CSE 311:
Data Communication

Instructor:

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Messages/Signals: Definition

Review

- A signal is a set of information or data.

- A signal is a function of independent variables that carry some information.

- A signal is a physical quantity that varies with time, space or any other independent variable by which information can be conveyed.

Example of Signals

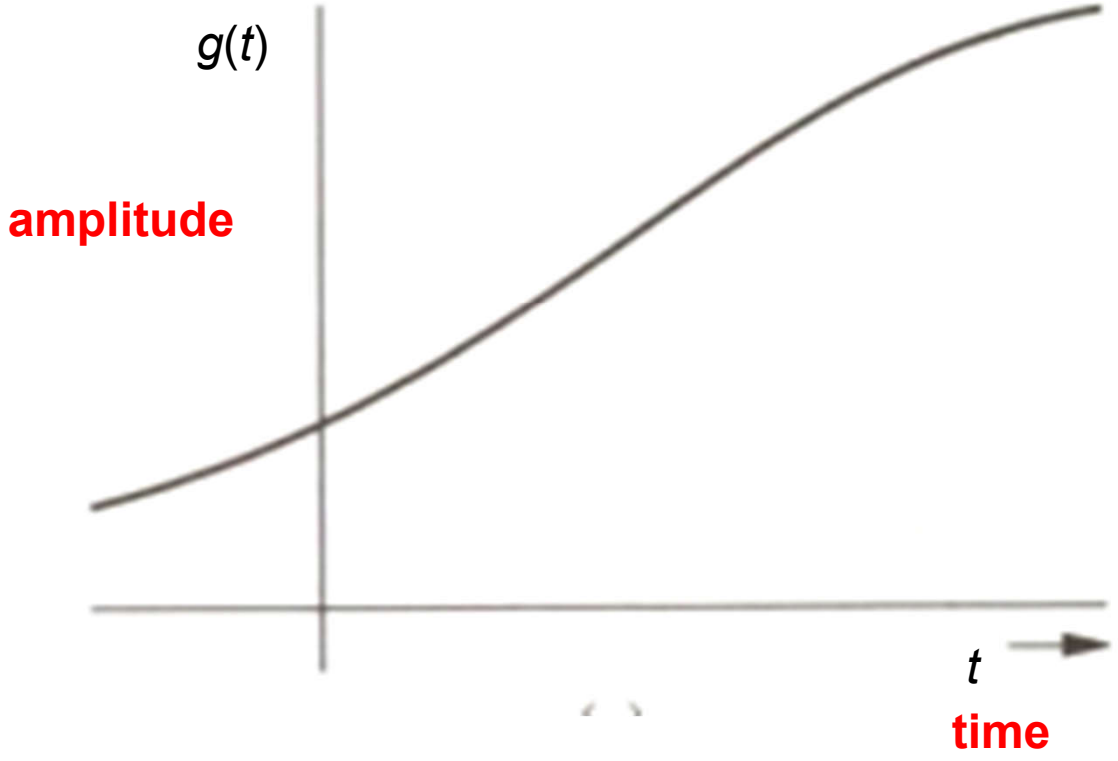
Review

- Voice signal
- Telephone or television signal
- Monthly sales figure
- Opening or closing stock prices
- Charge density over a surface

- In this course we deal with signals that are functions of time.

Signal representation: Time Domain

Review



Classification of Signals

- Based on continuity in time axis
  - Continuous time
  - Discrete time
- Based on continuity in amplitude axis
  - Continuous amplitude
  - Discrete amplitude

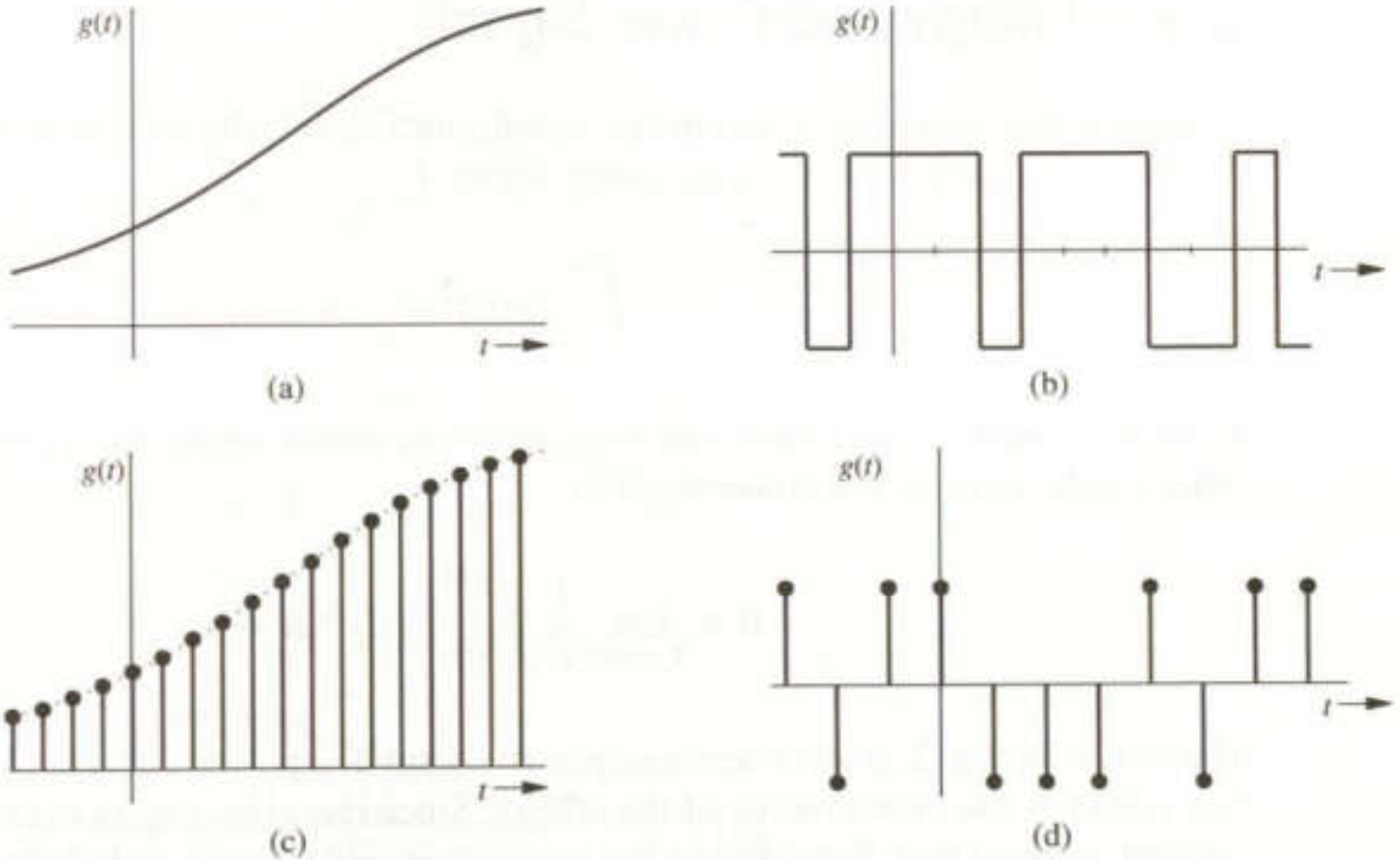
Classification of Signals

Continuous amplitude

Discrete amplitude

Continuous time

Discrete time



Analog and Digital Signal

Analog Signal

- Continuous amplitude, i.e., takes any value in a continuous range.
- May be both continuous and discrete time.

Digital Signal

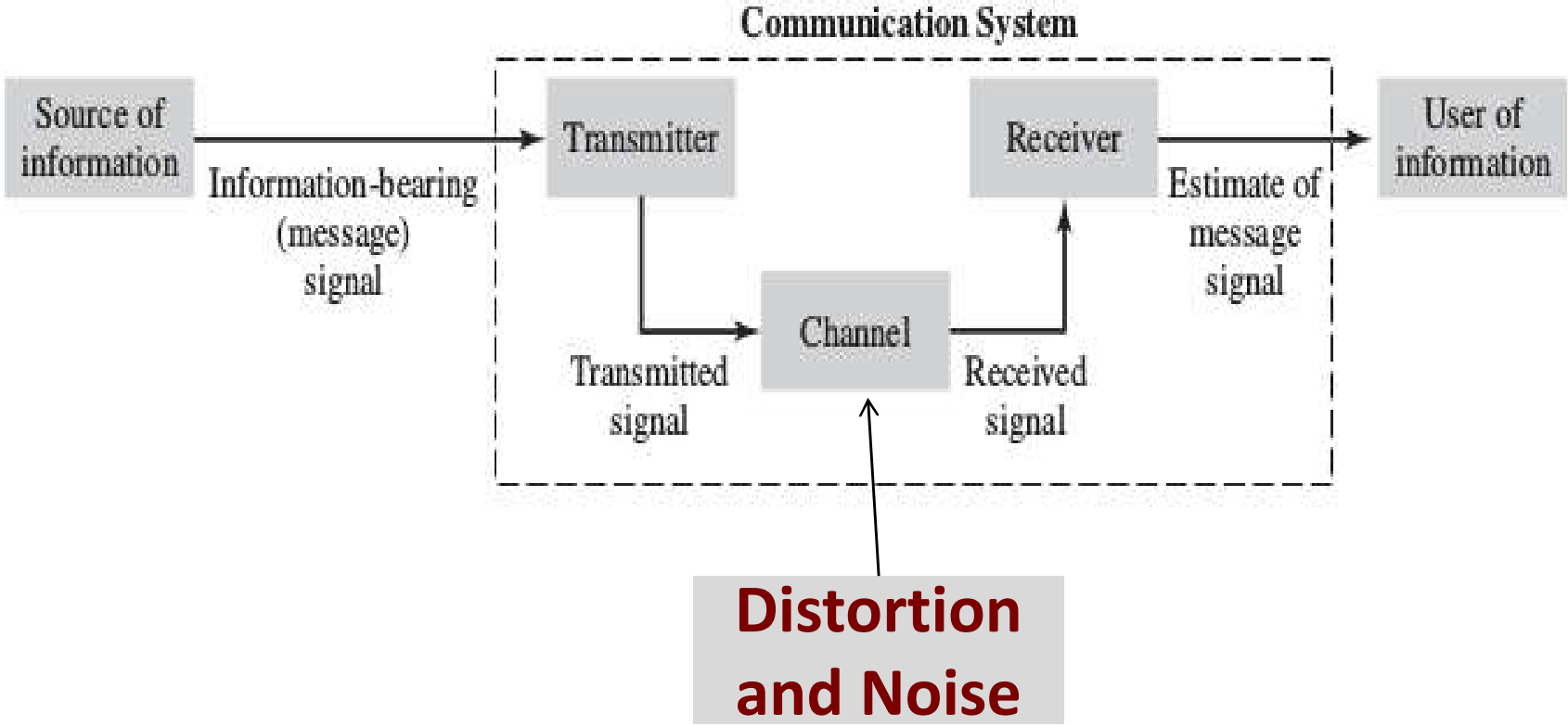
- Discrete amplitude, i.e., amplitude can take only a finite number of values.
- Values need not be always integer.
- Not necessarily always binary, rather M-ary.
- May be both continuous and discrete time.

Analog and Digital Signal: Examples

	Analog	Digital
Thermometer		
Clock		
Blood Pressure Monitor		

Components of Communication systems

Review



Main challenges

Challenges of Communication systems

Review

1. Distortion
   - –systematic undesirable changes in signals
   - –Linear or non-linear

2. Noise
   - – Unwanted signal that interfere with the transmitted signal
   - – Random signals from internal or external sources

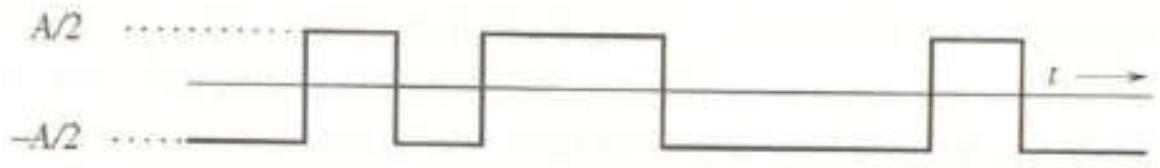
Benefits of Digital Message/Signal

1. Quality, e.g., enhanced noise immunity
2. Economics

Benefits of Digital Message/Signal

1. noise immunity
   - Represented by binary or M-ary pulses

Sent



Benefits of Digital Message/Signal

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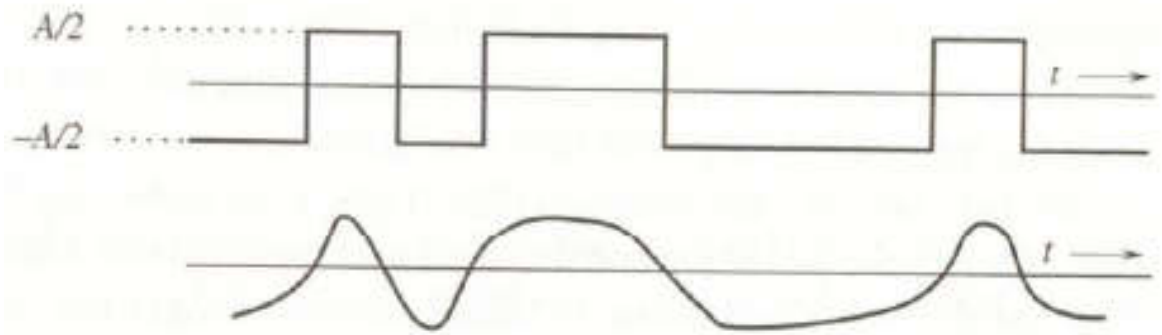
Sent

Received w/o noise



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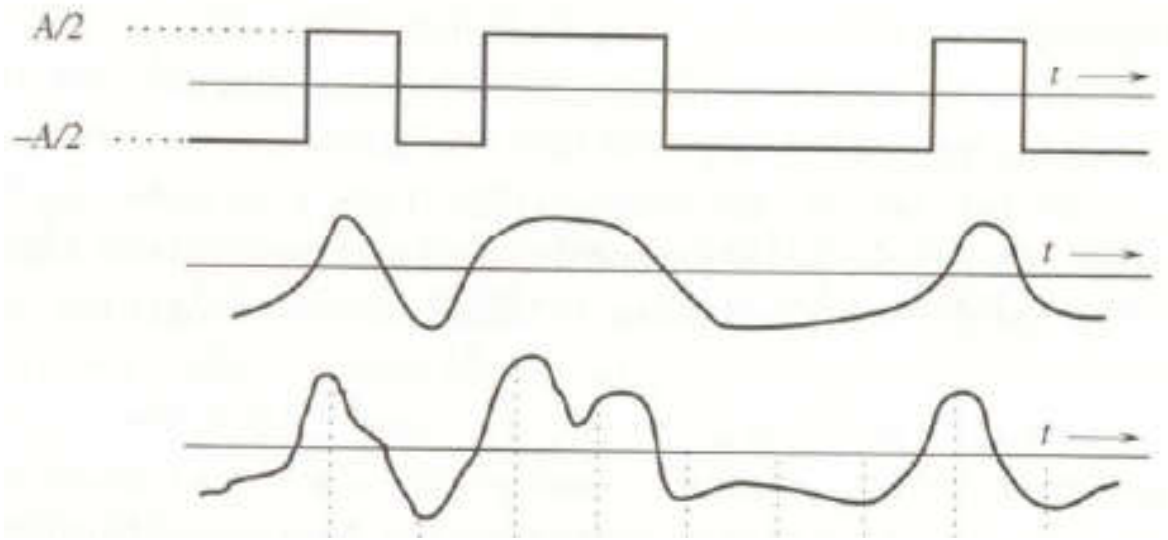
Received w/o noise

Received with noise



Benefits of Digital Message/Signal

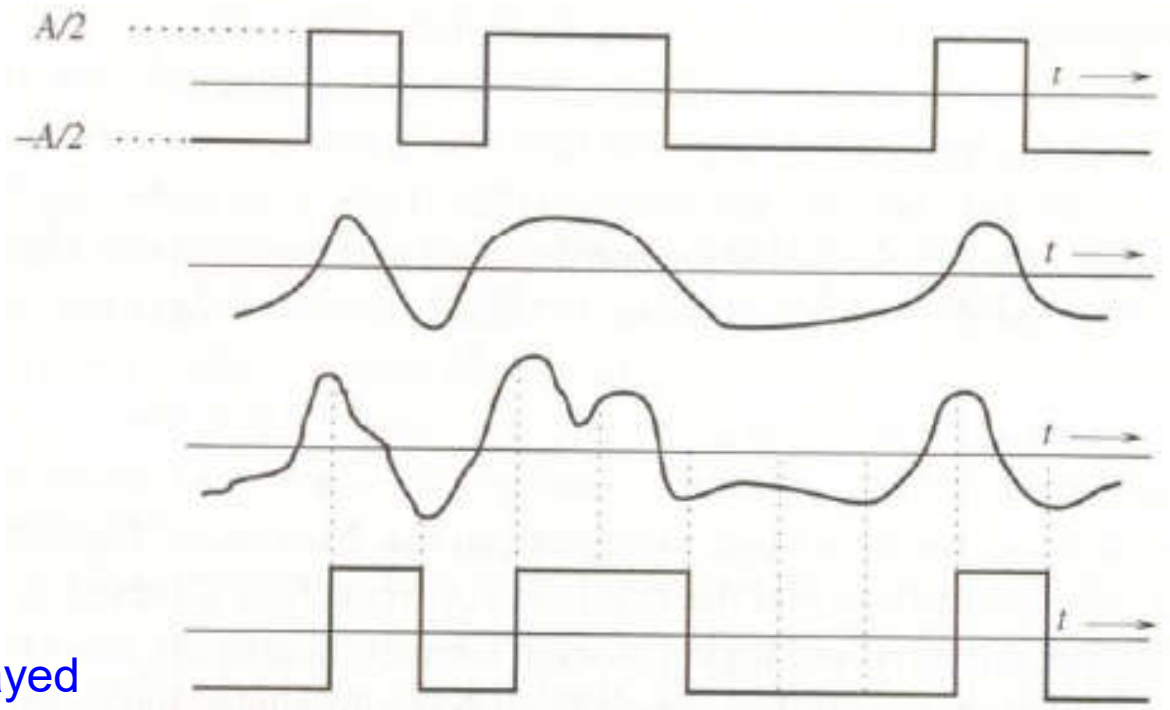
1. noise immunity
   - Recovered despite small distortion and noises

Sent

Received w/o noise

Received with noise

Recovered, though delayed



Repeater's Role in Digital Message/Signal

- Distortion and noise are unavoidable in channel
- Repeaters and nodes regenerates digital pulses

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Input digital signal

Distorted digital signal

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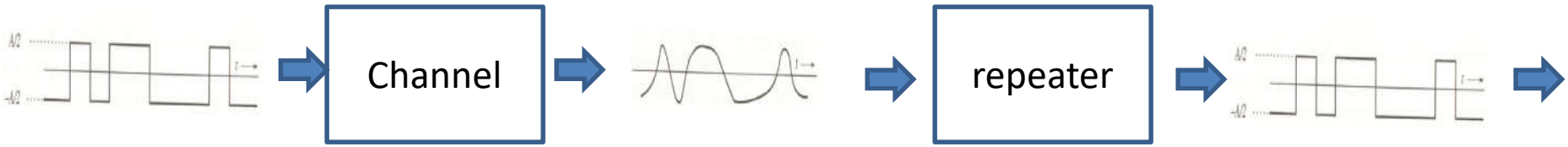

Input digital signal

Distorted digital signal

Regenerated digital signal

Repeater's Role in Analog Message/Signal

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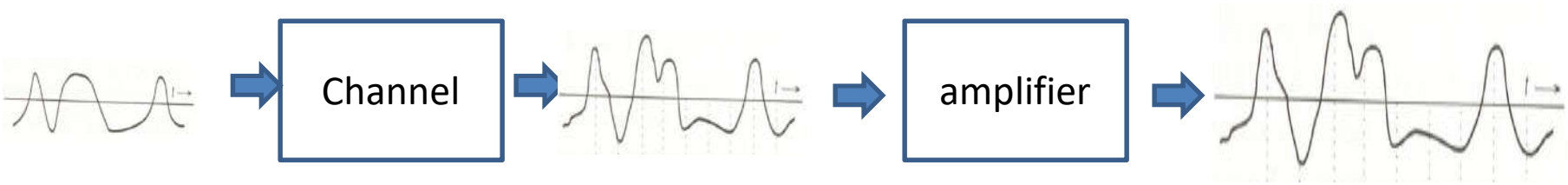

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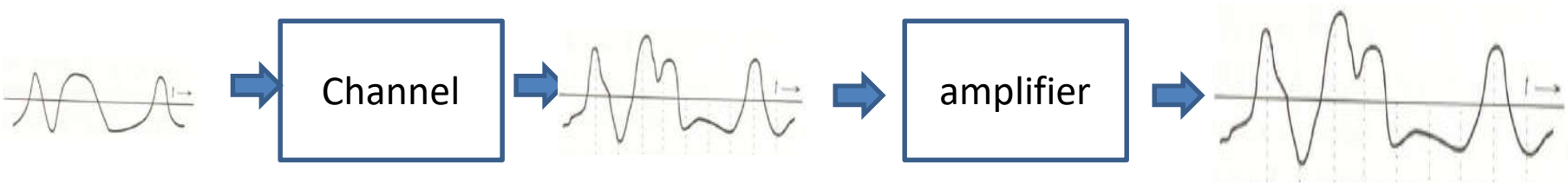

Input analog signal

Distorted analog signal

Signal with amplified noise

Noise accumulates along the path! No improvement at all !!

Analog to Digital Conversion of Message/Signal

- A/D conversion enables digital communication to convey analog signals

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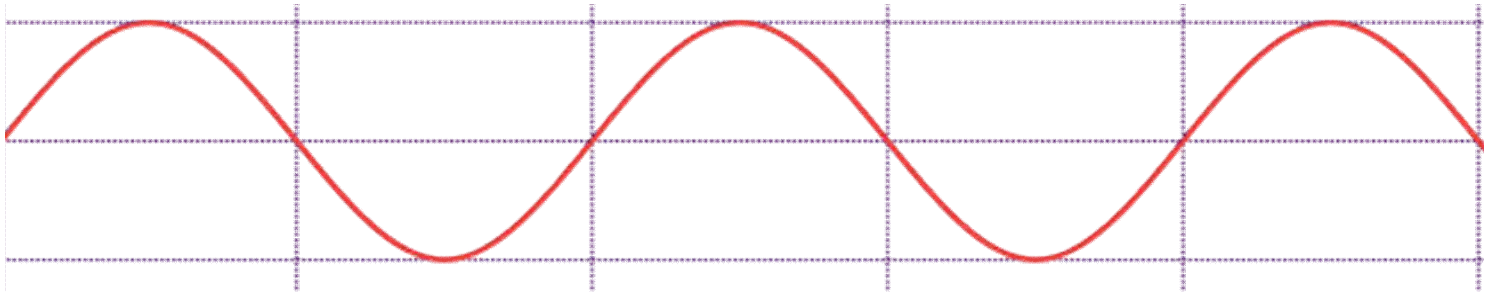
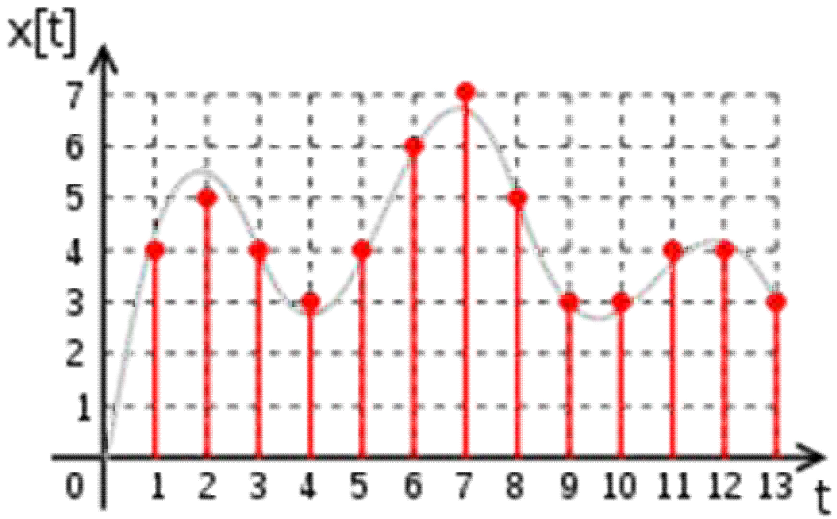
- Analog signal characteristics
  - values are continuous
  - defined over continuous/discrete time



Analog to Digital Conversion of Message/Signal

- A/D conversion enables digital communication to convey analog signals
- Digital signal characteristic's
  - values are a *finite discrete* set
  - defined over *preferably discrete time*

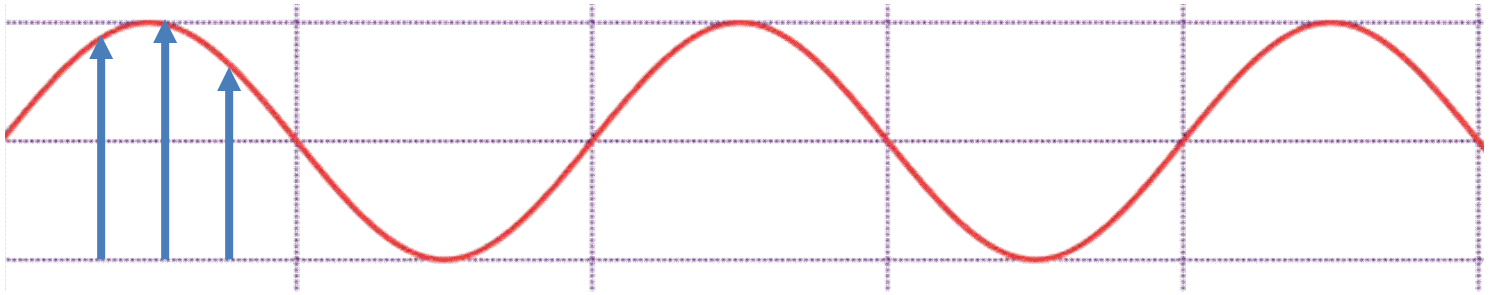


Analog to Digital Conversion of Message/Signal

- 2 major steps
  - Sampling
  - Quantization

Analog to Digital Conversion of Message/Signal

- Sampling
  - Governed by Nyquist ’s Sampling theory
  - Selects points for sampling



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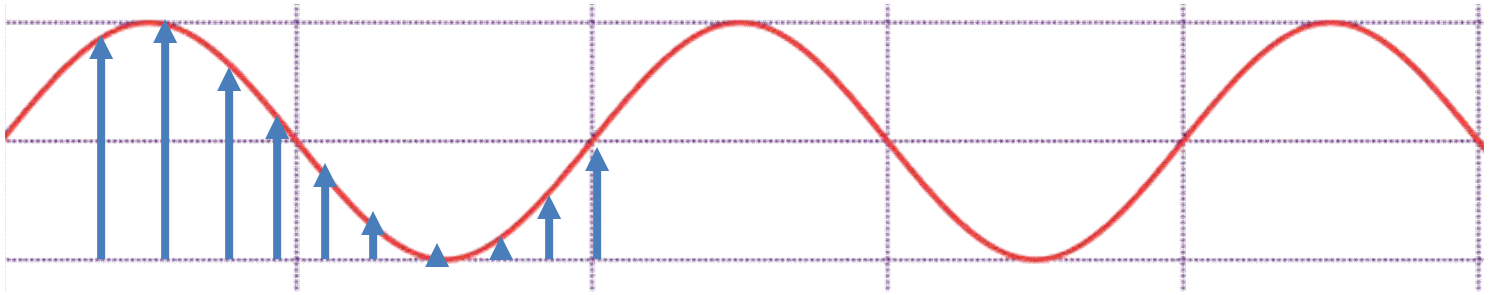

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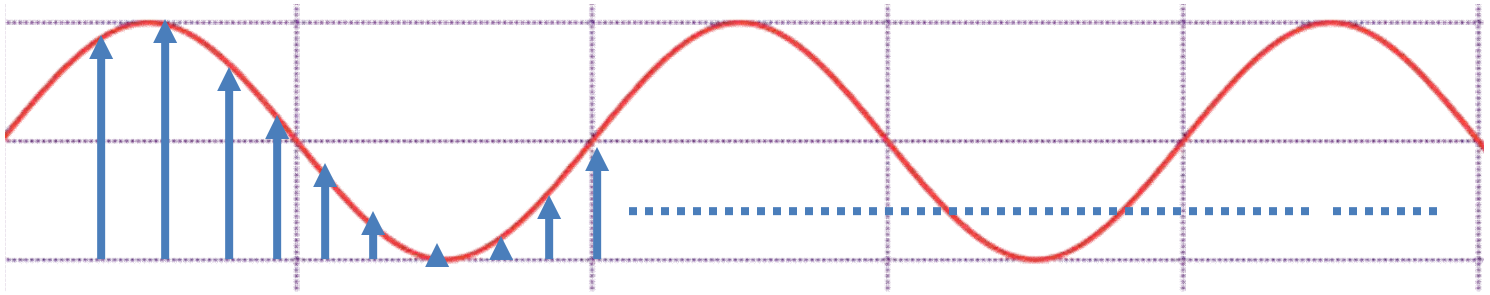
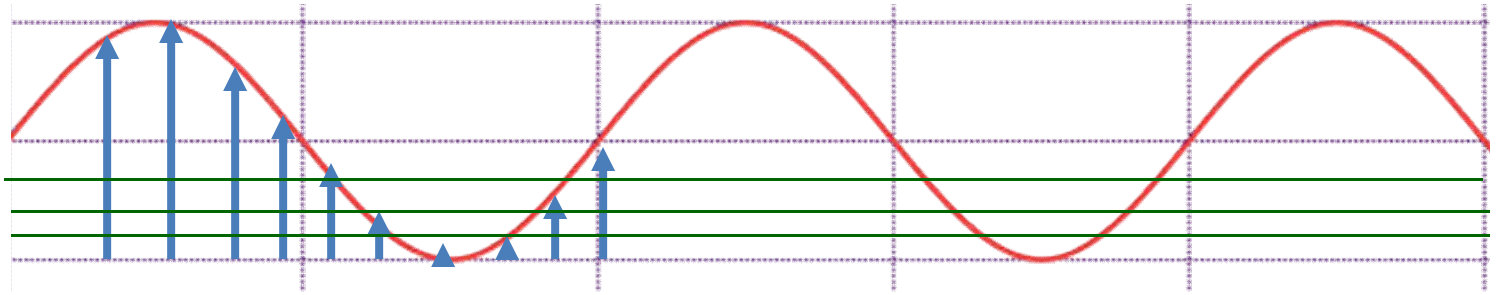


Analog to Digital Conversion of Message/Signal

- Quantization
  - Values replaced by a set of L distinct values
  - Usually $L = 2^k$



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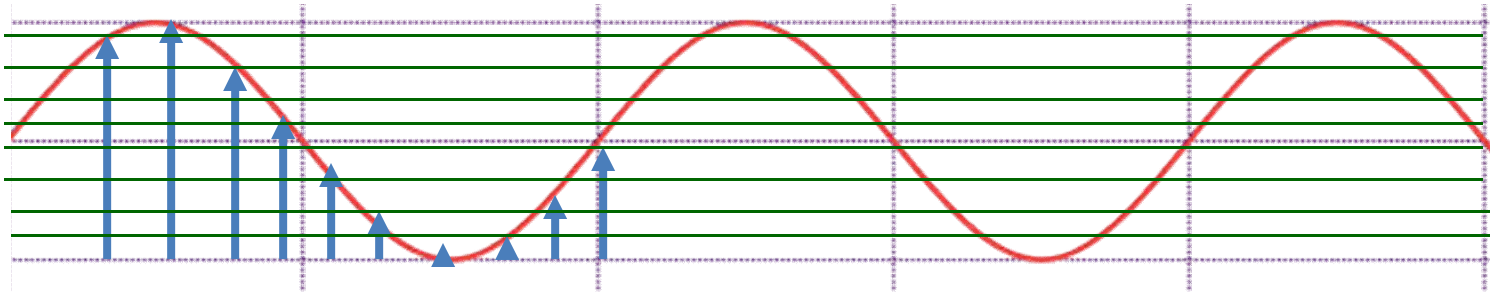
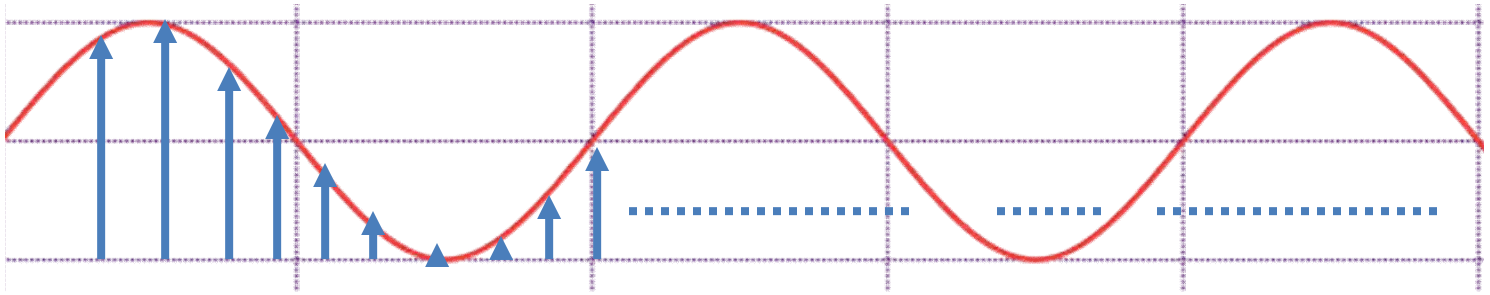


Analog to Digital Conversion of Message/Signal

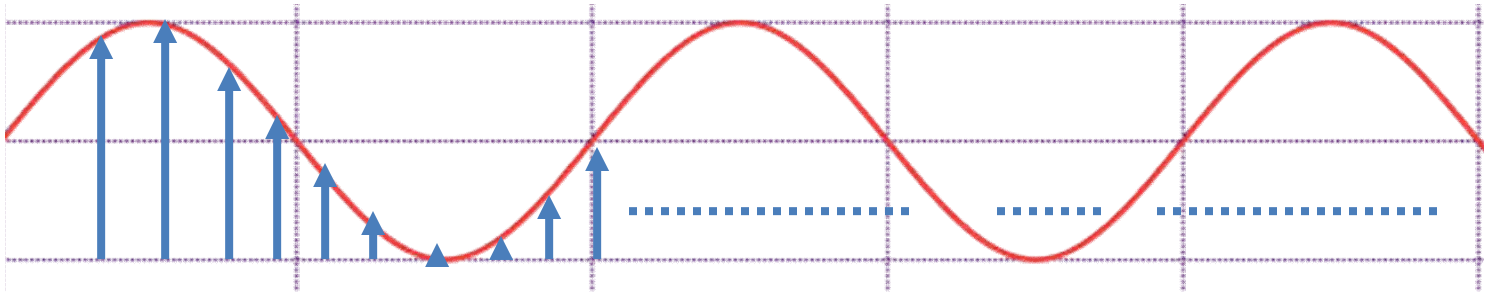
- Increasing sampling rate retains original shape



Analog to Digital Conversion of Message/Signal

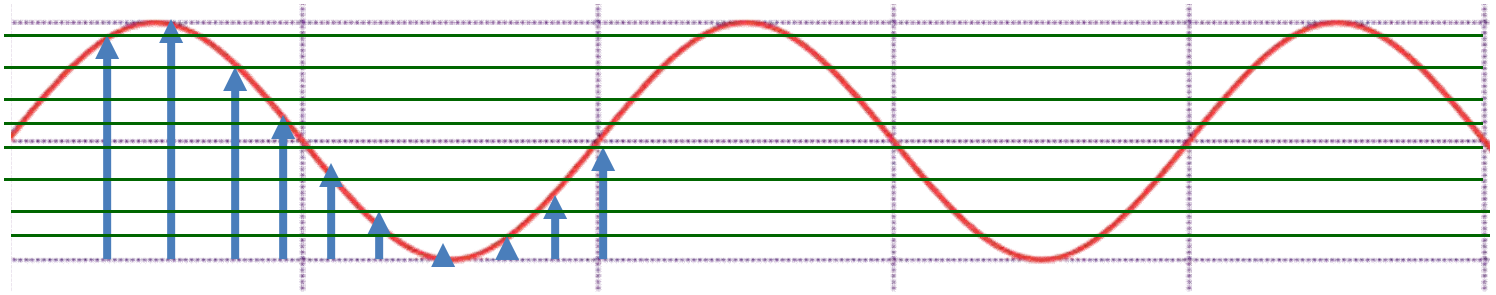
- Increasing sampling rate retains original shape

Remember
Nyquist's theorem!



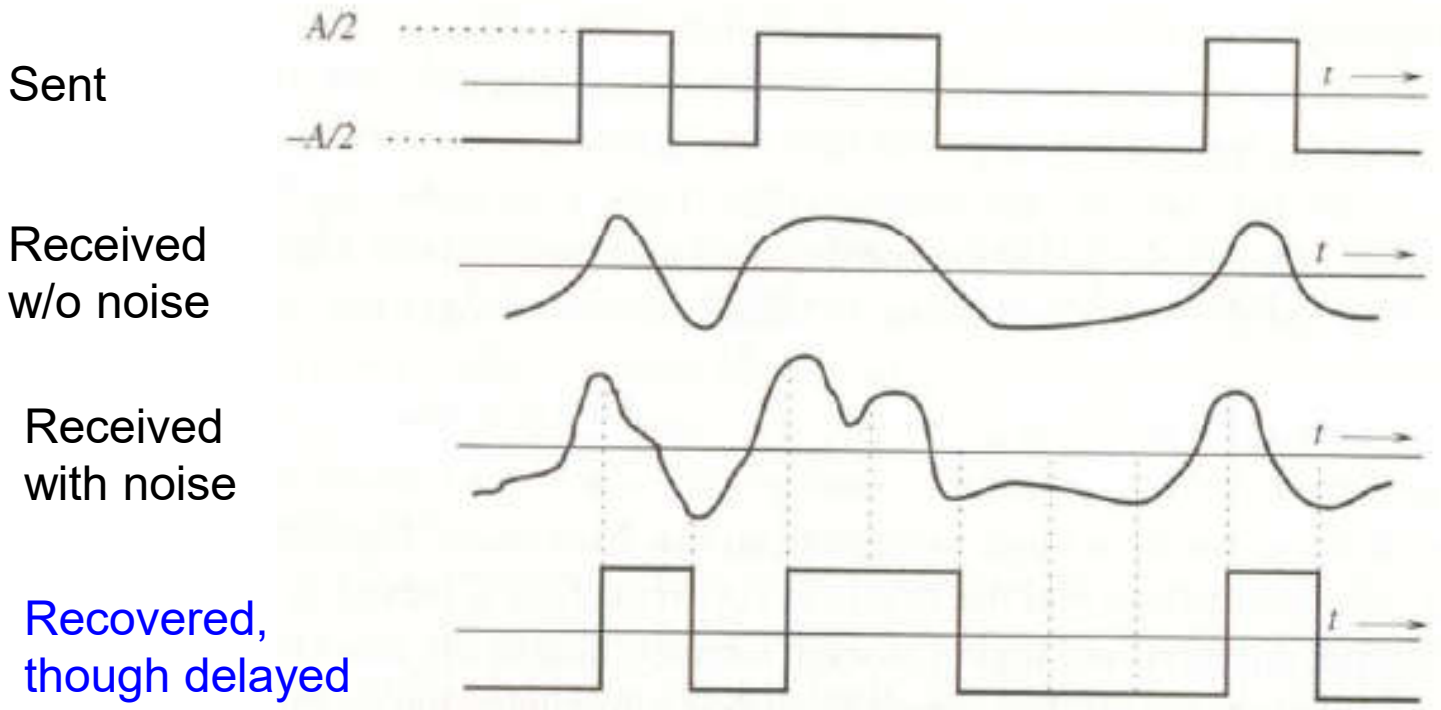
Analog to Digital Conversion of Message/Signal

- Increasing Quantization level *L*
  - increases accuracy
  - more noise immunity
  - but requires higher channel bandwidth



Analog to Digital Conversion of Message/Signal

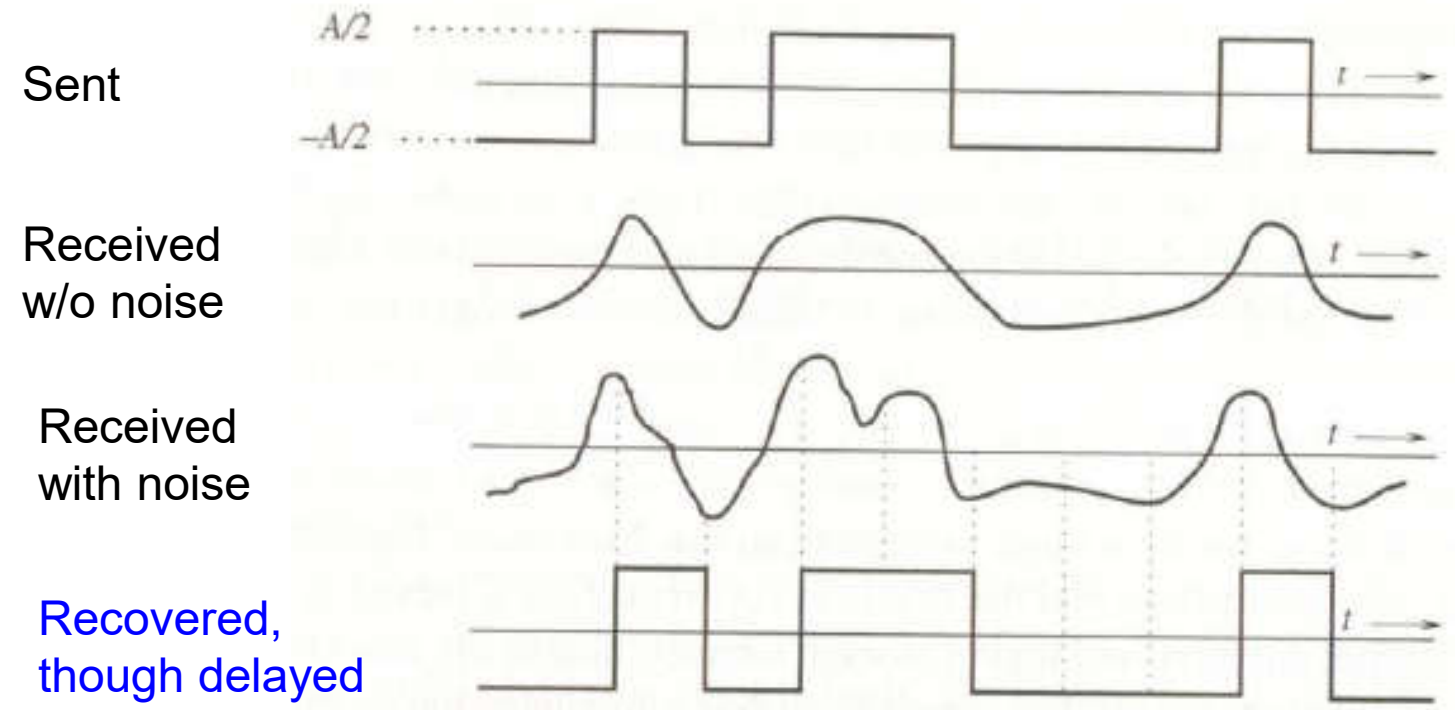
Recall this figure



Analog to Digital Conversion of Message/Signal

Recall this figure

- Detection is easy when A >> noise
- Usually A >> 5-10 times of noise



Analog to Digital Conversion of Message/Signal

- Problem: quantization error is unavoidable

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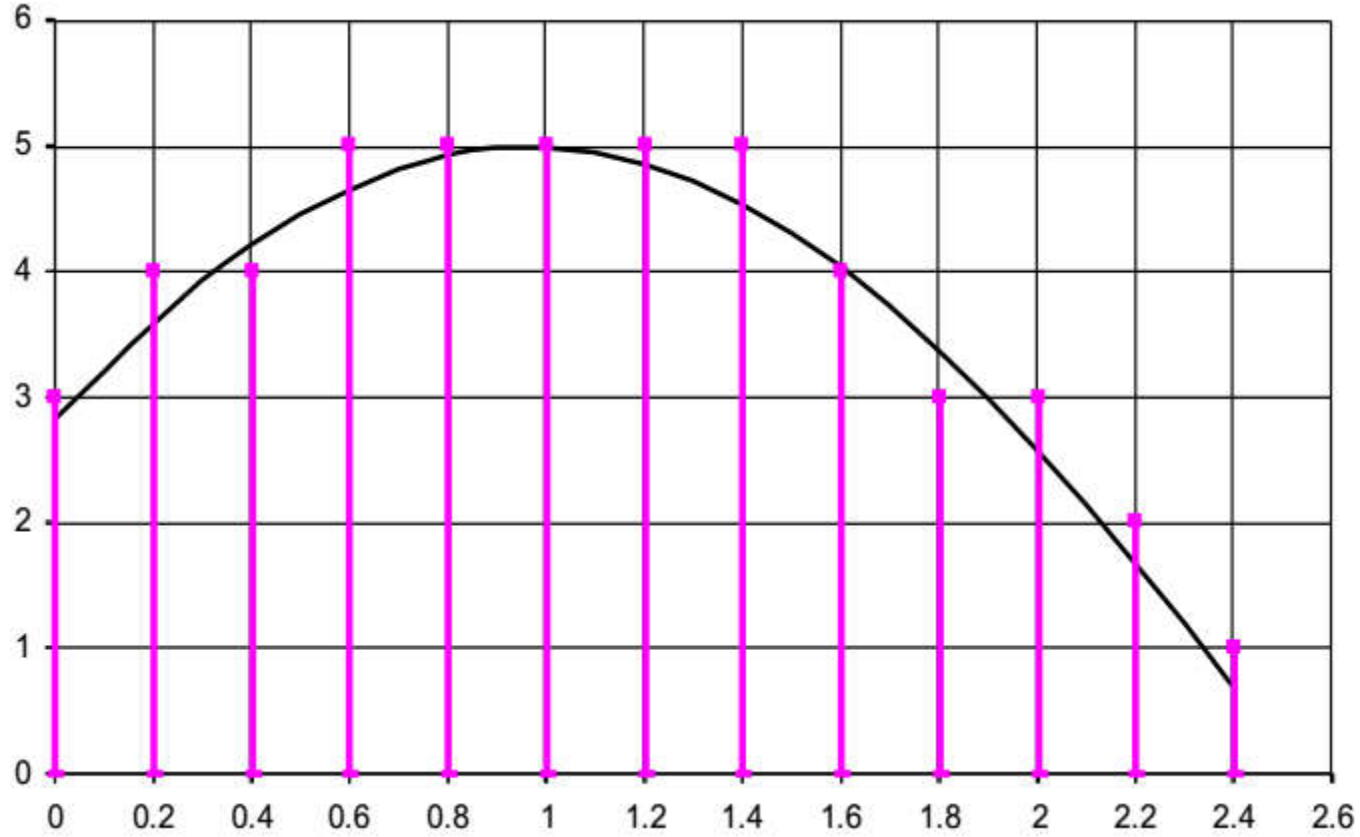

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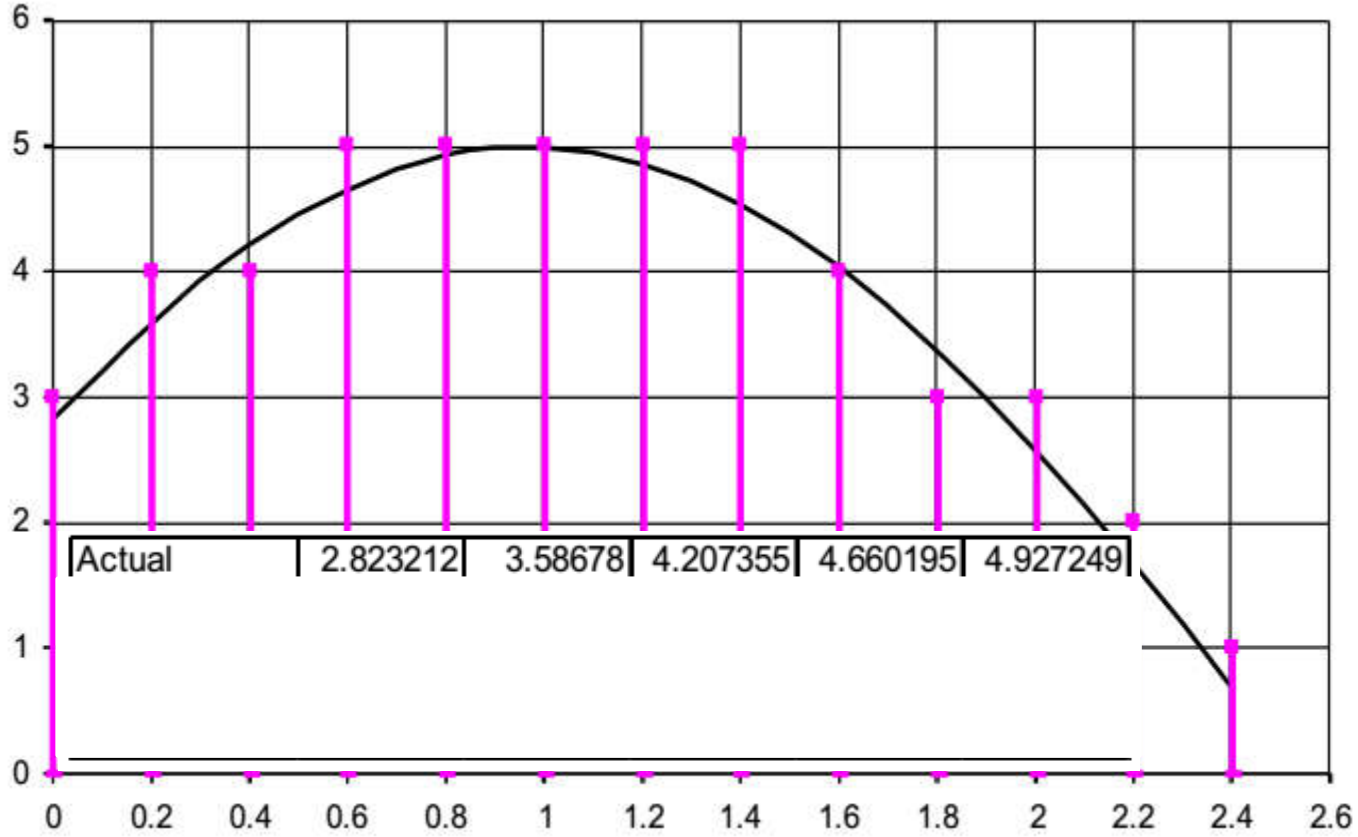

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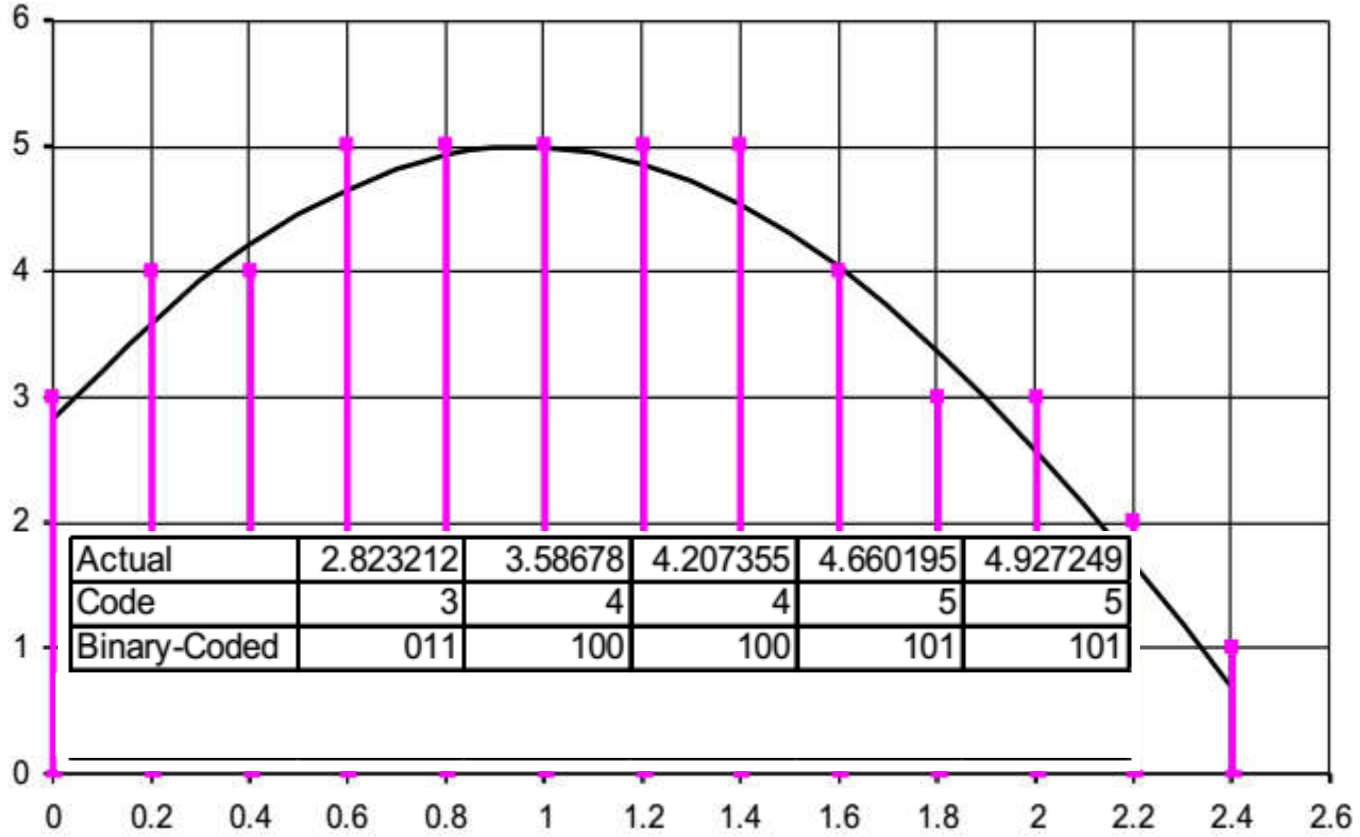

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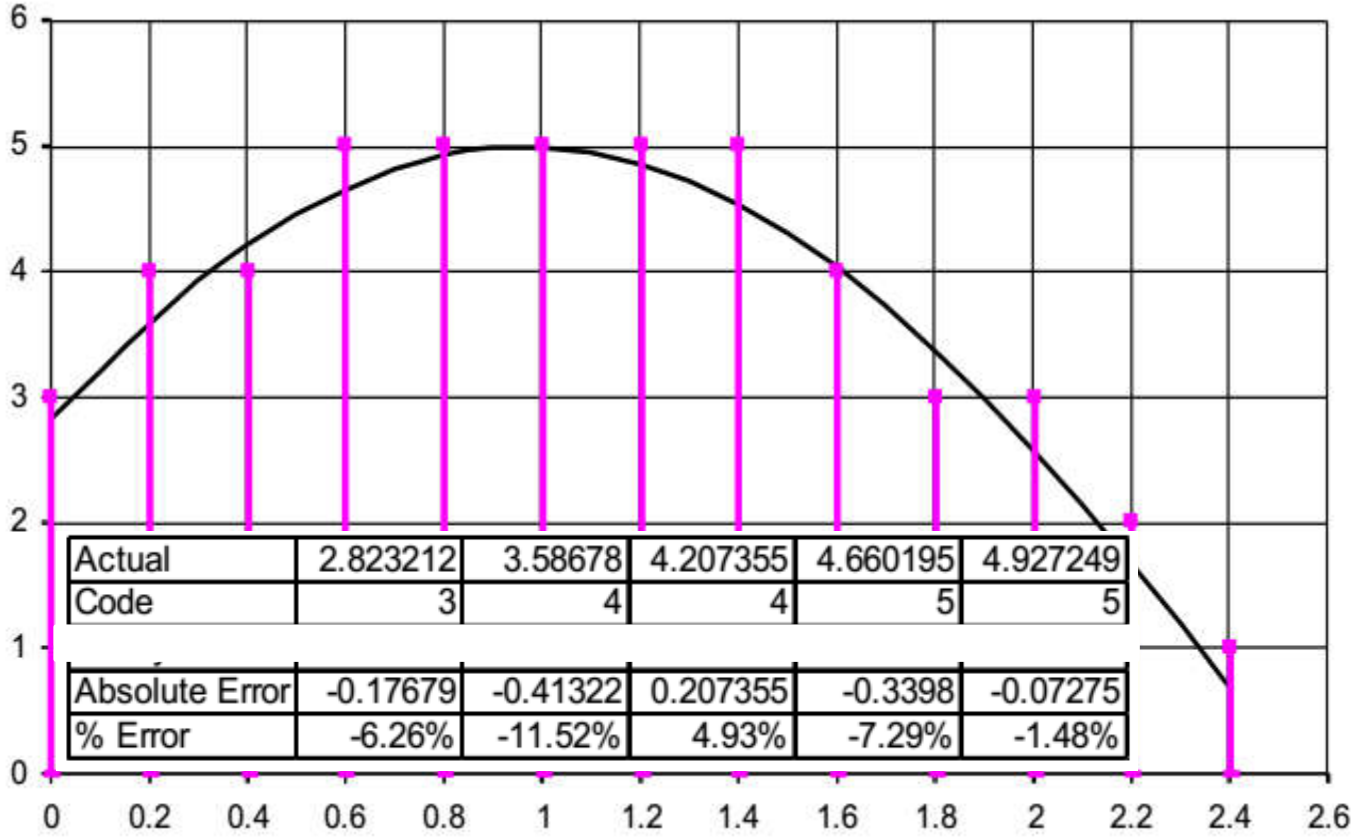
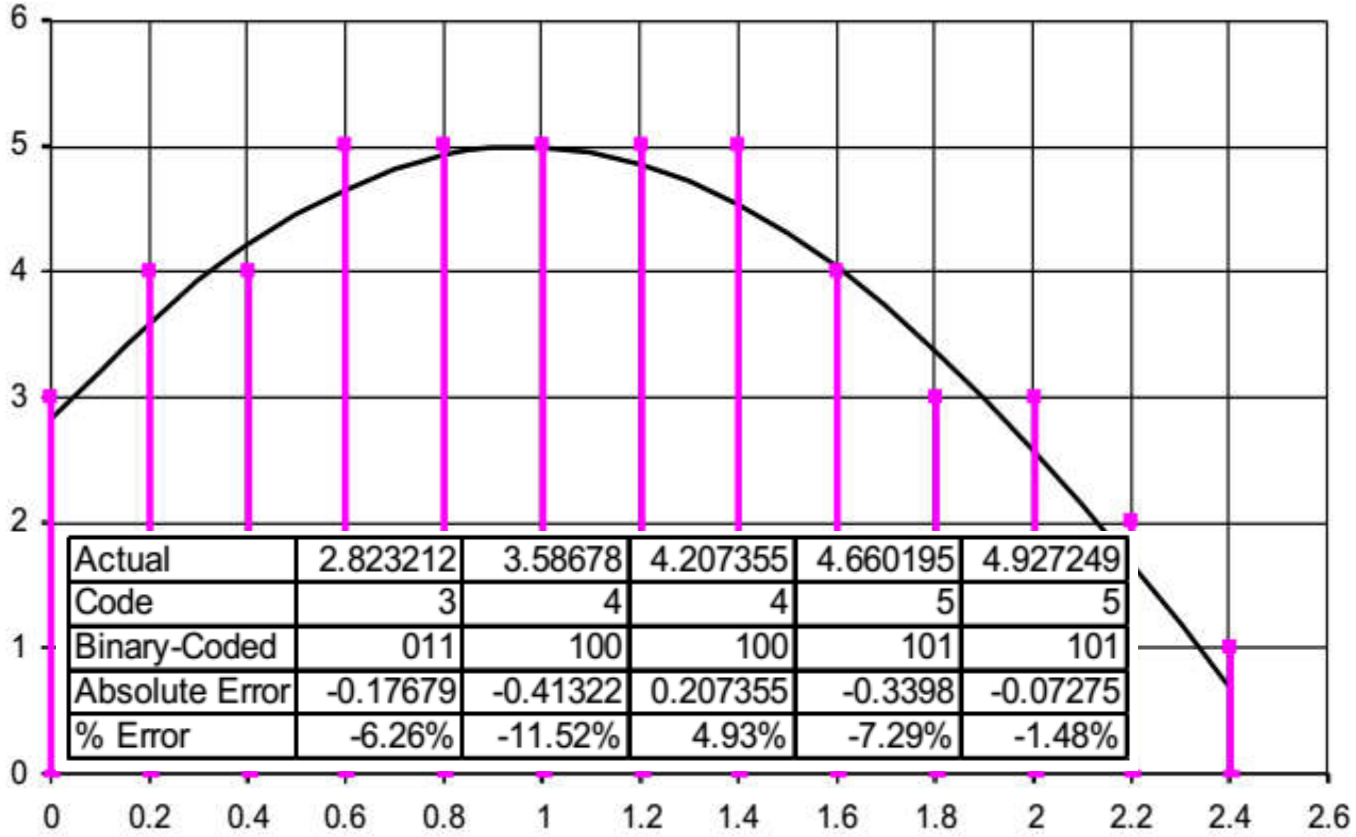


Actual	2.823212	3.58678	4.207355	4.660195	4.927249
Code	3	4	4	5	5
Absolute Error	-0.17679	-0.41322	0.207355	-0.3398	-0.07275
% Error	-6.26%	-11.52%	4.93%	-7.29%	-1.48%

Analog to Digital Conversion of Message/Signal

- Problem: quantization error is unavoidable

Quantization error can be minimized increasing *L*



Actual	2.823212	3.58678	4.207355	4.660195	4.927249
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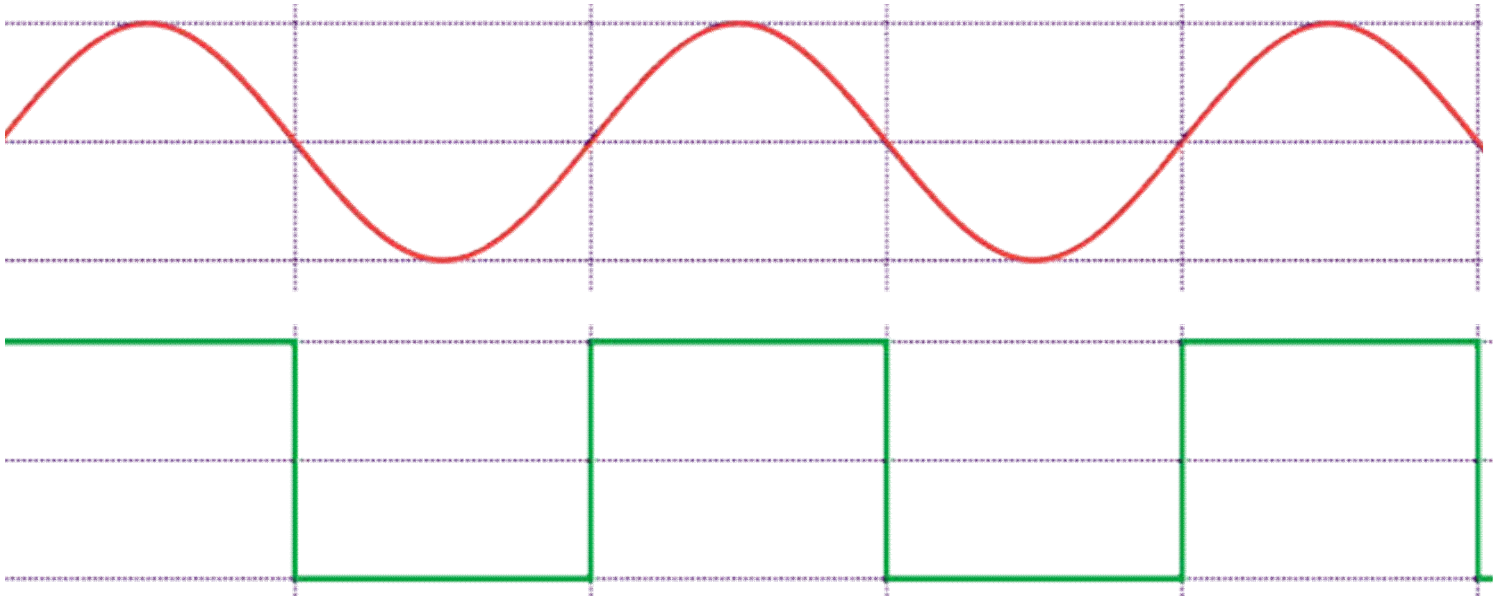
Representation of Digital Signal: Pulse Coded Modulation

- Assume, No. of quantization level, $L = 2$

Representation of Digital Signal: Pulse Coded Modulation

- Assume, No. of quantization level, $L = 2$
  - Easy to represent or transmit



Representation of Digital Signal: Pulse Coded Modulation

- If No. of quantization level, $L >> 2$

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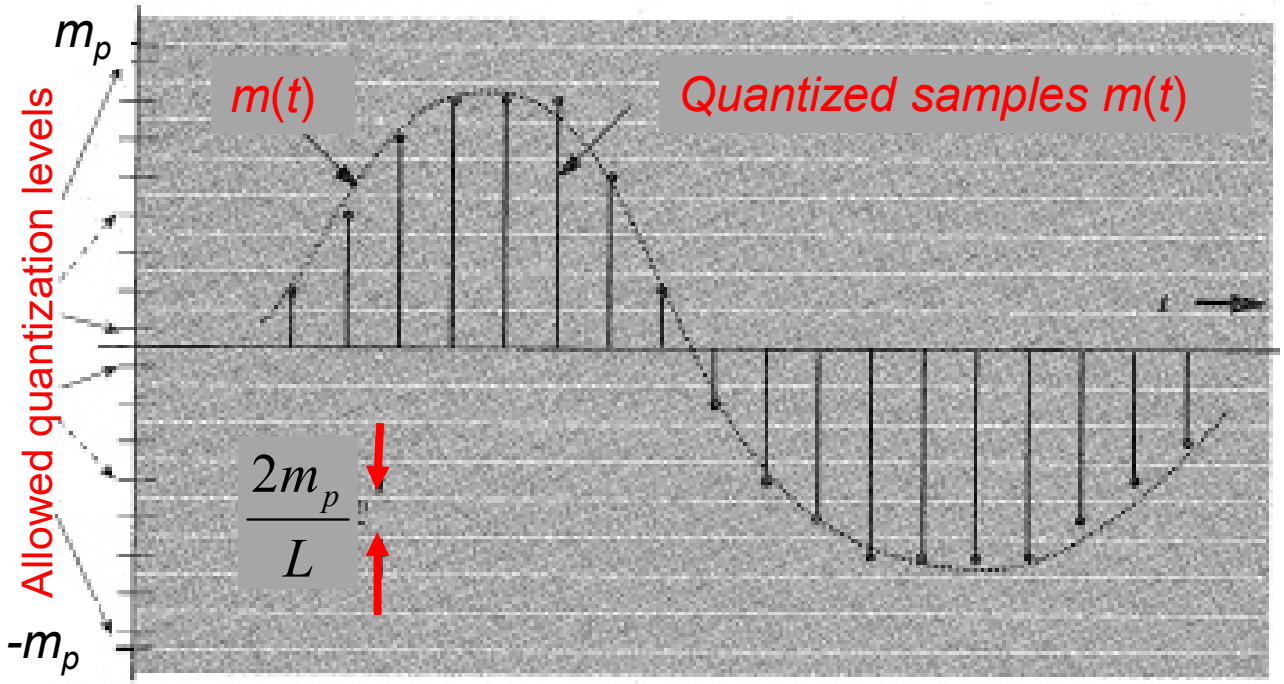


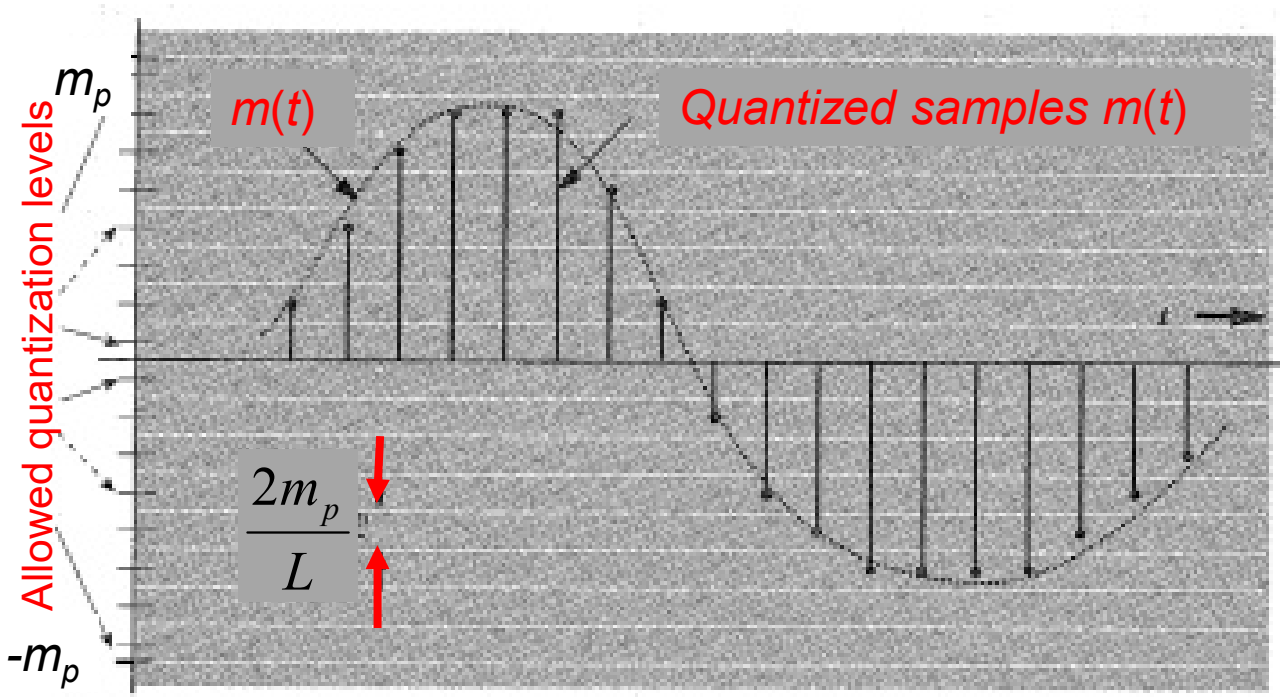
Each sample is represented by one of L levels

Representation of Digital Signal: Pulse Coded Modulation

- If No. of quantization level, $L >> 2$
  - Solution is PCM
  - Each quantized value is represented by a *sequence of binary pulses*.

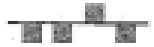
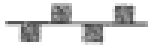
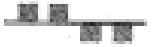
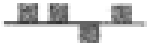
Representation of Digital Signal: Pulse Coded Modulation

- Assume, L =16



Representation of Digital Signal: Pulse Coded Modulation

- Assume, *L* =16
  - Each quantized value is represented by a *sequence of* **FOUR** *binary pulses*.

Digit	Binary equivalent	Pulse code waveform
0	0000	
1	0001	
2	0010	
3	0011	
4	0100	
5	0101	
6	0110	
7	0111	
8	1000	
9	1001	
10	1010	
11	1011	
12	1100	
13	1101	
14	1110	
15	1111