Title	Page No.	Teacher's Signature/ Remarks
Syallabus		
(i) Introduction to comm. system		
(ii) Random signals		
(iii) Distribution and density function		
(iv) Analog communication		
(v) Radio Transmission → (16 pages. pdf)		
(vi) Transmission lines.		
(vii) Noise.		

Modes of Propagation of Wireless Communication

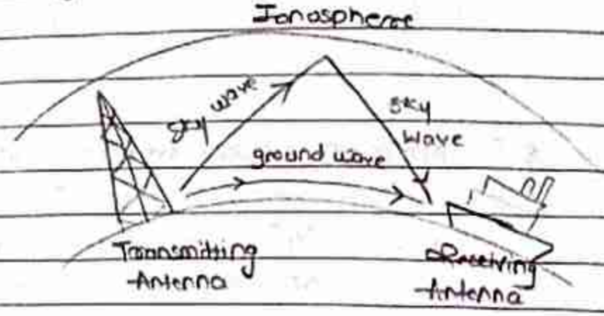
> Modes of propagation basically 4 types

1. Ground or source wave Propagation : upto 2 Mhz EMF induced in the receivers antenna

$$\boxed{E = \frac{120\pi h_t h_r I_s}{\lambda d} \ V/m}$$

• E/L where, L is the length of antenna

characteristics?



• Relation of radiated power & received powers by antennas:-

> Fundamental equation for free space wave propagation

> Two antennas are placed at some distance in free space as shown in Fig two anten

• Critical frequency

Critical frequency is the frequency in which above the waves pentrates the ionosphere and below which the waves are reflected back on the earth from the ionosphere. it is calculated from

$$\mu = \frac{\sin i}{\sin r} = \sqrt{1 - \frac{81 N}{f^2}}$$

$f = f_c$ when $\mu = 0$ then $N = N_{max}$

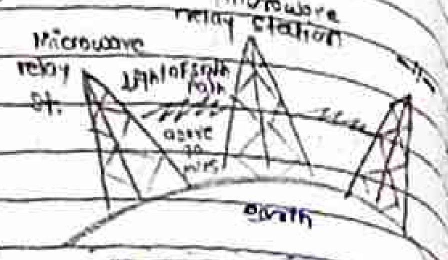
f_c is Mhz per cubic meter. N is electron density.

$$\mu = 0 = \sqrt{1 - \frac{81\,N_{max}}{f_c^2}}$$

$$0 = 1 - \frac{81\,N_{max}}{f_c^2}$$

$$81\,N_{max} = f_c^2$$

$$\therefore \boxed{f_c = 9\sqrt{N_{max}}}$$



$$\boxed{E_0 = \frac{88\sqrt{P}\,h_t h_r}{\lambda d}\ V/m}$$

where P is effective power radiation

* Maximum usable frequency (MUF) $f = f_{muf}$

$$\mu = \frac{\sin i}{\sin(90)} = \sqrt{1 - \frac{81\,N_m}{f_{muf}}}$$

$$\sin i = \sqrt{1 - \frac{81\,N_m}{f^2_{muf}}}$$

$$\sin i = \sqrt{1 - \frac{f_c^2}{f^2_{muf}}}, \quad \sin^2 i = 1 - \frac{f_c^2}{f^2_{muf}}$$

$$1 - \sin^2 i = \frac{f_c^2}{f^2_{muf}}$$

$$\cos^2 i = \frac{f_c^2}{f^2_{muf}}$$

$$f_c^2 = \cos^2 i\,(f^2_{muf})\ f_{muf} \Rightarrow f_c \sec i$$

Space wave / line of sight

- Satellite Microwave transmission
  > it involves sending of microwaves between two or more earth-based stations and a Satellite

* Uplink
  transmission of signal from earth station to satellite
  Called uplink and uses higher frequency

* Downlink
  Satellite sends the signal to another earth stations
  Called a downlink and uses a lower frequency.

Space wave (Line of sight) Propagation

> it also called as Microwave propagation.
> In spacewave Propagation is there
  i) High speed transmission
  ii) microwaves frequency range 1 Ghz to 300Ghz.

- Microwave transmission is of two types
  > terrestrial & satellite transmissions

Terrestrial Microwave transmission :-

These waves are sent b/w 2 microwave stations on the earth (earth station).

- it is the most common form of Long-distance communication
- it requires few repeaters.
- Parabolic dish is used to focused narrow beam.
- 1-10 Ghz frequency.
- it is a line of sight of propagation means transmitters must be visible to the receivers.

$$\boxed{E_0 = 88 \frac{\sqrt{P}}{\lambda d} h_t h_r \ V/m}$$ Where, P is effective power radiation.

Line of sight distance is d.

$$d\,(\text{straight}) = 3.57\left[\sqrt{h_t} + \sqrt{h_r}\right] km$$

- Line of sight distance increases after refraction curvature $d = 4.12\left[\sqrt{h_t} + \sqrt{h_r}\right]$ km

- Satellite communication coverage area is more and having higher bandwidth for use, as compared to terrestrial communication

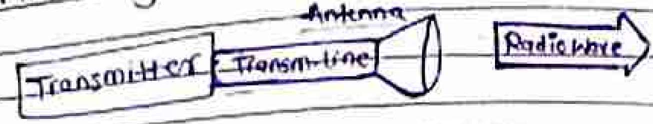
- Satellite communication is costly i.e. launching of satellites into geosynchronous orbit is costly

- Satellite communication having larger propagation delay as compared to the terrestrial communication.

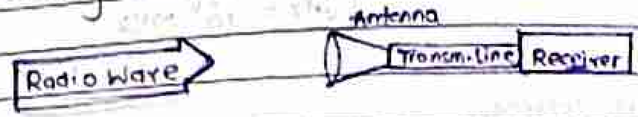
- ~~Atmospheric attenuation due to air & water~~
- Bad signal received on receiver during rain & fog
- Microwave signals transmitted using line of sight principle, therefore, the satellite signal reaches only some part of the earth.

Antenna

i) Transmitting antenna



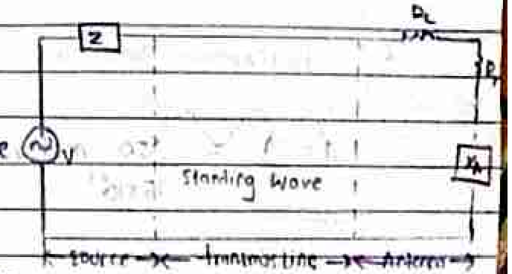
ii) Receiving antenna



- Source is an ideal source generator
- Transmission line having characterisized impedance Z_c

- The antenna impedance is Z_A

[Where $Z_A = (R_L + R_r) + jX_A$] connected to transmission line.



Where, R_r - Radiation resistance

Z_A - characteristic impedance of an antenna

X_A - imaginary component of antenna impedance

R_L - is ohmic losses, ideally $R_L = 0$

Z - internal impedance of source used to interface b/w the line and the antenna, it is integrated in such a way that, the max. power is delivered from source to the antenna.

$$\boxed{Z_A = R_r + jX_A} \qquad [X_A = X_L - X_C]$$

At resonance

$X_L = X_C$

$X_A = 0 \qquad |Z_A| = R_r$

- Length of Antenna

$$\lambda = \frac{c}{f} = \frac{300{,}000{,}000 \text{ meters}}{f(Hz)} \text{ or } \lambda = \frac{300}{f(MHz)} \text{ meters}$$

$$\boxed{1Hz = 10^{-6} MHz}$$

- Vertical Antennas

$$l = \frac{\lambda}{4} = \frac{75}{f(MHz)} \text{ meters} = 75m, \text{ if } f = 1MHz$$

$$l = \frac{\lambda}{4} = \frac{75}{15\times10^{-3}} \text{ meters} = 5000m, \text{ if } f = 15kHz = 15\times10^{-3} MHz$$

- Horizontal Antennas

$$l = \frac{\lambda}{2} = \frac{150}{15\times10^{+3}} \text{ meters} = 0.01m, \text{ if } f = 15GHz \Rightarrow 15\times10^{3} MHz$$

* RADIATION MECHANISM

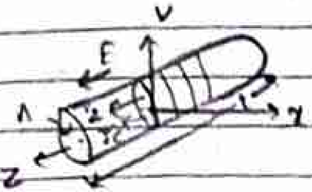
Accelerated electrons radiate energy as electromagnetic waves.

Electromagnetic waves are generated and detached from antenna when it is connected to the source.

- Single Wire Radiation:

In conducting wires current flows when it is connected to the source.

for radiation.



J = charge × velocity

$= q \times v$

Fundamental relation of EM wave for radiation:

Differentiating the above equation w.r to time, radiation takes place

$$\frac{dI}{dt} = q \times \frac{dv}{dt}$$

Single Wire transmission:

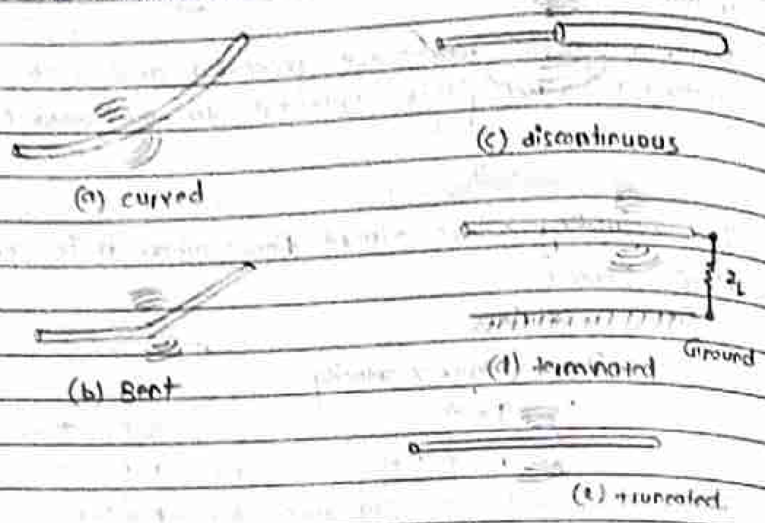
a) If a charge is not moving, no current, no radiation is there.

b) If charge is moving with uniform velocity:

i) There is no acceleration or deceleration (dc current) and no radiation if the wire is straight and indefinite in extent.

ii) Radiation takes place if the charges are accelerated and decelerated by making different provisions such as wire is curved, bent, discontinuous, terminated, or truncated as shown in fig.

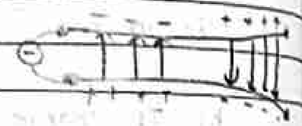
a] if charge is oscillating in a time motion (ac current) it radiates even if the wire is straight.



* Two wire Radiation

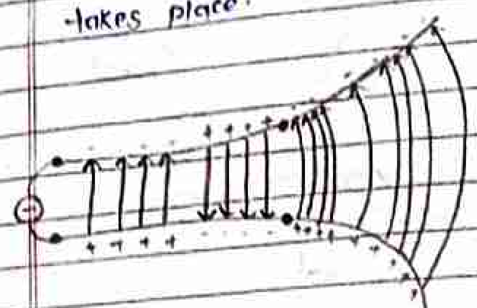
- Ac signal is given to the transmission line (straight line, Center fed).
- The current flows having same magnitude and opposite ph[ase]

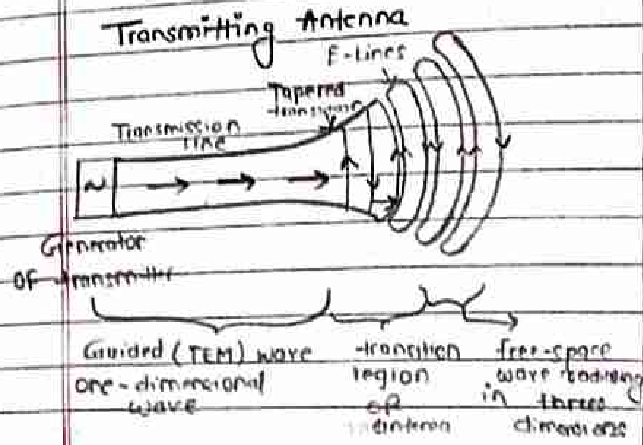
$d << \lambda$

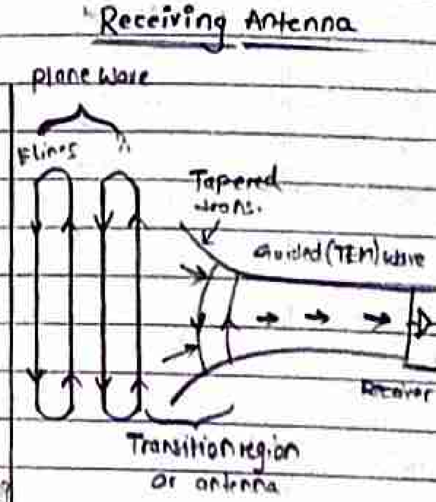


- No transmission of signal, current get cancelled to each other.
- For transmission of signal — 2 wire ends needed to be [...]
- Required total length of antenna is $\lambda/2$

- Transmission lines (circuit) is in resonance maximum radiation takes place.

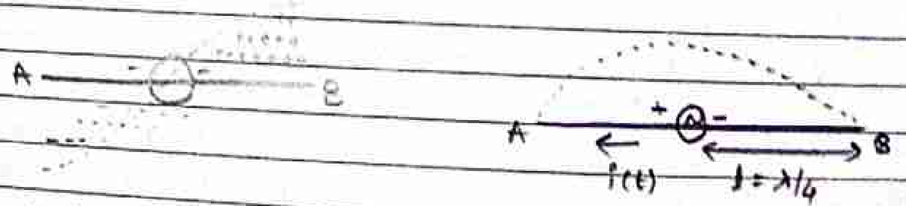






* Resonance :

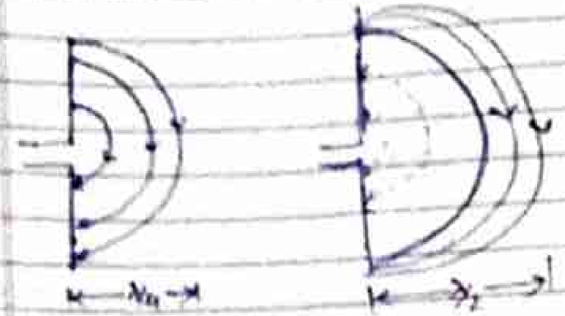
Dipole Antenna :- 2 wires each with length $l = \lambda/4$
- Attach ends to terminals of a high frequency AC generator.



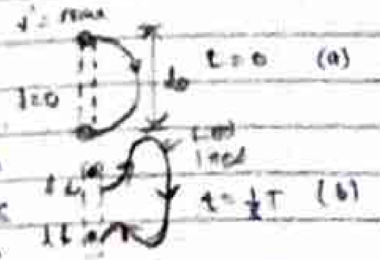
Voltage dis. at time t

current distt at time t

- **Radiation Mechanism**

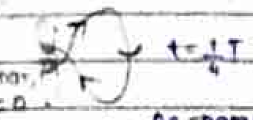


Radiation in Dipole : Dipole means sepration of charges from molecule in dielectric medium, distance two poles is $d << \lambda$



(a) electric field line or wave front with charges at ends of dipole
(b) wave front moves out as charges go in

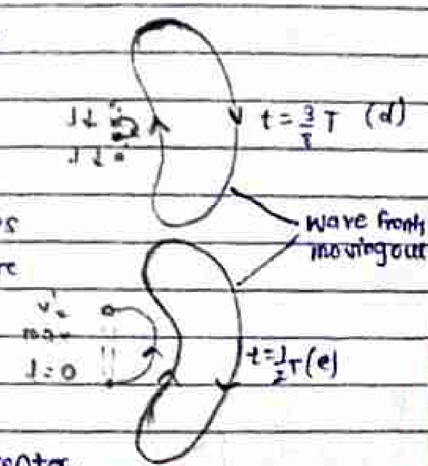
- first stage
AC signal (+ pulse) applied to the dipole then charges are moving outward to the end. The electric field free lines b/w the charges expand like a soap bubble with velocity $v=c$ in free space



(c) As charges pass the midpoint the field lines cut loose

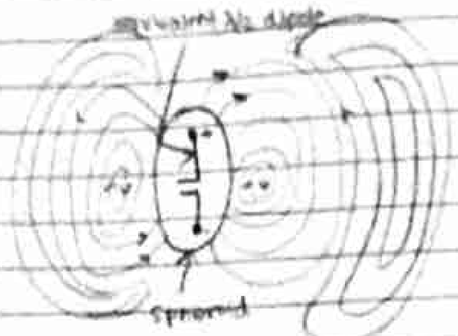
- Second stage (a middle):
The charges are reflected (bounceback) and moved inward towards the generator (due to force of attraction)

- Third stage :
The next negative pulse is given then again charges moves with velocity of $v=c$ but in opposite direction and reaches to the end.



- fourth stage :
At the same time electric field lines between the charges expand and are reflected from the end and bounces back again due to force of attraction
- charges are neutralizing at the center,
When no charges on the poles electromagnetic waves are detached from the dipole.

* Radiated waves in fee space



* Normalized Antenna Power pattern

Fundamental Parameters of Antenna

> Different Parameters of antennas
Transmitter power (Generated- W_t),
ohmic loss power (W_L),
Total radiated power (W_r) :

$W_t = W_L + W_r$

$W_r = \iint P_r \, ds$

ohmic loss $W_L = 0$

$ds = r^2 \sin\theta \, d\theta \, d\phi$

Power density (P_r)

$$\boxed{P_r = \frac{W_r}{4\pi r^2}}$$

$$\boxed{P_r = \frac{1}{2} \frac{|E|^2}{\eta}}$$

Radiation intensity (U or ϕ) :

$\phi = P_r r^2$

$$\boxed{\phi = \frac{W_r}{4\pi}}$$

Gain

gain is calculated in two ways
Gain w.r.t isotropic antenna - Power gain
Gain w.r.t test antenna - Directive gain

Power gain

$$\text{Gain } (G_p) = \frac{\text{Maximum intensity of test antenna}}{\text{Intensity of isotropic antenna (reference)}}$$

directive gain (directivity (D)) :

$$\text{Gain } (G_d) = \frac{\text{Max. Intensity of test antenna}}{\text{Average intensity of the same antenna}}$$

Efficiency of antenna

$$\boxed{\eta = \frac{G_p}{G_d}}$$

When $\eta = 100\%$ or $k=1$ means lossless antenna at that time $G_p = G_d$

Antenna Efficiency

$$\boxed{\eta = \frac{W_r}{W_r + W_L}}$$

$W_r \rightarrow$ total radiated power

$W_L \rightarrow$ ohmic loss power

Antenna bandwidth

$$\Delta\omega = \omega_2 - \omega_1 = \frac{\omega_r}{Q} = \text{band width}$$

$$2\pi\Delta f = \frac{2\pi f_r}{Q}$$

$$\boxed{\Delta f = \frac{f_r}{Q}}$$

f_r = centre or resonant or designed frequency

$$\boxed{Q = 2\pi \frac{\text{total energy stored by Antenna}}{\text{energy dissipated or radiated per cycle}}}$$

Polarization :-

It is the direction of electric field intensity of electromagnetic waves during the passage of least one full cycle.

Types of polarization

1) Linear Polarization
2) circular Polarization
3) elliptical Polarization

Effective Aperature :

$$\boxed{A_e = \frac{W_{received}}{P_r} = \frac{\text{total Radiated power}}{\text{Power density}}}$$

Antenna temperature :

$$T_A = \frac{S A_e}{K} \ {}^\circ K$$, S is power received per unit bandwidth

$K \Rightarrow$ boltzmann's constant $\Rightarrow 1.38 \times 10^{-23}\ T / {}^\circ K$

Effective length (l_e):

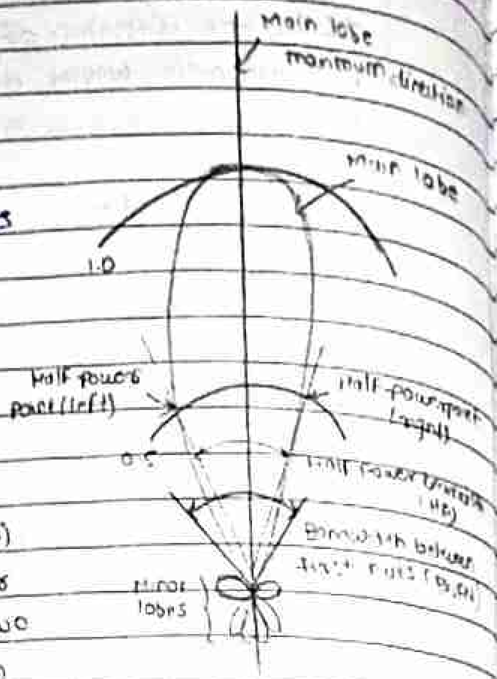
Active length through that the antenna radiates energy

$$\boxed{(l_e) = \frac{V_{rms}}{E_{rms}}}$$ m or wavelength

Antenna Beam - Width

Half - Power beam width

half power beam width is the angle between the half - Power (-3dB) Points of the main lobe.



First - null beam width (FNBW)

first null beam width (FNBW) is defined as the angular difference between the two nulls enclosing the main beam.

Band width generally expressed in terms of % of centre frequency

$$\boxed{B.W.\% = \frac{\text{operating range}}{\text{Centre frequency}} \times 100\%}$$

Q. Suppose antenna operates b/w min. frequency 98 MHz to max. frequency of 106 MHz then band width is 8 MHz. Determine the bandwidth in terms of %

$\Rightarrow$ $B.W\% = \frac{8 MHz}{102 MHz} \times 100 = 7.84$

operating range of antenna $\Rightarrow$ $106 - 98 \Rightarrow 8$ MHz

centre frequency $= \frac{106 + 98}{2} \Rightarrow \frac{204}{2} \Rightarrow 102$ MHz

$\therefore$ Bandwidth % $= \frac{\text{operating range}}{\text{Centre frequency}} \times 100$

$= \frac{55 MHz}{\cancel{72}} \quad \frac{8}{102} \times 100$

$= 7.84\%$

Q. Suppose antenna operates b/w min. Freq 45 MHz to max Freq of 100 MHz determine the bandwidth in terms of %

Sol^n $\Rightarrow$ operating range of antenna $\Rightarrow 100 - 45 \Rightarrow 55$ MHz

Centre Frequency $= \frac{100+45}{2} \Rightarrow \frac{145}{2} \Rightarrow 72.5$ MHz

Bandwidth % $= \frac{\text{operating range}}{\text{centre freq.}} \times 100$

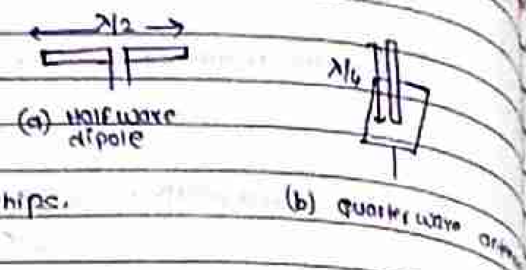
$= \frac{550}{725} \times 100$

$\Rightarrow 0.7586 \times 100$

$\Rightarrow 75.86$

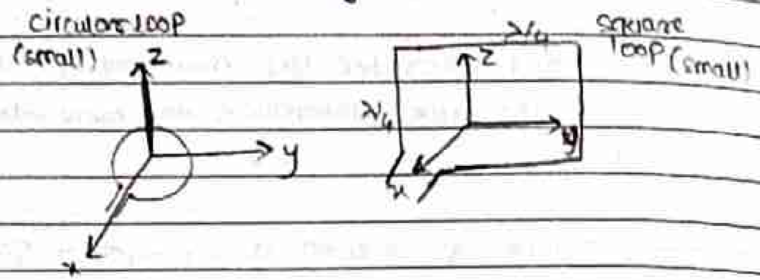
Types of antennas

Wire Antenna



Wire antennas are seen everywhere - on automobiles, buildings, ships, aircrafts, and so on.

Loop antennas are of various shapes —
circular, rectangle, square, ellipse, etc



Aperature Antennas

- Used for aircraft and spacecraft applications
- Covered with a dielectric material to protect them from hazardous conditions of the environment (rapid change)

Micro Strip Antennas :

- It consist of a metallic patch on a grounded substrate with different configurations (rectangular and circular patches)
- Now a day these antennas are used for government and commercial applications.
- It is mechanically robust - mounted on rigid surfaces
- It is very flexible in terms of resonant frequency and polarization pattern.
- Used in aircraft, spacecraft, satellites, cars and mobile telephones.

Antenna Arrays

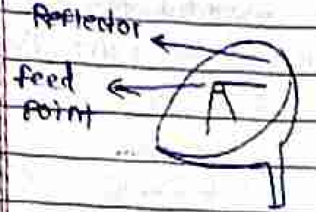
- It gives directional property, to receive the signal from long distance transmitting antennas.
- It needs multiple antenna elements to achieve this goal.
- Arrange the antenna elements, to get maximum radiation in a particular direction and minimum in other directions.

Reflector Antennas :

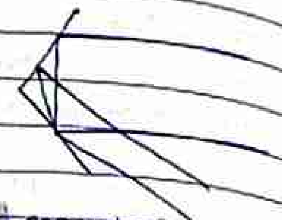
- for longer distance communication reflector antenna is used.
- large dimensions are needed to achieve the high gain.

to transmit or to receive the signals after millions of miles.

- Another form of reflector is corner reflector. It is used in radar, radio astronomy, and for microwave communication.



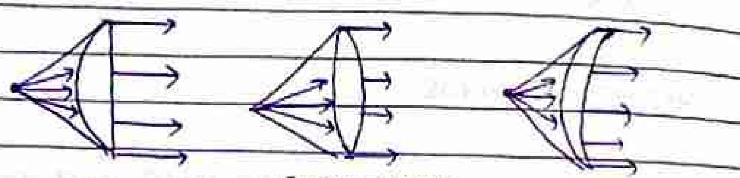
- Parabolic reflector



Concept of corner reflector

Lens Antenna

- It is used for higher frequency signal communication.
- It avoids energy distribution spreading in undesired directions by different lenses.
- Incident diverged energy converted into plane wave front by this lens antenna.



(a) Lens antennae with index of refraction n>1

Ex: A mobile is located 5 km away from a base station, and uses a vertical $\lambda/4$ monopole antenna with gain of 2.55 dB to receive cellular radio signal. The carrier frequency used is 900 MHz. Find the length of antenna.

$\Rightarrow$ $f = 900$ MHz

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{900\times10^6} = 0.33\ m$$

Length of receiving antenna,

$$L = \frac{\lambda}{4} = \frac{0.33}{4} = 0.0833\ m = 8.33\ cm$$

* Basics of satellite *

- Service Type of satellites

> Fixed Service satellite (FSS)
  - Ex: Point to Point communication

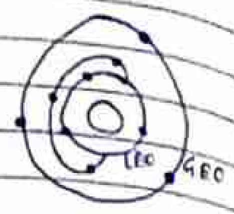
> Broadcast Service Satellite (BSS)
  - Ex. Satellite television / Radio

> Mobile service satellite (MSS)
  - Ex: satellite phones

★ Types of satellites

- Satellite orbits

  - GEO (geostationary ~~satell~~ Earth orbit)
  - LEO (Low Earth orbit)
  - MEO (Medium earth orbit)
  - Molniya orbit
  - HAPS (High Altitude platform)



- Frequency Bands
- Different kinds of Satellites use different frequency bands

L > L-band : 1 to 2 GHz, used by MSS (Mobile service Satellite)

S > S-Band : 2 to 4 GHz, used by MSS, NASA, deep space Re...

C > C-Band : 4 to 8 GHz, used by FSS (Fixed Satellite Service)

X > X-Band : 8 to 12.5 GHz, used by FSS and in terrestrial imaging, ex: millitary and meteorological satellite

Ku > Ku-Band : 12.5 to 18 GHz, used by FSS and BSS (Broadcasting Satellite service) (DBS - direct broadcast Satellite)

K > K-band : 18 to 26.5 GHz used by FSS and BSS

Ka > Ka-Band : 26.5 to 40 GHz used by FSS

Relation b/w watts and dBm

- $P(dBm) = 10 \log_{10} [P(mW)]$
- $P(dB) = 10 \log_{10} [P(W)]$
- $V(dB) = 20 \log_{10} [V(volts)]$

P(mW)	P(dBm)	P(W)	P(dB)
100	20	100	20
10	10	10	10
1	0	1	0
10^{-1}	-10	10^{-1}	-10
10^{-2}	-20	10^{-2}	-20
10^{-6}	-60	10^{-6}	-60

Q. A mobile is located 6km away from a base station, and uses a vertical $\lambda/4$ monopole antenna with a gain of 3.55 dB to receive cellular radio signals. The carrier frequency used is 800 MHz. Find the length of the antenna.

→ given, $f = 800$ MHz

$$\lambda = \frac{c}{f} \Rightarrow \frac{3 \times 10^8}{800 \times 10^6} \Rightarrow 0.375\ m$$

length of antenna ; $L = \lambda/4 \Rightarrow \frac{0.375}{4} \Rightarrow 0.09375\ m$

$\underline{L = 0.09375\ m}$

Analog Communication :

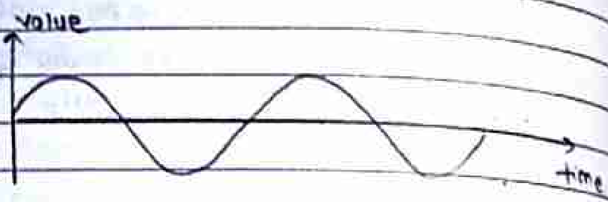
- Amplitude Modulation
- Types of amplitude modulation,
- Modulation index,
- Power relation in AM,
- Current relation in AM,
- AM transmitter,
- Angle modulation & its types
- Relationship between FM and PM

Analog Communication :- Periodic Analog signals

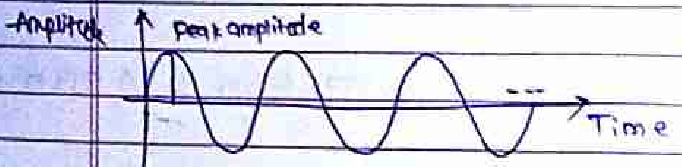
Periodic analog signals can be in the
- Simple form or
- Composite form

- A simple periodic signal is sine wave
- A composite periodic signal is composited of multiple sine waves And decomposed into numbers of sine waves

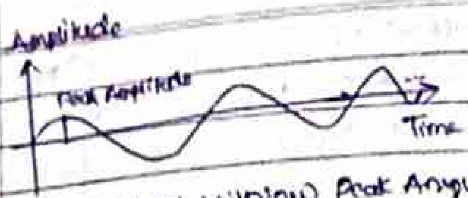
Sine wave :-



- Draw : Two signals with the same phase and frequency but different amplitudes.

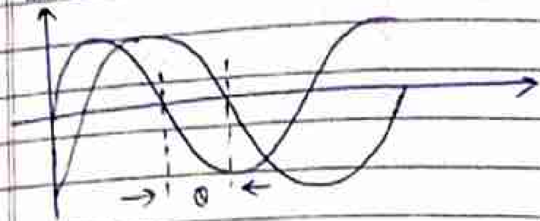


a) A signal with high peak amplitude

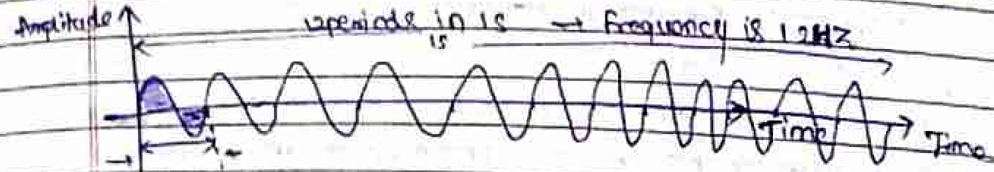


b) A signal with low Peak Amplitude

* Draw :- different phase, same frequency & amplitudes.

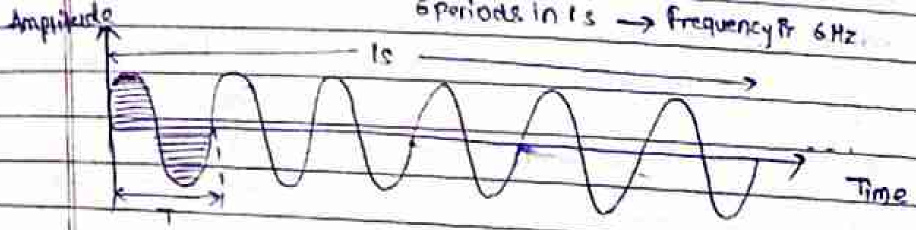


eg. Two signals with the same amplitude and phase, but different frequencies



Period: $\frac{1}{12}$ s

(a). A signal with a frequency of 12Hz.



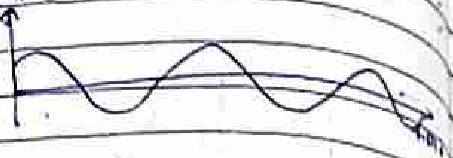
Period: $\frac{1}{6}$ s

b. A signal with frequency of 6 Hz.

Ex :- A sine wave is offset of 1/6 cycle with respect to time 0. What is its phase in degrees and radians? And draw the nature of signal in time domain.

Soln → We know that 1 complete cycle is 360°. therefore, 1/6 cycle

$\frac{1}{6} \times 360^\circ = 60^\circ$



$\Rightarrow \frac{60 \times 2\pi}{360}$ rad

$= \frac{\pi}{3}$ rad $\Rightarrow 1.046$ rad

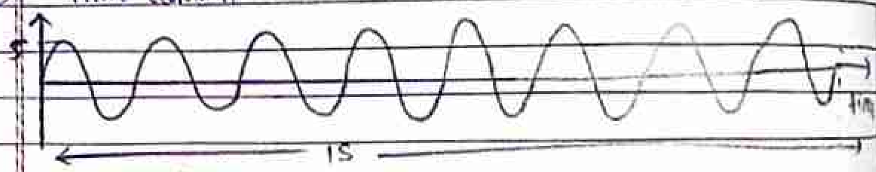
Signals in frequency domain

- A complete sine wave in time domain for 1 second represented by a one single spike in the frequency domain.

> Draw the Nature of signal, 0 Hz frequency with 5V amplitude

Q. draw the 8Hz frequency signal in time and frequency domain

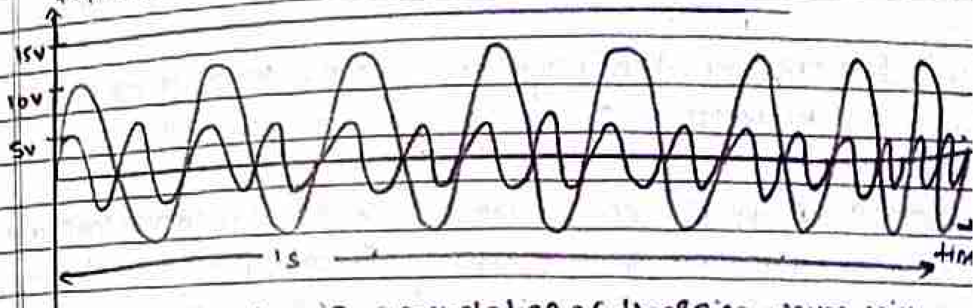
⟹ Time domain



frequency domain

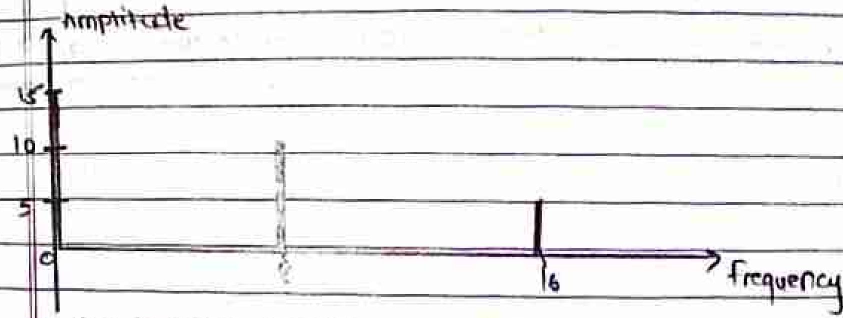
Composite signal :> Number of sine waves mixed together.

EX. three sine waves : 16 Hz and 5Hz amplitude, 8H and 10V amp zero Hz and 15 V respectively. Draw the domain on single axis and frequency domain nature of these three sine waves.



(a). time domain representation of three sine waves with

- ~~A single frequency~~ frequencies 0, 8 and 16.



(b) Frequency domain representation of the same 3 signals

- A single-frequency sine wave is not useful in Communication systems: we need to send a Composite signal,
  i.e. a signal is made by many simple sine waves

- If signal is composite, then it is having bandwidth

- The bandwidth of a composite signal is the difference between the highest and the lowest frequency contained in that composite signal.

★ Frequency Calculation :

EX: The period of signal is 100ms. What is its frequency in kilohertz ?

→ First we change 100 ms to seconds, and then we Calculate the frequency from the period ($1 Hz = 10^{-3} kHz$)

$100\ ms = 100 \times 10^{-3} s \Rightarrow 10^{-1} s$

$f = \frac{1}{T} = \frac{1}{10^{-1}} Hz \Rightarrow 10 Hz \Rightarrow 10 \times 10^{-3} kHz \Rightarrow 10^{-2} kHz$

Bandwidth -

Capacity of the system

In networking, bandwidth measured by 2 ways i.e Hz & bps
Higher bandwidth gives higher data rate.

* Bandwidth in Hertz :

- It is the range of frequencies in a composite signal or the range of frequencies that a channel can pass

*. Bandwidth in bits per second :

- It is the speed of bit transmission in channel or link often referred to as Capacity of channel.

EX - The bandwidth of a subscriber line is 4kHz for voice or data. The bandwidth of this line for data transmission can be up to 56,000 bps using a sophisticated modem to change the digital signal to analog. If the telephone company improves the quality of the line and increases the bandwidth to 8 kHz, how much bps can send through line ?

⇒ 112,000 bps

when it is 4kHz $\xrightarrow{\text{Bandwidth is}}$ 56000bps
then
for 8 kHz → ?

$\frac{\cancel{2}8 \times 56,000}{\cancel{4}} \Rightarrow 112,000$

Propagation time and transmission time

$$\text{Propagation time} = \frac{\text{distance travelled}}{\text{Propagation speed}}$$

$$\text{Transmission time} = \frac{\text{Message length}}{\text{Bandwidth of Network}}$$

Ex:- What are the propagation time and transmission time for a 2.5-kbyte message (an e-mail) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and travels at the speed of 2.4×10^8 m/s.

Sol^n → The propagation and transmission time :-

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} \Rightarrow \frac{\overset{10}{\cancel{120}} \times 10^6}{\underset{2}{\cancel{24}} \times 10^8} \Rightarrow \frac{10^7}{2 \times 10^8}$$

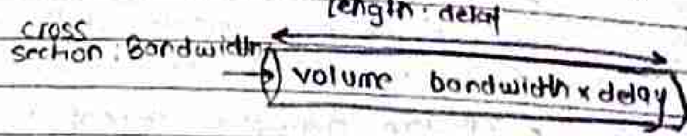
$$\Rightarrow \frac{1}{20} \Rightarrow \underline{\underline{50\,ms}}$$

$$\text{Transmission time} = \frac{2500 \times 8}{10^9} \Rightarrow \underline{\underline{0.020\,ms}}$$

- The message is short and the bandwidth is high, that's why the dominant factor is the propagation time, transmission time can be ignored.

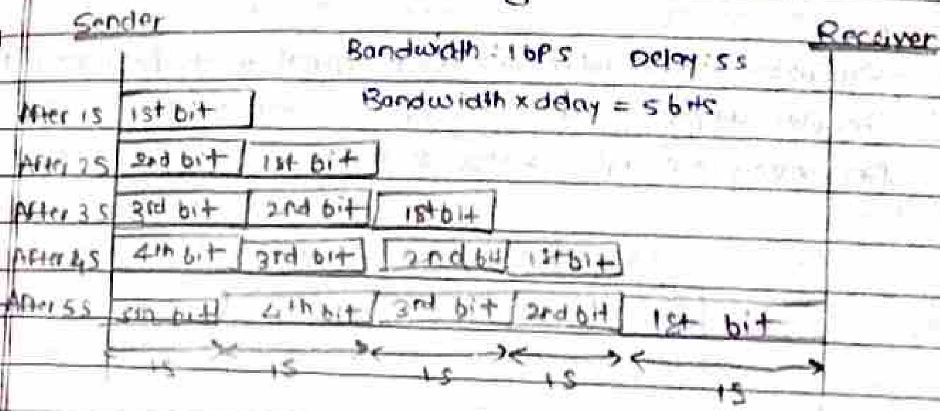
Bandwidth delay product

- Think about :- Link of starting and end point of elbow hollow pipe. The cross section of pipe represents the bandwidth. length of the pipe represents the delay. Then the volume of the pipe defines the bandwidth-delay product



Ex - Bandwidth 1bps & delay = 5 s, draw the representation of transmission of signal from sender to receiver.

→



Ex - Bandwidth is 5 bps & Delay is 5 s, draw the representation of transmission of signal from sender to receiver

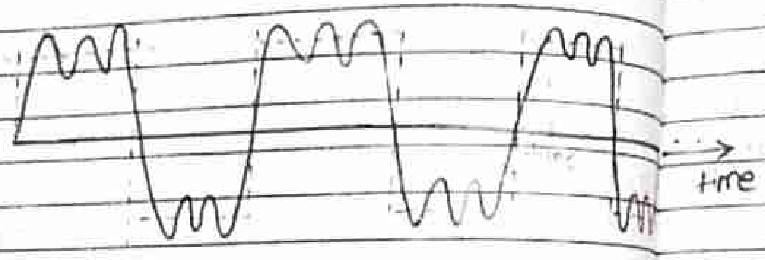
⟹

Composite signal
> Periodic
> Non-periodic

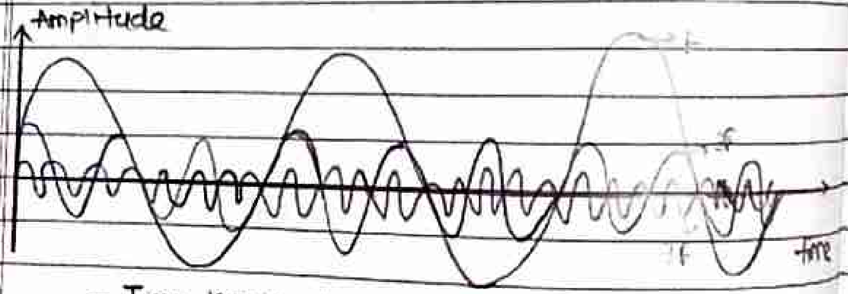
Decomposition of Composite signal

- If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies
- If the composite signal is non periodic, the decomposition gives a series of signals with continuous frequencies

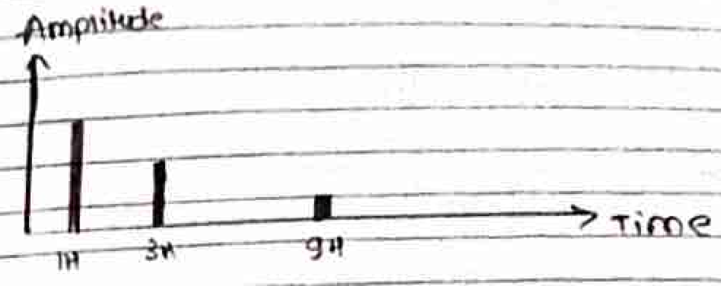
Fig. Shows a periodic composite signal with frequency f. Consider three alarms systems, each with a different frequency of 1HZ, 3HZ & 9HZ



Decompose the composite period signal in the time and frequency

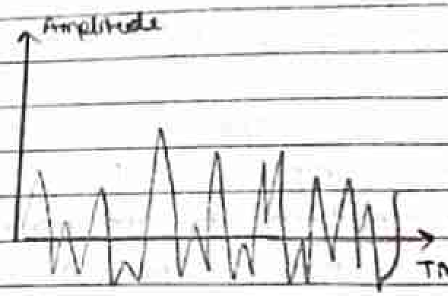


- Time domain decomposition of a composite signal

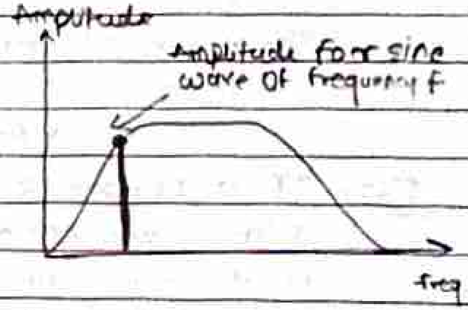


frequency-domain decomposition of the composite signal

A non periodic composite signal : EX : signal created by a microphone or a telephone set, when a word or two is pronounced Generates non periodic composite signal. The time and frequency domains of a non-periodic signal.



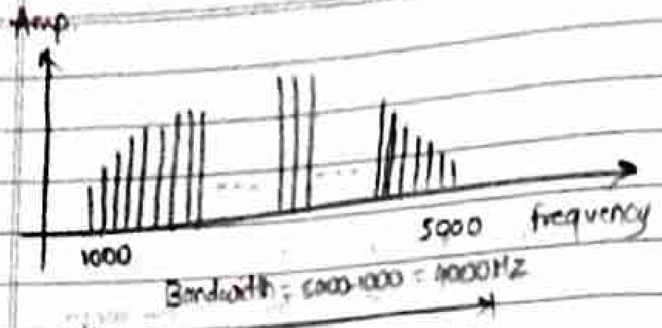
a) Time domain



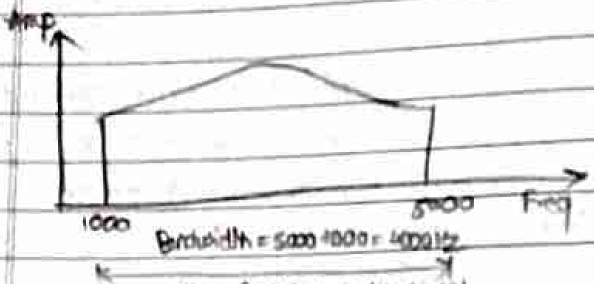
b. Frequency domain

* Bandwidth and signal frequency

- The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained that signal



(a) Bandwidth of periodic signal



(b) Bandwidth of non periodic signal

- The bandwidth of periodic and non-periodic Composite signals

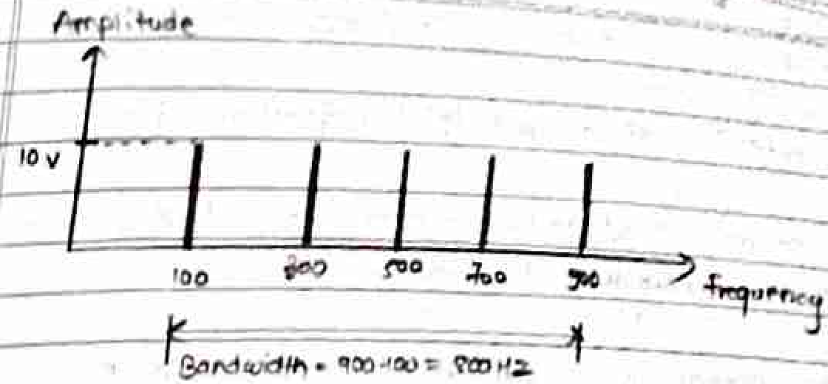
Ex: If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700 and 900 Hz, What is its bandwidth? Draw the spectrum, assuming all Components have a maximum amplitude of 10 V.

Soln ⟹ let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then

The spectrum has only five spikes, at 100, 300, 500, 700, and 900 HZ

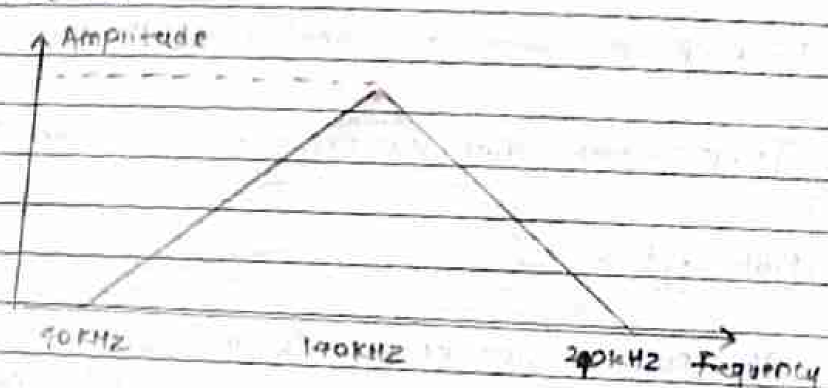
The bandwidth

$$B = f_h - f_l = 900 - 100 = 800 HZ$$



Ex: A non periodic composite signal has a bandwidth of 200 KHz, with a middle frequency of 140 KHz and peak amplitude of 20 V. The two extreme frequencies have an amplitude of 0. Draw the frequency domain of the signal.

Soln ⟹ The lowest frequency must be at 40 kHz and the highest at 240 KHz



Energy and Power for Continuous-time signal

$x(t)$ is a signal and it is a function of time

A signal is said to be an energy signal if the total energy transmitted is finite.

The signal Energy ~~used~~ in the signal $x(t)$ is $E = \int_{-\infty}^{\infty} |x(t)|^2 dt$

finite duration

The signal Power in the signal $x(t)$ is

$$P = \lim_{T\to\infty} \int_{-T}^{T} |x(t)|^2 dt \qquad \text{Infinite duration}$$

If $0 < E < \infty$, then the signal $x(t)$ is called an energy signal

If $0 < P < \infty$, then the signal is called an Power signal

Note that :-

The Power for an energy signal is zero ($P = 0$)
& the energy for a Power signal is infinite ($P = \infty$)

$P = i^2(t)R$ or $\frac{v^2(t)}{R}$

$P = x^2(t) \qquad P = \frac{dE}{dt} \qquad$ area of $|x(t)|^2$

$$E = \lim_{T\to\infty} \int_{-T/2}^{+T/2} |x(t)|^2 dt \; ; \; E = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

$$\boxed{P = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} |x(t)|^2 dt}$$

Energy signal are absolutely integrable signal

$$A = \int_{-\infty}^{\infty} x(t) dt \qquad E = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

* For energy signal, energy should be finite, Power power is zero

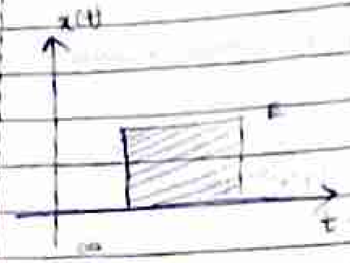
$$P = \frac{\text{Energy}}{T \to \infty} = 0 \; ; \; P = \frac{\text{Energy}}{T\to\infty} = 0, \; P = 0$$

$0 < E < \infty$

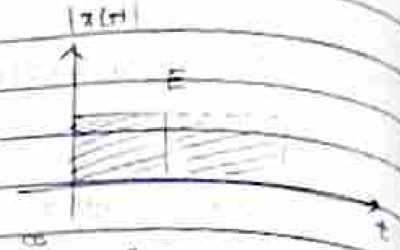
* for Power signal, the Power of signal is finite
i.e. $0 < P < \infty$, then $E \to \infty$ $\quad P = \frac{E \to \infty}{T \to \infty}$

* A signal in NENP if both energy and Power of the signal is infinite

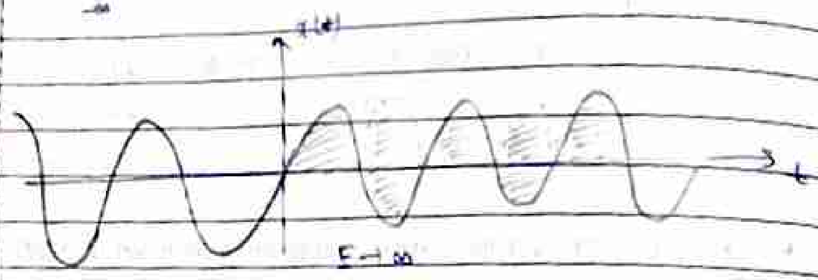
- Finite duration signal is always energy signal with zero Power.
- Infinite duration decreasing amplitude signal is also energy signal.
- Infinite duration signal is Power signal with infinite energy
- Any infinite amplitude signal is NENP signal



$\int_{-\infty}^{\infty} x(t)dt$



$\int_{-\infty}^{\infty} |x(t)|^2 dt$

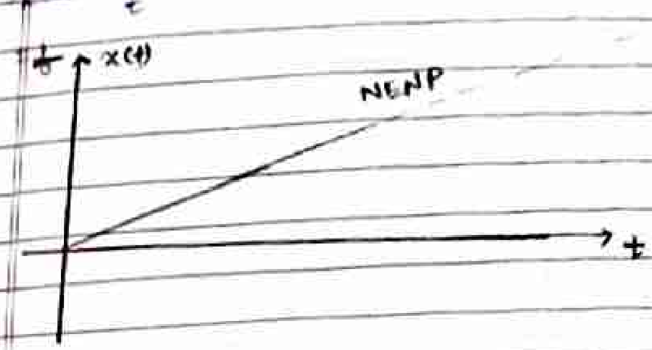


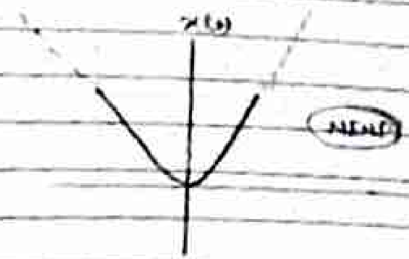
P = Power

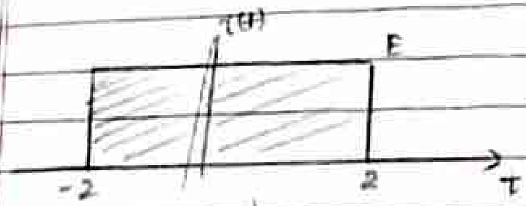
Energy & power signal

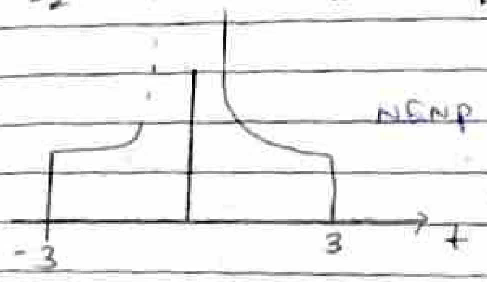
NENP $\qquad \lim_{t} = 0$

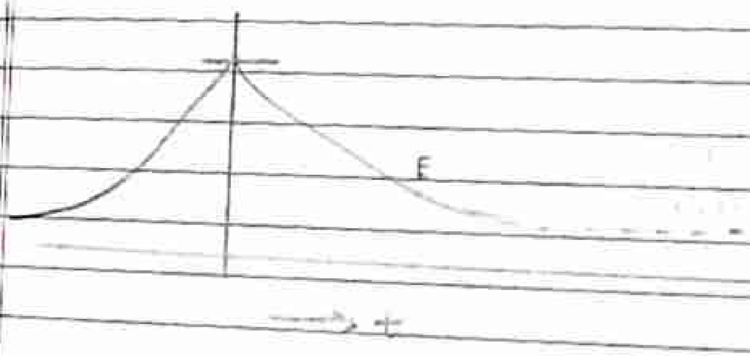
$x(t) = \frac{1}{t}$



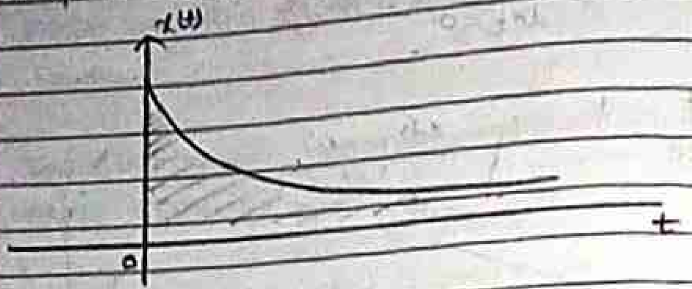


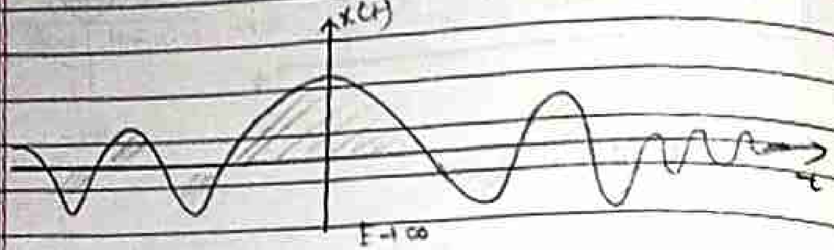






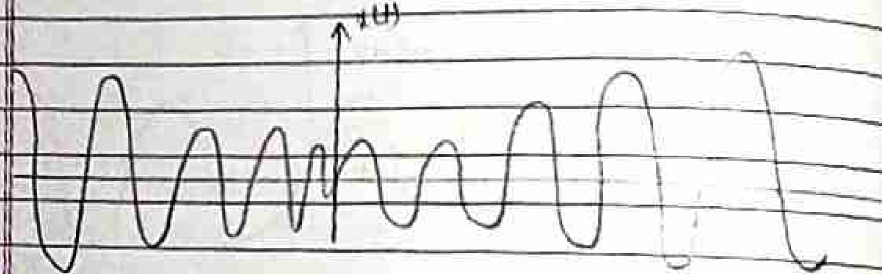
Energy & power signal

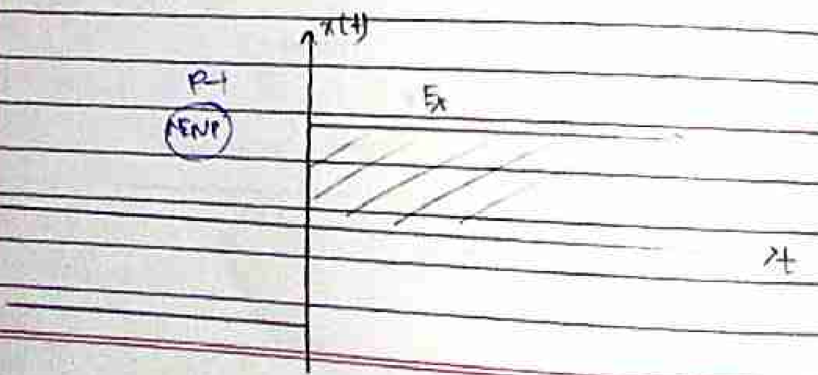




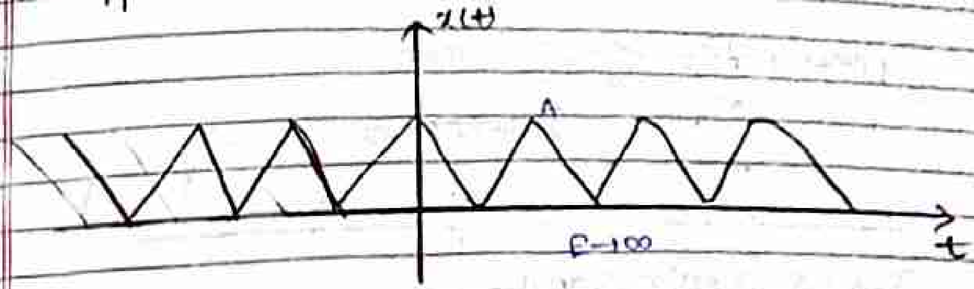
P= Power

Energy & power signal





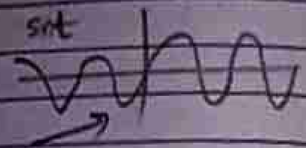
Energy & power signal



finite duration signal — E / NENP / Cannot be Power   P=0

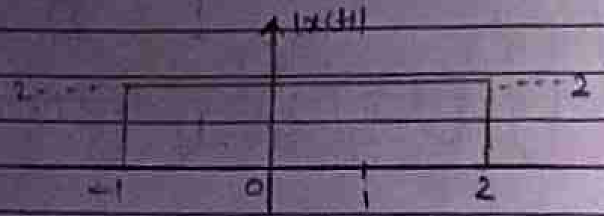
Infinite duration signal — E / NENP / Power

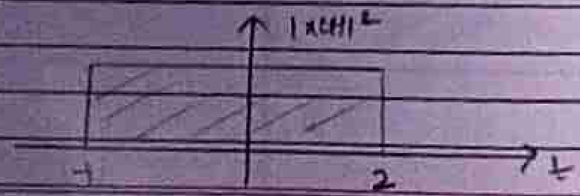
Periodic signal — Ex / NENP / power



sint = Powersignal   tanθ ; θ=90°

Calculate the energy of signal.





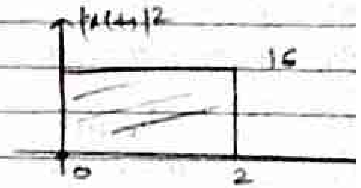
E = 4×3

= 12 units

Q. Calculate the energy of signal

|-4| = 4

|4| = 4



Energy = $\int_{-\infty}^{\infty} |x(t)|^2 dt$ = area of $|x(t)|^2$

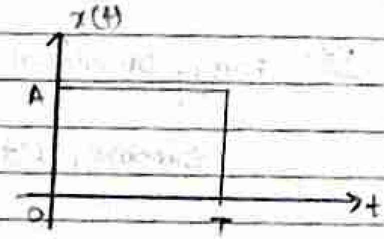
E = 16×2

= 32 units

* Check for energy & Power of given signal

$$x(t) = \begin{cases} A & 0<t<T \\ 0 & \text{else} \end{cases}$$

finite



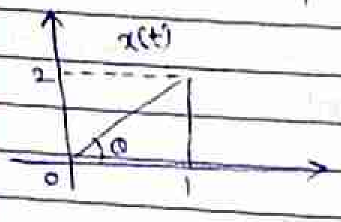
Energy = $\int_{-T}^{T} x^2(t)dt = \int_0^T A^2 dt$

$= A^2 \int_0^T 1\, dt = A^2 [t]_0^T$

$= A^2 [T-0]$

$= A^2 T$ Jouls

Q. Calculate the energy of signal.

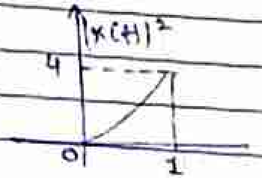


$x(t) = mt$

$m = \frac{y}{x} = \frac{2}{1}$

$m = 2$

$x(t) = 2t$



$|x(t)|^2 = 4t^2$

$$\text{Energy} = \int_{-\infty}^{\infty} |x(t)|^2 = \int_0^1 4t^2 dt = 4\left[\frac{t^3}{3}\right]_0^1 \Rightarrow \frac{4}{3}$$

$$\boxed{E = \frac{4}{3}}$$

Ex- Energy of signal from zero to infinity

Suppose, $x(t) = \begin{cases} e^{-t} & t \geq 0 \\ 0 & t < 0 \end{cases}$

$= e^{-t}$ unit/step function $u(t)$

$$E_x = \int_0^{\infty} |e^{-t}|^2 dt$$

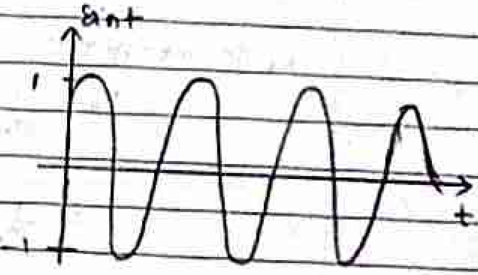
$$= \int_0^{\infty} e^{-2t} dt$$

$$= \left[\frac{-1}{2} e^{-2t}\right]_0^{\infty}$$

$$E_x = \frac{1}{2}$$

Here, the signal energy of signal is finite, E_x is finite, then the signal $|x(t)|$ is termed as an energy signal.

* $x(t) = \sin[u(t)]$



$$P_x = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} \sin^2 t \, u(t) dt$$

$$= \lim_{T\to\infty} \frac{1}{T} \int_0^{T/2} \left[\frac{1-\cos 2t}{2}\right] dt$$

$$= \lim_{T\to\infty} \frac{1}{T} \left[\frac{1}{2}\int_0^{T/2} dt - \frac{1}{2}\int_0^{T/2} \cos 2t \, dt\right]$$

$$= \lim_{T\to\infty} \frac{1}{T} \left[\left(\frac{1}{2} \times \frac{T}{2}\right) - \frac{1}{2}\left(\frac{\sin 2t}{2}\right)\right]_0^{T/2}$$

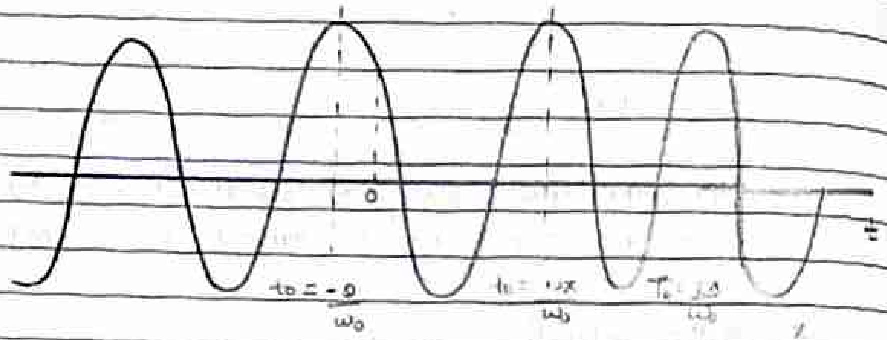
$$P_x = \lim_{T\to\infty} \frac{1}{T} \left[\frac{T}{4} - \frac{1}{4}\{\sin 2t\}\right]$$

$$= \left[\lim_{T\to\infty} \frac{1}{\cancel{T}} \times \frac{\cancel{T}}{4}\right] - \left[\lim_{T\to\infty} \frac{1}{T} \times \frac{\sin t}{4}\right]$$

$$\Rightarrow \frac{1}{4} - 0$$

$\boxed{P_x = \frac{1}{4}} \longrightarrow P_x$ is a power signal. $x(t)$

Ex.2 Let $x(t) = A\cos[\omega_0 t + \theta]$ is this a power signal or energy signal?



E_x is unbounded so

$$P_x = \frac{1}{T_0}\int_0^{\frac{2\pi}{\omega_0}} A^2\cos^2(\omega_0 t + \theta)\,dt$$

$$= \frac{1}{T_0}\int_{\frac{-\theta}{\omega_0}}^{\frac{-\theta+2\pi}{\omega_0}} A^2\cos^2(\omega_0 t + \theta)\,dt$$

$$= \frac{A^2}{T_0}\int_{\frac{-\theta}{\omega_0}}^{\frac{-\theta+2\pi}{\omega_0}} \frac{1+\cos(2\omega_0 t + 2\theta)}{2}\,dt$$

$$= \frac{A^2}{T_0}\left[\frac{t}{2} + \frac{\sin(2\omega_0 t + 2\theta)}{4\omega_0}\right]_{\frac{-\theta}{\omega_0}}^{\frac{-\theta+2\pi}{\omega_0}}$$

$$= \frac{A^2}{T_0}\left[\frac{1}{2}\left(\frac{-\theta+2\pi}{\omega_0}\right) + \frac{\sin\left(2\omega_0 \cdot \frac{-\theta+2\pi}{\omega_0} + 2\theta\right)}{2\omega_0} - \left(\frac{-\theta}{2\omega_0} + \frac{\sin\left(2\omega_0\left(\frac{-\theta}{\omega_0}\right)+2\theta\right)}{4\omega_0}\right)\right]$$

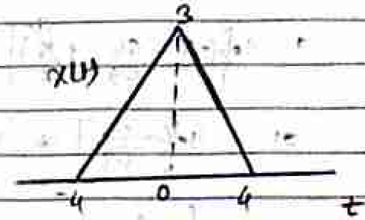
$$\Rightarrow \frac{A^2}{T_0}\left[\frac{-\theta+2\pi}{2\omega_0} + \frac{\sin(-2\theta+4\pi)+2\theta}{4\omega_0} + \frac{\theta}{2\omega_0} + \frac{\sin(-2\theta)+2\theta}{4\omega_0}\right]$$

$$\Rightarrow \frac{A^2}{T_0}\left[\frac{1}{2}\left(\frac{-\theta+2\pi}{\omega_0} - \frac{-\theta}{\omega_0}\right)\right]$$

$$\Rightarrow \frac{1}{2}\times\frac{A^2}{T_0}\times\frac{2\pi}{\omega_0}$$

$$\Rightarrow \frac{A^2}{2}$$

Ex. Consider the signal given below. is this power or energy type signal?



$$x(t) = \begin{cases} 3\left(1-\frac{t}{4}\right) & \text{if } 0 \le t \le 4 \\ 3\left(1+\frac{t}{4}\right) & \text{if } -4 \le t \le 0 \\ 0 & \text{otherwise} \end{cases}$$

$$E_x = \int_{-4}^{4} |x(t)|^2\,dt \Rightarrow \int_{-4}^{4} x^2(t)\,dt$$

$$= 9\int_{-4}^{0}\left(1+\frac{t}{4}\right)^2 dt + 9\int_0^4\left(1-\frac{t}{4}\right)^2 dt$$

$$\Rightarrow 9\left[\int_{-4}^{0}\left(1+\frac{t^2}{16}+\frac{t}{2}\right)dt + \int_0^4\left(1+\frac{t^2}{16}-\frac{2t}{8}\right)dt\right]$$

$$= 9\left[\left(t+\frac{t^3}{48}+\frac{t^2}{4}\right)_{-4}^{0} + \left(t+\frac{t^3}{48}-\frac{t^2}{4}\right)_0^4\right]$$

$$= 9\left[\left[-4 - \frac{64}{48} + \frac{16}{4} + 0\right] + \left(4+\frac{64}{48}-\frac{16}{4}\right)\right]$$

$$= 9\left[-4-\frac{32}{24}+4\right] + 9\left[4+\frac{32}{24}-4\right]$$

$$y = -\cancel{36} - \frac{32\times 9}{24} + \cancel{36} + \cancel{36} + \frac{32\times 9}{24} - \cancel{36}$$

$\Rightarrow$

$$\Rightarrow 9\left[\left(t + \frac{t^3}{48} + \frac{t^2}{4}\right)_{-4}^{0}\right] + 9\left[\left(t + \frac{t^3}{48} - \frac{t^2}{4}\right)_{0}^{4}\right]$$

$$\Rightarrow 9\left[0 + \frac{0^3}{48} + \frac{0^2}{4} - \left[-4 + \frac{(-4)^3}{48} + \frac{(-4)^2}{4}\right]\right] + 9\left[4 + \frac{(4)^3}{48} - \frac{(4)^2}{4} - 0\right]$$

$$\Rightarrow 9\left[-\left(-4 - \frac{64}{48} + \frac{16}{4}\right)\right] + 9\left[4 + \frac{64}{48} - \frac{16}{4}\right]$$

$$\Rightarrow 9\left[-\frac{64}{48}\right] + 9$$

$$\Rightarrow 9\left[-\left(-4 - \frac{64}{48} + \frac{16}{4}\right)\right] + 9\left[4 + \frac{64}{48} - 4\right]$$

$$\Rightarrow 9\left[4 + \frac{64}{48} - 4\right] + 9\left[\frac{64}{48}\right] \Rightarrow \frac{9\times 8}{6} + \frac{9\times 8}{6}$$

$$\Rightarrow 9\left[\frac{4}{3} + \frac{4}{3}\right] \Rightarrow 9\left[\frac{8}{3}\right] \Rightarrow 3(8) \Rightarrow \underline{\underline{24}}$$

Ex: Compute the energy signal $x[n]$ given by

$\Longrightarrow$

$$x[n] = \begin{cases} \left(\frac{1}{3}\right)^n & \text{if } n \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

$$E_x = \sum_{-\infty}^{\infty} x^2[n] \Rightarrow \sum_{0}^{\infty} x^2[n] = \sum_{0}^{\infty} \left(\left(\tfrac{1}{3}\right)^n\right)^2$$

$$= \sum_{0}^{\infty} \left(\frac{1}{3}\right)^{2n} = \sum_{0}^{\infty} \left(\frac{1}{9}\right)^n \Rightarrow \frac{1}{1 - \frac{1}{9}}$$

$$\Rightarrow \frac{1}{\frac{9-1}{9}} \Rightarrow \frac{1}{8/9} \Rightarrow \frac{9}{8}$$

Ex: What is the powers of the signal $x(t) = e^{j\omega_0 t}$? where $\left(T_0 = \frac{2\pi}{\omega_0}\right)$

$\longrightarrow$ given that $T_0 = \frac{2\pi}{\omega_0} \Rightarrow e^{j\omega_0 \frac{2\pi}{\omega_0}} \Rightarrow e^{j\omega_0\left(t + \frac{2\pi}{\omega_0}\right)}$

$$= e^{j(\omega_0 t + 2\pi)}$$

We know that $e^{j\theta} = e^{j(\theta + 2\pi)} = x(t)$ is periodic with a period of $\frac{2\pi}{\omega_0}$ therefore,

$$P_x = \frac{1}{T_0}\int_0^{T_0} |e^{j\omega_0 t}|^2\, dt \Rightarrow \frac{1}{T_0}\int_0^{T_0} 1 \cdot dt$$

$$\left[|e^{j\theta}| = 1 \ \forall \theta \Rightarrow |e^{j\omega_0 t}| = 1\right]$$

$$= 1$$

* Energy and power signal *

① If $x(t)$ is existing for infinite duration & decreasing in nature,

i.e.

$$\lim_{t\to\infty} f(t) = 0$$

then $f(t)$ will be an energy signal.

② If $x(t)$ exists for finite duration & value of $x(t)$ is finite at all points, $x(t)$ will be an energy signal.

Signals	Power
$A\sin\omega t$ or $A\cos\omega t$ $\rightarrow$	$\frac{A^2}{2}$
$A\,u(t)$ $\rightarrow$	$A/2$
$A.e^{j\omega t}$ $\rightarrow$	A^2
A $\rightarrow$	A^2

* All periodic signals are power signals but converse is not true

* If $x(t)$ is not a periodic signal but follows these conditions

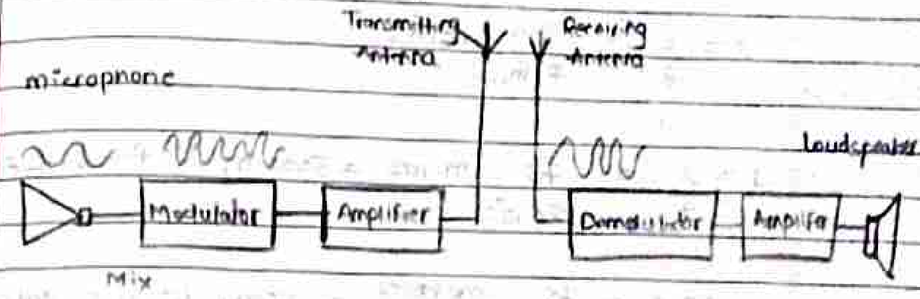
$$\lim_{t\to\infty} f(t) \neq 0$$

$$\lim_{t\to\infty} f(t) \neq \infty$$

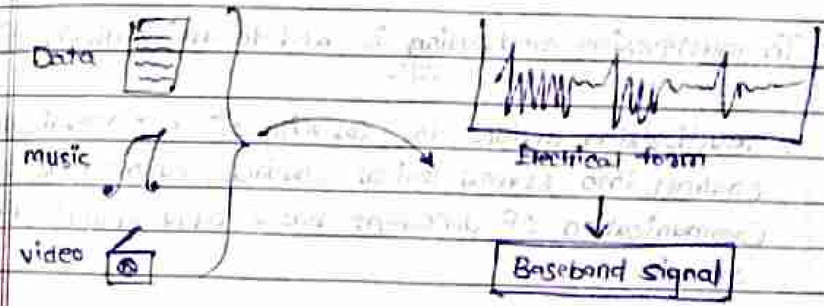
* Modulation and Demodulation *

> general Block diagram of communication

* Modulation and demodulation

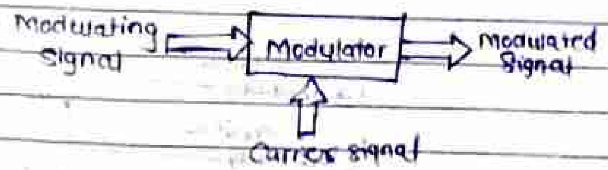


Modulating Signal is also base band Signal i.e. Input signal



Modulation :

How to get Modulated signal :



> Modulating Signal (i.e. information) superimposed on high frequency carrier signal (i.e. modulated signal) is called Modulation.

Need of Modulation

1. To reduce antenna Height in wireless Communication Modulation

$$\lambda = \frac{c}{f} = \frac{300}{f(MHz)} \text{ metres}$$

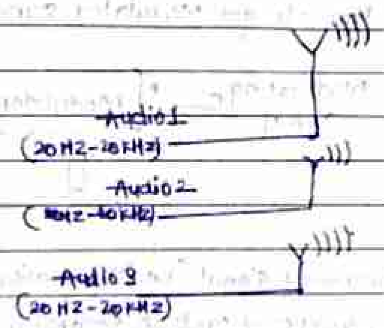
$$l = \frac{\lambda}{4} = \frac{75}{15\times10^{-3}} \text{ meters} = 5000m, \text{ if } f = 15KHz = 15\times10^{-3} MHz$$

$$l = \frac{\lambda}{4} = \frac{75}{f(MHz)} \text{ meters} = 75m, \text{ if } f = 1MHz$$

2. In multiplexing modulation is used to avoid mixing of signal.

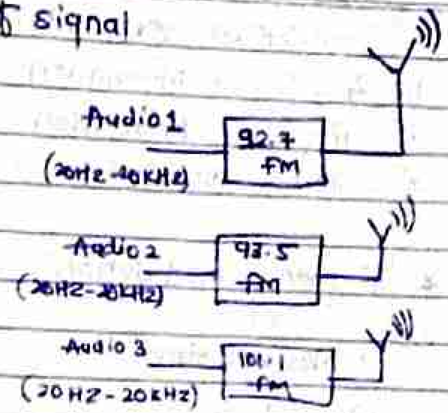
> Multiplexing divides the capacity of a communication channel into several logical channels, each one is used communication of different base band signal (data stream)

> Multiple signals send on a single wire at a same time is called as multiplexing

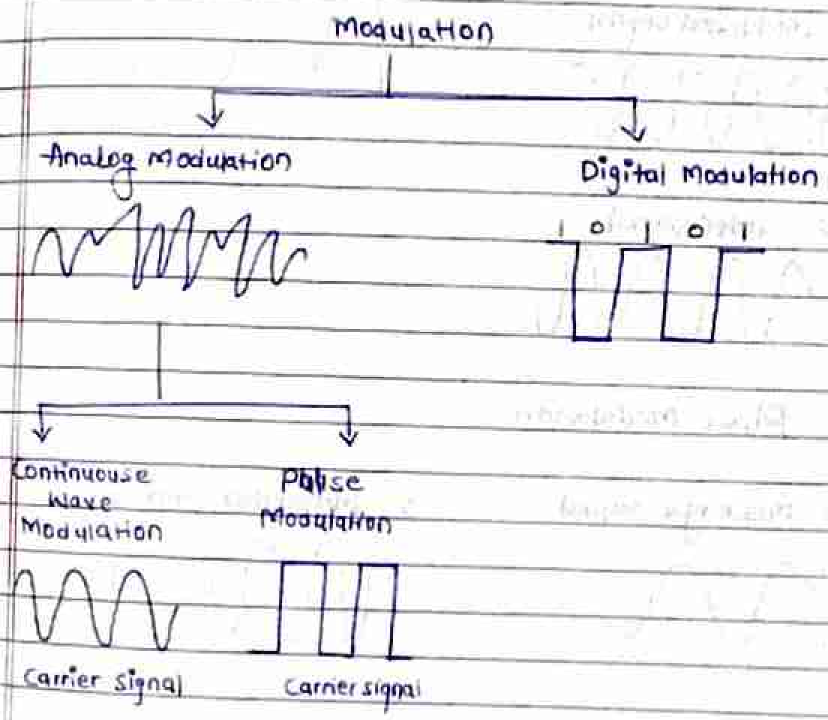


3. To avoid the interference of signal.

4. Modulation used for long distance transmission



Types of Modulation

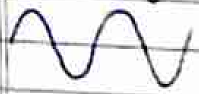


Continuouse Modulation

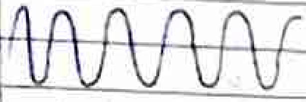
1) Amplitude Modulation
2) frequency Modulation
3) Phase Modulation

★ frequency Modulation

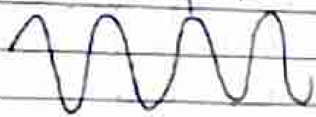
> Message signal



> Modulated signal

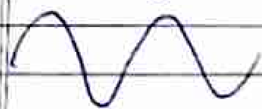


> Carrier signal

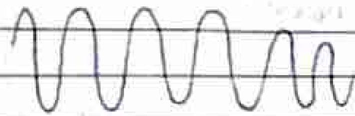


★ Phase Modulation

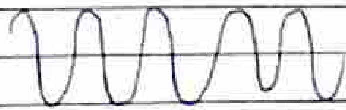
> Message signal



> Modulated signal

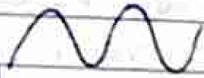


> Carrier signal →

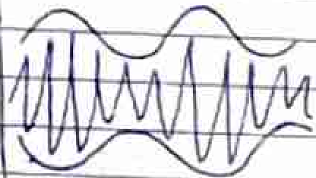


★ Amplitude Modulation

> Message signal



> modulated signal



> carrier signal

frequency Modulation

• Deviation of freq. ΔF

Amplitude Modulated Signal :-

- It is the Process in Amplitude of carrier signal changes w.r.t. message (modulating) signal.

→ $m(t)$ = modulating signal

$= A_m \sin \omega t$

Single Tone AM Modulation

AM signal transmitted power, efficiency & Retendency

→ AM signal

$$y(t) = \underbrace{A_c \sin \omega_c t}_{\text{Carrier signal}} + \underbrace{\frac{A_c \mu}{2} \cos(\omega_c + \omega_m)t}_{\text{USB signal}} + \underbrace{\frac{A_c \mu}{2} \cos(\omega_c - \omega_m)t}_{\text{LSB signal}}$$

→ total transmitted power

$$P_t = P_c + P_{USB} + P_{LSB} = P_c + P_s$$

P_c ↓ it is ~~Redunda~~ Redundancy, it doesn't Have information

P_s → It has Information

Power of carrier $P_c = \frac{A_c^2}{2}$

power of USB $P_{USB} = \frac{1}{2}\left(\frac{A_c \mu}{2}\right)^2 = \frac{1}{8} A_c^2 \mu^2$

power of LSB $P_{LSB} = \frac{1}{2}\left(\frac{A_c \mu}{2}\right)^2 = \frac{1}{8} A_c^2 \mu^2$

* Efficiency of the AM Modulator & Redundancy

Carrier power $= P_c = A_c^2/2$

$$\eta = \frac{\mu^2}{2+\mu^2}$$

after Modulations Side band Power

$$(P_s) = \frac{m_a^2 A_c^2}{4}$$

Redundancy

$$D = 1 - \eta$$

$$= 1 - \frac{\mu^2}{2+\mu^2}$$

$$= \frac{2+\mu^2-\mu^2}{2+\mu^2} = \frac{2}{2+\mu^2}$$

efficiency = $\frac{\text{sideband P.}}{\text{total P.}}$

$$\eta = \frac{P_s}{P_t} = \frac{P_s}{P_c + P_s}$$

$$\eta = \frac{P_s}{P_t} = \frac{\frac{m_a^2 A_c^2}{4}}{\frac{A_c^2}{2} + \frac{m_a^2 A_c^2}{4}}$$

$$\eta = \frac{P_s}{P_t} = \left[\frac{\frac{m_a^2}{2}}{1 + \frac{m_a^2}{2}}\right]$$

$$\therefore \eta = \frac{P_s}{P_t} = \left[\frac{m_a^2}{2 + m_a^2}\right]$$

$$\boxed{\eta = \frac{m_a^2}{2 + m_a^2}}$$

* Modulation Index.

$$\boxed{\mu = \frac{A_m}{A_c}}$$

where,

A_m = Amplitude of modulating signal

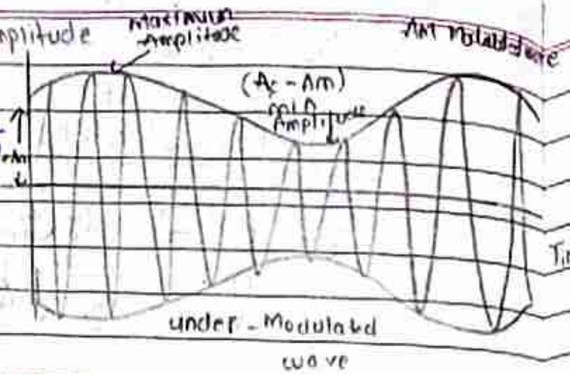
A_c = Amplitude of carrier signal

$$\mu = \frac{\text{change in Amplitude of carrier wave}}{\text{Amplitude of carrier wave}}$$

But, change in Amplitude of carrier wave = Amplitude of modulating wave (A_m)

$$\therefore \mu = \frac{A_m}{A_c} = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

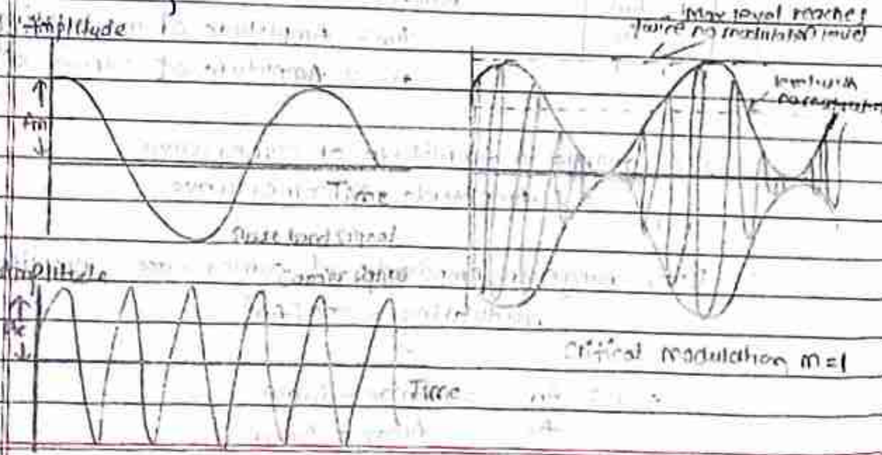
Where,
A_{max} and A_{min} are max. and min. voltage of AM wave, respectively

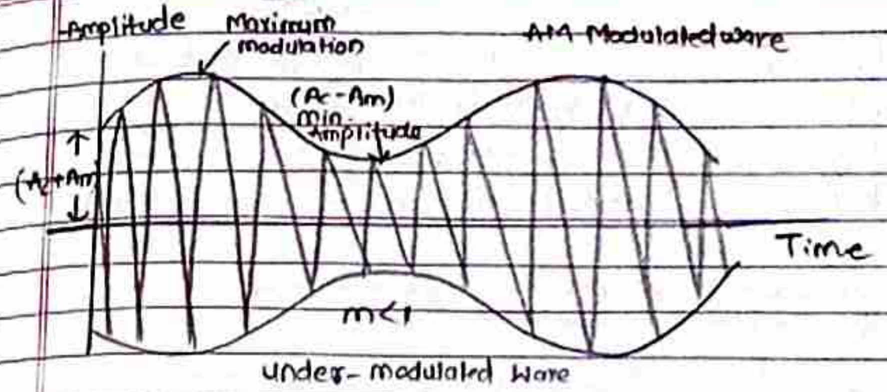


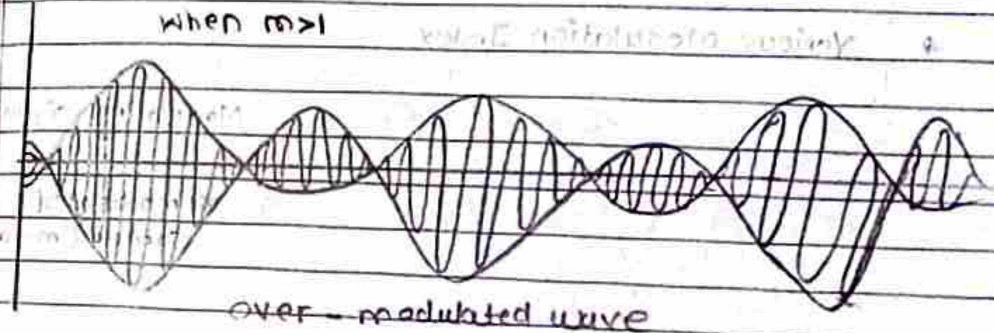
μ = change in amplitude of

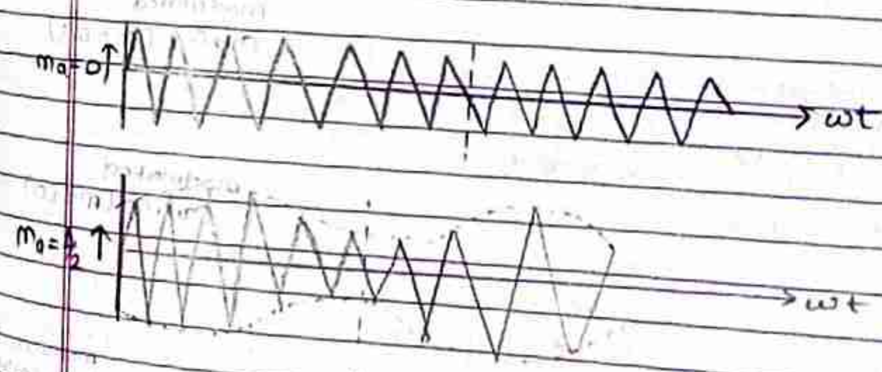
$$\boxed{\mu = \frac{A_m}{A_c} = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}}$$

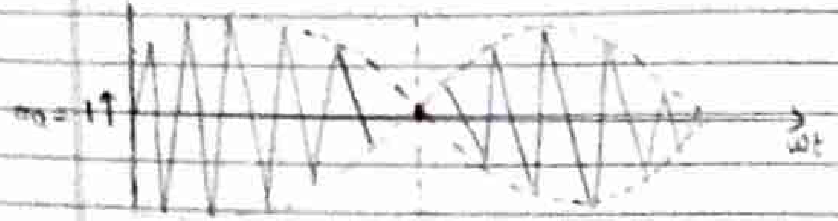
* Carrier wave, after being Modulated. if the modulated level is calculated, then such an attempt is called as Modulation Index or modulation Depth.
It states the level of modulation that an carrier wave undergoes
The maximum and minimum values of the envelope of the modulated wave are represented by A_{max} and A_{min} respectively

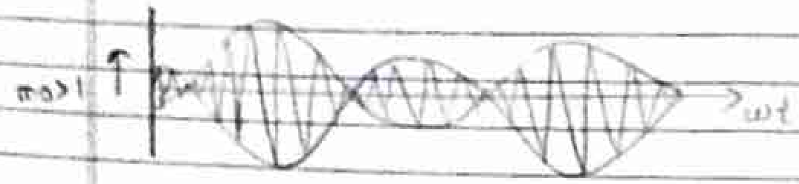




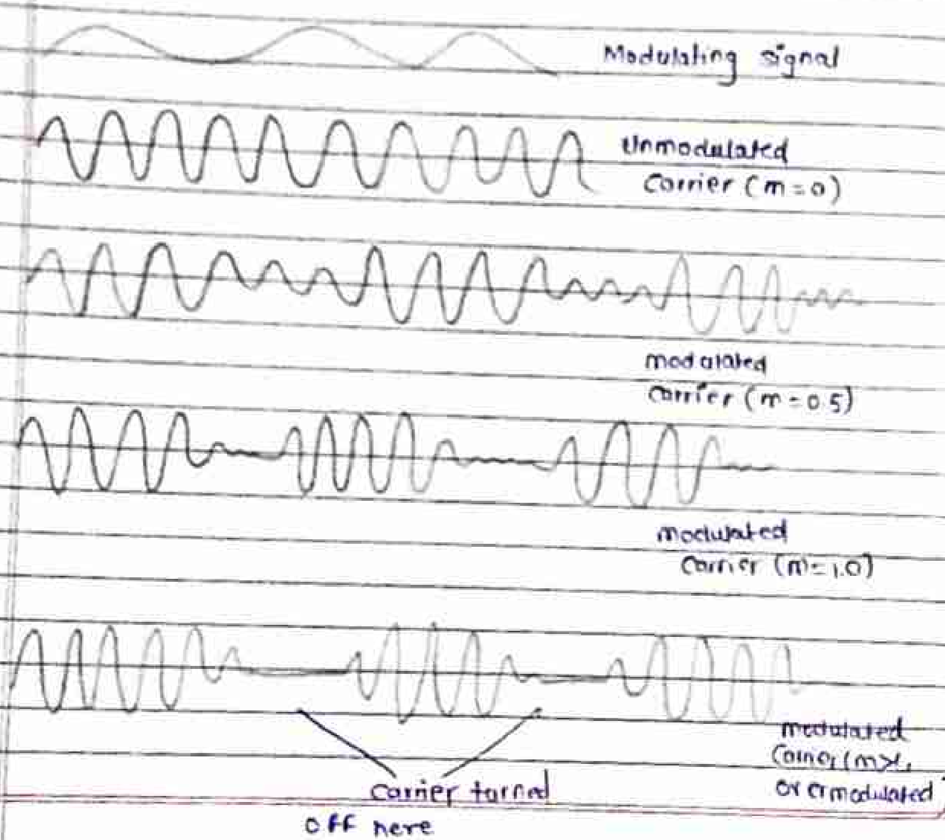








★ Various Modulation Index



$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

★ Multiple tone Amplitude Modulation

let's have carrier signal, $\underline{c(t) = A_c \sin \omega_c t}$

Multiple tone Modulating signal

$$m(t) = A_1 \sin \omega_1 t + A_2 \sin \omega_2 t + A_3 \sin \omega_3 t$$

Am signal will be

$$y(t) = A' \sin \omega_c t$$

$$= (A_c + m(t)) \sin \omega_c t$$

$$\Rightarrow (A_c + A_1 \sin \omega_1 t + A_2 \sin \omega_2 t + A_3 \sin \omega_3 t) \sin \omega_c t$$

$$y(t) = A_c\left(1 + \left(\frac{A_1}{A_c}\right)\sin \omega_1 t + \left(\frac{A_2}{A_c}\right)\sin \omega_2 t + \left(\frac{A_3}{A_c}\right)\sin \omega_3 t\right) \sin \omega_c t$$

$$\mu_1 = \frac{A_1}{A_c} \; ; \; \mu_2 = \frac{A_2}{A_c} \; , \; \mu_3 = \frac{A_3}{A_c}$$

$$y(t) = A_c\left(1 + \mu_1 \sin \omega_1 t + \mu_2 \sin \omega_2 t + \mu_3 \sin \omega_3 t\right) \sin \omega_c t$$

→ Carrier Power → Sideband Power

$$P_c = \frac{A_c^2}{2}$$

$$P_s = \frac{1}{4} A_c^2 \mu_1^2 + \frac{1}{4} A_c^2 \mu_2^2 + \frac{1}{4} A_c^2 \mu_3^2$$

$$P_s = \frac{1}{2} A_c^2 \left[\frac{1}{2}\left(\mu_1^2 + \mu_2^2 + \mu_3^2\right)\right]$$

$$P_s \Rightarrow \frac{P_c}{2}\left(\mu_1^2 + \mu_2^2 + \mu_3^2\right) \Rightarrow \frac{P_c}{2}\mu^2$$

where $\boxed{\mu^2 = \mu_1^2 + \mu_2^2 + \mu_3^2}$

$$P_t = P_c + P_s P_c + \frac{P_c \mu^2}{2} = P_c\left(1 + \frac{\mu^2}{2}\right)$$

$$P_t = P_c\left(1 + \frac{1}{2}\left(\mu_1^2 + \mu_2^2 + \mu_3^2\right)\right)$$

Total Power $(P_t) = P_c\left(1 + \frac{m_{a_1}^2}{2} + \frac{m_{a_2}^2}{2} + \dots + \frac{m_{a_n}^2}{2}\right)$

$$P_t = P_c\left[1 + \frac{1}{2}\sum_{t=1}^{n} m_{a_t}^2\right]$$

Current of single tone AM wave

$$P_t = I_t^2 R_t$$

$$P_c = I_c^2 R_t$$

Total Power $(P_t) = P_c\left(1 + \frac{m_a^2}{2}\right)$

$$I_t^2 R_t = I_c^2 R_t\left(1 + \frac{m_a^2}{2}\right)$$

$$\cancel{I_t^2 R_t = I_c^2 R_t}$$

$$I_t = I_c\sqrt{\left(1 + \frac{m_a^2}{2}\right)}$$

Q. Calculate amplitude of message signal, frequency of USB and frequency of LSB for given data

$\Longrightarrow$ given, frequency of carrier wave,

$$f_c = 1.5\,MHZ = 1500\,KHZ$$

frequency of sinusoidal (modulated) wave,

$$f_m = 10\,KHZ$$

Amplitude of carrier wave, $A_c = 50\,V$

Modulation index $\mu = 50\%$

$$= \frac{50}{100} = \frac{1}{2}$$

Modulation index, $\mu = \frac{A_m}{A_c}$

$$\frac{1}{2} = \frac{A_m}{50}$$

$$\boxed{A_m = 25\,V}$$

So, the amplitude of AM wave, $A_m = 25\,V$

As, we know the side bands are

USB $= f_c + f_m = 1500 + 10 = 1510\,KHZ$

LSB $= f_c - f_m = 1500 - 10 = 1490\,KHZ$

Q. The modulating signal $20\cos(2\pi * 10^3 t)$ is used to modulate a carrier signal $40\cos(2\pi * 10^4 t)$. find the modulation index, Percentage modulation, frequencies of sideband Components and their amplitudes. What is the bandwidth of the modulated signal?

Soln → The modulating signal is given as

$$\boxed{E_m = E_m \cos \omega_m t}$$

and the given signal is :

$$E_m = 20\cos(2\pi * 10^3 t)$$

on Comparing,

$E_m = 20$, $\omega_m = 2\pi \times 10^3$

$\therefore f_m = 1000\,Hz = 1\,kHz$

Also, the modulating carrier signal is $\boxed{E_c = E_c \cos \omega_c t}$

the given signal is, $E_c = 40\cos(2\pi * 10^4 t)$

on comparing,

$E_c = 40$; $\omega_c = 2\pi \times 10^4$

$f_c = 10^4 \Rightarrow 10000\,Hz = 10\,kHz$

The modulation index is given as,

$$m = \frac{E_m}{E_c} \Rightarrow \frac{20}{40} \Rightarrow 0.5$$

$\therefore m = 0.5 \times 100 \Rightarrow 50\%$

The frequencies are calculated as,

$f_{USB} = f_c + f_m \Rightarrow 10\,kHz + 1\,kHz \Rightarrow 11\,kHz.$

$f_{LSB} = f_c - f_m \Rightarrow 10\,kHz - 1\,kHz \Rightarrow 9\,kHz.$

The amplitude of each sidebands are,

$$\Rightarrow \frac{m E_c}{2} \Rightarrow \frac{0.5 \times 40}{2} \Rightarrow 10\ \text{volts}.$$

Bandwidth of modulated signal is $\Rightarrow 2f_m$

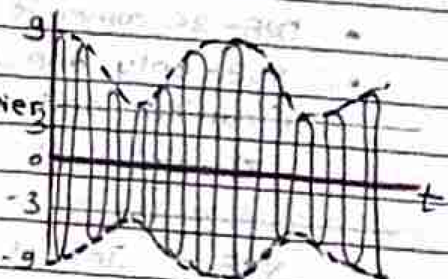
$\Rightarrow 2(1\,kHz) \Rightarrow 2\,kHz.$

Q. A sinusoidally modulated ordinary AM waveform is shown below.

a) determine the modulation index.

b) Calculate transmission efficiency.

c) Determine the amplitude of the carrier which must be added to attain a modulation index of 0.3.



(a) Using $\begin{cases} S_{max} = A_c(1+m_a) \\ S_{min} = A_c(1-m_a) \end{cases}$ $\therefore A_c = 6$ $\therefore$ the Modulation Index $(m_a) = 1/2$

(b) $\eta = \frac{\mu^2}{2+\mu^2} \Rightarrow \frac{\left(\frac{1}{2}\right)^2}{2+(1/2)^2} \Rightarrow \frac{1/4}{2+1/4} \Rightarrow \frac{1/4}{9/4} \Rightarrow \frac{1}{9}$

(c) Using $m_a \Rightarrow \frac{a_m}{A_c}$, $0.3 = \frac{a_m}{A_c} \Rightarrow \frac{3}{10} = \frac{a_m}{A_c}$

$$\boxed{A_c' = 10}$$

Various amplitude modulation systems

> Conventional AM,
> DSB - SC Double side band - supressed carrier.
> SSB - single side band
> VSB - vestigial side band

Properties of all

- Conventional AM signal contains carrier and 2 side band
- DSB-SC carrier is removed only side bands are present
- SSB- only one ~~singal~~ (single) side band is present (Carriers and one sided band is subtracted at Transmission)
- VSB - Instead of rejecting one side band completely (like SSB), a gradual cut off of one side is allowed
- Demodulation (detection) of conventional AM is easier in comparison to that of DSB-SC & SSB systems.
- Also demodulation of conventional AM is less expensive comparatively to the others.
- It is easy to produce conventional AM signals at high power levels, therefore, can be used for broadcasting services.
- DSB-SC & SSB systems required lesser power to transmit the same information, so, as in conventional AM large power is wasted (i.e. 2/3 rd) which contains no information.

Comparison

- DSB-SC & SSB are different efficient but are much more complex & expensive.
- Conventional AM scheme is simplest therefore, broadcasting system is very simple & less expensive using conventional AM.

Bandwidth Requirements.

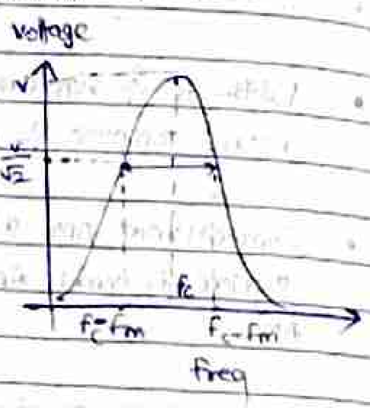
Conventional AM scheme is simplest. Therefore, broadcasting system is very simple & less expensive using conventional AM, DSB-SC & SSB

Applications :-

- Conventional AM mostly used in public broadcasting services.
- DSB-SC & SSB modulation systems are used in point to point communication.
- SSB is used for the long distance transmission of voice signals.
- VSB is used for the transmission of television signals.

* AM Modulator Square law Modulator

$C(t) = A_c \sin \omega_c t$



* Types of AM Modulators

The circuits which are used for the generation of amplitude modulated signals are known as AM Modulators.

AM Modulators are different types:

1. Square law Modulator
2. Switching modulator
3. Synchronous Modulators

The input output relation of the modulator device can be expressed as

$$\boxed{v_0 = a_1 v_{in} + a_2 v_{in}^2 + a_3 v_{in}^3 + \dots}$$

- It consists of linear and non linear characteristics

> Linear :-

If the output of the device is directly proportional to input given to the device, is called linear characteristics of device.

> Non linear :-

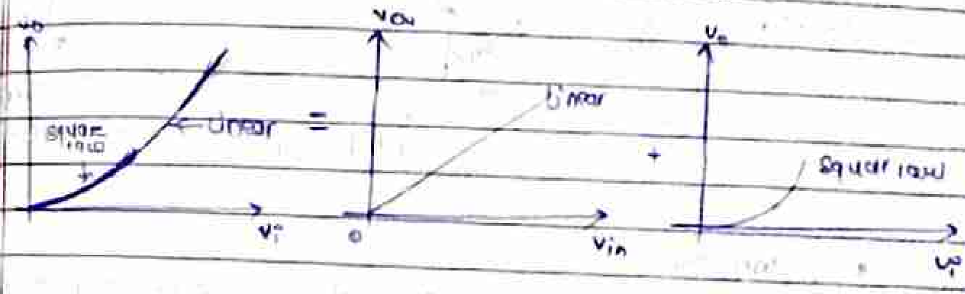
It the output of the device is not directly proportional to the input given to the device then it is called Non-linear characteristics of device.

- Diode is used as modulator

it gives :-

At low voltage : Non linear characteristics.

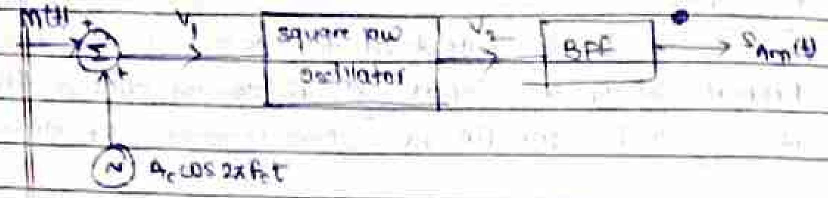
At High voltage : linear characteristics



* Square law Modulator :-

For smaller input voltage, higher order terms are neglected. The output is considered up to. The output is considered upto the square of input signal is called as square law device.

Ex, $v_0 = a_1 v_{in} + a_2 v_{in}^2$



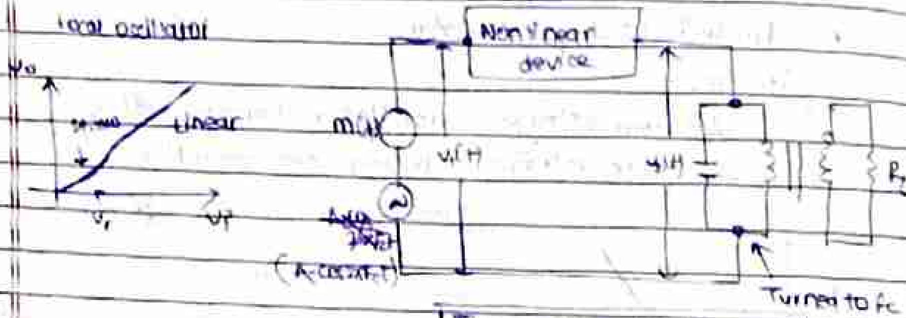


Fig - square law modulator

- Square law
  For smaller voltage diode can be operate in the Non linear characteristics region (square law)
- Sum of massage signal and generated carrier i.e. v_1 and its peak voltage is near to v_r

$$v_1 = c(t) + m(t)$$
$$v_1 = m(t) + A_c \cos(2\pi f_c t)$$

The output of square ~~law~~ of device is given as

$$v_2 = a_1 v_1 + a_2 v_1^2$$

The expression for Non linear AM modulators is given by

$$v_2 = a_1\left[m(t) + A_c \cos(2\pi f_c t)\right] + a_2\left[m(t) + A_c \cos(2\pi f_c t)\right]^2$$

$$v_2 = a_1\left[m(t) + A_c \cos(2\pi f_c t)\right] + a_2\left[m^2(t) + A_c^2 \cos^2(2\pi f_c t) + 2A_c m(t) \cos 2\pi f_c t\right]$$

Not passes through BPF

passes through Bandpass filt (BPF)

Band pass filter output will be the final modulated signal $S_{am}(t)$

$$(BPF)_{o/p} = S_{am}(t) = a_1 A_c \cos(2\pi f_c t) + 2a_2 A_c m(t) \cos(2\pi f_c t)$$

$$S_{AM}(t) = a_1 A_c\left[1 + \frac{2a_2}{a_1} m(t)\right] \cos(2\pi f_c t)$$

$$S_{AM}(t) = A_c'\left[1 + k_a m(t)\right] \cos 2\pi f_c t$$

$$A_c' = a_1 A_c \quad , \quad k_a = \frac{2a_2}{a_1}$$

where k_a is amplitude sensitivity

∴ Modulation index of the output signal is given by $\boxed{m = \frac{2a_2 A_m}{a_1}}$

Advantages and disadvantages of Conventional AM

Advantage of AM :-

Generation and

Demodulators :-

Types of Demodulators :

- It is the process of recovering the Information signal (baseband) from the incoming modulated signal at the receiver.

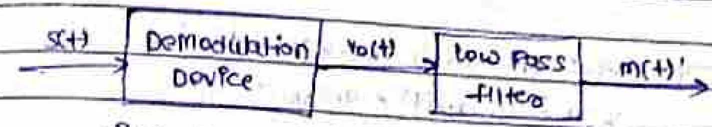


fig :- Demodulation of AM using square law device

- Demodulation of AM signals can be performed with the help of following demodulators

1. square law demodulator
2. Envelope detector or Diode detector — $\mu \le 1$ — simple
3. Synchronous detector or Coherent detector — for any values — complex

- Square law demodulator
- Consider a non-linear demodulator device, modulated AM signal $S_{AM}(t)$ is applied to it.
- When the level of $S_{AM}(t)$ is very small, the output can be considered up to square of an input called square law demodulator

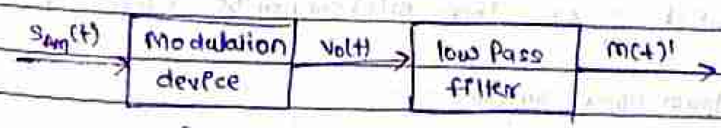


fig- Demodulation of AM using square law device

- If m(t) is the information signal (0-WHz)
- Carrier is $c(t) = A_c\cos(2\pi f_c t)$
- Amplitude modulated input signal is given to the non-linear

demodulator device is

$$S_{AM}(t) = A_c\left[1 + k_a m(t)\right]\cos(2\pi f_c t)$$
$$S_{AM}(t) = A_c\left[1 + k_a m(t)\right]\cos 2\pi f_c t$$
$$= A_c\cos(2\pi f_c t) + A_c k_a m(t)\cos 2\pi f_c t$$

- The output of square law demodulator is

$$V_1(t) = a_1 S_{AM}(t) + a_2 S_{AM}^2(t)$$

$$V_1 = a_1\left[A_c\cos(2\pi f_c t) + A_c k_a m(t)\cos(2\pi f_c t)\right] + a_2\left[A_c\cos(2\pi f_c t) + A_c k_a m(t)\cos(2\pi f_c t)\right]^2$$

$$V_1 = a_1 A_c\cos(2\pi f_c t) + a_1 A_c k_a m(t)\cos(2\pi f_c t) + a_2 A_c^2\left[\frac{1+\cos(4\pi f_c t)}{2}\right] + a_2 A_c^2 k_a^2 m^2(t)\left[\frac{1+\cos(4\pi f_c t)}{2}\right] + 2a_2 A_c^2 k_a m(t)\left[\frac{1+\cos(4\pi f_c t)}{2}\right]$$

$$(LPF)_{o/p} = \underbrace{\left[\frac{a_2 A_c^2 k_a^2 m^2(t)}{2}\right]}_{\text{Noise}} + \underbrace{\left[a_2 A_c^2 k_a m(t)\right]}_{\text{signal}}$$

→ if $\frac{S}{N} \gg 1$ Then m(t) can be completely reconstructed

→ if $\frac{S}{N} < 1$ Then m(t) cannot be completely reconstructed

from above equation

$$\frac{S}{N} = \left[\frac{a_2 A_c^2 k_a m(t)}{\frac{a_2 A_c^2 k_a^2 m^2(t)}{2}}\right] = \frac{2}{k_a m(t)}$$

$$\frac{S}{N} = \left[\frac{2}{k_a A_m\cos(2\pi f_m t)}\right] = \frac{2}{\mu\cos(2\pi f_m t)}$$

for $\cos(2\pi f_m t) = 1$; $\frac{S}{N} = \frac{2}{\mu}$

→ $\frac{S}{N}$ should be high for perfect reconstruction that means μ should be very low.

e.g. for S/N = 10 find efficiency of demodulator and calculate how much power is wasted

μ should be 0.2

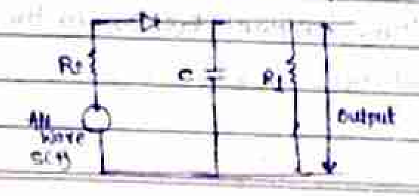
$$\eta = \frac{\mu^2}{2+\mu^2}$$

that means 98% Power wasted

- If μ is low, efficiency will be very low
- But for efficient power distribution η should be high so that square law demodulator is not preferred for AM demodulation

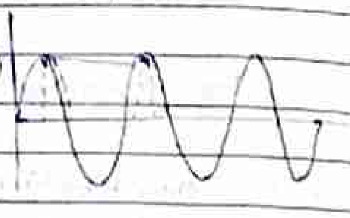
Envelop Detector

- Envelop detector is used for demodulation of signals.
- It is very simple, cheaper and used in most of the commercial AM radio receivers.
- Envelop detector extract +ve envelop of the applied signal and produce at the output
- Envelop detector can be designed with the help of diode & capacitor as shown in fig.



- Assume diode is ideal

P > N ......> F.B ......> S.C (short circuit)
P < N ......> R.B ......> O.C. (open circuit)



Assume the output of envelop detector is a sinusoidal wave as shown in fig

- The working of circuit as follows
- During the +ve half cycles of the input signals, diode D is forward biased and the capacitor C charges up rapidly to the peak of the input signal.

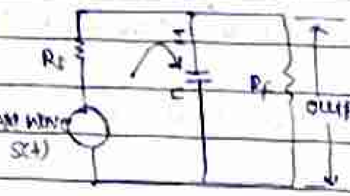


Fig Envelope Detector

- When the input signal falls below peak value and for -ve half cycles of the input signal, diode becomes reverse biased acting open circuit and the capacitor C discharge through the load resistor RL

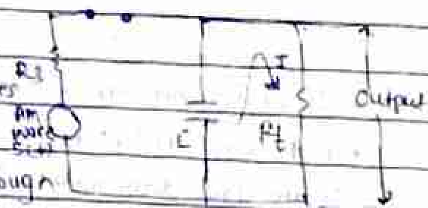


fig : envelope detector

Case (1) When $t = 0$ to t_1
→ time constant R_sC should be small, so that capacitor charges rapidly.

Case (2) When $t = t_1$ to t_2
→ Time constant R_LC should be high, so that capacitor discharges slowly.

Same Procedure
→ If capacitor discharges slowly the output signal

att-
Constant
Np/m

Γ (reflection coefficient) is a complex number that describes both the magnitude and the phase shift of the reflection. The simplest cases with Γ measured at the load are:

- $\Gamma = -1$; complete negative reflection, when the line is short-circuited,
  - * Short circuit
    $Z_L = 0 \rightarrow$

- Interference between incident and reflected waves along a transmission line.

the reflection coefficient $\Gamma = \dfrac{V_r}{V_f}$ $\quad \Gamma = \dfrac{Z_L - Z_0}{Z_L + Z_0}$

$$|V_{max}| = |V_f| + |V_r| = |V_f| + |\Gamma V_f| = (1 + |\Gamma|)|V_f|$$

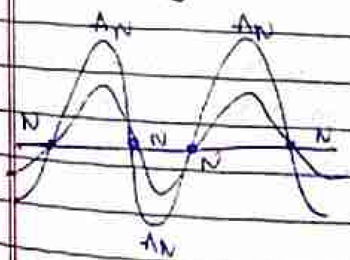
$$|V_{min}| = |V_f| - |V_r| = |V_f| - |\Gamma V_f| = (1 - |\Gamma|)|V_f|$$

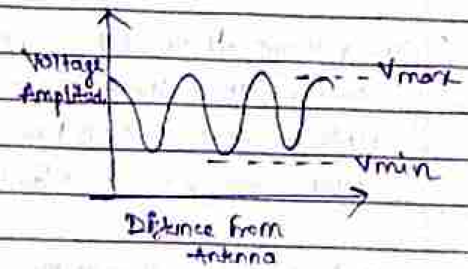
VSWR (voltage standing wave ratio) $= \dfrac{|V_{max}|}{|V_{min}|}$

$$\boxed{VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}}$$

$$\boxed{|\Gamma| = \frac{VSWR - 1}{VSWR + 1}}$$

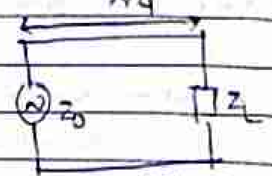
– Standing wave –





N = Node ; AN = antinode

Input impedance of ~~[illegible]~~ $\lambda/4$ length of Tx line :-



$$Z_{in} = Z_0 \left\{ \frac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l} \right\}$$

$$\beta l = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$$

$$\tan\left(\frac{\pi}{2}\right) = \infty$$

$$= \frac{Z_0 \tan\beta l \left[\frac{Z_L}{\tan\beta l} + jZ_0 \right]}{\tan\beta l \left[\frac{Z_0}{\tan\beta l} + jZ_L \right]}$$

$$Z_{in} = \frac{Z_0 \times jZ_0}{jZ_L} = \frac{Z_0^2}{Z_L}$$

$$\boxed{Z_{in} = \frac{Z_0^2}{Z_L}}$$

$$\boxed{\frac{V_{Reflected}}{V_{Forward}} = V_{Reflection} \quad \text{Reflection Coefficient.}}$$

Voltage Standing wave Ratio and reflection Coefficient

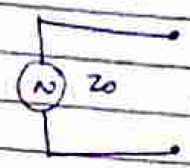
- The voltage travelled forward towards the load and reflected back, then they are superimposed on each other in a uniform transmission line forms a standing wave (with complex amplitude).

Node is present when voltage = 0

Voltage is max then antinodes is present

- A wave is partly reflected when a transmission line is terminated with impedance which is not equal to its characteristic impedance.

Input impedance of open circuit :-



$$Z_{in} = Z_0 \left[\frac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l} \right]$$

$$Z_{in} = \frac{Z_0 \times \cancel{Z_L} \left\{ 1 + \frac{jZ_0}{Z_L} \tan\beta l \right\}}{\cancel{Z_L} \left\{ \frac{Z_0}{Z_L} + j\tan\beta l \right\}}$$

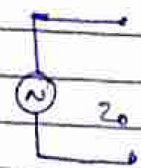
$$\boxed{Z_{in} = \frac{Z_0}{j\tan\beta l}}$$

$l \to$ length of transmission

$$\boxed{Z_{in} = -jZ_0 \cot\beta l}$$

Input impedance of short circuit :-

Put $Z_L = 0$



$$Z_{in} = Z_0 \left\{ \frac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l} \right\}$$

$$Z_{in} = \cancel{Z_0} \left\{ \frac{0 + jZ_0 \tan\beta l}{\cancel{Z_0} + 0} \right\}$$

$$\boxed{Z_{in} = jZ_0 \tan\beta l}$$

3) Distortion less transmission line :-

$$\boxed{\frac{R}{L} = \frac{G}{C}}$$

$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)} \Rightarrow \sqrt{R\left(1+\frac{j\omega L}{R}\right) G\left(1+\frac{j\omega C}{G}\right)}$$

$$\gamma = \sqrt{RG\left(1+j\frac{\omega C}{G}\right)^2}$$

$$= \sqrt{RG}\left(1+\frac{j\omega C}{G}\right)$$

Put $\gamma = \alpha + j\beta$.

$$\therefore \alpha + j\beta = \sqrt{RG}\left(1+j\frac{\omega C}{G}\right)$$

$\therefore \alpha = \sqrt{RG}$ & $\beta = \sqrt{RG}\,\frac{\omega C}{G}$ (on compairing)

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} \Rightarrow \sqrt{\frac{R(1+j\omega L/R)}{G(1+j\omega C/G)}} = \sqrt{\frac{R}{G}}$$

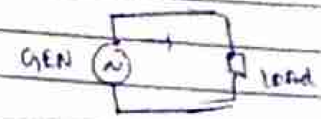
~~where~~ $\frac{R}{L} = \frac{G}{C}$

$$\boxed{Z_0 = \sqrt{\frac{R}{G}} = \sqrt{\frac{L}{C}}}$$

Date 11/05/2024

Different types of transmission line

1) lossless $R=0,\ G=0$
2) low loss $R \ll \omega L,\ G \ll \omega C \quad RG \ll \omega^2 LC$
3) Distortion loss $\frac{R}{L} = \frac{G}{C}$



1) lossless Tx line

$\boxed{R=0,\quad G=0}$

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

$\gamma = \sqrt{j^2\omega^2 LC}$

$\gamma = j\omega\sqrt{LC}$

$\alpha + j\beta = j\omega\sqrt{LC}$

3) low loss Tx line

$\boxed{R \ll \omega L,\ G \ll \omega C \quad RG \ll \omega^2 LC}$

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

$\gamma = \sqrt{j\omega L\left(\frac{R}{j\omega L}+1\right) j\omega C\left(1+\frac{G}{j\omega C}\right)}$

$= \sqrt{j\omega L\left(1-j\frac{R}{\omega L}\right) j\omega C\left(1-j\frac{G}{\omega C}\right)}$

$= j\omega\sqrt{LC}\left[\left[1-j\frac{R}{\omega L}\right]\left[1-j\frac{G}{\omega C}\right]\right]^{1/2}$

$j\omega\sqrt{LC}$

doubt

$j^2 = -1$

$= j\omega\sqrt{LC}\sqrt{1-j\frac{G}{\omega C}-j\frac{R}{\omega L}+j^2\frac{RG}{\omega^2 LC}}$

$= j\omega\sqrt{LC}\sqrt{1-j\left(\frac{R}{\omega L}+\frac{G}{\omega C}\right)-\frac{RG}{\omega^2 LC}}$

$\sqrt{1+x} = 1+\frac{x}{2}-\frac{x^2}{8} \quad (x \ll 1)$

$\gamma \simeq j\omega\sqrt{LC}\left[1-\frac{1}{2}j\left(\frac{R}{\omega L}+\frac{G}{\omega C}\right)\right]$

$\alpha \simeq \frac{1}{2}\left[R\sqrt{\frac{C}{L}}+G\sqrt{\frac{L}{C}}\right]$

$\beta \simeq \omega\sqrt{LC}$

$Z_0 = \sqrt{R+j\omega}$

Date
Page

Q6. A carrier wave of frequency 91 MHz is frequency modulated by a sine wave of amplitude 10 volts and 15 kHz. The frequency sensitivity of the modulator is 3 kHz/V. Determine the bandwidth by transmitting only those side frequencies with amplitudes that exceed 1% of the unmodulated carrier wave amplitude. Use universal curve for this calculation.

→ $f_c = 91\ MHz$; $A_m = 10V$ & $f_m = 15KHz$

$k_f = 3\ KHz/V.$

Q.7 An FM wave is defined below.

$$s(t) = 12 \sin(6 \times 10^8 \pi t + 5 \sin 1250 \pi t)$$

find carrier & modulating frequencies, the modulating index, and the maximum deviation of the FM wave. Also find the bandwidth of FM wave, what power will the FM wave dissipate in a 10 ohm resistor?

Q.4 A carrier wave of frequency 91 MHz is frequency modulated by a sine wave of amplitude 10 volts and 15 kHz. The frequency sensitivity of the modulator is 3 kHz/V.

(a) Determine the appropriate bandwidth of FM wave using carson's Rule.

→ $f_c = 91\ MHz$; $A_m = 10\ volt$; $f_m = 15\ kHz$

$k_f = 3\ kHz/V$

Bandwidth using carson's rule $= 2(\beta+1)f_m$

$\Delta f = k_f \cdot A_m$

$\Delta f = 3\ kHz \times 10$

$\boxed{\Delta f = 30 \times 10^3}$

$\beta = \frac{\Delta f}{f_m}$

$\beta = \frac{30 \times 10^3}{15 \times 10^3} = 2$

$\boxed{\beta = 2Hz}$

$\therefore B_T = 2(2+1) \cdot 15 \times 10^3$

$= 2(3) \cdot 15 \times 10^3 = 6 \times 15 \times 10^3$

$= \underline{90\ kHz}$

(b) Repeat part (a) assuming that the amplitude of modulating wave is doubled.

$A_m = 20\ volt.$

Bandwidth $B_T = 2(\beta+1)f_m$

$\Delta f = k_f \cdot A_m = 3 \times 10^3 \times 20 = 60 \times 10^3$

$\beta = \frac{\Delta f}{f_m} = \frac{60 \times 10^3}{15 \times 10^3} = 4$

$B_T = 2(\beta+1)f_m = 2(4+1) \cdot 15 \times 10^3$

$= 2(5) \cdot 15 \times 10^3$

$= 150\ kHz$//

(c) Repeat part (a) assuming frequency of modulated wave is doubled.

→ $f_c = 91\ MHz$, $A_m = 10V$; $f_m = 30\ kHz$

$k_f = 3\ kHz/V.$

$B_T = 2(\beta+1)f_m$

$\Delta f = k_f\ A_m = 3 \times 10^3 \times 10 = 30 \times 10^3$

$\beta = \frac{\Delta f}{f_m} = \frac{30 \times 10^3}{30 \times 10^3} = 1$

$B_T = 2(2)30\ kHz$

$\boxed{B_T = 120\ kHz}$

Q.5 ~~Find the bandwidth of a single tone modulated FM signal described by~~

determine the bandwidth of an FM signal. If the maximum value of frequency deviation Δf is fixed at 75 kHz for commercial FM broadcasting by radio and modulation frequency is $f_m = 15\ kHz$.

→ $\Delta f = 75\ kHz$

$f_m = 15\ kHz$

~~$\Delta f = k_f A_m = 75$~~

$\beta = \frac{\Delta f}{f_m} = \frac{75}{15} = \frac{15}{3} = 5\ Hz$

Q.1 A sinusoidal wave of Amplitude 10 volts & freq of 1 KHz is applied to an fm generator that has a frequency sensitivity constant of 40 Hz/volt. determine the frequency deviation and modulation index.

→ Message signal Amp = A_m = 10 volts, freq f_m = 1000 Hz & the freq. sensitivity k_f = 40 Hz/volt

freq. deviation $\Delta f = k_f A_m = 40 \times 10 = 400$ Hz

Modulation index $\beta = \Delta f / f_m = \frac{400}{1000} = 0.4$ (indicates a Narrow band fm)

Q.2 A modulating signal $m(t) = 10\cos(10000\pi t)$ modulates a carrier signal, $A_c\cos(2\pi f_c t)$. find the frequency deviation and modulation index of the resulting fm signal. Use k_f = 5 kHz/volt

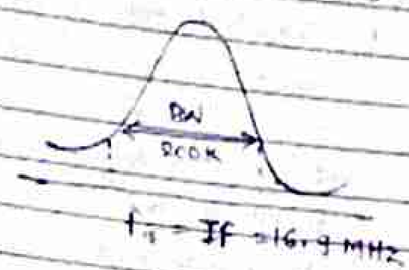
→ Mess. signal A_m = 10 volts, freq. f_m = 5000 Hz
~~freq. sensitivity, k_f = 5 kHz/volt~~

freq. deviation $\Delta f = k_f A_m = 5 \times 10 = 50$ kHz
Modulation index $\beta = \Delta f / f_m = \frac{50 \times 10^3}{5000} = 10$ (indicates a wide band fm)

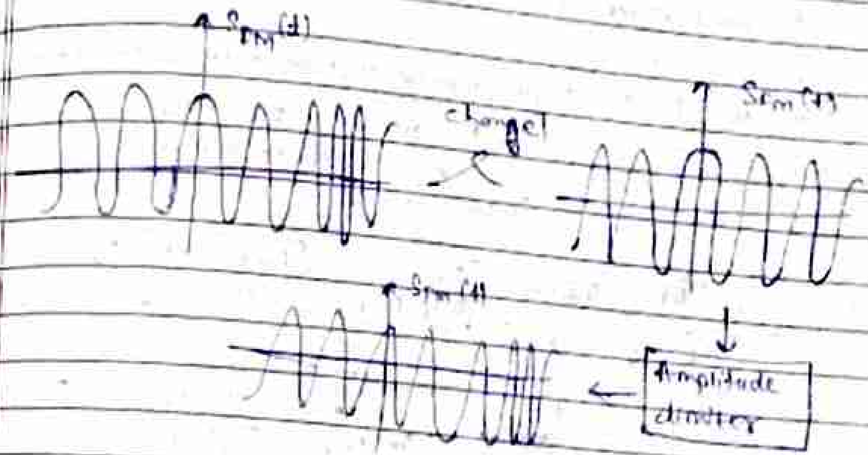
Q.3 Find the bandwidth of single tone modulated fm signal described by $s(t) = 10\cos[2\pi 10^8 t + 6\sin(2\pi 10^3 t)]$

→ fm signal $s(t) = A_m\cos[2\pi f_c t + \beta\sin(2\pi f_m t)]$
$\beta = 6$ $f_m = 1000$ Hz
by carsons rule
Transmission bandwidth $B_T = 2(\beta+1)f_m = 2(6+1)1000$
$= 2(7)1000$

IF Amplifier will be a standard tuned Amplifier



Amplitude limiter



→ The operation of Foster-seeley detector (FSD) is highly sensitive to peak voltage fluctuations of fm signal therefore Amplitude limiter is essential.

→ Ratio Detector provide high stablization towards voltage fluctuations of fm signal so Amplitude limiter is optional.

* FM Receivers :-

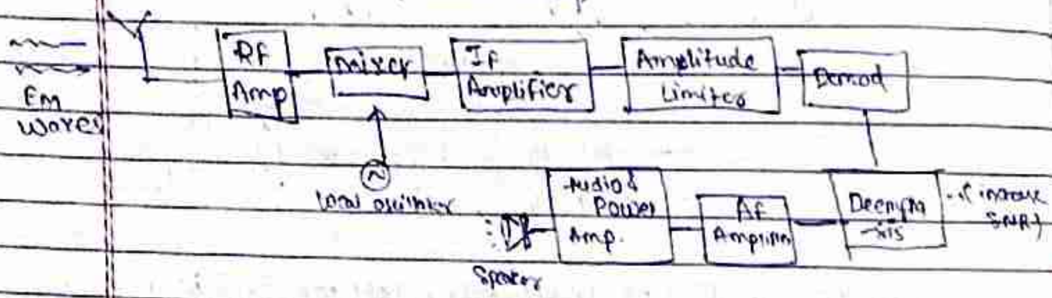
→ FM Receiver is used for Receiving frequency modulated signal.

→ In FM, message signal is stored in the form of frequency variations and these frequency variations are little affected by channel noise therefore FM transmission is very much of noise free.

→ for FM : Carrier Frequency (Range) : 88 MHZ - 108 MHZ

Bandwidth : 200 KHZ

IF (Intermediate freq) : 10.7 MHZ



– Block diagram of FM Receiver.

Quality factor for FM Receiver for low range

$= \frac{88 \times 1000}{200} = 440$ KHZ

$Q.F = \frac{108 \times 1000}{200} = 540$ KHZ.

> circuit having higher quality factor with lower frequency signal, cross talk takes place there.

> Then faces selectivity problem therefore,

> Superheterodyne receiver is designed, which is having fixed frequency signal.

Rejection of Image frequency

$$\boxed{f_{Img} = f_{RF} + 2f_{IF} \quad f_{lo} > f_{RF}}$$

$f_{lo} < f_{RF}$

~~$f_{img} = f_{RF} - 2f_{IF}$~~

$$\boxed{f_{img} = f_{RF} - 2f_{IF}}$$

Why Intermediate Frequency?

> Sensitivity depends on the gain, gain is more, Sensitivity is more, Sensitivity is more, but gain increases signal is unstable. To generate stable signal, frequency should be constant, it is (455 kHz) intermediate frequency.

> To design high freq. signal circuit is very difficult

$\left[f_i = f_c \pm f_i \right]$

* TRF Receiver having quality factor issue:

Selectivity depends on quality factor.

Freq Range of AM TRF receiver is 550 - 1600 kHz and BW (bandwidth) : 10 kHz

Selectivity :

$$\text{Quality factor } (Q) = \frac{f_c}{BW} \quad \left(\frac{\text{Centre Freq.}}{\text{Bandwidth}} \right)$$

Selectivity depends on quality factor

Sensitivity depends on gain

i.e. gain of Receiver $\propto$ gain of sensitivity

1600
550
2.9
1.5

> So having wide quality factor range

> To design circuit having higher quality factor is very difficult the circuit is very complex.

- Antenna :-

1. Receive the different frequencies EM waves from so many stations.
2. Convert it in to electric wave.

- RF Amplifier (Tuned at desired frequency)

1. Reject unwanted & image frequency signals and select desired carrier frequency.
2. Amplify weak frequency.
3. Signal provide better sensitivity, High SNR

- Mixer

1. Converts desired (tuned) frequency in to intermediate frequency with the help of local oscillator freq. Substraction.
2. Heterodyne means mixing of different frequencies, High freq. signal converts into constant intermediate freq. is called as superheterodyne.

$f_{RF} = f_{lo} \rightarrow$ synchronous detector.

$\boxed{\begin{matrix} f_{RF} > f_{lo} \\ f_{RF} < f_{lo} \end{matrix}}$ } Heterodyne.

$f_{lo} = f_{RF} + f_{IF}$

(local oscillator freq.) = Radio freq. + Intermediate freq.

$\boxed{f_{RF} < f_{lo}} \rightarrow$ superhetrodyne

> Tank circuit used for tuning purpose, variable capacitor and variable inductor forms this tank circuit

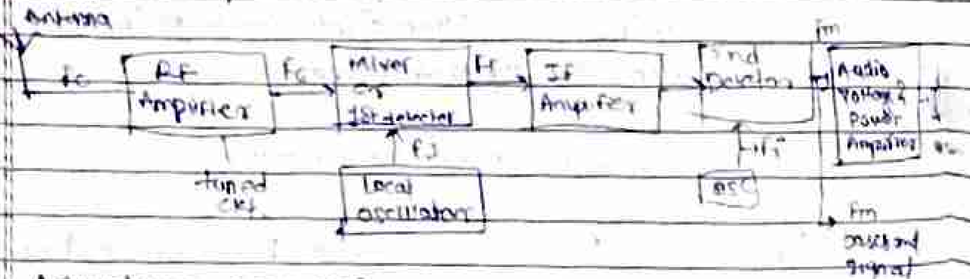
* Class C amplifier :- its efficiency is high while linearity is poor, giving efficient high performance gain and reduces noise effect. (Active element conduct for less than one half cycle of the input signal).

* RC Couple Amplifier :
It is used in multistage amplifier for coupling. It is low cost, compact, excellent frequency response and having constant gain.

* Push pull class B amplifier :
It enhance both the load capacity and switching speed.

Speaker : Convert electrical signal in to desired message signal.

Superhetrodyne Receiver



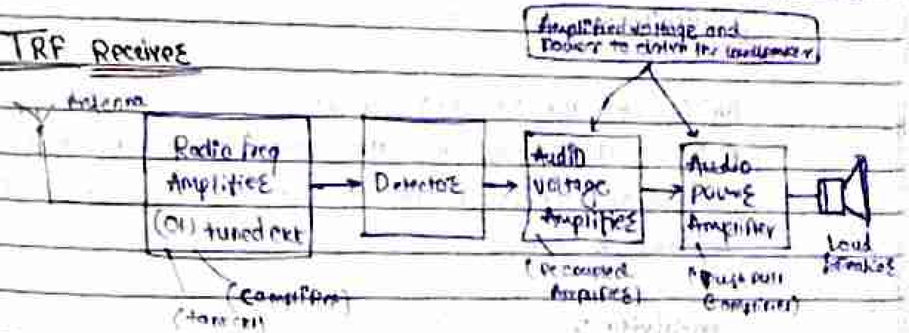
Advantages over TRF
1. Good Sensitivity
2. Good Selectivity
3. Good fidelity

fidelity :-
Ability of receiver to reproduce the signal faithfully for the range of all modulating signal frequencies of the signal at the output.

Types of AM Receivers

- Coherent Receiver (Synchronous Receiver)
The frequency generated in the receiver is synchronized to the carrier frequency in the transmission side.
- Non-coherent Receiver (Asynchronous receiver)
The frequency generated in the receiver is completely independent from the transmitter's carrier frequency.
  - Tuned Radio frequency (TRF) Receivers
  - Superhetrodyne Receiver

TRF Receiver



- Antenna :- is a conductor, it receives EM waves and convert it into electrical signal.
> it selects desired carrier frequency and reject all other freq.

AM Radio Receivers

A Radio Receiver is an electronic system that receives a desired modulated signal and recovers the original message signal from it.

Functions of Receivers :-

> Process to demodulate the incoming modulated signal.

> Carrier frequency tunning: to select the desired freq signal

> Filtering: To separate the desired frequency signal from other modulated signal.

> Amplification: To compensate the loss of signal during transmission.

Performance characteristics :-

Selectivity :-

Ability of the Receiver to select desired frequency signal & reject all others eg 93.5 MHz (tuned ckt) reject adjacent frequency signal. Fixed quality factor (Sharp peak of frequency response)

Sensitivity :-

> Ability of a receiver to detect the weakest possible received signal.

> Gain of receiver proportional to sensitivity of receiver for desired signal.

Now, recall Euler's equations :

$$e^{+j\beta l} = \cos\beta l + j\sin\beta l$$

$$e^{-j\beta l} = \cos\beta l - j\sin\beta l$$

using Euler's relationships, we can likewise write the input impedance can be radically different from without the complex exponentials

$$Z_{in} = Z_0\left[\frac{Z_L\cos\beta l + jZ_0\sin\beta l}{Z_0\cos\beta l + jZ_L\sin\beta l}\right] \text{ (or)}$$

$$= Z_0\left[\frac{Z_L + jZ_0\tan\beta l}{Z_0 + jZ_L\tan\beta l}\right]$$

Hence proved.

$$Z_{in} = Z_0\left[\frac{Z_L\cos\beta l + jZ_0\sin\beta l}{Z_0\cos\beta l + jZ_L\sin\beta l}\right]$$

Q. Prove that input impedance of transmission line is

$$Z_{in} = Z_0\left[\frac{Z_L\cos\beta l + jZ_0\sin\beta l}{Z_0\cos\beta l + jZ_L\sin\beta l}\right]$$

→ The input impedance is simply the line impedance seen at the beginning $(z=-l)$ of the transmission line, i.e.

$$Z_{in} = Z(z=-l) = \frac{V(z=-l)}{I(z=-l)}$$

Z_{in} equal to neither the load impedance Z_L nor the characteristic impedance Z_0!

$$Z_{in} \neq Z_L \;\&\; Z_{in} \neq Z_0$$

~~To determine exactly~~ Z_{in}, we

we know that

$$V(z=-l) = V_0^+\left[e^{+j\beta l} + \Gamma_L e^{-j\beta l}\right]$$

$$I(z=-l) = \frac{V_0^+}{Z_0}\left[e^{+j\beta l} - \Gamma_L e^{-j\beta l}\right]$$

Therefore,

$$Z_{in} = \frac{V(z=-l)}{I(z=-l)} = \frac{Z_0\left(e^{+j\beta l} + \Gamma_L e^{-j\beta l}\right)}{\left(e^{+j\beta l} - \Gamma_L e^{-j\beta l}\right)}$$

We can explicitly write Z_{in} in terms of load Z_L using the

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Combining these two expressions, we get:

$$Z_{in} = \frac{(Z_L+Z_0)e^{+j\beta l} + (Z_L-Z_0)e^{-j\beta l}}{(Z_L+Z_0)e^{j\beta l} - (Z_L-Z_0)e^{-j\beta l}} \times Z_0$$

$$= Z_0\left[\frac{Z_L\left(e^{j\beta l} + e^{-j\beta l}\right) + Z_0\left(e^{+j\beta l} - e^{-j\beta l}\right)}{Z_L\left(e^{+j\beta l} + e^{-j\beta l}\right) + Z_0\left(e^{j\beta l} - e^{-j\beta l}\right)}\right]$$

Note :-

Z_{in} equal to neither the load impedance Z_L nor the characteristic impedance Z_0!

$$Z_{in} \neq Z_L \text{ and } Z_{in} \neq Z_0$$

To determine exactly what Z_{in} is, we first must determine the voltage and current at the beginning of the transmission line $(x=-l)$

$$V(x=-l) = V_0^+\left[e^{+j\beta l} + \Gamma_L e^{-j\beta l}\right]$$

$$I(x=-l) = \frac{V_0^+}{Z_0}\left[e^{+j\beta l} - \Gamma_L e^{-j\beta l}\right],$$

Therefore:

$$Z_{in} = \frac{V(x=-l)}{I(x=-l)} = Z_0\left[\frac{e^{+j\beta l} + \Gamma_L e^{-j\beta l}}{e^{+j\beta l} - \Gamma_L e^{-j\beta l}}\right]$$

We can explicitly write Z_{in} in terms of load Z_L using the previously determined relationship:

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad \left(Z_L = \frac{1+\Gamma}{1-\Gamma} \times Z_0\right)$$

Q. Prove input impedance of transmission line is

$$Z_{in} = Z_0\left[\frac{Z_L\cos\beta l + jZ_0\sin\beta l}{Z_0\cos\beta l + jZ_L\sin\beta l}\right]$$ Euler's formula

$$I(x,t) = \frac{V^+ e^{-\gamma x}}{Z_0} - \frac{V^- e^{+\gamma x}}{Z_0}$$

at $x=0$

$$Z_L = \frac{V(0)}{I(0)} = \frac{V_0^+ + V_0^-}{V_0^+ - V_0^-} Z_0$$

$$Z_L = \frac{V^+\left\{1 + \frac{V^-}{V^+}\right\}}{V^+\left\{1 - \frac{V^-}{V^+}\right\}} Z_0$$

4. $\frac{V^-}{V^+}$ → Reflection coefficient, denoted by Γ

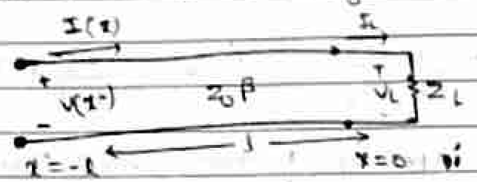
i.e. $\boxed{\Gamma = \frac{V^-}{V^+}}$

V^- is voltage of wave travelling back, load to generator and V^+ is source to load, ratio is the reflection coefficient

$$Z_L = \frac{1+\Gamma}{1-\Gamma} \times Z_0 \quad ; \quad \Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

5. Input Impedance

Consider a lossless line, length l, terminated with a load Z_L



The input impedance is simply the line impedance seen at the beginning ($x=-l$) of the transmission line i.e.

$$Z_{in} = Z(x=-l) = \frac{V(x=-l)}{I(x=-l)}$$

$$\therefore Z_0 = \frac{V^+}{I^+} = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$$

8. Phase velocity :-

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

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

for transmission

$j\frac{2\pi}{\lambda}$ $\quad \alpha = 0, \quad \beta = \frac{2\pi}{\lambda}$

$$j\frac{2\pi}{\lambda} = \sqrt{(R+j\omega L)(G+j\omega C)}$$

Multiply & divide by f

$$j\frac{2\pi f}{\lambda f} = \sqrt{(R+j\omega L)(G+j\omega C)}$$

$\lambda f = V_p$ (Phase velocity) & $2\pi f = \omega$

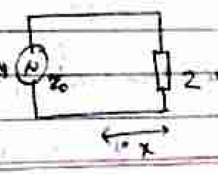
$$\frac{j\omega}{V_p} = \sqrt{(R+j\omega L)(G+j\omega C)}$$

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

3. load Impedance & 4. Reflection coefficient :-

$V(x,t) = V^+ e^{-\gamma x} + V^- e^{+\gamma x}$

$I(x,t) = I^+ e^{-\gamma x} + I^- e^{+\gamma x}$



When, characteristic impedance = Z_0

$$Z_0 = \frac{V^+}{I^+} \quad \Bigg| \quad -Z_0 = \frac{V^-}{I^-}$$

const. + 1 max const.

$x \to$ distance travelled.

$$V(x,t) = \underbrace{V^+\cos(\omega t - \beta x)}_{\substack{\text{Travelling in} \\ \text{+ve direction} \\ \text{forward direction}}} + \underbrace{V^-\cos(\omega t + \beta x)}_{\substack{\text{Travelling in -ve} \\ \text{direction} \\ \text{reverse direction}}}$$

* Parameters OF Transmission lines
  - characteristic Impedance.
  - > phase velocity
  - > Load Impedance
  - > Reflection coefficient
  - > Input impedance
    1) For open circuit
    2) For short circuit
    3) For quarter wavelength

* Characteristic Impedance

$$\frac{dv}{dx} = -(R + j\omega L) I$$

$$\frac{d}{dx}\left(V^+e^{-\gamma x} + V^-e^{+\gamma x}\right) = -(R+j\omega L)\left[I^+e^{-\gamma x} + I^-e^{+\gamma x}\right]$$

$$V^+e^{-\gamma x}(-\gamma) + V^-e^{+\gamma x}(+\gamma) = -(R+j\omega L)\left[I^+e^{-\gamma x} + I^-e^{+\gamma x}\right]$$

on comparing

$$V^+e^{-\gamma x}(-\gamma) = -(R+j\omega L) I^+e^{-\gamma x}$$

$$\frac{V^+}{I^+} = \frac{\cancel{-}(R+j\omega L)}{\cancel{-}\gamma} \Rightarrow \frac{R+j\omega L}{\gamma}$$

we know that $\gamma = \sqrt{(R+j\omega L)(G+j\omega C)}$

$$\frac{V^+}{I^+} = \frac{\sqrt{R+j\omega L}\,\sqrt{R+j\omega L}}{\sqrt{(R+j\omega L)(G+j\omega C)}} \Rightarrow \sqrt{\frac{R+j\omega L}{G+j\omega C}}$$

Solution of Transmission line equation :-

$$\frac{d^2V}{dx^2} = \gamma^2 V$$

~~Solution of transmission line equation:~~

EM wave or uniform plane wave equation

$$\frac{d^2E}{dx^2} = \gamma^2 E$$

Solution of wave equation

$$E = E_0 e^{-\gamma x} \quad \text{--- (1)}$$

$$\frac{dE}{dx} = -\gamma e^{-\gamma x} E_0$$

$$\frac{d^2E}{dx^2} = -\gamma(-\gamma) e^{-\gamma x} E_0$$

$$\frac{d^2E}{dx^2} = \gamma^2 e^{-\gamma x} E_0$$

$$\boxed{\frac{d^2E}{dx^2} = \gamma^2 \cdot E} \to \text{from (1)}$$

Above eq is in phasor form, how to convert it into time varying, take a real part and multiply by $e^{j\omega t}$

$$E(x,t) = Re(E_0 e^{-\gamma x}) e^{j\omega t}$$

gamma γ propagation constant $\boxed{\gamma = \alpha + j\beta}$

$\alpha \to$ attenuation constant

$\beta \to$ phase constant

$$E(x,t) = Re\left(E_0 e^{-(\alpha + j\beta)x}\right) e^{j\omega t}$$

$$E(x,t) = E_0 e^{-\alpha x} Re\left(e^{j(\omega t - \beta x)}\right)$$

Attenuation constant ; $\alpha = 0$

$$\boxed{E(x,t) = E_0 \cos(\omega t - \beta x)}$$

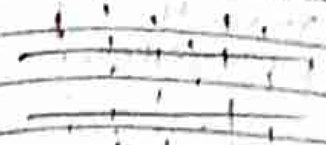
$$\frac{d^2V}{dx^2} = \gamma^2 V$$

Solution of transmission line equation

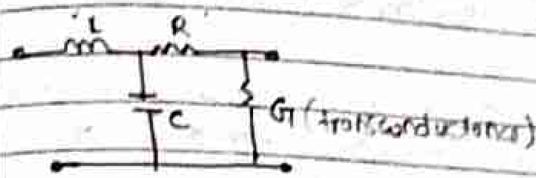
$$V(x,t) = \left(V^+e^{-\gamma x} + V^-e^{+\gamma x}\right) e^{j\omega t}$$

$$= V^+e^{j(\omega t - \beta x)} + V^-e^{j(\omega t + \beta x)}$$

primary constants of transmission line



$\Delta x \to 0$ (Measured in m)



$L \longrightarrow$ measured in henry/meter H/m
(Inductance)

$C \to F/m$

$R \to \Omega/m$

$G \to \mho/m$

Equivalent circuit & Equation of Transmission line

where output is $I + \Delta I$ (But ΔI is -ve)

$I_{out} = I + \Delta I$ & ΔI is -ve

$V_{out} = V + \Delta V$ & ΔV is -ve. ; $\Delta V = -(R\Delta x + j\omega L\Delta x)I$ .. (A)

Apply ohm's law

$V = IR$

$V = I\left[\frac{X_C X_G}{X_C + X_G}\right]$ impedance of $C\Delta x \to X_C$; impedance of $G\Delta x \to X_G$

G→C
R→L
γ→gamma

$I = \left[\frac{1}{X_C} + \frac{1}{X_G}\right]V$

$X_C = \frac{1}{j\omega C}$; $X_G = \frac{1}{G}$

$I = \left[j\omega C + G\right]V$

$\Delta I = -(G\Delta x + j\omega C\Delta x)V$ [At the output so ΔI is -ve]

$\lim_{\Delta x \to 0} \frac{\Delta I}{\Delta x} = -(G + j\omega C)V$

$\frac{dI}{dx} = -(G + j\omega C)V$ —— (2)

from eq (A)

$\Delta V = -(R\Delta x + j\omega L\Delta x)I$

voltage changes wrt distance.

$\frac{dV}{dx} = -(R + j\omega L)I$ —— (1)

After diff

$\frac{d^2V}{dx^2} = -(R + j\omega L)\frac{dI}{dx}$

$\frac{d^2V}{dx^2} = (R + j\omega L)(G + j\omega C)V$

$\gamma^2 = (R + j\omega L)(G + j\omega C)$; $\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$

$$\boxed{\frac{d^2V}{dx^2} = \gamma^2 V}$$

γ → gamma

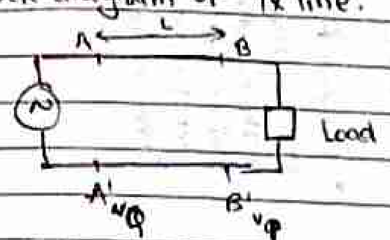
Transmission lines

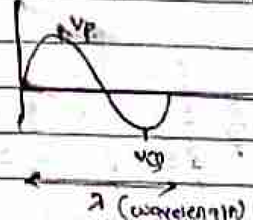
Date: 4/5/02

- Use : transfers the power from one place to another
- Tx. lines made up of conductors.
- Designed to carry an electrical signal for long distance.
- losses and distortion are minimum in Tx. lines.

- Types of transmission lines
  - > Parallel line
  - > Coaxial line
  - > Micro strip line

* Block diagram of Tx line.





* Transit Time

Required time to travel the voltage from one point to another point on Tx. lines

Signal travels, Potential changes point to point is because of transit time effect.

Transit time effect is proportional to the length of Tx. lines and frequency used.

$N = 72$

$$\boxed{t_t = \frac{l}{v}}$$ where $l \to$ length. $v \to$ velocity. $t \to$ transit time.

$T >> t_t$

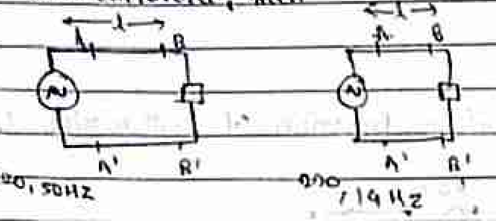
$T >> \frac{l}{v}$; $\frac{1}{f} >> \frac{l}{v}$; $\frac{v}{f} >> l$; $\lambda >> l$

(transit time is very less i.e. it can be negligible)

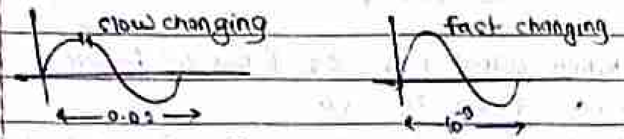
- $T >> l \to$ Transit time effect is negligible at the load
- $T << l \to$ then transit time effect is present in the output and effects the output.
- $T = l \to$ Transit time effect is zero.

* Transit time effect :-

length of transmission line is same, frequencies are ~~tim~~ different, then



$T = \frac{1}{50} = 0.02$ sec $\qquad T = \frac{1}{f} = \frac{1}{1 \times 10^9} = 10^{-9}$ sec



* smaller the frequency of signal i.e. wavelength is larger than slow change in Potential, ∴ transit time effect is less

But there is.

Noise

- Uncorrelated Noise
  - External Noise
    - Atmospheric Noise
      - It is static noise, due to electrical disturbance such as lightening, generally affects the frequency of signal less than 30 MHZ.
    - Extraterrestrial Noise
    - Industrial Noise
  - Internal Noise
    - Thermal Noise
    - Shot Noise
    - Low freq. or flicker noise
    - Excess Resistor Noise
    - Burst Noise or Popcorn Noise
    - > internally in the circuit
    - > electronic components such as resistors, diodes, & transistors produce this noise. The Noise power is directly proportional to generated temperature in the circuit.
- Correlated Noise
  - Harmonic Distortion
    - Presence of frequency component in the output waveform which is not in the input waveform (Phase change noise)
  - Intermodular distortion
    - Two or more signals are amplified in nonlinear device, then some unwanted sum and difference frequencies are generated. Distortion of these frequencies called Inter-modular distortion.

> Uncorelated Noise :> ~~Present all the time~~, Whether signal is present or not.

> Coreletad Noise :> Present only when signal is present.

> External noise :- this noise generated from variety of sources. it is natural and man maid noise. This generated noise is external, to receiving system.

> Extraterrestrial Noise –

Gen- solar & cosmic noise i.e. space noise

- solar →

sun reradiates broad band frequency of noise, and it varies with time. The sun cycle repeats after 11 years.

- Cosmic → Noise generated by stars.

1. Thermal Noise

> thermal noise power is given by $P = V^2/R = 4KTB$ – Watts

> For thermal noise, its spectral density given by $N_0 = KT$

(k = Boltzmann's const)

2. Shot Noise

(c) Noise voltage across parallel combination is given by

$$\frac{1}{Req} = \cancel{R_1 R_2} \quad \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{Req} \Rightarrow \frac{1}{5} + \frac{1}{5} + \frac{1}{5} \Rightarrow \frac{3}{5}$$

$$Req = \frac{5}{3} \Rightarrow 1.6666 \approx 1.67 K\Omega$$

$$E_n = \sqrt{4 \times 4 \times 10^{-21} \times 1 \times 10^{6} \times 1.67 \times 10^{3}}$$

$$= \sqrt{16 \times 1.67 \times 10^{-21} \times 10^{9}} \Rightarrow \sqrt{16 \times 1.67 \times 10^{-12}}$$

$$= 0.0000051691$$

$$= 5.169 \sim 5.17 \mu V$$

* general Comments

(5) Three five kohm resistors are connected in series. for room temperature. ~~for~~ ($kT = 4\times10^{-21}$ J) and an effective noise bandwidth of 1 MHz, determine

(b) The noise voltage appearing across series combination

(a) the noise voltage appearing across each resistor

(c) What is the rms noise voltage which appears across some three resistors connected in parallel under the same condition

→ (b) Noise voltage across series combination is given by

$$R_{eq} = R_1 + R_2 + R_3$$

$$= 5k\Omega + 5k\Omega + 5k\Omega = 15\,k\Omega$$

$$E_n = \sqrt{\quad}$$

(a) Noise voltage across each resistor is given by

$$\boxed{E_n = \sqrt{4KTB_N R}}$$

$$= \sqrt{4\times4\times10^{-21}\times1\times10^{6}\times5\times10^{3}}$$

Value of R is 5kΩ

$$= \sqrt{80\times10^{-21}\times10^{9}} = \sqrt{5\times10^{-21}\times10^{10}}$$

$$= \sqrt{5\times10^{-11}} = 2.23\sqrt{10^{-11}} = 0.00000891$$

$$= \underline{8.94\,\mu V}$$

(b) Noise voltage across series combination is given by

$$R_{eq} = R_1 + R_2 + R_3 = 5k\Omega + 5k\Omega + 5k\Omega = 15\,k\Omega$$

$$E_n = \sqrt{4\times4\times10^{-21}\times1\times10^{6}\times15\times10^{3}}$$

Here value of R is ~~15kΩ~~ 15 kΩ

$$= \sqrt{16\times15\times10^{-12}} = \sqrt{240\times10^{-12}} = 0.0000154$$

$$= 1.55\,\mu V \;/\; 15.4\,\mu V$$

(4) A receiver connected to an antenna whose resistance is 75 Ω has an equivalent noise resistance of 40 Ω. Calculate the receiver's noise figure in decibles and its equivalent temperature.

Resi. of antenna = 75 Ω = R_t

equi. noise resistance of receive = R_{eq} = 40 Ω

$$f = 1 + \frac{R_{eq}}{R_t} = 1 + \frac{40}{75} = 1.533$$

$$\underline{f = 1.855\,dB}$$

equivalent noise temp.

$10\log_{10}(1.533)$

$$T_{eq} = T_0(f-1)$$

$$T_{eq} = 290\,(1.533-1)$$

$$T_{eq} = \underline{154.57^\circ K}$$

(5) Determine the internal noise power of a microwave amplifier operating with a bandwidth of 500 MHz & a specified noise figure of 2.5 dB.

B = 500 dB,

$$f = 2.5\,dB = 10\log_{10} x$$

$$x = 10^{0.25} = 1.778$$

$$P_n = kT_eB \qquad T_e = T(f-1)$$

$$= 290(1.778-1) = 225.62\,K$$

$$P_n = 1.38\times10^{-23}\times225.62\times500\times10^{6}$$

$$=$$

convert in degrees

=

(3) A radio receiver with 10KHz B.W has a noise figure 30dB determine the signal power required at the input of receiver to achieve input SNR of 30dB

$P_{out} = KTB$ - watts

$f = \frac{P_{in}}{P_{out}}$

Noise fig $= 10\log_{10} f$

$30 = 10\log_{10} f$

$\boxed{f = 1000}$

P_{ni} = Noise Power at input

$= fKTB_W$ ↗ room temp

$= 1000 \times 1.38 \times 10^{-23} \times (273 + 27) \times 10 \times 10^{3}$

$= \cancel{4.002 \times 10^{-14} W}$

$P_{ni} \Rightarrow 4.14 \times 10^{-14} W$

$SNR_{dB} = 10\log\left(\frac{P_{si}}{P_{ni}}\right)$

$\cancel{30 = 10\log\left(\frac{P_{si}}{4.002}\right)}$

$30 = 10\log\left(\frac{P_{si}}{4.14 \times 10^{-14}}\right)$

$3 = \log\left(\frac{P_{si}}{4.14 \times 10^{-14}}\right)$

$10^{3} \times 4.14 \times 10^{-14} = P_{si}$

$\boxed{P_{si} \Rightarrow 4.14 \times 10^{-11}}$

• decibels

(dBW, dBm, dBuV, dB, dBuV/m, dBP, dBd)

Q. ex. of the following noise factors in dB

(1) (a) 1.0; (b) 1.15 (c) 3.0 (d) 10.0

$NF_{dB} = 10 \cdot \log(1.0) = 0\,dB$

$NF_{dB} = 10\log(1.15) = 0.607\,dB$

$NF_{dB} = 10 \cdot \log(3.0) = 4.771\,dB$

$NF_{dB} = 10 \cdot \log(10.0) = 10\,dB$

(2) thermal noise is 4×10^{-17} W for a given bandwidth & temp of $20°C$. what will be the noise power when temp is changed; (a) to $50°C$, (b) to $77°C$

$\boxed{P_n = KTB_W}$

$P_n \propto T$

$\frac{P_n}{P_{n1}} = \frac{T}{T_1}$

$P_{n1} = \frac{P_n \times T_1}{T} = \frac{4 \times 10^{-17}(273 + 50)}{(273 + 20)} = 4.41 \times 10^{-17} W$

for $77°C$

$P_{n1} = \frac{P_n \times T_1}{T} = \frac{4 \times 10^{-17}(273 + 77)}{(273 + 20)} \Rightarrow \frac{4 \times 10^{-17} \times 350}{293}$

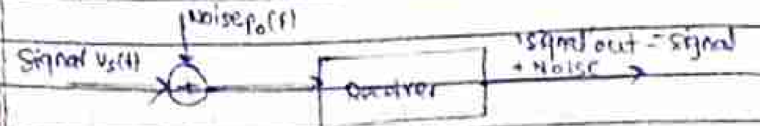
$\Rightarrow 1.1945 \times 4 \times 10^{-17}$

$\Rightarrow 4.778 \times 10^{-17} W$

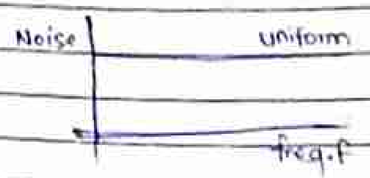
Types of Noise
> Additive
> White
> Gaussian Noise

- **Additive**

Noise is usually additive in that it adds to the information bearing signal. A model of the received signal with additive noise is shown below.



- **White**



$\boxed{\text{White noise} = P_0(f)} = \text{constant}$

- **Gaussian**

We generally assume that noise voltage amplitudes have a Gaussian or Normal distribution.

- **decibels**

(Power) $P_{(dB)} = 10\log_{10}\left(\frac{P}{P_{ref}}\right)$

(voltage) $V_{(dB)} = 20\log_{10}\left(\frac{V}{V_{ref}}\right)$

(current) $\Rightarrow I_{(dB)} = 20\log_{10}\left(\frac{I}{I_{ref}}\right)$

$c(t) = A_c\cos 2\pi f_c t \quad , \quad m(t) = A_m\cos 2\pi f_m t$

General exp. of DSB.SC or Simply DSB is given by

~~$S_{DSB}(t) = m(t)\,c(t)$~~

$S_{DSB}(t) = A_c\cos 2\pi f_c t \; A_m\cos 2\pi f_m t$

$= A_m A_c \cos 2\pi f_m t \cos 2\pi f_c t$

$\Rightarrow \frac{A_m A_c}{2}\left[\cos(2\pi f_m + 2\pi f_c)t + \cos(2\pi f_m - \cos 2\pi f_c)t\right]$

$S_{DSB}(t) \Rightarrow \frac{A_m A_c}{2}\left[\cos(f_m + f_c)t + \cos(f_c - f_m)t\right]$

decibels :-

Unit	Reference Power	Application
dBW	1 W	Absolute Power
dBm	1 mW	Absolute Power $\boxed{P(dBW) = P(dBm) - 30}$
dBµV	1 µV	Absolute voltage, typically at input terminals of a receiver.
dB	any	Gain or loss of network
dB µV/m	1 µV/m	Electric field strength.
dBi	Power radiated by and isotropic reference antenna	Gain of an antenna
dBd	Power radiated by a half-wave dipole	Gain of an antenna dBd = 2.15 dBi

② WDM :-

In this many data streams of different wavelengths are transmitted in the light spectrum
If wavelength increases, the frequency of signal decreas
ex :- optical fibre communications

④ Digital multiplexing :-
Digital represents the discrete bit of infor.

→ TDM :-
This technique is used to transmit a signal over a single communication channel, with alloting one slot for each message.

① Synchronous TDM :-
In this the sampling rate is common to each signals and hence same clock input is given

② Asynchronous TDM -
The sampling rate is different for each of the signals and the clock signal is also not in common.

e] Improves quality of reception :-
With FM and digital communications techniques like pcm, the effect of noise is reduced to great ~~effect~~ extent

* Multiplexing & its Types

→ Multiplexing is the process of combining multiple signals into one signal, over a shared medium. If analog signals are multiplexed, its analog multiplexing and if digital signal is multiplexed it is digital multiplexing.

Types of multiplexes :-

- Multiplexes
  - Analog
    - Frequency division multiplexing (FDM)
    - Wavelength division multiplexing (WDM)
  - Digital
    - Time division multiplexing (TDM)
      - Synchronous TDM
      - Asynchronous TDM

③ Analog multiplexing involve ~~signals which are~~ analog in nature

① FDM -
This technique uses various frequencies to combine stream of data, for sending them on a communication medium, as a single signal.
ex. Television Transmitter.

- Why Modulation is required?

⟹ Modulation is required because

1) Baseband signals can be transmitted directly, but these signals have many limitations which can be overcome using modulation.

2) In process of modulation, the baseband signals is translated i.e shifted from low to high frequency carrior

3) Advantages of modulation :-

a) Reduction in the height of antenna -

When the transmission occurs over free space the antenna radiate the signal out and receiver receives it. In order to operate efficiently antenna need to be in order of magnitude of wavelength of transmitted signal

b) Avoid mixing of signals :-

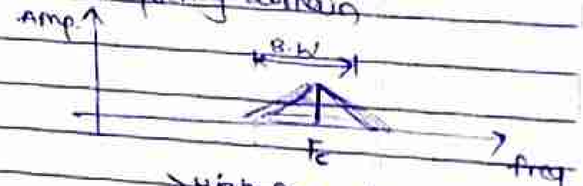
By using carrier waves of high frequencies and alloting a ~~wave~~ band of frequencies to each message, there is no mixing up of signals and the received signal are absolutely perfect

c] Increase the range of communication

Technique of modulation helped human to use wireless equipment in a big way in their life

d] Multiplexing is possible -

Multiplexing allows the same channel to be used by many signals

Baseband signal	Passband signal
1. All sources of information. Generates baseband signal, e.g Audio, video, image	1. Baseband signal transmitted at high frequency modulated signal e.g AM, FM, PM ...
2. Signals are transmitted without modulation e.g landline	2. It is high frequency modulated carrier signal e.g satellite signals.
3. (0 to 20 khz) audio signal (0 to 55 Mhz) video signal	3. (550 khz - 1650 khz) for AM (88 Mhz - 108 Mhz) for FM
4. Frequency domain  > Low freq signal	4. Frequency domain  > High freq signal
5. Baseband signals are unmodulated signals or demodulated signals.	6. Passband signals generated after modulation process