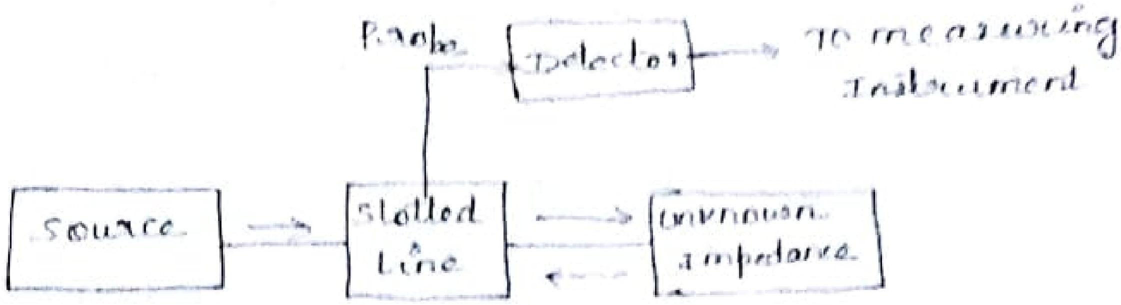
UNIT VIII

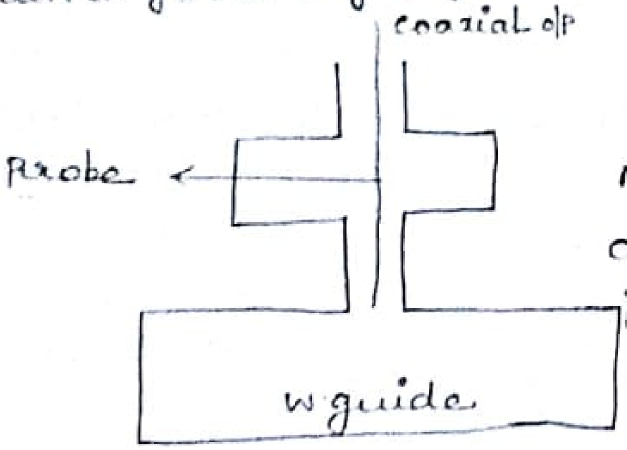
MICROWAVE MEASUREMENTS

Attn
freq
SWR
VSWR
Impedance

slotted Line:



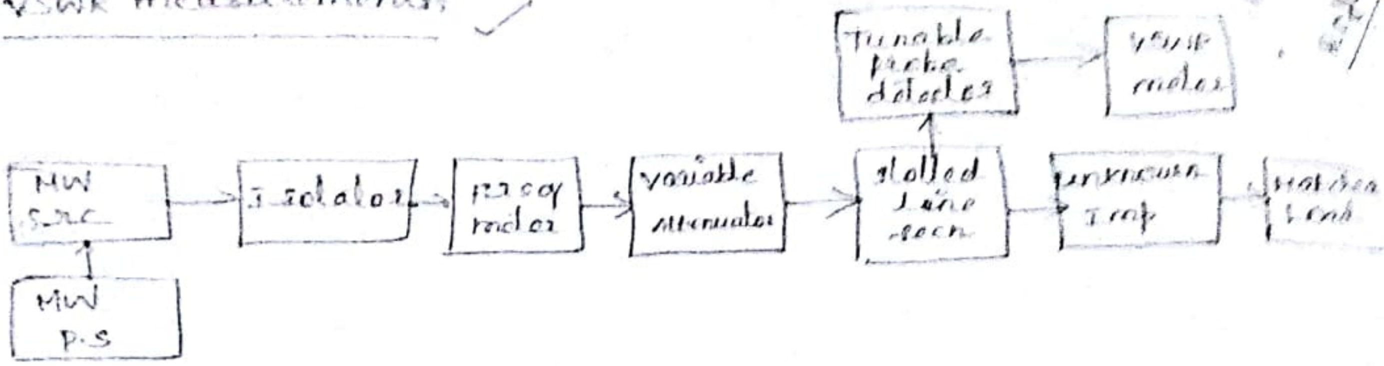
- slotted Line - consists of Longitudinal slot.
- The slot is 1mm wide and allows an electric field probe to enter the w guide for measurement of relative magnitude of filed at the location of probe.
- slot - located suitable in the wall of w guide such that the disturbance of wall current is max. For rec w.guide this locn is in middle of broadwall as shown in following fig



- slotted section is normally mounted in a carriage that supports probe moving inside the slot.

- probe - Thin conducting wire - couples fields in w.guide.
- slotted line measures S.waves. also measure VSWR, SW pattern, wavelength, Impedance, Refln co-eff and Return loss measurement by minima shift method

VSWR measurements:



- VSWR - measured by detecting V_{max} & V_{min}

$$SWR\ (S) = \frac{V_{max}}{V_{min}} = \frac{1+\Gamma}{1-\Gamma}$$

$$\Gamma - \text{refln coeff} = \frac{P_{ref}}{P_{Incident}}$$

* SWR is a measure of mismatch b/w Load & Line
* superposition of Incident & Reflected wave gives rise to standing waves

S varies from 1 to ∞

Γ varies from 0 to ∞.

Low VSWR (S < 20):

- value of VSWR < 20.
- direct measurement.
- variable attenuator set to 10dB.
- 1 KHz modn
- probe in slotted secn to max. (corresponding to Vmax).
- The attenuation is now adjusted to full scale reading - This full scale reading is noted.
- probe in slotted secn to min (Vmin).
- VSWR = Vmax/Vmin
- repeat for various freq.

High VSWR (S > 20):

- For High power, double min method is used.
- The superposition of 2 travelling waves (Incident & Reflected) gives rise to standing wave along with the line
- Find max field strength when 2 waves are INPHASE.
- Find min " " " " " " OUT OF PHASE.

The dis b/w 2 successive max or min is half the guide wavelength.

Reflection coeff

Ratio of elec field strength of reflected and Incident wave is called refln coeff.

$$\text{Refln coeff } \Gamma = \frac{E_r}{E_I} = \frac{Z - Z_0}{Z + Z_0}$$

Z - Impedance at a pt

Z_0 - char Imp

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

VSWR

→ Incident Vt

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

→ reflected Vt.

- In this method, the probe is inserted to a depth where the min can be read without difficulty.
- The probe is then moved to a pt where the power is twice the minimum. Let this posn be denoted by x_1.
- The probe is then moved to twice the power pt on other side of min (say x_2)

$$P_{min} \propto V^2_{min} \rightarrow (1)$$

$$2 P_{min} \propto V_x^2 \rightarrow (2)$$

$$\text{From (1) \& (2), } \frac{1}{2} = \frac{V^2_{min}}{V^2_x} \Rightarrow V_x^2 = 2(V_{min})^2$$

$$\boxed{V_x = \sqrt{2}\, V_{min}}$$

Guide wavelength

- By moving the probe b/w 2 successive maxima a distance equal to $\lambda g/2$ is found to det λg (i.e)

$$\lambda_g = \frac{\lambda_0}{\sqrt{1 - \left(\frac{\lambda_0}{\lambda_c}\right)^2}}$$

λ_g for TE_{10} mode, $\lambda_c = 2a$, $\lambda_0 = \frac{c}{f}$.

$$\boxed{S = \frac{\lambda_g}{\pi(x_1 - x_2)}}$$

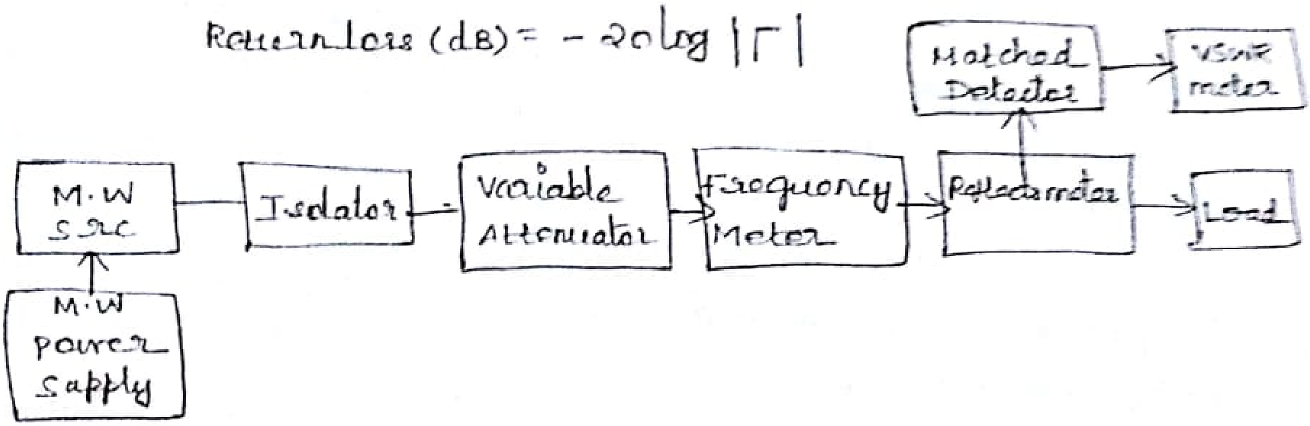
VSWR THROUGH RETURN LOSS MEASUREMENT

Return Loss:

Return loss is measure of power reflected by a line or n/w or device.

$$\text{Return loss (dB)} = 10 \log \frac{\text{I/p energy to the device}}{\text{Reflected energy at the i/p of the device}}$$

$$\text{Return loss (dB)} = -20 \log |\Gamma|$$



- The return loss and VSWR of a load can be determined by measuring the magnitude of the reflection co-efficient with a reflectometer.

Reflectometer consists of 2 identical Directional couplers are connected opposite to each other.

- one coupler couples to the fwd wave and other to the reverse wave
- let us assume that the Directional couplers have infinite Directivity, a voltage coupling coefficient C.
- when a unit I/P amp. is fed to port 1 voltages at ports 4 & 2 are

$$b_4 = C \longrightarrow ①$$

$$b_2 = (1-C^2)^{1/2} \longrightarrow ②$$

- Incident voltage at port 2 is reflected by the load. If Γ_L is the refln co-eff, the reflected wave amplitude at port 2 is

$$a_2 = (1-C^2)^{1/2} (\Gamma_L) \rightarrow ③$$

This will be coupled to port 3 to produce a voltage of

$$b_3 = (1-C^2)^{1/2} C (\Gamma_L) \rightarrow ④$$

using ① & ④, find b_3/b_4

$$\frac{b_3}{b_4} = (1-C^2)^{1/2} |\Gamma_L|$$

$$= K|\Gamma_L| \rightarrow ⑤$$

where $K = (1-C^2)^{1/2}$.

If coupling is extremely small (ie) $C << 1$, $K \approx 1$. ∴

$$\boxed{\left|\frac{b_3}{b_4}\right| = |\Gamma_L|} \rightarrow ⑥$$

$$VSWR = \frac{1+|\Gamma_L|}{1-|\Gamma_L|} \longrightarrow ⑦$$

$$\text{Return Loss} = -20\log|\Gamma_L| \longrightarrow ⑧$$

- Repeat expt by terminating port 2 & adjust o/p of DC 1 at port 4 to unity

POWER MEASUREMENTS:

Power:

Power is defined as the quantity of energy dissipated stored per unit time.

Power sensor

The Microwave power consists of a power sensor, which converts the μ-wave power into heat energy. The corresponding temperature rise provides a change in the electrical parameter resulting in an o/p current in the low freq circuitry and indicate the power.

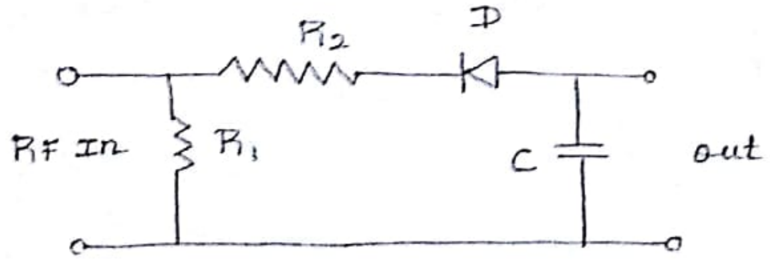
Sensors used for power measurements are

→ Schottky barrier Diode

→ Bolometer

→ Thorocoupler.

Schottky Barrier Diode sensor (SBD):



– can measure low power upto 70dBm.

Bolometer sensor.

A Bolometer is a power sensor whose resistance changes with temperature as its absorbs μ-wave power.

2 most common types of bolometer are.

(i) Barretter:

– It is a ~~thin~~ short thin metallic wire sensor which has a +ve temp co-eff of resistance.

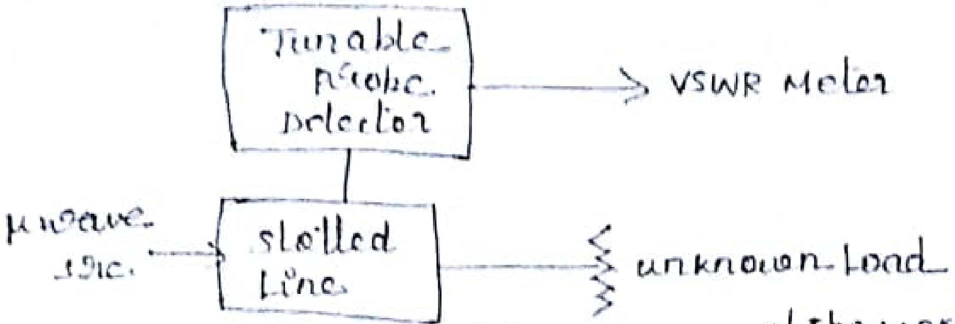
– Low power measurement

Impedance Measurement

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

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

1. Slotted line method:



$$Z_L = Z_0 \frac{1+\Gamma_L}{1-\Gamma_L} \rightarrow (1)$$

$$\Gamma_L = \rho_L e^{j\phi_L} \rightarrow (2)$$

$$S = (1+\rho_L)/(1-\rho_L) \rightarrow (3)$$

$$\phi_L = 2\beta d_{min} - \pi \rightarrow (4)$$

$$\beta = 2\pi/\lambda_g \rightarrow (5)$$

$\lambda_g = 2 \times$ dis b/w 2 successive minima

- * The unknown device is connected to the slotted line and the SWR S_0 and the position of one minima is determined.
- * The unknown device is replaced by movable short to the slotted line.
- * Two successive minima positions are noted.
- * Twice of the difference betwn minima position will be λg.
- * One of the minima is used as reference for Imp measurement.

Steps

1. Measure load VSWR to find ρ_L
2. Measured d
3. Measure d min
4. calc. $\Gamma_L = \rho_L e^{j\phi_L}$.
5. Z_L - calcn.

- * Find the difference of reference minima and minima position obtained from (1). Let it be 'd'. unknown load.
- * Take a smith chart with 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 $d/\lambda g$.
- * Join the center with this pt. Find the pt where it cut the drawn circle. The co ord of this pt this will show the normalised Imp of load.

2. Reactive Discontinuity

$$Z_L = \frac{R_0 \cdot jX}{R_0 + jX} \rightarrow (1)$$

$$\frac{Z_L}{R_0} = \frac{jX}{R_0 + jX} = \frac{X^2}{R_0^2 + X^2} + j\frac{XR_0}{R_0^2 + X^2}$$

$$= x + jy \rightarrow (2)$$

where

$$x = \frac{x^2}{R_0^2 + x^2}, \quad y = j\frac{x R_0}{R_0^2 + x^2}$$

$$d_{min} = (x_1 \sim x_2).$$

$$\frac{Z_L}{R_0} = x + jy - y/x.$$

3. Reflectometer

P_3 & P_4 cons

$$\frac{b_3}{b_4} = \frac{A\Gamma_L + B}{C\Gamma_L + D} \rightarrow (1).$$

$$\left|\frac{b_3}{b_4}\right| = \left|\frac{A}{D}\right| |\Gamma_L| = k\Gamma_L$$

$$\Gamma_L = \frac{1}{K}\left|\frac{b_3}{b_4}\right|$$

$$\phi_L = \frac{2\pi \Delta x}{\lambda g}.$$

steps as mentioned

$$\Gamma_L = k\left|\frac{b_3}{b_4}\right| e^{j\phi_L}$$

$$Z_L = Z_0 \frac{1 - \Gamma_L}{1 + \Gamma_L}$$

Measurement of S Parameters of a network:

— unit (1)

Thermistor:

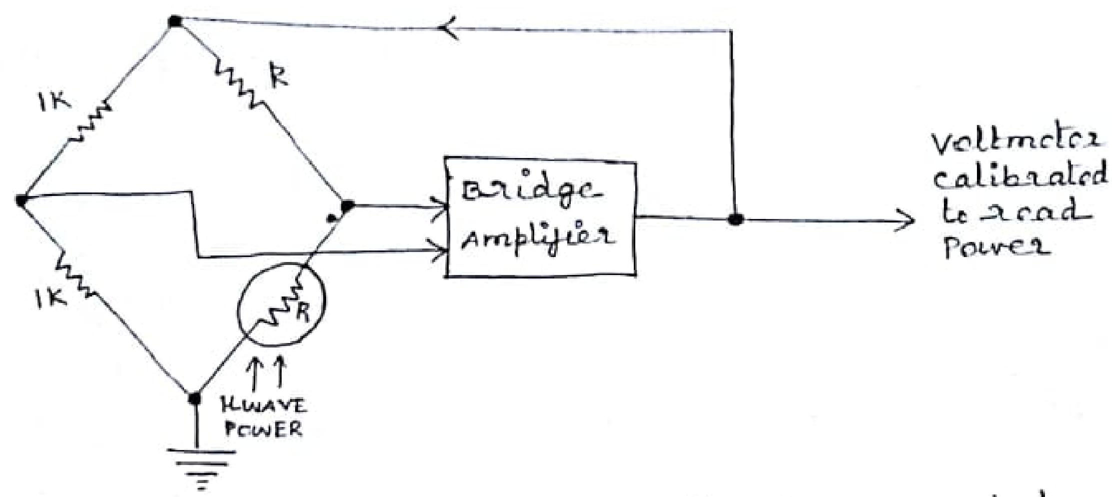
- It is a semiconductor sensor which has a -ve temp co-eff of resistance and can be easily mounted in μ wave devices due to its smaller and more compact size.
- Medium and High power measurement.

Power meter:

- These instruments are designed to process the output of bolometer and to represent the power level on a calibrated scale.
- The power meter is basically constructed from a balanced bridge ckt in which one of the arms is the bolometer.

Single Bridge power Meter:

Power Meter using Single Bridge



- μwave power applied to the arm will change the bolometers resistance causing an unbalance in the bridge from its initial balance condition under zero incident power.
- Heating effect causes the bolometers resistance to decrease and unbalances the bridge in proportion to the power applied.
- The non zero o/p is recorded on a voltmeter which is calibrated to read the level of i/p μ wave power.

Double Bridge power Meter: (2 bridges diagram)

- The upper bridge ckt measures the µwave power, and the lower bridge ckt compensates the effect of ambient temperature variation ($V_1 = V_2$).
- The initial zero setting

Power (c.c

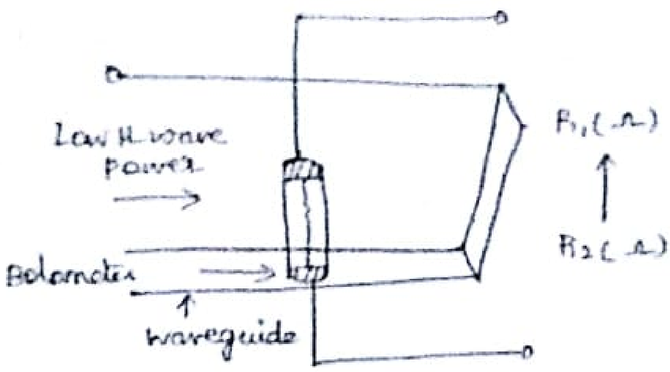
Power measurement

(0.01 mW – 10 mW) – Bolometer technique

(10 mW – 1 W) – calorimetric technique

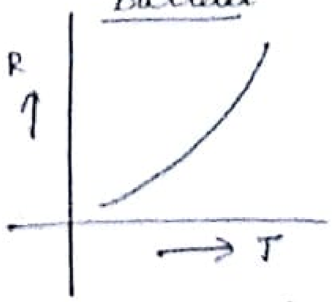
(>10 W) – calorimetric wattmeter

(i) Bolometer

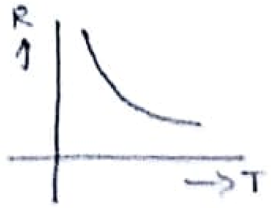


* Bolometer – Temperature sensitive device
* Resistance changes w.r.t applied power
* 2 types – Barretters & Thermistors.
* Barretter – has +ve temp co-eff & its R increases with temperature as shown in following fig

Barretter



thermistor – has –ve temp co-eff & its R decreases with temp



* Bolometer – sq. law device – produces a current as applied power (i.e.) square of the applied voltage.
* Here Bolometer is mounted inside a waveguide, where bolometer itself is used as a load with operation resistance $R_1(\Omega)$.
* Now low μ wave power which is to be measured is applied.
* Some power is absorbed in the bolometer load and dissipated as heat and the resistance changes to R_2. This change in resistance $(R_1 - R_2)$ is proportional to the μwave power which can be measured using a bridge.

Attenuation measurement:

$$A(dB) = \frac{P_{in}}{P_{out}}$$

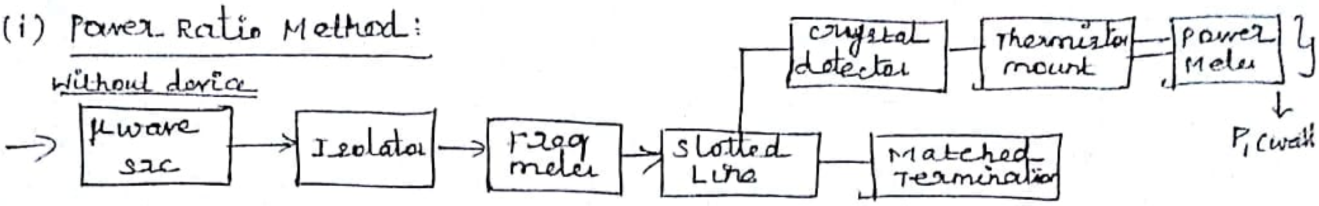
2 methods

(i) power Ratio method

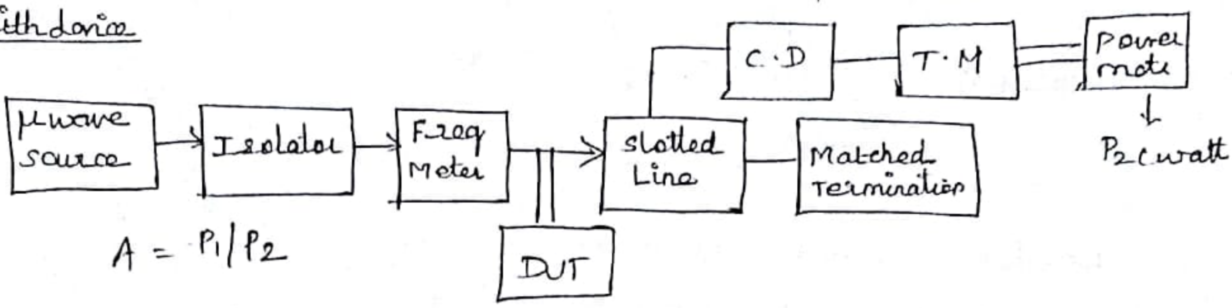
(ii) RF subtitution method

(i) Power Ratio Method:

Without device

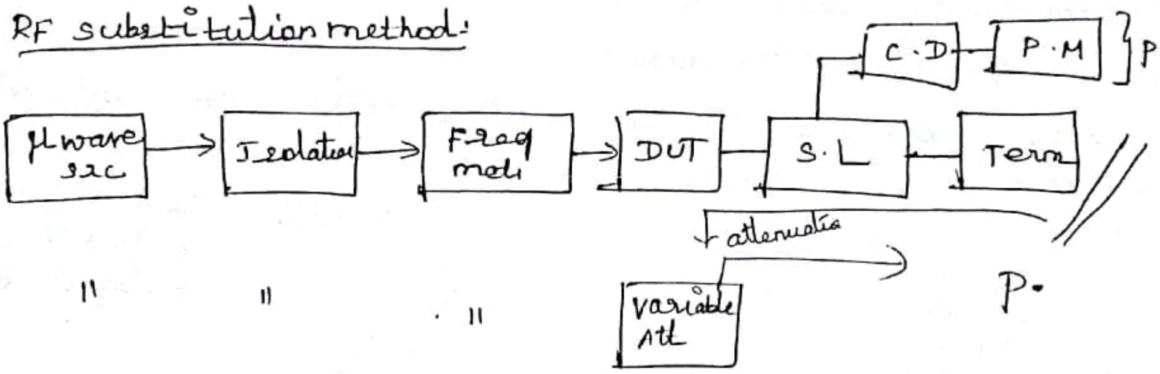


With device



$A = P_1/P_2$

(ii) RF substitution method:



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