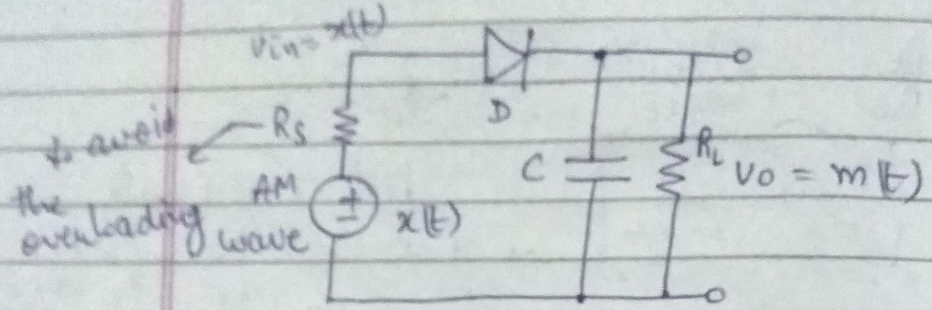
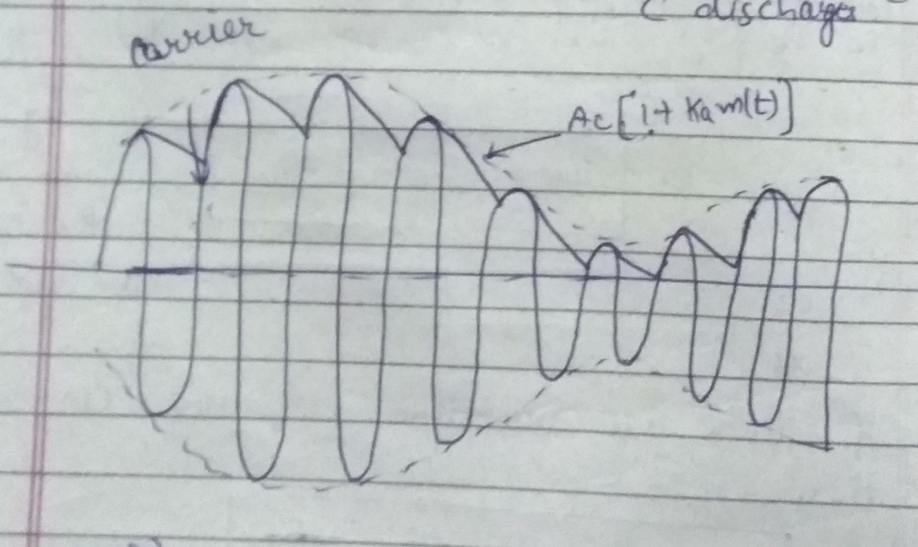
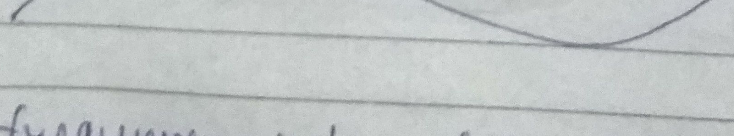
Envelope Detector



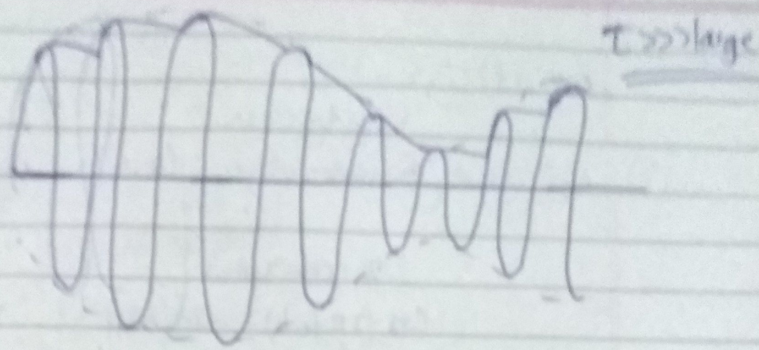
$V_{in} > V_{out}$ diode will be F.B. → C charge
$V_{in} < V_{out}$ diode will be R.B. → C discharge





frequency $\propto \frac{1}{\tau}$ $(\tau = R \cdot C)$

τ is very large so capacitor discharges very slowly.



If τ is very small, it traces the carrier signal.

** $\boxed{\frac{1}{f_c} <<< \tau <<< \frac{1}{f_m}}$ case to trace the message signal.

To utilize the side bands, we use the side band modulation. Either LSB or USB has to be removed and it is upto used which band to remove.

If it is DSB-SC, it will be mentioned.

In DSB-SC,

$$P_t = P_c \frac{\mu^2}{2}$$ [Pc component is removed in it]

Transmitted bandwidth = '2B', original message bandwidth = 'B'. Here Bandwidth is not utilized properly.

To utilize:

① QCM → (~~Quadratier~~ Quadrature Carrier Multiplexer)

2 - carriers

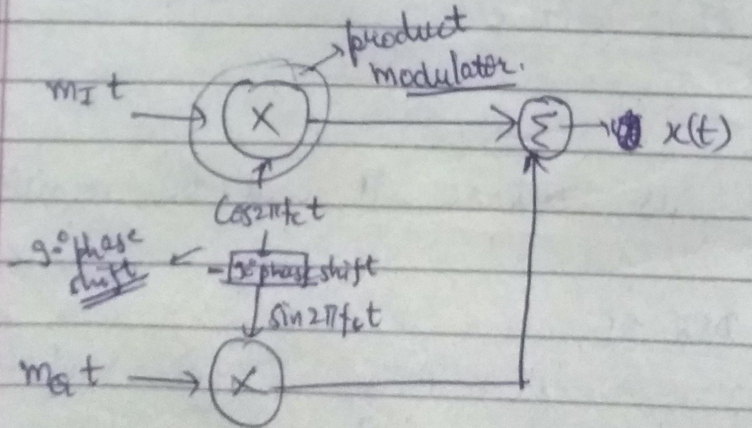
$\underbrace{\cos(2\pi f_c t),\ \sin(2\pi f_c t)}_{90^\circ \text{ phase shifted.}}$

$x(t)_{DSB-SC} = m(t) \cdot c(t)$

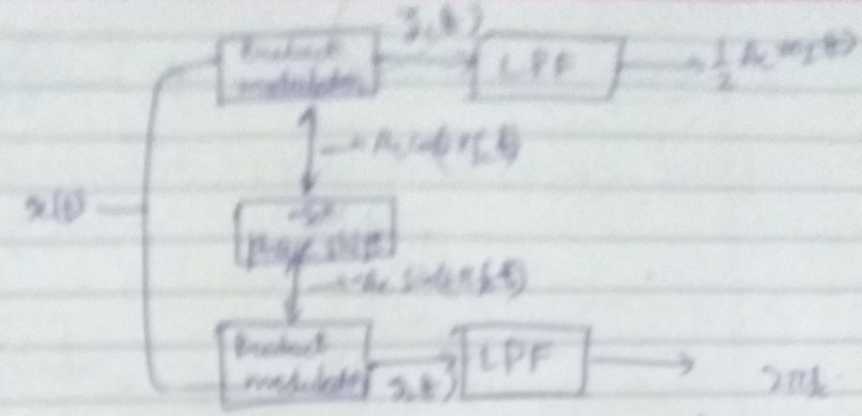
DSB-SC for Quadrature carrier.

$$x(t) = A_c \underbrace{\overset{\text{inphase}}{m_I(t)} \cos(2\pi f_c t) - A_c \overset{\text{quadrature pha...}}{m_Q(t)}}_{\text{two message signals.}} \sin(2...$$

~~At receiver~~



$$\sin(2\pi f_c t) \times \cos(2\pi f_c t) = \frac{1}{2} \underbrace{\sin(4\pi f_c t)}_{\text{High freq.}} \Rightarrow \boxed{LPF} = 0$$



$$z_1(t) = \left[A_c m_1(t)\cos(2\pi f_c t) - A_c m_2(t)\sin(2\pi f_c t)\right] \times A_c\cos 2\pi f_c t$$

$$= \frac{A_c m_1(t)}{2}\left(1+\cos(4\pi f_c t)\right) - \frac{A_c m_2(t)}{2}\sin 4\pi f_c t$$

$$= \frac{A_c m_1(t)}{2} + \underbrace{\frac{A_c m_1(t)}{2}\cos(4\pi f_c t)}_{2f_c} - \underbrace{\frac{A_c m_2(t)}{2}\sin(4\pi f_c t)}_{2f_c}$$

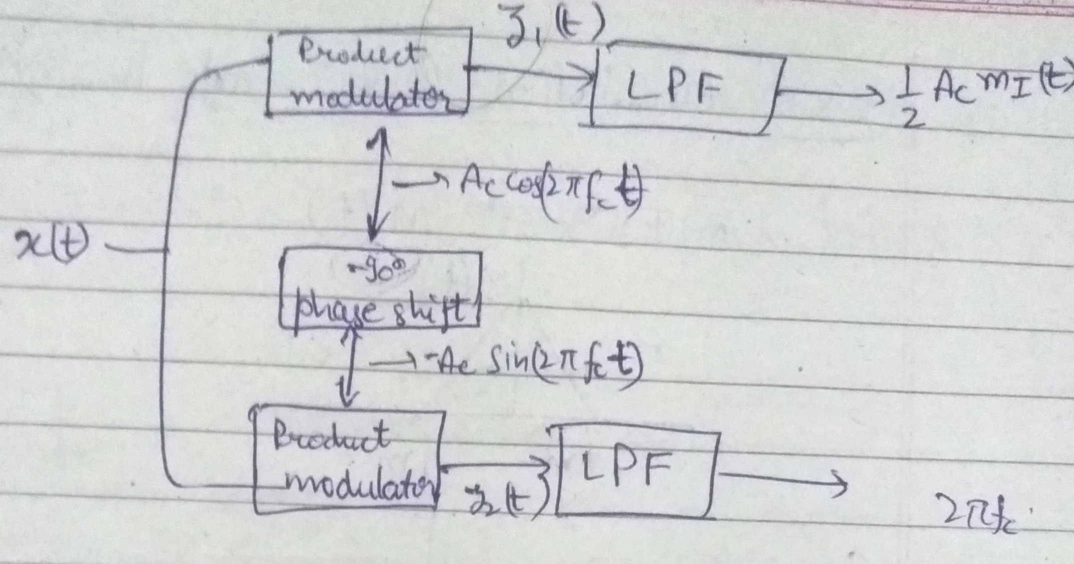
$\Downarrow$ $\boxed{\text{LPF}}$ High frequency

$$= \frac{1}{2}A_c m_1(t)$$

$$z_2(t) = \left[A_c m_1(t)\cos(2\pi f_c t) - A_c m_2(t)\sin(2\pi f_c t)\right](-\sin 2\pi f_c t)$$

$\Downarrow$ $\boxed{\text{LPF}}$

$$z_2(t) = \frac{1}{2}A_c m_2(t)$$



$$z_1(t) = \left[A_c m_I(t) \cos(2\pi f_c t) - A_c m_Q(t) \sin(2\pi f_c t)\right] \times A_c \cos 2\pi f_c t$$

$$= \frac{A_c m_I(t)}{2}\left(1 + \cos(4\pi f_c t)\right) - \frac{A_c m_Q(t)}{2} \sin 4\pi f_c t$$

$$= \underbrace{\frac{A_c m_I(t)}{2}}_{\Downarrow\ \boxed{LPF}} + \underbrace{\frac{A_c m_Q(t)}{2} \cos(4\pi f_c t)}_{2f_c} - \underbrace{\frac{A_c m_Q(t)}{2} \sin(4\pi f_c t)}_{2f_c}$$

High frequency

$$= \frac{1}{2} A_c m_I(t)$$

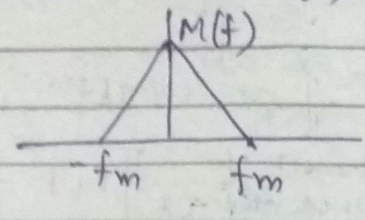
$$z_2(t) = \left[A_c m_I(t) \cos(2\pi f_c t) - A_c m_Q(t) \sin(2\pi f_c t)\right] (-\sin 2\pi f_c t)$$

$$\Downarrow\ \boxed{LPF}$$

$$z_2(t) = \frac{1}{2} A_c m_Q(t)$$

③ SSB Modulation (Single side band) modulat

$m(t) \longleftrightarrow M(f)$

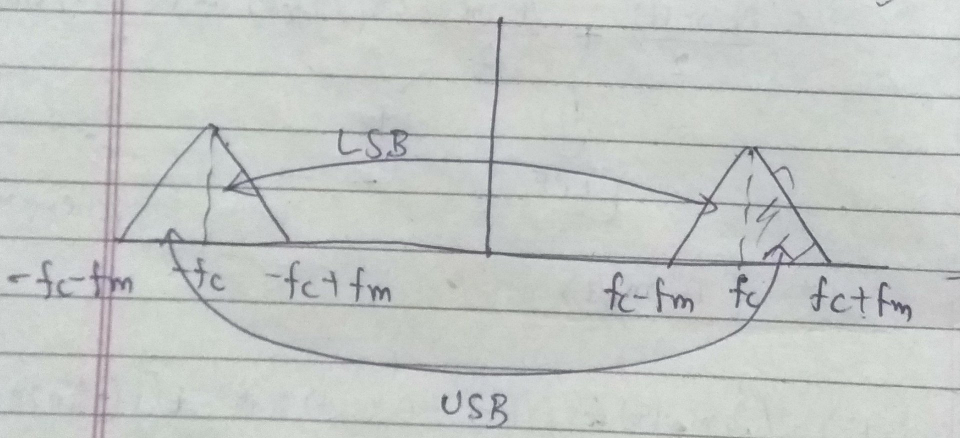


Consider,

$$x(t)_{DSB-SC} = m(t)\cdot \cos(2\pi f_c t)$$

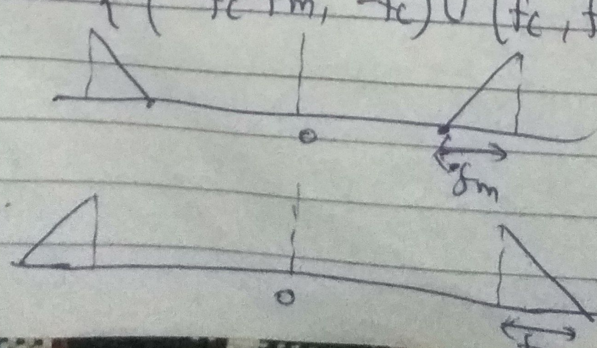
$$X(f) = M(f) \times \left[\frac{1}{2}\delta(f-f_c) + \frac{1}{2}\delta(f+f_c)\right]$$

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



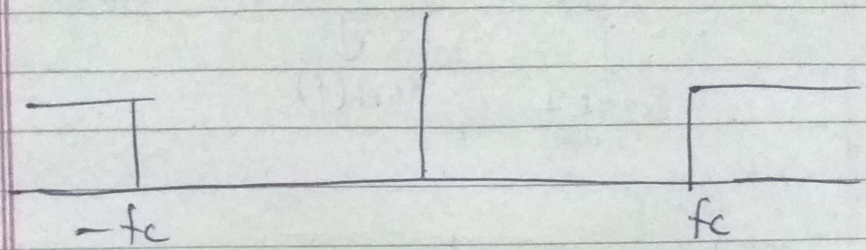
$$LSB = \{(-f_c, -f_c+f_m) \cup (f_c-f_m, f_c)\}$$

$$USB = \{(-f_c-f_m, -f_c) \cup (f_c, f_c+f_m)\}$$



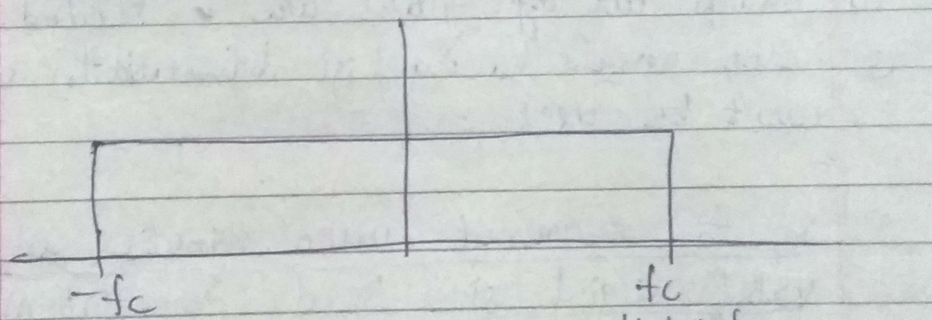
Consider generation of SSB modulation.

To generate LSB, use high pass filter.



$$H_{HPF}(f) = \begin{cases} 1 & ; |f_c| \geq f_a ; \\ 0 & ; \text{otherwise} \end{cases}$$

for USB;



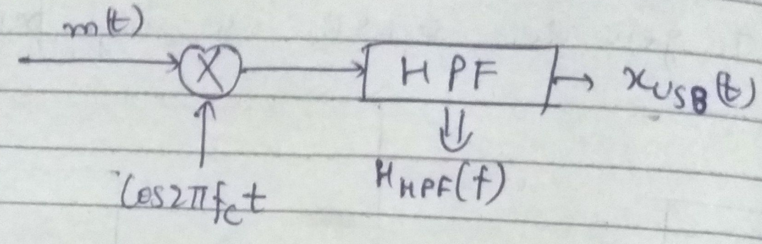
$$H_{LPF}(f) = \begin{cases} 1 & , |f_c| \leq f_a ; \\ 0 & , \text{otherwise} \end{cases}$$

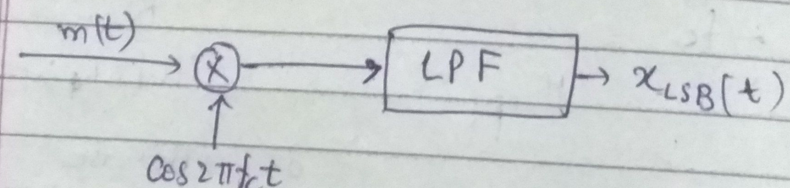
⇒ Frequency discrimination method for the SSB modulation.

⇒ Advantages of VSB:-

a) Easy to generate.
b) Have 25% large Bandwidth than SSB.
c) Filter design is easy.

SSB generation



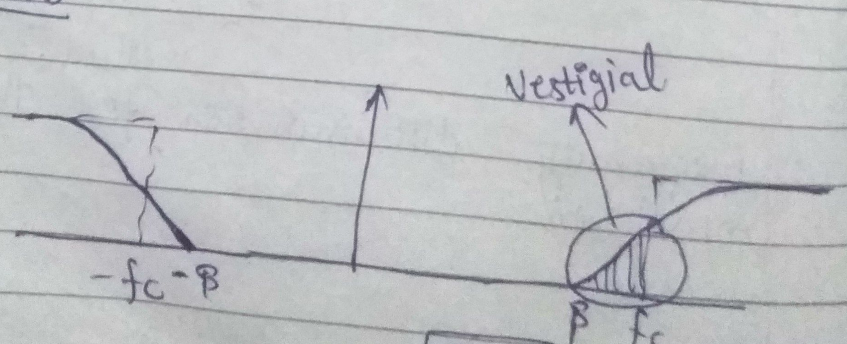


Major problem with SSB:-

① Sharp cut off filters are needed.
② video signals (having high bandwidth), we SSB can't be used.

⇒ So to transmit video signals we need VSB (vestigial side band modulation).

⇒ VSB

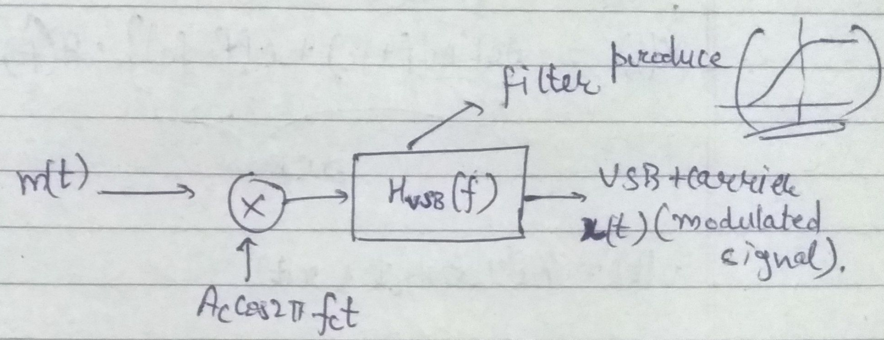


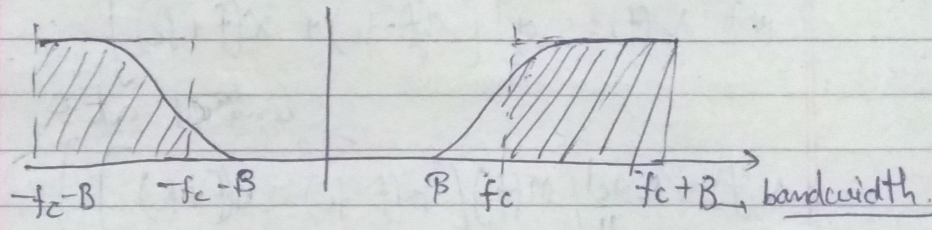
$\boxed{\beta << B}$ $\boxed{f_c - \beta \approx 0}$

One side ~~of~~ band is completely transferred along with partial other side band

* here freq. component is high (4-5 MHz) than the ~~freq.~~ freq. in SSB.

* SSB is used for speech signals (low bandwidth) and VSB is used for video signals.



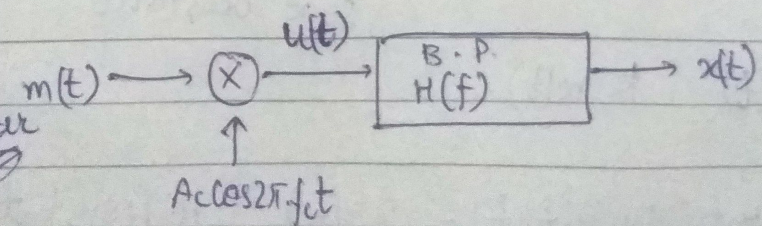


$\beta << B$

$$x(t) = \frac{A_c}{2}\left[1 + m(t)\right]\cos 2\pi f_c t - \frac{A_c}{2}\, y(t).\sin 2\pi f_c t$$

$$y(t) = f(m(t), \hat{m}(t))$$

$$B_T = B + \beta \quad [\because \beta << B]$$



at the transmitter end

$$x(t) \longrightarrow \otimes \xrightarrow{v(t)} \boxed{\text{LPF}} \longrightarrow v_o(t) \propto m(t)$$

at receiver end $\nearrow$ $\uparrow$ $A_c' \cos 2\pi f_c t$

demodulated signal

$$X(f) = \underbrace{U(f)}_{\text{DSB-SC}} \cdot \hat{H}(f).$$

$$X(f) = \underbrace{\frac{A_c}{2}\left[M(f+f_c) + M(f-f_c)\right]}_{\text{DSB}} \cdot H(\hat{f})$$

$$v(t) = A_c' \cos 2\pi f_c t \cdot x(t)$$

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

centered at 0

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

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

centered at $2f_c$.

$$V_o(f) = \frac{A_c A_c'}{4} M(f) \underbrace{\left[H(f-f_c) + H(f+f_c)\right]}_{\text{some constant}}$$

$$v_o(t) = k\, m(t)$$

$$H(f-f_c) + H(f+f_c) = 2H(f_c) = A \text{ (constant)}$$

$$H(f_c) = \frac{1}{2}$$

$$\boxed{H(f-f_c) + H(f+f_c) = 1} \Rightarrow \text{design filter like } \underline{\text{this}}.$$

If in VSB if $B = 0$, special case of ~~SSB~~ VSB $\Rightarrow$ SSB.
But in SSB if $B > 0$, no special case / don't act as VSB
because SSB is low freq. while VSB is high freq.

$\Rightarrow$ If in SSB, we do not have sharp cut off then we will have delay and phase distortion.

$\Rightarrow$ $s(t) = s_I(t)\cos 2\pi f_c t - s_Q(t)\sin 2\pi f_c t$

$$S_I(f) = \begin{cases} S(f-f_c) + S(f+f_c), & |f_c| < B \\ 0, & |f_c| > B \end{cases}$$

$\Rightarrow$ $S(f) = \frac{1}{2} A_c [M(f-f_c) + M(f+f_c)] \cdot H(f).$

$$S_I(f) = \begin{cases} \frac{1}{2} A_c\, M(f)\, [H(f-f_c) + H(f+f_c)], & |f| < B \\ 0, & |f| > B. \end{cases}$$

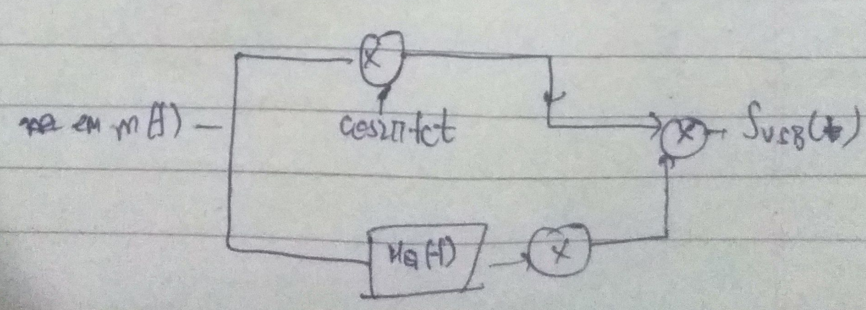
$s_I(t) = \frac{1}{2} A_c\, m(t)$

$$S_Q(f) = \begin{cases} j[S(f-f_c) - S(f+f_c)], & |f| \le B \\ 0, & |f| > B \end{cases}$$

$= \frac{j}{2} M(f)\, [H(f-f_c) - H(f+f_c)]$

$H_Q(f) = j[H(f-f_c) + H(f+f_c)].$

$m(t) \xrightarrow{H_Q(f)} m'(t)$



~~x_f~~

$$x(t) = x_I \sin 2\pi f_c t - x_Q \cos 2\pi f_c t$$

DSB-SC

$x_I(t) = m(t)$, $x_Q(t) = 0$

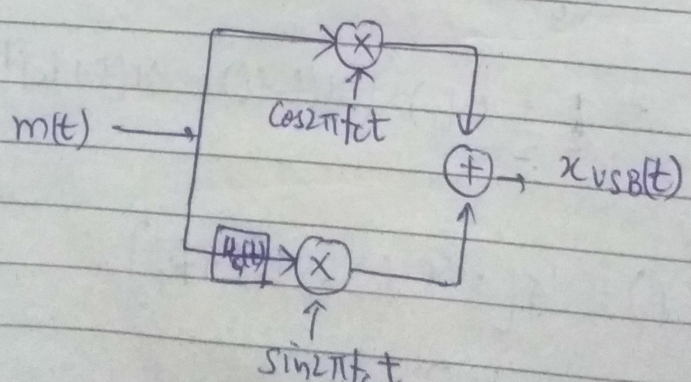
transfer function

$$X_I(f) = \begin{cases} \frac{1}{2} A_c M(f) \left[H(f-f_c) + H(f+f_c)\right] & , |f| < B \\ 0 & , |f| > B \end{cases}$$

$$x_I(t) = \frac{1}{2} A_c m(t)$$

$$X_Q(f) = \begin{cases} \frac{\cancel{A_c M}}{2} \; j \; S(f-f_c) - S(f+f_c) & , |f| < B \\ 0 & , |f| \geq B \end{cases}$$

$$x_{VSB}(t) = \frac{1}{2} A_c m(t) \cos 2\pi f_c t - \frac{1}{2} A_c m'(t) \sin 2\pi f_c t$$



$m(t)\cos\omega_1 t \longrightarrow \otimes \longrightarrow \boxed{B.P_{\omega_2}} \quad m(t)\cos\omega_2 t$

$\uparrow$

$\boxed{L.O.}$

$2\cos(\omega_1 \pm \omega_2)t$

⇒ Frequency translation of message signal.

$2m(t)\cos\omega_1 t \;\cos(\omega_1 \pm \omega_2)t$

$X\left(\cos(2\omega_1 \pm \omega_2) + \cos\omega_2 t\right)$

$\downarrow$

filtered out ⇒ $X\cos\omega_2 t$

if ⇒ $m(t)\cdot\cos(\omega_1 + 2\omega_2)t$

$\cos(2\omega_1 + 3\omega_2)$

$/\cos(\omega_2)$

→ Image frequency of ω_1.

message $k(t)\cos(\omega_1 \pm 2\omega_2)t$ local oscillator $= 2\cos(\omega_1 \pm \omega_2)t$

⇒ $k(t)\cos(2\omega_1 + 3\omega_2)t + k(t)\cos(\omega_2 t)$

L.O. $(\omega_1 + \omega_2)$ LO $(\omega_1 - \omega_2)$

IF $(\omega_1 + 2\omega_2)$ IF $(\omega_1 - 2\omega_2)$

⇒ The main use of the translators is to design the ~~oscillator~~ receivers.

Receivers :-

① **Freq. selectivity** :-

→ A ~~go~~ good receiver can catch multiple frequencies.

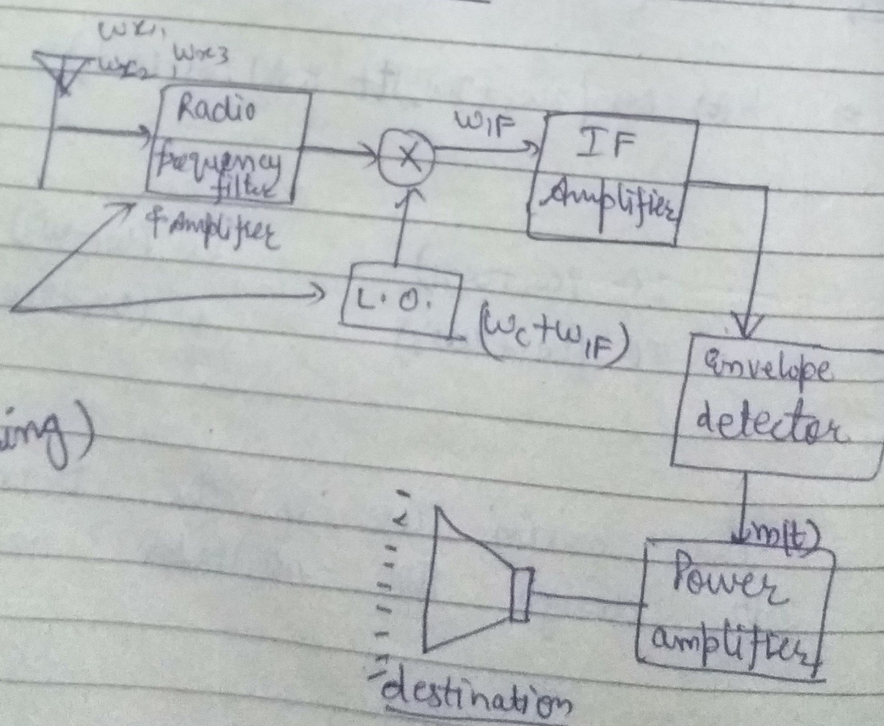
② **Sensitivity** :-

weak signal can also be received.

③ **Fedelity** :-

It should be able to produce ~~baseband~~ original baseband signal.

Superhetrodyne Receiver



both will be intune (~~damp~~ tuning) gang

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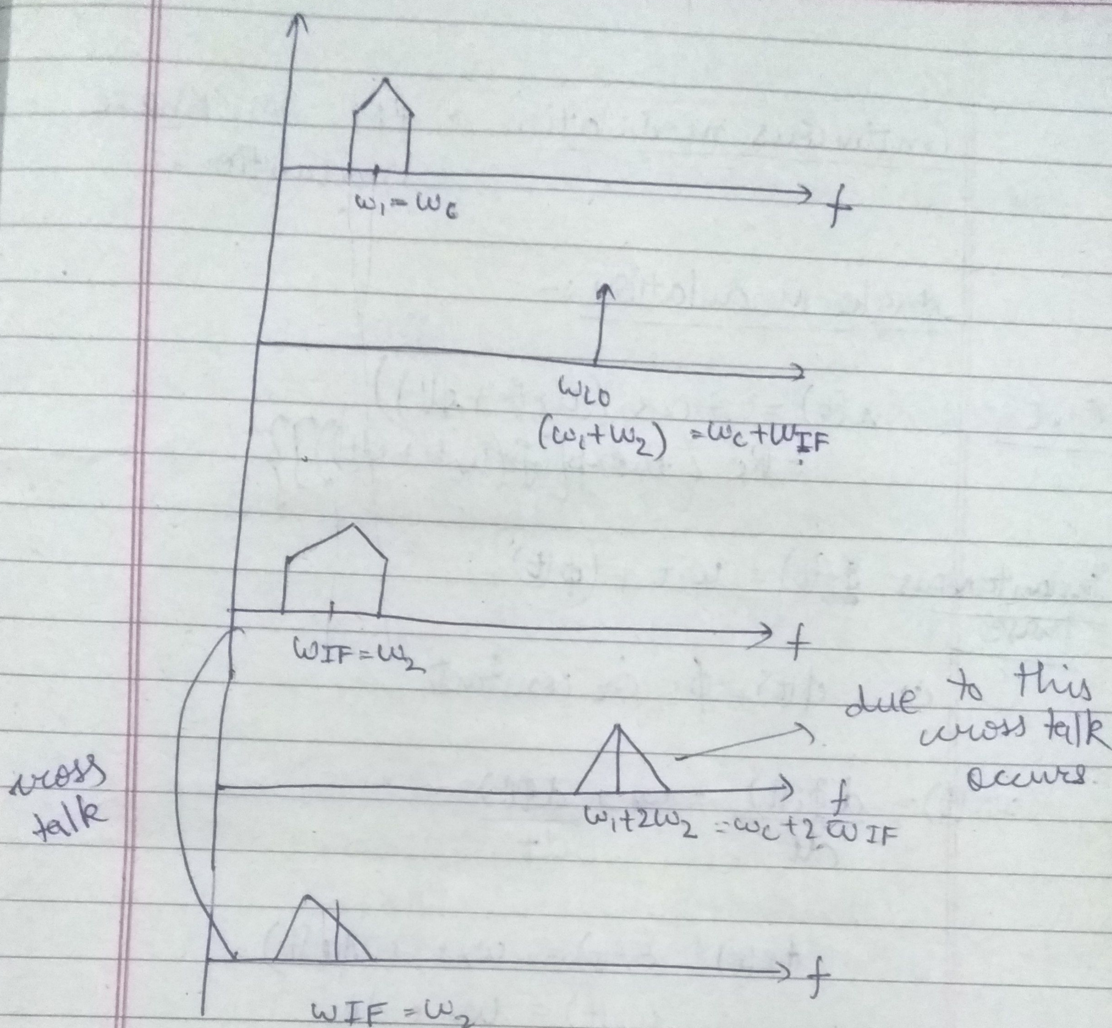

$\omega_{IF} = 455\,kHz$.

Date 16/3/18

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Continuous modulation → FM, AM, phase modulation.

Angle Modulation :-

G.E. :-

$$x(t) = A\cos(\omega_c t + \phi(t))$$

$$= Re\{A\exp[j(\omega_c t + \phi(t))]\}$$

Instantaneous phase $\theta_i(t) = \omega_c t + \phi(t)$

(i) $\phi(t) = \phi$ or constant

$$\omega_i(t) = \frac{d\theta_i(t)}{dt} = \omega_c + \frac{d\phi(t)}{dt}$$

~~$\phi_i(t)$~~ $\theta_i(t) = \omega_c t + \phi(t)$

$$\omega_i(t) = \omega_c + \frac{d\phi}{dt}$$

$$\phi(t) \propto m(t)$$

$$\phi(t) = k_p m(t)$$

$$\frac{d\phi(t)}{dt} \propto m(t)$$

$$\frac{d\phi(t)}{dt} = k_f m(t)$$

$$\phi(t) = K_f \int_{-\infty}^{t} m(\tau)d\tau$$

Instantaneous phase deviation $= \phi(t)$

$\frac{d\phi}{dt}$ = instantaneous frequency deviation.

$\cancel{\phi(t) \propto}$

$$\phi(t) = K_p\, m(t) \quad \text{(PM)}$$

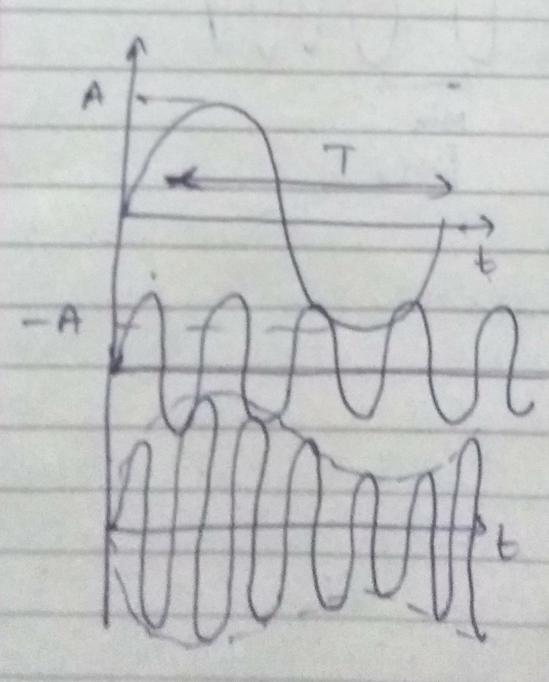
phase deviation

$$\frac{d\phi}{dt} = K_f\, m(t)$$

$$\phi(t) = K_f \int_{-\infty}^{t} m(\tau)\, d\tau \quad (FM)$$

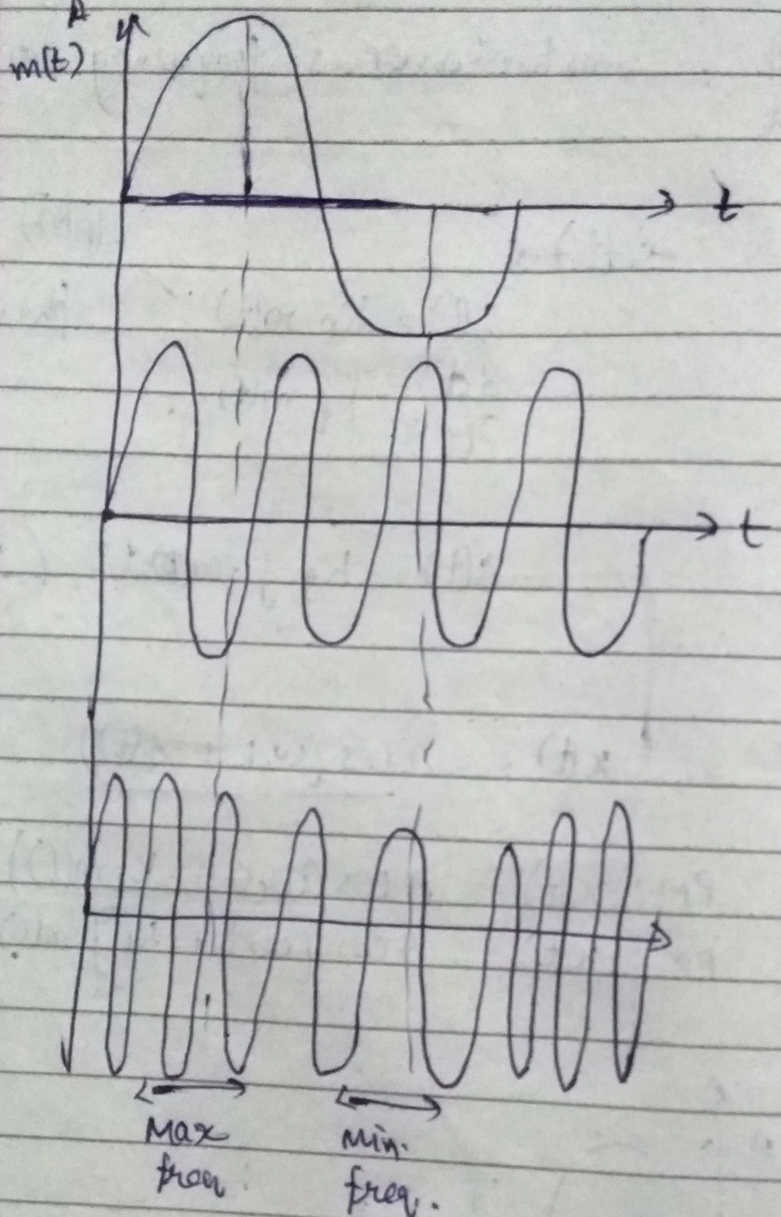
$$x(t) = A\cos(\omega_c t + \phi(t))$$

$$PM: x(t) = A\cos(\omega_c t + K_p m(t))$$
$$FM: x(t) = A\cos\left(\omega_c t + K_f \int_{-\infty}^{t} m(\tau)\, d\tau\right)$$

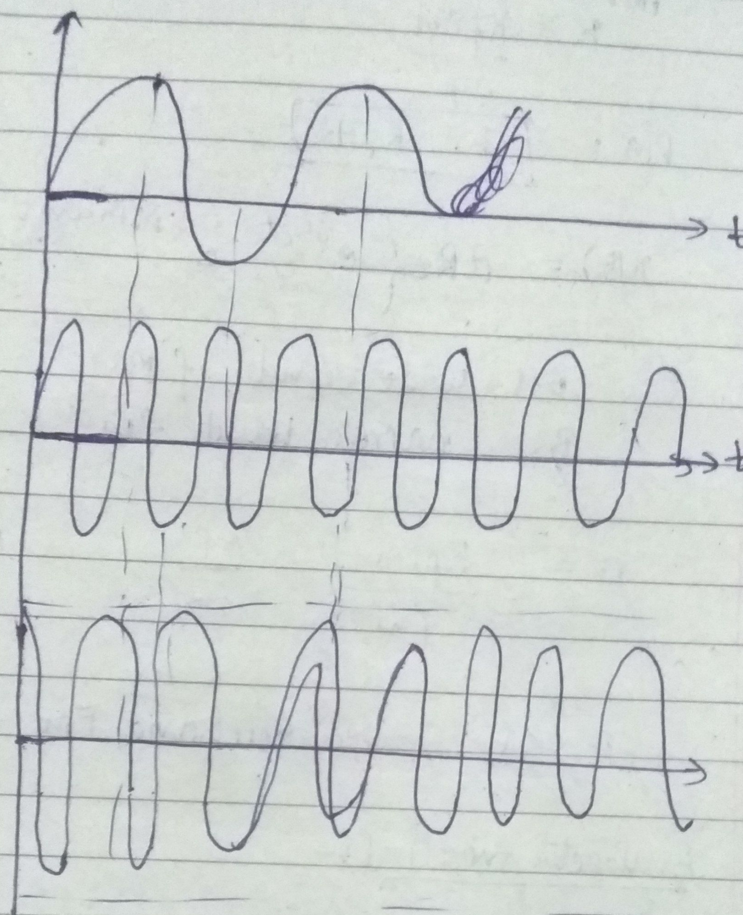


AM modulated wave

Freqiuency Modulated Wave



Phase modulated wave



⇒ FM and PM are non-linear and AM is linear.

⇒ Exact spectrum calculation for angle modulation is difficult.

⇒ Possible to study the spectrum when ~~m(t) is equal to A_m cos~~

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

PM $\phi(t) = K_p A_m \cos \omega_m t$

PM $\phi(t) = K_f A_m \sin \omega_m t$

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$$x_{FM}(t) = A\cos(\omega_c t + \beta\sin\omega_m t)$$

$$\beta = \frac{K_f A_m}{\omega_f}$$

PM : $\boxed{\beta = K_p A_m}$

$$x(t) = A\,Re\{e^{j\omega_c t}\, e^{j\beta\sin\omega_m t}\}$$

$\beta \geq 1$ wide band fM.
$\beta < 1$ narrow band fM.

$$\beta = \frac{K_f . A_m}{f_m} = \frac{\Delta f}{f_m}$$

K_f = sensitivity factor (radi/ vol)

$\beta << 1$ Narrowband FM ~~signal~~ generato

<u>Indirect method :-</u>

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

$$x_{FM}(t) = A\cos(2\pi f_c t + \beta\sin(2\pi f_m t))$$

$\frac{\Delta f}{f_m} << 1$

$\Delta f << f_m$ (Narrow band fM)

$$x_{NBFM}(t) = A\cos(2\pi f_c t + \beta\sin(2\pi f_m t))$$

$A\cos(C+D)$ → like

NBFM= narrow band FM

$$x_{NBFM}(t) = A(\cos(2\pi f_c t)\cos(\beta\sin 2\pi f_m t) - \sin(2\pi f_c t)\sin(\beta\sin(2\pi f_m t)))$$

$\boxed{\beta << 1}$ ~ 0

$$x_{NBFM}(t) = A(\cos(2\pi f_c t) \times 1 - \sin(2\pi f_c t) \times \theta)$$

(conti-)