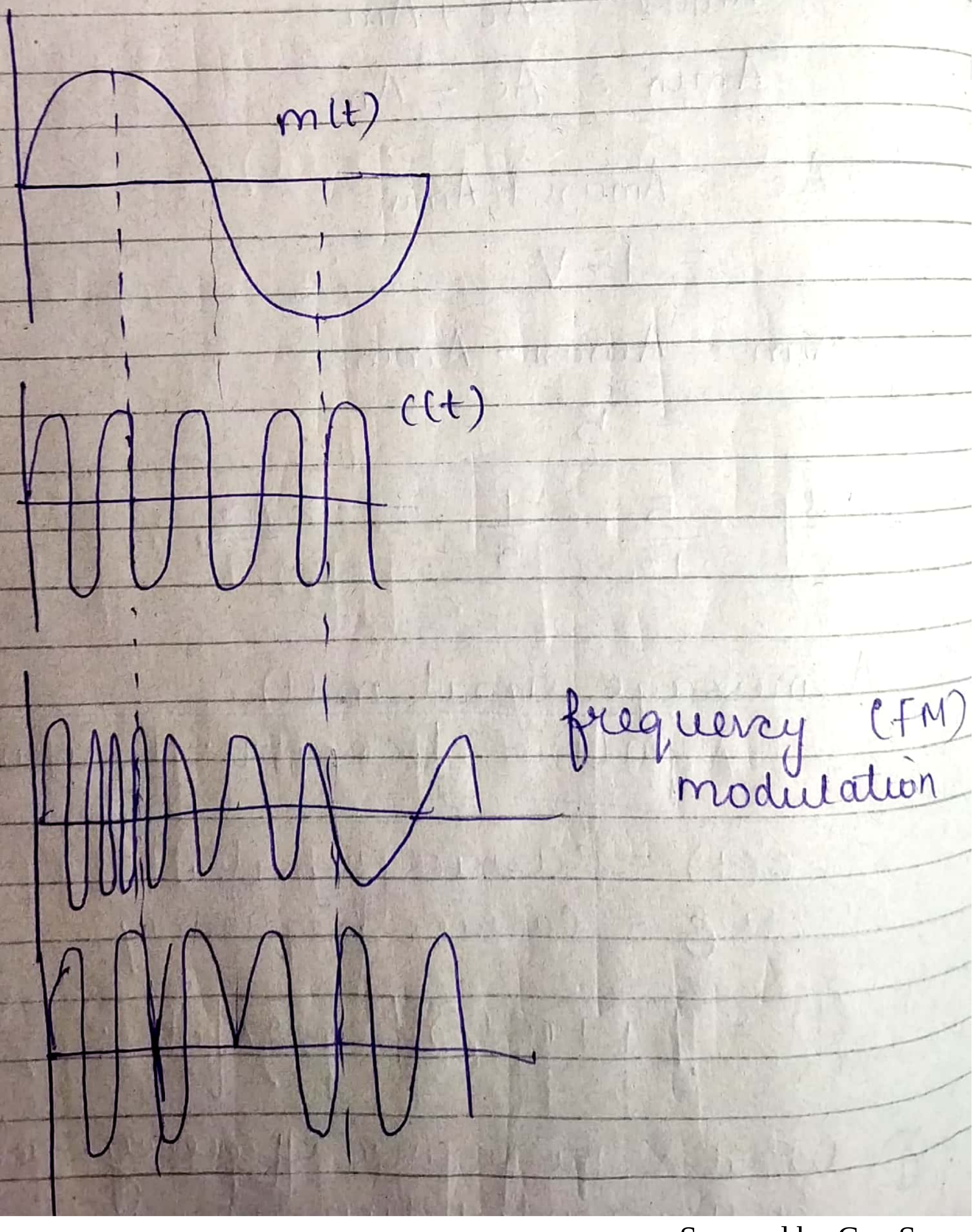
UNIT-3. Angle Modulation

Angle modulation

- Frequency modulation
- Phase modulation.



$f_i = f_c + K_f \cancel{\&} m(t)$

$\downarrow$

instantaneous frequency.

FM is that type of angle modulation in which instantaneous frequency is ~~leare~~ linearly varied with the message signal.

Instantaneous frequency will be equal to carrier frequency plus time varying baseband signal $m(t)$.

~~It means the~~

$$f_i = f_c + K_f m(t)$$

$$f_i = f_c + K_f A_m = f_c + \Delta f$$

(OR)

$$f_i = f_c - K_f A_m = f_c - \Delta f$$

$K_f \rightarrow$ frequency sensitivity

$A_m \rightarrow$ Amplitude of message signal.

$K_f A_m = \Delta f$ = frequency deviation.

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

$$\omega = \frac{d\theta}{dt}$$

$$\Rightarrow 2\pi f = \frac{d\theta}{dt}$$ (Taking integration on both sides)

$$\boxed{\Rightarrow 2\pi \int f\, dt = \theta}$$

$$\Rightarrow \theta_i = 2\pi \int f_i\, dt$$

$$\Rightarrow \theta_i = 2\pi \left[f_c t + k_f \int m(t)\, dt \right]$$

$$s_{FM}(t) = A_c \cos\left[2\pi \left(f_c t + k_f \int m(t) dt\right)\right]$$

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

$$\int m(t)\, dt = \frac{A_m \sin 2\pi f_m t}{2\pi f_m}$$

$$s_{FM}(t) = A_c \cos\left(2\pi f_c t + \frac{k_f}{f_m} A_m \sin 2\pi f_m t\right)$$

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

$$\frac{\Delta f}{f_m} = \text{modulation index} = \beta$$

$$= A_c \cos(2\pi f_c t + \beta \sin 2\pi f_m t)$$

$\beta < 1 \rightarrow$ narrow band FM

$\beta > 1 \rightarrow$ wide band FM.

Case 1 Narrow band FM.

$$= A_c \cos(2\pi f_c t + \beta \sin 2\pi f_m t)$$

$$= A_c [\cos(2\pi f_c t)\cos(\beta \sin 2\pi f_m t) - \sin 2\pi f_c t \sin(\beta \sin 2\pi f_m t)]$$

$$\cos\theta_{\theta = small} = 1$$

$$\sin\theta_{\theta = small} = \theta$$

as $\beta < 1$

$\cos \beta \sin 2\pi f_m t = 1$

$$= A_c [\cos 2\pi f_c t - \sin(2\pi f_c t) \cdot \beta \sin 2\pi f_m t]$$

As $\beta < 1$ $\sin(\beta \sin 2\pi f_m t) = \beta \sin 2\pi f_m t$.

$$= A_c[\cos 2\pi f_c t - \beta \sin 2\pi f_m t \sin 2\pi f_c t]$$

$$= A_c \cos 2\pi f_c t - A_c\beta \sin 2\pi f_m t \sin 2\pi f_c t$$

$$= A_c \cos 2\pi f_c t - \frac{A_c\beta}{2}[\cos 2\pi(f_m - f_c)t - \cos 2\pi(f_m + f_c)t]$$

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

<u>Power</u> $= \dfrac{A_c^2}{2} + \dfrac{\frac{A_c^2\beta^2}{4}}{2} + \dfrac{\frac{A_c^2\beta^2}{4}}{2}$

$$= \frac{A_c^2}{2}\left[1 + \frac{\beta^2}{2}\right]$$

$$\boxed{= P_c\left[1 + \frac{\beta^2}{2}\right]}$$

$\beta = \dfrac{K_f A_m}{f_m}$

$$= A_c\left[\frac{e^{j2\pi f_c t} + e^{-j2\pi f_c t}}{2}\right] - \frac{A_c\beta}{2}\left[\frac{e^{j2\pi(f_c - f_m)t} + e^{-j2\pi(f_c - f_m)t}}{2}\right]$$

$$+ \frac{A_c\beta}{2}\left[\frac{e^{j2\pi(f_m + f_c)t} + e^{-j2\pi(f_c + f_m)t}}{2}\right]$$

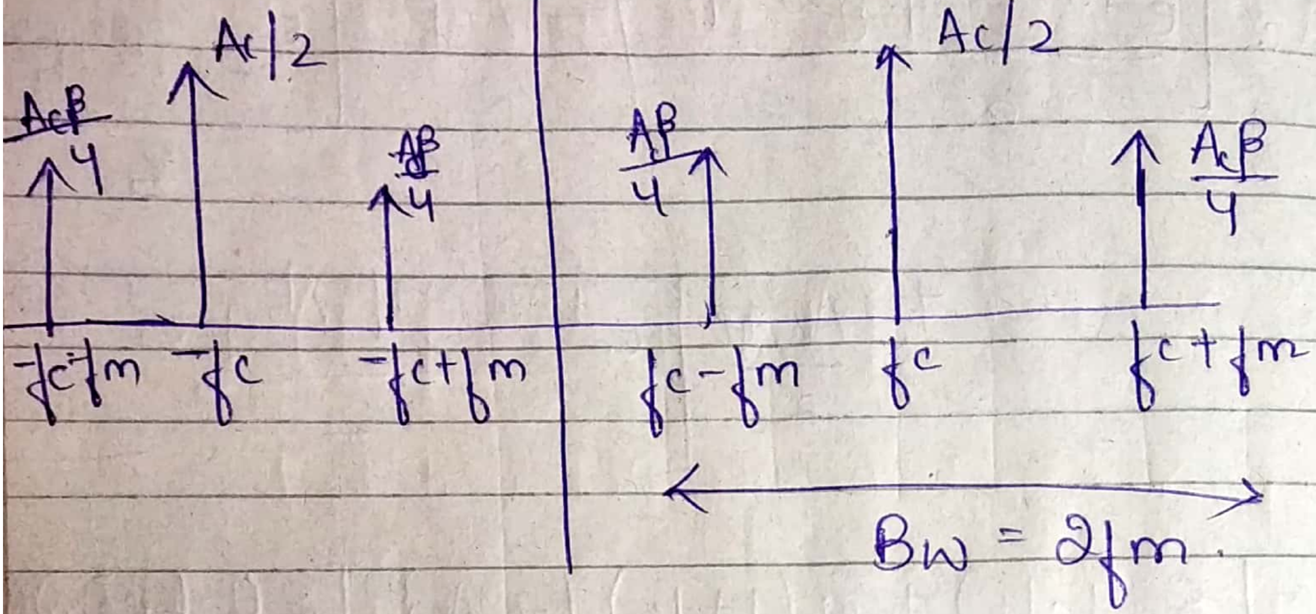
$$= \frac{A_c}{2}\left[\delta(f - f_c) + \delta(f + f_c)\right] - \frac{A_c\beta}{4}\left[\delta(f - (f_c - f_m)) + \delta(f + (f_c - f_m))\right]$$

$$+ \frac{A_c\beta}{4}\left[\delta(f - (f_c + f_m)) + \delta(f + (f_c + f_m))\right]$$

$$= \frac{A_c}{2}\left[\delta(f - f_c) + \delta(f + f_c)\right] - \frac{A_c\beta}{4}\left[\delta(f - (f_c - f_m)) + \delta(f + (f_c - f_m))\right]$$

$$+ \frac{A_c\beta}{4}\left[\delta(f - (f_c + f_m)) + \delta(f + (f_c + f_m))\right]$$

Frequency spectrum



Bandwidth $= 2f_m$.

Case 2 Wide band FM. $\beta > 1$.

$$s_{WBFM}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) \cos 2\pi (f_c t$$

$J_n(\beta)$ → β → modulation index

n → n^{th} order

Bessel function:

$$J_n(\beta) = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{j(\beta \sin\theta - n\theta)} d\theta$$

Properties of $J_n(\beta)$

① On increasing n ; $J_n(\beta)$ decrease.

$$n \uparrow\uparrow \rightarrow J_n(\beta) \downarrow$$

$$J_0(\beta) > J_1(\beta) > J_2(\beta)$$

② $J_{-n}(\beta) = (-1)^n J_n(\beta)$

$$J_{-1}(\beta) = -J_1(\beta)$$

③ $\sum_{n=-\infty}^{\infty} J_n^2(\beta) = 1$

$nf_m)t$

④ $J_n(\beta) \longrightarrow$ always real quantity

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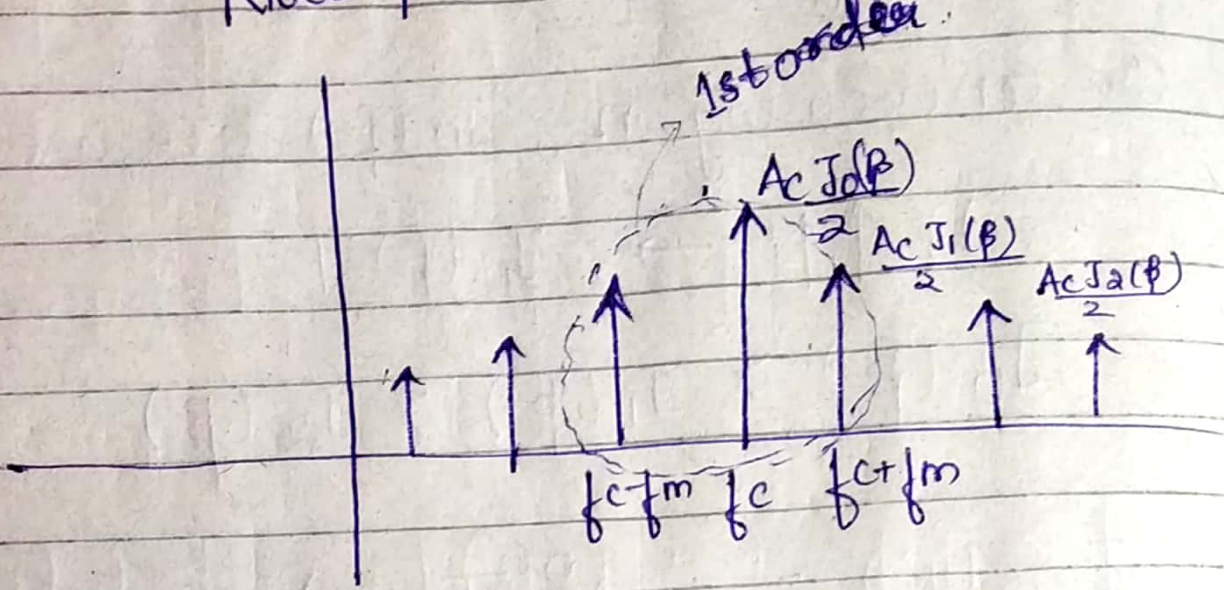
$$s_{WBFM}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) \cos[2\pi(f_c + nf_m)t]$$

$$= \cdots\cdots + A_c J_{-1}(\beta)\cos[2\pi(f_c - f_m)t] +$$

$$A_c J_0(\beta)\cos 2\pi f_c t + A_c J_1(\beta)\cos[2\pi(f_c + f_m)t] + \cdots\cdots$$

Now put cos in terms of e



For 1st Order:

$$BW = 2f_m$$

For 2nd order ; $BW = 4f_m$.

$$\boxed{\text{So In general, } BW = n(2f_m)}$$

Carson's rule for BW.

$$BW = 2(\beta+1)f_m$$

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

$$= 2(\Delta f + f_m)$$

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Modulation efficiency :

$$\eta = \frac{\text{Total side band power}}{\text{Total power}}$$

Our carrier = $A_c J_0(\beta) \cos 2\pi f_c t$

$$P_c = \frac{A_c^2 J_0^2(\beta)}{2}$$

$\beta = 2.4, 5.5, 8.6, 11.8$ (some specific values of β)

For these value of β ; $J_0(\beta) = 0$

So $P_c = 0$

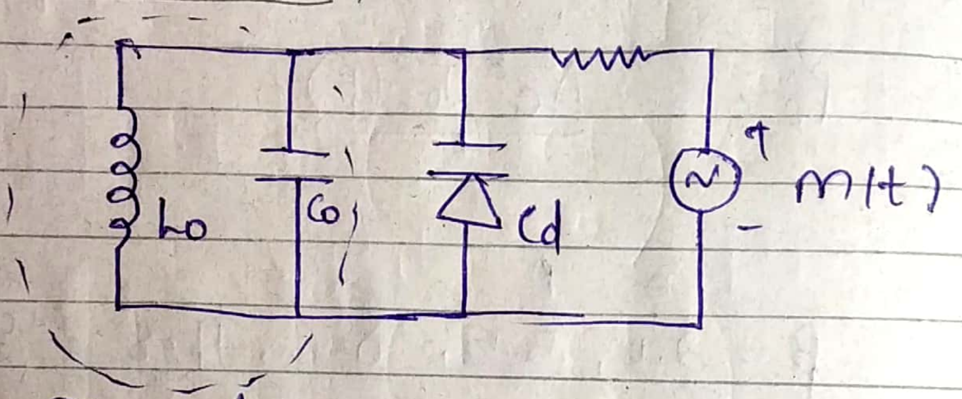
$$\eta = \frac{P_{SBP}}{P_c + P_{SBP}}$$

$$\eta = \frac{P_{SBP}}{P_{SBP}} = 100\%$$

Generation of FM.

1. Direct method. (Parameter variation method)
2. Indirect method. (Armstrong method).

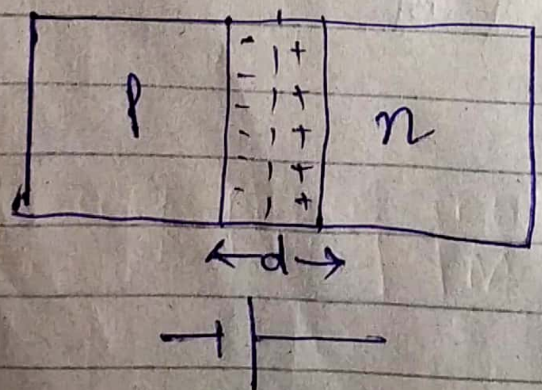
1. Direct method.



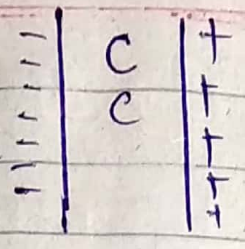
Tuned circuit.

Centre frequency or resonant frequency or intermediate frequency is the frequency of the tuned circuit

$$f_r = \frac{1}{2\pi\sqrt{L_o C_o}}$$



Vo (Bulleti potential)



Now in pn junction, capacitance is induced.

→ When we do reverse biasing, d will be more so c will be less.

$$\boxed{\downarrow C = \varepsilon_0 \frac{A}{d\uparrow}}$$

→ Now when we do less reverse biased, d will get decrease so capacitance c will be increased.

$$\boxed{\uparrow C = \varepsilon_0 \frac{A}{d\downarrow}}$$

→ When we changing $m(t)$; biasing or reversing biasing changes; then C will vary (i.e, capacitance will also change).

→ Here we have two ~~frequency~~ capacitance;

C_0 and C_d which are in parallel

so, $C_T = C_0 + C_d$.

$$f_i = \frac{1}{2\pi\sqrt{L_0 C_T}}$$

$$= \frac{1}{2\pi\sqrt{L_0(C_0+C_d)}}$$

$$= \frac{1}{2\pi\sqrt{L_0 C_0}} \times \frac{1}{\sqrt{1+\frac{C_d}{C_0}}}$$

$$f_i = f_r\left(1+\frac{C_d}{C_0}\right)^{-1/2}$$

$$\boxed{f_i = f_r\left(1-\frac{C_d}{2C_0}\right)}$$

When $x(t)$ is varying, then C_d varies which makes f_i vary. So, by changing message signal, we are varying frequency. Thus, we are doing frequency modulation.

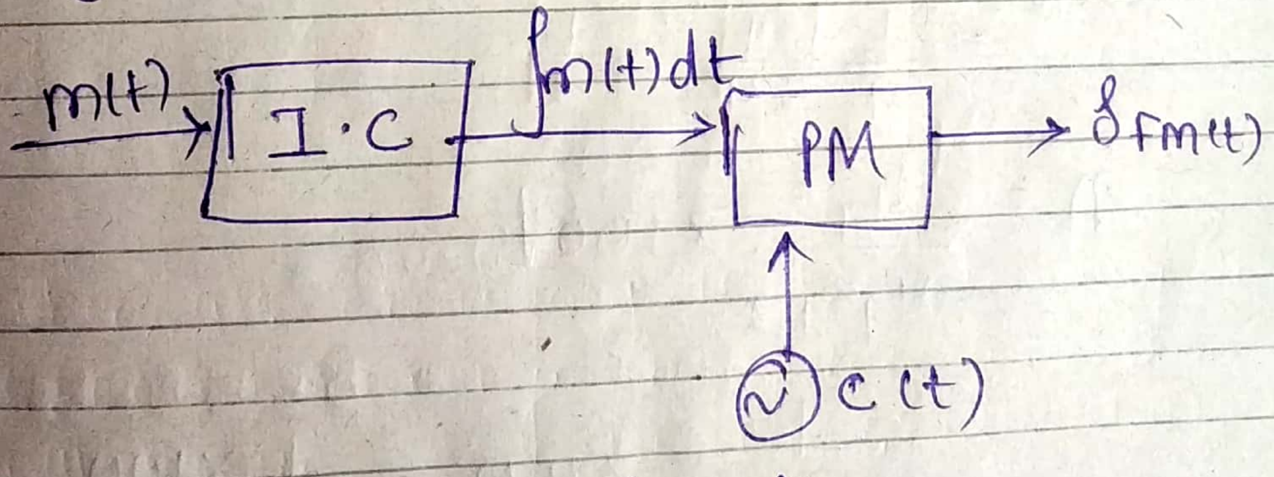
(2) Indirect method.

→ By using phase modulator (PM) we have generated FM.

$$m(t) \rightarrow \boxed{FM} \rightarrow A_c \cos\{2\pi[f_c t + k_f \int m(t)dt]\}$$

$$m(t) \rightarrow \boxed{PM} \rightarrow A_c \cos[2\pi f_c t + K_p m(t)]$$

Difference is that in PM we have used m(t) but in FM we have used $\int m(t)$ so we will first pass m(t) through integrated circuit and then through PM, which will ~~do~~ give us our desired Frequency modulation signal.



From here we will get,

$$s_{FM}(t) = A_c \cos[2\pi f_c t + K_p \int m(t)dt]$$

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TUTORIAL

Q

$$m(t) = \frac{1}{2}\cos\omega_1 t - \frac{1}{2}\sin\omega_2 t$$

$$s_{AM}(t) = [1 + m(t)]\cos 2\pi f_c t.$$

$K_a = 1$; $A_{m_1} = \frac{1}{2}$ $A_{m_2} = \frac{1}{2}$

$$\mu_1 = K_a A_{m_1} = \frac{1}{2}$$

$$\mu_2 = K_a A_{m_2} = \frac{1}{2}$$

$$\mu_T^2 = \mu_1^2 + \mu_2^2$$

$$= \frac{1}{4} + \frac{1}{4} = \frac{1}{2}$$

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

$$= \frac{\frac{1}{2}}{\frac{1}{2} + 2} \times 100 = \frac{1}{5} \times 100$$

$$= \underline{20\%}$$

Ans

Q: The antennae current of AM transmitter is 8 A when only the carrier is sent but it increases 8.93 A when the carrier is modulated by single sine wave. Find the % modulation ; determine the antennae current when the % of modulation changes to 0.8.

$\Rightarrow \quad I_T^2 = I_c^2 \left(1 + \frac{\mu^2}{2}\right)$

$\Rightarrow \frac{79.7449}{64} = \cancel{64} \left(1 + \frac{\mu^2}{2}\right)$

$\Rightarrow \cancel{15.7449 - 1} = \cancel{\frac{\mu^2}{2}}$

$= \cancel{14.7449 \times 2 = \mu^2}$

$= \cancel{5.430} \quad 0.4920 = \mu^2$

$\Rightarrow \mu = 0.7$

% of modulation = 70 % → Ans

$I_T^2 = 64\left(1 + \frac{0.8 \times 0.8}{2}\right)$

$= \frac{\cancel{64}^{32} \times 2.64}{\cancel{2}} = 84.48$

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$$= \cancel{14.7449 \times 2 = \mu^2}$$

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$$\Rightarrow \mu = 0.7$$

% of modulation = 70 % → Ans

$$I_T^2 = 64\left(1 + \frac{0.8 \times 0.8}{2}\right)$$

$$= \frac{\overset{32}{\cancel{64}} \times 2.64}{\cancel{2}} = 84.48$$

$\Rightarrow I_T = 9.19A$ $\rightarrow$ Ans

Q. A DSB-SC transmitter radiates 1KW when the modulation % is 60%. How much of carrier power is required if we want to transmit the same msg by an AM transmitter.

Sol

$P = 1000 W$

$\mu = 0.6$

$$1000 = P_c \left[\frac{\mu^2}{2}\right]$$

$$\Rightarrow P_c = \frac{1000 \times \cancel{2}}{0.6 \times \cancel{0.6}\,0.3}$$

$$= \frac{1000}{0.18} = 5555.56 W$$

$$= 5.555 KW$$

$\rightarrow$ Ans

Q. Calculate the % of power saving when the carrier & one of the SB are suppressed in an AM wave modulator to a depth of 100%.

Sol: $\mu = \dfrac{100}{100} = 1$.

$$\cancel{\eta = \dfrac{\dfrac{P_c \mu^2}{4}}{P_c\left[1+\dfrac{\mu^2}{2}\right]}}$$

$$\cancel{= \dfrac{\dfrac{1}{4}}{\left[1+\dfrac{1}{2}\right]}}$$

$$\cancel{= \dfrac{1}{4} \div \dfrac{3}{2} = \dfrac{1}{6}}$$

$$P_{SSB\text{-}SC} = \dfrac{P_c \mu^2}{4} = P_c \times \dfrac{1}{4}.$$

$$P_{AM} = P_c\left[1+\dfrac{\mu^2}{2}\right] = P_c \dfrac{3}{2}.$$

$$\text{saving} = \dfrac{P_c \dfrac{3}{2} - \dfrac{P_c}{4}}{P_c \dfrac{3}{2}} \times 100$$

$$= \dfrac{6-1}{4} \div \dfrac{3}{2} = \dfrac{5}{6} \times 100$$

$$\boxed{= 83.33\%}$$

Q. A VSB transmitter that transmits 25% of other side band along with wanted SB, radiates 0.625 KW when the modulation % is 60%. How much of carrier power is required if we want to transmit the same msg by an AM transmitter.

Sol.

$$P_{SSB-SC} = \frac{P_c \mu^2}{4}$$

$$P_{VSB-SC} = \frac{P_c \mu^2}{4} + \frac{25}{100}\left(\frac{P_c \mu^2}{4}\right)$$

$$\Rightarrow 625 = \frac{P_c \mu^2}{4} + \frac{P_c \mu^2}{16}$$

$$\Rightarrow 625 = \frac{5 P_c \mu^2}{16}$$

$$= \frac{5 \times P_c \times 0.36}{16}$$

$$\Rightarrow P_c = \frac{\overset{125}{\cancel{625}} \times \overset{4}{\cancel{16}}}{\cancel{5} \times \underset{0.09}{\cancel{0.36}}} = 5555.55 \text{ W}$$

$$= 5.55 \text{ KW}$$

Ans

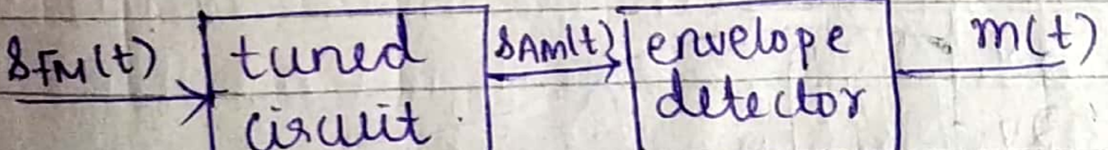
Demodulation of FM :-

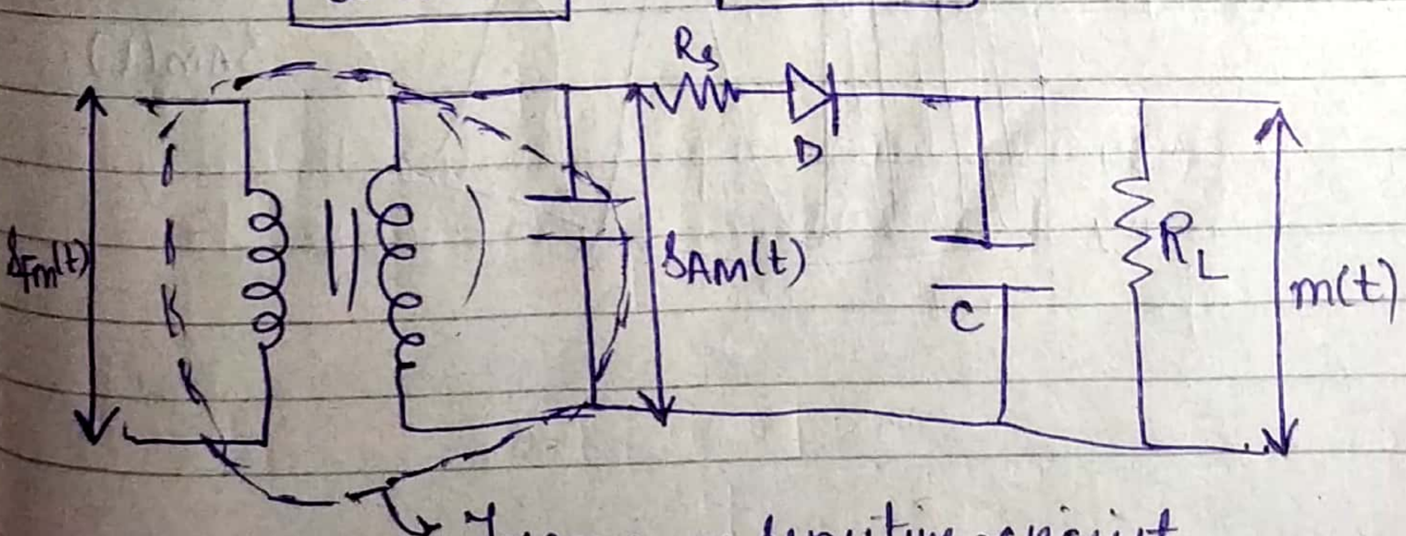
(i) Frequency discrimination
- Slope detector
- Balanced slope detector.

(ii) Phase discrimination
- Foster seelay detector
- ratio detector
- Phase logged loop (PLL)

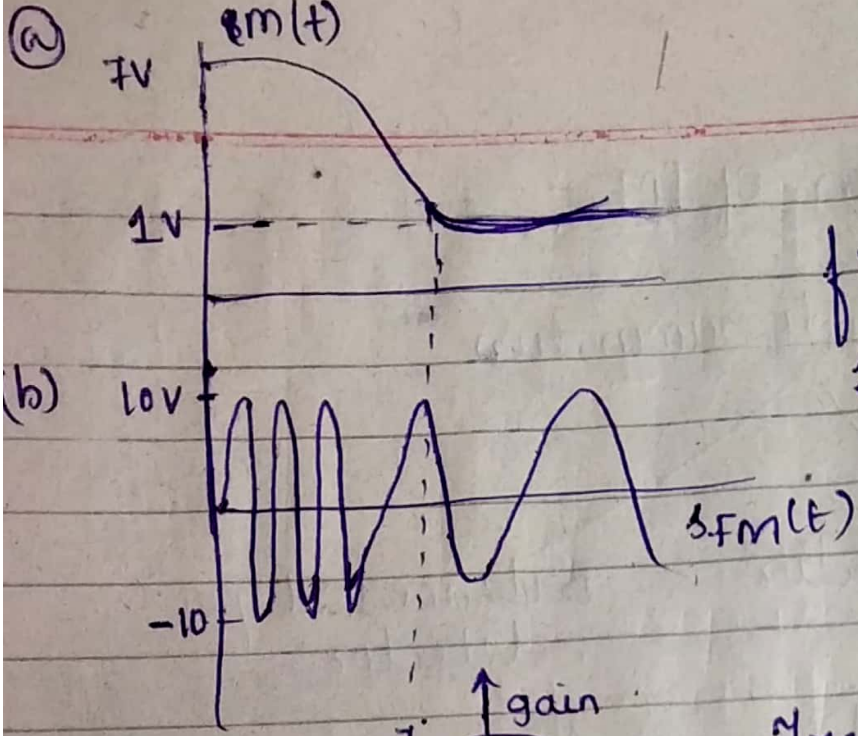
① Frequency discrimination

ⓐ Slope detector.



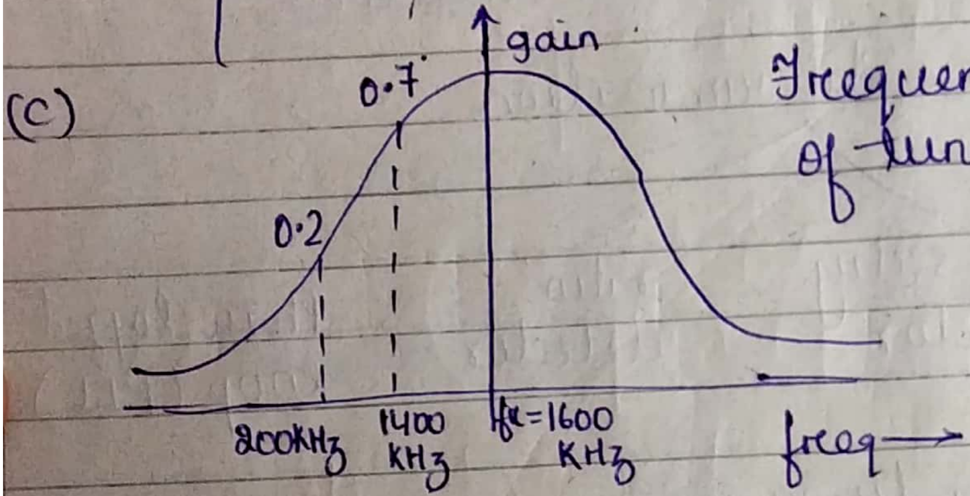


Frequency sensitive circuit
(Tuned circuit)



$f_{max} = 1400\,KHz$

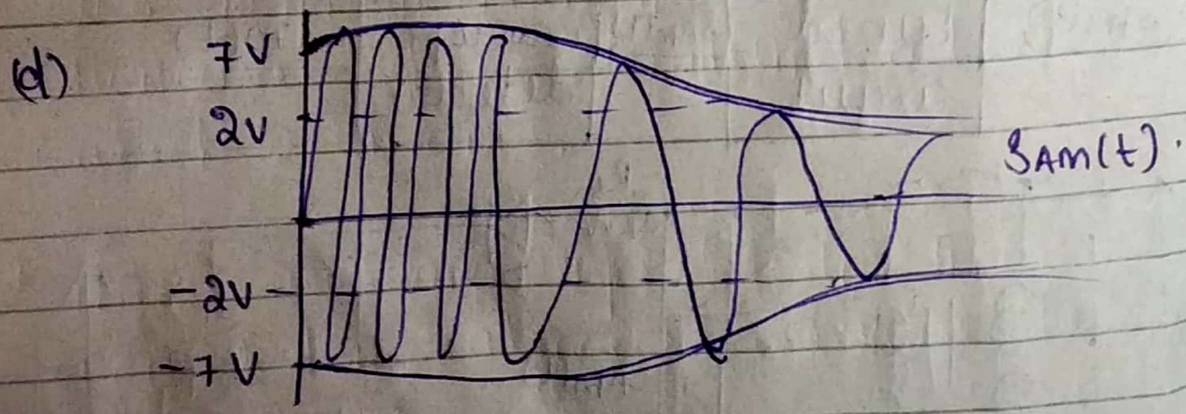
$f_{min} = 200\,KHz$



Frequency gain curve of tuned circuit.

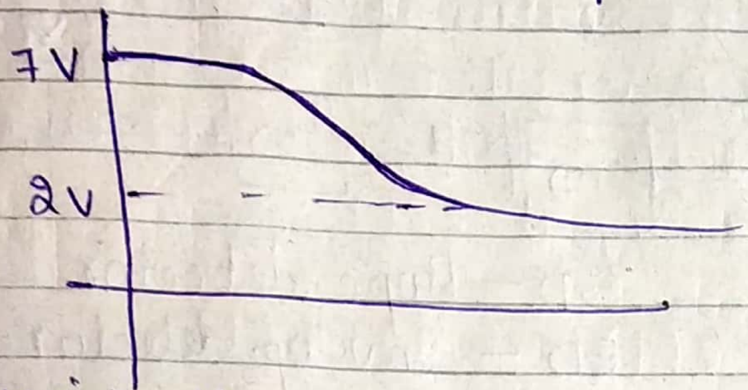
$0.2 \times 10 = 2$ (min) $\quad$ $0.7 \times 10 = 7$ (max)

when (b) is passed through the tuned circuit, we get (d)



from (d) $S_{AM}(t)$, message signal is recovered by passing through the envelope detector.

(e)



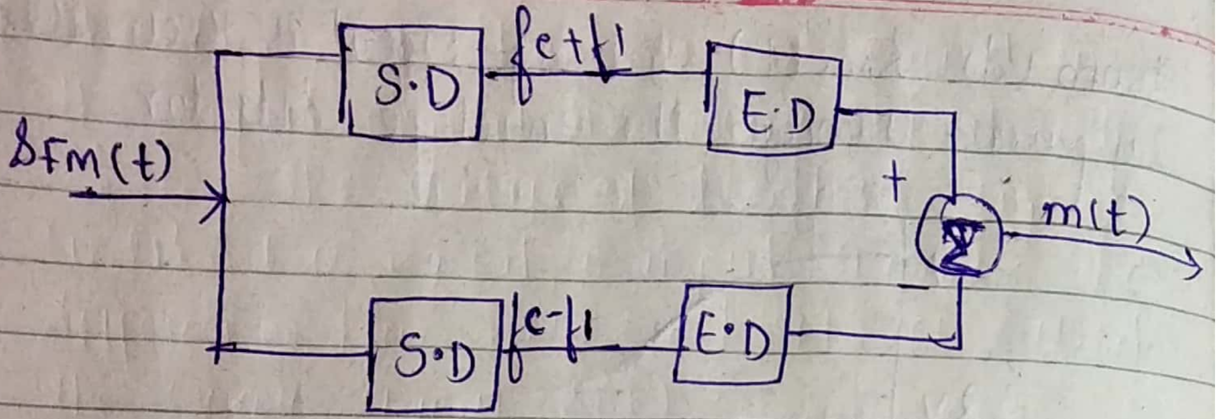
But originally our message signal (a) has min value at 1V so here in (e) we are getting 2V. So error occur due to the non-linear curve of frequency gain.

Drawback of slope detector:

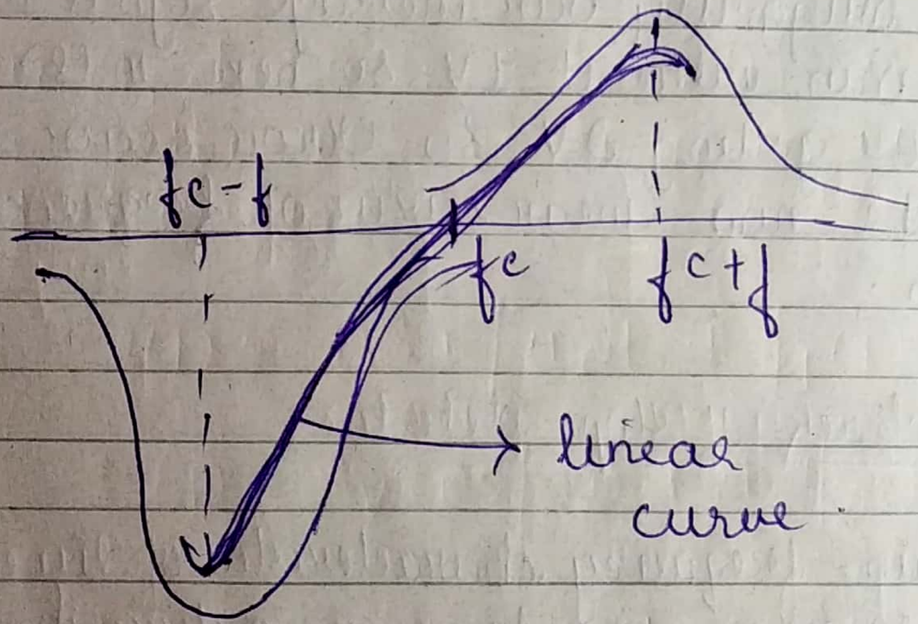
→ Gain-frequency characteristic of tuned amplifier are non-linear in nature. For frequency to voltage conversion a non-linearity will be introduced so when the message signal is reconstructed there will be slope error.

(b) Balanced slope detector :-

This method remove the error that occured in slope detector.



SD – slope detector.
ED – Envelop. detector.



The graph of both the tuned circuit are drawn and their resultant is taken which is linear.

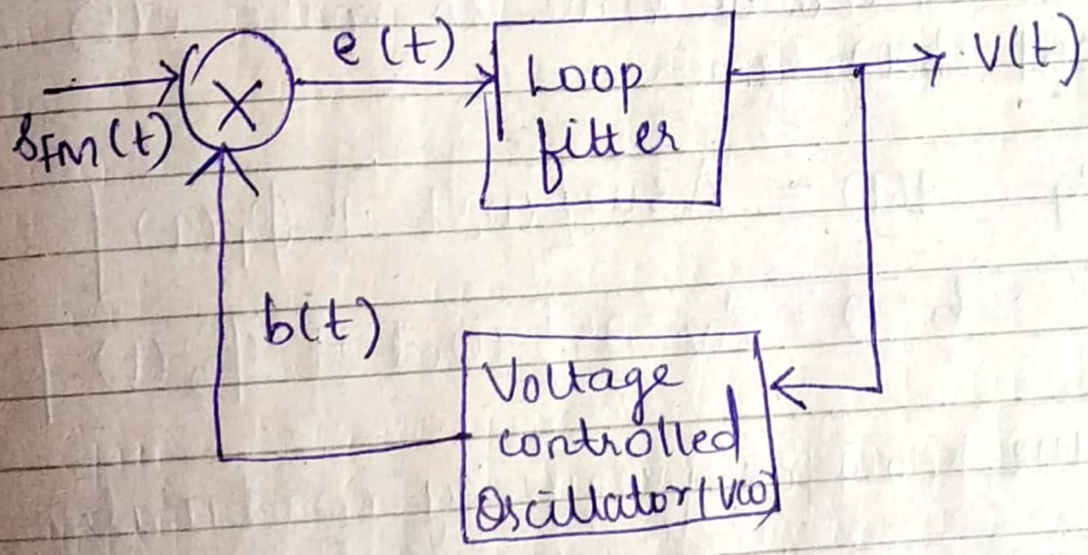
* There are two slope detector which are connected in balance to decrease the slope error.

Drawback.

In a balanced slope detector 3 tuned circuit are used. It is very difficult to tune three circuits.

② Phase discrimination

ⓐ Phase logged loop (PLL).



A phase logged loop is primarily used in tracking the phase and frequency of carrier component of an incoming FM signal. PLL is basically a -ve feedback system. It consists of 3 major components:-

(1) multiplier. (2) Loop filter.
(3) voltage controlled oscillator.

If the signal feedback is not equal to the input signal the error signal will change the value of feedback signal until it is equal to input signal. The difference b/w $b(t)$ and $s(t)$ is called the error signal $e(t)$.

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$$e(t) = s(t) - b(t)$$

Our objective is to reduce the error, so for this we have to make $e(t)$ and $b(t)$ same.

Eg:, $s(t) = A \sin[\omega_c t + \phi_1(t)] \rightarrow (1)$

$b(t) = A_v \cos[\omega_c t + \phi_2(t)] \rightarrow (2)$

We know for frequency modulation,

$$s(t) = A_c \sin[\omega_c t + \underbrace{2\pi k_f \int m(t)\,dt}_{\phi_1(t)}]$$

So for $b(t) = A_v \cos[\omega_c t + \underbrace{2\pi k_v \int v(t)\,dt}_{\phi_2(t)}]$

On multiplying the s(t) and b(t), as we have used multiplier

multiplier gain

$$= \frac{K_m A \cdot A_v}{2} \left[\sin\left(2\omega_c t + \phi_1(t) + \phi_2(t)\right) + \sin\left[\phi_1(t) - \phi_2(t)\right] \right]$$

We have used some filter to reject the additive term as it is not being used and our objective is to reduce the error.

$$= \frac{K_m A \cdot A_v}{2} \left[\sin\left(\phi_e(t)\right) \right]$$

and we know $\phi_2(t) = 2\pi k_v \int v(t)\,dt$.

$$\phi_e(t) = \phi_1(t) - \phi_2(t)$$

$$\boxed{\phi_e(t) = \phi_1(t) - 2\pi K_v \int_0^t v(t)\,dt}$$

Here in this case, we are replacing multiplier with different things so in this case we have used multiplier and filter.

Properties:-

$$x(t) \longleftrightarrow X(\omega) \,|\, X(j\omega)$$

$$\frac{d}{dt}[x(t)] \longleftrightarrow j\omega\, X(\omega)$$

$$\text{or } 2\pi f j\, X(f)$$

$$\int x(t)\,dt \longleftrightarrow \frac{X(\omega)}{j\omega}$$

$$= \frac{X(f)}{j2\pi f}$$

$$e(t) \longrightarrow \boxed{\text{Impulse response of loop filter } h(t)} \longrightarrow y(t)$$

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

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

$$= \int_{-\infty}^{\infty} e(\tau)\, h(t-\tau)\, d\tau.$$

$$e(t) = k_m A A_v \{ \sin \phi_e(t) \}$$ {we can write $\frac{k_m}{2} \cdot k_m$ as const}

Our objective,

$$\phi_e(t) = \phi_1(t) - \phi_2(t) \longrightarrow \text{small}.$$

$$\sin\theta \Big|_{\theta \to \text{small}} = \theta.$$

So $$\sin \phi_e(t) \Big|_{\phi_e \to \text{small}} = \phi_e(t).$$

So, $$e(t) = k_m A \cdot A_v \{ \phi_e(t) \}$$

$$\boxed{e(t) \propto \phi_e(t)}$$

$$\boxed{\int_{-\infty}^{\infty} e(\tau)\, h(t-\tau)\, d\tau = v(t)}$$

→ from block diag

On passing through loop filter

$$V(t) = \int_{-\infty}^{\infty} \left(K_m A A_v \phi_e(\tau)\right) \cdot h(t-\tau)\, d\tau$$

$$\phi e(t) = \phi_1(t) - \phi_2(t)$$

$$\phi_e(t) = \phi_1(t) - 2\pi K_v \int_0^t v(t)\, dt$$

$$\phi_e(t) = \phi_1(t) - 2\pi K_v \int_0^t \int_{-\infty}^{\infty} K_m A A_v \phi_e(\tau)\, h(t-\tau)\, d\tau\, dt$$

Now we are differentiating

$$\frac{d\phi_e(t)}{dt} = \frac{d\phi_1(t)}{dt} - 2\pi K_v \int_{-\infty}^{\infty} K_m A \cdot A_v \phi_e(\tau)\, h(t-\tau)\, d\tau$$

$$\frac{d\phi_e(t)}{dt} = \frac{d\phi_1(t)}{dt} - 2\pi K_v K_m A \cdot A_v \int_{-\infty}^{\infty} \phi_e(\tau)\, h(t-\tau)\, d\tau$$

Taking fourier transform:-

$$j2\pi f\, \phi_e(f) = j2\pi f\, \phi_1(f) - 2\pi K_v A A_v K_m \left[\phi_e(t) * h(t)\right]$$

$$= j2\pi f\,\Phi_e(f) = j2\pi f\,\Phi_1(f) - \underbrace{2\pi K_v K_m A \cdot A_v}_{2\pi K_0}\left[\Phi_e(f)\cdot H(f)\right]$$

$$= j2\pi f\,\Phi_e(f) + 2\pi K_0\,\Phi_e(f)\,H(f) = j2\pi f\,\Phi_1(f)$$

$$\Rightarrow \Phi_e(f) = \frac{j2\pi f\,\Phi_1(f)}{j2\pi f + 2\pi K_0 H(f)}$$

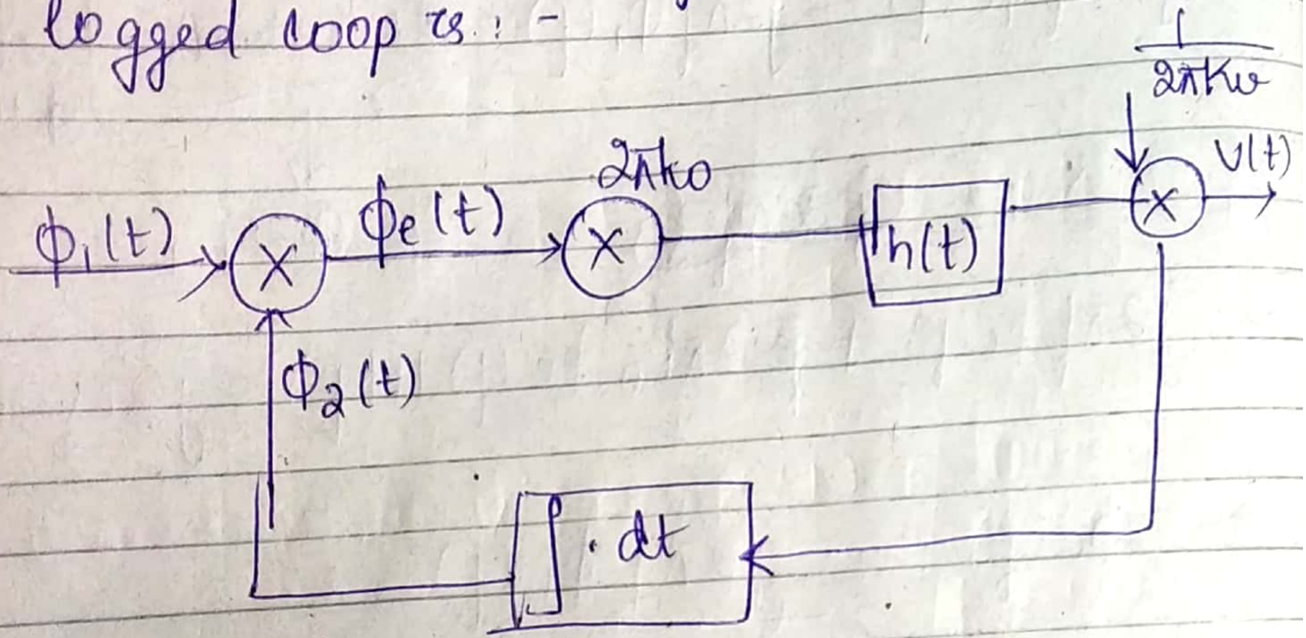
$$= \frac{jf\,\Phi_1(f)}{jf + K_0 H(f)} = \boxed{\frac{\Phi_1(f)}{1 + \frac{K_0}{jf}H(f)}}$$

$$\frac{K_0}{jf} H(f) = L(f)$$

$$\boxed{\Phi_e(f) = \frac{\Phi_1(f)}{1 + L(f)}}$$

When $L(f) >>> 1$ then $\Phi_e(f) \to 0$

Now our block diagram of phased logged loop is :-



$$v(t) = 2\pi k_o \left[\phi_e(t) * h(t) \right] \cdot \frac{1}{2\pi K_v}$$

$$v(f) = \frac{k_o}{K_v} \left[\phi_e(f) \cdot H(f) \right]$$

$$V(f) = \frac{k_o}{k_v} \left[\frac{\phi_1(f)}{1+L(f)} \cdot H(f) \right]$$

$$L(f) = \frac{k_o}{jf} \cdot H(f)$$

$$H(f) = \frac{L(f) \cdot jf}{k_o}$$

$$V(f) = \frac{\cancel{k_0}}{K_v}\left[\frac{\phi_1(f)}{1+L(f)} \cdot \frac{L(f)\, jf}{\cancel{k_0}}\right]$$

$$= \frac{1}{K_v}\left(\frac{1}{1+\frac{1}{L_f}}\right)\left(\phi_1(f)\, jf\right)$$

$$L_f >> 1 \qquad \frac{1}{L_f} = 0$$

$$V(f) = \frac{1}{2\pi K_v}\, j2\pi f\, \phi_1(f)$$

$$V(t) = \frac{1}{2\pi k_v}\frac{d}{dt}\left[\phi_1(t)\right]$$

$$V(t) = \frac{1}{2\pi K_v}\frac{d}{dt}\left[2\pi k_f \int x(t)\, dt\right]$$

$$= \frac{1}{2\pi K_v}\left(2\pi k_f\, x(t)\right)$$

$$= \frac{K_f}{K_v}\, x(t)$$

$$\boxed{V(t) = \frac{K_f}{K_v}\, x(t)}$$

Pass it through the amplifier with gain $\frac{K_v}{K_f}$.

Now, $v(t) = \frac{\cancel{K_f}}{\cancel{K_p}} \cdot \frac{K_v}{\cancel{K_f}} (x_p(t))$

$\boxed{\text{Now } v(t) = x(t)}$ Our message is recovered now.

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Tutorial

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

K_p = phase modulation.

In this modulation, one of the parameter of carrier which is phase will be linearly varied in accordance with the message signal.

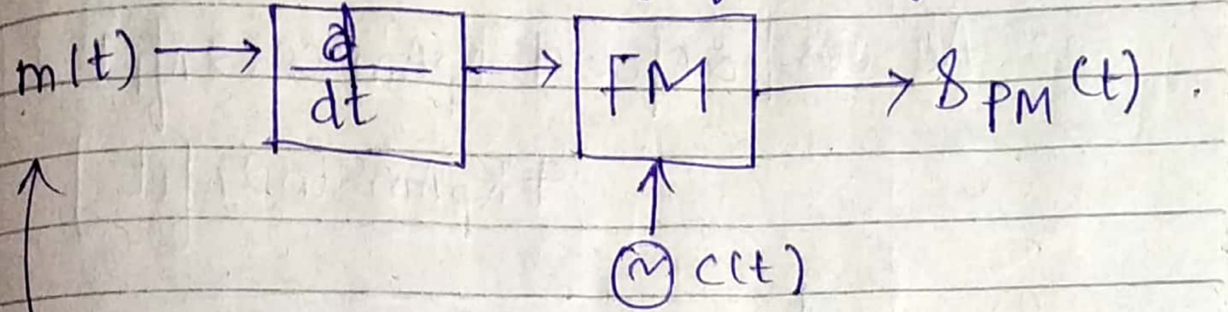
$$S_{pm}(t) = A_c \cos\left[2\pi f_c t + K_p A_m \cos 2\pi f_m t\right]$$

$$K_p A_m = \Delta\phi = \beta$$

phase deviation

$$s_{FM}(t) = A_c \cos\left[2\pi f_c + 2\pi k_f \int_0^t m(t)\,dt\right]$$

Phase modulation using frequency modulation



Generation of PM from FM

Envelope of cos and sin (max. amplitude).

Suppose, $x(t) = A\cos 2\pi f_1 t + B\cos 2\pi f_2 t$.

Max amplitude $= A + B$. {In cos frequency can be different} (Here instead of cos we can have sin also)

$x(t) = A\sin 2\pi f_0 t + B\cos 2\pi f_0 t$.

max amplitude $= \sqrt{A^2 + B^2}$ {In sine and cos frequency should be same}

Q An angle modulated signal is given by :-

$$s(t) = A_c\left[\cos\{2\times10^6 t + 30\sin 150t + 40\cos 150t\}\right].$$

Calculate the max $\Delta\phi$ of $s(t)$.

$$= A_c \cos[2\pi f_c t + K_p A_m \cos 2\pi f_1 t + K_p A_m \sin 2\pi f_1 t].$$

$$\max \Delta\phi = \sqrt{(30)^2 + (40)^2}$$

max $K_p A_m$.

$$= \sqrt{900 + 1600}$$

$$= \sqrt{2500} = 50 \rightarrow \underline{\underline{Ans}}$$

$\Delta\phi$ in radian $= 2\pi f$.

$$= 2\pi \cdot (50)$$

$$= 100\pi \longrightarrow \underline{\underline{Ans}}$$

$\underline{\underline{Q}}$ A modulated signal is given by

$s(t) = m_1(t) \cdot \cos 2\pi f_c t + m_2(t) \sin 2\pi f_c t$

BW $m_1(t) = 10$ KHz

BW $m_2(t) = 15$ KHz.

Find the bandwidth of the modulated signal

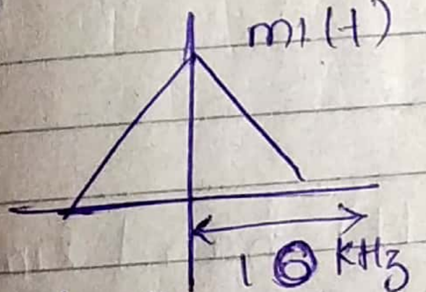
Sol: ~~Band~~ If $\overset{BW}{m_1(t)} > \overset{BW}{m_2(t)}$

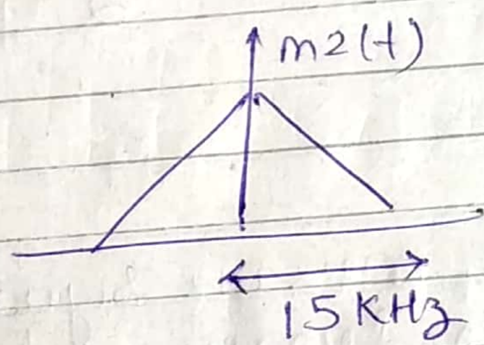
then $BW\,s(t) = 2 \cdot m_1(t)$

else $2 \cdot m_2(t)$

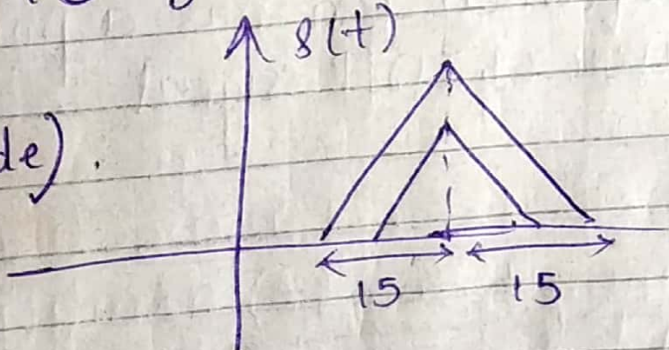
$BW\,s(t) = 15\,KHz \times 2$

$= 30\,KHz \rightarrow$ Ans





(Bandwidth is always the +ve side).



Now bandwidth $= 15 + 15$

$= 30\,KHz$

Q Consider an angle modulated signal

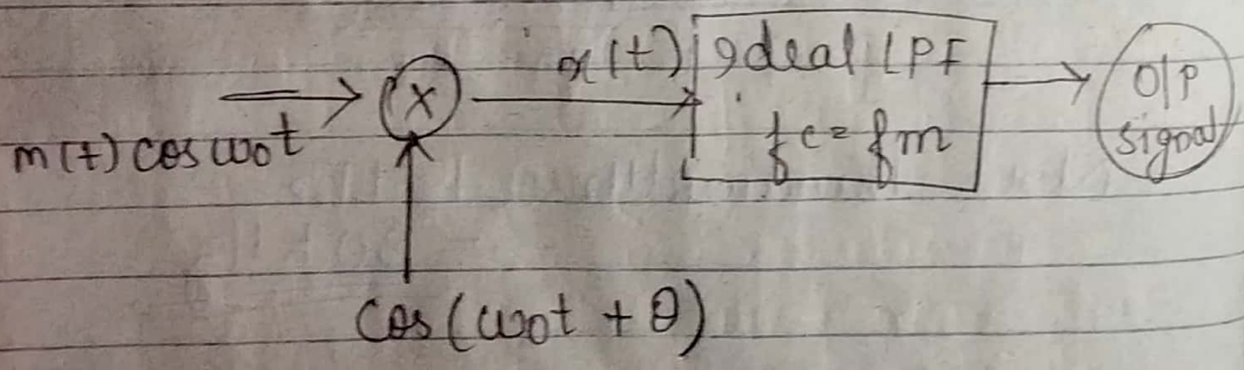
$$x(t) = 6\cos\left[2\pi 10^6 t + 2\sin(8000\pi t) + 4\cos(8000\pi t)\right]$$

Average power of signal.

$$\text{Power} = \frac{(6)^2}{2} = \frac{36}{2} = \underline{18\,W}$$

$\hookrightarrow$ **Ans**

Q A message signal m(t) band limited to frequency fm has a power Pm. The power of O/P signal ??



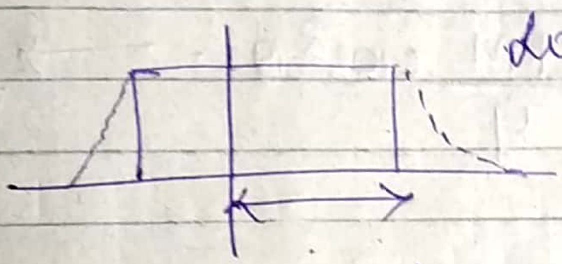
$x(t) = m(t)\cos w_0 t \cos(w_0 t + \theta)$

$\Rightarrow x(t) = \frac{m(t)}{2}\left[\cos(2\omega_0 t+\theta) + \cos(\theta)\right]$

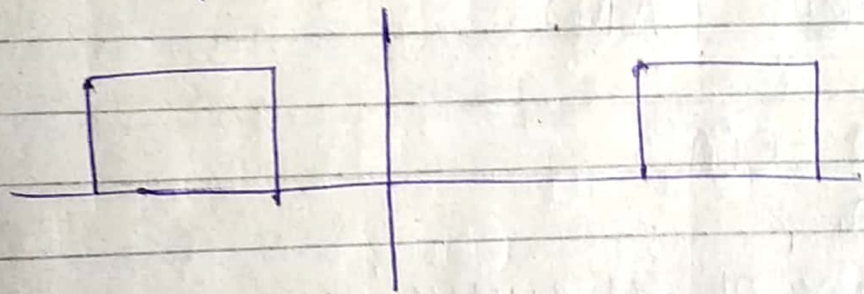
$\Rightarrow$ On passing through Ideal LPF.

$$\boxed{x(t) = \frac{m(t)}{2}\left[\cos\theta\right]}$$

Low pass filter.



Band pass filter.



$$\text{Power} = \frac{\left(\frac{Am}{2}\right)^2}{2} = \frac{PM}{4}.$$

$\rightarrow$ Low pass filter only passes lower frequency

$x(t) = \frac{m(t)}{2}\left[\cos(2\omega_0 t+\theta) + \cos(\theta)\right]$

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

After passing through LPF.

$$x(t) = \frac{m(t)}{2} \cos\theta$$

$$\text{Power} = P_M \left(\frac{\cos\theta}{2} \right)^2$$

$$= \frac{P_M}{4} \cos^2\theta \longrightarrow \text{Ans}$$

28/8/18

Receivers (AM).

Functions of receivers :-

① To collect the EM wave transmitted by transmitter. (receiving antennae).
② To select the desired signal and reject all others. (~~Receiver~~ & This is known as receiver selectivity
③ To amplify the selected modulated signal, it is known as sensitivity of the receiver.
Step ④. To detect the baseband signal from

the modulated radio frequency signal.

(5) To amplify the baseband signal so as to operate loud speaker.

AM **Range** — 540 to 1650 KHz.

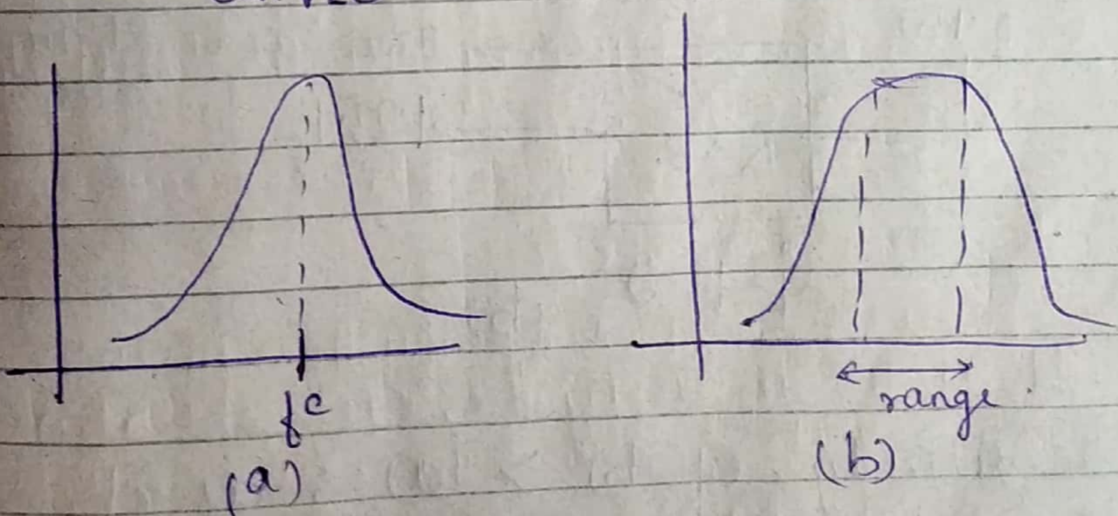
Bandwidth = 10 KHz.

If BW < 10 KHz → distortion.
BW > 10 KHz → cross talk.

Selectivity

* For an L-C circuit, the cutoff frequency fc

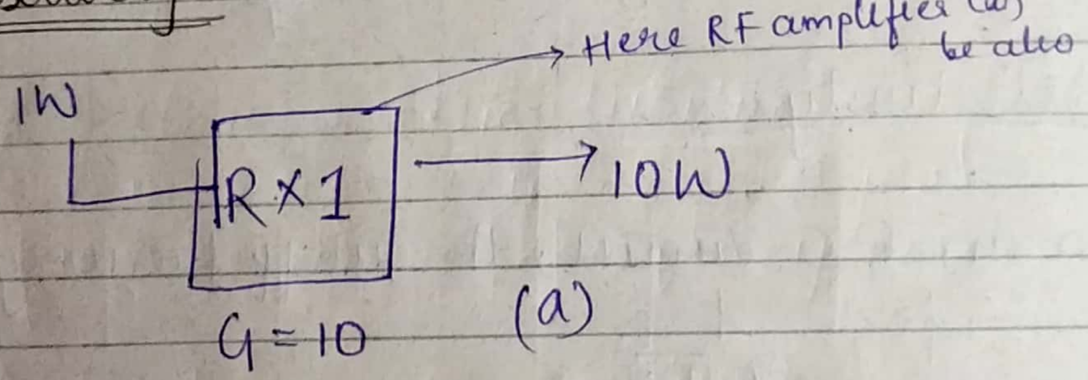
$$f_c = \frac{1}{2\pi\sqrt{LC}}.$$

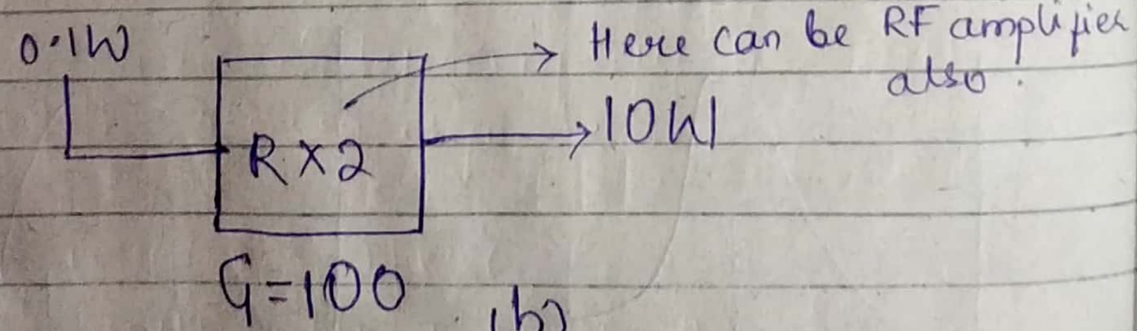


Selectivity of (a) > (b); because it is giving a particular value of frequency and it is giving a range of value of frequency

→ It depends upon the tuning of RF amplifier, it specify the ability of receiver to allow only desired frequency component and rejecting all possible undesired frequency component.
It mainly depends on the characteristic of tuned amplifier.

Sensitivity





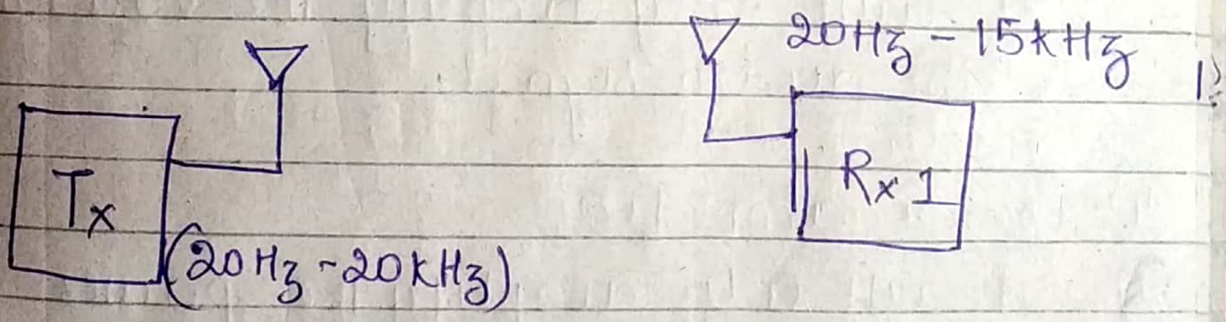
Sensitivity of (b) > (a) ; as it gives the same output for only 0.1 W.

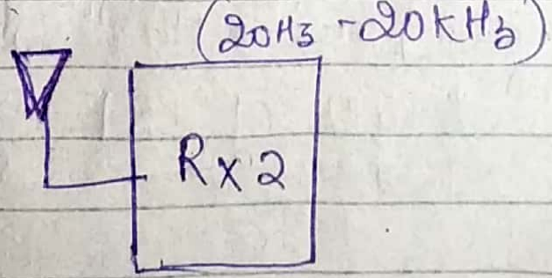
→ It specify the minimum possible strength of receiver input to be maintained to produce corresponding output.

Fidelity

→ Suppose there are 2 receivers which receive 20Hz to 15kHz (1) and 2nd receiver receive 20Hz to 20kHz. And we have send 20Hz to 20kHz; so receiver (2) has more fidelity than (1)

→ It specify the ability of receiver to produce all the frequency compon-ent of transmitted signal.





The receiver should accept all the frequency component send by Tx. It will have more fidelity.
So here Rx 2 have more fidelity.

Two types of AM receiver :

① TRF (Tuned radio frequency receiver)
② SHDR (super hetrodyne receiver)

ⓐ TRF :

① 1st stage is RF stage :- If we have to tune the receiver that it only take the desired frequency and reject other.

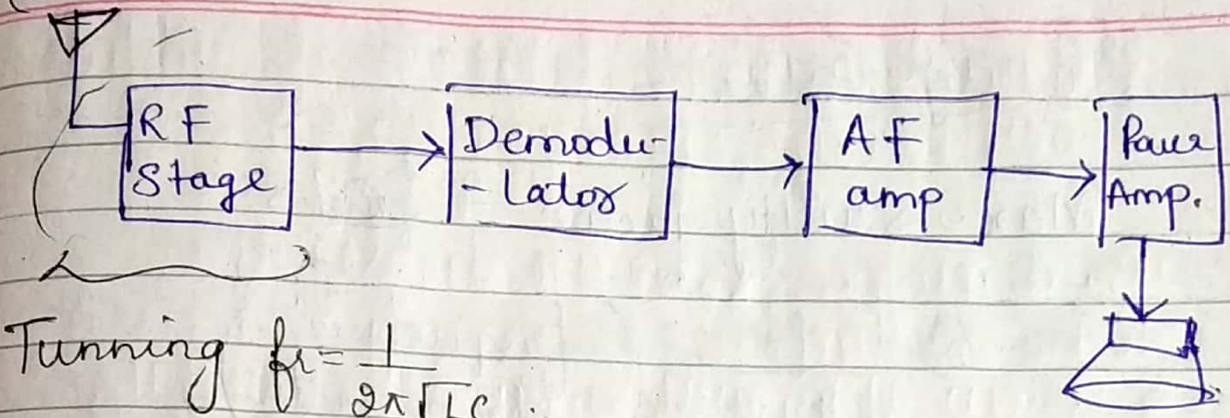
② 2nd stage is demodulator :- It will recover message signal from the desired frequency range.

③ stg Audio frequency amplifier : It will only amplify the voltage of the audio signal.

④ stg Power amplifier :
It will only amplify the power.
It will amplify the current also along with voltage so in turn power will be amplified (P=VI)

Stages of TRF :

(540-1650KHz)



Tunning $f_r = \frac{1}{2\pi\sqrt{LC}}$.

* RF → out of 540-1650kHz RF will tune the circuit and get frequency of desired range from that range.

→ RF Stage selects the desired signal and amplify it.

→ Amplified incoming signal is then applied to demodulator which demodulates the modulated signal.

→ Audio amplifier amplifies the audio signal (voltage).

→ Power amplifier :- amplifies the voltage & current i.e, power amplify.

→ Speaker :- act as a transducer and changes the electrical signal to sound signal.

/8/18

Quality factor:-

Max. Quality factor = ~~freq~~ 85

$Q = \frac{f}{BW}$ $\left(\frac{\text{frequency}}{\text{bandwidth}}\right)$.

$= \frac{545 \text{ KHz}}{10 \text{ KHz}}$

$\boxed{Q = 54.5}$ min.

$Q = \frac{1645}{10}$

$\boxed{Q = 164.5}$ max.

Quality factor can't be 164.5 but ~~it can't be 85~~. max is 85.

given $Q = 100$
$f = 1645$

$BW = \frac{1645}{100} = \boxed{16.45}$.

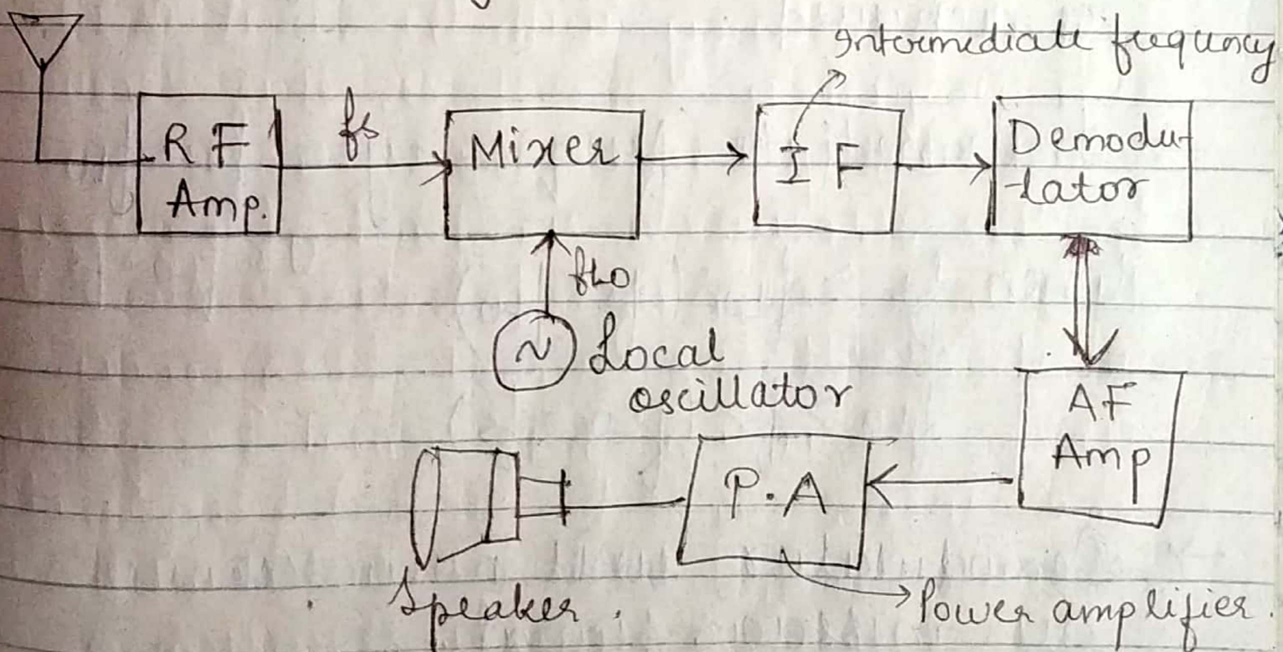
Now BW > 10KHz so there will be cross talk (in AM range)

Scanned by CamScanner

* Quality factor should be less than 85 so thus the drawback.

→ In TRF receiver value of Q varies between 54.5 to 164.5 but practical limitation of Q that is maximum possible value of Q is 85.
Resulting poor channel selectivity so the TRF receiver is suffering from the problem of adjacent channel interference / cross talk.

Super heterodyne receiver



We can tell super heterodyne as mixing because it is mixing fs and fLO.

→ The difference between f_s and f_{LO} should be 455 KHz (intermediate frequency), so we change f_{LO} accordingly.

→ Now IF will only let 455 KHz frequency to pass through it and reject all other frequency

→ So now always our Quality factor $= \frac{455}{10} = 45.5$ (< 85)

So our desired quality factor is achieved.

→ Intermediate frequency $= f_s - f_{LO}$ or $f_{LO} - f_s$.

When $f_s > f_{LO} = (f_s - f_{LO})$

$f_{LO} > f_s = (f_{LO} - f_s)$

→ Demodulator will now recover our message signal.

→ AF amplifier will amplify our voltage.

→ Power amplifier will amplify our current and voltage.

Eg: ① ✓ ② (x) ③ ✓

	①	②	③
f_s =	600KHz	1000KHz	1510KHz
f_{LO} (variable)	1055KHz	1055KHz	1055KHz
$f_{if} = f_L - f_s$	455KHz	55KHz	455KHz
Q	45.5	55.0	45.5

Now if we only want 600KHz but ③ is also same as ①. So it should only pass 600KHz (as it is our desired frequency) but it will pass 1510KHz also.

So, if there is a case like this then it says it is an <u>image frequency</u>.

Image frequency $(f_{si}) = f_s + 2f_{If}$

$= 600 + 2 \times 455$

$= 1510\,KHz$

So it tells us that it is the image frequency of 600kHz.

So ~~see~~ the IF will reject the ~~increase~~ image frequency and will pass the original frequency.

Teacher note

→ All the drawbacks in TRF receiver have been removed in superheterodyne receiver.

Heterodyne stands for mixing.

Here we have mixed the incoming signal frequency with the local oscill-ator frequency. Therefore, this receiver is called super heterodyne receiver.

→ In this receiver a constant frequency difference is maintained between the local oscillator signal frequency and incoming RF signal frequency.

→ The incoming RF signal frequency is combined with the local oscilla-tor signal frequency through a mixer and is converted into signal of lower fixed frequency. This lower fixed frequency is known as intermediate frequency

$$f_{IL} = f_s - f_L \quad (f_s > f_L)$$
$$\text{or } f_L - f_s \quad (f_L > f_s).$$

→ The intermediate frequency signal contains the same modulation as the original signal. This intermediate frequency signal is now amplified & demodulated to reproduce the original signal.
This audio signal is amplified by an audio amplifier to get a particular voltage level.
This amplified signal is further amplified by a power amplifier to get specified power level so that it may activate the loudspeaker.
Loudspeaker is a transducer which converts this audio electrical signal into audio sound signal.