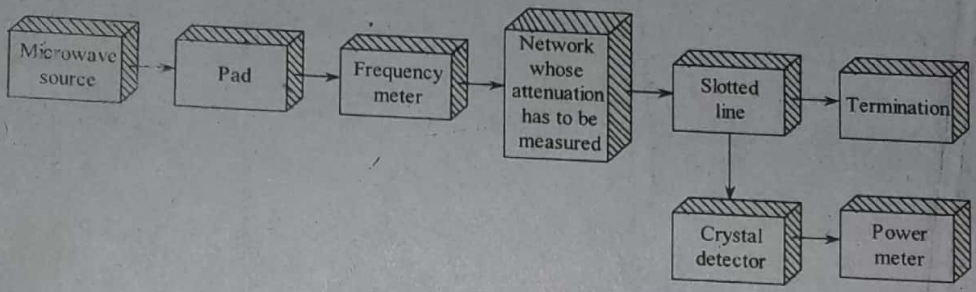


Figure (1)

In figure (2), the network is replaced by a precision calibrated attenuator.

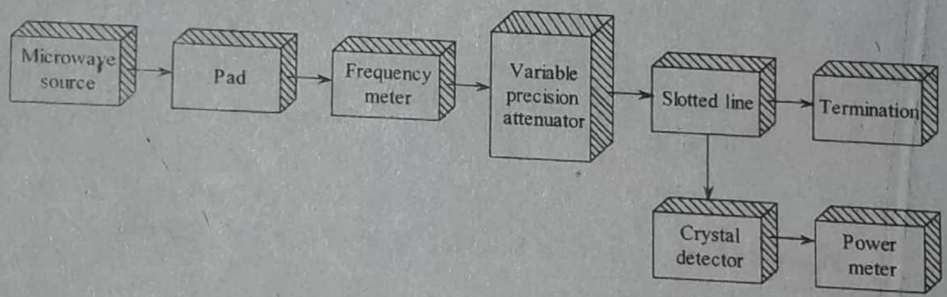


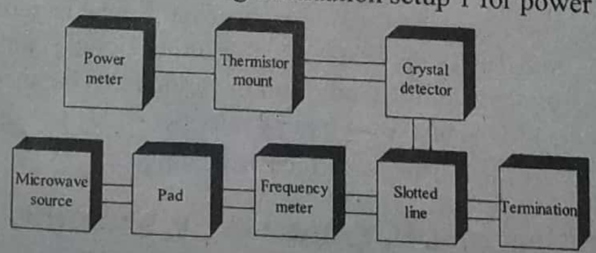
Figure (2)

The precision attenuator is adjusted to obtain the same power, P as measured in arrangement of figure (1). In this case the attenuation of the network is measured by directly reading value from precision attenuator.

Q33. Explain the power ratio method of measurement of attenuation.

Ans:

power ratio method is the most simplest way of measuring attenuation setup 1 for power ratio method is shown below:



Figure

In this method, input and output power are measured with or without the device whose attenuation is to be measured. In setup the device whose attenuation is to be measured is added in between the frequency meter and the slotted line. The ratio of power measured in each setup, i.e., P_1/P_2 gives the attenuation in decibels.

Limitations: The following are the limitations of power ratio method,

5.4 DESCRIPTION OF MICROWAVE BENCH – DIFFERENT BLOCKS AND THEIR FEATURES, ERRORS AND PRECAUTIONS

Q27. Describe a microwave bench.

(Model Paper-III, Q10(b) | May-10, Set-2, Q8(b) M[8])

(or)

Draw the block schematic of a typical microwave bench and explain the functionality of each component.

Dec.-14, (R09), Q8(a)

(or)

List out the precautions to be taken for microwave bench measurements. **April-11, Set-2, Q3(a)**

(Refer Only Precautions)

Ans:

Microwave Bench Setup: Figure below shows the general microwave bench setup, which is used for the measurement of any parameter in microwaves.

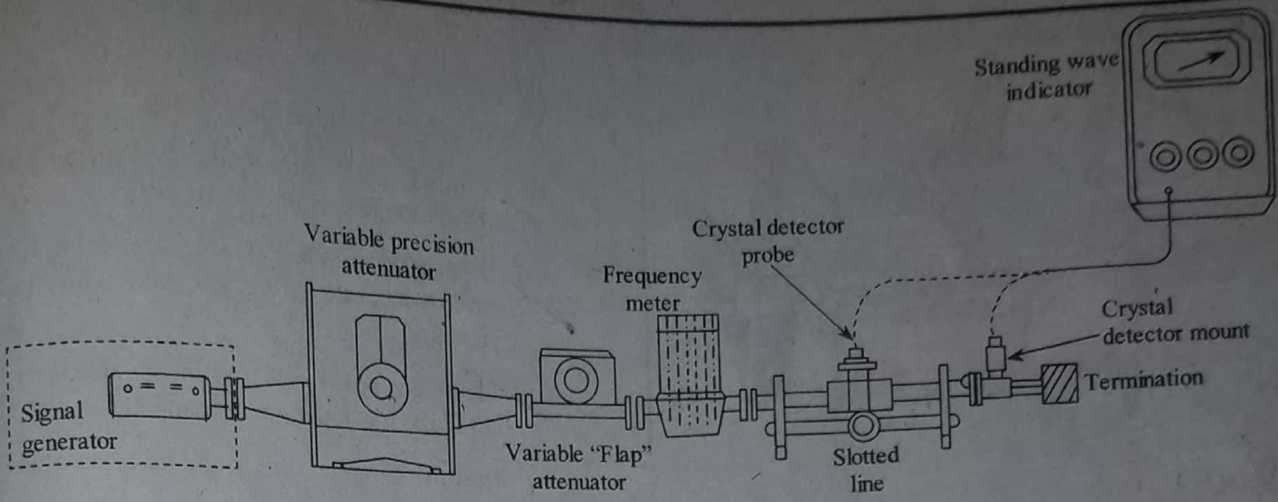


Figure: General Setup of Microwave Bench

The signal generator which may be a gunn diode oscillator or a reflex klystron tube can be used as a microwave source (whose output is in the order of milliwatts). This signal generator can produce a 1 kHz continuous wave or square wave. In some applications, sweep oscillator can also be used to produce the output whose frequency is varied periodically. An attenuation of 0 to 50 dB is provided by the precision attenuator. The variable flap attenuator is also used to check its calibration against readings of the precision attenuator. The frequency meter, which is a single cylindrical cavity and is slot coupled to the waveguide is used to measure the frequency directly. The slotted line carriage is used to detect the standing wave pattern present inside the waveguide. The crystal detector inserted in the '*E*' probe of the slotted line is used to detect the modulated signal. Finally, the direct reading of the standing wave ratio is given by a sensitive tuned voltmeter called SWR indicator.

There are two important causes of error in microwave measurements,

1. As the microwave power uses oscillation frequency and output power as its sources (or) input, thus, they depend on the reflection setup and oscillator load admittance of the system. The discontinuities and mismatched terminations result in the variations of oscillator power and frequency. These variations can not be eliminated until proper attenuation is provided between oscillator and system.

2. When excessive penetration is used, reflections are produced from detector probe which result in variation of standing wave position and measured standing wave ratio. Usually, unequal spacing between the nulls represent an excessive probe penetration. Inspite of propagation of higher order modes in waveguide, this effect is provided by discontinuties. Thus, care must have to be taken such that attenuation should not become high.

Precautions

The precautions to be taken are,

(i) Components should be connected tightly for avoiding power leakage.

(ii) Air cooling is required for reflex klystron oscillator.

(iii) Microwave power should not be measured directly as it effects the vision (harmful to eyes).

Q28. With a neat diagram, explain the construction of a slotted line.

Ans:

Construction of Slotted Line: The main function of slotted section is to detect the standing wave pattern present inside the waveguide. Figure shows the typical construction of slotted line.