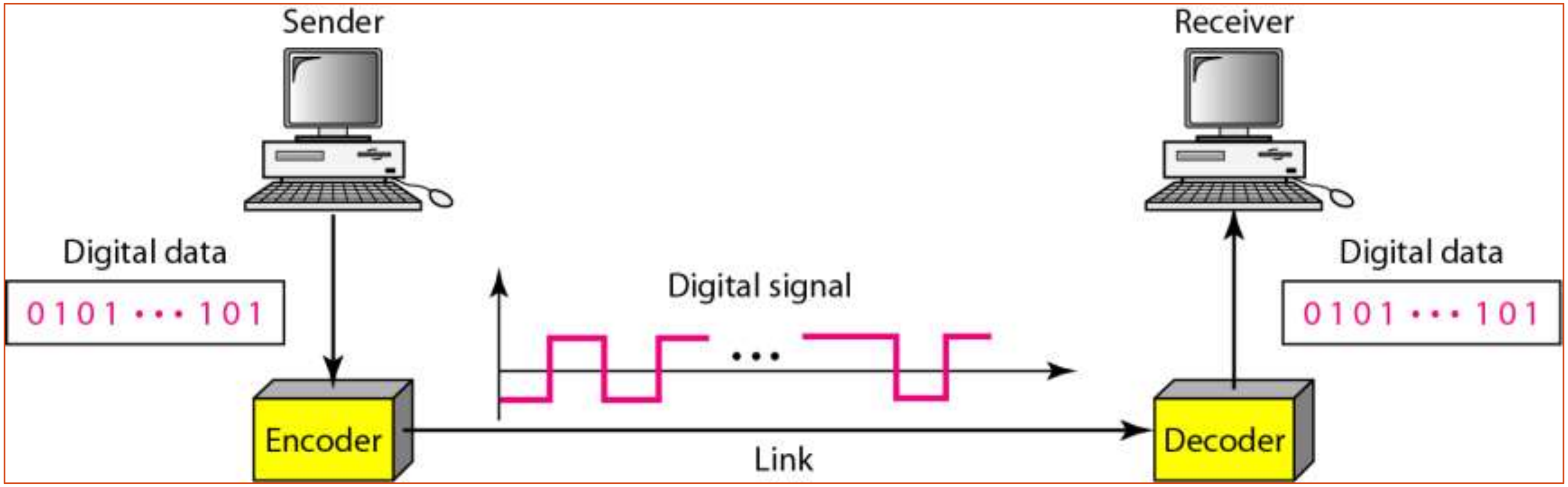
Unit 3

Digital Data Transmission

What is Line Coding?

- **The input to a digital system is in the form of sequence of digits.**
- The input can be from the sources such as data set, computer, digitized voice (PCM), digital TV or Telemetry equipment.
- ***Line coding*** **is the process in which the digital input is coded into electrical pulses or waveforms for the transmission over channel.**
- **Regenerative Repeaters** are used at regular intervals along a digital transmission line to detect the incoming digital signal and to transmit the new clean pulse for the further transmission along the line.

Line Coding


Sender
Receiver
Digital data
0101 ••• 101
Digital signal
Digital data
0101 ••• 101
Encoder
Link
Decoder

Line Coding

- There are many ways of assigning pulses (waveforms) to the digital data.

- For example a high voltage level (+V) could represent a "1" and a low voltage level (0 or -V) could represent a "0".

Line Coding-Examples

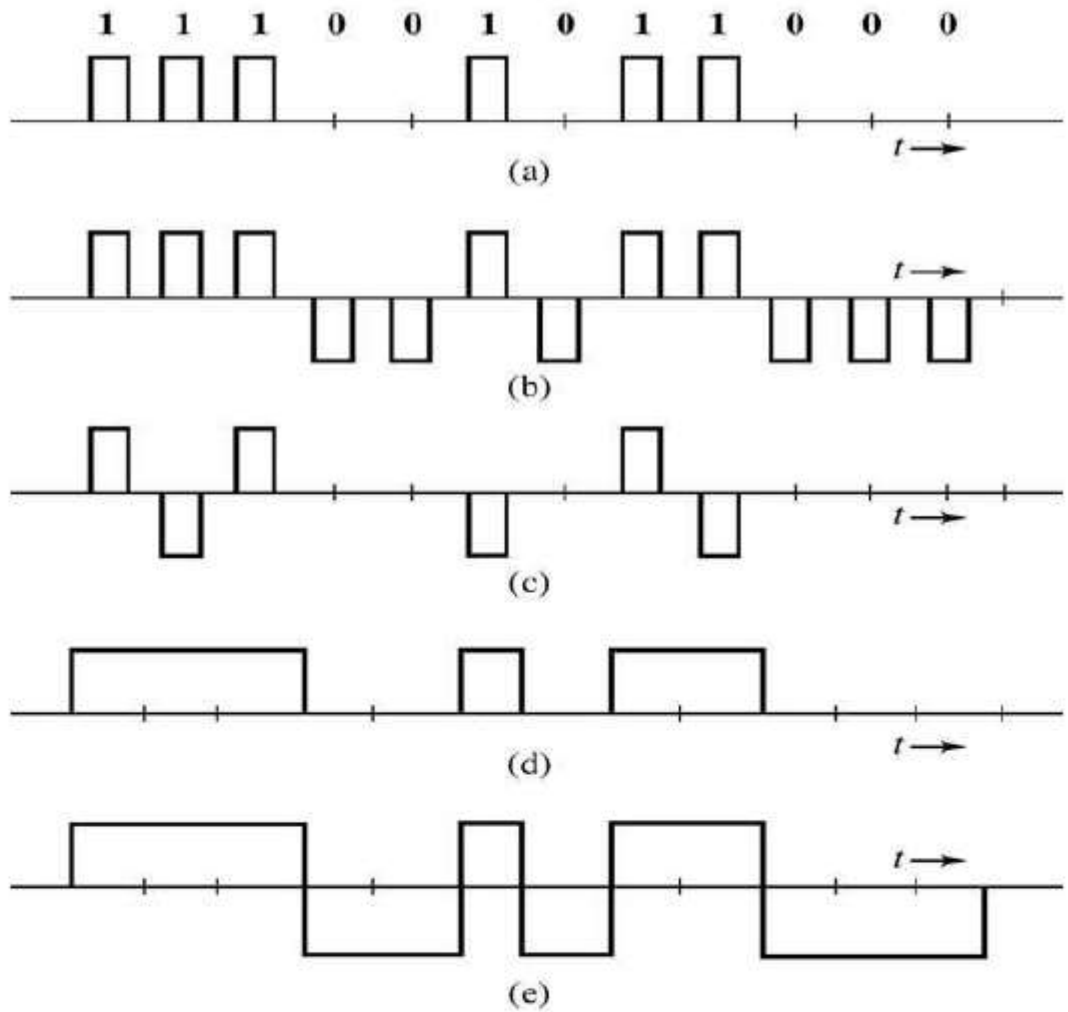
on-off (RZ)

polar (RZ)

bipolar/AMI (RZ)

on-off (NRZ)

polar (NRZ)



RZ = return to zero, NRZ = non return to zero

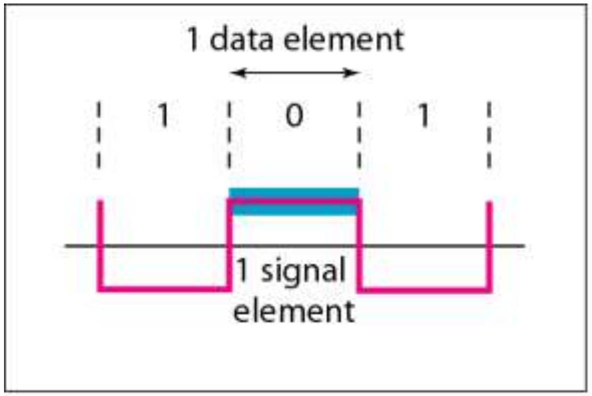
Line Coding

Signal element versus Data element

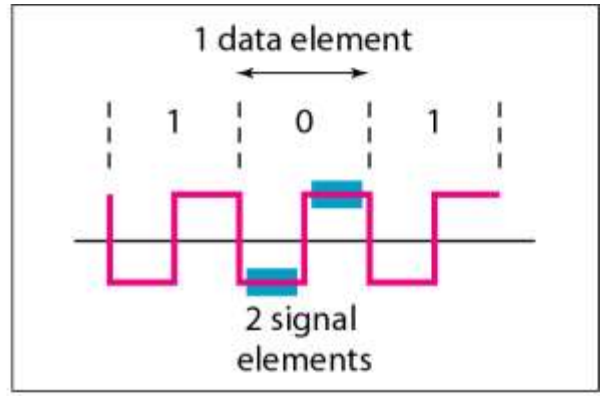
- Data element (1s & 0s) are what we need to send and signal elements (+V & -V voltages) are what we can send.
- Data elements are being carried and signal elements are the carriers.

- The data rate defines the number of bits sent per sec - 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**.

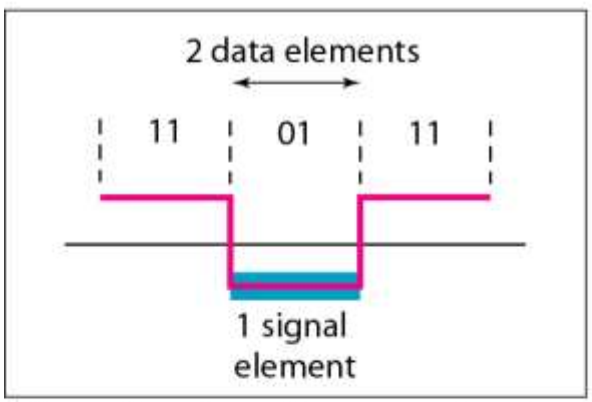
Line Coding



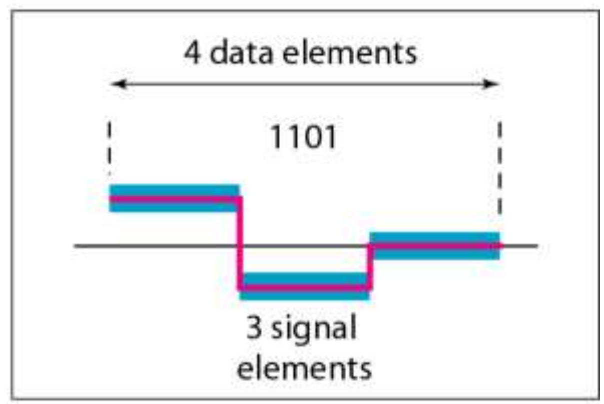
a. One data element per one signal element (r = 1)



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



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

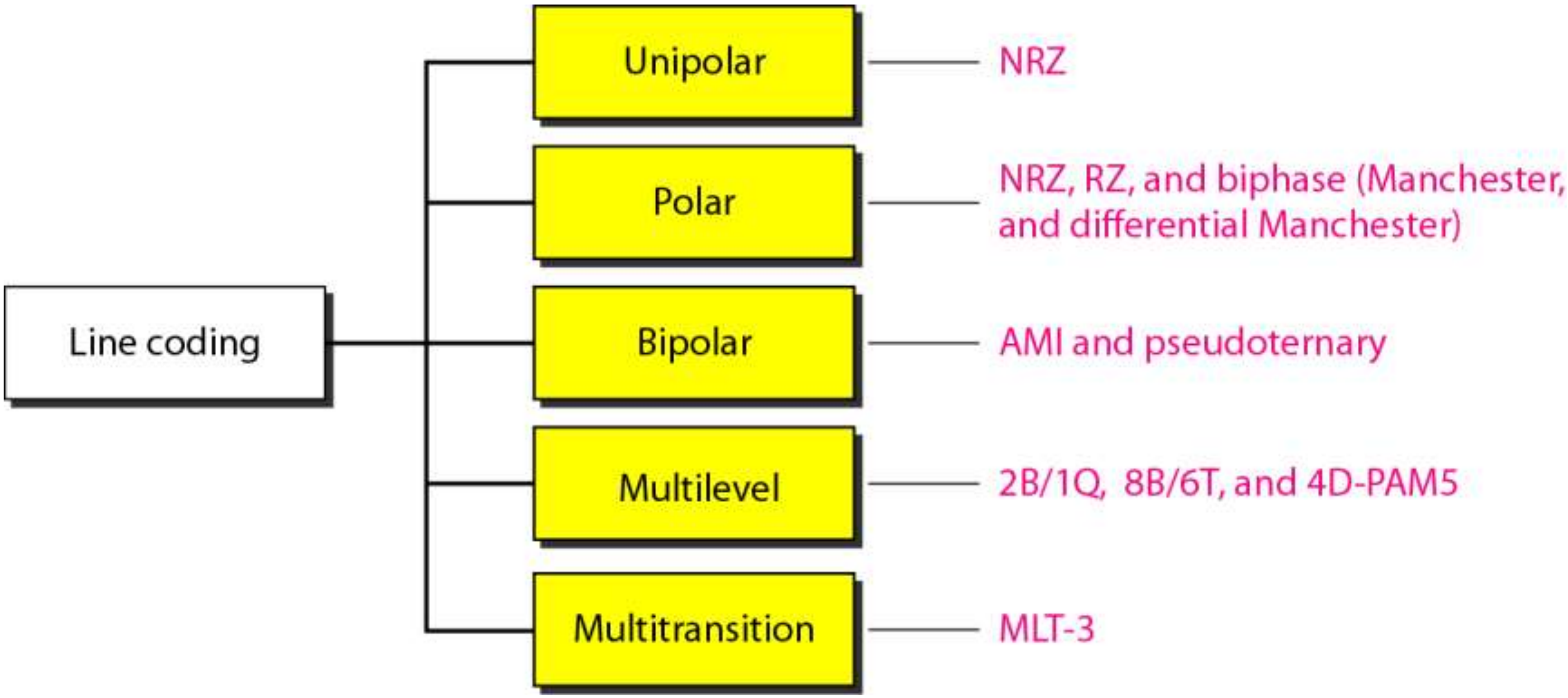


d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

Line Coding Requirements

- Small transmission bandwidth
- Power efficiency: as small as possible for required data rate and error probability
- Error detection/correction
- Timing information: clock must be extracted from data
- Transparency: all possible binary sequences can be transmitted.

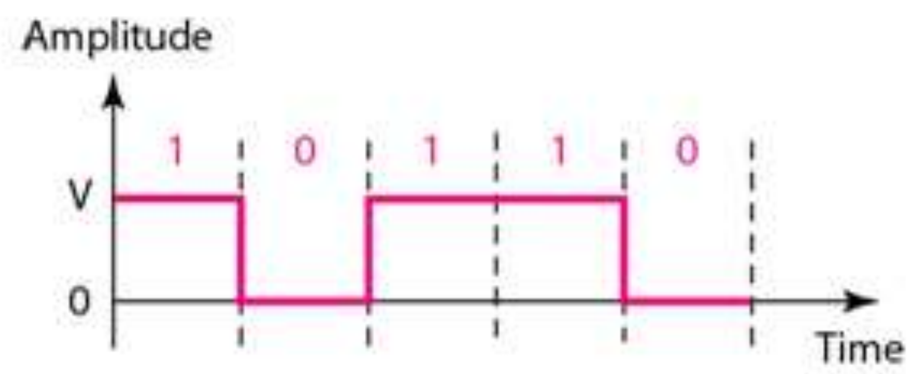
LINE CODING


Line coding
Unipolar
NRZ
Polar
NRZ, RZ, and biphase (Manchester, and differential Manchester)
Bipolar
AMI and pseudoternary
Multilevel
2B/1Q, 8B/6T, and 4D-PAM5
Multitransition
MLT-3

Unipolar NRZ

- **All signal levels are on one side of the time axis - either above or below.**

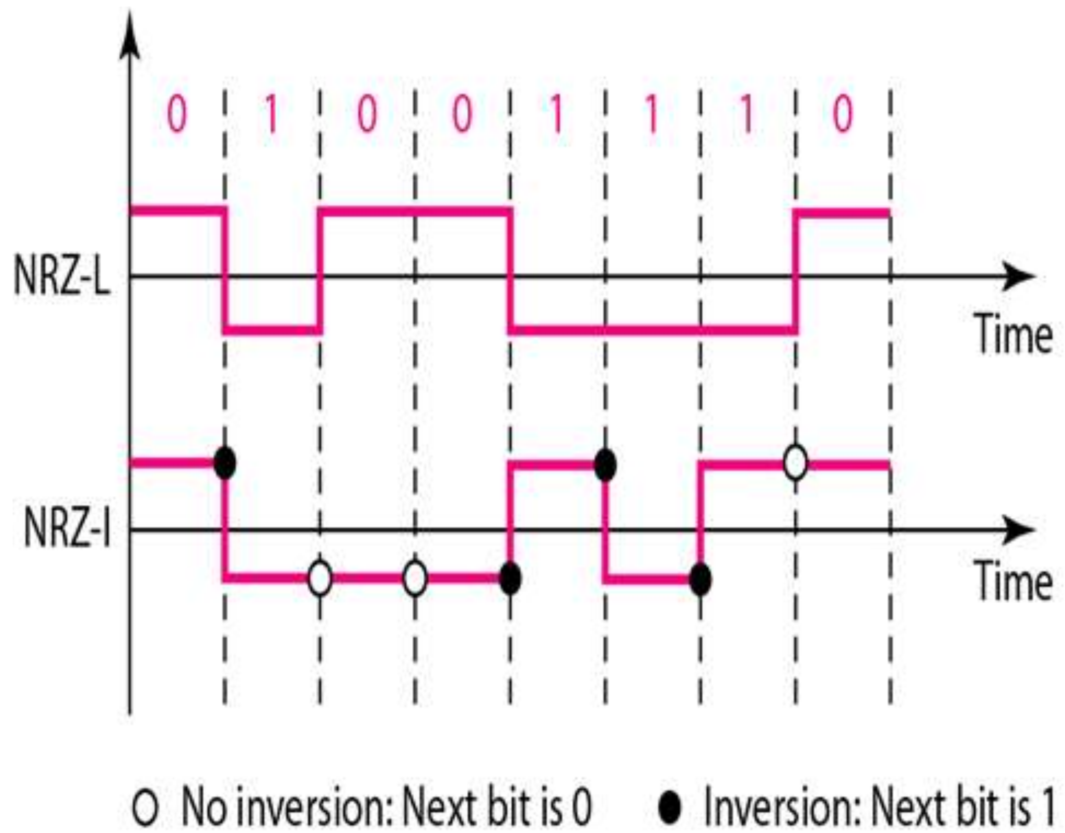
- NRZ - **Non Return to Zero** scheme is an example of this code. The signal level does not return to zero during a symbol transmission.



Polar - NRZ

- **The voltages are on both sides of the time axis.**
- Polar NRZ scheme can be implemented with two voltages. E.g. +V for 1 and -V for 0.
- There are two versions:
  - **NZR - Level (NRZ-L)** - positive voltage for one symbol and negative for the other.
  - **NRZ - Inversion (NRZ-I)** - the change or lack of change in polarity determines the value of a symbol. E.g. a “1” symbol inverts the polarity a “0” does not.

Polar - NRZ



0
1
0
0
1
1
1
0
NRZ-L
Time
NRZ-I
Time
No inversion: Next bit is 0
Inversion: Next bit is 1

Question

1. ***Draw the graph of the NRZ-I scheme using each of the following data stream assuming that the last signal level has been positive.***

    a. *11111111*

    b. *00000000*

    c. *00110011*

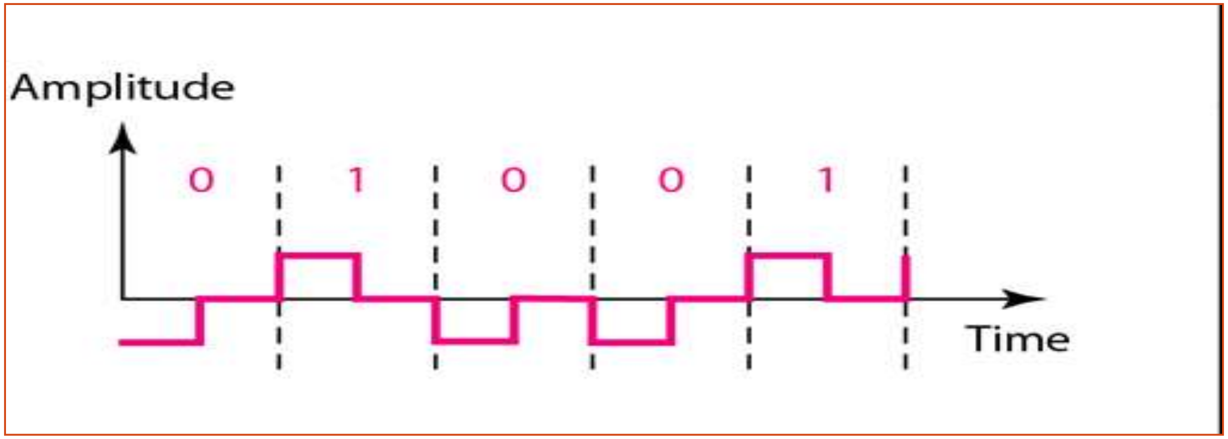
    d. *01010101*

Problem with NRZ coding

- 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.

Polar - RZ

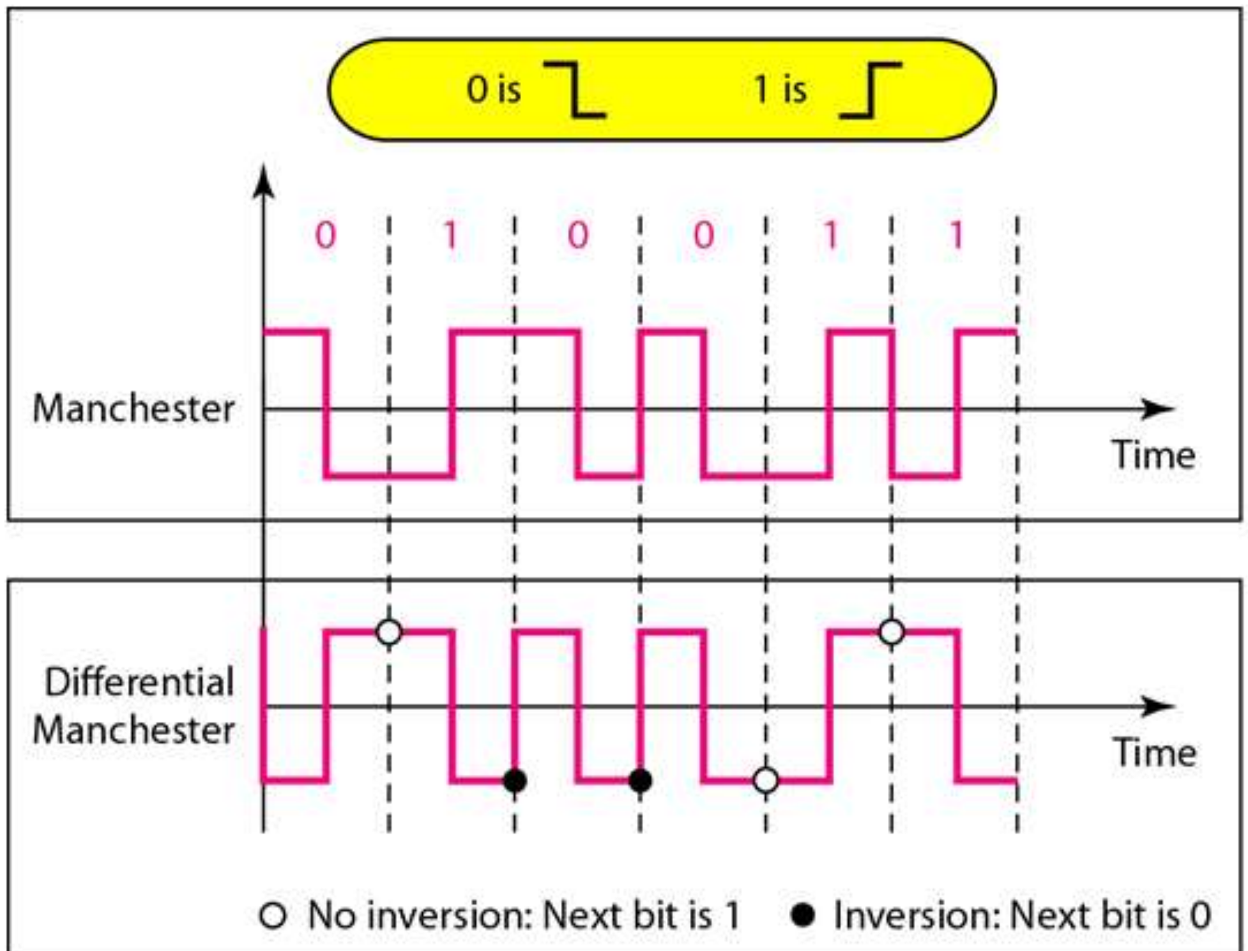
- The Return to Zero (RZ) scheme uses three voltage values. +, 0, - .
- **Each symbol has a transition in the middle. Either from high to zero or from low to zero.**
- **Self synchronization - transition indicates symbol value.**



Polar - Biphase: Manchester and Differential Manchester

- Manchester coding consists of combining the NRZ-L and RZ schemes.
  - Every symbol has a level transition in the middle: from high to low or low to high. Uses only two voltage levels.
- Differential Manchester coding consists of combining the NRZ-I and RZ schemes.
  - Every symbol has a level transition in the middle. But the level at the beginning of the symbol is determined by the symbol value. One symbol causes a level change the other does not.

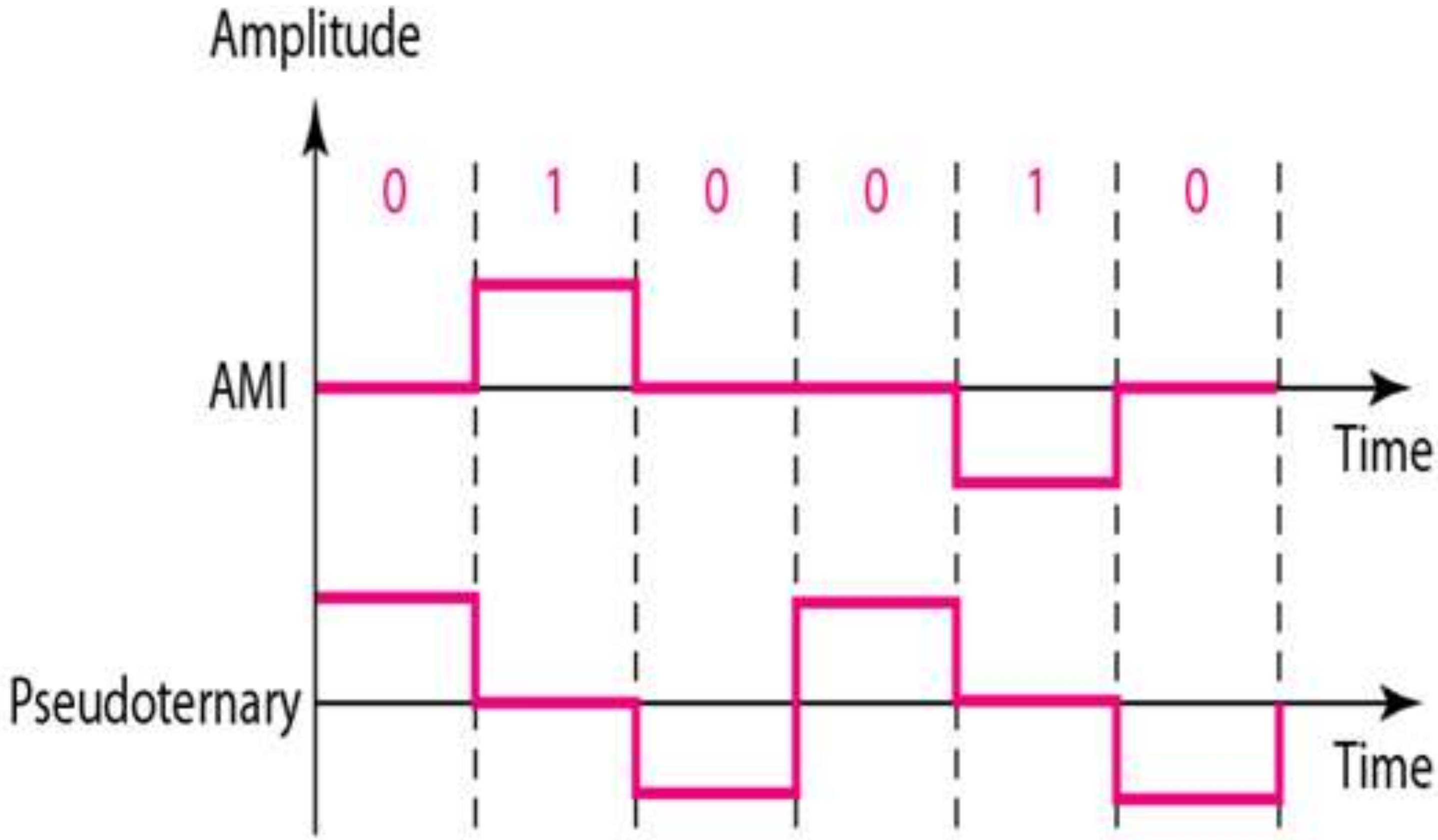
Polar - Biphase: Manchester and Differential Manchester



Bipolar - AMI and Pseudoternary

- Code uses 3 voltage levels: - +, 0, -, to represent the symbols (note not transitions to zero as in RZ).
- Voltage level for one symbol is at "0" and the other alternates between + & -.
- Bipolar Alternate Mark Inversion (AMI) - **the "0" symbol is represented by zero voltage and the "1" symbol alternates between +V and -V.**
- Pseudoternary is the reverse of AMI.

Bipolar - AMI and Pseudoternary



Multilevel Schemes

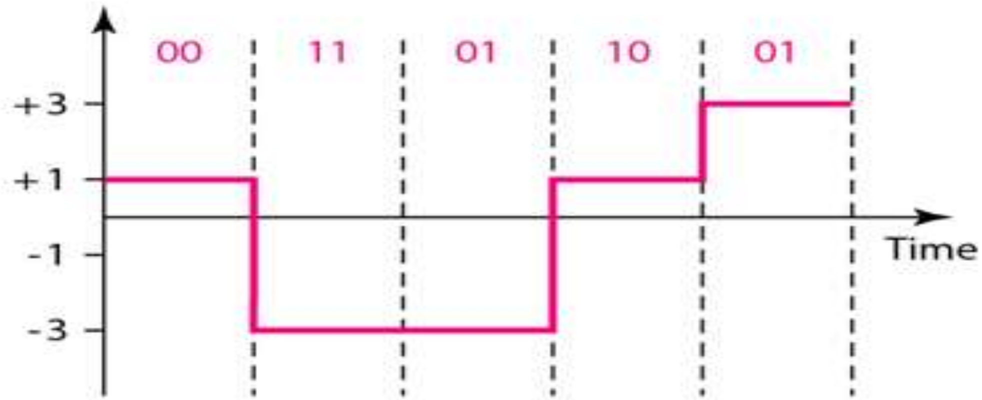
- We use the notation mBnL, where m is the no of data elements in a symbol, B represents binary data, n represents the length of the signal pattern and L is the number of signal levels.

- A letter is often used in place of L : B(binary) for L=2, T ternary) for L=3 and Q(quaternary) for L=4

Multilevel 2B1Q Scheme

	Previous level: positive	Previous level: negative
Next bits	Next level	Next level
00	+1	-1
01	+3	-3
10	-1	+1
11	-3	+3

Transition table



Assuming positive original level

Applications of Line Coding

- **NRZ encoding**: RS232 based protocols
- **Manchester encoding**: Ethernet networks
- **Differential Manchester encoding**: token-ring networks
- **NRZ-Inverted encoding:** Fiber Distributed Data Interface (FDDI)
- **2B1Q scheme**: high-bit-rate digital subscriber line (HDSL)

Scrambling

- **Scrambling** is a technique that does not increase the number of bits and does provide synchronization.

- Problem with technique like Bipolar AMI(Alternate Mark Inversion) is that continuous sequence of zero’s create synchronization problems.

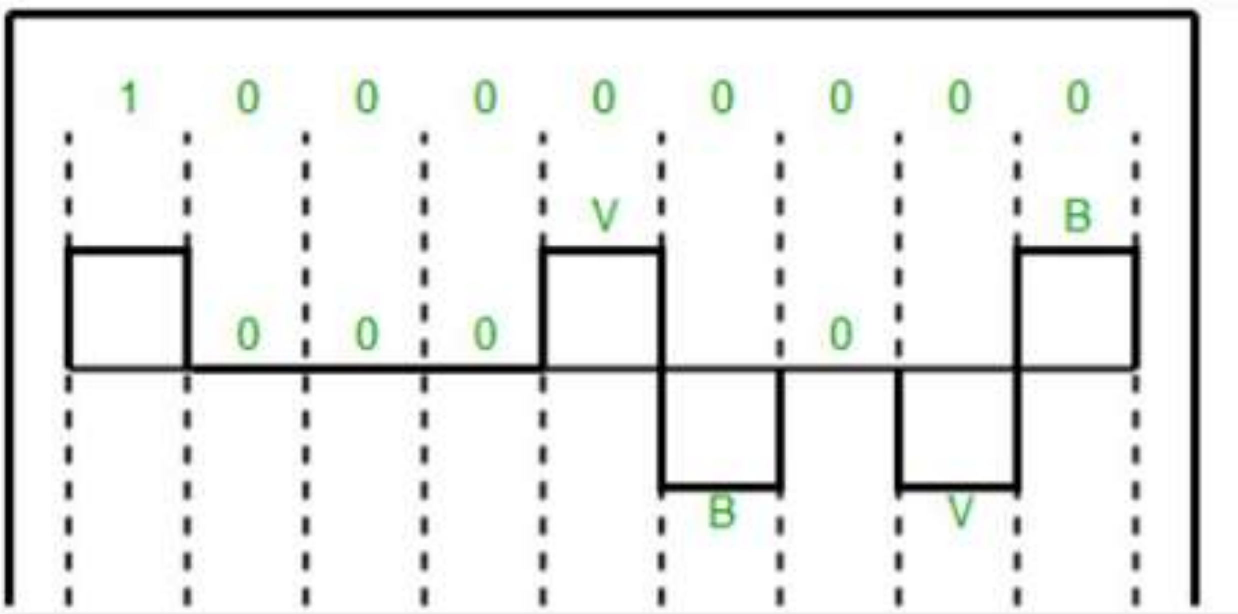
Scrambling techniques

- B8ZS(Bipolar with 8-zero substitution)

  This technique is similar to Bipolar AMI except when eight consecutive zero-level voltages are encountered they are replaced by the sequence,"000VB0VB".
- V(Violation), is a non-zero voltage which means signal have same polarity as the previous non-zero voltage. Thus it is violation of general AMI technique.
- B(Bipolar), also non-zero voltage level which is in accordance with the AMI rule (i.e., opposite polarity from the previous non-zero voltage).

B8ZS(Bipolar with 8-zero substitution)

Example: Data = 100000000

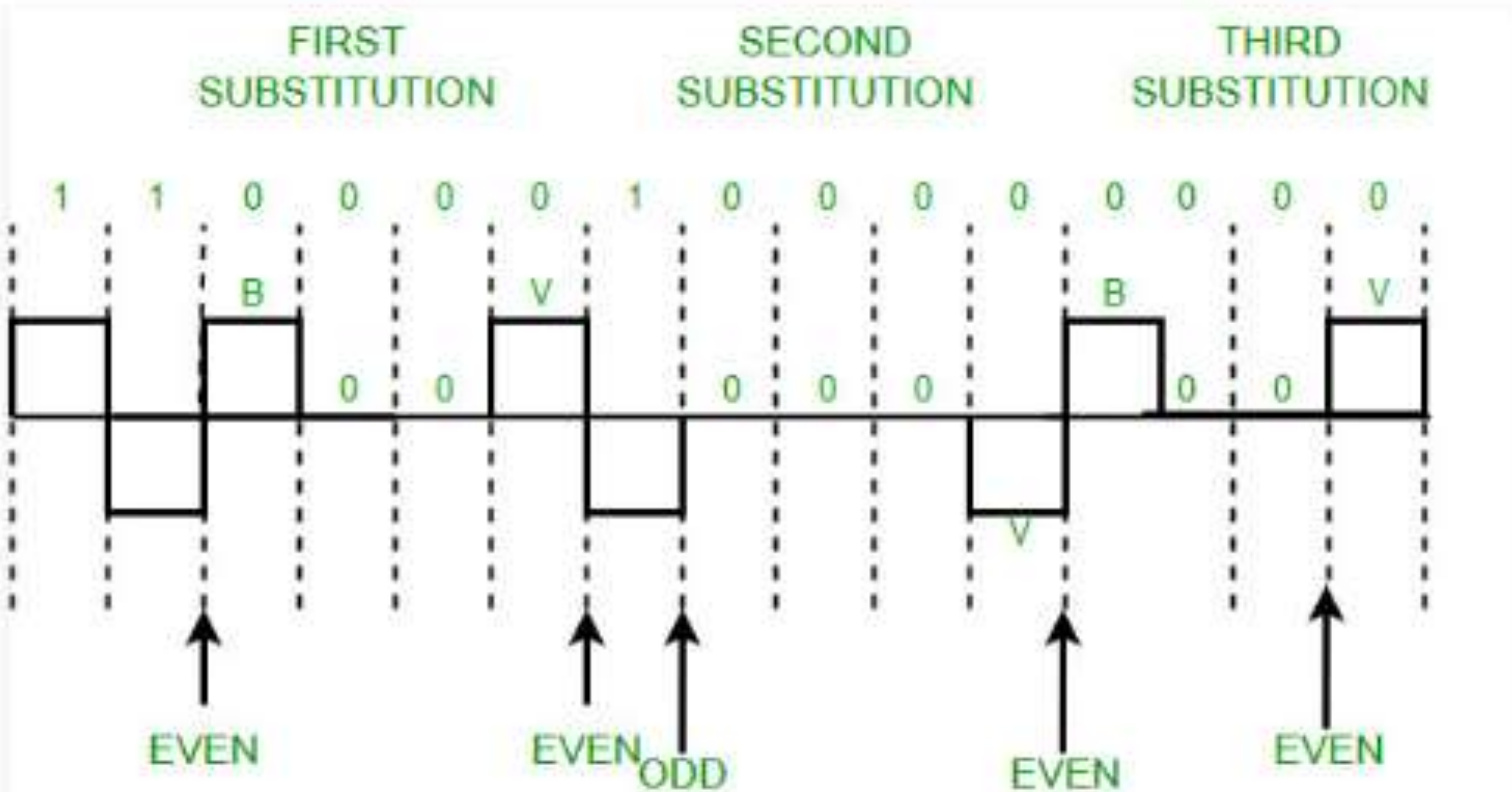


HDB3(High-density bipolar 3-zero)

- In this technique <u>four consecutive zero-level voltages are replaced with a sequence "000V" or "B00V".</u>
- Rules for using these sequences:
- If the number of nonzero pulses after the last substitution is odd, the substitution pattern will be "000V", this helps maintaining total number of nonzero pulses even.
- If the number of nonzero pulses after the last substitution is even, the substitution pattern will be "B00V". Hence even number of nonzero pulses is maintained again.

HDB3(High-density bipolar 3-zero)

Example: Data = 1100001000000000

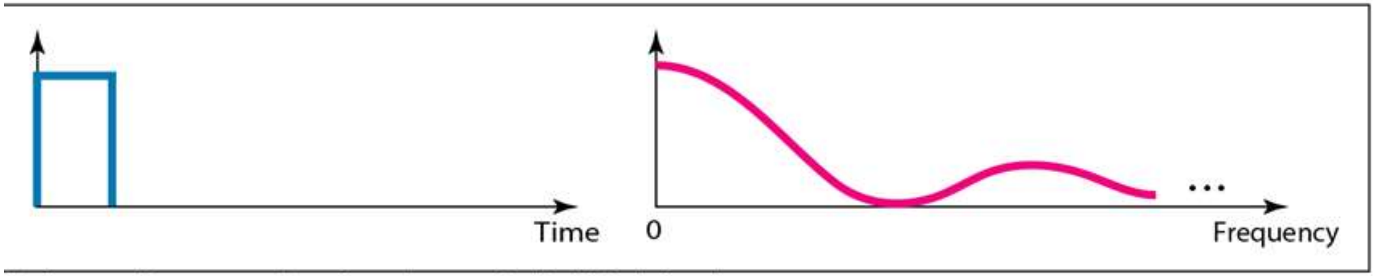


HDB3 scrambling technique:

- **Explanation –** After representing first two 1's of data we encounter four consecutive zeros. Since our last substitutions were two 1's(thus number of non-zero pulses is even).
- So, we substitute four zeros with "B00V".

Pulse Transmission over Band Limited Channel

- A digital signal is a composite analog signal with an infinite bandwidth.

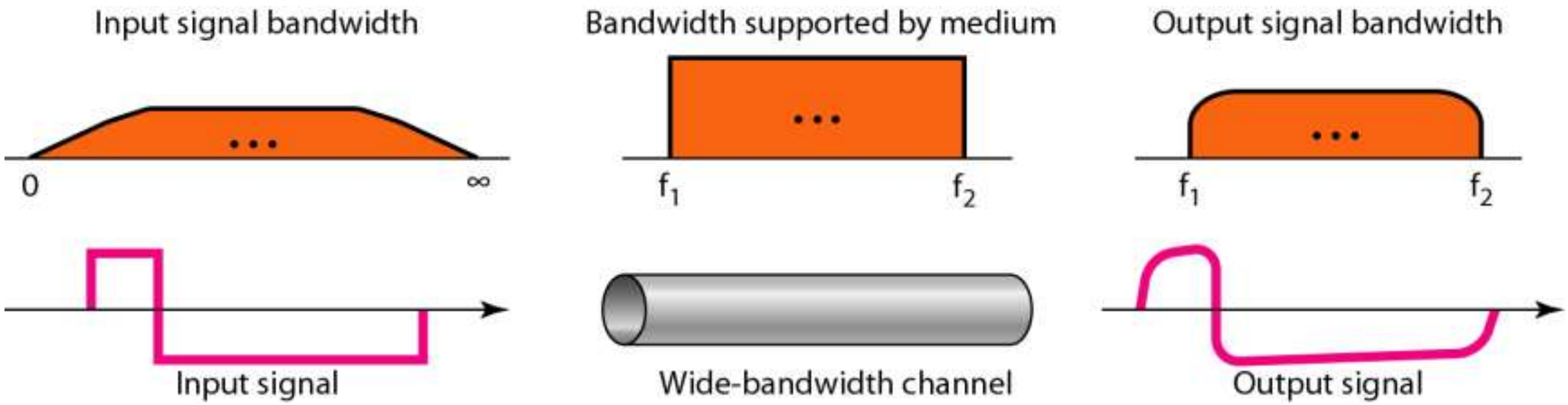


b. Time and frequency domains of nonperiodic digital signal

- A signal **can not be time-limited and band-limited** simultaneously.

Pulse Transmission over Band Limited Channel

- Baseband transmission of a digital signal that preserves the shape of the digital signal is possible only if we have a low-pass channel with an infinite or very wide bandwidth.



Pulse Transmission over Band Limited Channel

- In practice, **communications channels have a limited bandwidth, and hence transmitted pulses tend to deviate from the assumed rectangular shape and be spread during transmission.**

- Spreading of a pulse beyond its interval cause it to interfere with neighboring pulses. This is known as **Inter Symbol Interference (ISI)** which cause error in correct detection of the pulses.

Inter Symbol Interfernce

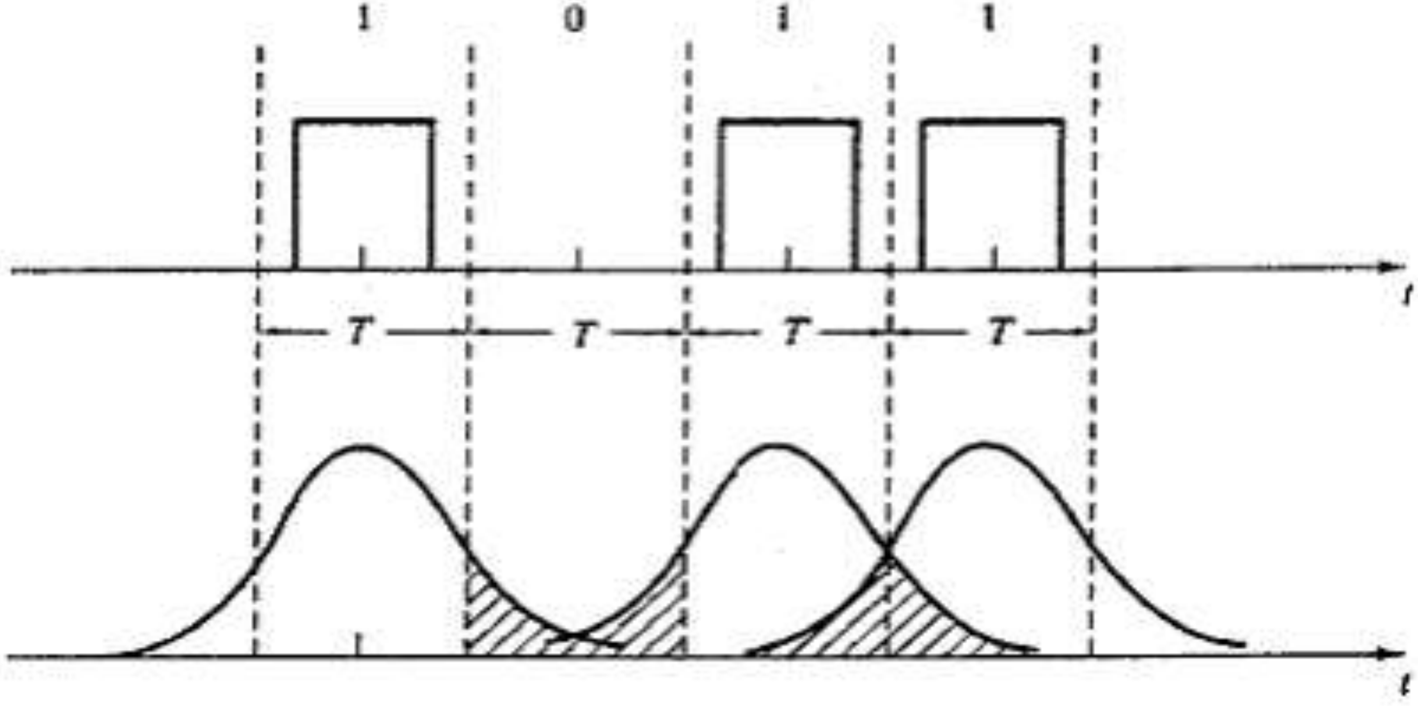
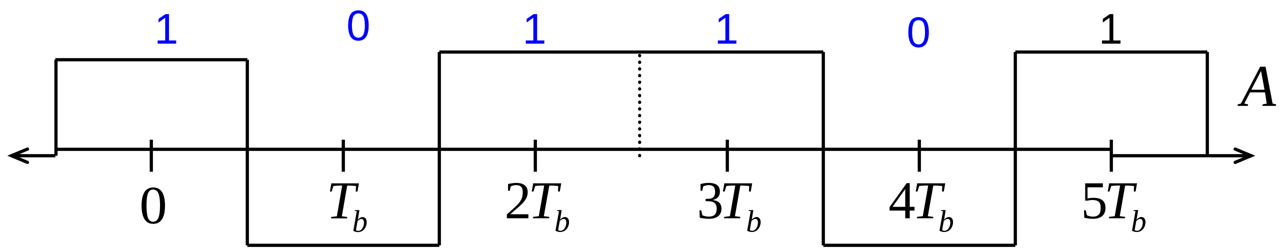


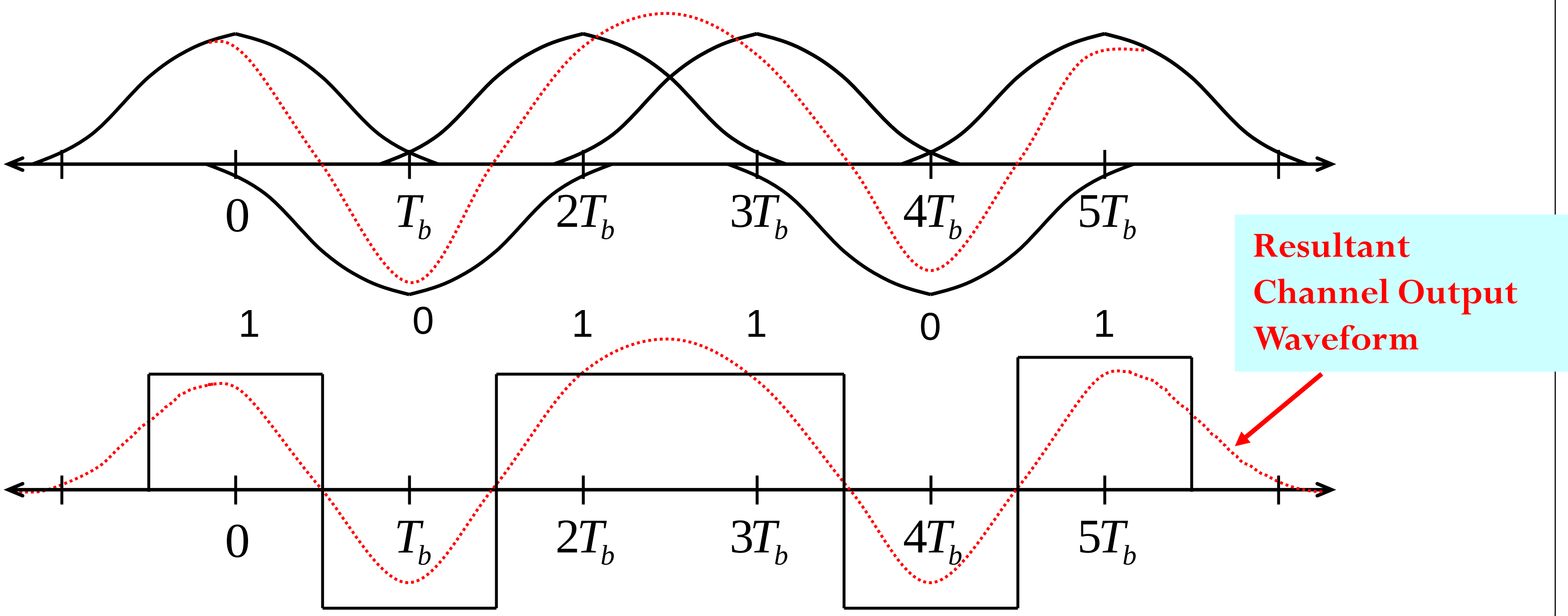
Fig. 5-12 Intersymbol interference in digital transmission

Intersymbol Interference

- For the input data stream:



- The channel output is the superposition of each bit's output:



Pulse Shaping

- Nyquist proposed that a zero–ISI pulse p(t) must satisfy the condition

$$p(t) = \begin{cases} 1, & t = 0 \\ 0, & t = \pm T_b, \pm 2T_b, \ldots \end{cases}$$

sinc pulse

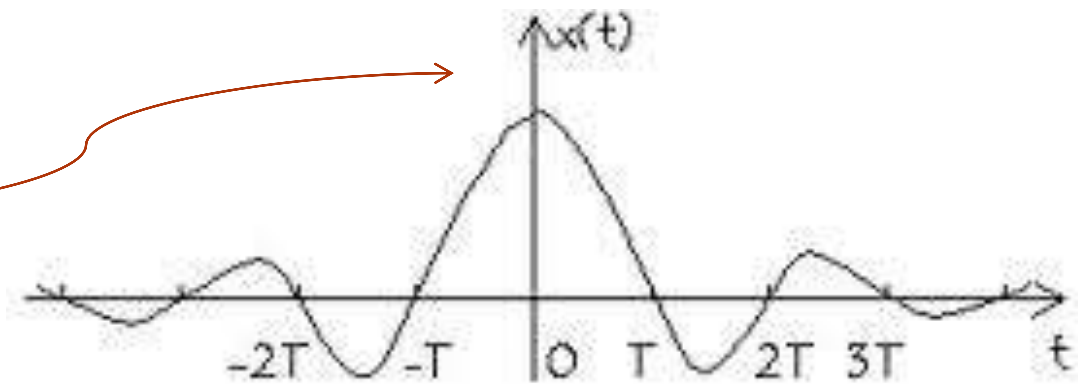
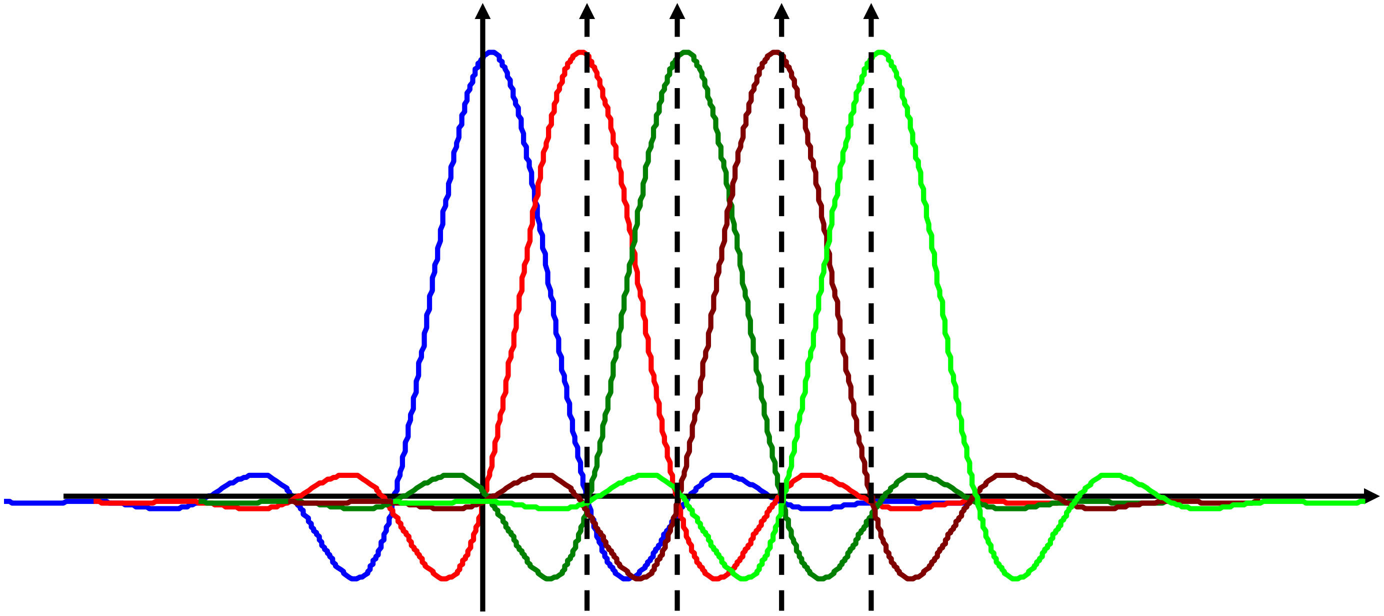


Figure 2.11 – Response (pulse) corresponding to no intersymbol interference

Nyquist's First Method for Zero ISI

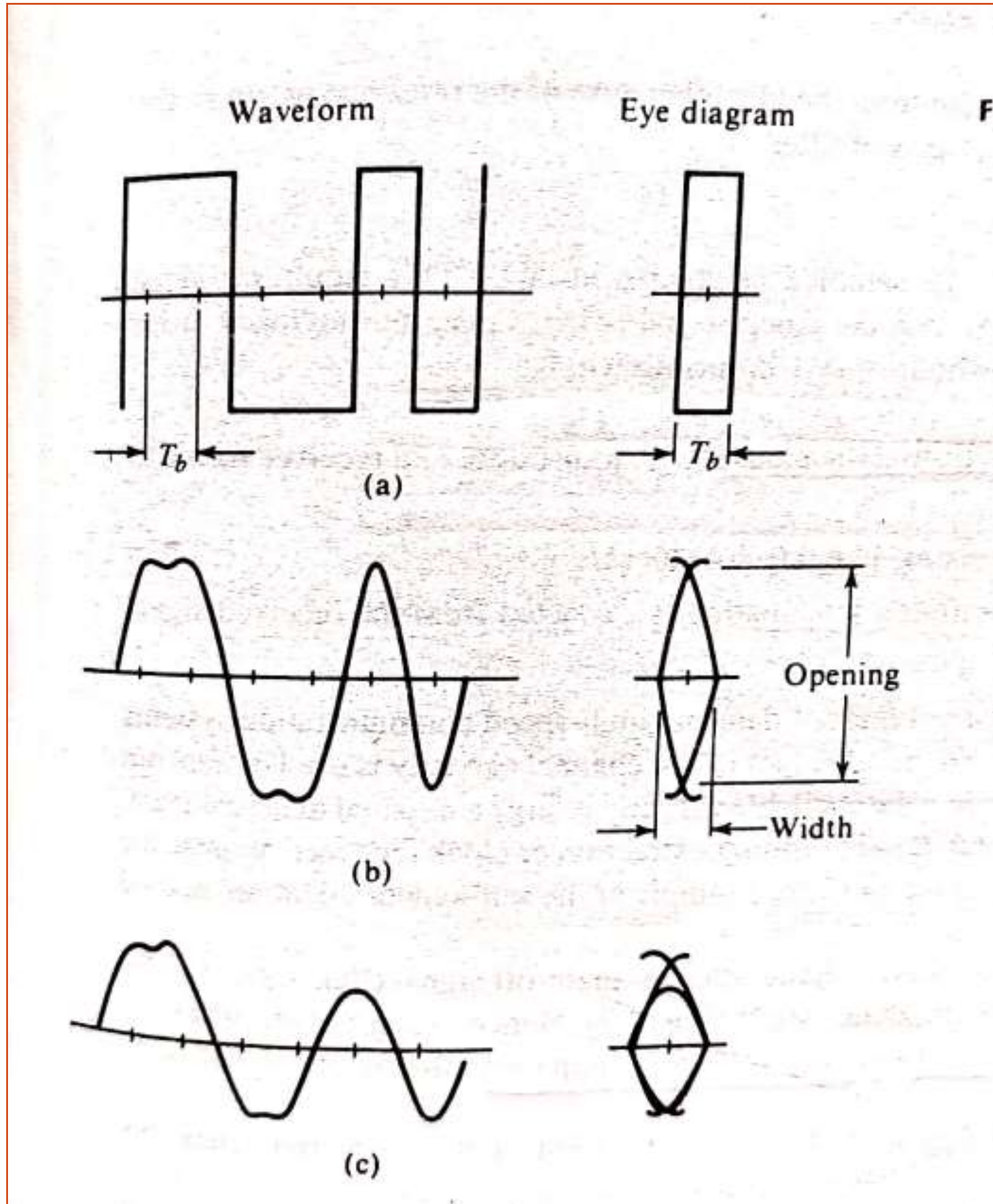


- ISI occurs but, NO ISI is present at the sampling instants.

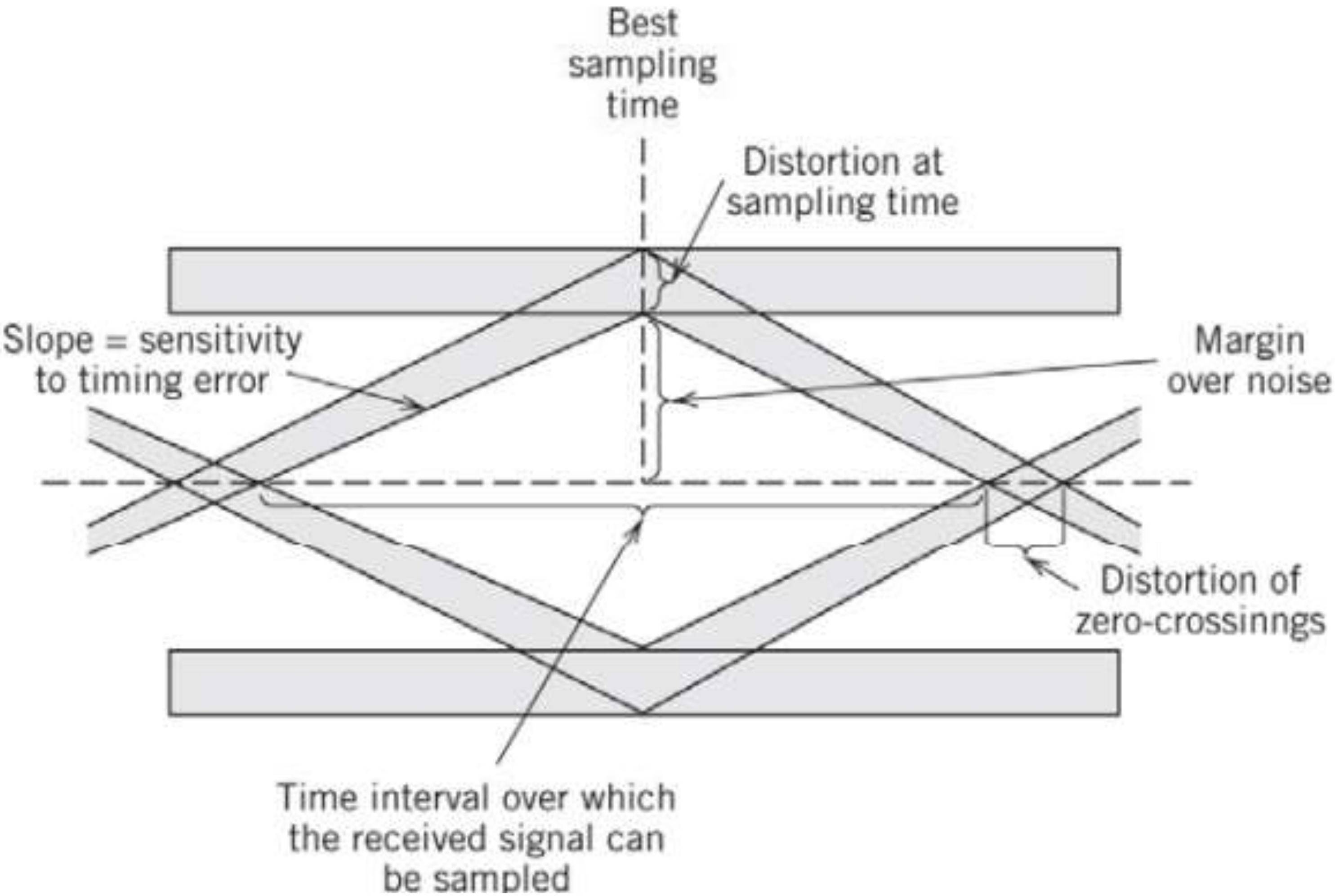
Eye Pattern

- The ISI & other signal degradation can be studied conveniently on oscilloscope through **Eye pattern.**
- A random binary pulse sequence is sent over the channel. The channel output is applied to the input of an oscilloscope.
- **The time base of the scope is kept same as the interval of one pulse (T_b).**
- **The oscilloscope shows the superposition of several traces which is the input signal cut up every Tb and then superimposed.**
- The eye pattern looks like a human eye and hence the name eye diagram.

- Consider the transmission of binary signal by polar rectangular pulses.
- If the channel bandwidth is infinite the eye pattern will be as shown in **fig. a**
- If channel is not distortion less, received pulses will ne rounded and spread out. If ISI is eliminated at the sampling instants, the eye pattern will be as shown in **fig. b.**
- If ISI is not zero at sampling instants, pulses values will deviate from thei full sacle values and which causes a blur and closing eye partially at midpoint**. Fig. c**



EYE PATTERN


Best sampling time
Distortion at sampling time
Slope = sensitivity to timing error
Margin over noise
Distortion of zero-crossinngs
Time interval over which the received signal can be sampled

Eye Pattern

- The **width of the eye opening** defines the time interval over which the received signal can be sampled without error from intersymbol interference. The preferred time for sampling is the instant of time at which the eye is open the widest.

- The sensitivity of the system to timing errors is determined by the **rate of closure of the eye** as the sampling time is varied.

- The **height of the eye opening** defines the noise margin of the system.

- When the effect of ISI is severe, traces from the upper portion of the eye pattern cross traces from the lower portion and the eye is completely closed.

- In this situation, it is impossible to avoid errors due to the presence of intersymbol interference in the system.