INTRODUCTION

Chapter-1 : Chapter Coverage : Introduction to communication system, dB, dBm, concept of bandwidth, spectral efficiency & Hilbert transform. Concept of pre-envelope, baseband and band pass signals. Basic block diagram of communication system, electromagnetic spectrum and need of modulation.

— xxx —

→ In communication system, information or data in the form of signal are transmitted from transmitter to receiver side.

* → Communication are of different types.

(i) Based on medium :

(a) Wire line/wired communication – Here cable is used as medium. No antenna is used.

(b) Wireless communication – Here medium is free space or vaccum. In this communication ANTENNA plays important role in transmitting & receiving receiving electromagnetic waves.

(ii) Based on signal used:

(a) Baseband Communication :- In this Communication original information containing signal i.e baseband signal is transmitted without the help of carrier wave.

(b) Pass band/ Bandpass Communication :- Here information containing baseband signal is transmitted with the help of carrier wave using modulation technique.

* carrier is non information wave.

(iii) Based on types of baseband signal

(a) Analog Communication :- Here the baseband signal is analog in nature.

(b) Digital Communication :- Here the baseband signal is digital in nature.

(iv) Based on ways of transmission

(a) Simplex

(b) Half-Duplex

(c) Full-Duplex

(V) Based on spectral/Frequency range of passband signal

(a) Radio Frequency commcenication :-

ex : Longwave, Medicem wave, Shortwave (SW) Commcenication

(b) Microwave commcenication

(c) milimeter-wave commcenication

(d) Infrared commcenication

(e) optical commcenication

(Vi) Based on Application Areas

(a) mobile/cellular commcenication

(b) Satellite commcenication

(c) Radio commcenication — AM Radio
→ FM Radio

(d) optical-Fibre commcenication

(e) Telephone commcenication

(Vii) Based on No. of Transmitter & No. of Receivers.

(a) point to point commcenication

(b) Broadcasting

~~(viii) Based on different Networks used~~

~~(a) LAN~~

~~(b) PAN~~

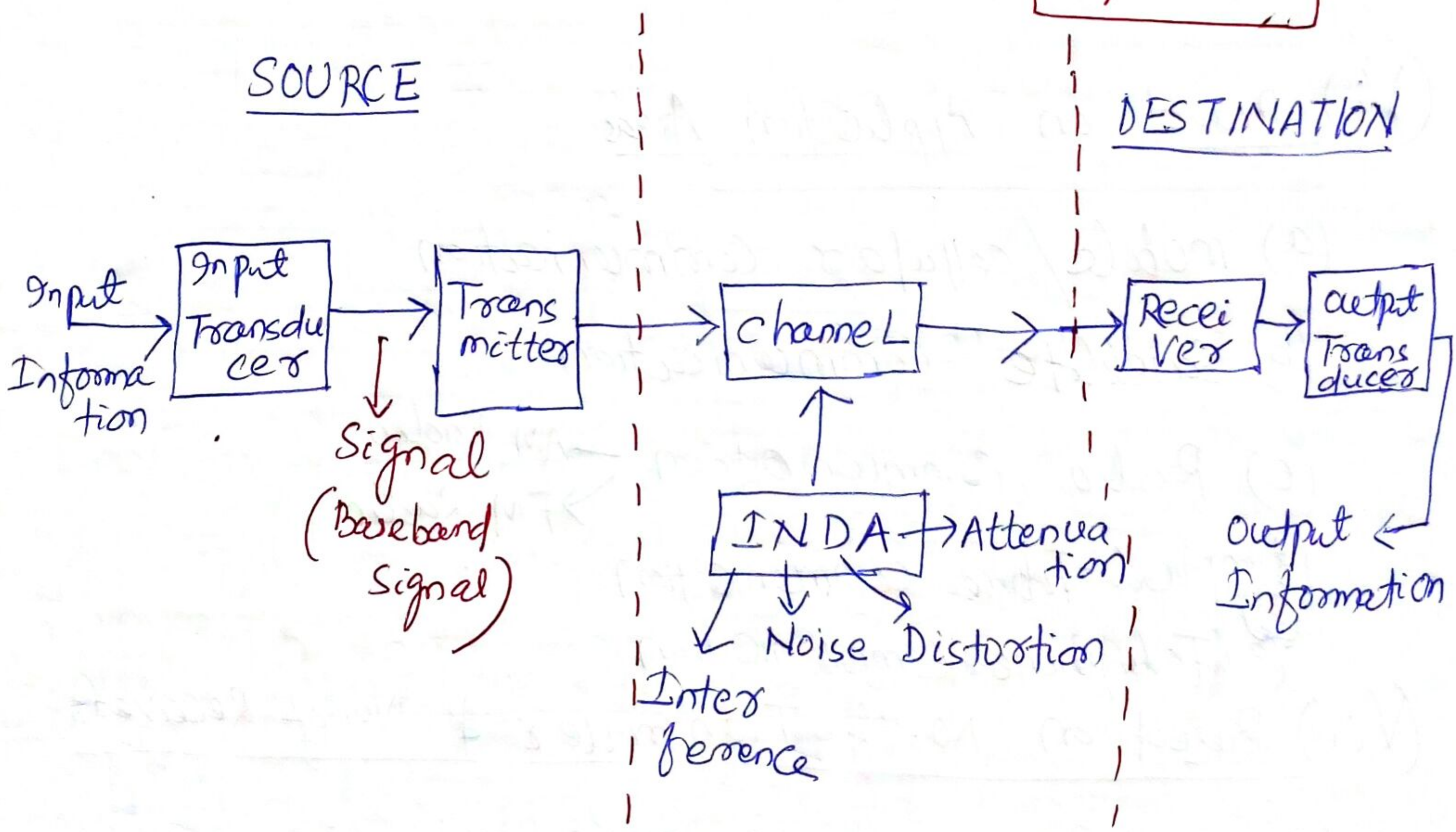
~~(c) MAN~~

~~(d) WAN~~

~~(e) BAN~~

~~(f) Internet~~

BASIC BLOCK DIAGRAM OF COMMUNICATION SYSTEM



① Transducer :- It converts non electrical information (sound, speech, music, image, text) to electrical signal.

ex:→ mike - It converts sound, speech and music to audio signal

→ camera - It converts image to video signal.

→ Keyboard/~~key~~ pad - It converts text to text signal.

* Transducer is a type of sensor.

* This electrical signal is known as baseband signal.

Signal: We can define signal in two ways.

(a) Qualitative def^n :- signal is defined as the thing which carries information.

(b) Quantitative def^n :- signal is a single valued function of one or more than one independent variables. ex:- time, space etc.

ex: $y = f(x, t \ldots)$
↓
signal

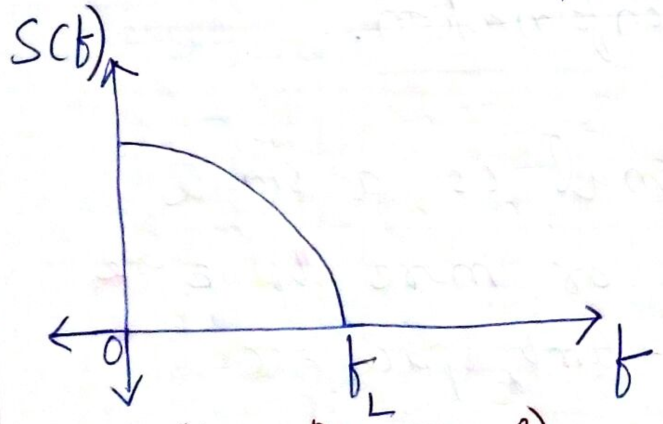
Signal Bandwidth:

→ Let a signal is $s(t)$. For band width realisation it is to be converted into frequency domain using Fourier Transform (→ Aperiodic) or Fourier Series (→ periodic).

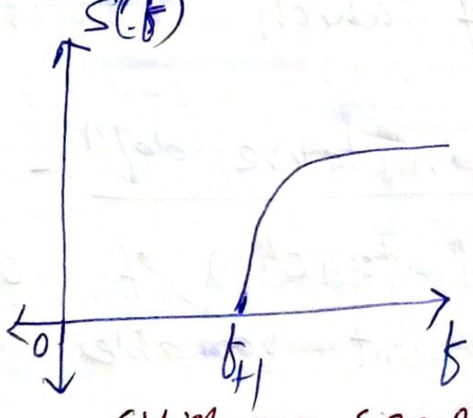
$$s(t) \underset{F^{-1}}{\overset{F}{\rightleftharpoons}} s(f)$$

→ The diagram containing signal parameter in y-axis and frequency in x-axis is called as Frequency domain diagram or Spectral diagram.

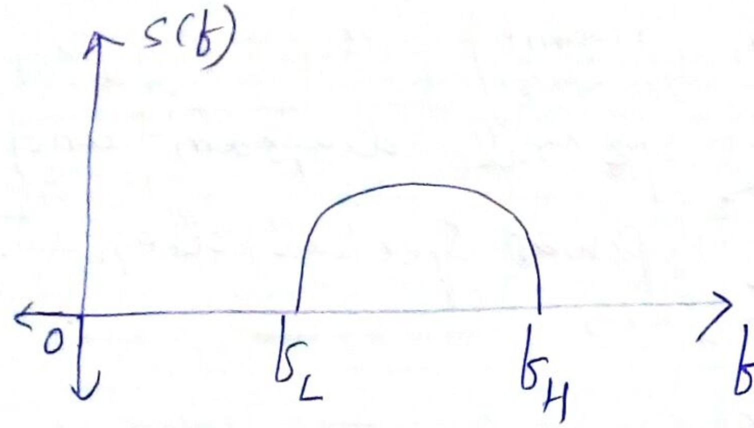
→ Based upon spectral diagram signals are of
(i) Low pass signal
(ii) High pass signal
(iii) Band pass signal → Narrow Band / → Wide Band



(Low pass signal)



(High pass signal)



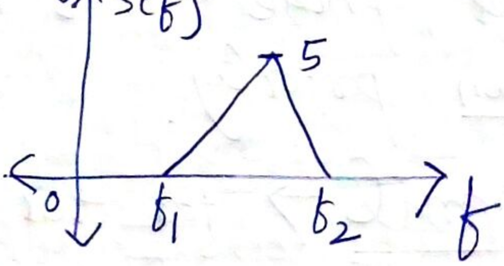
Band pass Signal → Narrow Band
→ Wide Band Signal

→ Bandwidth $= f_H - f_L$ (HZ). High frequency (f_H) and f_L (Low frequency) are calculated based upon some standards (ex - -3dB band width in amplifier or -10dB bandwidth in antenna engineering).

→ Spectral diagram can be drawn in two ways.

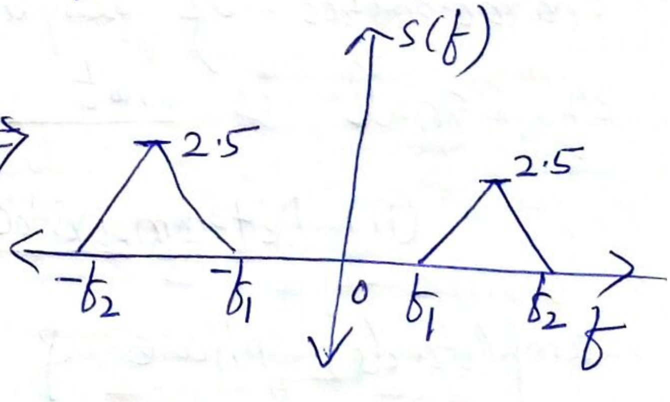
(i) single sided spectrum

(ii) Double sided Spectrum → Here negative frequency is also considered along with +ve frequency.



Single sided spectrum

⇔



Double sided spectrum

[* Here Assumption is that
S(t) = Real signal.]

→ Amplitude Vs frequency is known as Amplitude spectral diagram and power Vs frequency power spectral diagram.

~~→ Signal power~~:

Band of some well known Baseband Signal :⇒

	f_L	f_H	BW
① Voice signal	300	3400 Hz	3100 Hz
② Music signal	20	15000 Hz	14980 Hz
③ Video signal	0	5 MHz	5 MHz

~~* In ACT we will study about two types of base band signals.~~

~~(i) Random signal → In which the characteristics of amplitudes, phase and frequency of signal is not known priorly.~~

~~(ii) Deterministic signal → For this signal, amplitude, phase & frequency behaviour is previously known.~~

* All communicated signals are random in nature. Noise is also a random signal.

SNR in communication :

→ In communication, signal is always co-exists with some amount of noise. That noise may be of system noise or channel noise.

→ So it is important to calculate SNR.

SNR = signal to noise ratio

$$= \frac{\text{Average signal power}}{\text{Average Noise power}}$$

Let signal power $= S_p$

Noise power $= N_p$

$$SNR = \frac{S_p}{N_p}$$

$$SNR \text{ in } dB = 10 \log_{10}\left(\frac{S_p}{N_p}\right)$$

If $N_p = 1\text{Watt}$ then SNR in $dBW = 10\log_{10}\left(\frac{S_p}{1\text{Watt}}\right)$

If $N_p = 1\text{mWatt}$ then SNR in $dBm = 10\log_{10}\left(\frac{S_p}{1\text{mW}}\right)$

EM SPECTRUM FOR COMMUNICATION

Frequency Band	Name
3 – 30KHZ	Very Low frequency (VLF)
30 – 300KHZ	LF (Low Frequency)
300 – 3000KHZ	Medium Frequency (MF)
3 – 30MHZ	High Frequency (HF), Short Waves (SW)
30 – 300MHZ	Very High Frequency (VHF)
0.3 – 1GHZ	Ultra High Frequency (UHF)
1GHZ – 30GHZ	Microwave Frequency
30 – 300GHZ	Milimeter Waves
0.3THZ – 430THZ	THZ wave/Infra Red wave
430THZ – 750THZ	Light Wave
750THZ — 3000THZ	UV
	X-ray
	γ-ray

Channel Bandwidth: The range of frequencies a channel (medium) supports effectively known as channel bandwidth.

Resources in communication:

(1) Transmitted power (↓)

(2) channel Bandwidth (↑)

* In communication, our focus should be how to get/achieve

(i) Lesser transmitted power

(ii) Lesser Signal bandwidth

(iii) Larger channel bandwidth

Analogy to Auto - passenger - Money.

MODULATION & ITS NEEDS :

→ In modulation, two waves will take part.

① Baseband signal (which contains information)

② Carrier Wave (No information)

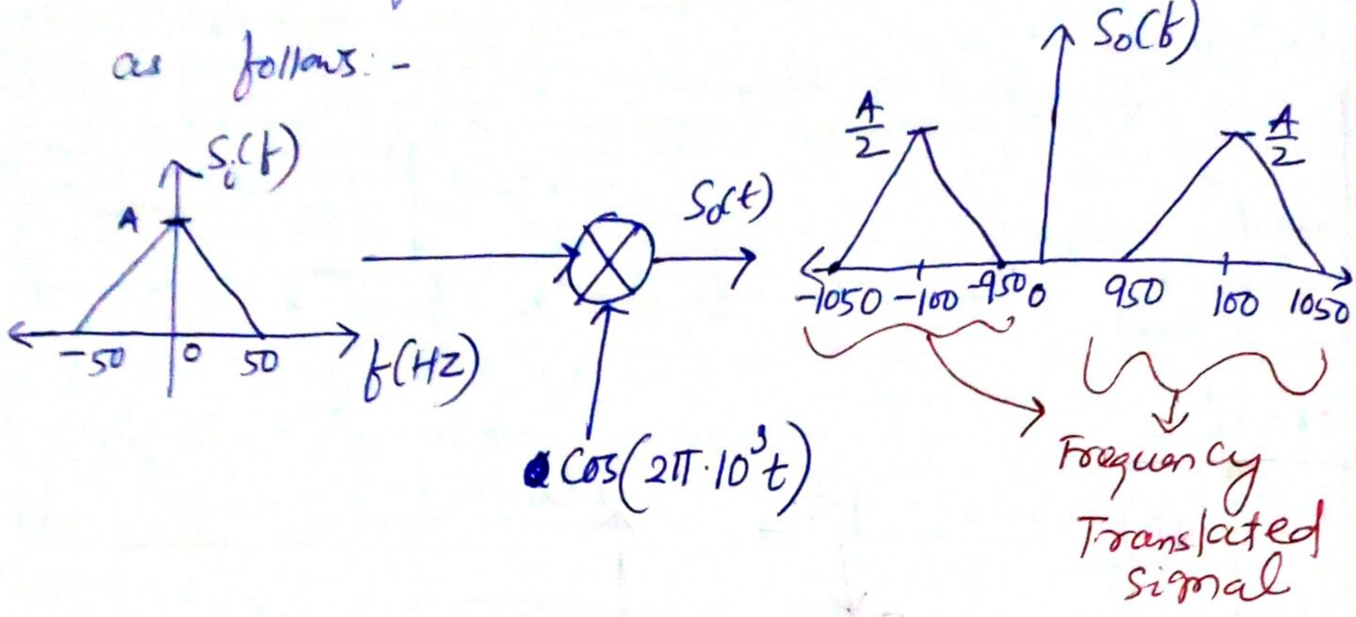
Defn: → In Modulation, characteristics (amplitude / frequency / phase) of carrier is changed according to baseband signal.

~~Why we need the help of carrier?~~

→ Using Modulation, one outcome we can achieve i.e <u>Frequency Translation</u> which is most important in communication.

→ Frequency Translation is defined as the change/shift in frequency range of a signal keeping content of signal unchanged.

ex:- Let a signal $s_i(t)$ has spectral diagram as follows:-



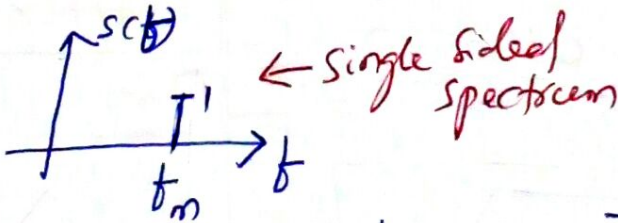
* Frequency translation uses the principle of multiplication of two sinusoidal / cosinusoidal functions.

ex:

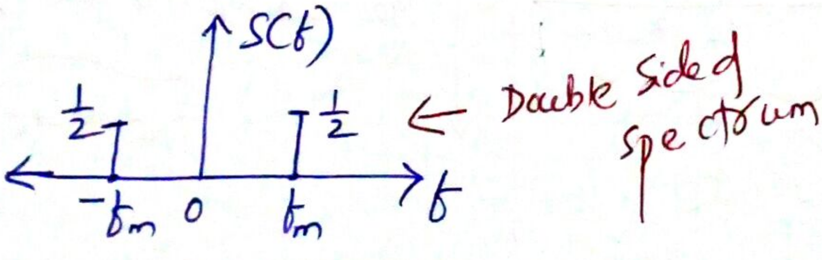
$$\cos A \cdot \cos B = \frac{1}{2}\underbrace{\cos(A+B)}_{\text{Frequency Translation}} + \frac{1}{2}\underbrace{\cos(A-B)}_{\text{Frequency Translation}}$$

Negative frequency Concept:

Consider $s(t) = \cos 2\pi f_m t$. In frequency domain



We can write $\cos 2\pi f_m t = \frac{1}{2} e^{j2\pi f_m t} + \frac{1}{2} e^{-j2\pi f_m t}$



NEED OF MODULATION / FREQUENCY TRANSLATION :→

① **Practicability of Antennas** (To reduce Antenna Size)

→ Usually baseband signals are lowpass signals. For wireless communication, to transmit low frequency signal we require antenna of larger dimension. That is impractical to use.

ex: The length of half wave dipole antenna $L = \frac{\lambda}{2}$. λ = wavelength $= \frac{c}{f}$

c = speed of light $= 3\times10^8$ m/s

Let $f = 1KHZ$ (audio tone)

$$\lambda = \frac{3\times10^8}{1\times10^3} = 3\times10^5$$

$$\text{Length of antenna} = \frac{3\times10^5}{2} = 1.5\times10^5 \text{ m} = 150 \text{Km}.$$

* Height of antenna should be 150Km i.e ~~impr~~ impractical.

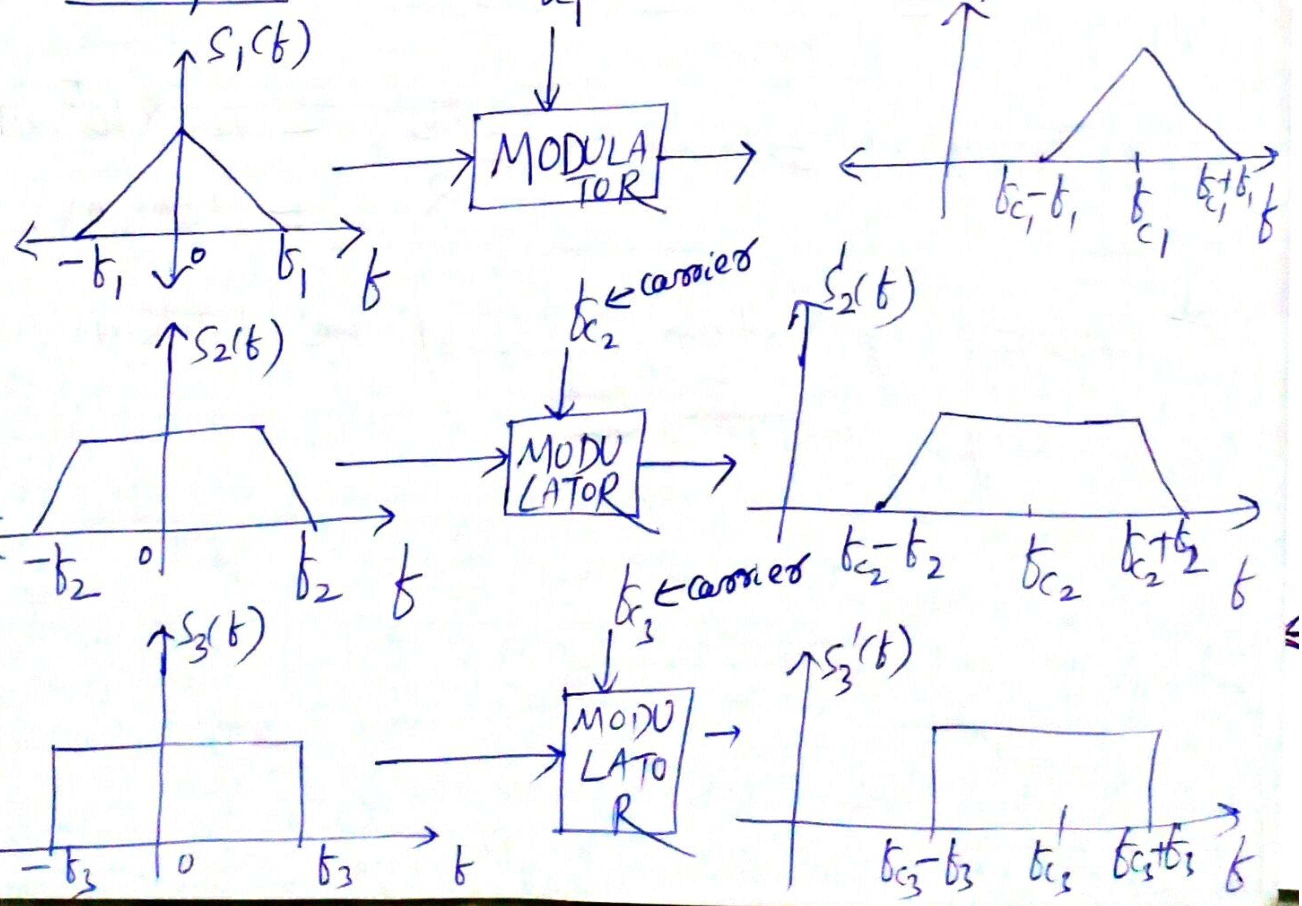
② Frequency Multiplexing : (To multiplex many signals)

→ Multiplexing is the technique to transmit more than one signal in a single channel.

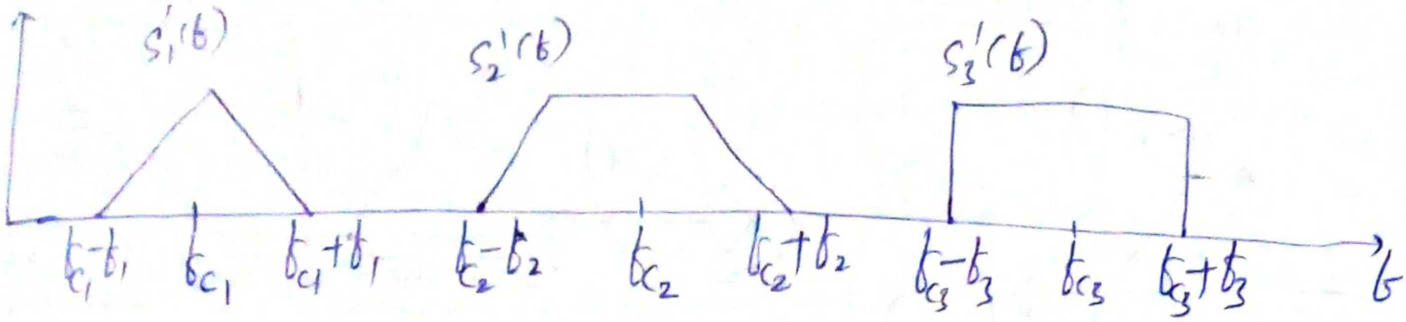
→ If we transmit more number of baseband signals in one channel, due to their common frequency range, they get interfered and information will be lost at the receiver sides.

→ So they all need to be different in their spectral ranges. In this scenario frequency translation is required and that is achieved with modulation.

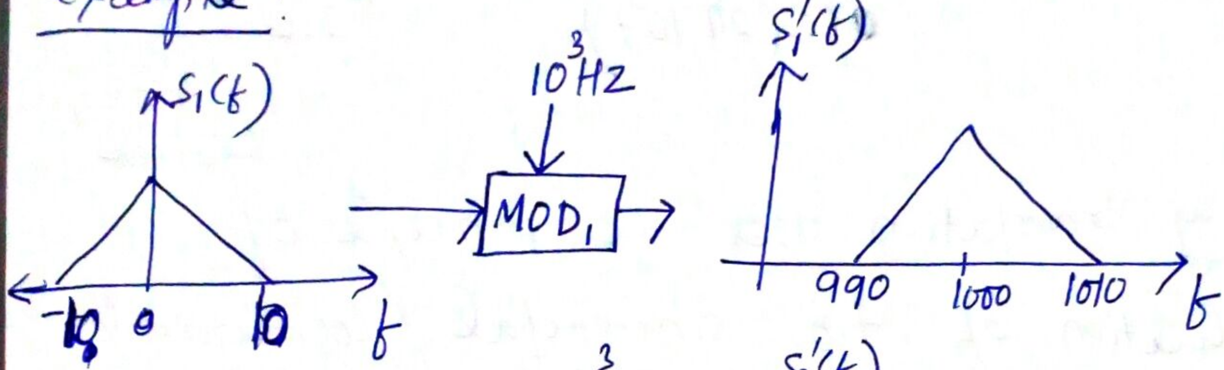
→ Example :

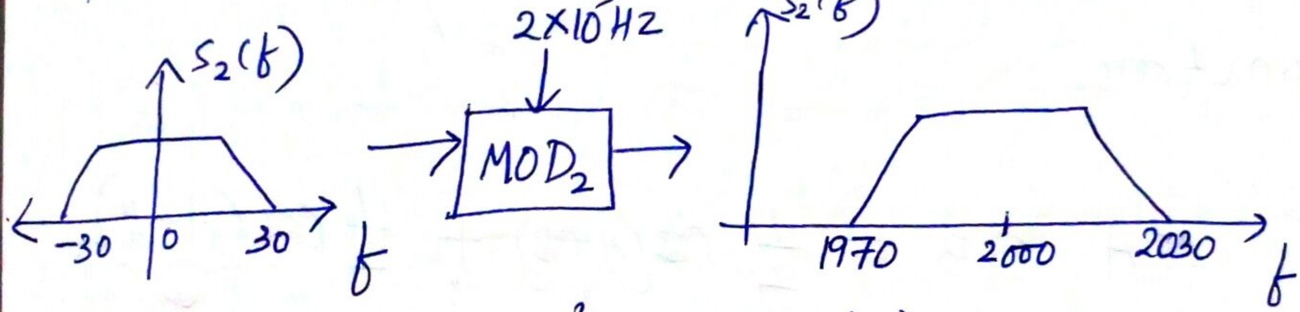


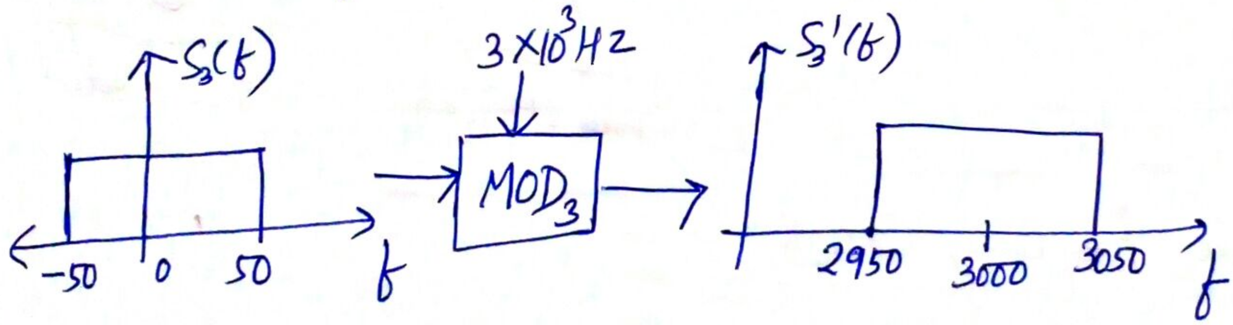
one channel



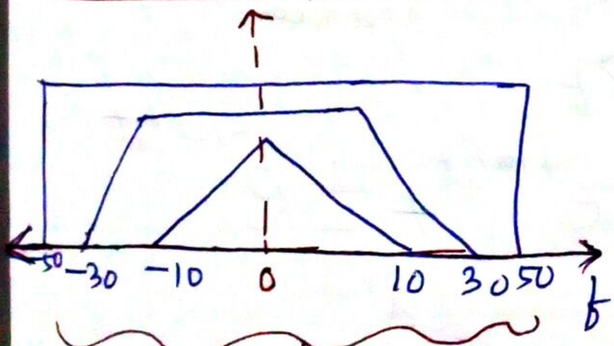
example:





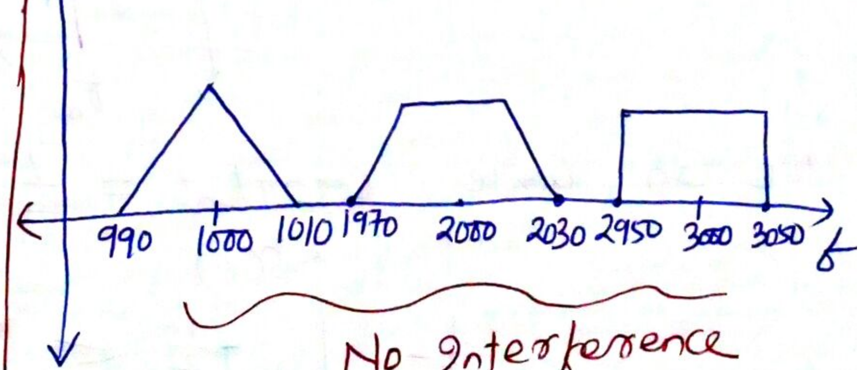


If multiplexing before modulation



Interference

After Modulation



No Interference

③ Common processing

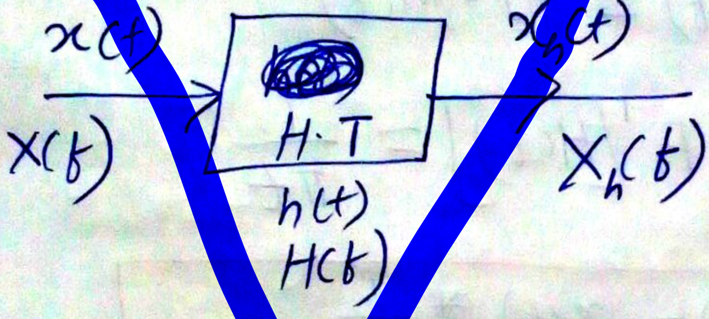
Consider a number of signals similar in general character but occupying different spectral ranges. To process those signals in one processor, defferent spectral range is converted into a common frequency range for common processing by a single processor. That can be done using Frequency Translation method.

ex:- Super heterodyne Receiver.

Hilbert Transform

Def^n: If $x(t)$ is a signal and its hilbert transform is represented by $x_h(t)$ or $\hat{x}(t)$ then $x_h(t)$ is obtained by providing $\frac{-\pi}{2}$ phase shift to every frequency components present in $x(t)$.

→

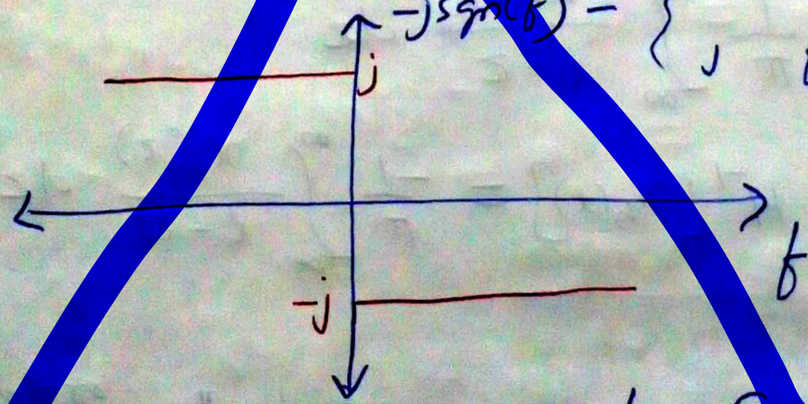


According to the definition

$$H(f) = -j\,\mathrm{sgn}(f)$$

sgn → signum function

$$-j\,\mathrm{sgn}(f) = \begin{cases} -j & f \geq 0 \\ j & f < 0 \end{cases}$$



→ The output of hilbert transform can be expressed as

$$x_h(t) = x(t) * h(t) \quad [* \rightarrow \text{Convolution}]$$

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

Using Fourier Transform & Inverse Fourier Transform formula as below

$$\boxed{\begin{aligned} X(f) &= \int_{-\infty}^{\infty} x(t)\, e^{-j2\pi f t}\, dt \\ x(t) &= \int_{-\infty}^{\infty} X(f)\, e^{j2\pi f t}\, df \end{aligned}}$$

For $H(f) = -j\,\mathrm{sgn}(f)$

$$h(t) = F^{-1}[H(f)] = \frac{1}{\pi t}$$

So
$$\boxed{\begin{aligned} x_h(t) &= x(t) * \frac{1}{\pi t} \\ \text{and} \quad X_h(f) &= -j\,\mathrm{sgn}(f)\, X(f) \end{aligned}}$$

$$x_h(t) = \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{x(\tau)}{t-\tau}\, d\tau$$

$$x(t) = H^{-1}[x_h(t)] = \frac{-1}{\pi} \int_{-\infty}^{\infty} \frac{x_h(\tau)}{t-\tau}\, d\tau$$

properties:

1. $x(t)$ and $x_h(t)$ are mutually orthogonal
2. If $H[x(t)] = x_h(t)$
   $\Rightarrow H[x_h(t)] = -x(t)$
3. If $F[x(t)] = X(f)$
   $F[x_h(t)] = -j\,\mathrm{sgn}(f)\, X(f)$

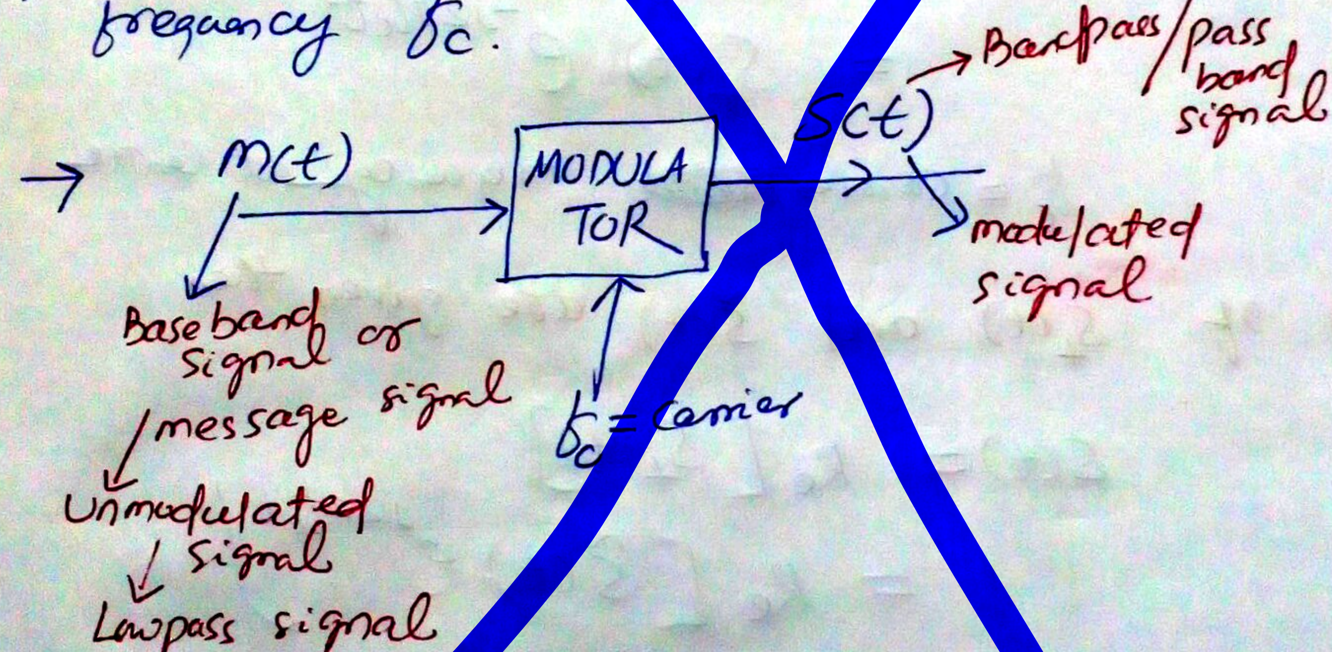
Applications:

→ H.T is used to find out Complex preenvelope of bandpass signal.

→ It is also used in SSB (Single sideband) modulation technique.

Complex preenvelope and envelope of Bandpass signal

→ Bandpass signal is centred around carrier frequency f_c.

→ 

* Baseband signal → Low pass signal
  band pass signal → band pass signal

* Bandpass signal is Frequency translated version of baseband signal.

Let $s(t)$ is a pass band signal & $s_h(t)$ or $\hat{s}(t)$ is its hilbert transform.

* Complex preenvelope

$$= S_+(t) = s(t) + j\, s_h(t)$$

* Complex envelope

$$= \tilde{s}(t) = [s(t) + j\, s_h(t)]\, e^{-j2\pi f_c t}$$

$$= S_+(t)\, e^{-j2\pi f_c t}$$

f_c = Carrier frequency at Centre

* If $S_+(t)$ and $\tilde{s}(t)$ are given then

$$s(t) = Re[S_+(t)]$$

$$= Re[\tilde{s}(t)\, e^{j2\pi f_c t}]$$

In frequency Domain

$$S_+(f) = F[s(t) + j\, s_h(t)]$$

$$= S(f) + j[-j\, sgn(f)\, S(f)]$$

$$= S(f) + sgn(f)\, S(f)$$

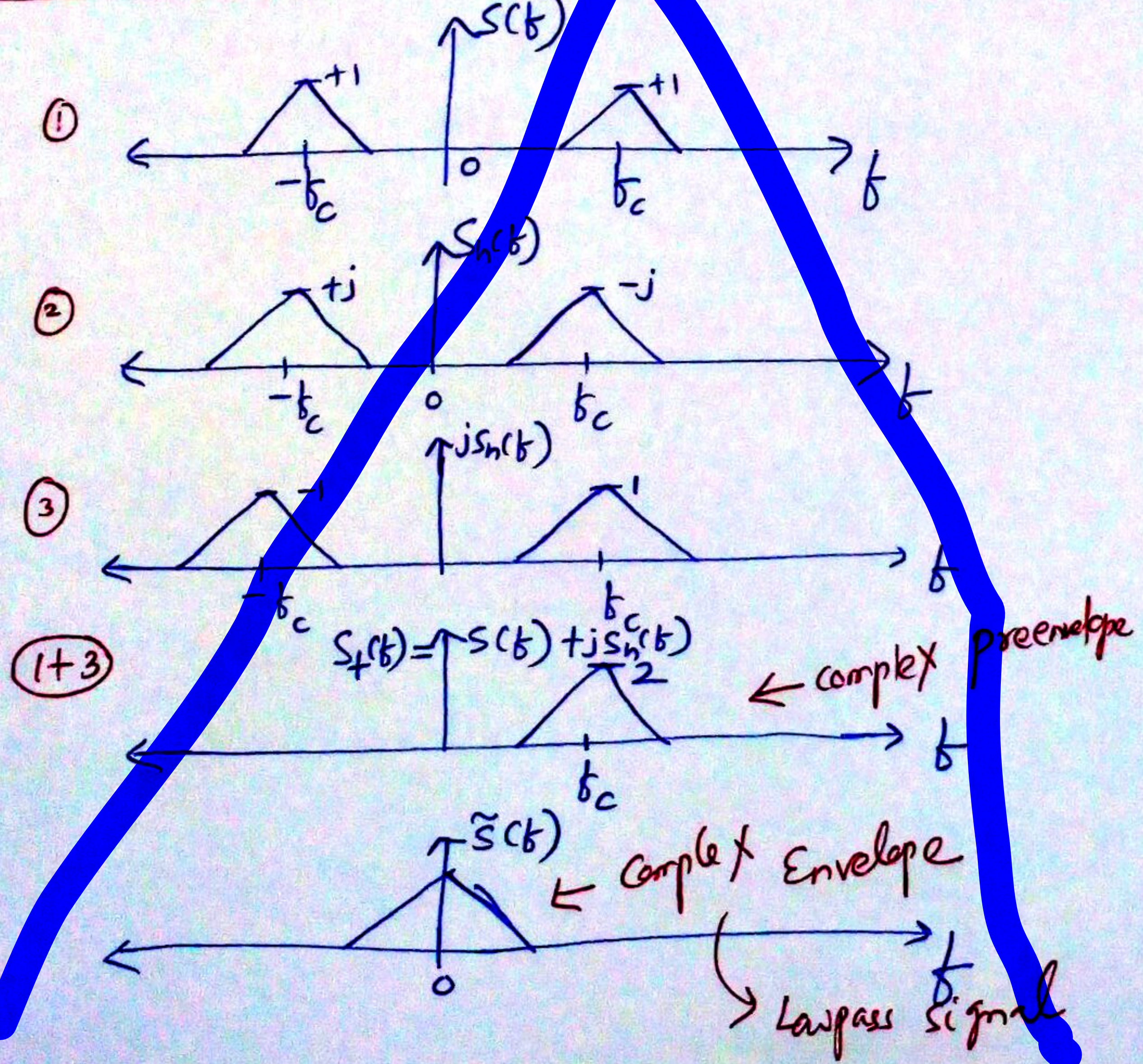
Using values of sgn(f)

$$S_+(f) = \begin{cases} s(f) + s(f) = 2s(f) & f > 0 \\ 0 & f < 0 \end{cases}$$

$$\rightarrow \tilde{S}(f) = F\left[S_+(t)\, e^{-j2\pi f_c t} \right]$$

$$\boxed{\tilde{S}(f) = S_+(f + f_c)}$$

In frequency/spectral diagram:-



CHAPTER-2 : Amplitude Modulation & Demodulation

Chapter Coverage: Amplitude modulation, different types of AM modulator and demodulator, DSB-SC modulator & demodulators, SSB-SC modulation & demodulation, Modified SSB, VSB-SC modulator, power and bandwidth Calculation of all AM schemes, FDM techniques & AM Radio Receivers.

→ Modulation is a process that causes a shift in the range of frequencies in a signal.

→ In ch-1 we have discussed the needs of modulation.

→ Communication without modulation i.e transmission of original baseband signal without Carrier wave is termed as baseband communication.

→ Transmission of baseband Signal with Carrier using modulation is termed as Bandpass/passband/Carrier Communication.

→ In Modulation, Characteristics (Amplitude/ Frequency/ phase) of Carrier are changed or varied according to baseband signal. As a result the frequency of baseband signal is changed or shifted to new frequency range Centred at carrier frequency.

→

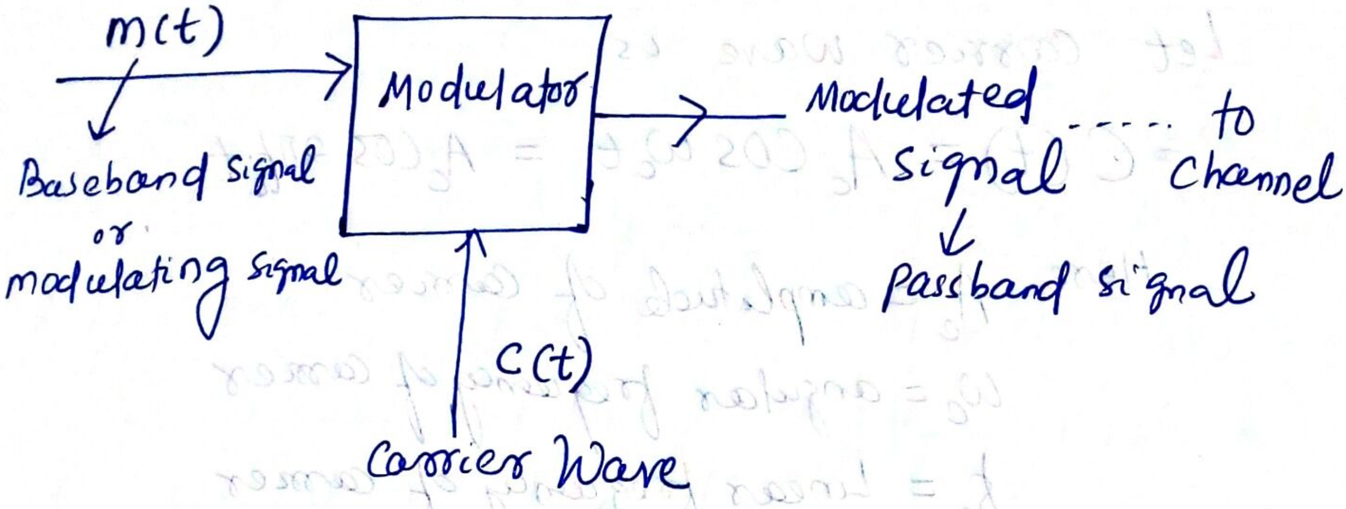
Analog Modulation

- Amplitude Modulation (AM)
- Angle Modulation
  - Frequency Modulation (FM)
  - Phase Modulation (PM)

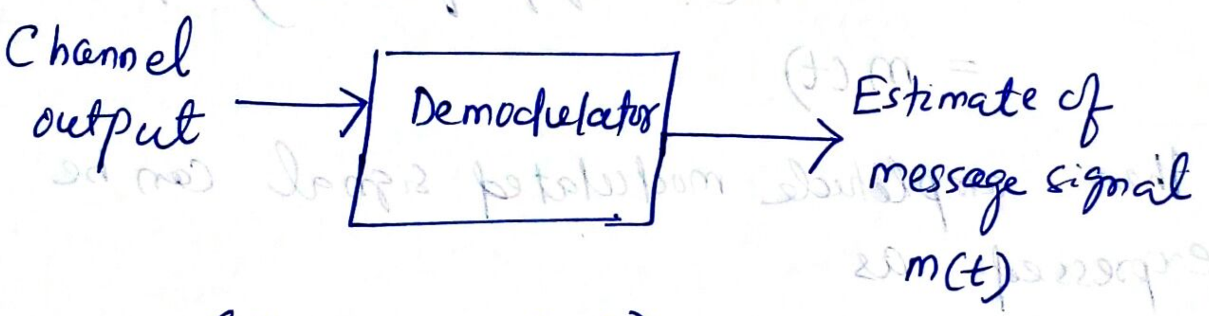
→ In the transmitter side modulation operation is carried out.

→ Demodulation is the reverse process of modulation, through which message/baseband signal is retrived/extracted from modulated signal.

→



(Transmitter side)



(Receiver side)

Amplitude Modulation:

→ It is known as Full-AM or DSB-FC (→ DSB-C modulation).

→ It is a Linear-type modulation.

- DSB-FC → Double side band Full-Carrier

① Definition:

→ In AM, the amplitude of carrier wave is varied in proportion to the baseband (message) signal. Here frequency and phase of carrier remain unchanged.

② Expression:

Let carrier wave is

$= C(t) = A_c \cos \omega_c t = A_c \cos 2\pi f_c t$

Here A_c = amplitude of carrier

ω_c = angular frequency of carrier

f_c = Linear frequency of carrier

* f_c should be very much greater than highest message frequency.

Let base band (message/information) signal is

$= m(t)$

then amplitude modulated signal can be expressed as

$$S_{AM}(t) = A_c'(t) \cos 2\pi f_c t$$

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

Here K_a = amplitude sensitivity. Its unit is $\frac{1}{\text{amplitude}}$.

→ After AM, carrier amplitude has been varied and Let

$A'_{c\,max}$ = maximum amplitude of modulated wave

$A'_{c\,min}$ = minimum amplitude

A_c = amplitude of unmodulated carrier then

modulation index in AM or ~~percentage~~ depth of modulation = $\dfrac{\text{change in amplitude of carrier}}{\text{original amplitude of unmodulated carrier}}$

$$\Rightarrow \mu_a = \frac{A'_{c_{max}} - A_c}{A_c} = \frac{A_c - A'_{c_{min}}}{A_c}$$

$$= \frac{A'_{c_{max}} - A'_{c_{min}}}{2A_c}$$

So we can write

$$A'_{c_{max}} = A_c(1+\mu_a)$$

$$A'_{c_{min}} = A_c(1-\mu_a)$$

$$\Rightarrow \boxed{\frac{A'_{c_{max}} - A'_{c_{min}}}{A'_{c_{max}} + A'_{c_{min}}} = \mu_a}$$

→ As $A'_c = A_c\left[1 + K_a m(t)\right]$

$$A'_{c_{max}} = A_c\left[1 + K_a\, m(t)_{max}\right]$$

$$A'_{c_{min}} = A_c\left[1 + K_a\, m(t)_{min}\right]$$

$$\mu_a = \frac{A'_{c_{max}} - A_c}{A_c} = \frac{A_c + A_c k_a m(t)_{max} - A_c}{A_c}$$

$$\mu_a = k_a m(t)_{max}$$

In General $\boxed{\mu_a = |k_a m(t)|_{max}}$

* k_a value is taken in proportion to $\frac{1}{A_c}$.

If $k_a = \frac{1}{A_c}$

then $\boxed{\mu_a = \frac{|m(t)|_{max}}{A_c}}$

* If

$\mu_a < 1 \rightarrow$ Undermodulation

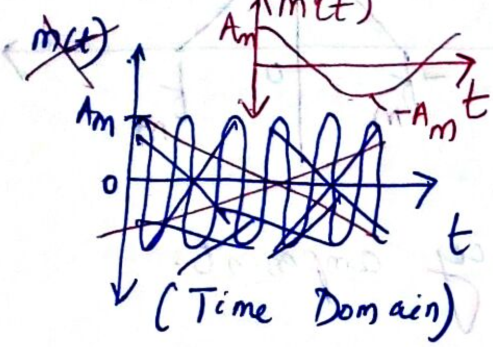
$\mu_a = 1 \rightarrow$ 100% modulation or critical modulation

$\mu_a > 1 \rightarrow$ over modulation.

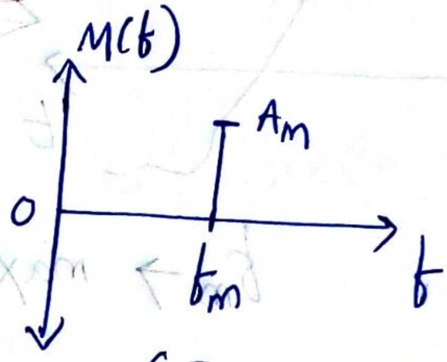
* In Communication, $c(t)$ is known to be a sinusoidal / cosinusoidal waveform. But $m(t)$ can not be known. $m(t)$ is a random signal. It can be of any shape (arbitrary).

To analyse modulation we will consider different cases.

Case-1 :- Single tone m(t) :



FS $\Longleftrightarrow$



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

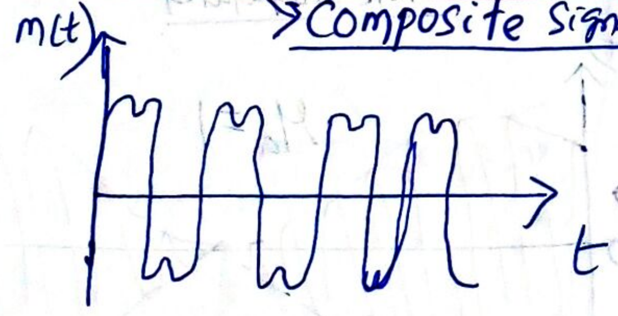
A_m = Amplitude of baseband signal

f_m = Maximum frequency of baseband signal.

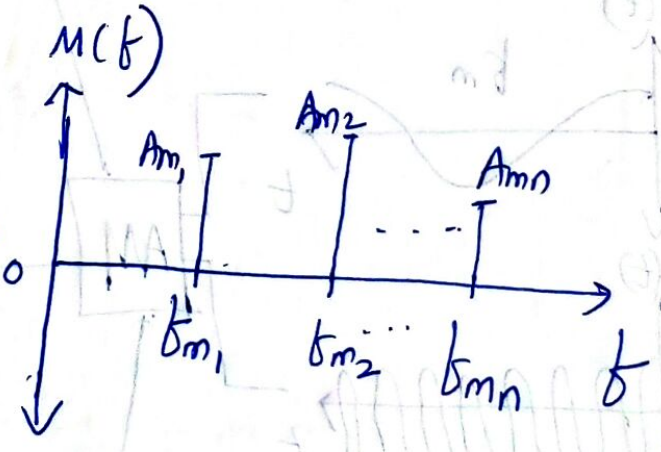
$$f_c >>> f_m$$

Case-2 :- Multitone m(t) :-

→ Composite Signal



FS $\Longleftrightarrow$



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

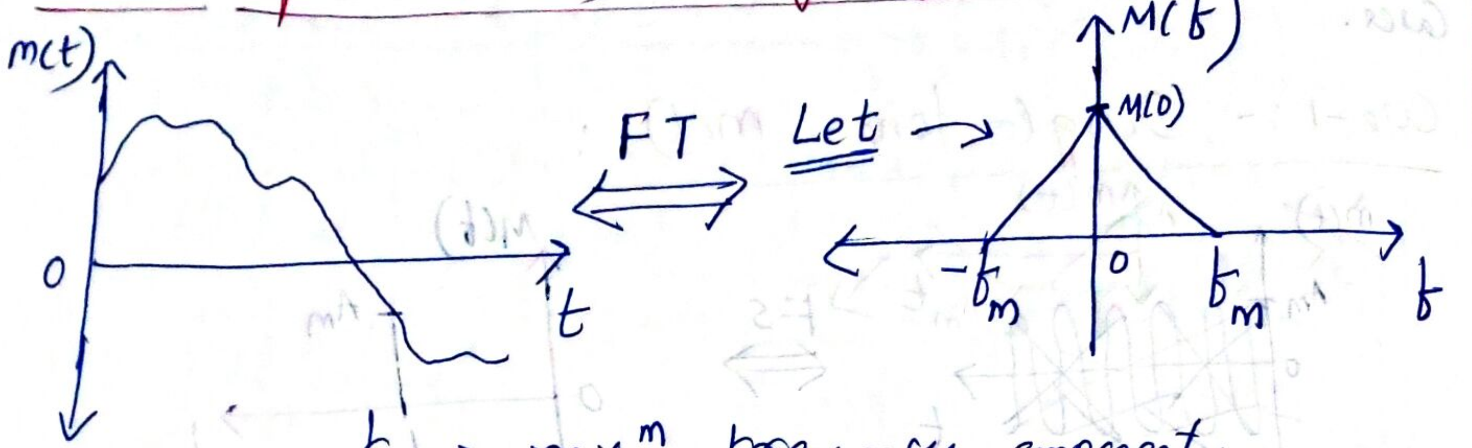
$A_{m_1} \cdots A_{m_n}$ → Different amplitudes

$f_{m_1} \cdots f_{m_n}$ → Different frequencies

f_{m_n} → Highest frequency components

* $f_c >>> f_{m_n}$

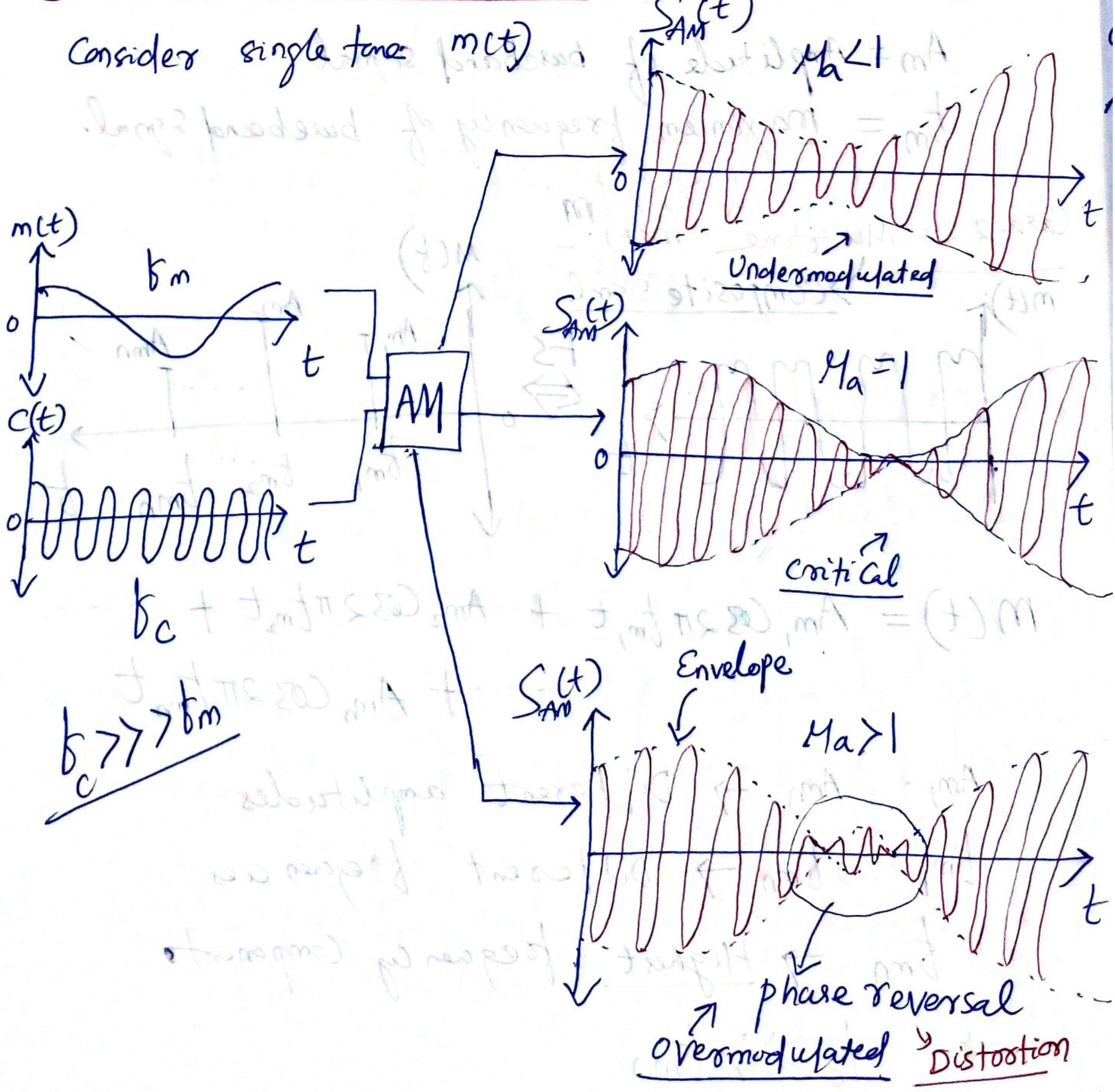
Case-3 : Aperiodic $m(t)$ of any shape :



$f_m \rightarrow max^m$ frequency component.

③ Time Domain Diagram :

Consider single tone $m(t)$

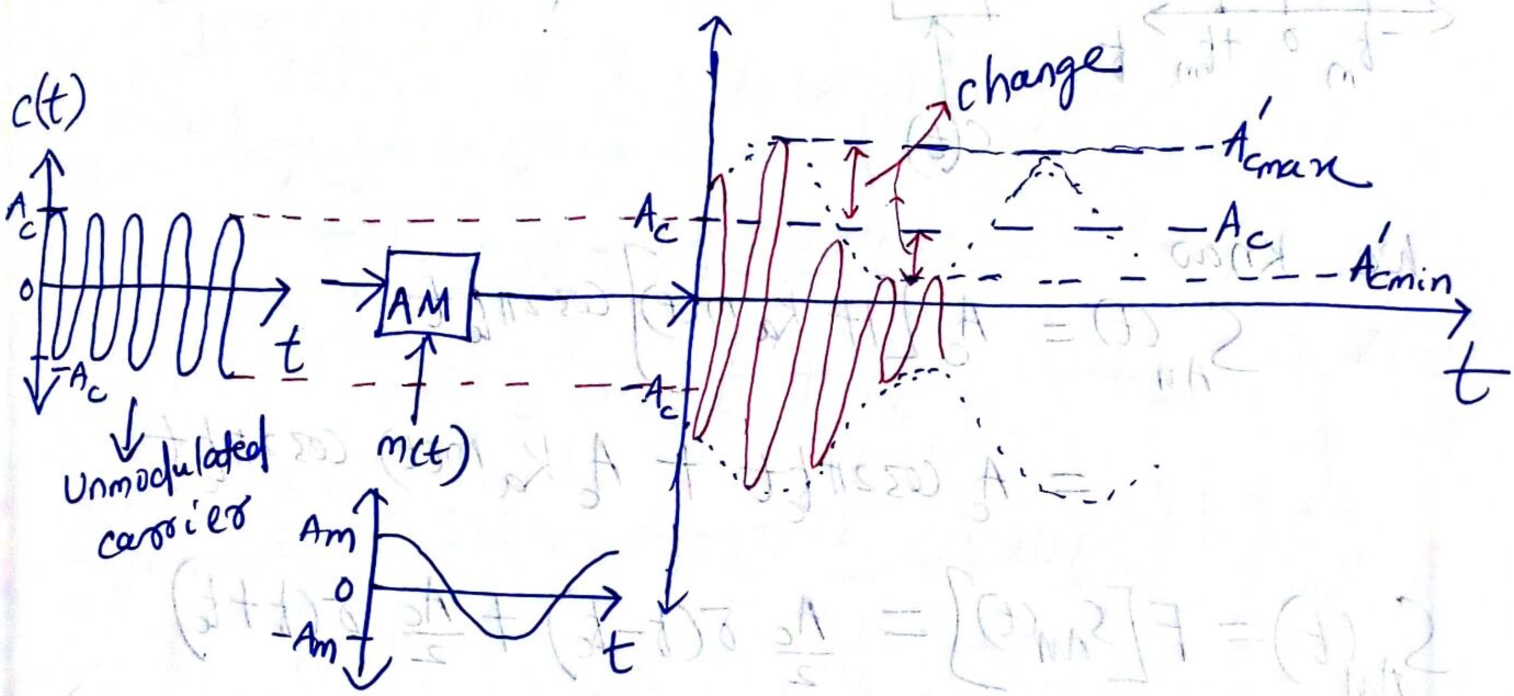


$f_c >>> f_m$

* We Know

$$S_{AM}(t) = \underbrace{A_c[1 + K_a m(t)]}_{\text{Envelope}} \cos 2\pi f_c t$$

∴ message m(t) lies in the envelope of modulated $S_{AM}(t)$.



* %age of modulation = $K_a \times 100\%$

④ Spectral Domain Diagram & Bandwidth Evaluation

→ Spectral diagram is also known as Frequency domain diagram.

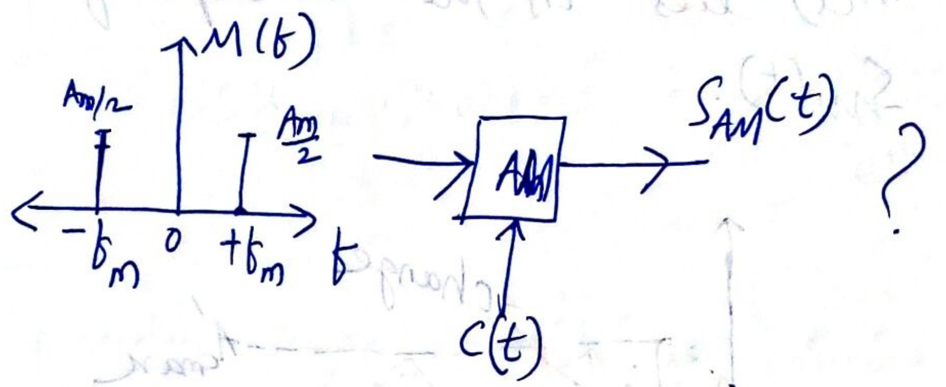
→ It may be represented as single sided or double sided.

→ Bandwidth of signal = $f_H - f_L$

Case-1:

$m(t)$ = single tone signal

and $M(f)$ is its spectral Domain signal



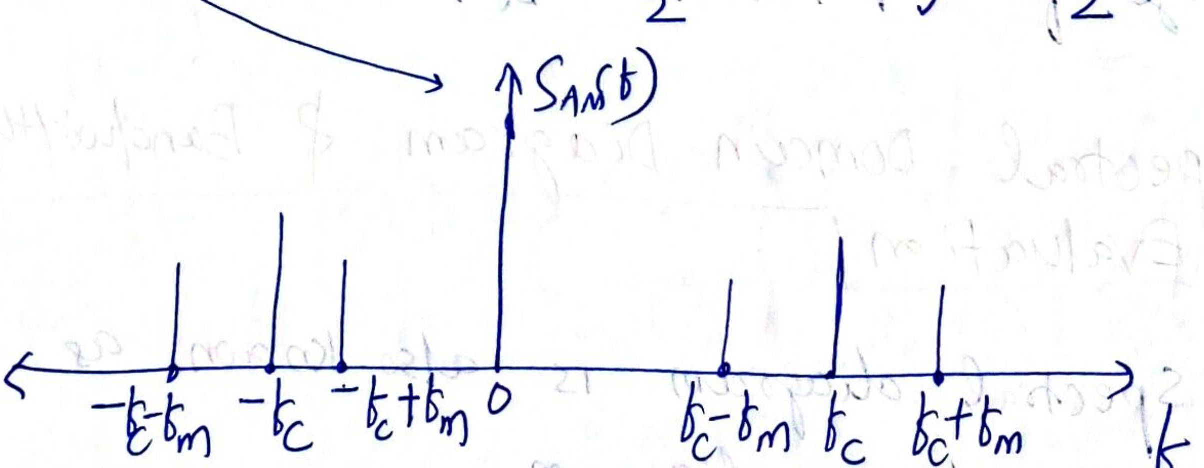
We know

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

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

$$S_{AM}(f) = F\left[S_{AM}(t)\right] = \frac{A_c}{2}\delta(f - f_c) + \frac{A_c}{2}\delta(f + f_c)$$

$$+ \frac{A_c k_a}{2} M(f + f_c) + \frac{A_c k_a}{2} M(f - f_c)$$



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

$$S_{AM_{\text{single tone}}}(t) = A_c \left[1 + k_a A_m \cos 2\pi f_m t\right] \cos 2\pi f_c t$$

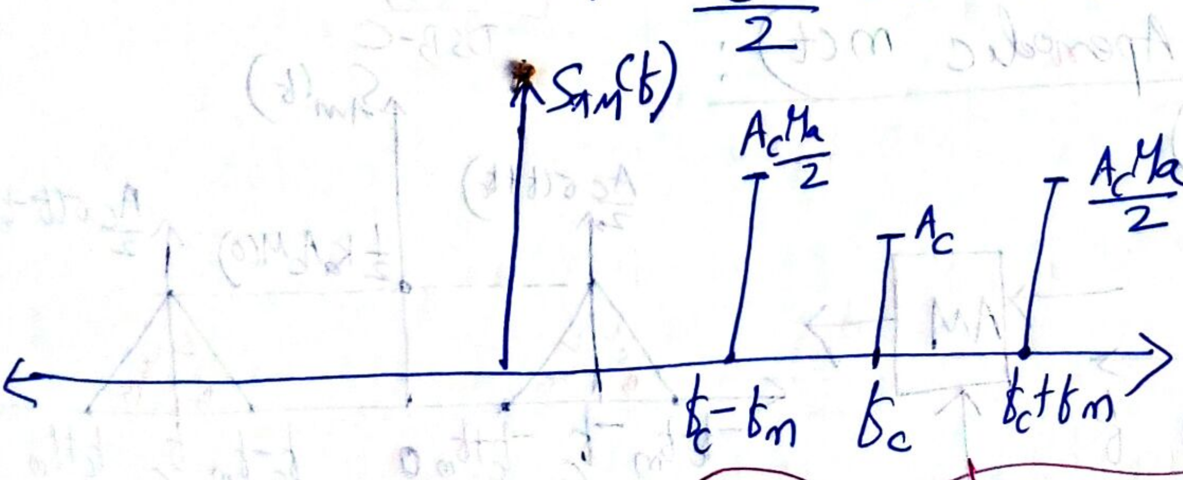
We can write

$$k_a A_m = \mu_a = \text{modulation index in AM}$$

$$\Rightarrow S_{AM_{\text{single tone}}}(t) = A_c \left[1 + \mu_a \cos 2\pi f_m t\right] \cos 2\pi f_c t$$

$$= A_c \cos 2\pi f_c t + A_c \mu_a \cos 2\pi f_m t \cdot \cos 2\pi f_c t$$

$$\Rightarrow S_{AM}(t) = A_c \cos 2\pi f_c t + \frac{A_c \mu_a}{2} \cos 2\pi (f_c + f_m) t + \frac{A_c \mu_a}{2} \cos 2\pi (f_c - f_m) t$$



(Single sided spectrum)

Double side band

f_c to $f_c + f_m$ → Upper side band (USB)

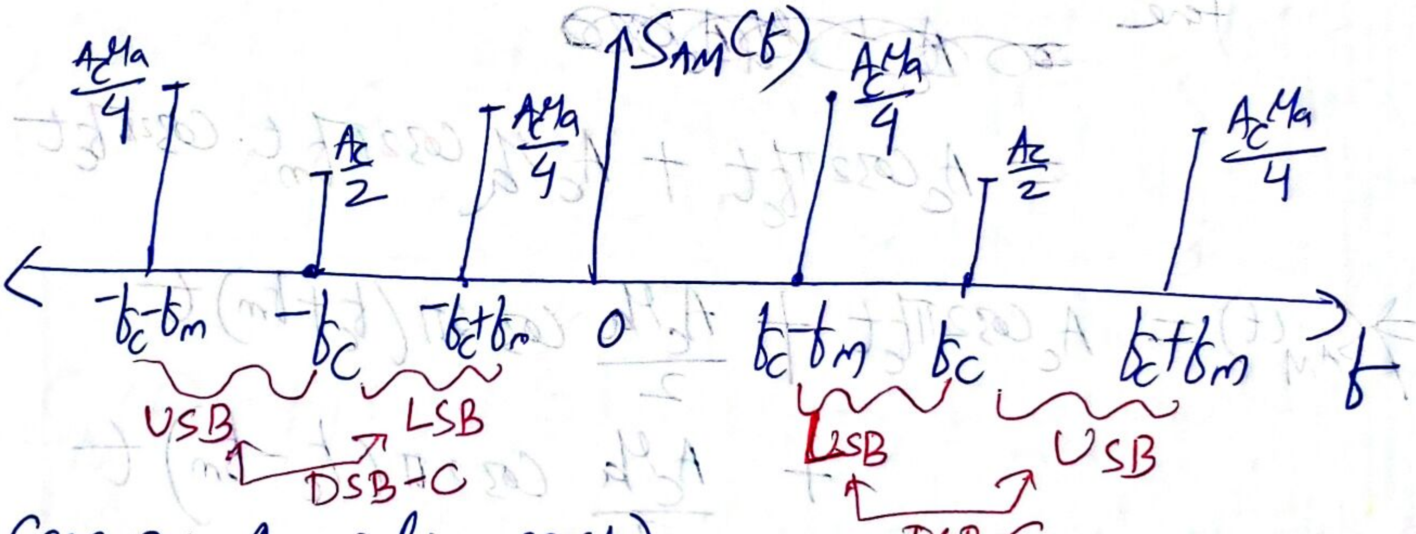
$f_c - f_m$ to f_c → Lower side band (LSB)

LSB + USB → DSB

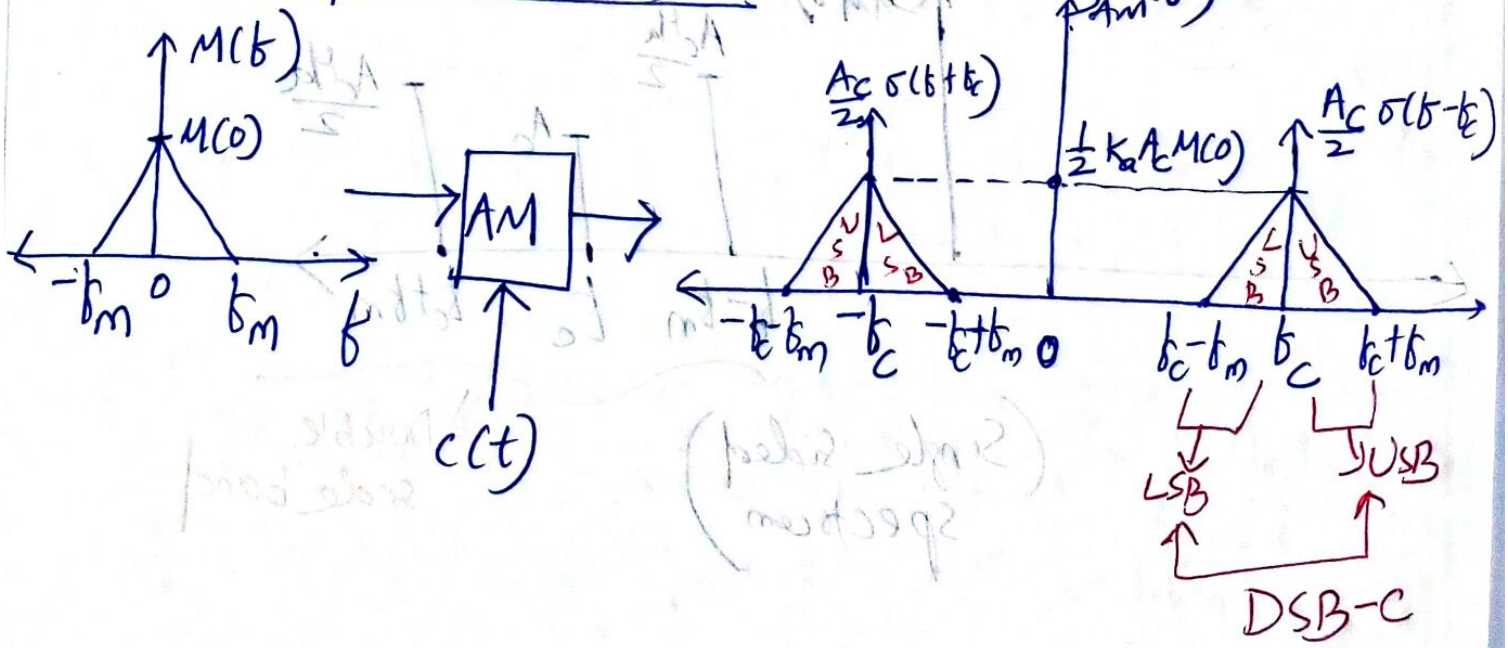
DSB + carrier → DSB-C or DSB-FC

→ Full AM

It can be represented in double sided spectrum as



Case-2: Aperiodic m(t):



Bandwidth of $S_{AM}(t)$ is

$$BW_{AM} = f_H - f_L$$

$$= f_c + f_m - (f_c - f_m)$$

$$\Rightarrow \boxed{BW_{AM} = 2f_m}$$

(5) power Calculation & Efficiency Evaluation

→ The graph b/w Amplitude Vs frequency is called as Amplitude spectrum. & the graph between power Vs frequency is called as power spectrum.

→ In AM, we have different power components.

We know

$$S_{AM}(t) = A_c \cos 2\pi f_c t + \frac{A_c M_a}{2} \cos 2\pi (f_c - f_m) t + \frac{A_c M_a}{2} \cos 2\pi (f_c + f_m) t$$

$$m(t) = A_m \cos 2\pi f_m t \text{ (Single tone)}$$

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

Before modulation

power of base band message

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

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

After modulation:

power of AM signal:

It consists of three terms

so total power $= \underbrace{\frac{A_c^2}{2}}_{P_c} + \underbrace{\frac{A_c^2 \mu_a^2}{8}}_{P_{LSB}} + \underbrace{\frac{A_c^2 \mu_a^2}{8}}_{P_{USB}}$

→ power of lower side band $(f_c - f_m) = \frac{\left(\frac{A_c \mu_a}{2}\right)^2}{2} = \frac{A_c^2 \mu_a^2}{8}$
$= P_{USB}$

→ power of AM $= P_T = P_c + P_{LSB} + P_{USB}$
$= P_c + P_{DSB}$

→ power of double side band $= P_{DSB} = 2 \times \frac{A_c^2 \mu_a^2}{8}$
$= \frac{A_c^2 \mu_a^2}{4} = P_c \frac{\mu_a^2}{2}$

Again $P_T = P_c + \frac{A_c^2 \mu_a^2}{4} = P_c + P_c \frac{\mu_a^2}{2} = P_c\left(1+\frac{\mu_a^2}{2}\right)$

$$\Rightarrow \boxed{P_T = P_c\left(1+\frac{\mu_a^2}{2}\right)}$$

power Efficiency:

$$\eta = \frac{\text{Desired power at receiver (Useful)}}{\text{Total power transmitted from transmitter}}$$

$$= \frac{P_{DSB}}{P_T} \quad \left(\text{Desired is side band power}\right)$$

$$= \frac{P_c \mu_a^2}{2} \bigg/ P_c\left(1+\frac{\mu_a^2}{2}\right)$$

$$\Rightarrow \boxed{\eta = \frac{\mu_a^2}{2+\mu_a^2}}$$

* For 100% modulation $\mu_a = 1 \Rightarrow \boxed{\eta = \frac{1}{3} = 33\%}$

→ We know that for $\mu_a > 1$, there will be signal distortion. So we can say without distortion

$$\eta_{max} = 33\%$$

→ For $\mu_a = 1$, 67% power is being wasted.

Disadvantages of DSB-C:

① It is bandwidth/spectrum inefficient as its total transmission BW $= 2f_m$ as here both USB & LSB are present.

② It is power inefficient as the carrier power present in it is the wastage of power.

③ Effect of noise is more.

* In communication, scientists are always searching for spectral efficient, energy efficient and hardware efficient communication system.

* Multitone DSB-FC:

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

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

So $S_{AM}(t) = A_c [1 + K_a m(t)] \cos 2\pi f_c t$ is written as

$$= A_c \left[1 + K_a A_{m_1} \cos 2\pi f_{m_1} t + K_a A_{m_2} \cos 2\pi f_{m_2} t + \cdots + K_a A_{m_n} \cos 2\pi f_{m_n} t\right] \cos 2\pi f_c t$$

Here individual modulation index is

$\mu_{a_1} = K_a A_{m_1}$, $\mu_{a_2} = K_a A_{m_2}$ ... $\mu_{a_n} = K_a A_{m_n}$

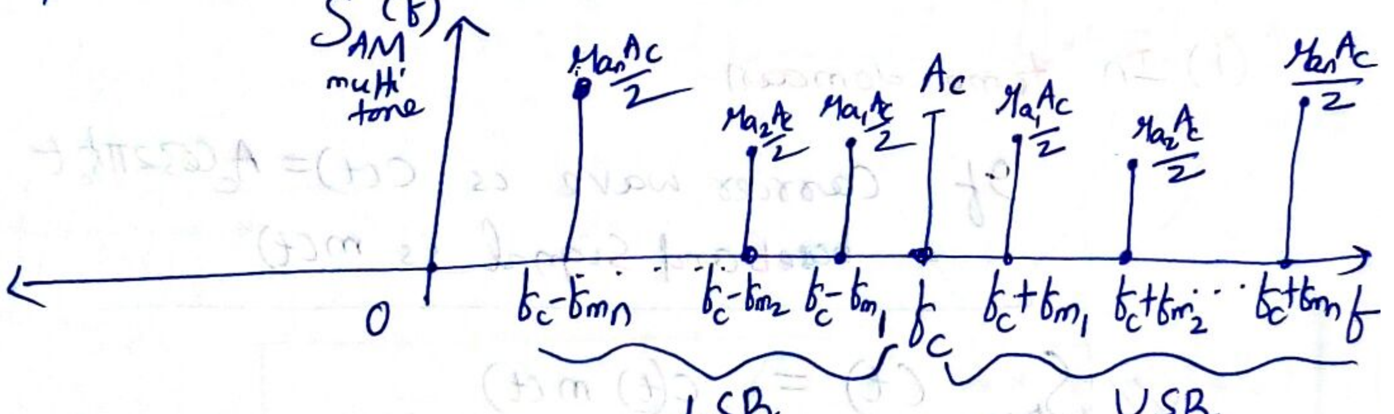
Total equivalent modulation index is

$$\mu_{a_T} = \sqrt{\mu_{a_1}^2 + \mu_{a_2}^2 + \cdots + \mu_{a_n}^2}$$

→ Total power $= P_T = P_c\left(1 + \frac{\mu_{a_T}^2}{2}\right)$

DSB power $= \frac{P_c \mu_{a_T}^2}{2}$

→ Spectral domain diagram:



$$\boxed{BW = 2 \times f_{m_n} = 2 \times \text{highest frequency}}$$

Double Side Band Supressed Carrier (DSB-SC)

→ DSB-SC is also called as double side band without carrier.

① Def^n → DSB-SC is more power efficient than DSB-C or DSB-FC as in DSB-SC carrier power 'P_c' is supressed.

② Expression of DSB-SC

(i) In time domain-

If carrier wave is $c(t) = A_c \cos 2\pi f_c t$

baseband signal is $m(t)$

$$\boxed{\begin{aligned} S_{DSB-SC}(t) &= c(t)\, m(t) \\ &= A_c \cos 2\pi f_c t\, m(t) \end{aligned}}$$

(ii) In frequency domain-

$$S_{DSB-SC}(f) = \frac{1}{2} A_c \left[M(f+f_c) + M(f-f_c) \right]$$

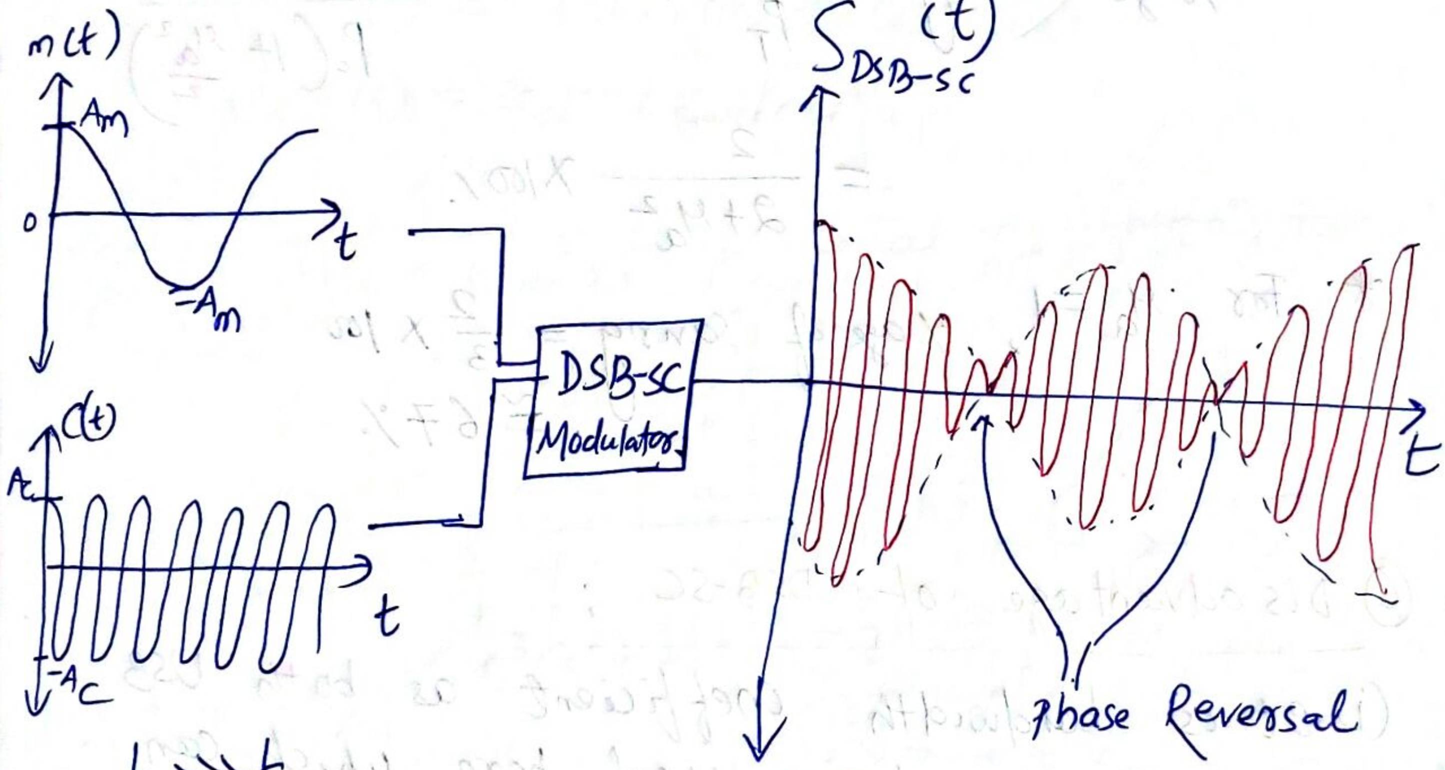
* Let $m(t) = A_m \cos 2\pi f_m t$ (single tone)

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

$$= \underbrace{\frac{A_c A_m}{2} \cos 2\pi (f_c + f_m) t}_{USB} + \underbrace{\frac{A_m A_c}{2} \cos 2\pi (f_c - f_m) t}_{LSB}$$

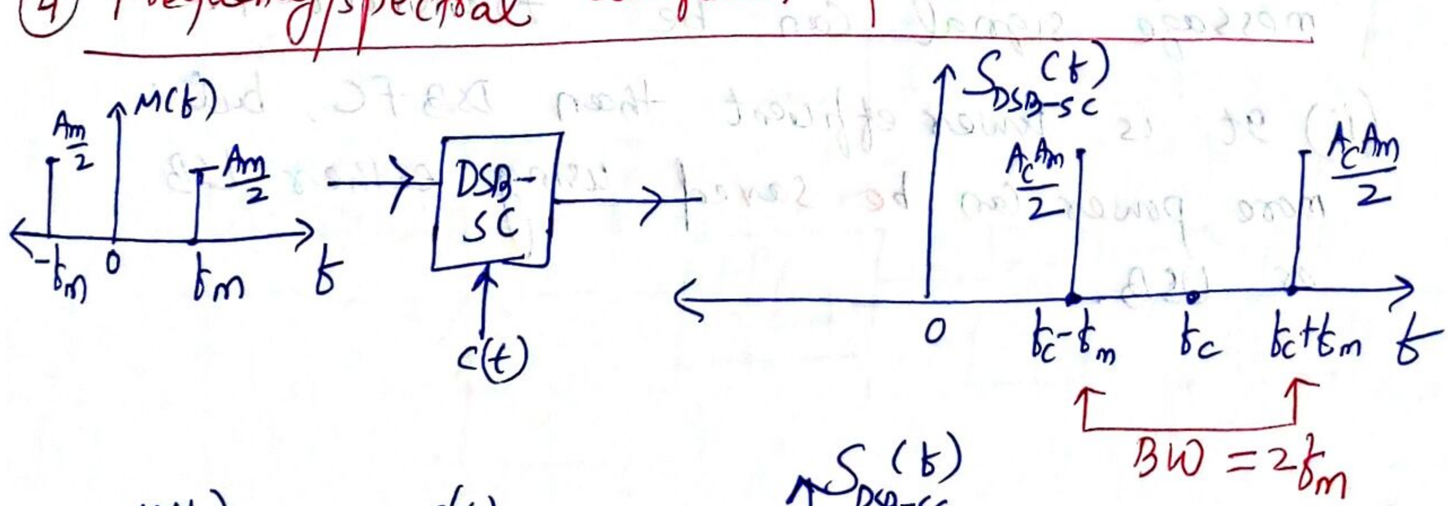
So we can confirm that in $S_{DSB-SC}(t)$, there is absence of '$A_c \cos \omega_c t$' (carrier). Hence it is known as double side band supressed carrier.

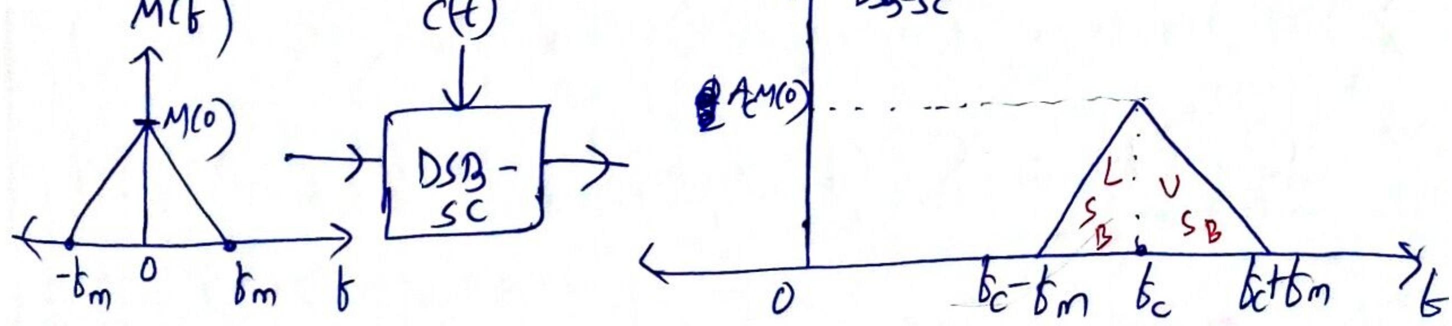
③ Time Domain Diagram :



$f_c >>> f_m$

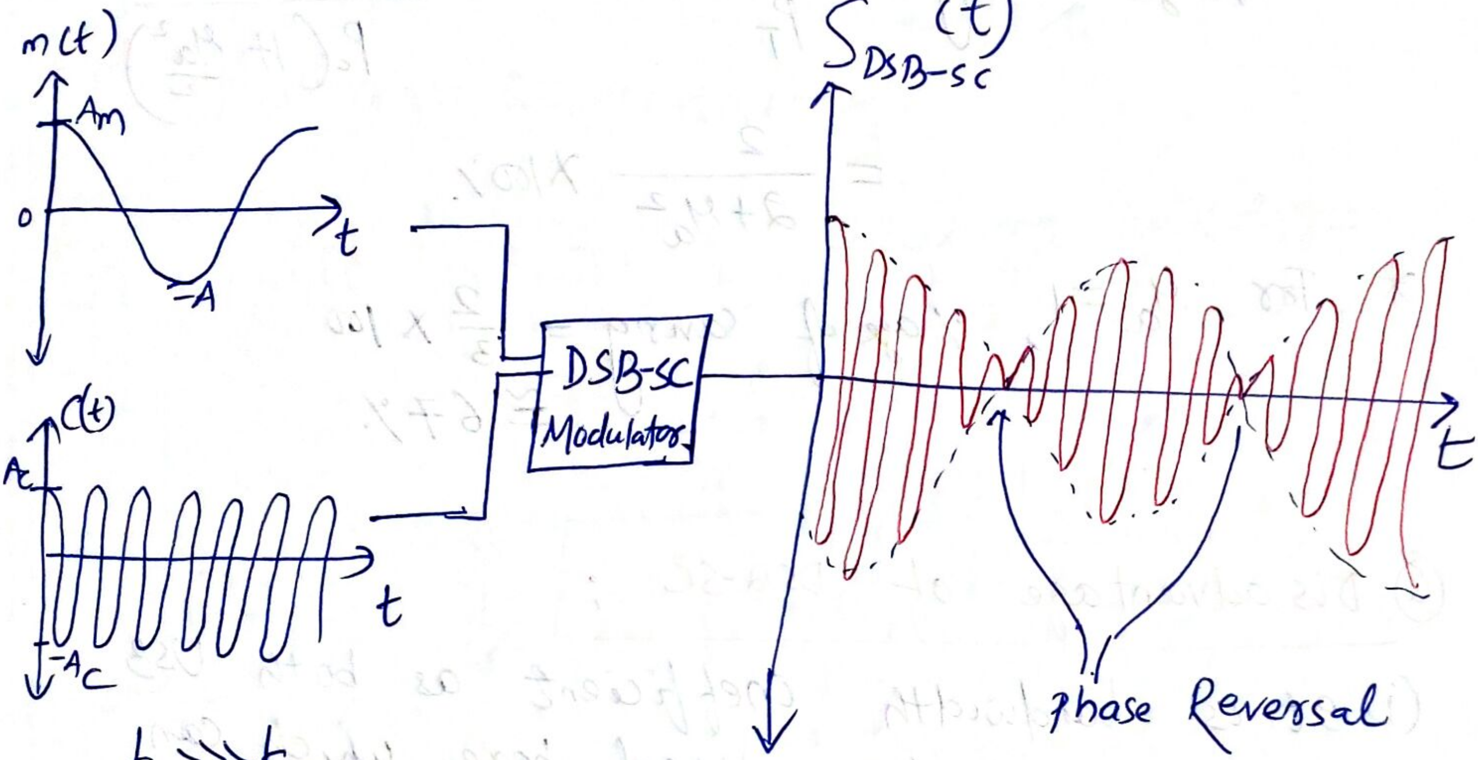
④ Frequency/spectral diagram & BW evaluation





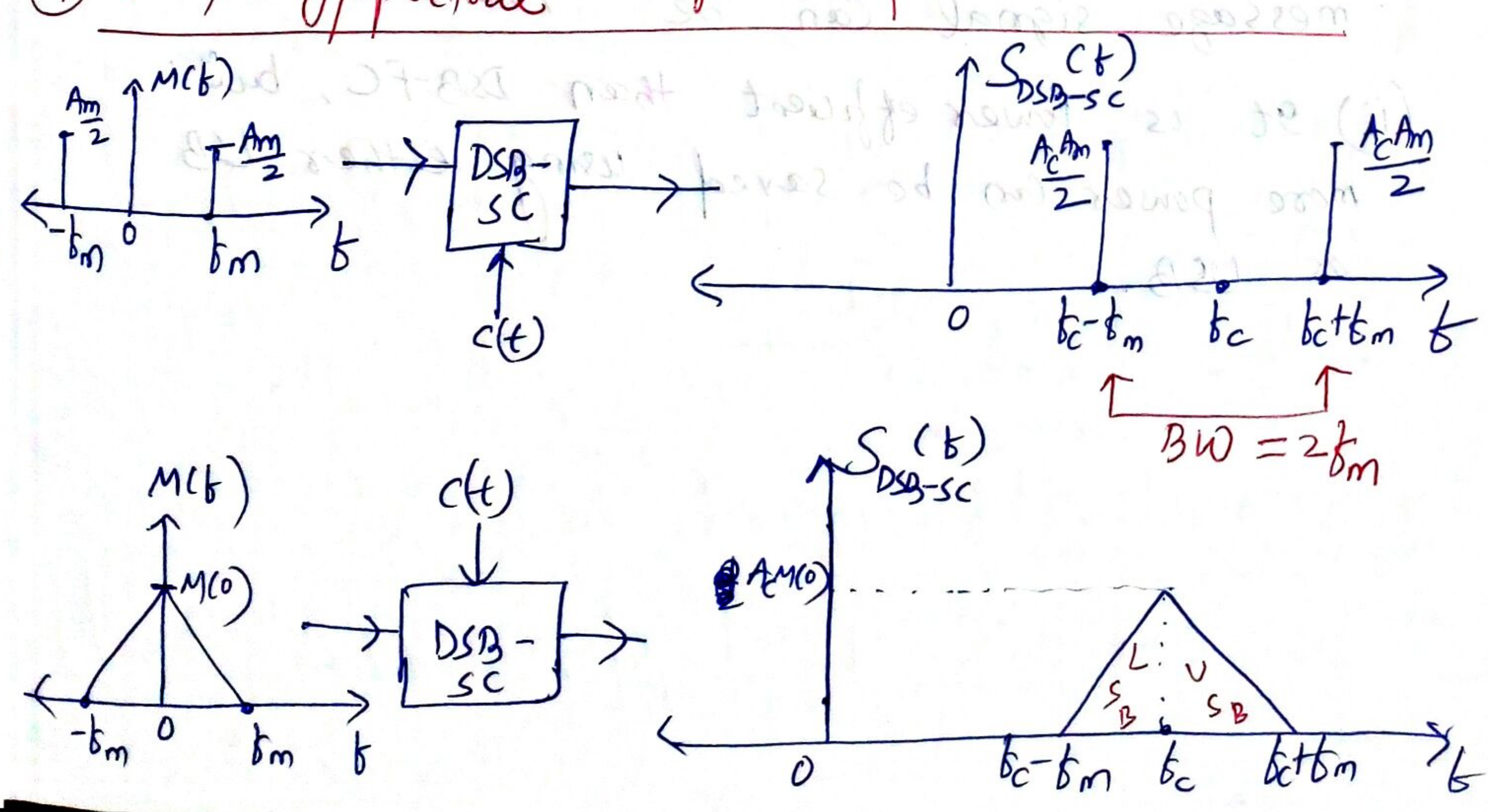
So we can confirm that in $S_{DSB-SC}(t)$, there is absence of '$A_c \cos \omega_c t$' (carrier). Hence it is known as double side band supressed carrier.

③ Time Domain Diagram :



$f_c >>> f_m$

④ Frequency/spectral diagram & BW evaluation



(5) Power efficiency & power saving :→

→ % age of power saving in DSB-SC with respect to DSB-FC is

$$\%\text{age saving} = \frac{P_c}{P_T} \times 100\% = \frac{P_c}{P_c\left(1+\frac{\mu_a^2}{2}\right)}$$

$$= \frac{2}{2+\mu_a^2} \times 100\%$$

* For $\mu_a = 1$, % age of saving $= \frac{2}{3} \times 100$

$\cong 67\%$

(6) Disadvantage of DSB-SC :

(i) It is bandwidth inefficient as both USB and LSB are transmitted here which can be avoided and using only LSB or USB message signal can be transmitted.

(ii) It is power efficient than DSB-FC, but more power can be saved using either LSB or USB.

Single Side Band Supressed Carrier (SSB-SC)

Def^n: In single side band either USB or LSB is transmitted.

Expression:

→ Time Domain

We know for single tone m(t)

$$S_{DSBSC}(t) = \underbrace{\frac{A_cA_m}{2}\cos 2\pi(f_c-f_m)t}_{LSB} + \underbrace{\frac{A_cA_m}{2}\cos 2\pi(f_c+f_m)t}_{USB}$$

→ SSBSC expression can be of two types.

$$\boxed{\begin{aligned} S_{USB-SC}(t) &= \frac{A_cA_m}{2}\cos 2\pi(f_c+f_m)t \\ S_{LSBSC}(t) &= \frac{A_cA_m}{2}\cos 2\pi(f_c-f_m)t \end{aligned}}$$

→ On Expanding we get

$$S_{USBSC}(t) = \frac{A_cA_m}{2}\cos 2\pi f_ct\cdot\cos 2\pi f_mt - \frac{A_cA_m}{2}\sin 2\pi f_ct\cdot\sin 2\pi f_mt$$

$$= 0.5A_c\,m(t)\cos 2\pi f_ct - 0.5A_c\,m_h(t)\sin 2\pi f_ct$$

$m_h(t)$ is the hilbert transform of m(t)

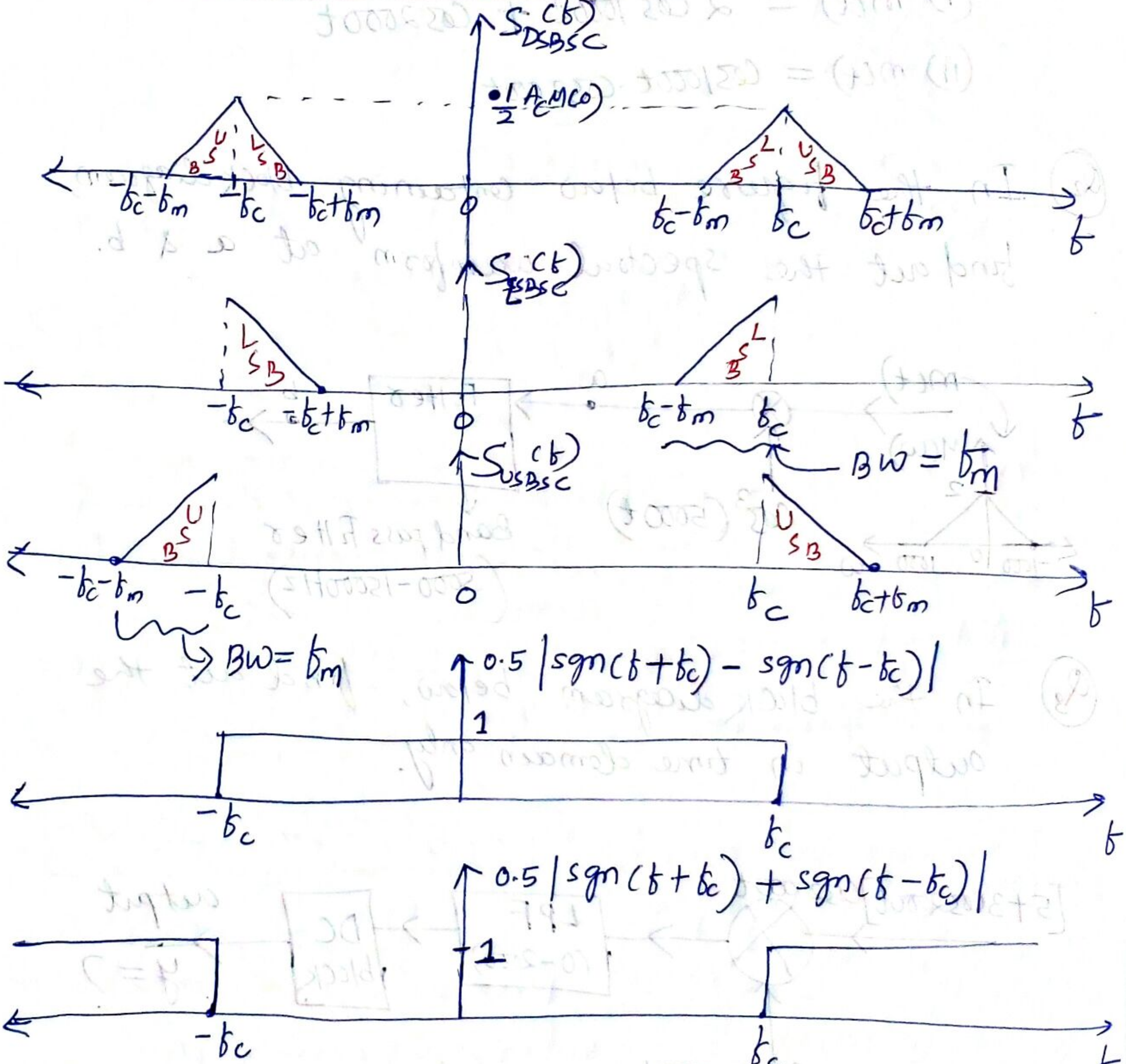
$$S_{LSB-SC}(t) = 0.5A_c\,m(t)\cos 2\pi f_ct + 0.5\,m_h(t)\sin 2\pi f_ct$$

So we can write ~~general~~

$$\boxed{S_{SSBSC}(t) = 0.5\, A_c\, m(t) \cos 2\pi f_c t \pm 0.5 A_c m_h(t) \sin 2\pi f_c t}$$

$\boxed{S_{SSBSC}(t) = 0.5\, m(t)\, c(t) \pm 0.5\, m_h(t)\, c_h(t)}$ + → LSB, − → USB

Spectral Domain diagram:



⇒ In frequency domain we can write the expression as

$$S_{SSBSC}(f) = S_{DSBSC}(f) \times \left[0.5\,|sgn(f+f_c) \pm sgn(f-f_c)|\right]$$

+ → USB, − → LSB.

% power saving in SSB-SC :

$$\% \text{ saving of power in SSB-SC w.r.t DSB-FC} = \frac{P_c + P_{SSB}}{P_T}$$

$$= \frac{P_c + \frac{P_c \mu_a^2}{4}}{P_c\left(1+\frac{\mu_a^2}{2}\right)} = \frac{4+\mu_a^2}{4+2\mu_a^2}$$

For $\mu_a = 1$, $\frac{4+1^2}{4+2\cdot1^2} = \frac{4+1}{4+2} = \frac{5}{6} \cong 83.33\%$

Advantages in SSB-SC :

→ In SSB-SC, power efficiency is more as compared to DSB-FC.

→ It is 2 times efficienty in bandwidth or spectral use as compared to DSB-FC & DSB-SC

Limitation in SSB-SC :

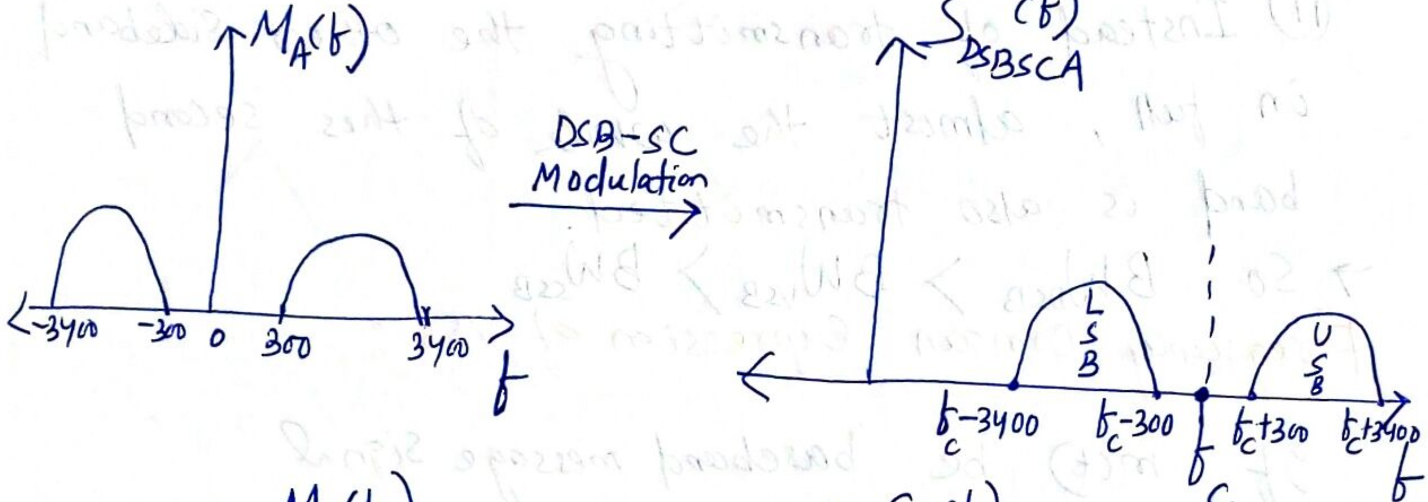
→ SSBSC signal is too defficult to generate when the baseband signal contains non negligible values at lower frequency i.e nearly around zero (0 Hz). This difficulty in generation is due to requirement of a strong sharp-cut off filter.

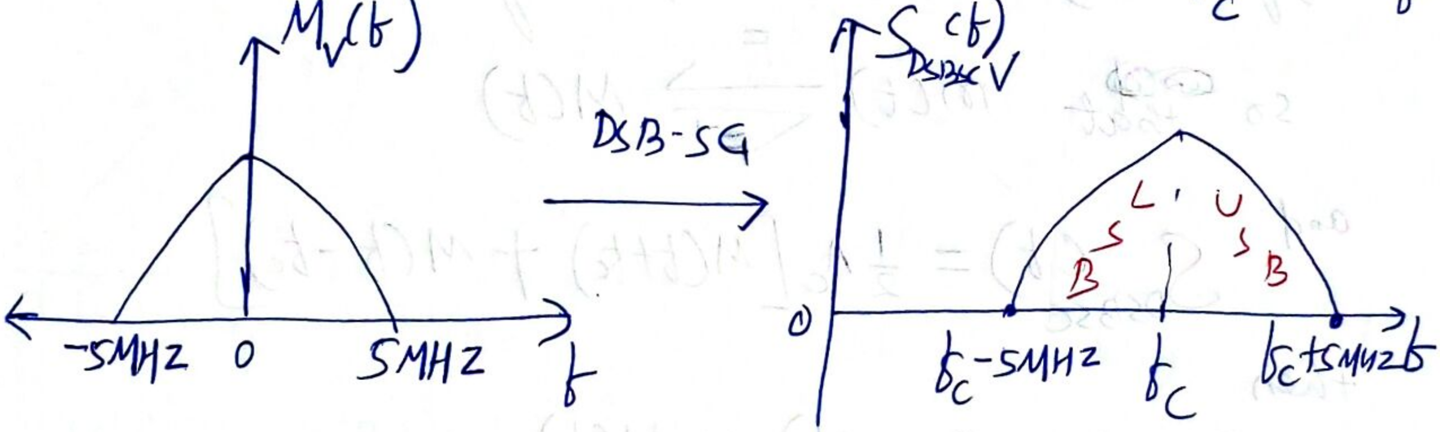
Explanation :

The inevitable use of sharp cut off filter can be understood considering following examples.

→ Consider two baseband signals (i) Audio (ii) Video

→ Let audio is represented as $m_A(t)$ and Video is represented as $m_V(t)$.





→ Now we can say that for Audio, to generate SSBSC from DSBSC is easy but for video we need a strongly sharp cut off filter i.e too difficult to realise.

* Hence we can use SSBSC for Audio communication not video communication.

* SSB is used for speech transmission in telephone communication.

Vestigial Sideband Modulation (VSB)

Def^n:

In VSB

(i) Instead of completely removing a sideband a trace or vestige of that sideband is transmitted; hence, the name "vestigial sideband"

(ii) Instead of transmitting the other sideband in full, almost the whole of this second band is also transmitted.

→ So $BW_{DSB} > BW_{VSB} > BW_{SSB}$

Frequency Domain Expression of VSB:

If $m(t)$ be baseband message signal

so that $m(t) \underset{F^{-1}}{\overset{F}{\rightleftharpoons}} M(f)$

and

$$S_{DSBSC}(f) = \frac{1}{2} A_c [M(f+f_c) + M(f-f_c)]$$

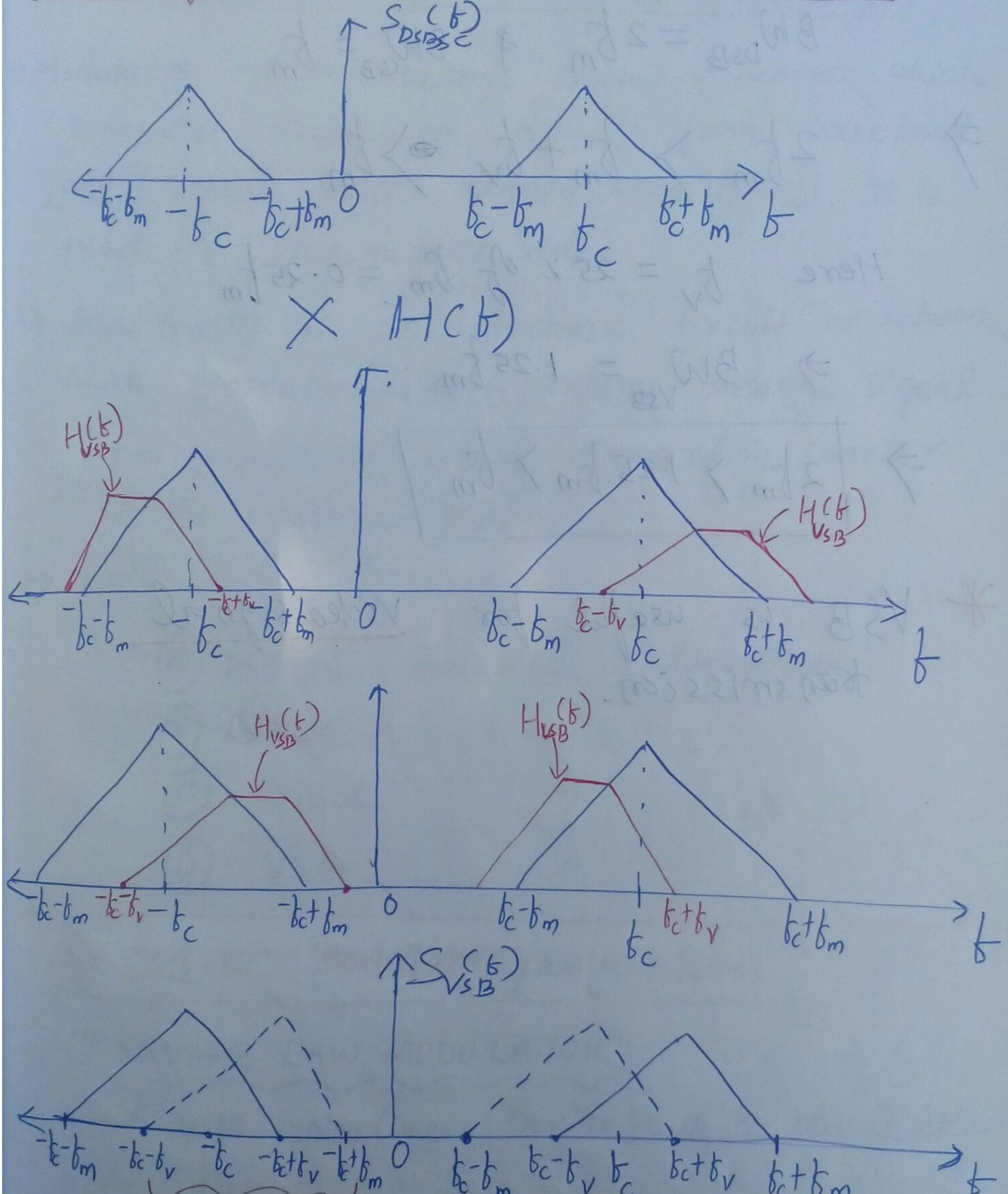
then

$$S_{VSB}(f) = S_{DSBSC}(f) \times H(f)$$

$$\Rightarrow \boxed{S_{VSB}(f) = \frac{1}{2} A_c [M(f+f_c) + M(f-f_c)] H(f)}$$

here $H(f)$ = Transfer function of VSB shaping filter.

Frequency Domain Diagram & BW Evaluation :



$BW = f_m + f_v$

$BW = f_c + f_m - (f_c - f_v)$

$$\boxed{BW = f_m + f_v}$$

Here f_v = width of vestigial band

* f_v is typically 25% of f_m.

Now we can compare $BW_{VSB} = f_m + f_v$ with

$BW_{DSB} = 2f_m$ & $BW_{SSB} = f_m$

$\Rightarrow \quad 2f_m > f_m + f_v > f_m$

Here $f_v = 25\%$ of $f_m = 0.25 f_m$

$\Rightarrow BW_{VSB} = 1.25 f_m$

$\Rightarrow \boxed{2f_m > 1.25 f_m > f_m}$

* VSB is useful for video signal transmission.

MODULATORS & DEMODULATORS:

→ Modulator is an electronic circuit or network which generates modulated signal from base band [m(t)] signal and carrier wave [c(t)]. It is used in Transmitter side.

→ Demodulator is an electronic circuit or network which generates/extracts/retrives message signal from modulated signal discarding carrier at the receiver side.

→ We will learn here

(A) DSB-FC modulators & demodulators

(B) DSB SC ,,

(C) SSB SC ,,

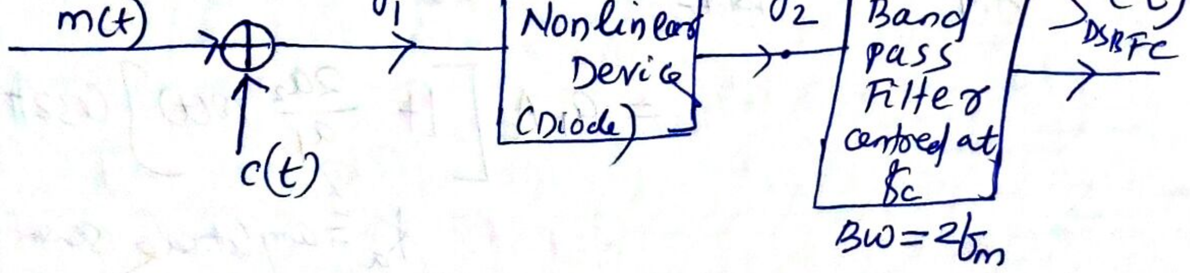
(D) VSB ,,

(A) DSB-FC Modulators / AM Modulators

(1) SQUARE LAW MODULATOR:

→ It uses Non linear Device such as diode etc...

BLOCK Diagram:



Explanation:

$\rightarrow y_1 = m(t) + c(t)$

$\rightarrow y_2 = a_1 y_1(t) + a_2 y_1^2(t)$

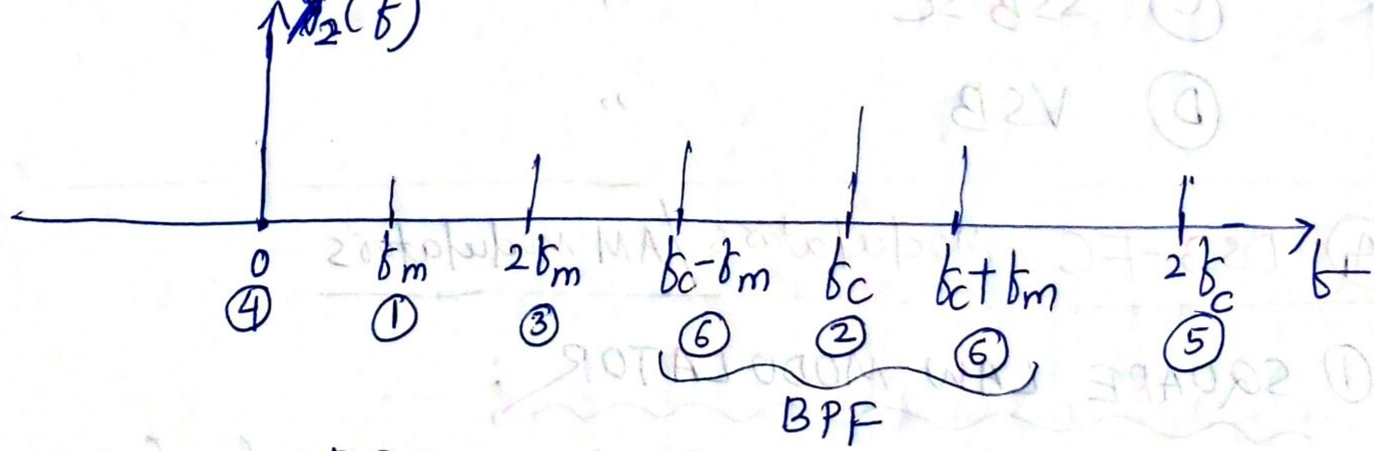
$$= a_1 [m(t) + c(t)] + a_2 [m(t) + c(t)]^2$$

$$= a_1 m(t) + a_1 c(t) + a_2 m^2(t) + a_2 c^2(t) + 2 a_2 m(t) c(t)$$

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

$$y_2 = a_1 m(t) + a_1 A_c \cos 2\pi f_c t + a_2 m^2(t) + a_2 A_c^2 \cos^2 2\pi f_c t + 2 a_2 m(t) \cdot A_c \cos 2\pi f_c t$$

$$\Rightarrow y_2 = \overset{1}{a_1 m(t)} + \overset{2}{a_1 A_c \cos 2\pi f_c t} + \overset{3}{a_2 m^2(t)} + \overset{4}{\frac{a_2 A_c^2}{2}} + \underset{5}{\frac{1}{2} a_2 A_c^2 \cos 4\pi f_c t} + \underset{6}{2 a_2 A_c m(t) \cos 2\pi f_c t}$$



→ After BPF

$$S_{AM}(t) = S_{DSBFC}(t) = a_1 A_c \cos 2\pi f_c t + 2 a_2 A_c m(t) \cos 2\pi f_c t$$

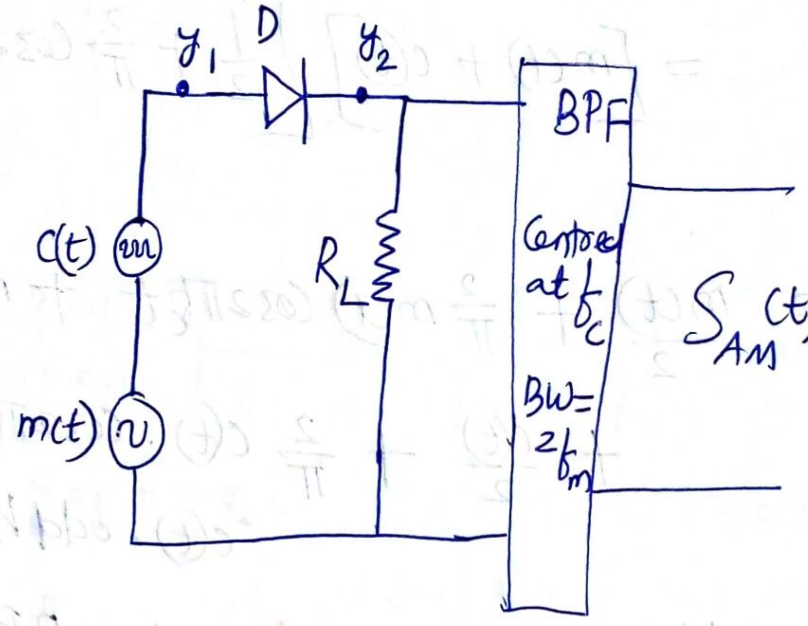
$$= a_1 A_c \Big[1 + \underbrace{\frac{2a_2}{a_1}}_{k_a} m(t) \Big] \cos 2\pi f_c t$$

k_a = amplitude sensitivity

② Switching Modulator :

Circuit Diagram :

$f_c >>> f_m$



→ Input to diode $y_1 = m(t) + c(t)$. We know that $f_c >> f_m$. Carrier will vary very fast than message. So switching operation of diode is controlled by c(t).

→ $y_2 = \begin{cases} y_1 & \text{if } c(t) > 0 \text{ due to Forward Biasing (FB)} \\ 0 & \text{if } c(t) < 0 \text{ due to Reverse Biasing (RB)} \end{cases}$

→ Diode will be on for FB and off for RB.

→ This on to off and off to on switching behaviour can be represented in mathematics as periodic pulse train i.e

$$SW(t) = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos(2\pi f_c t(2n-1))$$

$$= \frac{1}{2} + \frac{2}{\pi}\cos 2\pi f_c t - \frac{2}{3\pi}\cos(3 \cdot 2\pi f_c t) + \text{odd harmonics}$$

So

$$y_2 = y_1 \times sw(t)$$

$$= [m(t) + c(t)] \left[\frac{1}{2} + \frac{2}{\pi}\cos 2\pi f_c t - \frac{2}{3\pi}\cos 3\cdot 2\pi f_c t + \text{odd harmonics}\right]$$

$$\Rightarrow y_2 = \frac{m(t)}{2} + \frac{2}{\pi} m(t)\cos 2\pi f_c t + m(t)\cdot \text{odd harmonics} + \frac{c(t)}{2} + \frac{2}{\pi} c(t)\cdot \cos 2\pi f_c t + c(t)\cdot \text{odd harmonics}.$$

→ when y_2 will pass through BPF

$$o/p = S_{AM}(t) = \frac{2}{\pi} m(t)\cos 2\pi f_c t + \frac{c(t)}{2}$$

$$= \frac{A_c \cos 2\pi f_c t}{2} + \frac{2}{\pi} m(t)\cos 2\pi f_c t$$

$$\Rightarrow S_{AM}(t) = \frac{1}{2}A_c\left[1 + \underbrace{\frac{4}{\pi A_c}}_{K_a} m(t)\right]\cos 2\pi f_c t$$

(A2) Demodulation/Detection of DSB-FC/AM Signal

→ There are two types of demodulation methods.

① Non Coherent ← Nonsynchronous :- Here no extra carrier is required at the receiver.

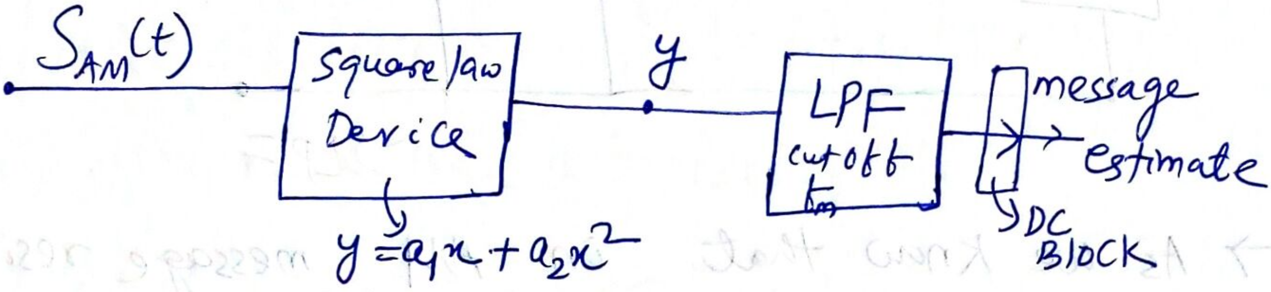
② Coherent ← Synchronous :- Here an extra carrier is required at the receiver and that carrier is generated from Local Oscillator.

Non Coherent Methods for DSBFC Detection :→

↳ Nonsynchronous

① SQUARE LAW DETECTOR :

Block Diagram :-



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

→ $y = a_1 S_{AM} + a_2 S_{AM}^2$

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

→ $y = a_1 A_c \cos 2\pi f_c t + a_1 A_c K_a m(t) \cos 2\pi f_c t + a_2 A_c^2 \cos^2 2\pi f_c t + a_2 A_c^2 K_a^2 m^2(t) \cos^2 2\pi f_c t + 2 a_2 A_c^2 K_a m(t) \cos^2 2\pi f_c t$

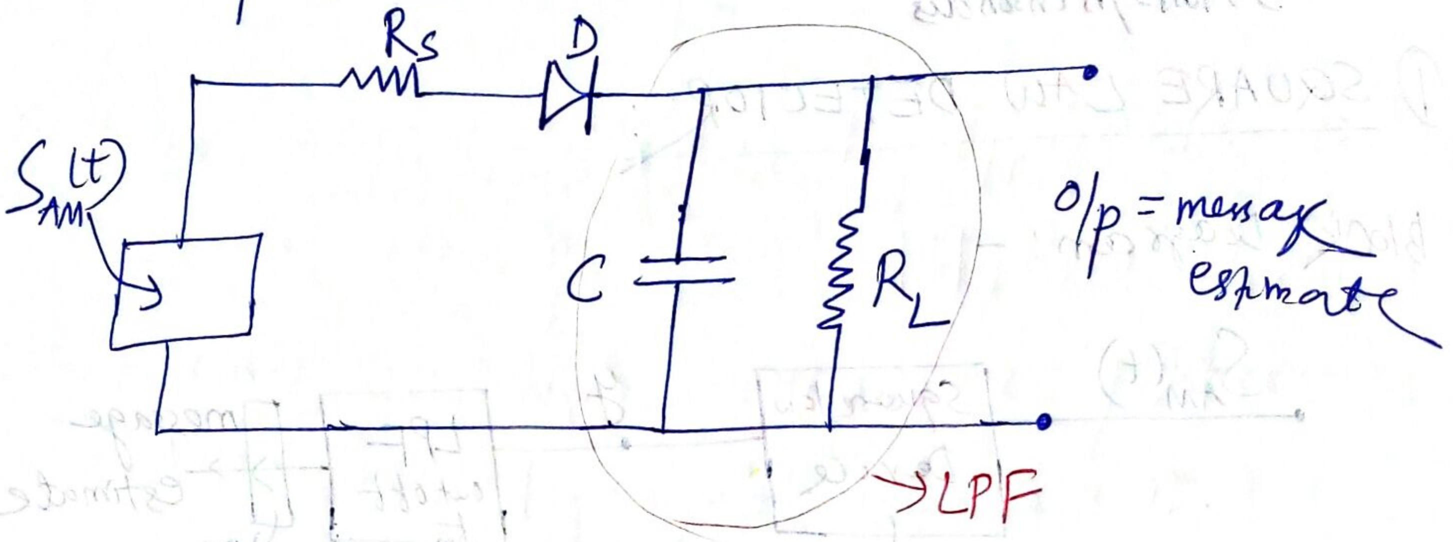
Applying $2\cos^2\theta = 1 + \cos 2\theta$

→ $y = \underset{①}{a_1 A_c \cos 2\pi f_c t} + \underset{②}{a_1 A_c K_a m(t) \cos 2\pi f_c t} + \underset{③}{\frac{a_2 A_c^2}{2}} + \underset{④}{\frac{a_2 A_c^2}{2} \cos 4\pi f_c t} + \underset{⑤}{\frac{a_2^2 A_c^2 K_a^2 m^2(t)}{2}} + \underset{⑥}{\frac{a_2 A_c^2 K_a^2 m^2(t)}{2} \cos 4\pi f_c t} + \underset{⑦}{a_2 A_c^2 K_a m(t)} + \underset{⑧}{a_2 A_c^2 K_a m(t) \cos 4\pi f_c t}$

→ o/p after LPF = $\frac{a_2 A_c^2}{2} + a_2 A_c^2 K_a m(t)$

→ After DC BLOCK o/p = $a_2 A_c^2 K_a m(t)$ → message estimate

② Envelope Detection Method :



→ As we know that in AM, message resides in the envelope. i.e

$$S_{AM}(t) = \underbrace{A_c[1 + K_a m(t)]}_{\text{Envelope}} \cos 2\pi f_c t$$

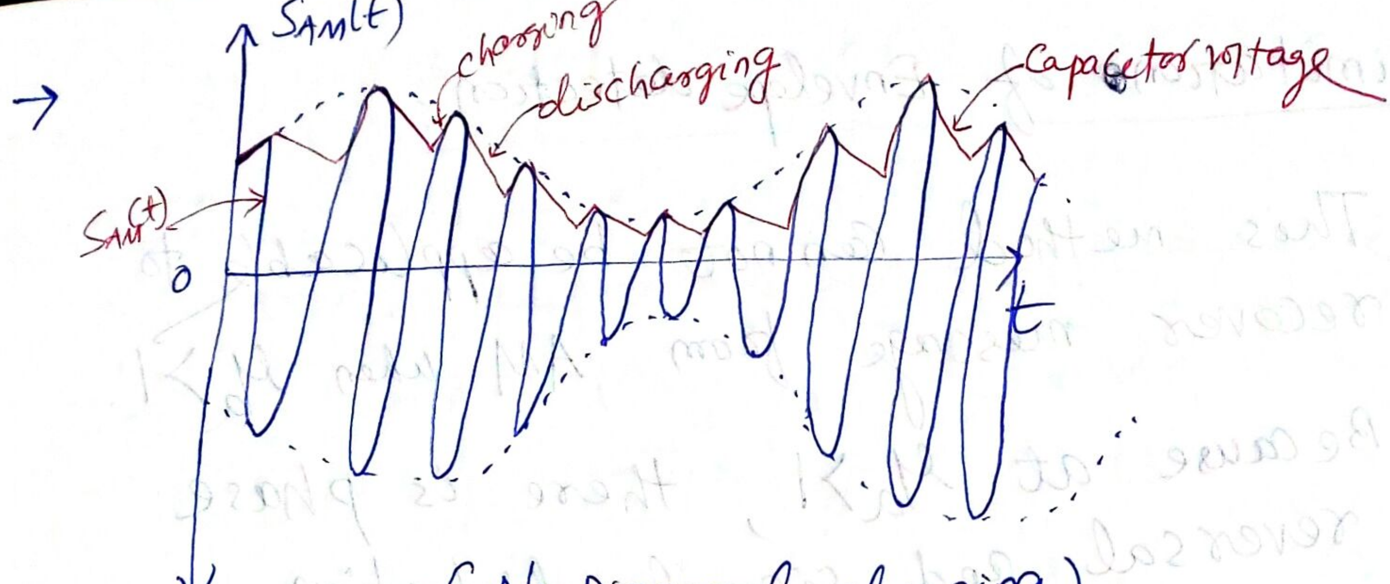
→ Hence if envelope is extracted then message can be retrived. This is the concept used here.

→ f_c = carrier frequency $\Rightarrow \frac{1}{f_c} = T_c$ = carrier time period

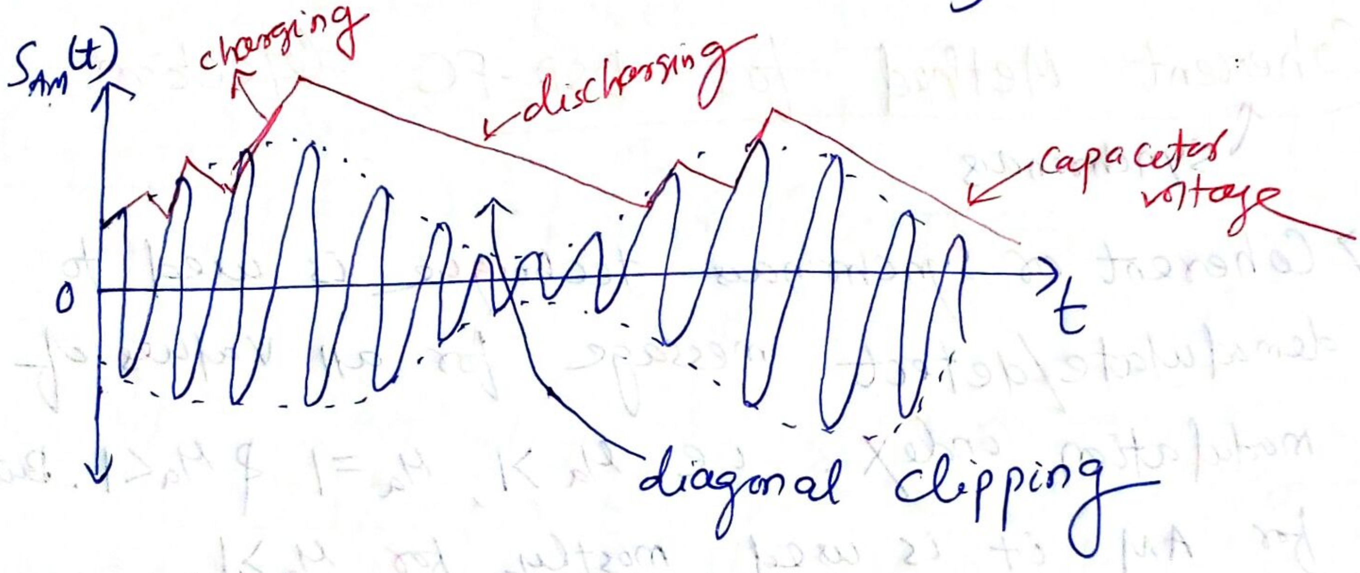
→ f_m = max^m frequency in message $\Rightarrow \frac{1}{f_m} = T_m$ = minimum message period

→ In the above circuit diagram, capacitor 'C' is charged through Diode and R_s having charging time constant $= R_s C$.

→ 'C' will discharge through R_L having discharging time constant $R_L C$.



(No Diagonal clipping)



→ In envelope detection if some peaks in the envelope are skipped and not reflected in the output then we get distorted output (message) at the received end. This is known as Diagonal clipping.

→ To avoid diagonal clipping:

$$\boxed{\begin{array}{l} R_s C \ll \dfrac{1}{f_c} \\ \dfrac{1}{f_c} \ll R_L C \ll \dfrac{1}{f_m} \;\;\&\;\; R_L C \le \dfrac{1}{2\pi f_m}\left(\dfrac{\sqrt{1-\mu_a^2}}{\mu_a}\right) \end{array}}$$

Limitations of Envelope detection:

→ This method can not be applicable to recover message from AM when $\mu_a > 1$.
Because at $\mu_a > 1$, there is phase reversal and signal distortion.

Coherent Method for DSB-FC detection:

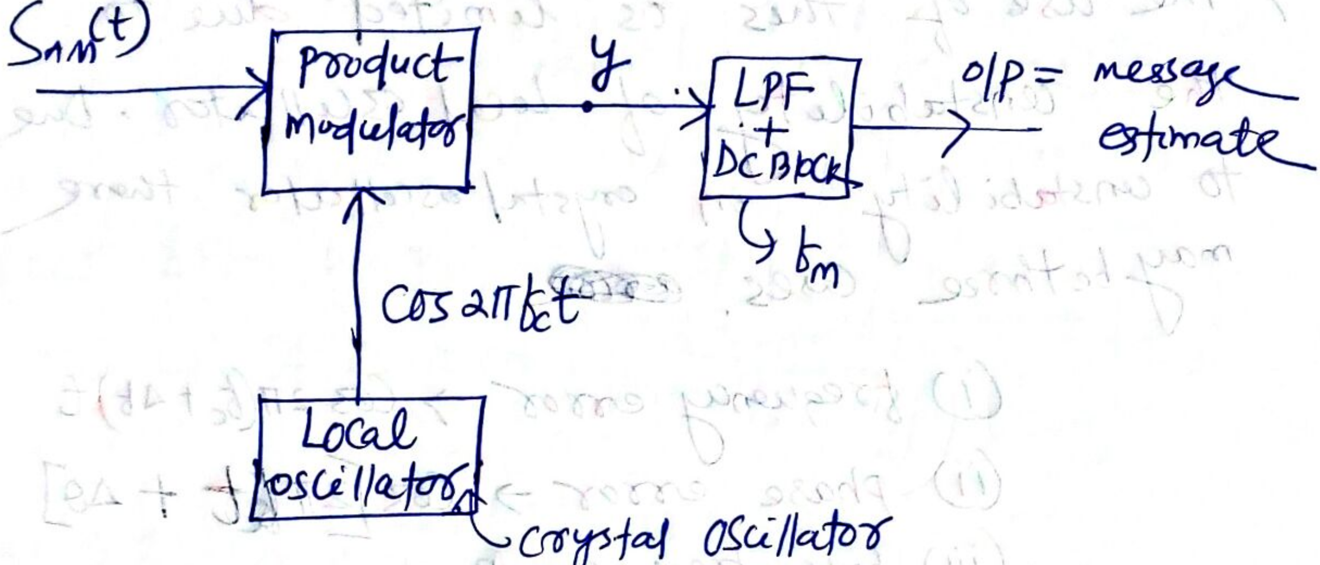
Synchronous

→ Coherent or synchronous technique is used to demodulate/detect message, for all values of modulation index. i.e. $\mu_a > 1$, $\mu_a = 1$ & $\mu_a < 1$. But for AM it is used mostly for $\mu_a \geq 1$.

→ Here an extra carrier is required at the receiver end and that is done using a Local oscillator.

→ This carrier of Local oscillator must have same frequency & same phase as that of transmitted carrier from transmitted side. This is why this technique is known as SYNCHRONOUS.

Block Dgm :



Explanation :

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

$$y = S_{AM}(t) \cdot \cos 2\pi f_c t$$

$$= [A_c \cos 2\pi f_c t + A_c k_a m(t) \cos 2\pi f_c t] \cdot \cos 2\pi f_c t$$

$$\Rightarrow y = A_c \cos^2 2\pi f_c t + A_c k_a m(t) \cos^2 2\pi f_c t$$

$$= \frac{A_c}{2} + \frac{A_c}{2} \cos 4\pi f_c t + \frac{A_c k_a m(t)}{2} + \frac{A_c k_a m(t)}{2} \cos 4\pi f_c t$$

$\rightarrow$ After LPF + DC block

$$o/p = \frac{A_c k_a}{2} m(t)$$

Limitations of Coherent method :

→ The use of this is limited due to the unstability of Local oscillator. Due to unstability in crystal oscillator there may be three cases.

(i) frequency error → $\cos 2\pi(f_c + \Delta f)t$

(ii) phase error → $\cos[2\pi f_c t + \Delta\theta]$

(iii) both frequency & phase error.

$$\cos[2\pi(f_c+\Delta f)t + \Delta\theta]$$

Case-1 : Due to frequency error :

$$y = S_{AM}(t) \cdot \cos 2\pi(f_c+\Delta f)t$$

$$= [A_c \cos 2\pi f_c t + A_c k_a m(t) \cos 2\pi f_c t][\cos 2\pi f_c t \cdot \cos 2\pi \Delta f t - \sin 2\pi f_c t \cdot \sin 2\pi \Delta f t]$$

$$= A_c \cos 2\pi f_c t \cdot \cos 2\pi f_c t \cdot \cos 2\pi \Delta f t - A_c \cos 2\pi f_c t \cdot \sin 2\pi f_c t \cdot \sin 2\pi \Delta f t + A_c k_a m(t) \cos^2 2\pi f_c t \cdot \cos 2\pi \Delta f t - A_c k_a m(t) \cos 2\pi f_c t \cdot \sin 2\pi f_c t \cdot \sin 2\pi \Delta f t$$

→ Considering only the m(t) containing terms as those will be blocked by LPF.

$$\tilde{y} = A_c k_a m(t) \cos 2\pi \Delta f t \left[\frac{1+\cos 4\pi f_c t}{2}\right] - \frac{A_c k_a m(t)}{2} \sin 4\pi f_c t \cdot \sin 2\pi \Delta f t$$

$$\Rightarrow \tilde{y} = \frac{A_c K_a m(t)}{2} \cos 2\pi \Delta f t + \frac{A_c K_a m(t)}{2} \cos 2\pi \Delta f t \cdot \cos 4\pi f_c t$$

$$- \frac{A_c K_a m(t)}{2} \sin 4\pi f_c t \cdot \sin 2\pi \Delta f t$$

(1) (2) (3)

After LPF with DC block

$$o/p = \frac{A_c K_a m(t)}{2} \cos 2\pi \Delta f t$$

* If Δf will be such value that

$$2\pi \Delta f t = 90°$$

then $o/p = \frac{A_c K_a m(t)}{2} \cos 90° = 0$

(NULL).

→ Following those above steps in similar way, we can have the output for phase error ($\Delta\theta$)

$$o/p = \frac{A_c K_a m(t)}{2} \cos \Delta\theta$$

If $\Delta\theta = 90°$

$$\Rightarrow o/p = 0$$

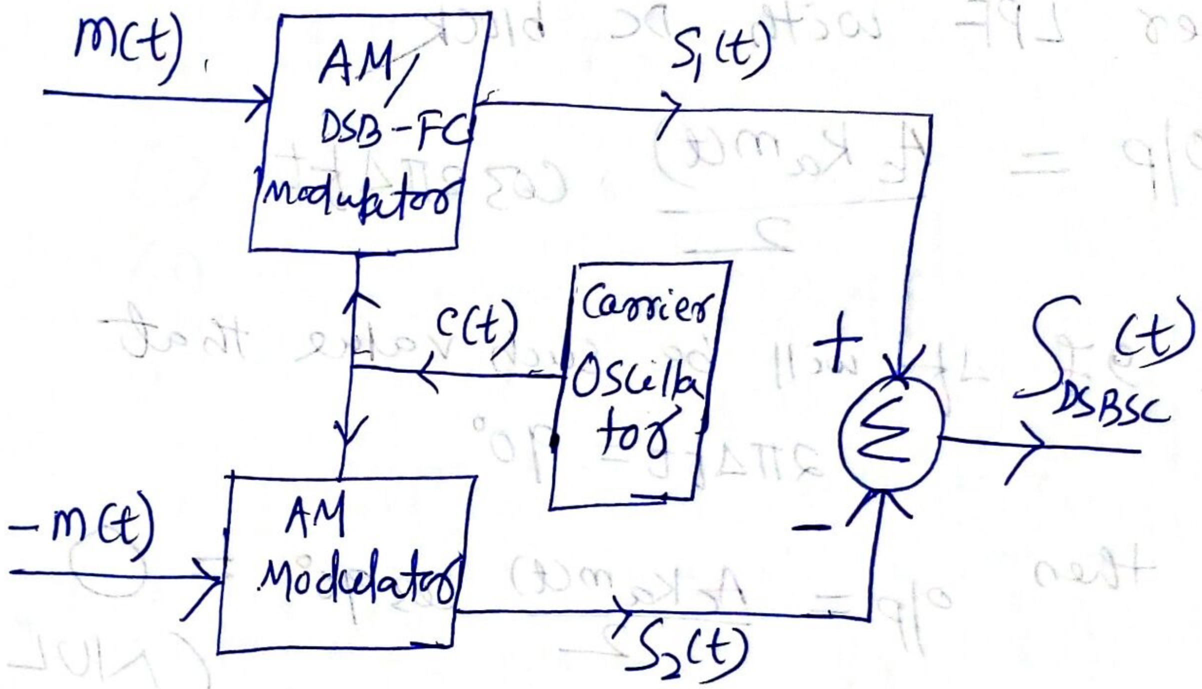
This is known as Quadrature Null Effect.

→ The same way we can prove for Case-3.

(B₁) DSB-SC Modulators :

① Using Balanced Modulator :

Block Dgm:



→ Balanced Modulator consists of two identical AM modulators. These two modulators are arranged in a balanced configuration in order to supress the carrier signal. Hence, it is termed/called as balanced Modulator.

Explanation :

$$S_1(t) = A_c[1 + k_a m(t)] \cos 2\pi f_c t$$

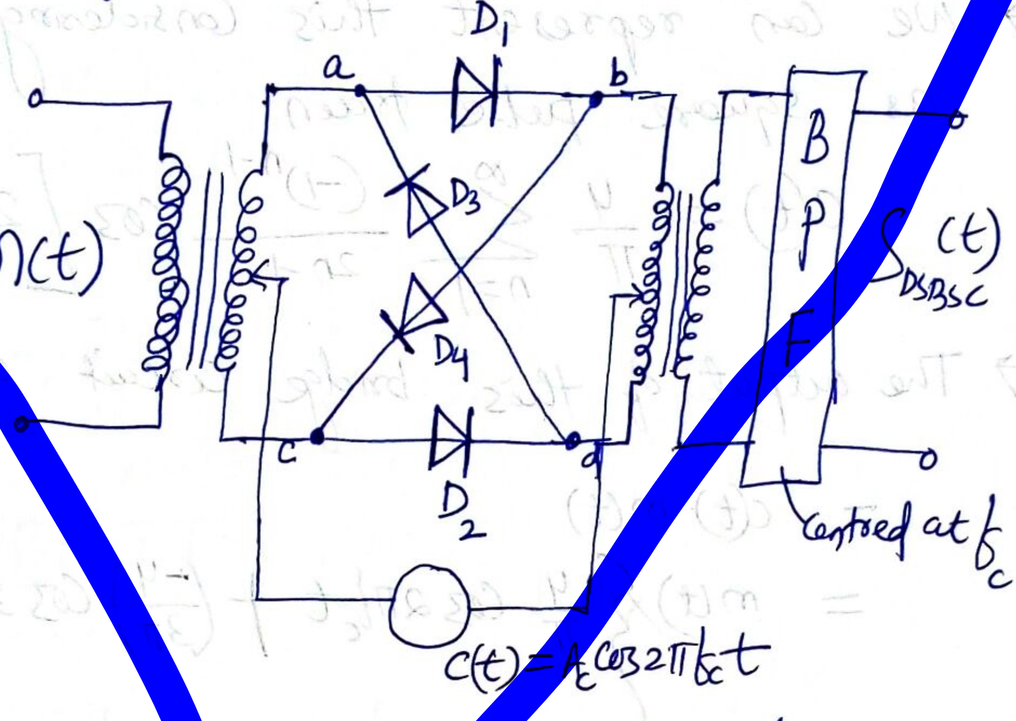
$$S_2(t) = A_c[1 - k_a m(t)] \cos 2\pi f_c t$$

$$S_1(t) - S_2(t) = 2A_c k_a m(t) \cos 2\pi f_c t$$

$$= 2k_a m(t)\, c(t) = S_{DSBSC}(t)$$

(2) Using Ring Modulator :

Ckt Dgm:



→ Ring modulator is also known as Lattice or Double balanced modulator.

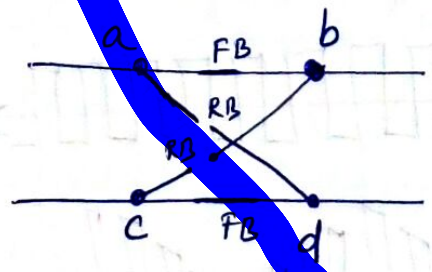
→ Here switching of diodes will be carried out as per change in carrier levels.

→ When carrier wave will be +ve then

D_1, D_2 → Forward biased

D_3, D_4 → Reverse biased

the circuit becomes



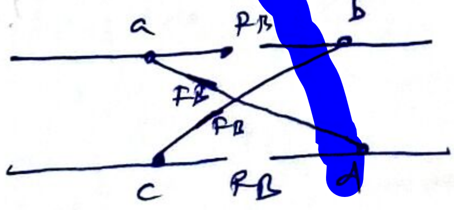
→ In this case m(t) will be multiplied by +1.

→ When carrier wave will be -ve then

D_1, D_2 → RB

D_3, D_4 → FB

⇒



→ In this m(t) will be multiplied by −1.

→ We can represent this considering carrier as square pulse train:

$$c(t) = \frac{4}{\pi}\sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1}\cos\left[2\pi f_c t(2n-1)\right]$$

→ The output of this bridge circuit is

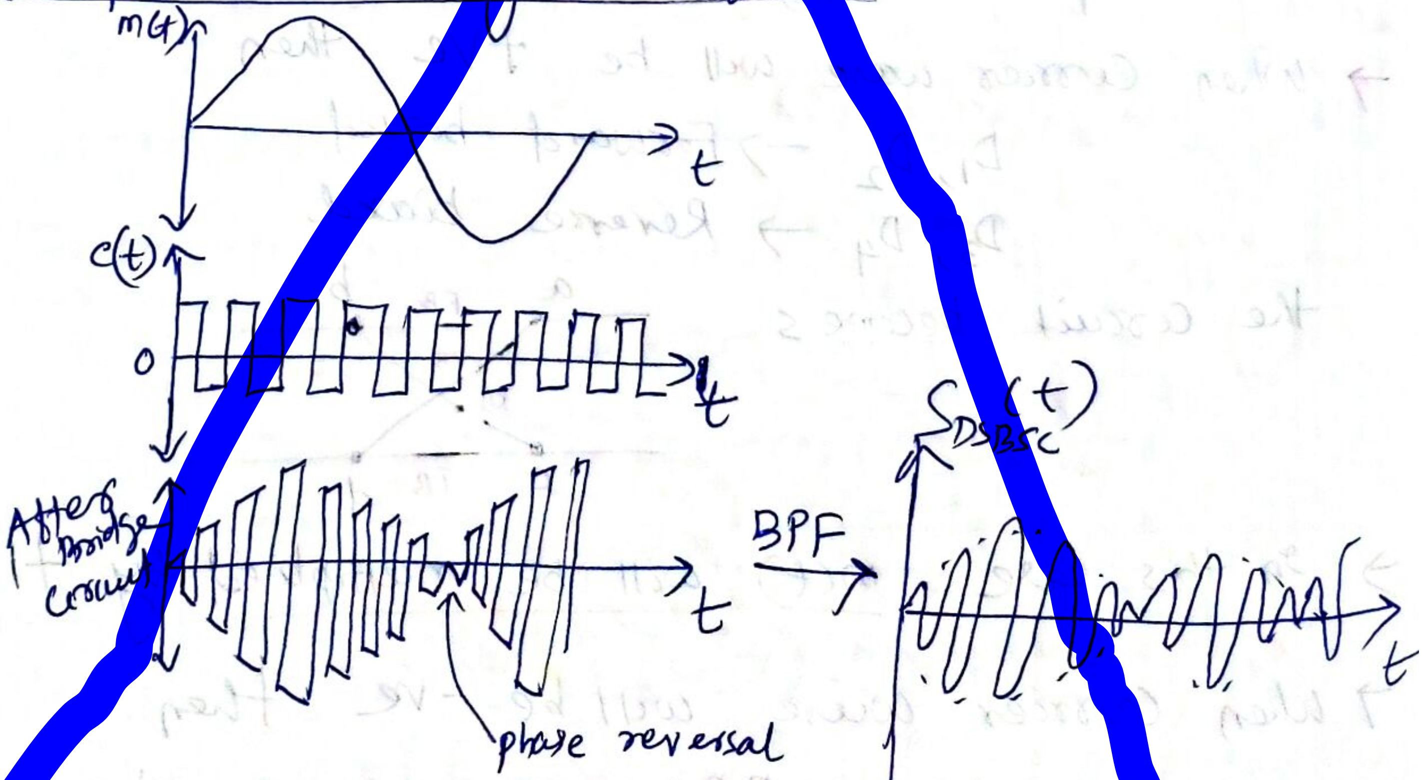
$$= c(t)\, m(t)$$

$$= m(t)\left\{\frac{4}{\pi}\cos 2\pi f_c t + \left(\frac{-4}{3\pi}\right)\cos 3\cdot 2\pi f_c t + \text{odd harmonics}\right\}$$

→ After band pass filter

$$o/p = \frac{4}{\pi} m(t)\cos 2\pi f_c t = S_{DSBSC}(t)$$

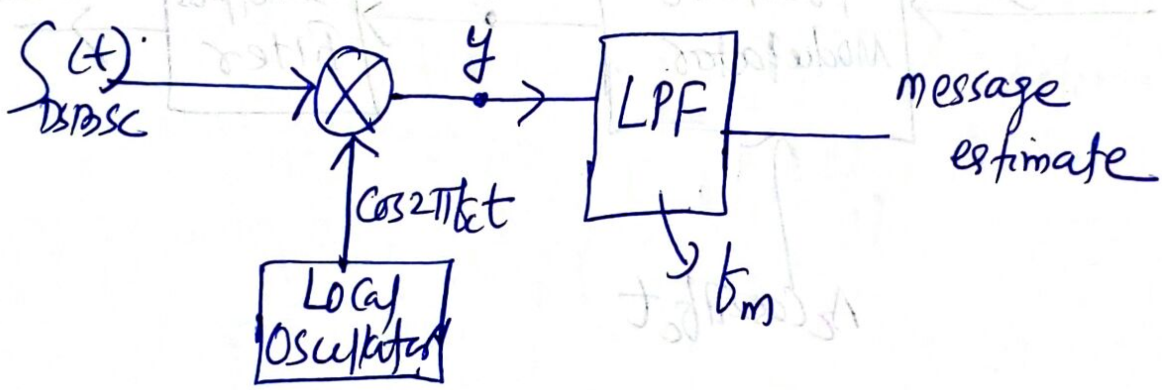
Explanation Using waveform:



(B2) Detection of DSBSC:

① Coherent Detection:

Block Dgm:



Explanation:

$$y = \underbrace{A_m \cos\omega_m t}_{m(t)} \cdot A_c \cos 2\pi f_c t \cdot \cos 2\pi f_c t$$

$$= A_m A_c \cos\omega_m t \cdot \cos^2 2\pi f_c t$$

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

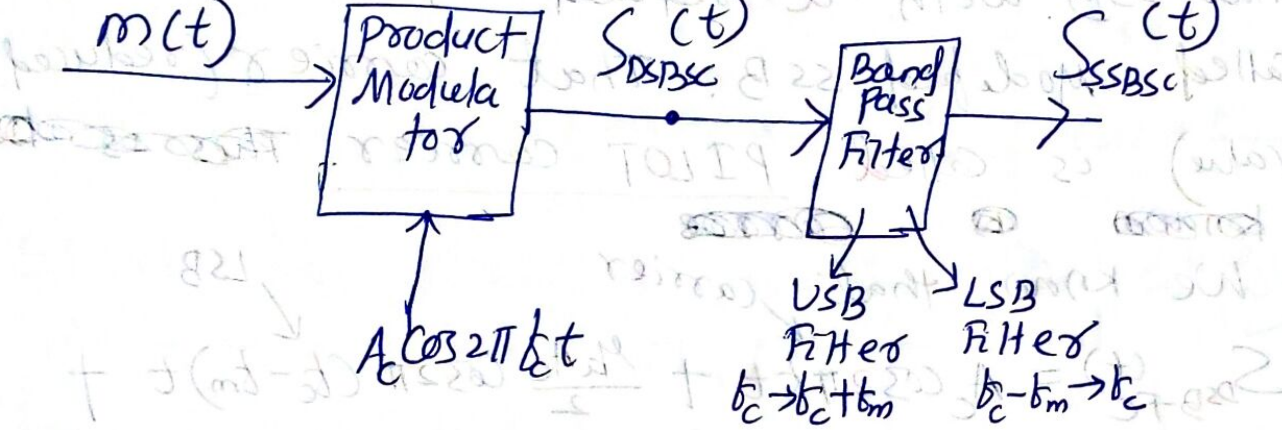
$$= \frac{A_c m(t)}{2} + \frac{A_c m(t) \cos 4\pi f_c t}{2}$$

$$y \xrightarrow{LPF} o/p = \frac{A_c m(t)}{2}$$ ✓

(4) SSBSC Modulators :

① Frequency Discrimination Method:

(i) Single stage: (It is done when the carrier frequency is comparatively low)



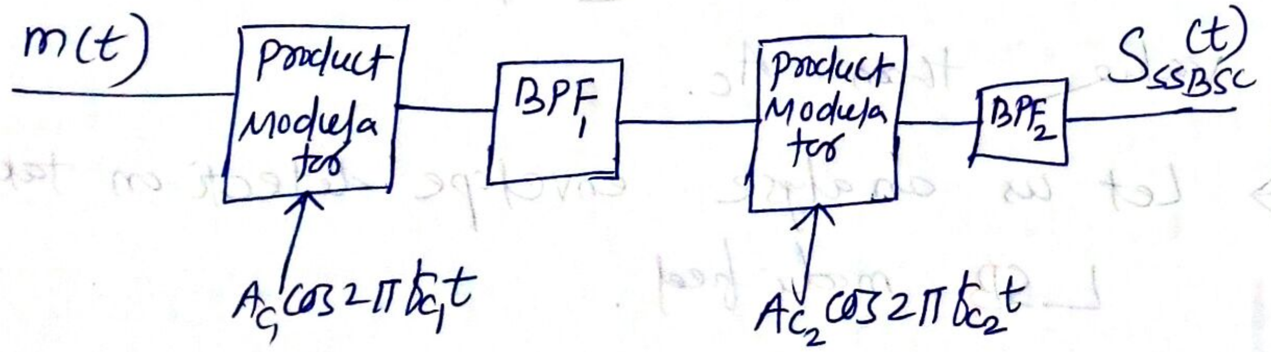
Explanation : —DO—

(ii) Multi stage Frequency discrimination :

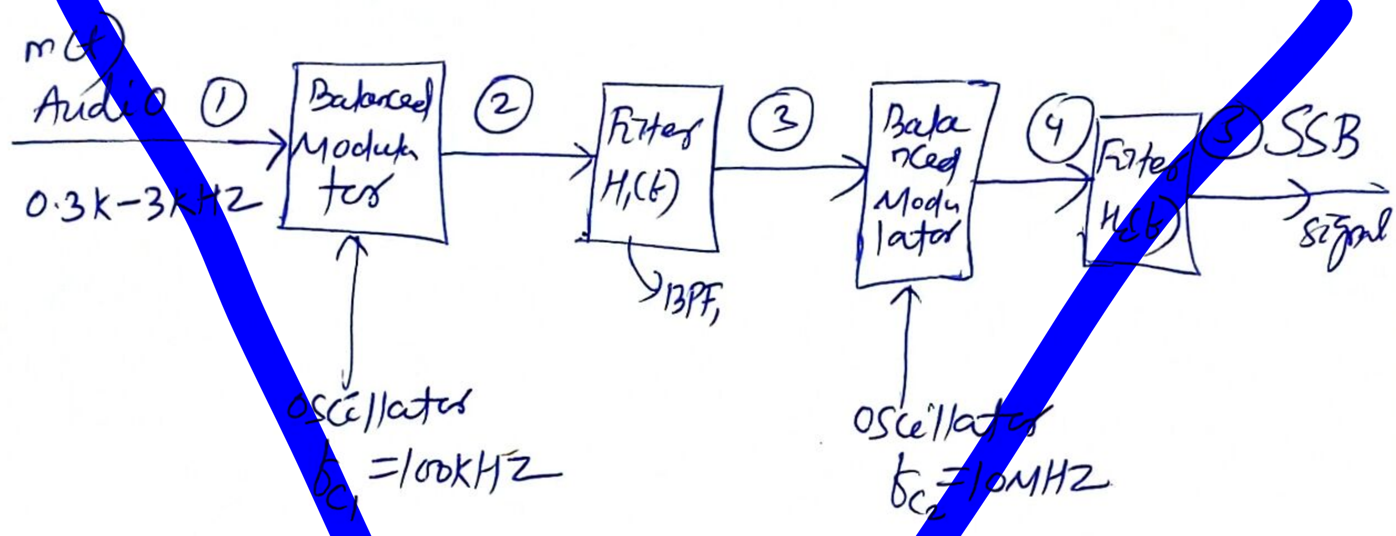
→ When the carrier frequency, centred on which USB or LSB is to be formed, is high, then single stage filtering is avoided.

→ Filtering is a critical operation & at higher frequencies sharpness of filter is not so good. Hence at higher centred carrier frequency we go for multistage filtering.

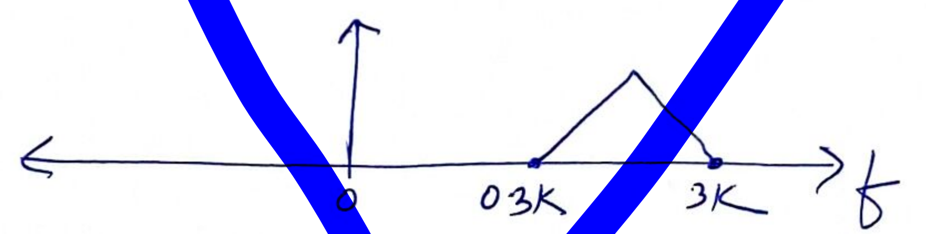
→ Block Diagram:



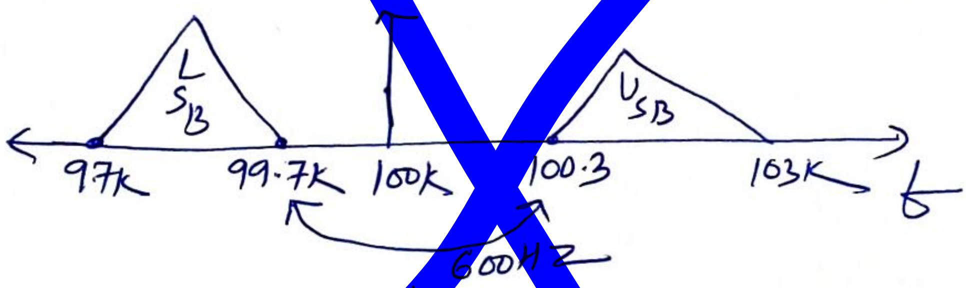
Example



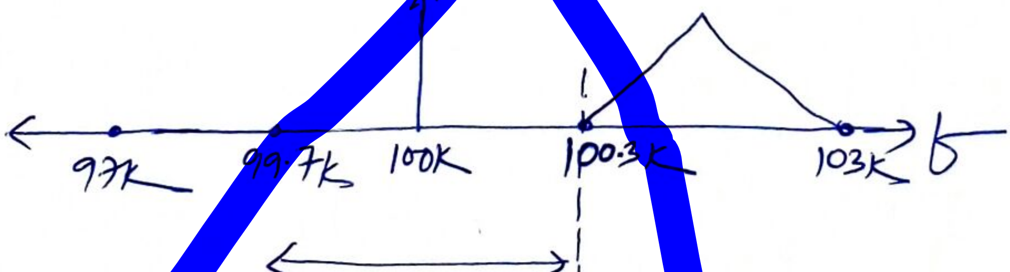
1



2

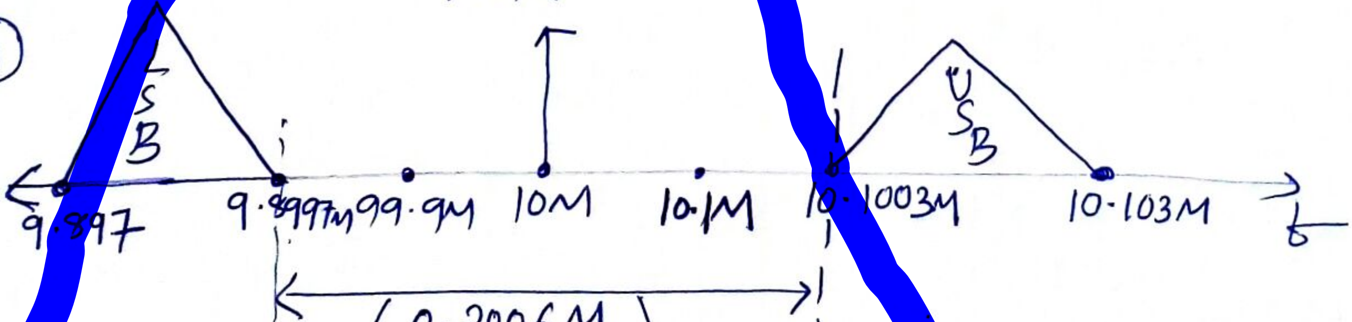


3



$$\frac{600HZ}{100K} \times 100 = 0.6\%$$

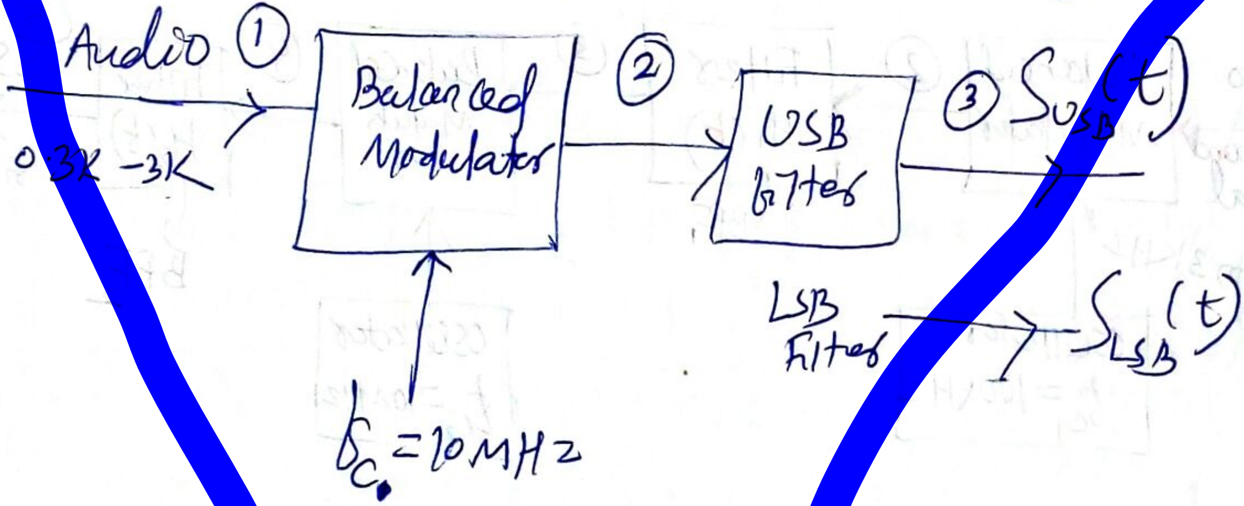
4



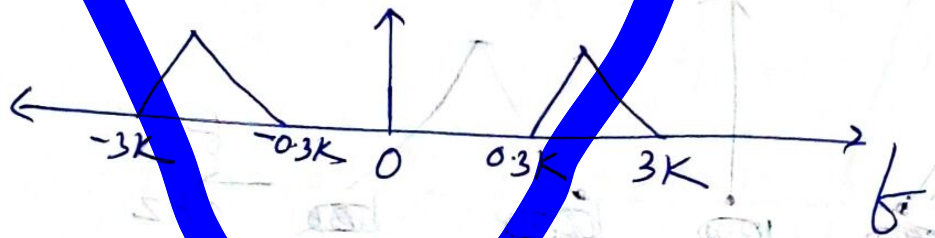
$$\left(\frac{0.2006M}{10M}\right) = 2\%$$

5

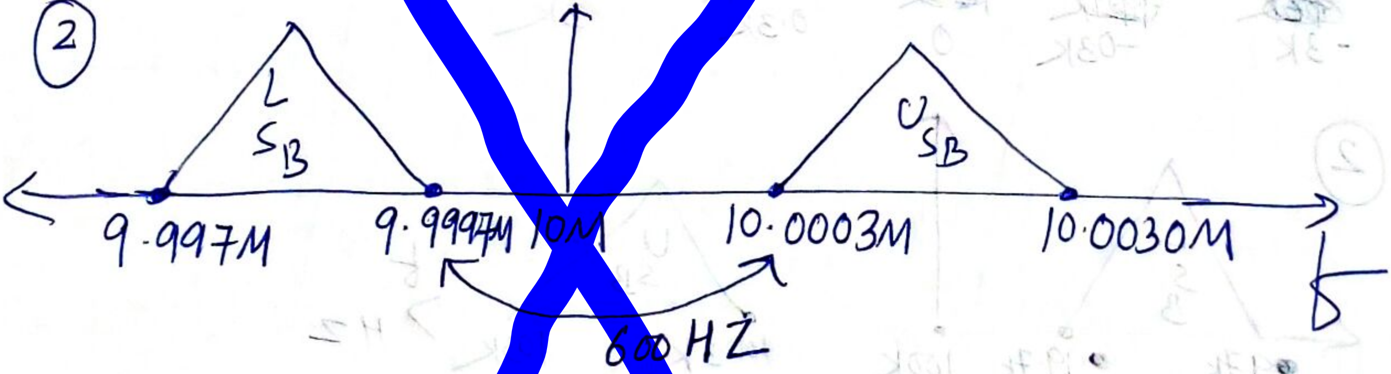
If it wouldbe singlestage filtering then



①

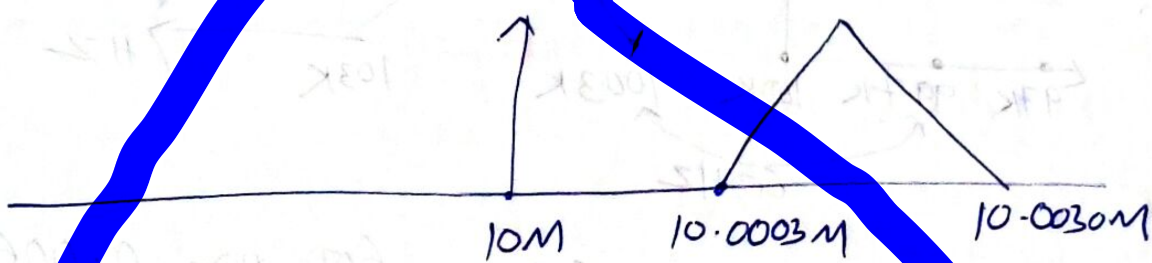


②



$$\frac{600\,HZ}{10\,MHZ} \times 100 = 0.006\,\%$$

③



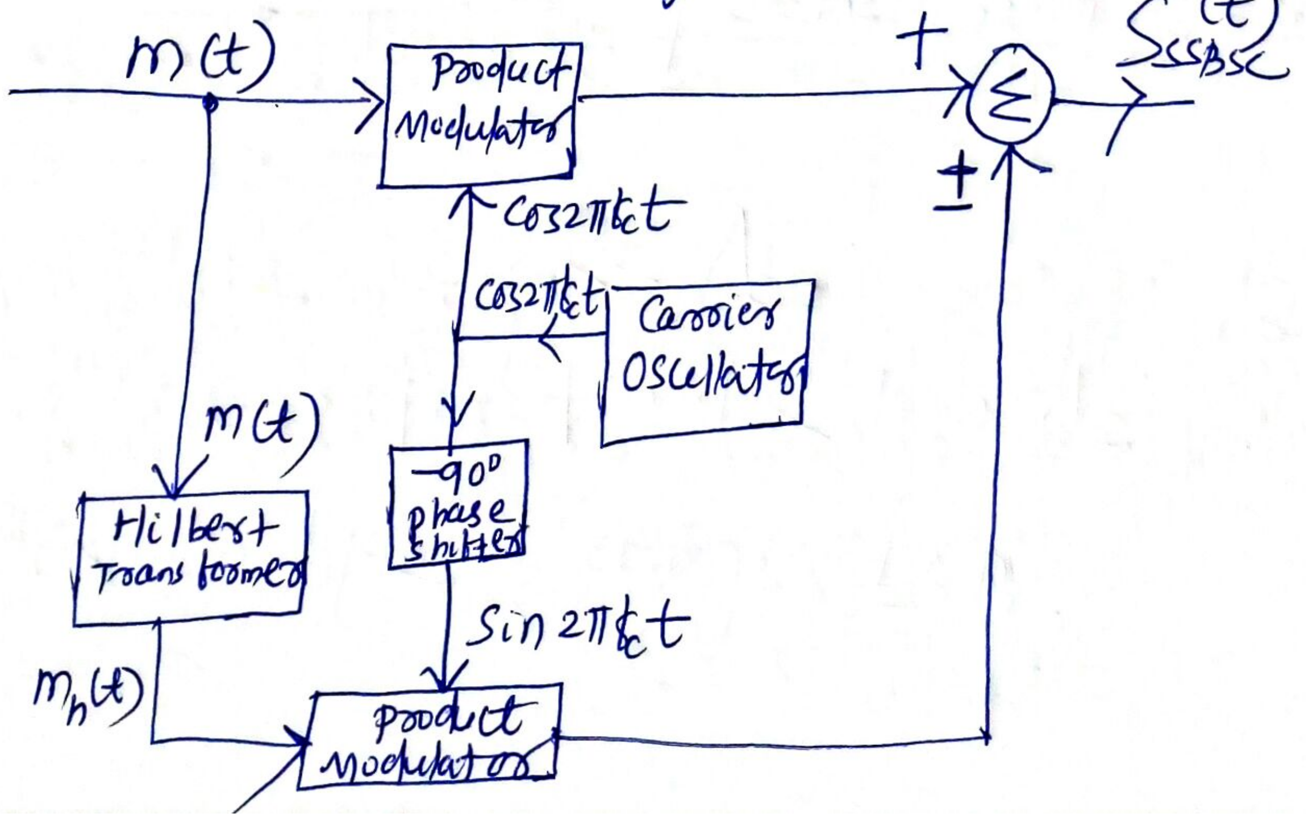
(Difficult)

(2) phase discrimination method :

→ To understand we need time domain expression of SSBSC

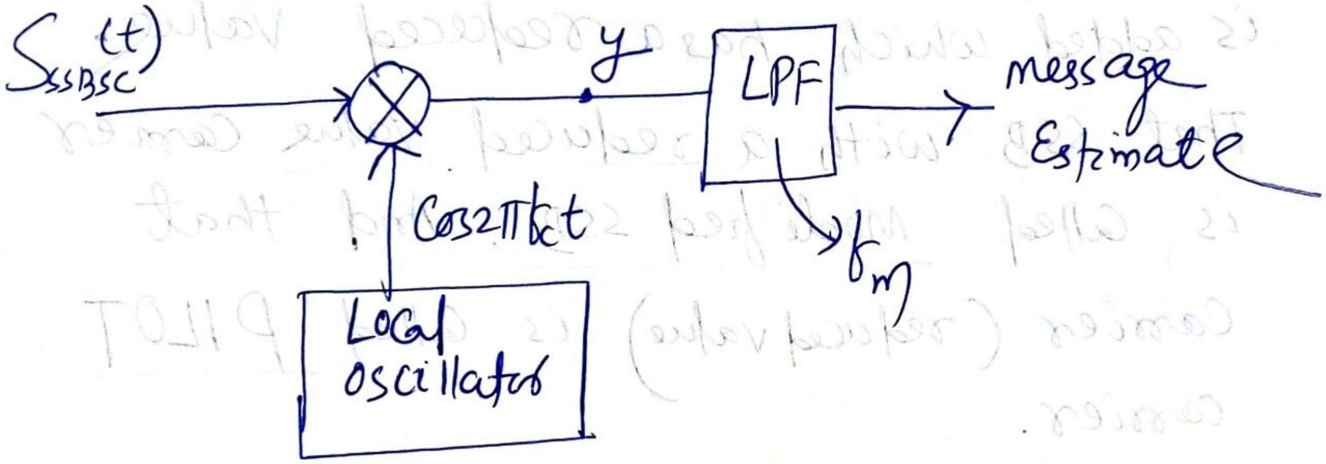
$$S_{SSBSC}(t) = 0.5\, m(t)\, A_c \cos 2\pi f_c t \underset{\text{USB}}{\overset{\text{LSB}}{\pm}} 0.5\, m_h(t)\, A_c \sin 2\pi f_c t$$

Block Dgm: It is according to above expression



C2) SSBSC Detectors / Demodulators

① Coherent / synchronous Detection :



Explain :-

— Do —

② Non Coherent Detection :

Envelope Detector Method :

→ If we analyse the expression of DSB-SC or SSB SC, it is clear that envelope detection method can not extract message from those modulation.

→ Envelope detection method is only applicable for Full-AM or DSB-FC for $\mu_a < 1$.

→ If we want to apply this non coherent technique (as there are limitations in coherent) to SSBSC, we have to modify the expression of original SSBSC. We can term that as Modified SSB.

→ In modified SSB, an extra carrier having reduced value is added to the original SSB. That SSB with a reduced value carrier is called Modified SSB. That carrier (reduced value) is called PILOT carrier.

→ We know that

$$S_{DSB\text{-}FC}(t) = \underbrace{A_c \cos 2\pi f_c t}_{\text{carrier}} + \underbrace{\frac{\mu_a A_c}{2} \cos 2\pi (f_c - f_m) t}_{\text{LSB}} + \underbrace{\frac{\mu_a A_c}{2} \cos 2\pi (f_c + f_m) t}_{\text{USB}}$$

So $S_{USB}(t) = \frac{\mu_a A_c}{2} \cos 2\pi (f_c + f_m) t$

$S_{LSB}(t) = \frac{\mu_a A_c}{2} \cos 2\pi (f_c - f_m) t$

This SSB is modified as

$$S_{\substack{\text{modified}\\ \text{USB}}} = \underbrace{a_c \cos 2\pi f_c t}_{\text{PILOT carrier}} + \frac{\mu_a A_c}{2} \cos 2\pi (f_c + f_m) t$$

$$S_{\substack{\text{modified}\\ \text{LSB}}} = a_c \cos 2\pi f_c t + \frac{\mu_a A_c}{2} \cos 2\pi (f_c - f_m) t$$

Here $a_c \ll A_c \Rightarrow a_c$ has reduced value than A_c.

→ Let us analyse envelope detection taking LSB modified.

$$S_{\substack{\text{modified} \\ \text{LSB}}} = a_c \cos 2\pi f_c t + \frac{\mu_a A_c}{2} \cos 2\pi (f_c - f_m) t$$

$$= a_c \cos 2\pi f_c t + \frac{\mu_a A_c}{2} \cos 2\pi f_c t \cdot \cos 2\pi f_m t + \frac{\mu_a A_c}{2} \sin 2\pi f_c t \cdot \sin 2\pi f_m t$$

$$= \left[a_c + \frac{\mu_a A_c}{2} \cos 2\pi f_m t\right] \cos 2\pi f_c t + \left[\frac{\mu_a A_c}{2} \sin 2\pi f_m t\right] \sin 2\pi f_c t$$

→ In envelope detection, envelope (amplitude) of modified LSB will be retrived.

→ Envelope of $S_{\substack{\text{modified} \\ \text{LSB}}}$ is

$$e(t) = \sqrt{\left[a_c + \frac{\mu_a A_c}{2} \cos 2\pi f_m t\right]^2 + \left[\frac{\mu_a A_c}{2} \sin 2\pi f_m t\right]^2}$$

$$= \sqrt{a_c^2 + \frac{\mu_a^2 A_c^2}{4} \cos^2 2\pi f_m t + a_c A_c \mu_a \cos 2\pi f_m t + \frac{\mu_a^2 A_c^2}{4} \sin^2 2\pi f_m t}$$

$$e(t) = \sqrt{a_c^2 + \frac{\mu_a^2 A_c^2}{4} + a_c A_c \mu_a \cos 2\pi f_m t}$$

If $\mu_a \ll 1 \Rightarrow \mu_a^2$ is also negligible and

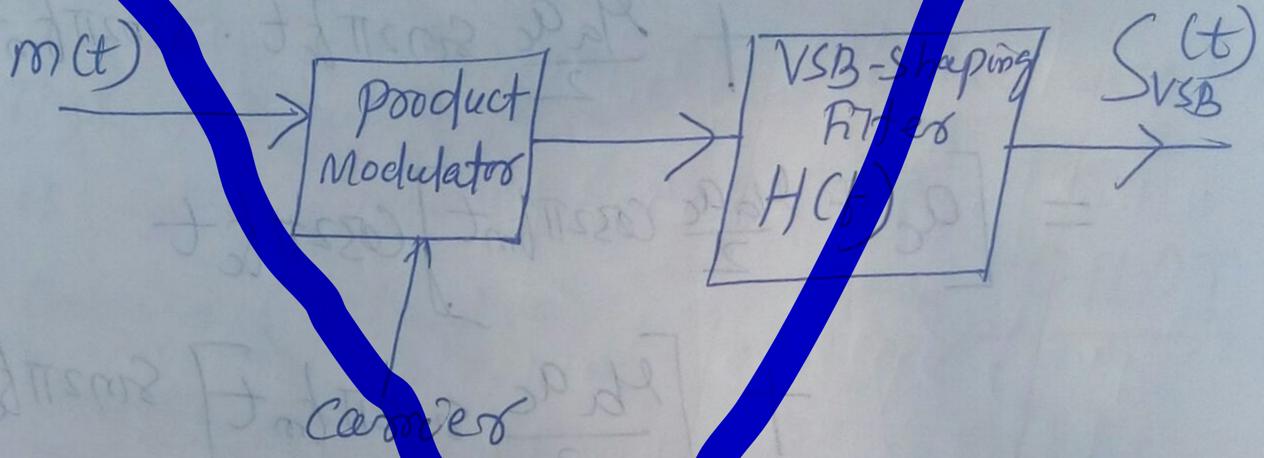
$$e(t) \approx \left[a_c^2 + a_c A_c \mu_a \cos 2\pi f_m t\right]^{\frac{1}{2}}$$

$$e(t) \approx a_c^2 + \frac{1}{2} a_c A_c \mu_a \cos 2\pi f_m t$$

→ message signal

D1 VSB Modulators:

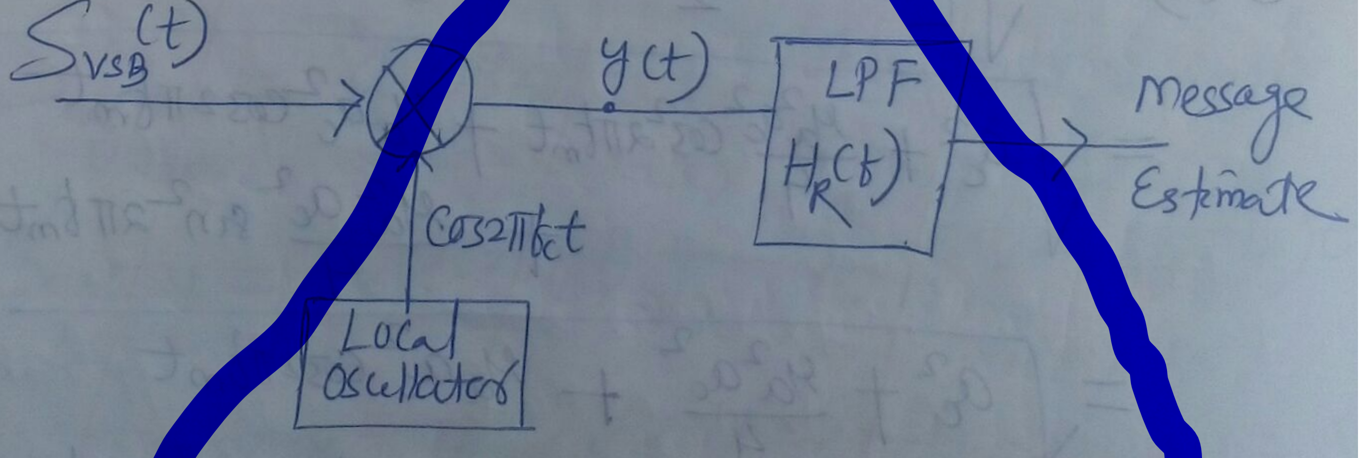
① Block Diagram:



Explanation: — DO —

D2 VSB Detectors

① Coherent detection:



$H_R(f)$ = Transfer function of LPF which recovers message.

Explanation :

$$y(t) = S_{VSB}(t) \cdot \cos 2\pi f_c t$$

we know

$$S_{VSB}(f) = \frac{1}{2} A_c \left[M(f+f_c) + M(f-f_c) \right] H(f)$$

so we can write $Y(f)$ as

$$Y(f) = \frac{1}{4} A_c \left[H(f+f_c) \cdot M(f+f_c+f_c) + H(f+f_c) M(f-f_c+f_c) \right]$$

$$+ \frac{1}{4} A_c \left[H(f-f_c) M(f+f_c-f_c) + H(f-f_c) \cdot M(f-f_c-f_c) \right]$$

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

→ When $Y(f)$ is passed through LPF

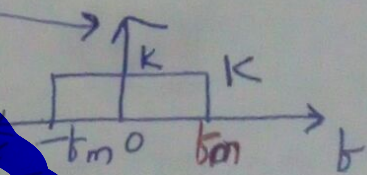
$$o/p = \frac{A_c}{4} H_R(f) \left[H(f+f_c) + H(f-f_c) \right] M(f)$$

* $H_R(f)$ and $H(f)$ is such that

condition

$$\boxed{H_R(f) \left[H(f+f_c) + H(f-f_c) \right] = \text{constant} = K}$$

over $-f_m \le f \le f_m$



$$\Rightarrow o/p = \frac{A_c}{4} K M(f)$$

So in time domain

$$o/p = \frac{A_c}{4} K m(t)$$

message

* Application :→ VSB is used in video transmission