* Power Measurement :

- Low Power (below 1mW or 0dBm)
- Medium Power (betw 1 to 10W or 0 to 40dBm)
- High Power (greater than 10W or 40 dBm)

* Use of Bolometer for Low Power Measurement :

- Bolometer is a simple temperature sensitive device whose resistance varies with applied power. They are capable of measuring low microwave power.

- Bolometers are of two types:
  1. Barretters 2. Thermistors.

- Barretters has +ve temp. coefficient and resistance increases with increase in temperature.

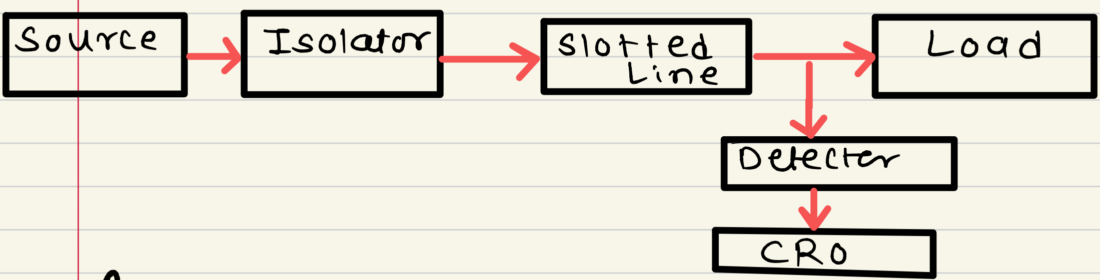
- Thermistor has -ve temp. coefficient and resistance increases with decreases in temp.

- Thermistor and Barretters are used with bridge circuit to convert resistance to power.
-

* Measurement of VSWR :

- Measuremet for Low VSWR ($S < 10$)
- Measurement for High VSWR ($S > 10$)

1. Low VSWR ($S < 10$) :



- As waveguide impedance is not matching with with unknown impedance, Standing wave pattern is generated along the length of waveguide

- The tunable probe is precisely moved along the length of waveguide.

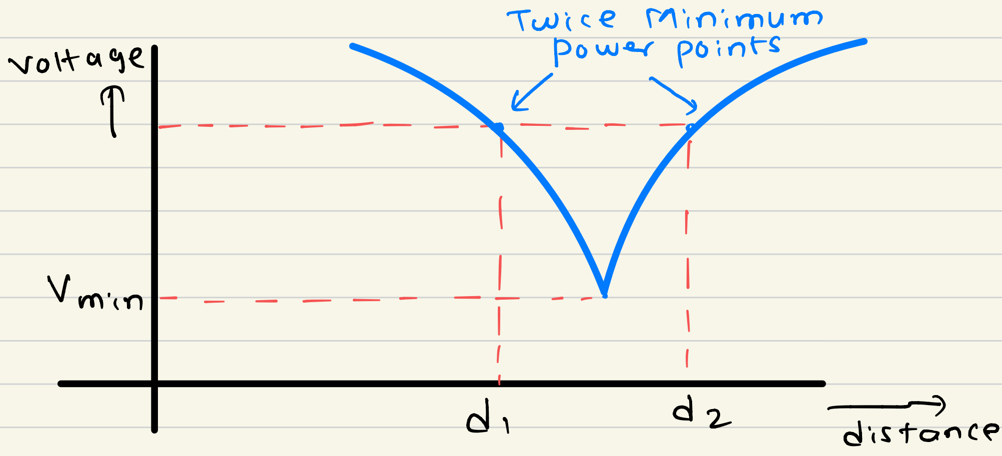
- The detector detects corresponding signal along the length.

- Observe maxima and minima on oscilloscope.

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

2. High VSWR (S > 10):

- For High VSWR, Double Minimum Method is used.
- In this method, the reading at the minimum value is taken, and the readings at the half point of minimum value in the crest before and the crest after are also taken.
-



- VSWR is calculated by :

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

where λg is guide wavelength.

$$\lambda g = \frac{\lambda c}{\sqrt{1 - \left(\frac{\lambda_o}{\lambda_c}\right)^2}}$$ where $\lambda_o = \frac{c}{f}$.

* Measurement techniques for frequency:

- The frequency of microwave signal can be measured using electronic and electromagnetic techniques.

- Electromagnetic techniques:
  1. Using Cavity Meter.
  2. Using slotted Lines.

- Two types in cavity meter:
  - → Absorption type
  - → Direct reading type.

* Absorption Type :

Micro wave source → Attenua-tor → Absorption cavity → Crystal detector → Power meter

Fig. Setup for measurement of frequency with cavity meter

- The cavity is connected to the source of energy where freq. is to be measured.
- Cavity has a small window which allows some energy to enter. Due to absorption of energy by cavity, it is called absorption type.

- When cavity is tuned exactly to the freq, the maximum absorption takes place by cavity.

- For accuracy, 'Q' of the cavity is made high as 10,000. It indicates that it is extremely sharp absorbing the energy.

- For exact dial setting, where the max. absorption takes place the accurate frequency can be measured.

- The power meter in the circuit indicates energy levels.

2. Using Slotted Lines:

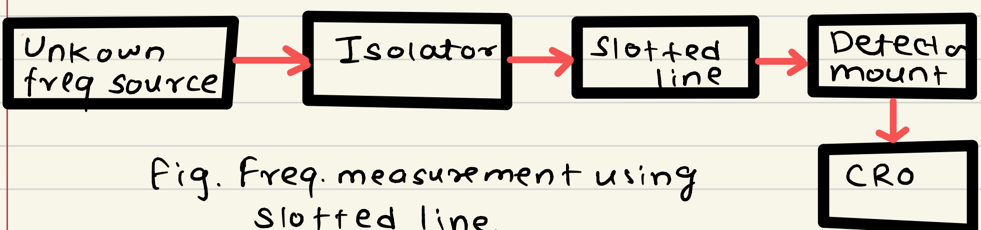


Fig. Freq. measurement using slotted line.

- As waveguide impedance is not matching with unknown impedance, Standing wave pattern is generated along the length of slotted waveguide.
- Tunable Probe is precisely moved along the length of waveguide.

- Detector detects corresponding signal along the length. On oscilloscope, we can observe either maxima or minima.

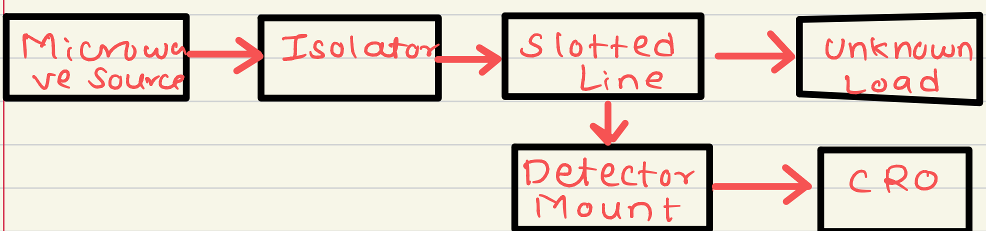
- Micrometer scale gives distance bet^{w} either two consecutive minima or maxima. This distance is $\lambda/2$ from which wavelength is measured.

* Measurement techniques for Impedance:

Slotted Line

Reflectometer.

1. Slotted Line:



- Due to mismatch of the load, standing waves are generated.

- Using slotted line and unknown load positions of V_{max} and V_{min} can be exactly determined.

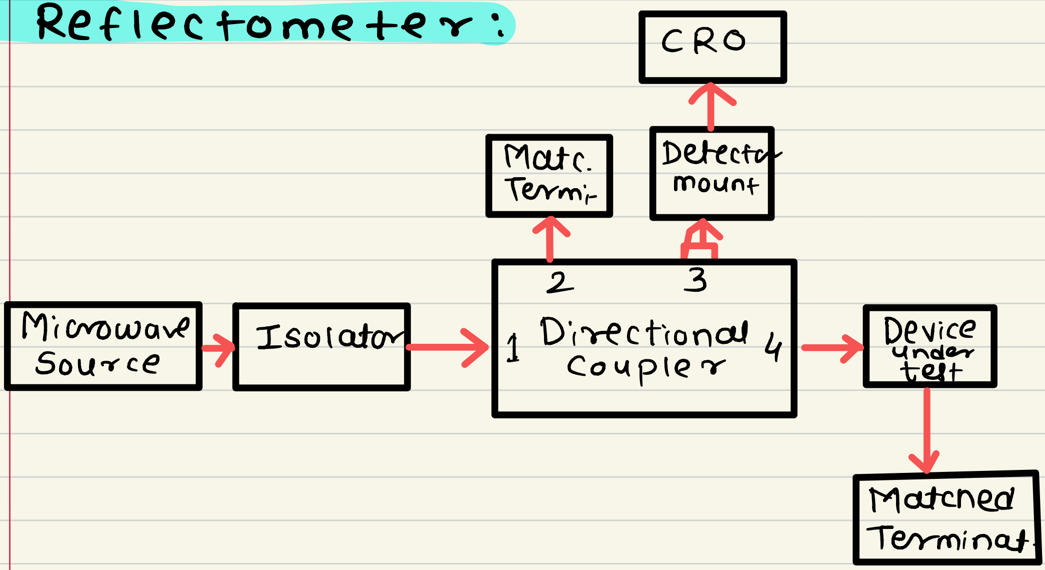
- Replace the unknown load with short circuit. Measure the shift in minima.

Minima is shifted to left $\Longrightarrow$ Impedance is inductive

Minima is shifted to right $\Longrightarrow$ mpedance is capacitive

2. Reflectometer :

-



- The first step is to measure the reflection coefficient magnitude. Once reflection coefficient magnitude is calculated, impedance can be calculated.

- The directional coupler is 4 port device, 2 main and 2 auxiliary line. The forward and reverse travelling waves on main line are separately coupled to to auxiliary lines.

- The VSWR meter reads forword voltage in dB when connected to Port 3 and Port 2 of DC.

- The VSWR meter reads reverse voltage in dB when connected to Port 2 and Port 3 of DC.

- Reflection coefficient is calculated by:

$$|P| = \frac{V_{ref}}{V_{in}}$$

$$SWR = \frac{1 + |P|}{1 + |P|}$$

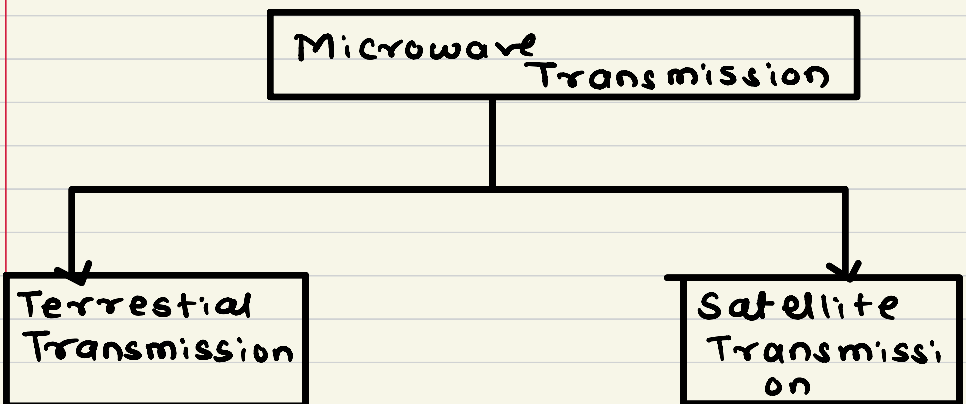
$$Z_L = Z_0 \times SWR.$$

Unit 6 : Microwave Systems

* Microwave Terrestial and Satellite Communication system:

- Microwave Transmission uses very-high freq to transmit signals between stations.

- Microwave transmission uses line of sight transmission where signals travels in straight line.



* Terrestial Microwave Transmission:

- Terrestial Microwave Transmission are sent between two stations on the earth.

- In terrestial communication, the line-of-sight communication occurs between the pairs of Earth-based transmitters and receivers.

- The transmitter and receivers are well

- positioned above ground levels on towers or tall buildings.

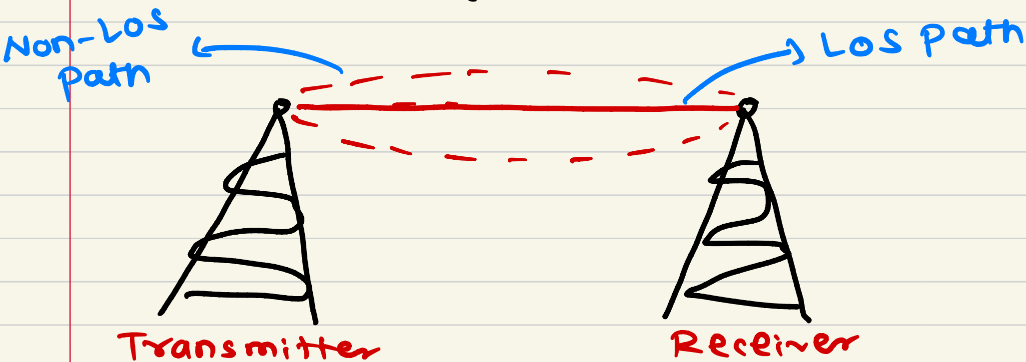


Fig. Terrestial Commⁿ.

* Advantages:

1. Cheaper than cables.
2. Communication over oceans achieved.
3. Free from land acquisition.
4. Easy communication is terrains.

* Disadvantages:

1. Susceptible to weather condition
2. Bandwidth is limited.

* Applications:

1. Used for long distance services.
2. Used for both voice and TV transmission.
3. Used for common carrier and also private network.

* Satellite Microwave Transmission:

- It is transmission between two or more earth based microwave stations and satellite.

- The signals are transmitted to space where satellite are positioned and retransmits the signal to appropriate location.

- It facilitates in communicating with any point on the globe.

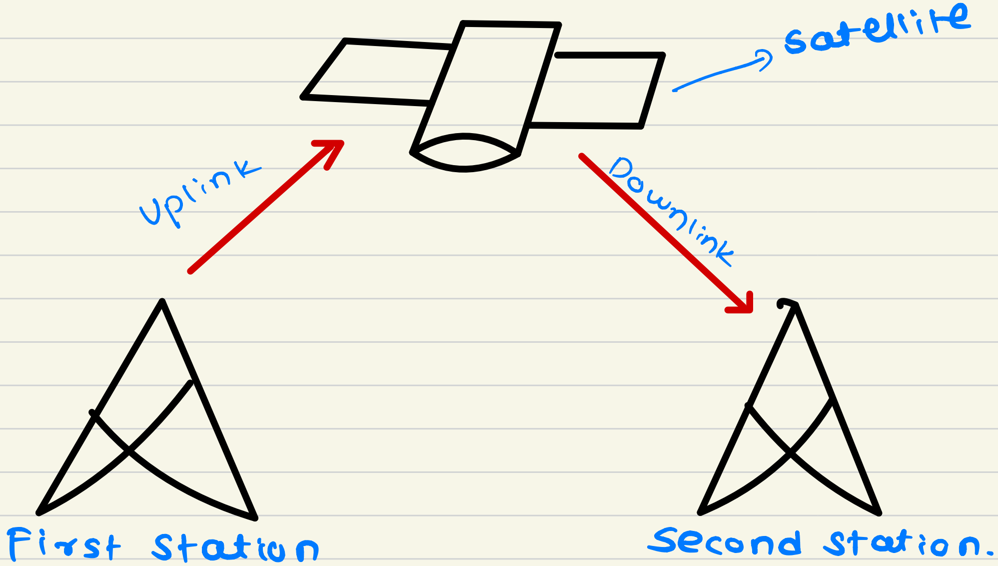


Fig. Satellite Communication.

* Advantage:

1. Coverage area more than terrestial.
2. More flexible and reliable than cable and fibre optic.
3. Used in mobile and wireless commⁿ.

Disadvantage:

1. Requires more time and cost.
2. Needs to be monitored and controll on regular periods.
3. Life of satellite is 12-15 years.

* Applications :-

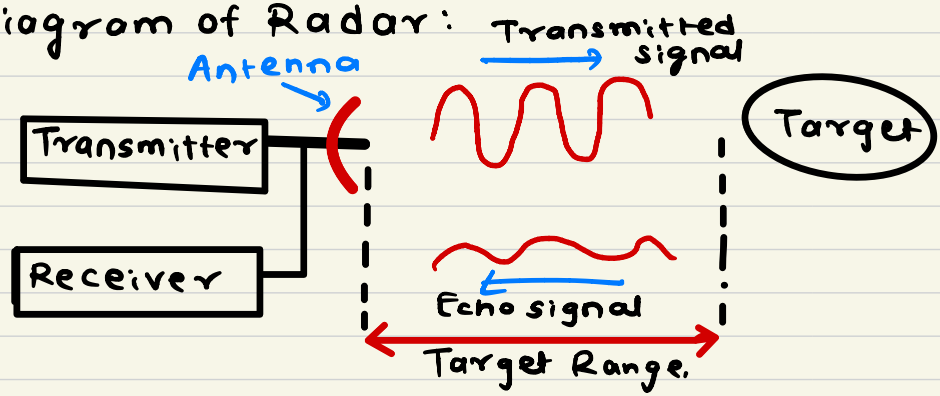
1. Used for radio/ TV broadcasting, weather forecasting, mobile Communication, etc.

* RADAR :-

RADAR → Radio Detection and Ranging.

- A system used for detecting and locating the presence of objects like ships, vehicles, etc by radiating EM signal in space is known as Radar System.

- Diagram of Radar:



- Working:
1. Radio waves are radiated out from rador into free space.
2. The radio woves are intercepted by the reflecting objects i.e. targets.
3. Due to target, the radio waves are reflected back in many directions. Some of the reflected waves are directed back towords the radar.
4. The rador receives reflected waves and the target information is obtained from the wave.

* Applications:-

1. Military
2. Air traffic controlling
3. Ship safety
4. Remote sensing.

* RADAR range equation:

- Radar range equation is useful to calculate the theoretical range of target.

- The power density at a distance, R from Radar from an isotropic antenna is:

$$P = \frac{P_t}{4\pi R^2} \quad \text{——} \; (1)$$

- Mostly directive antennas are used to radiate in particular direction. Thus, the power density at target from directive antenna is:

$$P = \frac{P_t G}{4\pi R^2} \quad \text{——} \; (2)$$

- The ability of target to reflect energy is characterised by Radar cross section, σ then reradiated power density back at radar is:

$$P' = \frac{P_t G}{(4\pi R^2)} \frac{\sigma}{(4\pi R^2)} \quad \text{——} \; (3)$$

- Receiving antenna captures a portion of echo energy incident on it. If effective area of receiving antenna A_e, then:

$$P_r = P' A_e$$

$$P_r = \frac{P_t G \sigma A_e}{(4\pi R^2)^2} \quad \text{—— (4)}$$

- Substituting $P_r = S_{min}$, we get the maximum supportable range of radar system.

$$\boxed{R_{max} = \left[\frac{P_t G \sigma A_e}{(4\pi)^2 S_{min}}\right]^{1/4}}$$

Radar range equation.

As,

$$G = 4\pi A_e / \lambda^2$$

modified Radar range eqn:

$$\boxed{R_{max} = \left[\frac{P_t \sigma A_e^2}{4\pi \lambda^2 S_{min}}\right]^{1/4}}$$

* Numericals:

Q. Calculate the maximum range of radar system which operates at 3 cm with peak pulse power of 600 kW if its antenna is $5m^2$, minimum detectable signal is 10^{-13} W and the radar cross sectional area of the target is $20 m^2$?

$\Rightarrow$

$\lambda = 3 cm$

$P_t = 600 \text{ kW} = 600 \times 10^3 \text{ W}$,

$A_e = 5 m^2$, $S_{min} = 10^{-13} W$,

$\sigma = 20 m^2$

The modified radar eqn is,

$$R_{max} = \left[\frac{P_t \sigma A_e^2}{4\pi \lambda^2 S_{min}}\right]^{1/4}$$

$$= \left[\frac{600 \times 10^3 \times 20 \times 25}{4 \times \pi \times 9 \times 10^{-13}}\right]^{1/4}$$

$$R_{max} = 717.657 \text{ km}$$

$1 \text{ nm} = 1.853 \text{ km}$

In nautical miles.

$$R_{max} = \frac{717.657}{1.853}$$

$$= 387 \text{ nm}$$

* Microwave Heating:

- Microwave Heating use EM energy in freq range 300-3000 MHz to heat any dielectric material.

- The heating of any material by microwave depends on it's shape, size, dielectric constant.

- The most important characteristic of microwave heating is volumetric heating.

- Volumetric heating means the materials can absorb microwave energy and convert it into heat.

- The dissipated power within dielectric material is given as,

$$P_d = \frac{1}{2} \varepsilon \, w_o \int \varepsilon''_r \, |E|^2 \, dV$$

V = Volume of material
E = Electric field intensity
ε''_r = Imaginary part of dielectric constant of material.

- Depth of microwave power penetration $\propto$ wavelength of signal

$$\propto \frac{1}{\text{freq. of signal.}}$$

* Applications:-

1. Frozen Food Tempering:

- Famous application of Microwave heating.
- It provides a uniform temp and texture for the product.
- It eliminates bacterial growth and spoilage.
- Performed in-carton without unpacking.

2. Cancer Treatment:

- Another application in cancer treatment, in particular hyperthermic oncology.
- This therapy involves subjecting tumour tissue to heating, without damaging the healthy tissue around it.

3. Chemical Processing:

- Effective for heating fluids, ensure uniform heating in manufacture of chemicals.
- Rapidly heat chemicals through critical temp zones.

* Microwave Diathermy :

- Diathermy is electrically induced heat or the use of high-frequency electromagnetic current as a form of physical therapy and in surgical procedures.

- Diathermy is used for muscle relaxation and to induce deep heating in tissue for therapeutic purposes in medicine.

- Main feature of diathermy is with the help of heat therapy it increases blood flow and elasticity in tissues.

- Produced by three techniques:

1. Ultrasound (ultrasonic diathermy)

2. Short-radio waves in range 1-100 MHz

3. Microwaves ranging bet^w 915 MHz or 2.45 GHz bands.

Differ in penetration capability.

- The electromagnetic energy use in diathermy can cause extreme heat in metal devices like bone pins, dental filings, etc. The procedure should not be used over these areas to avoid the risk of burning.