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S.Y. Diploma : Sem. IV [EJ/EX/ET/EN/IS/IC/IE/IU]

Analog Communication

Prelim Question Paper Solution

1. (a) (i) Block Diagram of Communication System

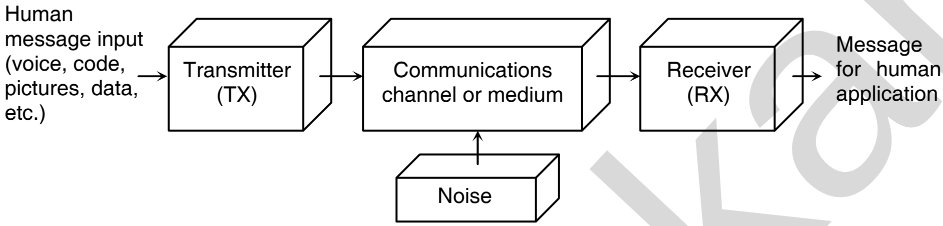


Fig.: The basic elements of any communications system

1. (a) (ii) Baseband Signals

Regardless of whether the original information signals are analog or digital, they are all referred to as baseband signals.

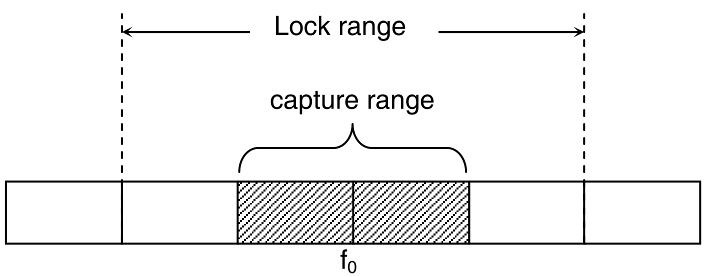
In a communications system, the information signals may be transmitted by themselves over the medium or may be used to modulate a carrier for transmission over the medium. Putting the original voice, video, or digital signals directly into the medium is referred to as baseband transmission. For example, in many telephone and intercom communications systems, it is the voice itself that is placed on the wires and transmitted over some distance to the receiver. In some computer networks, the digital signals are applied directly to coaxial cables for transmission to another computer.

1. (a) (iii)

- Amplitude, width or position of the pulse carrier is varied in proportion with the instantaneous value of modulating signal.
- Types of Pulse Modulation are :
  PAM, PWM, PPM, PCM, DM

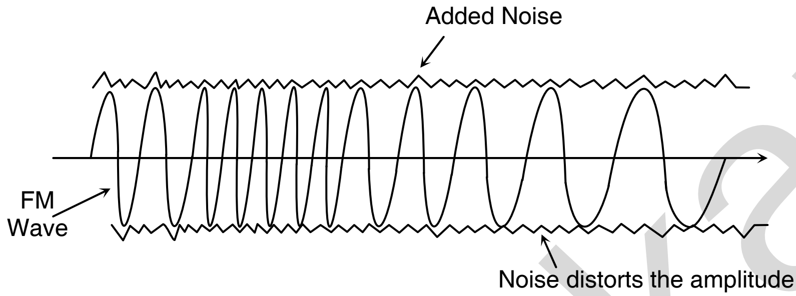
1. (a) (iv) **Lock range :** The range of frequencies over which the PLL will track the input signal and remain locked is called lock range.

Capture range : The range of frequencies over which the PLL will capture the input signal is known as capture range.



In locked phase, the voltage controlled oscillator output will be equal to the input signal and error signal will be identified to the original modulating signal of the frequency modulator input.

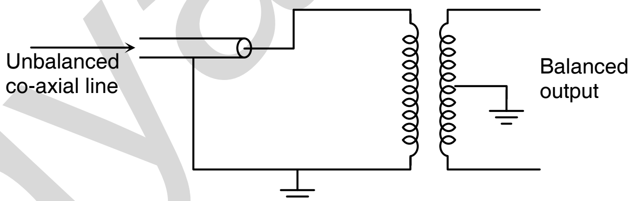
1. (a) (v) FM reception is noise free because



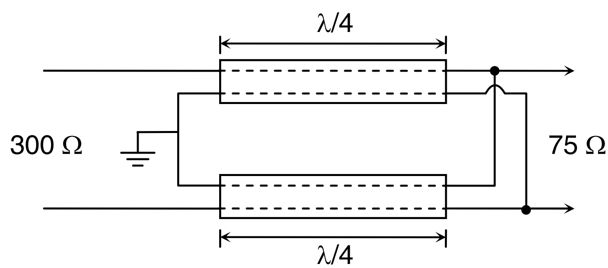
- As the FM wave travels from transmitter to receiver, the noise gets added to it.
- Due to noise the amplitude of FM wave gets distorted. But FM waves do not contain the information in their amplitude variations at all.
- Hence the noise cannot distort the information contained in the FM wave.
- So FM and PM waves are more immune to noise or more noise resistant.

1. (a) (vi) Baluns (Balanced to unbalanced)

- Balun is a special device used for connecting balanced transmission line to unbalanced load.
- It can also be used to connect an unbalanced transmission line to a balanced load such as antenna.



- It consists of a special transformer with an unbalanced primary and a center tapped secondary winding.
- The outer conductor i.e. shield of an unbalanced co-axial transmission line is connected to ground.
- The balun is used in TV receivers for matching the impedance of two pair or parallel to the input of the TV set.



- It consists of two quarter wave ($\lambda/4$) lines each having an impedance of 150 Ω. The two lines are connected in series at one end resulting in 300 Ω and connected in parallel at the other and resulting in 15 Ω.

1. (a) (vii) Electromagnetic radiation involves the creation of electric and magnetic field in the free space or in some other physical medium. The waves that propagate is known as Transverse Electromagnetic waves or Transverse Waves.

1. (a) (viii) Directivity

- The directive gain can be defined in any direction. However directivity means the maximum directive gain which is obtained in only one direction in which the radiation is maximum.
  $\therefore$ Directivity = Maximum directive gain

Power gain

- The power gain of an antenna is defined as ratio of power fed to an isotropic antenna to the power fed to a directional antenna, to develop the same field strength at the same distance, in the direction of maximum radiation.

$$\text{Power gain} = \frac{\text{Power fed to the isotropic antenna}}{\text{Power fed to the directional antenna}}$$

- Compare the power gain and the directive gain. The directive gain is the ratio of "radiated" powers while the power gain is the ratio of powers fed to the antennas.
- Thus the power gain takes into account the antenna losses.
- The relation between the power gain and directive gain is as follows :

$$A_p = \eta D \qquad \dots (1)$$

where, A_p = Power gain.
D = Directivity (maximum directive gain).
η = Antenna efficiency = 1 for ideal lossless antenna.

- The power gain has more practical importance than the directivity.

1. (b) (i) Electromagnetic Spectrum

Before it can be transmitted, information must be converted into electronic signals compatible with the medium. For example, a microphone changes voice into a voltage of varying frequency and amplitude. This baseband signal is then passed over wires baseband signal is then passed over wires to a receiver or head phone. This is the way the telephone system works. A tremendous amount of information is transmitted in this way.

Instead of using wires, free space can be used. The information is converted into electronic signals which radiate into space. Such signals consist of both electric and magnetic fields. These so called electromagnetic signals travel through space for long distances. Electromagnetic signals are also referred to as radio-frequency (RF) waves.

Electromagnetic waves are signals that oscillate; that is, the amplitudes of the electric and magnetic fields vary at a specific rate. The field intensities fluctuate up and down a given number of times per second. The electromagnetic waves vary sinusoidally. Their frequency is measured in cycles per second (cps) or hertz (Hz). These oscillations may occur at a very low frequency or at an extremely high frequency. This entire range of frequencies is referred to as the electromagnetic spectrum. It includes signals such as the 60-Hz power line frequency and audio (voice) signals at the low end. In the midrange are the most commonly used radio frequencies for two-way communications, television, and other applications. At the upper end of the spectrum are infrared and visible light. Figure below shows the entire electromagnetic spectrum. Both frequency and wavelength are given.

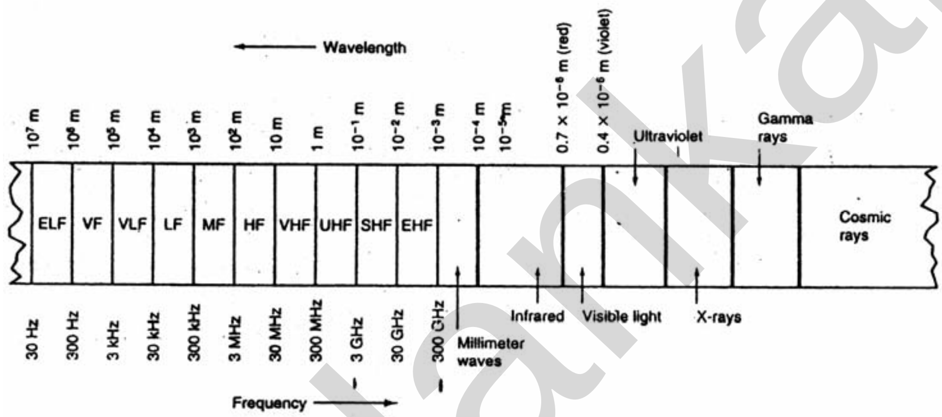


Fig. : The electromagnetic spectrum used in electronic communications.

Remember the relationship between frequency f and wavelength λ.

$$\lambda = \frac{300}{f}$$

where λ is in meters and f is in megahertz (MHz). For instance, if f = 21 MHz, then

$$\lambda = \frac{300}{f}$$
$$= 14.29 \text{ m}$$

If you know the wavelength in meters, you can compute the corresponding frequency with the expression

$$f = \frac{300}{\lambda}$$

A wavelength of 2.4 m expressed as a frequency is :

$$f = \frac{300}{2.4}$$
$$= 125 \text{ MHz}$$

1. (b) (ii) Types of microwave antennas are :
(1) Dish antenna
(2) Horn antenna.

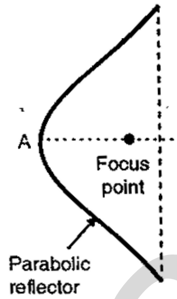


Fig. : Dish antenna with a parabolic reflector.

DISH ANTENNAS

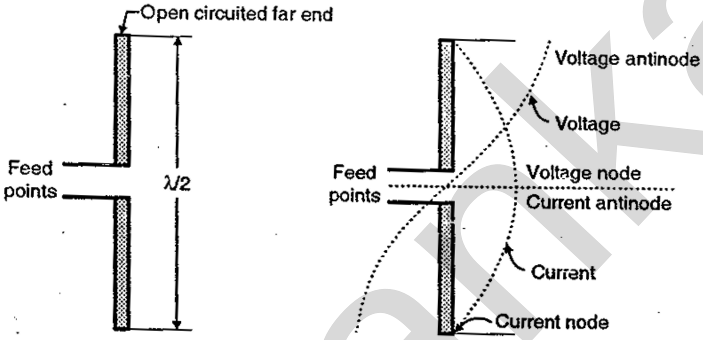
- Dish antennas are the microwave antennas which use a parabolic reflectors.
- The antenna is actually placed at the focal point of the parabolic reflector.
- The special geometric properties of a parabolic reflectors makes it very useful as a microwave or light reflector.
- Figure shows a dish antenna with a parabolic reflector.
- The dish antenna of figure can be a transmitting antenna or a receiving antenna.
- If it is a transmitting antenna, then all the waves coming out of the source (which is at the focal point) are reflected equally by the reflector from every point It should be noted that all the reflected waves are in phase with each other.
- So they will assist each other, get added to give out a strong radiation along the axis AB.
- However cancellation of waves will result in all other directions. This shows that the parabolic reflector leads to the, production of concentrated beams of radiation.
- We can use the dish antenna as a receiving antenna as well. The construction remains same but at the focal point, we need to use a receiver instead of a source.
- The parabolic reflector will bring only those rays together which are coming in direction BA. These rays are brought together at the focal point.
- The rays arriving from any other direction are canceled out. The reflector acts like a mirror to collect radiation from a large area.
- A practical parabolic reflector is a three dimensional bowl shaped surface which obtained by revolving the parabola about the axis AB.
- This three dimensional surface is called as paraboloid or a parabolic reflector or a microwave dish.
- The parabolic reflector actually increases the gain as well as the directivity of the microwave antenna.

1. (b) (iii) Comparison between Ground Wave and Space Wave Propagation

		Ground Wave	Space Wave
1)	Frequency range	It exists in the frequency range from 30 KHz to 3 MHz.	Used for frequency above 30 MHz.
2)	Method of wave propagation	Ground waves are surface waves which travels along.	Space wave travels in a straight line.

2. (a) **RESONANT ANTENNAS (HALF WAVE DIPOLE ANTENNAS) :**

- In the Radiation Mechanism and Evolution of Dipole Antenna, we have seen how a transmission line can be converted into a dipole antenna. The simplest dipole antenna is of length ($\lambda/2$) as shown in figure (a).
- The dipole antennas are also called as the resonant antennas. A resonant antenna corresponds to a resonant transmission line.
- A resonant transmission line has a resonant length i.e. a length which is multiple of half wavelength ($\lambda/2$).
- The dipole antennas have lengths of $\lambda/2$, λ, $3\lambda/2$ etc. which arc all multiples of $\lambda/2$. Hence the dipole antennas arc resonant antennas.



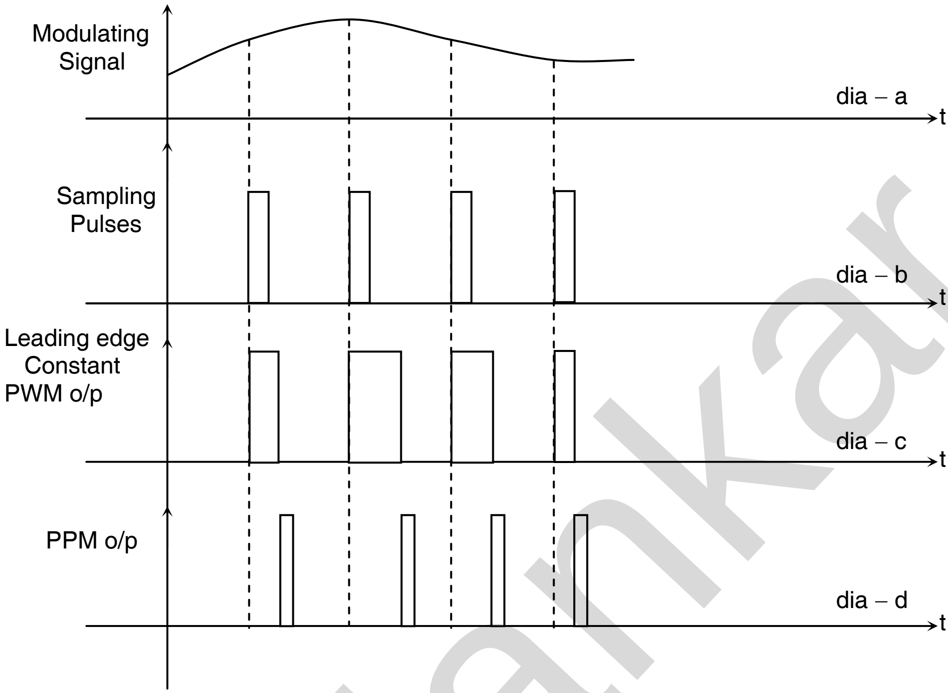
(a) Half wave dipole antenna. **(b)** Voltage and current distribution in dipole antenna.

Voltage and Current Distribution

- Figure (b) shows the voltage and current distribution along the length of a half wave length dipole.
- Due to the voltage applied by an RF generator at the feed points, travelling waves and standing waves are set up along the length of the antenna,
- As the conductors of the dipole are open circuited at the outer ends, the standing waves are produced due to reflections taking place at the open circuit (as discussed in Radiation Mechanism and Evolution of Dipole Antenna).
- Due to reflections, standing waves are set up which give rise to the nodes and antinodes of voltage and current.
- Due to the open circuit at the outer ends, current minima (nodes) are obtained at the extreme ends of the antenna, whereas voltage maxima's (antinodes) are obtained at the extreme ends.
- The voltage node and current antinode are observed at the feed points which are at a distance $\lambda/4$ from the end points.

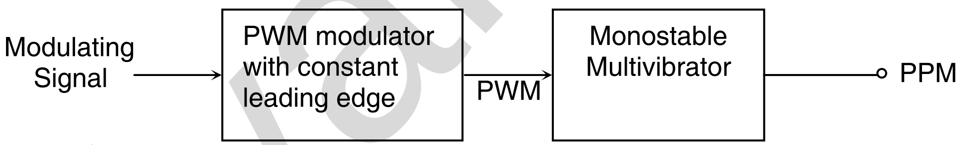
2. (b) **Pulse Position Modulation (PPM)**

The position of pulses are varied in accordance with the modulating signal. For increasing AF signal, pulses shift to right & for decreasing AF signal pulses shift to left.



PPM Modulator :

The PPM modulator is as shown below.



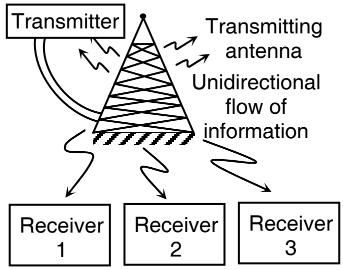
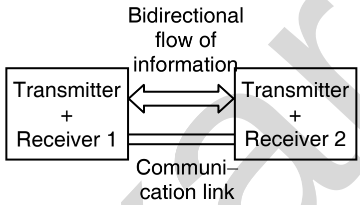
1) The modulating signal given to the PWM modulation at the output, we get PWM pulses as shown in diagram.

2) The PWM pulses are used to trigger monostable multi–vibrator at the negative edge of PWM pulses.

3) The monostable multivibrator goes into high state for predetermined small duration & come back to low state. Thus pulses are produced by monostable multi–vibrator with reference to negative going edges of PWM pulses.

4) With respect to leading edge of PWM pulses the output of monostable multivator shifted to right according to the modulating signal. Thus we get PPM.

2. (c) Difference between simplex and duplex mode of communication

	Parameters	Simplex	Duplex
1)	Definition	Communication is one way.	Communication is two way.
2)	Examples	Radio/TV broadcast.	Telephone
3)	Diagram		

2. (d) Super Heterodyne Receiver

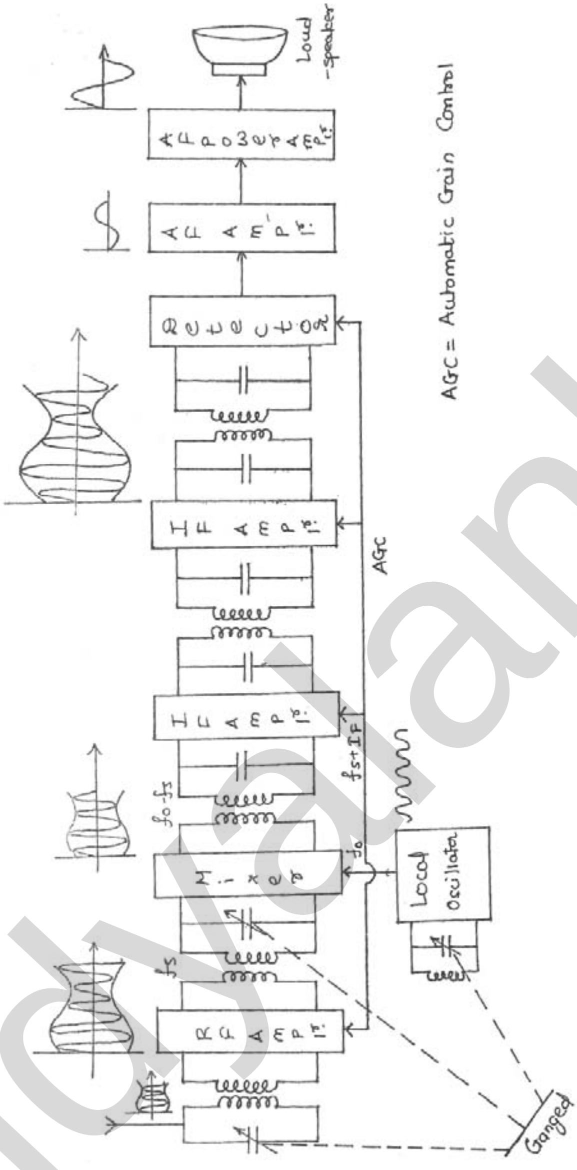
The features of heterodyne receiver is that all incoming radio frequency signals called intermediate frequency by using heterodyne process.

In this receiver, the received signal frequency is mixed with the local oscillator frequency f_0. The local oscillator is an LC oscillator which produce sinusoidal oscillations of frequency f_0. The frequency of local oscillator depends on the values of L & C of associated tuned circuit. The signal frequency f_s and signal f_0 gives to the mixer circuit. Mixer is a non-linear circuit. It will produce the output which contain different frequency component such as f_s, f_0, $f_0 \pm f_s$, harmonics of input frequencies and the IC components. The inputs tank circuit of IF amplifier is tuned to $f_0 - f_s$ which is always 455 KHz and is known as Intermediate frequency I_f. To get I_f always = 455 KHz, the local oscillator should be tuned such that whatever may be input signal frequency f_s, local oscillator frequency f_0 should be always 455 KHz, more than f_s. AM wave with 455 KHz is amplified to the desired level by 2 or 3 I_f amplifier and then it is fed to the detector which detects a taken out the AF information from the AM wave. This audio frequency signal is then amplified by voltage and power amplifier so that it can drive the loudspeaker.

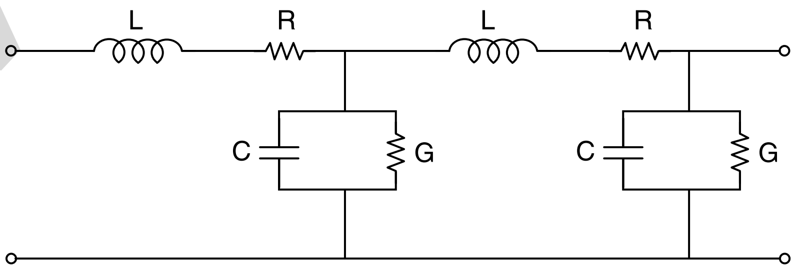
Advantages of Superheterodyne R_x over TRF R_x :

1) Since, major part of gain of receiver is provided by IF amplifiers which are tuned to 455 KHz, the neutralization capacitor can be easily designed for fixed IF. Thus unwanted feedback, eliminated and hence, it eliminates the possibility of instability at high frequency side of tuning range.
2) Since IF amplifier are tuned at fixed frequency. Therefore, the bandwidth remains constant and the adjacent channel does not pick up by the receiver. Thus we get better selectivity.
3) Gain of receiver is provided by IF amplifier and IF amplifier has constant bandwidth. Therefore the gain provided by IF amplifier is also constant over the tuning range of AM broadcasting.
4) Number of capacitors which are to be tuned simultaneously are less, hence easy to manufacture or tune.

Block diagram of superheterodyne receiver :



2. (e) Equivalent Circuit of a Transmission Line



- When RF energy flows through a normal conductor it is no longer a simple resistive conductor but instead appears to be a complex interconnection of inductor and capacitor as well as resistor.

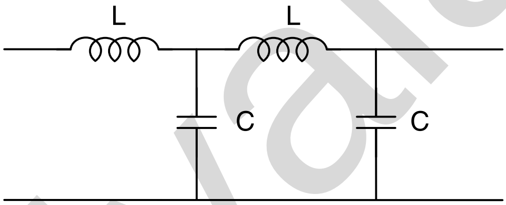
- Since each conductor has a certain length and diameter it will have resistance and magnetic is created along the conductor along the conductor when current is flowing so inductance is obtained.

- There are two wire used to each other. So there will be capacitance between them.

- The two wires are separated by a medium called dielectric which cannot be perfect in insulation the current leakage through it can be represented by shunt conductor.

- R, L, C, E, G are called as the distributed components their value are specified in per unit length of Transmission Line.
  Where
  - R $\rightarrow$ Series Resistant in ohm/unit length
  - L $\rightarrow$ Series capacitance in Henry/unit length.
  - C $\rightarrow$ Shunt capacitance in Farad / unit length.
  - G $\rightarrow$ Shunt conductance in susception unit length.

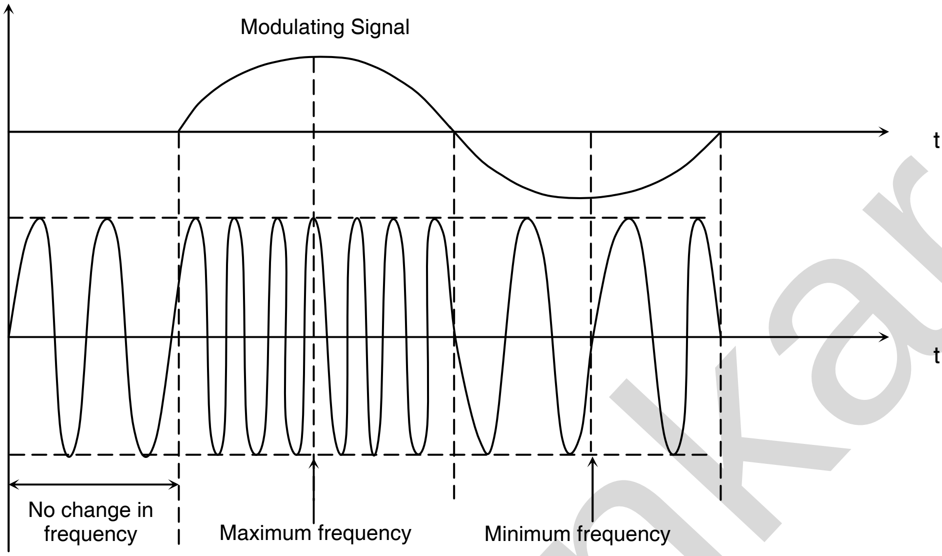
Audio frequency and Radio frequency circuit diagram



2. (f) **FREQUENCY MODULATION**

Definition : Frequency modulation is a system of modulation in which the frequency of carrier is changed according to the change in the amplitude of the modulating signal. The amplitude and phase of the carrier signal remain constant.

Carrier frequency	–	increases when modulating signals amplitude increases decreases when modulating signals amplitude decreases
Carrier amplitude	–	remains constant
Carrier phase	–	remains unchanged



Frequency Modulation Wave

Deviation (δ)

The amount by which the carrier frequency varies from its unmodulated value is called as deviation.

Deviation (δ) $\propto$ Modulating voltage (v_m)

(a) The rate at which this frequency variation or oscillations takes place is equal to the modulating frequency (f_m).

(b) The amplitude of the frequency modulation wave always remains constant.

Mathematical Representation of Frequency Modulation :

The modulating signal is a simple sine wave represented as

$$v_m = V_m \sin 2\pi f_m t = V_m \sin \omega_m t$$

(a) The unmodulated carrier is represented as :

$$v_c = V_c \sin (\omega_c t + \phi)$$

(b) The frequency modulation wave is represented as :

$$v_{FM} = V_c \sin\left[\omega_c t + \frac{\delta}{f_m} \sin \omega_m t\right]$$

Modulation Index

The modulation index of an frequency modulation wave is defined as

$$m_f = \frac{\text{Frequency deviation}}{\text{Modulating Frequency}}$$

$$m_f = \frac{\delta}{f_m}$$

(a) Modulation index decides the bandwidth of the frequency modulation wave.

(b) Modulation index also decides the number of sidebands having significant amplitudes.

3. (a) Given : Modulating signal $v_m = 10 \sin 2\pi (1 \times 10^3) t$
Carrier signal $v_c = 30 \sin 2\pi (1 \times 10^6) t$

But in general form modulating signal and carrier signal are represented as :

$v_m = V_m \sin 2\pi f_m t$
$v_c = V_c \sin 2\pi f_c t$

Comparing these with given equations,

$V_m = 10$ $f_m = 1 \times 10^2$ Hz
$V_c = 30$ $f_c = 1 \times 10^6$ Hz

i) Modulation factor / modulation index and percentage modulation :

modulation index, $m = \frac{V_m}{V_c} = \frac{10}{30} = 0.33$

% modulation = $0.33 \times 100 = 33\%$

ii) Frequencies of sidebands :
(a) frequency of upper sideband, $f_{USB} = f_c + f_m = 1000000 + 100 = 1000100$ Hz
(b) frequency of lower sideband, $f_{LSB} = f_c - f_m = 1000000 - 100 = 999900$ Hz

iii) Amplitudes of sidebands :

Amplitude of USB = Amplitude of LSB = $\frac{mV_c}{2} = \frac{0.33 \times 30}{2} = 4.95$ V

iv) Bandwidth, $BW = 2f_m = 2 \times 1 \times 10^2$ Hz = 200 Hz

3. (b) This unwanted signal at frequency f_{si} is known as the image frequency and it is said to be the image of the signal frequency f_s. The relation between f_s and f_{si} is :

∴ Image frequency :

$f_{si} = f_s + 2\ IF$

Given : R_F = 800 KHz
Local oscillator frequency (f_o) = 1255 KHz
I_F = 455 KHz

To find : Image frequency = ?

f_{si} (i.e., image frequency)

$f_{si} = f_o + IF$
= 1255 KHz + 455 KHz

∴ f_{si} = 1.710 KHz

∴ Image frequency
= 1.710 KHz

3. (c) Wave Attenuation and Absorption

Free space is vacuum, and there is no loss of energy occurs during propagation. As waves propagate through free space, they spread out, resulting in a reduction in power density. This is called as an attenuation, and it occurs in free space as well as in Earth's atmosphere. Since Earth's atmosphere is not a vacuum, it contains particles that can absorb electromagnetic energy. This type of reduction of power is called as "Absorption". It does not occurs outside the Earth's atmosphere.

Attenuation :

From inverse square law it is seen that there is reduction in power density with the distance from the source. As the waveform moves away from the source, the electromagnetic field spreads out. i.e. the waves moves away from each other and the number of waves per unit area decreases. None of the radiated power is lost or dissipated because the wavefront is moving away from the source, the wave simply spreads out or disperses over a larger area, decreasing the power density.

"The reduction in power density i.e. power loss with distance called as "attenuation". The attenuation is due to the spherical spreading of wave, and it is also called as "space attenuation" of the wave:

Attenuation is given by

$$\alpha = 10\log_e \frac{\rho_1}{\rho_2} \quad \ldots (1)$$

ρ_1 & $\rho_2 \Rightarrow$ power density at distance R_1 and R_2.

$$\therefore\ \alpha = 10\log_e \frac{\left(\frac{P_{rad}}{4\pi R_1^2}\right)}{\left(\frac{P_{rad}}{4\pi R_2^2}\right)}$$

$$\therefore \alpha = 10\ \log\frac{R_2^2}{R_1^2}$$

$$\therefore \alpha = 20\log_e \frac{R_2}{R_1}$$

$$\therefore \alpha = 20\log_e \frac{R_2}{R_1} \quad \text{decibels 'dB' or 'neper'.}$$

Ref. : The reduction in power density due to inverse square also presumes free space propagation (a vacuum) is called as wave attenuation.

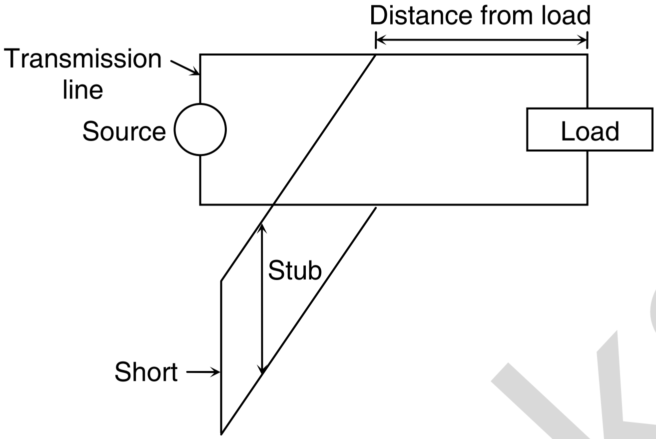
$$\alpha = \omega\sqrt{\frac{\mu \in}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega \in}\right)^2}-1\right]} \quad \text{for free space } \sigma = 0$$

$$\therefore \alpha \cong 0$$

3. (d) STUBS

- If the load connected to the transmission line is complex then we can cancel the reactive part of Z_L with an inductor or capacitor and then match the remaining resistive part of Z_L with quarter wave transformer.
- Stub is a piece of additional transmission line which is connected across the primary transmission line.
- In stub matching technique, either a shorted or an open stub can be used.
- But shorted stub are used because open stub tends to radiate at high frequencies.

Single Stub Matching



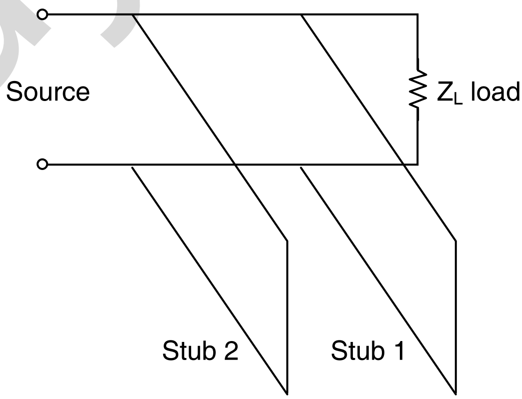
- The use of shorted stub is to nullify the susceptance of the load and match the load resistance to the characteristic impedance of the transmission line.
- Procedure for stub matching :
  1) Calculate the admittance of load.
  2) Calculate the susecptance of stub.
  3) Now connect the stub to the load. The resulting admittance is equal to the load conductance G.
  4) Convert conductance to resistance and calculate Z_0 of the quarter wave transformer.

Disadvantages

The matching condition are correct for only one particular frequency.

Double Stub Matching

- The problem of single stub matching is that it can take place only at a particular single frequency.
- This problem can be solved by using the multiple stub.
- The multiple stub allows matched conditions over a wide frequency range.



Double stub matching

3. (e) Given : Directive gain in dB = 5 dB

$$\text{Directive gain in dB} = 10\log_{10}\left[\frac{\text{Power radiated by the isotropic antenna}}{\text{Power radiated by the partical antenna}}\right]$$

$$5 = 10\log_{10}\left[\frac{P_i}{1200}\right]$$

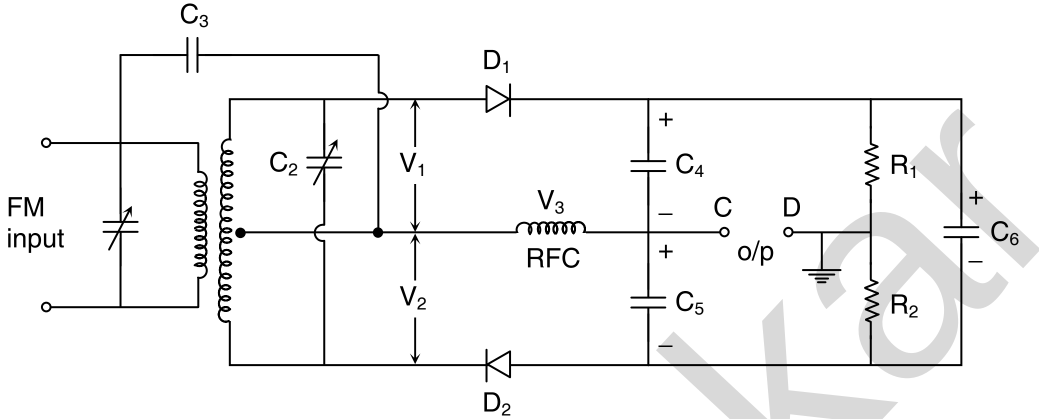
$$\therefore \quad P_i = 3794.7 \text{ watts}$$

3. (f) Comparison AM and FM

	Frequency Modulation	Amplitude Modulation
1)	**Amplitude** Amplitude of frequency modulation wave is constant. It is independent of the modulation index.	**Amplitude** Amplitude of amplitude modulation wave changes with the modulating voltage.
2)	**Frequency** Frequency of frequency modulation wave changes with the modulating voltage.	**Frequency** Frequency of amplitude modulation wave is constant.
3)	**Power** Transmitted power is constant. $P_t = \frac{V_c^2}{2R}$	**Power** Transmitted power depends on the modulation index. $P_t = \left[1 + \frac{m^2}{2}\right]P_c$
4)	All the transmitted power is useful.	One sideband power and carrier power is useless.
5)	The bandwidth depends on the modulation index. bandwidth = 2 [$\delta + f_m$ (max)]	Bandwidth is independent of the modulation index. bandwidth = 2fm
6)	Bandwidth is large. Hence wide channel is required.	Bandwidth is much less than frequency modulation.
7)	Frequency modulation receivers are immune to noise.	Amplitude Modulation receivers are not immune to noise.
8)	It is possible to decease noise further by increasing deviation.	There is no such feature to decrease the noise.
9)	Space wave is used for propagation therefore radius of transmission is limited to line of sight.	Ground wave and sky wave propagation is used. Therefore larger area is covered than frequency modulation.
10)	It is possible to operate several transmitters on same frequency.	Not possible to operate more channel on the same frequency.
11)	Frequency modulation transmission and reception equipment are more complex.	Amplitude Modulation equipment's are less complex.

4. (a) Ratio Detector

Circuit Diagram :



- The ratio detector is similar to the Foster–Seelay discriminator except direction of diode D_2 is reversed, a very large value capacitor C_6 is connected across the output and output is taken from between points C and ground in the circuit.
- The advantage of the ratio–detector is that it is insensitive to noise and amplitude variations. The reason for this is the very large capacitor C_6. The voltage across C_6 will not change instantaneously. It will increase very gradually.

4. (b) The standard equation of Frequency Modulation wave is,

$v_{FM} = V_c \sin [2\pi f_c t + m_f \sin (2\pi f_m t)]$

The given equation is,

$e = 10 \sin [10^8 t + 3\sin 10^4 t]$

Comparing the equation,

$2\pi f_c = 10^8$

$\therefore$ carrier frequency, $f_c = 10^8/2\pi$ = 15.91 MHz

$2\pi f_m = 10^4$

$\therefore$ modulating frequency, $f_m = 10^4/2\pi$ = 1591.5 Hz

Modulation index, $m_f = 3$

$\therefore$ frequency deviation, $\delta = m_f.f_m = 3 \times 1591.5 = 4.774$ KHz

Power dissipation in 100Ω resistance :

$$P = \frac{(V_c/\sqrt{2})^2}{R} = \frac{(10/\sqrt{2})^2}{100} = 0.5 \text{ watt}$$

4. (c) Given : $E_i = 6$ V and $E_r = 3$V

(i) Reflection coefficient, $\rho = \dfrac{E_r}{E_i} = \dfrac{3}{6} = 0.5$

(ii) Standing Wave Ratio (SWR) $= \dfrac{E_i + E_r}{E_i - E_r} = \dfrac{6+3}{6-3} = \dfrac{9}{3}$

$= 3$

4. (d) (i) Wave Front

The plane parallel to 'E' and 'H' field called as "wave–front". So the waves always travels in the direction normal to the wave front.

(ii) Inverse Square Law

The power density is inversely proportional to the square of the distance, from the source and this is called as "Inverse square law".
It is seen that as the distance from the source doubles the power density decreases by a factor $(2^2) = 4$.

4. (e)

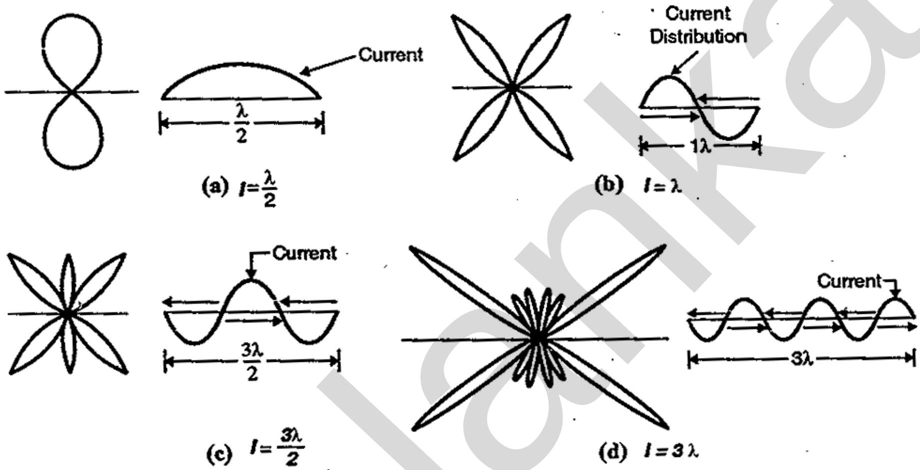


Fig. : Radiation patterns of various resonant dipoles.

4. (f) FADING

- As an e_m wave propagates through Earth's atmosphere, the signal may experience losses in signal strength beyond normal path poss.
- This valuation in signal loss is called fading and can be caused by natural weather disturbances such as rainfall, snowfall, fog, hail and extremely cold over a warm Earth.
- Fading can also be caused by manmade disturbances such as irrigation, etc.
- To accommodate temporary fading, an additional fade loss is added to the normal path loss. This loss is called "fade margin".

$$F_m = 30 \log D + 10 \log (6\ ABf) - 10 \log (1 - R) - 70$$

Where, F_m = fade margin (dB)
D = dist (km)
f = frequency (GHz)
R = reliability ($0.9999 \approx 99.99\%$)
A = roughness factor
B = factor relating to climate cendns.

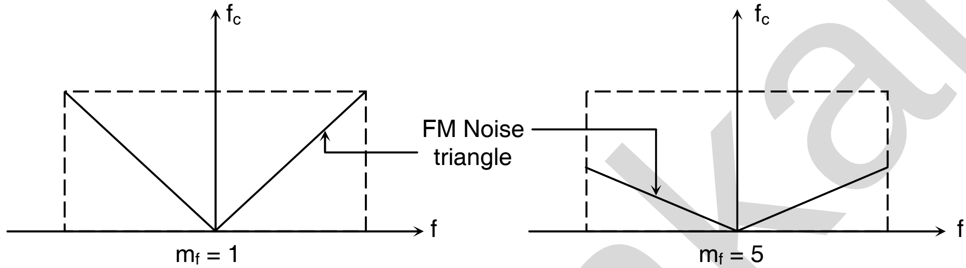
{ 4 over water
1 over avg. terrain.
0.25 over rough mountainous teenain} }

5. (a) Noise Triangle (effect of Noise)

(a) Noise is interference to a signal generated by lightning, motors, automotive ignition systems, and any power line switching that produces transients.

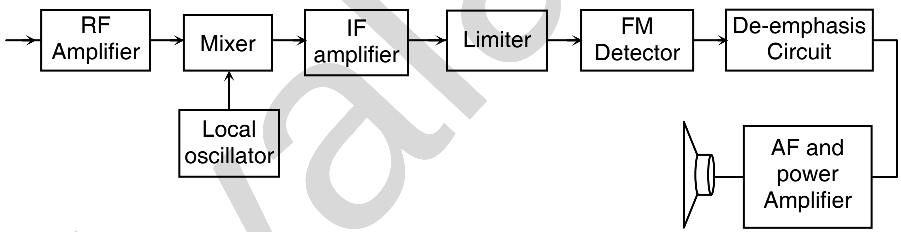
(b) *Capture effect* : If the signal of one is more than twice the amplitude of the other, the stronger signal will capture the channel and will totally eliminate the weaker interfering signal. This is called as the capture effect.

(c) In frequency modulation the effect of noise is more prominent at higher modulating frequencies.



(d) For a constant deviation (δ), the effect of noise increases with decrease in the modulation index (m_f).
Therefore modulating frequency decreases, m_f increases, effect of noise decreases.

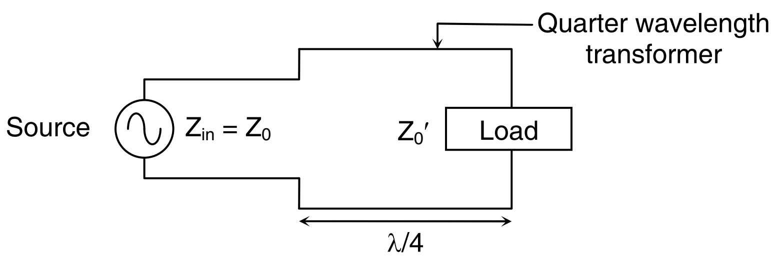
5. (b) FM Receiver



1) RF stage : it is used to select the wanted signal.
   - Reject unwanted signal.
   - Improve $\frac{S}{N}$ ratio.
   - Here the signal frequency is denoted by F_s.

2) AGC : It controls the gain of RF and IF amplifier to maintain a constant output when the signal level at the receiver is fluctuating.

5. (c) Quarter Wavelength Transformer for Impedance Matching



- If the load impedance is purely resistive and not equal to Z_0, then the quarter wavelength transformer matching technique is used.
- The quarter wavelength is actually not a transformer but it is a quarter wavelength ($\lambda/4$) section of transmission line that acts as a transformer.
- The input impedance of a transmission line varies from some maximum value to some minimum value or vice versa every quarter wave length.
- Hence, a transmission line of ($\lambda/4$) length acts as a step down or step up transformer depending on whether Z_L is greater than or less than Z_0.
- ($\lambda/4$) length transmission line acts as a transformer acts as a transformer at a single frequency. The input impedance is summarized as :
  1) $R_L = Z_0$ … $\lambda/4$ act as a 1:1 transformer
  2) $R_L > Z_0$ … $\lambda/4$ acts as a step down transformer
  3) $R_L < Z_0$ … $\lambda/4$ acts as a step up transformer

Characteristics (with $Z_L = \infty$)

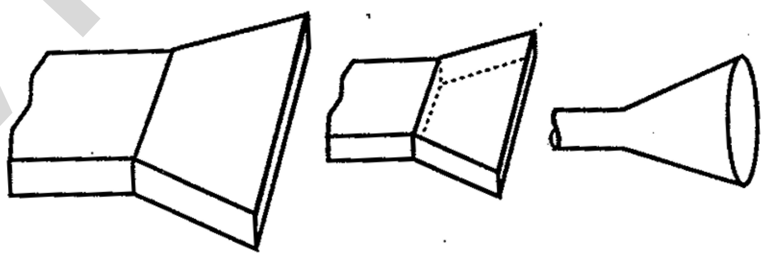
i) The voltage incident wave is reflected back without buy phase.
ii) The current incident wave is reflected back with phase shift of 180°.
iii) We get a voltage maximum at the load point.
iv) We get a voltage minimum at the load point.

5. (d) Horn Antennas

- A waveguide can radiate energy (i.e. act like an antenna) into space if we excites it from one end and if its other end is left open.
- The waveguide radiates a large amount of energy as compared to that radiated by a two wire transmission line.
- But the problem with waveguides is that a very small amount of energy out of the total is actually radiated and a large part of energy is reflected back due to open circuit.
- Similar to transmission line, the open circuit at the far end actually acts as a discontinuity. So the waveguide is very poorly matched to the space.
- A poor and nondirectional pattern will result due to the diffraction taking place around the edges of a waveguide.
- In order to improve the radiation, we have to open out the mouth of the waveguide.

  When a transmission line, is opened, it results into a dipole antenna but when a waveguide is opened, it results in an electromagnetic horn.

Basic Horns



(a) Sectoral (b) Pyramidal (c) Circular

Fig. 1 : Horn antennas

- Thus waveguides are terminated into horns. The basic horns are available in different shapes as shown in figure 1. Due to the horns used, the abrupt discontinuity existing between a waveguide and free space gets converted into a gradual transformation.
- If the impedance matching is ensured, then all the energy traveling in the forward direction will be radiated.
- The directivity is improved and diffraction is reduced.
- The three most commonly used horn configurations are :
  1. Sectoral 2. Pyramidal 3. Circular
- These are shown in figure 2.

Directional pattern :
The horn antennas are highly directional antennas. Their radiation pattern is shown in figure 2.

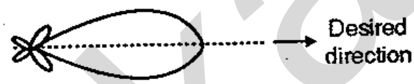


Fig.2 : Radiation pattern of born antennas.

Advantages : 1) Improvement in directivity.
2) Better matching.
3) Reduced diffraction.

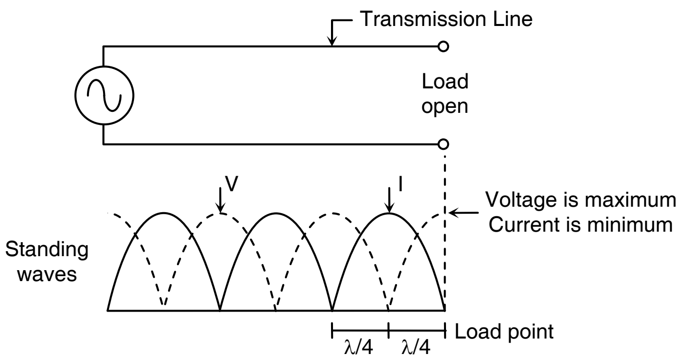
Applications : 1) As feed antennas.
2) All highly directional microwave antennas.
3) Satellite antennas.
4) Antennas on the space-crafts.

5. (e) Automatic Gain Control (AGC)

- If the gain of the radio receiver is kept constant then the output of the receiver depends on the strength of the input signal.
- Strength of all the input signal is not same all the time for all radio stations reaching the receiver.
- The gain of the radio receiver should change proportional to the strength of the received signals.
- Automatic Gain Control is used to adjust the receiver gain automatically.

Types of AGC :
(i) Simple AGC (ii) Delayed AGC

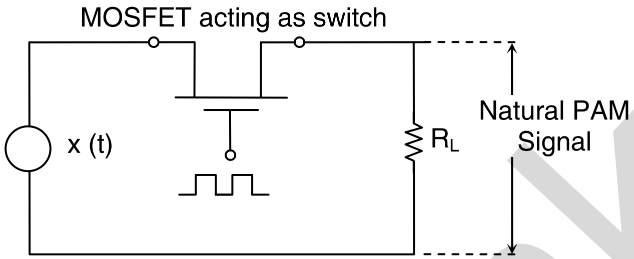
5. (f) V and I standing waves of a transmission line in an open loop :

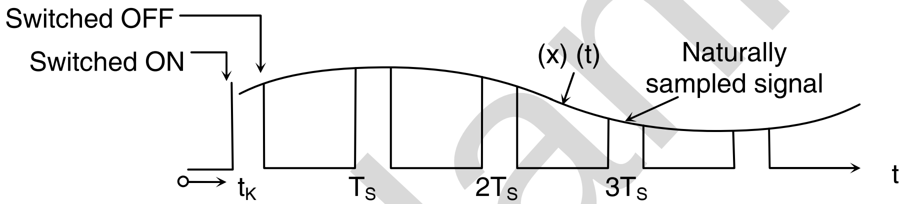


Characteristics of Transmission Line

(i) The incident wave travelling down the line is not affected in any way by the open circuit at the end of the line.
(ii) The resistance between the open ends of the line must be infinite.
(iii) The current at the open end is zero.
(iv) The value of reflection coefficient it 1.

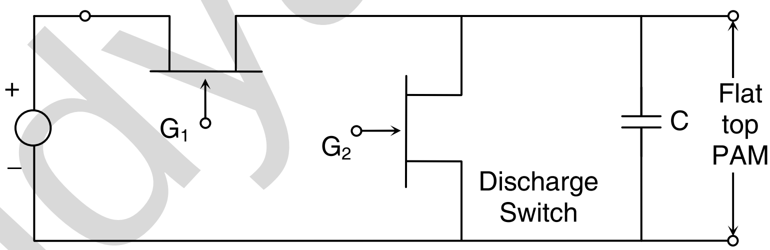
6. (a) Transistorized PAM modulator circuit and its operation

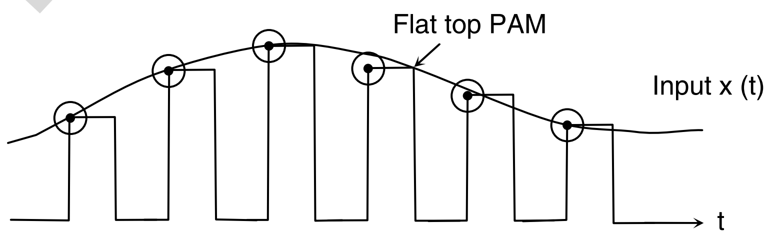




The circuit arrangement for the generation of natural PAM is as

- When the rectangular gate driving function c(t) is high the MOSFET operates as a closed switch and $V_O = V_{in} = x(t)$.
- When c(t) is low the MOSFET is OFF and $V_O = 0$. The natural PAM waveform.

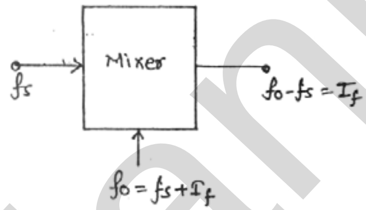




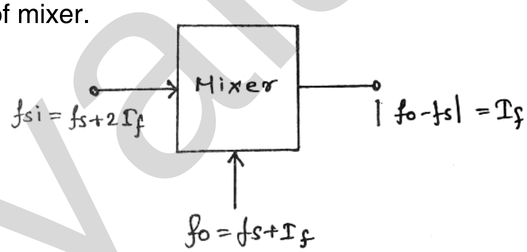
- A gate pulse will be applied to gate G_1 at the instant of sampling, for a very short time. The sampling switch will turn on and the capacitor charges through it to the sample value X (nTs).
- The sampling switch is then turned off. Both the FETs will remain off for a duration of "t" seconds and the capacitor will hold the voltage across it constant for this period. Thus the pulse is stretched to "t" second.
- At the end of the pulse is internal (t), a pulse is applied to G_2 i.e. gate terminal of discharge FET.
- This will turn on the discharge FET and short circuit the capacitor. The output voltage then reduces to zero.

6. (b) (i) Image Frequency

Image frequency is the problem of receiving two radio stations simultaneously at the same point of the receiver dial.
If the receiver is tuned to receive desired channel of frequency f_s then at the output of mixer, we get, I_f



At the same time, if another unwanted channel of frequency $f_{si} = f_s + 2I_f$ comes at the receiver, it will also be selected because it will also produce. I_F at the output of mixer.



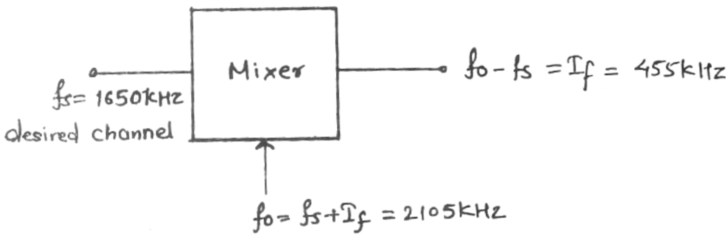
This signal will also amplify by I_F amplifier along with desired signal f_s. This will create interference because both these stations of frequency f_s and f_{si} received simultaneously at the same point of dial. The unwanted signal at frequency f_{si} is known as image frequency signal and it is said to be the image of signal frequency f_s.

Image Frequency = $F_{si} = f_s + 2\ I_f$

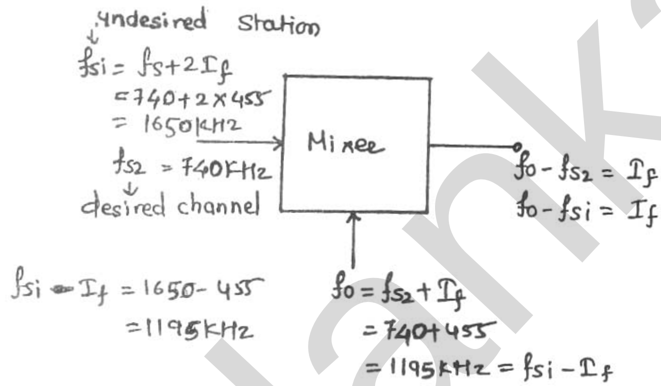
(ii) Double Spotting

Double spotting means the same signal (stations) gets picked up at two different point on the receiver dial and it is due to poor front end selectivity and poor image frequency rejection of receiver.

Double spotting happens in following way :
When the local oscillator tuned to $f_s + I_f$, then the signal received is $f_s - f_0 = I_f$ (desired channel). Since it is the desired signal, it will pick up with large gain.



Same signal f_s is received again when the local oscillator tuned to $f_s - I_f$ which is equal to 1650 – 455 = 1195 KHz.

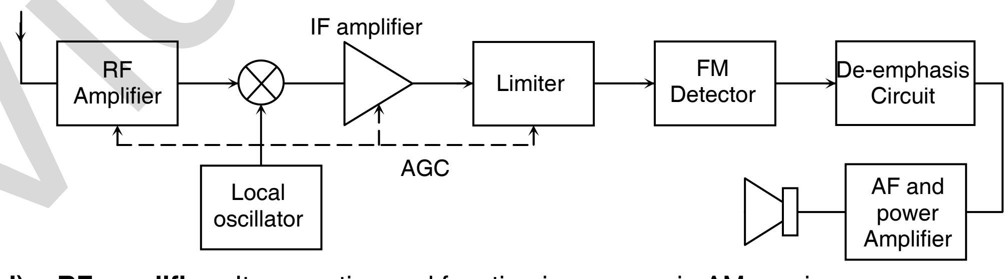


But this time it will be reduced in amplitude depending upon how good the image frequency rejection is. Thus by improving front end selectivity and image frequency rejection, the double spotting can be eliminated.

6. (c) FM Receiver

- The FM receiver also operates on the principle superheterodyning.
- The blocks in the AM and FM receiver are same upto the IF amplifier block.
- The FM receiver requires limiter and de–emphasis circuits after IF amplifier and FM demodulator respectively.
- The operating frequencies in FM are much higher than in AM.

Block diagram of FM receiver



i) **RF amplifier :** Its operation and function is same as in AM receiver.

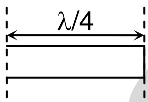
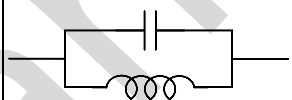
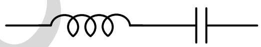
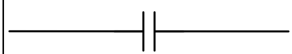
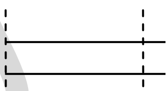
ii) **Mixer :** Same as AM receiver.
The intermediate frequency signal generated at the output of the mixer is at 10.7 MHz.

iii) IF amplifier : Same as in AM receiver.

iv) Limiter :

- In frequency modulation, the amplitude of the modulated signal remains constant.
- When the FM wave travelling through free space noise and other unwanted signals gets added to it and may change its amplitude.
- This change in amplitude produces distortion in the demodulated signal.
- Hence before demodulation, limiter is used to remove all the unwanted amplitude variations from the received signal.
- **Double limiting :** Two amplitude limiters can be connected in cascade to increase the limiting range. This is double limiting.
- **AGC :** AGC can be used in place of second limiter. The AGC will increase limiting range by ensuring that the input to the limiter will always be in the limiting range irrespective of the size of the input.

6. (d) Equivalent circuit of following lines :

Description	Line	Equivalent	
(i) Short circuited ($\lambda/4$) line			Parallel LC resonant
(ii) Open circuited ($\lambda/4$) line			Series LC
(iii) Short circuited line with length greater than $\left(\frac{\lambda}{4}\right)$			Pure Capacitance
(iv) Open circuited line with length greater than $\left(\frac{\lambda}{4}\right)$			Pure inductance

6. (e) Error Tracking

- The receiver has a number of tunable circuit such as the antenna or mixer or a local oscillator tuned circuits.
- The local oscillator frequency (f_O) must be precisely adjusted to a value which is above the signal frequency f_S by I_F i.e. $f_O = f_S + I_F$
- If this tuning is not done precisely then the frequency differences i.e. ($f_O - f_S$) is not correct.
- This type of errors are known as the "tracking errors" because tracking is a process in which the local oscillator frequency follows or tracks the signal frequency to have a correct frequency difference.

6. (f) Given : Baseband signal frequency range = 300 Hz to 3 KHz.

(i) Narrow band FM with maximum deviation of 5KHz
Given : the deviation δ_{max} = 5 KHz

$\therefore$ $B\omega = 2 (\delta_{max} + f_m)$
$= 2 (5 + 3) \times 10^3$
$= 16$ KHz

(ii) Wideband FM with maximum deviation of 75KHz
Given : the deviation δ_{max} = 75 KHz

$\therefore$ $B\omega = 2 (\delta_{max} + f_m)$
$= 2 (75 + 3)$ KHz

$\therefore$ $B\omega = 156$ KHz

❑ ❑ ❑ ❑ ❑