IES/GATE

Electronics & Telecommunication Engineering

VOLUME-V

Analog & Digital Communication Systems

Contents

COMMUNICATION SYSTEM :-

- Concept of Modulation
- AM
- DSB
- SSB
- VSB
- FDM
- Angle Modulation
  - FM
  - PM
- Receiver
  - TRF
  - SHS

Digital Modulation :-

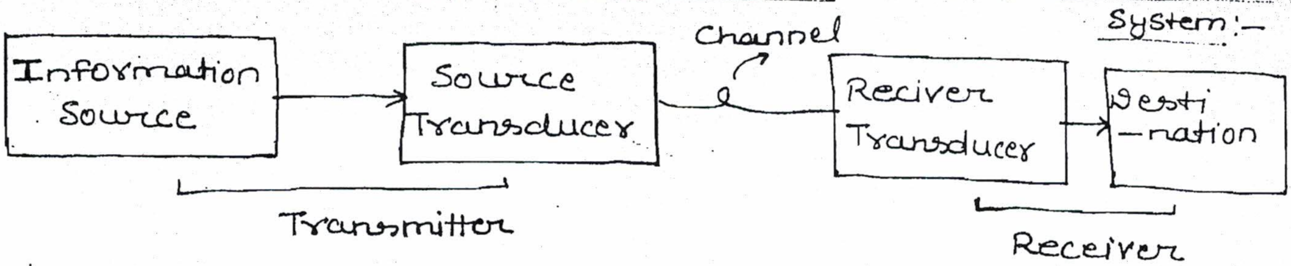
- Sampling theorem
- PCM
- DPCM
- DM
- ADM
- TDM
- ASK, PSK & FSK
- M-array Signalling
- Information Theory
- Random Variable
- Noise
- FoM of AM, DSB & SSB
- Matched Filter
- Pe of ASK, PSK & FSK

Lecture - 1

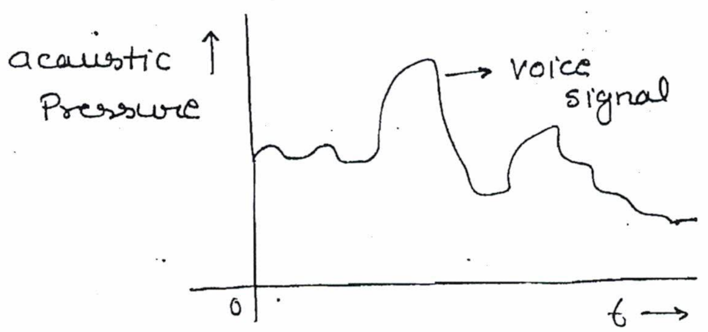
Communication :-

→ Communication is the process of transmitting the information from source to destination or transmitter to receiver.

Basic Block diagram of Communication :- (Wired Communication System :-



→ Voice signal – (300Hz – 3.5kHz) → anything we speak
→ Audio signal – (20Hz – 20kHz) → anything we hear
(5kHz)
→ Video signal – (0 – 4.5MHz) → w.r.t light
(1MHz)



→ Voice and audio signal are w.r.t acoustic pressure

→ For short distance communication, wired communi-cation system is used

Information source :-

→ Information source is the source of information

Source Transducer :-

→ It converts physical signal into electrical signal.
eg:- Mic.

Channel :-

→ Channel is the medium through which signal propagates from one place to another.

Note :-

→ Wired communication system is preferred for short distance communication only.

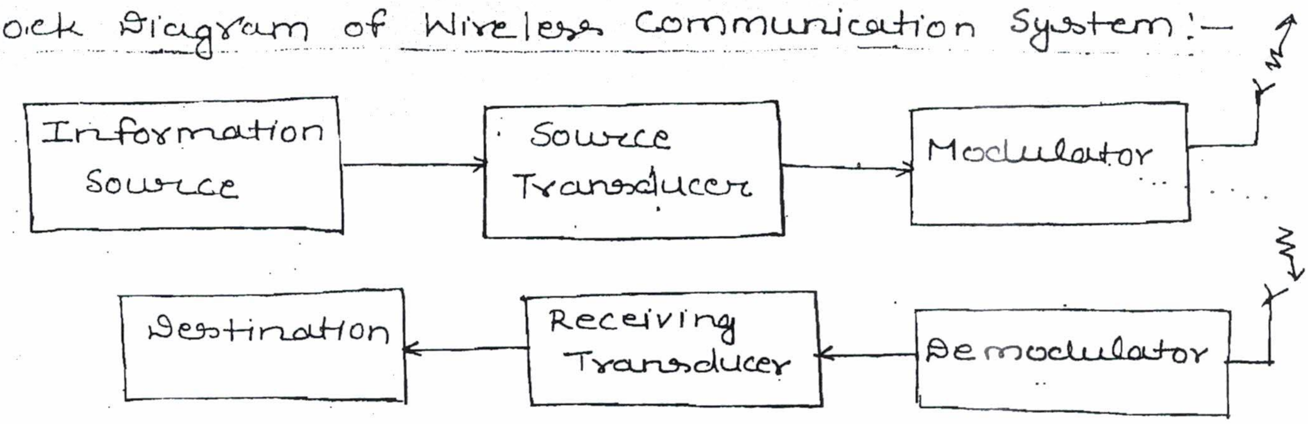
→ For long distance communication wireless system will be used in which signal propagates through space.

Receiving Transducer :-

→ It converts electrical signal into physical equivalent

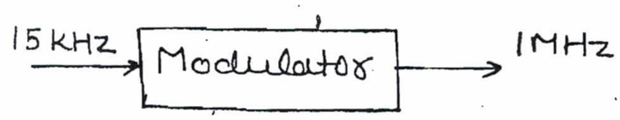
eg:- loudspeaker

Block Diagram of Wireless Communication System :-



→ Generally without modulation, long distance communication through free space is not possible

Need for Modulation :-



→ For faithful radiation of a signal, antenna height should be atleast $\lambda/4$

$$h_t = \frac{\lambda}{4}$$

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

Transmitting antenna converts electrical signal into electromagnetic signal and resulting will travel with velocity of light

$$\lambda = \frac{c}{f} \qquad h_t = \frac{c}{4f}$$

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

$$h_t = \frac{c}{4f}$$

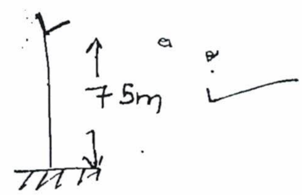
If $f = 15$ kHz then $h_t = \frac{3 \times 10^8}{4 \times 15 \times 10^3} = 5$ km

Note:-

→ Modulation is the process of increasing the frequency of signal to reduce antenna height

15 kHz → [Modulator] → 1 MHz

$$h_t = \frac{3 \times 10^8}{4 \times 10^6} = 75 \text{ m}$$



→ **Multiplexing :-**

→ It is the process of transmitting the multiple no. of signal through a common channel at the same time.

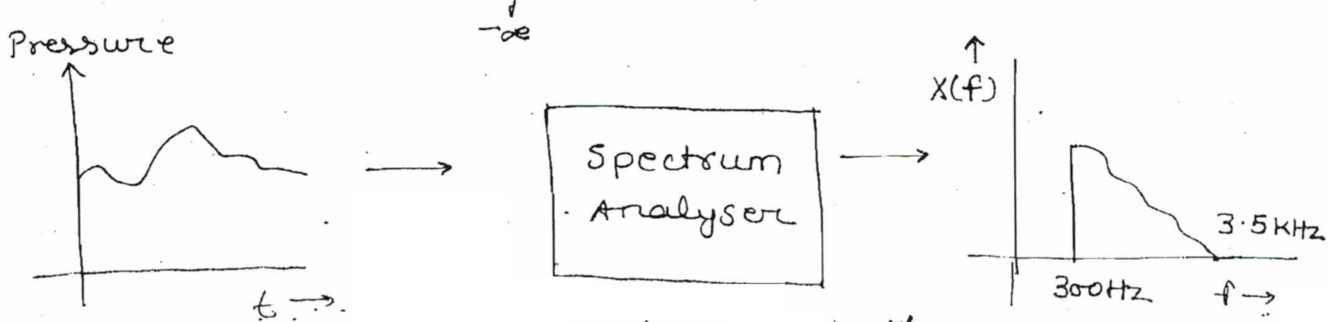
Generally without modulation multiplexing is not possible.

→ In wired communication, modulation is required for multiplexing.

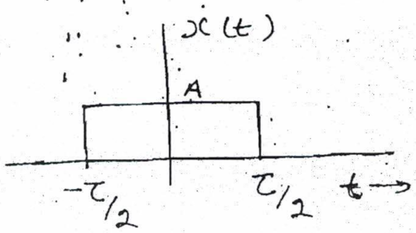
Fourier Transform :-

$$x(t) \xrightarrow{F.T} X(f)$$

$$X(f) = \int_{-\infty}^{\infty} x(t)\, e^{-j2\pi f t}\, dt$$



→ Fourier transform is basically used to find out frequency contain by given time domain signal.



$$X(f) = \int_{-\infty}^{\infty} x(t)\, e^{-j2\pi f t}\, dt$$

$$X(f) = \int_{-\tau/2}^{\tau/2} A\, e^{-j2\pi f t}\, dt$$

$$= A \cdot \left. \frac{e^{-j2\pi f t}}{-j2\pi f} \right|_{-\tau/2}^{\tau/2}$$

$$= \frac{-A}{j2\pi f} \left[e^{-j2\pi f \tau/2} - e^{-j2\pi f(-\frac{\tau}{2})} \right]$$

$$\Rightarrow \quad X(f) = \frac{A}{\pi f} \left[\frac{e^{j\pi f \tau} - e^{-j\pi f \tau}}{2j} \right]$$

$$= \frac{A}{\pi f} \sin(\pi f \tau)$$

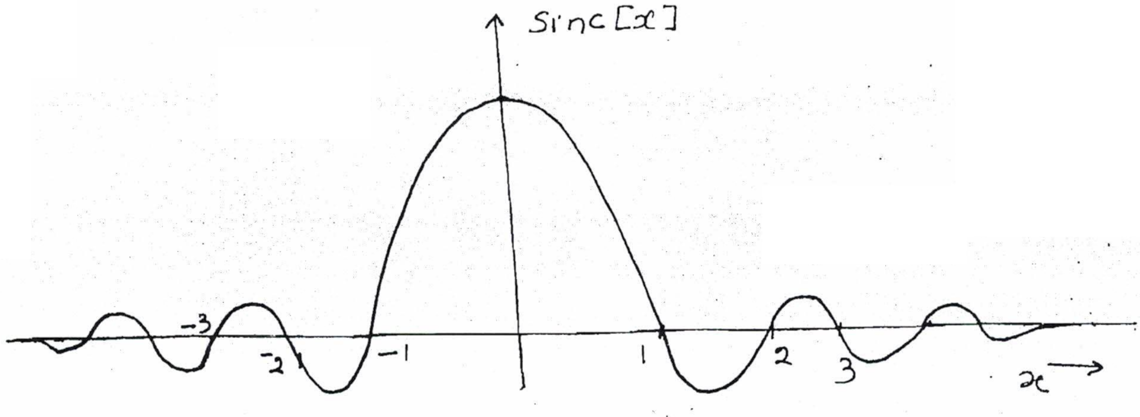
$$\Rightarrow \quad X(f) = A\, \frac{\sin(\pi f \tau)}{\pi f \tau} \times \tau$$

$$\Rightarrow \quad \boxed{X(f) = A\tau\, \mathrm{sinc}\,(f\tau)}$$

$$\mathrm{Sinc}\,[x] = \frac{\sin(\pi x)}{\pi x}$$

$$\mathrm{Sinc}\,[x] = 1 \quad ; \quad x = 0$$

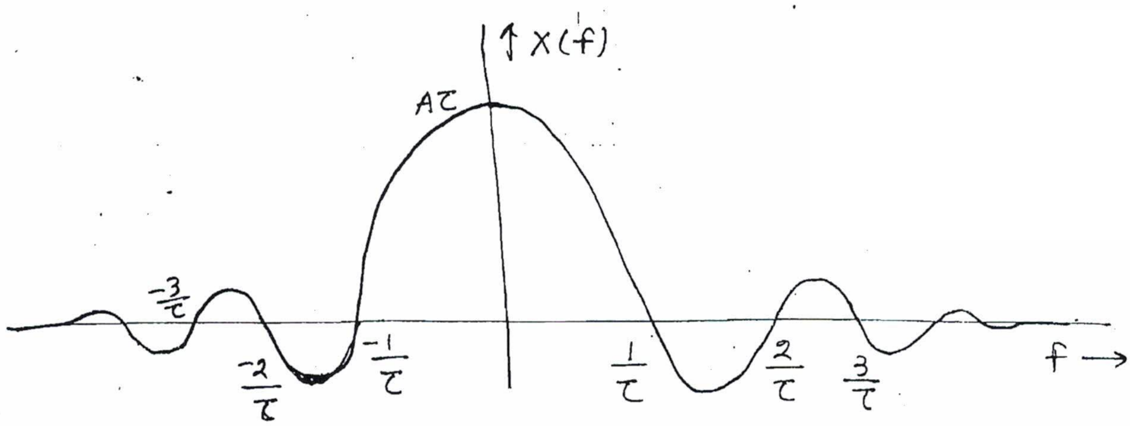
$$= 0 \quad ; \quad x = \pm 1, \pm 2, \pm 3, \ldots$$



$$\sin[f\tau] = 1 \quad ; \quad f = 0$$

$$= 0 \quad ; \quad f\tau = \pm 1, \pm 2, \pm 3$$

$$f = \pm \frac{1}{\tau}, \pm \frac{2}{\tau}, \pm \frac{3}{\tau}.$$



Signal BW = Highest +ve frequency − Lowest +ve frequency

$$= \infty - 0 = \infty$$

→ For faithful transmission, **Channel BW ≥ Signal BW**

→ Co-axial cable – (0 – 600 MHz)

→ Parallel Wire – (0 – 200 kHz)

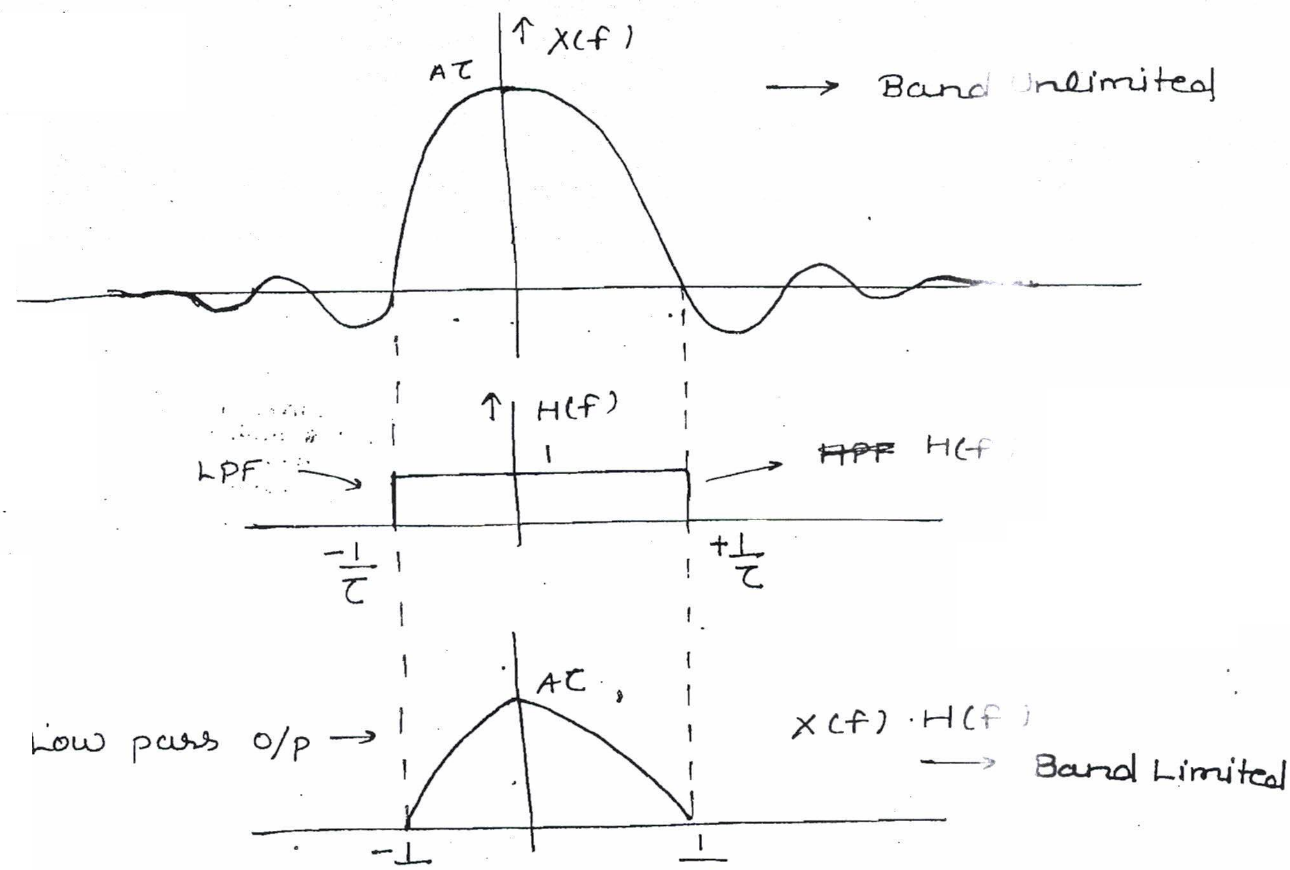
→ Fibre optical cable – GHz.

→ The given signal is not transmit through free space because of intereference, signal will be lost.

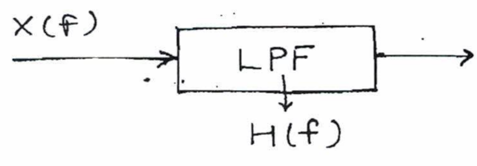
→ For proper transmission of above signal channel of BW infinite is required

→ But for practical channel, B.W will be finite

→ So that before transmission, signal should be band limited by using band limiting process



$$BW = \frac{1}{\tau} - 0 = \frac{1}{\tau}$$

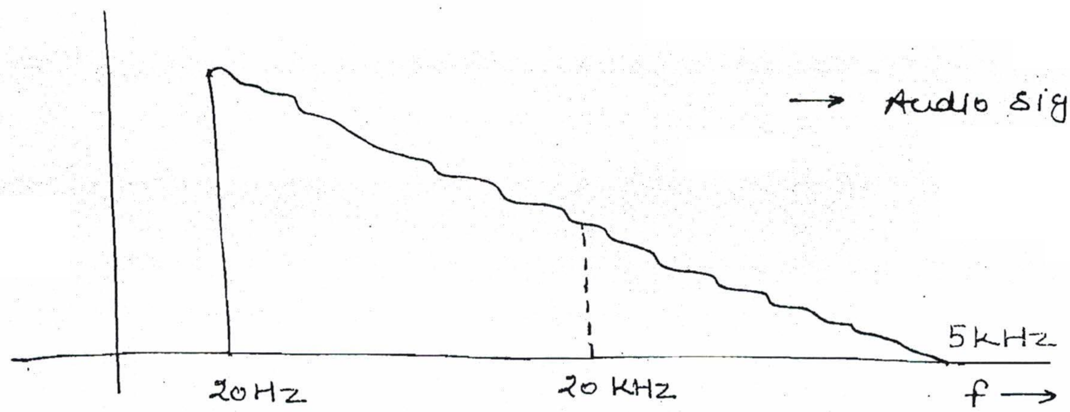


$$Y(f) = X(f)\, H(f)$$

→ To bandlimit a signal, all of its significant frequency component has to be retained and insignificant frequency component should be eliminated

→ ~~Sig~~ significant frequency contain almost of 95-99% of total strength of the given signal

→ Generally to bandlimit a signal proper low pass filter has to be used



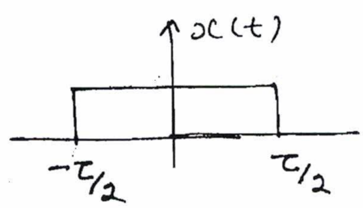
→ Generally for transmission of a signal significant frequencies will be given high importance for effective utilization of available channel bandwidth.

Properties of Fourier Transform :-

1) Duality Property :-

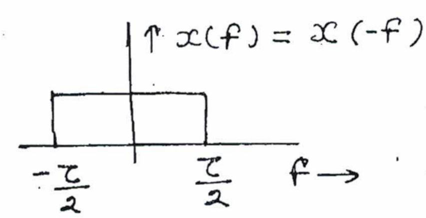
If $x(t) \longleftrightarrow X(f)$

then $X(t) \longleftrightarrow x(-f)$



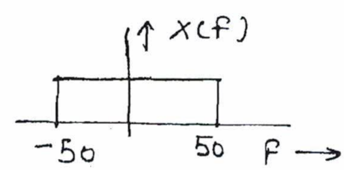
$\longleftrightarrow$ $A\tau \, \text{Sinc}[f\tau]$ → $X(f)$

$A\tau \, \text{Sinc}[t\tau]$ $\longleftrightarrow$
↓
$X(t)$



eg:- $\text{Sinc}[100t] \xrightarrow{NR} ?$

$\text{Sinc}[100t] \longleftrightarrow$



$NR = 2 \times 50 \text{ KHz}$

$= 100 \text{ KHz}$

$\delta(t) \longleftrightarrow 1$

$\downarrow \qquad\qquad \downarrow$

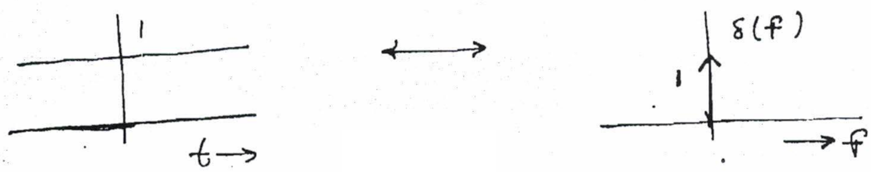
$x(t) \qquad\qquad X(f)$

$$\boxed{\begin{aligned} \delta(t) &= \infty \quad , t = 0 \\ &= 0 \quad , t \neq 0 \end{aligned}}$$

$1 \longleftrightarrow \delta(-f) = \delta(f)$

$$\boxed{\int_{-\infty}^{\infty} \delta(t)\,dt = 1}$$

$$\boxed{1 \longleftrightarrow \delta(f)}$$



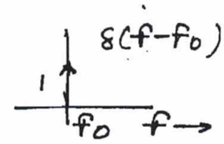
(11) <u>Frequency Shifting Property</u> :-

If $x(t) \longleftrightarrow X(f)$

then $x(t)\, e^{j2\pi f_0 t} \longleftrightarrow X(f - f_0)$

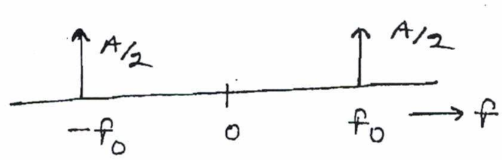
$x(t)\, e^{-j2\pi f_0 t} \longleftrightarrow X(f + f_0)$

→ $1 \cdot e^{j2\pi f_0 t} \longleftrightarrow \delta(f - f_0)$

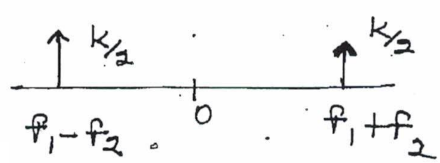


→ $e^{-j2\pi f_0 t} \longleftrightarrow \delta(f + f_0)$

→ $\cos 2\pi f_0 t \longleftrightarrow \dfrac{\delta(f - f_0) + \delta(f + f_0)}{2}$



→ $K \cos 2\pi (f_1 + f_2) t \longleftrightarrow$



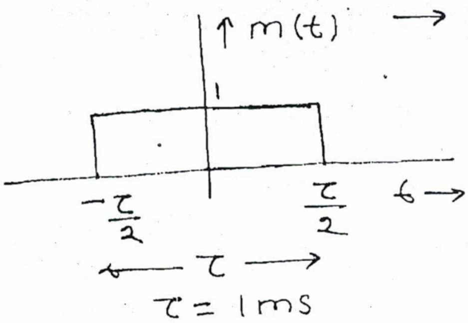
(III) Modulation Property:–

If $x(t) \longleftrightarrow X(f)$

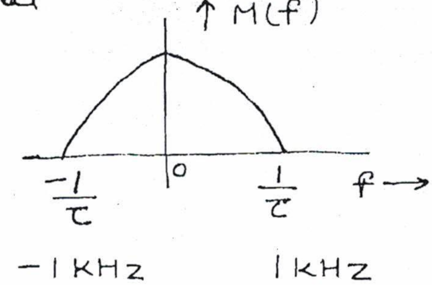
then $x(t)\cos 2\pi f_0 t \longleftrightarrow \dfrac{X(f-f_0)+X(f+f_0)}{2}$

Concept of Modulation:–

$\rightarrow$ Message Signal



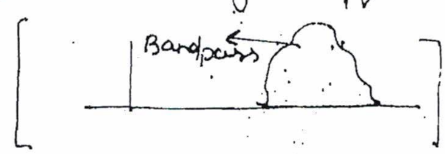
$\longleftrightarrow$



$\rightarrow$ Baseband / Low pass Signal

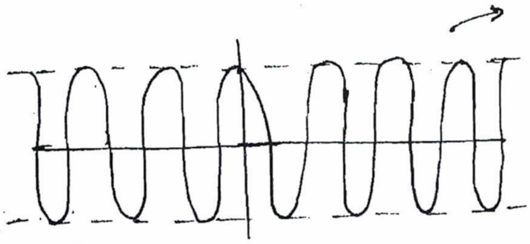
→ Baseband signal is that which contains low frequencies

→ Bandpass signal is that which contains high frequencies

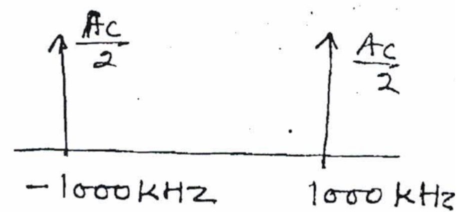


→ $c(t) = A_c \cos 2\pi f_c t \longleftrightarrow f_c = 1\,MHz = 1000\,kHz$

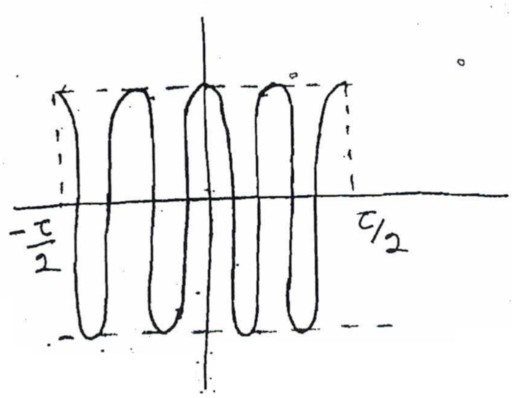
$\rightarrow$ Carrier signal.



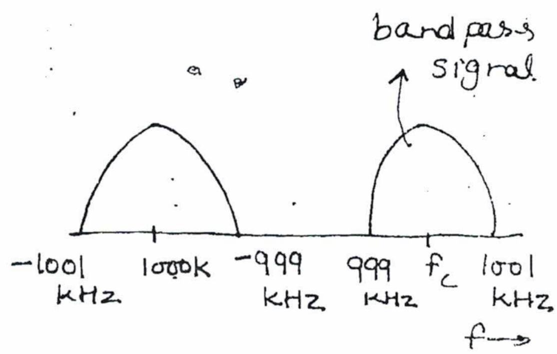
$\longleftrightarrow$



→ $s(t) = m(t) \times c(t)$ → Modulated Signal



$\longleftrightarrow$



$$S(t) = m(t) \times c(t) = A_c \, m(t) \cos 2\pi f_c t$$

$$= \frac{A_c}{2} \left[m(f-f_c) + m(f+f_c) \right]$$

Note:-

→ By modulation

(I) Signal is transmitted to low frequency to high frequency region

(II) Baseband signal becomes band pass signal

(III) Wideband signal becomes narrowband signal

$$WB \rightarrow \frac{HF}{LF} >>> 1$$

$$NB \rightarrow \frac{HF}{LF} \simeq 1$$

Demodulation:-

→ It is the process of reconstructing the original message signal from transmitted modulated signal.

Lecture-2

Types of Modulation:-

(I) Single tone modulation

(II) Multi tone modulation

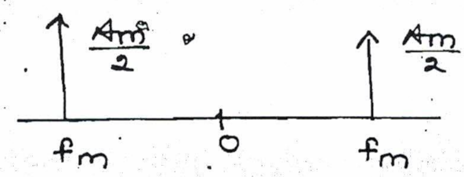
(I) Single tone modulation:-

→ If message signal contains single frequency component within it then it corresponds to single tone modulation

(II) Multi tone modulation:-

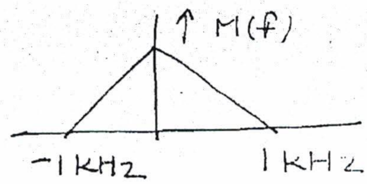
→ If message signal contains multiple frequency component within it then it corresponds to multi tone modulation.

$m(t) = A_m \cos 2\pi f_m t \longleftrightarrow$



→ Single tone modulation

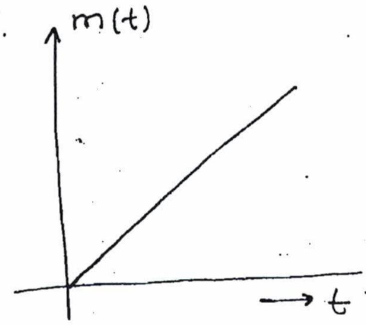
$m(t) \longleftrightarrow$



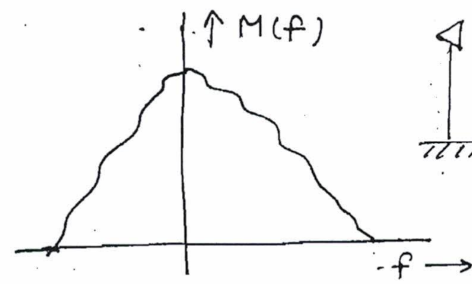
$m(t) = A_{m_1} \cos 2\pi f_{m_1} t + A_{m_2} \cos 2\pi f_{m_2} t$

→ Multi tone modulation

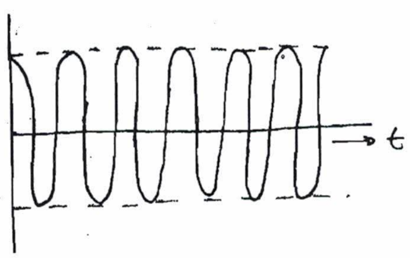
→ Practical significance is for multitone modulation and mathematical importance is for single tone modulation



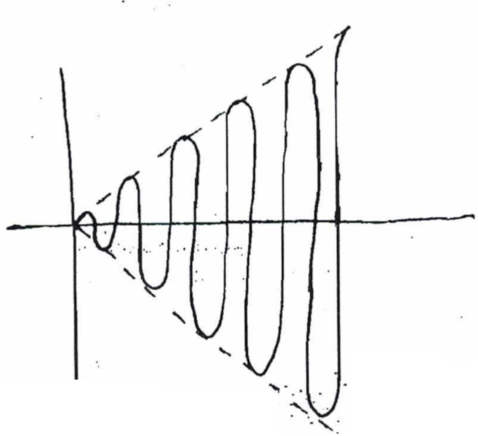
$\longleftrightarrow$



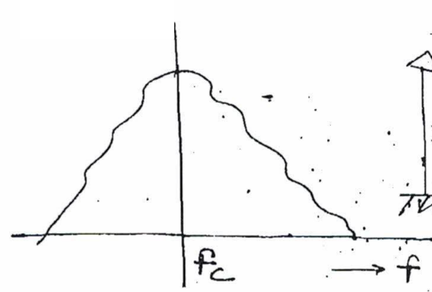
$c(t) = A_c \cos 2\pi f_c t$



$S(t) = m(t)\, c(t)$



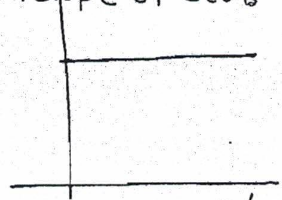
$\longleftrightarrow$



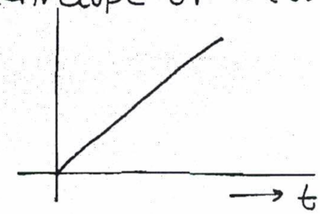
Envelope :-

→ A line which touches all the possible peak of a signal is known as envelope.

envelope of c(t)



envelope of s(t)



~~Modulation:-~~

→ The above corresponds to amplitude modulation in which message signal is stored in the form of peak amplitude variations of the carrier signal after modulation or in form of envelope of modulated signal s(t).

Modulation :-

→ It is the process in which one of the characteristics parameter i.e. amplitude, frequency or phase of the carrier signal will be varied w.r.t message signal amplitude variation.

Amplitude Modulation :-

→ It is the process in which peak amplitude of carrier signal will be varied w.r.t message signal amplitude variation

Assume message signal is m(t)

Carrier signal → $c(t) = A_c \cos 2\pi f_c t$

General expression of AM signal :-

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

where k_a → Amplitude sensitivity of AM modulator

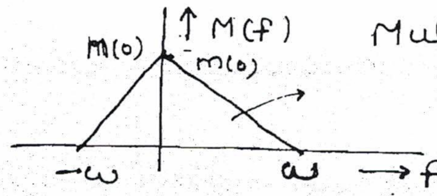
$$S_{AM}(t) = \underbrace{A_c \cos 2\pi f_c t}_{\text{Carrier signal}} + \underbrace{A_c k_a m(t) \cos 2\pi f_c t}_{\text{Modulated signal}}$$

$$S_{AM}(t) = c(t) + k_a m(t) c(t)$$

→ Because of additional carrier transmitter power will be wasted but demodulation becomes simple

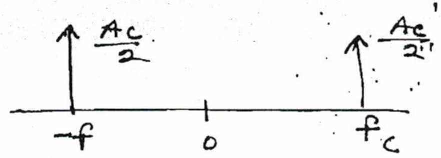
Spectrum Analysis :-

$m(t) \longleftrightarrow$

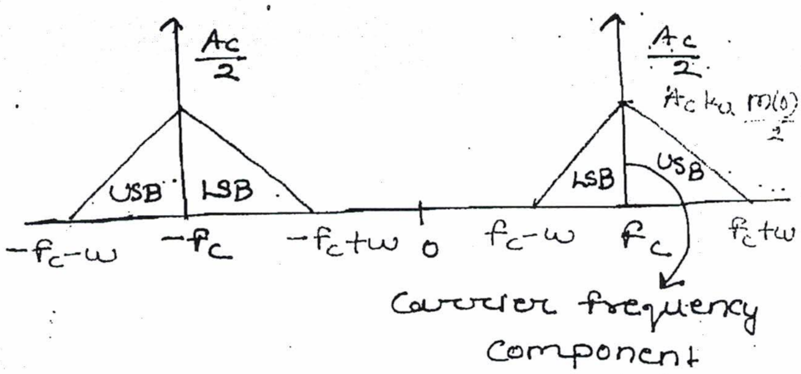


Multitone AM

$c(t) = A_c \cos 2\pi f_c t \longleftrightarrow$



$S_{AM}(t) \longleftrightarrow$



→ Message signal is stored in modulated signal in the form of USB and LSB in spectrum analysis.

→ $AM\ BW = (f_c + w) - (f_c - w) = 2w$

$= 2 \times$ message signal BW

→ AM spectrum contains

(I) Carrier frequency component

(II) USB exists above f_c

(III) LSB exists below f_c.

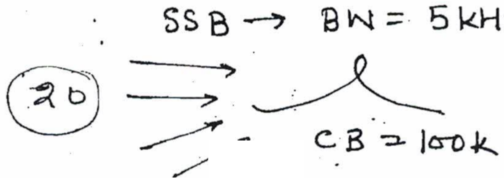
→ channel BW requirements of AM will be higher than SSB modulation.

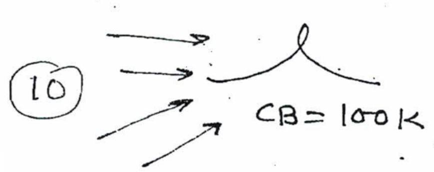
$m(t) \Rightarrow w = 5\,kHz$

$SSB \rightarrow BW = 5\,kHz$

$m(t) \Rightarrow w = 5\,kHz$

$AM \rightarrow BW = 2 \times 5 = 10\,kHz$





Practical Results:-

Msg → 0 − ω kHz
$S_{AM}(t) \rightarrow (f_c - \omega)$ to $(f_c + \omega)$
$BW = 2\omega$

→ To satisfy practical results −ve frequency is also consideration during using F.T in spectrum analysis

Single tone Amplitude Modulation:-

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

Assume $m(t) = A_m \cos 2\pi f_m t$

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

$k_a A_m = \mu$ → Modulation Index

$\mu \times 100$ → % of Modulation or depth of modulation.

$\mu < 1$	→	Under modulation
$\mu = 1$	→	Critical modulation
$\mu > 1$	→	over modulation

$\mu \leq 1$ → Practical.

→ For $\mu > 1$, demodulation becomes complex

** $$S_{AM}(t) = A_c[1 + \mu \cos 2\pi f_m t]\cos 2\pi f_c t \quad \text{—(I)}$$

** $$S_{AM}(t) = A_c \cos 2\pi f_c t + A_c \mu \cos 2\pi f_c t \cos 2\pi f_m t \quad \text{—(II)}$$

** $$S_{AM}(t) = A_c \cos 2\pi f_c t + \frac{A_c \mu}{2}\cos 2\pi (f_c + f_m)t + \frac{A_c \mu}{2}\cos 2\pi (f_c - f_m)t \quad \text{—(III)}$$

Carrier → $A_c \cos 2\pi f_c t$; USB → $\frac{A_c \mu}{2}\cos 2\pi (f_c + f_m)t$; LSB → $\frac{A_c \mu}{2}\cos 2\pi (f_c - f_m)t$