(~~AM~~).

Non-linear modulation / Angle modulation

(1) Freq modulation

(2) Phase modulation

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

radians

radians

$2\cancel{\pi f_c(t)}$ $2\pi f_c t + \phi(t) = \theta(t)$

$c(t) = A_c \cos(\theta(t))$

In Angle modulation, this changes in accordance to message signal.

Angle modulation

↳ angle of carrier changes in accordance to message signal $m(t)$

when we change freq. of angle part
⇒ frequency modulation

if we change phase (ϕ) ~~with~~
⇒ angle modulation

II- dependence of f_c is on $m(t)$, then it is called FM (frequency modulation)

PM (Phase modulation)

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

$$\boxed{\phi = k_p m(t)}$$

↳ phase sensitivity constant

* ϕ changes in accordance to $m(t)$

$$\boxed{S_{pm}(t) = A_c \cos(2\pi F_c t + k_p m(t))}$$

general expression

↳ if $m(t) = 0$, $\phi = 0 = k_p m(t)$,
no modulation,
$S_{pm}(t) = A_c \cos(2\pi f_c t)$
(modulated signal = carrier signal)

FREQUENCY MODULATION

$f_c \Rightarrow$ freq. of carrier before modulation.

$F_i \Rightarrow$ freq. of carrier after modulation

$$\boxed{f_i = f_c + K_F\, m(t)}$$

"Frequency sensitivity constant"

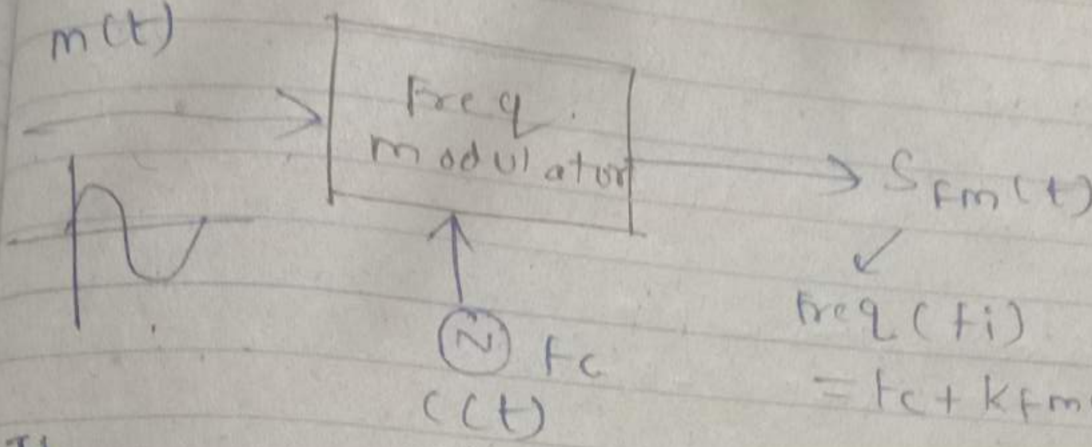
$$\boxed{\text{Unit of } K_F = \text{HZ/volts}}$$

If $m(t) = 0$, $f_i = f_c$, "NO MODULATION"

If $K_F = 25\,\text{kHz/V}$

↳ For 1 V of change in m(t), frequency changes by 25 kHz in carrier signal

→ It specifies the amount of freq. change in carrier for 1V of change in message signal.



If,

$m(t)$, $f_i = f_c$

$\boxed{k = 25\,kHz}$

$m(t) = 5v$, $f_i = f_c + 125K$ freq. of carrier increases

If $m(t) = \cancel{5}\ -5$,

$f_i = f_c - 125.K$ freq. of carrier decreases

i) $m(t) = 0$, $f_i = f_c$

ii) $m(t) > 0$, $f_i > f_c$

iii) $m(t) < 0$, $f_i < f_c$

FM is also called "voltage to frequency conversion"

" since change in m(t) in V changes freq. of carrier signal"

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

$f_i = f_c + K_f m(t)$

max. amp $= A_m$
min. amp $= -A_m$

Max. freq of FM signal

$$\boxed{f_{i_{max}} = f_c + K_f A_m}$$

min. freq of FM signal

$$\boxed{f_{i_{min}} = f_c + K_f(-A_m)}$$

MAX. FREQ DEVIATION IN FM

"f_c" => carrier frequency.

$$\boxed{\Delta f = K_f A_m}$$

TOTAL FREQ. SWING OF FM SIGNAL

$$f_c - K_f A_m \longleftarrow f_c \longrightarrow f_c + K_f A_m$$

$$\boxed{\text{Total freq. swing} = 2 K_f A_m}$$

Q1) A sinusoidal carrier of 20V amplitude and 2 MHZ of frequency is FM by msg. signal of ~~[illegible]~~ $10\sin(4\pi \times 10^3 t)$

$K_f = 50\,KHZ/volt$.

Find ΔF, f_{max}, ~~[illegible]~~ f_{min} ?

Soln:

~~M~~S

$$\Delta F = K_f A_m = 50\,KHZ/V \times 10\,V$$

$$= 500\,KHZ$$

$$f_{max} = f_c + \cancel{\Delta f}\, K_f (A_m)$$

$$= 2\,MHZ + 50\,KHZ/\cancel{V} \times 10\,\cancel{V}$$

$$= 2\,MHZ + \cancel{50\,KHZ}\ 500\,KHZ$$

$$2500\,KHZ$$

$$= 2000 + 500 = \cancel{2050\,KHZ}$$

$$f_{min} = 2\,MHZ - 50 \times 10\,KHZ$$

$$= 2\,MHZ - 500\,KHZ$$

$$= 2000\,KHZ - 500\,KHZ$$

$$= 1500\,KHZ$$

SS

$A_c = 20\,V$

$f_c = 2\,MHz$

$m(t) = 10 \sin(4\pi \times 10^3 t)$

$A_m = 10$

$f_m = 2 \times 10^3\,Hz$

$K_f = 50\,kHz/V$

$f_{max} = f_c + K_f A_m$

$= 2000 + 50 \times 10$

$= 2500\,kHz$

$f_{min} = f_c - K_f A_m$

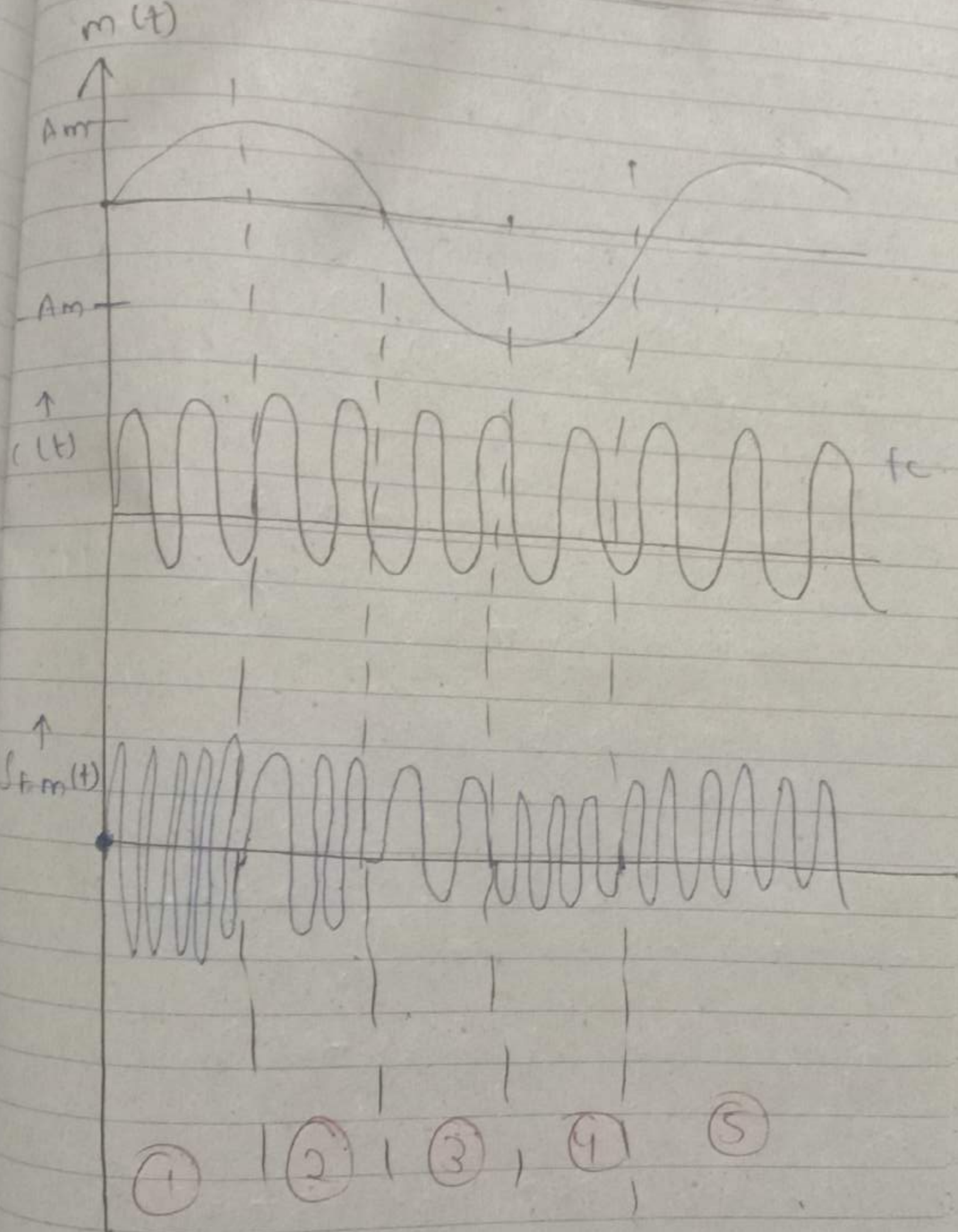
$= 2000 - 50 \times 10$

$= 1500\,kHz$

$\Delta F = k_f A_m$

$= 500\,kHz$

GRAPHICAL ANALYSIS OF FM



(1) → m(t) Amp. ↑, Freq ↑

(2) → m(t) Amp. ↓, Freq ↓

(3) → m(t) Amp. ↓, Freq ↓

(4) → m(t) Amp ↑, Freq ↑.

GENERAL EXPRESSION OF FM SIGNAL

$m(t)$ = message signal

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

$$\left(\omega = \frac{d\theta}{dt}, \quad \theta = \int \omega \, dt \right)$$

angular freq, angle

f_i = modulated signal freq.

$$f_i = f_c + k_f m(t) \quad \text{— (1)}$$

$$\theta(t) = \underbrace{\theta_c}_{2\pi f_c t} + \phi$$

multiplying 2π on (1), both sides

$$2\pi f_i = 2\pi (f_c + k_f m(t))$$

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

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

$$\theta_i(t) = \theta_c(t) + 2\pi K_f \int m(t)\,dt$$

$$s(t) = A_c \cos(\theta_i(t))$$

$$\boxed{s_{FM}(t) = A_c \cos\left(2\pi f_c t + 2\pi K_f \int m(t)\,dt\right)}$$

SINGLETONE FM

(single freq. component in m(t))

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

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

$$s_{FM}(t) = A_c \cos\left(2\pi f_c t + 2\pi K_f \int A_m \cos(2\pi f_m t)\,dt\right)$$

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

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

MODULATION INDEX OF FM SIGNAL (β)

$$\boxed{\frac{K_f A_m}{f_m} = \beta = \frac{\Delta F}{f_m}}$$

$$\boxed{S_{Fm}(t) = A_c \cos(2\pi f_c t + \beta \sin(2\pi f_m t))}$$

$\boxed{\beta : \text{modulation index}}$

Fm

- narrow band Fm $(\beta \leq 1)$
- wide band Fm $(\beta > 1)$

NARROW BAND FM (NBFM)

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

$\beta << 1$ (Narrow band)

$$= \cancel{A_c \cos(2}$$

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

~~θ very small~~

~~0 since β very small~~

For small values of θ,

$$\cos\theta \approx 1$$

$$\sin\theta \approx \theta$$

$$= A_c[\cos(2\pi f_c t)\cdot 1 - \sin(2\pi f_c t)\cdot \beta \sin(2\pi f_m t)]$$

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

$S_{NBFM}(t)$]

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

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

$\updownarrow$ compare

$$S_{Am}(t) = A_c\cos(2\pi f_c t)$$

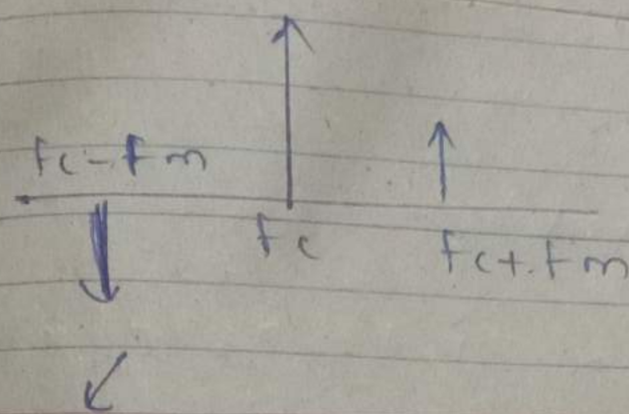
$$+ \frac{A_c\mu}{2}\cos(2\pi(f_c+f_m)t)$$

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

* NBFm many ~~[illegible]~~ similarities to Am

* ~~[illegible]~~ lower band of NBFm is inverted in respect to lower band of Am

SPECTRUM OF NBFM



* $\boxed{BW = f_c + f_m - f_c + f_m = 2f_m}$

* $\boxed{P_{NBFM} = P_c\left[1 + \beta^2/2\right]}$

* NBFM is not a significantly used version of FM since BW & power requirements same as AM. (Not getting much improvement).

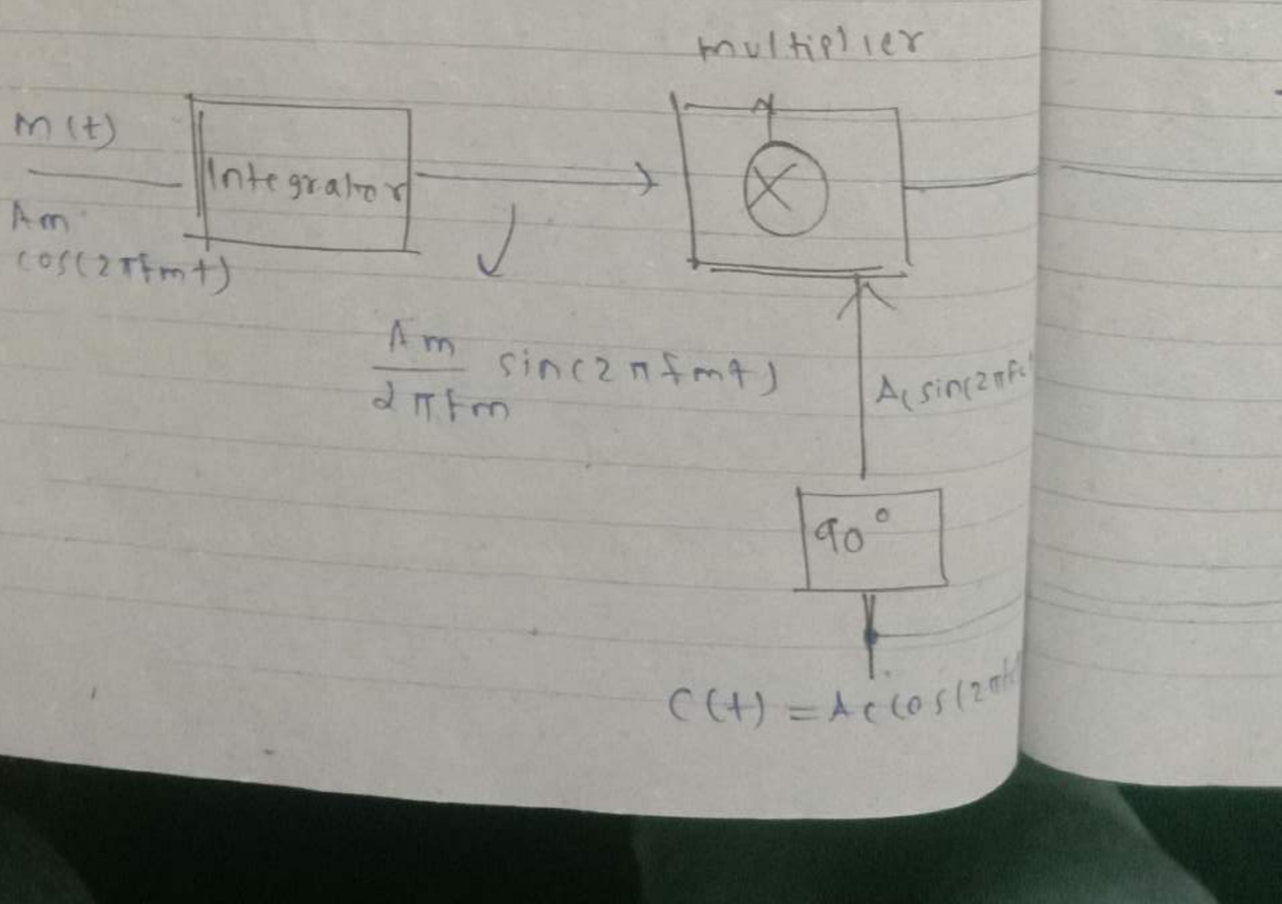
GENERATION OF NBFM Signal

$$S_{NBFM}(t)$$

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

$$= A_c \cos(2\pi f_c t) - \frac{A_c k_f A_m}{f_m} \sin(2\pi f_c t) \sin(2\pi f_m t)$$

CIRCUIT



GENERATION OF NBFM signal

$S_{NBFm}(t)$

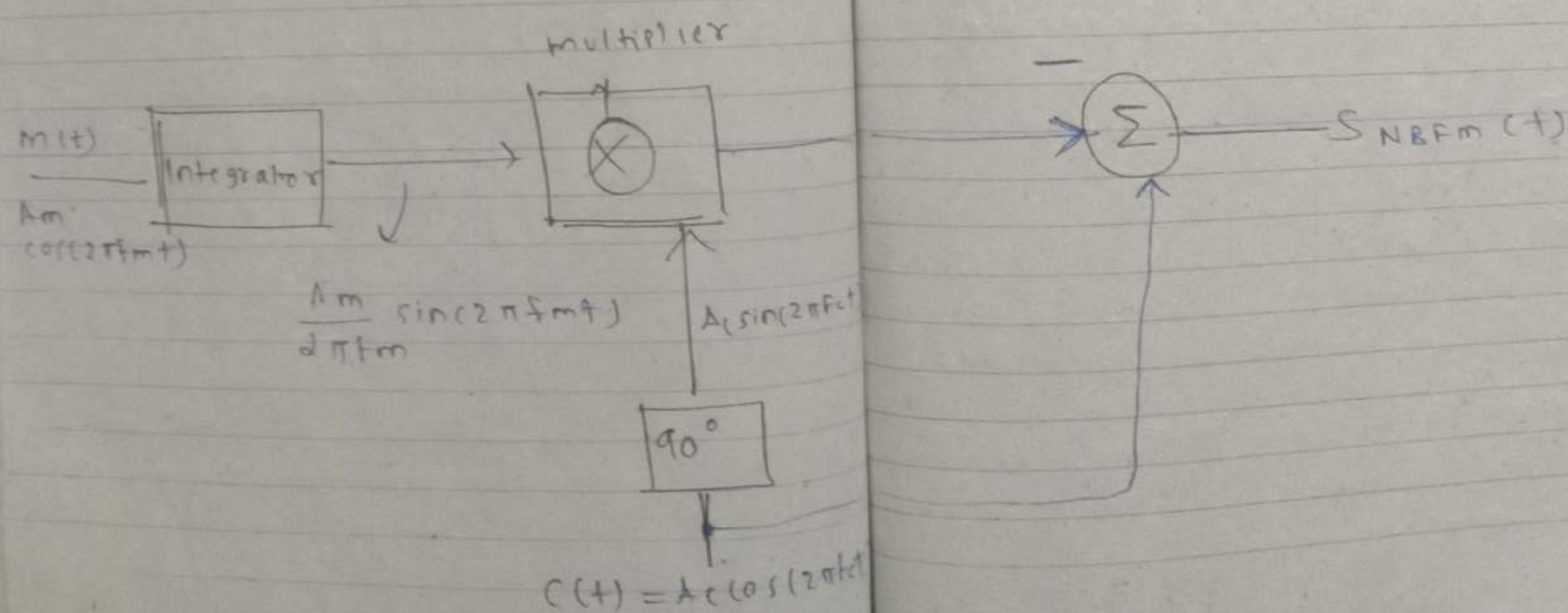
$= A_c \cos(2\pi f_c t)$

$- A_c \beta \sin(2\pi f_c t) \sin(2\pi f_m t)$

$= A_c \cos(2\pi F_c t)$

$- \frac{A_c k_f A_m}{f_m} \sin(2\pi f_c t) \sin(2\pi f_m t)$

CIRCUIT



POC-Lec 2 (After mid.)

RECAP

$f_i = f_c + k_f m(t)$

↳ freq. sensitivity constant

$= Hz/V$

$S_{FM}(t) = \cancel{A_c \cos(2\pi f_c t}$

$= A_c \cos(2\pi f_c t + 2\pi k_f \int m(t)\, dt)$

Single tone

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

β = mod. index

NBFM ($\beta \le 1$)

WBFM ($\beta > 1$)

$\beta = \frac{\Delta f}{f_m}$ → freq. deviation

$= \frac{k_f A_m}{f_m}$

NBFM $\leftrightarrow$ AM
similar

but $\hookrightarrow$ lower side band inverted !!

WIDE BAND FM

$$\beta > 1$$

BESSEL FUNCTION

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

n = order of Bessel.

θ = dummy variable

PROPERTIES:

(1) $J_n(x) \downarrow,\ n \uparrow$

$$J_0(x) > J_1(x) > - - - -$$

(2) $$\sum_{n \to -\infty}^{\infty} J_n^2(x) = 1$$

summation of square of coefficients

(3) Bessel function always a real quantity

GENERAL EXPRESSION OF WBFM

$$s_{FM}(t) = A_c \cos[2\pi f_c t + \beta \sin(2\pi f_m t)]$$

$$\cos\theta = Re[e^{j\theta}]$$

$$s_{FM}(t) = A_c \, Re[e^{j(2\pi f_c t + \beta \sin(2\pi f_m t))}]$$

$$= A_c \, Re[e^{j2\pi f_c t} \cdot \underbrace{e^{j\beta \sin(2\pi f_m t)}}]$$

continuous periodic signal (we find Fourier series of this component)

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

(1) ∞ terms

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

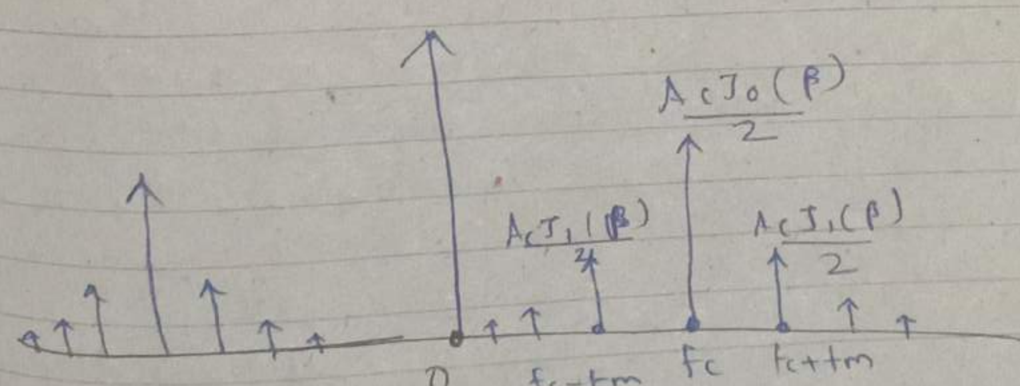
$+ A_c J_1(\beta)\cos(2\pi(f_c+f_m)t)$

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

$+ A_c J_2(\beta)\cos(2\pi(f_c+2f_m)t)$

$+ - - -$

SPECTRUM OF WBFM



* WBFM consists of carrier component & ∞ no. of side bands

* Actual BW of wideband FM is ∞

* For WBFM, lower order sideband are significant sidebands and higher order sidebands not significant

POWER OF WBFM

$$P_t = P_c + (P_{USB_1} + P_{USB_2} - - \infty) + (P_{LSB_1} + P_{LSB_2} - - \infty)$$

$$P_c = \frac{A_c^2 J_0^2(\beta)}{2} \qquad P_{LSB_1} = \frac{A_c^2 J_{-1}^2(\beta)}{2}$$

$$P_{USB_1} = \frac{A_c^2 J_1^2(\beta)}{2} \qquad P_{LSB_2} = \frac{A_c^2 J_{-2}^2(\beta)}{2}$$

$$P_{USB_2} = \frac{A_c^2 J_2^2(\beta)}{2}$$

$$P_t = \frac{A_c^2}{2}\left[\overbrace{\left(\cdots + J_{-2}^2(\beta) + J_{-1}^2(\beta) + J_0^2(\beta) + J_1^2(\beta) + J_2^2(\beta) \cdots\right)}^{=1 \text{ (according to prop. of Bessel function)}}\right]$$

$$\boxed{P_t = \frac{A_c^2}{2} = P_c}$$

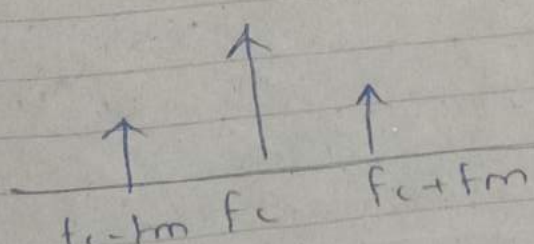
* Total Power of WBFM = power of carrier before modulation

PRACTICAL BW OF WBFM

derived using {CARSON'S RULE}

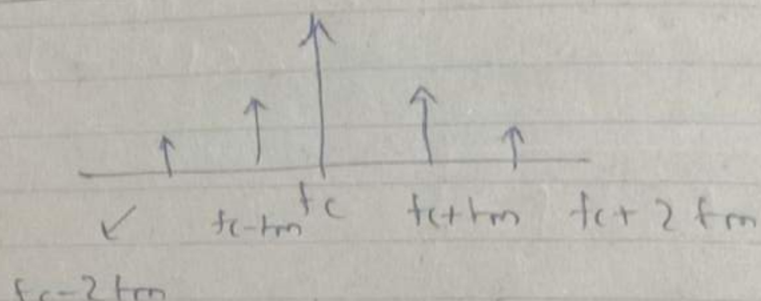
$$\boxed{BW_{WBFM} = \infty \text{ (Actual)}}$$

CASE 1: WBFM consists of significant sidebands upto 1st order



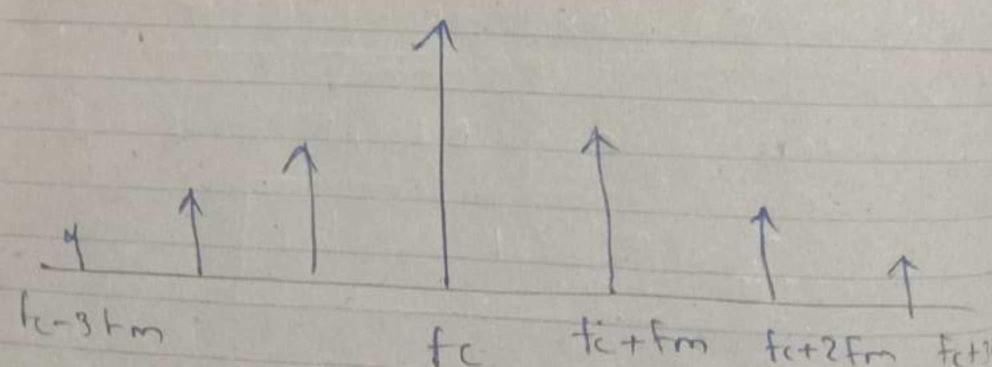
$BW = 2f_m$

CASE 2: Sidebands upto 2nd order



$$BW = 4f_m = 2 \times (2f_m)$$

CASE 3: Sidebands upto 3rd order



$$BW = 6f_m = 3 \times (2f_m)$$

Upto nth order

$$BW = n \times (2f_m)$$

CARSON'S RULE

WBFM consists of significant sidebands upto "$(\beta+1)$" order where β = modulation index

$$\boxed{BW = (\beta+1)\cdot 2f_m}$$

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

$$\boxed{BW = 2(\Delta f + f_m)}$$

Q1) A sinusoidal carrier of 20V and 2 MHZ is frequency modulated by a sinusoidal msg. of 10V & 50KHZ,

$K_f = 25\,KHZ/V$

Part 1

(i) Find Δf

(ii) Find β

(iii) Find BW

(iv) Find Power(P)

Part 2

(v) Repeat above (i-iv) if Amp. of msg. signal is doubled.

Soln:

$A_c = 20V$ $\quad$ $A_m = 10V$

$f_c = 2MHz$ $\quad$ $f_m = 50\ kHz$

$k_f = 25\ kHz/V$

* $\beta = \frac{\Delta f}{f_m} = \frac{k_f A_m}{f_m} = \frac{25 \times 10}{50} = 5$

" $\beta \geq 1$, WBFM "

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

$= (5+1) \times 2 \times 50\ kHz$

$= 600\ kHz$

* $P_t = \frac{A_c^2}{2} = \frac{20 \times 20}{2} = 200\ W$

Part 2:

$A_m = 10 \times 2 = 20V$

$\uparrow \Delta f = k_f A_m \uparrow$

A_m = doubled, Δf doubled

$\Delta f = 250 \times 2 = 500\ kHz$

$$\beta = \frac{\Delta F}{F_m} = \frac{K_f A_m}{f_m}$$

$\beta = 10$ ($A_m = 2$ times, $\beta = 2$ times)

WBFM"

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

$$= (10+1) \times 2 \times 50 = 11 \times 100$$

$$= 1100 \text{ kHz}$$

$$P_t = P_c = \frac{A_c^2}{2} = 200 \text{ W}$$

~~NOTE~~ NOTE:

~~Amp. litude of msg signal~~

Amp. of message signal

→ changes

1. ΔF
2. BW
3. β

→ not changes

1. P_t

$$2\pi f_c t = 2\pi \times 10^6 t$$

POC lec 3 (After midsem)

Q1) $c(t) = 5\cos(2\pi \times 10^6 t)$
$m(t) = \cos(4\pi \times 10^3 t)$

a) $c(t)$ & $m(t)$ are used to generate AM with $\mu = 0.707$ find bandwidth & power?

b) $c(t)$ & $m(t)$ are used to generate FM with max. freq deviation as 3 times the BW of AM. Find coefficient of $\cos(2\pi \times (1016 \times 10^3))t$ in FM expression?

Soln: MS

$A_c = 5$, $f_c = 10^6$ Hz
$A_m = 1$ $f_m = 2 \times 10^3$ Hz

a) $\mu = 0.707$
$BW = 2f_m = 4 \times 10^3$ Hz
$= 4$ kHz

$P = \frac{A_c^2}{2}\left(1 + \frac{\mu^2}{2}\right)$
$= \frac{5 \times 5}{2}\left(1 + \frac{0.707^2}{2}\right) = 15.62$

b) Δf
$= \Delta f$
$\beta =$
$\beta > 1$
$f_c +$
$10^3 \times$
coeff
$J_n(\beta)$

b) $\Delta f = 3 \cdot BW_{Am}$

$= \Delta f = 3 \times 4\,kHz = 12\,kHz$

$\beta = \frac{\Delta f}{f_m} = \frac{12 \cancel{\times 000}\,kHz}{2\,kHz}$

$= 6$

$\beta > 1$, WBFM

$f_c + n f_m = 1016 \times 10^3$

$10^3 \times 1\cancel{0^3} + n \times 2 \times 1\cancel{0^3} = 1016 \times 1\cancel{0^3}$

$1000 + 2n = 1016$

$2n = 1016 - 1000 = 16$

$n = 8.$

$\cancel{\text{Coefficient} = A_c \times J_n(8)}$

$\cancel{J_n(8) = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{j(8\sin\theta -}}$

SS

(Ans)

a) $m(t) = \cos(4\pi \times 10^3 t)$

$A_m = 1$

$f_m = 2\,kHz$

$c(t) = 5\cos(2\pi \times 10^6 t)$

$A_c = 5$

$f_c = 1000\,kHz$

$BW = 2f_m = 2 \times 2 = 4\,kHz$

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

$$= \frac{A_c^2}{2}\left(1 + \frac{\mu^2}{2}\right)$$

$$= \frac{25}{2}\left(1 + \frac{0.707^2}{2}\right)$$

$$= \frac{25}{2}\left(1 + \frac{1}{4}\right) = \frac{125}{8}\,W$$

b) $\Delta f = 3\, BW_{AM}$

$= 3 \times 4\, kHz = 12\, kHz$

$\beta_{FM} = \frac{\Delta f}{f_m} = \frac{12\, kHz}{2\, kHz}$

$= 6$

$\beta > 1$

$\Rightarrow WBFM$

$\cos [2\pi (1016 \times 10^3) t]$

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

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

$f_c + n f_m = 1016$

$1000 + n f_m = 1016$

$n = 16/2 = 8$

order of Bessel func $= 8$

$\beta = 6$

$coeff = A_c J_8(6)$

$= 5 J_8(6)$ (Ans)

Q2) A sinusoidal carrier of freq "Fc" is used for both AM & FM transmitter. msg signal freq is given by 5kHZ. Max. freq deviation = 2×BW Am, find modulation index of both Am & Fm. such that strength of freq component fc+5k is same in both Am & Fm spectrum.

$J_1(0) = 1$

$J_1(2) = 0.57$

$J_1(4) = 0.37$

Soln:

$f_m = 5\,kHZ$

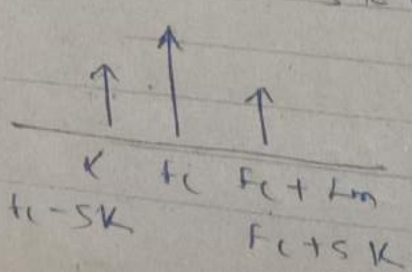
$BW_{Am} = 2 \times f_m$

$= 2 \times 5\,kHZ$

$= 10\,kHZ$ (Ans)

$\Delta f = 2 \times 10\,kHZ = 20\,kHZ$

$\beta = \frac{\Delta f}{f_m} = \frac{20\,kHZ}{5\,kHZ} = 4$ (Ans)



er of freq
AM & FM
nal freq
freq
and
th AM
of freq
in

12

(Ans)

"Strength ⇒ Power"

Power of sideband in AM $= \dfrac{A_c^2 \mu^2}{8}$

Power of SB wrt FM $= \dfrac{A_c^2}{4} J_n^2(\beta)$

$$\frac{A_c^2 \mu^2}{\cancel{8}\,2} = \frac{A_c^2}{\cancel{4}} J_n^2(\beta)$$

$$\mu^2/2 = J_n^2(\beta)$$

$n = 1$, $\beta = 4$

$$\frac{\mu^2}{2} = J_1^2(4)$$

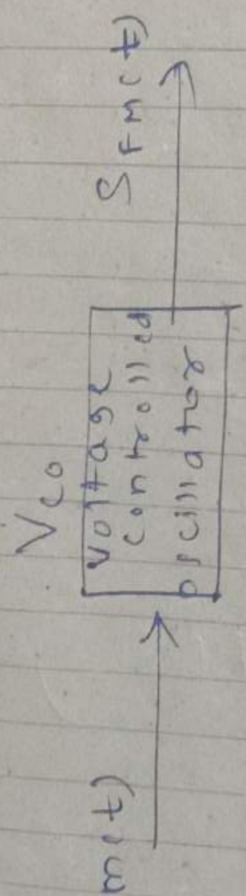
$$\mu^2 = 2 J_1^2(4)$$
$$= 2 \times (0.37)^2$$

$$\mu = \sqrt{2 \times (0.37)^2}$$
$$= 0.52 \text{ (Ans)}$$

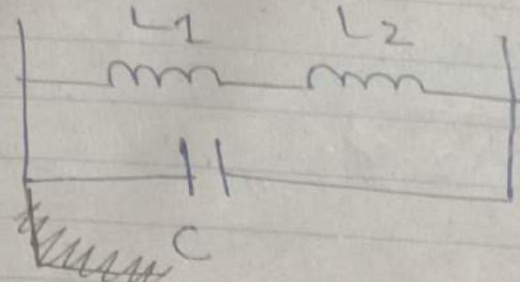
GENERATION OF ~~PM~~ FM

1. Direct method
2. Indirect method / Armstrong method

DIRECT METHOD



VCO :

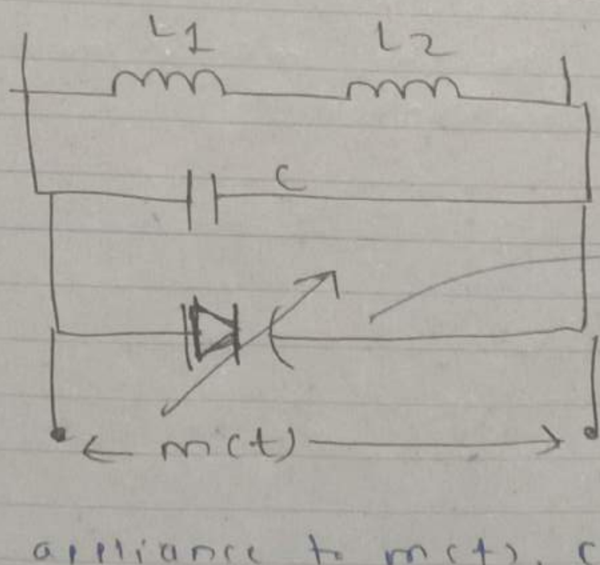


⇒ Hartlay oscillator

$$f_R = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$

↓
resonating freq.

VCO from hartlay oscillator :



→ varactor diode
(variable ~~[illegible]~~ voltage capacitor)

* In appliance to m(t), capicitance of varactor diode change

* let C' the capicitance of varactor diode

* C' changes, overall capicitance changes, f_r changes

$$f_r = \frac{1}{2\pi\sqrt{L_1 + L_2 \cdot C''}}$$

$$C'' = (C + C')$$

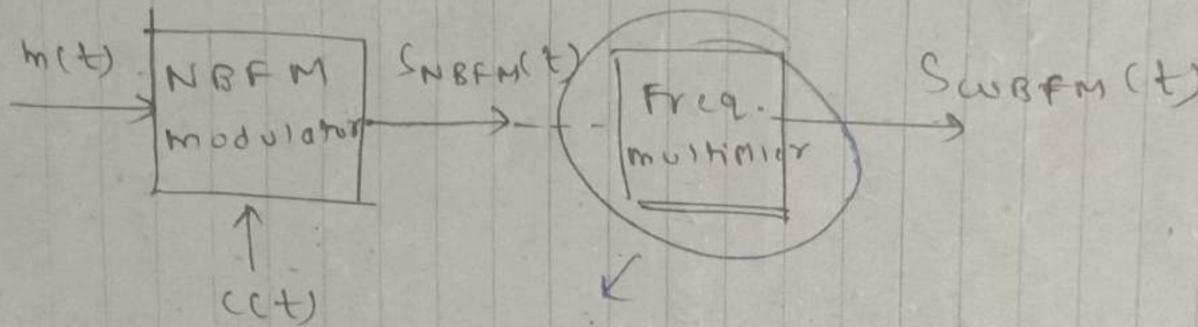
* Hence f_r varies in accordance to $m(t)$ signal.

NOTE:

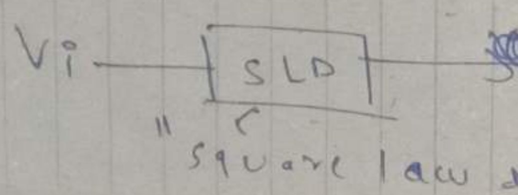
Here the freq. is varied in accordance to the msg. signal voltage variations.

INDIRECT METHOD (ARMSTRONG METHOD)

→ WBFM is generated from NBFM



It is a square law device followed by proper bandpass filter



$$v_2 = a_1 v_1 + a_2 v_2^2 + a_3 v_3^3 \dots$$

Let $a_1 = 1$

Ex)

$V_i = \cos(2\pi f_i t)$ → Squaring device → $V_o = V_i^2 = \cos^2(2\pi f_i t)$

freq = f_i $(n=2)$

multiplying by 2

$$\frac{1+\cos(4\pi f_i t)}{2}$$

$\boxed{\text{freq} = 2 f_i}$

$\cos\theta \longrightarrow$ Freq. multiplier $\longrightarrow \cos(n\theta)$

(n) = order

NOW PASSING ~~NBFM~~ NBFM :

NBFM

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

↓

Freq. multiplier

(order = n) → multiplication order

↓

$\underbrace{A_c \cos(2\pi \overset{n}{\wedge} f_c t + n\beta \sin(2\pi f_m t))}$

WBFM such that

"$n\beta > 1$".

I/P of freq. multiplier	O/P of freq. multiplier
f_c	nf_c
β	$n\beta$
f_m	f_m (No change in message signal frequency)
$\Delta f = \beta f_m$	$n\Delta F$

Q3) An FM is given as

$$s(t) = 10\cos(2\pi \times 10^6 t + 0.2\sin(2\pi \times 2 \times 10^3 t$$

It is passed through cascaded freq. multipliers having multiplication order as 4 & 5 respectively. Find all parameters of FM signal at the o/p of each multiplier?

Soln:

$$s(t) = 10\cos(2\pi \times 10^6 t + 0.2\sin(4\pi \times 10^3 t))$$

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

$A_c = 10$

$\beta = 0.2$

$f_c = 1\,MHz$

$f_m = 2\,kHz$

$\Delta f = \beta f_m = 0.4\,kHz$

After pa

$A_c = 1$

$f_c =$

$n\beta =$

$f_m =$

$\Delta f = n$

$BW = 2$

$P_t = \frac{A}{}$

$= \frac{10}{2}$

After pas

$A_c = 10\,V$

$n f_c = 5$

$\beta = n\beta =$

$f_m = 2k$

$\Delta f = n\Delta$

After Passing through $n=4$

$A_c = 10\,V$

$f_c = n f_c = 4 \times 1\,MHz = 4\,MHz$

$n\beta = 4 \times 0.2 = 0.8$ (NBFM)

$f_m = 2\,kHz$

$\Delta f = n \Delta f_{old} = 4 \times 0.4 = 1.6\,kHz$

$BW = 2 f_m = 4\,kHz$

$$P_t = \frac{A_c^2}{2}\left(1 + \frac{\beta^2}{2}\right)$$

$$= \frac{100}{2}\left(1 + \frac{0.64}{2}\right) = 66\,W$$

After Passing consecutive through $n=5$

$A_c = 10\,V$

$n f_c = 5 \times 4 = 20\,MHz$

$\beta = n\beta = 5 \times 0.8 = 4$ (WBFM)

$f_m = 2\,kHz$

$\Delta f = n \Delta f = 5 \times 1.6 = 8\,kHz$

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

$$= 20 kHz$$

$$P_t = \frac{A_c^2}{2} = 50 w$$

POC lec 4 (After midterm)

FM Detectors

Procedure
Fm to Am conversion
↓
Am demodulators
(Envelope detector)
↓
m(t)

→ Information in Fm signal is contained in the instances Frequency.

$$\boxed{\omega_i = \omega_c + K_f\, m(t)}$$

→ Fm demodulators are implemented by generating an Am signal whose amplitude is proportional to instantaneous freq of Fm signal.

$$x_{FM}(t) = A\cos\left[\omega_c t + k_f \int_{-\infty}^{t} m(\tau)\,d\tau\right]$$

$\Downarrow$

AM

$\Downarrow$

AM demodulator

$\Downarrow$

$m(t)$

FM to AM conversion

* (1) Differentiator

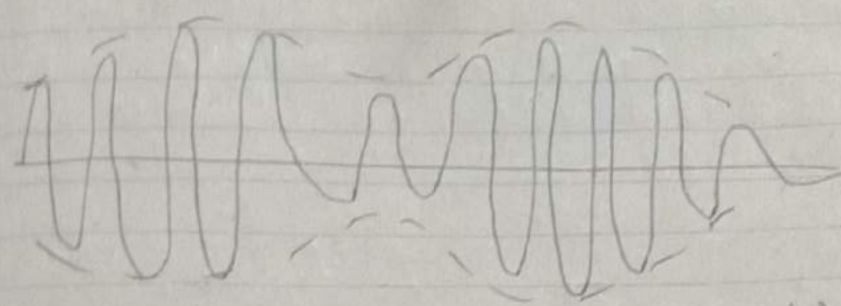
$$x_{FM}(t) \longrightarrow \boxed{\text{diff.}} \longrightarrow \ ?$$

$$\frac{dx_{FM}(t)}{dt} = \frac{d}{dt}\left[A\cos\left(\omega_c t + k_f \int_{-\infty}^{t} m(\tau)\,d\tau\right)\right]$$

$$= A\left[\omega_c + k_f\, m(t)\right] \sin\left[\omega_c t + k_f \int_{-\infty}^{t} m(\tau)\,d\tau\right]$$

It is both frequency & Amplitude modulated

PLOT OF THE above SIGNAL (Freq. & Amp. modulated)



$$\frac{d x_{Fm}(t)}{dt}$$

Envelope of signal

$= A(\omega_c + k_F m(t))$

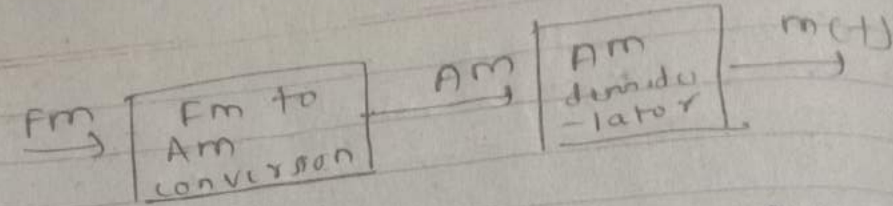
$x_{Fm}(t) \longrightarrow \boxed{\text{differentiator}} \longrightarrow \boxed{\text{Envelope detector}} \longrightarrow m(t)$

* The envelope of this wave is $A(\omega_c + k_F m(t))$

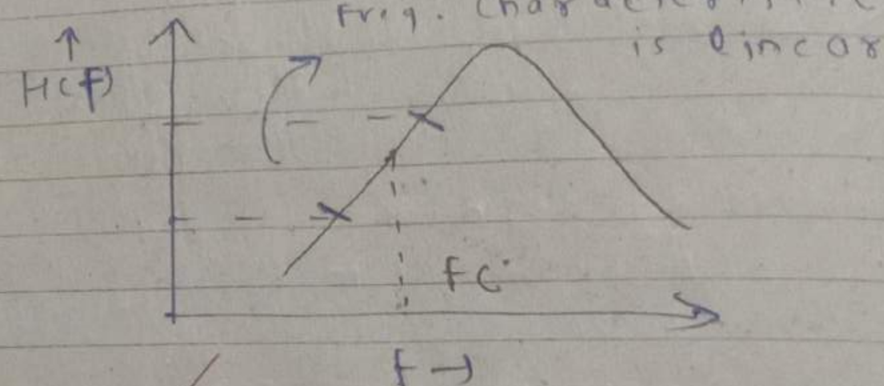
$\underbrace{A}\,(\underbrace{\omega_c} + \underbrace{k_F} m(t))$

constants, If we are able to remove this, we can get back the m(t) signal

S

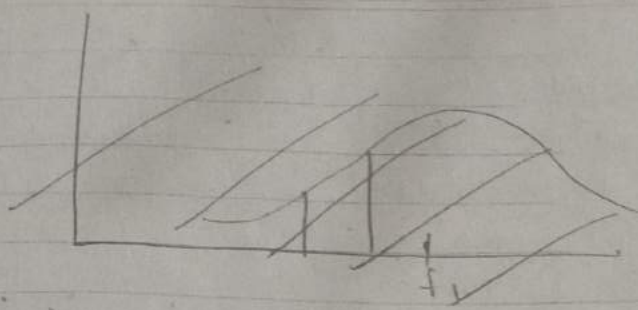


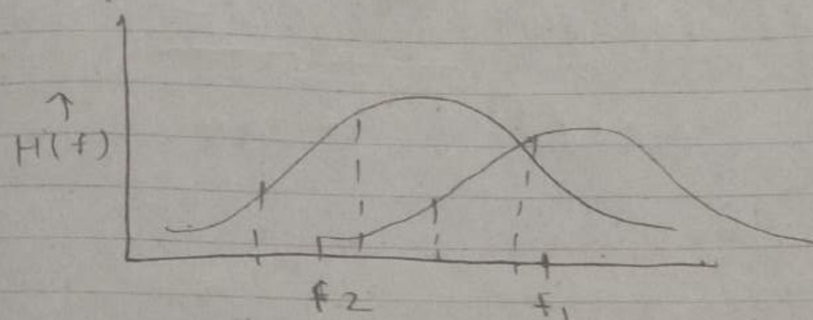
* A simple tuned circuit followed by an Am demodulator / envelope detector can serve as Fm demodulator

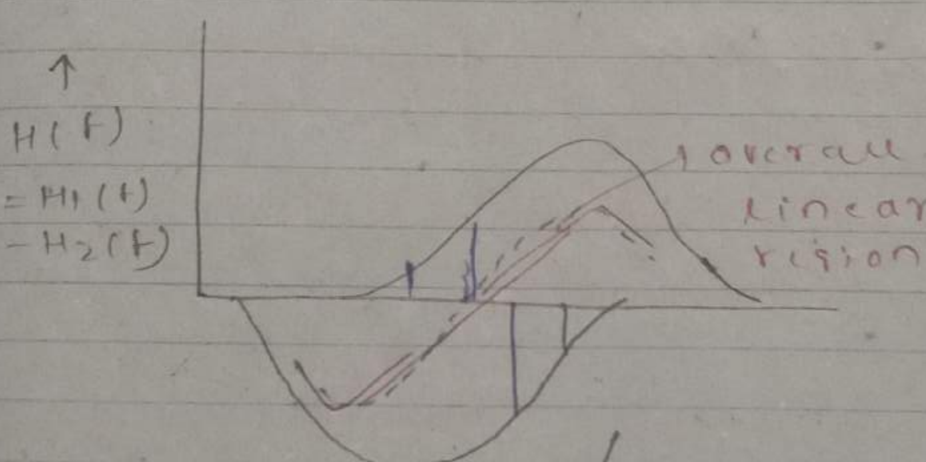


"Slope detection" = since detection on slope of freq. characteristic

P To get linear characteristic over a wide range of frequencies we used two tuned circuits at frequency f_1 & f_2 connected in a configuration ⇒ Balanced discriminator







Balanced demodulator

"exlond the working of demodulator"

RATIO DETECTOR

It provides
(better protection against
carrier amplitude variation)

PHASE LOCKED LOOP (PLL)

* most widely used FM demodulator

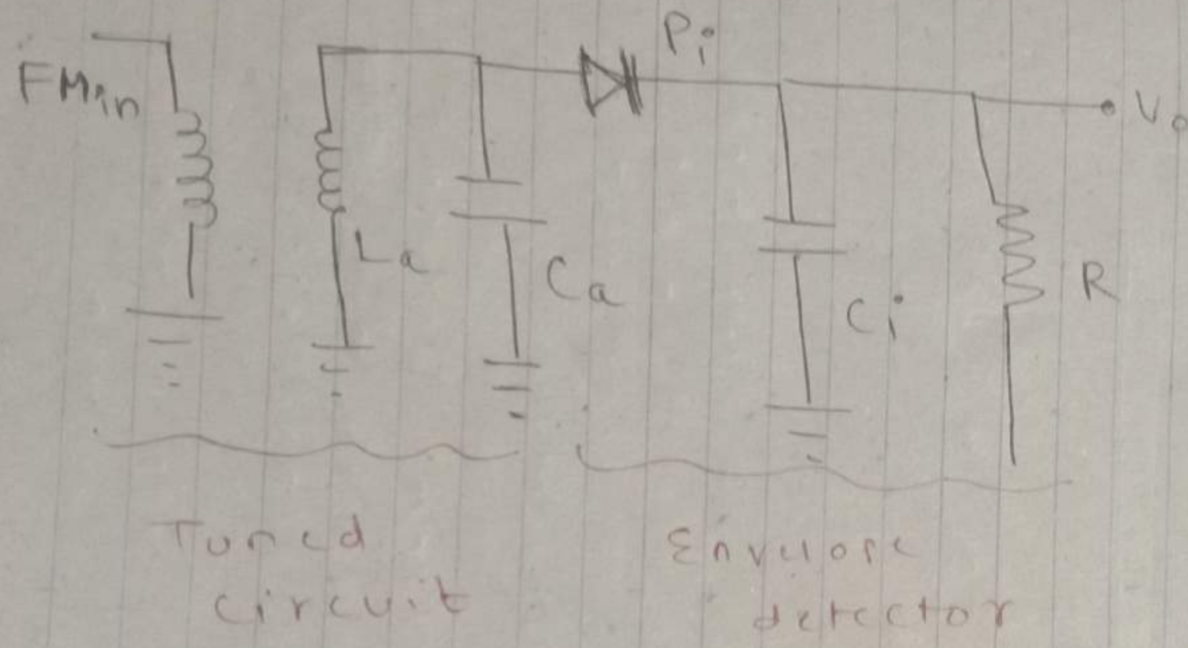
low cost

superior performance

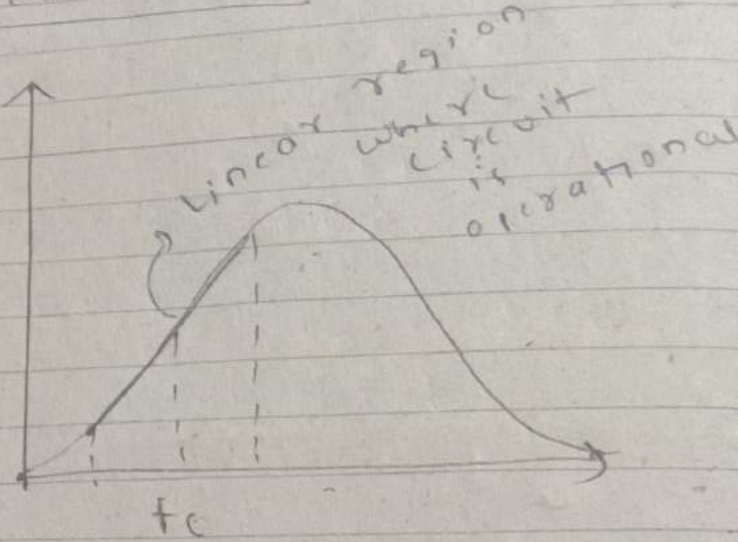
*

~~SLOPE DETECT~~

SLOPE DETECTOR



S FREQ. CHARACTERISTIC OF TUNED CIRCUIT



* f_c : resonating freq. of Tuned circuit

* Tuned circuit consisting of L_a & C_a produced an o/p voltage that is proportional to I/P frequency.

* At the resonant frequency f_c of tuned circuit, max. ~~Voltage o/p occurs~~ o/p voltage occurs.

* Freq. variation is mapped to Amplitude variation

Freq. $\uparrow$ by $\Delta F \Rightarrow$ O/P voltage $\uparrow$
(f_c)

Freq $\downarrow$ by $\Delta F \Rightarrow$ O/P voltage $\downarrow$
(f_c)

envelope detector

$\downarrow$

$m(t)$ = Final O/P

DISADVANTAGE

linear region very less, with most non-linear frequency characteristic

If 2 signals have constant phase diff over a period of time ⇒ both signals have same freq.

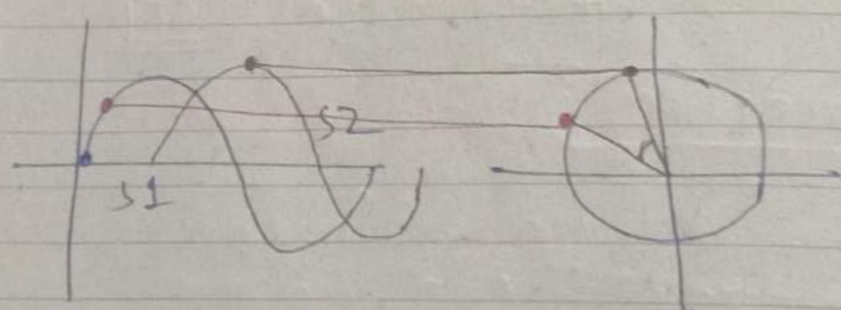
POC lecs (After midsem)

based on this fact

PHASE LOCKED LOOP (PLL)

* most extensively used type of demodulator

* Track the phase & frequency of incoming signal



Phase plane

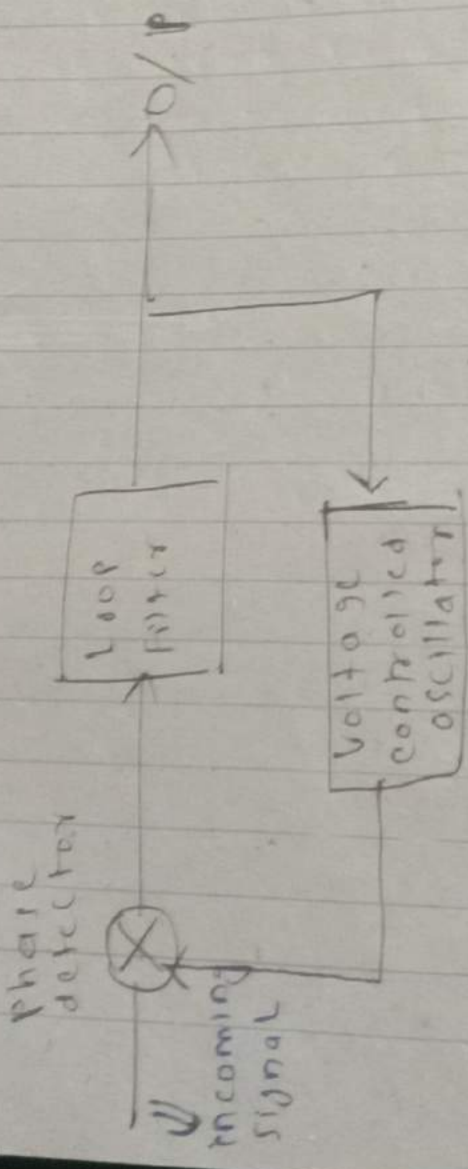
If both have same freq.
both move with same pace, & any point mapped onto Phase circle by both signals S1 & S2 will have the "same phase difference!!

USES OF PLL

1. Fm dimodulation
2. Synchronous dimodulation of Am signal
3. Clock recovery system
4. Timing recivery system

BASIC STRUCTURE OF PLL

PLL has 3 basic components



BASIC OPERATION OF PLL

* Typical feed back system, feedback tends to follow I/P signal.

* If diff. in feedback & I/P signal then FB signal brought close to I/P signal.

* We compare the phase of feedback signal with phase of incoming signal, if there is phase difference, then given to feedback circuit that changes the feedback signal so that phase difference minimized.

* V_{CO} adjusts its own frequency such that frequency & phase can track those of the I/P signal

Freq. of V_{CO}:

constanst of V_{CO}

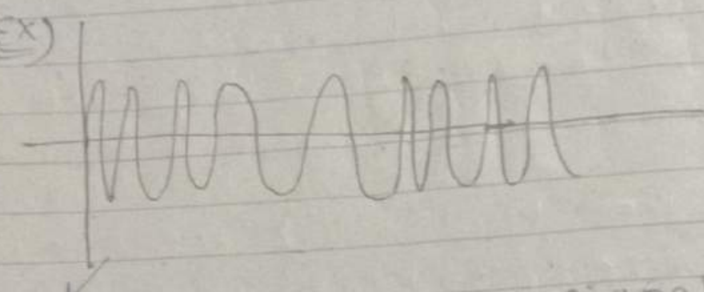
$$\omega = \omega_c + c\,\underbrace{e(t)}$$

free running frequency

error signal after loop filtering process

When $e(t) = 0$, $\omega = \omega_c$

Ex)



Let the incoming signal be FM signal

Let the ~~__~~ loop be in locked condition,
→ freq of incoming & freq. of feedback signal is same

When the freq. of incoming signal changes, feedback circuit
→ becomes operational, change in frequency ⇒ "new frequency captured & locked"

LOCK R
freq &
A PLL
frequenc
range of
range of

CAPTU
I/P and
close
may n
~~very~~
The ran
be ach
capture

BALA

This
of in
in pa
fed

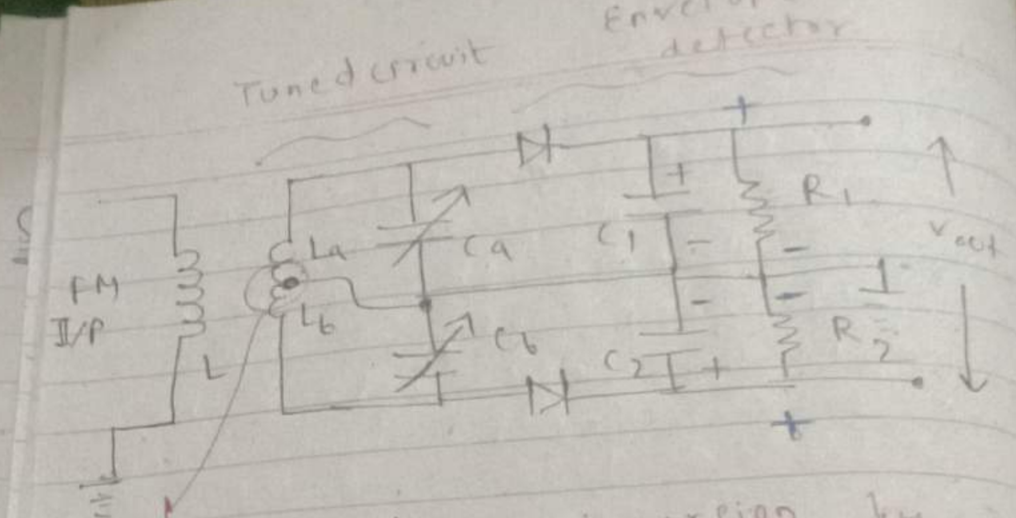
LOCK RANGE : V_{co} tracks the freq & Phase of incoming signal. A PLL can track the incoming frequency only over a finite range of frequency shift & the range of freq. Shift = Lock range.

CAPTURE RANGE : If initially, the I/P and the O/P freq. are not close enough, then the loop may not acquire lock ~~the~~ ~~very~~

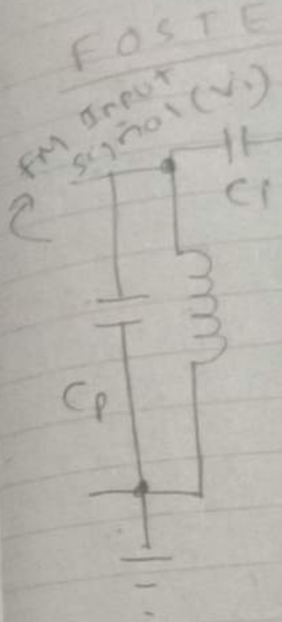
The range in which the lock can be achieved initially is called capture range.

BALANCED SLOPE DETECTOR

This circuit combines 2 circuits of individual slope detectors in parallel & FM I/P signal is fed 180° out of phase



provides phase inversion by center tapping



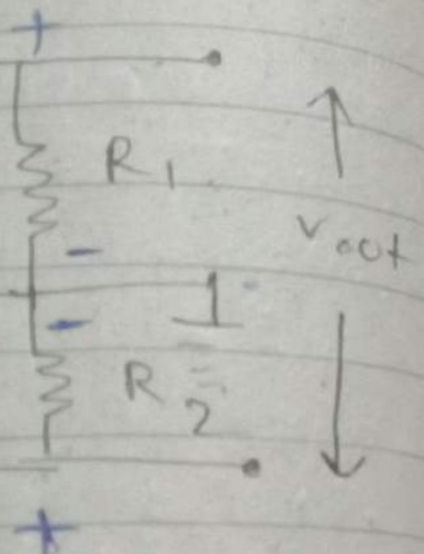
ADVANTAGE

- wider ~~range~~ range of frequency over which frequency characteristic linear

DISADVANTAGE

- * difficulty in tuning
- * Poor limiting (Amplitude variations cannot be limited with much efficiency)

lope
tector



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