# MAR GREGORIOS COLLEGE
# OF ARTS & SCIENCE


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## DEPARTMENT OF ELECTRONICS & COMMUNICATION SCIENCE

**SUBJECT NAME: ANTENNAS AND TELEVISION ENGINEERING**

**SUBJET CODE: TAG5B**

**SEMESTER: V**

**PREPARED BY: PROF.M.SATHIYA**

**UNIT I**

**FUNDAMENTALS OF ANTENNA –** Antenna parameters – Gain and directivity – Efficiency – Effective length –Bandwidth – Beam width – Radiation resistance – Polarization – Grounded and ungrounded antenna's – Effects of antenna height – Radiation Patterns

**UNIT II**

**TYPES OF ANTENNAS –** Microwave antenna's – Parabolic antenna – Horn antenna's – Lens antenna – Disc oneantenna – Rhombic antenna.

**UNIT III**

**WAVE PROPAGATION –** Electromagnetic radiation – Propagation of Waves – Surface wave propagation – skywave propagation – space wave propagation – Tropospheric scatter propagation – Virtual height – MUF – skip distance – Ionospheric abnormalitics – Introduction to waveguide.

**UNIT IV**

**ELEMENTS OF TV SYSTEM –** Picture transmission and reception – Sound transmission and reception – Synchronization – Receiver Controls – Colour television – Transmission & Reception – Image continuity – Number of Scanning lines – Scanning – Sequential – Interlaced Scanning – Picture tubes – Monochrome and colour picture tubes

**UNIT V**

**CAMERA TUBES** – Image orthicon – Plubicon– color television system – fundamental concepts of three coloursystem – additive and subtractive colours

**ADVANCE TECHNIQUES –** Introduction of CCD camera – HDTV – Digital TV – Video disc – Cable TV - VCR

## 1.0ANTENNA BASICS

### HISTORY OF AN ANTENNAS:

The first radio antennas were built by Heinrich Hertz, a professor at the Technical Institute in Karlsruhe, Germany. Heinrich Hertz‘s end-loaded half-wave dipole transmitting antenna and resonant half-wave receiving loop operating at $\lambda = 8$ m in 1886.

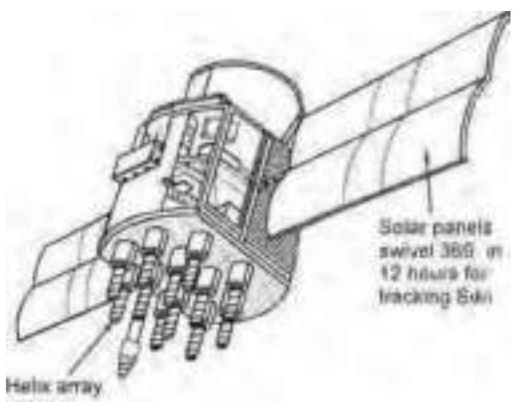
Hertz was the pioneer and father of radio, his invention remained a laboratory uriosity until 20-year-old Guglielmo Marconi of Bologna, Italy, went on to add tuning circuits, big antenna and ground systems for longer wavelengths, and was able to signal over large distances. In mid-December 1901 he startled the world by receiving signals at St. Johns, Newfoundland, from a transmitting station he had constructed at Poldhu in Cornwall, England.

Guglielmo Marconi‘s square conical antenna at Poldhu, England, in 1905 for sending transatlantic signals at wavelengths of 1000s of meters. Shown in fig. below. Rarely has an invention captured the public imagination as Marconi‘s wireless did at the beginning of the 20th century. With the advent of radar during World War II, centimeter wavelengths became popular and the entire radio spectrum opened up to wide usage.

Thousands of communication satellites bristling with antennas now circle the earth in low, medium, and geostationary orbits. The geostationary satellites form a ring around the earth similar to the rings around Saturn. Your hand-held Global Position Satellite (GPS) receiver gives your latitude, longitude and elevation to centimeter accuracy anywhere on or above the earth day or night, cloudy or clear.

Very Large Array (VLA) of 27 steerable parabolic dish antennas each 25 m in diameter operating at centimeter wavelengths for observing radio sources at distances of billions of light-years. The array is located at the National Radio Astronomy Observatory near Socorro,
New Mexico in **1980**. Shown in fig. below. Our probes with their arrays of antennas have visited the planets of the solar system and beyond, responding to our commands and sending back photographs and data at centimeter wavelengths even though it may take over 5 hours for the signals to travel one way. And our radio telescope antennas operating at millimeter to kilometer wavelengths receive signals from objects so distant that it has taken more than 10 billion years for the signals to arrive.

Helix antenna array on one of 24 Global Position Satellites (GPS) in Medium Earth Orbit (MEO) at 20,000km. Operating at $\lambda$ = 20 cm, these satellites provide you on or above the earth with your position (latitude, longitude and elevation) to an accuracy of better than 1 meter in **1985**. Shown in fig. below.



In the above image, the antennas help the communication to be established in the whole area, including the valleys and mountains. This process would obviously be easier than laying a wiring system throughout the area.

The ubiquitous, hand-held cellphone with half-wave antenna operating at $\lambda$ = 30 cm, which connects you to everybody. Antennas are the essential communication link for aircraft and ships. Antennas for cellular phones and all types of wireless devices link us to everyone and every thing. With mankind‘s activities expanding into space, the need for antennas will grow to an unprecedented degree. Antennas will provide the vital links to and from everything out there. The future of antennas reaches to the stars.

**INTRODUCTION:**

Antennas are our electronic eyes and ears on the world. They are our links with space.
They are an essential, integral part of our civilization.

An antenna (or aerial) is an electrical device which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an oscillating radio frequency electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves).

In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified. Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones and satellite communications, as well as other devices such as garage door openers, wireless microphones, blue tooth enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise.

Typically an antenna consists of an arrangement of metallic conductors ("elements"), electrically connected (often through a transmission line) to the receiver or transmitter. Antennas act as transformers between conducted waves and electromagnetic waves propagating freely in space. Their name is borrowed from zoology, in which the Latin word antennae is used to describe the long, thin feelers possessed by many insects.

In wireless communication systems, signals are radiated in space as an electromagnetic wave by using a receiving, transmitting antenna and a fraction of this radiated power is intercepted by using a receiving antenna. An antenna is a device used for radiating or receiving radio waves. An antenna can also be thought of as a transitional structure between free space and a guiding device (such as transmission line or waveguide).

Usually antennas are metallic structures, but dielectric antennas are also used now a days, a rigid metallic structure is called an "antenna" while the wire form is called an "aerial" With this introduction, in this first lecture let us see some common types of antennas that arein use:

**Ehat is meant by Dimension?** A *dimension* defines some physical characteristic.

**Types of Dimensions:**

1. Fundamental dimensions: The dimensions of length, mass, time, electric current, temperature, and luminous intensity are considered as the ***fundamnntal dimnnsions***. For

example Let the letters *L,M, T, I* , *T* , and *I* represent the dimensions of length, mass, time, electric current, temperature, and luminous intensity.

*2.* Secondary dimensions: A secondary dimension which can be expressed in terms of the fundamental dimension of length squared *(l2)*.

**WHAT is a Unit?** A *unit* is a standard or reference by which a dimension can be expressed numerically. The meter is a unit in terms of which the dimension of length can be expressed, and the kilogram is a unit in terms of which the dimension of mass can be expressed.

**Types of units**:-

1. **Fundamental units**:- The units for the fundamental dimensions are called the *fundamental* or *base units.* The International System of Units, abbreviated SI, is used, in this system the *meter, kilogram, second, ampere, kelvin,* and *candela* are the base units for the six fundamental dimensions of length, mass, time, electric current, temperature, and luminous intensity.

*2.* **Secondary units**:- The units for other dimensions are called *secondary* or *derived* units and are based on these fundamental unit.

**TYPES OF ANTENNAS**:

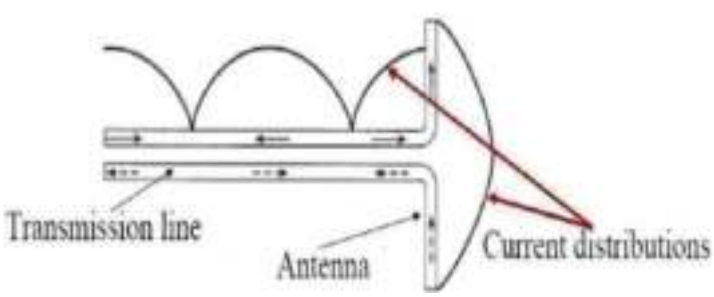
***Wirn antnnnas***: (fig 1,2 and 3)

- Dipole, monopole, loop antenna, helix antennas:- Usually used in personalapplications, automobiles, buildings, ships, aircrafts and spacecrafts.

Fig1

Fig 2

Fig 3




Conditions for radiation

***Apnrturn antnnnas***: (fig 4 and 5)

➢ Horn antennas, waveguide opening :- Usually used in aircrafts and space crafts, because these antennas can be flush.

***Fig4*** ***Fig 5***

***Rnflnctor antnnnas***: (fig 6)

➢ Parabolic reflectors, corner reflectors :- These are high gain antennas usually used in radio astronomy, microwave communication and satellite tracking.

***Fig 6***

***Lnns antnnnas***:

➢ Convex-plane, co vex-convex , convex-concave and concave-plane lenses oThese antennas are usually used for very high frequency applications.

***Microstrip antnnnas***: (fig 7)

➢ rectangular, circular etc. shaped metallic patch above a ground plane :- Usedin aircraft, spacecraft, satellites, missiles, cars, mobile phones etc.

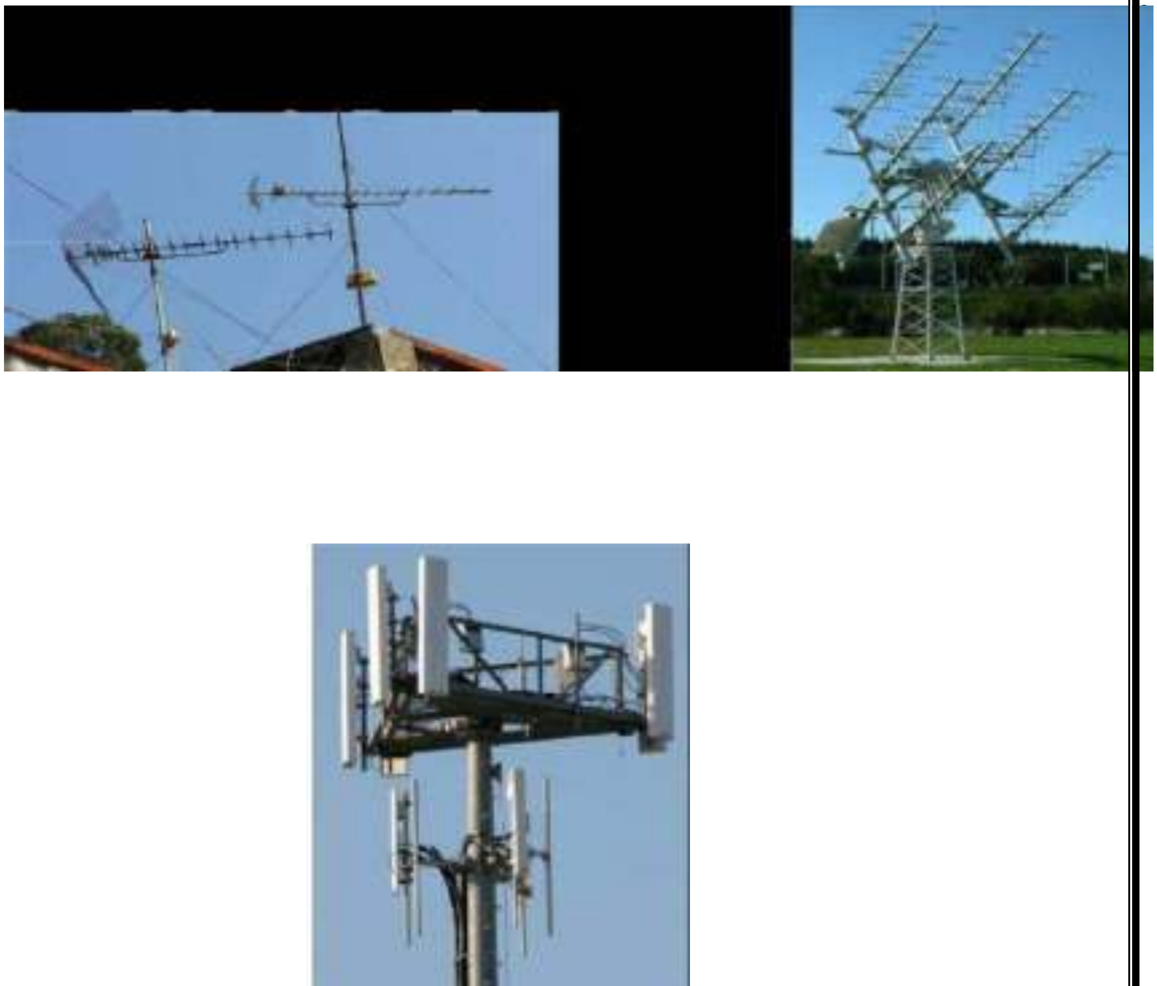


Fig 7

***Array antnnnas***: Yagi-Uda antenna, microstrip patch array, aperture array, slotted waveguide array :- Used for very high gain applications with added advantage, such as controllable radiation pattern.

**Radiation Mechanism**: When electric charges undergo acceleration or deceleration, electromagnetic radiation will be produced. Hence it is the motion of charges, that is current is the source of radiation. Here it may be highlighted that, not all current distributions will produce a strong enough radiation for communication.

Antennas radiate or couples or concentrates or directs electromagnetic energy in the desired or assigned direction. An antenna may be isotropic or non directional (omni-directional) and un isotropic or directional.

There is no proper rule for selecting an antenna for any particular frequency range or application. While choosing an antenna many electrical, mechanical and structural accepts are to be taken into account.

There accepts include radiation pattern, gain, efficiency, impedance, frequency characteristics, shape size, weight and look at antenna and above all these makes their economic viability. The cost, size and shape makes the main difference on usage of different frequencies.

High gain and Directivity are the basic requirements for the transmitting antennas. Where as low side lobes and large signal to noise ratio are key selection criteria for receiving antennas. Antenna may vary in size from the order of few millimetres(strip antenna) to thousands of feet (dishantennas for astronomical observations)

To give a mathematical flavour to it, as we know

$$A = \frac{\mu I d\bar{l}}{4\pi r}$$

$$dl\,\frac{d\bar{I}}{dt} = dlq\,\frac{dv}{dt} = dlqa$$

$$\boxed{E = -\nabla V - \frac{\partial A}{\partial t} = -\nabla V - \frac{\mu d\bar{l}}{4\pi r}\frac{\partial I}{\partial t} = -\nabla V - \frac{\mu d\bar{l}}{4\pi r}qa}$$

o As shown in these equations, to create radiation (electric field), there must be a time-varying current dI/dt or an acceleration (or deceleration) a of a charge q.

o If the charge is not moving, a current is not created and there is no radiation.

o If a charge is moving with an uniform velocity, there is no radiation if thewire is straight, and infinite in extent there is radiation if the wire is curved, bent, discontinuous, terminated or truncated , If the charge is oscillating in a time-motion, it radiates even if the wire is straight

So, it is the current distribution on the antennas that produce the radiation. Usually these current distributions are excited by transmission lines and waveguides as shown in the fig. 8.

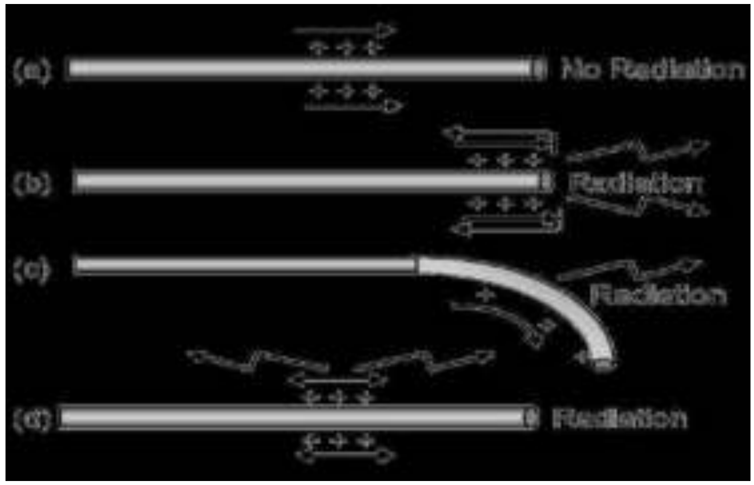



Fig 8. Antenna radiation mechanism

**BASIC PRINCIPLE OF RADIATION:-**

Under time varying conditions , Max wells equations predict the radiation of EM energy from current source(or accelerated charge). This happens at all frequencies , but is insignificant as long as the size of the source region is not comparable to the wavelength.While transmission lines are designed to minimize this radiation loss, radiation into free space becomes main purpose in case of Antennas.

For steady state harmonic variation, usually we focus on time changing current For transients or pulses ,we focus on accelerated charge The radiation is perpendicular to the acceleration. The radiated power is proportional to the square of .

I L or Q *V*

Where
I = Time changing current in Amps/sec

L = Length of the current element in meters Q= Charge in

Coulombs

*V*= Time changing velocity

**Transmission line opened out in a Tapered fashion as an Antenna:**

a) **As Transmitting Antenna**:– Here the Transmission Line is connected to source or generator at one end. Along the uniform part of the line energy is guided as Plane TEM wave with little loss. Spacing between line is a small fraction of λ. As the line is opened out and the separation between the two lines becomes comparable to λ, it acts like an antenna and launches a free space wave since currents on the transmission Line flow out on the antenna but fields associated with them keep on going. From the circuit point of view the antenna appears to be a resistance Rr, called Radiation resistance.

b) **As Receiving Antenna** –Active radiation by other Antenna or Passive radiation from distant objects raises the apparent temperature of Rr .This has nothing to do with the physical temperature of the antenna itself but is related to the temperature of distant objects that the antenna is looking at. Rr may be thought of as virtual resistance that does not exist physically but is a quantity coupling the antenna to distant regions of space via a virtual transmission line.

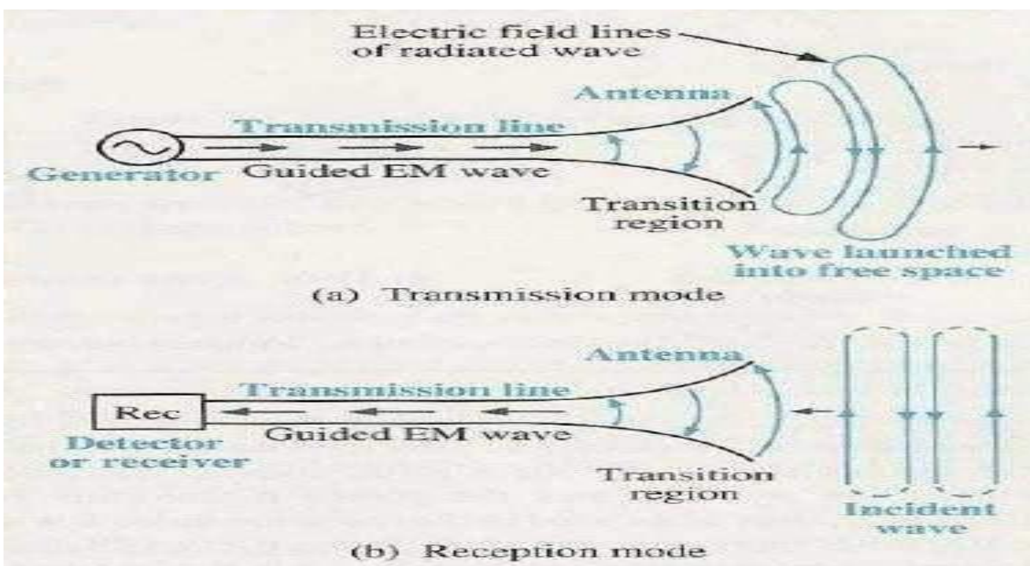



**Fig. 9:Antenna as a a) Transmission Mode b) Receiving Mode**

**Reciprocity-**An antenna exhibits identical impedance during Transmission or Reception, same directional patterns during Transmission or Reception, same effective height while transmitting or receiving **.** Transmission and reception antennas can be used interchangeably. Medium must be linear, passive and isotropic(physical properties are the same in different directions.) Antennas are usually optimised for reception or transmission, not both.

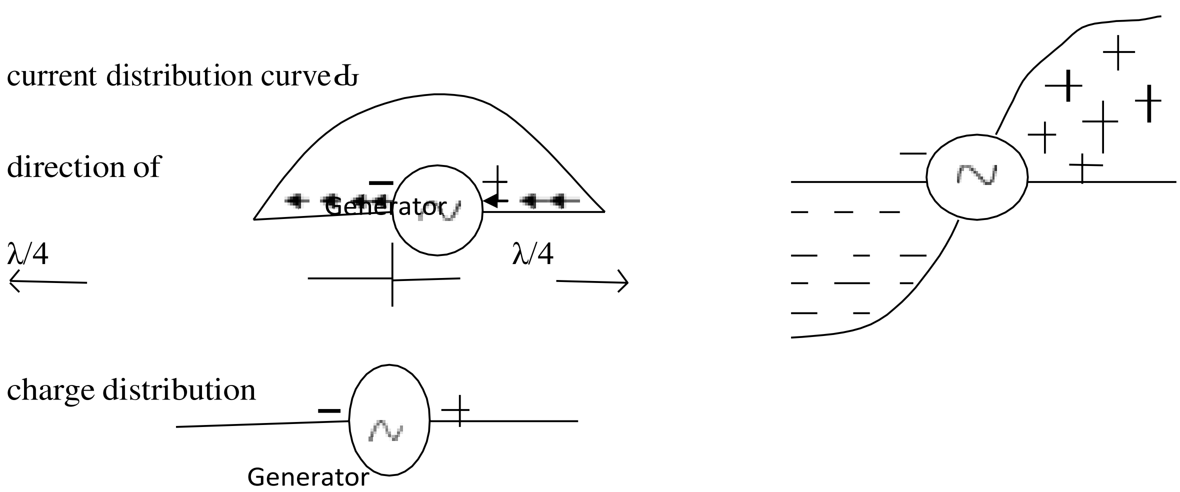
## 1.1 CURRENT AND VOLTAGE DISTRIBUTION:-

a) A current flowing in a wire of a length related to the RF produces an electromagnetic field. This field radiates from the wire and is set free in space. The principles of radiation of electromagnetic energy are based on two laws.

(1) A moving electric field creates a magnetic (H) field.
(2) A moving magnetic field creates an electric (E) field.

b) In space, these two fields will be in-phase and perpendicular to each other at any given moment. Although a conductor is usually considered to be present when a moving electric or magnetic field is mentioned, the laws governing these fields do not say anything about a conductor. Thus, these laws hold true whether a conductor is present or not

c) The current and voltage distribution on a half-wave Hertz antenna is shown in Figure 10 In view A, a piece of wire is cut in half and attached to the terminals of a high frequency (HF), alternating current (AC) generator. The frequency of the generator is set so each half of the wire is one-quarter wavelength of the output. The symbol for wavelength is the Greek letter lambda (D). The result is the common dipole antenna.




half wave Antenna
Fig: 10

1. A current flows in the antenna with an amplitude that varies with the generator voltage.
2. A sine wave distribution of charge exists on the antenna. The charges can reverse polarity for every half cycle.
3. The sine wave variation in charge magnitude lags the sine wave variation in current by one-quarter cycle.

**1.2 Antenna Parameters:**

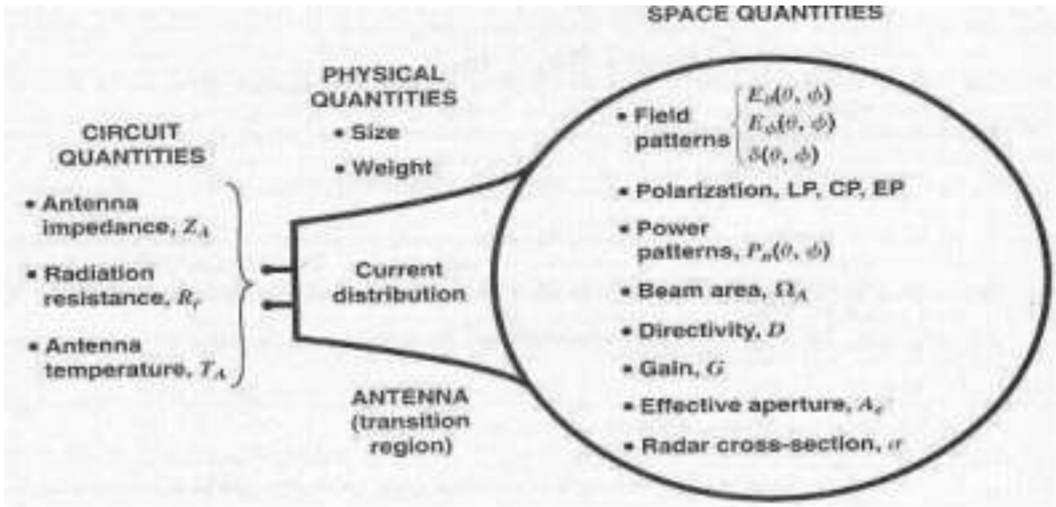



Figure 11: Schematic diagram of basic parameters

d) At a given moment, the generator's right side is positive and its left side is negative. A law of physics states that like charges repel each other. Consequently, electrons will flow away from the negative terminal as far as possible while the positive terminal will attract electrons. View B of Figure 1-1 shows the direction and distribution of electron flow. The distribution curve shows that most current flows in the center and none flows at the ends. The current distribution over the antenna is always the same, regardless of how much or how little current is flowing. However, current at any given point on the antenna will vary directly with the amount of voltage that the generator develops.

e) One-quarter cycle after the electrons begin to flow, the generator develops it; minimum voltage and the current decreases to zero. At that moment, the condition shown in view C of Figure 1-1 will exist. Although no current is flowing, a minimum number of electrons are at the left end of the line and a minimum number are at the right end. The charge distribution along the wire varies as the voltage of the generator varies (view C).

**DUAL CHARACTERISTICS OF AN ANTENNA:**

The duality of an antenna specifies a circuit device on one band and a space device on the other hand. Figure.11 shows the schematic diagram of basic antenna parameters, illustrating dual characteristics of an antenna.

Most practical transmitting antennas are divided into two basic classifications, HERTZ ANTENNAS (half-wave) and MARCONI (quarter-wave) ANTENNAS.

Hertz antennas are generally installed some distance above the ground and are positioned to radiate either vertically or horizontally. Marconi antennas operate with one end grounded and are mounted perpendicular to the earth or a surface acting as a ground. The Hertz antenna, also referred to as a dipole, is the basis for some of the more complex antenna systems used today. Hertz antennas are generally used for operating frequencies of 2 MHz and above, while Marconi antennas are used for operating frequencies below 2 MHz. All antennas regardless of their shape or size, have four basic characteristics: reciprocity, directivity, gain, and polarization.

**Isotropic Radiator**:An antenna does not radiate uniformly in all directions. For the sake of a reference, we consider a hypothetical antenna called an isotropic radiator having equal radiation in all directions.

**Directional Antenna**: A directional antenna is one which can radiate or receive electromagnetic waves more effectively in some directions than in others.

**Radiation Pattern:**

The relative distribution of radiated power as a function of direction in space (i.e., as function of and ) is called the radiation pattern of the antenna. Instead of 3D surface, it is common practice to show planar cross section radiation pattern. E-plane and H-plane patterns give two most important views. The E-plane pattern is a view obtained from a section containing maximum value of the radiated field and electric field lies in the plane of the section. Similarly when such a section is taken such that the plane of the section contains H field and the direction of maximum radiation. A typical radiation patter plot is shown in figure 12.

The main lobe contains the direction of maximum radiation. However in some antennas, more than one major lobe may exist. Lobe other than major lobe are called minor lobes. Minor lobes can be further represent radiation in the considered direction and require to be minimized.

HPBW or half power beam width: Refers to the angular width between the points at which the radiated power per unit area is one half of the maximum.

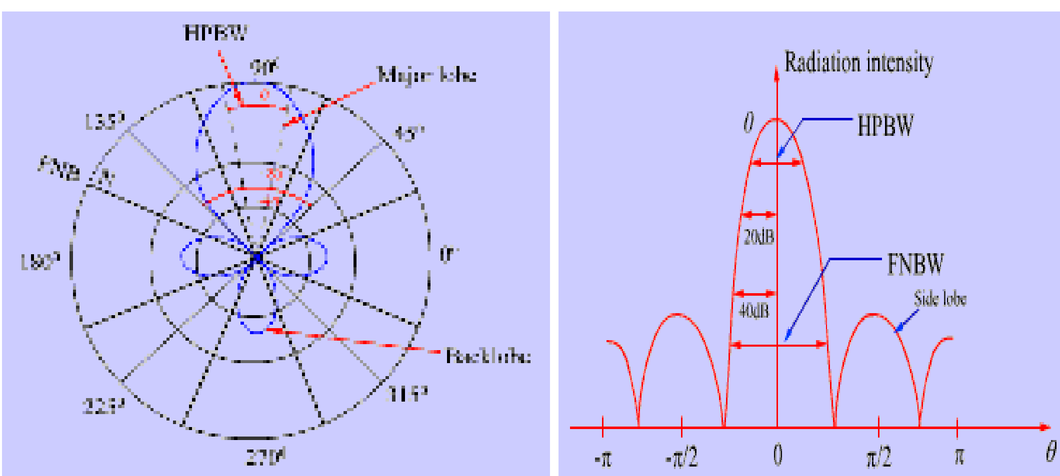



Figure 12: Radiation Pattern

Similarly FNBW (First null beam width) refers to the angular width between the first two nulls as shown in Figure 12. By the term beam width we usually refer to 3 dB beam width or HPBW.

RECIPROCITY (In terms of picture representation): Is the ability to use the same antenna for both transmitting and receiving. The electrical characteristics of an antenna apply equally, regardless of whether you use the antenna for transmitting or receiving. The more efficient an antenna is for transmitting a certain frequency, the more efficient it will be as a receiving antenna for the same frequency. This is illustrated by figure 13(view A). When the antenna is used for transmitting, maximum radiation occurs at right angles to its axis. When the same antenna is used for receiving (view B), its best reception is along the same path; that is, atright angles to the axis of the antenna.

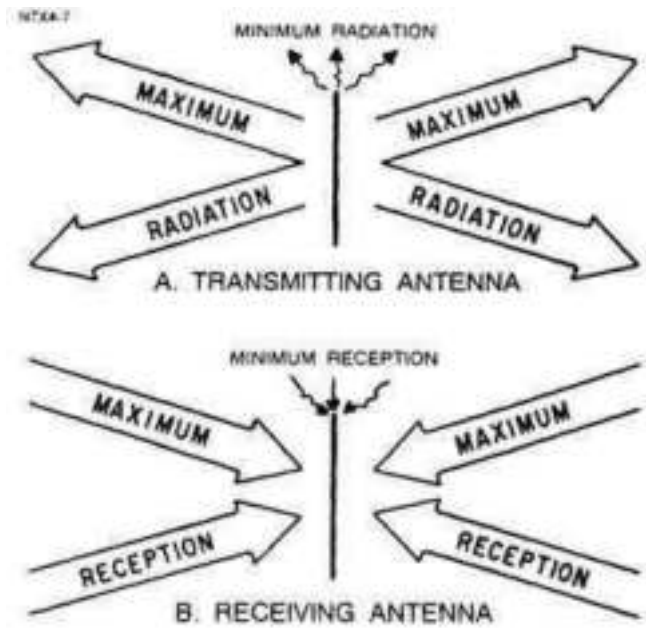



Figure. 13 Reciprocity of Antenna.

**1.3 POLARIZATION:-** Polarization of an electromagnetic wave refers to the orientation of the electric field component of the wave. For a linearly polarized wave, the orientation stays the same as the wave moves through space. If we choose our axis system such that the electricfield is vertical, we say that the wave is vertically polarized. If our transmitting antenna is vertically oriented, the electromagnetic wave radiated is vertically polarized since, as we saw before, the electric field is in the direction of the current in the antenna.

The convention is to refer to polarization with reference to the surface of the earth. Precise orientation is less problematic than one might think, since waves bounce of the ground and other objects so do not maintain their original orientation anyway. In space, horizontal and vertical lose their meaning, so alignment of linearly polarized sending and receiving antennas is more difficult to achieve. These difficulties are somewhat circumvented by circular polarization of waves. With circular polarization, the tip of the electric field vector traces out a circle when viewed in the direction of propagation.

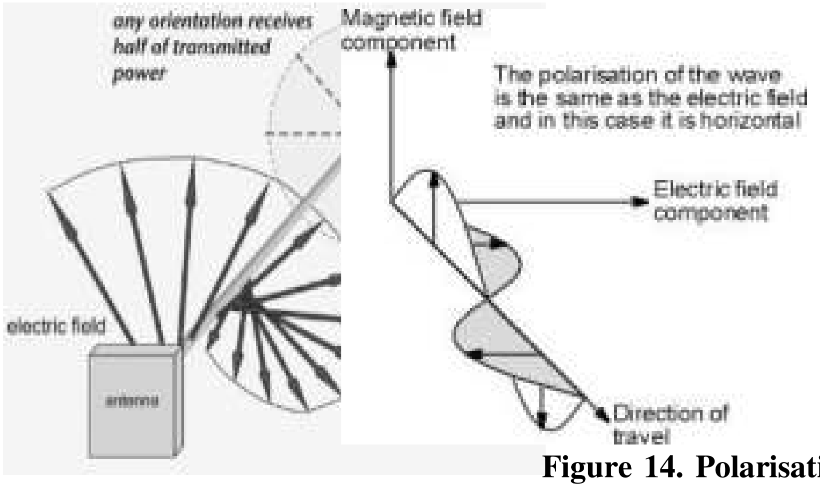



**Figure 14. Polarisation**

**POLARIZATION CATEGORIES:-**

Vertical and horizontal are the simplest forms of polarization and they both fall into a category known as linear polarization. However it is also possible to use circular polarization. This has a number of benefits for areas such as satellite applications where it helps overcome the effects of propagation anomalies, ground reflections and the effects of the spin that occur on many satellites.

Circular polarization is a little more difficult to visualize than linear polarization. However it can be imagined by visualizing a signal propagating from an antenna that is rotating. The tip of the electric field vector will then be seen to trace out a helix or corkscrew as it travels away from the antenna. Circular polarization can be seen to be either right or left handed dependent upon the direction of rotation as seen from the transmitter.

Another form of polarization is known as elliptical polarization. It occurs when there is a mix of linear and circular polarization. This can be visualized as before by the tip of the electric field vector tracing out an elliptically shaped corkscrew.

However it is possible for linearly polarized antennas to receive circularly polarized signals and vice versa. The strength will be equal whether the linearly polarized antenna is mounted vertically, horizontally or in any other plane but directed towards the arriving signal. There will be some degradation because the signal level will be 3 dB less than if a circularly polarized antenna of the same sense was used. The same situation exists when a circularly polarized antenna receives a linearly polarized signal.

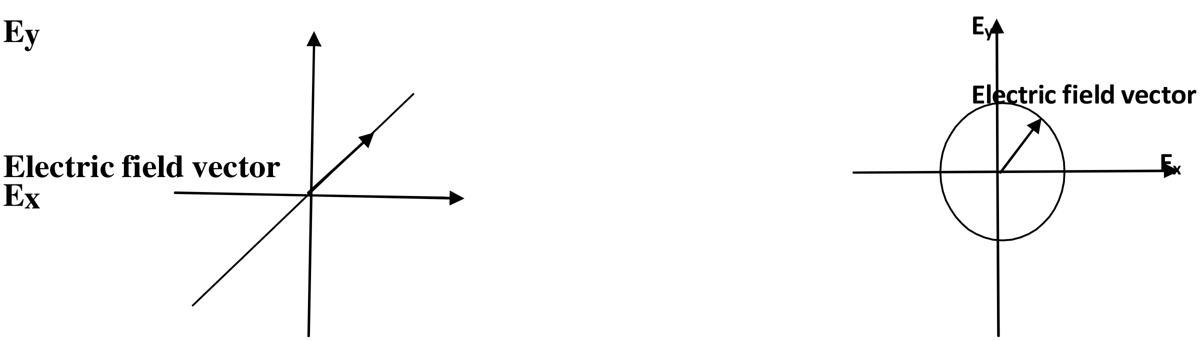



**Fig 15 (a) Linear Polarization (b) Circular Polarization**

**Ey**
**Electric field vector**

**Ex**

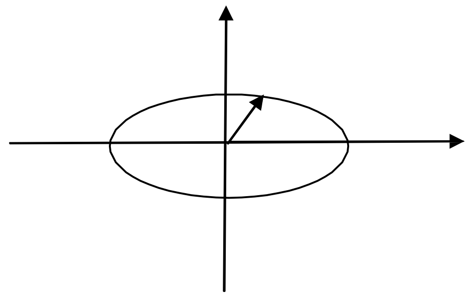


**Fig 15 (c) Elliptical Polarization**

**RADIATION PATTERN:-**

Practically any antenna cannot radiate energy with same strength uniformly in all directions- radiation will be large in one direction , while zero or minimum in other directions.

The radiation from the antenna in any direction is measured in terms of field strengthat a point located at a particular distance from an antenna.

The field strength can be calculated by measuring voltage at two points on an electric links of face and their dividing by distance between two points. Hence unit of radiation pattern is V/m. The radiation pattern of an antenna is the important characteristic of antenna because it indicates the distribution of energy radiated by an antenna in the space.

The radiation pattern is nothing but a graph which shows the variation of actual field strength of EM field at all the points equidistant from the antenna. Hence, it is 3-D graph.

Radiation patterns are of two types:

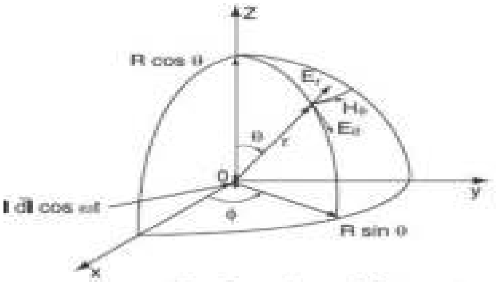
(i) If the radiation of the antenna is represented graphically as a function of direction it is called ***radiation pattnrn***. But if the radiation of the antenna is expressed in terms of the field strength E (V/m) , then the graphical representation is called ***finld strnngth pattnrn or finld radiation pattnrn.***

BASED ON MODE OF DIRECTION OF PATTERN, TYPES OF PATTERNS ARE:-(1)DIRECTIONAL PATTERNS AND OMNIDIRECTIONAL PATTERNS:-

A radiator acting as a lossless, hypothetical antenna radiating equally in all directions is called ***isotropic radiator***.

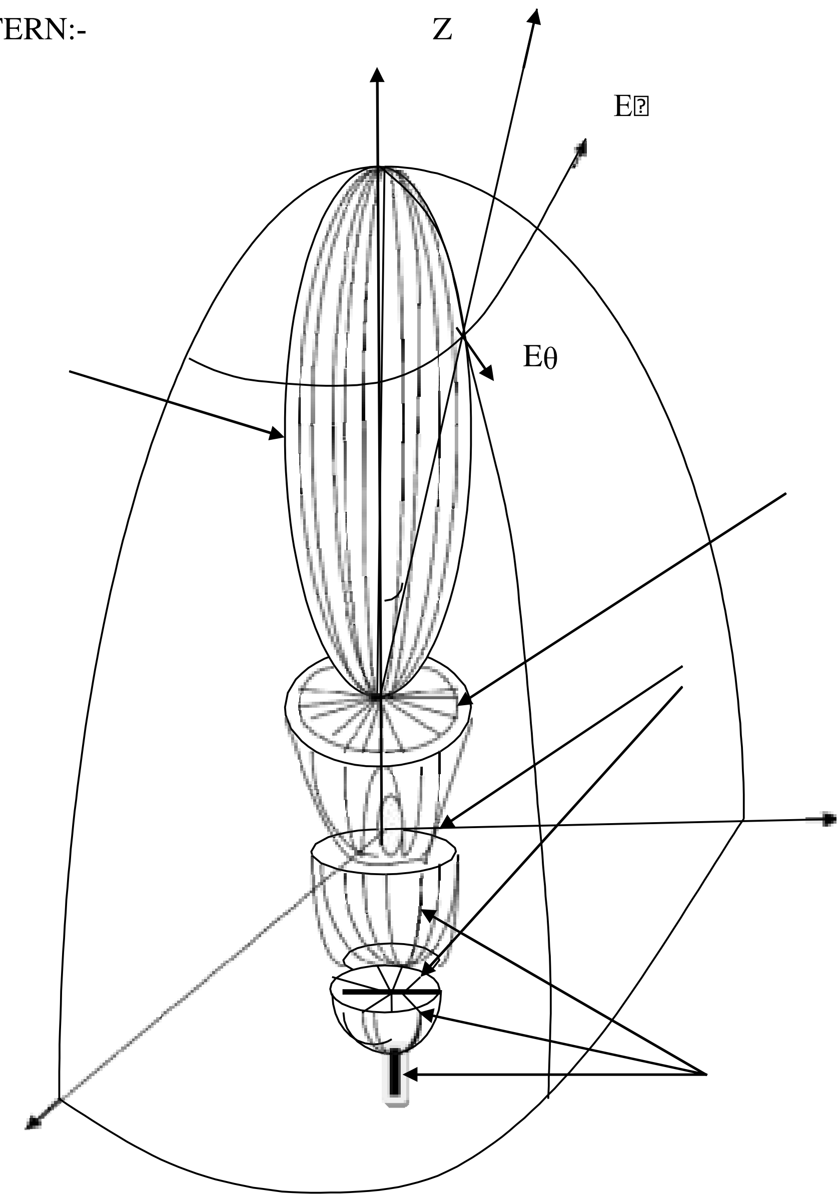
An antenna with a property of radiating or receiving the EM waves more effectively in same direction than in other directions is called ***dirnctional antnnna***.

The radiation pattern of such antenna is called directional pattern when antenna has max. directivity greater than that of a half wave dipole is know as directional antenna.




Configuration of filamentary current carrying conductor.

(2)FIELD RADIATION PATTERN:-




θ=0

Main lobe

side lobe

Θθθθ θ

Nulls

Y

**Back lobes**

**X**

**□=0**

**F**ig. 3-D radiation pattern with main lobe, side lobes and back lobes.

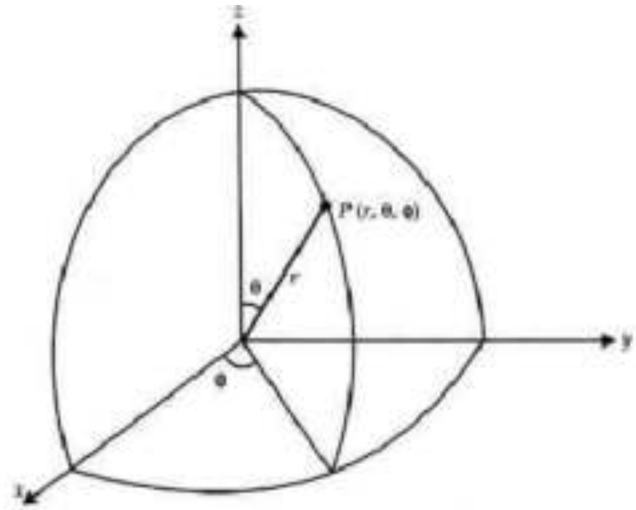



Figure 1.3 A point in spherical coordinate system

$$\theta = \cos^{-1}\frac{z}{\sqrt{x^2+y^2+z^2}} \qquad 0 \le \theta \le \pi$$

$$\phi = \tan^{-1}\frac{y}{x} \qquad 0 \le \phi \le 2\pi$$

The relations between the variables of cylindrical and spherical coordinates are given by

$$\begin{aligned} \mathbf{A} &= (A_r, A_\theta, A_\phi) \\ &= [(A_x \sin\theta\ \cos\phi + A_y \sin\theta\ \sin\phi + A_z\cos\theta), \\ &\qquad (A_x\cos\theta\ \cos\phi + A_y\cos\theta\ \sin\phi - A_z\sin\theta), \\ &\qquad (-A_x\sin\phi + A_y\cos\phi)] \end{aligned}$$

The dot products of $\mathbf{a}_x$, $\mathbf{a}_y$ and $\mathbf{a}_z$ with $\mathbf{a}_r$, $\mathbf{a}_\theta$ and $\mathbf{a}_\phi$ are given by

$$\mathbf{a}_x \cdot \mathbf{a}_r = \sin\theta\ \cos\phi$$
$$\mathbf{a}_x \cdot \mathbf{a}_\theta = \cos\theta\ \cos\phi$$
$$\mathbf{a}_x \cdot \mathbf{a}_\phi = -\sin\phi$$
$$\mathbf{a}_y \cdot \mathbf{a}_r = \sin\theta\ \sin\phi$$
$$\mathbf{a}_y \cdot \mathbf{a}_\theta = \cos\theta\ \sin\phi$$
$$\mathbf{a}_y \cdot \mathbf{a}_\phi = \cos\phi$$
$$\mathbf{a}_z \cdot \mathbf{a}_r = \cos\theta$$
$$\mathbf{a}_z \cdot \mathbf{a}_\theta = -\sin\theta$$
$$\mathbf{a}_z \cdot \mathbf{a}_\phi = 0$$

Here,

$$A_r = A_x\sin\theta\ \cos\phi + A_y\sin\theta\ \sin\phi + A_z\cos\theta$$
$$A_\theta = A_x\cos\theta\ \cos\phi + A_y\cos\theta\ \sin\phi - A_z\sin\theta$$
$$A_\phi = -A_x\sin\phi + A_y\cos\phi$$

The point $A(x, y, z) = A(\rho, \phi, z) = A(r, \theta, \phi)$ in Cartesian, cylindrical and spherical coordinate systems is shown in a single Figure 1.4 to explain the concept at a glance.

$$\rho = r \sin\theta$$
$$\phi = \phi$$
$$z = r\cos\theta$$
$$r = \sqrt{\rho^2 + z^2}$$
$$\theta = \tan^{-1}\frac{r}{z}$$
$$\phi = \phi$$

The unit vectors of spherical coordinates in terms of Cartesian coordinates are given by

$$\mathbf{a}_r = \sin\theta\ \cos\phi\, \mathbf{a}_x + \sin\theta\ \sin\phi\, \mathbf{a}_y + \cos\theta\, \mathbf{a}_z$$
$$\mathbf{a}_\theta = \cos\theta\ \cos\phi\, \mathbf{a}_x + \cos\theta\ \sin\phi\, \mathbf{a}_y - \sin\theta\, \mathbf{a}_z$$
$$\mathbf{a}_\phi = -\sin\phi\, \mathbf{a}_x + \cos\phi\, \mathbf{a}_y$$

A vector $\mathbf{A} = (A_x, A_y, A_z)$ is expressed in spherical coordinates as

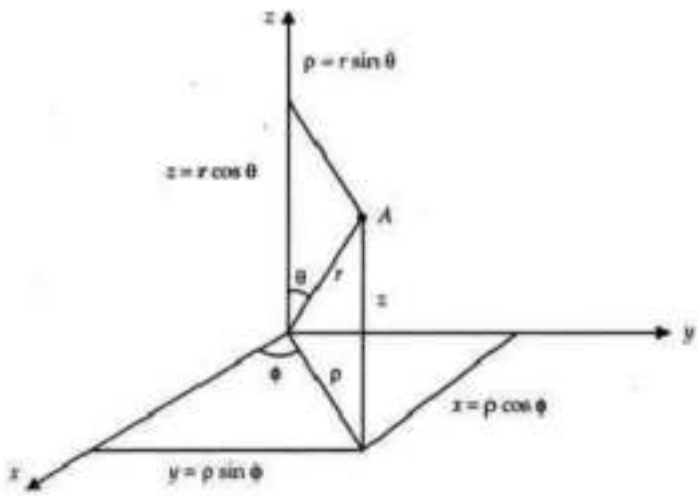
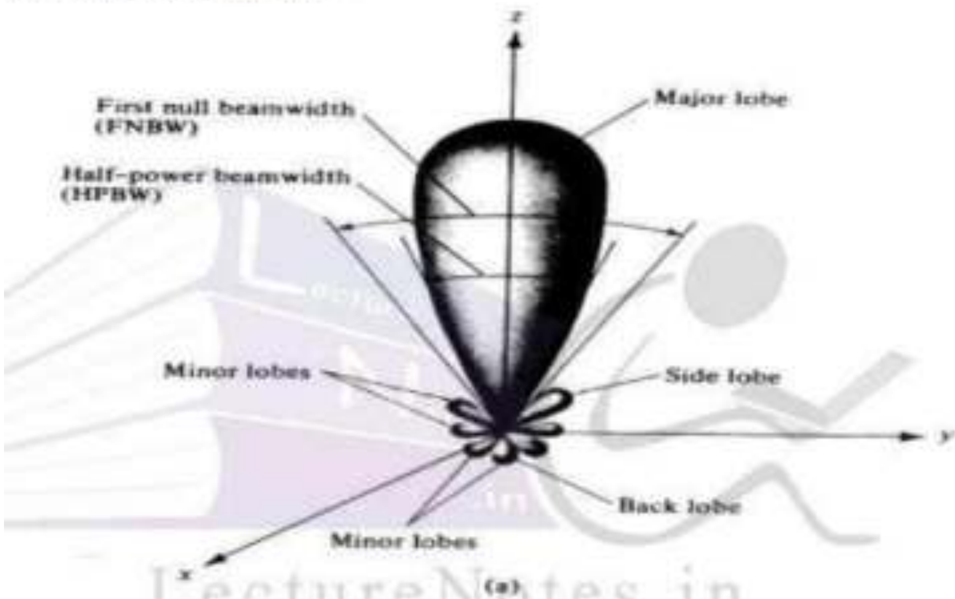



**Figure 1.4** *Coordinates in all the three systems*

**Pattern lobes and beam widths**




(a)

Pattern in spherical co-ordinate system

The relations for differential length, area and volume are given in Table 1.1.

**Table 1.1 Differential quantities in different coordinates**

| *Coordinate System* | *dL* | *dS* | *dv* |
|---|---|---|---|
| Cartesian | $dx\mathbf{a}_x + dy\mathbf{a}_y + dz\mathbf{a}_z$ | $dxdy\mathbf{a}_z$ or $dydz\mathbf{a}_x$ or $dzdx\mathbf{a}_y$ | $dx\,dy\,dz$ |
| Cylindrical | $d\rho\,\mathbf{a}_\rho + \rho\,d\phi\,\mathbf{a}_\phi + dz\,\mathbf{a}_z$ | $\rho d\rho\,d\phi\,\mathbf{a}_z$ or $\rho d\phi\,dz\,\mathbf{a}_\rho$ or $d\rho dz\,\mathbf{a}_\phi$ | $\rho\,d\rho\,d\phi\,dz$ |
| Spherical | $dr\mathbf{a}_r + rd\theta\mathbf{a}_\theta + r\sin\theta\,d\phi\mathbf{a}_\phi$ | $rdr\,d\theta\,\mathbf{a}_\phi$ or $r\sin\theta\,drd\phi\mathbf{a}_\theta$ or $r^2\sin\theta d\theta d\phi\,\mathbf{a}_r$ | $r^2\sin\theta\,dr\,d\theta\,d\phi$ |

The relations between the polar coordinates, $(\rho, \phi)$ and $(x, y)$ of Cartesian Coordinates are

$$x = \rho\cos\phi$$
$$y = \rho\sin\phi$$
$$\rho = \sqrt{x^2 + y^2}$$
$$\phi = \tan^{-1}\left(\frac{y}{x}\right)$$
$$dxdy = \rho d\rho d\phi.$$

,□) →The θ-component of the electric field as a function of angles θ and □ (v/m)
,□) → The □-component of electric field as a function of angle θ and □ (v/m)
,□) → The phase angles of both the field components (deg. Or rad.)

The field pattern is expressed in terms of relative field pattern which is commonly called normalized field pattern. The normalized field pattern is defined as the ration of the field component to its max. value.

Normalized field pattern is a dimensionless quantity with max. value =1.

The normalized field patterns for θ and □ components of Electric Field are given as

Eθn(θ,□) = Eθ(θ,□)/Eθ(θ,□)max.

Similarly E□n(θ,□) = E□(θ,□)/E□(θ,□)max.

We don‘t go for 3D pattern design instead we are preferring polar plots of the relative magnitude of the field in any desired plane are sketched.

These polar plots are plotted in two planes – one containing the antenna and the other normal to it. These planes are called –***Principln planns and thn two plots or pattnrns arn callnd Principln plann pattnrns.”*** These patterns are obtained by plotting by plotting the magnitude of the normalized field strengths. When the magnitude of the normalized field strength is plotted versus θ with constant □. The pattern is called E-plane pattern or vertical pattern.

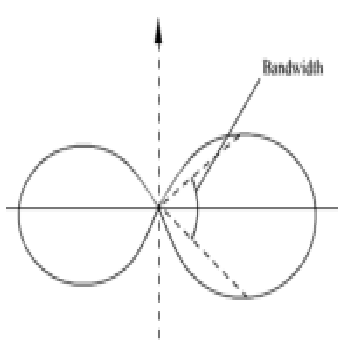



Figure16 (a) Principal E plane pattern

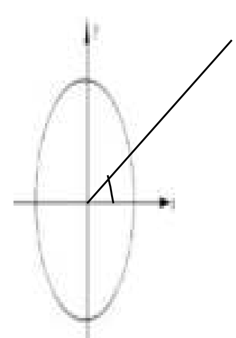
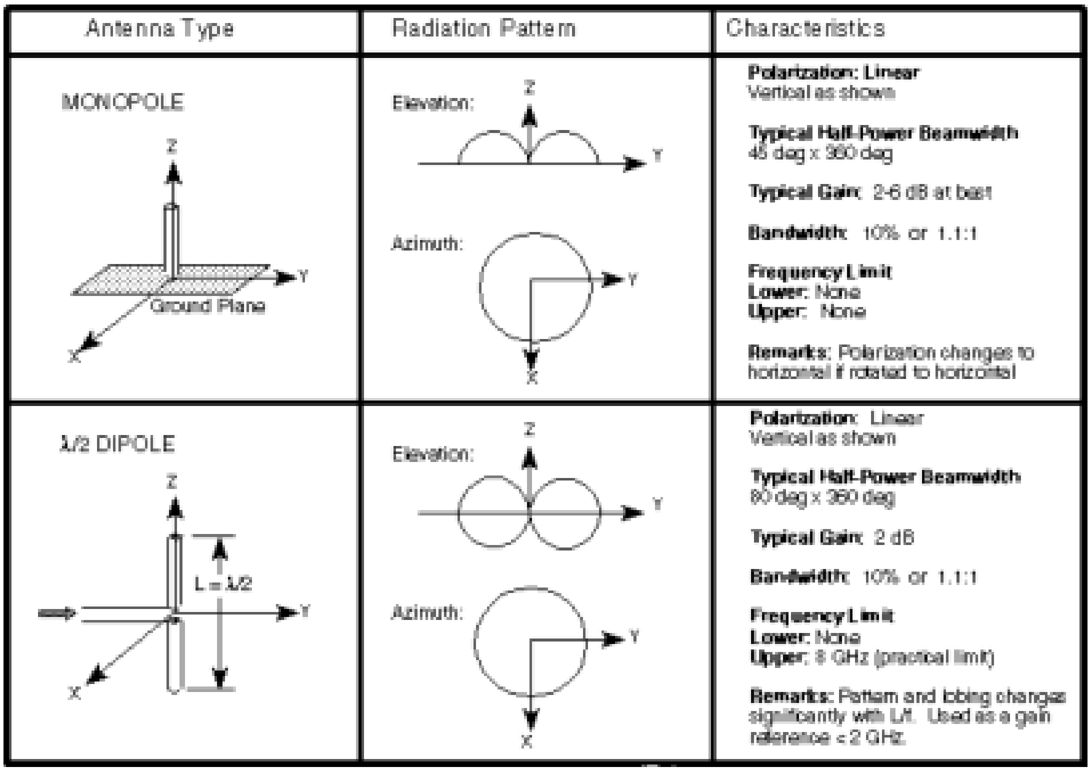


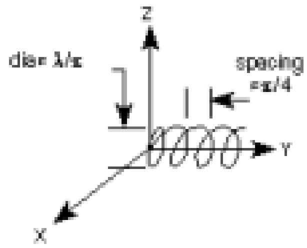
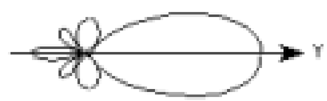
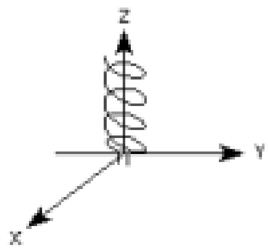
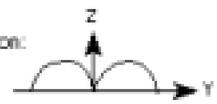
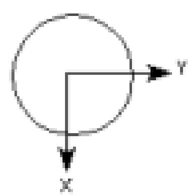
Fig ure16(b) Principal H plane pattern

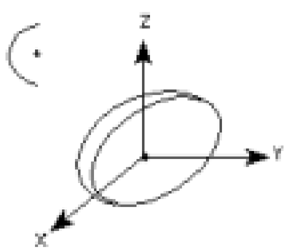
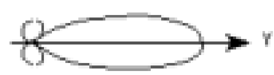
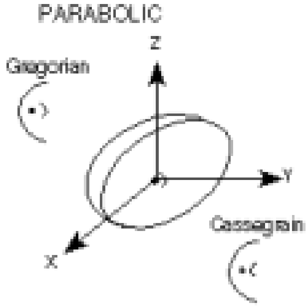
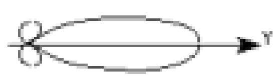
The bandwidth (3 dB beam width) can be found to be $90^0$ in the *E* plane.

**Different Antennas and its Radiation Patterns with their characteristics-**



| Antenna Type | Radiation Pattern | Characteristics |
|---|---|---|
| MONOPOLE<br>Z, Y, X, Ground Plane | Elevation: Z, Y<br>Azimuth: Y, X | **Polarization: Linear**<br>Vertical as shown<br>**Typical Half-Power Beamwidth**<br>45 deg x 360 deg<br>**Typical Gain:** 2-6 dB at best<br>**Bandwidth:** 10% or 1.1:1<br>**Frequency Limit**<br>**Lower:** None<br>**Upper:** None<br>**Remarks:** Polarization changes to horizontal if rotated to horizontal |
| λ/2 DIPOLE<br>Z, Y, X, L = λ/2 | Elevation: Z, Y<br>Azimuth: Y, X | **Polarization:** Linear<br>Vertical as shown<br>**Typical Half-Power Beamwidth**<br>80 deg x 360 deg<br>**Typical Gain:** 2 dB<br>**Bandwidth:** 10% or 1.1:1<br>**Frequency Limit**<br>**Lower:** None<br>**Upper:** 8 GHz (practical limit)<br>**Remarks:** Pattern and lobing changes significantly with L/f. Used as a gain reference < 2 GHz. |

| Antenna Type | Radiation Pattern | Characteristics |
|---|---|---|
| AXIAL MODE HELIX  | Elevation & Azimuth  | **Polarization:** Circular<br>Left hand as shown<br>**Typical Half-Power Beamwidth:** 50 deg x 50 deg<br>**Typical Gain:** 10 dB<br>**Bandwidth:** 52% or 1.7:1<br>**Frequency Limit**<br>**Lower:** 100 MHz<br>**Upper:** 3 GHz<br>**Remarks:** Number of loops >3 |
| NORMAL MODE HELIX  | Elevation:  Azimuth:  | **Polarization:**<br>Circular - with an ideal pitch to diameter ratio.<br>**Typical Half-Power Beamwidth:** 60 deg x 360 deg<br>**Typical Gain:** 0 dB<br>**Bandwidth:** 5% or 1.05:1<br>**Frequency Limit**<br>**Lower:** 100 MHz<br>**Upper:** 3 GHz |

| Antenna Type | Radiation Pattern | Characteristics |
|---|---|---|
| PARABOLIC (Prime)  | Elevation & Azimuth  | **Polarization:**<br>Takes polarization of feed<br>**Typical Half-Power Beamwidth:** 1 to 10 deg<br>**Typical Gain:** 20 to 30 dB<br>**Bandwidth:** 33% or 1.4:1<br>limited mostly by feed<br>**Frequency Limit:**<br>**Lower:** 400 MHz<br>**Upper:** 13+ GHz |
| PARABOLIC  | Elevation & Azimuth  | **Polarization:**<br>Takes polarization of feed<br>**Typical Half-Power Beamwidth:** 1 to 10 deg<br>**Typical Gain:** 20 to 30 dB<br>**Bandwidth:** 33% or 1.4:1<br>**Frequency Limit:**<br>**Lower:** 400 MHz<br>**Upper:** 13+ GHz |

**BEAM AREA or BEAM SOLID ANGLE (ǍA):-**

In polar two-dimensional coordinates an incremental area *dA* on the surface of sphere is the product of the length *r dθ* in the θ direction and *r sin θ dΦ* in the Φ direction as shownin figure.

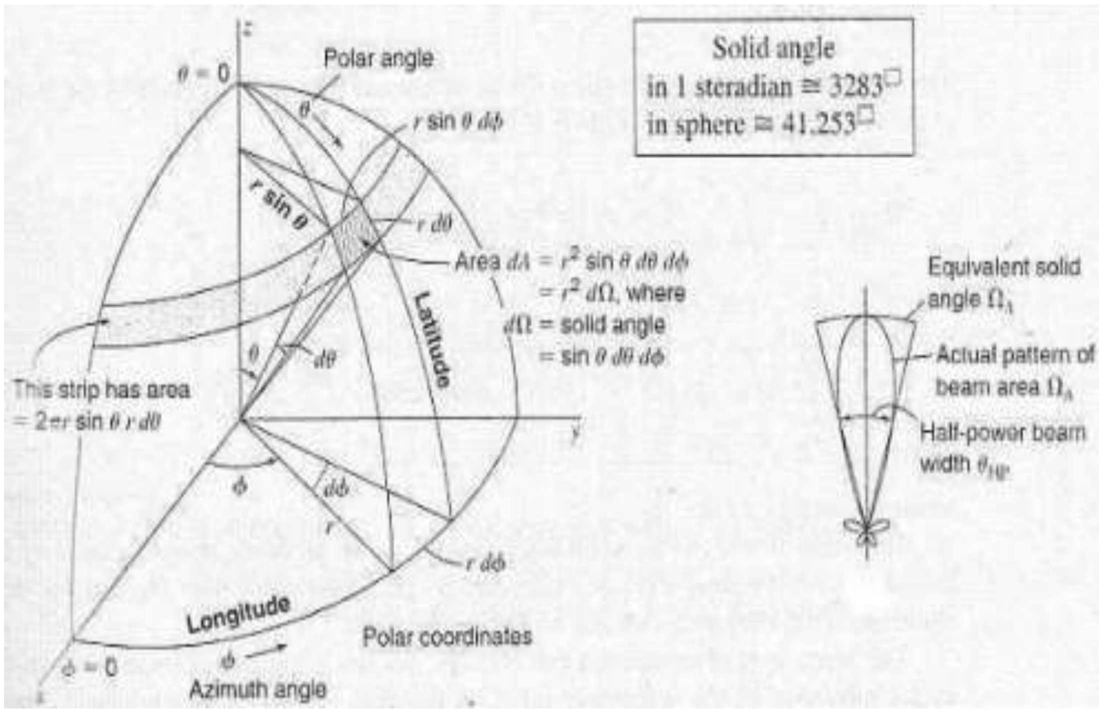
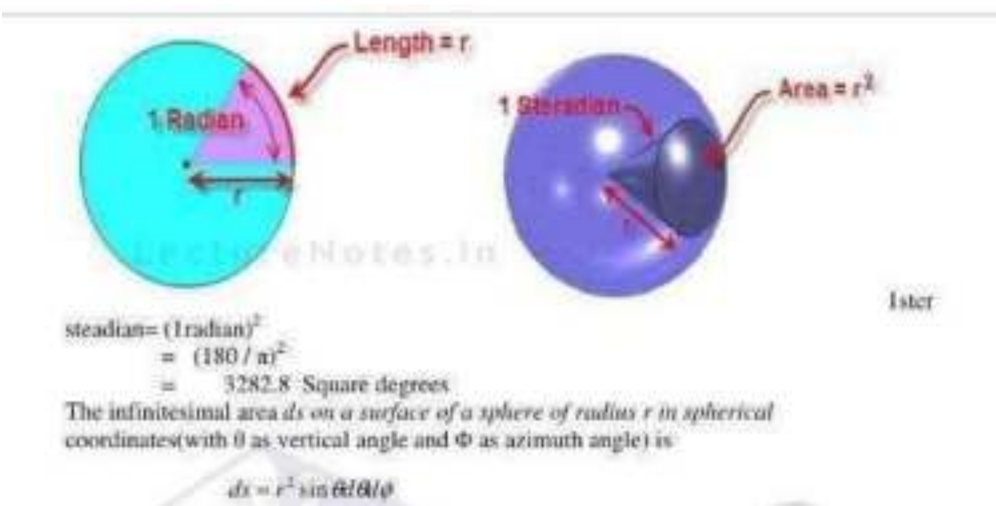



Figure 2: radian and steradian



Thus

$$dA = (r d\theta)(r \sin\theta\, d\Phi) = r^2\, d\Omega = dS$$

Where,

$d\Omega$ = solid angle expressed in steradians. = $\sin\theta\, d\theta\, d\phi$ steradian

The area of the strip of width $r\, d\theta$ extending around the sphere at a constant angle $\theta$ is given by $(2\pi r \sin\theta)(r\, d\theta)$. Integrating this for $\theta$ values from 0 to π yields the area of thesphere. Thus,

Area of sphere = $2\pi r^2$

$$= 2\pi r^2 \int_{\theta=0}^{\pi} \sin\theta\, d\theta = 4\pi r^2$$

Where,

4π = Solid angle subtended by a sphere

The beam area or beam solid angle or $\Omega_A$ of an antenna is given by the integral of the normalized power pattern over a sphere

$$\text{Beam area, } \Omega_A = \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} P_n(\theta,\phi) \sin\theta\, d\theta\, d\phi$$

$$= \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} P_n(\theta,\phi)\, d\Omega \text{ steradian}$$

Where, $d\Omega = \sin\theta\, d\theta\, d\Phi$

Many times $\Omega_A$ is described interms of the angles subtended by half power points of the main lobe.

Equivalent solid angle $\Omega_A$

Pattern Of beam area

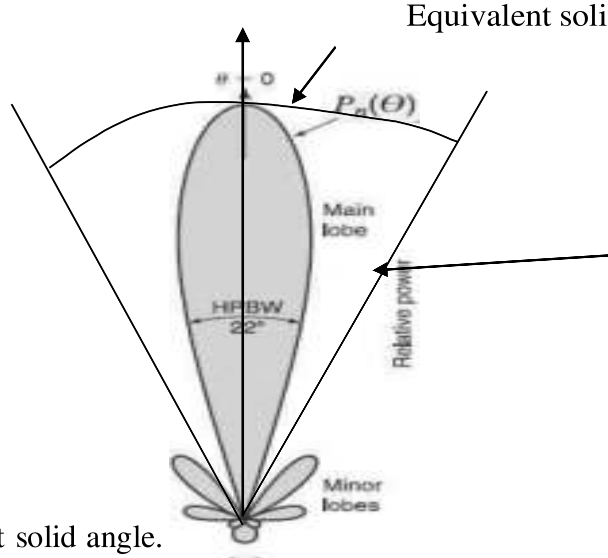
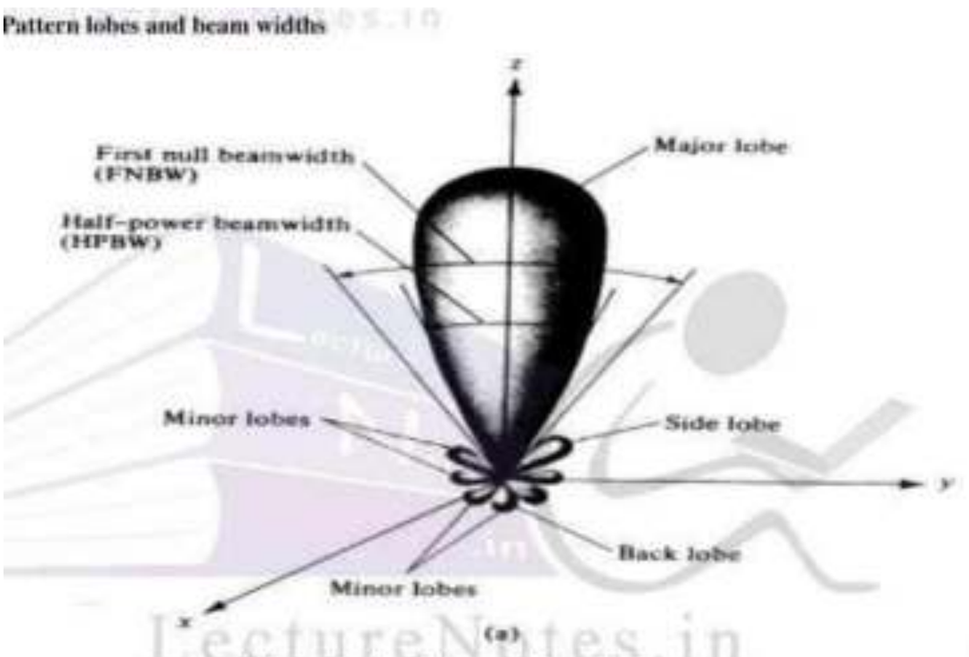



Fig. Representation of equivalent solid angle.

The beam area can be written as $\Omega_A \approx \theta_{HP}\, \phi_{HP}$ steradian , $\theta_{HP}$ & $\phi_{HP}$ hald power beam widths neglecting minor lobes.




Pattern in spherical co-ordinate system

**RADIATION INTENSITY:-**

The power radiated from an antenna per unit solid angle is called the radiation intensity *U* (watts per steradian or per square degree). The normalized power pattern of the previous section can also be expressed in terms of this parameter as the ratio of the radiation intensity *U (θ , Φ ),* as a function of angle, to its maximum value. Thus,

Pn(θ,Φ) = U(θ,Φ) /U(θ,Φ)max = S(θ,Φ)/S(θ,Φ)max.

Where as the Poynting vector *S* depends on the distance from the antenna (varying inversely as the square of the distance), the radiation intensity *U* is independent of the distance, assuming in both cases that we are in the far field of the antenna.

The total power radiated can be expressed in terms of radiation intensity

$$P_{rad} = \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} U(\theta,\phi)\, d\Omega$$

$U(\theta,\phi)$ is also time average power unit solid angle then $U_{avg} = \frac{P_{rad}}{4\pi}$ Average radiation intensity

)max.

$) = \frac{U(\theta,\Phi)}{U(\theta,\Phi)_{max}}$

**BEAM EFFICIENCY :-**

The beam area $\breve{A}A$ (or beam solid angle) consists of the main beam area (or solid angle) $\Omega M$ plus the minor-lobe area (or solid angle) $\Omega\ m$ . Thus,

$\Omega A = \Omega M + \Omega\ m$

The ratio of the main beam area to the (total) beam area is called the (main) beam efficiency ÄM Thus,

$$= \frac{POWER\ TRANSMITTED\ OR\ RECEIVED\ WITH\ IN\ THE\ CONE\ ANGLE\ \theta 1}{POWER\ TRANSMITTED\ OR\ RECEIVED\ BY\ ANTENNA}$$

Where θ1 = half angel of the cone within which the percentage of total power is forced. Mathematically beam efficiency is given by

$$BE = \frac{\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\theta 1} U(\theta,\phi) \sin\theta\, d\theta\, d\phi}{\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} U(\theta,\phi) \sin\theta\, d\theta\, d\phi}$$

The beam efficiency can be expressed in terms of the main beam area ($\Omega M$) and total area ($\Omega A$), then the beam efficiency is defined as the ratio of the main beam area to the total beam area, given by

Beam Efficiency = ÄM = $\Omega M / \Omega A$ (dimensionless)

And $\Omega A = \Omega M + \Omega m$ *(main beam area + minor lobe area)*

1= $\Omega M/\Omega A + \Omega m/\Omega A$ = ÄM + Äm

The ratio of the minor-lobe area ( $\Omega m$ ) to the (total) beam area *is* called the stray factor. Thus,

Stray factor = Äm = $\Omega\ m / \Omega A$.

**DIRECTIVITY:-**

Directivity of an antenna or array is a measure of the antenna_s ability to focus the energy in one or more specific directions. You can determine an antenna_s directivity by looking at its radiation pattern. In an array propagating a given amount of energy, more radiation takes place in certain directions than in others. The elements in the array can be arranged so they change the pattern and distribute the energy more evenly in all directions. The opposite is also possible. The elements can be arranged so the radiated energy is *focused* in one direction. The elements can be considered as a group of antennas fed from a common source.

It is defined as the ratio of maximum radiation intensity of subject or test antenna to the radiation intensity of an isotropic antenna.

(or)

Directivity is defined as the ratio of maximum radiation intensity to the average radiation intensity.

Directivity (D) in terms of total power radiated is,

$$D = 4\pi \times \frac{MAXIMUM\ RADIATION\ INTENSITY}{TOTAL\ POWER\ RADIATED}$$

**GAIN: -**

Gain is a parameter which measures the degree of directivity of the antenna's radiation pattern. A high-gain antenna will preferentially radiate in a particular direction. Specifically, the *antenna gain*, or *power gain* of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity radiated at the same distance by a hypothetical isotropic antenna.

GAIN=

$$\frac{INTENSITY\ RADIATED\ BY\ THE\ ANTENNA\ IN\ THE\ DIRECTION\ OF\ MA.OUT\ AT\ AN\ ORBITRARY\ DISTANCE}{INTENSITY\ RADIATED\ AT\ THE\ SAME\ DISTANCE\ BY\ A\ HYPOTHETICAL\ ISOTROPIC\ ANTENNA} \quad \text{—(1)}$$

As we mentioned earlier, some antennas are highly directional. That is, they propagate more energy in certain directions than in others. The ratio between the amount of energy propagated in these directions and the energy that would be propagated if the antenna were not directional is known as antenna GAIN. The gain of an antenna is constant. whether the antenna is used for transmitting or receiving.

□)
is defined by

$$D(□) = \frac{\text{Power radiated per unit solid angle}}{\text{Average power radiated per unit solid angle}} \text{---------(2)}$$

If Pr is the radiated power, the $\frac{dPr}{dA}$ gives the amount of power radiated per unit solid angle. Had this power beam uniformly radiated in all directions then average power radiated per unit solid angle is $\frac{Pr}{4\pi}$

$$D(□) = \frac{\frac{dPr}{d\Omega}}{\frac{P}{4\pi}} = 4\pi \times \frac{\frac{dPr}{d\Omega}}{Pr} \text{---------------------------(3)}$$

The maximum of directivity function is called the directivity.

In defining directivity function total radiated power is taken as the reference. Another parameter called the gain of an antenna is defined in the similar manner which takes into account the total input power rather than the total radiated power is used as the reference. The amount of power given as input to the antenna is not fully radiated.

$P_r = \eta P_{in}$ .......................................(4)
where η is the radiation efficiency of the antenna.

The gain of the antenna is defined as

$$G(□) = 4\pi \frac{\text{RADIATED POWER PER UNIT SOLID ANGLY}}{\text{INPUT POWER}} \text{-------------(5)}$$

□) ---------------------------------------------- (6)

The maximum gain function is termed as gain of the antenna.

Another parameter which incorporates the gain is effective isotropic radiated power or EIRP which is defined as the product of the input power and maximum gain or simply the gain. An antenna with a gain of 100 and input power of 1 W is equally effective as an antenna having a gain of 50 and input power 2 W.

**□)] and DIRECTIVITY[D]:-**

- An isotropic antenna is the omni directional antenna. If the antenna were isotropic i.e.,if it were to radiate uniformly in all directions, then the power density at all the points on the surface of a sphere will be same.
- The average power is expressed in terms of radiated power as

$P_{avg} = P_{rad}/4\pi r^2$ w/m$^2$

,□) to the average power radiated.

- For isotropic antenna, the value of the directive gain is unity.

□)/$P_{rad}/4\pi r^2$

□) =

D

Or

$$\frac{Pd(\theta,\phi)}{Prad/4\pi r2} \; r^2$$

- The numerator in the above ratio is the radiation intensity while the denominator is the average value of radiation intensity.
- So directive gain

G

D

$U avg$

□) = $U(\theta,\phi)$ $\overline{\phantom{xx}}$ = 4π $\frac{U(\theta,\phi)}{Prad}$

- Thus the directive gain can be defined as the measure of the concentration of the radiated ,□).
- The ratio of the max. Power density to the average power radiated is called max. Directive gain or directivity of the antenna, denoted by $G_{Dmax}$. Or D

-

$$D = G_{Dmax} = \frac{Pdmax}{Prad/4\pi r2}$$

Directivity can also be defined as ,

D = $G_{Dmax}$ = $U_{max.}$ / $U_{avg.}$ = 4π $U_{max.}$/$P_{rad}$

Directivity is a dimensionless quantity and can also be expressed in terms of Electric FieldIntensity as

□ =

$$D_{max} = \frac{4\pi |E_{max.}|^2}{\int_0^{2\pi}\int_0^{\pi} |(\theta, \phi)| \sin\theta \, d\theta \, d\phi}$$

0 0 0 0

Ee know that,

Pavg = $\frac{1}{4\pi}\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} P(\theta, \phi)$ sin θ dθ dφ

And, dΩ = sin θ dθ dφ

Therefore Pavg = $\frac{1}{4\pi}\int_{4\pi} P(\theta, \phi)\, d\Omega$ W/sr

Hence , D = $\frac{Pdmax.}{Pavg}$ = $\frac{P(\theta,\phi)max}{\frac{1}{4\pi}\int_{4\pi} P(\theta,\phi)\, d\Omega}$ , or D = $\frac{1}{\frac{1}{4\pi}\int_{4\pi}\left[\frac{P(\theta,\phi)}{P(\theta,\phi)max.}\right] d\Omega}$

□) = Normalised power pattern

D = $\frac{4\pi}{\int_{4\pi} P_n(\theta,\phi)\, d\Omega}$ = $\frac{4\pi}{\Omega A}$

If the half power beam widths of an antenna are known then,

D = 41253$^{d}$/ $\theta_{HP}^{\circ}$ $\phi_{HP}^{\circ}$

Where 41253$^{d}$ = no.of square degrees in sphere = 4π $\left(\frac{180}{\pi}\right)^2$ square degrees

$\theta_{HP^\circ}$ =HPBW in one principle plane

$\phi_{HP^\circ}$ = HPBW in other principle plane.

Above equation is obtained by neglecting minor lobes. If we consider minor lobes too, then the approximation formula for directivity is

D = 40000$^{db}$/ θ ° HP HP °

**DIRECTIVITY AND RESOLUTION**:-

The resolution of an antenna is defined as half of the beam width between first nulls,

$$\text{Resolution} = \frac{FNBW}{2}$$

But half the beam width between first nulls is approximately equal to the HPBW of an antenna.

$$\text{HPBW} \approx \frac{FNBW}{2}$$

*Practically , HPBW is slightly less than FNBW/2

Also we know that, the antenna beam area is given by the product of two half power beamwidth in two principle planes.

$$\Omega_A = \theta_{HP}\,\phi_{HP} \approx \left(\frac{FNBW}{2}\right)\theta\left(\frac{FNBW}{2}\right)\phi$$

If there are ‗N' no.of point sources of radiation distributed uniformly, then antenna resolve those and is given by

$$N = \frac{4\pi}{\Omega_A};$$ $\Omega_A$ =beam area expressed in sr.

But by the definition, the directivity of antenna isdefined as, $D = \frac{4\pi}{\Omega_A}$

Hence D = N → so ideally no. Of point sources resolved by an antenna is equal todirectivity of an antenna.

The resolution of antenna is also called Rayleigh Resolution. The expression $D = \frac{4\pi}{\Omega_A}$ represents no. Of beam area of antenna pattern. D = N represents no. Of point sourcesresolved by antenna in the sky which is ideally equal to directivity of an antenna.

**)] AND RADIATION EFFICIENCY:**

The practical antenna is made up of a conductor having finite conductivity. Hence we must consider ohmic power loss of the antenna. If the practical antenna has ohmic losses ($I^2R$) represented by $P_{loss}$, then the power radiated Prad is less than the power radiated Prad is less than the input power Pin

$P_{rad} = \eta_r P_{in}$ ; $P_{rad}/P_{in} = \eta_r$

Where $\eta_r$ is radiation efficiency of an antenna

But the total input power to the antenna is Pin = Prad + Ploss

$$\text{So, } \eta_r = \frac{P_{rad}}{P_{rad} + P_{loss}}$$

The power radiated and the ohmic power loss can be expressed in terms of r.m.s. current as $P_{rad} = I_{rms}^2 R_{rad}$ and $P_{loss} = I_{rms}^2 R_{loss}$

Then the radiation efficiency is given by

$$\eta = \frac{R_{rad}}{R_{rad} + R_{loss}}$$

The ratio of the power radiated in a particular direction , , to the actual power input to the antenna is called power gain of antenna.

The power gain of the antenna denoted by GP $\theta$, , and is given by

Gp $\theta$, , = Pd $\theta$, , /Pin

The maximum power gain can be defined as the ratio of the max. Radiation intensity to the radiation intensity due to isotropic lossless antenna.

$$G_{pmax} = \frac{\text{Maximum radiation intensity}}{\text{Radiation intensity due to isotropic loss less antenna}}$$

$$G_{pmax} = \frac{U_{max}}{\left(\frac{P_{in}}{4\pi}\right)}$$

Substituting value of Umax in the expression for maximum power gain

$G_{Pmax} = \frac{\eta_r (P_{in}/4\pi)\, G_{Dmax}}{(P_{in}/4\pi)}$. $G_{Pmax} = \eta_r\, G_{Dmax}$.

$= \eta_r D$

For many practical antennas the radiation efficiency $\eta_r$ is 100% then the maximumpower gain is approx. Same as the directivity or the max, directional gain of the antenna.

Power gain & directional gain are expressed in (dB)

**RADIATION RESISTANCE OF SHORT ELECTRIC DIPOLE:-**

Let us now calculate the radiation resistance of the short dipole of Fig. 6–1*b*. This may bedone as follows.The Poynting vector of the far field is integrated over a large sphere to obtain the total power radiated. This power is then equated to $I^2R$ where $I$ is the rms current on the dipole and $R$ is a resistance, called the radiation resistance of the dipole.

The *average* Poynting vector is given by

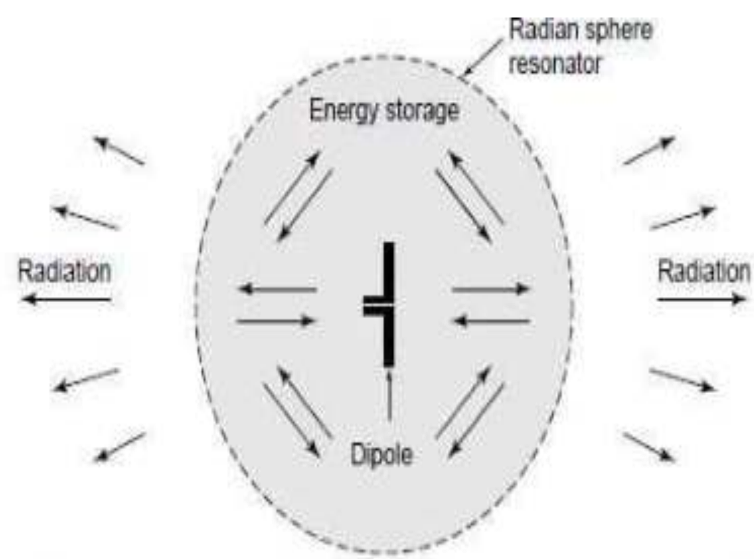



**Figure 6-6** Sketch suggesting that within the radian sphere at $r = \lambda/2\pi = 0.16\lambda$ the situation is like that inside a resonator with high-density pulsating energy accompanied by leakage which is radiated.

$$S = \frac{1}{2}\text{Re}(E \times H^*) \tag{1}$$

The far-field components are $E_\theta$ and $H_\phi$ so that the radial component of the Poynting vector is

$$S_r = \frac{1}{2}\text{Re}\, E_\theta H_\phi^* \tag{2}$$

where $E_\theta$ and $H_\phi^*$ are complex.

where the angles are as shown in Fig. 6-2 and $|H_\phi|$ is the absolute value of the magnetic field, which from (6-3-18) is

$$|H_\phi| = \frac{\omega I_0 L \sin\theta}{4\pi c r} \tag{6}$$

Substituting this into (5), we have

$$P = \frac{1}{32}\sqrt{\frac{\mu}{\varepsilon}}\frac{\beta^2 I_0^2 L^2}{\pi^2}\int_0^{2\pi}\int_0^{\pi} \sin^3\theta \, d\theta \, d\phi \tag{7}$$

The double integral equals $8\pi/3$ and (7) becomes

$$P = \sqrt{\frac{\mu}{\varepsilon}}\frac{\beta^2 I_0^2 L^2}{12\pi} \tag{8}$$

This is the *average* power or rate at which energy is streaming out of a sphere surrounding the dipole. Hence, it is equal to the power radiated. Assuming no losses, it is also equal to the power delivered to the dipole.

Therefore, $P$ must be equal to the square of the rms current $I$ flowing on the dipole times a resistance $R_r$ called the *radiation resistance* of the dipole. Thus,

$$\sqrt{\frac{\mu}{\varepsilon}}\frac{\beta^2 I_0^2 L^2}{12\pi} = \left(\frac{I_0}{\sqrt{2}}\right)^2 R_r \tag{9}$$

Solving for $R_r$,

$$R_r = \sqrt{\frac{\mu}{\varepsilon}}\frac{\beta^2 L^2}{6\pi} \tag{10}$$

For air or vacuum $\sqrt{\mu/\varepsilon} = \sqrt{\mu_0/\varepsilon_0} = 377 = 120\pi\,\Omega$ so that (10) becomes[1]

| | | |
|---|---|---|
| ***Dipole with uniform current*** | $R_r = 80\pi^2\left(\frac{L}{\lambda}\right)^2 = 80\pi^2 L_\lambda^2 = 790 L_\lambda^2 \quad (\Omega)$ | ***Radiation resistance*** |

(11)

As an example suppose that $L_\lambda = \frac{1}{10}$. Then $R_r = 7.9\ \Omega$. If $L_\lambda = 0.01$, then $R_r = 0.08\ \Omega$. Thus, the radiation resistance of a short dipole is small.

In developing the field expressions for the short dipole, which were used in obtaining (11), the restriction was made that $\lambda \gg L$. This made it possible to neglect the phase difference of field contributions from different parts of the dipole. If $L_\lambda = \frac{1}{2}$ we violate this assumption, but, as a matter of interest, let us find what the radiation resistance of a $\lambda/2$ dipole is, when calculated in this way. Then for $L_\lambda = \frac{1}{2}$, we obtain $R_r = 197\ \Omega$. The correct value is 168 $\Omega$ (see Prob. 6-6-1), which indicates the magnitude of the error introduced by violating the restriction that $\lambda \gg L$ to the extent of taking $L = \lambda/2$.

It has been assumed that with end loading (see Fig. 6-1*a*) the dipole current is uniform. However, with no end loading the current must be zero at the ends and, if the dipole is short, the current tapers almost linearly from a maximum at the center to zero at the ends, as in Fig. 2-12, with an average value of $\frac{1}{2}$ of the maximum. Modifying (8) for the general case where the current is not uniform on the dipole, the *radiated power* is

$$P = \sqrt{\frac{\mu}{\varepsilon}} \frac{\beta^2 I_{av}^2 L^2}{12\pi} \quad \text{(W)} \tag{12}$$

where $I_{av}$ = amplitude of *average current* on dipole (peak value in time)

The *power delivered* to the dipole is, as before,

$$P = \frac{1}{2} I_0^2 R_r \quad \text{(W)} \tag{13}$$

where $I_0$ = amplitude of *terminal current* of center-fed dipole (peak value in time). Equating the *power radiated* (12) to the *power delivered* (13) yields, for free space ($\mu = \mu_0$ and $\varepsilon = \varepsilon_0$), a radiation resistance

$$R_r = 790 \left( \frac{I_{av}}{I_0} \right)^2 L_\lambda^2 \quad (\Omega) \qquad (14)^2$$

For a short dipole without end loading, we have $I_{av} = \frac{1}{2} I_0$, as noted above, and (14) becomes

$$R_r = 197 L_\lambda^2 \quad (\Omega) \tag{15}$$

**NATURAL CURRENT DISTRIBUTIONS OF FAR FIELDS AND PATTERNS OF THIN LINEAR CENTER-FED ANTENNAS OF DIFFERENT LENGTHS:-**

In this section expressions for the far-field patterns of thin linear antennas will be developed. It is assumed that the antennas are symmetrically fed at the center by a balanced two-wire transmission line. The antennas may be of any length, but it is assumed that the current distribution is sinusoidal. Current-distribution measurements indicate that this is a good assumption provided that the antenna is thin, i.e., when the conductor diameter is less than, say, $\lambda/100$. Thus, the sinusoidal current distribution approximates the natural distribution on thin antennas. Examples of the approximate natural-current distributions on a number of thin, linear center-fed antennas of different length are illustrated in Fig. 6–7. The currents are in phase over each $\lambda/2$ section and in opposite phase over the next.

Referring to Fig. 6–8, let us now proceed to develop the far-field equations for a symmetrical, thin, linear, center-fed antenna of length $L$. The retarded value of the current at any point $z$ on the antenna referred to a point at a distance $s$ is

$$[I] = I_0 \sin\left[\frac{2\pi}{\lambda}\left(\frac{L}{2} \pm z\right)\right] e^{j\omega[t-(r/c)]} \tag{1}$$

In (1) the function

$$\sin\left[\frac{2\pi}{\lambda}\left(\frac{L}{2} \pm z\right)\right]$$

is the form factor for the current on the antenna. The expression $(L/2)+z$ is used when $z < 0$ and $(L/2)-z$ is used when $z > 0$. By regarding the antenna as made up of a series of infinitesimal dipoles of length $dz$, the field of the entire antenna may then be obtained by integrating the fields from all of the dipoles making up the antenna with the result1

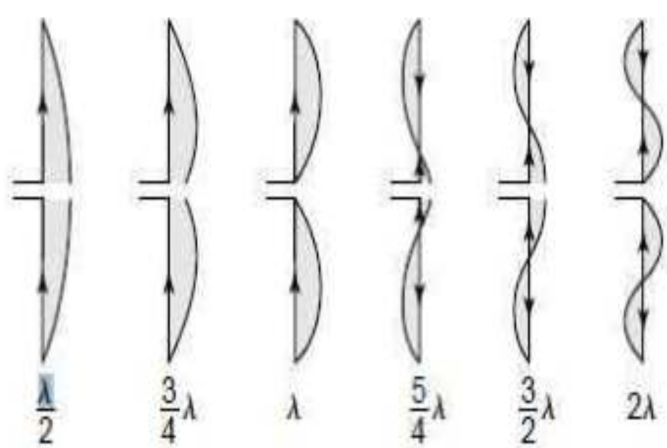



**Figure 6–7** Approximate natural-current distribution for thin, linear, center-fed antennas of various lengths.

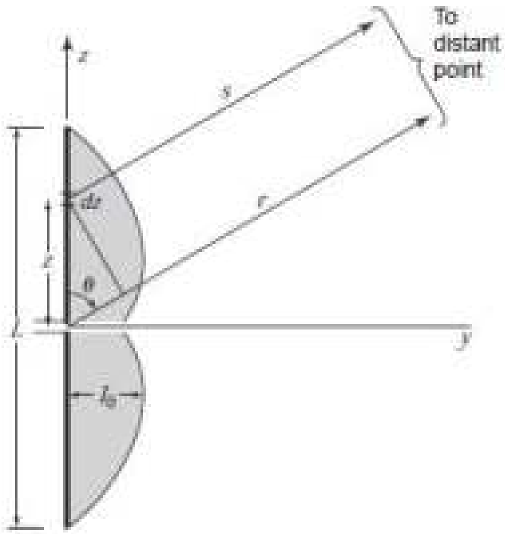



**Figure 6–8** Relations for symmetrical, thin, linear, center-fed antenna of length *L*.

***Far fields of center-fed dipole***

$$H_\phi = \frac{j[I_0]}{2\pi r}\left[\frac{\cos[(\beta L\cos\theta)/2] - \cos(\beta L/2)}{\sin\theta}\right] \tag{2}$$

$$E_\theta = \frac{j60[I_0]}{r}\left[\frac{\cos[(\beta L\cos\theta)/2] - \cos(\beta L/2)}{\sin\theta}\right] \tag{3}$$

where $[I_0] = I_0 e^{j\omega[t-(r/c)]}$ and

$$E_\theta = 120\pi H_\phi \tag{3a}$$

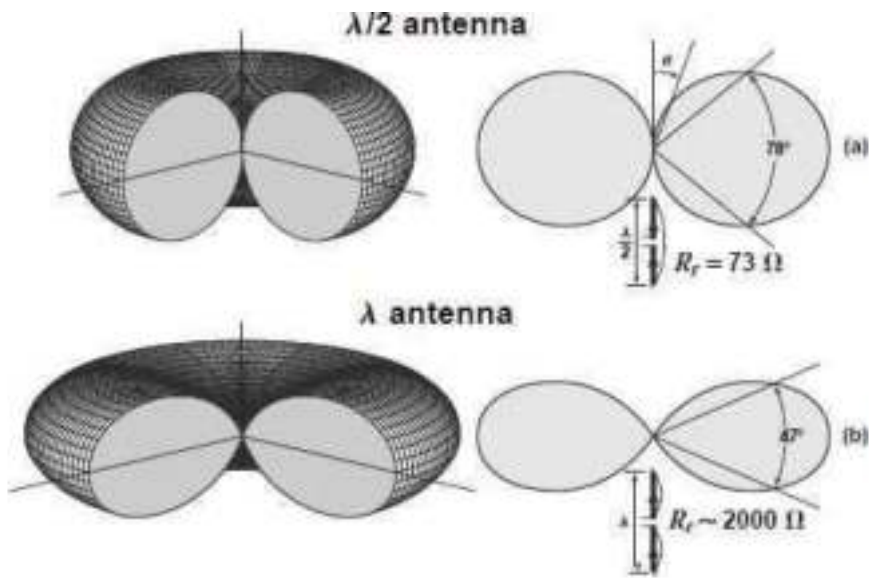
Equations (2), (3) and (3*a*) give the far fields $H\varphi$ and $E\theta$ of a *symmetrical, center-fed, thin linear antenna of length L.* The shape of the far-field pattern is given by the factor in the brackets. The factors preceding the brackets in (2) and (3) give the instantaneous magnitude of the fields as functions of the antenna current and the distance *r*. To obtain the rms value of the field, we let [*I*0] equal the rms current at the location of the current maximum. There is no factor involving phase in (2) or (3), since the center of the antenna is taken as the phase center. Hence any phase change of the fields as a function of $\theta$ will be a jump of 180◦ when the pattern factor changes sign.

As examples of the far-field patterns of linear center-fed antennas, three antennas of different lengths will be considered. Since the amplitude factor is independent of the length, only the relative field patterns as given by the pattern factor will be compared.

**EXAMPLE 6–5.1 $\lambda/2$ Antenna**

When $L = \lambda/2$, the pattern factor becomes $E = \cos[(\pi/2) \cos \theta] \sin \theta$

This pattern is shown in Fig. 6–9*a*. It is only slightly more directional than the pattern of an infinitesimal or short dipole which is given by $\sin \theta$. The beamwidth between half-power points of the




$\lambda/2$ antenna is 78° as compared to 90° for the short dipole.

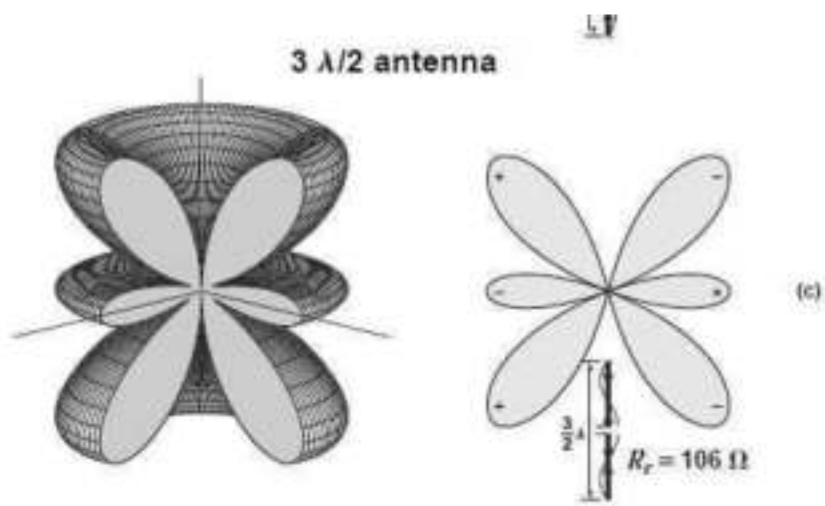



**Figure 6–9** Three-dimensional and polar plots of the patterns of λ/2, λ, and 3 λ/2 antennas. The antennas are center-fed with current distributions assumed sinusoidal as indicated.

## 6-6 Radiation Resistance of λ/2 Antenna

To find the radiation resistance, the Poynting vector is integrated over a large sphere yielding the power radiated, and this power is then equated to $(I_0/\sqrt{2})^2 R_0$, where $R_0$ is the radiation resistance at a current maximum point and $I_0$ is the peak value in time of the current at this point. The total power $P$ radiated was given in (6–4–5)[1] in terms of $H_\phi$ for a short dipole. In (6–4–5), $|H_\phi|$ is the absolute value. Hence, the corresponding value of $H_\phi$ for a linear antenna is obtained from (6–5–2) by putting $|j[I_0]| = I_0$. Substituting this into 6–4–5, we obtain

$$P = \frac{15 I_0^2}{\pi} \int_0^{2\pi} \int_0^{\pi} \frac{\{\cos[(\beta L/2)\cos\theta] - \cos(\beta L/2)\}^2}{\sin\theta} \, d\theta \, d\phi \tag{1}$$

$$= 30 I_0^2 \int_0^{\pi} \frac{\{\cos[(\beta L/2)\cos\theta] - \cos(\beta L/2)\}^2}{\sin\theta} \, d\theta \tag{2}$$

Equating the radiated power as given by (2) to $I_0^2 R_0/2$ we have

$$P = \frac{I_0^2 R_0}{2} \tag{3}$$

and

$$R_0 = 60 \int_0^{\pi} \frac{\{\cos[(\beta L/2)\cos\theta] - \cos(\beta L/2)\}^2}{\sin\theta} \, d\theta \tag{4}$$

where the radiation resistance $R_0$ is referred to the current maximum. In the case of a $\lambda/2$ antenna this is at the center of the antenna or at the terminals of the transmission line (see Fig. 6–7).

---

[1] $P = \iint \mathbf{S} \cdot d\mathbf{s} = \frac{1}{2}\sqrt{\mu/\epsilon} \iint |H_\phi|^2 \, ds$

Proceeding with the evaluation of (4) with the aid of the sine integral, $\mathrm{Si}(x)$, and the cosine integral, $\mathrm{Cin}(x)$, it may be shown that the radiation resistance of the $\lambda/2$ antenna is

$$\boxed{R_r = 30\,\mathrm{Cin}(2\pi) = 30 \times 2.44 = \mathbf{73\ \Omega}} \tag{5}$$

This is the well-known value for the radiation resistance of a thin, linear, center-fed, $\lambda/2$ antenna with sinusoidal current distribution. The terminal impedance also includes some inductive reactance as discussed in Chap. 18. That is,

$$\boxed{Z = 73 + j42.5\ \Omega} \tag{6}$$

To make the reactance zero, that is, to make the antenna resonant, requires that the antenna be shorted a few percent less than $\lambda/2$. This shortening also results in a reduction in the value of the radiation resistance to about 65 Ω.

**POEER RADIATED BY A CURRENT ELEMENT:-**

It can be noted that *E* has no *φ* component and *H* contains only a *φ* component and thus

$E = Erar + E\theta\ a\theta$ and $H = H\varphi a\varphi$ (1)

The power flow can be given by the Poynting vector *P*

$$P = E \times H = (E_r a_r + E_\theta a_\theta) \times H_\phi a_\phi = -E_r H_\phi a_\theta + E_\theta H_\phi a_r = P_\theta a_\theta + P_r a_r \quad (2)$$

where $P_\theta = -E_r H_\phi$

$$= -\frac{2I^2 dl^2 \sin\theta \cos\phi}{16\pi^2 \varepsilon}\left[-\frac{\omega \sin\omega t' \cos\omega t'}{r^3 \upsilon^2} + \frac{\cos^2 \omega t'}{r^4 \upsilon} - \frac{\omega \sin^2 \omega t'}{\omega r^4 \upsilon} + \frac{\sin\omega t' \cos\omega t'}{\omega r^5}\right]$$

$$= \frac{I^2 dl^2 \sin 2\theta}{16\pi^2 \varepsilon}\left[-\frac{\cos 2\omega t'}{r^4 \upsilon} - \frac{\sin 2\omega t'}{2\omega r^5} + \frac{\omega \sin 2\omega t'}{2r^3 \upsilon^2}\right] \quad (3)$$

As the average power in the terms involving sin 2*ωt′* and cos 2*ωt′* over a complete cycle is zero, *Pθ* represents the power which surges back and forth in the *θ* direction and there is no net power flow in the direction of propagation.

$$P_r = E_\theta H_\phi$$

$$= \frac{I^2 dl^2 \sin^2\theta}{16\pi^2 \varepsilon}\left[-\frac{\omega^2 \sin^2 \omega t'}{r^2 \upsilon^3} + \frac{\omega \cos\omega t' \sin\omega t'}{r^3 \upsilon^2} - \frac{\omega \sin^2 \omega t'}{\omega r^4 \upsilon} - \frac{\omega \sin\omega t' \cos\omega t'}{r^3 \upsilon^2} + \frac{\cos^2 \omega t'}{r^4 \upsilon} + \frac{\sin\omega t' \cos\omega t'}{r^5 \omega}\right]$$

$$= \frac{I^2 dl^2 \sin^2\theta}{16\pi^2 \varepsilon}\left[\frac{\cos 2\omega t'}{r^4 \upsilon} - \frac{\omega \sin 2\omega t'}{r^3 \upsilon^2} + \frac{\sin 2\omega t'}{2\omega r^5} + \frac{\omega(1 - \cos 2\omega t')}{2r^2 \upsilon^2}\right]$$

Since sin 2*ωt′* and cos 2*ωt′* terms will not contribute towards average power, all such terms can be eliminated. In view of the remaining terms

$$P_r = \frac{\omega^2 I^2 dl^2 \sin^2\theta}{32\pi^2 r^2 \upsilon^3 \varepsilon} = \frac{1}{2\varepsilon\upsilon}\left(\frac{\omega I dl \sin\theta}{4\pi r \upsilon}\right)^2 = \frac{\eta}{2}\left(\frac{\omega I dl \sin\theta}{4\pi r \upsilon}\right)^2 \text{ watts/sq.m} \quad (4)$$

The amplitudes of components contributing towards net power flow are

$$E_\theta = \frac{\omega I dl \sin\theta}{4\pi r \upsilon^2} = \frac{\eta I dl \sin\theta}{2\pi r} = \frac{60\pi I dl \sin\theta}{\lambda r} \quad (5)$$

$$H_\phi = \frac{\omega I dl \sin\theta}{4\pi r \upsilon} = \frac{I dl \sin\theta}{2\lambda r} \quad (6)$$

$$\frac{E_\theta}{H_\phi} = 120\pi = \eta_0 \approx 377\Omega \quad (7)$$

Parameter $\eta 0$ is called the ***charactnristic impndancn of frnn spacn.***

The total radiated power $P$ can be obtained by integrating the average power over the entire surface of an imaginary sphere of radius $r$.

$$P = \int P_{av} ds \quad \text{where} \quad ds = r d\phi \, r d\theta \sin\theta = 2\pi r^2 \sin\theta d\theta \quad (8)$$

$$P = \int_0^\pi \frac{\eta}{2} \left( \frac{\omega I dl \sin\theta}{4\pi r \upsilon} \right)^2 2\pi r^2 \sin\theta d\theta = \frac{\eta \omega^2 I^2 dl^2}{12\pi \upsilon^2} \text{ watts} \quad (9)$$

In (9), $I$ represents the peak current. If $P$ is to be obtained in terms of effective current $I_{eff}$ , the total power can be written as

$$P = \frac{\eta \omega^2 I_{eff}^2 dl^2}{6\pi \upsilon^2} = \frac{20\omega^2 I_{eff}^2 dl^2}{\upsilon^2} \quad (10)$$

On replacing $\omega$ by $2\pi f$ and $\upsilon$ by the velocity of light $c$, (10) yields

$$P = 20\frac{(2\pi f)^2}{c^2} I_{eff}^2 dl^2 = 80\pi^2 \left(\frac{dl}{\lambda}\right)^2 I_{eff}^2 = R_{rad} I_{eff}^2 \quad (11)$$

where $R_{rad}$ is the radiation resistance. In arriving at (9) from (8), the following relation is employed

$$\int_0^\pi \sin^3\theta d\theta = \left[\frac{1}{3}\cos 3\theta - \cos\theta\right]_0^\pi = 4/3 \quad (12)$$

From (11), the $R_{rad}$ obtained for three different cases of radiating elements shown in Fig. 4–6 are the following:

**Case (a)** Radiation resistance for an element of length $dl$ with uniform current distribution shown in Fig. 4–6a is given by

$$R_{rad} = 80\pi^2 (dl/\lambda)^2 \approx 800 (dl/\lambda)^2 \Omega \quad (13)$$

**Case (b)** Radiation resistance for an element of length $dl$ with non-uniform current distribution shown in Fig. 4–6b is given by

$$R_{rad} = 20\pi^2 (dl/\lambda)^2 \approx 200 (L/\lambda)^2 \Omega \quad (14)$$

**Case (c)** Radiation resistance for an element of length $h = 2dl = 2L$ with non-uniform current distribution

$$R_{rad} = 10\pi^2(L/\lambda)^2 = 100(L/\lambda)^2 \approx 400(h/\lambda)^2\Omega \quad (15)$$

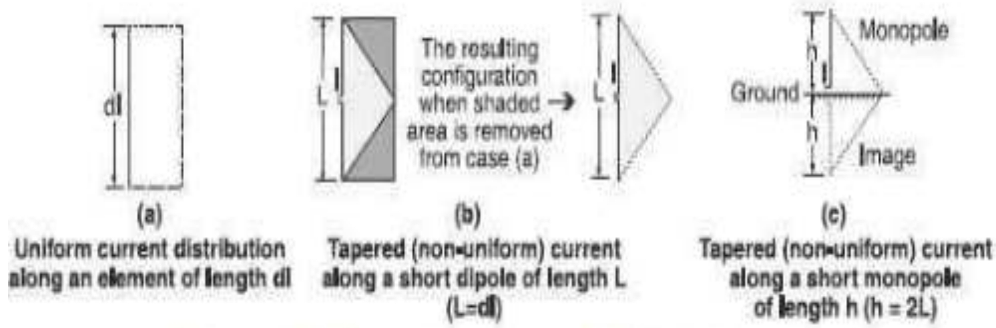



**Figure 4–6** Three different cases of radiating elements.

shown in Fig. 4–6c is given by

***Thnsn rnlations hold good for vnry short antnnnas, that is, up to λ/8 in lnngth***.

**CURRENT DISTRIBUTIONS OF QUARTER EAVE MONOPOLE AND HALF EAVE DIPOLE:**

A half-wave dipole and a quarter-wave monopole are shown. The currents are given as

$I = im \sin \beta(h - z)$ for $z > 0$ and $i = im \sin \beta(h + z)$ for $z < 0$ (1)

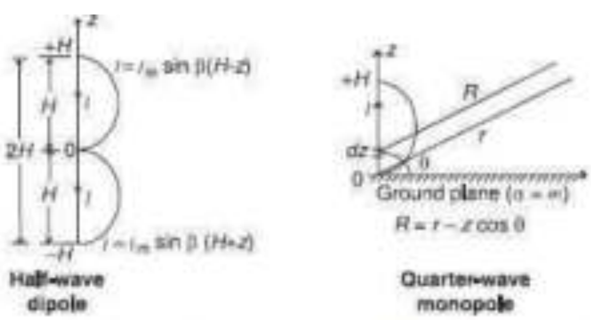



**Figure 4–7** Half-wave dipole or quarter-wave monopole with assumed sinusoidal current distribution.

The dipole or monopole is assumed to be located on a perfectly conducting ground. The field is to be obtained at a point which is so distantly located that the distances $r$ and $R$ (shown in the Fig. 4–7) can be considered to bear the following relation.

$R = r$ for the estimation of amplitude and $R = r - z$ cos for the estimation of phase. (2) Since the current in the dipole is in the $z$-direction, the $z$ component of the differential vector magnetic potential is

$$dA_z = \frac{\mu I dz}{4\pi R} e^{-j\beta R} \tag{3}$$

$$A_z = \frac{\mu}{4\pi} \int_{-H}^{0} \frac{I_m \sin\beta(H+z)}{R} e^{-j\beta R} dz + \frac{\mu}{4\pi} \int_{0}^{H} \frac{I_m \sin\beta(H-z)}{R} e^{-j\beta R} dz$$

$$= \frac{\mu I_m}{4\pi r} e^{-j\beta r} \left[ \int_{-H}^{0} \sin\beta(H+z) e^{j\beta z \cos\theta} dz + \int_{0}^{H} \sin\beta(H-z) e^{j\beta z \cos\theta} dz \right] \tag{4}$$

For $H = \lambda/4$, $\beta H = \pi/2$, $\sin\beta(H+z) = \sin\beta(H-z)$ and $\sin(\pi/2 + \beta z) = \sin(\pi/2 - \beta z) = \cos\beta z$

$$A_z = \frac{\mu I_m}{4\pi r} e^{-j\beta r} \int_{0}^{H} \cos\beta z (e^{j\beta z \cos\theta} + e^{-j\beta z \cos\theta}) dz$$

$$= \frac{\mu I_m}{4\pi r} e^{-j\beta r} 2 \int_{0}^{H} \cos\beta z \cos(\beta z \cos\theta) dz$$

$$= \frac{\mu I_m}{4\pi r} e^{-j\beta r} 2 \int_{0}^{H} [\cos\beta z(1+\cos\theta) + \cos\beta z(1-\cos\theta)] dz$$

$$= \frac{\mu I_m}{4\pi r} e^{-j\beta r} 2 \left[ \frac{\sin\beta z(1+\cos\theta)}{\beta(1+\cos\theta)} + \frac{\sin\beta z(1-\cos\theta)}{\beta(1-\cos\theta)} \right]_0^{\lambda/4}$$

$$= \frac{\mu I_m}{4\pi\beta r} e^{-j\beta r} \left[ \left[ (1-\cos\theta)\cos\left(\frac{\pi}{2}\cos\theta\right) + (1+\cos\theta)\cos\left(\frac{\pi}{2}\cos\theta\right) \right] \frac{1}{\sin^2\theta} \right]$$

$$= \frac{\mu I_m}{2\pi\beta r} e^{-j\beta r} \left[ \frac{\cos[(\pi/2)\cos\theta]}{\sin^2\theta} \right] \tag{5}$$

If $J = J_z$ and $B = \nabla \times A = B_\phi a_\phi$ only, thus $\mu H_\phi = -\frac{\partial A_z}{\partial r} \sin\theta$

$$H_\phi = \frac{j I_m e^{-j\beta r}}{2\pi r} \left[ \frac{\cos[(\pi/2)\cos\theta]}{\sin\theta} \right] \tag{6}$$

$$E_\theta = \eta H_\phi = 120\pi H_\phi = \frac{j60 I_m e^{-j\beta r}}{r} \left[ \frac{\cos[(\pi/2)\cos\theta]}{\sin\theta} \right] \tag{7}$$

The magnitudes of $E_\theta$ and $H_\phi$ are

$$|E_\theta| = \frac{60 I_m}{r} \left[ \frac{\cos[(\pi/2)\cos\theta]}{\sin\theta} \right] \tag{8}$$

$$|H_\phi| = \frac{I_m}{2\pi r} \left[ \frac{\cos[(\pi/2)\cos\theta]}{\sin\theta} \right] \tag{9}$$

$$P_{av} = |E_\theta||H_\phi| = \frac{\eta I_m^2}{8\pi^2 r^2} \left[ \frac{\cos^2[(\pi/2)\cos\theta]}{\sin^2\theta} \right] \tag{10}$$

The total radiated power $P$ is given by $\int Pav\, ds$. Thus

$$P = \frac{\eta I_m^2}{4\pi}\int_0^{\pi/2}\left[\frac{\cos^2[(\pi/2)\cos\theta]}{\sin^2\theta}\right]d\theta \qquad (11)$$

The evaluation of (11) gives

$$P = \frac{0.609\eta I_m^2}{4\pi} = \frac{0.609\eta I_{eff}^2}{2\pi} = 36.5 I_{eff}^2 = I_{eff}^2 R_{rad} \qquad (12)$$

where *Rrad* = 36.5*Ă* is the radiation resistance of a quarter-wave monopole. The radiation resistance of a half-wave dipole is twice of the above, i.e., 73 Ă.

**RADIATION RESISTANCE:**

The radiation resistance of an antenna is defined as the equivalent resistance that would dissipate the same amount power as is radiated by the antenna. For the elementary current element we have discussed so far. From equation (3.26) we find that radiated power density

$$P_{av} = |I|^2 \eta_o (dl)^2 K_o^2 \sin^2\theta / 32 \pi^2 r^2 \, a_r \qquad .(1)$$

**Radiated power :-**

□ o

θ=0 □=0

$= |I|^2 \eta_o (dl)^2 K_o \sin^2\theta / 32 \pi^2$ $2\pi$ □=0  $\pi$ d□ θ=0  $\sin^3\theta \, d\theta$ ……(2)

Where $/2$ $\sin n\theta$ θ=0 = n-1/n but here we have $\pi$ θ=0 $\sin 3\theta$ = 2x $\pi/2$ θ=0 $\sin 3\theta$= 2x2/3

$P_r = |I|^2 \eta_o (dl)^2 K^2 / 12 \pi$.............................................................................. (3)

Further dPr =

$dP_r / dĂ = |I|^2 \eta_o (dl)^2 K_o^2 \sin^2\theta / 32 \pi^2$ ……………………………………………(4)

From (3) and (4)

□) = 1.5 $Sin^2\theta$

□)|max which occurs at $\theta = \frac{\pi}{2}$. If $Rr$ is the radiation resistance of the elementary dipole antenna, then

$\frac{1}{2} |I|^2 R_r = P_r$

Substituting $P_r$ from eq(3) we get

$R_r = \eta_o /6\pi (2\pi \frac{dl}{\lambda 0})^2$ ……………………………………………………………… (5)

Substituting $\eta_o$ as 120π

$R_r = 480\pi^3/6\pi (\frac{}{\lambda 0})^2$ ……………………………………………………………………… (6)

$R_r = 480\pi^2/6\pi (\frac{}{\lambda 0})^2$ ………………………………………………………………………(7)

For such an elementary dipole antenna the principal *E* and *H* plane pattern are shown in Fig 16(a) and (b).

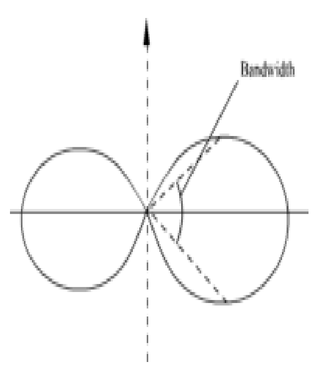



Figure16 (a) Principal E plane pattern

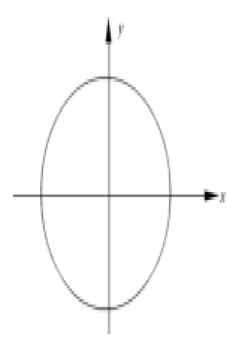



Fig ure16(b) Principal H plane pattern

The bandwidth (3 dB beam width) can be found to be $90^0$ in the $E$ plane.

### 1.8 EFFECTIVE AREA OF AN ANTENNA:-

An antenna operating as a receiving antenna extracts power from an incident electromagnetic wave. The incident wave on a receiving antenna may be assumed to be a uniform plane wave being intercepted by the antenna. This is illustrated in Fig 3.5. The incident electric field sets up currents in the antenna and delivers power to any load connected to the antenna. The induced current also re-radiates fields known as scattered field. The total electric field outside the antenna will be sum of the incident and scattered fields and for perfectly conducing antenna the total tangential electric field component must vanish on the antenna surface.

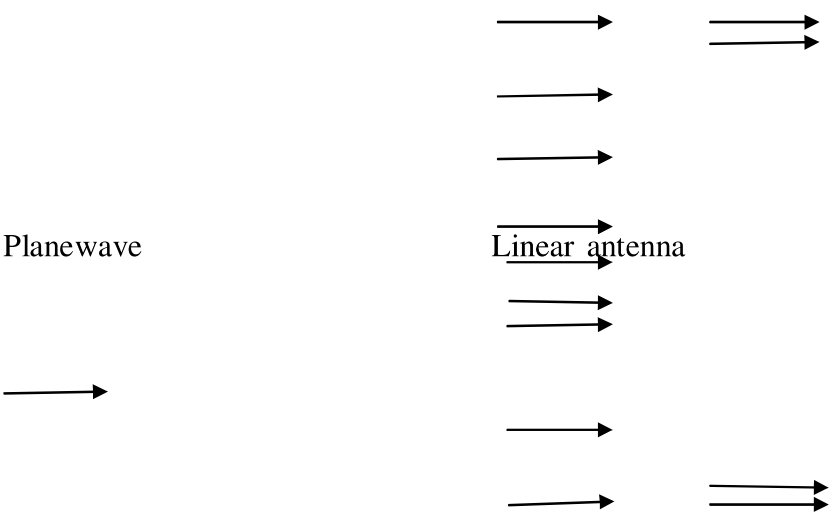



Fig. 1. Plane wave intercepted by an antenna

Let *Pinc* represents the power density of the incident wave at the location of the receiving antenna and *PL* represents the maximum average power delivered to the load under matched conditions with the receiving antenna properly oriented with respect to the polarization of the incident wave.

We can write,

$P_L = A_{ea} P_{inc}$ .......................................................(9)

Where $P_{inc} = E^2/2\eta_o$ and the term $A_{ea}$ is called the maximum effective aperture of the antenna. $A_{ea}$ is related to the directivity of the antenna $D$ as,

$D = \frac{4}{\lambda 2} A_{ea}$ ...............................*(10)*

If the antenna is lossy then some amount of the power intercepted by the antenna will be dissipated in the antenna.

From eqn. (2) we find that

$G = \eta D$ ......................................................................................... (11)

Therefore, from (5),

$G = \frac{4}{\lambda^2}(\eta A_e)_a = 4\pi/\lambda^2 A_e$ .......................................................................... (12)

Where $A_e$ is called the effective aperture of the antenna ( in $m^2$).

So effective area or aperture $A_e$ of an antenna is defined as that equivalent area which when intercepted by the incident power density $P_{in}$ gives the same amount of received power $P_R$ which is available at the antenna output terminals.

If the antenna has a physical aperture $A$ then aperture efficiency $\eta_e = A_e / A$

**EFFECTIVE LENGTH/HEIGHT OF THE ANTENNA:-**

When a receiving antenna intercepts incident electromagnetic waves, a voltage is induced across the antenna terminals. The effective length he of a receiving antenna is defined as the ratio of the open circuit terminal voltage to the incident electric field strength in the direction of antennas polarization.

$h_e = \frac{V_{0c}}{E}$ m ............................................................. (13)

where $V_{oc}$ = open circuit voltage

$E$ = electric field strength

Effective length he is also referred to as effective height.

1.9 Effects of Ground on Antenna Performance:

The Effects of Ground on Antenna Performance on a detailed discussion of the interaction (see Figure

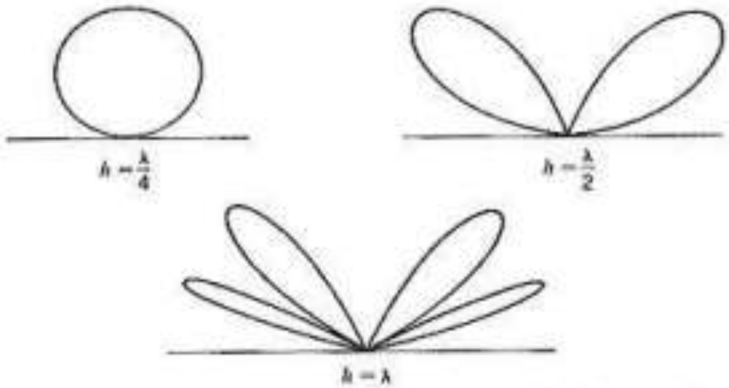



**FIGURE 9-11 Radiation patterns of an ungrounded half-wave dipole located at varying heights above the ground.**

**Ungrounded Antennas:**

As was know, when a radiation source is placed near a reflecting surface, the signal received at any distant point is the vector sum of the direct (sometimes called the incident) wave and the reflected wave. To simplify the explanation, an image antenna is visualized to exist below the earth's surface and is a true mirror image of the actual antenna (Figure 9-12).

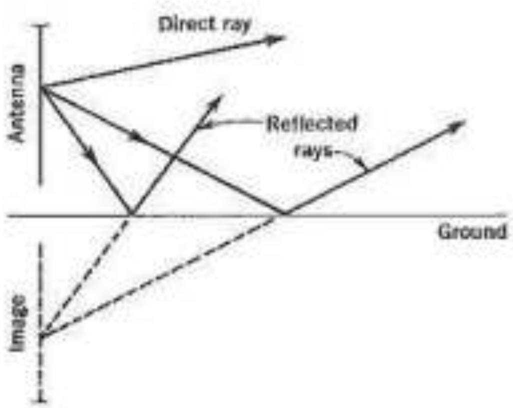



**FIGURE 9-12 Ungrounded antenna and image.**

When a wave is reflected, its polarity is changed by 180°. If direct and reflected waves of equal magnitude and phase angle are received at exactly the same time, the two signals will cancel each other out (the vector sum is equal to zero). This condition is rarely achieved in reality, but combinations of this effect can cause reception to fade (if the signals are out of phase) or increase (if the reflections happen to be in phase, i.e., voltage vector addition).

**Grounded Antennas:**

If an antenna is grounded, the earth still acts as a minor and becomes part of the radiating system. The ungrounded antenna with its image forms a dipole array, but the bottom of the grounded antenna is joined to the top of the image. The system acts as an antenna of double size. Thus, as shown in Figure 9-13a, a grounded quarter-wave vertical radiator effectively has a quarter-wavelength added to it by its image. The voltage and current distributions on such a grounded λ/4 antenna (commonly called the Marconi antenna), are the same as those of the half-wave dipole in space and are shown in Figure 9-13b.

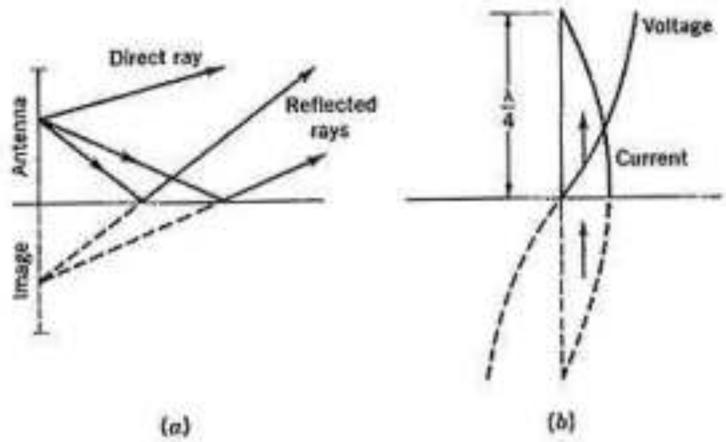



**FIGURE 9-13 Grounded antennas. (*a*) Antenna and image; (*b*) voltage and current distribution on basic Marconi antenna.**

The Marconi antenna has one important advantage over the ungrounded, or Hertz, antenna: to produce any given radiation pattern, it need be only half as high. On the other hand, since the ground here plays such an important role in producing the required radiation patterns, the ground conductivity must be good. Where it is poor, an artificial ground is used.

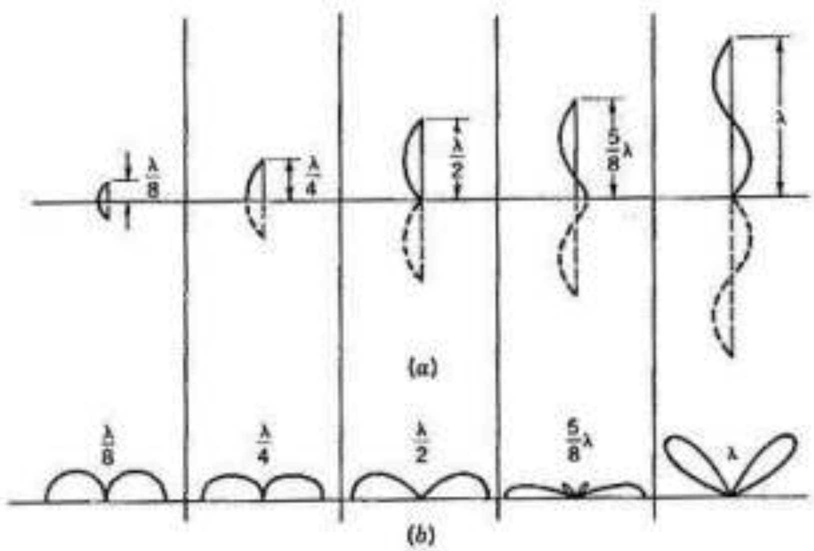



**FIGURE 9-14 Characteristics of vertical grounded antennas. (*a*) Heights and current distributions; (*b*) radiation patterns.**

The radiation pattern of a Marconi antenna depends on its height, and a selection of patterns is shown in Figure 9-14. It is seen that horizontal directivity improves with height up to a certain point (5/8 λ), after which the pattern "lifts off " the ground.

The effect is caused by cancellation of the wave in the horizontal direction because of opposing currents in the various parts of an Effects of Ground on Antenna Performance at this effective height.

**Grounding Systems:**

The earth has generally been assumed to be a perfect conductor so far. This is often not the case. For this reason the best ground system for a vertical grounded radiator is a network of buried wires directly under the

Effects of Ground on Antenna Performance. This network consists of a large number of "radials" extending from the base of the tower, like spokes on a wheel, and placed between 15 and 30 cm below the ground. Each radial wire has a length which should be at least λ/4, and preferably λ/2. Up to 120 such wires may be used to good advantage, and the whole assembly is then known as a ground screen.

A conductor joining all the radials, at a distance of about half the radial length, is often employed. The far end of each radial is grounded, i.e., attached to a metal stake which is driven deeply into the subsoil (especially if this is a better conductor than the topsoil, as in sandy locations).

**A good ground screen will greatly improve the field strength and distance of Marconi antennas, especially those used for medium-frequency broadcasting. The improvement is most pronounced for short antennas (under λ/4 in height) and/or with soils of poor conductivity. Even an antenna between λ/4 and λ/2, on soil with good conductivity, will have its radiation pattern improved noticeably.**

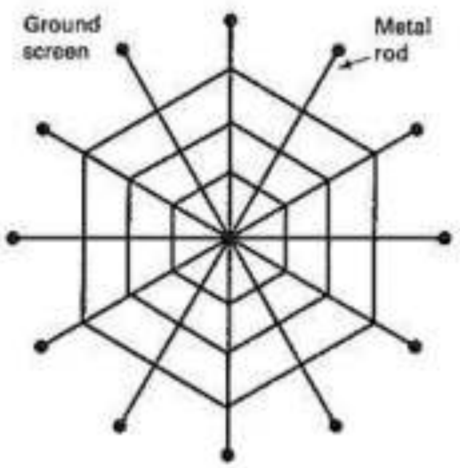



**FIGURE 9-15 Radial ground system for vertical antenna systems.**

**Where a ground screen is not practical, a counterpoise is used. A counterpoise consists of a system of radials, supported above ground and insulated from it. The supports should be few and far between and made of a material such as metal rods, with low dielectric losses. The counterpoise would be a substitute for a ground screen in areas of low ground conductivity, i.e., rock, mountains, and antennas on top of buildings**

**Yagi uda array**

Yagi-Uda or Yagi is named after the inventors Prof. S.Uda and Prof. H.Yagi around 1928.

The basic element used in a Yagi is λ/2 dipole placed horizontally known as driven element or active element. In order to convert bidirectional dipole into unidirectional system, the passive elements are used which include reflector and director. The passive or parasitic elements are placed parallel to driven element, collinearly placed close together.The Parasitic element placed in front of driven element is called director whose length is 5% less than the drive element. The element placed at the back of driven element is called reflector whose length is 5% more than that of driver element. The space between the element ranges between 0.1λ to 0.3λ.

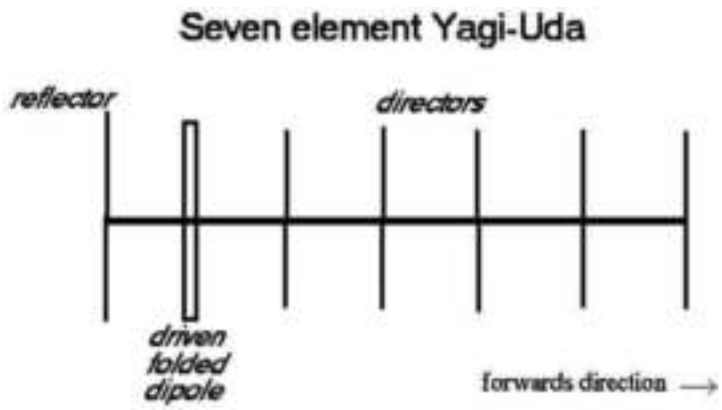



Fig 6.4: Seven segment yagi-uda antenna

For a three element system,

Reflector length = 500/f (MHz) feet Driven element

length = 475/f (MHz) feet Director length = 455/f

(MHz) feet.

The above relations are given for elements with length to diameter ratio between 200 to 400 and spacing between 0.1 λ to 0.2 λ.With parasitic elements the impedance reduces less than 73 and may be even less than 25 . A folded λ/2 dipole is used to increase the impedance.System may be constructed with more than one director. Addition of each director increases the gain by nearly 3 dB. Number of elements in a yagi is limited to 11.

**Basic Operation:**

The phases of the current in the parasitic element depends upon the length and the distance between the elements. Parasitic antenna in the vicinity of radiating antenna is used either to reflect or to direct the radiated energy so that a compact directional system is obtained.

A parasitic element of length greater than λ/2 is inductive which lags and of length less than λ/2 is capacitive which leads the current due to induced voltage. Properly spaced elements of length less than λ/2 act as director and add the fields of driven element. Each director will excite the next. The reflector adds the fields of driven element in the direction from reflector towards the driven element.

The greater the distance between driven and director elements, the greater the capacitive reactance needed to provide correct phasing of parasitic elements. Hence the length of element is tapered-off to achieve reactance.

A Yagi system has the following characteristics.

1. The three element array (reflector, active and director) is generallyreferred as —beam antenna.
2. It has unidirectional beam of moderate directivity with light weight, lowcost and simplicity in design.
3. The band width increases between 2% when the space between elementsranges between 0.1λ to 0.15 λ.
4. It provides a gain of 8 dB and a front-to-back ratio of 20dB.
5. Yagi is also known as super-directive or super gain antenna since thesystem results a high gain.
6. If greater directivity is to be obtained, more directors are used. Array upto 40 elements can be used.
7. Arrays can be stacked to increase the directivity.
8. Yagi is essentially a fixed frequency device. Frequency sensitivity and bandwidth of about 3% is achievable.
9. To increase the directivity Yagi‘s can be staked one above the other orone by side of the other.

**Lens antenna**

Like parabolic reflectors, lens is used to convert circular or spherical wave fronts into planar wave fronts, as a transmitter and vice-versa as a receiver. Lens is a medium through which the waves are transmitted or received.

Lenses are of two types like decelerating medium and accelerating medium. In decelerating system, the velocity with in the medium is les s than that of free space velocity. Pure dielectrics like Lucite or polystyrene, impure dielectrics or H-plane metal plates can be used as decelerating mediums.

Accelerating system is the one in which the velocity within the medium is morethan that of free space velocity. E -plane metal plates are the examples for accelerating types.

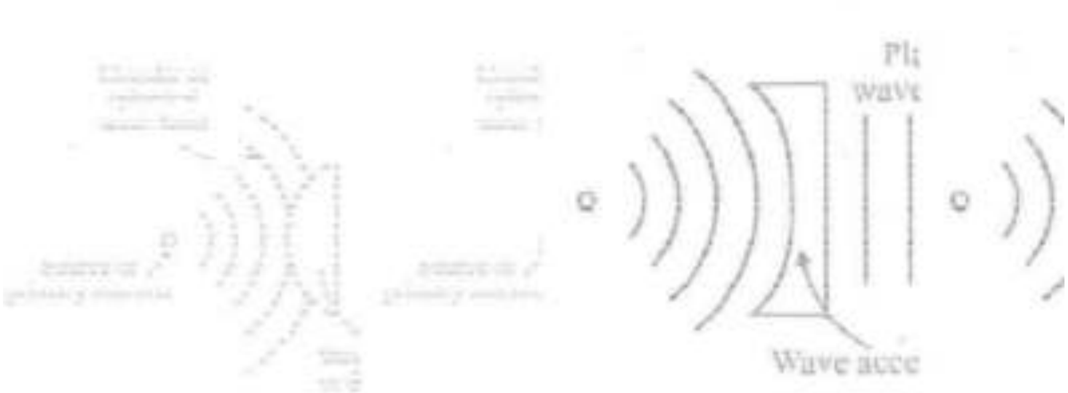


Fig 6.12: Lens Antenna

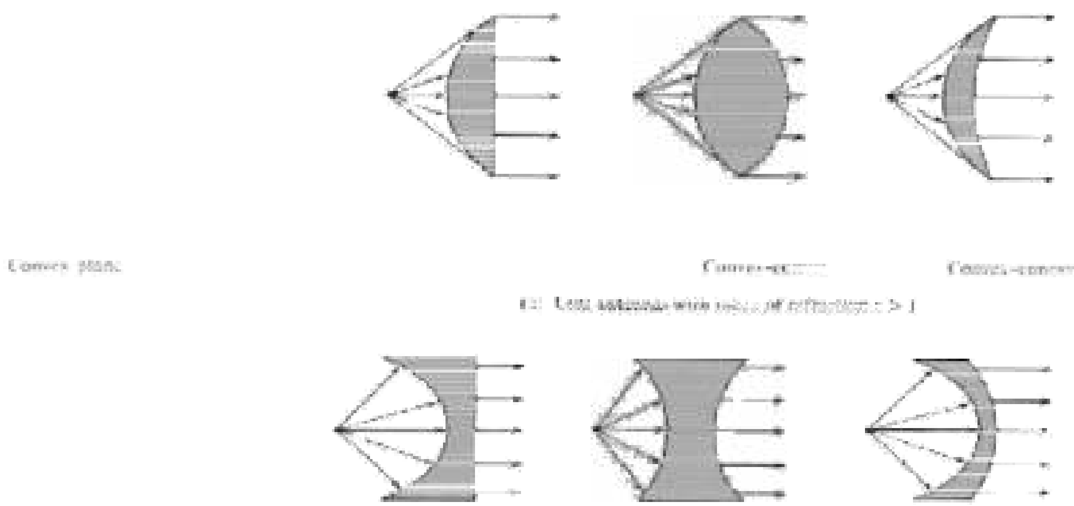


Fig 6.1 3 : Lens Antenna with different refractive index

## Dielectric Lens Antenna

The dielectric material used should have a refractive index more than 1 w.r.t.free space having minimum dielectric losses. Lucite and polystyrene can be used having a refractive index a=1.5. The system is constructed in the form of plane - convex lens. The source or primary antenna is placed at the focus point
‗O‘having focal length L.

Fig 6.14: Dielectric Lens Antenna

Planar wave fronts can be obtained at the aperture when the electrical path OQ' andOP remains same <u>*OP OQ QQ*</u>'

Consider the dielectric lens with a primary source at the focus point O as showwn in fig.6.15. Let P is the power density and U is radiation intensity at a distance y from the axis. Assuming P and U remain constant within the elemental aperture subte nded by dθ or dy, the power radiated through elemenntal aperture is

dW=$2\pi y.dy.P$ ........................................ *6.30*

Where $W= \iint U .d\Omega$

$2\pi\ \theta\ d\theta$

$W = \int \int U \sin\theta\ d\theta\ d\varphi$

$2\ \theta$

$\theta\ d\theta$

$W= U\ 2\pi \int \sin\theta\ d\theta$

$\theta$

$W= \quad 2\pi\ U \sin\theta\ d\theta$

---- (6.31)

**Relative electric field:**

Relative Electric field is as show n in fig.6.16

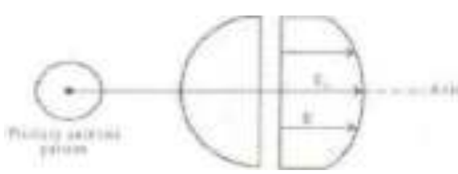


Fig 6.16 : Relative Electric Field

**Plane Metal Plate Lens**

The velocity in between E-Plane Metal Plate is more than the Free space velocity v0

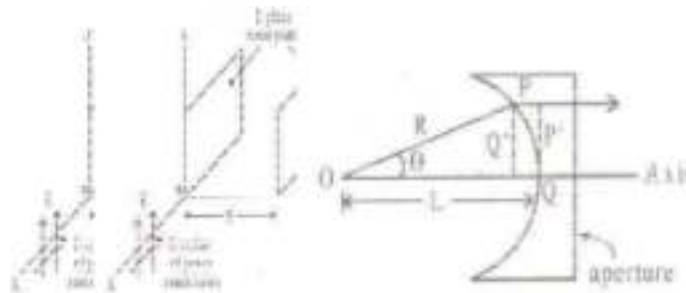



Fig 6.17 : E-Plane Metal Plate Lens

**Advantages of Lens Antenna**

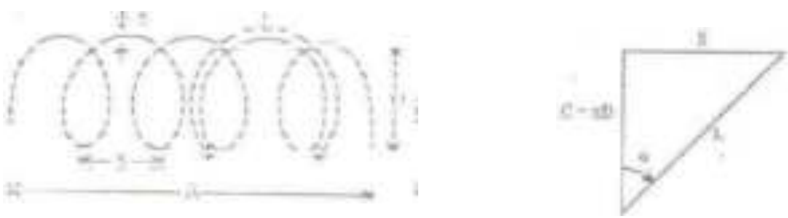
1. Can be used as Wide band Antenna since its shape is independent of frequency.
2. Provides good collimation.
3. Internal dissipation losses are low, with dielectric materials having low loss tangent.
4. Easily accommodate large band width required by high datarate systems.
5. Quite in-expensive and have goo d fabrication tolerance

**Disadvantages of Lens Antenna**

1. Bulky and Heavy
2. Complicated Design
3. Refraction at the boundar ies of the lens

**Helical Antenna**

Helical Antenna consists of a conducting wire wound in the form of a sc rew thread forming a helix. In the most cases the helix is used with a ground plane. The helix isusually connected to the center conductor of a co-axial transmission line and the outer conductor of the line is attached to the ground plane.Helical antenna is useful at very high frequency and ultra high frequencies to provide circular polarization.



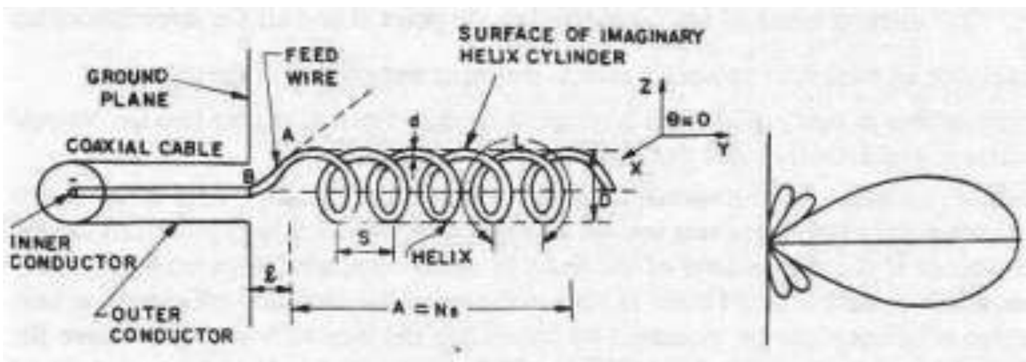


Fig 4.6.1 Helical antenna and its radiation pattern

Here helical antenna is connected between the coaxial cable and ground plane. Ground plane is made of radial and concentric conductors. The radiation characteristics of helical antenna depend upon the diameter (D) and spacing S.

In the above figure,

L= length of one turn $=\sqrt{S^2+(\pi D)^2}$ N = Number of turns D =

Diameter of helix = $\pi D$

$\alpha$ = Pitch angle = tanl($S/\pi D$)

l = Distance between helix and ground plane.

The radiation characteristics of the antenna can be varied by controlling the size of its geometrical properties compared to the wavelength.

Mode of Operation

- Normal Mode
- Axial Mode

**1. Normal mode of radiation**

Normal mode of radiation characteristics is obtained when dimensions of helical antenna are very small compared to the operating wavelength. Here, the radiation field is maximum in the direction normal to the helical axis. In normal mode, bandwidth and efficiency are very low. The above factors can be increased, by increasing the antenna size. The radiation fields of helical antenna are similar to the loops and short dipoles. So, helical antenna is equivalent to the small loops and short dipoles connected in series.

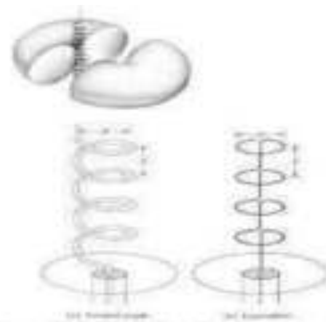


Fig 6.2: Normal mode Helocal antenna and its equivalent

We know that, general expression for far field in small loop is, $E\Phi = \{120\ \pi 2[I]\ \sin\theta/r\}[A/\lambda 2]$

Where,

r = Distance

$I = I0\ \sin\ \omega(t-r/C)$ = Retarded current A = Area of loop = $\pi D2/4$

D = Diameter

$\lambda$ = Operating wavelength.

The performance of helical antenna is measured in terms of Axial Ratio *(AR)*. Axial ratio is defined as the ratio of far fields of short dipole to the small loop.

Axial Ratio, AR =( $E\emptyset$)/($E\Phi$)

**2. Axial mode of radiation:** Helical antenna is operated in axial mode when circumference C and spacing S are in the order of one wavelength. Here, maximum radiation field is along the helical axis and polarization is circular. In axial mode, pitch angle lies between 12° to 18° and beam width and antenna gain depends upon helix length NS.

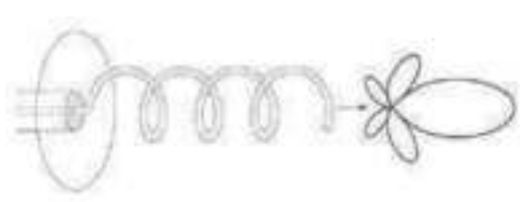


Fig 6.3: Axial mode of helix

General expression for terminal impedance is,

$R = 140C/\lambda$ ohms

Where,

R = Terminal impedanceC = Circumference.

In normal mode, beam width and radiation efficiency is very small. The above factors increased by using axial mode of radiation. Half power beam width in axial mode is,

HPBW = 52/C√λ3/NS Degrees. Where,

λ = Wavelength

C = Circumference N = Number of turns S =

Spacing.

Axial Ratio, AR = 1 + 1/2N

**MICROWAVE ANTENNAS**
**REFLECTOR ANTENNAS**

**NTRODUCTION**

The radiation pattern of a radiating antenna element is modified using reflectors. A simple example is that the backward radiation from an antenna may be eliminated with a large metallic plane sheet reflector. So, the desired characteristics may be produced by means of a large, suitably shaped, and illuminated reflector surface. The characteristics of antennas with sheet reflectors or their equivalent are considered in this chapter.

Some reflectors are illustrated in Figure 3.1. The arrangement in Figure 3.1a has a large, flat sheet reflector near a linear dipole antenna to reduce the backward radiation. With small spacing between the antenna and sheet this arrangement also yields an increase in substantial gain in the forward radiation. The desirable properties of the sheet reflector may be largely preserved with the reflector reduced in size as long as its size is greater than that of the antenna.

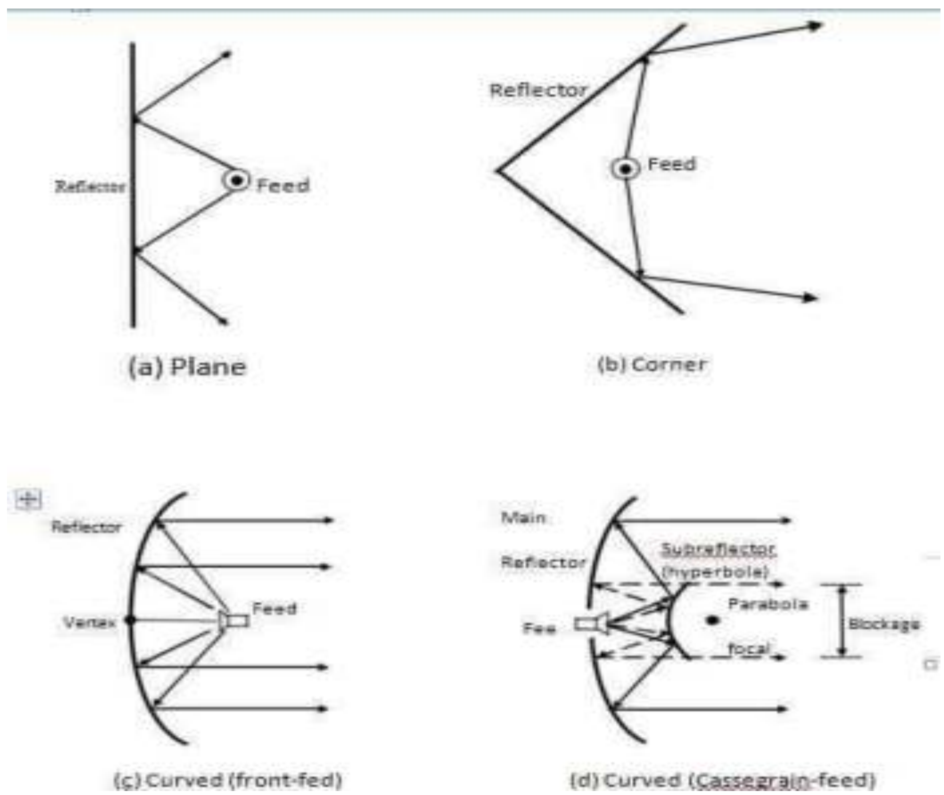



**Figure 3.1** Some configurations of reflector antennas

With two flat sheets intersecting at an angle ¯ (<180 ) as in Figure 3.1b, a sharper radiation pattern than from a flat sheet reflector (¯ =180 ) can be obtained. This arrangement, called *corner reflector antenna*, is most practical where apertures of 1 or 2¯ are of convenient size. A corner reflector without an exciting antenna can be used as a *passive reflector* or target for radarwaves. In this application the aperture may be many wavelengths, and the corner angle is *always* 90 . Reflectors with this angle have the property that an incidence wave is reflected back toward its source, the corner acting as a *retroreflector*.

When it is feasible to build antennas with apertures of many wavelengths, parabolic reflectorscan be used to provide highly directional antennas. A parabolic reflector antenna is shown in Figure 3.1c. The parabola reflects the waves originating from a source at the focus into a parallel beam, the parabola transforming the curved wave front from the feed antenna at the focus into a plane wave front. A front fed and a cassegrain – feed parabolic reflectors are depicted in Figures 3.1c and d. Many other shapes of reflectors can be employed for special applications. For instance, with an antenna at one focus, the elliptical reflector produces a diverging beam with all reflected waves passing through the second focus of the ellipse. Examples of reflectors of other shapes are the hyperbolic and the spherical reflectors.

The plane sheet reflector, the corner reflector, the parabolic reflector and other reflectors are discussed in more detail in the following sections. In addition, feed systems, aperture blockage, aperture efficiency, diffraction, surface irregularities, gain and frequency-selective surfaces are considered.

## PLANE REFLECTORS

Let an omnidirectional antenna is placed at a distance *h* above an infinite, flat, perfect electric conductor as shown in Figure 3.2. Power from the actual source is radiated in all directions in a manner determined by its unbounded medium directional properties. For an observation point $p_1$ ,there is a direct wave. In addition, a wave from the actual source radiated toward point $R1$ of the interface undergoes a reflection. The direction is determined by the law of reflection $\theta_i = \theta_r$ which assures that the energy in homogeneous media travels in straight lines along the shortest paths. This wave will pass through the observation point $p1$ . By extending its actual path below the interface, it will seem to originate from a virtual source positioned a distance *h* below the boundary. For another observation point $p2$ the point of reflection is $R2$ , but the virtual source is the same as before. The same is concluded for all other observation points above the interface.The amount of reflection is generally determined by the respective constitutive parameters of the media below and above the interface. For a perfect electric conductor below the interface, the incidence wave is completely reflected and the field below the boundary is zero. According to the boundary conditions, the tangential components of the electric field must vanish at all points along the interface. Thus for an incident electric field with vertical polarization shown by the arrows, the polarization of the reflected waves must be as indicated in the figure to satisfy the boundary conditions.

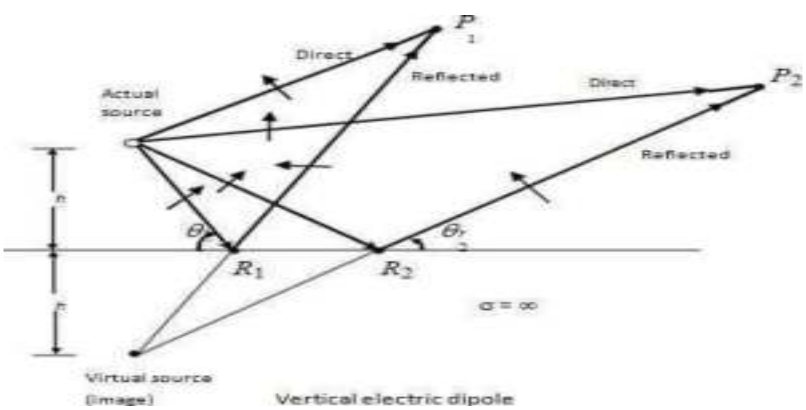
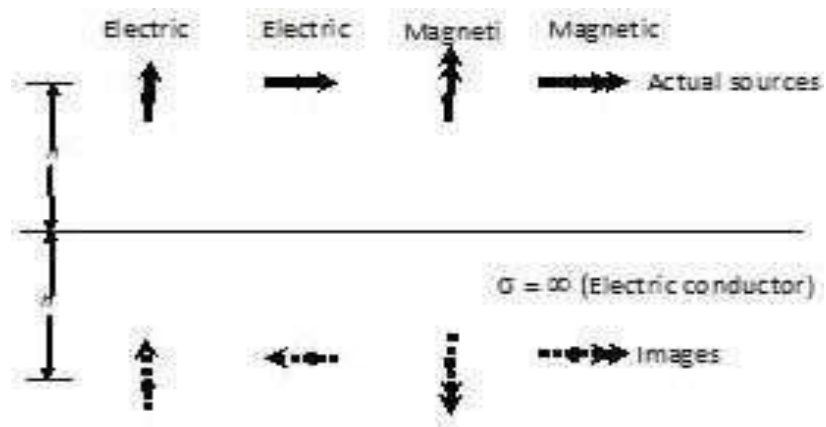



**Figure 3.2** Antenna above an infinite, flat, perfect electric conductor.

For a vertical dipole, to excite the polarization of the reflected waves, the virtual source must also be vertical and with a polarity in the same direction as that of the actual source (thus a reflection coefficient of +1). Another orientation of the source will be to have the radiating element in a horizontal position, as shown in Figure 3.3. As shown in Figures 3.3, the virtual source (image) is also placed at a distance *h* below the interface. For horizontal polarized antenna, the image will have a 180 polarity difference relative to the actual source (thus a reflection coefficient of -1).

In addition to electric sources, artificial equivalent —magneticÂ sources have been introduced to aid in the analyses of electromagnetic boundary value problems. Figure 3.3 displays the sources and their images for an electric plane conductor. The single arrow indicates an electric element and the double a magnetic one. The direction of the arrow identifies the polarity.




Electric conductor

**Figure 3.3** Electric and magnetic sources and their images near electric conductors

**CORNER REFLECTOR**

For better collimination of the power in the forward directions, an arrangement can be made with two plane reflectors joined so as to form a corner, as shown in Figure 3.10 (a). This is known as the corner reflector. Because of its simplicity in construction, it has many unique applications. For example, if the reflector is used as a passive target for radar or communication applications, it will return the signal exactly in the same direction as it received it when its included angle is 90 . This is illustrated geometrically in Figure 3.10(b). Because of this unique feature, military ships and vehicles are designed with minimum sharp corners to reduce their detection by enemy radar.

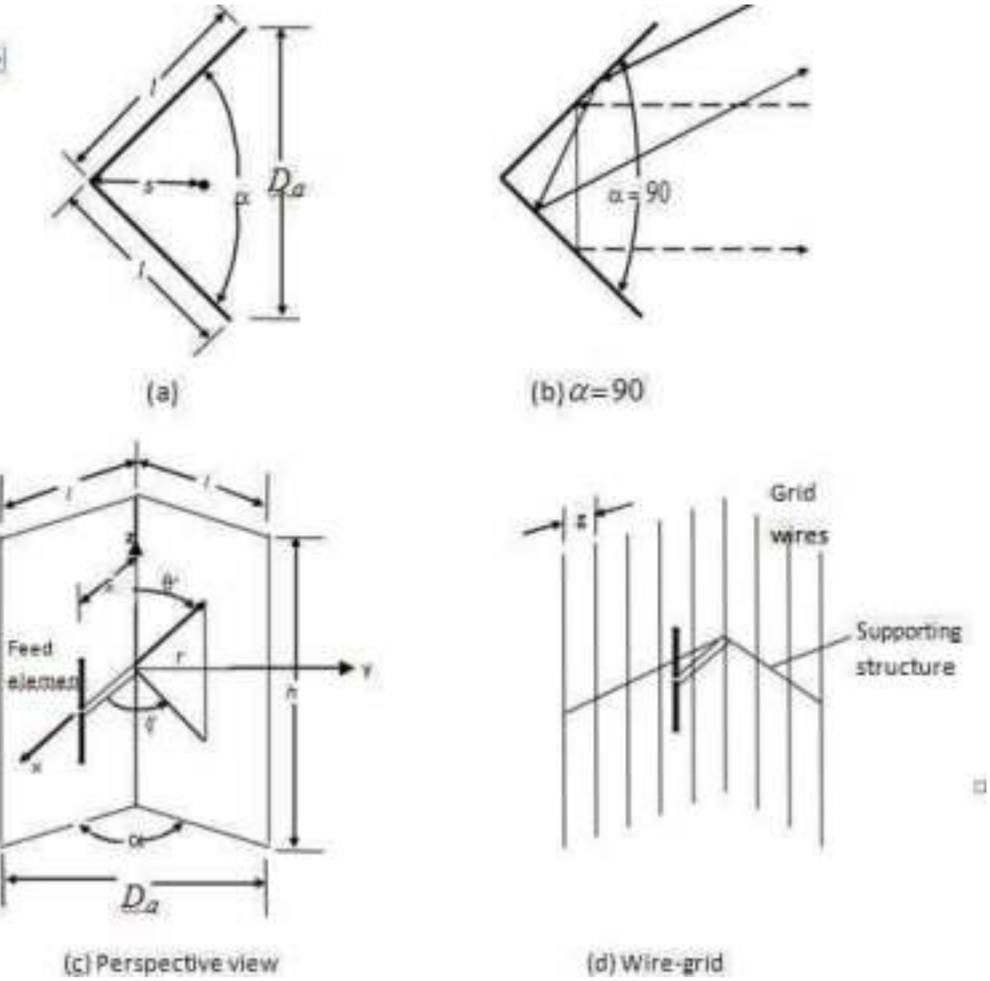



**Figure 3.10** Side and perspective views of solid and wire-grid corner reflectors

In most practical applications, the included angle formed by the plates is usually 90 ; however other angles are also used. To maintain a given system efficiency, the spacing between the vertex and the feed element must increase as the included angle of the reflector decreases, and vice- versa. For reflectors with infinite sides, the gain increases as the included angle between the planes decreases. This, however, may not be true for finite size plates. For simplicity, in this

chapter it will be assumed that the plates themselves are infinite in extent ($l$ = ¯). However, since in practice the dimensions must be finite, guidelines on the size of aperture $D_a$ , length ($l$), height (h) is given.

The feed element for a corner reflector is almost always a dipole or an array of collinear dipoles placed parallel to the vertex distance s away. Greater bandwidth is obtained when the feed elements are cylindrical or biconical dipoles instead of thin wires.

In many applications, especially when the wavelength is large compared to tolerable physical dimensions, the surfaces of the corner reflector are frequently made of grid wires rather than solid sheet metal.One of the reasons for doing that is to reduce wind resistance and overallsystem weight. The spacing g between wires is made a small fraction of a wavelength (usually g ¯ ¯/10).

For wires that are parallel to the length of the dipole, as is the case for the arrangement of Figure 3.10(d), the reflectivity of the grid-wire surface is as good as that of a solid surface. In practice, the aperture of the corner reflector ( $Da$ ) is usually made between one and two wavelengths ¯¯ ¯ $Da$ ¯ 2¯¯. The length of the sides of a 90 corner reflector is most commonly taken to be about twice the distance from the vertex to the feed ¯$l$ 2$s$¯.

For reflectors with smaller included angles, the sides are made larger. The feed-to-vertex distance (s) is usually taken to be between ¯/3 and 2¯/3 (¯/3 < s < 2¯/3). For each reflector, thereis an optimum feed-to-vertex spacing. If the spacing becomes too small, the radiation resistance decreases and becomes comparable to the loss resistance of the system which leads to an inefficient antenna. For very large spacing, the system produces undesirable multiple lobes, and it loses its directional characteristics. It has been experimentally observed that increasing the size of the sides does not greatly affect the beam width and directivity, but it increases the bandwidth and radiation resistance. The main lobe is somewhat broader for reflectors with finite sides compared to that of infinite dimensions. The height (h) of the reflector is usually taken to be about 1.2 to 1.5 times greater than the total length of the feed element, in order to reduceradiation toward the back region from the ends.

The analysis for the field radiated by a source in the presence of a corner reflector is facilitated when the included angle (¯) of the reflector is ¯ = ¯/n, where n is an integer (¯ = ¯, ¯/2, ¯/3, ¯/4, etc.). For these cases ¯¯ ¯ 180 , 90 , 60 , 45 , *etc.*¯it is possible to find a system of images, which when properly placed in the absence of the reflector plates, form an array that yields the same field within the space formed by the reflector plates as the actual system.

The number of images, polarity, and position is controlled by included angle and the polarizationof the feed element. The geometrical and electrical arrangement of the images for corner reflectors with included angles of 90, 60, 45 and 30.

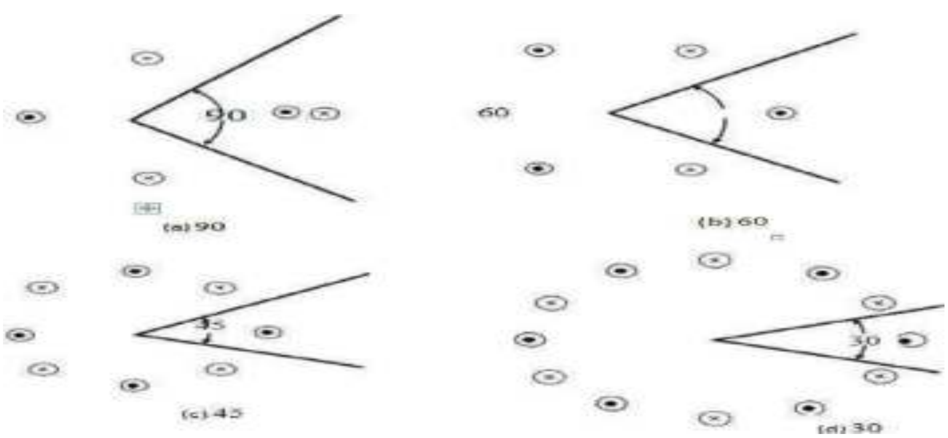



**Figure3.11** Corner reflectors and their images (with perpendicularly polarized feeds) for angles of 90 , 60 , 45 *and* 30 .

...............................................

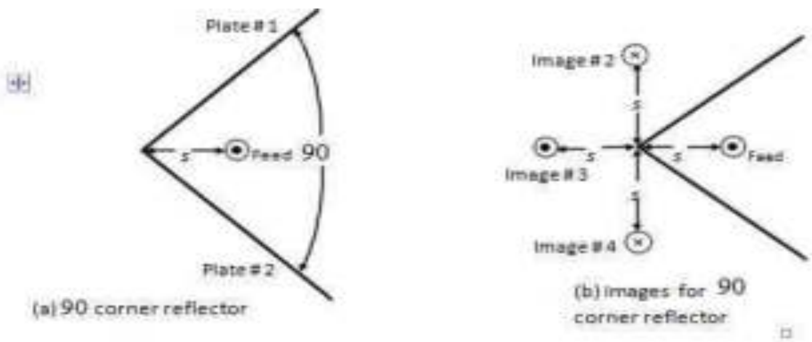



**Figure4.12** Geometrical placement and electrical polarity of images for a 90 corner reflector with a parallel polarized feed.

## PARABOLIC REFLECTOR

If a beam of parallel rays is incident upon a reflector whose geometrical shape is a parabola, the radiation will converge or get focused at a spot which is known as the *focal point*. In the same manner if a point source is placed at the focal point, the rays reflected by a parabolic reflector will emerge as a parallel beam. The symmetrical point on the parabolic surface is known as the *vertex*. Rays that emerge in a parallel formation are usually said to be *collimated*. In practice, collimation is often used to describe the highly directional characteristics of an antenna even though the emanating rays are not exactly parallel. Since the transmitter (receiver) is placed at the focal point of the parabola, the configuration is usually known as *front fed*.

A parabolic reflector can take two different forms. One configuration is that of the parabolic right cylinder, whose energy is collimated at a line that is parallel to the axis of the cylinder through the focal point of the reflector. The most widely used feed for this type of a reflector is a linear dipole, a linear array, or a slotted waveguide. The other reflector configuration is that which is formed by rotating the parabola around its axis, and it is referred to as a *paraboloid*

(parabola of revolution). A pyramidal or a conical horn has been widely utilized as a feed for this arrangement.

## CASSEGRAIN REFLECTORS

The disadvantage of the front-fed arrangement is that the transmission line from the feed must usually be long enough to reach the transmitting or the receiving equipment, which is usually placed behind or below the reflector. This may necessitate the use of long transmission lines whose losses may not be tolerable in many applications, especially in low-noise receiving systems. In some applications, the transmitting or receiving equipment is placed at the focal point to avoid the need for long transmission lines. However, in some of these applications, especially for transmission that may require large amplifiers and for low-noise receiving systems where cooling and weatherproofing may be necessary, the equipment may be too heavy and bulky and will provide undesirable blockage.

The arrangement that avoids placing the feed (transmitter and/or receiver) at the focal point is that shown in Figure 3.1(d) and it is known as the Cassegrain feed. Through geometrical optics, Cassegrain, a famous astronomer (N. Cassegrain of France, hence its name), showed that incident parallel rays can be focused to a point by utilizing two reflectors. To accomplish this,the main (primary) reflector must be a parabola, the secondary reflector (Subreflector) a hyperbola, and the feed placed along the axis of the parabola usually at or near the vertex. Cassegrain used this scheme to construct optical telescopes, and then its design was copied for use in radio frequency systems. For this arrangement, the rays that emanate from the feed illuminate the Subreflector and are reflected by it in the direction of the primary reflector, as if they originated at the focal point of the parabola (primary reflector). The rays are then reflected by the primary reflector and are converted to parallel rays, provided the primary reflector is a parabola and the subreflector is a hyperbola. Diffraction occurs at the edges of the subreflector and primary reflector and they must be taken into account to accurately predict the overall system pattern, especially in regions of low intensity. Even in regions of high intensity, diffraction must be included if an accurate formation of the fine ripple structure of the pattern is desired. With the Cassegrain-feed arrangement, the transmitting and/or receiving equipment can be placed behind the primary reflector. This scheme makes the system relatively more accessible for servicing and adjustments.

Cassegrain designs, employing dual reflector surfaces, are used in applications where pattern control is essential, such as in satellite ground-based systems, and have efficiencies of 65-80%. They supersede the performance of the single-reflector front-fed arrangement by about 10%. Using geometrical optics, the classical Cassegrain configuration, consisting of a paraboloid andhyperboloid, is designed to achieve a uniform phase front in the aperture of the paraboloid. By employing good feed designs, this arrangement can achieve lower spillover and more uniform illumination of the main reflector. In addition, slight shaping of one or both of the dual- reflector‘s surfaces can lead to an aperture with almost uniform amplitude and phase with substantial enhancement in gain. These are referred to as shaped reflectors. Shaping techniques have been employed in dual-reflectors used in earth station applications.

Two reflectors with ray geometry, with concept of equivalent parabola, are shown in Figure 3.19 The use of a second reflector, which is usually referred to as the subreflector or subdish, gives anadditional degree of freedom for achieving good performance in a number of different applications. For an accurate description of its performance, diffraction techniques must be used to take into account diffractions from the edges of the subreflector, especially when its diameteris small.

In general, the Cassegrain arrangement provides a variety of benefits, such as the

1. ability to place the feed in a convenient location
2.reduction of spillover and minor lobe radiation
3.ability to obtain an equivalent focal length much greater than the physical length 4.capability for scanning and/or broadening of the beam by moving one of the reflecting

surfaces

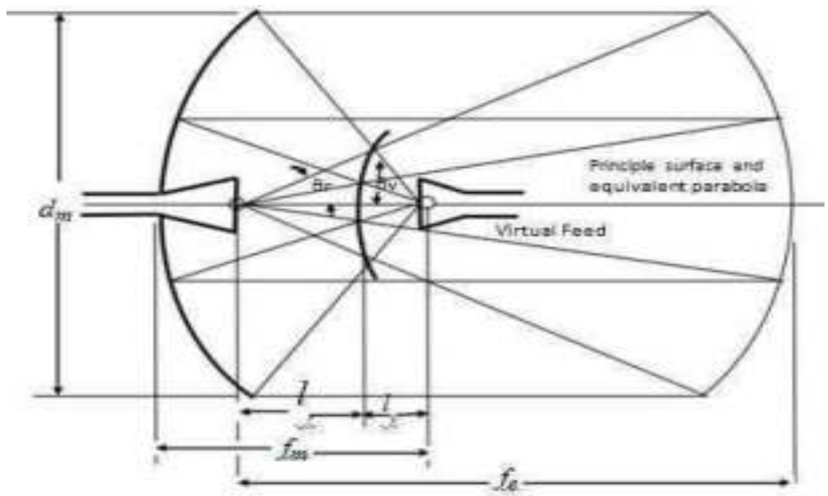



**Figure 3.19** Equivalent parabola concepts.

To achieve good radiation characteristics, the subreflector must be few wavelengths in diameter. However, its presence introduces shadowing which is the principle limitation of its use as a microwave antenna. The shadowing can significantly degrade the gain of the system, unless the main reflector is several wavelengths in diameter. Therefore the Cassegrain is usually attractive for applications that require gains of 40 dB or greater. There are, however, a variety of techniques that can be used to minimize the aperture blocking by the subreflector. Some of them are minimum blocking with simple Cassegrain, and twisting Cassegrains for least blocking

**Horn Antennas**

Flared waveguides that produce a nearly uniform phase front larger than the waveguide itself. Constructed in a variety of shapes such as sectoral E-plane, sectoral H-plane, pyramidal, conical,etc.

**Horn Antennas -Application Areas**

1. Used as a feed element for large radio astronomy, satellite tracking and communicationdishes.
2. A common element of phased arrays.
3. Used in the calibration, other high-gain antennas.
4. Used for making electromagnetic interference measurements

**Rectangular Horn antenna:**

A rectangular horn antenna is as shown in figure 4.6. This is an extension of rectangular wave guide. TE10 mode is preferred for rectangular horns.

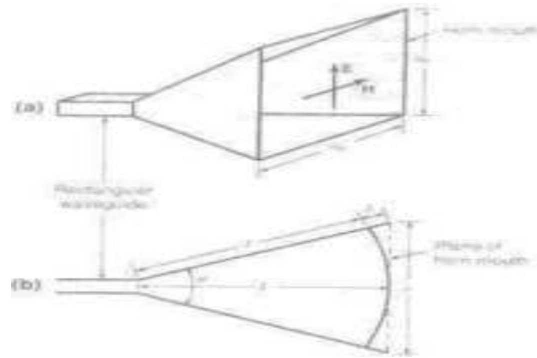


Fig 4.6: Rectangular Horn antenna

**Horn antennas** are very popular at UHF (300 MHz-3 GHz) and higher frequencies (I've heard of horn antennas operating as high as 140 GHz). Horn antennas often have a directional radiationpattern with a high antenna gain, which can range up to 25 dB in some cases, with 10-20 dB being typical. Horn antennas have a wide impedance bandwidth, implying that the input impedance is slowly varying over a wide frequency range (which also implies low valuesfor S11 or VSWR). The bandwidth for practical horn antennas can be on the order of 20:1 (for instance, operating from 1 GHz-20 GHz), with a 10:1 bandwidth not being uncommon.

The gain of horn antennas often increases (and the beamwidth decreases) as the frequency of operation is increased. This is because the size of the horn aperture is always measured in wavelengths; at higher frequencies the horn antenna is "electrically larger"; this is because a higher frequency has a smaller wavelength. Since the horn antenna has a fixed physical size (say a square aperture of 20 cm across, for instance), the aperture is more wavelengths across athigher frequencies. And, a recurring theme in antenna theory is that larger antennas (in terms of wavelengths in size) have higher directivities.

**Table:**

| Type of Aperture | Beam width, deg | |
|---|---|---|
| | Between First nulls | Between Half power points |
| Uniformly illuminated rectangular aperture or linear array | $\frac{115}{L_\lambda}$ | $\frac{51}{L_\lambda}$ |
| Uniformly illuminated circular aperture | $\frac{140}{D_\lambda}$ | $\frac{58}{D_\lambda}$ |
| Optimum E-plane rectangular horn | $\frac{115}{a_{E\lambda}}$ | $\frac{56}{a_{E\lambda}}$ |
| Optimum H-plane rectangular horn | $\frac{172}{a_{H\lambda}}$ | $\frac{67}{a_{H\lambda}}$ |

Horn antennas are typically fed by a section of a waveguide, as shown in Figure 4. The waveguide itself is often fed with a short dipole, which is shown in red in Figure 4. A waveguide is simply a hollow, metal cavity (see the waveguide tutorial). Waveguides are used to guide electromagnetic energy from one place to another. The waveguide in Figure 4 is a rectangular waveguide of width *b* and height *a*, with *b*>*a*. The E-field distribution for the dominant mode is shown in the lower part of Figure 1.

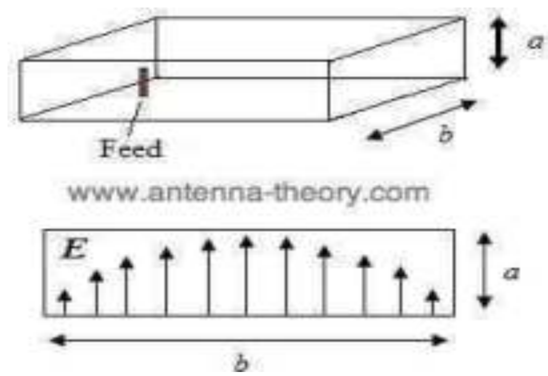



Figure 4. Waveguide used as a feed to horn antennas.

**Microstrip Antennas**

The Microstrip Patch Antenna is a single-layer design which consists generally of four parts (patch, ground plane, substrate, and the feeding part). Patch antenna can be classified as single – element resonant antenna. Once the frequency is given, everything (such as radiation pattern input impedance, etc.) is fixed. The patch is a very thin ($t \ll \lambda_0$, where $\lambda_0$ is the free space wavelength) radiating metal strip (or array of strips) located on one side of a thin no conducting substrate, the ground plane is the same metal located on the other side of the substrate. The metallic patch is normally made of thin copper foil plated with a corrosion resistive metal, such as gold, tin, or nickel. Many shapes of patches are designed some are shown in figure (2.1) and the most popular shape is the rectangular and circular patch. The substrate layer thickness is 0.01–0.05 of free-space wavelength ($\lambda_o$). It is used primarily to provide proper spacing and mechanical support between the patch and its ground plane. It is also often used with high dielectric-constant material to load the patch and reduce its size. The substrate material should be low in insertion loss with a loss tangent of less than 0.005. In this work we have used Arlon AD 410 with dielectric constant of 4.1 and tangent loss of 0.003. Generally, substrate materials can be separated into three categories according to the dielectric constant $\varepsilon r$ [1].

1. Having a relative dielectric constant $\varepsilon r$ in the range of 1.0–2.0. This type of material can be air, polystyrene foam, or dielectric honeycomb.
2. Having $\varepsilon r$ in the range of 2.0–4.0 with material consisting mostly of fiberglass reinforced Teflon.
3. With an $\varepsilon r$ between 4 and 10. The material can consist of ceramic, quartz, or alumina.

The advantages of the microstrip antennas are small size, low profile, and lightweight, conformable to planar and non planar surfaces. It demands a very little volume of the structure when mounting. They are simple and cheap to manufacture using modern printed-circuit technology. However, patch antennas have disadvantages. The main disadvantages of the microstrip antennas are: low efficiency, narrow bandwidth of less than 5%, low RF power due to the small separation between the radiation patch and the ground plane(not suitable for high-power applications).

## 2.2. Types of Patch Antennas

There are a large number of shapes of microstrip patch antennas; they have been designed to match specific characteristics. Some of the common types are shown in figure (2.1), for millimeter wave frequencies, the most common types are rectangular, square, and circular patches.

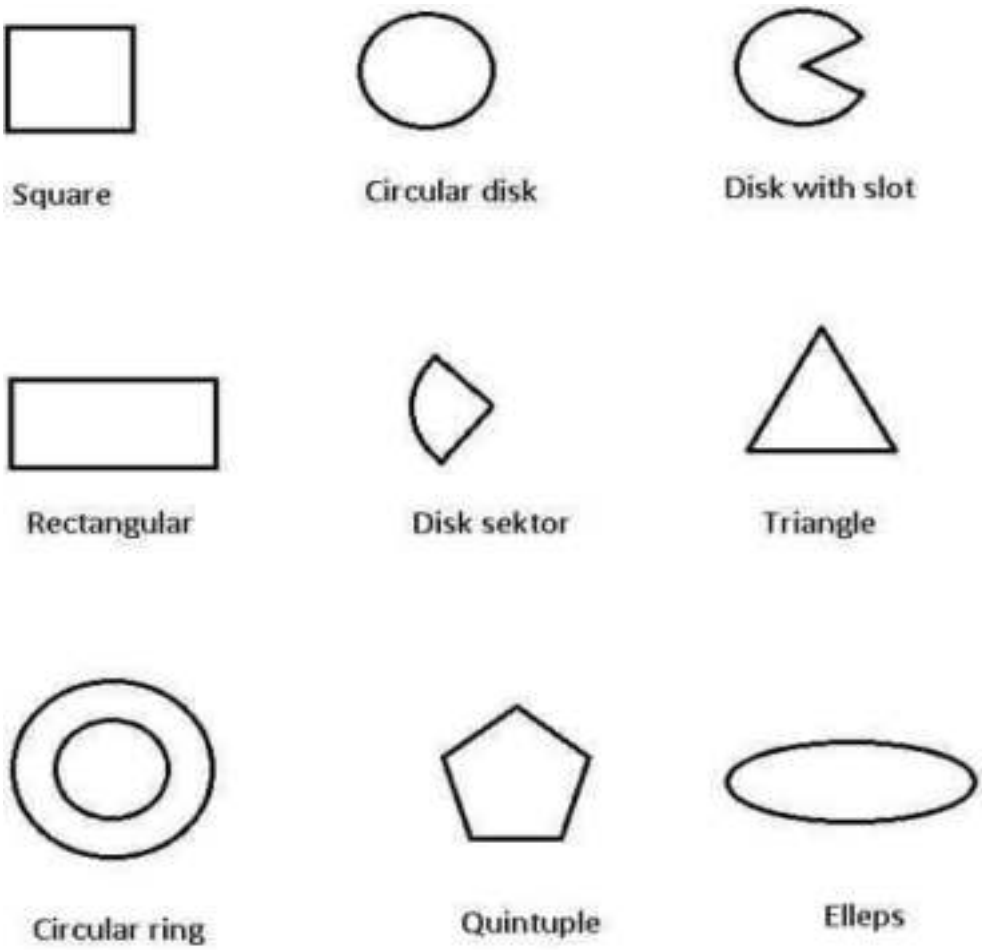



**Figure (2.1)** the most common shapes of patch antennas

Choose of substrate is also important, we have to consider the temperature, humanity, and other environmental ranges of operating. Thickness of the substrate $h$ has a big effect on the resonant frequency $fr$ and bandwidth BW of the antenna. Bandwidth of the microstrip antenna will increase with increasing of substrate thickness $h$ but with limits, otherwise the antenna will stop resonating.

## 2.3. Feeding Methods

There are many methods of feeding a microstrip antenna. The most popular methods are:

1. Microstrip Line.
2. Coaxial Probe (coplanar feed).
3. Proximity Coupling.
4. Aperture Coupling.

Because of the antenna is radiating from one side of the substrate, so it is easy to feed it from the other side (the ground plane), or from the side of the element.

The most important thing to be considered is the maximum transfer of power (matching of the feed line with the input impedance of the antenna), this will be discussed later in the section of Impedance Matching.

Many good designs have been discarded because of their bad feeding. The designer can build an antenna with good characteristics and good radiation parameter and high efficiency but when feeding is bad, the total efficiency could be reduced to a low level which makes the whole system to be rejected.

### 2.3.1 Microstrip Line Feed.

This method of feeding is very widely used because it is very simple to design and analyze, and very easy to manufacture. Figure (2.2) shows a patch with microstrip line feed from the side of the patch.

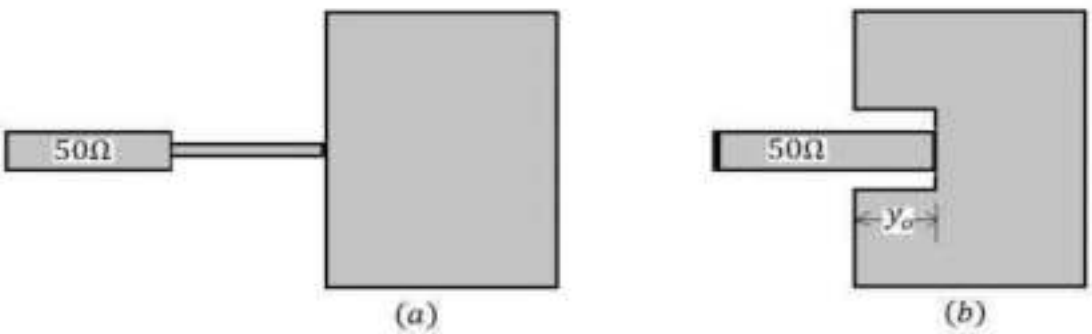



**Figure (2.2)** Microstrip patch antenna with feed from side

The position of the feed point ($y_o$) of the patch in figure (2.2b) has been discussed in details in the section of Impedance Matching.

Feeding technique of the patch in figure (2.2a) and figure (2.3) is discussed in [7]. It is widely used in both one patch antenna and multi-patches (array) antennas.

The impedance of the patch is given by [7]:

$$Z_a = 90\frac{\varepsilon r^2}{\varepsilon r-1}\left(\frac{L}{W}\right)^2 \qquad (2.1)$$

The characteristic impedance of the transition section should be:

$$Z_T = \sqrt{50 + Z_a} \qquad (2.2)$$

The width of the transition line is calculated from [7]:

$$Z_T = \frac{60}{\sqrt{\varepsilon_r}} ln(\frac{8d}{W_T} + \frac{W_T}{4d}) \qquad (2.3)$$

The width of the $50\Omega$ microstrip feed can be found using the equation (2.4) below:

$$Z_o = \frac{120\pi}{\sqrt{\varepsilon reff}\left(1.393+\frac{W}{h}+\frac{2}{3}\ln\left(\frac{W}{h}+1.444\right)\right)} \qquad (2.4)$$

Where $Z_o = 50\Omega$

The length of the strip can be found from (4.24)

$$R_{in(x=0)} = cos^2(\frac{\pi}{L} x_o) \qquad (2.5)$$

The length of the transition line is quarter the wavelength:

$$l = \frac{\lambda}{4} = \frac{\lambda_o}{4\sqrt{\varepsilon reff}} \qquad (2.6)$$

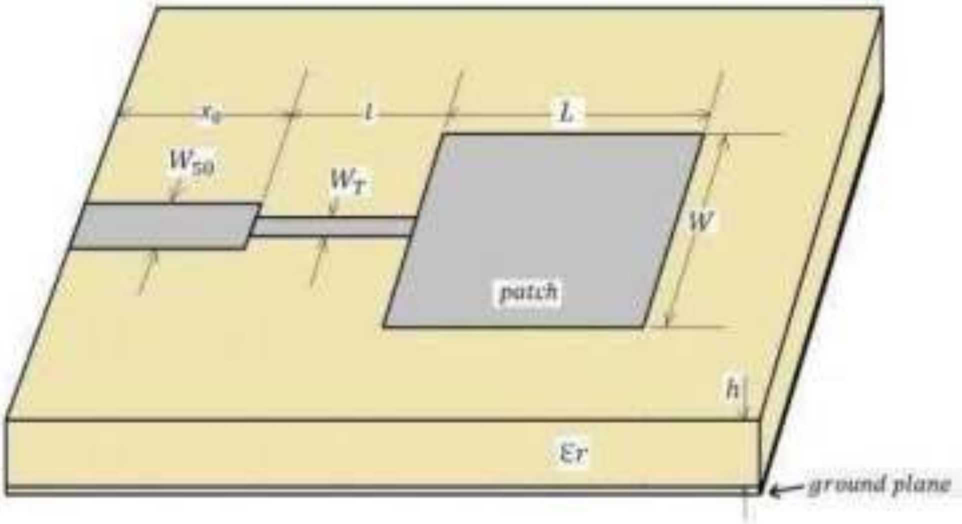


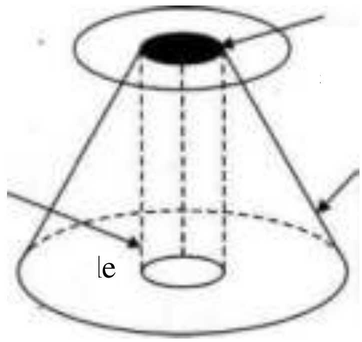

**Figure (2.3)** Rectangular microstrip patch antenna

## 6.17 DISCONE ANTENNA

It is an antenna which consists of a disc and a cone. The disc is fixed at the centre conductor of coaxial feed line so that it is perpendicular to its axis. The apex of the cone is connected to the outer shield of the coaxial line. Its variation of impedance and radiation characteristics as a function of frequency is much less when compared with those of a dipole of constant length.

Salient features o£ discone antenna

1. A disc and a cone together form a discone.
2. It is a ground plane antenna and is evolved from the vertical dipole.
3. It has a radiation pattern similar to that of vertical dipole.
4. A typical discone antenna is shown in Fig. 6.40. It is fed by a coaxial cable.
5. The cone semi-angle is about 30°, disc diameter is about three-fourth of the diameter of the base of the cone.




Discone antenna

6. It acts as if the disc is a reflector.
7. It is a broad-band antenna.
8. It is simple and easy to fabricate.
9. Voltage standing wave ratio and gain are low.
10. It is basically omni-directional antenna.
11. It can be used at VHF and UHF bands.
12. It is often used in airport communication systems.
13. It is an ideal antenna for mobile communication base stations.
14. It is compact, rugged and economical.
15. Its gain in the horizontal plane is comparable to that of a dipole antenna.
16. Its overall performance as a function of frequency is similar to a high pass filter.
17. It is inefficient below cut-off and voltage standing wave ratio becomes high.
18. The slant height of the cone is about X/4 at cut-off.

## 6.18 NOTCH ANTENNA

It is an antenna which consists of a notch in a metallic sheet.

Salient features of Notch antenna

1. It consists of a notch cut in the edge of a metallic surface.
2. It is an open ended slot antenna (Fig. 6.41).
3. It is a broad-band antenna.

Metallic sheet

Notch

Fig. 6.41 *Notch antenna*

4. A typical radiation pattern of notch antenna is shown in Fig. 6.42.

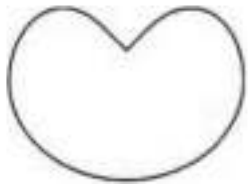
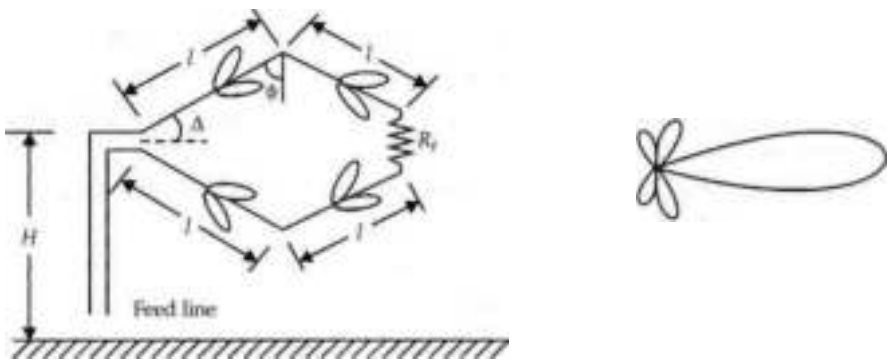


Fig. 6.42 Radiation pattern of notch antenna

5. Notch antennas can be easily made on the body of an aircraft.

## 6.1 RHOMBIC ANTENNA

This is an antenna which is in the shape of a rhombus. It is usually terminated in a resistance. The side of the rhombus, the angle between the sides, the elevation, termination and height above the earth are chosen to obtain the desired radiation characteristics. A typical Rhombic antenna and radiation



Radiation pattern

Fig. 6.26 Rhombic antenna and radiation pattern

pattern are shown in Fig. 6.26.

Salient features of Rhombic antenna

1. It is a long wire antenna and consists four non-resonant wires.
2. It provides greater directivity than *V* antenna.
3. Its band width is high.
4. It is a HF non-resonant antenna.
5. It is very useful for point-to-point communications.
6. It is a travelling wave antenna and there are no reflections.
7. It also finds wide applications where the angle of elevation of the main lobe (measured from the plane of the antenna to the radiation axis) is less than 30°.
8. At elevation angle above 30°, the gain is very low for practical applications.
9. The directivity of each wire is

*nl* *r* 而(1 - cos 0) (1 一 cos 0)

where $I$ = the magnitude of the current in element

9 = the polar angle

X = wavelength

$I$ = length of the radiator $r$ = the distance from the radiator to the elevation point.

The total directivity of the Rhombic antenna is the vector sum of directivity of each wire.

10. The length of equal radiators vary from 2 to 8X.
11. The tilt angle, Q varies between 40° and 75°.
12. (|)is determined from leg length.
13. The terminating resistance is about 800 Q.
14. The input impedance of Rhombic antenna lies between 650 to 700Q.
15. The directivity of Rhombic antenna varies between 20 and 90.
16. The power gain lies between 15 and 60 after taking power loss in terminating resistance into account.
17. It is a very useful antenna for transmission and reception in HF band.
18. It is easy and cheap to erect.
19. Its main disadvantages are:

(?) It requires more space for installation.

*(ii)* Its efficiency is less, as some power is lost in termination.

20. Its radiation pattern in a vertical plane is shown in Fig. 6.27.

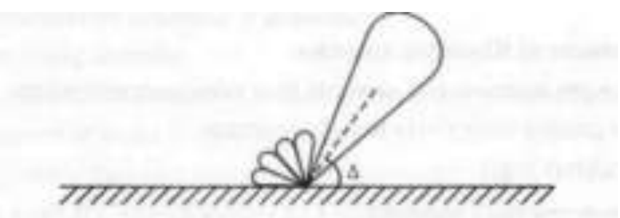



**Fig. 6.27** *Radiation pattern of Rhombic antenna in vertical plane*

In the design of Rhombic antennas the maximum point of the main lobe of the radiation pattern is aligned with the desired angle of elevation. The angle of elevation is also called angle of radiation.

The design parameters of Rhombic antenna are:

1. Rhombic height, $H$
2. Angle of elevation, 0
3. Wire length, /.

The design equations are

X

4 sin A …(6.12)

A = elevation angle

A is complement of tilt angle, e

$$\frac{X}{2\cos^2 ©} - \frac{X}{2\sin^2 A}$$ ...(6.13)

Alignment design equations.

Tilt angle, (|) = 90°- elevation angle

= 90°-A Rhombic …(6.14)

height,

H = ——

4 sin A 4 cos 0 …(6.15)

Wire length, $l = \frac{九}{2\sin^2 A} xK$

…(6.16)

~~ 7 xx

2 cos (]) 

where $K = 0.74$

The results are given in Table 6.2 for quick reference.

Table 6.2

(sin © = cos ∆)

| uency, f- 30 MHz,r X ■ TO /n | | | | | |
|---|---|---|---|---|---|
| le at ation I | 吕朴g疤甲 | mbic height X | meters | | i&ngth in rs |
| 10°<br>15°<br>20° | 80°<br>75°<br>70°<br>65°<br>60°<br>55°<br>50° | 9<br>6<br>0<br>1<br>0<br>5<br>0 | 9 | 8 | 65.8 |

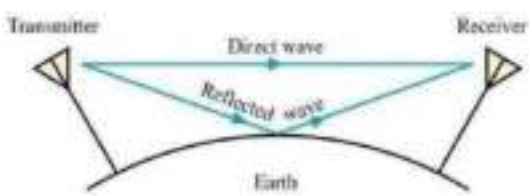
**UNIT III**

**WAVE PROPAGATION**

## Ground Eave Propagation:-

Propagation of EM wave near earth surface(including troposphere).When the Transmit and Receive antenna are on earth there can be multiple paths for communication. If the Transmit and Receive antenna are in line of sight (LOS)then direct path exist. The propagating wave is called direct wave. When EM wave encounters an interface between two dissimilar media, a part of energy will flow along the interface Known as Surface Wave. At LF and MF this is predominant mode of energy transfer for vertically polarized radiation. Interaction with the objects on ground will manifestas, Reflection, Refraction, Diffraction, Scattering. Waves are collectively called as Space Wave.

## Ground Reflection:

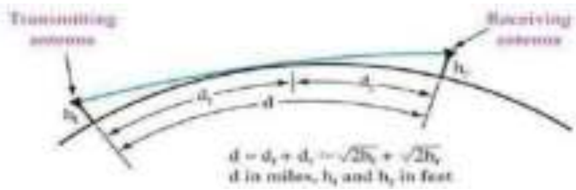



In LOS model,the assumption is that there is only one path for propagation of EM Wave from transmit antenna to receive antenna. The two antennas are kept in free space withno other objects intersecting radiation from transmitter antenna.If two antennas are situated close the ground due to discontinuity in the electrical properties at the air ground interface any wave that falls on the ground is reflected. The amount of reflection depending on factors like angle of incidence,Polarization of wave, Electrical Properties of the Ground i.e conductivity and dielectric constant,the frequency of the propagatingwave.Thus,the field at any point above the ground is a vector sum of the fields due to the direct and the reflected waves.

## Direct Wave-

It is limited to—line-of sightÂ transmission distances. The limiting factors are antenna height and curvature of earth. The Radiohorizonisabout80%greaterthanline of sight becauseof diffraction effects. A Part of the signal from the transmitter is bounced off the ground and reflected back to the receiving antenna. If the phase between the direct wave and the reflected wave are not in phase can cause problems

Detune the antenna so that the reflected wave is too weak to receive



## SURFACE EAVE

Travels directly without reflection on ground. Occurs when both antennas are in LOS

Spacewave bend near ground follows a curved path. Antennas must display a very low angle of emission.Power radiated must be in direction of the horizon instead of escaping in sky. A high gain and horizontally polarized antenna is recommended.

If dipole and the fieldpoints are on the surface of the earth but separated by a distanced, We have $R_2$=$R_1$=d and ψ=0
If ground has finite conductivity(typically10-3S/m-30*10-3S/m) then = -1,

The EF due to the direct and ground reflected wave will cancel each other. The EF due to the direct and ground reflected wave is also known as surface wave. Surface wave constitute the primary mode of propagation for frequencies in the range of few KHz- several MHz. In AM broadcast application, A vertical monopole above the ground is used to radiate power in the MW frequency b and.The receivers are placed very close to the surface of the earth and hence they receive the broadcast signal via surface wave. Achieve Propagation over hundreds of kilometers. Attenuation factor of the surface wave dependson

1. Distance between the transmitter and receiver.
2. The frequency of the electrical properties of the ground over which the

Ground propagates. At the surface of the earth the attenuation is also known as the ground wave attenuation factor and is designated as $A_{su}$

The numerical distance p=(πR/λχ)cosb, where b is the power factor angle b=tan-1(r+1/χ)

distance between the transmit and receive antennas and χis given asχ=ζ/ω0
For χ»r the power factor angle is nearly zero and the ground is almost resistive.
For a1MHz wave propagating over a ground surface with ζ=12*10-3S/m and$_r$=15 the valve of χis 215.7and is much greater than$_r$.
The power factor angle is $4.25^0$. At higher frequency100MHz the valve of χ is 2.157 and power factor angle becomes $82.32^0$

For large numerical distance the attenuation factor decreases by a factor of10 for every decade i.e 20dB/decade.Thus attenuation is inversely proportional to p and R.

The electric field intensity due to the surface wave is proportional to the product of As u and $e^{-jkR}/R$. The EF due to the surface wave at large distance from vertically polarized antenna is inversely propositional to the surface of the distance or the power is inverselypropositional to $R^4$.

The EF of a vertically polarized wave near the surface of the earth have a forward tilt. The magnitude of the wave tilt depends on the conductivity and permittivity of the earth. The horizontal component is smaller than the vertical component and they are not in phase. The EF is elliptically polarized very close to the surface of the earth.

## SPACE EAVE

The space wave follows two distinct paths from the transmitting antenna to the receiving antenna—one through the air directly to the receiving antenna, the other reflected from the ground to the receiving antenna. The primary path of the space wave is directly from the transmitting antenna to the receiving antenna. So, the receiving antenna must be located within the radio horizon of the transmitting antenna. Because space waves are refracted slightly, even when propagated through the troposphere, the radio horizon is actually about one-third farther than the line-of-sight or natural horizon.

Although space waves suffer little ground attenuation, they nevertheless are susceptible tofading. This is because space waves actually follow two paths of different lengths (direct path and ground reflected path) to the receiving site and, therefore, may arrive in or out of phase. If these two component waves are received in phase, the result is a reinforced or stronger signal. Likewise, if they are received out of phase, they tend to cancel one another, which results in a weak or fading signal.

## Sky ave

The sky wave, often called the ionospheric wave, is radiated in an upward direction and returned to Earth at some distant location because of refraction from the ionosphere. This form of propagation is relatively unaffected by the Earth's surface and can propagate signals over great distances. Usually the high frequency (hf) band is used for sky wave propagation. The following in-depth study of the ionosphere and its effect on sky waves will help you to better understand the nature of sky wave propagation.

## TROPOSPHERICPROPAGATION:

The lowest part of the earth‘s atmosphere is called the troposphere. Typically, the troposphere extends from the surface of the earth to an altitude of approximately 9km at the poles and 17km at the equator. This upper boundary is referred to as the tropo pause and is defined as the point at which the temperature in the atmosphere begins to increase with height. With in the troposphere, the temperature is found to decrease with altitude at a rate of approximately 7oCperkm.Theearth‘sweathersystemisconfinedtothe troposphere and the fluctuations in weather parameters like temperature, pressure and humidity cause the refractive index of the air in this layer to vary from one point to an other. It is in this context that the troposphere assumes a vital role in the propagation of radio waves at VHF (30- 300MHz)and UHF (300-3000MHz)frequencies. The meteorological conditions therefore influence the manner in which radio wave propagation occurs in the troposphere both ona spatial and temporal scale.

**Refractive Index, Refractivity and Modified Refractivity**

Transhorizon Radiowave Propagation due to Evaporation Ducting,The Effect of Tropospheric Weather Conditions on VHF and UHF Radio Paths Over the Sea

In general, the refractive index, n, of the troposphere decreases with altitude To simplify the mathematics involved variations in the horizontal are neglected and horizontal homogeneity of the refractive index of the troposphere is assumed in most discussions on this topic.A typical value for natsea levelis1.000350.Afewsabove sea level,this might decrease to a value such as1.000300.For all practical purposes,at this scale,this change in the refractive index is negligibly small,with hardly any visible deviation. However, immediately above the surface of the sea ,it is often this small(but rapid) change in the refractive index profile that facilitates the formation of meteorological phenomena called evaporation ducts .A convenient way of expressing these unwieldy numbers is to use the concept of refractivity instead. Refractivity, N, is defined as follows:

$N = (n-1)*10^6$

So, for example, when n=1.000350, N =350.
A well-known approximation for refractivity N is given below

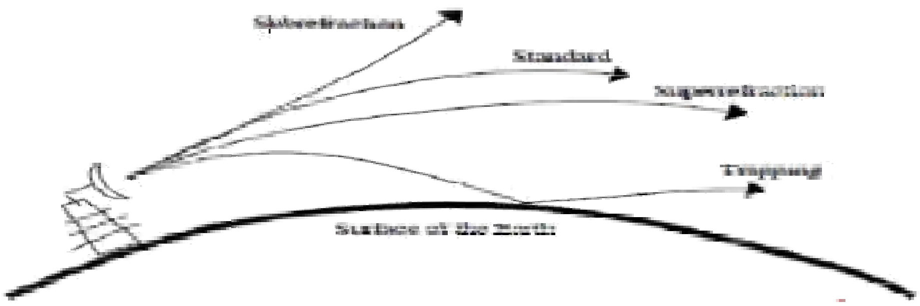
$$N = \frac{77.6}{T}\left(P + \frac{4810 * e}{T}\right)$$

Where P=total atmospheric pressure (in mb); T = atmospheric temperature (inK); e=water vapour pressure (in mb).

All three terms, P,T and e fall with height in an exponential manner, resulting in a corresponding decrease in N with height. A standard atmosphere, therefore is one in which the refractivity varies with altitude according to equation. Using Snell's law, a radio ray projected into the atmosphere will have to travel from a denser to rarer medium and will refract downwards towards the surface of the earth. The curvature of the ray, however, will still be less than the earth's curvature. The gradient of refractivity in this case generally varies from 0to–79N- units per kilo. When the refractivity gradient varies from–79to–157N-units per kilo, as uper refractive condition is said to prevail in the troposphere and the ray will refract downwards at a rate greater than standard but less than the curvature of the earth. A refractivity gradient that is even lessthan–157N-units per kilo will result in array that refracts to wards the earth's surface with a curvature that exceeds the curvature of the earth.This situation is referred to a strapping and is of particular importance in the context ofevaporation ducts. Finally, if the refractivity gradient is greater than 0N units per kilo, a sub refractive condition exists and a radio ray will now refract upwards, away from the surfaceof the earth.

Depending on the existing conditions in the troposphere, a radio wave will under go any of the types of refraction: sub refraction, standard refraction, super refraction or trapping. Figure1 illustrates the four refractive conditions discussed above.

While dealing with radio propagation profiles, the curved radio rays are rep aced with line arrays for the purpose of geometric simplicity.To account for drawing radio rays as straight lines, the earth radius has to be increased. The radius of this virtual sphere is




Known as the effective earth radius and it is approximately equal to four-thirds the true radius of the earth(i.e. roughly 8500km).A more classical form of representing n is that of modified refractivity, M. In this case, the surface of the earth is represented by a flat plane and the radio rays are constituted by curves that are determined by Snell‘s law and the corresponding value of M at each point along the radio link. The following is the expression for M

$$M = N + \left(\frac{h}{a}\right) * 10^6$$

N +0.157h,

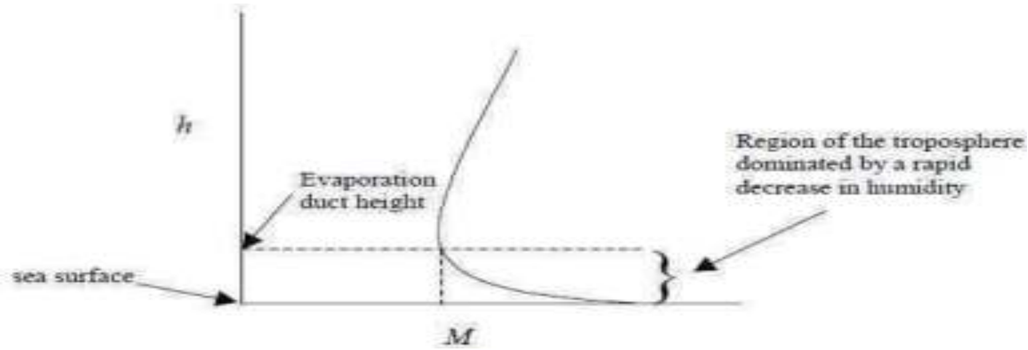
Where N=refractivity (in N-units),h= height above sea level(ins),a=radius of the earth (in s).

**Formation of Evaporation Ducts**

The air that is in immediate contact with these a surface is saturated with water vapour. As the height increases, the water vapour pressure in the atmosphere rapidly decreases until it reaches an ambient value at which it remains more or less static for a further increase in

height. There fore, for the first fews above the surface of the sea, it is the water vapour pressure, e, in the expression for N that dominates. This rapid decrease in e causes a steep fall in N.

This is reflected in the modified refractivity , M, which also correspondingly decreases.(The height term h,which increases,is more than off set by the rapidly decreasing N term). This behavior can be seen in the graph of h vs M




As that portion of the curve with a strong negative M gradient. Therefore, despite the fact that the height h is increasing, it is the sharp fall in the water vapour pressure, e, that contributes to the rapid decrease in M.

Once e has reached its ambient value at a given height, a further rise in altitude does not cause a substantial change in the humidity of the troposphere.Thus,as h increases further,N decreases more (since air pressure and temperature both decrease with height). But this decrease in N is very small over large height increments. Consequently, despite a decreasing N term, it is the h term that starts to domain at e in the expression for M. Thus,

M now gradually increases with height , and can be seen as the portion of the curve that has a positive M gradient.

The point at which the M gradient changes from negative to positive is referred to as the evaporation duct height(or thickness),and is a practical and realistic measure of the strength of the evaporation duct.

**Evaporation Ducts and the Troposphere**

By virtue of their nature of formation, evaporation ducts are nearly permanent features over the sea surface. Typically, the height of an evaporation duct is of the order of only a fews; however, this can vary considerably with geographical location and changes in atmospheric parameters such as humidity, air pressure and temperature. In the lower regions of the troposphere where the earth‘s weather is confined, these parameters do, in fact, fluctuate significantly. The turbulent nature of the atmosphere contributes to its unpredictability and a variable atmosphere, in turn, is one of the major causes of unreliable wireless communications. Depending on their location and the prevailing climate, evaporation duct heights may vary from a few meters to few tens of meters. Additionally,it is observed that calm sea conditions are more conducive for the creation of ducts. As a consequence of sporadic meteorological phenomena, evaporation duct heights undergo significant spatial and temporal variations. Evaporation ducts are weather-related phenomena; their heights cannot easily be measured directly using instruments like refractometers and radiosondes.

At best, the height of an evaporation duct can be deduced from the bulk meteorological parameters that are representative of the ongoing physical processes at the air-sea boundary.The dependence of evaporation ducts on the physical structure of the troposphere signifies that changing weather conditions can indeed result in alterations in radio wave propagation.

**Evaporation Ducts and Radio wave Propagation**

Over the years, much research has been undertaken to explain the mechanism of radio wave propagation in evaporation ducts. A key reason why evaporation ducts are so important for radio communications is because they are often associated with enhanced signal strengths at receivers. An evaporation duct can be regarded as a natural waveguide that steers the radio signal from the transmitter to a receiver that may be situated well beyond the radio horizon. The drop in the refractive index of the atmosphere with in the first few meters above the surface of the sea causes incident radio waves to be refracted towards the earth more than normal so that their radius of curvature becomes less than or equal to that of the earth‘s surface. The sudden change in the atmosphere‘s refractivity at the top of the duct causes the radio waves to refract back into the duct, and when it comes in contact with the surface of the sea, it gets reflected upwards again. The waves then propagate long ranges by means of successive reflections(refractions)from the top of the duct and the surface of the earth.

Since the top of an evaporation duct is not _solid‘(as in the case of an actual waveguide), there will be a small but finite amount of energy leakage in to the freespace immediately above the duct. However, despite this escape of energy, radiowaves are still capable of travelling great distances through the duct, with relatively small attenuation and path loss. The ducting effect of ten results in radio signals reaching places that are beyond the radio horizon with improved signal strengths. This naturally has far reaching implications on practical radio propagation patterns. For this reason, evaporation ducts and their impact on radio wave propagation have been studied extensively over the years. Numerous statistical models have been proposed to describe evaporation ducts and compute the duct heights under different atmospheric conditions.

The presence of evaporation ducts might not always indicate enhanced signal strengths. For instance, if there is an un wanted distant transmitter also located with in the duct, then there is always the possibility of the system under consideration being susceptible to signal interference and interception. This is dependent on the location of the radio paths being investigated. An other scenario that might arise is the interference between the various propagation modes that exist within the evaporation duct itself. Depending on the separation of the transmitter and receiver and the prevailing atmospheric conditions, there could be destructive interference between the direct and reflected rays, the latter of which is comprised of the various multiple hop (one-hop, two-hop, and so on) propagation modes. Additionally, signal degradation may also occur if there is destructive interference between various modes that arrive at the receiver after refraction from different heights in the troposphere. All these situations could possibly cause key problems in the domain of cellular mobile communication systems in littoral regions. Thus, in addition to aiding radio wave propagation, evaporation ducts could also be principal limiting factors in beyond line of sight over-the-sea UHF propagation.

**Introduction of Sky propaagation or IONOSPERIC Eave Propagation**

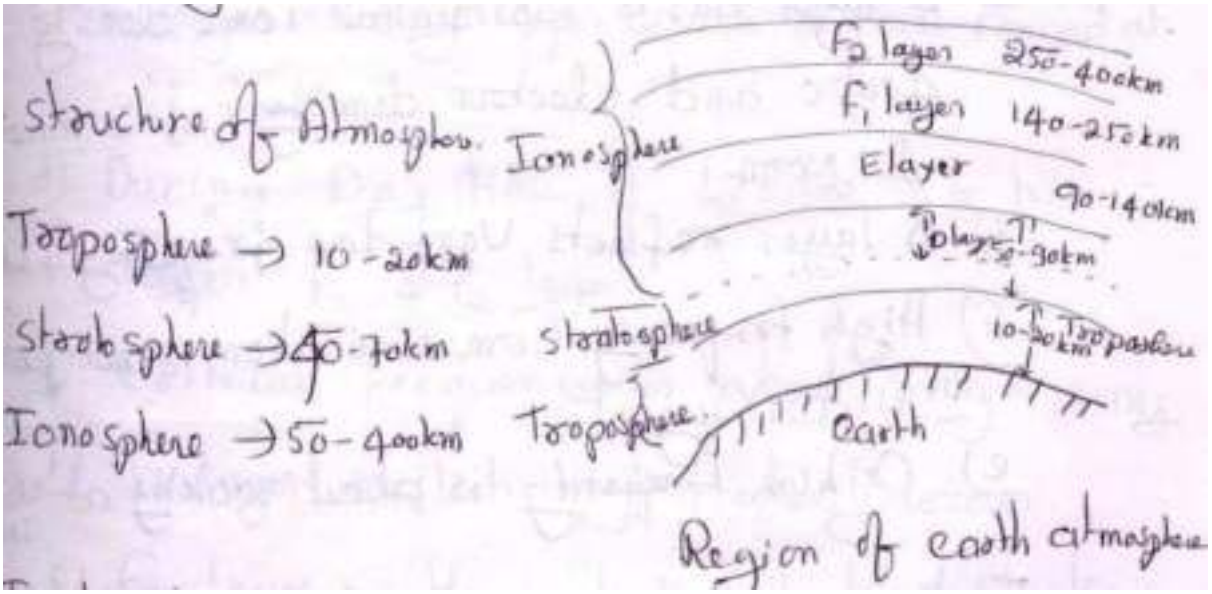
Medium and high frequencies of 2 to 30 MHz
Reflection from the ionized region in the upper atmosphere called Ionosphere (50Km to 400Km above earth surface).
Ionosphere – act as a reflected surface
More than 30 MHz- not reflected & penetrate into Ionosphere. Refection from Ionosphere called as ionosphere propagation. Suitable for 2 to 30 MHz called as short wave propagation.
Long distance point to point communication called as point to point propagation. Possible with multiple reflection extremely long distance communication.

**STRUCTURE OF THE IONOSPHERE**

As we stated earlier, the ionosphere is the region of the atmosphere that extends from about 30 miles above the surface of the Earth to about 250 miles. It is appropriately named the ionosphere because it consists of several layers of electrically charged gas atoms called ions. The ions are formed by a process called ionization.

**Ionization**

Ionization occurs when high energy ultraviolet light waves from the sun enter the ionospheric region of the atmosphere, strike a gas atom, and literally knock an electron free from its parent atom. A normal atom is electrically neutral since it contains both a positive proton in its nucleus and a negative orbiting electron. When the negative electron is knocked free from the atom, the atom becomes positively charged (called a positive ion) and remains in space along with the free electron, which is negatively charged. This process of upsetting electrical neutrality is known as IONIZATION. The free negative electrons subsequently absorb part of the ultraviolet energy, which initially freed them from their atoms. As the ultraviolet light wave continues to produce positive ions and negative electrons, its intensity decreases because of the absorption of energy by the free electrons, and an ionized layer is formed.
The rate at which ionization occurs depends on the density of atoms in the atmosphere and the intensity of the ultraviolet light wave, which varies with the activity of the sun.
Since the atmosphere is bombarded by ultraviolet light waves of different frequencies, several ionized layers are formed at different altitudes. Lower frequency ultraviolet waves penetrate the




atmosphere the least; therefore, they produce ionized layers at the higher altitudes. Conversely, ultraviolet waves of higher frequencies penetrate deeper and produce layers at the lower altitudes. An important factor in determining the density of ionized layers is the elevation angle of the sun, which changes frequently. For this reason, the height and thickness of the ionized layers vary, depending on the time of day and even the season of the year. Recombination Recall that the process of ionization involves ultraviolet light waves knocking electrons free from their atoms. A reverse process called RECOMBINATION occurs when the free electrons and positive ions collide with each other. Since these collisions are inevitable, the positive ions return to their original neutral atom state.

The recombination process also depends on the time of day. Between the hours of early morning and late afternoon, the rate of ionization exceeds the rate of recombination. During this period, the ionized layers reach their greatest density and exert maximum influence on radio waves.

During the late afternoon and early evening hours, however, the rate of recombination exceeds the rate of ionization, and the density of the ionized layers begins to decrease. Throughout the night, density continues to decrease, reaching a low point just before sunrise.

Four Distinct Layers

The ionosphere is composed of three layers designated D, E, and F, from lowest level to highest level as shown in figure, The F layer is further divided into two layers designated F1 (the lower layer) and F2 (the higher layer). The presence or absence of these layers inthe ionosphere and their height above the Earth varies with the position of the sun. At high noon, radiation in the ionosphere directly above a given point is greatest. At night it is minimum. When the radiation is removed, many of the particles that were ionized recombine. The time interval between these conditions finds the position and number of the ionized layers within the ionosphere changing.

Since the position of the sun varies daily, monthly, and yearly, with respect to a specified point on Earth, the exact position and number of layers present are extremely difficult to determine.

However, the following general statements can be made:

The D layer ranges from about 30 to 55 miles. Ionization in the D layer is low because it is the lowest region of the ionosphere. This layer has the ability to refract signals of low frequencies. High frequencies pass right through it and are attenuated. After sunset, the D layer disappears because of the rapid recombination of ions.

b. The E layer limits are from about 55 to 90 miles. This layer is also known as the Kennelly-Heaviside layer, because these two men were the first to propose its existence. The rate of ionic recombination in this layer is rather rapid after sunset and the layer is almost gone by midnight. This layer has the ability to refract signals as high as 20 megahertz. For this reason, it is valuable for communications in ranges up to about 1500 miles.

c. The F layer exists from about 90 to 240 miles. During the daylight hours, the F layer separates into two layers, the F1 and F2 layers. The ionization level in these layers is quite high and varies widely during the day. At noon, this portion of the atmosphere is closest to the sun and the degree of ionization is maximum. Since the atmosphere is rarefied at these heights, recombination occurs slowly after sunset. Therefore, a fairly constant ionized layer is always present. The F layers are responsible for high-frequency, long distance transmission.

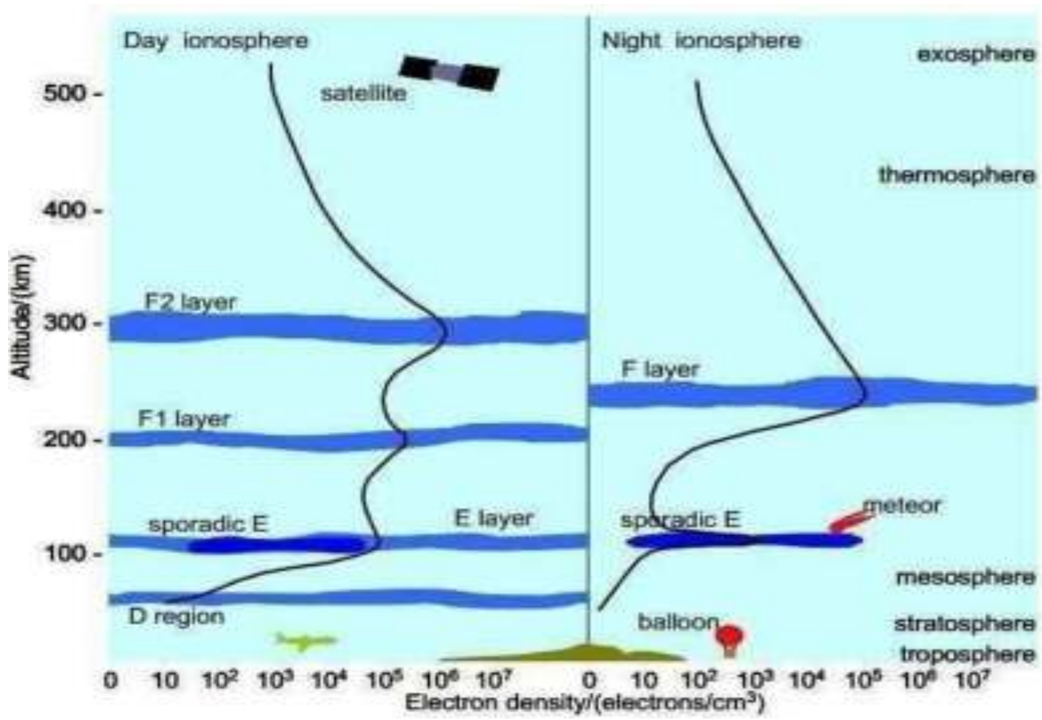
**REFRACTION IN THE IONOSPHERE**

When a radio wave is transmitted into an ionized layer, refraction, or bending of the wave, occurs. As we discussed earlier, refraction is caused by an abrupt change in the velocity of the upper part of a radio wave as it strikes or enters a new medium. The amount of refraction that occurs depends on three main factors: (1) the density of ionization of the layer, (2) the frequency of the radio wave, and (3) the angle at which the wave enters the layer.
Density of Layer the relationship between radio waves and ionization density. Each ionized layer has a central region of relatively dense ionization, which tapers off in intensity both above and below the maximum region. As a radio wave enters a region of INCREASING ionization, the increase in velocity of the upper part of the wave causes it to be bent back TOWARD the Earth. While the wave is in the highly dense center portion of the layer, however, refraction occurs more slowly because the density of ionization is almost uniform. As the wave enters into the upper part of the layer of DECREASING ionization, the velocity of the upper part of the wave decreases, and the wave is bent AWAY from the Earth.

If a wave strikes a thin, very highly ionized layer, the wave may be bent back so rapidly that it will appear to have been reflected instead of refracted back to Earth. To reflect a radio wave, the highly ionized layer must be approximately no thicker than one wavelength of the radio wave.

Since the ionized layers are often several miles thick, ionospheric reflection is more likely to occur at long wavelengths (low frequencies).

**Day and night structure of ionosphere:**




**Critical Frequency**

For any given time, each ionospheric layer has a maximum frequency at which radio waves can be transmitted vertically and refracted back to Earth. This frequency is known as the CRITICAL FREQUENCY. It is a term that you will hear frequently in any discussion of radio wave propagation.

Radio waves transmitted at frequencies higher than the critical frequency of a given layer will pass through the layer and be lost in space; but if these same waves enter an upper layer with a higher critical frequency, they will be refracted back to Earth. Radio waves of frequencies lower than the critical frequency will also be refracted back to Earth unless they are absorbed or have been refracted from a lower layer. The lower the frequency of a radio wave, the more rapidly the wave is refracted by a given degree of ionization. Figure 2-16 shows three separate waves of different frequencies entering an ionospheric layer at the same angle. Notice that the 5-megahertz wave is refracted quite sharply. The 20-megahertz wave is refracted less sharply and returned to Earth at a greater distance. The 100-megahertz wave is obviously greater than the critical frequency for that ionized layer and, therefore, is not refracted but is passed into space.

**Maximum Usable Frequency**

As we discussed earlier, the higher the frequency of a radio wave, the lower the rate of refraction by an ionized layer. Therefore, for a given angle of incidence and time of day, there is a maximum frequency that can be used for communications between two given locations. This frequency is known as the MAXIMUM USABLE FREQUENCY (muf).

Waves at frequencies above the muf are normally refracted so slowly that they return to Earth beyond the desired location, or pass on through the ionosphere and are lost. You should understand, however, that use of an established muf certainly does not guarantee successful communications between a transmitting site and a receiving site. Variations in the ionosphere may occur at any time and consequently raise or lower the predetermined muf. This is particularly true for radio waves being refracted by the highly variable F2 layer. The muf is highest around noon when ultraviolet light waves from the sun are the most intense. It then drops rather sharply as recombination begins to take place.

$$\therefore \sin\phi_i = \sqrt{1 - \frac{81 N_{max}}{f_{muf}^2}}$$

Squaring both sides

$$\sin^2\phi_i = 1 - \frac{81 N_{max}}{f_{muf}^2}$$

$$\therefore \frac{81 N_{max}}{f_{muf}^2} = 1 - \sin^2\phi_i = \cos^2\phi_i.$$

but $f_{cr} = \sqrt{81 N_{max}}$

$$\therefore \frac{f_{cr}^2}{f_{muf}^2} = \cos^2\phi_i$$

$$\therefore f_{muf} = \frac{f_{cr}}{\cos\phi_i} = \sec\phi_i \, f_{cr}$$

∴ The $f_{muf}$ is always greater than $f_{cr}$ of the layer by the factor $\sec\phi_i$. This is called Secant law.

## Lowest Usable Frequency

As there is a maximum operating frequency that can be used for communications between two points, there is also a minimum operating frequency. This is known as the LOWEST USABLE FREQUENCY (luf). As the frequency of a radio wave is lowered, the rate of refraction increases. So a wave whose frequency is below the established luf is refracted back to Earth at a shorter distance than desired, as shown in figure

The transmission path that results from the rate of refraction is not the only factor that determines the luf. As a frequency is lowered, absorption of the radio wave increases. A wave whose frequency is too low is absorbed to such an extent that it is too weak for reception. Likewise, atmospheric noise is greater at lower frequencies; thus, a low- frequency radio wave may have an unacceptable signal-to-noise ratio. For a given angle of incidence and set of ionospheric conditions, the luf for successful communications between two locations depends on the refraction properties of the ionosphere, absorption considerations, and the amount of atmospheric noise present.

## Optimum Eorking Frequency

Neither the muf nor the luf is a practical operating frequency. While radio waves at the luf can be refracted back to Earth at the desired location, the signal-to-noise ratio is still much lower than at the higher frequencies, and the probability of multipath propagation is much greater. Operating at or near the muf can result in frequent signal fading and dropouts when ionospheric variations alter the length of the transmission path. The most practical operating frequency is one that you can rely on with the least amount of problems. It should be high enough to avoid the problems of multipath, absorption, and noise encountered at the lower frequencies; but not so high as to result in the adverse effects of rapid changes in the ionosphere. A frequency that meets the above criteria has been established and is known as the OPTIMUM WORKING FREQUENCY. It is abbreviated "fot" from the initial letters of the French words for optimum working frequency, "frequence optimum de travail." The fot is roughly about 85 percent of the muf but the actual percentage varies and may be either considerably more or less than 85 percent.

## Skip Distance/Skip Zone

The relationship between the sky wave skip distance, the skip zone, and the ground wave coverage. The SKIP DISTANCE is the distance from the transmitter to the point where the sky wave is first returned to Earth. The size of the skip distance depends on the frequency of the wave, the angle of incidence, and the degree of ionization present.

**The SKIP ZONE** is a zone of silence between the point where the ground wave becomes too weak for reception and the point where the sky wave is first returned to Earth. The size of the skip zone depends on the extent of the ground wave coverage and the skip distance. When the ground wave coverage is great enough or the skip distance is short enough that no zone of silence occurs, there is no skip zone. Occasionally, the first sky wave will returnto Earth within the range of the ground wave. If the sky wave and ground wave are nearly of equal intensity, the sky wave alternately reinforces and cancels the ground wave, causing severe fading. This is caused by the phase difference between the two waves, a result of the longer path traveled by the sky wave.

$D_{skip} = 2h \sqrt{[(f_{muf} / f_c)2-1]}$

## MULTI -HOP PROPAGATIONS

The coverage of transmission distance between transmitter and receiver in more than one hop is called multi-hop propagation.
The longest single hop propagation is obtained when the transmitted ray is tangential at the earth surface.
The maximum practical distance covered by a single hop is 2000 km for E layer and 4000 km for F2 layer.
Multi-hop propagation paths occur when the semicircumference of the earth is just over 20,000 km.

## VIRTUAL HIGHT

Defined as the height to which a short pulse of energy sent vertically upward. It will always be greater than the actual height.
If it is known, it is easy to calculate the angle of incidence required for the wave to return at a desired point.
The measurement of virtual height is normally carried out by means of an instrument known as ionosonde.

H = CT/2 , C – velocity of light, T – Round trip time.

## METHOD OF VIRTUAL HIGHT MEASUREMENT

Transmit a signal that consists pulses of RF energy of short duration.
Receiver which is located close to the transmitter picks up both the direct and the reflected signals.
The spacing between these signals on the time axis of CRO gives a measurement of the height of the layer.
Useful in transmission path calculations.

**UNIT IV**

## 4.0 DEVELOPMENT OF TELEVISION

- It is widely used telecommunication system for broadcasting and receiving moving pictures and sound over a distance
- The word television is derived from latin word “Tele” means far and “Vision” means sight. Hence television means to see from a distance
- In the early years of the $20^{th}$ century many scientists experimented with the idea of using selenium photosensitive cells for converting light from pictures into electrical signals and transmittig them through wires
- First demonstration was given by J.L. Baird in UK and C.F. Jemkins in USA around 1927 – mechanical scanning technique employing rotating disc that did not scan a picture rapidly enough
- The real breakthrough occurred with invention of the cathode ray tube - the first camera tube (the iconoscope) based on the storage principle by V.K. Zworkykin of USA

- By 1930 electromagnetic scanning of both camera and picture tubes and otherancillary circuits were developed
- Television broadcast started in the year 1935

**TELEVISION SYSTEMS**

- In the absence of any international standards, three monochrome (black & white )systems grew independently
- 525 line American, 625 line European and 819 line French system
- It prevents direct exchange of programme between countries using different TVstandards
- All world committee on radio and television proved to have common 625 line system
- In India television transmission started in 1959, the 625-B monochrome system

**APPLICATIONS OF TELEVISION**

- Public entertainment
- Social education
- Mass communication
- Newscasts
- Weather reports
- Political organization and campaigns
- Announcements and guidance at public places like airport

**4.1 MONOCHROME TV TRANSMITTER**

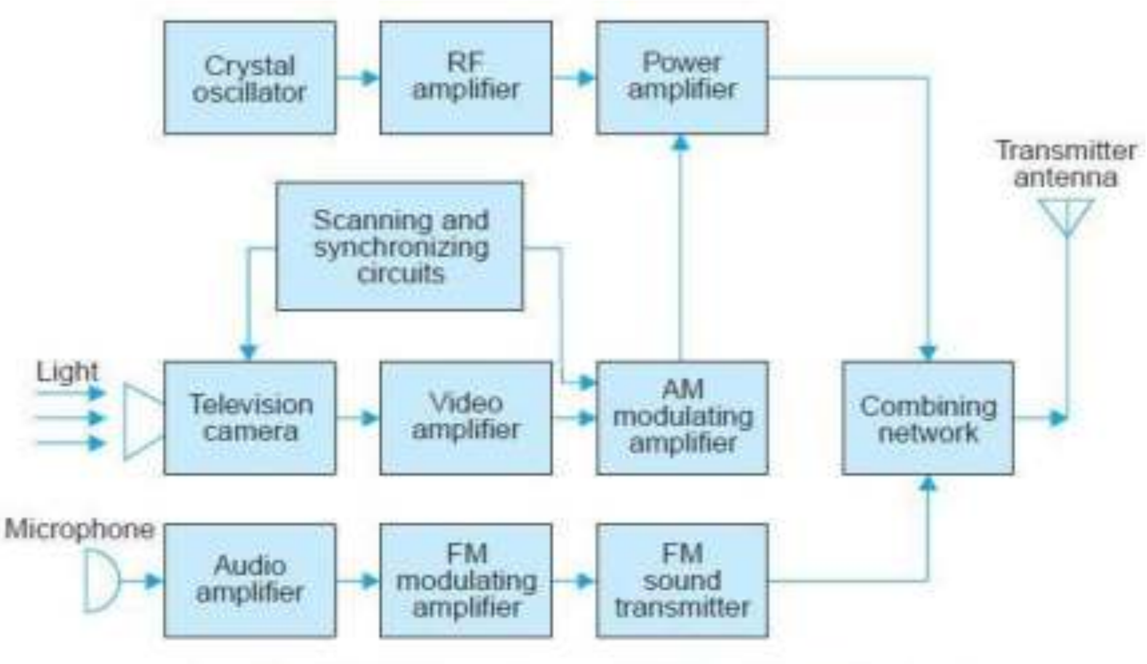



Fig. 1.1 (*a*) Basic monochrome television transmitter.

- In TV transmission both picture and sound are transmitted
  - For picture, AM modulation is used and for sound, FM modulation is usedFigure

shows the block diagram of TV transmission. It consists of

- Television camera

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

- Video amplifier

It is used for amplifying the video signal

- AM modulating amplifier

The video signals are AM modulated by the AM modulating amplifier to getthe modulated signal

- Microphone

It converts sound associated with picture being televised into proportionateelectrical signal

- Audio amplifier

It amplifies the electrical form of audio signal from the microphone

- FM modulating amplifier

The sound signals from audio amplifier are frequency modulated by FMmodulating amplifier

- FM sound transmitter

FM modulated amplified signal is transmitted through FM sound transmitter to transmitting antenna through the combining network

- Crystal oscillator

It generates the allotted picture carrier frequency

- RF amplifier

It amplifies the picture carrier frequency generated by crystal oscillator torequired level

- Power amplifier

It varies according to the modulating signal from AM modulating amplifier

- Scanning and Synchronising circuits

Scanning is the process where picture elements are converted intocorresponding varying electrical signals

- Combining network

It is used to isolate the AM picture and FM sound signal during transmission

- Transmitting antenna

It receives the AM picture signal and FM sound signal from combiningnetwork for radiation as electromagnetic waves

## MONOCHROME TV RECEIVER

- Block diagram of a monochrome TV receiver is shown in the figure.

- It consists of

- Receiver antenna

It intercepts the radiated RF signals and sent it to RF tuner

- RF Tuner

RF tuner selects the desired channel frequency band from the receivingantenna

- Common IF amplifier

There are 2 or 3 stages of IF amplifier

- Video detector

It is used to detect video signals from the last stage of IF amplifier

- Video amplifier

It amplifies the detected video signal to the level required

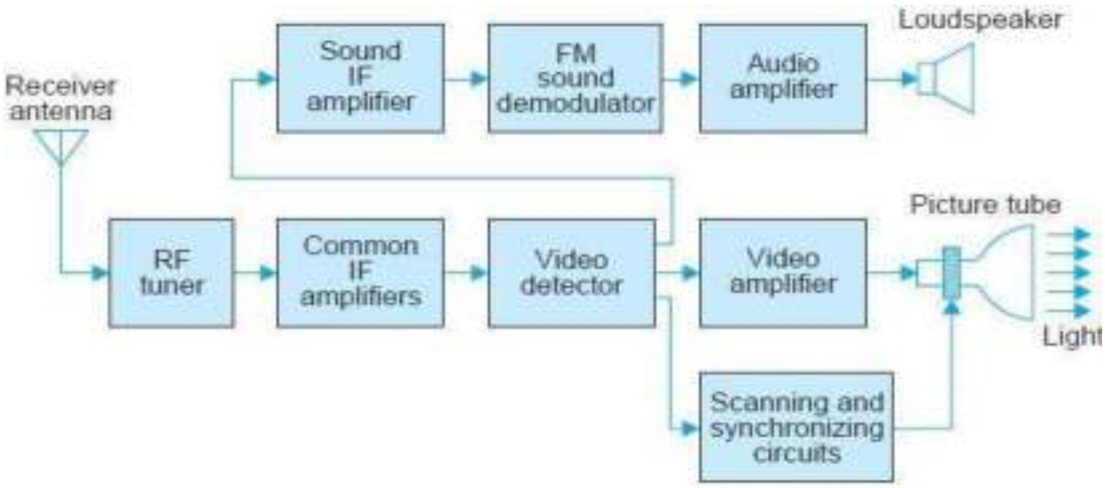



Fig. 1.1 (b) Basic monochrome television receiver.

- Scanning and synchronizing circuits

Scanning is the process where picture elements are converted intocorresponding varying electrical signals

- Sound IF amplifier

It detects the audio signals from video detector and selected for its IF rangeand amplified

- FM sound demodulator

FM sound signal is demodulated

- Audio amplifier

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

- Loud speaker

It 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

**SOUND TRANSMISSION**

- The microphone converts the sound associated with the picture being televised into proportionate electrical signal, which is normally a voltage
- This electrical output, regardless of the complexity of its waveform, is a single valuedfunction of time and so needs a single channel for its transmission
- The audio signal from the microphone after amplification is frequency modulated, employing the assigned carrier frequency
- In FM, the amplitude of the carrier signal is held constant, whereas its frequency isvaried in accordance with amplitude variations of the modulating signal
- The output of the sound FM transmitter is finally combined with the AM picturetransmitter output, through combining network
- From the combining network, it is fed to a common antenna for radiation of energy in the form of electromagnetic waves

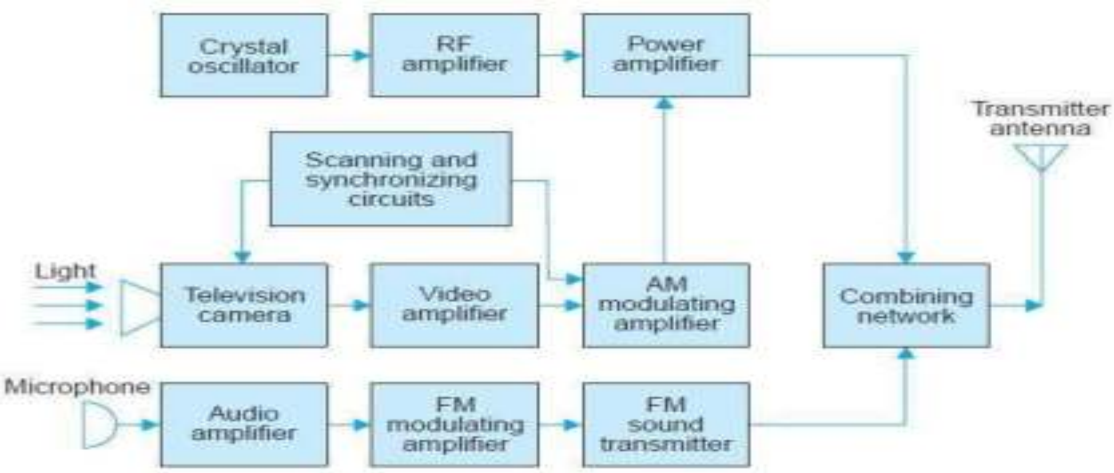



Fig. 1.1 (a) Basic monochrome television transmitter.

**SOUND RECEPTION**

- The path of the sound signal is common with the picture signal from antenna to the video detector section of the receiver
- The two signals are separate and fed into their respective channels
- The frequency modulated audio signal is demodulated after at least one stage ofamplification
- The audio output from the FM detector is given due amplification before feeding it tothe loudspeaker

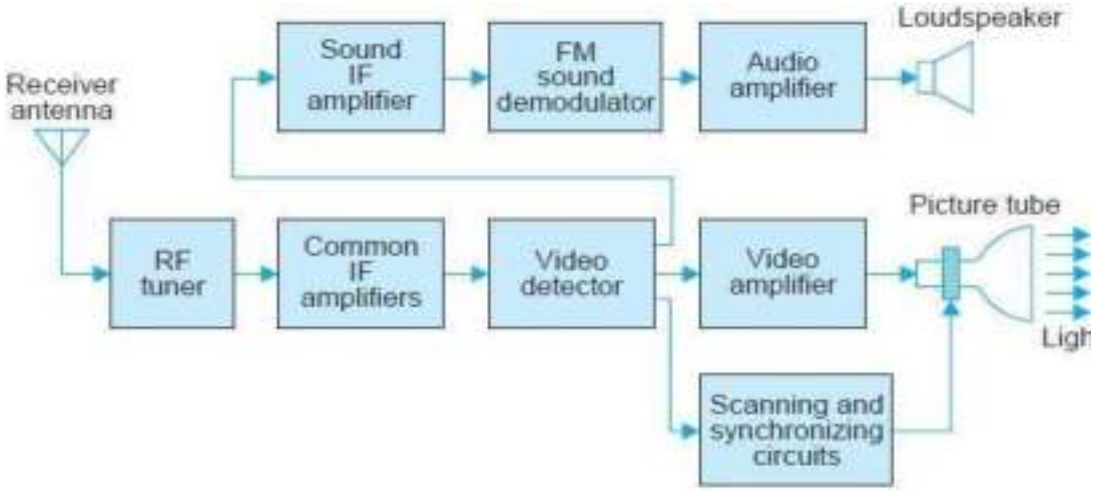
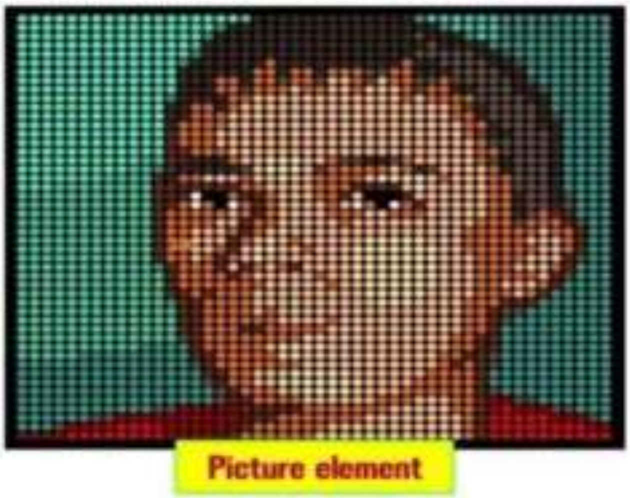



Fig. 1.1 (*b*) Basic monochrome television receiver.

**PICTURE TRANSMISSION**




- The picture information is optical in character

- An assemblage of a large number of bright and dark areas representing picture details
- The elementary areas into which the picture details may be broken up are known as ‘picture elements’ which when viewed together, represent the visual information ofthe scene
- The problem of picture transmission is fundamentally much more complex, because, at any instant there are almost an infinite number of pieces of information, existing simultaneously, each representing the level of brightness of the scene to the reproduced
- In other words, the information is a function of two variables, time & space
- Need an infinite number of channels to transmit optical information corresponding to all the picture elements simultaneously
- The method scanning is used to transmit all the information simultaneously anddecoding it at the receiving end seen insurmountable
- The conversion of optical information to electrical form and its transmission are carried out element by element, one at a time and in a sequential manner to cover the entire scene which is to be televised
- Scanning of the elements is done at a very fast rate and this process is repeated a large number of times per second to create an illusion of simultaneous pick-up and transmission of picture details

## 4.2 VIDICON – CAMERA TUBE

- A TV camera is the heart of the camera tube, is used to convert the optical information into a corresponding electrical signal, the amplitude of which varies in accordance with the variations of brightness
- Figure shows the elementary details of one type of camera tube – vidicon to illustrate the principle of camera tube
- An optical image of the scene to be transmitted is focused by a lens assembly on the rectangular glass face-plate of the camera tube
- The inner side of the glass face-plate has a transparent conductive coating on which islaid a very thin layer of photoconductive material
- The photolayer has a very high resistance when no light falls on it, but decreases depending on the intensity of light falling on it
- Depending on the light intensity variations in the focused optical image, the conductivity of each element of the photolayer changes accordingly

- The beam is formed by an electron gun in the TV camera tube
- On its way to the inner side of the glass face-plate it is deflected by a pair of deflecting coils mounted on the glass envelope and kept mutually perpendicular to each other to achieve scanning of the entire target area

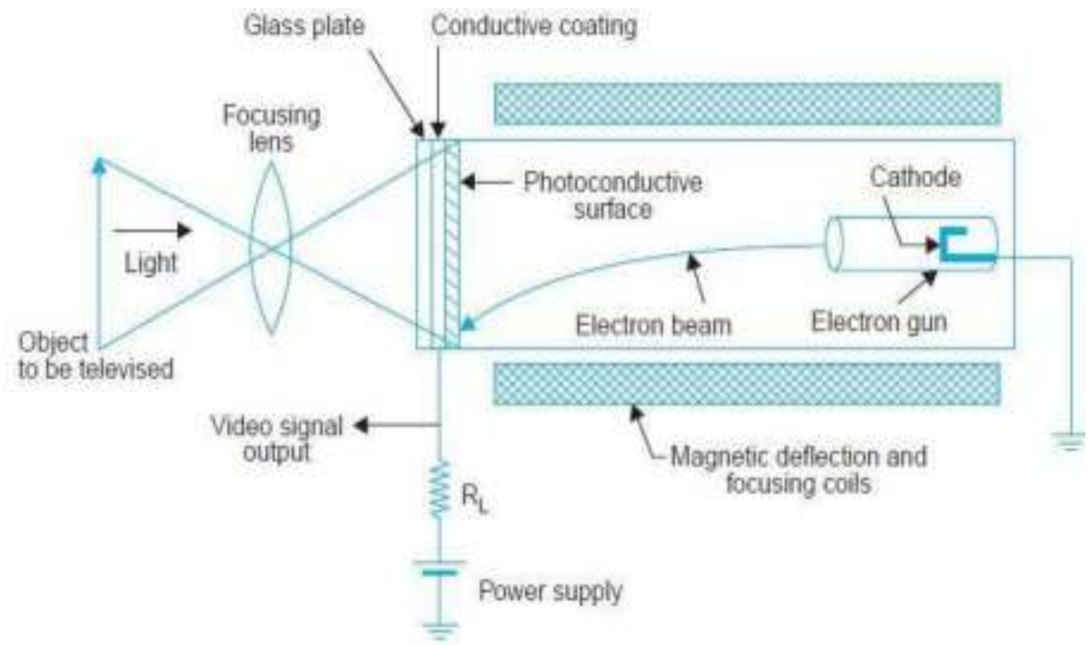



Fig. 1.2 (a) Simplified cross-sectional view of a Vidicon TV camera tube

- Scanning is done in the same way as one reads a written page to cover all the words inone line and all the lines on the page
- To achieve this the deflecting coils are fed separately from two sweep oscillators which continuously generate saw-tooth waveforms, each operating at a different desired frequency
- The magnetic deflection caused by the current in one coil gives horizontal motion to the beam from left to right at a uniform rate and then brings it quickly to the left side to commence the trace of next line
- The other coil is used to deflect the beam from top to bottom at a uniform rate and for its quick retrace back to the top of the plate to start this process all over again
- Two simultaneous motions are thus given to the beam, one from left to right acrossthe target plate and the other from top to bottom thereby covering the entire area on which the electrical image of the picture is available
- As the beam moves from element to element, it encounters a different resistance across the target-plate, depending on the resistance of the photoconductive coating
- The result is a flow of current which varies in magnitude as the elements are scanned

- This current passes through a load resistance $R_L$, connected to the conductive coating on one side and to a dc supply source on the other
- Depending on the magnitude of the current a varying voltage appears across the resistance $R_L$ ad this corresponds to the optical information of the picture

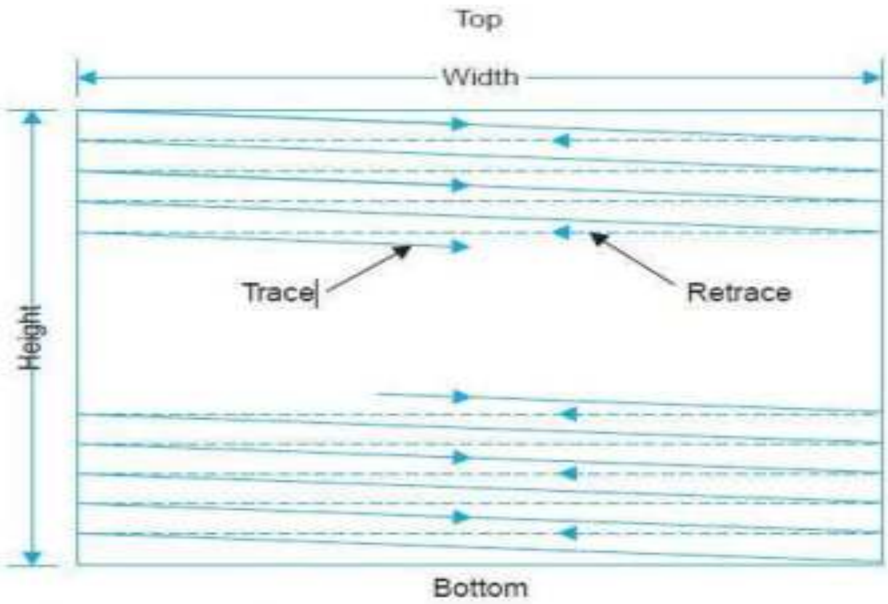



Fig. 1.2 (*b*) Path of scanning beam in covering picture area.

- If the scanning beam moves at such a rate that any portion of the scene content does not have time to move perceptibly in the time required for one complete scan of the image, the resultant electrical signal contains the true information existing in the picture during the time of the scan
- The desired information is now in the form of a signal varying with time and scanning may thus be identified as a particular process which permits the conversion of information existing in space and time coordinates into time variations only.
- The electrical information obtained from the TV camera tube is generally referred to as video signal
- This signal is amplified and then amplitude modulated with the channel picture carrier frequency
- The modulated output is fed to the transmitter antenna for radiation along with the sound signal

**PICTURE RECEPTION**

- The receiving antenna intercepts the radiated picture and sound carrier signals andfeeds them to the RF tuner

- The receiver is of the heterodyne type and employs two or three stages of intermediate frequency (IF) amplification
- The output from the last IF stage is demodulated to recover the video signal. This signal that carries the picture information is amplified and coupled to the picture tube which converts the electrical signal back into picture elements of the same degree of black and white

**PICTURE TUBE**

- The picture tube shown in figure is very similar to the cathode-ray tube used in an oscilloscope
- The glass envelope contains an electron gun structure that produces a beam of electrons aimed at the fluorescent screen
- When the electron beam strikes the screen, light is emitted
- The beam is deflected by a pair of deflecting coils mounted on the neck of the picturetube in the same way and rate as the beam scans the target in the camera tube
- The amplitudes of the currents in the horizontal and vertical deflecting coils are so adjusted that the entire screen, called raster, gets illuminated because of the fast rate of scanning.

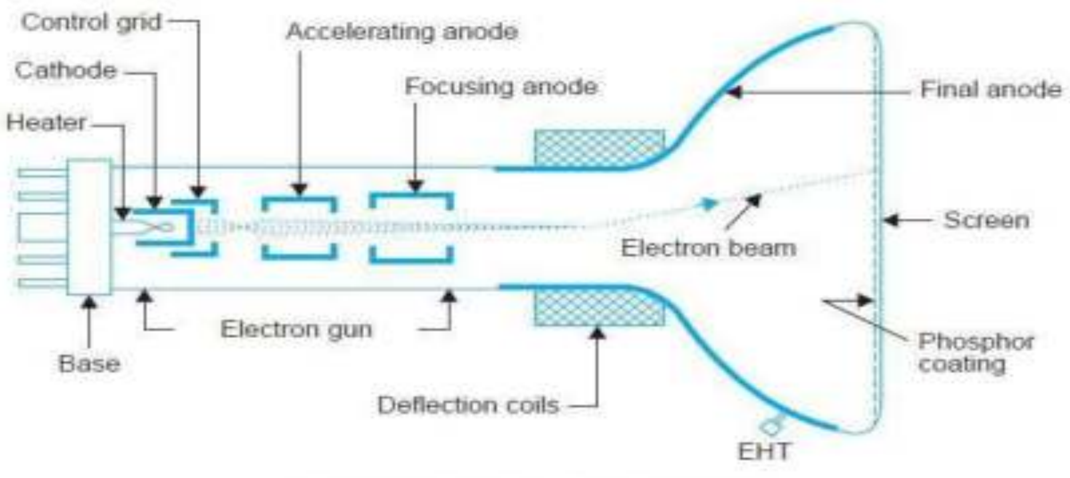


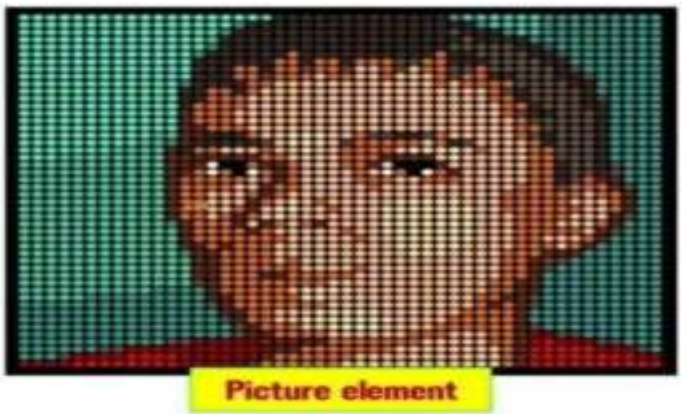

Fig. 1.3 Elements of a picture tube.

- The video signal is fed to the grid or cathode of the picture tube.
- When the varying signal voltage makes the control grid less negative, the beamcurrent is increased, making the spot of light on the screen brighter.

- More negative grid voltage reduces the brightness. if the grid voltages is negative enough to cut-off the electron beam current at the picture tube there will be no light. This state corresponds to black.
- Thus the video signal illuminates the fluorescent screen from white to black through various shades of grey depending on its amplitude at any instant.
- This corresponds to the brightness changes encountered by the electron beam of the camera tube while scanning the picture details element by element.
- The rate at which the spot of light moves is so fast that the eye is unable to follow it and so a complete picture is seen because of the storage capability of the human eye.

## SYNCHRONIZATION

- It is essential that the same coordinates be scanned at any instant both at the camera tube target plate and at the raster of the picture tube, otherwise, the picture details would split and get distorted.
- To ensure perfect synchronization between the scene being televised and the picture produced on the raster, synchronizing pulses are transmitted during the retrace, *i.e.,* fly-back intervals of horizontal and vertical motions of the camera scanning beam.
- Thus, in addition to carrying picture detail, the radiated signal at the transmitter also contains synchronizing pulses.
- These pulses which are distinct for horizontal and vertical motion control, are processed at the receiver and fed to the picture tube sweep circuitry thus ensuring that the receiver picture tube beam is in step with the transmitter camera tube beam.




## RECEIVER CONTROLS

✔The front view of a typical monochrome TV receiver, having various controls is shown in figure.

✔ The channel selector switch is used for selecting the desired channel.

✔The fine tuning control is provided for obtaining best picture details in the selected channel.

✔The hold control is used to get a steady picture in case it rolls up or down.

✔The brightness control varies the beam intensity of the picture tube and is set for optimum average brightness of the picture.

✔The contrast control is actually the gain control of the video amplifier.

✔This can be varied to obtain the desired contrast between the white and black contentsof the reproduced picture.

✔The volume and tone controls form part of the audio amplifier in the sound section, and are used for setting the volume and tonal quality of the sound output from the loudspeaker.

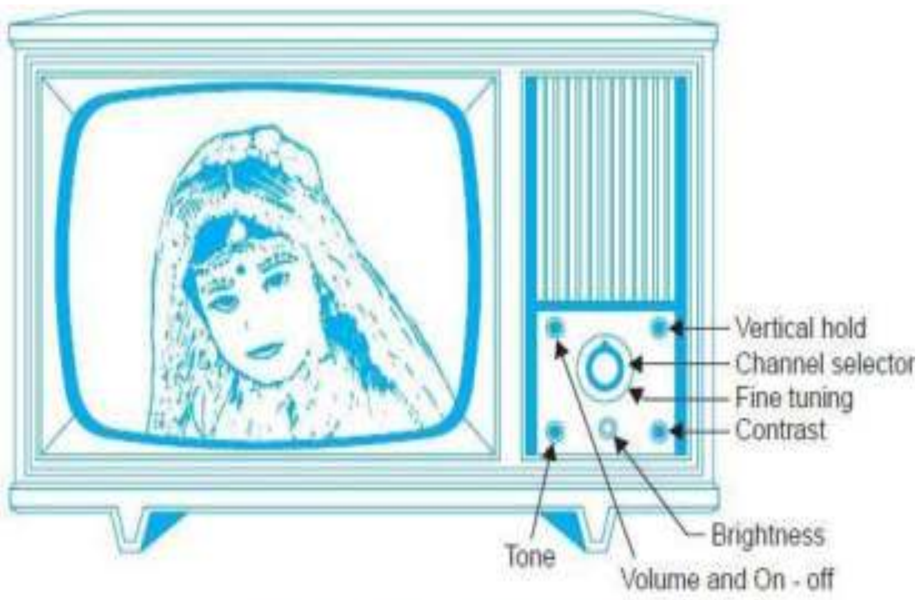



Fig. 1.4 Television receiver controls

**COLOUR TELEVISION**

- Colour television is based on the theory of additive colour mixing, where all coloursincluding white can be created by mixing red, green, and blue lights.
- The colour camera provides video signals for the red, green, and blue information.
- These are combined and transmitted along with the brightness (monochrome) signal.
- Each colour TV system is compatible with the corresponding monochrome system.

- Compatibility means that colour broadcasts can be received as black and white on monochrome receivers.
- Conversely colour receivers are able to receive black and white TV broadcasts.

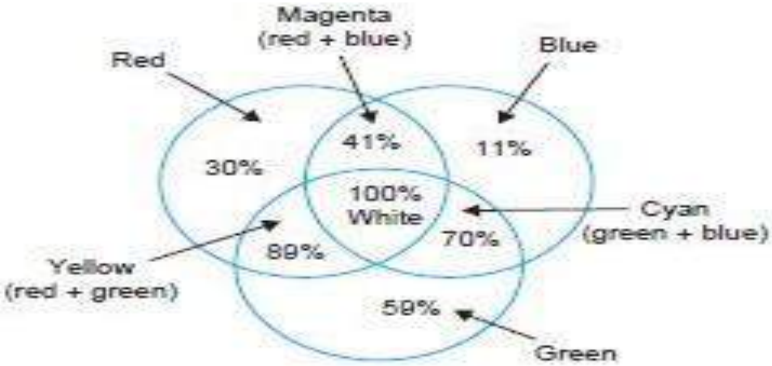



Fig. 25.3 (a). Additive colour mixing. The diagram shows the effect of projecting green, red and blue beams on a white screen in such a way that they overlap.

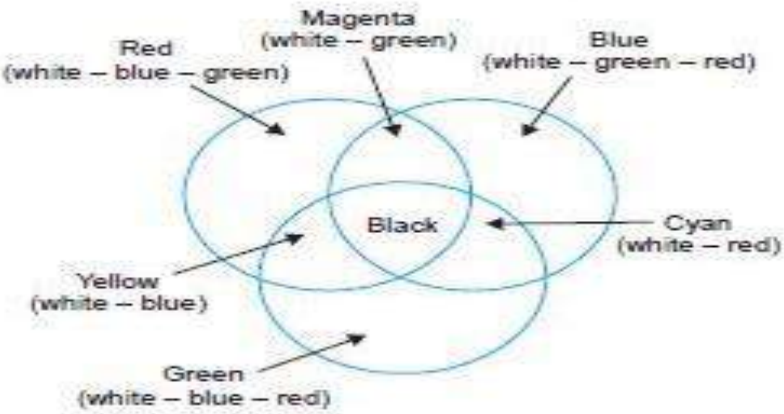



Fig. 25.3 (b). Subtractive colour mixing. The diagram shows the effect of mixing colour pigments under white light.

**TRANSMISSION & RECEPTION**

- Figure illustrate the transmission paths from the colour and monochrome cameras are shown to both colour and monochrome receivers.
- At the receiver, the three colour signals are separated and fed to the three electron guns of colour picture tube.
- The screen of the picture tube has red, green, and blue phosphors arranged in alternatedots.
- Each gun produces an electron beam to illuminate the three colour phosphorsseparately on the fluorescent screen.

- The eye then integrates the red, green and blue colour information and their luminance to perceive the actual colour and brightness of the picture being televised.
- The three compatible colour television systems are NTSC, PAL and SECAM.
- NTSC – National Television Standard Committee
- PAL – Phase Alternate Line
- SECAM – Sequential Color Memory

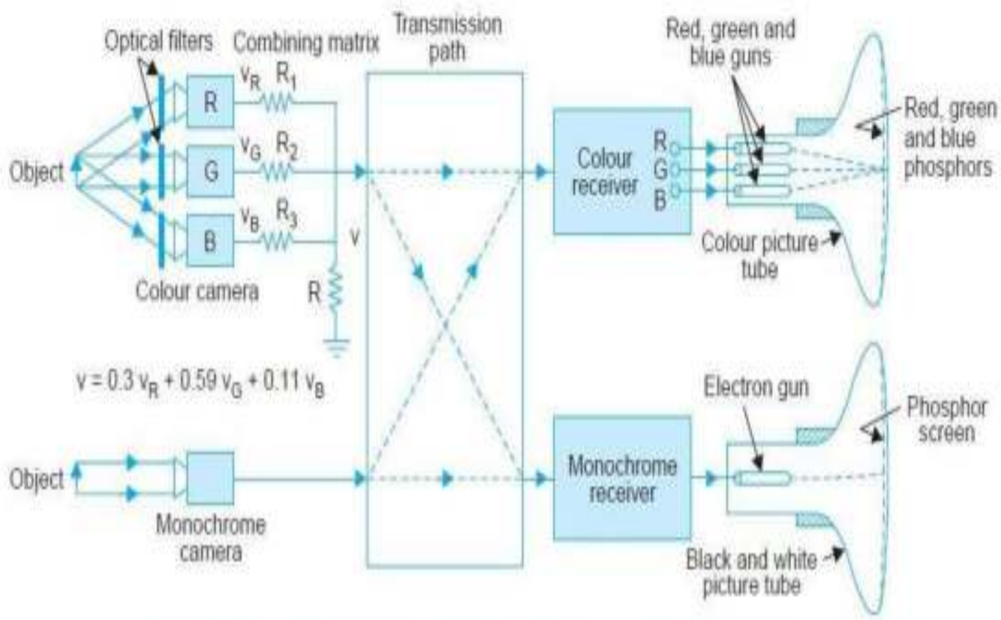



Fig. 1.5. Signal transmission paths illustrating compatibility between colour and monochrome TV systems. R, G and B represent three camera tubes which develop video signals corresponding to the red, green and blue contents of the scene being televised.

**COLOUR TELEVISION RECEIVER CONTROLS**

- NTSC colour television receivers have two additional controls, known as Colour andHue controls.
- These are provided at the front panel along with other controls.
- The colour or saturation control varies the intensity or amount of colour in thereproduced picture.
- For example, this control determines whether the leaves of a tree in the picture aredark green or light green, and whether the sky in the picture is dark blue or light blue.
- The tint or hue control selects the correct colour to be displayed.

- This is primarily used to set the correct skin colour, since when flesh tones are correct, all other colours are correctly reproduced.
- It may be noted that PAL colour receivers do not need any tint control while in SECAM colour receivers, both tint and saturation controls are not necessary.

**GROSS STRUCTURE**

□ The frame adopted in all television systems is rectangular with width/height ratio, *i.e.,* ***aspect* ratio = 4/3.**

□ There are many reasons for this choice.

□ In human affairs most of the motion occurs in the horizontal plane and so a larger width is desirable.

□ The eyes can view with more ease and comfort when the width of a picture is more than its height.

□ The usage of rectangular frame in motion pictures with a width/height ratio of 4/3 is another important reason for adopting this shape and aspect ratio.

□ This enables direct television transmission of film programmes without wastage of any film area.

□ It is not necessary that the size of the picture produced on the receiver screen be same as that being televised but it is essential that the aspect ratio of the two be same, otherwise the scene details would look too thin or too wide.

□ This is achieved by setting the magnitudes of the current in the deflection coils to correct values, both at the TV camera and receiving picture tube.

□ Another important requirement is that the same coordinates should be scanned at any instant both by the camera tube beam and the picture tube beam in the receiver.

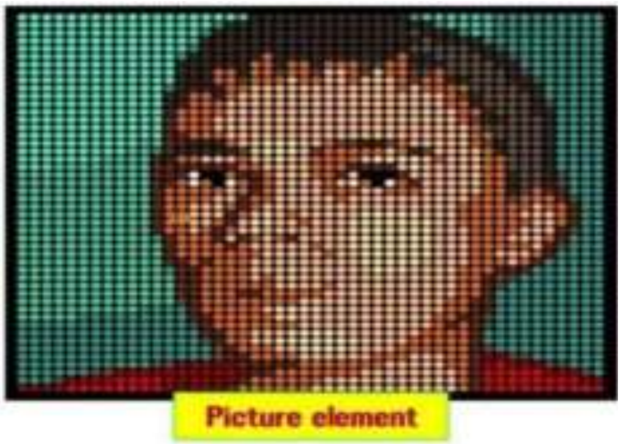
□ Synchronizing pulses are transmitted along with the picture information to achieve exact congruence between transmitter and receiver scanning systems.

**IMAGE CONTINUITY**

□ While televising picture elements of the frame by means of the scanning process, it is necessary to present the picture to the eye in such a way that an illusion of continuity is created and any motion in the scene appears on the picture tube screen as a smooth and continuous change.

□ To achieve this, advantage is taken of 'persistence of vision' or storage characteristics of the human eye.

- This arises from the fact that the sensation produced when nerves of the eye's retina are stimulated by incident light does not cease immediately after the light is removed but persists for about 1/16th of a second.
- Thus if the scanning rate per second is made greater than sixteen, or the number of pictures shown per second is more than sixteen, the eye is able to integrate the changing levels of brightness in the scene.
- So when the picture elements are scanned rapidly enough, they appear to the eye as a complete picture unit, with none of the individual elements visible separately.
- In present day motion pictures twenty-four still pictures of the scene are taken per second and later projected on the screen at the same rate.
- Each picture or frame is projected individually as a still picture, but they are shown one after the other in rapid succession to produce the illusion of continuous motion of the scene being shown.
- A shutter in the projector rotates in front of the light source and allows the film to be projected on the screen when the film frame is still, but blanks out any light from the screen during the time when the next film frame is being moved into position.
- As a result, a rapid succession of still-film frames is seen on the screen.
- With all light removed during the change from one frame to the next, the eye sees a rapid sequence of still pictures that provides the illusion of continuous motion.




**SCANNING**

- Scanning is the process used to convert the **optical into electrical signal**. Fastest movement of electron beam on the image is called scanning
- A similar process is carried out in the television system like in motion picture

- The scene is scanned rapidly both in the horizontal and vertical directions simultaneously to provide sufficient number of complete pictures or frames per second to give the illusion of continuous motion.
- Instead of the **24** as in commercial motion picture practice, the frame repetition rate is **25 per second** in most television systems.

Scanning process

- It is a technique similar to reading of written information on a page starting at the top left and processing line by lie downwards to the end at the bottom right
- Scanning is done frame by frame.
- Each frame consists of **625 horizontal lines**
- Each frame is scanned at a rate of **25 frames / sec**

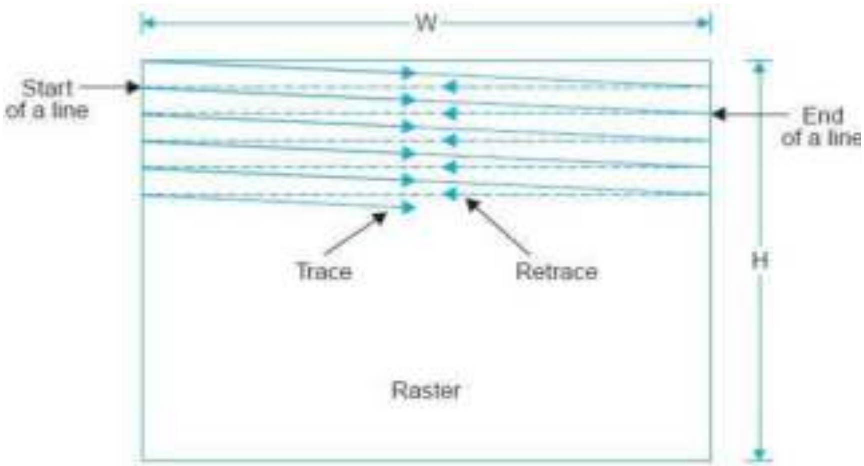


Fig. 2.1 (a) Path of scanning beam in covering picture area (Raster).

Horizontal scanning

- **Movement of electron beam from left to right on the screen is known as trace period. When the beam returns quickly from right to left is called retrace or flyback**
- Trace and retrace period together in horizontal direction is known as horizontal scanning
- Figure shows the trace and retrace of several horizontal lines.
- The linear rise of current in the horizontal deflection coils deflects the beam across the screen with a continuous, uniform motion for the trace from left to right.
- At the peak of the rise, the sawtooth wave reverses direction and decreases rapidly toits initial value.
- This fast reversal produces the retrace or flyback.

□ The start of the horizontal trace is at the left edge of raster.

□ The finish is at the right edge, where the flyback produces retrace back to the leftedge.

□ Note, that ‘up’ on the sawtooth wave corresponds to horizontal deflection to the right.

□ The heavy lines in figure indicate the useful scanning time and the dashed linescorrespond to the retrace time.

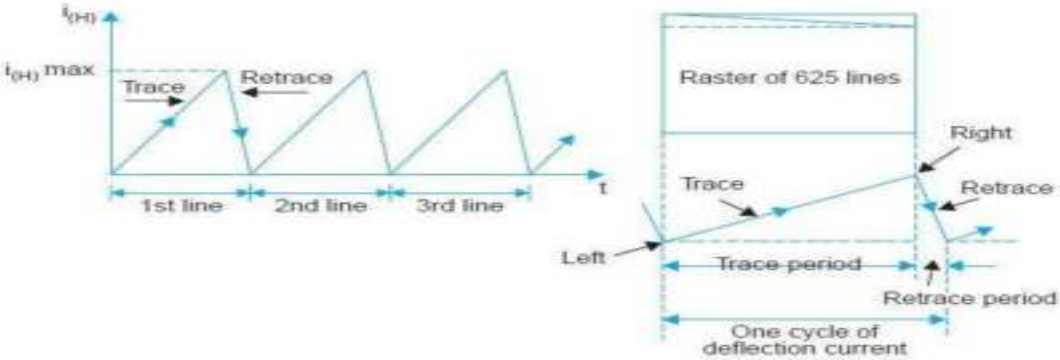



Fig. 2.1 (b) Waveform of current in the horizontal deflection coils producing linear (constant velocity) scanning in the horizontal direction.

Vertical scanning

- **Movement of electron beam from top to bottom on the screen is known as trace period. When the beam returns quickly from bottom to top of the frame is called retrace**
- 
- Trace and retrace period together in vertical direction is known as verticalscanning
- 

□ Figure shows the trace and retrace of vertical scanning

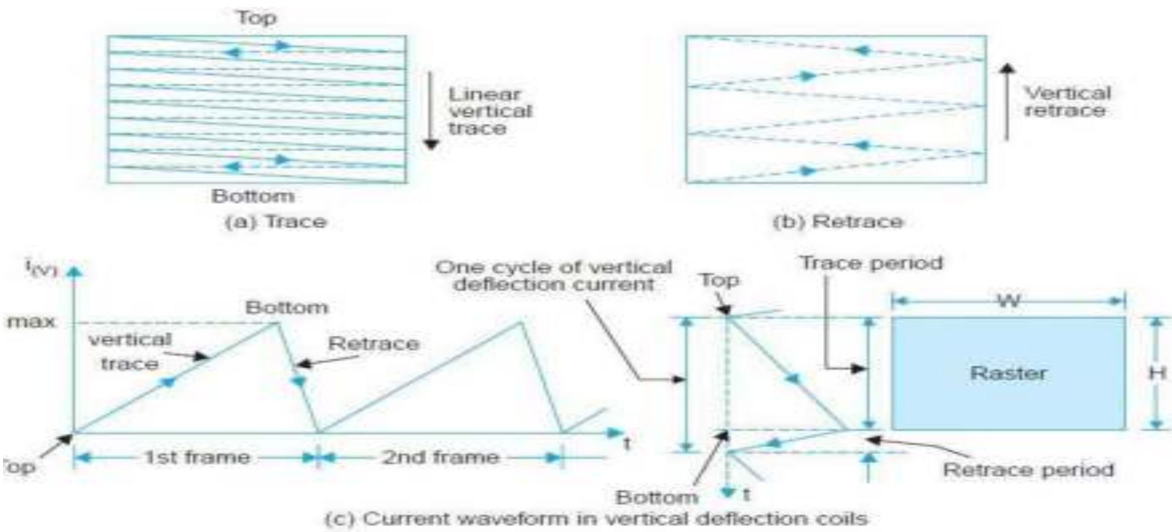



Fig. 2.2 Vertical deflection and deflection current waveform.

- The sawtooth current in the vertical deflection coils moves the electron beam from top to bottom of the raster at a uniform speed while the electron beam is being deflected horizontally.
- Thus the beam produces complete horizontal lines one below the other while moving from top to bottom.
- As shown in Fig.(c), the trace part of the sawtooth wave for vertical scanning deflects the beam to the bottom of the raster Then the rapid vertical retrace returns the beam tothe top.
- Note that the maximum amplitude of the vertical sweep current brings the beam to thebottom of the raster.
- As shown in Fig.(b) during vertical retrace the horizontal scanning continues and several lines get scanned during this period.
- Because of motion in the scene being televised, the information or brightness at the top of the target plate or picture tube screen normally changes by the time the beam returns to the top to recommence the whole process.
- This information is picked up during the next scanning cycle and the whole process is repeated 25 times to cause an illusion of continuity.
- The actual scanning sequence is however a little more complex than that just described
- It must however be noted, that both during horizontal retrace and vertical retrace intervals the scanning beams at the camera tube and picture tube are blanked and no picture information is either picked up or reproduced.
- Instead, on a time division basis, these short retrace intervals are utilized for transmitting distinct narrow pulses to keep the sweep oscillators of the picture tube deflection circuits of the receiver in synchronism with those of the camera at the transmitter.
- This ensures exact correspondence in scanning at the two ends and results in distortionless reproduction of the picture details.

## NUMBER OF SCANNING LINES

- The maximum number of alternate light and dark elements (lines) which can be resolved by the eye is given by $N_v = 1/\alpha\rho$

where Nv = total number of lines (elements) to be resolved in the vertical direction, α = minimum resolving angle of the eye expressed in radians, and ρ = D/H =viewing-distance/picture height.

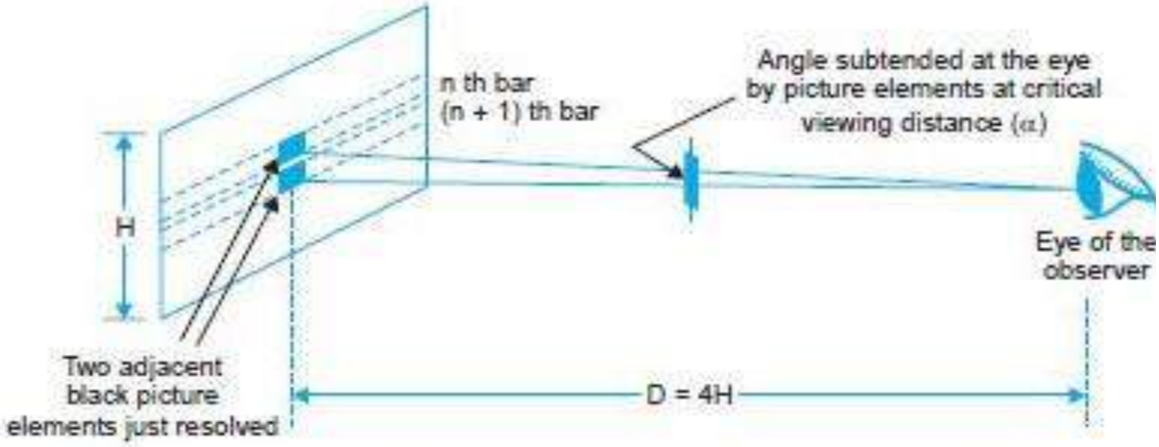



Fig. 2.3 (b) Critical viewing distance as determined by the ability of the eye to resolve two separate picture elements.

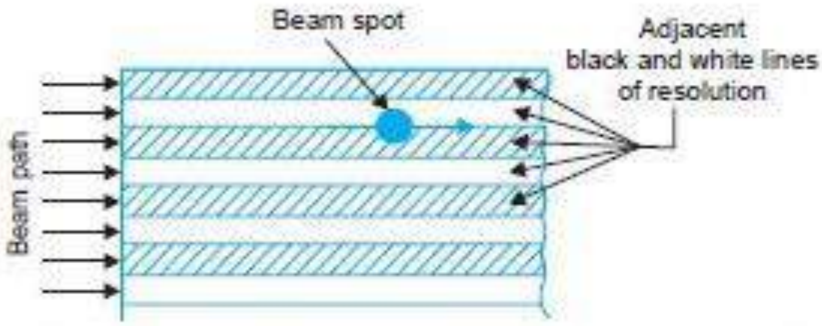



Fig. 2.3 (c) Scanning beam focused on the junction of black and white lines.

- For the eye this resolution is determined by the structure of the retina, and the brightness level of the picture, it has been determined experimentally that with reasonable brightness variations and a minimum viewing distance of four times the picture height (D/H = 4), the angle that any two adjacent elements must subtend at the eye for distinct resolution is approximately one minute (1/60 degree). This is illustrated in Fig.(b). Substituting these values of α and ρ we get

$$N_a = \frac{1}{(\pi / 180 \times 1/60) \times 4} \approx 860$$

- Thus if the total number of scanning lines is chosen close to 860 and the scanning beam as illustrated in Fig. (a) just passes over each bar (line) separately while scanning all the lines from top to bottom of the picture frame, a distinct pick up of the picture information results and this is the best that can be expected from the system.
- This perhaps explains the use of **819 lines in the original French TV system**

**<u>METHOD OF SCANNING</u>**

<u>There are two principal methods of scanning</u>

1. **Sequential scanning / Progressive scanning**
2. <u>Interlaced scanning</u>

<u>SEQUENTIAL SCANNING</u>

- Sequential scanning is also called as progressive scanning
- It is the process in which both horizontal and vertical directions are scanned simultaneously to provide complete pictures
- Horizontal lines are scanned one by one
- So complete picture will be scanned through this type
-

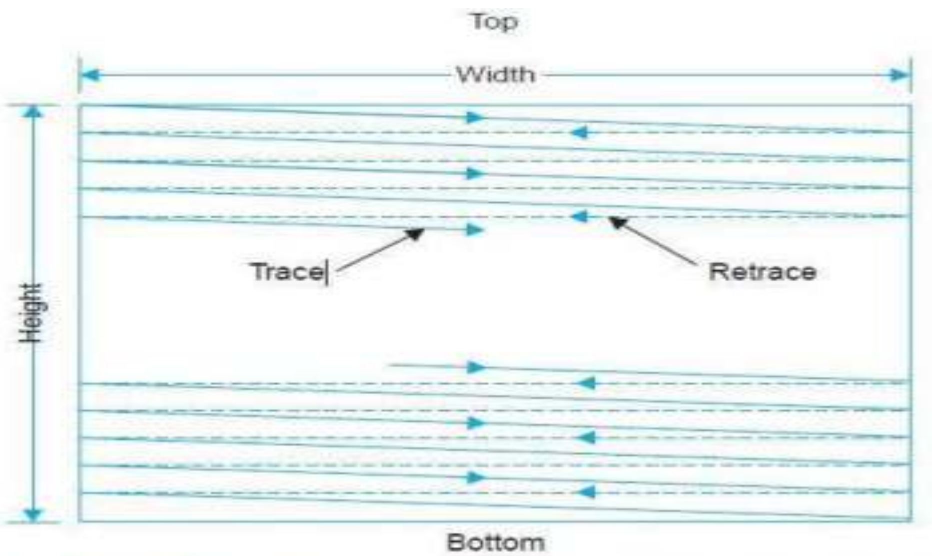
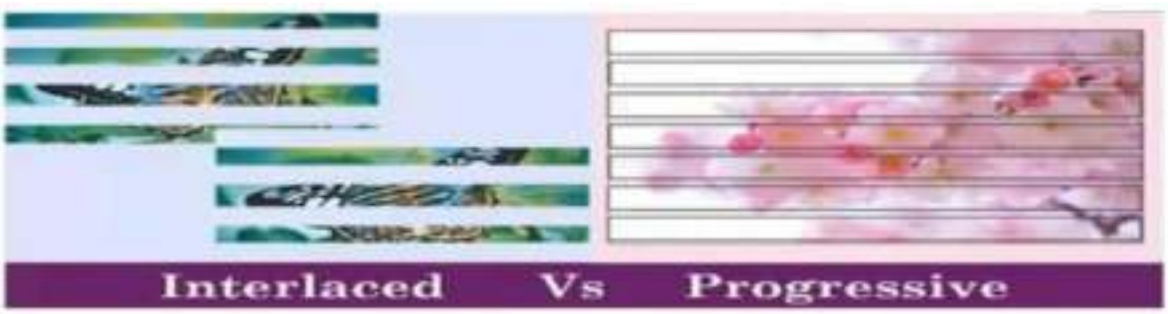




Fig. 1.2 (*b*) Path of scanning beam in covering picture area.

- The scanning rate of 25 frames per second in picture is called progressive scanning
- In sequential scanning, the vertical scanning frequency is 25Hz
- In sequential scanning, all the lines in the frame are being scanned in sequential order from top to bottom. There would be only 25 blank-outs per second, hence flickereffect is produced
- Scanning of 50 complete frames per second makes 50 blank-outs per second. Now this fast variation is not detected by human eyes, and hence flicker effect is avoided
- No. of horizontal lines per frame = 625
- No. of frames per second = 25
- Therefore, No. of Horizontal lines per second = 625 x 25 = 15625
- Horizontal line frequency = 15625 Hz
- Vertical frame frequency = 25 Hz
- Duration for single horizontal line frequency = 1/15625 = 64µS
- Duration for single frame scanning = 1/25 = 40mS

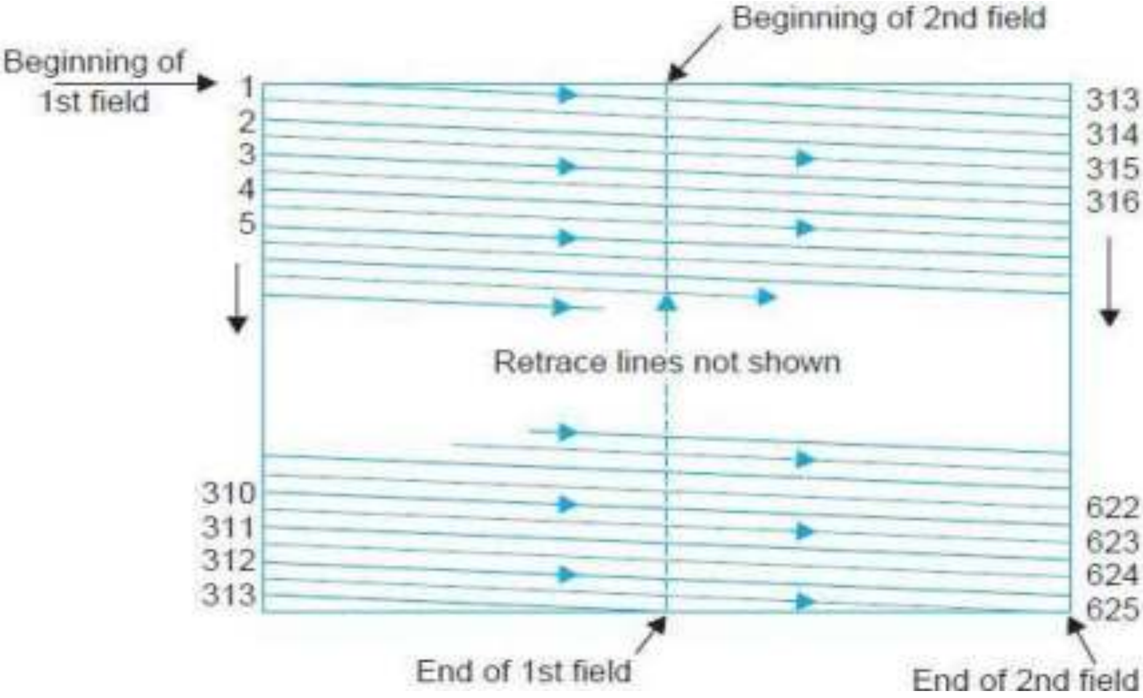
**FLICKER**

- The sensation produced by incident light on the nerves of the eyes retina does not cease immediately
- It persists for about **$1/25^{th}$ of a second (0.62 sec)**
- This storage characteristics is called **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



INTERLACED SCANNING

- To reduce flicker, the vertical scanning is done 50 time per second in TV system
- However only 25 frames are scanned per sec
- This is accomplished by increasing the downward rate of travel of the scanning electron beam, so that every alternate line gets scanned instead of every successiveline




- The total number of lines are divided into two fields. Each field is scanned alternatively
- In interlaced scanning, the total lines of each frame (625 lines) are grouped into two fields. They are called as even 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 first field (Odd lines) are scanned
- During next scan second field (Even lines) 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 or eliminated without increasing the speed of scanning, which in turn does not need any increase in the channel bandwidth


- It may be noted that the frame repetition rate of 25 (rather than 24 as used in motion pictures) was chosen to make the field frequency equal to the power line frequency of **50 Hz.**
- This helps in reducing the undesired effects of hum due to pickup from the mains, because then such effects in the picture stay still, instead of drifting up or down on thescreen.
- In the American TV system, a field frequency of 60 was adopted because the supply frequency is **60 Hz in USA**.
- This brings the total number of lines scanned per second ((525/2) × 60 = 15750) lines to practically the same as in the **625 line system**.

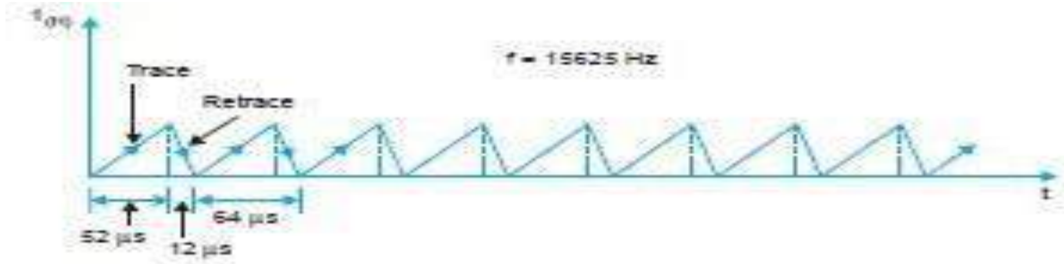



Fig. 2.5 (a) Horizontal deflection current.

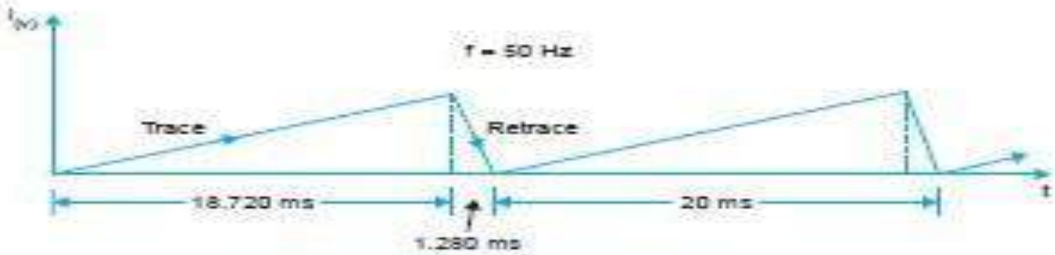
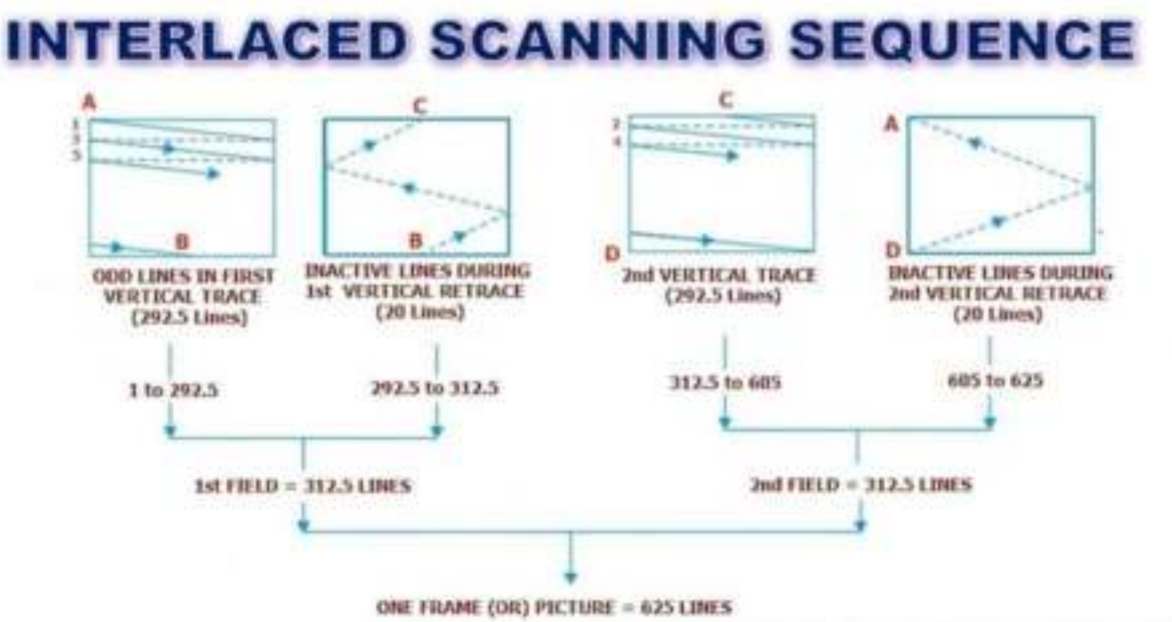



Fig. 2.5 (b) Vertical deflection current.




## PICTURE TUBE

- The picture tube or 'kinescope' that serves as the screen for a television receiver is aspecialized form of cathode-ray tube.
- It consists of an evacuated glass bulb or envelope, inside the neck of which is rigidly supported an electron gun that supplies the electron beam.
- A luminescent phosphor coating provided on the inner surface of its face plate produces light when hit by the electrons of the fast moving beam.
- A monochrome picture tube has one electron gun and a continuous phosphor coating that produces a picture in black and white.

- For colour picture tubes the screen is formed of three different phosphors and there are three electron beams, one for each colour phosphor.
- The three colours—red, green and blue produced by three phosphors combine to produce different colours.

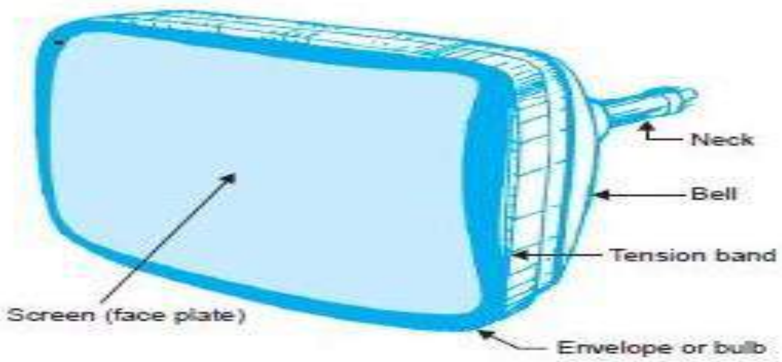



Fig. 5.1. A rectangular picture tube.

<u>MONOCHROME PICTURE TUBE</u>

✔Modern monochrome picture tubes employ electrostatic focussing and electromagnetic deflection.

✔A typical black and white picture tube is shown in figure

✔ The deflection coils are mounted externally in a specially designed yoke that is fixed close to the neck of the tube.

✔The coils when fed simultaneously with vertical and horizontal scanning currents deflect the beam at a fast rate to produce the raster.

✔The composite video signal that is injected either at the grid or cathode of the tube, modulates the electron beam to produce brightness variations on the screen.

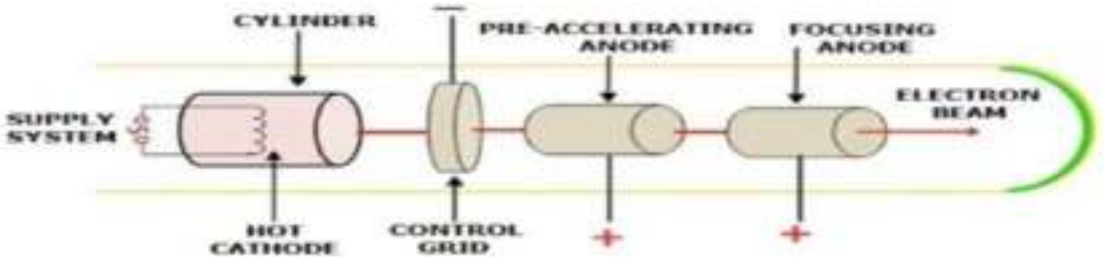
✔This results in reconstruction of the picture on the raster, bit by bit, as a function of time.

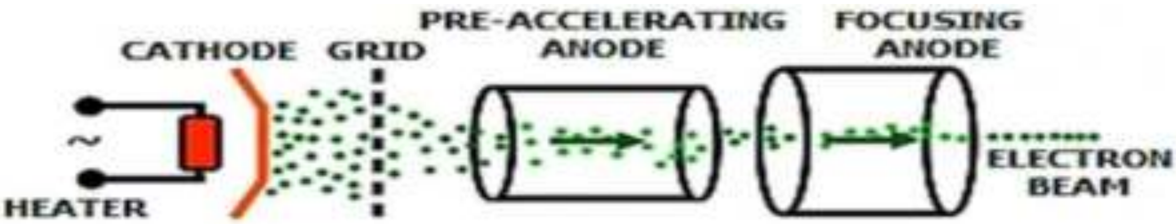
✔ However, the information thus obtained on the screen is perceived by the eye as a complete and continuous scene because of the rapid rate of scanning.

<u>Electron Gun</u>

- The various electrodes that constitute the electron gun are shown in Figure
- The cathode is indirectly heated and consists of a cylinder of nickel that is coated at its end with thoriated tungsten or barium and strontium oxides.

- These emitting materials have low work-function and when heated permit release of sufficient electrons to form the necessary stream of electrons within the tube.
- The control grid (Grid No. 1) is maintained at a negative potential with respect to cathode and controls the flow of electrons from the cathode.
- However, instead of a wiremesh structure, as in a conventional amplifier tube, it is a cylinder with a small circular opening to confine the electron stream to a small area.
- The grids that follow the control grid are the accelerating or screen grid (Grid No. 2) and the focusing grid (Grid No. 3).
- These are maintained at different positive potentials with respect to the cathode that vary between + 200 V to + 600 V.
- All the elements of the electron gun are connected to the base pins and receive their rated voltages from the tube socket that is wired to the various sections of thereceiver.




<u>Electrostatic Focussing</u>

- The electric field due to the positive potential at the accelerating grid (also known as 1st anode) extends through the opening of the control grid right to the cathodesurface.
- The orientation of this field is such that besides accelerating the electrons down the tube, it also brings all the electrons in the stream into a tiny spot called the crossover. This is known as the first electrostatic lens action.
- The resultant convergence of the beam is shown in Fig. 5.2.

- The second lens system that consists of the screen grid and focus electrode draws electrons from the crossover point and brings them to a focus at the viewing screen.
- The focus anode is larger in diameter and is operated at a higher potential than thefirst anode.
- The resulting field configuration between the two anodes is such that the electrons leaving the crossover point at various angles are subjected to both convergent and divergent forces as they more along the axis of the tube.
- This in turn alters the path of the electrons in such a way that they meet at another point on the axis.
- The electrode voltages are so chosen or the electric field is so varied that the second point where all the electrons get focused is the screen of the picture tube.
- Electrostatic focusing is preferred over magnetic focusing because it is not affected very much by changes in the line voltage and needs no ion-spot correction.

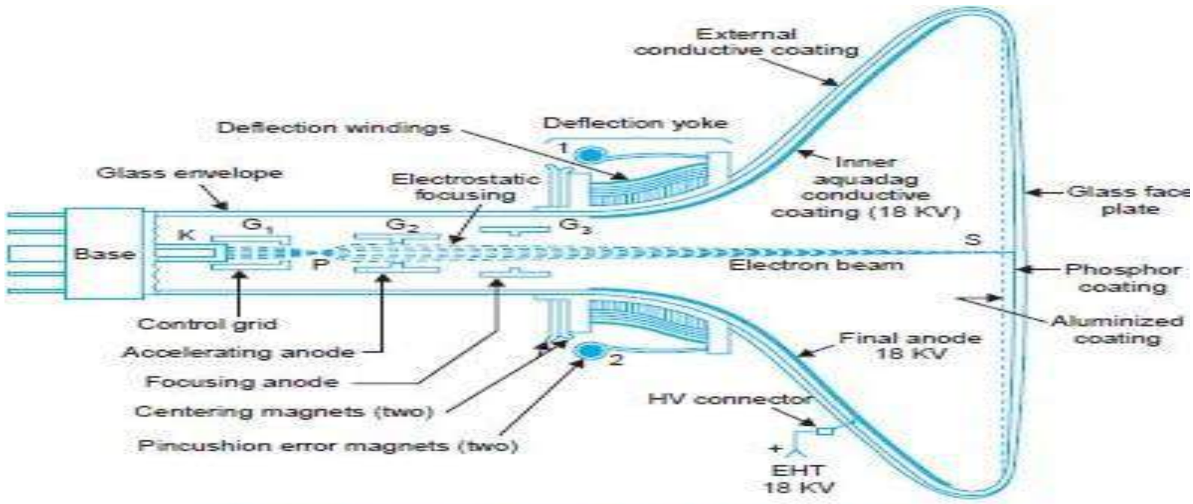



Fig. 5.2. Elements of a picture tube employing low voltage electrostatic focusing and magnetic deflection.

Beam Velocity

- In order to give the electron stream sufficient velocity to reach the screen material with proper energy to cause it to fluoresce, a second anode is included within the tube.
- This is a conductive coating with colloidal graphite on the inside of the wide bell of the tube.This coating, called aquadag, usually extends from almost half-way into the narrow neck to within 3 cm of the fluorescent screen as shown in Figure.
- It is connected through a specially provided pin at the top or side of the glass bell to a very high potential of over 15 kV.
- The exact voltage depends on the tube size and is about 18 kV for a 48 cm monochrome tube.

- The electrons that get accelerated under the influence of the high voltage anode area, attain very high velocities before they hit the screen.
- Most of these electrons go straight and are not collected by the positive coating because its circular structure provides a symmetrical accelerating field around all sides of the beam.
- The kinetic energy gained by the electrons while in motion is delivered to the atoms of the phosphor coating when the beam hits the screen.
- This energy is actually gained by the outer valence electrons of the atoms and they move to higher energy levels.
- While returning to their original levels they give out energy in the form of electromagnetic radiation, the frequency of which lies in the spectral region and is thus perceived by the eye as spots of light of varying intensity depending on the strength of the electron beam bombarding the screen
- Because of very high velocities of the electrons which hit the screen, secondary emission takes place.
- If these secondary emitted electrons are not collected, a negative space charge gets formed near the screen which prevents the primary beam from arriving at the screen.
- The conductive coating being at a very high positive potential collects the secondary emitted electrons and thus serves the dual purpose of increasing the beam velocity andremoving unwanted secondary electrons.
- The path of the electron current flow is thus from cathode to screen, to the conductivecoating through the secondary emitted electrons and back to the cathode through the high voltage supply.
- A typical value of beam current is about 0.6 mA with 20 kV applied at the aquadag coating.
- We all know how pleasing it is to see a picture in natural colours or watch a colour film in comparison with its black and white version.
- In fact monochrome reception of natural daylight scenes and pictures taken in black and white are totally unrealistic because they lack colour
- It is desirable that a TV system should produce a picture with realistic colours, adequate brightness and good definition that can be easily perceived by our eyes.
- A monochrome picture does contain the brightness information of the televised scene but lacks in colour detail of the various parts of the picture.
- To have a colour picture it is thus necessary to add colour to the picture produced on awhite raster.

- It may be recalled that in a monochrome TV system, the problem of picking up simultaneous information from the entire scene about the brightness levels is solvedby scanning.
- In colour TV it becomes necessary to pick up and reproduce additional information about the colours in the scene
- It did not seem to be an easy task and the difficulties in achieving this seemed unsurmountable.
- However, this challenge was met by the scientists and engineers working on it in U.S.A

COLOUR PICTURE TUBE

- All colour TV systems in use at present owe their origin to the NTSC system which was invented and developed in the United States of America.
- The Radio Corporation of America (RCA) played a prominent role in thedevelopment of colour TV.
- The invention and fabrication of the tricolour shadowmask tube was their major single contribution which made a high quality colour television system possible.


- The colour television picture tube screen is coated with three different phosphors, one for each of the chosen red, green and blue primaries.
- The three phosphors are physically separate from one another and each is energized by an electron beam of intensity that is proportional to the respective colour voltage reproduced in the television receiver.
- The object is to produce three coincident rasters with produce the red, green and blue contents of the transmitted picture.

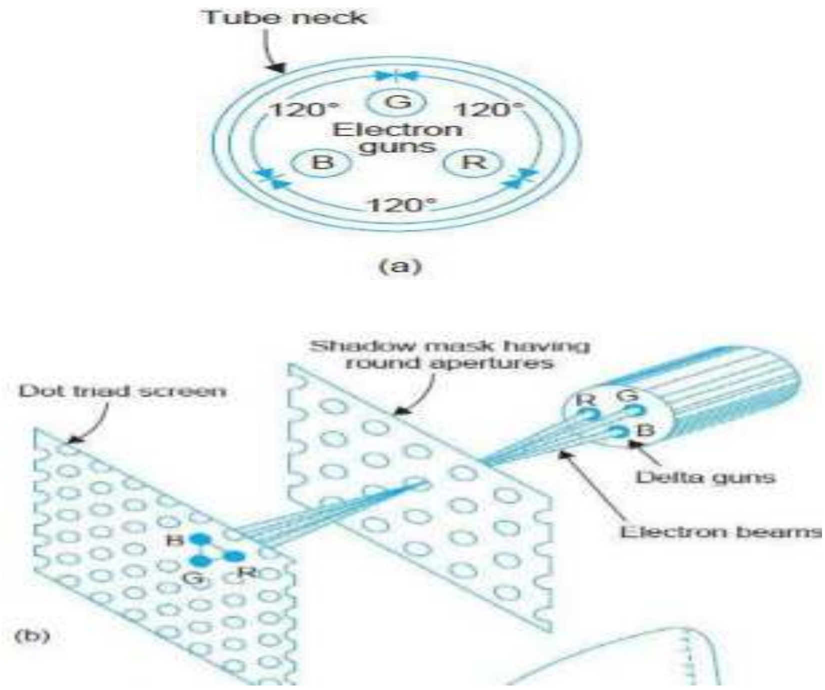
- While seeing from a normal viewing distance the eye integrates the three colour information to convey the sensation of the hue at each part of the picture.
- Based on the gun configuration and the manner in which phosphors are arranged on the screen, three different types of colour picture tubes have been developed.
- These are:

1. Delta-gun colour picture tube
2. Guns-in-line or Precision-in-line (P-I-L) colour picture tube.
3. Single sun or Trintron Colour picture tube.

**Delta-gun colour picture tube**

- This tube was first developed by the Radio Corporation of America (R.C.A.).
- It employs three separate guns, one for each phosphor.
- The guns are equally spaced at 120° interval with respect to each other and tilted inwards in relation to the axis of the tube.
- They form an equilateral triangular configuration.
- As shown in Figure(b) the tube employs a screen where three colour phosphor dots are arranged in groups known as triads.
- Each phosphor dot corresponds to one of the three primary colours.
- The triads are repeated and depending on the size of the picture tube, approximately 1,000,000 such dots forming nearly 333,000 triads are deposited on the glass face plate.
- About one cm behind the tube screen (see Figures (b) and (c)) is located a thin perforated metal sheet known as the shadow mask.
- The mask has one hole for every phosphor dot triad on the screen.
- The various holes are so oriented that electrons of the three beams on passing through any one hole will hit only the corresponding colour phosphor dots on the screen.
- The ratio of electrons passing through the holes to those reaching the shadow mask is only about 20 percent.
- The remaining 80 percent of the total beam current energy is dissipated as a heat loss in the shadow mask.

- While the electron transparency in other types of colour picture tubes is more, still, relatively large beam currents have to be maintained in all colour tubes compared to monochrome tubes.
- This explains why higher anode voltages are needed in colour picture tubes than are necessary in monochrome tubes.




<u>Generation of coloured raster</u>

- The overall colour seen is determined both by the intensity of each beam and the phosphors which are being bombarded.
- If only one beam is 'on' and the remaining two are cut-off, dots of only one colour phosphor get excited.
- Thus the raster will be seen to have only one of the primary colours.
- Similarly, if one beam is cut-off and the remaining two are kept on, the rasters produced by excitation of the phosphors of two colours will combine to create the impression of a complementary colour.
- The exact hue will be determined by the relative strengths of the two beams.
- When all the three guns are active simultaneously, lighter shades are produced on the screen.
- This is because red, green and blue combine in some measure to form white, and this combines with whatever colours are present to desaturate them.
- Naturally, intensity of the colour produced depends on the intensity of beam currents.

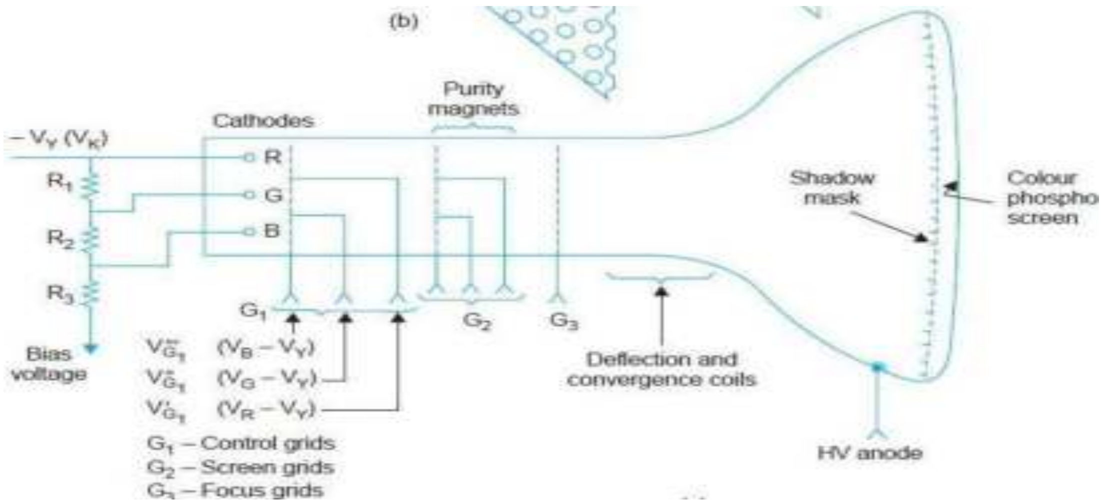
- Black in a picture  is just the absence of excitation when all the three beams are cut-off.
- If the amplitude of colour difference signals drops to zero, the only signal left to control the three guns would be the Y signal and thus a black and  white (monochrome) picture will be produced on the screen.

Primary Colour Signals

- The demodulators in the receiver recover (B – Y) and (R – Y) video signals. The (G –Y) colour video signal is obtained from these two through a suitable matrix.
- All the three colour difference signals are then fed to the three grids of colour picture tube (see Figure(c)).
- The inverted luminance signal (– Y) is applied at the junction of the three cathodes.
- The signal voltages subtract from each other to develop control voltages for the three guns, i.e.,

$$V'_{G1} - V_k = (V_R - V_Y) - (-V_Y) = V_R$$
$$V''_{G1} - V_k = (V_G - V_Y) - (-V_Y) = V_G$$
$$V'''_{G1} - V_k = (V_B - V_Y) - (-V_Y) = V_B$$

- In some receiver designs the Y signal is subtracted in the matrix and resulting colour voltages are directly applied to the corresponding control grids.
- The cathode is then returned to a fixed negative voltage.




Colour Purity

- For obtaining colour purity each beam should land at the centre of the corresponding phosphor dot irrespective of the location of the beams on the raster

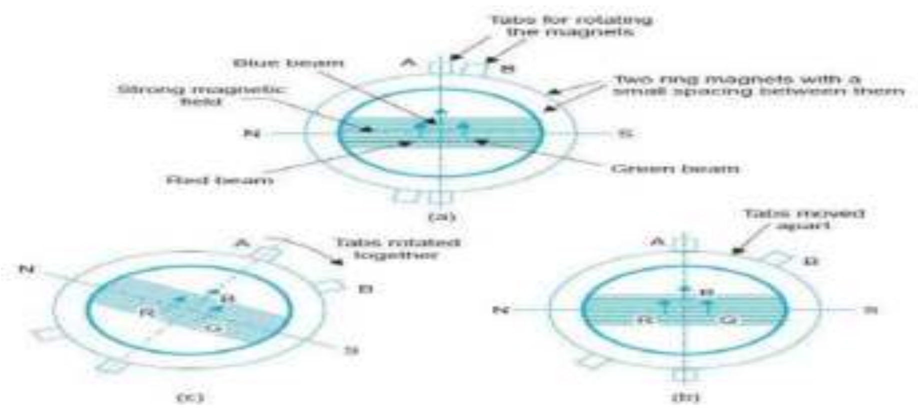
- Strong magnetic field when tabs (A and B) are nearly together. Spreading the tabs reduces magnetic field. Rotating the magnets together cause change in the directionof beam

<u>Yoke Position</u>

- The position of the yoke on the tube neck determines the location of the deflection centre of the electron beams
- A wrong setting will result in poor purity due to improper entry angles of the beams into the mask openings

<u>Convergence</u>

- The technique of bringing the beams together so that they hit the same part of the screen at the same time to produce three coincident rasters is referred to as convergence
- Convergence errors are caused by (*i*) non-coincident convergence planes, (*ii*) non uniformity of the deflection field and (*iii*) flat surface of the picture tube screen
- It falls into two parts referred to as (*i*) static and (*ii*) dynamic convergence
- Static convergence involves movement of the beams by permanent magnetic fields which, once correctly set, bring the beams into convergence in the central area of the screen
- Convergence over the rest of the screen is achieved by continuously varying (dynamic) magnetic fields, the instantaneous strengths of which depend upon the positions of the spots on the screen
- These fields are set up by electromagnets which carry currents at horizontal (line) and vertical (field) frequencies



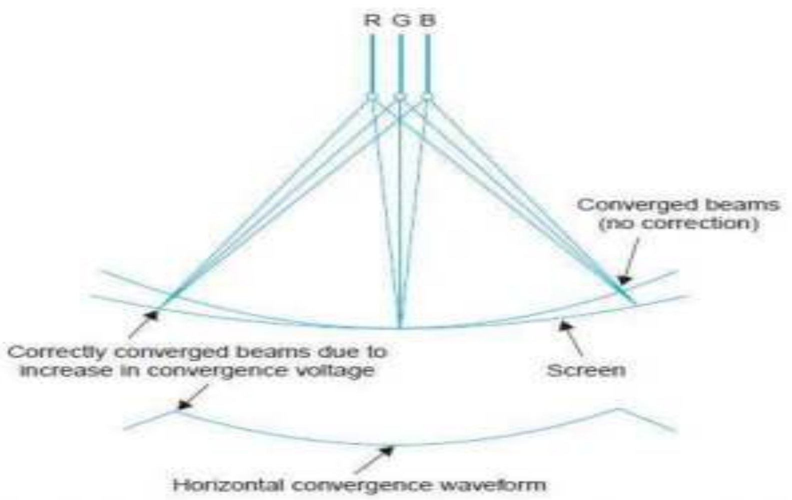



Fig. 25.13. Over-convergence of electron beams at the screen edges unless a corrective deflection field is utilized

Pincushion Correction

- The use of permanent magnets for the elimination of pincushion distortion is not feasible for colour receivers because the magnets would tend to introduce purity problems

- Therefore, dynamic pincushion correction is used with colour picture tubes. Such a correction automatically increases horizontal width and vertical size in those regions of the raster that are shrunken because of pincushion distortion.

Degaussing

- Degaussing means demagnetizing iron and steel parts of the picture tube mountings

- A magnetic object can be demagnetized by placing it in an alternating magnetic field which becomes weaker over a period of time

- This way the magnetized object is forced to assume the strength of the external degaussing field and becomes weaker and weaker as the degaussing field diminishes

- A degaussing coil is used for this purpose
- It is wrapped round the tube bowl close to the rim-band of the screen

- The circuit is so designed that when the receiver is first switched on, a strong mains current passes through the coil and then dies away to an insignificant level after a fewmoments

- This way the effects of localized magnetic fields are removed each time the receiveris used

Drawbacks of the Delta-gun Tube

- While the delta-gun colour picture tube has been in use for nearly two decades itsuffers from the following drawbacks:

(i) Convergence is difficult and involves considerable circuit complexity and service adjustments. In most delta-gun tubes, four static convergence magnets and a dynamic convergence assembly are employed. In all about 12 pre-set controls become necessary to achieve proper vertical and horizontal convergence over the entire screen.

(ii) The focus cannot be sharp over the entire screen because the focus and convergence planes cannot remain coincident for the three beams which emanate from guns positioned at 120° with respect to each other around the tube axis.

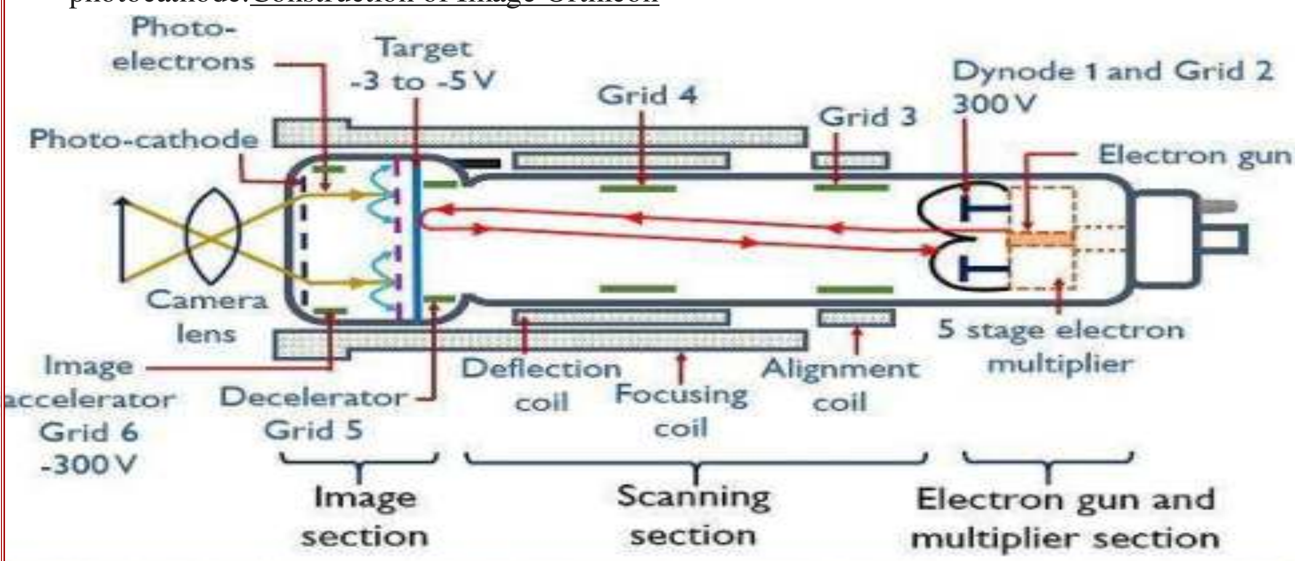
(iii) The electron transparency of the mask is very low since it intercepts over 80 percent of the beam currents.

Therefore the delta-gun tube has been superseded by the P.I.L. and Trintron colourpicture tubes. It is now manufactured mostly for replacement purpose

**UNIT V**

**5.0 Image Orthicon**

- Image Orthicon is a **photo emissive** type of camera tube. Photoemission is the basis of its working.
- This camera tube was invented in the year 1945 by Radio Corporation of America.
- Photocathode acts as a primary element in the operation of image orthicon. This is so because photocathode allows the emission of electrons from its surface when light from a scene is allowed to incident on it.
- We know the basic operation of camera tubes includes the change of optical energy into electrical energy. And to achieve this, an image orthicon makes use of photo emissive material i.e., photocathode.Construction of Image Orthicon




Structure representing operation of Image Orthicon

Electronics Desk

- As it is clear from the above figure that the whole structure is divided into 3 sections which are as follows:
- Image section,
- Scanning section and
- Electron gun and multiplier section.
- The image section consists of photocathode formed by coating the inner surface of a glass faceplate with silver-antimony-cesium. A lens system is used that focuses the image from a scene on the surface of the photocathode.
- This incident light from the image allows the emission of electrons from the surface of the photocathode.
- The surface of the photocathode is **semi-transparent** in nature. Thereby allowing penetration of incidenting light into the inner surface from where the electron emission is taking place.
- Photocathode emits the charge stored in it by the action of light energy. Therefore, the structure is designed in a way that electrons emitted from the surface of the photocathode are accelerated towards the target plate.
- Also, a thin wire-mesh screen is placed which is composed of **300 meshes / cm$^2$** at a distance of **50 to 75 microns** from the target plate to avoid interference with electron image.
- In the structure of image orthicon, the focusing coil allows focused striking of the electron beam at the target. The structure holds the electron gun and multiplier stage that provides the desired video signal.

Working Principle

- **Image Section**

When light from a scene falls on the surface of photocathode then electrons are emitted from its surface. Due to the semi-transparent nature of the cathode surface, the light penetrates in order to reach the inner surface of the material.

The *number of emitted electrons will be directly proportional to the intensity of the optical image* falling on the surface.
The emission of electrons from the surface of the cathode leads to the formation of an **electron image** on the target side of the photocathode.

- **Scanning Section**

The electron gun emits an electron beam for scanning the charges at the target plate. Basically, the beam emitted by the cathode of the gun is focussed towards the target by the help of the magnetic field produced by an external focus coil and the potential at grid 4.

The potential at the target is nearly 0 V thus electrons in motion stop their movement at the target surface. To prevent the emission of secondary electrons at the surface of the target, certain deceleration is provided to the beam approaching the target by grid 5.

So, the electrons in the beam reaches the target with almost zero velocity and neutralizes the positive charge present on the plate. But only the number of electrons required to neutralize the positive charge is deposited on the plate while the rest returns towards the first electrode of the multiplier.

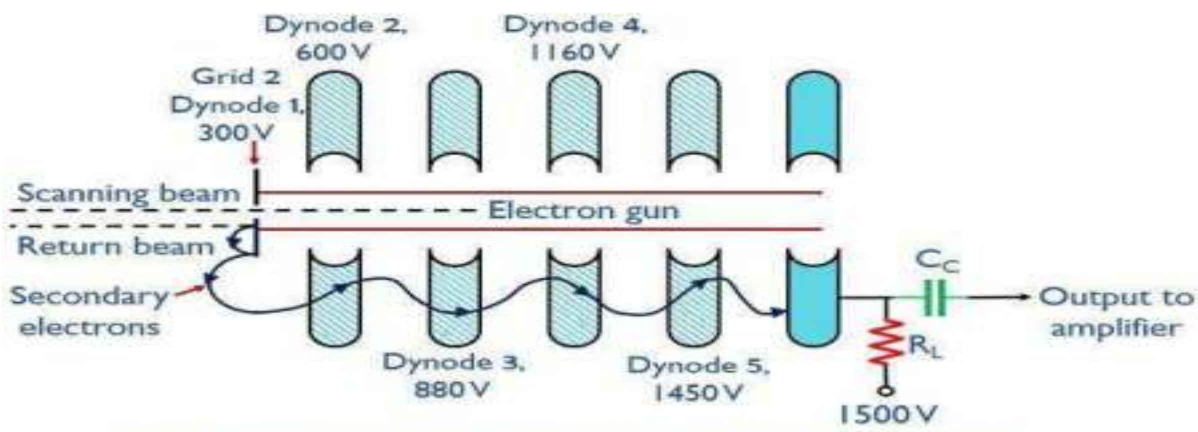
- **Electron multiplier section**

  The beam returning from the target plate reaches a disc which covers the gun electrode present close to the aperture from where the beam emerged.

  The potential at the disc is nearly 300 V wrt the target and this disc acts as the initial stage of the multiplier.

  The figure below shows the complete multiplier stage which is composed of 5 different stages having different potential:

  The return beam when strikes the disc then secondary emission of electrons takes place. So, these secondary electrons get attracted towards the dynodes present at successively greater potentials, as shown in the figure




Electron-multiplier section of Image Orthicon

**5.1 Plumbicon**

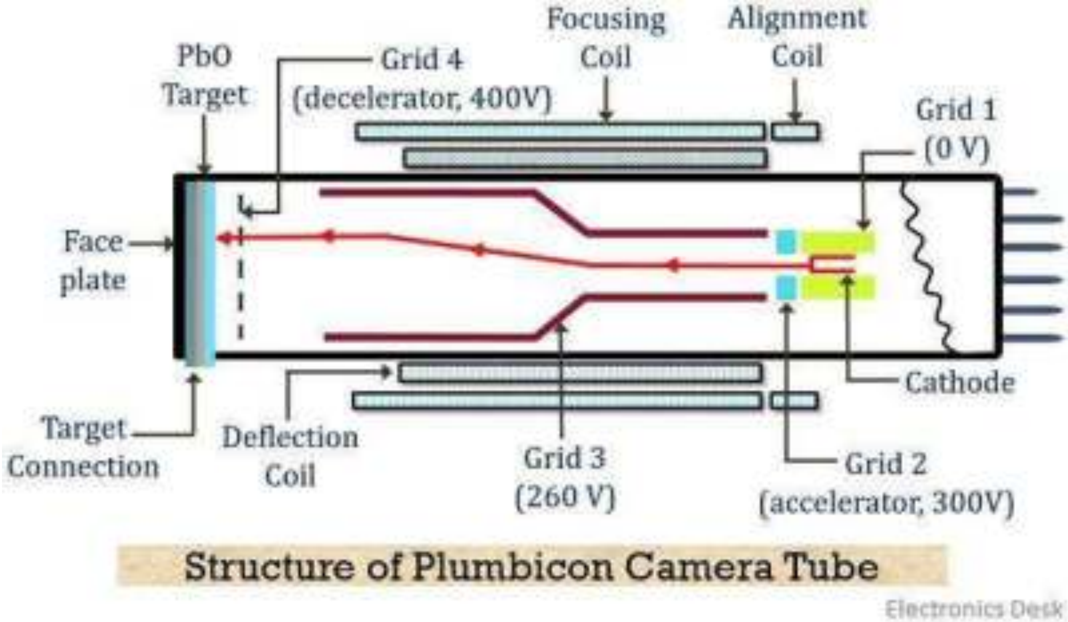
- Plumbicon camera tube is a **photoconductive type of** camera tube as photoconduction is the basis of its operation.

- This camera tube was invented in the year **1963** by Philips.

- One of the major reasons behind the invention of Plumbicon is the drawback of image lag associated with Vidicon tubes. To eliminate this drawback, the target of Plumbicon is fabricated in the form of a PIN diode.

**Construction of Plumbicon**

- The tube consists of a faceplate whose inner region is coated with a layer of tin-oxide that forms a strong n-type surface. It shows transparency towards the light that is allowed to fall on its surface and holds conductive property. It acts as a signal plate of the target.




- Over this layer, a *photoconductive layer of lead monoxide (PbO) is deposited that acts as intrinsic region*. And in order to form the P region, pure PbO is doped with a p-type material so as to form a complete PIN diode structure that acts as a target.

- The structure holds an electron gun section that basically comprises of a cathode that emits the electrons, a **control grid $G_1$** and an **accelerating grid $G_2$**.

- The beam emerging from the cathode of the gun scans the target plate.

- The electrostatic and magnetic focusing is provided to the travelling electron beam by the use of **grid 3** and external focusing coil. Here electrostatic focusing is given by $G_3$ while external focusing coils gives the desired magnetic focusing.

- A wire-mesh screen is present near the target that functions as a sort of covering for the electron gun. It is the **grid 4** of the tube structure.

Working of Plumbicon

- **Photoconductivity** forms the basis of operation of Plumbicon. This means that the action of light falling from a scene on the target varies the conductivity of the material. We know that camera tubes convert optical energy into electrical energy.
- Vidicon is also used for the same but a major drawback of image lag is associated with it. Therefore, Plumbicon was invented.
- As we have already discussed that the target plate of Plumbicon operates as a PIN diode. So let us now understand how a Plumbicon operates by considering the figure
- When light is allowed to fall on the surface of the target then electrons are emitted from the n region of the PIN target structure.
- The intrinsic layer provides a high electric field gradient this leads to sweeping of released electrons from the target plate rapidly. Thereby preventing the chances of image lag present in case of Vidicon.
- The PIN structure of the target acts as a capacitor

- Due to the photoconductive nature of the target (capacitor), in the absence of light, the material offers high resistance. And so the applied bias voltage appears across the capacitor.
- So, we can say that when the bright image falls on the target (capacitor) then it reduces the resistance, thereby causing emission of charge and this leads to increase in voltage existing on one side of the capacitor.
- Further, a scanning beam is allowed to an incident on the surface of the target. The beam is emitted from the cathode and potential at G2 provides required acceleration to the moving electrons. Also electrostatic and magnet focusing is provided to the beam by G3 and the focusing coil.
- This causes the striking of electrons to the target with almost zero velocity. Thus the positive charge at the plate gets neutralized without causing secondary emission. This resultantly produces video signal at load.

**Advantages**

1. It offers more sensitivity than Vidicon.
2. Plumbicon eliminates the problem of image lag.
3. It possesses high SNR of about 47 dB.
4. The value of dark current is almost negligible i.e., 1 nA.
5. It is small in size than the image orthicon.

**Disadvantages**

1. It is less sensitive than image orthicon.
2. Plumbicon has a large size than Vidicon tube and thus bulkier that the latter.
3. It offers less resolution than a Vidicon tube.

**Applications**

As the problem of image lag is eliminated in Plumbicon thus is highly suited for colour TV applications. These camera tubes are also used in studious and outdoor shooting.

## 5.2 COLOUR TV FUNDAMENTALS:

In system we are sending only the luminance information. But in colour system we have to send information about the colours also. All colour TV system are based on the principle of our eye.

Here wavelength unit is Arm strong. Visible spectrum – 4000 $A^0$to 7000 $A^0$.

$1A^0 = 10^{-10}$m 1nm = $10A^0$

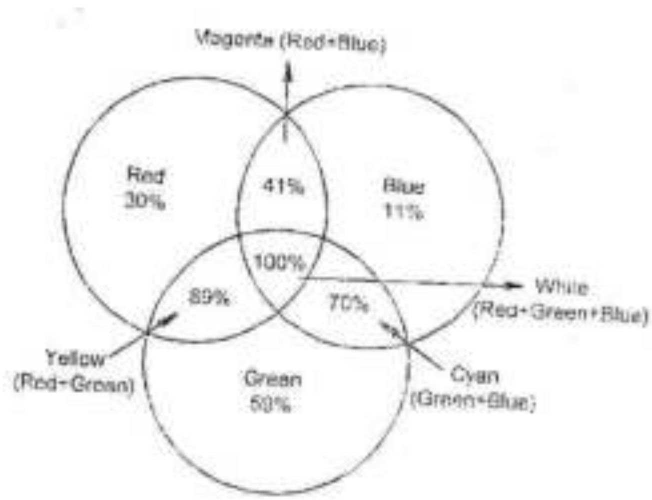
The three basic colors are called as primary colors. They are Red, Green and Blue. To get different color shading we have to mix primary colors. We have two types of mixing

1. Additive Mixing
2. Subtractive Mixing.

**ADDITIVE MIXING:**

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

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 colours is called as complementary colours.

| Primary | | Complementary |
|---|---|---|
| Red + Green | = | Yellow |
| Red + Blue | = | Magenta |
| Blue + Green | = | Cyan |

**SUBTRACTIVE MIXING.**

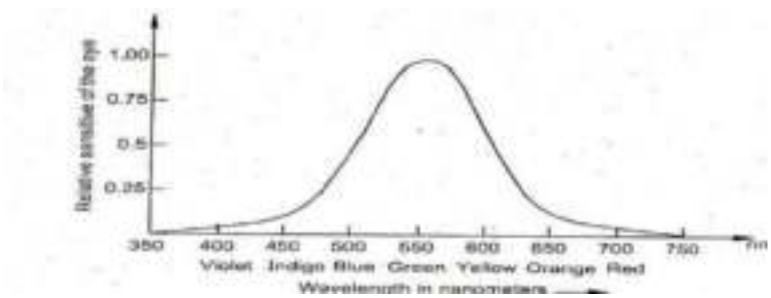
In Subtractive mixing, the reflecting properties of colour pigments are used. A colour pigment can absorb all the colour wavelength except its characteristic colour wavelength. Its characteristic colour frequency alone is reflected. If we are mixing two or three colour pigments, then a color wavelength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

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

**COLOUR PERCEPTION:**

The retina on the backside of our eye has light sensitive organs. They can be able to sense the light variations. Also the retina is connected to optical centre of the brain optical nerves.

We have two types of light sensitive organs. They are called rods and cones. Rods are used to identify brightness variations. Cones are used to identify color information. The colours are transferred to optical nerves. They are then mixed together to identify the original colour.




**CHROMATICITY DIAGRAM:**

Chrominance or chromaticity diagram is a graphical representation of primary colours and all other colours in a space co-ordinate. Based on principle of tristimulus value, white color is formed by mixing 30% red, 59% green and 11% blue.

Below Fig is a two dimension graph representing hue and saturation on x-y plane. In 3D representation 2 axis is used to identify the brightness of the color.

Chromaticity diagram is in shape of horse shoe. On the three corners we have primary colours and on perimeter different colours are available. On moving towards centre pure colours are mixed with white and desaturated. Point ‘C’ represents white color. This point is at co-ordinate of x = 31, y = .32. Sunlight, sky light and day light are all different forms of white light.

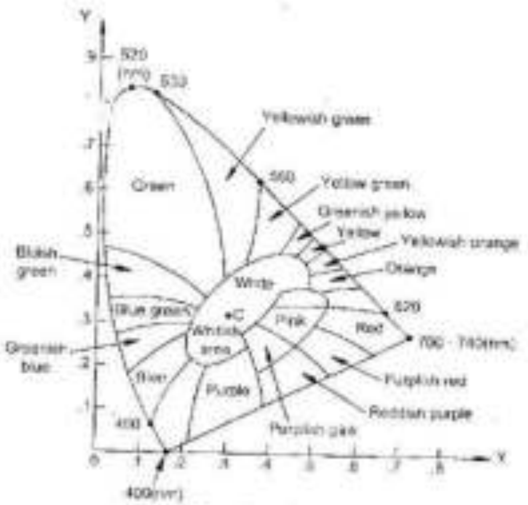
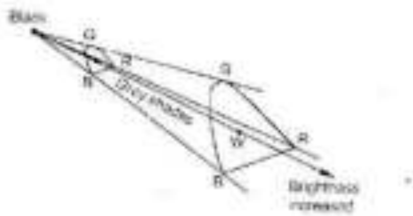


Fig.1.18(a) Chromaticity diagram.




**ADVANTAGES:**

Using this diagram we can identify the color obtained by additive mixing process. If bright increases, Z axis also increase and chrominance diagram becomes enlarged in 3D representation.

**LUMINANCE, HUE AND SATURATION:**

All the colours 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 colour. It is also called as brightness signal, y signal, and white signal.

- **HUE (TINT)**

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

- **SATURATION:**

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

- **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 colour,

$$y = R + G$$

$U = -.29 + (-.15)$

$= -.44$

$V = .61 + (-.52) = .09$

Yellow colourchrominace signal

$$C = \sqrt{u^2 + v^2}$$

$$= \sqrt{(-.44)^2 + (.09)^2}$$

$$C = \pm .44$$

Yellow colour y signal value,

$$y = R + G$$

$$= .3 + .59 = .89$$

Table of PAL system.

| **o.** | **our** | **c Colour** | | | | |
|---|---|---|---|---|---|---|
| | te | 1B | | | | |
| | ow | | | | | |
| | n | | | | | |
| | en | | | | | 9 |
| | enta | | | | | |
| | | | | | | |
| | e | | | | | |
| | k | | | | | |

## 5.3Introduction of CCD camera

- A CCD camera is a video camera that contains a charged-coupled device (CCD), which is a transistorized light sensor on an integrated circuit.

- CCD devices convert or manipulate an electrical signal into some kind of output, including digital values.

- In cameras, CCD enables them to take in visual information and convert it into an image or video. They are, in other words, digital cameras.

- This allows for the use of cameras in access control systems because images no longer need to be captured on film to be visible.

- Security cameras, using the techniques of CCD, can relay live visual information, which is hugely important when monitoring your facility.

- When combined with other security measures, these security cameras become a foolproof way to protect your space.

- In terms of the working principle of CCD cameras, these video cameras capture an image and transfer it to the camera's memory system to record it as electronic data. CCD cameras' main accomplishment is the production of quality images without any distortion. Basically, the camera turns light into electricity. A CCD camera forms light sensitive elements called pixels which sit next to each other and form a particular image. CCD cameras have been in production for a long period of time and tend to have high quality pixels that produce a higher quality, low-noise image than any other camera.

## 5.4 ADVANCED TELEVISION SYSTEMS

### TELEVISION BROADCASTING

- Broadcasting means transmission in all directions by electromagnetic waves from the transmitting station. Broadcasting that deals mostly with entertainment and advertising is probably the most familiar use of television. Millions of television sets in use around the world attest to its extreme popularity.
- Most programmes produced live in the studio are recorded on video tape at a convenienttime to be shown later. Initially television transmission was confined to the VHF band only but later a large number of channel allocations were made in the UHF band also. The distance of transmission, as explained earlier, is confined to line of the sight between the transmitting and receiving antennas.
- The useful service range is up to 120 km for VHF stations and about 60 km for UHF stations. Television broadcasting initially started with monochrome picture but around 1952 colour transmission was introduced.
- Despite its complexity and higher cost, colour television has become such a commercial success that it is fast superseding the monochrome system.

CABLE TELEVISION

- In recent year's master antenna (MATV) and community antenna (CATV) television systems have gained widespread popularity. The purpose of a MATV system is to delivera strong signal (over 1 mV) from one or more antennas to every television receiver connected to the system.
- Typical applications of a MATV system are hotels, motels, schools, apartment buildingsand so on. The CATV system is a cable system which distributes good quality television signal to a very large number of receivers throughout an entire community.
- In general, this system feeds increased TV programmes to subscribers who pay a fee forthis service. A CATV system may have many more active (VHF and UHF) channels than a receiver tuner can directly select. This requires use of a special active converter in thehead-end.

v)

**(a)** MATV

- The block diagram of a basic MATV system is shown in Fig. One or more antennas are usually located on roof top, the number depending on a available telecasts and their direction.
- Each antenna is properly oriented so that all stations are received simultaneously. In order to allow a convenient match between the coaxial transmission line and components that make up the system, MATV systems are designed to have a 75 Ω impedance. Since most antennas have a 300 Ω impedance, a balun is used to convert the impedance to 75 ohms.

- As shown in the figure, antenna outputs feed into a 4-way hybrid. A hybrid is basically a signal combining linear mixer which provides suitable impedance matches to prevent development of standing waves.
- The standing waves, if present, result in ghosts appearing in an otherwise good TV picture. The output from the hybrid feeds into a distribution amplifier via a preamplifier. The function of these amplifiers is to raise the signal amplitude to a level which is sufficient to overcome the losses of the distribution system while providing an acceptable signal toevery receiver in the system.
- The output from the distribution amplifier is fed to splitters through coaxial trunk lines. A splitter is a resistive-inductive device which provides trunk line isolation and impedance match. Coaxial distribution lines carry television signals from the output of splitters to points of delivery called subscriber tap-offs.
- The subscriber taps, as shown in Fig, can be either transformer coupled, capacitive coupled or in the form of resistive pads. They provide isolation between receivers on the same line thus preventing mutual interference. The taps look like ac outlets and are normally mounted in the wall.
- Wall taps may be obtained with 300 Ω output 75 Ω output and a dual output. The preferredmethod is to use a 75 Ω type with a matching transformer. The matching transformer isusually mounted at the antenna terminals of the receiver and will have a VHF output and a UHF output.
- Since improperly terminated lines will develop standing waves, the end of each 75 Ω distribution cable is terminated with a 75 Ω resistor called a terminator.

**(b)** CATV

- Formerly CATV system were employed only in far-fringe areas or in valleys surrounded by mountains where reception was difficult or impossible because of low level signal conditions.
- However, CATV systems are now being used in big cities where signal-level is high butall buildings render signals weak and cause ghosts due to multipath reflections. In either case, such a system often serves an entire town or city.
- A single antenna site, which may be on top of a hill, mountain or sky-scraper is chosen for fixing antennas. Several high gain and properly oriented antennas are employed to pick up signals from different stations. In areas where several signals are coming from one direction, a single broad based antenna (log-periodic) may be used to cover those channels.
- Most cable television installations provide additional services like household, business and educational besides commercial TV and FM broadcast programmes. These include news, local sports and community programmes, burglar and fire alarms, weather reports, commercial data retrieval, meter reading, document reproduction etc.
- Educational services include computer aided instructions, centralized library services and so on. Many of the above options require extra subscription fee from the subscriber.

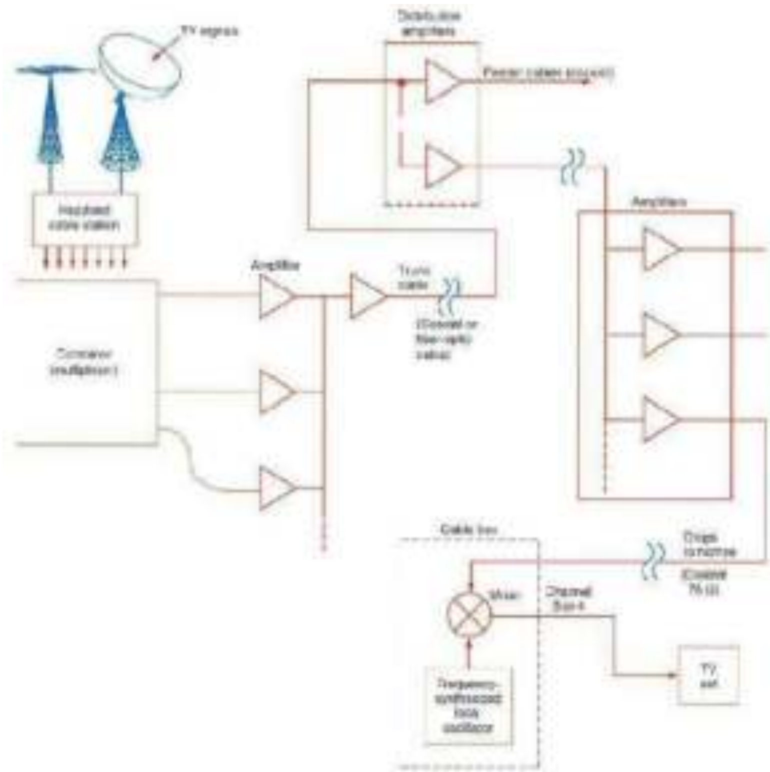



Figure. The modern cable TV system

- Since several of the above mentioned service need two-way communication between the subscriber and a central processor, the coaxial distribution network has a large number of cable pairs, usually 12 or 24.

- This enables the viewer to choose any channel or programme out of the many that are available at a given time. CATV Plan. Figure 10.2 shows the plan of a typical CATV system. The signals from various TV channels are processed in the same manner as in a MATV system. In fact, a CATV system can be combined with a MATV set-up.

- When UHF reception is provided in addition to VHF, as often is the case, the signal from each UHF channel is processed by a translator. A translator is a frequency converter which hterodynes the UHF channel frequencies down to a VHF channel.

- Translation is advantageous since a CATV system necessarily operates with lengthy coaxial cables and the transmission loss through the cable is much greater at UHF than at VHF frequencies. As in the case of MATV, various inputs including those from translators are combined in a suitable mixer.

- The set-up from the antennas to this combiner is  called a head-end. Further, as shown in the figure the CATV outputs from the combiner network are fed to a number of trunk cables through a broadband distribution amplifier. The trunk cables carry signals from the antenna site to the utilization site (s) which may be several kilometers away. Feeder amplifiers are provided at several points along the line to overcome progressive signal attenuation which occurs due to cable losses.

- Since cable losses are greater at higher frequencies it is evident that high-band attenuation will be greater than low-band attenuation. Therefore, to equalize this the amplifiers and signal splitters are often supplemented by equalizers. An equalizer or tilt control consists of a band pass filter arrangement with an adjustable frequency response. It operates by introducing a relative low-frequency loss so that outputs from the amplifiers or splitters have uniform relative amplitude response across the entire VHF band.

- The signal distribution from splitters to tap-off points is done through multicore coaxial cables in the same way as in a MATV system. In any case the signal level provided to a television receiver is of the order of 1.5 mV.

- This level provides good quality reception without causing accompanying radiation problems from the CATV system, which could cause interference to other installations andservices.

Signal Processing

- The TV signals to be redistributed by the cable company usually undergo some kind of processing before they are put on the cable to the TV set. Amplification and impedance matching are the main processes involved in sending the signal to remote locations over what is sometimes many miles of coaxial cable. However, at the head end, other types of processes are involved.(Coaxial or fiber-optic cable)Frequency synthesized local oscillator

Straight-Through Processors.

- In early cable systems, the TV signals from local stations were picked up with antennas, and the signal was amplified before being multiplexed onto the main cable. This is called *straight-through processing*. Amplifiers called *strip amplifiers* and tuned to the received channels pass the desired TV signal to the combiner.
- Most of these amplifiers include some kind of gain control or attenuators that can reducethe signal level to prevent distortion of strong local signals. This process can still be used with local VHF TV stations, but today heterodyne processing is used instead.

Heterodyne Processors.

- *Heterodyne processing* translates the incoming TV signal to a different frequency. This isnecessary when satellite signals are involved.
- Microwave carriers cannot be put on the cable, so they are down-converted to someavailable 6-MHz TV channel.

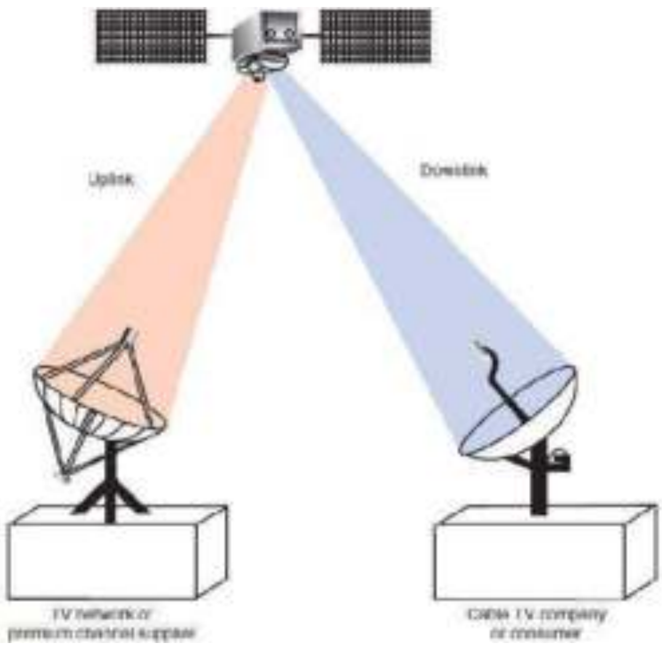
- In addition, heterodyne processing gives the cable companies the flexibility of putting the signals on any channel they want to use.
- The cable TV industry has created a special set of non-broadcast TV channels, some of the frequency assignments correspond to standard TV channels, but others do not. Since all these frequencies are confined to a cable, there can be duplication of any frequency that might be used in radio or TV broadcasting.
- Note that the spacing between the channels is 6 MHz.

Satellite TV

- One of the most common methods of TV signal distribution is via communication satellite. A communication satellite orbits the equator about 22,300 mi out in space. It rotates in synchronism with the earth and therefore appears to be stationary. The satellite is used as a radio relay station.
- The TV signal to be distributed is used to modulate a microwave carrier, and then it is transmitted to the satellite. The path from earth to the satellite is called the uplink. The satellite translates the signal to another frequency and then retransmits it back to earth. This is called the downlink. A receive site on earth picks up the signal.
- The receive site may be a cable TV company or an individual consumer. Satellites are widely used by the TV networks, the premium channel companies, and the cable TV industry for distributing signals nationally.
- A newer form of consumer satellite TV is direct broadcast satellite (DBS) TV. The DBS systems are designed specifically for consumer reception directly from the satellite. The new DBS systems feature digitally encoded video and audio signals, which make transmission and reception more reliable and provide outstanding picture and sound quality.
- By using higher-frequency microwaves, higher-power satellite transponders, and very low-noise GaAs FETs in the receiver, the customer’s satellite dish can be made very small. These systems typically use an 18-in dish as opposed to the 5- to 12-ft-diameter dishes still used in older satellite TV systems.

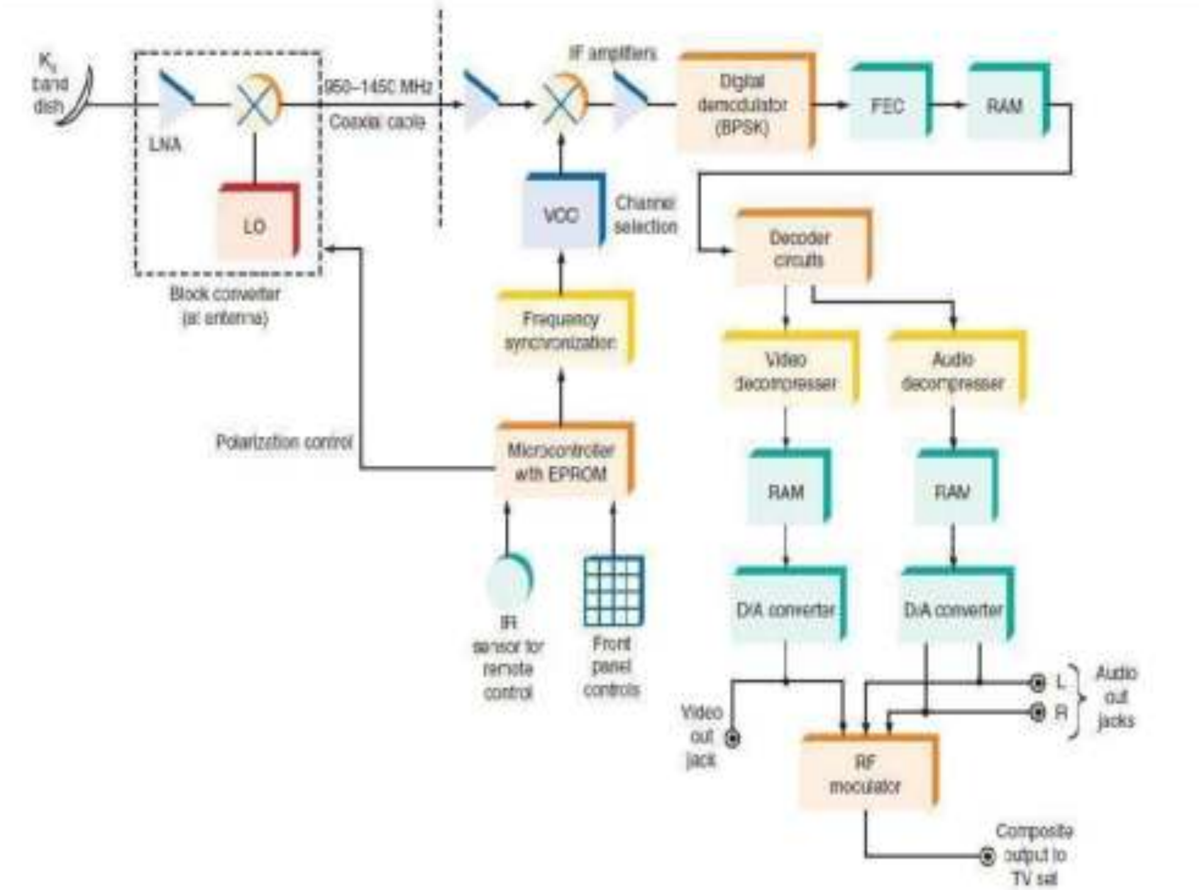
Direct Broadcast Satellite Systems

- The direct broadcast satellite (DBS ) system was designed specifically to be an all-digital system. Data compression techniques are used to reduce the data rate required to produce high-quality picture and sound.
- The DBS system features entirely digital uplink ground stations and satellites. Since the satellites are designed to transmit directly to the home, extra high-power transponders are used to ensure a satisfactory signal level.
- To receive the digital video from the satellite, a consumer must purchase a satellite TV receiver and antenna.

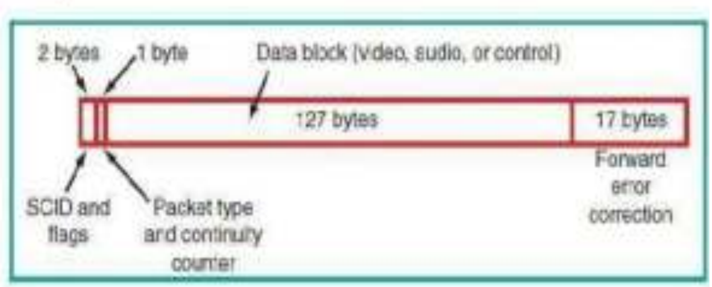



- These satellite receivers operate in the band. By using higher frequencies as well as higher-power satellite transponders, the necessary dish antenna can be extremely small. The new satellite DBS system antennas have only an 18-in diameter.
- Several special digital broadcast satellites are in orbit, and two of the direct satellite TV sources are DirecTV and DISH Network. They provide full coverage of the major cable networks, and the premium channels usually distributed to homes by cable TV and can be received directly.
- In addition to purchasing the receiver and antenna, the consumer must subscribe to one of the services supplying the desired channels. Satellite Transmission. The video to be transmitted must first be placed into digital form. To digitize an analog signal, it must be sampled a minimum of 2 times per cycle for sufficient digital data to be developed for reconstruction of the signal.
- Assuming that video frequencies of up to 4.2 Mbps are used, the minimum sampling rate is twice this, or 8.4 Mbps. For each sample, a binary number proportional to the light amplitude is developed. This is done by an A/D converter, usually with an 8-bit output. The resulting video signal, therefore, has a data rate of 8 bits, 8.4 Mbps, or 67.2 Mbps. Thisis an extremely high data rate.
- However, for a color TV signal to be transmitted in this way, there must be a separate signal for each of the red, green, and blue components making up the video. This translates to a total data rate of or 202, Mbps. Even with today’s technology, this is an extremely high data rate that is hard to achieve reliably.
- To lower the data rate and improve the reliability of transmission, the new DBS system uses compressed digital video. Once the video signals have been put into digital form, they are processed by digital signal processing (DSP) circuits to minimize the full amount of data to be transmitted.

- Digital compression greatly reduces the actual transmitting speed to somewhere in the 20- to 30-Mbps range. The compressed serial digital signal is then used to modulate the uplinked carrier using BPSK.
- The DBS satellite uses the band with a frequency range of 11 to 14 GHz. Uplink signals are usually in the 14- to 14.5-GHz range, and the downlink usually covers the range of
  10.95 to 12.75 GHz. The primary advantage of using the band is that the receiving antennas may be made much smaller for a given amount of gain.
- However, these higher frequencies are more affected by atmospheric conditions than are the lower microwave frequencies. The biggest problem is the increased attenuation of the downlink signal caused by rain.
- Any type of weather involving rain or water vapor, such as fog, can seriously reduce the received signal. This is so because the wavelength of band signals is near that of water vapor. Therefore, the water vapor absorbs the signal.
- Although the power of the satellite transponder and the gain of the receiving antenna are typically sufficient to provide solid reception, there can be fadeout under heavy downpour conditions.
- Finally, the digital signal is transmitted from the satellite to the receiver by using circular polarization. The DBS satellites have right-hand and left-hand circularly polarized (RHCP and LHCP) helical antennas.
- By transmitting both polarities of signal, frequency reuse can be incorporated to double the channel capacity. DBS Receiver. A block diagram of a typical DBS digital receiver is shown in Fig. The receiver subsystem begins with the antenna and its low-noise block converter.
- The horn antenna picks up the band signal and translates the entire 500-MHz band used by the signal down to the 950- to 1450-MHz range, as explained earlier. Control signals from the receiver to the antenna select between RHCP and LHCP. The RF signal from the antenna is sent by coaxial cable to the receiver.
- A typical DBS downlink signal occurs in the 12.2- to 12.7-GHz portion of the band. Each transponder has a bandwidth of pproximately 24 MHz. The digital signal usually occurs at a rate of approximately 27 Mbps. Figure shows how the digital signal is transmitted. Thedigital audio and video signals are organized into data packets.
- Each packet consists of a total of 147 bytes. The first 2 bytes (16 bits) contain the service channel identification (SCID) number. This is a 12-bit number that identifies the video program being carried by the packet. The 4 additional bits are used to indicate whether the packet is encrypted and, if so, which decoding key to use.
- One additional byte contains the packet type and a continuity counter. The data block consists of 127 bytes, either 8-bit video signals or 16-bit audio signals. It may also contain digital data used for control purposes in the receiver.
- Finally, the last 17 bytes are the error detection check codes. These 17 bytes are developed by an error-checking circuit at the transmitter. The appended bytes are checked at the receiver to detect any errors and correct them.




Digital data packet format used in DBS TV.




- The received signal is passed through another mixer with a variable-frequency local oscillator to provide channel selection. The digital signal at the second IF is then demodulated to recover the originally transmitted digital signal, which is passed through a forward error correction (FEC) circuit.

- This circuit is designed to detect bit errors in the transmission and to correct them on the fly. Any bits lost or obscured by noise during the transmission process are usually caught and corrected to ensure a near-perfect digital signal.
- The resulting error-corrected signals are then sent to the audio and video decompression circuits. Then they are stored in random access memory (RAM), after which the signal is decoded to separate it into both the video and the audio portions.
- The DBS TV system uses digital compression-decompression standards referred to as *MPEG2 (MPEG* means *Moving Picture Experts Group,* which is a standards organization that establishes technical standards for movies and video).
- MPEG2 is a compression method for video that achieves a compression of about 50 to 1 in data rate. Finally, the signals are sent to D/A converters that modulate the RF modulator which sends the signals to the TV set antenna terminals.
- Although the new DBS digital systems will not replace cable TV, they provide the consumer with the capability of receiving a wide range of TV channels. The use of digital techniques provides an unusually high-quality signal.

## 5.5 Digital TV (DTV)

- Digital TV (DTV), also known as high-definition TV (HDTV), was designed to replace the National Television Standards Committee (NTSC) system, which was invented in the 1940s and 1950s.
- The goal of HDTV is to greatly improve the picture and sound quality. After more than a decade of evaluating alternative HDTV systems, the FCC has finalized the standards and decreed that HDTV will eventually become the U.S. TV standard by April 2009.
- The first HDTV stations began transmission in the 10 largest U.S. cities on September 1, 1998. HDTV sets can now be purchased by the consumer, but they are still expensive. As more HDTV stations come online and as more HDTV programming becomes available, more consumers will buy HDTV receivers and the cost will drop dramatically.
- The HDTV system is an extremely complex collection of digital, communication and computer techniques.
- A full discussion is beyond the scope of this book. However, this section is a brief introduction to the basic concepts and techniques used in HDTV. HDTV Standards HDTV for the United States was developed by the Advanced Television Systems Committee (ATSC) in the 1980s and 1990s.
- HDTV uses the scanning concept to paint a picture on the CRT, so you can continue to think of the HDTV screen in terms of scan lines, as you would think of the standard NTSC analog screen. However, you should also view the HDTV screen as being made up of thousands of tiny dots of light, called pixels.
- Each pixel can be any of 256 colors. These pixels can be used to create any image. The greater the number of pixels on the screen, the greater the resolution and the finer the detail that can be represented.

- Each horizontal scan line is divided into hundreds of pixels. The format of a HDTV screen is described in terms of the numbers of pixels per horizontal line by the number of vertical pixels (which is the same as the number of horizontal scan lines).
- One major difference between conventional NTSC analog TV and HDTV is that HDTV can use progressive line scanning rather than interlaced scanning. In progressive scanning each line is scanned one at a time from top to bottom.
- Since this format is compatible with computer video monitors, it is possible to display HDTV on computer screens. Interlaced scanning can be used on one of the HDTV formats. Interlaced scanning minimizes flicker but complicates the video compression process. Progressive scanning is preferred and at a 60-Hz frame rate, flicker is not a problem.

| Standard | Aspect Ratio | Pixels/ Horizontal Line | Vertical Pixels* | Scan Rate, Hz |
|---|---|---|---|---|
| 480p | 4:3 | 640 | 480 | 24, 30, 60 |
| 480i/p | 4:3 or 16:9 | 704 | 480 | 24, 30, 60 |
| 720p | 16:9 | 1280 | 720 | 24, 30, 60 |
| 1080i | 16:9 | 1920 | 1080 | 24 or 30 |

*Number of scan lines.
†Standard PC VGA format.

- The FCC has defined a total of 18 different formats for HDTV. Most are variations of the basic formats as given in Table. Most plasma, LCD and larger screens only display these formats.The 480p (the *p* stands for "progressive") standard offers performance comparable to that of the NTSC system. It uses a 4:3 aspect ratio for the screen.
- The scanning is progressive. The vertical scan rate is selectable to fit the type of video being transmitted. This format is fully compatible with modern VGA computer monitors.
- The format can use either progressive or interlaced scanning with either aspect ratio at the three vertical scan rates shown in Table.
- The 720p format uses a larger aspect ratio of 16:9 (a 4:3 format is optional at this resolution also). This format is better for showing movies. Figure shows the difference between the current and new HDTV aspect ratios.
- The 1080i format uses the 16:9 aspect ratio but with more scan lines and more pixels perline. This format obviously gives the best resolution. The HDTV set should be able to detect and receive any available format. The 720p at 60 Hz and 1080i formats are those designated HDTV.

<u>HDTV Transmission Concepts</u>

- In HDTV both the video and the audio signals must be digitized by A/D converters and transmitted serially to the receiver.

- Because of the very high frequency of video signals, special techniques must be used totransmit the video signal over a standard 6-MHz-bandwidth TV channel.
- And because both video and audio must be transmitted over the same channel, multiplexingtechniques must be used. The FCC's requirement is that all this information be transmitted reliably over the standard 6-MHz TV channels now defined for NTSC TV. Assume that the video to be transmitted contains frequencies up to 4.2 MHz.
- For this signal to be digitized, it must be sampled at least 2 times per cycle or at a minimumsampling rate of 8.4 MHz. If each sample is translated to an 8-bit word (byte) and the bytesare transmitted serially, the data stream has a rate of , or 67.2 MHz.
- Multiply this by 3 to get 67.2 _ 3 = 201.6 MHz. Add to this the audio channels, and the total required bandwidth is almost 300 MHz. To permit this quantity of data to be transmitted over the 6-MHz channel, special encoding and modulation techniques are used.

<u>HDTV Transmitter</u>

6 TV picture standards. (a) Current standard. (b) HDTV standard.

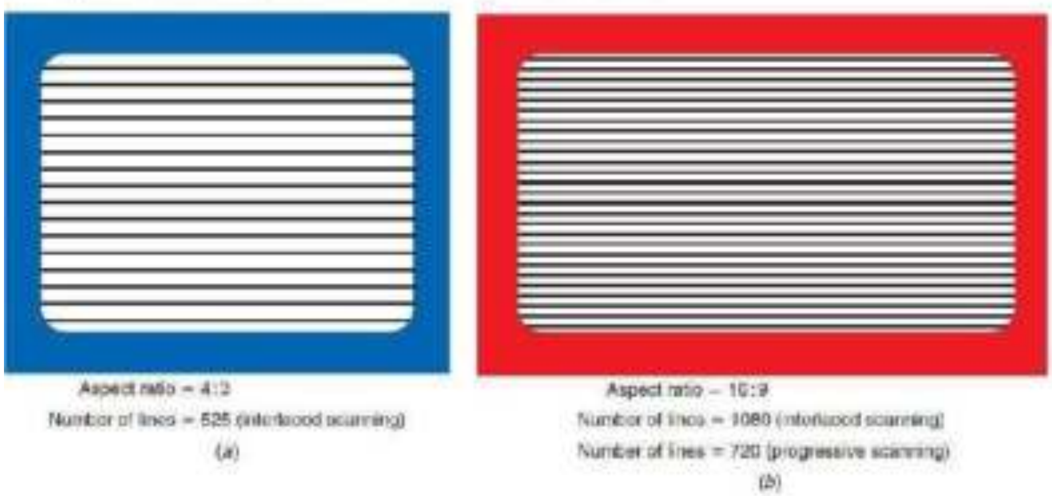
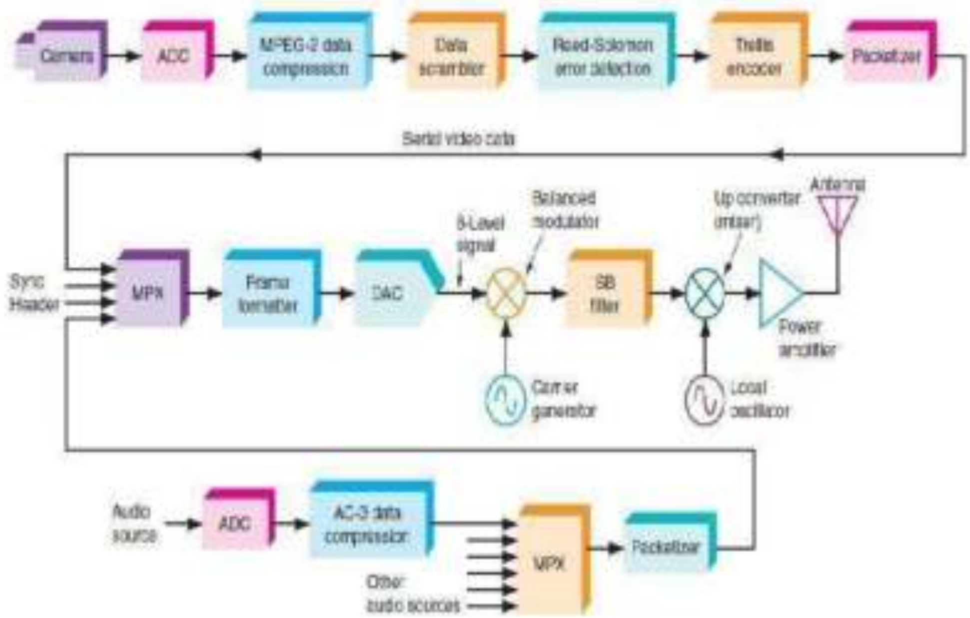


Figure 23-27 HDTV transmitter.




- Figure shows a block diagram of an HDTV transmitter. The video from the camera consistsof the *R*, *G*, and *B* signals that are converted to the luminance and chrominance signals. These are digitized by A/D converters. The luminance sampling rate is 14.3 MHz, and the chroma sampling rate is 7.15 MHz.
- The resulting signals are serialized and sent to a data compressor. The purpose of this device is to reduce the number of bits needed to represent the video data and therefore permit higher transmission rates in a limited-bandwidth channel. MPEG-2 is the data compression method used in HDTV.
- The MPEG-2 data compressor processes the data according to an algorithm that effectively reduces any redundancy in the video signal. For example, if the picture is one-half lightblue sky, the pixel values will be the same for many lines.
- All this data can be reduced to one pixel value transmitted for a known number of times. The algorithm also uses fewer bits to encode the color than to encode the brightness because the human eye is much more sensitive to brightness than to color.
- The MPEG-2 encoder captures and compares successive frames of video and comparesthem to detect the redundancy so that only differences between successive frames are transmitted. The signal is next sent to a data randomizer. The randomizer scrambles or randomizes the signal.
- This is done to ensure that random data is transmitted even when no video is present or when the video is a constant value for many scan lines. This permits clock recovery at the receiver.
- Next the random serial signal is passed through a Reed-Solomon (RS) error detection and correction circuit. This circuit adds extra bits to the data stream so that transmission errors

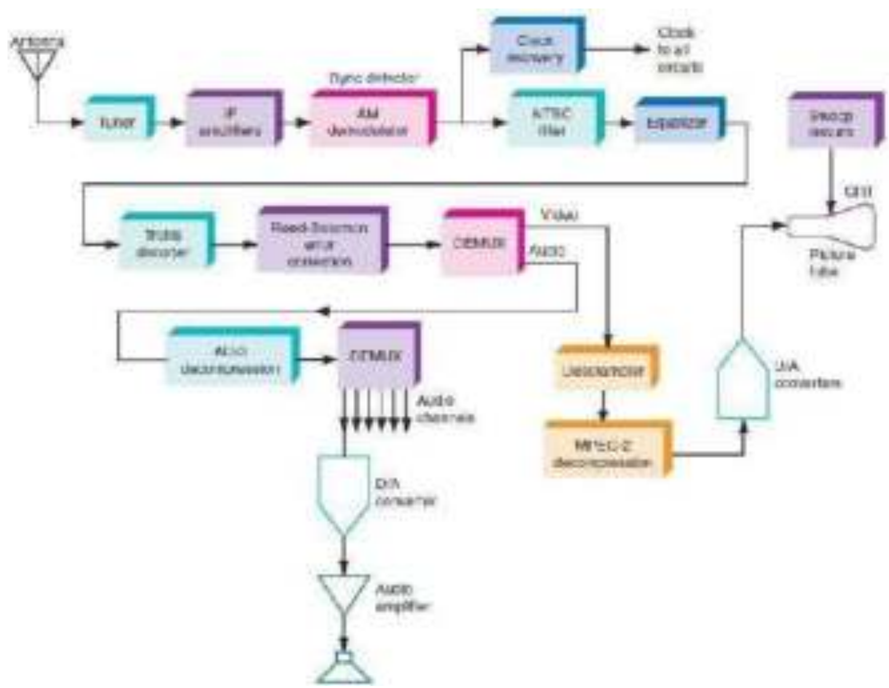
can be detected at the receiver and corrected. This ensures high reliability in signal transmission even under severe noise conditions.

- In HDTV, the RS encoder adds 20 parity bytes per block of data that can provide correctionfor up to 10 byte errors per block. The signal is next fed to a trellis encoder. This circuit further modifies the data to permit error correction at the receiver. Trellis encoding is widely used in modems.
- Trellis coding is not used in the cable TV version of HDTV. The audio portion of the HDTV signal is also digital. It provides for compact disk (CD) quality audio. The audio system can accommodate up to six audio channels, permitting monophonic sound, stereo, and multichannel surround sound.
- The channel arrangement is flexible to permit different systems. For example, one channel could be used for a second language transmission or closed captioning. Each audio channel is sampled at a 48-kbps rate, ensuring that audio signals up to about 24 kHz are accurately captured and transmitted.
- Each audio sample is converted to an 18-bit digital word. The audio information is time- multiplexed and transmitted as a serial bit stream at a frequency of A data compression technique designated AC-3 is used to speed up audio transmission.
- Next the video and audio data streams are packetized; i.e., they are converted to short blocks of data bytes that segment the video and audio signals.
- These packets are multiplexed along with some synchronizing signals to form the final signal to be transmitted. The result is a 188-bit packet containing both video and audio data plus 4 bytes of synchronizing bytes and a header. See Fig.
- The header identifies the number of the packet and its sequence as well as the video format. Next the packets are assembled into frames of data representing one frame of video. Thecomplete frame consists of 626 packets transmitted sequentially. The final signal is sent tothe modulator.
- The modulation scheme used in HDTV is 8-VSB, or eight-level vestigial sideband, amplitude modulation. The carrier is suppressed, and only the upper sideband is transmitted.
- The serial digital data is sent to a D/A converter where each sequential 3-bit group isconverted to a discrete voltage level. This system encodes 3 bits per symbol, thereby greatly increasing the data rate within the channel. An example is shown in Fig. Each 3-bit group is converted to a relative level of or This is the signal that amplitude-modulates thecarrier.
- he resulting symbol rate is 10,800 symbols per second. This translates to a data rate of . Eliminating the extra RS and trellis bits gives an actual video/audio rate of about 19.3 Mbps. A modified version of this format is used when the HDTV signal is to be transmittedover a cable system. Trellis coding is eliminated and 16-VSB modulation is used to encode 4 bits per symbol.
- This gives double the data rate of terrestrial HDTV transmission (38.6 Mbps). The VSB signal can be created with a balanced modulator to eliminate the carrier and to generate thesidebands.
- One sideband is removed by a filter or by using the phasing system. The modulated signal is up-converted by a mixer to the final transmission frequency, which is one of the standard

TV channels in the VHF or UHF range. A linear power amplifier is used to boost the signal level prior to transmission by the antenna.

HDTV Receiver**.**

- An HDTV receiver picks up the composite signal and then demodulates and decodes the signal into the original video and audio information. A simplified receiver block diagramis shown in Fig.
- The tuner and IF systems are similar to those in a standard TV receiver. From there the 8- VSB signal is demodulated (using asynchronous detector) into the original bit stream. A balanced modulator is used along with a carrier signal that is phase-locked to the pilotcarrier to ensure accurate demodulation.
- A clock recovery circuit regenerates the clock signal that times all the remaining digital operations. The signal then passes through an NTSC filter that is designed to filter out any one channel or adjacent channel interference from standard TV stations.
- The signal is also passed through an equalizer circuit that adjusts the signal to correct for amplitude and phase variations encountered during transmission. The signals are de- multiplexed into the video and audio bit streams.
- Next, the trellis decoder and RS decoder ensure that any received errors caused by noiseare corrected. The signal is descrambled and decompressed. The video signal is then converted back to the digital signals that will drive the D/A converters that, in turn, drive the red, green, and blue electron guns in the CRT.
- The audio signal is also de multiplexed and fed to AC-3 decoders. The resulting digitalsignals are fed to D/A converters that create the analog audio for each of the six audio channels.



SCRAMBLING AND CONDITIONAL ACCESS SYSTEMS:

- Scrambling: It is to suppress the sync signals at transmitting end The picture without H and V sync cannot lock into steady picture seen as rolling picture and diamond bars. For descrambling, a pilot carrier containing the sync timing information is transmitted on separate carrier.
- Another method with great security and complexity is baseband scrambling, the scrambled coded lines are decoded and it requires demodulation process.
- Scrambling is possible by digital processing of video and audio and introducing complex encryption and smart keyboard for controlled access.
- Now Addressable converters: includes tunable converters and address recognization circuitry which is controlled by computer so specific channels are turned OFF or ON to subscriber.

CONDITIONAL ACCESS

**Features:**

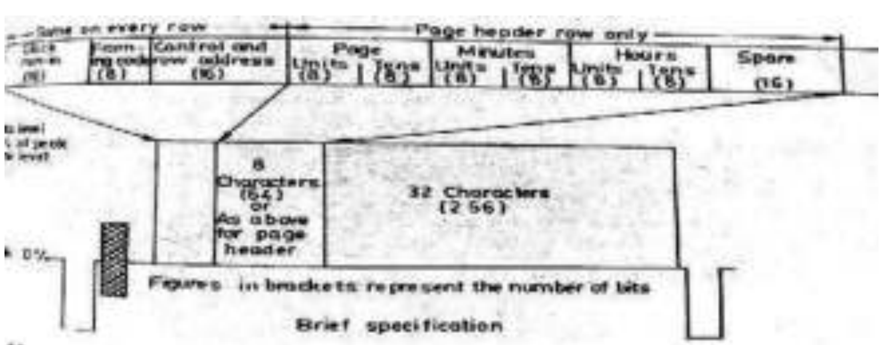
- Equipment compatibity access, support, user system interface, telephone communication module. The techniques used are scramblers and injectors upstream and descrambler modules.In cable and satellite systems, 3 different operational are projected

1. Access to a given channel for fixed duration
2. Pay per view with preselected choice of channel
3. Pay per view without preselction.

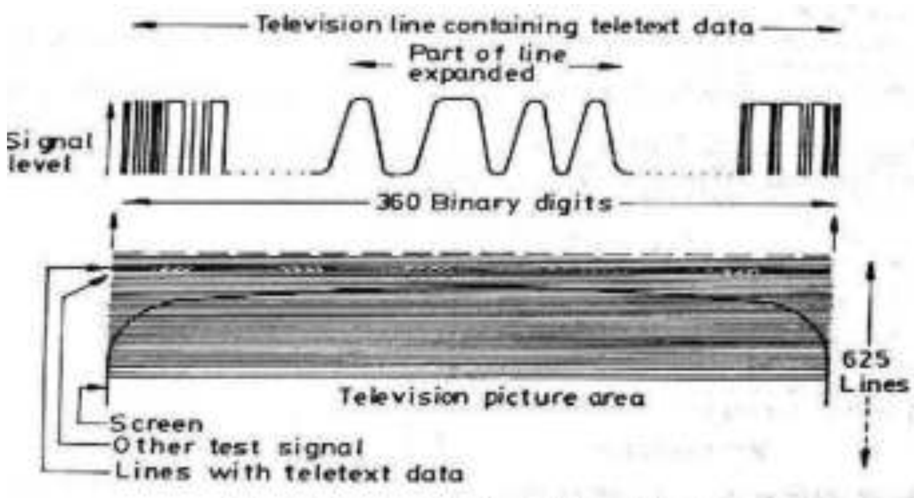
TELETEXT O F VIDEO TEXT SYSTEM

- Videotext is a two-way information service as video display unit or crt terminal.Thisinformation service generally provides data in 4 major areas,

1. Finance stock exchanges
2. Money markets and reservation
3. Messaging- topical news and reviews a subscriber to database can select desired information via keypad accessory.
4. Prestel - first video text service.



- View data systems use all kinds of host computers, from minicomputers to mainframes depends upon power require for service.



The position of the teletext data signal

View data chip (lucy)

It performs most of hardware functions of a viewdata terminal- autodialer circuit, band demodulator and asynchronous receiver, baud modulator and asynchronous transmitter. It includes a tape interface for recording and character codes. View data terminals CRT displays are used to display the information for viewing and editing. It can be an intelligent terminal or microcomputers. Intelligent terminals- equipped with microprocessor and data storage memory capacity to process the data. Microcomputers – with software for data storage and local processing capability. TV monitor is enhanced with video bandwidth to improve resolution as CRT display monitor or VDU.

DIGITAL TV SYSTEM

- Analog signals suffers degradation due to noise, crosstalk, linear and non-linear distortion. In this, analog is converted to digital by analog to digital converter ADC performs sampling, quantization and encoding.

Sampling:

- The TV signal is sampled at rate of twice the maximum band limit frequency- Nyquistcriteria.
- Fourier transform of band limit signal at T seconds is scaled by 1/T and given by wo $=2\pi/T$.
- If input signal is not band limited or sampling frequency does not meet the requirement ofsampling theorem, the various components of spectrum overlap.
- It suffers from distortion called aliasing effect and moiré patterns appear in picture.

- To avoid aliasing errors, the sampling frequency must exceed 10mhz.

Quantization:

- The sampled output, discrete in time in continuous in amplitude and assigned a discretenumerical values as ADC.
- Since DAC is reverse process.

Encoder:

- The sampled value is assign a binary code along with additional coding like parity for error detection , scrambling,etc.
- Errors occurred are eliminated by redundancy in digital signals.
- Because of this, delay may occurs in TV , so forward error correction (FEC) is obtained.
- Block coding and convolution coding are two approaches in this direction.

3DTV

For 3D picture, we have to show the depth also along with length and breadth.
( L + B + H)

Principle:

- The left and right eye of human see a different image of same object, so brain interpretsthese as a single composite image in 3D.
- Two different images are generated by 2 cameras, like our eyes located.
- For stereo sound transmitter, the left and right channel signals are FM at 5.5MHz audiocarrier.
- The combined audio and video signals are amplitude modulated by channel carrier using separate modulators.
- USB and LSB selected and combined before final transmission.

**3-D** Display methods:

By using 3 set of color signals we reproduce the 3-D effect on picture tube screen.

First method:

- All green color phosphor strips excited by green(G) video signal right. Similarly red colorphosphor strips excited by red(R) video signal left.
- Blue (B) color phosphor strips are not exited at all.
- If viewer wears, G filter at right eye and R filter at left eye, than brain combined to formvarious Y shades.

Second method:

- Two video display units(VDU) are used, to create 3D pictures in natural colors.
- A polarizing film is fitted in front of VDU and light outputs are reflected using a mirrorarrangement on screen.

Third method:

- This is known as ABDY 3D system.
- In this, R color information are delayed by nearly 600ns and it is obtain by using delaycircuits.
- So, double image is formed on screen of picture tube.

VCR- VIDEO CASSETTE RECORDERINTRODUCTION

- The main purpose of the video recorder is recording and replaying video and audio signals. Although built-in tuners and timers have become integral parts of the average video recorder, they are not prerequisites for reaching the main goal: audio and video registrationand playback.

THE HELICAL SCAN SYSTEM

- In an audio cassette deck, which only registers audio signals, the tape passes over a staticrecording/playback head at constant speed.
- The higher the speed of the tape, the more tape particles pass the head opening and the higher the frequencies that can be registered. Thanks to the extremely narrow head opening, it is possible to record and play back the entire tone range, up to 18,000 or 20,000 Hz, despite a slow tape speed of no more than 4.75 centimeters per second.
- However, to register video signals, a range of 3.2 MHz is required and so a tape speed ofapproximately 5 meters per second is a prerequisite. This is over 100 times as fast as the tape speed for an audio cassette deck.
- The required high recording speed for video recorders is realized by the helical scan systemwithout such high tape speeds. The system basically consists of a revolving head drum,that has a minimum of two video heads.
- The head drum has a diameter of approximately 5 cm and rotates at a speed of 1500 revolutions per minute. The 1/2" (12.65 mm) wide videotape is guided around half the surface of this drum, in a slightly oblique manner. This is achieved by positioning the head drum at a slight angle.
- The tape guidance mechanism then ensures that the tape is guided through the device at a speed of approximately 2 cm per second (half of the low tape speed that is used in audio cassette decks).

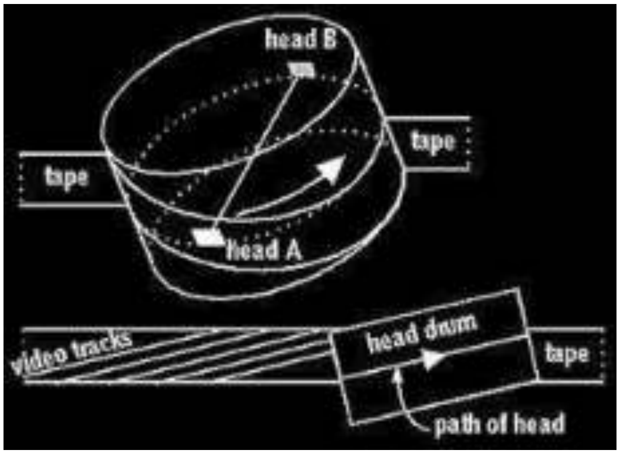



Fig:Tape guidance along the head drum with the video heads writing tracks on the tape.

- In the meantime, the rapidly revolving video heads write narrow tape tracks of no more than 0.020 to 0.050 mm wide on the tape, next to each other, diagonally. Every half revolution, each of the two heads writes one diagonal track which equals half an image. The first head writes one track, i.e., the first field (the odd numbered scanning lines).
- The second head writes a second track, i.e., the other half of the image (the second field: the even numbered scanning lines), which precisely fits in the first image. This corresponds to the interlacing principle, as applied in television.
- One full revolution of both heads results in two diagonal tracks right next to each other, together forming one entire image scan (a frame). This means that two apparently contradictory requirements can be realized simultaneously: low tape speed of only 2 cm per second and at the same time a high registration speed (relative tape speed) of no less than 5 meters per second.
- These two requirements make it possible to record the high video frequencies up to 3.2 MHz. At the same time, the low tape speed gives a time capacity up to three hours.

SYNCHRONIZATION TRACK

- The revolutionary speed of the head drum and the video heads needs to maintain a constancy within strict parameters. Moreover, the tracks must be scanned during playback in precisely the same way as they were recorded.
- Each tape track is synchronized at the recording stage by means of field synchronization pulses. These pulses are generated in the video recorder by a separate head which are recorded on a separate narrow track at the side of the video tape.
- This is called the synchronization, servo or control track.

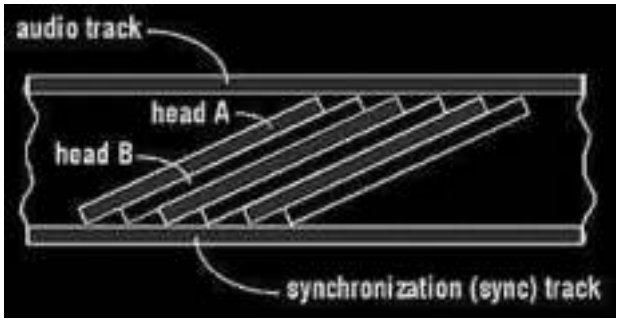



Fig: Position of the video, audio and synchronization tracks on the tape.

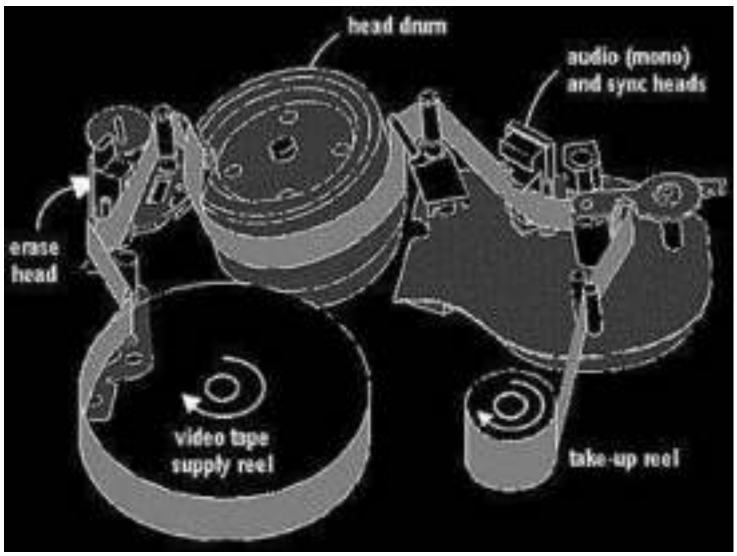



**Fig: Position of the audio, sync and erase heads inside the VCR. VIDEO**

**DISC SYSTEMS**

There are three major video systems in use today:

1. Video Home System (VHS)
2. Betamax
3. Video Hi8

- When the video recorders were first introduced, Philips also developed a system called V2000. Despite the fact that is was a high quality system, it was not successful in the market.
- Although Betamax was reasonably successful at first, its popularity waned and VHS was adopted as the world standard.

BETAMAX

- The Sony Betamax System, launched in 1975, was based on the pre-existing professional Sony U-matic-system. In the Betamax system, the video tape is guided along the head drum in a U-shape for all tape guidance functions, such as recording, playback and fast forward/backward.
- When the cassette is inserted, the tape is guided around the head drum (called threading). Threading the tape takes a few seconds, but once the tape is threaded, shifting from one tape function to another can be achieved rapidly and smoothly.

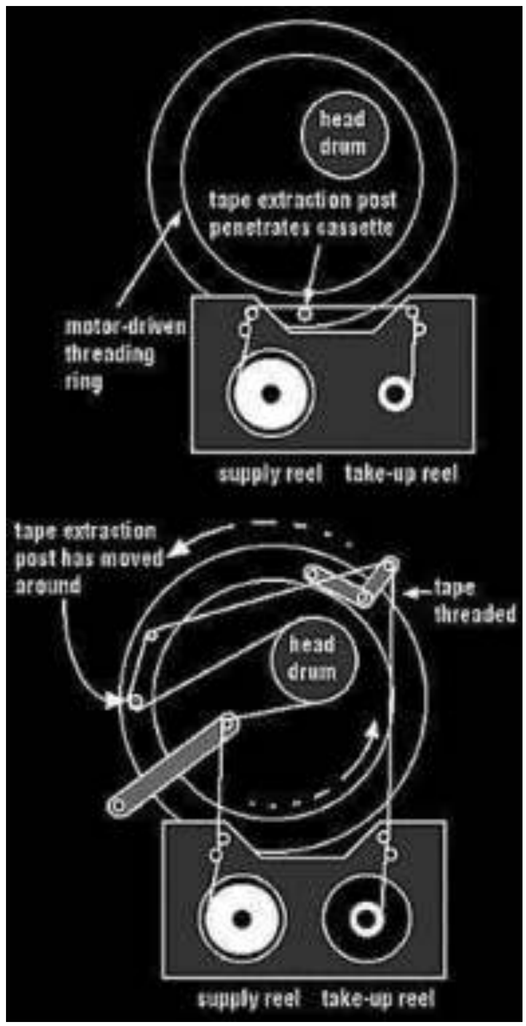



Fig:The Betamax U-system before (top) and after (bottom) threading.

**VIDEO HOME SYSTEM (VHS)**

- JVC's VHS S ystem was introduced one year after the launch of Betamax. In VHS, the tape is guided through in an M-shape; the so-called M-tape guidance system.

- It is considered simpler and more compact than the U-system. Threading is faster and is done every time the tape guidance function is changed. It is therefore somewhat slower and noisier than the U-system.
- This problem is being solved by "Quick-start" VHS video recorders, which allow fast and silent changes in tape guidance functions. To avoid excessive wear, M-tape guidance system recorders are provided with an automatic switch-off feature, activated some minutes after the recorder is put on hold, which automatically unthreads the tape.
- An improvement of the basic VHS system is HQ (High Quality) VHS.
- In the VHS system different starting points were used than in Betamax, such as track size and relative speed. VHS has rather wide video tracks, but a slightly lower relative tape speed, and that also counts for the audio track. In general, the advantages of one aspect are tempered by the disadvantages of the other.
- The end result is that there is not too much difference between the sound and image qualities of both systems.

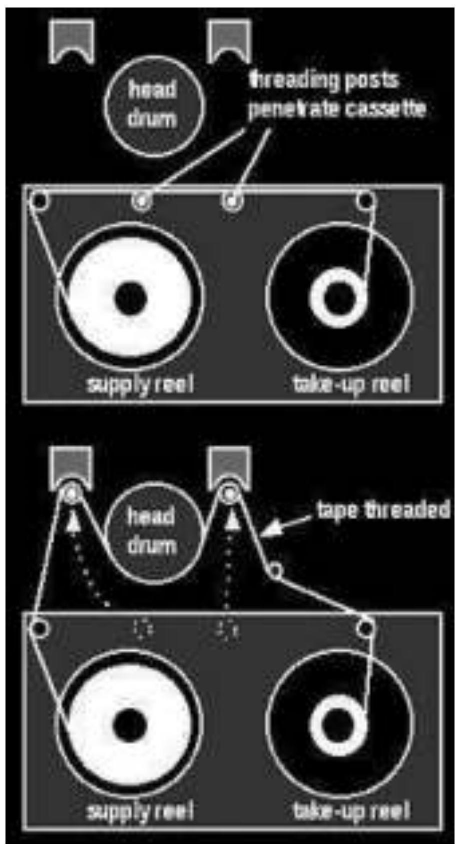



Fig: The VHS M-system before (top) and after (bottom) threading.

- As a direct addition to the Video-8 camcorders, there is a third system: Video Hi8, which uses a smaller cassette than VHS and Betamax.
- The sound recording takes place digitally, making its sound quality very good. When using the special Hi8 Metal Tape, the quality of both image and sound are equivalent to that of Super-VHS.
- The Video-Hi8-recorder can also be used to make audio recordings (digital stereo) only. Using a 90 minute cassette, one can record 6 x 90 minutes, making a total of 18 hours ofcontinuous music.
- The video Hi8-system also allows manipulating digital images, such as picture-in-picture and editing. Video Hi8 uses a combination of the M- and U-tape guidance system.

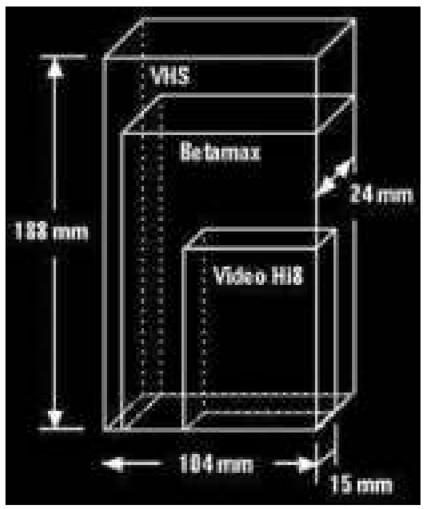



Fig: Cassette sizes compared.

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