# Unit-1

## Antenna:

**Def:** An antenna is a device, that is made up of metallic material and it can tranmits and receives electromagnetic waves is called Antenna.

## *Antenna parameters:

-> Typical parameters of antenna are.

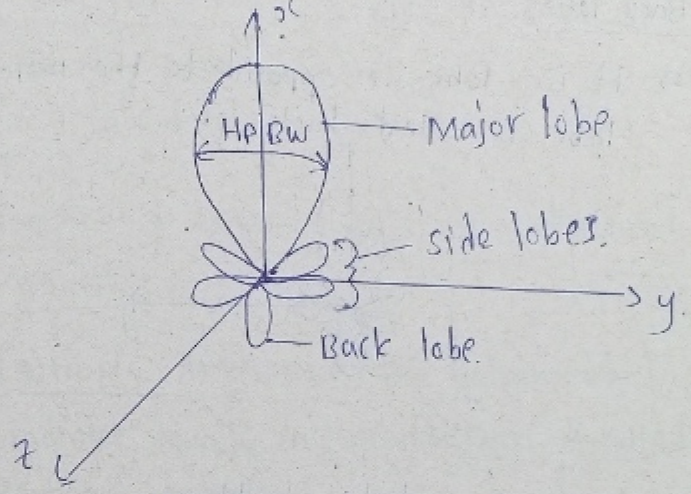
### (1). Radiation pattern

-> Radiation pattern is a antenna pattern.

-> **Def:** It is defined as graphical representation of the radiation properties of the antenna is called R.P.

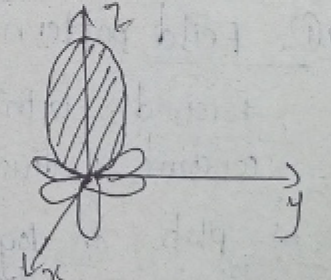
-> Determined in far-feild region.

-> graphical representation of radiation shows in below figure.




**Major lobe** It is defined as radiation ~~main beam~~ lobe, containing the direction of max radiation is called major lobe.

-> major beam.

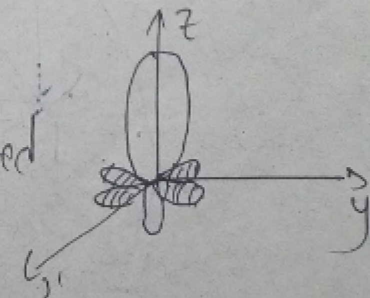



**Minor lobe:**

-> The lobe which is adjacent to be major lobe and radiation distributes in side wards, is called minor lobe.

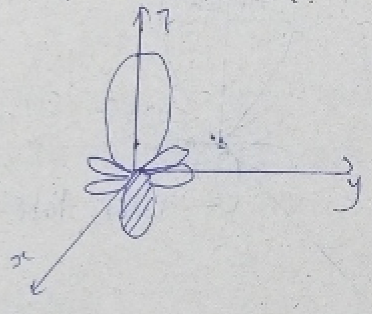
-> side lobes.

-> minor lobes are unwanted lobes.



Back lobe:

-> It is a lobe, i.e opposide to the major lobe is called back lobe.



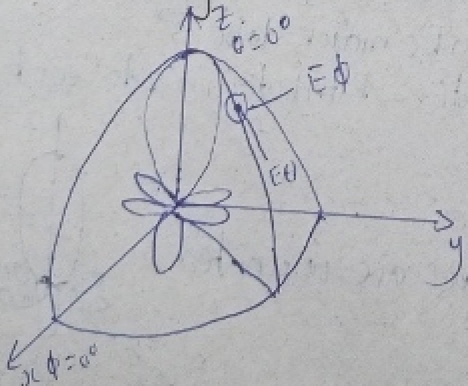

=> Types of Radiation patterns

-> Radiation pattern is of two types.

1. Feild pattern. 2. power pattern.

①. Feild pattern : A plot of the received electric (or) magnetic feilds at constant radius is called feild pattern

-> plots on logarithmic scale.

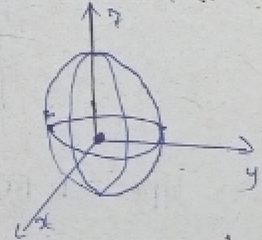



②. power pattern : A plot in terms of power per unit area i.e $|E|^2$ (or) $|H|^2$ is called power pattern.

=> Examples of radiation patterns on different Antennas

* Isotropic Antenna : The antenna which radiates equally in all directions is called Isotropic antenna.

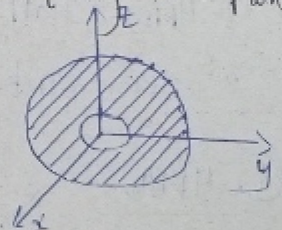
-> Radiation pattern is sphere.




* omni-directional Antenna :

-> The antenna which radiates equally in a plane

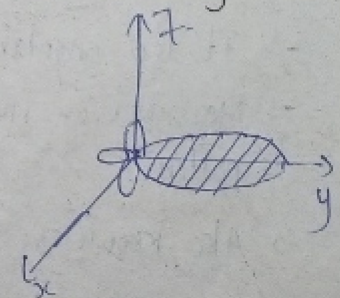
-> Ex: walkie-Talkie.




* Directional Antenna

-> The antenna which radiates the signal in particular direction

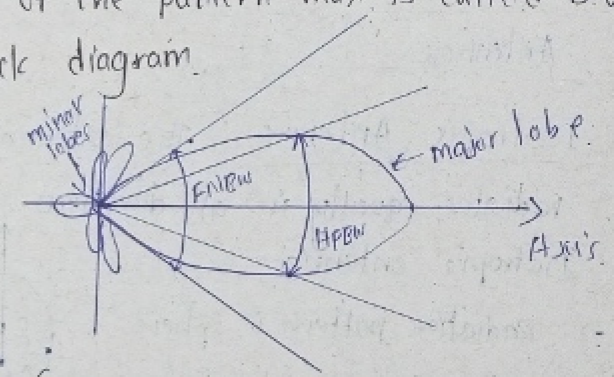
-> Ex: Tv antenna.



## Beam widths :-

**Def** The angular seperation b/w two identical points on opposite sides of the pattern max is called B.W

-> Block diagram.




-> Types of Beam widths

1. HPBW - Half power beam width.
2. FNBW - First-Null beam width

### 1. HPBW :-

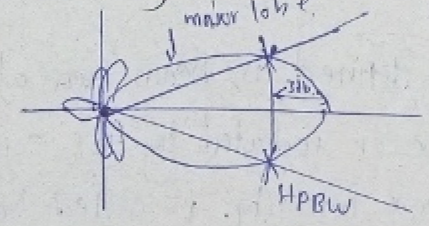
-> HPBW - Half power beam width.

-> It is a angular width in degrees.

-> Measured on major lobe of its radiation pattern.

-> Also known as 3db beam width

-> Block diagram.




-> Directivity $\propto \frac{1}{\text{Beam width}}$

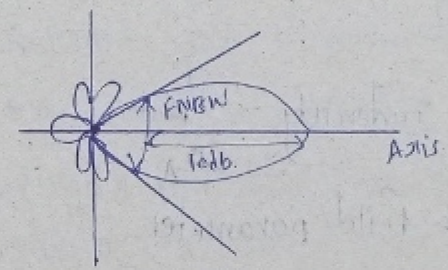
### 2. FNBW

-> FNBW - First Null Beam width.

-> The angular width b/w first side lobes is called FNBW.

-> Also known as 10db beamwidth.

-> Block diagram.




-> Factors affecting beam width

1. Dimensions
2. wavelength.
3. shape of radiation pattern.

## Beam Area :

**Def** :- It is defined as, beam area at which all the power radiated by the comes out with max intensity. is called beam area

-> Beam area is also called as beam solid angle.

-> Denoted by $\Omega_A$.

-> units - watt.

## Radiation Intensity

-> Radiation Intensity is defined as power radiated by antenna per unit beam area is called R.I.

-> Radiation Indensity = $\frac{P_{Rad}}{\Omega_A}$

-> It is far-feild parameter.

## Beam efficiency :

-> It is defined as the ratio of power radiated by antenna to the total input power given to the antenna, is called B.F.

-> Denoted by $\eta$

-> Beam Efficiency = $\frac{P_{rad}}{P_{in}}$

## Directivity :

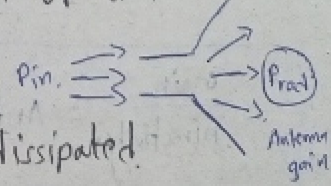
-> It is defined as the ratio of the max. radiation intensity to the average radiation Intensity. is called Directivity.

$$\boxed{D = \frac{u(\theta,\phi)_{max}}{u(\theta,\phi)_{avg}}}$$

## Antenna gain :

-> Antenna gain is defined as the ratio of Max radiation intensity from subject antenna to the max radiation intensity from reference antenna is called gain of antenna

-> Measured in dB.




-> gain in interms of power dissipated.

$$G = \frac{\text{Max radiation Intensity from subject antenna}}{\text{Max '' '' '' reference antenna}}$$

→ gain in terms of power received

$$G = \frac{\text{Max power received from subject antenna}}{\text{Max power received from reference antenna}}$$

→ Types of gain.

→ gain is of two types.

- Directive gain ($G_d$)
- power gain ($G_p$).

## Relation b/w gain and Directivity

∵ Antenna gain $= \frac{4\pi U_{max}}{P_{in}}$ — ①, Directivity $= \frac{4\pi U_{max}}{P_{rad}}$ — ②

→ Divide eq ① and ②. we get

$$\frac{\text{gain}}{\text{Directivity}} = \frac{\frac{\cancel{4\pi U_{max}}}{P_{in}}}{\frac{\cancel{4\pi U_{max}}}{P_{rad}}}$$

$$= \frac{P_{in}}{P_{rad}}$$

$$\boxed{\frac{P_{in}}{P_{rad}} = k}$$

$$\boxed{\frac{\text{Gain}}{\text{Directivity}} = \text{Antenna efficiency } (k)}$$

## Antenna Resolution

Antenna resolution is defined as "equal to half the beam width b/w first Nulls."

$$\boxed{A.R = \frac{FNBW}{2}}$$

Ex: if FNBW = 2.

$$\boxed{AR = \frac{2}{2} = 1}$$

## Aperture efficiency

**Def:** Apperture efficiency is defined as "The ratio effective aperture to physical aperture is known as apperture efficiency.

$$\boxed{\mathcal{E}_{ap} = \frac{A_e}{A_p}}$$

## Effective height

→ Effective height of an antenna is the height of the antenna's center of radiation above the ground is called Eeffective height.

→ It is the ratio of induced voltage to the incident feild.

## Effective length:

Def; The length required to radiate same power with uniform current is called effective length.

~~* Dipole Antenna~~

## Radiation from small electric dipole

-> Small electric dipole is also known as short electric dipole.

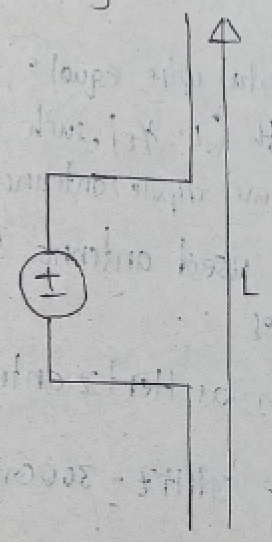
Def: -> A small electric dipole is a simple wire antenna, one end of the wire is open circuited and other end fed with AC source is called small electric dipole.

-> Frequency range 3KHZ - 30MHZ.

-> Construction and working

-> The small dipole is the dipole antenna, having the length of it wire is smaller than wavelength.

-> Block diagram




-> voltage source is connected at one end

-> The diagram shows circuit of small dipole with length 'L'.

-> The wire leads to antenna must be less than one-tenth of wavelength.

$$\boxed{\text{i.e } L < \frac{\lambda}{10}}$$

where L = length.
$\lambda$ = wavelength.

## Applications

-> used in narrow band applications.

-> used in tuner ckts.

## Half-wave dipole antenna :

**Def:** The length of total wire equals to half of the wavelength ($L = \lambda/2$), such antenna is called half-wave dipole antenna.

-> It is most widely used antenna because of its advantages.

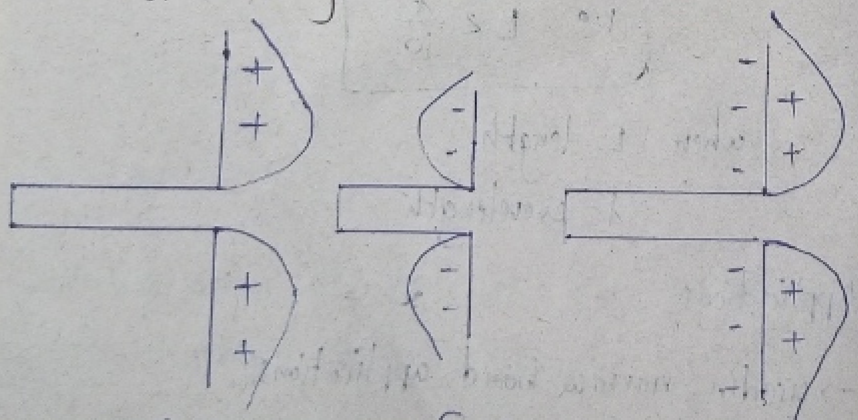
-> It is also known as Hertz antenna.

-> Frequency range 3KHZ - 300GHZ.

=> Construction and working

-> The half-wave dipole is dipole antenna having the length of it's wire is half of it's wavelength.

-> Block diagram:



(1) (2) (3)

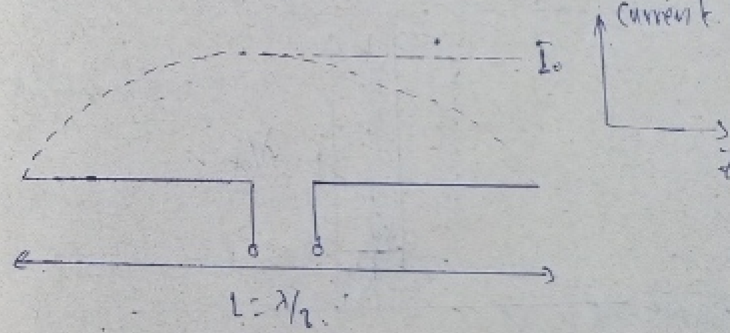
-> The above three figures shows working of half-wave dipole.

-> The edge of the dipole has max voltage, i.e Aalternating voltage

-> At the +ve peak, electrons move in one direction.

-> At the -ve peak, electrons move in other direction.

-> current distribution in half-wave dipole.




Applications

-> used in TV Receivers

-> used in radio receivers.

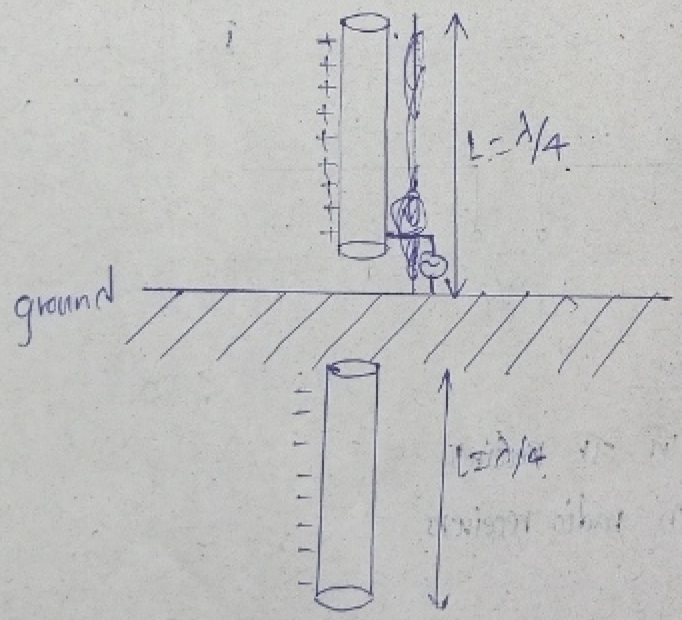
# Qurtar wave monopole Antenna

**Def** The length of total wire equal to $\lambda/4$ of the wavelength, such antenna is called Quarter-wave monopole antenna.

-> It is a ground plane dependent antenna

-> Frequency range 1.7GHZ - 2GHZ.

=> construction and working




-> Above figure shows the construction of quarter wave monopole antenna.

-> Above the ground have +ve peak antenna.

-> Below the ground is -ve peak.

-> power supply is connected to ±ve peak antenna.

-> $\lambda/4$ antenna located on a conducting ground plane.

-> current distribution:

The current distribution in quarter wave monopole antenne is assumed to be sinusoidal.

## Applications

-> mobile communicationi

-> Internet networks.

## Arrays with parasitic Elements

A parasitic element is an element, which depends on others feed.

-> It does not have it own feed.

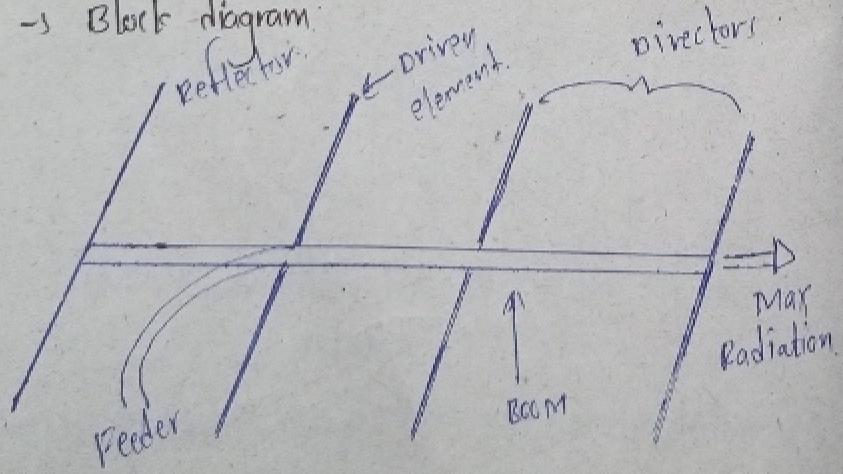
-> The parasitic elements are not directly connected to the feed.

### Construction and working of parasitic array

-> Important parts of parasitic array.

- Driven element.
- parasitic elements:
  - Reflector.
  - Director.
- Boom

-> Block diagram.




① Driven element:

The dipole that is connected to the feed is called driven element.

② parasitic elements

The elements which are added but do not posses connection b/w driven elements, they are called parasitic elements.

i Reflector : The element which is 5% longer than driven element and acts as concave mirror is called reflector.

ii Director : The element which is 5% shorter than driven element and act as convex lens is called director.

③. Boom :- The elements on which all these are placed is called Boom.

## Radiation resistances and directivities of small and large loops

-> The radiation resistance of loop antenna is given by $R_r = 31,200 \left(\frac{NA}{\lambda^2}\right)^2$ when the loop is small

$R_r = 592\, C_\lambda$, when the loop is large.

where $C_\lambda$ = circumference in wavelength.

-> The directivity of loop antenna is given by

Directivity (D) $= \frac{3}{2}$, when the loop is small

Directivity (D) $= 0.68\, C_\lambda$, when the loop is large.

-> Application of loop Antenna

- Radio receivers.
- Aircraft receivers.

## Comparision of far feilds of small loop and short dipole

-> The following table gives the comparision of far feilds of small loop and short dipole.

| Feild | Short dipole | loop antenna |
|---|---|---|
| Electric feild | $E_\theta = \frac{j 60\pi [I] l \sin\theta}{r\lambda}$ | $E_\phi = \frac{120\pi^2 [I] A \sin\theta}{r\lambda^2}$ |
| Magnetic feild | $H_\phi = \frac{j [I] l \sin\theta}{2r\lambda}$ | $H_\theta = \frac{\pi [I] A \sin\theta}{r\lambda^2}$ |

-> feild components of short dipole includes the parameter 'j'.

-> short dipole in time phase quadrature.

-> feild components of short dipole inversely proportional to 'λ'.

## * Ratiated power

Def Radiated power is defined as sum of all power radiated by an antenna connected to a transmitter is called Radiated power.

## * Radiation mechanism.

Def Radiation mechanism is defined as when the electromagnetic feild is generated by the source is transmitted to the antenna system through

### o Radiation mechanism in single wire

-> It is a fundamental single wire Antenna.

-> By the principle of radiation, the current must be varying with time.

-> For single wire Antenna.

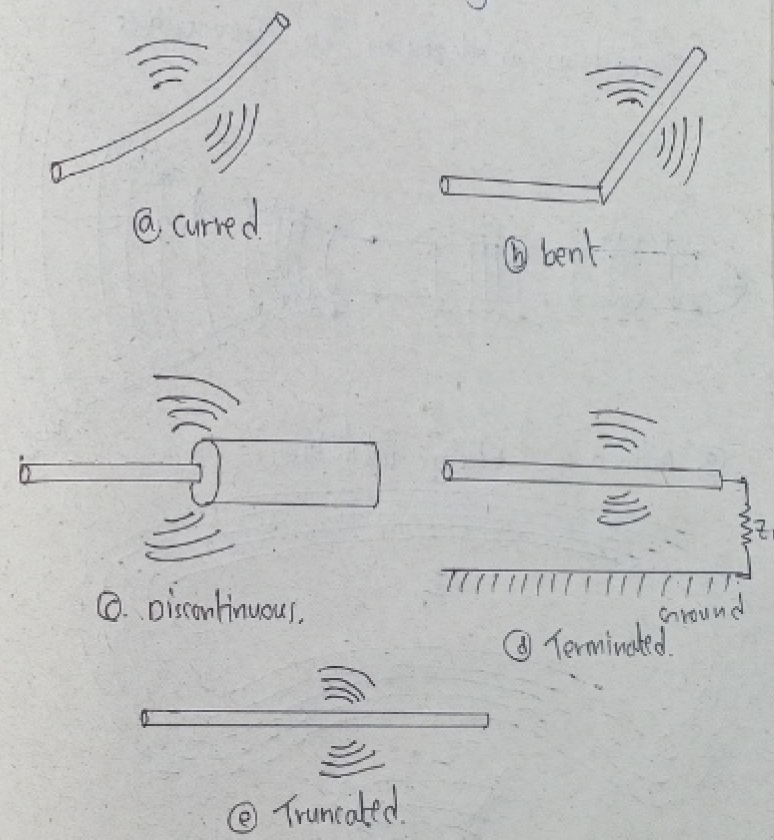
o If the charge is stationary, no current is developed, so no radiation is observed.

-> If the charge is moving,

o. No radiation is observed for straigh wire is is $\infty$.

o. Radiation is observed if wire is bent, discontinuous, terminated etc

-> Radiation mechanism in single wire.




### o Radiation mechanism in Two wire.

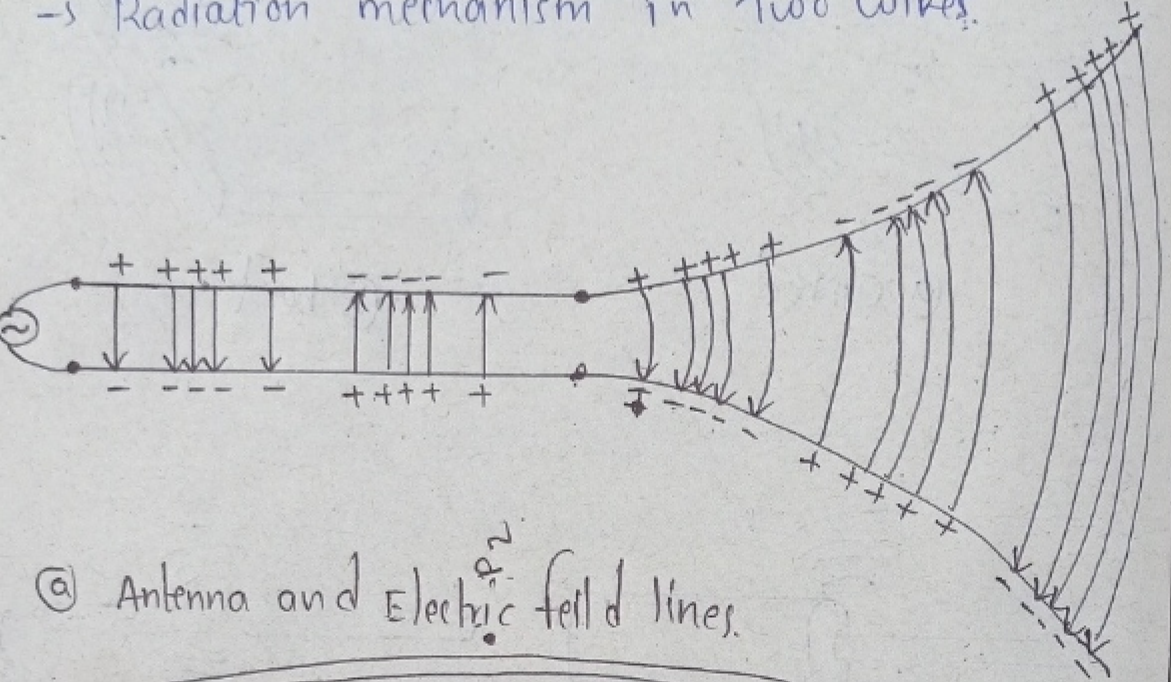
->. consider a antenna driver by a transmission line with a voltage source conductor.

->. The strength of electric lines of force $\propto$ electric feild Intensity.

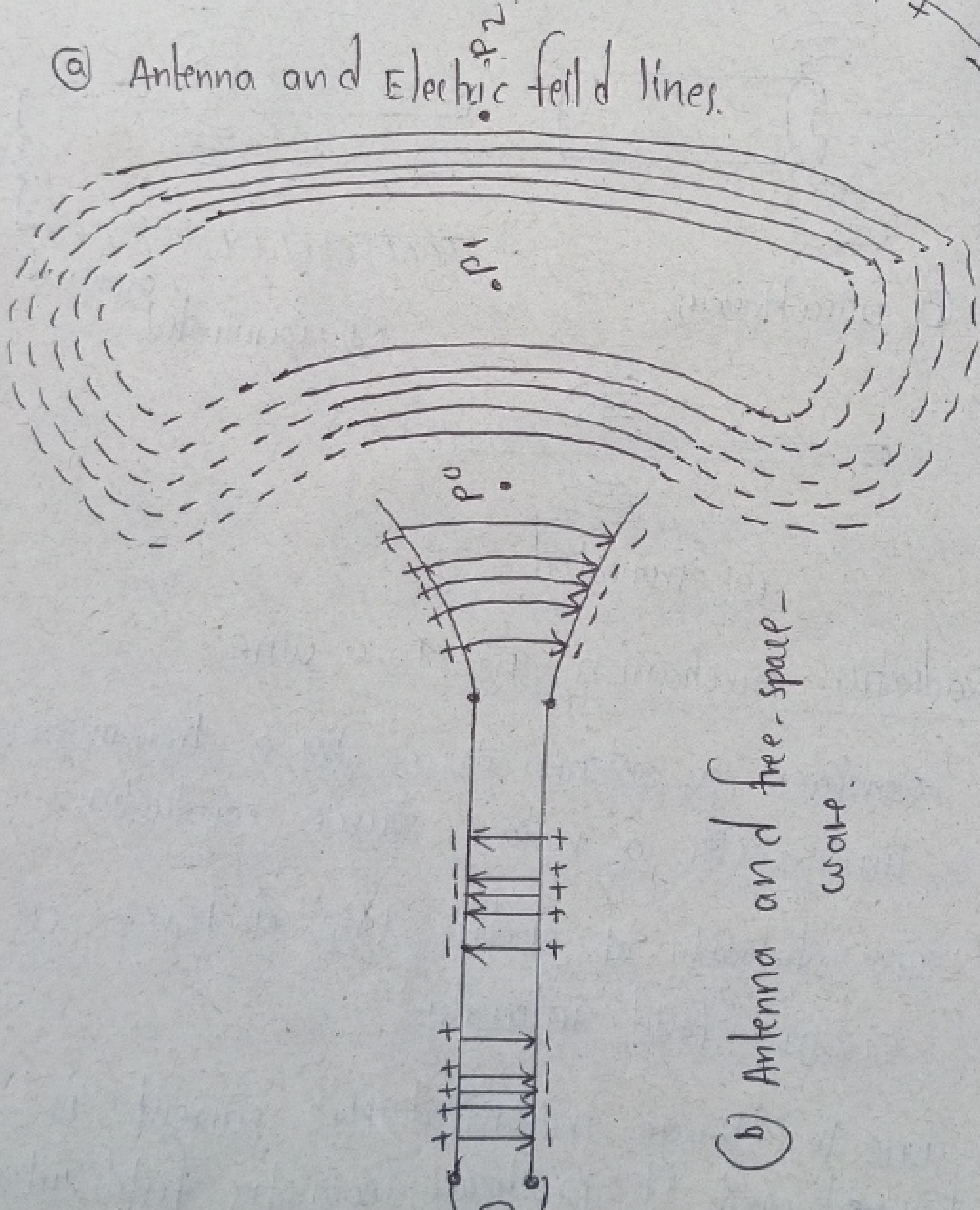
->. Due to charge movement, the current is produced ~~prod~~ and it produces magnetic feild Intensity

-> The electric feild lines travel from positive charges to negative charges.

-> Radiation mechanism in Two wires.



(a) Antenna and Electric feild lines.




(b) Antenna and free-space wave

# MID-I

1. <u>Radiation Resistance</u> : Radiation resistance is hypothetical resistance which is used to express the power dissipation in it. is called radiation resistance

-> It is a effective resistance.

<u>Effective length</u> ; Effective length of antenna defined as effectiveness of antenna as radiator of collector of EM wave energy.

$$\boxed{\text{Effective length} = \frac{\text{open circuited voltage}}{\text{incident feild strength}}}$$

<u>Radiation Intensity</u> Radiation intensity is defined as the amount of power radiated by antenna per unit solid angle

-> units are w/sr.

$$\boxed{\text{Ratiation Intensity} = \frac{P_{rad}}{\Omega_A}}$$

<u>Beam Area</u> : Beam area (or) beam solid angle is the area through which the total power is transmitted (or) receive d is called beam area.

-> unit : square degree (or) square radians.

## ② Yagi - uda Antenna

-> Basics

-> It is a directional antenna.

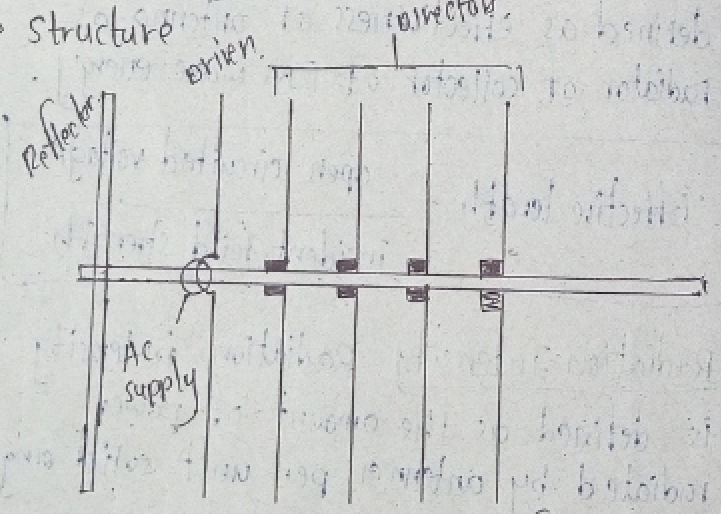
-> It has operating freq above 10 MHz.

-> It can be used for 40 to 80 km.

-> It has two types of elements

- Active elements
- passive elements.

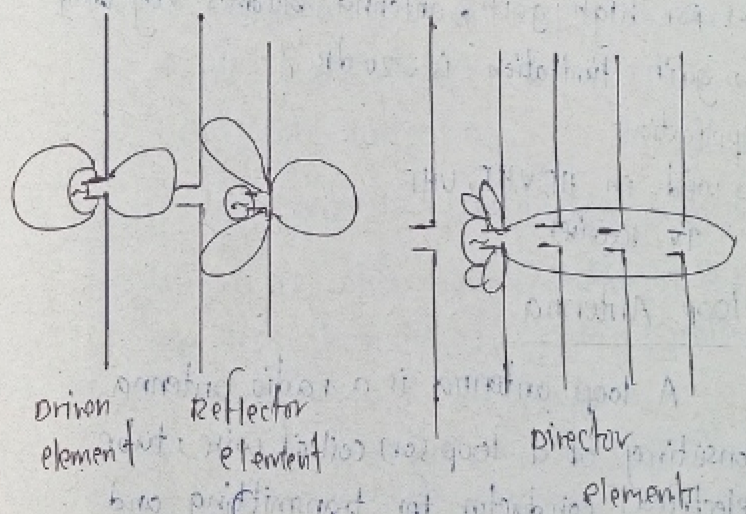
-> Structure




-> Diagram shows the structure of yagi-uda antenna.

-> Diagram consist of Reflector, AC supply, Directors, Driven etc.

-> Radiation of Yagi- uda antenna




-> Design of 3 elements.

i length of Active element.

$$L_a = \frac{478}{f_{MHz}} (ft)$$

-> length of Reflector element.

$$L_R = \frac{492}{f_{MHz}} (ft)$$

-> length of director element.

$$L_D = \frac{461.2}{f_{MHz}} (ft)$$

Advantages

-> High gain -> light weight.

-> Cheap

Disadvantages

-> For high gain, antenna becomes very long
-> gain limitation is 20 dB

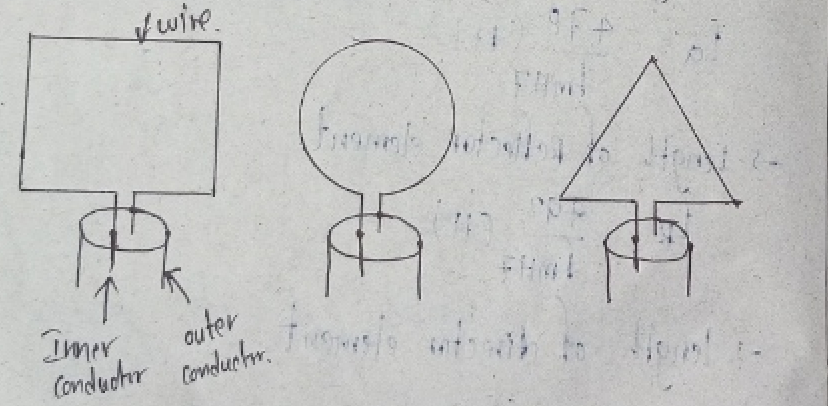
Applications

-> used in HF, VHF, UHF.
-> TV Receiver.

## * loop Antenna

A loop antenna is a radio antenna consisting of a loop (or) coil of wire, tube, electrical conductor for transmitting and receiving feeds is called loop antenna.

-> Basic loop antennas




(a). Rectangular loop antenna. (b) Circular loop antenna. c). ~~Squ~~ Triangular loop antenna.

=> Types of loop antenna

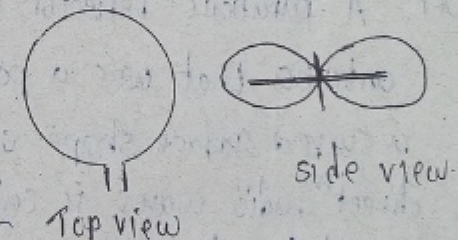
-> There are two types of loop antennas.

1. small loop antenna.
2. large loop antenna.

① Small loop antenna :- Small loop antenna is defined as, when overall length of loop is ~~λ/10~~ less than $\lambda/10$, is called small loop antenna.

-> For N no. of terms. $N(2\pi r) < \lambda/10$.

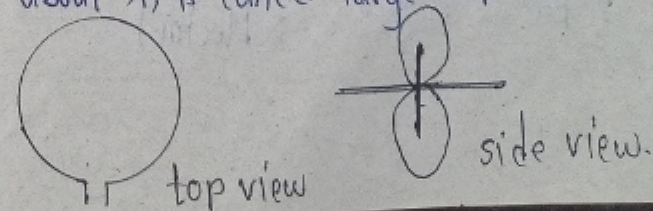
-> Diagram.




-> properties of small loop antenna.

- It has less radiation resistance.
- " " efficiency.

② large loop Antenna :- large loop antenna is defined as, when overall length of a loop is about $\lambda$, is called large loop antenna.



-> properties of large loop antenna,

- Radiates ⊥er to plane of loop.
- Hig Radiation resistance and efficiency

-> Applications

- HFC (3-30 mHZ)
- VHF (30-300mHZ)
- UHF (300-3000 mHZ)

## * parabolic Reflector antenna :

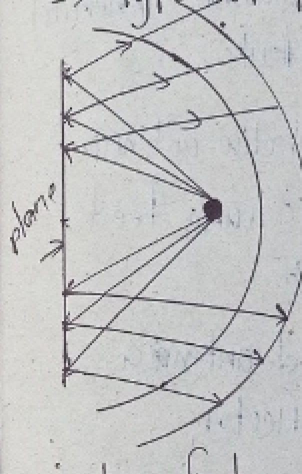
**Def** : A parabolic reflector antenna is an antenna that uses a parabolic reflector, a curved surface shape of parabola to direct the radio waves is called parabolic Reflector antenna.

-> It is used for very long distance communication, such as satellite communication

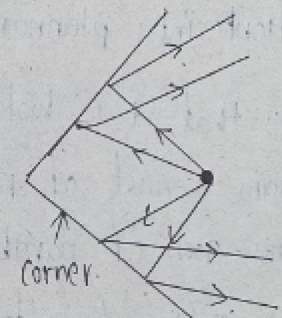
-> It cosists two types of elements.

1. Active element (Feed antenna)
2. passive element (Reflector)

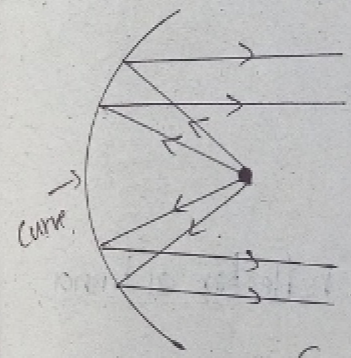
-> Types of parabolic reflector antenna.




1 plane reflector.

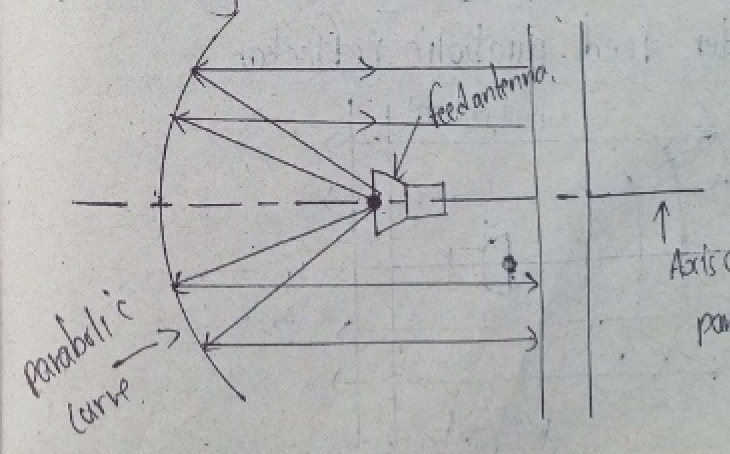



2. corner reflector.




3. curved reflector (parabola)

-> working of parabolic curved reflector



-> parabolic reflector antenna converts spherical wavefronts into plannar wave fronts.

-> Due to that, it is highly directive antenna.

-> Diagram consist of parabolic curve, feed antenna, Axis of parabola etc.

-> Here Active element - feed antenna
passive element - Reflector.

## Applications

-> satellite communication.

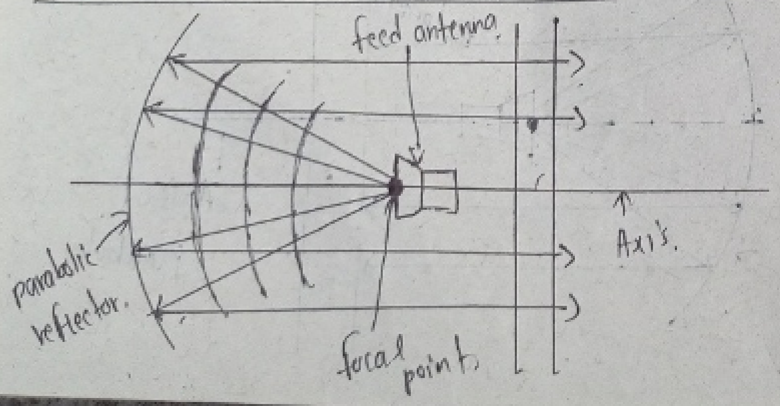
-> space communication.

-> microwave communication.

## * Feed methods of parabolic reflector antenna

-> Types of feeding

### 1 center feed parabolic reflector



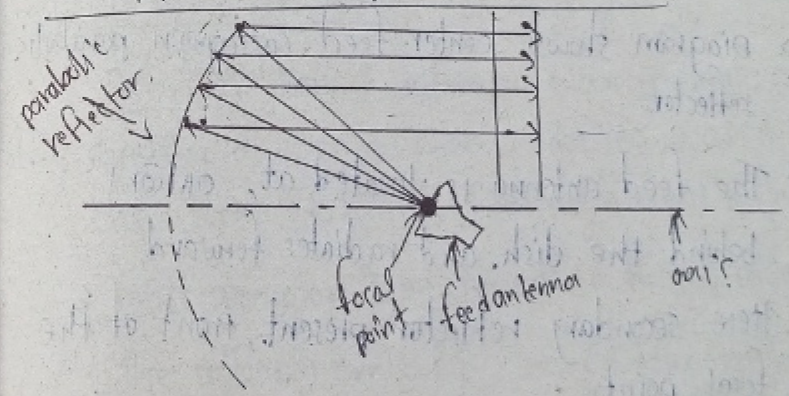

-> Diagram shows center feed parabolic reflector.

-> This is the most common type of feed method.

-> The feed antenna is located at the center of ~~ant~~ axis (or) front of the dish.

-> Some disadvantages are there in center feed.

### 2. OFFset feed parabolic reflector :




-> Diagram shows OFF-set feed parabolic reflector.

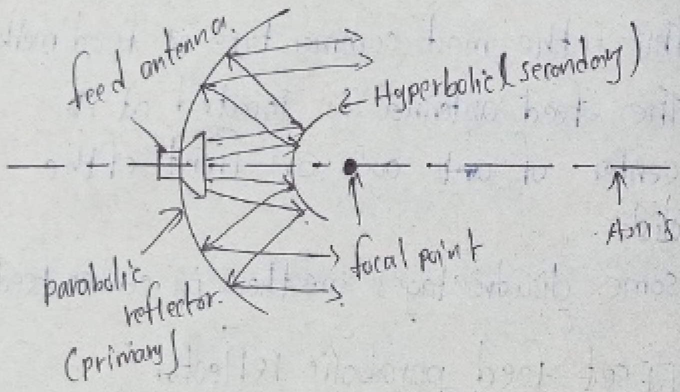
-> The feed antenna is located ~~at the~~ to the one side of the dish.

-> It is widely used in home satellite television dishes.

-> To overcome the limitations arised in center feed, offset feed is proposed.

-> It is also used in cassegrain and Gregorian.

## 3. center feed cassegrain parabolic reflector



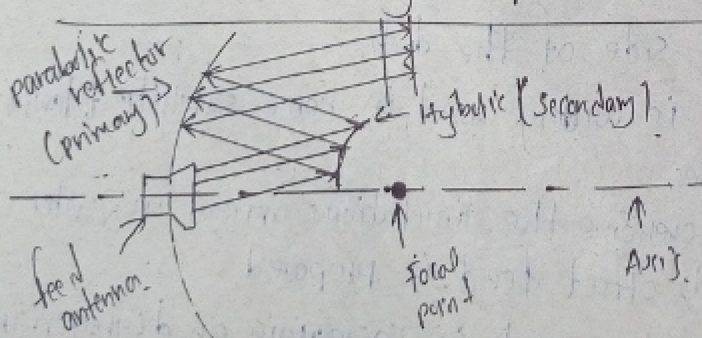

-> Diagram shows: center feed cassegrain parabolic reflector.

-> The feed antenna is located at, on (or) behind the dish. and radiates forward.

-> Here secondary reflector present, front of the focal point.

-> used for large satellite communication.

## 4. OFFset feed cassegrain parabolic antenna




-> Diagram shows OFFset feed cassegrain parabolic reflector.

-> Feed antenna is present at, on (or) behind the dish.

-> It is similar to center feed cassegrain, but feed antenna works only at top of the axis.

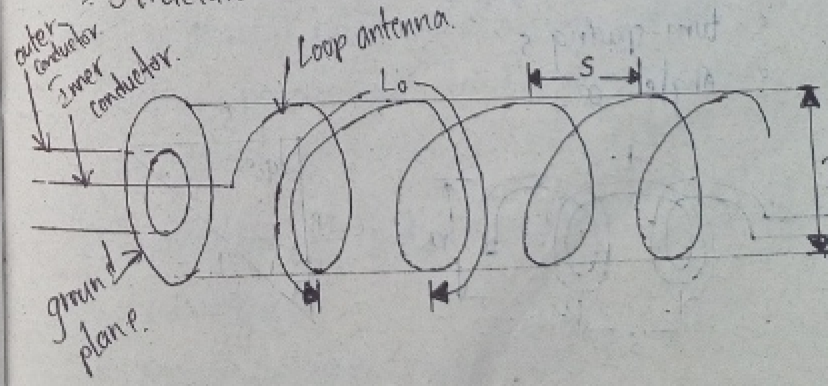
## * Helical Antenna

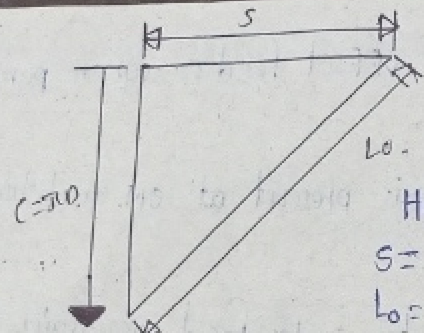
Def: A helical antenna is an antenna consisting ~~consting~~ of one (or) more conducting wound in the form of helix, is called Helical antenna.

-> Most common type is monofilar helical antenna.

-> The antennas ~~can~~ with two (or) four wires in helix is called bifilar (or) quadrafilar etc.

-> Structure of helical antenna.



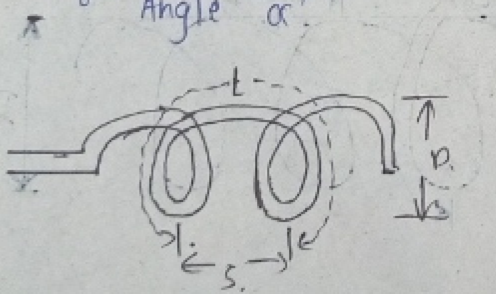


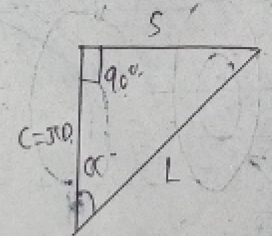

Here.
S = spacing
$L_0$ = length of one turn
D = diameter of helix
C = circumference

-> Above diagram show structure of helical antenna.
-> structre of helical antenna consist of loop antenna, Inner and outer conductors, ground plane etc.
-> Here the wire is thick copper wire which is connected to ground plane

=> Design parameters

-> The radiation depends on the
- diameter of helix 'D'
- turn spacing 'S'
- Angle 'α'



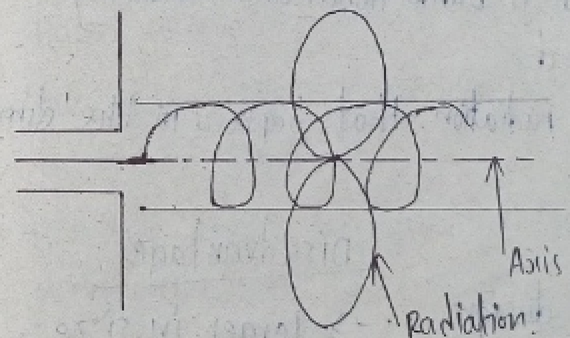

- $C = \pi D$
- $L = \sqrt{S^2 + C^2} = \sqrt{S^2 + (\pi D)^2}$
- $\alpha = \tan^{-1}\left(\frac{S}{C}\right) = \tan^{-1}\left(\frac{S}{\pi D}\right)$

-> Modes of operation of helical antenna

-> There are two modes in helical antenna
1. Normal mode helix (or) perpendicular
2. Axial mode helix

1. Normal mode helix (or) perpendicular mode helix

-> Below figure shows Normal mode helix

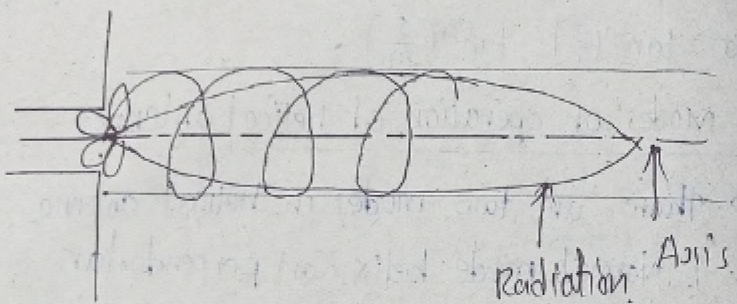



-> In Normal mode operation, the radiation i.e acting perpendicular to the axis of helix is called perpendicular mode of helix.

-> Radiation is bidirectional & circularly polarized.

-> Major radiation happens ⊥er to axis.

2. Axial mode of Helix




-> In Axial mode of operation, the radiation i.e acting in the direction of helix is called Axial mode of operation.

-> Radiation is bidirectional and circularly polarized.

-> Major radiation that happens in the direction helix.

Advantages

-> simple to design.

-> wide bandwidth.

Disadvantages

-> larger in size.

-> more space required.

Applications

-> In satellite communication.

-> In space "

-> In VHF & UHF

* Horn Antenna :

Def : Horn antenna is defined as, a horn shaped waveguide to collect radio waves and direct them in one direction is called Horn antenna

-> It is a directional antenna.

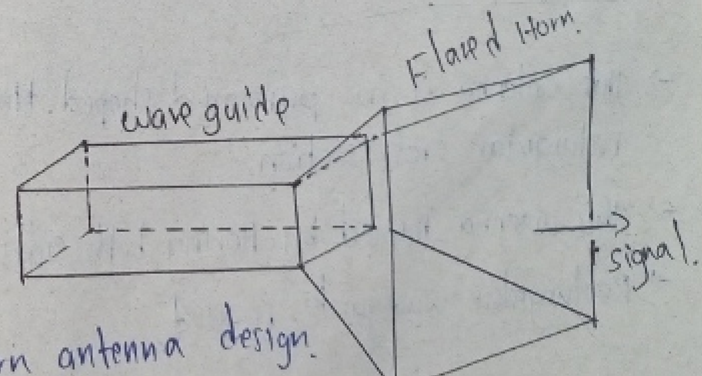
-> It is used for long distance communications

Design and working

-> Horn antenna design can be done with flared waveguide which is formed as horn.

-> This Horn antenna is used to transmit & receive RF signals.

-> Here the shape anything like square, conical rectangular etc.




-> Horn antenna design.

-> Diagram consist of waveguide and flared horn.

-> For proper working, antenna should be in minimum size.

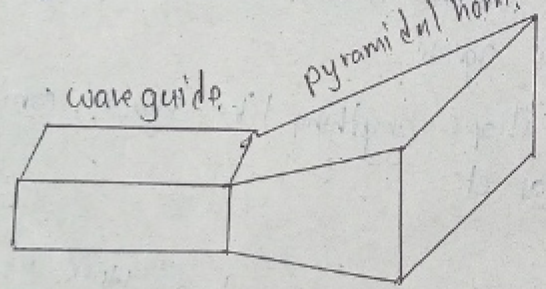
-> when a microwave signal is applied to the horn antenna Input,

-> The waveguide ~~or~~ directs towards the flared end.

-> The flared horn radiates the waves into free space.

-> Types of Horn antennas

1 pyramidal horn antenna.




-> This antenna is in pyramid shaped through rectangular cross section.

-> This antenna formed by flaring both sides

-> Rectangular waveguide is used

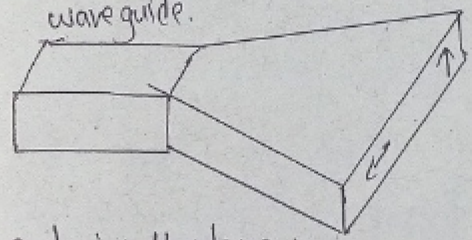
2. Sectorial horn antenna

-> This antenna is in sectorial ~~&~~ shaped through rectangular cross section.

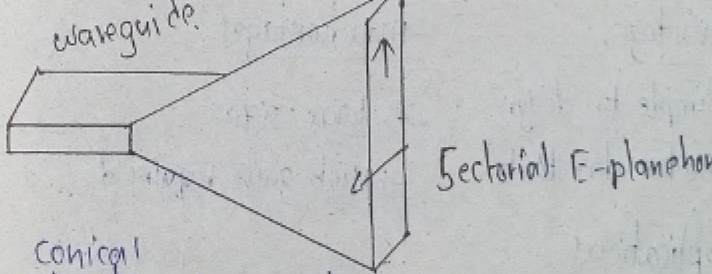
-> This antenna flares only one direction.

-> Rectangular waveguide is used.

-> It produces
- Sectorial E-plane horn.
- Sectorial H-plane horn.

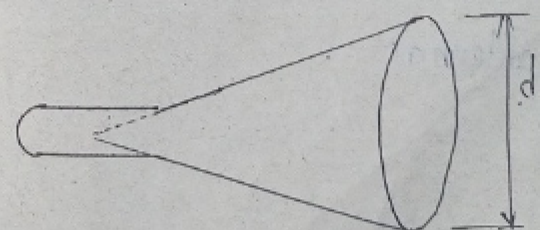



o. Sectorial H-plane horn




Sectorial E-planehorn.

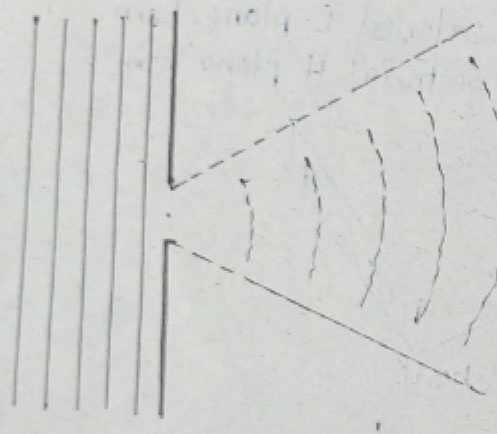
3. ~~Circular~~ conical Horn antenna



-> This antenna is in a cone shape with circular cross-section is known as conical horn antenna.

-> cylindrical waveguides are used

-> Radiation pattern of horn antenna



**Advantages**

-> Simple to design.

-> Better directivity

**Disadvantages**

-> large size.

-> High gain required

**Applications**

-> Satellite communication

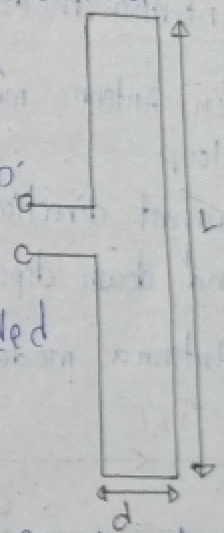
-> In Dish antennas.

## * Folded Dipole Antenna

**Def:** Folded dipole antenna is defined as folded full-wave loop antenna, where the loop has been bent connects two ends together is called folded dipole antenna.

-> Folded dipole antenna shown in side figure of length 'L' and diameter 'D'.

-> Two dipoles are connected in parallel to form folded dipole antenna.

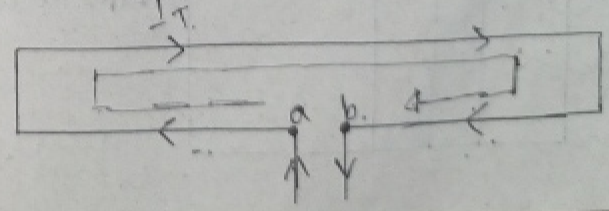



**operation:**

-> It operated on two different modes

1. Transmission line mode
2. Antenna mode

**1. Transmission line mode**



-> In Transmission line mode, current flows in loop.

-> current direction is opposite in both upper and down dipole.

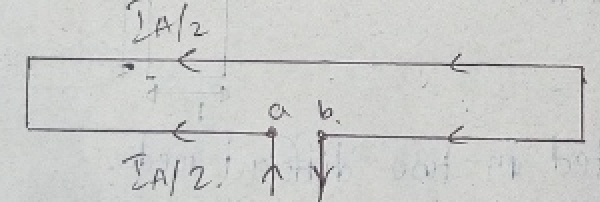
-> Transmission line mode does not radiates.

2. Antenna mode :

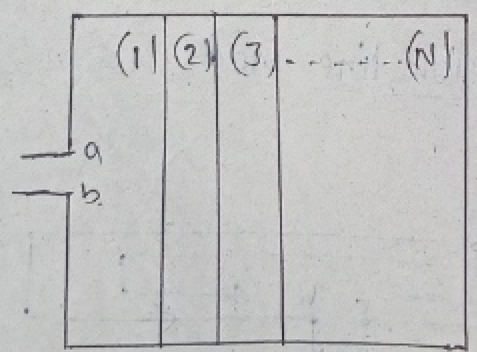
-> In Antenna mode, current doesn't flows in loop.

-> current direction is same in both upper and down dipole.

-> Antenna mode does radiates.




-> N- element folded Dipole antenna




$Z_{in} = N^2 Z_0$

Application

-> TV antenna

-> In VHF

-> yagi antenna

unit-2

## Microstrip Antennas

**Def:** A microstrip Antenna is an antenna fabricated using photolithographic techniques on PCB. is called micro-strip antenna (or) patch antenna

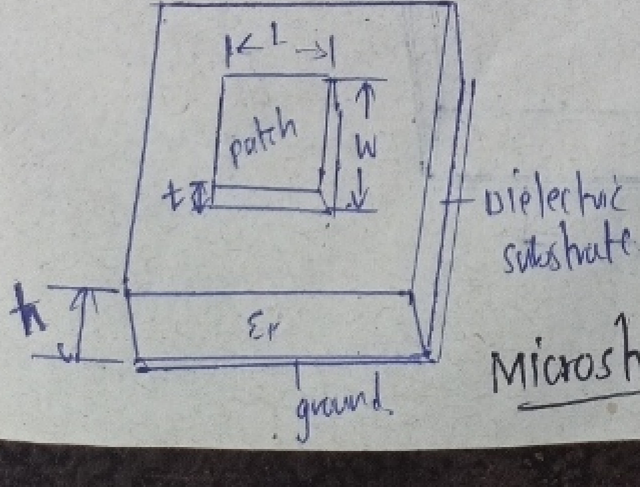
- It is also known as printed antenna.
- It is a Internal antenna.
- It is mostly used in microwave frequencies.

### Advantages

- Small in size.
- weight less.
- Easy to design.
- Installation is easy.
- low cost.

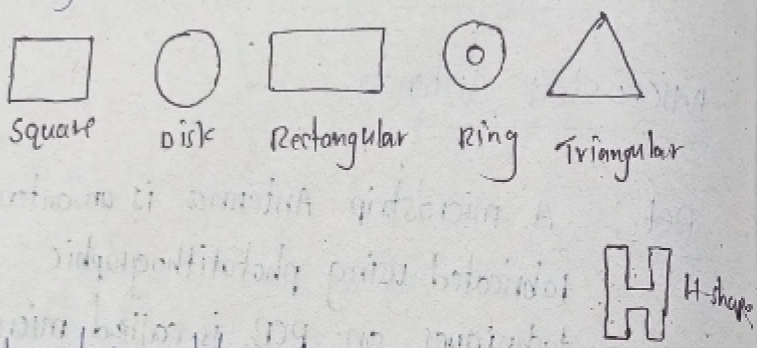
### Disadvantages:

- less gain.
- less efficiency
- less power handing capacity
- less Bandwidth.
- Dielectric losses.
- poor performance.
- low power.




Microstrip Antenna

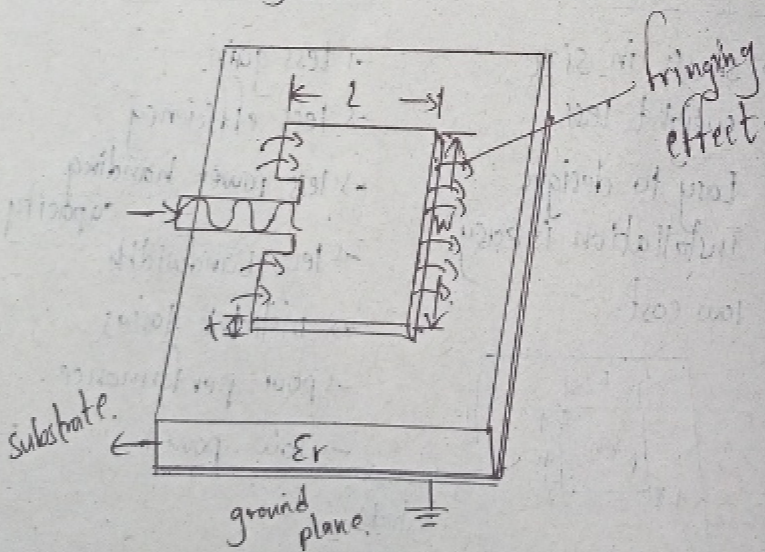
-> Types of microstrip antennas




## Rectangular patch Antenna

Def : A rectangular patch antenna is a form of antenna which consist of rectangular patch.

-> Block diagram




-> consider a rectangular patch antenna of length(L), width (w) thickness (t) etc.

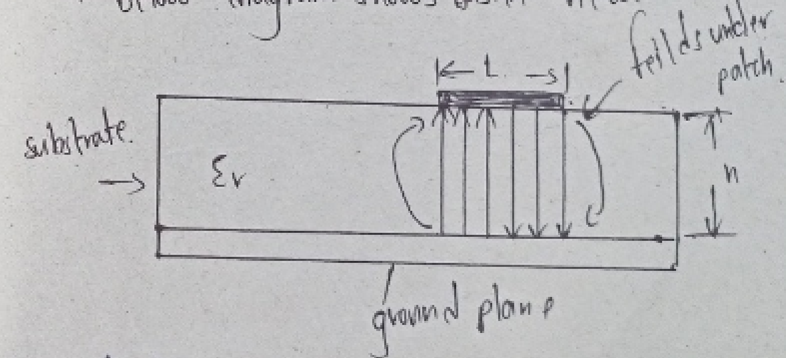
-> Block diagram consist of patch, substrate, ground plane, etc.

-> Here

- $0.3333\lambda_0 < L < 0.5\lambda_0$,
- $t << \lambda_0$.

-> microstrip antenna radiate primarily because of the fringing feild b/w patch and ground plane.

-> Below diagram shows inside view.




## Applications

-> Aircraft
-> Spacecraft
-> satellite
-> missile
-> mobile.

## Characteristics of microstrip Antenna

-> The microstrip Antenna characteristics include the following.

-> The microstrip antenna shoul d be thin conductive region.

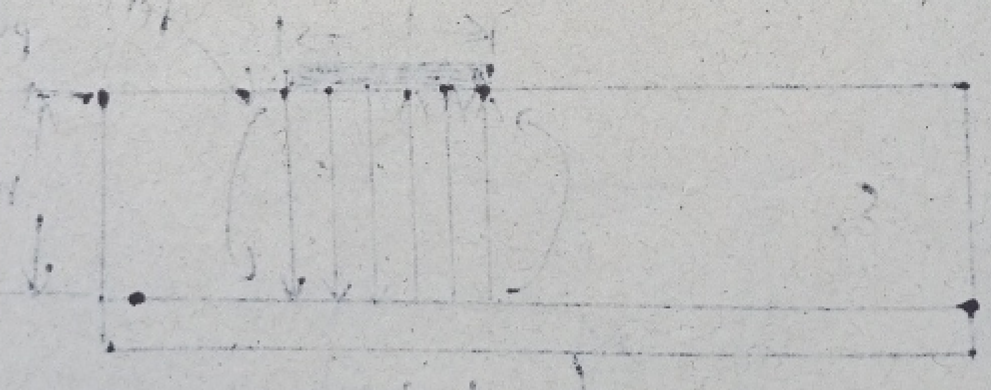
-> Ground plane have large dimensions.

-> offers high beam width.

-> low efficiency & Bandwidth.

-> low weight

-> small in size.

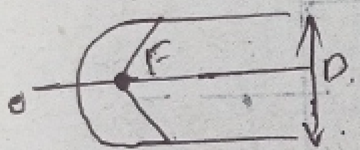


# pattern characteristics of Reflector antenna

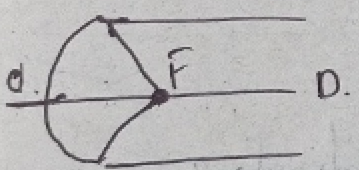
→ The ratio of focal length 'f' to aperture size 'D' is known as 'f/D' aperture Number.

→ Aperture No. varies b/w 0.25 – 0.5

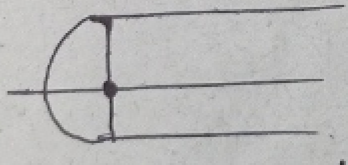
(i) 'f' is small, focus Point lies inside the aperture.




ii 'f' is large, focus point lies beyond the open mouth.




iii The focus point lies in the plane of aperture



→ $BWFN = \dfrac{140\lambda}{D}$ degree

→ $HPBW = \dfrac{58\lambda}{D}$ degree

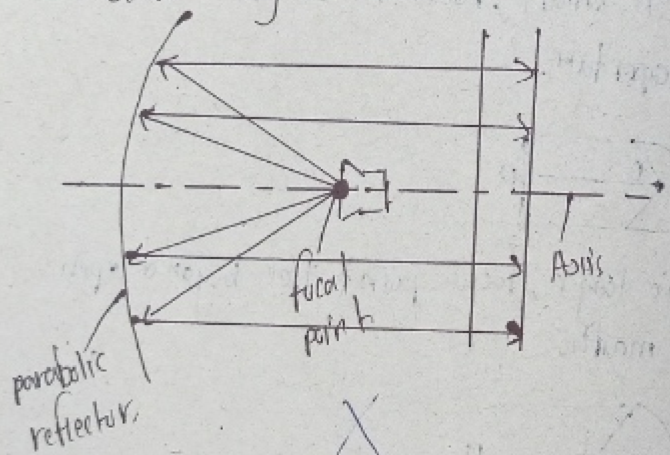
→ $\text{Directivity} = \dfrac{4\pi A_0}{\lambda^2}$

## Feed methods of reflector Antenna

-> Types of feeding.

①. center feed parabolic reflector :

-> Block diagram.




**Advantage**

-> less cross-polarization.

**Disadvantage**

-> Blockge due to feed.

②. offset fed

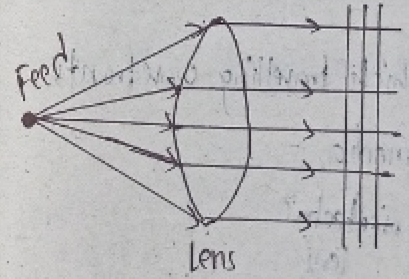
## * lens Antennas :

**Def :** The three dimensional electromagnetic device i.e used mainly for high frequency applications is known as lens antenna.

-> It consists a electromagnetic lens with feed.

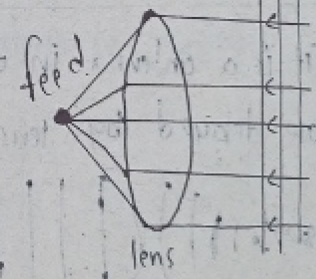
-> It is heavier, thicker, difficult to construct.

### principle of lens Antenna




Transmitter lens

(1)




Receiver lens

(2)

-> figure (1) shows Transmitter lens.

-> figure (2) shows Receiver lens.

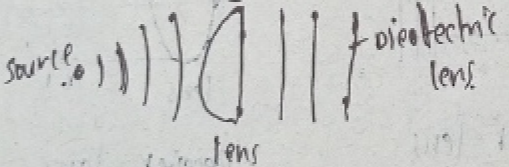
-> Feed plays vital role here.

Types of lens Antenna

- Dielectric lens Antenna. [H-plane]
  - Non-metallic dielectric type of lens.
  - metallic dielectric type of lens.
- metal plate lens Antenna [E-plane]

Dielectric lens Antenna

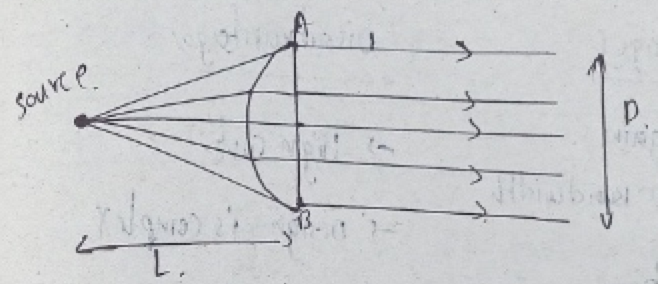
It is a antenna in which travelling wavefronts are delayed by lens media.




(i). Non-metallic dielectric lens Antenna

-> The lens is made up of polystyrene, (or) polyethylene.

-> Diagram.




-> Here Non-metallic dielectric lens is used.

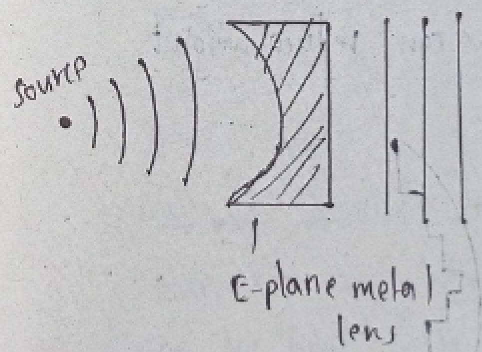
-> L = length

D = Directivity

-> All paths from source to lens is equal

Metal plate lens Antenna

-> Also knows as E-plane lens antenna.




-> Here E-plane lens is used.

-> wavefronts are speed up by lens.

| Advantages | Disadvantages |
|---|---|
| -> High gain | -> High cost. |
| -> narrow Bandwidth. | -> Design is complex. |

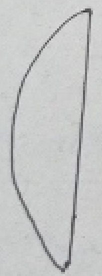
**Applications**

-> Satellite communication
-> microwave applications.

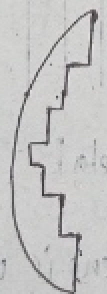
## Zoning

-> when we use lens antenna, it is very bulky so reduce it's weight we can provide zoning.

-> By cutting lens we can reduce weight.



Before Zoning



After Zoning.

-> Zoning is of two types

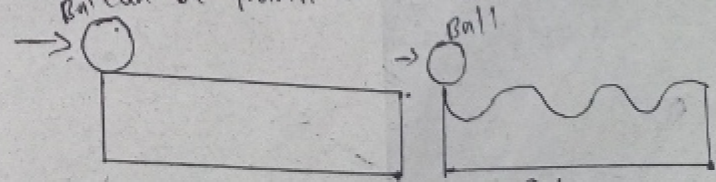
| curved surface Zoning | plane surface Zoning |
|---|---|
| -> less weight. | -> more weight |
| -> mechanically strong. | -> mechanically weak. |
| -> less power dissipation. | -> more power dissipation |

## Fermats principle.

Def: Fermat's principle is also known as principle of least time.

-> It is the link b/w wave optics and ray optics.

-> fermats principle states that - The path taken by ray between two points can be travelled in the least time.




(1) (2)

-> In fig(1) Ball reaches end in least time.

| VHF | UHF |
| --- | --- |
| -> VHF - very high frequency. | -> ultra high frequency. |
| -> VHF Antennas length is ~~short~~ longer. | -> UHF Antennas length is short. |
| -> signal strength is stronger. | -> The signal strength is weaker. |
| -> VHF is less expensive | -> UHF is more expensive. |
| -> VHF can travel upto 100 miles. | -> UHF is used for short distances. |
| -> VHF is ideal for outdoor environments. | -> UHF is ideal for indoor environments. |
| -> VHF operates b/w 30-300 MHZ. | -> UHF operates b/w 403-407 MHZ. |
| -> VHF requires less power. | -> UHF requires more power. |
| -> Applications<br>o Marine applications.<br>o forestry.<br>o golf courses. | -> Applications<br>o Medical staff.<br>o schools.<br>o warehouses. |

# unit-3

## * Different modes of wave propagation

wave propagation : The path taken by the wave to travel from transmitter to receiver is called wave propagation.

-> Types of wave propagation.

1. Ground wave propagation.
2. Space " "
3. Sky " "

### (1). Ground wave propagation:-

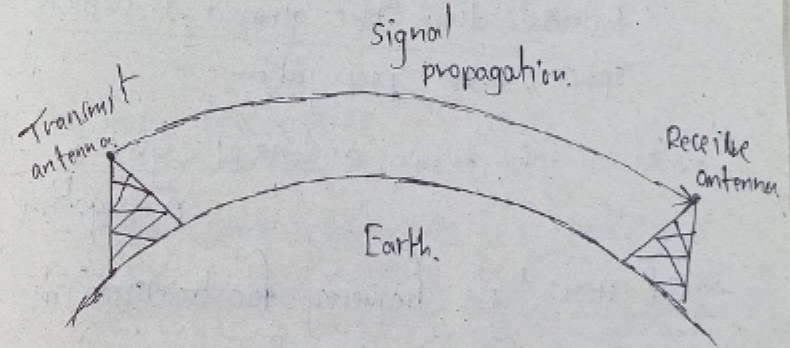
Def: The propagation in which, the wave propagate near the earth surface is called ground wave propagation.

-> This type of propagation is possible when transmitting and receiving antennas are closed to earth surface

-> It is used for short range communication.

-> It is used for low freq operation.

-> Diagramatic representation




-> It is also known as surface wave propagation.

-> communication Range · 100km to 1000km.

-> Frequency range is 3khz - 3mhz.

Advantages

-> Not affected by atmospheric conditions

Disadvantage

-> covers only short distances.

## Space wave propagation

**Def** The propagation in which, the wave signal propagate directly from transmitting antenna to receiving antenna (or) reflected from the ground is called space wave propagation.

-> It is also known as line of sight propagation.

-> It uses high frequency for transmission.

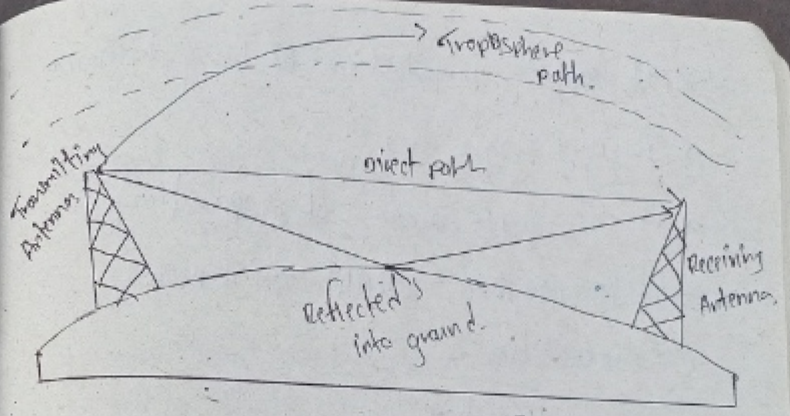
-> This waves travel in troposphere region, which is 20 km above from the ground level.

-> space wave propagation mostly done in troposphere.

-> Frequency range is b/w 30MHZ-300MHZ.

-> Due to high freq they are less wavelength.

-> Diagramatic representation.




## * sky wave propagation

-> sky wave propagation is a radio wave propagation.

-> In skywave propagation waves emitted from transmitting antenna to upward at great angles and reflected back to earth by inosphere is called sky wave propagation.

-> In this propagation, the waves go from transmitting antenna to receiving antenna through sky.

-> used for long distance communication.

-> frequency range 30MHZ-40MHZ

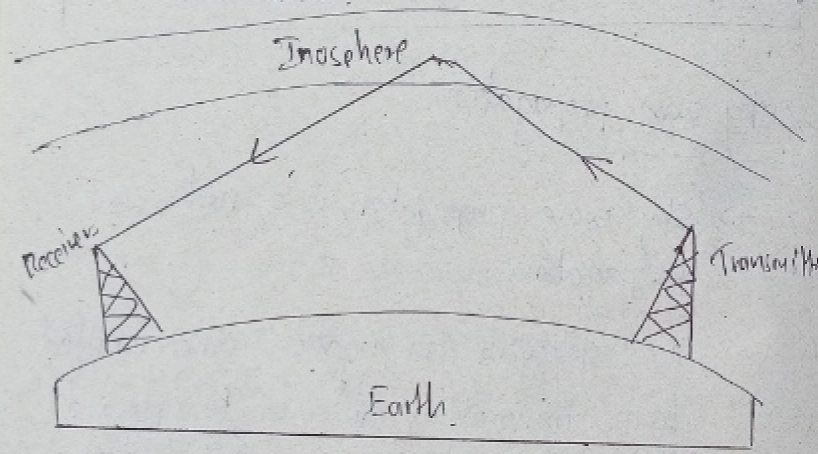
-> It is also known as skip wave propagation

-> It supports propagation at long distances.

-> It uses high freq.

-> It is simple mode of propagation.

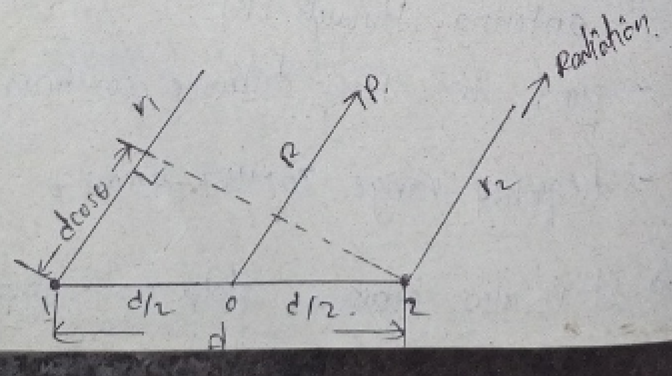
-> It is used in satellite and mobile communication.




## * Array of two Isotropic sources

Case (i)

-> Consider Array of two Isotropic sources with equal Amplitude and phase.




-> The total distance b/w two point sources is d.

-> And half is $d/2$.

-> Two isotropic points are symmetrical w.r.to origin O. with same amplitude and phase

-> ~~Bore~~ Equal current is applied two both points, Electric feild magnitude is equal.

$$\boxed{E_1 = E_2 = E_0}$$

-> Total path difference $= d\cos\theta$

-> Total phase " " $= \beta d\cos\theta + \alpha$.

-> Electric feild

$E_1$ = Electric feild at point 'p' due to source 1.

$E_2$ = " " " " " " source 2.

->

$$E = \underbrace{2E_0}_{\text{AMP.}} \cos\left[\underbrace{\frac{\beta d\cos\theta}{2}}_{\text{phase.}}\right] - (1).$$

-> Maxima direction - $\phi_{max} = 90^\circ$ (or) $270^\circ$

-> minima " -> $\phi_{min} = 0^\circ$ (or) $180^\circ$.

-> $\phi_{HPPD}$ = direction -> $60^\circ$ (or) $120^\circ$

(Case ii)

-> Equal Amplitude and opposite phase

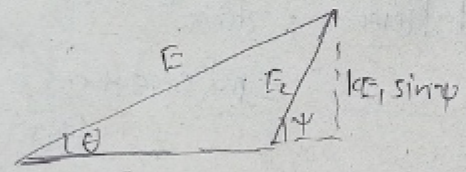
-> $E_T = j(2E_0)\sin\left[\frac{\beta d\cos\phi}{2}\right]$

-> Maxima direction - $\phi_{max} = 0^\circ$ (or) $180^\circ$.

-> minima direction - $\phi_{min} = \pm 90^\circ$.

-> $\phi_{HPPO} = 60^\circ$ (or) $120^\circ$

(Case iii)




-> $\psi = \frac{2\pi}{\lambda}\cos\phi + \alpha$

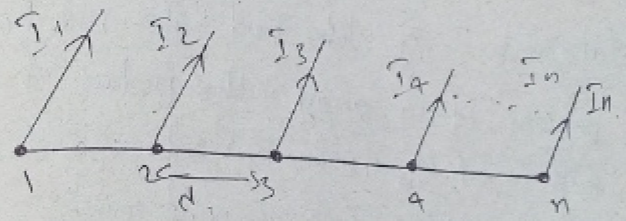
let $\frac{E_2}{E_1} = k$

$\theta = \tan^{-1} \frac{k\sin\psi}{1+k\sin\psi}$

## * Binomial Arrays

Def: Binomial array is non-uniform antenna array, in which elements are equally spaced with unequal amplitude.

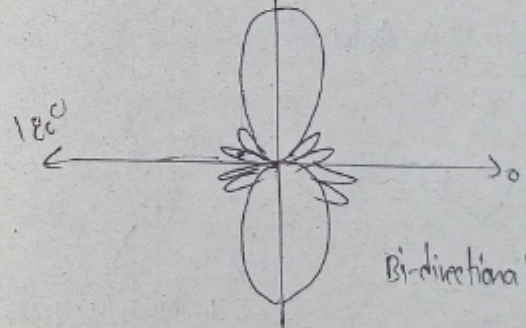
-> spacing of elements




-> N elements are placed with equal spacing of 'd'.

-> $d = \lambda/2$.

-> There is no sidelobes




Bi-directional pattern

-> length(L) = $(n-1)\lambda/2$.

-> HPBW $= \frac{1.75}{\sqrt{L/\lambda}}$

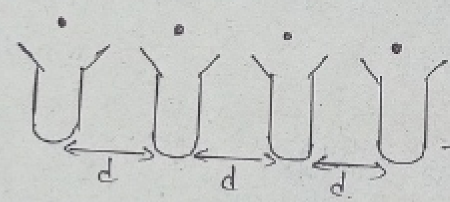
-> Directivity (D) = $1.77\sqrt{n}$

-> Array factor (AF) = $(1+z)^{n-1}$

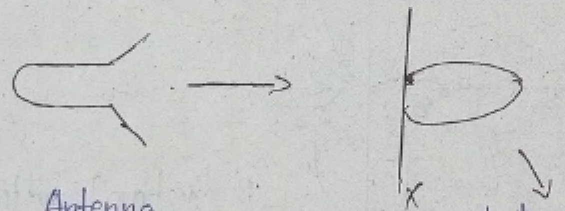
## principle of pattern multiplication :-

Statement : It states that "The radiation pattern of an array is the product of pattern of the individual antenna with array pattern of the Isotropic point sources.

->



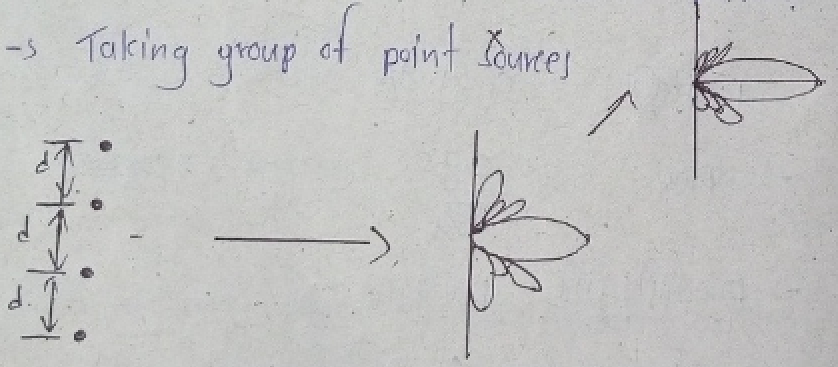

-> Taking one Antenna




Antenna

Radiation pattern.

-> Taking group of point Sources




-> principle of pattern multiplication

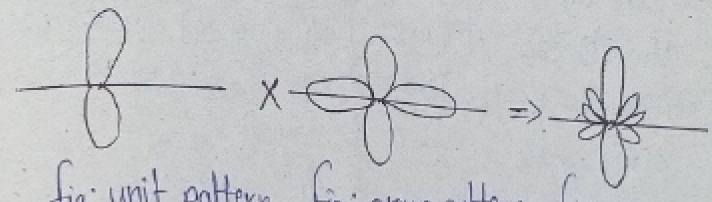



fig: unit pattern. fig: group pattern. fig: Total pattern.

-> By making multiplication of unit and group patterns we get total pattern.

-> let E = Total feild

$E_i(\theta,\phi)$ = Feild pattern of individual source.

$E_a(\theta,\phi)$ = Feild " " array of Isotropic point sources

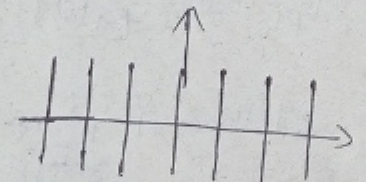
$E_{pi}(\theta,\phi)$ = phase " " Individual sources

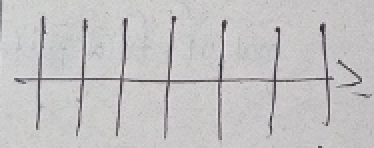
$E_{pa}(\theta,\phi)$ = " " " array of Isotropic point sources

$$E = \{E_i(\theta,\phi) \times E_a(\theta,\phi)\} \times \{E_{pi}(\theta,\phi) + E_{pa}(\theta,\phi)\}$$

mul of feild pattern. Addition of phase pattern.

| Broadside array | End-fire array |
|---|---|
| → In broadside array, the direction of max. radiation is ⊥er to array axis. | → In End-fire array, the direction of max. radiation is along the array axis |
| → phase difference $\alpha = 0$. | → phase difference $\alpha = -\beta d$ |
| → Directivity $D = 2$. | → Directivity $D = 4$ |
| → Radiation pattern is bidirectional. | → Radiation pattern is unidirectional. |
| → All elements are equally spaced and equal magnitude and same phase. | → All elements are equally spaced, and equal magnitude and different phase. |
| → Direction of radiation pattern. | → Direction of radiatio pattern. |

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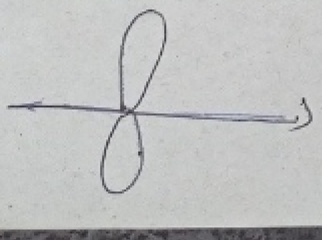

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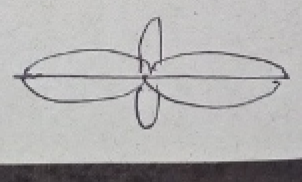


# 3rd unit - PART - II

**waveguides** A waveguide consist of metallic tube of rectangular (or) circular shape used to guide an electromagnetic wave is called waveguide

→ waveguides are easy to manfacture.

*** phase velocity** :- It is defined as, "the velocity with which the wave travells in the waveguide is called phase velocity ($v_p$)

$$v_p = \lambda g . f$$

$$= \frac{2\pi}{2\pi} \lambda g . f$$

$$= \frac{2\pi f}{2\pi} . \lambda g .$$

$$= \frac{2\pi f}{2\pi / \lambda g}$$

$$= \frac{2\pi f}{\beta}$$

$$\boxed{v_p = \frac{\omega}{\beta}}$$

$$\boxed{2\pi / \lambda g = \beta}$$

$$\boxed{\omega = 2\pi f}$$

**Group velocity** :- It is defined as, "The rate of which the wave propagate through waveguide is called group velocity ($v_g$)

$$V_g = \frac{d\omega}{d\beta}$$

## * Rectangular waveguide

<u>Def</u>: A Rectangular waveguide is a metallic tube with rectangular cross-section area is called. Rectangular waveguide.

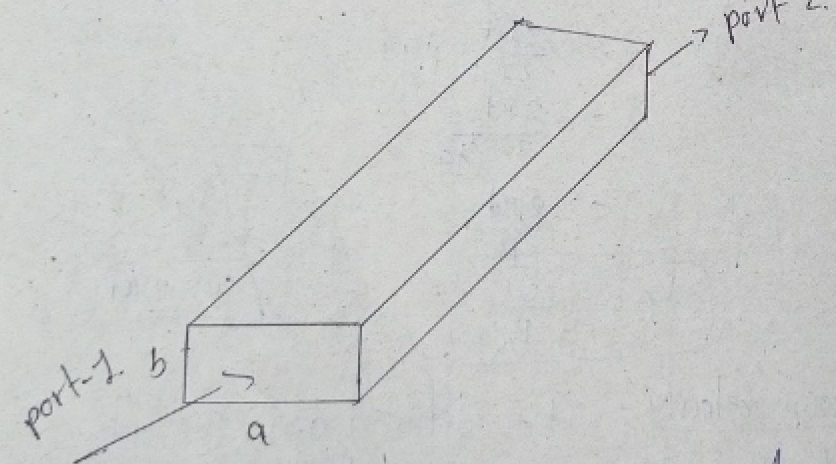
-> Rectangular waveguide supports only TE & TM modes.

-> It does not support TEM.

-> It is most commonly used waveguide.

-> It is used at microwave frequency range.

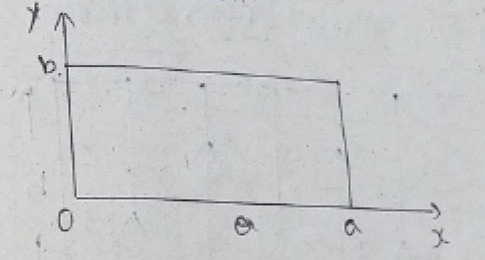
-> Diagram.




-> Diagram shows 2-port rectangular waveguide.

-> It is used in microwave communication.

-> Transverse cross section




-> It is used as Transmission lines.

-> The power flow is in the form of electric or magnetic feild.

-> conditions of wave propagation.

(i) $\lambda_c > \lambda_0$.

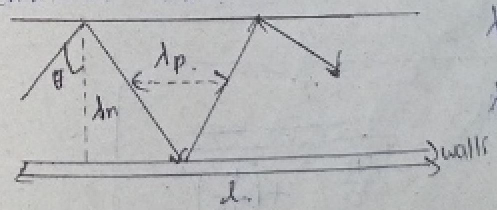
(ii) $f_c < f_0$.

-> For rectangular waveguide $TE_{10}$ is dominant mode

-> cut-off frequency. $f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

-> cut-off wavelength. $\lambda_c = \frac{2ab}{\sqrt{m^2b^2 + n^2a^2}}$

-> <u>Internal Reflection</u>.

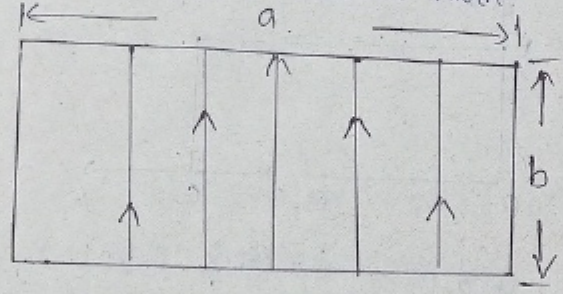



$\lambda_n$ = Normal component

$\lambda_p$ = parallel component.

## TE mode of Rectangular waveguide:

-> TE- Transverse Electric mode




-> In TE mode electric feild of the signal ⊥er to direction of propagation through waveguide.

-> It is labelled as TE(m,n)

-> where m,n are Integers.

-> The wave impedence of TE mode is given by

$$\boxed{Z_0 = \frac{377}{\sqrt{1-(\lambda/\lambda_c)^2}}}$$

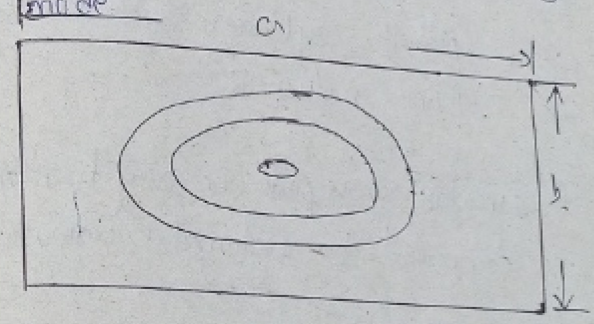
-> The cut-off wavelength of TE(m,n) is given by

$$\boxed{\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2+\left(\frac{n}{b}\right)^2}}}$$

## TM mode of Rectangular waveguide

-> TM mode stands for Transverse magnetic mode

->




-> In TM mode magnetic feild of the signal ⊥er to direction of propagation through waveguide

-> magnetic feild exists and changing in x-direction and also exist and changing in y-direction.

-> It is labelled as TM(m,0)

-> The wave impedence of TM mode is given by

$$\boxed{Z_0 = 377\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2}}$$

## Circular waveguide

**Def:** A circular waveguide consist of a metallic cylinder with an ~~int~~ inner radius R.

-> circular waveguide is easy to manfacture compared to rectangular waveguide.

-> It can be easily joined compared to rectangular waveguide

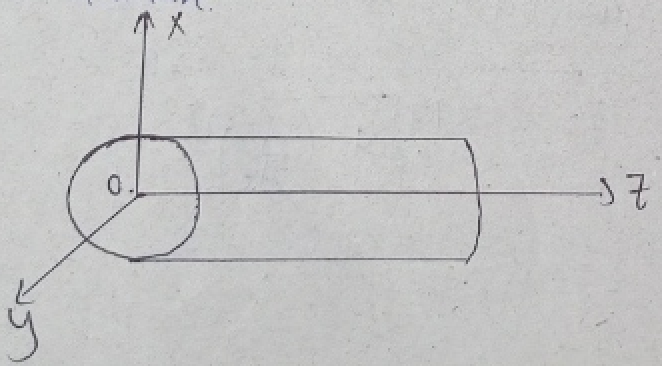
-> It does not support TEM

-> It occupy more space compared to rectangular waveguide.

-> For circular waveguide $TE_{11}$ is dominant mode.

-> The $TE_{01}$ and $TM_{01}$ modes are rationally symmetric.

-> structure




-> It supports only TE and TM modes.

-> cut-off frequency -> cut-off wavelength

$$f_c = \frac{X_{np}}{2\pi a\sqrt{\mu\epsilon}} \qquad \lambda_c = \frac{v}{f_c} = \frac{2\pi a}{X_{np}}$$

-> phase velocity $v_p = \frac{v}{\sqrt{1-(f_c/f)^2}}$

-> Guide wavelength $\lambda_g = \frac{\lambda}{\sqrt{(1-(f_c/f)^2}}$

## * Endfire Array with Increased Directivity

-> The max radiation can be obtained along the axis of the uniform end fire array.

-> The progressive phase shift is given by

$\alpha = \pm\beta d$

$= -\beta d$ for max in $\theta = 0^\circ$ direction.

$= +\beta d$ for max in $\theta = 180^\circ$ direction.

->

1. For max radiation along $\theta = 0^\circ$

$|\psi| = |\beta d\cos\phi + \alpha|_{\phi=0^\circ} = \frac{\pi}{n}$ and $|\psi| = |\beta d\cos\phi + \alpha|_{\phi=180^\circ}$

$= \pi$.

2. For max radiation along $\theta = 180^\circ$

$|\psi| = |\beta d\cos\phi + \alpha|_{\phi=180^\circ} = \frac{\pi}{n}$ and $|\psi| = |\beta d\cos\phi + \alpha|_{\phi=0^\circ} = \pi$

-> $0^\circ$ and $\theta = 180^\circ$, $d = \left(\frac{n-1}{n}\right)\lambda/4$.

-> If the no. of elements is large, then

$d = \lambda/4$.

-> The array factor of element is given by

$$(AF)_n = \frac{1}{n}\left[\frac{\sin\frac{n\psi}{2}}{\sin\frac{\psi}{2}}\right] \qquad \psi = \beta d\cos\theta + \alpha$$

$$(AF)_n = \frac{1}{n}\left[\frac{\sin\frac{n}{2}[\beta d\cos\theta + \alpha]}{\sin\frac{1}{2}[\beta d\cos\theta + \alpha]}\right]$$

-> For smaller values of $\psi$, equation becomes

$$(AF)_n = \frac{1}{n}\left[\frac{\sin\frac{n}{2}[\beta d\cos\theta + \alpha]}{\frac{1}{2}[\beta d\cos\theta + \alpha]}\right]$$

put $\alpha = -\beta d$.

$$(AF)_n = \frac{1}{n}\left[\frac{\sin\frac{n}{2}[\beta d\cos\theta - \beta d]}{\frac{1}{2}[\beta d\cos\theta - \beta d]}\right]$$

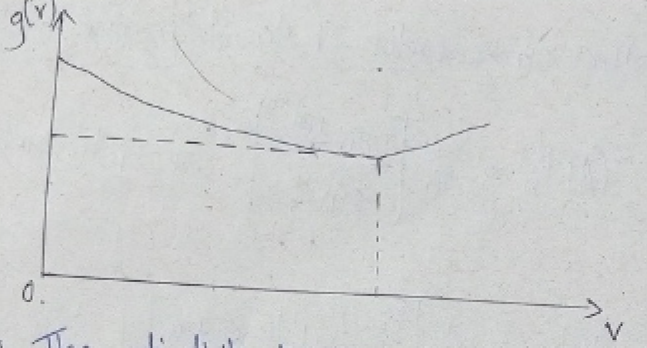
$$= \frac{1}{n}\left[\frac{\sin\frac{nd}{2}[\beta d\cos\theta - p]}{\sin\frac{d}{2}[\beta d\cos\theta - p]}\right]$$

$$= \frac{1}{n}\left[\frac{\sin q[\beta d\cos\theta - p]}{q[\beta d\cos\theta - p]}\right]$$

$\boxed{\frac{nd}{2} = q}$

$\boxed{q[\beta d\cos\theta - p] = z}$

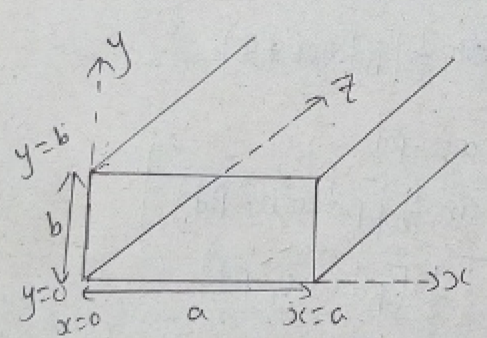
$$\boxed{(AF)_n = \left[\frac{\sin z}{z}\right]}$$




→ The directivity becomes =

$$D = 1.789\,(L/\lambda)$$

## * Power Transmission in Rectangular waveguide




→ Average poynting factor along the z-axis

$$P_{avg} = \frac{1}{2} Re\left[E \times H^*\right]$$

$$P_{avg} = \frac{E_0^2}{2\eta} \hat{a}_z.$$

In general,

$$P_{avg} = \frac{power}{area} \Rightarrow power = P_{avg} \times area$$

$$P = P_{avg} \cdot d\bar{s} = \frac{E_0^2}{2\eta} \hat{a}_z \cdot dx\,dy\,\hat{a}_z.$$

$$P = \frac{E_0^2}{2\eta} \cdot dx\,dy$$

$$P = \frac{E_0^2}{2\eta} \int_{x=0}^{a} dx \int_{y=0}^{b} dy$$

$$\boxed{P = \frac{E_0^2}{2\eta} ab.}$$

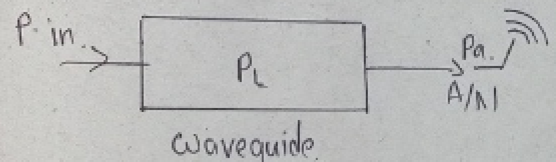
→ For TE mode

$$\boxed{P = \frac{E_0^2}{2\eta_{TE}} \cdot ab}$$

→ For TM mode

$$\boxed{P = \frac{E_0^2}{2\eta_{TM}} \cdot ab}$$

## * Power Attenuation (or) losses in Rectangular waveguide




→ $P_{in} = P_a + P_L$

$$P_{avg} = P_{in}\, e^{-2\alpha z}.$$

$$P_L = \frac{-d\,P_{avg}}{dz} = -\frac{d}{dz}\left[P_{in} e^{-2\alpha z}\right]$$

$$P_L = -\left[P_{in} e^{-2\alpha z} \times (-2\alpha)\right]$$

$$P_L = P_{in} \times 2\alpha e^{-2\alpha z}.$$

$$= 2\alpha P_{avg}$$

$$\boxed{\alpha = \frac{P_L}{2 P_{avg}}}$$

$$\alpha = \alpha_c + \alpha_d.$$

conduction loss

dielectric loss.

$$\boxed{\alpha_d = \frac{\left(\frac{\sigma \varepsilon}{2}\right)}{\sqrt{1-(f_c/f)^2}}}$$

$$\alpha_c = \frac{R_s}{b\varepsilon\sqrt{1-(f_c/f)^2}}\left[1 + \frac{2b}{a}\left(\frac{f_c}{f}\right.\right.$$

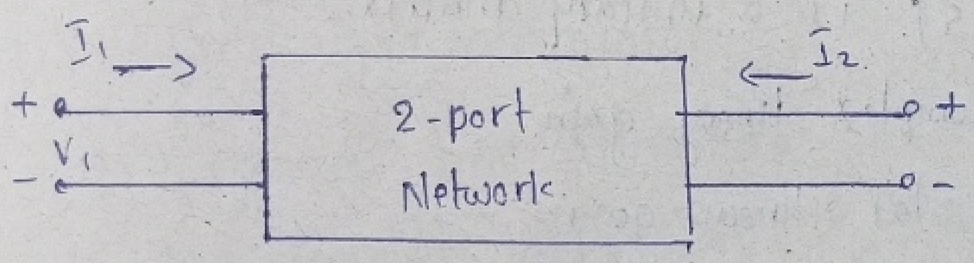
# Unit-4

## Introduction to scattering parameters and their properties

**Scattering parameter**: scattering parameters describes the electrical behaviour of linear electrical networks. is called scattering parameters

-> S-parameters also describes I/p, o/p relationships b/w ports in an electrical system.

-> consider two port electrical network.




structure of 2-port network.

-> In above network $V_1$ (or) $V_2$ applied, then $I_1$ (or) $I_2$ current flows respectively.

-> For 2-port network four combinations will occur.

-> Scattering parameters which is represented in matrix form, called scattering matrix.

-> The elements in matrix are called "scattering coefficients".

Ex:- $\begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ \vdots \\ b_n \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} \cdots S_{1n} \\ S_{21} & S_{22} & S_{23} \cdots S_{2n} \\ & \vdots & \\ S_{n1} & S_{n2} & S_{n3} \cdots S_{nn} \end{bmatrix} \times \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_n \end{bmatrix}$

## Properties of scattering parameter:

-> ~~[S] is always square matrix of order nxn.~~

-> ~~[S] is a symmetric matrix.~~

-> ~~[S] is a unitary matrix~~

-> complex linear gain.

-> scalar linear gain.

-> scalar logarithmic gain.

-> I/p return loss.

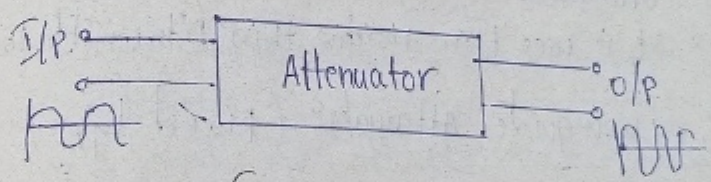
-> o/p return loss.

-> Insertion loss.

-> Reflection coefficient.

## * Attenuators:

<u>Def</u>:- An Attenuators are two-port microwave passive devices, used to control power levels in a micro wave system, is called attenuators.




-> Types of Attenuators

(i) Fixed type attenuator.

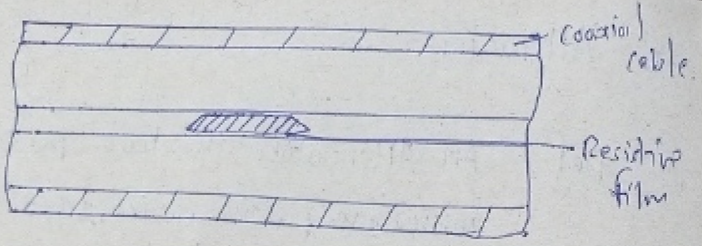
o. coaxial line attenuator.

o. waveguide attenuator < Fixed / variable

(ii) precision type variable Attenuator.

## (i) Fixed type attenuator.

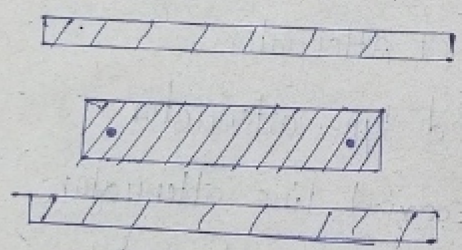
o. coaxial line attenuator




-> Above diagram shows structure of coaxial-line attenuator.

-> It is uses thin resistive thin film with loses.

## (i) 0.1 waveguide Attenuator (Fixed type)

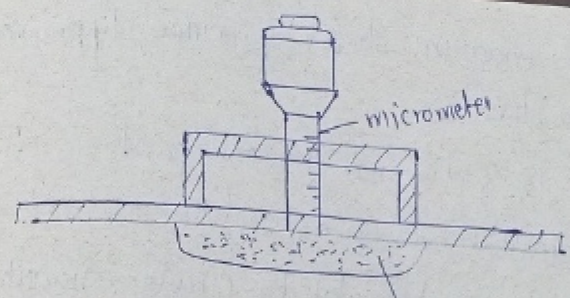


-> Above diagram shows Fixed waveguide attenuator.

-> Here attenuator is placed b/w two co-axial cables,

-> It consist of thin dielectric strip coated with resistive film.

## waveguide Attenuator (variable type)

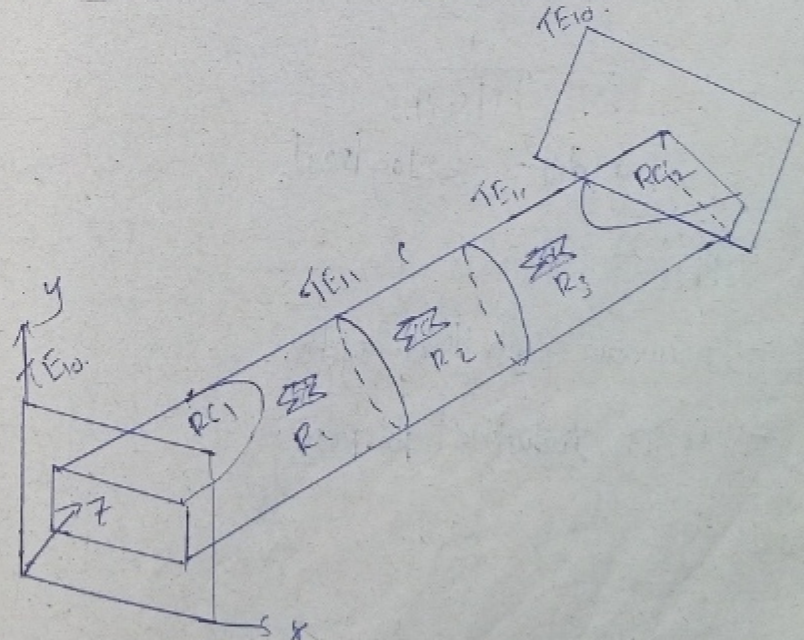




-> Above diagram shows ~~fixed~~ variable waveguide attenuator.

-> A variable type attenuator can be constructed by moving micrometer screw.

## 2. precision type variable Attenuator.

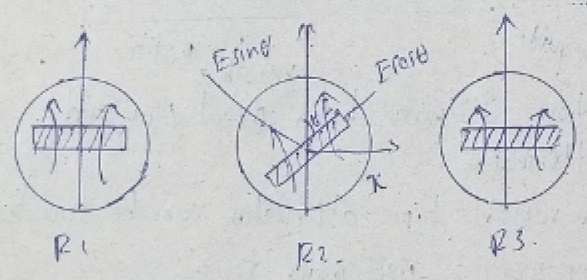


-> Above diagram shows precision type variable attenuator.

-> $R_1, R_2, R_3$ -> Tapered resistive cards.

C - circular waveguide section.

$RC_1, RC_2$ - Rectangular to circular Transitions.




$$\alpha = \frac{E}{E\sin^2\theta} \Rightarrow \frac{1}{\sin^2\theta}$$

$$\alpha = \frac{1}{|S_{21}|}$$

$$\alpha(dB) = -20\log|S_{21}|$$

Applications

-> microwave controlling system.

-> To In Industrial purpose.

PART-II

## Linear beam tubes

Linear beam tubes are most versatile devices used for the generation and amplification of energy at microwave frequencies.

### Two cavity klystron

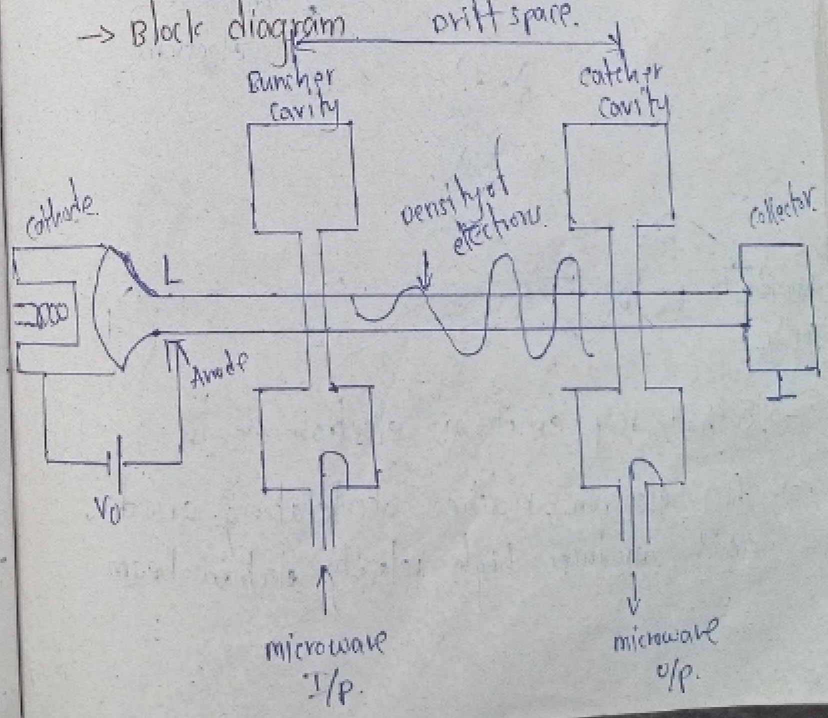
Def :- -> It is a low-power microwave amplifier.

-> It is a velocity modulated tube.

-> It consist of two cavities. they are

i Buncher cavity ii) catcher cavity.

-> Block diagram



-> Above diagram shows Two cavity klystron Amplifier.

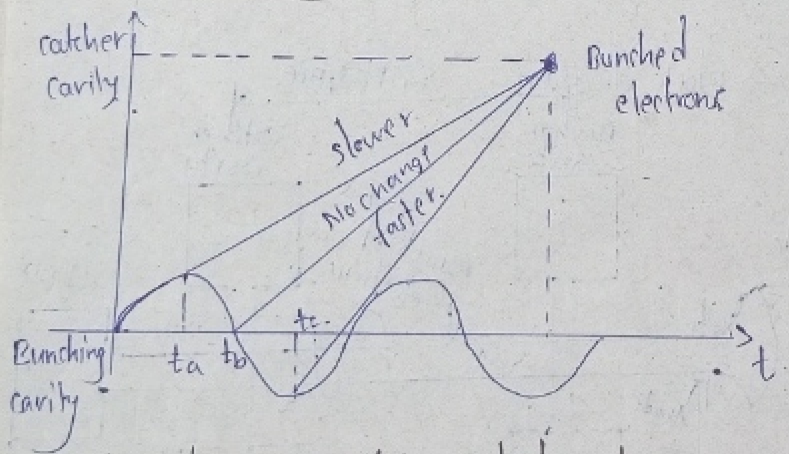
-> Here input is microwave input given to Buncher cavity.

-> Here output is microwave output coming out from catcher cavity

-> The space b/w Buncher and catcher cavities is called drift space.

-> Density of electrons are collected by collector.

## operation




-> cathode ray emits an electron beam,

-> This electrons reaches accelerating anode, which produces high velocity electron beam.

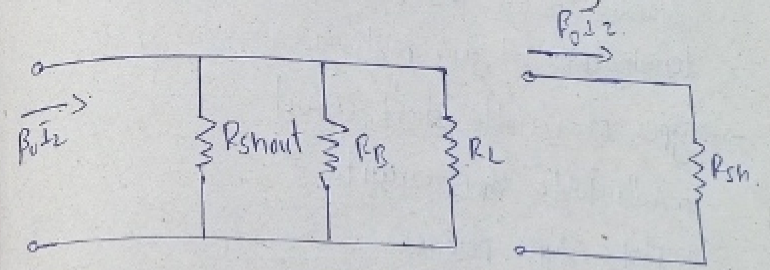
-> processes.

i. Bunching process

ii velocity modulation

iii catcher cavity.

-> Equivalent circuit of o/p cavity




-> output power

$$P_{out} = \frac{\beta_0 I_2 V_2}{2}$$ $V_2$ = catcher cavity voltage.

-> Efficiency

$$\eta = \frac{P_{out}}{P_{in}} \Rightarrow \eta_{max} = 58.2\%$$

## Applications

-> Satellite communication

-> Radar "

-> In ~~UF~~ UHF TV Transmitters

## * Variable short circuit

-> In waveguide form, it consist of short circuit.

-> It reflects all the incident power.

-> Termination must be a length of $\lambda/2$.

-> manually move the screw to lock. the termination at any position.

-> Types of variable short circuit.

- o Adjustable short circuit.
- o. choke-type plunger.
- o Alternative choke type plunger.

-> Applications

- o Feild measurements.
- o. Requiring low VSWR.
- o Laboratory measurements.

## * Microwave devices empolying faraday rotation

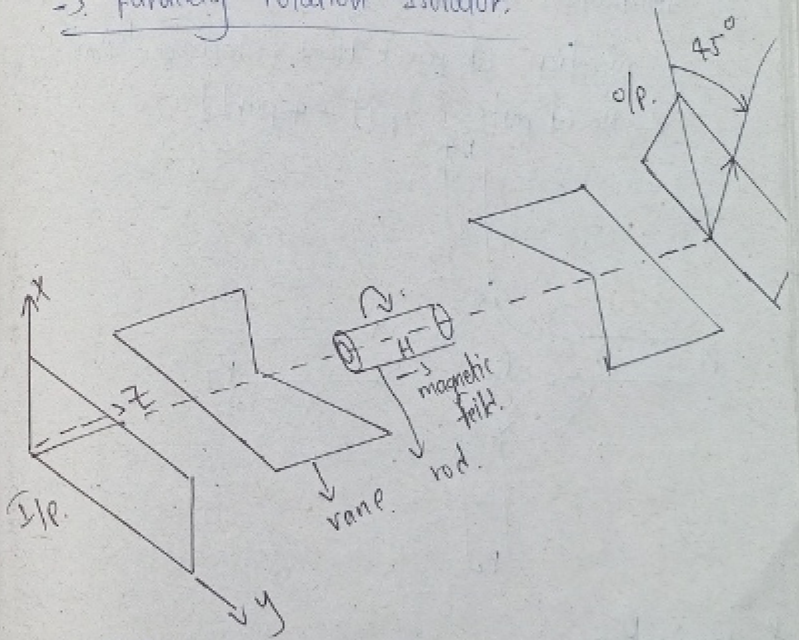
o Isolator :- Isolator is a 2-port, non reciprocal device.

-> Isolator produces minimum attenuation in one direction and very high attenuation in opposite direction.

-> The isolator is inserted between source and load.

-> Isolators can be constructed by many ways.

-> Faraday rotation Isolator.




Applications

- o Matching networks.
- o Tuning Networks.

## * Circulator :-

-> It is a multiport non-reciprocal device.

-> The wave can travel from one port to another in one direction only.

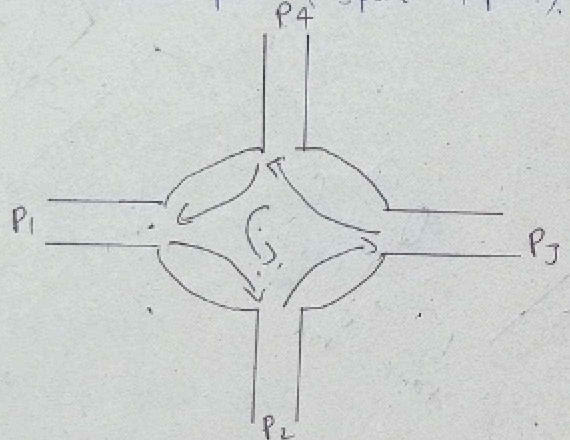
-> i.e wave can travel from $n^{th}$ port to $(n+1)^{th}$ port.

-> Transmission of wave take place in cyclic order only.

-> An ideal circular is perfectly lossless.

-> classification of circulator based on

- o Direction of power flow. (clock and Anticlock)
- o No. of ports (3 port - 4 port)




## * Terminations

-> A termination is a one-port component, means absorb all the power applied to it.

-> ~~Types of Terminations~~

o Matched Termination : Matched termination, only purpose to Absorb all the incident energy.

-> Basic characteristics

- o VSWR
- o Frequency range

o Types of Terminations

- o Matched Load.
- o variable short circuit.

o Matched Load : Any lossy material which is not a conductor can be used as matched load.

-> Types of matched Load.

- o Lossy wedge.
- o Tapered resistive card.

## * Hybrid TEEs

-> waveguide Tees are 3-port components.

-> Hybrid tees are used in microwave technology

-> Tee junction : A waveguide with 3 independent ports is commonly referred as Tee junction.

-> Types of hybrid TEEs

- o H-plane Tee.
- o E-plane Tee.
- o Magic Tee.

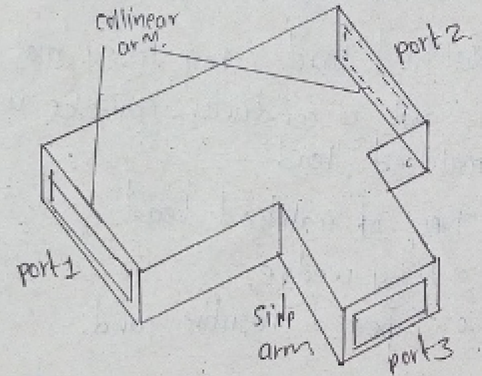
## 1. H-plane Tee

-> It is also called as shunt Tee.

-> The axis of side arm ||el to the H-field.

-> Here

- port 3 - E arm (or) side arm.
- port 1 and 2 - collinear arm.




-> If two inputs are fed into port 1 & port 2, the o/p will be at port 3.

## 2. E-plane Tee

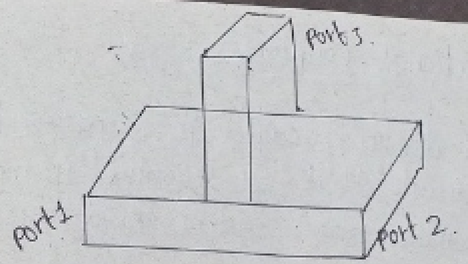
-> It is also called as series Tee.

-> The axis of side arm is ||el to main guide.

-> Here,

- port 3 - E arm (or) side arm.
- port 1 and 2 - collinear arm.

-> If input is fed into port-3 and is equally divided into arm 1 and 2, the o/p will be at port 1 and 2.




## 3. Magic Tee

-> It is a 4-port device.

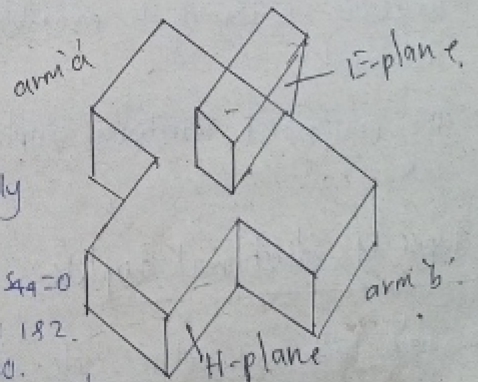
-> Magic Tee is combination of H-plane and E-plane.

-> Magic Tee is called hybrid Tee.

-> It produces sum and difference of it's 2 I/ps simultaneously.

-> It contains 4 arms.

- one shunt arm.
- one series arm.
- Two side arm.
- No coupling b/w shunt and series.




-> All ports perfectly matched

$S_{11} = S_{22} = S_{33} = S_{44} = 0$

-> No coupling b/w 1 & 2.

$S_{12} = S_{21} = 0.$

-> No coupling b/w 2 and 3

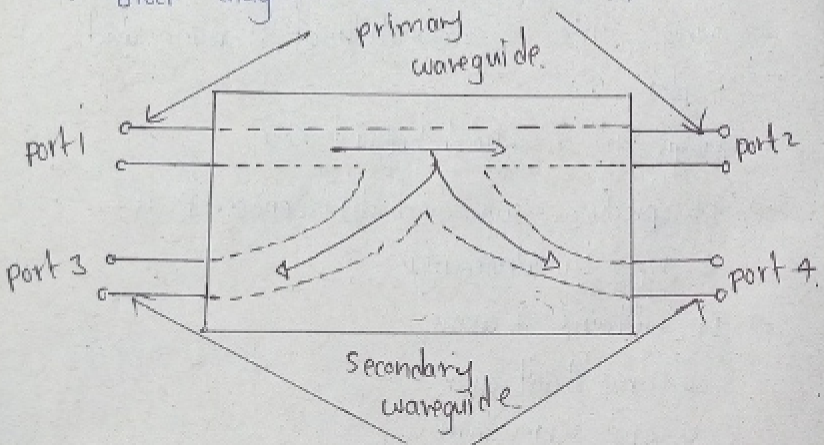
$S_{34} = S_{43} = 0.$

# * Directional couplers

-> A directional coupler is a passive devices (or) circuits, that are essential in many optical communications systems and microwave bands

-> A directional coupler is 4-port waveguide junction.

-> Block diagram of directional coupler.




-> Directional coupler is used to couple the microwave power which may be uni (or) bi-directional

-> The principle of directional coupler is electromagnetic:

## o Types of directional couplers

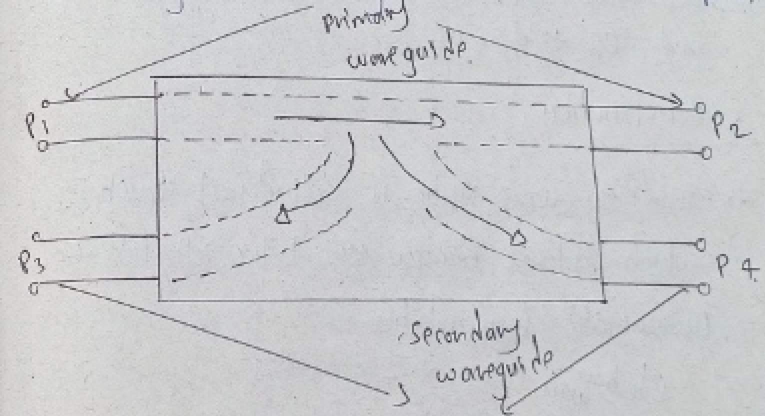
o Single hole (or) Bethe hole Directional coupler
o Two-hole directional coupler

## o Single hole directional coupler

-> Single hole directional coupler function is a single aperture (or) hallow inside the major Transmission line

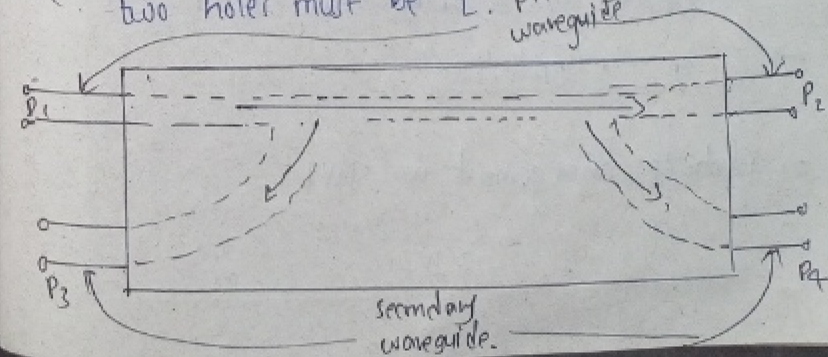
-> It is simple to design.

-> Diagram of single hole directional coupler.




## o Two-hole directional coupler

-> Two-hole directional coupler is a two aperture and the spacing b/w the center of two holes must be $\frac{\lambda}{4}$.



## * Travelling wave Tube (TWT)

-> TWT- Travelling wave tube.

-> Travelling wave tubes are broadband microwave devices.

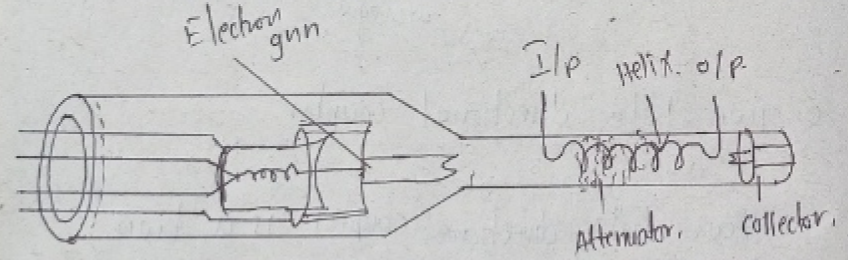
-> TWTs do not have cavity resonators like klystrons.

-> In TWTs amplification done b/w electron beam and RF field.

### o construction

-> Travelling wave Tube is cylindrical structure which contains electron gun, helix, collector etc.

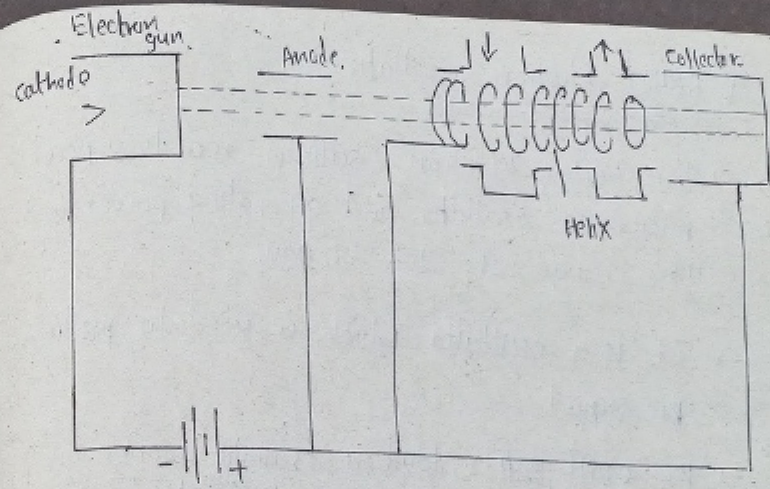
-> Diagramatic representation




-> The amplified o/p is obtained at o/p of TWT.

-> $v_p = v_c(\text{pitch}/2\pi r)$

-> Electrode arrangement in TWT.




### Applications

-> TWT used in microwave receivers.

-> TWT used in wide-band communication.

-> TWT used co-axial cables.

-> TWT used in satellites.

# * Reflex klystron oscillator

-> The Reflex klystron oscillator is a low power microwave oscillator and generating power in the range of 10-500 mW.

-> It is a oscillator which is used to produce RF signal.

-> ~~RF oscill~~ Reflex klystron oscillator works on the principle called velocity modulation.

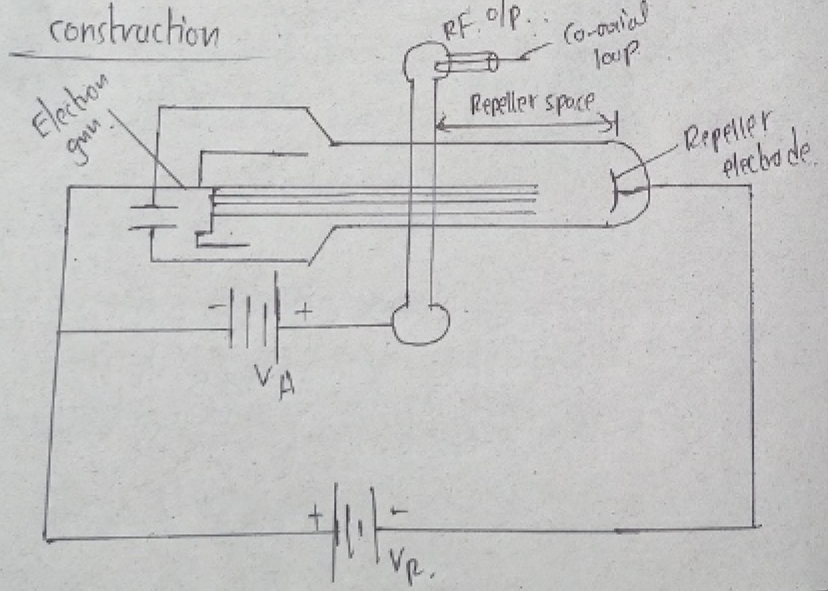
-> The construction include two voltages (dc)

- Accelerating voltage ($V_A$).
- Repeller voltage ($V_R$)

-> $V_A$ - used to generate $e^-$ beam.

$V_R$ - Reflect the $e^-$ towards gap.

## construction




-> Due to the application of accelerating voltage ($V_A$), there will be three different electrons

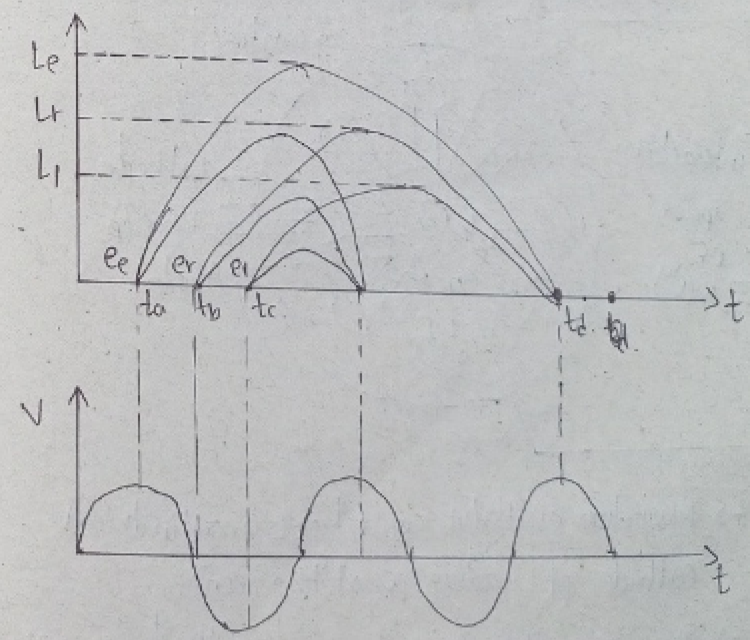
- $e_R$ - Reference electron ($V_0$)
- $e_e$ - early electron ($V > V_0$)
- $e_l$ - late electron ($V < V_0$)

-> $e_R$ - goes upto some distance in Repeller space

-> $e_e$ - goes upto much " " "

-> $e_l$ - goes very small distance " "

## o Bunching process



# * Cross feild Tubes

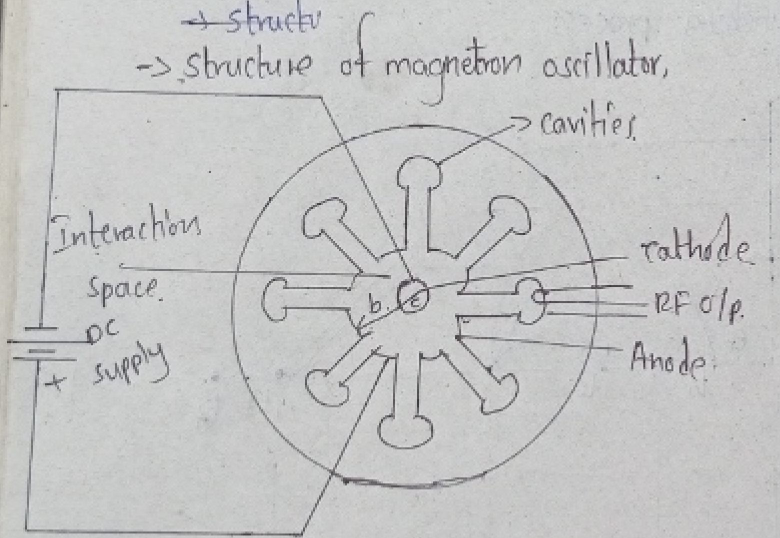
## * Magnetron oscillator :

Def : It is a high power microwave oscillator having multiple cavities.

-> It is a cross-feild Tube, in which electric ~~feid~~ feild and magnetic feild are crossed each other.

~~-> structu~~

-> Structure of magnetron oscillator,




-> Magnetron oscillator consist of a cylindrical cathode of radius 'a' at the centre.

-> The space b/w anode and cathode is called Interaction space.

-> Here. the dc voltage is applied b/w anode and cathode.

-> Here, permanent magnet is used

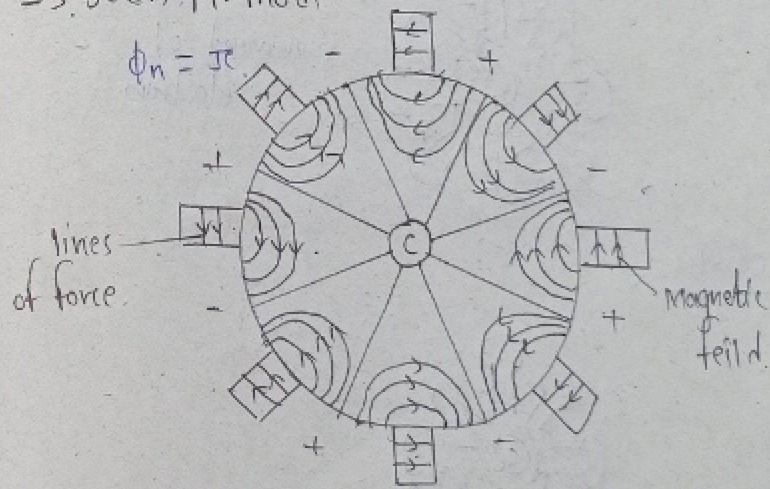
-> Mode of operation

-> If there are N-resonant cavities and there exist 'N' resonant frequencies.

-> $\boxed{\phi_n = \frac{2\pi n}{N}}$

-> $\pi$ (or) pi-mode

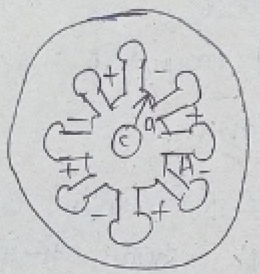
$\phi_n = \pi$



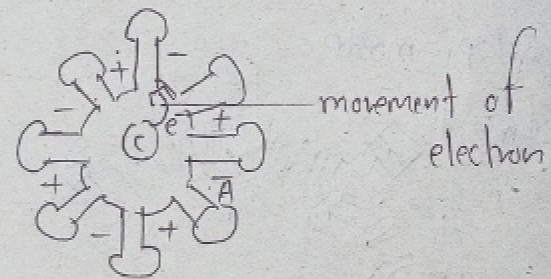

-> The dc voltage is applied b/w anode and cathode.

-> Cases :-

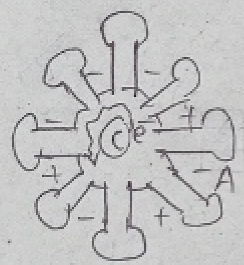
case i : B=0.



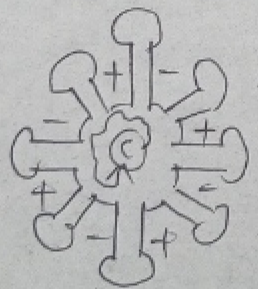
case ii




case iii



case IV



Characteristics

-> very high efficiency.
-> power o/p : 800kW.
-> operating freq. : upto 10GHz.

Applications

-> RADAR.
-> Industrial heating Applications.
-> oven
-> satellite.

## * Hartree conditions

-> Hartree condition is determined as follows
"The electron flow is assumed to be exist".

-> voltage at Hartree condition is given by

$$V_0 = \frac{\omega B d}{\beta} - \frac{m}{2e} \cdot \frac{\omega^2}{\beta^2}$$

~~GUNN 1~~

unit-5

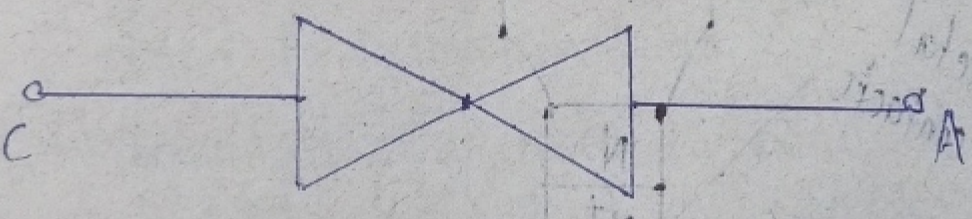
## * Gunn Diode :-

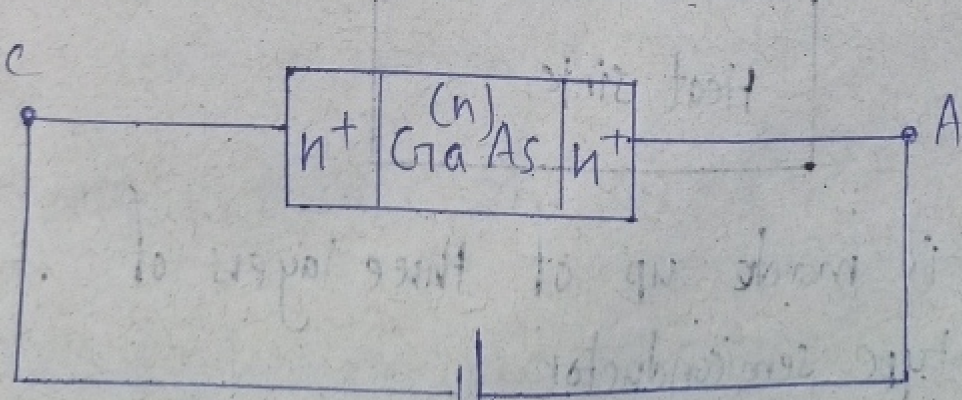
Def : A gunn diode is a two ~~dimensional~~ terminal semiconductor diode, with -ve resistance property.

-> used in very high frequency

-> It is also known as Transferred Electron Device (TED).

-> symbol of Gunn diode.



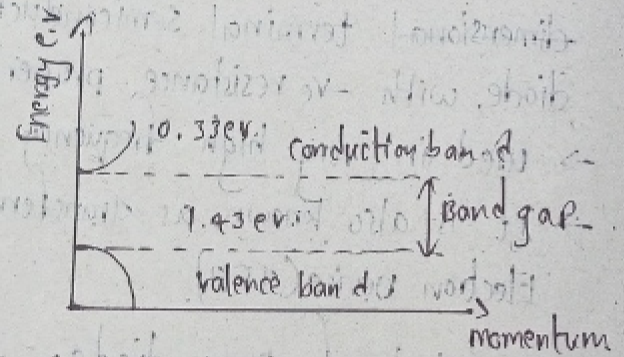



-> Gunn diode is based on Gunn effect (or) TED.

-> It consist of two Electrodes.

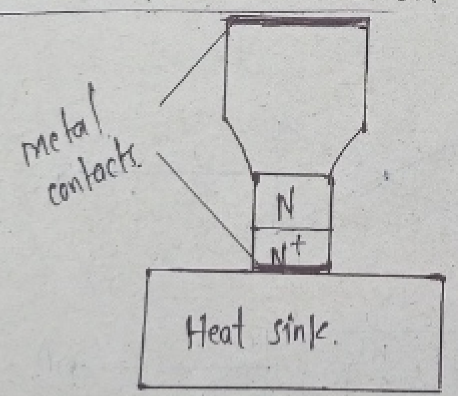
-> used in microwave applications.

## Gunn Effect




Ex: GaAs.

-> Structure of Gunn diode.




-> It is made up of three layers of N-type semiconductor.

-> semiconductors - GaAs, CdTe etc.

-> Top and bottom layers fully doped white middle layer is lightly doped.

## operation of Gunn diode :

-> Gunn diode is not actually a P-N junction diode, because there is no P-region and junction

-> But still it is diode.

-> Here active region is middle layer of the diode.

-> This is Transferred Electronic device (TED) So it deals with electrons only.

-> In gunn diode, there is valence band, conduction band is there.

-> Therefore Electrons move from valence band to conduction band.

-> Again electrons move to band above conduction band, due to this -ve resistance region is created.

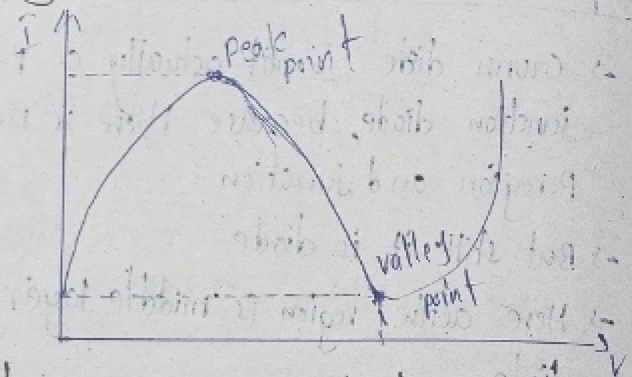
## => characteristics of gunn diode

-> V-I characteristics in gunn diode.

-> current initially increasing in gunn diode.

due to applied voltage.

-> At particular point this current starts decreasing this point is called peak point.




-> Advantages

- Small size device.
- low cost.
- Reliable & stable
- High bandwidth.

Disadvantages

- poor temperature stability.
- More power dissipation.
- low efficiency.

Applications

- used in Radio, communication
- tachometers,
- oscillators and Amplifiers.

## Two valley model

-> Gunn diode was proposed by J. B Gunn in 1963.

-> Gunn effect can be explained on the basis of two valley model.

-> It is a Transferred electron mechanism (or) RWH.

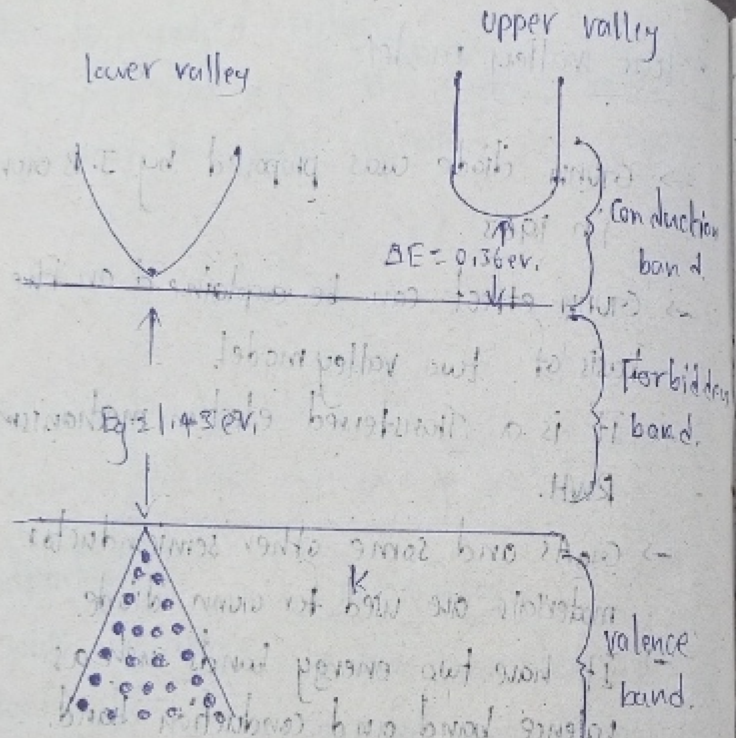
-> GaAs and some other semiconductor materials are used for Gunn diode.

-> It have two energy bands such as valence band and conduction band.

-> one extra band is also there, empty at initial.

-> Basic mechanism involved in electron transfer from valence to conduction band.

-> Block diagram of two valley model theory shown in below figure.




→ Explain diagram

→ Lower valley

- Low mass and high mobility

→ upper valley

- High mass and low mobility.

## * Impatt Diode

Def :-

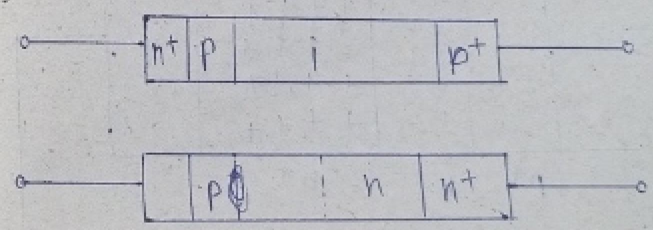
→ IMPATT stands for -

Impact ionization Avalanche Transit Time.

→ IMPATT diodes are high power PN junction semiconductor diodes.

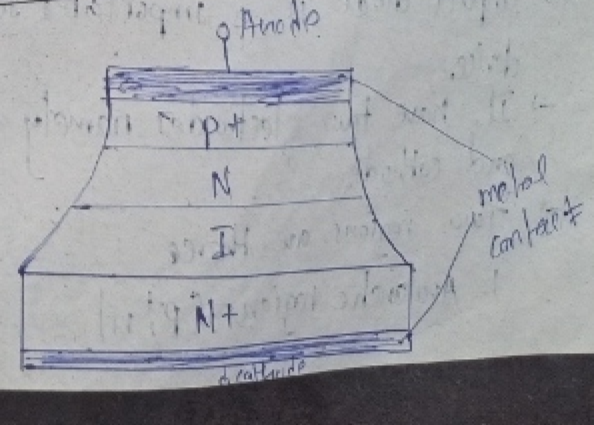
→ used in microwave frequency.

→ symbol.




→ P-N junction is involved.

⇒ structure (or) construction of Impatt diode



-> Above figure shows structure of Impatt diode.

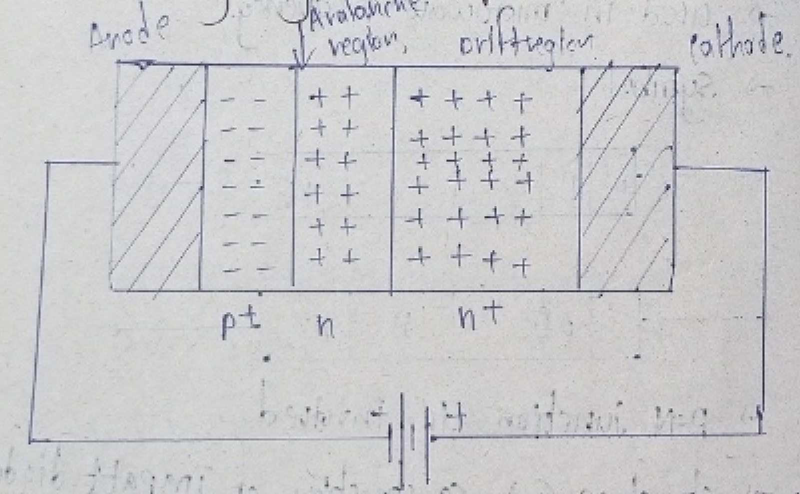
-> It has vertical structure, which have high power handling capacity.

-> It is made up of GaAs etc

-> It have two electrodes.

=> working (or) operation

-> working layout of impatt diode.




-> Impatt diode is a important semiconductor device.

-> It have two electrodes namely Anode and cathode.

-> Two regions are there

1. Avalanche region (p+, n)

2. Drift region (n+)

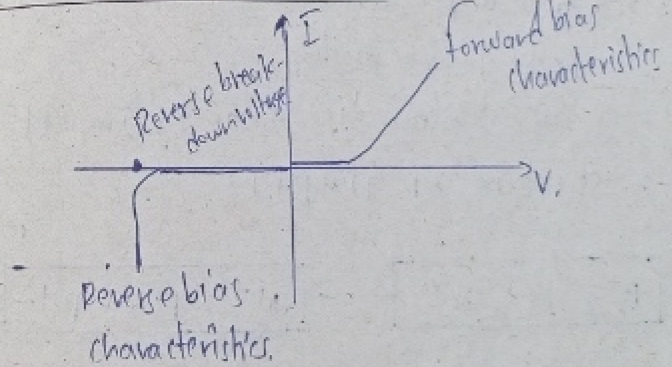
-> Anode contected to -ve terminal of the voltage source.

-> cathode connected to +ve terminal of the voltage source.

-> Here we use high DC voltage.

-> Drift region have +ve electrons and avalanche region have both +ve and -ve electrons.

-> V-I characteristics




-> Advantages.
- low cost.
- moderate efficiency.
- Reliable.

-> Disadvantages
- low efficiency.
- Noisy.

-> Applications
- -> microwave generators
- -> " oscillators.

# * TRAPATT Diode

-> TRAPATT - stands for
Trapped plasma Avalanche Triggered Transit Device.

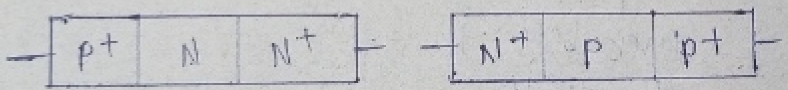
**Def:** It is a microwave generator which operates b/w hundreds of MHz - GHz.

-> It is a high efficiency microwave generator,

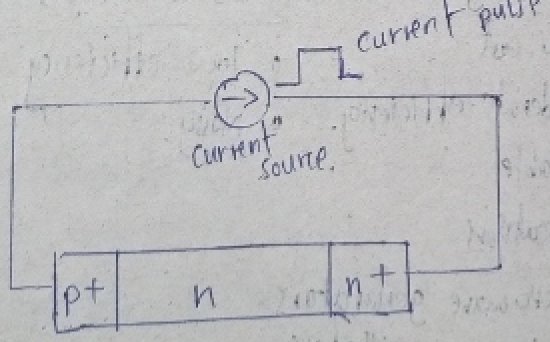
-> It is a p-n junction diode, and high peak-power diode.

-> It's structure is similar to Impatt.

-> structure of TRAPATT




-> operation of TRAPATT




-> operation of TRAPATT Diode shown in above figure.

-> There are two structures (or) configurations of TRAPATT, they are
$p^+ N N^+$, $N^+ p p^+$

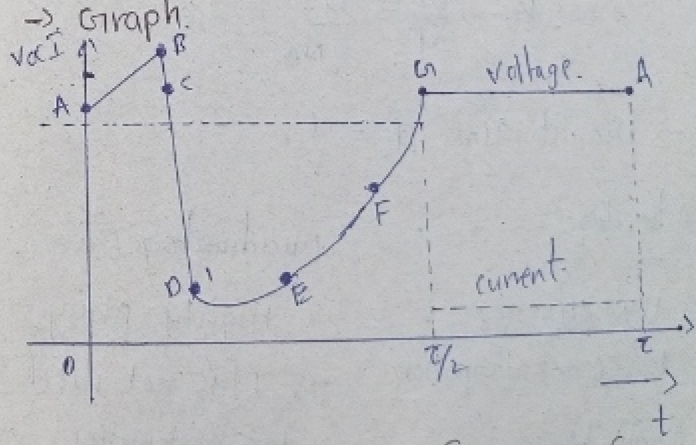
-> Here we use $p^+ N N^+$ configuration

-> current pulse is applied as input for TRAPATT.

-> current source is placed b/w $p^+ N^+$

-> current passes from $p^+$ to $N^+$

-> Graph




-> At point 'A' electric feild is uniform but less than avalanche breakdown.

-> At point B plasma of electrons and holes is generated.

- At point C dense plasma of holes and electrons are created.
- At point 'D' voltage decreases, long time required to clear plasma.
- At point 'E', plasma is cleared or removed.
- At 'E to F' voltage increases.
- At 'F' the diode charges like a capacitor.
- At 'G' the voltage remains constant.
- Avalanche zone velocity

$$V_s = \frac{dx}{dt} = \frac{J}{qN_A}$$

- Transit Time $T_s = \frac{L}{V_s}$

**Advantages**

- High efficiency.
- low power dissipation.

**Disadvantages**

- Highly Noisy.
- It is not used for continuous operation.

**Applications**

- local osillators.
- Industrial heating & welding.

| IMPATT | TRAPATT |
|---|---|
| Impact Ionisation Avalanche Transit Time. | Trapped plasma Avalanche Triggered Transit. |
| Developed by RL. Johnson. | Developed by HJ prager. |
| operates on Avalanche multiplication. | operates on Avalanche plasma. |
| Noise is low. | Noise is high. |
| low cost. | High cost |
| low efficiency. | High efficiency. |
| operating freq. 4- 200 GHZ. | operating freq. 1- 3 GHZ. |
| Small in size. | small in size. |
| Application. microwave generator. | Application. Amplifier, oscillator. |

## Impedence Measurements

Apart from magic tee, we have two different methods. they are.

1. Impedence using slotted line.
2. Impedence using Reflectometer.

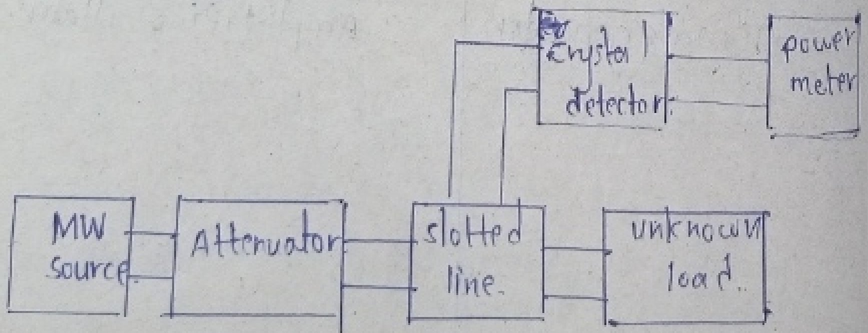
### 1. Impedence using slotted line :-

-> In this method, impedence is measured using slotted line and load $Z_L$.

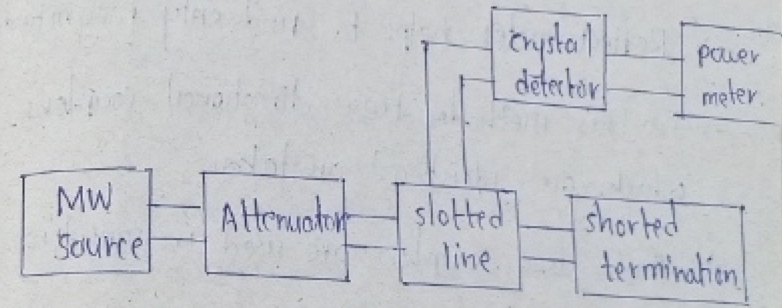
-> From this method $V_{max}$ and $V_{min}$ can be determined.

-> step 1: Determining $V_{min}$ using load $Z_L$.
step 2: " " " short circuiting load.

=> step 1




=> step-2



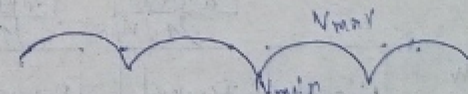

-> when we try to obtain $V_{max}$ and $V_{min}$ using load, we get certain values

-> when we try to obtain $V_{max}$ and $V_{min}$ using short circuiting load, we get. $V_{max}$ can shifted.

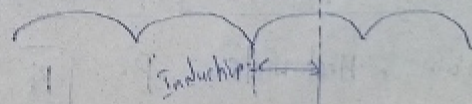
-> If shift is left load is inductive.

-> If shift is right load is capacitive.

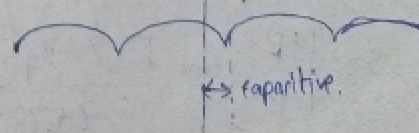
step 1




step 2.




step 2.



## Impedence using Reflectometer

-> Reflectometer helps to find only magnitude

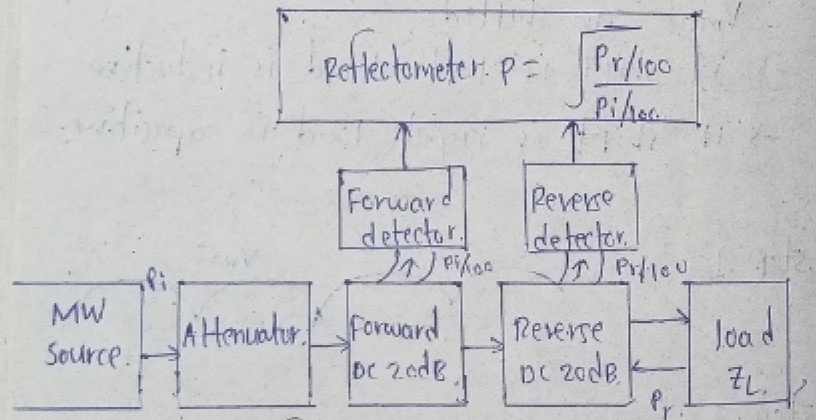
-> In this methods two directional couplers which are identical are taken.

-> These two coupler are used in sampling

$P_i$ = Incident power.

$P_r$ = Reflected power.

-> Block diagram




-> From Reflectometer $P = \sqrt{\frac{P_r}{P_i}}$

-> $S = \frac{1+P}{1-P}$ and $\frac{Z - Z_g}{Z + Z_g} = P$ $Z_g$ = known Impedence, $Z$ = unknown impedence

## Measurement of 'Q' of cavity

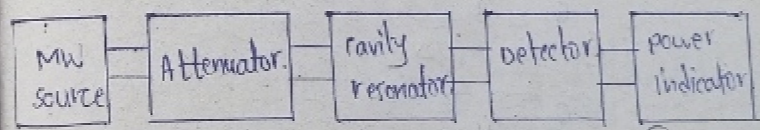
-> For measuring of 'Q' of cavity, there are three methods such as

i Transmission method.
ii Impedence method.
iii Decrement method.

-> The easiest and most followed method is Transmission method.

### Transmission method.

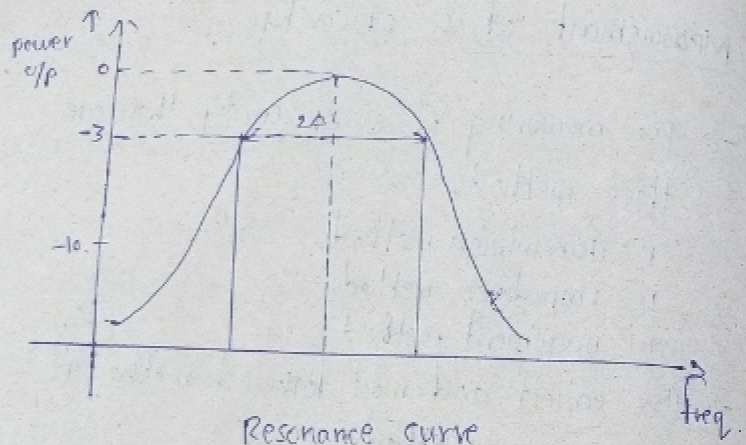
-> Block diagram




-> Above block diagram shows set up for measurement of 'Q' of cavity using Transmission method.

-> Block diagram consist of MW source, Attenuator, cavity resonator, Detector, power indicator etc.

-> Here input is MW source, output signal is plotted as frequency.




Resonance curve

Half power Bandwidth = $2\Delta$.

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

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

$$\boxed{Q_L = Q_0}$$

## Measurement of Attenuation

-> microwave components and devices provide Some attenuation

-> The amount of attenuation can be measured in two ways, they are

i power Ratio method

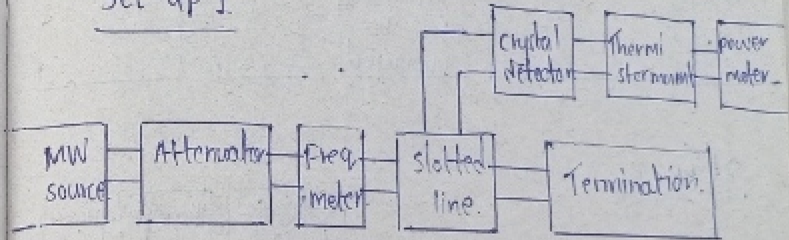
ii RF substitution method.

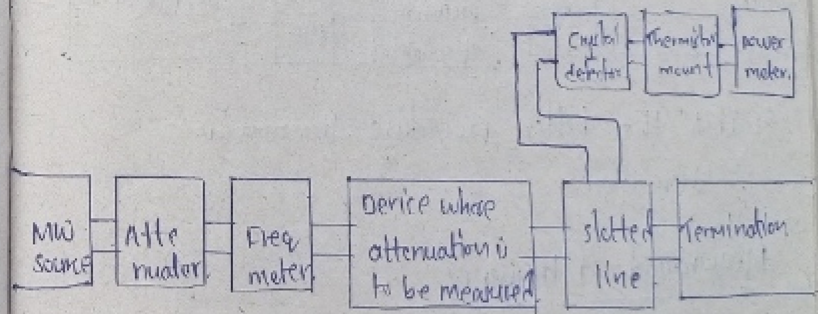
-> $\boxed{\text{Attenuation} = 10 \log \frac{P_{in}}{P_{out}}}$

i power Ratio method

-> In this method measurement of attenuation takes place in two steps they are

Set-up 1



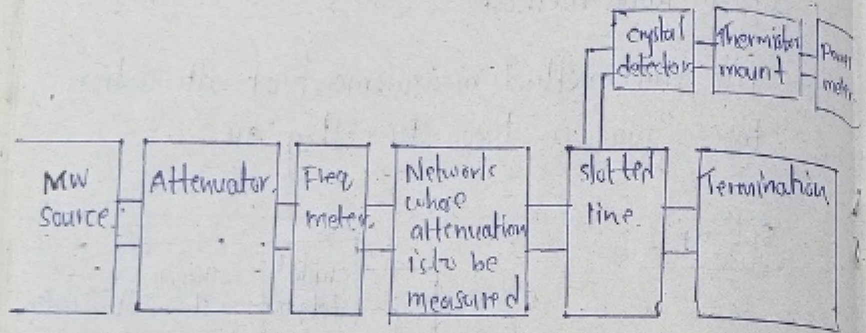




-> Explain diagrams ;

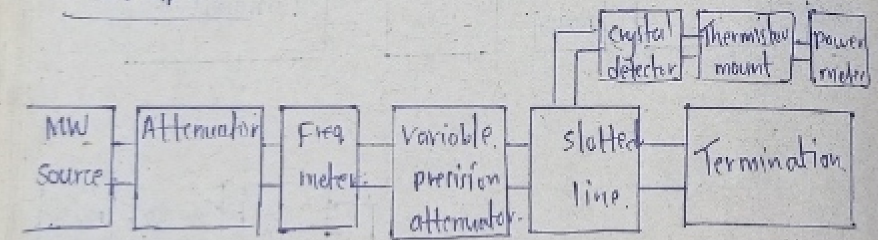
ii RF substitution method

-> In this method measurement of attenuation takes place in two steps they are

Set-up 1




Set-up - 2




-> It is the better procedure to measure attenuation.

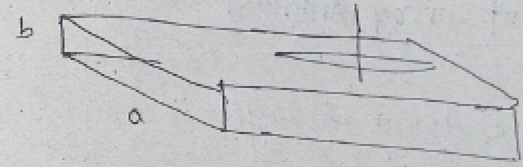
## Measurement of frequency

-> To measure the frequency of the microwave signal, the waveguide is coupled to slotted line.

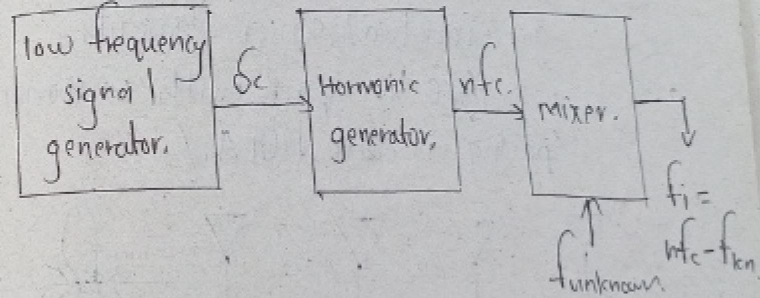
-> Frequency is specific to microwave range 4 GHZ - 300 GHZ.

-> Taking rectangular waveguide

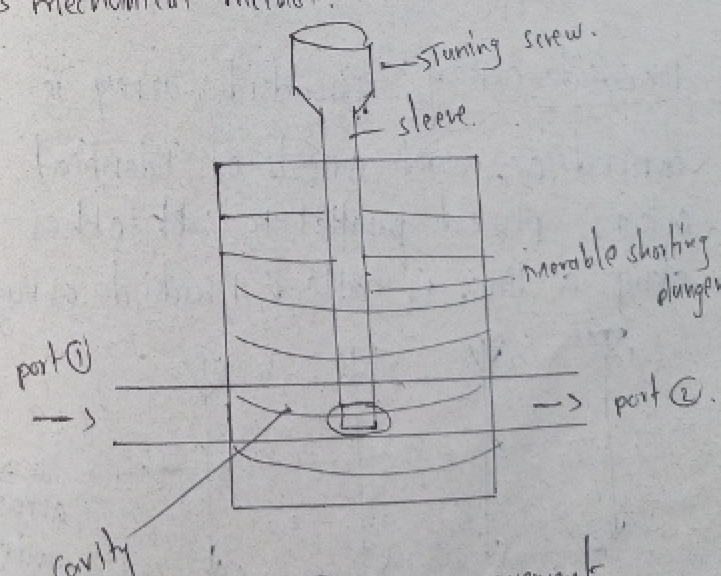
$\lambda_c = 2a \Rightarrow \lambda_c$




-> Block diagram.




-> mechanical method.

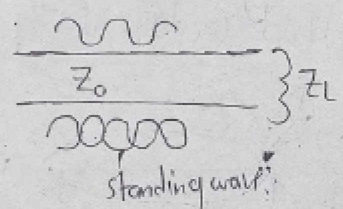



Frequency measurement

## * Measurement of VSWR.

-> VSWR - voltage standing wave ratio.

-> consider on transmission line.




$Z_0 = Z_L$ -> No reflection

$Z_0 \neq Z_L$ - Reflection is there

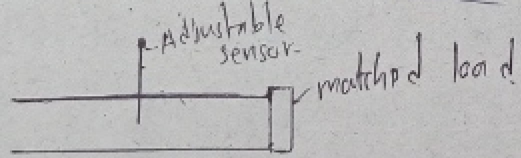
-> $VSWR = \frac{V_{max}}{V_{min}} \Rightarrow \frac{1+e}{1-e}$

where $e = \frac{P_{reflected}}{P_{incident}}$

-> VSWR can measured in two methods.

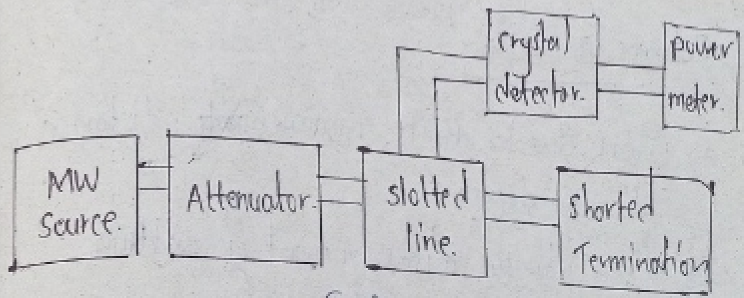
1. VSWR $S<10$ (low VSWR)
2. VSWR $S>10$ (High VSWR)

### (1) Measurement of low VSWR ($S<10$):-



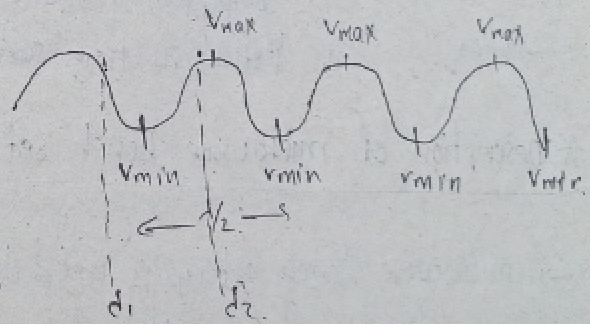

-> connect the load at end of bench setup.

-> Adjustable sensor, it can adjust forward and backward direction and inserted into bench setup

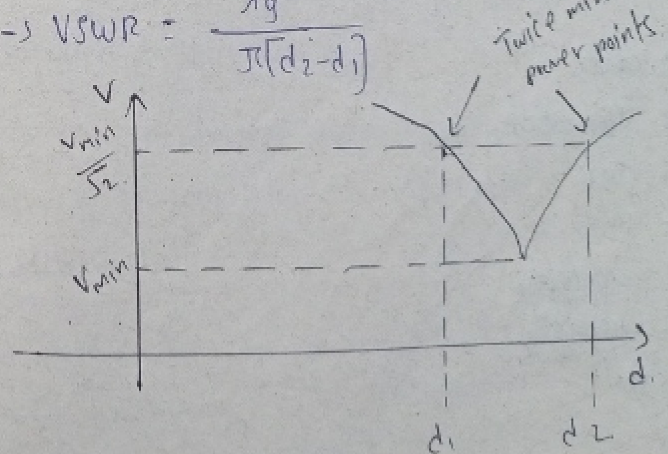



### (2). Measurement of High VSWR ($S>10$).

-> This VSWR can be measured by the process called double "minima method"




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



## Sources of Errors:

-> Errors due to finite measurements distance b/w antennas.

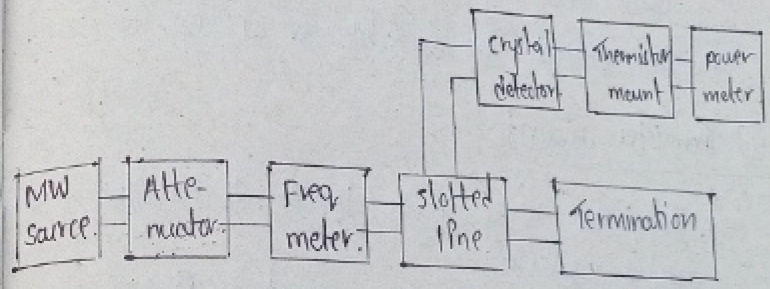
-> Errors due to misalignment of antenna
-> " " manmade interface
-> " " atmosphere effects
-> " " cables
-> " " Impedence mismatch
-> " " Imperfections of devices
-> " " Reflections from surroundings

## * Description of microwave bench set up:-

-> microwave bench set up is used to find the following parameters

1. power.
2. Attenuation
3. VSWR
4. gain
5. Impedence
6. wavelength
etc.

-> Block diagram of microwave bench setup:.




### ① MW source

-> MW - microwave source
-> It is used to generate EM signal at ~~...~~ MW freq

### ② Attenuator:

-> Attenuator is used to attenuate the signal.
-> It stabilize the energy of the signal
-> It is used to avoid fluctuations in waveguide.

### ③. Frequency meter:

-> It is measures the frequency of the signal present in waveguide.

### ④ slotted-line:

-> Slotted line is a waveguide with a slot.
-> By moving the slotted line, modulation of the wave can be changed in CRO.

(5) crystal detector :

-> crystal detector is used for detecting UHF and SHF signals.

-> It enables the demodulation of signals

(6) Thermistor mount :

-> Thermistor is a small bead of semiconductor material.

-> The detected signal given input to the Thermistor mounts

(7) power meter

-> power meter is also known as vswr meter.

-> It shows the power on display.

(8) Termination :

-> Termination is nothing but matched termination.

-> standing wave can be avoided by Termination.

* Errors and precautions of microwave bench setup

~~precautions~~

-> Never place metal items ~~inside of the oven.~~

~~Errors~~

* Gain measurements

-> Gain can be measured in three methods

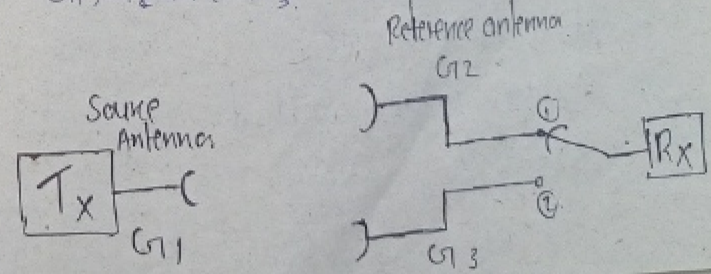
They are.

1. By comparision method.
2. By Absolute "
3. By three antenna method.

(1). comparision method :

-> In comparision method :-

It requires three antennas :of gain $G_1, G_2$ and $G_3$.



→ Tx - Transmitter end

Rx - Receiver end

→ Gain

$G_1$ - ~~Refere~~ source antenna

$G_2$ - Reference antenna

$G_3$ - ?

→ Switch is at position ①.

$$P_{R_2} = P_T G_1 G_2 \left(\frac{\lambda}{4\pi R}\right)^2 \quad -①$$

→ Now switch is at position ②.

$$P_{R_3} = P_T G_1 G_3 \left(\frac{\lambda}{4\pi R}\right)^2 \quad -②$$

Ratio of ① and ②

$$\frac{P_{R_2}}{P_{R_3}} = \frac{G_2}{G_3} \Rightarrow G_3 = G_2 \left(\frac{P_{R_3}}{P_{R_2}}\right)$$

$$G_3 = G_{ref} \left(\frac{P_{R_3}}{P_{R_2}}\right)$$

## ② Absolute method

→ It is of two types

- Two antenna method
- Three " "

### Two antenna method

→ In two identical antennas

→ From Friss transmission formula

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi R}\right)^2$$

Apply log on B.S

$$(G_T)_{dB} + (G_R)_{dB} = 20\log\left(\frac{4\pi R}{\lambda}\right) + 10\log\left(\frac{P_R}{P_T}\right) \quad -①$$

∴ Two antennas are identical

$$(G_T)_{dB} = (G_R)_{dB} \quad -②$$

from ① and ②

$$(G)_{dB} = \frac{1}{2}\left[20\log\left(\frac{4\pi R}{\lambda}\right) + 10\log\left[\frac{P_R}{P_T}\right]\right]$$

### Three Antenna method

→ If we don't have two identical antennas, then we use three different antennas of gain $G_1$, $G_2$ and $G_3$.

→ combining antennas ① and ②

$$(G_1)_{dB} + (G_2)_{dB} = 20\log\left(\frac{4\pi R}{\lambda}\right) + 10\log\left(\frac{P_{R_2}}{P_{T_1}}\right) \quad ①$$

→ Combining Antennas (1) and (3)

$$(G_1)_{dB} + (G_3)_{dB} = 20\log\left(\frac{4\pi R}{\lambda}\right) + 10\log\left(\frac{PR_3}{PT_1}\right) \quad (2)$$

→ combining Antennas (2) and (3).

$$(G_2)_{dB} + (G_3)_{dB} = 20\log\left(\frac{4\pi R}{\lambda}\right) + 10\log\left(\frac{PR_2}{PT_3}\right) \quad (3)$$

By solving (1) and (2) (3) we get gains $G_1, G_2, G_3$. etc

## * Directivity measurement :

Ratio of maximum power density to the average power radiated

$$D = G_{D max} = \frac{P_{d max}}{\frac{P_{rad}}{4\pi r^2}}$$

→ Directivity interms of electric feild

$$D = \frac{4\pi}{\int_{\theta=0}^{2\pi}\int_{\theta=0}^{\pi} (f(\theta,\phi))^2 \sin\theta \, d\theta \, d\phi}$$

$f(\theta,\phi)$ = Relative radiation energy in terms of half power beam width

$$D = \frac{~~41,25~~ \; 41,253}{\theta_1 \cdot \theta_2}$$

$\theta_1$ = magnetic feild

$\theta_2$ = electric feild