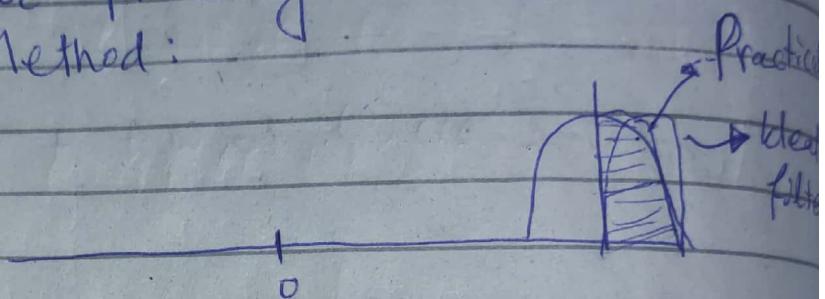


Com Sys After Mids:-

29/11/2023

* Generation of SSB

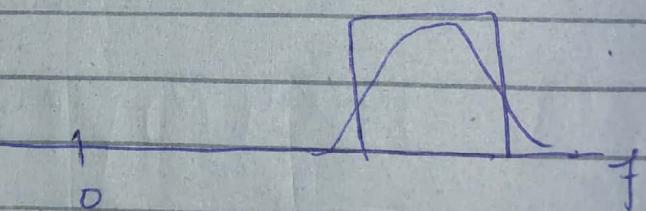
ii) Selective Filtering Method:



Can we do this?

No.

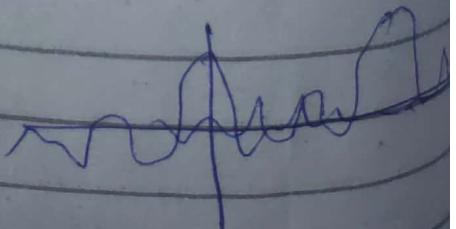
Why?



Butterworth Filter

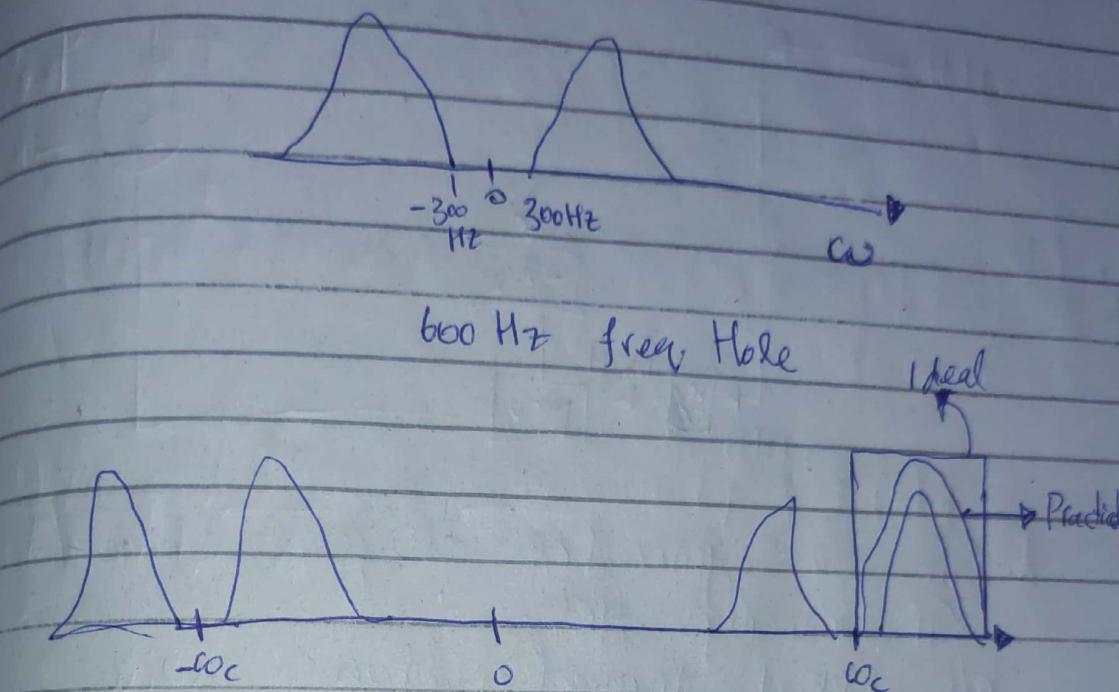
$$H(j\omega) = \frac{1}{\sqrt{1 + \left(\frac{\omega}{2\pi B}\right)^{2n}}}$$

$$\text{rect}\left(\frac{\omega}{2W}\right)$$



* Speech Signal

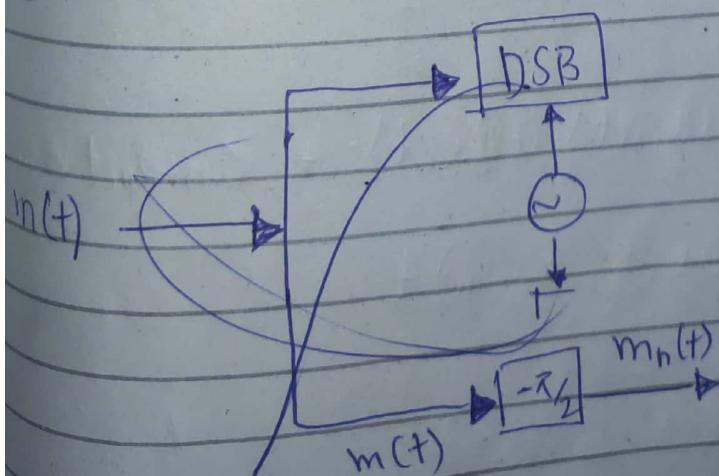
0.3 KHz to 3.4 KHz

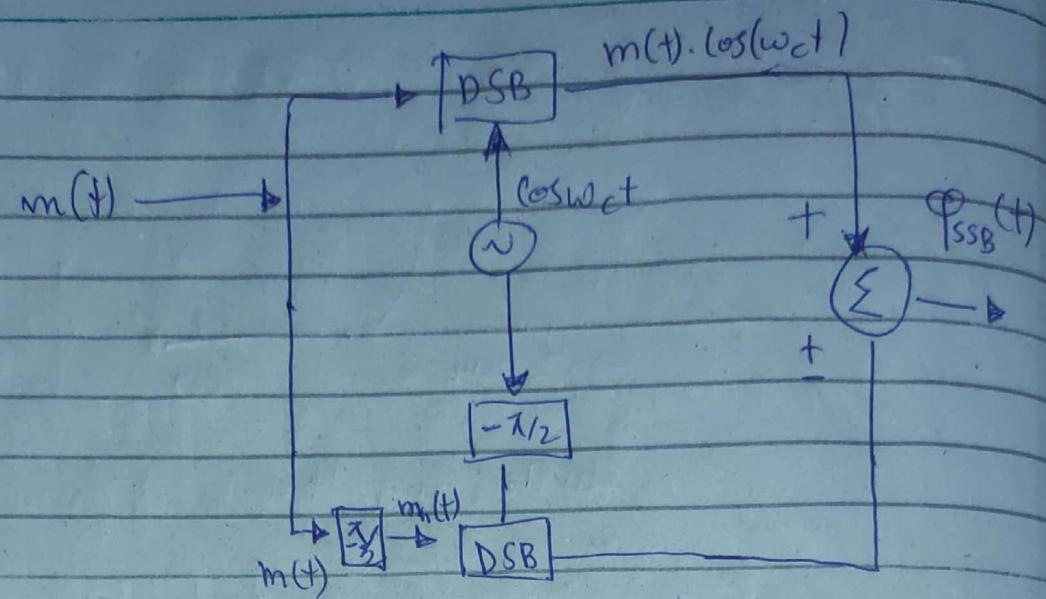


Speech signal can be isolated by practical filter bcz freq. Hole

Now possible method.

(ii) Phase Shift Method :-



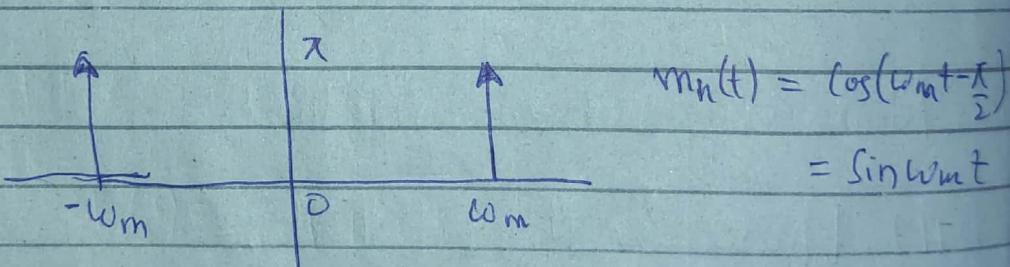


* Can we generate using above diagram
 Theoretically yes.

b/c hilbert transformation will

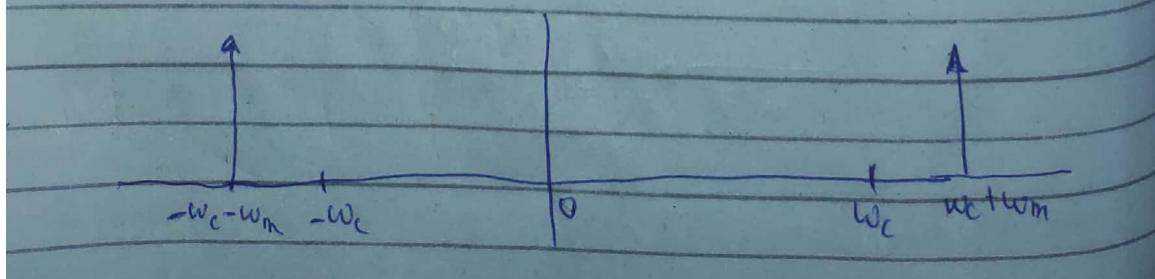
* applying constant transformation on
 every freq. component (ideal case).

$$\underline{m(t) = \cos \omega_m t}$$



$$\phi_{SSB}(+) = \cos(\omega_m t) \cos(\omega_c t) + \sin \omega_m t \sin \omega_c t$$

$$\text{II} = \cos(\omega_c + \omega_m)t$$



Multiplying $\Phi_{SSB}(t)$ with $\cos \omega_c t$

$$\Phi_{SSB}(t) = m(t) \cos^2 \omega_c t + m_n(t) \cdot \sin \omega_c t$$

$$\Phi_{SSB}(t) = \frac{m(t)}{2} + \frac{m(t) \cos(2\omega_c t)}{2} + \frac{m_n(t) \sin \omega_c t}{2}$$

$$= M(\omega)$$

Low Pass filter (coherent Detection)

Now we will send carrier along.

$$\Phi_{SSB}(t) = A \cdot \underline{\cos \omega_c t} + m(t) \cdot \cos \omega_c t + m_n(t) \cdot \sin \omega_c t$$

$$|| = (A + m(t)) \cdot \cos \omega_c t + m_n(t) \cdot \sin \omega_c t$$

$$|| = E(t) \cdot \cos(\omega_c t + \theta)$$

$$\text{as } \frac{a+ib}{\sqrt{a^2+b^2}}$$

$$\text{Now if } E(t) = \sqrt{(A+m(t))^2 + m_n^2(t)}$$

Similar to
 $a_n \cdot \cos n\omega_0 t + b_n \cdot \sin n\omega_0 t$

$$c_n = \sqrt{a_n^2 + b_n^2}$$

Now $E(t) = \left(A^2 + m^2(t) + 2 \cdot A \cdot m(t) + m_n^2(t) \right)^{\frac{1}{2}}$

$$E(t) = A \left[1 + \frac{2m(t)}{A} + \frac{m^2(t)}{A^2} + \frac{m_n^2(t)}{A^2} \right]^{\frac{1}{2}}$$

if $m(t) \ll A$

then

$$E(t) \approx A \left[1 + \frac{2m(t)}{A} \right]^{\frac{1}{2}}$$

Now using binomial theorem

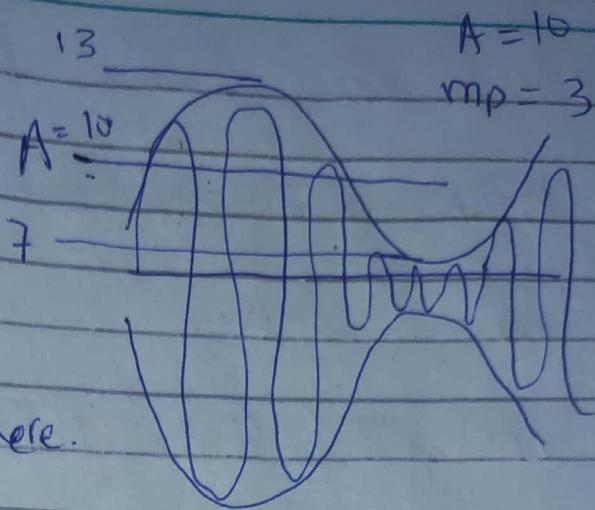
$$E(t) \approx A \left[1 + \frac{1}{2} \times \frac{2m(t)}{A} \right]$$

$$E(t) \approx A + m(t)$$

Now put in above equations

$$\varphi_{SSB}(t) = (A + m(t)) \cos(\omega_c t + \vartheta)$$

We are using extra power here.



$$\eta = \frac{M^2}{2+M^2} = \frac{1}{3} \times 100 = 33.33\%$$

012 | 2023

$$\varphi_{\text{DSB-SC}}(t) = m(t) \cdot \cos(\omega_c t)$$

$$\varphi_{\text{DSB+C}}(t) = [A + m(t)] \cos(\omega_c t)$$

$$\varphi_{\text{PAAM}}(t) = m_1(t) \cos(\omega_c t) + m_2(t) \sin(\omega_c t)$$

$$\varphi_{\text{SSB}}(t) = m(t) \cos(\omega_c t) \mp m_n(t) \sin(\omega_c t)$$

- i) Selective Filtering Method
- ii) Phase shift

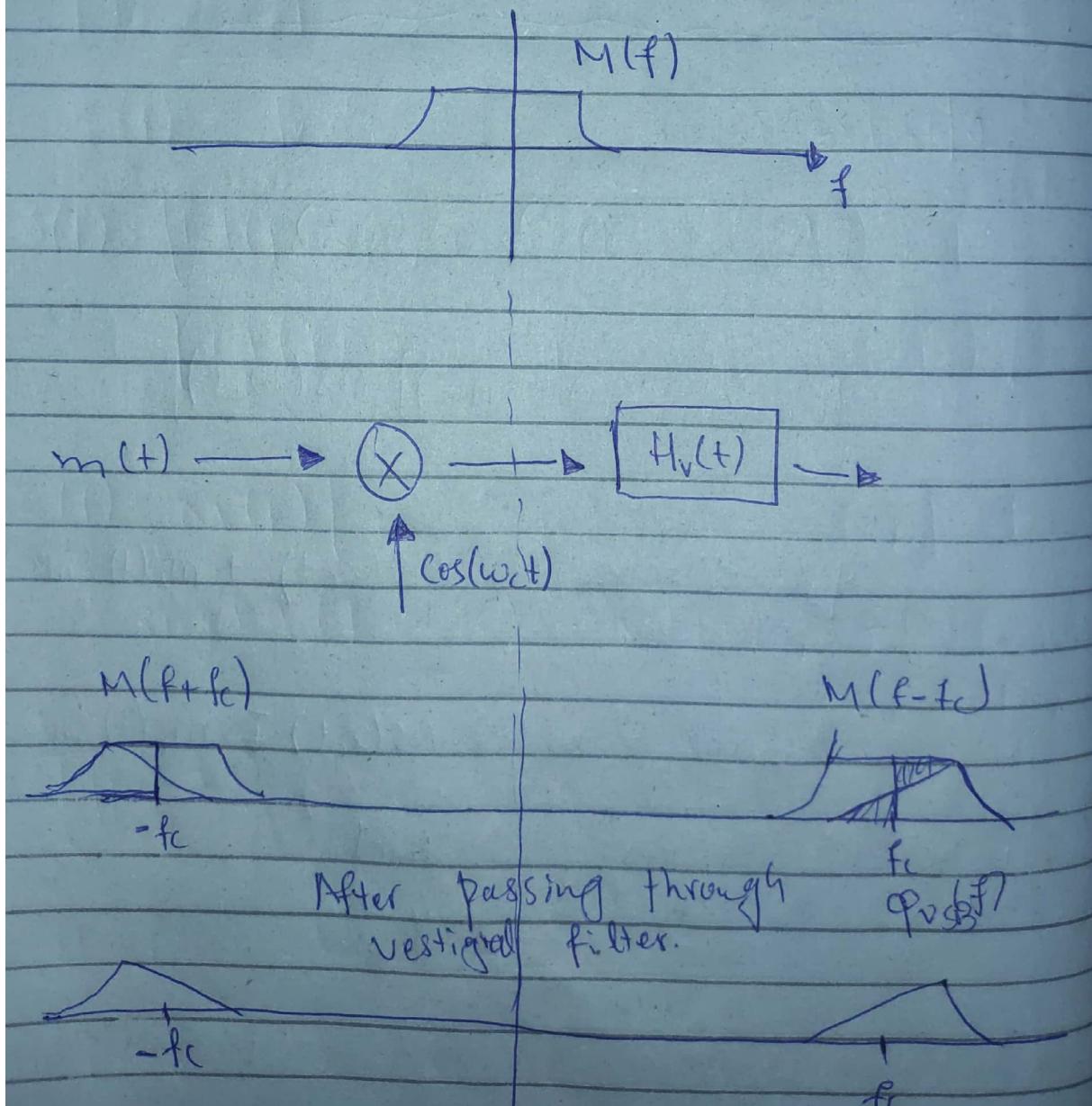
We have two extremes here.

DSB \rightarrow 2B Hz SSB \rightarrow B Hz

Now comes:

★ Vestigial Side Band Modulation:-

$$B_{Hz} < B_T < 2B_{Hz}$$



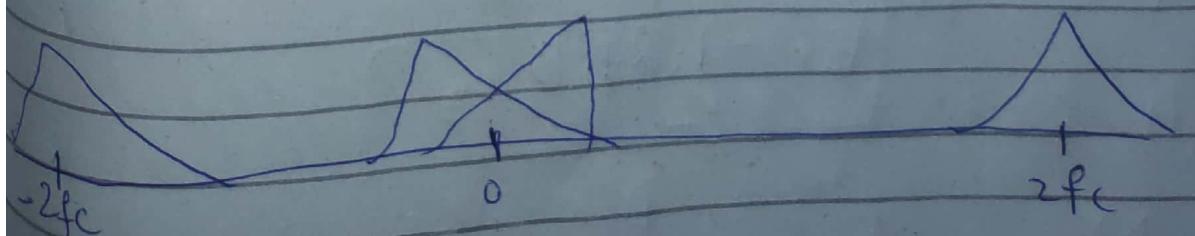
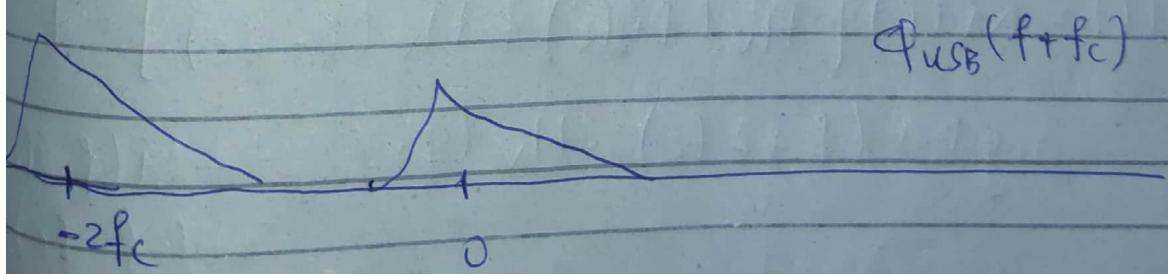
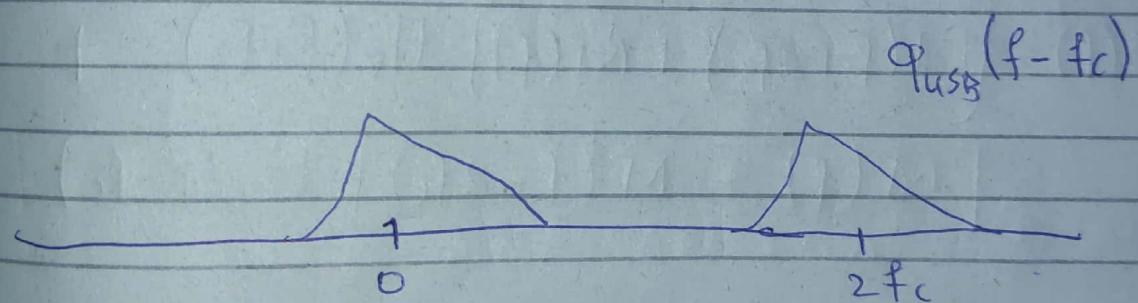
W Demodulation.

$$\Phi(+)_\text{DSB-SC} = m(+). \cos(\omega_c t)] \text{ Modulation}$$

Multiply $\cos(\omega_c t)$ at receiver's end.

$$s(t) = \Phi_{VSB}(t) \cdot \cos(\omega_c t)] \text{ demodulation.}$$

$$s(t) = \Phi_{VSB}(t - \frac{f_c}{2}) + \Phi_{VSB}(t + \frac{f_c}{2})$$



Now at sender's end we have

$$\Phi_{VSB}^{(f)} = [M(f+f_c) + M(f-f_c)] H_v(f)$$

$$\begin{aligned} \text{Now } \left[\Phi_{VSB}^{(f+f_c)} = \{M(f+2f_c) + M(f)\} H_v(f+f_c) \right] \\ \left[\Phi_{VSB}^{(f-f_c)} = \{M(f) + M(f-2f_c)\} H_v(f-f_c) \right] \end{aligned}$$

Now If we add these two, get

$$S(f) = \Phi_{VSB}^{(f+f_c)} + \Phi_{VSB}^{(f-f_c)}$$

$$\begin{aligned} S(f) = & [M(f+2f_c) + M(f)] H_v(f+f_c) + \\ & [M(f) + M(f-2f_c)] H_v(f-f_c) \end{aligned}$$

$$\begin{aligned} S(f) = & M(f) [H_v(f+f_c) + H_v(f-f_c)] + \\ & M(f+2f_c) H_v(f+f_c) + M(f-2f_c) H_v(f-f_c). \end{aligned}$$

Typical value of Bandwidth is;

$$B_T = 1.25 B \text{ Hz}$$

Now to recover $M(f)$ we

will pass it through low pass filter.

$$M(f) = S(f) \cdot H_{LPF}(f)$$

Hence.

$$M(f) = M(f) [H_V(f + f_c) + H_V(f - f_c)]$$
$$H_{LPF}(f)$$

$$O = H_V(f + f_c) +$$

$$H_{LPF}(f) = \frac{1}{H_V(f + f_c) + H_V(f - f_c)}$$

* Carrier Acquisition:-

$$m(t) \cdot \cos \omega t \cdot \cos((\omega_c + \Delta\omega)t + \delta)$$

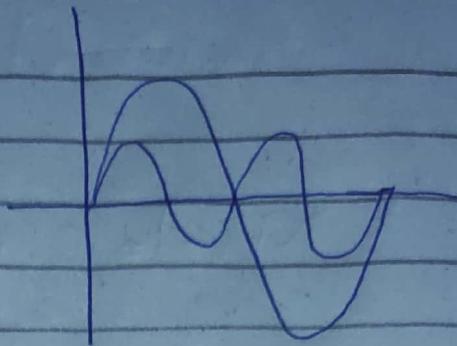
$$\text{Now } \cos \alpha \cdot \cos \beta = \cos(\alpha + \beta) + \cos(\alpha - \beta)$$

$$m(t) \cdot \cos(\Delta\omega t + \delta) + m(t) \cdot \cos(2\omega_c t + \Delta\omega t + \delta)$$

By passing through LPF

$$m(t) \cdot \cos(\Delta\omega t + \delta)$$

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



case

① Now if $\Delta\omega = 0$, $\delta = \text{const.}$

$$m(t) \cdot \cos(\delta)$$

e.g.

$$0.8 \cdot m(t)$$

Hence, shape of $m(t)$ will not be changed. Hence it is distortionless.

case ②

$\Delta\omega = \text{some value}$, $\delta = 0$

$$m(t) \cdot \cos(\Delta\omega t)$$

Signal will be distorted.

So, we need Carrier acquisition.

Carrier Acquisition:-

(i) Pilot Signal :-

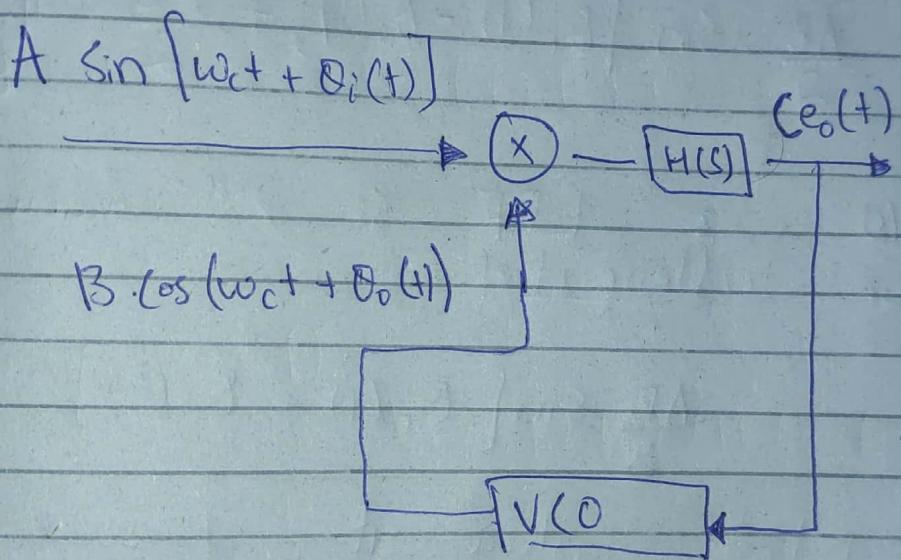
DSB-WC

$$(A + m(t)) \cos \omega_c t$$

- (ii) Phase Loop Lock :-
 (iii) Squearing Method:-

Phase Loop Lock :-

System. This is a feedback



VCO: Voltage Control
Oscillator.

$$\{ \theta_i(t) - \theta_o(t) \} \propto e_o$$

will create Voltage

$$\dot{\omega}_i = \omega_c + C \cdot e_o(t) - \ddot{\theta}_o$$

$$\dot{\theta}(t) = \omega_c t + \theta_o(t)$$

$$\frac{d}{dt} \dot{\theta}(t) = \frac{d}{dt} (\omega_c t) + \frac{d}{dt} (\theta_o(t))$$

$$\omega_i = \omega_c + \theta_o(t) \quad \text{--- (ii)}$$

Compare (i) and (ii)

$$\theta_o(t) = C \cdot e_o(t)$$

Now output of multiplier B:

$$A \cdot \sin(\omega_c t + \theta_i(t)) \cdot B \cdot \cos[\omega_c t + \theta_o(t)]$$

$$\frac{AB}{2} \cdot \sin[\theta_i(t) - \theta_o(t)] + \frac{AB}{2} \sin[2\omega_c t + \theta_i(t) + \theta_o(t)]$$

$H(s)$ β LPF so 2nd term will be attenuated.

$$\frac{AB}{2} \sin[\theta_i(t) - \theta_o(t)]$$

Now when it passes through $h(t)$.

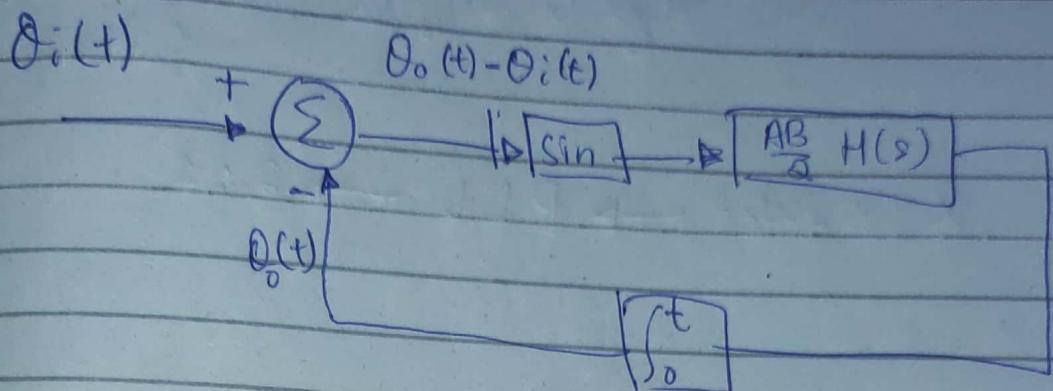
$$\frac{AB}{2} \left[h(t) * \sin[\theta_i(t) - \theta_o(t)] \right]$$

$$C e_o(t) = \frac{AB}{2} \int_0^t h(t-x) \cdot \sin[\theta_i(x) - \theta_o(x)] dx$$

$$\text{Put } C e_o(t) = \theta_o(t)$$

$$\theta_o(t) = \frac{AB}{2} \int_0^t \dots dx$$

$$\theta_o(t) =$$



(iii) Squaring Method:-

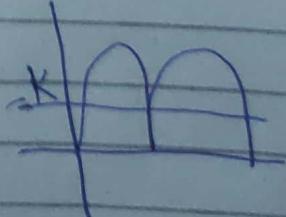
$$(m(t))^2 (\cos \omega_c t)^2$$

$$m^2(t) \cdot \left[\frac{1 + \cos(2\omega_c t)}{2} \right]$$

$$\frac{m^2(t)}{2} + \frac{m^2(t) \cos(2\omega_c t)}{2}$$

Let $\frac{m^2(t)}{2} = k + \varphi(t)$

Average value



$$\frac{m^2(t)}{2} + (k + \varphi(t)) \cos(2\omega_c t)$$

$$m(t) \rightarrow B \text{ Hz}$$

$$m^2(t) \rightarrow 2B \text{ Hz}$$

$$\frac{m^2(t)}{2} + \frac{K \cos 2\omega_c t}{2} + \frac{\varphi(t) \cos 2\omega_c t}{2}$$

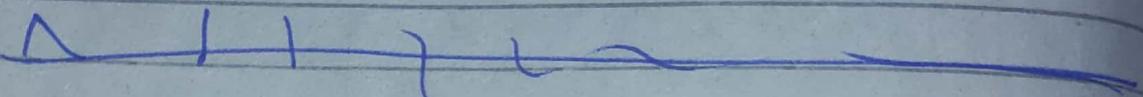
High Quality Q Narrowband
filter

$K \cos 2\omega_c t \rightarrow \text{PLL} \rightarrow 2:1$

$$\frac{m^2(t)}{2} + \frac{K \cos 2\omega_c t}{2} + \frac{\Phi(t) \cos 2\omega_c t}{2}$$

High Quality Q Narrowband
Filter

$$K \cos 2\omega_c t \rightarrow \text{PLL} \rightarrow 2:1$$



Date 13/12/2023

Angle Modulation :-

$A \cos \theta(t)$ may or may not
be linear.

$\Phi_{EM}(t)$ PM
FM

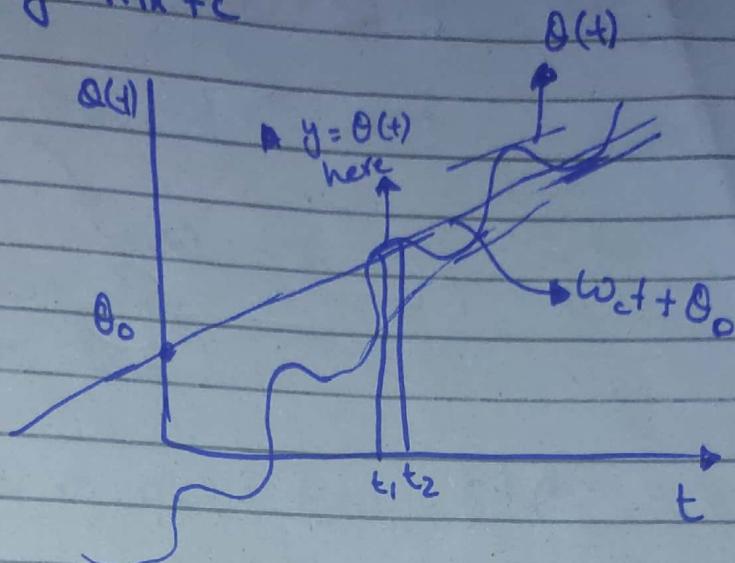
A.M \rightarrow Linear \rightarrow No Additional Component,
 \rightarrow No loss in shape
 \rightarrow Bandwidth is limited.

PM, FM \rightarrow Non-Linear

↳ Some additional components
will be present.
↳ Bandwidth is unlimited

$A \cos(\omega_c t + \theta_0)$ \rightarrow Linear

$$y = mx + c$$



$$\Theta(t) = \omega_c t + \Theta_0 \quad t_1 \leq t \leq t_2$$

~~ds~~
At every instance of time, we have instantaneous frequency.

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

$$\cancel{\omega_i} \quad d.\Theta(t) = \omega_i(t) dt$$

PM & FM are closely related.

Taking integral.

$$\int d.\Theta(t) = \int \omega_i(t).dt$$

Generalized curve

$$\boxed{\Theta(t) = \int_{-\infty}^t \omega_i(\alpha).d\alpha}$$

$$\Phi_{PM}(t) = A \cdot \cos(\omega_c t + \theta_0 + k_p m(t))$$

Now $\theta(t) = \omega_c t + \theta_0 + k_p m(t)$

Zyada

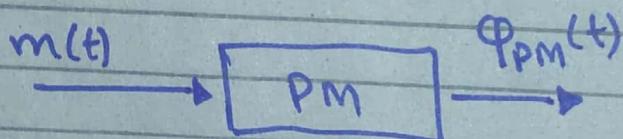
Yeh nahi iska

and we can remove it

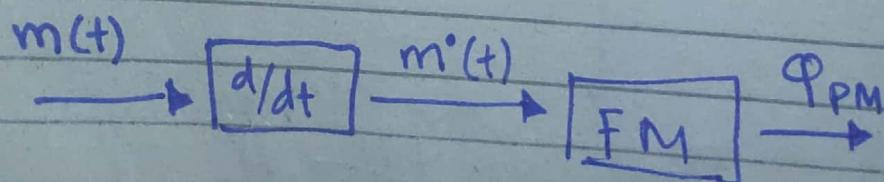
$$\theta(t) = \omega_c t + k_p m(t)$$

Now derive it to get
instantaneous freq.

$$\omega_i = \frac{d\theta(t)}{dt} = \omega_c + k_p \cdot m'(t)$$



$$\Phi_{PM}(t) = A \cdot \cos(\omega_c t + k_p m(t))$$



$$\frac{2\pi f_i}{2\pi} = \frac{2\pi f_c + k_p \cdot m(t)}{2\pi}$$

$$f_i = f_c + \frac{k_p \cdot m(t)}{2\pi}$$

FM :-

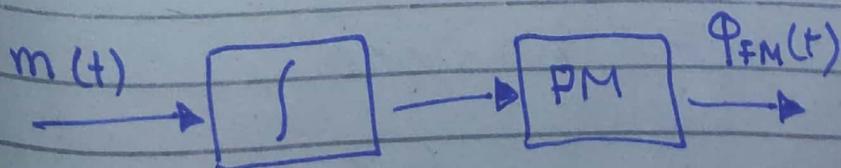
$$\omega_i = \omega_c + k_f \cdot m(t)$$

Now

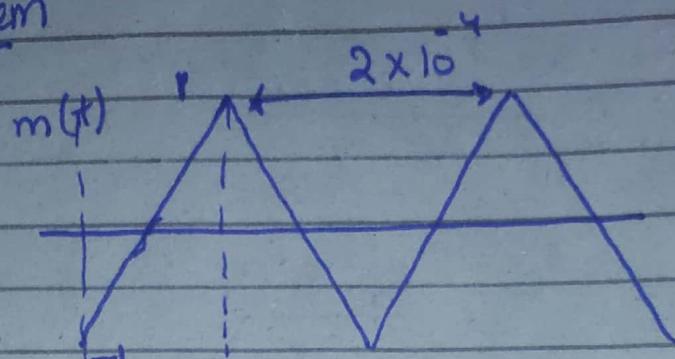
$$\frac{d\theta(t)}{dt} = \omega_c + k_f \cdot m(t)$$

$$\theta(t) = \omega_c t + k_f \cdot \int_{-\infty}^t m(\alpha) d\alpha$$

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



★ Problem



$$f_c = 100 \text{ MHz}$$

$$K_p = 10\pi$$

PM :-

$$\text{for 1 slope :- } \omega_i = \omega_c + K_p \cdot m'(t)$$

$$K_f = 2\pi \times 10^5$$

$$f_i = f_c + \frac{K_p}{2\pi} \cdot m'(t)$$

$$m'(t) = \frac{2}{1 \times 10^4} = \boxed{20,000}$$

$$f_i = 100 \text{ MHz} + \frac{10\pi}{12\pi} \times 20,000$$

$$f_i = 100 \text{ MHz} + 0.1 \text{ MHz}$$

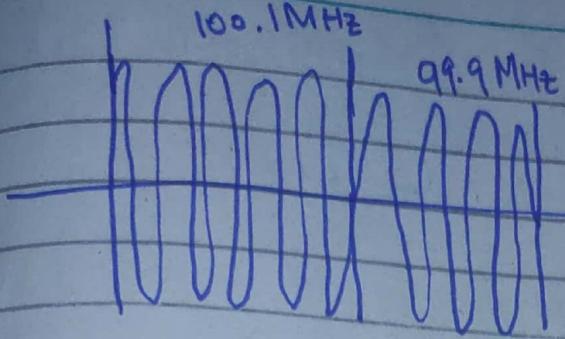
$$f_{i_{\max}} = 100.1 \text{ MHz}$$

f_{oc}

$$f_{i_{\min}} = f_c - 5 \times 20,000$$

$$f_{i_{\min}} = 100 \text{ MHz} - 0.1 \text{ MHz}$$

$$f_{i_{\min}} = 99.9 \text{ MHz}$$



→ Frequency instance isn't changing at every hence it is PM.

FM :-

$$\omega_i = \omega_c + K_f \cdot m(t)$$

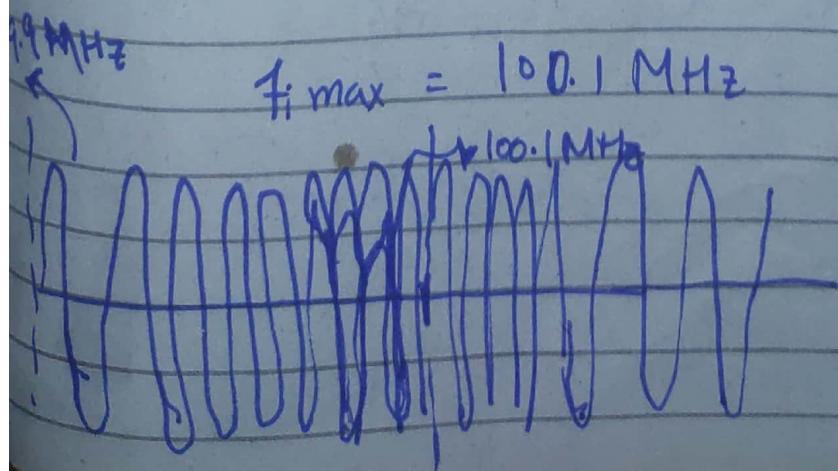
$$f_i = f_c + \frac{K_f}{2\pi} m(t)$$

$$f_{i \min} = 100 \text{ MHz} + \frac{2 \times 10^5 (t)}{2\pi} \quad \text{take } m(t) = -1$$

$$f_{i \min} = 100 \text{ MHz} - 0.1 \text{ MHz}$$

$$f_{i \max} = 99.9 \text{ MHz}$$

Now for $f_{i \max}$, $m(t) = 1$



At every instance ω_i is changing

POWER OF ANGLE MODULATED SIGNAL :-

$$\underline{\Phi}_{EM}(t) = A \cdot \cos(\theta(t))$$

$$P_{EM} = A^2/2$$

BANDWIDTH OF EM SIGNAL :-

$$\Phi_{FM}(t) = A \cos(\omega_c t + K_f \int_{-\infty}^t m(\alpha) d\alpha)$$

for convenience take
 $\int_{-\infty}^t m(\alpha) d\alpha \approx a(\alpha)$

$$\Phi_{FM}(t) = A \cdot \cos(\omega_c t + K_f a(\alpha))$$

$$\hat{\Phi}_{FM}(t) = A \cdot e^{j(\omega_c t + K_f a(\alpha))}$$

Now $e^{j\theta} = \cos \theta + j \sin \theta$

$$\Phi_{FM}(t) = \operatorname{Re} \{ \hat{\Phi}_{FM}(t) \}$$

$$\hat{\Phi}_{FM}(t) = A \cdot e^{j\omega_c t} \cdot e^{jK_f a(\alpha)}$$

Open it using power series

ISSC
Bandwidth
Ka Path Choke

$$\hat{\Phi}_{FM}(t) = A \cdot e^{j\omega_c t} \left[1 + j k_f a(t) - k_f^2 a^2(t) + \dots - \frac{j^n k_f^n a^n(t)}{n!} \right]$$

$$\hat{\Phi}_{FM}(t) = A \left[(\cos(\omega_c t) + j \sin(\omega_c t)) \right] //$$

Now $\Phi_{FM}(t) = \operatorname{Re}\{\hat{\Phi}_{FM}(t)\}$

So we ignore terms with j .

$$\Phi_{FM}(t) = \operatorname{Re}\{\hat{\Phi}_{FM}(t)\} = A \cos \omega_c t - A k_f a(t) \sin \omega_c t - A \frac{k_f^2 \cdot a^2(t)}{2!} \cos \omega_c t + \dots - \dots$$

$$\dots - A \frac{k_f^n \cdot a^n(t)}{n!} \cos \omega_c t$$

$$m(t) \rightarrow B \text{ Hz}$$

$$m^2(t) \rightarrow 2B \text{ Hz}$$

$$m^3(t) \rightarrow 3B \text{ Hz}$$

|
|

$$m^n(t) \rightarrow nB \text{ Hz}$$

Now if $|k_g \cdot a(t)| \ll 1$

We can ignore the nth terms.

$$\Phi_{FM}(t) = A \cdot \cos \omega_c t - A \cdot k_f \cdot a(t) \cdot \sin \omega_c t$$

This is called narrowband FM

It's max band is $2B\text{ Hz}$

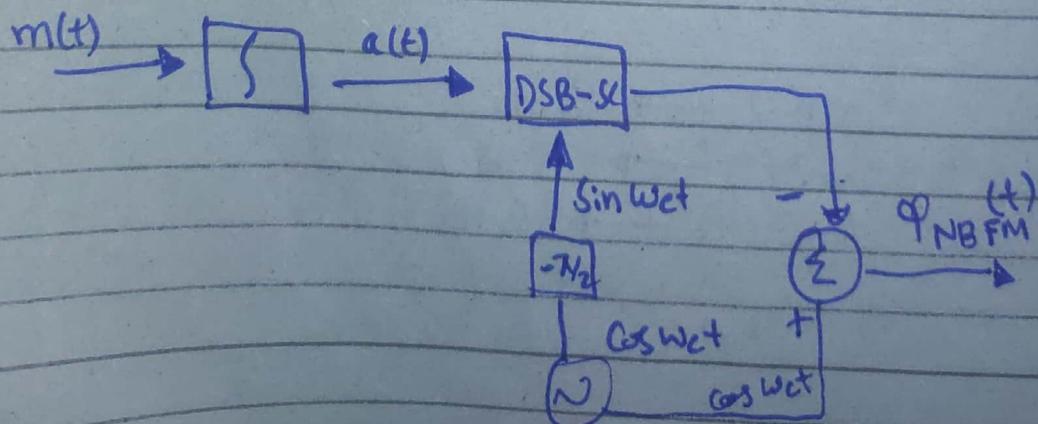
Here kan se kam ^{minimum} band is $2B\text{ Hz}$

where as in DSB-SC Max Band was $2B\text{ Hz}$

We can compare it with.

$$\Phi_{DSB-SC}(t) = A \cdot (\cos \omega_c t + m(t) \cdot \cos \omega_c t)$$

Now we generate it using DSB-SC generator.



Date 14/12/2023

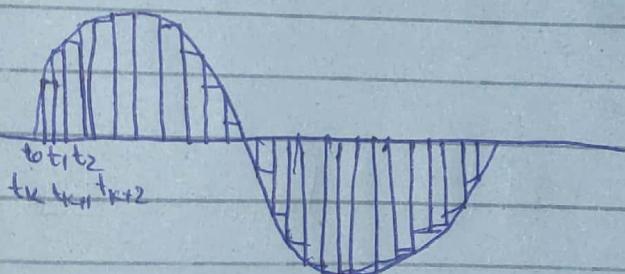
$$|\kappa_f \cdot a(t)| \ll 1 \rightarrow \text{Wide Band does not fulfill this criterion}$$
$$\Phi_{NBPM}^{(+)} = A \left[\cos \omega_c t - \kappa_f \cdot a(t) \cdot \sin \omega_c t \right]$$

$$\Phi_{NBPM}(t) = A \left[\cos \omega_c t - \kappa_p \cdot m(t) \cdot \sin \omega_c t \right]$$

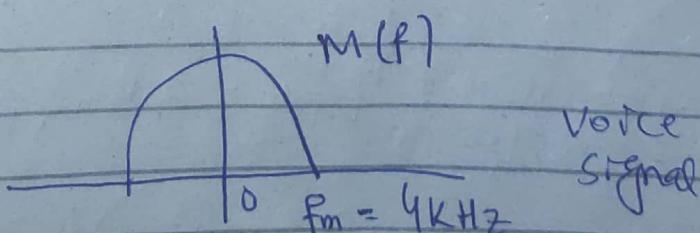
* Wide Band Angle Modulated Signal:-

$$\omega_i = \omega_c + \kappa_f m(t)$$

$$f_i = f_c + \frac{\kappa_f \cdot m(t)}{2\pi}$$



Sampling Theorem

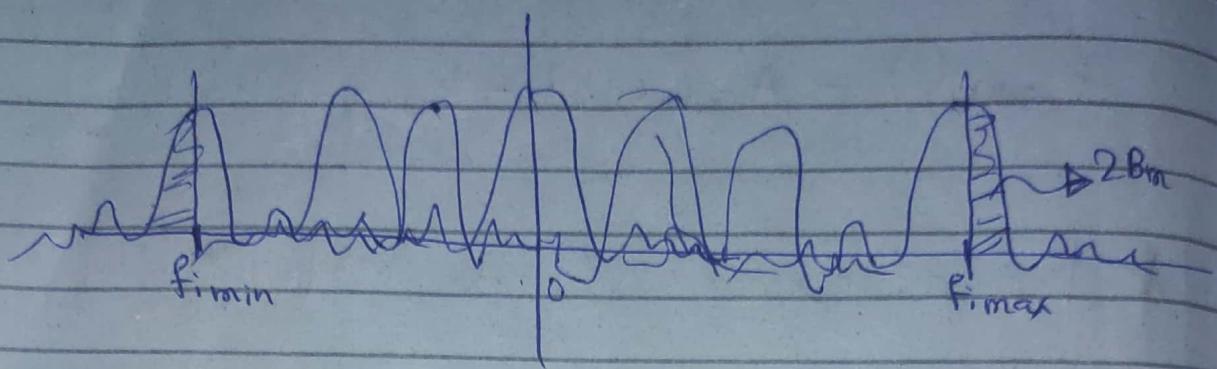


$$R_s = 2B_m$$

$$R_s = 2 \times 4 K$$

Nyquist Criteria = 8K Samples/Sec

$$\text{rect}\left(\frac{t}{T}\right) \Leftrightarrow T \cdot \sin\left(\frac{\omega_c t}{2}\right)$$



$$f_{\max} = f_c + \frac{k_f}{2\pi} \cdot m_p$$

$$f_{\min} = f_c - \frac{k_f}{2\pi} \cdot m_p$$

$$B_{FM} = 2B_m + f_{\max} - f_{\min} = 2 \frac{k_f}{2\pi} m_p + 4B_m$$

$$B_{FM} = 2\Delta f + 4B_m$$

$$B_{FM} = 2B_m \left[\frac{\Delta f}{B_m} + 2 \right]$$

~~Not a generalized expression for all cases~~

$$\beta = \frac{\Delta f}{B_m}$$

If we take $\Delta f \rightarrow 0$ in

$$B_{FM} = 2[\Delta f + 2B_m]$$

$$B_{FM} = 4B_m$$

Then Carson presented Carson's Rule to find Bandwidth and remove 2 in expression

$$B_{FM} = 2(\Delta f + B_m)$$

* $m(t) = d \cdot \cos \omega_m t$

$$\begin{aligned}\Phi_{FM}(t) &= A \cdot \cos \omega_c t \left[\omega_c t + k_f \cdot \int_{-\infty}^t m(\alpha) d\alpha \right] \\ &= A \cos (\theta(t))\end{aligned}$$

$$\omega_i = \omega_c + k_f \cdot m(t)$$

$$\frac{d\theta(t)}{dt} = \omega_c + k_f \cdot m(t).$$

$$\theta(t) = \omega_c t + k_f \int_{-\infty}^t m(\alpha) d\alpha$$

→ $\Phi_{FM}(t) = A \cos [\omega_c t + k_f \cdot \theta(t)]$

$$\hat{\Phi}_{FM}(t) = A \cdot e^{j\omega_c t} \cdot e^{jk_f \cdot \theta(t)}$$

$$a(t) = \int_{-\infty}^t d \cdot \cos \omega_m t dt$$

$$a(t) = \frac{d}{\omega_m} \cdot \sin \omega_m t$$

$$\hat{\Phi}_{FM}(t) = A \cdot e^{j\omega_m t} \cdot e^{j \frac{K_f d}{w_m} \sin \omega_m t}$$

$$\beta = \frac{\Delta f}{B_m} = \frac{K_f \cdot d}{w_m} \Rightarrow \frac{\Delta f}{B_m}$$

$$\Delta f = \frac{K_f m_p}{2\pi}$$

$$m_p = \infty$$

$$\hat{\Phi}_{FM}(t) = A \cdot e^{j\omega_m t} \cdot e^{j\beta \cdot \sin \omega_m t}$$

Constant term Variations in here

Fourier Series Expansion

$$e^{j\beta \sin \omega_m t} = \sum_{n=0}^{\infty} D_n \cdot e^{jn\omega_m t}$$

$$D_n = \frac{1}{T} \int_{-T/2}^{T/2} g_{T_0}(t) \cdot e^{-jn\omega_m t} dt$$

$$D_n = \frac{1}{T} \int_{-T/2}^{T/2} e^{jB \cdot \sin \omega_m t} \cdot e^{-jn\omega_m t} dt$$

$$T = \frac{2\pi}{\omega_m}$$

$$\omega_m = \frac{2\pi}{T}$$

$$D_n = \frac{\omega_m}{2\pi} \int_{-\pi/\omega_m}^{\pi/\omega_m} e^{jB \sin \omega_m t} \cdot e^{-jn\omega_m t} dt$$

$$\text{Let } \omega_m t = x$$

$$\omega_m = \frac{dx}{dt}$$

$$dt = \frac{dx}{\omega_m}$$

$$D_n = \frac{\omega_m}{2\pi} \int_{-\pi/\omega_m}^{\pi/\omega_m} e^{j(B \sin x - nx)} \cdot \frac{dx}{\omega_m}$$

$$D_n = \frac{1}{2\pi} \int_{-\pi/\omega_m}^{\pi/\omega_m} e^{j(B \sin x - nx)} dx$$

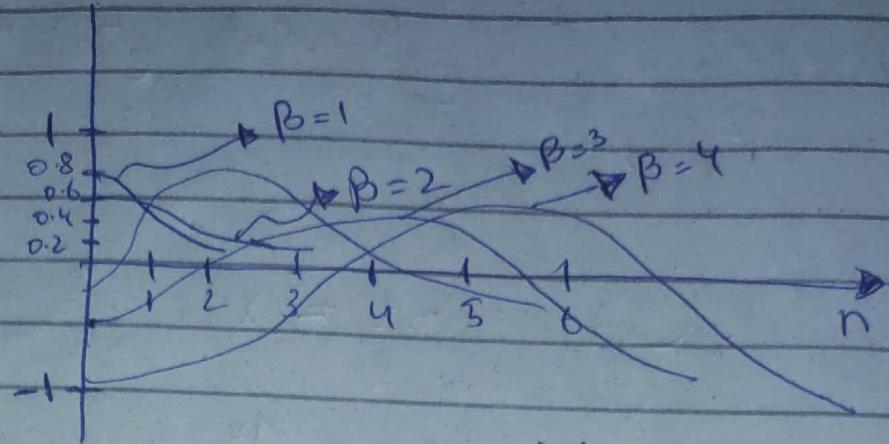
Scale changed here, so our period is now 2π

$$D_n = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{j(B \sin x - nx)} dx$$

This integration is very complex, so we use Bessel's functions.

$$J_n(B)$$

$J_n(\beta)$



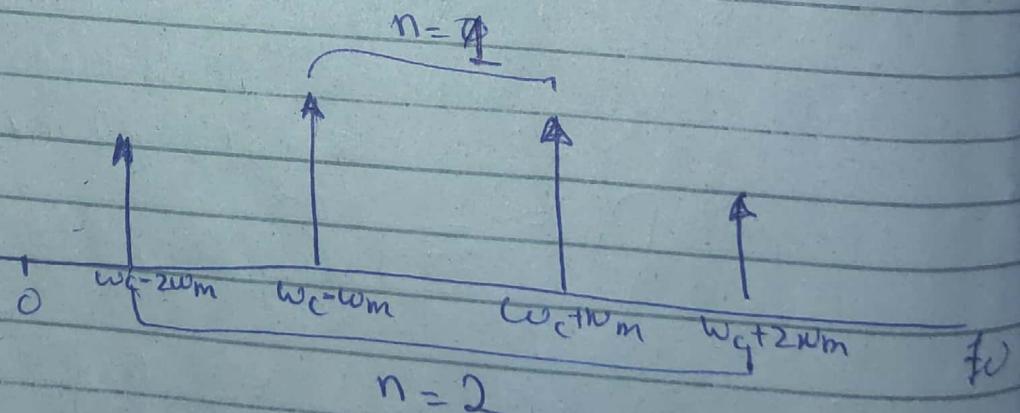
$$n = \beta + 1 \quad j_n(\beta) = 0$$

$$\hat{\Phi}_{FM}(t) = A \cdot e^{j\omega_c t} \sum_{n=-\infty}^{\infty} j_n(\beta) \cdot e^{jn\omega_m t}$$

$$\Phi_{FM}(t) = \operatorname{Re} [\hat{\Phi}_{FM}(t)] = A \cdot \sum_{n=-\infty}^{\infty} j_n(\beta) e^{j(\omega_c t + n\omega_m)} \quad (n = \beta + 1 = 0)$$

$$= A \cdot \sum_{n=-\infty}^{\infty} j_n(\beta) \cdot \cos(\omega_c t + n\omega_m)$$

In free
Domain



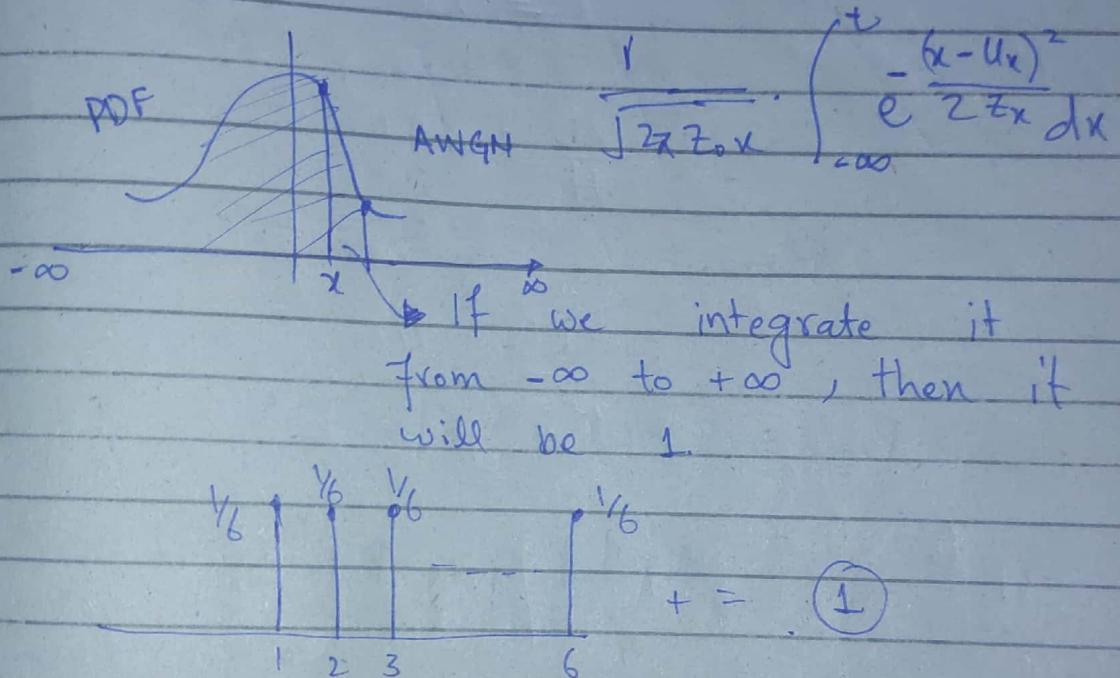
2. $B_m(n)$

$$B_{FM} = 2 \cdot B_m(\beta+1)$$

$$f_1 = 2 \cdot B_m \left(\frac{\Delta E}{B_m} + 1 \right)$$

$$B_{FM} = 2(\Delta f + B_m)$$

Date 20/12/2023



Q function Table

$$\Phi_{FM}(t) = e^{j\omega_c t} \cdot e^{jK_f A \sin \omega_m t}$$

$$|K_f \alpha(t)| \ll 1$$

$\approx B_m$

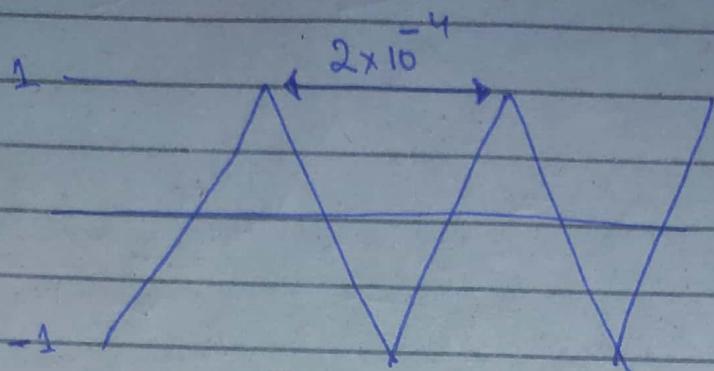
$$B_{FM} = 2(\Delta f + B_m)$$

Carson's Rule

Ex

$$K_f = 2\pi \times 10^5$$

$$K_p = 5\pi$$



$$B_{FM} = ? , \quad B_{PM} = ?$$

$$B_{FM} = 2 [\Delta f + B_m]$$

$$= 2 \left(\frac{K_f m_p}{2\pi} + B_m \right)$$

~~for this we~~

for this we
need to calc.
It's Fourier
series.

Will be given
directly.

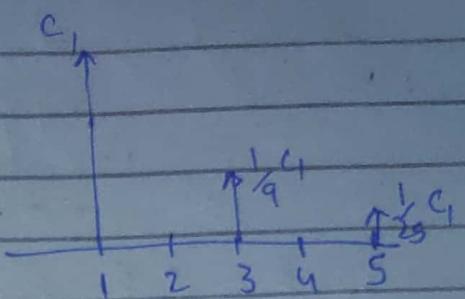
$$\sum_{n=-\infty}^{\infty} C_n \cos(n \omega_0 t + \phi_n)$$

$$C_n = \begin{cases} \frac{8}{n^2 \pi^2} & \text{for } n = \text{odd} \\ 0 & \text{for } n = \text{even} \end{cases}$$

$$C_1 = \frac{8}{\pi^2}$$

$$C_3 = \frac{1}{9} \cdot \frac{8}{\pi^2} = \frac{1}{9} C_1$$

$$C_5 = \frac{1}{25} C_1$$



Mag. ϵ_0 is shrinking very much.

$$P_1 = \frac{1}{2} \left(\frac{8}{\pi^2} \right)^2$$

$$P_3 = \frac{1}{2} \cdot \frac{1}{81} C_1^2$$

So, it's good to take very few samples here. We take the significant band. (e.g. upto C_3)

$$\text{So } B_m = 3 f_m \rightarrow \text{fundamental frequency}$$

$$B_m = 3 \cdot \frac{1}{T} = \frac{3}{2} \times 10^4 = 15 \text{ kHz}$$

$$B_{FM} = 2 \left[\frac{2\pi \times 10^5}{2\pi} (1) + 15 \times 10^3 \right]$$

$$= 2 \left[100 \times 10^3 + 15 \times 10^3 \right]$$

$$= 2 \left[115 \times 10^3 \right]$$

$$= 230 \times 10^3 \text{ Hz}$$

$$B_{PM} = ?$$

$$B_{PM} = 2(\Delta f + B_m)$$

But Δf is changed here

$$\Delta f = \frac{k_p \cdot m_p}{2\pi}$$

$$\Delta f = 5 \times \frac{10000}{2\pi}$$

$$\Delta f = 5000 = 50 \text{ kHz}$$

Now repeat it:

- ① Doubling the amplitude
② D. // P. // Period.

Ex

$$\Phi_{EM}(t) = 10 \cdot \cos(60\pi t + 5 \sin 3000t + 10 \sin 2000\pi t)$$

$$P = ?$$

$$\Delta f = ?$$

$$B = ?$$

$$\Delta \varphi = ?$$

$$B_{FM} = ?$$

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

$$P = 50 \text{ Watts}$$

$$\omega_i = 2\pi \times 10^5 + 15000 \cos 3000t + 20000 \cos 2000\pi t$$

$$\omega_i = \omega_c + 15000 \cos 3000t + 20000 \cos 2000\pi t$$

$$\Delta \omega = 15000 + 20000\pi$$

li \$V_0, 4

la \$a0,

syscall

li \$V0, 5

syscall

move \$t2, \$V0

li \$V0, 1

move \$t0, \$t2

syscall

$$\Delta f = \frac{15000 + 20000\pi}{2\pi}$$

$$\beta = \frac{\Delta f}{B_m}$$

$$\omega_m = 2000\pi$$

$$\text{So } f_m = \frac{2000\pi}{2\pi} = 1000 \text{ Hz}$$

$$\beta =$$

Now for phase angle,

$$\Delta \phi = 5(\sin 3000t)_{\max} + 10(\sin 2000\pi t)_{\max}$$

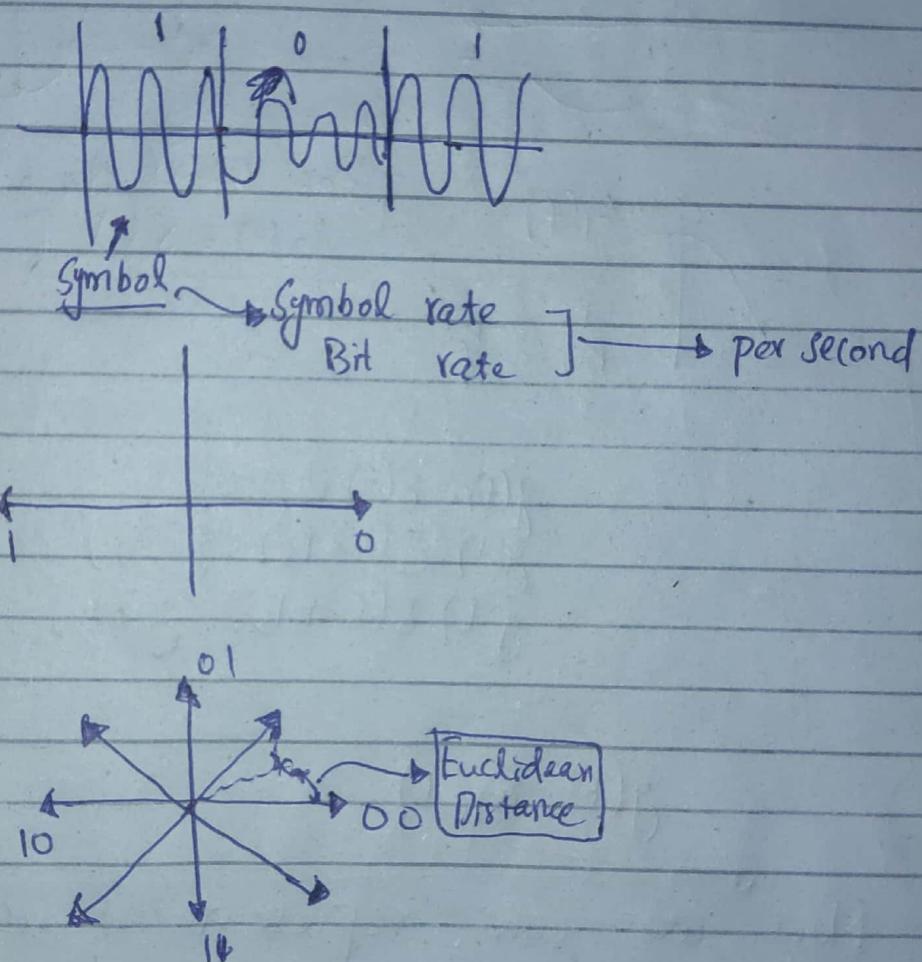
$$\Delta \phi = 5 + 10 = 15 \text{ radians}$$

$$B_{EM} = 2(\Delta f + B_m)$$

Com Sys Part (2) :-

Date 27/12/2023

Analog to Digital Conversion:-



Now at receiver's end, it's difficult to determine the signals.

By increasing Symbols, error rate also increases.

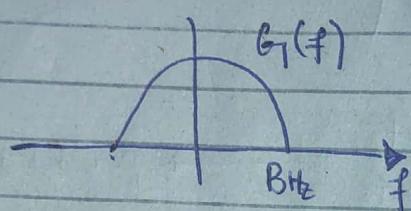
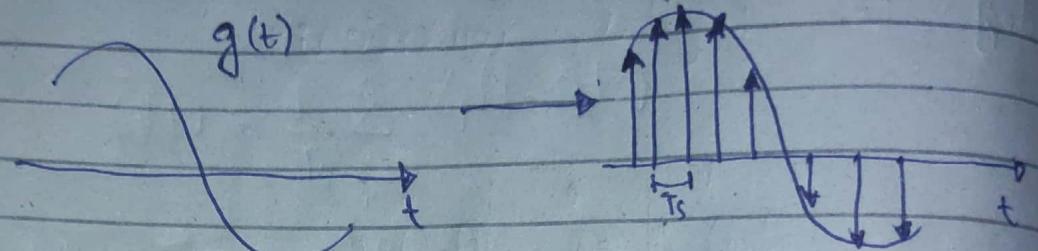
Digital Information:-

- can be stored
- can be compressed.

* Sampling :-

$$f_s \geq 2B$$

Then signal can be reconstructed (ideal chan)



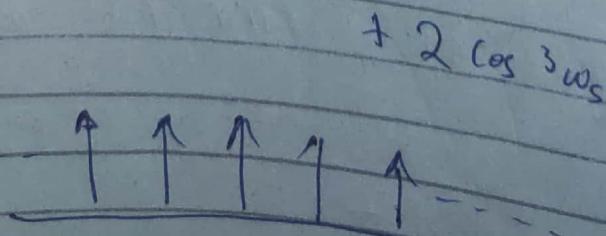
For ideal channel
 $h(t) = \delta(t)$

$$\begin{aligned} g(t) \cdot \delta(t) &= g(0) \\ g(t) \cdot \delta(t - T_s) &= g(T_s) \\ g(t) \cdot \delta(t - nT_s) &= g(nT_s) \end{aligned}$$

$$g(t) \cdot \delta_{T_s}(t)$$

Now we can represent it as Fourier series

$$\delta_{T_s}(t) = \frac{1}{T_s} \left(1 + 2 \cos \omega_s t + 2 \cos \frac{2}{T_s} \omega_s t + \dots \right)$$



$$\delta_{T_s}(t) = \frac{1}{T_s} \sum_n e^{j \omega_s n t}$$

Nyquist Criteria :-

$$f_s = 2B$$

$$f_s = 1/T_s = 2B$$

$$\boxed{T_s = 1/2B}$$

Now we multiply $g(t)$ with $\delta_{T_s}(t)$.

$$\begin{aligned}\bar{g}(t) &= g(t) \cdot \delta_{T_s}(t) \\ &= g(t) \cdot \frac{1}{T_s} \sum_{n=-\infty}^{\infty} e^{jn\omega_s t} \\ &= \frac{1}{T_s} \sum_{n=-\infty}^{\infty} g(t) \cdot e^{jn\omega_s t}\end{aligned}$$

or we can write as

$$\bar{g}(t) = \frac{1}{T_s} \sum_{n=-\infty}^{\infty} g(nT_s) \delta(t - nT_s)$$

$$g(t) \iff G(f)$$

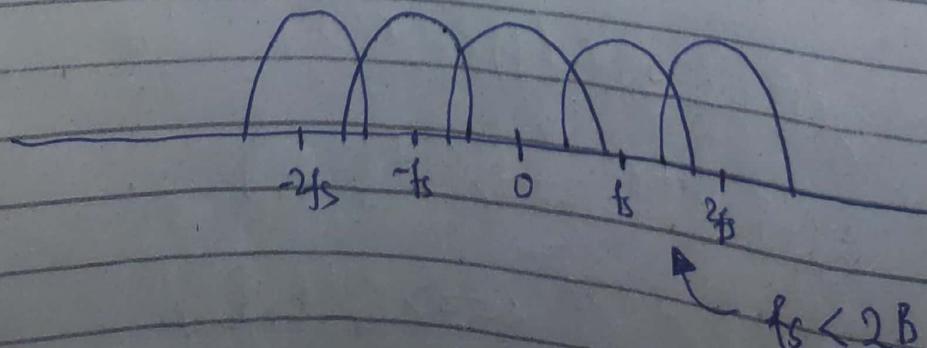
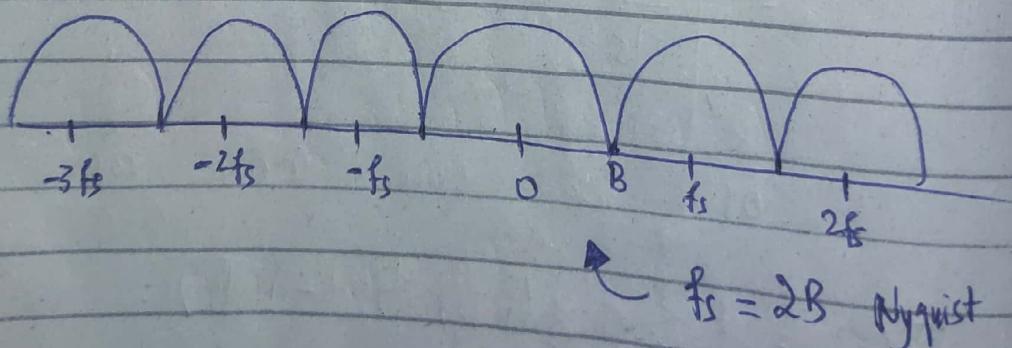
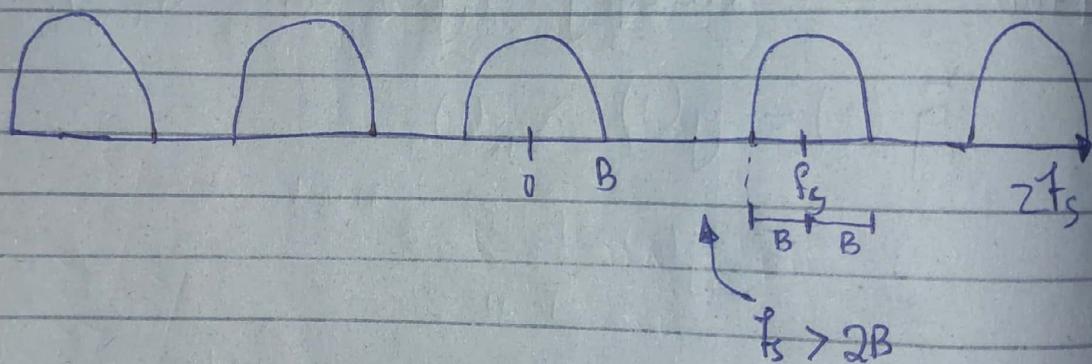
$$g(t) \cdot e^{jn\omega_s t} \iff G(f - f_s)$$

$$g(t) \cdot e^{-jn\omega_s t} \iff G(f + f_s)$$

$$\bar{g}(t) = \frac{1}{T_s} \sum_{n=-\infty}^{\infty} g(t - nT_s) e^{j\omega_n t}$$

$$\bar{G}(f) = \frac{1}{T_s} \sum_{n=-\infty}^{\infty} G(f - n f_s)$$

Now in frequency domain



Signal Reconstruction :-

Use Low Pass Filter

$$H(f) = T_s \operatorname{rect}\left(\frac{f}{2B}\right)$$

or

$$H(\omega) = T_s \cdot \operatorname{rect}\left(\frac{\omega}{4\pi B}\right)$$

From table,

$$\frac{N}{\pi} \operatorname{sinc}(Nt) \Leftrightarrow \operatorname{rect}\left(\frac{\omega}{2N}\right)$$

$$\omega = 2\pi B$$

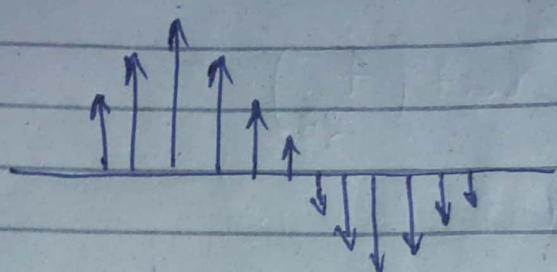
$$\frac{2\pi B}{\pi} \cdot \operatorname{sinc}(2\pi B t) \Leftrightarrow \operatorname{rect}\left(\frac{2\pi f}{4\pi B}\right)$$

$$2B \cdot \sin c(2\pi B t) \Leftrightarrow \operatorname{rect}\left(\frac{f}{2B}\right)$$

Now $h(t) = T_s \cdot 2B \cdot \operatorname{sinc}(2\pi B t)$

↳ [Low Pass Filter Response]

$$g(t) = \sum_{k=-\infty}^{\infty} g(kT_s) \cdot h(t - kT_s)$$



Zero of Sinc :-

$$h(t) = 2B T_s \text{Sinc}(2\pi B t)$$

$$2\pi B t = \pm n\pi$$

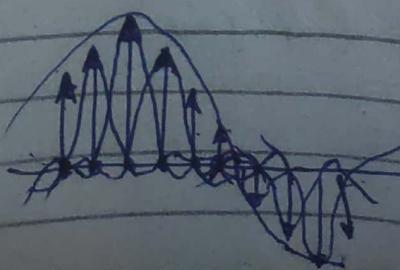
Interpolation
Formula

$$t = \frac{\pm n\pi}{2\pi B} = \pm n \cdot \frac{1}{2B}$$

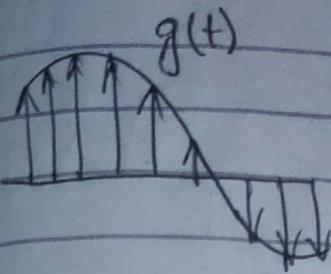
$$g(t) = \sum_{k=-\infty}^{\infty} g(kT_s) \cdot h(t - kT_s)$$

$$= \left[\sum_{k=-\infty}^{\infty} g(kT_s) \cdot \text{Sinc}\left(\frac{\pi}{B}(t - kT_s)\right) \right]$$

Nyquist



28/12/2023



$$f_s = \frac{1}{T_s}$$

$$f_s \geq 2B \text{ Hertz}$$

$$g(t) \cdot \delta(t) = g(0)$$

$$g(t) \cdot \delta_{T_s}(t)$$

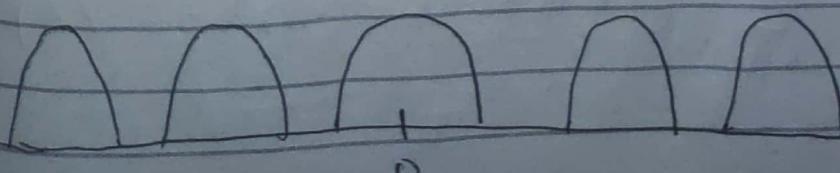
$$\bar{g}(t) = \sum_n g(kT_s) \cdot \delta(t - nT_s)$$

$$\bar{g}(t) = \frac{1}{T_s} \sum_{n=-\infty}^{\infty} g(t) \cdot e^{jn\omega_s t}$$

$$g(t) \Leftrightarrow G(f)$$

$$g(t) \cdot e^{jn\omega_s t} \Leftrightarrow G(f - n f_s)$$

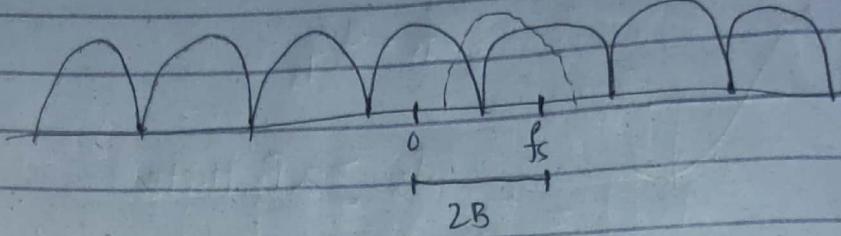
$$\tilde{G}(f) = \frac{1}{T_s} \sum_{n=-\infty}^{\infty} G(f - n f_s)$$



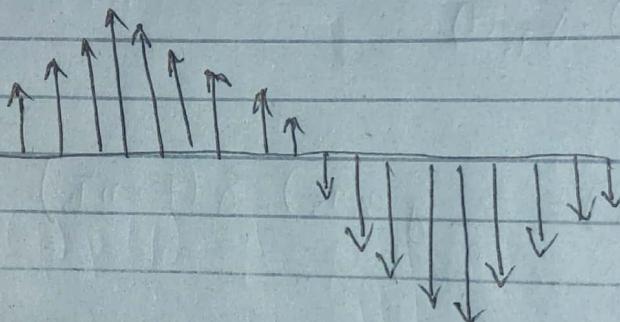
$$f_s < 2B$$

$$f_c > 2B \text{ Hz}$$

$f_s = 2B$ Hz Nyquist
Criteria



$$\text{sinc}(2\pi B t) \longleftrightarrow \text{rect}\left(\frac{t}{2B}\right)$$



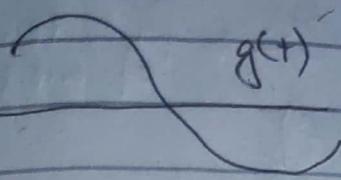
$$\bar{g}(t) \rightarrow h(t) \underline{g(t)}$$

$$\sum_{k=-\infty}^{\infty} g(kT_s) h(t - kT_s).$$

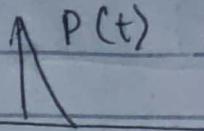
$$\sum_{k=-\infty}^{\infty} g(kT_s) \cdot \text{sinc}(2\pi B(t - kT_s))$$

$$\sum_{k=-\infty}^{\infty} g(kT_s) \cdot \text{sinc}(2\pi Bt - k\pi)$$

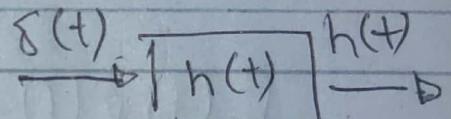
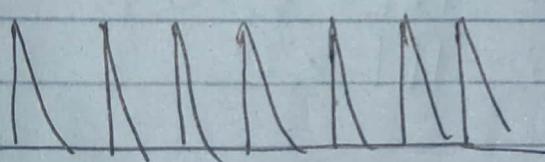
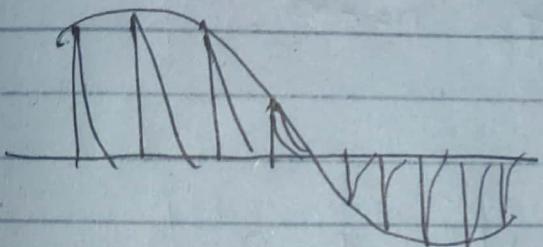
Practical Issues:-



$$g(t) \cdot \delta(t) = g(0)$$



$$\tilde{g}(t) = \sum_{k=-\infty}^{\infty} g(kT_s) \cdot p(t - kT_s)$$



Impulse Response
of system

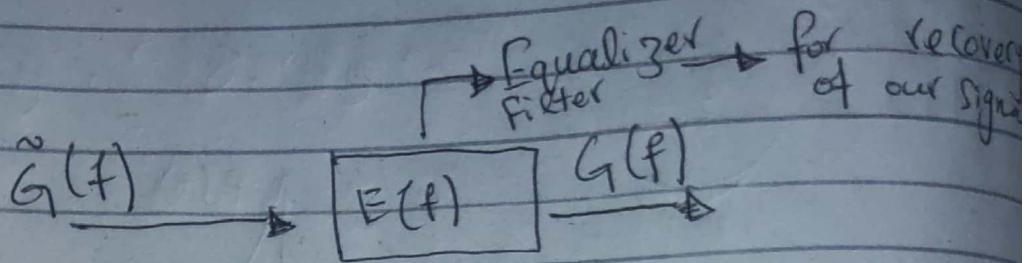
$$\tilde{g}(t) = p(t) * \sum_{k=-\infty}^{\infty} g(kT_s) \cdot \delta(t - kT_s)$$

mathematical representation

$$\tilde{G}(f) = P(f) \cdot \frac{1}{T_s} \left[\sum_{n=-\infty}^{\infty} G(f - n f_s) \right] \text{ Practical case}$$

Now we want to recover our signal.

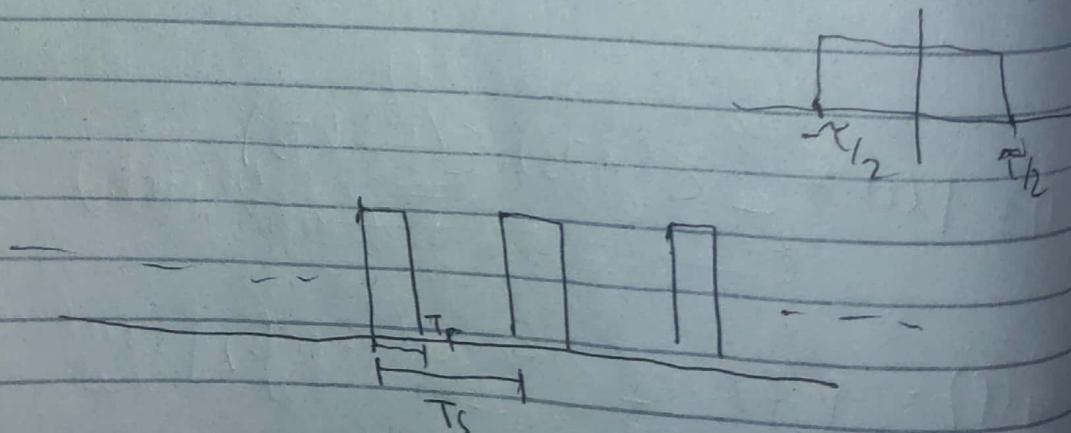
Reconstruction of our Signal :-



$$G(f) = E(f) \cdot \tilde{G}(f)$$

$$G(f) = E(f) \cdot \frac{P(f)}{T_s} \sum_{n=-\infty}^{\infty} g(f - n T_s)$$

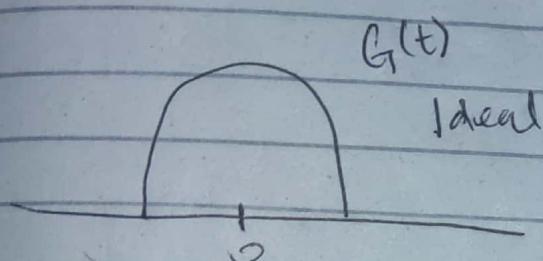
$$E(f) P(f) = T_s \quad |f| = f_s - B \\ 0 \quad |f| > B$$



$$\text{rect} \left(\frac{t - 0.5 T_p - n T_s}{T_p} \right)$$

All signals are time limited.
Hence, it cannot be band limited
Both at same time not possible.

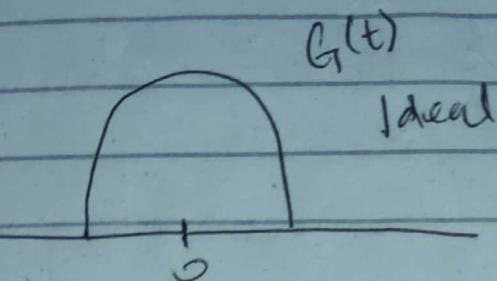
Opposite of ~~above statement 1~~
B possible.



All signals are time limited.
Hence, it cannot be band limited

Both at same time not possible.

Opposite of ~~above~~ statement 1
is possible.



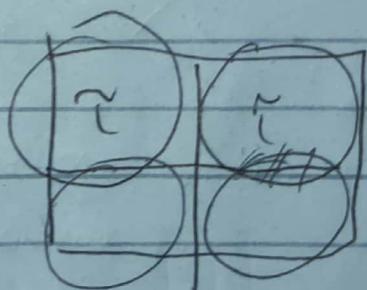
Date 11/11/2023

Hexagon \rightarrow allow no free space

Towers in cells.

called microcells.

radius
500 m - 1 km



Basic switching circle

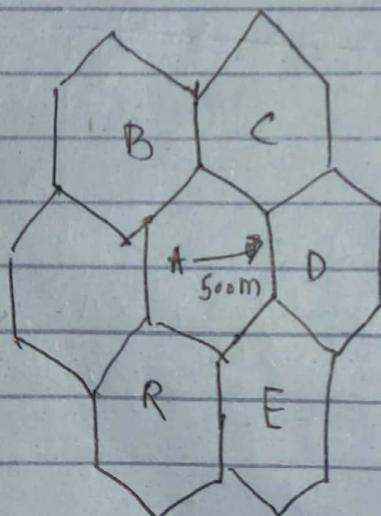
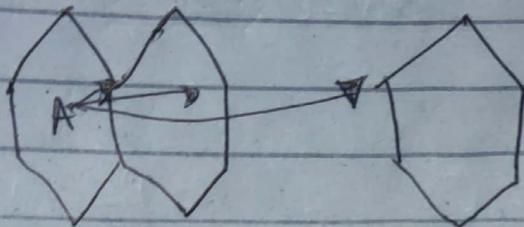
$$P_8 \propto \frac{P_T}{d^n} \rightarrow \text{path loss exponent}$$

lies b/w For eg in LSB
2-4 (3-5)

Frii's Equation

$$Pr \propto \frac{1}{d^2} \rightarrow \text{no multipath}$$

- 80 dBm
- 100 dBm



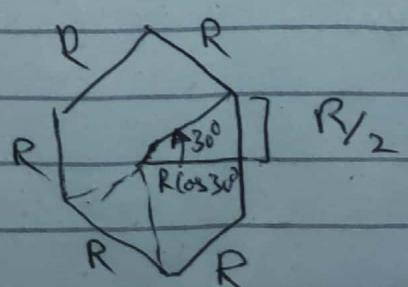
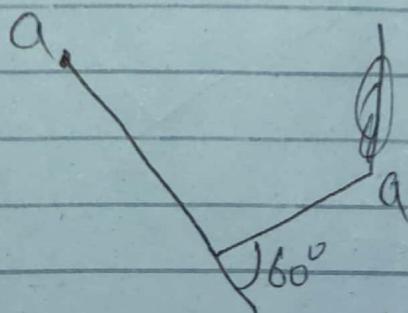
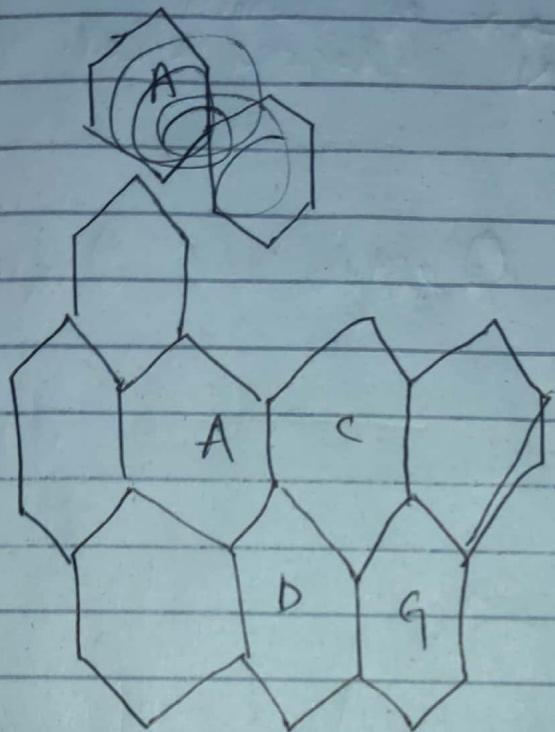
$$\text{cluster size } N = i^2 + ij + j^2$$

i, j cannot be 1, 1

Normally, $N = 7$, for $i=2, j=1$

$N=4$ is valid but doesn't obey formula.

For Finding Co-cell :-



Area of hexagon

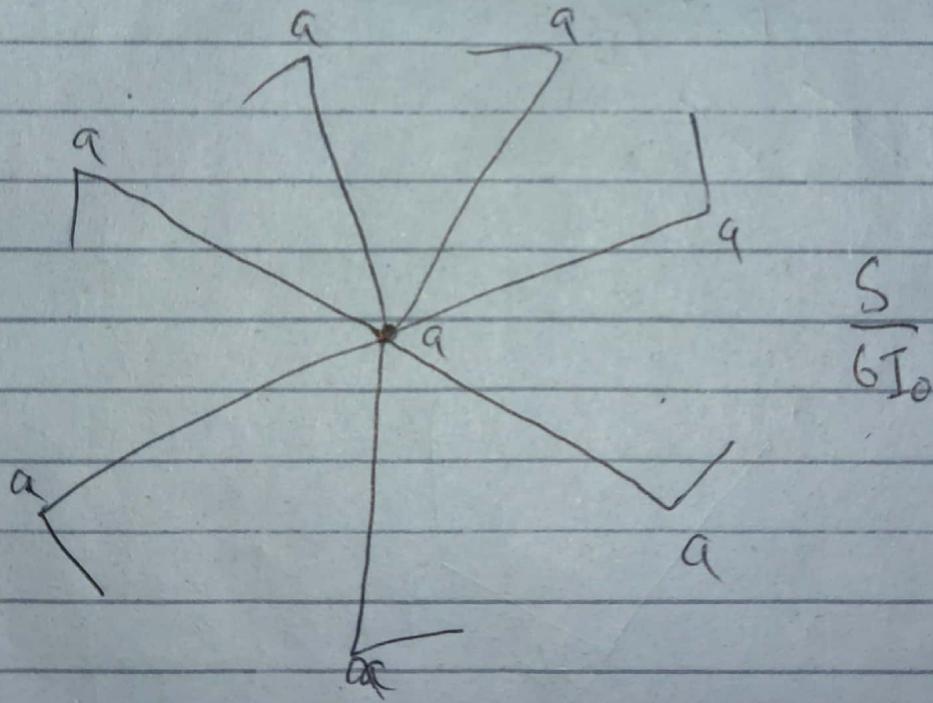
$$12 \times \frac{R}{2} \times R \cos 30^\circ$$

~~void myfunc()~~

$S \rightarrow$ no. of channels in
a cluster

$S = KN$ \rightarrow no. of channels
allocated to cell.

trade off: b/w Quality and Capacity



$$\Delta = 10 \text{ dBm} - 5 \text{ dBm}$$

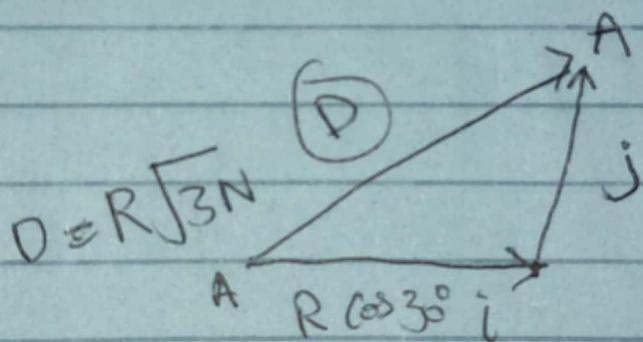
$$\Delta = 5 \text{ dB}$$

struct sigaction act,
act.sa_handler = myfunc;

sigaction(SIGCHLD, &act, NULL);

Sigemptyset(&set);

only two
signals ← can be blocked
Sigfillset(SIG_BLOCK, &set, NULL);

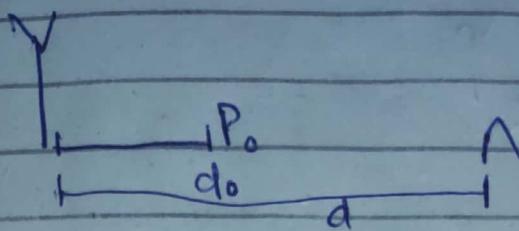


$$D = \sqrt{(R \cos 30^\circ i)^2 + (j)^2 + 2(R \cos 30^\circ i)(j) \cos(\theta)}$$

Dwell time B random.

VLR
HLR

$n \rightarrow$ varies from place to place



$$P_0 \propto \frac{P_T}{d^n}$$

$$P_r \propto \frac{P_T}{d^n}$$

$$P_0 = \text{const. } \frac{P_T}{d_0^n}$$

$$P_r = \text{const. } \frac{P_T}{d^n}$$

~~BOB~~

$$\frac{P_r}{P_0} = \frac{1/d^n}{1/d_0^n}$$

$$P_r = P_0 \left(\frac{d_0}{d} \right)^n$$

$$P_r \Big|_{dBm} = P_0 \Big|_{dBm} + 10 n \log \left(\frac{d_0}{d} \right)$$

Sensitivity \rightarrow Min received power at vertex of hexagon.

$(10^{\frac{d}{10}})$ for conversion to linear scale.

$$P_r = -100 \text{ dBm}$$

When P_r is sensitivity then $d=R$.

$$P_r = P_o \left(\frac{d_o}{d} \right)^n$$



$\text{MSC} \rightarrow$ Mobile Switching Centre.

Intersystem handover \rightarrow ~~between~~ handover

b/w MSCs.

initial call \rightarrow when channel is assigned

Priority policy \rightarrow Some channels are reserved for handover.

cell dragging: \rightarrow drag the cell along with you.

1-2 sec \rightarrow minimum time for handoff.

$$\log_{10} \left(\frac{1000 \text{ W}}{1 \text{ W}} \right) = 30 \\ (10^{\frac{30}{10}})$$

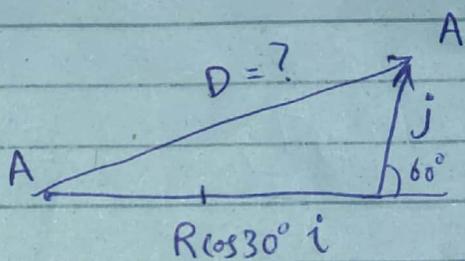
intra sys handover \rightarrow handover from one sys to another sys

$\Delta = \frac{P_{HO}}{P_{min}}$ must be greater than 1.

$$\Delta = 0 - 6 \text{ dB}$$

Q 2-6

$$D = \sqrt{R^2 (\cos 30^\circ i^2 + j^2)}$$



$$D = R \sqrt{3N}$$

$$N = i^2 + j^2$$

Quality factor $\leftarrow \frac{D}{R} = \sqrt{3N}$

$$\frac{S}{I} = \left(\frac{D}{R} \right)^n$$

$$\frac{S}{I} = \frac{R^{-n}}{D^{-n}}$$

Q $\log_{10} 10^{-10}$

$$10 \times (-10) \log_{10} 10$$

$$SNR = S_{dBm} + N_{dBm}$$

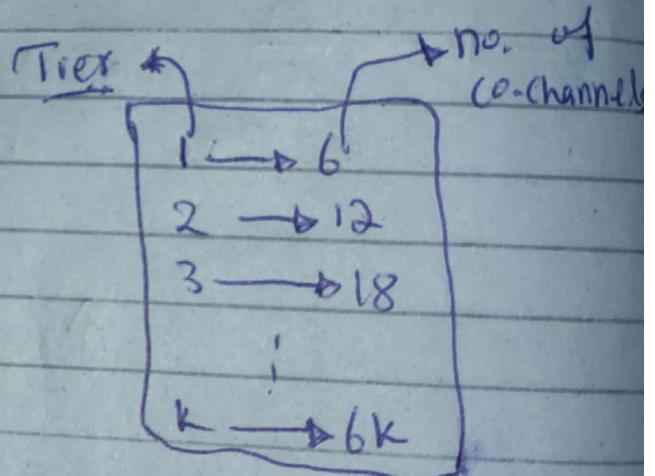
$$SNR = 0 \text{ dBm} + 100 \text{ dBm}$$

$$SNR = +100 \text{ dBm}$$

$$D_K = K D$$

$$\sum_{k=1}^K 6 \cdot k \cdot D^n$$

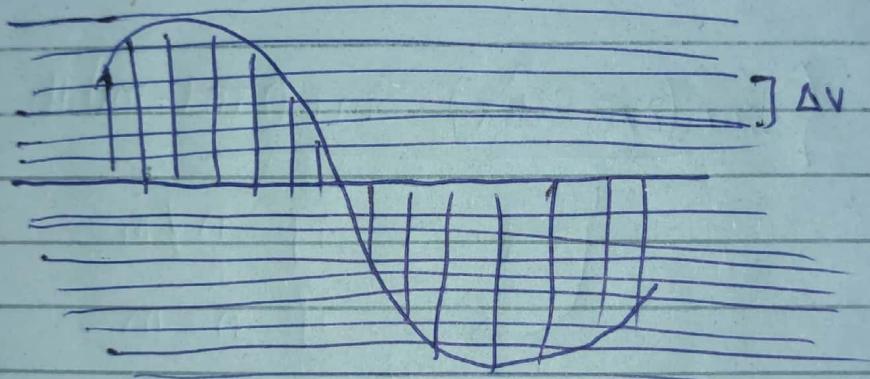
Adjacent
channel
interference



PCM

$$\sum_n g(1-nfs)$$

$$g(t) = \sum_{m(t)} m(kTs) \operatorname{sinc}(2\pi Bt - kx)$$



$$\Delta V = \frac{2 m_p}{L} \rightarrow \text{No. of levels}$$

Quantization noise

$$q_v(t) = \hat{m}(t) - m(t)$$

$$q_v(t) = \sum_k [\hat{m}(kTs) - m(kTs)] \operatorname{sinc}\left(\frac{2\pi B t}{kx}\right)$$

Now

$$\hat{m}(t) = \sum_k \hat{m}(kTs) \operatorname{sinc}\left(2\pi B t - kx\right)$$

$$q_v(t) = \sum_k q_v(kT_s) \cdot \text{sinc}(2\pi Bt - k\pi)$$

$$\begin{aligned} P_{q_v} &= \lim_{T \rightarrow \infty} \frac{1}{T} \int_{-T/2}^{T/2} q_v^2(kT_s) \cdot \text{sinc}^2(2\pi Bt - k\pi) dt \\ &= \lim_{T \rightarrow \infty} \sum_k q_v^2(kT_s) \frac{1}{T} \int_{-T/2}^{T/2} \text{sinc}^2(2\pi Bt - k\pi) dt \end{aligned}$$

Now pop. of sinc is

$$\int \text{sinc}(2\pi Bt - \frac{n\pi}{B}) \cdot \text{sinc}(2\pi Bt - m\pi) dt$$

→ 0 if $n \neq m$
 → $\frac{1}{2B}$ if $n = m$

$$P_{q_v} = \frac{1}{2BT} \sum_k q_v^2(kT_s)$$

We are going to transmit voice signal.

$$f = 4 \text{ kHz}$$

$$f_s = 8 \text{ kHz}$$

$$\Delta V = 2 \text{ mP}$$

$$\tilde{q}^2 = \frac{1}{\Delta V} \int_{-\frac{\Delta V}{2}}^{\frac{\Delta V}{2}} q^2 dq$$

$$II = \frac{1}{\Delta V} \frac{q^3}{3} \Big|_{-\frac{\Delta V}{2}}^{\frac{\Delta V}{2}}$$

$$II = \frac{1}{\Delta V} \frac{1}{3} \left(\frac{(\Delta V/2)^3}{8} - (-\Delta V/2)^3 \right)$$

$$II = \frac{1}{3 \Delta V} \left(\frac{\Delta V^3}{8} + \frac{\Delta V^3}{8} \right)$$

$$II = \frac{1}{3 \Delta V} \left(\frac{\Delta V^3}{4} \right)$$

$$II = \frac{\Delta V^3}{12 \Delta V} = \boxed{\frac{\Delta V^2}{12}}$$