

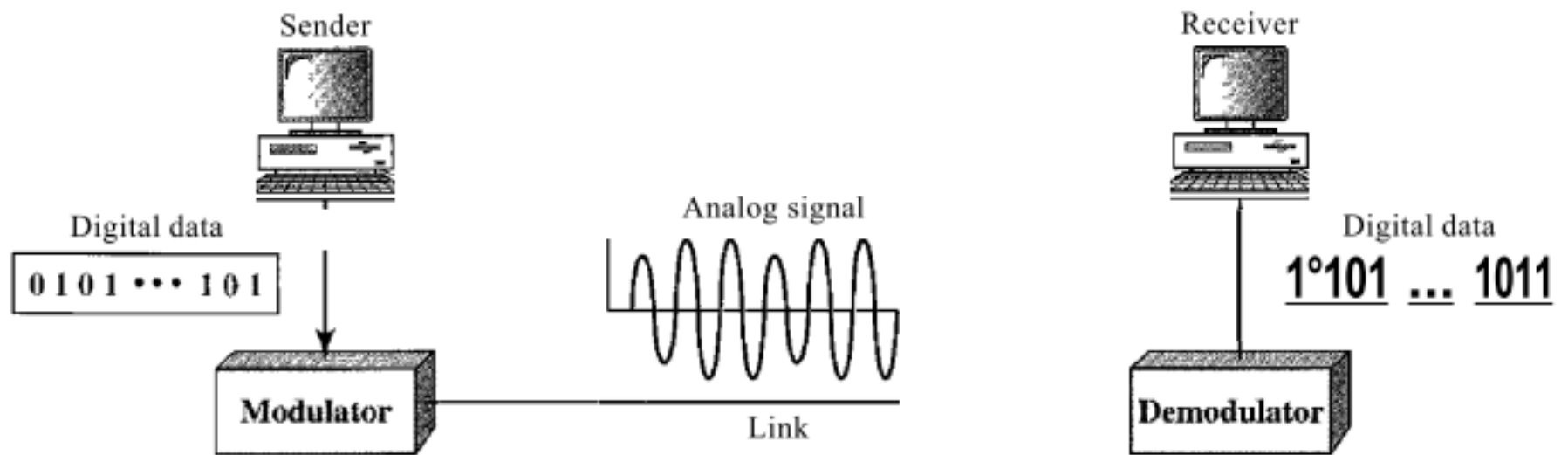
Data Communications

Analog Transmission
Modulation

Analog Transmission

- A computer network is designed to send information from one point to another.
- This information needs to be converted to an analog signal for transmission.
- The converted information is added to an analog wave called a carrier for transmission.
- Adding information to the carrier is called **Modulation**

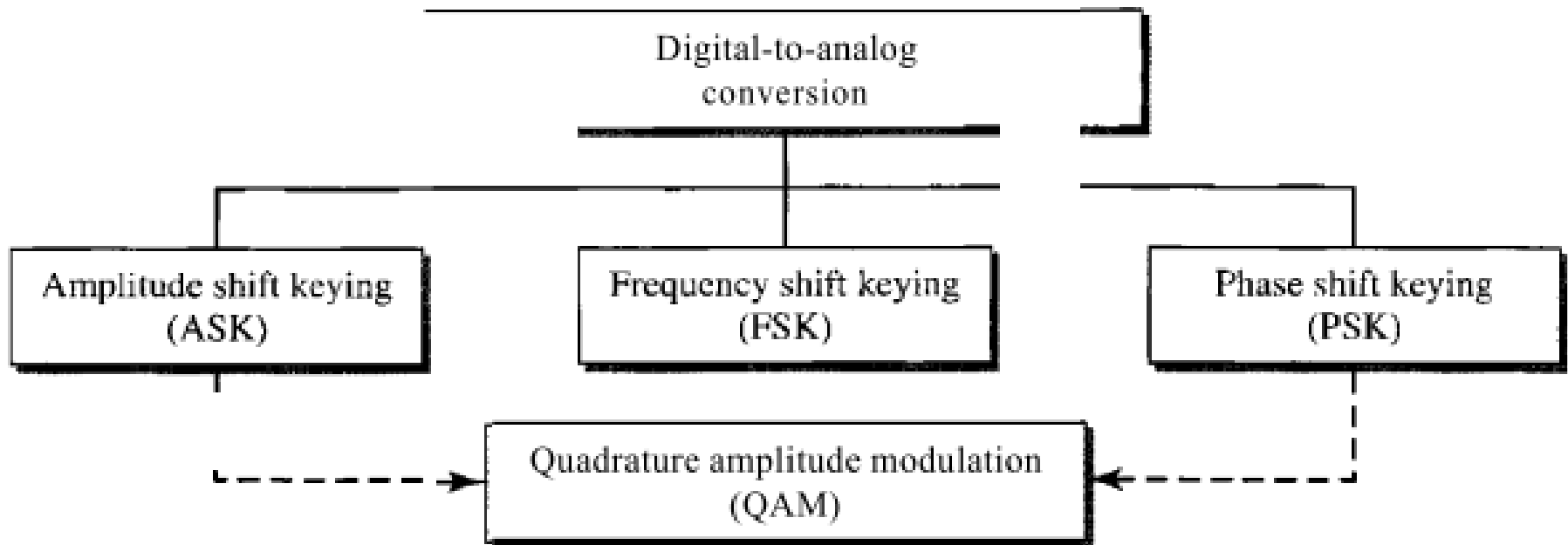
Digital-to-analog Conversion



Types of Modulation

- Changing Amplitude
- Changing Frequency
- Changing Phase
- Changing both Amplitude and Phase

Types of Modulation



Aspects of Digital-to-Analog Conversion

- Data Element: the smallest piece of information to be exchanged, the bit.
- Signal Element: the smallest unit of a signal that persists for a fixed period of time
- Data Rate (bit rate): the number of data elements (bits) sent in 1 second
- Signal Rate (baud rate): the number of signal elements sent in 1 second

Relationship between Data Rate and Signal Rate

- The relationship between data rate and signal rate is given by:

$$N = S \times r \quad \text{bps (bits per second)}$$

where r is the number of bits carried per signal element ($r = \log_2 L$)

N is the data rate

S is signal rate

Example

- An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.
- $N = 1000 \times 4 = 4000 \text{ bps}$

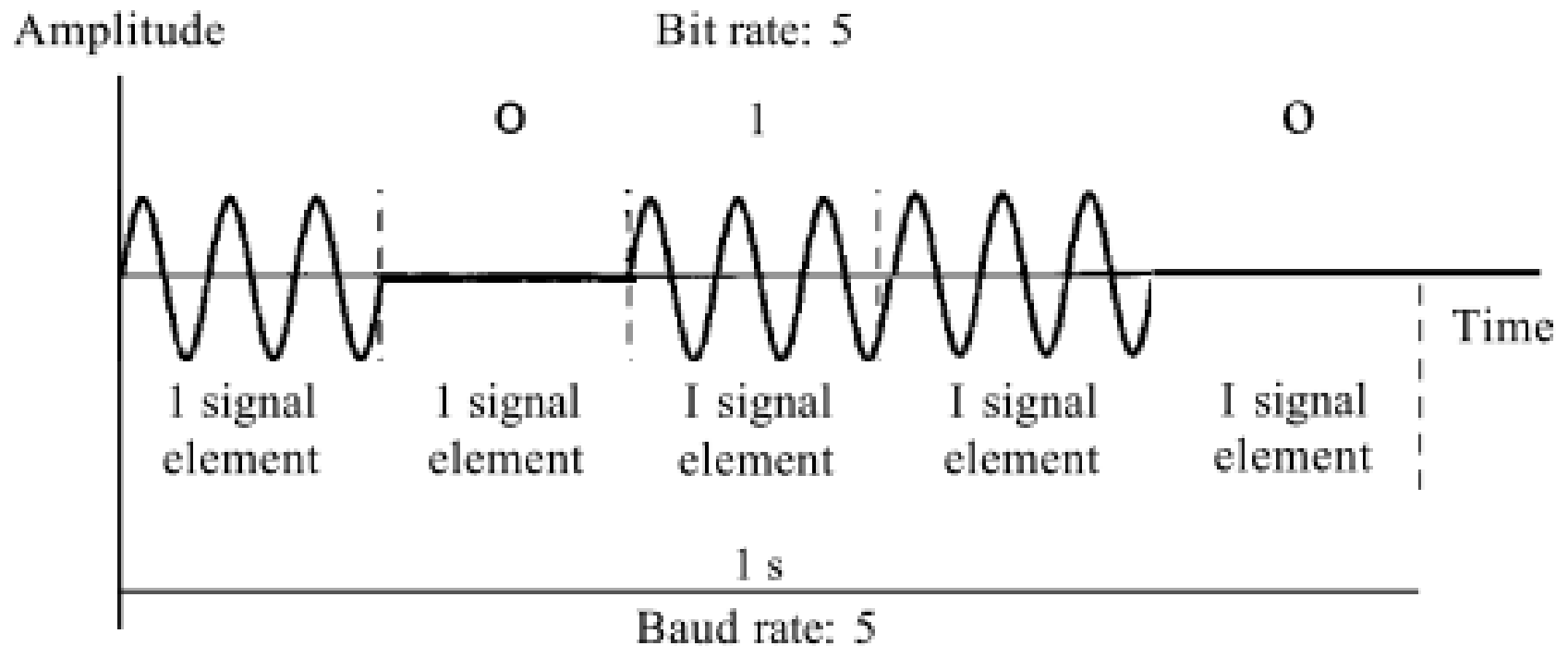
Example

- 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 different signal elements do we need?
- $r = N/S = 8000/1000 = 8$ bits per signal element
- # elements needed = $2^8 = 256$

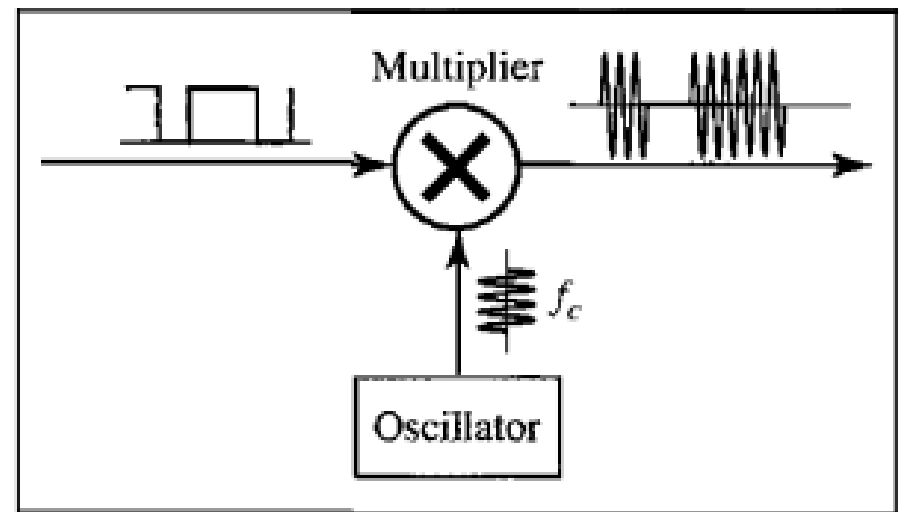
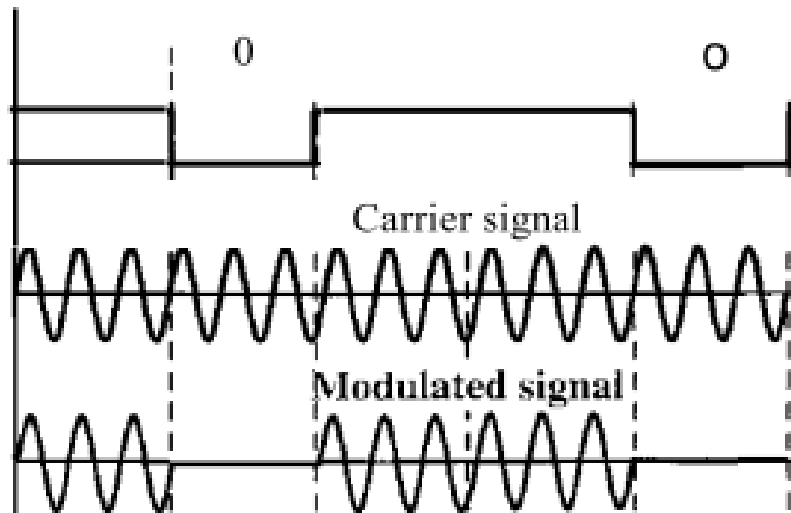
Modulation through Changing Amplitude

- Amplitude Shift Keying (ASK): In amplitude shift keying, the amplitude of the carrier is varied to create signal elements.
- Both frequency and phase remain constant while the amplitude changes.
- ASK is used in binary and multi-level formats.

Binary ASK



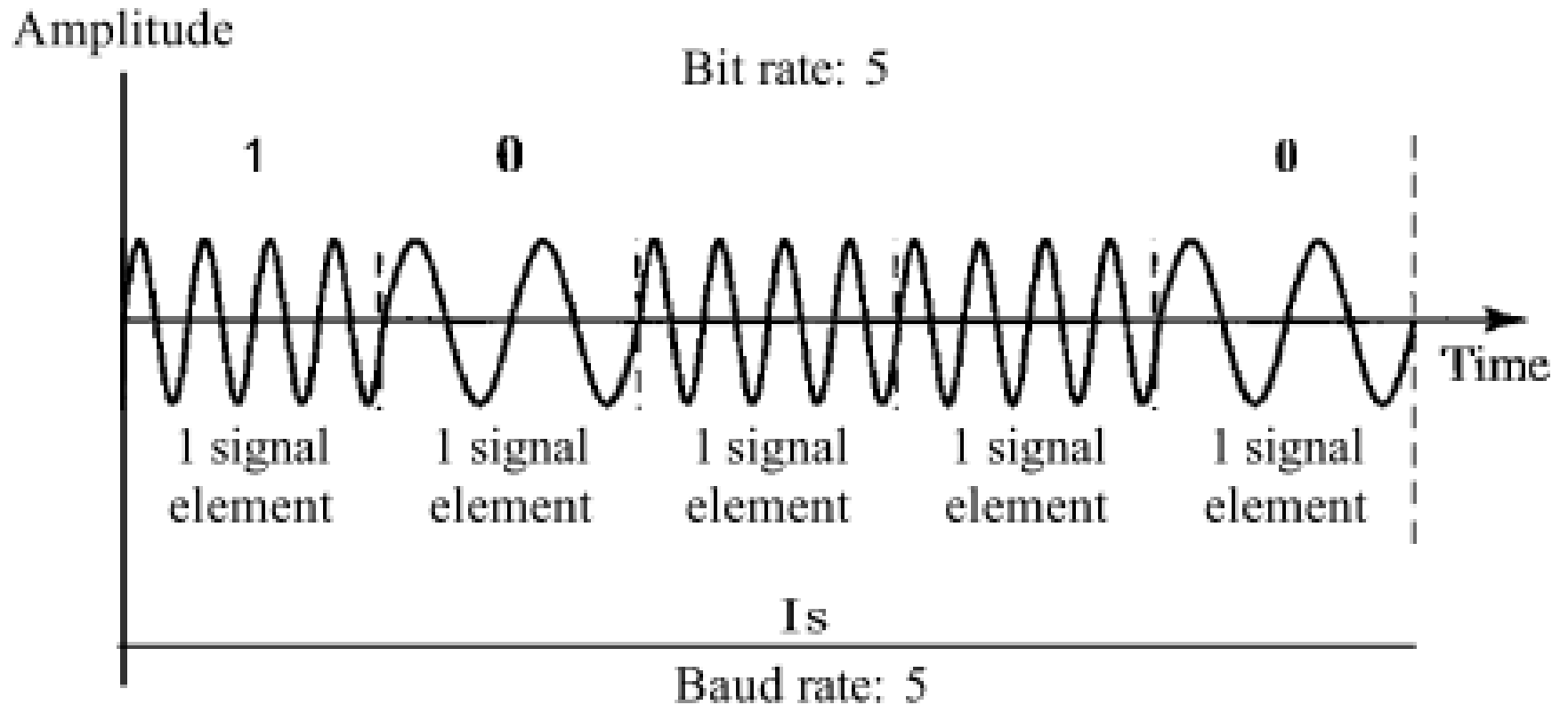
Implementing Binary ASK



Frequency Shift Keying

- In frequency shift keying (FSK), the frequency of the carrier signal is varied to represent data.
- The frequency of the modulated signal is constant for the duration of one signal element, but changes for the next signal element if the data element changes.
- Both peak amplitude and phase remain constant for all signal elements.

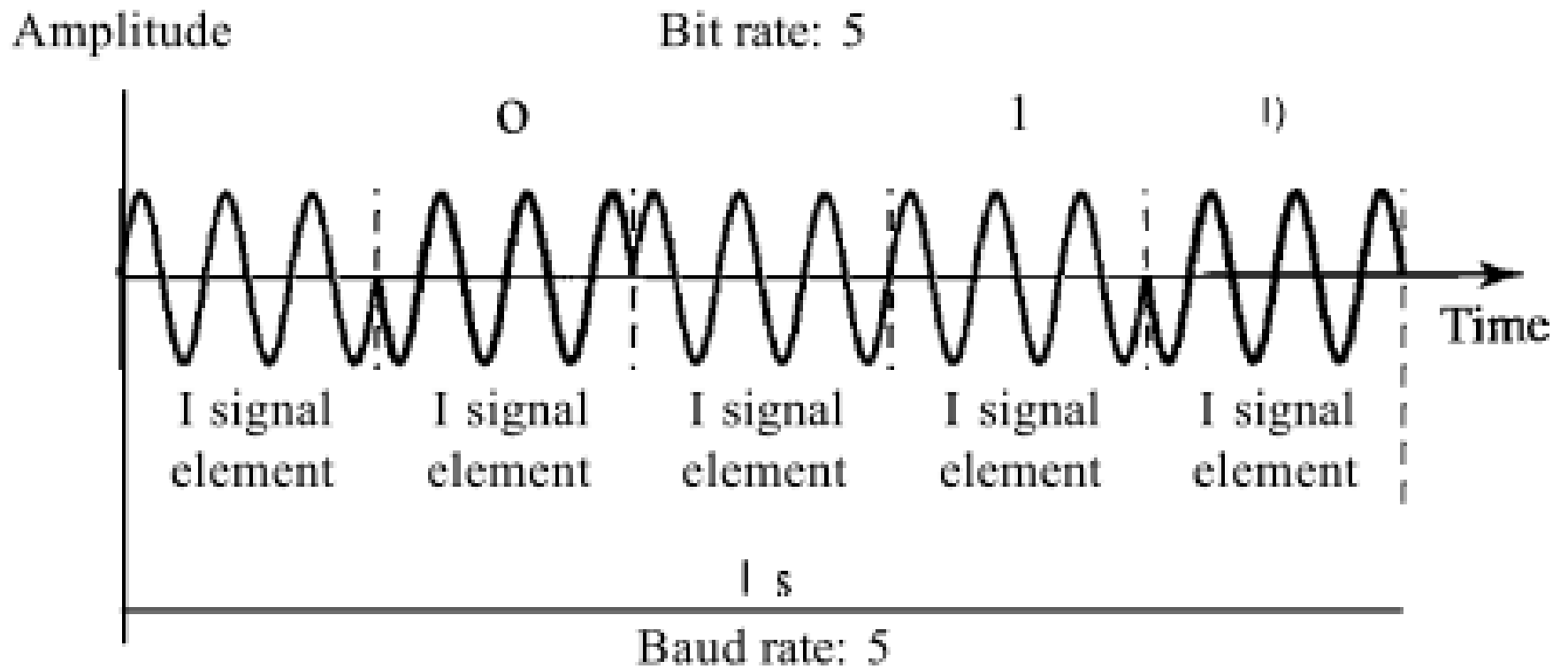
Frequency Shift Keying



Phase Shift Keying

- In phase shift keying (PSK), the phase of the carrier is varied to represent two or more different signal elements.
- Both peak amplitude and frequency remain constant as the phase changes.
- PSK is more common than ASK or FSK.

Phase Shift Keying

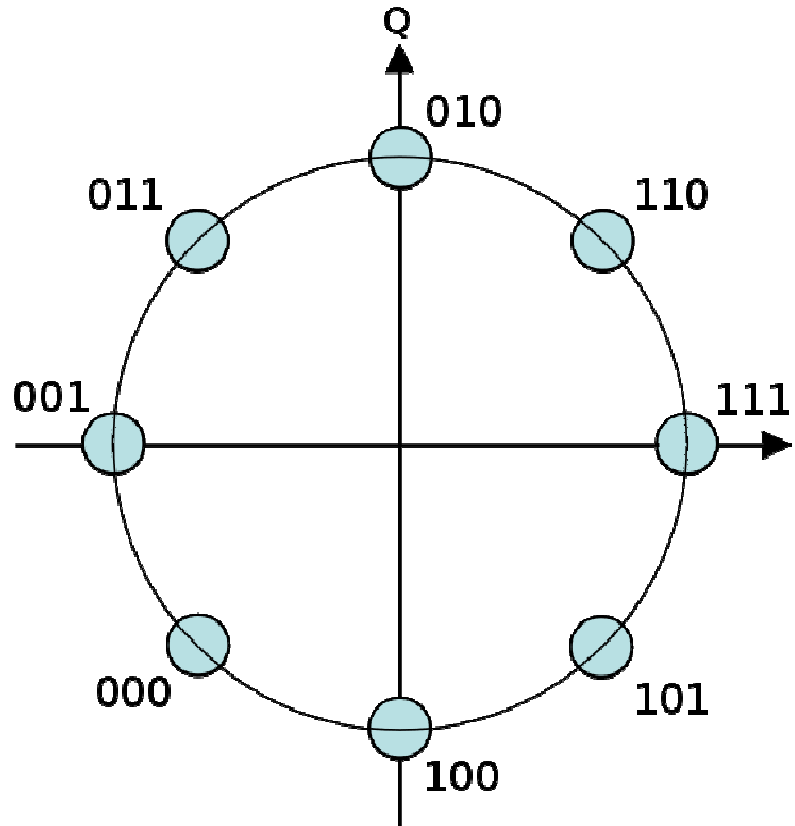


Quadrature PSK (QPSK)

- Uses 90 degrees phase difference to transmit 2 bits in each signal element.
- Phases are -135, -45, 45, 135

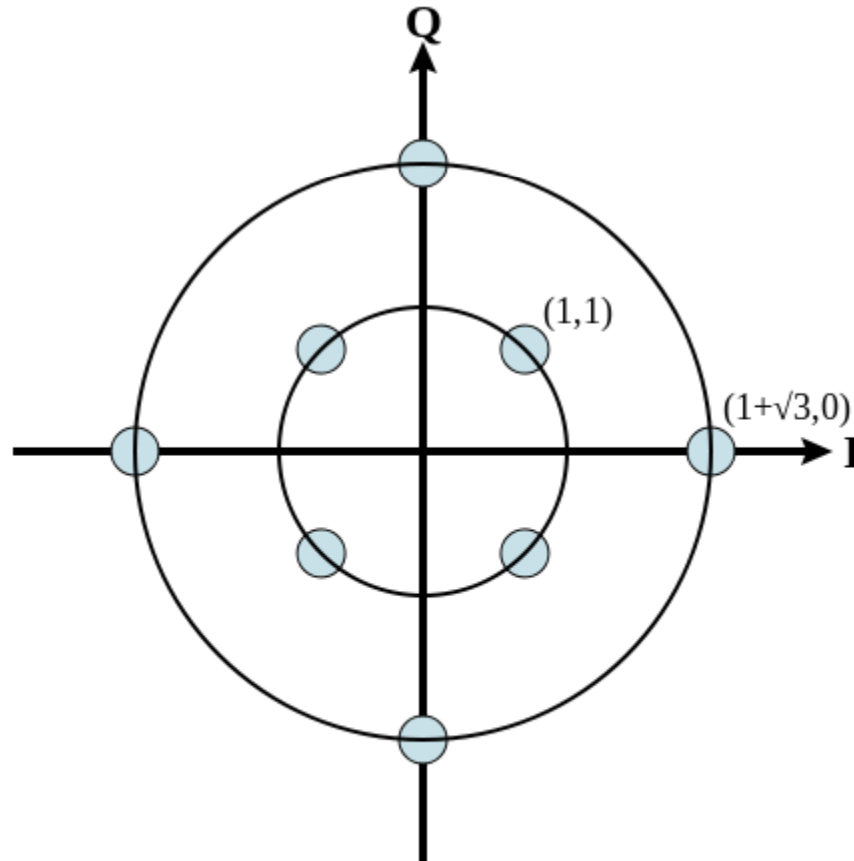
Constellation Diagram

- A constellation diagram can help us define the amplitude and phase of a signal element



Quadrature Amplitude Modulation

- Quadrature Amplitude Modulation (QAM) is a combination of ASK and PSK



Example

- Using QAM with 8 signal elements (8-QAM) draw the wave form for the following bit string:

001110010010000111