ITT300
Introduction To Data Communication and Networking

Chapter 3
Data and Signal (Part 2)

Mazlan Osman, FSKM, UiTM (Terengganu) 2011

3-7 DIGITAL-TO-DIGITAL CONVERSION

- In this section, we will discuss how we can represent digital data by using digital signals.
- The representation involves three techniques:
  - line coding
  - block coding
  - scrambling.

LINE CODING

- Process of converting digital data (sequence of bits) to digital signals
- At the sender, digital data are encoded into a digital signal; at the receiver, the digital signal are decoded into digital data.

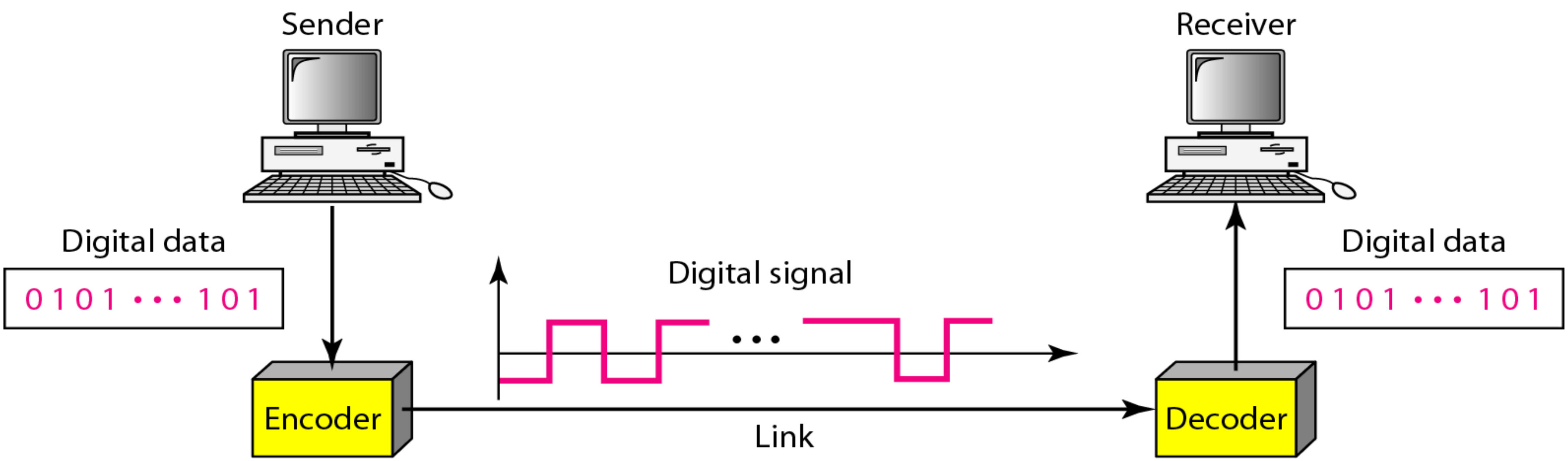


Figure 3.17 ***Line coding and decoding***

DATA ELEMENT AND SIGNAL ELEMENT

- **Data element** : The smallest entity that can represent a piece of information (bit).
- **Signal element** : The shortest unit (timewise) of a digital signal to carry data element.
- Data elements are what we need to send; signal elements are what we can send

DATA ELEMENT AND SIGNAL ELEMENT

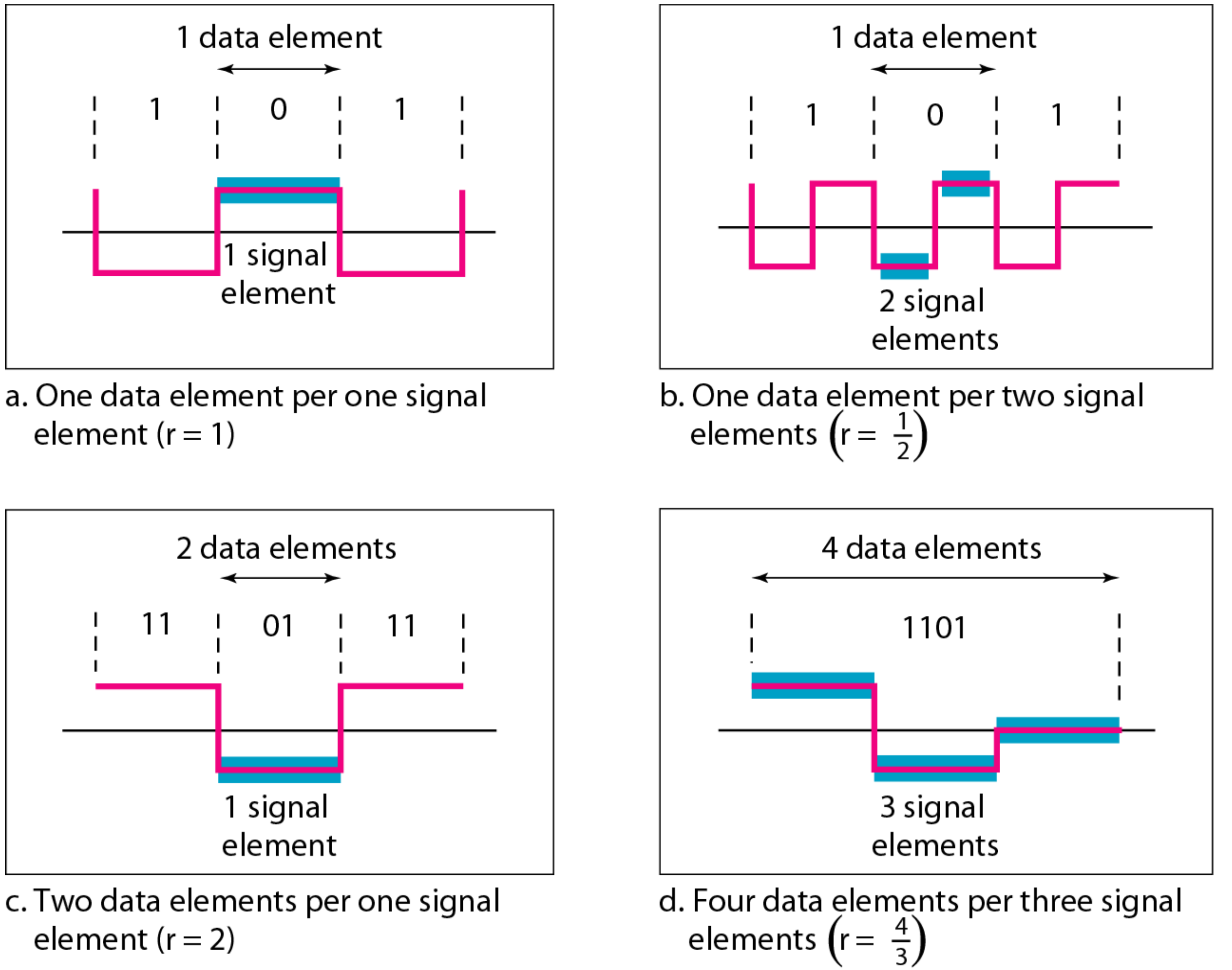


Figure 3.18 ***Signal element versus data element***

DATA RATE AND SIGNAL RATE

- **Data rate** : The number of data elements (bits) sent in 1s. Unit : bps
- **Signal rate** : The number of signal elements sent in 1s. Unit : baud
- Relation between data rate and signal rate (baud rate):

$$S = c \text{ x } N \text{ x } 1/r$$

- **Example 4.1**

  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 0.5?

  Solution

  The baud rate is then

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

DC COMPONENTS & SELF-SYNCHRONIZATION

DC Components

- *Direct-current components*
- The signal that have zero frequency and the average amplitude is nonzero

Self-synchronization

- The method to correctly interpret the signals received from the sender

LACK OF SYNCHRONIZATION

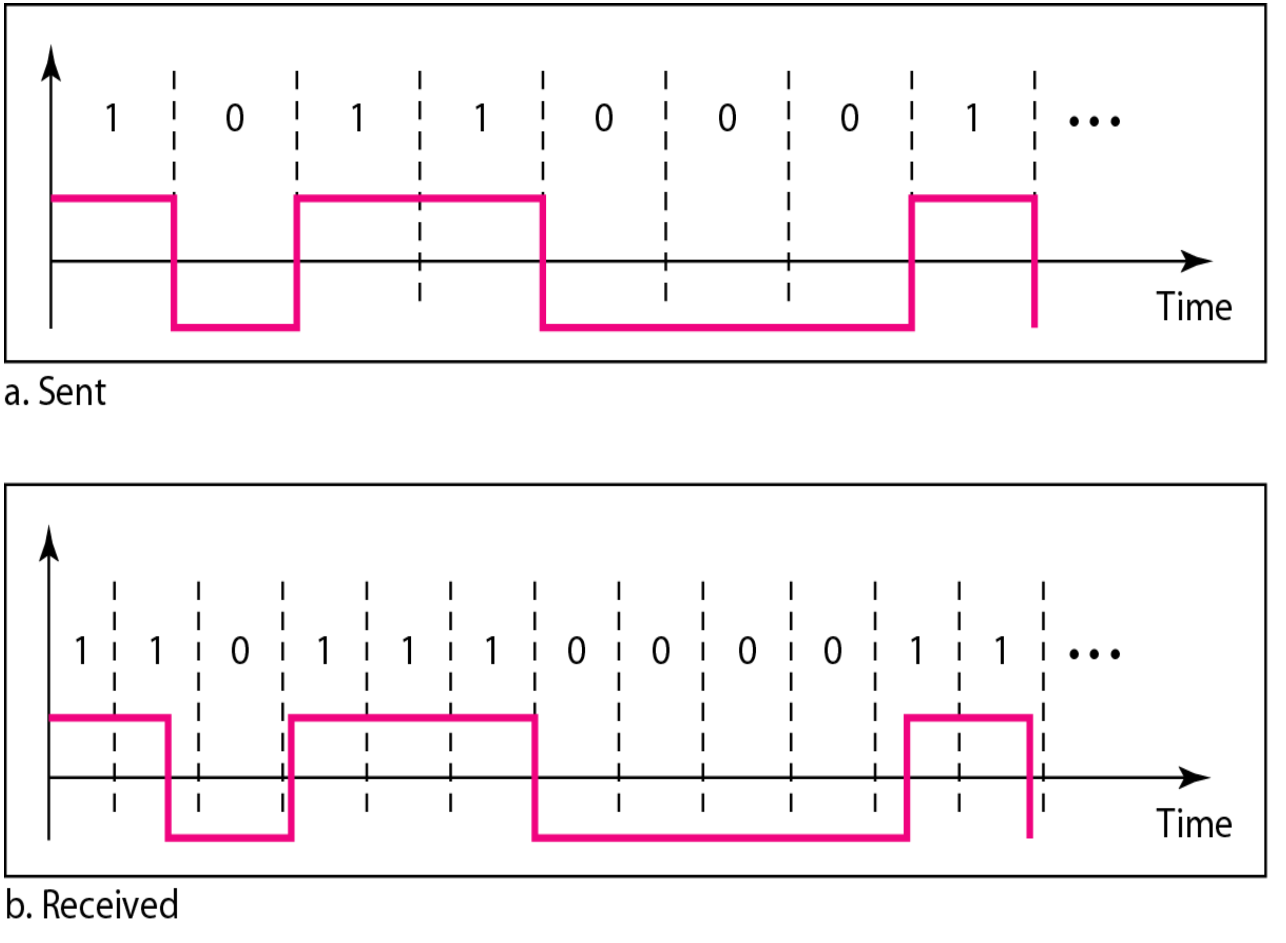


Figure 3.19 ***Effect of lack of synchronization***

LINE CODING SCHEMES

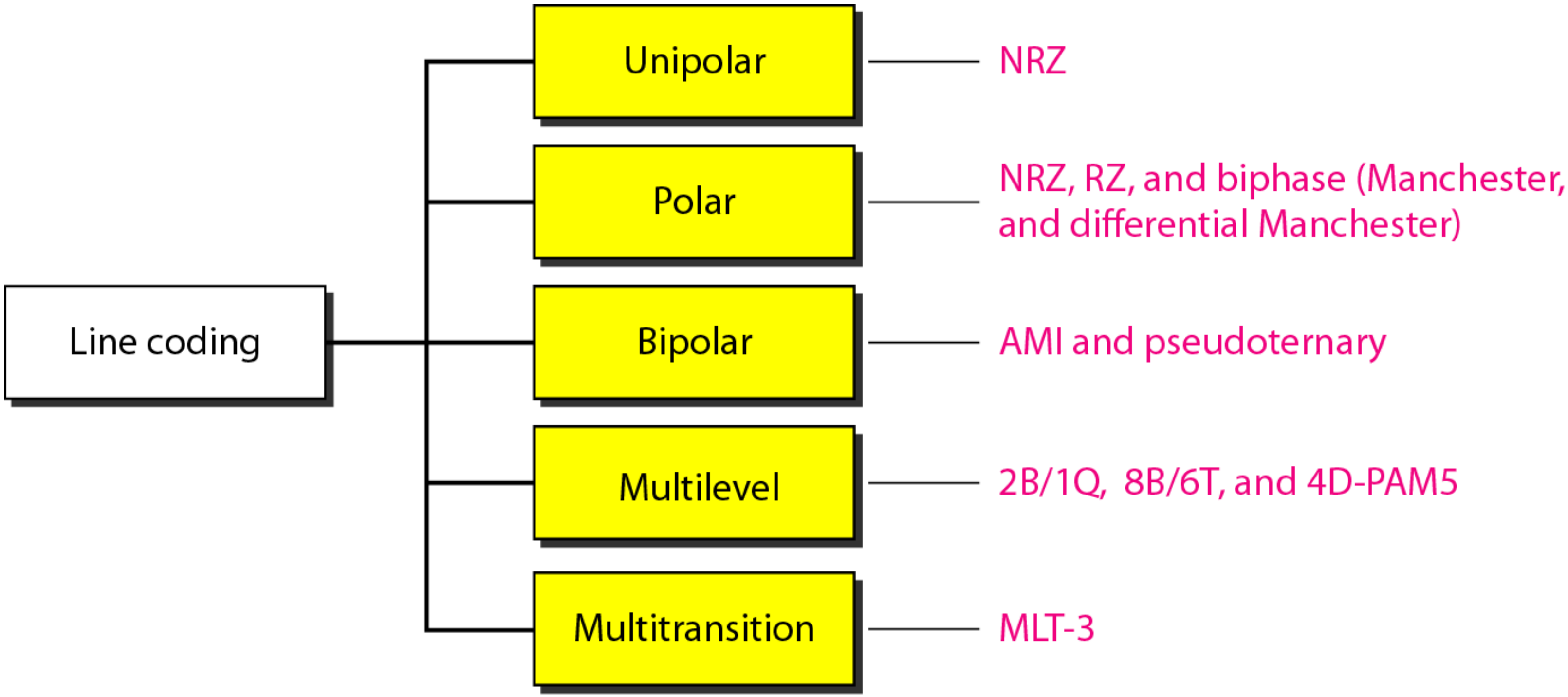


Figure 3.20 ***Line coding schemes***

UNIPOLAR SCHEME

Uses only one voltage level

- Positive voltage defines bit 1 and the zero voltage defines bit 0

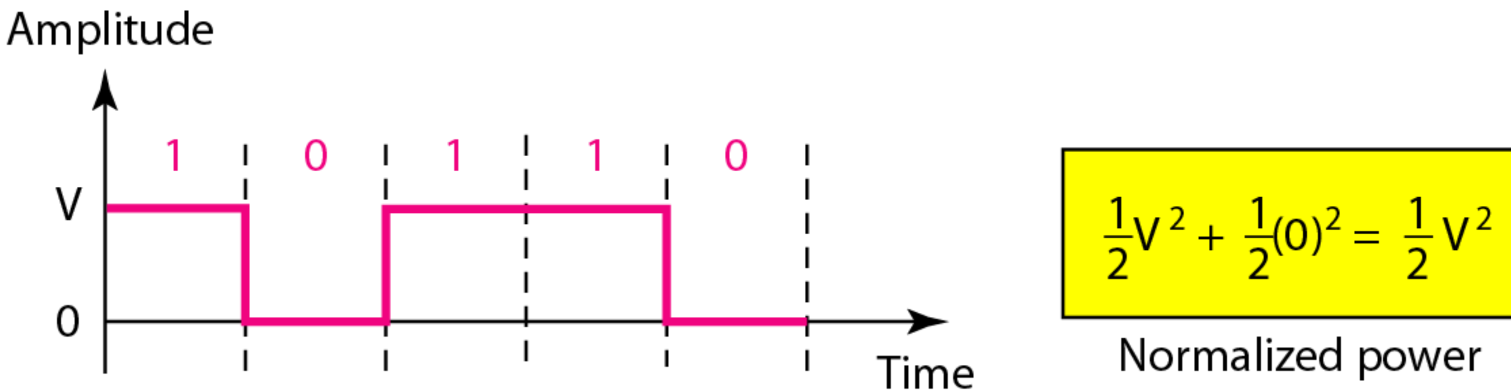


Figure 3.21 ***Unipolar NRZ scheme***

POLAR SCHEME

NRZ (Non-Return-to-Zero)

- Have two versions of polar NRZ:

i. NRZ-L (NRZ-Level)

– Bit 1 is represented by negative voltage, bit 0 represented by positive voltage.

ii. NRZ-I (NRZ-Invert)

– Bit 1 is represented inversion of voltage, bit 0 is represented by no change.

POLAR SCHEME

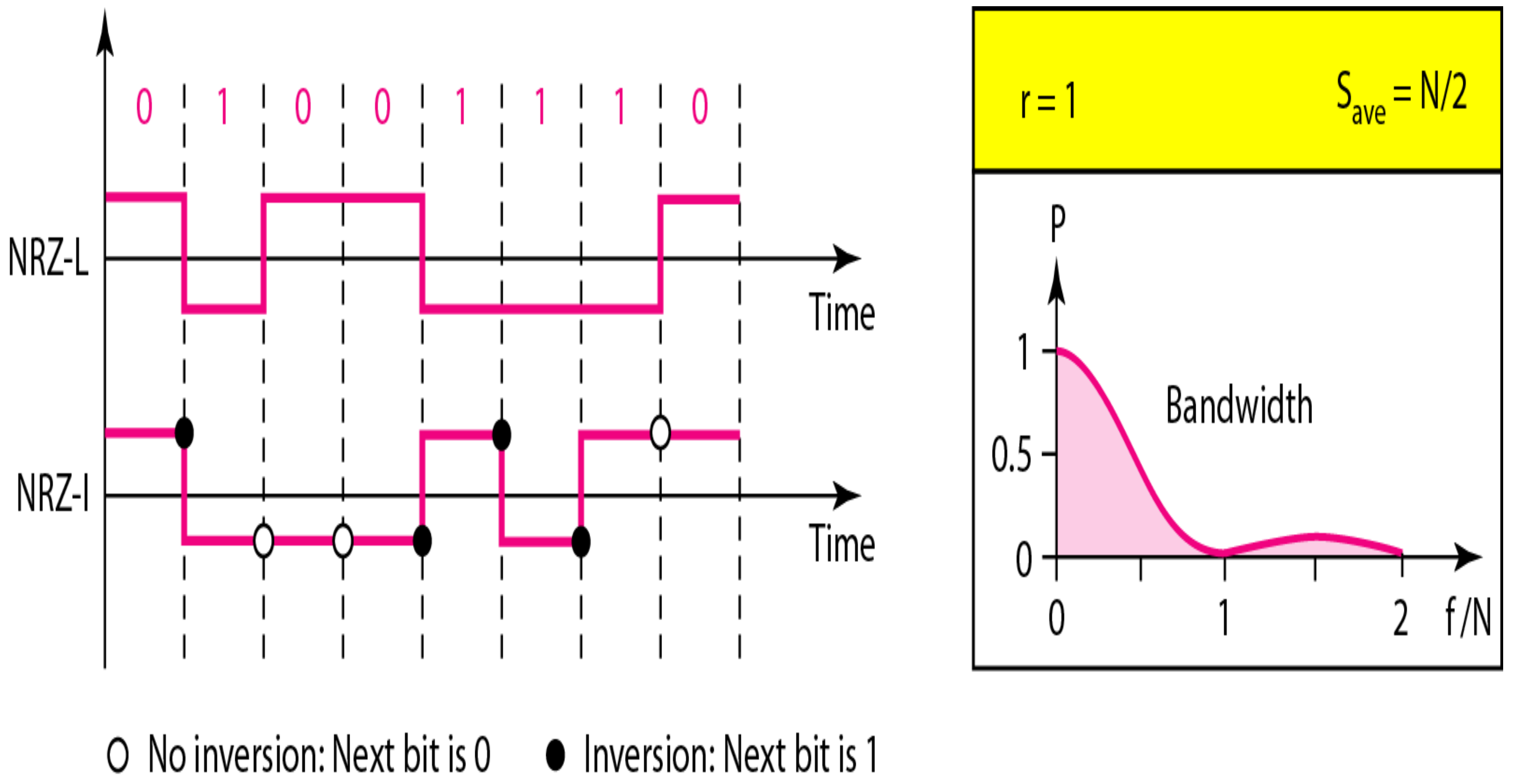
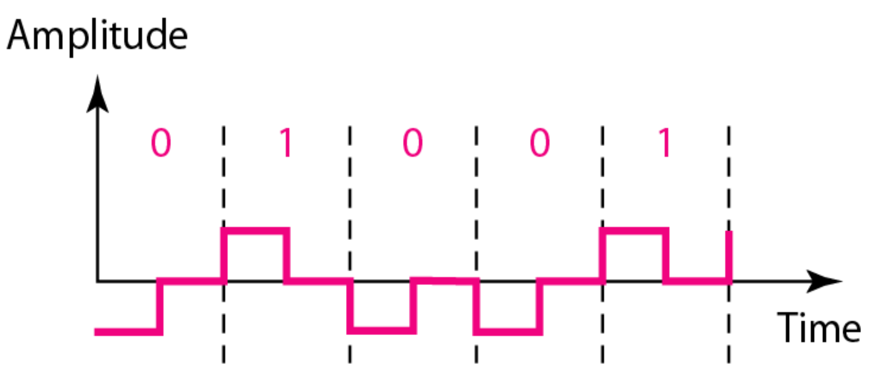


Figure 3.22 ***Polar NRZ-L and NRZ-I schemes***

RZ (Return-to-Zero)

- Uses three values: positive, negative, and zero
- In RZ, bit 1 is represented by positive-to-zero voltage, bit 0 is represented by negative-to-zero voltage.



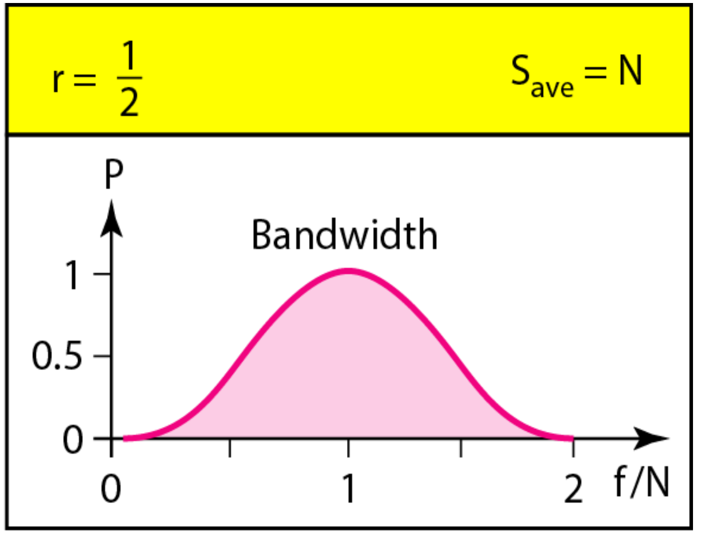


Figure 3.23 ***Polar RZ scheme***

POLAR SCHEME

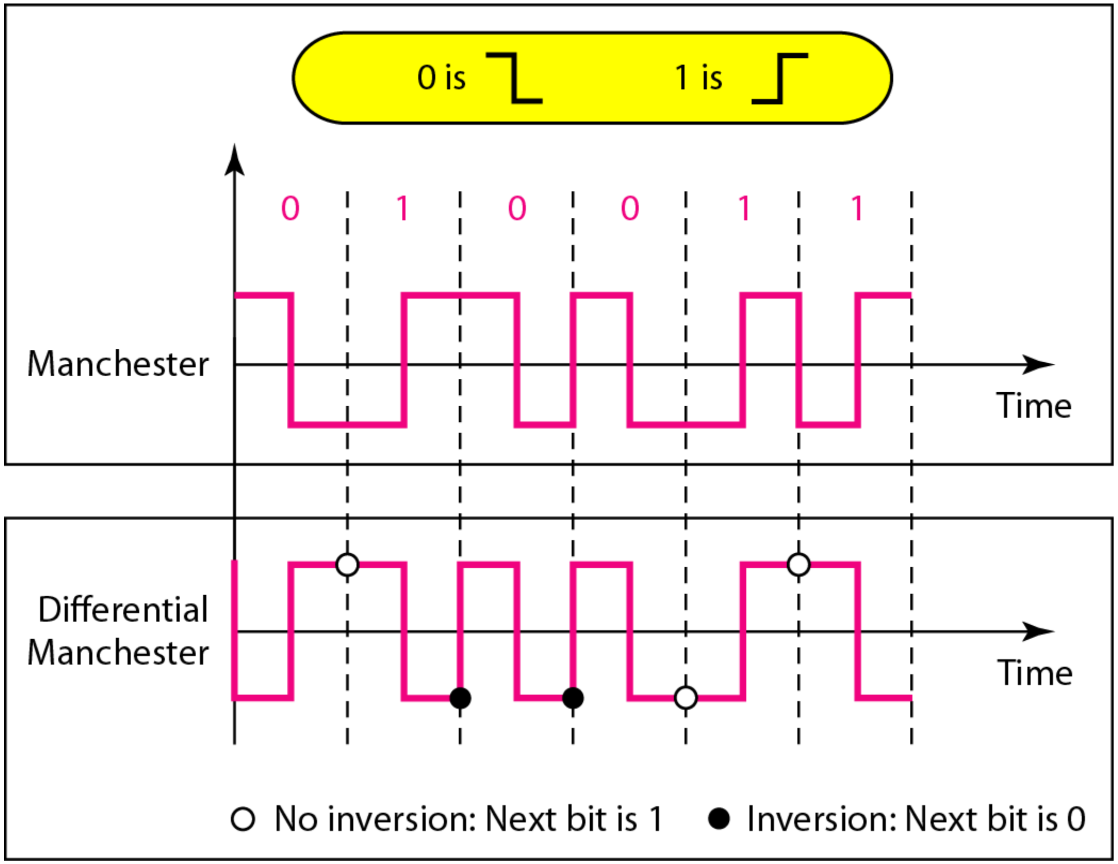
Biphase : Manchester and Differential Manchester

- Best solution for synchronization problems

- **Manchester** (RZ + NRZ-L)
  - Bit 1 is represented by negative-to-positive transition; bit 0 is represented by positive-to-negative transition.

- **Differential Manchester** (RZ + NRZ-I)
  - Bit 1 is represented by no transition; bit 0 is represented by transition.

POLAR SCHEME



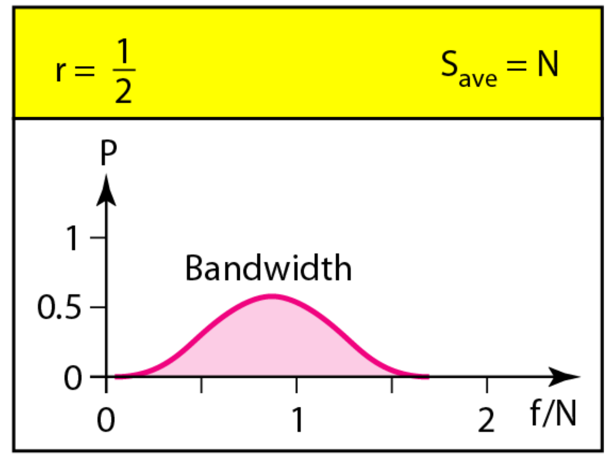
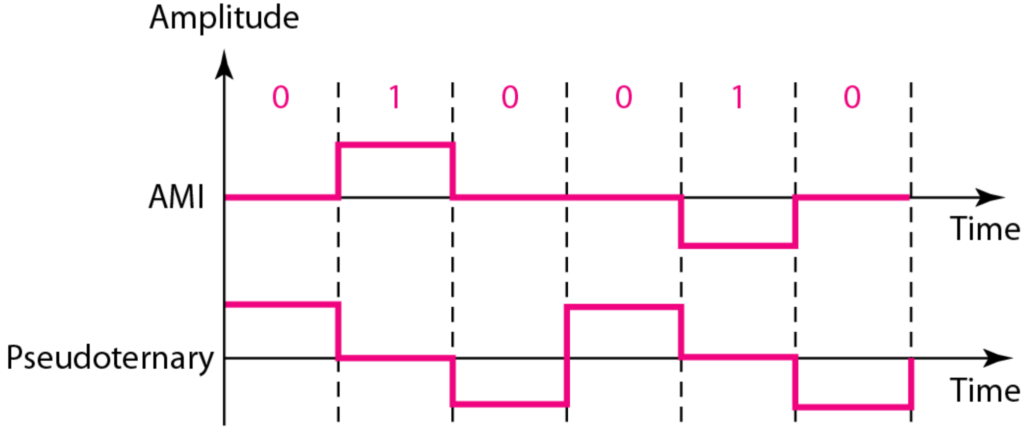


Figure 3.24 ***Polar biphase: Manchester and differential Manchester schemes***

BIPOLAR SCHEME

- **Alternate Mark Inversion (AMI)**
  - A bit 1 is represented by positive and negative voltage alternately; bit 0 is represented by zero voltage.
  - Advantages : DC component is zero and provide synchronization for a long strings of 1s.



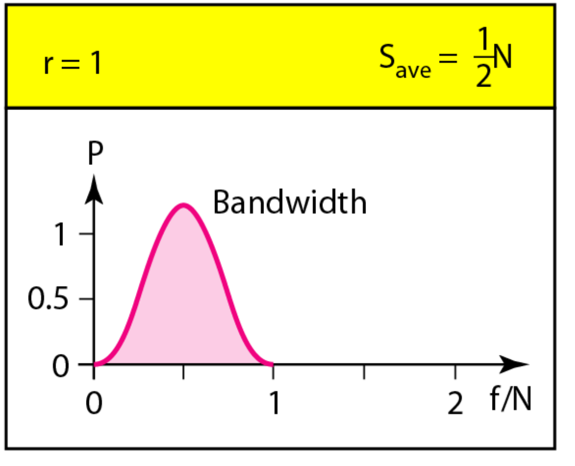


Figure 3.25 ***Bipolar schemes: AMI***

Summary of Line Coding Scheme

Category	*Scheme*	*Bandwidth (average)*	*Characteristics*
Unipolar	NRZ	$B = N/2$	Costly, no self-synchronization if long 0s or 1s, DC
Unipolar	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
Multiline	MLT-3	$B = N/3$	No self-synchronization for long 0s

Table 3.1 ***Summary of line coding schemes***

3-8 DIGITAL-TO-ANALOG CONVERSION

- Digital-to-analog conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data.

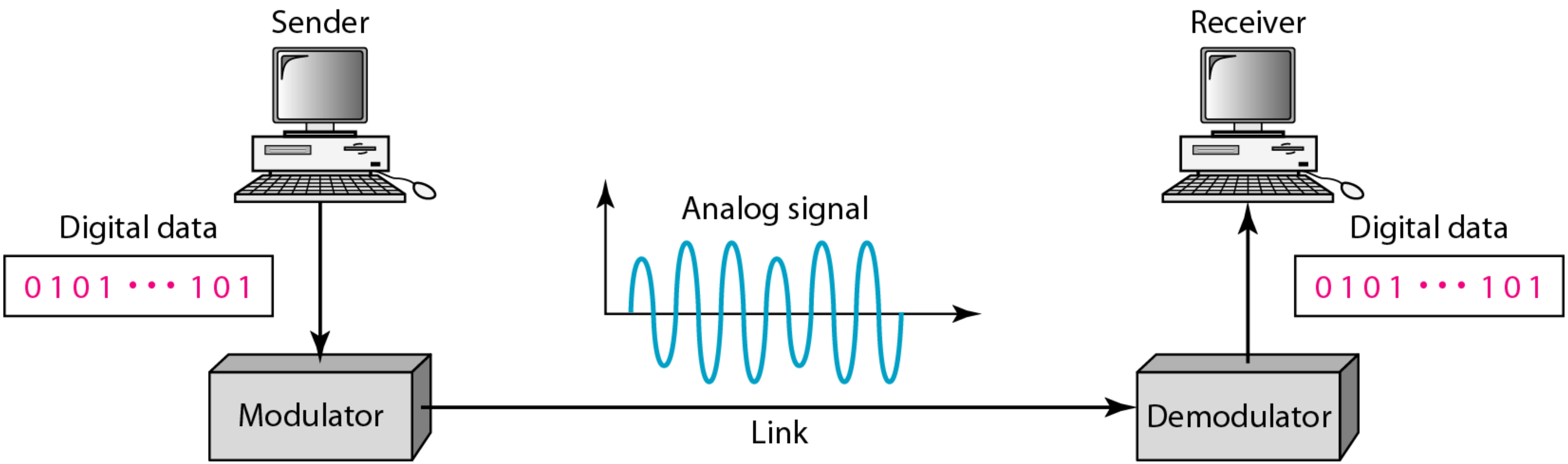


Figure 3.26 ***Digital-to-analog conversion***

DIGITAL-TO-ANALOG CONVERSION

Data Elements Vs Signal Elements

- Data element : Smallest piece of information to be exchanged, it means, the bit.
- Signal element : Smallest unit of a signal that is constant.

Data Rate Vs Signal Rate

- Bit rate (N) is the number of bits per second. Baud rate (S) is the number of signal elements per second.
- Relationship between S and N:

$$S = N \text{ x } \frac{1}{r} \text{ baud} \qquad (r = \log_2 L)$$

- The baud rate is less than or equal to the bit rate.

DIGITAL-TO-ANALOG CONVERSION

- **Example 5.1**
  An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.

- **Example 5.2**
  An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

CARRIER SIGNAL

- A high-frequency signal that acts as a basis for the information signal produced by sender.
- Digital information then modulated on the carrier signal by modifying one or more its characteristic (amplitude, frequency or phase).
- This process is called modulation (shift keying) and the information signal is called modulation signal.
- The middle of the bandwidth is called carrier frequency, f_c.

DIGITAL-TO-ANALOG CONVERSION

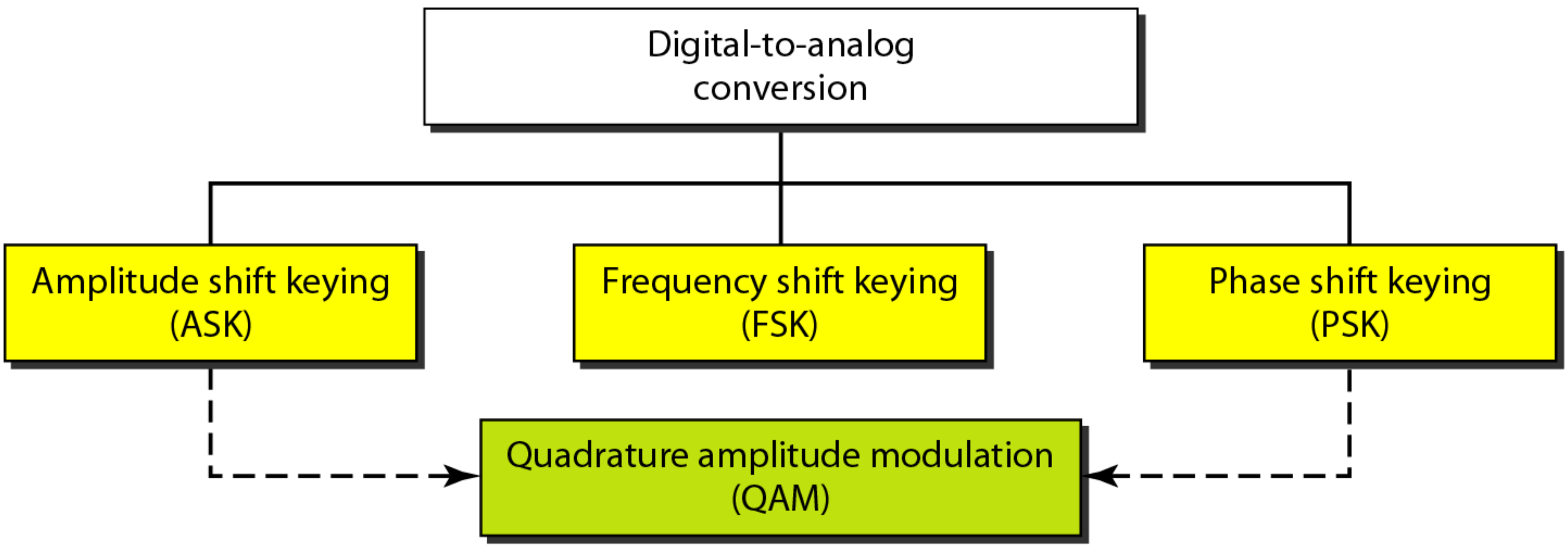


Figure 3.27 ***Types of digital-to-analog conversion***

AMPLITUDE SHIFT KEYING

- In ASK, the amplitude of the carrier signal is changed to create signal elements
- Both frequency and phase remain constant

Binary ASK (BASK)

- A popular ASK technique is called *on-off keying* (OOK) whereas the peak amplitude of one signal level is 0

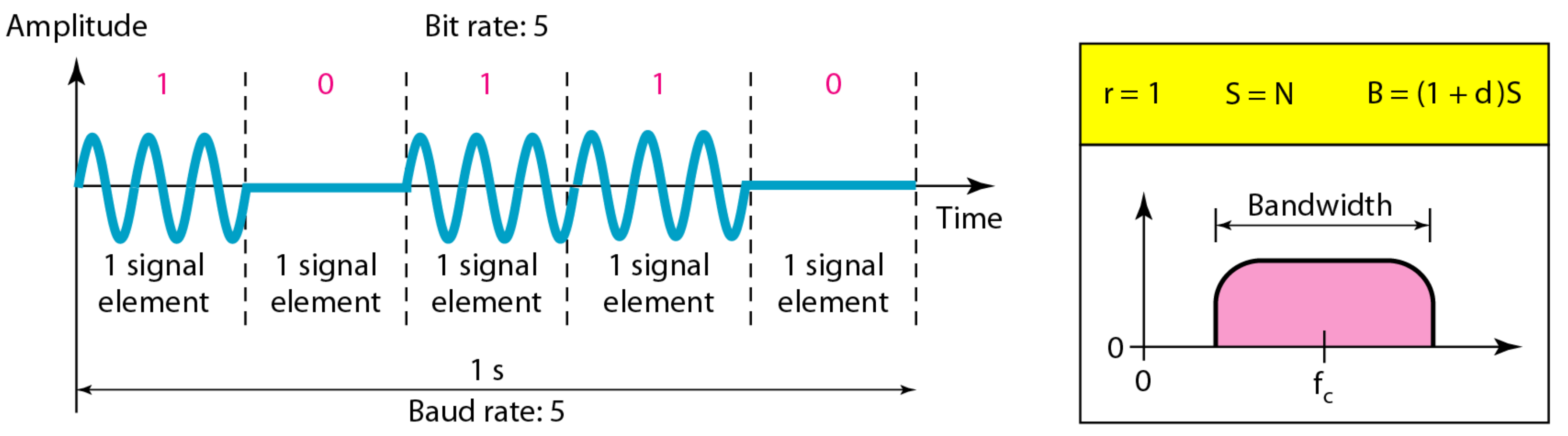


Figure 3.28 ***Binary amplitude shift keying***

BANDWIDTH FOR ASK

$$\boxed{B = (1 + d) \times S}$$

where *B* is bandwidth, *S* is baud rate and d is a factor related to the modulation process (value of *d* is between 0 and 1)

Example 5.3

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate if we modulated our data by using ASK with d = 1?

Figure 5.4 ***Implementation of binary ASK***

BANDWIDTH FOR ASK

Solution

The middle of the bandwidth is located at 250 kHz. This means that our carrier frequency can be at fc = 250 kHz. We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

$$B = (1 + d) \times S = 2 \times N \times \frac{1}{r} = 2 \times N = 100\text{ kHz} \Rightarrow N = 50\text{ kbps}$$

FREQUENCY SHIFT KEYING

- In FSK, the frequency of carrier signal is varied to represent data
- Both peak amplitude and phase remain constant

Binary FSK (BFSK)

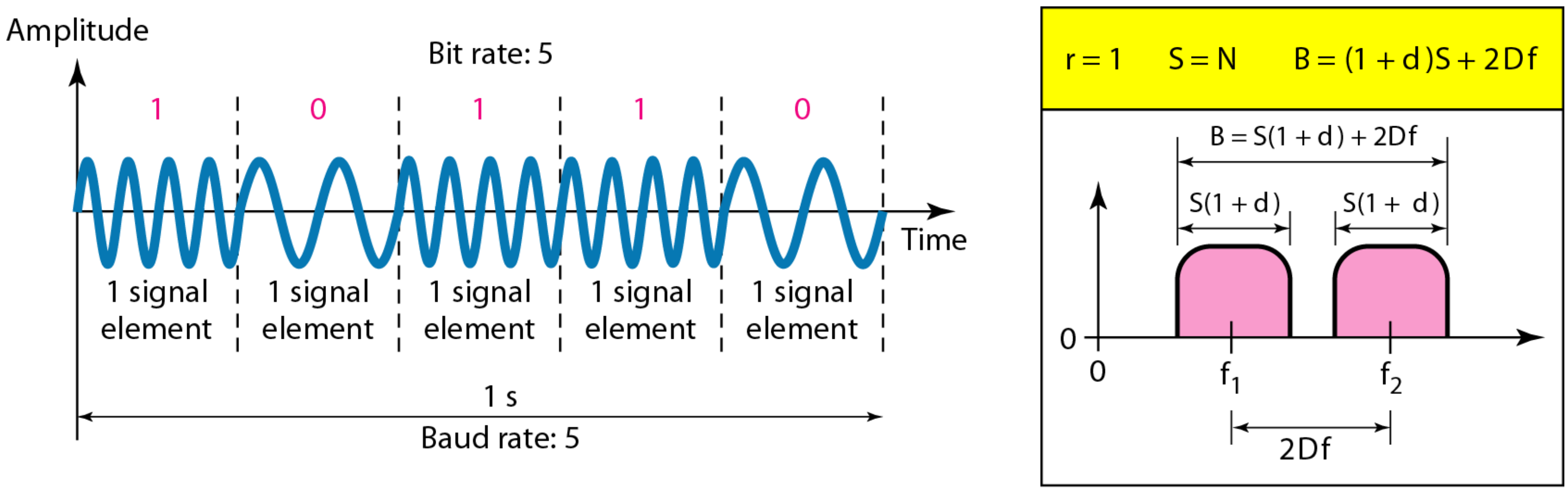


Figure 3.29 ***Binary frequency shift keying***

BANDWIDTH FOR FSK

$$\boxed{B = (1 + d) \text{ x } S + 2\Delta f}$$

where B is bandwidth, S is baud rate, d is a factor related to the modulation process (value between 0 and 1), and $2\Delta f$ is difference between 2 frequencies

- **Example 5.5**

  We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?

  Solution

  This problem is similar to Example 5.3, but we are modulating by using FSK. The midpoint of the band is at 250 kHz. We choose 2Δf to be 50 kHz; this means

$$B = (1 + d) \times S + 2\Delta f = 100 \quad \longrightarrow \quad 2S = 50 \text{ kHz} \quad S = 25 \text{ kbaud} \quad N = 25 \text{ kbps}$$

PHASE SHIFT KEYING

- In FSK, the phase of the carrier is varied to represent two or more different signal elements.
- Both amplitude and frequency are remains constant

Binary PSK (BPSK)

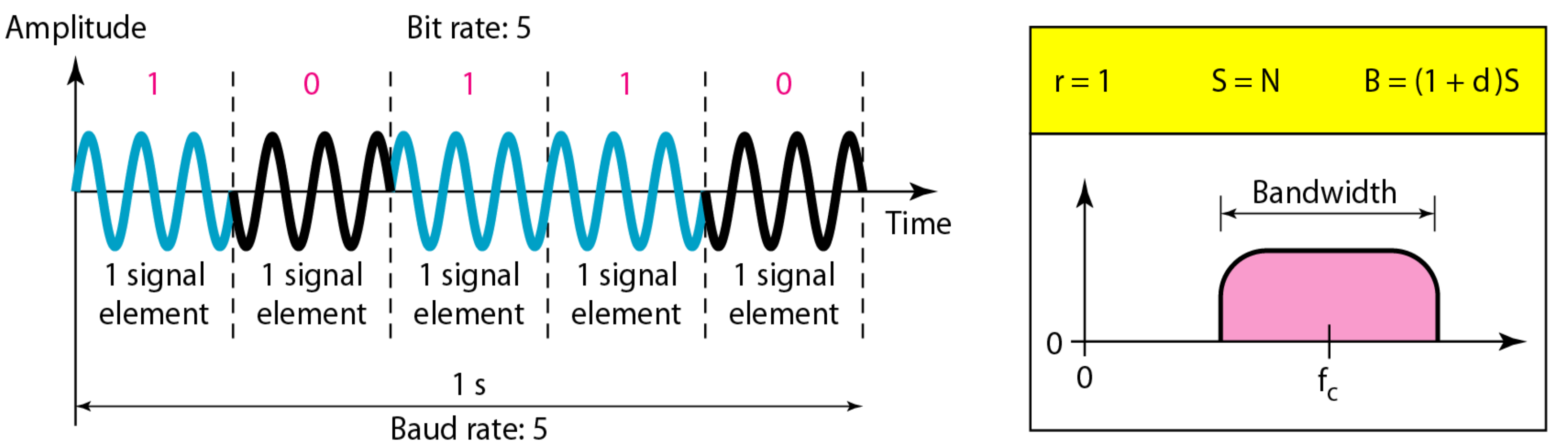


Figure 3.30 ***Binary phase shift keying***

BANDWIDTH FOR PSK

- Same as that for BASK, but less than that for BFSK. No bandwidth is wasted for separating two carrier signals

- **Example 5.7**
  Find the bandwidth for a signal transmitting at 12 Mbps for QPSK. The value of d = 0

Solution

For QPSK, 2 bits is carried by one signal element. This means that r = 2. So the signal rate (baud rate) is $S = N \times (1/r) = 6$ Mbaud. With a value of d = 0, we have B = S = 6 MHz

Figure 5.10 ***Implementation of BASK***

CONSTELLATION DIAGRAM

- Define the relationship between amplitude and phase of a signal elements, particularly when using two carriers (one in-phase and one quadrate).

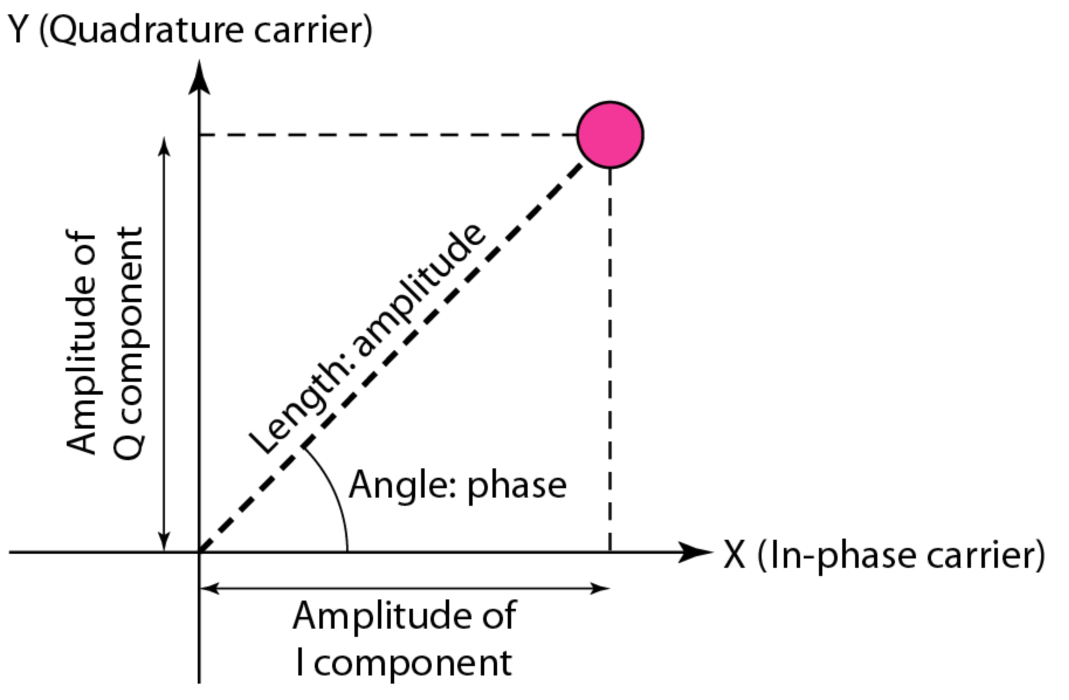


Figure 3.31 ***Concept of a constellation diagram***

CONSTELLATION DIAGRAM

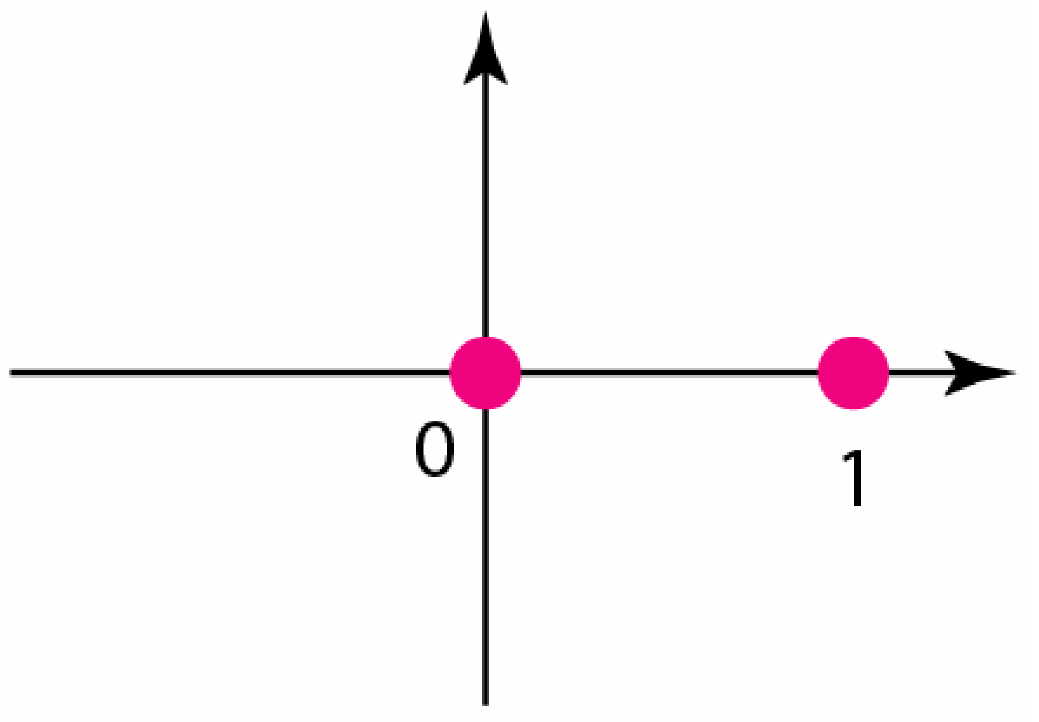


Figure 3.31a ***Constellation diagrams for ASK (OOK)***

CONSTELLATION DIAGRAM

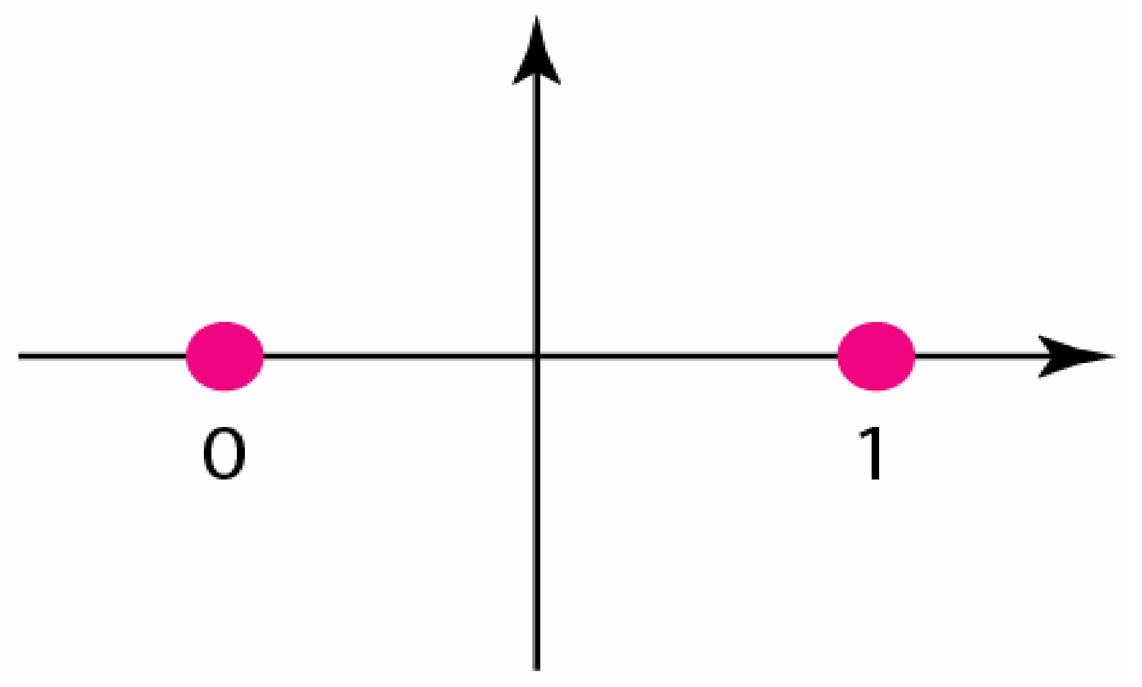


Figure 3.31b ***Constellation diagrams for BPSK***

CONSTELLATION DIAGRAM

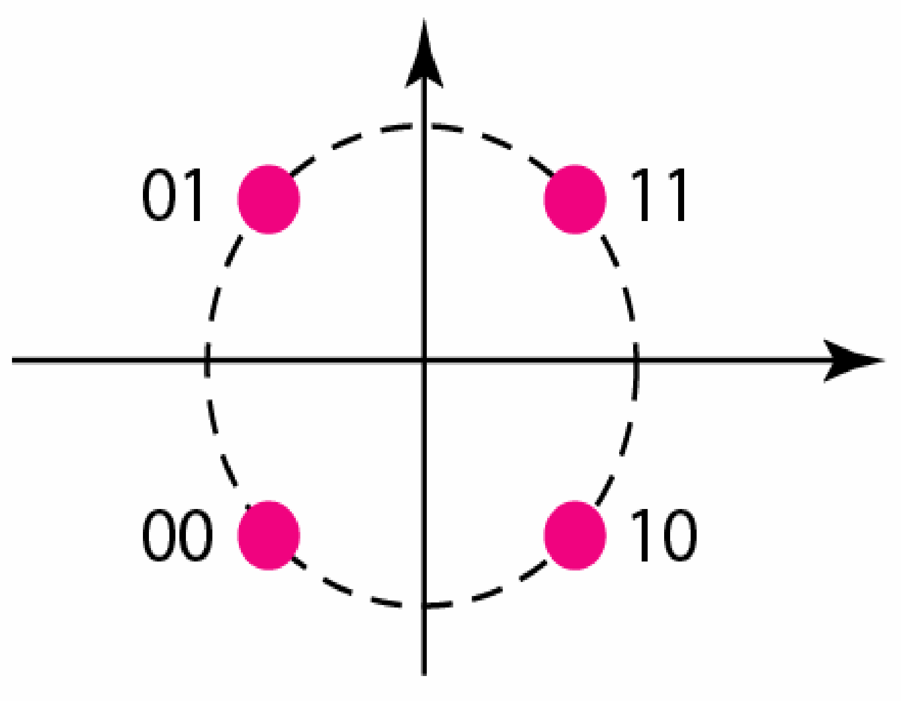


Figure 3.31c ***Constellation diagrams for QPSK***

QUADRATURE AMPLITUDE MODULATION

- QAM is a combination of ASK and PSK

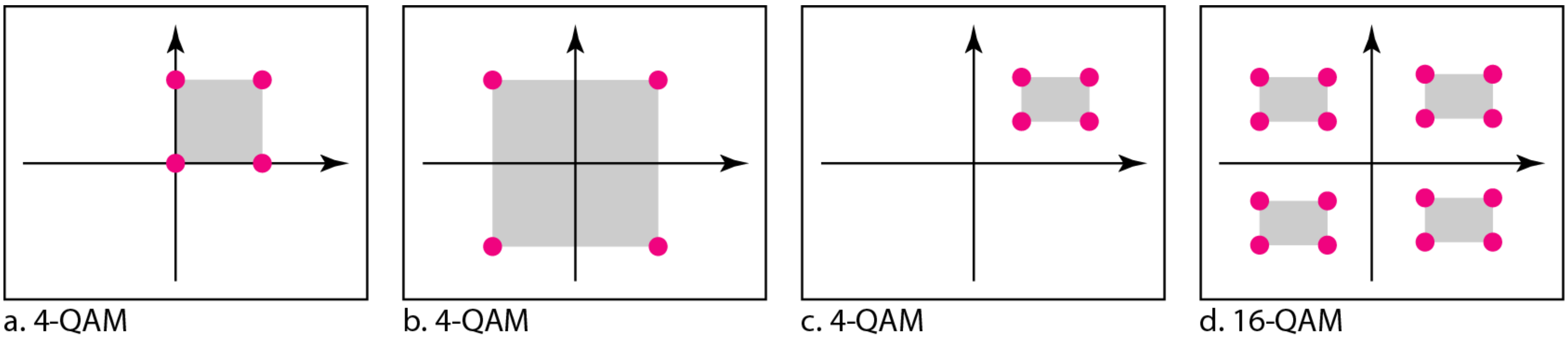


Figure 3.32 ***Constellation diagrams for some QAMs***

a. 4-QAM scheme using unipolar NRZ, same mechanism for ASK (OOK)
b. 4-QAM using polar NRZ, but exactly same as QPSK
c. 4-QAM use signal with 2 positive levels to modulate each of the carriers
d. 16-QAM constellation of signal with 8 levels, 4 positive and 4 negative