CSE320 : Data Communications

Chapter 05
Analog Transmission

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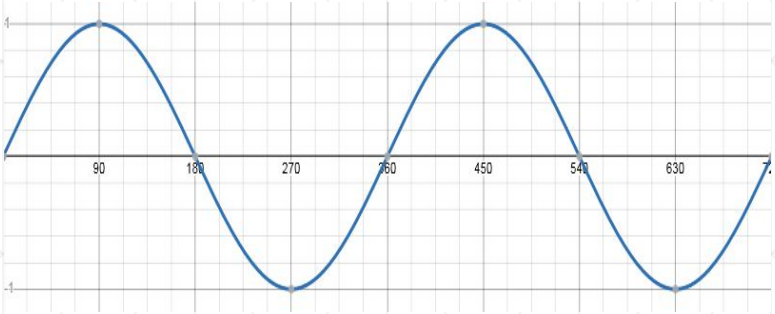
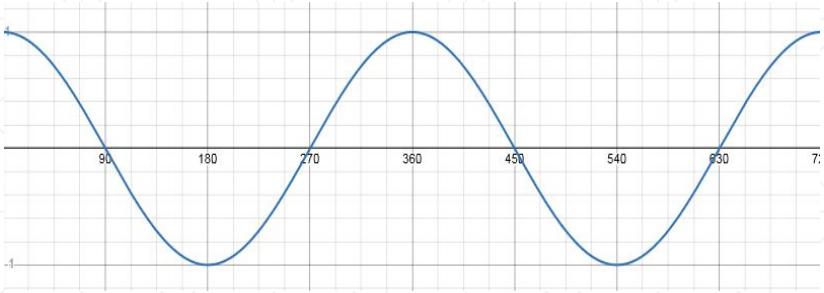
Basics

- Data vs signal
  - Data is the actual information (text, file, etc)
  - Signal is the means by which information is transmitted (electrical signal, radio wave, etc)
- Characteristics / properties of an analog signal
  - Amplitude
  - Frequency
  - Phase

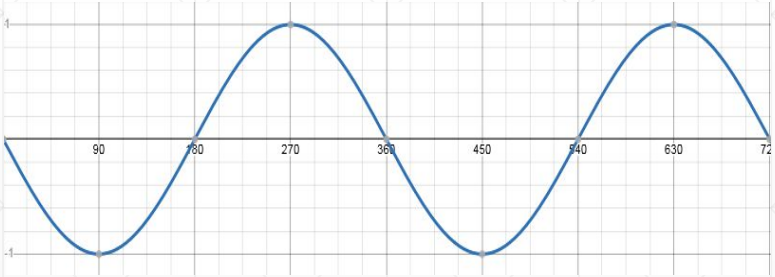
Phase



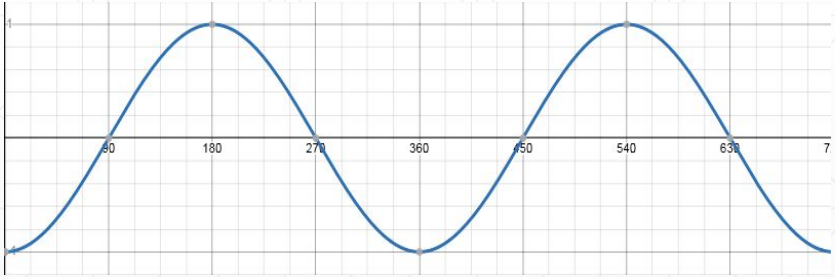
Phase = 0°



Phase = 90°

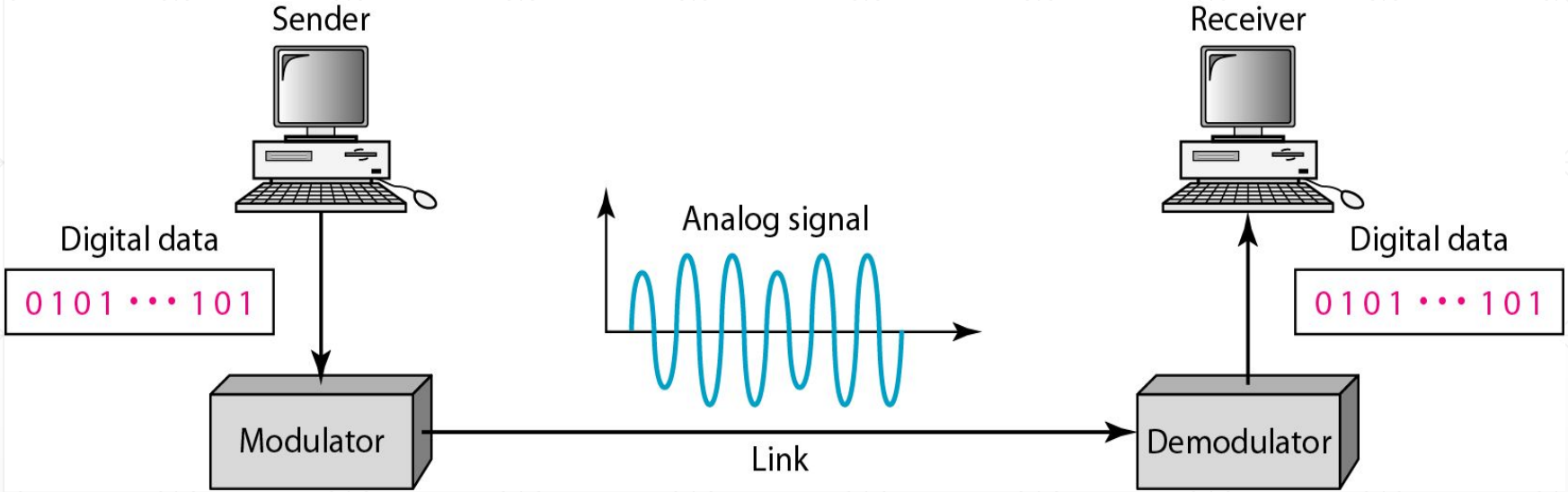


Phase = 180°



Phase = 270°

Digital-to-Analog Conversion (DAC)



Modulation

Digital-to-Analog Conversion (DAC)

- Digital-to-analog conversion (DAC) is the process of **converting digital data** (typically represented by bits) **into an analog signal** (a continuous signal that can vary over time)

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

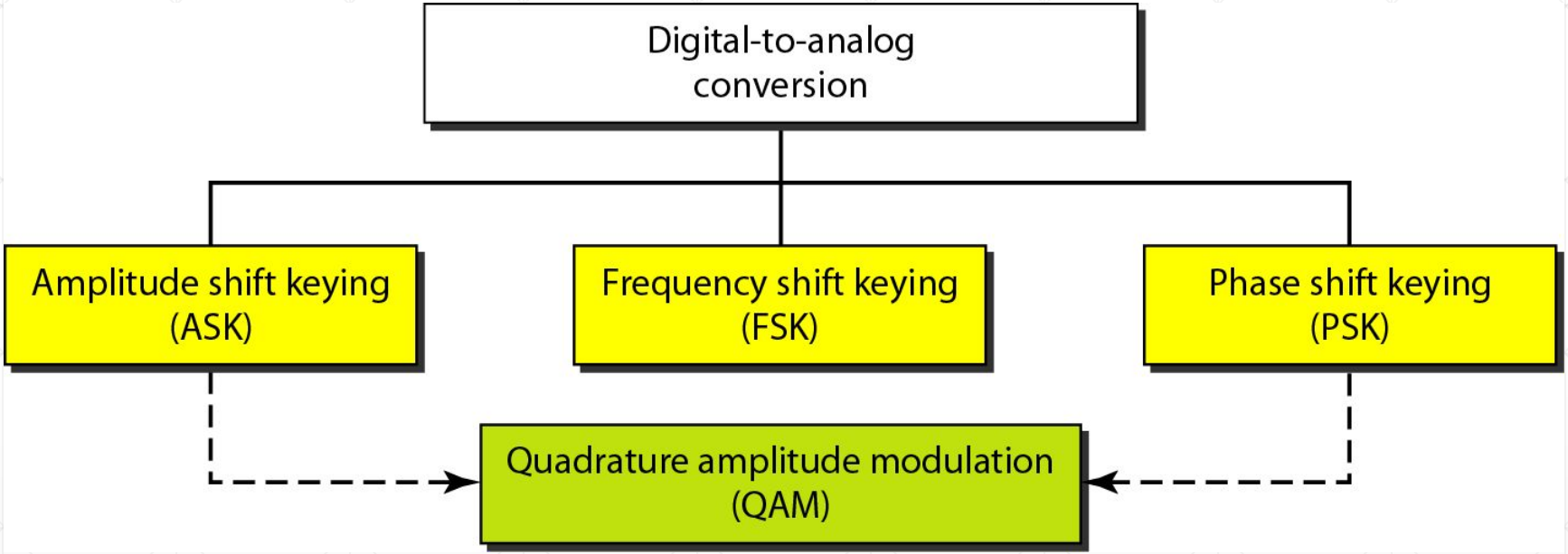
DAC: HOW

- Choose a **carrier** signal
  - **Carrier:** A signal with fixed properties (*amplitude*, *frequency*, or *phase*)
- **Modulate** the carrier signal **(keying)**
  - Encode digital data by **modifying** a **property** of the **carrier**
- **Transmit** over communication channel (radio wave / cable / fiber)
- **Decode** at receiver end

DAC: Definitions

- **Carrier:** A signal that transports digital data in analog waveform
- **Keying:** Manipulating the carrier signal to uniquely identify the digital data being carried
  - **Modulation** is applicable to both **analog and digital signals**
  - **Keying** is a type of **digital modulation**

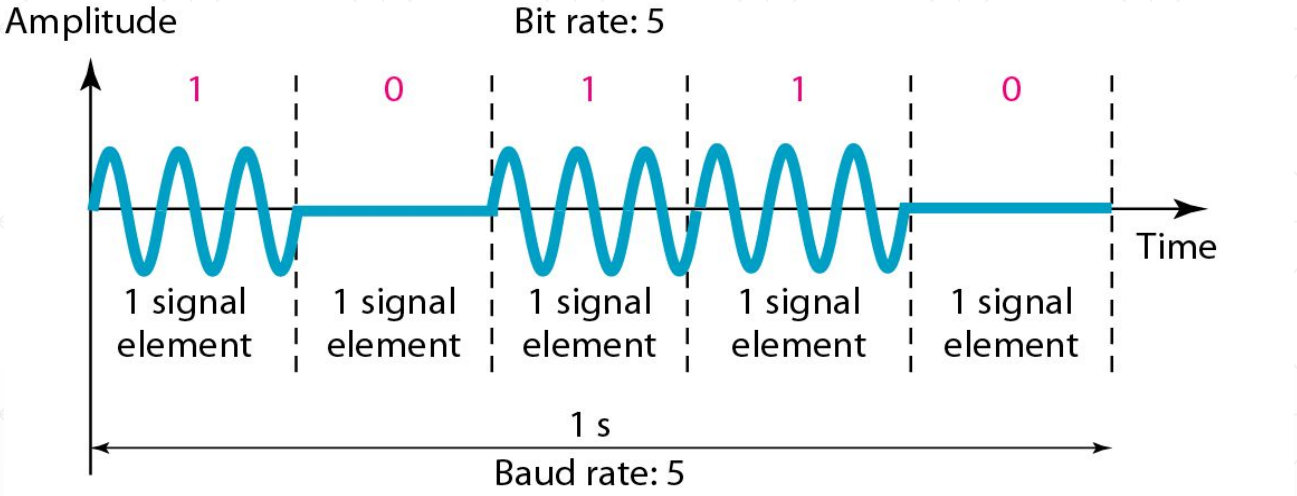
Types of Digital-to-Analog Conversion



Amplitude Shift Keying (ASK)

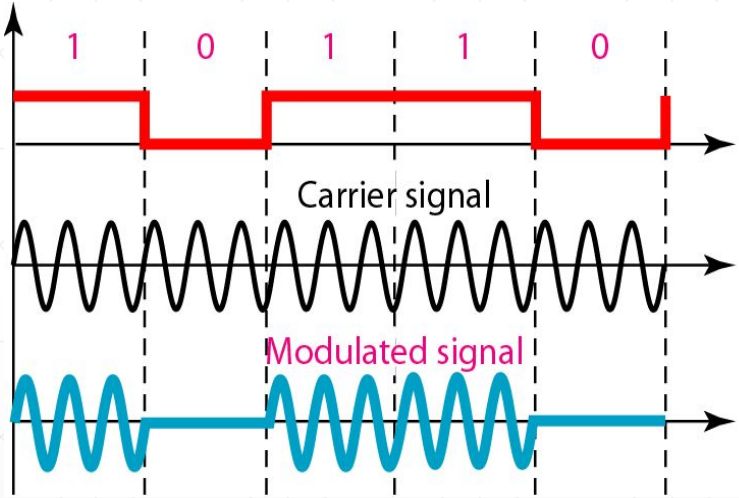
- In ASK, digital data is represented by **changing** the **amplitude** of the carrier
- Start with a carrier signal with amplitude *'A'*
- Modulation
  - **'1':** Keep amplitude **unchanged**
  - **'0':** Make amplitude **zero**

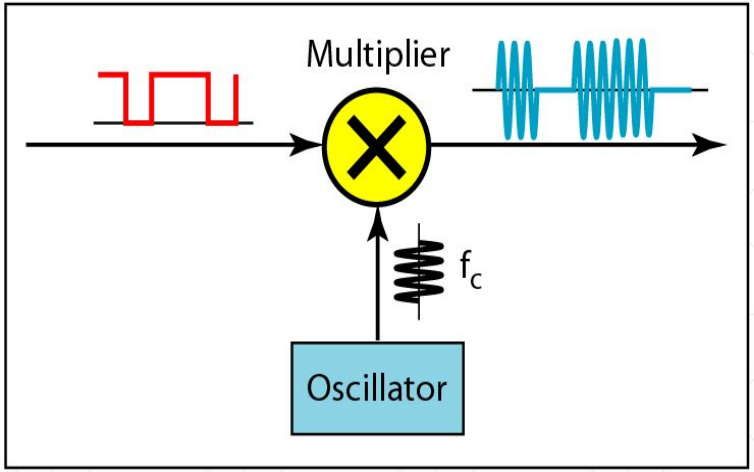
Binary Amplitude Shift Keying (BASK)



- Also known as **On Off Keying (OOK)**

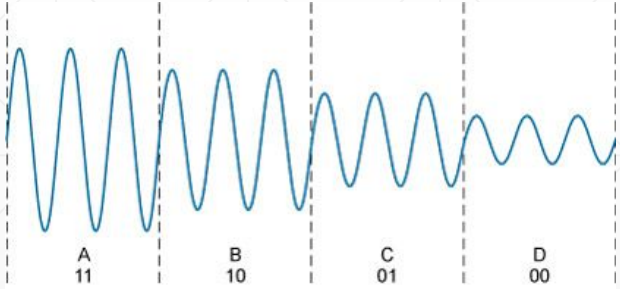
Implementation of BASK



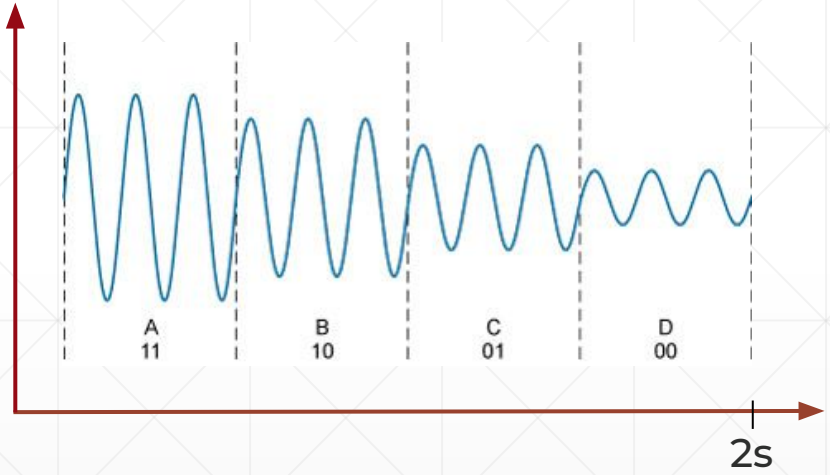


Multi-level ASK (MASK)

- Sending a single bit per signal element is wasteful
- Efficient approach: Send **multiple** bits per signal element **(MASK)**
- **4-ASK:** 4 different amplitude levels to represent two bits at a time (00, 01, 10, 11)
- Double bit rate compared to BASK



Multi-level ASK (MASK)



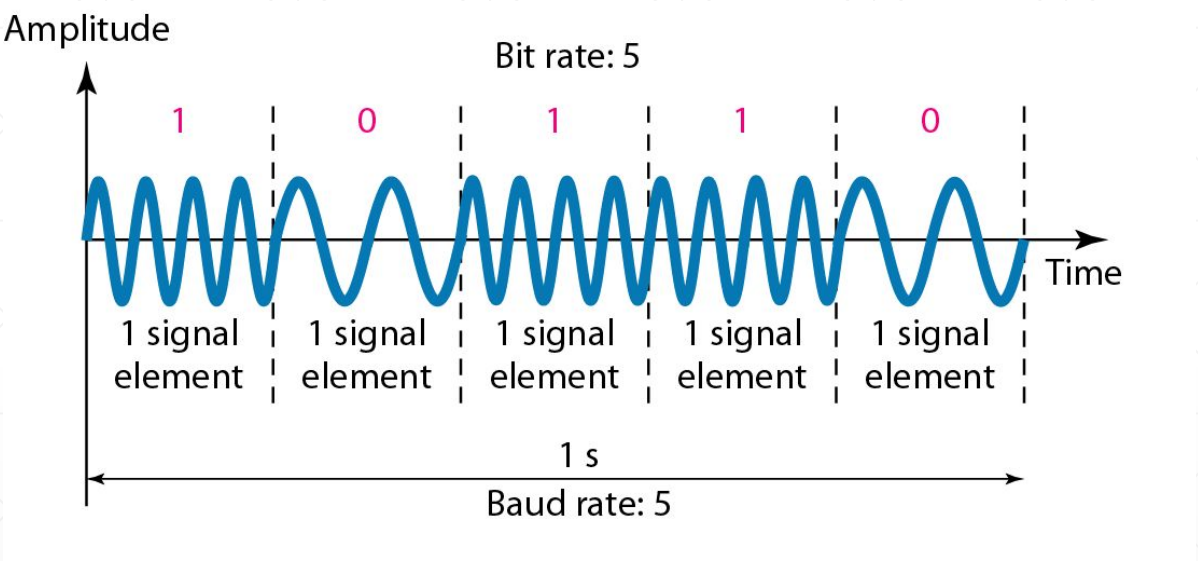
Bit rate = 4

Baud rate = 2

Frequency Shift Keying (FSK)

- In FSK, digital data is represented by **changing** the **frequency** of the carrier
- Start with a carrier signal with frequency 'f_c'
- Modulation
  - **'1':** Increase frequency $f_1 = f_c + \Delta f$
  - **'0':** Decrease frequency $f_2 = f_c - \Delta f$

Binary Frequency Shift Keying (BFSK)



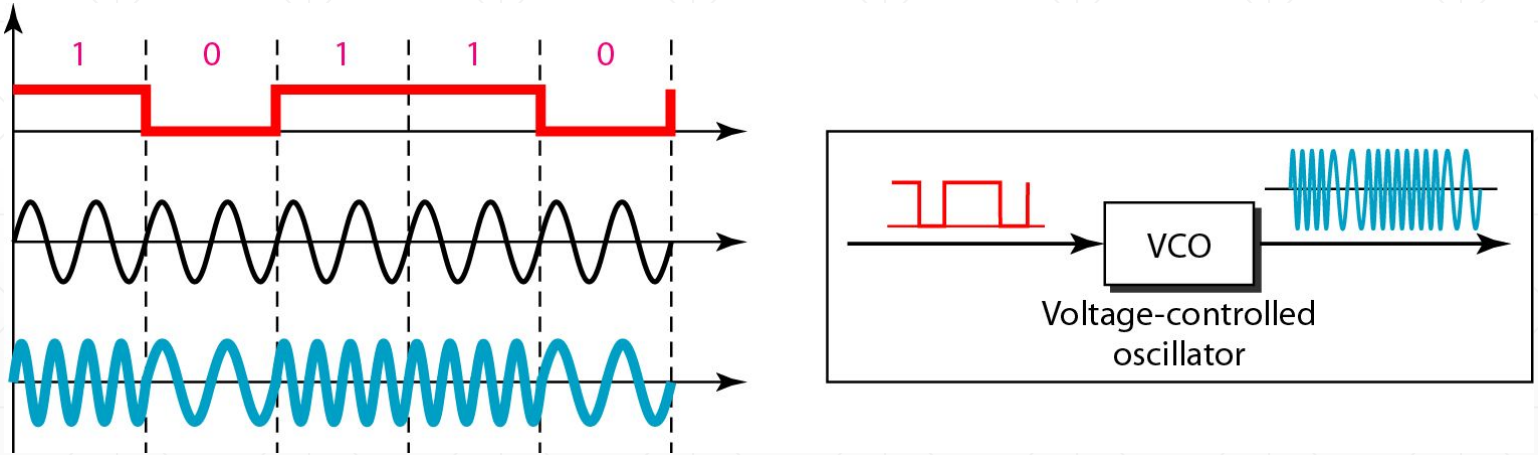
Coherent & Non-coherent FSK

- **Non-coherent FSK Scheme**: When we change from one frequency to another, the **phase** of the carrier signal **can change abruptly**

- **Coherent FSK Scheme:** When we change from one frequency to another, the **phase** of the carrier signal **remains consistent**

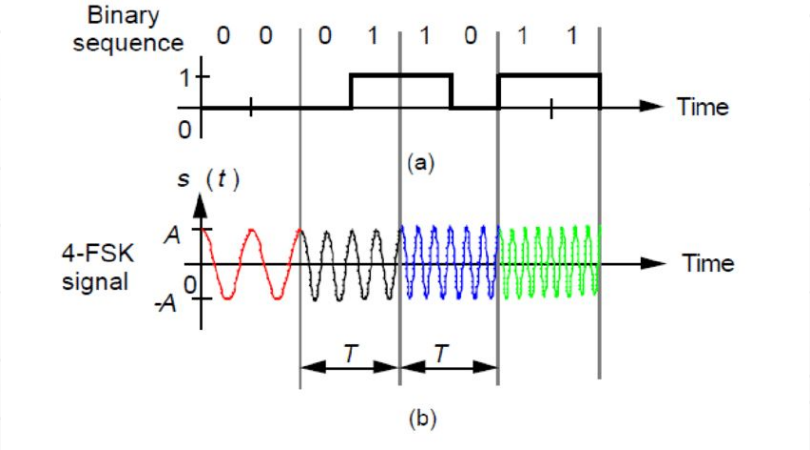
Implementation of Coherent BFSK

- Coherent B-FSK can be implemented by using one ***Voltage-controlled Oscillator (VCO)***, that changes its frequency according to the input voltage



Multi-level FSK (MFSK)

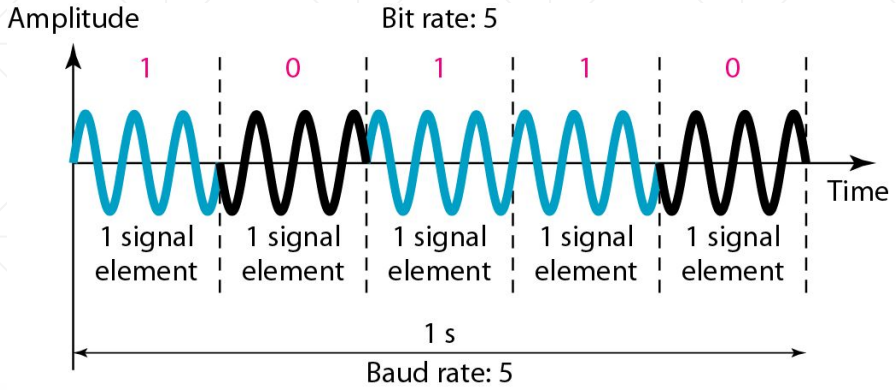
- Like ASK, FSK can also send **multiple** bits per signal element **(MFSK)**
- **4-FSK:** 4 different frequencies to represent two bits at a time (00, 01, 10, 11)



Phase Shift Keying (PSK)

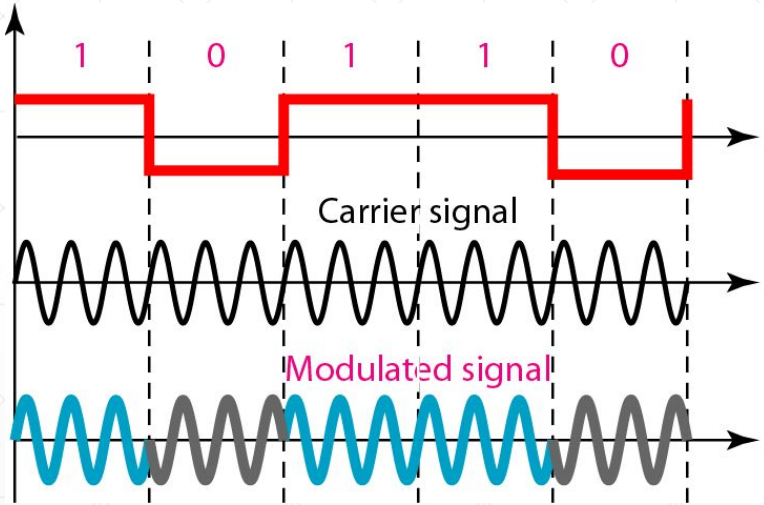
- In PSK, digital data is represented by **changing** the **phase shift** of the carrier
- **Phase** of a signal refers to its **starting position (angle)** within a cycle, expressed in degrees ($0° \leq \theta < 360°$) or radians ($0 \leq \theta < 2\pi$)
- Advantages of PSK:
  - Less sensitive to noise than ASK
  - Can achieve higher bit rate than FSK

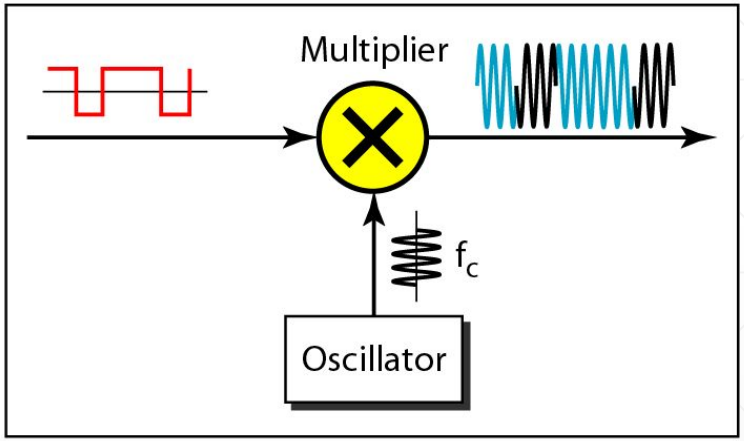
Binary Phase Shift Keying (BPSK)



- Modulation
  - **‘1’:** phase = 0°
  - **‘0’:** phase = 180°

Implementation of BPSK





Quadrature PSK (QPSK)

- In QPSK we -
  - Parallelize the bit stream by splitting every two incoming bits
  - Apply two BPSKs in parallel (one carrier frequency is phase shifted 90° from the other)
  - Combine the two signals to get the modulated signal
- Double bit rate compared to BPSK

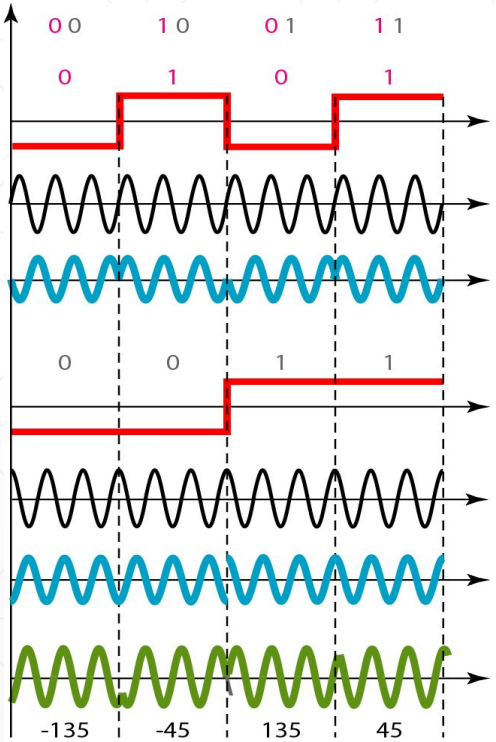
Implementation of QPSK

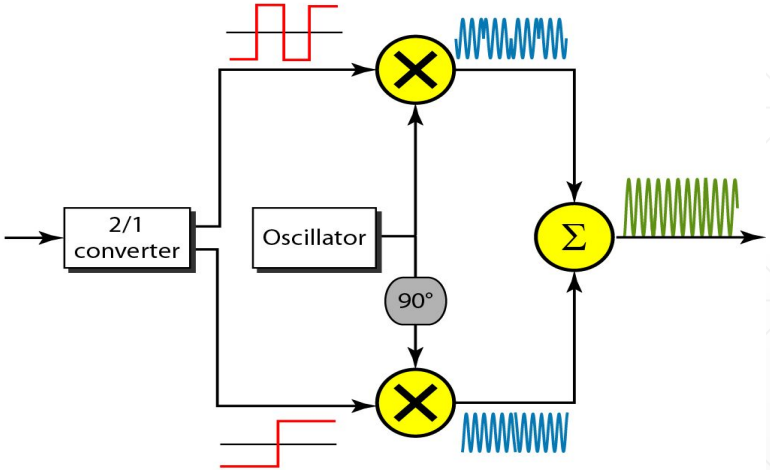
‘1’: phase = 0°

‘0’: phase = 180°

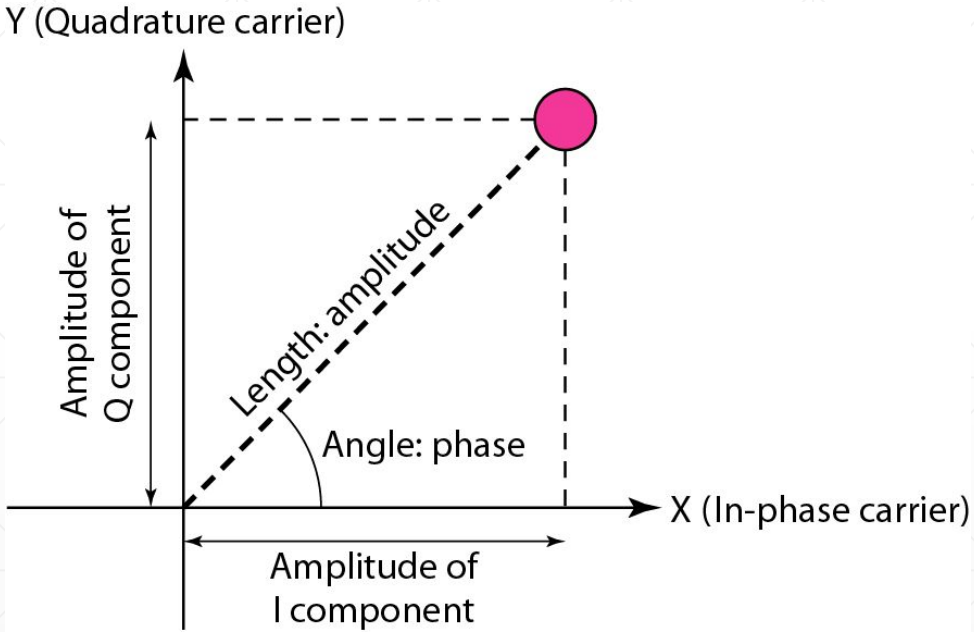
‘1’: phase = 90°

‘0’: phase = 270°



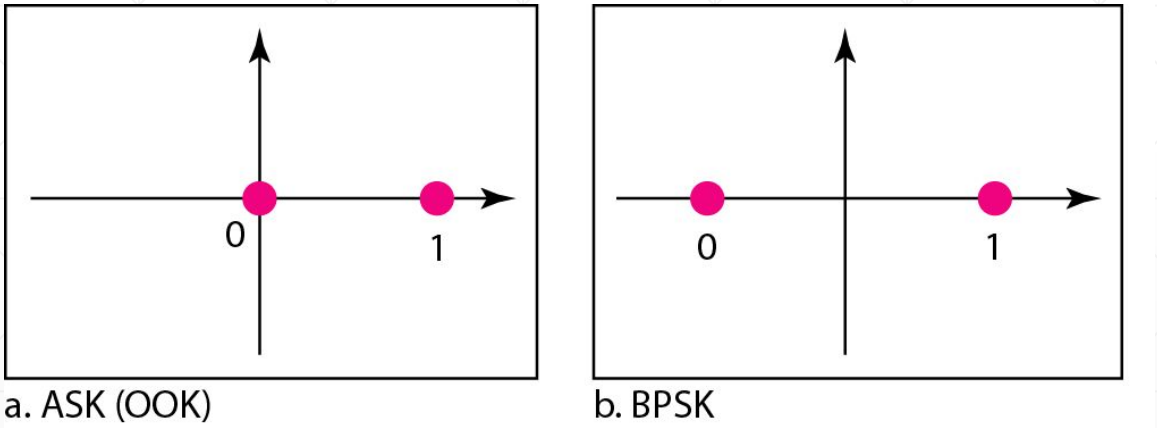


Concept of a Constellation Diagram



Constellation Diagram for BASK & BPSK

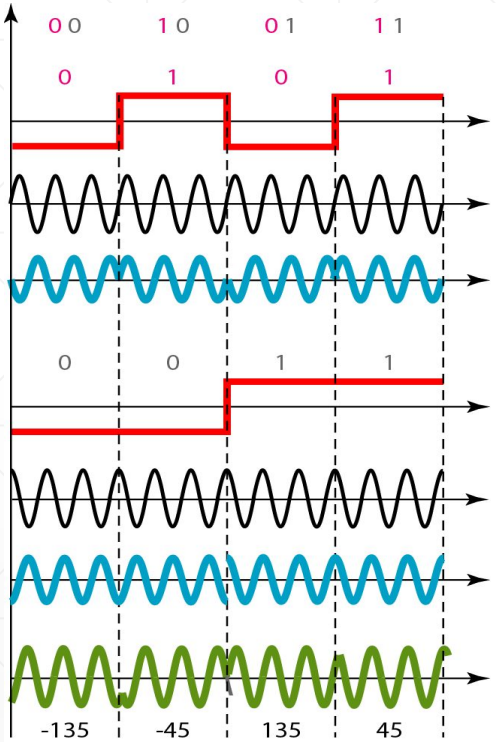
- Show constellation diagrams for ASK (OOK) and BPSK



a. ASK (OOK)

b. BPSK

Constellation Diagram for QPSK

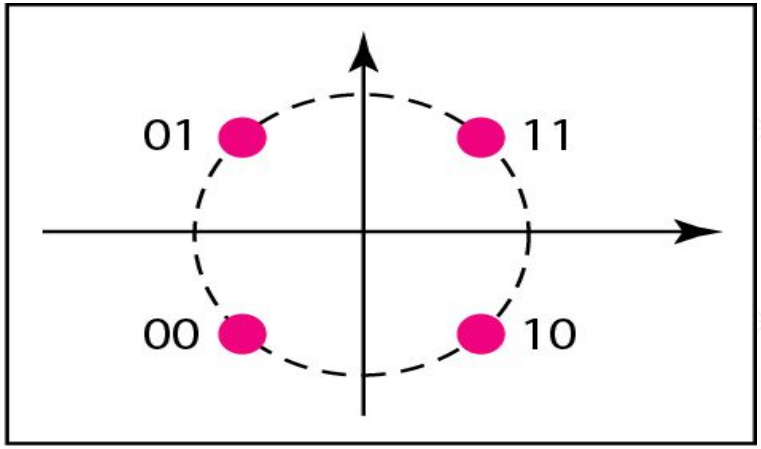


'1': phase = 0°

'0': phase = 180°

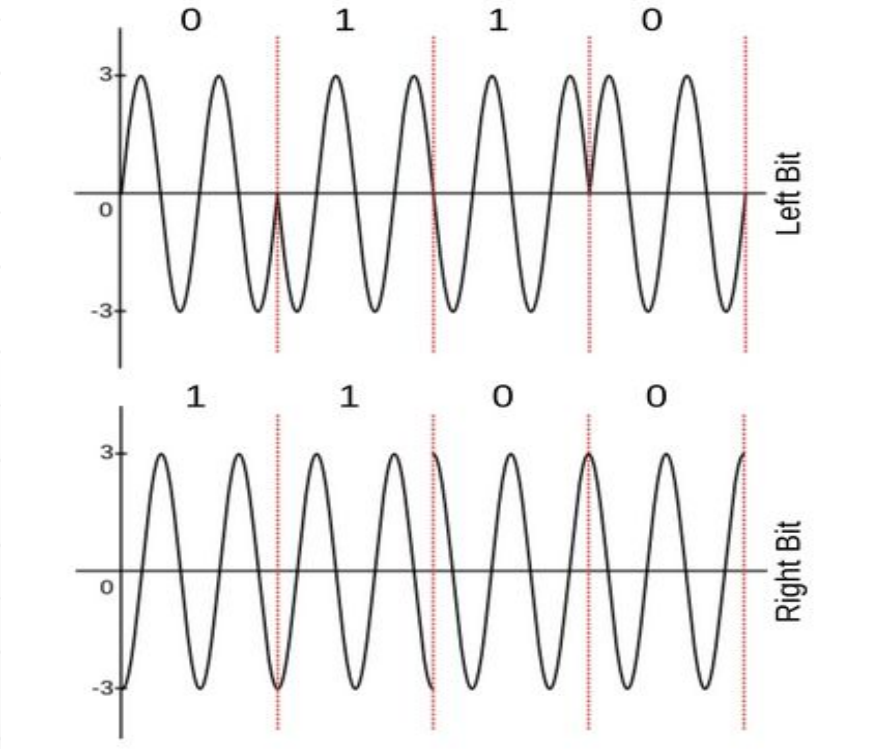
'1': phase = 90°

'0': phase = 270°



c. QPSK

Constellation Diagram for QPSK



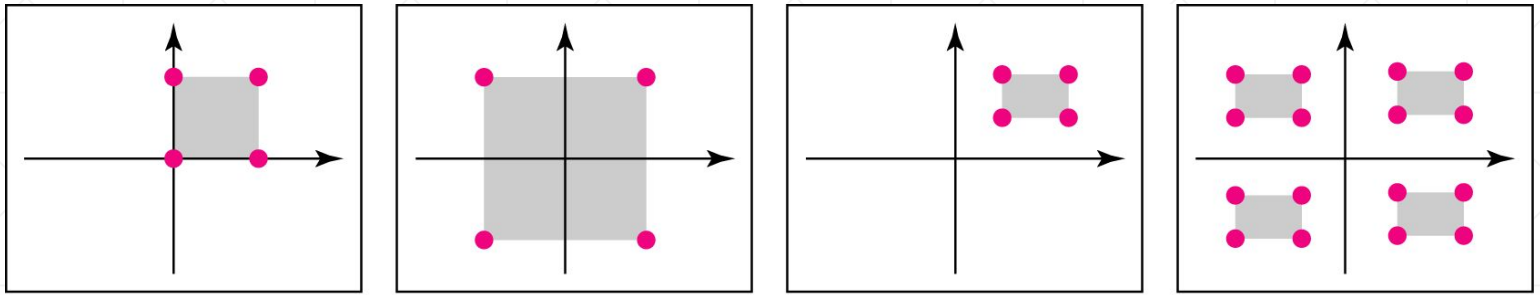
Quadrature Amplitude Modulation (QAM)

- Can we change **two** signal components **simultaneously?**

- QAM is a combination of ASK and PSK
  - Benefit: **QAM can transmit more bits per signal element**

- Can we change **all three components** simultaneously?
  - **It will increase the complexity of both transmitter and receiver**

Constellation Diagram for QAMs



a. 4-QAM b. 4-QAM c. 4-QAM d. 16-QAM