CS311: Data Communication

Transmission of Digital Signal - I

by

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Outline of the Lecture

- Introduction
- Important characteristics of Line Coding
- Popular line coding techniques:
  - Unipolar
  - Polar
  - Bipolar
- Modulation rate of various code
- Comparison of line coding techniques

- Scrambling Coding schemes

- Basic concepts of Block Coding
- Block coding examples

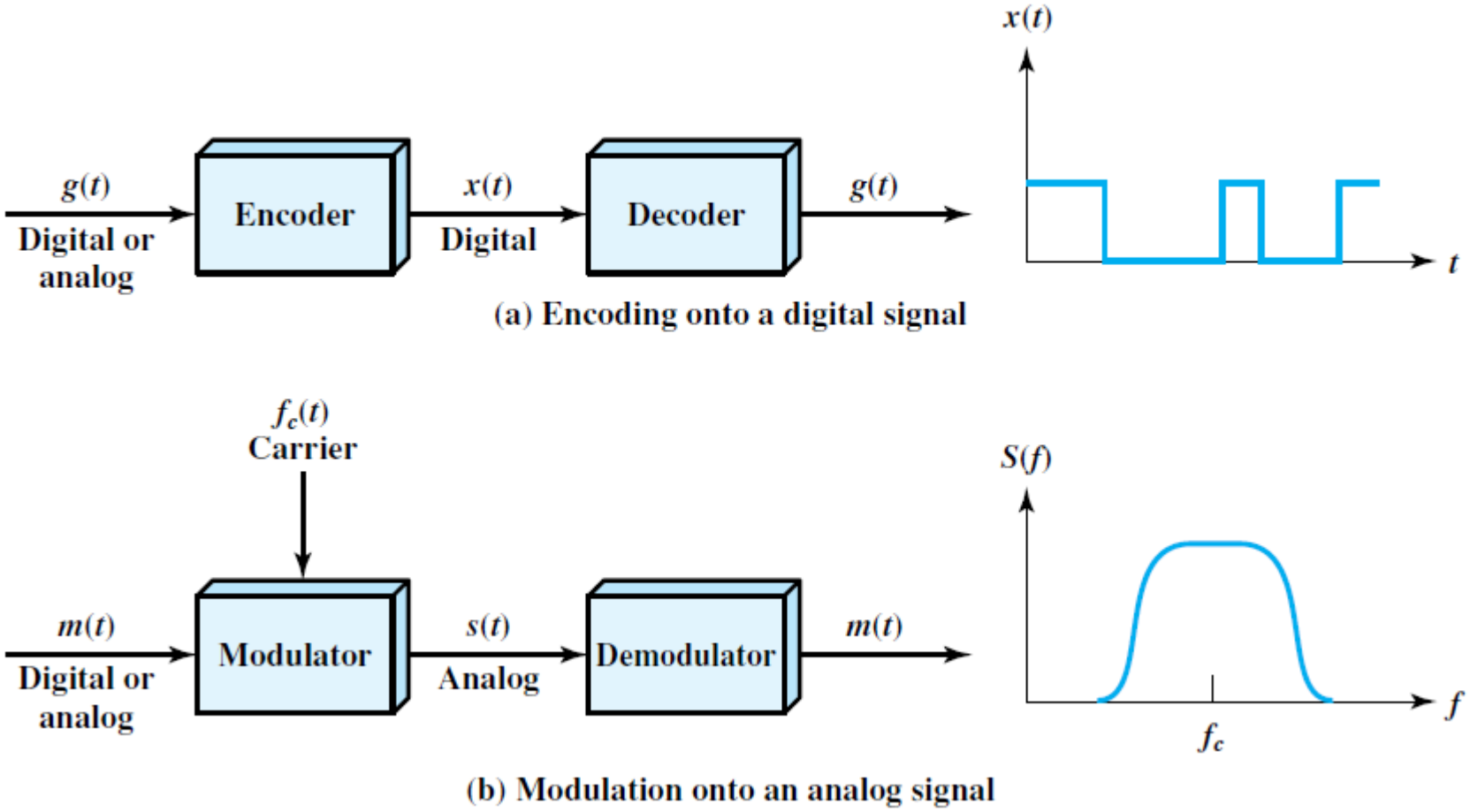
Introduction

- Both analog and digital information can be encoded as either analog or digital signals.

- Various conversion technique used

Data	Singal	Approach
Digital	Digital	Encoding
Analog	Digital	Encoding
Analog	Analog	Modulation
Digital	Analog	Modulation

Cont…



- What type of signal should we use?
  - It depends on the situation and available bandwidth

Digital Data - Digital Signal

- Digital or Analog data is converted to digital signal for tansmission.

- A digital signal is a sequence of discrete, discontinuous voltage pulses. Each pulse is a signal element.

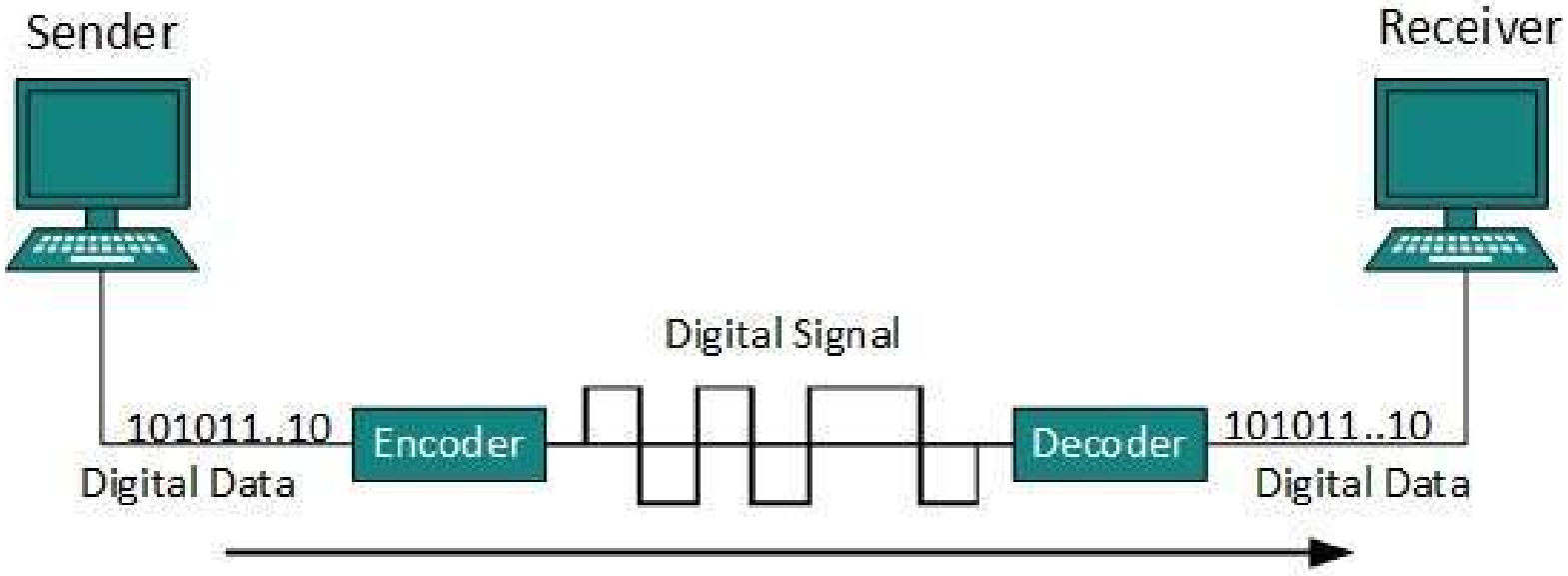


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Table 5.1 Key Data Transmission Terms

Term	Units	Definition
Data element	Bits	A single binary one or zero
Data rate	Bits per second (bps)	The rate at which data elements are transmitted
Signal element	Digital: a voltage pulse of constant amplitude	That part of a signal that occupies the shortest interval of a signaling code
	Analog: a pulse of constant frequency, phase, and amplitude	
Signaling rate or modulation rate	Signal elements per second (baud)	The rate at which signal elements are transmitted

- If the signal elements all have the same algebraic sign, that is, all positive or negative, then the signal is unipolar.

- In polar signaling, one logic state is represented by a positive voltage level, and the other by a negative voltage level.

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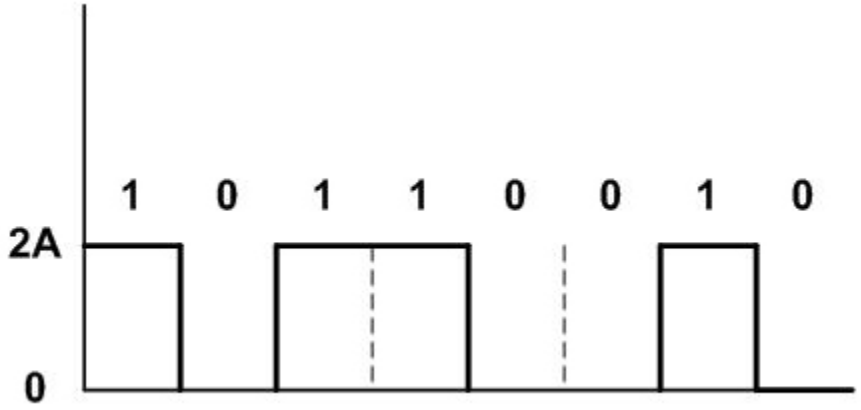
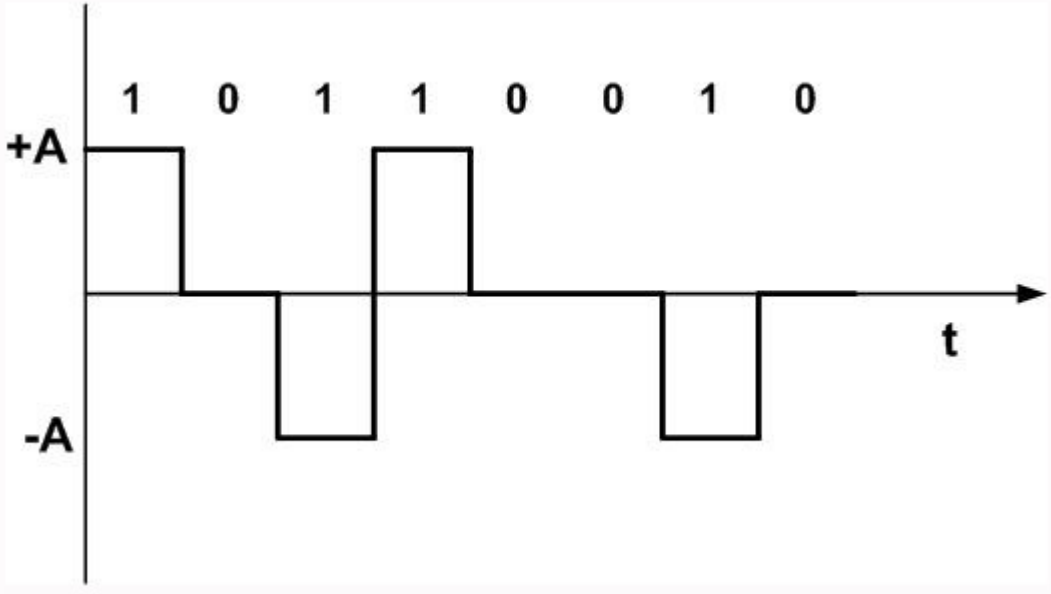


Two data levels and two signal levels



Two data levels and three signal levels

Encoding Schemes

- The encoding scheme is simply the mapping from data bits to signal elements.

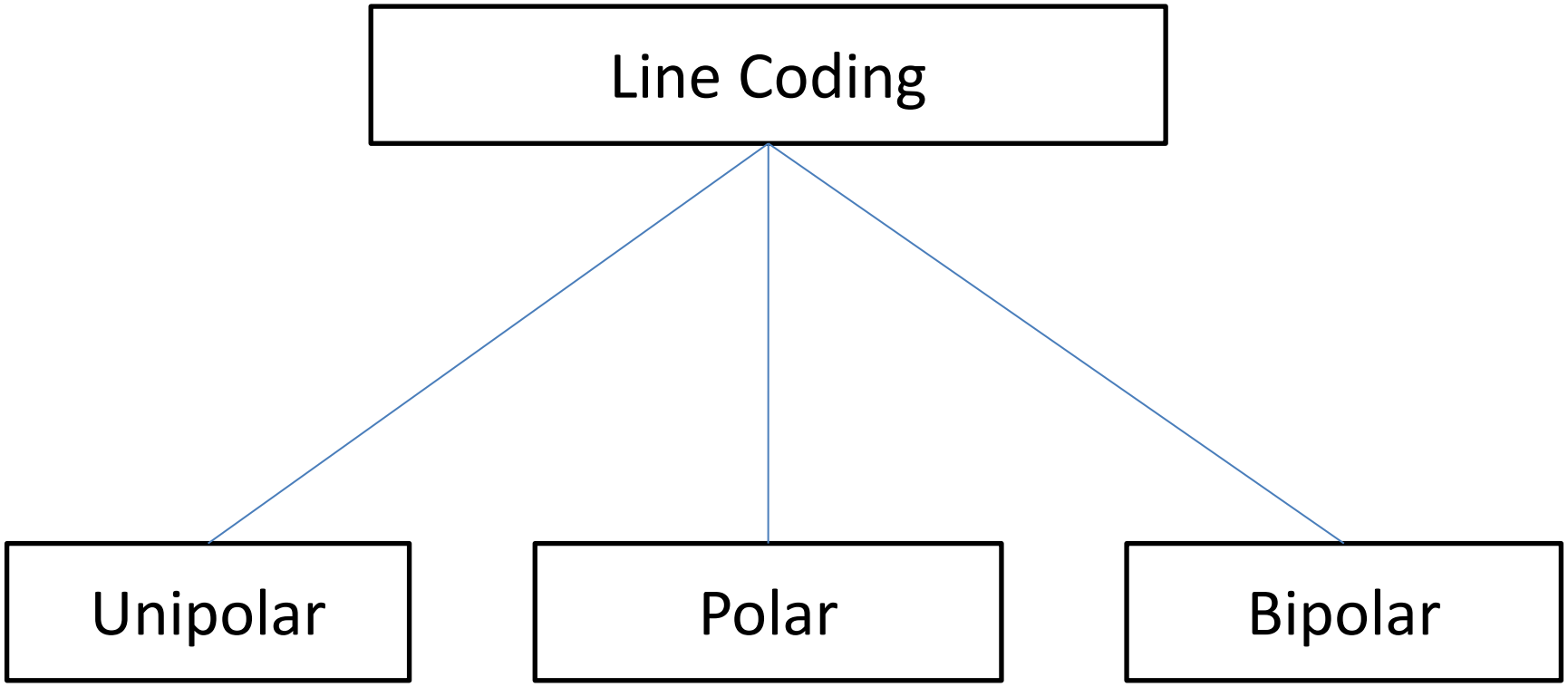
- The conversion / mapping involves three techniques:
  - Line Coding
  - Block Coding
  - Scrambling

Cont…

- Important Characteristics considered for evaluating or comparing the various techniques are:
  - No of signal levels
  - Bit rate and Baud rate
  - DC components : non-zero average signal power
  - Synchronization
    - clock is generated and synchronized from the received signal with the help of a special hardware known as Phase Lock Loop (PLL). This can be achieved if the received signal is self-synchronizing having frequent transitions (preferably, a minimum of one transition per bit interval) in the signal.
  - Signal Spectrum
  - Noise Immunity
  - Error Detection
  - Cost and complexity of Implantation

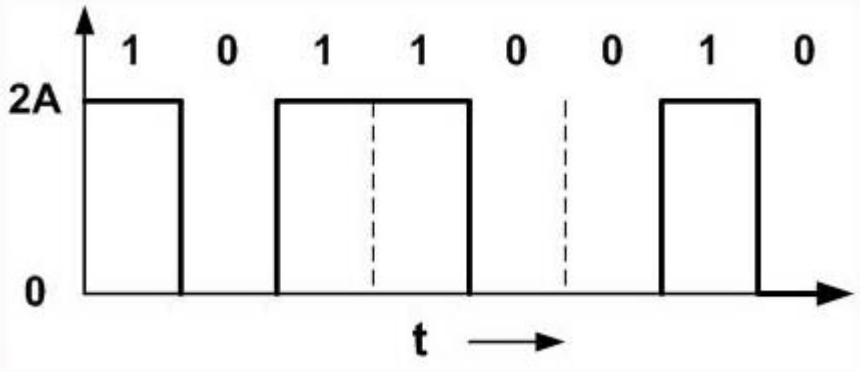
Line Coding Schemes

Converting a string of 1's and 0's (digital data) into a sequence of signals that denote the 1's and 0's.



Unipolar

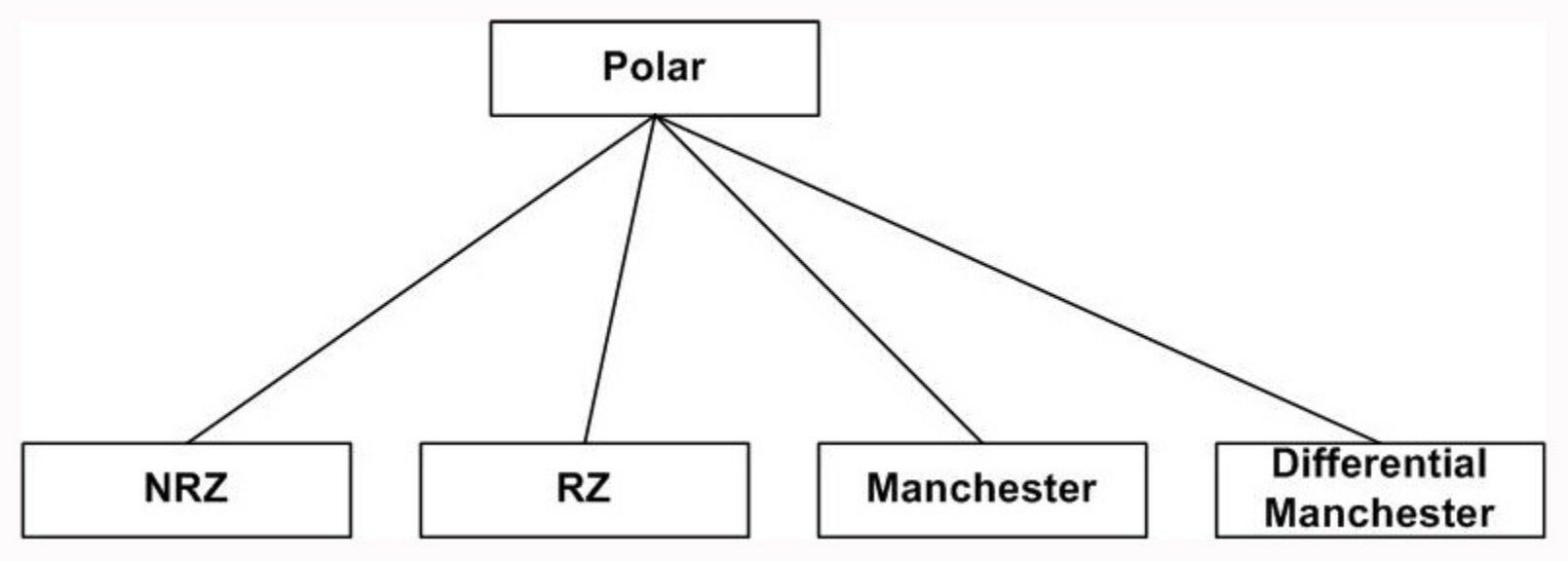
- Only two voltage levels are used



- It uses only one polarity of voltage level
- Bit rate is same as data rate
- DC components present
- Loss of synchronization for long sequences of 0's and 1's
- Simple but obsolate

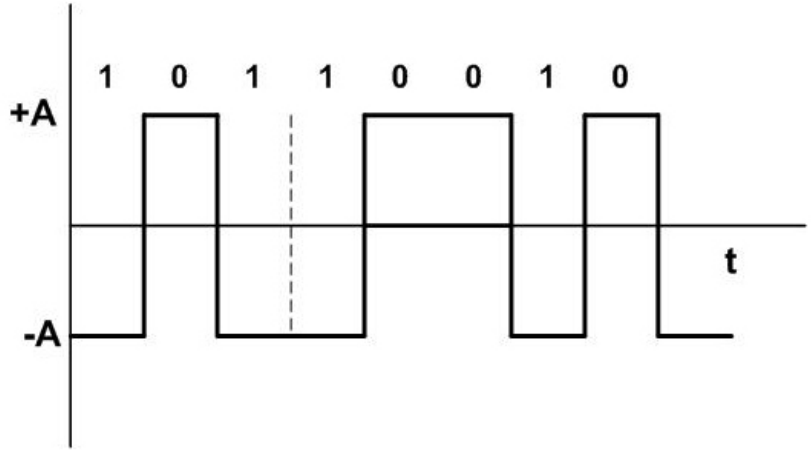
Polar

- Uses Two voltage levels - one positive and the other one negative



Non-Return to Zero (NRZ)

- Use two different voltage levels for two binary digits
- Voltage level is constant during a bit interval
- There are two NRZ schemes
  - Nonreturn to Zero-Level (NRZ-L)
  - Nonreturn to Zero Inverted (NRZI)

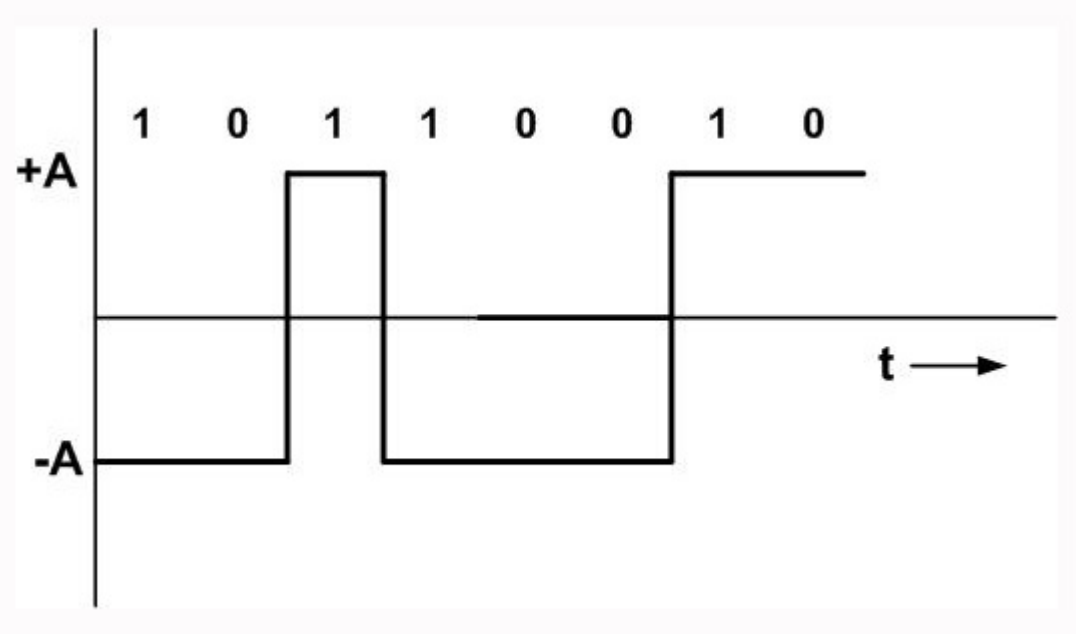


NRZ-L

1 = low level

0 = high level

NRZI



- For each 1 in the bit sequence, the signal level is inverted.
- A transition from one voltage level to the other represents a 1.

- NRZI is an example of differential encoding.
- In differential encoding, the information to be transmitted is represented in terms of the changes between successive signal elements rather than the signal elements themselves.

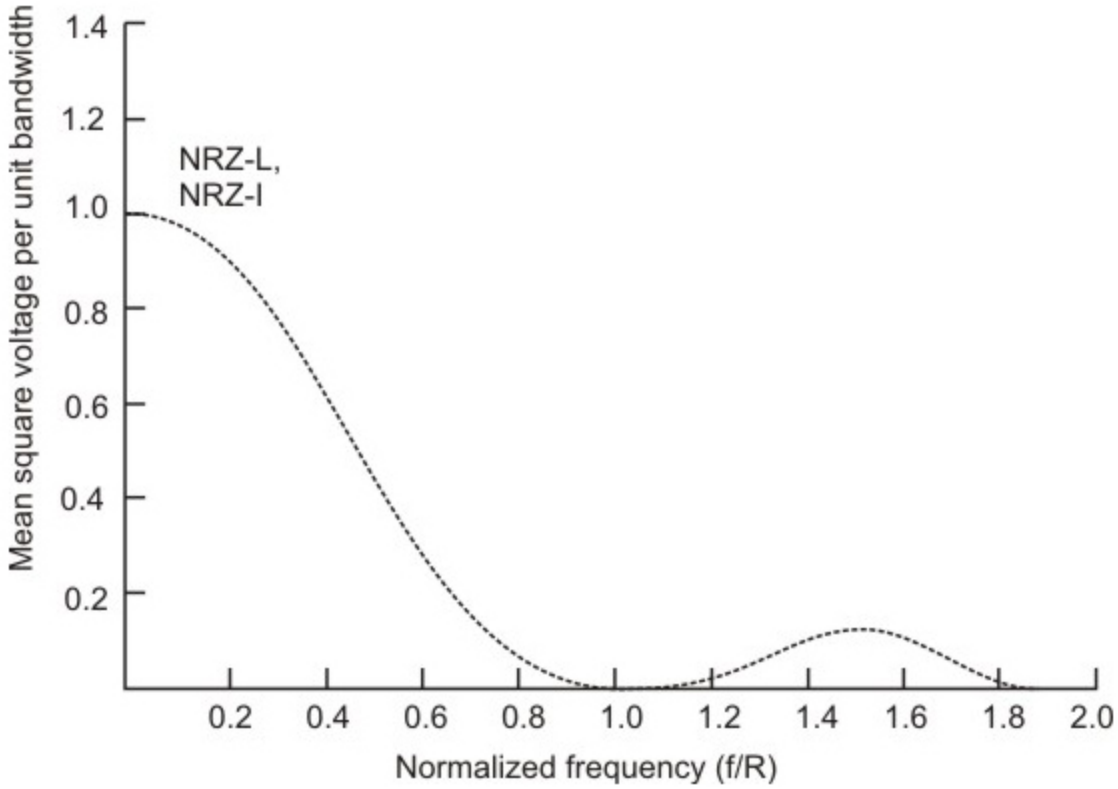
Characteristics of NRZ

- Two levels
- Bit rate same as baud rate

- Advantages:
  - Detecting a transition in presence of noise is more reliable than to compare a value to a threshold.
  - NRZ codes are easy to engineer and it makes efficient use of bandwidth
  - Most of the energy is concentrated between 0 and half the bit rate

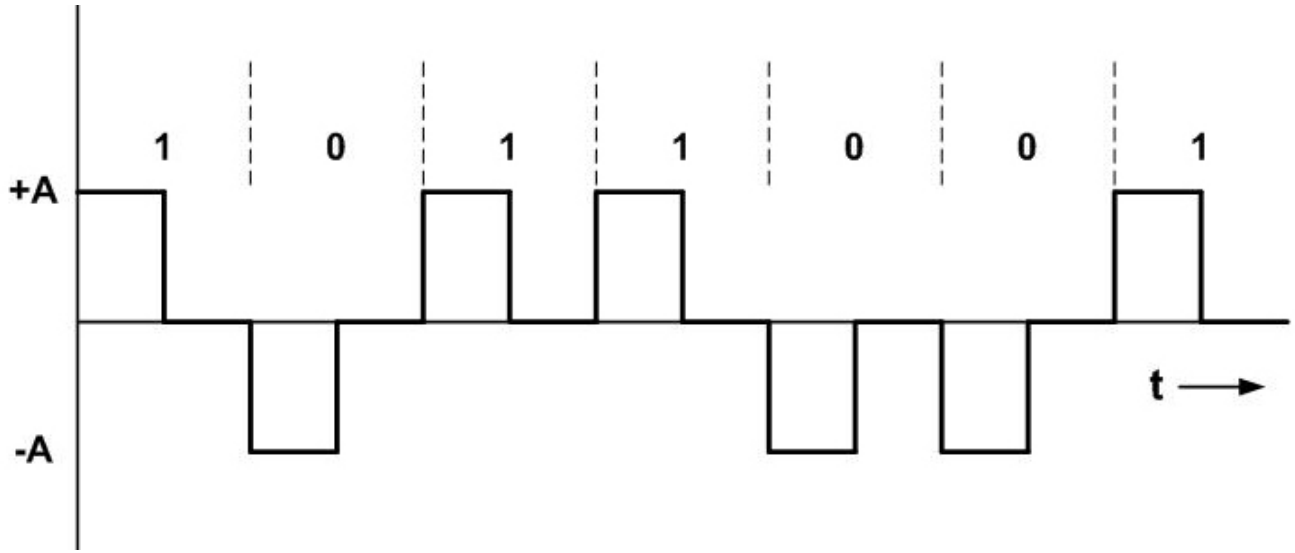
- Disadvantages:
  - DC component is present
  - Loss of synchronization for long sequences of 0's and 1's.

Signal Spectrum for NRZ



Return to Zero (RZ)

- To ensure synchronization there must be a signal transition in each bit



Characteristics of RZ

- Three levels
- Baud rate is double that of data rate

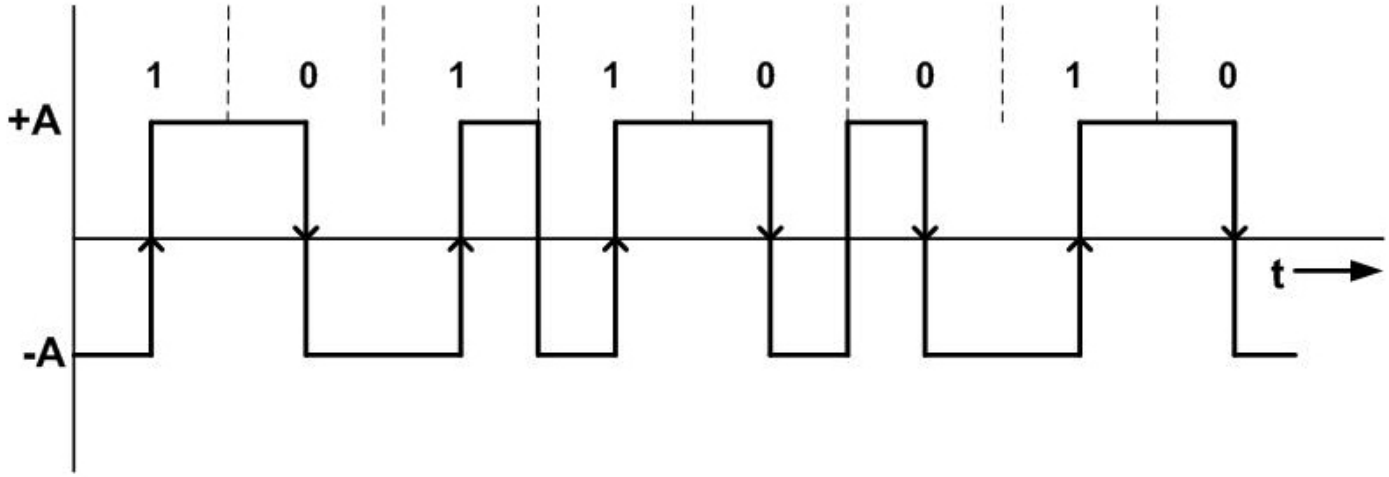
- Advantages:
  - No dc component
  - Good synchronization

- Disadvantages:
  - Increase in bandwidth requirement

Manchester Encoding

- It is Biphase encoding technique designed to overcome the limitations of NRZ

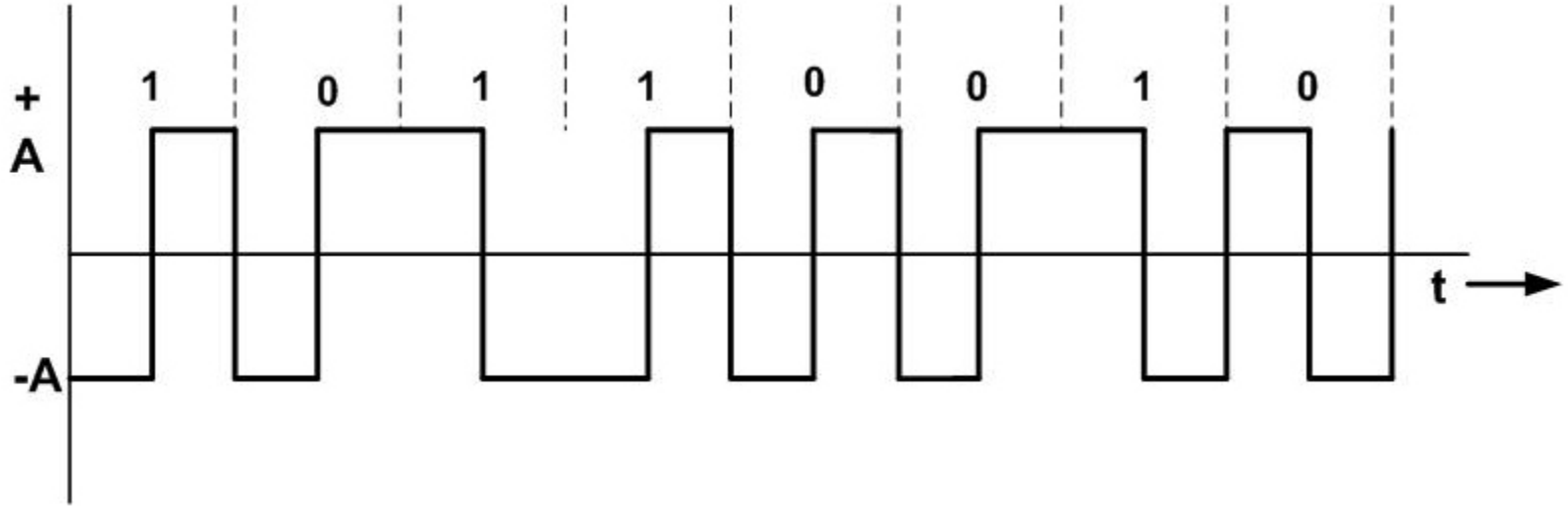
- the mid-bit transition serves as a clocking mechanism and also as data
- Low-to-high = 1 High-to-low = 0



Differential Manchester Encoding

- The encoding of a 0 is represented by the presence of a transition both at the beginning and at the middle
- 1 is represented by a transition only in the middle of the bit period.

- inversion in the middle of each bit is used for synchronization
- Uses differential encoding



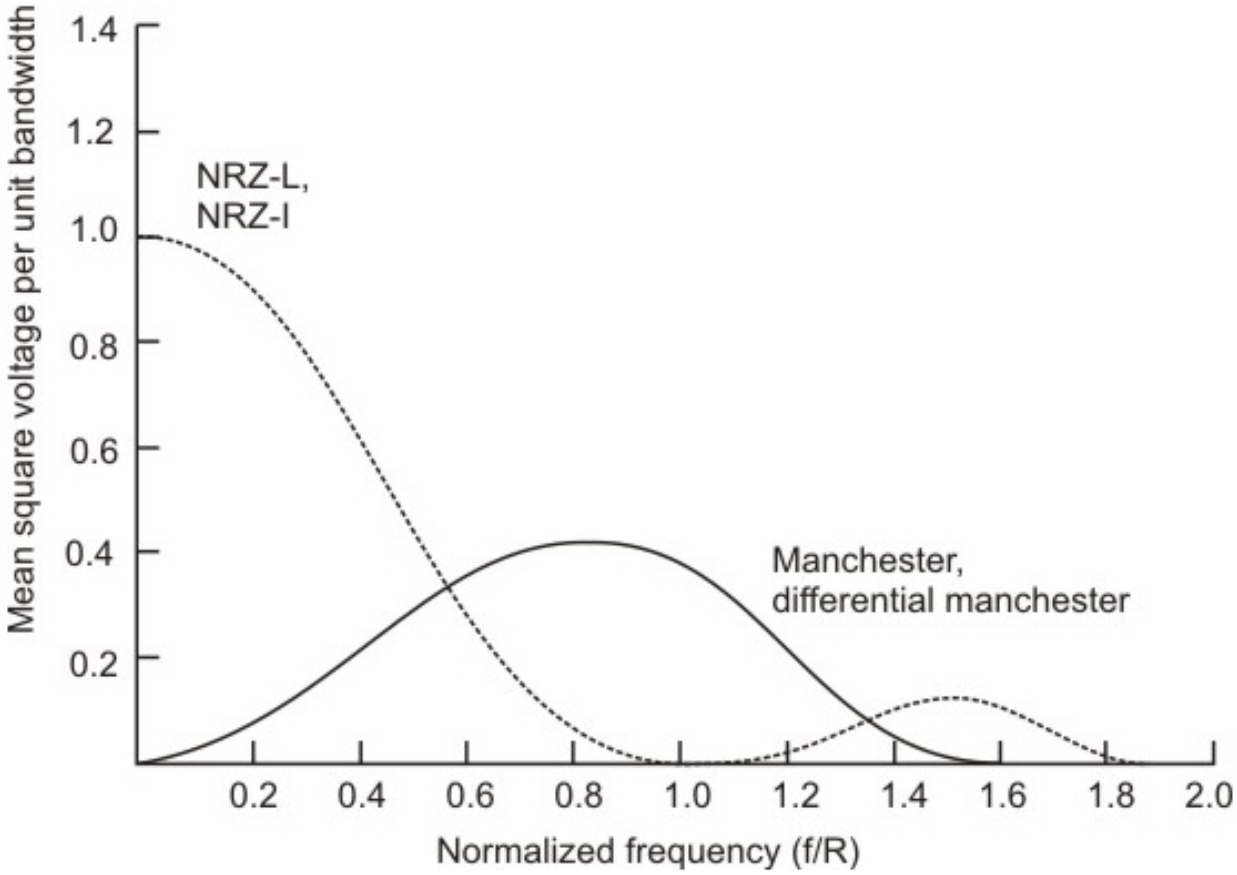
Characteristics of Biphase Encoding

- Two levels
- Transition in each bit
- Manchester code is used in IEEE 802.3 (Ethernet) standard for baseband coaxial cables and twisted pair CSMA/CD bus LANs.
- Differential Manchester is used in the IEEE 802.5 token ring LAN, using shielded twisted pair.

- Advantage:
  - Good Synchronization
  - No DC component

- Disadvantage:
  - Higher bandwidth requirement due to doubling of baud rate with respect to data rate

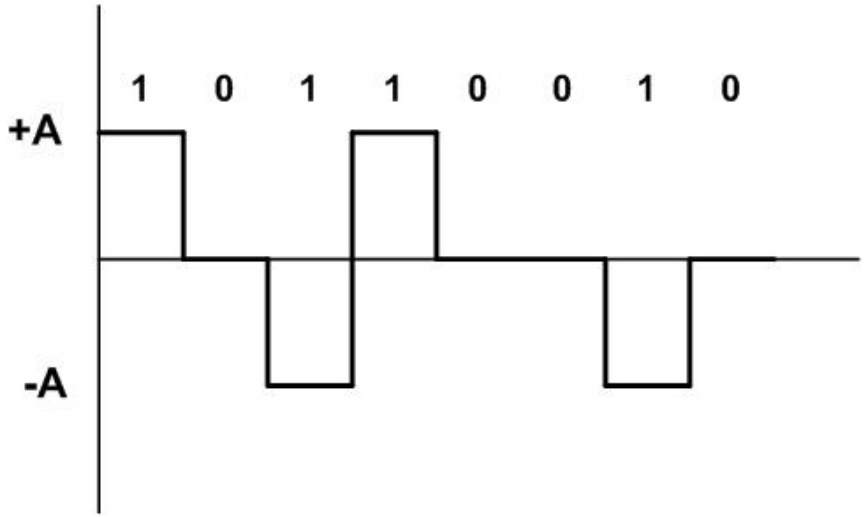
Bandwidth Comparison



Bandwidth requirement is more in Biphase encoding techniques.

Bipolar AMI

- Alternate mark inversion (AMI)
- uses three voltage levels
- Unlike RZ, the zero level is used to represent a 0
- Binary 1s are represented by alternating positive and negative voltages.



Pseudoternary :

Same as AMI, but alternating positive and negative pulse occur for binary 0 instead of binary 1

Characteristics of Bipolar AMI

- Three levels

- Advantages:
  - No DC component
  - Lesser bandwith

- Disadvantages:
  - Loss of synchronization for long sequences of 0's

Spectral Density Comparison

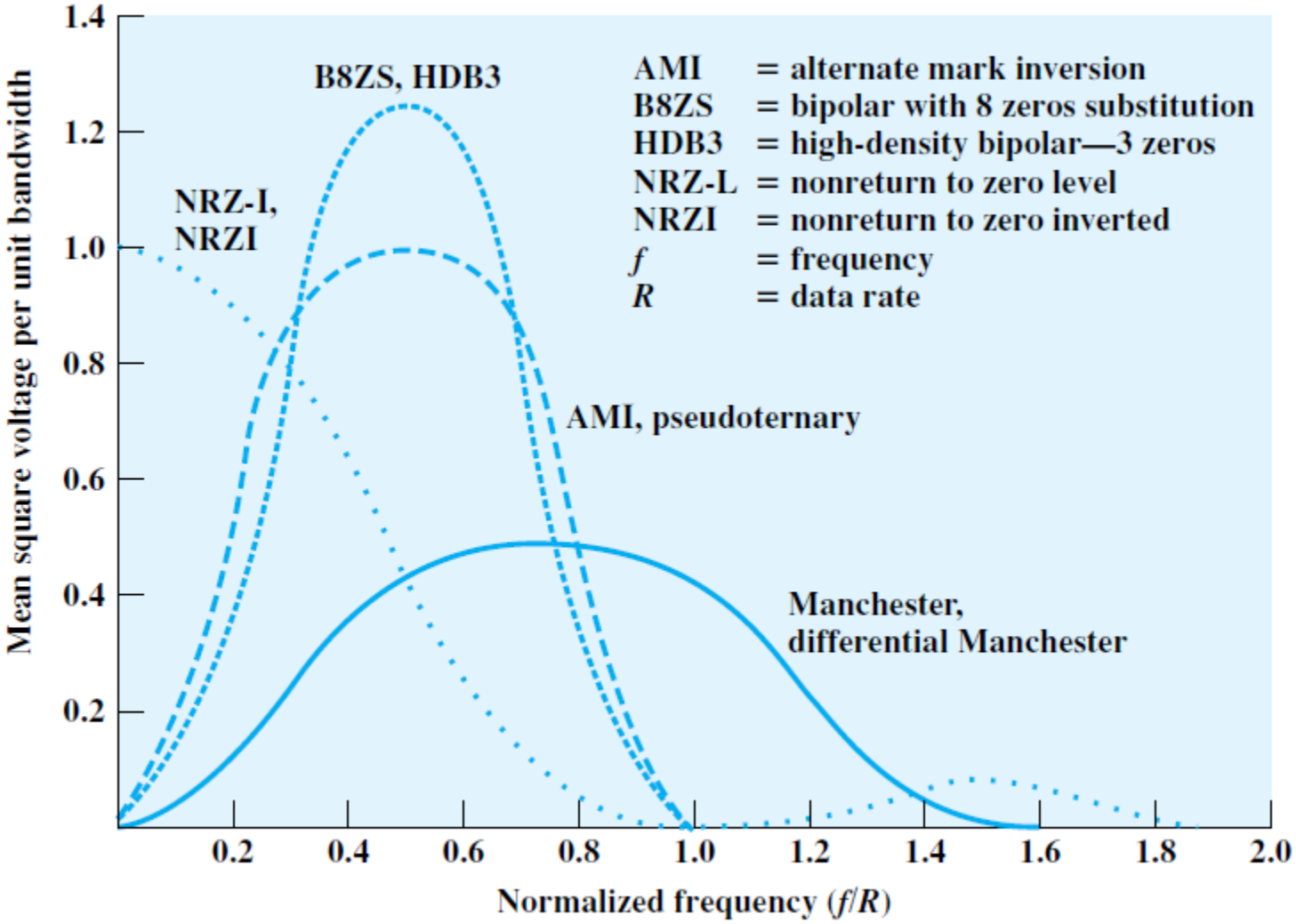


Figure 5.3 Spectral Density of Various Signal Encoding Schemes

Modulation (Baud) Rate

- Data rate is expressed in bits per second.
- Modulation rate is expressed in bauds per second.

- General relationship :

$$D = R/b = R/\log_2 L$$

  - D is the modulation rate in bauds
  - R is the data rate in bps
  - L is the number of different signal levels
  - b is the number of bits per signal element

Scrambling Techniques

- the biphase techniques have not been widely used in long-distance applications
  - As a high signalling rate is required relative to the data rate

- Alternate Scheme:
  - Scrambling (e.g., B8ZS, HDB3)

- Design goals:
  - No dc component
  - No long sequences of zero-level line signals
  - No reduction in data rate
  - Error-detection capability

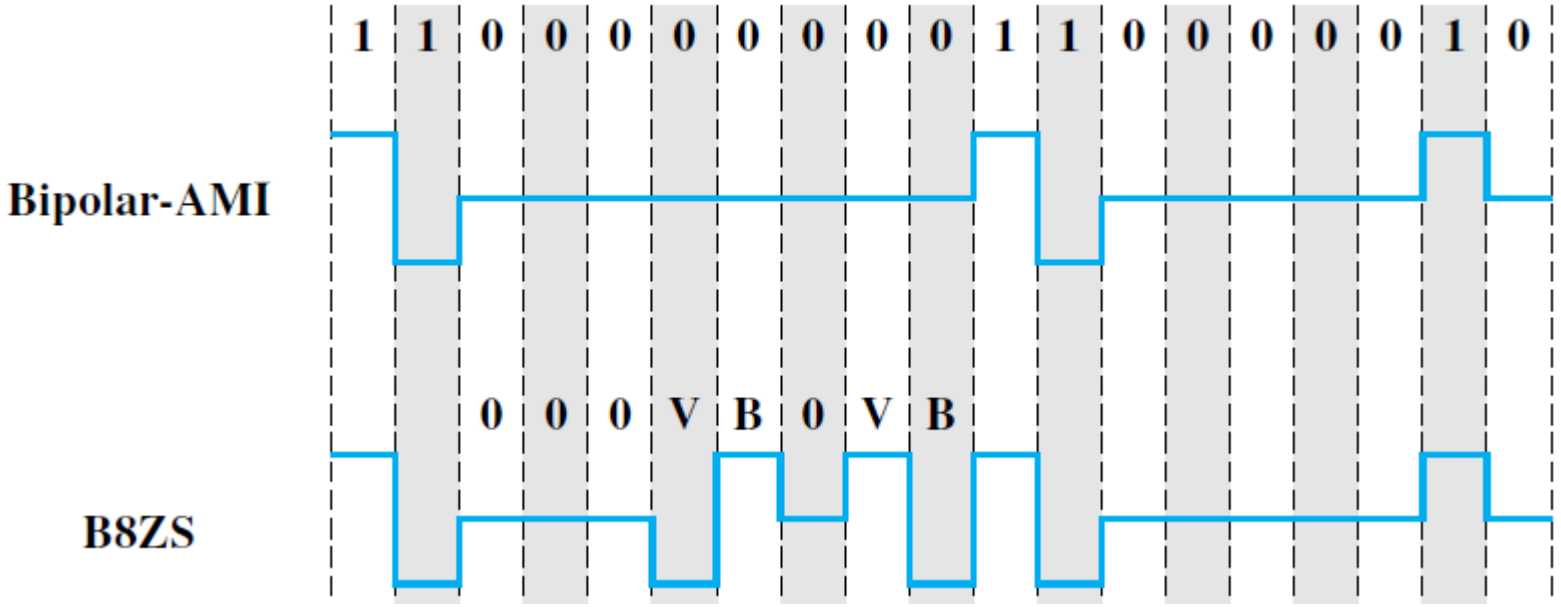
Bipolar with 8-zeros substitution

- B8ZS coding scheme is based on a bipolar-AMI
- Removes the synchronization issue of AMI

- How?
  - If an octet of all zeros occurs and the last voltage pulse preceding this octet was positive, then the eight zeros of the octet are encoded as 000+-0-+
  - If an octet of all zeros occurs and the last voltage pulse preceding this octet was negative, then the eight zeros of the octet are encoded as 000-+0+-

  - The receiver recognizes the patterns and interprets the octet as consisting of all zeros.

Cont…



High-Density Bipolar-3 Zeros

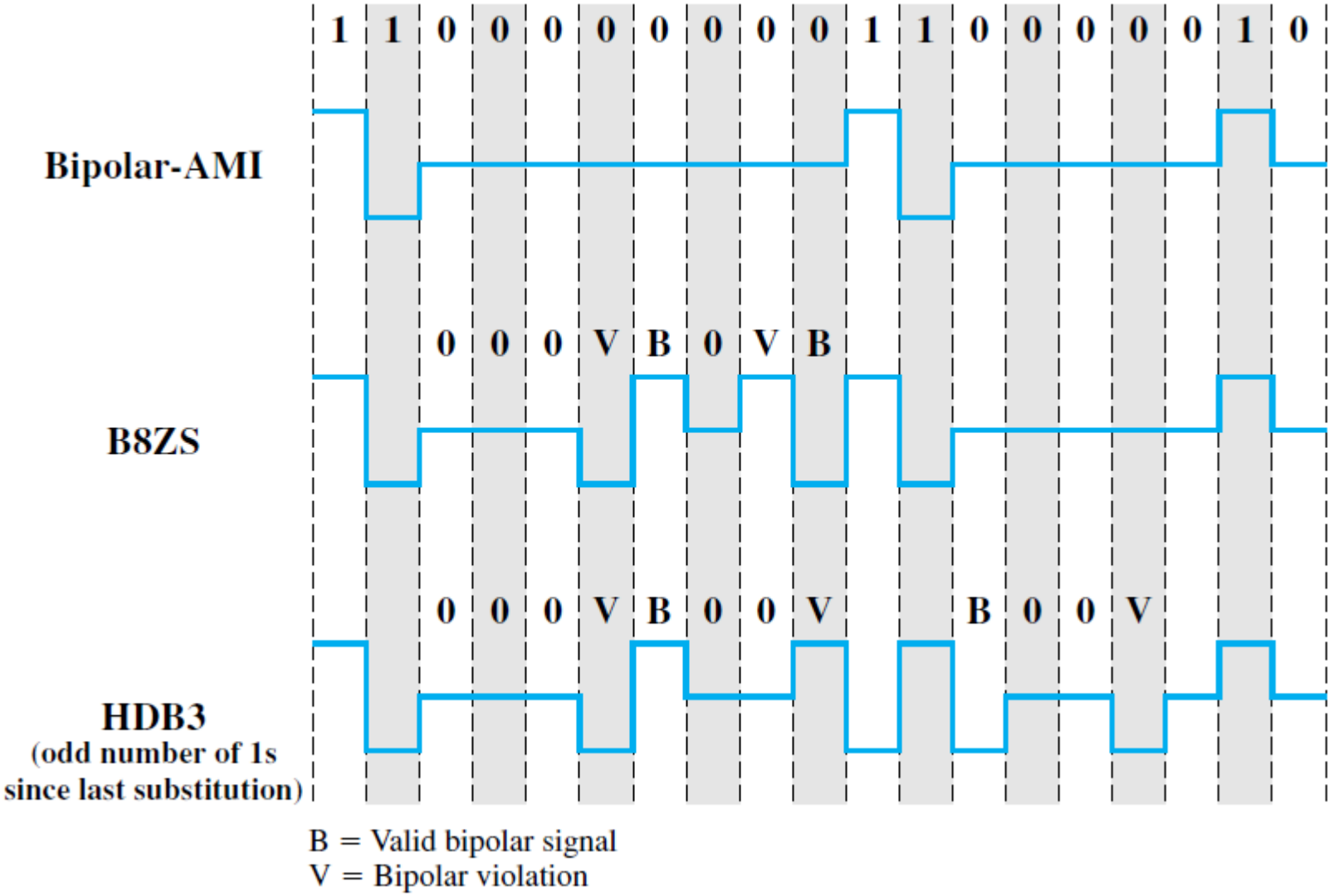
- HDB3 coding scheme is based on a bipolar-AMI
- Removes the synchronization issue of AMI

- How?
  - the scheme replaces strings of four zeros following the rules:

Table 5.4 HDB3 Substitution Rules

	Number of Bipolar Pulses (ones) since Last Substitution	
Polarity of Preceding Pulse	**Odd**	**Even**
−	0 0 0 −	+ 0 0 +
+	0 0 0 +	− 0 0 −

Cont…


1 1 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 1 0
Bipolar-AMI
0 0 0 V B 0 V B
B8ZS
0 0 0 V B 0 0 V B 0 0 V
HDB3
(odd number of 1s
since last substitution)
B = Valid bipolar signal
V = Bipolar violation

B8ZS and HBD3 Characteristics

- Three levels

- Advantages:
  - No DC component
  - Good synchronization
  - Most of the energy is concentrated around a frequency equal to half the data rate
  - Well suited for high data-rate transmission over long distances

Spectral Density Comparison

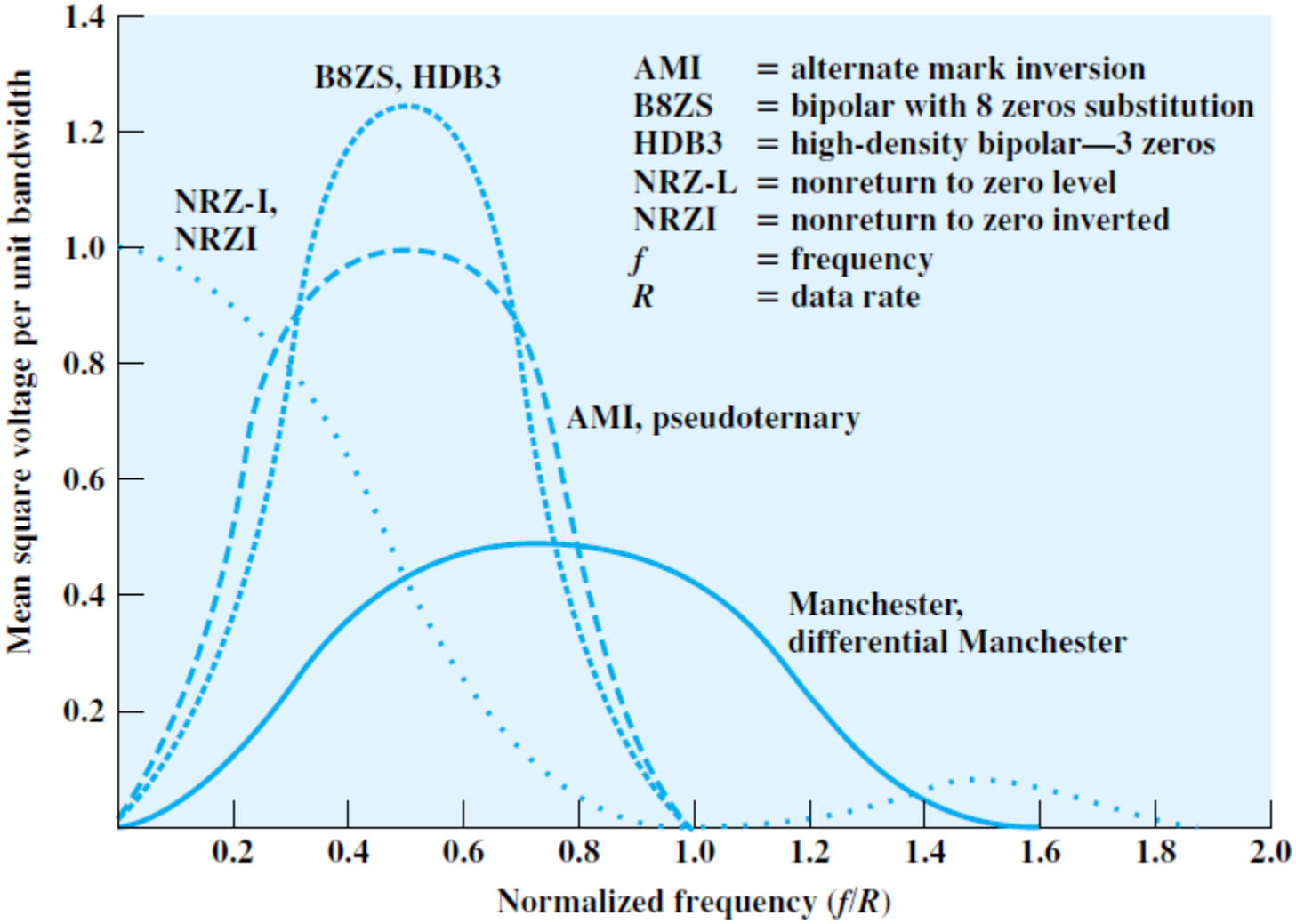


Figure 5.3 Spectral Density of Various Signal Encoding Schemes

Block Coding

- Block coding was introduced to improve the performance of the line coding
- Introduces redundancy to achieve synchronization
- allows error detection to some extent
- encodes data in blocks
- acts on a block of *k* bits of input data to produce *n* bits of output data (n,k)

4B/5B Encoding

- the 5-bit output that replaces the 4-bit input
- The 5-bit code has no more than one leading zero (left bit) and no more than two trailing zeros (right bits)
- More than three consecutive 0's do not occur
- 4B/5B-NRZI encoding is used in FDDI LAN

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Table 4.2 *4B/5B mapping codes*

Data Sequence	*Encoded Sequence*
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

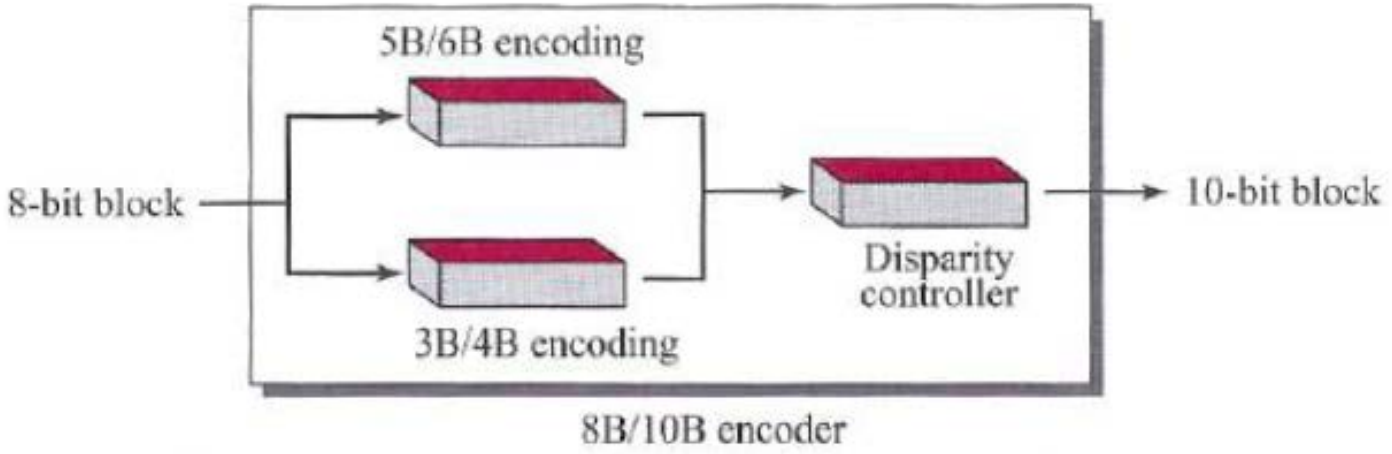
- Advantages:
  - It solves the problem of synchronization
  - It overcomes few deficiencies of NRZI
- Disadvantages:
  - Increases the signal rate
  - Does not solve DC component problem

8B/10B Encoding

- 8-bit data blocks are substituted by 10-bit code

- Provides more error detection capability
- Leads to increase in bandwidth
- Bandwidth can be reduced by using suitable line coding

- The 8B/10B block coding is actually a combination of 5B/6B and 3B/4B encodings



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

- Suppose that the spectrum of a channel is between 3 MHz and 4 MHz; and SNR_{dB}=24dB. Assume that we can achieve the theoretical limit of channel capacity. Then, how many signalling levels are required? (Show the steps of computation). **5**
-
- How much thermal noise is found in a bandwidth of 1Hz in a device or conductor? **2**
-
- Differentiate between an analog and a digital signal. **1**
- A signal is carrying data in which one data element is encoded as one signal element. Let r defines the ratio of the number of data elements carried by each signal element. If the bit rate is 100 kbps, what is the baud rate? 2