Finals Course

→ **Distortion less transmission** ~

$g(t) \rightarrow \boxed{h(t)} \rightarrow$ $y(t) = g(t) * h(t)$

$Y(\omega) = G(\omega) \cdot H(\omega)$

→ Delay ✓

→ same frequency attenuation.

$y(t) = k\,g(t - t_d)$

$Y(\omega) = k\,G(\omega)\,e^{-j\omega t_d}$

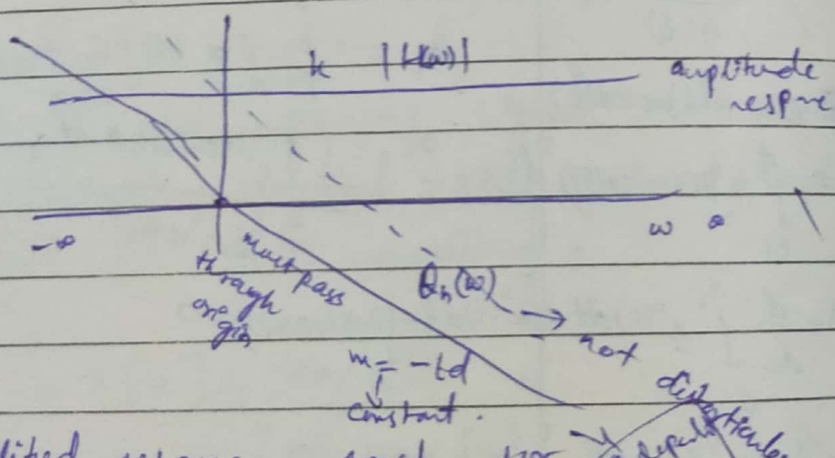
$H(\omega) = \underset{\text{magnitude}}{k}\,e^{-j\omega t_d}$

$\theta_h(\omega) = -\omega t_d$

$\frac{d\theta_h(\omega)}{d\omega} = -t_d$

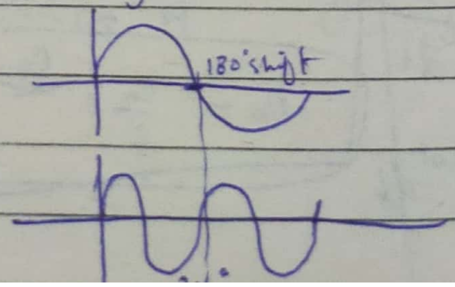
{ delay possible but shape not change.

→ every freq component delay with same Q



→ amplited respone const for all freq components. (attentuate with same amount, shape of sig will not change).

→ all compenents delay with same (higher freq undergoes more delay).



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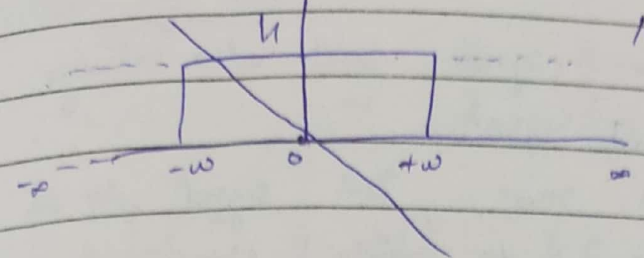
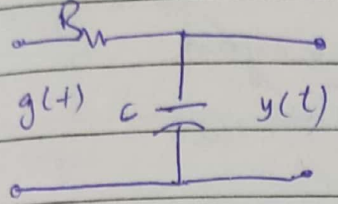
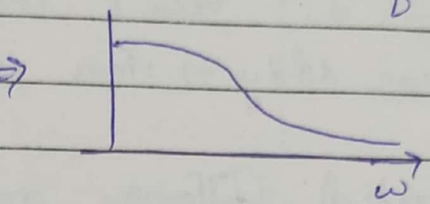
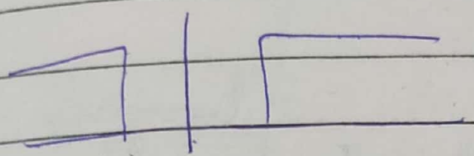


low pass filter (remove some frequencies)
→ allows freq higher that 0.
→ reject higher frequencies.



⇒





high pass filter

→ **Ideal Filters:-**

$-\omega$ to $+\omega$ or $-2\pi B$ to $+2\pi B$.

Constant gain. (all higher frequencies will be rejected)

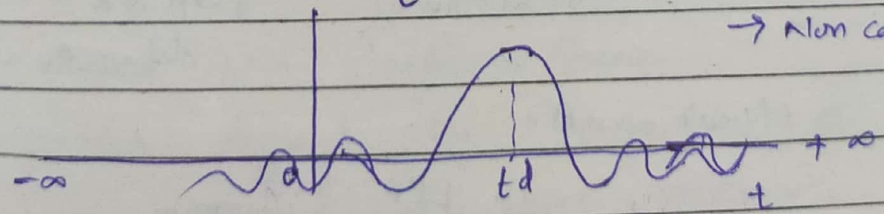
Not exists in reality:

$$H(\omega) = \text{rect}\left(\frac{\omega}{2w}\right)e^{-j\omega t_d}$$

→ variation independent of frequency. $\text{rect}\left(\frac{t}{\tau}\right)$

$$h(t) = \frac{w}{\pi}\,\text{sinc}\left[w(t-t_d)\right]$$

→ Non casual



→ non-casual never exist in history.

→ removes components before 0.

$$h^{u}(t) = h(t).u(t)$$

$$u(t) = 0 \quad t < 0$$

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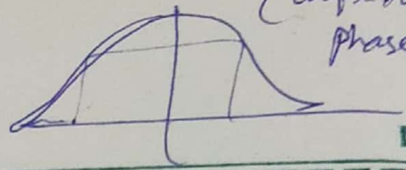


(amplitude + phase → change)

M T W T F S — DATE:

→ freq domain signal will also change.
(not a rect signal

→ If t_d is more, the signal will be more approximated to ideal signal.

→ $t_d \to \infty$, becomes ideal again.
↳ more delay → slows system.

Practical Filters:-

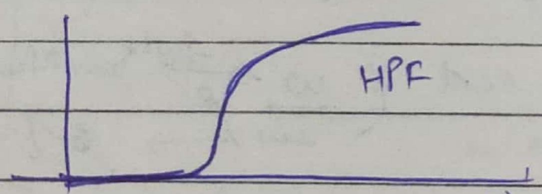
1) → Butterworth Filter:-

→ For lower freq, it will attenuate signal

$$|H(\omega)| = \frac{A_0}{\underbrace{\sqrt{1+(\omega_0/\omega)^{2n}}}_{B}}$$

if $\omega = 0$, $B = \infty$, $\Rightarrow 1/\infty = 0$

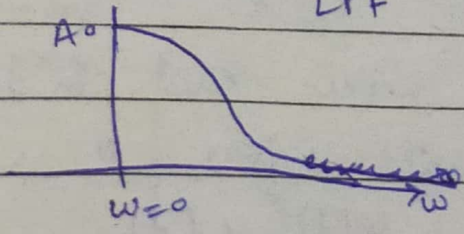
$|H(\omega)| = 0$



$$H(\omega) = \frac{A_0}{\sqrt{1+(\omega/\omega_0)^{2n}}}$$

If $\omega = 0$
denominator = 1

$H(\omega) = A_0$



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1 + 2

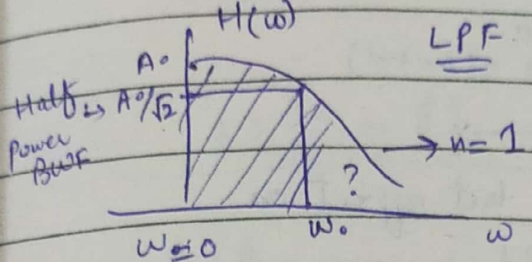
M T W T F S DATE:

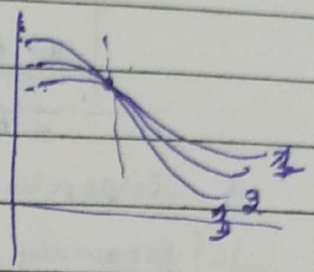
Values of n :-

n = 1 first order BWF.

n = 2 2^{nd} order BWF ..

⋮ ⋮





→ increasing n → more approximated to ideal.

Assignment :-

→ draw BWF for diff values of n in MATLAB. (vary ω from 0 → ∞)

→ write note on ideal & practical filters.

→ Bodes Plot :

n = 1. −20 db/decade , n = 2, −40 db/decade

n = ∞ , ∞/decad.

→ Linear Distortions :-

→ Nonlinear Distortions :- (will not discuss)

→ $y(t) = a_0 + a_1 g(t) + a_2 g^2(t) + \dots + a_n g^n(t)$.

derived from Maclaurins Theorem.

→ * distortion caused by imperfection of magnitude or phase response :

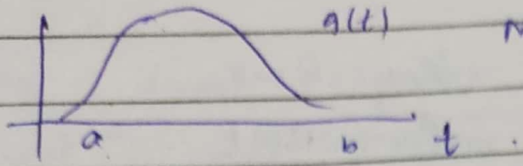
→ * Linear distortion is due to dispersion (time)

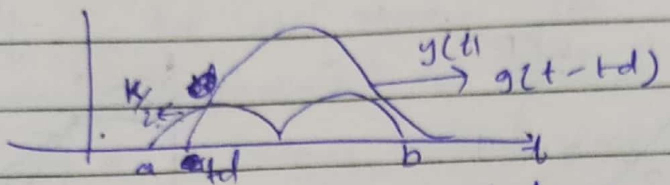
* diff signal b/w ...

then they give a signal b/w a & b and nullified other components.

M T W T F S DATE:

Marvellous balancing act



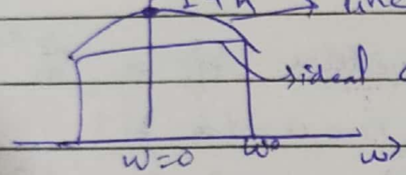


→ dispersion in time but affect on frequency domain.

$$H(\omega) = \underbrace{(1 + k\cos T\omega)}_{mag}\ \underbrace{e^{-j\omega t_d}}_{angle} \rightarrow slope$$

→ amp varies by cosine,

1+k → linear distortion (response)



$$H(\omega) = (1 + k\cos T\omega) e^{-j\omega t_d}$$

$$= e^{-j\omega t_d} + k\cos T\omega\ e^{-j\omega t_d}$$

$$Y(\omega) = G(\omega) e^{-j\omega t_d} + G(\omega)\frac{k}{2} e^{-j\omega(T - T_d)} + G(\omega)\frac{k}{2} e^{-j\omega(T + T_d)}$$

$$y(t) = g(t - t_d) + \frac{k}{2} g(t + T - t_d) + \frac{k}{2} g(t - T - t_d)$$

⇝ Linear distortion in Time & Frequency

→ in time domain → in form of signal dispersion

In time domain, 3 Terms.

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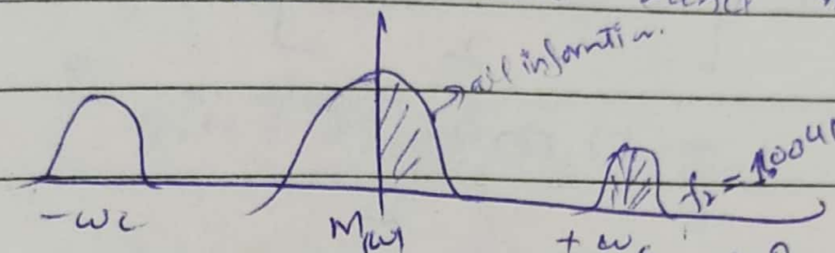
1) DSB: double side band modulation

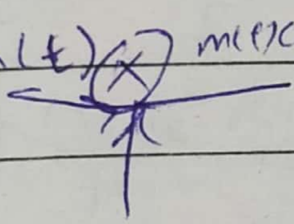
Amplitude modulation



$B = 4kHz$

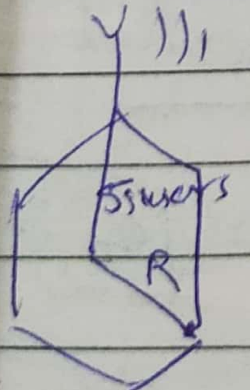
figure.

2)

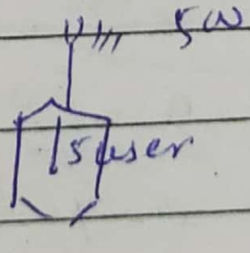


$$\Rightarrow \frac{1}{2} M(\omega+\omega_c) + \frac{1}{2} M(\omega-\omega_c)$$

→ modulation and demodulation can be done with same signal.



→



⇒ to reduce region/size of hexagon, power should be reduced

⇒ More antenna will be used

frequency can be reuse.

M T W T F S DATE:

demodulation example :-

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

$$\uparrow \cos\omega_c t$$

→ open formula.
→ write in exponential.

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

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

$$\frac{mt}{2} + \frac{m(t)}{2}\left[\frac{e^{j2\omega_c t}+e^{-j2\omega_c t}}{2}\right]$$

$$\frac{m(t)}{2} + \frac{m(t)\,e^{j\omega_c t}}{4} + \frac{m(t)\,e^{-j\omega_c t}}{4}$$

$$= \frac{M(\omega)}{2} + \frac{M(\omega+2\omega_c)}{4} + \frac{M(\omega-2\omega_c)}{4}$$

If pass through low pass filter, last two terms will be omitted

$$\frac{1}{a+j\omega} \times \frac{a-j\omega}{a-j\omega}$$

$$\frac{a-j\omega}{a^2+\omega^2}$$

$$\boxed{\frac{a}{a^2+\omega^2} - j\frac{\omega}{a^2+\omega^2}}$$

$$G(\omega) = \sqrt{\left(\frac{a}{a^2+\omega^2}\right)^2 + \left(\frac{-\omega}{a^2+\omega^2}\right)^2}$$

$$G(\omega) = \sqrt{\frac{a^2}{(a^2+\omega^2)^2} + \frac{\omega^2}{(a^2+\omega^2)^2}}$$

$$G(\omega) = \sqrt{\frac{\cancel{a^2+\omega^2}}{\cancel{(a^2+\omega^2)^2}}}$$

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Modulation :- a process that cause[illegible] the range of frequencies in a signal.

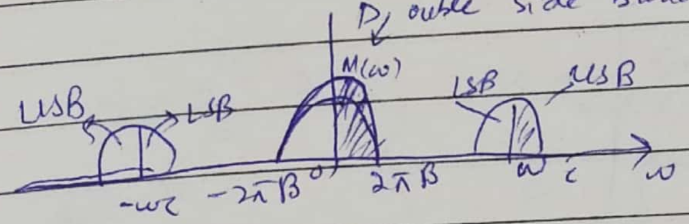
M T W T F S Baseband (doesn't use modul[illegible]) Communication —— Carrier Commun. (uses modul[illegible]) DATE:

Amplitude Modulation :-

$m(t)\cos\omega_c t$.

$m(t) \Leftrightarrow M(\omega)$

Double side band with suppressed carrier



→ Not transmitting carrier signal with this

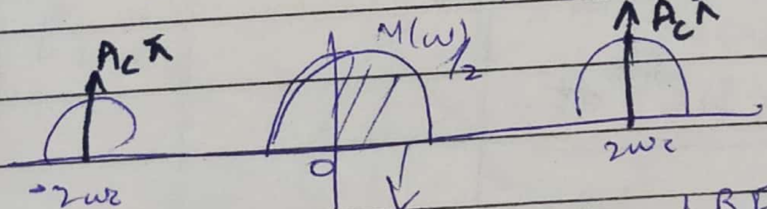
Demodulation :-

mix again with carrier

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

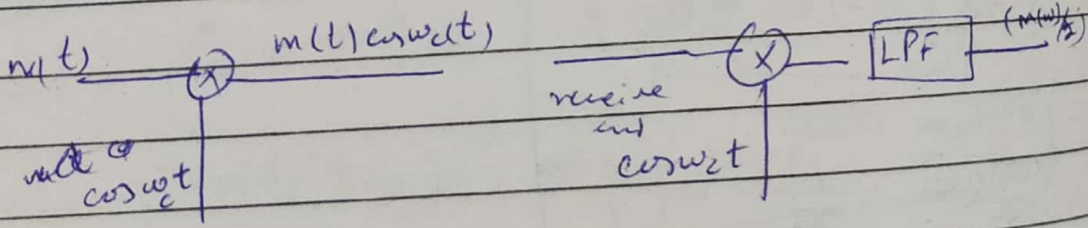
$$\frac{m(t)}{2} + \frac{m(t)\cos 2\omega_c t}{2}$$

$$\frac{M(\omega)}{2} + \frac{M(\omega+2\omega_c)}{4} + \frac{M(\omega-2\omega_c)}{4}$$



fig

pass through LPF, will retrieve original signal.



Coherent detection / synchronize :-

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

$$m(t)\left(\frac{\cos(\omega_c+\omega_c+\Delta\omega)t + \cos(\omega_c-\omega_c-\Delta\omega)t}{2}\right)$$

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* But when ..., there will be some delay

$g(t) = g(t-td) \Leftrightarrow G(\omega) e^{-j\omega td}$

$\theta_h(\omega) = -\omega td$

M T W T F S   DATE:

$= \frac{m(t) \cos(2\omega_c + \Delta\omega)t}{2} + \frac{m(t) \cos \Delta\omega t}{2}$ → damaging

at receiver, initially zero

$= m(t) \cos (\omega_c + \theta_0)$

→ transmitts carrier with signal & then demodulate it to overcome the failure.

$\phi_{AM}(t) = m(t) \cos \omega_c t + A_c \cos \omega_c t$

↓ transmitts modulated signal with carrier signal

DSB = LC

Large carrier amplitude enough that it can ... full ... signal ...

$A_c \frac{(e^{j\omega_c t} + e^{-j\omega_c t})}{2}$

F.T $= 2\pi \delta(\omega - \omega_c)$

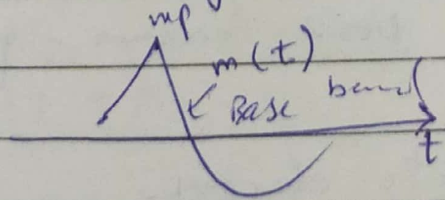
~~Full Amplitude~~ modulation.

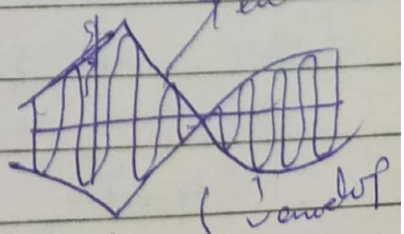
also called

∴ overall figure ⇒ fig

$\phi_{AM}(t) = (mt + A_c) \cos \omega_c t$

→ without sendin carrier with signal represented by,





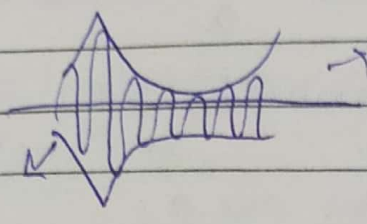
we can't do envelop detection of signal c/z it not representing the original signal

can't do envelop detection

→ For envelop detection all values must positive

M T W T F S DATE:

$m(t) + A_c \geq 0$ for all t. (→ DC component; → constraint of)



→ now envelop to detect original signal.

Coherent detection but of envelop detection

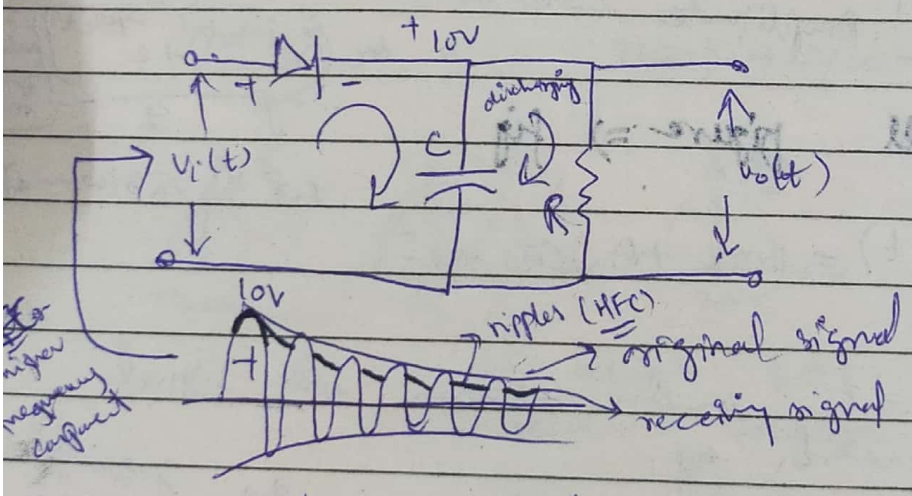
(same signal, carrier)

→ envelop detection → to detect original signal → easy circuitary

b/c more receiver than transmitter

advantage → easy, inexpensive

→ **How we do envelop detection?**



→ More voltage, diode becomes forward bias

→ Capacitor starts charging.

→ it does on peak

→ when input goes down, diode → reverse and act as open circuit, no current flows.

→ it starts discharging.

→ again voltage/amplitude increases, current flows and cycle repeats.

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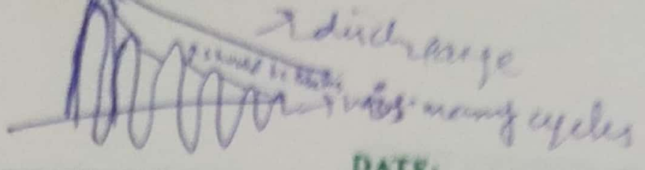
* To ove... RC should be adjusted



M T W T F S DATE:

→ RC time constant $e^{-t/RC}$ time constant

→ we can trace envelop here. ½ of discharge (black signal)

> this envelop representing original signal

Ques: Can we send base band over wireless ?

Ans → No, coz base band have very low freq and high (λ), so antenna length will be greater that is impossible

Ques 2 $m(t) = \cos(1000)t$

$v_c(t) = \cos(10000t)$

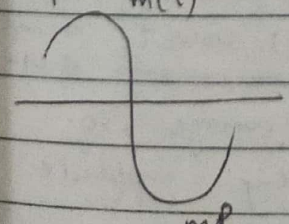
$\omega_m = 1000$

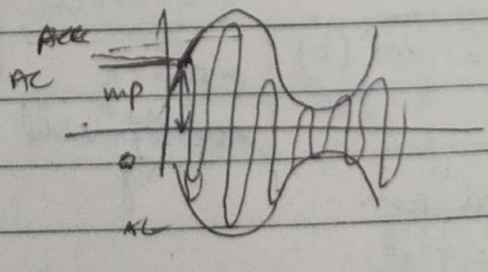
$f_m = \frac{1000}{2\pi}$

Lecture # →

Modulation Index →

$m(t) + A_c \geq 0$ Constraint equ





all values should be +, for envelop detection,

$\mu = \frac{m_p}{A_c}$ → Peak amplitude

→ P.A of carrier signal

$\mu < 1$

for ~~...~~, $A_c > m_p$ (must greater)

if less than, over modulation

$$\boxed{0 \le \mu \le 1}$$

Modulation index

let suppose $\mu > 1$,

Condition of overmodulations. ⇒ $\boxed{m_p > A_c}$

⇒ Power Efficiency of DSB-LC.

we are occupying double band for single,

$$\phi_{AM}(t) = \underbrace{m(t)\cos w_c t}_{\text{useful sig}} + \underbrace{A_c \cos w_c t}_{\text{Additional}}$$

→ additional sig will facilitate signal but not part of original signal.

Additional power

$$\boxed{P_c = \frac{A_c^2}{2}}$$ ← power of carrier signal

$$\boxed{P_s = \frac{m^2(t)}{2}}$$ ← power of modulated sig

useful power

$\boxed{m(t).\cos w_c t}$ ↓ find average, so finding amplitude of $\cos w_c t$.

suppose m_t = amplitude of cos

M T W T F S DATE:

$$\text{Efficiency} = \eta = \frac{\text{useful power}}{\text{Total power}} = \frac{P_s}{P_c + P_s}$$

$$\eta = \frac{m^2(t)/\cancel{2}}{A_c^2/\cancel{2} + m^2(t)/\cancel{2}} = \frac{m^2(t)}{A_c^2 + m^2(t)}$$

power efficiency of signal

In percentage:

$$\eta\% = \frac{m^2(t)}{A_c^2 + m^2(t)} \times 100$$

If $m(t)$ is a Tone signal; (signal of same frequency)

impulse signal → 1 freq ($\cos w_c t$), f_c → single frequency. composite signal → f_1 f_2 multiple freq

$m(t) = m_p \cos w_m t = \frac{m_p^2}{2}$

$= \frac{\mu^2 A^2}{2}$

$\mu = m_p/A$

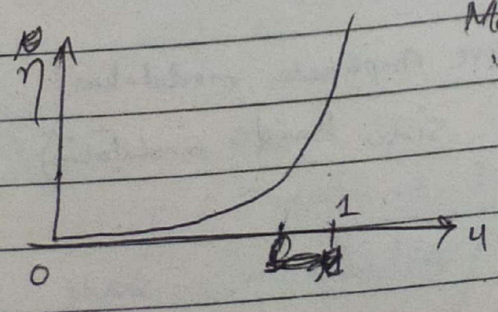
$\Rightarrow m_p = \mu A$

$$\eta = \frac{\mu^2 \cancel{A_c^2}/2}{\cancel{A_c^2} + \mu^2 \cancel{A_c^2}/2} = \frac{\mu^2}{2+\mu^2}$$

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

, percentage of performance of power

Graphically representation:



Mathematically increasing function

∴ $\boxed{\text{MATLAB}}$

∴ increasing efficiency

$\mu = 0.5, \eta = 11.1\%$ $\mu = 0.25, \eta = 4.5\%$

M T W T F S DATE:

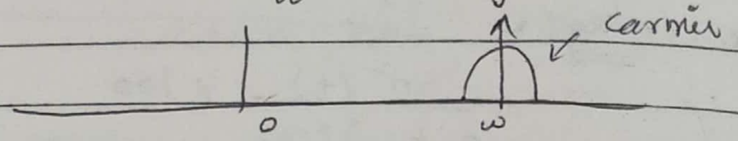
$$\eta = \frac{1}{1+2} \times 100 = 33.3\ \%$$

→ 66.66% utilize by carrier signal itself.

$\varphi_{AM}(t) = m(t) \cos \omega_c t$ (33.33%) $+ A_c \cos \omega_c t$ → 66.66

→ Not a power efficient system.

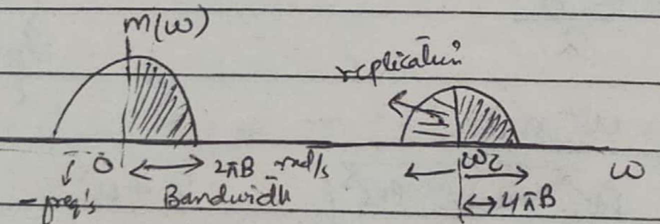
definition

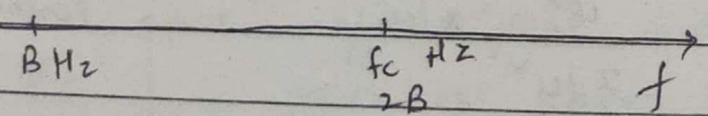


Assignment:-

Note on Modulation index.
and implementation in Matlab:-

→ # Bandwidth Efficiency:-





Not Bandwidth efficient coz wasting band.

Methods:-

* QAM (Quadrature Amplitude modulation)
* SSB (single side Band modulation)

M T W T F S DATE:

→ QAM:-

→ orthogonal signals, correlation zero.

→ can be separated

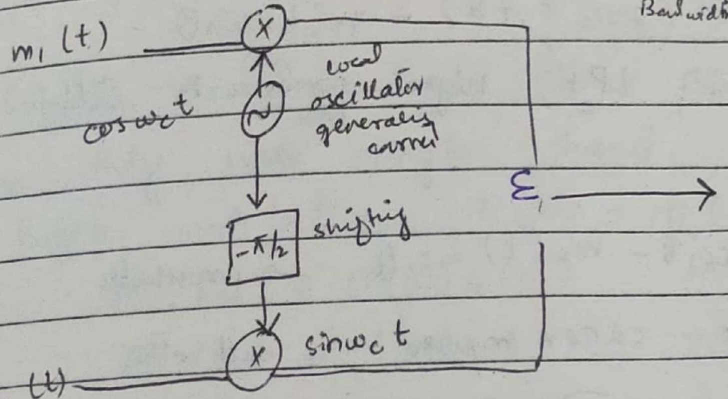
for example; $\cos\omega_c t$, $\sin\omega t$, lie in single frequency but can be separated as orthogonal. (not mix with each other)

Demodulation.

$$\phi_{QAM}(t) = [m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t] \cdot 2\cos\omega_c t$$

division/2 will cancel out, gain original signal

Bandwidth centered on ω_c.



formula:

$$\Rightarrow \phi_{QAM}(t) = 2m_1(t)\cos^2\omega_c t + m_2(t) \cdot \sin 2\omega_c t.$$

$$= m_1(t) + m_1(t)\cos\omega_c t + m_2(t)\sin 2\omega_c t.$$

Passing all through LPF,

$M_1(\omega)$ → I-phase

$$\Rightarrow \phi_{QAM}(t) = [m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t] \cdot 2\sin\omega_c t$$

LPF

$= M_2(\omega)$ → Q-Phase

→ in phase modulation / demodulating.

→ I-phase / ($M_1(\omega)$

$\cos(\omega_c t + \theta)$

in Demodulation,

$\phi_{QAM} = [m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t]\, 2\cos(\omega_c t+\theta)$

$= m_1(t) 2\cos\omega_c t \cdot \cos(\omega_c t+\theta) + 2m_2(t)\sin\omega_c t \cdot \cos(\omega_c t+\theta)$

$m_1(t) \cdot 2\cos(2\omega_c t + \theta) + m_1(t)\cos\theta$.

$m_2(t)\sin(2\omega_c t + \theta) + m_2(t)\sin\theta$.

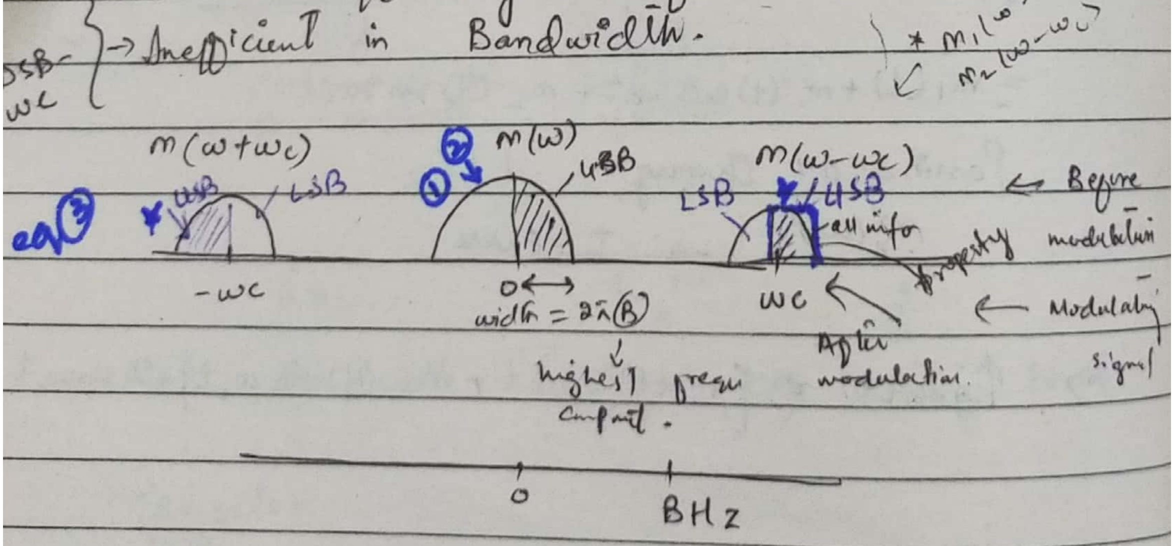
After passing LPF, higher frequencies will ignore.

$\rightarrow m_1(t)\cos\theta - m_2(t)\sin\theta$. $\rightarrow$ crosstalk

↳ Both are super imposed on each other.

DSB-SC
→ Power inefficiency even for $\mu = 1$

SSB-WC
→ Inefficient in Bandwidth.



→ half band is going to lost.

Solutions:

↳ Quadrature Amplitude Modulation

↳ dual signal in same band.

→ not losing any band

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Generat...
* QAM
* phase shift method
* Frequency Selective Filtering

$m_1(t) \Leftrightarrow M_1(\omega)$ ✓ one signal

$m_2(t) \Leftrightarrow M_2(\omega)$ → second signal

Both signals are in same band but orthogonal to each other and can be distinguished and at receiver end, original signal can be recovered.

$m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t$

2) Solution → Single Side Band Modulation -

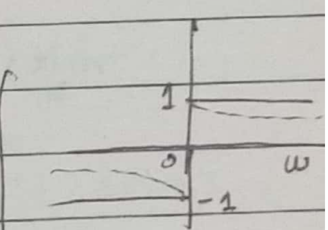
uses only single band.

* Before modulation - $M(\omega) = M_+(\omega) + M_-(\omega)$

$M_+(\omega) = M(\omega)u(\omega)$ → casual

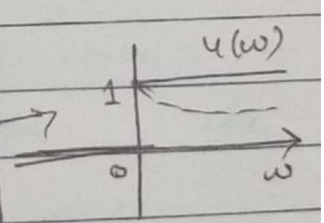
$M_-(\omega) = M(\omega)u(-\omega)$ → Non casual.

* $M_+(\omega) = M(\omega)\left[\dfrac{1+\text{sgn}(\omega)}{2}\right]$



⇝ $M_+(\omega) = \dfrac{M(\omega)}{2} + \dfrac{M(\omega)\,\text{sgn}(\omega)}{2}$ ~~to put~~ H. Transform

Hilbert Transform -



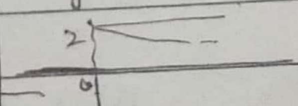
① Const Amplitude responese (unit respon)

② $\pi/2$ phase shifter. (shift every component by 90°)

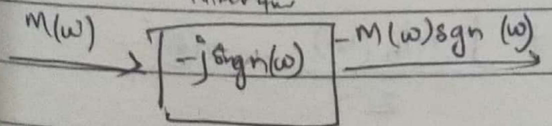
useful for narrow band (wide band ✗)

$H_h(\omega) = -j\,\text{sgn}(\omega)$

① add 1 to signal.



② ~~divid by 2~~



$X(\omega) \rightarrow Y(\omega)$

$Y(\omega) = X(\omega)\cdot H(\omega)$

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x-tion in freq. dom (convolution in time)

$$M_h(\omega) = M(\omega)[-j\,\text{sgn}(\omega)]$$

$$M_h(\omega) = -jM(\omega)\,\text{sgn}(\omega)$$

$$H_h(\omega) \begin{cases} = -j\,\text{sgn}(\omega) = 1e^{-j\pi/2} & \omega > 0 \\ = 1e^{j\pi/2} & \omega < 0 \end{cases}$$

phase shift

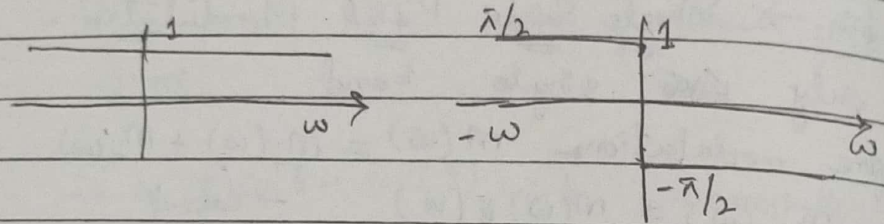
$\omega < 0 \rightarrow \text{sgn} = -1$

$-j \times -1 = j$

phase shift

Amplitude $\rightarrow$ const (1)

phase shift $\rightarrow \pi/2$



Time Domain of Sign :-

$$\frac{1}{\pi t} \Leftrightarrow -j\,\text{sgn}(\omega)$$

$$m_h(t) = m(t) * \frac{1}{\pi t}$$

$$= \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{m(\alpha)}{(t-\alpha)}\, d\alpha$$

∴ introduce dummy var 'α' scroll from $-\infty$ to $+\infty$.

$\boxed{H_h(\omega) = -jM(\omega)\,\text{sgn}(\omega)}$ compare

*** $$M_+(\omega) = \frac{M(\omega)}{2} + \frac{M(\omega)\,\text{sgn}(\omega)}{2}$$

~~To form → (Hilbert form) x & ÷ by '-j'~~

$$\cancel{M_+(\omega) = \frac{M(\omega)}{2} + \frac{-jM(\omega)\,\text{sgn}(\omega)}{2(-j)}}$$

$$M_+(\omega) = \frac{M(\omega)}{2} + \frac{jM_h(\omega)}{2} \rightarrow (1)$$

$$m_+(t) = \frac{m(t)}{2} + \frac{jm_h(t)}{2} \rightarrow (1)$$

M T W T F S   DATE: ____

For $M_-(\omega)$:-

$$m_-(\omega) = m(\omega)\left[\frac{1-\text{sgn}(\omega)}{2}\right]$$

$$M_-(\omega) = \frac{M(\omega)}{2} - jM_h(\omega) \rightarrow ②$$

small m. $m_-(t) = \frac{m(t)}{2} - \frac{jm_h(t)}{2} \rightarrow ②$

We are going to describe modulated signal.

$$\phi_{USB}(\omega) = M_+(\omega - \omega_c) + M_-(\omega + \omega_c)$$

In time domain :-

$$\phi_{USB}(t) = m_+(t)e^{j\omega_c t} + m_-(t)e^{-j\omega_c t} \rightarrow ③$$

put ① and ② in ③

$$= m(t)\left(\frac{e^{j\omega_c t} + e^{-j\omega_c t}}{2}\right) - m_h(t)\left(\frac{e^{j\omega_c t} - e^{-j\omega_c t}}{2j}\right)$$

$$\phi_{USB}(t) = m(t)\cos\omega_c t - m_h(t)\sin\omega_c t.$$

For $\phi_{LSB}(t) = m(t)\cos\omega_c t + m_h(t)\sin\omega_c t$.

$$\phi_{SSB}(t) = m(t)\cos\omega_c t \mp m_h(t)\sin\omega_c t$$

For do & DSB.

$$\phi_{DSB}(t) = m(t)\cos\omega_c t.$$

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Example :-

Let $m(t) = \cos \omega_m t$ → tone signal

Want to do SSB Modulation.

$m_h(t) = \cos(\omega_m t - \pi/2)$ (only 1 freq) $\omega > 0$

$\phi_{USB}(t) = \cos\omega_m t \cos\omega_c t - \sin\omega_m t \cdot \sin\omega_c t$

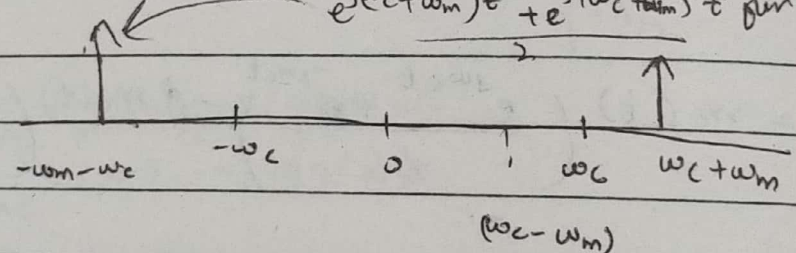
$= \cos(\omega_c + \omega_m) t$

$\phi_{LSB}(t) = \cos\omega_m t \cos\omega_c t + \sin\omega_m t \cdot \sin\omega_c t.$

$$\phi_{USB}(t) = \frac{e^{j(\omega_c+\omega_m)t} + e^{-j(\omega_c-\omega_m)t}}{2}$$

↓ Dirac delta

$\frac{e^{j(\omega_c+\omega_m)t} + e^{-j(\omega_c+\omega_m)t}}{2}$ pun.



DEMODULATION :-

$$\phi_{SSB}(t) = \left[m(t)\cos\omega_c t \mp m_h(t)\sin\omega_c t\right] 2\cos\omega_c t$$

↑ coherent

$= m(t) + m(t)\cos 2\omega_c t \pm m_h(t)\sin 2\omega_c t$

$\phi_{SSB}(\omega) = M(\omega) + M(\omega + 2\omega_c) + M(\omega - 2\omega_c) + \ldots$

Pass through Low Pass Filter

$$\boxed{\phi_{SSB}(\omega) = M(\omega)}$$

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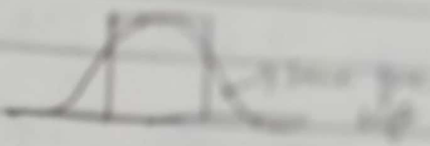
Ways to Generate SSB.

→ Case ①

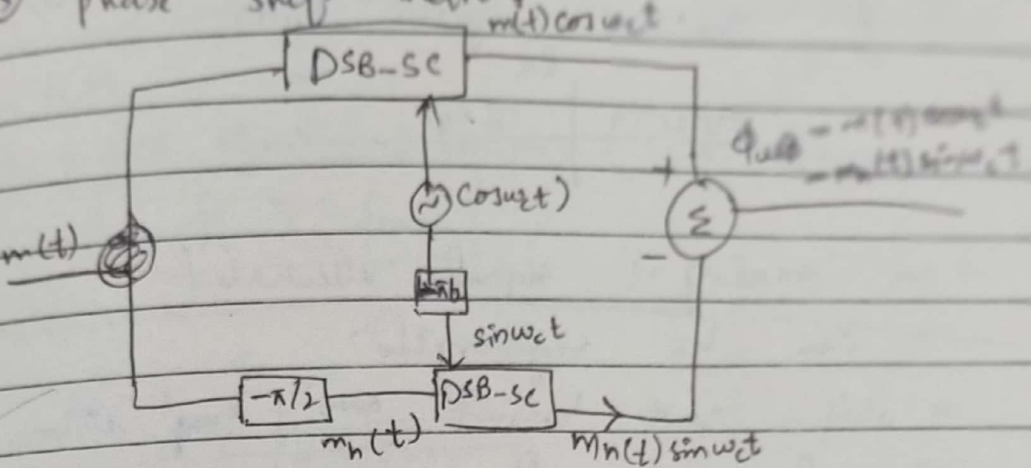
→ ② Frequency selective Filtration.

is unrealizable.

Can't cut sharply all components



③ phase shift method



③ Vestigeal Side Band.

B/w DSB and SSB.

Can implement Through phase

$$\phi_{SSB}(t) = m(t)\cos\omega_c t \mp m_h(t)\sin\omega_c t$$

$$m(t) = \cos\omega_m(t)$$

$$\phi_{SSB}(t) = m(t)\cos\omega_c t - m_h(t)\sin\omega_c t$$

$$m_h(t) = \cos(\omega m\, t - \pi/2)$$

$$= \sin\omega m t.$$

M T W T F S

lecture

DATE:

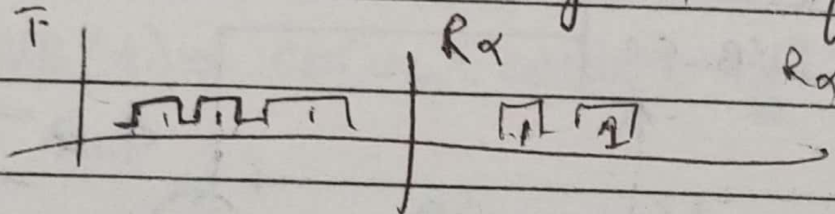
Analog Modulation

⇝ ↳ AM, FM, PM (Analog)

⇝ ↳ PSK, FSK, ASK (digital)

regenerative type (advantage)

→ if transmit digital infor,

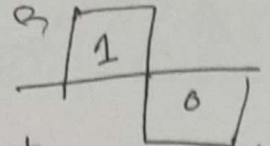


→ in analog signal attenuated, can be regenerated

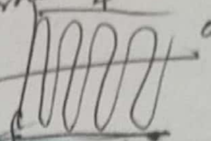
→ dis cant transmit over long distance

→ analog always transmitt

in computer



carrier

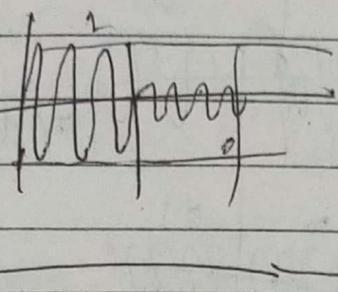


analog transmit

must convert this into analog: Big (can transmit over a long distance)

→ analog bears properties of digital signal.
→ duration of carrier equals to digital.

signal analog but properties like digital

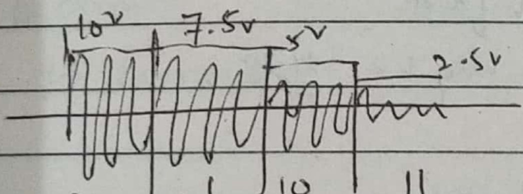


ASK Modulation

through modem convert Digital into Analog.

→ PCM
→ analog signal → samples (sampling theorem

$f_s \geq 2 f_{max}$



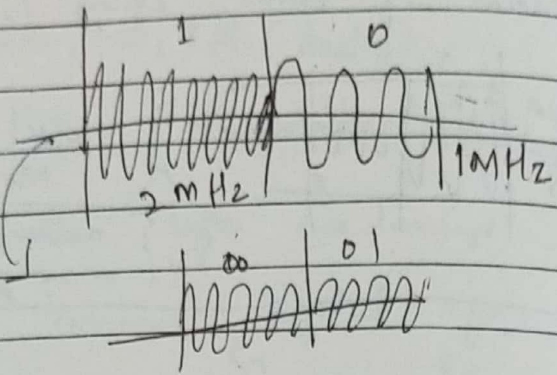
→ 1 symbol → transmits two bits.
→ speed double.
→ duration same.
→ no of bits increases (more bits transmitted)

→ next no of levels $= 2^n = 8$

disadvantage:-
→ difficult to recognize each.
→ error increases → (bit error rate (BER) will be increases)
→ Need more sophisticated and expensive receivers.

as # of symbols increases.

→ Frequency Shift keying :-

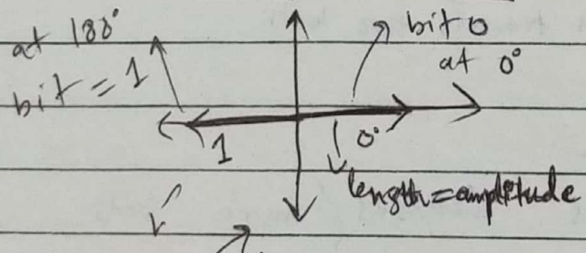


→ Phase Shift Keying :-

to represent detail, may be symbols are shifted.

→ 1 0, other may be 180°.

→ Constellation Diagram :-



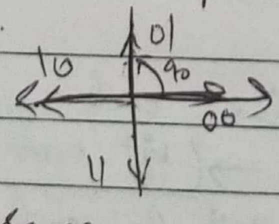
→ amplitude const

→ phase shifted

→ symbols of 2^1.

set 2^2 = 4 symbols

every symbol represented by 90° phase shift.



one symbol carries two bits.

→ bits per second increase,

→ bandwidth increases

→ duration same

→ signal will be analog. (properties 1-1 correspondence with digital)

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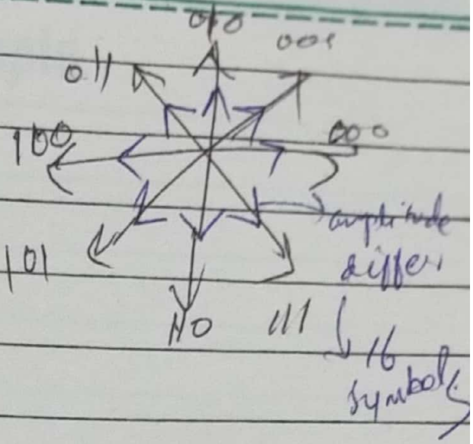
2×6 ... 10

16 symbols carry 4 bits

DATE:

$\rightarrow$ $2^3 = 8 \rightarrow$ symbols



Hybrid Modulation $\rightarrow$

ASK + PSK

$\rightarrow$ ~~Euclid~~ Euclidean distance

at receiver end (match closest point)

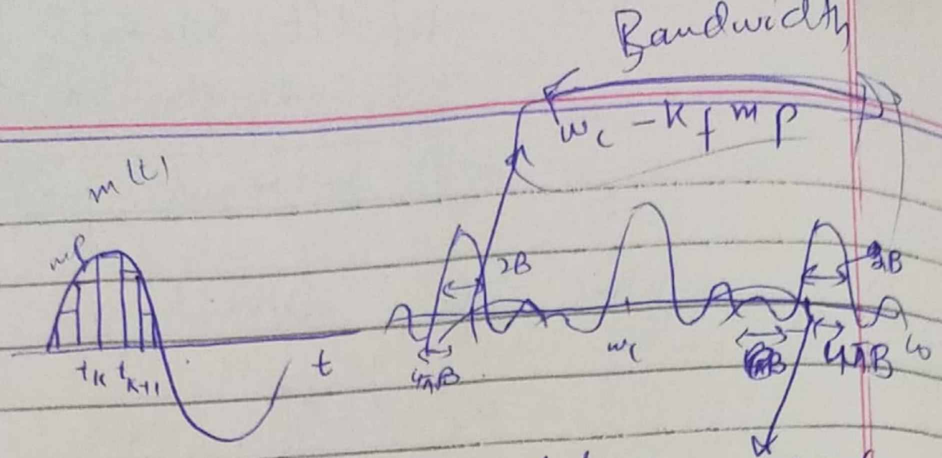
finds short distance (with nearer points)

$\downarrow$

error bites rate increases as points increases on constellation diagram.

$\hookrightarrow$ Retransmit signal $\rightarrow$ error correction.

FM :-



duration $t_{k+1} - t_k = 1/2B$

max fre
$\boxed{\omega_c + k_f m_p}$

$B_s \geq 2B$, $T = 1/2B$

$f_s = 2B$.

$\text{rect}\left(\frac{t}{T}\right) = \text{sinc}\left(\frac{\omega T}{2}\right)$

$$\frac{\omega T}{2} = \pm n\pi$$

$$\omega_o = \pm \frac{2n\pi}{T} \Rightarrow \omega = \pm 2n\pi \times 2B = 4\pi B$$

For FM :-

$\boxed{\omega_c + K_f m(t)}$ Frequency Modulation

carrier signal $\leftarrow A\cos(\underline{\omega_c t} + \theta_o)$

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

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

assume 0

For PM :-

$\omega_c t + \theta_o + k_p m(t)$

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

change in phase

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

$\boxed{\omega_i = \omega_c + k_p \dot{m}(t)}$ (2)

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$\cos w_c t - k_t\, a(t) \sin w_c t$] Narrow Band

Band width = 2B

increasing $m(t)$ increases frequency

→ negative side, subtract from w_c

$$w_i = w_c + k_f m(t_k)$$

$$2\pi B_{FM} = w_c + k_f m_p - w_c + k_f m_p$$

$$B_{FM} = 2\left(\frac{k_f m_p}{2\pi}\right) \rightarrow \Delta f$$

Adding Bandwidth of remaining signal

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

$$= 2[\Delta f + 2B]$$

4πB + 4πB → 2π(2B)

2B + 2B $\boxed{= 4B}$

For narrow Band, more appropriate

$$B_{FM} = 2[\Delta f + B] \rightarrow *$$

Carson's Rule

Same values

$$B_{PM} = 2[\Delta f + B]$$

But difference is,

$$\Delta f_{FM} = \frac{k_f\, m(p)}{2\pi}$$

$m(t) = m(p)$ → peak value

$$\Delta f_{PM} = \frac{k_p\, m'(t)}{2\pi}$$

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theoretical bandwidth of sinc function is infinite

For narrow band

Δf is much lesser than B

$$B_{FM} \simeq 4B$$

for B is much lesser than Δf

$$B_{FM} \approx 2\Delta f$$

$$\boxed{\beta = \Delta f / B} \rightarrow \text{Modulation index.}$$

$$\boxed{\Delta f = \beta B}$$

put Δf in eq $\star$.

$$\Rightarrow B_{FM} = 2[\beta B + B]$$

$$B_{FM} = 2B[\beta + 1]$$

Same for B_{PM}.

$$B_{PM} = 2[\beta B + B]$$

$$B_{PM} = 2B[\beta + 1]$$

Example:- Page 222

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

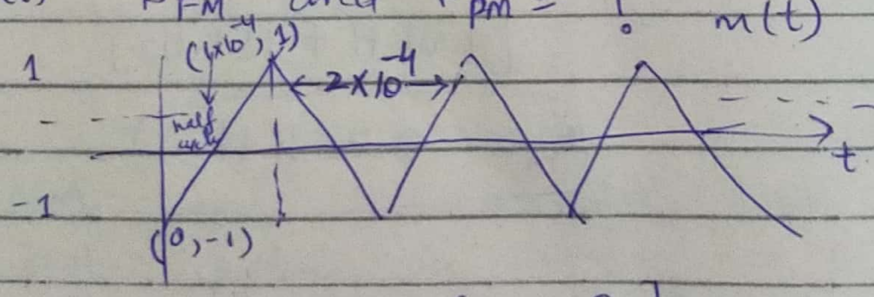
$$k_p = 5\pi$$

B_{FM} and B_{PM} = ? m(t)

vertical → m(t)

hor → t.

Periodic signal



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

$$\Delta f = \frac{k_f m_p}{2\pi} = \frac{2\pi \times 10^5 \times 1}{2\pi}$$

$$\boxed{\Delta f = 0.1 MHz}$$

For finding Bandwidth,
Fourier Series

$$\sum_n C_n \cos(n\omega_0 t + \theta_n)$$

amplitude of signal if expanded by F. series

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

C_n will be given in exam

Power negligible
11% small

$$= \frac{8}{\pi^2}\cos 2\pi(5k)t + \frac{8}{9\pi^2}\cos 3\omega_0 t \quad (15 \text{ kHz})$$

$$+ \frac{8}{25\pi^2}\cos 5\omega_0 t + \ldots$$

4% very signal

$f_0 = \frac{1}{T_0}$

$= \frac{1}{2\times10^{-4}}$

$\boxed{f_0 = 5\text{kHz}}$

$\Delta f = 10^5$ Hz
100 kHz

weight reduces as ~~freq~~ components increases, so ignore higher components

$$B_{FM} = 2[10^5 \text{Hz} + 15 \text{kHz}]$$

$$= 2[100 \text{kH} + 15 \text{kHz}]$$

$$\boxed{B_{FM} = 230 \text{kHz}}$$

$\omega = 2\pi f$ — Hz

ω = rad/sec

f = cycl/sec

$$\Rightarrow B_{PM} = 2[\Delta f + B] \quad B \rightarrow \text{same}$$

$$\Delta f = \frac{k_p \dot{m}_p}{2\pi} \rightarrow \text{derivative}$$

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taking derivative of m(t) :-

$$\frac{m(t)+1}{1+1} = \frac{t-0}{1\times10^{-4}-0}$$ $\rightarrow \frac{y-y_1}{y_2-y_1} = \frac{x-x_1}{x_2-x_1}$

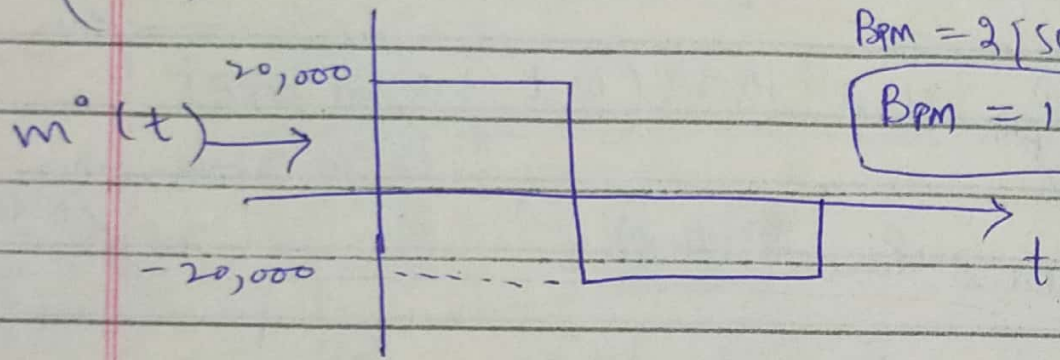
$$\Rightarrow \boxed{m(t) = 2\times10^{4}t - 1}$$

derivative of signal.

$\Delta f = \left(\frac{5\pi \times 20000}{2\pi}\right)$ $\quad \dot{m}(t) = 2\times10^{4} = 20,000$

$B_{PM} = 2[50kHz + 15kHz]$

$\boxed{B_{PM} = 130\,kHz}$



new problem → If double m(t)
No effect on Bandwidth.
coz time period is not changed
as fundamental frequency remains same
Δf changes coz depend
on m(t).

$\boxed{\Delta f \rightarrow 2\Delta f}$ ✓

Not need to calculate again
just explain in words.

Example #5-4 :-

expand time by 2

$\boxed{t = 4\times10^{-4}}$

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5.3, 5.4 + similar questions.

Bandwidth changes
cos signal is expanding in time, so compressed in freq domain
time → double → Bandwith → half.

Example # 5.5 :

i) Find Power of modulated signal.

FM
PM
changes angle

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

when max, cos will max, Δ freq will increase. gives peak

angle modulated : Power = $(Amp)^2/2$

$$\boxed{Power = \frac{10^2}{2} = 50}$$

2) frequency deviation Δf = ?

depend on max peak

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

(if not 't' then freq modulated)

$$\Delta f = \frac{\Delta\omega}{2\pi}$$

angle modulated wave

$$\theta(t) = \omega_c t + 5\sin 3000t + 10\sin 2000\pi t$$

↓ derivative

$$\omega_i = \omega_c + 5\times 3000\cos(3000t) + 10\times(2000\pi)\cos(2000\pi t)$$

max devi from ω_c

carrier freq + some deviation

$$\omega_i = \omega_c + 15000\cos(3000t) + \underbrace{20{,}000\pi}_{\Delta f}\cos(2000\pi t)$$

deviation in freq

representing bandwidth

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how much deviation depends on cycles of cosine and max 1

~~when both are in same~~ and will add

$\omega_i = \omega_c + \Delta f \Rightarrow \Delta f = \frac{\Delta\omega}{2\pi}$

will max when both are 1 at same phase angle. $(\cos = 1)$

when in phase with one another gives (1)

$$\Delta f = \frac{15000 + 20,000\pi}{2\pi}$$

$$\boxed{\Delta f = 12887 \text{ Hz}}$$

max freq deviation

$\therefore \boxed{\beta = \Delta f / B}$

ratio

find bandwidth of both, then max will be bandwidth.

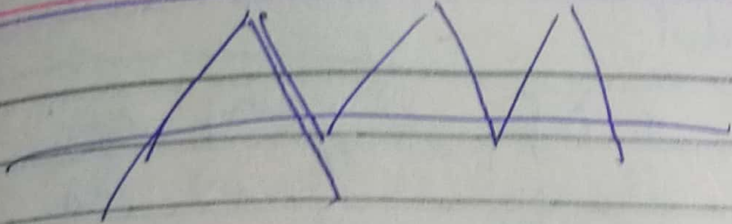
$\omega =$

i) $\omega_1 = 3000$, $f_1 = 3000/2\pi$. less than 1000

ii) $\omega_2 = 2000\pi$, $f_2 = 2000\cancel{\pi}/2\cancel{\pi}$
$= 1000$

So bandwidth $= 1000$

$$\boxed{\beta = \frac{12887}{1000} =}$$



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

$\Delta f = \frac{k_f m_p}{2\pi} = \frac{\cancel{2\pi} \times 10^5 \times 2}{\cancel{2\pi}}$ $\boxed{\Delta f = 2\times 10^5}$

$B_{FM} = 2[2\times 10^5 + 15kHz]$

$\boxed{B_{FM} = 430kHz}$

$B_{PM} = 2[\Delta f + B]$

$B_{PM} = 2[\qquad + 15kHz]$

$\Delta f = 2\Delta f$

$\Delta f =$

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