10EC61

DIGITAL COMMUNICATION

UNIT 2

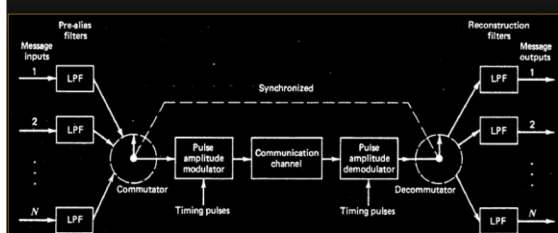
OUTLINE

- PAM, TDM.
- Waveform Coding Techniques, PCM, Quantization noise and SNR, robust quantization.

PULSE AMPLITUDE MODULATION (PAM)

- The amplitude of a carrier pulses is varied in proportion to sample values of a message signal by keeping constant pulse duration.
- PAM is same as flat top sampling

TIME DIVISION MULTIPLEXING



TDM….

- Conservation of time
- Different time intervals are allocated for different message signals.
- So, a common channel is utilized for transmission of these signals without any interference
- Pre-alias filters are used for removing high frequency components
- Commutator: implemented using electronic switching circuitry
- Functions of Commutator:
  1. Taking narrow sample of each of the 'N' i/p signals at a rate $f_s >= 2W$

     ('W' is the cut off frequency of pre-alias filters)
  2. To sequentially interleave these 'N' samples inside a sampling interval $T_s=1/f_s$.

TDM….

- Multiplexed signal is applied to a pulse amplitude modulator whose purpose is to transform the multiplexed signal in to a form suitable for transmission over a common channel.

Waveform illustrating TDM for two message signals

TDM

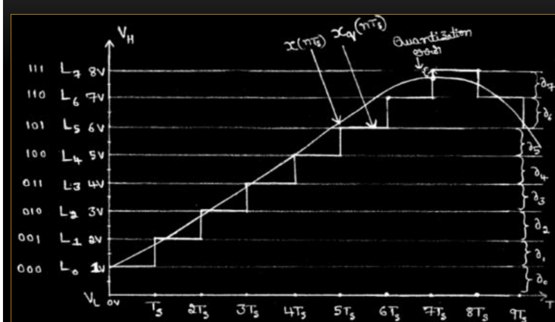
- Suppose that the 'N' Message signals to be multiplexed have the same spectral properties (BW),
  - Then the sampling rate for each message signal is determined in accordance with the sampling theorem
- Let 'T_s" → sampling period
- Let 'T_x' → the spacing between adjacent samples in the TDM signal.

Then, $T_x = T_s/N$

QUANTIZATION

- The process of transforming sampled amplitude values of a message signal in to a discrete amplitude value (levels) is referred to as quantization.
- Quantization approximates each of input sample value to nearest prefixed level.

QUANTIZATION...



QUANTIZATION...

- The signal x(t) whose excursion is confined to the range from V_L to V_H being divided into 8 equal levels.
- Step size is denoted by 'δ' or 'Δ'

$$\Delta = (V_H - V_L)/L$$

- Where $L = 2^N$, N→ No. of bits

$$\therefore \Delta = (V_H - V_L)/2^N$$

If the step size is maintained same throughout the process of quantization, then it is called ***'Uniform Quantization'***

QUANTIZATION ERROR

- The difference between the continuous amplitude sample level and quantized signal level is known as quantization error.
  - $e(t) = x_q(nT_s) - x(nT_s)$
- Quantization error varies from –δ/2 to +δ/2

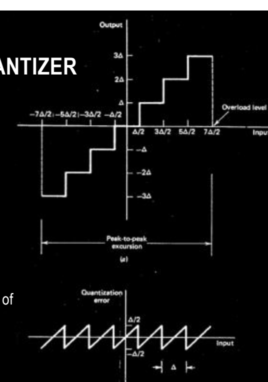
- **Quantization Noise**
  - The random errors due to quantization process produces a noise at the o/p of the quantizer and this noise is referred to as quantization noise.

MID TREAD TYPE QUANTIZER

- The decision threshold of the quantizer are located at ± δ/2, ±3δ/2, ±5δ/2…. And the representation levels are located at 0, ±δ, ±2δ, ±3δ….

where δ is the step size

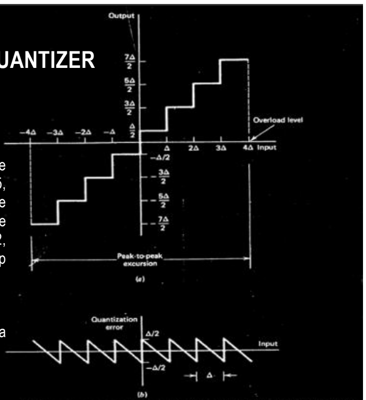
- Symmetric quantizer
- Origin lies in the middle of a tread of a staircase waveform



(a) Transfer characteristic of quantizer of midtread type. (b) Variation of the quantization error with input.

MID RISER TYPE QUANTIZER

- The decision threshold of the quantizer are located at 0, ±δ, ±2δ, ±3δ… and the representation levels are located at ± δ/2, ±3δ/2, ±5δ/2…. where δ is the step size
- Symmetric quantizer
- Origin lies in the middle of a riser of a staircase waveform



(a) Transfer characteristic of quantizer of midriser type. (b) Variation of the quantization error with input.

PULSE CODE MODULATION

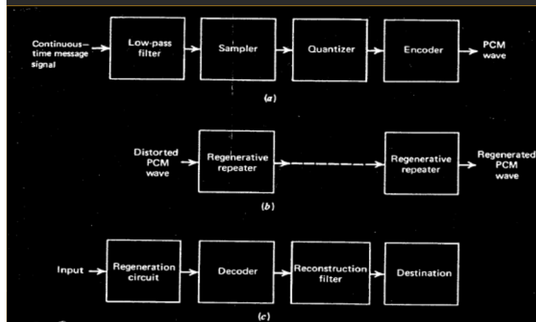


Fig ①: Basic elements of a PCM system. (a) Transmitter. (b) Transmission path. (c) Receiver.

ENCODER

- Quantized samples are encoded in the encoder.
- The process of encoding involves allocating some digital code to each level.
- These coded levels are transmitted as a bit stream of data, i.e. 0's and 1's.
- The encoder o/p consists of pulses depending on code combination

PULSE DEGRADATION

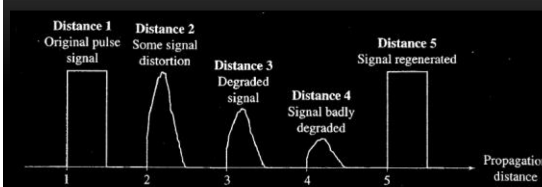
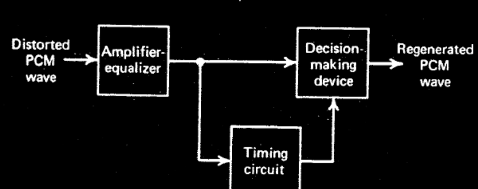


Figure Pulse degradation and regeneration.

- The pulse is affected mainly by two mechanisms
  i. Unwanted electrical noise or other disturbance
  ii. Non-ideal transfer function of the transmission medium

REGENERATIVE REPEATER

- The PCM signal is reconstructed by means of a regenerative repeater located at suitable distance along the transmission path.
- Noise is removed and the Pulse amplitude is boosted

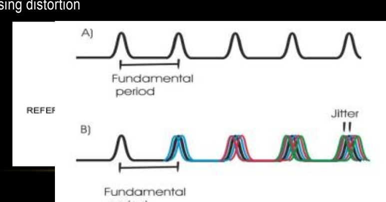


Block diagram of a regenerative repeater.

REGENERATIVE REPEATER LIMITATIONS

i. The presence of channel noise and interference causes the regenerative repeater to make wrong decision.

ii. Timing jitter is introduced into the regenerated pulses due to decision device, causing distortion



PROBLEMS WITH UNIFORM QUANTIZATION

– Only optimal for uniformly distributed signal

– Real audio signals (speech and music) are more concentrated near zeros

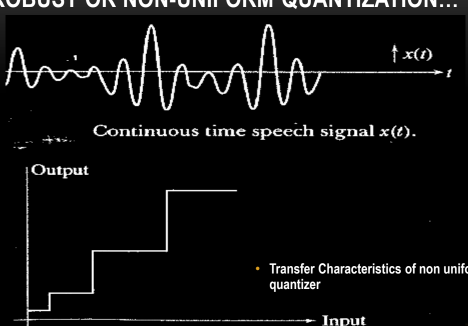
-- quantization noise is same for all signal amplitudes, hence small amplitude levels are more affected than the bigger sample values

– Human ear is more sensitive to quantization errors at small values

ROBUST OR NON-UNIFORM QUANTIZATION…

- To have high signal to quantization noise ratio, we must use a signal which is large in comparison with the step size.
  - Small step size for small magnitude signals and higher step size for higher magnitude signal
- Changing the step size according to signal magnitude?
  - **Very difficult!!!!** So not preferred.
- Solution?
- Change the characteristic of the signal so that lower amplitudes are amplified without affecting the higher amplitudes.

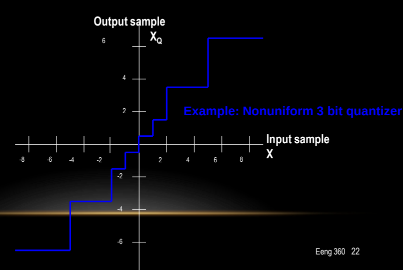
ROBUST OR NON-UNIFORM QUANTIZATION…



- Transfer Characteristics of non uniform quantizer

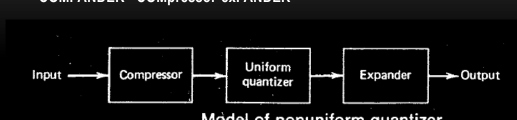
NONUNIFORM QUANTIZATION

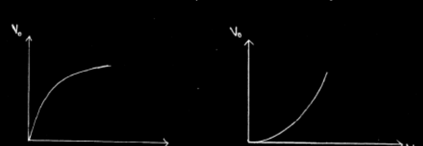
- Many signals such as speech have a nonuniform distribution.
  - The amplitude is more likely to be close to zero than to be at higher levels.
- ***Nonuniform quantizers*** have unequally spaced levels
  - The spacing can be chosen to optimize the SNR for a particular type of signal.



COMPANDING….

- **COMPANDER - COMpressor-exPANDER**





Compressor Characteristics Expander Characteristics

COMPANDING

- Nonuniform quantizers are difficult to make and expensive.
- An alternative is to first pass the speech signal through a nonlinearity before quantizing with a uniform quantizer.
- The nonlinearity causes the signal amplitude to be ***Compressed***.
  - The input to the quantizer will have a more uniform distribution.
- At the receiver, the signal is ***Expanded*** by an inverse to the nonlinearity.
- The process of compressing and expanding is called ***Companding***.

COMPANDING…..

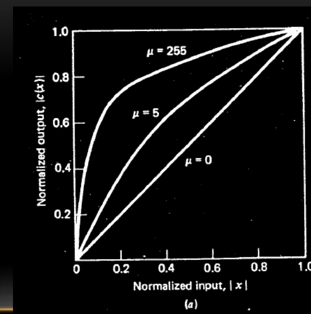
Two Types

- μ - Law Companding
- A – Law Companding

μ - LAW COMPANDING

μ-law :

$$y(x)=\frac{\ln\left(1+\mu\left|\frac{x}{x_{max}}\right|\right)}{\ln(1+\mu)}\operatorname{sgn}(x)\quad \text{for}\left|\frac{x}{x_{max}}\right|\le 1$$



A – LAW COMPANDING

$$\frac{c(|x|)}{x_{max}}=\begin{cases}\dfrac{A|x|/x_{max}}{1+\ln A} & 0\leqslant\dfrac{|x|}{x_{max}}\leqslant\dfrac{1}{A}\\[2ex] \dfrac{1+\ln(A|x|/x_{max})}{1+\ln A} & \dfrac{1}{A}\leqslant\dfrac{|x|}{x_{max}}\leqslant 1\end{cases}$$