Computer Networks (ITPC-205)

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Physical Layer

Digital Transmission and Analog Transmission

Digital transmission

- We shall understand, 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.

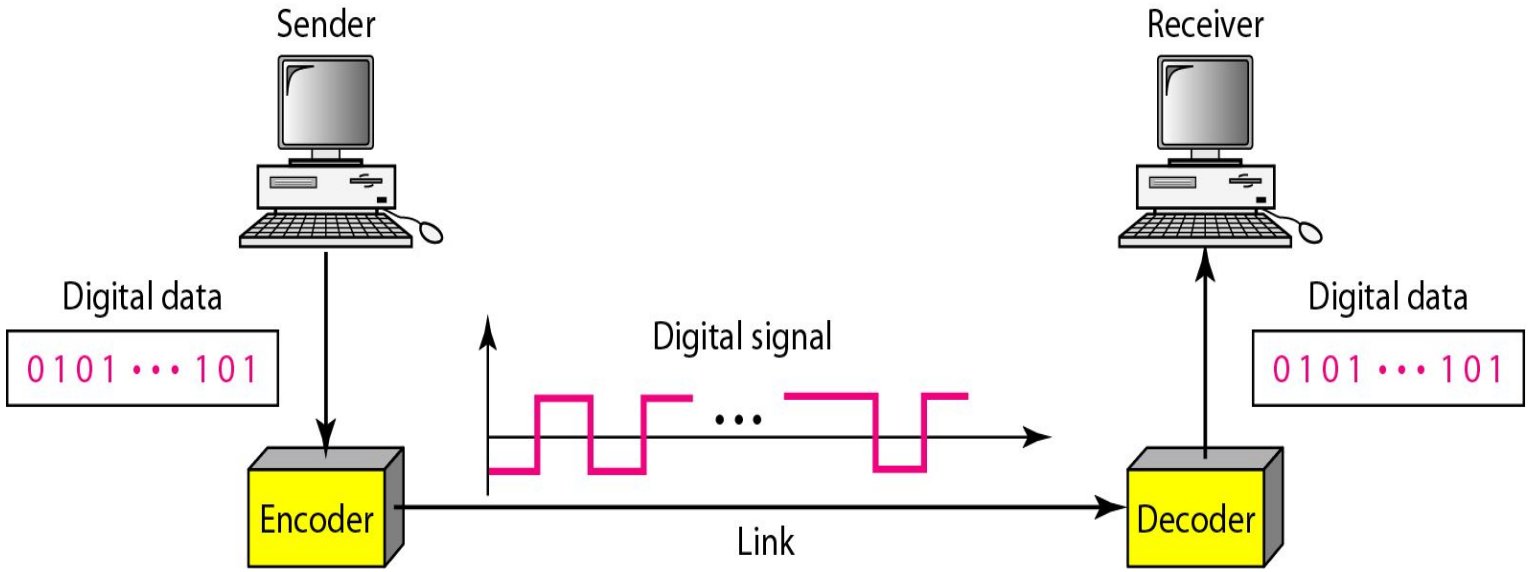


Figure: Digital communication

Data rate and signal rate

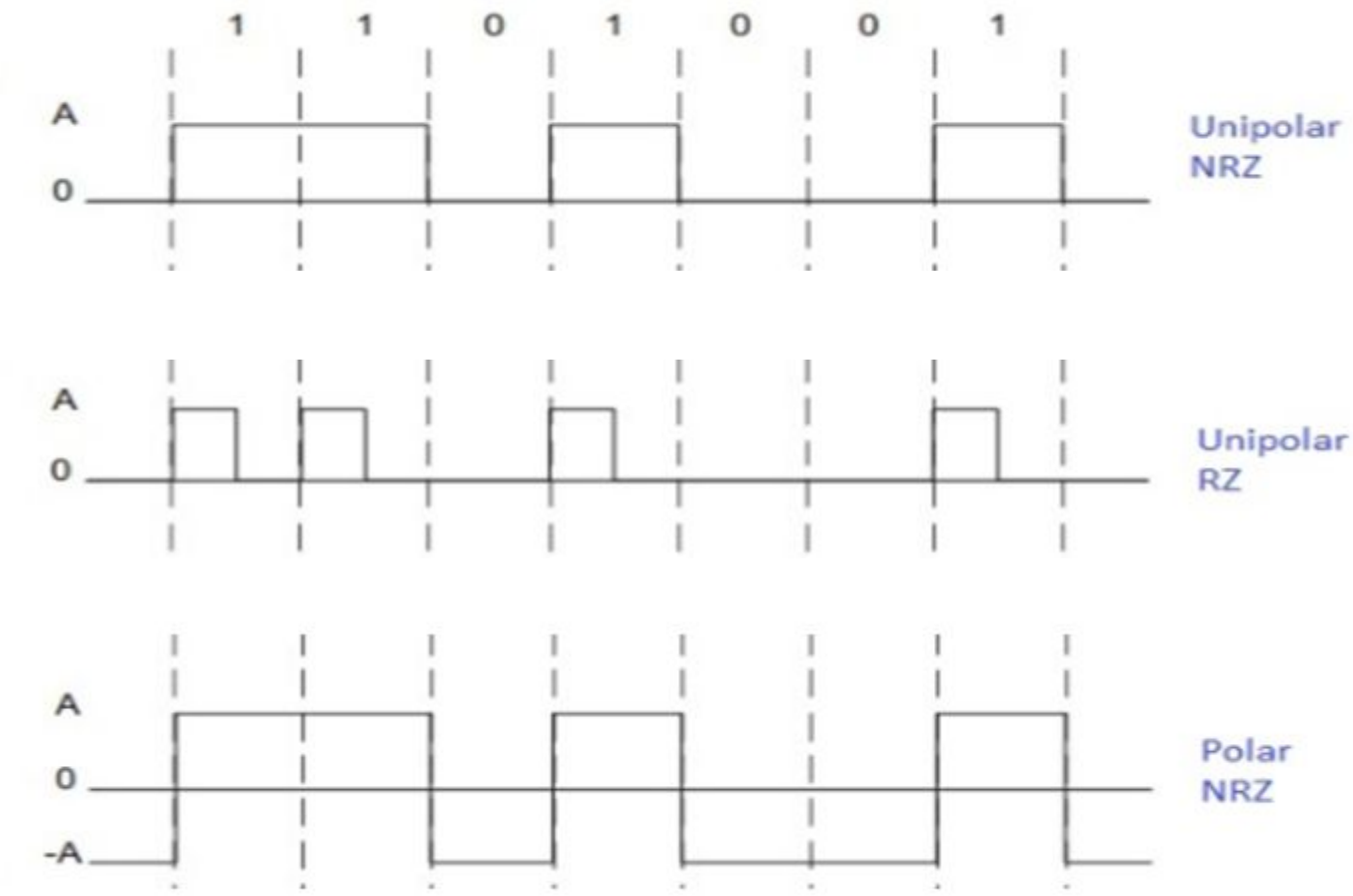
- Data rate is number of data elements (bits) transmitted per second
  - Units is bits per second (bps)
  - Also called bit rate
- Signal rate is number of signal elements transmitted per second.
  - Units is baud
  - Also called pulse rate/modulation rate/ baud rate
- Goal of signal communication is increase the data rate while decreasing the signal rate.
  - Increasing data rate increases speed of transmission
  - Decreasing signal rate decreases band width requirements

Line Coding

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

- Types of line coding
  - Unipolar line coding
  - Polar line coding
  - Bipolar line coding
  - Multilevel line coding

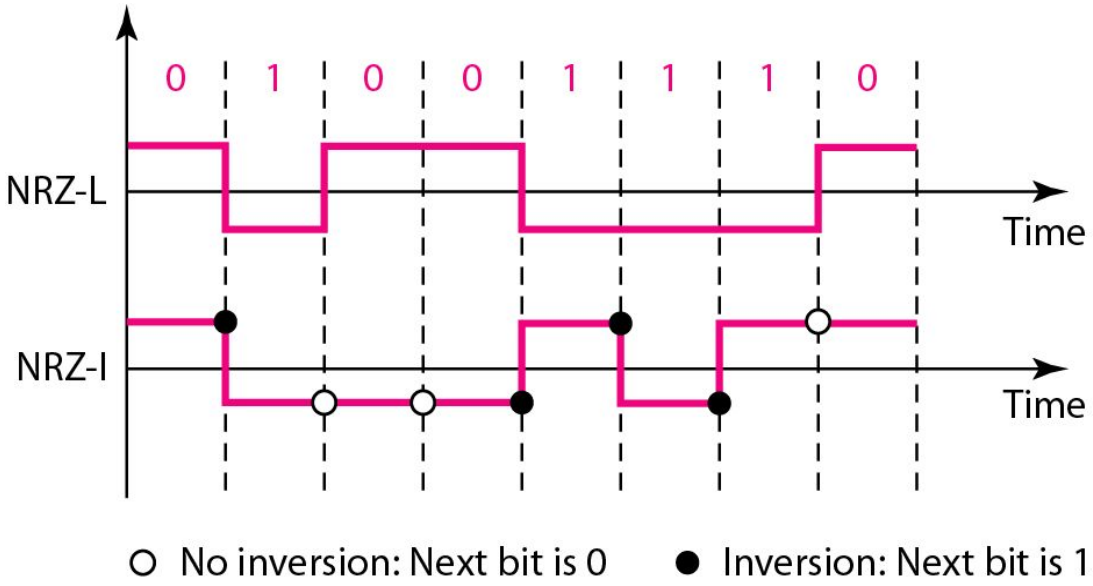
Unipolar NRZ & RZ and Polar NRZ & RZ

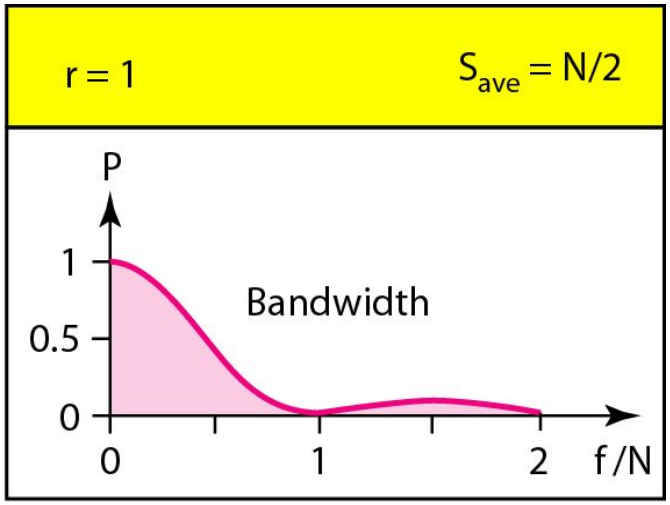


Polar - NRZ

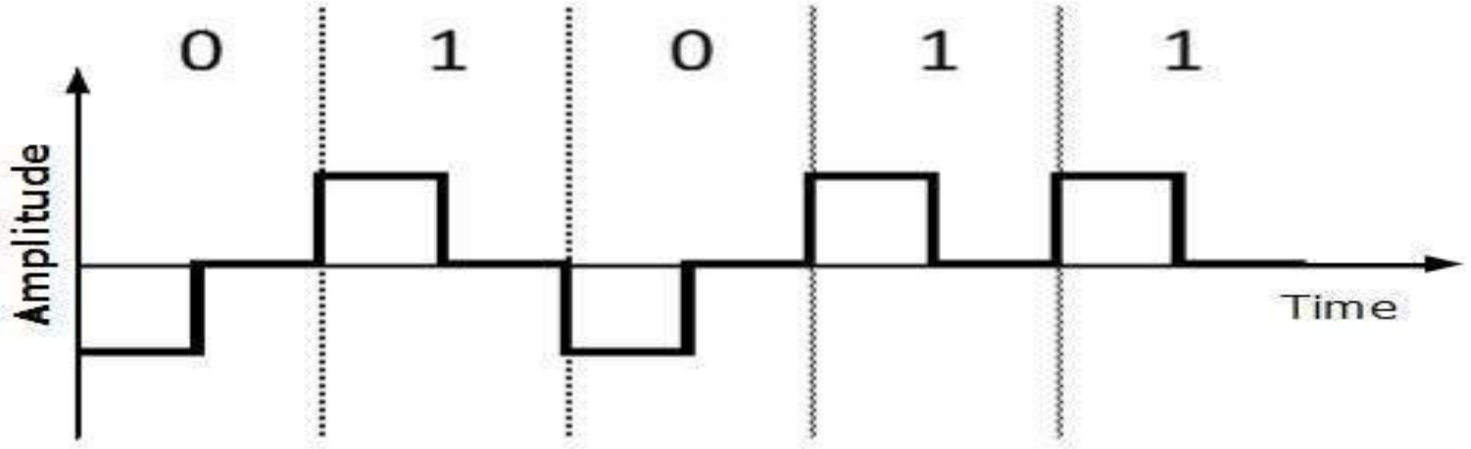
- The voltages are on both sides of the time axis.
- Polar NRZ scheme can be implemented with two voltages. E.g. +V for 1 and -V for 0.
- There are two versions:
  - NZR - Level (NRZ-L) - positive voltage for one symbol and negative for the other
  - NRZ - Inversion (NRZ-I) - the change or lack of change in polarity determines the value of a symbol. E.g. a “1” symbol inverts the polarity a “0” does not.

Polar NRZ-L and NRZ-I schemes



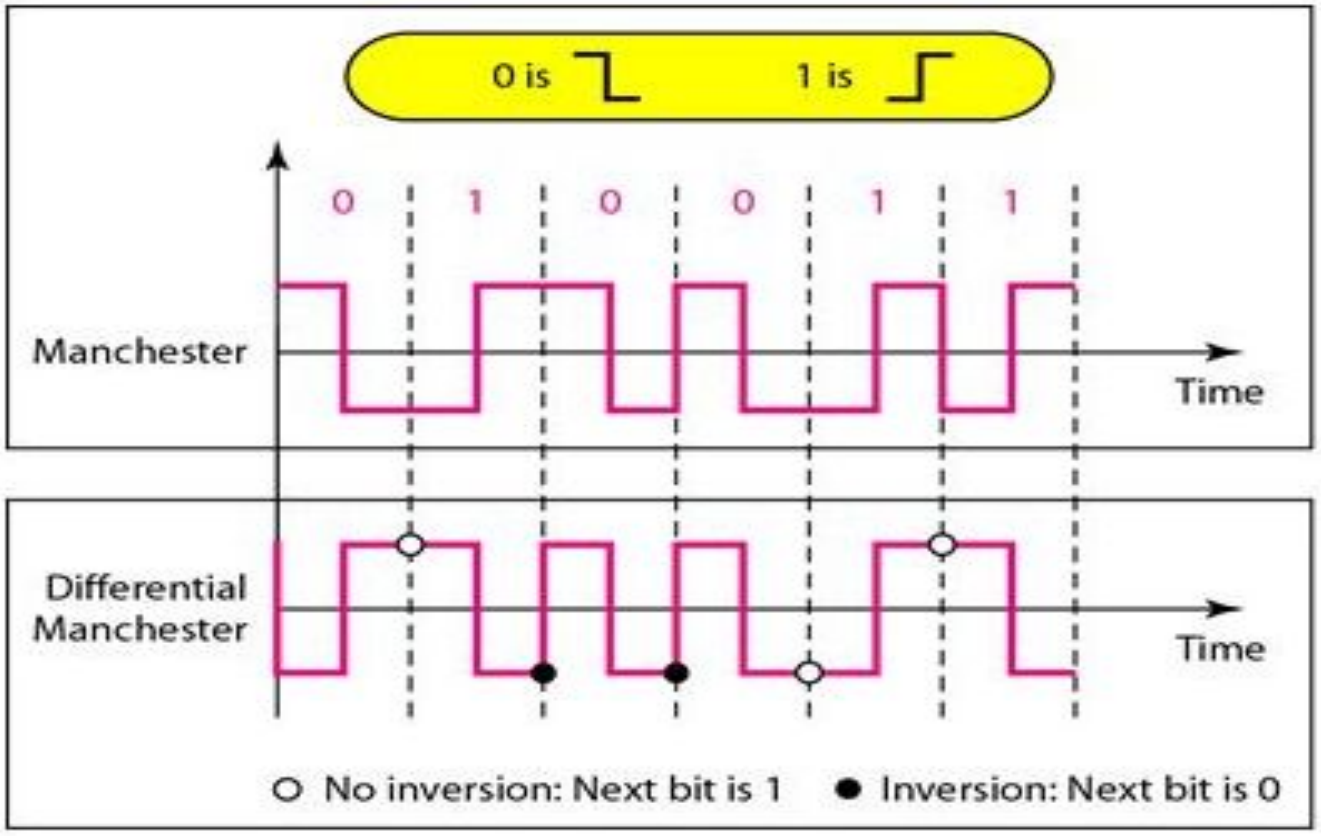


Polar RZ



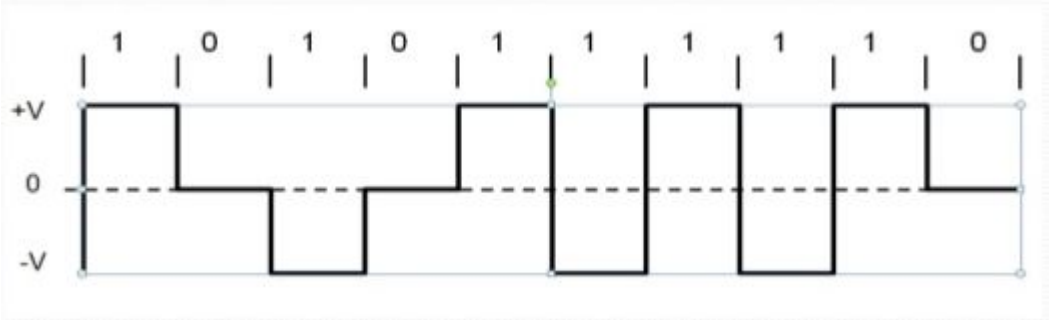
Manchester & Differential Manchester

- Manchester and differential manchester coding are the type of polar line coding.

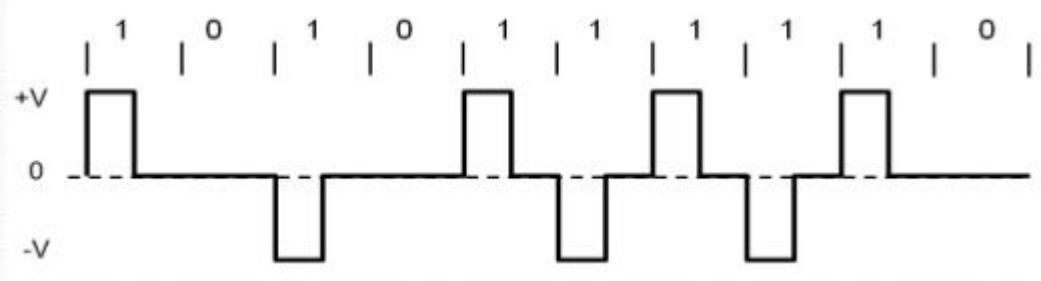


Bipolar NRZ and RZ

- Bipolar NRZ



- Bipolar RZ



Block coding concept

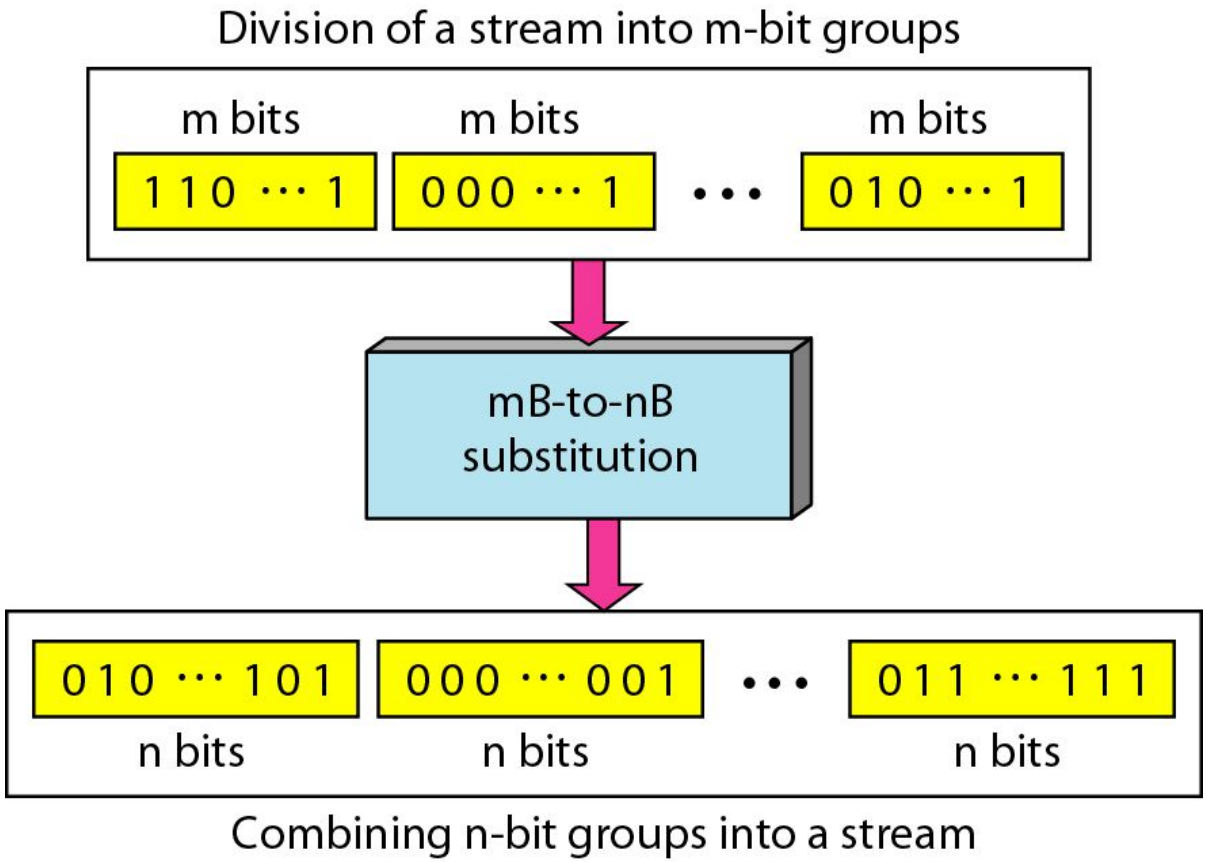
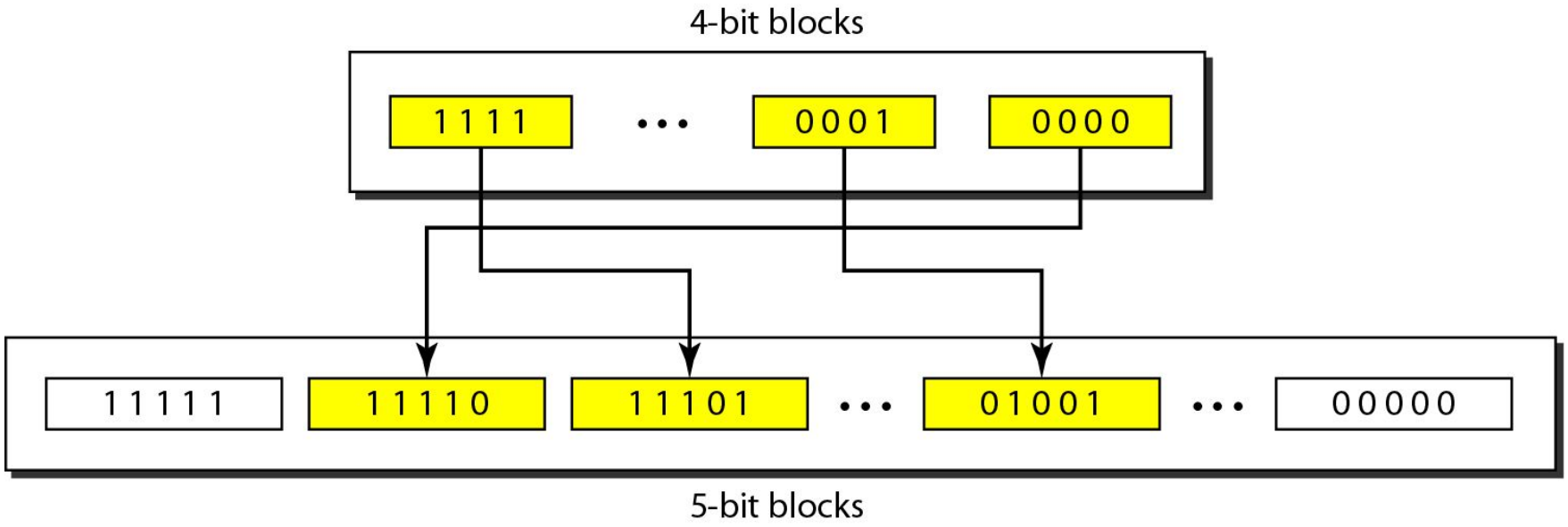


Figure 4.16 *Substitution in 4B/5B block coding*



Scrambling

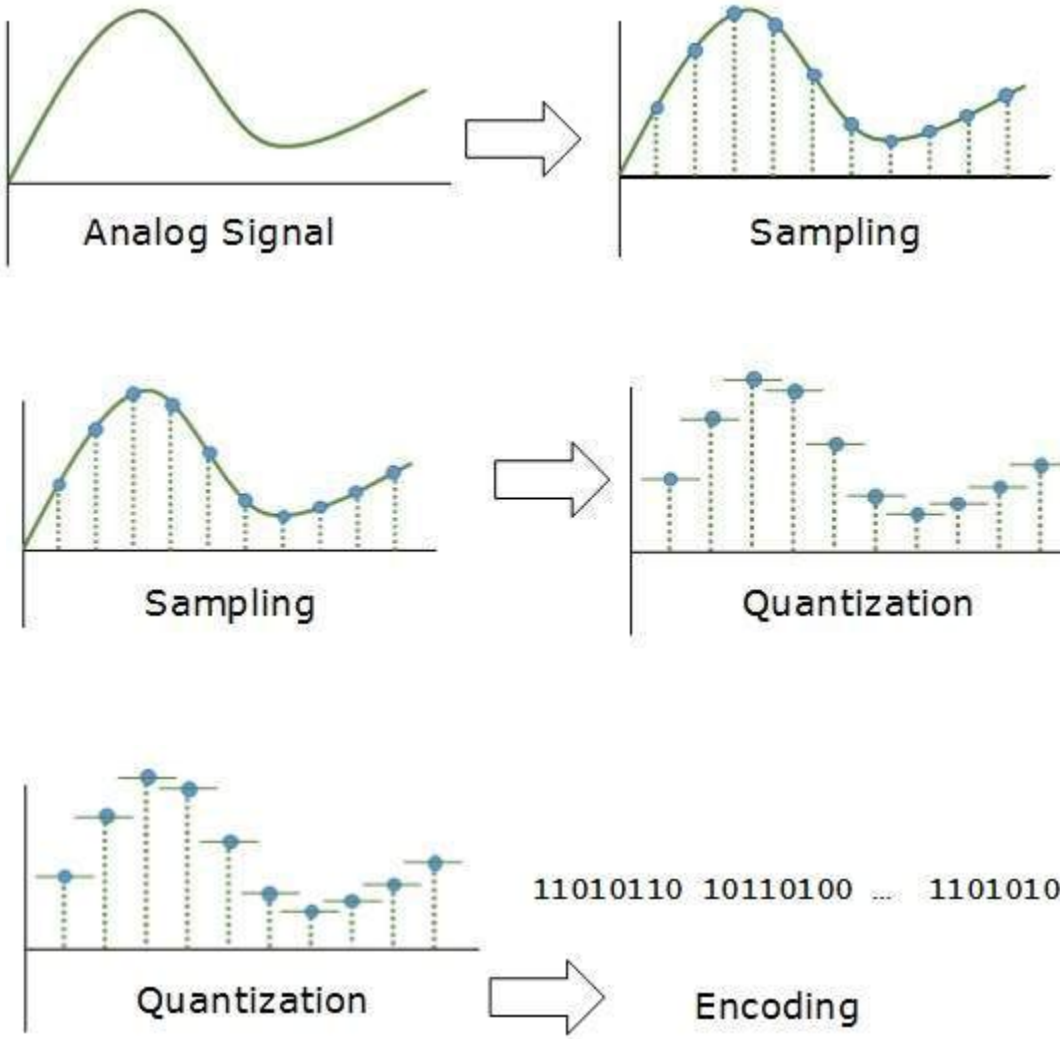
- The best code is one that does not increase the bandwidth for synchronization and has no DC components.
- Scrambling is a technique used to create a sequence of bits that has the required c/c's for transmission - self clocking, no low frequencies, no wide bandwidth.

Analog-to-Digital Conversion

- Microphones create analog voice and camera creates analog videos, which are treated in analog data. To transmit this analog data over digital signals, we need analog to digital conversion.

- To convert analog wave into digital data, we use Pulse Code Modulation (PCM).

- PCM is one of the most commonly used method to convert analog data into digital form. It involves three steps:
  - Sampling
  - Quantization
  - Encoding.


Analog Signal
Sampling
Sampling
Quantization
Quantization
11010110 10110100 ... 11010101
Encoding

Delta Modulation (DM)

- PCM is a very complex technique. Other techniques have been developed to reduce the complexity of PCM.
- The simplest is delta modulation. PCM finds the value of the signal amplitude for each sample; DM finds the change from the previous sample.
- Figure shows the process. Note that there are no code words here; bits are sent one after another.

Figure: The process of delta modulation

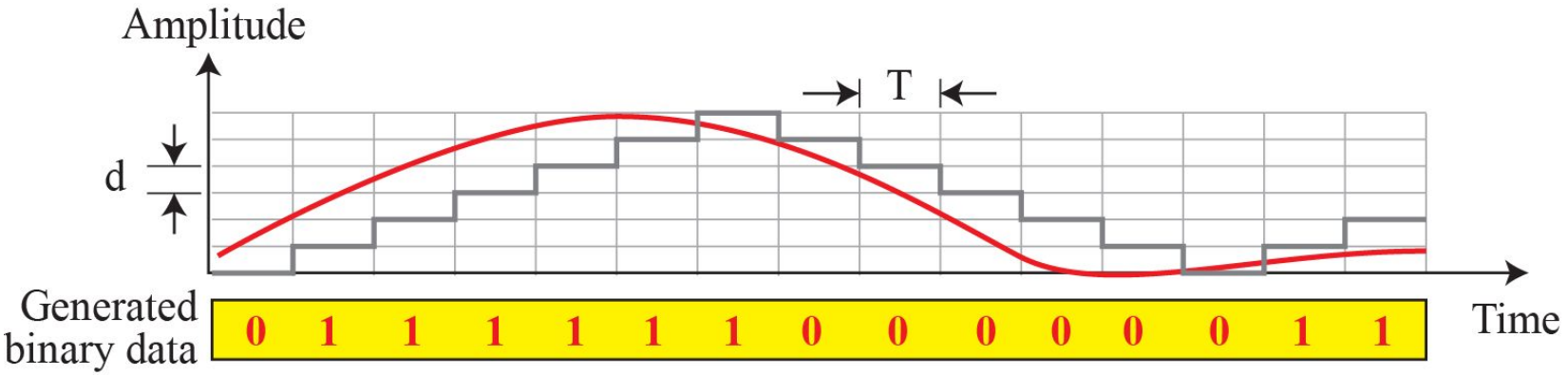


Figure: Delta modulation components

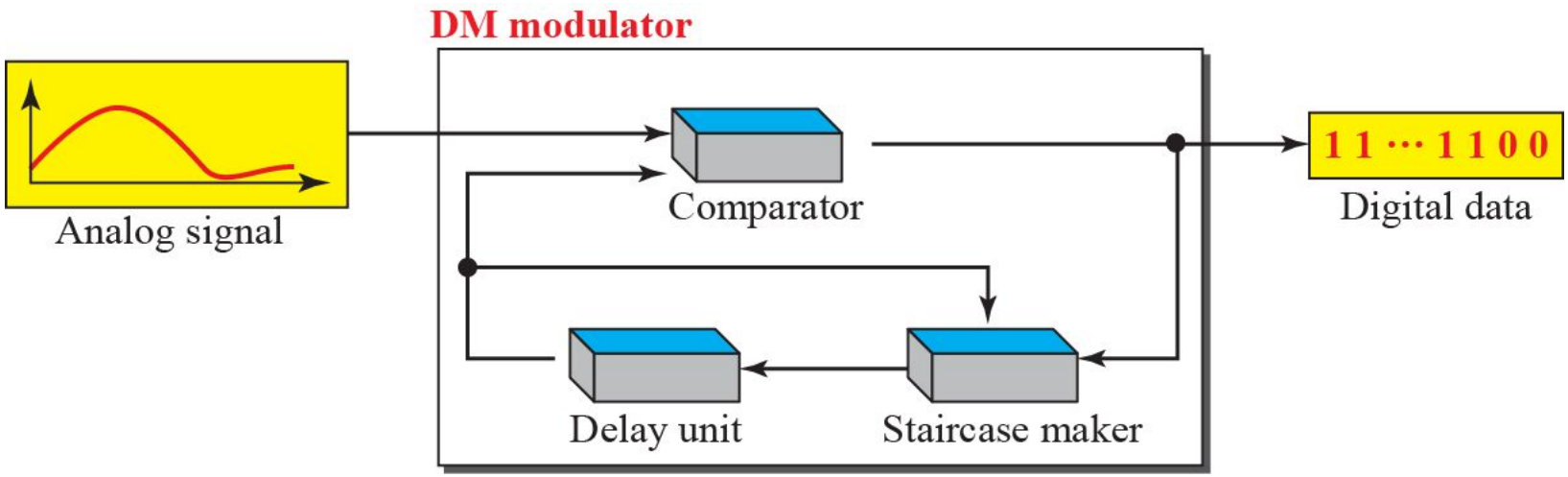
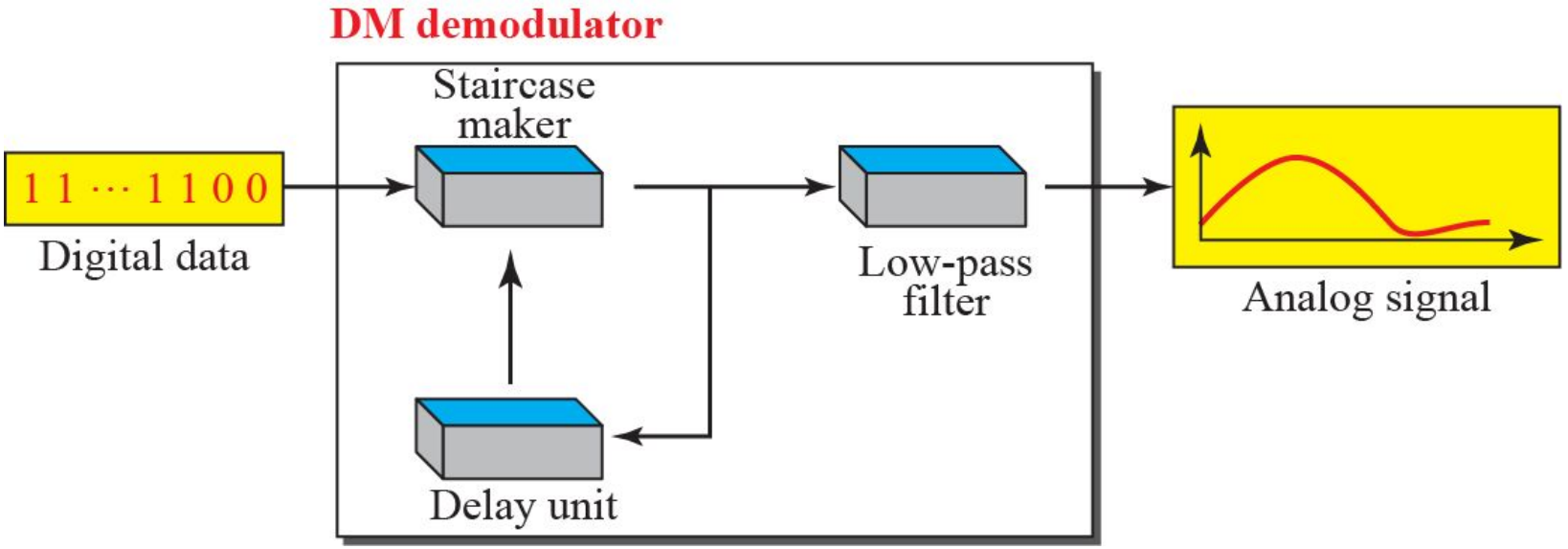


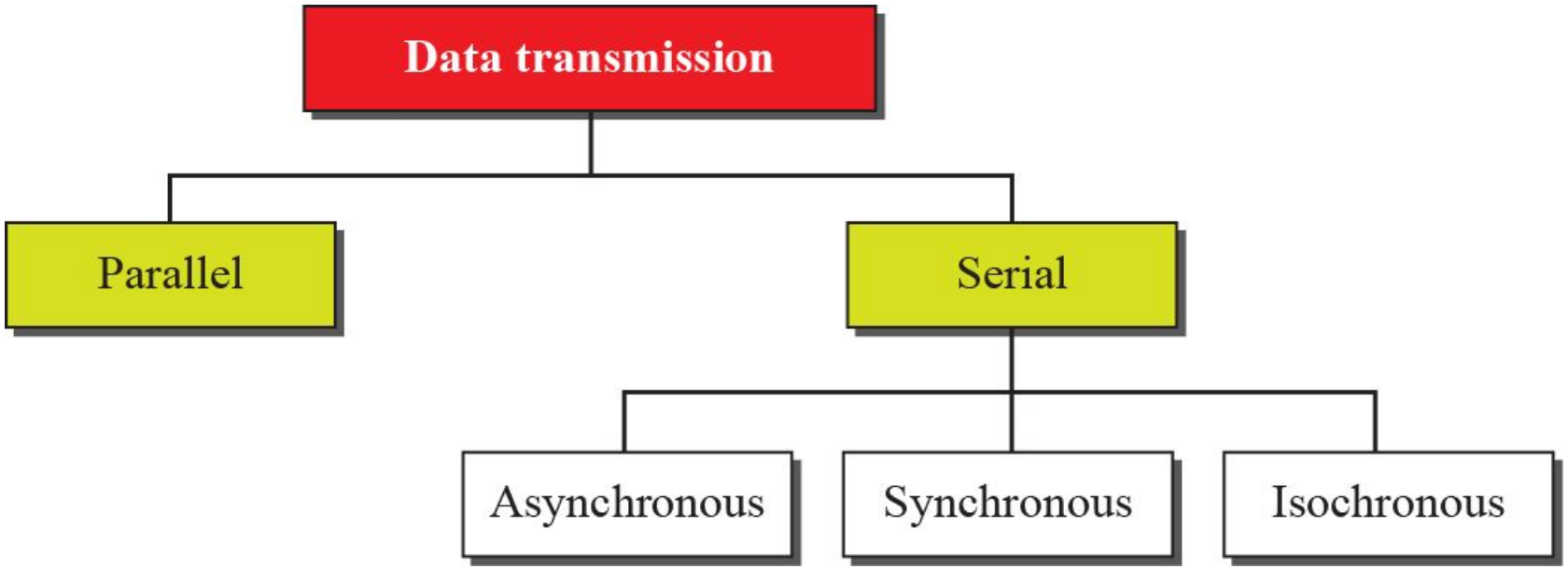
Figure: Delta demodulation components



Transmission Modes

- Of primary concern when we are considering the transmission of data from one device to another is the wiring, and of primary concern when we are considering the wiring is the data stream.
- Do we send 1 bit at a time; or do we group bits into larger groups and, if so, how?
- The transmission of binary data across a link can be accomplished in either parallel or serial mode.

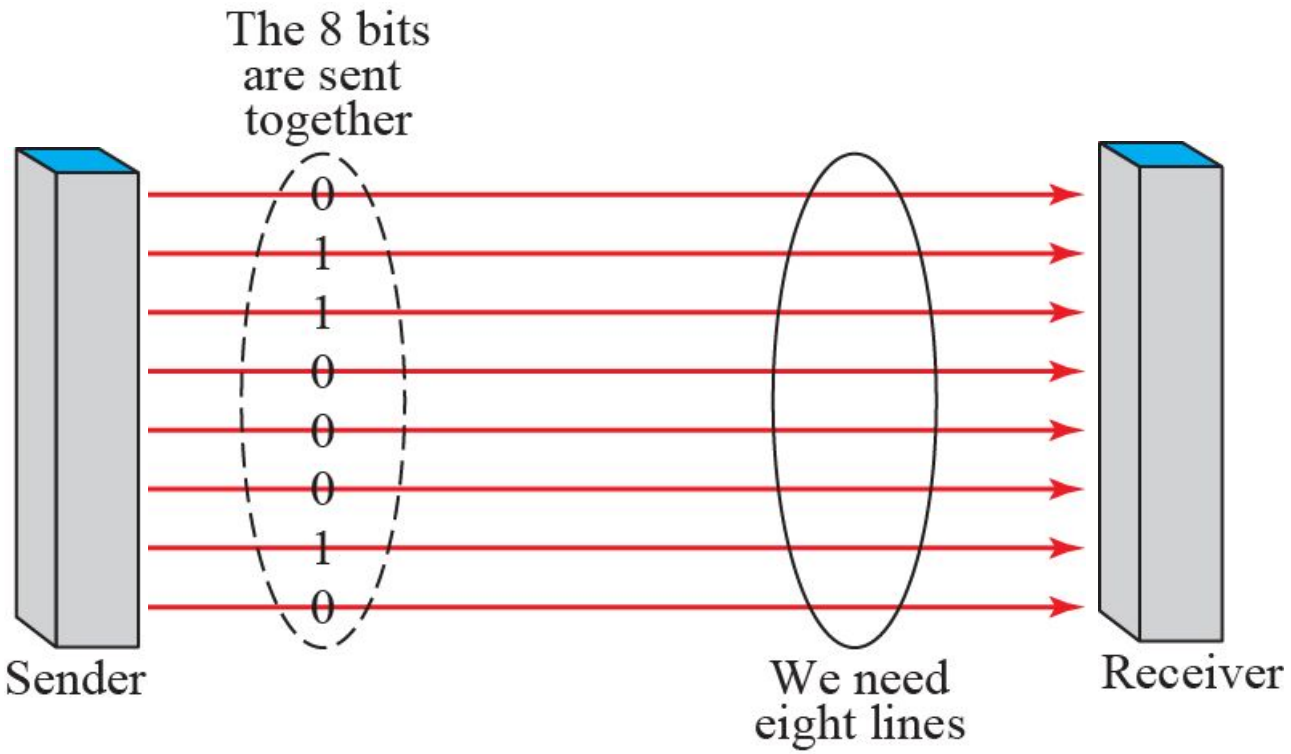
Figure: Data transmission modes



1 Parallel Transmission

- Line coding is the process of converting digital data to digital signals.
- We assume that data, in the form of text, numbers, graphical images, audio, or video, are stored in computer memory as sequences of bits.
- Line coding converts a sequence of bits to a digital signal.
- At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal.

Figure: Parallel transmission



2 Serial Transmission

In serial transmission one bit follows another, so we need only one communication channel rather than n to transmit data between two communicating devices.

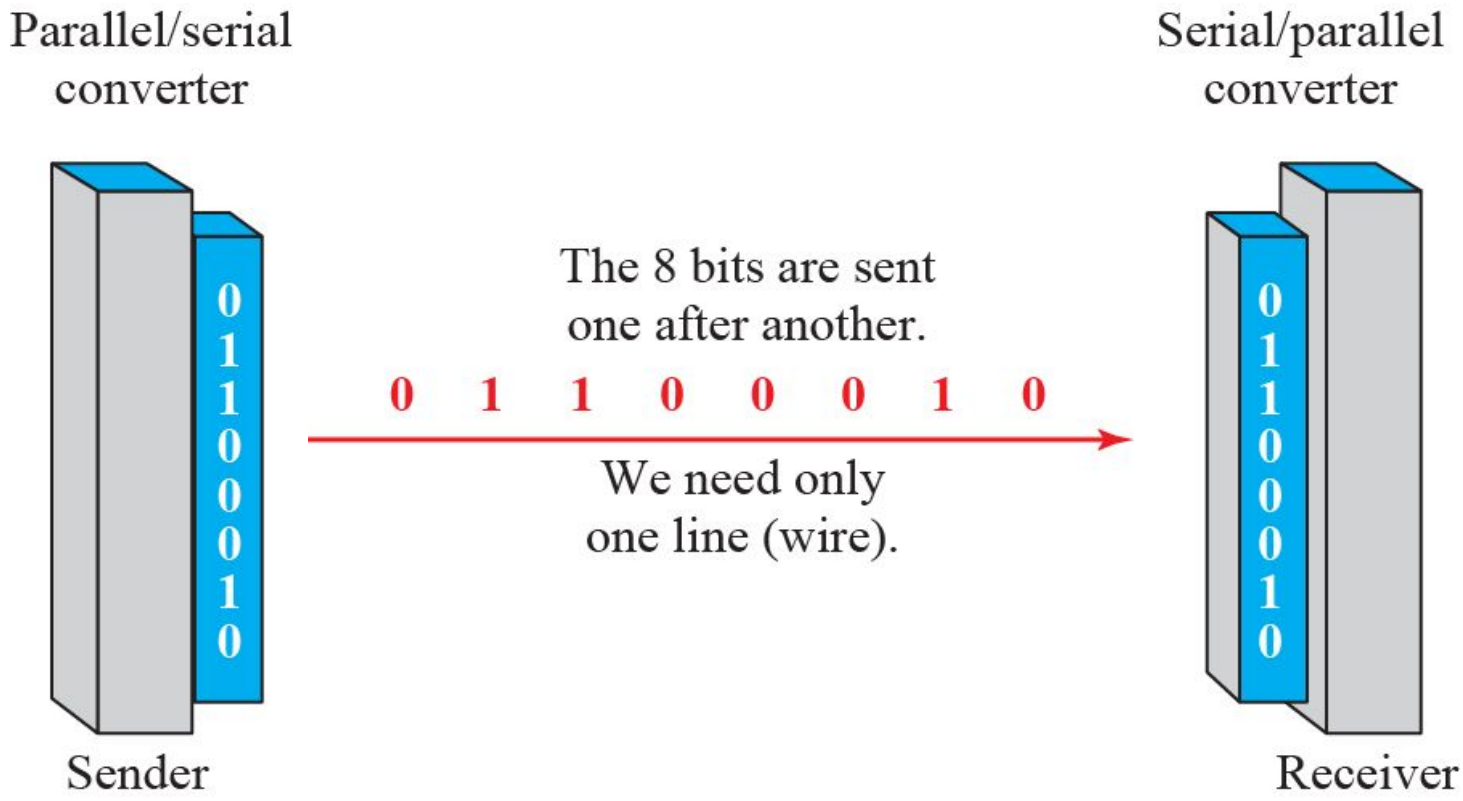


Figure: Asynchronous transmission

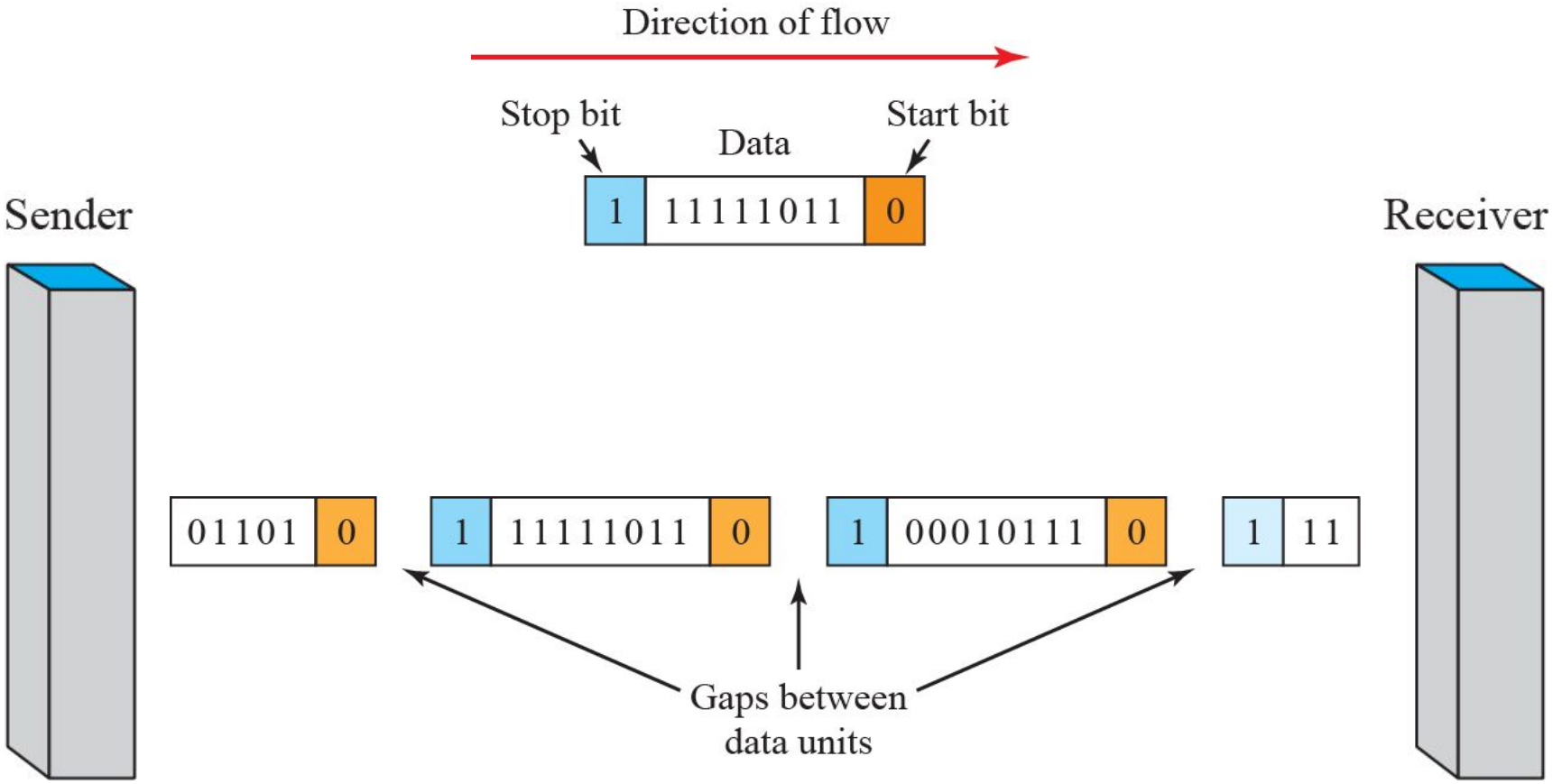


Figure: Synchronous transmission

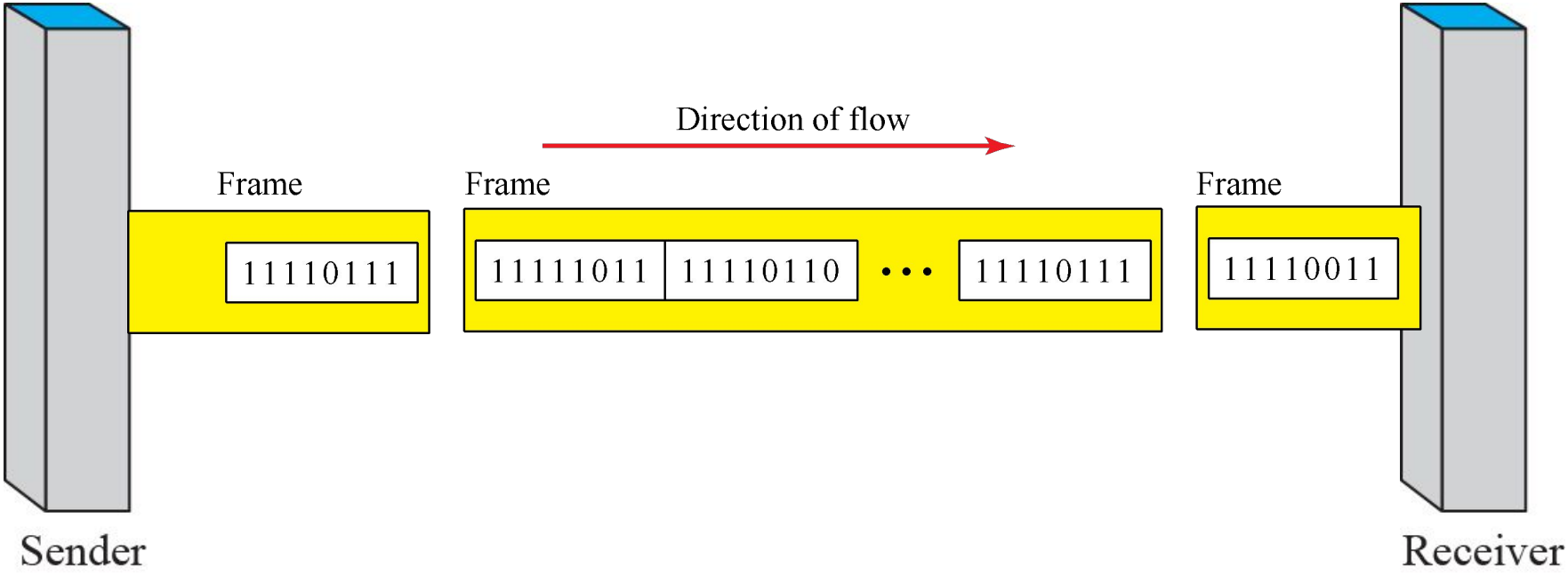


Figure: Isochronous transmission

- An isochronous data transfer system combines the features of an asynchronous and synchronous data transfer system.
- Each transmission begins with a start packet. Once the start packet is transmitted, the data must be delivered with a guaranteed bandwidth.
- Isochronous data transfer is commonly used for where data must be delivered within certain time constraints, like streaming video.
- Isochronous systems do not have an error detection mechanism (acknowledgment of receipt of packet) because if an error were detected, time constraints would make it impossible to resend the data.

Analog Transmission

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

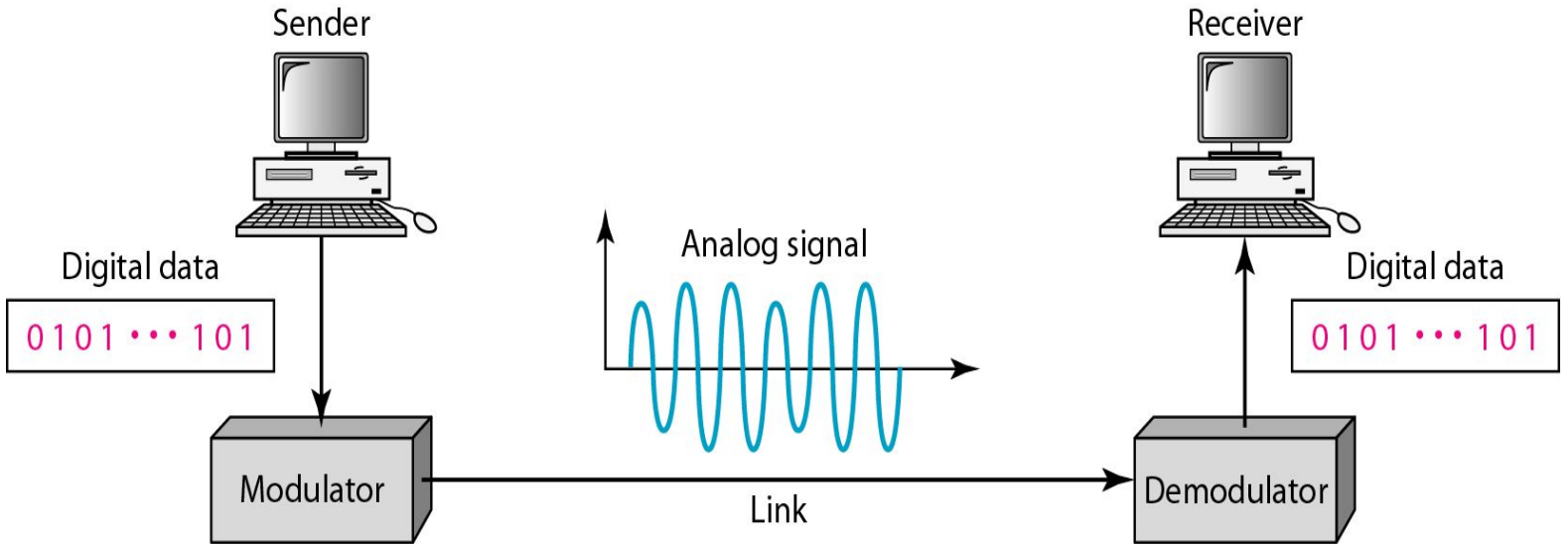
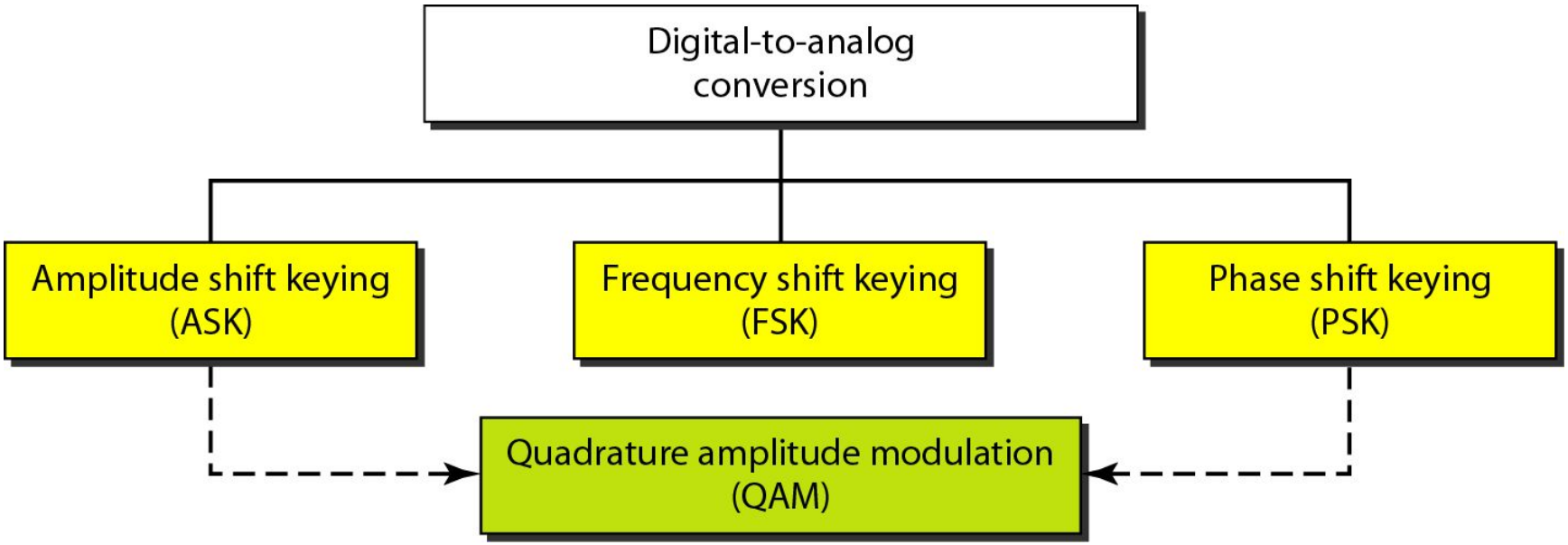
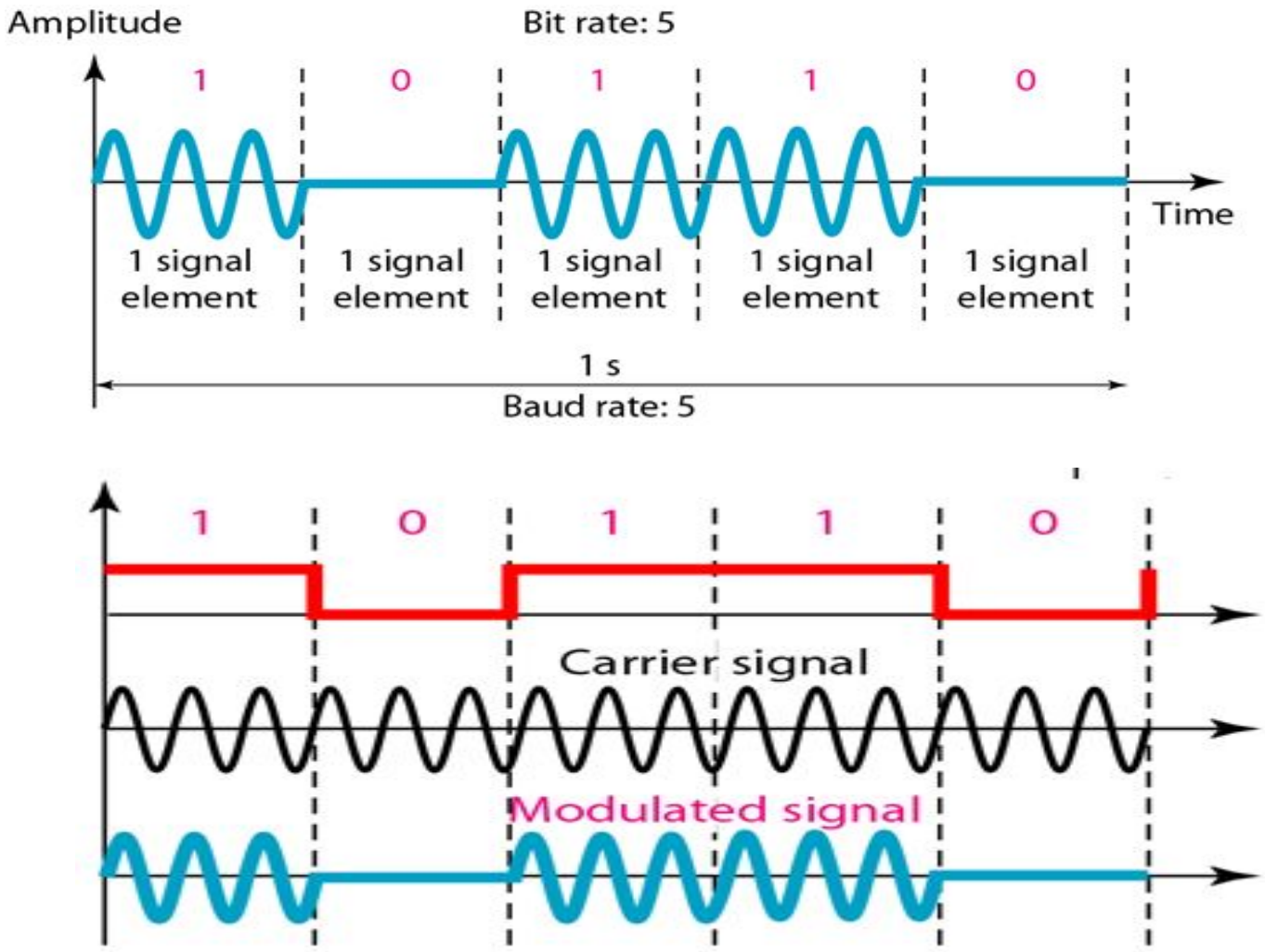


Figure: Analog Communication

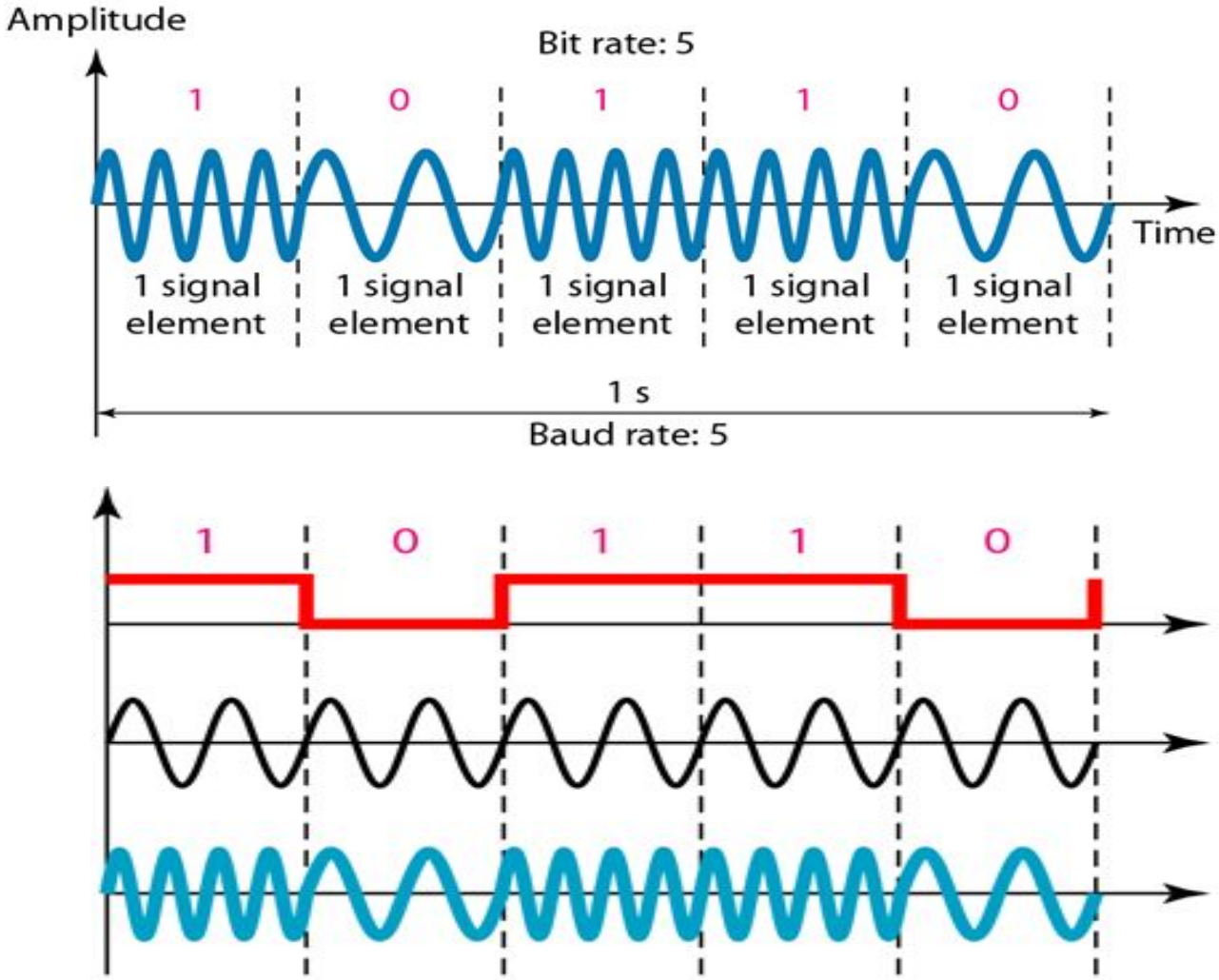
Types of digital-to-analog conversion



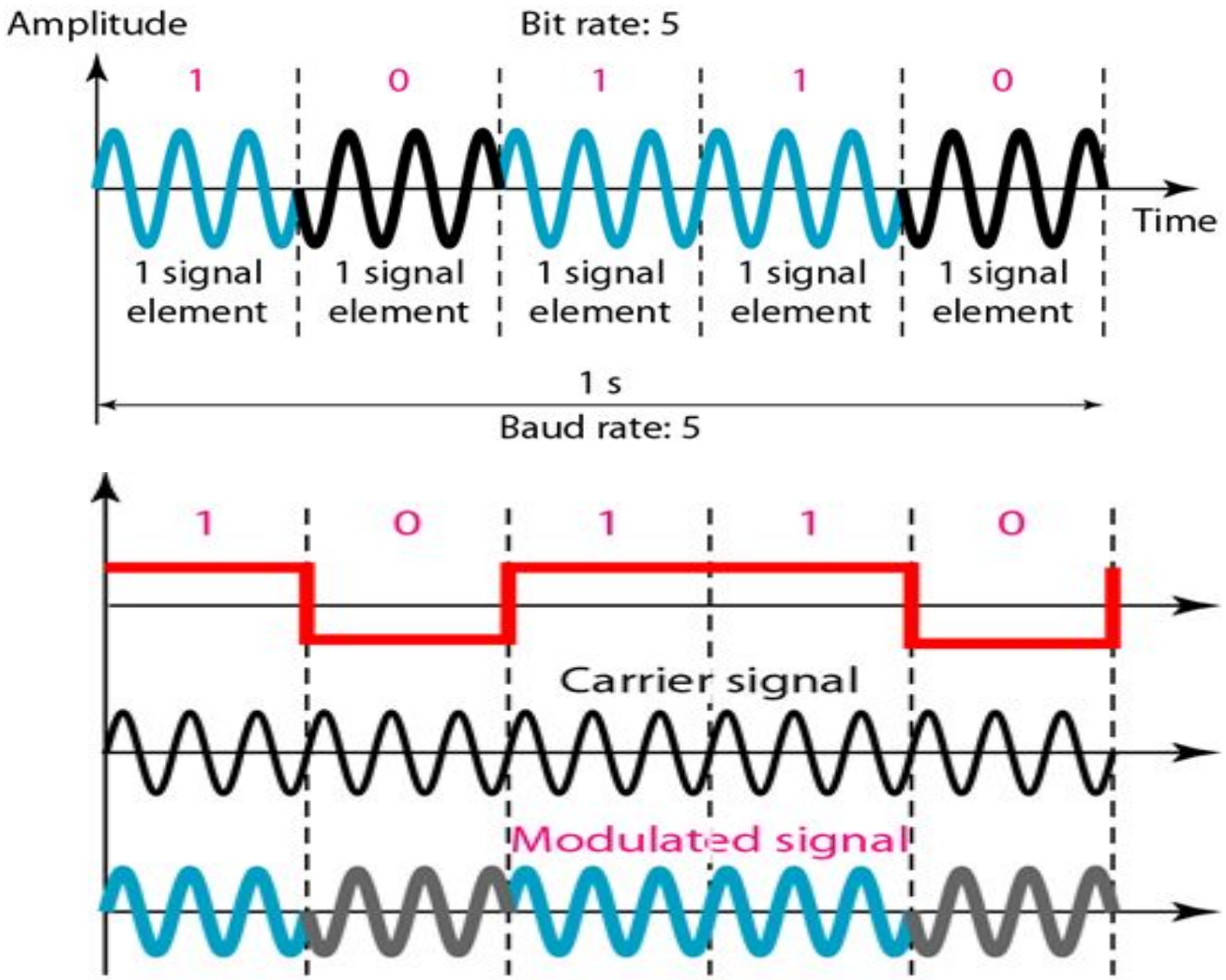
Amplitude Shift Keying (ASK)



Frequency Shift Keying

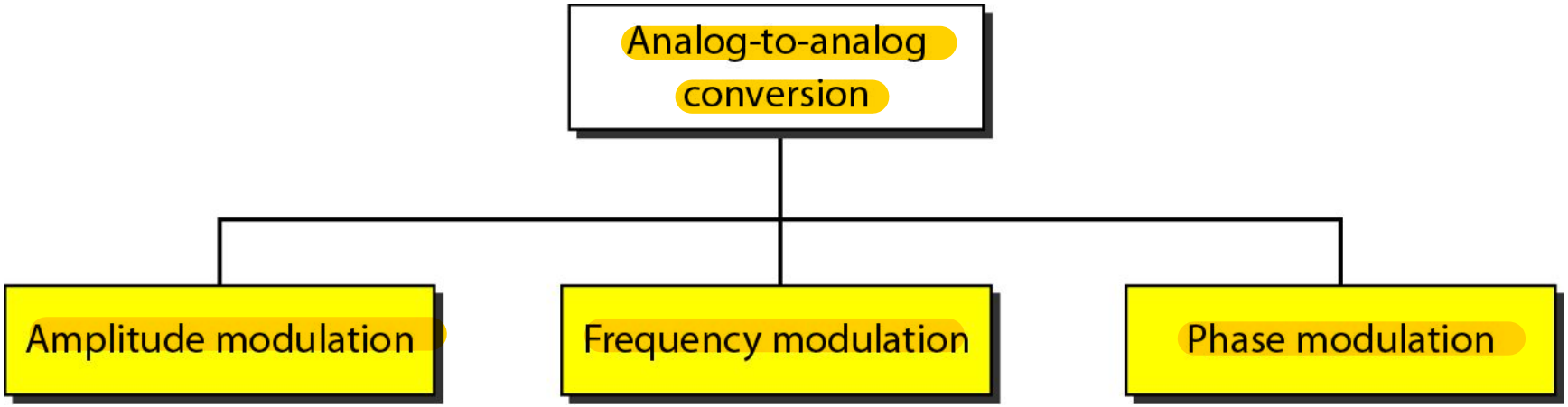


Phase Shift Keyeing

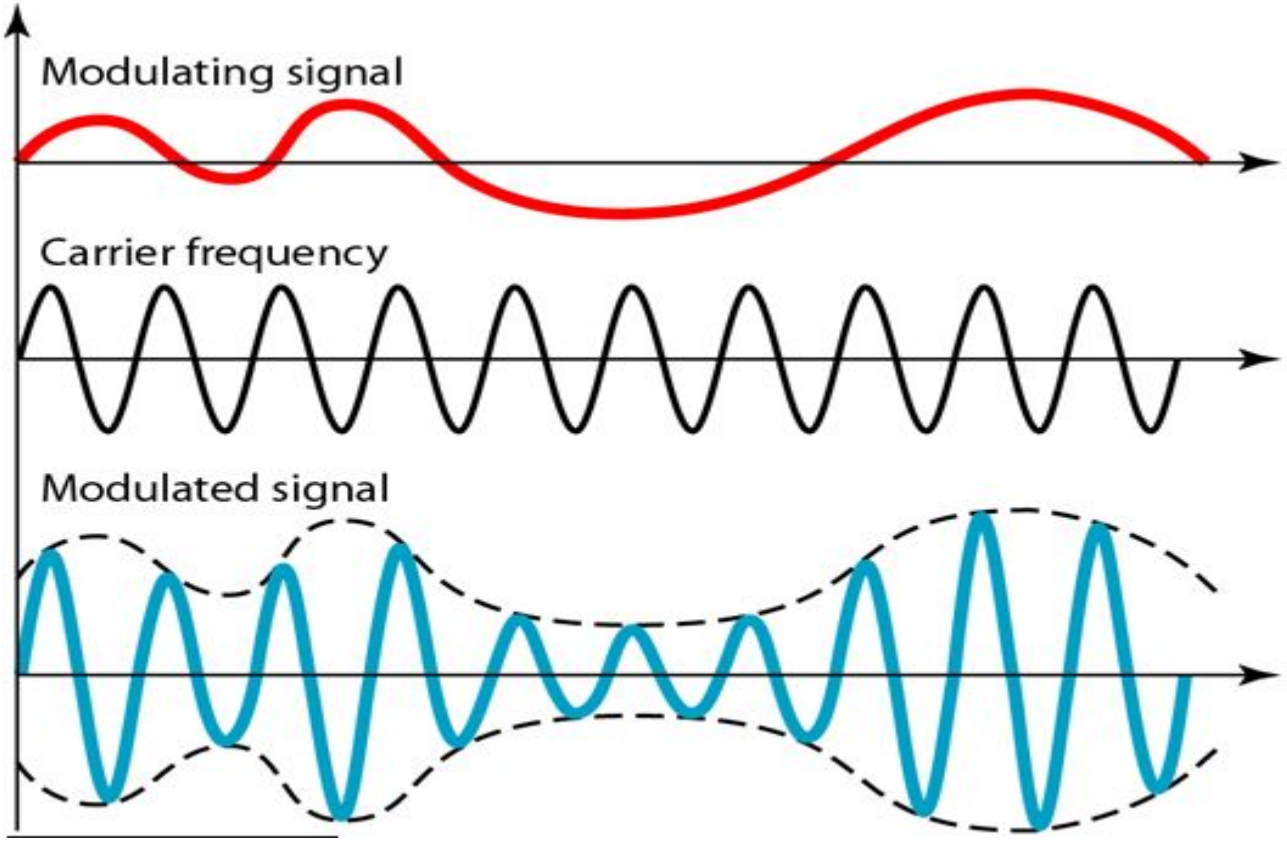


Analog to analog conversion

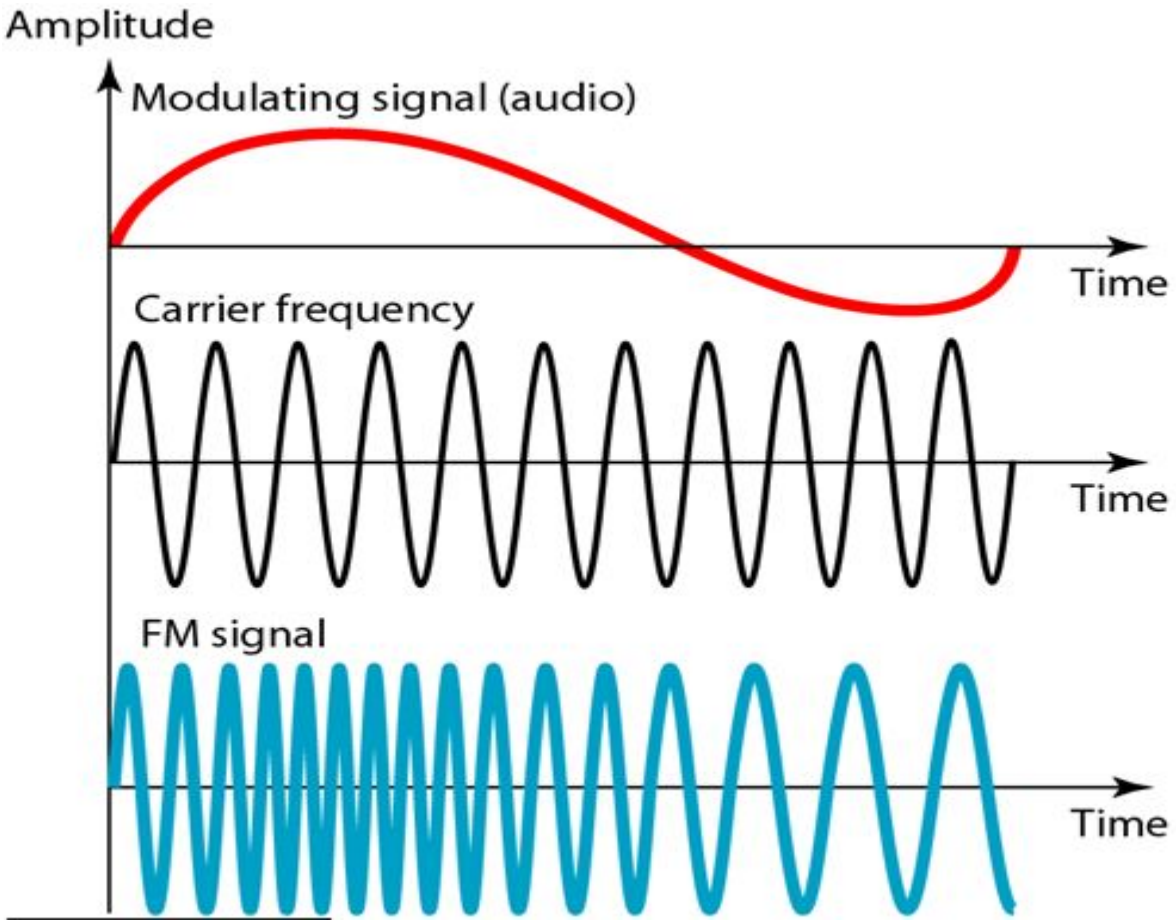
- Analog-to-analog conversion is the representation of analog information by an analog signal.



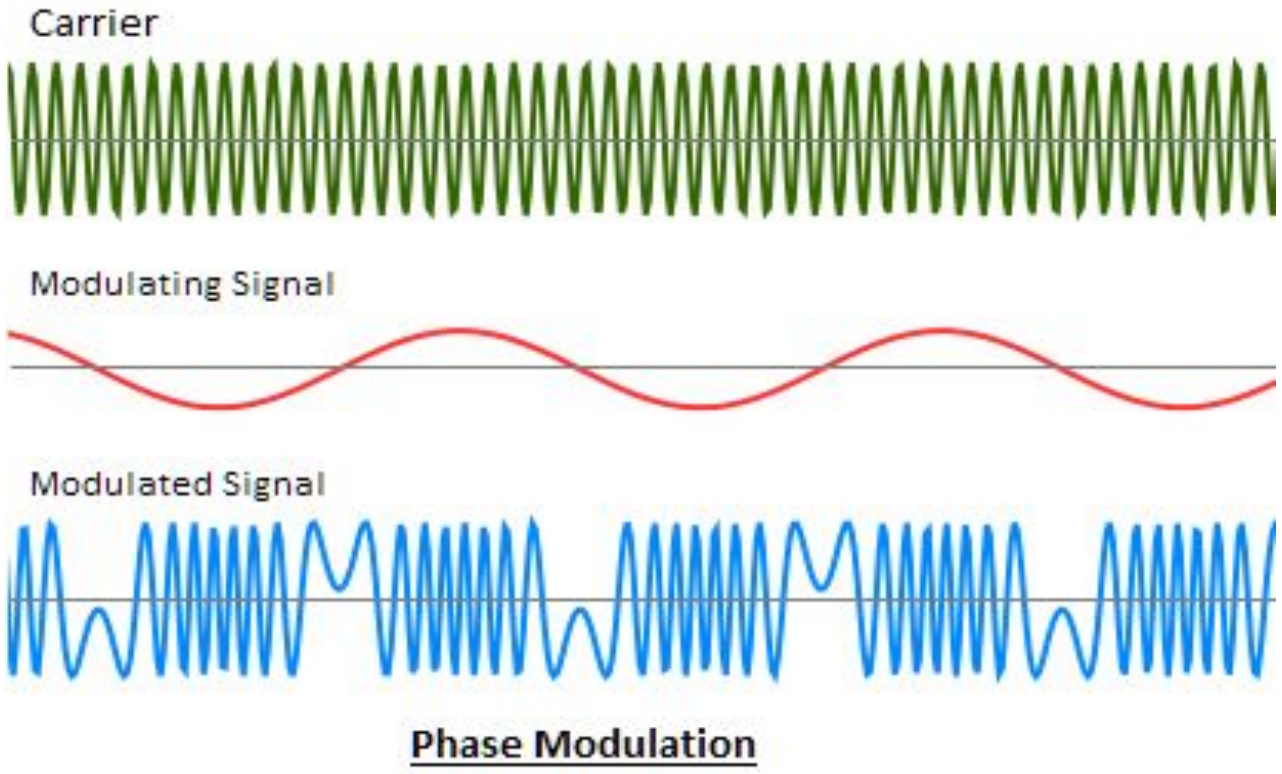
Amplitude Modulation



Frequency Modulation



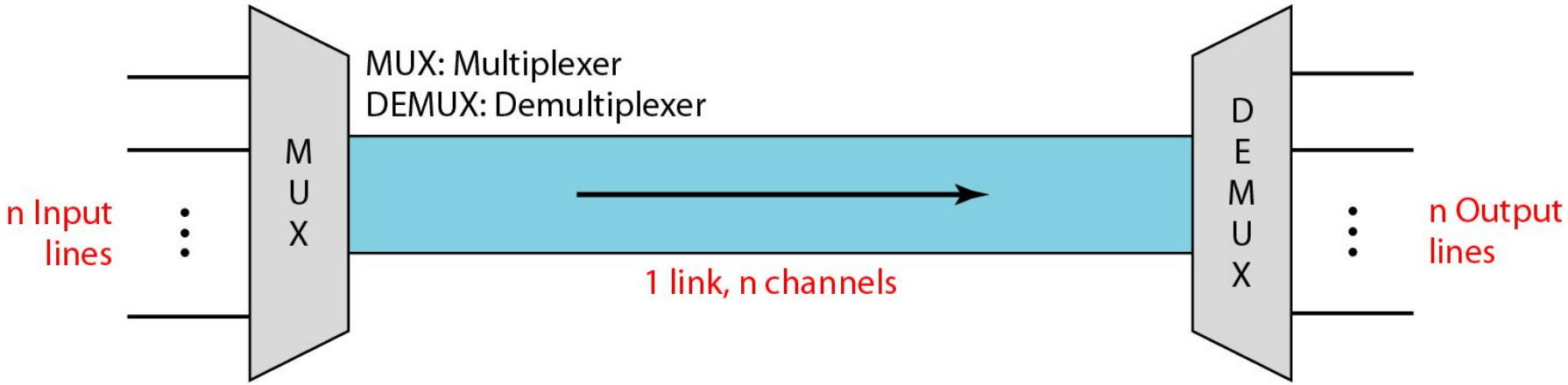
Phase Modulation (PM)



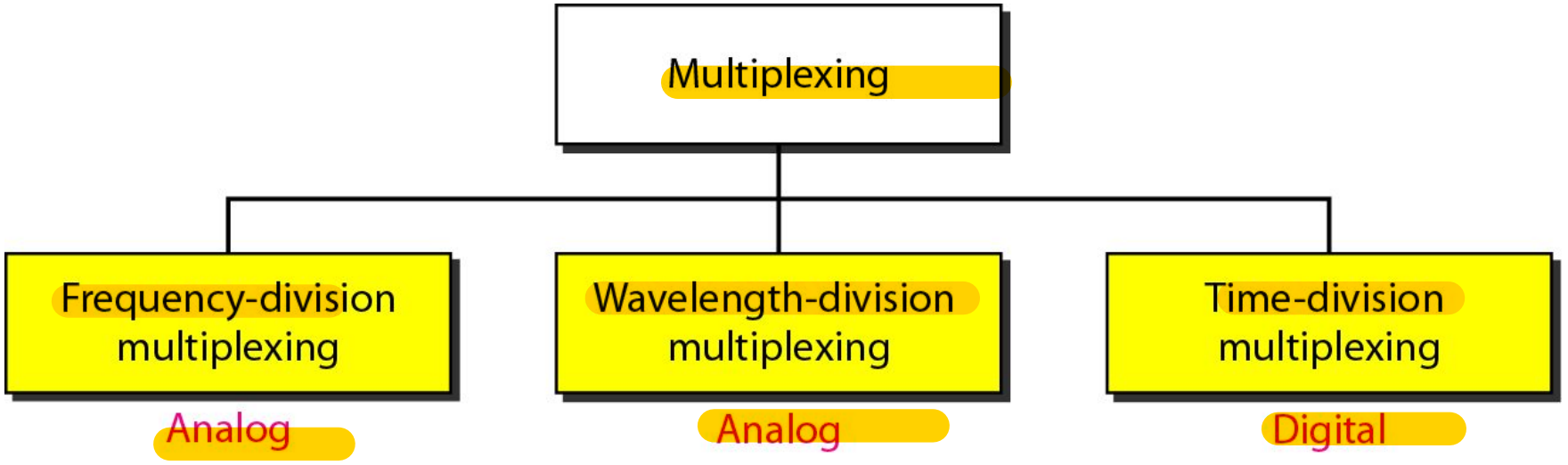
Phase Modulation

MULTIPLEXING

- Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared.
- Multiplexing is the set of techniques that allows the (simultaneous) transmission of multiple signals across a single data link.
- Dividing a link into channels



Categories of multiplexing



Frequency-division multiplexing (FDM)

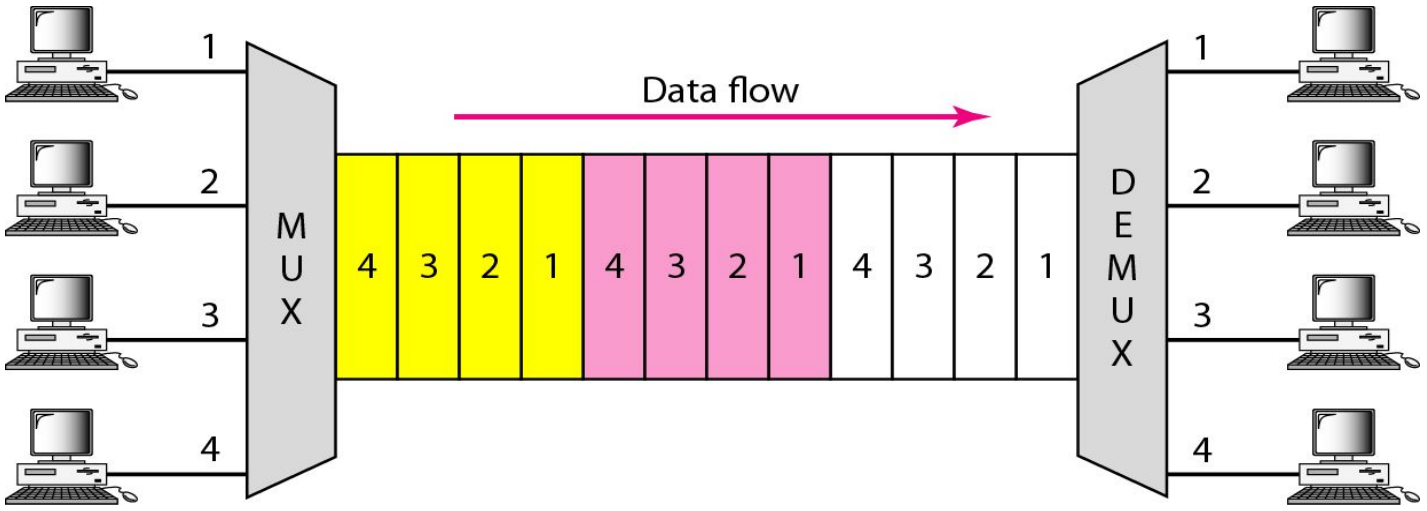
- Analog multiplexing technique
- For digital signals, they must be converted to analog signals first
- Individual signals modulates different carrier frequencies
- Each carrier frequency is separated by a guard band (unused bandwidth) to prevent signals from overlapping In addition, choice of carrier frequencies must ensure that they do not interfere with data being carried
- These are then combined into a single composite signal that can be transported over the data link

WDM

- WDM is conceptually the same as FDM, except that the multiplexing and demultiplexing involve optical signals transmitted through fiber-optic channels.
- The idea is the same: We are combining different signals of different frequencies. The difference is that the frequencies are very high.
- WDM is designed to use the high-data-rate capability of fiber-optic cable.
- The optical fiber data rate is higher than the data rate of metallic transmission cable.
- Using a fiber-optic cable for one single line wastes the available bandwidth. Multiplexing allows us to combine several lines into one.

Time Division Multiplexing

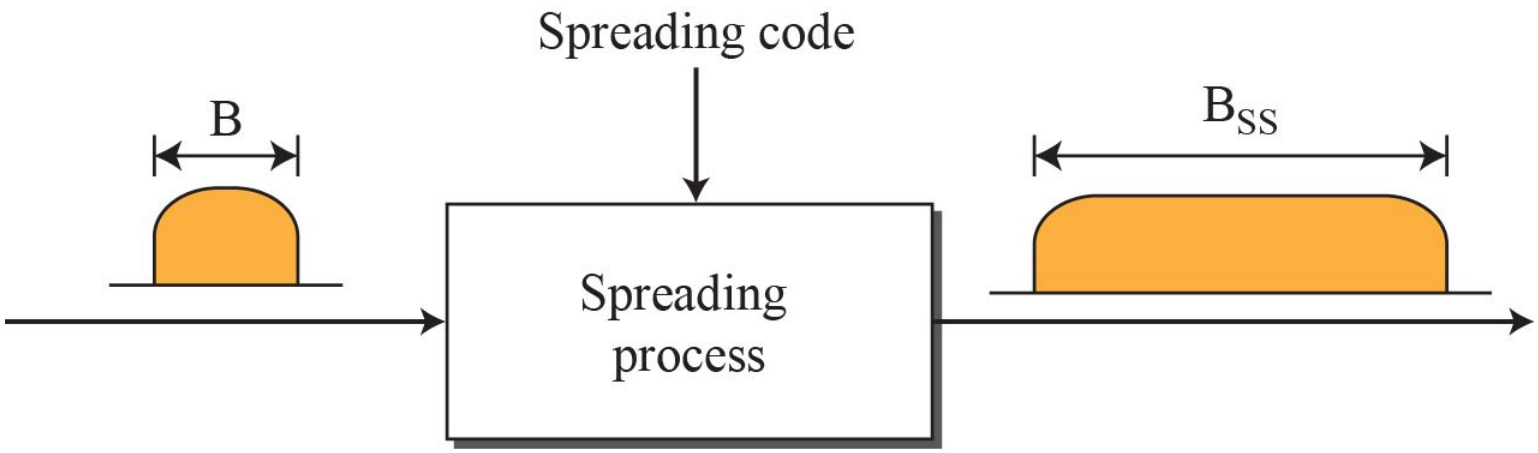
- Digital Multiplexing technique
- Analog data should be digitized prior of TDM
- Instead of sharing portion of bandwidth, time is shared



Spread Spectrum

- In some applications, we have some concerns that outweigh bandwidth efficiency.
- In wireless applications, stations must be able to share this medium without interception by an eavesdropper and without being subject to jamming from a malicious intruder.
- To achieve these goals, spread spectrum techniques add redundancy.

Figure: Spread spectrum



1 FHHS

- *Frequency-hopping spread spectrum (FHSS) is a method of transmitting radio signals by rapidly switching a carrier among many frequency channels, using a pseudorandom sequence known to both transmitter and receiver.*

- *Each available frequency band is divided into sub-frequencies. Signals rapidly change ("hop") among these in a predetermined order.*

Figure: Frequency hopping spread spectrum (FHSS)

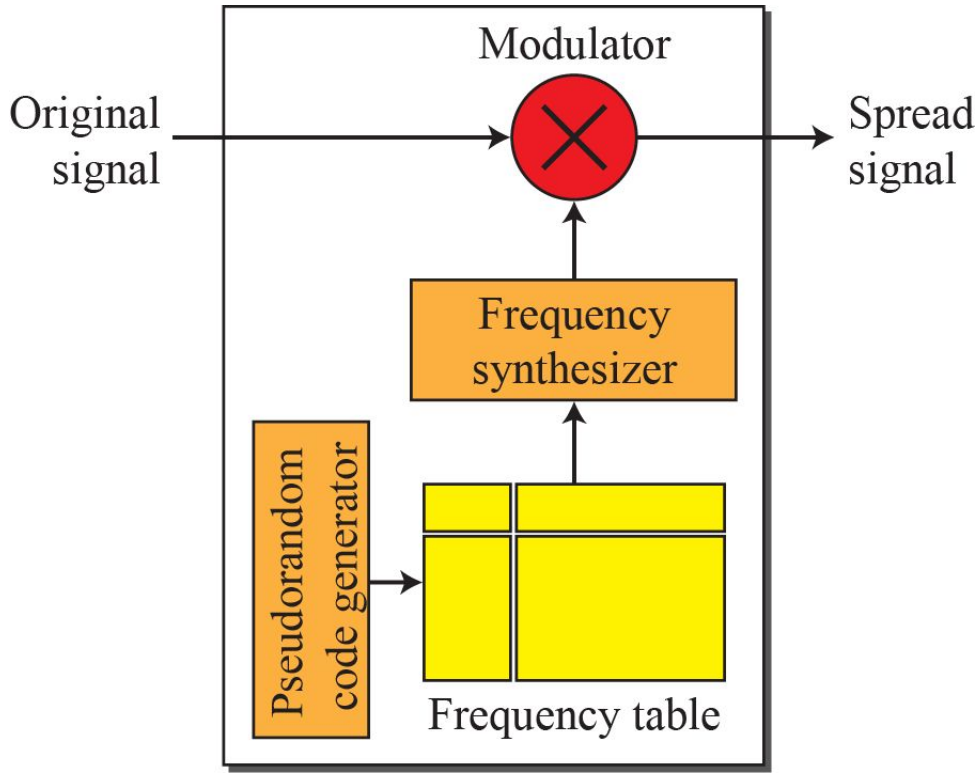


Figure: Frequency selection in FHSS

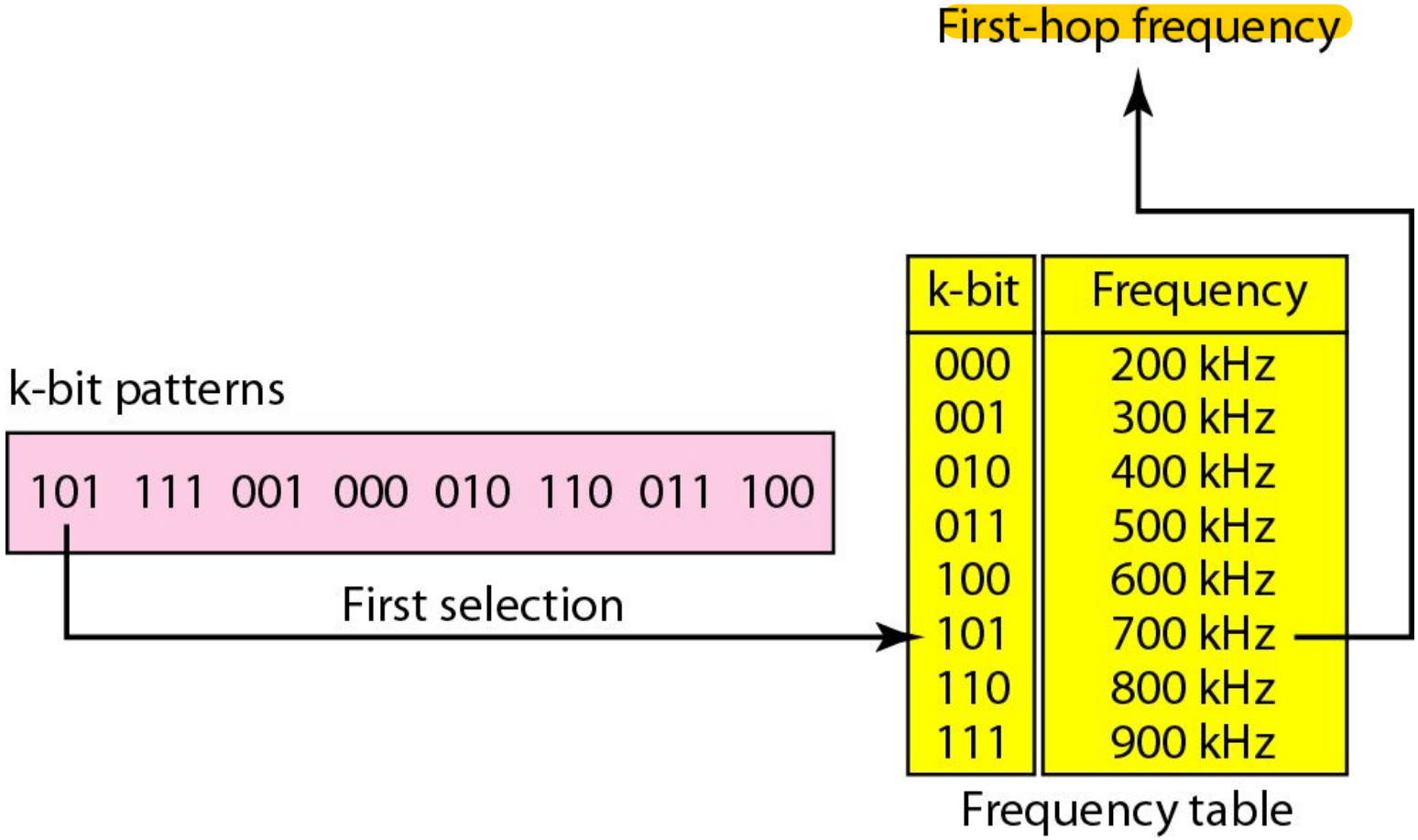


Figure: FHSS cycles

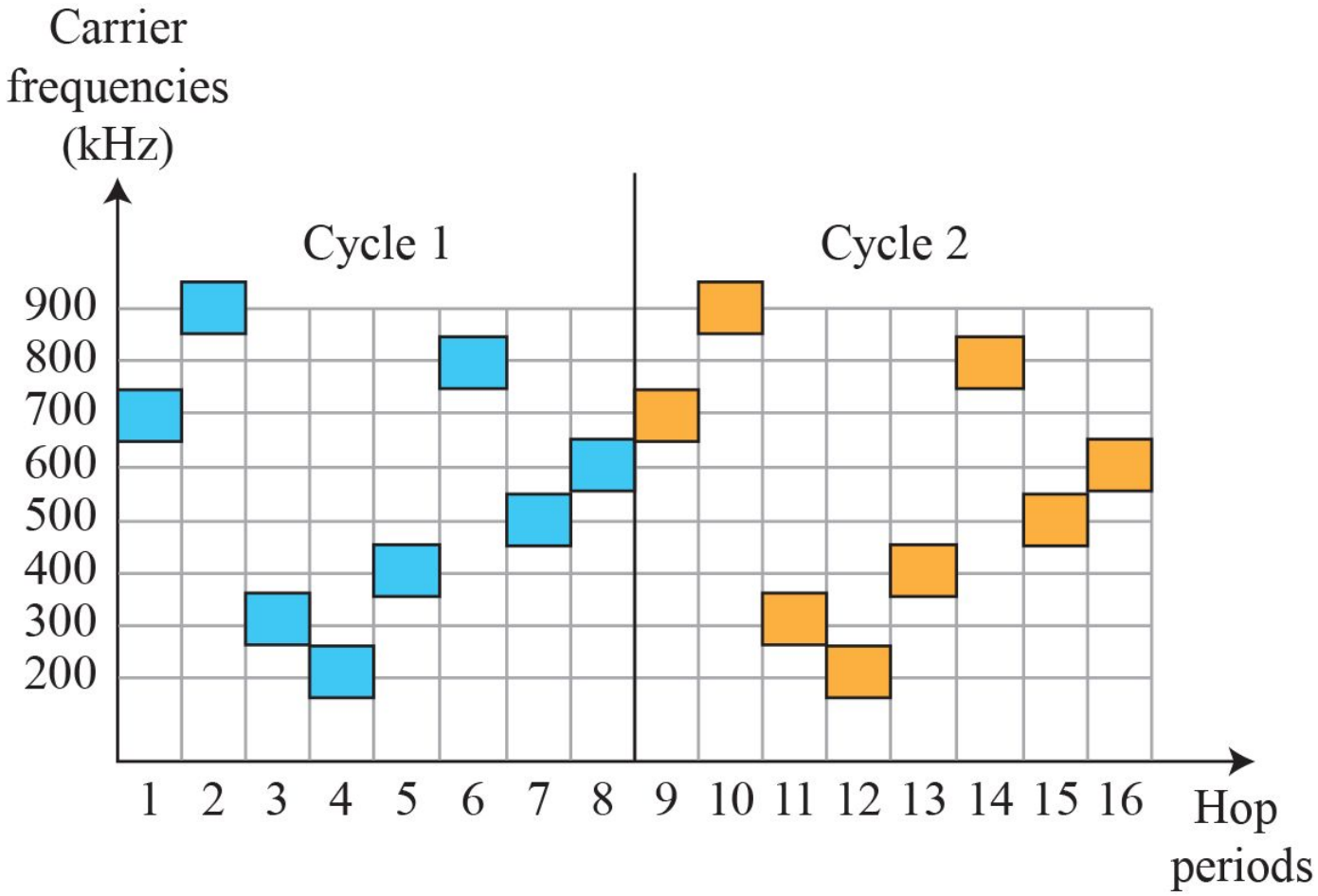
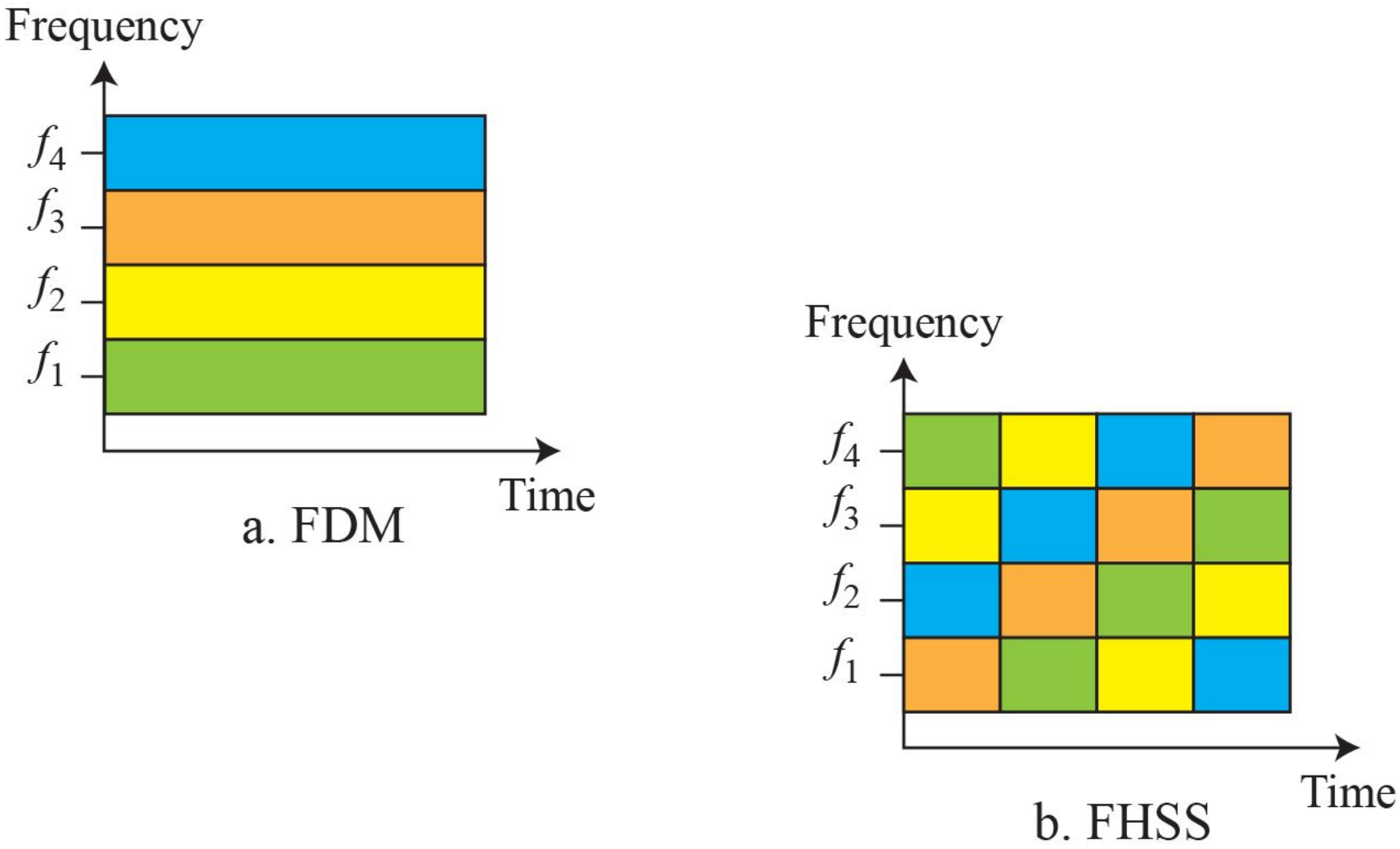


Figure: Bandwidth sharing



2 DSSS

- *The direct sequence spread spectrum (DSSS) technique also expands the bandwidth of the original signal, but the process is different.*
- *In DSSS, we replace each data bit with n bits using a spreading code.*
- *In other words, each bit is assigned a code of n bits, called chips, where the chip rate is n times that of the data bit. Next figure shows the concept of DSSS.*

Figure: DSSS

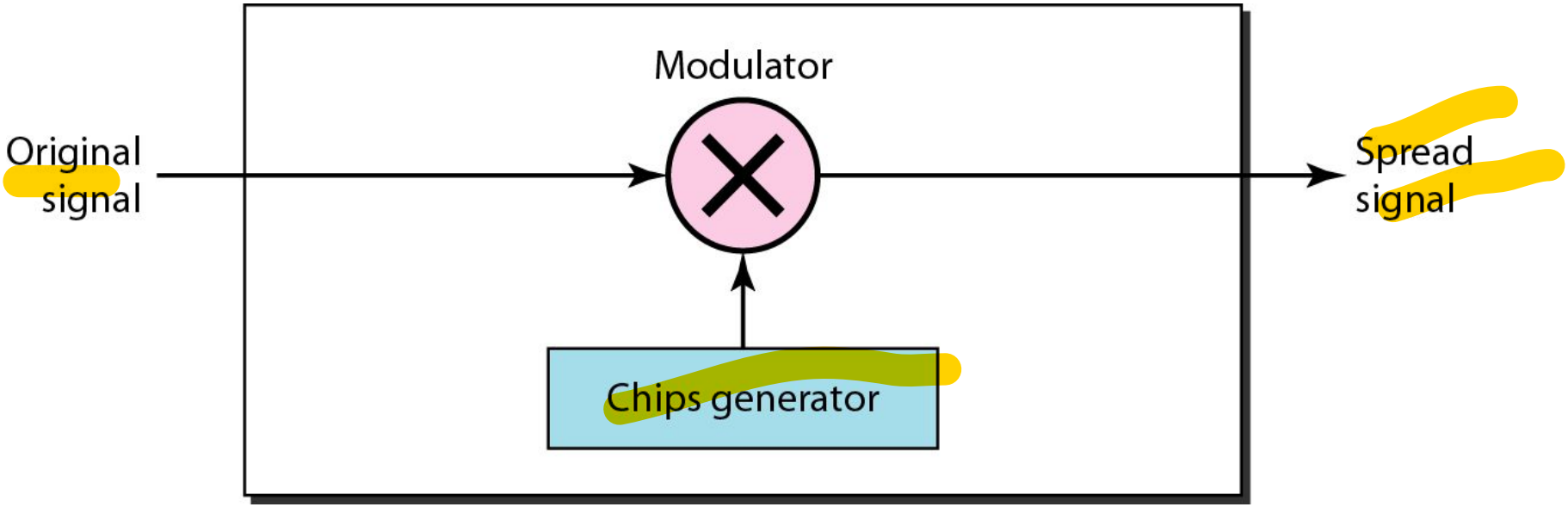
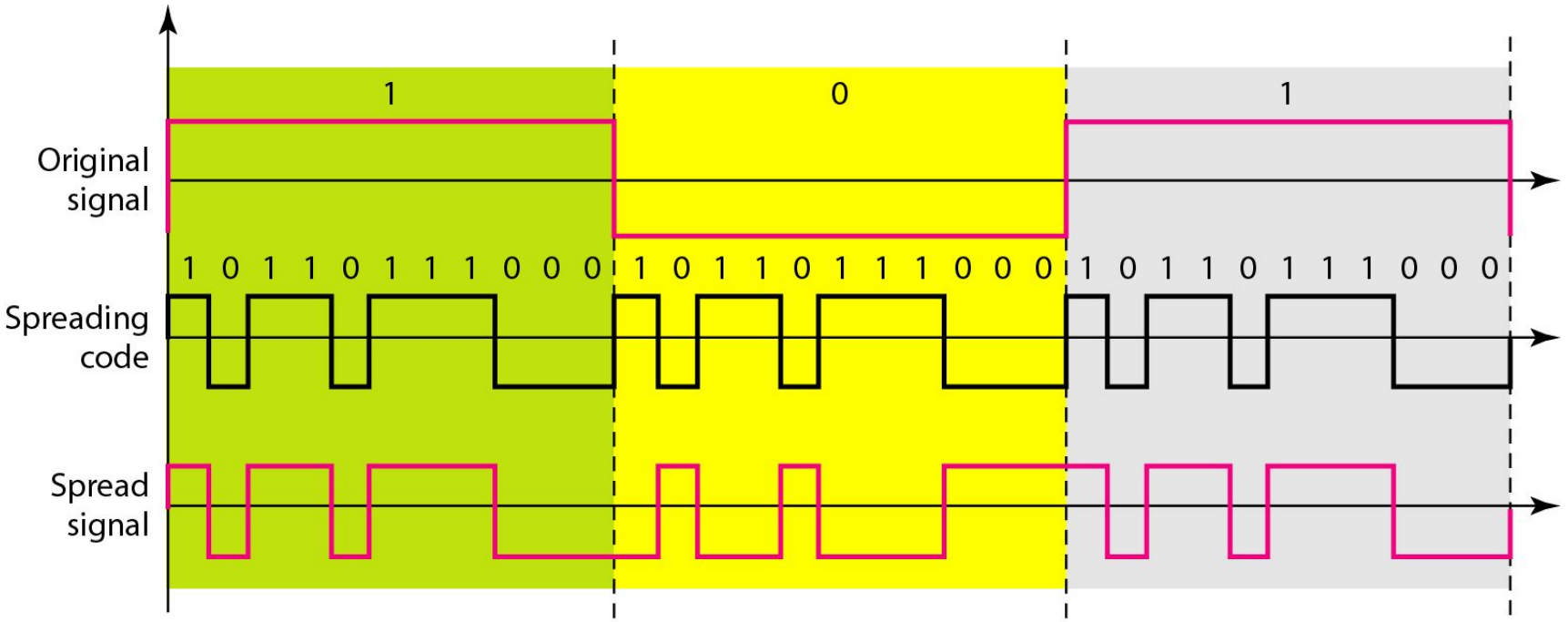


Figure: DSSS example



Examples:

- A digital signal has eight levels. How many bits are needed per level? Calculate the number of bits from the formula?

- Assume we need to download text documents at the rate of 100 pages per second. A page is an average of 24 lines with 80 characters in each line. What is the required bit rate of the channel?

- 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?