CS311: Data Communication

Transmission of Digital Signal - II

by

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Outline of the Lecture

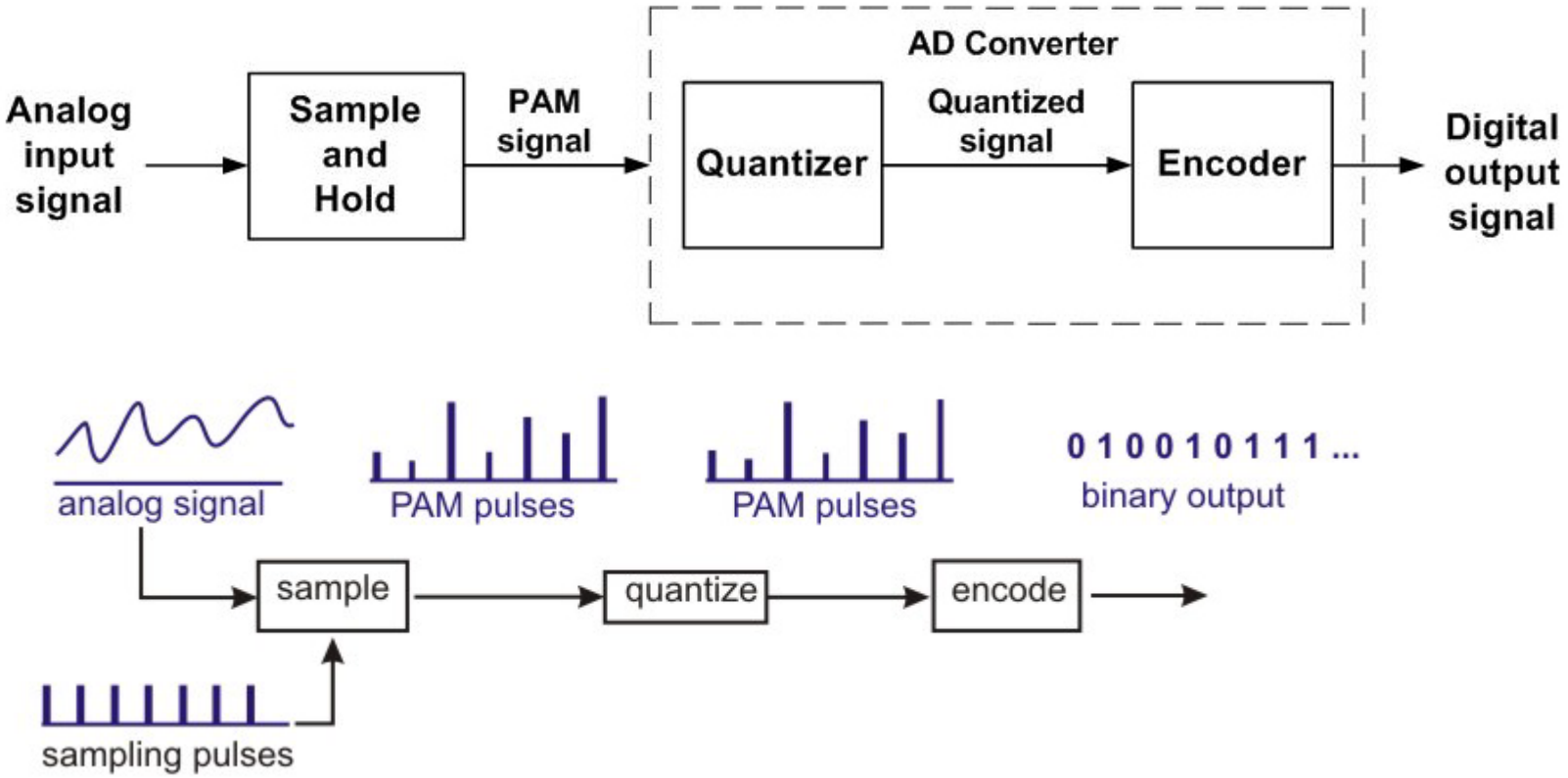
- Introduction
- Conversion of Analog data to Digital signal
- Two basic approaches:
  1. Pulse coding modulation (PCM)
  2. Delta modulation (DM)
- Limitations of PCM and DM
- Comparisons of the two approaches

Analog Data to Digital Signal

- Digital signal is superior to an Analog signal
- Analog data such as voice, videos, and music, are to be converted into digital signal for communication through transmission media.
- Strictly speaking, we would convert analog data into digital data; this process is known as digitization
- Two basic approaches
  - -Pulse Code Modulation (PCM)
  - -Delta Modulation (DM)
- After digitization, we could use any encoding for converting into digital signal

Pulse Code Modulation

- PCM involves the three basic steps:
  - Sampling -> PAM
  - Quantization
  - Line coding



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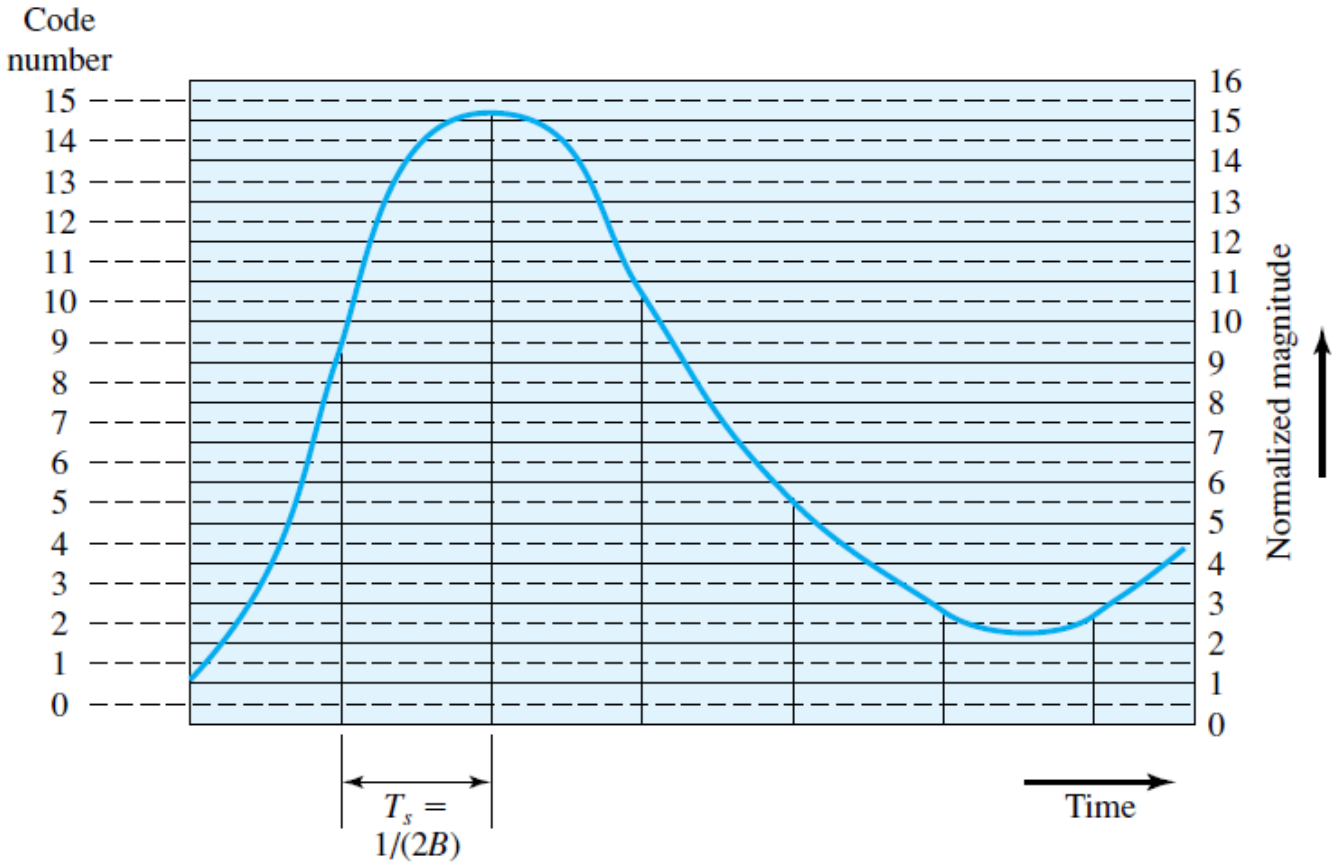
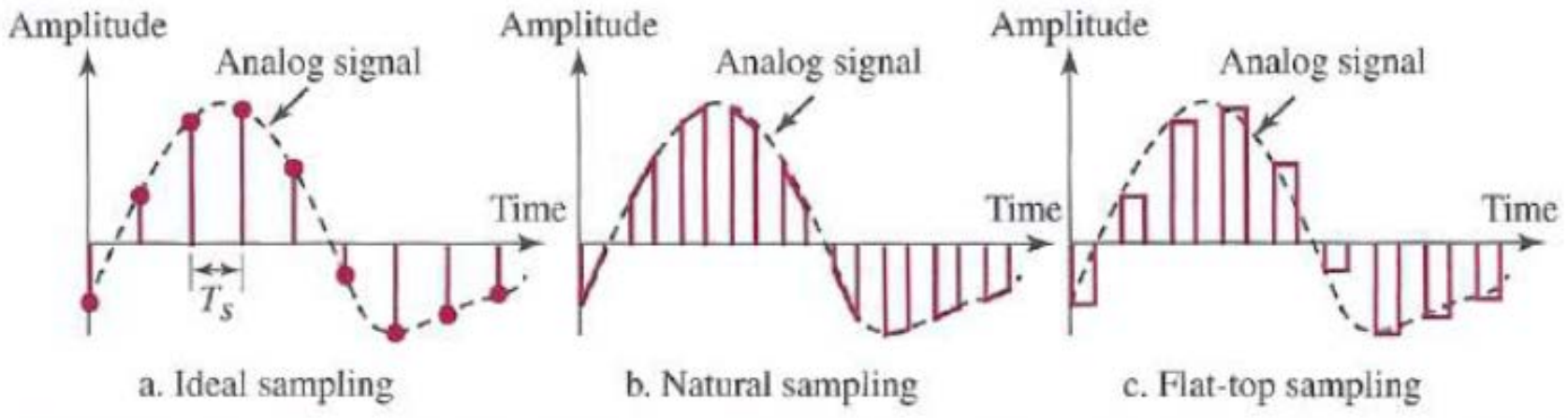


PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
Quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

Figure 5.16 Pulse Code Modulation Example

Sampling

Figure 4.22 *Three different sampling methods for PCM*



What should be the sampling rate or frequency?

Nyquist Theorem:

If a signal $f(t)$ is sampled at regular intervals of time and at a rate higher than twice the highest signal frequency, then the samples contain all the information of the original signal.

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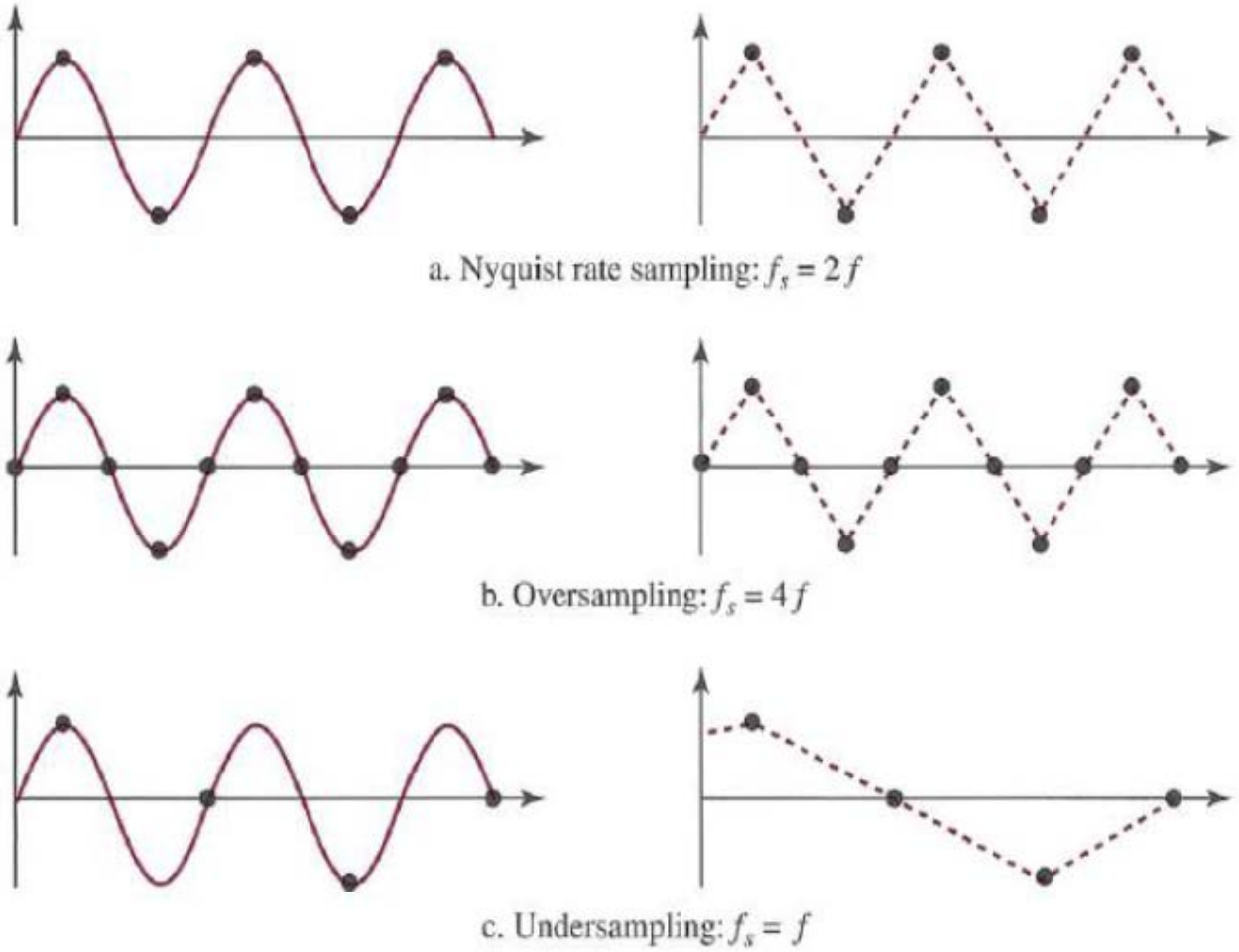
Figure 4.24 *Recovery of a sampled sine wave for different sampling rates*



a. Nyquist rate sampling: $f_s = 2f$

b. Oversampling: $f_s = 4f$

c. Undersampling: $f_s = f$

Quantization

- The PAM samples are quantized and approximated to *n*-bit integer (i.e. $L = 2^n$ levels) by using analog-to-digital converter.

- We assume that the original analog signal has instantaneous amplitudes between V_{min} and $V_{max.}$
- We divide the range into *L* zones, each of height Δ (delta).

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

- We assign quantized values of 0 to (*L* – 1) to the midpoint of each zone.
- We approximate the value of the sample amplitude to the quantized values.

Quantization Error

- By quantizing the PAM pulse, the original signal is now only approximated and cannot be recovered exactly. This effect is known as quantizing error or quantization noise.
- Quantization error depends on step size Δ
- The signal-to-noise ratio for quantizing noise can be expressed as

  $SNR_{dB} = 20 \log 2^n + 1.76 \text{ dB} = 6.02n + 1.76 \text{ dB}$

- Use of uniform step size leads to poorer S/N ratio for small amplitudes signals
- With the constraint of a fixed number of levels, the situation can be improved using variable step size
- Companding : Use of non-linear encoding during quantization

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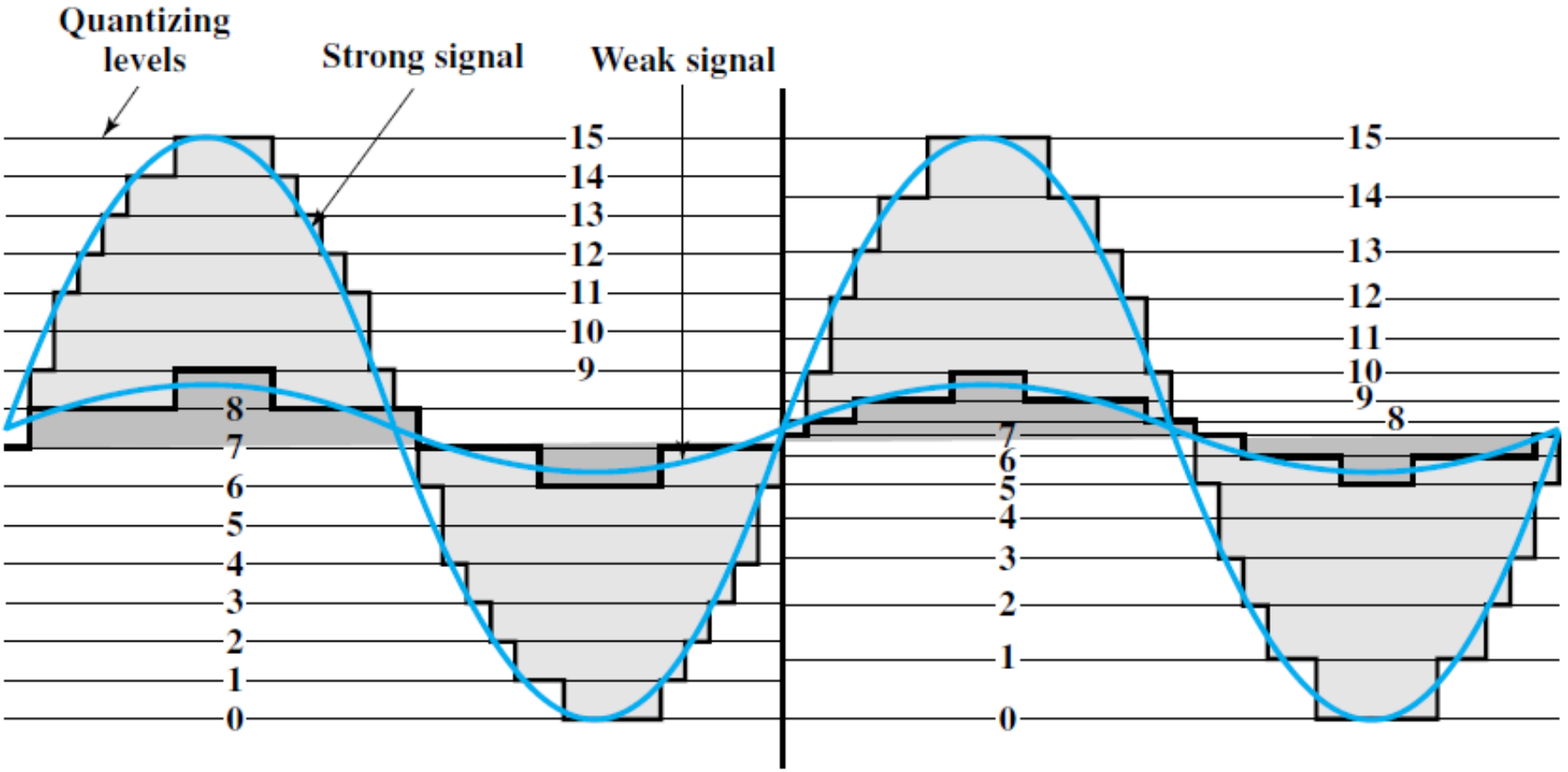

Figure 5.18 Effect of Nonlinear Coding

Limitations of PCM

- The PCM signal requires high bandwidth
- Example:

  let a voice signal as input with bandwidth of 4 kHz.

  the Sampling frequency (f_s) should be 8 kHz.

  let an 8-bit ADC is used for conversion to digital data

  So, to send voice signal a data rate of 64 Kbps is required.

- Solution: Differential PCM (DPCM)
- It is based on the observation that voice signal changes slowly
- So difference between two consecutive sample values, instead of the sample values, may be sent

Delta Modulation (DM)

- DM: It is a special case of DPCM
- In DM, an analog input is approximated by a staircase function that moves up or down by one quantization level Δ at each sampling interval T_s
- If the difference between analog input and the feedback signal is positive, then encoded output is 1, otherwise 0
- Only one bit is sent at a time

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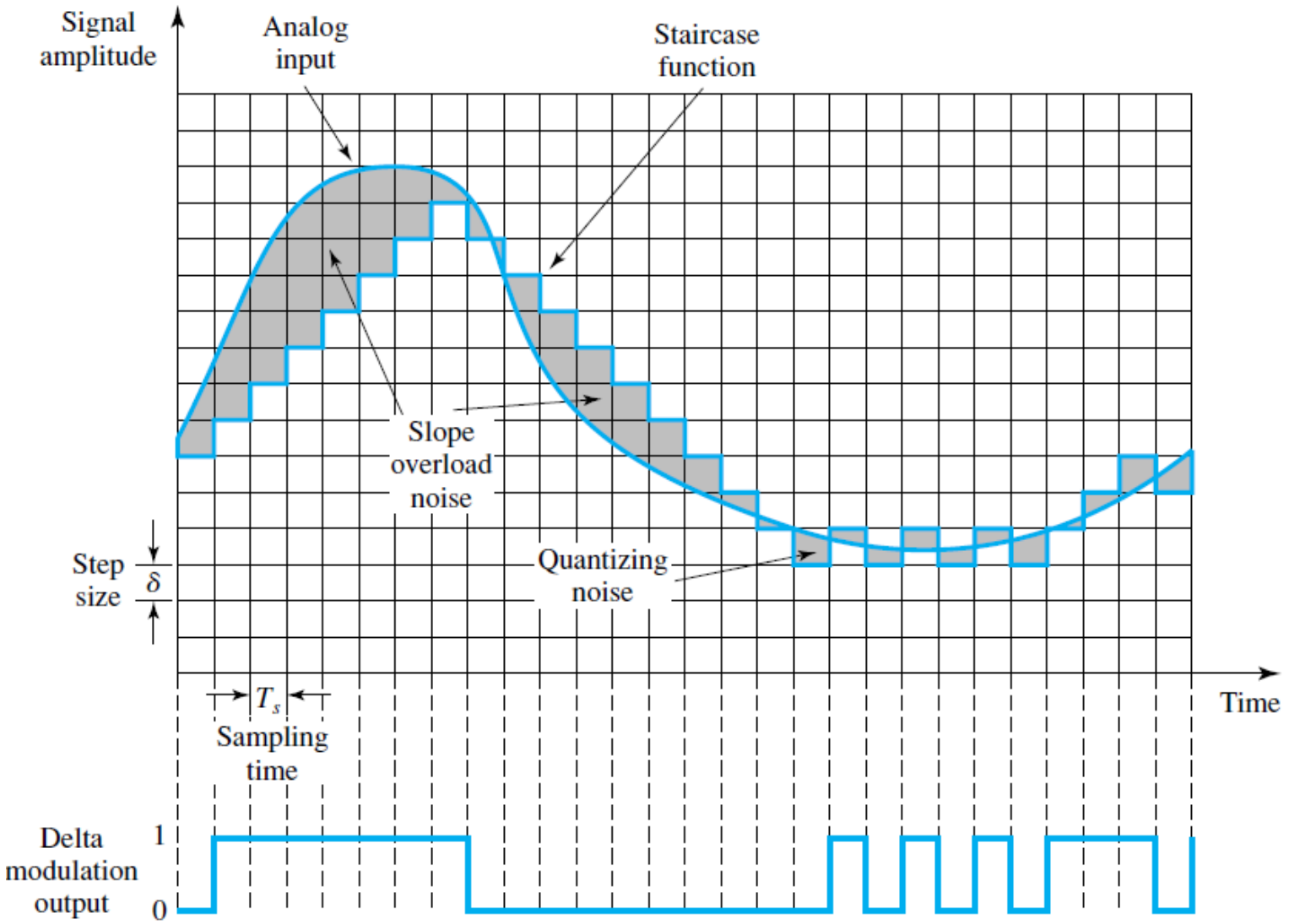

Figure 5.20 Example of Delta Modulation

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- Advantages:
  - Simplicity of implementation
  - Each samples is represented by a single binary digit, which makes it more efficient than the PCM technique
  - Two important parameters :
    - The step size
    - The sampling rate

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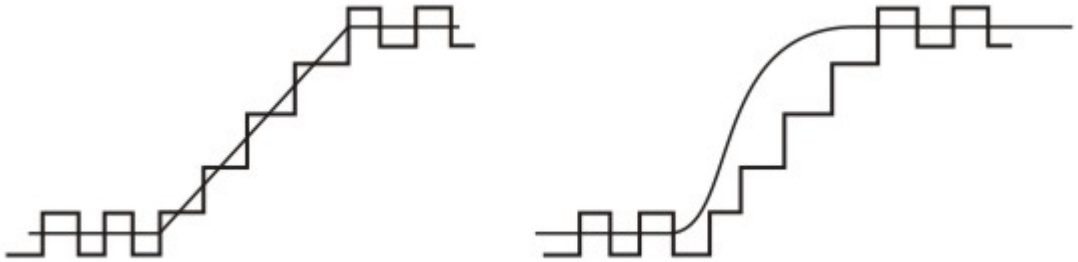
- Disadvantages:
  - Fixed step size leads to overloading
  - Overloading occurs not only due to higher voltage but due to its slope (i.e. Slope-overloaded)



  - Solution: adaptive delta modulation (ADM)
  - The steps sizes are small when the signal changes are small, and sizes are large when the signal changes are large

PCM vs. DM

- PCM: For the voice signal with 256 quantization levels the data rate is 64 Kbps
- This requires a channel having bandwidth of 32KHz
- More complex hardware
- PCM is used in public Switched Telephone Network(PSTN)

- DM: To obtain comparable quality, a sampling rate of 100 KHz is required
- If compromise in quality and intelligibility is allowed, DM requires lesser bandwidth
- Simpler hardware
- ADM was selected as the standard for all NASA communications between mission control and space-craft.

Thanks!

Figure and slide materials are taken from the following sources:

1. W. Stallings, (2010), Data and Computer Communications
2. NPTL lecture on Data Communication, by Prof. A. K. Pal, IIT Kharagpur
3. B. A. Forouzan, (2013), Data Communication and Networking