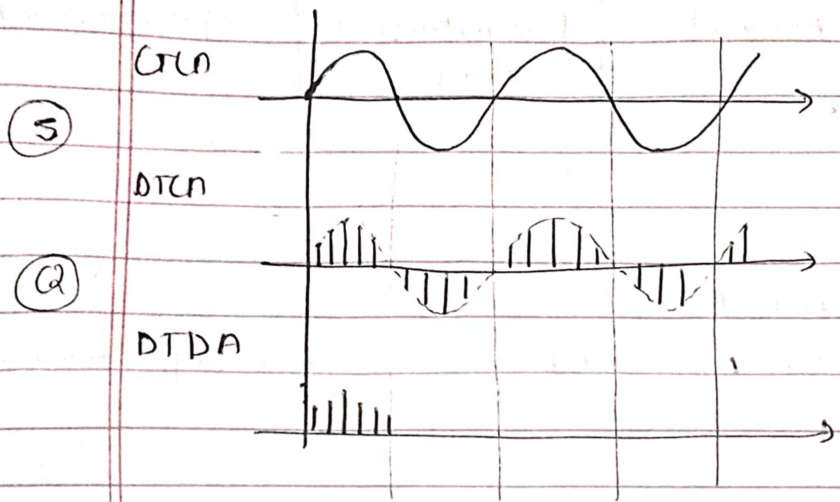
* PCM:

— Discrete Time, discrete amplitude waveform coding process by means of which analog signals can be directly represented as sequence of coded pulses

Analog → PAM → A to D → Digital → D to A → Decoder →
Analog

A to D

PAM → Quantizer | Encoder



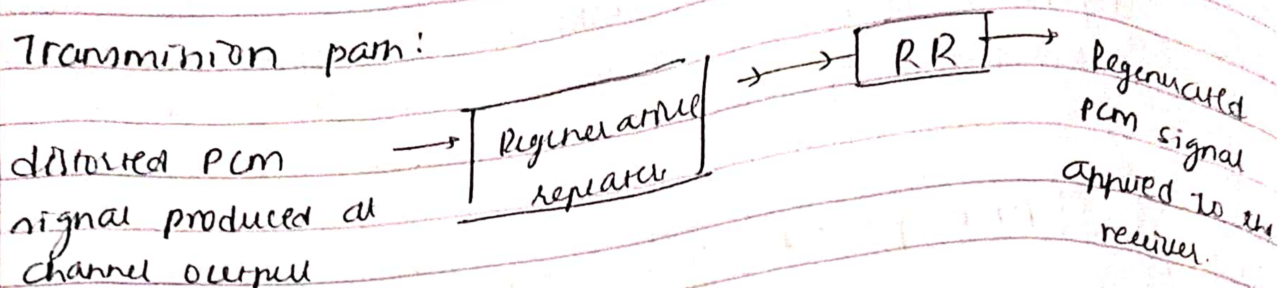
* Transmitter:

Source of continuous Time message signal → LPF → Samples → Quantizer
↓
Encoder
↓
PCM signal applied to channel's I/P

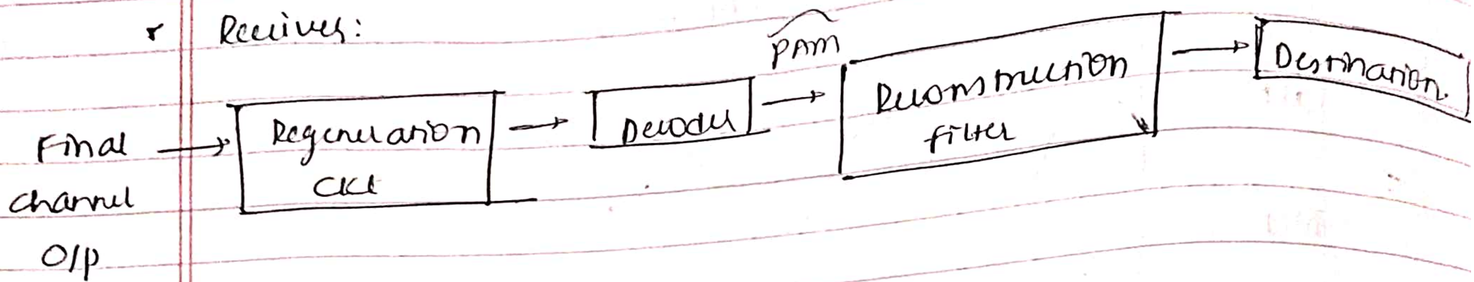
1) Basic operations performed :
— Sampling
— Quantizing.
— Encoding.

2) LPF : to prevent message signals aliasing.
3) A to D converter : Quantizer & Encoder.

* Transmission path:



* Receiver:



→ Sampling in Transmitter:

1) Incoming message signal is sampled with train of rectangular pulses

→ Quantization in Transmitter:

1) The PAM representation of msg is then quantized in A to D converter, providing new representation of signal that is discrete in both time & amplitude.

→ Encoding in Transmitter:

1) Last operations on signal is the coding, to represent each binary codeword by sequence of pulses.

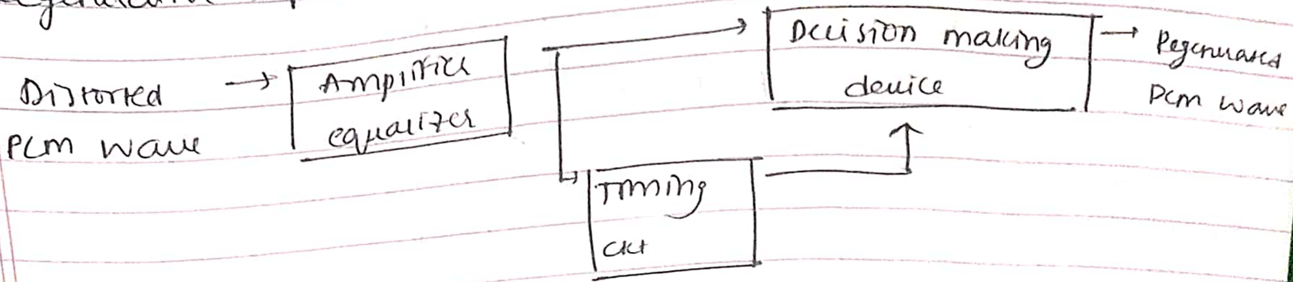
Ex: symbol 1 : used to represent presence of pulse.
symbol 0 : " " " absence " ".

→ Receivers opⁿ:

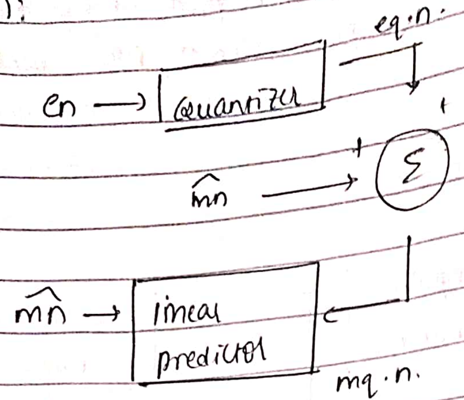
1) 1st operation is to regenerate the received pulses.
2) These clean pulses are then regrouped into codewords & decoded into Quantized PAM signals.
3) signal reconstruction →

An estimate of original signal is produced by passing decoder output through a low pass reconstr filter. whose fc = message bandwidth.

Regenerative repeater:

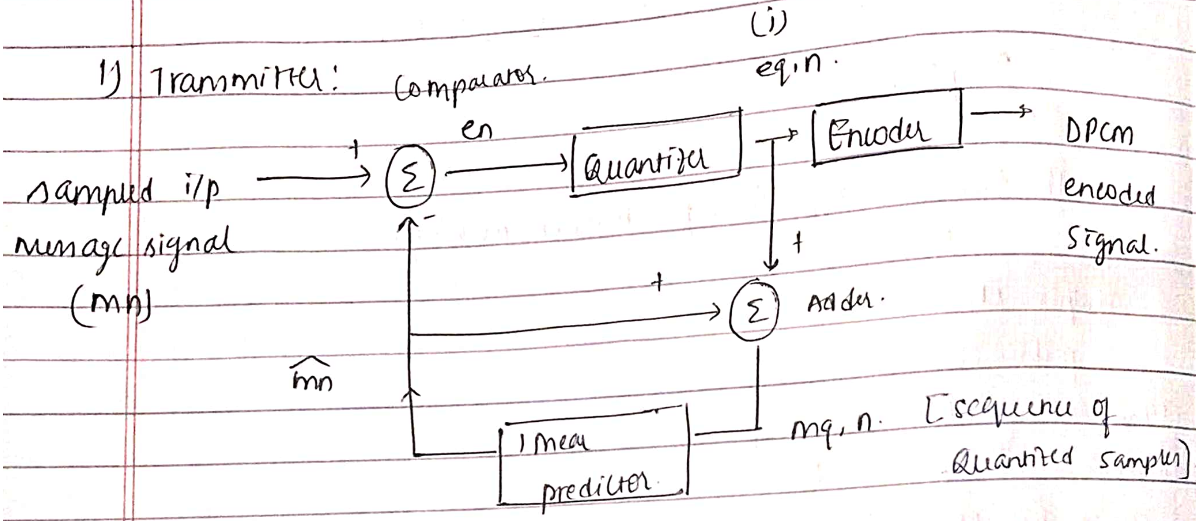


2) DPCM:



Differential Quantizer

1) Transmitter:



$$eq,n = en + qn \rightarrow \text{quantization Noise}$$

$$mq.n = eq.n + \hat{mn} \rightarrow \text{predicted value of original message signal.}$$

$$\therefore \cancel{mq,n = eqn + en + qn}$$

$$\cancel{en = mn - \hat{mn}}$$

$$\cancel{mqn = eqn + mn - \hat{mn} + qn}$$

$$en = mn - \hat{mn}$$

$$\Rightarrow mqn = eqn + \hat{mn}$$

$$= en + qn + \hat{mn}$$

$$= mn - \hat{mn} + qn + \hat{mn}$$

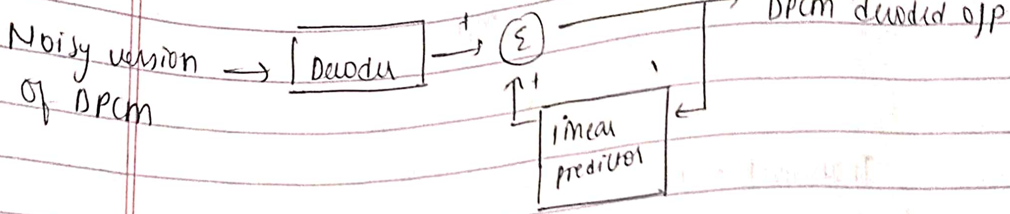
$$\boxed{mqn = mn + qn.}$$

Quantized version of original signal.

Opⁿs at Transmitter:

1) Given predicted message signal $\hat{m}n$, comparator computes en (prediction error).
2) en is quantized to produced eqn (quantized version of en). $mn - \hat{m}n$. $mq.n$
3) Adder produces quantized version of mn
4) $\hat{m}n$ is produced by applying sequence of Quantized samples to a linear FIR predictor of order P.

* Receiver:



$mqn = \hat{m}n + eqn$

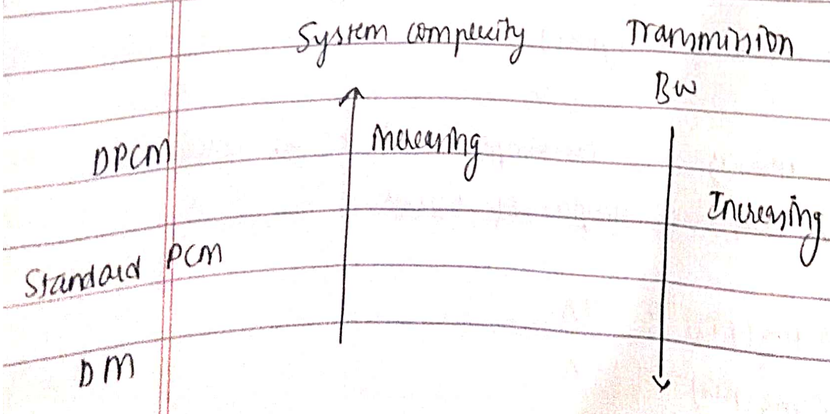
$= mn - en + eqn$

$= en + qn + mn - en$

$mqn = qn + mn$

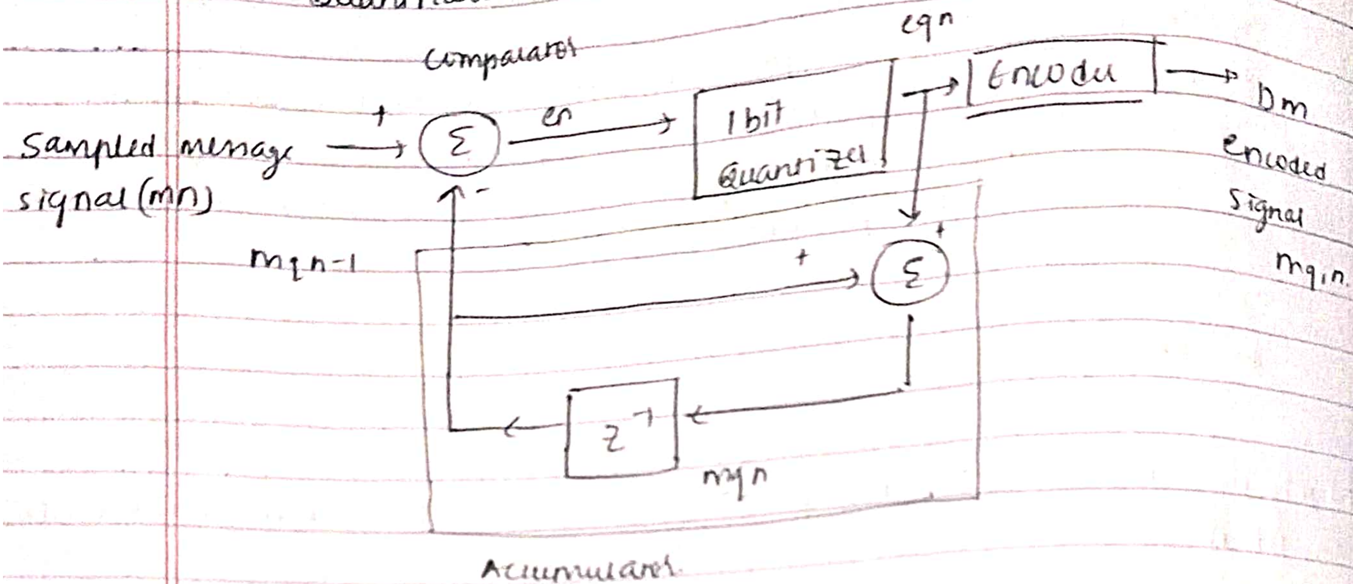
→ Opⁿs at Receiver:

1) simpler structure
2) Decoder reconstructs quantized version of prediction error (eqn)
3) Estimate of original o/p message sample mn is then computed by applying decoder o/p to the same predictor as used in the Transmitter.



3) Delta modulation: Provides staircase approx^n to oversampled msg

- 1 bit quantization.



Transmitter op^n:

→1) Try to reduce system complexity by:

(i) single bit quantizer : only 2 decision levels $\pm\Delta$

(ii) single unit ~~time~~ delay element: primitive form of predictor.

$$e_n = m_n - \hat{m}_n$$
$$= m_n - m_{q\,n-1}$$
$$e_{qn} = \begin{cases} +\Delta & \text{if } e_n > 0 \\ -\Delta & \text{if } e_n < 0 \end{cases}$$
$$m_{qn} = m_{q\,n-1} + e_{qn}$$

@ accumulator:

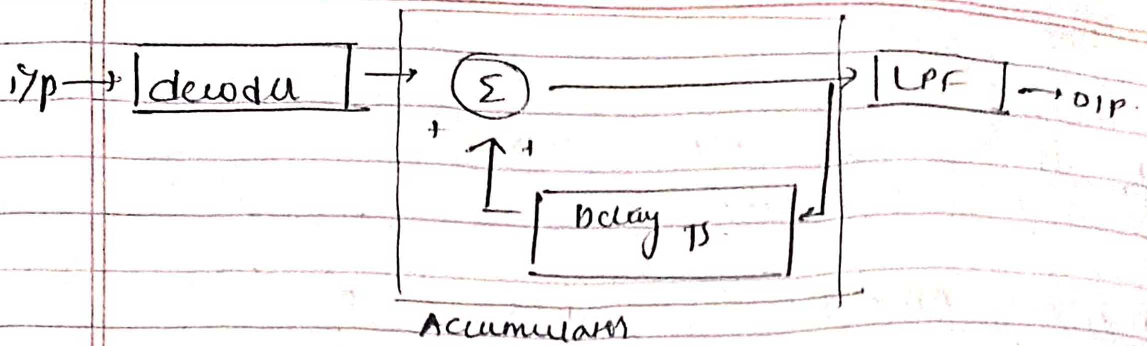
If e_n = +ve : $\hat{m}_n = m_{q\,n-1}$ is increased by Δ, hence encoder sends out symbol 1.

If e_n = -ve : $\hat{m}_n = m_{q\,n-1}$ is reduced by Δ, hence encoder sends out symbol 0.

2) Incoming message are oversampled — to increase correlation between adjacent samples of signals.

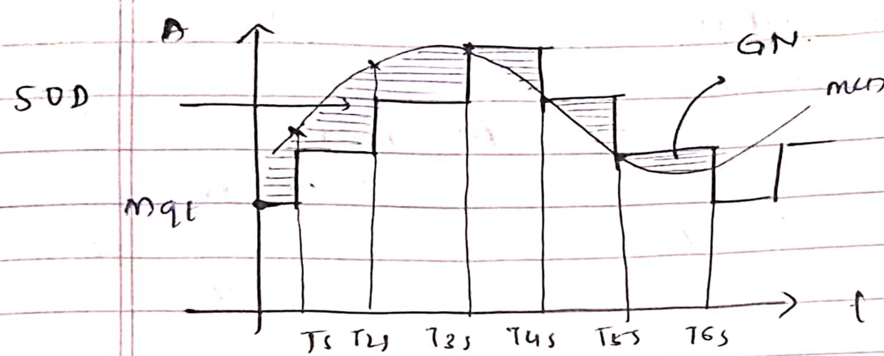
3) $m(nT_s) > m_q(nT_s) = +\Delta$

$m(nT_s) < m_q(nT_s) = -\Delta$



→ mq(t) is reconstructed by passing sequence of '+'ve & '-'ve pulses, produced at decoder O/P.

→ The Quantization Noise in High frequency mq(t) is rejected by passing through "LPF".



Noise :-

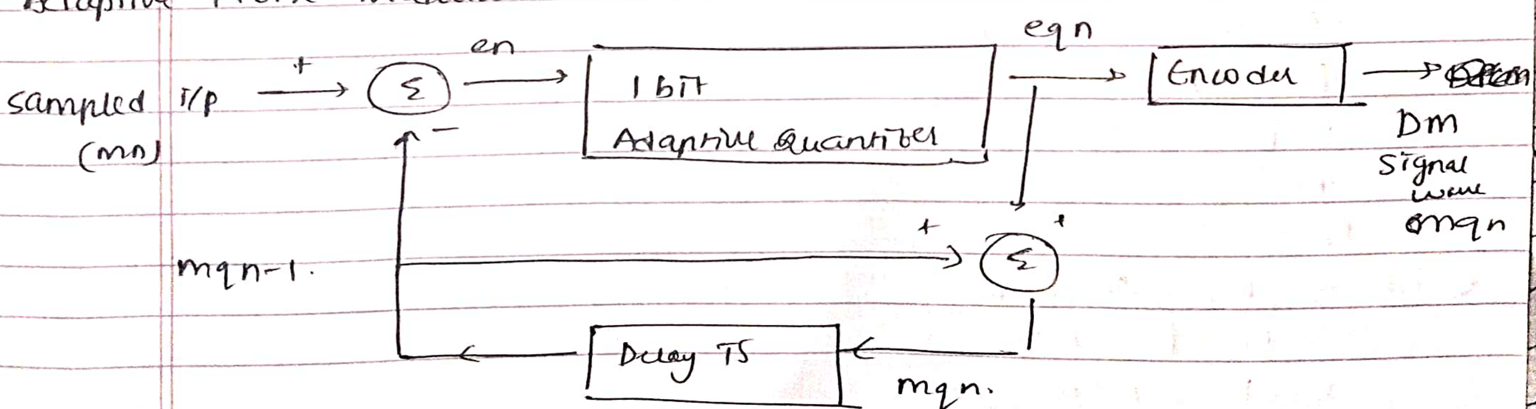
Slope overload distortion

- If x(t) is much higher than xq(t), over a long duration, then xq(t) will not be able to follow x(t).

Granular Noise

— When i/p signal x(t) is relatively constant in amplitude xq(t) is bouncing up & down which will cause GN distortion.

Adaptive Noise Modulator:



2)

SNR:

$SNR = \frac{P_S}{P_N} = \frac{\text{Power signal}}{\text{Power Noise}}$

Consider input 'm' with range $[-m_{max}, m_{max}]$
↳ continuous amplitude

$$\Delta = \frac{m_{max} - (-m_{max})}{L}$$

$$\Delta = \frac{2m_{max}}{L}$$

Let R = no. of bits / sample

$$L = 2^R$$

$$\Rightarrow \Delta = \frac{2m_{max}}{2^R} \quad \text{--- (1)}$$

∴ The Quantiz^n error 'Q' for uniform midrise quantizer will have samples.

$$-\frac{\Delta}{2} < q < \frac{\Delta}{2}$$

$$f_Q(q) = \begin{cases} \frac{1}{\Delta} & : -\frac{\Delta}{2} \le q \le \frac{\Delta}{2} \\ 0 & : \text{otherwise} \end{cases}$$

$$\sigma^2_Q = E(Q^2)$$

$$\Rightarrow = \int_{-\Delta/2}^{+\Delta/2} f_Q(q) \cdot q^2 \cdot dq$$

$$= \frac{1}{\Delta} \int_{-\Delta/2}^{+\Delta/2} q^2 \cdot dq$$

$$= \frac{1}{3\Delta} \cdot \left[\frac{\Delta^3}{8} + \frac{\Delta^3}{8}\right]$$

$$= \frac{1}{3\Delta}\left[\frac{2\Delta^3}{8}\right]$$

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

$$\sigma^2_Q = \frac{1}{12} \times \left[\frac{4\,m^2_{max}}{2^{2R}}\right]$$

$$= \frac{1}{3} \times \left[\frac{m^2_{max}}{2^{2R}}\right]$$

$$(SNR)_0 = \frac{P}{\sigma_Q^2}$$

$$= \frac{P}{1 \times m^2_{max}} \times 3 \times 2^{2R}$$

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

but $\frac{A_m^2}{2} = \frac{m^2_{max}}{2}$

$$= \frac{\cancel{A}\, \cancel{m^2_{max}}}{2 \times \cancel{m^2_{max}}} \times 3 \times 2^{2R}$$

$$= \frac{3 \times \cancel{1} \times 2^{2R}}{2}$$

$$(SNR)_0 = \frac{3 \times 2^{2R}}{2}$$

'10 log' on both sides ⇒

$$10\log(SNR)_0 = 10\log\left(\frac{3}{2} \times 2^{2R}\right)$$

$$10\log(SNR)_0 = 10\log(1.5) + 2R\,10\log(2)$$

$$= 1.8 + 6R$$