DIGITAL COMMUNICATION

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QUANTIZATION AND PULSE SHAPING

What is Digital Communication

Pulse Code Modulation

Differential Pulse Code Modulation

Delta Modulation

Baseband Shaping For Data Transmission – Introduction

Discrete PAM Signals

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What is Digital Communication System

Morse code, which involved transmission of fixed symbols of dot(.), dash(-) and space ( ) for Telegram was one of the first examples of digital communication.

Some of its advantages over analog communication are:

- Can recover the original symbol from the noisy one
- Error correction and coding is possible
- Data compression is possible.
- Data encryption and hence enhanced security is also possible.

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Advantages over analog communication

- Processor or Algorithm instead of components or circuits and hence easy to modify or upgrade the communication system

- Common format or protocol for storage or communication of different types of signals

Ex: Audio, Video, Image etc.

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Block diagram of digital communication system

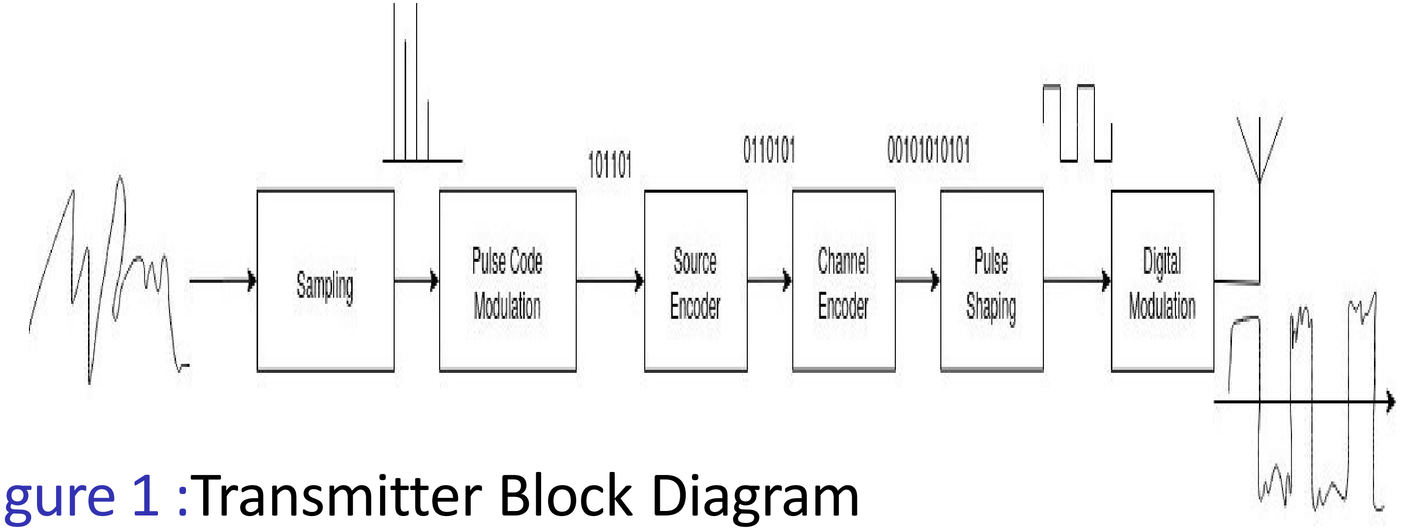

Figure 1 :Transmitter Block Diagram

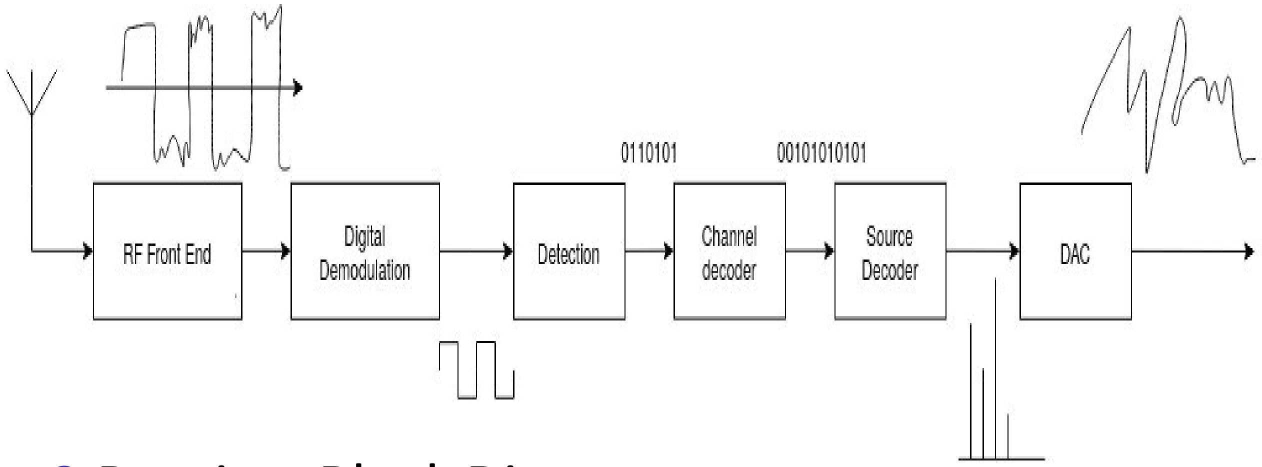

Figure 2:Receiver Block Diagram

Sampling

- Sampling Converts a continuous time random process to a discrete time random process.

- "Discrete time random process" – Random variable at discrete time (i.e. sequence of continuous random variables).

- Sampling results in a sequence of continuous random variables. Each sample has an amplitude taken from a continuous range of values.

Pulse Code Modulation

PCM is the process of representing the sequence of samples by a sequence of bits. Here each sample is represented by a bit pattern.

PCM involves two steps:

1) Quantization

2) Bit Encoding

Quantization

- Quantization is the process of approximating each sample by the nearest value from a discrete set of values.

- We assume that all sample values are within the overload represented by $\pm A$ volt.

- The range [-A, A] is divided into L levels. Each sample is approximated by the mid-point of the level it belongs to.

- Quantization converts a set of continuous random variables to a set of discrete random variables.

Quantization Equations

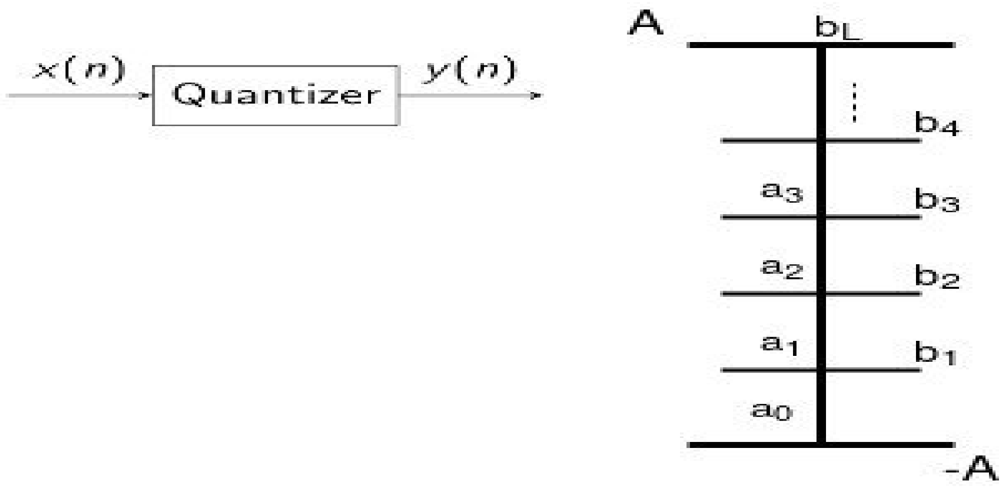

Figure 3:Quantization Scale Reprsentation

- The range [-A,A] as shown in figure (3), is divided into L levels. Let $b_0, b_1, b_2, ..b_L$ indicate the level boundary and $a_0, a_1, a_2, ..a_{L-1}$ indicate the mid-point of the level.
- The quantization rule is given by $y(n) = a_k$ if $b_k \le x(n) \le b_{k+1}$
- Suppose each sample is represented using N bits, then we have 2^N levels. $L = 2^N$ Levels .
- Such a Quantizer which divides the range [-A,A] into $L = 2^N$ levels of equal width is called Uniform Quantization.

Quantization Equations

Each level has a step size denoted by Δ. So, $\boxed{\Delta = \frac{2A}{2^N}}$

The Quantization Error is given by $q(n) = y(n) - x(n)$.

This error $q(n)$ cannot be removed.

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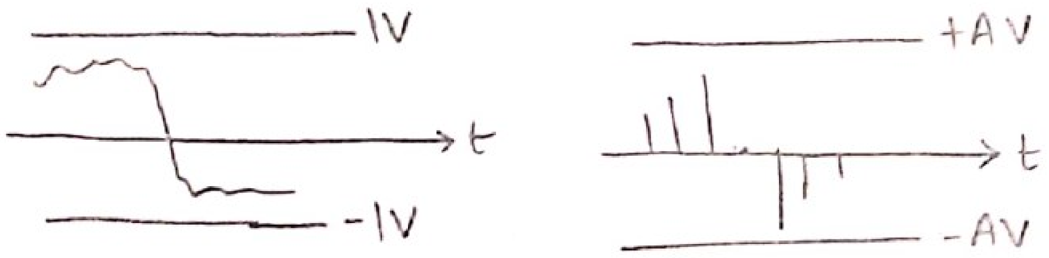
Example

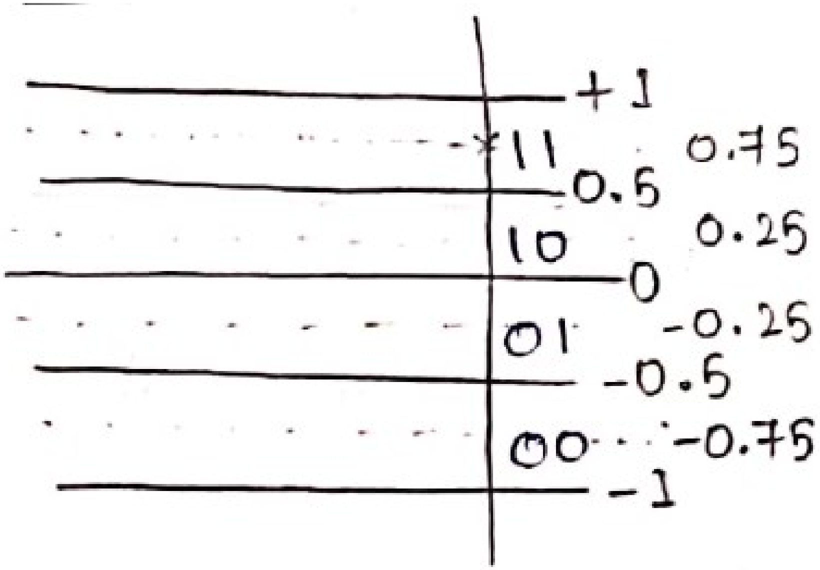
Ex:



Let the sequence of samples be 0.35, 0.51, 0.64, 0.28, -0.06, -0.43.

Let each sample be represented by 2 bits.

L = 4 levels.



Quantization:

x(n)	y(n)	Bit Encoding
0.35	0.25	10
0.51	0.75	11
0.65	0.75	11
0.28	0.25	10
-0.06	-0.25	01
-0.43	-0.25	01
-0.71	-0.75	00
⋮	⋮	⋮

Mid Riser and Mid Tread Quantizer

Uniform Quantization is of two types:

1) Mid Riser Quantizer

2) Mid Tread Quantizer

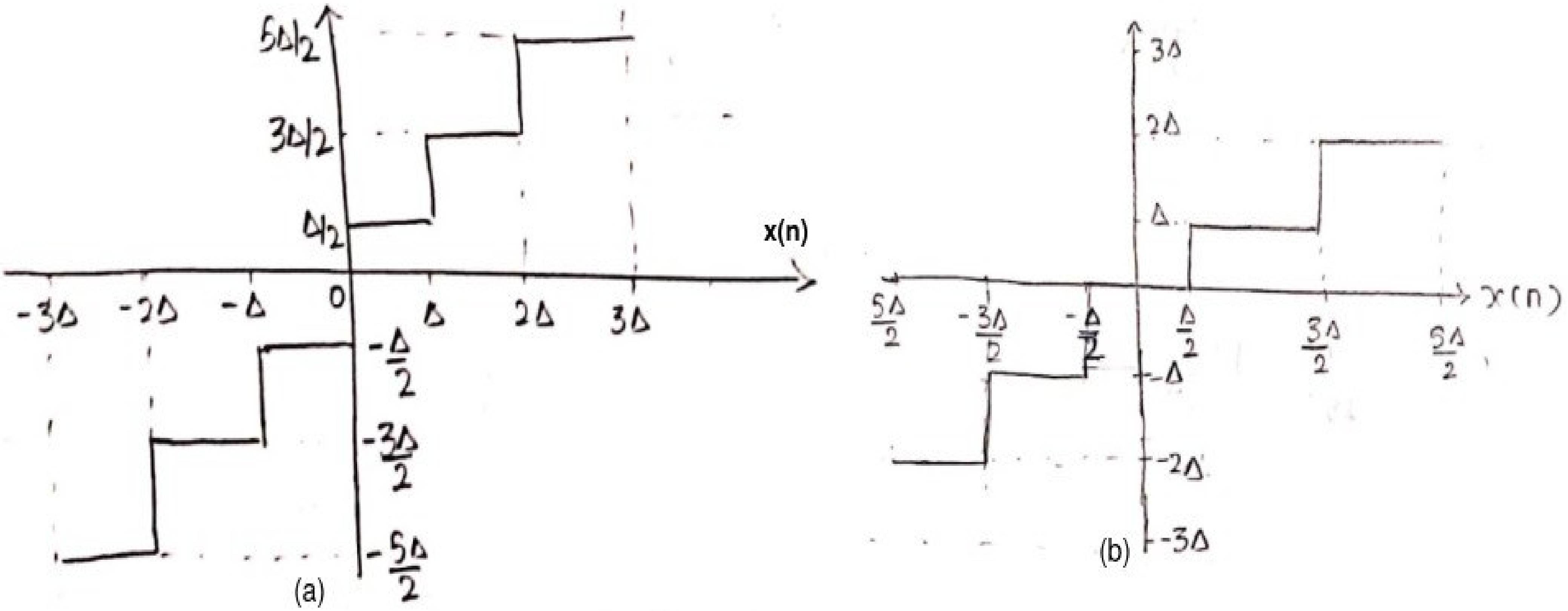


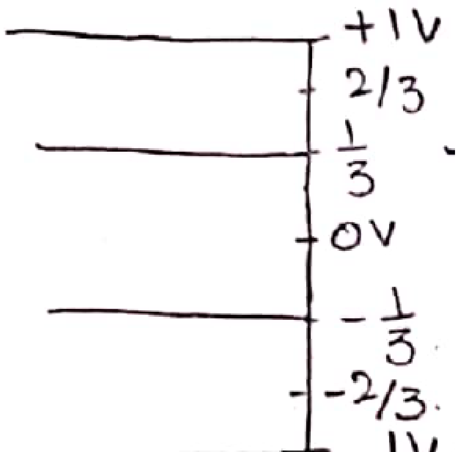
Figure 4:The input-output characteristics for Mid-Riser and Mid Tread Uniform Quantization method.

Mid Riser and Mid Tread Quantizer

Figure (4a) shows the I/O characteristics for Mid-Riser quantizer. The level boundaries are 0, $\pm\Delta$, $\pm 2\Delta$ …. The mid-points are at $\pm\Delta/2$, $\pm 3\Delta/2$ $\pm 5\Delta/2$….

Note: Quantization introduces an error q(n) that cannot be removed

Due to stray noise samples, there will be bits even though there is no signal because the stray noise gets mapped to $\pm\Delta/2$. This can avoided by taking off 0 as a boundary as shown in figure (4b). Such a quantizer is called Mid-Tread Quantizer.



Have only 3 levels instead of 4 levels

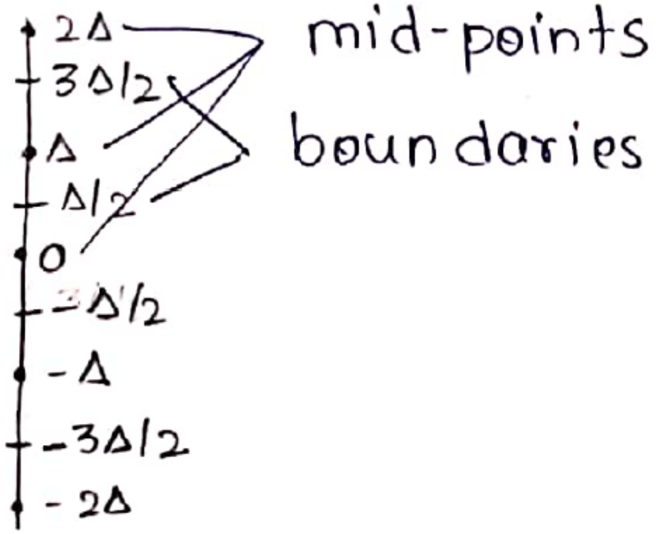
So stray noise samples will be mapped to zero

Mid Riser and Mid Tread Quantizer

Its level boundaries are
$\pm\Delta/2$, $\pm 3\Delta/2$ $\pm 5\Delta/2$.... and the mid points are 0, $\pm\Delta$, $\pm 2\Delta$ ....

Here the number of levels L is 2^N in Mid-Riser and $2^N - 1$ in Mid-tread quantizer. For large values of N, L can be approximated as 2^N for both quantizers. So, the step width Δ can be calculated as $2A/2^N$ for Mid-riser and $2A/(2^N - 1)$ for Mid-Tread quantizer.

<u>Mid Tread Quantizer:</u>



Here the boundaries and mid-points are flipped when compared to the Mid-Riser Quantizer

Mid Riser Vs Mid Tread Quantizer

In Mid-Riser quantizer when the signal is not present the output alternates between
$+\Delta/2$ *and* $-\Delta/2$ due to noise samples resulting in a spurious bit pattern

This problem is avoided in Mid-Tread quantizer

The number of levels L is 2^N in Mid-Riser and $2^N - 1$ in
Mid-tread quantizer. For large values of N, L can be approximated as 2^N for both quantizers.

So, the step width Δ can be calculated as $2A/2^N$ for Mid-riser and $2A/(2^N - 1)$ for Mid-Tread quantizer.

THANK YOU

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