DATA COMMUNICATION

CSE 225/233

WEEK-4, LESSON-1

DIGITAL TRANSMISSION

Digital to Digital Conversion

In this section, we see how we can represent digital data by using digital signals. The conversion involves three techniques: *line coding, block coding, and scrambling*. **Line coding is always needed;** block coding and scrambling may or may not be needed.

Topics discussed in this section:

Line Coding

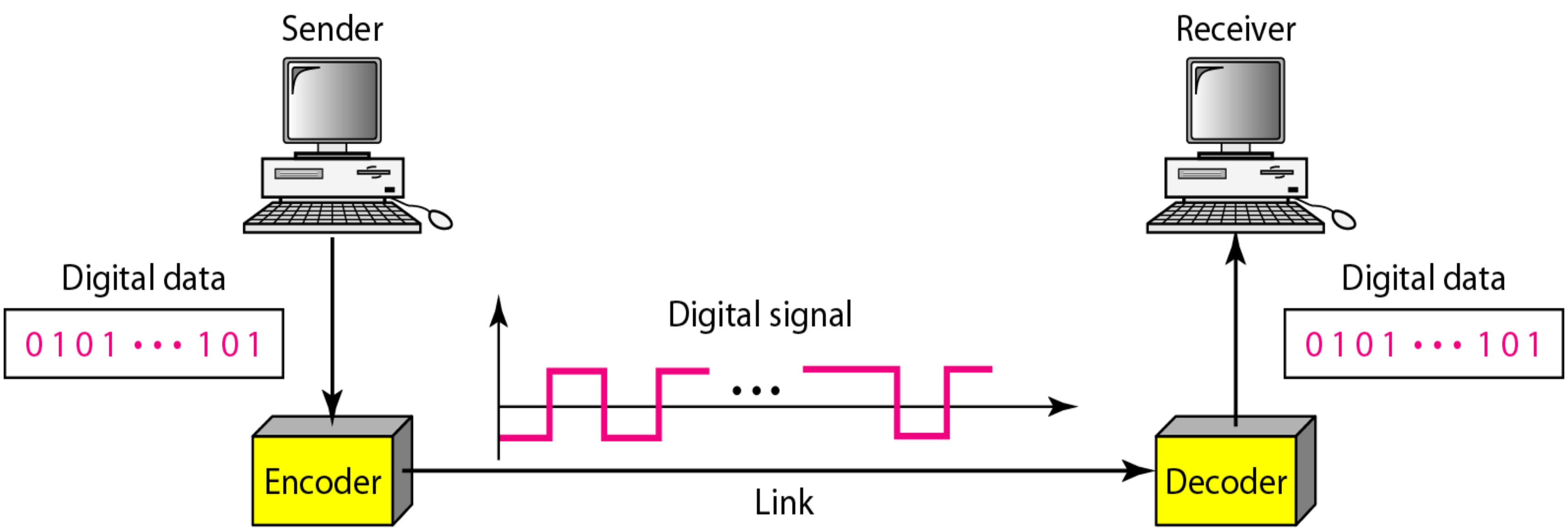
Line Coding Schemes

Block Coding

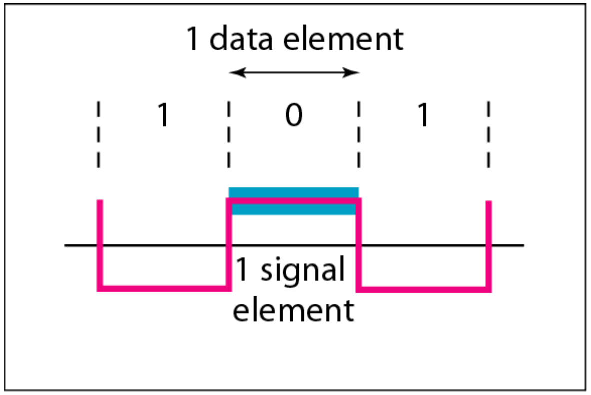
Scrambling

Line coding and decoding

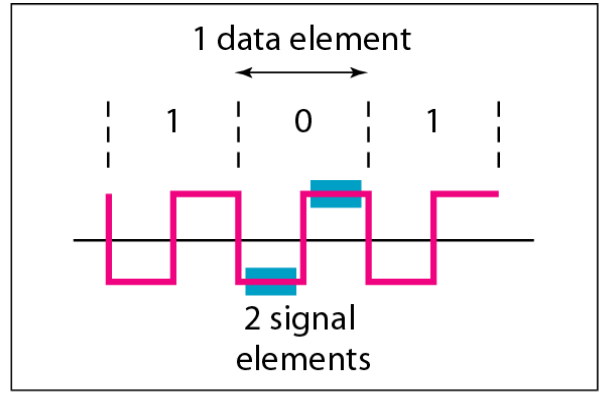
Line coding is the process of converting binary data i.e. a sequence of bits, into a digital signal



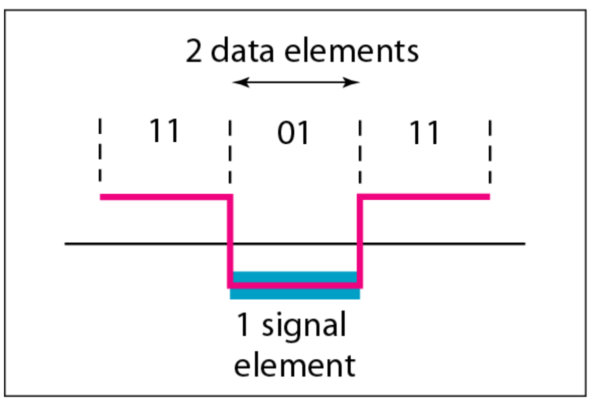
Signal element versus data element



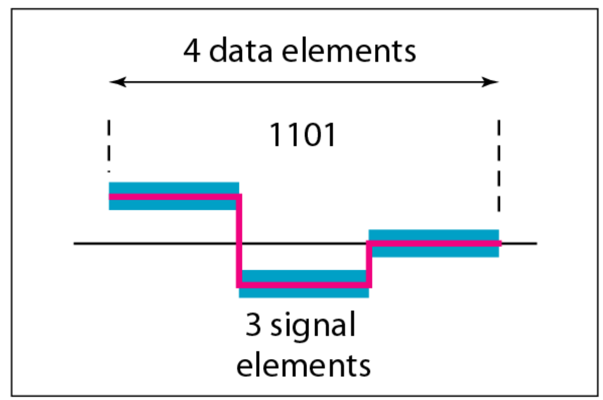
a. One data element per one signal element (r = 1)



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

Example

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?

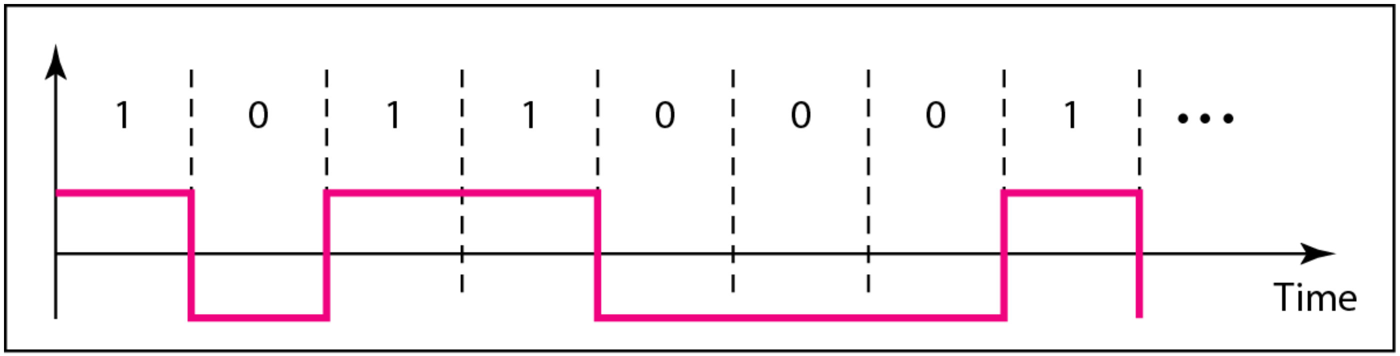
Solution

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

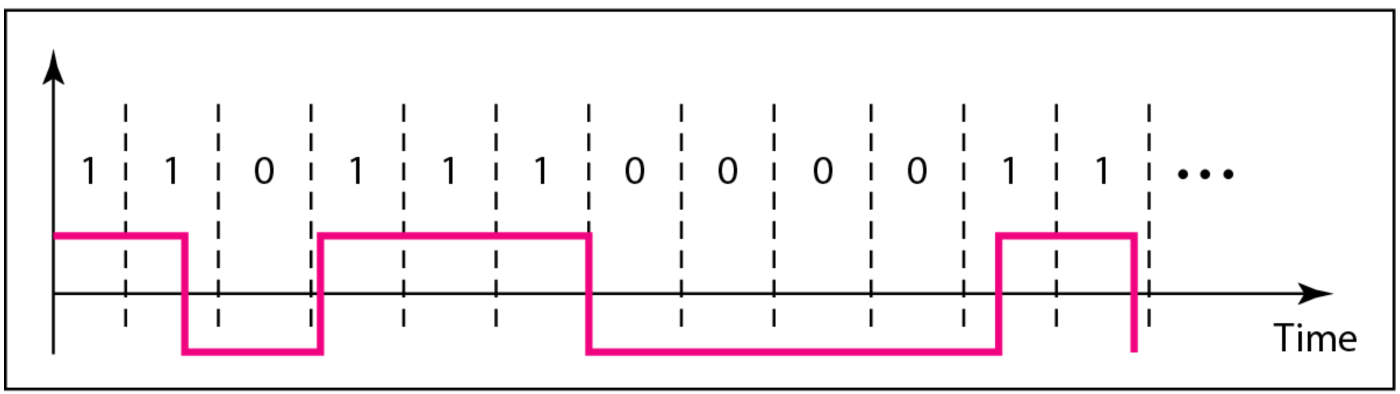
$$\boxed{S = c \times N \times \frac{1}{r} = \frac{1}{2} \times 100{,}000 \times \frac{1}{1} = 50{,}000 = 50 \text{ kbaud}}$$

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

Effect of lack of synchronization



a. Sent



b. Received

Example

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

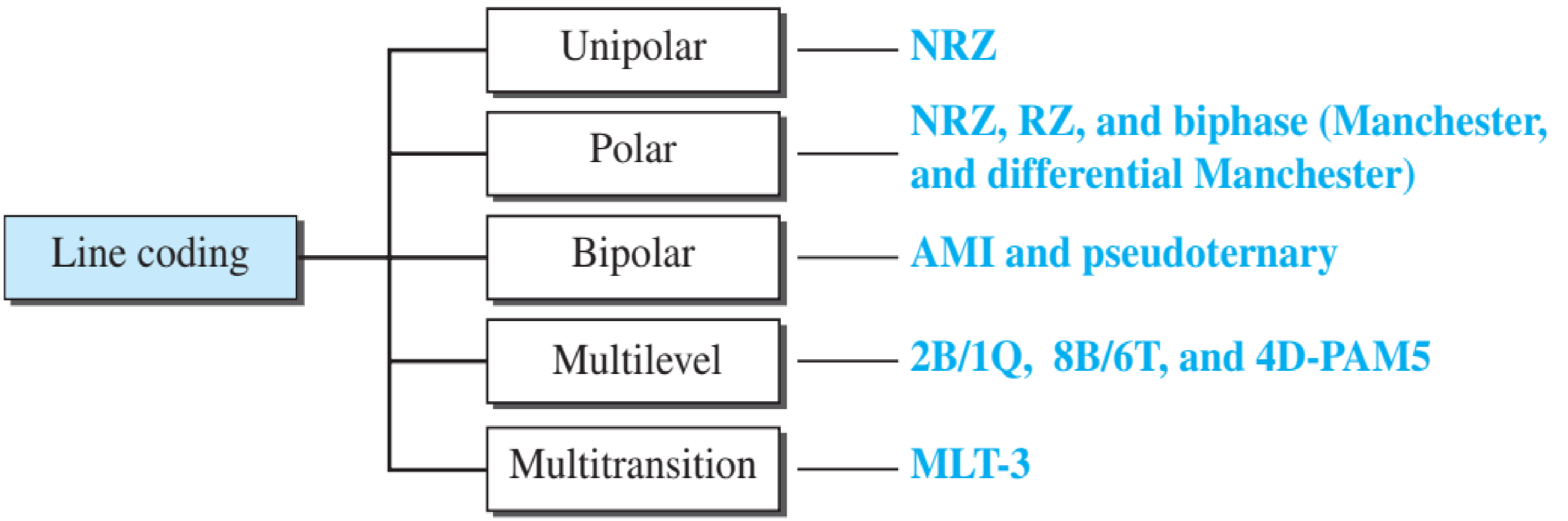
At 1 kbps, the receiver receives 1001 bps instead of 1000 bps.

1000 bits sent	1001 bits received	1 extra bps

At 1 Mbps, the receiver receives 1,001,000 bps instead of 1,000,000 bps.

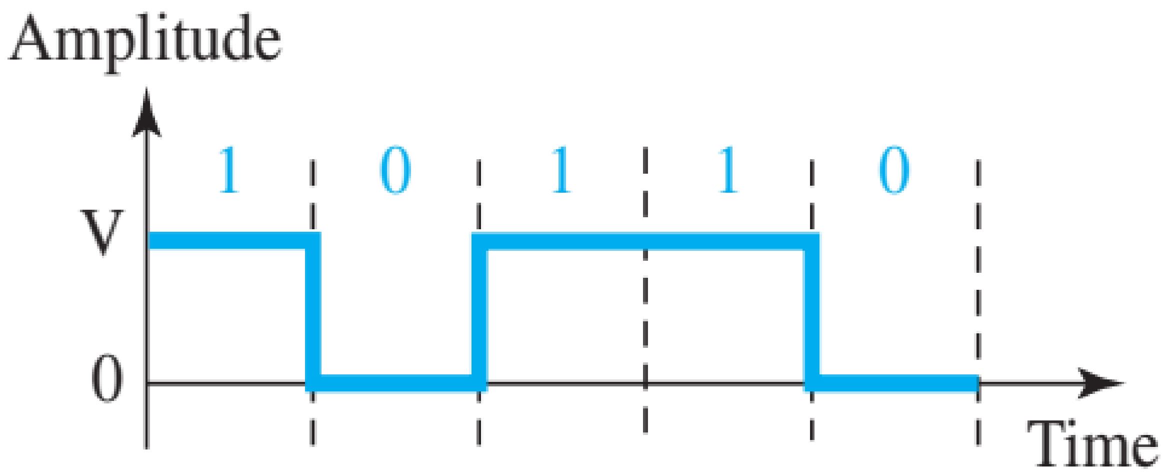
1,000,000 bits sent	1,001,000 bits received	1000 extra bps

Line Coding Scheme



Unipolar NRZ

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.

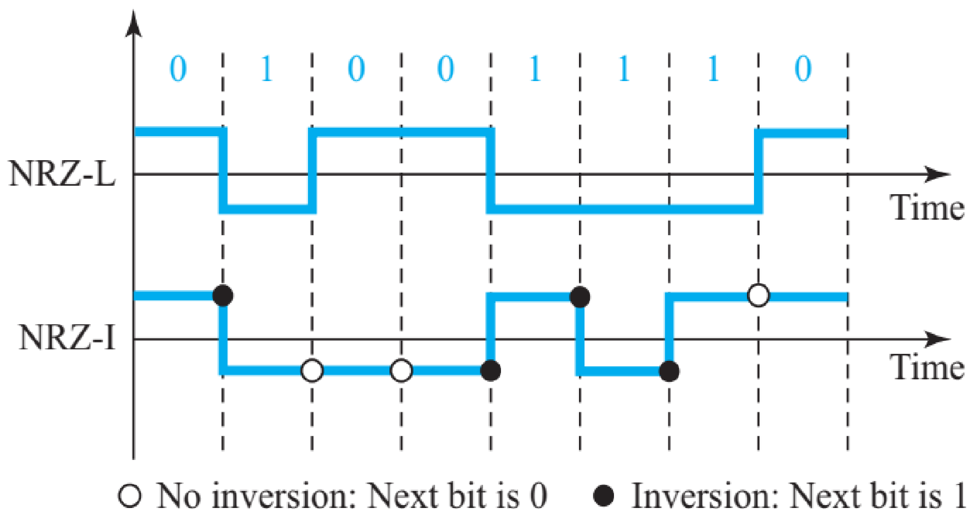


Polar NRZ

In polar NRZ encoding, we use two levels of voltage amplitude. We can have two versions of polar NRZ: NRZ-L and NRZ-I.

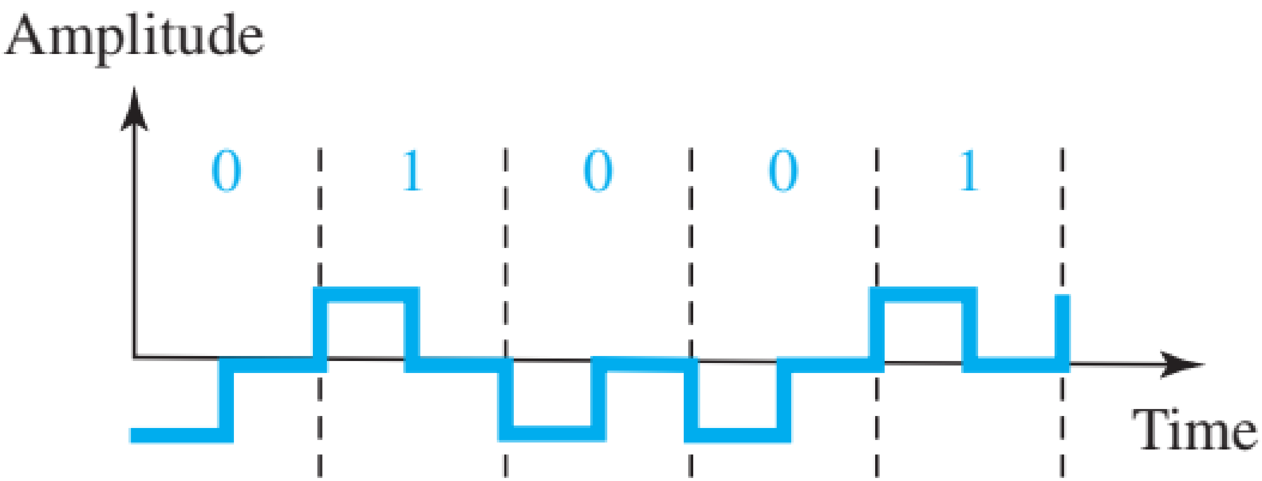
NRZ-L (NRZ-Level), the level of the voltage determines the value of the bit. In the second variation.

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.



Polar RZ

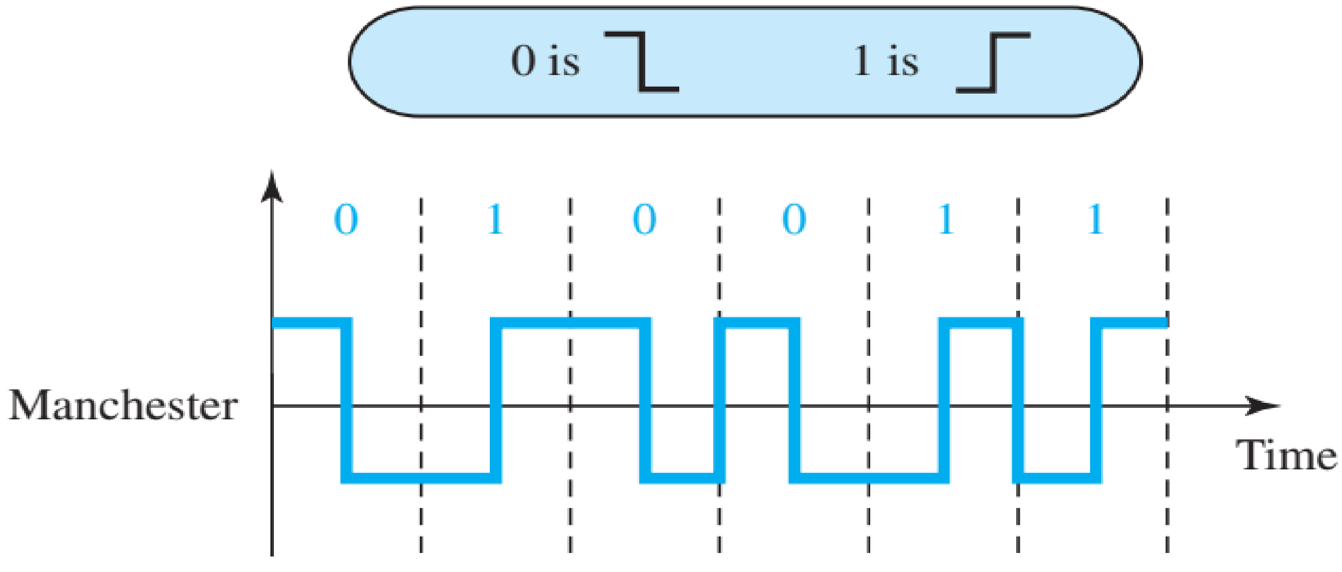
In Return-to-Zero (RZ) scheme, which uses three values: positive, negative, and zero. In RZ, the signal changes not between bits but during the bit.



The main disadvantage of RZ encoding is that it requires two signal changes to encode a bit and therefore occupies greater bandwidth.

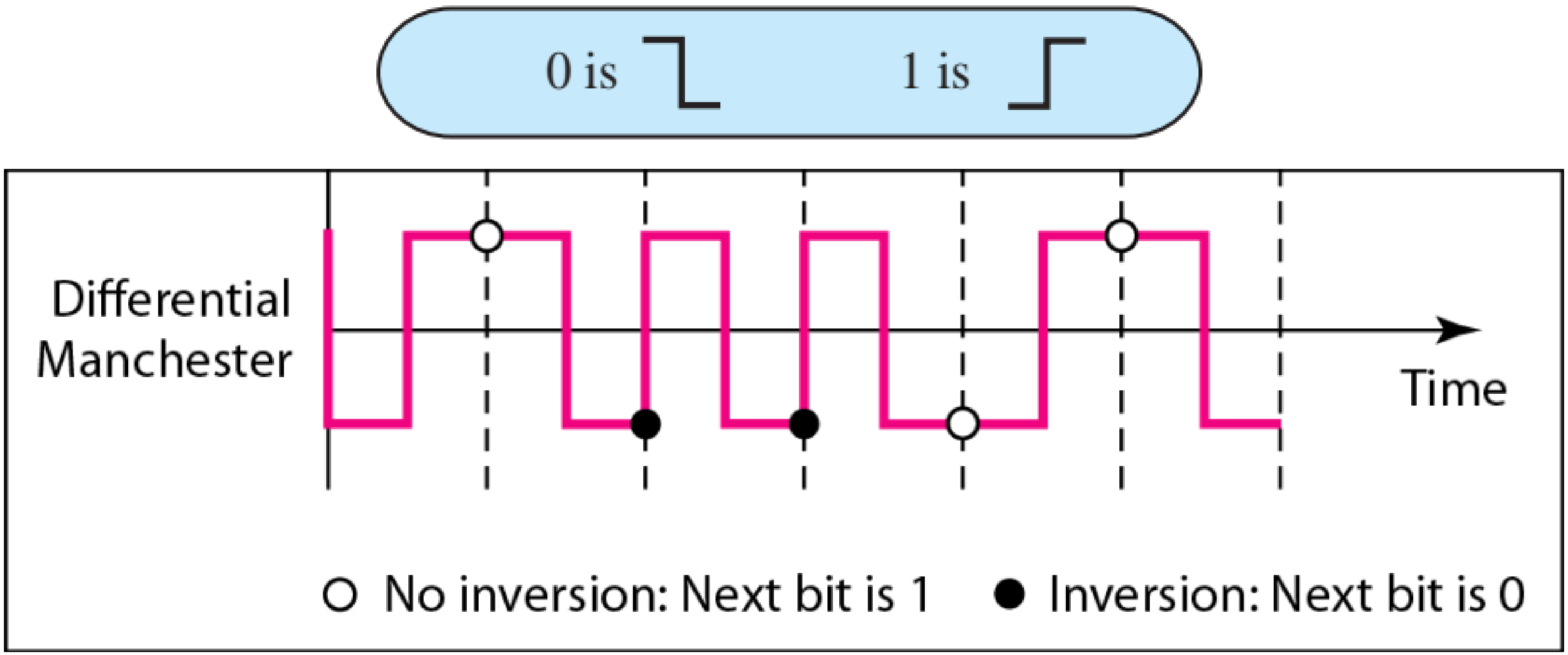
Biphase: Manchester

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.



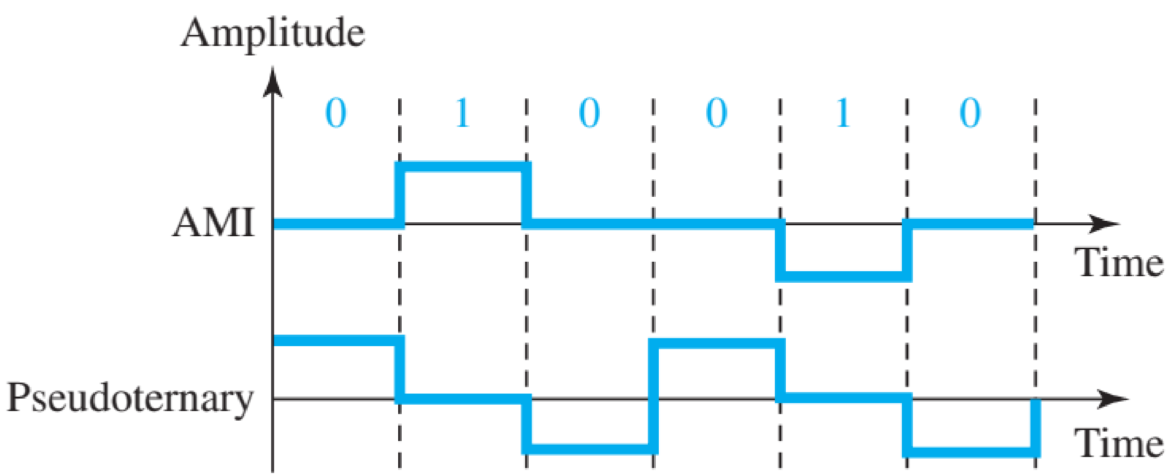
Biphase: Differential Manchester

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.



Bipolar: AMI and Pseudoternary

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.

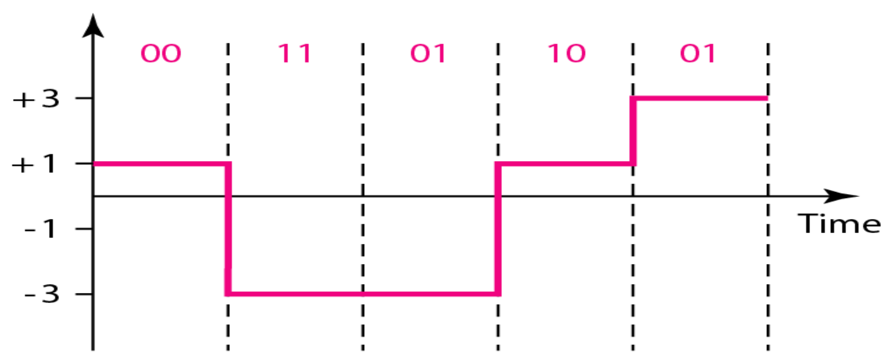


Multilevel: 2B1Q Scheme

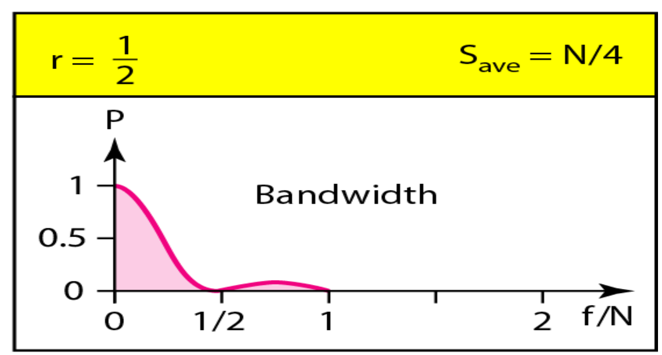
Two binary, one quaternary (2B1Q), uses data patterns of size 2 and encodes the 2-bit patterns as one signal element belonging to a four-level signal. In this type of encoding *m* = 2, *n* = 1, and *L* = 4 (quaternary).

	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

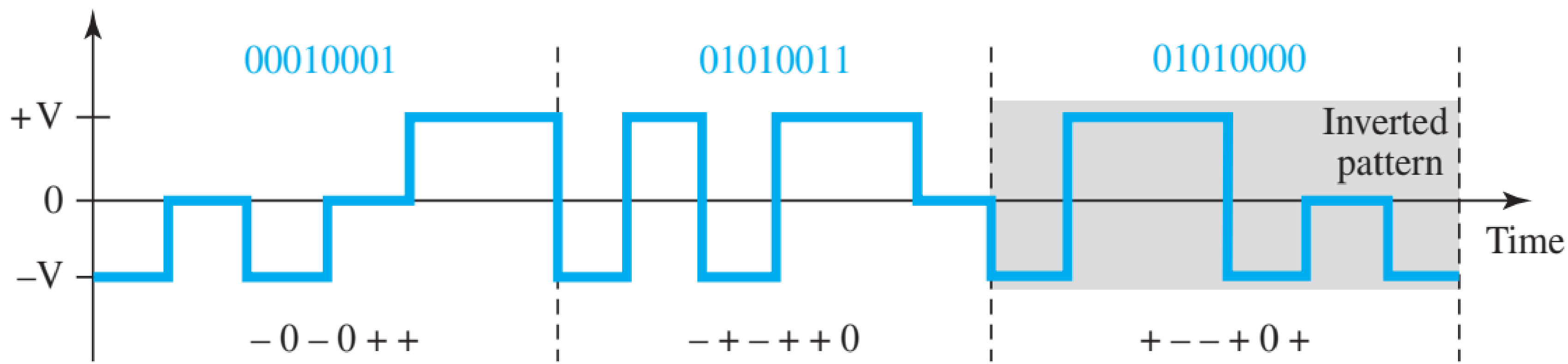


Assuming positive original level



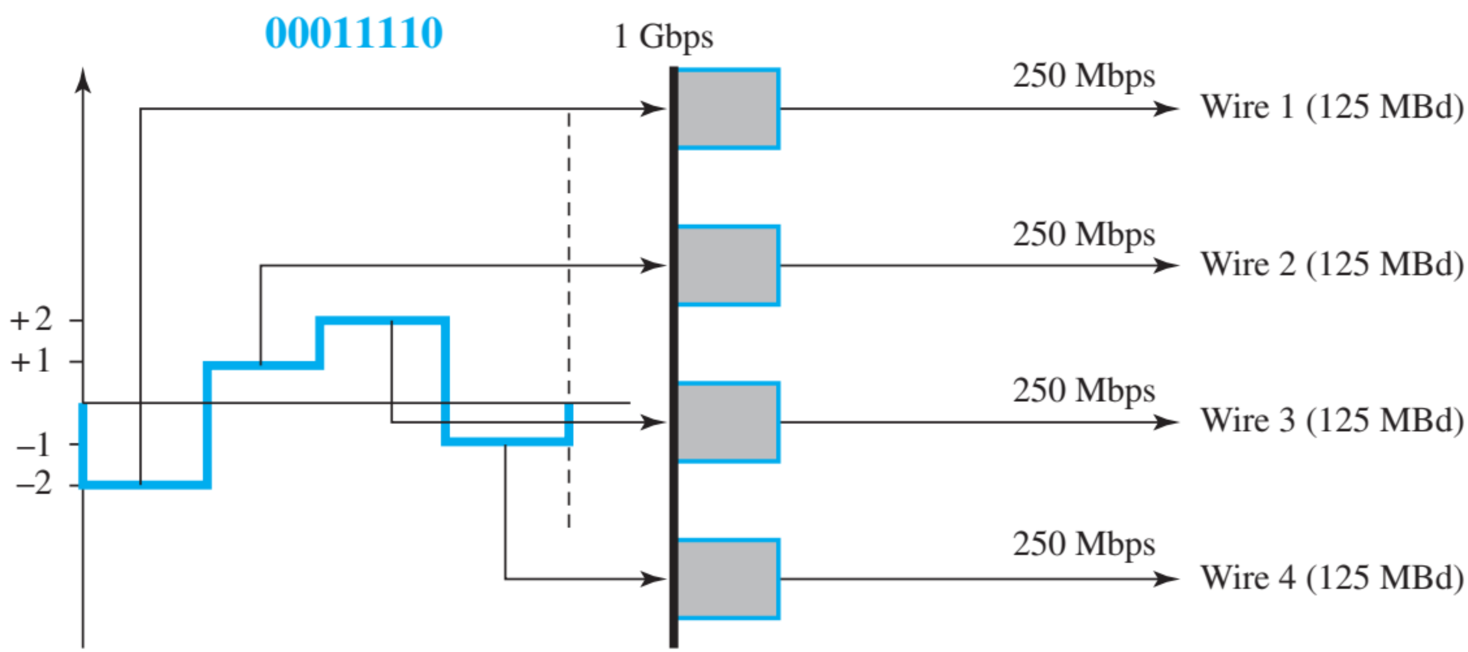
Multilevel: 8B6T Scheme

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).



Multilevel: 4D-PAM5

In 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.



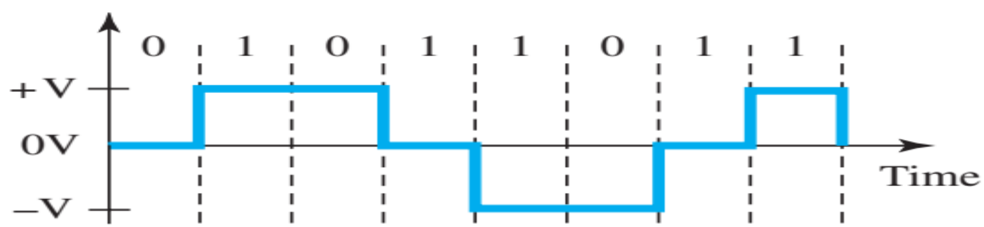
Multitransition: MLT-3 scheme

The **multiline transmission, three-level (MLT-3) scheme uses** three levels ($+V$, 0, and $-V$) and three transition rules to move between the levels.

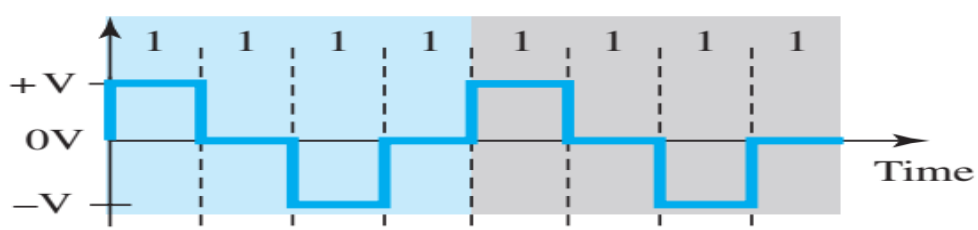
1. If the next bit is 0, there is no transition.

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.



a. Typical case



b. Worst case

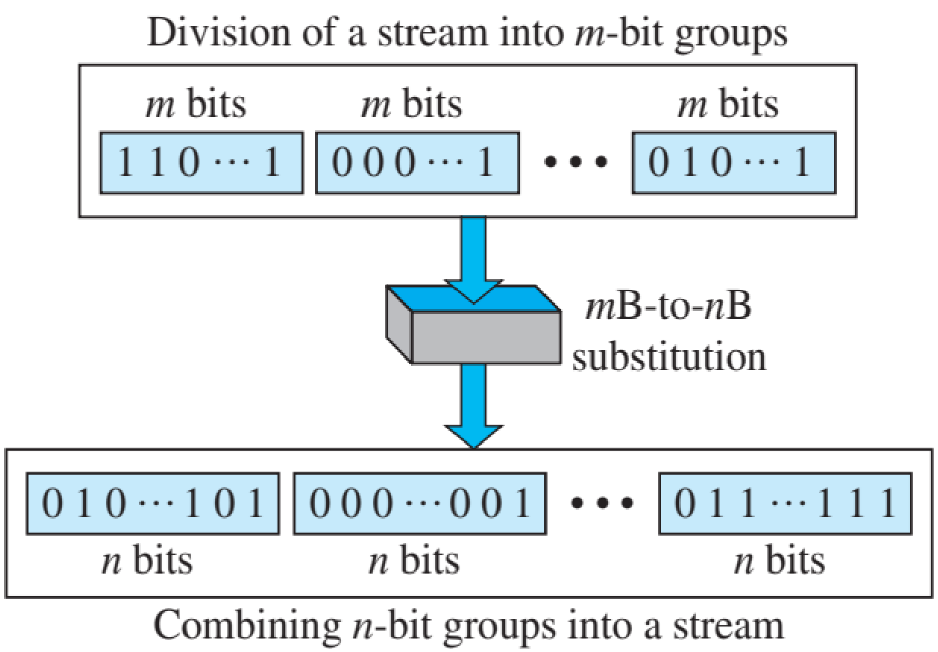
Summary: Line Coding Schemes

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

Block Coding

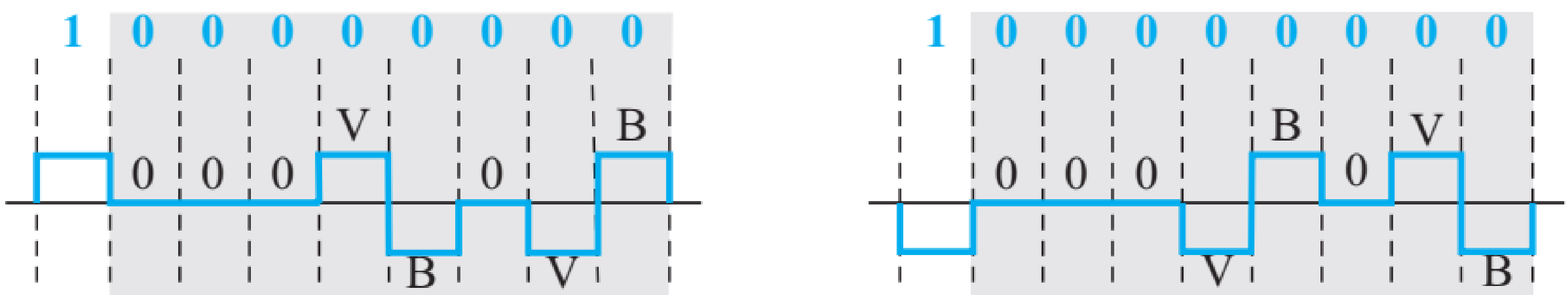
We need redundancy to ensure synchronization and to provide some kind of inherent error detecting. Block coding can give us this redundancy and improve the performance of line coding. In general, block coding changes a block of m bits into a block of n bits, where n is larger than m. Block coding is referred to as an mB/nB encoding technique.

Concept:



Scrambling: 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. There are two cases. See the picture below.



a. Previous level is positive.

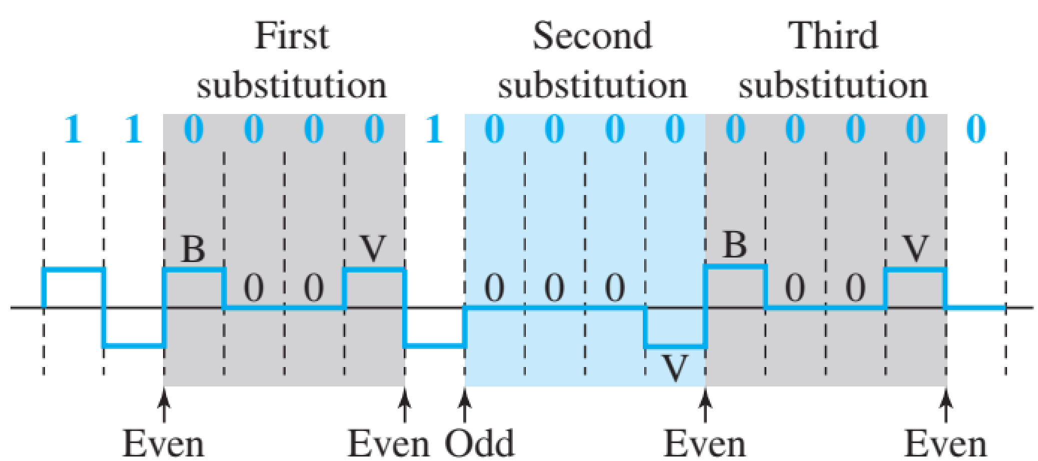
b. Previous level is negative.

Scrambling: 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.




THANK
YOU