Computer Networks

UNIT-I

Lecture6- Encoding

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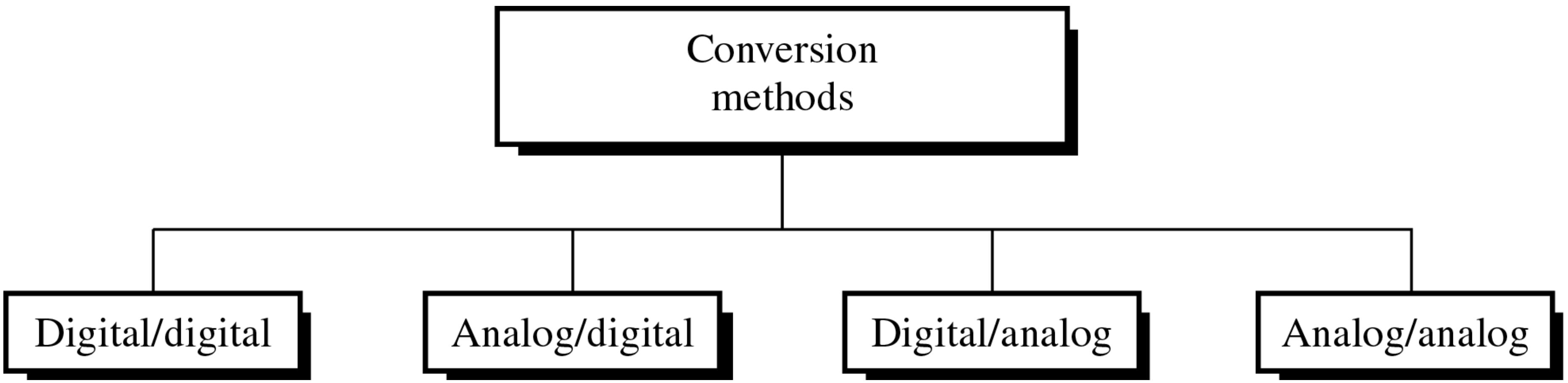
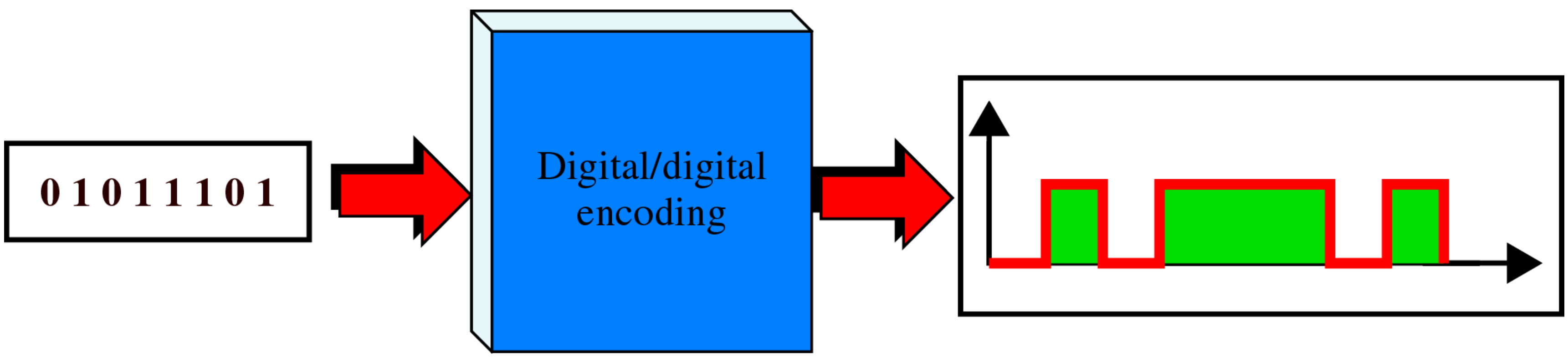
Different Conversion Schemes



Data	Signal	Approach
Digital	*Digital*	*Encoding*
Analog	*Digital*	*Encoding*
Analog	*Analog*	*Modulation*
Digital	*Analog*	*Modulation*

Various approaches for conversion of data to signal

Digital to Digital Encoding



Line Coding

- Line coding is the process of converting digital data to digital signals.

Line coding characteristics

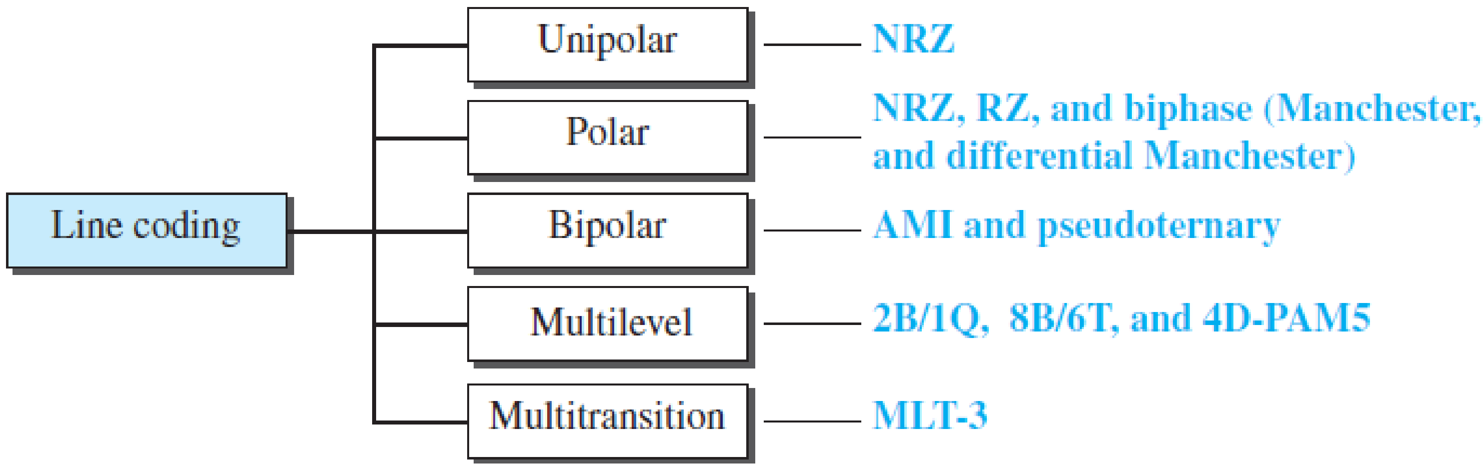
- No. of signal levels: This refers to the number values allowed in a signal, known as signal levels, to represent data.
- Bit rate versus Baud rate: The bit rate represents the number of bits sent per second, whereas the baud rate defines the number of signal elements per second in the signal. Depending on the encoding technique used, baud rate may be more than or less than the data rate.
- DC components: After line coding, the signal may have zero frequency component in the spectrum of the signal, which is known as the direct-current (DC) component. DC component in a signal is not desirable because the DC component does not pass through some components of a communication system such as a transformer. This leads to distortion of the signal and may create error at the output. The DC component also results in unwanted energy loss on the line.

Line coding characteristics (Cont…)

- Signal Spectrum: Different encoding of data leads to different spectrum of the signal. It is necessary to use suitable encoding technique to match with the medium so that the signal suffers minimum attenuation and distortion as it is transmitted through a medium.
- Synchronization: To interpret the received signal correctly, the bit interval of the receiver should be exactly same or within certain limit of that of the transmitter. Any mismatch between the two may lead wrong interpretation of the received signal.
- Cost of Implementation: It is desirable to keep the encoding technique simple enough such that it does not incur high cost of implementation.

Types of Digital to Digital Encoding

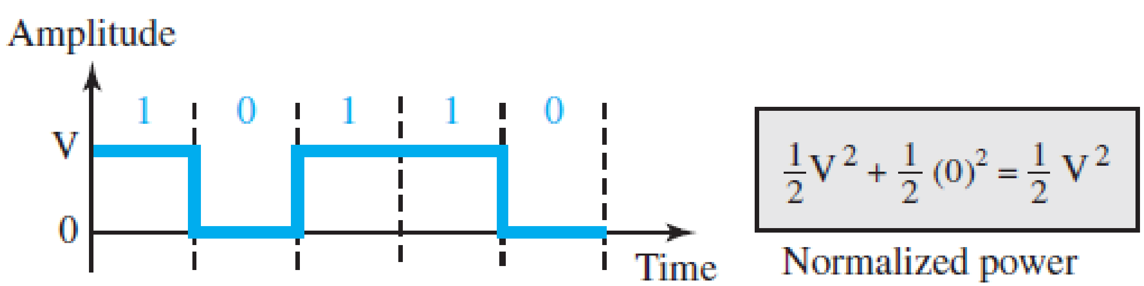
Figure 4.4 *Line coding schemes*



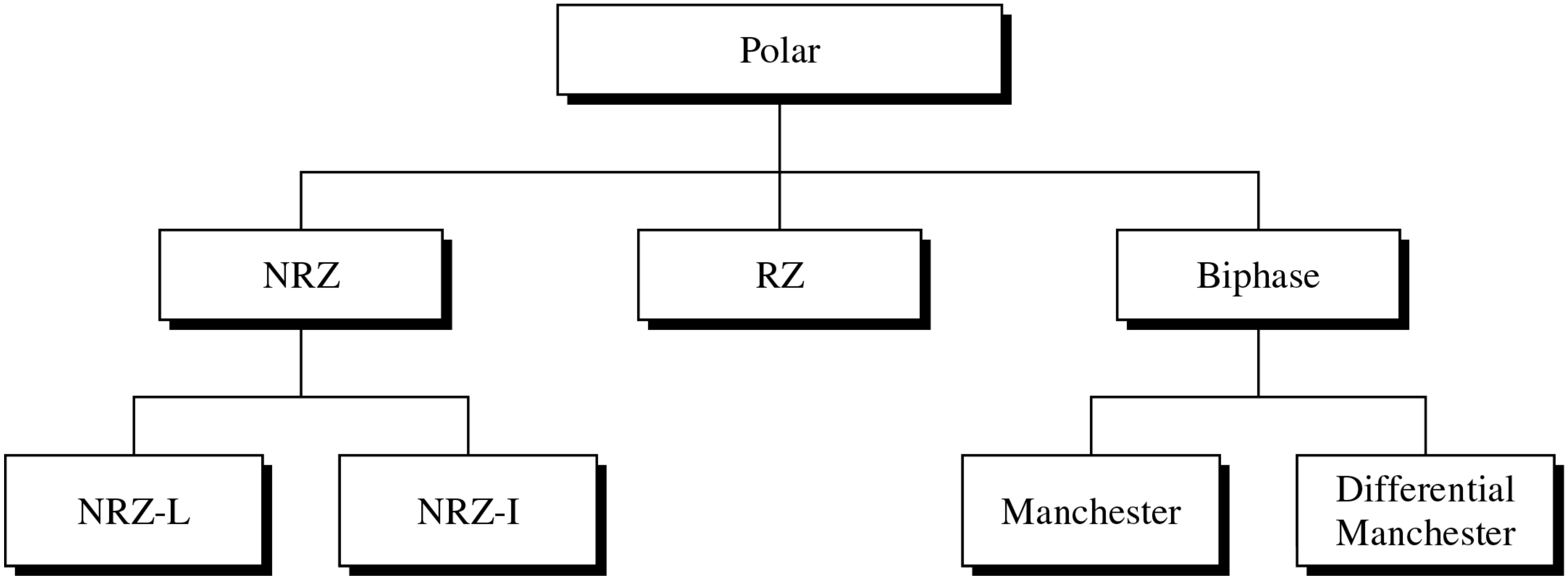
Unipolar Encoding

- NRZ (Non-Return-to-Zero)
- Traditionally, a unipolar scheme was designed as a non-return-to-zero (NRZ) scheme in which the positive voltage defines bit 1 and the zero voltage defines bit 0.
- It is called NRZ because the signal does not return to zero at the middle of the bit.

Figure 4.5 *Unipolar NRZ scheme*



Types of Polar Encoding

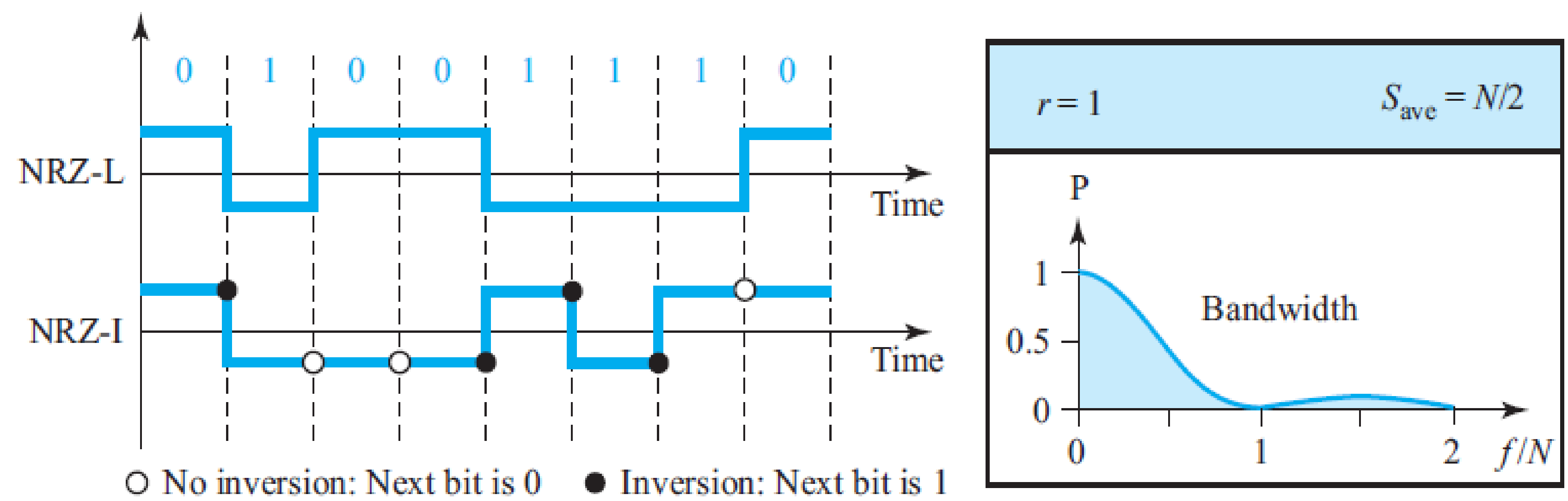


Non-Return-to-Zero (NRZ)

- In polar NRZ encoding, we use two levels of voltage amplitude.
- We can have two versions of polar NRZ: NRZ-L and NRZ-I
- In the first variation, NRZ-L (NRZ-Level), the level of the voltage determines the value of the bit.
- In the second variation, NRZ-I (NRZ-Invert), the change or lack of change in the level of the voltage determines the value of the bit. If there is no change, the bit is 0; if there is a change, the bit is 1.

NRZ-L and NRZ-I Encoding

Figure 4.6 *Polar NRZ-L and NRZ-I schemes*

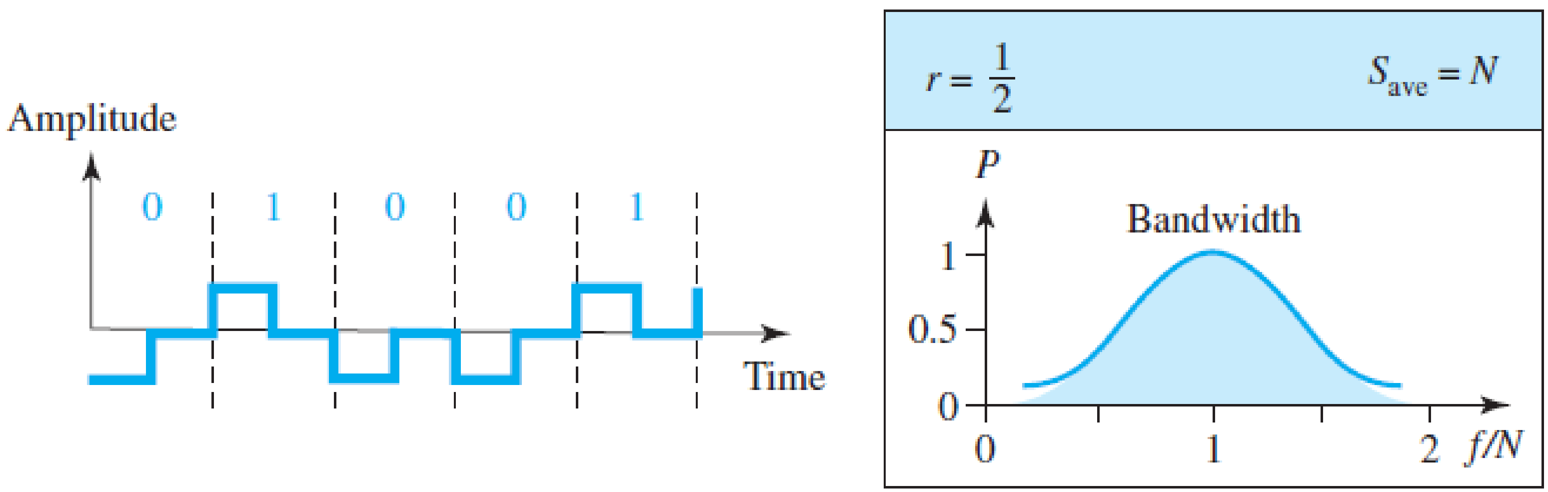


Return-to-Zero (RZ)

- 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.
- One solution is the return-to-zero (RZ) scheme, which uses three values: positive, negative, and zero.
- In RZ, the signal changes not between bits but during the bit.
- The main disadvantage of RZ encoding is that it requires two signal changes to encode a bit and therefore occupies greater bandwidth.
- A sudden change of polarity resulting in all 0s interpreted as 1s and all 1s interpreted as 0s, still exists here, but there is no DC component problem.
- Another problem is the complexity: RZ uses three levels of voltage, which is more complex to create and discern. As a result of all these deficiencies, the scheme is not used today. Instead, it has been replaced by the better-performing Manchester and differential Manchester schemes

Polar RZ Encoding

Figure 4.7 *Polar RZ scheme*



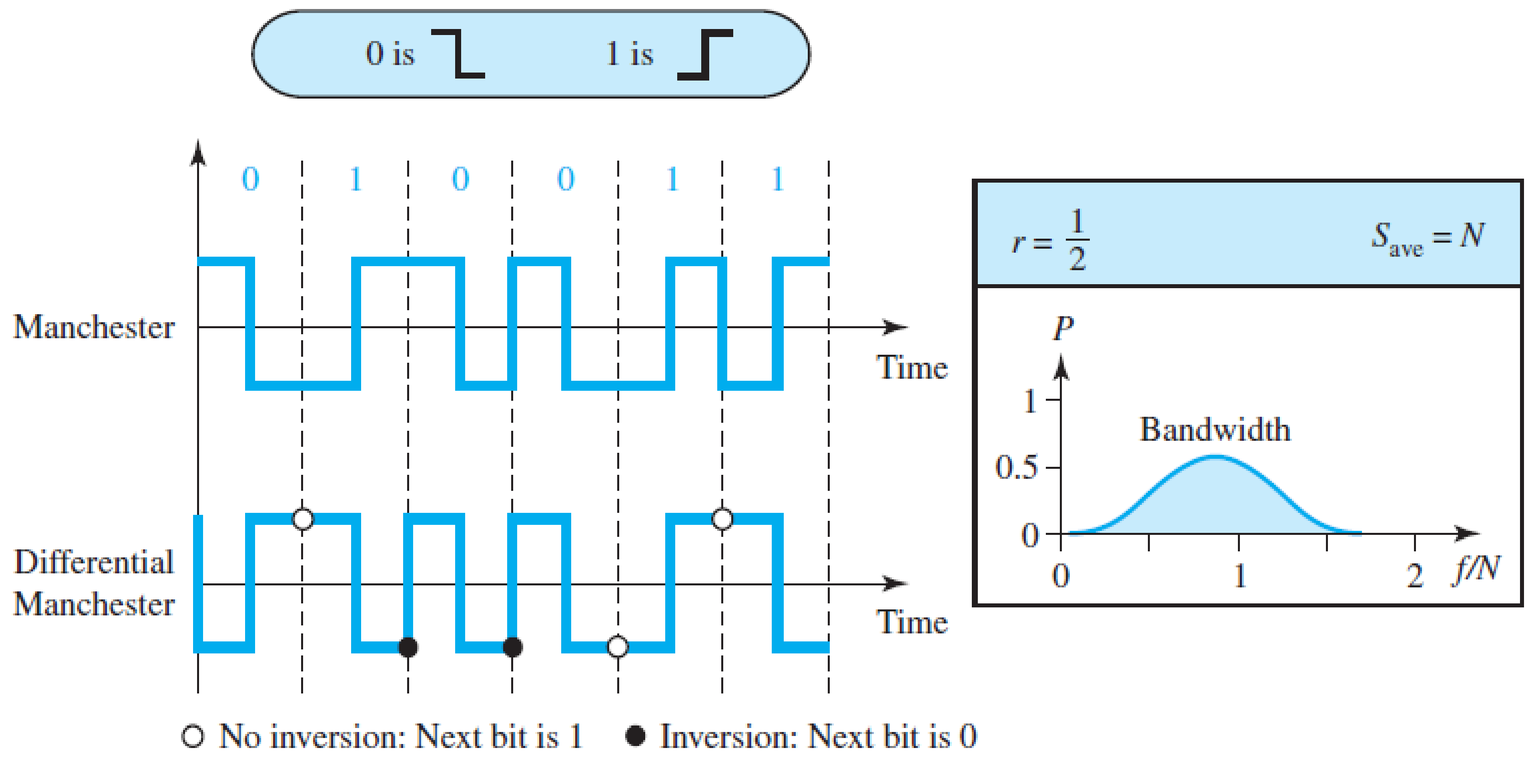
Biphase: Manchester and Differential Manchester

- The idea of RZ (transition at the middle of the bit) and the idea of NRZ-L are combined into the Manchester scheme. In Manchester encoding, the duration of the bit is divided into two halves. The voltage remains at one level during the first half and moves to the other level in the second half. The transition at the middle of the bit provides synchronization.

- Differential Manchester, on the other hand, combines the ideas of RZ and NRZ-I. There is always a transition at the middle of the bit, but the bit values are determined at the beginning of the bit. If the next bit is 0, there is a transition; if the next bit is 1, there is none.

Biphase: Manchester and Differential Manchester

Figure 4.8 *Polar biphase: Manchester and differential Manchester schemes*



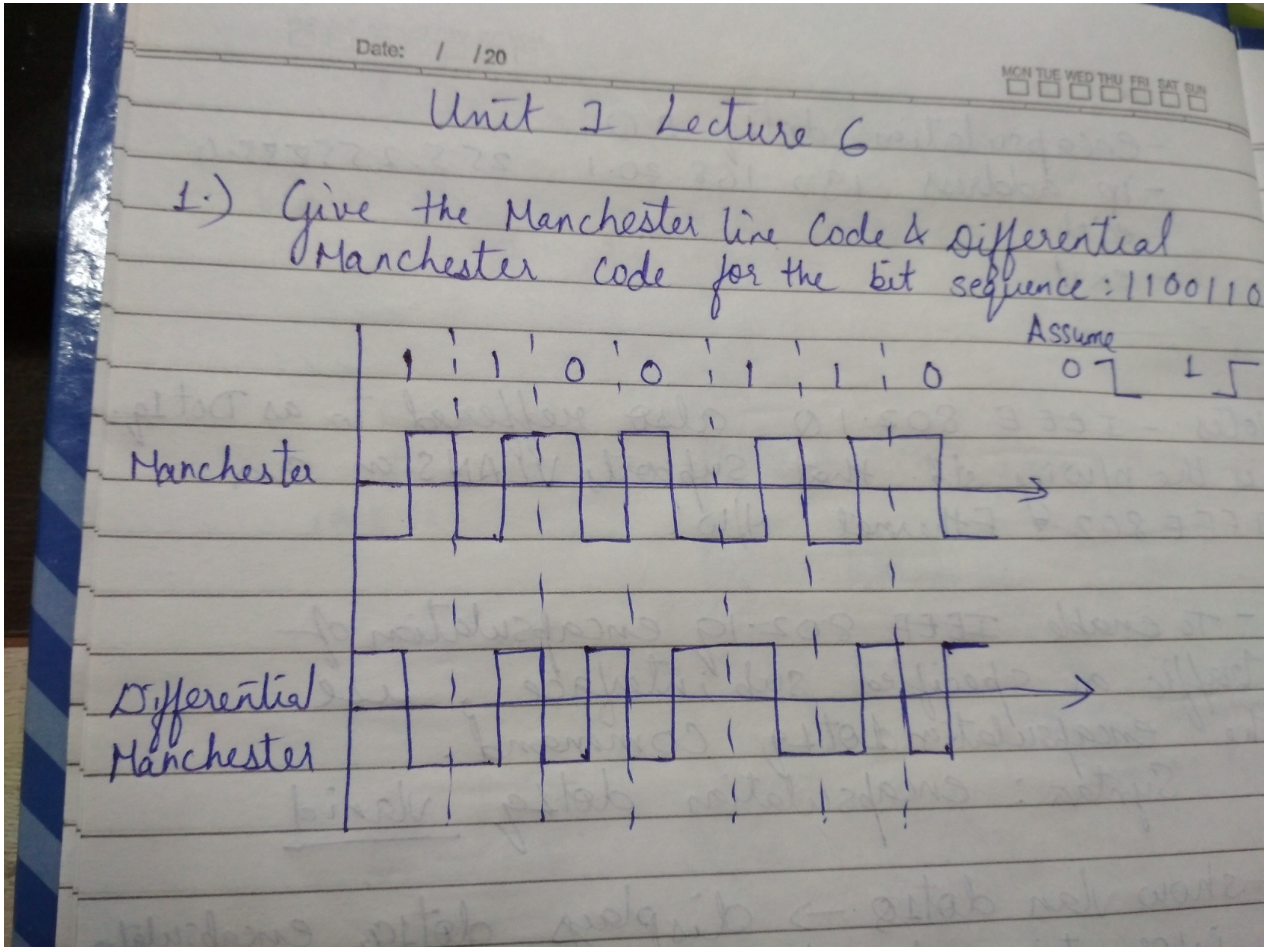
Previous Year Questions

1. what is Line encoding? Give the Manchester line code and Differential Manchester code for the bit sequence: 1100110 [5]

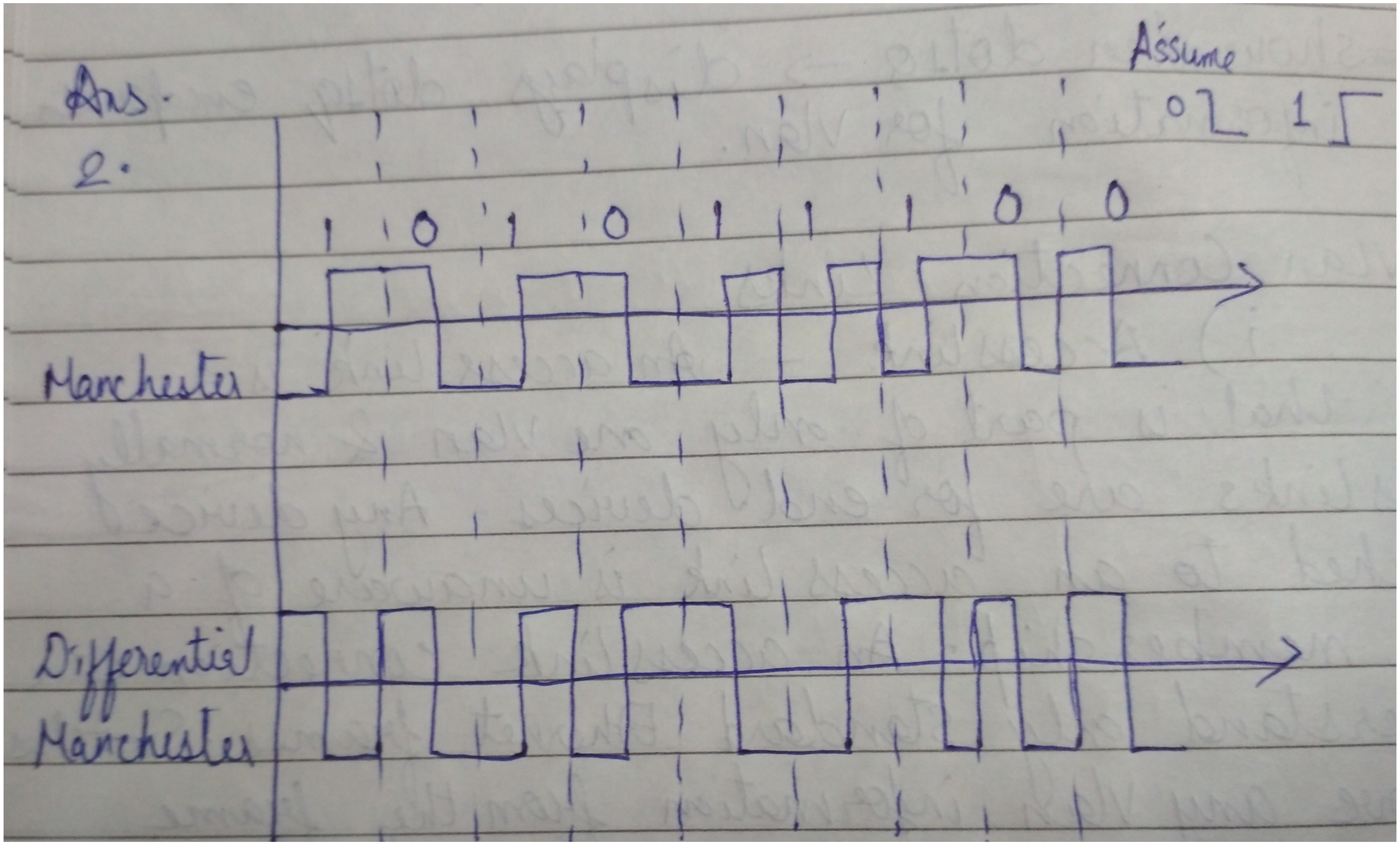
2. Represent 101011100 using Manchester and Differential Manchester line coding technique. [4]

3. For the bit sequence 10000101111 draw the waveform for Manchester and Differential Manchester Encoding? [4]

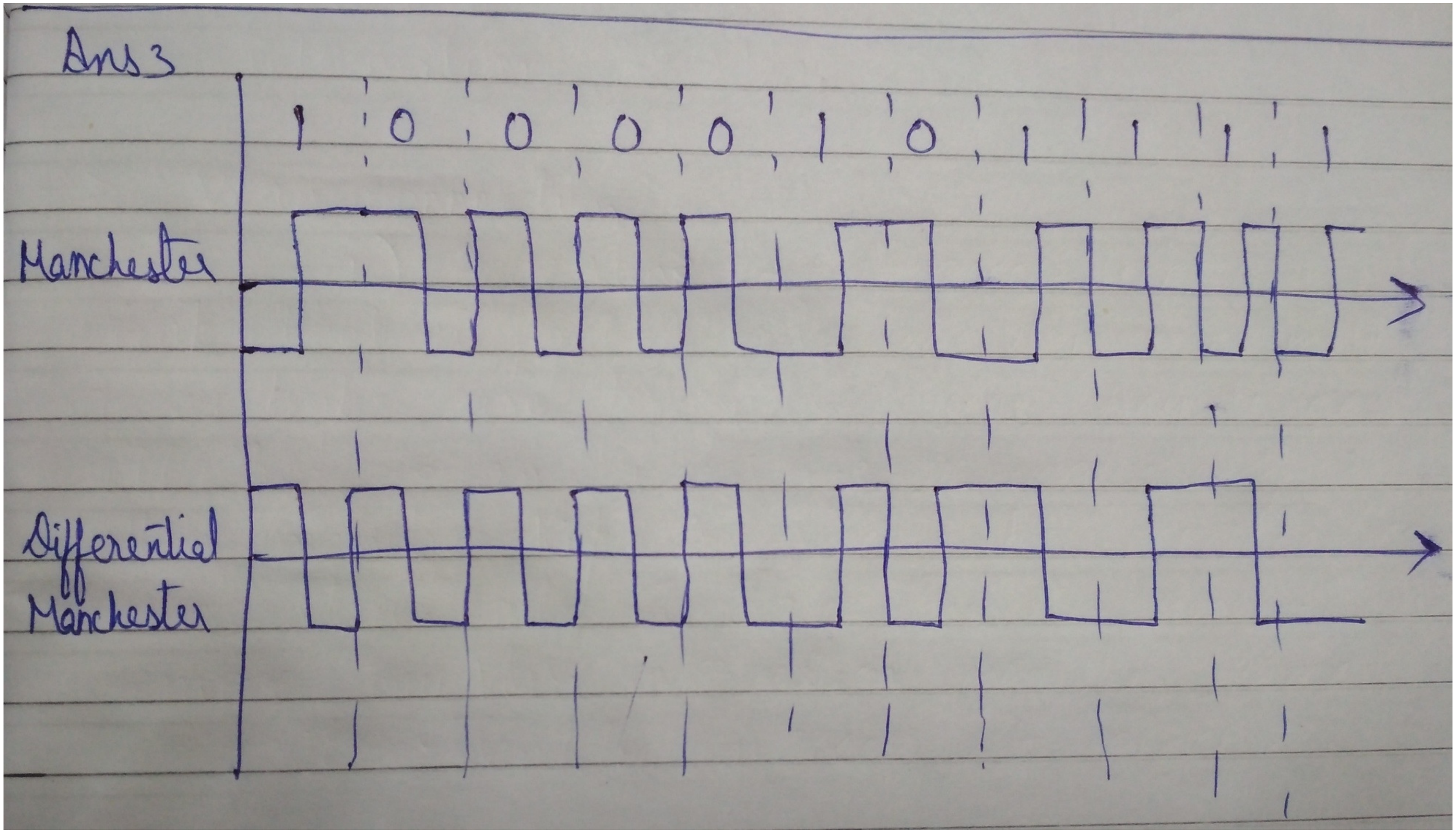
Question 1 Solution



Question 2 Solution



Question 3 Solution

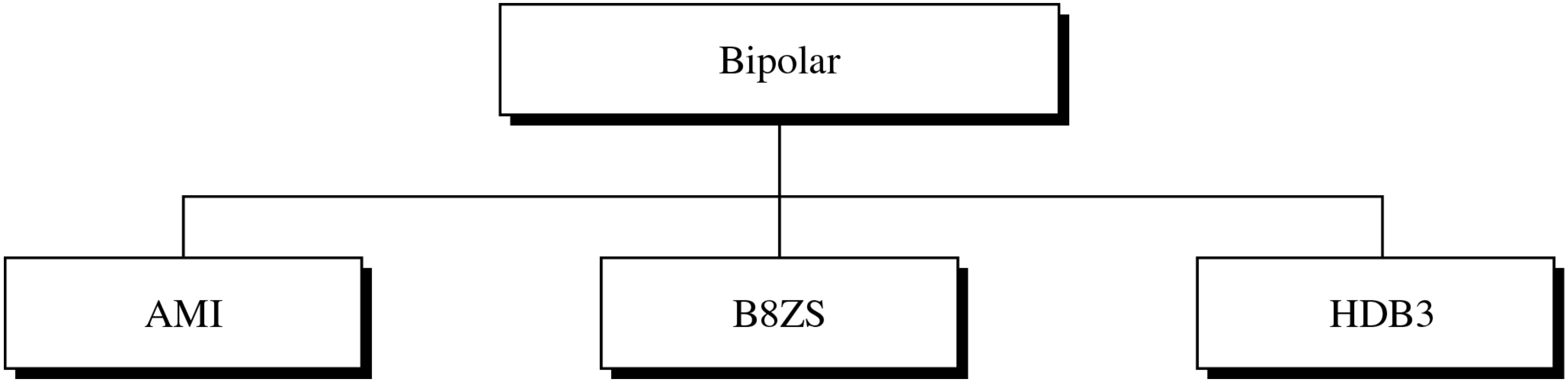


Biphase Encoding

- Key characteristics are:
  - Two levels
  - No DC component
  - Good synchronization
  - Higher bandwidth due to doubling of bit rate with respect to data rate

Bipolar Schemes

- In bipolar encoding (sometimes called multilevel binary), there are three voltage levels: positive, negative, and zero.
- The voltage level for one data element is at zero, while the voltage level for the other element alternates between positive and negative.

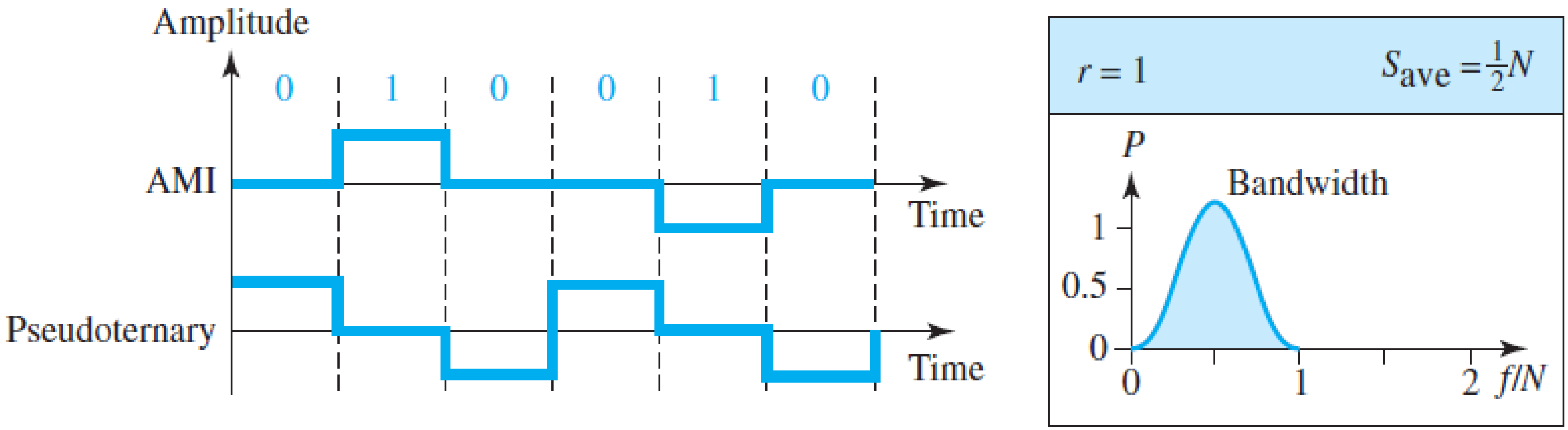


Bipolar AMI and Pseudoternary Encoding

- A common bipolar encoding scheme is called bipolar **alternate mark inversion (AMI).**
- **In** the term *alternate mark inversion, the word mark comes from telegraphy and means 1.*
- So AMI means alternate 1 inversion. 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.

Bipolar AMI and Pseudoternary Encoding

Figure 4.9 *Bipolar schemes: AMI and pseudoternary*



Multilevel Schemes

- The desire to increase the data rate or decrease the required bandwidth has resulted in the creation of many 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.*

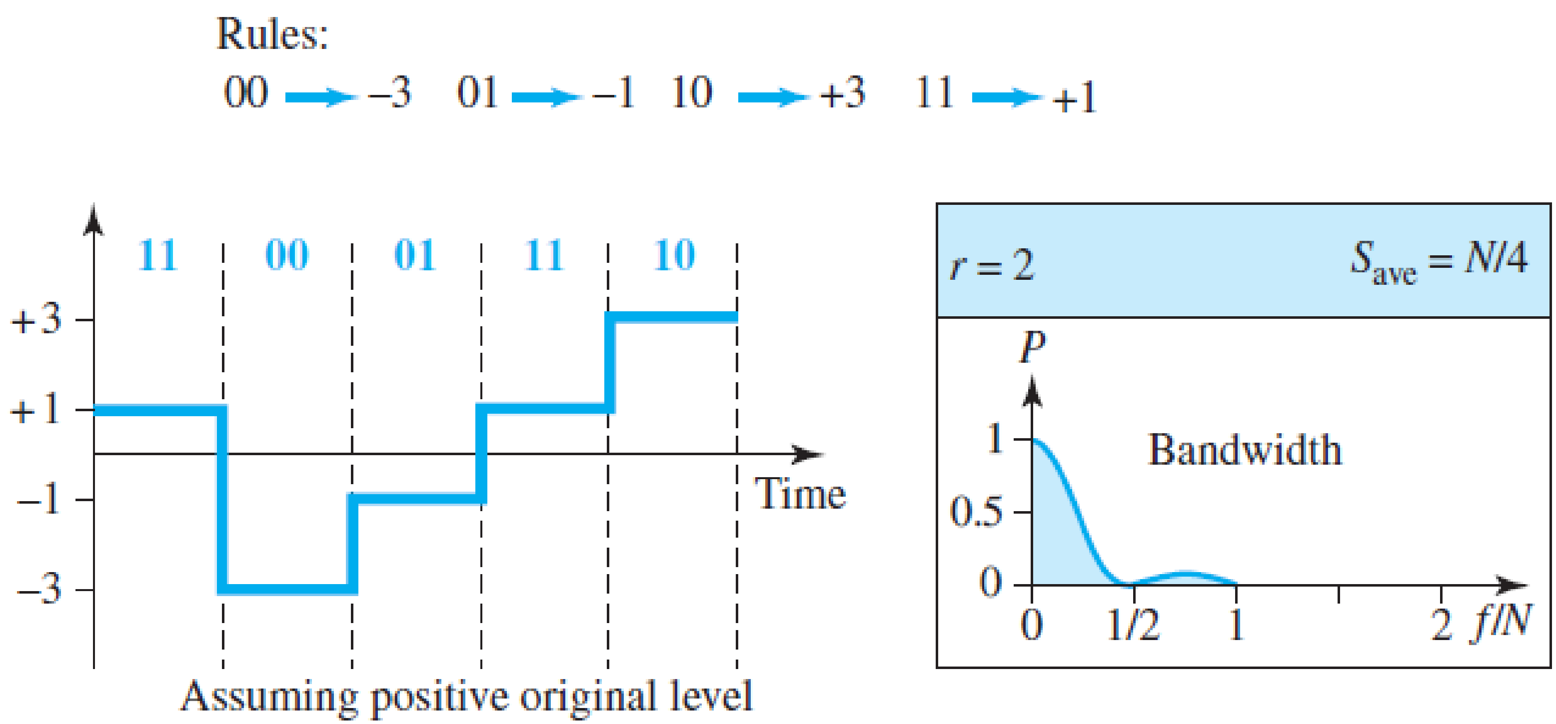
In $mBnL$ schemes, a pattern of m data elements is encoded as a pattern of n signal elements in which $2^m \leq L^n$.

2B1Q

- *Two binary, one quaternary (2B1Q), uses data* patterns of size 2 and encodes the 2-bit patterns as one signal element belonging to a four-level signal.
- In this type of encoding $m = 2$, $n = 1$, *and* $L = 4$ *(quaternary)*.

2B1Q

Figure 4.10 *Multilevel: 2B1Q scheme*

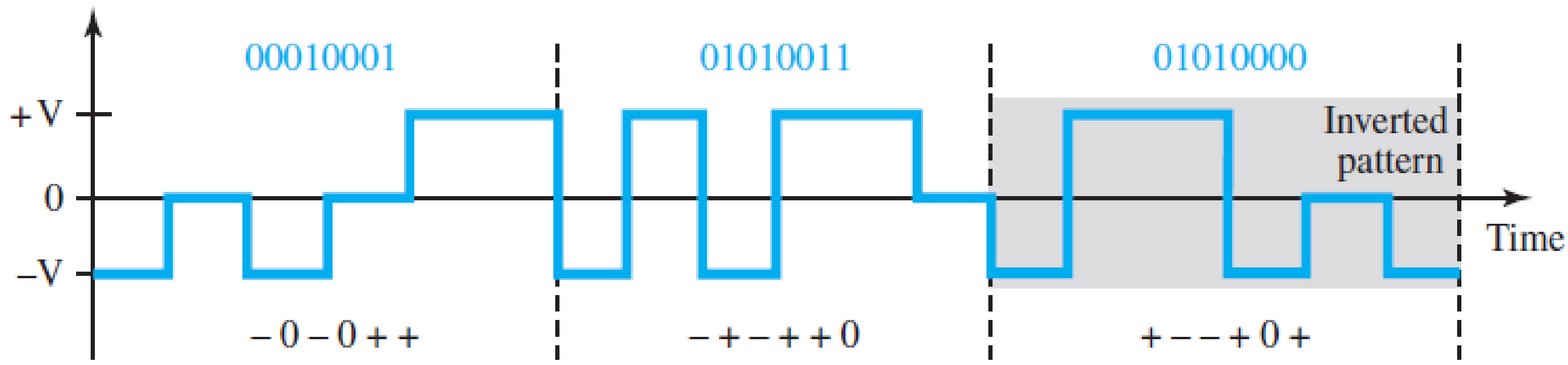


8B6T

- A very interesting scheme is eight binary, six ternary (8B6T).
- This code is used with 100BASE-4T cable.
- The idea is to encode a pattern of 8 bits as a pattern of six signal elements, where the signal has three levels (ternary).
- In this type of scheme, we can have $2^8 = 256$ different data patterns and $3^6 = 729$ different signal patterns.

8B6T

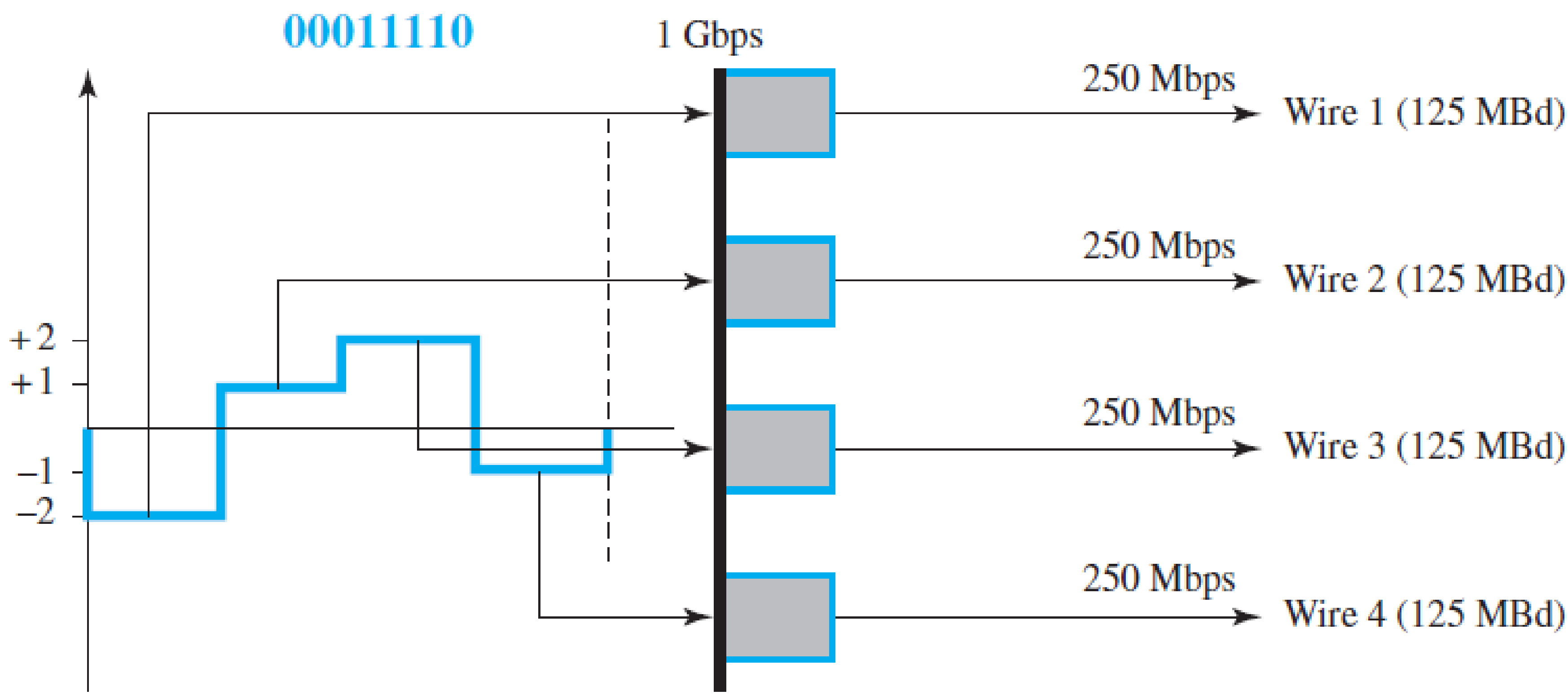
Figure 4.11 *Multilevel: 8B6T scheme*



4D-PAM5

- The last signaling scheme we discuss in this category is called four-dimensional five level pulse amplitude modulation (4D-PAM5).
- The 4D means that data is sent over four wires at the same time. It uses five voltage levels, such as –2, –1, 0, 1, and 2.
- However, one level, level 0, is used only for forward error detection

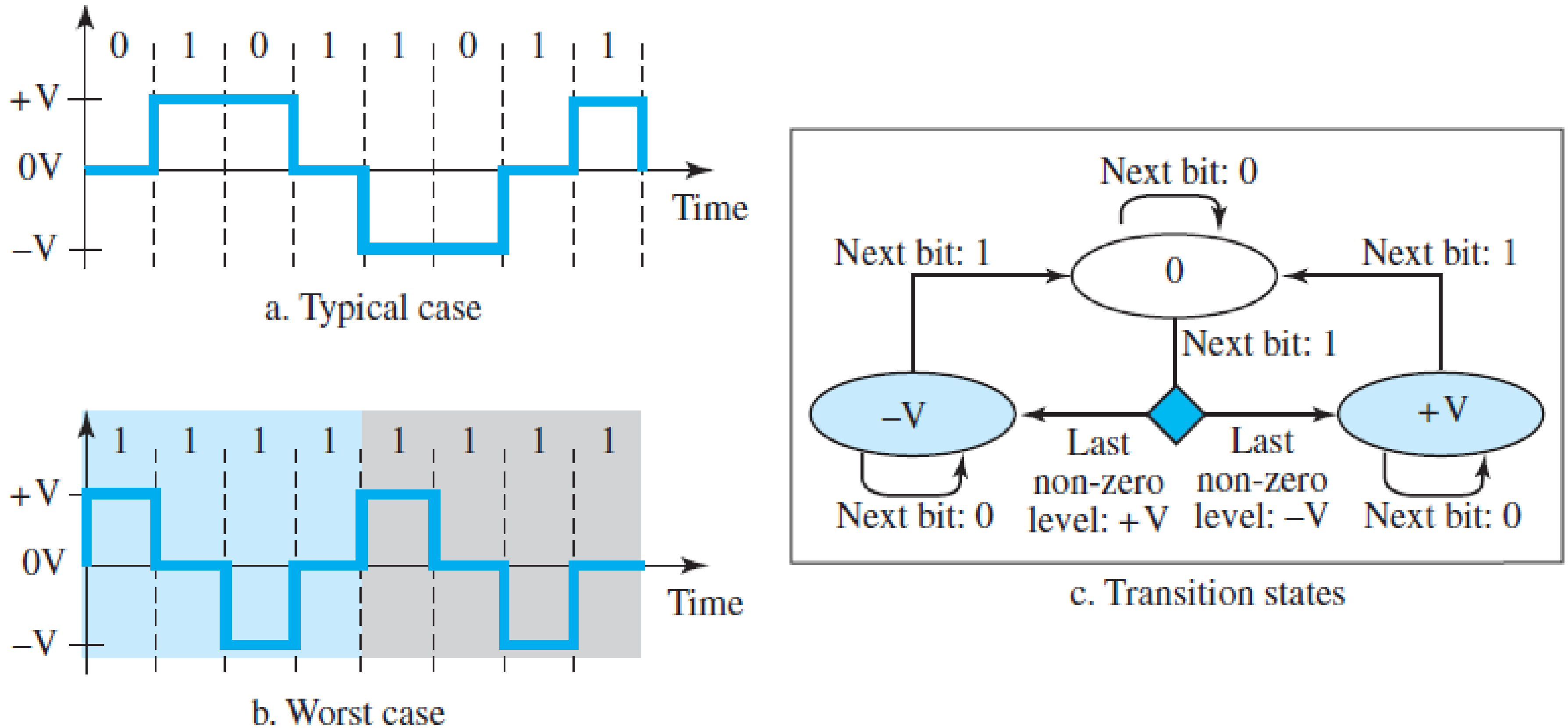
Figure 4.12 *Multilevel: 4D-PAM5 scheme*



Multitransition: MLT-3

- NRZ-I and differential Manchester are classified as differential encoding but use two transition rules to encode binary data (no inversion, inversion).
- If we have a signal with more than two levels, we can design a differential encoding scheme with more than two transition rules. MLT-3 is one of them.
- The multiline transmission, three-level (MLT-3) scheme uses three levels (+*V, 0, and* –*V) and three transition rules to move between the* levels.
    1. If the next bit is 0, there is no transition.
    2. If the next bit is 1 and the current level is not 0, the next level is 0.
    3. If the next bit is 1 and the current level is 0, the next level is the opposite of the last nonzero level.

Figure 4.13 *Multitransition: MLT-3 scheme*



a. Typical case

b. Worst case

c. Transition states

Summary of Line Coding Schemes

We summarize in Table 4.1 the characteristics of the different schemes discussed.

Table 4.1 *Summary of line coding schemes*

Category	*Scheme*	*Bandwidth (average)*	*Characteristics*
Unipolar	NRZ	$B = N/2$	Costly, no self-synchronization if long 0s or 1s, DC
Polar	NRZ-L	$B = N/2$	No self-synchronization if long 0s or 1s, DC
	NRZ-I	$B = N/2$	No self-synchronization for long 0s, DC
	Biphase	$B = N$	Self-synchronization, no DC, high bandwidth
Bipolar	AMI	$B = N/2$	No self-synchronization for long 0s, DC
Multilevel	2B1Q	$B = N/4$	No self-synchronization for long same double bits
	8B6T	$B = 3N/4$	Self-synchronization, no DC
	4D-PAM5	$B = N/8$	Self-synchronization, no DC
Multitransition	MLT-3	$B = N/3$	No self-synchronization for long 0s

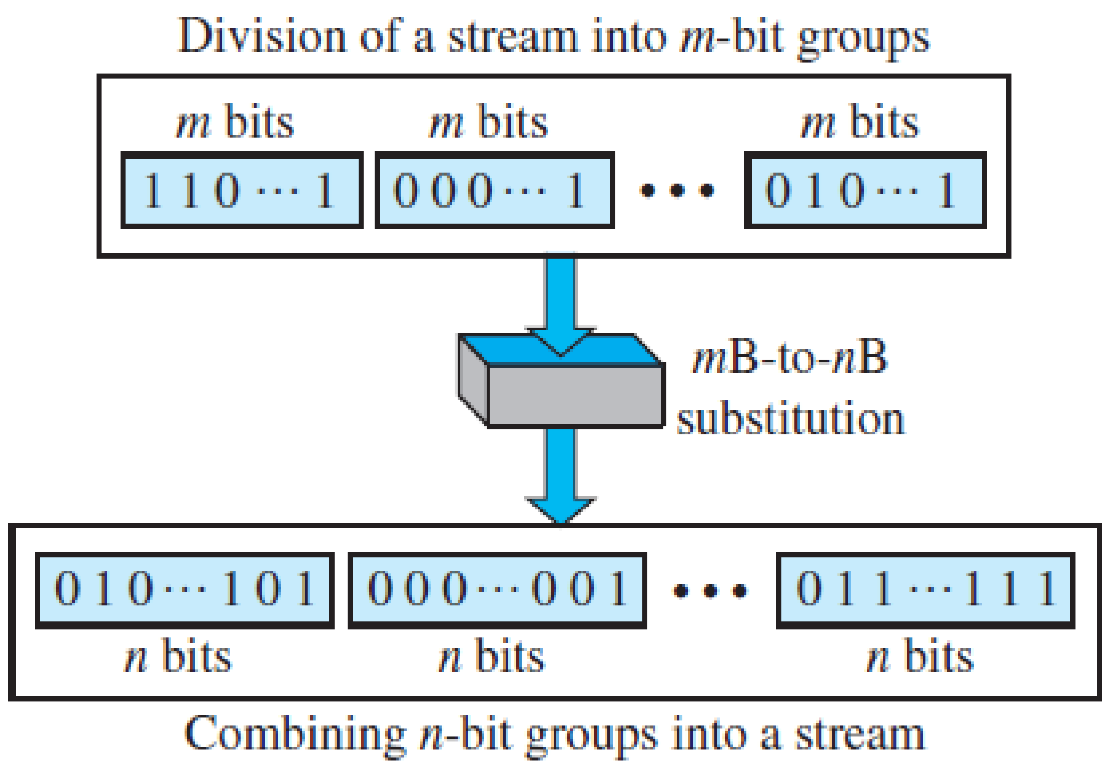
Exercise

1. Represent 1100100111 using following line coding schemes.
   - (i) AMI (ii) Manchester code (iii) Polar NRZ
2. Encode the following binary data stream into unipolar, polar (RZ, NRZ), Manchester and differential Manchester encodings for given data stream: 11100101

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.

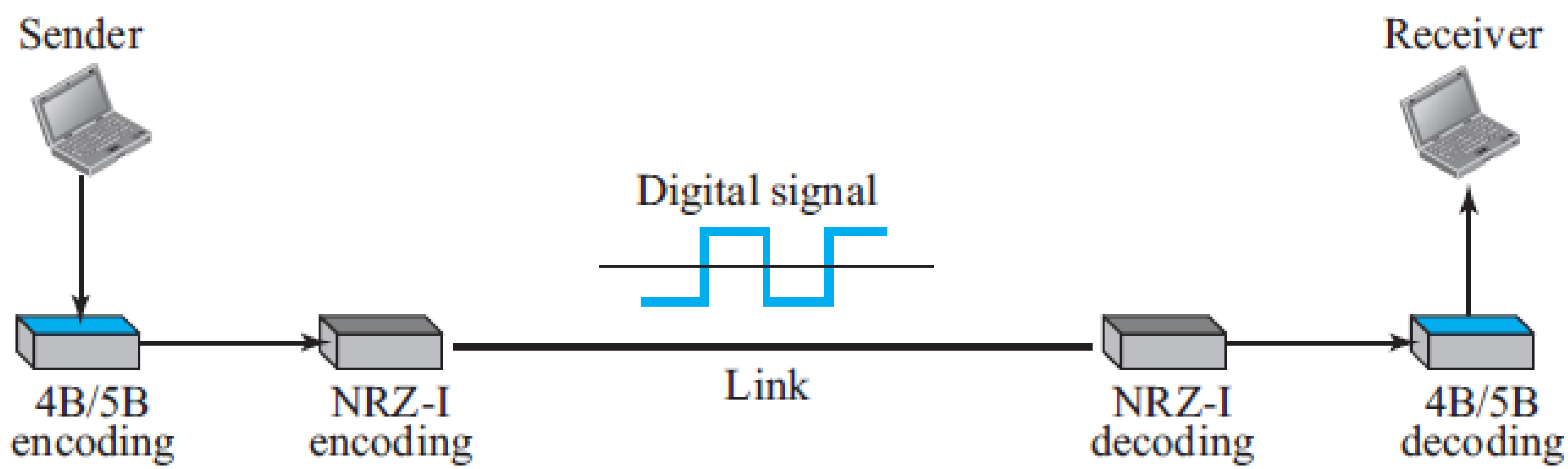
Figure 4.14 *Block coding concept*



4B/5B

- The four binary/five binary (4B/5B) coding scheme was designed to be used in combination with NRZ-I.
- Recall that NRZ-I has a good signal rate, one-half that of the biphase, but it has a synchronization problem.
- A long sequence of 0s can make the receiver clock lose synchronization.
- One solution is to change the bit stream, prior to encoding with NRZ-I, so that it does not have a long stream of 0s.
- The 4B/5B scheme achieves this goal.
- The block-coded stream does not have more that three consecutive 0s.
- the receiver, the NRZ-I encoded digital signal is first decoded into a stream of bits and then decoded to remove the redundancy.

Figure 4.15 *Using block coding 4B/5B with NRZ-I line coding scheme*



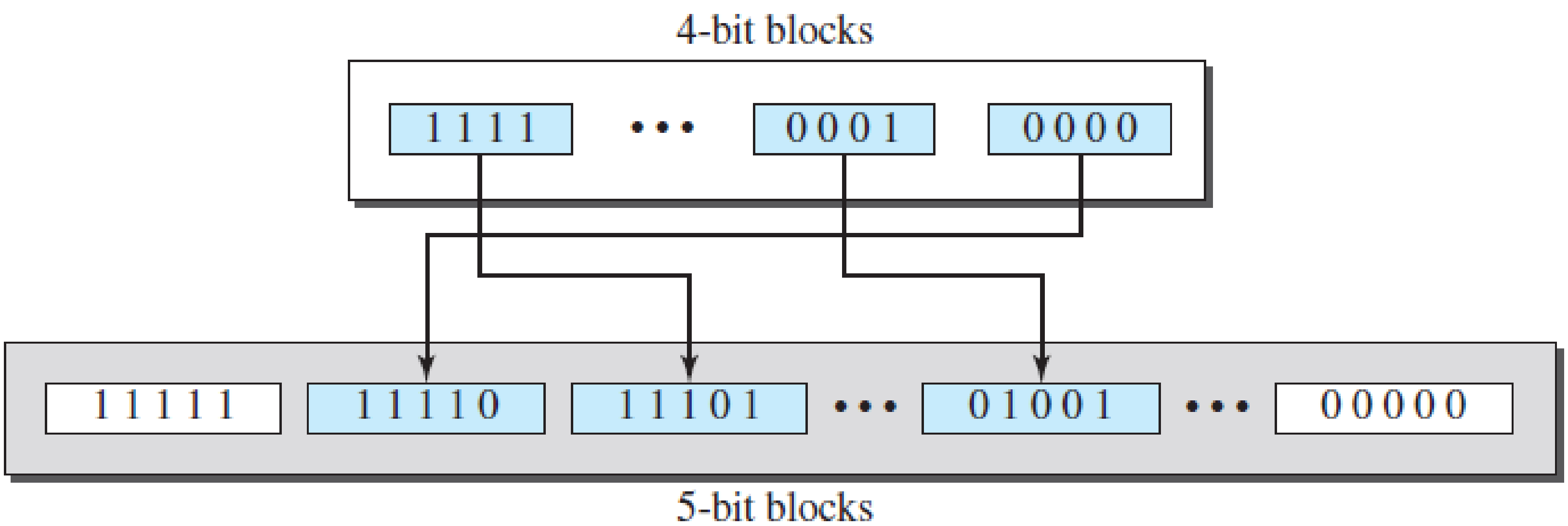
4B/5B

- In 4B/5B, the 5-bit output that replaces the 4-bit input has no more than one leading zero (left bit) and no more than two trailing zeros (right bits). So when different groups are combined to make a new sequence, there are never more than three consecutive 0s.
- A group of 4 bits can have only 16 different combinations while a group of 5 bits can have 32 different combinations.
- This means that there are 16 groups that are not used for 4B/5B encoding.
- Some of these unused groups are used for control purposes; the others are not used at all.
- The latter provide a kind of error detection.
- If a 5-bit group arrives that belongs to the unused portion of the table, the receiver knows that there is an error in the transmission.

Table 4.2 *4B/5B mapping codes*

Data Sequence	*Encoded Sequence*	*Control Sequence*	*Encoded Sequence*
0000	11110	Q (Quiet)	00000
0001	01001	I (Idle)	11111
0010	10100	H (Halt)	00100
0011	10101	J (Start delimiter)	11000
0100	01010	K (Start delimiter)	10001
0101	01011	T (End delimiter)	01101
0110	01110	S (Set)	11001
0111	01111	R (Reset)	00111
1000	10010		
1001	10011		
1010	10110		
1011	10111		
1100	11010		
1101	11011		
1110	11100		
1111	11101		

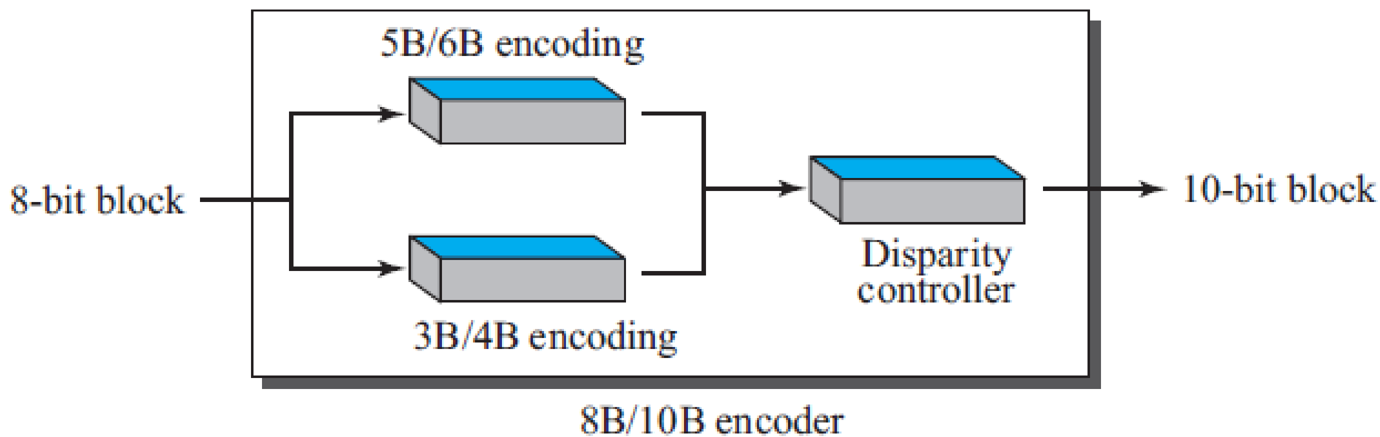
Figure 4.16 *Substitution in 4B/5B block coding*



8B/10B

- The eight binary/ten binary (8B/10B) encoding is similar to 4B/5B encoding except that a group of 8 bits of data is now substituted by a 10-bit code.
- It provides greater error detection capability than 4B/5B.
- The 8B/10B block coding is actually a combination of 5B/6B and 3B/4B encoding.
- The five most significant bits of a 10-bit block are fed into the 5B/6B encoder; the three least significant bits are fed into a 3B/4B encoder.
- The split is done to simplify the mapping table.
- To prevent a long run of consecutive 0s or 1s, the code uses a disparity controller which keeps track of excess 0s over 1s (or 1s over 0s).

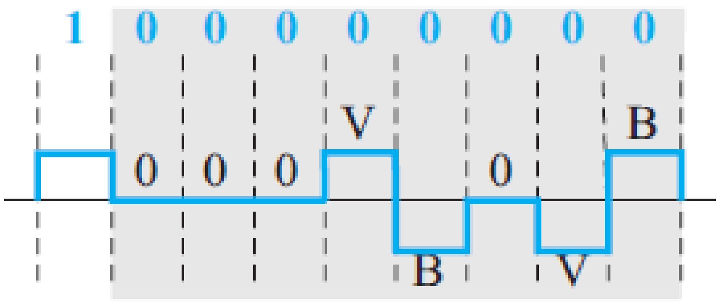
Figure 4.17 *8B/10B block encoding*



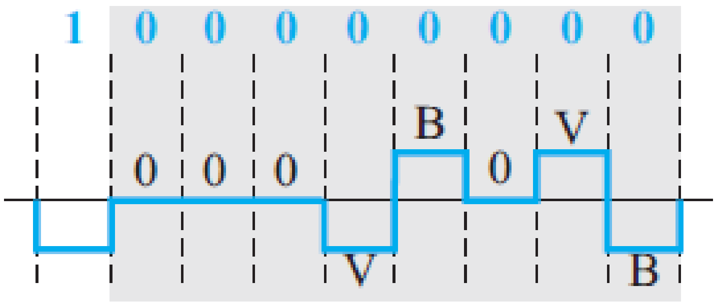
B8ZS

- Bipolar with 8-zero substitution (B8ZS) is commonly used in North America.
- In this technique, eight consecutive zero-level voltages are replaced by the sequence 000VB0VB.
- The V in the sequence denotes *violation; this is a nonzero voltage that* breaks an AMI rule of encoding (opposite polarity from the previous).
- The B in the sequence denotes *bipolar, which means a nonzero level voltage in accordance with the* AMI rule.

Figure 4.19 *Two cases of B8ZS scrambling technique*



a. Previous level is positive.

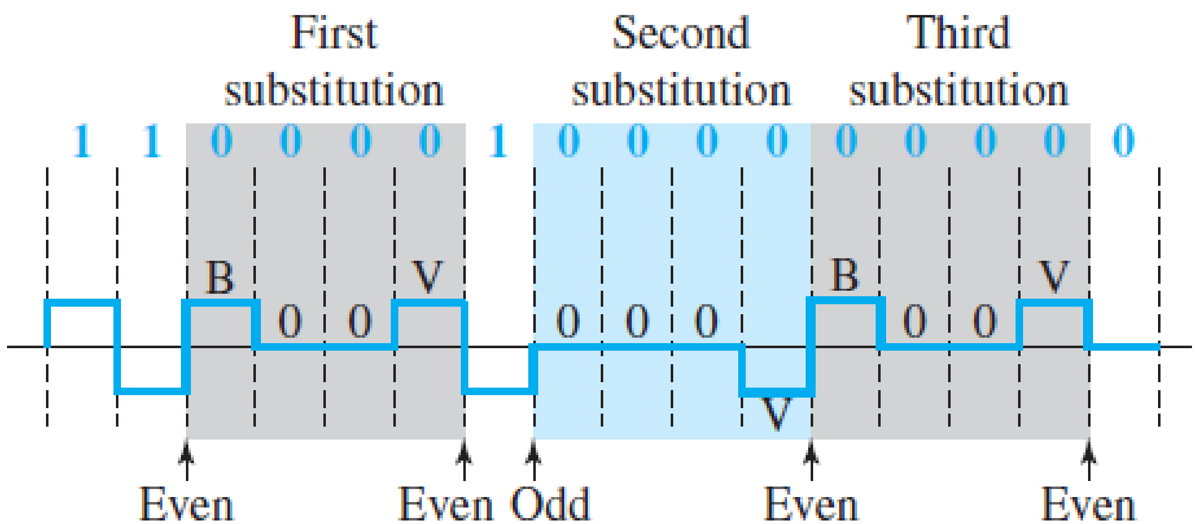


b. Previous level is negative.

High-density bipolar 3-zero (HDB3)

- High-density bipolar 3-zero (HDB3) is commonly used outside of North America.
- In this technique, which is more conservative than B8ZS, four consecutive zero-level voltages are replaced with a sequence of 000V or B00V.
- The reason for two different substitutions is to maintain the even number of nonzero pulses after each substitution.
- The two rules can be stated as follows:
    1. If the number of nonzero pulses after the last substitution is odd, the substitution pattern will be 000V, which makes the total number of nonzero pulses even.
    2. If the number of nonzero pulses after the last substitution is even, the substitution pattern will be B00V, which makes the total number of nonzero pulses even.

Figure 4.20 *Different situations in HDB3 scrambling technique*



Suggested Readings

1. Chapter 4, Fourauzan B., "Data Communications and Networking", 5th Edition, Tata McGraw- Hill, Publications, 2006