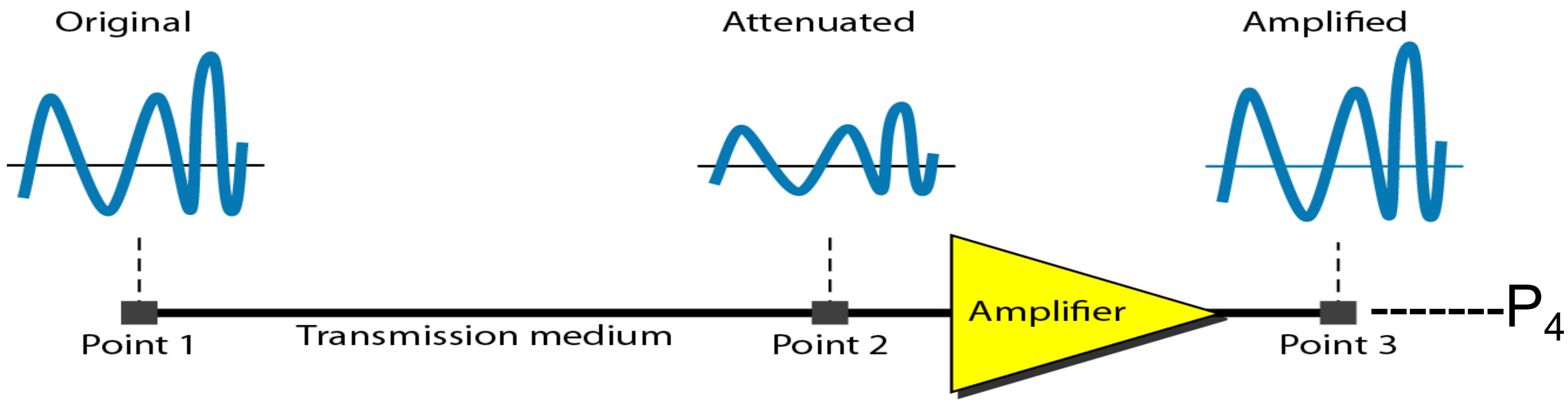
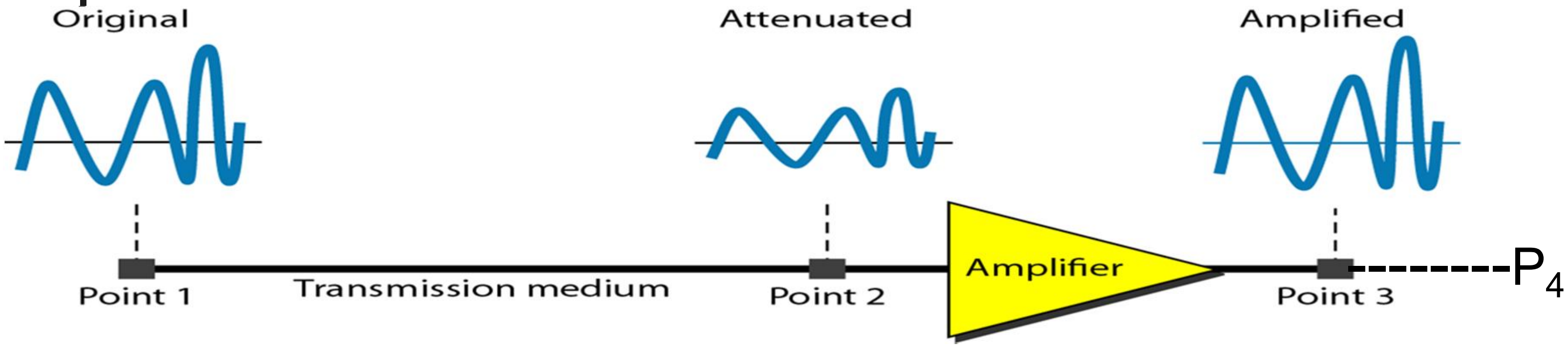
Attenuation (Güç yitirimi)



- Signal strength falls off with distance
- Received signal strength:
  - must be enough to be detected
  - must be sufficiently higher than noise to be received without error
- We measure both attenuation and amplification-gain in decibels(db)
- Attenautio formula is $10 \log_{10} (P_1/P_2)$ dB; P_1, P_2, P_3:watts
- Amplification formula is $10 \log_{10} (P_3/P_2)$ dB

Example1



Assume A trans channel has three sections;
1_{st} section introduce an attenuation of 16 dB,
2_{nd} section a amplification-gain of 20 dB,
3_{rd} section an attenuation of 10 dB ?
Assume input power level of 400 mW, power level at P2, P3, P4?

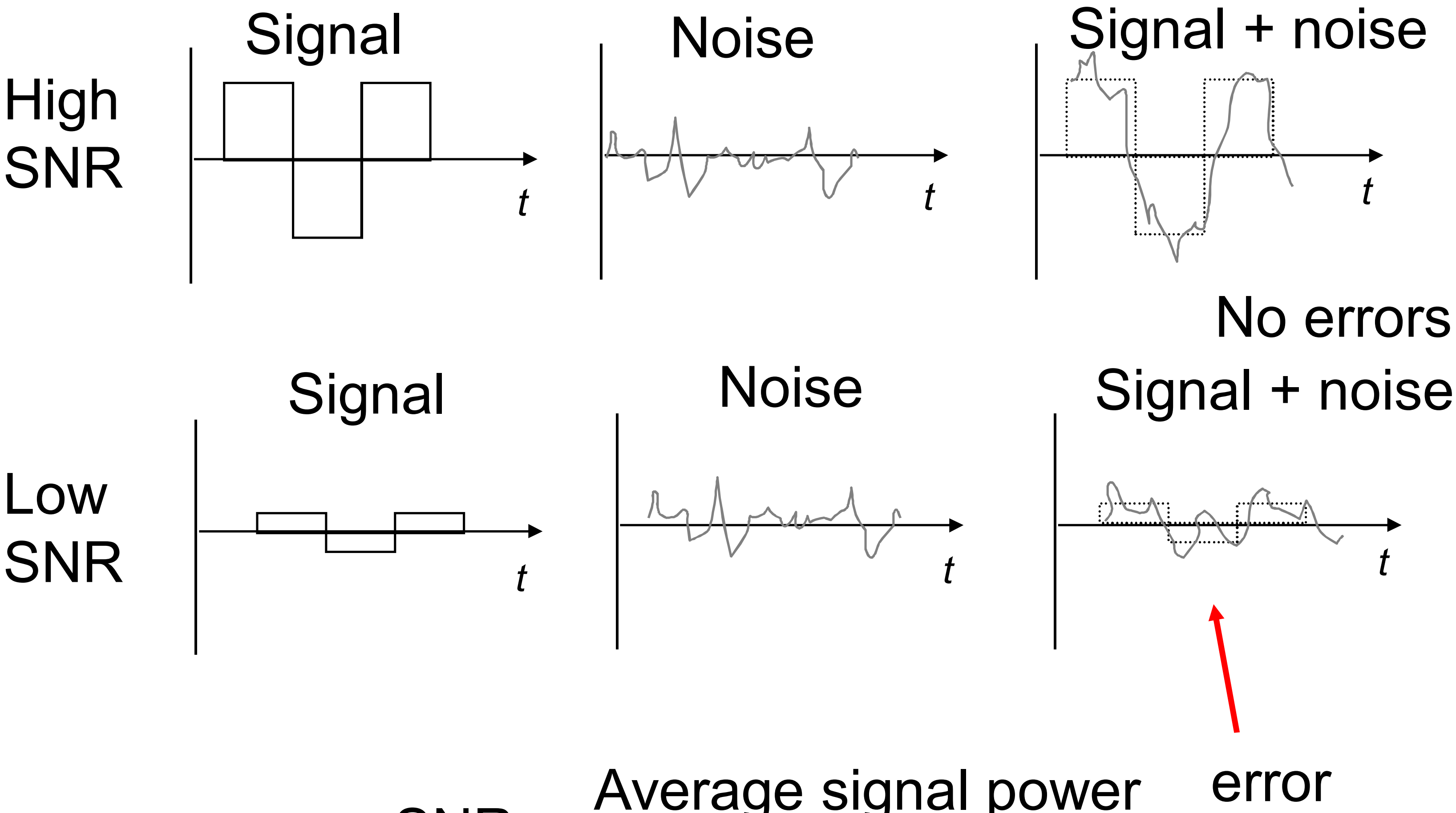
Solution

a. 16$= 10 \log_{10} (400/P_2) \rightarrow P_2 = 10{,}0475$ mW

b. $20 = 10 \log_{10} (P_3 / 10{,}0475) \rightarrow P_3 = 1004{,}75$ mW

c. $10 = 10 \log_{10} (1004{,}75 / P_4) \rightarrow P4 = 100{,}475$ mW

Formula for Signal-to-Noise Ratio



$$\text{SNR} = \frac{\text{Average signal power}}{\text{Average noise power}}$$

$$\text{SNR (dB)} = 10 \log_{10} \text{SNR}$$

Example1

The power of a signal is 10 mW and the power of the noise is 1 μW; what are the values of SNR and SNR_{dB} ?

Solution

The values of SNR and SNR_{dB} can be calculated as follows:

$$\mathrm{SNR} = \frac{10{,}000\ \mu\mathrm{W}}{1\ \mathrm{mW}} = 10{,}000$$

$$\mathrm{SNR_{dB}} = 10 \log_{10} 10{,}000 = 10 \log_{10} 10^4 = 40$$

Channel Capacity

- Data rate
  - In bits per second
  - Rate at which data can be communicated
- Bandwidth
  - In cycles per second of Hertz (Analog bandwidth)
  - Constrained by transmitter and medium
  - In bits per second, bps (**digital bandwidth**)

DATA RATE LIMITS

Data rate depends on three factors:

1. ***The bandwidth available***
2. ***The level of the signals we use***
3. ***The quality of the channel (the level of noise)***

Noiseless Channel: Nyquist Bit rate

- $b = 2\ B \log L$ (log is to base 2)

b : bit rate

B : Bandwidth (in Hertz)

L : number of levels

Nyquist Theorem

- Nyquist gives the upper bound for the bit rate of a transmission system by calculating the bit rate directly from the number of bits in a symbol (or signal levels) and the bandwidth of the system (assuming 2 symbols/per cycle and first harmonic).
- Nyquist theorem states that for a noiseless channel:

$$b = 2\ B \log_2 L$$

b = bit rate (capacity) in bps

B = bandwidth in Hz, L = number of levels

Example3

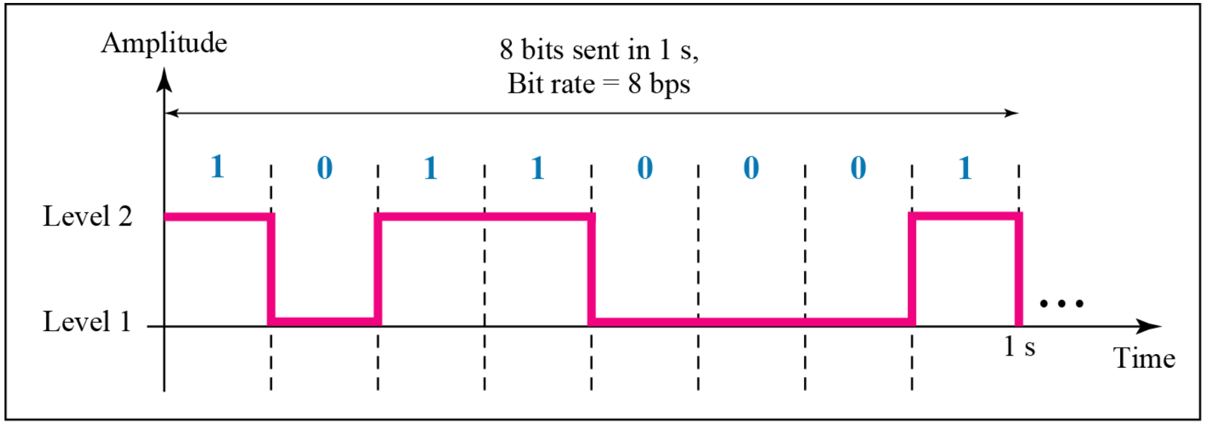
Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as

$$\text{BitRate} = 2 \times 3000 \times \log_2 2 = 6000 \text{ bps}$$

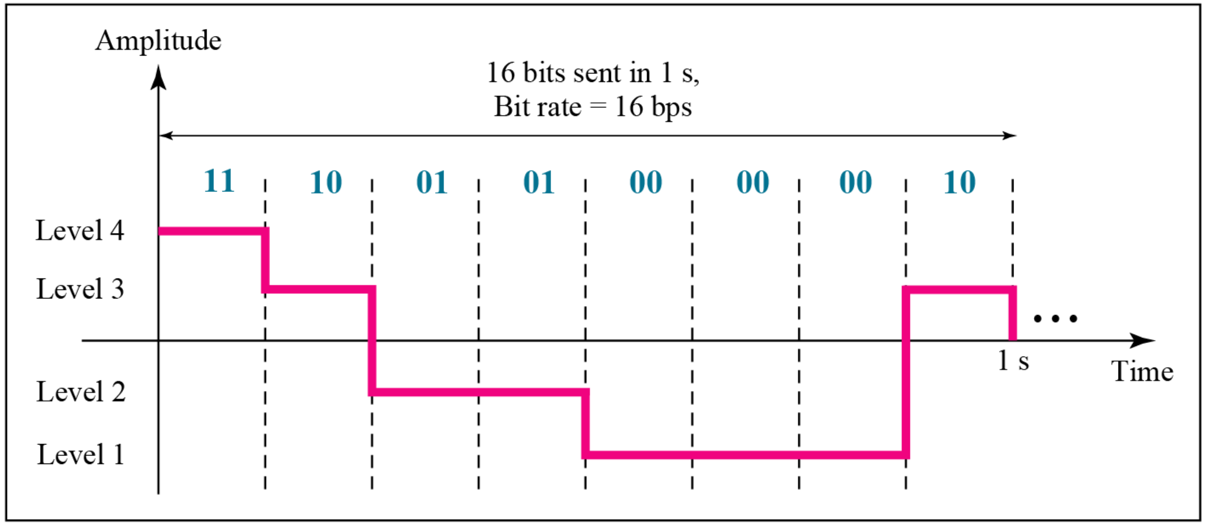
Consider the same noiseless channel transmitting a signal with four signal levels (for each level, we send 2 bits). The maximum bit rate can be calculated as

$$\text{BitRate} = 2 \times 3000 \times \log_2 4 = 12{,}000 \text{ bps}$$

Two digital signals: one with two signal levels and the other with four signal levels



a. A digital signal with two levels



b. A digital signal with four levels

Example 4

We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?

Solution

We can use the Nyquist formula as shown:

$$265{,}000 = 2 \times 20{,}000 \times \log_2 L$$

$$\log_2 L = 6.625 \qquad L = 2^{6.625} = 98.7 \text{ levels}$$

Since this result is not a power of 2, we need to either increase the number of levels or reduce the bit rate. If we have 128 levels, the bit rate is 280 kbps. If we have 64 levels, the bit rate is 240 kbps.

Noisy channel : Shannon Capacity

- Shannon's theorem gives the capacity of a system in the presence of noise.
- $\mathbf{C = B \log_2 (1 + SNR)}$

C = capacity of the channel in bps

B = Bandwidth, in Hertz

SNR = signal to noise ratio; (not dB)

Example

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

$$C = B \log_2 (1 + \text{SNR}) = B \log_2 (1 + 0) = B \log_2 1 = B \times 0 = 0$$

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

Example

We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

$$C = B \log_2 (1 + \text{SNR}) = 3000 \log_2 (1 + 3162) = 3000 \log_2 3163$$
$$= 3000 \times 11.62 = 34{,}860 \text{ bps}$$

This means that the highest bit rate for a telephone line is 34.860 kbps. If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

Example

The signal-to-noise ratio is often given in decibels. Assume that SNR_{dB} = 36 and the channel bandwidth is 2 MHz. The theoretical channel capacity can be calculated as

$$SNR_{dB} = 10 \log_{10} SNR \rightarrow SNR = 10^{SNR_{dB}/10} \rightarrow SNR = 10^{3.6} = 3981$$

$$C = B \log_2 (1 + SNR) = 2 \times 10^6 \times \log_2 3982 = 24 \text{ Mbps}$$

Usages of Both Formula

- In practice we use both the limits to determine, given the channel bandwidth, what should be the number of levels a signal should have.
- **The Shannon capacity gives us the upper limit; the Nyquist formula tells us how many signal levels we need.**

Example

We have a channel with a 1-MHz bandwidth. The SNR for this channel is 63. What are the appropriate bit rate and signal level?

Solution

First, we use the Shannon formula to find the upper limit of the channel capacity.

$$C = B \log_2 (1 + \text{SNR}) = 10^6 \log_2 (1 + 63) = 10^6 \log_2 64 = 6 \text{ Mbps}$$

Example

The Shannon formula gives us 6 Mbps, the upper limit. For better performance we choose something lower, 4 Mbps, for example. Then we use the Nyquist formula to find the number of signal levels.

$$4 \text{ Mbps} = 2 \times 1 \text{ MHz} \times \log_2 L \quad \Rightarrow \quad L = 4$$

PERFORMANCE

One important issue in networking is the performance of the network—how good is it?

Bandwidth
Throughput: how fast data can pass through an entity; number of bits that can pass this wall in one second
Propagation Speed: measures the distance a bit can travel a medium in one second. Depends on medium and frequency
Propagation Time: the time required for a bit to travel from one point to another.

Propagation time (T2 – T1) = distance / propagation speed

In networking, we use the term bandwidth in two contexts.

- The first, bandwidth in hertz, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.

- The second, bandwidth in bits per second, refers to the speed of bit transmission in a channel or link.

Example

A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

Solution

We can calculate the throughput as

$$\text{Throughput} = \frac{12{,}000 \times 10{,}000}{60} = 2 \text{ Mbps}$$

The throughput is almost one-fifth of the bandwidth in this case.

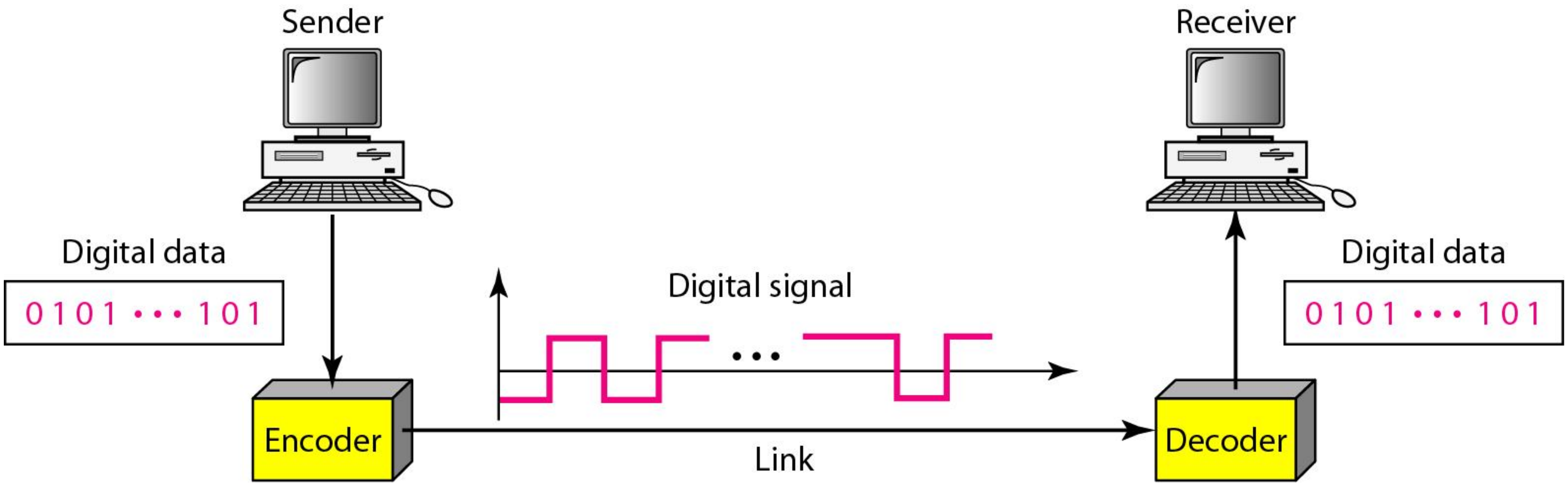
Digital Transmission
1. DIGITAL-TO-DIGITAL CONVERSION

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.

Line coding and decoding



Relationship between data rate and signal rate

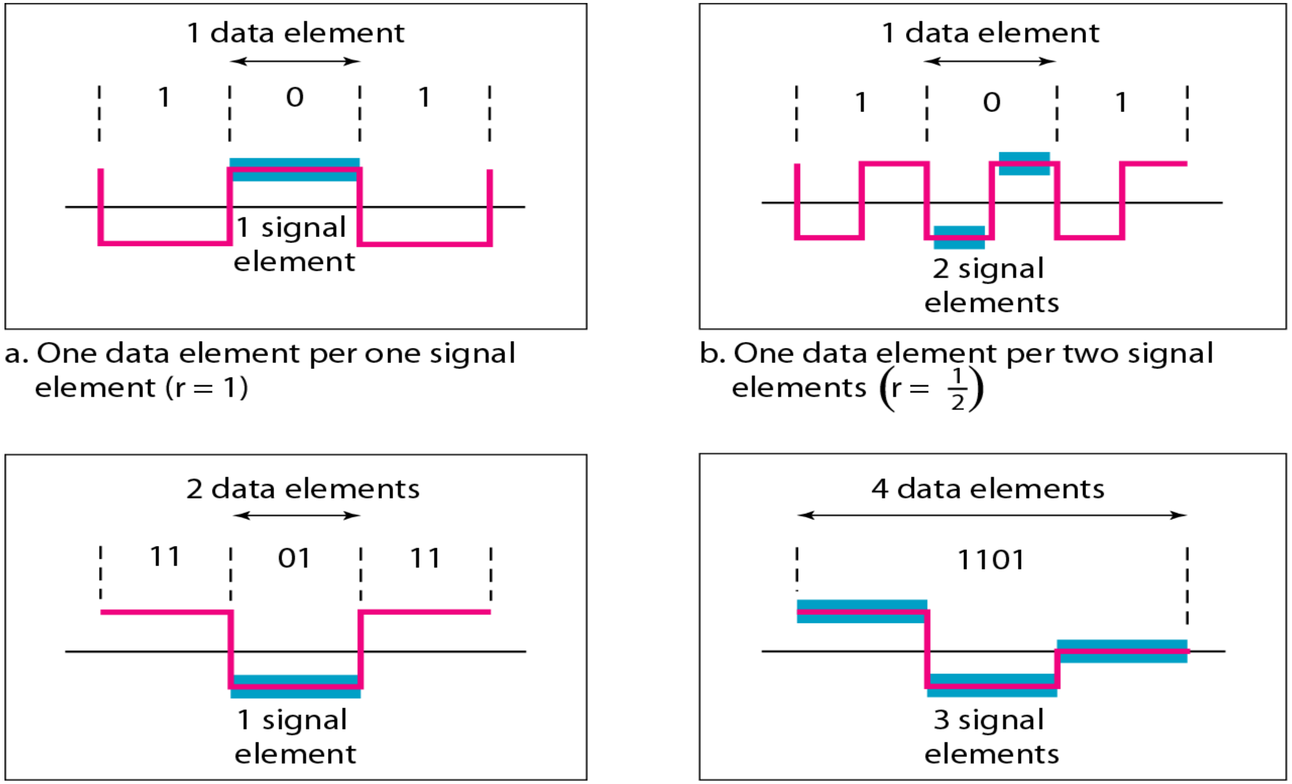
- The data rate defines the number of bits sent per sec - bps. It is often referred to the bit rate.
- The signal rate is the number of signal elements sent in a second and is measured in bauds. It is also referred to as the modulation rate.
- Goal is to increase the data rate whilst reducing the baud rate.

Note

Bit rate is the number of bits per second. Baud rate is the number of signal elements per second.

In the analog transmission of digital data, the baud rate is less than or equal to the bit rate.

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

The ratio ‘r’ is the number of data elements carried by a signal element

Data rate and Baud rate

- The baud or signal rate can be expressed as:

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

where N is data rate

c is the case factor (worst, best & avg.)

r is the ratio between data element & signal element

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 between 0 and 1?

Solution

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

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

Block coding is normally referred to as *m*B/*n*B coding;
it replaces each *m*-bit group with an *n*-bit group.

2. ANALOG-TO-DIGITAL CONVERSION

We have seen that a digital signal is superior to an analog signal. The tendency today is to change an analog signal to digital data.

- ***Sampling**: To store a recording in the computer or send it digitally, change it via sampling*

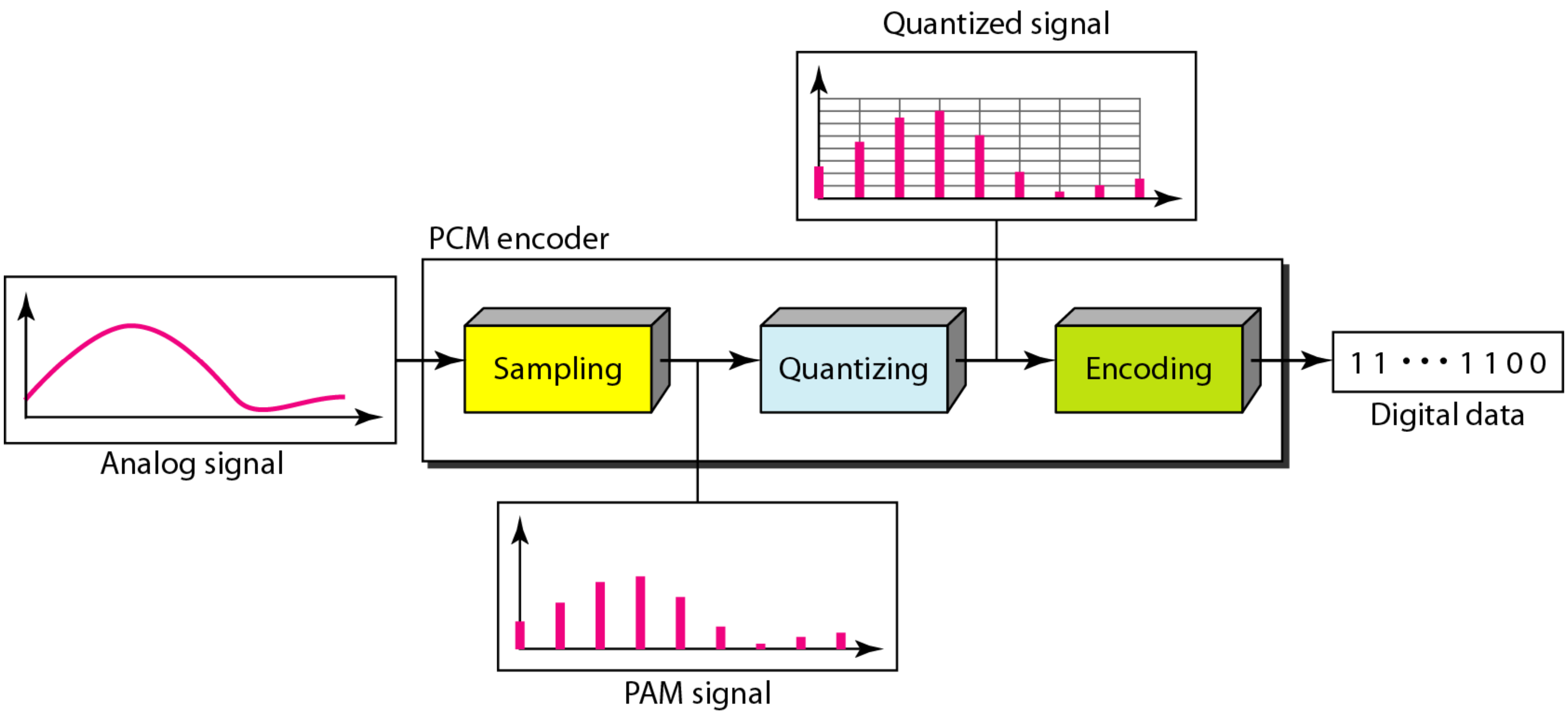
two techniques,

- ***pulse code modulation* (PCM)**
- ***delta modulation* (DM)**

PCM

- PCM consists of three steps to digitize an analog signal:
  1. Sampling
  2. Quantization
  3. Binary encoding
- Before we sample, we have to filter the signal to limit the maximum frequency of the signal as it affects the sampling rate.
- Filtering should ensure that we do not distort the signal, ie remove high frequency components that affect the signal shape.

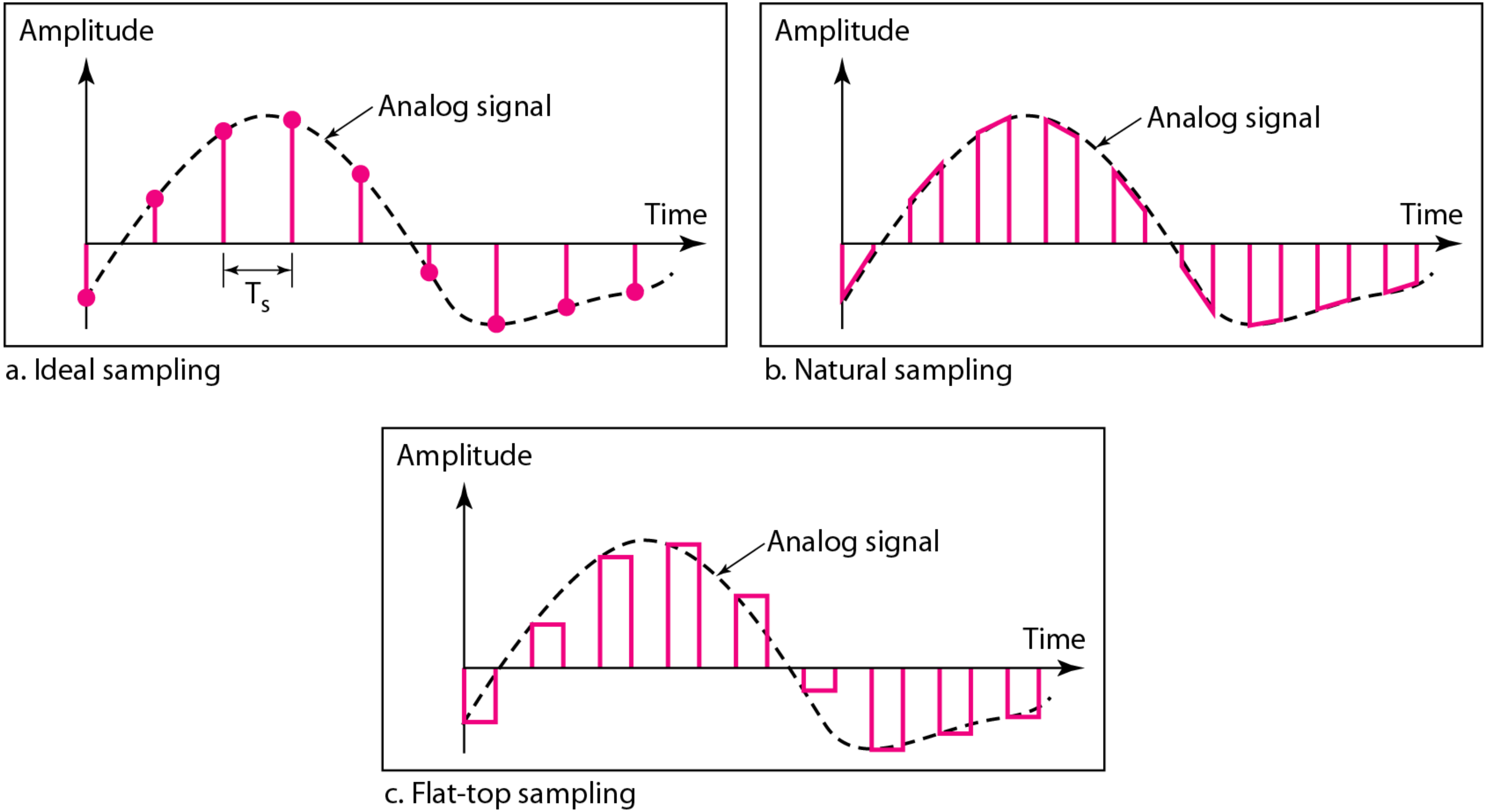
Figure 4.21 *Components of PCM encoder*



Sampling

- Analog signal is sampled every T_S secs.
- T_s is referred to as the sampling interval.
- $f_s = 1/T_s$ is called the sampling rate or sampling frequency.
- There are 3 sampling methods:
  - Ideal - an impulse at each sampling instant
  - Natural - a pulse of short width with varying amplitude
  - Flattop - sample and hold, like natural but with single amplitude value
- The process is referred to as pulse amplitude modulation PAM and the outcome is a signal with analog (non integer) values

Figure 4.22 *Three different sampling methods for PCM*



a. Ideal sampling

b. Natural sampling

c. Flat-top sampling

TRANSMISSION MODES

The transmission of binary data across a link can be accomplished in either parallel or serial mode. In parallel mode, multiple bits are sent with each clock tick. In serial mode, 1 bit is sent with each clock tick. While there is only one way to send parallel data, there are three subclasses of serial transmission: asynchronous, synchronous, and isochronous.

Topics discussed in this section:

Parallel Transmission
Serial Transmission

Figure 4.31 *Data transmission and modes*

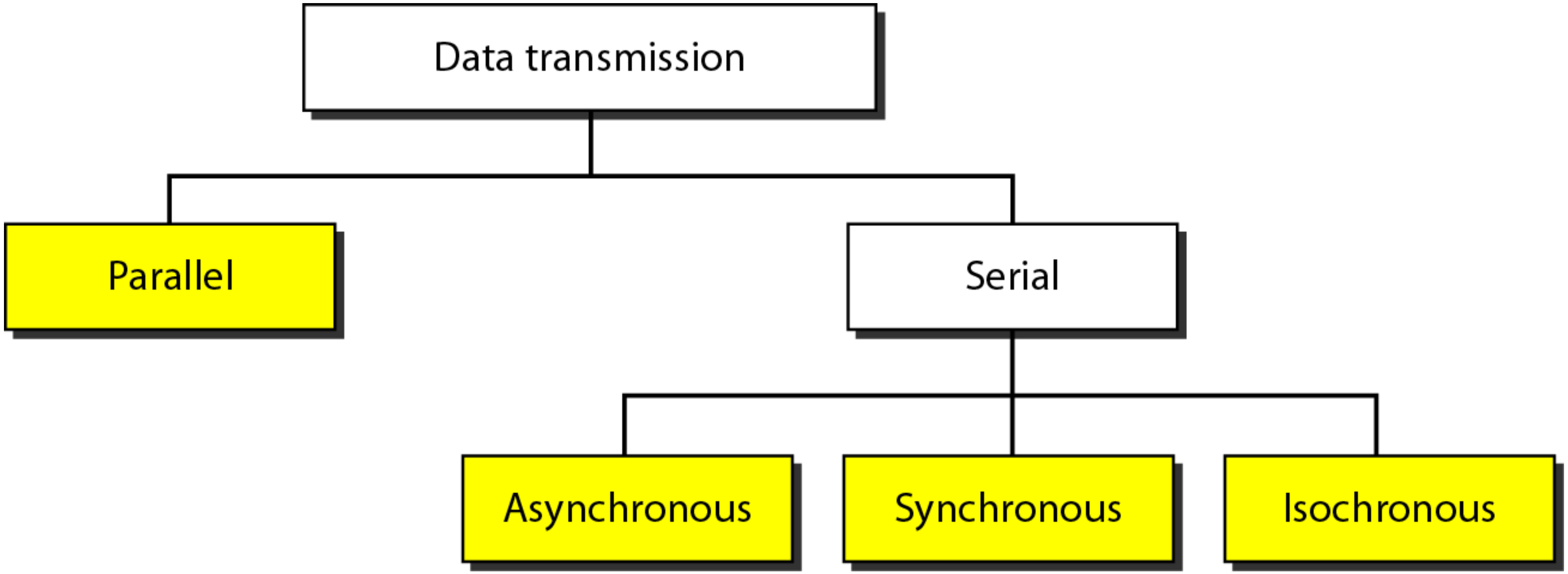


Figure 4.32 *Parallel transmission*

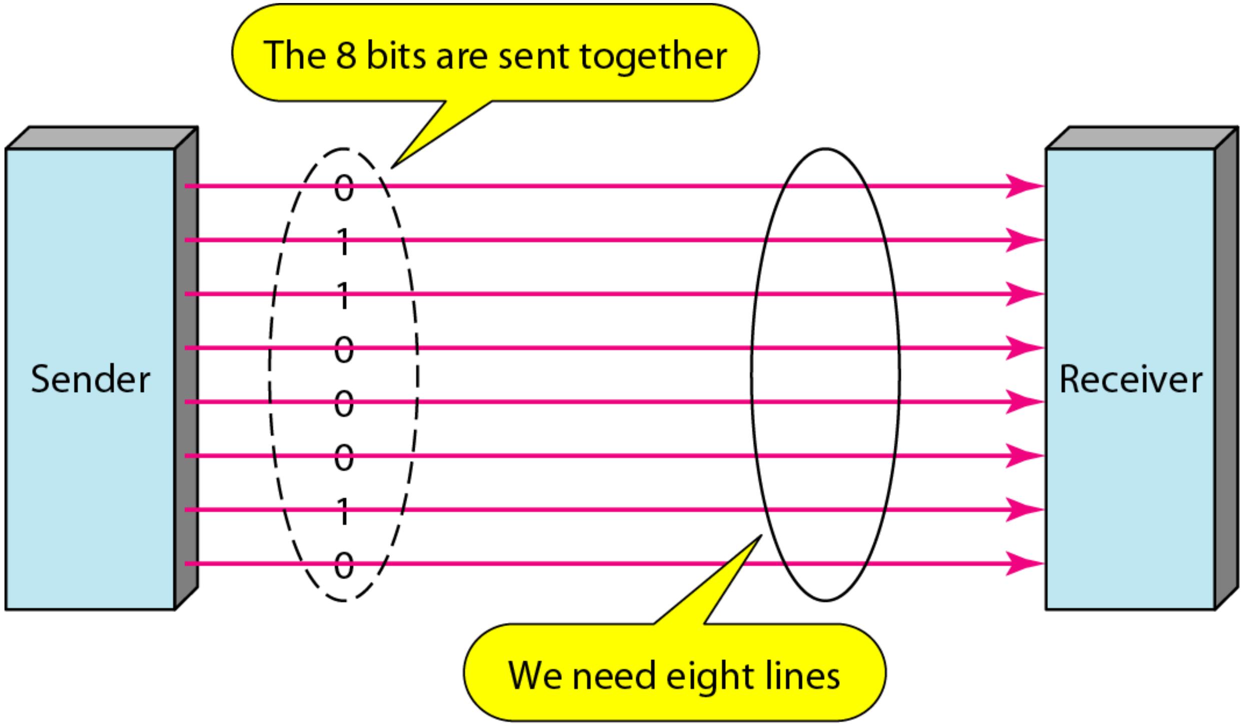
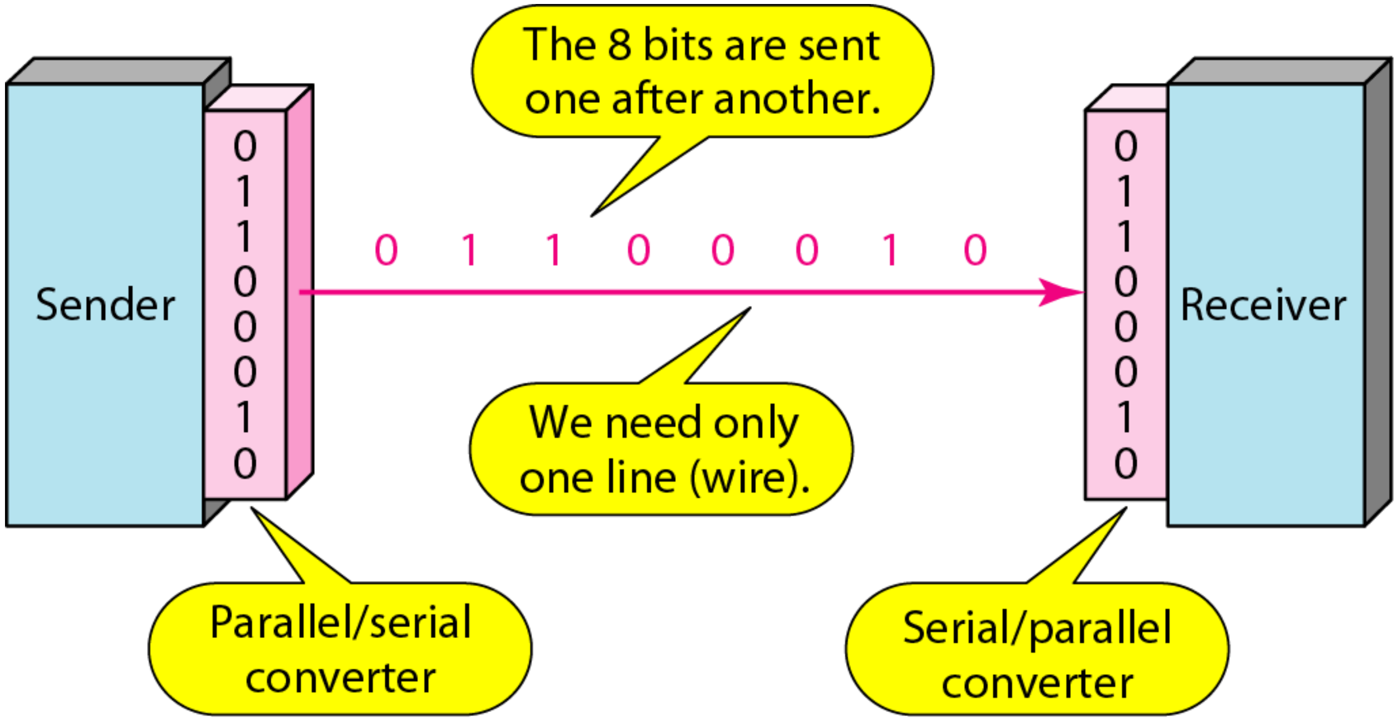


Figure 4.33 *Serial transmission*



Analog Transmission
3. DIGITAL-TO-ANALOG CONVERSION

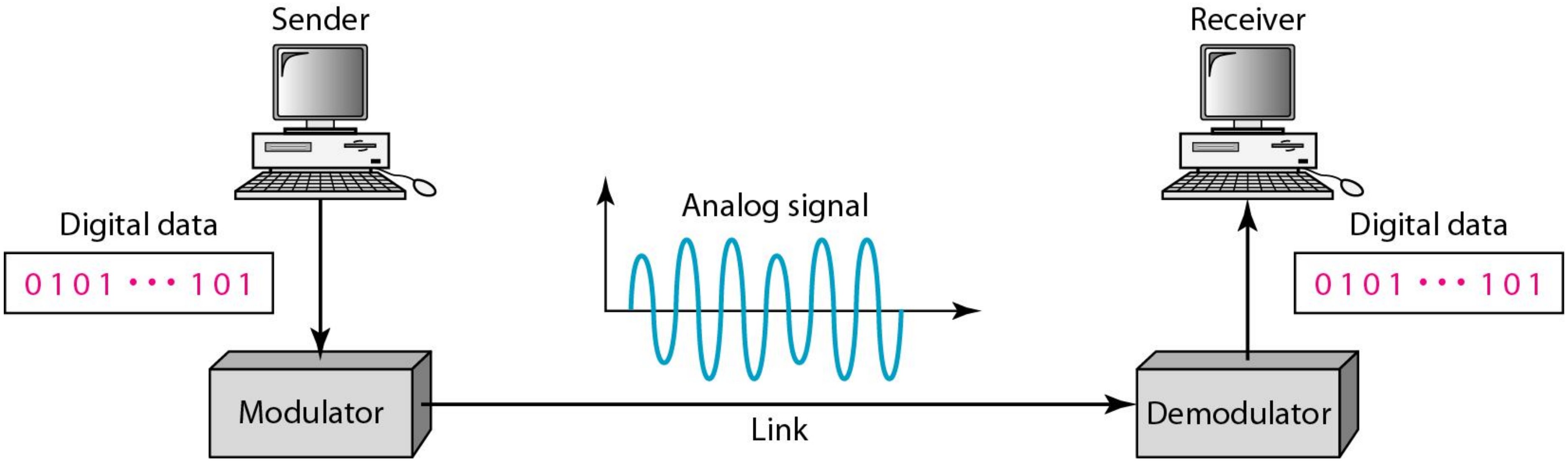
Digital-to-analog ***conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data.***

Amplitude Shift Keying
Frequency Shift Keying
Phase Shift Keying
Quadrature Amplitude Modulation

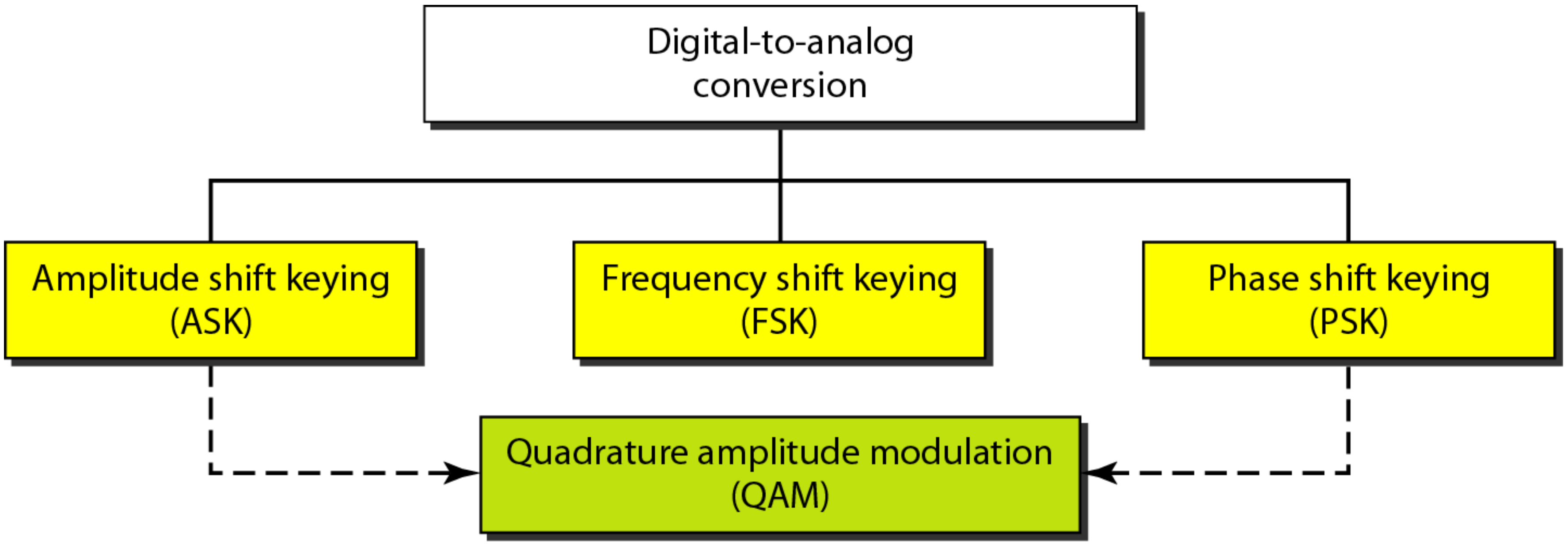
Digital to Analog Conversion

- Digital data needs to be carried on an analog signal.
- A carrier signal (frequency f_c) performs the function of transporting the digital data in an analog waveform.
- The analog carrier signal is manipulated to uniquely identify the digital data being carried.

Digital-to-analog conversion



Types of digital-to-analog conversion



Note

Bit rate, N, is the number of bits per second (bps). Baud rate is the number of signal elements per second (bauds). In the analog transmission of digital data, the signal or baud rate is less than or equal to the bit rate.

S=Nx1/r bauds

Where r is the number of data bits per signal element.

Example 5.1

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

Solution

In this case, r = 4, S = 1000, and N is unknown. We can find the value of N from

$$S = N \times \frac{1}{r} \qquad \text{or} \qquad N = S \times r = 1000 \times 4 = 4000 \text{ bps}$$

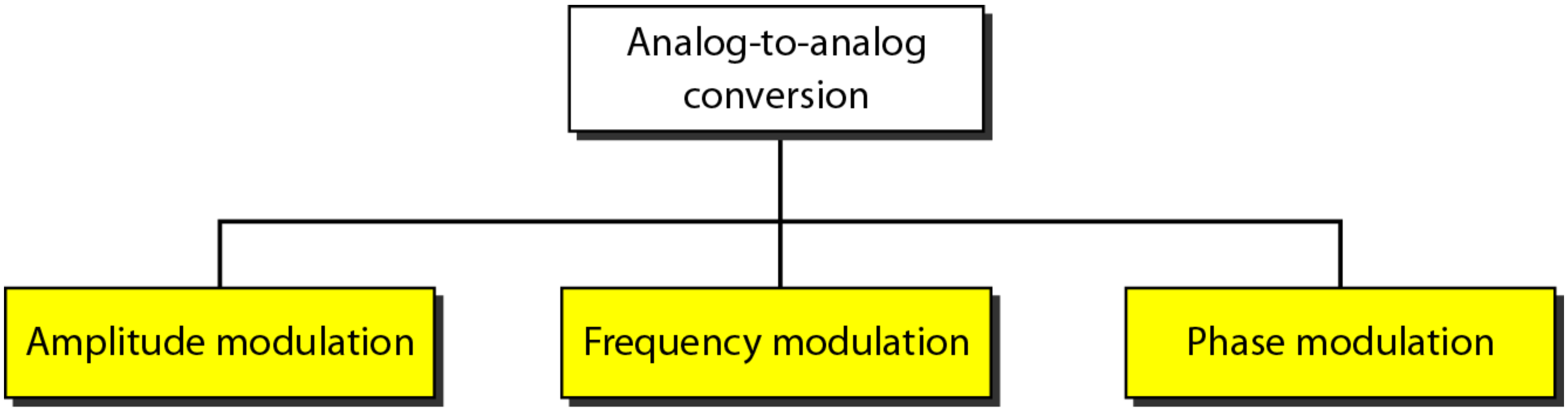
4. *Analog-to-analog conversion*

Modulation of Analog Signal

Analog-to-analog conversion is the representation of analog information by an analog signal. One may ask why we need to modulate an analog signal; it is already analog. Modulation is needed if the medium is bandpass in nature or if only a bandpass channel is available to us.

Amplitude Modulation
Frequency Modulation
Phase Modulation

Types of analog-to-analog modulation



Amplitude Modulation

- A carrier signal is modulated only in amplitude value
- The modulating signal is the envelope of the carrier
- The required bandwidth is 2B, where B is the bandwidth of the modulating signal
- Since on both sides of the carrier freq. f_c, the spectrum is identical, we can discard one half, thus requiring a smaller bandwidth for transmission.

Amplitude modulation