TELEVISION ENGINEERING

3.1

Aspect ratio

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

Aspect ratio = Width/ Height = 4/3 or 4: 3

Reasons for having this ratio is,

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

2. Our eye can see the movement of object comfortably only in horizontal plane than in vertical plane. The Fovea, the region of maximum resolution at the centre of retina, has greater area along width than height.

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

Rectangular Scanning

For a picture raster of rectangular shape, rectilinear scanning is most convenient. There are two scanning procedures taking place simultaneously, one moving the beam horizontally from left to right at fast rate and the other moving the beam vertically downwards at a slower rate. Movements of the beam are at constant speeds during the forward and the downward scans and thus linear in both directions.

Persistence of vision

The image formed on the retina is retained for about 20 ms even after optical excitation has ceased. This property of the eye is called persistence of vision, an essential factor in cinematography and TV for obtaining the illusion of continuity by means of rapidly flashing picture frames. If the flashing is fast enough, the flicker is not observed and the flashes appear continuous. The repetition rate of flashes at and above which the flicker effect disappears is called the critical flicker frequency (CFF). This is dependent on the brightness level and the color spectrum of the light source.

In cinema, a film speed of 16 frames per second was used in earlier films to obtain the illusion of movement.

Flicker

Flicker is a visible change in brightness between cycles displayed on video displays. It applies especially to the refresh interval on cathode ray tube (CRT) televisions and computer monitors, as well as plasma computer displays and televisions.

Although the rate of 24 pictures per second in motion pictures and that of scanning 25 frames per second in television pictures is enough to cause an illusion of continuity, they are not rapid enough to allow the brightness of one picture or frame to blend smoothly into the next through the time when the screen is blanked between successive frames. This results in a definite flicker of light that is very annoying to the observer when the screen is made alternately bright and dark.

This problem is solved in motion pictures by showing each picture twice, so that 48 views of the scene are shown per second although there are still the same 24 picture frames per second. As a result of the increased blanking rate, flicker is eliminated.

Vertical resolution

The ability of the scanning system to resolve picture details in vertical direction is known as vertical resolution. This depends on the number of horizontal scanning lines used per frame.

For comfortable viewing optimum viewing angle of 10 to 15 degrees is chosen. Best viewing distance for watching television is 4 to 8 times the height of the picture i.e., a visual angle of about 10 degrees.

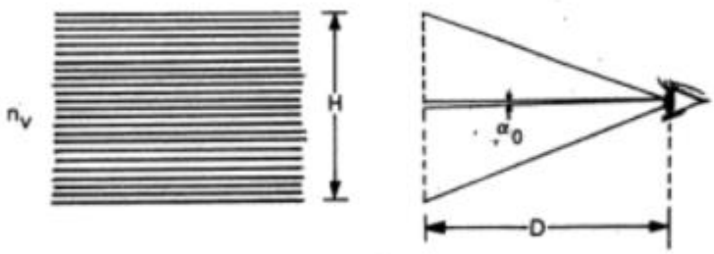


Fig. 2.7 Minimum number of scanning lines

The maximum number of dark and white elements which can be resolved by the human eye in the vertical direction in a screen of height H is given by n_v, the number of lines of vertical resolution, according to the relation

$$\frac{H}{D} = n_v \times \alpha_0$$

where n_v is the number of black and white lines of resolution, α_0 the minimum angle of resolution in radians, and D the distance of the viewer.

Thus, for $D/H = 6$, i.e. visual angle about 10°

$$n_v = \frac{H}{D\alpha_0}$$

$$= \frac{1}{6} \times \frac{60}{1} \times \frac{180}{\pi}$$

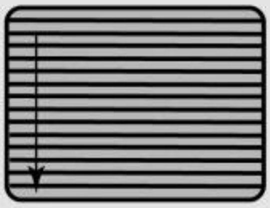
$$= 600 \text{ lines}$$

and for $D/H = 4$, i.e. visual angle about 15°

$$n_v = \frac{1}{4} \times \frac{60}{1} \times \frac{180}{\pi}$$

$$= 900 \text{ lines}$$

The maximum number of alternate dark and white elementary horizontal lines which can be resolved by the eye are thus 600 for a 10° visual angle, or 900 for a 15° visual angle. There has been a large difference of opinion about what constitutes a sufficient number of lines because of the subjective assessment involved. This has been made further difficult to assess because of the effects of the finite size of the scanning beam spot.



Vertical resolution

2.12 THE KELL FACTOR

In a practical scanning systems, the maximum vertical resolution obtainable is less than the active number of lines available for scanning. This is because of the finite beam size and its alignment not coinciding with the elementary resolution lines. Consider a finite size of a beam spot scanning a series of closely spaced horizontal black and white lines of minimum resolvable thickness, when the beam spot also is nearly as much in size as the thickness of the line, as shown in Fig. 2.8.

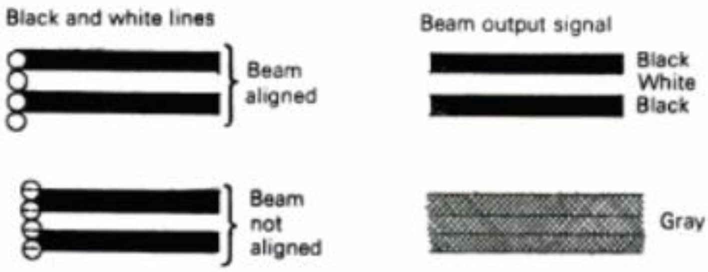


Fig. 2.8 Effect of beam spot size on vertical resolution

If the beam is in perfect alignment, the output will be exactly following the lines as black or white levels, as shown in the figure. If, however, the beam spot is shifted slightly and happens to align on the junction of the black and white lines, it actually senses both black and white areas simultaneously..Hence, it integrates the effects of both areas to give a resultant gray level output, in between the black and white levels. This happens for all scanning positions and the output as well as the reproduced picture will be a continuous gray without any vertical resolution at all. In positions of intermediate alignment of the beam, it will be more on one line than on the adjacent one and the output lines will be reproduced with diminished contrast.

This indicates that there is a degradation in vertical resolution due to finite beam size. Statistical analysis as well as subjective tests based on a bar pattern consisting of tapered wedges of almost horizontal, converging, alternate black and white bars, have indicated that the average number of effective lines is of the order of 0.7 times the total active scan lines present. This factor indicating the reduction in effective number of lines is called the 'Kell factor'. It is obviously not a precisely determined quantity, and values from 0.64 to 0.85 are ascribed to it.

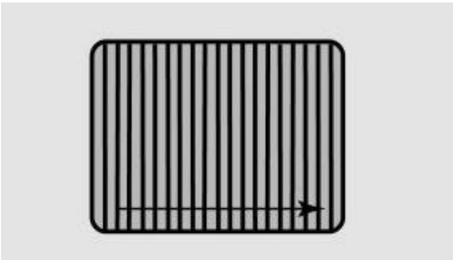
What the Kell factor indicates is that it is unrealistic to state that the vertical resolution is equal to the number of active lines. In a picture, not all lines or parts of lines are fully effective at all times. The

number of active lines multiplied by the Kell factor leads to a smaller figure for a more realistic assessment of available vertical resolution.

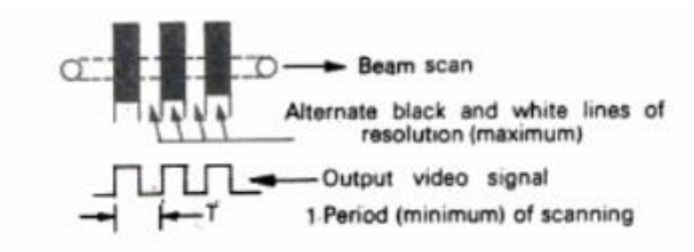
In the 625-line system, the number of active lines left after deducting lines lost in vertical blanking (as explained in Sec. 2.13) are (625 – 40 =) 585 lines. With a Kell factor of 0.7, the vertical resolution is (0.7 × 585 =) 409.5 lines. The horizontal resolution may not exceed this value, multiplied by the aspect ratio.

Horizontal resolution

The horizontal resolution defines the capability of the system to resolve vertical lines. It depends on the camera and display capabilities, as well as the bandwidth and the high-frequency amplitude and phase response of the transmission medium. In a 4:3 aspect ratio television system, it is expressed as the number of distinct vertical lines, alternately black and white, which can be satisfactorily resolved in three quarters of the width of a television screen. A system with a horizontal to vertical aspect ratio of 4:3, as in conventional television, needs to allow for (4:3) NV horizontal details to be resolved over the width of the display.



Horizontal resolution



In 625 line system, there are about 410 lines of vertical resolution. The horizontal resolution with aspect ratio 4:3 the number of vertical lines for horizontal resolution will be 410*(4/3) = about 546 black and white alternate lines. This means 546/2=273 cycles of black and white alternations.

In 625 line system horizontal scan or line frequency f_H=Number of lines per picture*Picture scan rate=625*25=15624 Hz as each picture line is scanned 25 times in one second.

The total line period is thus T_H=1/ f_H=1/15625= 64 µs

Of this period 12 µs are used for the blanking of fly back retrace. Thus 546 black and white alternations i.e., 273 cycles of complete square waves are scanned along a horizontal raster line during forward scan time of 60-12= 52 µs. The period of this square wave is 52/273=about 0.2 µs, giving highest fundamental frequency of 5 MHz.

Interlaced Scanning

In television pictures an effective rate of 50 vertical scans per second is utilized to reduce flicker. 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 successive line. Then, when the beam reaches the bottom of the picture frame, it quickly returns to the top to scan those lines that were missed in the previous scanning. Thus the total numbers of lines are divided into two groups called ‘fields’. Each field is scanned alternately. This method of scanning is known as interlaced scanning.

2.14 INTERLACED SCANNING

From considerations of flicker, it has been found that 50 picture frames per second is the minimum requirement in television scanning. For a 625-line system, this means that the horizontal line scanning frequency should be 31,250 Hz, with the line period of 32 μs. For a desired resolution of 546/2 alternations in the horizontal line, this leads to a very high bandwidth requirement, viz. $\left(\frac{546}{2} \times \frac{1}{(32-6)} \approx\right)$ 10 MHz, if the line scanning is the simple sequential way.

An ingeneous method of reducing the bandwidth requirement, while still maintaining an effective vertical picture scan rate of 50 Hz is to employ 'interlaced scanning', rather than the simple sequential raster. In interlaced scanning, the picture is divided into two more sets of fields each containing half or other fractional number of interlaced lines, and the fields are scanned sequentially. In 2 : 1 interlace, the 625 lines are divided into two sets of $312^1/_2$ lines each.

The first set of $312^1/_2$ odd number lines in the 625 lines, called the first field or the *odd field*, are first scanned sequentially. Halfway through the 313th line, the spot is returned to the top of the screen and the remaining $312^1/_2$ even number lines, called the second field or the *even field* are then traced interleaved between the lines of the first set as shown in Fig. 2.10.

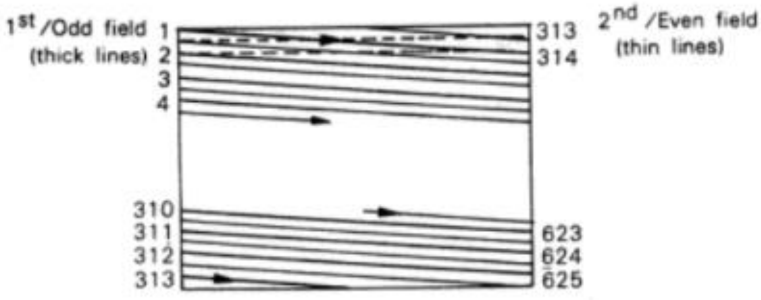


Fig. 2.10 Interlaced raster

This is done by operating the vertical field scan at 50 Hz so that the two successive interlaced scans, each at a 25 Hz rate, make up the complete picture frame. This keeps the line scanning speed down, as only $312^1/_2$ lines are scanned in 1/50 second. The 625 lines of the full picture are scanned in 1/25 second, thus keeping down the bandwidth requirement.

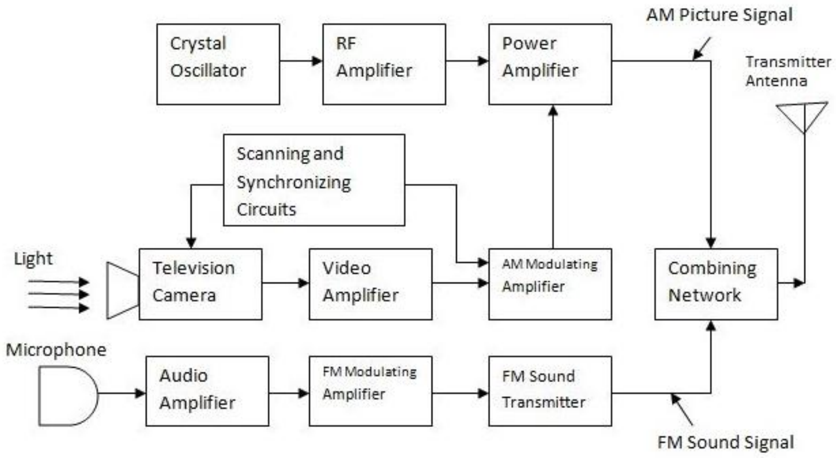
Here, though the picture is scanned 25 times per second, the area of the screen is covered in an interlaced fashion at twice the rate, viz. 50 times per second. A close examination may reveal the small area 'interline flicker', as actually each individual line repeats only 25 times per second. But this is tolerable and the overall effect is closer to that of a 50 Hz scanning. The flicker becomes noticeable at high brightness levels only.

In practice, the flyback from the bottom to the top is not instantaneous and takes a finite time equal to several line periods. Up to 20 lines are allowed for vertical flyback after each of the two fields that make a complete picture. This means that out of 625 lines, only (625 – 40 =) 585 lines actually bear picture information. These are called the active lines.

For interlaced scanning, the number of lines for the picture must be odd. It is then necessary to supply two regularly spaced synchronizing pulses to the field time base for every picture frame. One of the pulses must be sent at the middle of the last line in the odd field, while the other must be sent at the end of the last full line of the even field. The odd-line field starts at the top left and ends at the bottom centre, while the even-line field begins at the top centre and ends at the bottom right. This interleaves the two fields exactly, giving a complete scanning. By doubling the vertical deflection speed, the apparent picture frequency is doubled. The lines now slant twice as much but this is not noticeable. Vertical flyback occupies, in practice, a period equivalent to the time required to trace 5 to 10 lines. The path of the return line becomes a multiple zigzag under the influence of horizontal as well as vertical deflection.

The flyback times must be exactly the same, following both odd and even fields, and the size and position of both should repeat exactly. A difference of as little as 0.1 μs in the flyback time following the fields, causes the two to be dislocated by about 10% of the line length, enough to cause noticeable 'pairing of lines' reducing vertical resolution significantly.

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



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

- **TELEVISION CAMERA:**

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

- **VIDEO AMPLIFIER:**

The video signals obtained from camera tube are applied to a number of video amplifier stages. First stage is located in camera housing to increase weak signal voltage to such a level as to be transmitted over a coaxial cable to the succeeding amplifier stages. Video amplifier amplifies the video signal.

SCANNING AND SYNCHRONIZING CIRCUITS

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

- **SYNCHRONIZING GENERATOR**

Synchronizing generator produces sets of pulses to operate the system at appropriate timings. This unit includes wave generating and shaping circuits. Eg: Multi vibrator circuit, blocking oscillator circuit and clipping circuits etc. The repetition rates of the pulse trains are controlled by frequency stabilized master oscillator.

The horizontal synchronizing pulses are applied to horizontal saw-tooth generator; vertical synchronizing pulses are applied to vertical deflection saw-tooth generator; two sets of blanking pulses are applied to control grid of camera tube to blank it during vertical and horizontal retrace; and a pulse train consisting all above pulse groups is applied to video-amplifier channel for transmission to receiver.

- **CRYSTAL OSCILLATOR:**

Crystal Oscillator generates the allotted picture carrier frequency. The carrier frequency generated from a crystal controlled oscillator is passed through a number of frequency multiplier and amplifier stages. This results in a production of a carrier wave of desired frequency and energy content. The level of image signals, together with synchronizing and blanking pulses, is raised to modulate this carrier frequency. A high level grid modulation is usually employed.

• **AM MODULATING AMPLIFIER**

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

The carrier when amplitude modulated with video signal (BW = 5 MHz) generates two sidebands and the total bandwidth, required for TV channel would be 10 MHz which is too large. Therefore vestigial sideband transmission in which one sideband – (say upper) is transmitted in full along with reduced second sideband is used. For this purpose, output of the final RF amplifier is applied to a vestigial sideband filter which suppresses the undesired portion of the lower sideband of the modulated wave.

VSB is used because-

a) Video signal exhibits large bandwidth but significant low frequency component.
b) VSB transmission one sideband fully and other side band partially hence low bandwidth requirement.
c) VSB uses simple circuit as envelop detection at the receiver.

• **AUDIO AMPLIFIER**

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

• **FM MODULATING AMPLIFIER:**

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

Frequency modulation gives a better quality of **transmission because it has a larger bandwidth and is relatively immune to noise**. The transmission of information of FM signal is in the form of frequency variations. ... Frequency modulation is, therefore, preferred over amplitude modulation.

• **FM SOUND TRANSMITTER:**

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

• **RF AMPLIFIER:**

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

• **POWER AMPLIFIER:**

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

COMBINING NETWORK

Combining network is used to isolate the AM picture and FM sound signal during transmission.Both, sound and picture signals are transmitted by the same antenna by using a diplexer called picture – sound diplexer.

TRANSMITTING ANTENNA:

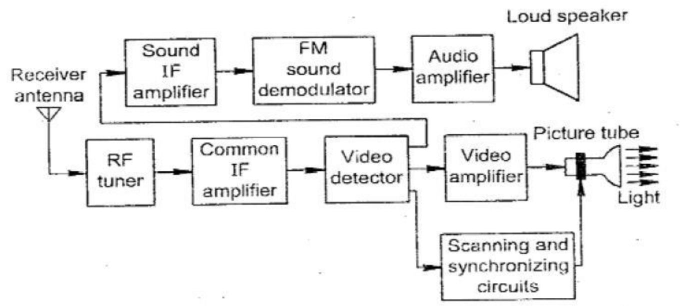
Transmitting antenna receives the AM picture signal and FM sound signal from combining network for radiation as electromagnetic waves.

The modulated RF energy is carried from transmitter to the transmitting antenna by means of a co-axial transmission line. The antenna elevation is kept high for large transmission area.

MICROPHONE:

Converts sound associated with picture being televised into proportionate electrical signal.

RECEPTION BASIC MONOCHROME TV



RECEIVER

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

RECEIVER ANTENNA:

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

RF TUNER:

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

COMMON IF AMPLIFIER:

There are 2 or 3 stages of IF amplifiers.

VIDEO DETECTOR:

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

VIDEO AMPLIFIER:

It amplifies the detected video signal to the level required.

SCANNING AND SYNCHRONIZING CIRCUITS:

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

SOUND IF AMPLIFIER:

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

FM SOUND DEMODULATOR:

FM Sound signal is demodulated in this stage.

AUDIO AMPLIFIER:

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

LOUD SPEAKER:

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

PICTURE TUBE:

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

COLOUR FUNDAMENTALS

There are 3 primary ways to describe a color and since the book added it, I'll add a 4th way to describe color as well.

Hue — another word for color

Saturation (chroma) — the intensity or purity of a hue

Lightness (value) — the relative degree of black or white mixed with a given hue

Temperature — the perceived warmth or coolness of a color

Hues are colors and what hue we see is dependent on the wavelength of light being reflected or produced. I doubt I need to tell you what a color is and since color and hue are synonymous you should know what a hue is as well. One thing I will remind you about is we all perceive color differently. The hue you see may not be the same hue I see.

Saturation refers to how pure or intense a given hue is. 100% saturation means there's no addition of gray to the hue. The color is completely pure. At the other extreme a hue with 0% saturation appears as a medium gray. The more saturated (closer to 100%) a color is, the more vivid or brighter it appears. Desaturatedcolors, on the other hand, appear duller.

How saturated a hue appears also depends to a degree on what colors it's next to. A 50% saturated hue placed next to a 25% saturated hue will appear more vivid than were the same hue placed next to a 75% saturated hue.

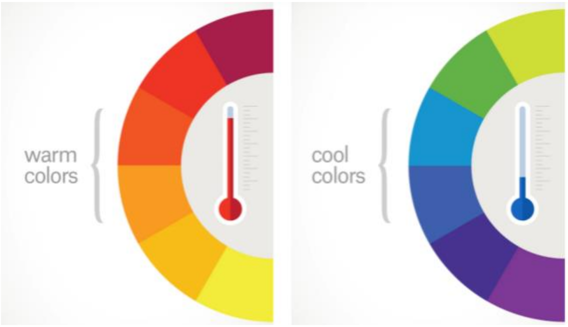
Lightness measures the relative degree of black or white that's been mixed with a given hue. Adding white makes the color lighter (creates tints) and adding black makes it darker (creates shades). The effect of lightness or value is relative to other values in the composition. You can make a color seem lighter by placing it next to a darker color.

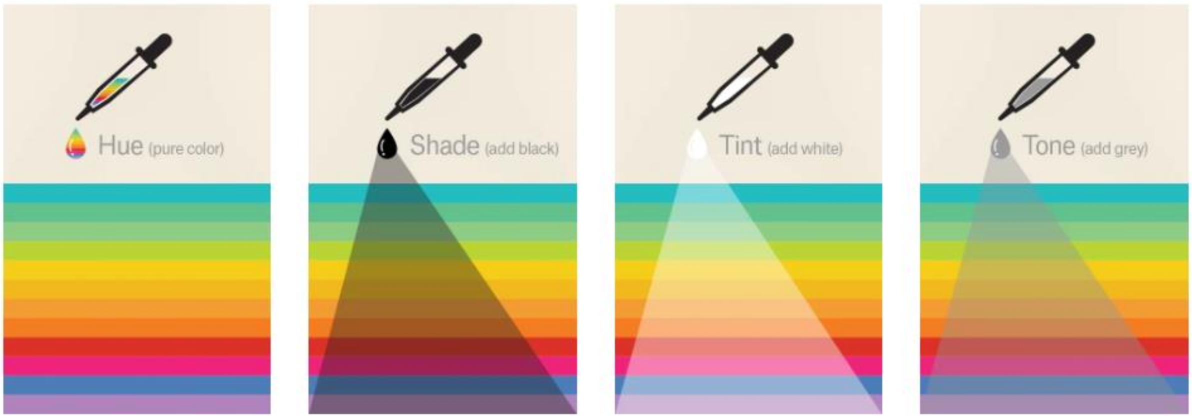
The greater the difference in value between elements, the greater the contrast between them. Because of this, lightness is a good way to show contrast and indicate hierarchy among elements. About 7 steps of lightness is the maximum variation the human eye can discern. Beyond that it becomes hard to distinguish the differences.

Temperature is the perceived warmth or coolness of a color. Warm colors are red, orange, and yellow, while cool colors are green, blue, and violet. Somewhere in the green and violet spectrums the temperature changes between warm and cool.

How the eye recognizes color temperature can change based on the source of light. For example the actual temperature of a computer monitor can affect the perceived color temperature.

Warm colors are generally associated with energy, brightness, and action, whereas cool colors are often identified with calm, peace, and serenity.



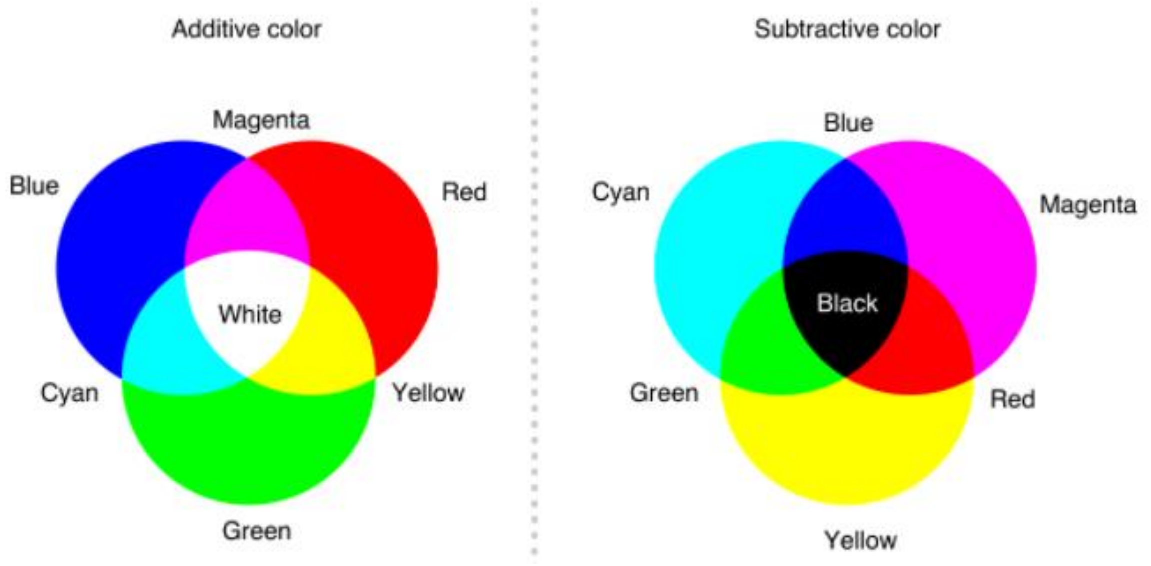


COLOUR MIXING TYPES

There are two main types of color mixing: additive color mixing and subtractive color mixing.

Additive color mixing is creating a new color by a process that adds one set of wavelengths to another set of wavelengths. Additive color mixing is what happens when lights of different wavelengths are mixed. When we add all of the different wavelengths of sunlight, we see white light rather than many individual colors. It is called additive because all of the wavelengths still reach our eyes. It is the combination of different wavelengths that creates the diversity of colors.

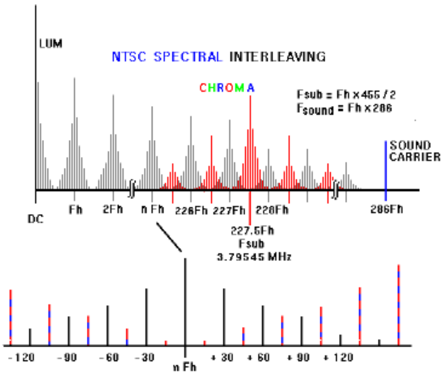
Subtractive color mixing is creating a new color by the removal of wavelengths from a light with a broad spectrum of wavelengths. Subtractive color mixing occurs when we mix paints, dyes, or pigments. When we mix paints, both paints still absorb all of the wavelengths they did previously, so what we are left with is only the wavelengths that both paints reflect. It is called subtractive mixing because when the paints mix, wavelengths are deleted from what we see because each paint will absorb some wavelengths that the other paint reflects, thus leaving us with a lesser number of wavelengths remaining afterward.



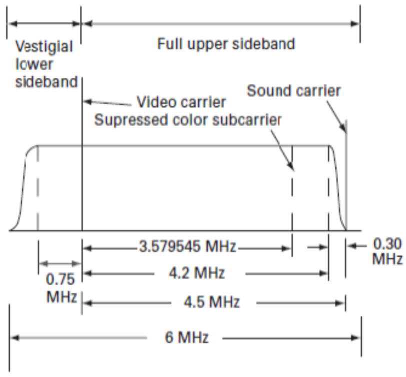
The color wheel consists of three primary colors (red, yellow, blue), three secondary colors (colors created when primary colors are mixed: green, orange, purple) and six tertiary colors (colors made from primary and secondary colors, such as blue-green or red-violet).

NTSC Color System

The image in NTSC Television is transmitted using three components .The first and most important is the Luminance (Y). As described above, Luminance specifies how bright a given spot on the display, and is the only signal used on black and white displays or receivers .The broadcast signal has a much lower resolution than the luminance signal. The number of lines of horizontal resolution in NTSC broadcast video is about (333) lines across the screen. It able to display a maximum of (166.5) pairs of alternating black and white stripes, drawn vertically on the screen . That's the horizontal luminance resolution , so it only covers the resolution of the black and white detail of the image so this system uses a line - locked subcarrier at (3. 79545 MHz) (Figure 6) . NTSC system uses (VSB) amplitude modulated with a suppressed carrier(Figure 7) following two orthogonal axes by two signals, I (in phase) and Q (quadrature),carrying the chrominance information.



Figure(6) NTSC spectral[7]



Figure(7)Vestigial Sideband Modulation[7]

Luminance Signal

Luminance (Y)

It is a weighted sum of the three colors of light used in color television and computer displays , which are RGB at a given point on the screen .A stronger Luminance signal indicates a more intense brightness of light at a given spot on the screen. It is given by[4]:

Y =0.299R + 0.587G + 0.1145B the luminance signal……………………..……..(2)

Chrominance

The Chrominance signal specifies what color is to be shown at a given point on the display as well as how saturated or intense the shade of color that is shown and given by[4]:

U =0.493(B−Y) is called the blue chrominance ……………………….............. (3)

V = 0.877(R –Y) is called the red chrominance …………………………….…... (4)

In this system instead of transmitting the red, blue, and green (RGB) signals on an equal basis, three linear combinations are used , one of these , the luminance signal (Y) , is chosen to be the brightness signal that would have been produced by a monochrome camera the other two linear combinations(I&Q) are given by [9] :

I = 0.74(R−Y) −0.27(B−Y) ……………………………………………..……………(5)

Q= 0.48(R−Y) + 0.41(B−Y)…………………………………………………..…….. (6)

Red, green, and blue are three primary additive colors and are represented by a three-dimensional, Cartesian coordinate system, all of the color spaces (YUV , YIQ , YCbCr , HSV , XYZ…and another)can be derived from the RGB information supplied by devices such as cameras and scanners ,from equation (3) yields:

R-Y=R-(0.299R+0.587G+0.114B) =0.701R-0.587G-0.114B……………………..………(7)

B-Y=B-(0.299R+0.587G+0.114B) = -0.299R-0.587G+0.886B……………….……… (8)

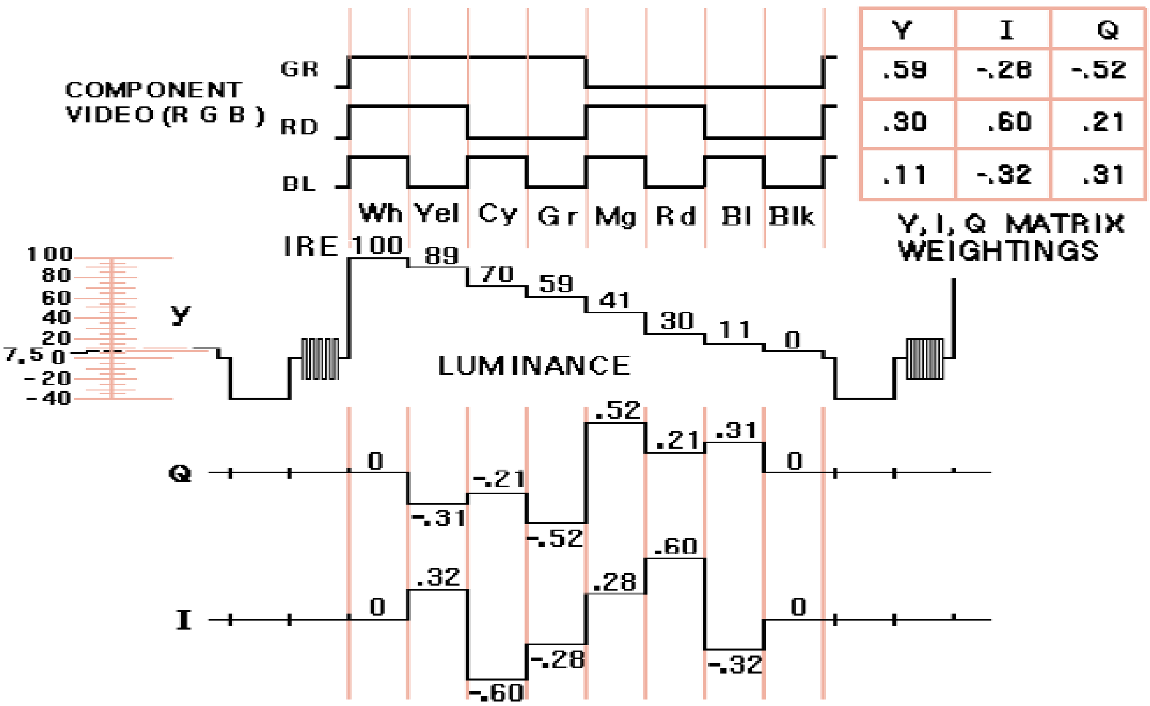
Rearranging equations (3,6,7,8, 9) yields the matrix:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.595716 & -0.274453 & -0.321263 \\ 0.211456 & -0.522591 & 0.311135 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \text{.................. (9)}$$

Then, the inverse matrix becomes:

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} 1 & 0.9563 & 0.6210 \\ 1 & -0.2721 & -0.6474 \\ 1 & -1.1070 & 1.7046 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix} \quad \text{...(10)}$$

Two things to note regarding the RGB transformation matrix, the top row is identical to that of the Y,U and V (equal Y, I and Q) because the YIQ color space is derived from the YUV color space(Figure 8) . The additional components transmitted are "I" and "Q", these contain combinations of the Red, Green and Blue information to describe the color or chrominance that should appear on the given spot on the screen.



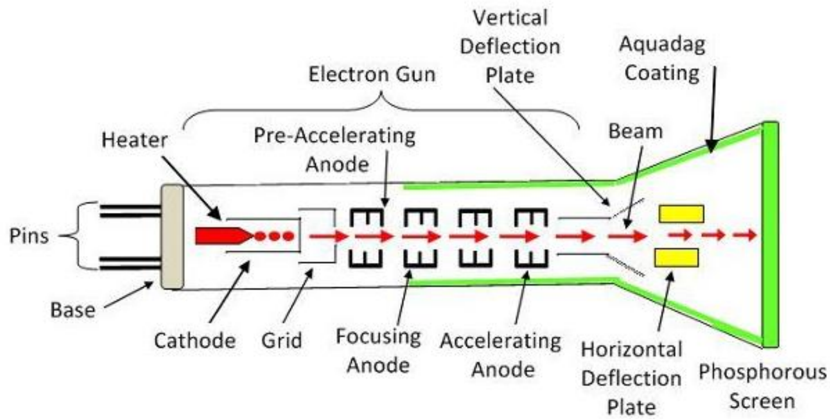
Figure(8) The Y, I and Q matrix with (RGB) representation in NTSC[10].

Cathode Ray Tube (CRT)

Definition: The CRT is a display screen which produces images in the form of the video signal. It is a type of vacuum tube which displays images when the electron beam through electron guns are strikes on the phosphorescent surface. In other Words, the CRT generates the beams, accelerates it at high velocity and deflect it for creating the images on the phosphorous screen so that the beam becomes visible.

Working of CRT

The working of CRT depends on the movement of electrons beams. The electron guns generate sharply focused electrons which are accelerated at high voltage. This high-velocity electron beam when strikes on the fluorescent screen creates luminous spot



After exiting from the electron gun, the beam passes through the pairs of electrostatic deflection plate. These plates deflected the beams when the voltage applied across it. The one pair of plate moves the beam upward and the second pair of plate moves the beam from one side to another. The horizontal and vertical movement of the electron are independent of each other, and hence the electron beam positioned anywhere on the screen.

The working parts of a CRT are enclosed in a vacuum glass envelope so that the emitted electron can easily move freely from one end of the tube to the other.

Construction of CRT

The Electrons Gun Assembly, Deflection Plate Assembly, Fluorescent Screen, Glass Envelope, Base are the important parts of the CRT. The electron gun emits the electron beam, and through deflecting plates, it is strikes on the phosphorous screen. The detail explanation of their parts is explained below.

Electrons Gun Assembly

The electron gun is the source of the electron beams. The electron gun has a heater, cathode, grid, pre-accelerating anode, focusing anode and accelerating anode. The electrons are emitted from the highly emitted cathode. The cathode is cylindrical in shape, and at the end of it, the layer of strontium and barium oxide is deposited which emit the high emission of electrons at the end of the tube.

The electron passes through the electron in the small grid. This control grid is made up of nickel material with a centrally located hole which is coaxial with the CRT axis. The electron which is emitted from the electron gun and passes through the control grid have high positive potential which is applied across the pre-accelerating and accelerating anodes.

The beam is focused by focusing anode. The accelerating and focusing electrodes are cylindrical in shape which has a small opening in the centre of each electrode. After exiting the focusing anode, the beams passes through the vertical and horizontal deflecting plates.

The pre-accelerating and accelerating anode are connected to the positive high voltage of about 1500V and the focusing anode are connected to the lower voltage of about 500V.There are two methods of focusing the electron beam. They are the Electrostatic Focussing Beam and the Electromagnetic Focusing.

Electrostatic Deflection Plates

The deflection plate produces the uniform electrostatic field only in the one direction. The electron beam entering into the deflection plates will accelerate only in the one direction, and hence electrons will not move in the other directions.

Screen For CRT

The front of the CRT is called the face plate. The face plate of the CRT is made up of entirely fibre optics which has special characteristics. The internal surface of the faceplate is coated with the phosphor. The phosphorous converts the electrical energy into light energy. The energy level of the phosphorous crystal raises when the electron beams strike on it. This phenomenon is called cathodoluminescence.

The light which is emitted through phosphorous excitation is called fluorescence. When the electron beam stop, the phosphorous crystal regain their original position and release a quantum of light energy which is called phosphorescence or persistence.

Aquadag

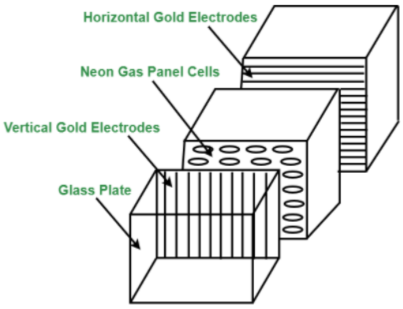
The Aquadag is the aqueous solution of graphite which is connected to the secondary of the anode. The Aquadag collects the secondary emitted electrons which are necessary for keeping the CRT screen in the state of electrical equilibrium.

Plasma Display Panel

Plasma Display Panel are an emissive display which means that the panel itself is the light source. In comparison to a transmissive display, where the light source is separate and light is passed through the panel to create an image, PDP’s are extremely bright and light-tolerant flat panel display technology that utilizes a gas discharge principle thus also knows as gas discharge display.

Plasma gives a big display screen length which degrees normally from 42” to 63”. It works properly in dimly lit rooms tremendous for looking movies, gives excessive assessment ratios, gorgeously saturated shades, and permits for extensive viewing angles each seat with inside the residence is a tremendous one.

The working of Plasma Display Panel is as follows :



Plasma Panel Display

Plasma Display Panel are composed of two parallel sheets of glass which enclose a mixture of discharge gases composed of helium, neon and xenon.

On the inner side of the glass plates are Ribs, which help keep the glass plates parallel.

Groups of electrodes sit at right angles between the panes forming rectangular compartments, or cells, between the glass sheets.

Phosphorus are embedded within each cell that individually emit red, green or blue light and collectively create a single color pixel.

Selectively applying voltages to the electrodes causes them to generate a discharge in the panel's dielectric layer and on its protective surface. This generates ultraviolet light that excites the phosphors, stimulating them to emit light.

The picture definition is stored in a Refresh Buffer, voltage is applied to refresh the pixel positions 60 times per second.

Advantages of Plasma Display Panel :

Plasma Display Panel are thin lightweight and take up less space than other displays which makes them easy to install anywhere.

Plasma Display Panel offer uniform brightness.

They show images without distortion and avoid problems such as misregistered colors and lack of focus.

They also resist interference from magnetic fields, are free from distortion and viewable from a wide angle.

Plasma Display Panel capable of producing deeper blacks allowing superior contrast ratio.

It provides wider viewing angle than those of LCD due to which images do not suffer from degradation at high angles.

Plasma Display Panel are suitable for multimedia usage because they can display computer images as well as full-color, full-motion pictures.

Disadvantages of Plasma Display Panel :

Plasma Display Panel use more electricity, an overlay than an LCD TV.

Earlier generation Plasma Display Panel were more susceptible to screen burn-in and image retention, recent models have a pixel orbiter that moves the entire picture faster than is noticeable to the human eye, which reduces the effect of burn-in but does not prevent it.

Earlier generation displays had phosphors that lost luminosity over time, resulting in gradual decline of absolute.

Due to the strong infrared emissions inherent with the technology standard Infra-red repeater systems cannot be used in the viewing room. A more expensive “plasma compatible” sensor needs be used.

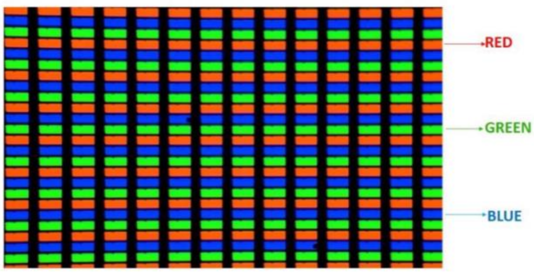
LCD :

LCD stands for Liquid Crystal Display. It is a display which is non-emissive device and it uses light source for the display; the light source is blacklight and convert it to graphical image. LCD for the display uses two major components which are as follows:

Polarized light

Liquid Crystal Material

In LCD display, it consists of millions of pixels made of crystal and arranged in a rectangular grid. In LCD it has backlights that provide light to each pixel. Each pixel has a red, green, and blue (RGB) sub-pixel that can be turned on or off. When all of the sub-pixels are turned off, then it’s black and when all the sub-pixels are turned on 100%, then it’s white.



LCD is a combination of two states of matter, the solid and the liquid. The solid part is crystal and this liquid and crystal together make the visible image. LCD consists of two layers which are two polarized panels- filters and electrodes. LCD screen works by blocking the light rather than emitting the light. There are two types of pixel grids in LCD:

Main characteristics of LCD are:

Voltage: 3V to 12V

Operating temperature: Normally it ranges from 0^0C to $+60^0C$, but for extreme cases it varies from -40^0C to $+85^0C$.

Frequency: 30Hz to 60 Hz

Average Current consumption: $1.2\mu A$ to $6\mu A$

Opening Time: 100 ms

Also LCD has other characteristics in terms of many areas, that are

Resolution: LCD is made up of liquid crystal, which is neither liquid nor solid, and this thing reflects the light in a well-formed way, lights enter into the crystal and reflect very clearly. So the image made with this liquid crystal is very accurate. LCD is a Digital display, which addresses each individual pixel using a fixed matrix of horizontal and vertical dots. LCD scales the image according to the resolution the device provided. So the quality of the image is not degraded.

Brightness: Brightness means the light provided by the LCD, which is nothing but the intensity of visible light, it is measured using nits. Nits is defined as one candela per square meter. In LCD brightness is very much accurate for the good resolutions and pixels.

Contrast Ratio: It is the ratio of the brightest color and the darkest color for a particular position of the screen provided by the display. To calculate contrast ratio(CR) see the below formula:

Contrast Ratio(CR) = \frac{brightness of the screen when pixels are white} {brightness of the screen when pixels are white}

Typically the ratios of modern monitors are 1000:1 and TVs are 4000:1.

Response Rate: Response Rate is high in LCD, it means the time required for changing colors of the pixels is very much less, so that the refresh rate is very high in LCD than CRT. There is no lagging between the pixels when the image is changed.

Advantages of LCD :

The main advantage of LCD is, it has low in cost and energy efficient and very less power consumption.

LCD is thinner and lighter and very flexible.

LCD provides excellent contrast, brightness and resolution, so the picture quality is very clear like a crystal.

Radiation of LCD monitors are much less than CRT monitors

LCDs can be suitable with CMOS integrated circuits so that making of LCD is very easy.

It gives perfect sharpness at the native resolution

Zero geometric distortion at the native resolution of the pane

It provides various conveniences like portability as compared to previous technology based screens.

Disadvantages of LCD :

LCD require additional light sources for lighting the pixels, so if the light source is destroyed then the LCD is not providing any image on the display.

LCD is less reliable display.

The image visibility depends on light intensity

The aspect ratio and resolution are fixed for LCD.

LCD has an irregular intensity scale and it produce lower than 256 discrete intensity levels.

In LCD color saturation is reduced at the low intensity level due to poor black-level.

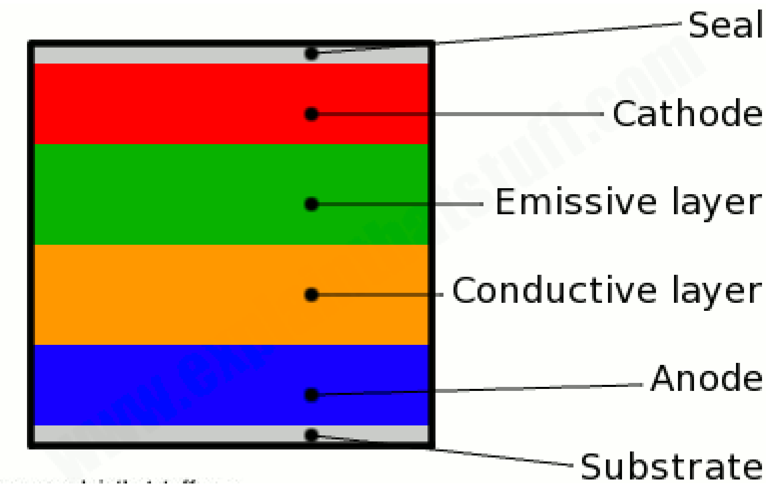
LCD provide limited viewing angle, it effects the brightness. if we are watching the screen by an angle then the color of the image is changed in our eyes.

Digital Light Processing (DLP)

Digital Light Processing (DLP) TVs were invented by Texas Instruments in the 1980s, using a completely novel technological approach. DLPs use an optical semiconductor chip with over 1 million mirrors that process digital signals by tilting to varying degrees, reflecting light in deferent directions to create an image. The resulting smooth viewing experience has several advantages over cathode-ray tube and plasma TVs, including longer lifespans, lighter weight, and 3D projection compatibility. However, newer technologies that are thinner, quieter, have faster response rates, and use less energy have also caused the shutdown of DLP TV production as of 2012. Used and refurbished models are available, with costs comparable to similarly dated plasma TV models.

OLED

OLEDs work in a similar way to conventional diodes and LEDs, but instead of using layers of n-type and p-type semiconductors, they use organic molecules to produce their electrons and holes. A simple OLED is made up of six different layers. On the top and bottom there are layers of protective glass or plastic. The top layer is called the seal and the bottom layer the substrate. In between those layers, there's a negative terminal (sometimes called the cathode) and a positive terminal (called the anode). Finally, in between the anode and cathode are two layers made from organic molecules called the emissive layer (where the light is produced, which is next to the cathode) and the conductive layer (next to the anode).



How an OLED emits light

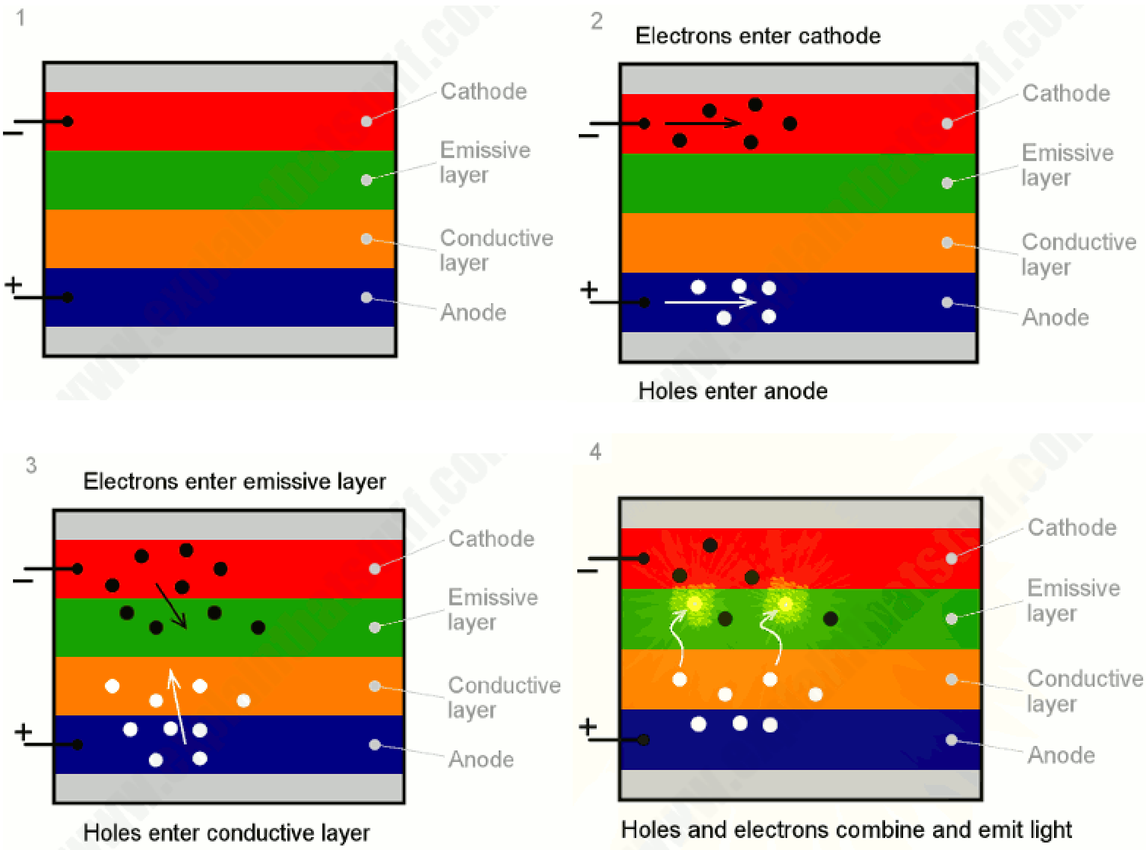
To make an OLED light up, we simply attach a voltage (potential difference) across the anode and cathode.

As the electricity starts to flow, the cathode receives electrons from the power source and the anode loses them (or it "receives holes," if you prefer to look at it that way).

Now we have a situation where the added electrons are making the emissive layer negatively charged (similar to the n-type layer in a junction diode), while the conductive layer is becoming positively charged (similar to p-type material).

Positive holes are much more mobile than negative electrons so they jump across the boundary from the conductive layer to the emissive layer. When a hole (a lack of electron) meets an electron, the two things cancel out and release a brief burst of energy in the form of a particle of light—a photon, in other words. This process is called recombination, and because it's happening many times a second the OLED produces continuous light for as long as the current keeps flowing.

We can make an OLED produce colored light by adding a colored filter into our plastic sandwich just beneath the glass or plastic top or bottom layer. If we put thousands of red, green, and blue OLEDs next to one another and switch them on and off independently, they work like the pixels in a conventional LCD screen, so we can produce complex, hi-resolution colored pictures.



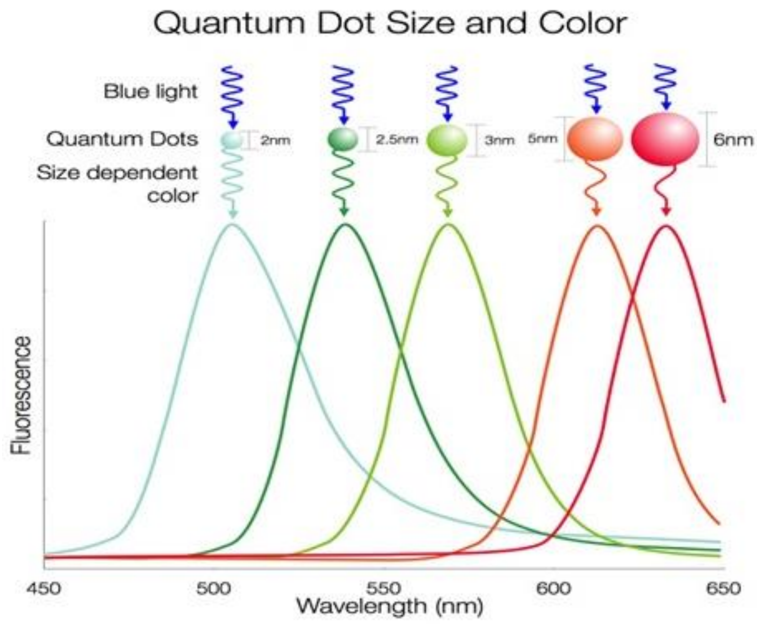
QLED | Quantum-dot Light Emitting Diode

What are Quantum dots ?

• They are tiny semiconductor neon scale crystals having size between 2 nm to 10 nm.

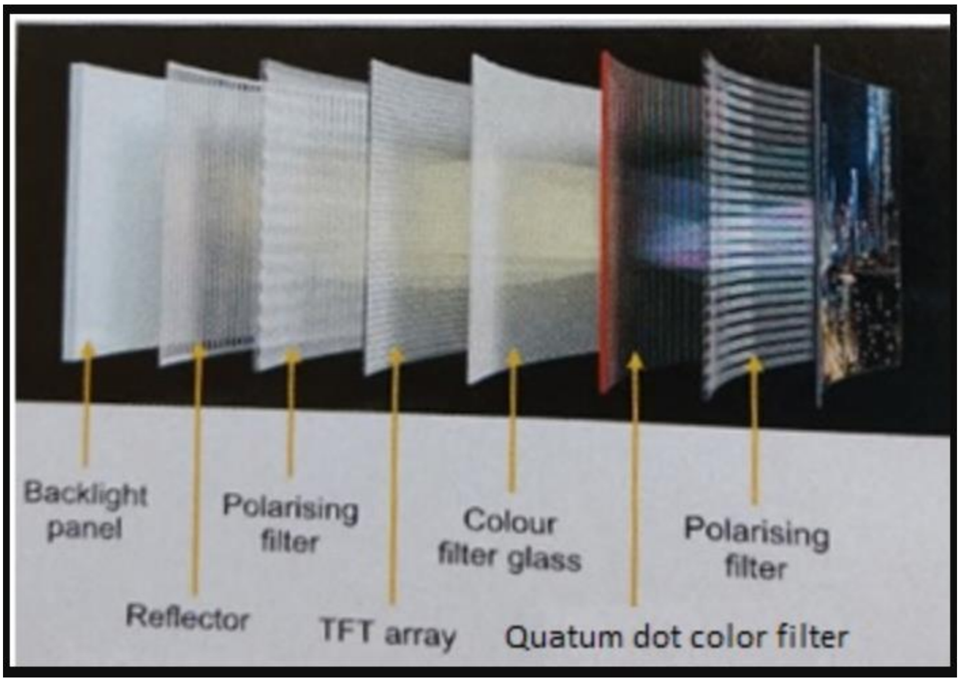
• Quantum dots emit colors based on their size and energy gap of materials used. The bigger the dimension, larger is the emitted wavelength.

• The figure-2 depicts graph of wavelength versus fluorescence.



Many different semiconductor materials are used to make quantum dots viz. CdSe, CdS, PbSe, PbS, InAs, InP etc.

• Now-a-days Cadmium-free technologies are used as these technologies generate numerous color combinations which provide better light efficiency.



• In QLED construction, thin layer of quantum dots is used in front of backlight.

• As shown in the figure-3, 6 layers are used to construct the color image viz. backlight panel, reflector, polarising filter, TFT array, colour filter glass, quantum dots colour filter and polarising filter.

• Backlight panel: It illuminates LED from side or back of display panel. It uses special source of light to produce visible image. This light is passed to the reflector.

• Reflector: It enhances uniformity of the illuminance distribution on target region of the image plane.

• Polarising filter: It is used to change the settings of the image passed by the reflector in order to suppress glare or blur in image. There are various polarisers used in display technology.

• TFT array: It matches size with quantum dots in the color filter and carries out colour re-production. It handles display of pixels on the screen.

• Colour filters with blue LED can produce billions of colours with peak brightness and better clarity.

• Polarising filter: It gives final touch to display in order to generate crystal clear image of the screen.

Technology **Parameter**	CRT	LCD	Plasma	OLED
Static Contrast ratio	Typical 200-300:1[1][2]	150 to 8,100:1[3][4]	3,800:1[5]	"∞" "Inf:1"[6] Unable to be calculated as black levels are zero.
Peak Luminosity	176 cd/m²[1]	200–4000 cd/m²[7][8]	50–200 cd/m²[1]	100–700 cd/m²[9]
Color depth	8-bit per subpixel resolution; offers better resolution for grayscale[citation needed]	6 to 10-bit per subpixel panels;[10] smaller dot pitch, better detail[11]	6 to 8-bit per subpixel panels	8 to 10-bit per subpixel, with some HDR models capable of 12-bit per subpixel.[12]

Response time	0.01 ms[13] to less than 1 μs[14]	1–8 ms typical (according to manufacturer data), older units could be as slow as 35 ms[15]	Typically less than 0.001 ms, as low as 0.00001 ms[13]	Estimates varying from under 0.01 ms to as low as 0.001 ms.[16][17]
Frame rate (Refresh rate)	60–85 fps typically, some CRTs can go even higher (200 fps at reduced resolution[18]); internally, display refreshed at input frame rate speed	60 fps typically, gaming monitors can do up to 360 fps; internally, display refreshed at up to 360 fps[19][20]	60 fps typically, some can do 120 fps; internally, display refreshed at e.g. 480 or 600 fps[21]	60 fps typically. Up to 120 fps.

Flicker	Perceptible on lower refresh rates (60 fps and below)[22]	Depends; in 2013 most LCDs used PWM (strobing) to dim the backlight[23] However, since then many flicker free LCD computer monitors were introduced. [24]	Does not normally occur due to a high refresh rate higher than FPS[25]	Does not normally occur at 100% brightness level. At levels below 100% flicker often occurs with frequencies between 60 and 255 Hz, since often pulse-width modulation is used to dim OLED screens.[26] [27]
Risk of image persistence or burn-in	High[28]	Low[28]	High[28]	Medium[29]
Energy consumption and heat generation	High[30]	Low[30]	Varies with brightness but usually higher than LCD[31][32][33][34]	Varies based on image brightness and color. For the majority of images it will consume 60–80% of the power of an LCD.

				OLED displays use 40% of the power of an LCD displaying an image that is primarily black as they lack the need for a backlight,[35] while OLED can use more than three times as much power to display a mostly white image compared to an LCD.[36]
Environmental influences	Sensitive to ambient magnetic fields, which can adversely affect convergence and color purity.	Prone to malfunctions on both low (below -4 °F/-20 °C) or high (above 45 °C/113 °F) temperatures[37]	High altitude pressure difference may cause poor function or buzzing noises[38]	Can have poor brightness.
Electro-magnetic radiation emission	Can emit a small amount of X-ray radiation.	Only emits non-ionizing radiation.[39]	Emits strong radio frequency electromagnetic radiation[40]	No, control circuitry may emit radio interference

Size	Up to 43" (1.09 m)[41]	Up to 120" (3.04 m)[42]	Up to 150" (3.8 m)[43] (152" experimental)[44]	Up to 88" (2.24 m)[45]
Maintenance	Hazardous to repair or service due to high-voltage, requires skilled convergence calibration and adjustments for geographic location changes.[46] Glass display tube is evacuated and carries risk of implosion if improperly handled.	Risky and expensive to repair due to complexity of the display;[47] units with mercury CCFL backlight lamps are an environmental health hazard[48]	Screen itself cannot be repaired if the gas used to generate images leaks[49]	

Other	No native resolution. Currently, the only display technology capable of multi-syncing (displaying different resolutions and refresh rates without the need for scaling).[50] Display lag is extremely low due to its nature, which does not have the ability to store image data before output, unlike LCDs, plasma displays and OLED displays.[51] Extremely bulky and heavy construction in comparison to other display technologies. Large displays would be unsuitable for wall mounting. New models are no longer produced.	The LCD grid can mask effects of spatial and grayscale quantization, creating the illusion of higher image quality. [52] Is the cheapest display technology currently produced, with some entry-level models selling for less than $100.	Screen-door effects are more noticeable than LCD when up close, or on larger sizes. [53] New models are no longer produced.	Colored sub-pixels may age at different rates, leading to a color shift. Sensitive to UV light from direct sunlight. Is considered the highest quality but also the most expensive display technology currently produced, with products rarely being available for less than $1200.

Large-screen television technology

Large-screen television technology (colloquially big-screen TV) developed rapidly in the late 1990s and 2000s. Prior to the development of thin-screen technologies, rear-projection television was used for many larger displays, and jumbotron, a non-projection video display technology, was used at stadiums and concerts. Various thin-screen technologies are being developed, but only liquid crystal display (LCD), plasma display (PDP) and Digital Light Processing (DLP) have been released on the public market. However, recently released technologies like organic light-emitting diode (OLED), and not-yet-released technologies like surface-conduction electron-emitter display (SED) or field emission display (FED), are on their way to replacing the first flat-screen technologies in picture quality.

These technologies have almost completely displaced cathode ray tubes (CRT) in television sales, due to the necessary bulkiness of cathode ray tubes. The diagonal screen size of a CRT television is limited to about 40 inches because of the size requirements of the cathode ray tube, which fires three beams of electrons onto the screen, creating a viewable image. A larger screen size requires a longer tube, making a CRT television with a large screen (50 to 80 inches diagonally) unrealistic. The new technologies can produce large-screen televisions that are much thinner.

The viewing distance should be roughly two to three times the screen size for standard definition (SD) displays.

Screen size (in)	Viewing distance (ft)	Viewing distance (m)
15–26	5–8	1.5-2.4
26–32	8–11.5	2.4-3.5
32–42	11.5–13	3.5-4
42–55	>13	>4

Comparison of television display technologies

CRT

Main article: Cathode Ray Tube

Though large-screen CRT TVs/monitors exist, the screen size is limited by their impracticality. The bigger the screen, the greater the weight, and the deeper the CRT. A typical 32-inch television can weigh about 150 lb or more. The Sony PVM-4300 monitor weighed 440 lb (200kg) and had the largest ever CRT with a 43" diagonal display.[14] SlimFit televisions exist, but are not common.

LCD

Advantages

- Slim profile
- Lighter and less bulky than rear-projection televisions

- Is less susceptible to burn-in: Burn-in refers to the television displaying a permanent ghost-like image due to constant, prolonged display of the image. Light-emitting phosphors lose their luminosity over time and, when frequently used, the low-luminosity areas become permanently visible.
- LCDs reflect very little light, allowing them to maintain contrast levels in well-lit rooms and not be affected by glare.
- Slightly lower power usage than equivalent sized Plasma displays.
- Can be wall-mounted.

Disadvantages

- Poor black level: Some light passes through even when liquid crystals completely untwist, so the best black color that can be achieved is varying shades of dark gray, resulting in worse contrast ratios and detail in the image. This can be mitigated by the use of a matrix of LEDs as the illuminator to provide nearly true black performance.
- Narrower viewing angles than competing technologies. It is nearly impossible to use an LCD without some image warping occurring.
- LCDs rely heavily on thin-film transistors, which can be damaged, resulting in a defective pixel.
- Typically have slower response times than Plasmas, which can cause ghosting and blurring during the display of fast-moving images. This is also improving by increasing the refresh rate of LCDs.[15]

Plasma display

Advantages

- Slim cabinet profile
- Can be wall-mounted
- Lighter and less voluminous than rear-projection television sets
- More accurate color reproduction than that of an LCD; 68 billion (2^{36}) colors vs. 16.7 million (2^{24}) colors [16]
- Produces deep, true blacks, allowing for superior contrast ratios (+ 1:1,000,000)[16][17][18]
- Wider viewing angles (+178°) than those of an LCD; the image does not degrade (dim and distort) when viewed from a high angle, as occurs with an LCD[16][17]
- No motion blur; eliminated with higher refresh rates and faster response times (up to 1.0 microsecond), which make plasma TV technology ideal for viewing the fast-moving film and sport images

Disadvantages

- No longer being produced
- Susceptible to screen burn-in and image retention; late-model plasma TV sets feature corrective technology, such as pixel shifting[13]

- Phosphor-luminosity diminishes over time, resulting in the gradual decline of absolute image-brightness; corrected with the 60,000-hour life-span of contemporary plasma TV technology (longer than that of CRT technology)[13]
- Not manufactured in sizes smaller than 37-inches diagonal
- Susceptible to reflective glare in a brightly lighted room, which dims the image
- High rate of electrical power consumption
- Heavier than a comparable LCD TV set, because of the glass screen that contains the gases
- Costlier screen repair; the glass screen of a plasma TV set can be damaged permanently, and is more difficult to repair than the plastic screen of an LCD TV set[16][17]

Projection television

Front-projection television

Advantages

- Significantly cheaper than flat-panel counterparts
- Front-projection picture quality approaches that of movie theater
- Front-projection televisions take up very little space because a projector screen is extremely slim, and even a suitably prepared wall can be used
- Display size can be extremely large, typically limited by room height.

Disadvantages

- Front-projection more difficult to set up because projector is separate and must be placed in front of the screen, typically on the ceiling
- Lamp may need to be replaced after heavy usage
- Image brightness is an issue, may require darkened room.

Rear-projection television[edit]

Advantages

- Significantly cheaper than flat-panel counterparts
- Projectors that are not phosphor-based (LCD/DLP) are not susceptible to burn-in
- Rear-projection is not subject to glare

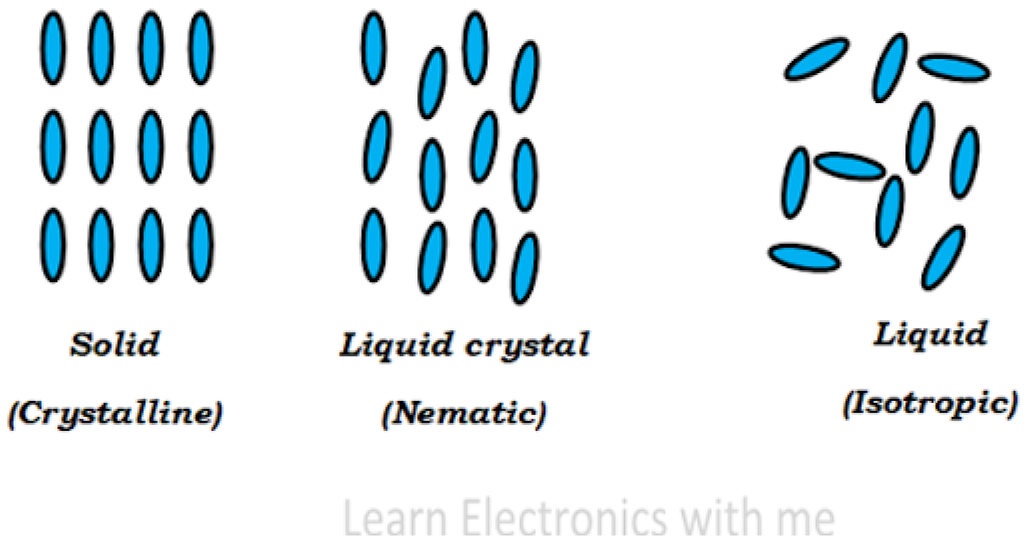
Disadvantages

- Rear-projection televisions are much bulkier than flat-panel televisions
- Lamp may need to be replaced after heavy usage
- Rear-projection has smaller viewing angles than those of flat-panel displays

What is Liquid Crystal Display:

Liquid Crystal Display (LCD) is an flat display screen used in electronic devices such as laptop, computer, TV, cellphones and portable video games. As the name says liquid crystal is a material which flows like a liquid and shows some properties of solid. These LCD are vey thin displays and it consumes less power than LEDs.

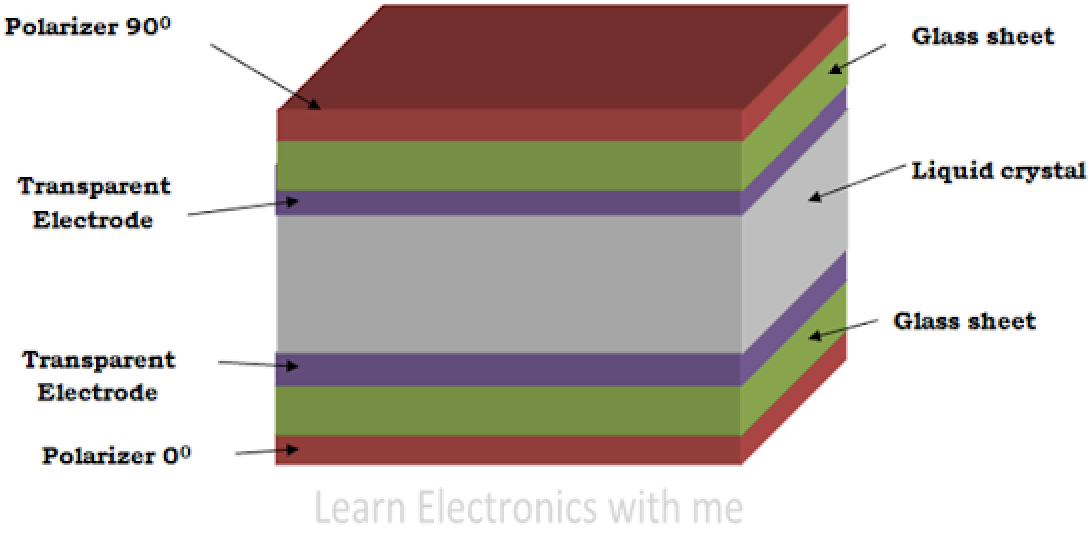
Molecular arrangement of Liquid Crystal:



Molecular arrangement of liquid crystal

As the name says the molecular structure of liquid crystal is in between solid crystal and liquid isotropic. In Liquid crystal display (LCD) nematic type of liquid cyrstal molecular arrangement is used in which molecules are oriented in some degree of alignment. For example when we increase the temperature the ice cube melts and liquid crystal is like the state in between ice cube and water

Construction of Liquid Crystal Display:

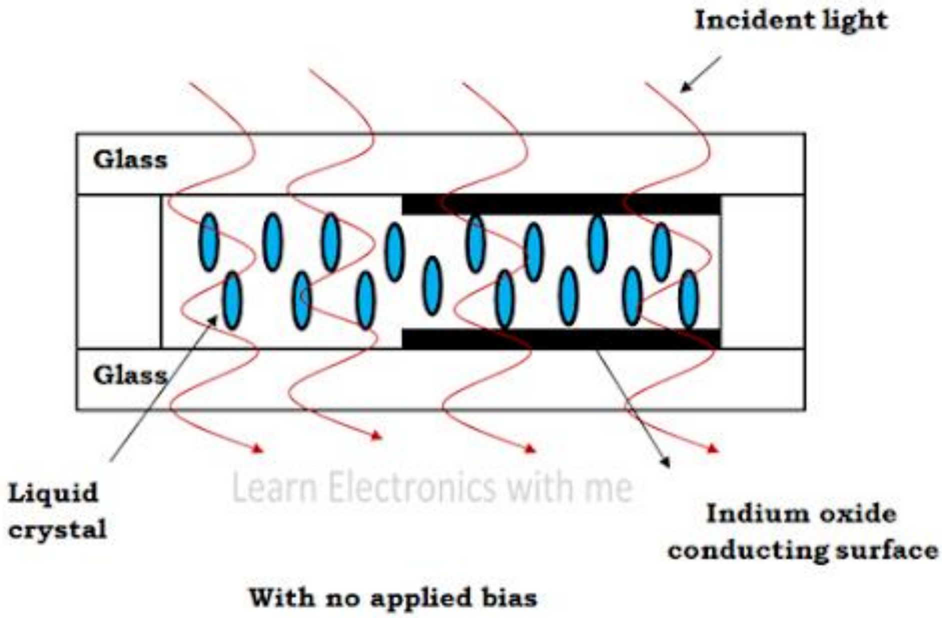


Construction of LCD

Construction of LCD consists of two polarized glass pieces. Two electrodes are used, one is positive and the other one is negative. External potential is applied to LCD through this electrodes and it is made up of indium-tin-oxide. Liquid crystal layer of about 10µm- 20µm is placed between two glass sheets. The light is passed or blocked by changing the polarization.

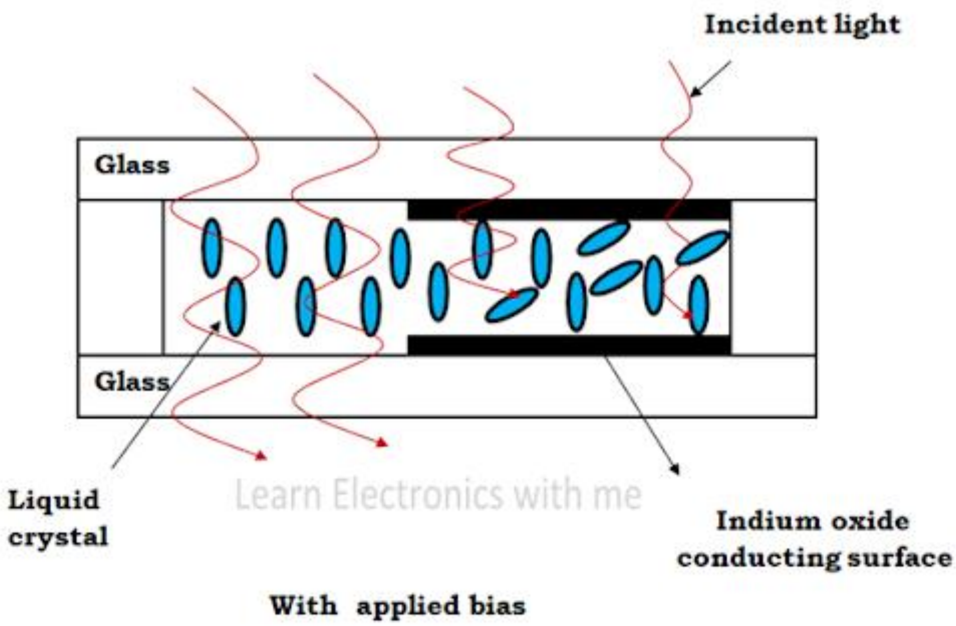
Working of Liquid Crystal Display

The basic working principle of LCD is blocking of light. It does not produce light on its own. So external light source is used. When the external light passes from one polarizer to the next polarizer, external supply is given to the liquid crystal ,the polarized light aligns itself so that the image is produced in the screen.



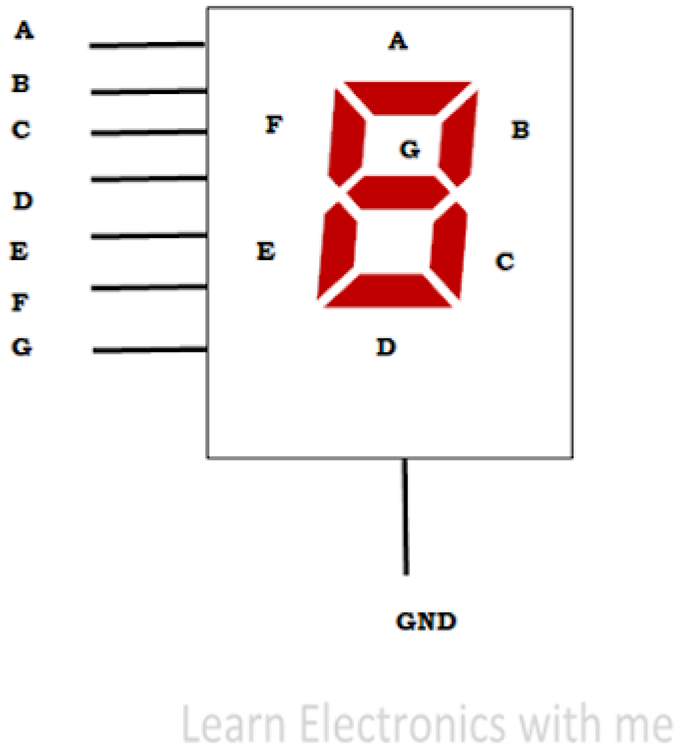
Working of LCD

The indium oxide conducting surface is a transparent layer which is placed on both the sides of the sealed thick layer of liquid crystal . When no external bias is applied the molecular arrangement is not disturbed.



Working of LCD

When the external bias is applied the molecular arrangement is disturbed and it and that area looks dark and the other area looks clear.



LCD Display

In the segment arrangement, the conducting segment looks dark and the other segment looks clear. To display number 2 , the segments A,B,G,E,D are energized.

Cable TV Networks

Cable TV network started its business only as a video service provider, but with the new advancement in technology, it's moved to the business of Internet access. It also refers to the system that distributes Television signals with the utilization of transmission media.

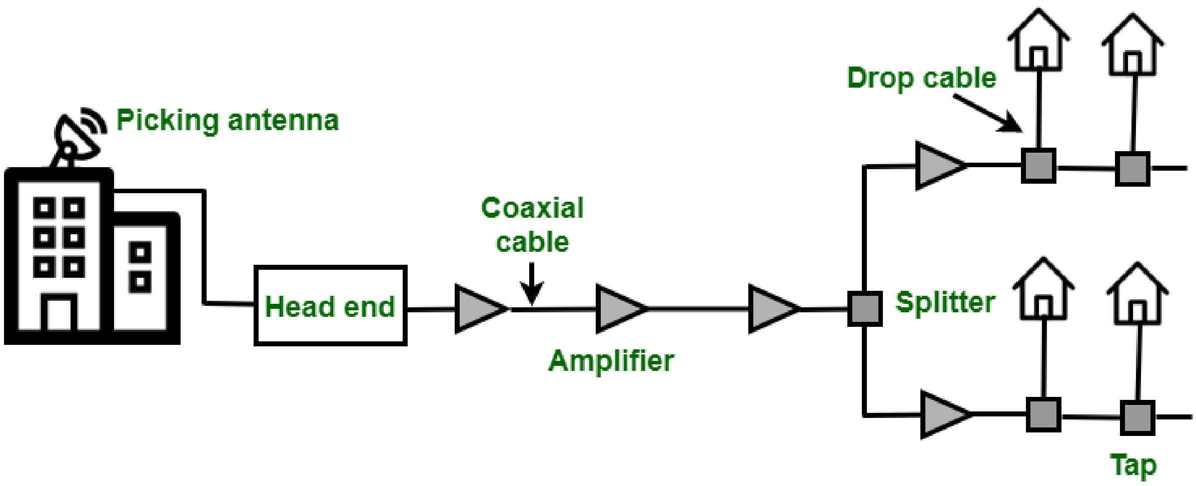
Types of Cable TV Networks are a follows –

Traditional Cable Networks

Hybrid Fiber-Coaxial Network

Traditional Cable Network :

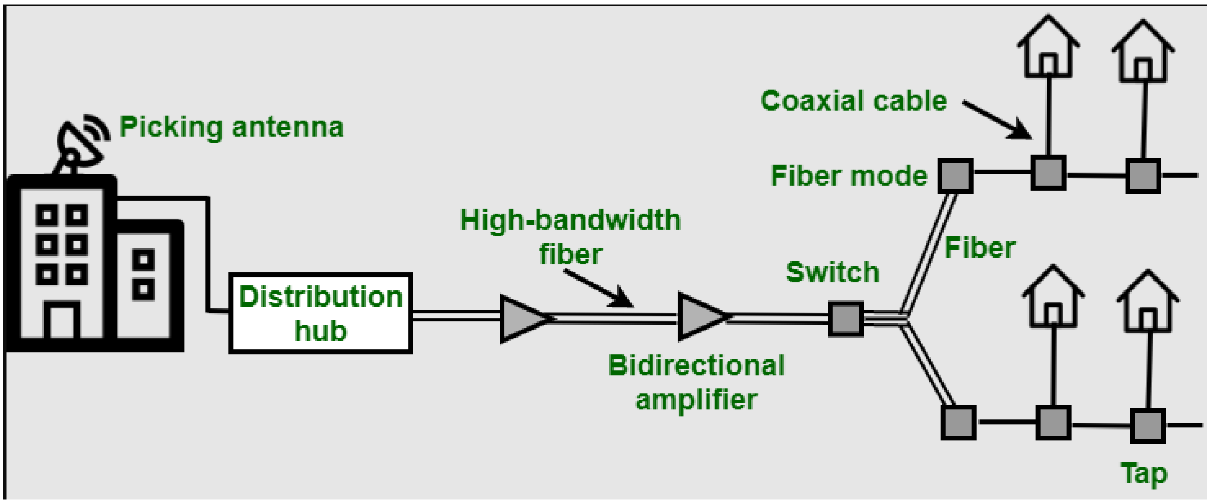
This network began to distribute the broadcast video signals to the locations with poor or no reception. Traditional Cable Network also called community antenna TV because this antenna is present at the highest of the building to receive signals from the TV stations then distribute these signals via coaxial cables to the community. The following is the schematic diagram of the traditional cable TV network.



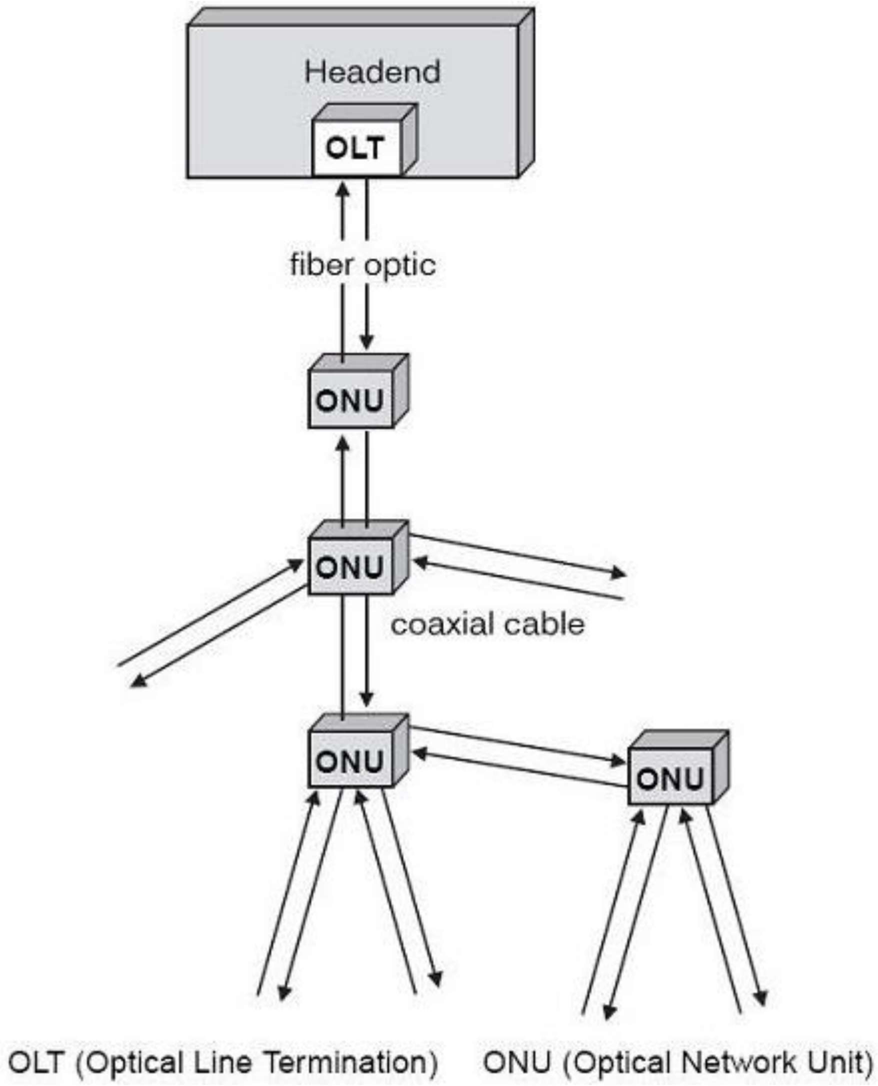
In this, Cable TV office is referred to as the head end which can receive the video signals from broadcasting stations and then feeds the signals into coaxial cables. Due to the distance increases, the signals are getting weaker, for this purpose amplifiers were installed through this network to regenerate the signals. During this network, we have more than 35 amplifiers between the head end and the premises of subscribers. At the other end of the Cable TV network, splitters were placed to split the signal and the tap and drop cables make the connections to the subscriber premises. Communication in this network is unidirectional. The video signals were transmitted downstream from the head end to the subscriber premises.

Hybrid Fiber-Coaxial Network :

Hybrid Fiber-Coaxial Network is that the second generation of the cable network. which is a combination of fiber-optic and coaxial cable is used in this type of network. The transmission mode is used is fiber node i.e. fiber mode. The schematic diagram of the HFC network is as follows –



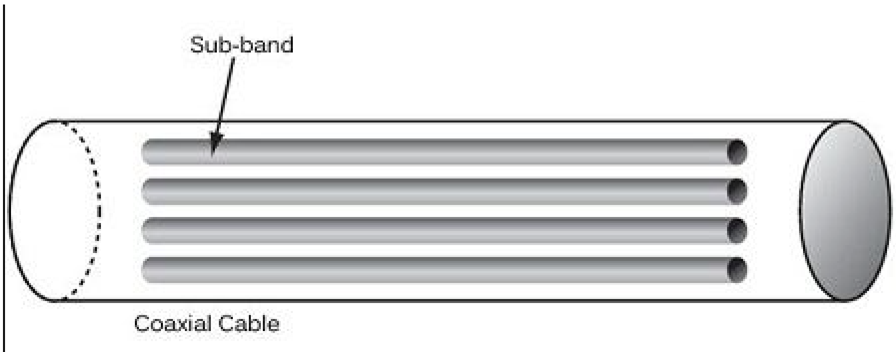
There are nearly 400, 000 subscribers served by Regional Cable Head (RCH). Modulation and demodulation of the signal are done through the distribution hubs after these signals are sent to the fiber nodes through fiber-optic cables. The fiber node split the analog signal so that the same signal is sent to each coaxial cable. Approx. 1000 subscribers are served by coaxial cable. Communication in this is bidirectional.



HFC TOPOLOGY DIAGRAM

This solution has many advantages but also some major defects. Its main advantage is the ability to optimize what is transmitted in different channels, since each channel is independent of the other channels. Multimedia is easily supported by assigning a media per sub-band, each sub-band having the opportunity to be optimized. Simply keep the analog information or scanning.

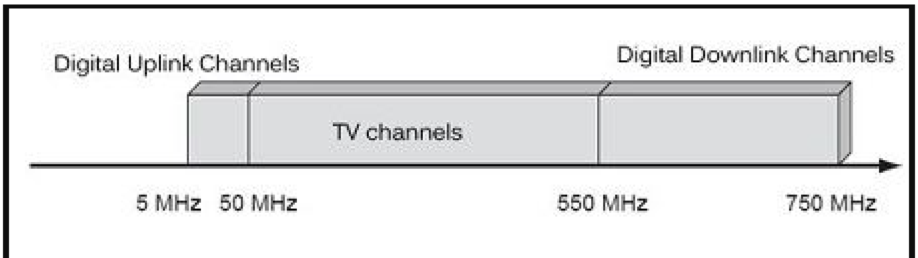
Television channels pass through separate subbands. A specific sub-band can be dedicated to a telephone voice connection and one sub-band to the internet. This Internet access requires the use of a cable modem, which allows access to the sub-band connected to the Internet. This type of modem requires a determined frequency corresponding to the selected sub-band for the Internet connection. Its speed can reach through a high bandwidth several megabits per second.



Frequency Multiplexing CATV

The distribution of bandwidth between different subbands is illustrated in FIG. The band of 50-550 MHz is reserved for analogue TV channels. Each channel requesting a bandwidth of 6 MHz, it is possible to stream and up to 80 TV channels. Digital television requires a lower bandwidth, allowing to multiply by three or four the number of TV channels carried by the cable.

The band of 5-550 MHz corresponds to channels from the user to the network head. The 550-750 MHz band from the headend to serve the user terminal. It can be used both for telephone speech and Internet connections.

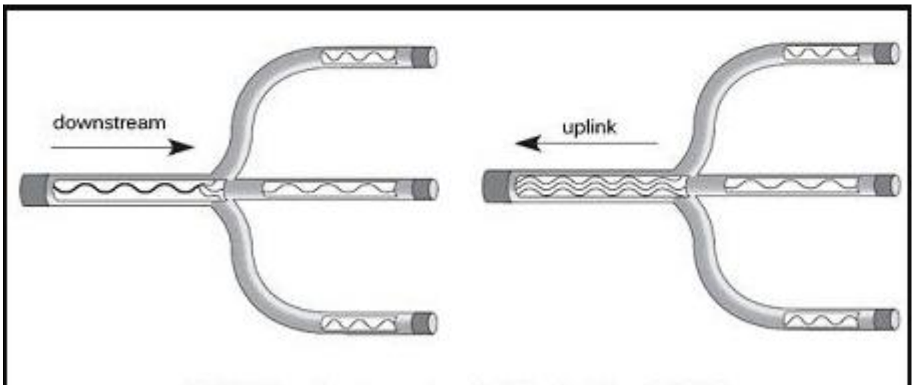


Distribution of the Spectrum within a CATV

The weakness of this technique is that the frequency multiplexing is not the best use of bandwidth and does not really allow the integration of different services transiting the CATV. Time multiplexing bring better use of available bandwidth and integrate in a single component access to all the information to the access point. A packet transfer would also represent a suitable solution, provided you completely change the end components.

In summary, a multimedia application can be carried over the coaxial cable of câbloopérateurs but being obliged to consider the transport of media on parallel bands and not on a single band.

HFC is another solution, which is to use fiber optics to allow the network to carry up to a little distance away from the user broadband communications, being relayed by the coaxial cable to the user socket. Due to its very large capacity, the optical fiber can convey as many channels as there are users to be reached, what is unable CATV soon as the number of users becomes large. For the latter, we must find a multiplexing solution upstream channels to the heart string to get to transit all requests from users on the network. This problem is illustrated in figure.



Multiplexing of upstream channels in the local loop in CATV

Suppose a channel associated with the Internet connection has a flow rate of 34 Mbit/s, which is now the standard case. If, on a CATV tree 10000 outlets are connected and active, the total throughput on the downlink and the uplink is 3.4 kbit/s per user. To offer a better rate, we must realize statistical multiplexing to recover the bandwidth not used by some users. However, it is obvious that if there are too many simultaneous users, the flow is insufficient.

The following standards have been proposed as access techniques to allow users time multiplexing on a common band:

• MCNS-DOCSIS (Multimedia Cable Network System-Data Over Cable Service Interoperability Specification), used primarily in North America but adopted by some European cable operators.

• IEEE 802.14, which uses ATM technology.

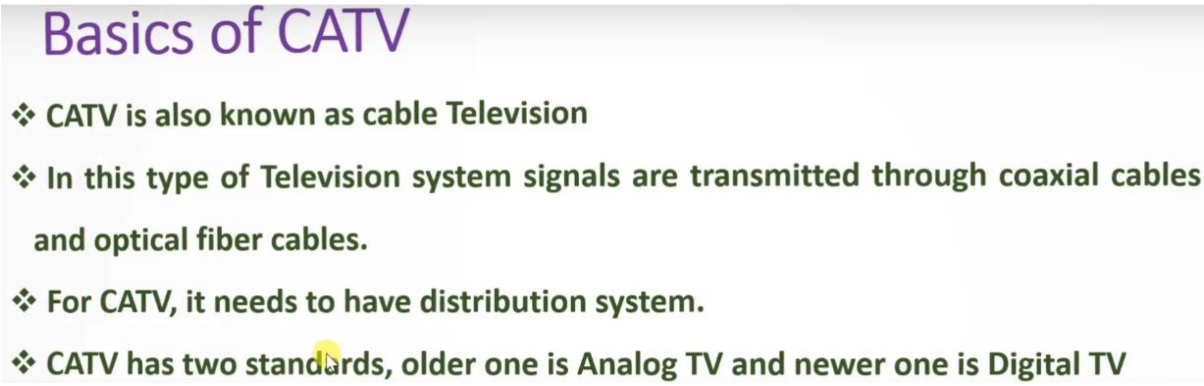
• DVB-DAVIC (Digital Video Broadcasting-Digital Audio Visual Council), which comes an industrial video group.

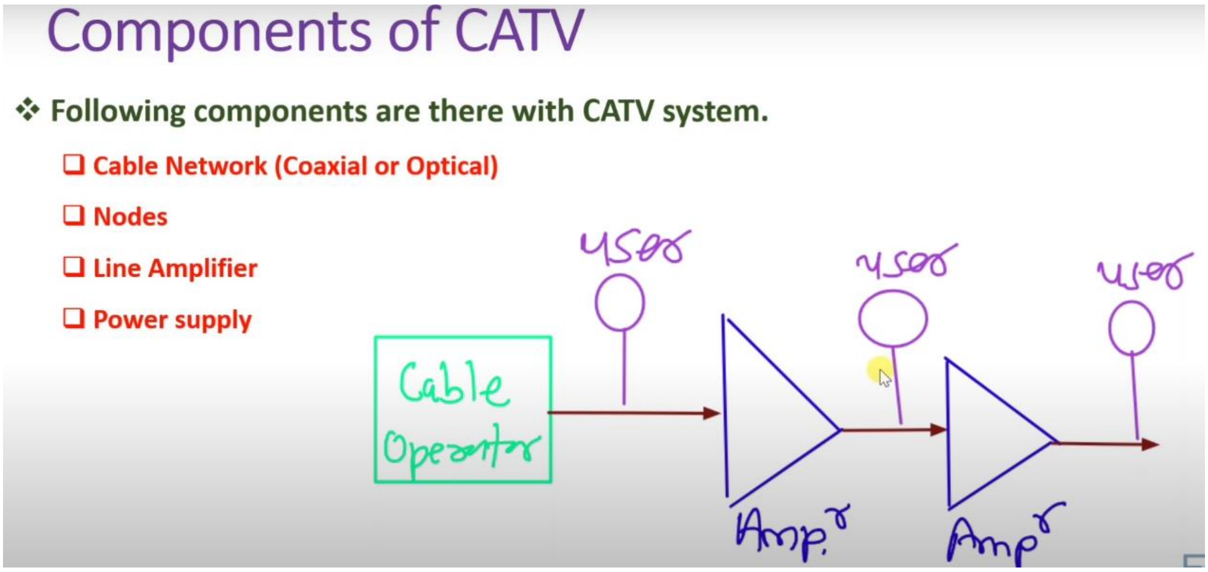
Advantages of Cable TV Network :

- Cable TV is stable in its service.
- It is fairly inexpensive.

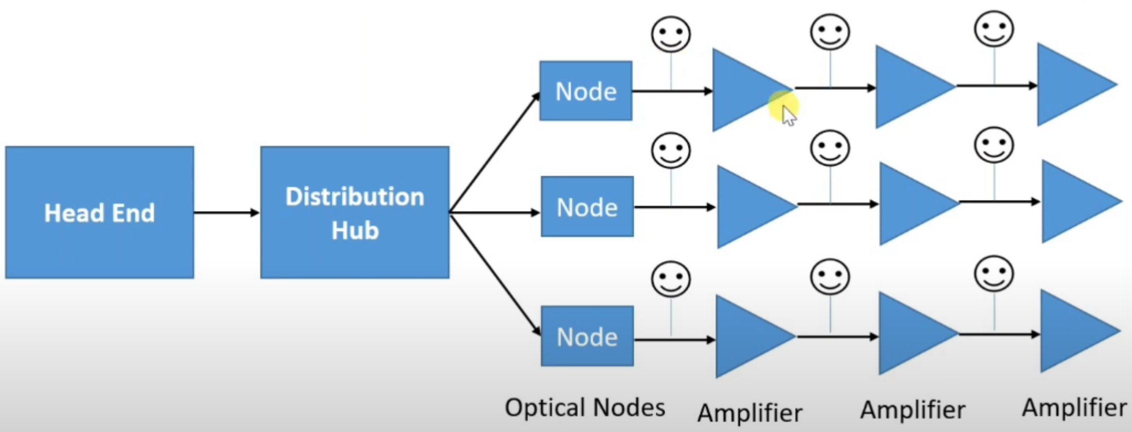
Disadvantages of Cable TV Network :

- Due to the supply of single provider, it creates monopoly.
- It will cause to less privacy, when out TV cable it connected to the internet or World Wide Web.





Block Diagram of CATV



Working of CATV

- Television channel transmitted by Head at particular frequency.
- Distribution hub is having amplifier at reasonable distance to keep signal strong.
- Separate TV signals do not interfere here with this channel.

Advantages of CATV

- Cable TV are available at low cost.
- Cable TV gives good service.
- They offers good packages of programs.
- Service cost is cheap.
- Cable TV provides good signals in bad weather conditions like heavy rainfall.

Disadvantages of CATV

- Some privet company has different cost.
- VOD is not available.
- Internet is not available.
- Gaming is not available.

The following section will give the advantages and disadvantages of Digital TV.

Advantages

- The digital broadcast offers better quality of picture and sound.
- The digital broadcast consumes less bandwidth than the analog one. This will free space for more wireless networks, which on the other hand will improve the communication services.
- With the digital television, you will have access to more channels.
- Digital TV is clearer. In most cases digital TV can improve the quality of TV pictures and sound.
- Digital television can be received in more ways. Digital TV is more flexible than the old analogue television system as you can pick it up on digital cable, digital satellite, digital terrestrial or broadband/DSL.

Digital information is made up of symbols, e.g., bits taking a finite number of distinct hence easily identifiable values. This reduces the effect of noise.

Having video in digital format allows us to use the digital electronics and digital signal processing techniques to modify the video information like any other computer data.

For example, we can perform: – Data compression, – Error Control Coding, – Using new digital modulation techniques, – Translation between formats, – Changing the rate of transmission according to user's demand, – Performing advanced video editing such as collage, zooming, special effects, – Easy storage of information as well as easy retrieval, content search, etc.

Digital TV allows non-linear TV, i.e., stopping the program, forward, backward, schedule recording, etc. The viewers do not have to lose content because they cannot sit in front of the TV all the time.

Digital TV moves the video from a stream based system into a file based system. The file can be retrieved, parts of it extracted or some other video be added to it. It is also possible to add metadata allow the viewers to effortlessly discover the content they want to watch across multiple platforms.

Being able to change between formats and adding metadata, DTV brings forward TV Everywhere (TVE) allowing the people watch programs of their choice on TV, over the PC, Tablet, smartphone, even in metro stations.

Disadvantages

- The biggest disadvantage of the digital TV is the fact that you will need special equipment.
- For the old analog broadcast, the only thing that you needed was an antenna, but for the new digital broadcast you will need digital converter box.
- Furthermore, you will need a new antenna if yours is too old
- Another disadvantage of the digital broadcast is the loss of signals.
- With the old analog broadcast, you are probably used to bad picture when the weather is bad, but with the new digital one you will loose all your channels entirely.

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- Nyquist criteria. • Fourier transform of band limit signal at T seconds is scaled by 1/T and given by wo = 2π/T. • If input signal is not band limited or sampling frequency does not meet the requirement of sampling theorem, the various components of spectrum overlap. • It suffers from distortion called aliasing effect and moiré patterns appear in picture

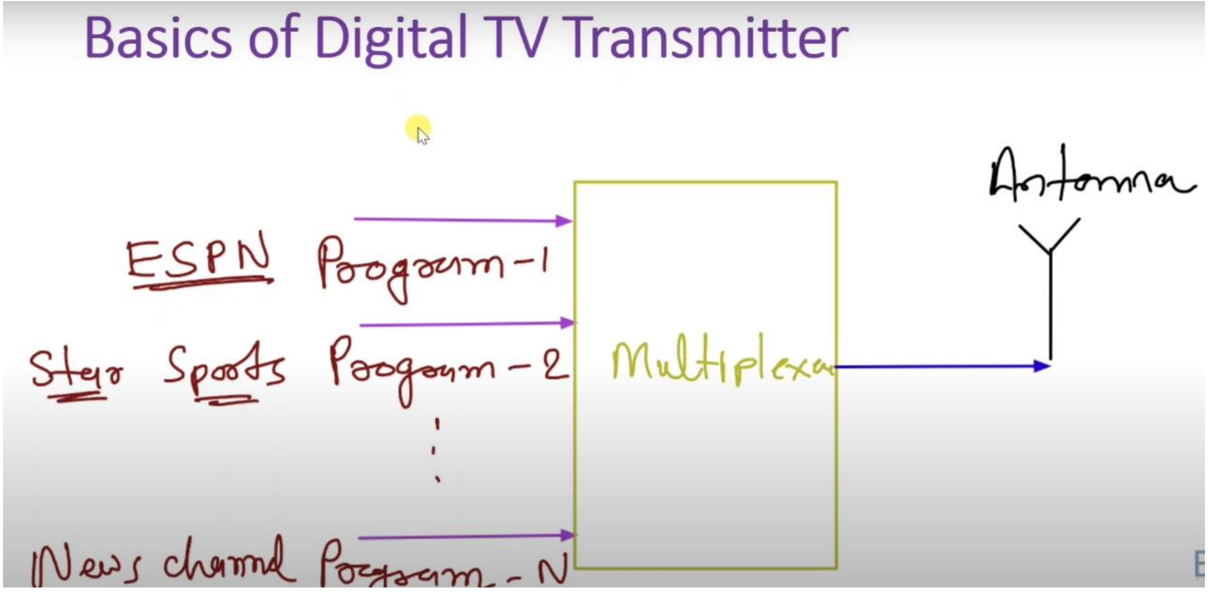
To avoid aliasing errors, the sampling frequency must exceed 10mhz. Quantization: • The sampled output, discrete in time in continuous in amplitude and assigned a discrete numerical values as ADC. • Since DAC is reverse process. Encoder: • The sampled value is assign a binary code alongwith additional 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.

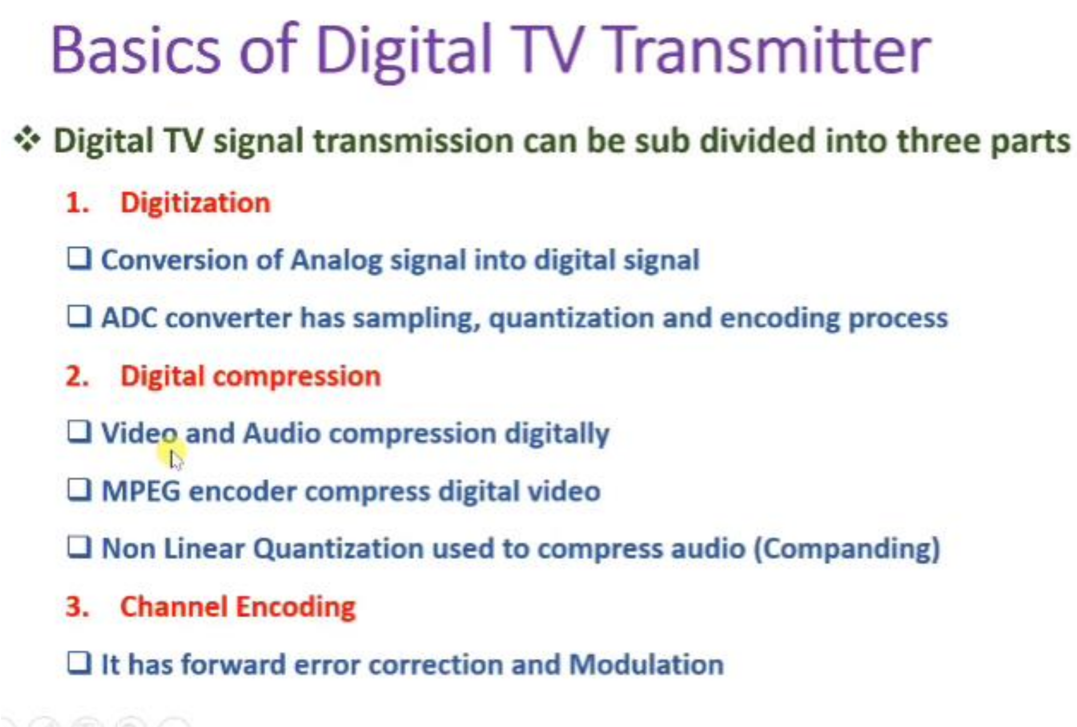
Analog signals suffer degradation in transmission path due to noise, crosstalk linear and non linear distortion in the circuitry.

But digital signals consists of binary pulse train immune to amplitude degradation by regeneration of pulses.They can be easily stored delayed and manipulated by microcomputer chips.Error detection and correction is easy.

Digital TV Transmitter

There are multiple programs that are transmitted simultaneously by digital TV Transmitter





Digitization

First we convert the picture signal from analog to digital by ADC.

ADC does this by three steps- Sampling, Quantization, Encoding

Sampling

Here we convert Analog signal to discrete time signal. For a band limited signal Sampling must be at Nyquist rate. If the input signal is not band limited or sampling is not done at a rate more than nyquist rate then, aliasing effect may occur by which there may be distortion in picture signal.

Quantization

Here we convert the discrete time but continuous amplitude signal to discrete amplitude signal.

Encoding

Here we give digital data to the discrete amplitude signal.That means the sample numerical value is assigned a binary code with additional codes like parity for error detection.

Digital Compression

Here we compress the audio and video.For video we use MPEG encoding.

In audio data compression we use non linear quantization or Companding(a law and mu law).

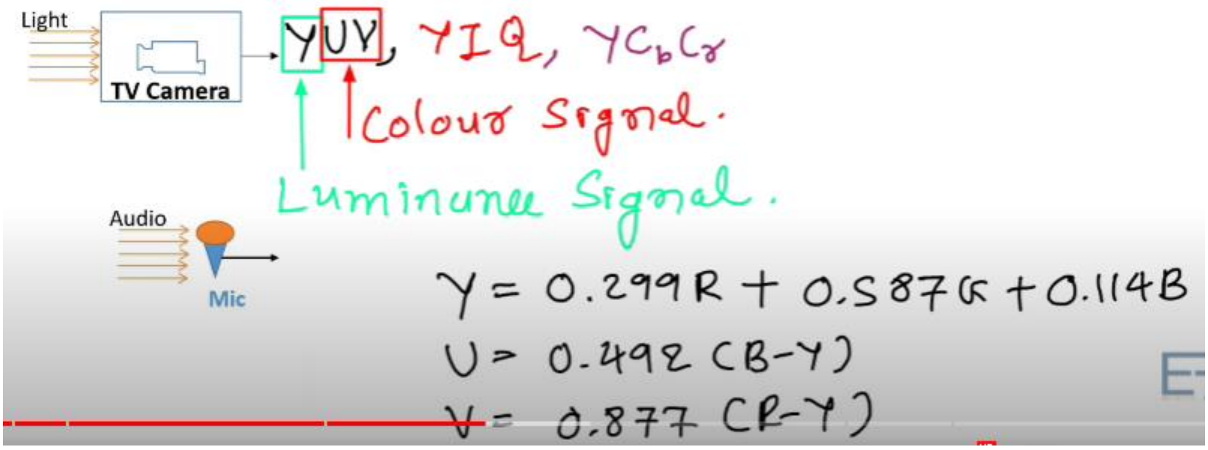
Channel Encoding

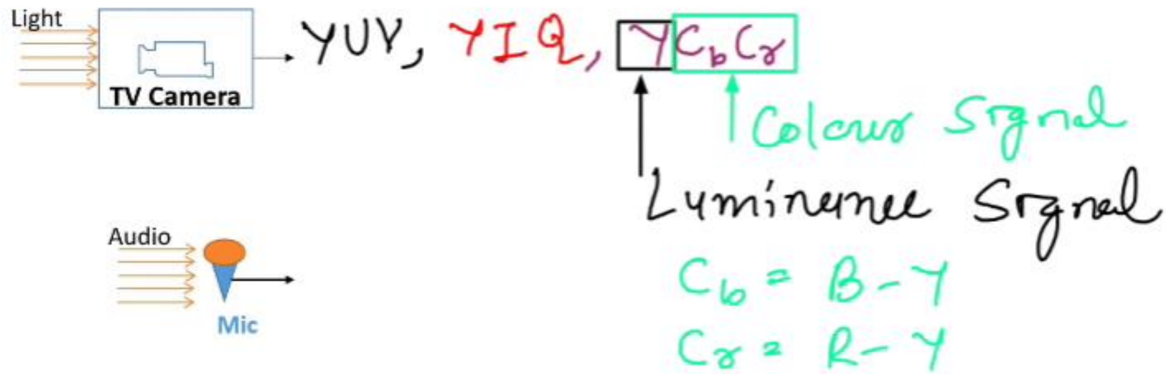
Here we have forward error correction and modulation.

<u>Now let us discuss transmission for a single program.</u>

First video is recorded by a TV camera. Audio is recorded by mic.Both give out as analog signals.

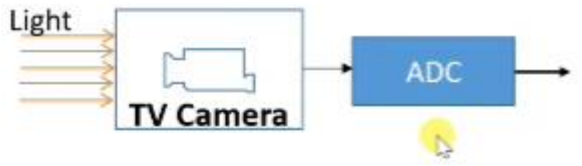
The output of TV camera can be YUV,YIQ and YCbCr in format where,



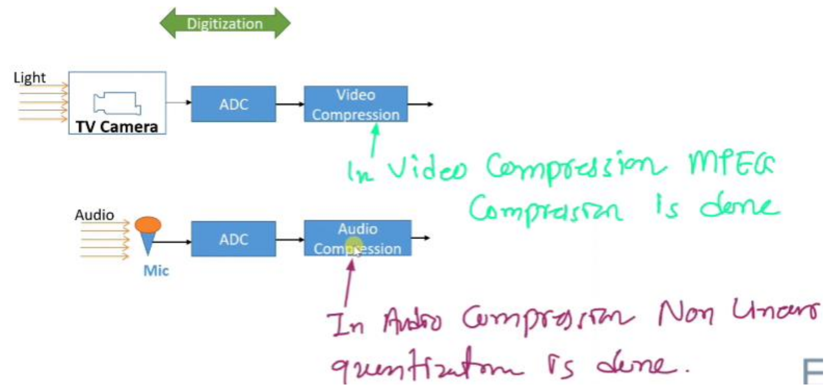


In digital TV transmission we use YUV data only.

The audio signal after being received will be amplified as it is very weak.

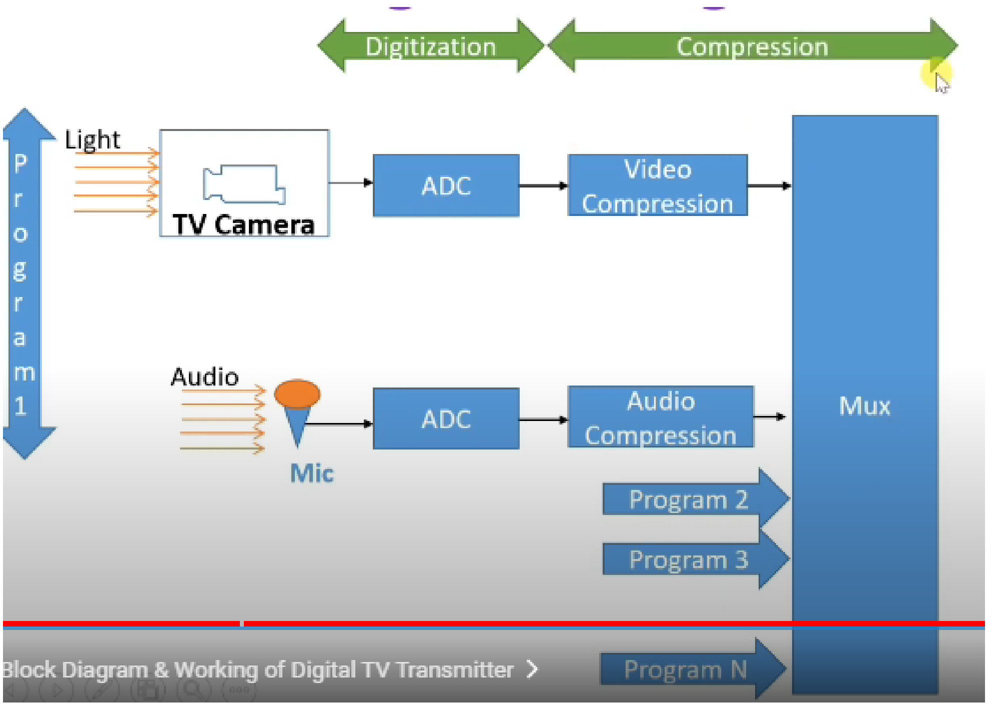


Now we feed both the analogsignals to ADC which does the process of Digitization- Sampling , Quantization, Encoding.

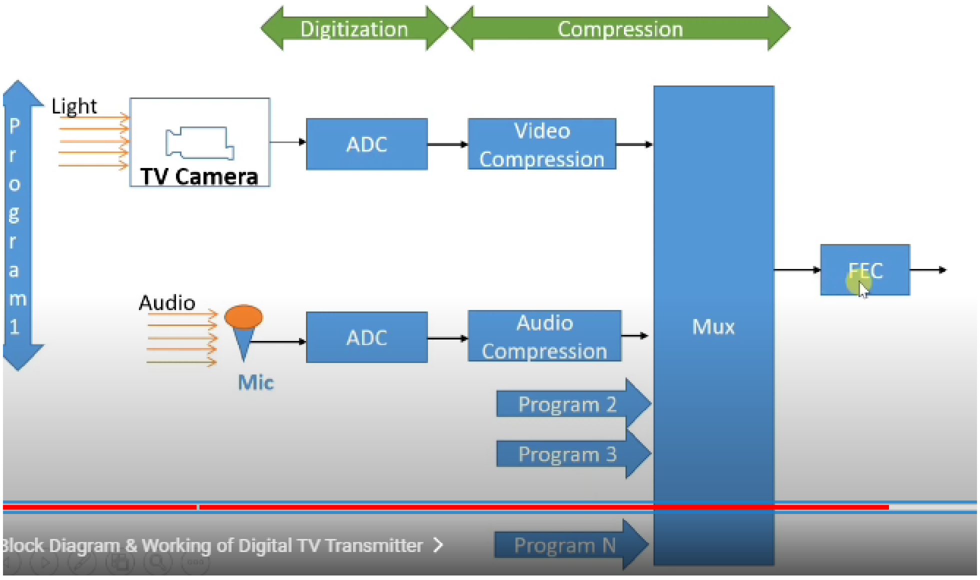


This is for one program.

For multiple programs , these signals are fed to a multiplexer and they are multiplexed to generated one signal. This process is compression.

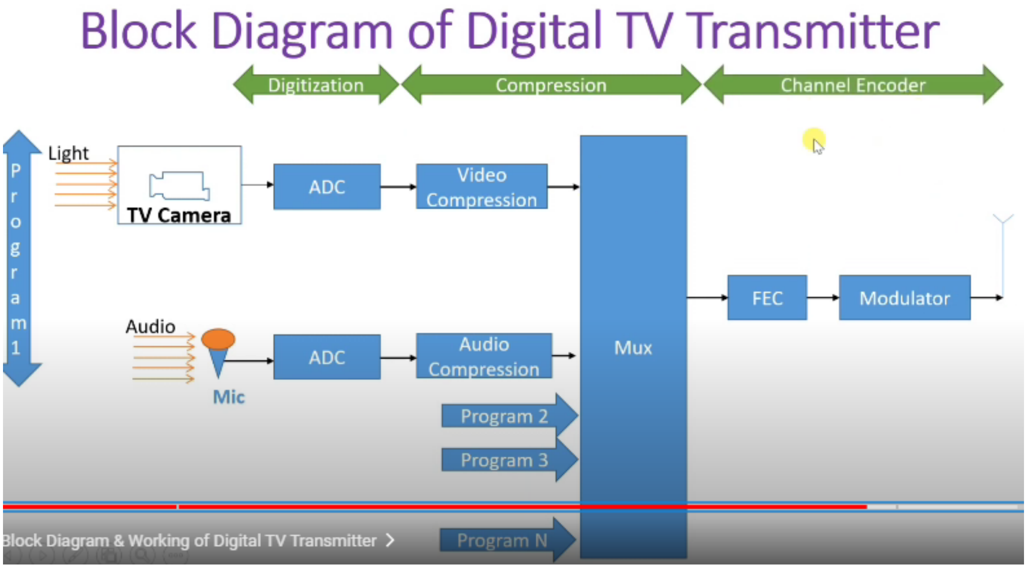


After this stage we use forward error correction. Because when we transmit data it is possible that the channel may have noise which can generate error.



After that we use modulation techniques.Different modulation techniques can be used. For HDTV we use QPSK Modulation.

After that we can transmit the signal by Antenna or by digital broadcast cable.



<u>Now we will discuss basics of digital TV reception</u>

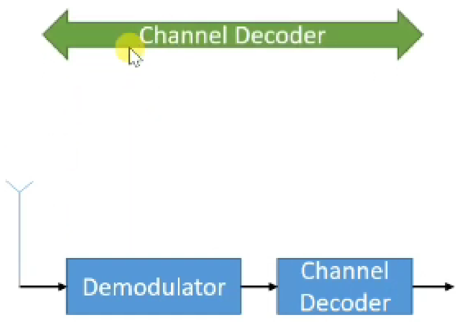
❖ **Digital TV signal Receiver can be sub divided into three parts**

1. **Channel Decoding**
   - ❑ **Demodulation of received signal**
   - ❑ **Error Detection and correction**
2. **Digital Decompression**
   - ❑ **Video and Audio Decompression**
   - ❑ **MPEG decoder decompress digital video**
   - ❑ **Expanding (Non Linear Dequantization) to decompress audio**
3. **Analog Conversion**
   - ❑ **Digital data converted into analog signal to display TV program on Television**

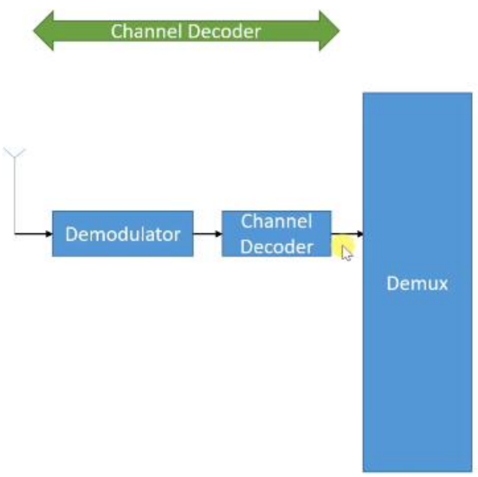
<u>Components Of Digital TV Reception</u>

Now let us see various **components of Digital TV reception**.

First the signal is received by receiving antenna, and then it is fed to demodulator for recovering the signal. The channel decoder will correct the digital error from the channel. This comple block is channel decoder.

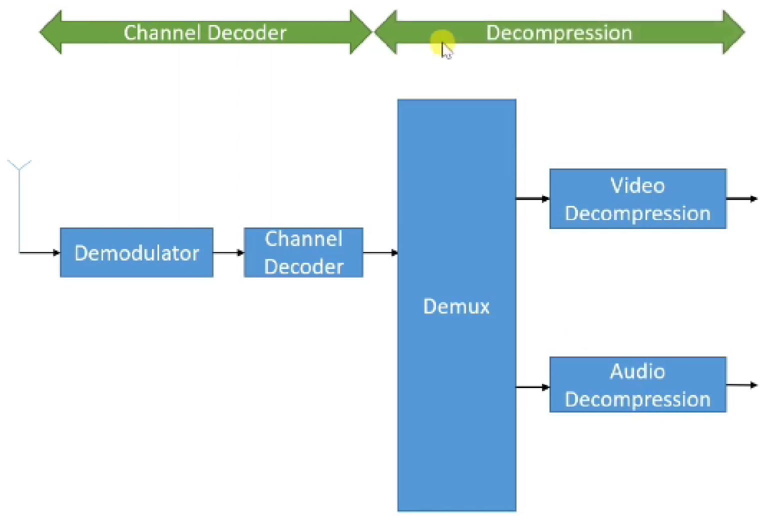


Then a de multiplexer will be used to select a particular channel as required by the user.



Now suppose channel number 1 is selected, then we will have to decompress the video and audio.

For video decoding we will use MPEG decoding and for audio Decompression we will use non lineardequantization where we do the expanding process of audio.

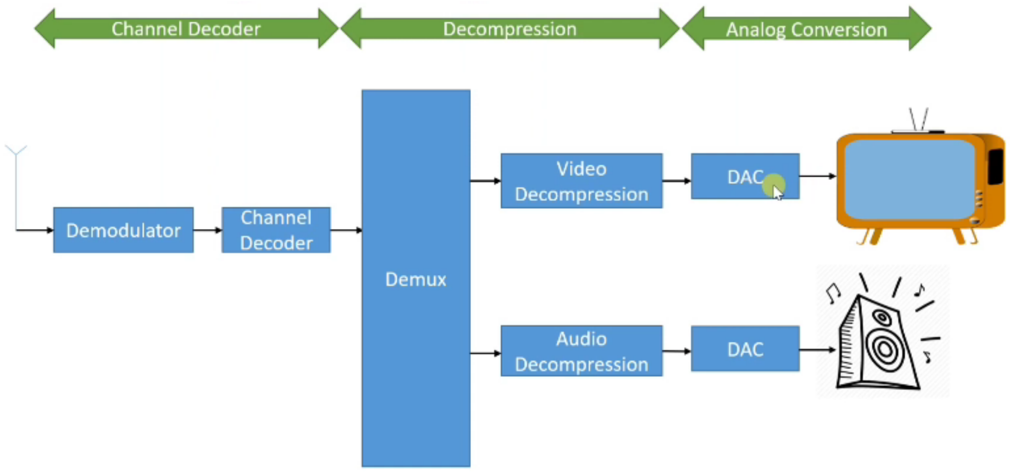


This process is the decompression of the signal.

Next we will use ADCs to convert the video and audio signals.

The audio signal will be amplified to be sent to a speaker.

The video signal will be converted to YUV signals to the display unit.

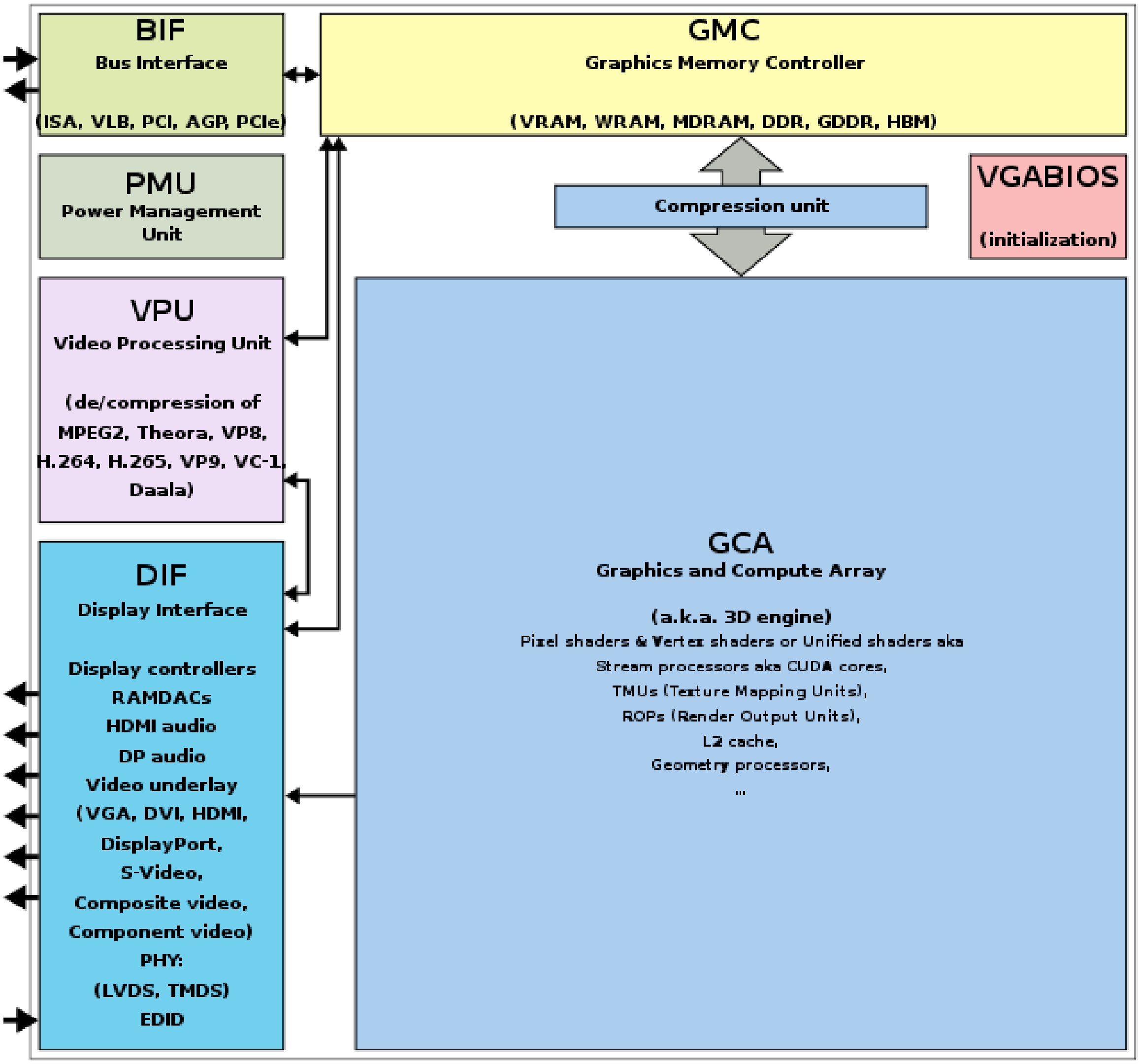


Video programme processor unit

It is an Image Processing Unit (IPU). Because processing a video stream means performing calculation on each pixel value of multiple frames of the video, which is a huge amount of data, which isnt possible without a VPU. VPUs/IPUs contain accelerators which speed up the calculations and few compressors which extract the pith of the data given.

A graphics processing unit (GPU) is a specialized electronic circuit designed to rapidly manipulate and alter memory to accelerate the creation of images in a frame buffer intended for output to a display device. GPUs are used in embedded systems, mobile phones, personal computers, workstations, and game consoles.

Modern GPUs are very efficient at manipulating computer graphics and image processing. Their highly parallel structure makes them more efficient than general-purpose central processing units (CPUs) for algorithms that process large blocks of data in parallel. In a personal computer, a GPU can be present on a video card or embedded on the motherboard.



Most GPUs made since 1995 support the YUV color space and hardware overlays, important for digital video playback, and many GPUs made since 2000 also support MPEG primitives such as motion compensation and iDCT. This process of hardware accelerated video decoding, where portions of the video decoding process and video post-processing are offloaded to the GPU hardware, is commonly referred to as "GPU accelerated video decoding", "GPU assisted video decoding", "GPU hardware accelerated video decoding" or "GPU hardware assisted video decoding".

More recent graphics cards even decode high-definition video on the card, offloading the central processing unit. The most common APIs for GPU accelerated video decoding are DxVA for Microsoft Windows operating system and VDPAU, VAAPI, XvMC, and XvBA for Linux-based and UNIX-like operating systems. All except XvMC are capable of decoding videos encoded with MPEG-1, MPEG-2, MPEG-4 ASP (MPEG-4 Part 2), MPEG-4 AVC (H.264 / DivX 6), VC-1, WMV3/WMV9, Xvid / OpenDivX (DivX 4), and DivX 5 codecs, while XvMC is only capable of decoding MPEG-1 and MPEG-2.

As Softaware

VPU is a video codec. This video codec is responsible for video encoding and decoding that is why it is also called video encoder and decoder.

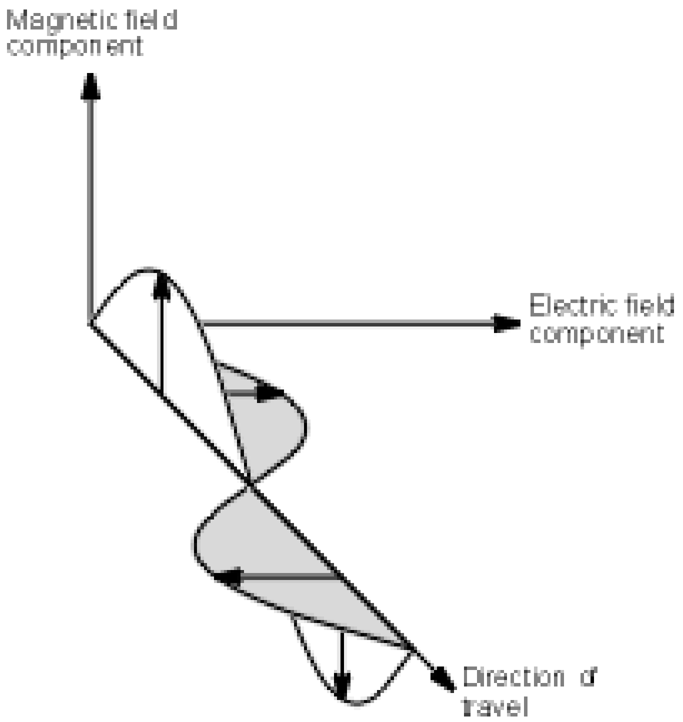
How it works?

Your TV - It will take video data from your Dish cable and that analog data is converted into digital signal and fed to the “VPU” Here “VPU” will act like Video decoder and it will decode it and display it on your screen.

Your Camera - Here “VPU” will act like Video encoder. It will take data from Vision Processing unit(Processor which is responsible for taking visual data from your camera) and then encode it and store it in your SD-Card. Now, again you need Video Decoder to read it from your SD-card.

Electromagnetic waves – e/m radiation basics

Electromagnetic waves or e/m radiation has two constituents. The radiation is made from electric and magnetic components that are inseparable. The planes of the fields are at right angles to each other and to the direction in which the wave is travelling.



The electric component of the wave results from the voltage changes that occur as the antenna element is excited by the alternating waveform. The lines of force in the electric field run along the same axis as the antenna, but spreading out as they move away from it. This electric field is measured in terms of the change of potential over a given distance, e.g. volts per metre, and this is known as the field strength. This measure is often used in measuring the intensity of an electromagnetic wave at a particular point.

The other component, namely the magnetic field is at right angles to the electric field and hence it is at right angles to the plane of the antenna. It is generated as a result of the current flow in the antenna.

Like other forms of electromagnetic wave, radio signals can be reflected, refracted and undergo diffraction.

Electromagnetic wave wavelength, frequency & velocity

There are a number of basic properties of electromagnetic waves, or any repetitive waves for that matter that are particularly important.

Frequency, wavelength and speed are three key parameters for any electromagnetic wave.

- ***E/m wave speed:*** Radio waves travel at the same speed as light. For most practical purposes the speed is taken to be 300 000 000 metres per second although a more exact value is 299 792 500 metres per second. Although exceedingly fast, they still take a finite time to travel over a given distance. With modern radio techniques, the time for a signal to propagate over a certain distance needs to be taken into account. Radar for example uses the fact that signals take a certain time to travel to determine the distance of a target. Other applications such as mobile phones also need to take account of the time taken for signals to travel to ensure that the critical timings in the system are not disrupted and that signals do not overlap.

- ***E/m wave wavelength:*** This is the distance between a given point on one cycle and the same point on the next cycle as shown. The easiest points to choose are the peaks as these are the easiest to locate. The wavelength was used in the early days of radio or wireless to determine the position of a signal on the dial of a set. Although it is not used for this purpose today, it is nevertheless an important feature of any radio signal or for that matter any electromagnetic wave. The position of a signal on the dial of a radio set or its position within the radio spectrum is now determined by its frequency as this provides a more accurate and convenient method for determining the properties of the signal.

- ***Frequency :*** This is the number of times a particular point on the wave moves up and down in a given time (normally a second). The unit of frequency is the Hertz and it is equal to one cycle per second. This unit is named after the German scientist who discovered radio waves. The frequencies used in radio are usually very high. Accordingly the prefixes kilo, Mega, and Giga are often seen. 1 kHz is 1000 Hz, 1 MHz is a million Hertz, and 1 GHz is a thousand million Hertz i.e. 1000 MHz. Originally the unit of frequency was not given a name and cycles per second (c/s) were used. Some older books may show these units together with their prefixes: kc/s; Mc/s etc. for higher frequencies.

$$\lambda = c/f$$

Where

λ = the wavelength in metres

f = frequency in Hertz

c = speed of radio waves (light) taken as 300 000 000 metres per second for all practical purposes.

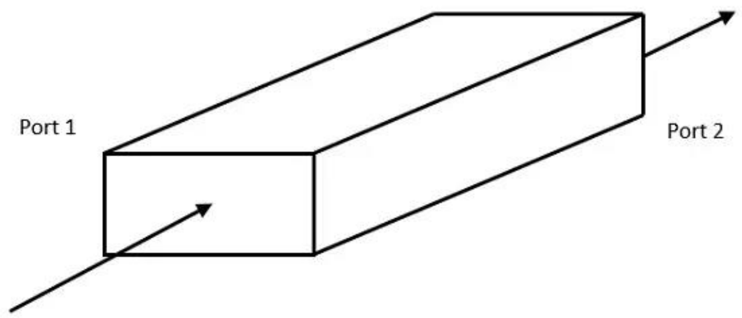
Electromagnetic waves are the key to radio and wireless communications. The fact that they can travel over vast distances as well as being reflected, refracted and diffracted means that they have been used for many years as the basis for radio communications over all distances from a few centimetres to many hundreds of thousands or millions of miles.

A Waveguide

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

Definition

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



A two-port rectangular waveguide

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

The Main Characteristics of A Waveguide Are

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

Advantages of Waveguides

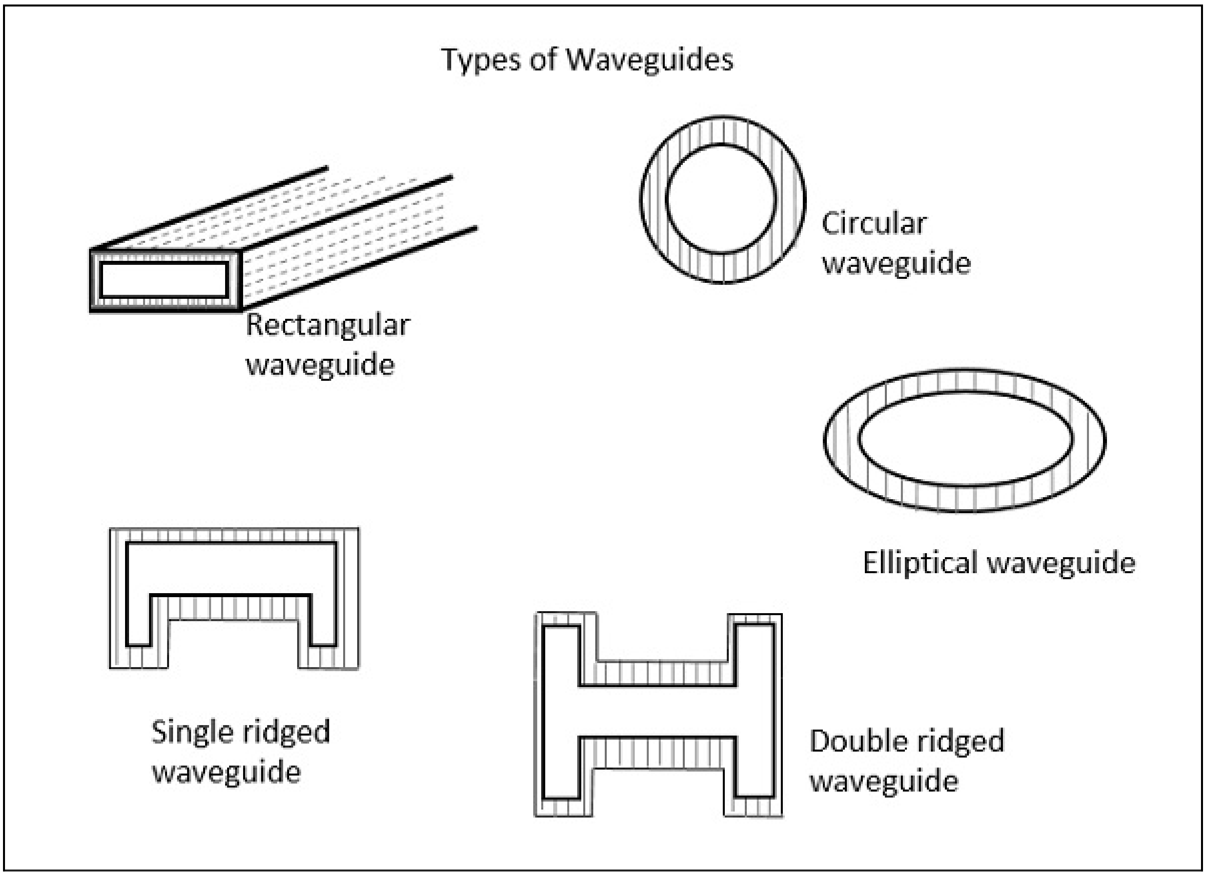
- Waveguides are easy to manufacture.
- They can handle very large power (in kilowatts)

- Power loss is very negligible in waveguides
- They offer very low loss (low value of alpha-attenuation)
- The microwave energy when travels through the waveguide, experiences lower losses than a coaxial cable.

Types of Waveguides

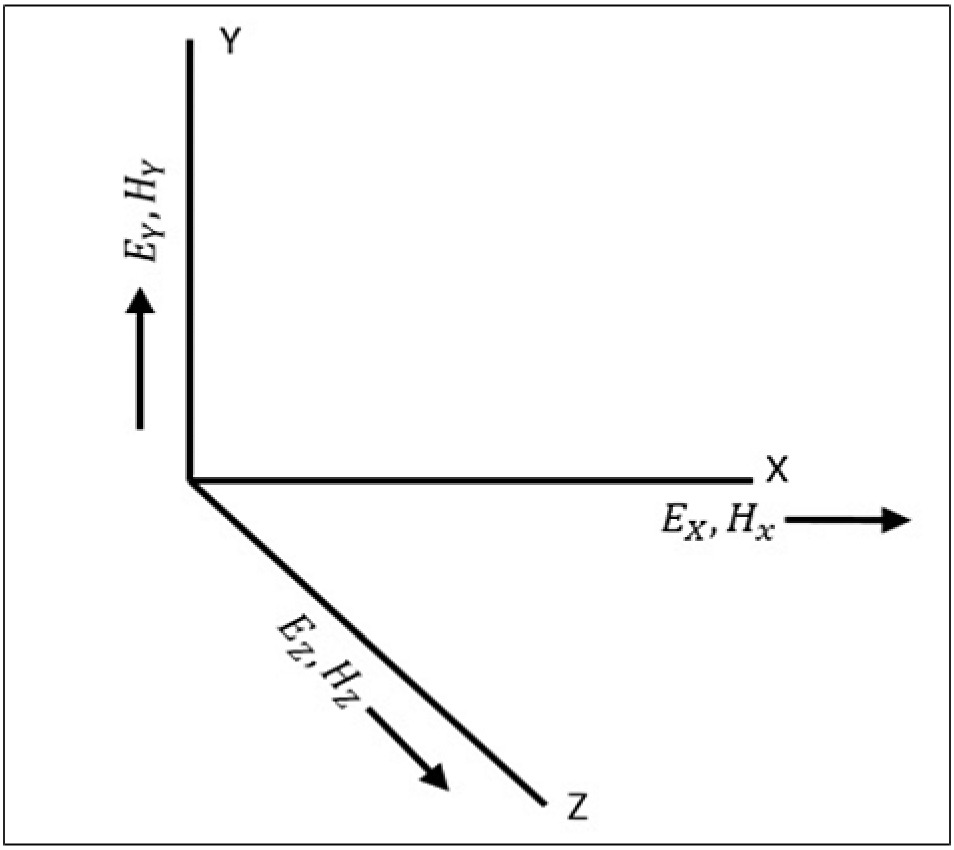
There are five types of waveguides. They are:

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



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

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



Types of Modes

The modes of propagation of microwaves are −

TEM TransverseElectromagneticWave

In this mode, both the electric and magnetic fields are purely transverse to the direction of propagation. There are no components in 'Z' direction.

Ez=0andHz=0

TE TransverseElectricWave

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

Ez=0andHz≠0

TM TransverseMagneticWave

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

Ez≠0andHz=0Ez≠0andHz=0

HE HybridWave

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

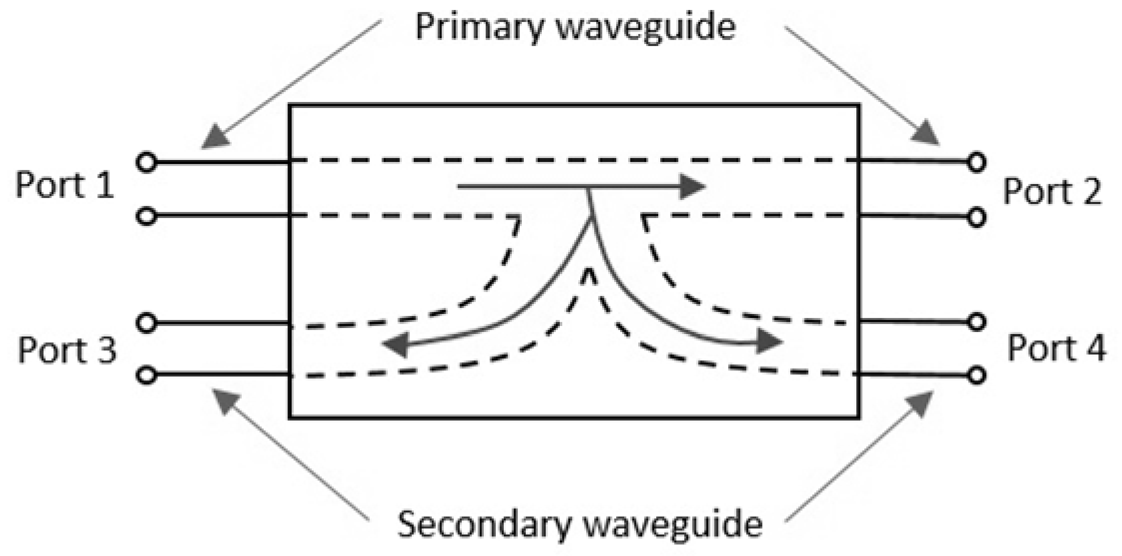
Ez≠0andHz≠0

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

Microwave Engineering - Directional Couplers

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

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



Directional Coupler

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

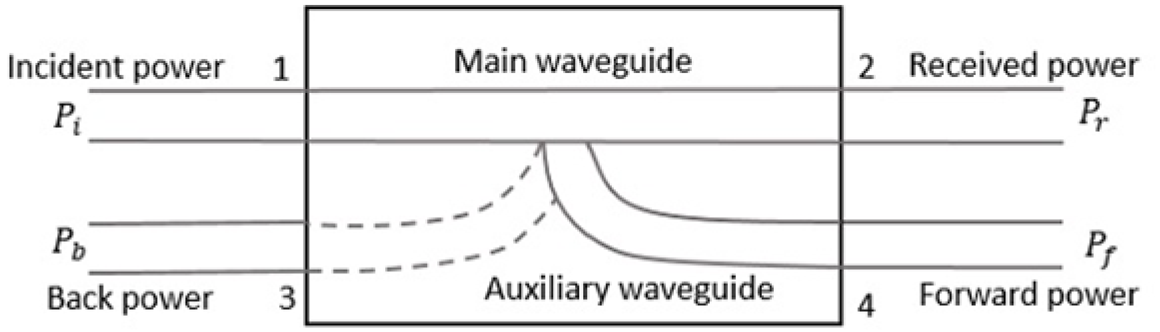
Properties of Directional Couplers

The properties of an ideal directional coupler are as follows.

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

- If the power is incident through Port 4, a portion of it is coupled to Port 1, but not to Port 2.
- Port 1 and 3 are decoupled as are Port 2 and Port 4.

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



Directional Coupler indicating powers

Where

- Pi = Incident power at Port 1
- Pr = Received power at Port 2
- Pf = Forward coupled power at Port 4
- Pb = Back power at Port 3

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

Coupling Factor C

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

$$C=10\log_{10} P_i/P_f \text{ dB}$$

Directivity D

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

$$D=10\log_{10} P_f/P_b \text{ dB}$$

Isolation

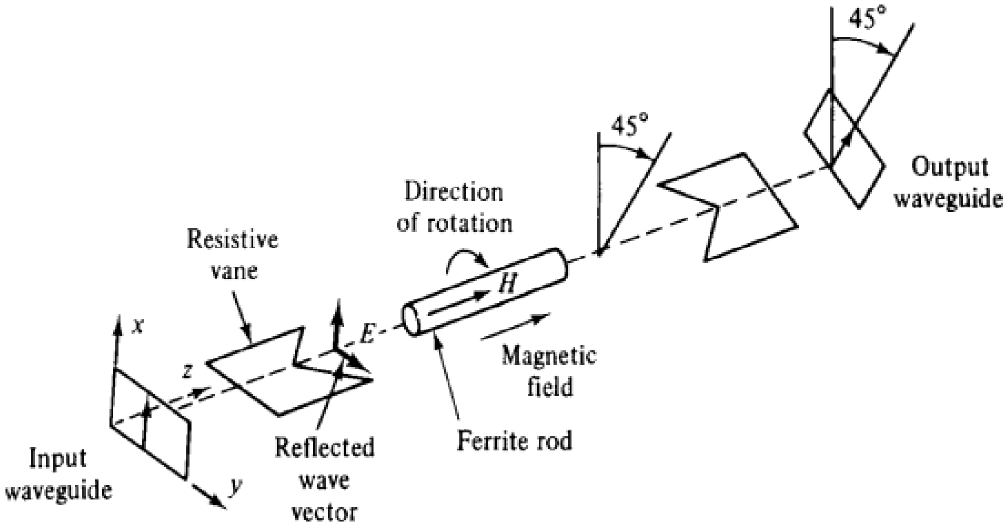
It defines the directive properties of a directional coupler. It is the ratio of incident power to the back power, measured in dB.

$$I = 10\log_{10} P_i / P_b \text{ dB}$$

Isolation in dB = Coupling factor + Directivity

MICROWAVE ISOLATORS:

An isolator is a nonreciprocal transmission device that is used to isolate one component from reflections of other components in the transmission line. An ideal isolator completely absorbs the power for propagation in one direction and provides lossless transmission in the opposite direction. Thus the isolator is usually called uniline. Isolators are generally used to improve the frequency stability of microwave generators, such as klystrons and magnetrons, in which the reflection from the load affects the generating frequency. In such cases, the isolator placed between the generator and load prevents the reflected power from the unmatched load from returning to the generator. As a result, the isolator maintains the frequency stability of the generator. Isolators can be constructed in many ways. They can be made by terminating ports 3 and 4 of a four-port circulator with matched loads. On the other hand, isolators can be made by inserting a ferrite rod along the axis of a rectangular waveguide as shown below. The isolator here is a Faraday-rotation isolator. Its operating principle can be explained as follows . The input resistive card is in the y-z plane, and the output resistive card is displaced 45° with respect to the input card. The dc magnetic field, which is applied longitudinally to the ferrite rod, rotates the wave plane of polarization by 45°. The degrees of rotation depend on the length and diameter of the rod and on the applied de magnetic field. An input TEIO dominant mode is incident to the left end of the isolator. Since the TEIO mode wave is perpendicular to the input resistive card, the wave passes through the ferrite rod without attenuation. The wave in the ferrite rod section is rotated clockwise by 45° and is normal to the output resistive card. As a result of rotation, the wave arrives at the output.



MICROWAVE CIRCULATOR:

What are the functions of circulators?

A circulator is passive equipment that is used in RF and microwave equipment. This device can be used to improve the stability, performance, and reliability of the system. The function of the circulator is to absorb the energy entering the port and to pass it to the next port.

How do circulators work?

The circulator works according to the faraday's rotation, if we send a wave through the circulator the ferrite rod that has magnetic influence and the wave will be split and it travels through the port. The circulator has three or more ports and in this device, the power will be transmitted from one port to the other. This means that in a circulator that has three-port, the power entering the port1 leaves port 2, port 3 is decoupled and a similar process will take place if the power enters through the other two ports. So each port is connected to one arm of the symmetrical Y junction that is coupled to magnetic biased ferrite material. When one port is terminated then the other ports are isolated in the reverse direction. The circulator would only have less loss while transmitting the signal from one port to the other.

ISOLATORS

What is the difference between a circulator and an isolator? Can a circulator be used as an isolator?

The working principle of the circulator is similar to the isolator, the circulator can be considered as an isolator with matched termination, it means that in a circulator if one port is terminated then the other ports are isolated in the reverse direction, a circulator won't do isolation until a port is terminated. The isolator will only allow the signal to pass in one direction and in the other direction it will be attenuated, while the circulator can separate the signal.

What are the advantages of circulators?

We can use circulators to get bidirectional transmission over a single fiber. It is used for applications related to optical sensors because of its isolation properties.

What are the disadvantages of a circulator?

- It is expensive
- Circulators are heavy
- The static magnetic field produced is very high
- Insertion loss is high too

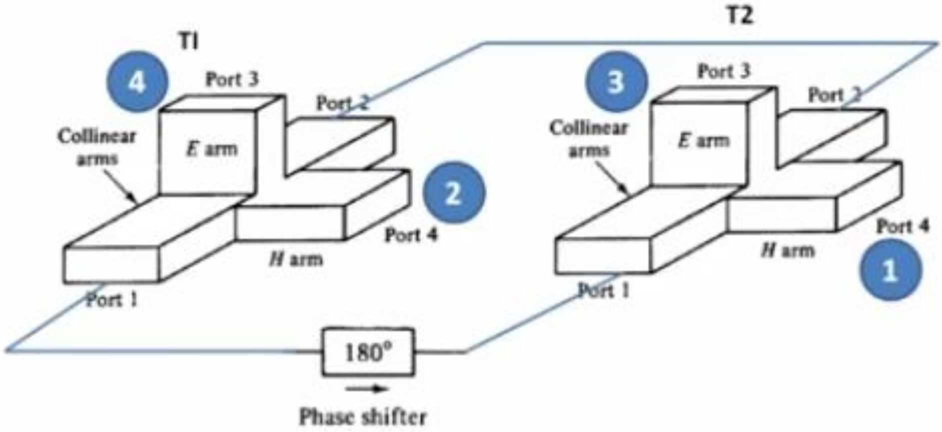
How to select a circulator?

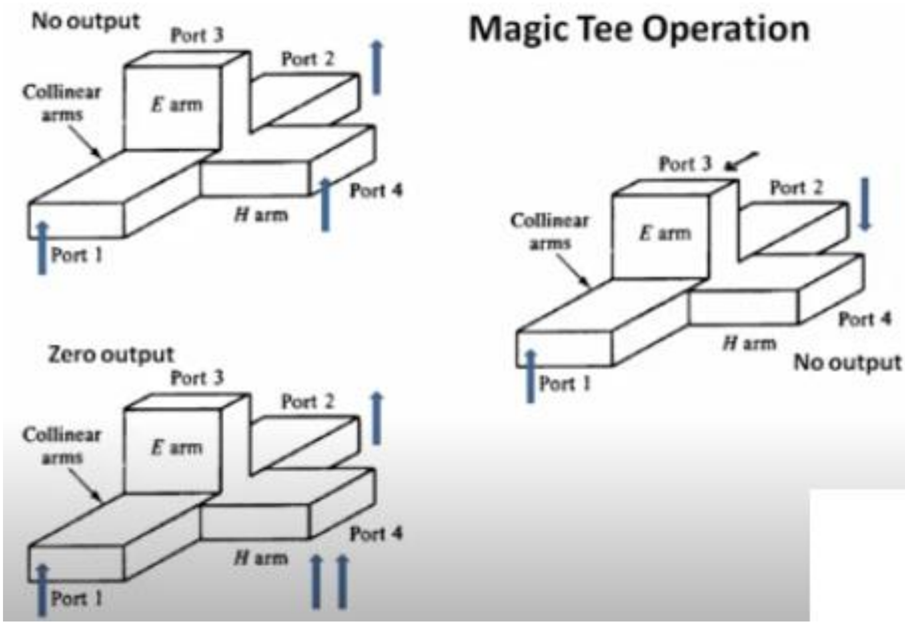
We must choose a circulator according to some electrical specifications and by checking these specifications we can know if it can be used according to our needs. We must consider certain things while selecting a circulator they are insertion loss, VSWR, power handling, group delay, operating temperature range, and isolation. Power handling is the amount of power that the circulator could pass without and signal distortion and group delay is the time taken by the signal to travel from port 1 to port 2. Insertion loss is the loss of the energy that took place while transferring signals from one port to the other.

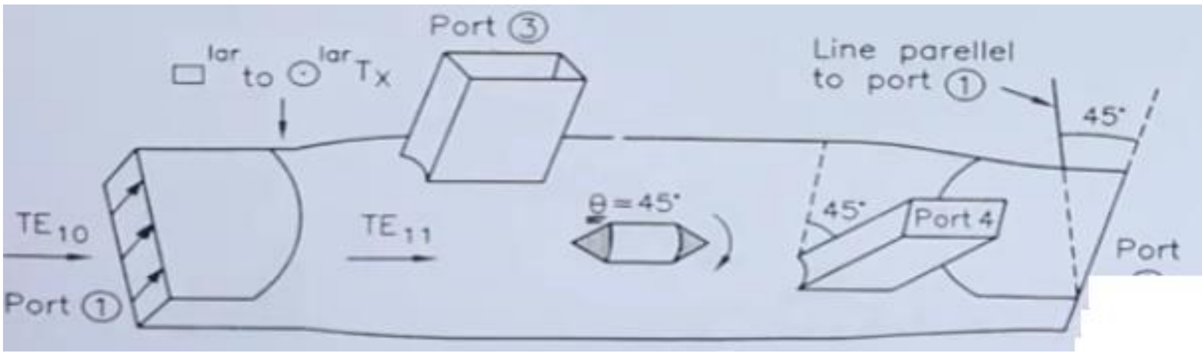
What are the applications of circulators?

- It has applications in radar system
- It is used in antenna for transmitting and receiving purpose
- It is used as the coupling element in the amplifiers
- Duplexers
- It is used in phase lock injection circuits
- Test instruments
- Reflective power handling isolators

Circulator Construction



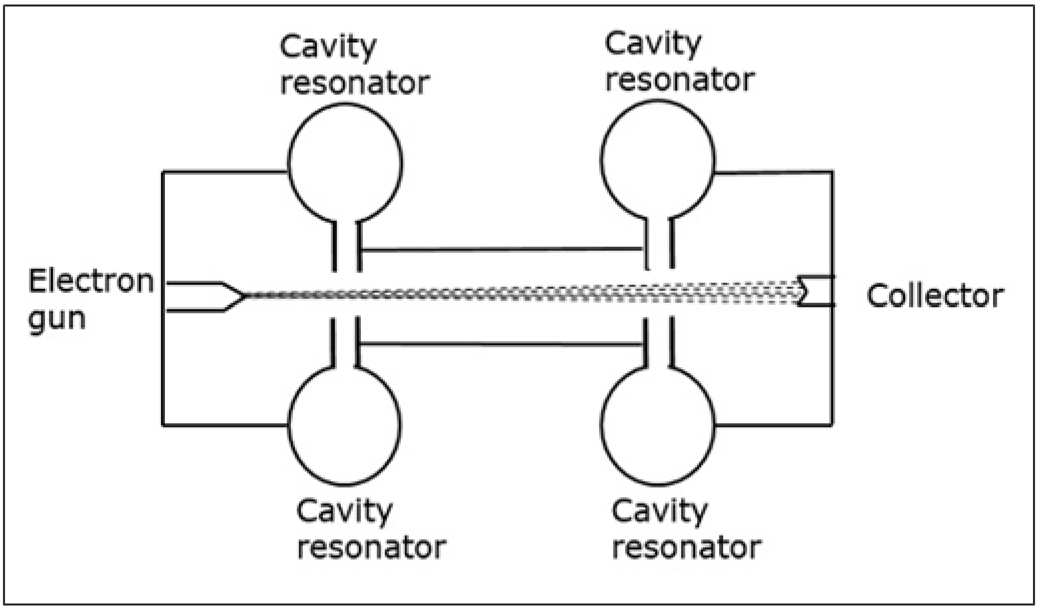




Microwave Engineering - Cavity Klystron

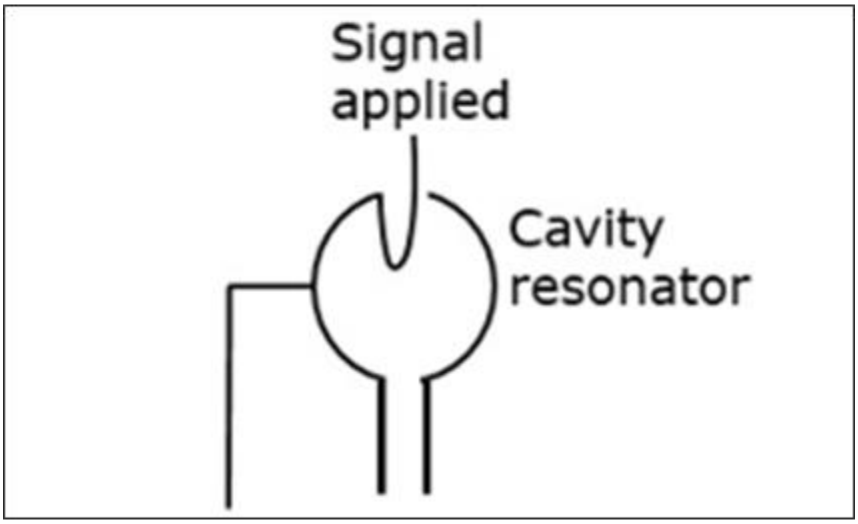
For the generation and amplification of Microwaves, there is a need of some special tubes called as **Microwave tubes**. Of them all, **Klystron** is an important one.

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



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

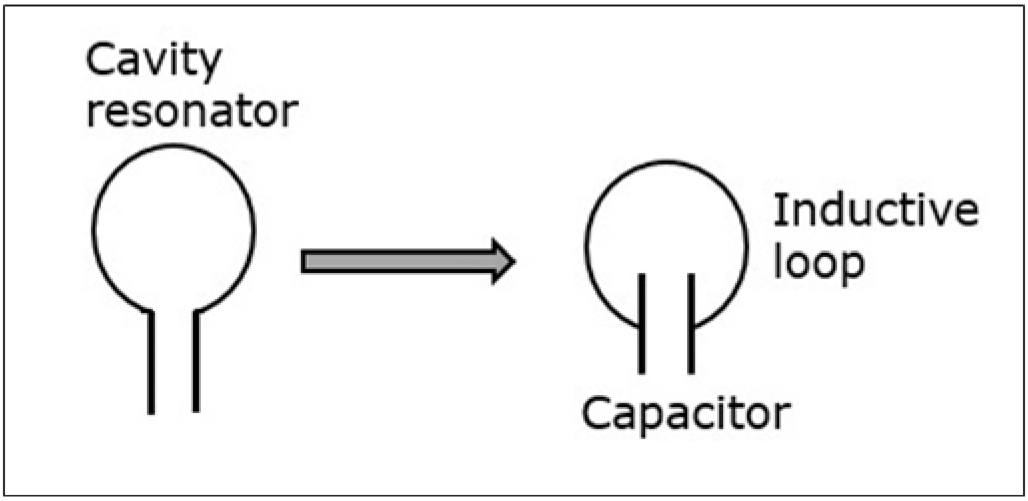
Initially, the first cavity resonator is supplied with a weak high frequency signal, which has to be amplified. The signal will initiate an electromagnetic field inside the cavity. This signal is passed through a coaxial cable as shown in the following figure.



Due to this field, the electrons that pass through the cavity resonator are modulated. On arriving at the second resonator, the electrons are induced with another EMF at the same frequency. This field is strong enough to extract a large signal from the second cavity.

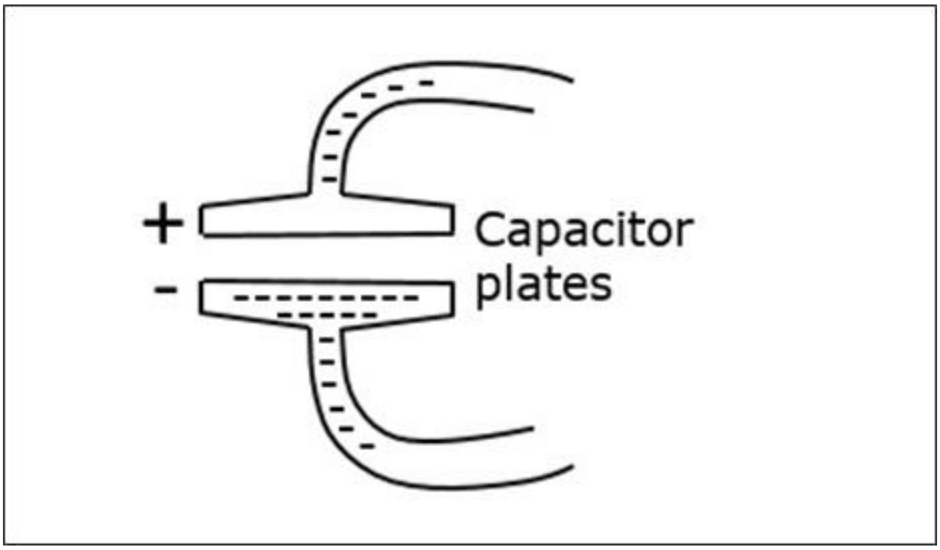
Cavity Resonator

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



A simple resonant circuit which consists of a capacitor and an inductive loop can be compared with this cavity resonator. A conductor has free electrons. If a charge is applied to the capacitor to get it charged to a voltage of this polarity, many electrons are removed from the upper plate and introduced into the lower plate.

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



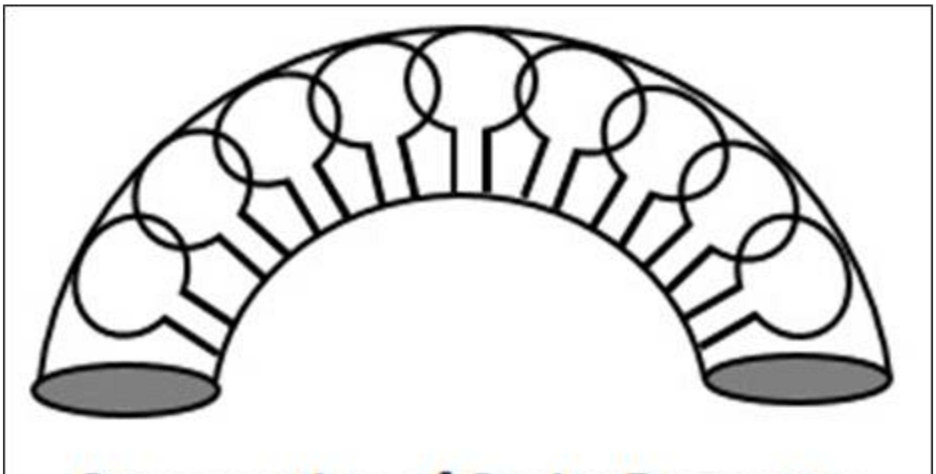
The electric field lines are directed from the positive charge towards the negative. If the capacitor is charged with reverse polarity, then the direction of the field is also reversed. The displacement of electrons in the tube, constitutes an alternating current. This alternating current gives rise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

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

Closed Resonator

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

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



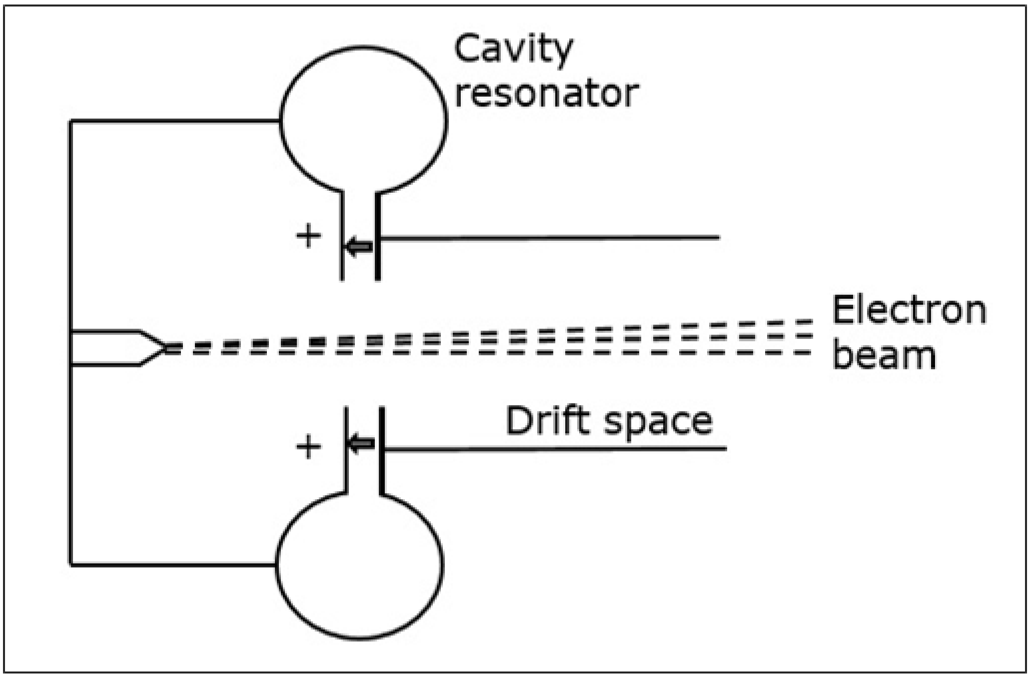
Cross-section of Cavity Resonator

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

Working of Klystron

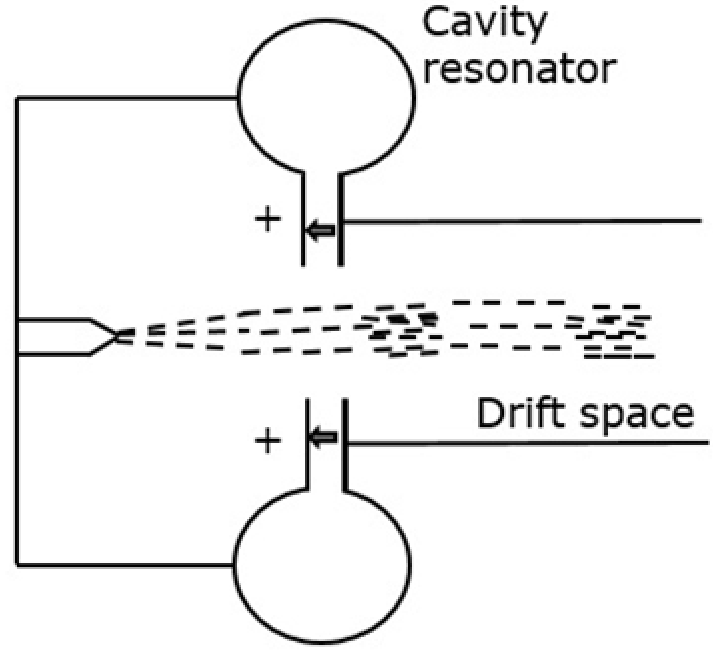
To understand the modulation of the electron beam, entering the first cavity, let's consider the electric field. The electric field on the resonator keeps on changing its direction of the induced field. Depending on this, the electrons coming out of the electron gun, get their pace controlled.

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



While moving, these electrons enter the field free space called as the **drift space** between the resonators with varying speeds, which create electron bunches. These bunches are created due to the variation in the speed of travel.

These bunches enter the second resonator, with a frequency corresponding to the frequency at which the first resonator oscillates. As all the cavity resonators are identical, the movement of electrons makes the second resonator to oscillate. The following figure shows the formation of electron bunches.



Formation of electron bunches

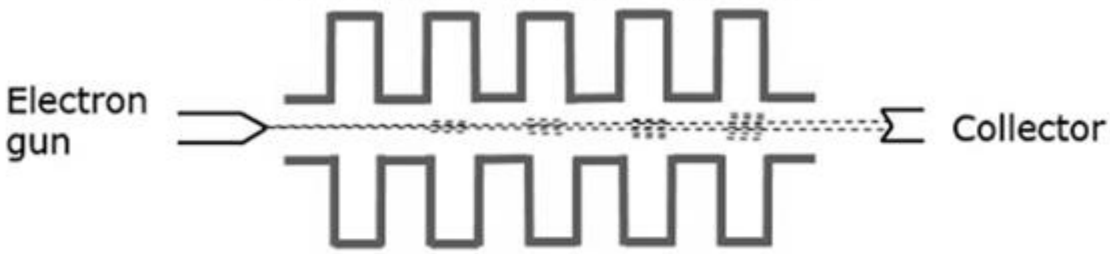
The induced magnetic field in the second resonator induces some current in the coaxial cable, initiating the output signal. The kinetic energy of the electrons in the second cavity is almost equal to the ones in the first cavity and so no energy is taken from the cavity.

The electrons while passing through the second cavity, few of them are accelerated while bunches of electrons are decelerated. Hence, all the kinetic energy is converted into electromagnetic energy to produce the output signal.

Amplification of such two-cavity Klystron is low and hence multi-cavity Klystrons are used.

The following figure depicts an example of multi-cavity Klystron amplifier.

Cascading of multiple klystrons



Bunches of electrons getting strengthened

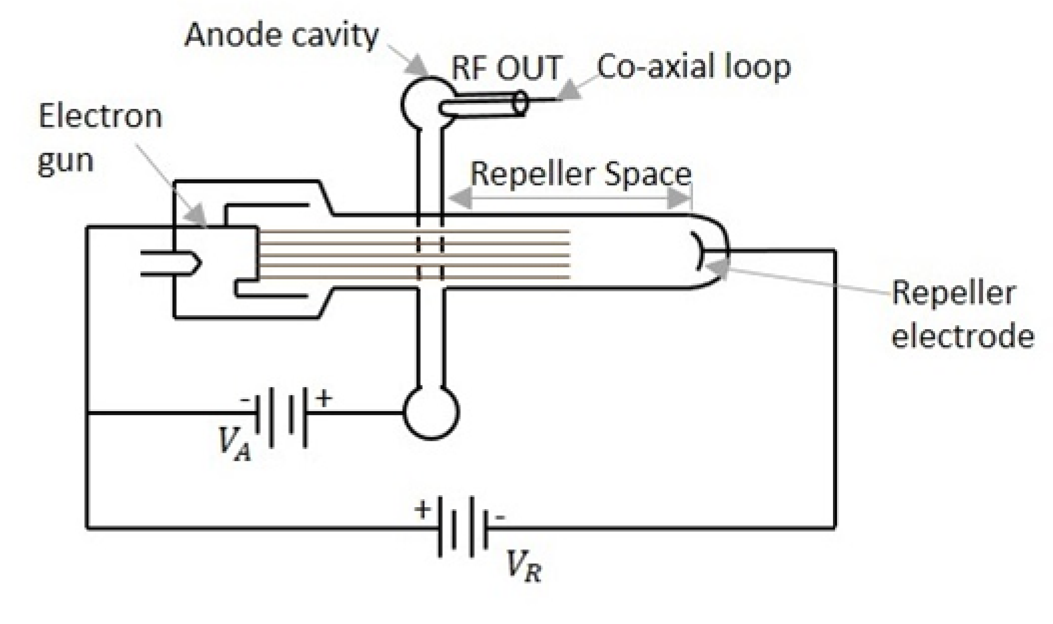
With the signal applied in the first cavity, we get weak bunches in the second cavity. These will set up a field in the third cavity, which produces more concentrated bunches and so on. Hence, the amplification is larger.

This microwave generator, is a Klystron that works on reflections and oscillations in a single cavity, which has a variable frequency.

Reflex Klystron consists of an electron gun, a cathode filament, an anode cavity, and an electrode at the cathode potential. It provides low power and has low efficiency.

Construction of Reflex Klystron

The electron gun emits the electron beam, which passes through the gap in the anode cavity. These electrons travel towards the Repeller electrode, which is at high negative potential. Due to the high negative field, the electrons repel back to the anode cavity. In their return journey, the electrons give more energy to the gap and these oscillations are sustained. The constructional details of this reflex klystron is as shown in the following figure.



Constructional details of Reflex Klystron

It is assumed that oscillations already exist in the tube and they are sustained by its operation. The electrons while passing through the anode cavity, gain some velocity.

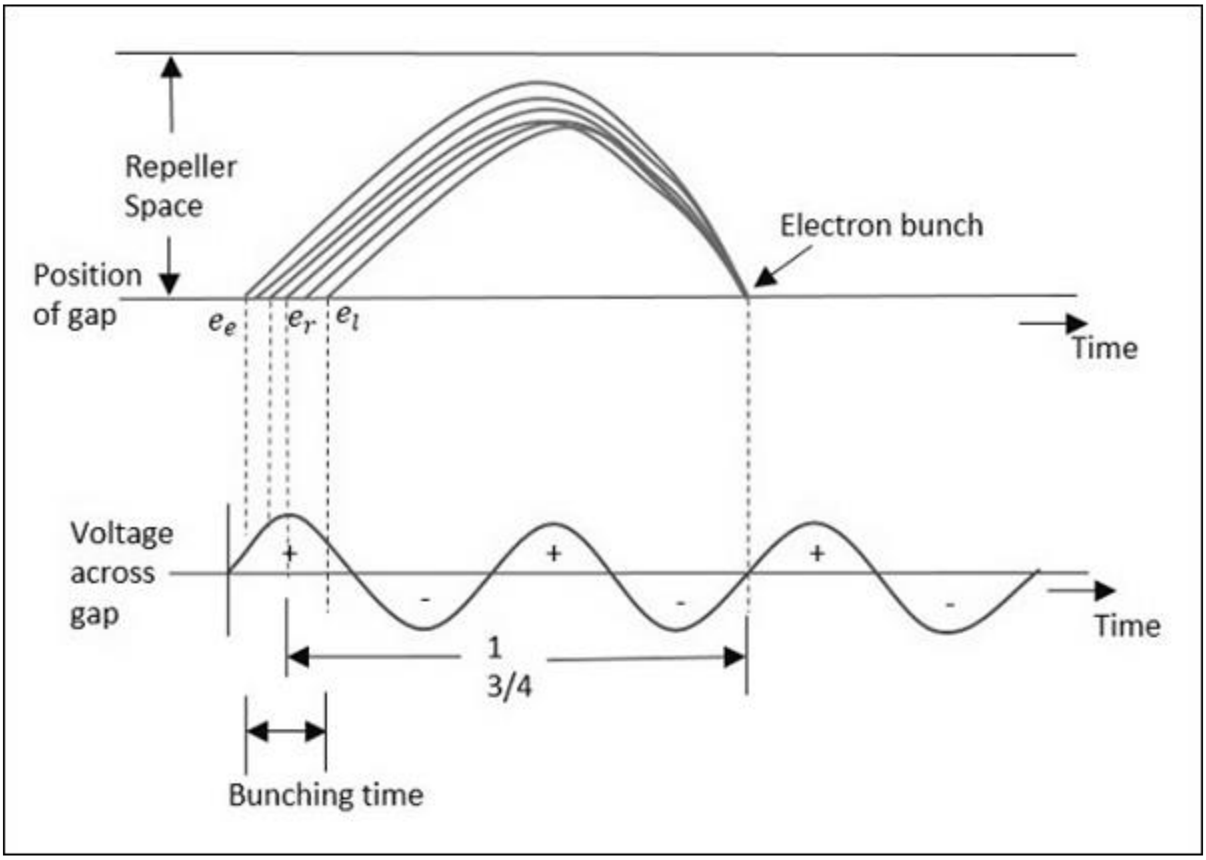
Operation of Reflex Klystron

The operation of Reflex Klystron is understood by some assumptions. The electron beam is accelerated towards the anode cavity.

Let us assume that a reference electron **e_r** crosses the anode cavity but has no extra velocity and it repels back after reaching the Repeller electrode, with the same velocity. Another electron, let's say **e_e** which has started earlier than this reference electron, reaches the Repeller first, but returns slowly, reaching at the same time as the reference electron.

We have another electron, the late electron e_l, which starts later than both e_r and e_e, however, it moves with greater velocity while returning back, reaching at the same time as er and ee.

Now, these three electrons, namely e_r, e_e and e_l reach the gap at the same time, forming an **electron bunch**. This travel time is called as **transit time**, which should have an optimum value. The following figure illustrates this.



The anode cavity accelerates the electrons while going and gains their energy by retarding them during the return journey. When the gap voltage is at maximum positive, this lets the maximum negative electrons to retard.

The optimum transit time is represented as

$$T=n+3/4 \text{where n is an integer}$$

This transit time depends upon the Repeller and anode voltages.

Applications of Reflex Klystron

Reflex Klystron is used in applications where variable frequency is desirable, such as −

- Radio receivers
- Portable microwave links

- Parametric amplifiers
- Local oscillators of microwave receivers
- As a signal source where variable frequency is desirable in microwave generators.

Travelling Wave Tube

Travelling wave tubes are broadband microwave devices which have no cavity resonators like Klystrons. Amplification is done through the prolonged interaction between an electron beam and Radio Frequency RFRF field.

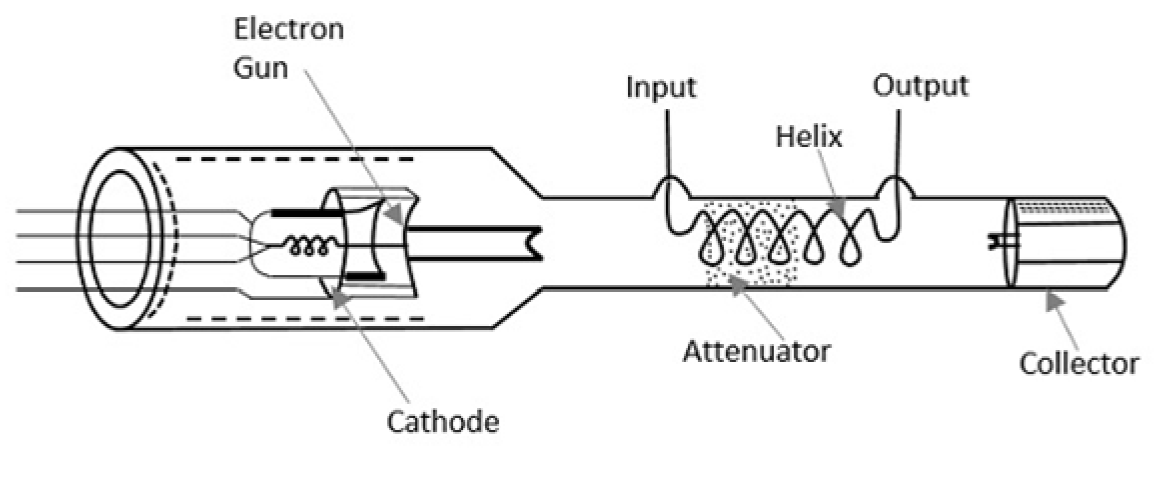
Construction of Travelling Wave Tube

Travelling wave tube is a cylindrical structure which contains an electron gun from a cathode tube. It has anode plates, helix and a collector. RF input is sent to one end of the helix and the output is drawn from the other end of the helix.

An electron gun focusses an electron beam with the velocity of light. A magnetic field guides the beam to focus, without scattering. The RF field also propagates with the velocity of light which is retarded by a helix. Helix acts as a slow wave structure. Applied RF field propagated in helix, produces an electric field at the center of the helix.

The resultant electric field due to applied RF signal, travels with the velocity of light multiplied by the ratio of helix pitch to helix circumference. The velocity of electron beam, travelling through the helix, induces energy to the RF waves on the helix.

The following figure explains the constructional features of a travelling wave tube.

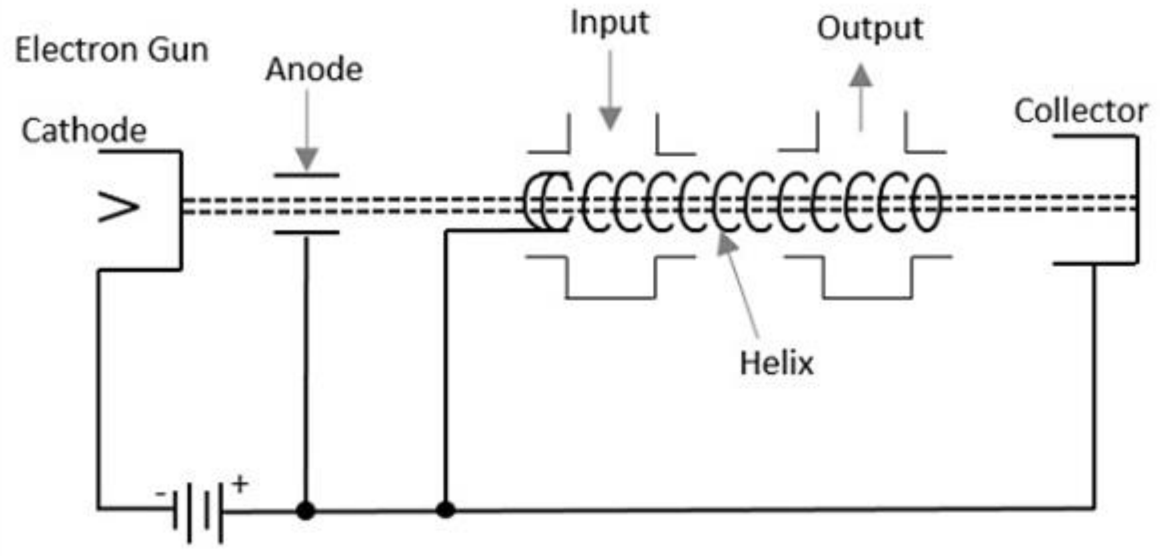


Physical construction of TWT

Thus, the amplified output is obtained at the output of TWT. The axial phase velocity V_pVp is represented as

$$V_p=V_c(Pitch/2\pi r)Vp=Vc(Pitch/2\pi r)$$

Where **r** is the radius of the helix. As the helix provides least change in V_pVp phase velocity, it is preferred over other slow wave structures for TWT. In TWT, the electron gun focuses the electron beam, in the gap between the anode plates, to the helix, which is then collected at the collector. The following figure explains the electrode arrangements in a travelling wave tube.



Schematic Electrode Arrangement in TWT

Operation of Travelling Wave Tube

The anode plates, when at zero potential, which means when the axial electric field is at a node, the electron beam velocity remains unaffected. When the wave on the axial electric field is at positive antinode, the electron from the electron beam moves in the opposite direction. This electron being accelerated, tries to catch up with the late electron, which encounters the node of the RF axial field.

At the point, where the RF axial field is at negative antinode, the electron referred earlier, tries to overtake due to the negative field effect. The electrons receive modulated velocity. As a cumulative result, a second wave is induced in the helix. The output becomes larger than the input and results in amplification.

Applications of Travelling Wave Tube

There are many applications of a travelling wave tube.

- TWT is used in microwave receivers as a low noise RF amplifier.
- TWTs are also used in wide-band communication links and co-axial cables as repeater amplifiers or intermediate amplifiers to amplify low signals.
- TWTs have a long tube life, due to which they are used as power output tubes in communication satellites.

- Continuous wave high power TWTs are used in Troposcatter links, because of large power and large bandwidths, to scatter to large distances.
- TWTs are used in high power pulsed radars and ground based radars.

Microwave Engineering - Magnetrons

Unlike the tubes discussed so far, Magnetrons are the cross-field tubes in which the electric and magnetic fields cross, i.e. run perpendicular to each other. In TWT, it was observed that electrons when made to interact with RF, for a longer time, than in Klystron, resulted in higher efficiency. The same technique is followed in Magnetrons.

Types of Magnetrons

There are three main types of Magnetrons.

Negative Resistance Type

- The negative resistance between two anode segments, is used.
- They have low efficiency.
- They are used at low frequencies $<500MHz$

Cyclotron Frequency Magnetrons

- The synchronism between the electric component and oscillating electrons is considered.
- Useful for frequencies higher than 100MHz.

Travelling Wave or Cavity Type

- The interaction between electrons and rotating EM field is taken into account.
- High peak power oscillations are provided.
- Useful in radar applications.

Cavity Magnetron

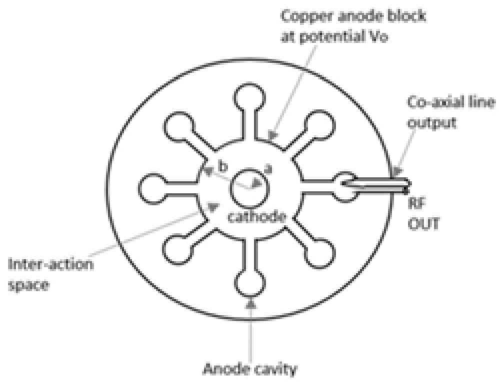
The Magnetron is called as Cavity Magnetron because the anode is made into resonant cavities and a permanent magnet is used to produce a strong magnetic field, where the action of both of these make the device work.

Construction of Cavity Magnetron

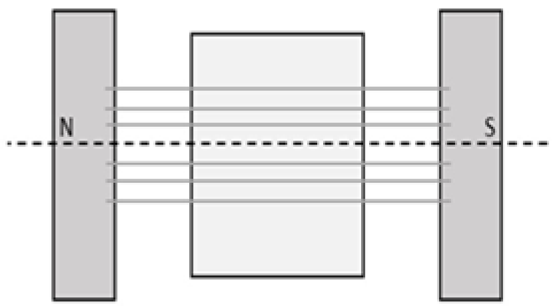
A thick cylindrical cathode is present at the center and a cylindrical block of copper, is fixed axially, which acts as an anode. This anode block is made of a number of slots that acts as resonant anode cavities.

The space present between the anode and cathode is called as **Interaction space**. The electric field is present radially while the magnetic field is present axially in the cavity magnetron. This magnetic field is produced by a permanent magnet, which is placed such that the magnetic lines are parallel to cathode and perpendicular to the electric field present between the anode and the cathode.

The following figures show the constructional details of a cavity magnetron and the magnetic lines of flux present, axially.



Construction details of a Cavity Magnetron



Magnetic flux lines in Magnetron (axial)

This Cavity Magnetron has 8 cavities tightly coupled to each other. An N-cavity magnetron has N modes of operations. These operations depend upon the frequency and the phase of oscillations. The total phase shift around the ring of this cavity resonators should be $2n\pi$ where n is an integer.

If ϕ_v represents the relative phase change of the AC electric field across adjacent cavities, then

$$\phi_v = 2\pi n/N$$

Where $n = 0, \pm 1, \pm 2, \pm(N/2 - 1), \pm N/2$

Which means that $N/2$ mode of resonance can exist if N is an even number.

If,

$$n = N/2 \quad \text{then} \quad \phi_v = \pi$$

This mode of resonance is called as π−mode

$$n = 0 \text{ then } \phi_v = 0$$

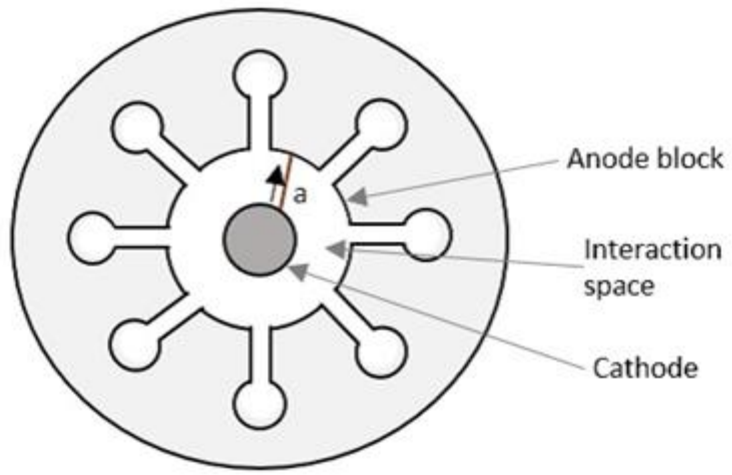
This is called as the **Zero mode**, because there will be no RF electric field between the anode and the cathode. This is also called as **Fringing Field** and this mode is not used in magnetrons.

Operation of Cavity Magnetron

When the Cavity Klystron is under operation, we have different cases to consider. Let us go through them in detail.

Case 1

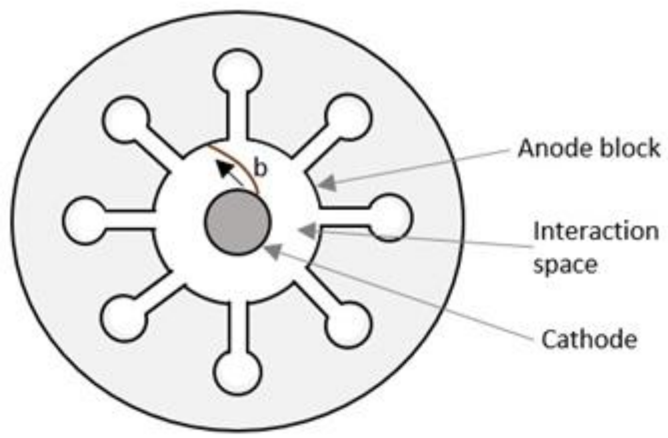
If the magnetic field is absent, i.e. B = 0, then the behavior of electrons can be observed in the following figure. Considering an example, where electron **a** directly goes to anode under radial electric force.



Movement of electron **a**, when no magnetic field is present

Case 2

If there is an increase in the magnetic field, a lateral force acts on the electrons. This can be observed in the following figure, considering electron **b** which takes a curved path, while both forces are acting on it.



Movement of electron **b** when small magnetic field is present

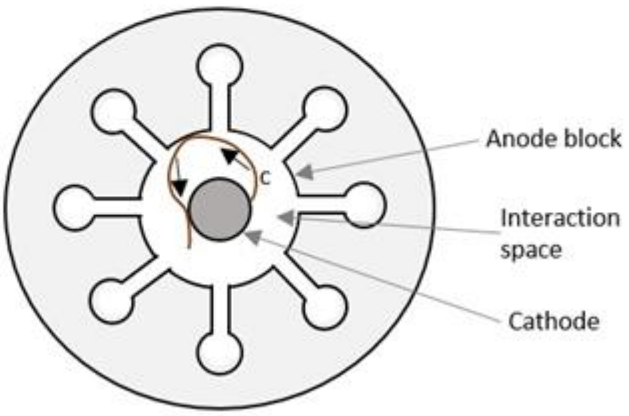
Radius of this path is calculated as

$$R=mv/(eB)$$

It varies proportionally with the velocity of the electron and it is inversely proportional to the magnetic field strength.

Case 3

If the magnetic field **B** is further increased, the electron follows a path such as the electron **c**, just grazing the anode surface and making the anode current zero. This is called as "**Critical magnetic field**" (B_c), which is the cut-off magnetic field. Refer the following figure for better understanding.



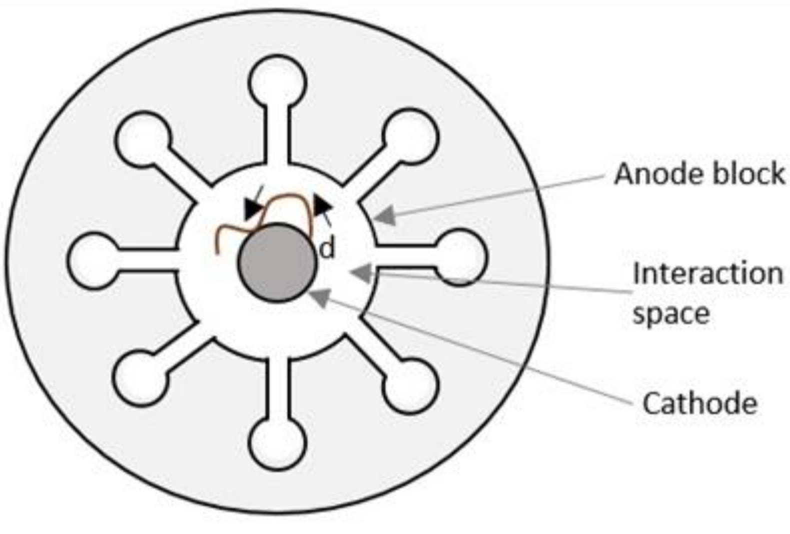
Movement of electron **c** when the magnetic field is critical magnetic field i.e. $B = B_c$

Case 4

If the magnetic field is made greater than the critical field,

$$B > B_c$$

Then the electrons follow a path as electron **d**, where the electron jumps back to the cathode, without going to the anode. This causes "**back heating**" of the cathode. Refer the following figure.



Movement of electron **d** when excessive magnetic field is present

This is achieved by cutting off the electric supply once the oscillation begins. If this is continued, the emitting efficiency of the cathode gets affected.

Operation of Cavity Magnetron with Active RF Field

We have discussed so far the operation of cavity magnetron where the RF field is absent in the cavities of the magnetron static case. Let us now discuss its operation when we have an active RF field.

As in TWT, let us assume that initial RF oscillations are present, due to some noise transient. The oscillations are sustained by the operation of the device. There are three kinds of electrons emitted in this process, whose actions are understood as electrons **a**, **b** and **c**, in three different cases.

Case 1

When oscillations are present, an electron **a**, slows down transferring energy to oscillate. Such electrons that transfer their energy to the oscillations are called as **favored electrons**. These electrons are responsible for **bunching effect**.

Case 2

In this case, another electron, say **b**, takes energy from the oscillations and increases its velocity. As and when this is done,

- It bends more sharply.
- It spends little time in interaction space.
- It returns to the cathode.

These electrons are called as **unfavored electrons**. They don't participate in the bunching effect. Also, these electrons are harmful as they cause "back heating".

Case 3

In this case, electron **c**, which is emitted a little later, moves faster. It tries to catch up with electron **a**. The next emitted electron **d**, tries to step with **a**. As a result, the favored electrons **a**, **c** and **d** form electron bunches or electron clouds. It called as "Phase focusing effect".

This whole process is understood better by taking a look at the following figure.

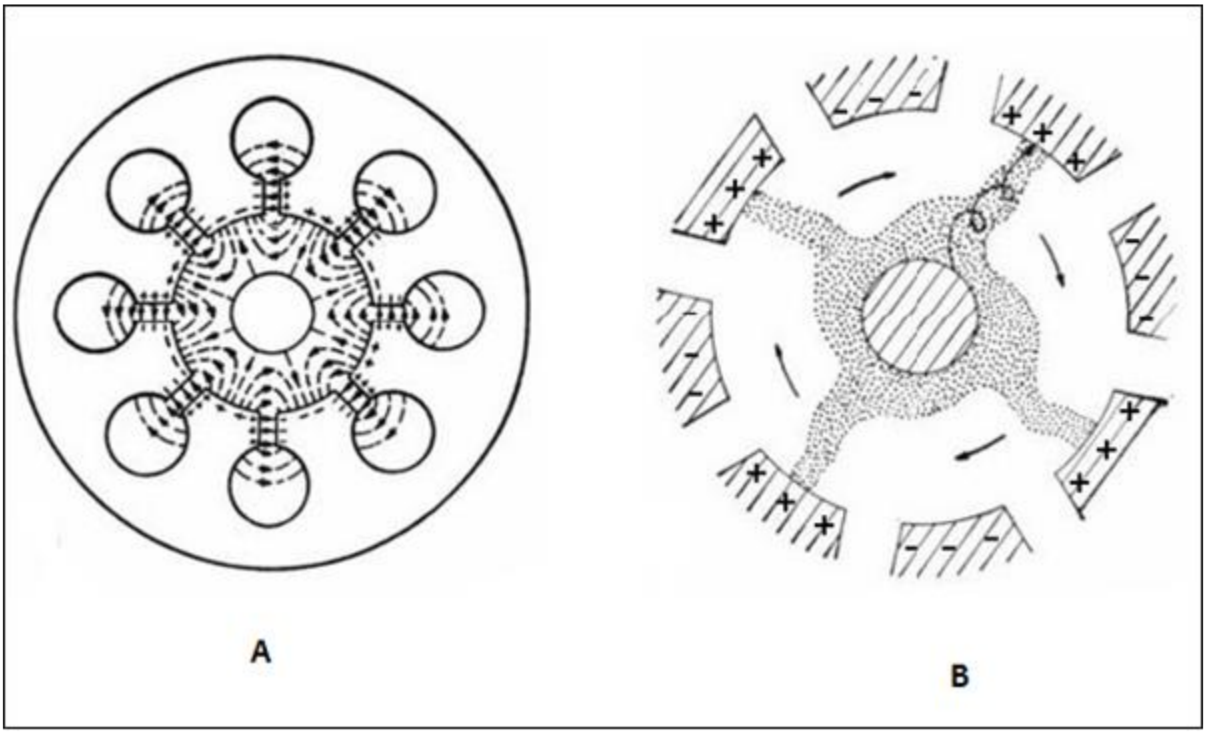


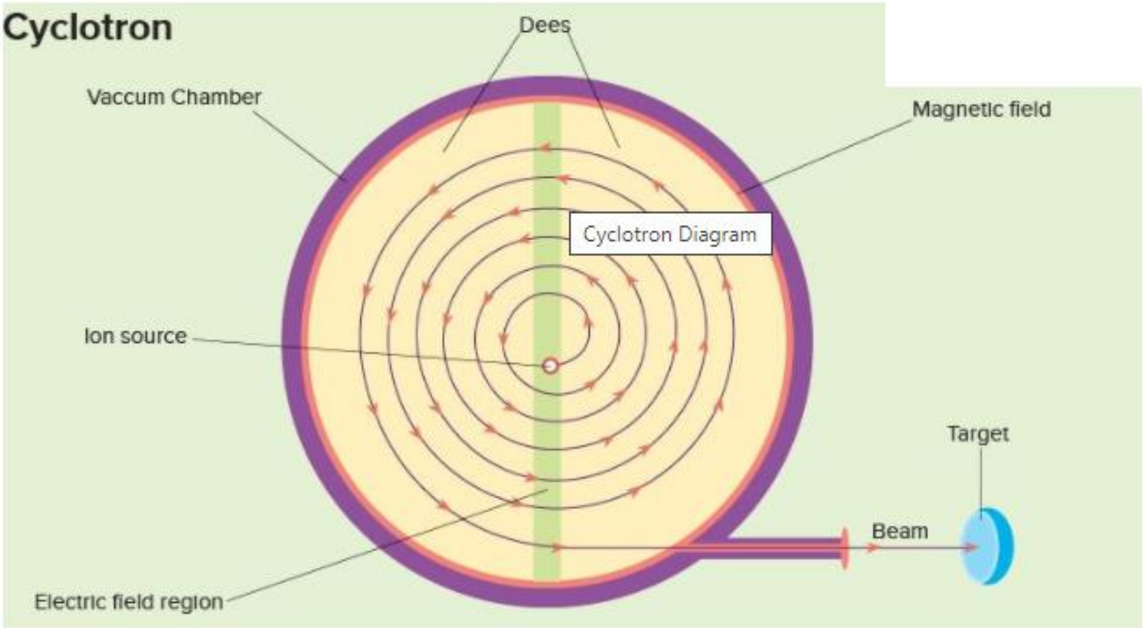
Figure A shows the electron movements in different cases while figure B shows the electron clouds formed. These electron clouds occur while the device is in operation. The charges present on the internal surface of these anode segments, follow the oscillations in the cavities. This creates an electric field rotating clockwise, which can be actually seen while performing a practical experiment.

While the electric field is rotating, the magnetic flux lines are formed in parallel to the cathode, under whose combined effect, the electron bunches are formed with four spokes, directed in regular intervals, to the nearest positive anode segment, in spiral trajectories.

What is Cyclotron?

A cyclotron is a machine that accelerates charged particles or ions to high energies. It was invented to investigate the nuclear structure by E.O Lawrence and M.S Livingston in 1934. Both electric and magnetic fields are used in the cyclotron to increase the energy of the charged particles. As both the fields are perpendicular to each other, they are called cross fields.

In a cyclotron, charged particles accelerate outwards from the centre along a spiral path. These particles are held to a spiral trajectory by a static magnetic field and accelerated by a rapidly varying electric field.



Working Principle of Cyclotron

A cyclotron accelerates a charged particle beam using a high frequency alternating voltage which is applied between two hollow “D”-shaped sheet metal electrodes known as the “dees” inside a vacuum chamber.

The dees are placed face to face with a narrow gap between them, creating a cylindrical space within them for particles to move. Particles are injected into the center of this space.

Dees are located between the poles of electromagnet which applies a static magnetic field B perpendicular to the electrode plane.

The magnetic field causes the path of the particle to bend in a circle due to the Lorentz force perpendicular to their direction of motion.

An alternating voltage of several thousand volts are applied between the dees. The voltage creates an oscillating electric field in the gap between the dees that accelerates the particles.

The frequency of the voltage is set so that particles make one circuit during a single cycle of the voltage. To achieve this condition, the frequency must be set to particle’s cyclotron frequency.

Expression for Cyclotron Frequency

Expression for Cyclotron Frequency

> $$f = \frac{qB}{2\pi m}$$

B is the magnetic field strength
q is the electric charge of the particle
m is the relativistic mass of the charged particle

Expression for Particle Energy

The energy of the particles depends on the strength of the magnetic field and the diameter of the dees.

The centripetal force required to keep the particles in a curved path is given by the formula:

$$F_c = \frac{mv^2}{r}$$

The force is provided by the Lorentz's force F_B on the magnetic field B

$$F_B = qvB$$

Equating these equations, we get

$$\frac{mv^2}{r} = qvB$$

$$v = \frac{qBR}{m}$$

Hence, the output energy of the particles is given by the expression

$$E = \frac{q^2B^2R^2}{2m}$$

Uses of Cyclotron

For several decades, these were the best sources of high-energy beams for nuclear physics experiments. However, these are still in use for this type of research.

Treatment of cancer:

Cyclotrons can be used in particle therapy to treat cancer, using the ion beams from cyclotrons can be used to penetrate the body and kill tumours by radiation damage.

limitations to Cyclotron

Cyclotron cannot accelerate electrons because electrons are of very small mass.

A cyclotron cannot be used to accelerate neutral particles.

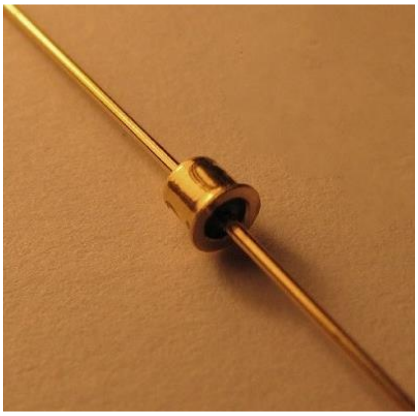
It cannot accelerate positively charged particles with large mass due to the relativistic effect.

The oscillator circuit that is built using a tunnel diode is called as a Tunnel diode oscillator. If the impurity concentration of a normal PN junction is highly increased, this **Tunnel diode** is formed. It is also known as **Esaki diode**, after its inventor.

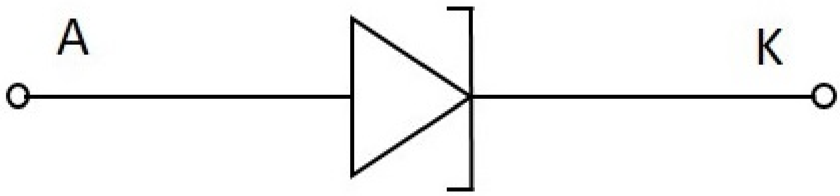
Tunnel Diode

When the impurity concentration in a diode increases, the width of depletion region decreases, extending some extra force to the charge carriers to cross the junction. When this concentration is further increased, due to less width of the depletion region and the increased energy of the charge carriers, they penetrate through the potential barrier, instead of climbing over it. This penetration can be understood as **Tunneling** and hence the name, **Tunnel diode**.

The following image shows how a practical tunnel diode looks like.



The symbols of tunnel diode are as shown below.



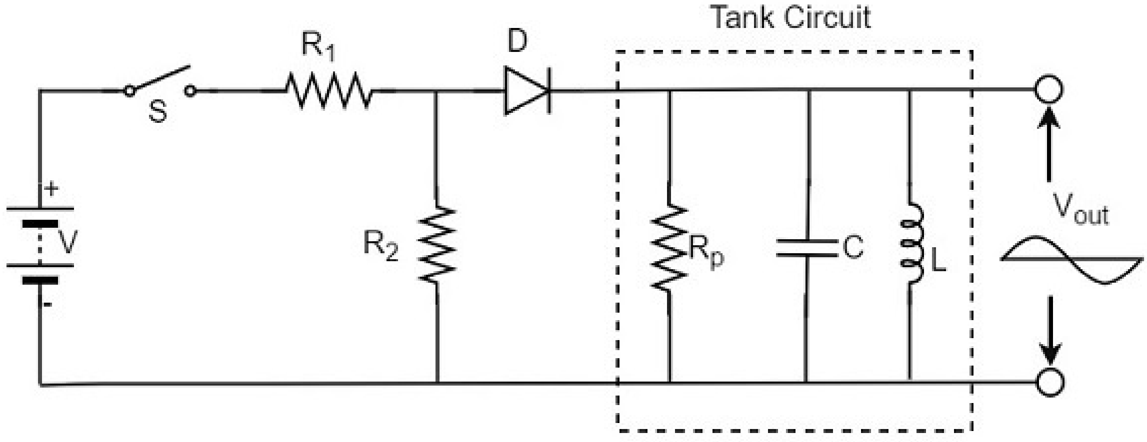
Symbol of Tunnel diode

Tunnel Diode Oscillator

The tunnel diode helps in generating a very high frequency signal of nearly 10GHz. A practical tunnel diode circuit may consist of a switch S, a resistor R and a supply source V, connected to a tank circuit through a tunnel diode D.

Working

The value of resistor selected should be in such a way that it biases the tunnel diode in the midway of the negative resistance region. The figure below shows the practical tunnel diode oscillator circuit.



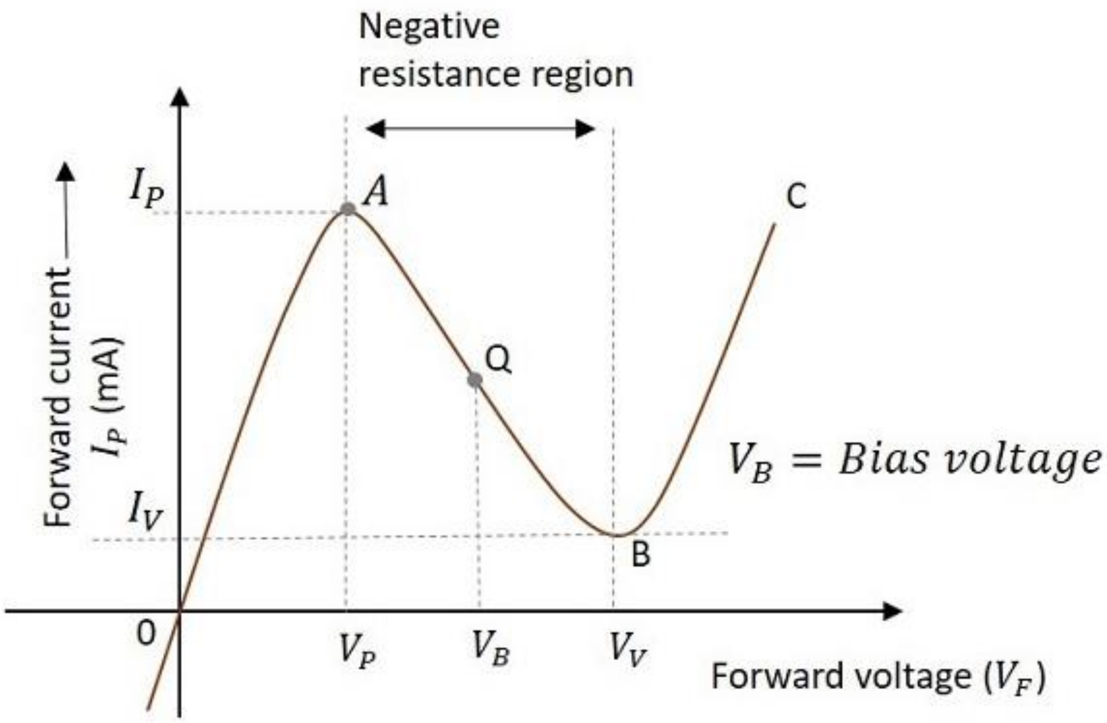
In this circuit, the resistor R_1 sets proper biasing for the diode and the resistor R_2 sets proper current level for the tank circuit. The parallel combination of resistor R_p inductor L and capacitor C form a tank circuit, which resonates at the selected frequency.

When the switch S is closed, the circuit current rises immediately towards the constant value, whose value is determined by the value of resistor R and the diode resistance. However, as the voltage drop across the tunnel diode V_D exceeds the peak-point voltage V_p, the tunnel diode is driven into negative resistance region.

In this region, the current starts decreasing, till the voltage V_D becomes equal to the valleypoint voltage V_v. At this point, a further increase in the voltage V_D drives the diode into positive resistance region. As a result of this, the circuit current tends to increase. This increase in circuit will increase the voltage drop across the resistor R which will reduce the voltage V_D.

V-I characteristic curve

The following graph shows the V-I characteristics of a tunnel diode −



The curve AB indicates the negative resistance region as the resistance decreases while the voltage increases. It is clear that the Q-point is set at the middle of the curve AB. The Q-point can move between the points A and B during the circuit operation. The point A is called **peak point** and the point B is called **valley point**.

During the operation, after reaching the point B, the increase in circuit current will increase the voltage drop across the resistor R which will reduce the voltage V_D. This brings the diode back into negative resistance region.

The decrease in voltage V_D is equal to the voltage V_P and this completes one cycle of operation. The continuation of these cycles produces continuous oscillations which give a sinusoidal output.

Advantages

The advantages of a tunnel diode oscillator are as follows −

- It has high switching speeds.
- It can handle high frequencies.

Disadvantages

The disadvantages of a tunnel diode oscillator are as follows −

- They are low power devices.
- Tunnel diodes are a bit costly.

Applications

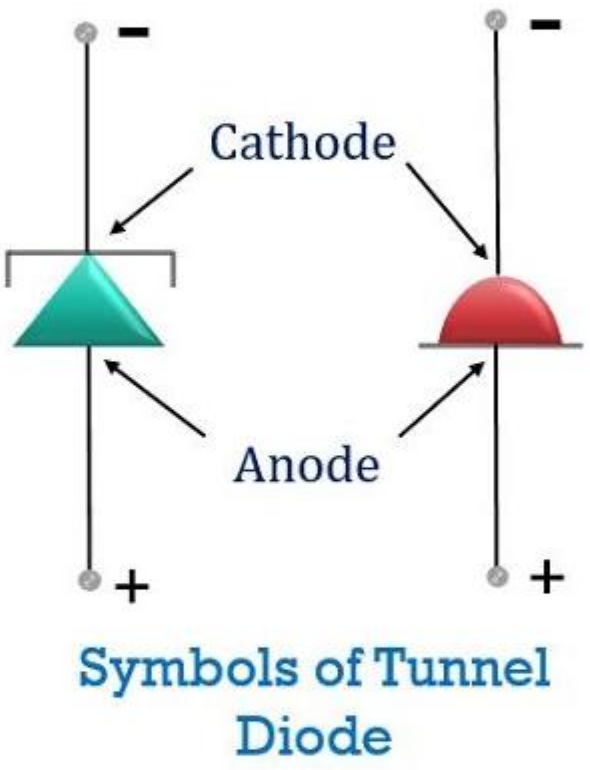
The applications of a tunnel diode oscillator are as follows −

- It is used in relaxation oscillators.
- It is used in microwave oscillators.
- It is also used as Ultra high speed switching device.
- It is used as logic memory storage device.

Tunnel Diode

Definition: A heavily doped two-terminal semiconductor device through which electric current flows because of tunneling (or tunnelling) of electrons is known as Tunnel Diode. It possesses the negative resistance characteristic in which current decreases even when the applied voltage is increased.
Tunneling basically denotes the penetration of electrons through the depletion region. As highly doped diode has a thin depletion region. It works on the principle of **Quantum mechanical tunneling**. As tunnel diodes show fast switching characteristics thus it finds extensive applications in the field of the microwave.
Symbol of Tunnel diode

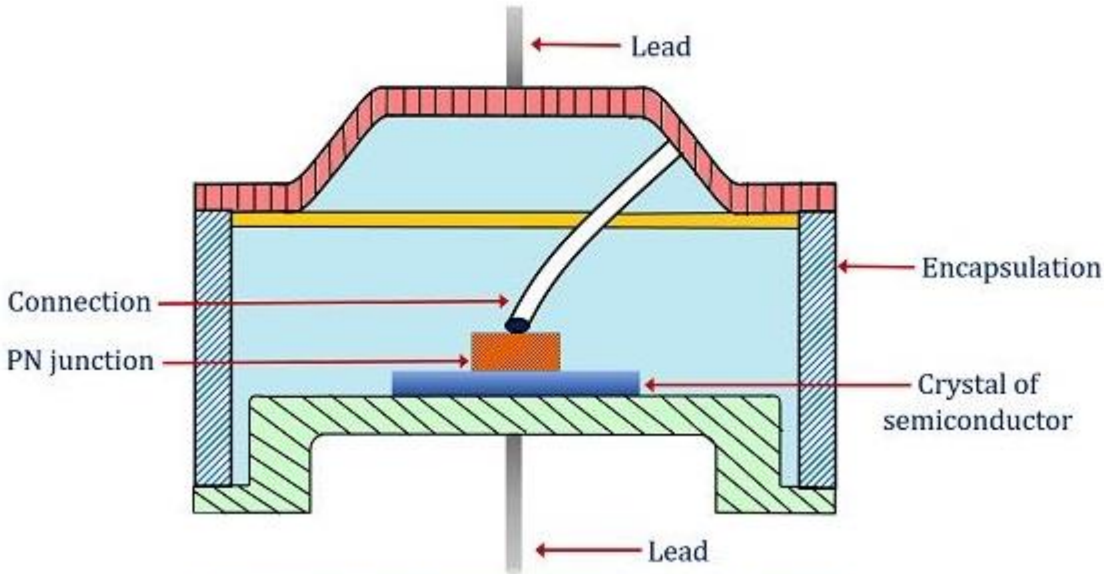
The symbolic representation of tunnel diode is shown below:



Construction of Tunnel Diode

The basic manufacturing material of a tunnel diode is germanium, gallium arsenide or gallium antimonide. It is not formed using silicon as its basic material. This is so because the ratio of maximal value of forward current to valley current in case of silicon is very low. However, gallium arsenide has the maximum value of this ratio thus is widely used.

The structural representation of tunnel diode is shown below:



Constructional structure of Tunnel diode

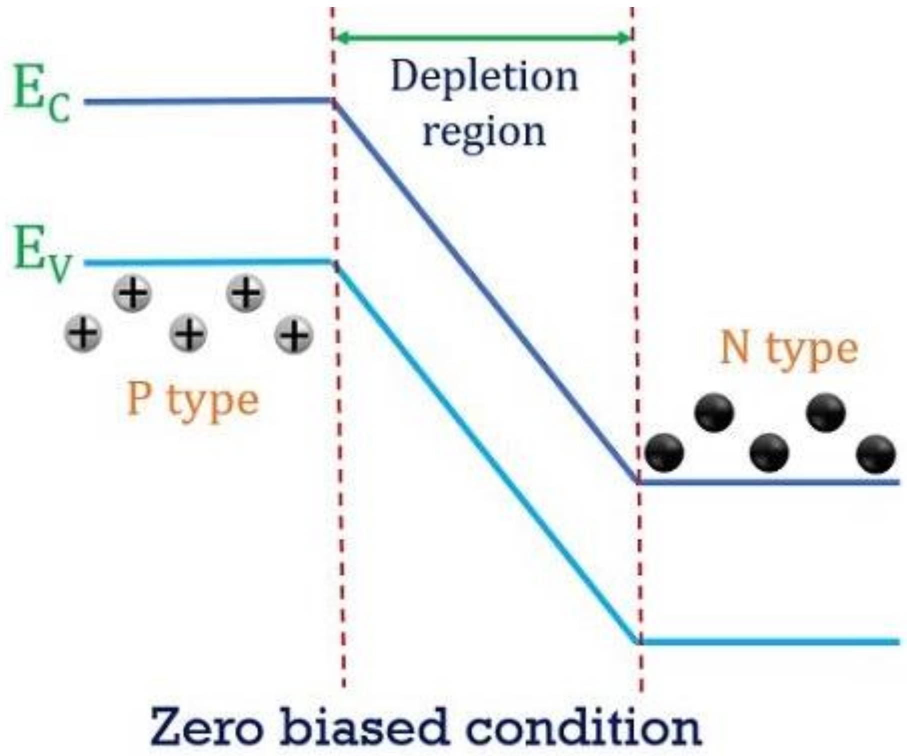
In the tunnel diode, the doping concentration is very high. The concentration of doped impurity in a tunnel diode is **thousand times** more as compared to any normal diode. This is done so as to have thin depletion region, that is the basis of tunneling effect.
This diode was invented by **Dr Leo Esaki in 1957**. Hence it is also known as **Esaki Diode**.

Working principle of Tunnel Diode

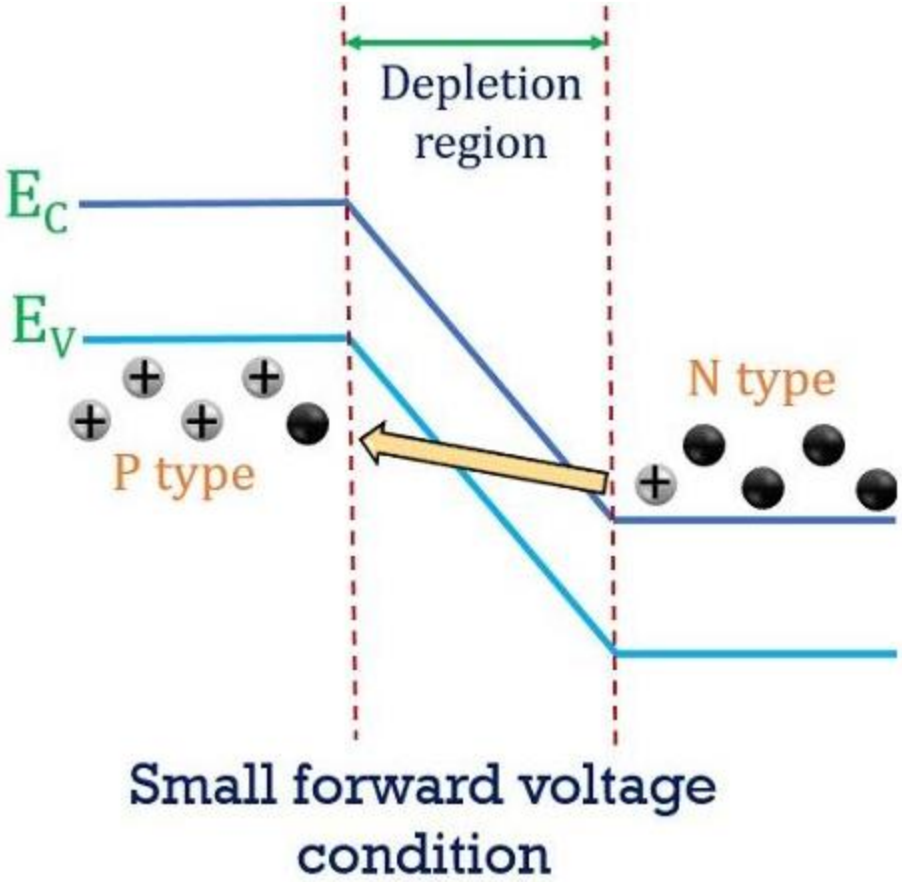
The doping concentration in case of tunnel diode is very high. Due to this, the reduced width of the depletion region causes the penetration of charge carriers across the junction even when the carriers do not have enough energy to jump across it.

Let us understand the working of a tunnel diode by considering some conditions.

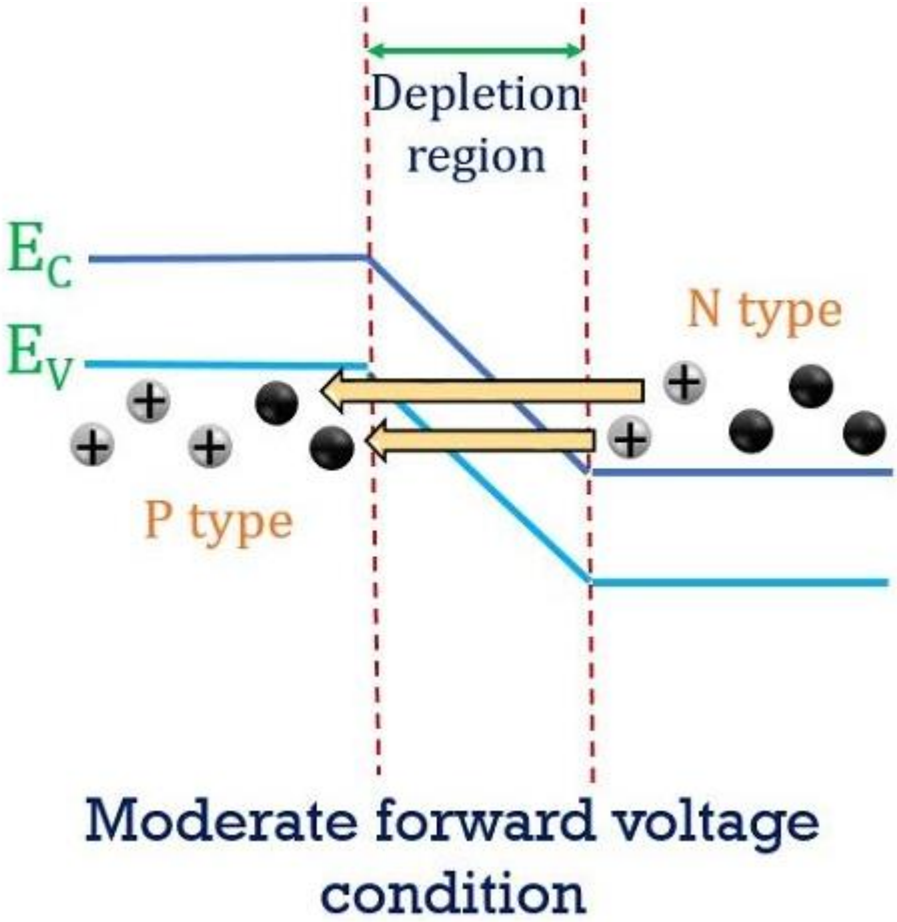
1. In a zero biased condition, the highly doped diode is not provided with any input voltage. So, in no biased condition, an overlapping is noticed between the conduction band of n region and valence band of p region.



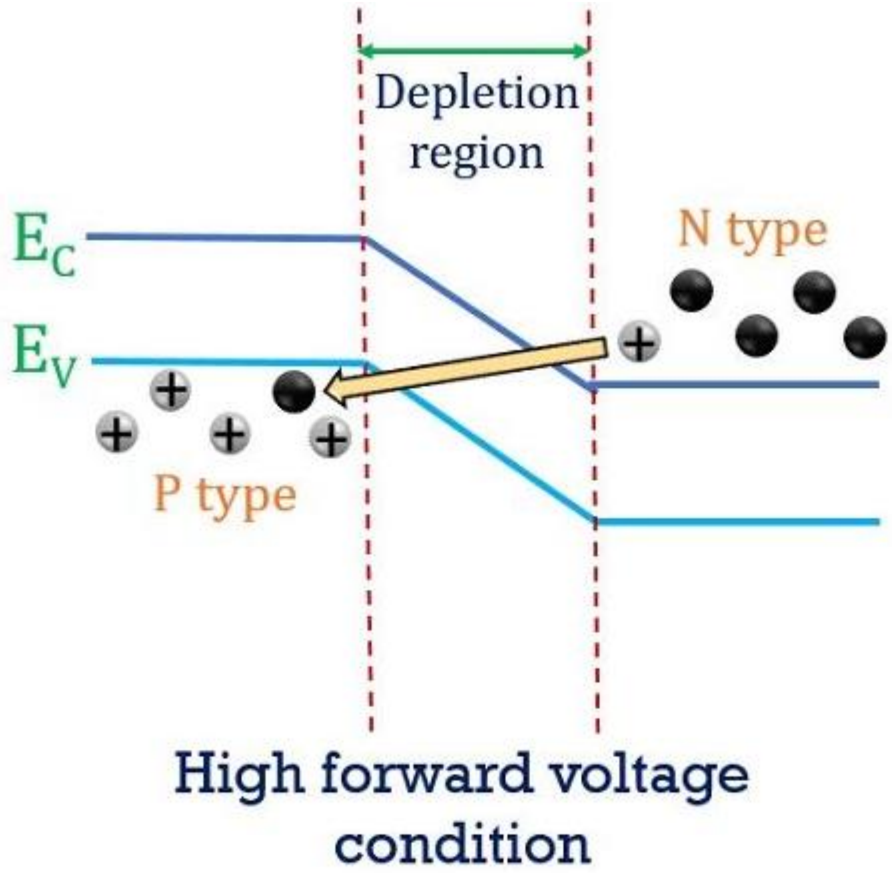
1. This overlapping causes the two bands to appear at the almost same energy level. As the depletion width is very small thus, without any applied potential, due to temperature variation, electrons from n side tunnels to p side.
   Similarly, holes from p side tunnels to n side.
   As the tunneling is equal for both the carriers thus **no current is noticed in case of zero biased condition**.
2. Now, when a certain forward voltage is applied to the diode, no any current will flow due to this applied potential. As this forward voltage is less than the barrier potential of the depletion region.



1. But, still, a small current flows through the device. This is so, because, the electrons in the conduction band of n region will penetrate over thin depletion region and reaches valence band of p region.
   The velocity of punching of these electrons is somewhat similar to the velocity of light. Hence, this **punching generates a forward current through the device**.
2. Now, when the applied forward voltage is increased further. So, in this case, a large current starts to flow through the device. The electrons that have sufficient energy moves across the junction. But those which has less energy will also penetrate the junction due to thin depletion width.



1. In this case, more electrons tunnel through the junction to reach p region. This is so because now, the conduction band of n region is parallel with the valence band of p region. Thus, the **highest (peak) current is achieved in this condition**.
2. If the forward potential applied to the device is increased further. Then the conduction band and valence band shows some overlapping. This causes a small current to flow through the device. However, here with the increased potential current through the device now starts decreasing.

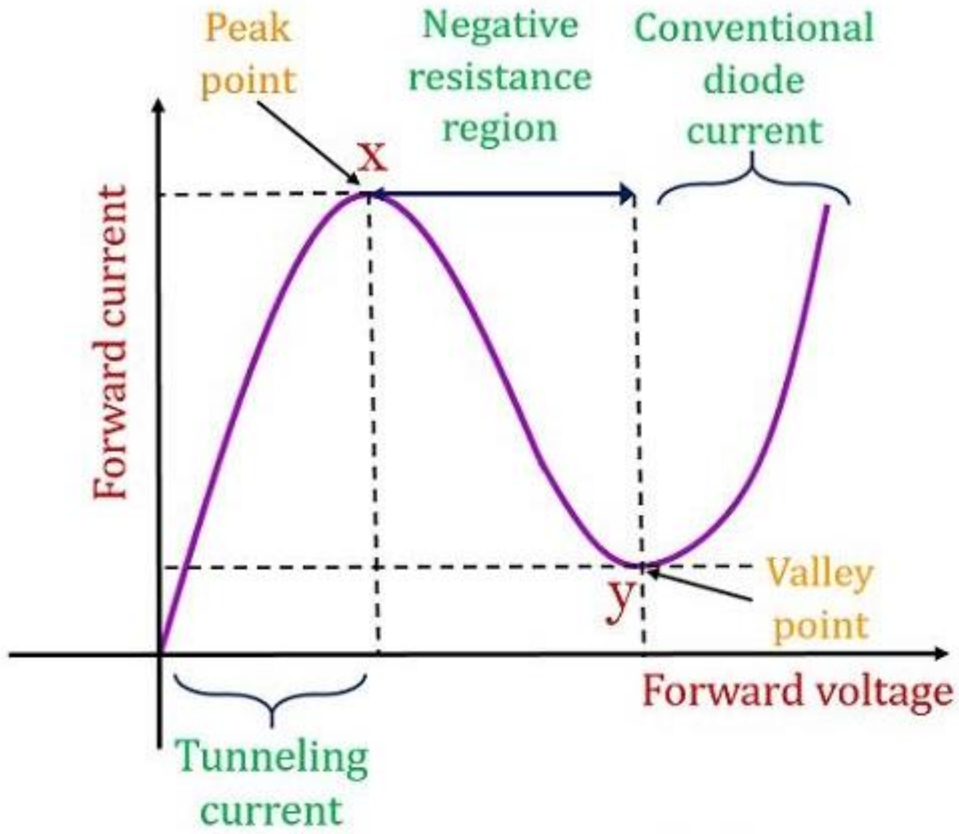


1. After this, the applied potential is increased further. But now this applied voltage will cause the current through the device to reach nearly zero. As the conduction and valence are no longer forming an overlap connection. But, the applied potential will now overcome the barrier potential of the depletion region. So, current as in case of the normal diode will flow through the tunnel diode also.

This is how a tunnel diode works.

Characteristics of Tunnel Diode

The figure below represents the VI characteristics of a tunnel diode:



V-I Characteristics of Tunnel Diode

Here we can see the origin of the graph shows the zero biased condition of the tunnel diode. Where no any input voltage is provided and so no current is noticed in the device. As the input voltage is increased, the current is noticed to flow through the device. This current increases with the increase in the voltage applied and a peak of forward current is reached. This is clearly represented by point **x** in the above figure.
As we discussed already that after reaching the maximum value, the current now starts decreasing. This region of the decrease in current in the graph is specifically termed as a **negative resistance region**. After this region valley point is achieved which shows the decrement of the current nearly up to zero.
But, as the potential has increased the device now starts behaving as normal junction diode. Thus, the current begins to increase from this particular point.

Advantages of Tunnel Diode

1. It is a low power consuming device.
2. It is not expensive.
3. A tunnel diode is easy to operate and provides high-speed operation.

Disadvantages of Tunnel Diode

1. The abrupt change in load current with applied voltage is sometimes treated as its drawback.
2. Proper isolation between input and output is not maintained as it is a two terminal device.

Applications of Tunnel Diode

It is widely used in microwave and high-frequency applications because of its fast response. It can be also used as amplifiers and in oscillator circuits.

Key terms related to Tunnel Diode

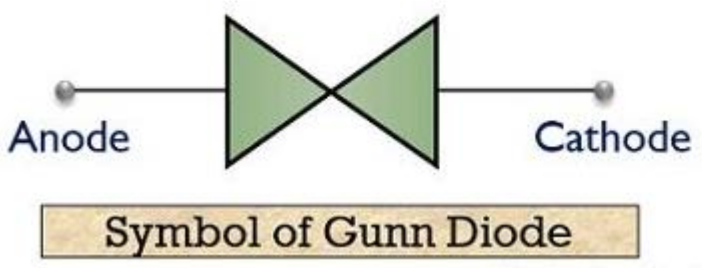
Tunneling current: It is the current flowing through the device due to the punching of electrons across the junction. The thin depletion width allows some free electrons to tunnel the junction rather than jumping over it. This penetration of electrons generates a current known as Tunneling current.
Negative resistance characteristics: The negative resistance characteristic is the special ability of tunnel diode in which current represents fall even when the voltage provided to it rises.
Valley current: When tunneling reaches its minimum value with the increase in forward potential. Then the lowest value of tunneling current is the valley point of the device.
So, we can conclude that the device possesses conduction initially due to quantum mechanics. After reaching some specified large forward potential the tunnel diode begins to behave like a normal diode.

Gunn Diode

Definition: A Gunn diode is a semiconductor device formed by only N-type material. It is also termed as a **transferred electron device**. As in n-type material, electrons acts as majority carriers and these are transferred from one valley to another.
It is a two terminal device basically made up of semiconductor material like **GaAs**, **InP** etc. As these materials exhibit the property of producing microwave oscillations.

Gunn effect is the basis of working of Gunn diode. It was discovered by a physicist **J B Gunn in 1963**.
A Gunn diode does not contain a pn junction yet it is termed as diode due to the two terminals of the externally applied dc voltage. It possesses negative resistance characteristic due to which these are widely used in high-frequency applications.

Gunn diodes have the ability to generate continuous power in the range of several milliwatts, and frequency nearly **1 to 200 GHz** holding efficiency about **5 to 15%**.
The figure below shows the symbolic representation of Gunn diode:



What is Gunn Effect?

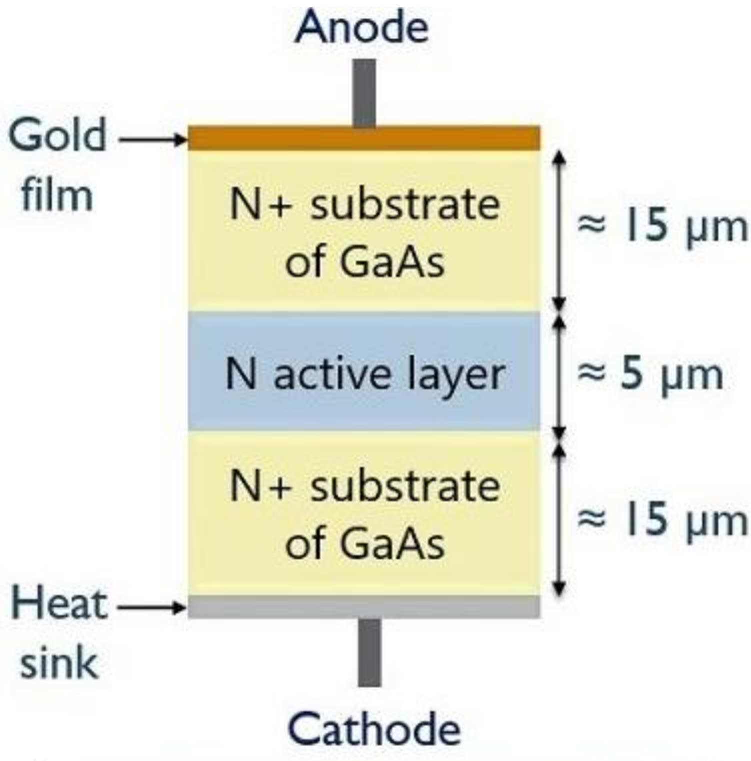
In semiconductor materials like GaAs, the electrons are present in high mass low-velocity state and low mass but a high-velocity state. By the application of sufficient electric field, these low mass high-velocity state electrons are forced towards the high mass state.

At this particular state, electrons form a cluster and thus moves at a uniform rate. Thus causing a flow of current in the form of a series of pulses.

This is termed as **Gunn effect** and is utilized by Gunn diodes, hence, named so.

Construction of Gunn diode

We have already discussed that a Gunn diode is not a pn junction diode as it is composed of only n-type semiconductor material. The figure below represents the constructional structure of a Gunn diode:



Structure of Gunn Diode

Here, a lightly doped n-type semiconductor layer is present between two heavily doped n-type material. The middle portion is termed as an active layer. The thickness of this region is around a few microns to several hundred microns.

The arrangement of Gunn diode is formed by growing an epitaxial n-type layer over an n+ substrate. The 2 highly doped regions provide better conductivity to the device.

The whole structure is mounted on a conducting base that acts as a heat sink for the heat produced during operation. Also, the other terminal is formed by connecting a gold film over the top surface of the structure.

Working of Gunn Diode

When a voltage is applied to the device, then this external potential appears across the active layer thereby causing the flow of electrons present in that region. This flow of majority carriers causes the current to flow across the active region of the device.

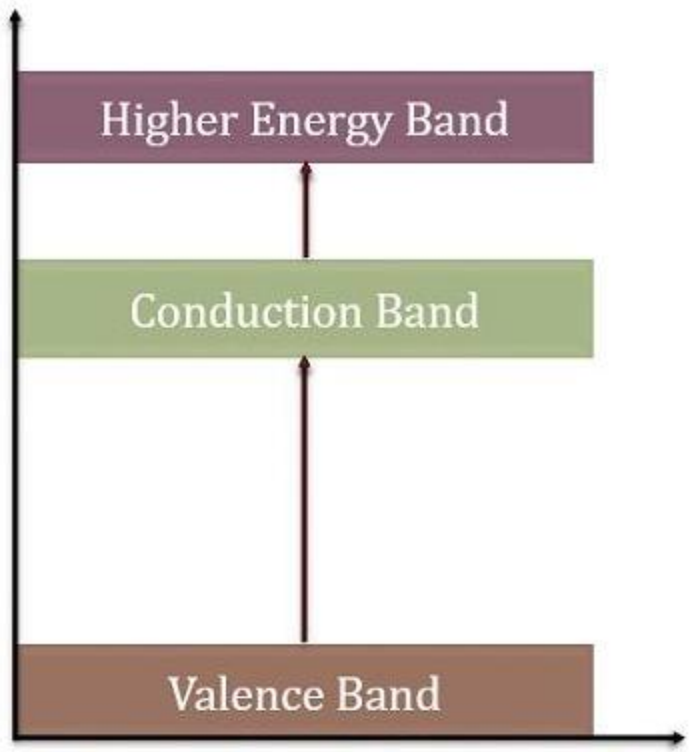
Once the current pulse starts traversing inside the active region, the potential at that region falls. Due to which no further formation of the current pulse occurs.

But once the previously created current pulse reaches the other end of the active region then the potential again rises leading to the generation of another current pulse.

Thus, the frequency of operation of the device depends on the time taken by the pulse to travel to another end, resultantly on the rate of pulse generation.

Unlike a normal junction diode, a Gunn diode consists of 3 energy bands namely, valence band, conduction band and an extra band above the conduction band.

The figure below represents the energy level structure of the gallium arsenide:



Energy level diagram of Gunn Diode

When a certain voltage is applied to the device then electrons in the valence band starts moving towards the conduction band thereby allowing the flow of current.

But when the voltage further increases then instead of allowing a large flow of current the electrons in the conduction band move towards the energy band present above the conduction band.

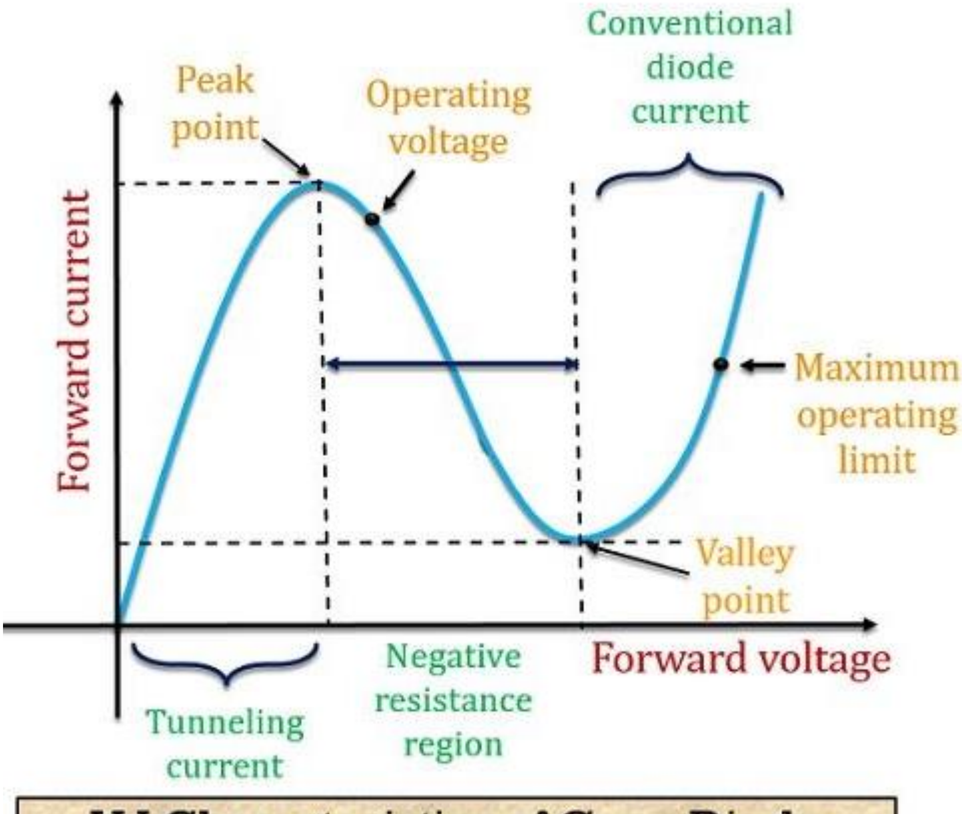
Due to this the effect is known as the transferred electron effect. This is so because electrons are transferred from conduction band to a higher energy state.

At this particular state as the electrons are less mobile hence current decreases with the increase in voltage. Thereby, giving rise to a negative resistance phenomenon where current decreases with the increase in voltage.

After a certain point of time when the applied voltage increases further then the electrons in the higher energy state gains sufficient energy and moves back to the lower energy state. Thus, further the current flowing through the device increase with the increase in the applied external potential.

Characteristic curve of Gunn Diode

The figure below shows the characteristic curve of a Gunn diode:



V-I Characteristics of Gunn Diode

Initially, with the increase in the applied voltage, the current through the device also increases.

However, a point is reached when on increasing the voltage the current through the device starts decreasing. The point of maximum current is known as the **peak point**.
The region on the curve that shows the decrease in current with an increase in voltage is known as the negative resistance region of the curve.

The negative resistance characteristic is also exhibited by a tunnel diode but the two show variation in their operating manner.

Advantages of Gunn Diode

- The manufacturing cost of gunn diode is low.
- Gunn diodes are highly reliable.
- It exhibits comparatively low operating voltage than normal diodes.
- Its installation in circuits is easy.

Disadvantages of Gunn Diode

- These are less stable.
- The efficiency of gunn diodes is very low.
- Sometimes noise effects are more in case of gunn diodes.

Applications of Gunn Diodes

Gunn diodes find their applications in oscillators and amplifiers, in ultrasonic detectors. These are also used in tachometers and in the radio communication system.

Broadband Communication

Fixed Broadband:

Fixed broadband refers to those technologies where the end user must remain at the same location to use the broadband service.

Access network is associated with the specific physical location.

Fixed broadband can be provided by wireline , wireless or satellite technologies.

Wireline Fixed Broadband

Wireline fixed broadband service can be received in many ways as well.

1. DSL Fixed Wireline Broadband

Traditional xDSL (ADSL, VDSL etc.) service is one way of having fixed wireline broadband service. Today in many continent most common access network technology is DSL.

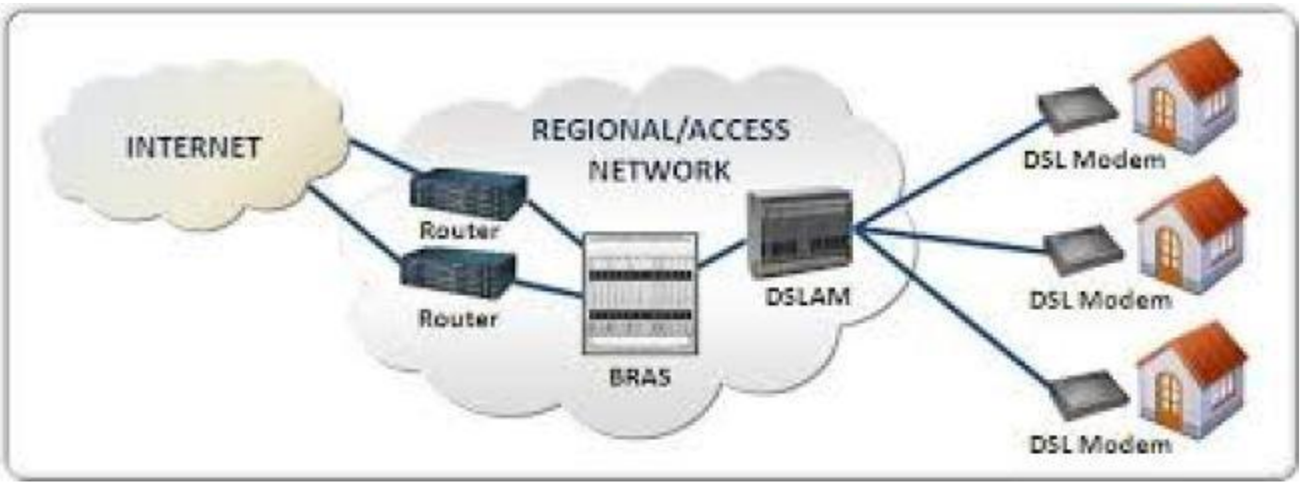


Figure 2: DSL deployment and the components

In DSL access, traditional copper line of the telephone network equipped with digital subscriber line technology.

DSLAM is used at the Service Provider network and customer modem connection is terminated at the DSLAM.

2. Cable Fixed Wireline Broadband

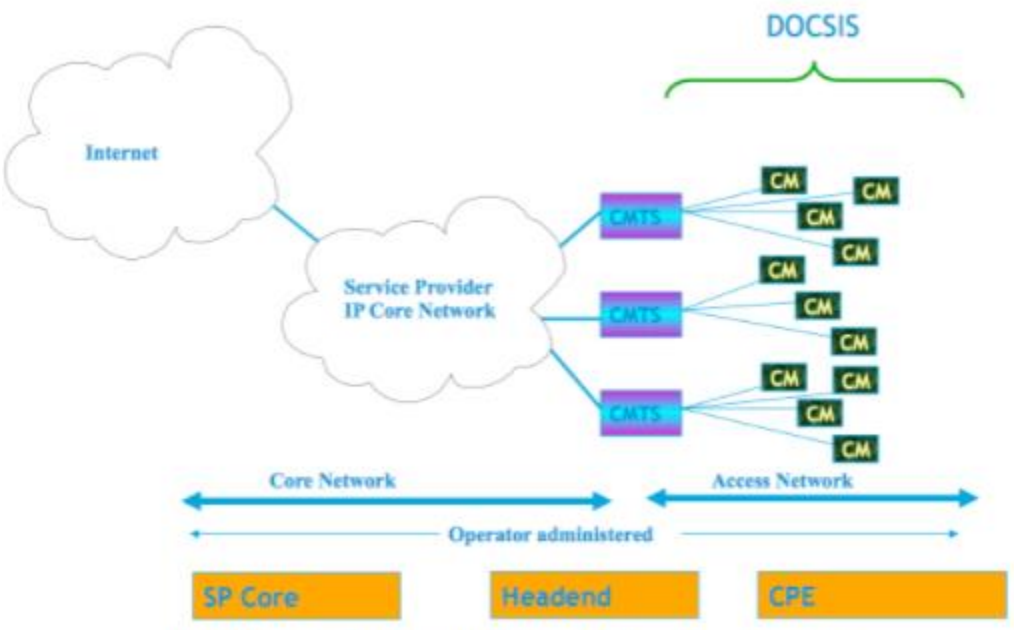


Figure 3: Cable Broadband simplified architecture

Second fixed wireline broadband access technology is Cable Broadband. Broadband service is received through cable access by upgrading traditional cable television network.

Customers can receive both broadband Internet service as well as TV service over the same cable.

Figure 3: Cable Broadband simplified architecture

3. Fiber Fixed Wireline Broadband

Third and last fixed broadband access technology is Fiber. You probably heard FTTx before. There are many deployment options of FTTX access for sure.

You may have heard FTTH (Fiber to the home) , FTTP (Fiber to the Premise) , FTTB (Fiber to the Building) and so on.

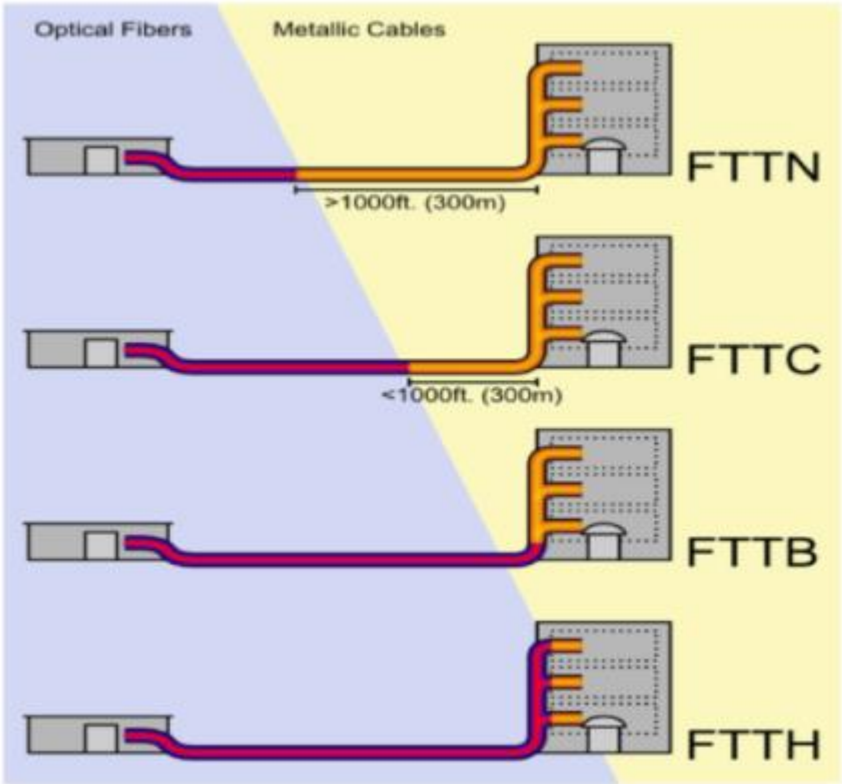


Figure 4: Different FTTx Deployment Options

Fiber access infrastructure is different from DSL and Cable in many ways.

With Fiber to the Home, from the fiber termination device of the Service Provider up to the modem in the customer home, entire access network is fiber.This is the fastest option customer can get.

As you might know finer has much less attenuation and loss compare to copper and coaxial cable.

Much higher data rates can be achievable through fiber. (In theory you can send 300.000km/s over fiber, because the limit is speed of light).

Between customer and the street cabinet can be copper based and DSLAM can be located at the street.

DSLAM to the fiber termination device which is located at the Service Provider Telephone Exchange (In U.S it is generally called as CO (Central Office)) can be fiber.

This is another way of deploying FTTx service and called Fiber to the Premises/Cabinet or Curb.

In the above figure, third deployment model which is Fiber to the Building is shown.

In this deployment option, fiber is brought up to the building and between DSLAM and the customer modem, connection is copper based.

Wireless Fixed Broadband

Most common technology for the fixed wireless is WIMAX (Worldwide Interoperability for Microwave Access).

Microwave access is much cheaper compare to fiber access for the wireless access operators.

Fiber access infrastructure can be leased from the fiber infrastructure providers by the wireless operator (This is very common among the Mobile Service Providers) or wireless operator can deploy it’s own fiber infrastructure.

In both methods, capital expenditure is higher compare to wireless based access systems.

Thus, today most common wireless backhaul is deployed via microwave as you can see from the below picture as well.

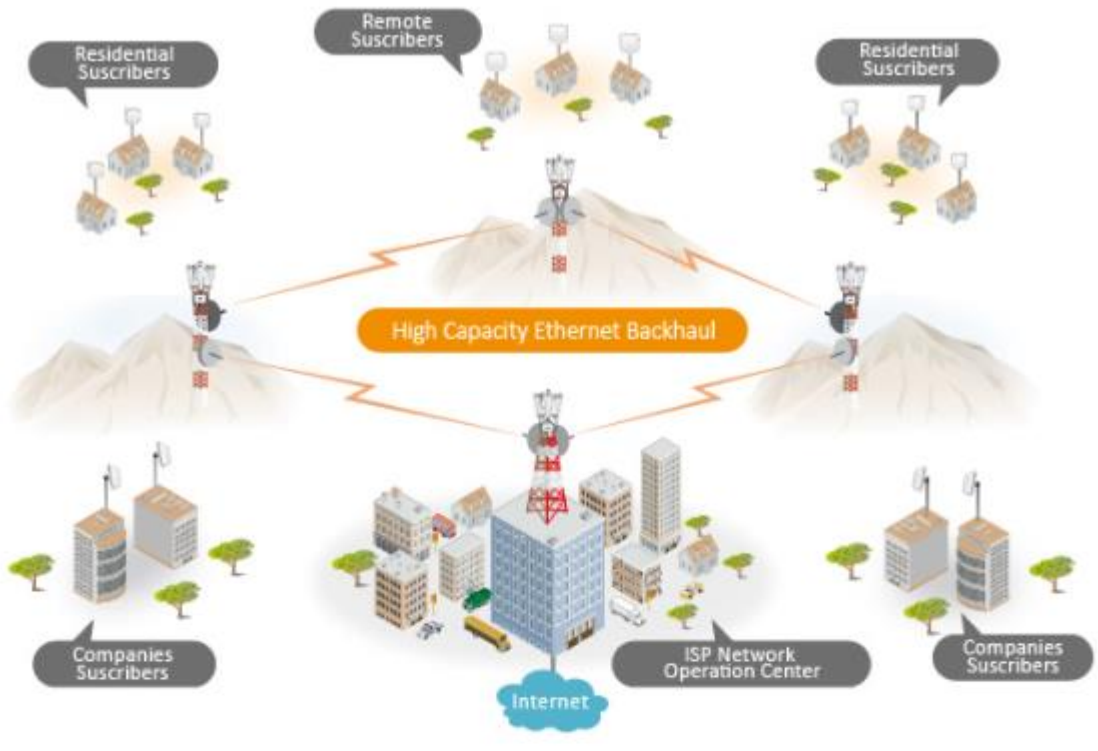


Figure 5: Fixed Wireless Network

With WIMAX, access speed can reach up to 1Gbps and the customer connection speeds depends on the distance from the wireless base station.

Satellite Fixed Broadband

Satellite connections generally used in rural areas where there is no other access network options available.

By the way, when you work in the Network Operator or Service Provider environment, especially if you are doing any kind of capacity planning work (Transport , Access or IP network) , you always hear urban , sub-urban, metro and rural areas.

These are related the number of people per square kilometre.

If the area is so crowded (Generally 4000 people/ sq km) it is called metro, after metro, urban, then sub-urban , least crowded places are called as rural areas.

Satellite connection has much higher latency compare to other fixed broadband access technologies.

Speed increases by reducing latency, increasing bandwidth doesn't mean faster connection.

This is another long discussion probably we should make.

When people increase their bandwidth , they tend to say we have faster connection. Thats completely wrong.

When you have shortcut (so lower latency) you have a faster connection.

satellite connection

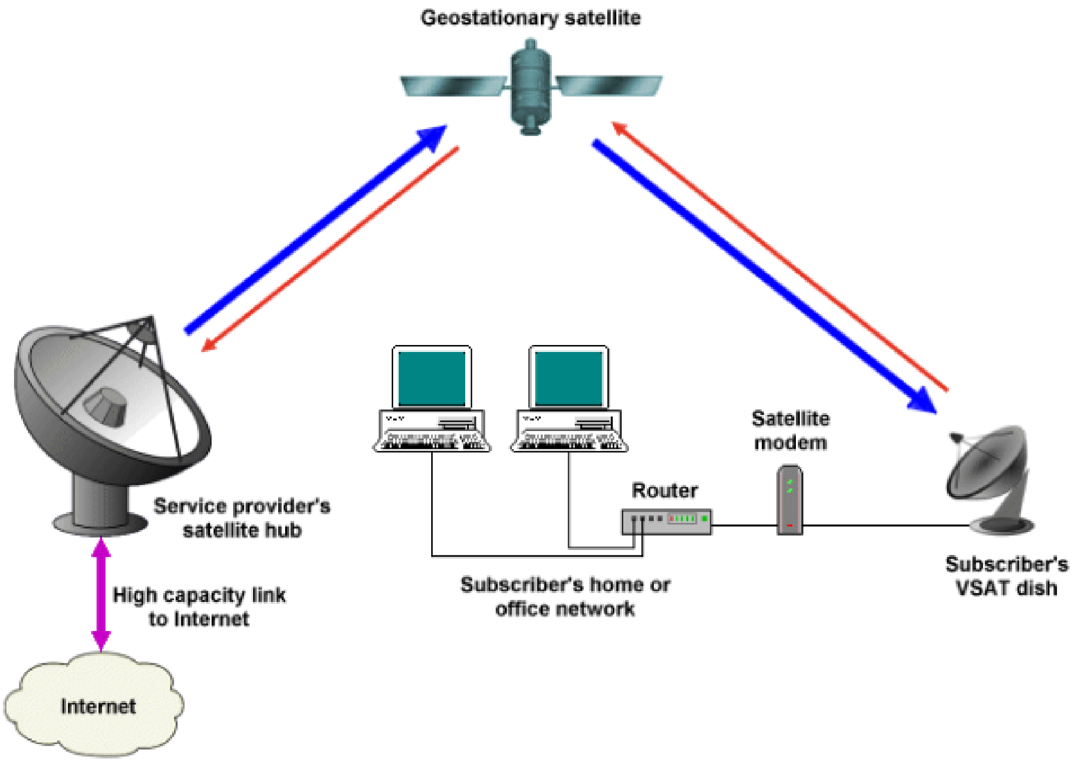


Figure 6: Satellite Communication

Last but not least, satellite connection almost always more expensive for the same speed, compare to other fixed broadband access technologies.

Mobile Broadband

Mobile broadband refers to those technologies where the end user can use the broadband service while on the move and from any physical location.

Two main mobile broadband technologies in 2017 very common, these are 3G and 4G.

These technologies provide different service speeds to the customers and the Service Provider access and the backbone infrastructure is designed in a completely different way.

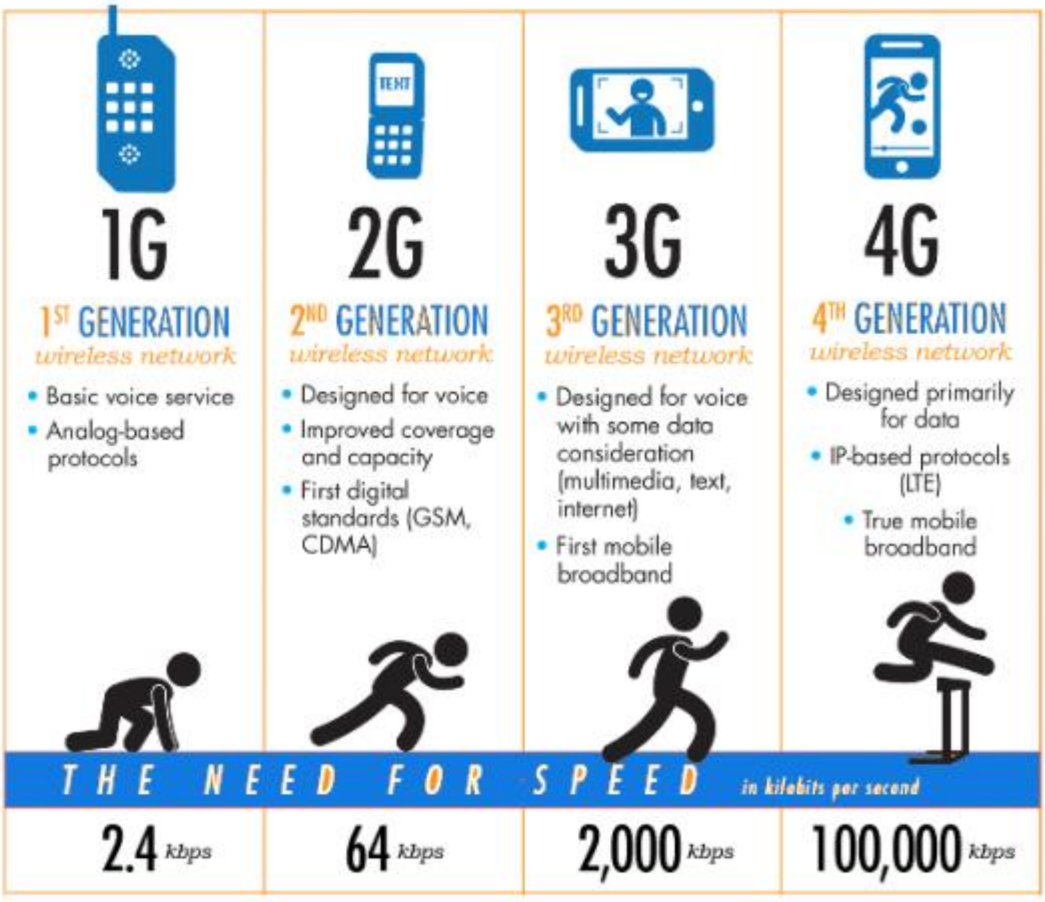


Figure 7: Different mobile broadband connection speeds

As I told you in the beginning, we have many mobile broadband technology posts in the website and you can watch Mobile Broadband Technologies webinar which I did with one of the mobile broadband experts worldwide earlier this year.

Fixed broadband technologies due to technical and financial aspects, tend to be prevalent in highly populated areas (Metro, Urban) and mobile broadband technologies are more prevalent in less densely populated places. (Rural areas).