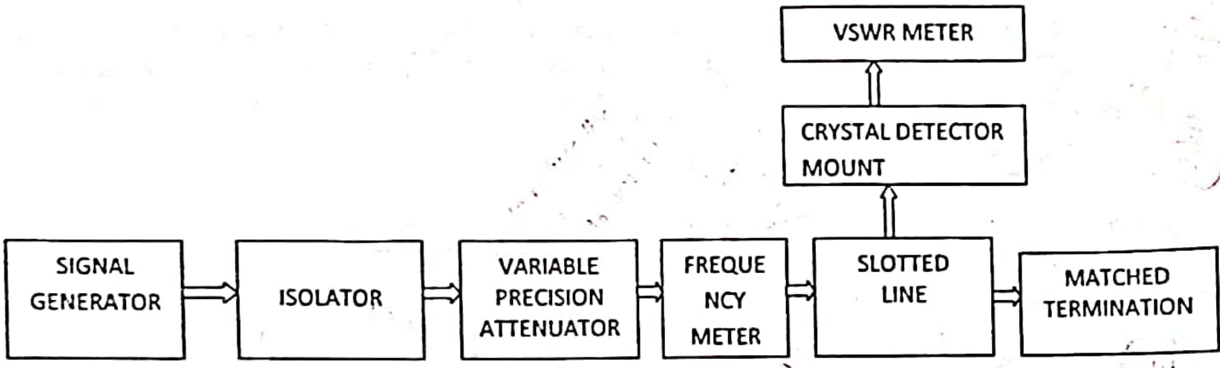
IV ECE - MW - LML

MICROWAVE ENGINEERING

UNIT V

MICROWAVE BENCH SETUP:-



The general bench setup for measurement of any parameter at microwave frequencies is called **MICROWAVE TEST BENCH.** It mainly consists of

SIGNAL GENARATOR:-

A signal generator is a microwave source whose output is in the order of milli-watts. Generally it may be a Reflex Klystron or Gunn Diode Oscillator or Backward wave Oscillator. These are used to generate continuous waves which are square-wave modulated at a frequency of 1 GHz.

ISOLATOR:-

A microwave source is followed by an Isolator which is used to prevent source due to load variations that causes reflections in the circuit.

PRECISION ATTENUATOR:-

Attenuator is used to adjust the power or to reduce the power flowing in waveguide. The power level is reduced to a particular stage to prevent overloading. It produces attenuation in the range of 0 to 40dB.

FREQUENCY METER:-

It is used for direct measurement of frequency and it consists of cylindrical cavity. The cavity is adjusted to resonance and is slot coupled to the waveguide. It provides high resolution.

SLOTTED LINE:-

It is basically used for measuring the Standing Wave Ratio. It consists of slotted line section of waveguide, travelling probe and the facility for attaching the instrument. A slot is made in the center of the broader dimension of waveguide. A small probe is inserted through the slot which senses the relative field strength of standing waves inside the waveguide. As the position of probe is varied along the transmission line, it gives an output proportional to the standing wave pattern in the waveguide. The low frequency modulated signal can be detected by tunable probe with a slotted line. At the position of probe, the detector gives an output proportional to the square of the input voltage.

MATCHED TERMINATION:-

The waveguide transmission line operating at low average power can be terminated using matched load. The loads are carefully designed such that all the applied power is absorbed avoiding the reflected power.

Pavg

VSWR METER:-

G, Q, low NVA

A high gain, high quality factor, low noise voltage amplifier that is tuned to a fixed frequency is called VSWR Meter. The VSWR Meter along with slotted waveguide is used to measure standing wave ratio directly in decibels.

ERRORS & PRECAUTIONS:-

Different errors in microwave measurements are

i) **Errors due to frequency Instability:-**

The frequency instability in a microwave causes the standing wave to shift during the measurement. This is due to the thermal changes, mechanical vibrations and inadequate regulation from the source.

ii) **Coupling errors:-**

These are due to coupling between the components and the measuring device. To remove these errors the coupling should be tight and properly align to avoid reflections.

iii) **Probe Errors:-**

The probes introduce field's distortions which affects the standing wave pattern. These are minimized by reducing the length of probe.

iv) **Slot Errors:-**

Slot in the slotted line section loads in the waveguide and produces variations in the guide wavelength which introduces discontinuity effect. To remove these errors slot should be narrow and cut symmetrically with proper tapering.

2

ATTENUATION MEASUREMENT:-

The attenuation is defined as the decrease in power at the load by inserting a device between source and load. This device has a factor called **Attenuation** which decreases or adjust the power levels of microwave signal. It is defined as the ratio of input power to output power in dB.

$$\text{Attenuation in (dB)} = 10 \log (P_1/P_2)$$

$\text{Gain} = \frac{P_{out}}{P_{in}} = P_2/P_1$

Where P_1= power at load without attenuator in the line.
P_2= power at load with attenuator in the line.

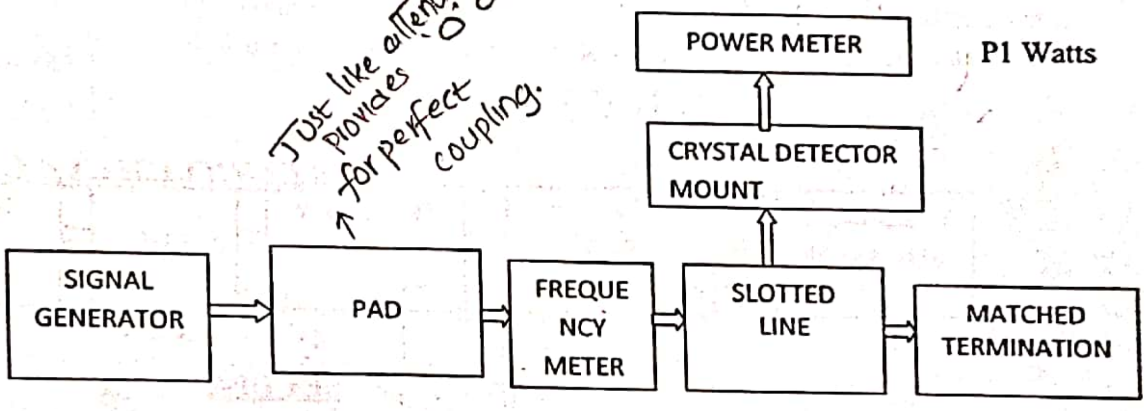
To calculate attenuation, various techniques are applied depending on frequency range, accuracy and type of attenuator. They are

1) Power Ratio Method
2) RF Substitution Method.

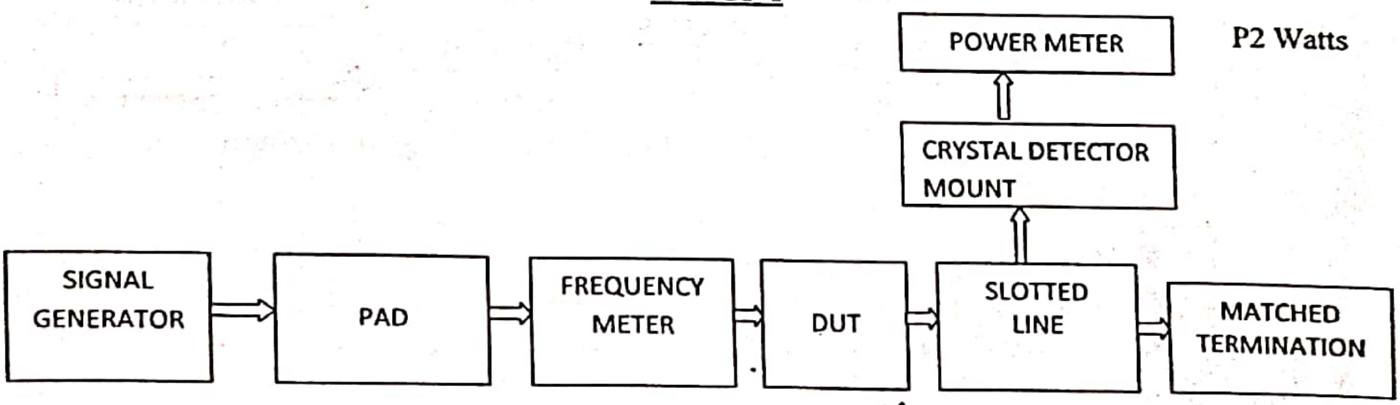
FR, A, TA.

POWER RATIO METHOD:-

Just like attenuator provides for perfect coupling. ô attenuator



SET UP-I



SET UP-II

Device undertest and calculate the power.

This is simple method for measuring attenuation. This method is useful where the accuracy is not required. This method traces the linearity of power meter used.

The power P_1 is measured without DUT (Device Under Test) from set up-I.

The power P_2 is measured with DUT (Device Under Test) inserted from set up-II.

The attenuation of DUT is calculated by taking the ratio of P_1 & P_2.

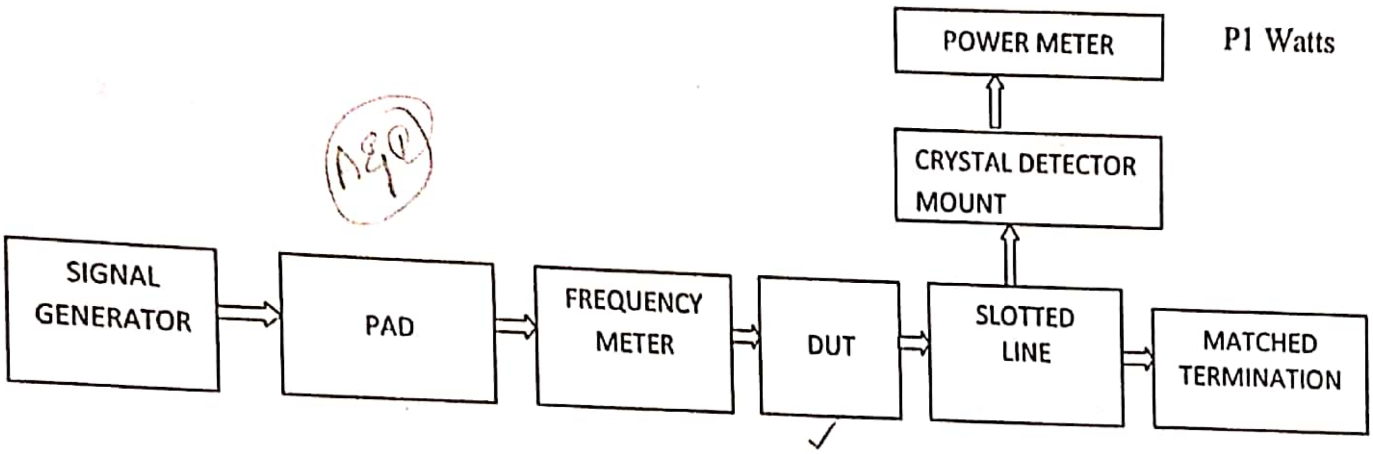
$$Attenuation\ (A) = \frac{P_1}{P_2}$$

→Not accurate because it is non-linear.

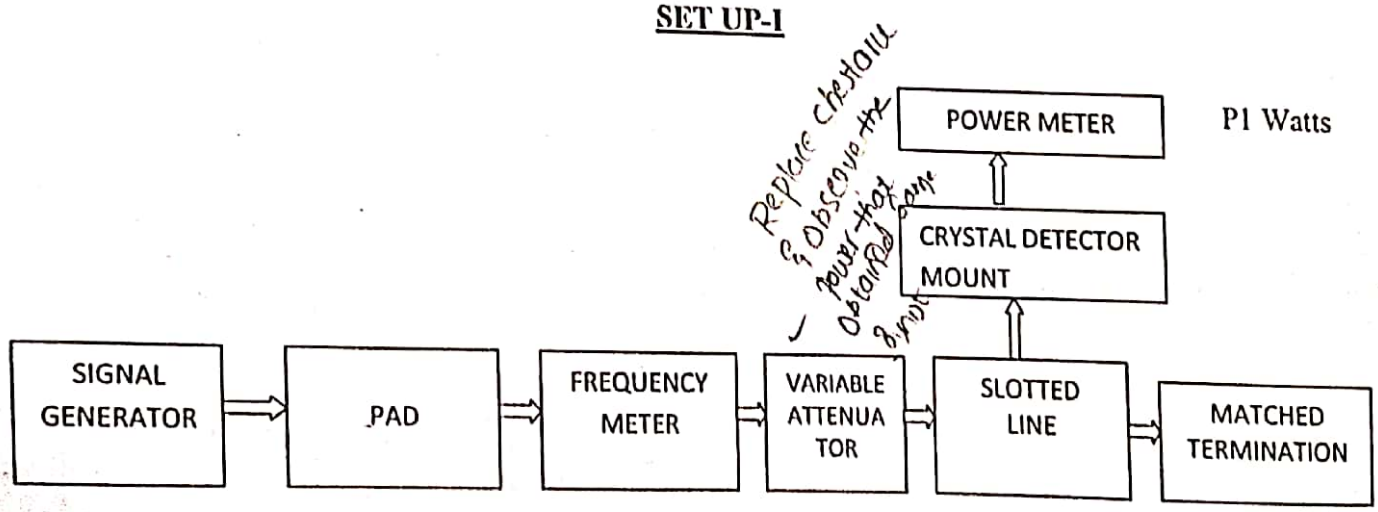
$$A(dB) = 10\ \log {}^{P_1}/_{P_2}$$

This method is having low accuracy because of different insertion points in the slotted line section and the powers are non linear. To measure perfect attenuation the insertion points are to be matched by using tuners or matching pads.

RF SUBSTITUTION METHOD:-



SET UP-I



SET UP-II

This method is having very high accuracy to calculate attenuation. In this method the power P1 is measured by inserting DUT whose attenuation is to be measured from setup-I.

In setup-II, the DUT is replaced with variable attenuator which is varied to get same power P1 on the power meter. At this point the reading on the attenuator gives directly the attenuation of DUT. In this method the accuracy is high since the powers are measured at the same insertion points on the slotted line section.

(2) MEASUREMENT OF VSWR:-

TWT
low noise device
High Gain
Delivers a high peak power
mode pe

Generally VSWR occurs if there is any mismatch between the termination and the operating circuit and there are reflections along the length of slotted line.

wide - band device
due to the non-resonant wave

Generally $S = \frac{1+\rho}{1-\rho} = \frac{V_{max}}{V_{min}}$

where ρ is the reflection Co-efficient.

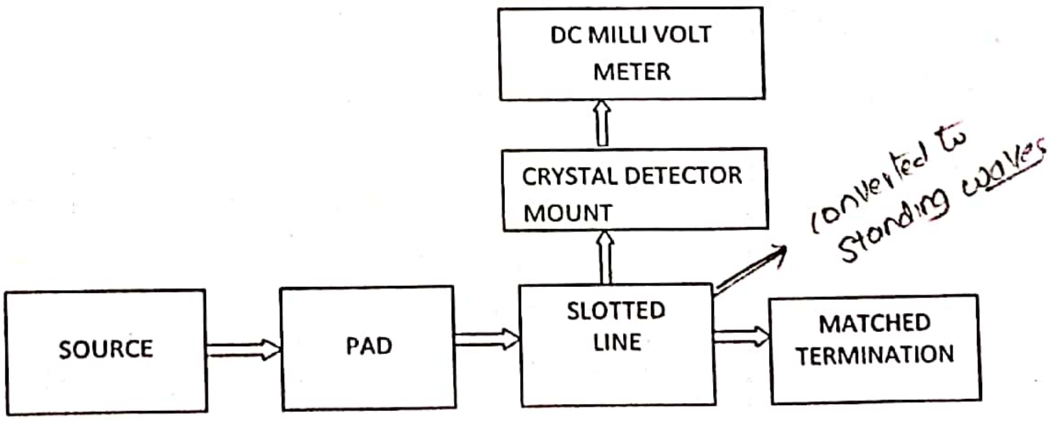
$\rho = \frac{\text{Reflected power}}{\text{Incident power}}$

$$\rho = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

The minimum value of ρ is 0 and maximum is 1. Similarly the minimum value of S is 1 and maximum is ∞. If S is in the range of 1 to 10, it is represented as low VSWR and if S>10, it is represented as high VSWR.

VP → (W)

MEASUREMENT OF LOW VSWR:-

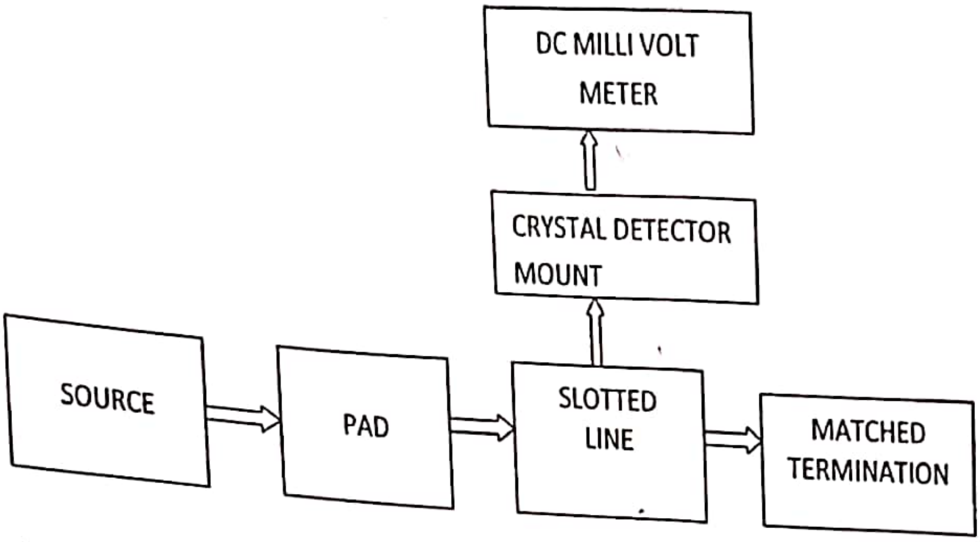


If VSWR < 10, it can be measured directly on VSWR meter. This method basically depends on adjusting of probe on slotted line to give maximum and minimum voltage on the DC voltmeter. The probe on the slotted line is adjusted to get maximum reading on DC voltmeter by varying attenuator to get full scale reading. i.e.. V_{max}

Again the probe is moved on the slotted line to get minimum reading i.e.. V_{min}.

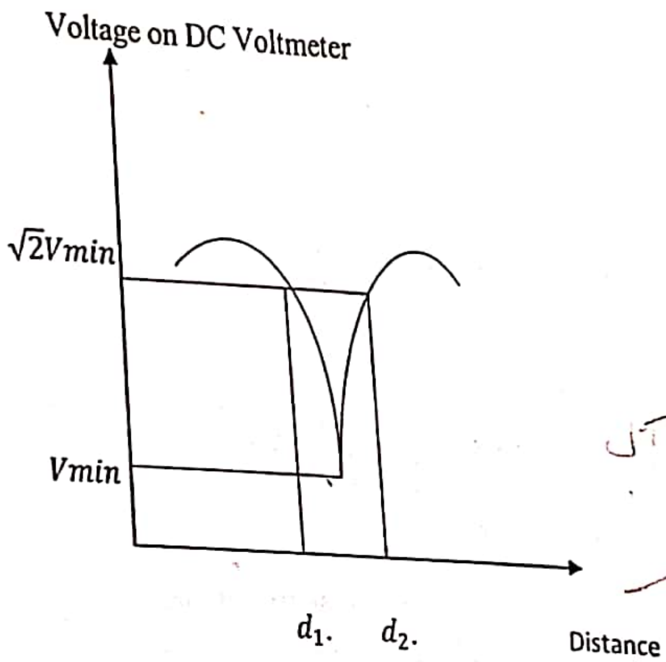
The SWR is given by $S = \frac{V_{max}}{V_{min}}$

MEASUREMENT OF HIGH VSWR:-



If S > 10, double minimum method is used to measure VSWR. In this method, probe is adjusted to get minimum reading at the DC Voltmeter. Then the probe is adjusted to a point where the power is $\sqrt{2}$ times of minimum and this position is indicated as d_1.

Again the probe is moved to get $\sqrt{2}$ times of minimum value on the other side of minimum value which is indicated as d_2.



$S = \frac{\lambda g}{\pi(d_2 - d_1)}$

$S = \frac{\lambda g}{\pi(d}$

The empirical relation for High VSWR is $S = \frac{\lambda_g}{\pi(d_2 - d_1)}$

For TE_{10} mode, $\lambda_c = 2a$, $\lambda_g = \frac{\lambda_0}{\sqrt{1 - \frac{\lambda_0^2}{\lambda_c^2}}}$ $\lambda g = \frac{\lambda_0}{\sqrt{1 - \frac{\lambda_0^2}{\lambda_c^2}}}$

The above formula is applicable only for high VSWR and it is approximate value.

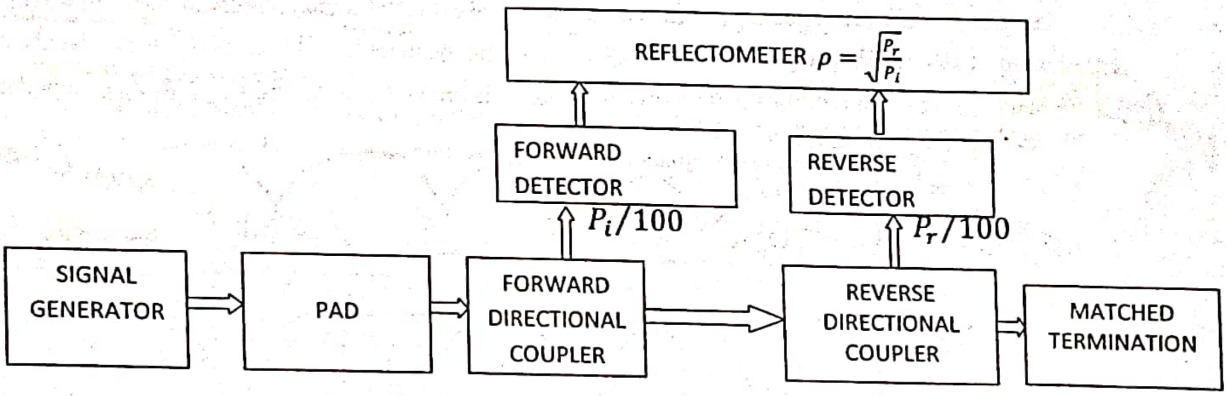
MEASUREMENT OF IMPEDANCE:-

To measure the impedance at microwave frequencies there are 3 different ways.

Applicatn

1. Using Magic Tee
2. Using Slotted Line
3. Using Reflectometer

MEASUREMENT OF IMPEDANCE USING REFLECTOMETER:-



In the above setup the directional couplers are identical and are used to sample the incident power P_i and reflected power P_r. The magnitude of reflection coefficient is obtained directly from reflectometer which is given by $\rho = \sqrt{\frac{P_r}{P_i}}$. The relation between impedance and reflection coefficient is

$$\rho = \frac{Z_L - Z_0}{Z_L + Z_0}$$

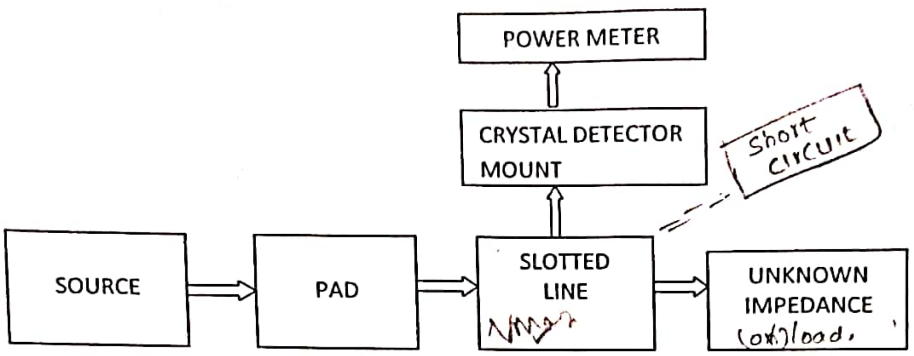
Where $Z_L = Unknown\ Impedance$

2 → M # φ

$Z_0 = Characterstic\ Impedance$

From this method only the magnitude of impedance is measured but not phase angle. This method is suitable for low VSWR i.e.. for low reflection coefficients. The accuracy is very high if the ρ is in the range of 0 to 0.3

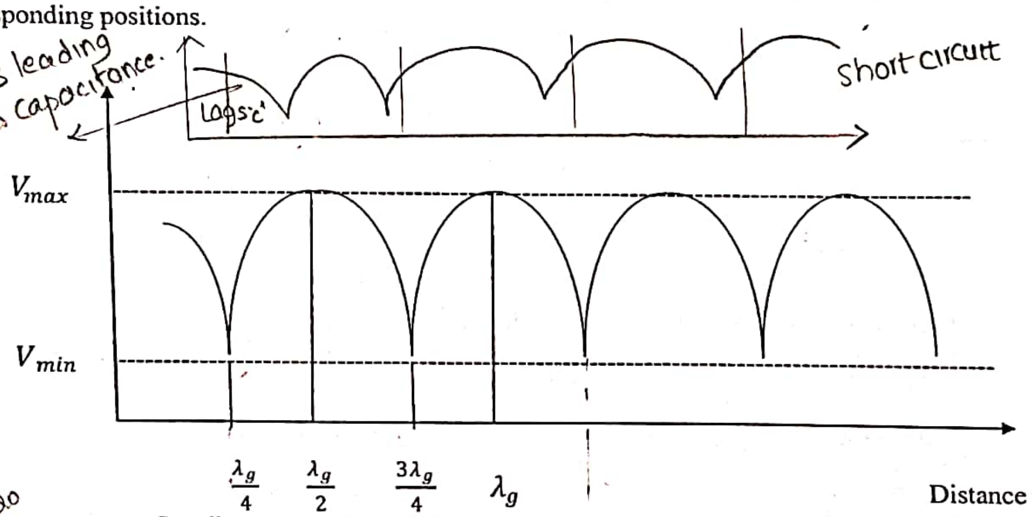
MEASUREMENT OF IMPEDANCE USING SLOTTED LINE:-



In the above setup, the load whose impedance is to be measured is placed as termination and due to mismatch there are reflected waves. The incident and reflected waves results in standing waves. With the help of slotted line the positions of V_{max} & V_{min} can be determined accurately. From the above setup the standing wave pattern for the unknown impedance is drawn by detecting V_{max} & V_{min} and their corresponding positions.

m→RN.

current is leading ∴ It is capacitance.



Standing wave pattern of Unknown Impedance.

If Vmin current exists voltage → zero

The positions of maximum and minimum voltage may vary according to load impedance.

open circuit :-
Lead → Inductance
lag → capacitance

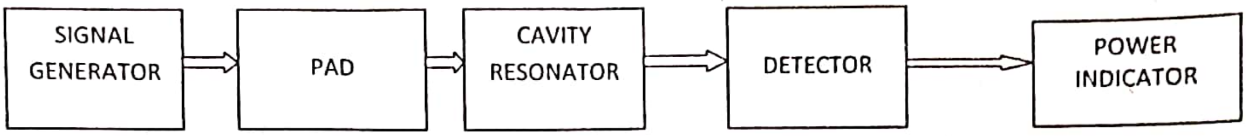
Short circuit
lag → capacitance
Lead → Inductance

MIA - L → Ql → L

To find the information about phase angle, the load is replaced with short circuit i.e.. $Z_L = 0$. Due to short circuit the positions of V_{max} & V_{min} are varied. If the minimum is shifted to left, the impedance is inductance and if the minimum is shifted to right the impedance is capacitance. The magnitude of impedance is measured and from smith chart the phase angle is measured by using the difference of positions of minimum for load and short circuit. From this method both impedance and phase angle are measured.

2L MEASUREMENT OF QUALITY FACTOR:-

→ Here we will passes the microwaves.



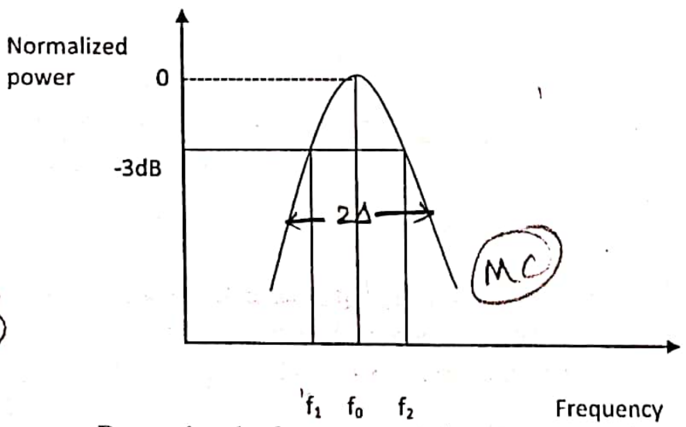
To measure the quality factor of a cavity resonator there are three methods.

0/p → Δf

1. Transmission Method
2. Impedance Method
3. Transient delay or Decrement Method.

Among these methods , the transmission method is simple and having high accuracy.In this method, cavity resonator is used as a transmission device and the output signal (or) power is measured asa function of frequency. The power in the power indicator is varying with the frequency from the microwave source. The resonance curve of cavity resonator is shown below.

For resonant circuits the quality factor will present.



G =
P → f → Δf

By varying the frequency of microwave source and keeping magnitude as constant, the output power atr the power indicator is drawn which is called as resonance curve. From the resonance curve the 3dB bandwidth is $2\Delta = \pm\frac{1}{Q_l}$ where Q_l is quality factor with load.

$2\Delta = \pm \frac{1}{Ql}$

Gunn diode operation mode:

Depending on the material parameters and operating conditions. A gunn effect oscillator can be made to scillate in any of the four frequency modes.

1) Domain mode or transit time mode or gunn mode
2) Delay or inhibited domain mode
3) Quenched domain mode
4) Limited space charge accumulator (LSA) Mode.

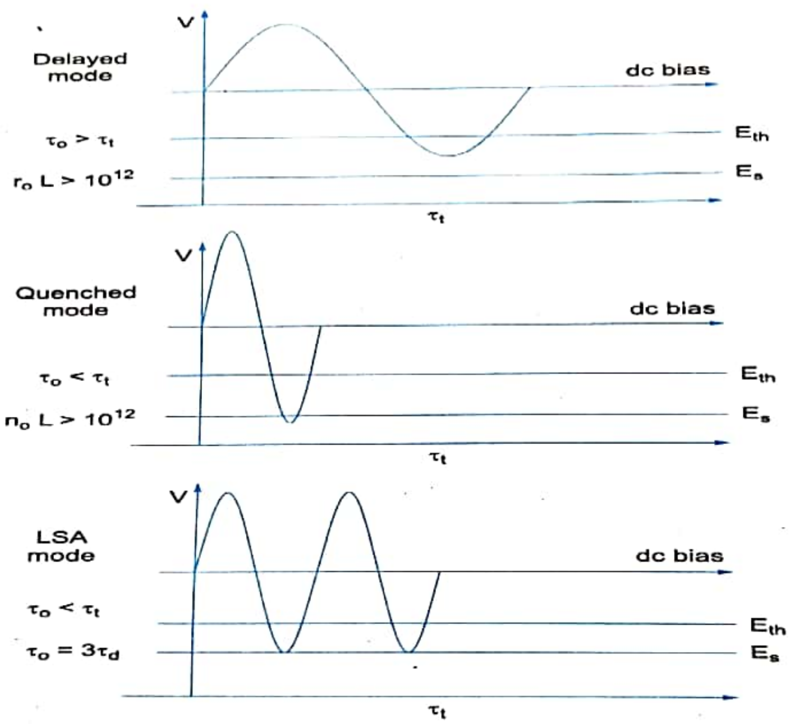
Transit time mode (V_d=fL=10^7 cm/sec):

This is also called the Gunn mode. Here fL = 10^7 cm/sec, when $V_d=V_s$ the sustaining velocity, the high field domain is stable. In that case the oscillatory period = transit time i.e, $\tau_0 = \tau_t$. Efficiency is below 10% because the domain arrives at the anode at a lower current level.

It is a low power, low efficiency mode and requires that the operating frequency be lesser than 30 GHz.

Delay domain mode (10^6 cm/sec <fL<10^7 cm/sec):

When the transit time is chosen so that the domain is collected while $E<E_{th}$, a new domain cannot form until the field rises again above threshold. Here oscillation period is greater than transit time $\tau_0 > \tau_t$. This delay inhibited mode has an efficiency of 20% approximatley. Hence the operating frequency can be equal to or less than that in Gunn diode.



Limited space charge Accumulator mode ($fL>2*10^7$ cm/sec):

This is the most important mode of operation for Gunn oscillator as this mode gives high power with high efficiency. In this mode, the domain is not allowed to form at all. The frequency and RF voltages are also chosen that the domains do not have sufficient time to form while the field is above the threshold voltage. As a result most of the domains are maintained in the negative resistance region. The oscillating frequency is determined by the external components only and not by transit carrier time. And output obtained in LSA mode is much greater. The output power of the oscillator in LSA mode is given as $p = \eta I_o V_o$.

The LSA mode yield high power and high efficiency (20%).

GUNN DIODE CHARACTERISTICS:

It typically uses 10 -12V supply with typical bias current of 250 mA giving a continuous wave power of 25mW in the X band.

1. CW power : 25 mW to 250mW, X band (5 – 15 GHz)
2. Pulsed power : 5W (5 – 12 GHz)
3. Efficiency : 2 to 12 %

Applications:

1. In radar transmitters (police Radar, CW radar)
2. Pulsed Gunn diode oscillators used in transponders for air traffic (ATC) control and in industry telemetry systems.
3. Broad band linear amplifier
4. Fast combinational and sequential logic circuits.
5. Low and medium power oscillator in MW receivers.
6. As a pump sources in paramertric amp