វិទ្យាស្ថានបច្ចេកវិទ្យាកម្ពុជា
INSTITUTE OF TECHNOLOGY OF CAMBODIA

Department of Information and Communication Engineering

DIGITAL AND ANALOG TRANSMISSION

DC-L02

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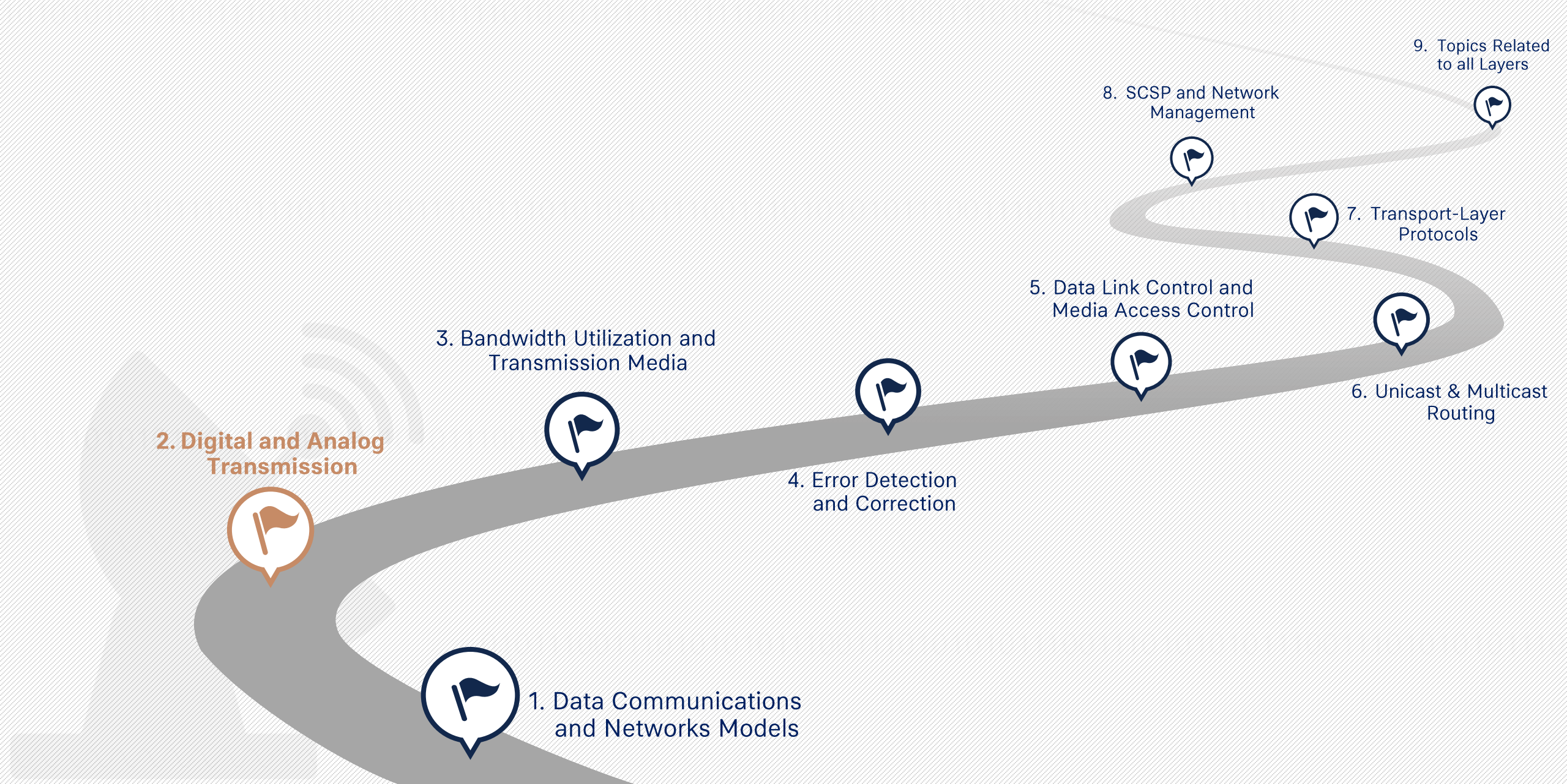
LEARNING MAP



DIGITAL TRANSMISSION

PART-II

LEARNING OBJECTIVES

Discusses on digital-to-digital conversion techniques such as: line coding, block coding, and scrambling.

Discusses on analog-to-digital conversion techniques such: pulse code modulation and delta modulation.

Discusses on transmission modes to transmit data digitally: parallel transmission and serial transmission.

LECTURE CONTENTS

1 DIGITAL-TO-DIGITAL CONVERSION

2 ANALOG-TO-DIGITAL CONVERSION

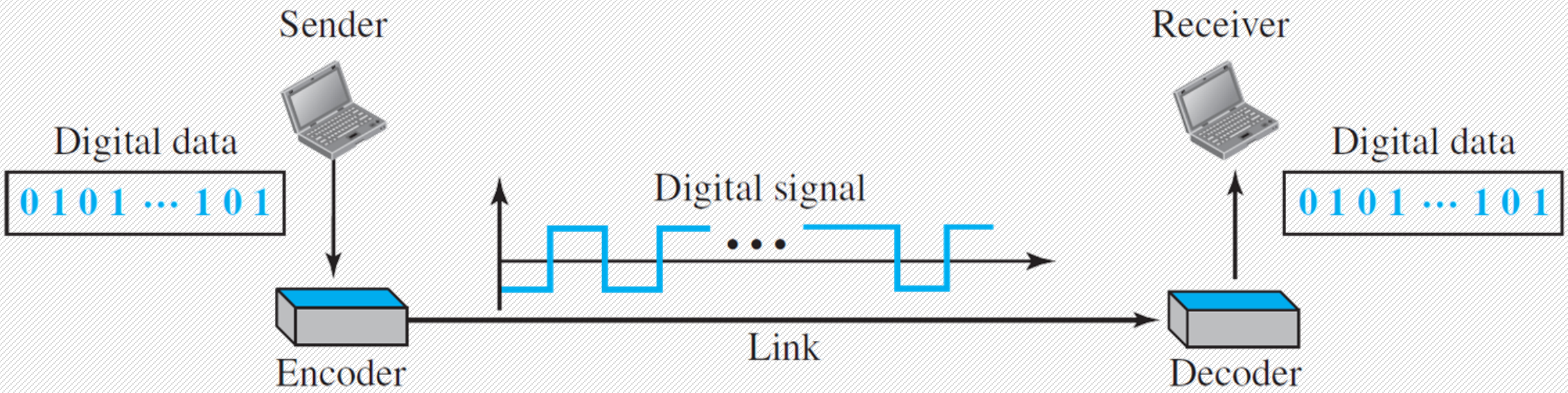
3 TRANSMISSION MODES

4 SUMMARY

5 HOMEWORK

Line Coding

- Line coding is the process of converting digital data to digital signals. It converts a sequence of bits to a digital signal. At the sender, digital data are encoded into a digital signal, at the receiver, the digital data are recreated by decoding the digital signal.

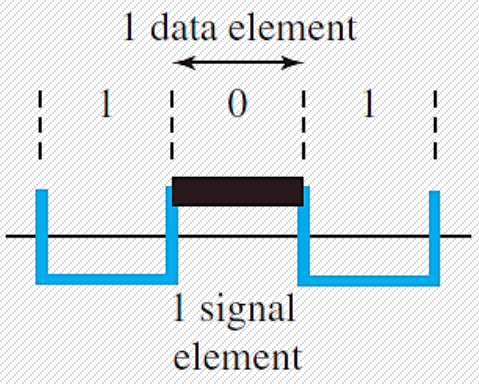


Line coding and decoding

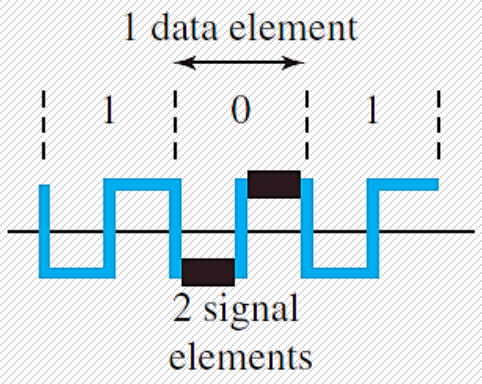
Characteristics

Signal Element vs Data Element

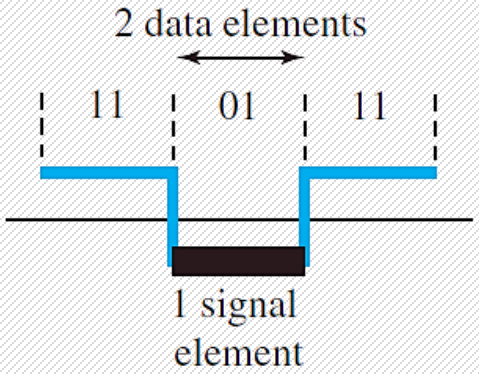
- A data element is the smallest entity that can represent a piece of information (bit). A signal element is the shortest unit of a digital signal which carrier data element.
- In other word, data elements are what we need to send; signal elements are what we can send.
- We define a ratio ***r*** which is the number of data elements carried by each signal element.



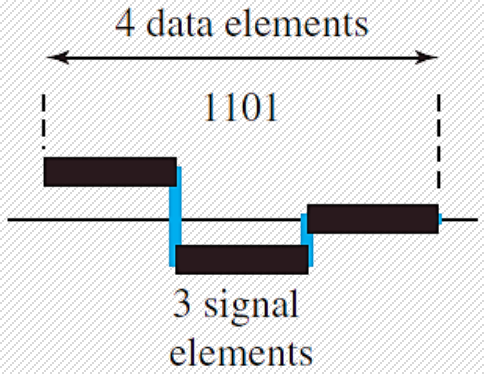
a. One data element per one signal element ($r = 1$)



b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$



c. Two data elements per one signal element ($r = 2$)



d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

Characteristics

Data Rate vs Signal Rate

- The data rate defines the number of data elements sent in 1s (bps); the signal rate is the number of signal elements sent in 1s (baud). Increasing the data rate increases the speed of transmission; decreasing the signal rate decreases the bandwidth requirement.
- The relationship between the data rate (N) and signal rate (S): $S = N/r$
- In data communication, we are usually interested in the average case: $S_{\text{ave}} = c \times N \times (1/r)$

Bandwidth

- Although the actual bandwidth of a digital signal is infinite, the effective bandwidth is finite. The minimum bandwidth can give as: $B_{\min} = c \times N \times (1/r)$
- We can solve for the maximum data rate if the bandwidth of the channel is given

$$N_{\max} = (1/c) \times B \times r$$

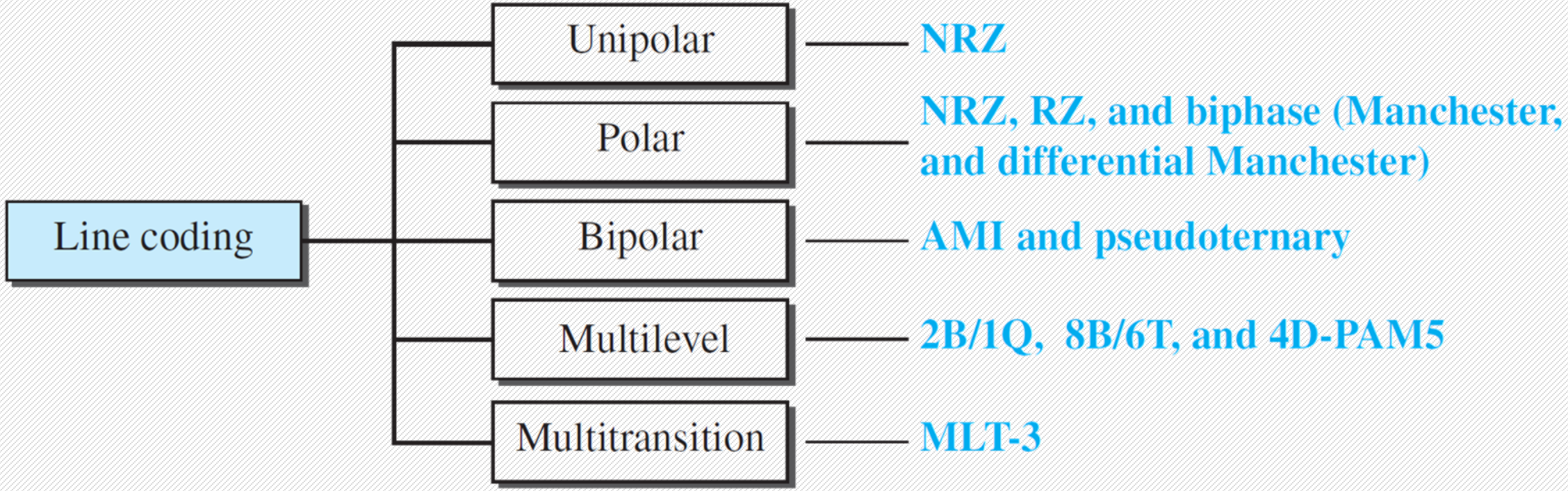
Example

1. A signal is carrying data in which one data element is encoded as one signal element (r=1). If the bit rate is 100 kbps, what is the average value of the baud rate if c is between 0 and 1?

2. The maximum data rate of a channel is $N_{\max} = 2 \times B \times \log_2 L$ (defined by Nyquist formula). Does this agree with the previous formular for N_{max}?

Line Coding Schemes

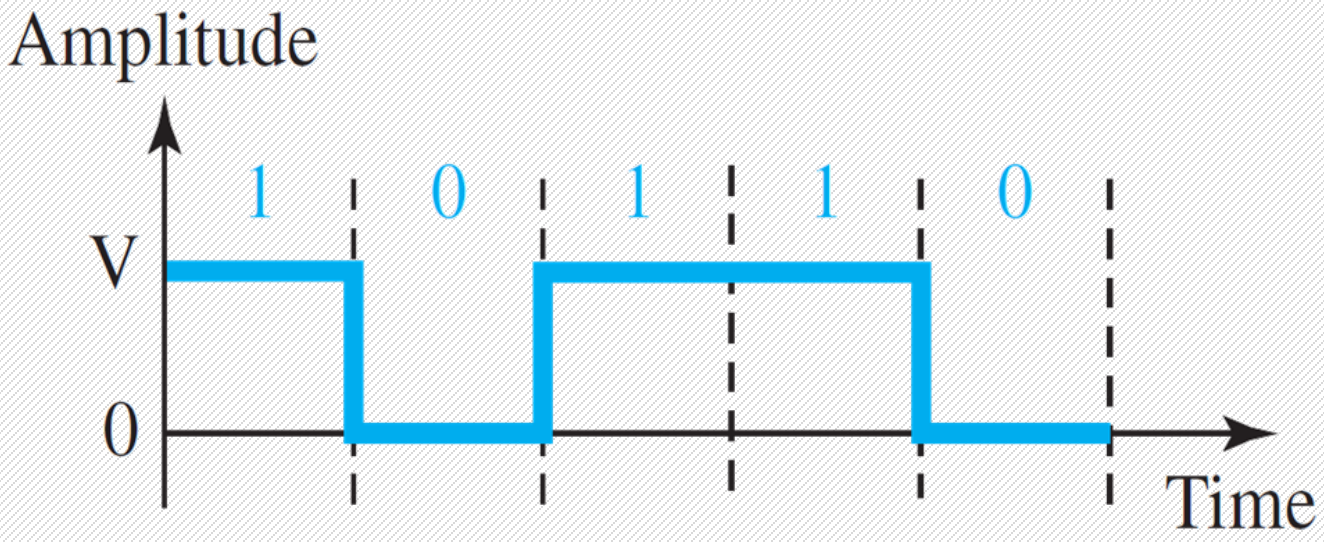
- We can roughly divide line coding schemes into five broad categories: **unipolar**, **polar**, **bipolar**, **multilevel**, and **multitransition**.



Line Coding Schemes

Unipolar Schemes - NRZ

- In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below. Traditionally, a unipolar scheme was designed as a **Non-Return-to-Zero (NRZ)**.
- It is called NRZ because the signal does not return to zero at the middle of the bit; which the positive voltage defines bit 1 and the zero voltage defines bit 0.



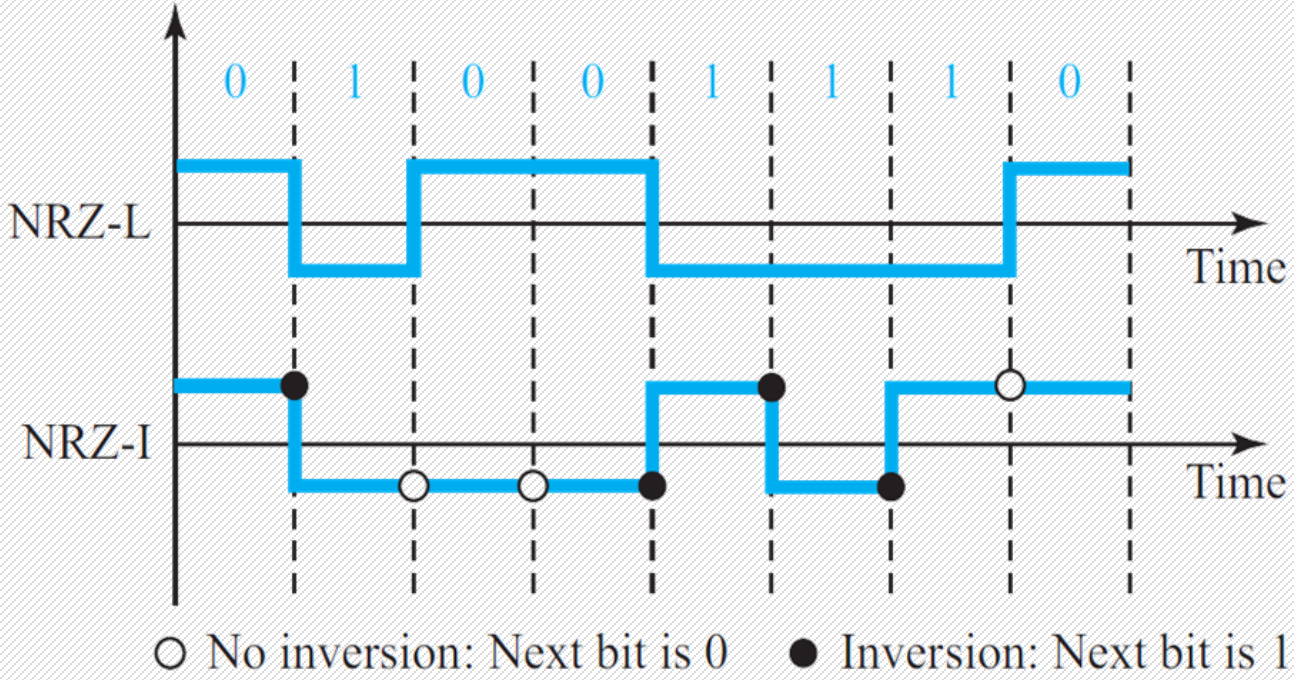
$$\frac{1}{2}V^2 + \frac{1}{2}(0)^2 = \frac{1}{2}V^2$$

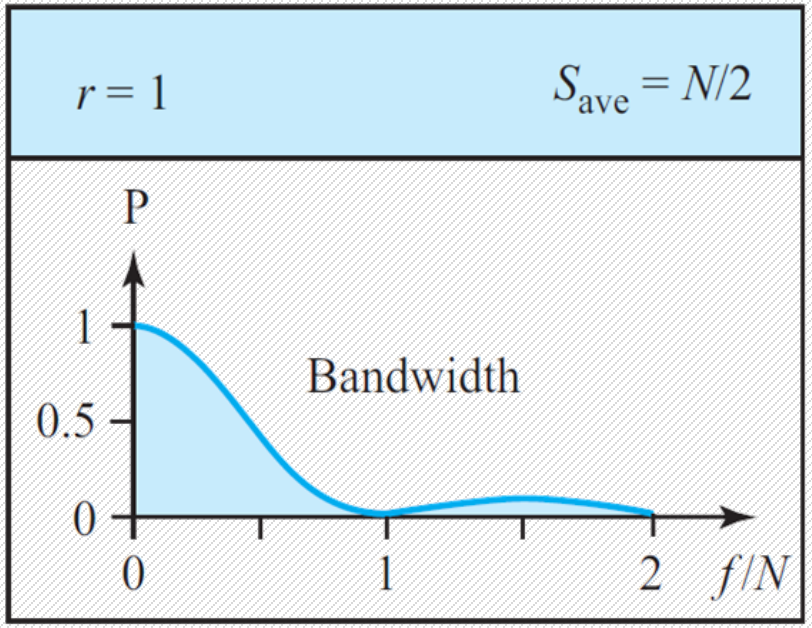
Normalized power

Line Coding Schemes

Polar Schemes - NRZ

- In polar NRZ encoding, we use two levels of voltage amplitude and also can have two version of polar NRZ: NRZ-L (NRZ-Level) and NRZ-I (NRZ-Invert).
- In NRZ-L, the level of the voltage determines the value of the bit; and NRZ-I, the inversion or the lack of inversion determines the value of the bit.

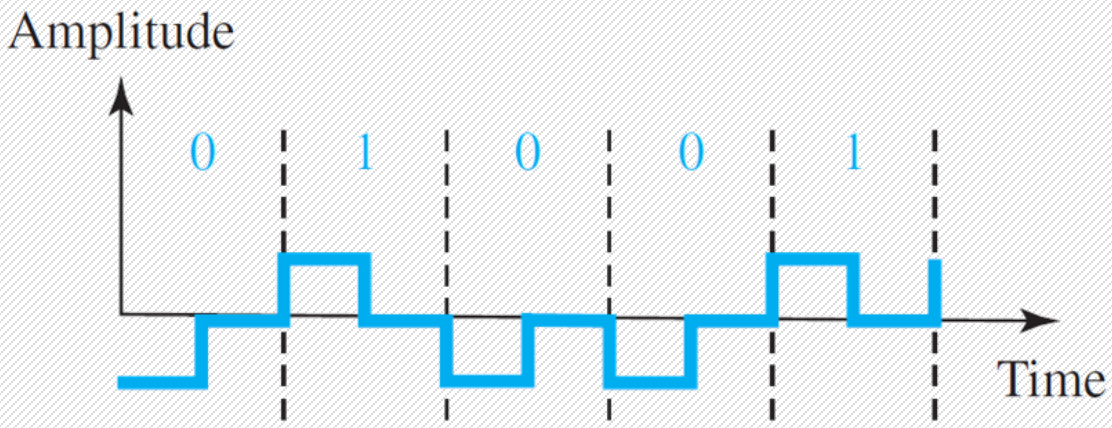


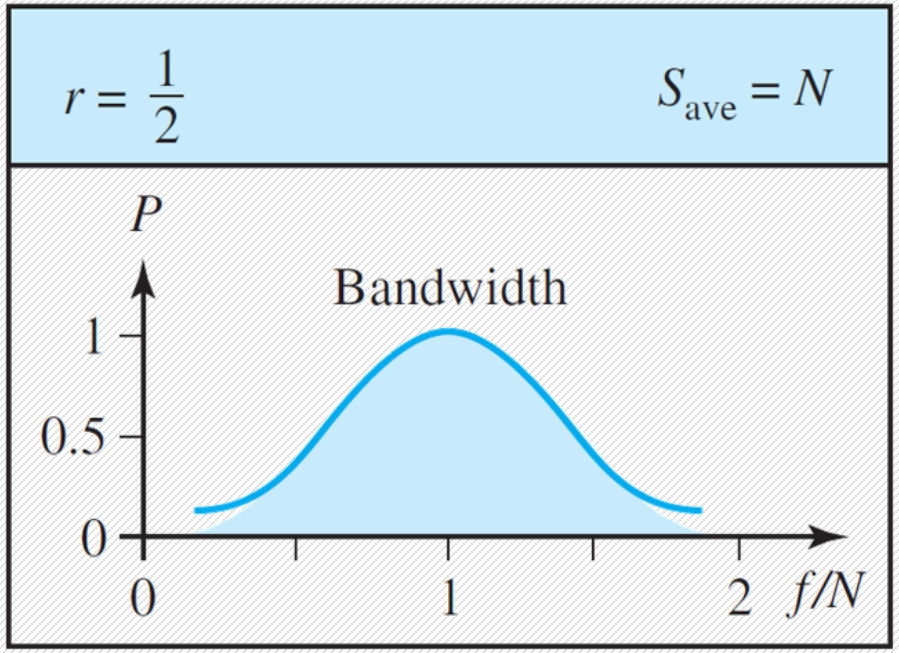


Line Coding Schemes

Polar Schemes - RZ

- The main problem with NRZ encoding occurs when the sender and receiver clocks are not synchronized. The receiver does not know when one bit has ended and the next bit is starting. In RZ, the signal changes not between bits but during the bit.

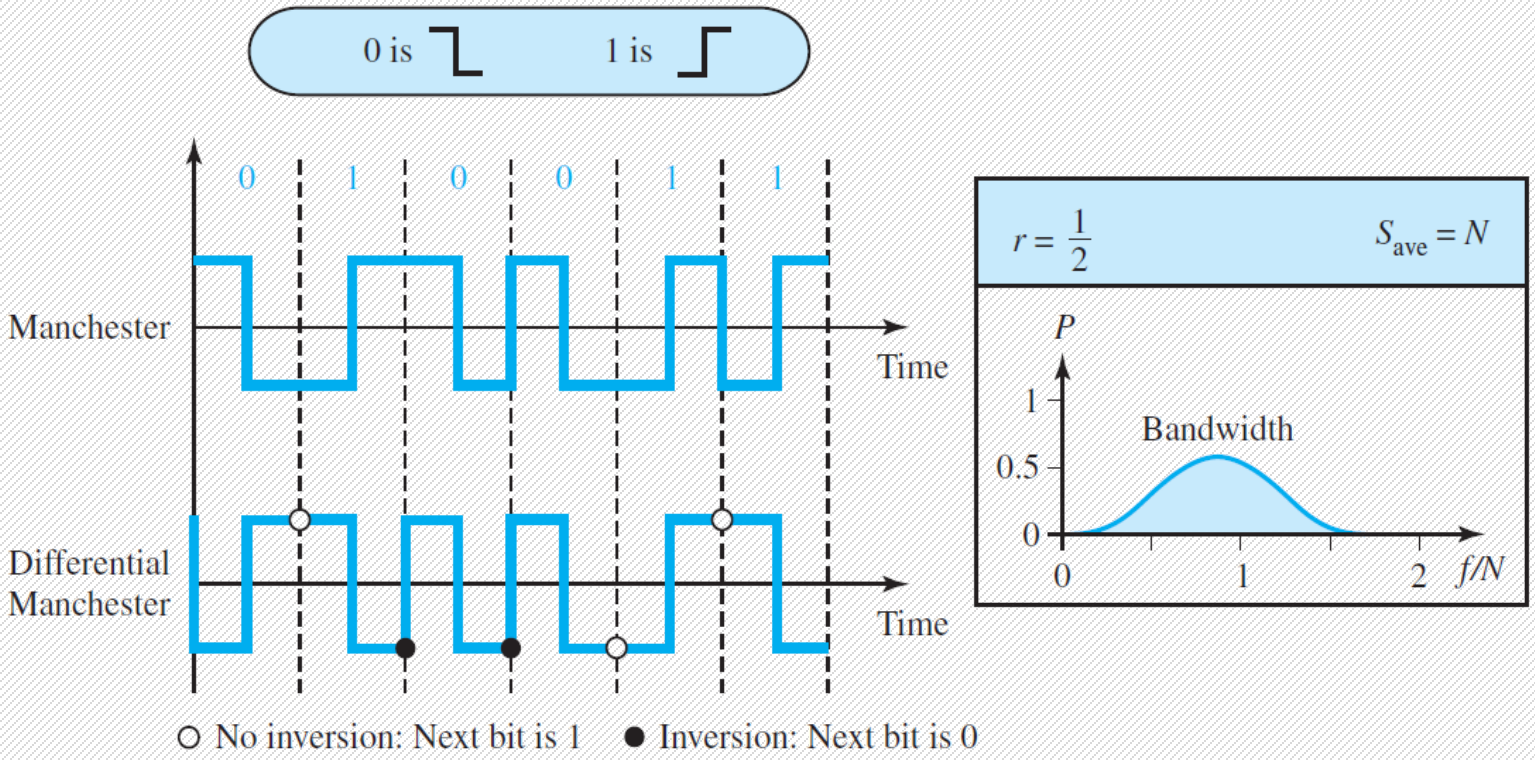




Line Coding Schemes

Biphase: Manchester and Differential Manchester

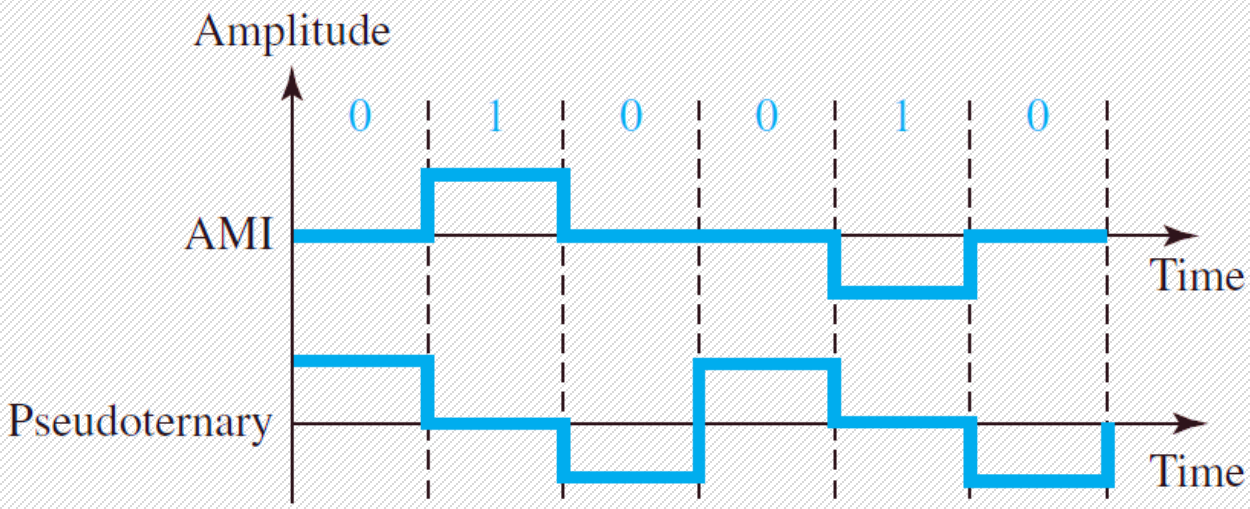
- In Manchester and differential Manchester encoding, the transition at the middle of the bit is used for synchronization. The minimum bandwidth of Manchester and differential Manchester is 2 times that of NRZ.

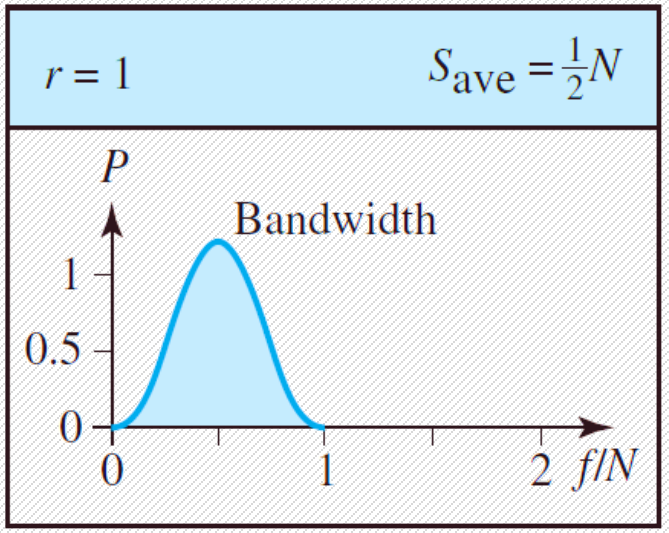


Line Coding Schemes

Bipolar Schemes – AMI and Pseudoternary

- In bipolar encoding, we use three levels: positive, zero, and negative. A neutral zero voltage represents binary 0; binary 1s are represented by alternating positive and negative voltages.
- A variation of AMI encoding is called pseudoternary in which the 1 bit is encoded as a zero voltage and the 0 bit is encoded as alternating positive and negative voltages.





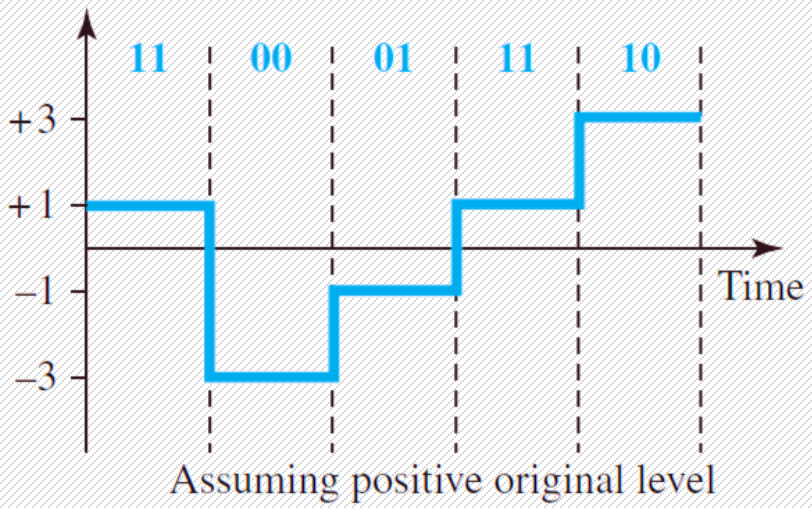
Line Coding Schemes

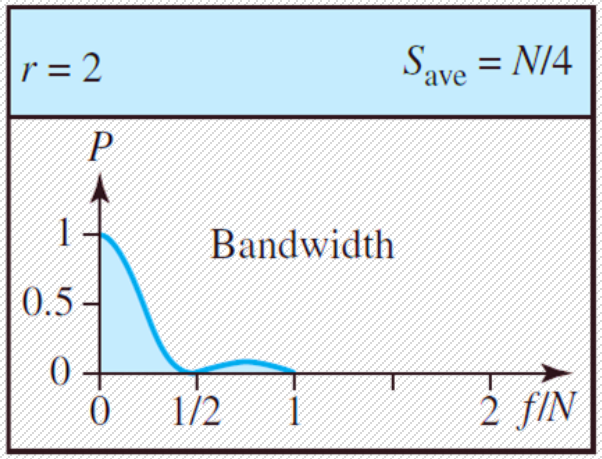
Multilevel Schemes

- The goal is to increase the number of bits per baud by encoding a pattern of m data elements into a pattern of n signal elements.
- A group of m data elements can produce a combination of 2^m data pattern; different types of signal elements by allowing L different signal levels can produce L^n.

Rules:

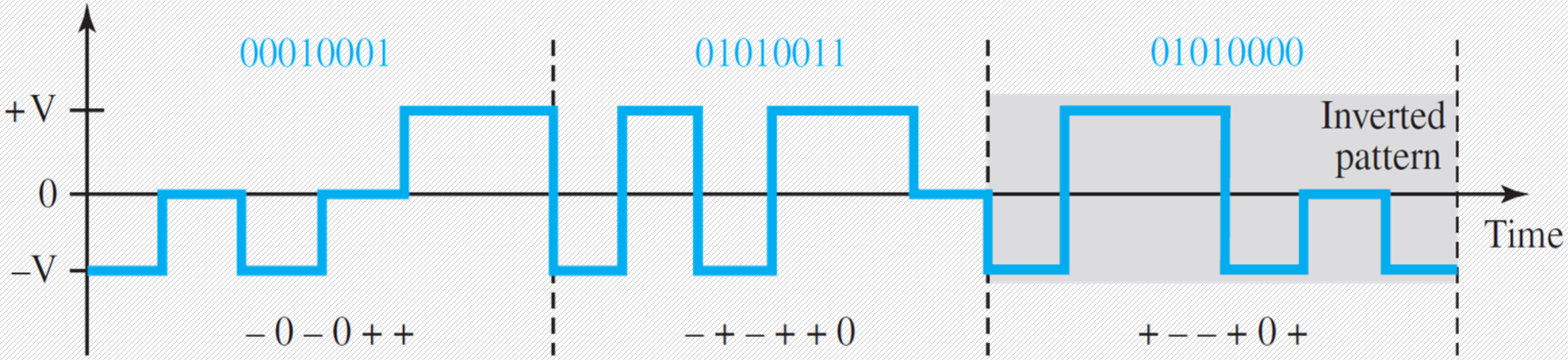
00 → −3 01 → −1 10 → +3 11 → +1





Line Coding Schemes

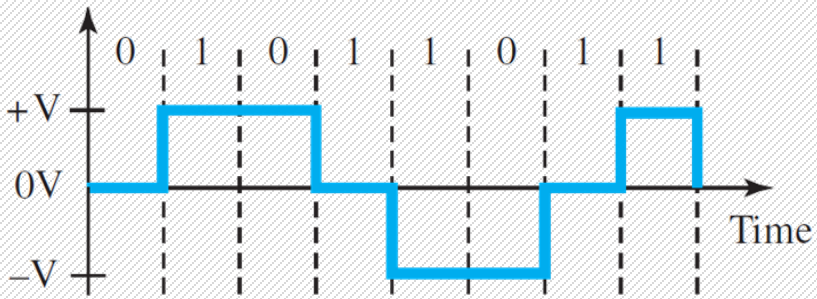
Multilevel Schemes-8B6T



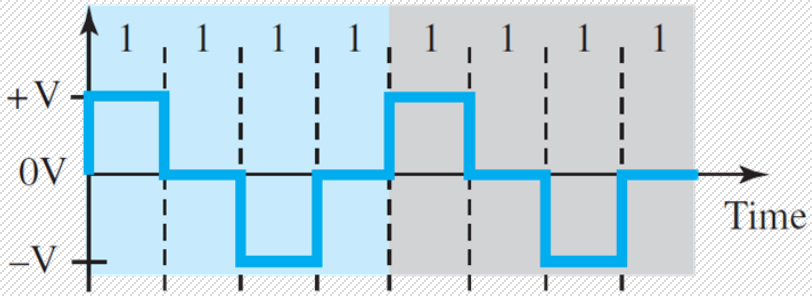
Line Coding Schemes

Multitransition: MLT-3

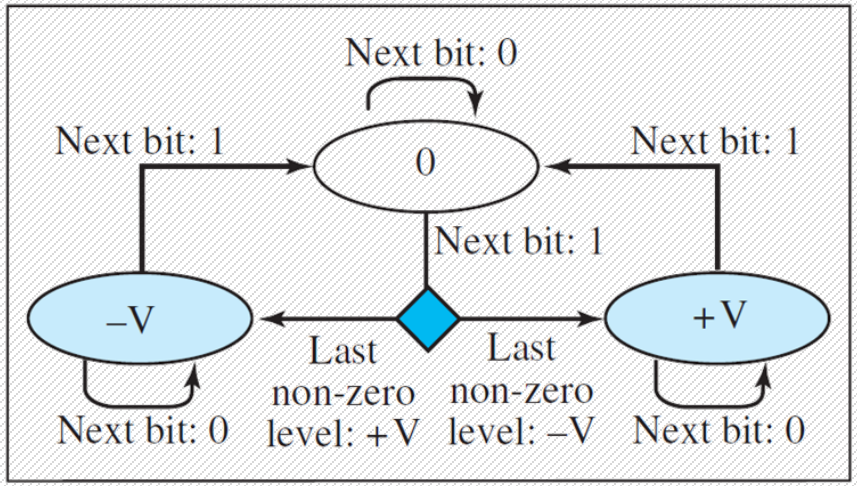
- The multiline transmission, three-level (MLT-3) scheme uses three level (+V, 0, and –V) and more between the levels.



a. Typical case



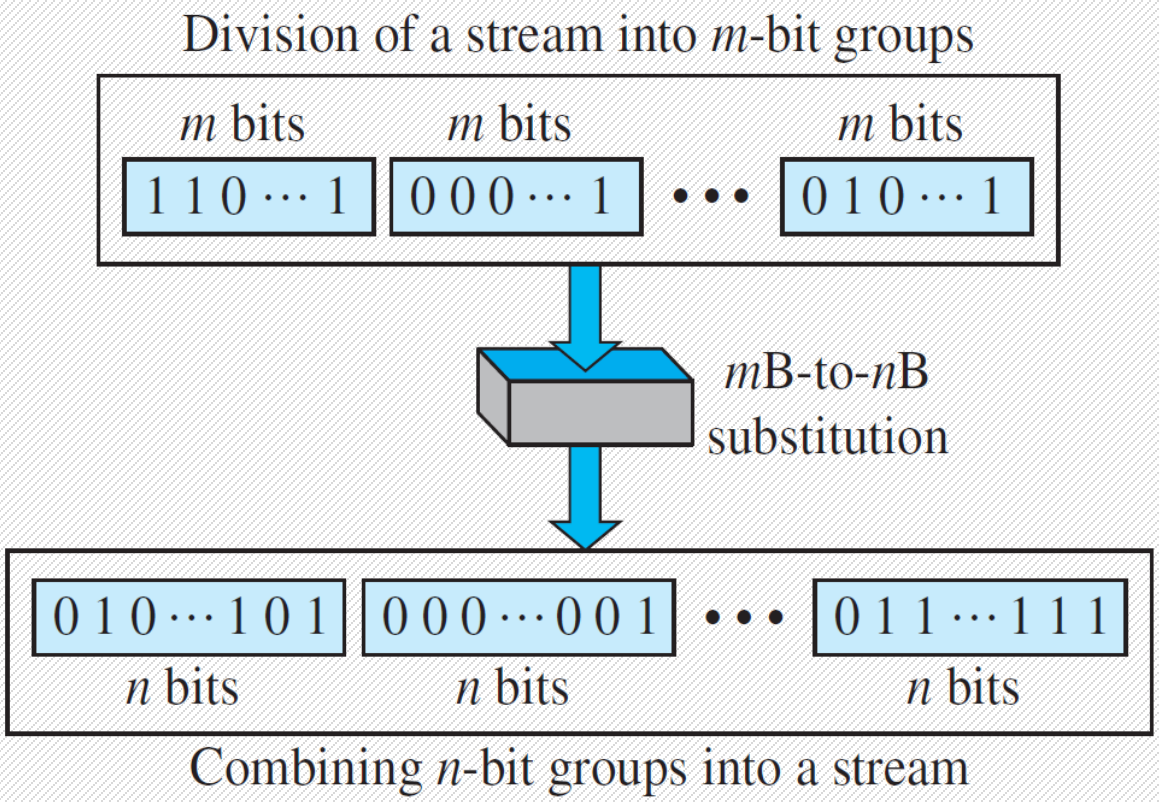
b. Worst case



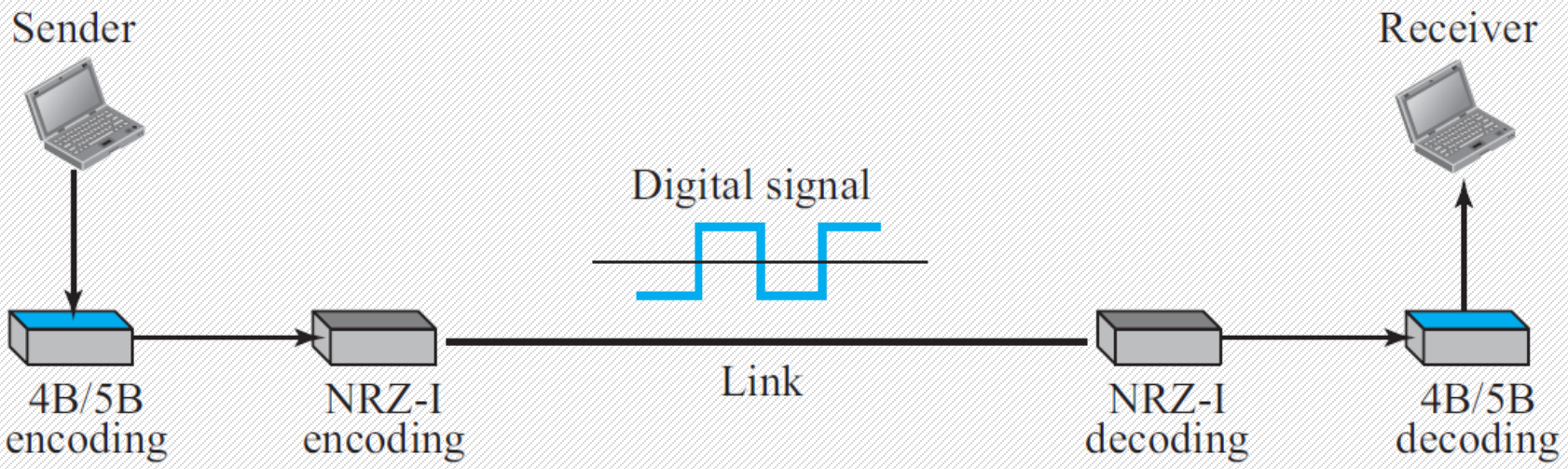
c. Transition states

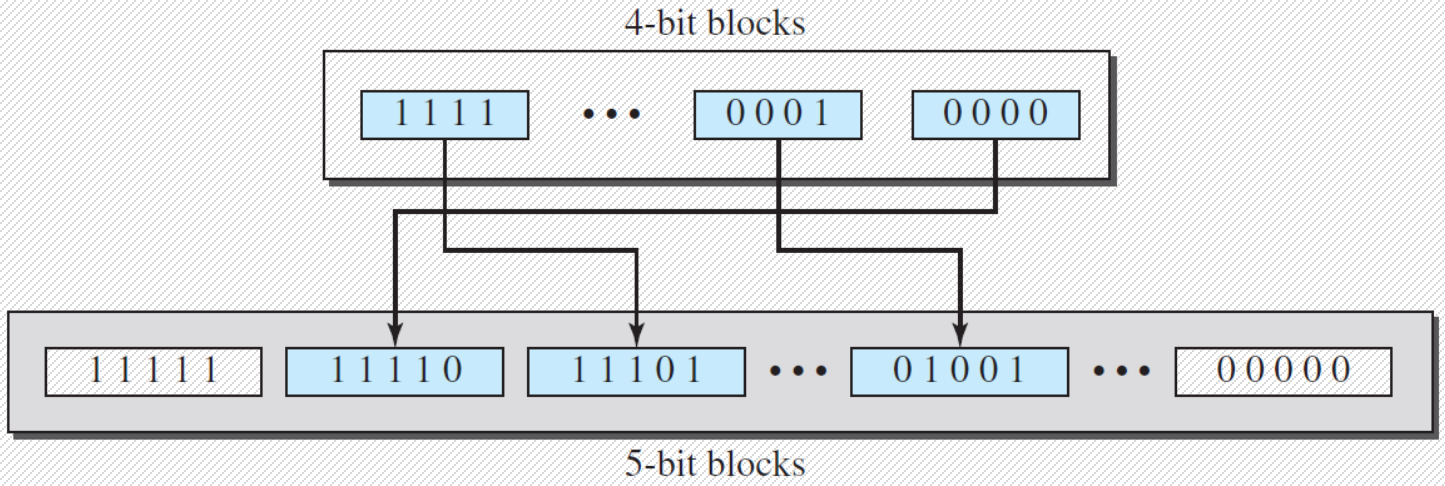
Block Coding

- In general, block coding changes a block of *m* bits into a block of *n* bits, where *n* is larger than *m*. Block coding is referred to as an *mB/nB* encoding technique.
- Block coding normally involves three steps: **division**, **substitution**, and **combination**.
- In the division step, a sequence of bits is divided into group of m bits.
- In substitution step, we substitute an m-bit group with an n-bit group.
- Finally, the n-bit groups are combined to form a stream. The new stream has more bits then the original bits.



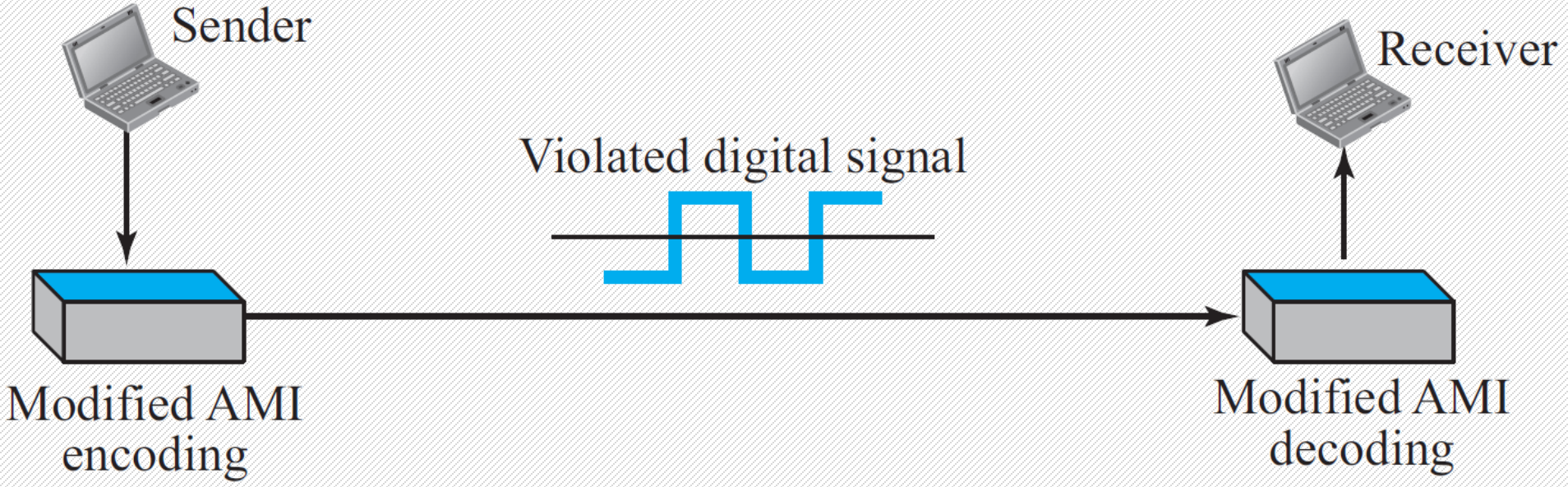
Block Coding – 4B/5B





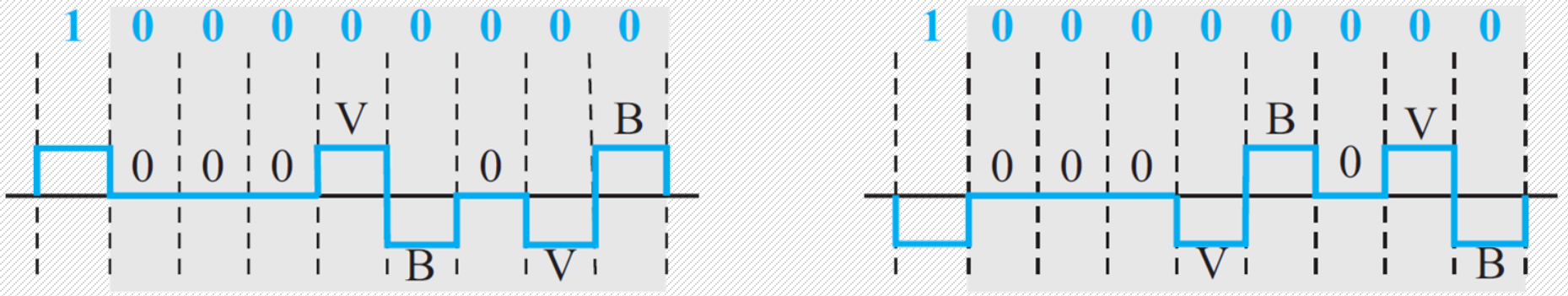
Scrambling

- A technique that does not increase the number of bits and does provide synchronization that suitable for long-distance communication with wide bandwidth requirement, called **scrambling**.



Scrambling – B8ZS

- In B8ZS technique, eight consecutive zero-level voltages are replaced by the sequence **000VB0VB**.
- V in the sequence denotes violation; this is nonzero voltage that breaks an AMI rule of encoding. B in the sequence denotes bipolar, which means a nonzero level voltage in accordance with the AMI rule.

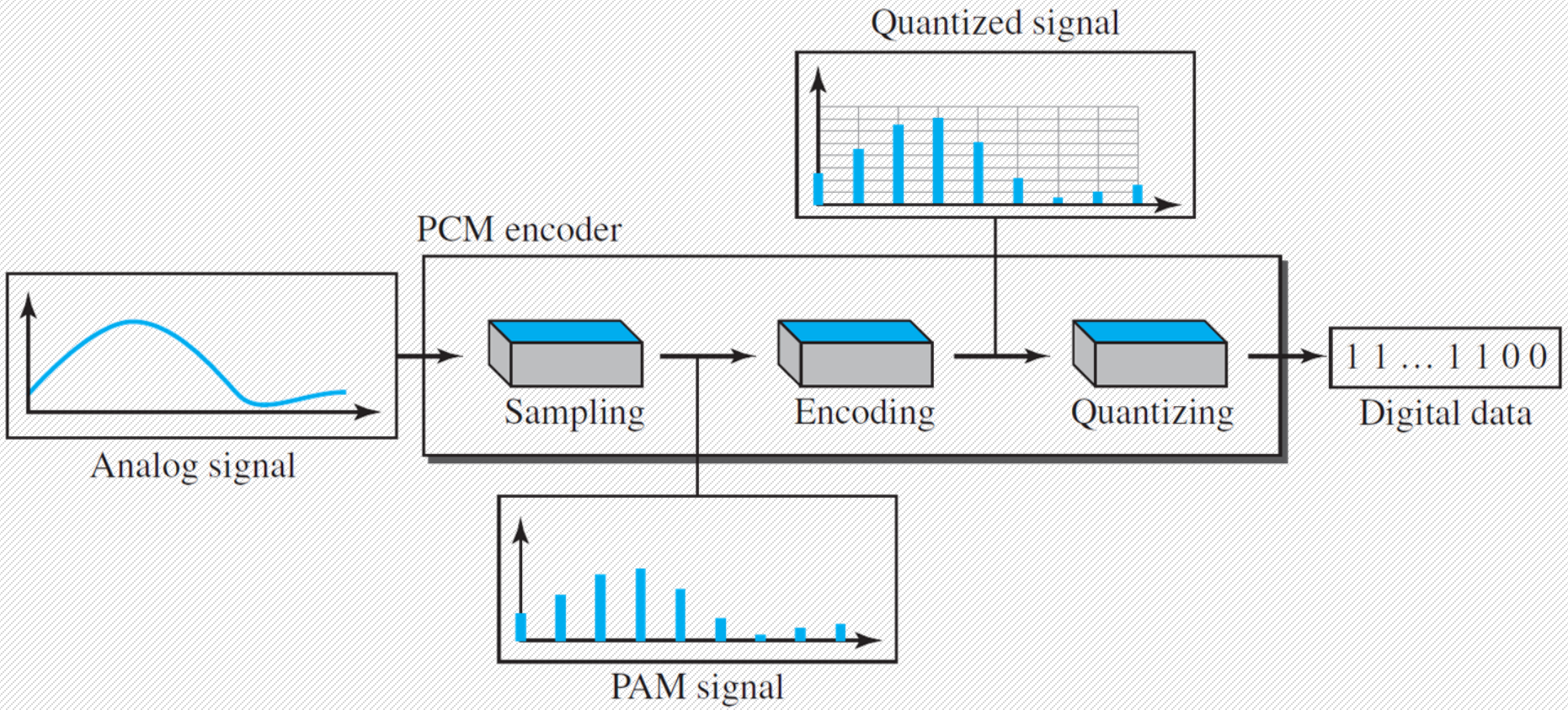


a. Previous level is positive.

b. Previous level is negative.

Pulse Code Modulation (PCM)

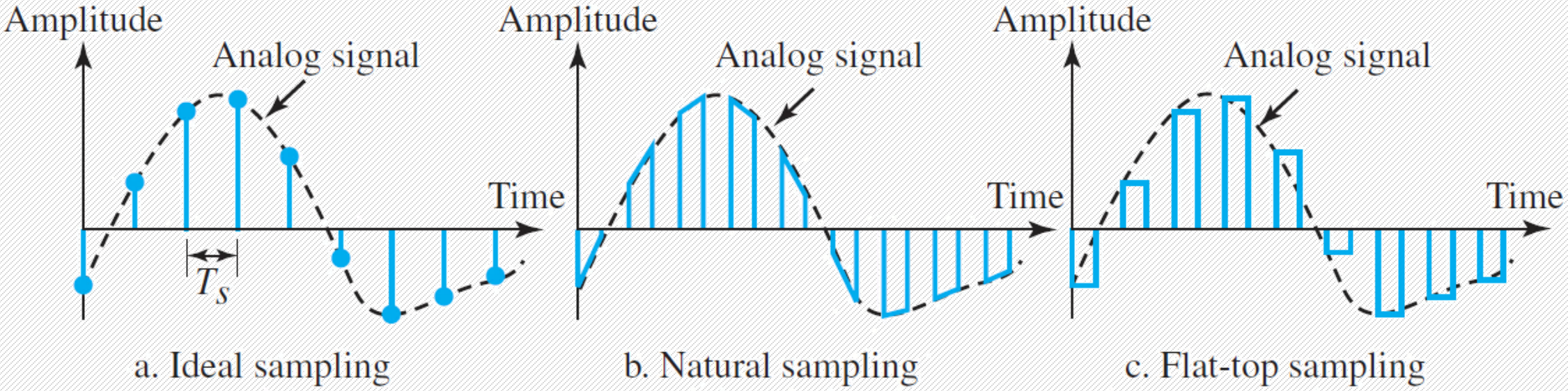
- PCM is the most common technique to change an analog signal to digital form; it encoder has three processes: **sampling** (analog signal is sampled), **quantizing** (sampled signal is quantized), and **encoding** (quantized values are encoded as stream bits).



Pulse Code Modulation (PCM)

Sampling

- The analog signal is sampled every T_s s, where T_s is the sample interval or period. The inverse of the sampling interval is called the sampling rate or sampling frequency and denoted by f_s where $f_s = 1/T_s$.



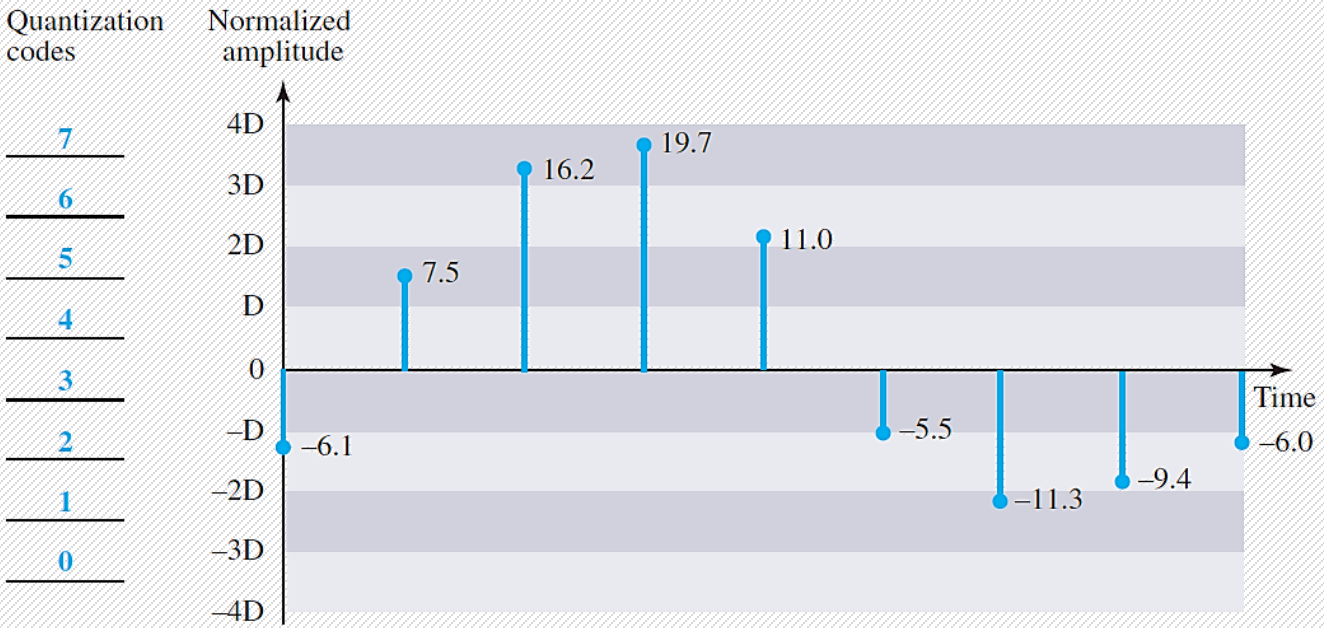
Pulse Code Modulation (PCM)

Quantization

1. Assume that the original analog signal has the instantaneous amplitude between $V_{\min}$ and $V_{\max}$.
2. We divide the rage into L zones, each of height Δ (delta).

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

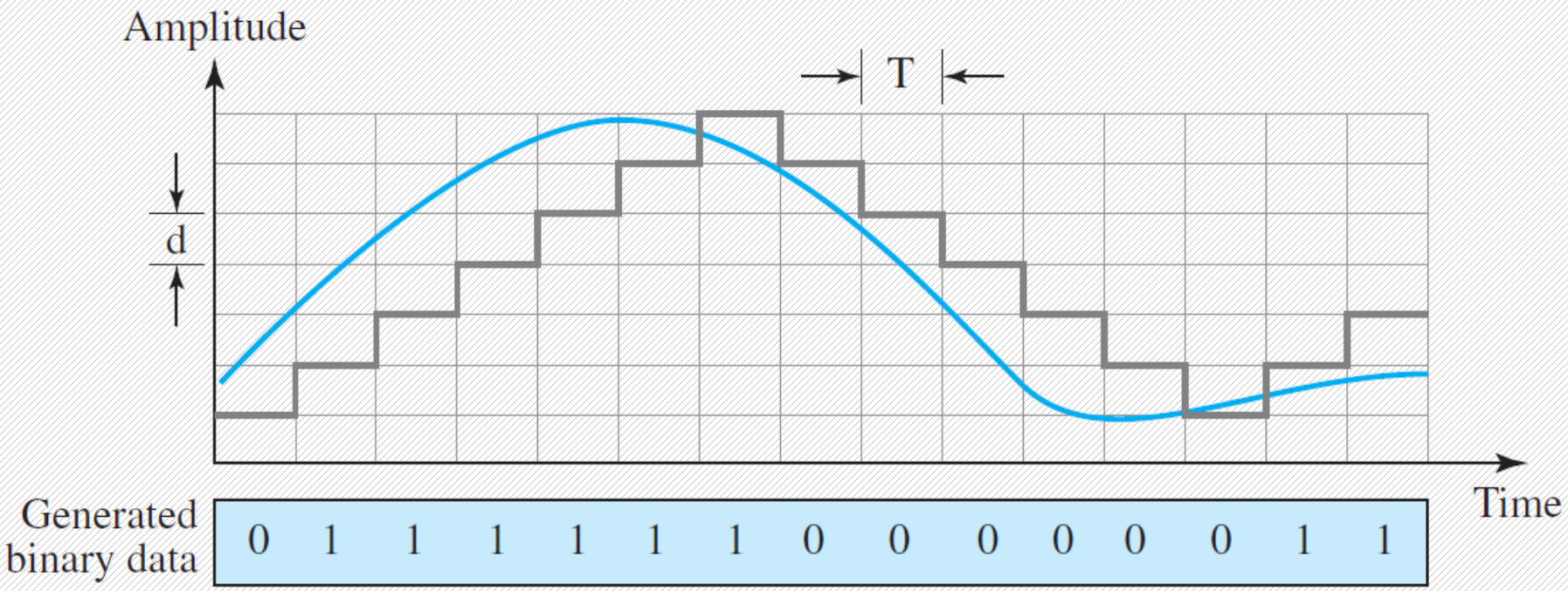
3. We assign quantized values of 0 to L-1 to the midpoint of each zone.
4. We approximate the value of the sample amplitude to the quantized values.



Normalized PAM values	–1.22	1.50	3.24	3.94	2.20	–1.10	–2.26	–1.88	–1.20
Normalized quantized values	–1.50	1.50	3.50	3.50	2.50	–1.50	–2.50	–1.50	–1.50
Normalized error	–0.38	0	+0.26	–0.44	+0.30	–0.40	–0.24	+0.38	–0.30
Quantization code	2	5	7	7	6	2	1	2	2
Encoded words	010	101	111	111	110	010	001	010	010

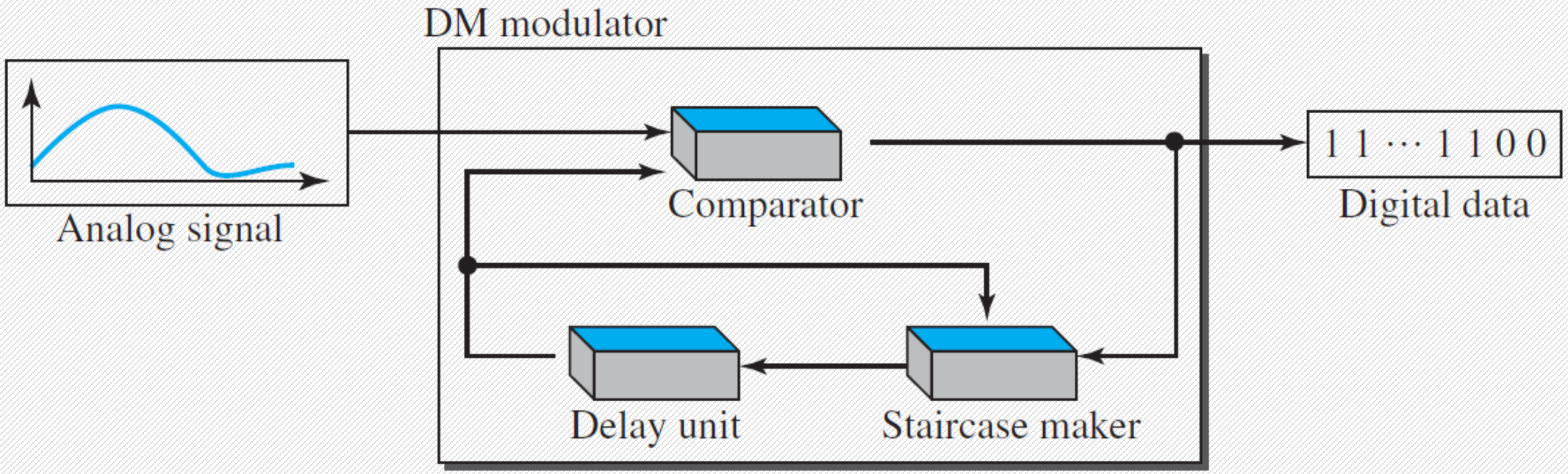
Delta Modulation (DM)

- **PCM** is very complex techniques; other techniques have been developed to reduce the complexity of PCM, called delta modulation.
- PCM finds the values of the signal amplitude for each sample; DM finds the change from the previous sample. The process records the small positive or negative changes, called delta δ.



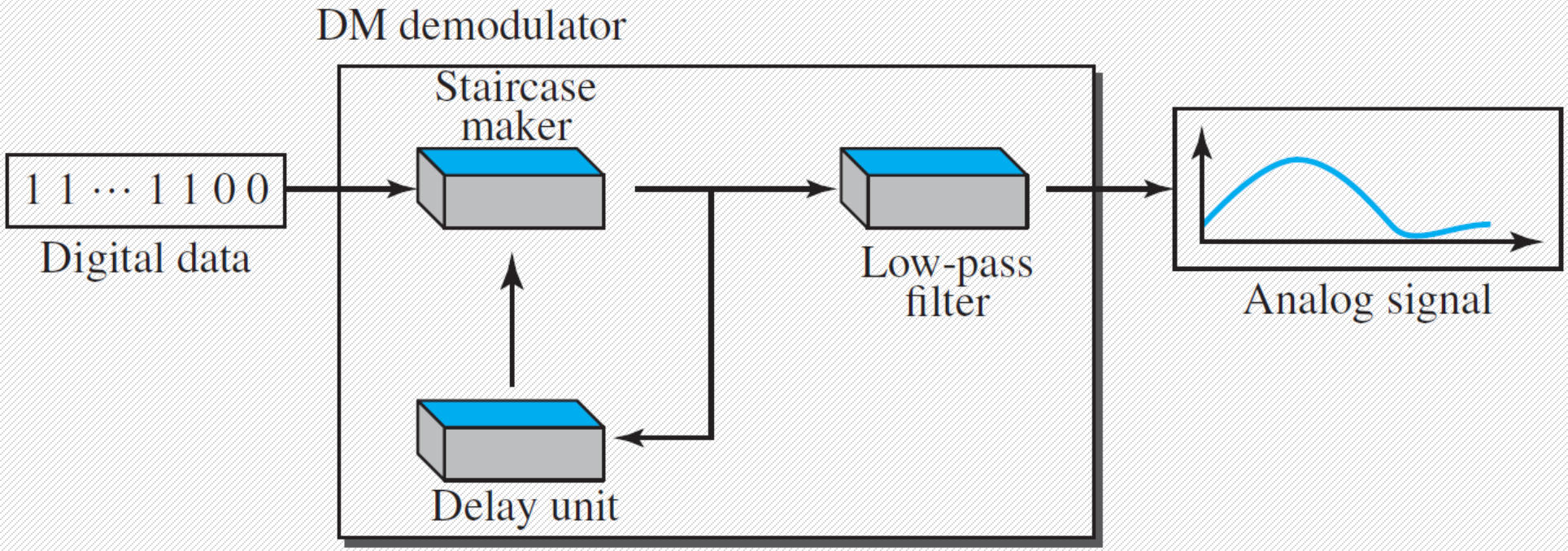
Modulator

It is used at the sender site to create a stream of bits from an analog signal. The process records the small positive or negative changes, called delta δ. If the δ is positive, the process records a 1; if it is negative the process records a 0.



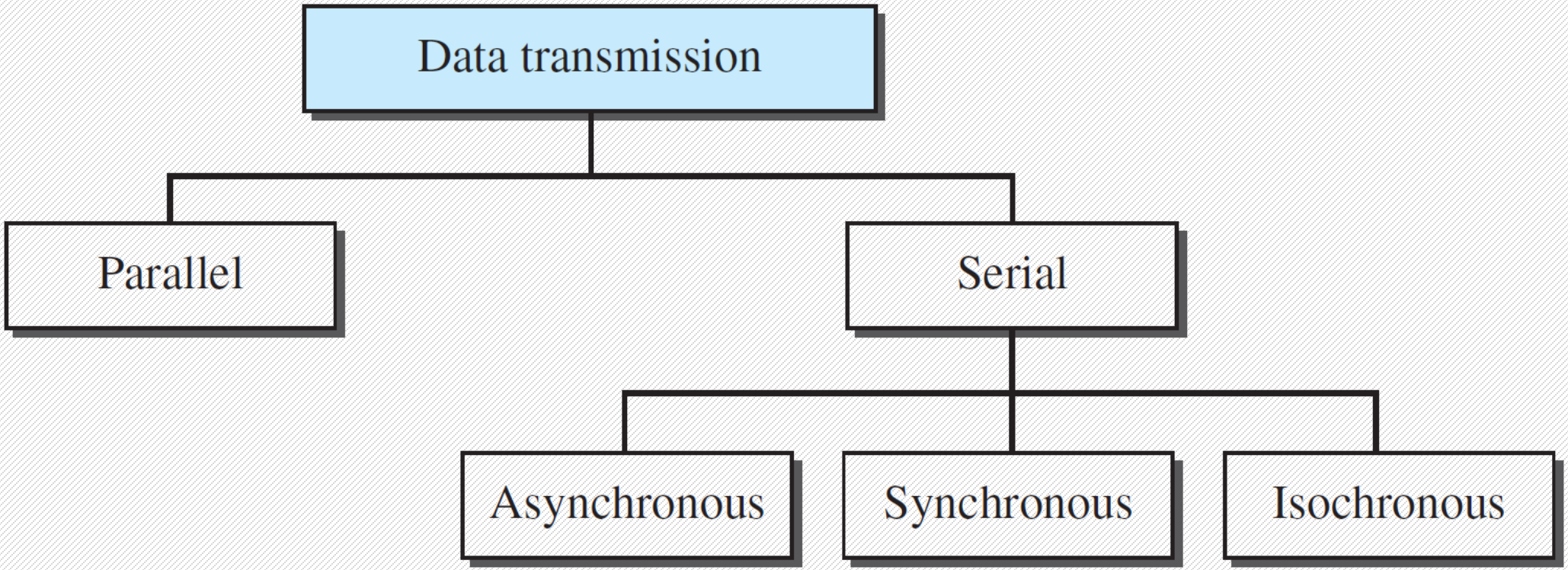
Demodulator

It takes the digital data and, using the staircase maker and the delay unit, create the analog signal. The created analog signal, however, needs to pass through a low-pass filter for smoothing.



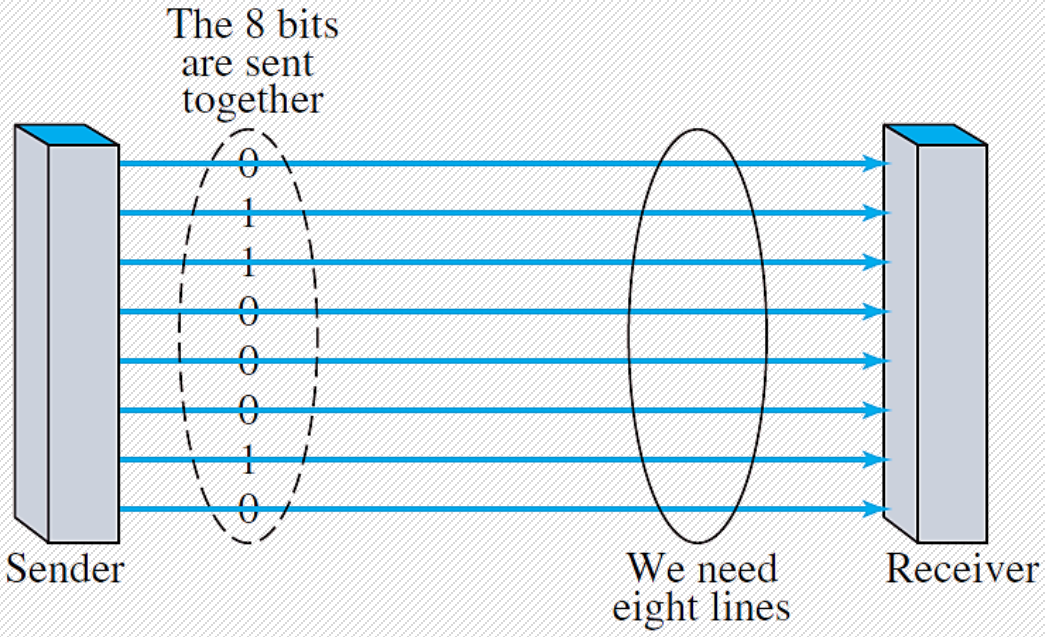
3. TRANSMISSION MODES

- The transmission mode decides how data is transmitted from one device to another; where the transmission binary data (1s and 0s) across a link can be accomplished in either parallel or serial mode.



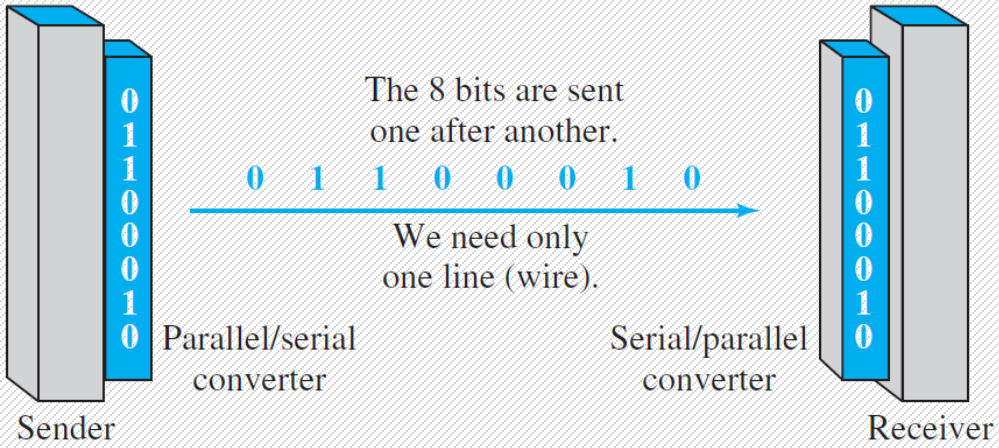
Parallel Transmission

- Binary data, consisting of 1s and 0s, may be organized into group of *n* bits each.
- By grouping, we can send data *n* bits at a time instead of 1, called **parallel transmission**.



Serial Transmission

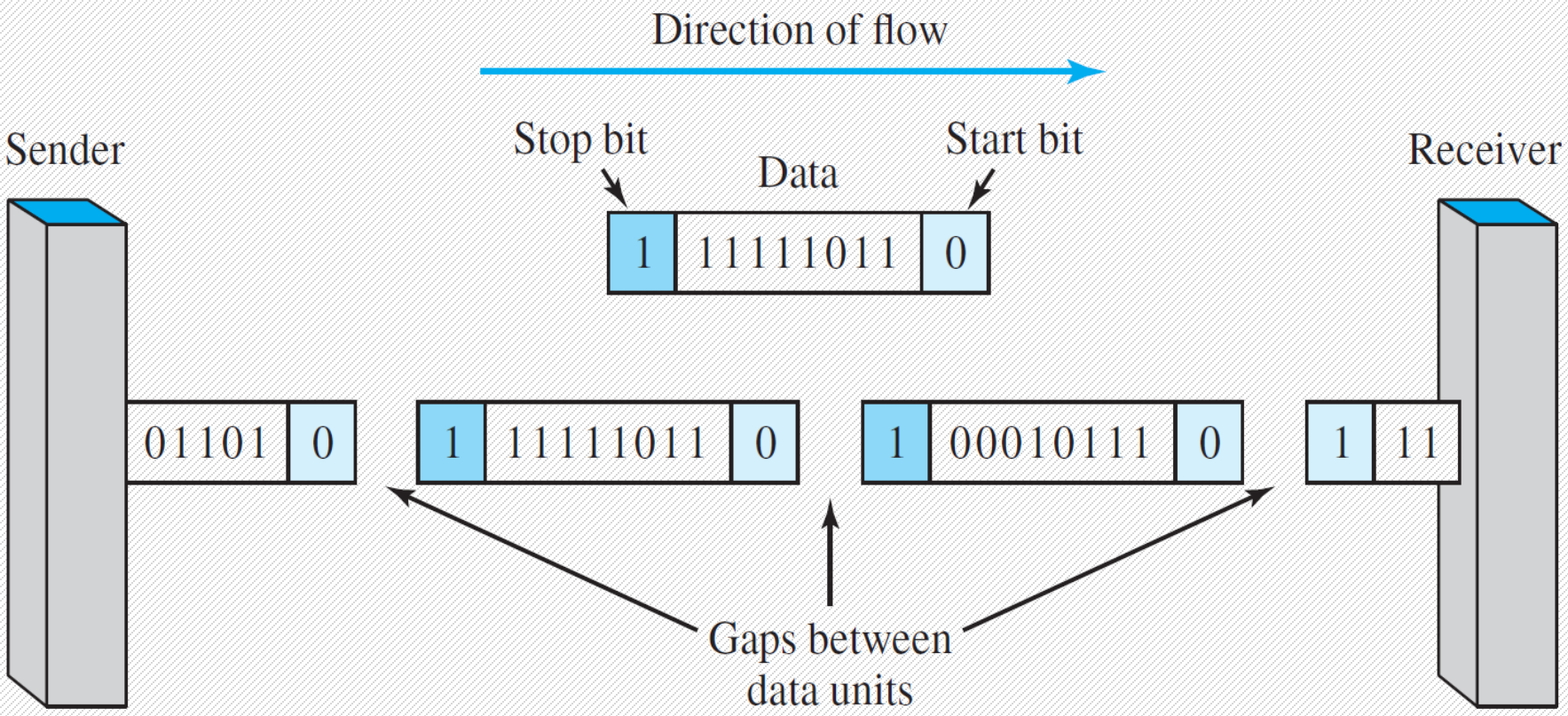
- In serial transmission, one bit follows another and only one communication channel rather than n to transmit data.
- Serial transmission occur in one of three ways: **asynchronous**, **synchronous**, and **isochronous**.



Serial Transmission

Asynchronous Transmission

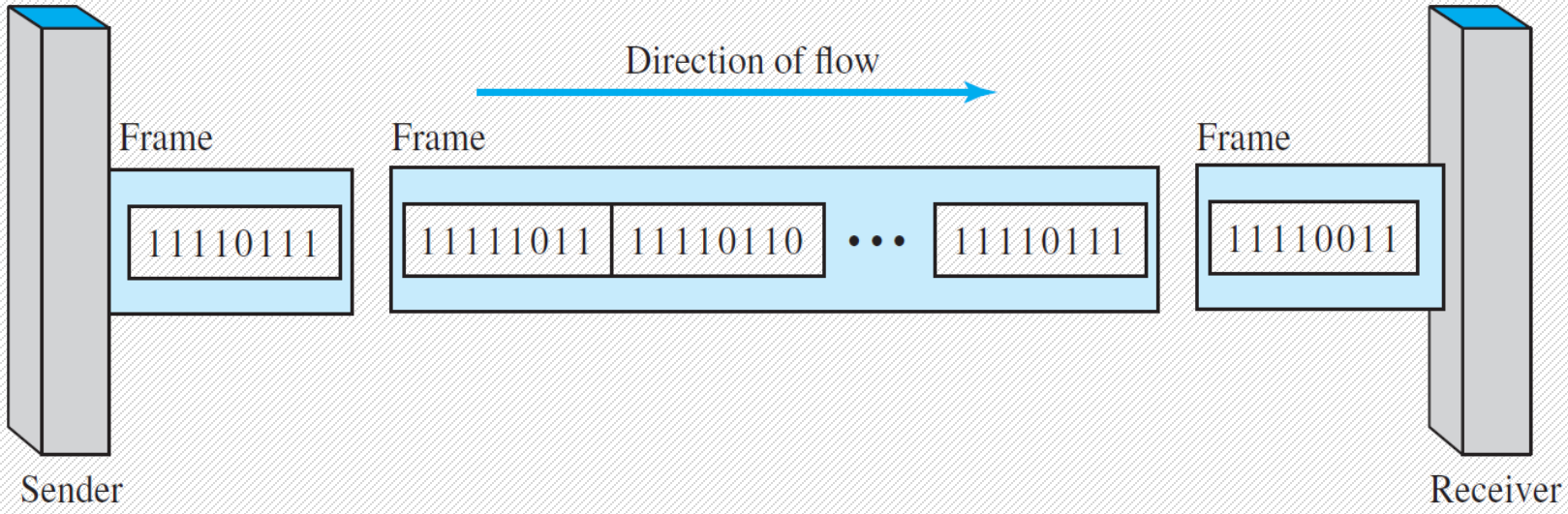
- In asynchronous transmission, we send 1 start bit (0) at the beginning and 1 or more stop bits (1s) at the end of each byte. There may be a gap between bytes.



Serial Transmission

Synchronous Transmission

- In synchronous transmission, we send bits one after another without start or stop bits or gap. It is the responsibility of the receiver to group the bits.



Isochronous Transmission

- similar to synchronous transmission but the time interval between blocks is almost zero which in real time transmission and at a fixed rate.

4. SUMMARY

Digital-to-digital conversion involves three techniques: line coding, block coding, and scrambling. Line coding is the process of converting digital data to a digital signal; block coding provides redundancy to ensure synchronization and inherent error detection; scrambling provides synchronization without increasing the number of bits.

The most common technique to change an analog signal to digital data is called pulse code modulation (PCM) and other sampling techniques have been developed to reduce the complexity of PCM is delta modulation (DM).

While there is only one way to sent parallel data, there are three subclasses of serial transmission: asynchronous, synchronous, and isochronous.

5. HOMEWORK

1. Distinguish between data rate and signal rate.
2. What are the advantages and disadvantages of parallel and serial transmission? What are the differences between parallel and serial transmission?
3. Draw the graph of NRZ-L scheme using each of the following data streams, assuming that the last signal level has been positive. From the graphs, guess the bandwidth for this scheme using the average number of changes in the signal level

   a. 00000000 **b.** 11111111 **c.** 01010101 **d.** 00110011

4. What is the Nyquist sampling rate for each of the following signals?
   a. A low-pass signal with bandwidth of 200 KHz?
   b. A band-pass signal with bandwidth of 200 KHz if the lowest frequency if 100 KHz?

ANALOG TRANSMISSION

PART-III

Thank you!

Any Question?