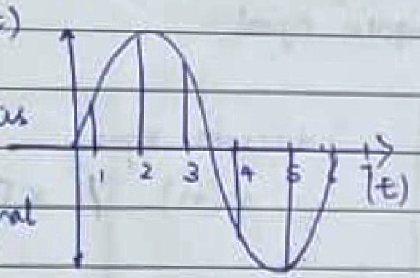
Communication System

I/P source (audio picture speech) → Transmitter → Channel → Receiver

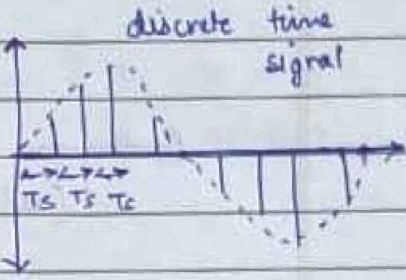
$x(t)$

Continuous time signal



Sampling
$\longleftrightarrow$

discrete time signal



Analog

$f_s \rightarrow \frac{1}{T_s}$

sampling rate — time period of sample

Quantization

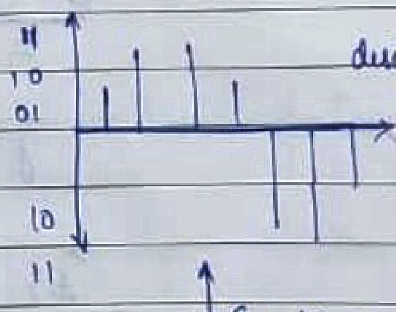
no. of levels = ~~no of bits~~ 2^n

where n is no. of bits to represent the signal

$n = 1 \quad 2^1 = 2 \quad \left.\begin{matrix} 0 \\ 1 \end{matrix}\right\}$

$n = 2 \quad 2^2 = 4 \quad \left.\begin{matrix} 00 \\ 01 \\ 10 \\ 11 \end{matrix}\right\}$

After quantisation



discrete time and discrete valued signal.

Encoding

[00 10 11 11 00 10 11 11 00]

modulating signal → message
modulated → after mapper

* Modulation

Modulation is defined as the process by which some characteristics of the signal called carrier is varied in accordance with instantaneous value of another signal called modulating signal.

→ Signals containing infos are modulating signal (also called base band signal)

→ Carrier frequency is greater than modulating freq.

→ Signal resulting from process of modulation is called modulated signal

* Need of Modulation

→ To reduce the height of antenna : Antenna height must be a multiple of $\lambda/4$

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

$$h \propto \frac{1}{f} \qquad f\uparrow \; h\downarrow$$

→ Avoid interference : ~~It increase range of communication, multiplexing is possible, reduction in noise.~~

→ It Increase range of communication
→ Multiplexing is possible
→ reduction in noise : ~~noise~~ noise is the major limitation of any communication. Although it cannot be eliminated completely but with several modulation schemes noise can be reduced.

* ~~Com~~ Channel

- Channels
  - Propagation through physical medium (wired)
    - coaxial cable
    - optical fibres
    - Twisted pair cables
  - Propagation of signal through air
    - Sattelite communication channel
    - Vaccum
    - air

* Classification of Electronic Communication System

- Electronic Communication System
  - Unilateral
    - Simplex System
      - eg: Radio, TV
  - Bilateral
    - Half Duplex
      - eg. walkie talkie
    - Full Duplex
      - eg. telephone
  - Nature of info signal
    - Analog
    - Digital.

Signal: physical quantity which varies with time or any other independent variable

Basic Signals: → sinusoidal (sine & cosine) $x(t) = A \sin \omega_c t$

$x(t) = A \sin 2\pi f_c t$

→ unit step signal

→ unit ramp signal

→ unit impulse signal.

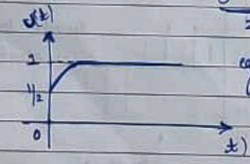
Continuous signal	discrete signal
$(x(t))$	$x(n)$ / $x[n]$

* **unit step signal** → $u(t) = \begin{cases} 1 & t > 0 \\ 0 & t < 0 \end{cases}$

Gibbs phenomena → at the same time the system transition from one state to another

$$u(0) = \frac{u(0^-) + u(0^+)}{2}$$

$$= \frac{0 + 1}{2} = \frac{1}{2}$$

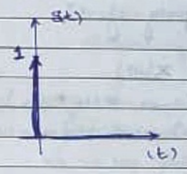


eg. $u(t) = \begin{cases} A & t > 0 \\ A/2 & t = 0 \\ 0 & t < 0 \end{cases}$

* **unit impulse signal** → $\delta(t)$ & $\delta(n)$

$$\delta(t) = \begin{cases} 1 & t = 0 \\ 0 & t \neq 0 \end{cases}$$

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

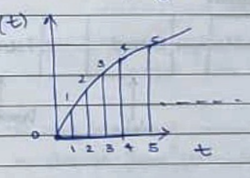


$$\delta(n) = \begin{cases} 1 & n = 0 \\ 0 & n \neq 0 \end{cases}$$

* **unit ramp signal** → $r(t)$

$$r(t) = t\,u(t) = \begin{cases} t & t \geq 0 \\ 0 & t < 0 \end{cases}$$

$u(t)$ → unit step signal



$$r(n) = n\,u(n) = \begin{cases} n & n > 0 \\ 0 & n < 0 \end{cases}$$

* Fourier Transform

$$x(t) \xleftrightarrow{CTFT} x(\omega)$$

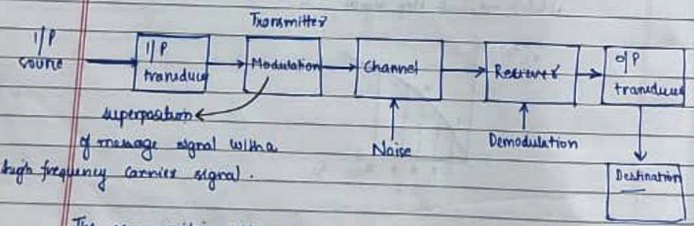
$$x(\omega) = \int_{-\infty}^{+\infty} x e^{-j\omega t} dt$$

time shifting property of FT

$$x(t) \rightarrow x(\omega)$$
$$e^{-j\omega_0 t} x(t) \rightarrow x(\omega + \omega_0)$$
$$e^{j\omega_0 t} x(t) \rightarrow x(\omega - \omega_0)$$

$$e^{-j\omega_0 t} \delta(t) \rightarrow \delta(\omega - \omega_0)$$
$$e^{+j\omega_0 t} \delta(t) \rightarrow \delta(\omega + \omega_0)$$

* Block Diagram of Communication System



The communication is the process of establishing connection / link b/w 2 points for infor. exchange. In other words communication is the process of exchanging info. through a physical medium of channel

→ **Information Source**: It produce the required message which has to be transmitted

→ **Input Transducer**: It converts one form of energy into another form. The message from the info source may or may not be electrical in nature. In case the message produced is not electrical in nature an input transducer is used to convert it into time varying electrical signal.

⇒ **Transmitter**: Its function is to process the electrical signal from diff aspects. Modulation is the main function of transmitter. We can say that inside the transmitter signal processing such as restriction of range of audio frequencies, amplification and modulation are achieved.

⇒ **Channel & Noise**: Channel is the medium through which messages travels from source to receiver. Noise is an unwanted signal which tends to interfer with the required signal. Noise signal is always random in nature. Noise has its greatest effect on signal.

⇒ **Receiver**: The main function of receiver is to reproduce message signal in electrical form from the distorted received signal. This reproduction of signal is done by demodulation / detection.

⇒ **Output Transducer**: They convert electrical signal into original form of signal.

→ **Destination**: It is final stage which is used to give the original signal.

classmate
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$m(t) = A_m \sin \omega_m t \rightarrow$ message
$c(t) = A_c \sin \omega_c t \rightarrow$ carrier

~~Amplitude~~ $A = A_c + m(t)$

amp. of modulated wave

A_c → Amp. of carrier wave.

$= A_c + A_m \sin \omega_m t$

$= A_c \left(1 + \frac{A_m}{A_c} \sin \omega_m t\right)$

$\frac{A_m}{A_c}$ → M = modulation index (0 to 1)

Imp

$v = A \sin \omega_c t \rightarrow$ value of amplitude modulated wave

$= A_c(1 + M \sin \omega_m t) \sin \omega_c t$

$v = A_c \sin \omega_c t + mA_c \sin \omega_m t \sin \omega_c t$

$$v = A_c \sin \omega_c t + \underbrace{\frac{mA_c}{2} \cos(\omega_c - \omega_B)}_{\text{Lower side Band (-ve portion)}} - \underbrace{\frac{mA_c}{2} \cos(\omega_c + \omega_B)}_{\text{Upper side band (+ve portion}}$$

↓

eq^n of amplitude modulated wave.

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→ Noise
→ Types ~~Noise~~ of Noise
→ Internal / External.
→ Short Noise
→ White noise
→ Thermal noise
→ Flicker noise / Pink noise.
→ Transit time noise

Noise

- External
  - → Environmental
- Internal.
  - → Thermal noise → $P = KTB$ (B ↑ band width)
  - → White noise (same intensity through all frequencies)
  - → short noise
  - → flicker noise (pink noise) → (low frequency noise)
  - → transit time noise (high freq. noise).

* SNR (signal noise ratio)

$\frac{\text{signal power}}{\text{noise power}}$ $\quad (SNR)_{dB} = 10 \log_{10} \frac{\text{sig power}}{\text{noise power}}$

→ Noise Figure

To calculate strength of signal

$$\frac{\text{SNR of input}}{\text{SNR of output}}$$

→ Friis equation

→ ~~Modulation~~

→ Amplitude modulation

$m(t) = A_m \cos 2\pi f_m t$
message signal.

carrier signal

→ Analog modulation

- → Amp modulation → DSB - FC, DSB - SC, SSB - SC, VSB
- → angle modulation
  - → frequency modulation
  - → phase modulation.

→ Amplitude Modulation

single ← $m(t)$ ⇒ message signal ~~tone~~ → to tone frequency.
tone $c(t) \Rightarrow A_c \cos(\omega_c) t$ → carrier frequency
single ↓ magnitude of carrier signal.

single tone → single frequency
multi tone → multiple frequencies.

modulated signal $s(t)$

$$\left[s(t) = A_c \cos \omega_c t + m(t) \cos \omega_c t \right]$$

$$m(t) = A_m \cos \omega_m t$$

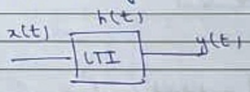
$$s(t) = A_c \cos \omega_c t + A_m \cos \omega_m t \cos \omega_c t$$

$$\cos \omega_c t \xRightarrow{FT} \pi \left[\delta(\omega - \omega_c) + \delta(\omega + \omega_c) \right]$$

$$s(\omega) = A_c \pi \left[\delta(\omega - \omega_c) + \delta(\omega + \omega_c) \right]$$

$$x(t)\,\delta(t) \longrightarrow x(t) \longrightarrow (1).$$

using above property



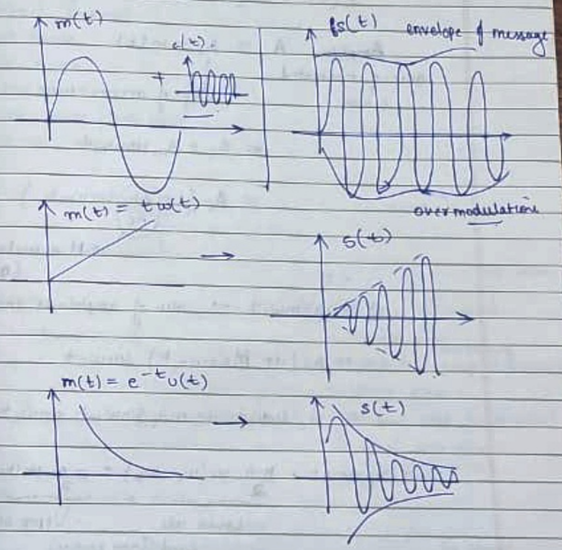
$$y(t) = x(t) * h(t)$$

$$y(t) = \int_{-\infty}^{+\infty} x(t)\, h(t - \tau)\, d\tau$$

Classification of Basis of Analog & Digital Communication

- Electronic System
  - Analog CS
    - Continuous wave –
      - Amplitude Modulation (AM)
      - Frequency Modulation (FM)
      - Phase Modulation (PM)
    - Analog Pulse Modulation
      - Pulse Amplitude Modulation (PAM)
      - Pulse width modulation (PWM)
      - Pulse position modulation (PPM)
  - Digital CS.
    - Pulse Code modulation (PCM)
    - Amplitude Shift Keying (ASK)
    - Delta Modulation (DM)
    - Adaptive DM
    - Frequency Shift Keying (FSK)
    - Phase Shift Keying (PSK)

Amplitude Modulation (AM)



Ans:

Equation of Amplitude Modulation

In Amp. modulation amp. of carrier wave is varied in accordance with message signal keeping frequency & phase constant

* <u>For single tone modulation</u>

Let message signal be

$$m(t) = A_m \cos \omega_m t$$

$\omega_m \rightarrow$ max. frequency

carrier signal

$$c(t) = A_c \cos \omega_c t$$

AM signal $=$ ~~$s(t) = A_m \cos \omega_m t + A_c \cos \omega_c t$~~

$$s(t) = A_c \cos \omega_c t + m(t) \cos \omega_c t$$
$$= (A_c + m(t)) \cos \omega_c t$$

$$s(t) = (A_c + A_m \cos \omega_m t)(\cos \omega_c t)$$

$$s(t) = A_c \cos \omega_c t + A_m \cos \omega_m t \cos \omega_c t$$

$$s(t) = A_c \left[\cos \omega_c t + \frac{A_m}{A_c} \cos \omega_m t \cos \omega_c t\right]$$

$$\left[m_a = \frac{A_m}{A_c}\right]$$

$$s(t) = A_c \left[1 + m_a \cos \omega_m t\right] \cos \omega_c t$$

$$s(t) = A_c \cos \omega_c t + A_c \frac{m_a}{2} \cdot 2 \cos \omega_m t \cos \omega_c t$$

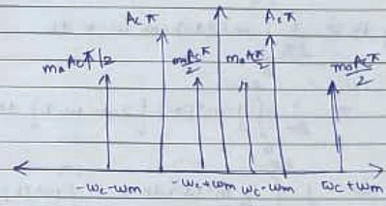
$$= A_c \cos \omega_c t + \frac{m_a A_c}{2}\left[\cos(\omega_m + \omega_c)t + \cos(\omega_c - \omega_m)t\right]$$

$\downarrow$

carrier signal $+ \frac{m_a A_c}{2} \underbrace{(\cos(\omega_m + \omega_c)t)}_{USB}$

$$+ \frac{m_a A_c}{2} \cos(\omega_c - \omega_m)t$$

$$S(\omega) = A_c \pi \left[\delta(\omega - \omega_c) + \delta(\omega + \omega_c)\right]$$
$$+ \frac{m_a A_c \pi}{2} \left[\delta(\omega - \omega_c - \omega_m) + \delta(\omega + \omega_c + \omega_m)\right]$$
$$+ \frac{m_a A_c \pi}{2} \left[\delta(\omega - \omega_c + \omega_m) + \delta(\omega + \omega_c - \omega_m)\right]$$



$\rightarrow$ <u>Power content of AM wave</u>

AM signal is

$$s(t) = \underbrace{A_c \cos \omega_c t}_{\substack{\text{carrier signal power} \\ (P_c)}} + \underbrace{m(t) \cos \omega_c t}_{\substack{\text{side band} \\ (P_s)}}$$

$$\left[P_t = P_s + P_c\right]$$

P_c

If $x(t)$ is signal $\quad P_t = \frac{1}{2\pi} \int_0^{2\pi} |x(t)|^2 dt.$

$$P_c = \frac{1}{2\pi} \int^{2\pi} A_c^2 \cos^2 \omega_c t \, dt$$

$$P_c = \frac{A_c^2}{2\pi}\int_0^{2\pi} \cancel{1 - \cos \omega_c t\, dt}\ \frac{\cos 2\omega_c t + 1}{2}$$

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

$$P_s = \frac{1}{2\pi}\int_0^{2\pi} m^2(t)\cos^2\omega_c t\, dt$$

$$= \frac{1}{2\pi}\int_0^{2\pi} \frac{1}{2} m^2(t)\left[2\cos^2\omega_c t\right] dt$$

$$= \frac{1}{2\pi}\int_0^{2\pi} \tfrac{1}{2} m^2(t)\,dt + \underbrace{\frac{1}{2\pi}\int_0^{2\pi} m^2(t)\cos 2\omega_c t}_{=0}$$

$$= \frac{1}{2}\left[\frac{1}{2\pi}\int_0^{2\pi} m^2(t)\,dt\right]$$

$$= \widehat{m^2(t)}.$$

$$P_s = \frac{1}{2}\widehat{m^2(t)}$$

Now consider $m(t) = A_m \cos \omega_m t$

$$P = \frac{A_m^2}{2}$$

$$P_s = \frac{1}{\cancel{4}} \frac{A_m^2}{4}$$

$$\boxed{P_t = \frac{A_c^2}{2} + \frac{A_m^2}{4}}$$

Power efficiency $= \eta = \dfrac{P_s}{P_c + P_s} = \dfrac{P_s}{P_t}$

$$= \cancel{A_m} \frac{A_m^2}{4\left(A_c^2/2 + A_m^2/4\right)}$$

P_t can be written as $\dfrac{A_c^2}{2}\left[1 + \dfrac{m_a^2}{2}\right]$

$$\boxed{\eta = \frac{A_m^2/4}{\frac{A_c^2}{2}\left[1 + \frac{m_a^2}{2}\right]} \times 100\%}$$

$$\boxed{\eta = \frac{m_a^2}{2\left[1 + m_a^2/2\right]} \times 100}$$

case 1 if $m_a = 1$

$$\eta = \frac{1}{2(1 + 1/2)} \times 100$$

$$= 33.33\%$$

~~case 2 if m_a~~

& using convolution property

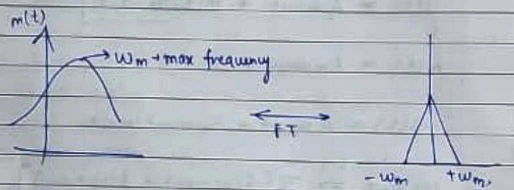
$$x(t)\,(h(t)) \xleftrightarrow{FT} X(\omega) * h(\omega) \quad \to (2)$$

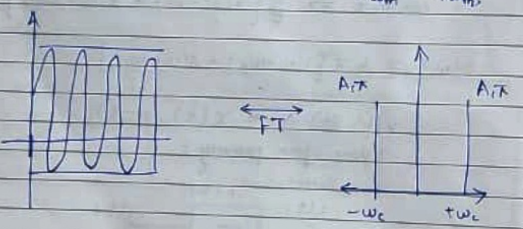
using (1) & (2)

$$s(\omega) = A_c\pi\left[\delta(\omega-\omega_c)+\delta(\omega+\omega_c)\right] + \pi\left[M(\omega-\omega_c) + M(\omega-\omega_c)\right]$$

$$s(\omega) = M(\omega) * \pi\left[\delta(\omega-\omega_c)+\delta(\omega+\omega_c)\right]$$

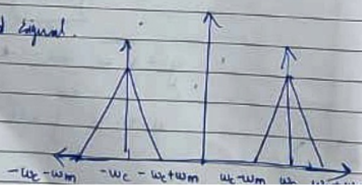
$$= \pi\left[M(\omega)*\delta(\omega-\omega_c) + M(\omega)*\delta(\omega+\omega_c)\right]$$





spectrum of modulated signal.

Bandwidth → $2\omega_m$



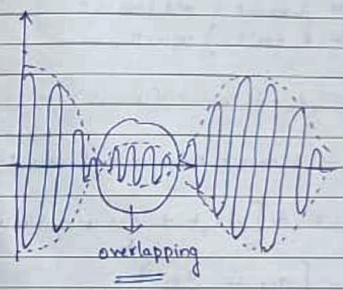
Modulation Index

$$m_a = \frac{|x(t)|_{max}}{\text{max amplitude of carrier}}$$

$$= A_m / A_c \qquad A_m \to \text{message signal}$$

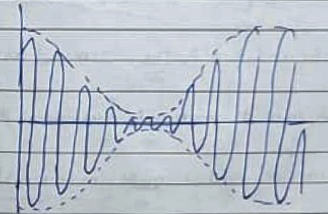
(1) If $m_a < 1$ $\quad A_c > A_m$ $\quad$ under modulation
(2) If $m_a > 1$ $\quad A_c < A_m$ $\quad$ over modulation
(3) If $m_a = 1$ $\quad A_c = A_m$ $\quad$ 100% modulation

(1)



proper recovery only possible in (2) & (3).

(3)



100% modulation

→ Current Relationship of AM signal

$$P = I^2 R$$

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

$$P_t / P_c = 1 + \frac{m_a^2}{2}$$

$$\frac{I_t^2 R}{I_c^2 R} = 1 + \frac{m_a^2}{2}$$

$$\frac{I_t^2}{I_c^2} = 1 + \frac{m_a^2}{2}$$

$$I_t = I_c\sqrt{1 + m_a^2/2}$$

Ques A 300 W carrier is modulated to a depth of 60%. Determine the total power of modulated wave / signal.

Sol

depth → modulation index = 0.6

$P_c = 300\,W \quad m_a = 0.6$

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

$$= 354\,W$$

Ques Determine efficiency of & % of total power carried by the side band of Amplitude modulated wave for tone modulation for $m_a = 0.5$ & $m_a = 0.3$.

Sol

$$\eta = \frac{m_a^2}{2\left[1 + m_a^2/2\right]} \times 100\%$$

1) $m_a = 0.5 \quad \eta = \frac{0.25}{2 + 0.25} \times 100$

$= 11.11\%$

2) $m_a = 0.3 \quad \eta = \frac{0.09}{2 + 0.09} \times 100$

$= \frac{0.9}{2.09} = 4.3\%$

* Power content of Multiple tone Amplitude modulation

Let your carrier signal be

$$c(t) = A_c \cos\omega_c t$$

Modulating / Base band signal

$$m(t) = A_{m_1}\cos\omega_{m_1}t + A_{m_2}\cos\omega_{m_2}t + A_{m_3}\cos\omega_{m_3}t$$

Amplitude modulated signal ⇒

$$x_{AM}(t) = A_c\cos\omega_c t + m(t)\cos\omega_c t$$

$$x_{AM}(t) = A_c\cos\omega_c t + \left\{A_{m_1}\cos\omega_{m_1}t + A_{m_2}\cos\omega_{m_2}t + A_{m_3}\cos\omega_{m_3}t\right\}\cos\omega_c t$$

$$= A_c\left\{1 + \underbrace{\frac{A_{m_1}}{A_c}}_{m_{a_1}}\cos\omega_{m_1}t + \underbrace{\frac{A_{m_2}}{A_c}}_{m_{a_2}}\cos\omega_{m_2}t + \underbrace{\frac{A_{m_3}}{A_c}}_{m_{a_3}}\cos\omega_{m_3}t\right\}\cos\omega_c t$$

→ Power saving in case of DSB-SC Modulation

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

power saving → P_c is neglected ~~is only part of total transfer~~

% power saving → $\frac{\text{total power saved}}{\text{total transmitted power}} \times 100$

$$\rightarrow \frac{P_c}{P_c\left(1+\frac{m_a^2}{2}\right)} \times 100$$

$$\Rightarrow \text{\% power saving} = \frac{2}{2+m_a^2} \times 100$$

case 1:- If $m_a = 1$

$$\text{\% power saving} = \frac{2}{3} \times 100$$
$$= 66.66\%$$

If $m_a = 0.5$

$$\Rightarrow \frac{2}{2.25} \times 100$$
$$= 88.88\%$$

→ Single sideband Suppressed Carrier Modulation

In case of AM → transmitting carrier plus both side bands

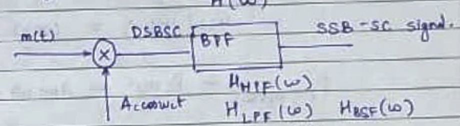
DSBSC → transmitting only sidebands & not carrier

But the sidebands contain the same info so we can further ~~of pow~~ reduce power usage & transmitt only one side band.

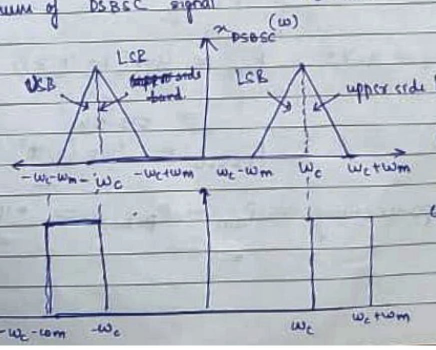
Two methods for generation of SSB-SC signal
1) Frequency discrimination method
2) Phase discrimination method.

→ Frequency Discrimination method

also known as filtering method because we apply BPF to just remove a single side band.



spectrum of DSBSC signal



Amplitude of filter can be equal or higher than message signal amp

$$x_{AM}(t) = \{A_c + m_{a_1} A_c \cos\omega_{m_1} t + m_{a_2} A_c \cos\omega_{m_2} t$$

$$+ m_{a_3} A_c \cos\omega_{m_3} t\} \cos\omega_c t$$

P_t = carrier power + sideband power.

$$= P_c + P_s$$

$$= \frac{A_c^2}{2} + \frac{1}{2}\left[\frac{m_{a_1}^2 A_c^2}{2} + \frac{m_{a_2}^2 A_c^2}{2} + \frac{m_{a_3} A_c^2}{2}\right]$$

$$= \frac{A_c^2}{2} + \frac{A_c^2}{4}\left[m_{a_1}^2 + m_{a_2}^2 + m_{a_3}^2\right]$$

$$\boxed{P_t = \frac{A_c^2}{2}\left[1 + \underbrace{\frac{m_{a_1}^2}{2} + \frac{m_{a_2}^2}{2} + \frac{m_{a_3}^2}{2}}_{m_t^2/2}\right]}$$

Ques For AM transmission with carrier power 150W is modulated by 4 modulating signal → $m_{a_1} = 0.3$, 0.4, 0.5 & 0.6 now determine
① Total modulation index
② Total transmitted power
③ Each side band power.

Sol

$$m_t = \sqrt{(0.3)^2 + (0.4)^2 + (0.5)^2 + (0.6)^2}$$

$$= 0.927.$$

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

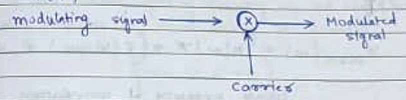
$$P_t = 150\left[1 + \frac{(0.3)^2}{2} + \frac{(0.4)^2}{2} + \frac{(0.5)^2}{2} + \frac{(0.6)^2}{2}\right]$$

$$= 214.5\ W.$$

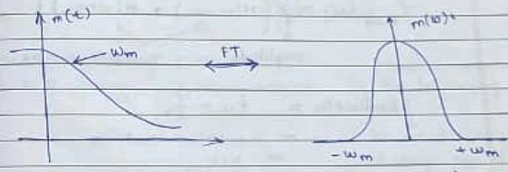
$$P_s = \frac{150}{8}\left(m_t^2\right) = 31.74\ W$$

Each sideband (as there are 4 signals)

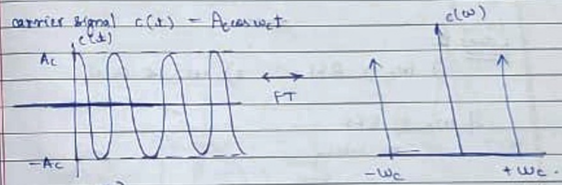
* Double Sideband Suppressed ~~Signal~~ Carrier (DSBSC):

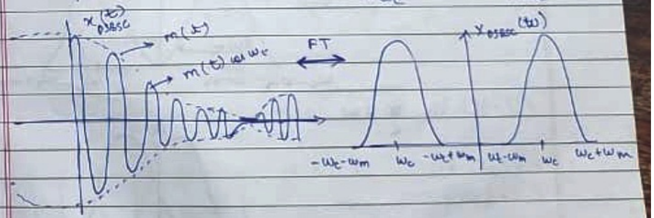


$$x_{DSBSC}(t) = m(t) \cos\omega_c t$$



carrier signal $c(t) = A_c \cos\omega_c t$





It is difficult to desing an ideal band pass filter. so to overcome this we have phase discrimination method.

~~Hilbert Transform~~

Ques 1) A 400W carrier is amplitude modulated to a depth of 100% ($m_a = 1$). Calculate the total power of AM & DSB SC modulation. How much power saving is achieved in DSBSC signal.

2) If depth of modulation is changed to 75% ($m_a = 0.75$) then how much power is required for transmitting DSBSC signal.

Compare the power requirement for DSBSC in both case.

Sol 1) $m_a = 1$ $\quad P_c = 400W$ $\quad$ { If P_m is also given then ignore it }

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

$$= 400\left(1 + 1/2\right) = 600W.$$

$$P_{t(DSBSC)} = \frac{P_c m_a^2}{2} = 200W.$$

→ 400W power saving

2) $m_a = 0.75$

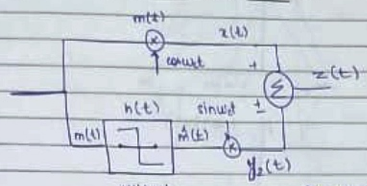
$$P_{am} = 400\left(1 + \frac{(0.75)^2}{2}\right)$$

$$= 512.5W$$

$$P_{DSBSC} = 400\frac{(0.75)^2}{2} = 112.5W$$

$$\text{power saving} = P_{am} - P_{DSBSC} = 400W$$

* **Phase ~~Discrimation~~ Discrimation Method**



Hilbert Transform

One disadvantage is that this hilbert transform causes the phase shift of 90°. But practically achieving 90° phase shift is not possible.

$$h(t) = \frac{1}{\pi t}$$

$$\hat{m}(t) = m(t) * h(t)$$

$$\hat{m}(t) = m(t) * \frac{1}{\pi t}$$

$$\hat{M}(\omega) = M(\omega) - j\,sgn(\omega)$$

$$y_1(t) = m(t)\cos\omega_c t$$

$$y_1(\omega) = \frac{1}{2j}\left[\hat{M}(\omega - \omega_c) - \hat{M}(\omega + \omega_c)\right]$$

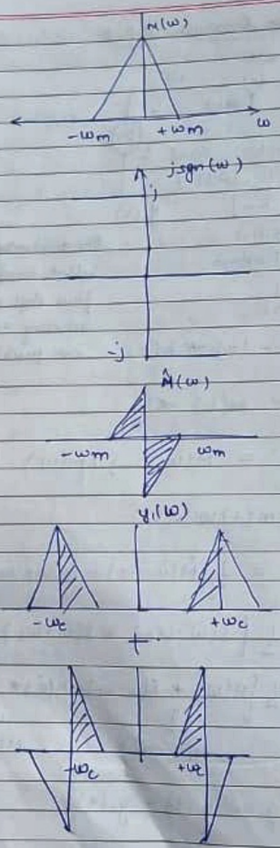
$$M(\omega) * \frac{1}{2}\left[\delta(\omega - \omega_c) + \delta(\omega + \omega_c)\right]$$

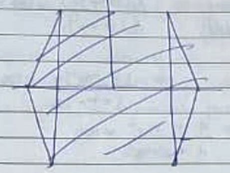
$$= \frac{1}{2}\left[\underbrace{M(\omega) * \delta(\omega - \omega_c)}_{M(\omega - \omega_c)} + \underbrace{M(\omega) * \delta(\omega - \omega_c)}_{M(\omega + \omega_c)}\right]$$

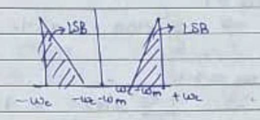
$$z(t) = y_1(t) + y_2(t)$$

or

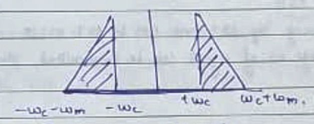
$$z(t) = y_1(t) - y_2(t)$$







or if we subtract them then



addition → lower side band
subtraction → upper side band.

→ Power saving in case of SSB - SC modulation

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

or

$$P_t = \underbrace{\underset{\text{carrier}}{P_c} + \underset{\text{1 side band}}{\frac{P_c m_a^2}{4}}}_{\text{power saving}} + \underset{\text{2nd sideband}}{\frac{P_c m_a^2}{4}}$$

so

Total power saving is $P_c \times \left(1 + \frac{m_a^2}{4}\right)$

$$= \frac{A_m A_c^2}{4}\cos(2\pi f_m t) + \frac{A_m A_c^2}{4}\cos(2\pi(f_c - f_m)t)$$

$\underbrace{\qquad\qquad}_{\text{scaled version of message signal.}}$ $\downarrow$ LPF.

$$y(t) = \frac{A_m A_c^2}{4}\cos(2\pi f_m t).$$

⇒ ~~Limitation of~~ <u>Asynchronous Detection</u>

$$x_{DSB\,SC} = A_c\, m(t)\cos(\omega_c t)$$

$$y_1(t) = A_c\, m(t)\cos(\omega_c t)\cos(\omega_c t + \theta)$$

$$y_1(t) = \frac{A_c\, m(t)}{2}\left[\underbrace{\cos(2\omega_c t + \theta)}_{\text{discarded. (LPF)}} + \cos\theta\right]$$

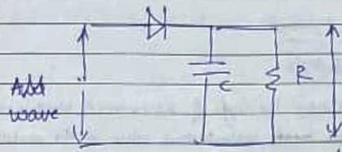
$$y(t) = \frac{1}{2}A_c\, m(t)\cos\theta$$

But if $\theta = \{\pi/2\}$ $y(t) = 0$

that why asynchronous detection is not used.
this effect is known as <u>quadrature null effect</u>.

When phase of transmitted carrier & locally generated carrier signal are not exactly synchronised the detected base band signal is always distorted & if $\theta = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2} \dots$ $y(t) = 0$ is the effect is known as quadrature null effect.

⇒ <u>Asynchronous detection</u> / <u>envelope detection</u> / <u>diode detection</u>



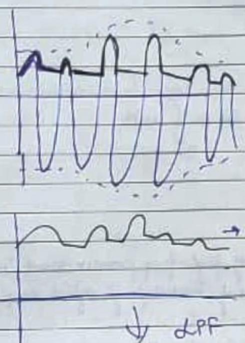
$v_0(t)$ ⇒ LPF ⇒ DC blocking capacitor

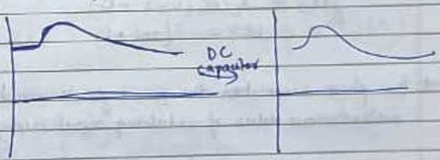
If RC component is very small → capacitor discharge very fast

If RC is large → capacitor discharge very slowly

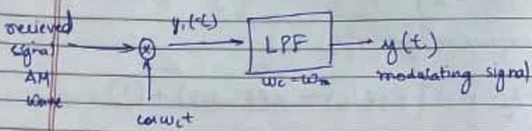
so we want in b/w these two i.e.

$$\left(\frac{1}{f_c} \ll RC \leq \frac{1}{f_m}\right)$$





The product of recieved signal & locally generated carrier is passed through LPF to get original modulating signal



$$X_{am}(t) = [A_c + m(t)]\cos\omega_c t$$

$$y_1(t) = \{A_c + m(t)\}\cos^2\omega_c t$$

$$= \left(\frac{A_c}{2} + \frac{m(t)}{2}\right)(1 + \cos 2\omega_c t)$$

$$y_1(t) = \frac{A_c}{2} + \frac{m(t)}{2} + \frac{A_c}{2}\cos 2\omega_c t + \frac{m(t)}{2}\cos 2\omega_c t$$

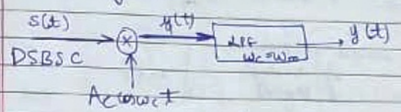
after LPF

$$y(t) = \frac{A_c}{2} + \frac{m(t)}{2}$$

and we pass it through capacitor only AC component

$$y(t) = \frac{m(t)}{2}$$

⇒ Detection of DSB-SC



$$X_{DSBSC}(t) = A_c\, m(t)\cos\omega_c t$$

$$y_1(t) = m(t)\cos^2\omega_c t$$

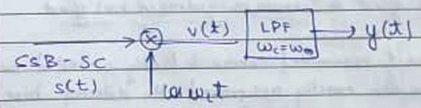
$$y_1(t) = \frac{m(t)}{2}[1 + \cos 2\omega_c t]$$

$$y_1(t) = \frac{m(t)}{2} + \frac{m(t)}{2}\cos\omega_c t$$

after LPF

$$y(t) = \frac{m(t)}{2}$$

⇒ Detection of SSB-SC



$$s(t) = \frac{A_m A_c}{2}\cos\{2\pi(f_c - f_m)t\}$$

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

$$v(t) = c(t)\, s(t)$$

$$v(t) = \frac{A_m A_c^2}{2}\cos(2\pi(f_c - f_m)t)\cos(2\pi f_c t)$$

$$= A_m A_c^2 \{\cos 2\pi(2f_c - f_m)t + \cos(2\pi f_m)(t)\}$$

$$\theta_i(t) = \omega_c t + k_p m(t)$$

$$X_{PM} = A_c \cos[\omega_c t + k_p m(t)]$$

⇒ **Relation b/w FM & PM**

1). FM & PM are closely related to each other because in both their is a variation in total phase angle.
In PM the phase angle varies linearly with modulating signal whereas in FM the phase angle varies linearly with integral of modulating signal. Thus FM wave can be obtained using FM.

To get FM using PM we first integrate the modulating & then apply to the phase modulator.

Similarly PM may be generated by using frequency modulator by first differentiating modulating signal & then apply to frequency modulator.

$$X_{FM} = A_c \cos[\omega_c t + k_f \int_0^t m(t)\,dt]$$

↳ frequency sensitivity constant

$$X_{PM} = A_c \cos[\omega_c t + k_p m(t)]$$

↳ phase sensitivity constant

$$m(t) \rightarrow \frac{d}{dt} \rightarrow FM \rightarrow PM \text{ signal}$$

$$y(t) = A_c \cos[\omega_c t + k_p \int_0^t \frac{d}{dt} m(t)$$

⇒ **Single Tone FM**

Frequency of carrier is varied according to modulation signal keeping max A_c constant. The change in the carrier frequency either above or below the center frequency is called frequency deviation $\delta\omega$.

Total variation in frequency from lowest to highest point is called carrier swing

carrier swing = 2 × frequency deviation
$= 2 \times \Delta\omega$

The amount of frequency variation / deviation depends upon amplitude of modulating signal.

→ **Modulation Index** In frequency modulation : ratio of frequency deviation to modulating frequency.

$$\left[m_f = \frac{\Delta\omega}{\omega_m}\right]$$

→ **Angle Modulation**

$$c(t) = A_c \cos \underbrace{(\omega t + \theta_0)}_{\text{Angle}}$$

In this type of modulation the angle of the carrier wave is varied in accordance with the ~~~~ instantaneous value of the modulating ~~~~ signal

$$\theta_c = \omega_c t$$

$$\omega = \frac{d\theta}{dt} \qquad \theta = \int_0^t \omega dt$$

⇒ **Frequency Modulation**

In FM the frequency of high freq. carrier wave is varied in accordance with instantaneous value of modulating signal keeping Amplitude constant

$$y(t) = A_c \cos(\omega_c t + \theta)$$

$$\omega_c(t) = F(m(t))$$

⇒ In phase modulation the phase angle are varied in accordance with instantaneous value of modulating signal keeping Amplitude constant.

$$\theta = F(m(t))$$

* **Mathematical representation**

1). Let $m(t)$ be modulating signal

$$c(t) = A_c \cos \omega_c t$$

$$\theta_c(t) = \omega_c t$$

$$X_{FM}(t) = A_c \cos \theta_i(t)$$

↳ instantaneous total phase angle

$$\boxed{\omega_i = \omega_c + k_f m(t)}$$

The max deviation of signal will occure when $m(t)$ has max value

$$\theta_i(t) = \int_0^t \omega_i dt$$

$$\theta_i(t) = \int_0^t [\omega_c + k_f m(t)] dt$$

$$\theta_i(t) = \omega_c t + k_f \int_0^t m(t) dt$$

* $$X_{FM}(t) = A_c \cos\left[\omega_c t + k_f \int_0^t m(t) dt\right]$$

2). $m(t)$ ⇒ modulating signal

$$c(t) = A_c \cos \omega_c t$$

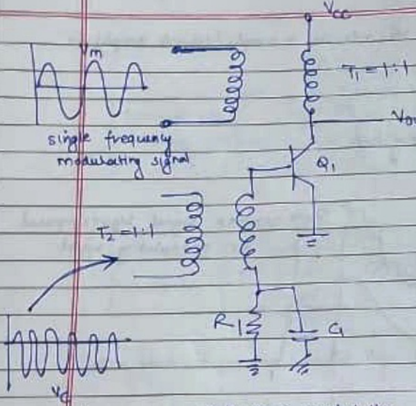
$$\theta_c(t) = \omega_c t \rightarrow \text{assumption}$$

$$c(t) = A_c \cos \theta_c t$$

$$X_{PM}(t) = A_c \cos \theta_i t$$

$$\theta_i = \theta_c t + k_p m(t)$$

↳ proportionality constant



Collector modulation

→ Generation of DSBSC signal

↳ Product modulator

$$x_{DSBSC}(t) = m(t)\cos\omega_c t$$

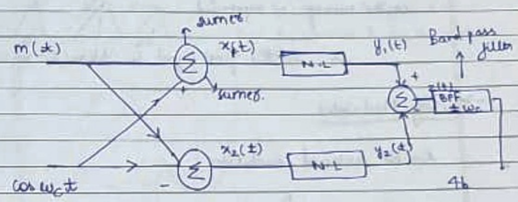
↳ Balance modulator

↳ Ring modulator

→ Balance modulator

↳ Non linear modulator

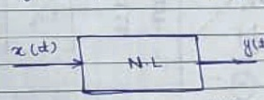
↳ Device used to achieve modulation is non linear



$x_1(t), x_2(t)$ ... i/p of non linear device.

$y_1(t), y_2(t)$ ... o/p of non linear device.

The sign is decided based on the terminals of the summer



$$y(t) = a(x(t)) + b\,x^2(t)$$

$$x_1(t) = m(t) + \cos\omega_c t$$
$$x_2(t) = m(t) - \cos\omega_c t$$

$$y_1(t) = a(x_1(t)) + b(x_1^2(t))$$
$$y_2(t) = a\,x_2(t) + b\,x_2^2(t)$$

$$z(t) = y_1(t) - y_2(t)$$

$$z(t) = [a x_1(t) + b x_1^2(t)] - [a x_2(t) + b x_2^2(t)]$$

$$z(t) = a\{\cancel{\cos\omega_c t} + m(t)\} + b\{\cos\omega_c t + m(t)\}^2 - a\{\cancel{\cos\omega_c t} - m(t)\} - b\{\cos\omega_c t - m(t)\}^2$$

→ Concept of Guard Band.

% power saving (compared to AM) $= \frac{P_c(1+m_a^2/4)}{P_c(1+m_a^2/2)} \times 100$

$= \frac{1+m_a^2/4}{1+m_a^2/2} \times 100.$

$\Rightarrow \frac{4+m_a^2}{4+2m_a^2} \times 100.$

Case 1 $m_a = 1$

$\Rightarrow \frac{5}{6} \times 100 = 83\%.$

Case 2 $m_a = 0.5$

$\Rightarrow \frac{4.25}{4.5} \times 100 = 94.4\%.$

→ Benifit of SSB

→ power saving by 83% w.r.t AM & 50% DSBSC

→ ~~lesser~~ large no. of signals can be transmitted since bandwidth requirement is half.

Ques A 450 W carrier is modulated to depth of 100%. calculate total

1) power in SSBSC modulation

2). Calculate power saving in SSBSC w.r.t AM & DSBSC.

3) If depth of modulation is changed to 60%. calculate total power in SSBSC technique & power saving in SSBSC w.r.t AM & DSBSC.

Ans $m_a = 1$

Ab. $P_t = P_c(1+\frac{m_a^2}{4})$

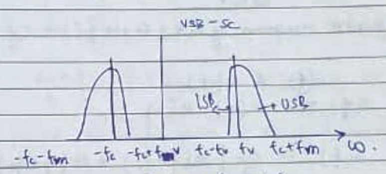
$= \cancel{450(1+\frac{1}{4}) = 450(\frac{5}{4})}$

$P_t = \frac{450}{4} = 112.5 W$

* Vestigial side Band suppressed carrier (VSB-SC)

since DSBSC requires bandwidth of $2f_m$

SSBS requires bandwidth of f_m but it is only used for audio signals. so to overcome these we used VSB-SC.



$BW = f_m + f_v$

USB + some part of LSB is transmitted.

Expression of DSB-SC

$x(t) = m(t)\cos\omega_c t$

$s(t) = m(t)\{\frac{1}{2}(e^{j\omega_c t} + e^{-j\omega_c t})\}$

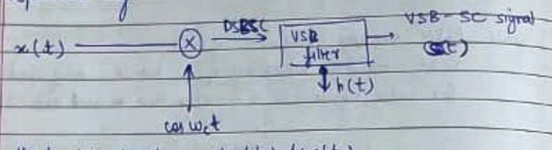
$s(\omega) = \frac{1}{2}[M(\omega-\omega_c) + M\frac{1}{2}(\omega+\omega_c)]$

→ ~~vestigial~~ single side band suppressed carrier depends on being able to filter out one of the side bands. It is well suited for voice transmission because of frequency gap that exists in the spectrum of voice signal 0 to 100 Hz.

⇒ Disadvantages of SSB & comparison with VSB-SC.

⇒ VSB is a process in which each part of signal called vestige is also modulated along with one side band like along with upper

→ Generation of VSB - SC



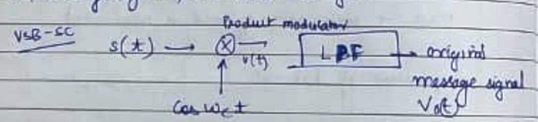
the fourier transform of x(t) & s(t)

$$s(f) \ \& \ x(f)$$

$$s(f) = X(f) \cdot H(f)$$

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

⇒ Extracted message signal from VSB - SC signal



this process of detection is known as synchronous / coherent detection because same carrier signal is used for generation & detection of message signal.

$$V(t) = s(t) \cdot c(t) - A_c \cos 2\pi f_c t$$

$$v(t) = A_c \cos \omega_c t \cdot s(t)$$

$$v(f) = \frac{A_c}{2}\left[s(\omega - \omega_c) + s(\omega + \omega_c)\right]$$

$$s(f) = \frac{A_c}{2}\left[M(\omega-\omega_c) + M(\omega+\omega_c)\right] H(f)$$

$$s(f-f_c) = \frac{A_c}{2}\left(M(f-2f_c) + M(f)\right) H(f-f_c)$$

$$s(f+f_c) = \frac{A_c}{2}\left[M(f) + M(f+f_c)\right] H(f+f_c)$$

final expression for $v(f)$ is:

$$v(f) = \frac{A_c^2}{4} M(f)\left[H(f-f_c) + H(f+f_c)\right] + \text{①}$$

$$\frac{A_c^2}{4}\left[M(f-2f_c)H(f-f_c) + M(f+2f_c)H(f+f_c)\right]$$

this is passed through LPF & the final expression we get is

$$v_0(f) = \frac{A_c^2}{4} M(f)\left[H(f-f_c) + H(f+f_c)\right]$$

In the above equation the term ① represents the scaled version of desired message signal frequency spectrum & it can be extracted by passing the signal through LPF

★ Demodulation of AM wave

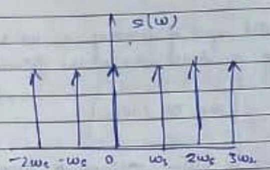
process of recovery of baseband signal from the modulated signal is known as demodulation or detection. Two methods.

1). synchronous detection
2) asynchronous detection

1). synchronous detection is also known as coherent detection / square law detector.

In this a local carrier is generated at receiver whose phase must be exactly synchronised with transmitted carrier's phase.

$x(t) = m(t)\, s(t)$



$$x(t) = m(t) \cdot \sum_{n=-\infty}^{+\infty} \delta(t - nT_s)$$

$$x(t) = m(t)\, s(t)$$

$$x(\omega) = m(\omega) * s(\omega) \cdot \frac{1}{2\pi}$$

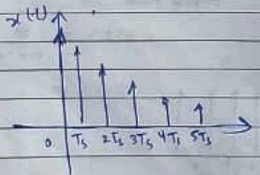
$$s(\omega) = \frac{2\pi}{T_s} \sum_{n=-\infty}^{+\infty} \delta(\omega - n\omega_s)$$

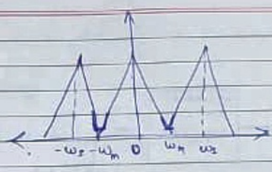
amplitude

$$X(\omega) = m(\omega) * \frac{2\pi}{T_s} \sum_{n=-\infty}^{\infty} \delta(\omega - n\omega_s) \frac{1}{2\pi}$$

$$= \frac{1}{2\pi} \frac{2\pi}{T_s} \left[M(\omega) * \sum_{n=-\infty}^{\infty} \delta(\omega - n\omega_s) \right]$$

$$= \frac{2\pi}{T_s} \cdot \frac{1}{2\pi} \left[\sum_{n=-\infty}^{+\infty} M(\omega - n\omega_s) \right].$$



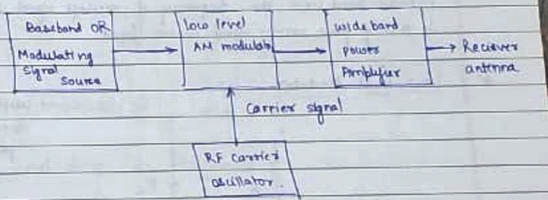


* Generation of ~~AM~~ Amplitude Modulation

↳ Amplitude Modulator

1). Low level AM
2) High Level AM generation

→ Low level AM



→ Modulation is done at low level using less power ~~level~~.
There are 2 ~~techniques~~ techniques for low level modulation
→ 1) Square law diode modulation
2) Switching modulation

→

$x_{DSBSC}(\omega) = m(t)\cos\omega_c t$

$\downarrow$ FT $\qquad \downarrow M(\omega) \qquad \pi[\delta(\omega-\omega_c)+\delta(\omega+\omega_c)]$

$$x_{DSBSC}(\omega) = M(\omega) * \pi\{\delta(\omega-\omega_c) + \delta(\omega+\omega_c)\}$$

using property of convolution.

$$x_{DSBSC}(\omega) = \pi\left[M(\omega-\omega_c) + M(\omega+\omega_c)\right]$$

$\pi \downarrow$ amplitude $\qquad$ two side spectra.

Bandwidth $= f_H - f_L$

$= \omega_m + \omega_c - \omega_c + \omega_m$

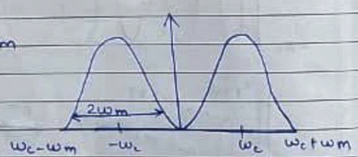
$= 2\omega_m$

Cases:

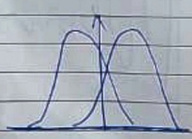
1) $\omega_c \geq BW$ $\qquad$ 2) $\omega_c < BW$

If $\omega_c = BW$

$= 2\omega_m$



If $\omega_c < BW$



* Sampling Theorem

For a band limited signal of frequency ω_m we say that the sampling frequency ω_s should satisfy the following

$$[\omega_s \geq 2\omega_m]$$

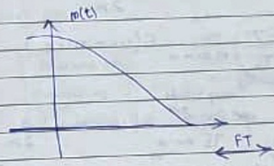
If $\omega_s = 2\omega_m \rightarrow$ Nyquist Frequency

$T_s = \frac{1}{\omega_s} \rightarrow$ Nyquist Period

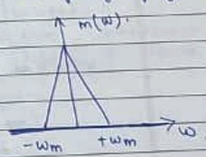
Three types of sampling process

(1) Ideal sampling $\qquad$ (2) Natural sampling $\qquad$ (3) Flat top sampling (Practical application)

$\downarrow$ We are able to generate a specific type of signal.

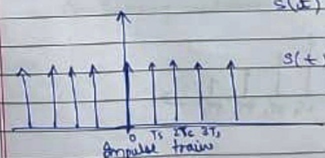


FT $\leftrightarrow$



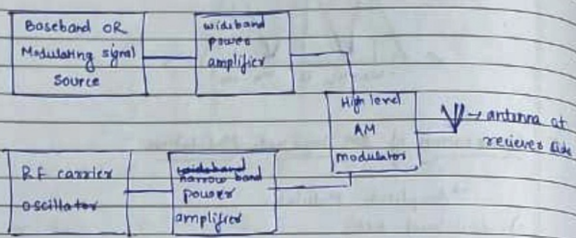
$$s(t) = \sum_{n=-\infty}^{+\infty} \delta(t - nT_s)$$

$s(t) = \ldots \delta(t-T_s) + \delta(t) + \delta(t+T_s)$



Impulse train

→ High level AM

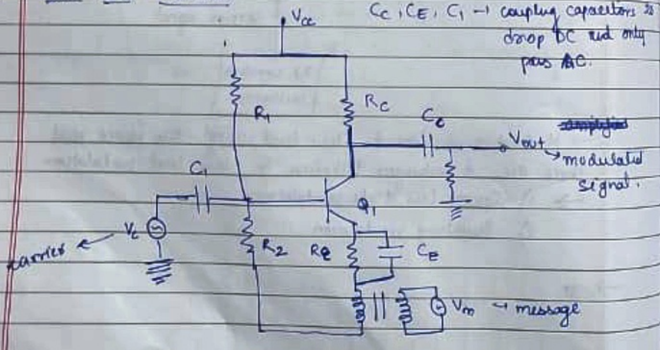


It is used to preserve complete info of modulating & carrier signal

narrow band since the frequency of message signal is variable & that of ~~pass~~ carrier signal is not fixed.

* Low level Modulator

C_C, C_E, C_1 → coupling capacitors to drop DC and only pass AC.

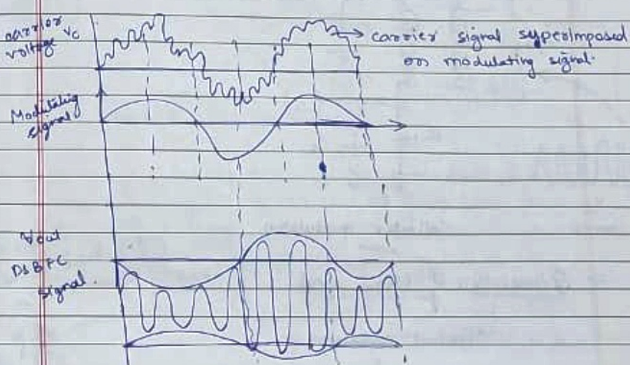


class A amplifier (small signal)

If only V_c is present then this acts as a simple class A amplifier

Disadvantages

→ Power dissipation is very high



→ High level Amplitude Modulator

↳ we use collector modulation

$$\underbrace{z(t) = 2a\,m(t)}_{\text{message}} + \underbrace{4b\,m(t)\cos\omega_c t}_{\text{modulated signal.}}$$

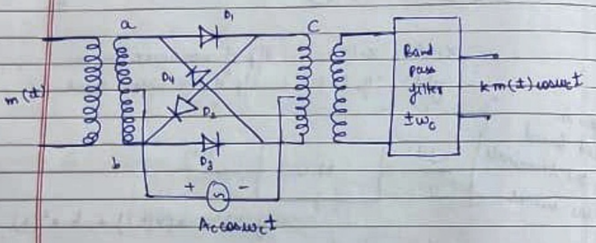
when this is passed through band pass filter with freq. $\pm\omega_c$

so the message is suppressed.

so ~~z(t)~~ final signal is $4b\,m(t)\cos\omega_c t$

→ **Ring Modulator**

Double balanced modulator



1). During +ve half cycle of carrier

D_1 & D_3 → conduct $\quad a \to c$

D_2 & D_4 → open $\quad b \to d$

$o/p \propto m(t)$

2). During negative half cycle of carrier

D_2 & D_4 → conduct $\quad a \to d$

D_1 & D_3 → open $\quad b \to c$.

$o/p \propto -m(t)$

m(t)	c(t)	o/p
+ve	+ve	D_1 & D_3 conducts & o/p is +ve
+ve	−ve	D_2 & D_4 conducts & o/p is −ve
−ve	+ve	D_1 & D_3 conducts & o/p is +ve
−ve	−ve	D_2 & D_4 conducts & o/p is −ve