AM Modulation :-

Amplitude Modulation (AM) is defined as a process in which the amplitude of the carrier wave ($c(t)$) is varied about a mean value, linearly with the baseband signal $m(t)$.

$$s(t) = A_c\left[1 + K_a m(t)\right] \cos(2\pi f_c t).$$

Modulating signal, e_m.

$$e_m = E_m \cdot \sin\omega_m t$$

Carrier signal, e_c

$$e_c = E_c \cdot \sin\omega_c t.$$

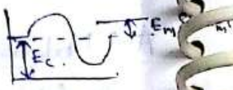
$E_m \rightarrow$ Max^m amplitude of modulating signal.

$E_c \rightarrow$ " " " carrier "

$\omega_m \rightarrow$ Frequency of modulating signal

$\omega_c \rightarrow$ Frequency of carrier signal.

Amplitude of AM wave is



$$A = V_c + V_m$$
$$= V_c + V_m \sin\omega_m t$$

$$E_{AM} = E_c + E_m$$
$$= E_c + E_m \sin\omega_m t$$

w.k.t. $m = \frac{E_m}{E_c}$.

$$\Rightarrow \boxed{E_m = m \cdot E_c}.$$

$$\Rightarrow E_{AM} = E_c + m \cdot E_c \cdot \sin\omega_m t$$
$$= E_c(1 + m\sin\omega_m t)$$

The Instantaneous Voltage of the resulting amplitude modulated waveform is

$$e_{AM} = E_{AM} \cdot \sin\omega_c t$$
$$= \left[E_c(1 + m\sin\omega_m t)\right]\sin\omega_c t$$
$$= E_c\sin\omega_c t + m \cdot E_c \cdot \sin\omega_m t \cdot \sin\omega_c t$$

$$\sin A \sin B = \frac{1}{2}\cos(A-B) - \frac{1}{2}\cos(A+B).$$

$$e_{AM} = E_c\sin\omega_c t + m \cdot E_c \frac{1}{2}\left\{\cos(\omega_c - \omega_m)t - \cos(\omega_m + \omega_c)t\right\}$$

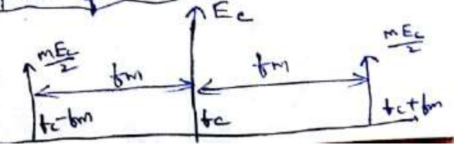
$$= \underbrace{E_c\sin\omega_c t}_{\text{Un modulated Carrier.}} + \underbrace{\frac{mE_c}{2}\cos(\omega_c - \omega_m)t}_{\text{Lower Side Band.}} - \underbrace{\frac{mE_c}{2} \cdot \cos(\omega_c + \omega_m)t}_{\text{Upper Side Band.}}$$

w.k.t. $\omega_c = 2\pi f_c$
$\omega_m = 2\pi f_m$.

$$e_{AM} = E_c\sin 2\pi f_c t + \frac{mE_c}{2}\cos 2\pi(f_c - f_m)t - \frac{mE_c}{2}\cos 2\pi(f_c + f_m)t.$$

$$= E_c\sin 2\pi f_c t + \frac{mE_c}{2}\cos 2\pi \cdot (f_{LSB})t - \frac{mE_c}{2}\cos 2\pi(f_{USB})t.$$

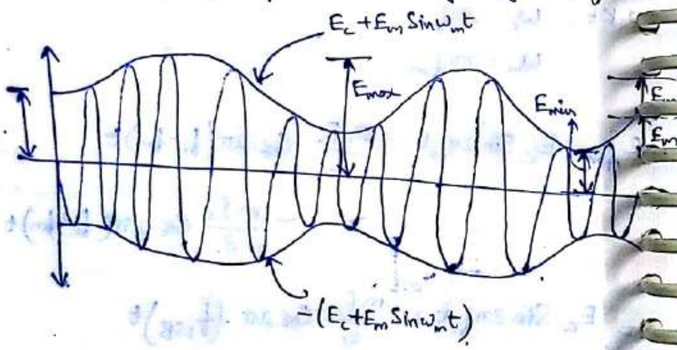
Frequency spectrum of AM wave:-



∴ B.W of AM wave is

$$B.W = f_{USB} - f_{LSB}$$
$$= (f_c + f_m) - (f_c - f_m)$$
$$= 2 f_m.$$

=> BW required for AM modulation is twice the maximum frequency of the modulating signal, f_m.



Modulation Index :- (m)

$$E_m = \frac{E_{max} - E_{min}}{2}$$

$$E_c = E_{max} - E_m \Rightarrow E_{max} - \frac{E_{max} - E_{min}}{2}$$

$$\Rightarrow \frac{2E_{max} - E_{max} + E_{min}}{2}$$

$$\boxed{= \frac{E_{max} + E_{min}}{2}}$$

$$m \Rightarrow \frac{E_m}{E_c} = \frac{(E_{max} - E_{min})/2}{(E_{max} + E_{min})/2}$$

$$\boxed{m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}}$$

Power relation in AM wave :-

W.K.T. AM signal has 3 components., unmodulated carrier, LSB, & USB.

Hence, total Power, $P_{Total} = P_c + P_{USB} + P_{LSB}$.

$$= \frac{E_c^2}{R} + \frac{E_{LSB}^2}{R} + \frac{E_{USB}^2}{R}.$$

$$P_c = \frac{E_c^2}{R} = \frac{(E_c/\sqrt{2})^2}{R} = \frac{E_c^2}{2R}$$

$$\boxed{\frac{E_c}{\sqrt{2}} \Rightarrow \text{r.m.s Value}}$$

$$P_{LSB} = \frac{E_{LSB}^2}{R}$$

$$= \frac{\left(\frac{mE_c/2}{\sqrt{2}}\right)^2}{R} = \frac{\frac{m^2 . E_c^2}{(4)(2)}}{R} = \frac{m^2 E_c^2}{8R}$$

$|||^{ly}$ $P_{USB} = \frac{m^2 E_c^2}{8R}$.

$$P_{Total} = \frac{E_c^2}{2R} + \frac{m^2 E_c^2}{8R} + \frac{m^2 E_c^2}{8R}$$

$$= \frac{E_c^2}{2R}\left[1 + \frac{m^2}{4} + \frac{m^2}{4}\right] = \frac{E_c^2}{2R}\left[1 + \frac{m^2}{2}\right]$$

$$P_{Total} = P_c\left(1 + \frac{m^2}{2}\right)$$

$$\boxed{\frac{P_{Total}}{P_c} = 1 + \frac{m^2}{2}}$$

To avoid distortion, Max^m value of $m = 1$ (100%)

$\Rightarrow \frac{P_{Total}}{P_c} = 1.5$ $\Rightarrow \boxed{P_{Total} = 1.5\, P_c}$

$\Rightarrow m = \sqrt{2\left(\frac{P_{Total}}{P_c} - 1\right)}$

Current Calculations :-

$$P = I^2 R.$$

$$P_{Total} = I_{Total}^2 R.$$

$|||^{ly}$ the Carrier Current & Carrier power will be [re]lated as.,

$$P_c = I_c^2 R.$$

w.k.t. $P_{Total} = P_c\left(1 + \frac{m^2}{2}\right)$.

$$\cancel{P_{Total}}\ I_{Total}^2 R = \left(I_c^2 . R\right)\left(1 + \frac{m^2}{2}\right).$$

$$I_{Total}^2 = I_c^2\left(1 + \frac{m^2}{2}\right)$$

$$I_{Total} = I_c \sqrt{1 + \frac{m^2}{2}}$$

$$\frac{I_{Total}^2}{I_c^2} = 1 + \frac{m^2}{2}$$

$$\frac{m^2}{2} = \frac{I_{Total}^2}{I_c^2} - 1$$

$$m^2 = 2\left[\frac{I_{Total}^2}{I_c^2} - 1\right]$$

$$\boxed{m = \sqrt{2\cdot\left(\frac{I_{Total}^2}{I_c^2} - 1\right)}}$$

① A 10MHz Sinusoidal Carrier wave of amplitude 10mV is modulated by a 5KHz Sinusoidal audio signal wave of amplitude 6mV. Find the frequency Components of the resultant modulated wave and their amplitudes.

Solution :- $V_c = 10mV$; $V_m = 6mV$

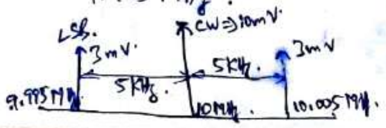
$f_c = 10MHz$; $f_m = 5KHz = 0.005\,MHz$

$\boxed{m = \frac{V_m}{V_c} = 0.6}$

① Carrier wave, $f_c = 10MHz$.

② U.Side frequency, (USF) $= f_c + f_m = 10.005\,MHz$.

③ LSF $= 9.995\,MHz$.



Amplitude of LSF = USF

$= \frac{m.V_c}{2}$

$= \frac{0.6(10)}{2}$

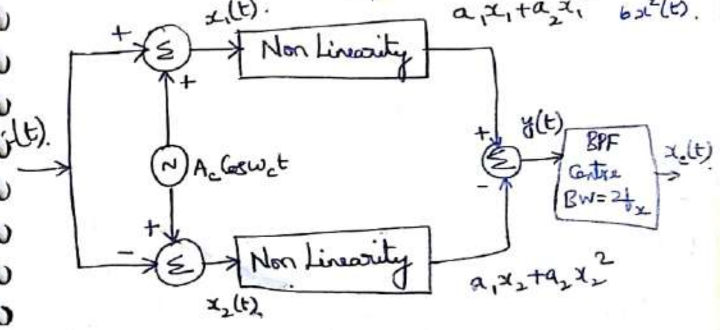
$= 3mV$.

Balanced Modulator :-

I/O ch. of the non-linear elements be represented (or) approximated by a power Series ⇒ $y(t) = ax(t) + bx^2(t)$.

$a_1x_1 + a_2x_1^2$

(1)



$$y(t) = a_1\left[A_c\cos\omega_c t + x(t)\right] + a_2\left[A_c\cos\omega_c t + x(t)\right]^2$$

$$-\left[a_1\left\{A_c\cos\omega_c t - x(t)\right\} + a_2\left\{A_c\cos\omega_c t - x(t)\right\}^2\right]$$

$$= a_1A_c\cos\omega_c t + a_1 x(t) + a_2\left[A_c^2\cos^2\omega_c t + x^2(t) + 2A_c x(t).\cos\omega_c t\right]$$

$$-\left[a_1A_c\cos\omega_c t - a_1x(t) + a_2\left[A_c^2\cos^2\omega_c t + x^2(t) - 2A_c\cos\omega_c t.x(t)\right]\right]$$

$=$

$I = av$ (For linear device).

$I = av + bv^2 + cv^3 + \ldots$ (For Non Linear devices)

$$= \cancel{a_1 A_c \cos\omega_c t} + a_1 x(t) + \cancel{a_2 A_c^2 \cos^2\omega_c t}$$

$$+ \cancel{a_2 x^2(t)} + 2 a_2 A_c x(t) \cos\omega_c t$$

$$- \cancel{a_1 A_c \cos\omega_c t} + a_1 x(t) - \cancel{a_2 A_c^2 \cos^2\omega_c t} - \cancel{a_2 x^2(t)}$$

$$+ 2 a_2 A_c \cos\omega_c t . x(t).$$

$$\Rightarrow 2a_1 x(t) + 4a_2 A_c x(t). \cos\omega_c t.$$

$\boxed{f_c > 2f}$ So we get only the ...

WKT. $x(t) \Rightarrow$ Modulating wave $\Rightarrow A_m \cos\omega_m t$.

and RF Carrier $\Rightarrow A_c \cos\omega_c t$.

$$\Rightarrow y(t) = 2a_1 (A_m \cos\omega_m t) + 4a_2 A_c A_m \cos\omega_m t. \cos\omega_c t$$

$$\cos A . \cos B = \frac{\cos(A+B) + \cos(A-B)}{2}$$

$$\Rightarrow y(t) = 2.a_1 A_m \cos\omega_m t + \underline{2a_2} A_c A_m \left[\cos(\omega_m+\omega_c)t + \cos(\omega_m-\omega_c)t\right]$$

$$\boxed{y(t) = 2a_1 A_m \cos\omega_m t + 2a_2 A_c A_m \cos(\omega_m+\omega_c)t + 2a_2 A_c A_m \cos(\omega_m-\omega_c)t}$$

$2a_2 A_c A_m \cos(\omega_m+\omega_c)t \rightarrow$ USB

$2a_2 A_c A_m \cos(\omega_m-\omega_c)t \rightarrow$ LSB

Baseband term

Carrier is suppressed

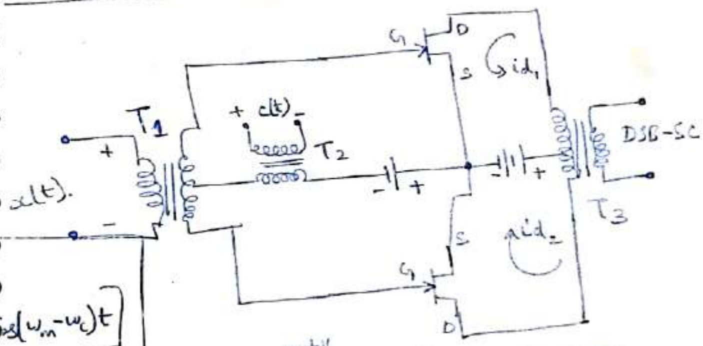
∴ output voltage, {∵ T_2 & T_3 are RF Transformers} (2)

$$y(t) = 2a_2 A_c A_m \left[\cos(\omega_m+\omega_c)t + \cos(\omega_m-\omega_c)t\right]$$

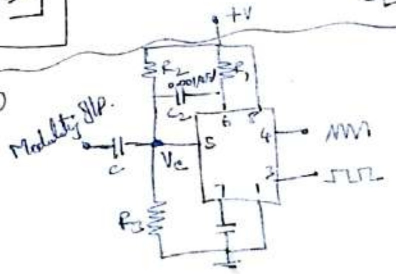
$$\boxed{y(t) = K\left[\cos(\omega_m+\omega_c)t + \cos(\omega_m-\omega_c)t\right]}$$

The output is DSB-SC. $K \rightarrow$ Current-to voltage conversion factor.

FET Balanced Modulator:-



V.C.O



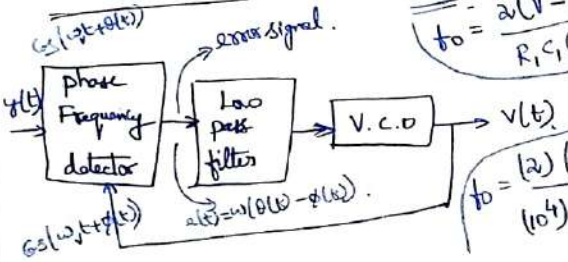
NE/SE565VCO

Phase Locked Loop :-

$v_c = 9.5 \Rightarrow 41$
$v_c = 11.5 \Rightarrow 8.2$

V.C.O

$$f_0 = \frac{2(V - V_c)}{R_1 C_1 (V)}$$



$$f_0 = \frac{(2)(12 - V_c)}{(10^4)(10^{-9})(12)}$$

0.001 μF

(*) phase detector Compares two input signals & produces an error signal which is proportional to their phase difference.

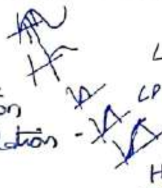
* The error signal is low pass filtered and used to drive a V.C.O which creates an output phase.

* If the phase from the oscillator falls behind that of the reference (The Input is the reference).
[ie., Input frequency increases] , the phase detector changes the Control voltage of the oscillator, so that the V.CO speeds up.

* Likewise, if the phase from the oscillator creeps of the reference, (ie., reference (Input) frequency decreases), the phase detector changes the Control voltage to slow down the oscillator.

Linear Modulation :-

(i) Base modulation
(ii) Collector modulation



L	I	D
LPF	Int	DeEmp.
H	D	P.
HPF	Diff.	Pre

(i) Base Modulation :-

Square law modulation :-

1). The signal applied to the non-linear device is $v_2(t) = a_1 v_1(t) + a_2 \cdot v_1^2(t)$.

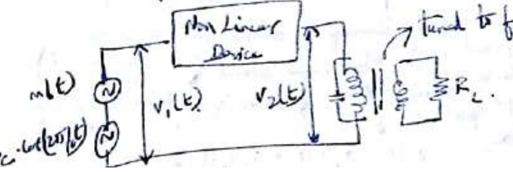
$a_1, a_2 \rightarrow$ Constants.
$v_1(t) \rightarrow$ Input Voltage
$v_2(t) \rightarrow$ Output Voltage.

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

(a) Evaluate the output Voltage, $v_2(t)$.

(b) Specify the frequency response that the Tuned Circuit must satisfy in order to generate an AM signal with f_c as the Carrier frequency.

(c) what is the amplitude Sensitivity of this AM signal.



Solution:-

$$v_2(t) = a_1 v_1(t) + a_2 v_1^2(t)$$

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

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

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

$$+ \underbrace{a_1 m(t) + a_2 m^2(t) + a_2 A_c^2 \cos^2(2\pi f_c t)}_{\text{Unwanted terms removed by filters}}$$

$$\boxed{K_a = \frac{2a_2}{a_1}}$$

A square law modulator requires 3 features;

(i) Summing the Carrier & modulating waves.

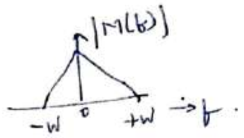
(ii). Non-Linear element (Semiconductor diodes & Transistors)

(iii). BPF for extracting the desired modulation products.

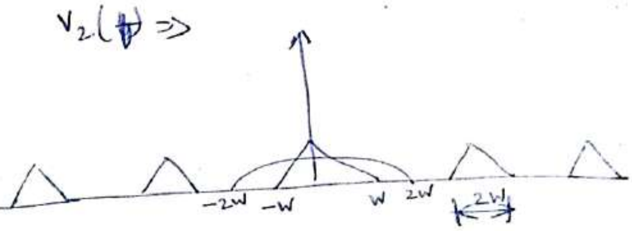
The Transfer characteristic of the diode-load resistor combination can be represented closely by a square law:-

$$\boxed{\text{Square law:-} \quad v_2(t) = a_1 v_1(t) + a_2 v_1^2(t)}$$

(b) Let the modulating wave $m(t)$ be limited to the band $-\omega \le f \le \omega$ as in figure.,



$V_2(f) \Rightarrow$



The Unwanted terms are removed from $v_2(t)$ by designing the tuned filter at the modulator output to have a mid-band frequency 'f_c' & B.W "2W" which satisfies the requirements that $f_c > 3W$.

(c) Amplitude sensitivity:-

$$\boxed{K_a = \frac{2a_2}{a_1}}.$$

① Using the message signal $m(t) = \frac{1}{1+t^2}$, determine ~~and~~ ~~sketch~~ the modulated waves for the following methods of modulation :-

(a) Amplitude modulation with 50 percent modulation

(b) Double sideband - suppressed Carrier modulation

(c) Single sideband modulation with only the upper sideband transmitted.

(d) Single sideband modulation with only the lower sideband transmitted.

<u>Solution</u> :-

a) <u>Amplitude Modulation</u> :-

$$s(t) = A_c(1 + K_a m(t)) \cdot \cos 2\pi f_c t$$

$$= A_c\left(1 + K_a\left(\frac{1}{1+t^2}\right)\right) \cos 2\pi f_c t.$$

To ensure 50% modulation; $K_a = 0.5$;

$$s(t) \Rightarrow A_c\left(1 + \frac{0.5}{1+t^2}\right) \cos 2\pi f_c t.$$

(b). <u>Double side band suppressed Carrier modulation</u>:

$$s(t) = 2a_1 x(t) + 4a_2 A_c x(t) \cdot \cos w_c t \qquad \{f_c > 2f_x\}.$$

$$\Rightarrow A_c m(t) \cdot \cos(2\pi f_c t).$$

$$s(t) = A_c\left(\frac{1}{1+t^2}\right) \cdot \cos(2\pi f_c t).$$

Hilbert Transform $\left(\frac{1}{1+t^2}\right) = \frac{t}{1+t^2}$

(c). SSB with USB transmitted :-

$$S_u(t) = \frac{A_c}{2}\left[m(t) \cdot \cos(2\pi f_c t) - \hat{m}(t) \cdot \sin(2\pi f_c t)\right].$$

$$S_u(t) = \frac{A_c}{2}\left[\left(\frac{1}{1+t^2}\right) \cdot \cos(2\pi f_c t) - \left(\frac{t}{1+t^2}\right) \cdot \sin(2\pi f_c t)\right].$$

(d) SSB with LSB transmitted :-

$$S_L(t) = \frac{A_c}{2}\left[\left(\frac{1}{1+t^2}\right)\cos(2\pi f_c t) + \left(\frac{t}{1+t^2}\right)\sin(2\pi f_c t)\right].$$

---

(2). The single-tone modulating signal, $m(t) = A_m \cos(2\pi f_m t)$ is used to generate the VSB signal,

$$s(t) = \tfrac{1}{2} a \cdot A_m \cdot A_c \cdot \cos\left[2\pi(f_c + f_m)t\right] + \tfrac{1}{2} A_m A_c (1-a) \cdot \cos\left[2\pi(f_c - f_m)t\right].$$

where "a" is a Constant, less than unity, representing the attenuation of the ~~upper~~ upper side frequency.

(i) Find the Quadrature Component of the VSB signal $s(t)$.

(ii) The VSB signal, plus the Carrier $A_c \cos(2\pi f_c t)$, is passed through an envelope detector. Determine the distortion produced by the Quadrature Component.

(iii) what is the Value of Constant "a" for which this distortion reaches its worst possible Condition?

Solution :- $\cos(A+B) + \cos(A-B)$.
$[\cos A \cos B - \sin A \sin B] + [\cos A \cos B + \sin A \sin B]$

$\boxed{\cos(A+B)}$.

$\cos(2\pi(f_c + f_m)t)$

$$s(t) = \frac{1}{2} a A_m A_c \cdot \cos(2\pi f_c t) \cdot \cos(2\pi f_m t) - \frac{1}{2} a A_m A_c \sin(2\pi f_c t) \cdot \sin(2\pi f_m t)$$

$$+ \tfrac{1}{2}(1-a) A_m A_c \cos(2\pi f_c t) \cdot \cos(2\pi f_m t) + \tfrac{1}{2}(1-a) A_m A_c \cdot \sin(2\pi f_c t) \cdot \sin(2\pi f_m t).$$

$\cos(A+B) - \cos(A-B)$

$\cos(A-B) + \cos(A+B)$

$\cos(A-B) - \cos(A+B)$

$$= \tfrac{1}{2} A_m A_c \cos(2\pi f_c t) \cdot \cos(2\pi f_m t) + \frac{1}{2}(1-2a) A_m A_c \cdot \sin(2\pi f_c t) \cdot \sin(2\pi f_m t).$$

Therefore the Quadrature Component is

$$\boxed{\tfrac{1}{2}(1-2a) \cdot A_m A_c \sin(2\pi f_m t)}$$

(ii). $s(t) = A_c \cos(2\pi f_c t) + \tfrac{1}{2} A_m A_c \cos(2\pi f_c t) \cdot \cos(2\pi f_m t) + \tfrac{1}{2}(1-2a) A_m A_c \sin(2\pi f_c t) \cdot \sin(2\pi f_m t)$.

$$= A_c\left[1 + \tfrac{1}{2} A_m \cos(2\pi f_m t)\right] \cos(2\pi f_c t) + \tfrac{1}{2} \cdot (1-2a) \cdot A_m A_c \sin(2\pi f_c t) \cdot \sin(2\pi f_m t).$$

The envelope detector equals,

$$a(t) = A_c \sqrt{\left[1 + \tfrac{1}{2} A_m \cos(2\pi f_m t)\right]^2 + \left[\tfrac{1}{2}(1-2a) \cdot A_m \cdot \sin(2\pi f_m t)\right]^2}$$

$$= A_c\left(1 + \tfrac{1}{2} A_m \cos(2\pi f_m t)\right) \sqrt{1 + \left(\frac{\tfrac{1}{2}(1-2a) \cdot A_m \cdot \sin(2\pi f_m t)}{1 + \tfrac{1}{2} A_m \cos(2\pi f_m t)}\right)^2}$$

$$= A_c\left[1 + \tfrac{1}{2} A_m \cos(2\pi f_m t)\right] \cdot d(t).$$

$d(t)$ is the distortion defined by :,

$$d(t) = \sqrt{1 + \left(\frac{1/2\, A_m (1-2a) \cdot \sin(2\pi f_m t)}{1 + 1/2\, A_m \cdot \cos(2\pi f_m t)}\right)^2}$$

(iii) $d(t)$ is greatest when ; $\underline{\underline{a=0}}$.

---

3. An angle modulated signal with carrier frequency, $\omega_c = 2\pi \times 10^5$ is described by the equation

$$\phi_{EM}(t) = 10 \cos(\omega_c t + 5 \sin 3000t + 10 \sin 2000\pi t).$$

(i) Find the power of the modulated signal
(ii) Find the frequency deviation Δf
(iii) Find the deviation ratio β.
(iv) Find the phase deviation $\Delta\phi$
(v). Estimate the bandwidth of $\phi_{EM}(t)$.

Solution:-

~~___~~ The signal bandwidth is the highest frequency of $m(t)$

$$B = \frac{2000\pi}{2\pi} = 1000\,Hz.$$

(i). Power, $P = \frac{(10/\sqrt{2})^2}{1\Omega} = \underline{50\,W}$.

(ii). To find the frequency deviation Δf; we find the Instantaneous frequency, ω_i;

$$\omega_i = d/dt\ \theta(t).$$

$$= \omega_c + 15{,}000 \cos 3000t + 20{,}000\pi \cdot \cos 2000\pi t$$

The carrier deviation is $15{,}000 \cos 3000t + 20{,}000\pi \cos 2000\pi t$.

$\omega = 3000$. $f = \frac{3000}{2\pi}$

$$\Delta f = \frac{3000}{2\pi} \quad ; \quad \Delta f = \frac{2000}{2\pi}.$$

$$\Delta f = \frac{15{,}000}{2\pi} \qquad \Delta f = \frac{20{,}000\pi}{2\pi}$$

$$= 2386.36\,Hz \qquad = 10{,}000\,Hz$$

The two sinusoids will add in phase at some point, & the maximum value of this expression is $15{,}000 + 20{,}000\pi$.

Hence, $\boxed{\Delta f = 12{,}386.36\,Hz}$

(iii). Deviation ratio,

$$\beta = \frac{\Delta f}{B} = \frac{12{,}386.36}{1000} = \underline{\underline{12.386}}.$$

Freq deviation. $\Delta f = \frac{\Delta\omega}{2\pi} = \frac{15000 + 20{,}000\pi}{2\pi}$

$$= 12{,}387.32\,Hz.$$

(iv) The angle $\theta(t) = \omega t + (5 \sin 3000t + 10 \sin 2000\pi t)$

The phase deviation is the maximum value of the angle inside the parentheses, $\Rightarrow \Delta\phi = 15$ rad.

(v) $B_{FM} = 2(\Delta f + B)$. (or) $2(\Delta f + f_m)$

$= 2(12386.36 + 1000)$

$$\boxed{B_{FM} = 26{,}774.65 \text{ Hz}.}$$

(2) $\omega_c = \pi \times 10^5$.

$f(t) = 5 \cos(\omega_c t + 3 \sin 2000t + 5 \sin 2000\pi t)$

$B \Rightarrow f_m = \frac{2000\pi}{2\pi} = 1000$ Hz.

$\omega_i(t) = \frac{d}{dt}\theta(t) = \omega_c + 6000 \cos 2000t + 10{,}000\pi \cos 2000\pi t$.

Carrier deviation is $6000 \cos 2000t + 10{,}000\pi \cos 2000\pi t$

The max^m value of this deviation occurs when both the sinusoids add in phase.

$\therefore$ Max^m carrier deviation is $6000 + 10{,}000\pi$.

Freq deviation, $\Delta f = \frac{\Delta\omega}{2\pi} = \frac{6000 + 10{,}000\pi}{2\pi} = 5935$ Hz.

Deviation ratio, $\beta = \frac{\Delta f}{f_m} = 5.935$.

Angle, $\theta(t) = \omega t + (3 \sin 2000t + 5 \sin 2000\pi t)$

phase deviation is the max^m value of the angle inside the bracket & is $\Delta\phi = 8$ rad.

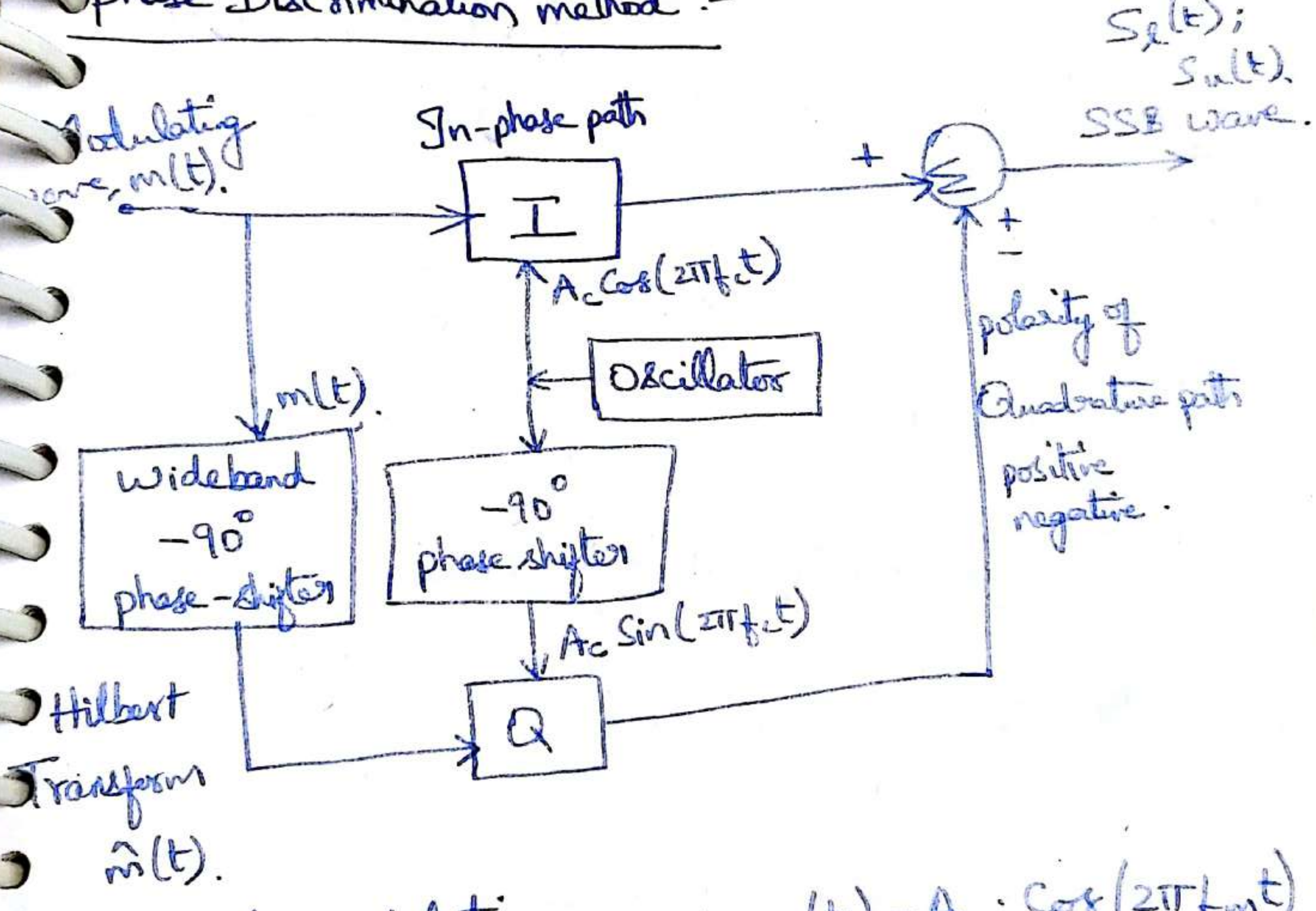
Bandwidth, $B = 2(\Delta f + f_m) = 2(5935 + 1000)$
$= 13.9$ kHz.

Single Side band Modulation (SSB) :-

only the upper sideband (or) lower sideband is transmitted.

* Requires minimum transmitted power
* Requires minimum channel bandwidth for conveying a message signal.

phase Discrimination method :-



Sinusoidal modulating wave, $m(t) = A_m \cos(2\pi f_m t)$.

The Hilbert Transform of this signal is obtained by passing it through a $-90°$ phase shifter

$$\hat{m}(t) = A_m \cdot \sin(2\pi f_m t).$$

SSB modulated wave,

$m(t) = A_m \cdot \cos(2\pi f_m t)$
$\hat{m}(t) = A_m \cdot \sin(2\pi f_m t)$

$$S_u(t) = \frac{A_c}{2}\left[m(t)\cdot\cos(2\pi f_c t) - \hat{m}(t)\cdot\sin(2\pi f_c t)\right]$$

$$\therefore s(t) = \frac{A_c}{2}\left[A_m \cdot \cos(2\pi f_m t)\cdot\cos(2\pi f_c t) - A_m \sin(2\pi f_m t)\sin(2\pi f_c t)\right]$$

$\left\{ \cos A \cos B \Rightarrow \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right] \; ; \; \sin A \cos B \Rightarrow \frac{1}{2}\left[\sin(A+B) + \sin(A-B)\right]. \right.$
$\left. \cancel{\sin A \cos B} \Rightarrow \sin A \sin B \Rightarrow \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]. \right\}$

$$= \frac{A_m A_c}{4}\left[\left(\cos(f_m + f_c) + \cancel{\cos(f_m - f_c)}\right) - \left(\cancel{\cos(f_m - f_c)} - \cos(f_m + f_c)\right)\right]$$

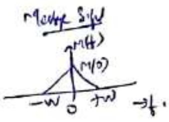
$$= \frac{A_m A_c}{4}\left[\cos(f_m + f_c) + \cos(f_m + f_c)\right]$$

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

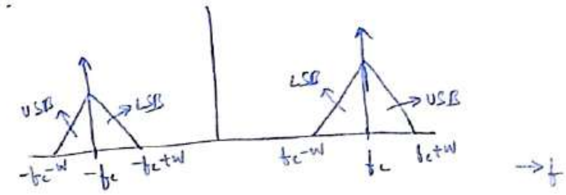
$$\boxed{s(t) = \frac{A_m A_c}{2}\cdot\cos\left[2\pi(f_c + f_m)t\right]}$$

The use of plus sign at the summing junction yields an SSB wave with only the lower side band, whereas the use of a minus sign yields an SSB wave with only the upper sideband.

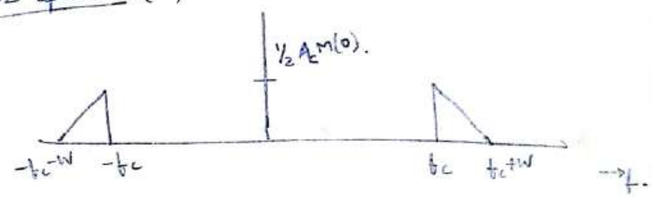
Demodulation of SSB waves :-



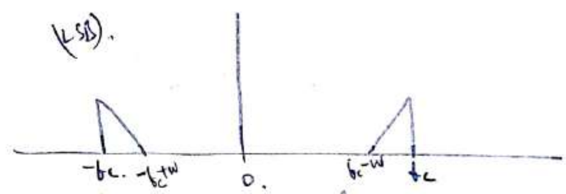
DSBSC.



SSB spectrum (USB)



(LSB).



To recover the baseband signal $m(t)$ from the SSB wave, $s(t)$; equal to $S_u(t)$ (or) $S_l(t)$, we have to shift the spectrum by the amounts of $\pm f_c$ so as to convert the transmitted sideband back to the baseband signal. This can be accomplished using coherent detection which involves applying the SSB wave $s(t)$, together with a locally generated carrier $\cos(2\pi f_c t)$; assumed to be of unit amplitude for convenience, to a product modulator and then low-pass filtering the modulated output.

w.r.t.

$$\cancel{S_u(t) = \frac{A_m A_c}{4}} \Big[$$

$$S_u(t) = \frac{A_c}{2}\left[m(t)\cdot\cos(2\pi f_c t) - \hat{m}(t)\cdot\sin(2\pi f_c t)\right]$$

$$v(t) = \cos(2\pi f_c t)\cdot S_u(t).$$

$$= \frac{A_c}{2}\left[m(t)\cdot\cos(2\pi f_c t)\cdot\cos(2\pi f_c t) - \hat{m}(t)\cdot\sin(2\pi f_c t)\cos(2\pi f_c t)\right]$$

(or)

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

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

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

$$= \underbrace{\frac{A_m A_c}{4}\cos 2\pi(2f_c+f_m)t}_{\substack{\text{Unwanted Component} \\ \text{(Removed by low-pass filtering).}}} + \underbrace{\frac{A_m A_c}{4}\cos 2\pi f_m t}_{\text{Scaled message signal.}}$$

Synchronous detection (or) Coherent Detection :-

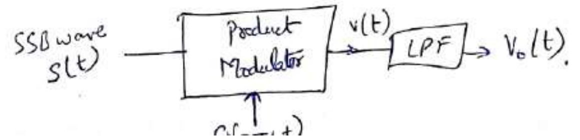
The carrier used at the detector part is exactly the same frequency (and phase) as the carrier used for modulation. Thus at the demodulator part the frequency and phase coherence (synchronism) are maintained with the carrier used at the modulator.

Non-Coherent detection :-

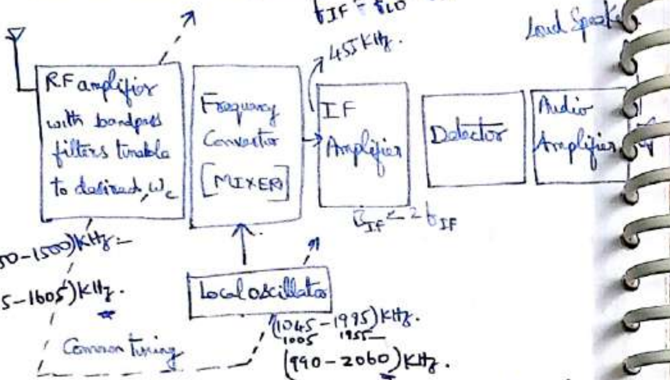
If the phase in the received RF pulse $\sqrt{2}\,p(t)\cdot\cos(\omega_c t+\phi)$ is unknown; we cannot use coherent detection techniques.

Hence when the phase ϕ of the received pulse is random; the optimum detector is a filter matched to the R.F. pulse followed by an envelope detector, a sampler and a comparator to make the decisions.

Coherent detection of an SSB modulated wave :-



AM Super heterodyne receiver:-



The radio receiver used in an AM system is called the Superheterodyne AM receiver.

The receiver not only has the task of demodulating the incoming modulated signal; but it is also required to perform some other system functions.

* Carrier frequency tuning:-
* Filtering :- Separate the desired signal from other modulated signals.
* Amplification :- Compensate the loss of signal power incurred in the course of transm...

1) Incoming Amplitude modulated wave is picked up by the receiving antenna

2) Incoming wave is amplified in the R.F section. R.F amplifier is tuned to the Carrier frequency of the incoming wave

3) Heterodyning function ⇒ (Mixer + Local oscillator)

Incoming signal is converted to a predetermined fixed I.F lower than the incoming Carrier frequency

4) The o/p of the I.F amplifier is applied to the demodulator; the purpose of which is to recover the base band signal.

(535-1605).
(...2060)

$$f_{IF} = -(f_L - f_c)$$

$$\boxed{f_{LO} = f_c - f_{IF}}$$

$$-f_{IF} = f_L - f_c.$$

$$\cancel{f_{IF}} = (80-1150)\text{ KHz}.$$

$f - f_{IF}$.
535-455 = 80.
1605-455 = 1150.

f_L | Ratio of Highest to lowest frequency = 11:1

535+455
1605+455

$$f_{IF} = f_L - f_c.$$

$$f_L = (990 \rightarrow 2060)\text{ KHz}.$$

↓

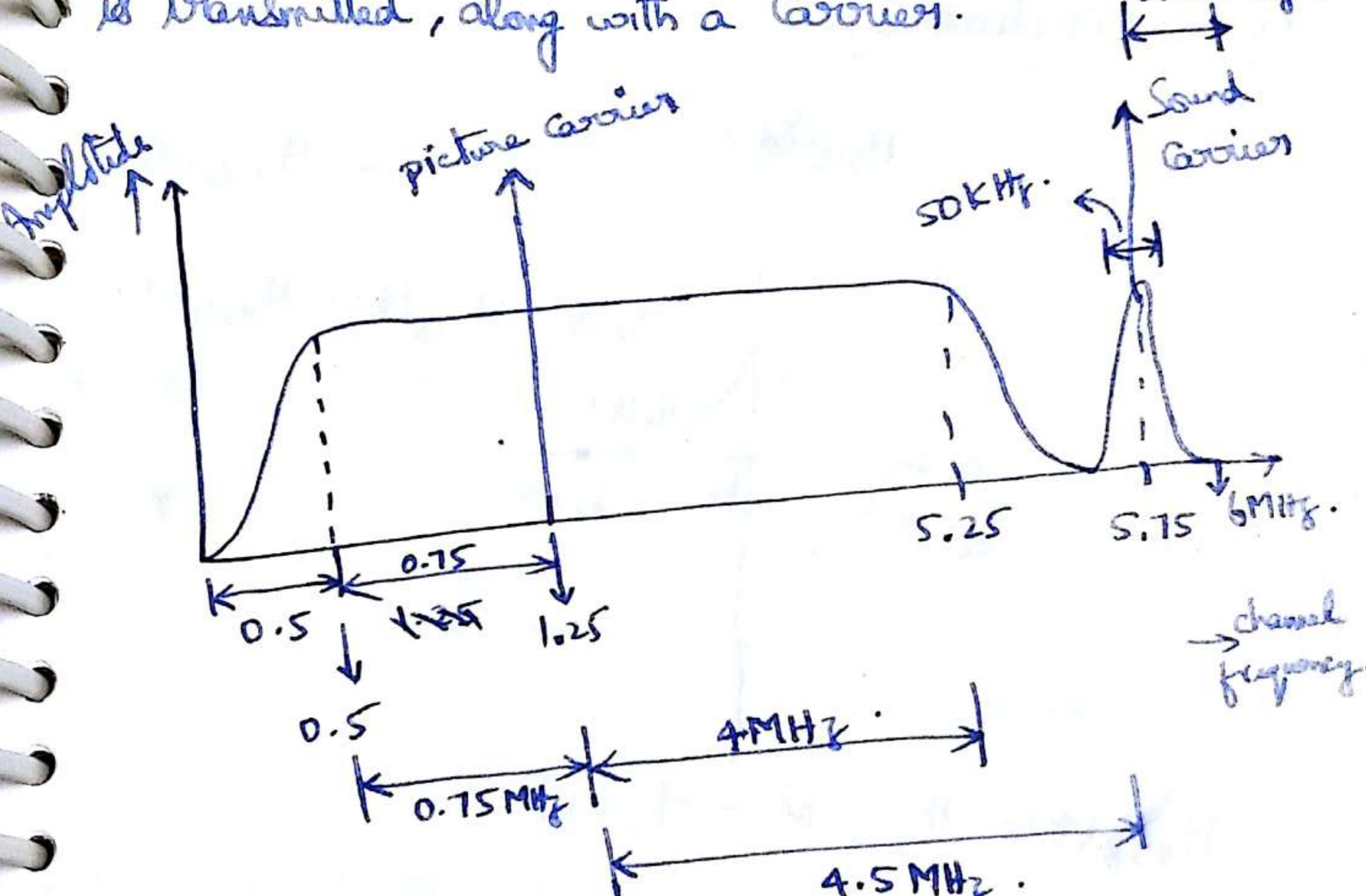
⇒ 2:1
which can be easily achieved.

Vestigial Sideband System (VSB) :-

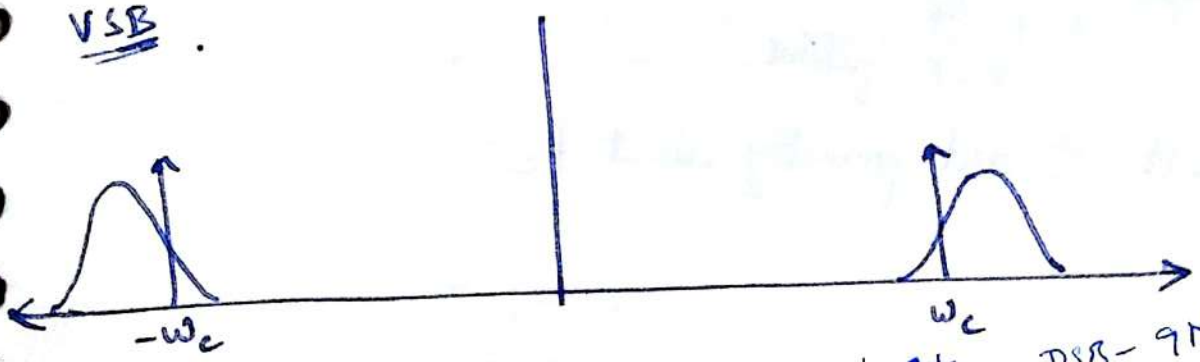
PAL → phase Alternating line. NTSC → National Television System Committee

Video baseband signal has bandwidth of 6MHz (NTSC).

In VSB, full upper sideband of bandwidth ~~4MHz~~ 4.5MHz and partial lower sideband of bandwidth 1.25MHz is transmitted, along with a Carrier.



VSB.



VSB → 6MHz. DSB - 9MHz. SSB - 4.5MHz

VSB

To generate a VSB signal, we begin by generating a DSB-SC AM signal & passing it through a side band filter with frequency response, $H(f)$.

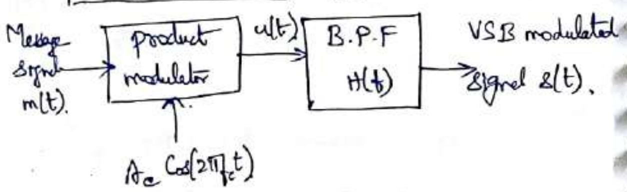
VSB signal in time domain.

$$s(t) = \left[A_c\, m(t) \cdot \cos(2\pi f_c t)\right] * h(t) \rightarrow (1)$$

$h(t) \rightarrow$ Impulse response of the VSB filter.

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

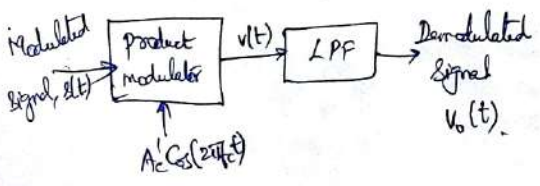
$$\boxed{S(f) = U(f) \cdot H(f)} \rightarrow (4)$$



$$s(t) \rightarrow \boxed{s(t) = u(t) * h(t)} \rightarrow (3)$$

Step 1:- Receiver side:-

$$v(t) = A_c' \cos(2\pi f_c t) \times s(t). \rightarrow (5)$$



w.r.t $v(t) = A_c' \cos(2\pi f_c t) \times s(t)$.

$$\therefore V(f) = \frac{A_c'}{2}\left[S(f-f_c) + S(f+f_c)\right] \rightarrow (6).$$

Substitution of (2) in (6) we get:

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

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

The LPF rejects the double-frequency terms & passes only the components in the frequency range $|f| \le f_m$.

$$\therefore V_0(f) = \frac{A_c}{4} M(f)\left[H(f-f_c) + H(f+f_c)\right]$$

The Transfer function, $H(f)$ must satisfy the condition, $H(f-f_c) + H(f+f_c) = 2H(f_c)$.

To simplify the exposition, we set $H(f_c) = 1/2$

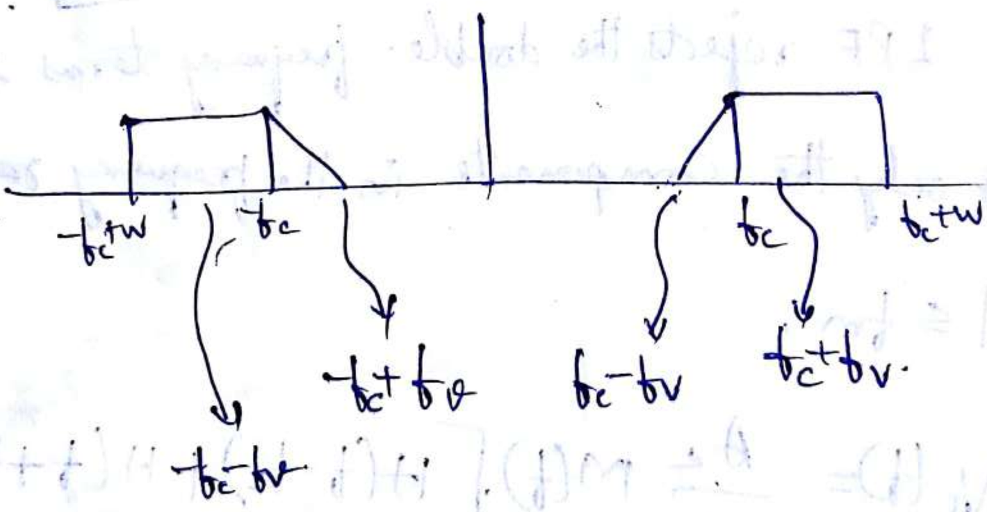
$= H(f-f_c) + H(f+f_c) = 1$.

$$\therefore v_o(t) = \frac{A_c A_c'}{4} m(t) \left[2H(f_c)\right].$$

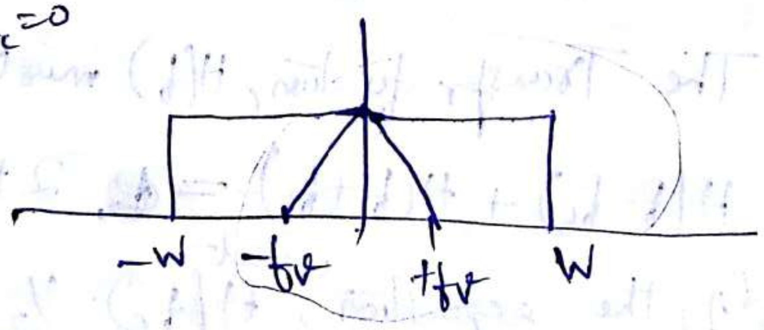
$$\boxed{v_0(t) = \frac{A_c A_c'}{2} m(t)}$$

SSB

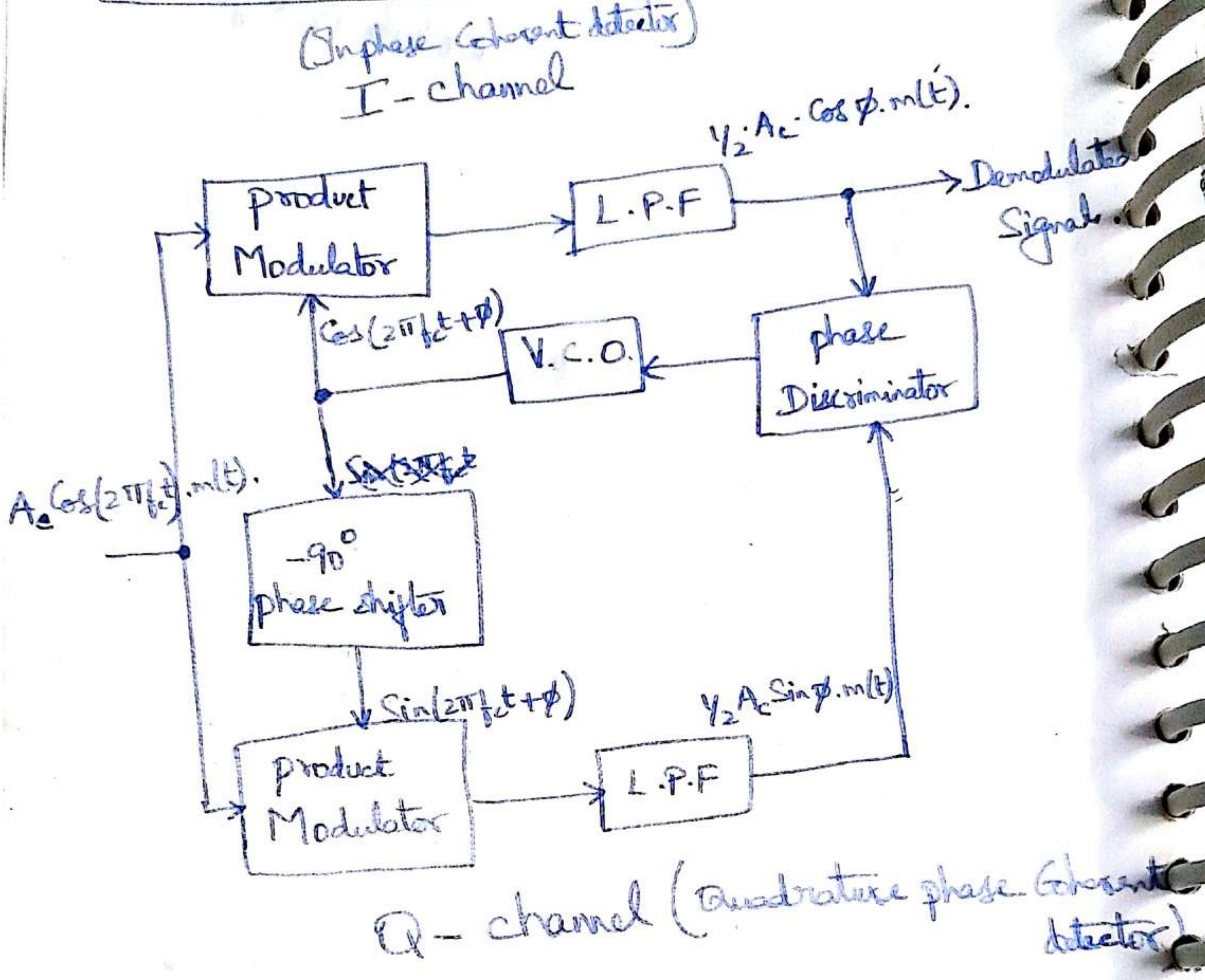
VSB



Demodulate $f_c = 0$



COSTAS RECEIVER:-



* One method of obtaining a practical synchronous receiving system with DSBSC modulated waves, is to use the Costas loop.

* Receiver Consists of two Coherent detectors supplied with the same input signal (DSBSC modulated wave).

* Frequency of the local oscillator is adjusted to be the same as the Carrier frequency, f_c.