Digital communication

Continuous is also called Analog signal, where demodulation is difficult, Disortion is happening.

Converting Analog to digital and these we will transmit we have regeneration Block.

* Noise can't distort digital signal and digital is Immune to Noise.
* Analog is used in 1G communication.
* 2G - Till now [digital]
* Threshold value is fixed greater than it's 1 less than it is zero.

Sampling

It is a process which we convert analog [continuous] signal to digital signal.

Analog
↓
Sampling
↓
Quantization
↓
Encoding
↓
Digital

* Sampling Theoram states that sampling frequency must be greater than twice fm

$\boxed{f_s > 2f_m}$ → Nightquist Rate

f_m = Maximum frequency of message signal

* Major criteria for sampling.

$m(t) = 1 + \sin 100\pi t + \cos 200\pi t + \sin 150\pi t$

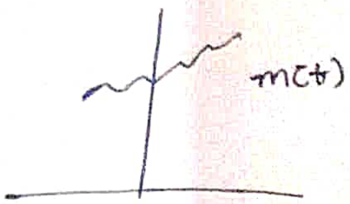
$\omega = 2\pi f$ find frequency and Highest frequency is considered as f_m.

$\boxed{f_s > 2f_m}$ $\quad f_s > 200Hz$

$$\boxed{T_s < \frac{1}{2f_m}}$$

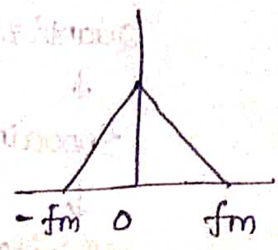
Sampling
- over Sampling $f_s > 2f_m$
- Critical Sampling $f_s = 2f_m$
- under Sampling $f_s < 2f_m$

Over Sampling

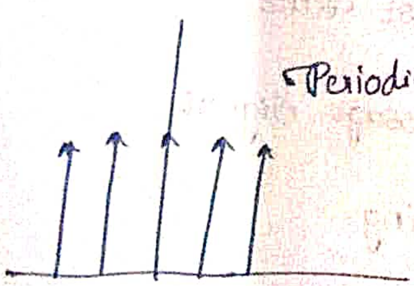


Aperiodic

$\xrightarrow{FT}$

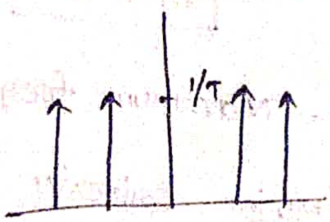


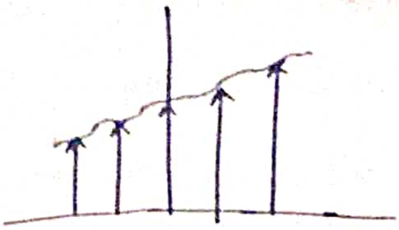
multiply it with an Impulse then we get

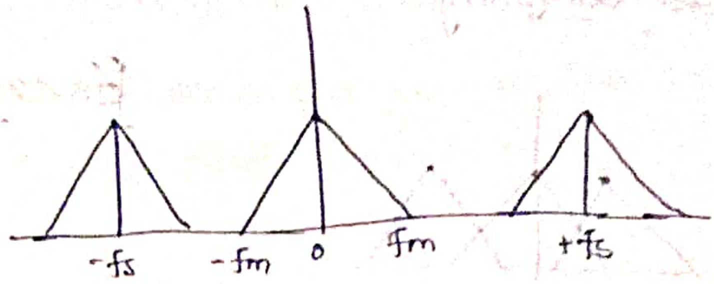


Periodic

$\xrightarrow{FS}$







anything x Impulse = Anything.

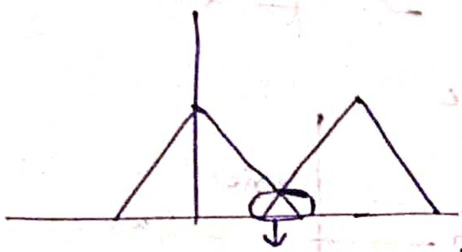
Shifted version of Impulse x anything = Shifted version of Anything

$\boxed{f_s > 2f_m}$

We can Easily get Back the original Signal.

Critical Sampling

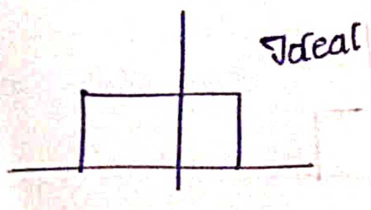
$\boxed{f_s = 2f_m}$

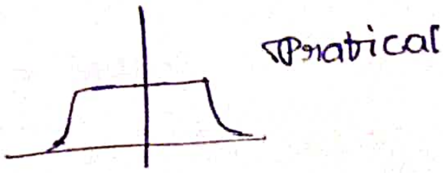


Some part is overlapping.

In case of Critical sampling Some Sort of distortion is happening.

We can get two types of Filters

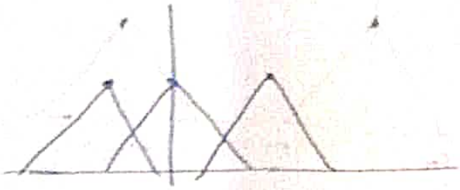




Where Pratically It is not possible and Theoritically possible.

Under Sampling

$\boxed{f_s < 2f_m}$

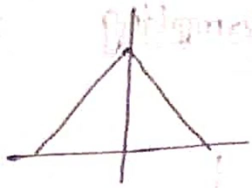


Overlapping of msg signal is called as Aliasing filter

* We can't bring back the original signal

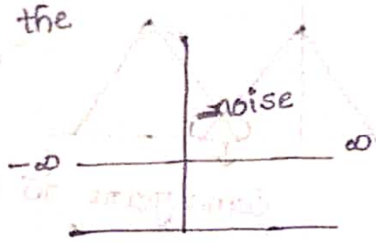
* So we always prefer over sampling.

Anti-Aliasing filter



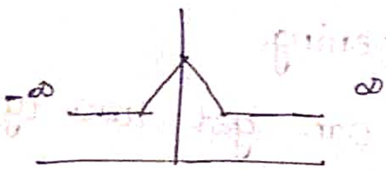
* In order to limit the signal we will pass it through a LPF.

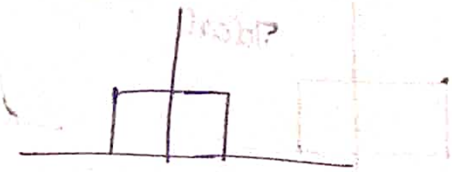
* But we can't avoid inside the range.

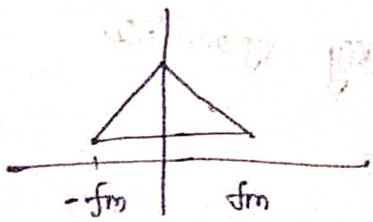


* outside the range we can avoid the noise.

* That LPF is also known as Anti-Aliasing filter

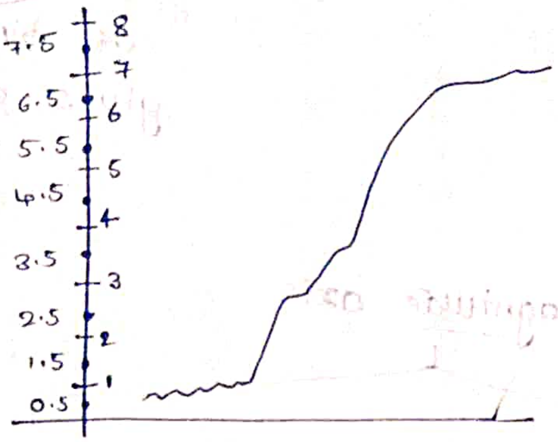






Quantization [utilise less memory] To save the memory.

It is a process by which we can divide Entire range to segments and it's mind points are assigned with codes [000, 001, ...]



If we Increase the length of the segments then accuracy is also Increasing.

For this case we require more memory & more time.

We have to store Each and Every Element with a particular code.

Encoding we Encode the signal, we assing the quantized values with a particular code.

Quantization Error = Actual value - Quantization value.

* We can't completely remove the Error But we can reduce the Error by Increasing accuracy and decrease the range of signal.

Maximum Quantization Error = $\pm \frac{\Delta}{2}$

Δ = segment length.

$[8] = 2^3$ [000, 001, 010, ...]

Time axis

Continuous

Every Instant of time.

Discrete

Particular Instance of time It gives any value.

Magnitude axis

Analog

Magnitude could be anything within the range.

Digital

Some particular value, Specific set of values.

$$m(t) = \sin 200\pi t * \cos 400\pi t$$

$$= \sin A \cdot \cos B$$

$$= \sin(A+B) + \sin(A-B)$$

$$= \sin 600\pi t + \sin 200\pi t$$

[convert two frequencies into single term and then we have to find the maximum.

Substitue the form, divide and then do it again

$$2\pi f = 600\pi$$

$$f_m = 300\,Hz$$

$$f_s > 2 \cdot f_m \qquad f_s > 600\,Hz$$

Modulation

- Analog
  - Amp Mod.
    - A.M
    - DSB-SC
    - SSB-SC
  - Angle Mod.
    - F.M
    - P.M
- Digital
  - [wire] Base Band Modulation
    - Pulse analog Mod
      - PAM
      - PWM
      - PPM
    - Pulse-digital
      - PCM
      - DPCM
      - DM
      - ADM
  - [wireless] Band pass Modulation
    - I-array Mod
      - ASK
      - PSK
      - FSK
    - M-array Mod
      - QAM
      - QPSK
      - M-array PSK

Pulse Analog Modulation

* Carrier is always Series of pulses.

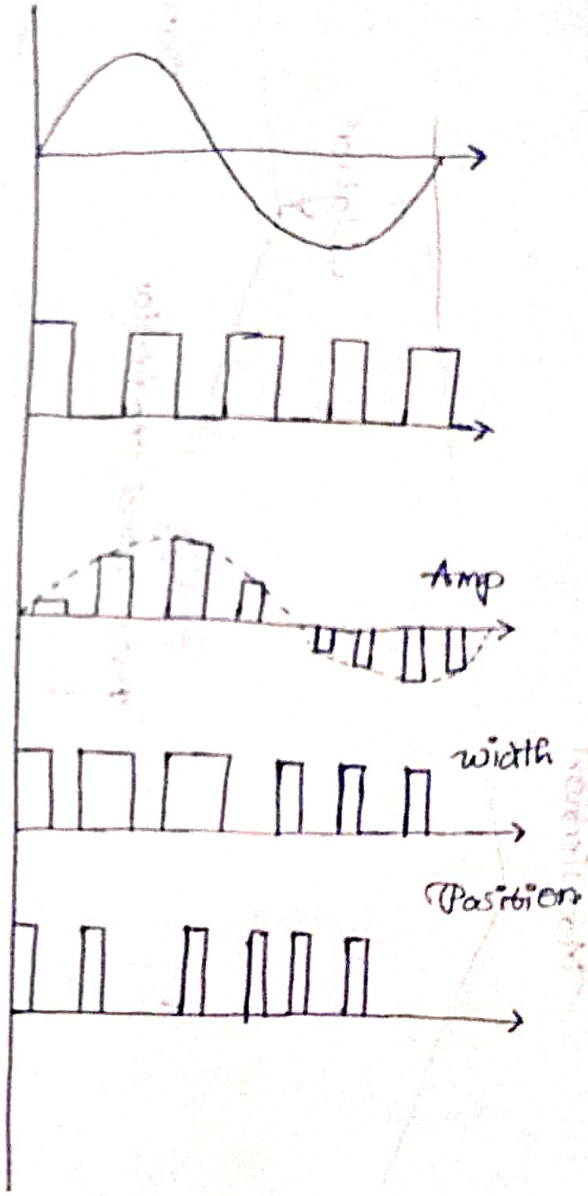
message signal → m(t)

Carrier Signal c(t)

magnitude of the pulse vary according to the msg signal. PAM

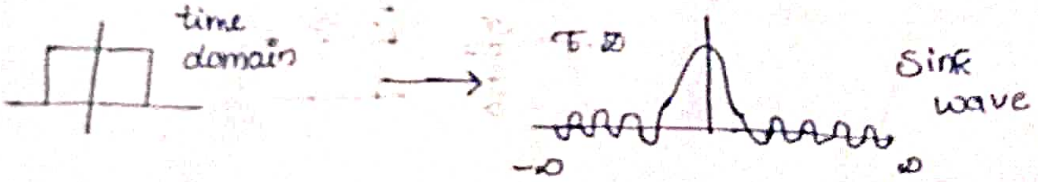
W⇑ M⇑
W⇓ M⇓ PWM

M⇑ when Distance B/w the pulse ⇑ PPM



Disadvantages

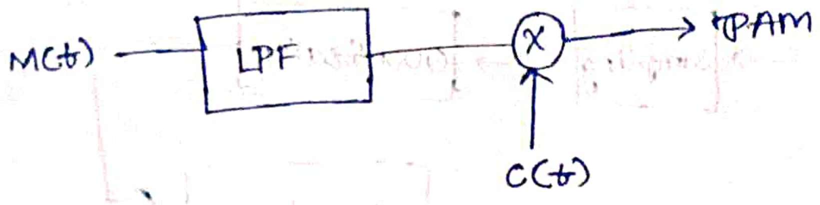
* Pulse as Carrier Signal.



Larger B.W → Not Effective In the case of frequency

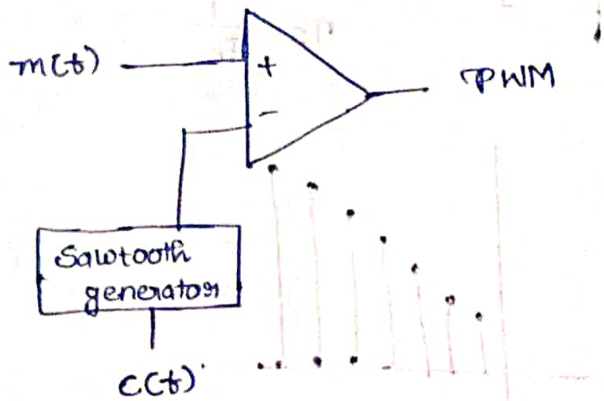
* ∞ B.W Can't Transmit through wire..
* Pulse Amplitude Modulation is not more affective as Amplitude changes accordingly.
* PWM & PPM are More Effective It won't Effect magnitudal changes.

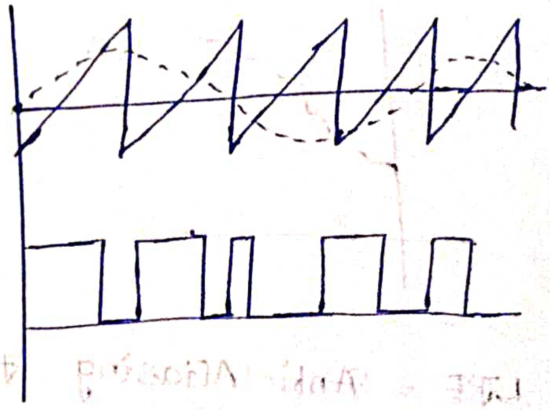
Modulation of PAM



LPF is used as Anti-Aliasing to avoid noise.

Modulation of PWM





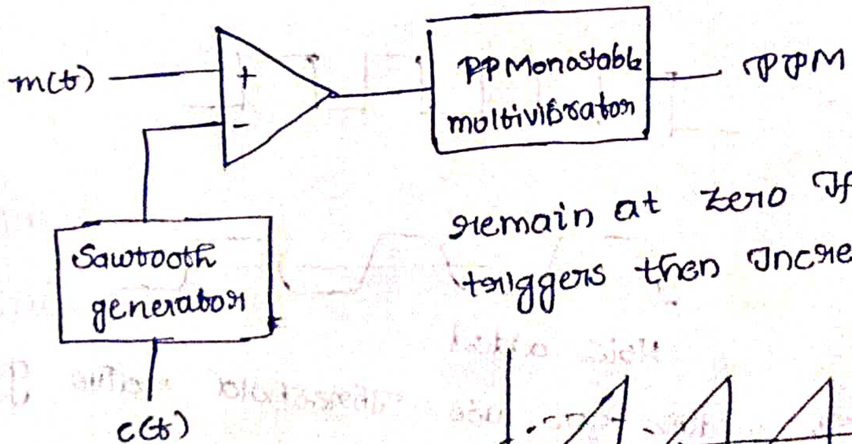
msg > sawtooth signal output = HIGH

msg < sawtooth signal output = LOW

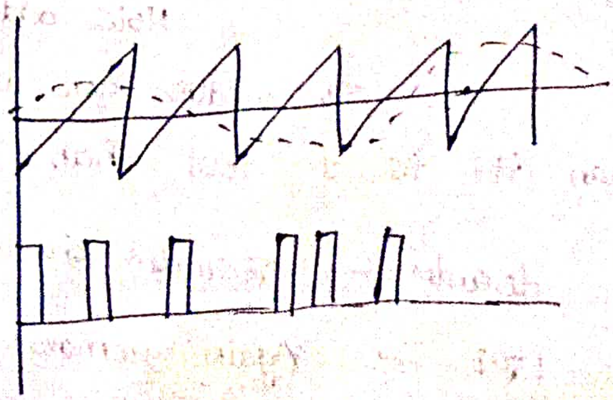
m⇑ w⇑ m⇓ w⇓

op-amp act as comparator.

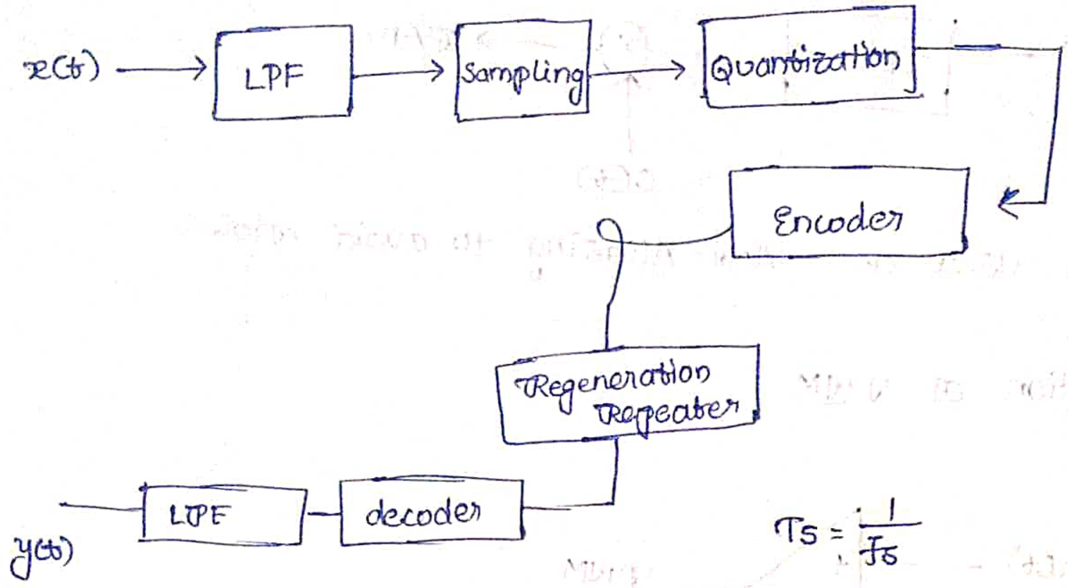
Modulation of PPM



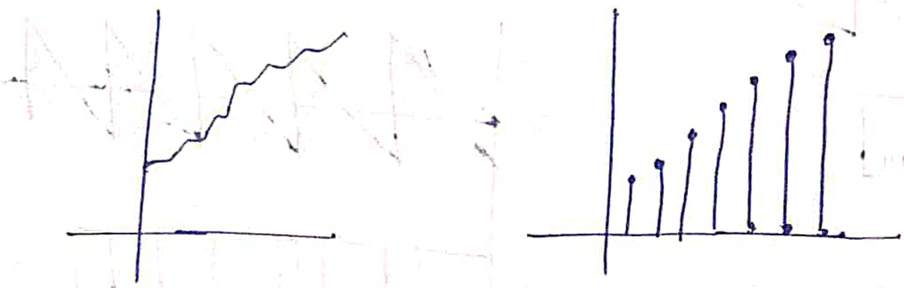
remain at zero if any input triggers then increase.



Pulse Code Modulation



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



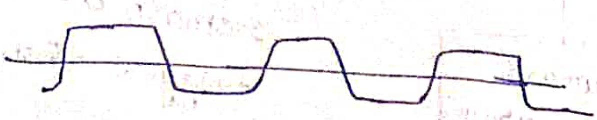
LPF = Anti-Aliasing Filter to reduce B.W

Sampling = Continuous ⟶ Discrete

Quantization = Save Memory.

Encoder = assigns a particular value.

Regeneration Repeater =



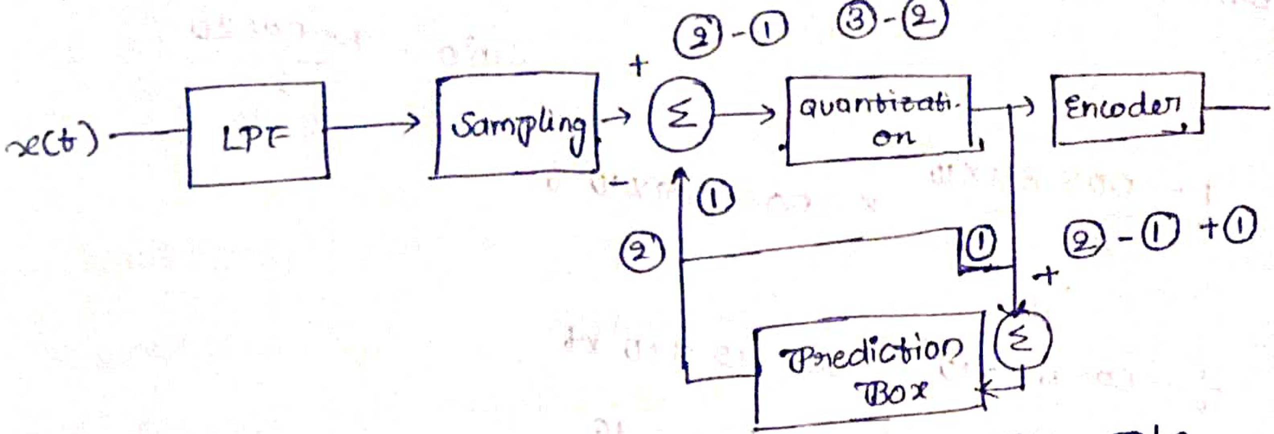
Noise added

To reduce we use Threshold value greater than it is 1 less than it is Zero.

decoder → Decodes the signal

LPF → Again removes the noise added in Travelling.

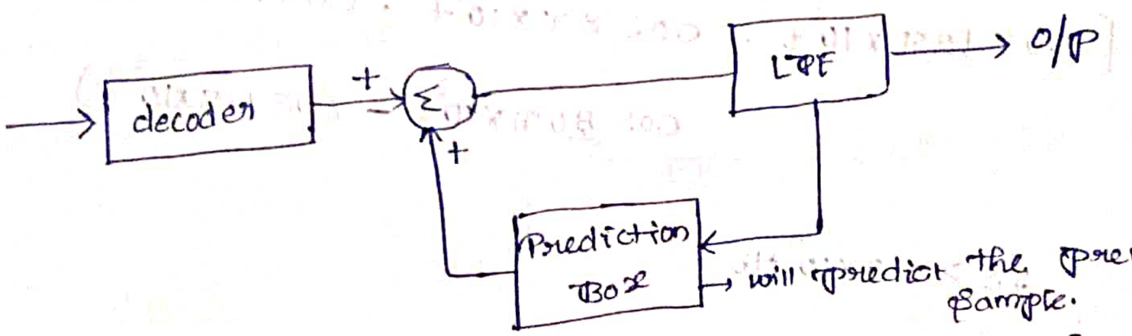
Differential Pulse code Modulation



* we don't transmit codes we Transmit diff B/w two consecutive Signals [points]
* where range ⇓ and Quantization Error reduces.

SCI HUB

demodulation of DPCM



→ will predict the previous sample.

In Modulation we subtract the previous signal.

In demodulation we add the previous signal.

(i) $10 \sin 8\pi \times 10^3 t$ → $f_s > 8 \times 10^3$ Hz

(ii) $6 \sin 4\pi \times 10^3 t + 8 \cos 12\pi \times 10^3 t$ → $f_s > 12 \times 10^3$ Hz

(iii) $\sin 4\pi \times 10^3 t \cdot \cos 12\pi \times 10^3 t$ → $f_s > 16 \times 10^3$ Hz

(iv) $\sin^2 4\pi \times 10^0 t \cdot \cos 12\pi \times 10^3 t$ →

(v) $\sin c\,100t$

$\sin 2\pi f t$

$c = 3 \times 10^8$

$\cancel{2\pi} f = \overset{4}{\cancel{8\pi}} \times 10^3$ f

$\sin^2\theta = \frac{1 - \cos 2\theta}{2}$

$\sin(A+B) + \sin(A-B)$

$\sin^2 4\pi \times 10^3 t * \cos 12\pi \times 10^3 t$

$$\sin^2\theta = \frac{1-\cos 2\theta}{2}$$

$= \dfrac{1-\cos 8\pi \times 10^3}{2} \times \cos 12\pi \times 10^3 t$

$= \frac{1}{2} - \cos 4\pi \times 10^3 \cdot \cos 12\pi 10^3 \times t$

16

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

$f_s > 16 \times 10^3$ Hz

$\cos A \cdot \cos B$

$= \cos \frac{A+B}{2} - \cos \frac{A-B}{2}$

$= \frac{1}{2} [\cos 12\pi \times 10^3 t - \cos 8\pi \times 10^3 t \cdot \cos 12\pi 10^3 t)$

$\cos 20\pi \times 10^3 t - \cos 4\pi \times 10^3 t)$

$=$

$f_s > 20 \times 10^3$ Hz

5) $\text{sinc } 100t$ [sinR widtR]

$$\boxed{\text{sinc } 100t = \frac{\sin 100\pi t}{100\pi}}$$

$2\cancel{\pi}f = 100\cancel{\pi}$

$f = 50$ Hz

$\frac{1}{100\pi} \sin 100\pi t$

$f_s > 100$ Hz

n = no. of bits per sample

$L = 2^n$, [No. of segments]

$$\Delta = \frac{V_{max} - V_{min}}{L}$$

Max Quantisation Error $= \pm \frac{\Delta}{2}$

Quantisation Error = Actual value - Quantised value.

$$\text{Bit duration} = \frac{\text{Sampling duration (period)}}{\text{No. of bits per sample}}$$

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

$$\text{Bit rate} = \frac{1}{\text{Bit duration}}$$

(speed of data per sec)

Band width = Bit rate

1. A message signal $10 \cos 8\pi \times 10^3 t$ is transmitted using pulse code modulation system, Find all the parameters of PCM system.

$f_m = 4000$

$m(t) = 10 \cos 8\pi \times 10^3 t$

$f_s > 2 f_m$

$n = 4$

$L = 16$

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

$$\Delta = \frac{10 - (-10)}{16}$$

$$T_s = \frac{1}{8000}$$

$$\Delta = \frac{20}{16}$$

$$\text{Max Quanisation Error} = \pm \frac{\frac{20}{16}}{2} = \pm \frac{20}{32}$$

Quantisation Error =

$$\text{Bit durations} = \frac{\frac{1}{8000}}{4}$$

$$= \frac{1}{32000}$$

Bit rate = 32000

Band width = 32000

A sinusoidal msg signal $4 \sin 4\pi \times 10^3 t$ transmitted through 8 level PCM system $[n = 3]$ with sampling frequency has 5 times of Nighbquist rate.

1. Find all the parameters.

2. Given. Sampled value - $-3.2\,V$, $-2.8\,V$, $-0.1\,V$, $1.5\,V$, $3.9\,V$ Find corresponding Quantised & Encoded output.

$n = 3$

$L = 8$

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

$\Delta = \frac{8}{8}$ $\quad \Delta = 1$

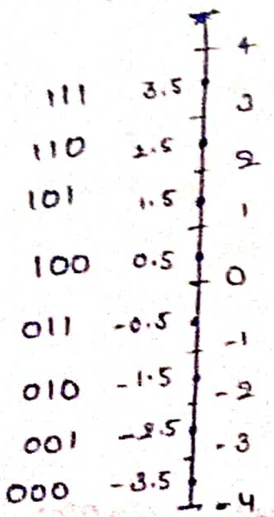
$2f_m \quad 20k$

M.Q.E $= \pm \frac{1}{2}$ $\quad = \frac{1}{20000}$

Bit duration $= \dfrac{\frac{1}{20000}}{3} = \frac{1}{60000}$

Bit rate = 60k bits/sec = Band width.

2. Dynamic range +4 to -4



$-3.2 \longrightarrow -3.5$ $\quad$ 000

Actual Value $\quad$ Quantized Value $\quad$ $-3.2 + 3.5$

Q.E = +0.3

$-2.8 \longrightarrow -2.5$ $\quad$ 001

Q.E = -0.3

$-0.1 \longrightarrow -0.5$ $\quad$ 011

$-0.1 + 0.5$

Q.E = +0.4

once quantised value we can resolve.

$1.5 \longrightarrow 1.5$ $\quad$ 101

Q.E = 0

$3.9 \longrightarrow 3.5$ $\quad$ 111

Q.E = 0.4

$\downarrow [Qe]_{max} = \pm \frac{\Delta}{2} \downarrow$

$\downarrow \Delta = \frac{V_{max} - V_{min} \downarrow}{2^n \uparrow}$

Line Coding:
It is a way to represent Bits in the form of signal.

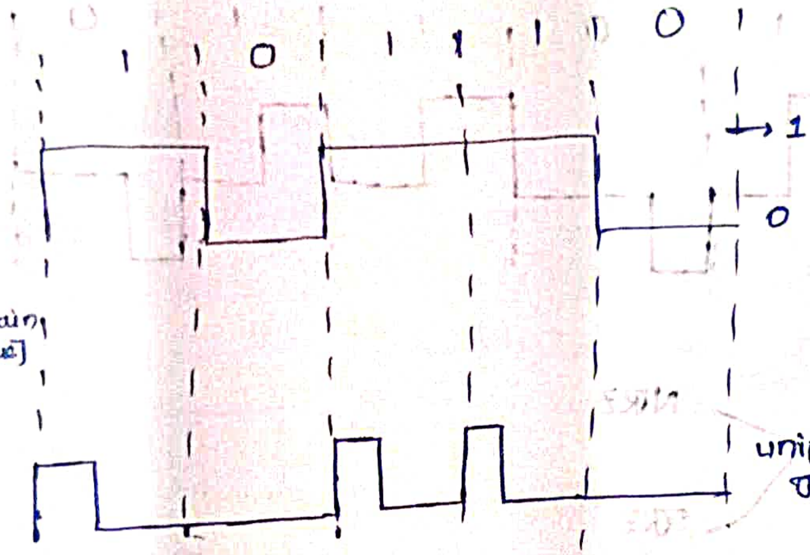
1. Unipolar [ON-OFF Switching] — Non-returning zero / returning zero
2. Polar
3. Bipolar

unipolar NRZ

1 → +V [certain value]

0 → 0

unipolar RZ



unipolary RZ

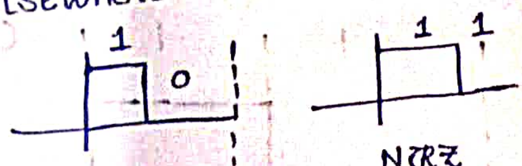
unipolar RZ

0 — ON

1 — +V for first $T_b/2$ duration, 0 Elsewhere

T_b = Bit duration.

1



RZ   NRZ

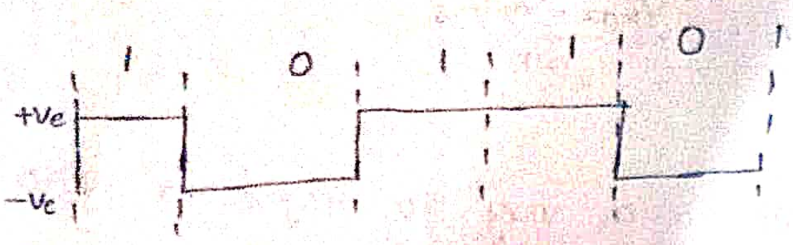
Polar — NRZ / RZ

NRZ — 0 = −V

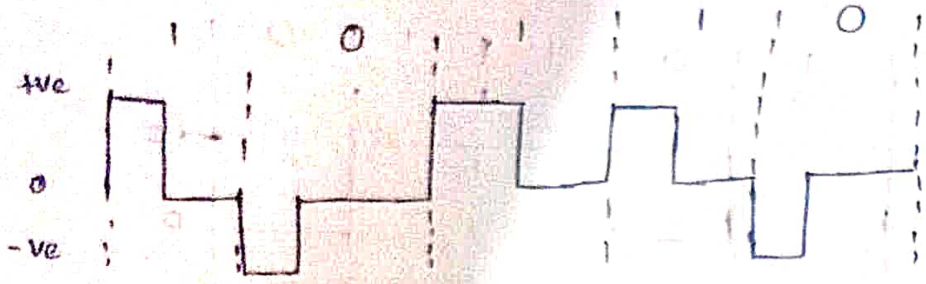
1 = +V

NRZ
- 1 +V
- 0 −V

Polar NRZ



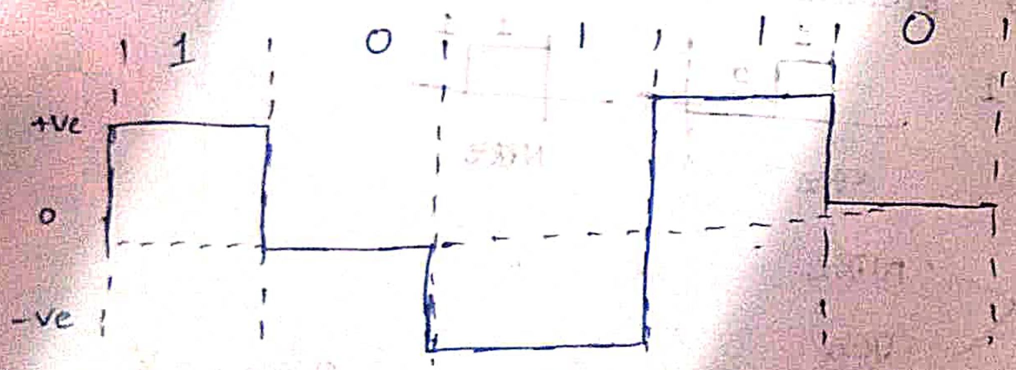
RZ
- 0
  - −ve for first Tb/2
  - 0 otherwise
- 1
  - +ve for Tb/2 duration for first Tb/2
  - 0 otherwise



Bipolar
- NRZ
- RZ

NRZ
- 0 — 0V
- 1
  - 1 positive
  - 1 Negative

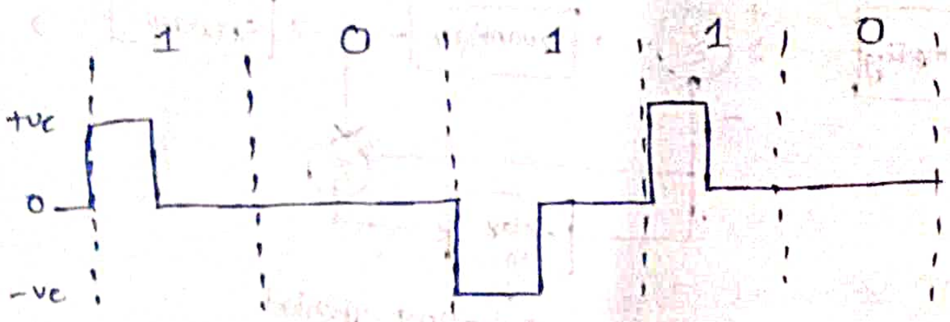
odd 1 → +ve
Even 1 → −ve



Alternatively

Okati positive +V Inkokati −V ki velladi

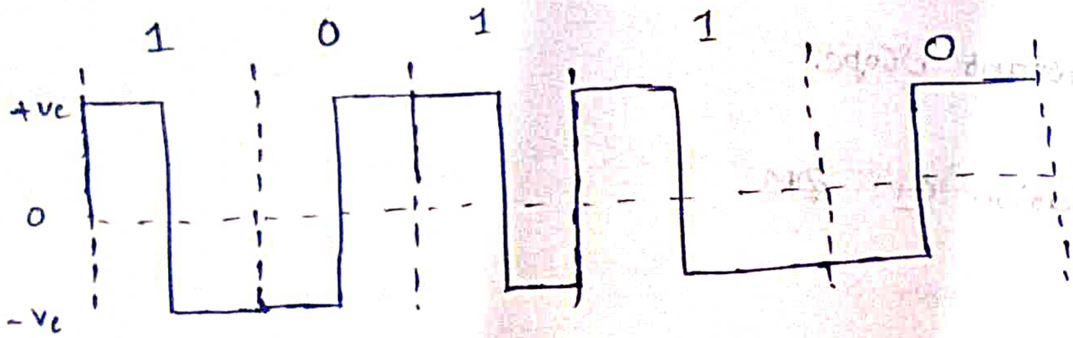
RZ — 1 — odd 1 half +ve Tb/2 +ve
Even 1 half -ve Tb/2 -ve
0 — 0V



Manchester Coding

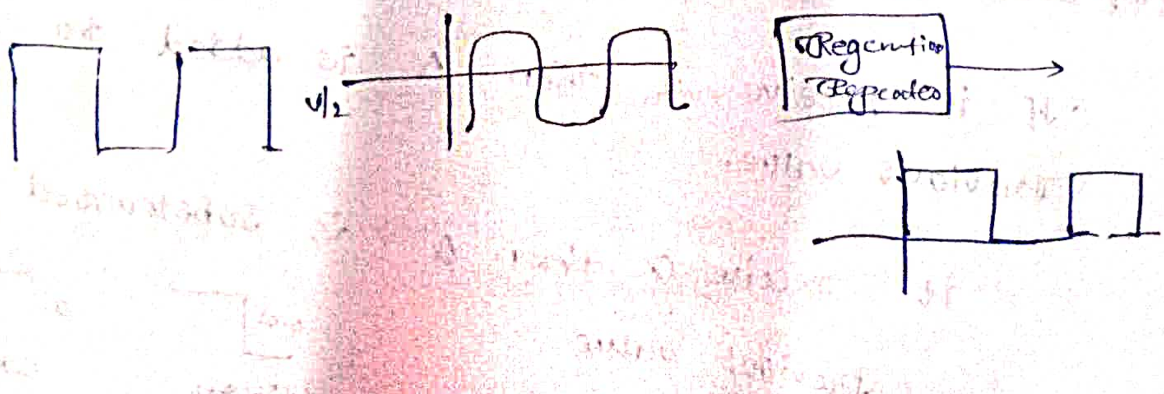
0 — 0 - Tb/2 -ve
Tb/2 - Tb +ve

1 — 0 - Tb/2 +ve
Tb/2 - Tb -ve

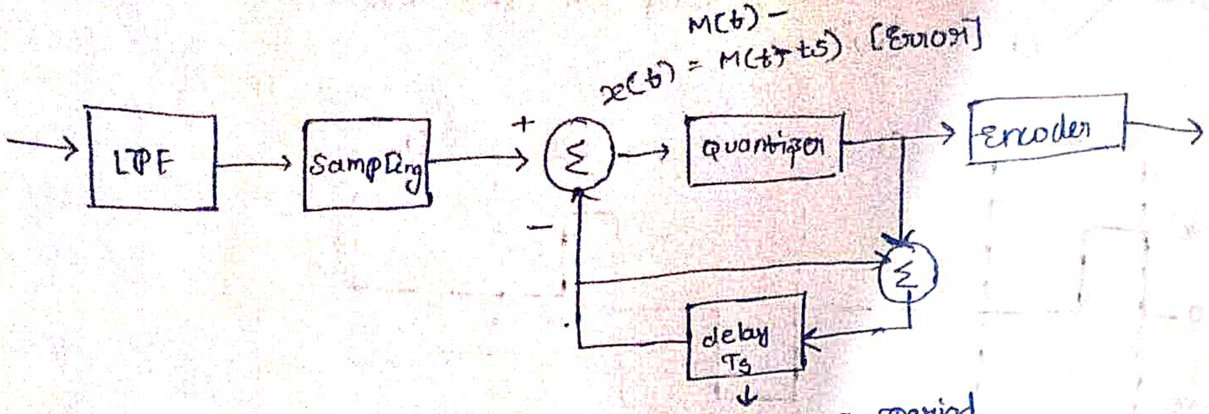


1. Channel noise → Regenerator, Repeater

2. Quantised noise — code length ⇑
range ⇓



Delta Modulation



only one Bit is transmitted

present is compared with the past sample

Present > previous then 1

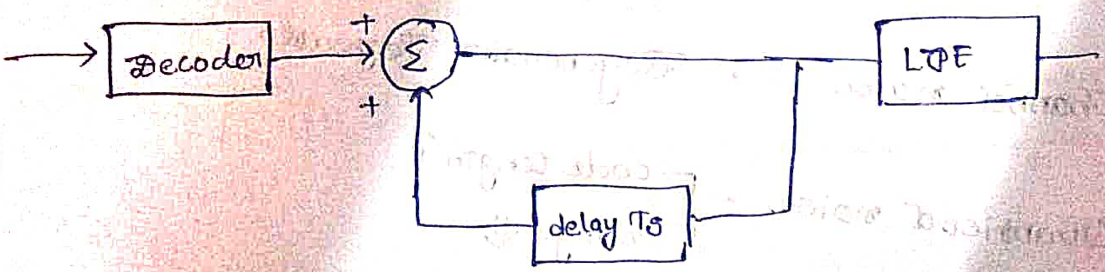
Present < previous then 0

$x(t) = M(t) - M(t-ts)$ +ve then 1
-ve then 0

* One Bit per sample

* Constant slope.

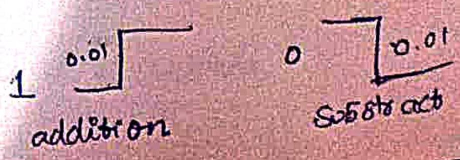
Demodulation of DM



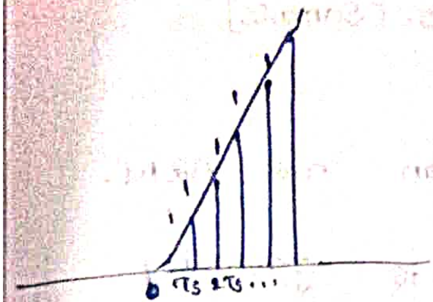
Step size = Δ

If it receive 1 then Δ is added to previous value.

it receive 0 then Δ is substracted from previous value



Slope is Same then we can get the Same Signal.



→ Easily reconstructed.

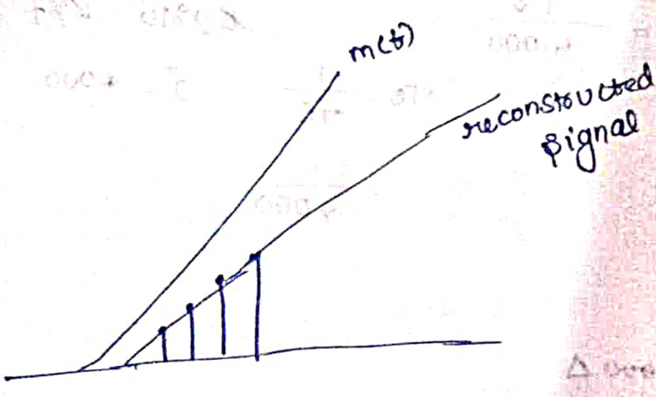
$$\frac{d}{dt} m(t) = \frac{\Delta}{T_s} \quad \frac{(y_2-y_1)}{(x_2-x_1)}$$

Slope of msg Signal [Slope of reconstructed signal]

If it's 1 Δ will added to the previous signal.

$$\frac{d}{dt} M(t) > \frac{\Delta}{T_s}$$

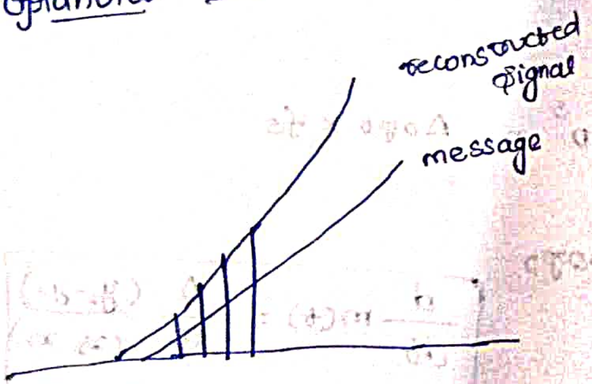
[when the step size is small]



* Slope overload Error

* overcome it by Increasing step size.

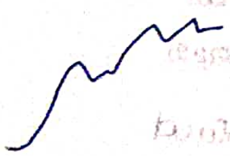
Granular Error



$$\frac{d}{dt} M(t) < \frac{\Delta}{T_s}$$

[more step size]

* overcome by reducing step size



→ can't construct as step size is not constant (or) slope is not constant [Adaptive Delta Modulation]

→ constant we can use delta Modulation.

ADM → Step size may vary only difference from DM.

Based on the consecutive signals. [Sample]

Everything is same as DM

* for any kind of real signal we can use ADM.

A continuous signal $8 \sin 8\pi \times 10^3 t$ is passed through delta modulation whose pulse rate is 4.000 pulses/sec then determine the optimal step sized

Sampling

$= 0.25 \times 10^{-3}$ $\quad = \frac{1\,s}{4{,}000}$ $\quad 8\pi \times 10^3 = 2\pi f$

$= 0.00025$ $\quad T_s = \frac{1}{f_s}$ $\quad f = 4000$

$$\frac{d}{dt} m(t) = \frac{\Delta}{\frac{1}{4000}} \times \qquad = \frac{1}{4000}$$

$$8 \frac{d}{dt} \sin 8\pi \times 10^3 t = 4000\,\Delta$$

$$8 \cos 8\pi \times 10^3 t = \Delta_{opt}$$

$$8 \cancel{\cos(8\pi \times 10^3 t)} \times 8\pi \times 10^3 = \Delta_{opt} \times f_s$$

$$8^2 \times 8\pi \times 10^3 = 4000 \times \Delta_{opt}$$

$$\boxed{\Delta_{opt} = 16\pi}$$

$$\boxed{\frac{d}{dt} m(t) = \frac{\Delta}{T_s} \frac{(y_2 - y_1)}{(x_2 - x_1)}}$$

$$\frac{d}{dt} m(t) = \frac{\Delta}{T_s} \frac{(y_2 - y_1)}{(x_2 - x_1)} > \frac{\Delta}{T_s} \Rightarrow \text{granular error}$$

$$\frac{d}{dt} m(t) = \frac{\Delta}{T_s} \frac{(y_2 - y_1)}{(x_2 - x_1)} < \frac{\Delta}{T_s} \Rightarrow \text{overload error.}$$

A Sinusoidal msg signal of frequency fm and amplitude Am is passed through delta Modulation whose step size is 0.628 Volt. Given sampling rate is 4000 samples/sec. For which of the following delta modulation will slope overload Error.

$2\pi(1\times10^3) = \omega$

$\frac{d}{dt} m(t) = 0.628$

$2\pi f = 2000\pi$

1. Am = 3V fm = 1K ✓
2. Am = 2V fm = 1.5K ✓ 5π
3. Am = 2V fm = 2.5K $2.5 \times \frac{10\pi}{4}$
4. Am = 1V fm = 2.5K $2\pi(1)$

2π

$\frac{d}{dt} m(t) \geq \frac{\Delta}{T_S} \frac{(y_2-y_1)}{(x_2-x_1)} > \frac{\Delta}{T_S}$ 0.628×4000

$\omega = 2\pi f = 2\pi(1.5)$

$3\sin 2\pi\times10^3 t = \Delta opt \times 4000$

3π

$3\ \cancel{\sin 2\pi\times10^3 t} \times 2\pi\times10^3 t = \Delta opt \times 4000$

$\frac{6}{4}$

$3\pi = \Delta opt \times 4$

$\Delta opt = 2.356 < 2512$ ✓

4.712 18.72 > 0.628

$\Rightarrow 2\sin 3\pi\times10^3 t = \Delta opt \times 4000$ 18.72 > 0.628

31.41 > 0.628

$2\ \cancel{\cos 3\pi\times10^3 t} \times \cos 3\pi\times10^3 = \Delta opt \times 4000$ 15.73 >

fm = 1000

$6\pi\times10^3 = \Delta opt \times 4000$

Am sin ωt

$\Delta opt = 4.712$

$\omega = 2\pi fm$
$= 2\pi(1\times10^3)$
$\omega = 2\pi\times10^3$

$6\pi > 0.628$ ✓

(2) $6\pi > 0.628$

$$\boxed{\frac{d}{dt} m(t) > \frac{\Delta}{T_S}}$$

3. $\frac{d}{dt} 2 \sin 5\pi \times 10^3 > 0.628 \times 4000$

$2 \cancel{\cos 5\pi \times 10^3} \times 5\pi \times 10^3 > 0.628 \times 4000$

$10\pi \times \cancel{10^3} > 0.628 \times 4\cancel{000}$

$10\pi > 0.628 \times 4$

$31.41 > 2.512$ ✓

4. $\frac{d}{dt}\, 1 \sin 5\pi \times 10^3 > 0.628 \times 4000$

$= 5\pi \times \cancel{10^3} > 0.628 \times 4\cancel{000}$

$5\pi > 2.512$

$15.7 > 2.512$ ✓

$\frac{d}{dt} m(t) > \frac{\Delta}{T_S}$

$\Delta = 0.628$

$f_s = 4000$

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

1. $A_m = 3V$ $\quad f_m = 1k$

$\frac{d}{dt}\, 3 \sin 2\pi \times 10^3 t > 0.628 \times 4000$

$3 \boxed{\cos 2\pi \times 10^3 t}^{1} \times 2\pi \times 10^3 > 2.512 \times 1000$

$3 \times 2\pi \times \cancel{10^3} > 2.512 \times \cancel{1000}$

$6\pi > 2.512$

$4.512 > 2.512$ (overload Error)

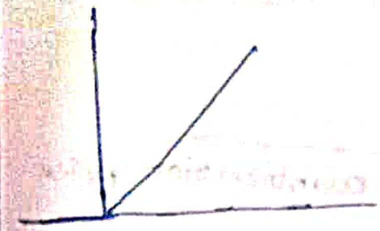
$x(t) = 125\{u(t) - u(t-1)\} + (250 - 125t)\{u(t-1) - u(t-2)\}$

For the following msg signal the optimal step size with sampling frequency as 1000 samples / sec.

$t = \frac{1}{1000}$ $t = 10^{-3}$

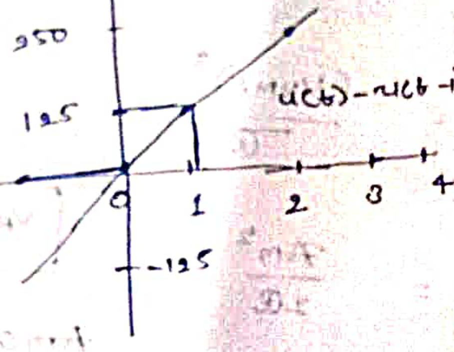
$fs = 1000$

$= (125t)\{u(t) - u(t-1)\} + (250 - 125t)\{u(t-1) - u(t-2)\}$

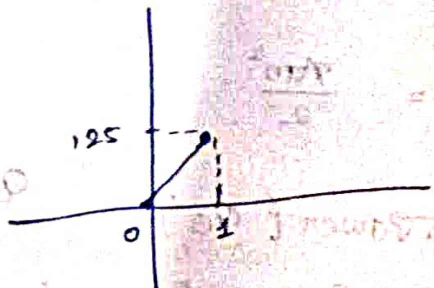


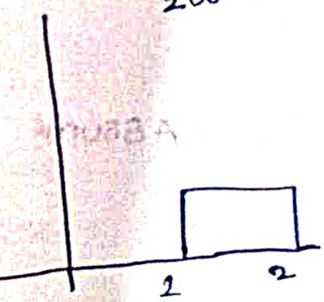
$r(t) = t \quad t > 0$

$0 \quad$ otherwise.



250 - 125t



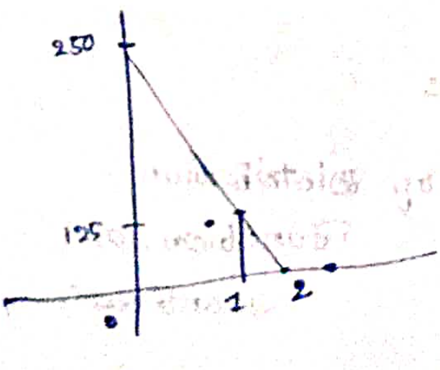


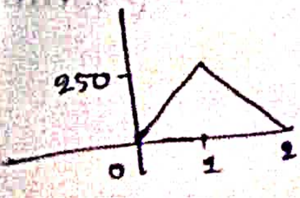
=> $u(t-1) - u(t-2)$

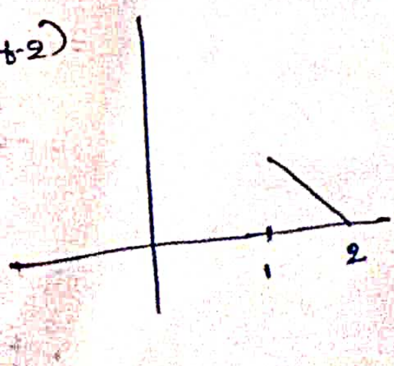
$[125t] - u(t) - u(t-1)$

$+ \; 250 - 125(t) \times$

$u(t-1) \times (u(t-2))$







$$\frac{d}{dt} m(t) > \frac{\Delta}{T_S} \times \cancel{125}$$

$$\frac{d}{dt} r(t) > \frac{\Delta}{} \times 125 \times 1000$$

Slope of msg signal $> \frac{\Delta}{T_S}$

$125 > \Delta \times 1000$

$$\boxed{\Delta_{opt} = 0.125}$$

Signal to Quantization noise power ratio [SQNR]

$$SQNR = \frac{\text{Signal Power}}{\text{Noise power [Power associated with Quantization Noise}}$$

$$\text{Signal power} = \frac{(V_{RMS})^2}{R}$$

$$= \frac{A_m^2}{2R}$$

$$\boxed{V_{RMS} = \frac{A_m}{\sqrt{2}}}$$

$A_m \cos 2\pi f_m t$

Assume $R = 1$. [Resistance]

$$= \frac{A_m^2}{2}$$

Noise Power : Power { Qe }

Qe → Quantization Error = random number.

Mean Square Error to get Power.

$$= MSE \{ Qe \}$$

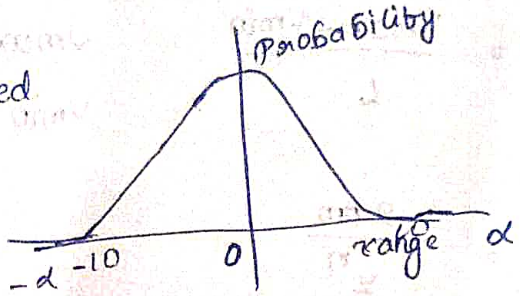
$$= \int_{-\alpha}^{\alpha} Qe^2 \, F(Qe) \, dQe$$

$F(Qe)$ → Probability Distribution Function of Quantization.

Probability

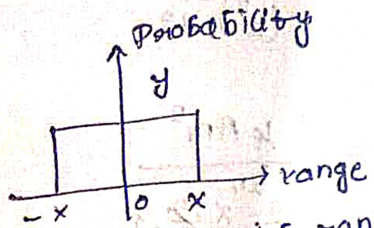
Random number is generated near to zero itself.

$$\int_{-\infty}^{\infty} F(x)dx = 1$$



Guassian PDF
[Bell Shape PDF]

In that range we will get Equal probability.
[uniform Distribution]



which range the random number distributed.

Range of Quantization Error is $\frac{-\Delta}{2}$ to $\frac{+\Delta}{2}$

Magnitude is $1/\Delta$ which is gives us area = 1

$$= \int_{-\Delta/2}^{+\Delta/2} \frac{1}{\Delta} Qe^2 \, dQe \qquad F(Qe) = \frac{1}{\Delta}$$

$$= \frac{1}{\Delta} \left. \frac{Qe^3}{3} \right|_{-\Delta/2}^{\Delta/2}$$

$$= \frac{1}{\Delta} \times \frac{1}{3} \left[\frac{\Delta}{2}\right]^3 - \left[-\frac{\Delta}{2}\right]^3$$

$$= \frac{2}{3\Delta} \times \frac{\Delta^3}{2^3} \Rightarrow \frac{1}{\Delta} \times \frac{\Delta^3}{24} + \frac{\Delta^3}{24}$$

$$= \frac{2}{3\Delta} \times \frac{\Delta^3}{8} \qquad = \frac{1}{\Delta} \times \frac{2\Delta^3}{24}$$

$$= \frac{\Delta^2}{6} \qquad = \frac{\Delta^2}{12}$$

$$\Delta = \frac{V_{max} - V_{min}}{L} \qquad V_{max} = A_m$$

$$V_{min} - A_m$$

$$\Delta = \frac{2A_m}{2^n}$$

$$= \frac{(2A_m)^2}{(2^n)^2 12}$$

$$= \frac{\cancel{4}^{1} A_m^2}{2^{2n} \times \cancel{12}_{3}}$$

$$= \frac{A_m^2}{3.2^{2n}} \quad \text{[Noise power]}$$

$$SQNR = \frac{\frac{\cancel{A_m^2}}{2}}{\frac{\cancel{A_m^2}}{3.2^{2n}}} = \frac{3.2^{2n}}{2} \quad \frac{\text{Signal power}}{\text{Noise power}}$$

$$= \frac{3}{2} \cdot 2^{2n}$$

$$SQNR = (1.5)\, 2^{2n}$$

$$\overset{8}{\cancel{16}} \times \frac{3}{2}$$

$$\overset{32}{\cancel{64}} \times \frac{3}{2}.$$

n	
1	6
2	24
3	96
4	384
5	1536

$$(SQNR)_2 = \underline{4}\,(SQNR)_1 \qquad 2^{2}$$

$$(SQNR)_3 = \overset{4}{\cancel{2}}\,(SQNR)_2 \qquad 2^{2.2}$$

$$(SQNR)_5 = 2^{2.4}\,(SQNR)_1 \qquad 2^{2.2.2}$$

Has $n \longrightarrow n+k$, The SQNR Increases

$1+4=5$

By $\underline{2^{2.k}}$

SQNR in terms of DB.

$= 10 \log_{10}(SQNR)$

$= 10 \log_{10}\left[\frac{3}{2} \cdot 2^{2n}\right]$

$= 2n \times 10 \log_{10}[3]$

$= 1.76 + 6.02n$

$$\begin{array}{r} 12.06 \\ 1.76 \\ \hline 13.82 \end{array}$$

n	
1	7.78
2	13.82
3	19.82
4	25.84
5	31.86
6	37.88

6.02 dB

6.02 dB

12 dB

Has $n \rightarrow n+k$ The SQNR Increase in decibel then

20dB then 6 bits.

A msg signal of $8 \sin 8\pi \times 10^3 t$ is to be transmitted through PCM where sampling rate is 50% higher than nightquist rate. The minimum SQNR required for Transmission is 22 dB, determine Transmission Bandwidth required, SQNR in dB.

$n=4$ $\quad 2^4 = 16$ $\quad f_s = \frac{1}{T_s}$

$8\pi \times 10^3 = 2\pi f_m$

$f_s > 2f_m$ $\quad [8 \times 10^3]$ $\quad T_s = \frac{1}{f_s}$

50% higher than 8000

$$8000 \times \frac{\cancel{50}}{\cancel{100}_2}$$

12000

$$= 4000$$

$$= \frac{\frac{1}{12000}}{4}$$

$$B.D = \frac{1}{48000}$$

$8 \Rightarrow 16000$

Bit rate = 48000

A msg signal of peak to peak voltage 1.536 volts is passed through PCM system having 128 quantisation level. Find quantisation noise power

$n =$

$2Am = 1.536$

$$Am = \frac{1.536}{2}$$

$$= \frac{Am^2}{3 \cdot 2^{2n}}$$

$$= \frac{(1.536)^2}{3 \cdot 2^{2 \cdot 7}}$$

$$= \frac{1}{3} \times \frac{(1.536)^2}{2^{14}}$$

$$= \frac{1}{3} \times \frac{2.359}{16384}$$

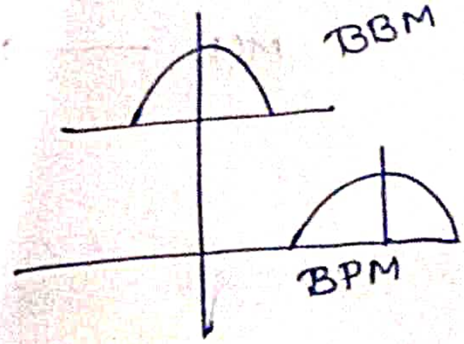
$$= \frac{2.359}{49{,}152}$$

$$= 1.2 \times 10^{-5}$$

Band pass Modulation

After modulation BPM

Before modulation (or) msg signal is called Base Band Modulation.



* Band pass for larger distance (or) wireless signal Transmission.

Binary Signaling [Single - Bit transmission]

M-array signaling. [Symbols - group of Bits]

2-Bits, 6-Bits, 8-Bits (or) 16-Bits

ASK	PSK	FSK
Amplitude Shift Keying	Phase Shift keying	Frequency shift Keying.

ASK - [on/off keying]

$0 \longrightarrow 0$

$1 \longrightarrow A_c \cos 2\pi f_c t$

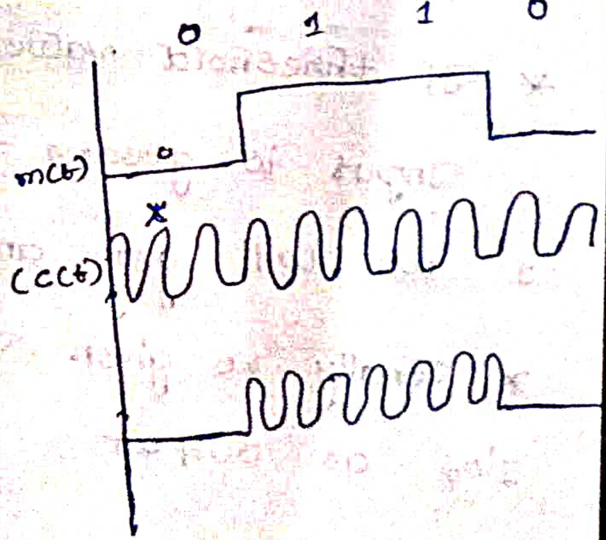
1 - then some signal [some Transmission]

0 - No signal [zero Transmission (or) no signal]

For zero Transmission we don't transmit any kind of signal

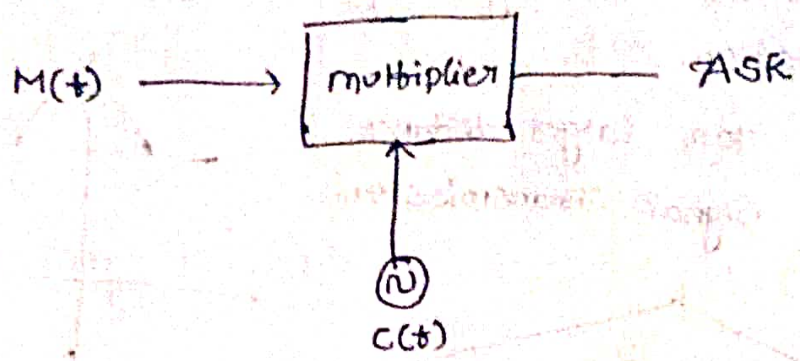
$0 \times$ anything $= 0$

$1 \times$ anything $=$ anything

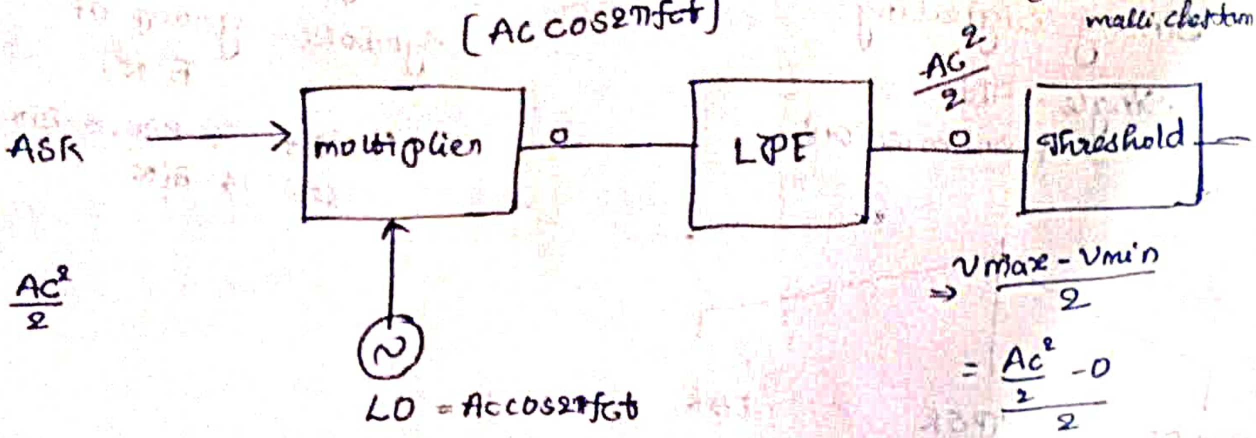


Phase Shift Keying

Modulation :



De-Modulation



$\frac{A_c^2}{2}$

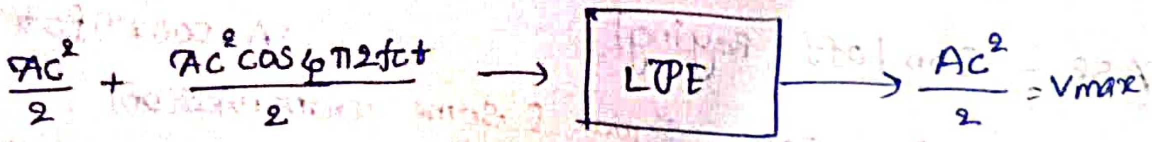
$\rightarrow \frac{V_{max} - V_{min}}{2}$

$= \frac{\frac{A_c^2}{2} - 0}{2}$

$= \frac{A_c^2}{4}$

$A_c^2 \cos^2 2\pi f_c t$

$A_c^2 \left[1 + \frac{\cos 2\pi 2 f_c t}{2} \right]$



* If threshold value is greater than ASK is 0 Input is greater than threshold value then 1 we will get and vice-versa is Zero.

* Finally we given Input as 1 & 0's we get 1's as output

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

$A_c^2 \cdot \cos(2\pi f_c t) \cos(2\pi f_c t + \phi)$ $\qquad \cos A \cdot \cos B$

$\cos(A+B) + \cos(A-B)$

$= \frac{A_c^2 \cos\phi}{2}$

It is Quadrature Null Effect.

<u>Energy for Bit</u>

1 → Carrier signal. (Energy requried for Transmitting 1)

$0 \rightarrow \int_0^{T_b} (0)\, dt = 0$

$1 \rightarrow \int_0^{T_b} (A_c \cos 2\pi f_c t)^2 \, dt$ $\qquad \int \cos t = -\sin t$

$= \int_0^{T_b} \frac{A_c^2}{2} + \frac{A_c^2 \cos 2\pi 2 f_c t}{2} \, dt$ $\qquad t = \frac{t^2}{2}$

$= \frac{A_c^2}{2} \int_0^{T_b} \frac{A_c^2 \cos 2\pi 2 f_c t}{2} \, dt$ $\qquad A_c^2 c$ $\qquad \cos^2\theta = \frac{1+\cos 2\theta}{2}$

$= \frac{A_c^2}{2} \int_0^{T_b} [1 + \cos 2\pi 2 f_c t] \, dt$

$= \frac{A_c^2}{2} \left[[t_b + \sin 2\pi 2 f_c t] \, dt \right]_0^{t_b}$ $\qquad$ Integrate a sin signal over one period is zero.

$= \frac{A_c^2 t_b}{2} + \cancel{\frac{A_c^2 \sin 2\pi 2 f_c t_b}{2}} \; 0$

$$\boxed{E_b = \frac{A_c^2}{2} t_b}$$

$1 \rightarrow \frac{A_c^2}{2} t_b$ $\Big\}$ Energy requtred

$0 \rightarrow 0$

$1 \rightarrow A_c \cos 2\pi f_c t$

$$E_b = \frac{A_c^2 T_b}{2}$$

$1 \rightarrow \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t$

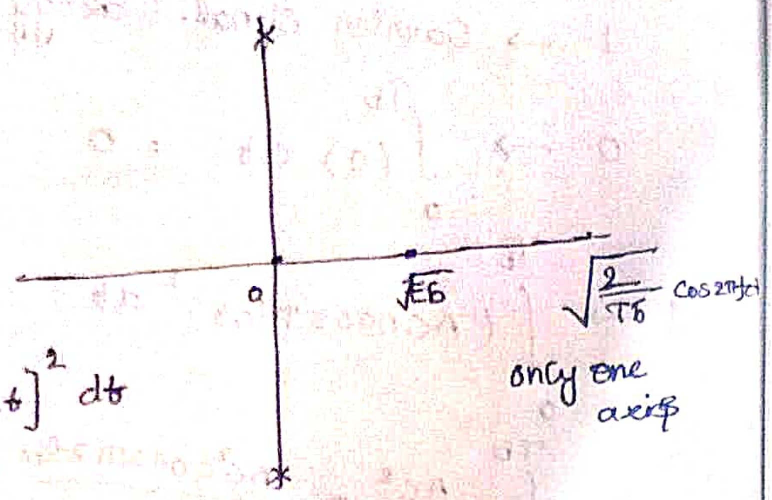
$$A_c^2 = \frac{2E_b}{T_b}$$

$$A_c = \sqrt{\frac{2E_b}{T_b}}$$

Constellation Diagram

$1 \rightarrow \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t$

$0 \rightarrow 0$



$$E_b = \int_0^{T_b} \left(\sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t \right]^2 dt$$

$E = 1 \Rightarrow$ Normalised functions

$$\cancel{E_b} = \cancel{E_b} \int_0^{T_b} \left(\sqrt{\frac{2}{T_b}} \cos 2\pi f_c t \right]^2 dt$$

1 we will get and called as Normalised function.

Binary ASK, where one axis and two points 0 & 1

Energy from Constellation diagram

Energy = (Distance from original$)^2$ ~~to~~ ~~final~~.

$E_0 = 0$

$E_1 = (\sqrt{E_b})^2 = E_b$

Probability of Error = distance B/w two Symbols

giving 1 getting 0 $= \sqrt{E_b} - 0$

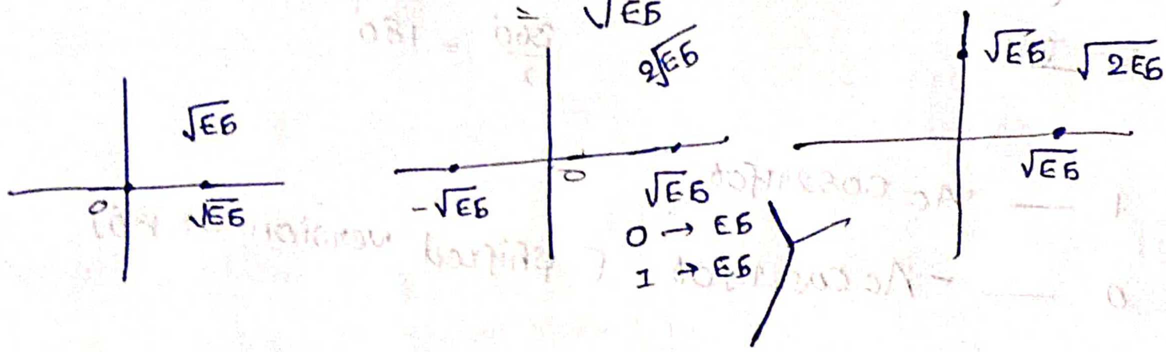
is Error. $= \sqrt{E_b}$

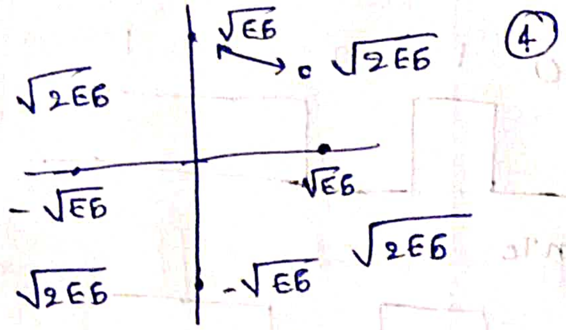
Probability of Error $\propto$ distance B/w two Symbols

giving 1 getting 0 is Error.

$= \sqrt{E_b} - 0$

$= \sqrt{E_b}$



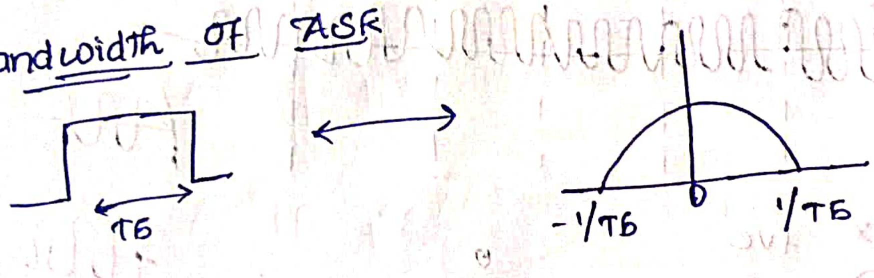


more distance is, 2 then It has least probability of Error.

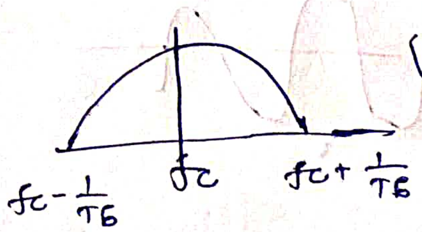
4 has the least at that case [less distance] and It has more probabition of Error.

Energy then $[\sqrt{E_b}]^2 \to$ (distance from origin)^2

Bandwidth of ASK



ASK



$\left(f_c + \frac{1}{T_b}\right) - f_c + \frac{1}{T_b}$

$= \frac{2}{T_b}$

$B.W = 2 \cancel{f_c} \times \frac{1}{T_b}$

$B.W = \frac{2 \times 1}{T_b} = 2R_b$ [twice of Bit rate]

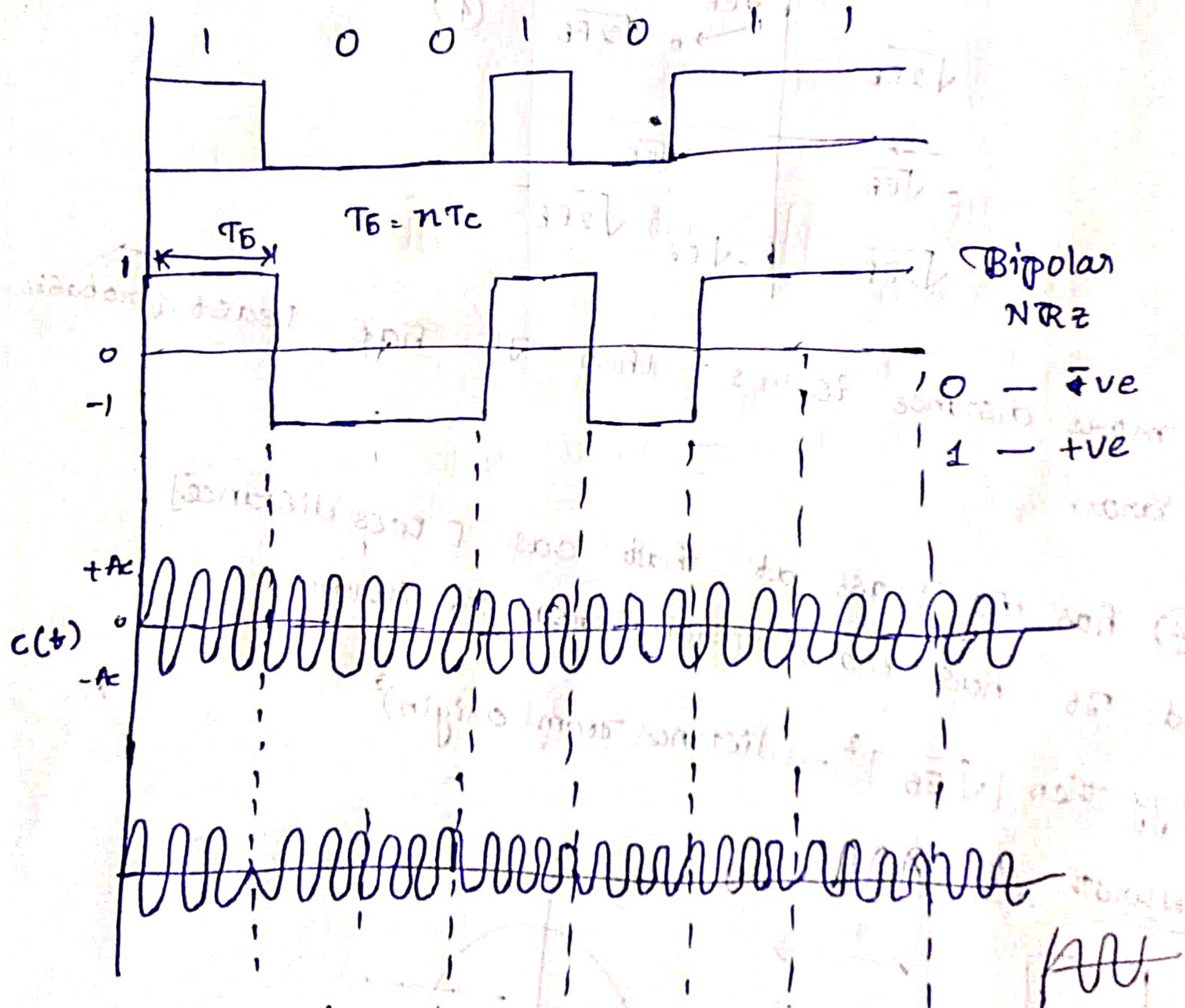
PSK : Phase Shift Keying

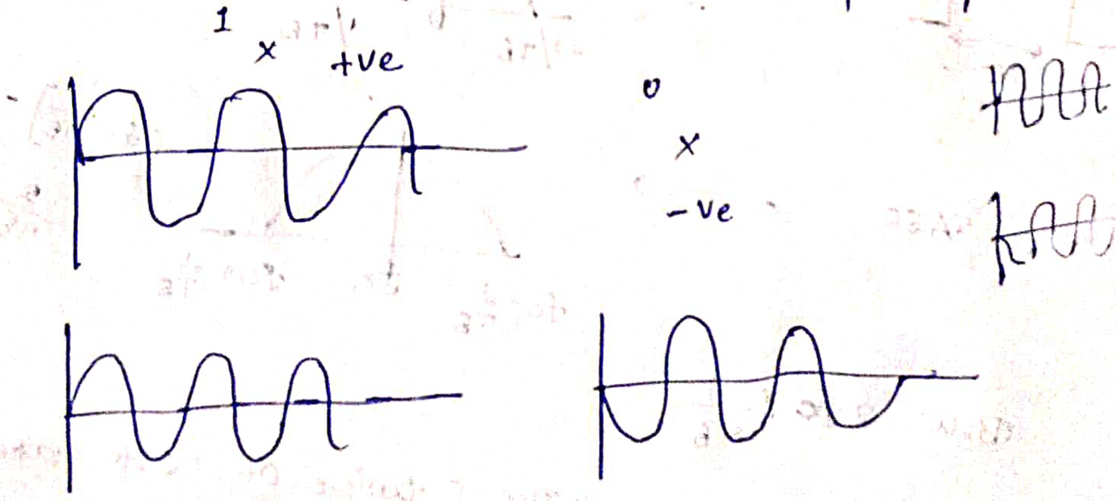
Binary PSK $\quad$ 360° But 2 then

2 - PSK : $\quad \frac{360°}{2} = 180°$

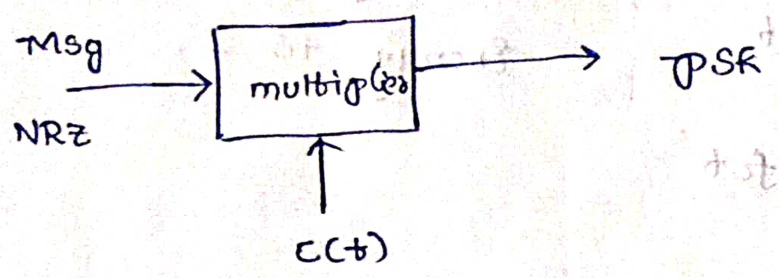
1 — $A_c \cos 2\pi f_c t$

0 — $-A_c \cos 2\pi f_c t$ [shifted version of 180°]





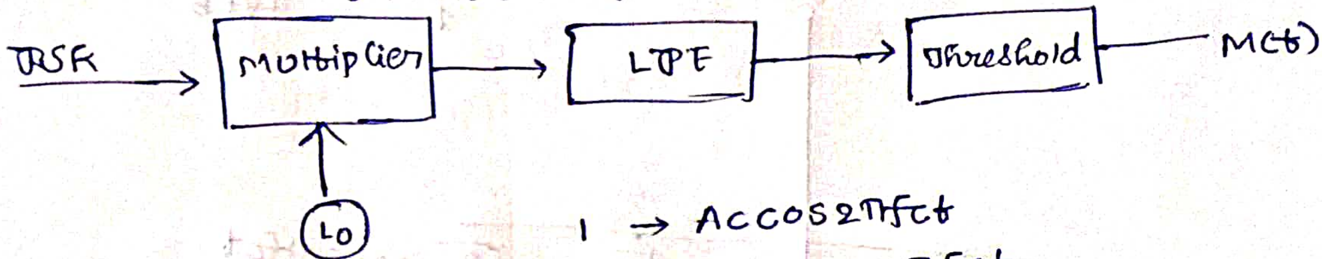
Modulation of PSK



Demodulation

$1 \rightarrow A_c^2 \cos^2 2\pi f_c t$

$0 \rightarrow -A_c^2 \cos^2 2\pi f_c t$



Same as ASK.

$1 \rightarrow A_c \cos 2\pi f_c t$

$0 \rightarrow -A_c \cos 2\pi f_c t$

Multiplier

$$1 \rightarrow \frac{A_c^2}{2} + \frac{A_c^2}{2}\cos(2\pi\, 2 f_c t)$$

$$0 \rightarrow -\frac{A_c^2}{2} + \frac{A_c^2}{2}\cos(2\pi\, 2 f_c t)$$

LPF

$$1 \rightarrow \frac{A_c^2}{2}$$

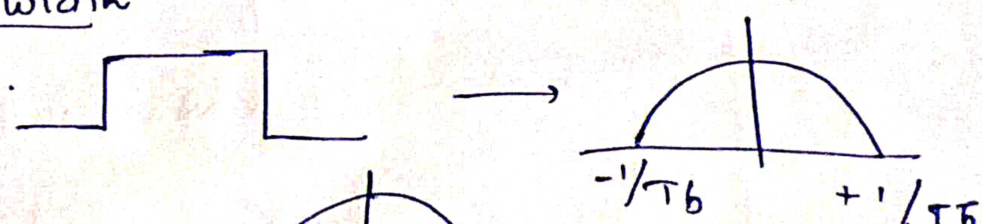
$$0 \rightarrow -\frac{A_c^2}{2}$$

Threshold $\quad \frac{V_{max} + V_{min}}{2} = 0 \Rightarrow \frac{\frac{A_c^2}{2} - \frac{A_c^2}{2}}{2} = 0$

greater than 0 It is 1.

~~greater~~ less than 0 It is 0.

Bandwidth



$$\boxed{B.W = 2 \times \frac{1}{T_b} = 2R_b}$$

Constellation diagram

N.F ⇒ any function whose Energy is 1.

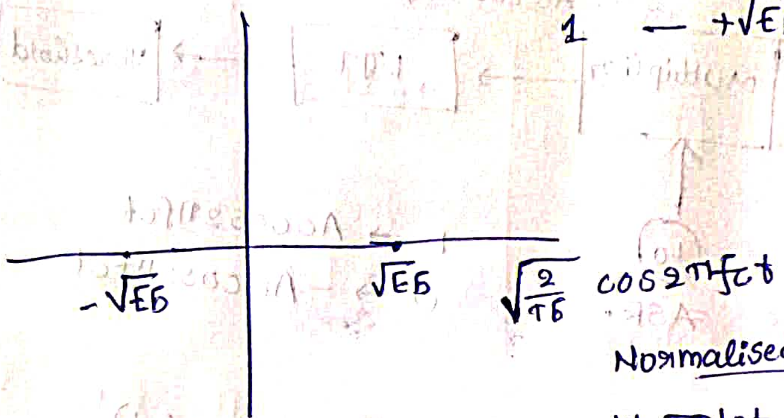
$1 \longrightarrow A_c \cos 2\pi f_c t$

$= \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t$

$0 \longrightarrow -\sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t$

$0 \; — \; -\sqrt{E_b}$

$1 \; — \; +\sqrt{E_b}$



Normalised Function

we will plot y-axis

But won't consider it