Introduction

1.) What are waves? OR What do you mean by waves?

Ans- A wave is defined as a disturbance or variation that transfers energy progressively from one point to another in a medium.

* A wave transmits information or energy from one point to another in the form of signals.

Types of Waves

Based on orientation of particle motion and direction of energy, there are 3 categories:

i) Mechanical Waves
ii) Electromagnetic Waves
iii) Matter waves

Mechanical Waves

→ A mechanical wave is a wave that is an oscillation of matter and is responsible for the transfer of energy through a medium.

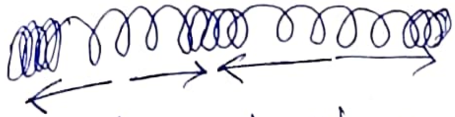
→ There are two types of mechanical waves:

* Longitudinal waves :-
In this type of wave, the movement of particle are parallel to the motion of the energy i.e., the displacement of the medium is in the same direction to which the wave is coming.

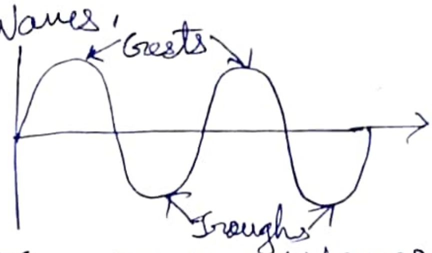
Examples :- Sound waves

* Transverse Waves :-
When the movement of the particles is at right angle of perpendicular to the motion of energy, then this type of wave is known as Transverse Wave.

Example — Light, Electromagnetic Waves,



Longitudinal Waves



Transverse Waves

* Water waves are an example of a combination of both longitudinal and transverse motions.

* Surface Waves :- In this type, the particles travel in a circular motion. These waves usually occurs at ~~surfa~~ interfaces
→ Waves in the ocean and ripples in a cup of water are example of such waves.

Electromagnetic Waves

→ Electromagnetic waves are created by a fusion of electric and magnetic fields.
The light you see, the colours around you are visible because of electromagnetic waves.

→ One interesting property here is that unlike mechanical waves, EM waves do not need a medium to travel. All EM waves travels through a vacuum at the same speed, i.e., 3×10^8 m/s.

Followings are the different types of electromagnetic waves

* Radio waves
* Microwaves
* Infrared waves
* Visible light rays
* Ultraviolet waves
* X-rays
* Gamma Rays.

*EM waves in increasing order of frequency: (in Hz)

Radio waves < Microwave < IR < Visible light < UV < X-rays < γ rays

Radio waves ($<3\times10^{9}$), Microwave ($3\times10^{9}-3\times10^{12}$), IR ($3\times10^{12}-4.3\times10^{14}$), Visible light ($4.3\times10^{14}-7.5\times10^{14}$), UV ($7.5\times10^{14}-3\times10^{16}$), X-rays ($3\times10^{16}-3\times10^{19}$), γ rays ($>3\times10^{19}$)

* EM waves in increasing order of wavelength: (in nm)

γ-rays < X-rays < UV < Visible < IR < Microwave < Radiowaves

γ-rays (<1), X-rays ($1-10$), UV ($10-400$), Visible ($400-700$), IR ($700-10^{5}$), Microwave ($10^{5}-10^{8}$), Radiowaves ($>10^{8}$)

Matter Waves

Matter waves are a central part of the theory of quantum ~~physics~~ mechanics, being an example of wave-particle duality.

2.) What is an antennae?

Ans An antennae is a transducer, which converts electrical ~~power~~ signals into electromagnetic waves and vice-versa.

* An antennae can be used either as a transmitting antennae or a receiving antennae.
    - A transmitting antennae is one, which converts electrical signals into EM waves and radiates them.
    - A receiving antennae is one, which converts EM waves from the received beam into electrical signals.
    - In two way communication, the same antennae can be used for both transmission and reception

→ Types of antennaes according to modes of applications:

i) Point-to-point Communication
ii) Broadcasting Applications
iii) Radar communications
iv) Satellite communications

Unit–I : Wave Propagation and Antennae

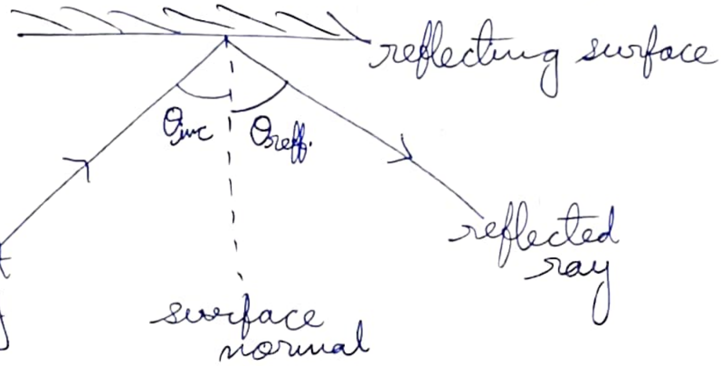
→ Wave Propagation is any of the ways in which the waves travels.

Environmental Effects on the Propagation of Waves :-

1.) **Reflection** :- Reflection is defined as the change in direction of propagation of a wave that strikes the boundary between different mediums.

→ The reflection of electromagnetic radiation involves the returning or throwing back of the radiation by a surface upon which the radiation is incident.

→ A reflecting surface is generally the boundary between two materials of different electromagnetic properties.



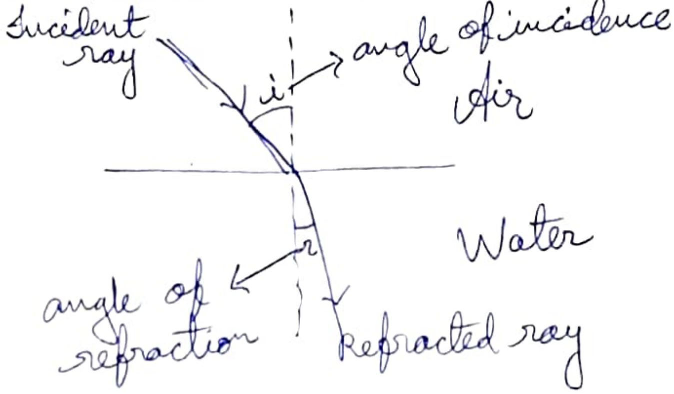
If the reflecting surface is smooth, $\theta_{inc.} = \theta_{reff.}$

~~2.) Refraction :-~~

→ Reflection does not change the wavelength and frequency of the incident signal/ray.

→ ~~If the medium (and its properties) is changed, the speed of the wave is changed.~~

2.) **Refraction** :- Refraction is the change in direction of propagation of a wave when the wave passes from one medium into another, and changes its speed



3.) <u>Diffraction</u> :- Diffraction is the tendency of a wave emitted from a finite source or passing through a finite aperature to spread out as it propagates.

4.) <u>Interference</u> :- Interference is a phenomenon in which two waves superpose to form a resultant wave of greater, lower or same amplitude.

→ There are 2 types of interference :

i) Constructive interference :- the amplitudes of the two waves adds together resulting in a higher wave at the point they meet.

ii) Destructive interference :- the two waves cancel out resulting in a lower amplitude at the point they meet.

5.) <u>Absorption</u> :- Absorption in wave motion is the transfer of the energy of a wave to matter as the wave passes through it.

→ ~~Wave~~ When a wave is absorbed, the matter takes in energy from the wave and, in doing so, lowers the amplitude.

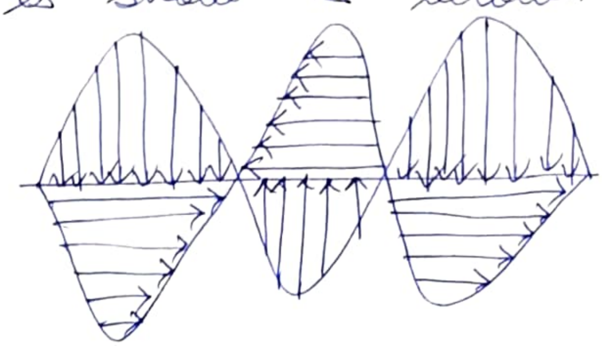
→ For example, when a sound wave hits foam padding, the energy travels through the materials and is sometimes converted into heat and other forms of energy.

6) Attenuation :- Attenuation is defined as the rate of amplitude loss an EM wave experiences as it propagates.

→ Attenuation decreases the intensity of electromagnetic radiation due to absorption or scattering of photons.

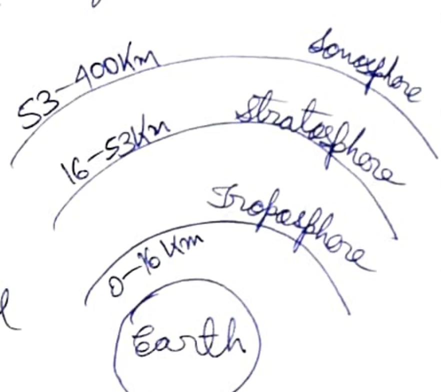
Wave Propagation

Electromagnetic Waves :- It is a combination of electric as well as magnetic waves. The propagation of EM Wave is shown as below:



Layers of Earth

Based on the range/distance covered and the peculiar properties the layers of earth are classified into 4 types :-



1) Troposphere :- It is the immediate layer after the surface of the earth. It ranges upto 16Km and consists of several gasses, particles as well as water droplets. This layer is used for ground wave propagation.

2.) Stratosphere :- This layer consists of very little gasses such as nitrogen and helium. It ranges from (16 – 53) Kms. It is useful for space wave propagation.

3.) Ionosphere :- It is the largest layer which ranges from 53Km to 400Km. It consists of very inactive elements called 'ions'. This layer is used for sky wave propagation.

4.) External space.

→ According to International Telecommunication Department, the wave propagation is classified into 3 types:

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

* Any wave which is having frequency less than 2MHz is termed as ground wave.
* Sky wave propagation :- 5MHz to 30MHz.
* Space wave propagation :- Greater than 500MHz.

Importance of Ionosphere

The ionosphere layer is a very important consideration in the phase of wave propagation because of the following reasons:

→ The layer below ionosphere has higher amount of air particles and lower UV radiation. Due to this, more collisions occur and ionization of particles is minimum and not constant.

→ The layer above ionosphere has very low amount of air particles and density of ionization is also quite low. Hence, ionization is not proper.

→ The ~~ionization~~ ionosphere has good composition of UV radiation and average air density that does not affect the ionization.

Ground Wave Propagation

Ground Wave Propagation is a type of radio propagation which is also known as a surface wave. These waves propagate over the earth's surface in low and medium frequencies.

→ These are mainly used for transmission between the surface of the earth and the ionosphere. These are made up of the number of constituent waves.

→ The reason why it is known as ground wave is that it is the sum of the waves that are reflected by the earth's surface or any hills.

→ The waves follow the curvature of the earth, enabling them to cover beyond the horizon. Beyond the horizon the waves get blocked by the curvature of the earth and the signals are produced by the diffracted surface wave.

Advantages of Ground Wave Propagation

→ These waves have the tendency to bend around the corners or obstructions during the propagation which makes them more efficient and also these are not affected by the change in atmospheric conditions.

Disadvantages

→ High frequency waves cannot be transmitted as the energy loses are more because of the absorption of energy in the earth's atmosphere.

→ These are used to cover short ranges and also involves attenuation of waves as they interact with the eddy currents produced by the surface of the earth.

Applications of Ground Wave Propagation

→ These can be used for one-way communication from the military to submerged submarines as they penetrate to a significant depth into sea water.

→ AM, FM and television broadcasting can be done with the help of ground waves

Sky Wave Propagation

→ The sky wave is also termed as short wave and it is also used for long distance communication.

→ Any frequency which is in the range of 5MHz to 30MHz is termed as sky wave, it is used in radio astronomy telecommunications and T.V broadcasting.

→ It is either the reflected or refracted back waves to the earth from the ionosphere which is an electrically charged layer of the upper atmosphere.

→ Medium and short wave frequencies can be refracted back to earth which is beyond the horizon which makes them useful in transcontinental transmission of waves.

Application of Sky Wave Propagation

→ Satellite communication takes place with the help of skywave propagation as it is dependent on the upper atmospheric conditions.

→ Mobile communications.

Space Wave Propagation

→ Space Wave Propagation is defined for the radio waves that occur within 20 Km of the atmosphere i.e; troposphere, comprising of a direct and reflected waves. These waves are also known as tropospheric propagation as they can travel directly from the earth's surface to the troposphere surface of the earth.

→ It is also known as a line of sight propagation as the signals are sent in a straight line from the transmitter to the receiver.

→ In order to prevent attenuation and loss of signal strength, the height of the antennae and distance b/w them can be given as:

$$D_m = (2RH_t)^{-1/2} + (2RH_r)^{-1/2}$$

where, D_m = distance b/w the two antennaes

R = Radius of the earth

H_t = height of transmission antennae

H_r = height of receiver antennae

Applications of Space Wave Propagation

It is used in various communications systems like

→ LOS communication and satellite communication

→ RADAR communication

→ Microwave linking

Space Wave Propagation Limitations

→ These waves are affected by the curvature of the earth.

→ The propagation of these waves happens along the line of sight distance which is defined as the distance between the transmitting antennae and the receiving antennae which is also known as the range of communication.

Definations

1.) Critical Frequency :- The highest frequency that returns from an ionospheric layer at a vertical incidence is called the critical frequency for that particular layer.

→ For a regular layer it is proportional to the square root of maximum electron density in the layer.

→ It is denoted by f_c.

2.) Maximum Usable Frequency :- The maximum usable frequency (MUF) is the highest frequency delivered by the transmitter regardless of the power of the transmitter. The highest frequency, which is reflected from the ionosphere to the receiver is called as critical frequency, f_c.

→ Beyond MUF, the wave will not return.

$$MUF = \frac{\text{Critical frequency}}{\cos\theta} = f_c \sec\theta$$

* Lowest Usable Frequency :- The frequency below which the entire power gets absorbed is referred to as the lowest usable frequency (LUF).

* Optimum Working Frequency (OWF) :- The frequency, which is being used mostly for a particular transmission and which has been predicted to be used over a particular period of time, over a path, is termed as Optimum Working Frequency (OWF).

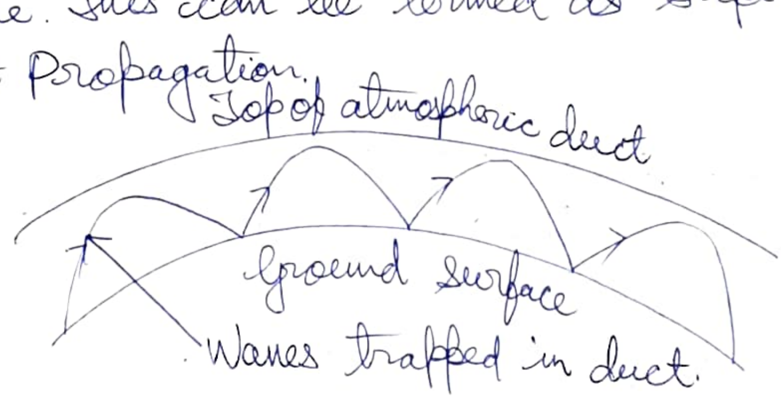
3) <u>Skip Distance</u> :- The minimum distance at which the wave returns to the ground at a critical angle ϕ_c, is termed as skip distance.

4) <u>Fading</u> :- The decrease in the quality of the signal can be termed as fading. This happens because of atmospheric effects and/or reflections due to multipath.

→ Fading refers to the variation of the signal strength with respect to time/distance. It is widely prevalent in wireless transmissions. The most common causes of fading in the wireless environment are multipath propagation and mobility (of objects as well the communicating devices).

5) <u>Duct Propagation</u> :- At a height of around 50 meters from the troposphere, a phenomenon exists; the temperature increases with the height. In this region of troposphere, the higher or microwave frequencies tend to refract back into earth's atmosphere, instead of shooting into ionosphere, to reflect. These waves propagate around the curvature of the earth even upto a distance of 1000 Kms.

This refraction goes on continuing in this region of troposphere. This can be termed as super refraction or Duct Propagation.



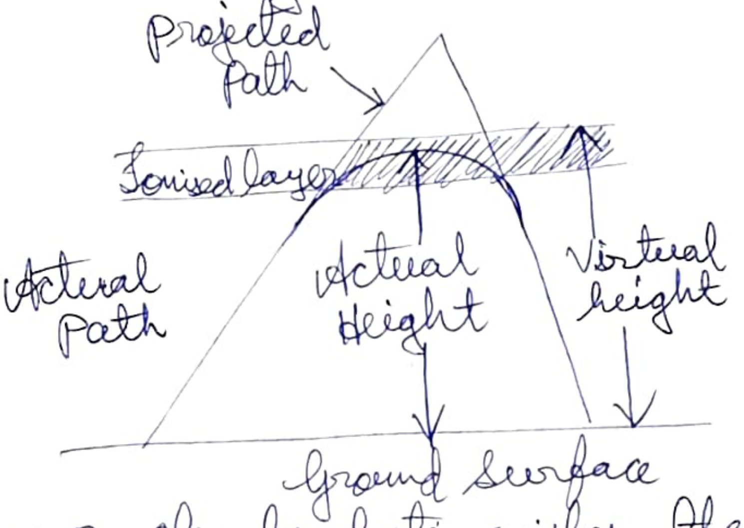
The above image shows the process of Duct Propagation. The main requirement for the duct formation is the temperature inversion. The increase of tempera-ture with height, rather than the decrease in temperature is known as the phenomenon of temperature inversion.

6) Tropospheric Scatter Propagation :- Tropospheric scatter propagation is a means of beyond-the-horizon propagation for UHF signals.

→ Tropospheric scattering occurs at a frequency above 30MHz. So, this occurs in Space Wave Propagation.

7.) Actual Height and Virtual Height

When a wave is refracted, it is bent down gradually, but not sharply. However, the path of incident wave and reflected wave are same if it is reflected from a surface located at a greater height of this layer. Such a greater height is termed as virtual height.



The above figure clearly distinguishes the virtual height (height of wave, supposed to be reflected) and actual height (the refracted height).

Radiation Mechanism of an Antenna – Maxwell's Equation

Maxwell's Equations are set of four vector-differential equations that govern all of electromagnetics.

→ The four equations (written only in terms of E and H, the electric field and the magnetic field), are given as:

$$\nabla \cdot E = \frac{\rho_v}{\varepsilon} \quad \text{(Gauss' law)} \text{ — } ①$$

$$\nabla \cdot H = 0 \quad \text{(Gauss' law of magnetism)} \text{ — } ②$$

$$\nabla \times E = -\mu \frac{\partial H}{\partial t} \quad \text{(Faraday's law)} \text{ — } ③$$

$$\nabla \times H = J + \varepsilon \frac{\partial E}{\partial t} \quad \text{(Ampere's law)} \text{ — } ④$$

* In Gauss' law, ρ_v is the volume electric charge density, J is the electric current density (Amp/m²), ε is the permittivity and μ is the permeability.

* Eqn ③ and ④ are responsible for electromagnetic radiation. When the E-field travels, it is altered in space, which gives rise to a time-varying magnetic field. A time varying magnetic field then varies as a function of location (space), which gives rise to a time-varying electric field.

Radiation Mechanism

The sole functionality of an antenna is power radiation or reception. Antenna (whether it transmits or receives or does both) can be connected to the circuitry at the station through a transmission line. The functioning of an antenna depends upon the radiation mechanism of a transmission line.

→ A conductor, which is designed to carry current over large distances with minimum losses, is termed as a transmission line.

For example — a wire, which is connected to an antenna.

→ The wire or the transmission line has some power, which travels from one end to the other end. If both the ends of the transmission lines are connected to circuits, then the information will be transmitted or received using this wire between these two circuits.

→ If one end of the wire is not connected, then the power in it tries to escape. This leads to wireless communication. If one end of the wire is bent, then the energy tries to escape from the transmission line more effectively than before. This purposeful escape is known as radiation.

* A transmission line conducting current with uniform velocity, and the line being a straight one with infinite extent, radiates no power.

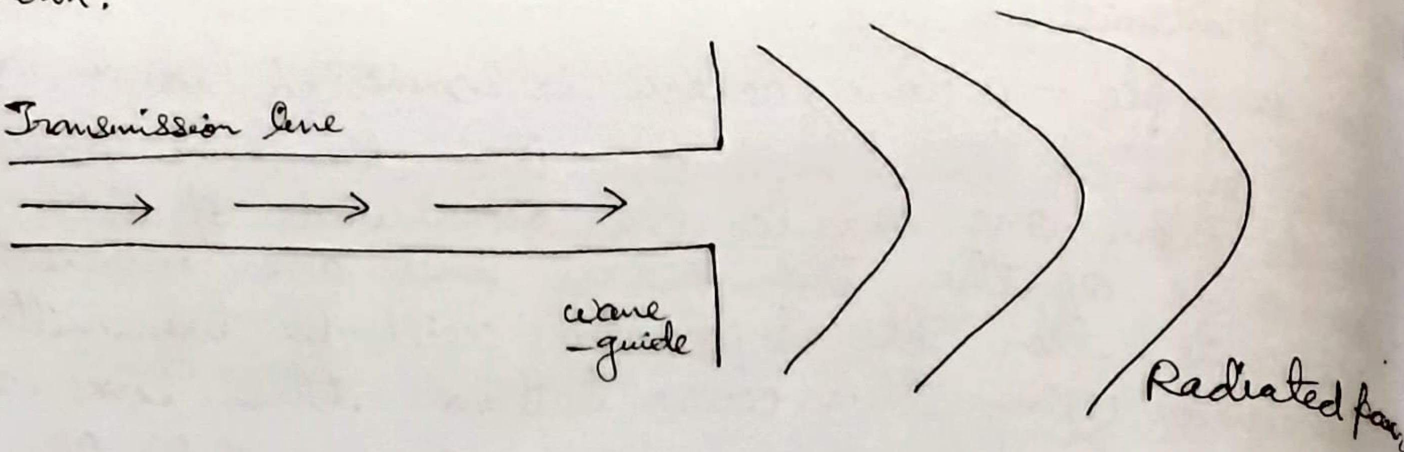
→ For a transmission line to become a waveguide or to radiate power, has to be processed as such.

* If the power has to be radiated, though the current conduction is with uniform velocity, the wire or transmission line should be bent or terminated.

* If the transmission line has current, which accelerates or decelerates with a timevarying constant, then it radiates the power even though the wire is straight.

* The device or tube, if bent or terminated to radiate energy, then it is called as waveguide. These are especially used for microwave transmission and reception.

This can be well understood by observing the following diagram:



The above diagram represents a waveguide, which acts as an antenna. The power from the transmission line travels through the waveguide which has an aperture to radiate the energy.

Radiation Pattern

Radiation is the term used to represent the emission or reception of the wave at the antenna, specifying its strength. In any illustration, the sketch drawn to represent the radiation pattern.

* Radiation patterns are diagrammatical representations of the distribution of radiated energy into space, as a function of direction.

* The figure shows the radiation patterns of a dipole antenna. The energy being radiated is represented by the patterns drawn in a particular direction. The arrows represents direction of radiation.

→ The radiation patterns can be field patterns and power patterns.

* The field patterns are plotted as a function of electric and magnetic fields. They are plotted on logarithmic scale.

* The power patterns are plotted as a function of square of the magnitude of electric and magnetic fields. They are plotted on logarithmic or commonly on dB scale.

Definations

1) **Antennae Gain**:- Gain of an antennae is defined as the ratio of radiation intensity that would be obtained if the power accepted by the antennae were radiated isotropically.

Gain, $G = \eta_e D$

where G = gain of the antennae

η_e = antennae's efficiency

D = directivity of the antennae.

* Unit of gain is decibels (dB).

2) **Directivity**:- The ratio of radiation intensity of the subject antennae to the radiation intensity of an isotropic or reference antennae, radiating the same total power is called the directivity.

The radiated power is a function of angular position and the radial distance from the circuit. Hence, it is expressed by considering both the terms θ and ϕ.

$$\text{Directivity} = \frac{\text{Maximum radiation intensity of subject antennae}}{\text{Radiation Intensity of an isotropic antennae}}$$

$$D = \frac{\phi(\theta, \phi)_{max} \text{ (from subject antennae)}}{\phi_0 \text{ (from isotropic antennae)}}$$

where, $\phi(\theta, \phi)_{max}$ = maximum radiation intensity of subject antennae

ϕ_0 = radiation intensity of an isotropic antennae (antennae with zero losses).

3) **Directive Gain** :- Directive gain of an antennae in a given direction, 4π times the ratio of the radiation intensity in that direction to the total power radiated by the antennae.

4) **Effective Aperature** :- The effective aperture of an antennae is that region of the receiving antennae that effectively collects the electromagnetic energy from the radiated wave out of the overall antennae region.

5) **Polarization** :- Polarization may be defined in terms of the orientation of electric field vector with reference to the ground (or surface of the earth, assumed to be perfectly smooth and flat).

* It is of 3 types : i) linear, ii) elliptical, iii) circular

6) **Input Impedance** :- The input impedance of antennae is basically the impedance offered by the antennae by its terminals.

* It is defined as the ratio of voltage to the current across the two input terminals of the antennae.

Generally, the input impedance of antennae is given by :

$$Z_a = R_a + jX_a,$$

where R_a is the resistance at antennae terminals and X_a is the reactance at antennae terminals.

7. **Efficiency** :- Antennae efficiency is the ratio of the radiated power of the antennae to the input power accepted by the antennae.

$$\text{Antennae efficiency, } \eta_e = \frac{P_{rad}}{P_{input}}$$

8) **Radiation Resistance** :- It is defined as the fictious resistance that when substituted in series with an antennae will consume the same power as is actually radiated by the antennae.

9.) Antennae Bandwidth :- It is defined as the range of frequ. over which an to antennae maintain its certain required characteristics, i.e., gain, radiation resistance, polarization, impedance, etc.

10.) Beam Width :- Beam width is defined as the measure of directivity of an antennae.

11.) Radiation Pattern :- Radiation pattern is the graphical representation of the field pattern of radiation from an antennae as a function of direction/space coordinate

Types of Antenna

Antennas have to be classified to understand their physical structure and functionality more clearly. There are many types of antennas depending upon the applications

Types of Antennas	Examples	Applications
1) Wire Antennas	Dipole Antennas, Monopole Antenna, Helix antenna, loop antenna	Personal applications, building, ships, automobiles, space craft
2) Aperture Antennas	Waveguide (opening), Horn antennas	Flush mounted applications, aircraft, space-craft.
3) Reflector Antennas	Paraboloic reflector, corner reflector.	Microwave communication, satellite tracking, radio astronomy.
4.) Lens Antenna	convex-plane, concave-plane, convex-convex, concave-concave lenses	Used for very high frequency applications.
5) Micro strip antennas	Circular shaped, rectangular shaped metallic patch above the ground plane	aircraft, space craft, satellite, missiles, cars, mobile phones etc.
6) Array Antennas	Yagi-Uda Antenna, Micro strip patch array, aperture array, slotted wave guide array.	Used for very high gain applications, mostly when needs to control the radiation pattern

Dipole Antenna

→ A dipole antenna is the simplest type of radio antenna, consisting of a conducting wire rod that is half the length of the maximum wavelength the antenna is to generate.

→ This wire rod is split in the middle, and the two sections are separated by an insulator. Each rod is connected to a coaxial cable at the end closest to the middle of the antenna.

→ The dipole antenna is one of the most important forms of RF antenna. The dipole can be used on its own, or it can form part of a more complecated antenna array.

→ The name 'di-pole' indicates that the dipole antenna consists of two poles ~~or~~ — two conductive elements. Current flows in these two conductive elements and the current and the associated voltage causes an electromagnetic wave or radio signal to be radiated outwards from the antenna.

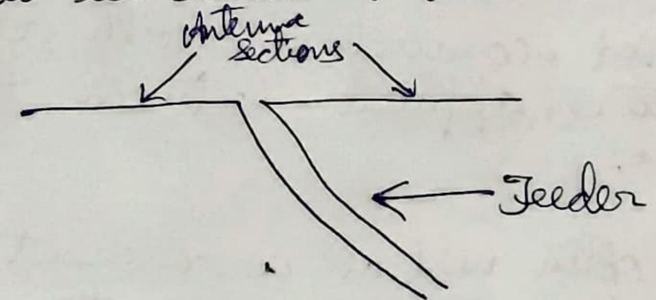


Fig Basic Dipole Antenna

As seen, the basic antenna consists of a radiating element that is split into two separate conductor. These are normally on the same axis, and the dipole antenna is normally split in the ~~middle~~ center. Power from a transmitter may be applied to be radiated, or power picked up by the antenna may be connected to a receiver. Normally, the receiver or transmitter is connected to the dipole antenna via an intermediate feeder which enables the power to be transferred from one point to another.

Monopole Antenna

→ A monopole antenna is one half of a dipole antenna, almost always mounted above some sort of ground plane.

→ A monopole antenna is a class of radio antenna consisting of a straight rod-shaped conductor, often mounted perpendicularly over some type of conductive surface called a ground plane.

→ The driving signal from the transmitter is applied, or for receiving antennas the output signal to the receiver is taken, between the lower end of the monopole and the ground plane. One side of the antenna feedline is attached to the lower end of the monopole, and the other side is attached to the ground plane, which is often the Earth. This contrasts with dipole antenna which consists of two identical rod conductors, with the signal from the transmitter applied between the two halves of the antenna.

→ The monopole is often used as a resonant antenna; the rod functions as an open resonator for radio waves oscillating with standing waves of voltage and current along its length. Therefore, the length of the antenna is determined by the wavelength of the radio waves it is used with.

→ The most common form is the quarter-wave monopole, in which the antenna is approximately one-quarter of the wavelength of the radio waves

Omnidirectional Antenna

→ In radio communication, an omnidirectional antenna is a class of antenna which radiates equal radio power in all directions perpendicular to an axis (azimuthal directions), with power varying with angle ~~to~~ the axis (elevation angle), declining to zero on the axis.

→ When graphed in 3D, this radiation pattern is often described as doughnut-shaped.

→ It is different from an isotropic antenna, which radiates equal power in all directions, having a spherical radiation pattern.

→ Omnidirectional antennas ~~are~~ oriented vertically are widely used for non-directional antennas on the surface of the earth because they radiate equally in all horizontal directions, while the power radiated drops off with elevation angle so ~~little~~ little radio energy is aimed into the sky or down towards the earth and wasted.

→ Omnidirectional antennas are widely used for radio broadcasting antennas, and in ~~mobil~~ mobile devices that uses radio such as cell phones, FM radios, GPS, as well as for base stations that communicate with mobile radios such as police ~~stations~~ and taxi dispatchers and aircraft communications.

* Azimuthal direction:- an arc of the horizon measured between a fixed point (such a true north), and the vertical circle passing through the center of an object clockwise from the north point through 360° degrees.

* The figure shows the radiation patterns of a dipole antenna. The energy being radiated is represented by the patterns drawn in a particular direction. The arrows represents direction of radiation.

→ The radiation patterns can be field patterns and power patterns.

* The field patterns are plotted as a function of electric and magnetic fields. They are plotted on logarithmic scale.

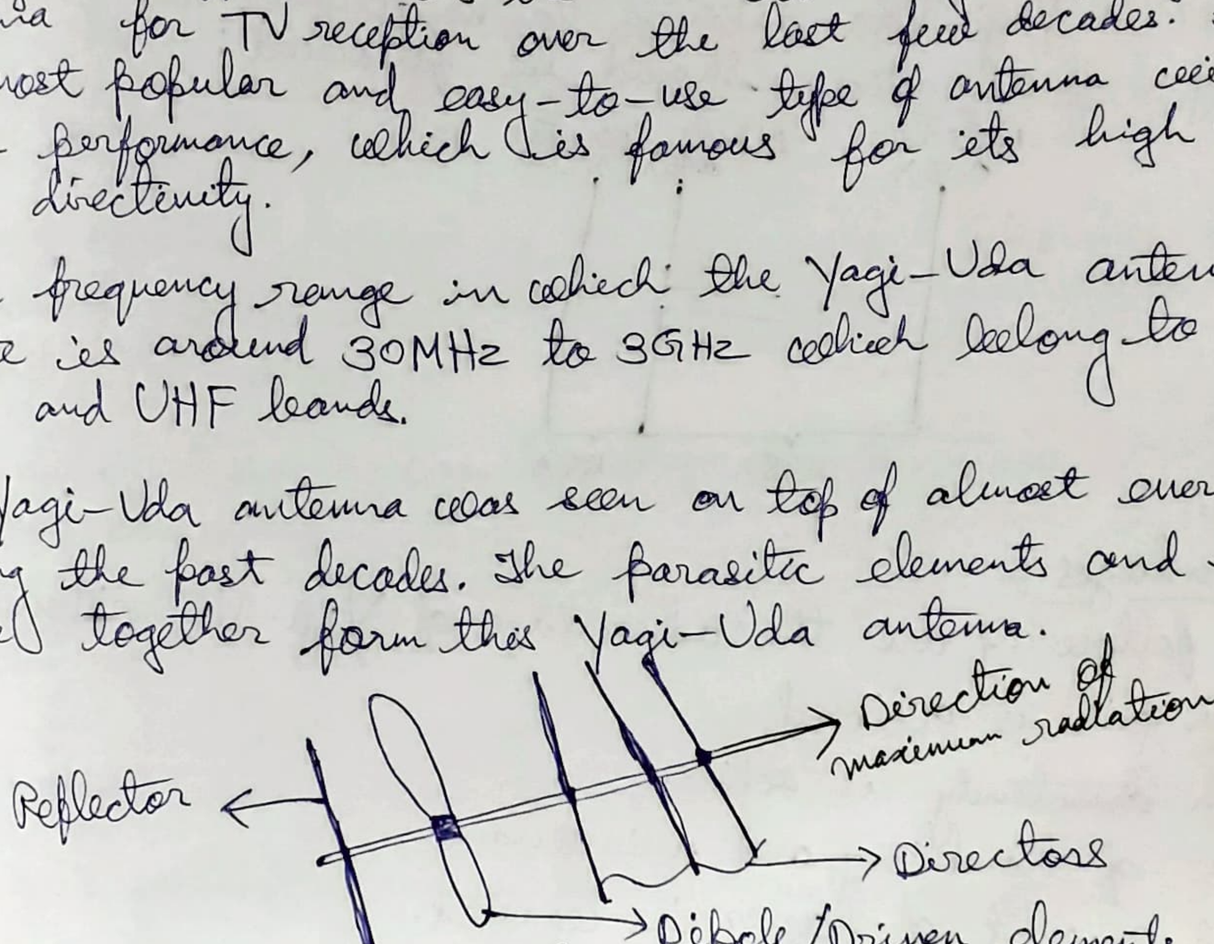
* The power patterns are plotted as a function of square of the magnitude of electric and magnetic fields. They are plotted on logarithmic or commonly on dB scale.

Yagi-Uda Antenna

→ Yagi-Uda Antenna is the most commonly used type of antenna for TV reception over the last few decades. It is the most popular and easy-to-use type of antenna with better performance, which is famous for its high gain and directivity.

→ The frequency range in which the Yagi-Uda antennas operate is around 30MHz to 3GHz which belong to the VHF and UHF bands.

→ A Yagi-Uda antenna was seen on top of almost every house during the past decades. The parasitic elements and the dipole together form this Yagi-Uda antenna.

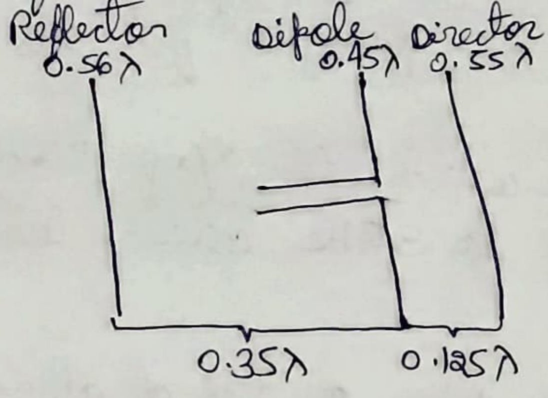


Yagi-Uda Antenna

The figure shows a Yagi-Uda antenna. It is seen that there are many directors placed to increase the directivity of the antenna. The feeder is the folded dipole. The reflector is the lengthy element, which is at the end of the structure.

→ The figure depicts a clear form of the Yagi-Uda antenna. The center rod like structure on which the elements are mounted is called as boom. The element to which a thick black head is connected is the driven element to which the transmission line is connected internally, through that black stud. The single element present at the back of the driven element is the reflector, which reflects all the energy towards the direction of the radiation pattern. The other elements, before the driven element, are the directors, which direct the beam towards the desired angle.

→ For a Yagi-Uda antenna to be designed, the following design specifications should be followed:



Advantages :-

The following are the advantages of Yagi-Uda antenna:

→ High gain is achieved
→ High directivity is achieved
→ Ease of handling and maintenance
→ Less amount of power is wasted.
→ Broader coverage of frequencies.

Disadvantages

The following are the disadvantages of Yagi-Uda antennas—

→ Prone to noise

→ prone to atmospheric effects

Applications

The following are the applications of Yagi-Uda antennas—

→ Mostly used for TV reception

→ Used where a single-frequency application is needed.

Rhombus Antenna

→ The rhombic antenna is an equilateral parallelogram shaped antenna.

→ Generally, it has two opposite acute angles. The tilt angle θ is approximately equal to 90° minus the angle of major lobe.

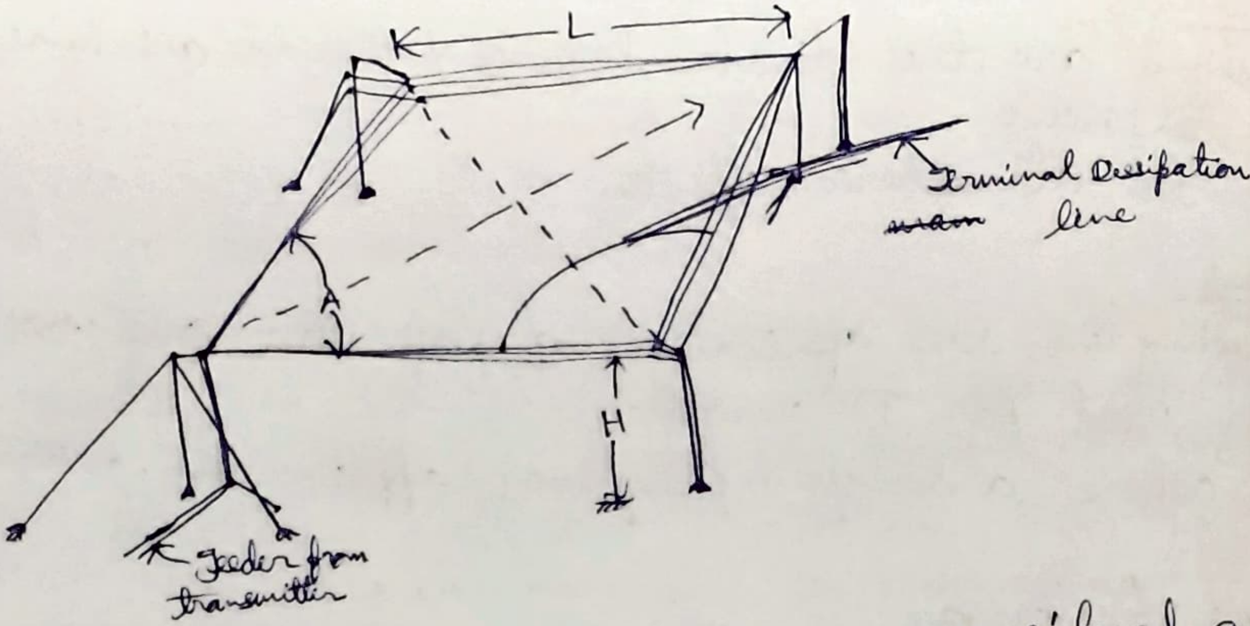
→ Rhombic antenna works under the principle of travelling wave radiator. It is arranged in the form of a rhombus or diamond shaped and suspended horizontally above the surface of the earth.

→ The frequency range of operation of a Rhombic antenna is around 3MHz to 300MHz. This antenna works in HF and VHF ranges.

→ Rhombic antenna can be regarded as two V-shaped antennas connected end-to-end to form obtuse angles. Due to its simplicity and ease of construction it has many uses:

- In HF transmission and reception
- commercial point-to-point communication.

The construction of the rhombic antenna is in the form a rhombus, as shown in the figure



→ The two sides of the rhombus is considered as the conductor of a two-wire transmission line. When the system is properly designed, there is a concentration of radiation along the main axis of radiation. In practice, half of the power is dissipated in the terminating resistance of the antenna. The rest of the power is radiated. The wasted power contributes to the minor lobes.

→ The maximum gain from a rhombic antenna is along the direction of the main axis, which passes through the feed point to terminate in free space. The polarization obtained from a horizontal rhombic antenna is in the plane of rhombus, which is rhombus.

→ The radiation pattern of the rhombic antenna is shown in the figure. The resultant pattern is the cumulative effect of the radiation at all four legs of the antenna. This pattern is uni-directional.

Radiation pattern of Rhombic Antenna

→ The main disadvantage of rhombic antenna is that the portions of the radiation, which do not combine with the main lobe, result in considerable side lobes having both horizontal and vertical polarization.

Advantages

The following are the advantages of Rhombic antenna—

→ Input impedance and radiation pattern are relatively constant.

→ Multiple rhombic antennas can be connected.

→ Simple and effective transmission.

Disadvantages

The following are the disadvantages of Rhombic antenna—

→ Wastage of power in terminating resistor.

→ Requirement of large space

→ Reduced transmission efficiency.

Applications

The following are the applications of Rhombic antenna—

→ Used in HF communications

→ Used in long distance sky wave propagations.

→ Used in point-to-point communications

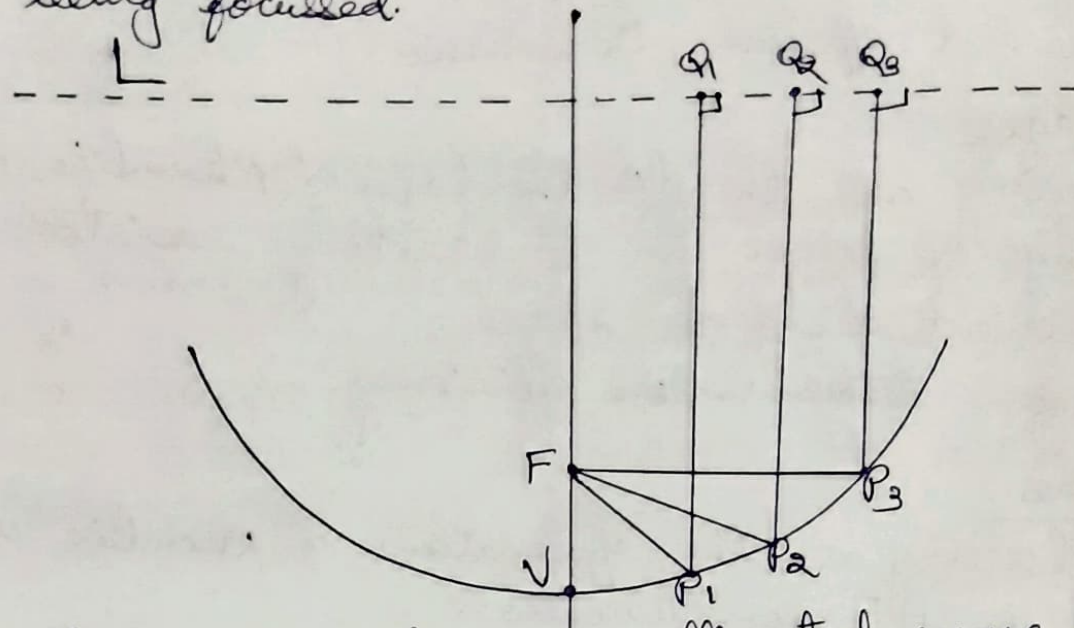
Dish Antenna (Parabolic Reflector)

→ Parabolic reflectors are microwave antennas. The frequency range used for the application of parabolic reflector antennas is above 1MHz. These antennas are widely used for radio and wireless applications.

Construction and Working / Operation of a Parabolic Reflector

→ The standard definition of a parabola is — locus of a point, which moves in such a way that its distance from the fixed point (called focus) plus its distance from a straight line (called directrix) is constant.

→ The following figure shows the geometry of parabolic reflector. The point F is the focus (feed is given) and V is the vertex. The line joining F and V is the axis of symmetry. PQ are the reflected rays where L represents the line directrix on which the reflected points lie (to say that they are being collinear). Hence, as per the above definition, the distance between F and L lie constant w.r.t the waves being focussed.



→ The reflected wave forms a collimated wave front, out of the parabolic shape. The law of reflection states that the angle of incidence and the angle of reflection are equal. This law when used along with a parabola, helps the beam focus. The shape of the parabola when used for the purpose of reflection of waves, exhibits some properties of parabola, which are helpful building an antenna, using the waves reflected.

* Properties of Parabola :-

→ All the waves originating from focus, reflects back to the parabolic axis. Hence, all the waves reaching the aperture are in phase.

→ As the waves are in phase, the beam of radiation along the parabolic axis will be strong and concentrated.

Following these points, the parabolic reflectors help in producing high directivity with narrower beam width.

→ If a Parabolic Reflector antenna is used for transmitting a signal, the signal from the feed, comes out of a dipole or a horn antenna, to focus the wave on to the parabola. It means that the waves comes out of the focal point and strikes the paraboloidal reflector. This wave now gets reflected as collimated wave front, as discussed previously, to get transmitted.

→ The same antenna is used as a receiver. When the electromagnetic wave hits the shape of the parabola, the wave gets reflected onto the feed point. The dipole or the horn antenna, which acts as the receiver antenna at its feed, receives this signal, to convert it to electric signal and forward it to the receiver circuitry.

Advantages:-

The following are the advantages of parabolic reflector antenna :-

→ Reduction of minor lobes.

→ Wastage of power is reduced

→ Equivalent focal length is achived.

→ Feed can be placed in any location, according to our convinience.

→ Adjustment of beam (narrowing or widening) is done by adjusting the reflecting surfaces.

Disadvantages:-

→ Some of the power that gets ~~reflector~~ reflected from the parabolic reflector is obstructed. This becomes a problem with small dimension paraboloid.

Applications:-

→ Used in wireless telecommunication systems.

→ The cassegrain feed parabolic reflector is mainly used in satellite communications.

Horn Antenna

→ To improve the radiation efficiency and directivity of the
beam, the waveguide should be provided with an
extended aperture to make the abrupt discontinuity
of the wave into a gradual transformation. So that
all the energy in the forward direction gets radiated.
This can be termed as Flaring. Now, this can be
done using a horn antenna.

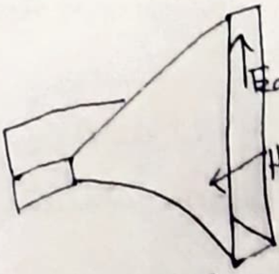
→ The operational frequency range of a horn antenna
is around 300 MHz to 30 GHz. This antenna works in
UHF and SHF frequency ranges.

Construction and Operation of Horn Antenna

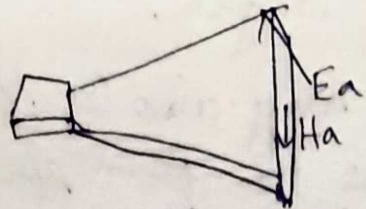
→ The energy of the beam when slowly transform into
radiation, the losses are reduced and the focusing of the beam
improves. A horn antenna may be considered as a flared
out wave guide, by which the directivity is improved and
the diffraction is reduced.

→ There are several horn configurations out of which,
three configurations are most commonly used:

i) Sectoral Horn — This type of horn antenna, flares
out in only one direction. Flaring in the direction
of Electric vector produces the sectoral E-plane
horn. Similarly, flaring in the direction of Magnetic
vector, produces the sectoral H-plane horn.

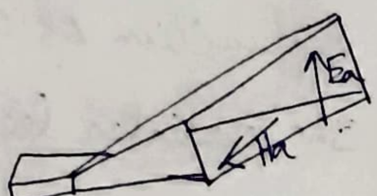


E-plane sectoral horn



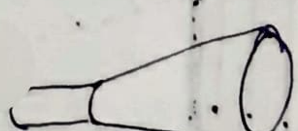
H-plane sectoral horn

ii) Pyramidal Horn — This type of horn antenna has flaring on both sides. If flaring is done on both the E and H walls of a rectangular waveguide, then pyramidal horn antenna is produced. This antenna has the shape of a truncated pyramid



Pyramidal Horn

iii) Conical Horn — When the walls of a circular waveguide are flared, it is known as a conical horn. This is a logical termination of a circular waveguide.



conical Horn antenna

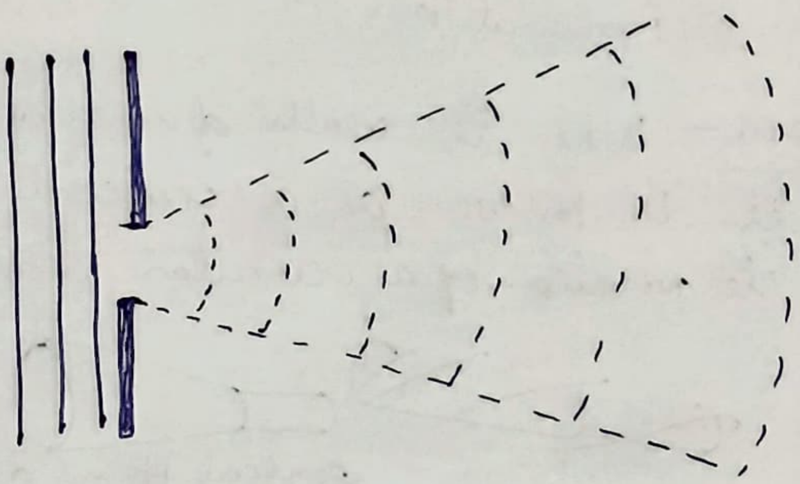
→ Flaring helps to match the antenna impedance with the free space impedance for better radiation. It avoids standing wave ratio and provides greater directivity and narrower beam width. The flared waveguide can be technically termed as Electromagnetic Horn Radiator.

→ Flare angle ϕ, of horn antenna is an important factor to be considered. If this is too small, then the resulting wave will be spherical instead of plane and the radiated beam will not be directive. Hence, the flare angle should have optimum value and is closely related to its length.

→ Horn antennas, may also be combined with parabolic reflector antennas to form special type of horn antennas. These are —

i) Cass-horn antenna
ii) Hog-horn or triply folded horn reflector.

→ The radiation pattern of a horn antenna is a spherical wavefront. The wave radiates from the aperture, minimizing the diffraction of waves. The flaring keep the beam focussed. The radiated beam has high directivity



Advantages —

→ Small minor lobes are formed.
→ Impedance matching is good
→ Greater directivity
→ Narrower beam width
→ Standing waves are avoided.

Disadvantages —

→ Designing of flare angle, decides the directivity
→ Flare angle and length of the flare should not be very small.

Applications —

→ Used for astronomical studies
→ Used in microwave applications

Basic Concepts of Smart Antennas

Smart Antennas (also known as adaptive array antennas, digital antenna arrays, multiple antennas, and recently, MIMO) are antenna arrays with smart signal processing algorithms used to identify spatial signal signatures such as the direction of arrival (DOA) of the signal, and use them to calculate beam forming vectors which are used to track and locate the antenna beam on the mobile/target.

→ Smart antennas are used to increase the efficiency in digital wireless communication systems. It works by taking the advantage of the diversity effect at the transceiver of the wireless system that is the source and the destination. The term diversity effect refers to the transmission and reception of multiple radio frequencies that are used to decrease the error during data communication and also to increase data speed between the source and the destination.

A smart antenna has mainly two basic functions.

1.) <u>Estimation of Direction of Arrival</u> (DOA)—

In smart antennas various techniques like MUSIC (Multiple Signal Classification) and estimation of signal parameters via rotation invariance techniques (ESPRIT) algorithms are used to find the DOA of a signal. This method requires a lot of computations and algorithms. The antenna acts like a sensor in which a spatial spectrum of the array is selected and the DOA is found out from the peaks of this spectrum.

2.) <u>Beamforming Method</u> —

The mobiles or targets at which the signals are to be sent are first sought out and then a radiation pattern of the antenna array is created by adding the signal phases. At the same time the mobiles which will not need the signal will be out of pattern. Through this method may seem a little complicated, it can be done easily with the help of a FIR tapped delay line filter. According to the signal used the weight of the FIR filter can also be changed accordingly.

<u>Benefits of Smart Antennas</u>

→ Enhance coverage through range extension.

→ Fully controlled by software so less manual operation.

→ Reduction in transmitted power.

→ Reduced co-channel interference and multi-channel interference

→ Provides high security

→ Improve system capacity

→ Compatibility, it can be applied to various multiple access techniques such as TDMA, FDMA and CDMA.

Transmission Lines

A **transmission line** is a connector which transmits energy from one point to another. The study of transmission line theory is helpful in the effective usage of power and equipment.

There are basically four types of transmission lines:

- Two-wire parallel transmission lines
- Coaxial lines
- Strip type substrate transmission lines
- Waveguides

While transmitting or while receiving, the energy transfer has to be done effectively, without the wastage of power. To achieve this, there are certain important parameters which has to be considered.

Main Parameters of a Transmission Line

The important parameters of a transmission line are resistance, inductance, capacitance and conductance.

Resistance and inductance together are called as transmission line **impedance**.

Capacitance and conductance together are called as **admittance**.

Resistance

The resistance offered by the material out of which the transmission lines are made, will be of considerable amount, especially for shorter lines. As the line current increases, the ohmic loss $(I^2R\ loss)$ also increases.

The resistance **R** of a conductor of length "**l**" and cross-section "**a**" is represented as

$$R = \rho \frac{l}{a}$$

Where

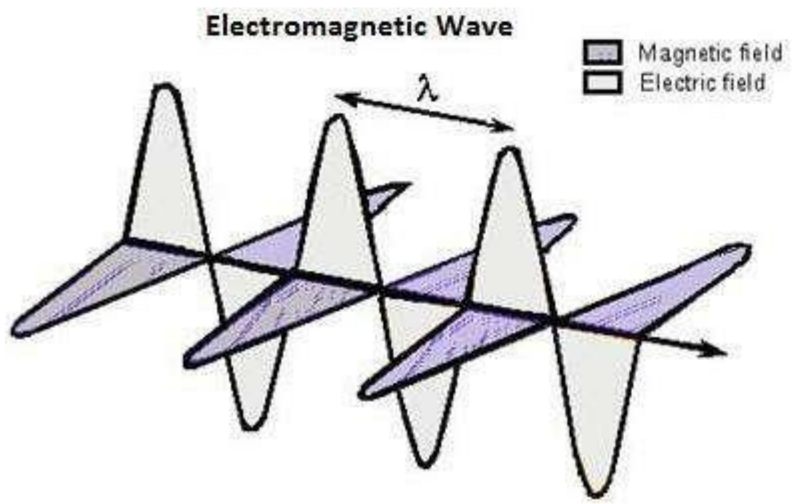
ρ = resistivity of the conductor material, which is constant.

Temperature and the frequency of the current are the main factors that affect the resistance of a line. The resistance of a conductor varies linearly with the change in temperature. Whereas, if the frequency of the current increases, the current density towards the surface of the conductor also increases. Otherwise, the current density towards the center of the conductor increases.

This means, more the current flows towards the surface of the conductor, it flows less towards the center, which is known as the **Skin Effect**.

Inductance

In an AC transmission line, the current flows sinusoidally. This current induces a magnetic field perpendicular to the electric field, which also varies sinusoidally. This is well known as Faraday's law. The fields are depicted in the following figure.



This varying magnetic field induces some EMF into the conductor. Now this induced voltage or EMF flows in the opposite direction to the current flowing initially. This EMF flowing in the opposite direction is equivalently shown by a parameter known as **Inductance**, which is the property to oppose the shift in the current.

It is denoted by "**L**". The unit of measurement is "**Henry (H)**".

Conductance

There will be a leakage current between the transmission line and the ground, and also between the phase conductors. This small amount of leakage current generally flows through the surface of the insulator. Inverse of this leakage current is termed as **Conductance**. It is denoted by "**G**".

The flow of line current is associated with inductance and the voltage difference between the two points is associated with capacitance. Inductance is associated with the magnetic field, while capacitance is associated with the electric field.

Capacitance

The voltage difference between the **Phase conductors** gives rise to an electric field between the conductors. The two conductors are just like parallel plates and the air in between them becomes dielectric. This pattern gives rise to the capacitance effect between the conductors.

Characteristic Impedance

If a uniform lossless transmission line is considered, for a wave travelling in one direction, the ratio of the amplitudes of voltage and current along that line, which has no reflections,

is called as **Characteristic impedance**.

It is denoted by Z_0

$$Z_0 = \sqrt{\frac{voltage\ wave\ value}{current\ wave\ value}}$$

$$Z_0 = \sqrt{\frac{R + jwL}{G + jwC}}$$

For a lossless line, $R_0 = \sqrt{\frac{L}{C}}$

Where **L** & **C** are the inductance and capacitance per unit lengths.

Impedance Matching

To achieve maximum power transfer to the load, impedance matching has to be done. To achieve this impedance matching, the following conditions are to be met.

The resistance of the load should be equal to that of the source.

$$R_L = R_S$$

The reactance of the load should be equal to that of the source but opposite in sign.

$$X_L = -X_S$$

Which means, if the source is inductive, the load should be capacitive and vice versa.

Reflection Co-efficient

The parameter that expresses the amount of reflected energy due to impedance mismatch in a transmission line is called as **Reflection coefficient**. It is indicated by **ρ (rho)**.

It can be defined as "the ratio of reflected voltage to the incident voltage at the load terminals".

$$\rho = \frac{\boldsymbol{reflected\,voltage}}{\boldsymbol{incident\,voltage}} = \frac{\boldsymbol{V_r}}{\boldsymbol{V_i}}\ \boldsymbol{at\,load\,terminals}$$

If the impedance between the device and the transmission line don't match with each other, then the energy gets reflected. The higher the energy gets reflected, the greater will be the value of **ρ** reflection coefficient.

Voltage Standing Wave Ratio (VSWR)

The standing wave is formed when the incident wave gets reflected. The standing wave which is formed, contains some voltage. The magnitude of standing waves can be measured in terms of standing wave ratios.

The ratio of maximum voltage to the minimum voltage in a standing wave can be defined as Voltage Standing Wave Ratio (VSWR). It is denoted by "**S**".

$$S = \frac{|V_{max}|}{|V_{min}|} \qquad 1 \le S \le \infty$$

VSWR describes the voltage standing wave pattern that is present in the transmission line due to phase addition and subtraction of the incident and reflected waves.

Hence, it can also be written as

$$S = \frac{1+\rho}{1-\rho}$$

The larger the impedance mismatch, the higher will be the amplitude of the standing wave.

Therefore, if the impedance is matched perfectly,

$$V_{max} : V_{min} = 1:1$$

Hence, the value for VSWR is unity, which means the transmission is perfect.

Efficiency of Transmission Lines

The efficiency of transmission lines is defined as the ratio of the output power to the input power.

$$\%\ \boldsymbol{efficiency\ of\ transmission\ line}\ \eta = \frac{\boldsymbol{Power\ delievered\ at\ reception\ end}}{\boldsymbol{Power\ sent\ from\ the\ transmission\ end}} \times \mathbf{100}$$

Voltage Regulation

Voltage regulation is defined as the change in the magnitude of the voltage between the sending and receiving ends of the transmission line.

$$\%voltage\ regulation = \frac{sending\ end\ voltage - receiving\ end\ voltage}{sending\ end\ voltage} \times 100$$

Losses due to Impedance Mismatch

The transmission line, if not terminated with a matched load, occurs in losses. These losses are many types such as attenuation loss, reflection loss, transmission loss, return loss, insertion loss, etc.

Attenuation Loss

The loss that occurs due to the absorption of the signal in the transmission line is termed as Attenuation loss, which is represented as

$$Attenuation\ loss\ (dB) = 10\ log_{10}\left[\frac{E_i - E_r}{E_t}\right]$$

Where

- E_i = the input energy
- E_r = the reflected energy from the load to the input
- E_t = the transmitted energy to the load

Reflection Loss

The loss that occurs due to the reflection of the signal due to impedance mismatch of the transmission line is termed as Reflection loss, which is represented as

$$Reflection\ loss\ (dB) = 10 \log_{10}\left[\frac{E_i}{E_i - E_r}\right]$$

Where

- E_i = the input energy
- E_r = the reflected energy from the load

Transmission Loss

The loss that occurs while transmission through the transmission line is termed as Transmission loss, which is represented as

$$Transmission\ loss\ (dB) = 10 \log_{10} \frac{E_i}{E_t}$$

Where

- E_i = the input energy
- E_t = the transmitted energy

Return Loss

The measure of the power reflected by the transmission line is termed as Return loss, which is represented as

$$Return\ loss\ (dB) = 10 \log_{10} \frac{E_i}{E_r}$$

Where

- E_i **=** the input energy
- E_r **=** the reflected energy

Insertion Loss

The loss that occurs due to the energy transfer using a transmission line compared to energy transfer without a transmission line is termed as Insertion loss, which is represented as

$$Insertion\ loss\ (dB) = 10 \log_{10} \frac{E_1}{E_2}$$

Where

- E_1 **=** the energy received by the load when directly connected to the source, without a transmission line.

- E_2 **=** the energy received by the load when the transmission line is connected between the load and the source.

Stub Matching

If the load impedance mismatches the source impedance, a method called "Stub Matching" is sometimes used to achieve matching.

The process of connecting the sections of open or short circuit lines called **stubs** in the shunt with the main line at some point or points, can be termed as **Stub Matching**.

At higher microwave frequencies, basically two stub matching techniques are employed.

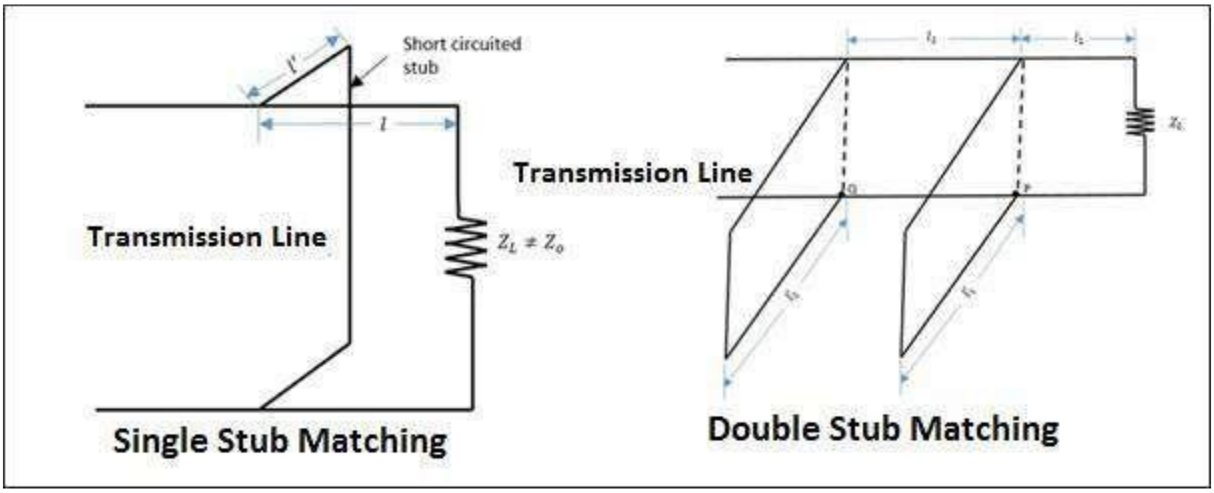
Single Stub Matching

In Single stub matching, a stub of certain fixed length is placed at some distance from the load. It is used only for a fixed frequency, because for any change in frequency, the location of the stub has to be changed, which is not done. This method is not suitable for coaxial lines.

Double Stub Matching

In double stud matching, two stubs of variable length are fixed at certain positions. As the load changes, only the lengths of the stubs are adjusted to achieve matching. This is widely used in laboratory practice as a single frequency matching device.

The following figures show how the stub matchings look.



The single stub matching and double stub matching, as shown in the above figures, are done in the transmission lines to achieve impedance matching.

UNIT-3

TELEVISION ENGINEERING

ASPECT RATIO:

The ratio between width to height of rectangle picture frame adopted in TV system is known as aspect ratio.

$$\text{Aspect ratio} = \text{Width} / \text{height} = 4/3 \text{ or } 4:3$$

Reasons for having this ratio is

1. Most of the objects are moving only in horizontal plane.

2. Our eye can see the movement of object comfortably only in horizontal plane than in vertical plane.

3. The frame size of motion picture already existing is having the aspect ratio of 4 : 3

FLICKER:

The sensation produced by incident light on the nerves of the eyes retina does not cease immediately. It persists for about 1/25th of a second (.062 Sec.) This storage characteristic is called as persistence of vision of eye.

Flicker means if the scanning rate of picture is low, the time taken to move one frame to another frame will be high. This results in alternate bright and dark picture in the screen. This is called "Flicker".
To avoid flicker, the scanning rate of the picture should be increased i.e. 50 frames/Sec

HORIZONTAL AND VERTICAL RESOLUTION :

The ability of the image reproducing system to resolve the fine details of the picture distinctly in both horizontal and vertical direction is called as "resolution".

- **VERTICAL RESOLUTION:** The ability to resolve and reproduce fine details of picture in vertical direction iscalled as Vertical resolution.

Vertical resolution (VR) = No. of active lines * Kell factor or resolution factor

- **HORIZONTAL RESOLUTION :**

__The ability of the system to resolve maximum number of picture elements along the scanning determines the horizontal resolution

Horizontal resolution = VR * Aspect ratio

VIDEO BANDWIDTH :

$$\text{Video Bandwidth signal} = \frac{\text{One horizontal line}}{\text{One horizontal line tracing}}$$

$$= \frac{267}{52 * 10^{-6}} = 5 \text{ MHz}$$

$$\text{Video Bandwidth} = \frac{\text{Horizontal Resolution}}{2 * \text{One Horizontal line scan}} = \frac{534}{2 * 52 * 10^{-6}} = 5 \text{ MHz}$$

SCANNING:

Scanning is the process used to convert the optical into electrical signal. Fastest movement of electron beam on the image is called scanning.

INTERLACED SCANNING:

To reduce flicker, the vertical scanning is done 50 times per second in TV system. However only 25 frames are scanned per sec.

In interlaced scanning the 625 lines are grouped into two fields. They are called as even field and odd field. Each field contains 312.5 lines. Even field contains even numbered lines and odd field contains odd numbered lines. During first scanning line numbers 1, 3, 5 are scanned. During next scan, line numbers 2, 4, 6.... are scanned. That is alternate lines are scanned every time. So to cover each frame, scanning is done two times. Here the vertical rate of scanning is increased twice. So it will reduce flicker.

Interlaced scanning is shown. Now the vertical frequency is 50 Hz. But there is no change in horizontal frequency.

Horizontal frequency = Number of lines in a Frame * Number of frames/sec

= 312.5 * 50 = 15,625 Hz

COMPOSITE VIDEO SIGNAL (CVS):

CVS consists of,

- Camera signal corresponding to the picture to be transmitted.
- Blanking pulses to made the retrace invisible.
- Sync pulse to synchronize the transmitter and receiver.

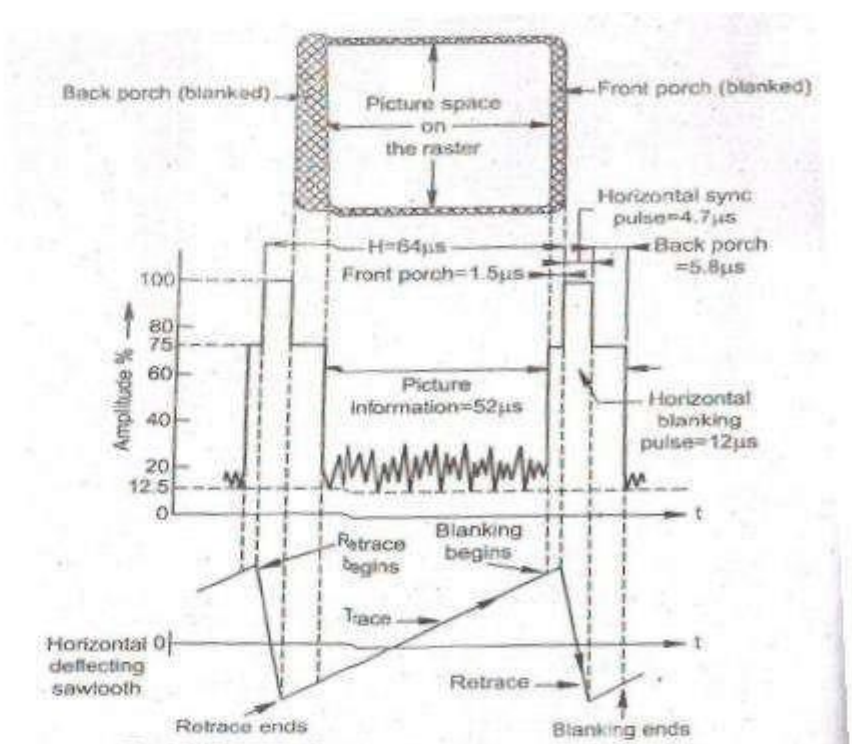
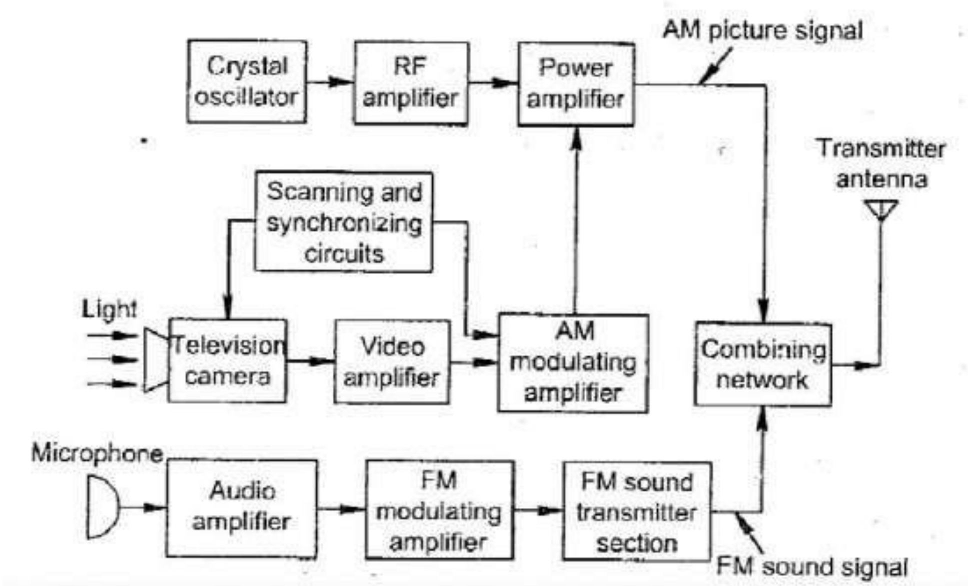


Fig.1.11 Composite video signal for one horizontal line

TV Transmitter – Block diagram & function of each block

Television means Tele + Vision, i.e., Television is used to see the picture telecast from long distance. In TV transmission both picture and sound are transmitted. For picture AM Modulation is used and for sound FM modulation is used.

The simplified block diagram of a Monochrome TV Transmitter is shown.



It consists of Television Camera, Video amplifier, AM Modulating amplifier, Audio amplifier, FM Modulating amplifier, FM sound transmitter, Crystal oscillator, RF amplifier, Power amplifier, Scanning and Synchronizing Circuits, Combining network, Transmitting antenna and Microphone

TELEVISION CAMERA:
Its function is to convert optical image of television scene into electrical signal by the scanning process.

- **VIDEO AMPLIFIER:**

Video amplifier amplifies the video signal.

- **AM MODULATING AMPLIFIER**

The video signals are amplified by the modulating amplifier to get the modulated signal.

- **AUDIO AMPLIFIER**

Audio amplifier amplifies the electrical form of audio signal from the microphone.

- **FM MODULATING AMPLIFIER:**

Sound signal from audio amplifier is frequency modulated by FM Modulating amplifier.

FM SOUND TRANSMITTER:
FM modulated amplified signal is transmitted through this FM sound transmitter to transmitting antenna through the combining network.

- **CRYSTAL OSCILLATOR:**

Crystal Oscillator generates the allotted picture carrier frequency.

- **RF AMPLIFIER**:

RF amplifier amplifies the picture carrier frequency generated by crystal oscillator to required level.

- **POWER AMPLIFIER:**

Power amplifier varies according to the modulating signal from AM modulating amplifier.

SCANNING AND SYNCHRONIZING CIRCUITS
Scanning is the process where picture elements are converted into corresponding varying electrical signal

COMBINING NETWORK

Combining network is used to isolate the AM picture and FM sound signal during transmission.

TRANSMITTING ANTENNA:

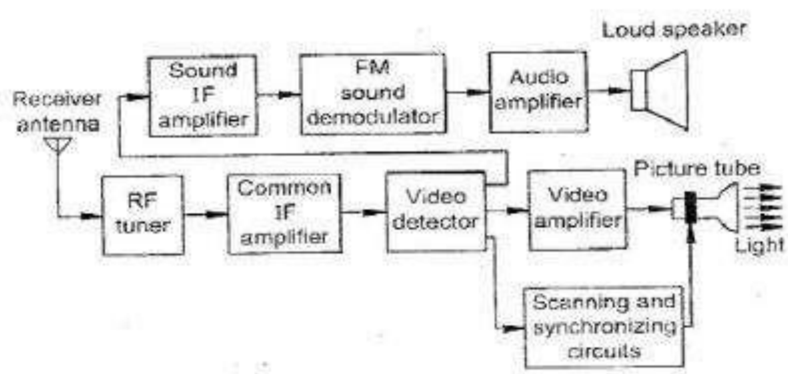
Transmitting antenna receives the AM picture signal and FM sound signal from combining network for radiation as electromagnetic waves.

MICROPHONE:

Converts sound associated with picture being televised into proportionate electrical signal

Monochrome TV Receiver -Block diagram & function of each block.

RECEPTION BASIC MONOCHROME TV



RECEIVER

Block diagram of a monochrome TV receiver is shown. It consists of RF Tuner, Receiver antenna, common IF amplifier, video detector, video amplifier, scanning and synchronizing circuits, sound IF amplifier, FM Sound demodulator, Audio amplifier, Loud Speaker, Picture tube. **RF TUNER:**

RF Tuner selects the desired channel frequency band from the receiving antenna.

RECEIVER ANTENNA:

Receiver antenna intercepts the radiated RF signals and sends it to RF Tuner.

COMMON IF AMPLIFIER:

There are 2 or 3 stages of IF amplifiers.

VIDEO DETECTOR:

Used to detect video signals coming from last stage of IF amplifiers.

VIDEO AMPLIFIER:

It amplifies the detected video signal to the level required.

SCANNING AND SYNCHRONIZING CIRCUITS:

Scanning is the process where picture elements are converted into corresponding varying electrical signals.

SOUND IF AMPLIFIER:

Detected audio signal is separated and selected for its IF range and amplified.

FM SOUND DEMODULATOR:

FM Sound signal is demodulated in this stage.

AUDIO AMPLIFIER:

FM demodulated audio signal is amplified to the required level to feed into the loud speaker.

LOUD SPEAKER:

Loud Speaker converts FM demodulated amplifier signal associated with picture being televised into proportionate sound signal.

PICTURE TUBE:

In picture tube the amplified video signal is converted back into picture elements.

SCANNING:

Scanning is the process used to convert the optical into electrical signal. Fastest movement of electron beam on the image is called scanning

NEED FOR SYNCHRONIZATION:

At any time the same co-ordinate will be scanned by the electron beam in both the camera tube and picture tube. Otherwise distorted picture will be seen on the screen. So synchronization between the transmitter and receiver is needed. For that we are using Sync pulses.

At the receiver side these pulses are identified, separated and used for triggering the oscillator circuit.

Horizontal Sync pulse time period = 4.7 μSec.

Horizontal Sync pulse Frequency =15,625 Hz. Vertical Sync pulse time period = 160 μSec. Vertical Sync pulse frequency = 50 Hz.

Color TV signals (Luminance Signal & Chrominance Signal) :

COLOUR TV FUNDAMENTALS:

In system we are sending only the luminance information. But in color system we have to send information about the colors also. All color TV system are based on the principle of our eye. Here wavelength unit is Arm strong. Visible spectrum – 4000 A^o to 7000 A^o.

1A^o = 10-10m 1nm = 10A^o

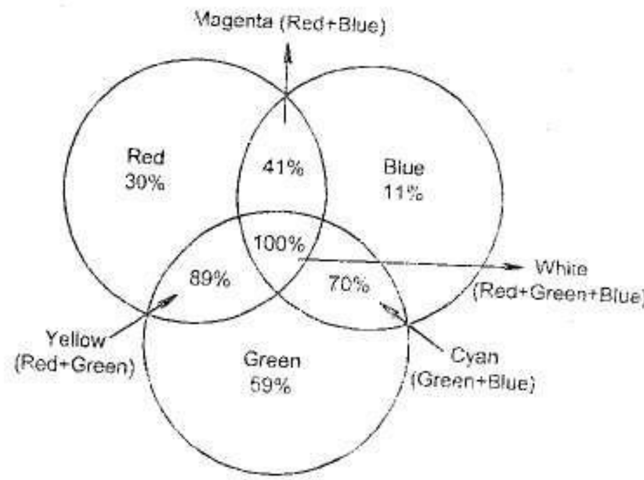
The three basic colors are called as primary colors. They are Red, Green and Blue. To get different color shading we have to mix primary colors. We have two types of mixing

1. Additive Mixing
2. Subtractive Mixing.

ADDITIVE MIXING:

In this method two or three primary colors are mixed together to form a new color. By mixing primary colors with different intensities we can obtain all types of colors.

Fig shows the method of additive mixing. By mixing 30% Red, 59% Green and 11% blue we can get white color



Y = 0% + 59%9+11%B

Red + Blue = Magenta (41%).

Blue + Green = Cyan (70%)

Red + Green = yellow (89%)

COMPLEMENTARY COLOUR:

Color obtained by mixing only two primary colors is called as complementary colors. Primary	Complementary
Red + Green	= Yellow
Red + Blue	= Magenta
Blue + Green	= Cyan

SUBTRACTIVE MIXING. :

In Subtractive mixing, the reflecting properties of color pigments are used. A color pigment can absorb all the color wavelength except its characteristic color wavelength. Its characteristic color frequency alone is reflected. If we are mixing two or three color pigments, then a color wavelength common to them only reflected. This method of mixing is generally used in color printing and color painting. By mixing primary colors, black color is got.

Different colors are obtained by subtracting primary and secondary colors from white. So this is called as subtractive mixing.

LUMINANCE, HUE AND SATURATION:

All the colors are having the following three characteristics. 1. Hue, 2. Saturation, 3.Luminance.

• **LUMINANCE**:

It is the amount of light intensity as perceived by the eye regardless of the color. It is also called as brightness signal, y signal, and white signal. • **HUE (TINT)**

It is the predominant spectral color. For example, green leaf has a green hue and red apple has red hue.

• **SATURATION:**

It will indicate the spectral purify of color. i.e., it will indicate how much white mixed with a particular color.

CHROMINANCE:

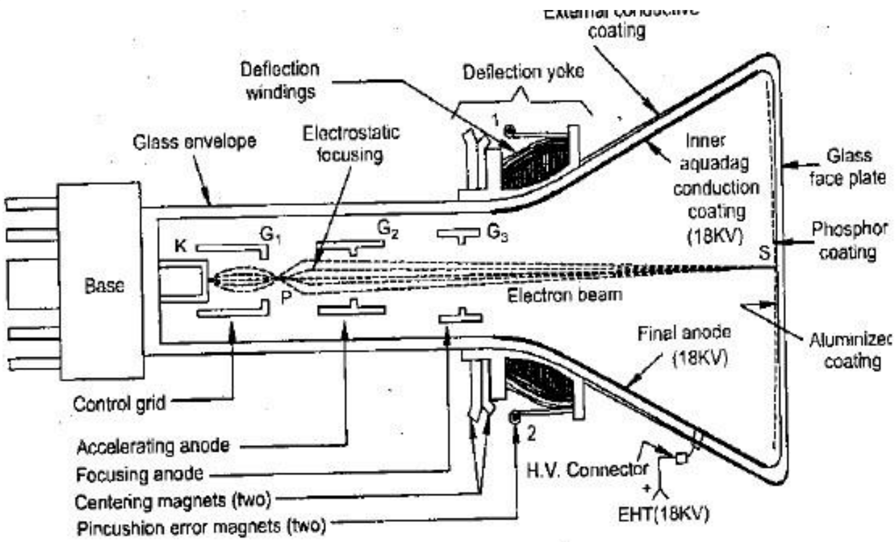
Hue and Saturation together are called as chrominance or chroma signal.

FORMATION OF CHROMINANCE SIGNAL IN PAL SYSTEM WITH WEIGHTING FACTOR:

PAL system u or v signals.
U = .44 B - .29G .15 R
V = .61R - .52G - .1B Es: Yellow color, y = R + G U = -.29 +(-.15)
= -.44
V = .61 + (-.52)= .09
Yellow color chrominace signal
C = √u2 + v2
= √(-.44)2 + (.09)2
C = ± .44
Yellow color y signal value,
y = R +G
= .3 + .59 = .89

Types of Televisions by Technology-

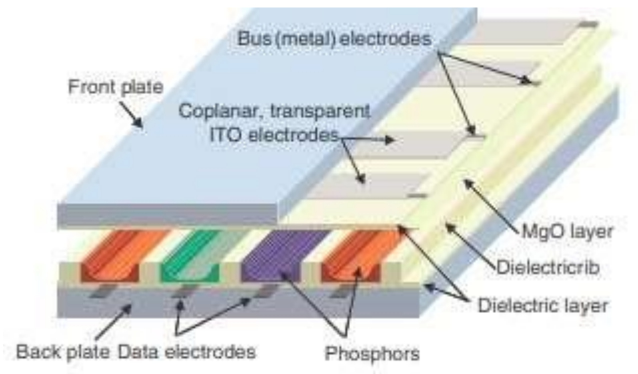
cathode-ray tube TVs



Mainparts :

- Electron gun
- Focusing anode
- Deflection Coils
- Final anode.
- Phosphor screen

Plasma Display Panels:



LIQUID CRYSTAL DISLAY:

What's Liquid Crystals (LC) Intermediary substance between a liquid and solid state of matter. e.g.

soapy water light passes through liquid crystal changes when it is stimulated by an electrical charge.

Introduction to Liquid Crystal Displays

Consists of an array of tiny segments (called pixels) that can be manipulated to present information.

Using polarization of lights to display objects.

Use only ambient light to illuminate the display.

CommonwristwatchandpocketcalculatortoanadvancedVGAcomputerscreen

Different types of LCDs

Passive Twisted Nematic Displays(TNLCD)

Super Twisted nematic LCD (STNLCD)

Thin Film Transistor LCD (TFT LCD)

Reflective LCD

Rear Projection LCD

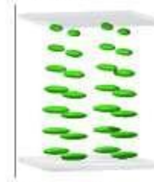
Operating Principle

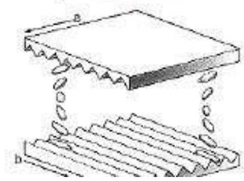
- The parallel arrangement of liquid crystal molecules along grooves
- When coming into contact with grooved surface in a fixed direction, liquid crystal molecules line up parallel along the **grooves**.

Molecules movement

Offline (no voltage is applied)

- Along the upper plate : Point in direction 'a'
- Along the lower plate : Point in direction 'b'
- Forcing the liquid crystals into a twisted structural arrangement. (Resultant force)



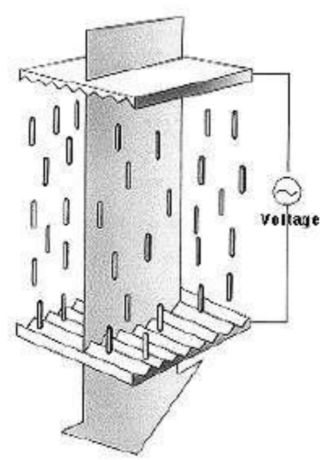


Operating Principle

Molecules movement

Online (voltage is applied)

- Liquid crystal molecules straighten out of their helix pattern
- Molecules rearrange themselves vertically (Along with the electric field)
- No twisting thoughout the movement
- Forcing the liquid crystals into a straight structural arrangement. (Electric force)



Organic Light-Emitting Diode (OLED) Display :

An organic light-emitting diode (OLED) is a light-emitting diode (LED), in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. OLED's are used to create digital displays in devices such as television screens, computer, portable systems such as mobile phones, handheld game consoles and PDAs. A major area of research is the development of white OLED devices for use in solid-state lighting applications. OLED display devices use organic carbon-based films, sandwiched together between two charged electrodes. One is a metallic cathode and the other a transparent anode, which is usually glass. OLED displays can use either passivematrix (PMOLED) or active matrix (AMOLED) addressing schemes. Active-matrix OLEDs (AMOLED) require a thin film transistor backplane to switch each individual pixel on or off, but allow for higher resolution and larger display sizes. An OLED display works without a backlight; thus, it can display deep black levels and can be thinner and lighter than a liquid crystal display (LCD). In low ambient light conditions (such as a dark room), an OLED screen can achieve a higher contrast ratio than an LCD, regardless of whether the LCD uses cold cathode fluorescent lamps or an LED backlight. **Construction** : A typical OLED is composed of a layer of organic materials situated between two electrodes, the anode and cathode, all deposited on a substrate. The organic molecules are electrically conductive as a result of delocalization of pi electrons caused by conjugation over part or the entire molecule. These materials have conductivity levels ranging from insulators to conductors, and are therefore considered organic semiconductors. The highest occupied and lowest unoccupied molecular orbitals (HOMO and LUMO) of organic semiconductors are analogous to the valence and conduction bands of inorganic semiconductors.

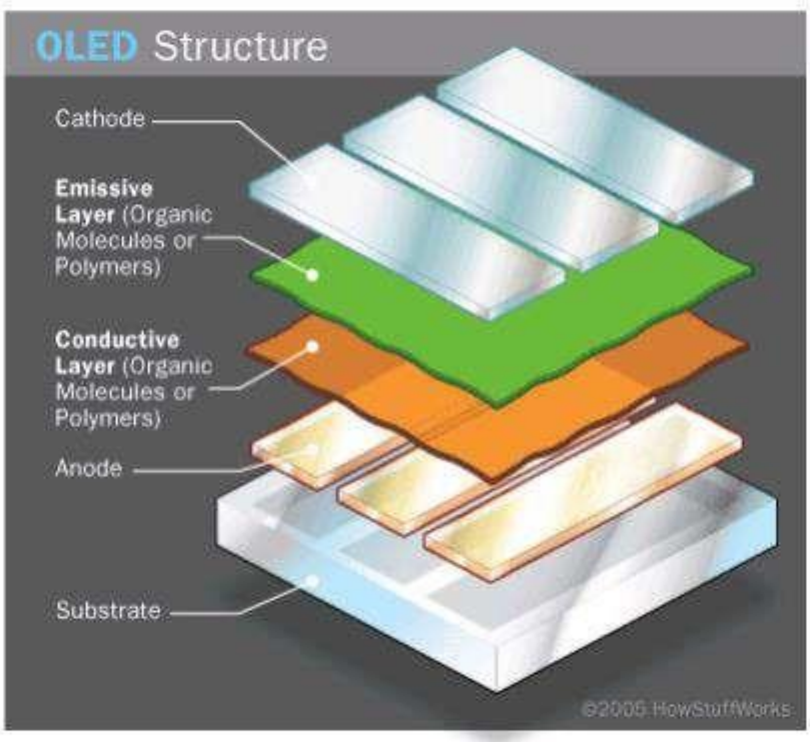
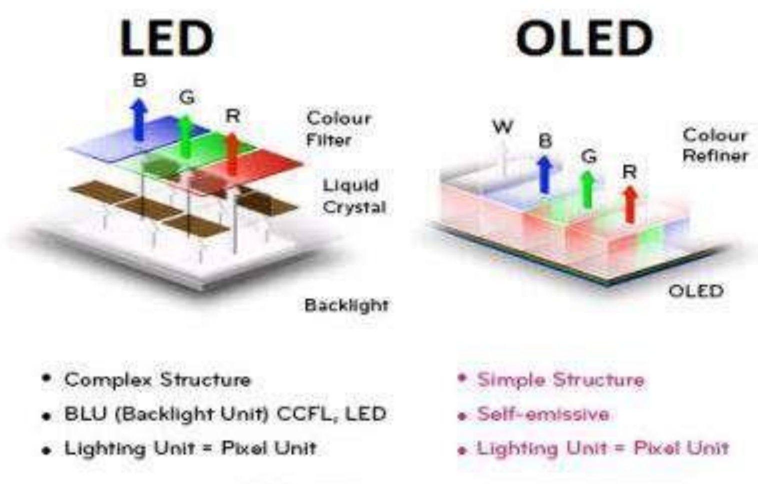


Figure 1: Basic OLED structure

Comparison Between LED and OLED: Although OLED name has been heard much more recently, it is not a new terminology in the technology world. In the beginning of 2000s, we used them in mobile phone screens. However LED took place much more in daily life afterwards. Technically, OLEDs emit light but LEDs diffuse or reflect and this seems the main difference between these two light sources. What is LED? : Light-emitting diode is one of the widely used and known light sources these days. But its history is about a solid state device that makes light with the help of electrons through a semi-conductor. Also this type is smaller than some other sources such as compact fluorescent and incandescent light bulbs. However it provides higher brightness than its rivals. Although it has some advantages in this area, it is not enough to be used as a pixel of the television just because of its size. Therefore it became popular in lighting industry. What is OLED? : Organic light-emitting diode includes some organic compounds that light when electricity supplied. There is not much difference about architecture between LED and OLED but being thin, small and flexible are the main advantages of OLEDs. Also each pixel on OLED televisions works individually. As can be seen from the definitions of LED and OLED, they have some differences and these strongly affect the quality of the end product. For instance, backlight is used to illuminate their pixels in LED but pixels produce their own light in OLED. OLED's pixels called emissive. Therefore OLEDs provide the flexibility of brightness control through pixel by pixel changes. Tests of a LED display in dark conditions show that parts of an image are not perfectly black because backlight is showed through. The great advantage for LEDs looks about economy since its production costs are much cheaper. However after OLED market is developed, it is predicted that the difference will be made up. Production of an OLED is easier and it is possible to produce it in larger sizes. Its content plays the main role for this because plastic is a suitable material for this but it is harder to do it with liquid crystals.



Quantum Light-Emitting Diode (QLED):

Quantum dot light-emitting diode (QLED) attracted much attention for the next generation of display due to its advantages in high color saturation, tunable color emission, and high stability. Compared with traditional LED display, QLED display has advantages in flexible and robust application, which makes wearable and stretchable display possible in the future. In addition, QLED display is a self-emissive display, in which light is generated by individual sub pixel, each sub pixel can be individually controlled.

Each sub pixel in LED display is constituted by liquid crystal and color filter, which make LED display have lower power efficiency and less enhanced functionality. This chapter introduces the QLED based on the QLED structure and light-emitting mechanism of QLED. Then, a novel method for fabricating QLEDs, which is based on the ZnO nano particles (NPs) incorporated into QD nano particles, will be introduced. The QLED device was fabricated by all-solution processes, which make the QLED fabrication process more flexible and more suitable for industrialization. What is more, as QLED devices were planned to integrate into a display, all-solution fabrication processes also make printing QLED display device possible in the near future.

Light emission mechanism of QLED The emission mechanism of QLED is discussed in this subsection. A QLED has a similar structure and behavior as an OLED. In the QLED, the emitter is a semiconductor nano particle, while in the OLED, the emitter is an organic material.

CATV systems & Types & networks :

Cable television is a technical system for distribution of television by cable (coaxial, twisted pair or fiber optic) with potential for largest bandwidth and integrated return channel for interactive services. With the introduction of new technology, the CATV networks will have more active components than at present. Access of an end-user to services in the CATV network is realised by the help of access network. Access network must be enhanced to carry various multimedia services. There are several options to introduce fiber in the access network, to the cabinet/curb FTTCa/C with a last copper drop based on very high rate DSL on one hand and fibre to the building/fibre to the home FTTB/H on the other. FTTCa/FFTC avoids the installation cost of fibre to the costumer premises, but introduces a high exploitation cost, since network operator personnel will have to travel to the cabinet or curb unit for every alteration or maintenance action. Moreover, the process by which the operator becomes entitled to site a cabinet or curb unit in suitable position is complex, and powering will require a large investment. Because of these reasons it is assumed here that network operators will make the strategic choice of introducing fibre directly to the costumer premises with FTTB/H. Residential broadband access network technology based on Asynchronous Transfer Mode (ATM) will soon reach commercial availability. The capabilities provided by ATM access network promise integrated services bandwidth available in excess of those provided by traditional networks. Other services such as desktop video teleconferencing and enhanced server-based application support can be added as part of future evolution of the network.

THE STRUCTURE OF THE INTERACTIVE NETWORK:

At present, the great importance of CATV is in the best transferring of information, mainly in association with satellite transmission of TV and R signals. It indicates that possibilities of CATV are much bigger and they reach to other spheres. Therefore, it is necessary to come nearer CATV from another point of view. This point of vie is the information approach, and new conception of CATV doesn’t deal with system, which transfers the TV and R signals, but with the system transferring whatever information to arbitrary direction. By this new approach, primary sense of CATV fades and the network becomes the universal data network, where it is possible to create and realise almost arbitrary services. In interactive CATV, there are three levels, similarly as in distribution network. Tree structure is shown in figure 1:

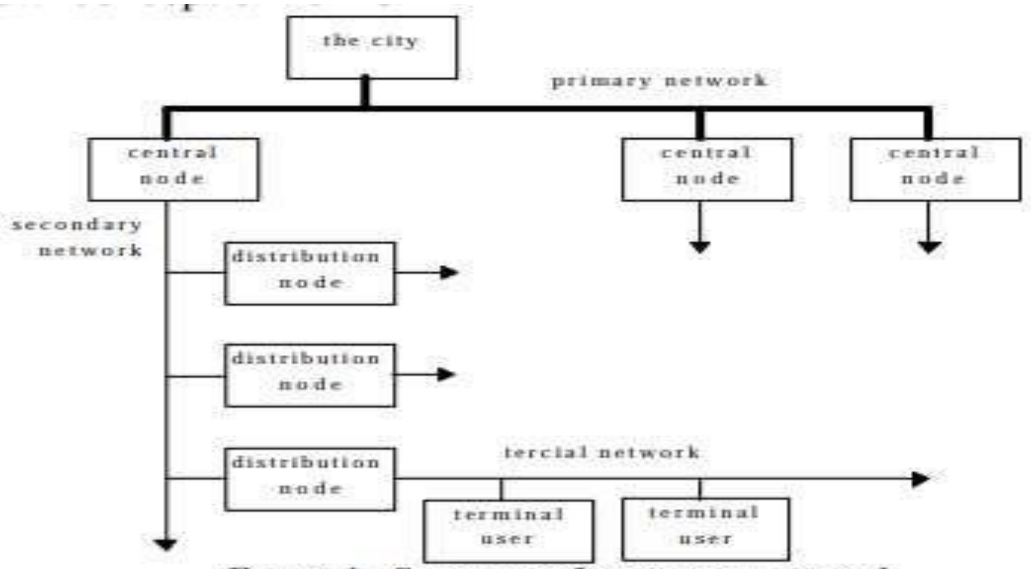


Figure 1 - Structure of interactive network

In a city or another larger region, there is a set of mutually connected central nodes, which create the primary network. Each of them serves respective part of the city e.g. and habitation, a street or likewise. Interactive CATVs can be independent networks, which exist simultaneously with other ones. But, it is economically better and efficiently when the primary network of CATV is an access network of certain great national network (WAN, MAN, B-ISDN etc...). Communication in the primary network must be enough wideband and of larger distance than in primary network of distribution CATV. Therefore, there is directly offered using of optical fibres with standard transfer rates here, e.g. 155Mb/s, 622Mb/s or much.

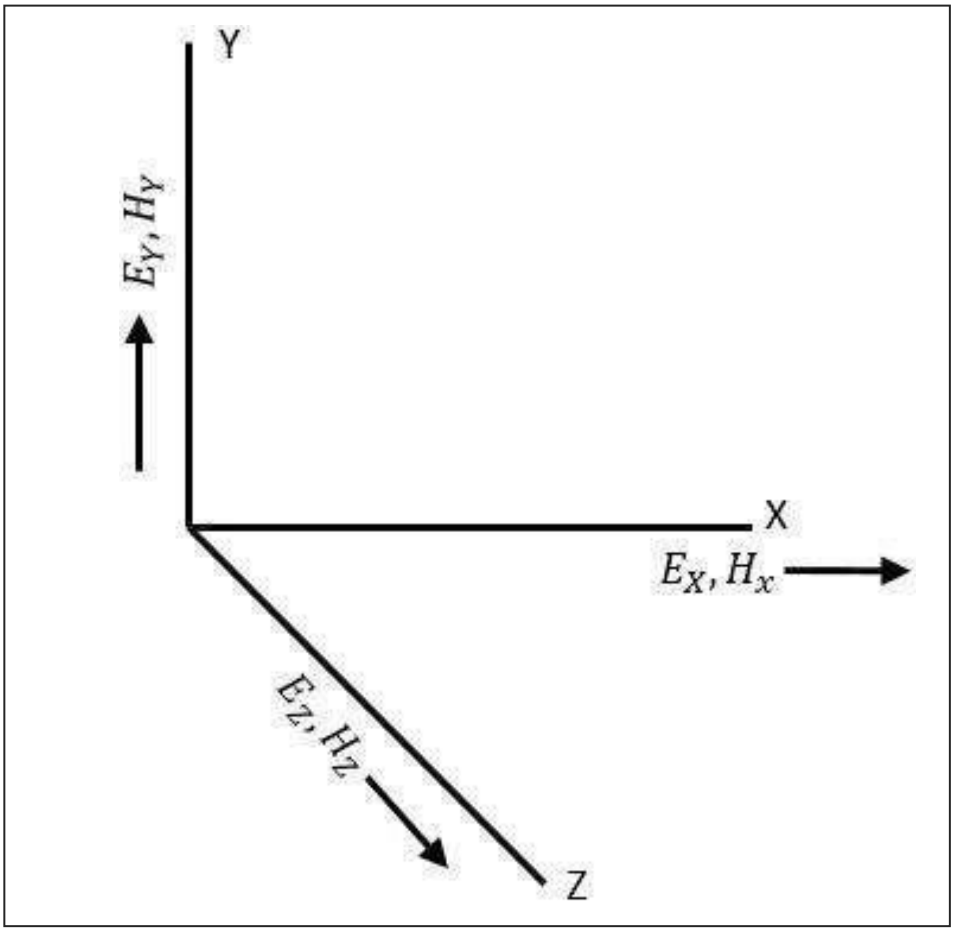
2. The central node is connected to set of distribution nodes and so it is created the secondary network in star form. Each of distribution nodes covers set of flats or offices in small area, e.g. in multi-storey building. Wideband connection through optical fibres uses standard transfer rates, e.g. 155Mb/s, 622Mb/s or much. Physical layer is the same as in primary network.

3. Distribution node creates its own tercial network in star form, which connects user's terminal devices. The transfer medium is coax cable, therefore for this subnetwork is possible use the existing lines which were created for distribution CATVs. Tercial network is possible alternative to present LAN with transfer rate 10Mb/s. One connection in tercial network contain several Ethernet channels. So, the connection of terminal user is indeed wideband.

Modes of Propagation

A wave has both electric and magnetic fields. All transverse components of electric and magnetic fields are determined from the axial components of electric and magnetic field, in the **z** direction. This allows mode formations, such as TE, TM, TEM and Hybrid in microwaves. Let us have a look at the types of modes.

The direction of the electric and the magnetic field components along three mutually perpendicular directions x, y, and z are as shown in the following figure.



Types of Modes

The modes of propagation of microwaves are -

TEM (Transverse Electromagnetic Wave)

In this mode, both the electric and magnetic fields are purely transverse to the direction of propagation. There are no components in '**Z**' direction. $E_z = 0 \ and \ H_z = 0$

TE (Transverse Electric Wave)

In this mode, the electric field is purely transverse to the direction of propagation, whereas the magnetic field is not.

$$E_z = 0 \ and \ H_z \neq 0$$

TM (Transverse Magnetic Wave)

In this mode, the magnetic field is purely transverse to the direction of propagation, whereas the electric field is not.

$$E_z \neq 0 \ and \ H_z = 0$$

HE (Hybrid Wave)

In this mode, neither the electric nor the magnetic field is purely transverse to the direction of propagation.

$$E_z \neq 0 \ and \ H_z \neq 0$$

Multi conductor lines normally support TEM mode of propagation, as the theory of transmission lines is applicable to only those system of conductors that have a go and return path, i.e., those which can support a TEM wave.

Waveguides are single conductor lines that allow TE and TM modes but not TEM mode. Open conductor guides support Hybrid waves. The types of transmission lines are discussed in the next chapter.

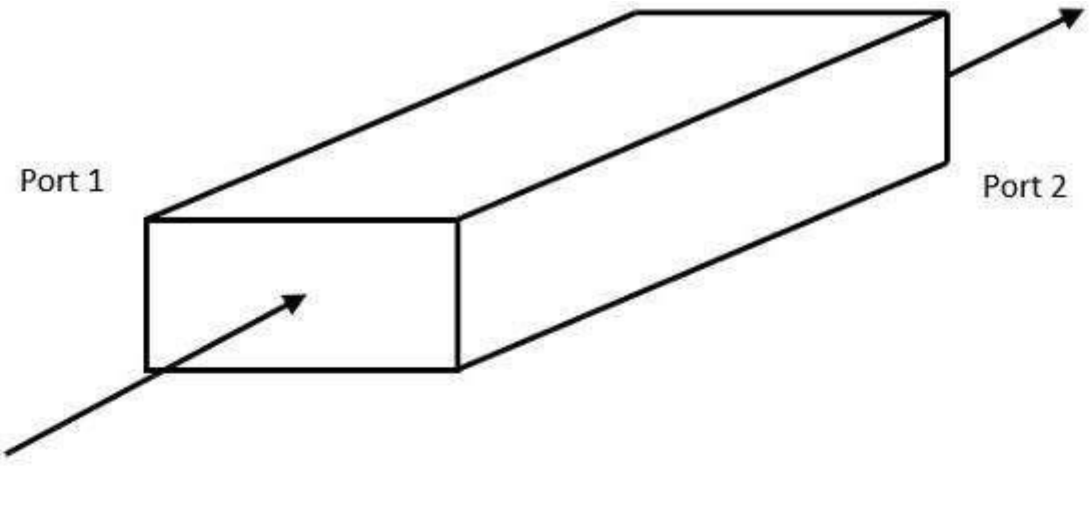
Generally, if the frequency of a signal or a particular band of signals is high, the bandwidth utilization is high as the signal provides more space for other signals to get accumulated. However, high frequency signals can't travel longer distances without getting attenuated. We have studied that transmission lines help the signals to travel longer distances.

Microwaves– Waveguides

Microwaves propagate through microwave circuits, components and devices, which act as a part of Microwave transmission lines, broadly called as Waveguides.

A hollow metallic tube of uniform cross-section for transmitting electromagnetic waves by successive reflections from the inner walls of the tube is called as a **Waveguide**.

The following figure shows an example of a waveguide.



A two-port rectangular waveguide

A waveguide is generally preferred in microwave communications. Waveguide is a special form of transmission line, which is a hollow metal tube. Unlike a transmission line, a waveguide has no center conductor.

The main characteristics of a Waveguide are -

- The tube wall provides distributed inductance.
- The empty space between the tube walls provide distributed capacitance.
- These are bulky and expensive.

Advantages of Waveguides

- Easy to manufacture
- They can handle very large power (in kilo watts).
- Power loss is very negligible in waveguides.

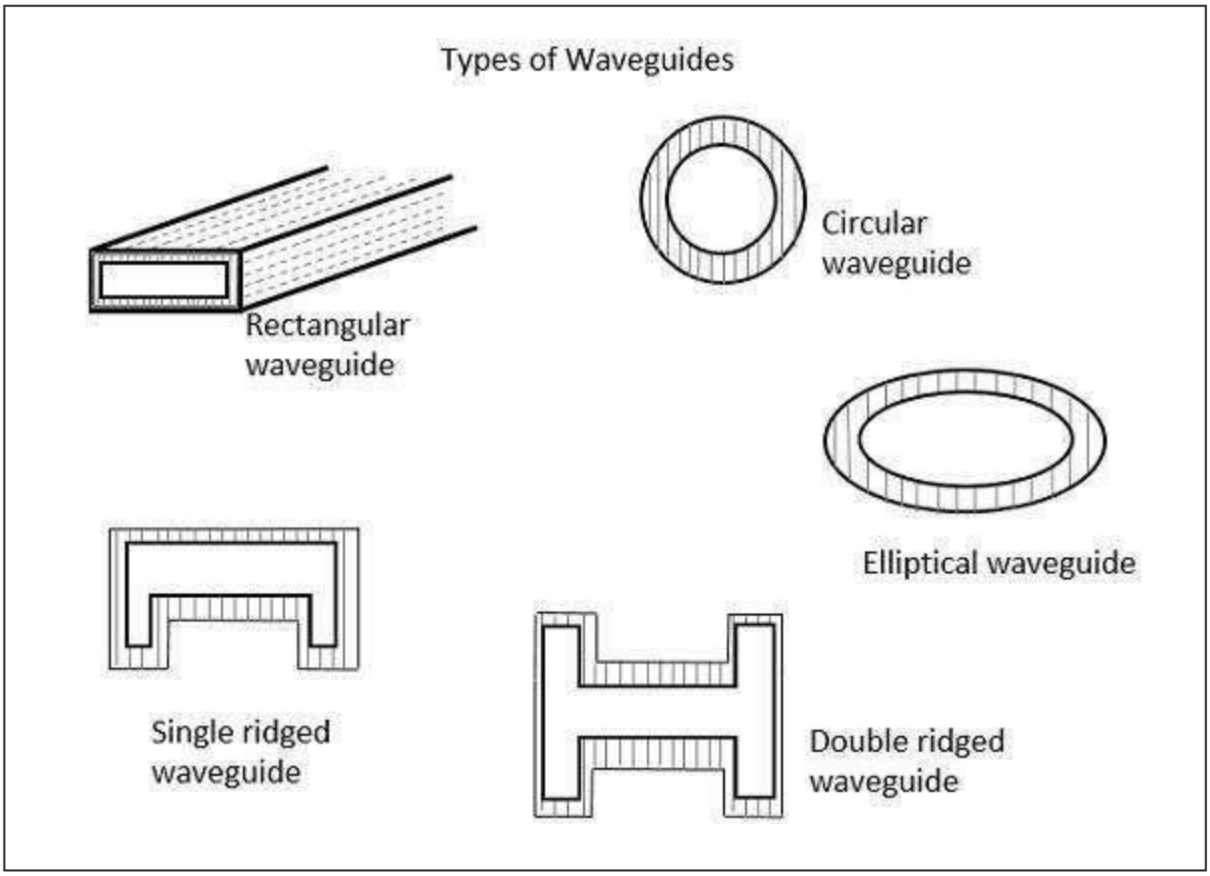
- They offer very low loss (low value of alpha-attenuation).
- When microwave energy travels through waveguide, it experiences lower losses than a coaxial cable.

Types of Waveguides

There are five types of waveguides.

- Rectangular waveguide
- Circular waveguide
- Elliptical waveguide
- Single-ridged waveguide
- Double-ridged waveguide

The following figures show the types of waveguides.



The types of waveguides shown above are hollow in the center and made up of copper walls. These have a thin lining of Au or Ag on the inner surface.

Let us now compare the transmission lines and waveguides.

Transmission Lines Vs Waveguides

The main difference between a transmission line and a wave guide is -

A **two conductor structure** that can support a TEM wave is a transmission line.

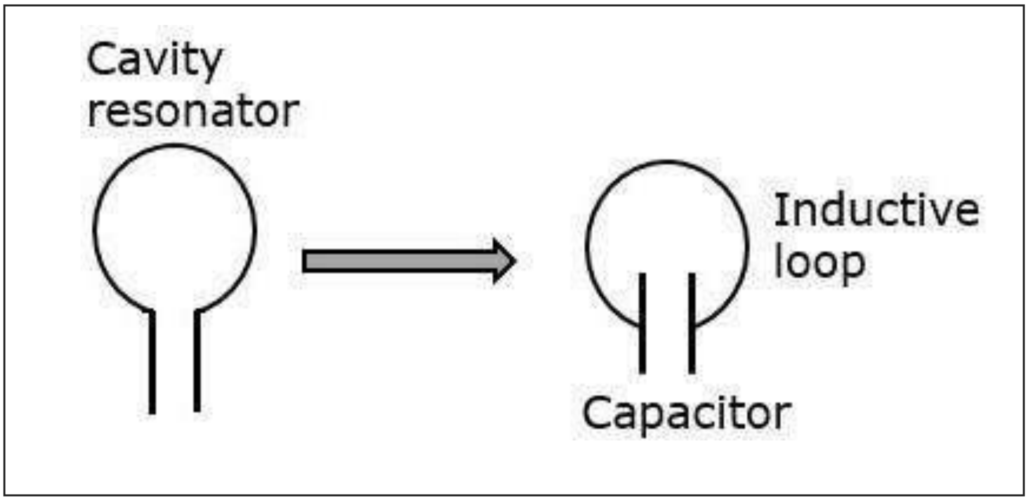
A **one conductor structure** that can support a TE wave or a TM wave but not a TEM wave is called as a waveguide.

The following table brings out the differences between transmission lines and waveguides.

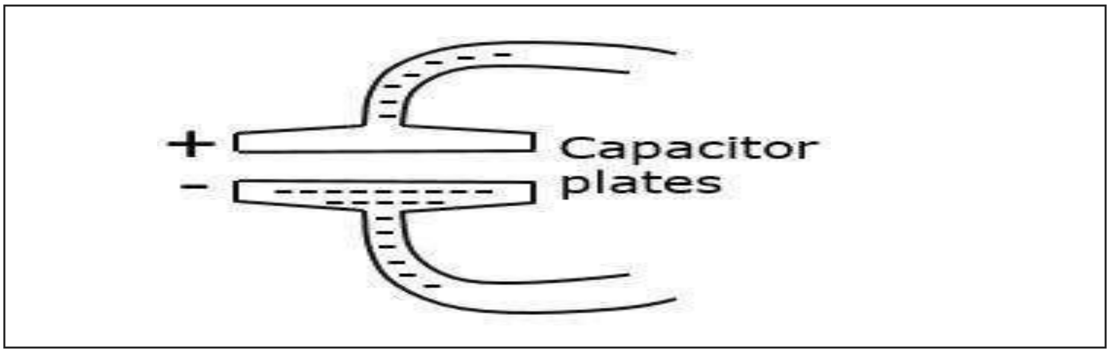
Transmission Lines	**Waveguides**
Supports TEM wave	Cannot support TEM wave
All frequencies can pass through	Only the frequencies that are greater than cut-off frequency can pass through
One conductor transmission	Two conductor transmission
Reflections are less	Wave travels through reflections from the walls of waveguide
It has characteristic impedance	It has wave impedance
Propagation of waves is according to "Circuit theory"	Propagation of waves is according to "Field theory"
It has a return conductor to earth	Return conductor is not required as the body of the waveguide acts as earth
Bandwidth is not limited	Bandwidth is limited
Waves do not disperse	Waves get dispersed

Cavity Resonator

Let us try to understand the constructional details and the working of a cavity resonator. The following figure indicates the cavity resonator.



A simple resonant circuit which consists of a capacitor and an inductive loop can be compared with this cavity resonator. A conductor has free electrons. If a charge is applied



to the capacitor to get it charged to a voltage of this polarity, many electrons are removed from the upper plate and introduced into the lower plate.

The plate that has more electron deposition will be the cathode and the plate which has lesser number of electrons becomes the anode. The following figure shows the charge deposition on the capacitor.

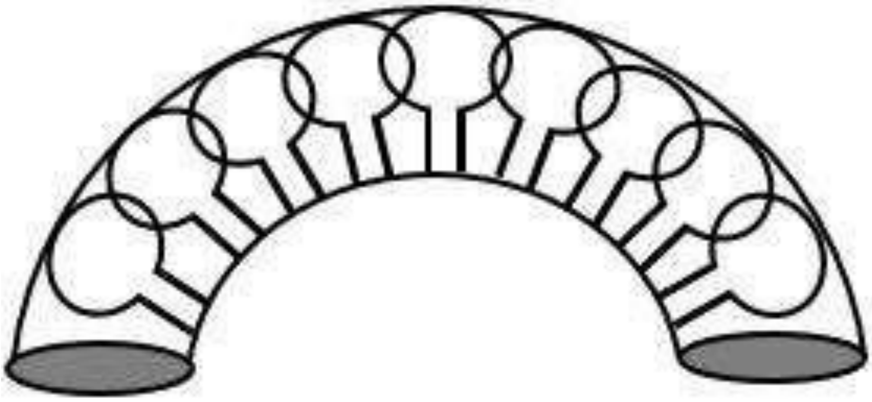
The electric field lines are directed from the positive charge towards the negative. If the capacitor is charged with reverse polarity, then the direction of the field is also reversed. The displacement of electrons in the tube, constitutes an alternating current. This alternating current gives rise to alternating magnetic field, which is out of phase with the electric field of the capacitor.

When the magnetic field is at its maximum strength, the electric field is zero and after a while, the electric field becomes maximum while the magnetic field is at zero. This exchange of strength happens for a cycle.

Closed Resonator

The smaller the value of the capacitor and the inductivity of the loop, the higher will be the oscillation or the resonant frequency. As the inductance of the loop is very small, high frequency can be obtained.

To produce higher frequency signal, the inductance can be further reduced by placing more inductive loops in parallel as shown in the following figure. This results in the formation of a closed resonator having very high frequencies.



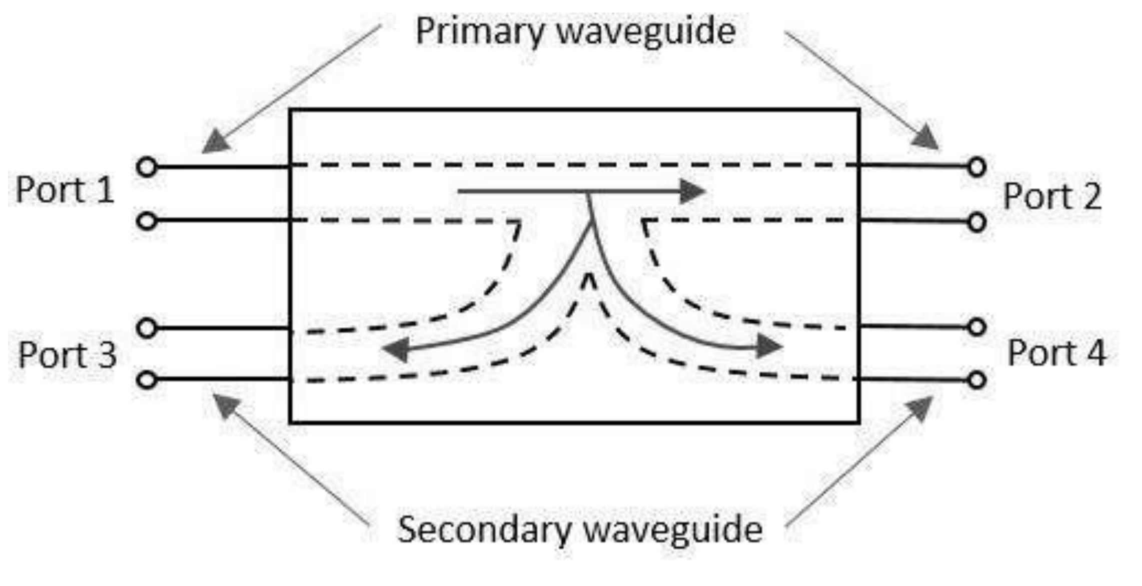
Cross-section of Cavity Resonator

In a closed resonator, the electric and magnetic fields are confined to the interior of the cavity. The first resonator of the cavity is excited by the external signal to be amplified. This signal must have a frequency at which the cavity can resonate. The current in this coaxial cable sets up a magnetic field, by which an electric field originates

Microwaves – Directional Couplers

A **Directional coupler** is a device that samples a small amount of Microwave power for measurement purposes. The power measurements include incident power, reflected power, VSWR values, etc.

Directional Coupler is a 4-port waveguide junction consisting of a primary main waveguide and a secondary auxiliary waveguide. The following figure shows the image of a directional coupler.



Directional Coupler

Directional coupler is used to couple the Microwave power which may be unidirectional or bi-directional.

Properties of Directional Couplers

The properties of an ideal directional coupler are as follows.

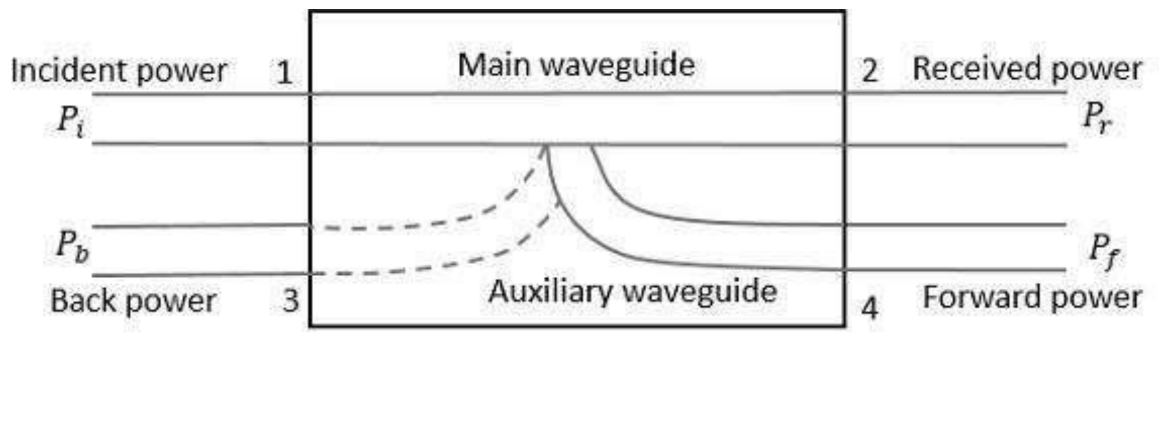
- All the terminations are matched to the ports.
- When the power travels from Port 1 to Port 2, some portion of it gets coupled to Port 4 but not to Port 3.
- As it is also a bi-directional coupler, when the power travels from Port 2 to Port 1, some portion of it gets coupled to Port 3 but not to Port 4.

- If the power is incident through Port 3, a portion of it is coupled to Port 2, but not to Port 1.

- If the power is incident through Port 4, a portion of it is coupled to Port 1, but not to Port 2.

- Port 1 and 3 are decoupled as are Port 2 and Port 4.

Ideally, the output of Port 3 should be zero. However, practically, a small amount of power called **back power** is observed at Port 3. The following figure indicates the power flow in a directional coupler.



Directional Coupler indicating powers

Where

- **P_i =** Incident power at Port 1
- **P_r =** Received power at Port 2
- **P_f =** Forward coupled power at Port 4
- **P_b =** Back power at Port 3

Following are the parameters used to define the performance of a directional coupler.

Coupling Factor (C)

The Coupling factor of a directional coupler is the ratio of incident power to the forward power, measured in dB.

$$C = 10 \log_{10} \frac{P_i}{P_f} \, dB$$

$$D = 10 \log_{10} \frac{P_f}{P_b} \, dB$$

Directivity (D)

The Directivity of a directional coupler is the ratio of forward power to the back power, measured in dB.

Isolation

It defines the directive properties of a directional coupler. It is the ratio of incident power to the back power, measured in dB.

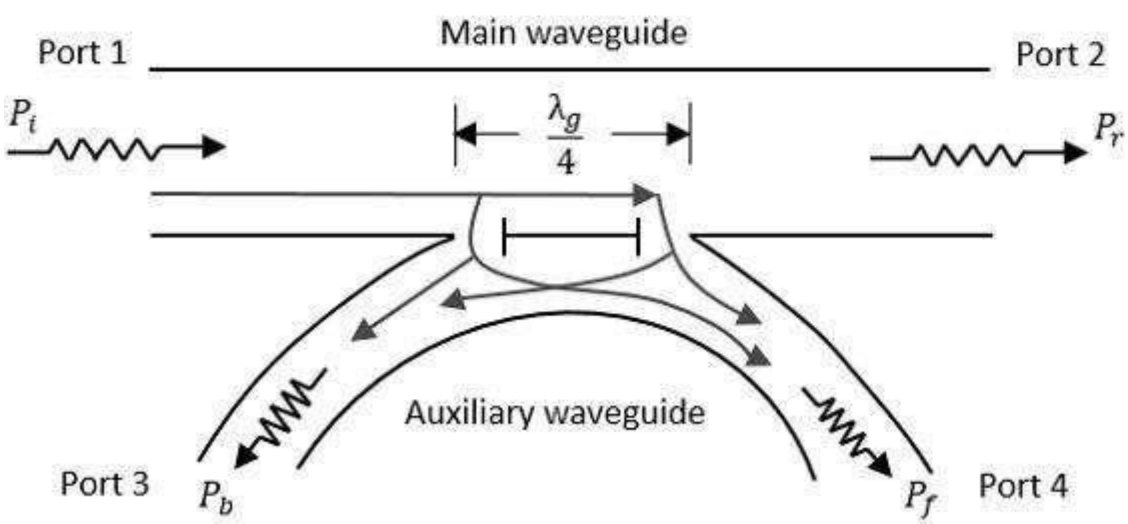
$$I = 10\log_{10}\frac{P_i}{P_b}\,dB$$

Isolation in dB = Coupling factor + Directivity

Isolation in dB = Coupling factor + Directivity

Two-Hole Directional Coupler

This is a directional coupler with same main and auxiliary waveguides, but with two small holes that are common between them. These holes are $\lambda_g/4$ distance apart where λg is the guide wavelength. The following figure shows the image of a two-hole directional coupler.



Two-hole directional coupler

A two-hole directional coupler is designed to meet the ideal requirement of directional coupler, which is to avoid back power. Some of the power while travelling between Port 1 and Port 2, escapes through the holes 1 and 2.

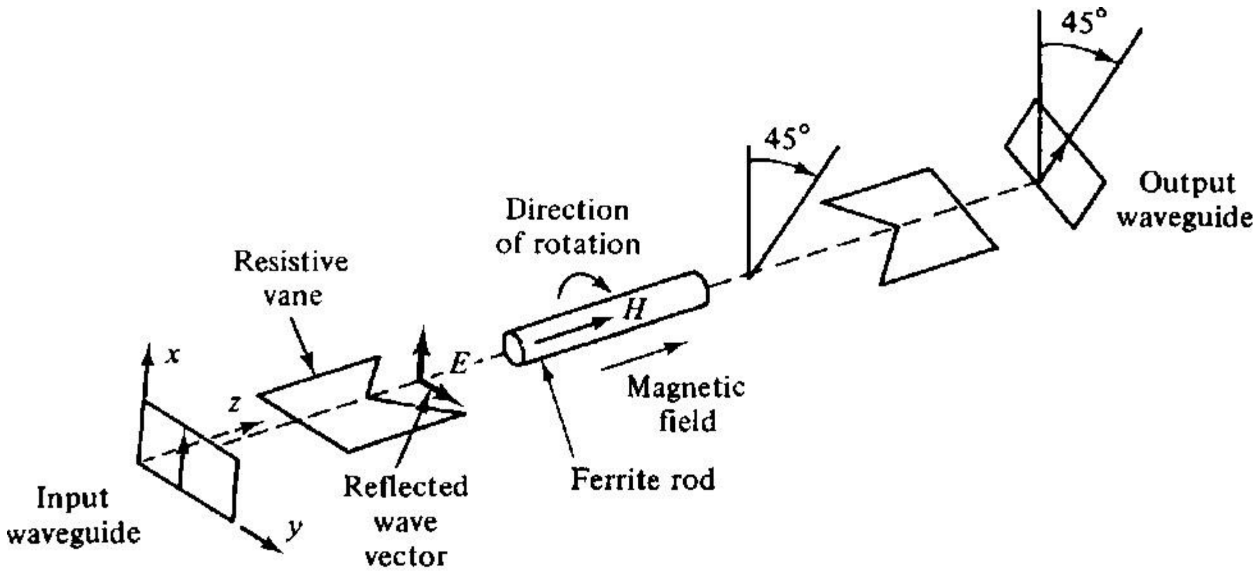
The magnitude of the power depends upon the dimensions of the holes. This leakage power at both the holes are in phase at hole 2, adding up the power contributing to the forward power $\mathbf{P_f}$. However, it is out of phase at hole 1, cancelling each other and preventing the back power to occur.

Hence, the directivity of a directional coupler improves.

MICROWAVE ISOLATORS:

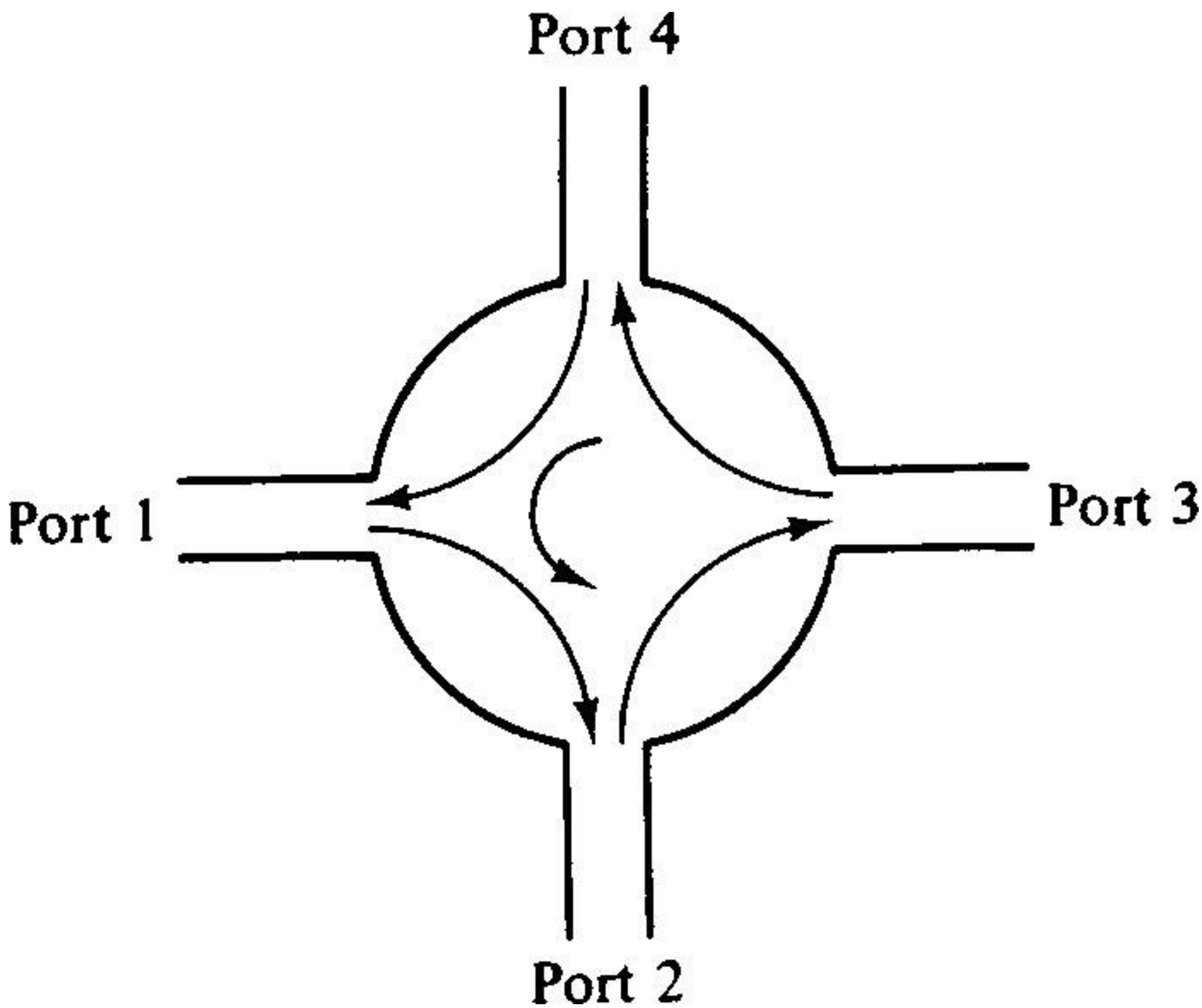
An *isolator* is a nonreciprocal transmission device that is used to isolate one component from reflections of other components in the transmission line. An ideal isolator completely absorbs the power for propagation in one direction and provides lossless transmission in the opposite direction. Thus the isolator is usually called *uniline.*

Isolators are generally used to improve the frequency stability of microwave generators, such as klystrons and magnetrons, in which the reflection from the load affects the generating frequency. In such cases, the isolator placed between the generator and load prevents the reflected power from the unmatched load from returning to the generator. As a result, the isolator maintains the frequency stability of the generator**.**



MICROWAVE CIRCULATORS:

A *microwave circulator* is a multiport waveguide junction in which the wave can flow only from the *nth* port to the *(n* + I)th port in one direction Although there is no restriction on the number of ports, the four-port microwave circulator is the most common. One type of four-port microwave circulator is a combination of two 3-dB side hole directional couplers and a rectangular waveguide with two non reciprocal phase shifters.

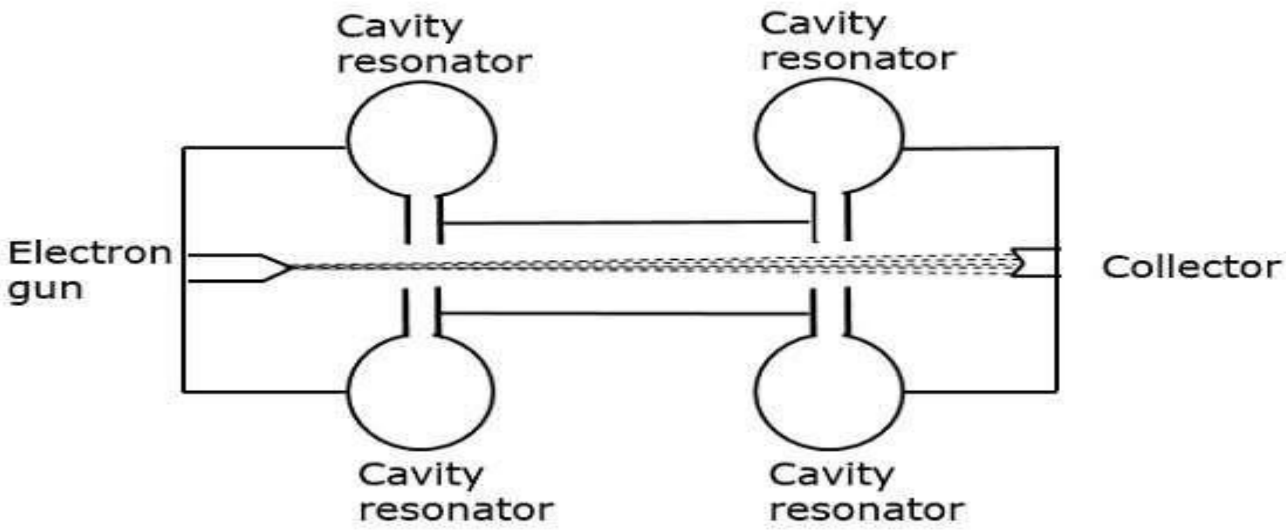


The symbol of a circulator.

Microwave tubes-Principle of operational of two Cavity Klystron

For the generation and amplification of Microwaves, there is a need of some special tubes called as **Microwave tubes**. Of them all, **Klystron** is an important one.

The essential elements of Klystron are electron beams and cavity resonators. Electron beams are produced from a source and the cavity klystrons are employed to amplify the signals. A collector is present at the end to collect the electrons. The whole set up is as shown in the following figure.



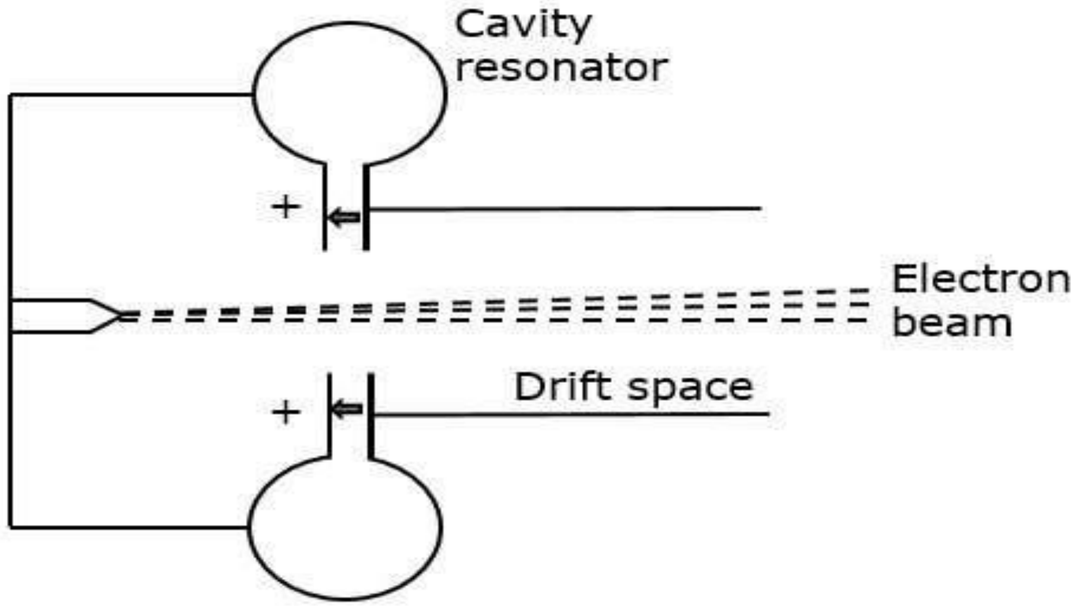
The electrons emitted by the cathode are accelerated towards the first resonator. The collector at the end is at the same potential as the resonator. Hence, usually the electrons have a constant speed in the gap between the cavity resonators.

Initially, the first cavity resonator is supplied with a weak high frequency signal, which has to be amplified. The signal will initiate an electromagnetic field inside the cavity. This signal is passed through a coaxial cable as shown in the following figure

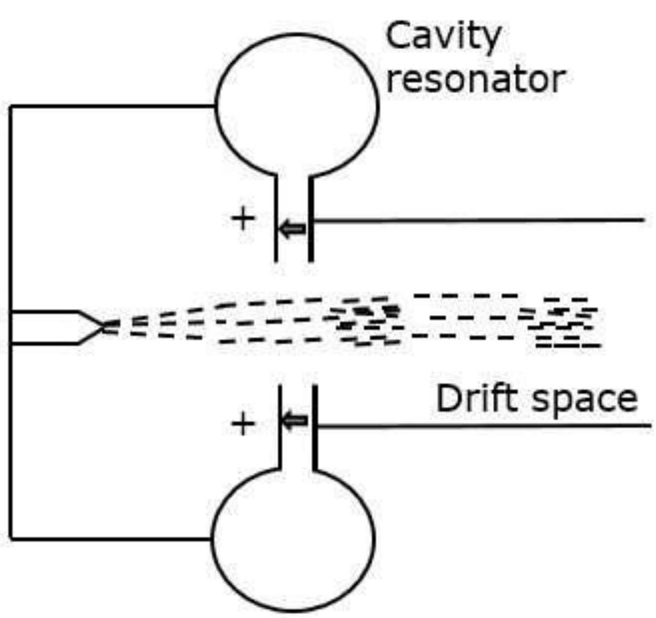
Working of Klystron

To understand the modulation of the electron beam, entering the first cavity, let’s consider the electric field. The electric field on the resonator keeps on changing its direction of the induced field. Depending on this, the electrons coming out of the electron gun, get their pace controlled.

As the electrons are negatively charged, they are accelerated if moved opposite to the direction of the electric field. Also, if the electrons move in the same direction of the electric field, they get decelerated. This electric field keeps on changing, therefore the electrons are accelerated and decelerated depending upon the change of the field. The following figure indicates the electron flow when the field is in the opposite direction.



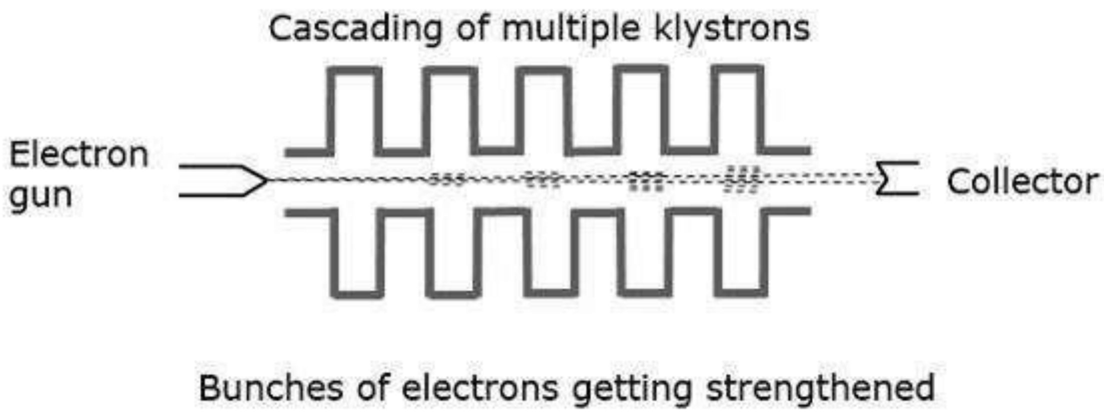
While moving, these electrons enter the field free space called as the **drift space** between the resonators with varying speeds, which create electron bunches. These bunches are created due to the variation in the speed of travel.
These bunches enter the second resonator, with a frequency corresponding to the frequency at which the first resonator oscillates. As all the cavity resonators are identical, the movement of electrons makes the second resonator to oscillate. The following figure shows the formation of electron bunches.



Formation of electron bunches

The induced magnetic field in the second resonator induces some current in the coaxial cable, initiating the output signal. The kinetic energy of the electrons in the second cavity is almost equal to the ones in the first cavity and so no energy is taken from the cavity. The electrons while passing through the second cavity, few of them are accelerated while

bunches of electrons are decelerated. Hence, all the kinetic energy is converted into electromagnetic energy to produce the output signal.
Amplification of such two-cavity Klystron is low and hence multi-cavity Klystrons are used. The following figure depicts an example of multi-cavity Klystron amplifier.



With the signal applied in the first cavity, we get weak bunches in the second cavity. These will set up a field in the third cavity, which produces more concentrated bunches and so on. Hence, the amplification is larger

Traveling wave tube (TWT)

Travelling Wave Tube Amplifier:

_ High gain > 40 dB
_ Low NF < 10 dB
_ Wide Band > Octave
Frequency range:0.3 – 50 GHz

_ Contains electron gun, RF interaction circuit, electron beam focusing magnet, collector
_ Amplify a weak RF input signal many thousands of times

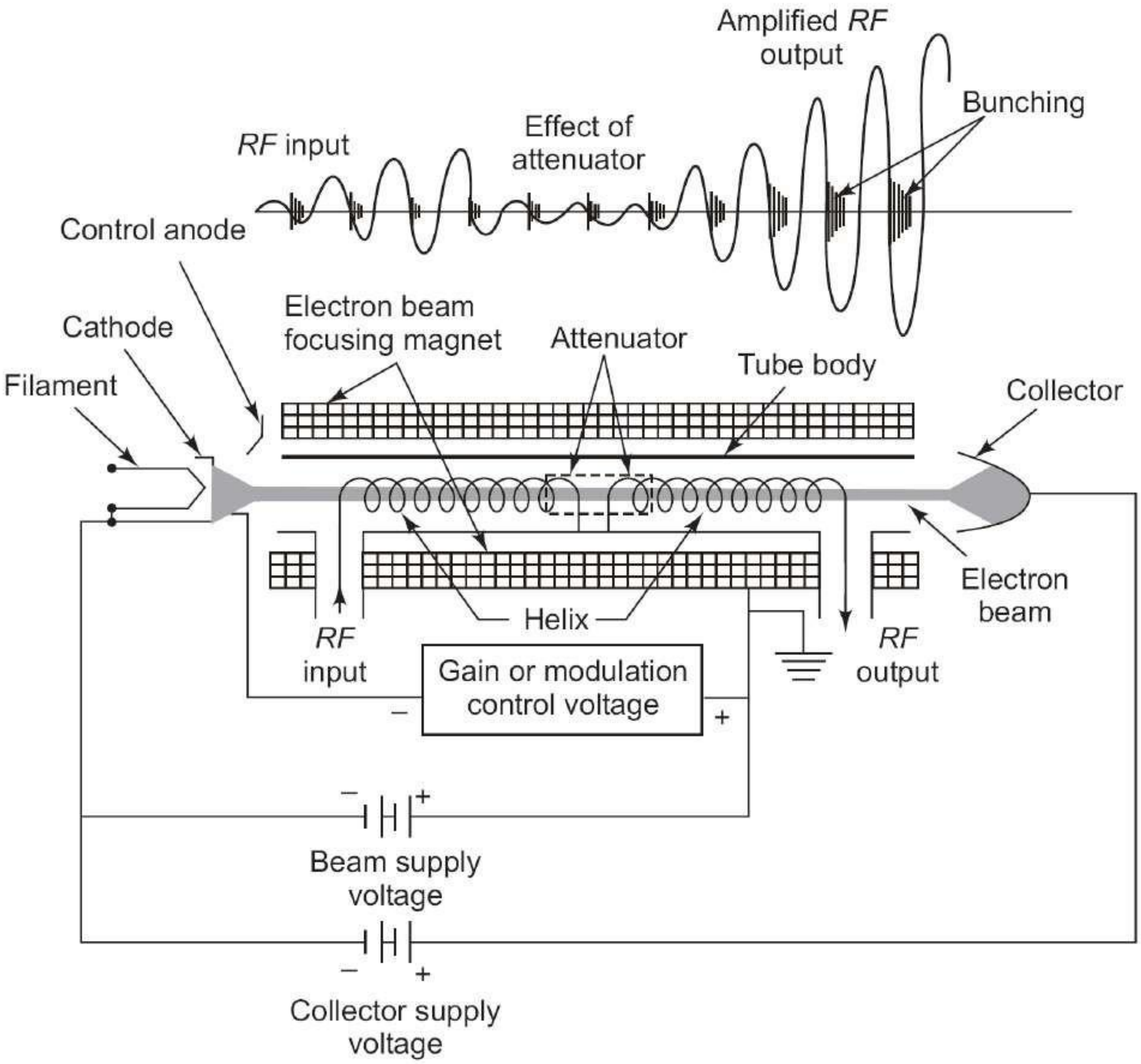


Fig. 9.18 *TWT amplifier tube and circuit*

a) Electron gun

_ To get as much electron current flowing into as small a region as possible without distortion or fuzzy edges

Sources of electrons for the beam- 6 elements:

gun shells
heater cathode
control grid
focus electrode
anode

b) **RF interaction circuit**

_ Interaction structures : helix, ring bar, ringloop, coupled cavity
_ RF circuit – complex trade off analysis, based on many interlocking parameters
_ Low power level : helix
_ Medium power level : ring loop, ring bar
_ Power level & frequency increased: RF losses on the circuit become more appreciate able. **c) Electron beam focusing**

_ A magnetic field – to hold the electron beam together as it travels through the interaction structure of the tube
_ The beam tends to disperse or spread out as a result of the natural repulsive forces between electrons.
_ Methods of magnetic focusing
_ Solenoid magnetic structure
_ Permanent magnet
_ Periodic permanent magnet (PPM)
_ Radial magnet PPM **d) The collector**

_ To dissipate the electrons in the form of heat as they emerge from the slow wave structure
_ Accomplished by thermal conduction to a colder outside surface – the heat is absorbed by circulated air or a liquid
1. Gain compression

_ the amount of gain decrease from the small signal condition (normally 6dB)
2. Beam Voltage

_ the voltage between the cathode and the RF structure
3. Synchronous Voltage

_ the beam voltage necessary to obtain the greatest interaction between the electrons in the electron beam and the RF wave on the circuit
4. Gain

_ the ratio of RF output power to RF input power (dB)
5. Phase Characteristic

_ Phase shift – the phase of output signal relative to the input signal
_ Phase sensitivity – the rate of phase change with a specific operating parameter

Solid State Devices

The classification of solid state Microwave devices can be done –
Depending upon their electrical behavior ○ Non-linear resistance type.

Example: Varistors (variable resistances) ○ Non-Linear reactance type.

Example: Varactors (variable reactors) ○ Negative resistance type. Example:

Tunnel diode, Impatt diode, Gunn diode ○ Controllable impedance type.

Example: PIN diode

Gunn Effect Devices

J B Gunn discovered periodic fluctuations of current passing through the **n-type GaAs** specimen when the applied voltage exceeded a certain critical value. In these diodes, there are two valleys, **L & U valleys** in conduction band and the electron transfer occurs between them, depending upon the applied electric field. This effect of population inversion from lower L-valley to upper U-valley is called **Transfer Electron Effect** and hence these are called as **Transfer Electron Devices** (TEDs). **Applications of Gunn Diodes**

Gunn diodes are extensively used in the following devices:

- Radar transmitters
- Transponders in air traffic control
- Industrial telemetry systems
- Power oscillators
- Logic circuits
- Broadband linear amplifier

Gunn Diodes:

Single piece of GaAs or Inp and contains no junctions Exhibits negative differential resistance ***Applications:*** low-noise local oscillators for mixers (2 to 140 GHz). Low-power transmitters and wide band tunable sources

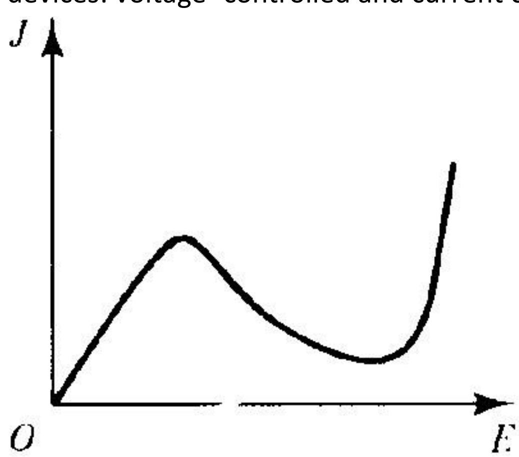
Continuous-wave (CW) power levels of up to several hundred mill watts can be obtained in the X-, Ku-, and Ka-bands. A power output of 30 mW can be achieved from commercially available devices at 94 GHz.

Higher power can be achieved by combining several devices in a power combiner.

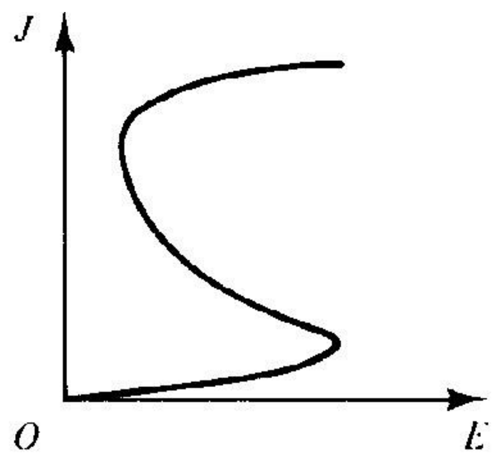
Gunn oscillators exhibit very low dc-to-RF efficiency of 1 to 4%.

Differential Negative Resistance:

The fundamental concept of the Ridley-Watkins-Hilsum (RWH) theory is the differential negative resistance developed in a bulk solid-state III-V compound when either a voltage (or electric field) or a current is applied to the terminals of the sample. There are two modes of negative-resistance devices: voltage- controlled and current controlled Modes.



(a) Voltage-controlled mode



(b) Current-controlled mode

MODES OF OPERATION OF GUNN DIODE:

A gunn diode can operate in four modes:

1. Gunn oscillation mode
2. stable amplification mode
3. LSA oscillation mode
4. Bias circuit oscillation mode

Gunn oscillation mode: This mode is defined in the region where the product of frequency multiplied by length is about 107 cm/s and the product of doping multiplied by length is greater than 1012/cm2.In this region the device is unstable because of the cyclic formation of either the accumulation layer or the high field domain.

When the device is operated is a relatively high Q cavity and coupled properly to the load, the domain I quenched or delayed before nucleating.

***2.*stable amplification mode :**

This mode is defined in the region where the product of frequency times length is about 107 *cmls* and the product of doping times length is between l011and *1O12/cm2*

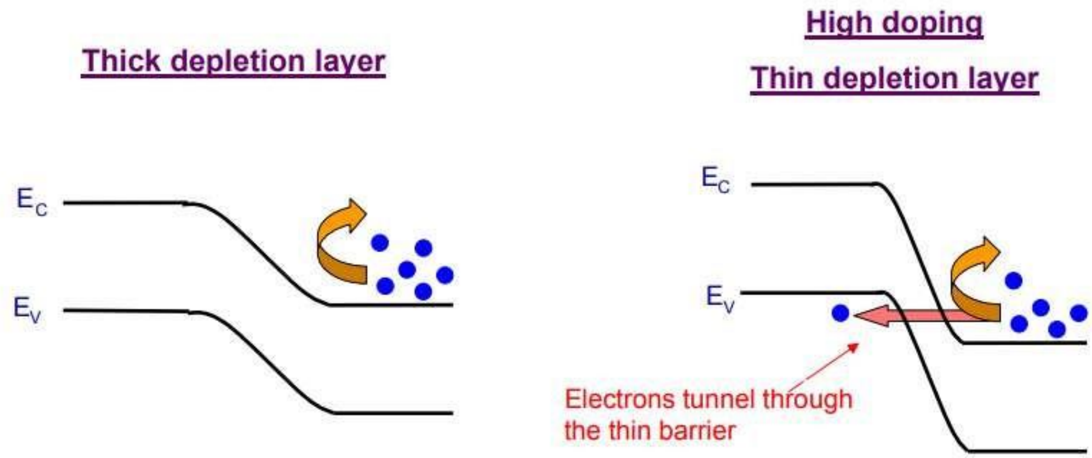
3.LSA oscillation mode: This mode is defined in the region where the product of frequency times length is above 107 *cmls* and the quotient of doping divided by frequency is between 2 x 104 and 2 x 105.

4.Bias-circuit oscillation mode: This mode occurs only when there is either Gunn or LSA oscillation. and it is usually at the region where the product of frequency times length is too small to appear in the figure. When a bulk diode is biased to threshold. the average current suddenly drops as Gunn oscillation begins.

Tunnel Diode:

When the p and n region are highly doped, the depletion region becomes very thin (~10nm).

- In such case, there is a finite probability that electrons can tunnel from the conduction band of nregion to the valence band of p-region
- During the tunneling the particle ENERGY DOES NOT CHANGE

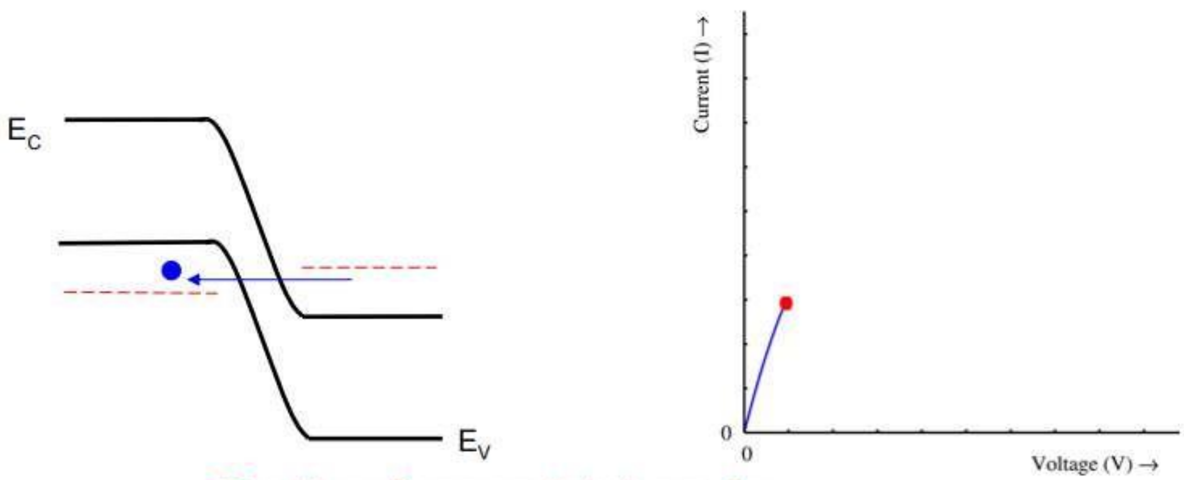


- When the semiconductor is very highly doped (the doping is greater than N o) the Fermi level goes above the conduction band for n-type and below valence band for ptype material. These are called degenerate materials.

Under Forward Bias

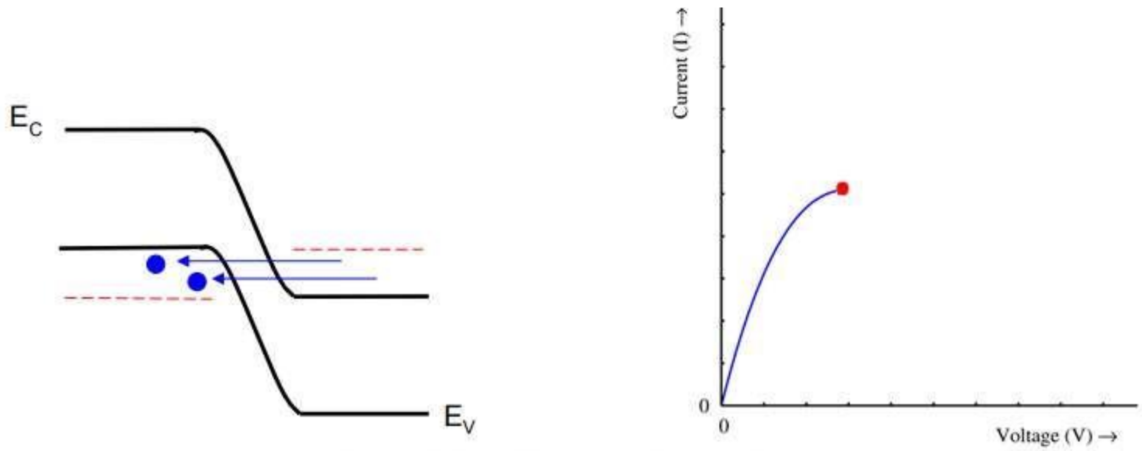
Step 1: At zero bias there is no current flow

Step 2: A small forward bias is applied. Potential barrier is still very high – no noticeable injection and forward current through the junction. However, electrons in the conduction band of the n region will tunnel to the empty states of the valence band in p region. This will create a forward bias tunnel current



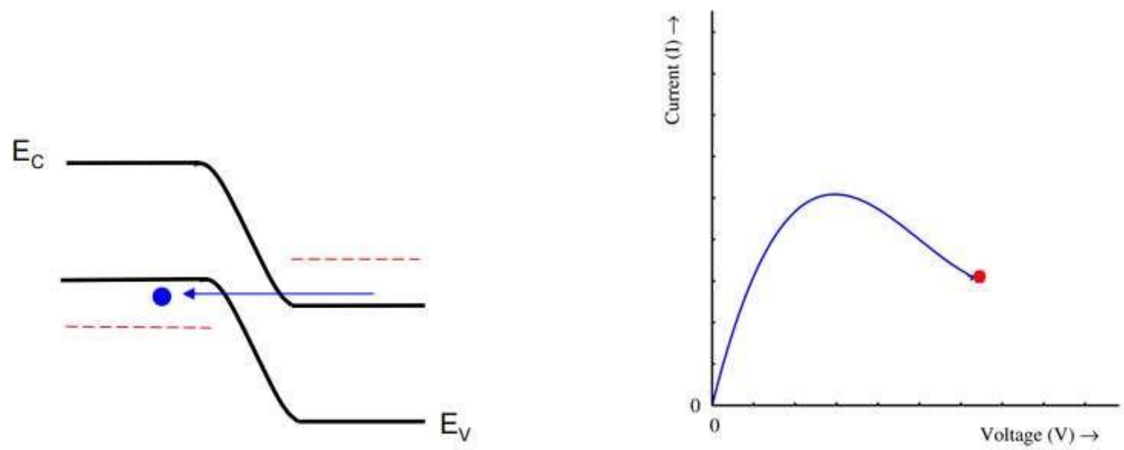
Direct tunneling current starts growing

Step 3: With a larger voltage the energy of the majority of electrons in the n-region is equal to that of the empty states (holes) in the valence band of p-region; this will produce maximum tunneling current



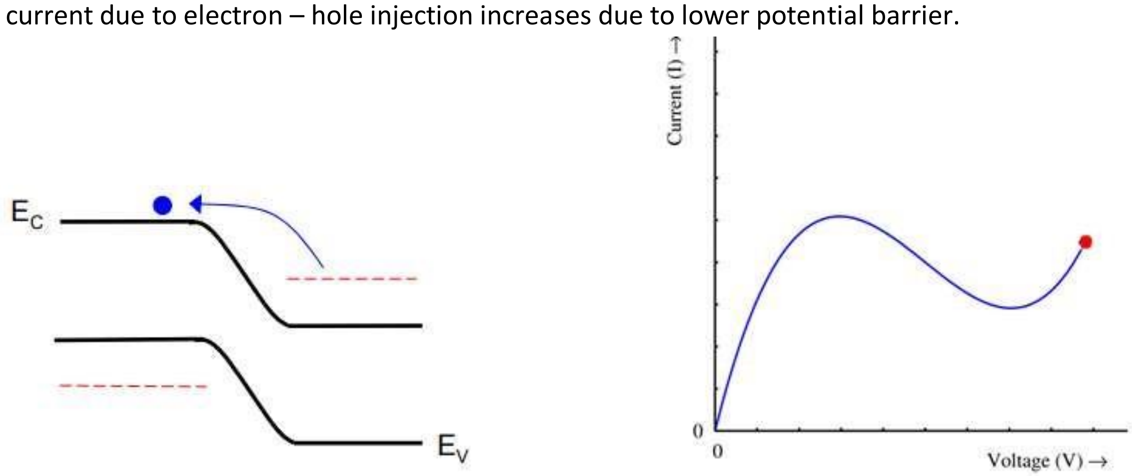
Maximum Direct tunneling current

Step 4: As the forward bias continues to increase, the number of electrons in the n side that are directly opposite to the empty states in the valence band (in terms of their energy) decrease. Therefore decrease in the tunneling current will start.



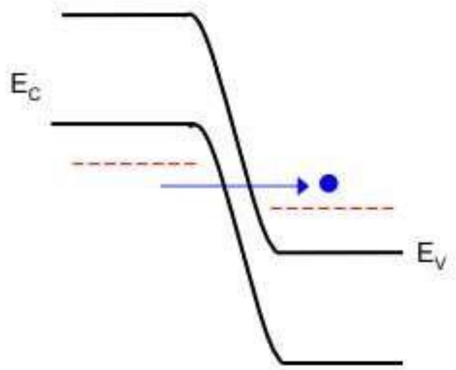
Direct tunneling current decreases

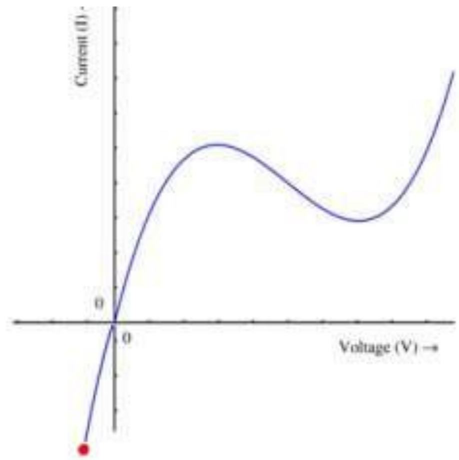
Step 5: As more forward voltage is applied, the tunneling current drops to zero. But the regular diode forward current due to electron – hole injection increases due to lower potential barrier.



No tunneling current; diffusion current starts growing

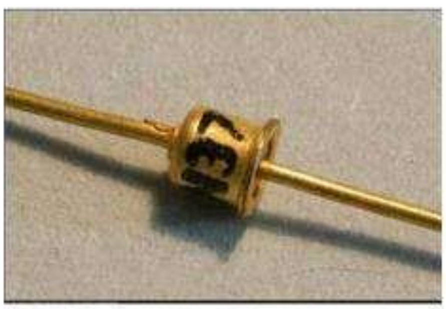
Under Reverse Bias In this case the, electrons in the valence band of the p side tunnel directly towards the empty states present in the conduction band of the n side creating large tunneling current which increases with the application of reverse voltage. The TD reverse I-V is similar to the Zener diode with nearly zero breakdown voltage.

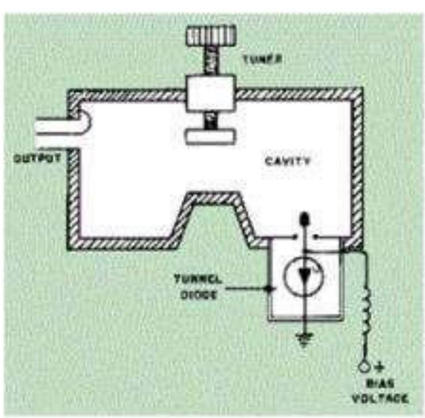


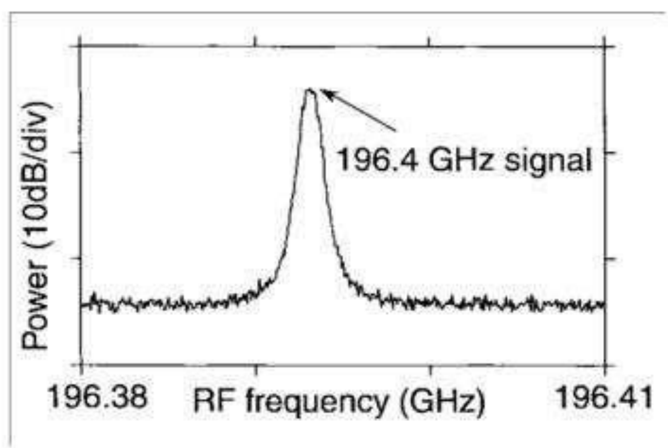


Applicatio:

Tunnel Diode microwave oscillators







After: M. Reddy et.al,

IEEE ELECTRON DEVICE LETTERS, VOL. 18, NO. 5, MAY 1997

~ 600 GHz oscillation frequencies has been achieved.

SONET (Synchronous Optical Network)-

Synchronous optical network (SONET) is a standard for optical telecommunications transport. It was formulated by the ECSA for ANSI, which sets industry standards in the United States for telecommunications and other industries. The comprehensive SONET/synchronous digital hierarchy (SDH) standard is expected to provide the transport infrastructure for worldwide telecommunications for at least the next two or three decades.

The increased configuration flexibility and bandwidth availability of SONET provides significant advantages over the older telecommunications system. These advantages include the following:

- reduction in equipment requirements and an increase in network reliability
- provision of overhead and payload bytes—the overhead bytes permit management of the payload bytes on an individual basis and facilitate centralized fault sectionalization
- definition of a synchronous multiplexing format for carrying lower level digital signals (such as DS–1, DS–3) and a synchronous structure that greatly simplifies the interface to digital switches, digital cross-connect switches, and add-drop multiplexers
- availability of a set of generic standards that enable products from different vendors to be connected
- definition of a flexible architecture capable of accommodating future applications, with a variety of transmission rates

In brief, SONET defines optical carrier (OC) levels and electrically equivalent synchronous transport signals (STSs) for the fiber-optic–based transmission hierarchy.

Basic SONET Signal

SONET defines a technology for carrying many signals of different capacities through a synchronous, flexible, optical hierarchy. This is accomplished by means of a byte-interleaved multiplexing scheme. Byte-interleaving simplifies multiplexing and offers end-to-end network management.

The first step in the SONET multiplexing process involves the generation of the lowest level or base signal. In SONET, this base signal is referred to as

synchronous transport signal–level 1, or simply STS–1, which operates at 51.84 Mbps. Higher-level signals are integer multiples of STS–1, creating the family of STS–N signals in *Table 1*. An STS–N signal is composed of N byte-interleaved STS–1 signals. This table also includes the optical counterpart for each STS–N signal, designated optical carrier level N (OC–N).

Table 1. SONET Hierarchy

Signal	Bit Rate (Mbps)	Capacity
STS–1, OC–1	51.840	28 DS–1s or 1 DS–3
STS–3, OC–3	155.520	84 DS–1s or 3 DS–3s
STS–12, OC–12	622.080	336 DS–1s or 12 DS–3s
STS–48, OC–48	2,488.320	1,344 DS–1s or 48 DS–3s
STS–192, OC–192	9,953.280	5,376 DS–1s or 192 DS–3s
Note: STS = synchronous transport signal OC = optical carrier		

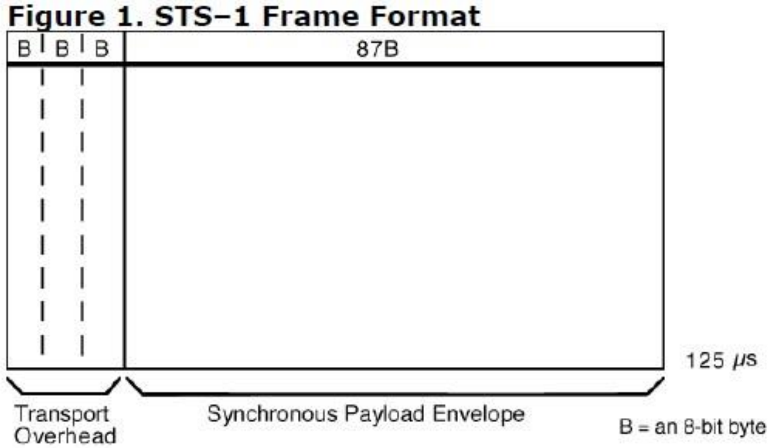
3. Frame Format Structure

SONET uses a basic transmission rate of STS–1 that is equivalent to 51.84 Mbps. Higher-level signals are integer multiples of the base rate. For example, STS–3 is three times the rate of STS–1 (3 x 51.84 = 155.52 Mbps). An STS–12 rate would be 12 x 51.84 = 622.08 Mbps.

STS–1 Building Block

The frame format of the STS–1 signal is shown in *Figure 1*. In general, the frame can be divided into two main areas: transport overhead and the synchronous payload envelope (SPE).

Figure 1. STS–1 Frame Format



9. What Are the Benefits of SONET?

The transport network using SONET provides much more powerful networking capabilities than existing asynchronous systems.

Pointers, MUX/DEMUX

As a result of SONET transmission, the network's clocks are referenced to a highly stable reference point. Therefore, the need to align the data streams or synchronize clocks is unnecessary. Therefore, a lower rate signal such as DS–1 is accessible, and demultiplexing is not needed to access the bitstreams. Also, the signals can be stacked together without bit stuffing.

For those situations in which reference frequencies may vary, SONET uses pointers to allow the streams to float within the payload envelope. Synchronous clocking is the key to pointers. It allows a very flexible allocation and alignment of the payload within the transmission envelope.

Reduced Back-to-Back Multiplexing

Separate M13 multiplexers (DS–1 to DS–3) and fiber-optic transmission system terminals are used to multiplex a DS–1 signal to a DS–2, DS–2 to DS–3, and then DS–3 to an optical line rate. The next stage is a mechanically integrated fiber/multiplex terminal.

Optical Interconnect

Because of different optical formats among vendors' asynchronous products, it is not possible to optically connect one vendor's fiber terminal to another. For example, one manufacturer may use 417–Mbps line rate, another 565–Mbps.

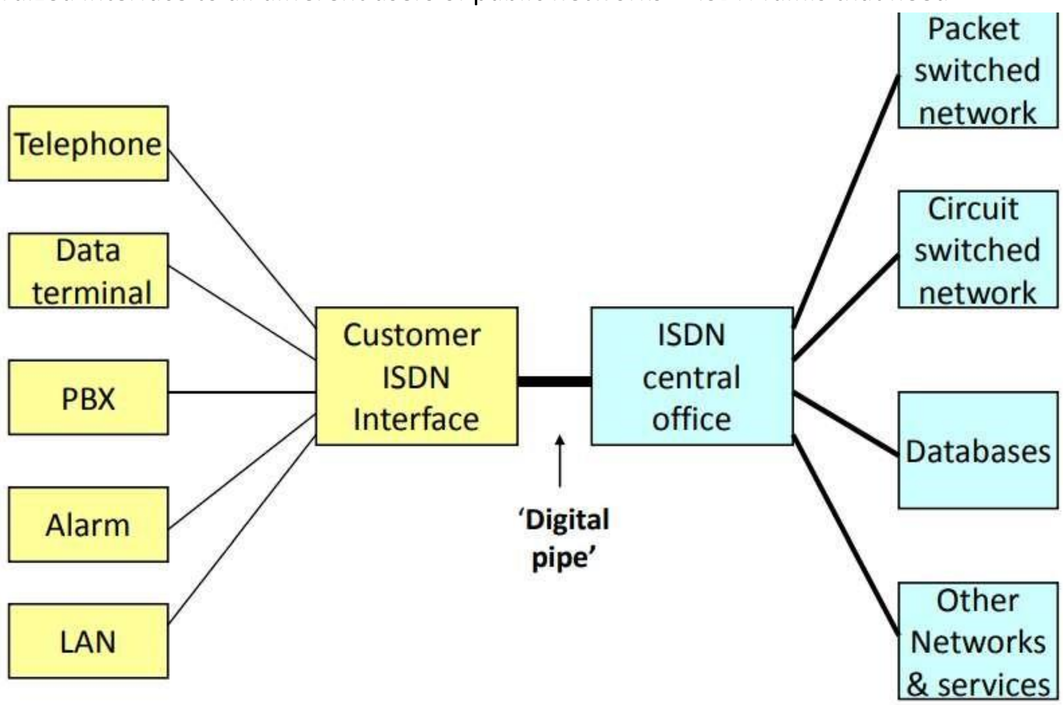
A major SONET value is that it allows midspan meet with multivendor compatibility. Today's SONET standards contain definitions for fiber-to-fiber interfaces at the physical level. They determine the optical line rate, wavelength, power levels, pulse shapes, and coding. Current standards also fully define the frame structure, overhead, and payload mappings. Enhancements are being developed to define the messages in the overhead channels to provide increased OAM&P functionality.

SONET allows optical interconnection between network providers regardless of who makes the equipment. The network provider can purchase one vendor's equipment and conveniently interface with other vendors' SONET equipment at either the different carrier locations or customer premises sites. Users may now obtain the OC–N equipment of their choice and meet with their network provider of choice at that OC–N level.

<u>ISDN</u> (INTEGRATED SERVICES DIGITAL NETWORK)

• Users have a variety of equipment to connect to public networks

–Telephones
– Private Branch Exchanges
–Computer Terminals or PCs
– Mainframe Computers
• A variety of physical interfaces and access procedures are required for connection
• The telephone network has evolved into a digital one with digital exchanges and links • The signaling system has become a digital message-oriented common channel signaling system (SS#7)
• The term
'Integrated Digital Network' is used to describe these developments
• The Public Switched Telephone network is still analogue from the subscriber to the local exchange
• The need has arisen to extend the digital network out to subscribers and to provide a single standardized interface to all different users of public networks • ISDN fulfils that need

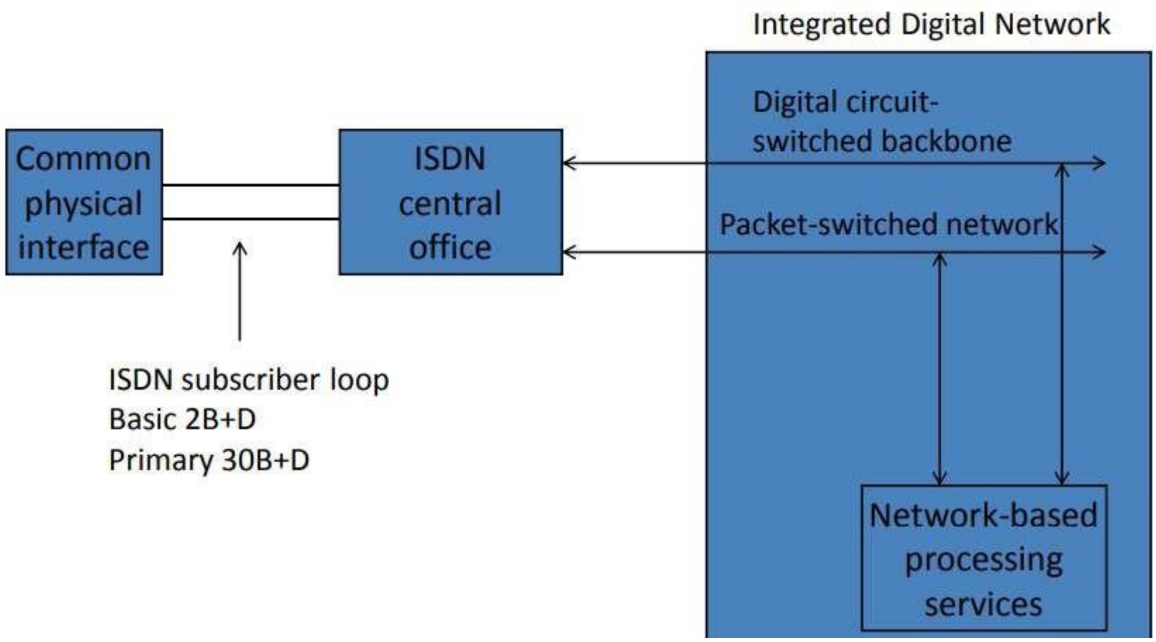


• In Practice there are multiple networks providing the service nationally
• The user however, sees a single network

Benefits to Subscribers

• Single access line for all services
• Ability to tailor service purchased to suit needs
• Competition among equipment vendors due to standards
• Availability of competitive service providers

Architecture



ISDN Channels

- The Digital pipe is made up of channels - one of three types
- B channel, D channel or H channel
- Channels are grouped and offered as a package to users

B Channel

- B channel-64 kbps
- B is basic user channel – can carry digital data or PCM-encoded voice – or mixture of lower rate traffic.
- Four kinds of connection possible
- Circuit-switched
- Packet-switched - X.25
- Frame mode - frame relay (LAPF)
- Semi permanent - equivalent to a leased line

D Channel

- D Channel - 16 or 64 kbps
- Carries signaling information to control circuit-switched calls on B channels
- Can also be used for packet switching or low speed telemetry

H Channel

- Carry user information at higher bit rates 384kbps or 1536kbps or 1920kbps
- Can be used as a high-speed trunk
- Can also be subdivided as per user's own TDM scheme
- Uses include high speed data, fast facsimile, video, high-quality audio

ISDN Basic Access

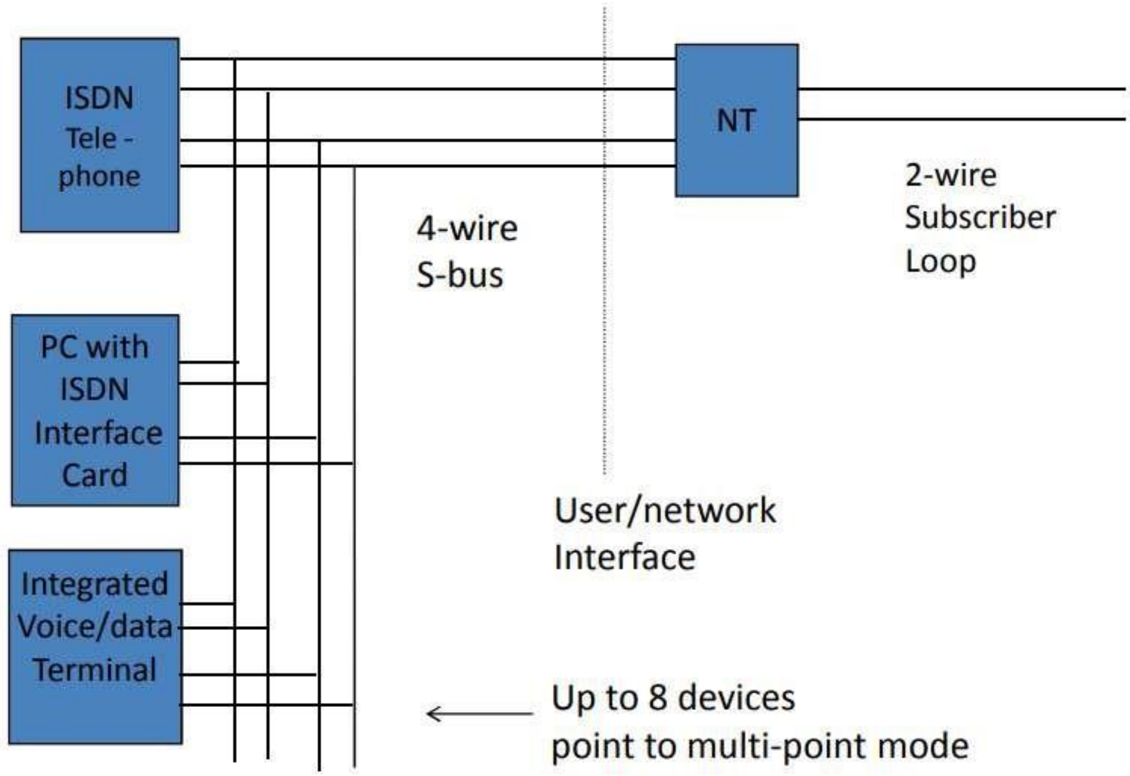
• Intended for small business and residential use
• A single physical interface is provided
• Data rate is 144kbps plus 48kbps overhead bits totaling 192 kbps
• Most existing subscriber loops can support basic access

ISDN Primary Interface

• Multiple channels multiplexed on single medium
• Only point to point configuration is allowed
• Typically supports a digital PBX and provides a synchronous TDM facility

User Access

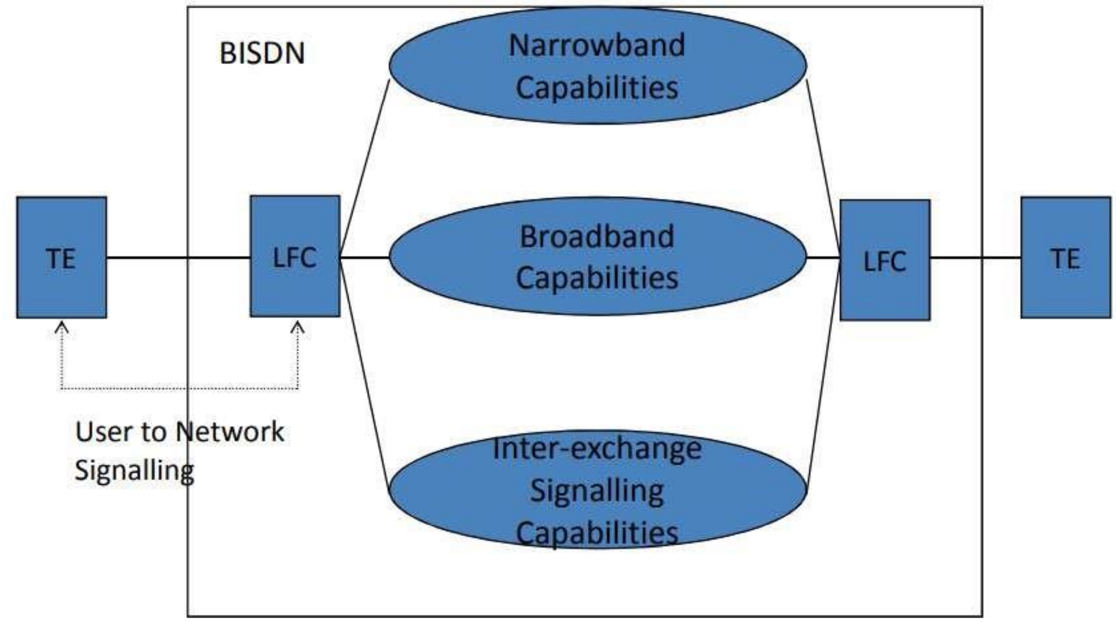
• Defined using two concepts
– Functional groupings of equipment
–Reference points to separate functional groupings **User access Layout:**



Broadband ISDN (BISDN)

• Recommendations to support video services as well as normal ISDN services
• Provides user with additional data rates – 155.52 Mbps full-duplex – 155.52 Mbps / 622.08 Mbps – 622.08 Mbps full-duplex
• Exploits optical fiber transmission technology

B-ISDN Architecture



TE = Terminal equipment LFC = Local function capabilities

- ATM is specified for Information transfer across the user-network interface
- Fixed size 53 octet packet with a 5 octet header
- Implies that internal switching will be packet based

BISDN Protocol Structure