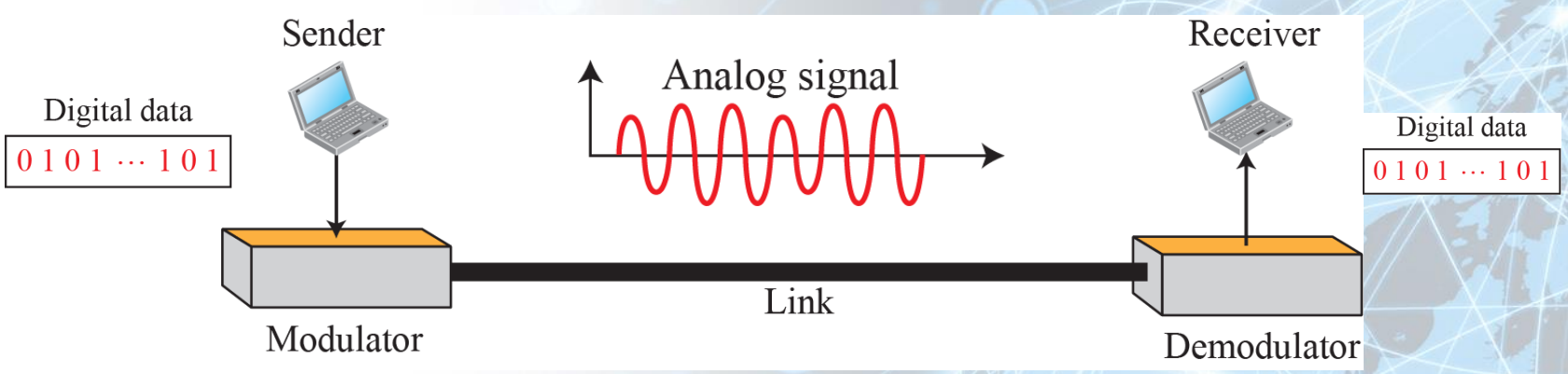
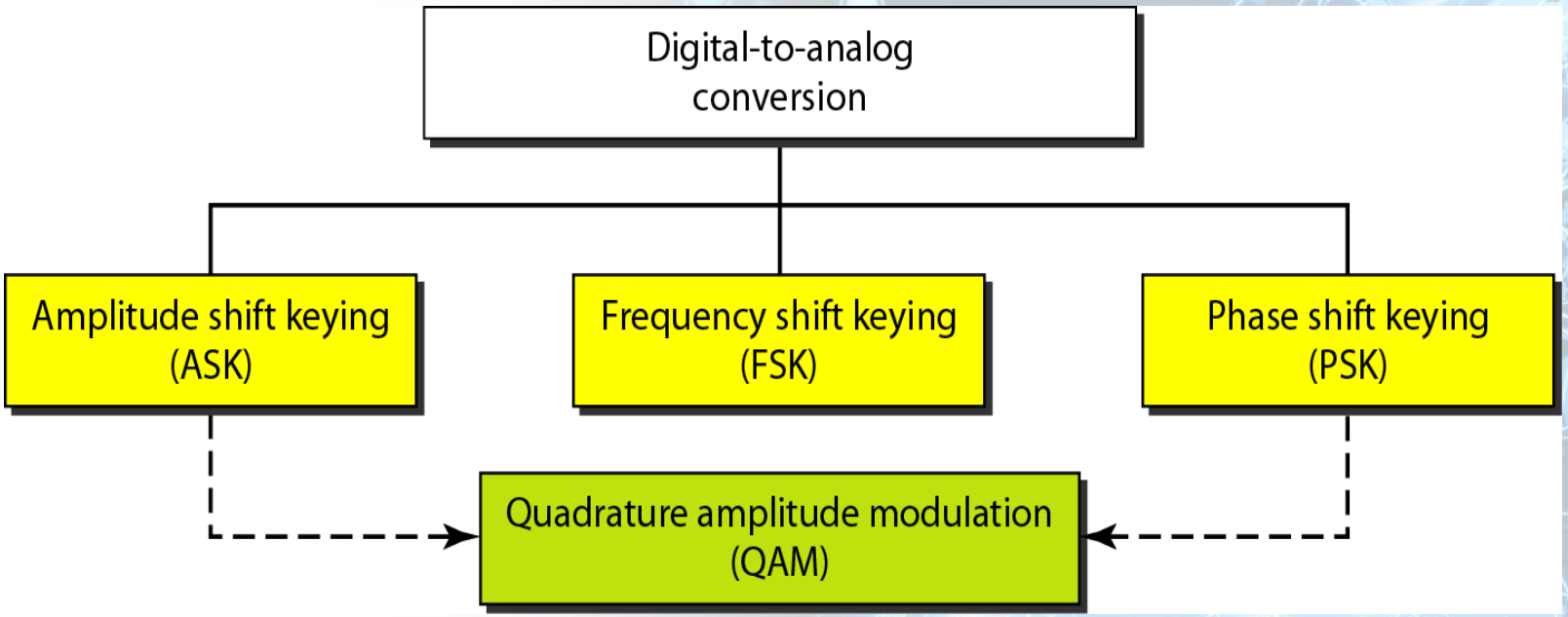
Digital-to-Analog Conversion

- Process of changing one of the characteristics of analog signal based on the information in digital data
- A sine wave is defined by 3 characteristics:
  - ✓ Amplitude
  - ✓ Frequency
  - ✓ Phase
- By changing one of these characteristics, we can use it to represent a digital signal

Digital-to-Analog Conversion



Types of Digital to Analog Conversion



Aspects of Digital to Analog Conversion

- **Before we discuss specific methods of digital-to-analog modulation, two basic issues must be reviewed:**
  - ✓ **Bit and Baud rates and**
  - ✓ **The Carrier Signal**

Aspects of Digital to Analog Conversion

- In Analog Transmission of Digital Data, Baud Rate is less than or equal to the Bit Rate
  - ✓ Data Element vs. Signal Element
  - ✓ Data Rate vs. Signal Rate
- Bandwidth Required ∝ Signal Rate (except FSK)
- Carrier Signal

Aspects of Digital to Analog Conversion

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  - ✓ **The Carrier Signal**

Example

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

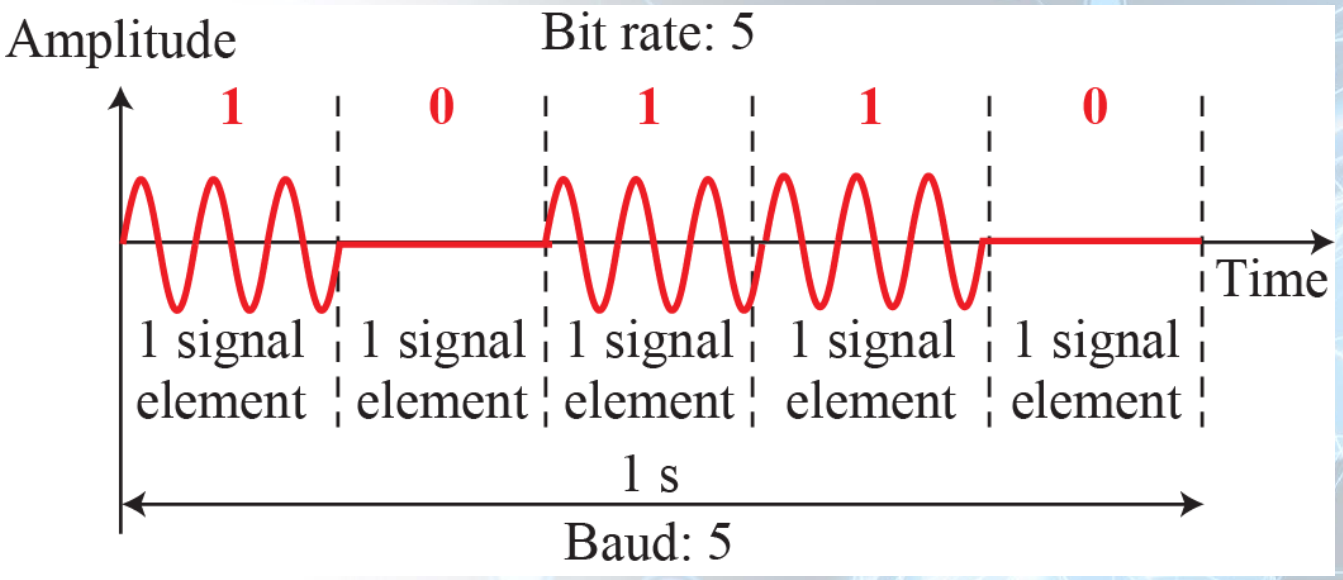
Example

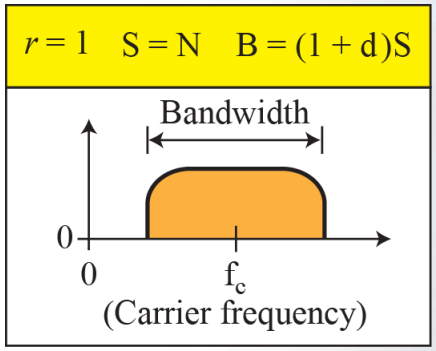
An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

Amplitude Shift Keying (ASK)

- The amplitude of the carrier signal is varied to create signal elements
- Both frequency and phase remain constant while the amplitude changes
- Binary ASK or On-Off Keying (OOK)

Binary Amplitude Shift Keying (Binary ASK)





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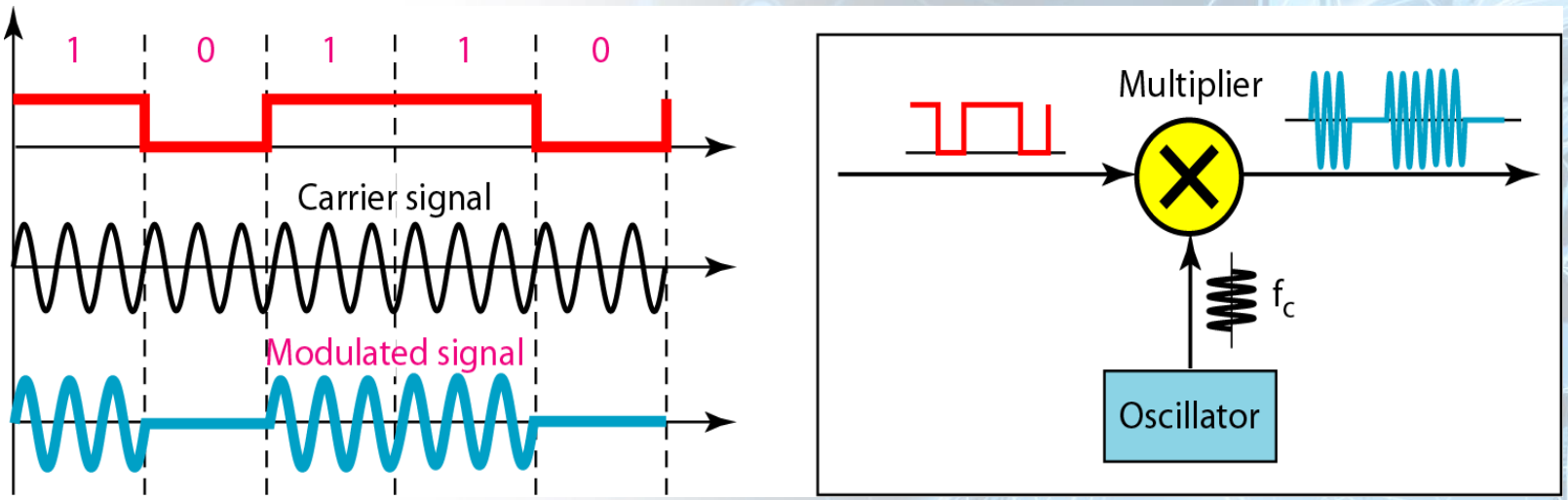
Implementation of Binary ASK



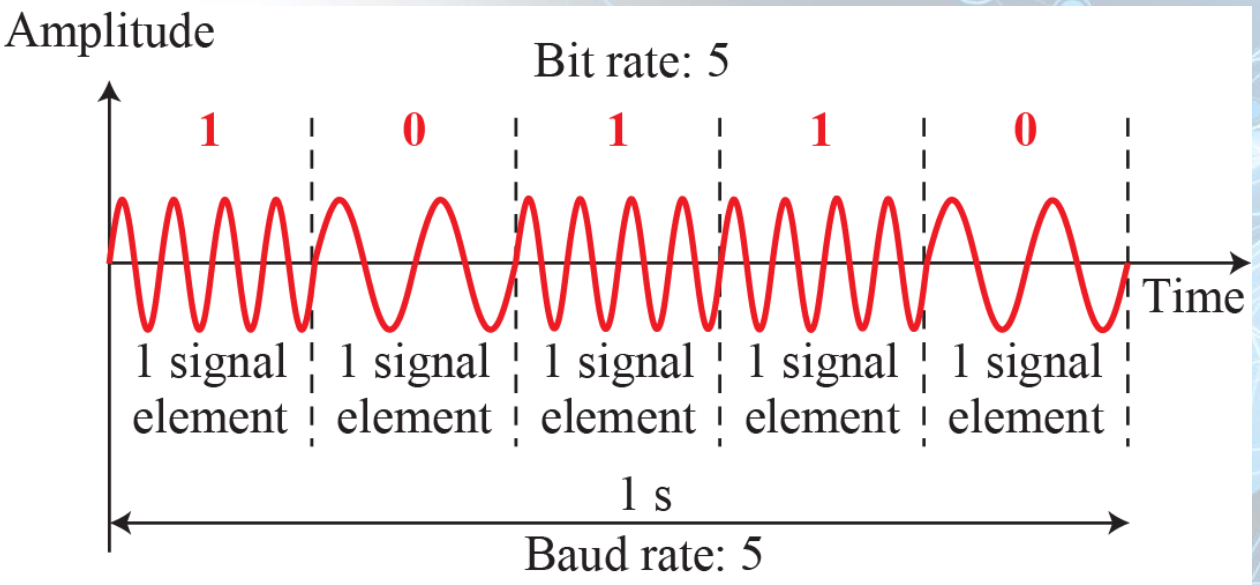
Example

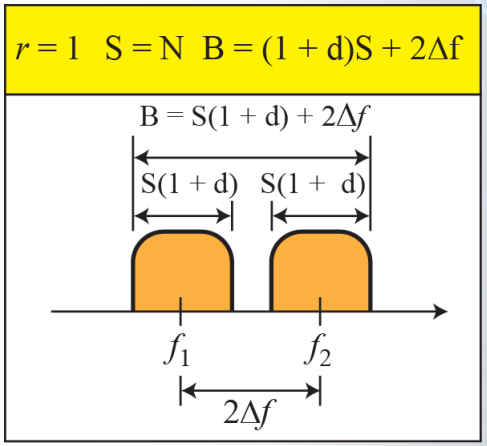
We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate if we modulated our data by using ASK with d = 1?

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

Binary Frequency Shift Keying





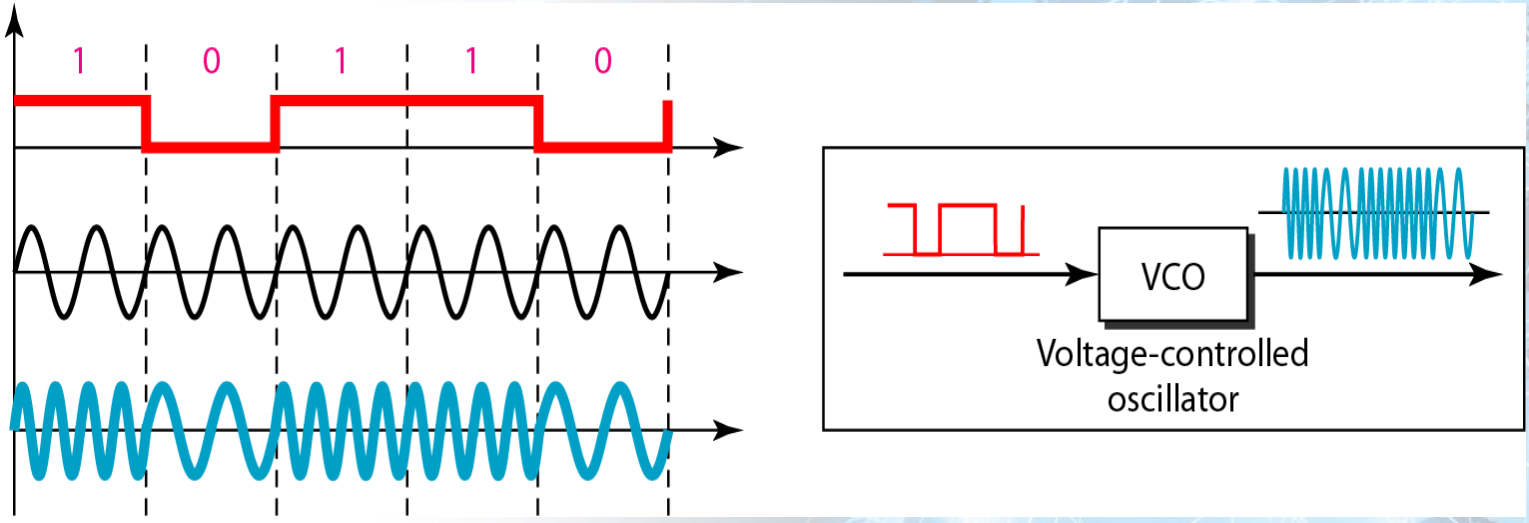
Frequency Shift Keying (FSK)

- The frequency of the carrier signal is varied to represent data
- Both peak amplitude and phase remain constant

Example

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?

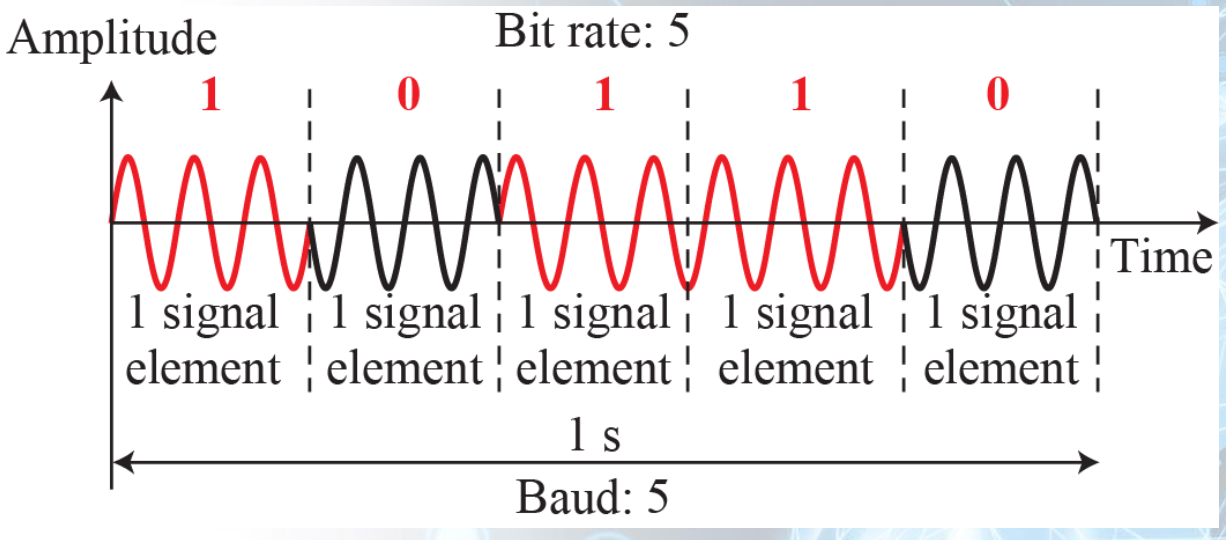
Implementation of BFSK

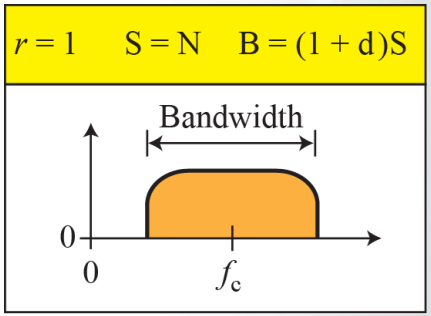


Phase Shift Keying (PSK)

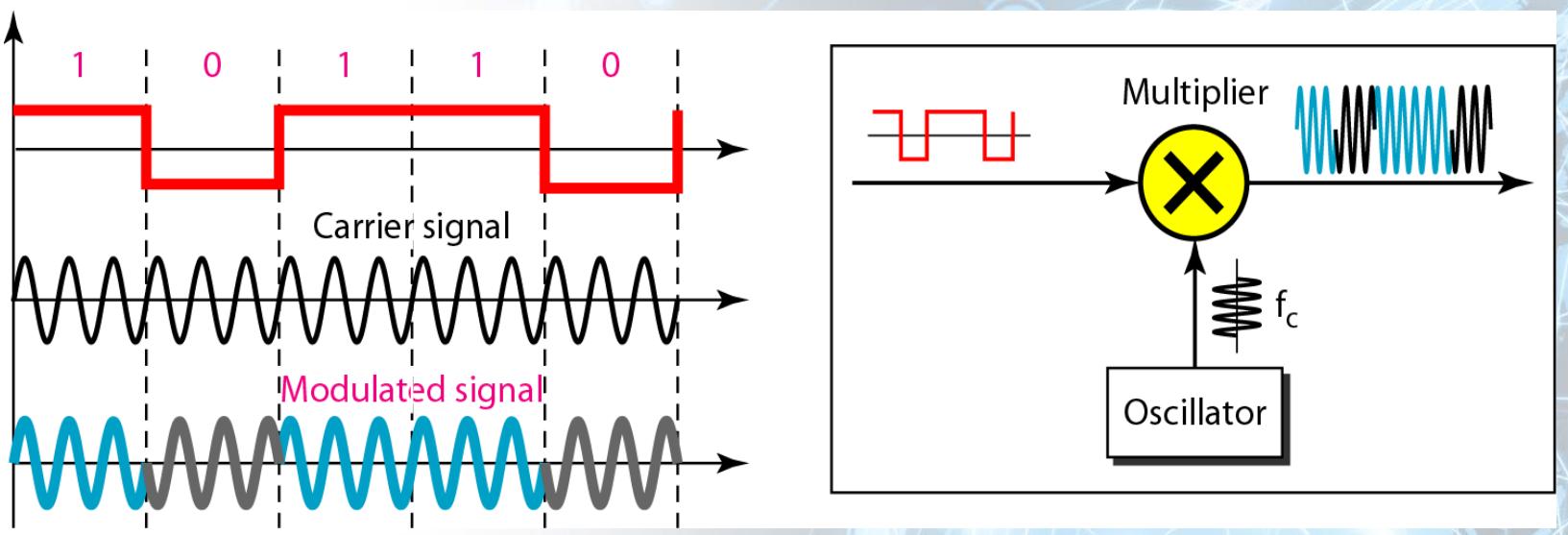
- The phase of the carrier is varied to represent two or more different signal elements
- Both peak amplitude and frequency remain constant
- PSK is relatively common than ASK or FSK

Binary Phase Shift Keying

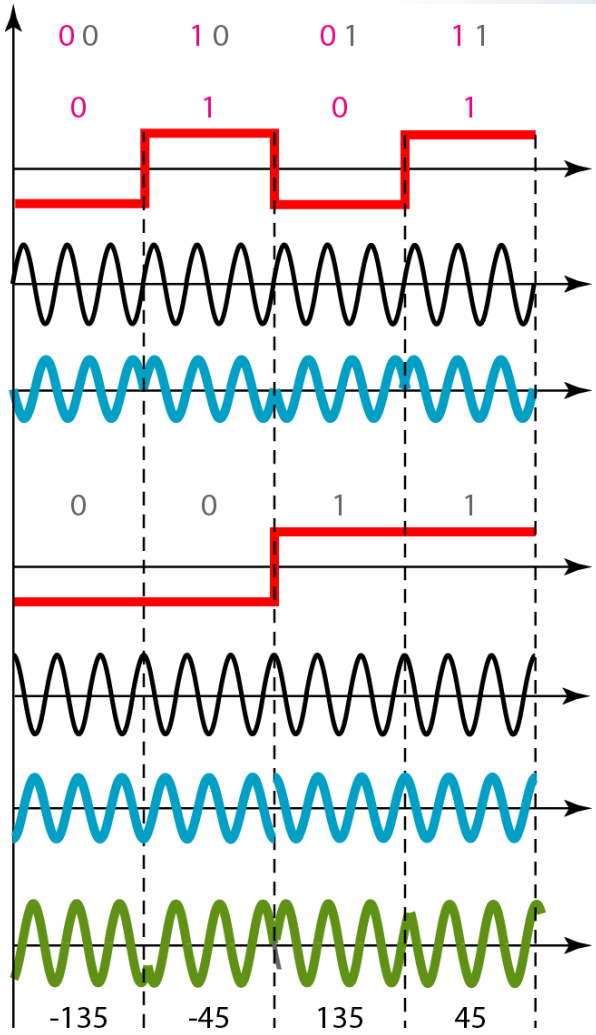


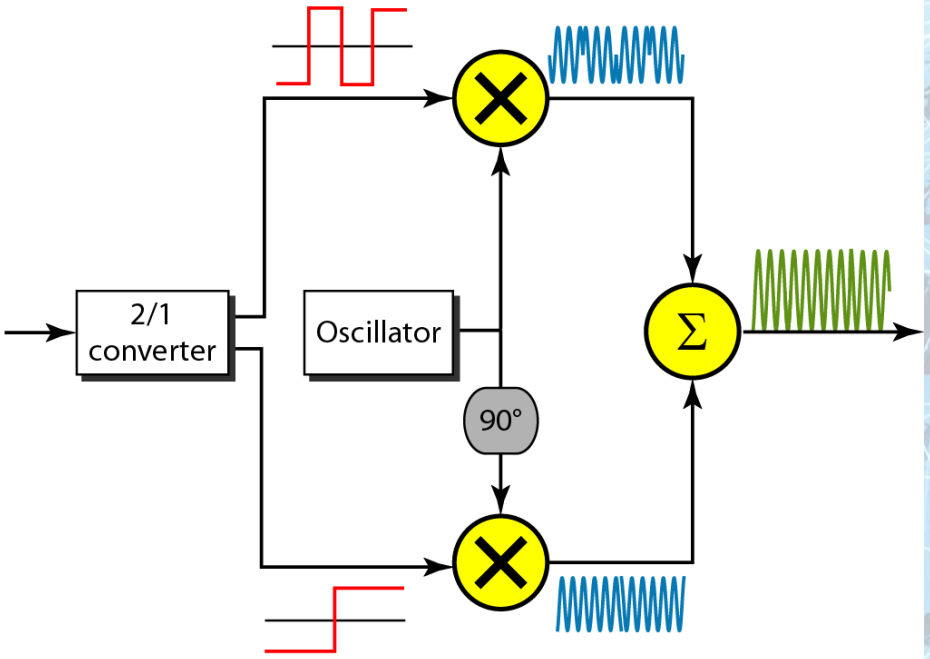


Implementation of BPSK



QPSK and its Implementation





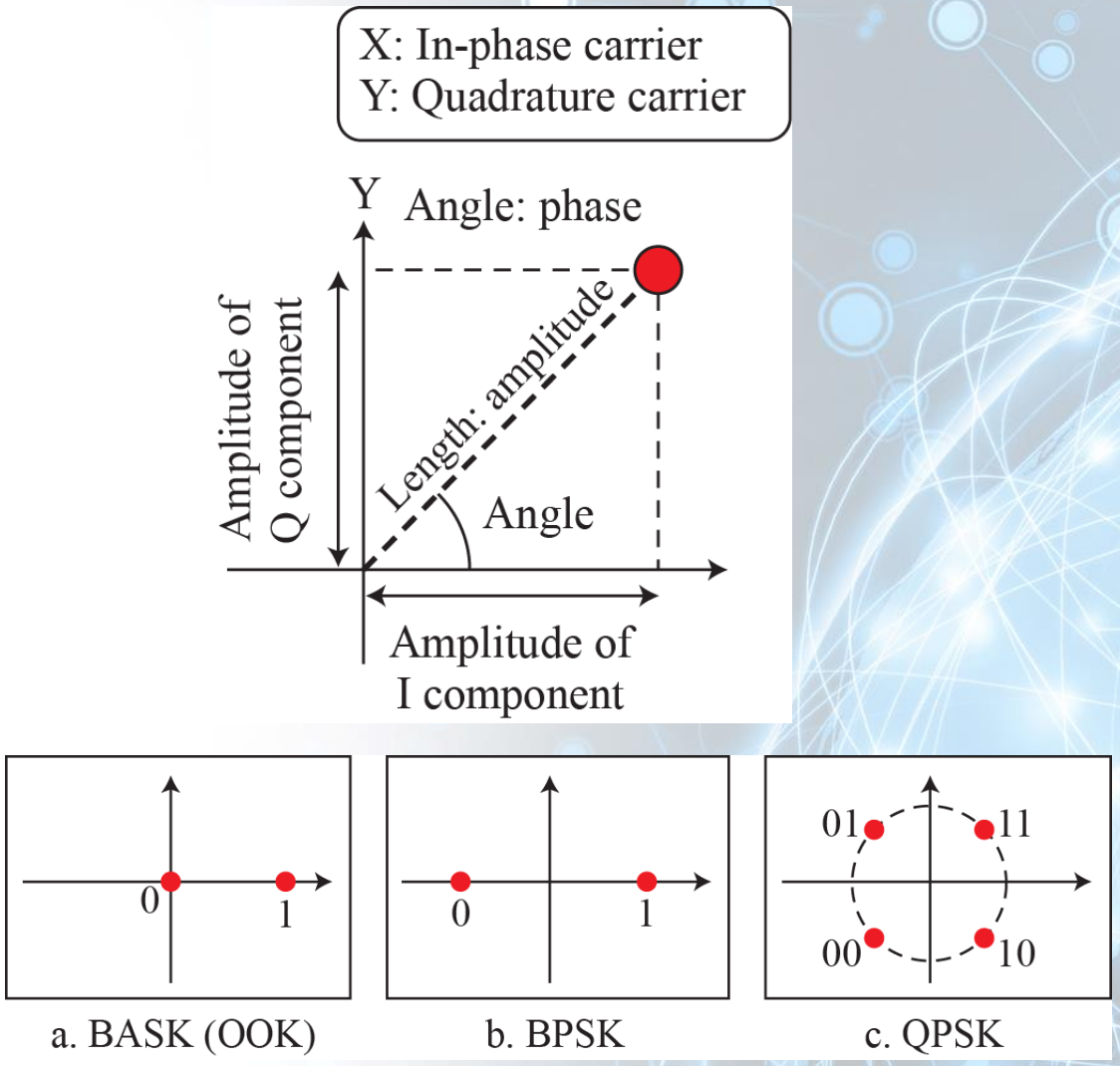
Example

Find the bandwidth for a signal transmitting at 12 Mbps for QPSK. The value of d = 0.

Constellation Diagram

- Helps us define the phase and amplitude of a signal element when we are using two carriers (one in phase and other in quadrature)
- Signal element is represented as a dot

Constellation Diagram



a. BASK (OOK)

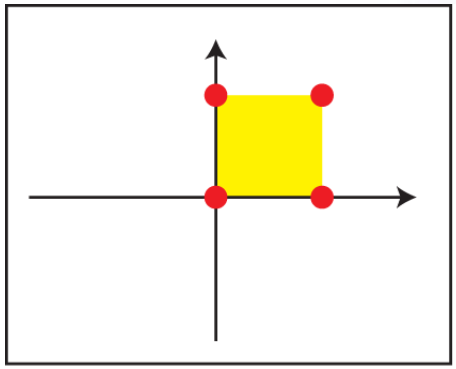
b. BPSK

c. QPSK

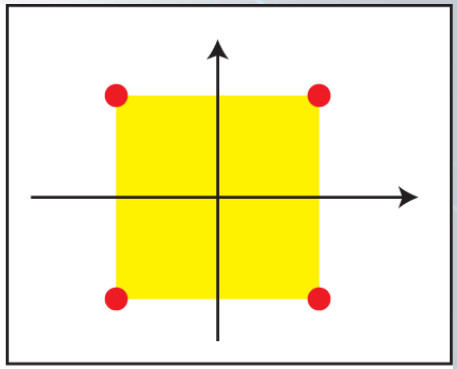
Quadrature Amplitude Modulation (QAM)

- PSK is limited by the ability of the equipment to distinguish small differences in phase which limits its potential bit rate
- We have been altering only one of the three characteristics of a sine wave at a time; but what if we alter two?
- Why not combine ASK and PSK?

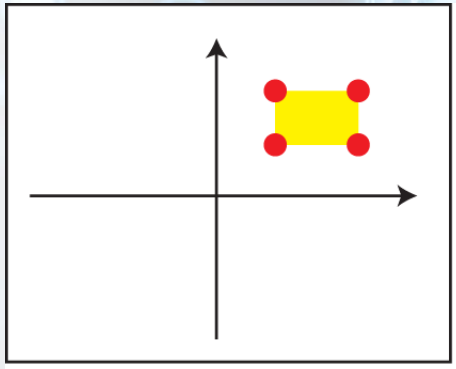
Constellation diagrams for some QAMs



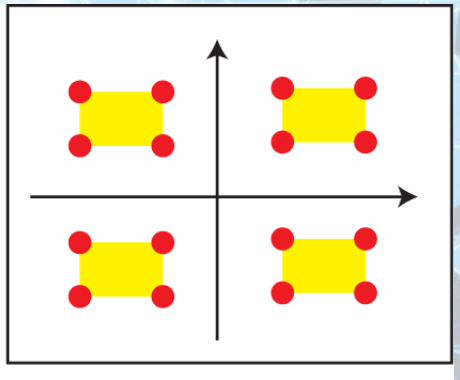
a. 4-QAM



b. 4-QAM



c. 4-QAM

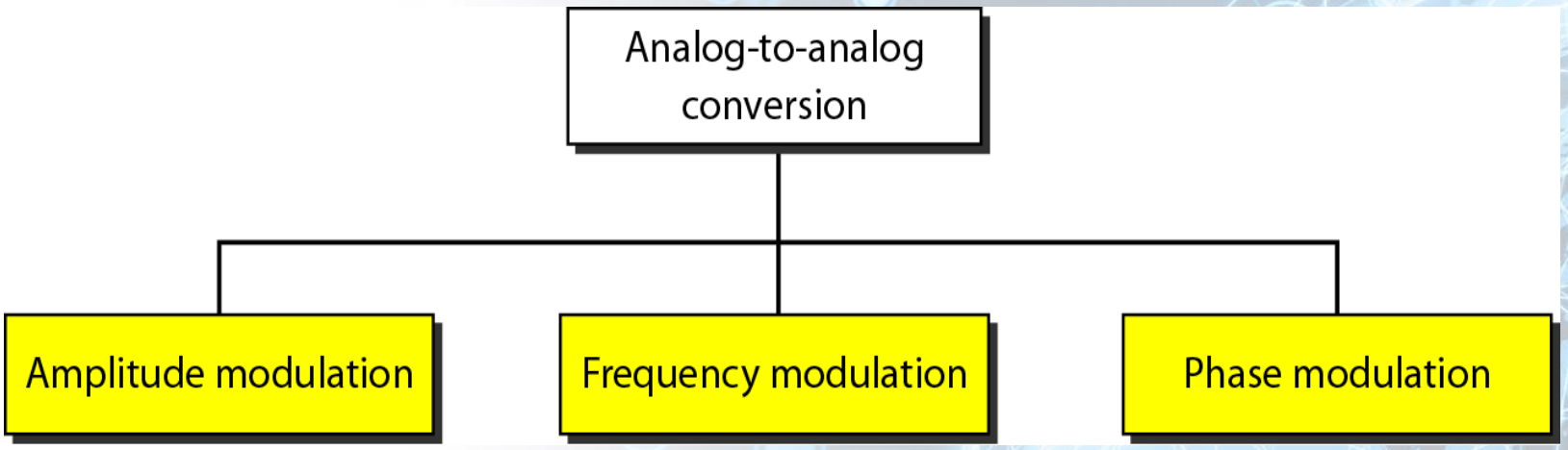


d. 16-QAM

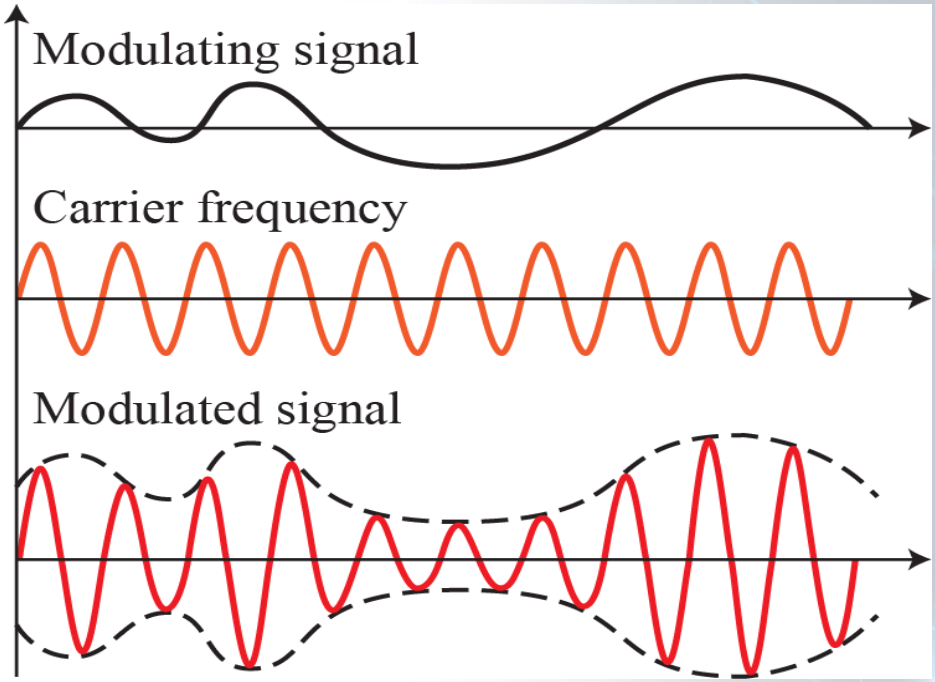
Analog-to-Analog Conversion

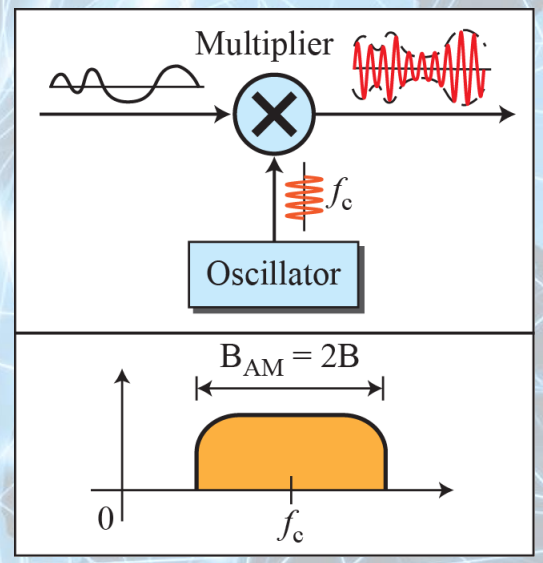
- Representation of Analog information by an Analog signal
- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Phase Modulation (PM)

Types of Analog-to-Analog Modulation

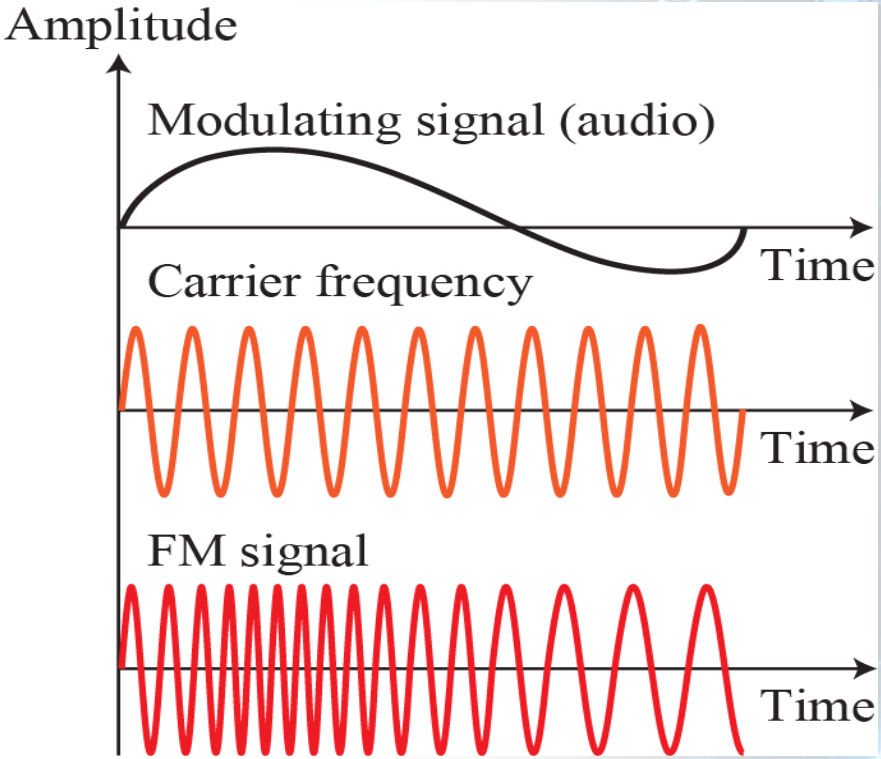


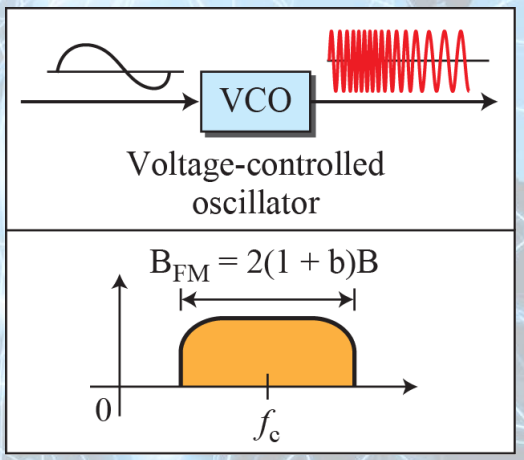
Amplitude modulation





Frequency Modulation





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Phase Modulation