IT2004 – Introduction to Data Communication & Networks

Week 3 – Basic Principles of Data Communication- Part2

Data Transmission & Modulation

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Transmission Terminology

- Data transmission occurs over some **transmission medium**.
- Transmission media may be **guided or unguided.**
- A direct link between two devices is a **point-to-point link**.
- More than two devices communicate over a **multipoint link**.
- Transmission may be **simplex, half-duplex, or full-duplex**

Analog and Digital Transmission

- **Analog**--continuous time signals.
- **Digital**--discrete time signals.
- Three Contexts
  - **Data**--entities that convey meaning; **signals** are electric or electromagnetic encoding of data.
  - **Signaling**--the physical propagation of the signal along a suitable medium.
  - **Transmission--**the communication of data by the propagation and processing of signals.

Analog and Digital Transmission--Data

- **Analog data--**continuous values on some interval.
  - Ex.: audio, video, temperature and pressure sensors.
- **Digital data--**discrete values.
  - Ex.: text, integers.
  - Encoding using binary patterns: Ex: ASCII

Analog and Digital Transmission--**Signals**

- **Analog signal--**a continuously varying electromagnetic wave that may be propagated over a variety of media, depending on bandwidth.
- **Digital signal--**a sequence of voltage pulses that may be transmitted over a wire medium.

Analog and Digital Transmission--**Signals**

- **Analog** data can also be represented by **digital** signals and **digital** data can be represented by **analog** signals.
- Digital Data can be represented by analog signals: **modem**.
- Analog Data can be represented by digital signals: **codec**.

Examples

- **Analog to analog**
  - Voice (Analog Data) → Telephone → Analog Signal
- **Digital to analog**
  - PC (Digital Data) → Modem → Analog Signal
- **Analog to digital**
  - Voice (Analog Data) → CODEC → Digital Signal
- **Digital to Digital**
  - PC (Digital Data) → Digital Transmitter → Digital Signal

Analog and Digital Transmission

- **Analog transmission**--transmission of analog signals without regard to content.(whether it represents digital or analog data)
  - For long distances, amplifiers are used .
  - Amplifiers boost noise, and are "imperfect".
  - Analog voice is tolerant of the distortion, but for digital data errors will be introduced.

Analog and Digital Transmission

- **Digital transmission--** transmission of digital data (using either analog or digital signals).
  - Concerned with the content of the signal
  - For long distances, repeaters are used.(which recover the pattern of 0's and 1's and re-transmits)
  - Can be used with analog signals if it carries digital data
  - Preferred because of: digital technology, data integrity(error coding), capacity utilization, security, integration (of voice, data and more.)

Advantages of Digital Transmission

- The signal is exact
- Signals can be checked for errors
- Noise/interference are easily filtered out
- A variety of services can be offered over one line
- Higher bandwidth is possible with data compression

Why Use Analog Transmission?

- Already in place
- Significantly less expensive
- Lower attenuation rates
- Fully sufficient for transmission of voice signals

Modulation and Demodulation

- If either analog or digital signals were used exclusively, communications would be simplified.
- In reality, there is a wide mix of analog devices communicating using digital signals and digital devices communicating using analog signals.
- Most computer communications are digital such as terminal-to-computer or computer-to-disk transmissions use digital signals.
- In addition, most local area networks rely entirely on digital signals.
- So where do analog signals enter the picture?

Modulation and Demodulation

- The answer is remote communications.
- Many people use PCs in their home to communicate with a computer at work.
- PCs also allow access to stock quotations, air line reservation systems, and etc. In most cases, there is no direct connection such as a local area network.
- The physical connection uses existing hardware found in the telephone system.
- However, because the telephone is an analog device, the PC cannot communicate with it directly.

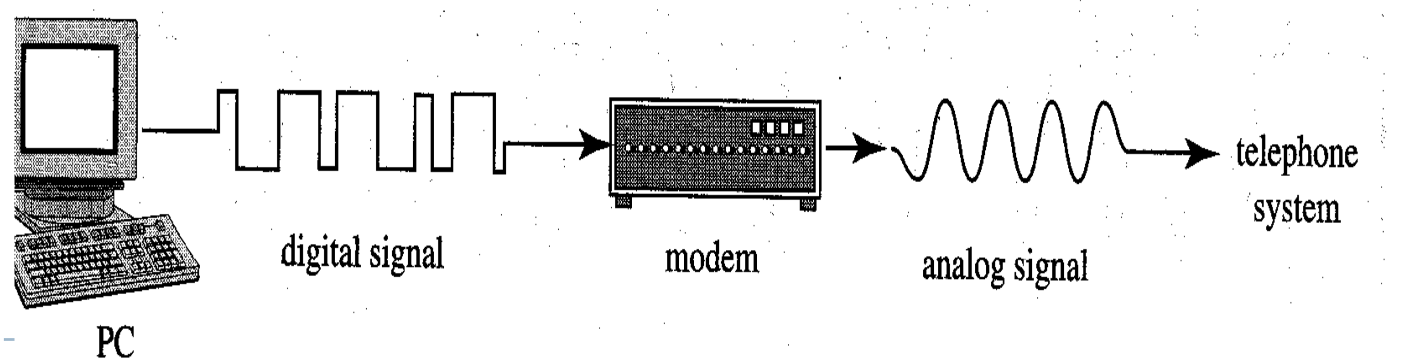
Modulation and Demodulation

- The solution to this problem is a device that convert a PC's digital signal to analog signal: a MODEM (Modulation/ DEModulation) .
- It fits between a PC and the telephone.

Modem=**Mo**dulation and **Dem**odulation

- A **modem** (*modulator-demodulator*) is a device that modulates an analog carrier signal to encode digital information, and also demodulates such a carrier signal to decode the transmitted information.
- The goal is to produce a signal that can be transmitted easily and decoded to reproduce the original digital data.

Figure 2.40 Computer Data Transmitted over Telephone Lines



Modem=**Mo**dulation and **Dem**odulation

- The PC sends a digital signal out its modem port, where the modem intercepts it and converts **(modulates)** it to an analog signal.
- From there it goes through the telephone system and it treated as any voice signal.
- The process is reversed at the receiving end or for any signal destined for the PC.
- The analog signal comes through the telephone line and into the modem, and the modem converts it to a digital signal and sends it to the PC via the modem port.

CODEC (coder-decoder)

- A *codec* is a device or computer program capable of encoding or decoding a digital data stream or signal.

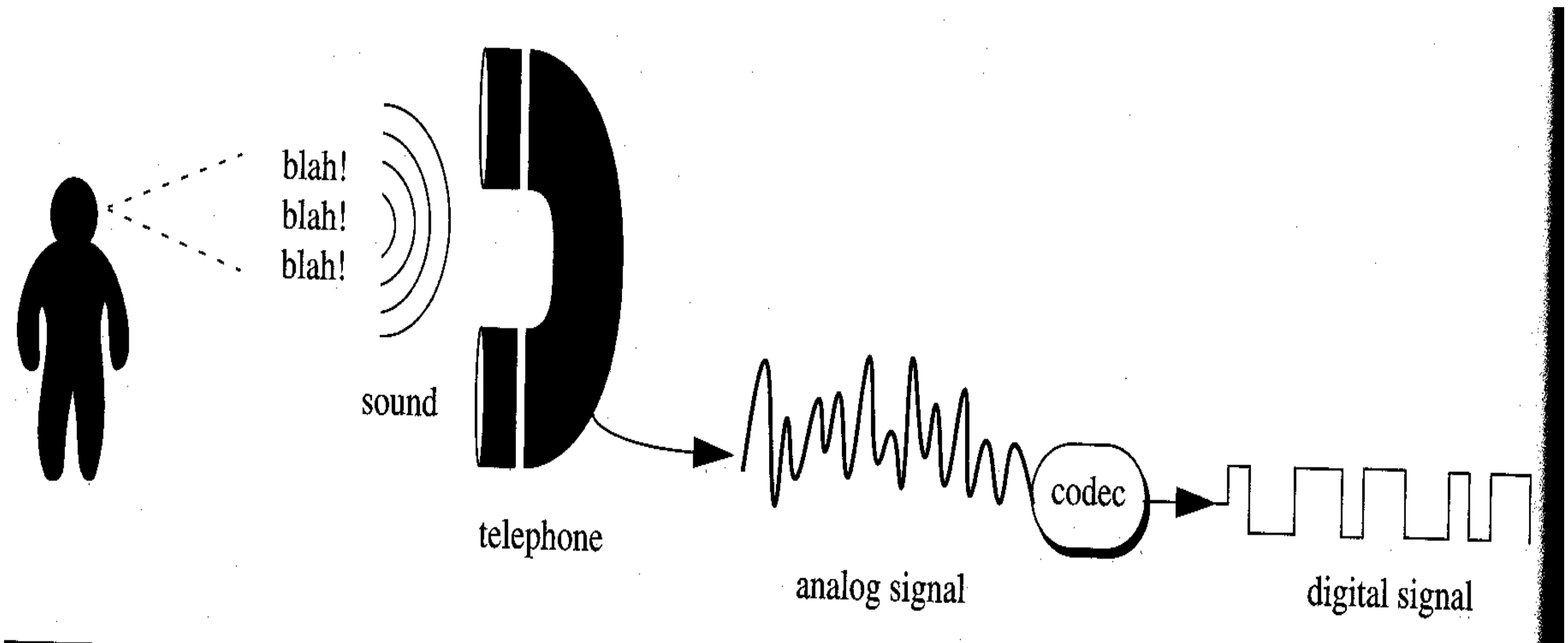


Figure 2.41 Voice Information Transmitted Digitally

Modulation

- The direct transmission of an audio / Voice signal is difficult
- consists of a wide range of frequencies
- Separation of wanted and unwanted frequencies is difficult when near by stations transmit at the same frequency range at the same time.
- a weak analog signal is associated with a strong e.m.w known as a **carrier signal** in some way.
- This association is carried out by a technique known as **modulation.**
- The resulting wave is known as a **modulated Signal**

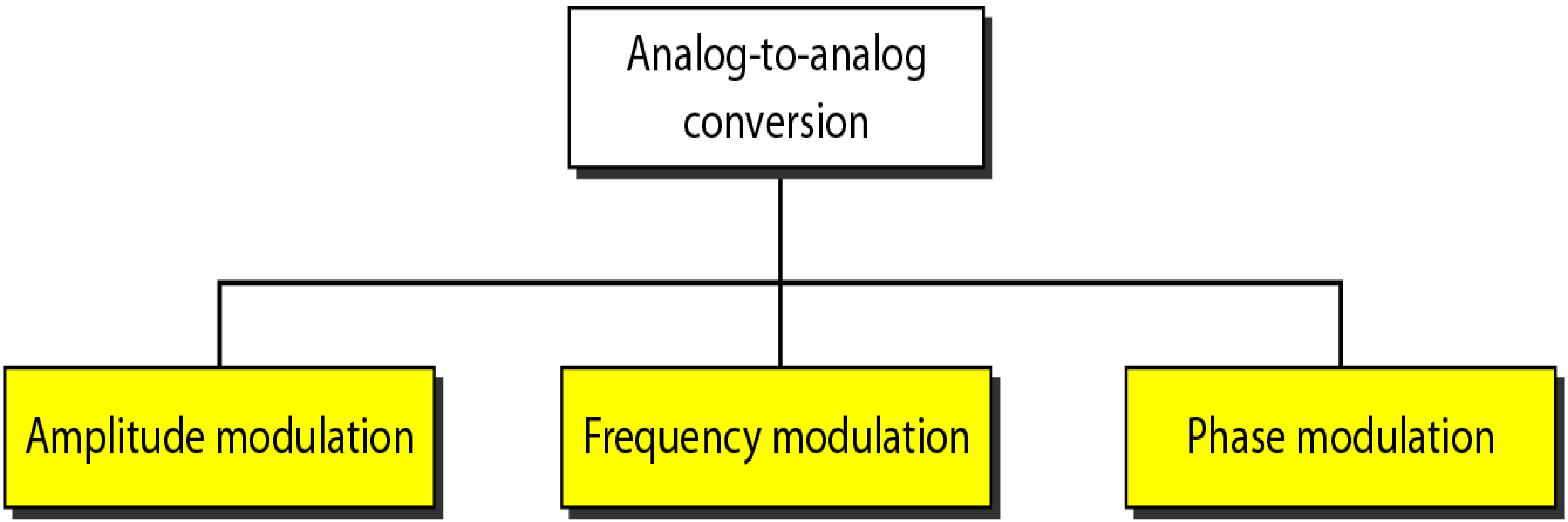
Modulation - Definition

- **Modulation** is a process of mixing a signal with a sinusoid to produce a new signal. This new signal, conceivably, will have certain benefits of an un-modulated signal, especially during transmission
- Simply, Modulation is the combining of an information signal (also known as the modulating signal) with a carrier signal.

Analog Transmission

Analog Transmission

- **Analog to Analog (Analog modulation)**
  - Is the representation of analog information by an analog signal



Types of analog to analog modulation

Analog Transmission

- Analog to Analog (Analog modulation)

1. Amplitude Modulation (AM)
    - The instantaneous amplitude of the carrier wave is varied in accordance with the modulating wave.

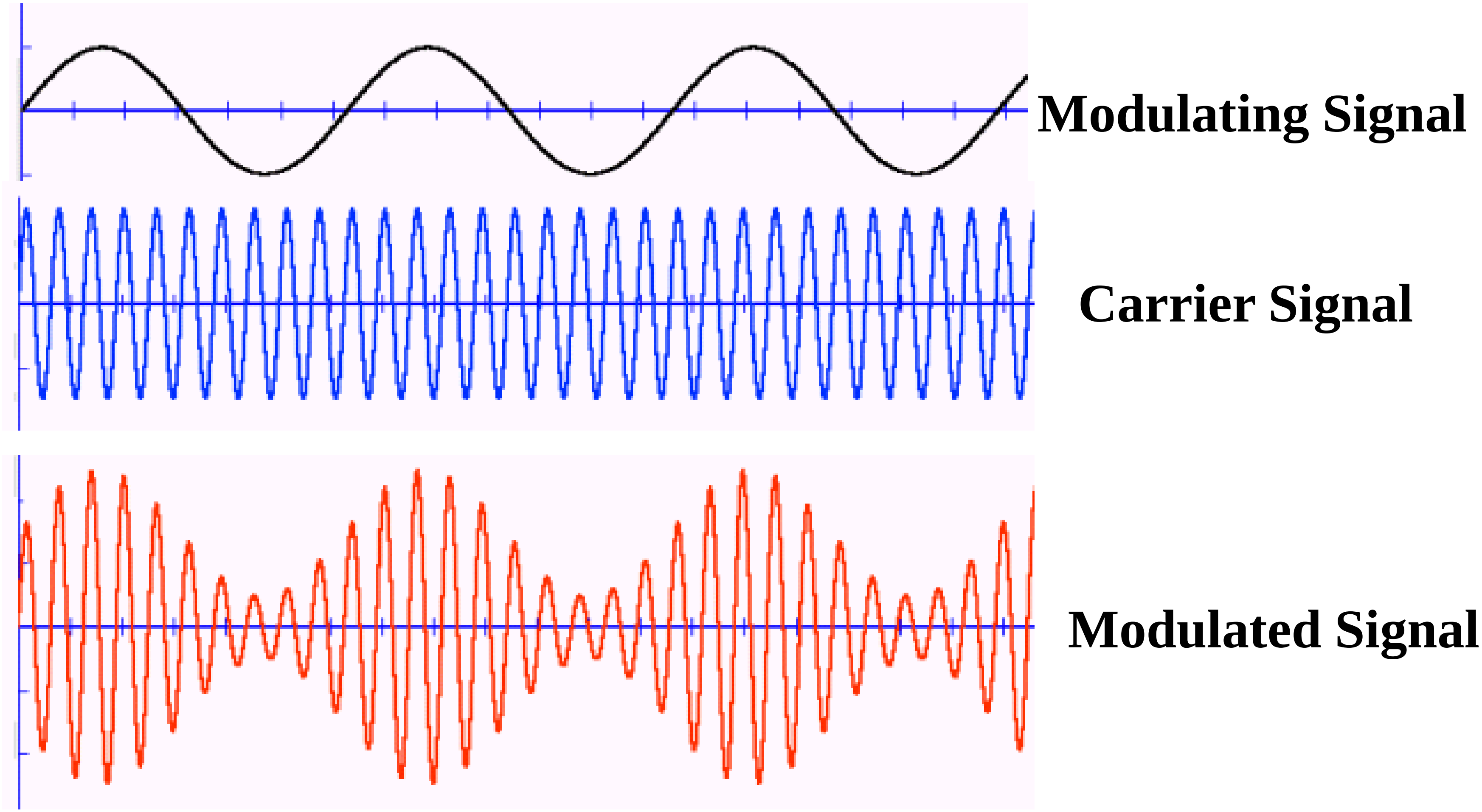
2. Frequency Modulation (FM)
    - The instantaneous frequency of the carrier wave is varied in accordance with the modulating wave.

3. Phase Modulation (PM)
    - The instantaneous phase of the carrier wave is varied in accordance with the modulating wave

Amplitude modulation

- Carrier signal is modulated varies with the changing amplitudes of the modulating signal.
- The frequency and phase of the carrier remain the same.
- Only the amplitude changes to follow variations in the information

Amplitude modulation



Frequency Modulation

- The frequency of the carrier signal is modulated to follow the changing voltage level(amplitude) of the modulating signal
- Peak amplitude and phase of the carrier signal remain constant

Frequency Modulation

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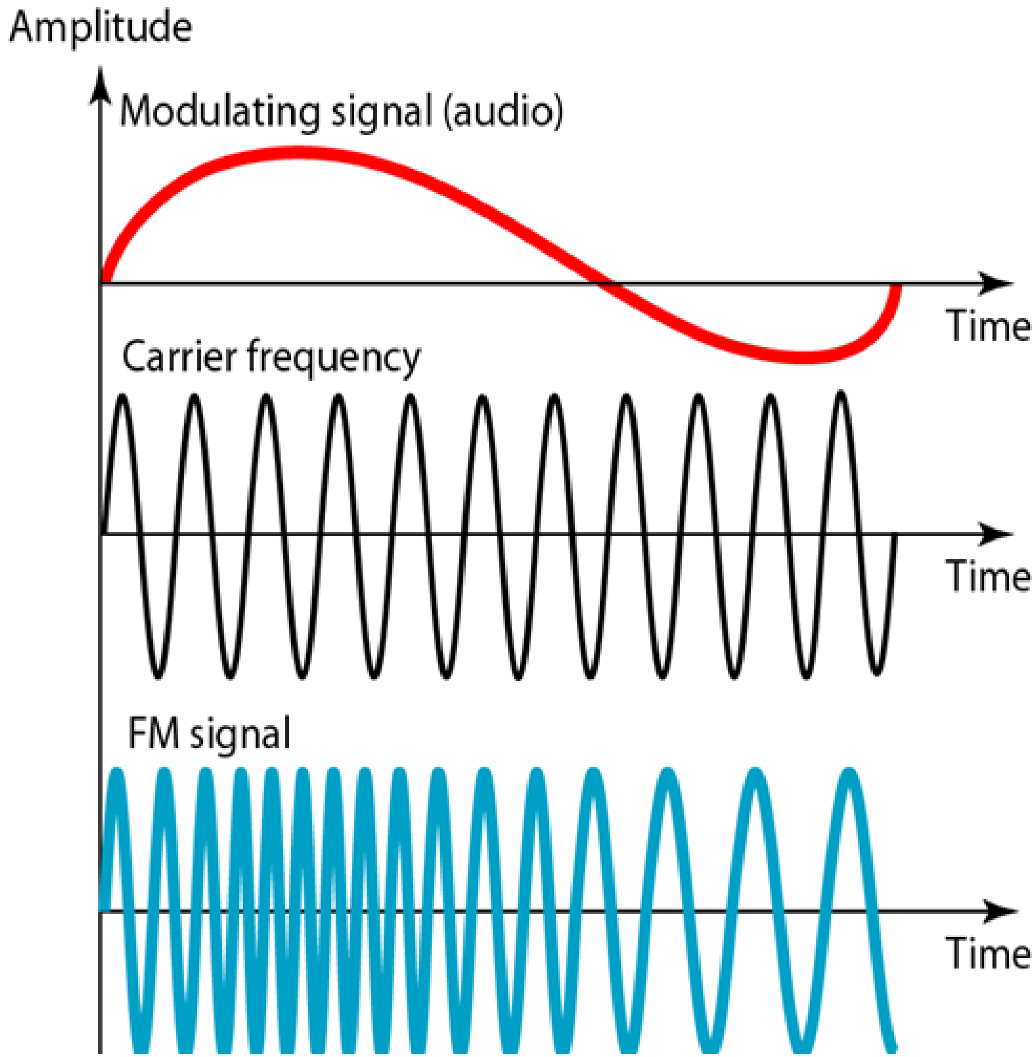

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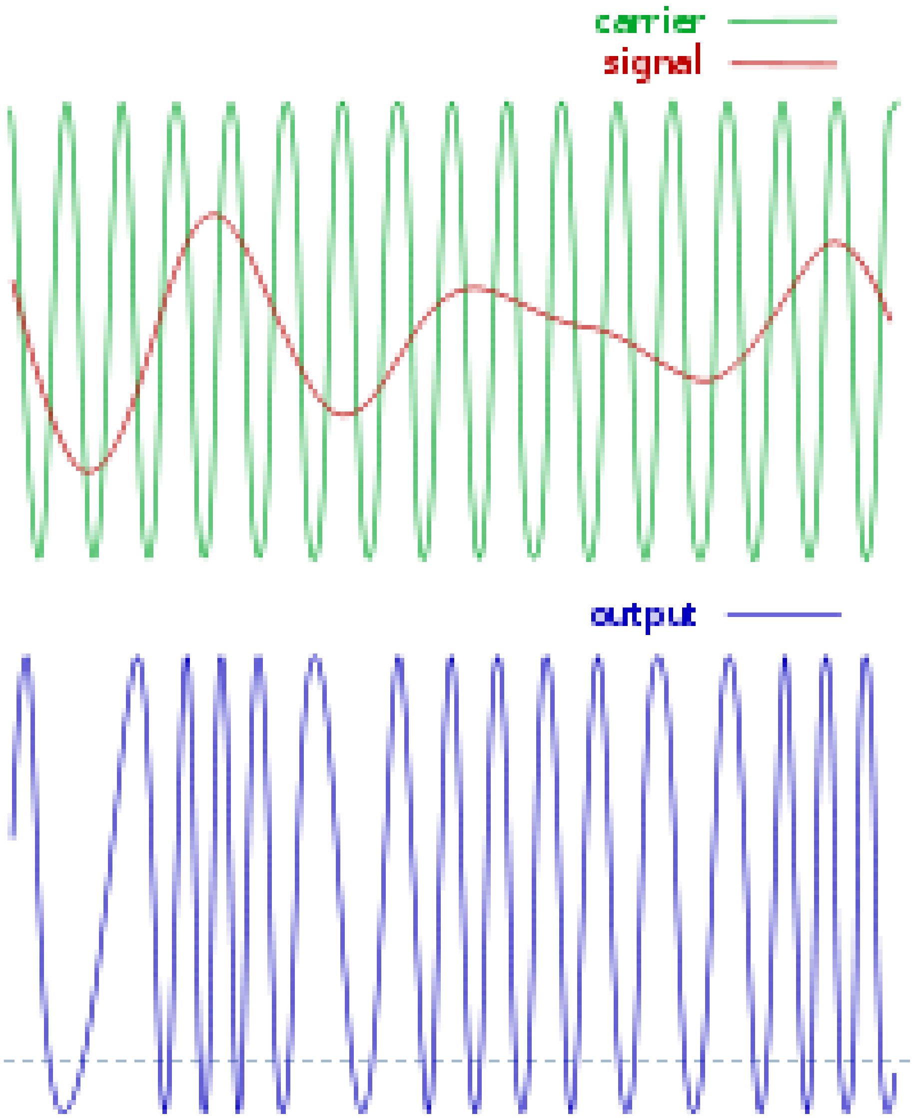
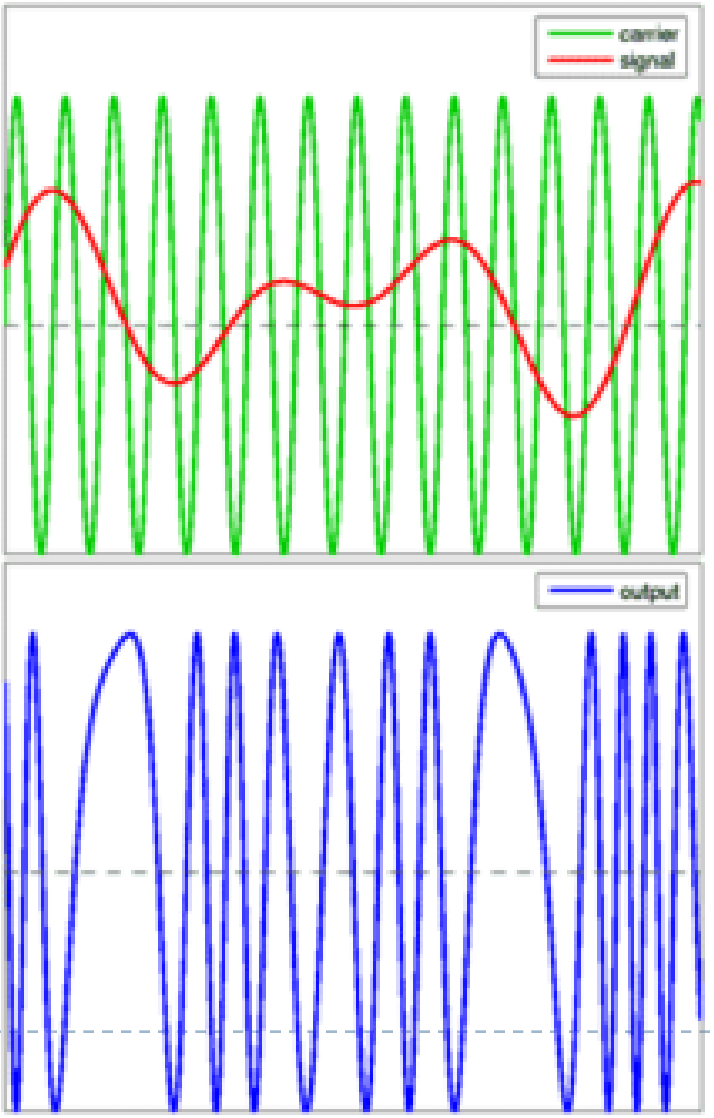
Frequency Modulation



Phase modulation

- The phase of the carrier signal is modulated to follow the changing voltage level(amplitude) of the modulating signal.
- The peak amplitude & carrier frequency of the carrier signal remain constant
- Phase of the carrier signal changes correspondingly

Phase Modulation



Analog Transmission

- **Digital to 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.
  - There are three parameters of the carrier wave to vary and therefore three basic types of shift keying are:
    1. Amplitude Shift Keying (ASK)
    2. Frequency Shift Keying (FSK),
    3. Phase Shift Keying (PSK).

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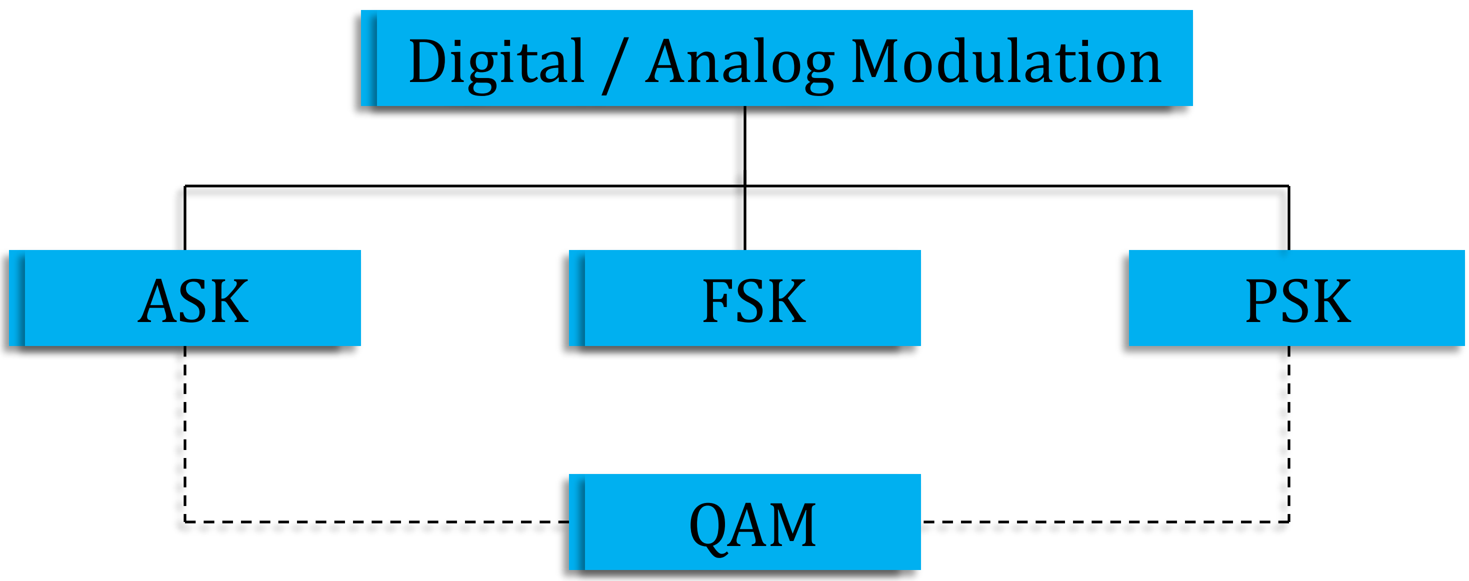
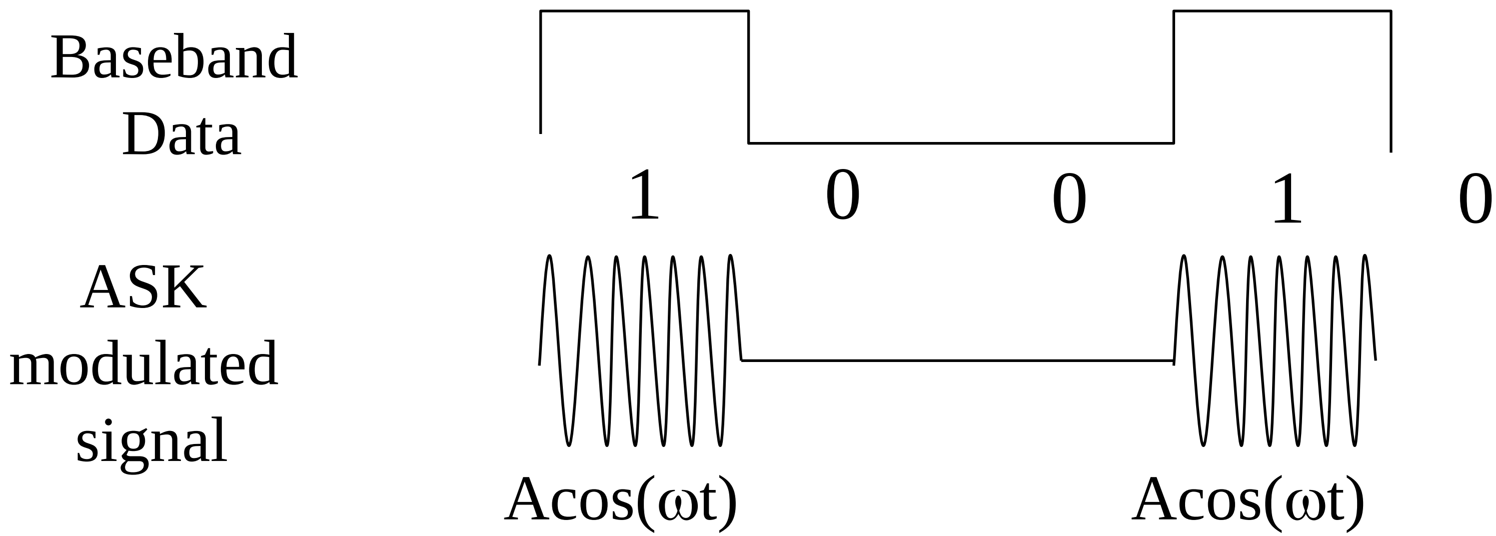
Analog Transmission

- Digital to Analog transmission



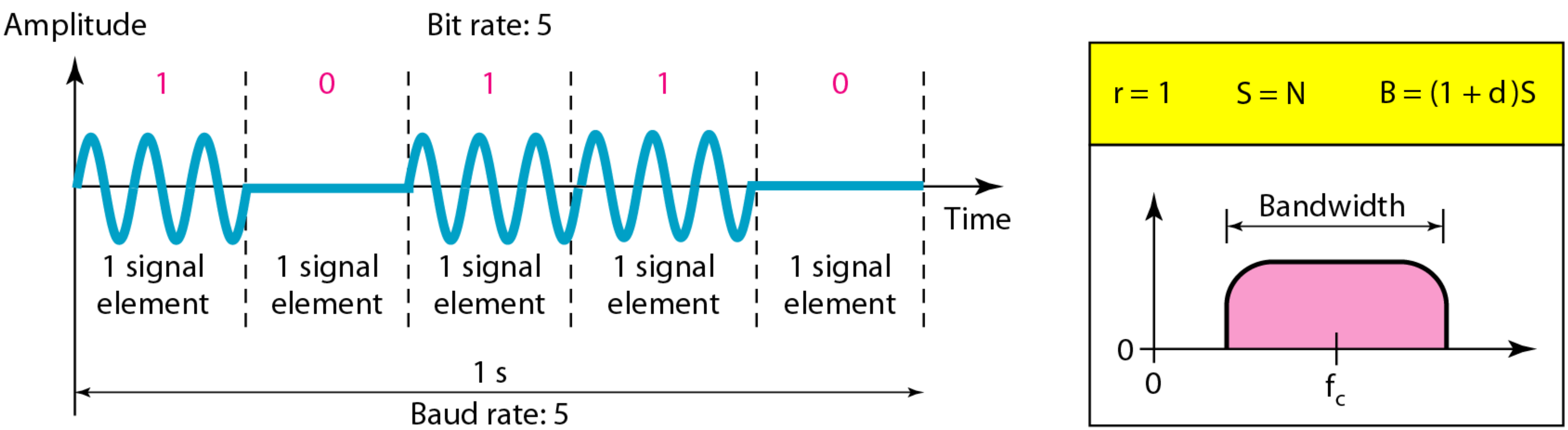
Amplitude Shift Keying (ASK)



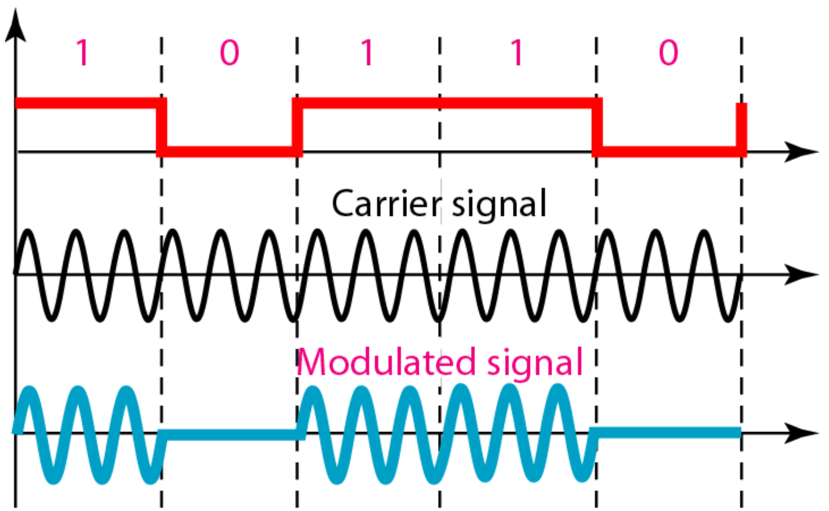
- ASK demonstrates poor performance, as it is heavily affected by noise, fading, and interference

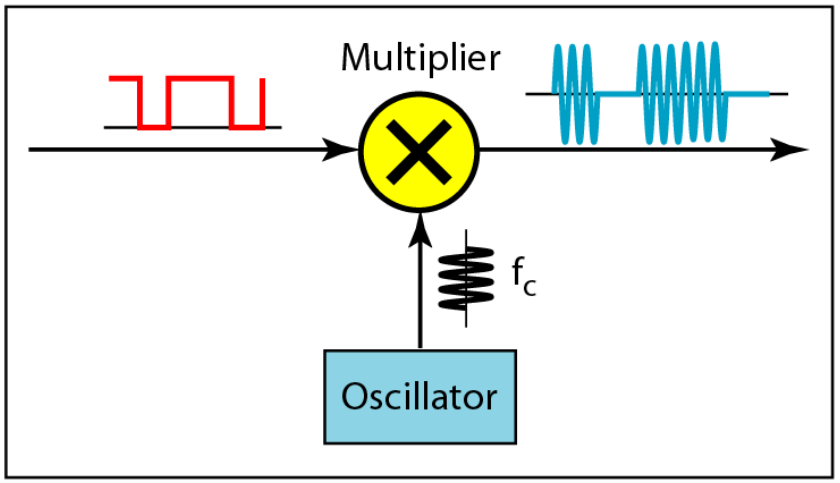
Binary amplitude shift keying

Figure 5.3 *Binary amplitude shift keying*



Implementation of binary ASK



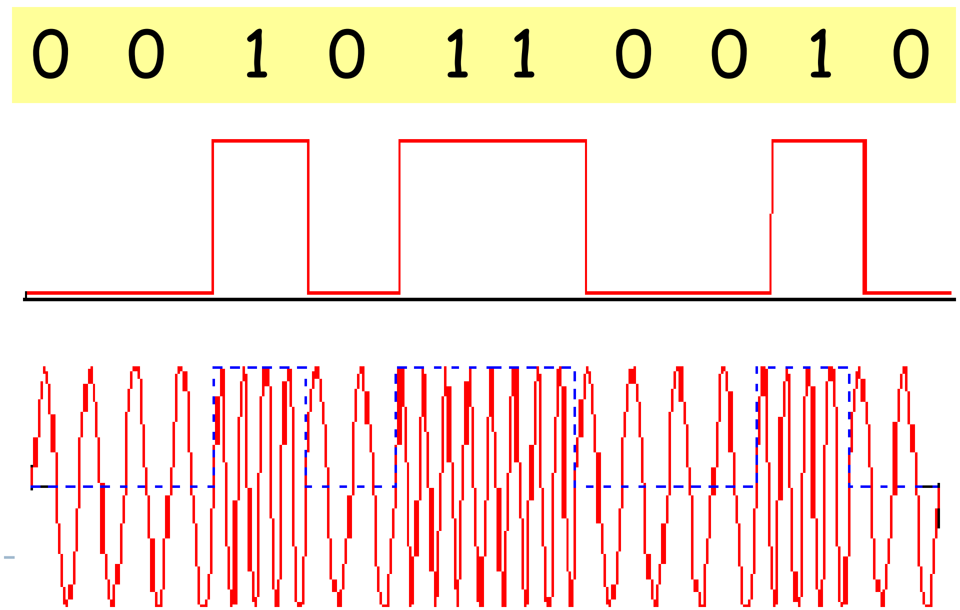


Frequency Shift Keying(PSK)

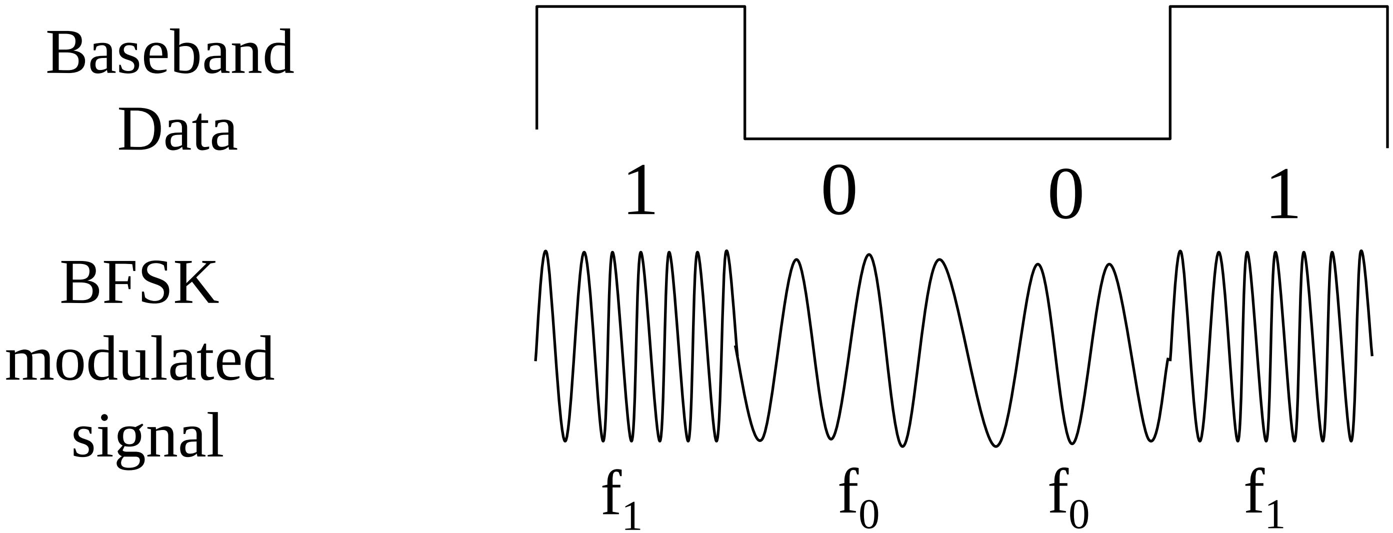
- The most common form of FSK is BFSK (Binary Frequency Shift Keying).
- Two bits are represented by two different frequencies near the carrier frequency
- $s(t) = A\cos(2\pi f_1 t) \Rightarrow 1$

  $= A\cos(2\pi f_2 t) \Rightarrow 0$

Centre frequency(fc) = $(f_1 + f_2)/2$

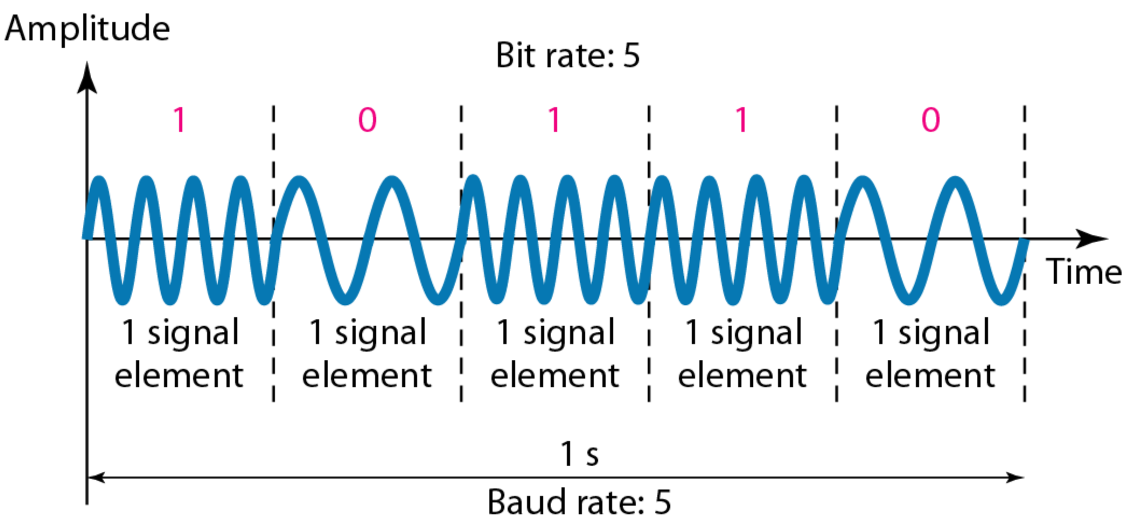


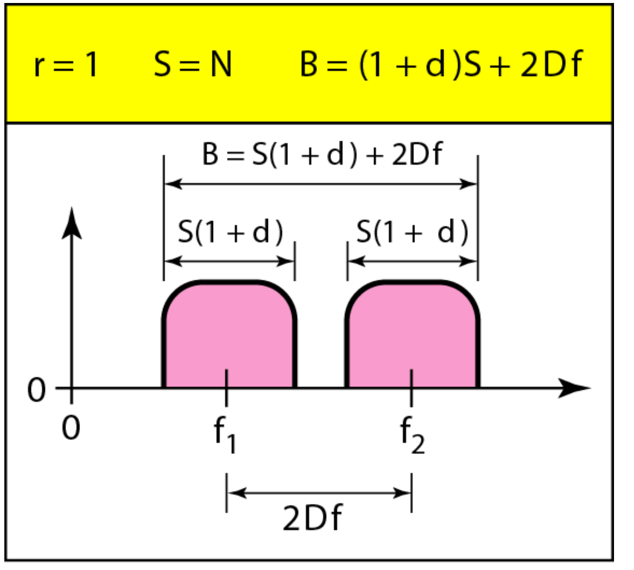
Frequency Shift Keying (FSK)



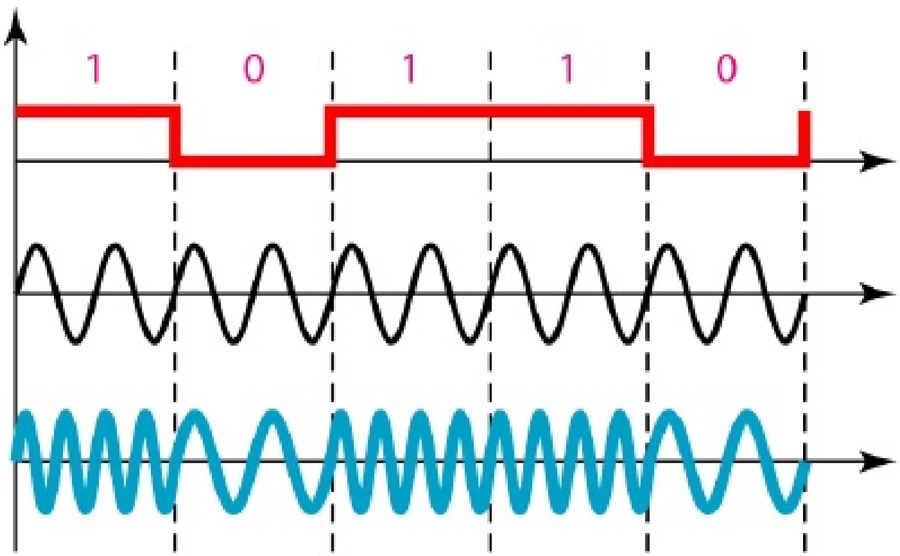
where $f_0 = A\cos(\omega_c - \Delta\omega)t$ and $f_1 = A\cos(\omega_c + \Delta\omega)t$

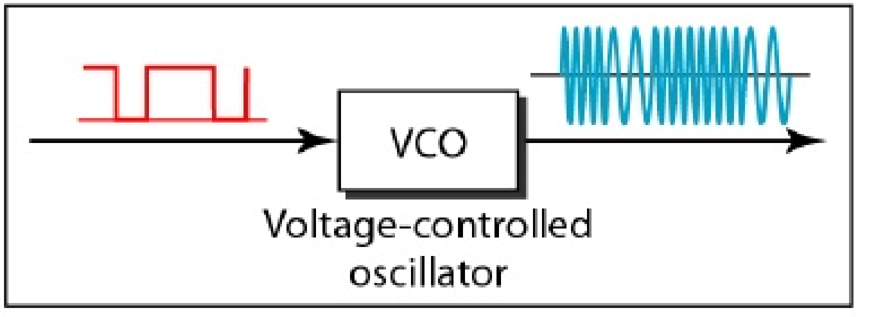
Binary frequency shift keying



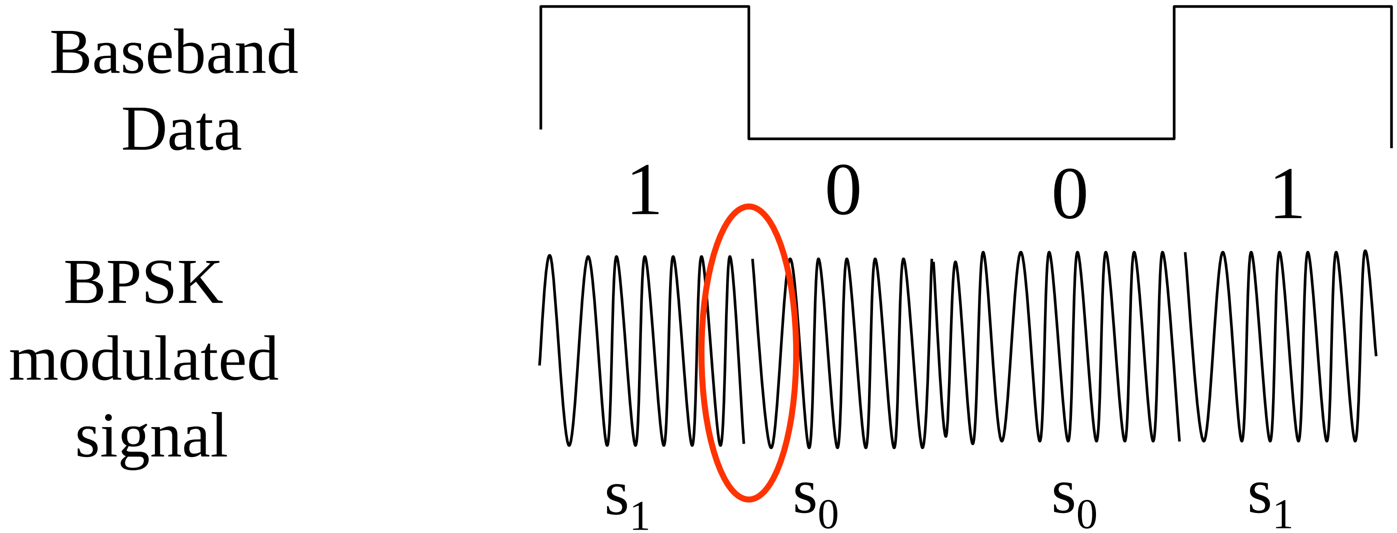


Implementation of binary FSK





Phase Shift Keying (PSK)



where $s_0 = -A\cos(\omega_c t)$ and $s_1 = A\cos(\omega_c t)$

Major drawback – rapid amplitude change between symbols due to phase discontinuity, which requires infinite bandwidth. Binary Phase Shift Keying (BPSK) demonstrates better performance than ASK and BFSK
BPSK can be expanded to a M-ary scheme, employing multiple phases and amplitudes as different states

Phase Shift Keying(PSK)

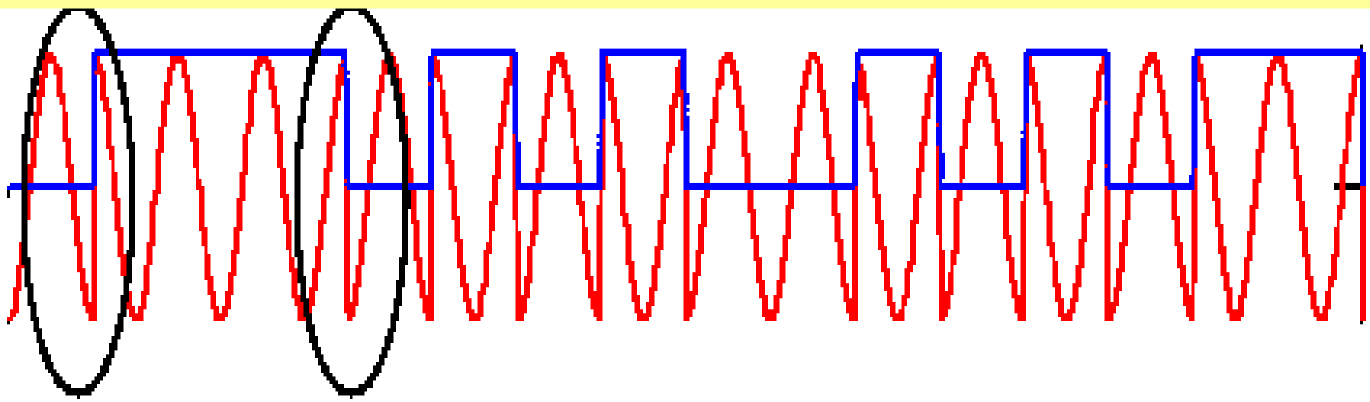
- The phase of the carrier is shifted to represent data.

i) BPSK

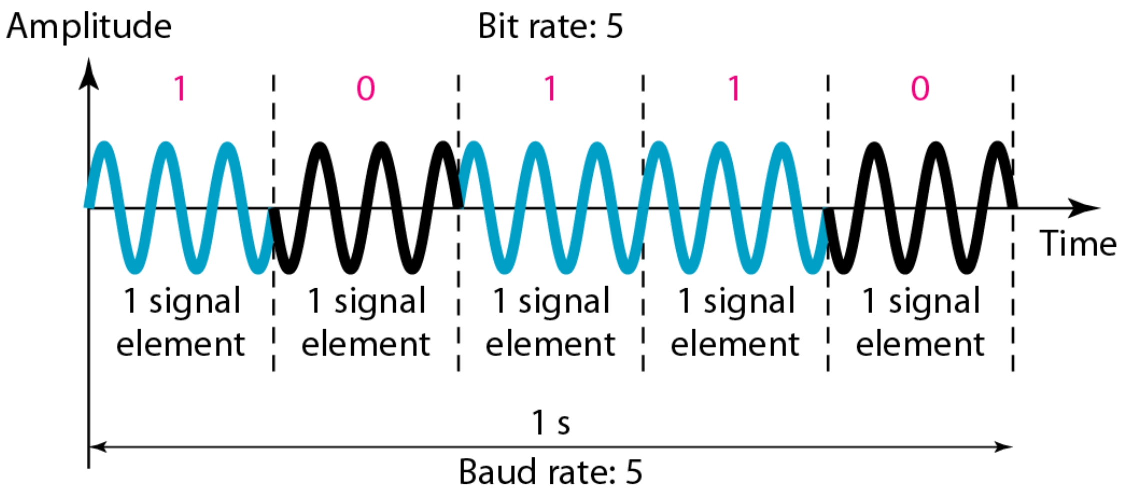
$$s(t) = A\cos(2pf_c t) = A\cos(2pf_c t) \Rightarrow 1$$

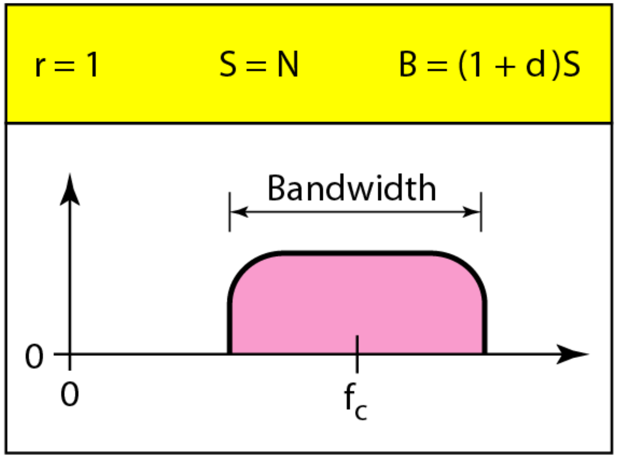
$$A\cos(2pf_c t + p) = - A\cos(2pf_c t) \Rightarrow 0$$

0 1 1 1 0 1 0 1 0 0 1 0 1 0 1 1



Binary phase shift keying





Implementation of BASK

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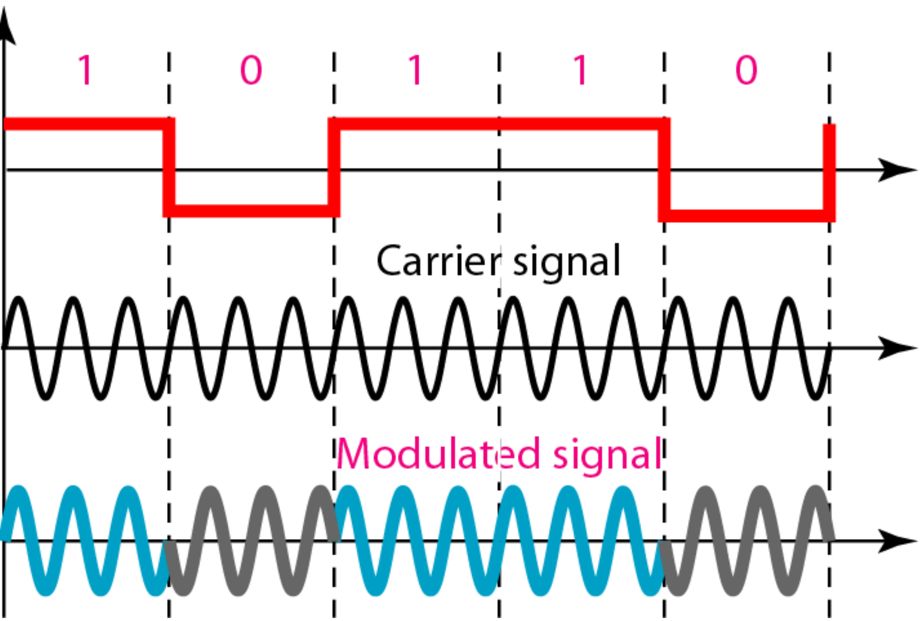
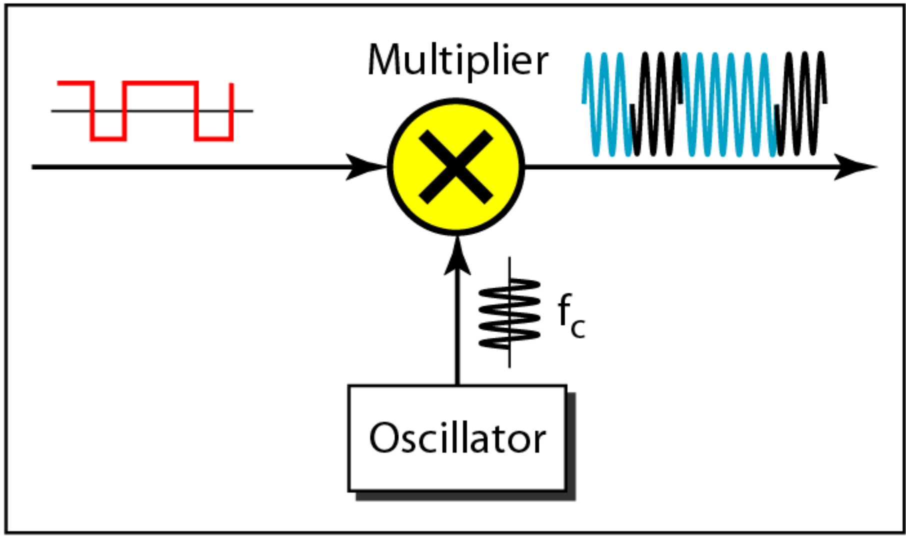




Digital transmission

Digital Transmission

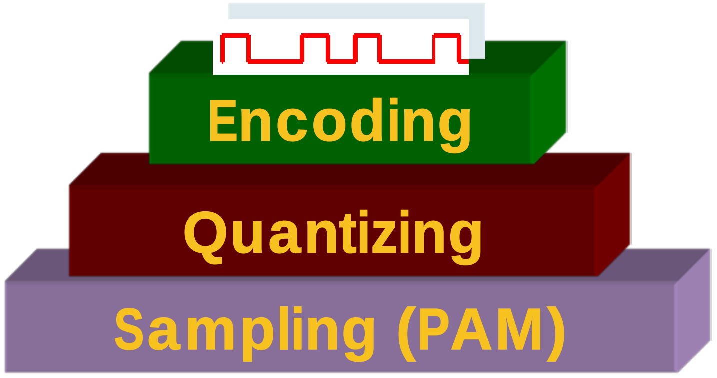
- **Analog to Digital transmission**

  Two ways:

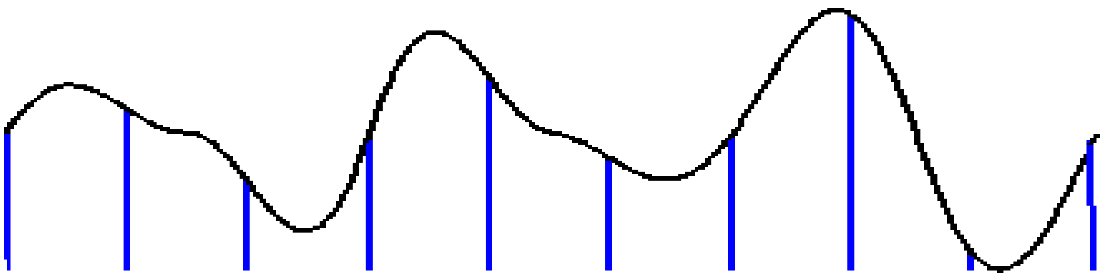
  1. Pulse Code Modulation (PCM)
  2. Delta Modulation (DM)

Pulse Code Modulation(PCM)

- Done in three steps
  1. The analog signal is sampled
  2. The sample signal is quantized
  3. The quantized values are encoded as stream of bits

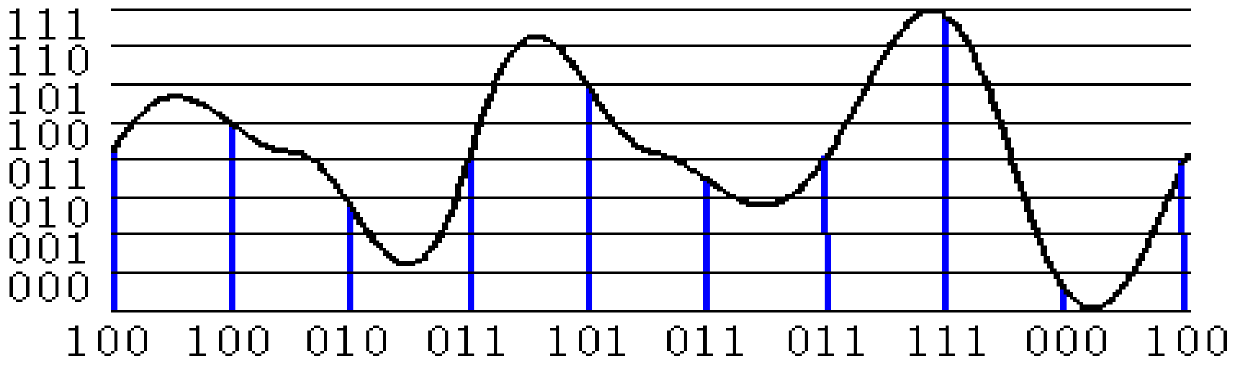


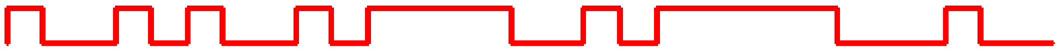
Pulse Code Modulation(PCM)



Quantizing and

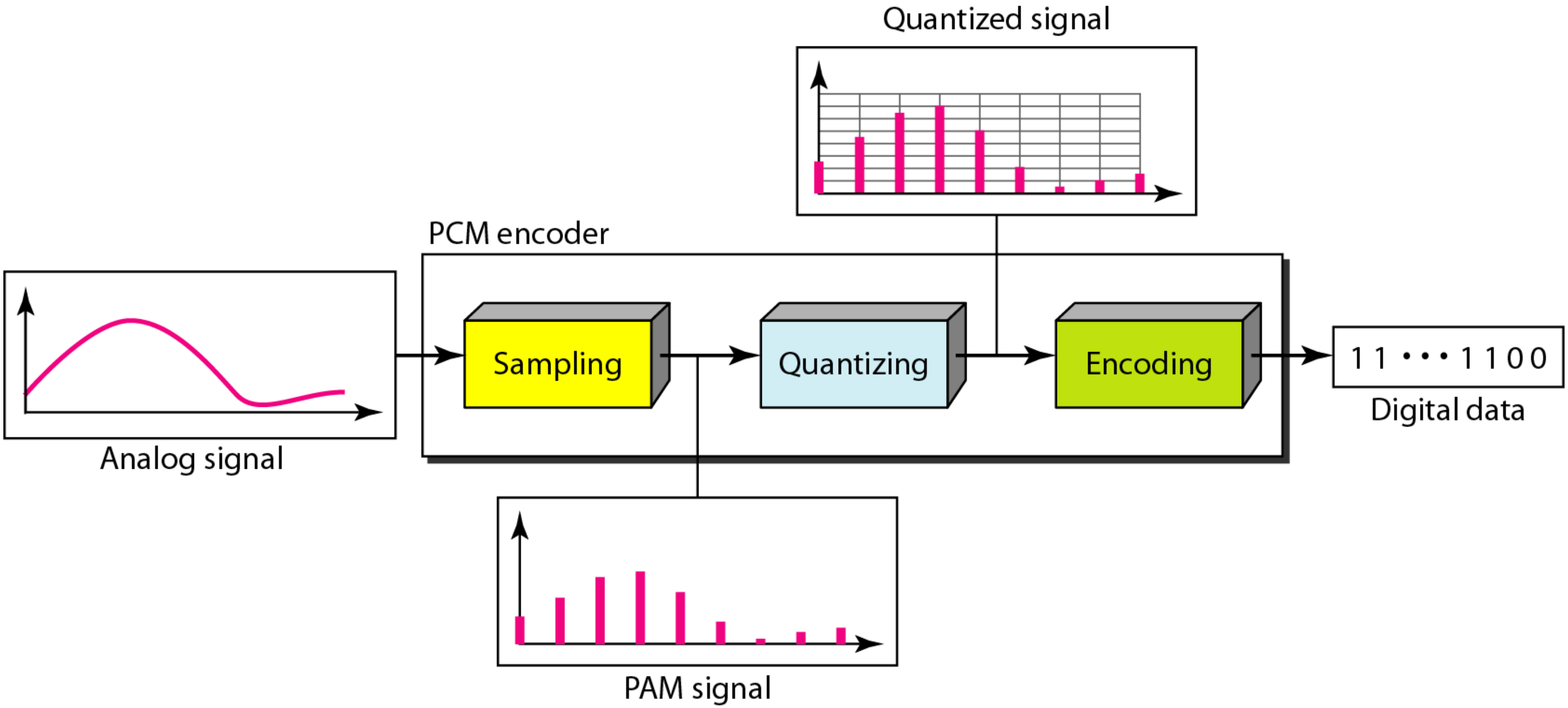
Linear Encoding



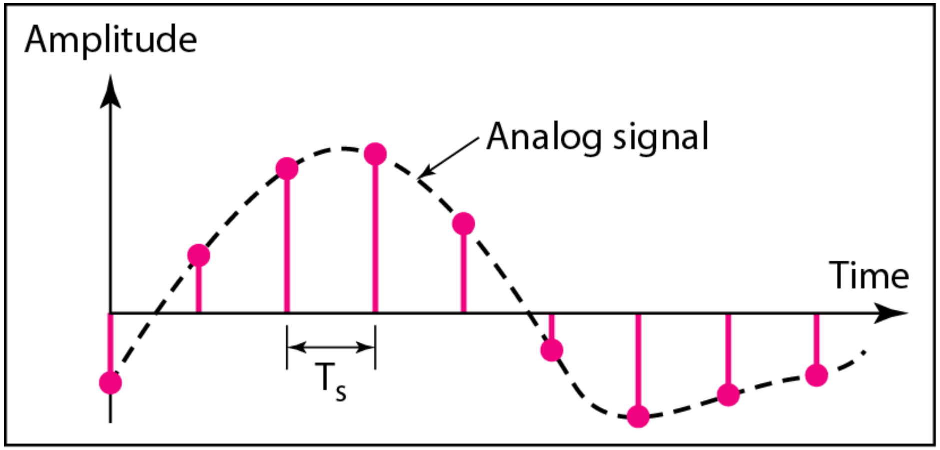


Binary Stream

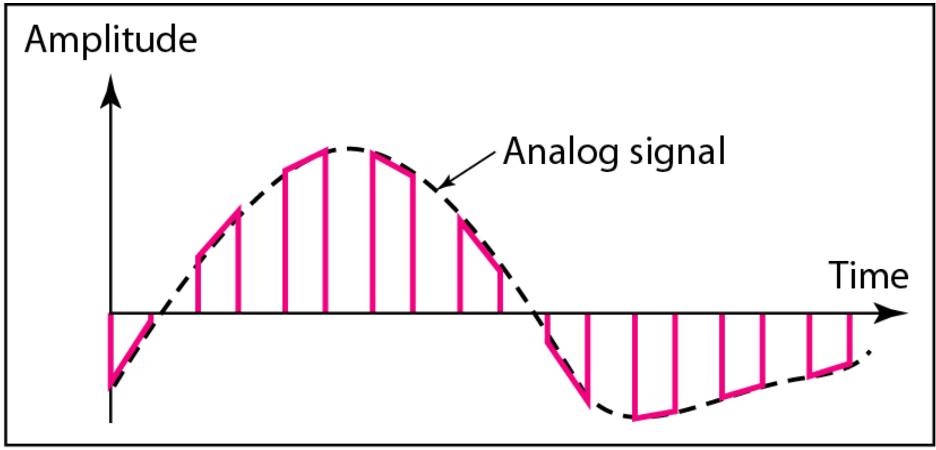
Pulse Code Modulation (PCM)



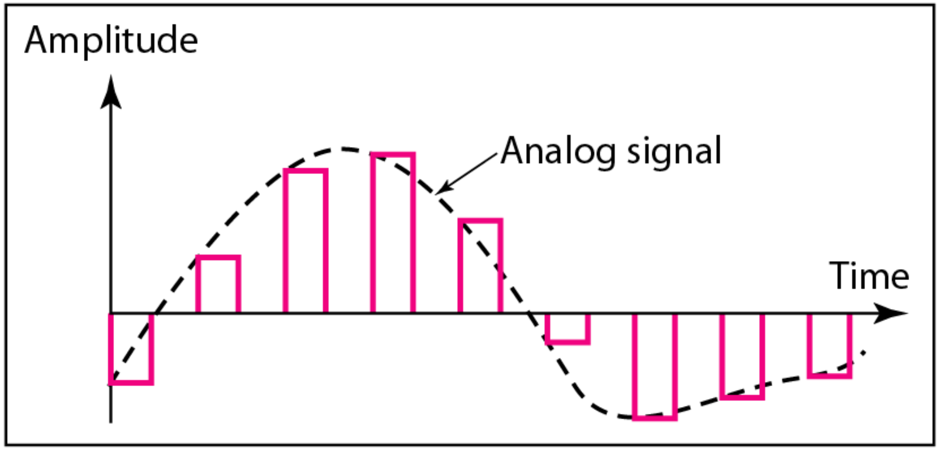
Sampling



a. Ideal sampling

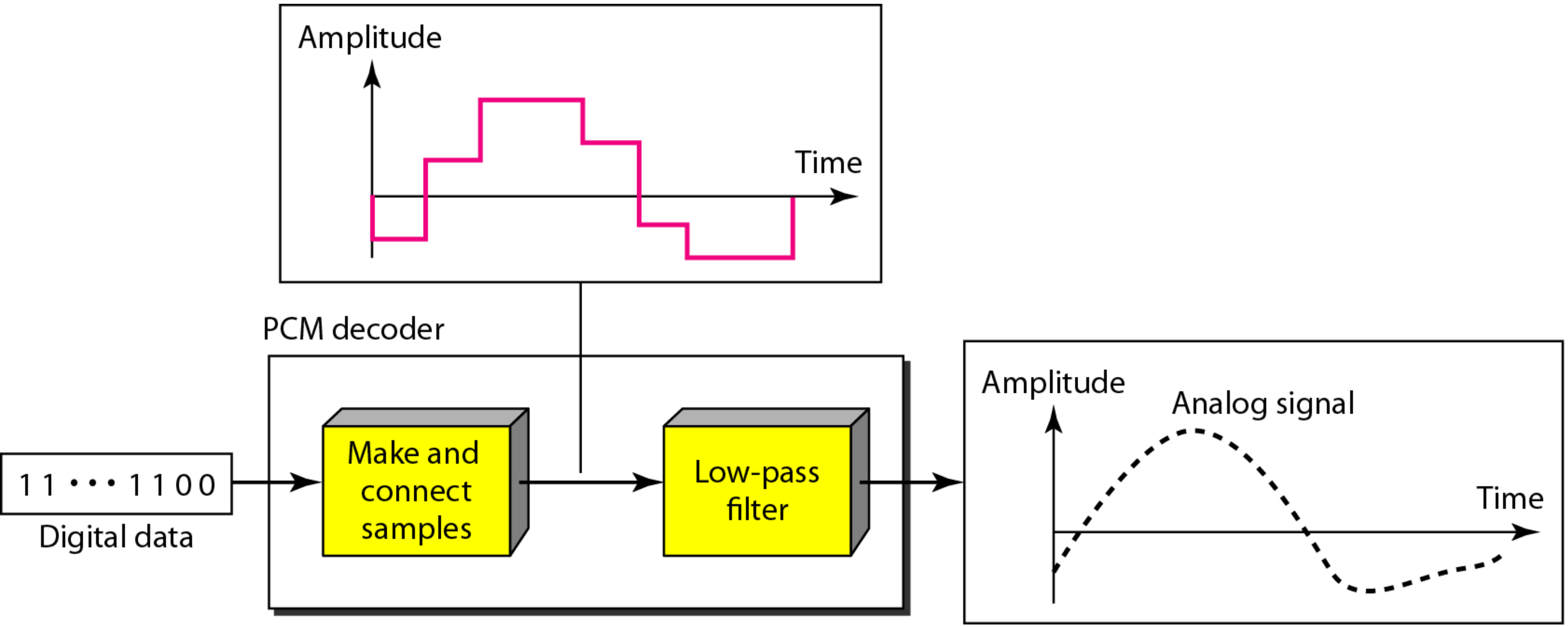


b. Natural sampling



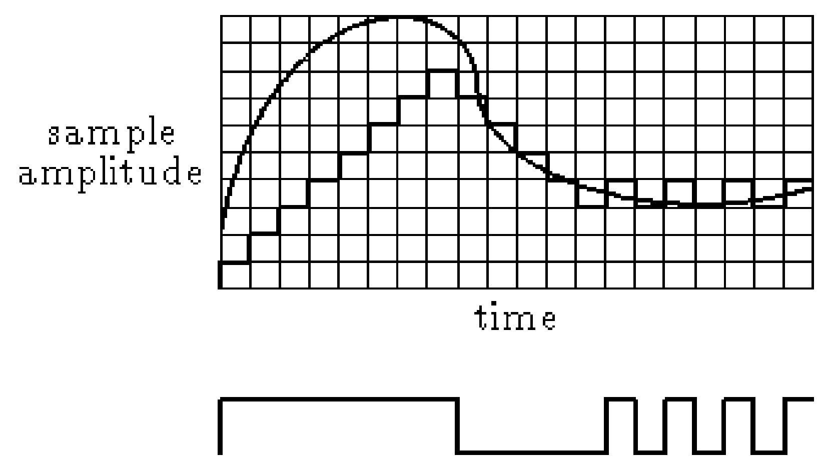
c. Flat-top sampling

PCM Decoder

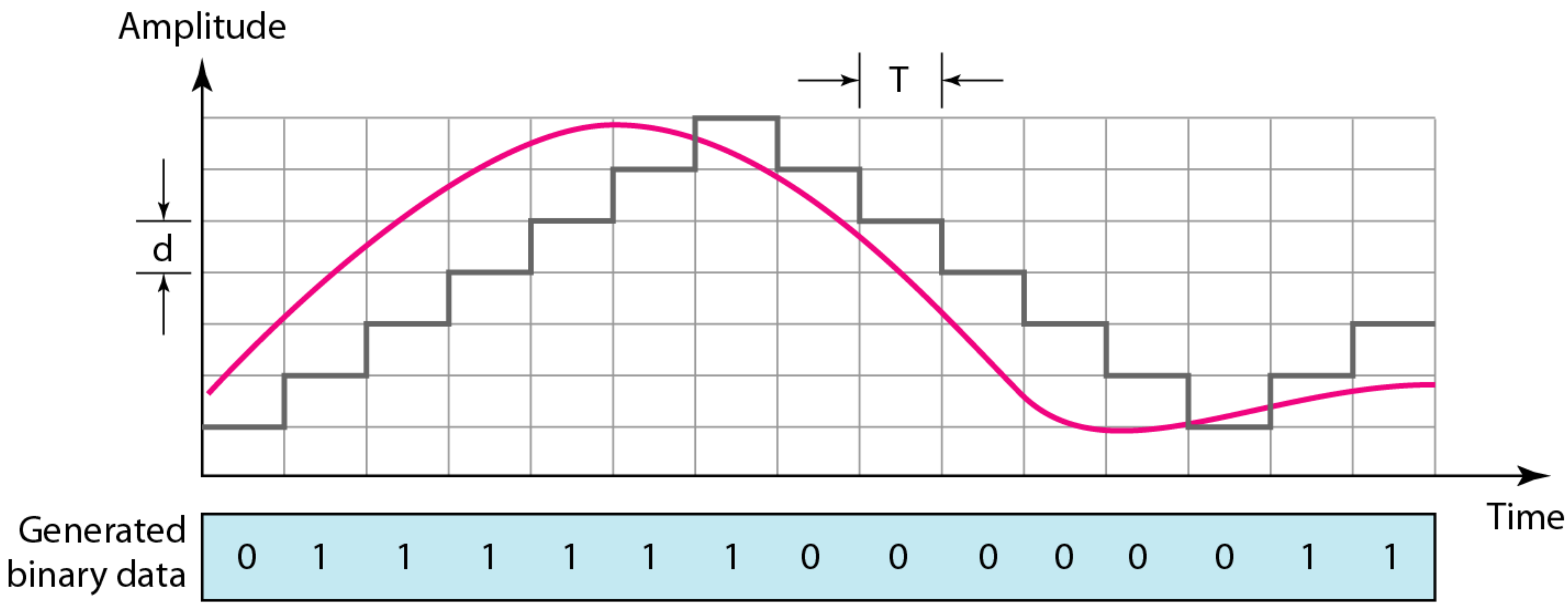

Amplitude
Time
PCM decoder
11 ••• 1100
Digital data
Make and connect samples
Low-pass filter
Amplitude
Analog signal
Time

Delta Modulation (DM)

- A modulation scheme that improves the performance of PCM and reduce its complexity.
- An analog input is approximated by a staircase function that moves up or down by one quantization level (d) at each sampling interval
- The staircase function is overlaid as the original analog waveform.
- The o/p of the DM process can be represented as a single binary digit for each sample.



Process of Delta Modulation (DM)



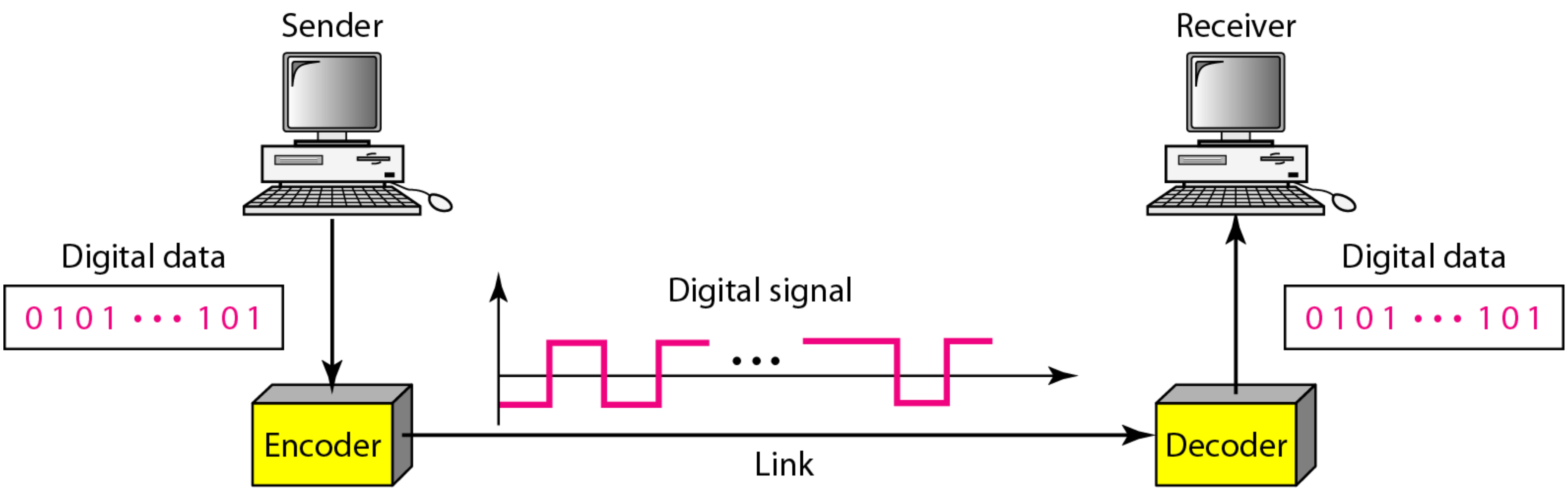
Digital Transmission

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

Line Coding

- 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 sequence 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 4.1 shows the process

Line coding and decoding



Characteristics

- Before discussing different line coding schemes, we address their common characteristics
- Signal Element versus Data Element- Let us distinguish between a data element and a signal element

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- Data Element- In data communication, our goal to send data elements. A data element is the smallest entity that can represent a piece of information: this is the bit.
- Signal Element- A signal element is the shortest unit (timewise) of a digital signal.

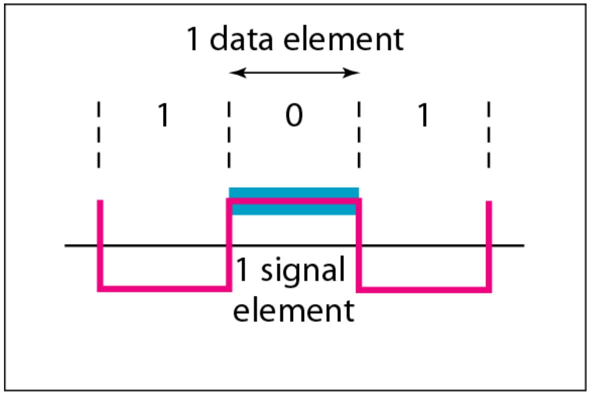
Characteristics (contd)

Note

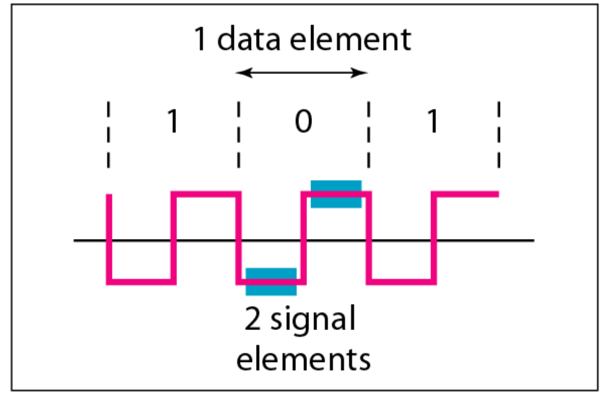
In other words data element are what we need to send; signal elements are what we can send. Data elements are being carried; signal elements are the carriers.

We define a ratio *r* which is the number of data elements carried by each signal element. Figure 4.2 shows several situation with different values of *r*.

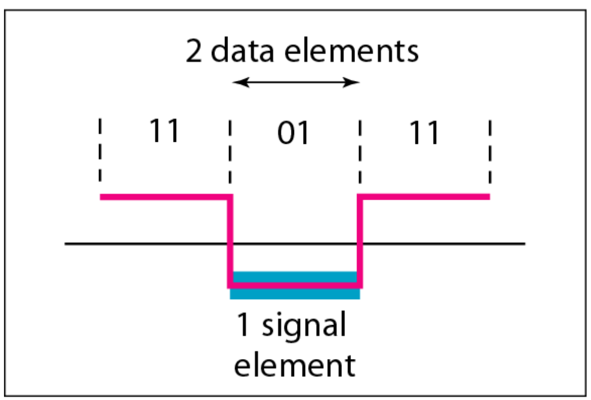
Figure 4.2 *Signal element versus data element*



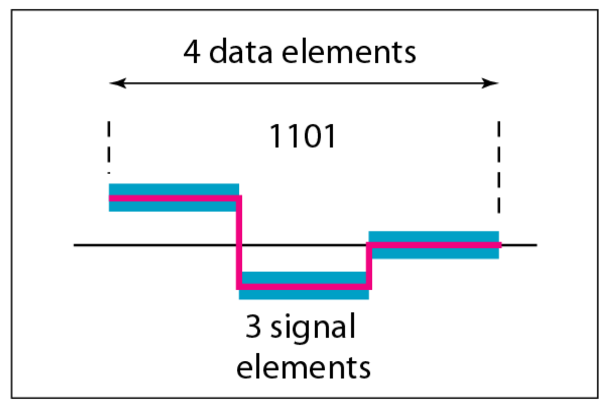
a. One data element per one signal element (r = 1)



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

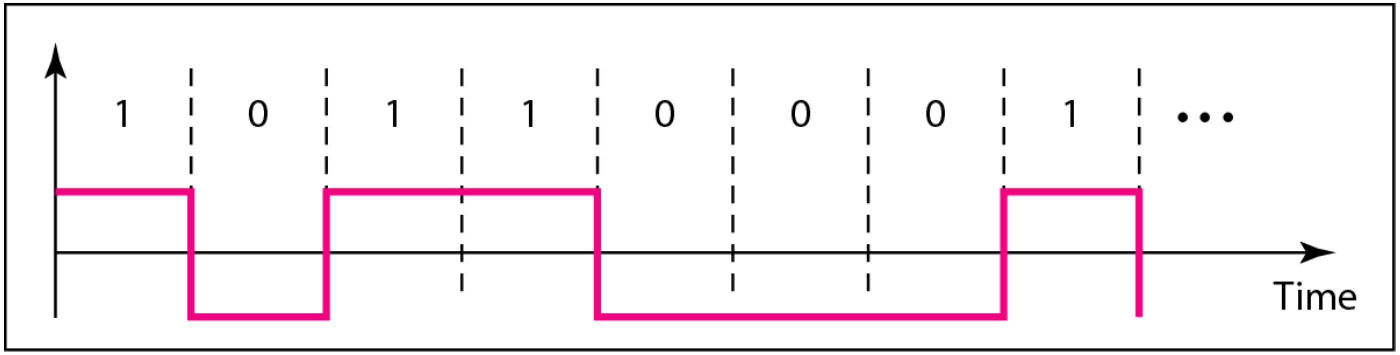
Data Rate vs Signal Rate

- Data Rate- The rate at which data elements are transmitted. Data rate is sometimes called bit rate. The unit is bits per second (bps).
- Signaling Rate- The rate at which signal elements are transmitted. The unit is baud. The signal rate is sometimes called pulse rate, the modulation rate, or the baud rate.
- One goal in the data communication is to increase the data rate while decreasing the signaling rate (analogy-vehicle & people)

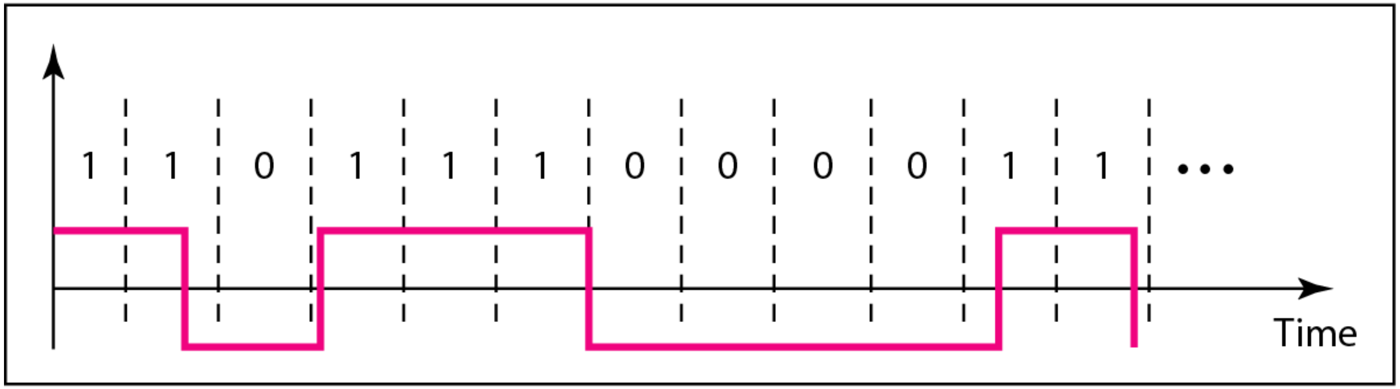
Self synchronization

- When transmitting digital signals they should be synchronize with receiver. Must match the senders clock and the receivers clock (Figure 4.3)
- A self-synchronization digital signal includes timing information in the data being transmitted.
- This can be achieved if there are transitions in the signal that alert the receiver to the beginning, middle, or end of the pulse.
- If the receiver's clock is out of synchronization, these points can reset the clock.

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 10

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 Schemes

- We can roughly divide line coding schemes into five broad categories, as shown in Figure 4.4

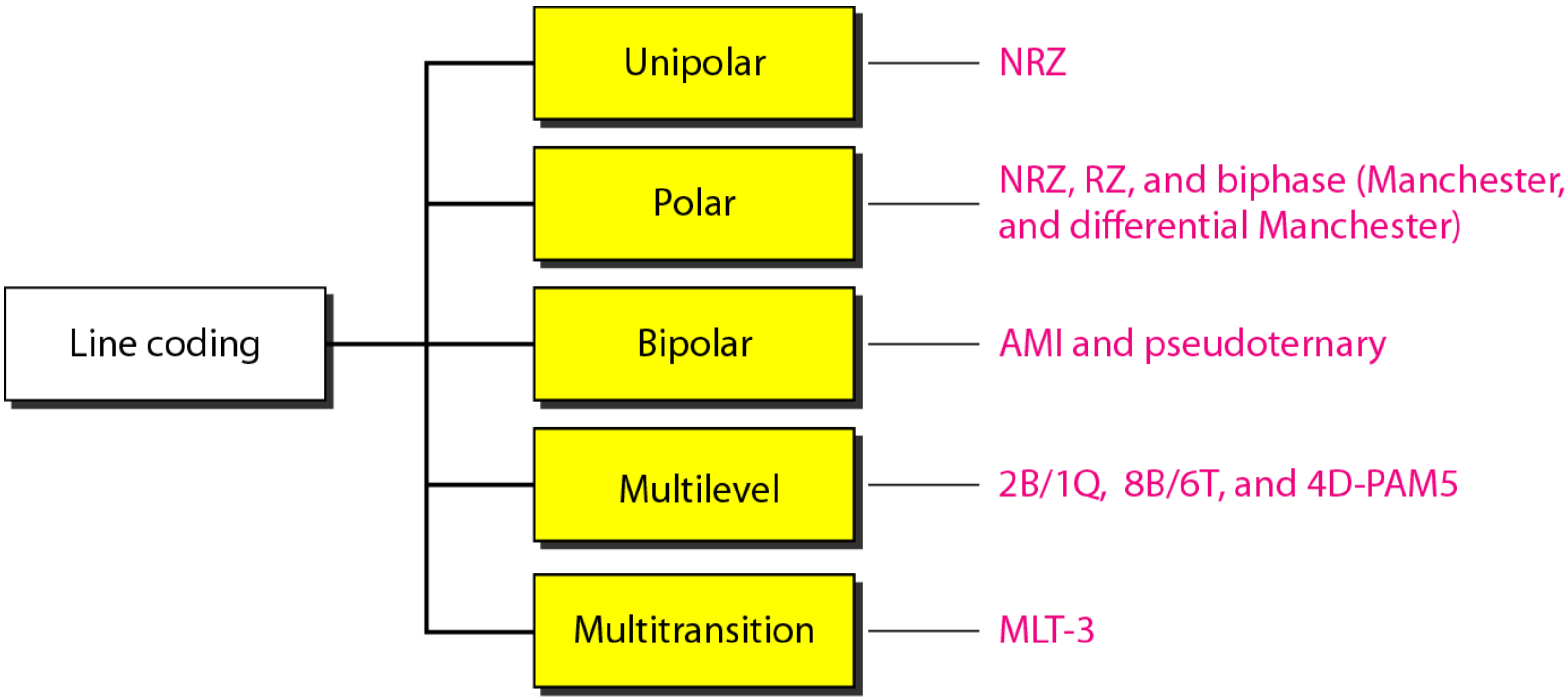


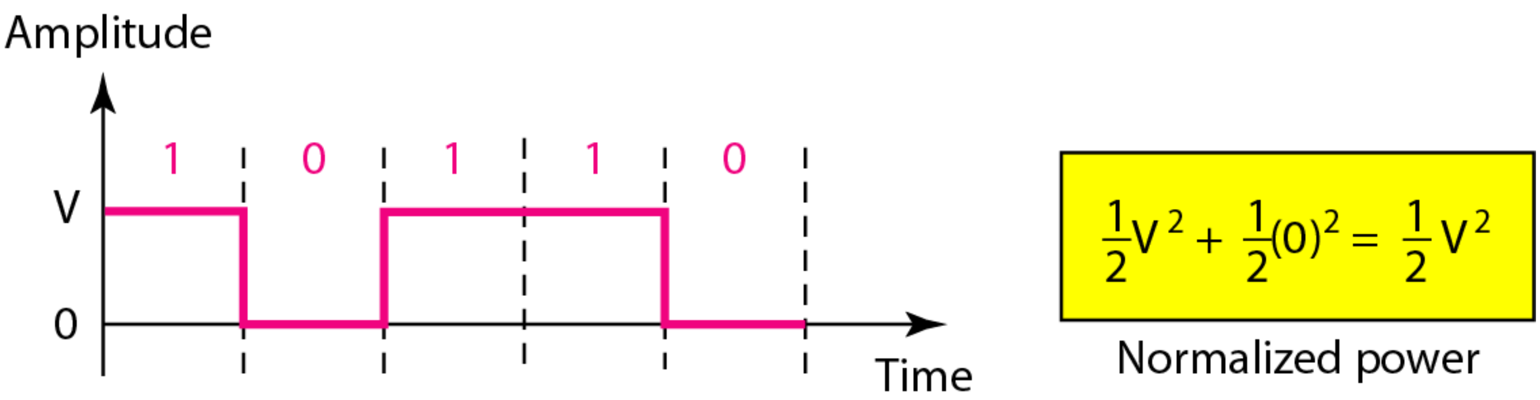
Figure 4.4 ***Line coding schemes***

unipolar scheme

NRZ (Non-Return-to-Zero)

- Traditionally, a unipolar scheme was designed as a NRZ scheme in which the positive voltage defines bit 1 and the zero voltage defines bit 0. It is called because the signal does not return to zero at the middle of the bit.
- In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below.
- Figure 4.5 show a unipolar scheme

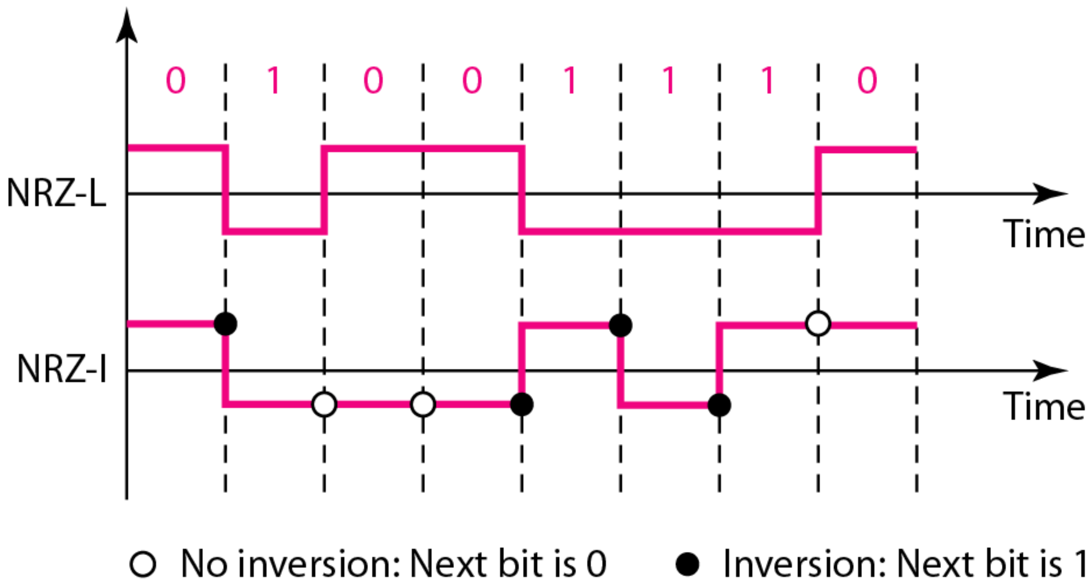
Unipolar NRZ scheme

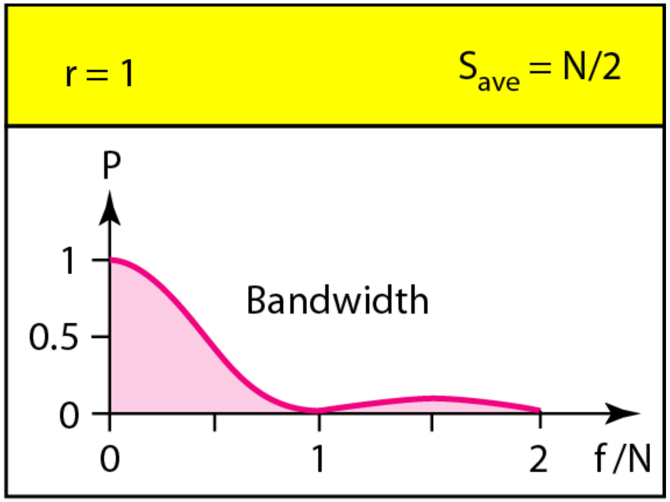


Polar Schemes

- In polar schemes, the voltage are on the both sides of the time axis. For example, the voltage level for 0 can be positive and the voltage level 1 can be negative
- In polar NRZ encoding, we can use two levels of voltage amplitude. We can have two versions of polar NRZ: NRZ-L and NRZ-I, as shown in Figure 4.6
- NRZ-L :- NRZ-Level, the level of the voltage determines the value of the bit.
- NRZ-I:- NRZ-Invert, the change of 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 NRZ-L and NRZ-I schemes





Note

In NRZ-L the level of the voltage determines the value of the bit.
In NRZ-I the inversion or the lack of inversion determines the value of the bit.

Note

NRZ-L and NRZ-I both have an average signal rate of N/2 Bd.

NRZ-L and NRZ-I both have a DC component problem.

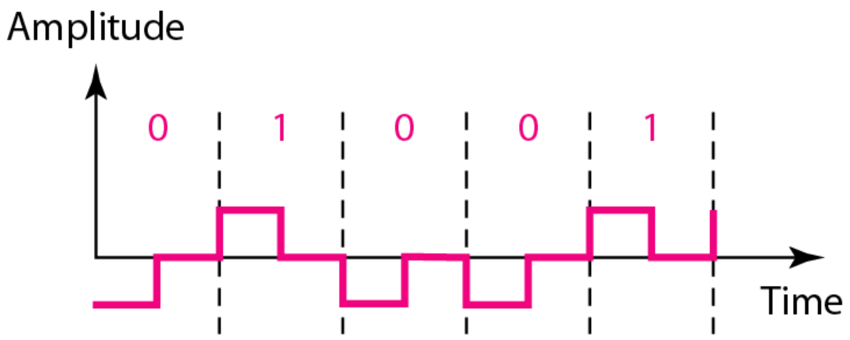
DC Component

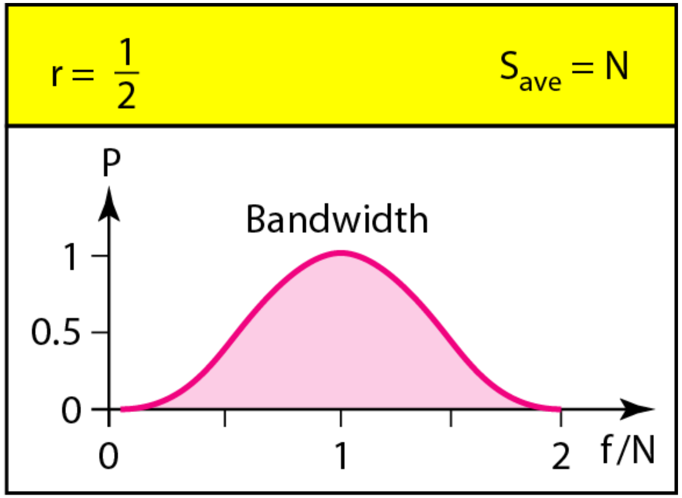
- When the voltage level in a digital signal is constant for a while, the spectrum creates very low frequencies. These frequencies around zero, is called DC components, present problems for a system that cannot pass low frequencies.

Polar RZ (Return-to-Zero) Schemes

- 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.
- In figure 4.7 we see that the signal goes to 0 in the middle of each bit.

Polar RZ scheme





Polar RZ (Return-to-Zero) Schemes

- The main disadvantage of RZ encoding is that it requires two signal changes to encode a bit and therefore occupies greater bandwidth.
- Another problem is complexity: Uses three levels of voltage
- No DC component problem
- Solution for problems in RZ is Manchester and Differential Manchester

END.

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