Comp Systems

Ch 4 → BP Lathi
Amplitude Modulation (AM)
Ch 5 → FM
Ch 6 → Digital communication
Mobile comm.

Comm. sys.

communication → exchange of msgs.
system

↳ exchange of msgs over a large distance

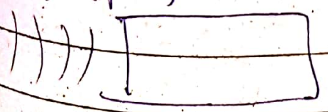
~~Telecommunication:~~

long distance
- (1) Telegraph (written)
- (2) Telephone (voice)
- (3) Television (visuals)

→ Exchange of msgs over a large distance using electro-technical aid.

→ Transmitter → channel → Receiver

(longitudinal wave (speech))

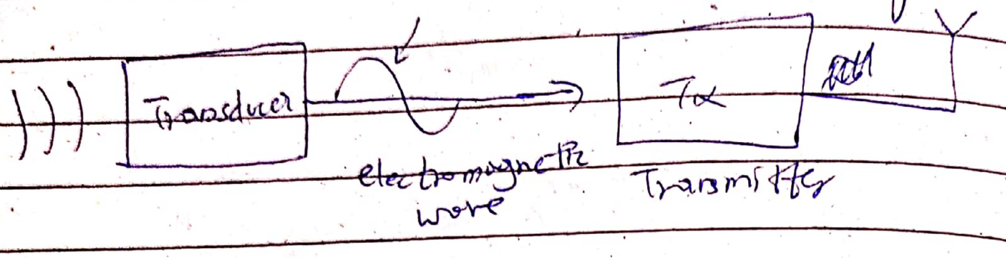


Source / Transducer
↳ convert 1 form of energy to another

Amplifier
↳ convert voice into electrical signal

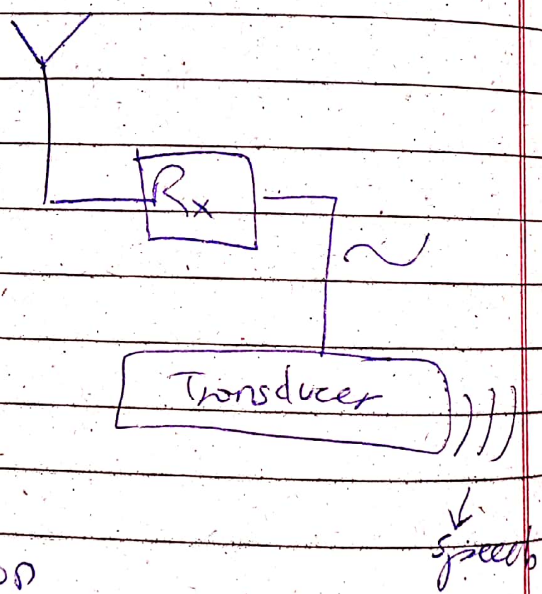
mic → Transducer

↳ convert input to electrical output



Now this converted electrical energy has the capability to converge over last distance.

Receiver



Modulation

Conversion of Analogue → digital

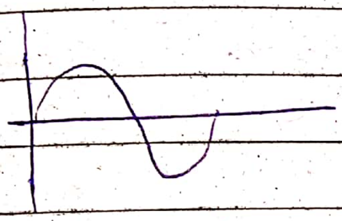
If we vary Any attribute of the carrier signal in accordance with the instantaneous value of base band signal The process is called Modulation output of Transducer

base band signal → **Modulator** → Modulated signal

multiply bb with c

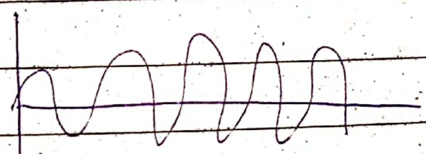
↑ carrier signal

↳ high freq signal



base band signal

$V_m = V_m(\cos \omega_m t + \theta_m)$



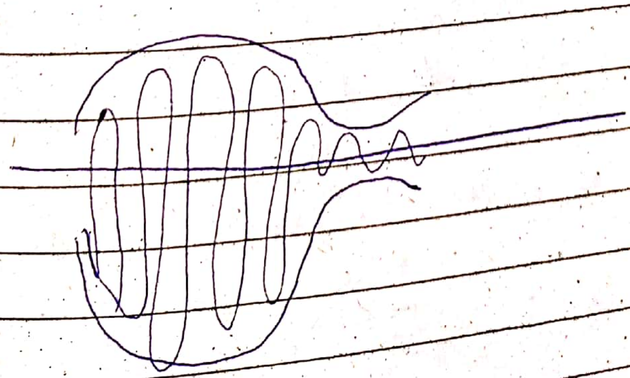
carrier signal

$V_c = V_c \cos(\omega_c t + \theta_c)$

(AM)

↳ bcz amplitude is varying (Multiply both)

Attributes
Amplitude
Frequency



Modulated signal
↓
Ability to be transmitted over a large distance

Modulation occur at Transmitter.

Date:

Why Modulation?

(i) Practicality of Antenna.

Antenna theory states that size of Antenna must be comparable with the λ of signal.

$$c = f\lambda$$

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

speech signal 0.3 – 3.4 normally 4 kHz band

Band of speech signal

0 kHz —— 4 kHz

$$\lambda = \frac{3\times10^8 \text{ m/s}}{4 \text{ kHz}}$$

$$= 75 \text{ km.}$$

Size of Antenna $\simeq$ 37.5 km.

Mobile → microscriped Antenna.

$\lambda \downarrow$ f $\uparrow$ size $\downarrow$

To increase freq, we pass it through Modulator

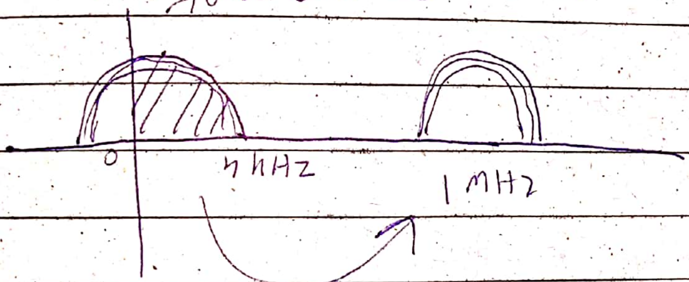
$$\lambda = \frac{3\times10^8}{1\times10^6} = 300 \text{ metre.}$$

Mobile → 900 MHz — 1800 MHz

Frequency Modulation → if we change frequency - - - - - - - - - .

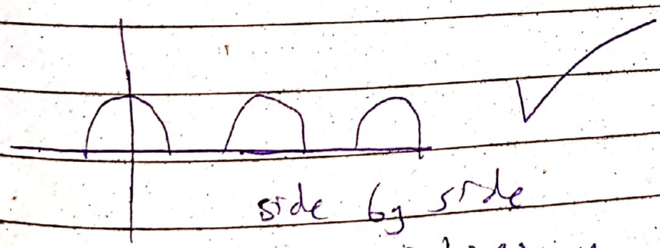
(ii) Frequency Translation

→ base band signal → freq domain



utha ke Translate

All signals will interfere.

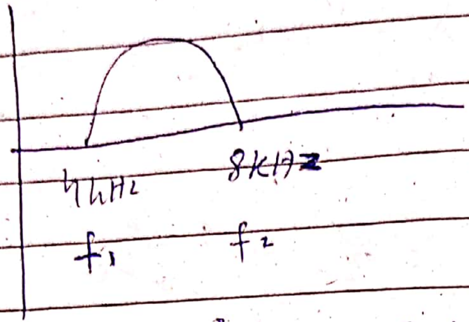


side by side
No interference

Hr signal ko different freq se modulate krna hai

Date:

(iii) Narrow banding



$$\lambda_1 = \frac{3\times10^8}{4kHz} = 75\ km$$

$$\lambda_2 = \frac{3\times10^8}{4kHz} = 37.5\ km$$

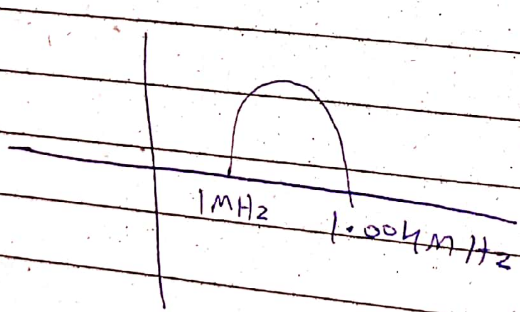
Single Antenna won't work.

issue ?

- ~~band bohat bada hai !~~

we need to narrow

↳ logical



$\lambda_1' = 300\ m$

$\lambda_2' \cong 300\ m$

$$\frac{\begin{array}{r}1000\ kHz\\ 4\ kHz\end{array}}{1004\ kHz}$$

$1.004\ MHz$

$m(t)$, $\cos\omega_c t$
↳ carrier signal

modulate → $m(t)\cos\omega_c t$
$(\times)$

$\overline{\text{ye}}$ ↗ Iske magnitude bn joega.

Digital communication terminologies

Source →binary→ source encoder
↳ PCM structure

↳ Redundant bits remove
↳ Jinki zarurat nahi

for system to be more efficient

Plain text → Encryption
↓
data secure

cyfer → channel encoder ← receiver ko btane ke liye data sahi hai ya galat

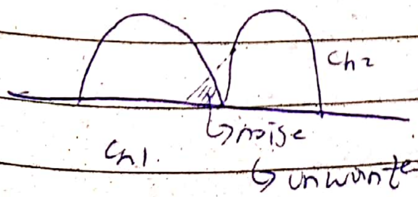
channel encoder → channel decoder

↓
Adds redundancy
(increase no. of bits)

bcz route me what issues hai jese noise etc.

channel decoder → decryption → source decoder

$y(t) = m(t) * h(t) + n(t)$
↳ noise



Internal noise ⇒ additive in nature
↳ inside machine

Date: ______

$$y(t) = m(t) * h(t) + n(t)$$

$h(t)$ → channel Property.

$n(t)$ → AWGN

Additive white Guassian noise

2 elements are distorting our channel

$h(t)$ and $n(t)$

↓ multiplicative ↓ Additive

* SNR

Signal to Noise Ratio

$$SNR = \frac{P_{signal}}{P_{noise}}$$

P → Power

$P_s \uparrow$ $P_n \downarrow$ communication $\uparrow$ better

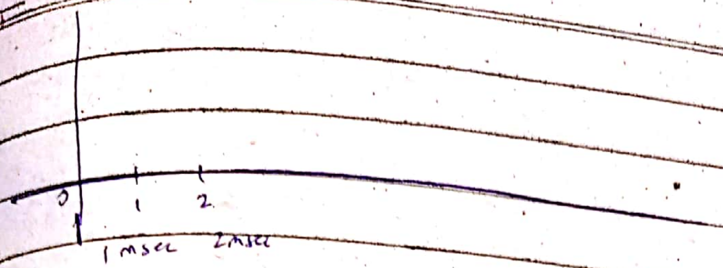
→ unitless quantity

→ Its not linear → scale

→ But its represented as dbs

Why dbs ?

→ To represent all values on a single scale, linear scale is not the capable, Thus we use decibels.



where to place 1sec in this graph?

chote se chota, aur bare se bara unit iss scale pr aa skta hai.

↳ dbs.

↳ logrithmic scale

↳ represent all values on single graph.

If $\frac{P_s}{P_n} = 100 = 20\,dB$

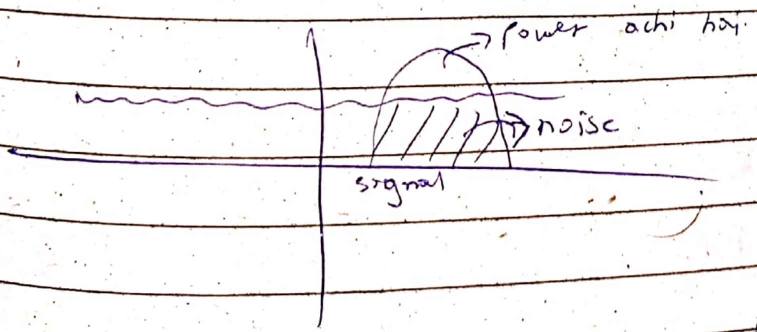
$= 10 \log 100.$

Signal power

Noise power

↳ never zero

↳ always same at all frequencies

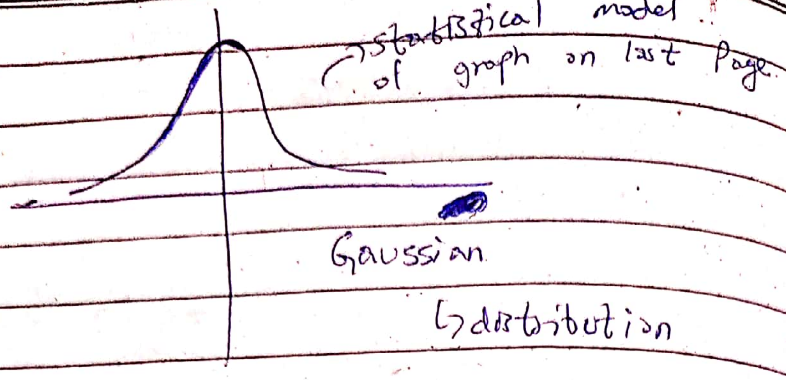


we're talking about additive noise.

Not $h(t)$

↳ channel resp.

Date:



If $\frac{P_s}{P_n} = 30dB = 1000$

Bit error rate

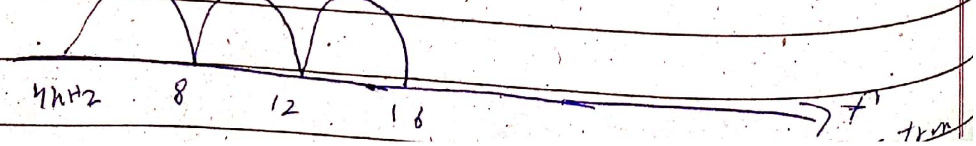
Let $BER = 10^{-4}$

$= \frac{1}{10,000}$

= 1 bit in 10,000

Multiplexing

→ Many inputs, one output.
→ Many signals are supposed to be sent via single channel.
→ FDM → purani technology
  ↳ used in AMPS
  ↳ end user ko kia mil raha ?
  ↳ Frequency division multiplexing
  ↳ 30 KHz channel.
→ FDMS
  ↳ " " multiple access

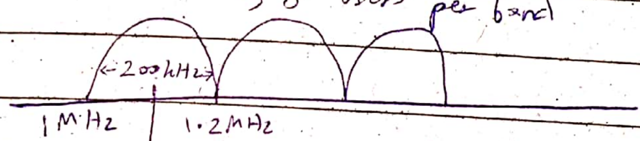


f spectrum is ÷ among users.
↳ FDM

And all signals are passed through single channel → many to one → FDM.

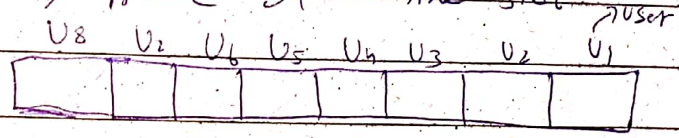
If users are given access of frequency too → FDM / FDMA.

2^{nd} generation → mobiles
→ bands → 200 kHz
↳ GSM signal
↳ 8 users per band



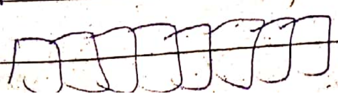
→ Huge band for small info is or loss.

→ frame of Time slot



TDMA frame - 1μsec

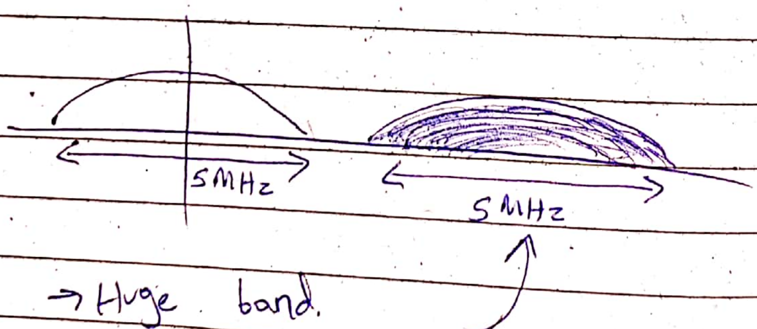
- 1 band → multiple users
- U1 is asked to send his/her data in 1μsec
- U2 is asked to send data using same band.
- 8 users used their slots for very less time.
- Next TDMA



Date:

- Ui is again given opportunity. It remained idle when other users were using the band for 7 μ sec.
- Communication will be continuous. bcz 7usec is very less.
- Time is ÷ among users rather than frequency.
- 200 kHz is allocated to 8 users. Next 200 kHz is allocated to next 8 users.
- So at top level frequency is divided
- Pehle FDM then TDMA.
- ∴ FDM/TDMA technology.

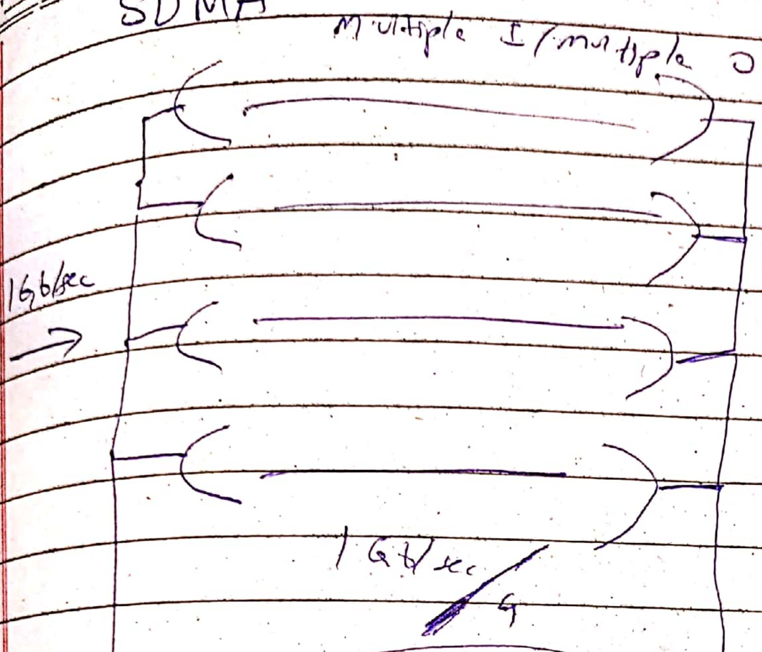
- Next technology
  CDMA → 3G
  → code division multiple access
  → code is divided.
  → F & t X.
  → band → 5 MHz



→ Huge band.
→ 1 band → overlapped users
→ every user is separated by some code
→ codes are orthogonal $C_1 \cdot C_2 = 0$
$C_1 \cdot C_1 = 1$

Comm. Systems

SDMA



space is ÷ among users

antenna → antenna

smart Antenna

↳ points / track user and continue to give stream

other user → other stream

→ space is divided

↳ different streams de rha!

CDMA

$C_1 = \frac{1}{4}[1 \quad 1 \quad 1 \quad 1]$

$C_2 = \frac{1}{4}[-1 \quad 1 \quad -1 \quad 1]$

multiply $\frac{1}{\text{length}}$

Date:

$$C_1 \cdot C_2 = \left[\frac{1}{\sqrt{4}} \quad \frac{1}{\sqrt{4}} \quad \frac{1}{\sqrt{4}} \quad \frac{1}{\sqrt{4}}\right]$$

$\therefore$ Transpose $\begin{bmatrix} -1/\sqrt{4} \\ 1/\sqrt{4} \\ -1/\sqrt{4} \\ 1/\sqrt{4} \end{bmatrix}$

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

$= 0$ → orthognal

$$C_1 \cdot C_1 = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} + \frac{1}{4}$$

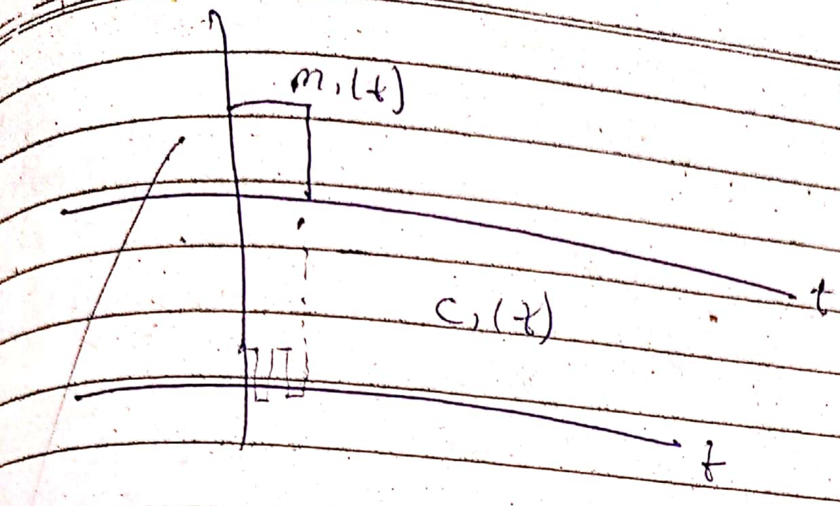
$$= 4/4 = 1$$

$$y.(t) = \left[m_1(t) * C_1(t) + m_2(t) * C_2(t)\right] * C_1(t)$$

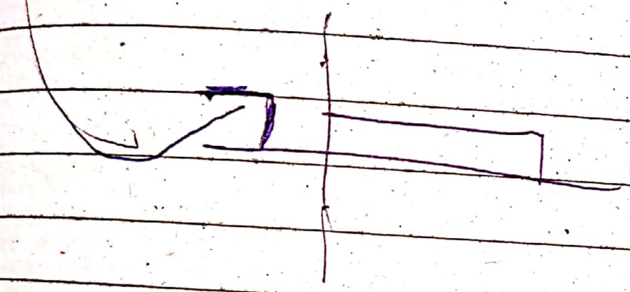
$$= 1 + 0$$

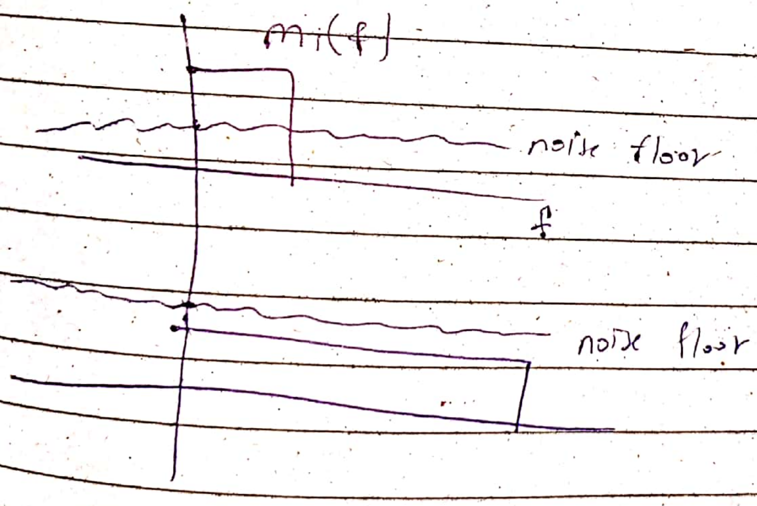
$y(t) = 1$

↳ 1 user ko band ka part mil gya with the help of some code



when signal is multiplied with some code → multiple transitions
→ As a result, BW increase
↳ 5MHz





→ signals also becomes secure.

WDMA → λ → fiber
Packet radio → No dedicated source
↳ Jb moga mile, apna signal transmit hoga.

hr time transmission

Date:

packet radio
- ALOHA → packet → transmit → dusra aya → transmit → collision → packet wait
- Slotted ALOHA → slot maqhsoos hai packet bhejne ka. hr time nhi kia jaa skta.

Skype → packet radio

packet/ Data rate	&	Throughput
no. of packet transmitted per sec		no. of successful packet per unit time. (recieved at a receiver)

→ $\frac{P_1}{P_2}$ (power)

$10 \log \frac{P_1}{P_2}$ → decibels

→ imp for SNR
↳ signal to noise ratio

SNR ↑ data rate ↑

$dB + 30 = dBm$

watt → dB
$P_{dB} = 10 \times \log_{10}(P(\text{watt})/1\text{watt})$

dB → watt
$P_{dB} = 10 \times \log_{10}(P)$

$mW \to dB = P_{dBm} - 30$

mW → dBm
$P_{dBm} = 10 \times \log_{10}(P_{mW}/1mW)$

$10 \log \frac{S}{N}$ $\frac{\text{watts}}{\text{watt}}$ → unitless

If $10 \log 100$

$= 20 dB$

$P = 10 mW$
$= 10 \log 10 = 10 dBm$.
$P = 10^{-2}$ watts
$10 \log 10^{-2}$
$-20 dBW$

let $P = 100 mW$
$= 20 dBm$

$= -10 dBW$

dBm → dBW
$dBW = dBm - 30$
dBW → dBm
$dBm = dBW + 30$

$\boxed{dBm \xrightarrow{-30} dBW \quad \text{minus 30}}$

$20 dBm - 10 dBm = 10 dB$

log → me — is division

$\frac{P_1}{P_2} = \frac{\cancel{m}}{\cancel{m}}$

Date:

$20\ dBW + 10 = 30\ dBW$.

$\therefore\ 2 \times 10$ watt $= 20$ watt

$10\ dBW + 10\ dBm = ?$

10 watts $+ 10\ mW = ?$

not possible ?

1 unit me ho bhai !

$40\ dBm + 10\ dBm = 50\ dBm$

Data rate

Shannon Capacity:

↳ without error, with reasonable feadolity (correlation b/w transmitted & received signal) signal can be transmitted.

$$C = B \log_2(1 + SNR)$$

If $SNR \to \infty$

$C = \infty$

~~$= 4000 \log_2(1 + 100)$ bits/sec~~

match ?

$m(t) \longrightarrow \hat{m}(t)$

measure of fedality.

$P_e = 10^{-7} = \frac{1}{1000}$ are in error

↳ prob of error

h bits → add with info → redundant bits

m bits → information bits

→ hamming code

how many additional bits ?

$2^h \geq m+h+1$ → hamming.

let $m = 8$

$h = 1,2,3$ → not true

$2^4 \geq 8+4+1$

8 bit hi info he liye → 4 redundant bits

8+4

If $m = 16$
$h = 5$

1100	1011	1010	1001	1000	0111	0110	0101	0100	0011	0010	0001
12	11	10	9	8	7	6	5	4	3	2	1
D_7	D_6	D_5	D_4	C_8	D_3	D_2	D_1	C_4	D_0	C_2	C_1

redundant bits are elevated over the msg

if last 1 are 1

2^n → gives error bits

$n = 0,1,2,3 --- n$

0	0 →	0
0	1 →	1
1	0 →	1
1	1 →	0

XoR operation of message bits

Date:

$C_1 = D_0 \oplus D_1 \oplus D_3 \oplus D_4 \oplus D_6$

LSB → jisha 1

$= 1$

$C_2 = D_0 \oplus D_2 \oplus D_3 \oplus D_5 \oplus D_6$

Second last → 1

$= 1$

$C_4 = D_1 \oplus D_2 \oplus D_3 \oplus D_7$

next bit → 1

$= 0$

$C_8 = D_4 \oplus D_5 \oplus D_6 \oplus D_7$

↳ MSB → 1

$= 0$

C_8	C_4	C_2	C_1
0	0	1	1

During comm. D_7 lost

↳ 1 hi jaga

0 ho aa rha

12	11	10	9	8	7	6	5	4	3	2	1
D_7	D_6	D_5	D_4	C_8	D_3	D_2	D_1	C_4	D_0	C_2	C_1
0	1	1	1	0	1	1	1	0	1	1	1
X											

D_7 wale masla hoega

invert

C_8 C_4 C_2 C_1

0 0 1 1 Tran

⊕ 1 1 1 1 Rec

1 1 0 0 → 12

↓

bit 12 is in error

D_7 → 0 → 1

correct

if D_7 → no error

0 0 1 1

0 0 1 1

0 0 0 0 → No error

if C_1 → lost

C_8 C_4 C_2 C_1

0 0 1 0

0 0 1 1

0 0 0 1 → error in 1st

0001

0010
0100

1000

0000

No need of correction

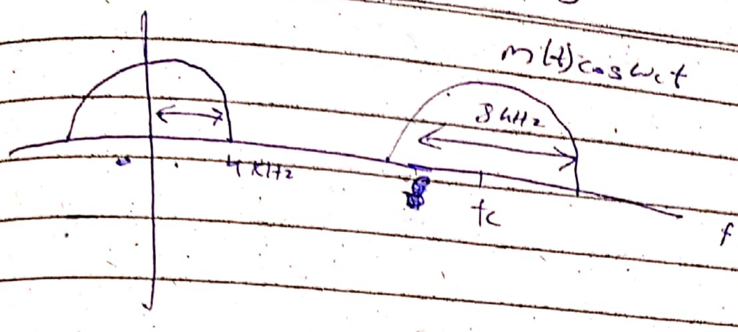
Comm. Systems

$m(t) \rightarrow$ time domain signal
to modulate it we
have to do multiplication
with cos ftn

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

signal will shift in frequency
domain cos is a carrier

if $m(t)$ is speech signal



$f \uparrow$

bandwidth $\uparrow$

At receiver, it will demodulate
~~[illegible]~~ bcz receiver requirement

$$\boxed{m(t)\cos\omega_c t}\cos\omega_c t$$

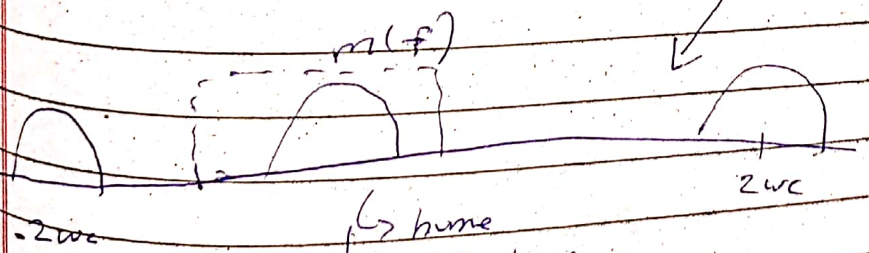
$$= m(t)\cos^2\omega_c t$$

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

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

$\downarrow$ fourier Transform

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



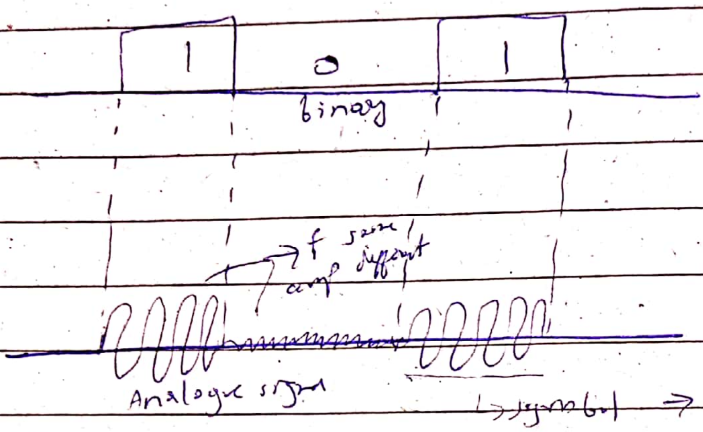
↳ hume ye chayiye
↳ apply low pass filter & extract your desired

This phenomenon is modulation
↳ amplitude/analogue modulation

& demodulation

Date:

why ~~analogue~~ digital ?

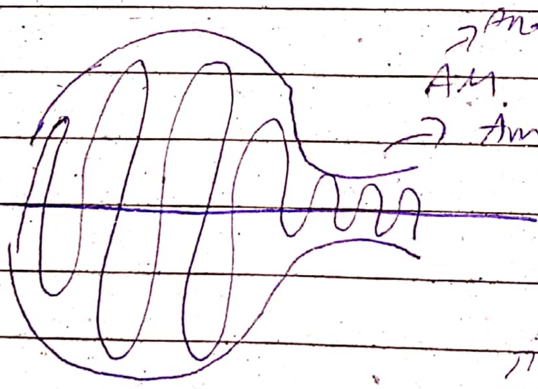


signal bit → bit/sec

ASK → Amplitude shift kink

bcz this analogue signal has 1-1 corresponderse with digital signal

Amplitude is same.



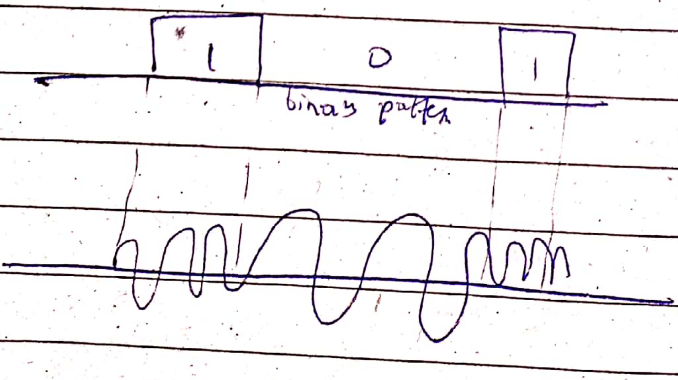
→ Analogue modulation

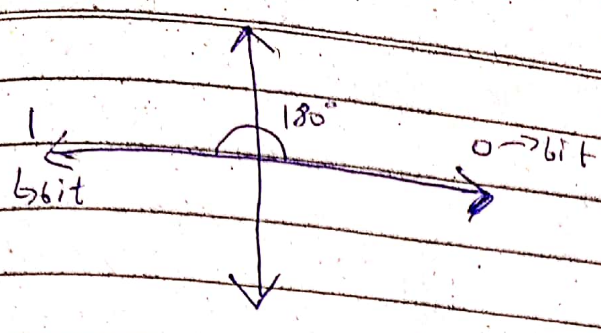
AM

→ Amplitude varying

,, frequency

FSK



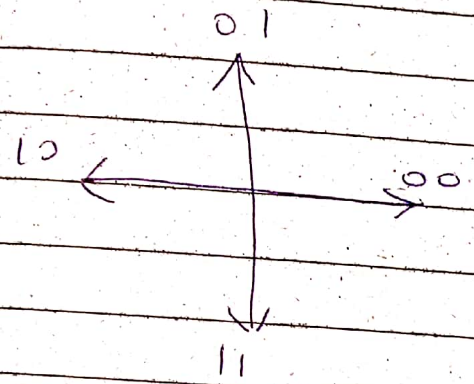


Phase 0° → 0 bit

Phase 180° → 1 bit

↳ symbols → 2.

vectors → 2

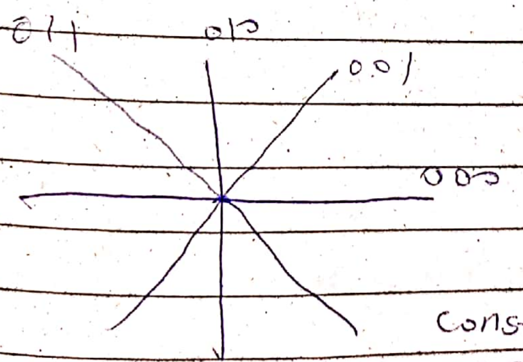


4 symbol
4 vectors

symbols are containing 2 bits.

bit rate doubles

Phase se vector detect krlega receiver.



Constellation Diagram

bit rate ↑

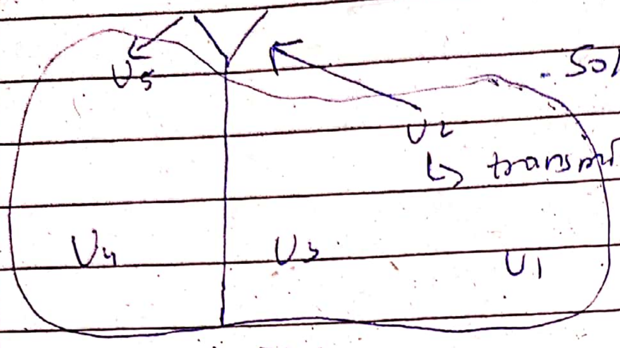
P_e

detection ↓

error ↑

Date: ________

Mobile communication



50km coverage

U_2 ↳ transmit here hein dur hai, losses hoin zyada power chahiye hoga

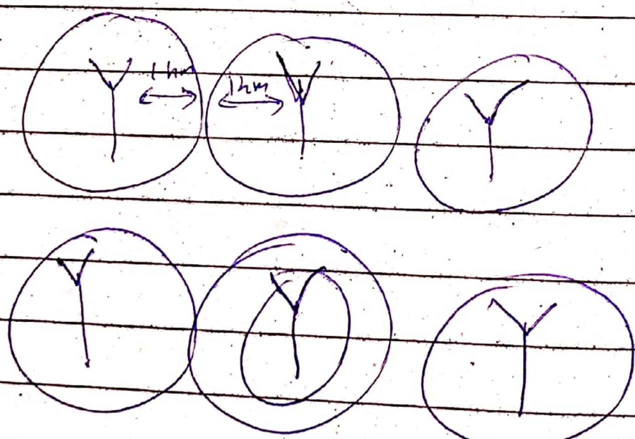
High rise tower

~~Power low~~

$$P_r \propto \frac{1}{d^n}$$

n ↳ path loss exponent $(n = 2-6)$

~~$P_r \propto \frac{1}{d^2}$ free space~~



cells ↳ Hexagonal

Now transmission → better
Mobile battery → less use

Motorway → High rise tower

when ~~we~~ enter new cell, we disconnect from initial tower → drop

→ Signal Transmission through LTI system

$$g(t) \longrightarrow \boxed{LTI} \longrightarrow y(t)$$

$y(t) = ?$

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

↳ property of $h(t)$

→ freq domain

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

input → impulse $\delta(t)$ ⟶ output impulse response

$$y(t) = \delta(t) * h(t)$$
$$= h(t)$$

$$|Y(\omega)|\, e^{j\theta_y(\omega)} = G(\omega)\, e^{j\theta_g(\omega)}\, H(\omega)\, e^{j\theta_h(\omega)}$$

freq dom ⇒ ① phase
② Amplitude

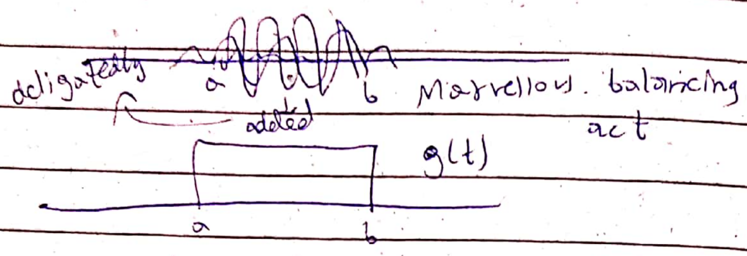
① — $|Y(\omega)| = |G(\omega)|\,|H(\omega)|$ → Amplitude

$\theta_y(\omega) = \theta_g(\omega) + \theta_h(\omega)$ → phase

Date: ______ → properties of system

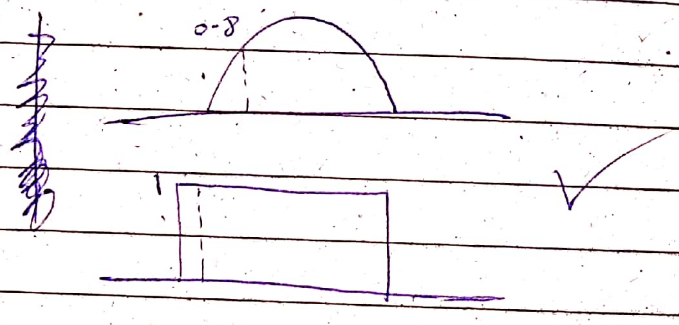
$$H(\omega) = |H(\omega)| e^{j\theta_n(\omega)}$$

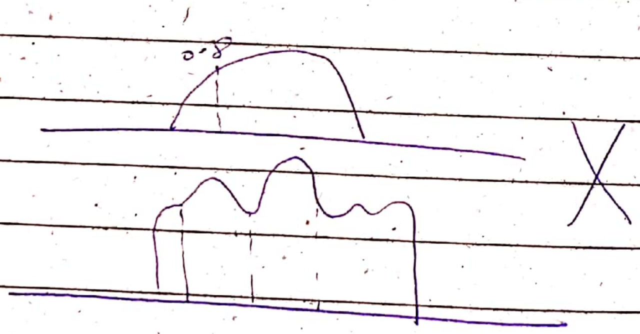
↳ freq response of LTI system

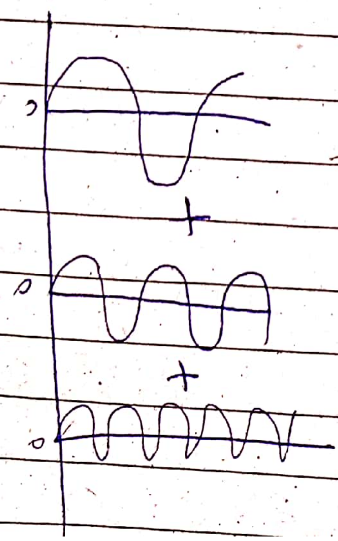


freq comp ++++ → Aperiodic signal

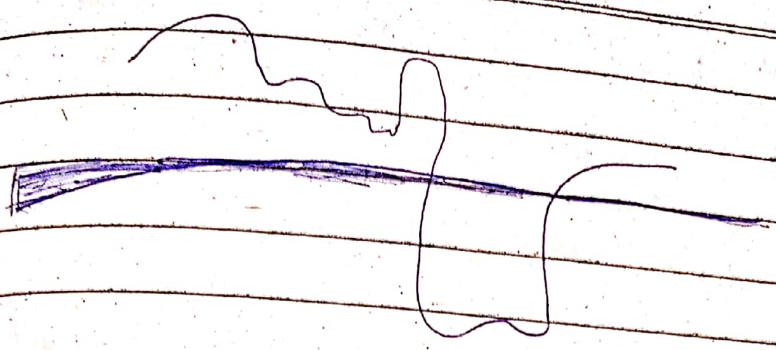
bahar ki waves negate kr ke
khatam hui v hain



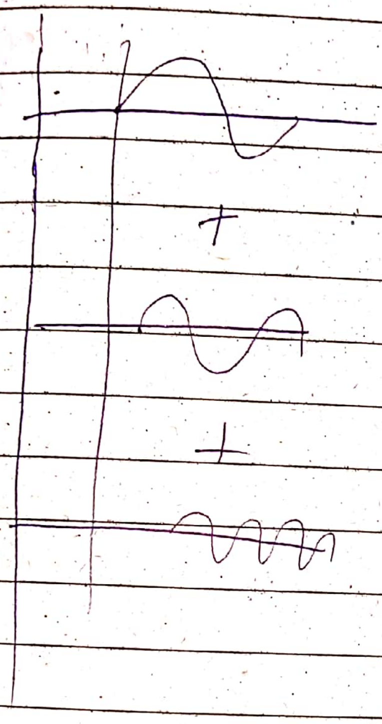


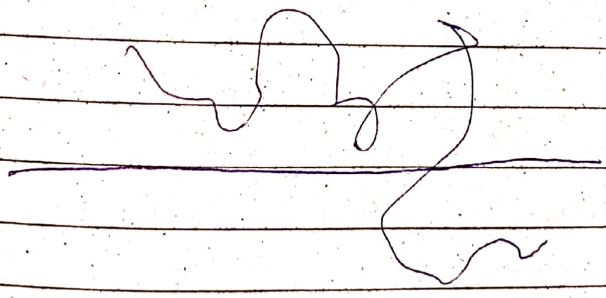


lets add



At receiver





→ Time delays ki wajah se receiver ne diffrent signal receive kia

→ distorted signal due to phase response of system $e^{j\theta h(\omega)}$

Date:

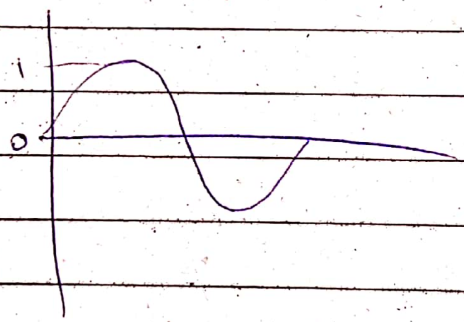
* Distortion less communication

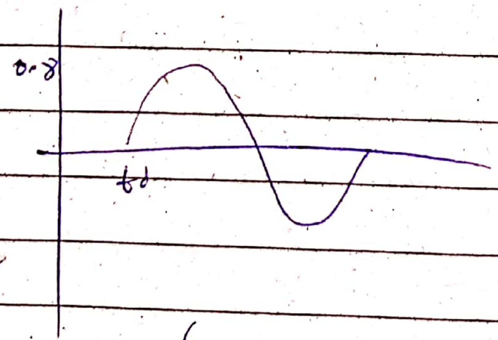
$$\overset{\rightarrow \text{output}}{y(t)} = K\, g(t - t_d)$$

↳ if acheived → distortionless.

→ Delay doesnt cause distortion if signal shape is intact. Provided that each & every component of signal is delayed by the same amount and its magnitude is consistent all the time. ↳ amplitude

Let $k = 0.8$





(In time domain)

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

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

compare with ①

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

$$|H(\omega)| = k$$ → constant for all freq

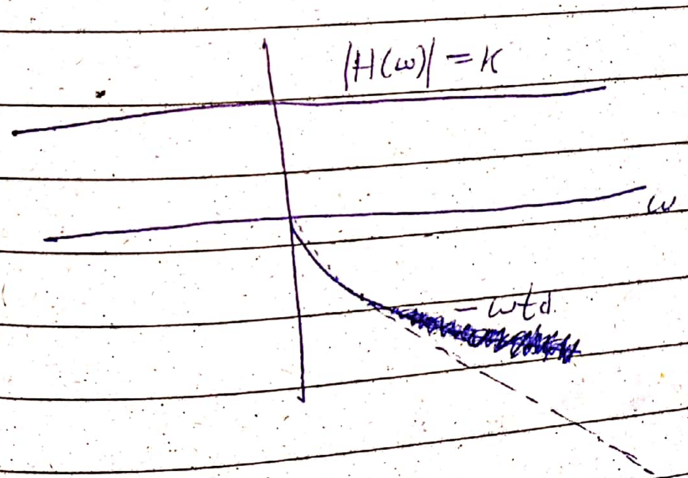
$$\theta_h(\omega) = -\omega t_d$$

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

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

phase response → constant slope

signal → distortionless

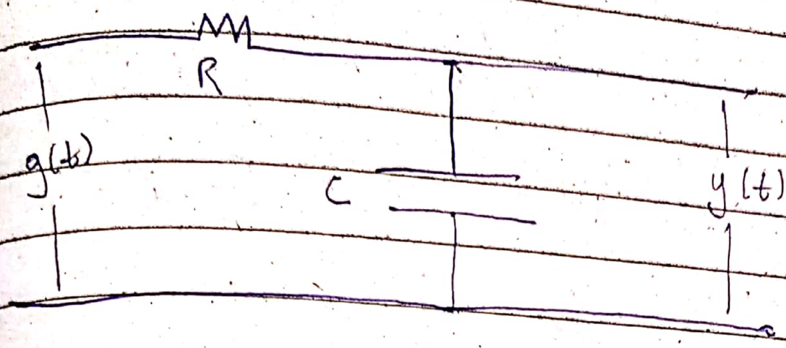


Communication Systems
(week 3 task)

Date: ______

→ There are some transmission properties
→ whenever we have a channel so if you're going to transmit a signal, channel will definetely distort that signal to some extent.
→ Degree of distortion is another Q.
→ So we want a signal at the receiver end, that makes some similarity to original signal.
→ Itni distortion na peda ho ke hm original signal ko recover na kr sken.
→ So we see the benchmark there; for this, we see ideal cases & how can we acheive the ideal cases. or approach them atleast.
→ Distortionless transmissions ke andar we have got signal amplitude response of a system, impulse response of the system in terms of its amplitude remain constant for some band of frequency & its phase response should be linear in terms of the frequencies there.
→ So iss qism ki properties hongi so we stated that our signal is not going to be distorted. & its now going to be received at the receiver with perfection.
→ Only thing is, signal will be delayed but not distorted.

Problem:



$$Y(\omega) = \frac{1/j\omega C}{R + 1/j\omega C} \, G(\omega)$$

$$H(\omega) = \frac{1/j\omega C}{R+\frac{1}{j\omega C}} = \frac{1}{1+j\omega RC} = \frac{a}{a+j\omega}$$

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

$$\theta_h(\omega) = -\tan^{-1}\left(\frac{\omega}{a}\right)$$

if $\omega <<<< a$

$\omega \to 0$

$$H(\omega) = \frac{a}{a} = 1$$

$$|H(0)| = 1$$

If we ~~see~~ find delay

Date: ______

$t_d \rightarrow$ rate of change of $\theta_h(\omega)$ w.r.t ω

$$t_d = \frac{\theta_h(\omega)}{d\omega} = \frac{a}{a^2+\omega^2}$$

if delay $= \omega = 0$

$$t_d = \frac{a}{a^2} = \frac{1}{a}$$

Why this not ideal?

Ideal $\rightarrow$ constant response for all frequencies.

when $\omega = 0$

→ it will give us maximum gain of 1

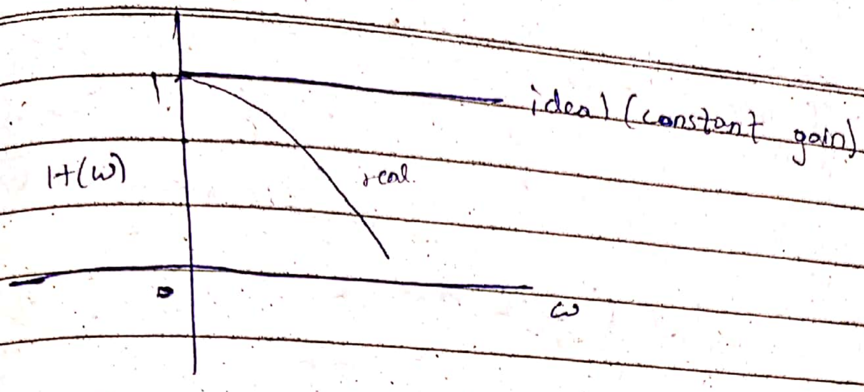
→ DC pr bara acha response de rha hai (bcz frequency $= 0 \rightarrow$ DC)

→ No distortion

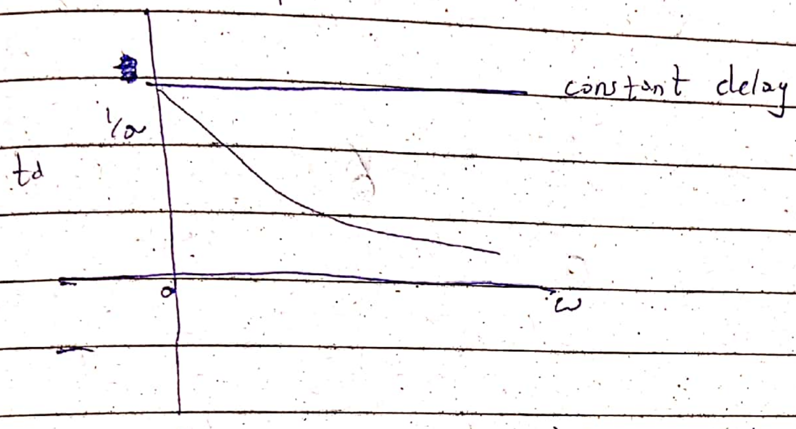
→ Lower freq ho bhi koi zyada distort nahi kr rha.

→ if $\omega \uparrow$ amplitude response $\downarrow$

bcz denom $\uparrow$ overall value $\downarrow$



To plot td

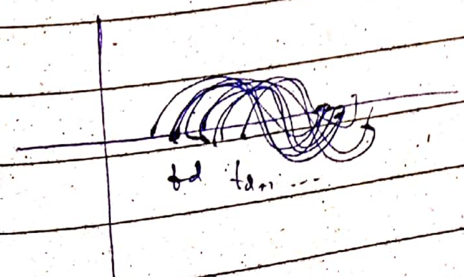


→ Higher freq component reach the destination with less delay.

→ So freq components ek hi time pr delay nahi ho rhe. i.e they have got variation in that delay. (td = constant for all freq)

→ So signal received at receiver will be distorted bcz of variation in diff freq components of delay.

→ ideal → constant delay



Date: ________

in a system using RC circuit

If we want 2% variation then what will be the required bandwidth to achieve this?

No distortion → answer was 1 → ideal

max is 1

$$|H(\omega)| \geq 0.98 \times 1 \rightarrow 2\ \%\ \text{variation.}$$

$$\frac{a}{\sqrt{a^2+\omega^2}} \geq 0.98$$

cross multiplication & squaring

$$a^2 \geq 0.96(a^2+\omega^2)$$

$$a^2 \geq 0.96a^2 + 0.96\omega^2$$

$$\omega_0 \leq \sqrt{\frac{a^2 - 0.96a^2}{0.96}}$$

$$\omega_0 \leq \sqrt{\frac{0.04a^2}{0.96}}$$

$$\omega_0 \leq \sqrt{\frac{0.04}{0.96}}\ a$$

since $a = 1/RC = 10^6$

$$\omega_0 \leq \sqrt{\frac{0.04}{0.96}} \times 10^6$$

$$\omega_0 = 203000\ \text{rad/sec}$$

↳ 2% var band

→ How much tolerance in time domain wrt ω?

~~[illegible]~~

If 5% time delay is tolerable

$$t_d = \frac{a}{a^2+\omega^2}$$

$$t_d \le 0.95$$

$$\frac{a}{a^2+\omega^2} \le 0.95 \times \frac{1}{a}$$

→ maximum
→ 95% of this

$$\omega_0 = \_\_\_\_$$

Ideal and Practical Filters:

Filter → some of freq band. ✓
others ✗.

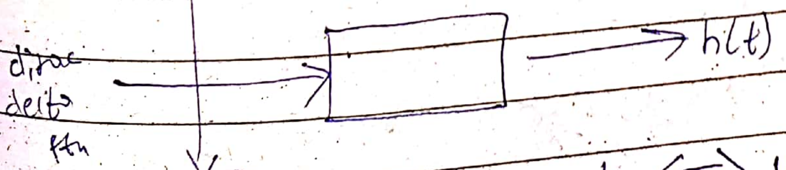
Kinds
- → Low pass filters
- → Band pass filters
- → High pass filters.

For ideal filters

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

If we are to find impulse response of this rect, we'll do inverse Fourier transform (time domain)

$$F^{-1}\left[rect\left(\frac{w}{2W}\right) e^{-j\omega t_d}\right]$$



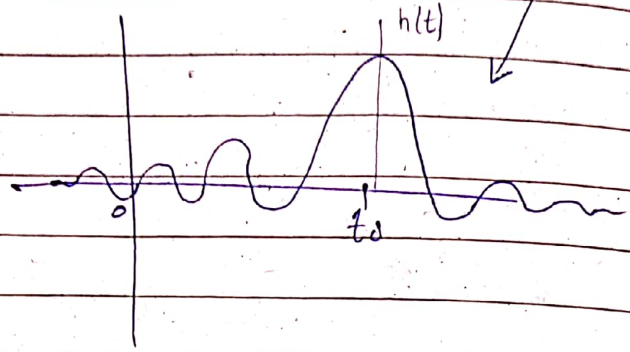
$$h(t) = \frac{W}{\pi} \sin Wt \Longleftrightarrow rect\left(\frac{w}{2W}\right)$$

$W \to$ fixed frequency

$\omega \to$ variable frequency

Date:

if $\frac{W}{\pi} \sin W(t-t_d) \Longleftrightarrow rect\left(\frac{\omega}{2W}\right) e^{-j\omega t_d}$



For sinc function

when $W(t-t_d) = \pm n\pi$

Those points are zero

$$t - t_d = \pm \frac{n\pi}{W} = \underbrace{\frac{\pi}{W}, \frac{2\pi}{W}, \frac{3\pi}{W}, \ldots}_{\text{zero points}}$$

Now, this is an ideal case

bcz response zero se pehle bhi mojood hai

pichle lamhe me hm jaa skte hain?

(ye idealism hai)

$h(t)$ exist $t < 0$.

$\therefore$ unrealisable

To check if signal is unrealisable or not

Paley weiner Criteria:

$$\int_{-\infty}^{\infty} \frac{|\ln|H(\omega)||}{1+\omega^2} \, d\omega$$

if this is finite $\to$ realisable

→ Non causal response (response before zero) will never exist.

→ If $H(\omega) = 0$ for some bands of frequency

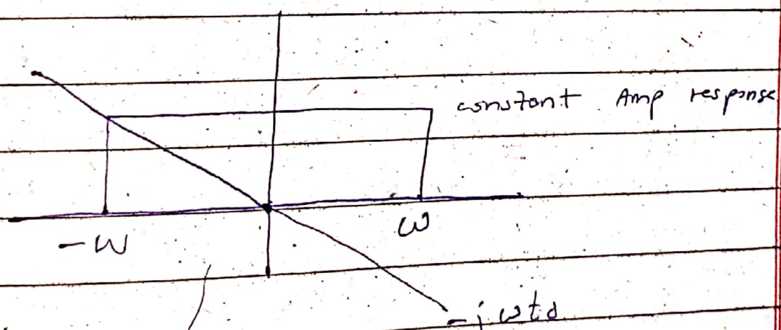
$\int \rightarrow$ infinite

→ For discrete values, it will be finite.

Ideal vs practical filters

→ Amplitude response remain constant for some band of frequency.

→ Phase response should be linear ftn of ω



$$H(\omega) = \text{rect}\ \frac{\omega}{2W}\ e^{-j\omega t_d}$$ → ideal filter

if;

$$F^{-1}\left[\text{rect}\ \frac{\omega}{2W} \cdot e^{-j\omega t_d}\right]$$

↳ Impulse response of system

Date:

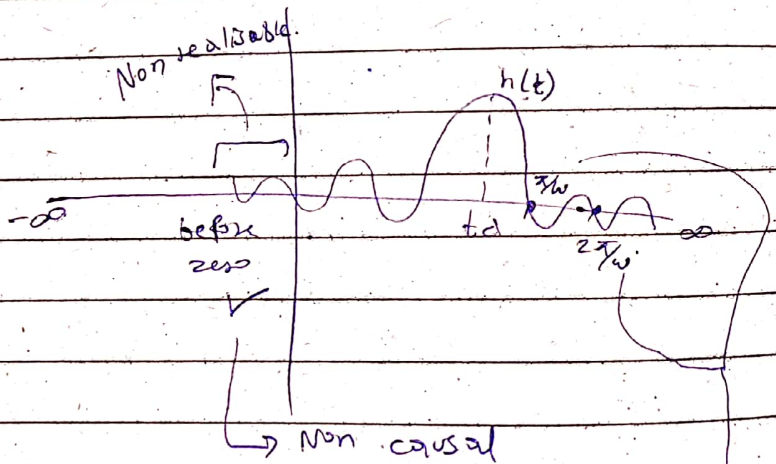
Impulse response of system means whenever you give impulse to the system, the output will be said to be whatever is the property of sys is going to be reflect at the output.

$$F^{-1}[H(\omega)] = \frac{\omega}{\pi} \operatorname{sinc} \omega(t-t_d)$$

property no 18 in Fourier T table

$$\frac{\omega}{\pi} \operatorname{sinc} \omega t \Longleftrightarrow \operatorname{rect} \frac{\omega}{2W}$$

$$\omega(t-t_d) = \frac{\pm n\pi}{W}$$



sinc → zero se h.b pass hota hai

$$\omega(t-t_d) = \frac{\pm n\pi}{W}$$

So to make non causal → causal

Tail → Truncate.

$$\hat{h}(t) = h(t)\, u(t).$$

Now realizable impulse response of system

More practical

td ? to approach more realizable signal

→ The more delay, the more values of signal would be taken into consideration

→ But now, system is going to be delayed.

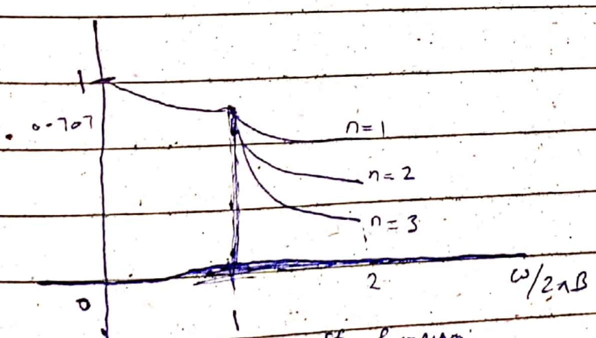
→ 3 to 4 times of π/ω signal can be delayed to keep intact the feasibility.

Realistic filters

Butterworth filter

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

Why more realistic ?



cutt off frequency

if $\frac{\omega}{2\pi B} = 0$, $H(\omega) = 1$

If $\frac{\omega}{2\pi B} = 1$, $H(\omega) = 0.707$ → Half power band width.
$= 3dB$

Date:

if $n=2$ & keeping $\omega/2\pi B = 1$

→ no change

→ will again pass through cuttoff freq.

if $n=2$ & Lets consider

$$\frac{\omega}{2\pi B} = (0.8)^2 = 0.64$$

or

$$(0.8)^4 = 0.36$$

$n \uparrow$ $\omega/2\pi B \downarrow$

rate of Δ is more lesser in $|H(\omega)|$

Take $n = \infty$

exactly ideal → sharp cutt off

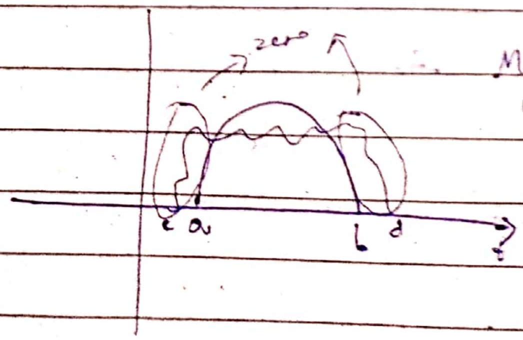
Types of distortions

1- Linear

2 - Non-Linear

Linear:

$g(t) \longrightarrow$ $\boxed{\text{channel}}$ $\longrightarrow y(t)$



Marvellous Balancing Act.

$a \to b \Rightarrow g(t)$

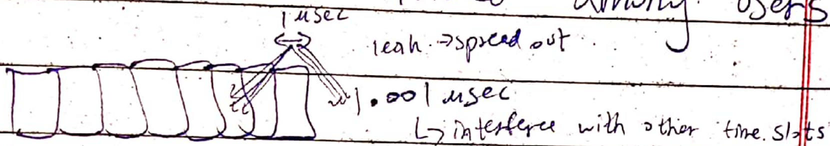
$c \to d \to y(t) \to$ resultant

→ But whenever a signal is linearly distorted, signal b/w a & b will not be produced and it will be spreaded.
→ will voilate Marvellous Balancing Act.

What is its effect in different systems?

→ TDM

↳ Time is divided among users.



→ Whenever your channel disperse your signal in time domain, channels interfere with one another & this is said to be cross talk.

Solution:

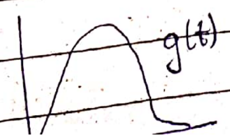
Add guard band in between to increase time slots & separate them. but with addition of guard bit, bit rate is reduced but it was necessary.

So Linear Distortion will cause a severe affect on TDM.

But it doesn't effect the FDM system. bcz yaha hr eh apni frequency pr transmit kr rha hai.

Example:

$$H(\omega) = (1 + k\cos T\omega)e^{-j\omega t_0}$$



Date:

Since $\cos\theta = \dfrac{e^{j\theta} + e^{-j\theta}}{2}$ (eveler)

$$H(\omega) = \left[1 + \frac{k}{2} e^{j\omega t} + \frac{k}{2} e^{-j\omega t}\right] e^{-j\omega t_d}$$

$Y(\omega) = ?$

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

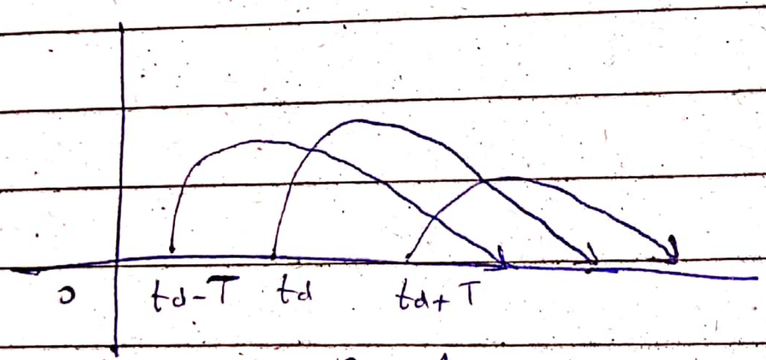
$$Y(\omega) = G(\omega) e^{-j\omega t_d} + \frac{k}{2} G(\omega) e^{-j\omega(t_d - T)} + \frac{k}{2} G(\omega) e^{-j\omega(t_d + T)}$$

equivalent

(non ideal transfer ftn)

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

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



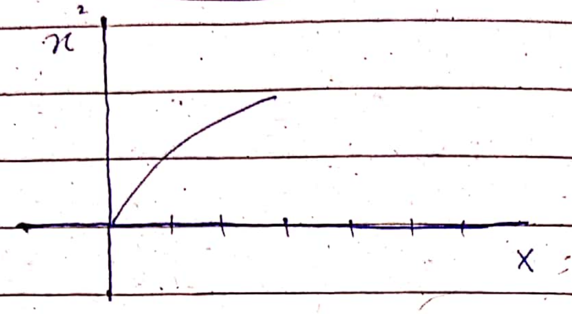
Time domain → signal will spread out & will interfere with other slots

Non Linear distortion

→ cause spreading in frequency domain.

Example:

$$y(t) = x(t) + 0.001\, x^2(t)$$



$$x(t) = \frac{1000}{\pi} \operatorname{sinc} 1000t$$

Non Linear distortion effect into the system?

To find Fourier transform of $Y(t)$

$$\cancel{y(t) = x(t) + 0.001\, x^2(t)}$$

$$y(t) = \frac{1000}{\pi} \operatorname{sinc} 1000t + \frac{10^3}{\pi^2} \operatorname{sinc}^2 1000t$$

$$Y(\omega) = \operatorname{rect} \frac{\omega}{2000} + 0.316\, \Delta\left(\frac{\omega}{4000}\right)$$

~~Table - 18~~: $\frac{\omega}{\pi} \operatorname{sinc} \omega t \longrightarrow \operatorname{rect} \omega/2\omega$

~~20~~: $\frac{\omega}{2\pi} \operatorname{sinc}^2 \omega t/2 \longrightarrow \frac{1}{\pi}\left(\frac{\omega}{2W}\right)$

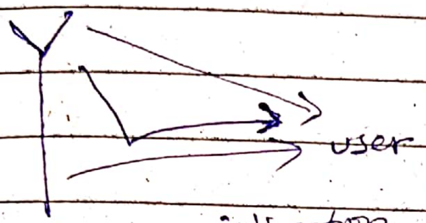
$$\frac{10^3}{\pi^2} \operatorname{sinc}^2 1000t \rightarrow \frac{1}{\pi^2}\left(\frac{10^3}{2\times10^3}\right)$$

$$\frac{\omega}{2\pi} \operatorname{sinc}^2 1000t \rightarrow \frac{1}{\pi}\left(\frac{\omega}{2W}\right)$$

Communication Systems

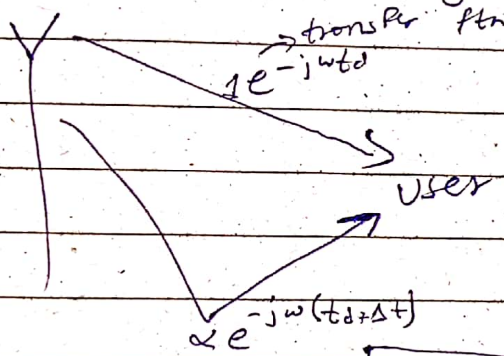
Multipath:

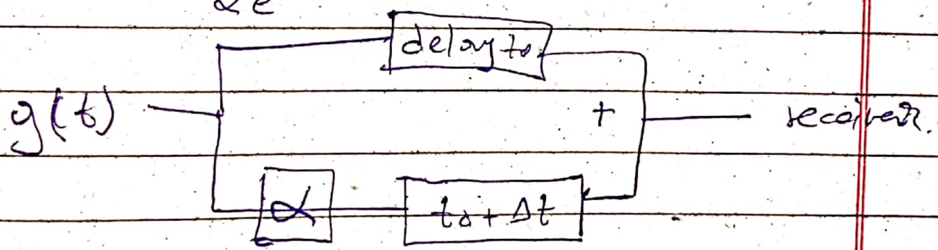
→ factor of distortion



- omnidirection communication
- copies of signal received at received
- signal received by multipath

Let only 2 regions





$$1e^{-j\omega t_d} + \alpha e^{j\omega t_d+\Delta t}$$ → ideal bcz amplitudes constant, phase res Linear

$$= e^{j\omega t_d}\left(1+\alpha e^{-j\omega t_d}\right)e^{-j\omega t_d}$$

$$= \left(\underbrace{1+\alpha\cos\omega\Delta t}_{real} \underbrace{-j\sin\omega\Delta t}_{imaginary}\right)e^{-j\omega t_d}$$

→ Phase angle → Linear ftn → ideal

=

Aisa Lana

$$|\;| = \sqrt{a^2 + b^2}$$

Date:

$$|H(\omega)| = \sqrt{1 + \alpha\cos\omega\Delta t + \alpha^2\sin^2\omega\Delta t} \cdot e^{-j\left[\tan^{-1}\left(\frac{\alpha\sin\omega\Delta t}{1+\cos\omega\Delta t}\right) + \omega t_d\right]}$$

$$= \sqrt{1+\alpha^2(1) + 2\alpha\cos\omega\Delta t} \cdot e^{-j\left[\tan^{-1}\left(\frac{\alpha\sin\omega\Delta t}{1+\cos\omega\Delta t}\right) + \omega t_d\right]}$$

sinusoid

sinusoid

=) Non on ideal case now

$$\left[\begin{array}{c} \text{if } \cos\omega\Delta t = 1 \\ \alpha = 1 \end{array}\right]$$

$= \sqrt{4}$ $\qquad \omega\Delta t = n\pi$

$= 2$ $\qquad$ for even $n = 0, 2, 4, 6$

good gain in amplitude $\qquad$ gives $\cos\omega\Delta t = 1$

constructive addition

if n = odd

1, 3, 5

distructive addition will occur

signal lost at some frequency

signal distortion

At some freq. constructive and at some destructive.

$$\omega = \frac{n\pi}{\Delta t}$$

→ frequency selective fading

* Energy of a signal

$g(t) \rightarrow$ energy?

$$E_g = \int_{-\infty}^{\infty} g^2(t)\, dt$$

$$E_g = \int_{-\infty}^{\infty} |g(t)|^2\, dt \rightarrow \text{complex signal}$$

$$E_g = \int_{-\infty}^{\infty} g(t) \cdot \underset{\downarrow \text{FT}}{g^*(t)}\, dt$$

$a+ib$

$= (a+ib)(a-ib)$

$=$ magnitude

$$E_g = \int_{-\infty}^{\infty} g(t) \left[\frac{1}{2\pi} \int_{-\infty}^{\infty} G^*(\omega) e^{-j\omega t}\, d\omega \right]_{-\infty}^{\infty} dt$$

cyege

$$g(t) \rightarrow \int_{-\infty}^{\infty} g(t) e^{-j\omega t}\, dt \rightarrow G(\omega)$$

$$G(\omega) \rightarrow \frac{1}{2\pi} \int_{-\infty}^{\infty} G(\omega) e^{j\omega t}\, d\omega \rightarrow g(t)$$

$$\boxed{\frac{1}{2\pi} \int_{-\infty}^{\infty} G^*(\omega) e^{j\omega t}\, d\omega}$$

2 integrals

$$E_g = \frac{1}{2\pi} \int_{-\infty}^{\infty} \left[\int_{-\infty}^{\infty} g(t) e^{j\omega t}\, dt \right] G^*(\omega)\, d\omega$$

$$= \frac{1}{2\pi} \int_{-\infty}^{\infty} G(\omega)\, G^*(\omega)\, d\omega.$$

Date:

$$E_g = \frac{1}{2\pi}\int_{-\infty}^{\infty} |G(\omega)|^2 \, d\omega$$

$E_g \to$ area under curve of that signal.

→ Parseval's theorem.

→ energy in frequency domain.

Example:

$$g(t) = e^{-at} u(t) \qquad a > 0$$

$$E_g = \frac{1}{2a}$$ ← same

$$G(\omega) = \int_{-\infty}^{\infty} e^{-at} e^{-j\omega t} \, dt$$

$$= \int_{-\infty}^{\infty} e^{-(at + j\omega t)} \, dt$$

$$=$$

$$= \frac{1}{a + j\omega}$$

$$G|\omega) = \frac{1}{\sqrt{a^2 + \omega^2}}$$

$$|G(\omega)|^2 = \frac{1}{a^2 + \omega^2}$$

Since

$$E_g = \frac{1}{2\pi}\int_{-\infty}^{\infty} |G(\omega)|^2 \, d\omega$$

$$= \frac{1}{2\pi}\int_{-\infty}^{\infty} \frac{1}{a^2+\omega^2} \, d\omega$$

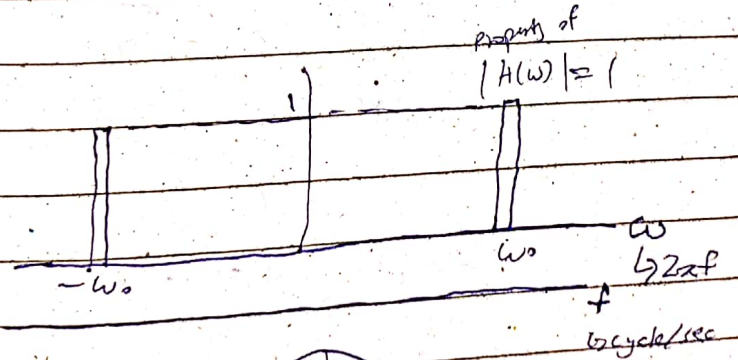
$$= \frac{1}{2\pi a} \tan^{-1}\frac{\omega}{a}\Big|_{-\infty}^{\infty}$$

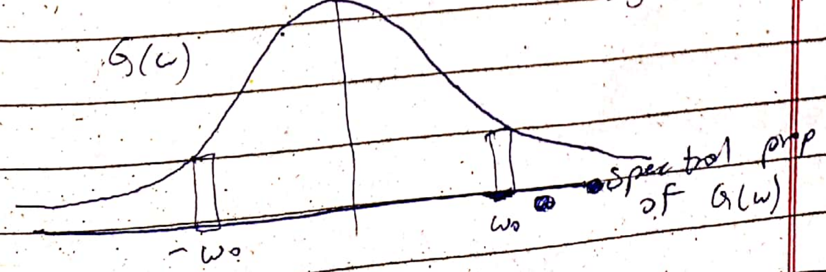
$$= \frac{1}{2\pi a}\Big[\underbrace{\tan^{-1}\infty}_{\pi/2} - \underbrace{\tan^{-1}-\infty}_{\pi/2}\Big]$$

$$= \frac{1}{2\pi a}[\pi]$$

$$= \frac{1}{2a}$$

* Energy Spectral density.





Date:

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

energy

$$E_y(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} |G(\omega)\ H(\omega)|^2\, d\omega$$

$$= \frac{1}{2\pi}\int_{-\infty}^{\infty} |G(\omega)|^2\, d\omega$$

OR

$$= \int_{-\infty}^{\infty} |G(\omega_0)|^2\, df$$

$\Rightarrow$ Now no need of $-\infty \longleftrightarrow \infty$ since we took ω_0

$$E_y(\omega) = 2\,|G(\omega_0)|^2\, df$$

↳ 2 ω_0's
↳ we can skip bcz -ve freq do not exist.

$$\frac{E_y(\omega)}{df} = |G(\omega_0)|^2$$

↳ Energy per unit frequency

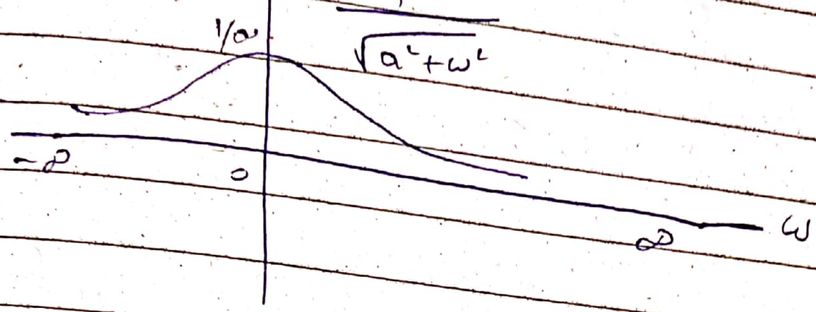
↓

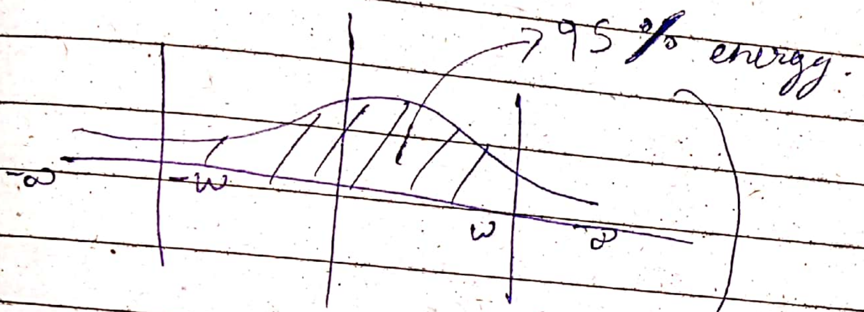
Energy spectral density of signal

$$g(t) = e^{-at}\, u(t) \qquad a > 0$$

$$|G(\omega)|^2 = \frac{1}{a^2+\omega^2}$$

$$|G(\omega)| = \frac{1}{\sqrt{a^2+\omega^2}}$$





Find this particular band?

band ↓ error ↑ freq loss ↑

~~bit error rate~~ ↑

distortion ↑

shape ×

detection of signal ×

$$\overset{E_g}{\frac{1}{2a}} = \frac{1}{2\pi}\int_{-\infty}^{\infty} |G(\omega)|^2\, d\omega$$

$$\frac{0.95}{2a} = \frac{1}{2\pi}\int_{-W}^{W} |G(\omega)|^2\, d\omega$$

Date:

$$\frac{0.95}{2a} = \frac{1}{2\pi}\int_{-w}^{w} \frac{1}{a^2+\omega^2}\, d\omega$$

$$\frac{0.95}{2a} = \frac{1}{2\pi a} \tan^{-1}\frac{\omega}{a}\Bigg|_{-w}^{w}$$

$$= \frac{1}{2\pi a}\left[\tan^{-1}\frac{w}{a} - \tan^{-1}\frac{(-w)}{a}\right]$$

$$\frac{0.95}{2a} = \frac{1}{2\pi a}\, 2\tan^{-1}\frac{w}{a}$$

$$\frac{0.95}{2a} = \frac{1}{\pi a}\tan^{-1}\frac{w}{a}$$

$$\tan^{-1}\frac{w}{a} = \frac{0.95\pi}{2}$$

$$\frac{w}{a} = \tan\frac{0.95\pi}{2}$$

$$\boxed{W = a\tan\left(\frac{0.95\pi}{2}\right)}$$

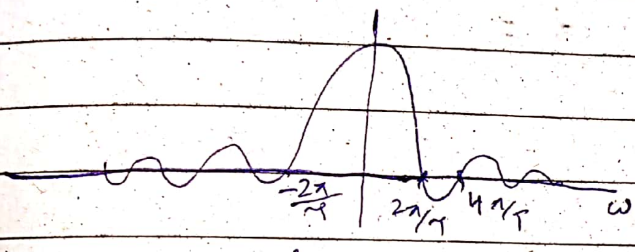
→ wo band hai jisme 95% energy hai → essential bandwidth

$g(t) = \text{rect}\ \dfrac{t}{\tau}$

90% energy
essential bandwidth = ?

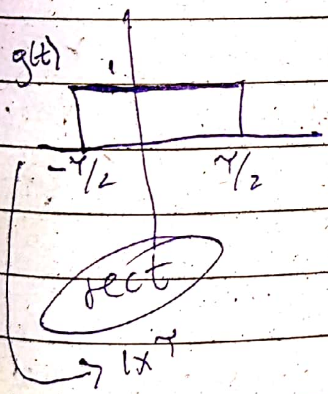
$$E_g(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} |G(\omega)|^2\, d\omega$$

$$\text{rect}\ \frac{t}{\tau} \Longleftrightarrow \tau\ \text{sinc}\ \frac{\omega\tau}{2}$$



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

$$\omega = \pm\frac{2\pi n}{\tau} \rightarrow \text{zero points}$$



$$E_g = \frac{1}{2\pi}\int_{-\infty}^{\infty} \tau^2\, \text{sinc}^2\, \frac{\omega\tau}{2}\, d\omega$$

$$0.9\,\tau = \frac{1}{2\pi}\int_{-\infty}^{\infty} \tau^2\, \text{sinc}^2\, \frac{\omega\tau}{2}\, d\omega$$

$\omega =$ ______

→ essential bandwidth
→ 90% energy reside within this band.

Week 5

Amplitude Modulation

→ carrier communication

↳ sum of carrier signals are transmitted

↳ frequency translation

signal ki 3 cheezain hain.

1. Amplitude
2. freq
3. phase

→ If we vary amplitude of carrier signal in accordance with instantaneous value of base band signal.

$m(t)$

↳ we need to transmit

↳ first we'll modulate it

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

$$\uparrow \cos \omega_c t$$

$\downarrow$

Amp mod signal

→ time domain

$$\varphi_{AM}(t) = m(t)\cos\omega_c t$$

~~Now~~ this will shift ~~the freq domain~~ in some other freq spectrum.

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

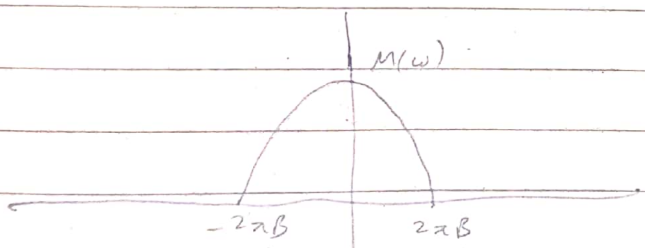
$$= \frac{m(t)\,e^{j\omega_c t}}{2} + \frac{m(t)\,e^{-j\omega_c t}}{2}$$

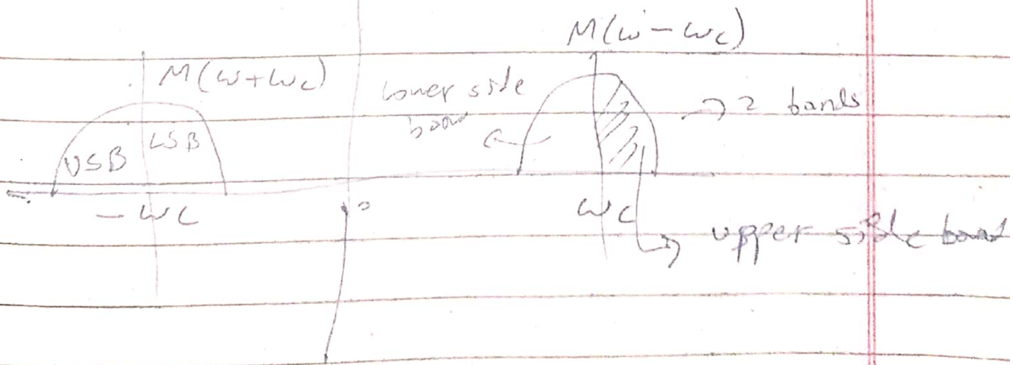
$$\Rightarrow m(t)\,e^{j\omega_c t} \xleftrightarrow[FT]{} M(\omega+\omega_c)$$

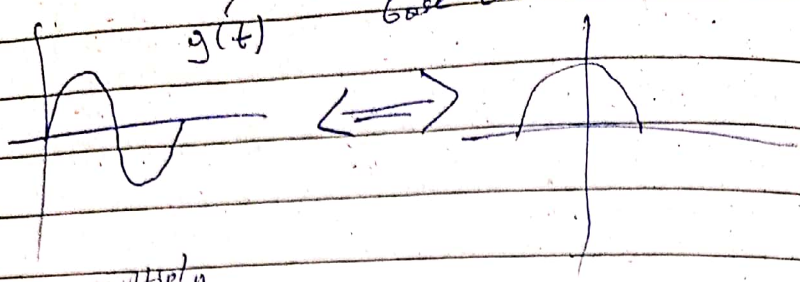
$$m(t)\,e^{-j\omega_c t} \Longleftrightarrow M(\omega-\omega_c)$$

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

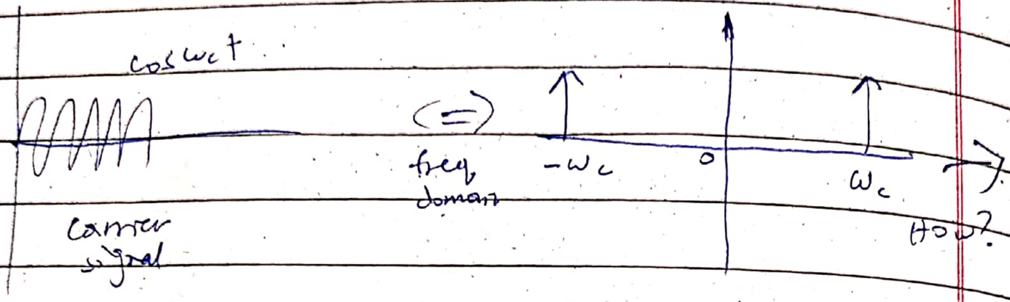
→ freq domain

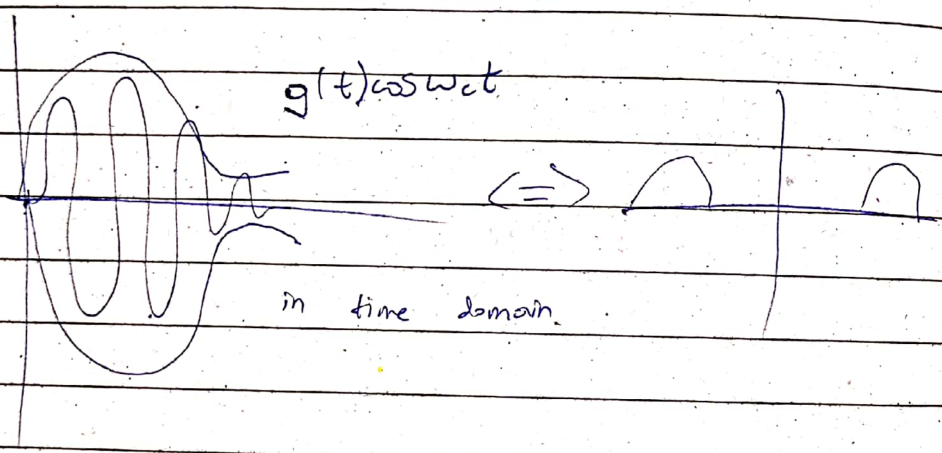






multiply





→ This is called Amplitude modulation with suppressed carriers.

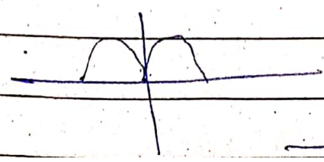
→ Carrier itself will not be transmitted rather suppressed

→ Double side band with suppressed carriers

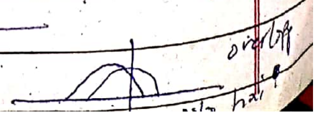
ω_c kitna dur ho?

$$\omega_c \geq 2\pi B.$$

if =

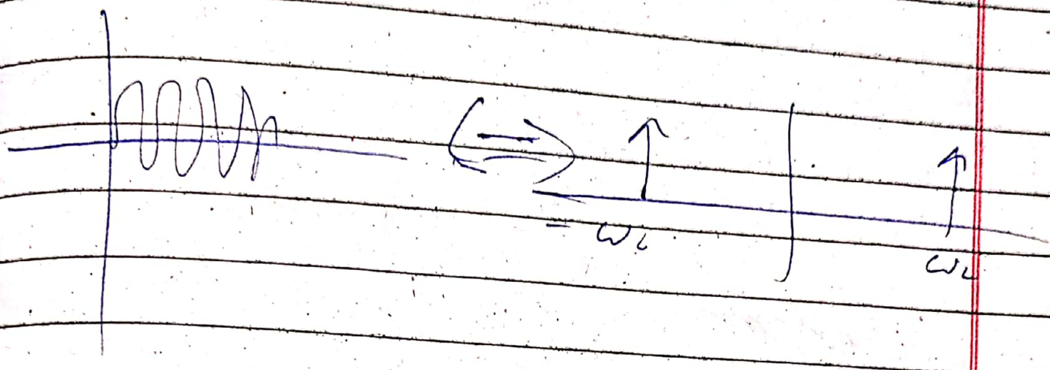


if <



$\cos \omega_c t$

$$= \frac{e^{j\omega_c t} + e^{-j\omega_c t}}{2} \overset{FT}{\Longleftrightarrow} \delta(\omega - \omega_c)$$



demodulate

$$\{m(t)\cos\omega_c t\}\cos\omega_c t$$

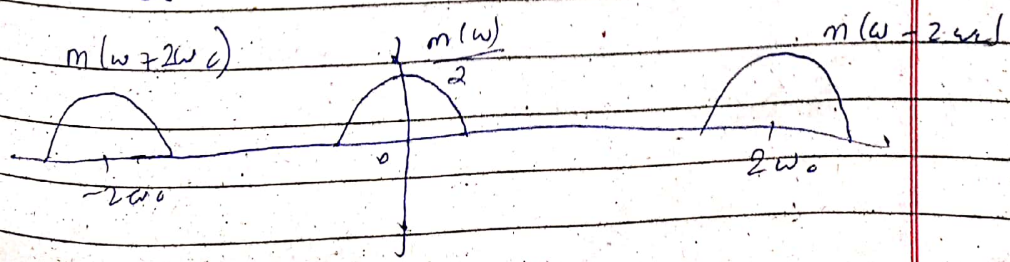
$$= m(t)\cos^2\omega_c t = m(t)\left\{\frac{1+\cos 2\omega_c t}{2}\right\}$$

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

$$\frac{m(t)}{2} + \frac{m(t)e^{j2\omega_c t}}{4} + \frac{m(t)e^{-j2\omega_c t}}{4}$$

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

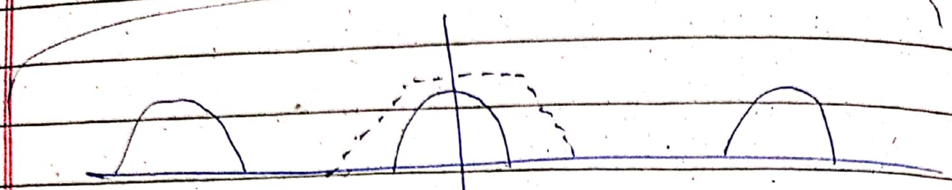
$$= \frac{m(\omega)}{2} + \frac{m(\omega - 2\omega_c)}{4} + \frac{m(\omega + 2\omega_c)}{4}$$



Date:

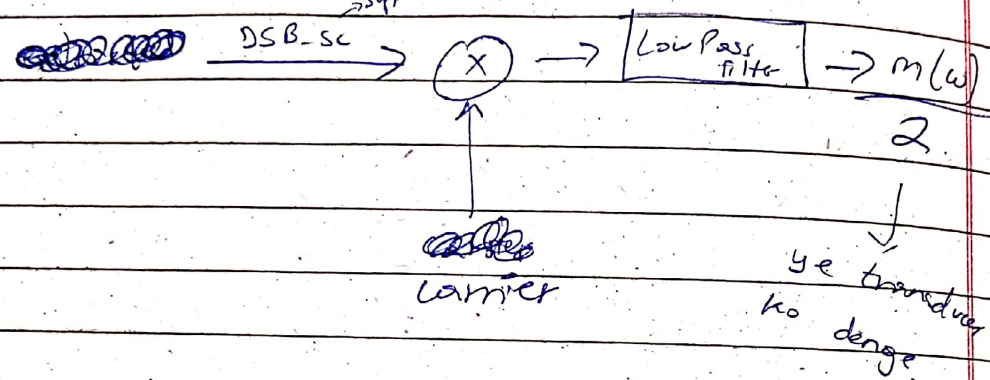
Apply Low pass filter

DSB → double side band



→ bcz we're not transmitting carrier & only using using

→ suppressed carrier



→ Synchronous coherent detection

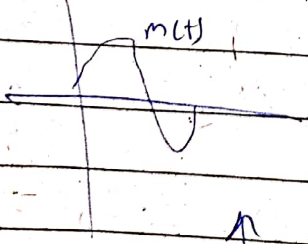
⇒ Abhi carrier ko transmit nhi kia so cohesancy me issue aa rha.

→ if carrier is send too, then SCD will become possible

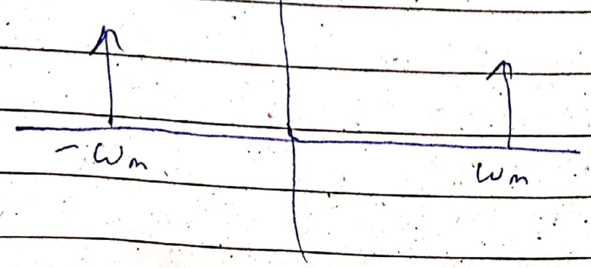
→ $m(t) = \underbrace{\cos \omega_m t}_{\text{base band signal}}$ → tone signal

→ transmitted

Recap:



in freq domain



Assignment

AM

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

⇒ Comm. Systems

$m(t) \cos \omega_c t$

DSB-SC

→ carrier is not transmitted

→ Double side Band

→ Excessive BW is going to be lost

$\{m(t) \cos \omega_c\} \cos \omega_c t$

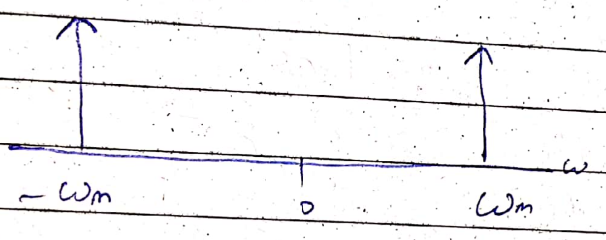
↳ synchronous coherent demodulation

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

→ freq domain expression

↳ Tone signal bcz its a single sinusoid.

$M(\omega)$ ⇒ represent in exp



$M(\omega) = M(\omega + \omega_m) - M(\omega - \omega_m)$.

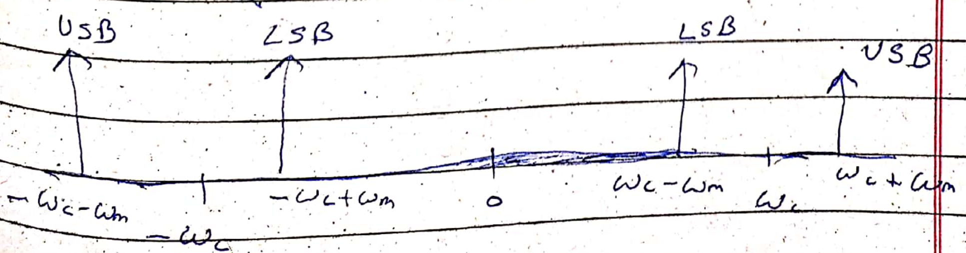
$|M(\omega)| \cdot e^{j\theta m(\omega)}$ if phase angle is given.

graph them

If AM

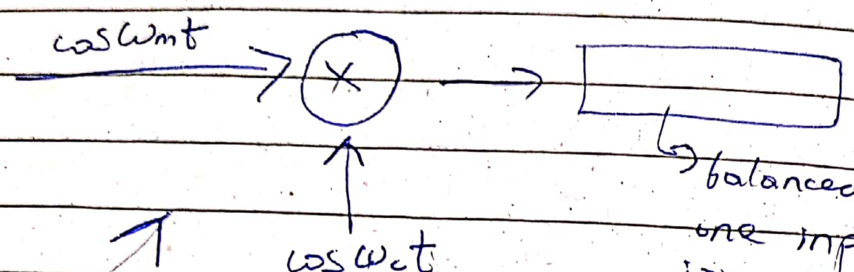
$\underbrace{\cos \omega_m t}_{m(t)} \cdot \underbrace{\cos \omega_c t}_{carrier}$

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



Date:

$\cos\omega_c t \rightarrow$ input ha use to hr the hain but graph says we didn't used ω_c.



balanced to one input & ignores the other

This is called balanced modulator.

Modulators

→ Electronic devices that do modulation practically

Types

① Multiplier → 2 inputs are going to be "X" with one another

But this type of direct xion will be complex, it would give error and is expensive.

maintaining Linearity is difficult in direct multiplication

Non Linear Modulators:

- Higher order of inputs.

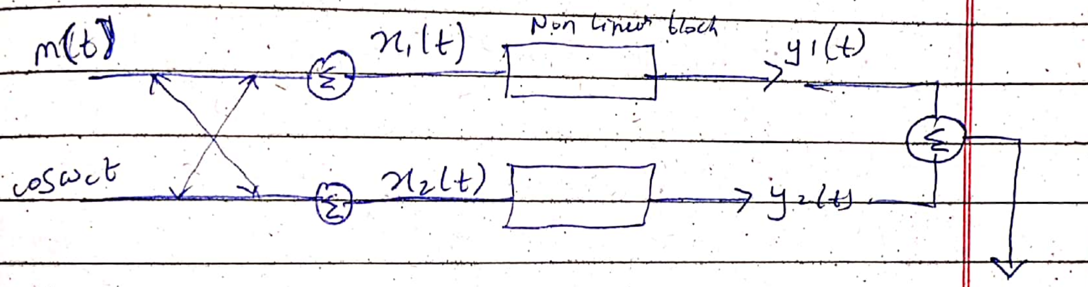
$$y(t) = a x(t) + b x^2(t)$$

↳ higher order component.

$$z(t) = y_1(t) - y_2(t)$$

$$x_1(t) = \cos\omega_c t + m(t)$$

$$x_2(t) = \cos\omega_c t - m(t)$$



$$z(t) = y_1(t) - y_2(t)$$

$$x_1(t) = \cos\omega_c$$

$a^2 + b^2 + 2ab$

$$x_1^2(t) = (\cos\omega_c)^2 + (m(t))^2 + 2(\cos\omega_c)\cdot(m(t))$$

$$x_2^2(t) = (\cos\omega_c)^2 + (m(t))^2 - 2(m(t))(\cos\omega_c)$$

$$y_1(t) = a x_1(t) + b x_1^2(t)$$

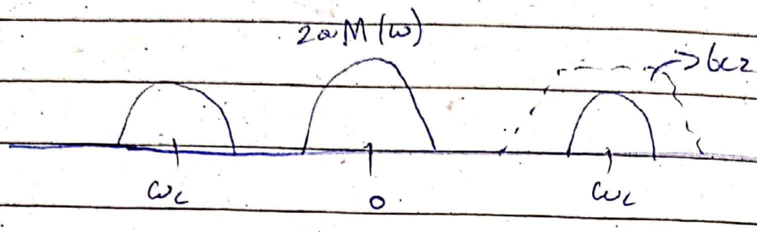
$$= a\cos\omega_c t + a m(t) + b\cos^2\omega_c t + b m^2(t) + 2b\, m(t)\cos\omega_c t$$

$$y_2(t) = a\cos\omega_c t - a m(t) + b\cos^2\omega_c t + b m^2(t) - 2b\, m(t)\cos\omega_c t$$

$$z(t) = y_1(t) - y_2(t) = 2a\, m(t) + \underbrace{4b\, m(t)\cos\omega_c t}_{\text{modulated signal}}$$

Date:

$$z(\omega) = 2a M(\omega) + 4B\{M(\omega + \omega_c) \\ M(\omega - \omega_c)\}$$



→ bcz we need modulated signal that's why we use band pass filter.

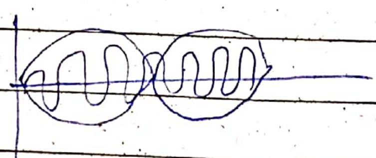
This all is happening at transmitter.

$\cos\omega_c t \rightarrow$ single frequency hai

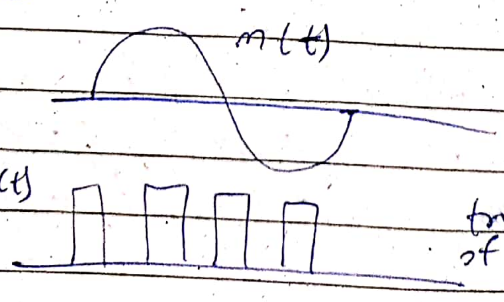
$m(t)\cos\omega_c t \rightarrow$ band of freq.

If we're passing modulated signal, so pass it through band pass filter and 2 parts of signal would get separated.

$4 b\, m(t)\cos\omega_c t \rightarrow$ draw in time domain.

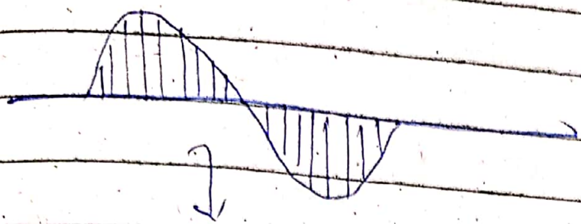


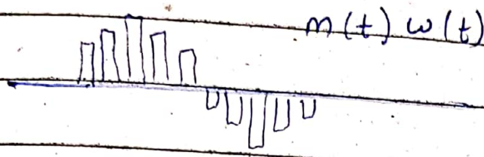
③ Switching Modulators



train of pulses → periodic

super impose them by using modulation





we can find eq. of this periodic pulses using F. series → ch 2

$$a_0 + \sum_{n=0}^{\infty} a_n \{\cos n\omega_0 t + b_n \sin n\omega_0 t\}$$

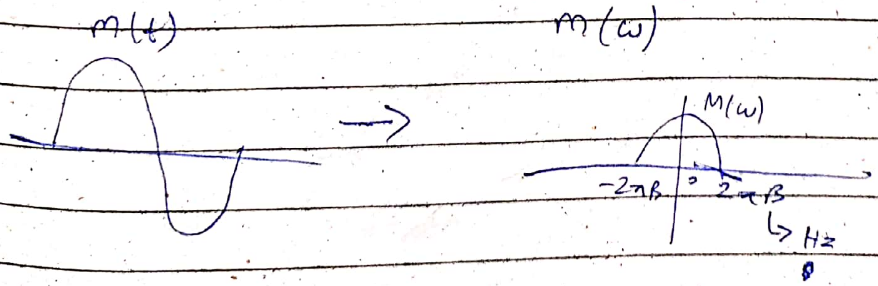
OR

$$\sum_{n=0}^{\infty} C_n \cos(n\omega_0 t + \theta_n)$$

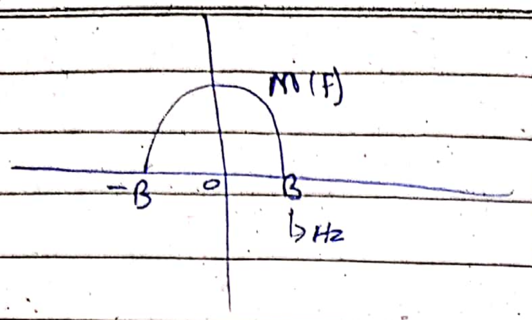
→ Assignment

↓ Answer

(1) $\omega(t) = \frac{1}{2} + \frac{2}{\pi}\left(\cos \omega_c t - \frac{1}{3}\cos 3\omega_c t + \frac{1}{5}\cos 5\omega_c t + \text{———}\right)$



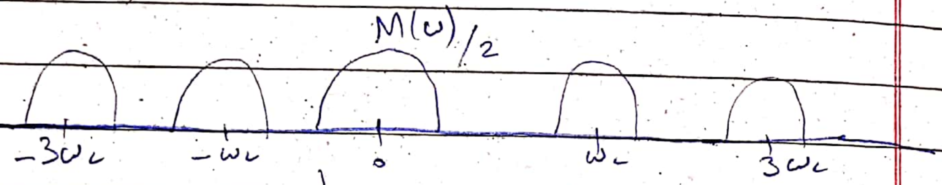
Date:

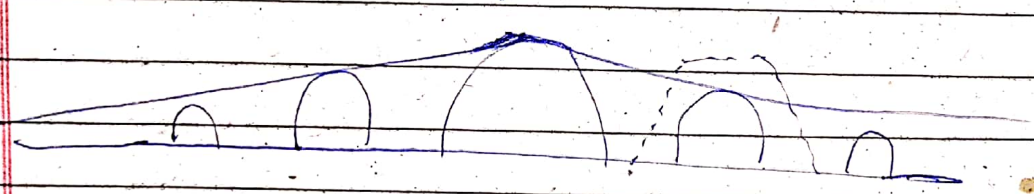


LSF represented in f.

To draw $\omega(t) \rightarrow$ in frequency domain (eq 1)

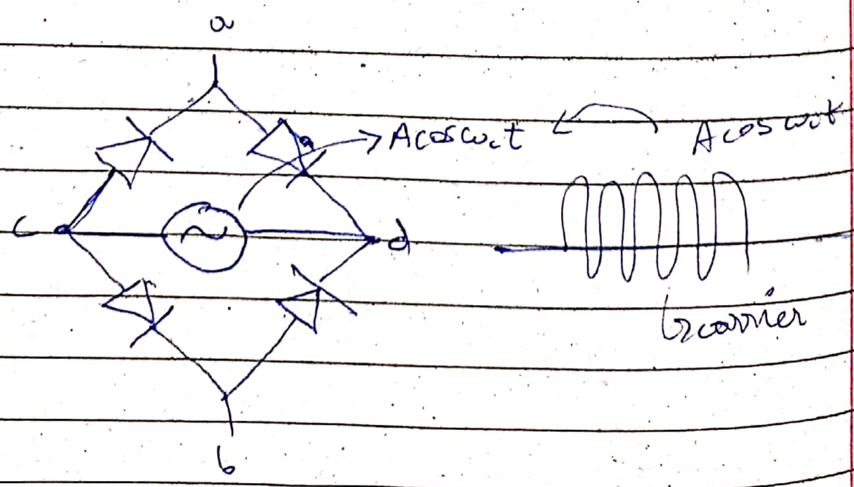
$m(t)\omega(t) = m(t)\frac{1}{2} + m(t)\frac{2}{\pi}$ ----------



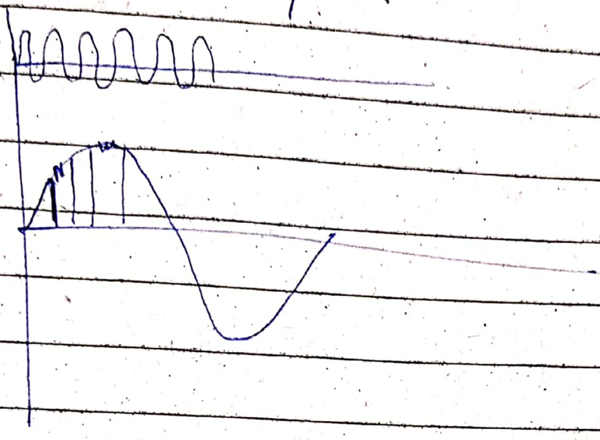


Magnitude drops.

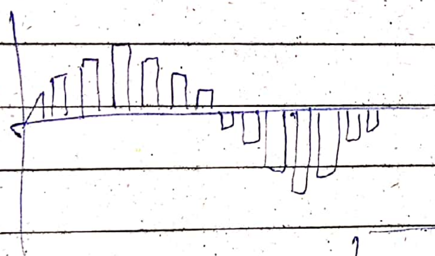
Apply band pass filter
& then transmit

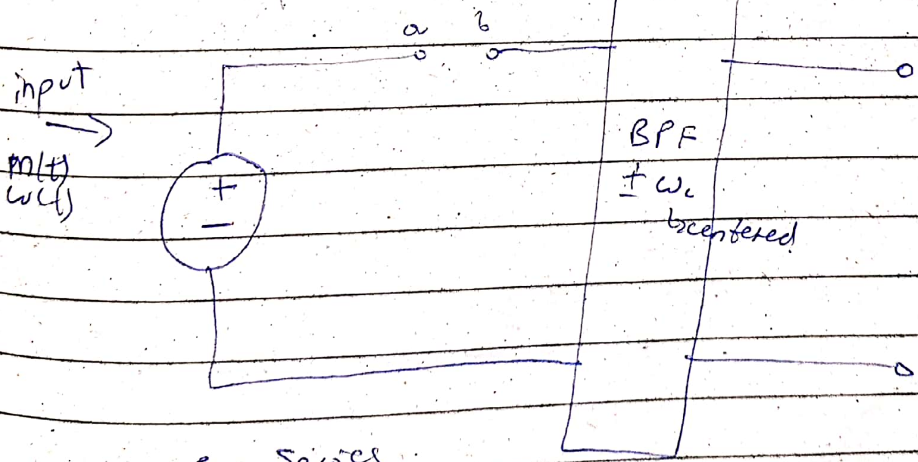


In case of +ve cycle
All diodes forward biased
and $m(t)$ would pass.



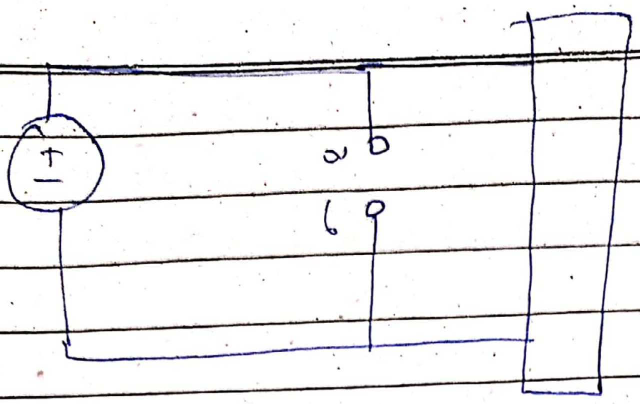
In −ve cycle, all diodes are reverse biased and nothing would pass → open circuit





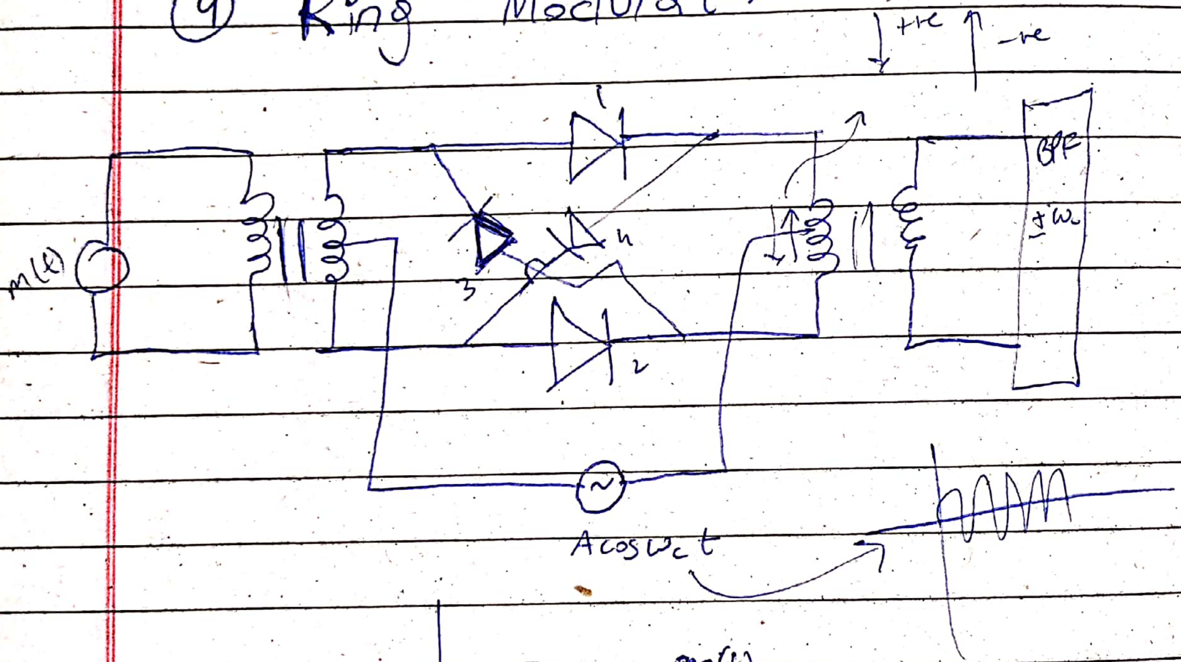
∴ Series bridge modulator

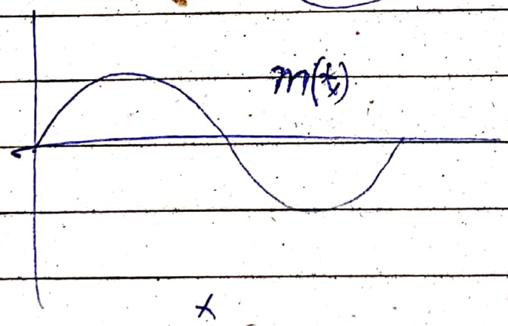
Date:



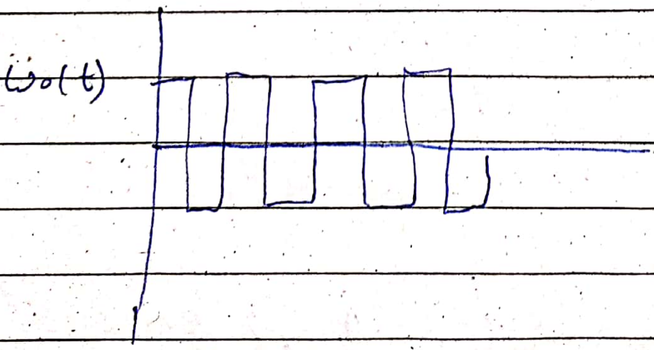
shunt
↳ see book

④ Ring Modulator





×



F Series eq

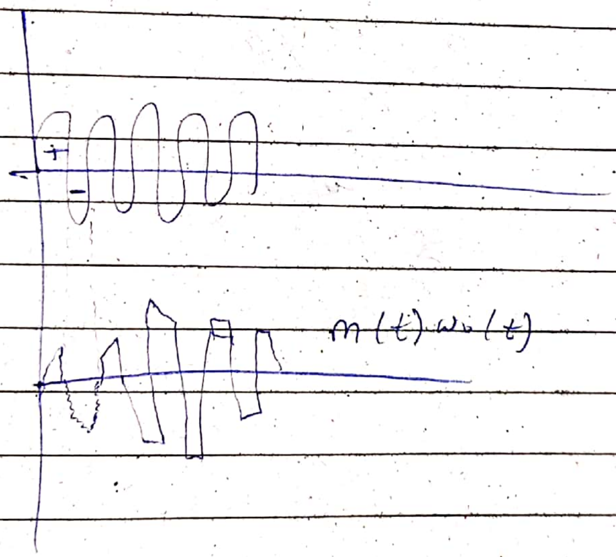
$$\omega_0(t) = \frac{4}{\pi}\left(\cos\omega_c t - \frac{1}{3}\cos 3\omega_c t + \frac{1}{5}\cos 5\omega_c t - \dots\right)$$

for +ve cycle

1 and 2 are forward biased

and something is induced at output

(only for +ve cycle)



for -ve cycle, 1 & 2 reverse biased

3, 4 forward biased.

Frequency mixer

$\rightarrow m(t)\cos\omega_c t \cos\omega_{mix} t$

$m(t)\{\cos(\omega_c + \omega_{mix})t + \cos(\omega_c - \omega_{mix})t\}$

$m(t)\cos(\omega_c + \omega_{mix})t + m(t)\cos(\omega_c - \omega_{mix})t$

Date:

$$\omega_{mix} = \omega_c + \omega_I$$

$$\omega_{mix} = \omega_c - \omega_I$$

$$= m(t)\cos(\omega_c + \omega_c + \omega_I) + m(t)\cos(\omega_c - \omega_c$$

$$= m(t)\cos(2\omega_c + \omega_I) + m(t)\cos(\omega_I)$$

so we transformed 1 freq into another frequency.

This is frequency mixing or hetrodyme process.

Communication System

$m(t)\cos\omega_c t$

DSB - SC

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

$M(\omega)$

$A\left[\frac{e^{j\omega_c t} + e^{-j\omega_c t}}{2}\right]$

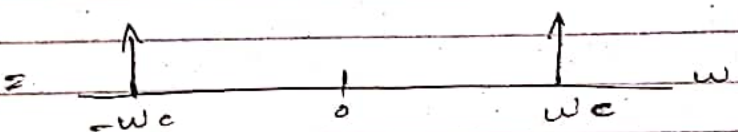
$e^{j\omega_c t} \Longleftrightarrow 2\pi\,\delta(\omega + \omega_c)$

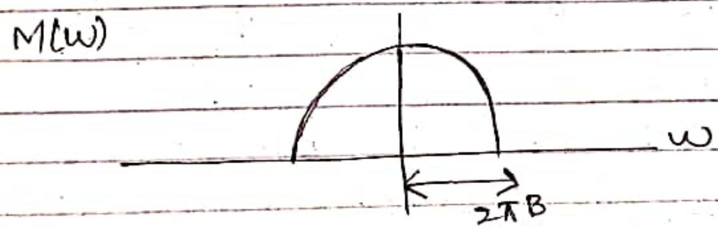
$(m(t)\cos\omega_c t)\cos(\omega_c + \Delta\omega)t$

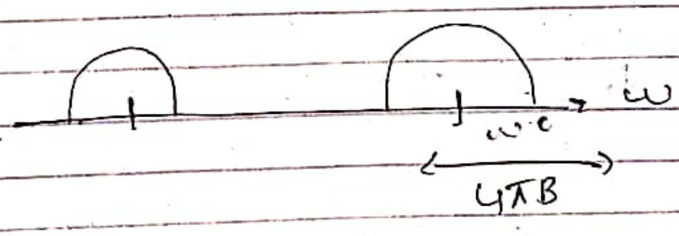
★ Amplitude modulation

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

=

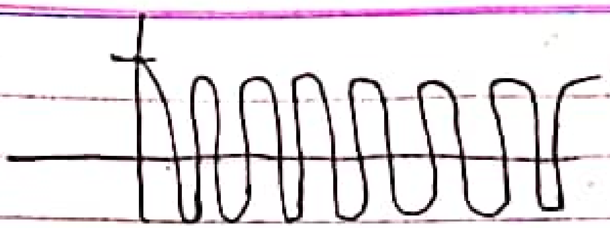


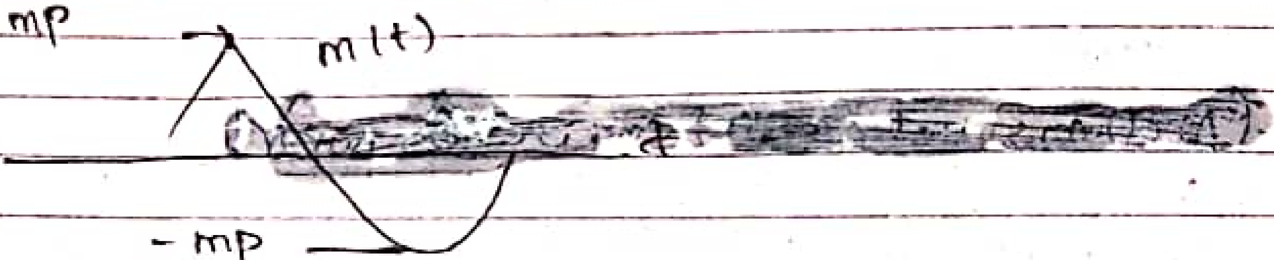




$$\phi_{AM}(\omega) = \pi\left[\delta(\omega - \omega_c) + \delta(\omega + \omega_c)\right] + \frac{M(\omega + \omega_c)}{2} + \frac{M(\omega - \omega_c)}{2}$$

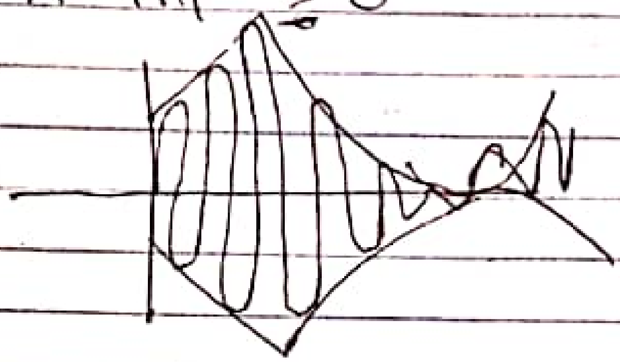
$$\phi_{AM}(t) = [1 + m(t)]\cos\omega_c t$$

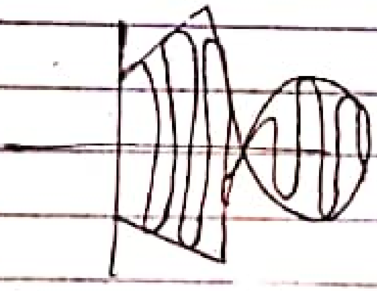




$A + m(t) \geq 0$ for all "t" Envelop detection.

$A - mp \geq 0$



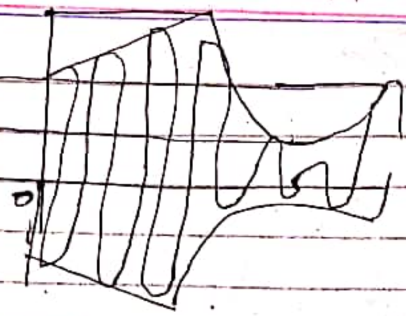


$A + m(t) \ngeq 0$

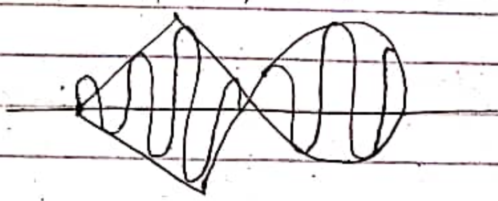
Modulation Index:

$$\mu = \frac{mp}{A} \qquad 0 < \mu \leq 1$$

Let $\mu < 0.5$



$\mu > 1$



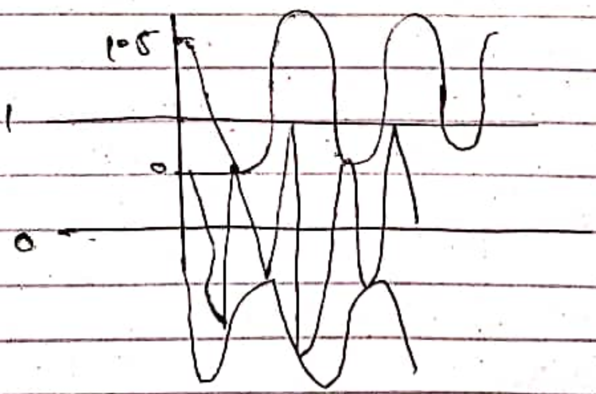
let $m(t) = B\cos\omega_m t$

$\phi_{AM}(t) = [A + m(t)]\cos\omega_c t$

$= [A + B\cos\omega_m t]\cos\omega_c t$

$= [A + \mu A\cos\omega_m t]\cos\omega_c t$

$= A[1 + \mu\cos\omega_m t]\cos\omega_c t$



carrier power & side band :-

$A \cos w_c t$

$$= \frac{1}{T}\int_{-T/2}^{T/2} A^2 \cos^2 w_c t \; dt$$

$$= \frac{A^2}{T}\int_{-T/2}^{T/2} \left[\frac{1+\cos 2w_c t}{2}\right] dt$$

$$\frac{A^2}{2T}\int_{-T/2}^{T/2} 1 \; dt + 0$$

$$\frac{A^2}{2\cancel{T}} \times \cancel{T} = \frac{A^2}{2} = P_c$$

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

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

$$m(t) = B \cos w_m t$$

$$\mu = \frac{B}{A}$$

$$B = \mu A$$

$$\frac{B^2}{2} = \frac{\mu^2 A^2}{2} = \text{Power of tone signal}$$

Now finding the power efficiency

$$\frac{P_m}{P_c + P_m} = \frac{\overset{\longrightarrow \text{mean}}{\overline{m^2(t)}}/2}{A^2/2 + m^2(t)/2}$$

$$= \frac{\overline{m^2(t)}}{A^2 + \overline{m^2(t)}} = \frac{\mu^2 \cancel{A^2}/2}{\cancel{A^2} + \frac{\mu^2 \cancel{A^2}}{2}}$$

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

Now finding %

let $\mu = 1$

$$\frac{(1)^2}{2+(1)^2} = \frac{1}{3} \times 100$$

$$= 33.33\%$$

let $\mu = (0.5)^2 = \frac{(0.5)^2}{2+(0.5)^2} = \frac{0.25}{2.25} =$

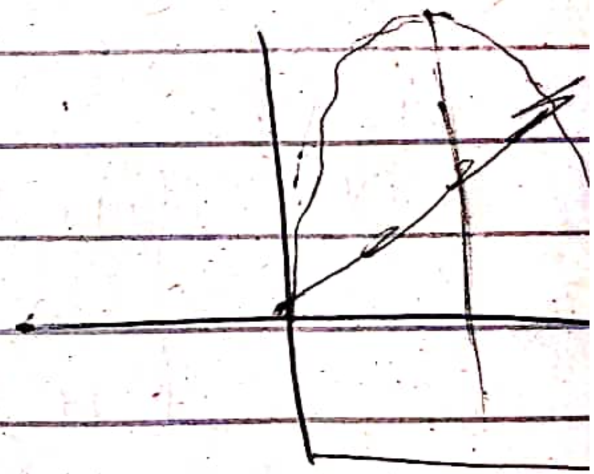
$$= 11.11$$

Index = $\mu = \dfrac{mP}{A}$

$\longleftrightarrow$

EE LEC #
Chapter no 2

Lecture Review



AM:

DSB-SC

$m(t)\cos\omega_c t \Rightarrow$ transmit

Disadvantage bcz of at forend

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

P_c P_m

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

↓
~~carrier~~
itself

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

cost pay for it?

$P_c >>> P_m$

efficiency → modulation index → its value $0 \leq \mu \leq 1$

$$\eta = \frac{\mu^2}{2+\mu^2} \times 100 \quad \text{→ for percentage}$$

$$\mu = \frac{m_p}{A} \Rightarrow m_p \leq A$$

if $\mu > 1$, i.e $m_p > A$

↳ some part of m_p is below zero line.

↳ over modulation

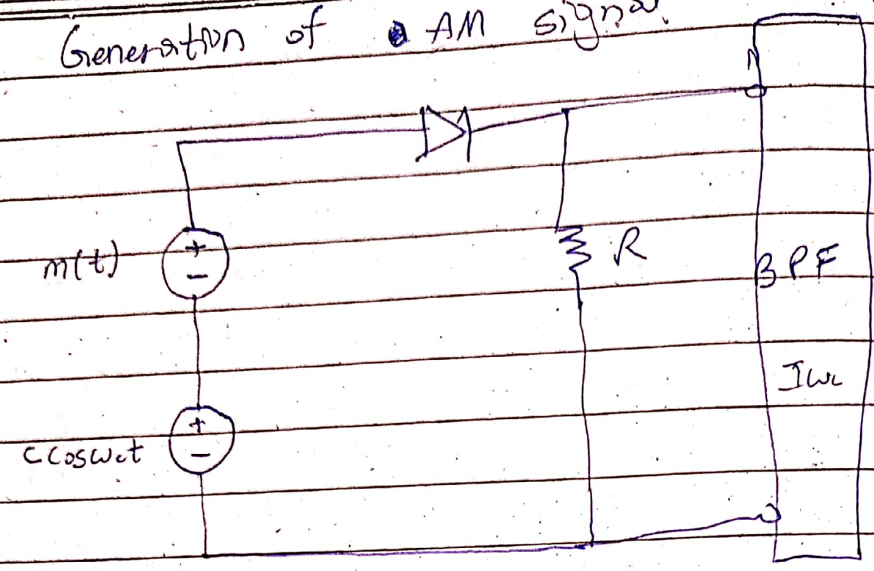
and we donot have option of envelope detection & coherent direction ✓

$$\eta = \frac{1}{3} ~~\times 100 = 33.33\%~~$$

~~↳ going to be~~ used in that signal rather than this.

Date:

Generation of AM signal

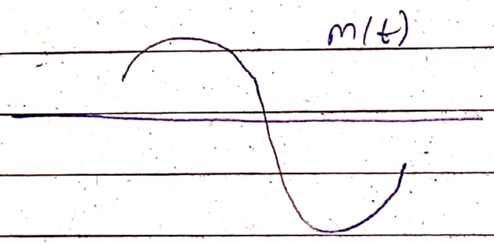


voltage across R

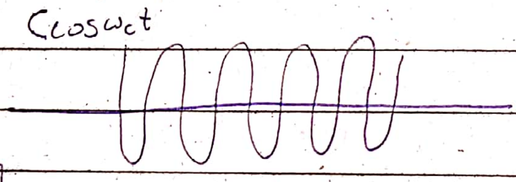
$C\cos\omega_c t + m(t)$ $\qquad$ $C \gg m(t)$

↓

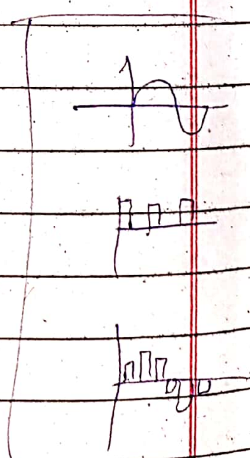
diode is controlling the switching



×



For +, transmit
For −, No transmit



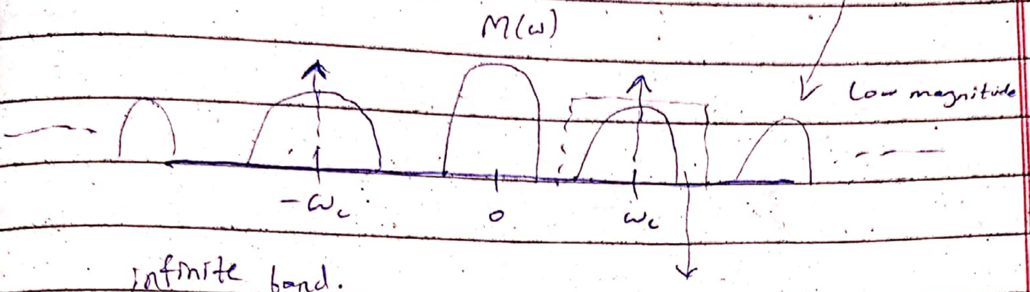
→ train of pulses

$\left[C\cos\omega_c t + m(t)\right] W(t)$ $\qquad$ bits after

FS

$\left[C\cos\omega_c t + m(t)\right]\left[\frac{1}{2} + \frac{2}{\pi}\left(\cos\omega_c t - \frac{1}{3}\cos\omega_c t + \frac{1}{5} \dots\right)\right]$

$\frac{c}{2}\cos\omega_c t + \underline{2m(t)}\cos\omega_c t$ + other terms



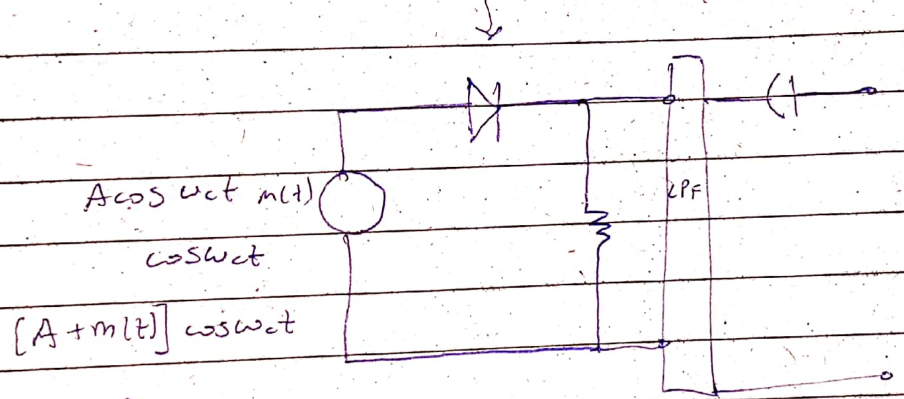
infinite band.

pass it through BP filter

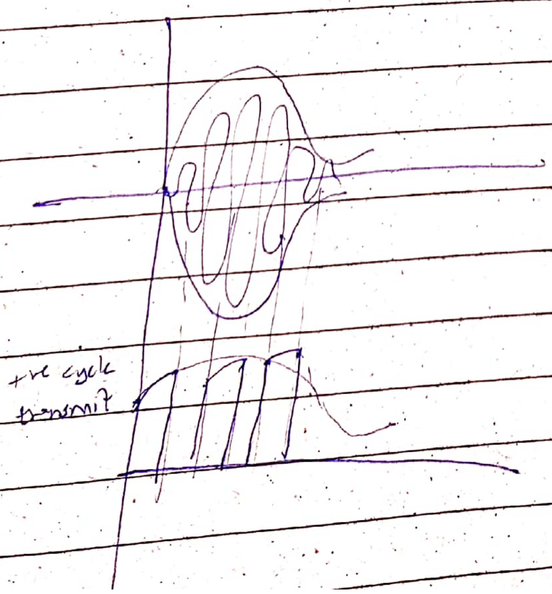
This is called AM with carrier

Receiver ⇒ demodulation of AM signal

↳ Rectifier detector / envelope detection



Received signal :
ignore c/2 & 2/π



Date:

$$\left\{[A+m(t)]\cos\omega_c t\right\} W(t)$$

$\downarrow$ FS.

$$\frac{1}{2}+\frac{2}{\pi}\left[\cos\omega_c - \frac{1}{3}\cos 3\omega_c t \ldots\right]$$

goal → extract $m(t)$

multiply $\{A+m(t)\cos\omega_c t\}$ and $\frac{2}{\pi}\cos\omega_c$

$$\frac{2A}{2\pi}+\frac{2}{2\pi}m(t)+\text{other terms.}$$

$$\frac{A}{\pi}+\frac{1}{\pi}m(t)+\text{other terms (Higher order terms)}$$

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

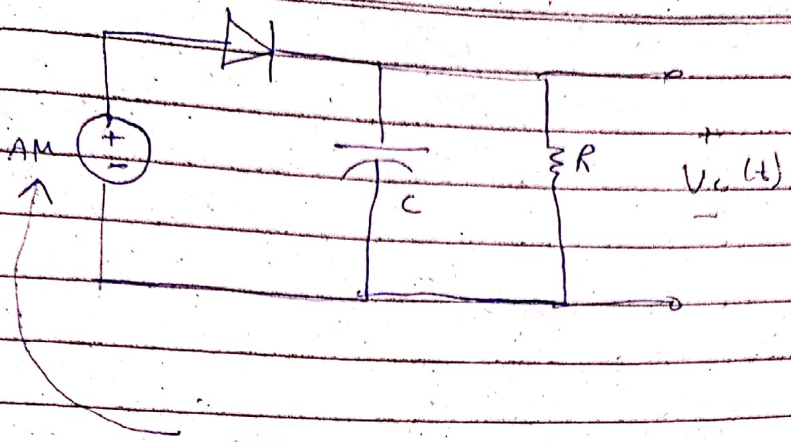
$$\frac{2}{\pi}\left[\frac{[A+m(t)]}{2}+\frac{[A+m(t)]\cos 2\omega_c t}{2}\right]$$

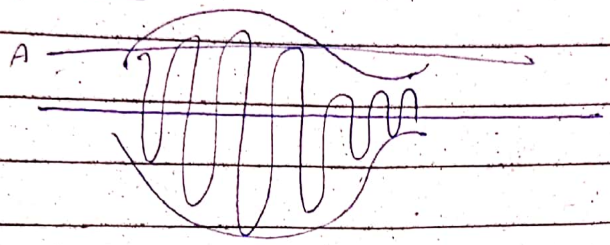
$$\frac{2}{\pi}\frac{A}{2}+\frac{2}{\pi}\frac{m(t)}{2}+\text{other terms}$$

$$\frac{A}{\pi}+\frac{1}{\pi}m(t)$$

$\downarrow$
dc
↳ capacitor block dc
↳ see circuit.

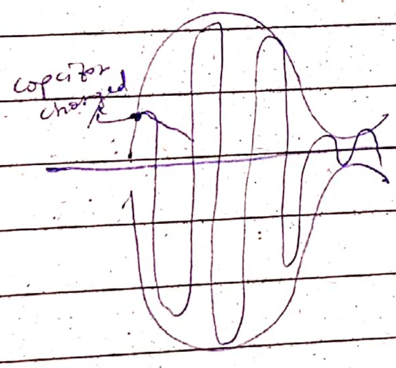
Envelope detection → ED.
Isolate envelope of signal

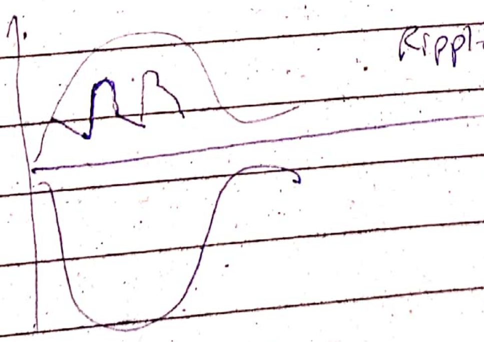




$[A + m(t)] \cos \omega_c t \to 0 \le \mu \le 1$

$M_p \le A$ → For ED





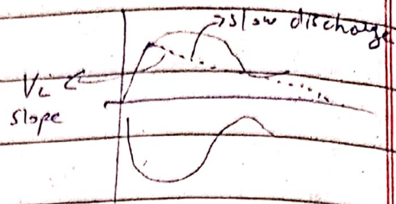
Rippled output but tracking envelope.

$$V_c(t) = E e^{-t/RC}$$

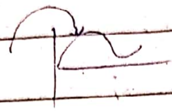
exponential decay

Date:

$RC >> \frac{1}{\omega_c}$ → agar na hui



E → actual slope



$$\left|\frac{dV_c(t)}{dt}\right| \geq \left|\frac{dE(t)}{dt}\right|$$

$$V_c(t) = E e^{-t/RC}$$

$$V_c(t) \approxeq E\left(1 - \frac{t}{RC}\right)$$

$$\frac{dV_c(t)}{dt} = -E/RC.$$

$$\left| \;\; " \;\; \right| = E/RC$$

Example:

→ tone signal

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

ED ?

RC ?

↳ kitna ho ke apna sys envelop ka detection hoga

$$E(t) = \mu A\cos\omega_m t$$

$$\frac{dE(t)}{dt} = \mu A\omega_m \sin\omega_m t.$$

$$\frac{dV_c(t)}{dt} \geq$$

$$\frac{E}{RC} > \mu A\omega_m \sin\omega_m t$$

$$E(t) = A + m(t)$$

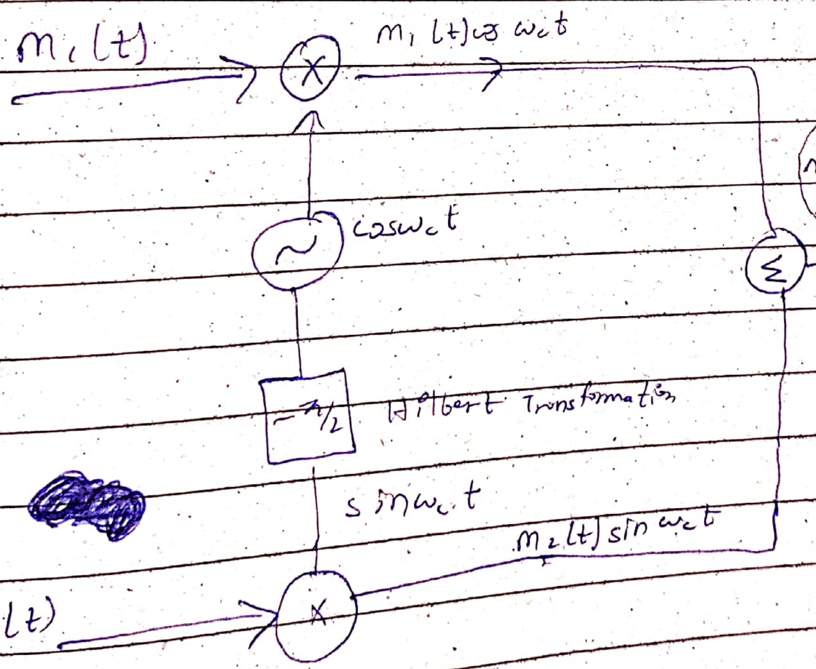
$$\cancel{= A + \mu A\cos\omega_m t}$$

$$\frac{A(1+\mu\cos\omega_m t)}{RC} > \mu A\omega_m \sin\omega_m t$$

$$RC < \frac{1+\mu\cos\omega_m t}{\mu\omega_m \sin\omega_m t}$$

Quadrature Amplitude Modulation QAM

→ much efficient in terms of BW



Both DSB-SC but phase diff

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

↓

will not fre although same freq but due to diff in phase.

↓

orthogonal

↓

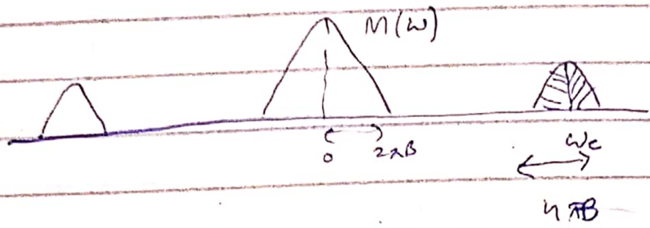
are now seperable

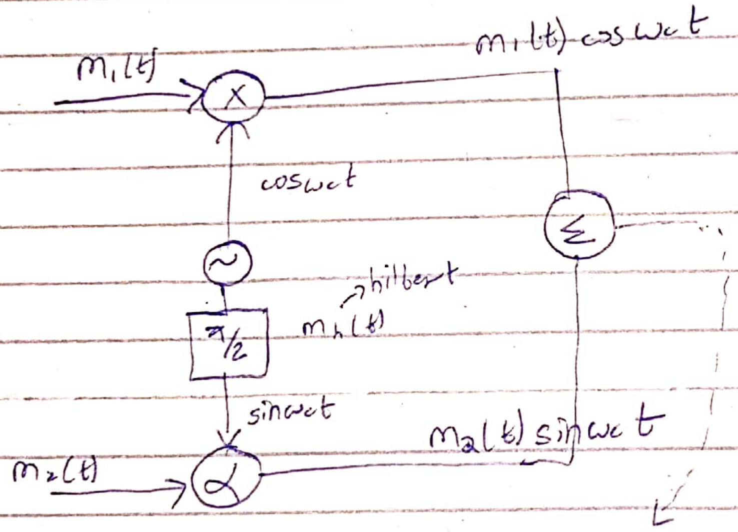
Comm. Systems

Quadrature Amplitude Modulation

$m(t)\cos\omega_c t \rightarrow$ DSB-SC

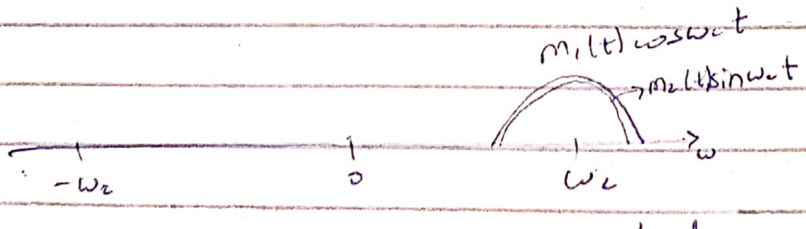
$[A+m(t)]\cos\omega_c t \rightarrow$ with carrier
↳ cost → power





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

If we take FT



- same band
- overlapping
- Never recoverable

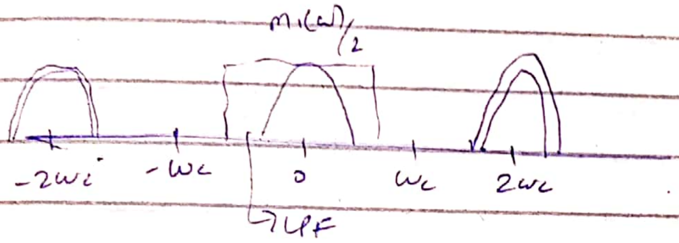
using QAM, we can recover,

bcz of orthogonality property

Receiver:

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

$$\phi_{QAM} \text{ "} = \frac{m_1(t)}{2} + \frac{m_1(t)\cos 2\omega_c t}{2} + \frac{m_2(t)\sin 2\omega_c t}{2}$$

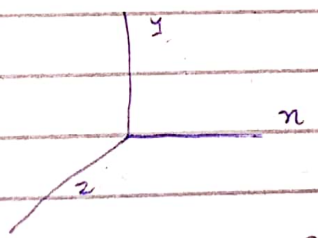


$\phi_{QAM}(t)\sin\omega_c t =$ TYS

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

If they were not ogthogonal, they were not recoverable.

vector → 3 dimensions → cartesian coordinate sys.



* cylindrical coordinate system.
* Spherical " " .

$\phi_{QAM}(t) \cdot \cos(\omega_c t + \theta)$

$\cos[(\omega_c + \Delta\omega)t]$

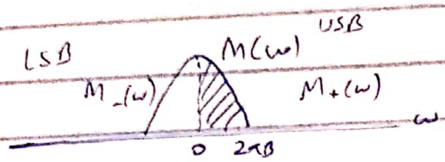
$\cos[\omega_c t + \Delta\omega t]$

$\cos[\omega_c t + \theta]$

Assignment

Single side band amplitude Modulation.

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



$$M(\omega) = M_+(\omega) + M_-(\omega)$$

$$m_+(t) \Longleftrightarrow M_+(\omega)$$

$$m_-(t) \Longleftrightarrow M_-(\omega)$$

$$m(t)\cos\omega_c t \Longleftrightarrow M(\omega+\omega_c) + M(\omega-\omega_c)$$

we want to transmit this

To represent ½ band

$M_-(\omega+\omega_c)$ $\qquad$ $M_+(\omega-\omega_c)$

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

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

$$M(\omega) = M_+(\omega) + M_-(\omega).$$

$$m_+(t) = \frac{1}{2}\left[m(t) + j\,m_h(t)\right] \quad —(1)$$

$$m_-(t) = \frac{1}{2}\left\{m(t) - j\,m_h(t)\right\}$$

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

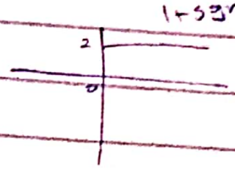
↳ unit step

sgn

$= M(\omega)\left[\frac{1 + sgn(\omega)}{2}\right]$

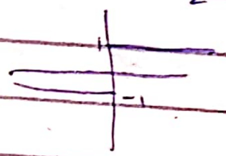
$= \frac{M(\omega)}{2} + \frac{M(\omega)sgn(\omega)}{2}$ — (2)

1+sgn



compare (1) & (2)

$\frac{1+sgn}{2}$



$= u(\omega)$

$jm_h(t) \Longleftrightarrow M(\omega)sgn(\omega)$

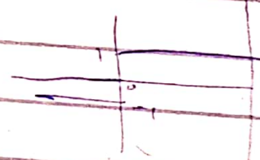
↳ To keep it even

$m_h(t) \Longleftrightarrow -j\,M(\omega)sgn(\omega)$

$M(\omega) \longrightarrow \boxed{H(\omega)} \xrightarrow{Y(\omega)}$

$Y(\omega) = M(\omega)H(\omega) = -j\,sgn(\omega)\,M(\omega)$

$H(\omega) = -j\,sgn(\omega)$.



if $\omega > 0$

$H(\omega) = 1\,e^{-j\pi/2}$

if $\omega < 0$

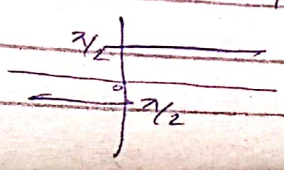
$H(\omega) = 1\,e^{j\pi/2}$

Hilbert Transformation

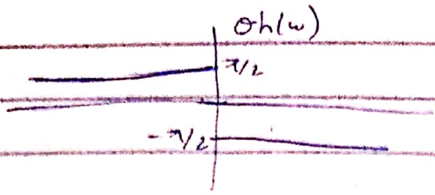
Amp resp → same for all freq.

$H(\omega) = |H(\omega)|\,e^{j\theta_h(\omega)}$

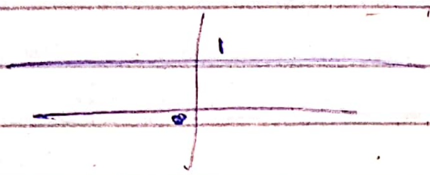
↳ independent of frequency.



$\theta_h(\omega) = -\pi/2$



$|H(\omega)|$



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

$$= m_+(t)e^{j\omega_c t} + m_-(t)e^{-j\omega_c t}$$

$$m(t)e^{j\omega_c t} \Leftrightarrow M(\omega-\omega_c)$$

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

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

$$\boxed{j = \angle 90^\circ}$$

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

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