KIITPOLYTECHNIC

LECTURE NOTES

ON

WAVE PROPAGATION AND BROADBAND COMMUNICATION

Prepared by

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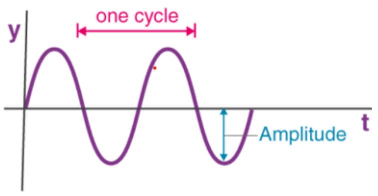
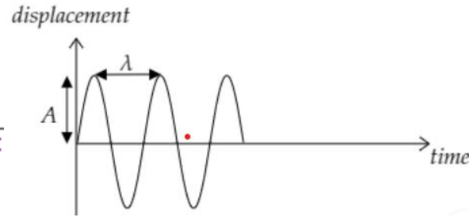
CHAPTER -1
Wave Propagation and Antenna

- Frequency: The number of cycles completed in 1 second is known as frequency.

 Symbol – f
 Unit-- Hz/ C/sec
- Time period: The time taken to complete one full cycle is known as time period.

 Symbol—T
 Unit --- Second





- Wavelength: The distance between two consecutive crest and trough is known as wavelength.

 Symbol—λ
 Unit- nm, μm, mm, cm, m
- Signal: Signal is a time varying quantity with some useful information in it. (Ex: Simple digital data ,audio, video, pictures, symbols etc.)

Relate f,c and λ:

F= frequency
C= Speed of light= 3 x 10^8 m/sec, λ = Wavelength
We know
F α 1/ λ
F= c / λ
Where c= proportionality constant.

Q. Convert 60 GHz into kilo hertz.
 60 GHz= 60x 10^9
 KHz= $(60\times10^9)/10^3$
 = 60×10^6 KHz
 = 6×10^7 KHz

Electromagnetic Wave

- EM wave is present in space through an antenna.
- EM signals has 2 fields:-
 1. Electric Fields (E), volt
 2. Magnetic Fields(H), Amp-Turn
- Both are perpendicular to each other.
- The electric fields depend upon permittivity (€), and magnetic fields depend upon permeability(μ) of the medium.

Where $€= €_0 €_r$

$\mu = \mu_0 \mu_r$

Here, $€_0$ = Absolute Permittivity (Constant)

$= 8.854 \times 10^{-12}$ F/M

$€_r$ = relative permittivity (Variable)

μ_0 = Absolute Permittivity (Constant)

$= 4\pi \times 10^{-7}$ H/M

μ_r = Relative Permittivity (Variable)

- As we know the electric voltage and current are related to each other by

V= IZ

- Similarly in EM wave we have a relationship like $E= Z_c H$.

Where Z_c is characteristics impedance, also it is expressed as $Z_c= \sqrt{\frac{\mu}{€}}$

Z_c depends upon μ and €. i.e., E and H.

The orienetation of Electromagnetic wave in space:

- ✓ Practically or physically if we want to represent something in co-ordinates or axis, we always use X, Y and Z axis.
- ✓ The electromagnetic wave is always drawn in Z axis.
- ✓ To cover the waves or complete the wave we draw dotted lines.
- ✓ EM waves drawn in the sine waves.
- ✓ As they are moving in sine waves so each half cycle the direction of the field changes.

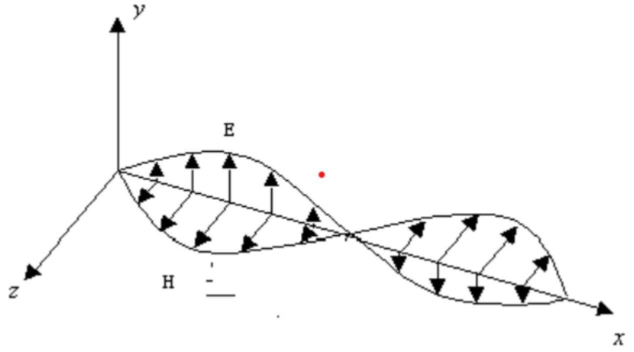


Fig 1: Orientation of EM wave in space.

E—Electric field

H- Magnetic field * Both are perpendicular to each other.

Frequency Bands in Atmosphere:

Extremely Low frequency	: 30 Hz- 300 Hz
Voice Frequency	:300 Hz- 3 KHz
Very Low Frequency	: 3 KHz-30 KHz
Low Frequency	:30 KHz-300 KHz
Medium Frequency	:300 KHZ-3 MHz
High Frequency	:3 MHz-30 MHz
Very High Frequency	:30 MHz-300 MHz
Ultra-High Frequency	:300 MHz-3 GHz
Super High Frequency	: 3 GHz-30 GHz

Extremely High Frequency	:30 GHz-300 GHz
Infrared Frequency	:300 GHz-30 THz
Visible Light Spectrum	:30 THz-300 THz
Ultraviolet Light	:300 THz onwards

<u>Effect of Environment on EM wave</u>

When EM wave passes through space, there are many types atmospheric conditions that effect the propagation of EM wave.

The effects are listed below,

- Reflection
- Refraction
- Diffraction
- Absorption
- Scattering
- Interference
- Attenuation

When EM wave moves in space, obstacles from atmosphere reduces the signal strength. The effects of each effect will be discussed one by one.

1. <u>Reflection:</u> Reflection occurs when light or EM wave falls on a conducting medium. The angle with which EM wave strikes the surface, is called <u>angle of Incidence</u>.

The angle with which the wave s reflected is called <u>angle of reflection</u>.

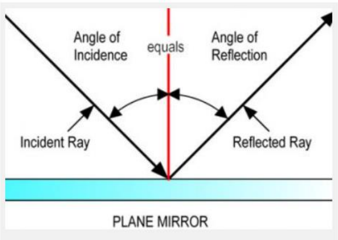
The Wave at which the wave is incident is same as the velocity of the reflected wave.

Reflection Coefficient 'ρ' is the ratio of reflected field to the incident field.

Mathematically, $\rho = \frac{E_r}{E_i}$

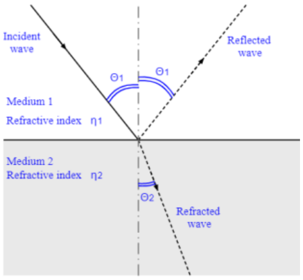
If ρ=1, that means $E_r = E_i$ (This happens for a perfect conductor)

If ρ <1, then $E_i < E_r$ this happens for an imperfect conductor or a lossy medium.



Light reflection

2. Refraction: Refraction occurs when the EM wave passes through 2 different mediums (Unlike in reflection that requires only one medium). The direction of EM wave changes after refraction. If 'ø' is the angle of incidence and 'ø₁' is the angle of refraction then, $\frac{sin ø}{sin ø 1} = \frac{1}{\mu}$ (Where μ-Coefficient of refraction or refractive index). In refraction, the direction as well as the velocity of the EM wave changes.



Q. Differentiate between Reflection and refraction

Reflection	Refraction
1. It occurs when the light or EM wave falls on a conducting material	1. It occurs when the EM wave passes through different mediums.
2. Here the velocity at which wave is incident is same as the velocity at which the wave is reflected.	2. Here the velocity at which wave is incident is not same as the wave is refracted.
3. Angle of incidence is equal to angle of reflection i.e., ø= ø	3.Angle of incidence is not equal to angle of refraction ø= ø
4. Here the incident wave and reflected wave are in same medium.	4.Here, the incident wave and reflected wave are in 2 mediums.
5. Here, reflection coefficient is given as $\rho = \frac{E_r}{E_i}$	5.Here Coefficient is given by, $\frac{sin\phi}{sin\phi 1} = \frac{1}{\mu}$

2. <u>Diffraction:</u>

Meaning of diffraction is change in direction of EM wave when it falls on the edge, moderately rough surface. Due to diffraction, the intensity of the signal strength gets reduced. After diffraction, a single wave becomes a number waves of different strengths. In this case the wavelength (λ) of the signal gets changed. So, before diffraction, the strength of the signal is acceptable.

Assignment-1:

1. What is ground wave?

Answer: Ground wave propagation is a method of radio wave propagation that uses area between the surface of the earth and ionosphere for transmission.

- ✓ The propagation taken place in medium frequency range i.e., 0.3 MHz-3 MHz).
- ✓ The groundwave propagation is limited to 100 miles.
- ✓ Here the atmospheric noise, man-made noise, thermal noise from electric field create disturbance in ground wave propagation.

2. Discuss the effect of Earth's curvature on groundwave.

- ➢ The surface wave is also dependent upon the nature of the ground over which the signal travels like ground conductivity, terrain roughness and the dielectric constant all effect the signal attenuation.
- ➢ In addition to this the ground penetration varies becoming greater at lower frequencies and gets reduced at higher frequencies.
- ➢ Despite all these variables, it is found that terrain with good conductivity gives the best result.

3.Scattering:

- Scattering of EM wave occurs when the wave faces a non -reflective, smooth surface also non conducting.
- After scattering a single EM wave of a particular frequency is converted to multi frequencies or multiwavelength numerous EM waves.
- The propagation with scattering problem becomes really difficult because the receiver has to work with multimode propagation method.

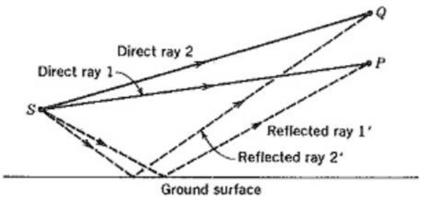
5.**Aborption:**

- ❖ In atmosphere, the vapour and humid content become responsible to absorb the strength of EM wave.
- ❖ Due to absorption the signal becomes eventually weak.

6.**Attenuation**:

- o Attenuation means fall in signal strength.
- o when an EM wave travels in free space, from transmitter it can go a particular distance but if the distance is increased, the signal strength may fall.
- o Transmitters have to be designed keeping in mind the attenuation factors of signal.

7.**Interference:**



- ✓ As shown in the figure, the EM wave from a single source is intended to be received by two receivers P and Q.
- ✓ The EM wave can reach directly to the receiver or they may get reflected from a reflecting surface
- ✓ The distance covered by reflected wave is more than direct wave. However, there is a chance of interference when the direct ray meets the reflected ray.

ANTENNA

- ❖ It is a device that converts RF electric signal into EM Wave.
- ❖ At the transmitter side the antenna behaves as a transducer because a physical quantity gets converted into EM signal into EM signal.
- ❖ T the receiver side the antenna behaves as a sensor because the EM wave is reconverted to a physical quantity.

Types of Antennas:

1. Wire Antenna
2. Dipole antenna
3. Yagi-Uda Antenna
4. Rhombic Antenna
5. Dish Antenna
6. Horn Antenna
7. Array Antenna

8. Microstrip Antenna
9. Smart Antenna

Properties of Antenna

- Bandwidth
- Beamwidth
- Polarization
- Radiation Resistance
- Losses and efficiency
- Directivity
- Gain

Bandwidth:

The range of frequencies over which the antenna operates most efficiently is known as bandwidth.

$$BW = f_H - f_L$$

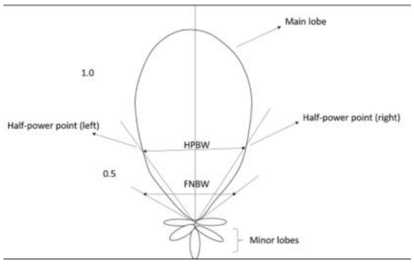
F_H= Higher cut- off Frequency

F_L= Lower cut-off frequency

Unit of Bandwidth is KHz, MHz, Hz etc.

Beamwidth:

Beamwidth of an antenna is defined as the angles created by the mainlobe along the direction of propagation.



- ✓ As shown in the figure □+□= 2 □ refers to beamwidth of antenna.
- ✓ By coming 3 dB down from the maximum point of the main lobe, two more lines are obtained. That is called half Power Beam width (HPBW). So, □+□= 2 □
- ✓ At HPBW, the antenna has maximum radiation or radiates with maximum power.
- ✓ Unit of Beamwidth – Radians (As it is a solid angle).

Polarization:

According to the installation of antenna the polarization can be of two types:

- Horizontally polarized
- Vertically polarized

According to the structure of antenna the field patterns created in the space polarization can be of three types

I. Linearly polarized (LP)
II. Circular Polarized (CP)
III. Elliptical Polarized (EP)

Radiation Resistance:

- ✓ It is defined as the ratio of radiated power to the square of current at feed point(supply).

Mathematically,

$$R_r = \frac{P_r}{I_{rms}^2}$$

- ✓ Where, P_r = Radiating power
  I_{rms} = Rms value of current at field point.

Losses and Efficiency:

- ✓ The total power delivered by an antenna from the source (feed) is equal to the total power radiated with total power lost.

Mathematically, $P_t = P_{rad} + P_{lost}$

So, efficiency = $\frac{P_{rad}}{P_t} * 100$ %

⇨ efficiency = $\frac{P_{rad}}{P_{rad+} P_{lost}}$

- We know, $P = I^2R$
  So, $P_{rad} = I^2rms * R_{rad}$
  $P_{lost} = I^2_{rms} . R_{lost}$
  $P_t = I^2_{rms}(R_{rad}+R_L)$

So Efficiency= $(I^2_{rms}.R_{rad})/[\ I^2_{rms}(R_{rad}+R_{lost})]*100\%$

Efficiency= $[P_{rad}/(P_{rad}+P_{lost})]*100\%$

Here, P_{rad}- Radiated Power
P_{lost}-Lost Power
P_t-Total power generated from feed
I_{rms}-RMS value of current from feed.

Q. If an antenna R_{rad}= 60 Ω, R_L= 20 Ω, the feed point supply is 2 mV. Then calculate the efficiency of antenna.

Ans: 60/(60+20)= 75%

Directivity:

It is the ratio of radiation intensity (U) of a particular directive antenna (only radiates in particular direction) to the radiation intensity of an isotropic Antenna (U_0).

Mathematically,
D= U/U_0

It is a hypothetical or imagining or ideal antenna that can radiate equally in all direction. It has 100% efficiency and gain. It is also omnidirectional antenna. It does not exist in real.

Gain:

In an antenna we can see two types of gain

1. Power Gain
2. Directive Gain

Power Gain- It is the ratio of radiated power to the power present at the feed point.

Power Gain= $10 \log_{10}(P_{rad}/P_t)$ dB

P_{rad}=output radiated power
P_t=Power at feed point

Directive Gain: Directive gain is same as directivity of an antenna. It is same as directivity of an antenna. It is the ratio of radiation intensity of directive antenna to the radiation intensity of Isotropic Antenna. Mathematically,

Directive Gain = 10 $\log_{10}(U/U_0)$ dB.

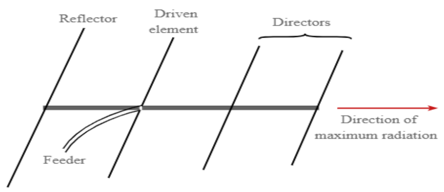
Yagi- Uda Antenna

- This is highly directional super gain antenna.
- It is also known as beam Antenna.
- Is named after two Japanese scientists Shintaro Uda and Hidsugu Yagi.

Construction:

It has 3 parts in it,

I. Driven Element
II. Reflector
III. Directors



Basic concept of Yagi antenna

- The driven element is of λ/2 length.
- The spacing between elements are shown in figure above.
- The dipole or driven element is always smaller than the reflector.
- The director length is smaller than dipole, subsequent directors have smaller length than the previous ones.
- The Yagi Antenna may be of 3 elements, 5 elements, seven elements, 9 elements or 11 elements. In all these types reflector and dipole are single but directors are many numbers.
- The source or feed is connected to driven element or dipole that helps to convert RF electric energy into EM wave.
- The reflector and directors are not connected to any source but they help in radiation. So, directors and reflectors are called as parasitic elements because they depend on dipole for supply.
- All these elements are parallel to each other.
- All are fitted to common rod called boom. Aluminium is preferred for construction because of its light weight and cheapness.

Operation:

- The driven element is connected to source(feed).
- All other elements are parasitic in nature. Reflector has a length λ/2 more than dipole [λ/2+ λ/2= λ] which is inductive in nature that means current lags the source voltage.
- The directors are shorter than dipole and are capacitive in nature. Hence, current in each directors leads the source voltage.
- When the dipole converts RF electric energy into EM energy or wave, some signal goes to reflector (backward) and maximum signal goes towards directors.
- As the directors have leading property so they lead the EM wave in direction of propagation.

- That is why the more the number of directors the strong directivity Yagi-Uda antenna has.
- Efficiency of Yagi-Uda Antenna is more than 85%.

Advantages

- It is called super gain antenna for its high gain and high beam width per unit area.
- It has a good relative broadband.
- It is very cheap.

Disadvantages

- According to frequency of operation size is big.
- It is not suitable for remote area application.

Design Of Yagi-Uda Antaenna

Yagi-Uda antenna has three elements

a. Reflector
b. Dipole
c. Directors

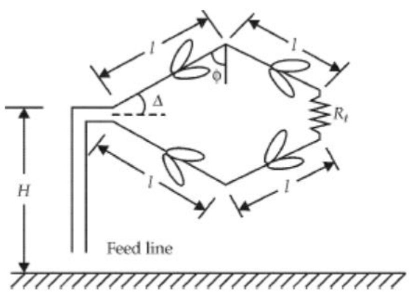
Reflector length = 0.995λ
Dipole length = 0.5 λ
D_1= 0.44 λ
D_2= 0.435 λ
D_3=0.430 λ

RHOMBIC ANTENNA

The rhombic antenna has got its name from Rhombus. Because the shape of antenna is like a rhombus. It has four wire antenna which are placed on the surface of the earth with the help of four poles in the shape of rhombus. A terminating resistance R_L is connected at the last to prevent reflection, so that no standing waves are created.

***Construction*:**

As shown in the figure the individual radiators or wires when combined give one main radiation in the direction of propagation (along the diagonal of Rhombus). If the antenna is in horizontal plane, then the radiation is in the horizontal axis but if the antenna is in the vertical plane, the radiation is at some angle Delta(δ). The angle δ depends height of poles



Features of Rhombic Antenna:

- ✓ It is a non-resonant antenna (multi frequency)
- ✓ It operates over 3-30 MHz for both transmission and reception.
- ✓ Terminating resistance R_L is in the range of 650-700 **Ω**.
- ✓ Radiation pattern is unidirectional.
- ✓ It is a broadband Antenna.

Advantages:

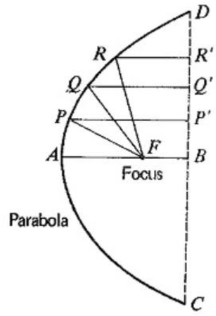
- ✓ It's input impedance and radiation pattern are relatively constant.
- ✓ If the impedance is not constant then more than one rhombic antenna is connected end to end fashion to make a group rhombic antenna. Such an arrangement is called MUSA (Multiple Unit Steerable Antenna).
- ✓ Rhombic Antenna is useful for effective transmission also it is useful for high frequency HF reception.

DISH ANTENNA

It is an UHF antenna that operates in the frequency range of 300 MHz- 3 GHz. A Dish Antenna with parabolic reflector is also called parabolic antenna.

Here a parabolic shape reflector is whose cross-sectional area is like a parabola. The antenna is a Horn Antenna which is actually responsible for EM conversion. Such antennas are used for satellite communication so the other name of this antenna is satellite Dish Antenna.

Geometry of parabola to be used as a reflector:



The parabola is a plain curve defined as the locus of a point that moves so that when it moves its distance from focus(F) added with distance from directrix is a constant (k).

i.e., FA+AA'= FB+BB'=FC+CC'=k

As shown in equation, here

K= constant that differs according to size of parabola

F=Focus point

= Major axis

=Directrix

This property of parabola helps to give strong Radiation pattern along the direction of propagation.

<u>Reflector Property</u>

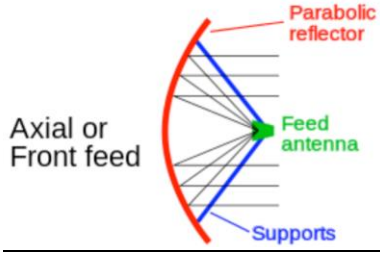
- ✓ Parabolic reflector has very high gain around 30-40 dB.
- ✓ Reflector has a wide bandwidth.
- ✓ The small size reflectors can operate in the frequency range of 2-2.8 GHz whereas large size reflectors operate from 300 MHz- 8GHz.
- ✓ A typical parabolic antenna consists of a parabolic reflector and horn antenna placed at the focus of the parabola.
- ✓ A reflector is a sheet metal or metal screen or wire grill construction.

Types of Dish Antenna

There are two types of DISH antenna according to position of feed:

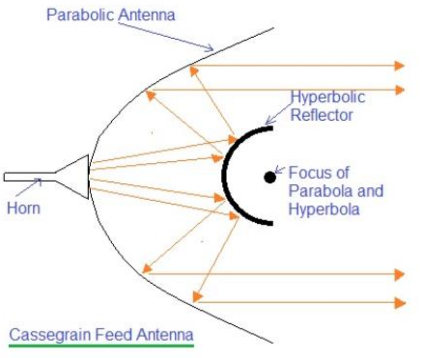
1- Front feed
2- Cassegrain Feed

<u>1-Front Feed:</u>



In this case the feed element (horn Antenna) is placed at the focus of the parabola facing towards the reflector. The beam generated from horn gets reflected towards the space in the direction of propagation. Unfortunately, maximum reflected beams are absorbed by horn antenna itself creating huge reflection. By such reflection the efficiency of antenna reduces to 50-60%. Again, the metallic support to hold the reflector also obstructs the EM wave propagation. To avoid this problem Cassegrain invented a new position of field element in Dish Antenna.

Cassegrain Antenna:



In this method a secondary reflector of hyperbola is placed along with the metal support. The horn feed is placed on the primary reflector body facing towards the secondary reflector. When the horn radiates the full beam on secondary reflector and from that the beam is reflected to primary reflector. From primary reflector all the beams again reflected towards the space in the direction of propagation. Although the metal support obstructs some of the signal but the posing of horn feed helps to get efficiency of 70%.

Advantages of DISH antenna:

- ✓ Most of the structure of the antenna is non resonant, so it can function over a wide range of frequencies.
- ✓ Wide bandwidth
- ✓ High Directivity
- ✓ High Gain

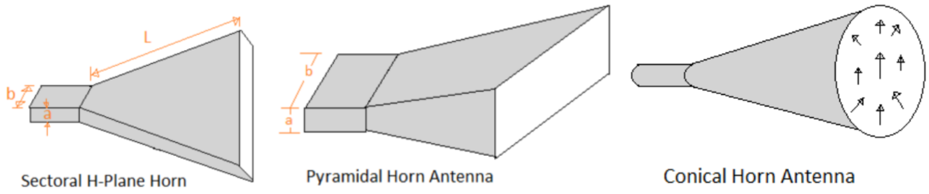
Disadvantages of DISH antenna:

- ✓ It requires the feed system to be placed at the focus of the reflector.
- ✓ This type of antenna is costly
- ✓ This type of antenna is not as small as some types of antennas although many used for satellite television reception are quite compact.

HORN ANTENNA

A Waveguide can radiate suitably as compared to transmission line. But the waveguide must be excited properly at the input side. But Waveguide also suffers from difficulty when it is kept open as in the case of transmission line. If the waveguide is kept open at the load side, then maximum signal gets reflected from end towards the source. The open circuit is like a discontinuity in space. To avoid the said problem a Horn Antenna can be used to terminate the waveguide so that the discontinuity from the waveguide can be replaced by a smooth transformation electric to EM energy. A proper excitation at the input side will result in good radiation from the waveguide. There are several possible Horn configurations. The most popular three Horn configurations are:

I. Sectoral ii. Pyramidal iii. conical



The sectoral Horn flares out (open mouth) mostly in both directions and has shape of a truncated pyramid (cutting from top of pyramid).
If the flare angle 'ø' is very small, then the radiating beam will not be directive so 'ø' should have a nominal value as per the application. The same is applicable to pyramidal Horn. Therefore, it is desired to choose the flare angle very carefully which depends upon the wavelength of the signal 'λ' and length of the flare 'L'.

*Applications:

- Used as a radiator in DISH or parabolic antenna.
- Use in Waveguides
- Very large size Horn Antenna are used for satellite communication. They are called Cass Horn.
- In Mangal yaan maximum antennas were Horn Antennas.

*Advantages

- Good Directivity
- Adequate Bandwidth
- Simple Mechanical construction

*Disadvantages

- The directivity of Horn antenna is low as compared to Dish Antenna (Both are UHF antennas).

SMART ANTENNA:

A smart antenna consists of several antenna elements whose signal is processed to fit the application. Actually, antennas are not smart but the systems are smart. A smart antenna combines an antenna array (Group of antennas) with a digital signal processing capability (DSP) to transmit and receive signal in an intelligent and adaptive way. It can change the directivity of the radiation pattern in response to its signal environment. These antennas are also called adaptive array antenna which uses signal processing algorithms.

The algorithms are: -

I. Direction of Arrival
II. Beam forming vectors

*Types of Smart Antenna
There are two types of smart Antenna: - Switch beam smart antenna and Adaptive array smart Antenna.

*Advantages

- Reduction in co channel interference.
- Range Improvement
- Increase in capacity
- Reduction in transmitter power

*Applications:

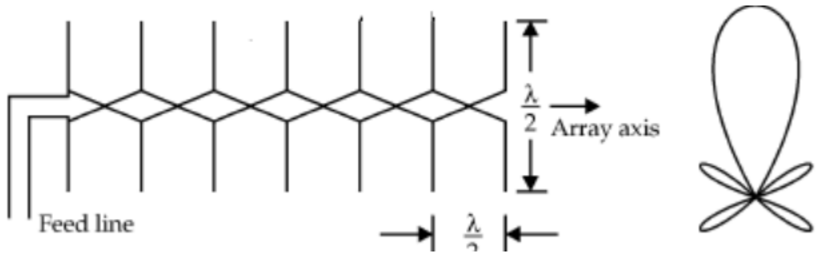
- In Track and scan RADARS
- Radio Astronomy
- Radio Telescope
- Cellular systems like WCDMA and UMTS etc.

ANTENNA ARRAY

Single antenna does not satisfy the requirement of the particular application. An antenna array is a radiating system consisting of group of radiators or antennas as elements. These are placed close to each other so that each element is under the inductive field of the other. They therefore interact with each other to produce a resulting radiation pattern i.e., the vector sum of all elements.
Antenna array are of two types:

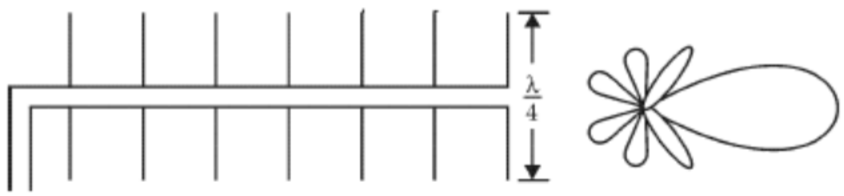
- Broad side Array
- End Fire Array

Broadside Array:



- In this type the elements are of equal size ($\lambda/2$) and all are equally spaced ($\lambda/2$).
- These arrays are strongly directional from single source at right angle to the plane of array.
- As shown in the figure there are six elements connected in the array fashion but we can increase the number of elements. We can go up 12 elements. We should decide the number of elements according to the transmitting power or feed or source.
- The more the number of elements the better is the directivity.
- As the radiation is maximum, in the perpendicular direction so the array is called broadside array.

End-fire Array



- The array which is consisting of more than one element and all are fed from same source but each element is with phase difference of other then such arrangement is called End-fire array.
- As shown in the figure the element size is λ/2 and they are spaced with a distance of λ/4.
- As the elements are with phase difference so the radiation is maximum in the plane of array and minimum in the direction perpendicular to the array.

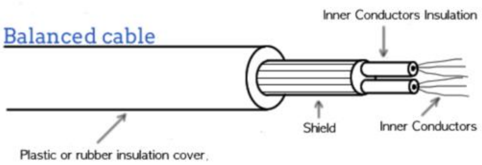
Differentiate between Broadside and End-fire Array

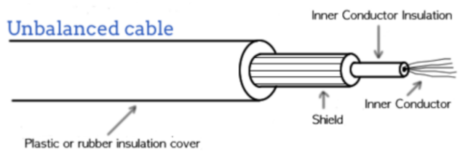
Broad side Array	*End-fire Array*
1.Here elements are connected in same phase.	1.Elements are connected in out
2.Here radiation is maximum in radiation	2.Here radiation is maximum in plane of array.
3.Here the elements are spaced at λ/2 distance.	3.Here the elements are spaced at λ/4 distance.
4.Here, radiation is maximum in parallel plane.	4.Here, the radiation is minimum in the perpendicular direction.

Chapter-2
TRANSMISSION LINE

Transmission line is a media to pass signal through it from the transmitter to receiver. Broadly transmission line can be of two types

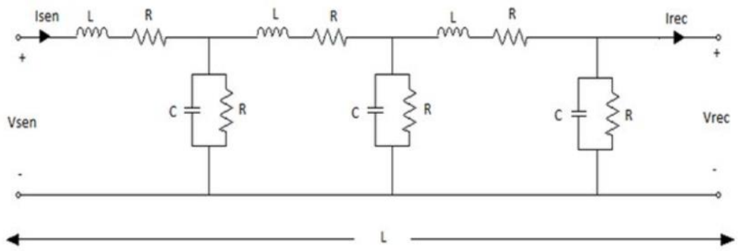
- Balanced Transmission line
- Unbalanced Transmission line





The parallel wire line is used where balanced properties is required. Ex. Connecting a Yagi antenna to a receiver or connecting a rhombic antenna to a TV receiver or connecting a rhombic antenna to a TV transmitter. Coaxial cable is used where unbalanced properties are required. Ex. Interconnection of broadcast antenna (transmitter) to its grounded antenna.

Equivalent circuit of Transmission Line:



Since each conductor has some length and diameter so it will have resistance and inductance R=(ρL)/A. Since there are 2 wires close to each other separated by a dielectric, so there is existence of capacitance (c= A€/d). The wires are separated by dielectric or insulator which is not perfect so leakage current exists between two wires. The conductance G is present due to this leakage region. Due to all these reasons, we find four components R, L, C and G in the equivalent circuit of transmission line. Here we are dealing with microwave range of frequency i.e., it may go to UHF. In the high frequency application, the resistance is less as compared to X_L (X_L= 2πfL). Hence, R can be ignored for high frequency application. Similarly in the shunt circuit 'G' is very high as compared to X_c (X_c=1/(2πfC). Hence in the shunt circuit G can be neglected. After neglecting 'R' and 'G', the only left out components are 'L' and 'C'. So, for high frequency application the equivalent circuit of transmission line will look as follows.

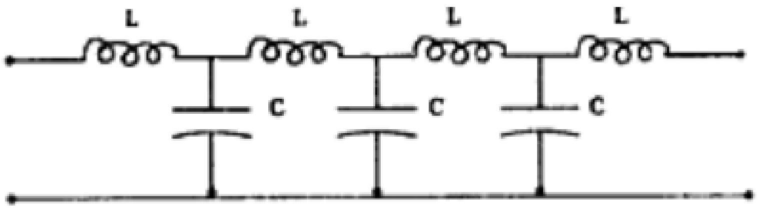


Fig: Modified equivalent circuit of transmission line.

<u>*Losses in Transmission Line</u>

There are three ways by which energy applied to transmission line may be dissipated before reaching the load.

- Radiation Loss
- Conductor Heating Loss
- Dielectric Heating Loss

<u>*Radiation loss:-</u>

- It occurs because the transmission line may behave as an antenna, if the conductor is nearly equal to (λ/2 or λ/4 size).
- This loss is more in parallel wire than in coaxial cable.
- Radiation losses are difficult to estimate(measure). Hence, they are experimentally measured.
- Radiation loss increase when the frequency increases and also when the length of the transmission.

<u>*Conductor Heating loss:-</u>

- I^2R loss is directly proportional to the current through the conductor. So, it is inversely proportional to z_0(characteristics impedance).

i.e. $I^2R_{loss} \alpha I$

$I^2R_{loss} \alpha 1/z_0$

This loss also increases with increase in frequency.

<u>*Dielectric Heating Loss:-</u>

- Dielectric heating is proportional to the voltage across the dielectric. So, it is inversely proportional to z_0(characteristics impedance).
- This loss also increases with increase in frequency then the quality of the dielectric is affected. So, signal property gets lowered.
- However, if the dielectric is air, then the loss is negligible.

Classification of Transmission Line

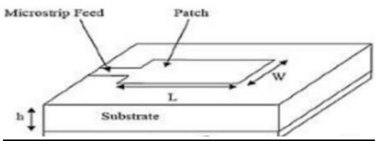
i. Coaxial cable
ii. Microstrip Line
iii. Strip line
iv. Twisted Pair
v. Power Line
vi. RF line

Coaxial Cable:

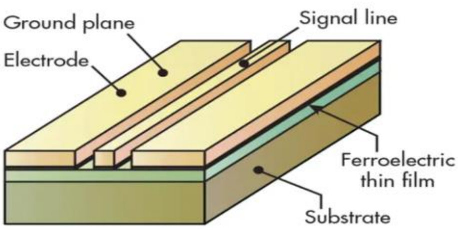
Coaxial cable is an electrical cable surrounded by an insulating material and a conducting shield or cover. The term coaxial means the inner conductor and the outer shield have same axis. This transmission line carries lower frequency signal such as audio signal(20 Hz-20 Khz).

Microstrip Line:

It is a type of electrical transmission line which can be fabricated using printed circuit technology. It consists of a conductor strip separated from a ground plane by a dielectric layer known a s substrate. Microstrip lines are used in high-speed PCB design where signals are directed one part to another without crosstalk.



Strip line: Strip line means a flat strip of metal which is sandwiched between two ground planes. It consists of a conducting strip separated from ground plane by a dielectric layer known as substrate. The width of the strip, the thickness of the strip, the thickness of the substrate and relative permittivity ($€_r$) determines the characteristics impedance (Z_0) of the strip line.



Twisted Pair:

A twisted pair cable is a type of transmission line in which two conductors, one is forward and others are twisted together to avoid electromagnetic interference (EMI) from external sources.

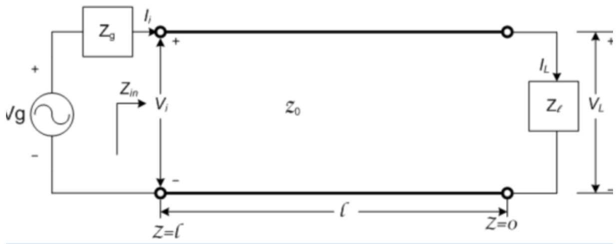
Power Line :

Power line mostly uses three phase AC. But sometimes single-phase AC can be carried by it.

RF line:

These are hollow, flat metal transmission device in which RF energy simply gets radiated through one point to another. They are used primarily for UHF band of frequencies. Impedance of such transmission line increases with the signal frequency. If the frequency is increased more then, attenuation occurs and loss to propagation happens.

Characteristics Impedance of Transmission Line:



Any circuit that consists of series and shunt element has an input impedance. For transmission line, this input impedance depends on the type of line, its length and the termination at the end. For simplicity we can say, the input impedance at any point on the transmission line is same which is called characteristics impedance (Z_c). So, Z will be measured at the input when output is terminated by Z_L. As per maximum power transformation theorem, if $Z_L=Z_C$ then maximum power is delivered from source to load. Z_L depends transmission line parameter like length, cross sectional area distance etc,

$$Z_L=\sqrt{\frac{Z}{Y}}$$

$$Z_L=\frac{R+j\omega L}{G+j\omega C}$$

Where Z=R+jωL (Series impedance)

Y= G+jωC (Shunt impedance)

- The impedance at any point on the transmission line is the ratio of voltage across the line to the current flowing through the circuit

For high frequency application R and G are neglected. Hence Z_0 or $Z_L=\sqrt{\frac{j\omega L}{j\omega C}}=\sqrt{\frac{L}{C}}$

The range of Z_C varies from 150Ω to 600 Ω, for balanced transmission line and varies from 40 Ω - 150 Ω for unbalanced transmission line.

Primary and secondary constants in a transmission line:

Primary Constant

These constants define the physical parameters of the transmission line. So, the primary constants are R, L, C and G.

R and L are series elements of the line which describe the properties of conductor (Length and cross-sectional Area).

G and C are the shunt elements of the line that describe the property of dielectric between the lines.

The term "constant" refers to line length means the line is homogeneous throughout its length.

Though R, L, C and G are constant but their value changes when the frequency is increased. This type of effect is called Skin Effect.

Due to Skin Effect the propagation quality of the signal decreases.

Secondary Constants

Secondary constants are also called propagation constants. The propagation constant 'γ' is defined as the ratio of amplitude of the signal at the source to the amplitude of the signal at distance x.

Mathematically, $e^{\gamma x}= \frac{A}{A_x}$

Where, A= Amplitude of the signal at source.

A_x= Amplitude of signal at distance x.

γ = Propagation constant

The changes of A to A_x is not linear rather is exponential

γ is a complex quantity that means it has a real part and imaginary part.

$\gamma = \alpha + j\beta$

α = Real part, Attenuation constant

β = Imaginary part, phase constant

Secondary constants can be represented in terms of primary constants, by the following relation, $\gamma = \sqrt{Z.Y}$

$= \sqrt{(R + j\omega L)(G + j\omega C}$

Reflection

When a transmission Line is incorrectly terminated, the power from the generator is not fully absorbed by the load.

So, some signals are reflected that is some signal come back from load to generator. This is called reflection. This happens when $Zc \neq Z_L$.

The more the mismatch between Z_C and Z_L, more is the reflection. This leads to loss of propagation.

So, if $Z_C = Z_L$ the line is perfectly matched and if $Zc \neq Z_L$ the line is mismatched. When the load or Z_L is purely resistive then that type of load is called matched termination. Such circuits are called non-resonant/resistive/flat line.

The voltage and current remain constant throughout the line for a matched termination.

When the line is terminated by a short circuit or open circuit power is not at all absorbed rather all the signals are reflected (Fully mismatched).

Standing Wave:

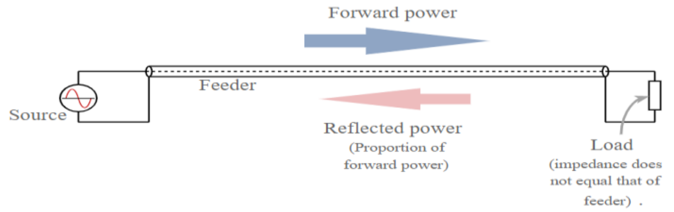
When signal is transmitted from source to load and the signal is fully absorbed, then in the line only travelling wave is present.

If $Zc \neq Z_L$, some of the signal gets absorbed and some get reflected. In this case in the line there are two signals:

1- Travelling wave
2- Reflected Wave

The travelling wave and reflected wave are 180^0 out of phase (phase reversal).

The interference or overlapping of travelling wave and reflected wave is called standing wave.



Power is reflected when feeder and load impedances do not match

Standing Wave Ratio (SWR)

Standing wave is defined as the ratio of maximum voltage to minimum voltage in a transmission line.

OR

It can also be defined as the ratio of maximum current to minimum current in a transmission line.

Mathematically,

SWR= $\frac{V_{max}}{V_{min}}$ or $\frac{I_{max}}{I_{min}}$

It is an unitless quantity

SWR of transmission line gives the idea of mismatch in a line.

If SWR= 1, that is $V_{max}=V_{min}$, No standing wave and the line is perfectly matched.

If SWR>1, then $V_{max}>V_{min}$, , then $Z_c \neq Z_L$, so line is mismatched.

Reflection Coefficient:

This is denoted by the symbol 'г' gamma

We know for a mismatched line, there are 2 waves: Travelling wave and Reflected wave.

Reflection occurs as a result of mismatching so, reflection coefficient is given by:-

$$\Gamma = \frac{V_R}{V_F}$$

V_R= Strength of reflected wave

V_F= Strength of forward wave or travelling wave.

г is a complex that means it has a real part(magnitude) and imaginary part(phase)

i.e. $\Gamma=\alpha+j\beta$

For $\Gamma=1$, max positive reflection (open circuit)

For $\Gamma=0$, $V_R=0$, Hence no mismatching or perfectly matched (pure resistive)

For $\Gamma=-1$, Maximum negative reflection (short circuit)

Relationship between VSWR and reflection coefficient

VSWR = Voltage standing wave ratio

г= Reflection Coefficient

$$SWR = \frac{1+\Gamma}{1-\Gamma}$$

Then г in terms of VSWR = $SWR(1-\Gamma) = 1+\Gamma$

$$\Gamma = \frac{SWR-1}{SWR+1}$$

Chapter -3

Television Engineering

TV System:

It is a telecommunication system that transmits images of objects (stationary or moving) between distant point.

*TV systems

American-525 lines/Frame

European-625lines/Frame

French -819lines/Frame

Scanning

It is done by camera and it is done in the same way as one reads a written page line by line from top to bottom.

Inside Camera:

- ✓ Two deflecting coils are kept perpendicular to each other.
- ✓ An electron gun is there which continuously generates the electron beam.
- ✓ Two sweep oscillators continuously generate saw tooth waveforms of desired frequency.

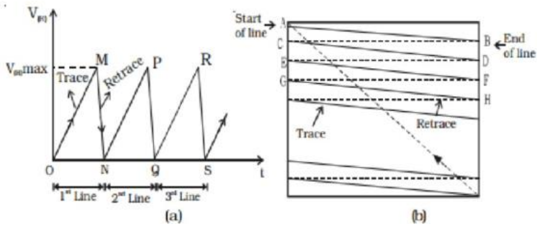
Horizontal Scanning:

The line which moves from start to end point is called Trace.

The line that flies back to the starting point of another trace is called retrace.

Generally, trace period takes longer time than the retrace period.

So, trace period is light and retrace period is dark.

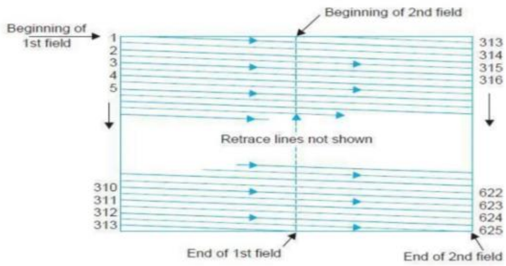


Vertical Scanning:

The sawtooth current in the vertical deflection coil moves the electron beam from top to bottom. During this period the electron beam is deflected horizontally. Thus, the beam produces complete horizontal lines one below the other while moving from top to bottom. During the retrace period narrow pulses are transmitted along with the transmitted signal to keep the sweep oscillator of the picture tube and camera at synchronous to each other. Horizontal scanning is made faster than vertical scanning by varying the frequency of sawtooth waveforms generated by sweep oscillator.

Interlaced Scanning:

It is a display type in which one half of the horizontal pixel rows are refreshed in 1 cycle and the other half the next, meaning that 2 complete scans are required to display the screen image.



Aspect Ratio:

It is defined as the ratio of width of frame to the height of frame.

Mathematically,

Aspect Ratio = $\frac{width\ of\ frame}{Height\ of\ frame} = \frac{4}{3}$

The width frame is more than the height of the frame because the human eyes can view more easily if the width is more than height.

Flicker:

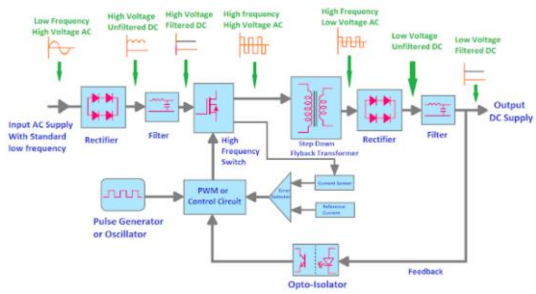
24 fps is used for motion pictures and 25 fps is used for TV picture.

If the scanning interval between two frames is not sufficient than a flicker may arise.

Flicker is the outcome of a darkness between two brightness or vice versa.

SMPS (Switched Mode Power Supply)

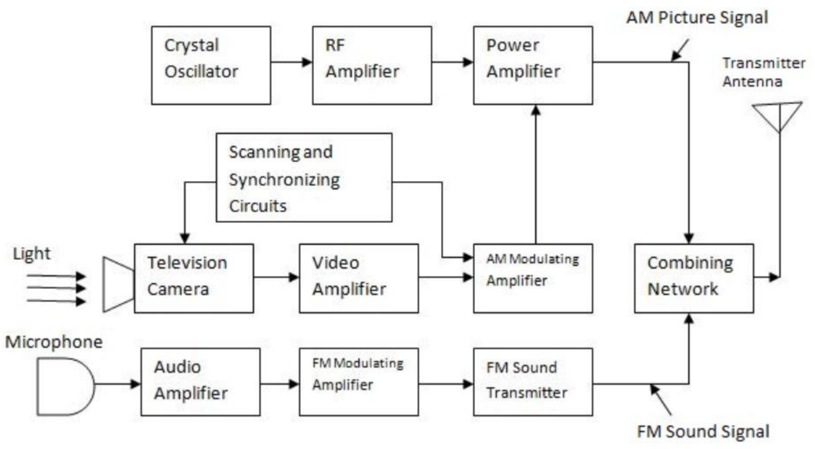
Block diagram:



Circuit Diagram:

- SMPS fulfils various DC requirement of TV receiver.
- First Input AC is converted into unregulated DC by rectifier.
- Then the inverter converts DC to AC of around 20 KHz frequency.
- Then 20 KHz is transferred to output network by transformer.
- At the output of transformer again rectification is required.
- The regulation of DC is carried out by controlling of chopper which varies the duty cycle.
- The controlled circuit compares the output voltage with reference voltage and regulates it.

Monochrome TV transmitter:



- The above is the block diagram representation of a monochrome TV transmitter, which is basically having two channels Audio channel and video channel.
- Both the channels are having processing unit, Amplifier units modulator and oscillator units
- The details about channels are as follows:

Audio Channel

The channel is for processing, modulation, and transmission of audio or sound signal.

1- Audio processing Unit

It is basically a transducer section. It contains a microphone which converts the audio signal into its electrical equivalent also it provides necessary noise futurization.

2- Audio Amplifier

It is a voltage amplifier; it increases the strength of the audio signal before feeding into modulator stage.

3- Pre-Emphasis Circuit

This circuit is used in the channel of frequency modulation (FM). This circuit is used to improve noise immunity. Which can be achieved by increasing signal to noise ratio.

4- **FM Modulator**

The audio signal is fed to FM modulator where it gets combined with carrier signal generated by crystal oscillator. Frequency modulator is adopted for sound because of noise free and high-fidelity property. During frequency modulation the modulation frequency should remain constant. Any deviation in the modulation frequency is overcome by Automatic Frequency Control (AFC) circuit. The AFC produces a DC equivalent voltage corresponding to the frequency deviation. Then the voltage is feedback to the tank circuit of local oscillator (LO) by which the resonant frequency of local oscillator can be changed. This change in resonant frequency brings back the frequency of the modulated signal to its correct value.

5- Frequency Multiplier

The frequency multiplier circuit increases frequency of sound carrier to the desired level for a particular TV system.

6- Power Amplifier

At last the audio signal gets amplified to raise the power level to the desired value.

Video Channel

This channel is for the processing, modulation and transmission of video signals. The different sections are:

1- TV camera

It is the video processing unit. It contains the camera tube, camera amplifier and deflection and sync pulse generator. The camera tube produces the electrical equivalent of the picture signal. Then the electrical equivalent signal is added with the deflecting and sync pulses and get amplified by the camera amplifier or video amplifier.

2- **DC Amplifier**:

It is another voltage amplifier whose function is to raise the signal level until it is sufficient for modulation.

3- **Modulated RF Amplifier**:

The necessary value of carrier frequency and amplitude can be achieved due to the presence of frequency multiplier and RF Amplifier along with crystal oscillator.

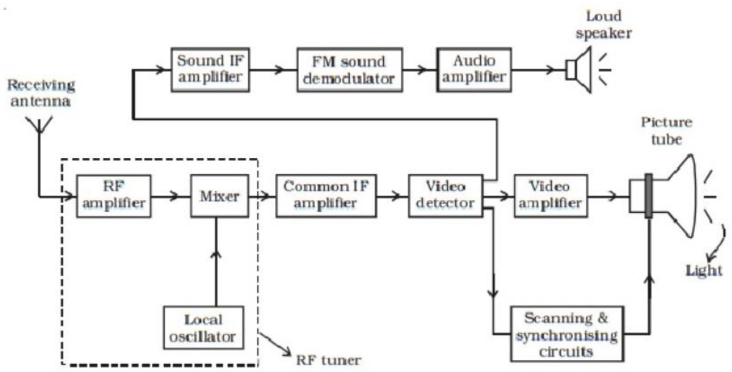
4- Power Amplifier

It is the final video amplifier which amplifies the composite video signal before transmission.

VSB Filter and Combining Network

At last the output of the two power amplifiers of both audio and video channels are mixed with each other by a combining network. Then the vestigial sideband Filter which is a band pass filter allows the necessary band to pass to the transmitting antenna for transmission. This filter is LC type so capable of handling high power.

MONOCHROME TV RECIEVER



It consists of various sections like Antenna, RF tuner, IF circuits, video detector, video amplifiers, AGC, synchronization and deflection circuit, audio section and picture tube etc.

<u>Antenna</u>:

Various receiving antennas are used to operate on VHF and UHF bands. When the receiving antenna comes across any electric or magnetic wave in space then some signal is induced which is of radio frequency range. This RF signal is transmitted to the first section of TV receiver through a transmission line. The first section is known as RF tuner.

<u>RF Tuner</u>

This section is so called because it selects the required frequency during reception of TV signal. It provides impedance matching to deliver maximum power to the rest section of receiver. This section is basically combination of RF amplifier, Mixer and Local oscillator.

<u>Local Oscillator:</u>

It provides a desired frequency to heterodyne with the signal of RF amplifier at mixer to produce necessary IF signal. The local oscillator is provided with fine tuning circuit so that its frequency can be adjusted accurately. Generally, the signal from RF amplifier contains both picture and sound. When this picture and sound signal gets heterodyned with local oscillator frequency picture IF and sound IF results at the output of mixer. The standard intermediate frequency for picture is 38.9 MHz and for sound 33.4 MHz.

IF Amplifier

This stage is a combination of 2 to 3 IF amplifiers. These IF amplifiers are basically voltage amplifiers to provide high gain so that a IF signal could be produced. High IF signal is required for easy filtering at video detector stage.

Video Detector

This section detects the amplitude modulated (AM) carrier to produce video signal at output. It also separates inter carrier sound IF and sends that to the sound section. The video detector is basically a diode detector which demodulates the video IF by the process of rectification.

Video Amplifier

The output of video detector is of few volts so it is required to strengthen the video signal before feeding to the picture tube. Video Amplifier stage is nothing but one of the two satges of single stage amplifiers. The gain adjustment of this stage provides contrast control of picture signal. The video amplifier gives signals to sound section, sync separator and keyed AGC beside driving the picture tube.

Sound Section:

At the input of detector when 38.9 MHz picture IF carrier beats with 33.4 MHz sound IF carrier then produces a different component of 5.5 MHz. This is called intercarrier beat signal which contains the sound information.

I. ***5.5 MHz Trap:***

It is a resonant circuit which isolate the second signal from picture tube. 5.5 MHz inter carrier beat signal is trapped by this resonant circuit from detector. In some receivers the 5.5 MHz intercarrier sound signal is trapped after the stage of amplification by video amplifier.

II. ***Sound Amplifier:***

The amplitude of inter carrier signal at the output of the video detector is quite low so it is amplified by one or two stages of IF amplifiers then fed to the FM detector.

III. ***FM Sound detector:***

The FM sound detector is a ratio detector provided by a limiter which detects the audio frequency signal from 5.5 MHz carrier frequency. The limiter eliminates any unwanted fluctuations in amplitude due to noise.

IV. ***Audio voltage and power Amplifier:***

The audio signal after detection need to amplify. The voltage amplifier strengthens the audio signal and the power amplifier raises the power level to drive the loud speaker. The volume and tune control of loud speaker is done by their amplifiers.

Sync Separator and deflection circuits:

The video signal at the output of video detector contains horizontal and vertical sync pulses. The sync separator circuits takes the composite video signal from the output of detector and only provides output clearing the sync pulse period. The sync separator circuit acts as a clipper circuit and produces a train of pulses. The train of pulses are simultaneously applied to the vertical as well as horizontal deflection circuits.

i.Vertical deflection circuit

The vertical deflection circuit consists of an integration, an oscillator and a power amplifier. The train of pulses when applied to the integrator, it behaves as a low pass filter, it passes the frequency pulses to the oscillator. These low frequency pulses are vertical sync pulses. The oscillators by getting the pulses produces the necessary saw tooth signal. The sawtooth signal is coupled to the vertical deflection coil of picture tube after single stage amplification.

ii.Horizontal deflection circuit:

The train of pulses from sync separator is fed to the differentiator. The differentiator acts as a high pass filter so it provides high frequency pulses to the horizontal oscillator present. These high frequency pulses are nothing but the horizontal sync pulses. The horizontal oscillator produces the necessary sawtooth signal. The frequency of operation of horizontal oscillator is controlled by AFC (Automatic Frequency Control) circuit. The sawtooth wave produced by the oscillator is coupled to the horizontal deflection coil after single stage amplification.

Note: A high Anode voltage is required in picture tube. This high voltage can be obtained by stepping up the voltage of horizontal amplifier output which can be done by EHT (Extra High Tension) circuit.

Automatic Gain Controller (AGC):

The output of video amplifier may tend to change as the strength of signal from antenna changes from time to time. AGC circuit provides fixed output at video amplifier in spite of wide variation in input from antenna. AGC controls the gain of RF amplifier and IF amplifier present before video detection. Function of keyed AGC is to conduct during the sync period only. This can be done by supply of keying pulse to the AGC circuit from the horizontal amplifiers.

LCD:

LCD is defined as Liquid crystal Display. It is defined as combination of two states of matter, the solid state and liquid state. It stands for liquid crystal to produce a visible image.

Construction:

It consists of a mirror 2 glass filter a liquid crystal layer, a negative electrode, a positive electrode 2 polarizing film and a cover glass.

Operation:

The principle behind the LCDs is that when an electrical current is applied to the liquid crystal , molecule tends to un-twist. This causes the angle of light which is passing through the molecule of the polarized glass through a particular area of the LCD. Thus, that particular area will become dark compared to other. The LCD works on the principle of blocking light. While constructing the LCDs a reflected mirror is arranged at the back. An electrode plane is made of Indium-Tin oxide which is kept on top and a polarized glass with a polarizing film is also added on the bottom of the device. Next comes to the second piece of glass with an electrode in the form of rectangle on the bottom and on the top, another polarising film. It must be considered that both the pieces are kept at right angles. When there is no current, light passes through the front of LCD it will be reflected by the mirror and get bounce back. As the electrode is connected to a battery, the current from it will cause the liquid crystals between the common plane electrode shaped like a rectangle to untwist. Thus, the light is blocked from passing through. That particular area appears black.

- **Applications:** In Liquid crystal thermometers, optical imaging, used in medical applications.

Terms Related to TV:

Aspect Ratio:

The TV system has a rectangular frame with a specific width and height. The ratio width to height of a frame is called Aspect Ratio.

Aspect Ratio = $\frac{width}{Height} = \frac{4}{3}$

In human affairs most of the motion occurs in horizontal plane. So larger width of the frame is desirable. Because the eyes can view more easily if the width is more than height.

Image continuity:

In TV system it is necessary to present the picture in such a way that an illusion of continuity is created and any motion in the scene appears on the screen is very smooth. To achieve this, persistence of human eye is considered. The human eye's retinas are stimulated by incident light and becomes easy immediately after the light is removed but persists for almost 1/16 of a second. Thus, if the scanning rate per second is made greater than 16or the number of pictures shown per second is more than 16, then the eye is not able to integrate the changing levels of brightness in the scene. So, when the picture elements are scanned rapidly enough, they appear to the eye as a complete picture unit with some of the individual elements visible separately.

Scanning:

The picture once created must be scanned properly. In this process if the scene is scanned both horizontally and vertically to provide sufficient number of pictures or frames per second to give illusion of continuous motion. Fundamental practice is 24fps bu actually TV system uses 25 fps.

Horizontal and Vertical scanning

(Discussed Earlier)

Flicker:

Although the rate of frame repetition is 25 Fps in TV picture to give 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 the successive frames. This results in flicker of light i.e, very uncomfortable to the viewer when the screen is made light and dark alternatively. This problem of flicker is solved by showing each picture twice so that 48 to 50 views are shown per second. Although there are still same 24 pictures Fps is available. As result of the increased frame rate, flicker is eliminated.

Composite video signal:

It is an analog video signal format that carries video as a single channel and the video information is encoded on the same channel.

Luminance Signal

Luminance refers to brightness and chrominance refers to colour.

Luma- y

Chrominance Signal

In video systems, chrominance refers to the signal used to convey the colour information of the picture. Chrominance is usually represented as two colour difference components,

i.e, U= B'- Y'

V=R'-Y'

According the colour frequency response of our eye,

Y= 0.30R+0.59G+0.11B

Y= White or Luma or brightness, R, G, B are primary

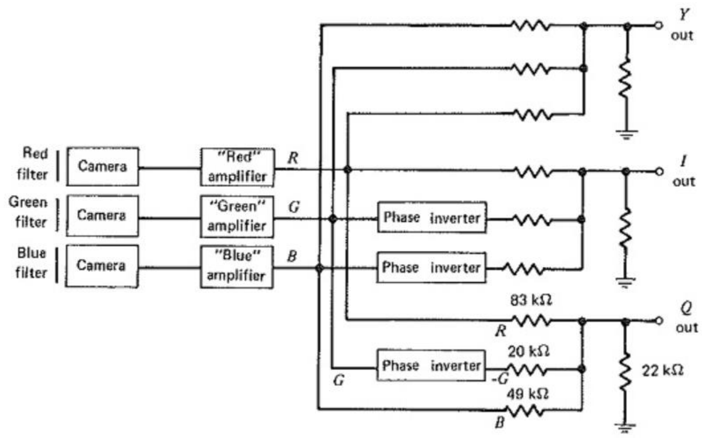
NTSC (National Television Standards Committee) refers two more component of signal to be sent for proper colour reproduction.

I=0.60R-0.28G-0.32B

Q=0.21R-0.52G+0.31B

Where, I= in phase, Q= Quadrature phase

Colour Camera Tube and Matrix arrangement



<u>PLASMA TV</u>

Plasma displays are bright, have a wide colour range and can be produced in fairly large sizes up to 3.8mt (150 inches). Power consumption varies greatly with plasma content with bright scenes drawing significantly more power than darker ones. The plasma that illuminates the screen can reach temperature of at least 1200^0 C. Typical power consumption is 400 watts for a 50-inch screen. The lifetime of a latest generation of plasma displays is estimated at 100000 hours (11 years). Plasma screens are made out of glass, which may result in glare on the screen from nearly light sources.

Advantages:

- Capable of producing deeper blocks allowing for a superior contrast ratio.
- As they use the similar phosphorous are used in CRT displays, plasma's colour reproduction is very similar to that of CRTs.
- Wider viewing angles than those of LCD.
- Less visible motion blur.
- Unaffected by clouding from the polishing process.

Disadvantages:

- Due to the bistable nature of the colour and intensity generating method, some people will notice that plasma displays have a shimmering or lightening effect with a number of hues and intensities.
- Uses more electrical power.
- Plasma displays are heavier than LCD and may require careful handling.

LCD display:

A liquid crystal display (LCD) is a flat panel display or other electrically modulated optical device that uses the light modulating properties of liquid crystals combined with polarizers. Most colour LCDs use the same technique, with colour filters used to generate red, green and blue pixels. The LCD colour filters are made with a photolithography process on a large glass sheet that are glued with liquid crystal.

Advantages:

- Very compact, thin and light.
- Low power consumption.
- Little heat emitted during operation.
- Emits almost no undesirable electromagnetic radiation.
- It can be made in almost any size and shape.
- Unaffected by magnetic fields, including the Earth's unlike most colour CRTs.

Disadvantages:

- Limited viewing angle in some older or cheaper monitors causing colour, saturation and brightness to vary with user position even within the intended viewing angle.

- Uneven back lighting in some monitors causing brightness distortion especially towards the edges.
- Loss of contrast in high temperature environment.
- Loss of brightness and much slower response times in low temperature environment.

LED Display:

A LED display is a flat panel display that uses an array of light emitting diodes as pixels for a video display. LED display can offer higher contrast ratios than a projector. Very early models were monochromatic by a design. In late 1980s Aluminium Indium Gallium Phosphide LEDs arrived.

Advantages:

- ✓ LEDS have very long-life times and are generally very robust.
- ✓ Low maintenance.
- ✓ Low power consumption.
- ✓ Brightness
- ✓ Heat produced is less.
- ✓ Cost is low.

Disadvantages:

- ✓ High initial price
- ✓ Temperature dependence
- ✓ Voltage sensitivity
- ✓ Light quality
- ✓ LEDs can only emit light with correct electrical property.
- ✓ The efficiency of LED decreases as the current increases.
- ✓ LEDs are much more attractive to insects than sodium vapour lights.
- ✓ In winter conditions, LEDs used for traffic light can have snow obscuring them, leading to accidents.

OLED:

▪ An organic light emitting diode (OLED or Organic LED) also known as organic electroluminescent.

There are two main families of OLED,

- These based on small molecules
- Those employing polymers

An OLED display works without backlight because it emits visible light. Thus, it can display deep black levels and can be thinner and lighter than an LCD display. The OLED was first developed in the year 1987. It used a two-layer structure with separate hole transporting electrons.

Advantages:

- ✓ Low cost
- ✓ Light weight and flexible plastic substrate
- ✓ Better picture quality
- ✓ Better power efficiency and thickness
- ✓ OLEDs have much faster response time.

Disadvantages:

- ✓ Limited life span (1000 hours)
- ✓ Water can instantly damage the organic materials of the display.
- ✓ OLED consume 40% more power as compared to normal LED or LCD display.

<u>QLED Display:</u>

A quantum dot display device that uses quantum dots (QD), semiconductors, nanocrystals which can produce pure monochromatic red, green and blue light.

QLEDs can achieve the same contrast as LED and micro-LED displays with ‘perfect’ black levels in the off state. The idea of using quantum dots as a light source is emerged in the 1990s. Quantum LEDs can be photo sensitive or electro emissive. Quantum dots naturally produce monochromatic light, so they are more efficient than white light sources.

Advantages:

- ▪ Very much useful in ultra-HD applications.
- ▪ Longer life span and energy efficiency
- ▪ Wider and promising applications

Disadvantages:

- ▪ Slower response time.
- ▪ Poorer viewing angles, when compared to LED display.
- ▪ Poor outdoor visibility.
- ▪ Immediate and irreplaceable damage due to water exposure.

Comparison between plasma TV and LED TV

Parameter	***Plasma TV***	***LED TV***
Thickness	Thicker	Thinner
Power Consumption	Consumes more power	Consumes less power
Screen Size	42 inches and above	Up to 90 inches
Life Span	Around 20000-60000 hours	Around 100000 hours
Cost	Cheaper than LED TV	Costlier than plasma
Viewing Angle	Looks the same from almost any angle	Shifts noticeably on the screen
Brightness and colour	Not as bright as LED TV	Brighter than plasma TV
Energy Used	More	Less
Back light	No	Yes
Contrast Ratio	Better	Worse than Plasma

<u>Difference between OLED and QLED</u>

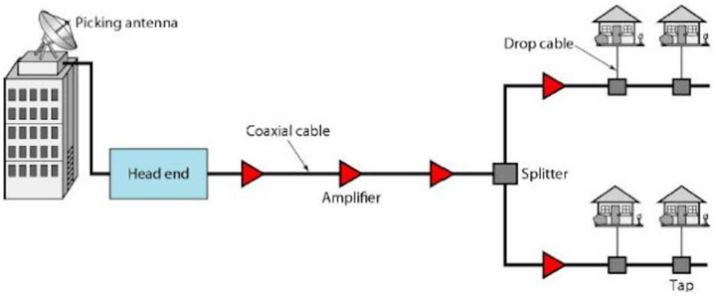
OLED	***QLED***
It stands for organic light emitting diode	It stands for quantum dots light Emitting Diode
The emissive electroluminescent layer is a film of organic compound, which emits light in response to an electric current.	Based on quantum dots Light emitting diodes with a quantum dot layer instead of OLED emitting layer.
OLED has a clear advantage over QLED when it comes to drastic viewing angles.	QLED displays tends to lose significant colours and lustre at far off viewing angles.
OLED enjoys stunning picture quality without losing out on contrast.	QLED displays are awfully brighter than OLEDs making them appropriate for brighter rooms.
This is clearly the winner in terms of achieving deeper blacks.	QLED suffer a little a little from light bleed as they still rely on back light from LCD panels.
Power consumption is less	Power consumption is more
More Expensive	Less expensive

CATV Systems

Types of cables used in cable TV:

Coaxial Cable- Through which radio frequency signals are transmitted.

*Fibre Optic Cables-*Through which light pulses are sent.



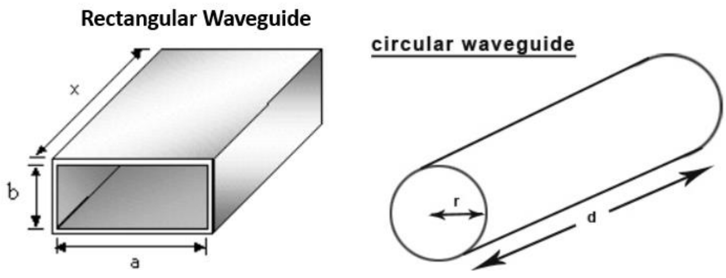
Chapter 4
Microwave Engineering

Waveguide is a hollow metallic structure having a particular cross-sectional area.

There are two types of waveguides:

1- Rectangular waveguide
2- Circular waveguide

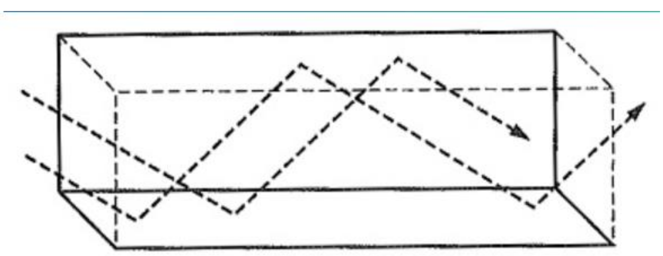
The hollow structure with rectangular cross-sectional area is called "rectangular wave guide". The hollow structure with circular cross-sectional area is called "circular waveguide".



Advantages of waveguide over transmission line:

- It looks like coaxial cable with inner conductor removed.
- Since there is no inner conductor, so construction is easier.
- Power handling capacity of waveguide is 10 times higher than the transmission line.
- As the inner conductor is not present, so there is no need of dielectric, hence no dielectric heating loss.
- Waveguides can transmit signals of very high frequency up to 300 GHz, i.e, nearly 30 times higher than transmission line.

Basic principle of waveguide:



The EM signal has two fields in it:

a) Electric field(E)
b) Magnetic Field(H)

The figure shows a rectangular waveguide through which signal will pass. As we know, the electric and magnetic fields are perpendicular to each other we can't send signal straight into the waveguide. If we do s, the electric field will be short circuited in contact with the metallic body of waveguide. In result of that the propagation is stopped. To avoid this condition, the signal is sent to the waveguide by zig-zag manner (at an angle). So that, the maximum signal is at the centre of the waveguide and minimum at the walls of the waveguide. The velocity of the signal inside the waveguide is decreased than 'V_c' (Free space Velocity $3x10^8$ m/sec). The signal is no more TEM rather than TE or TM.

Modes of Waveguide

There are two modes in waveguide:

a) Transverse Electric (TE)
b) Transverse Magnetic (™)

Transverse Electric

In this mode, the electric field is zero in the direction of propagation but E field will exist in the perpendicular direction.

Transverse Magnetic

In this mode, the magnetic field is 0 in the direction of propagation but H field will exist in perpendicular direction

Mode format

Generally mode in a waveguide is represented by $TE_{m,n}$ or $TM_{m,n}$

Where, m= No of half cycles along 'a'

n= No. of half cycles along 'b'

a = Width of rectangle cross section of waveguide

b = Height of rectangle cross section of waveguide

Examples: $TE_{0,1}$, $TE_{1,1}$, $TE_{2,1}$ etc

or, $TM_{1,1}$, $TM_{2,1}$, $TM_{1,2}$ etc

Dominant Mode

It is the smallest or minimum mode of a rectangular waveguide with which the signal can propagate inside the waveguide.

$TE_{1,0}$ = It is the dominant mode for TE.

$TM_{1,1}$= It is the dominant mode for TM.

Cut-off frequency

It is the minimum frequency with which the signal can propagate inside the waveguide. It is given by,

$$f_c = 1.5 \times 10^8 \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

Where, f_c= cut off frequency

m=No. of cycles along 'a'

n= No. of half cycles along 'b'

a= breadth of cross-section of rectangular waveguide.

b= height of cross section of rectangular waveguide.

Circular Waveguide:

If the cross section of the hollow metallic structure is circular then it is called a circular waveguide.

Advantages:

It is easier to manufacture as compared to rectangular waveguide.

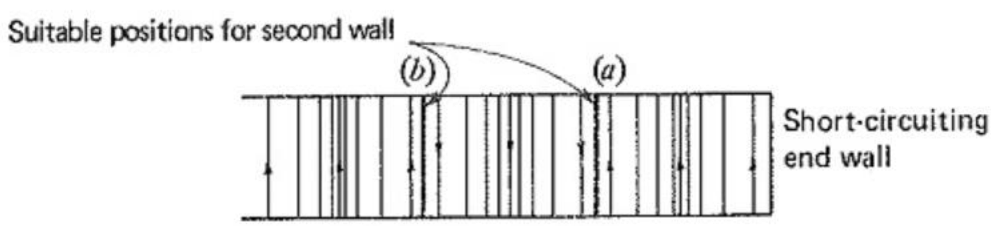
It is easier to couple or join two circular waveguides as compared to two rectangular waveguides.

Application:

- Used for rotational coupling.
- Frequencies above 10GHz cannot be used in rectangular waveguides only circular waveguides can take high frequency.

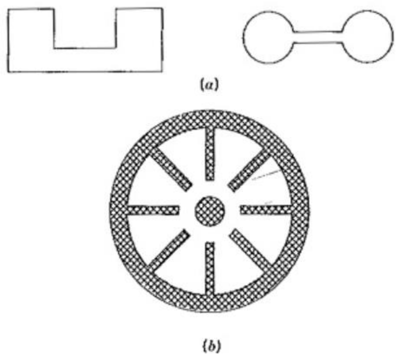
Microwave Devices:

Cavity Resonator (Microwave Oscillator):



Quality Factor $=2\pi \times \frac{Total\ energy\ stored}{Total\ energy\ dissipated\ per\ cycle}$

- ✓ Wave guides when not properly matched gives reflection. Hence, standing waves are created.
- ✓ If conducting walls are placed in the waveguide then oscillation takes place. But to start oscillation there must be a source in between the walls.
- ✓ We can assume the distance between the walls is $(n\lambda_p)/2$ where 'n' is an integer 1,2,3…
- ✓ The position of first wall gives standing wave but second wall gives oscillations.
- ✓ They will continue to oscillate unless the total energy gets dissipated.
- ✓ There are different kinds of cavity resonators as shown below.



Application:

Cavity resonator can act as Cavity wavemeter.

These are used as frequency measuring device.

These are used where LC tuned circuit cannot be used.

Two Cavity Klystron Amplifier

Construction:

A high-speed electron beam is created by the cathode when heated by heater. The electron beam is focussed by the help of focussing electrodes. There are two 2 cavities present in this amplifier. One is input cavity or buncher cavity. Another is output cavity or catcher cavity. The input RF signal is applied through the input or buncher cavity. The electron beam is attracted by high voltage collector terminal (B^+) (1000 volt) at the end. In gap A the electron interacts with the RF signal so electron beam interacts with the RF signal so electron bunches are created. The electron bunches move from gap A to gap B through drift space.

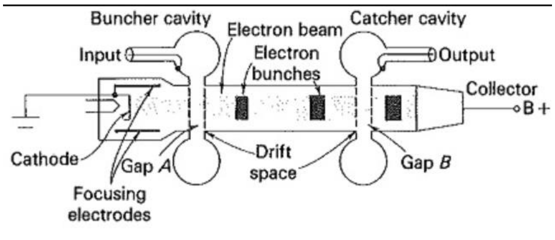
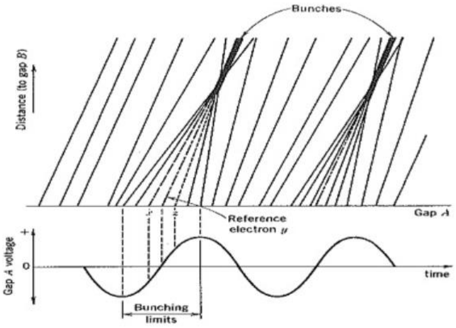


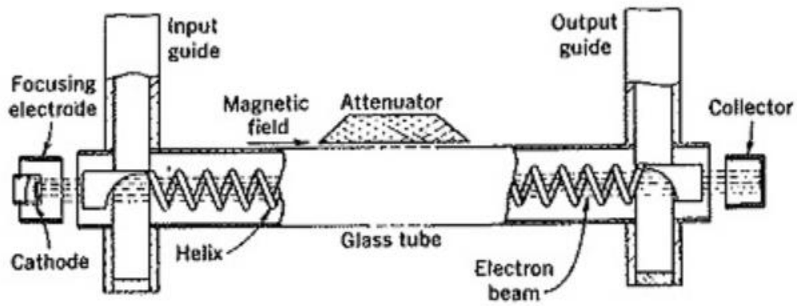
FIGURE 11-4 Klystron amplifier schematic diagram.



Operation:

The electron beam is created by the cathode and moves to the collector. In gap A RF signal is applied. The RF signal and the electron beam interact with each other to create electron bunches. To understand the bunching process, 3 reference electrons x, y, z is considered. First electron ‘x’ comes across negative peak of RF signal so the electron is retarded. The electron ‘y’ comes across the RF signal when the signal moves from negative to positive half (0 level), so the speed of the electron is constant and it easily reaches ‘x’ electron. The ‘z’ electron originated last from the cathode but it comes across positive peak of the RF signal so its speed is accelerated to catch the electron x and y. In this way we could see how electrons with the help of RF signal create bunches and the RF signal is amplified. The amplified RF signal is collected/ taken out from catcher cavity.

T**RAVELLING WAVE TUBE**



Introduction:

The drawback in 2 cavity klystron was the bunching occurs only at gap A.

It takes time to have another bunch because in that case the RF field was stationary (not moving).

Hence, the gain of the amplifier is minimized. So, to overcome this problem a slow wave structure called TWT is used. In order to have good interaction of electron beam with the RF field along with the electron beam it is necessary to move the RF field.

Operation:

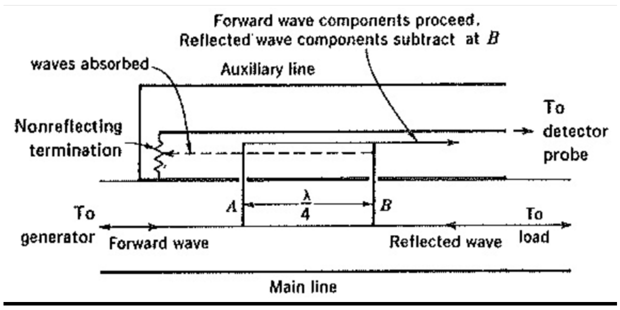
RF signal is applied through the input wave which propagates along the helix with the speed of light ($3x10^8$ m/sec).

An electron gun produces very narrow electron beam i.e., sent around the helix.

The RF field and the electron beam both interact continuously creating electron bunches and giving energy to the field. Hence very high gain can be obtained.

The RF field is controlled and focussed through the permanent magnet. For continuous bunching creation, the speed of RF field and electron beam should match. But the speed of RF field and electron beam should match. But the speed of RF field is very high i.e., $3x10^8$ m/sec and speed of electron beam is only 10% of it. So, to match the RF field and electron beam speed it is necessary to pass the RF field through helix. Because with the help of RF field can be reduced. The process continues and both the RF field and electron beam move towards the end of the helix.

DIRECTIONAL COUPLER



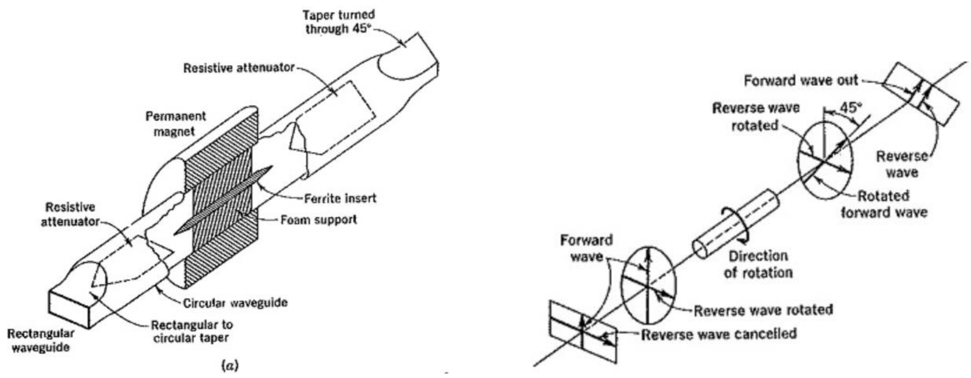
- ✓ It is necessary to measure the power being delivered to a load through a waveguide without reflection. So, a coupling unit is used i.e., Directional coupler.
- ✓ A two hole (A, B) directional coupler consists of a main wave guide in series with two holes A, B.
- ✓ The waveguides don’t actually touch the inner conductors, rather they couple the energy by being near to it.
- ✓ If they do touch then most of the energy in the main waveguide is coupled to the auxiliary waveguide.

- ✓ The auxiliary waveguide is terminated with a resistive load. This absorbs all the energy fed to it and other side of the auxiliary waveguide goes to the measuring device for VSWR measurement.
- ✓ When wave in the auxiliary waveguide waveforms moves from right to left (←), it is absorbed by the resistive load and terminated.
- ✓ So, only forward wave of the main waveguide travel from left to right (→) i.e., from source to load.
- ✓ The outgoing wave entering the position ‘A’ will meet the wave at position ‘B’ to be measured.
- ✓ When reverse wave travels in the auxiliary waveguide, it is cancelled by the forward wave or measured by the device. So, directivity of the directional coupler is a standard method to measure the unwanted wave or reflected wave.

Directivity

If the ratio forward wave to reverse wave measured by the device is 30 dB then it is the directivity of the directional coupler.

ISOLATOR



Introduction:

At microwave frequencies the coupling between microwave generator and load should in one way i.e., from generator to the load side. So, that the output amplitude and frequency cannot be affected by the changes in the load impedance. A number of semiconductor devices used for microwave amplification and oscillation. So, input and output always try to interface unless some means of isolation is employed. So, to avoid interference, generally isolators are used.

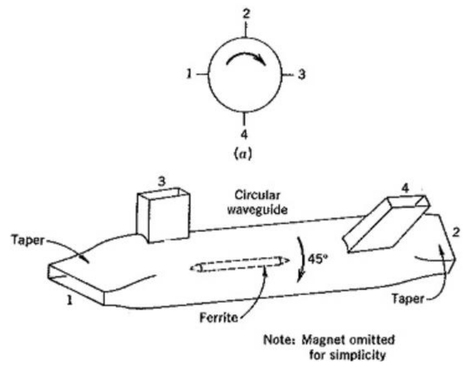
Construction:

The of isolators purely depends upon ferrite. Ferrite is an insulator derived from ferrous (Iron) having magnetic property same as iron. When EM wave travels through ferrite, they produce RF magnetic field in the material at right angle to the direction of propagation. If a permanent magnet is kept near to it, then it gives a rotation of 45^0 to the field. As shown in the diagram, a piece of circular waveguide at both the ends (transitions gives 45^0 to the field that is circular to rectangular). A thin pencil of ferrite is located near the circular waveguide and that is surrounded by a permeant magnet.

Operation:

Because of the DC magnetic field is applied, a wave passing through the ferrite in the forward direction is shifted 45^0 clockwise by the time it reaches the transition. It then attains or receives another 45^0 shifts at the transition and smoothly emerges from the taper. When the microwave tries to propagate through the isolator in the reverse direction, it is also rotated by 45^0 clockwise at the ferrite and another 45^0-transition located at the input side and finally absorbed by the resistive attenuator. So, isolation of forward to reverse wave is possible.

<u>Circulator:</u>



- ✓ A circulator is a ferrite device somewhat like a rat race (Signal enters from 1, emerges from 2 not from 3 or 4). It is a 4 port (terminal) device as shown in the figure.
- ✓ It has the property that each terminal is connected only to the next clockwise port or terminal.
- ✓ Port 1 is connected to port 2, port2 to port 3, port3 to port 4 and port 4 to port1.

- ✓ Main application of such circulator is either the isolation of transmitter and receiver connected to the same antenna as in case of RADAR. On isolation of input and output in 2 terminals amplifying devices such as parametric amplifiers.

Operation:

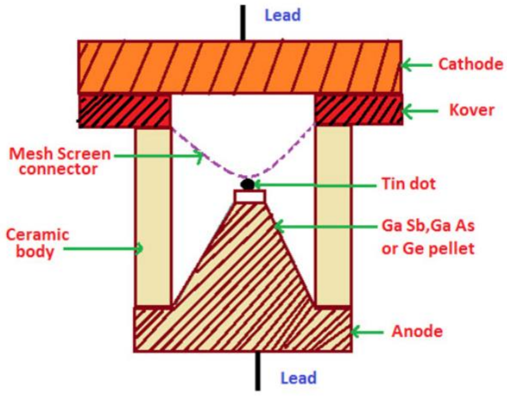
A four-port circulator is shown in figure above very much similar to Faraday Rotation Isolator. Power is entering port 1 is connected to TE_1 mode in the circular waveguide, passes port 3 unaffected because the electric field does not get space there and continues to cross port 2 just as it was as it was in isolator. Power fed to port 2 will undergo the same result as in isolator but now it is rotated so that although it cannot come out from port1 it has port 3 suitably aligned as it comes from it. Similarly, port 3 is coupled only to port 4 and port 4 to port 1. It is suitable for low power device. Its use is restricted to high frequencies i.e., not suitable for low frequencies.

TUNNEL DIODE:

The diode with very thin junction is called Tunnel Diode. The other name of diode is ESAKI Diode. It exhibits negative resistance with forward bias. As it has very much useful in microwave application.

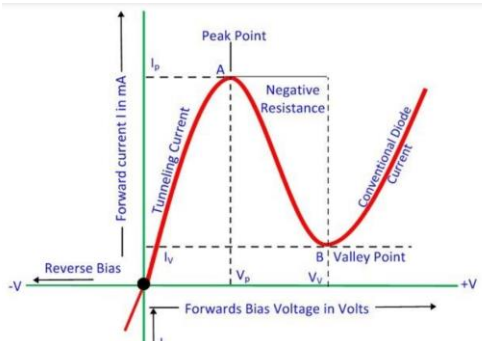
Material and Construction:

- Germanium and Gallium arsenide are preferrable semiconductors to make TUNNEL Diode.
- This diode has very simple construction.
- A very small tin dot about 50 µm in diameter is soldered or alloyed to a heavily doped pellet of N-type Ge or Ga As.
- The pellet is then soldered to a kovar pedestal used for heat dissipation which forms the anode contact.
- The cathode contact of kovar is connected to the tin dot, which helps to reduce inductance.
- The diode has a ceramic body and a hermatically sealing lid on top.



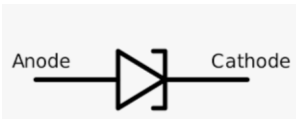
operation:

- ⇨ These are heavily doped, 1000 times higher than normal diode.
- ⇨ The thickness of depletion layer is around 0.1µm. The thickness of layer is so small that tunnelling occurs with very small forward voltage.
- ⇨ Initially with application of forward voltage application the current decreases. This is called negative resistance effect.
- ⇨ This special behaviour of diode makes it useful for Amplifier as well as oscillator application.



The forward bias is given, the current reaches peak point. As the forward bias is increased above this point, the current drops till it reaches valley point is achieved if the forward bias is increased further, then again current increases till peak point.

Symbol:



CYCLOTRON

A cyclotron is a type of compact particle accelerator which produces radioactive isotopes that can be used for imaging procedures. Stable non-radio-active isotopes are put into the cyclotron which accelerates charged particles(photons) to high energy in a magnetic field.

Principle of operation:

A cyclotron accelerates a charged particle beam between two hollow D-shaped sheet metal electrodes known as the ‘dees’ inside the 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 centre of this space. The dees are placed face with a narrow gap between them, creating a cylindrical space within them for particles to move. Particles are injected into the centre 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 Lorenntz 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 particle. The frequency of the voltage is set so that particles make a circuit during a single cycle of the voltage. To achieve this condition, the frequency must be set to particles cyclotron frequency

$f=(qB)/2\pi m$

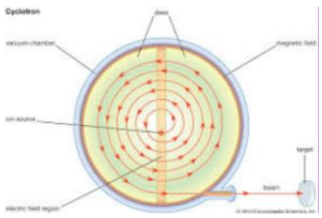
where, B= Magnetic field strength

q=electric change of the particle

m=relativistic mass of the charged particle.

Each time after the particles pass to the other dee electrode the polarity of the RF voltage reverses. Therefore, each time the particles cross the gap from one dee electrode to the other, the electrode to the other, the electric field is in correct direction to accelerate them. The particles increasing speed due to these pushes causes then to move in a larger radius circle with each rotation, so the particles move in a spiral path outward from the center to the rim of the dee.

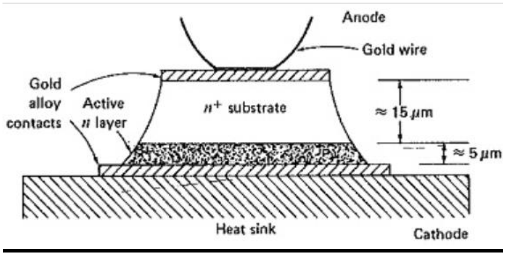
When they reach the rim a small voltage on a metal plate deflects the beam so it exists the deeps through a small gap between them so it exists the deps through a small gap between them and hits a target located at the exit point at the rim of the chamber or leaves the cyclotron through an evacuated beam tube to hit a remote target. Various materials may be to the collisions will create secondary particles which may be guided outside of the cyclotron and into instruments for analysis. The cyclotron was first cyclical accelerator. The advantage of the cyclotron design over the existing electrostatic accelerator and Van de Graff generator was that in these machines the particles were only accelerated by the voltage, So, the particles energy was equal to the accelerating voltage on the machine, which was limited by the air breakdown to a few million volts. In the cyclotron, in contrast, the particles encounter the accelerating voltage many times their spiral path and so are accelerated many times, so the output energy can be many times the accelerating voltage.



GUNN EFFECT

In 1963, Gunn discovered the transferred electron effect which now bears his name. This effect is instrumental in the generation of microwave oscillations in bulk semiconductor materials. The effect was found by Gunn to be exhibited by Gallium Arsenide and Indium Phosphide but cadmium telluride and indium arsenide have also subsequently been found to possess it.

Introduction:



Introduction:

- If a relatively small dc voltage is placed across a thin slice of gallium arsenide, such as shown in the figure then negative resistance will manifest itself under certain conditions.
- These consists merely of ensuring that the voltage gradient across the slice is in excess of about 3300v/cm.
- Oscillations will occur if the slice of GaAs is very high and the electron velocity is also high, so the oscillations will occur at microwave frequencies.

- Gunn effect is a bulk property of semiconductors and does not depend on either junction or contact properties.
- This effect is independent of total voltage or current and does not affect by magnetic fields or different types of contacts.
- It occurs in N-types material only and associated with electrons rather than holes.
- The voltage required was proportional to the sample length the inverter concluded that the electric field in volts per cm was the factor determining the presence or absence or absence of oscillations takes place.
- The frequency of oscillations produced corresponded closely to the time that electrons would take to traverse such a slice of n-type material as a result of the voltage applied. The bunch of electrons here are called a domain. It is formed once per cycle and arrives at the positive end of the slice to excite oscillations in the tuned circuit.

Facts about Gunn diode

- The Gunn diode (oscillator has received various names). Although only GaAs diodes have been considered, Indium Phosphide (In-P) Gunn diodes are becoming widely used especially at the highest frequencies. In-P has properties quite similar to those of GaAs while also offering the advantages of higher peak -to -valley ratio in its negative resistance characteristics and lower noise.
- ‘Oddball’ operating principles are used by the majority of solid-state microwave devices and IMPATT diodes are not used here because all the simple devices get themselves inverted a long time ago and they did not work at microwave frequencies.

Applications:

- Gunn diodes are grown epitaxially out of GaAs or In P doped with silicon, tellurium or selenium.
- The substrate used here as an ohmic contact is highly doped for good conductivity while the thin active layer is less heavily doped.
- The gold alloy contacts are electrode deposited and used for ohmic contact and heat transfer for subsequent dissipation.
- Diodes have been made with active layers varying in thickness from 40 to about 1μm at highest frequencies.
- The actual structure is normally square and so far Ga As diodes predominate commercially.

Plasma TV:

- Plasma displays are bright, have a wide colour range and can be produced in fairly large sizes up to 3.8 m (150 inches).
- Power consumption varies greatly with plasma content with bright scenes drawing significantly more power than darker ones.
- The plasma that illuminates the screen can reach temperature of at least 1200’C. Typical power consumption is 400 watts for a 50 inch screen
- The Lifetime of a latest generation of plasma display is estimated at 100000 hours (11 hours).
- Plasma screens are made out of glass, which may result in glare on the screen from nearly high sources

Advantages:

- Capable of producing deeper blacks allowing for a superior contrast ratio.
- As they use the same or similar phosphorous are used in CRT displays, plasma’s colour reproduction is very similar to that of CRTs.
- Wider viewing angles than those of LCD
- Less visible motion blur
- Superior uniformity.
- Unaffected by clouding from the polishing process

Disadvantages:

- Due to the bistable nature of the color and intensity generating method, some people will notice that plasma displays have a shimmering or flickering effect with a number of hues and intensifies
- Uses more electrical power.
- Plasma display are heavier than LCD and may require careful handling.

References:

1. Kennedy's Electronic communication systems, G kennedy, B Davis, S R M Prasanna, Mc Grew Hill Education.
2. Analysis and Design by C A Balani, the discipline of antenna Theory, Wiley publication.
3. T V and Video Engineering A M Dhake.