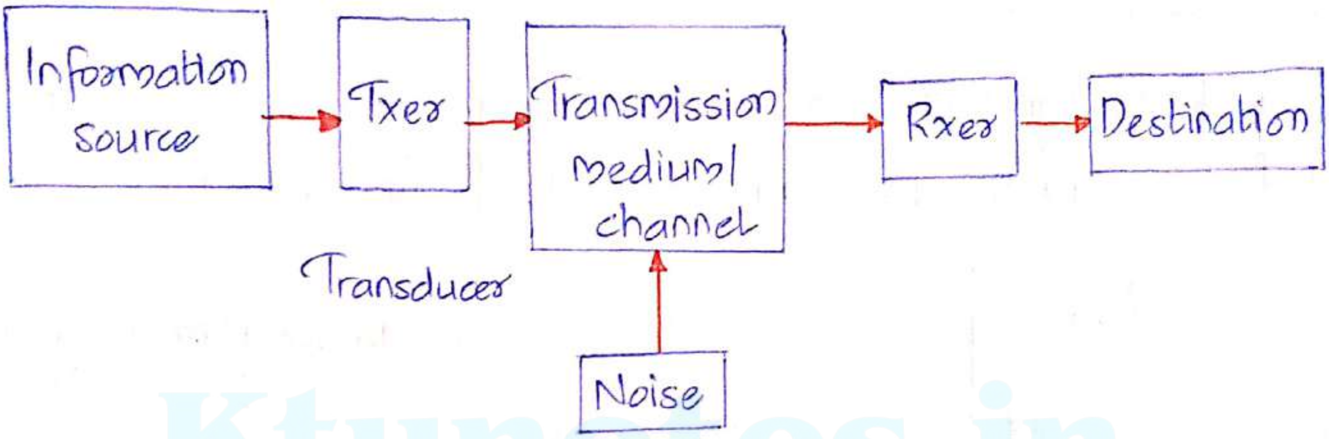
MODULE-1

→ Basic blocks of a communication system:
- → source
- → Transmitter
- → Channel
- → Receiver
- → Destination

Block diagram:



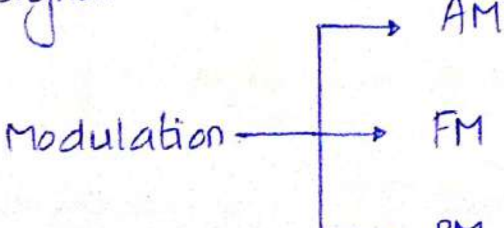
→ Information signals generates a modulating signal which is a low frequency signal which is our message signal (20 Hz – 20 kHz)

→ Inorder to transmit the msg signal, we need to process the information signal before sending it. All such processes take place at the transmitter section.

→ The low freq signal cannot be transmitted to long distances. So we need to ↑ the freq via modulation.

→ During modulation, we use a high freq carrier signal to carry the message signal to the destination.

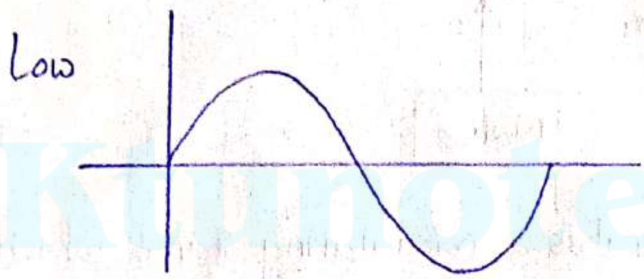
carrier signal : high freq
msg signal : low freq



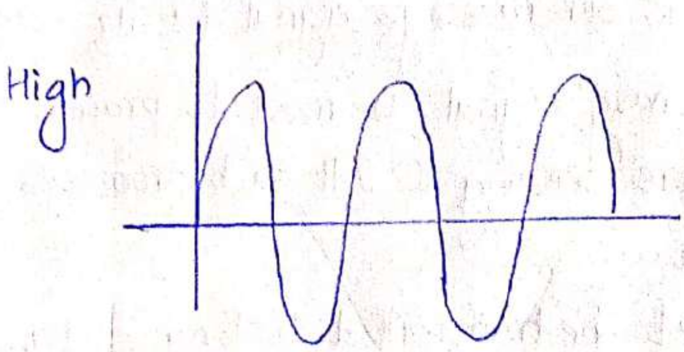
- Channel (medium through which signal is sent) can be wired or wireless. Wired egs: optic fibre cables, coaxial cables.
- We need to remove the noise signals (using filters etc).
- The reversealal of processes done at transmitter take place at receiver.
- The demodulator separates the msg signal from the carrier signal. Then transducer converts electrical signal → normal form.

Modulation

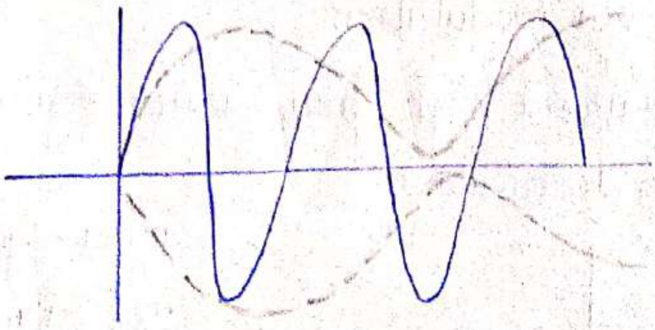
The freq of the signal is ↑ to a high freq range; for that, we change some of its characteristics say, amplitude, frequency and phase.



modulating / msg signal



carrier signal



amplitude modulation.

AM → It is defined as the process of changing the amplitude of the high freq signal according to the instantaneous amplitude of the low freq msg signal.

FM → Freq of the high freq carrier signal is changed according to the instantaneous amplitude of the msg signal.

PM → The phase of the carrier signal is changed according to the instantaneous amplitude of the msg signal.

Need for modulation

height of antenna; $h = \frac{\lambda}{4}$

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

Eg: Consider a signal with freq $f = 15\,kHz$. For transmitting the signal, the antenna height required is __?

$$15\times10^3 = \frac{3\times10^8}{\lambda} \Rightarrow \lambda = \frac{3\times10^8}{15\times10^3} = \frac{30\times10^4}{15} = 20k$$

$$h = \frac{20000}{4} = \underline{\underline{5000m}}$$

→ So we modulate it with 1MHz freq carrier signal.

$$\lambda = \frac{3\times10^8}{1\times10^6} = 300$$

$h = 75m$. It reduces to 75m.

So first need is reduction of height of antenna

(ii) Avoid mixing up of signals from diff. stations.

→ The sound signals are concentrated within the range 20Hz to 20kHz. So the transmission of these signals from different stations / different sources cause mixing of signals and it is difficult to separate at the receiver end. So each signal is given diff. band width ~~for~~ / diff carrier freqs for different signal sources.

→ A tuned circuit / a tuner is used at the receiver side in order to select the desired frequency.

(iii) Power radiated by the antenna can be increased.

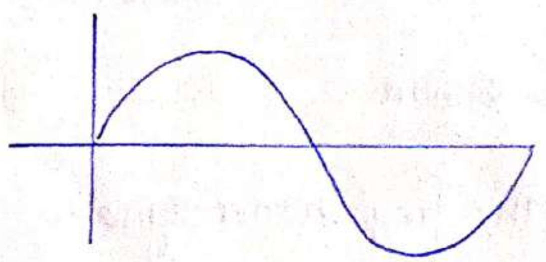
Power radiated by the antenna, $P \propto \left(\frac{1}{\lambda}\right)^2$

(iv) Improves the quality of reception or the effect of noise can be reduced to a large extent mainly in the case of FM.

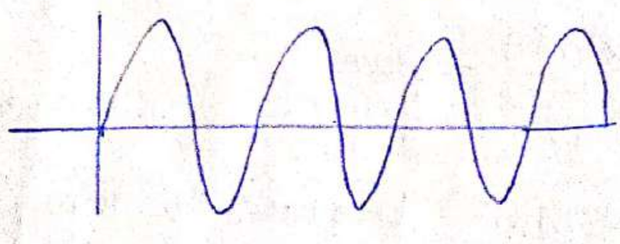
(v) Increase the range of communication.

At low freq, the radiation is poor and signal gets highly attenuated. By modulation process, it effectively ↑ the freq of signal to be radiated.

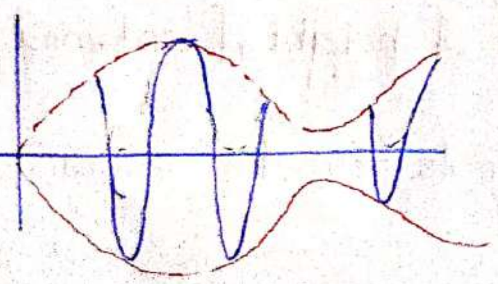
AM



msg signal $V_m t$



carrier signal $V_c t = V_c \sin\omega_c t$



AM signal $V_{am} t$

Mathematical representation of AM signal:

$V_c(t) = V_c \sin \omega_c t$ —— ①

$V_m(t) = V_m \sin \omega_m t$ —— ②

$\omega_c = 2\pi f_c$ high freq

$\omega_m = 2\pi f_m$

where V_c is the peak carrier amplitude.

V_m is the peak msg signal amplitude.

ω_c and ω_m are carrier signal radiating freq and modulating signal freq.

Amplitude of modulated signal (A).

$$A = V_c + V_m(t)$$

$$A = V_c + V_m \sin \omega_m t \text{ —— ③}$$

The amplitude modulated signal (AM signal) is

$$V_{am}(t) = A[\sin \omega_c t]$$

$$= [V_c + V_m \sin \omega_m t][\sin \omega_c t]$$

$$= V_c \Big[1 + \underbrace{\frac{V_m}{V_c}}_{\text{Modulation Index}} \sin \omega_m t\Big][\sin \omega_c t]$$

Ratio of V_m to V_c.

$$= V_c [1 + m \sin \omega_m t][\sin \omega_c t]$$

where m is the modulation index

$$V_{am}(t) = V_c \sin \omega_c t + m V_c \underbrace{\sin \omega_c t \sin \omega_m t}_{\sin A \sin B}$$

Using trigonometric eqn:

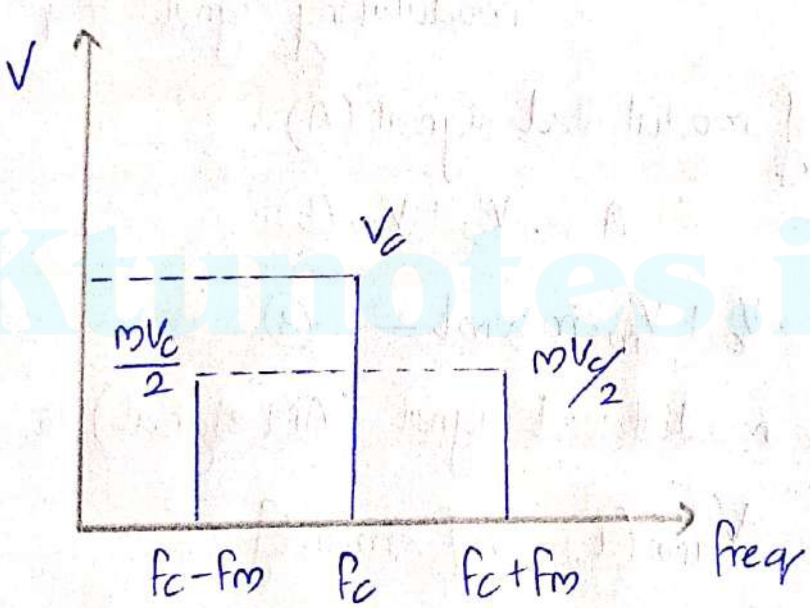
$$V_{am}(t) = V_c \sin\omega_c t + mV_c\left(\frac{\cos(\omega_c-\omega_m)t - \cos(\omega_c+\omega_m)t}{2}\right)$$

$$= V_c \sin\omega_c t + \frac{mV_c}{2}\cos(\omega_c-\omega_m)t - \frac{mV_c}{2}\cos(\omega_c+\omega_m)t.$$

① carrier frequency component

② Lower side band freq term

③ Upper side band freq term



→ Frequency spectrum of a waveform consists of all the freqs contained in the waveform and their amplitudes plotted in frequency domain.

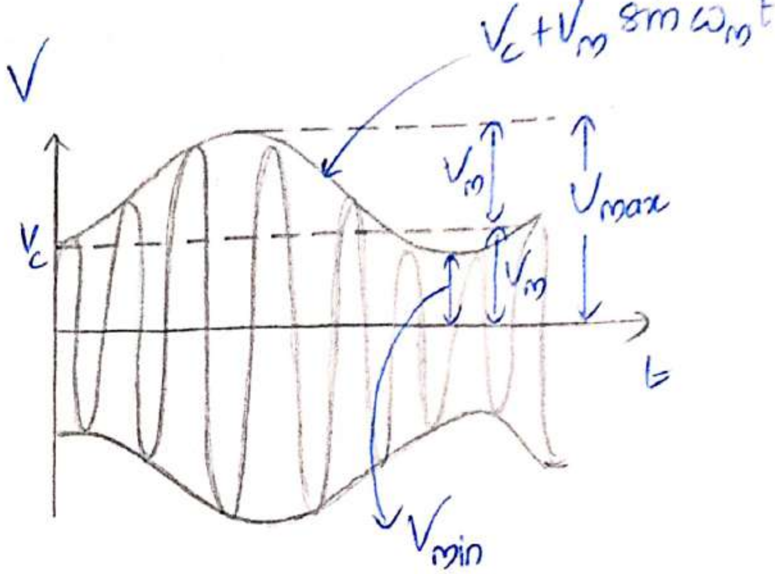
Band width $= f_c+f_m-(f_c-f_m)$

$= 2f_m$ (freq of msg signal - f_m).

bandw of an Amplitude mod signal = 2 x freq of msg signal.

Modulation Index

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



$$2V_m = V_{max} - V_{min}$$

$$\boxed{V_m = \frac{V_{max} - V_{min}}{2}} \quad \text{——— (1)}$$

$$V_c = V_{max} - V_m$$

Subs (1);

$$= V_{max} - \frac{V_{max} + V_{min}}{2}$$

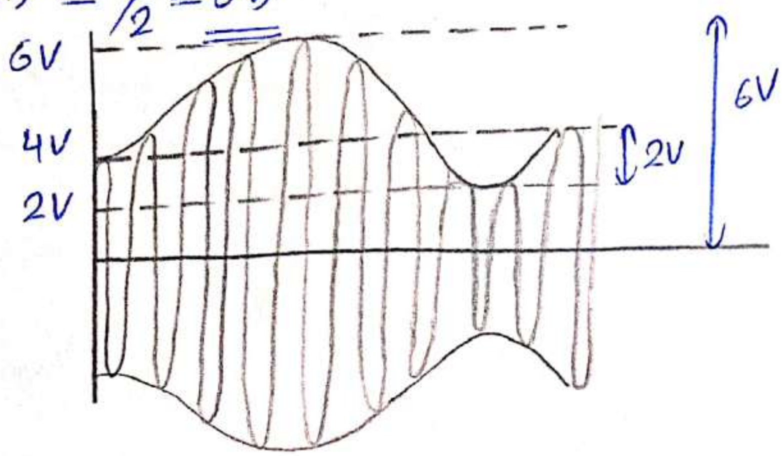
$$\boxed{V_c = \frac{V_{max} + V_{min}}{2}} \quad \text{——— (2)}$$

$$m = \frac{V_m}{V_c} = \frac{\frac{V_{max} - V_{min}}{2}}{\frac{V_{max} + V_{min}}{2}}$$

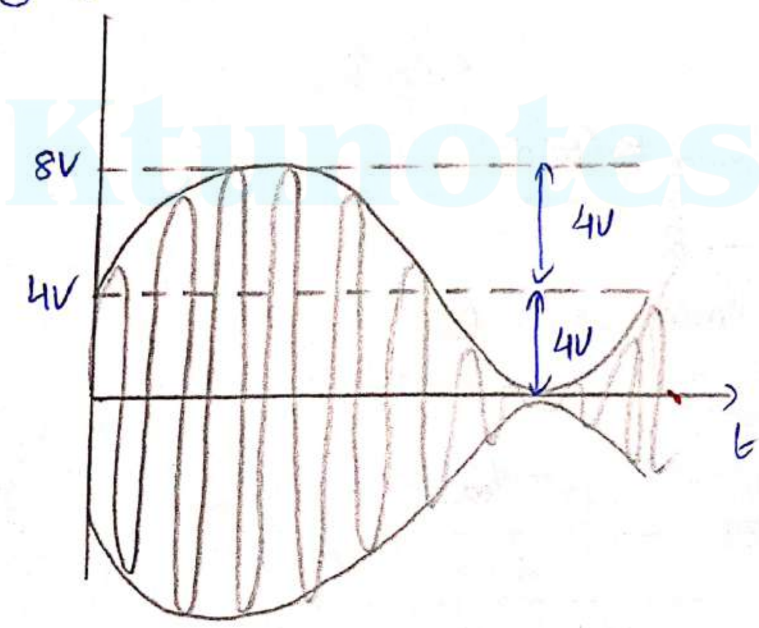
$$\boxed{m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}} \quad \text{——— (3)}$$

Qn: Given that msg signal amp $V_m = 2V$ and carrier signal amp $V_c = 4V$ calculate m and draw the waveform.

$m = \frac{1}{2} = 0.5$



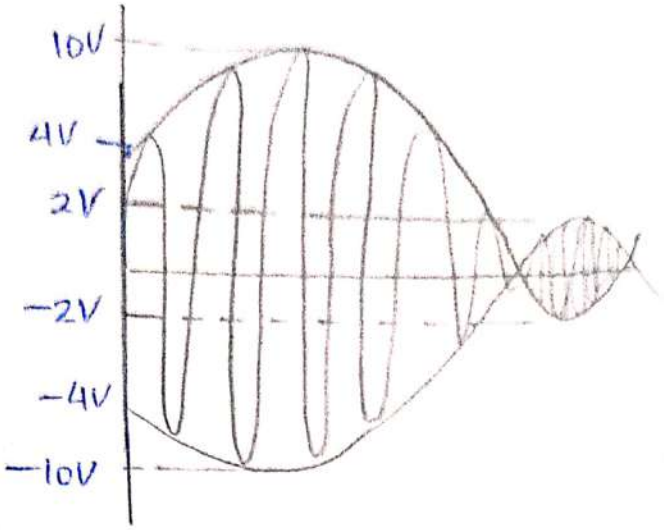
If the msg signal amp $V_m = 4V$ and $V_c = 4V$, calculate m, waveform



If $V_m = 6V$, $V_c = 4V$, what will be m and how will be the waveform representation.

$$m = \frac{V_m}{V_c} = \frac{6}{4} > 1$$

$= 1.5 > 1$ overmodulated signal



Power distribution in an AC signal

The total power of the amplitude modulated waveform is the sum of carrierpower and side band powers.

$$P_t = P_c + P_{USB} + P_{LSB} \longrightarrow \text{lower sideband power}$$

$\downarrow$ upperside band power

$$= \frac{V_c^2}{R} + \frac{V_{USB}^2}{R} + \frac{V_{LSB}^2}{R} \quad \text{—— (1)}$$

carrier power $P_c = \frac{V_c^2}{R}$ Since V_c is rms value, we can rewrite it as

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

$$P_c = \frac{V_c^2}{2R} \quad \text{—— (2)}$$

Similarly $P_{USB} = P_{LSB} = \frac{V_{SB}^2}{R}$

$$= \frac{\left(\frac{mV_c/2}{\sqrt{2}}\right)^2}{R} = \frac{m^2V_c^2}{8R} \quad \text{—— (3)}$$

$$P_{USB} = P_{LSB} = \frac{m^2}{4} \cdot \frac{V_c^2}{2R} \quad \text{---} (3)$$

Subs. (2) and (3) in eqn (1),

$$P_t = \frac{V_c^2}{R} + \frac{m^2}{4}\frac{V_c^2}{2R} + \frac{m^2}{4}\frac{V_c^2}{2R}$$

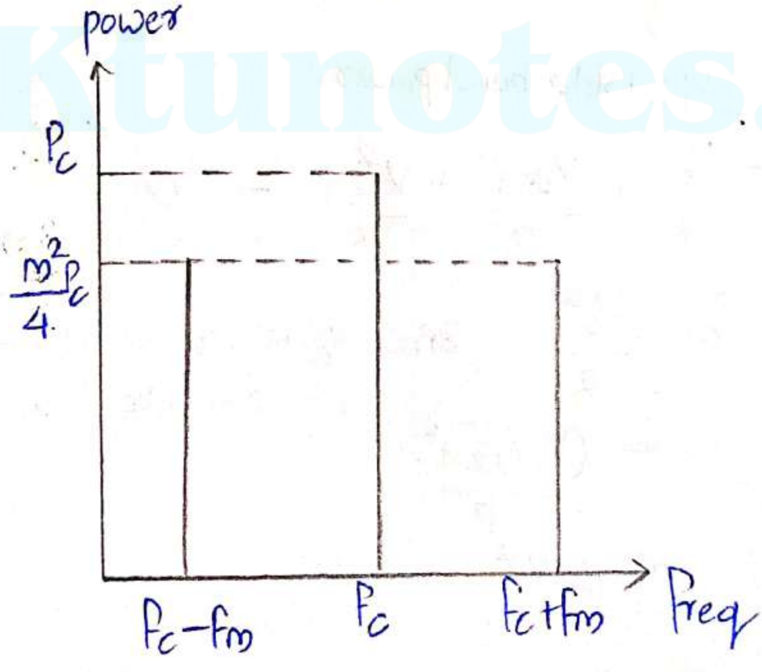
$$= P_c + \frac{m^2}{4}P_c + \frac{m^2}{4}P_c$$

$$= P_c + \frac{m^2}{2}P_c$$

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

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

If it is a 100% modulated signal, $P_t = \frac{3P_c}{2} = 1.5P_c$



Current eqn of an amplitude modulated signal

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

$$\frac{P_t}{P_c} = \frac{I_t^2 R}{I_c^2 R} = \left(1+\frac{m^2}{2}\right)$$

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

If multiple signals are modulated at a certain time;

Multiple modulation Index $= M_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + \dots}$

Amplitude modulation techniques

1) DSB–FC → Conventional double side band full carrier method.
2) DSB–SC → Double side band suppressed carrier signal.
3) SSB → Single side band ~~suppressed~~ method.
4) ISB
5) VSB

SC FC RC

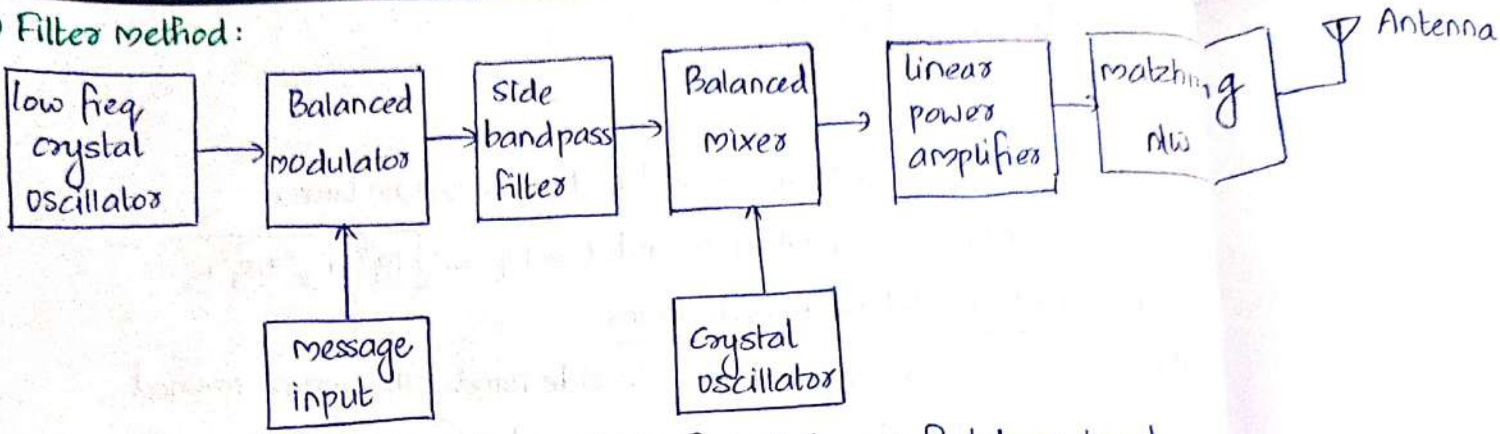
Single Side band modulation

In conventional AM, carrier power constitutes two–third of the total transmitted power. This is the major drawback bcoz the carrier contains no information, the side bands contains the information. Also, conventional AM system utilizes twices as much bandwidth as needed with SSB system. With DSB transmission, the information contained in the USB is identical to the information carried in the LSB. ∴ transmitting ~~more~~ both side bands is redundant and conventional AM is both power and band width inefficient.

Generation of SSB signal (Transmitter):

1) Filter method 2) Phase shift method 3) Third method

D) Filter method:



The filter characteristics should be such that it has a flat pass band characteristics and sharp attenuation outside the pass band.

→ LC filter is the simplest one and they cannot be used beyond 100 kHz, i.e above this frequency, the attenuation outside the pass band is insufficient.

→ Ceramic/crystal filters: They are cheaper but are preferrable only at freqs above 1MHz.

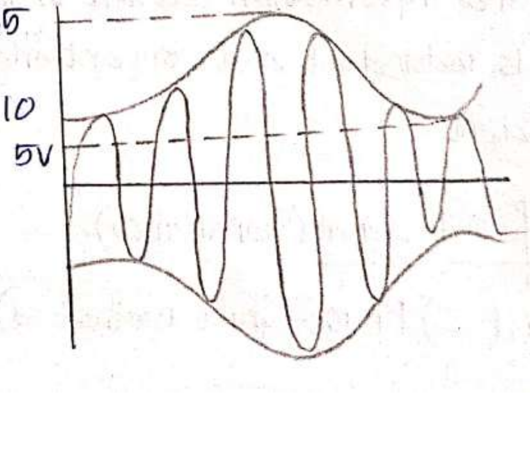
→ Mechanical filters: The upper freq limit of mech. filter is 500 kHz.

Qn: A carrier wave is represented by the eqn is $V_c(t) = 10 \sin \omega_c t$. Draw the waveform of an AM wave for modulation index $m = 0.5$.

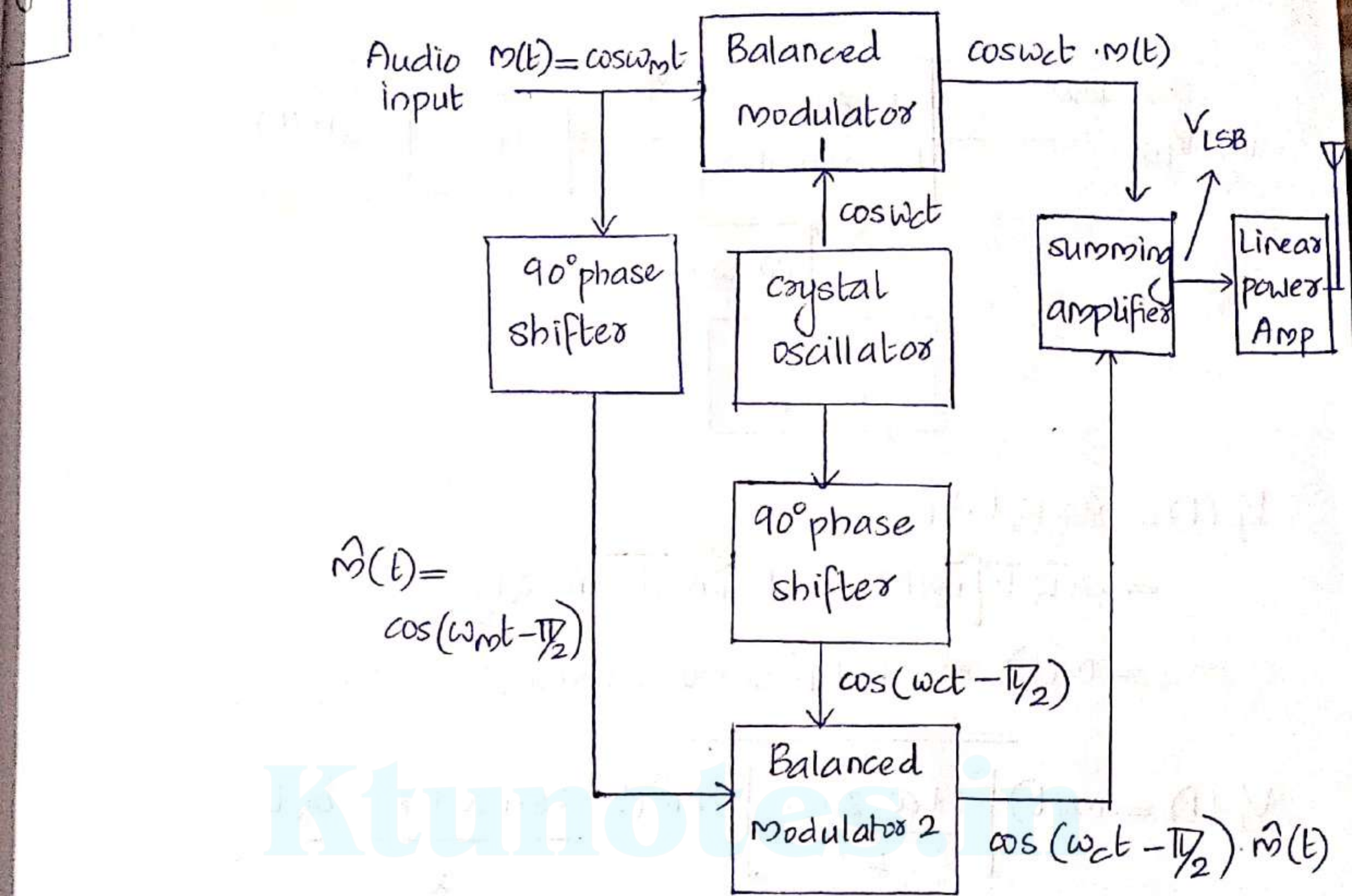
$$m = \frac{V_m}{V_c}$$

$$0.5 = \frac{V_m}{10}$$

$$V_m = 5V$$



2) Phase shift method:- SSB Generation



$$V_{LSB} = \Big[\underbrace{\cos \omega_c t \cdot m(t)}_{\text{o/p of balance mod 1}} + \underbrace{\cos(\omega_c t - \pi/2) \cdot \hat{m}(t)}_{\text{o/p of bm 2}}\Big]$$

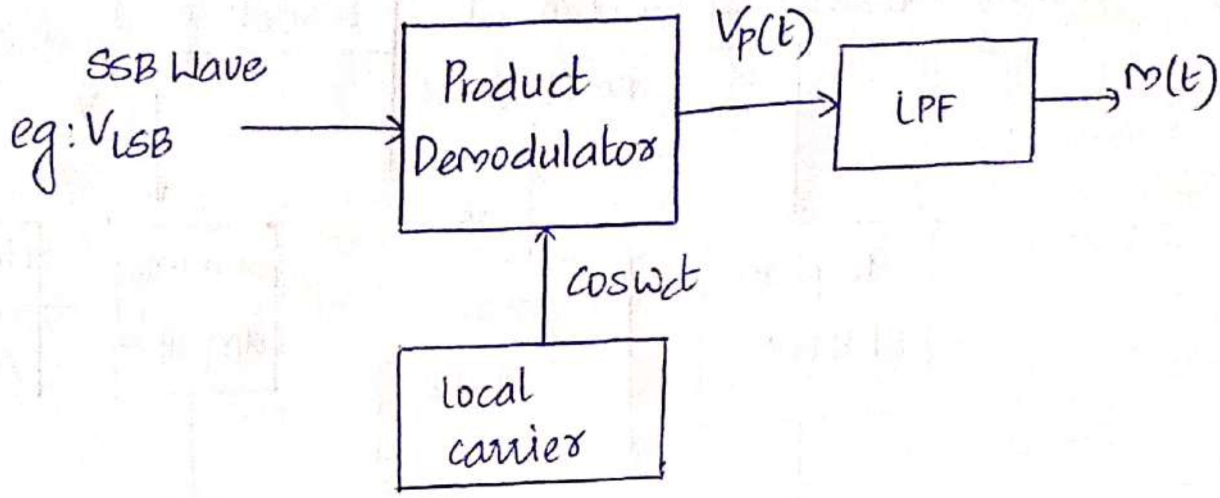
$$= \cos\omega_c t \cdot \cos\omega_m t + \cos(\omega_c t - \pi/2) \cdot \cos(\omega_m t - \pi/2)$$

$$= \cos\omega_c t \cdot \cos\omega_m t + \sin\omega_c t \cdot \sin\omega_m t$$

$$= \cos(\omega_c - \omega_m)t$$

For V_{USB}, use a difference amplifier instead of summing amplifier.

Coherent Detection of method – SSB



$$V_p(t) = \cos\omega_c t \cdot V_{LSB}$$
$$= \cos\omega_c t\left[m(t)\cos\omega_c t + \hat{m}(t)\sin\omega_c t\right]$$
$$= m(t)\cos^2\omega_c t + \hat{m}(t)\cos\omega_c t\sin\omega_c t$$

$$V_p(t) = m(t)\left[\frac{1+\cos 2\omega_c t}{2}\right] + \hat{m}(t)\,\frac{2\sin\omega_c t\,\cos\omega_c t}{2}$$
$$= \frac{m(t)}{2}\left(1+\cos 2\omega_c t\right) + \frac{\hat{m}(t)}{2}\left(\sin 2\omega_c t\right)$$
$$= \underbrace{\frac{1}{2}m(t)}_{\omega_m(t)} + \frac{1}{2}\left(\underbrace{m(t)\cos 2\omega_c t}_{2\omega_c(t)} + \underbrace{\hat{m}(t)\sin 2\omega_c t}_{2\omega_c}\right)$$

Here, m(t) gets separated

Qn: A sinusoidal carrier has amplitude of 10V and freq 30 kHz. It is amplitude modulated by a sinusoidal voltage of amp 3V and freq 1kHz. Modulated voltage is developed across 50Ω resistance.

(i) Write the eqn for modulated wave
(ii) Plot the waveform showing the max and min voltage.
(iii) Determine the modulation index.
(iv) Draw the spectrum of the modulated wave.

$$V_{am}(t) = V_c(1 + m \sin \omega_m t)(\sin \omega_c t)$$

$f_c = 30\,kHz$

$\omega_c = 2 \times \pi \times 30 \times 10^3$

$= 18.84 \times 10^4$

$= 188.4\ KHz.$

$V_m = 3V$

$\omega_m = 2\pi \times 1K$

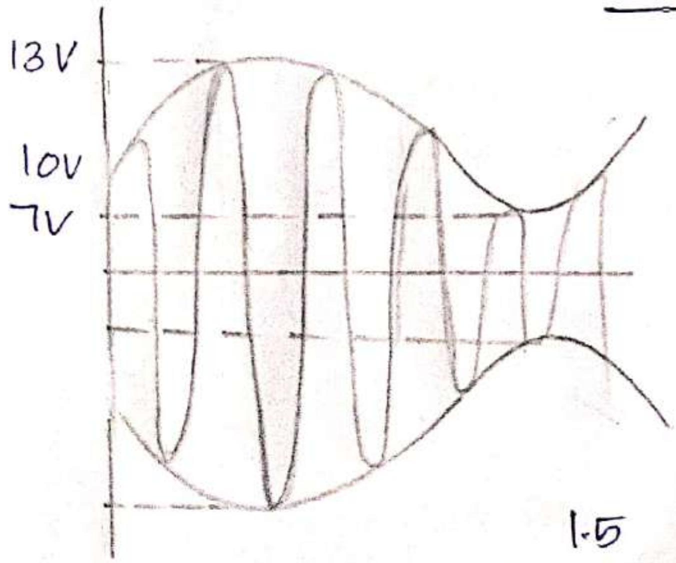
$= 6.28\ KHz.$

$m = V_m / V_c = \underline{0.3}$

$V_c = 10V$

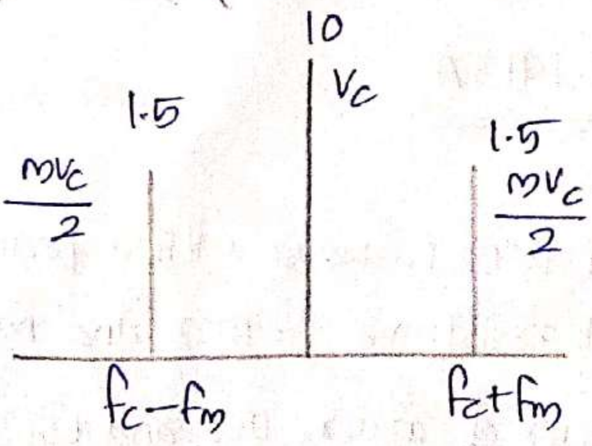
$$V_{am}(t) = 10(1 + 0.3 \sin 2\pi \times 10^3 t)(\sin 2\pi \times 30 \times 10^3 t)$$

$$= 10(1 + 0.3 \sin 6280t)(\sin 188400t)$$



$V_{max} = 13V$

$V_{min} = 7V$



Qn. The antenna current of an AM transmitter is 8 A only if the carrier is sent. But it increaseds to 8.93 A if the carrier is modulated by a single sinusoidal wave. Determine the % modulation. Also find the antenna current if the % of modulation changes to 0.8.

$$I_c = 8A \qquad I_t = 8.93\,A$$

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

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

$$m^2 = 2\left(\frac{I_t^2}{I_c^2} - 1\right)$$

$$m = \sqrt{2\left(\frac{8.93^2}{8^2} - 1\right)}$$

$$= \underline{\underline{0.7014}}$$

$$m\,\% = 70.1\% \approx 70\%$$

(ii) $m = 0.8$.

$$I_t = 8\sqrt{1 + \frac{0.8^2}{2}}$$

$$= \underline{\underline{9.1913\,A}}$$

Qn: For an A&M DSB-FC wave with a peak unmodulated carrier voltage $V_c = 10V$ and load resistance $R = 10\Omega$ and modulation coefficient $m = 1$, determine the power of carrier, USB and LSB (ii) Total SB power (iii) Total power of the modulated wave (iv) draw power spectrum

$V_c = 10V \quad R = 10\Omega$

$$P_c = \frac{V_c^2}{2R} = \cancel{10W}\ 5W$$

$m = 1$

$$P_{USB} = P_{LSB} = \frac{m^2 V_c^2}{8R}$$

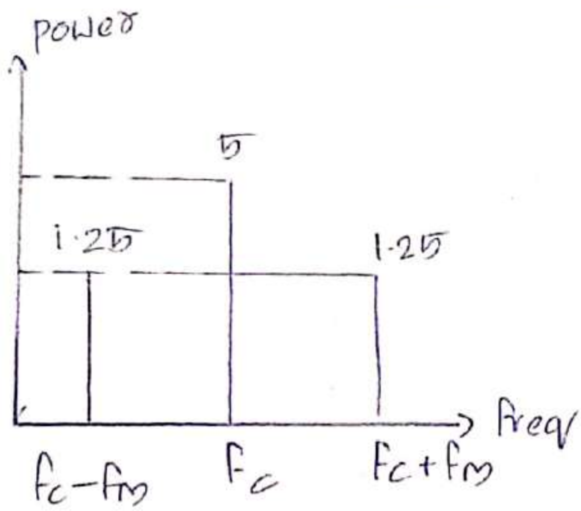
$$= \frac{100}{80} = 1.25W$$

$P_{SB} = 2.5W$

$$\text{Total power} = P_c\left(1 + \tfrac{1}{2}\right)$$

$$= \cancel{10}\ 5 \times 1.5$$

$$= 7.5W$$



Qn: A modulating signal $10 \sin(2\pi \times 10^3 t)$ is used to modulate a carrier signal $20 \sin(2\pi \times 10^4 t)$. Determine the mod index, % modulation, freqs. of the SB components and their amplitudes, bandwidth.

$$m = \frac{10}{20} = 0.5$$

% of mod = 50%

$$\text{Freq of LSB} = f_c - f_m$$

$$= 10kHz - 1kHz$$

$$= 9kHz$$

Freq of USB = 11kHz

$$\text{Amplitudes of SB} = \frac{mV_c}{2} = \cancel{\frac{10 \times 20}{}}\ \frac{0.5 \times 20}{2} = 5V$$

$$bw = 2f_m = 2kHz$$

Angle modulation

FM and PM are together known as angle modulation.

$$V_c = V_c \cos \theta(t).$$

Advantages : noise reduction, improved system fidelity and more efficient usage of power.

Disadvantages: Wider bandwidth, more complex circuits in both the transmitter and receiver section.

The modulating signal $m(t)$ is used to vary ~~represent~~ the carrier signal. So the change in carrier freq will be proportional to the modulating signal $m(t)$.

$$f_0 \propto m(t)$$

$f_0 = km(t)$ where k is a constant called frequency variation constant.

Unit of k : Hz/V.

$\therefore$ the instantaneous carrier frequency $f_i(t) = f_c + km(t)$

where f_c is the frequency of carrier signal

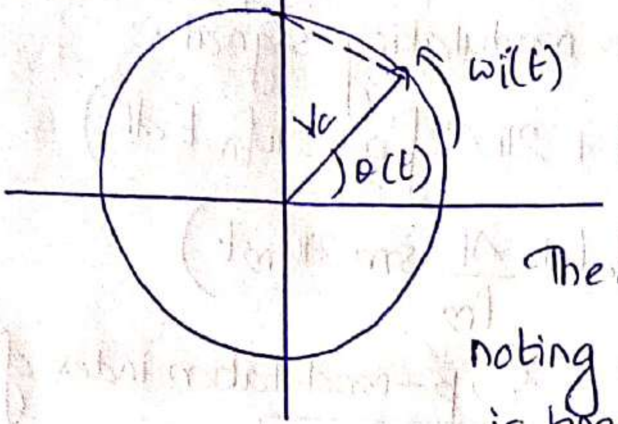
$km(t) \rightarrow$ change in freq.

→ f_c is the unmodulated carrier frequency.

$\therefore$ corresponding angular velocity,

$$\omega_i(t) = 2\pi f_i(t)$$

Generation of the modulated carrier can be represented graphically by means of a rotating phasor diagram as shown:



$$\omega_i(t) = \frac{d\theta(t)}{dt}$$

The angle $\theta(t)$ is found by noting that the angular velocity is time rate of change of angle (phase angle) $\theta(t)$.

$$\theta(t) = \int \omega_i(t)\,dt = \int 2\pi f_i(t)\,dt$$

$$= 2\pi \int (f_c + k m(t))\,dt$$

$$= 2\pi f_c t + 2\pi k \int m(t)\,dt \,.$$

The modulating signal; from the above eqn, we can see that the modulating signal $m(t)$ is contained in the angle in an indirect way. The cosine fn representing the carrier signal is given by:

$$v_c = V_c \cos\theta(t)$$

$\therefore$ the modulated carrier signal $v_{FM}(t) = v_c$

$$\boxed{V_{FM}(t) = V_c \cos\left[2\pi f_c t + 2\pi k \int m(t)\,dt\right]}$$

Sinusoidal freq modulation

For sinusoidal freq mod, $m(t) = V_m \cos 2\pi f_m(t)$ $\therefore$ the expression for sinusoidally modulated signal becomes:

$$\boxed{V_{FM}(t) = V_c \cos\left(2\pi f_c t + 2\pi k \int V_m \cos 2\pi f_m(t)\,dt\right)}$$

Subs $kV_m = \Delta f$ where Δf is the peak freq variation which is proportional to the modulating signal.

$$V_{FM}(t) = V_c \cos\left(2\pi f_c t + 2\pi \Delta f \int \cos 2\pi f_m t \, dt\right)$$

$$= V_c \cos\left(2\pi f_c t + \frac{\Delta f}{f_m} \sin 2\pi f_m t\right)$$

$\hookrightarrow \beta$ - modulation Index of freq modulated signal

$$= \boxed{V_c \cos\left(2\pi f_c t + \beta \sin 2\pi f_m t\right)}$$

where $\beta = \frac{\Delta f}{f_m}$.

FREQUENCY SPECTRUM OF SINUSOIDAL FM SIGNAL

The eqn for freq mod signal is:

$$V_{FM}(t) = V_c \cos\left[2\pi f_c t + \beta \sin 2\pi f_m t\right]$$

The freq domain representation can be obtained by Bessel function identity given by

$$\cos\left[A + \beta \sin B\right] = \sum_{n=-\infty}^{\infty} J_n(\beta) \cos(A + nB).$$

$$V_{FM}(t) = V_c\left[J_0(\beta)\cos\omega_c t + J_1(\beta)\left[\cos \omega_c t + \omega_m t\right] - J_1(\beta)\left[\cos \omega_c t - \omega_m t\right] + J_2(\beta)\left[\cos(\omega_c t + 2\omega_m t)\right) + J_2(\beta)\left(\cos(\omega_c t - 2\omega_m t)\right) + J_3(\beta) \ldots\right.$$

$$J_n(\beta) = \left(\frac{\beta}{2}\right)^n \left[\frac{1}{n!} - \frac{(\beta/2)^2}{1!(n+1)!} + \frac{(\beta/2)^4}{2!(n+2)!} + \ldots\right]$$

FREQUENCY MODULATION

$$V_{FM}(t) = V_c \cos(\omega_c t + \beta \sin \omega_m t)$$

$$V_{FM}(t) = V_c \{ J_0(\beta) \cos \omega_c t + J_1(\beta) [\cos(\omega_c + \omega_m)t - \cos(\omega_c - \omega_m)t] +$$

$$J_2(\beta)[\cos(\omega_c + 2\omega_m)t + \cos(\omega_c - 2\omega_m)t] +$$

$$J_3(\beta)[\cos(\omega_c + 3\omega_m)t - \cos(\omega_c - 3\omega_m)t] + \cdots$$

$$J_{-n}(\beta) = (-1)^n J_n(\beta)$$

Bessel fn for a sinusoidal FM carrier of unmodulated amplitude 1V.

Modulation Index (β)	Carrier $J_0(\beta)$	1st $J_1(\beta)$	2nd $J_2(\beta)$	3rd $J_3(\beta)$	4th $J_4(\beta)$	5th $J_5(\beta)$	6th $J_6(\beta)$
0.25	0.98	0.12	0.01				
	ω_c	$\omega_c \pm \omega_m$	$\omega_c \pm 2\omega_m$				
0.5	0.94	0.24	0.03				
1	0.77	0.44	0.11	0.02			
1.5	0.51	0.56	0.23	0.06	0.01		
2	0.22	0.58	0.35	0.13	0.03	0.01	

From the above table, we can see that for $\beta = 0.5$, the spectral components and the corresponding bessel coefficient values are

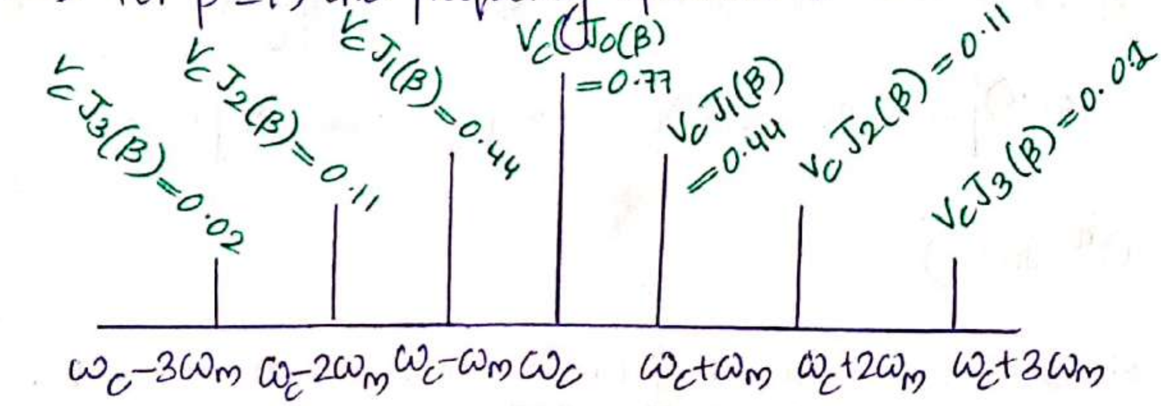
0.94 for ω_c — spectral components

0.24 for $\omega_c \pm \omega_m$

etc..

From the expanded eqn of FM signal, we can see that it contains a carrier term $V_c J_0(\beta) \cos \omega_c t$, a first pair of side frequencies $V_c J_1(\beta) \cos(\omega_c \pm \omega_m)t$, second pair of side freqs $V_c J_2(\beta) \cos(\omega_c \pm 2\omega_m)t$ and so on. The amplitude coefficient is the Bussel fn coefficient $J_n(\beta)$.

→ For $\beta = 1$, the frequency spectrum is



- Bandwidth (no. of side bands) ie calculating bw in terms of side bands) $= 2nf_m$ —— ①

When $n = 1$, $B.W = 2f_m$ (bw of AM signal is $2f_m$)

These type of FM signals are called narrowband FM signals.

- Bandwidth in terms of $\beta = 2(\beta + 1) f_m$

$$\beta = \frac{\Delta f}{f_m} = \frac{\text{freq deviation}}{\text{freq of modulating signal}}$$

$$B.W = 2\left(\frac{\Delta f}{f_m} + 1\right) f_m$$

$$= 2(\Delta f + f_m) \quad \text{—— ②}$$

This eqn is called Carson's rule

Carson's rule states that bw of a freq mod signal is equal to twice the sum of peak freq deviation and highest modulating signal frequency.

→ Unlike AM, where there are only 3 freq components, FM has an infinite no of sidebands as well as carrier.

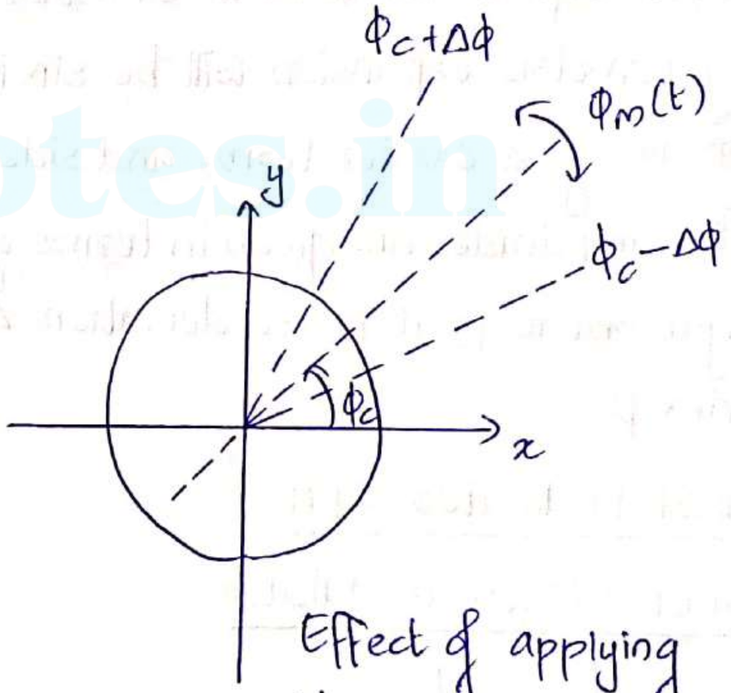
→ The Bessel fn coefficients (J_n coefficients) decreases in value as n increases.

→ The modulation index determines how many side band components have significant amplitude.

→ The sidebands at equal distance from the f_c have equal amplitudes and are symmetrical about the carrier freq.

PHASE MODULATION

$$V_c(t) = V_c \cos \theta(t)$$
$$= V_c \cos(\omega_c t + \phi(t))$$



Effect of applying phase modulation

A change in phase of the carrier signal is proportional to the message signal m(t).

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

$$\text{ie. } \phi(t) = K m(t)$$

where K is the phase deviation constant.

Unit of K is rad/V

$$V_{PM}(t) = V_c \cos(\omega_c t + \phi(t))$$

$$= V_c \cos(\omega_c t + k m(t)) \quad \text{—②}$$ Common eqn for for PM signal.

Sinusoidal phase modulation

$$m(t) = V_m \sin \omega_m t$$

Subs in eqn ②,

$$V_{PM}(t) = V_c \cos(\omega_c t + \underbrace{k V_m}_{\Delta\phi} \sin \omega_m t)$$

$$= V_c \cos(\omega_c t + \Delta\phi \sin \omega_m t)$$

$\Delta\phi$ is the peak phase deviation

Above eqn is identical to sinusoidal FM eqn where $\Delta\phi = \beta$. So the trigonometric expansion will be similar to that of the sinusoidal FM, containing a carrier term, and side freqs at $f_c \pm n f_m$.

The amplitudes are given in terms of Bessel fns $J_n(\Delta\phi)$. In this case, argument is peak phase deviation $\Delta\phi$ rather than frequency modulation index β.

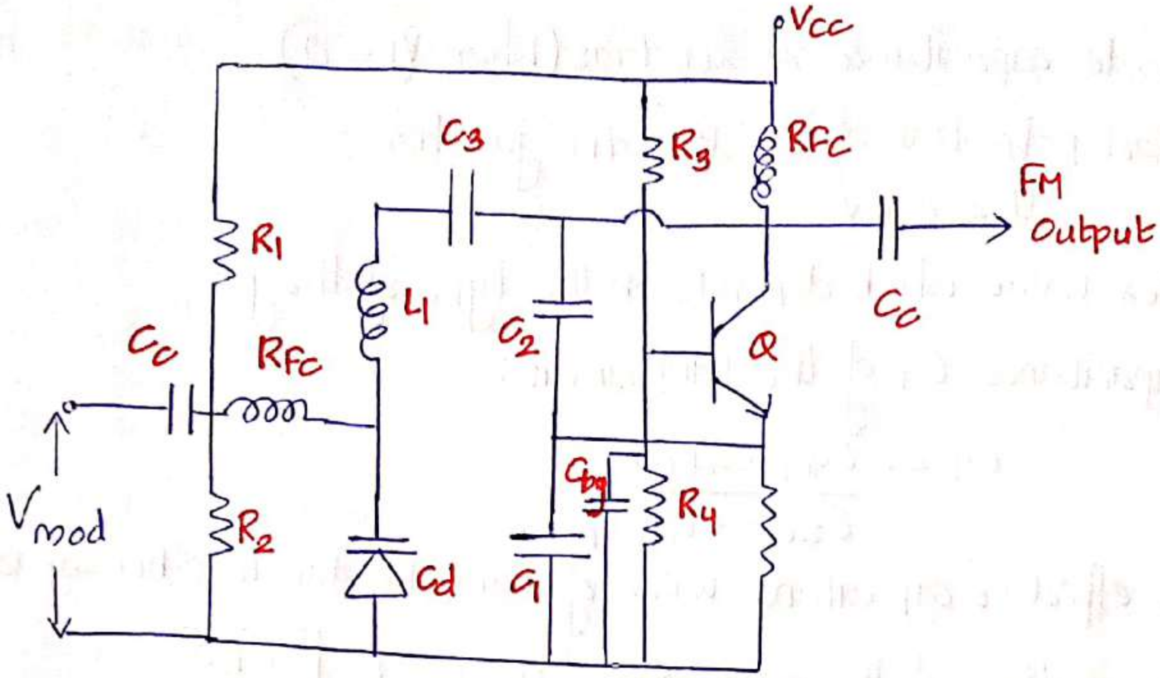
Direct Modulator – FM

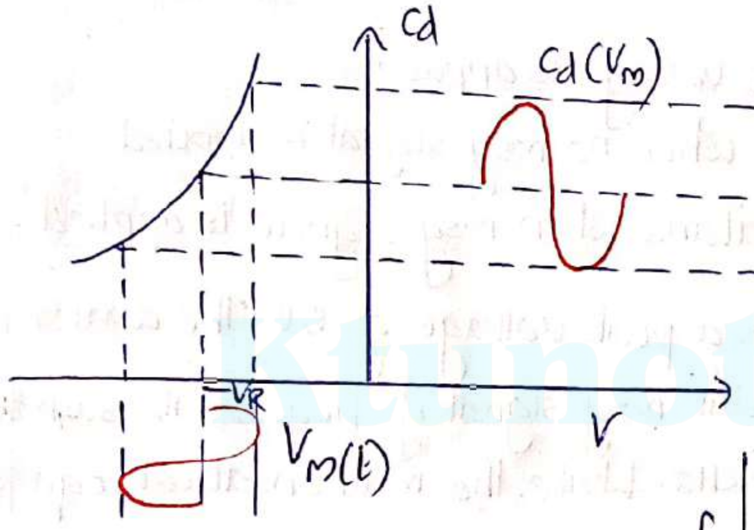
Varactor Diode modulator

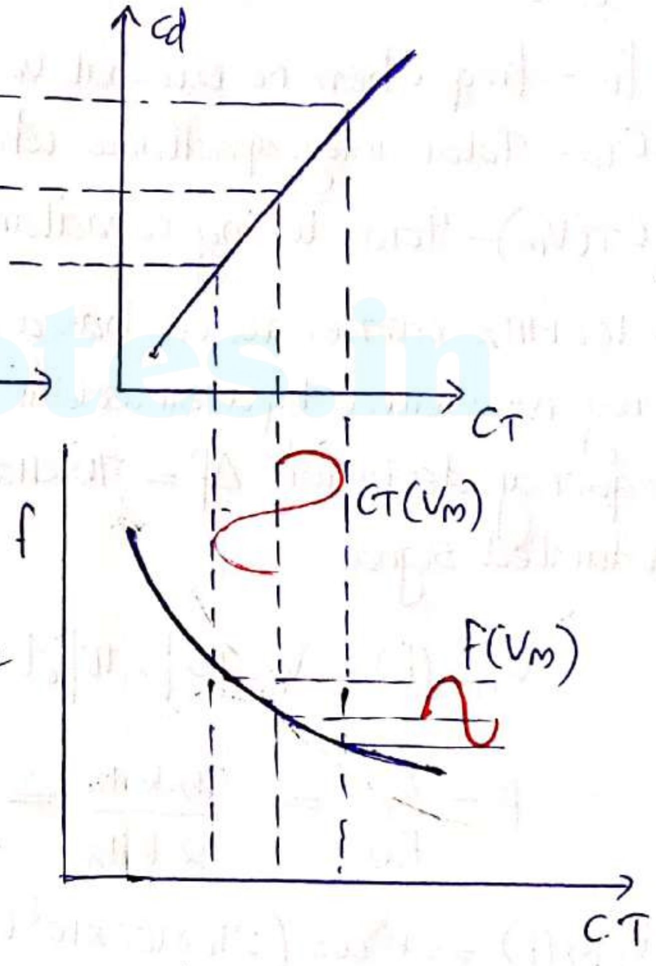
$$f = \frac{1}{2\pi\sqrt{LC}}$$

We use varactor-diode modulator as an oscillator circuit.

Internal capacitance of varactor diode $\propto$ externally applied bias voltage







Vd is the externally applied voltage to varactor diode.

$$V_d(V_M) = -(V_R + V_M)$$

V_M - msg/modulating signal

V_R - fixed reverse bias voltage

Varactor diode capacitance, $C_d(V_M) = \dfrac{C_0}{\left(1 - \dfrac{V_d(V_M)}{\psi}\right)^{\alpha}}$

C_0 is the diode capacitance at zero bias (when $V_d = 0$).

ψ is the contact potential of the Varactor junction

$$\psi \approx 0.5V$$

α is the index value which depends on the type of the jn.

Total capacitance C_T of the tank circuit:

$$C_T = \frac{C_{ser} \cdot C_d(V_m)}{C_{ser} + C_d(V_m)}.$$

C_{ser} is the effective capacitance value of tank ckt due to other capacitors

Frequency of oscillation of the modulator, $f(V_m) = f_0 \sqrt{\frac{C_{T0}}{C_T(V_m)}}$

f_0 – freq when no external voltage is applied

C_{T0} – Total tuning capacitance when no msg signal is applied

$C_T(V_m)$ – Total tuning capacitance when msg signal is applied.

Qn) A 100MHz carrier wave has a peak voltage of 5V. The carrier is frequency modulated by a sinusoidal msg signal of freq 2KHz such that the frequency deviation $\Delta f = 75$KHz. Write the mathematical eqn for the modulated signal.

$$V_{FM}(t) = V_c \cos\left[2\pi f_c t + \beta \sin 2\pi f_m t\right]$$

$$\beta = \frac{\Delta f}{f_m} = \frac{75\,kHz}{2\,kHz} = \underline{\underline{37.5}}$$

$$V_{FM}(t) = 5\cos\left(2\pi \times 100 \times 10^6 t + 37.5 \sin 2\pi \times 2 \times 10^3 t\right)$$

$$= 5\cos\left(2 \times 10^8 \pi t + 37.5 \sin 4 \times 10^3 \pi t\right)$$

Qn) A 7KHz modulating signal modulates 107.6 MHz carrier wave so that the frequency deviation is 50KHz. Find the carrier swing in the FM signal, modulation index and the highest and lowest freqs attained by the FM signal.

$$\text{Carrier Swing} = f_c + \Delta f - (f_c - \Delta f)$$

$$= 2\Delta f$$

$$= 2 \times 50\,kHz$$

$$= \underline{\underline{100\,kHz}}$$

$$\beta = \frac{\Delta f}{f_m} = \frac{50\,kHz}{7\,kHz} = \underline{\underline{7.143}}$$

$$\text{highest freq} = f_c + \Delta f$$

$$= 107.6\,MHz + 50\,kHz = 107600\,kHz + 50\,kHz$$

$$= \cancel{157.6}\ 107650\,kHz = \underline{\underline{107.65\,MHz}}$$

$$\text{lowest freq} = f_c - \Delta f$$

$$= 107.6\,MHz - 50\,kHz$$

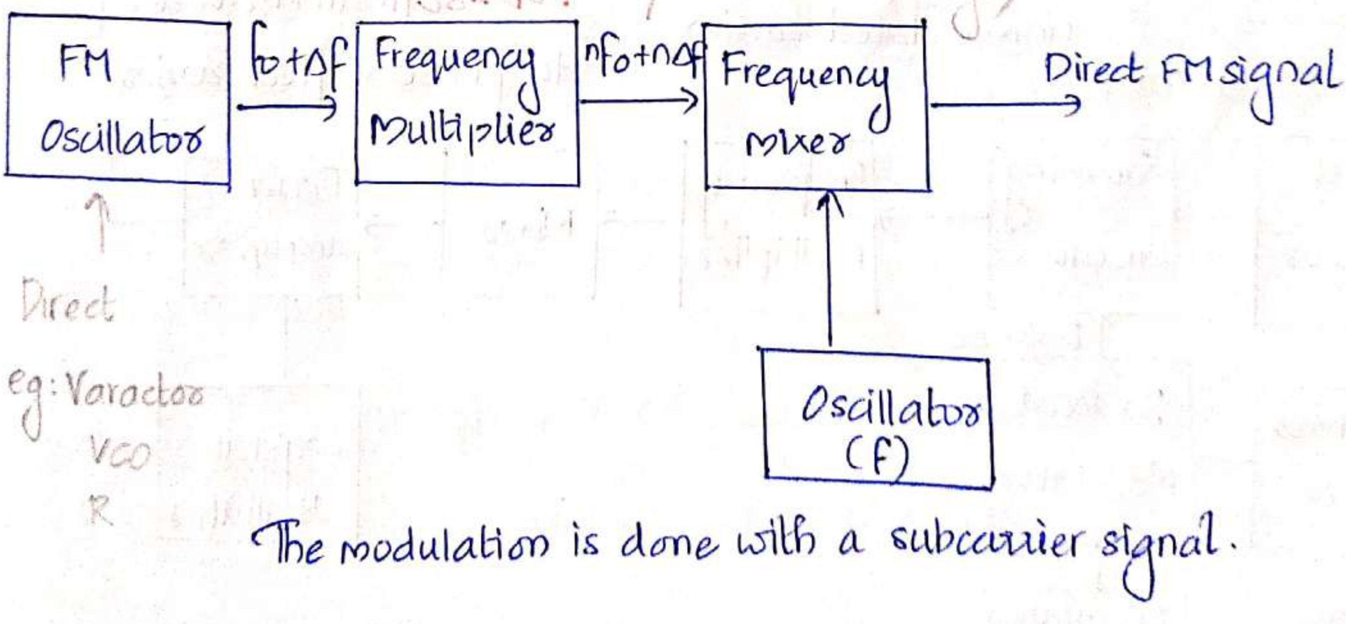
$$= 107600 - 50$$

$$= 107550\,kHz$$

$$= \underline{\underline{107.55\,MHz}}$$

DIRECT FM TRANSMITTER

upconversion of frequency (no change in message)



The modulation is done with a subcarrier signal.

INDIRECT FM TRANSMITTER

AM signal $\longrightarrow$ FM signal
conversion
$\Downarrow$ hence
it is dindirect

- → Amstrong Indirect transmitter for generating angle modulated signal
- → An angle modulated signal is given by:

$$V(t) = V_c \cos[\omega_c t + km(t)]$$

$$= V_c[\cos\omega_c t \cos km(t) - \sin\omega_c t \sin km(t)]$$

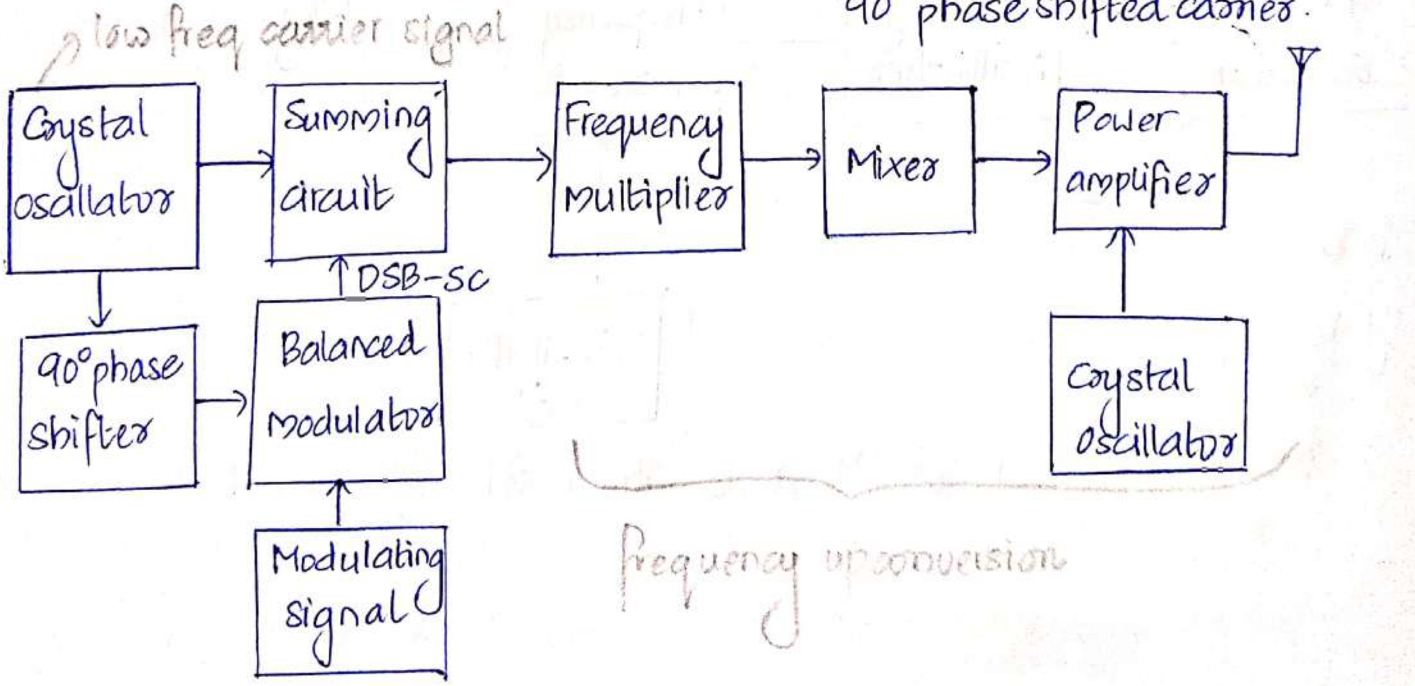
Consider **narrow band modulated signal**, the change in frequency or phase is very small.

$$\therefore \sin km(t) \cong km(t)$$

$$\cos km(t) \cong 1$$

$$\therefore V(t) = V_c[\cos\omega_c t - km(t)\sin\omega_c t]$$

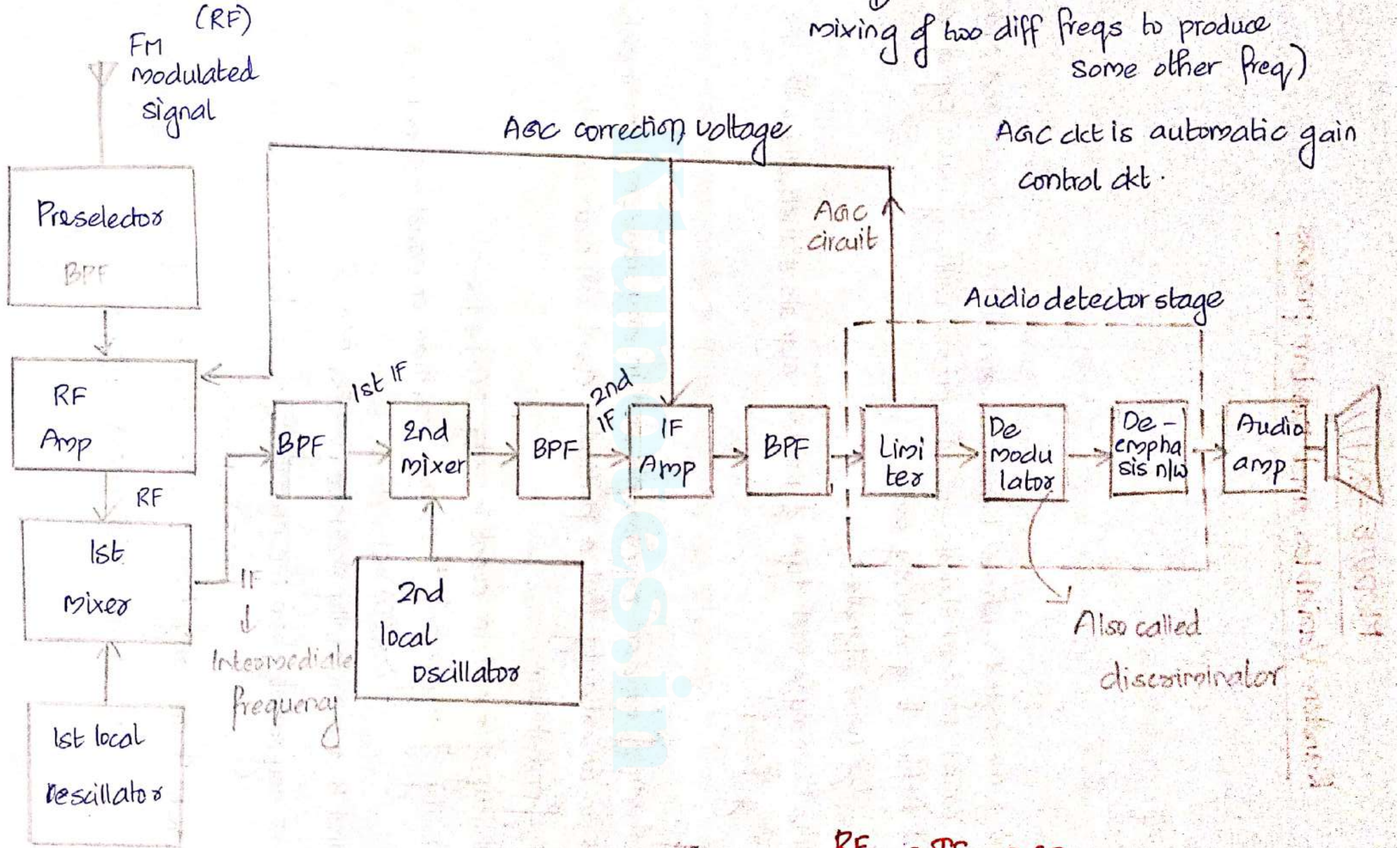
$$= \underbrace{V_c \cos\omega_c t}_{\text{unmodulated carrier}} - kV_c \underbrace{m(t)\sin\omega_c t}_{\text{DSB-SC (mathematical eqn) - with } 90^\circ \text{ phase shifted carrier.}}$$



FM RECEIVER

(heterodyne receiver → mixing of two diff freqs to produce some other freq)

AGC ckt is automatic gain control ckt.



RF → IF → AF