LINE CODES

Module-3

Topics to be discussed

- Introduction and need for the codes
- Representation of line codes
- Properties and applications of line codes
- Power spectral density of
  - NRZ unipolar,
  - NRZ polar,
  - NRZ bipolar and
  - Manchester Codes

Introduction

- In this section, we see how we can represent digital data by using digital signals.
- The conversion involves three techniques:

1. Line Coding,
2. Block Coding and
3. Scrambling.

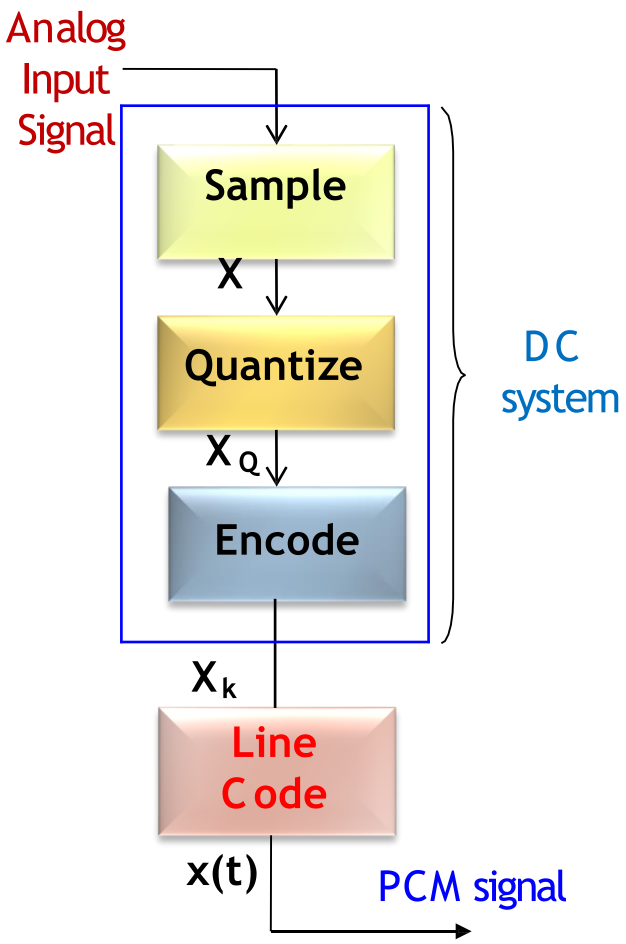
- **Line coding** is always needed.
- Block coding and Scrambling may or may not be needed.

Introduction

- The output of an Digital Communication System or ADC can be transmitted over a baseband channel.
- The digital information must first be converted into a physical signal.
- The physical signal is called a **line code**.
- Line coders use the terminology

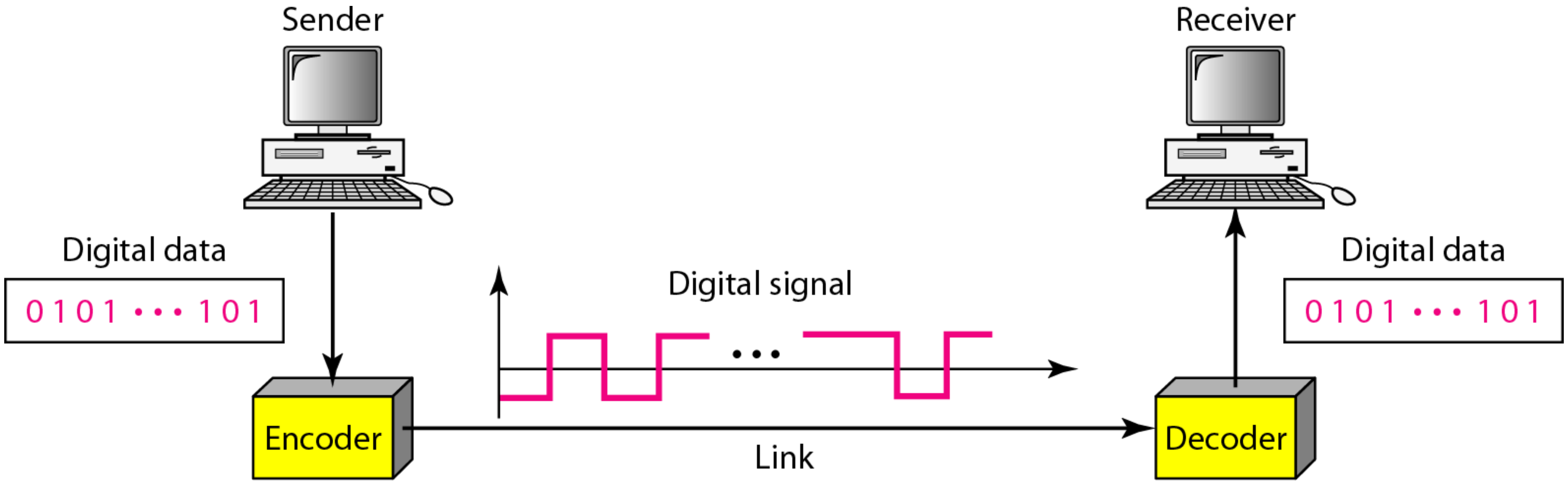
❑ **MARK** to mean **binary one** and

❑ **SPACE** to mean **binary zero**.



Introduction

- Converting a string of 1's and 0's (digital data) into a sequence of signals that denote the 1's and 0's.
- For example a high voltage level (+V) could represent a "1" and a low voltage level (0 or -V) could represent a "0".



Introduction

Mapping Data symbols onto Signal levels

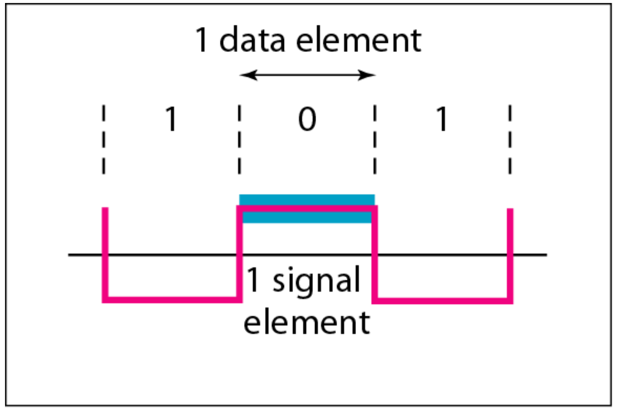
- A data symbol (or element) can consist of a number of data bits:
  - 1 ,0 or
  - 11,10,01,... ...
- A data symbol can be coded into a single signal element or multiple signal elements
  - $\mathbf{1} \rightarrow +\boldsymbol{V}$ and $\mathbf{0} \rightarrow -\boldsymbol{V}$
  - $\mathbf{1} \rightarrow +\boldsymbol{V}\ \&\ -\boldsymbol{V}$ and $\mathbf{0} \rightarrow -\boldsymbol{V}\ \&\ +\boldsymbol{V}$
- The **ratio 'r'** is the number of data elements carried by a signal element.

Introduction

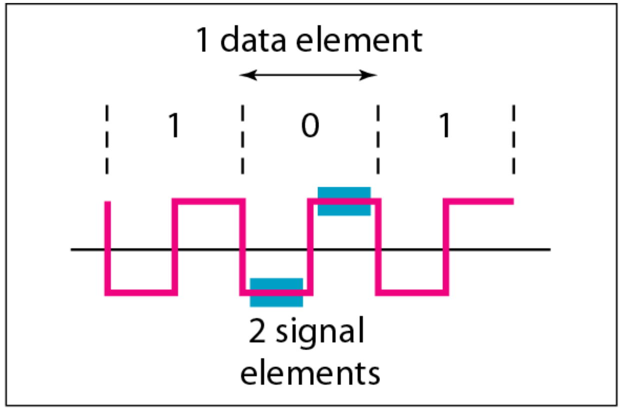
Relationship between data rate and signal rate

- The data rate defines the number of bits sent per second **(bps)**.
- It is often referred to the bit rate.
- The signal rate is the number of signal elements sent in a second and is measured in **bauds**.
- It is also referred to as the modulation rate.
- Goal is to increase the data rate whilst reducing the baud rate.

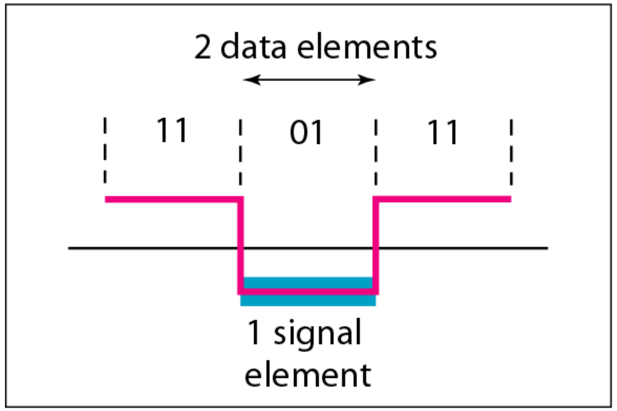
Introduction



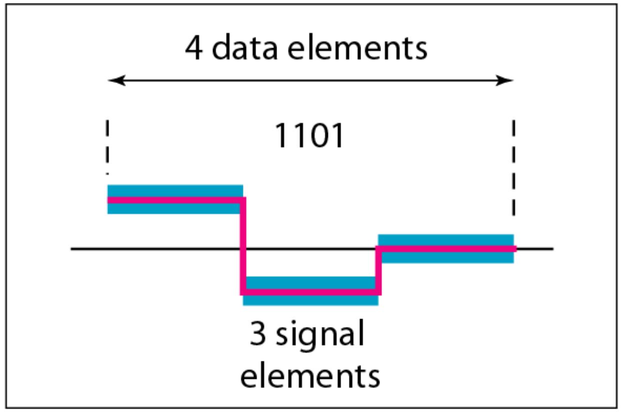
a. One data element per one signal element (r = 1)



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 $\left(r = \frac{4}{3}\right)$

Introduction

Data rate and Baud rate

- The baud or signal rate can be expressed as:

$$S = C \times N \times \frac{1}{r} \; (bauds)$$

  - where N is data rate
  - C is the case factor (worst,best & avg.)
  - r is the ratio between data element & signal element

Although the actual bandwidth of a digital signal is infinite,the effective bandwidth is finite.

Numerical

- 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?

Solution:

Numerical

- 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?

Solution:

- We assume that the average value of C is 1/2. The baud rate is then

$$\boxed{S = c \times N \times \frac{1}{r} = \frac{1}{2} \times 100{,}000 \times \frac{1}{1} = 50{,}000 = 50 \text{ kbaud}}$$

Desirable Properties of a Line Code

- Properties that should be taken in to considerations for choosing a good signal element referred to as line encoding:

1. Baseline Wandering
2. DC components
3. Self Synchronization
4. Error Detection
5. Noise and Interference
6. Complexity

Desirable Properties of a Line Code

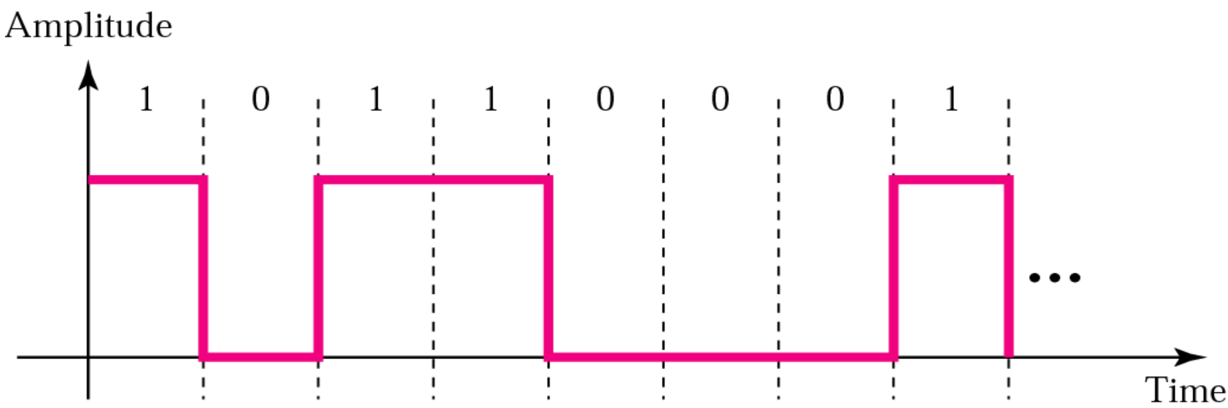
Baseline wandering

- In decoding a digital signal, the receiver calculates a running average of the received signal power.
- This average is called the baseline.
- The incoming signal power is evaluated against this baseline to determine the value of the data element.
- A long string of 0s or 1s can cause a drift in the baseline (baseline wandering) and make it difficult for the receiver to decode correctly.
- A good line coding scheme needs to prevent baseline wandering.

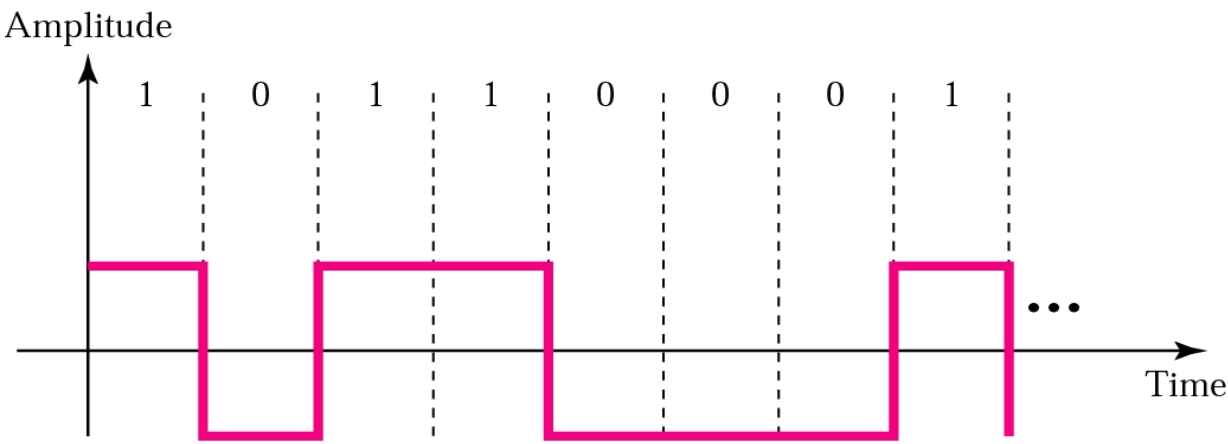
Desirable Properties of a Line Code

DC component

- When the voltage level in a digital signal is constant for a while, there is an increase in the low frequencies of the signal (results of Fourier analysis).
- These frequencies around zero, are called DC (direct-current) components.
- Most of the channels are bandpass and may not support low frequencies



a. A signal with dc component



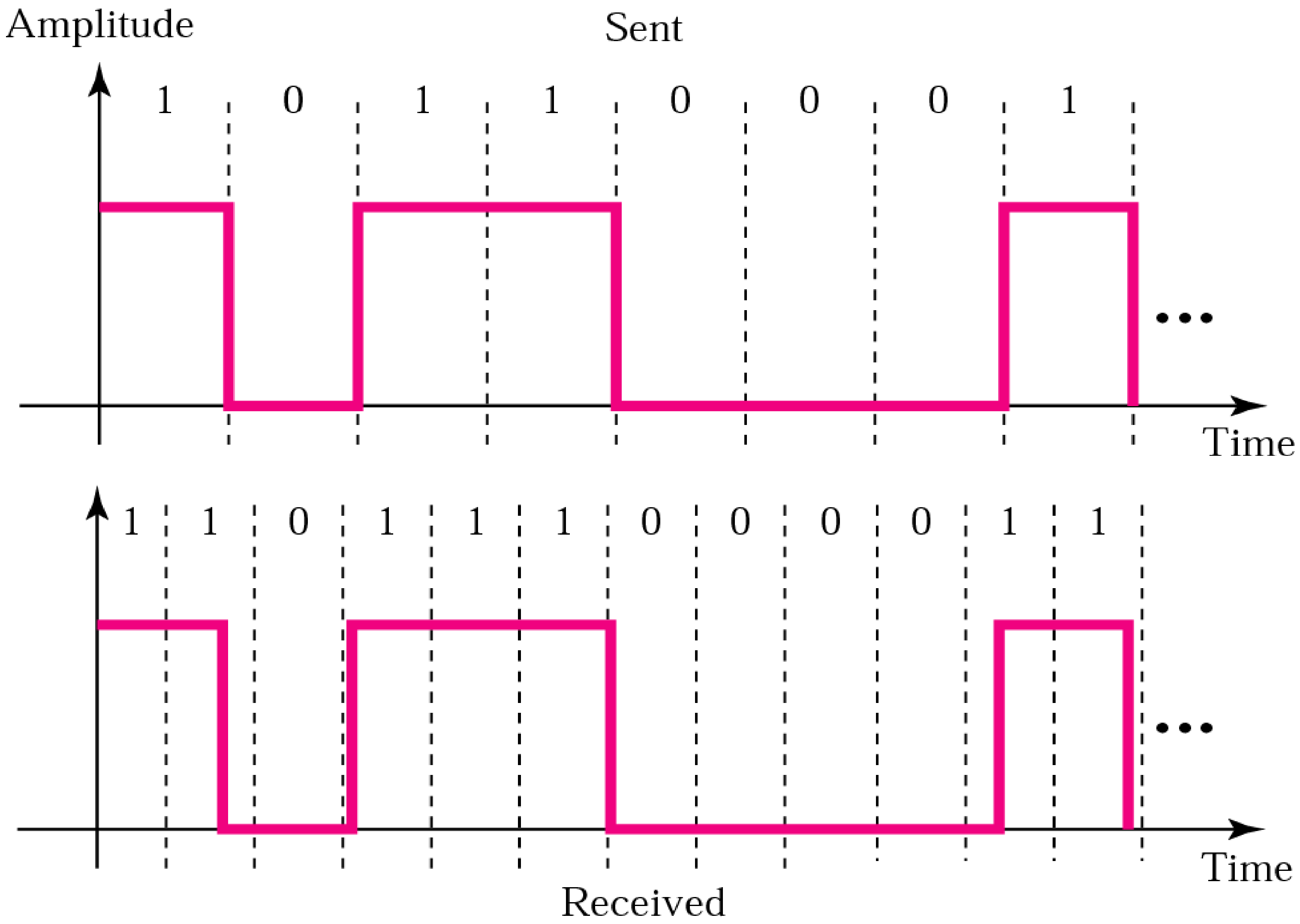
b. A signal without dc component

Desirable Properties of a Line Code

Self Synchronization

- To correctly interpret the signals received from the sender, the receiver's bit intervals must correspond exactly to the sender's bit intervals.
- If the receiver clock is faster or slower, the bit intervals are not matched and the receiver might misinterpret the signals.
- Self-synchronizing signal includes timing information.
- This can be achieved if there are transitions in the signal that alert the receiver to the beginning, middle, or end of the pulse.

Desirable Properties of a Line Code



Desirable Properties of a Line Code

- In a digital transmission, the receiver clock is 0.1 percent faster than the sender clock. How many extra bits per second does the receiver receive if the data rate is 1 Kbps? How many if the data rate is 1 Mbps?
- **Solution:**

Desirable Properties of a Line Code

- In a digital transmission, the receiver clock is 0.1 percent faster than the sender clock. How many extra bits per second does the receiver receive if the data rate is 1 Kbps? How many if the data rate is 1 Mbps?
- **Solution:**
  - **At 1 Kbps:**

    1000 bits sent ➔1001 bits received➔1 extra bps
  - **At 1 Mbps:**

    1,000,000 bits sent ➔1,001,000 bits received➔1000 extra bps

Desirable Properties of a Line Code

Error detection

- Errors occur during transmission due to line impairments.
- Some codes are constructed such that when an error occurs it can be detected.

For example:

  - A particular signal transition is not part of the code.
  - When it occurs, the receiver will know that a symbol error has occurred.

Desirable Properties of a Line Code

Noise and interference

- There are line encoding techniques that make the transmitted signal “immune” to noise and interference.
- This means that the signal cannot be corrupted, it is stronger than error detection.

Complexity

- The more robustness and resilient the code becomes, the more complex it is to implement the code.
- And the price is often paid in baud rate or required bandwidth.