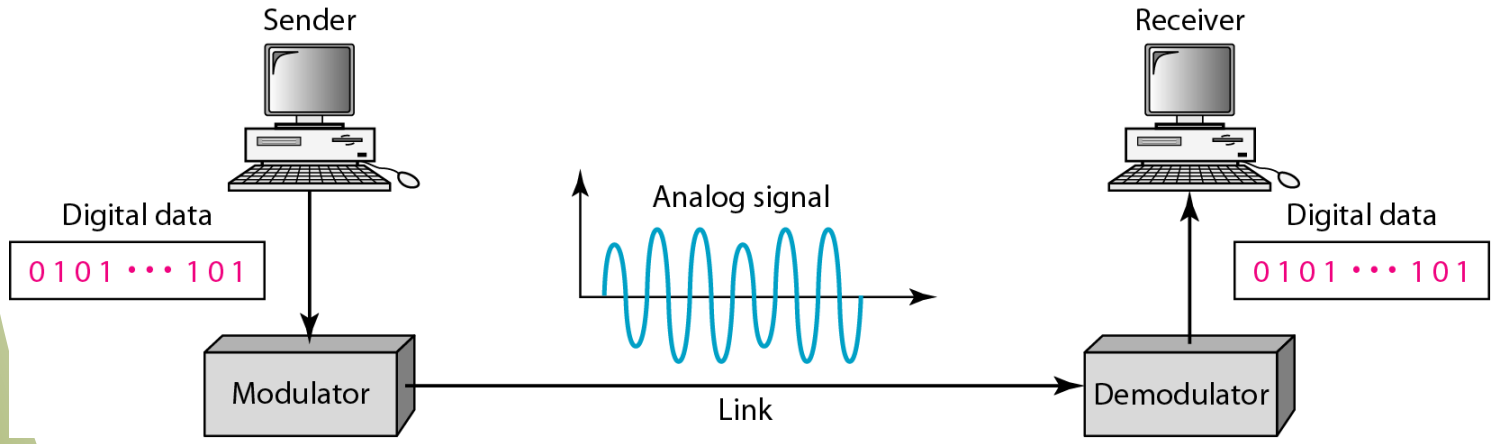
Chapter 5. Analog Transmission

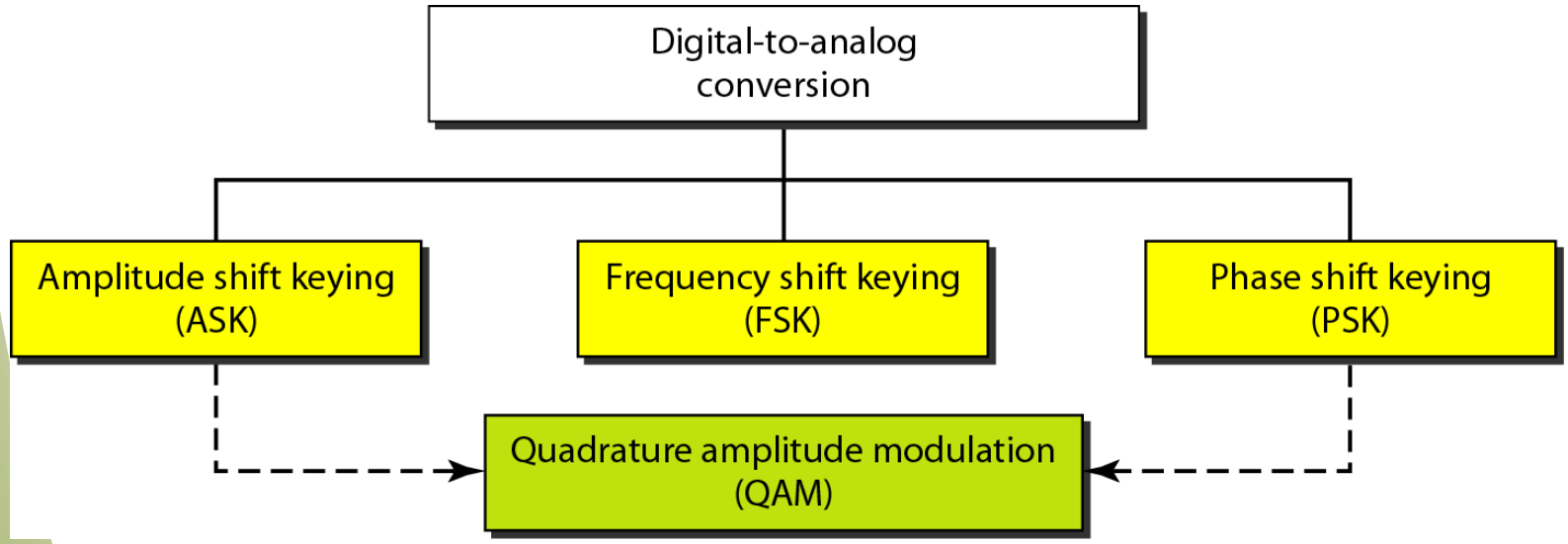
1. Digital-to-Analog Conversion
2. Analog-to-Analog Conversion

Digital-to-Analog Conversion

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



Types of Digital-to-Analog Modulation



Aspects of D/A Conversion

- Data element versus signal element
- Data rate (bit rate) versus signal rate (baud rate)
  - $S = N \times 1/r$ baud

    S (signal rate), N (data rate),

    r (number of data element in one signal element)
  - Bit rate: bits per second (in bps)
  - Baud rate: signal elements per second (in baud)
  - Bit rate ≥ baud rate
- Carrier signal (carrier frequency)
  - High-frequency signal used to modulate the information
  - Modulated signal: information modulated by the carrier signal

Examples 5.2

- 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?

Solution

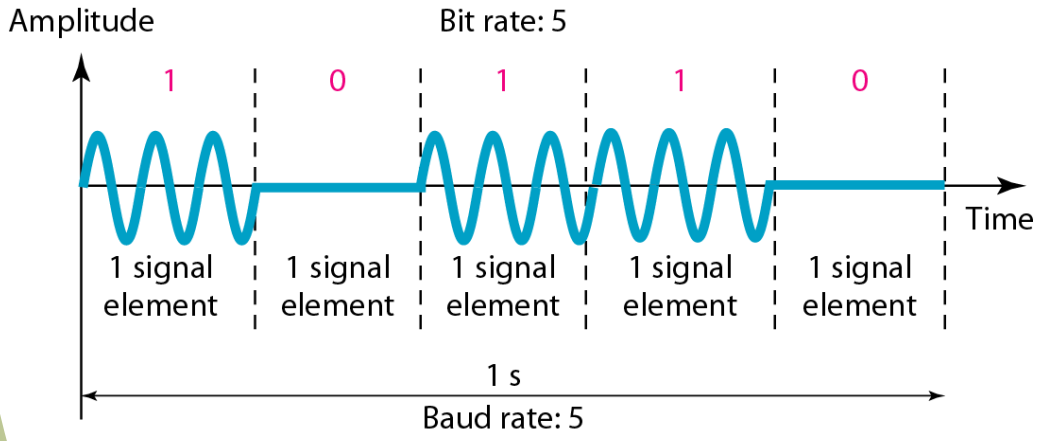
S = 1000, N = 8000, and r and L are unknown. We find first the value of r and then the value of L.

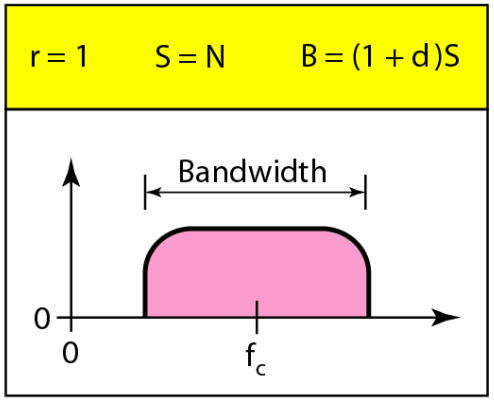
$$S = N \times \frac{1}{r} \rightarrow r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/baud}$$

$$r = \log_2 L \rightarrow L = 2^r = 2^8 = 256$$

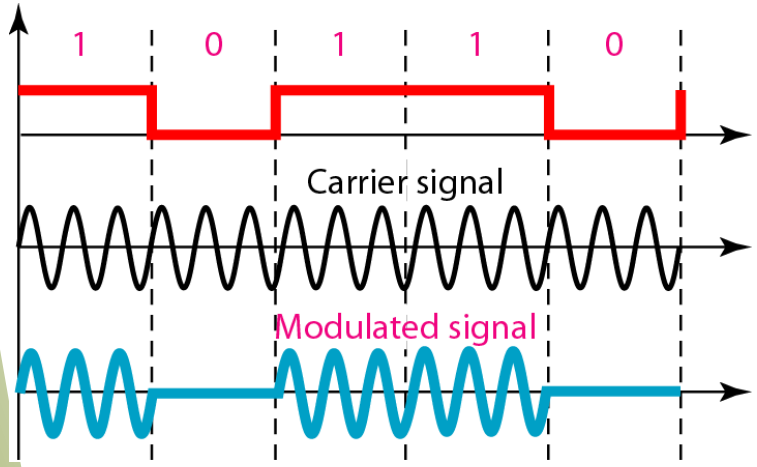
ASK : Binary ASK

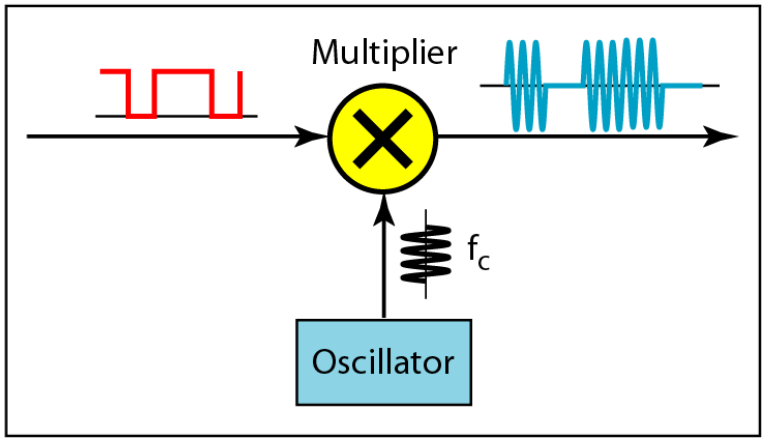
- BASK or OOK (on-off keying)
- Bandwidth for ASK: B = (1 + d) x S





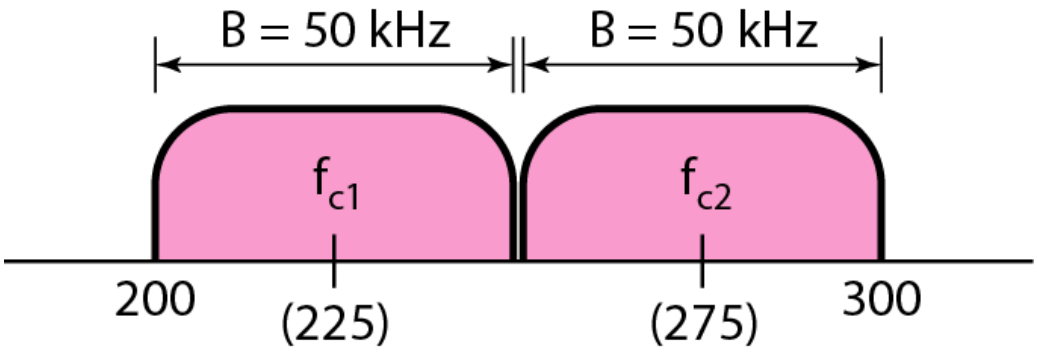
Implementation of Binary ASK





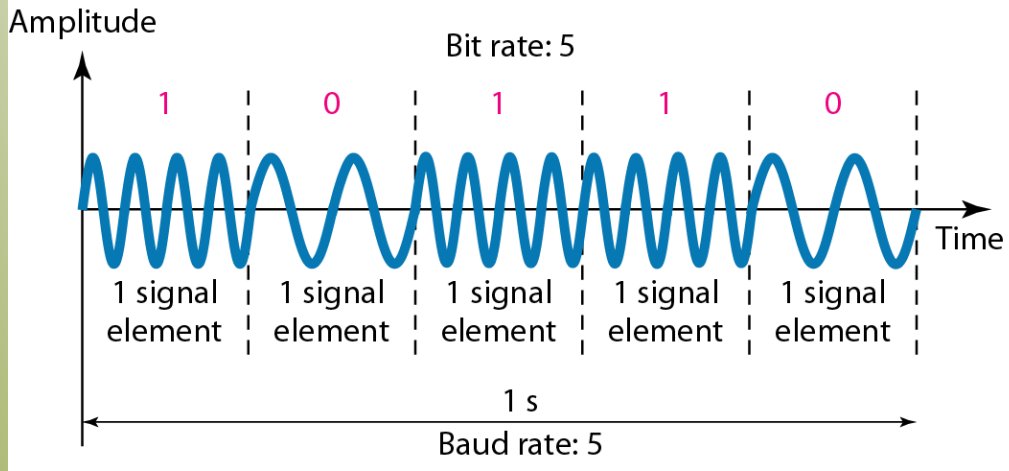
Full-duplex ASK: Example

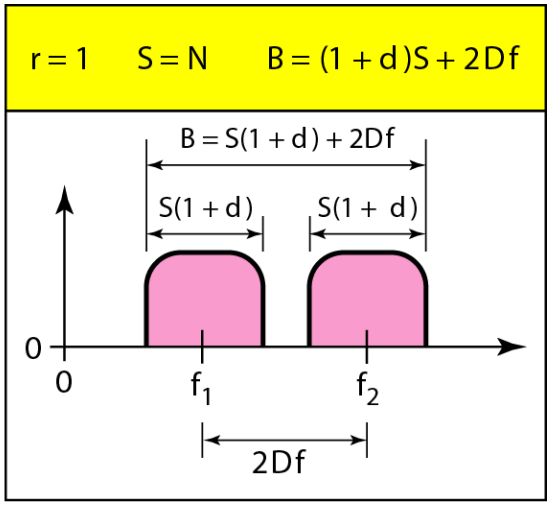
- In data communications, we normally use full-duplex links with communication in both directions. We need to divide the bandwidth into two with two carrier frequencies. In this example, the available bandwidth for each direction is now 50 kHz, which leaves us with a data rate of 25 kbps in each direction.



FSK: Binary FSK

- Bandwidth for ASK: B = (1 + d) x S + 2Δf





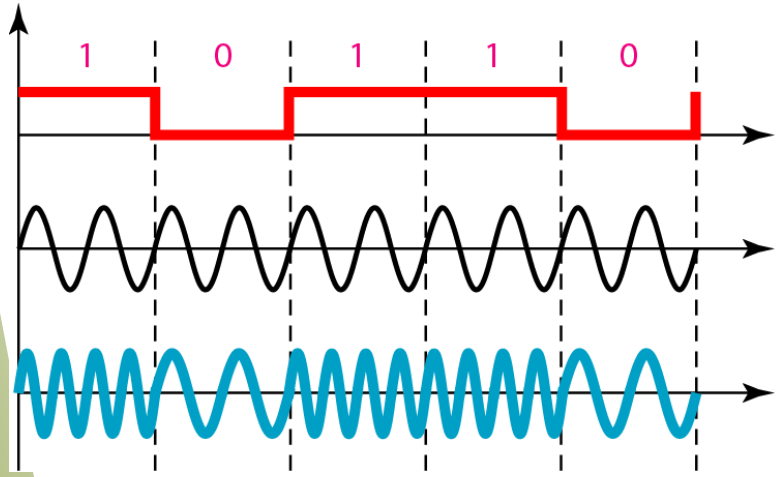
BFSK: Example

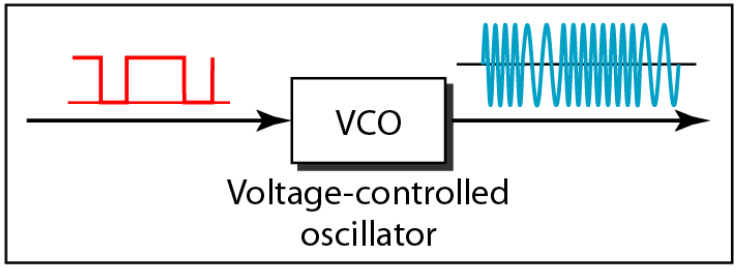
- We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?

The midpoint of the band is at 250 kHz. We choose 2Δf to be 50 kHz; this means

$$B = (1 + d) \times S + 2\Delta f = 100 \rightarrow 2S = 50 \text{ kHz} \quad S = 25 \text{ kbaud} \quad N = 25 \text{ kbps}$$

Implementation of Binary FSK

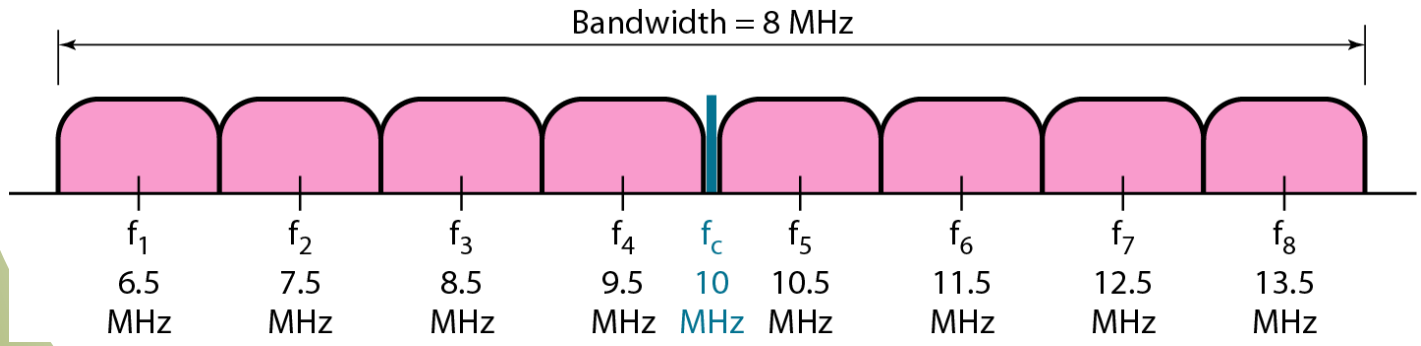




Multilevel FSK

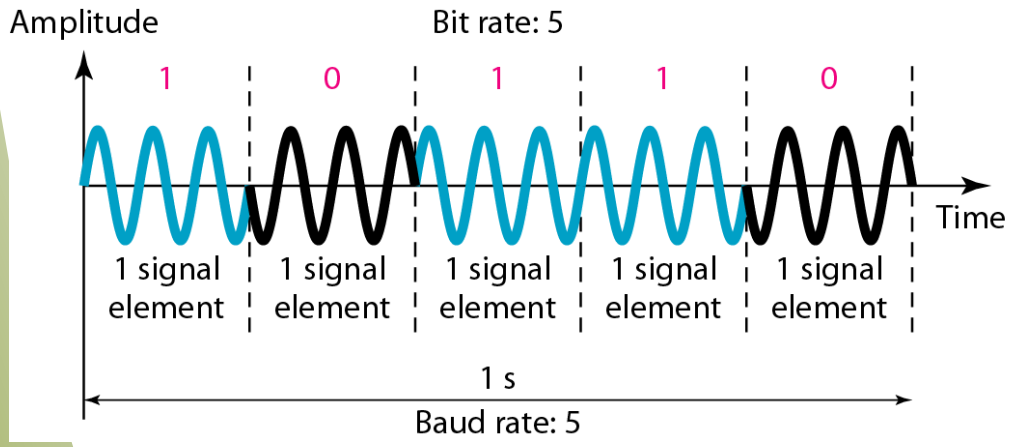
- The frequencies need to be $2\Delta f$ apart. Min. value $2\Delta f$ needs to be S.
- $B = (1 + d) \times S + (L - 1)\, 2\Delta f \rightarrow B = L \times S$ with $d = 0$
- Example: We need to send data 3 bits at a time at a bit rate of 3 Mbps. The carrier frequency is 10 MHz. Calculate the number of levels (different frequencies), the baud rate, and the bandwidth

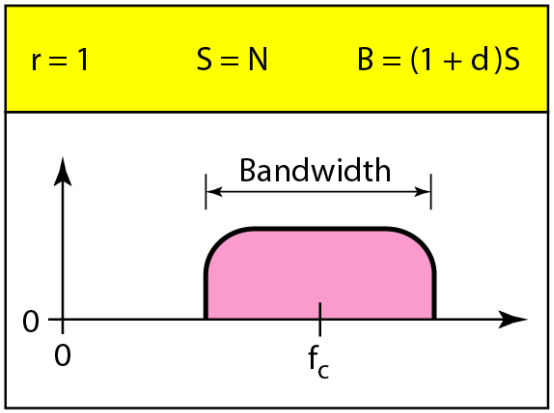
  $L = 2^3 = 8$. The baud rate is $S = 3$ MHz/3 = 1000 Mbaud. This means that the carrier frequencies must be 1 MHz apart ($2\Delta f = 1$ MHz). The bandwidth is $B = 8 \times 1000 = 8000$.



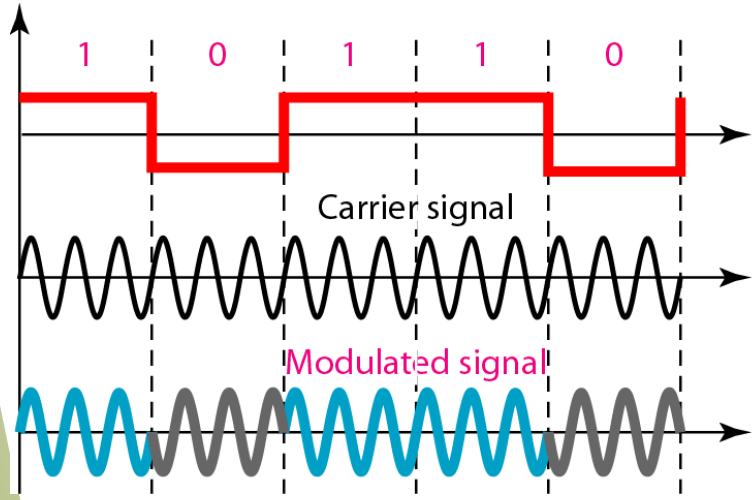
PSK: Binary PSK

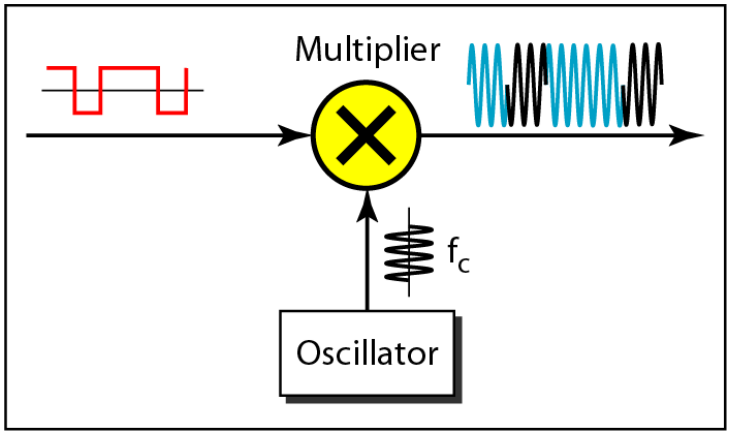
- Bandwidth : the same as BASK, B = (1 + d) x S
- Less than that for BFSK



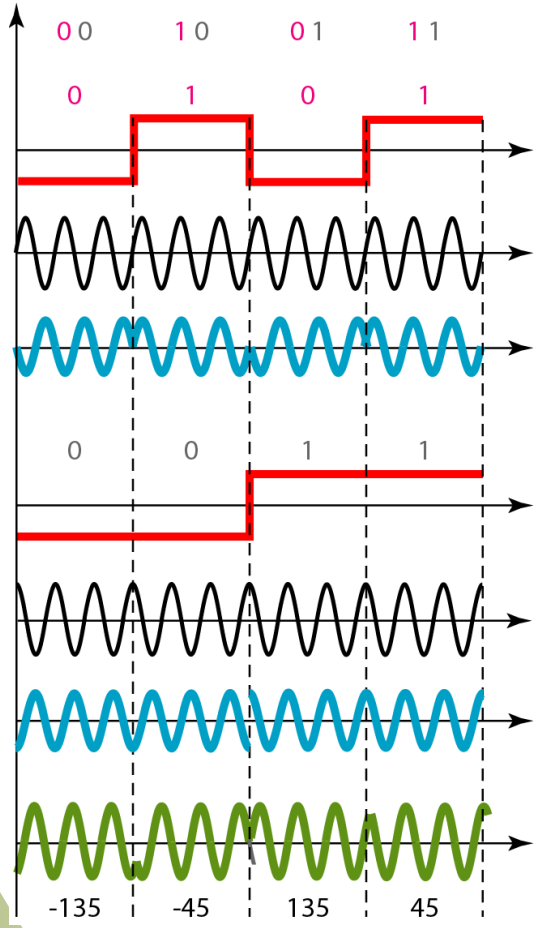


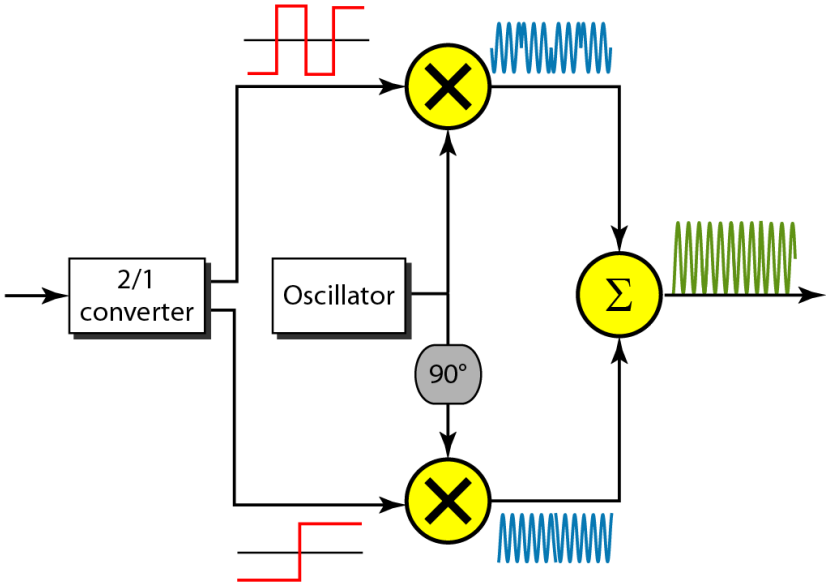
Implementation of Binary PSK





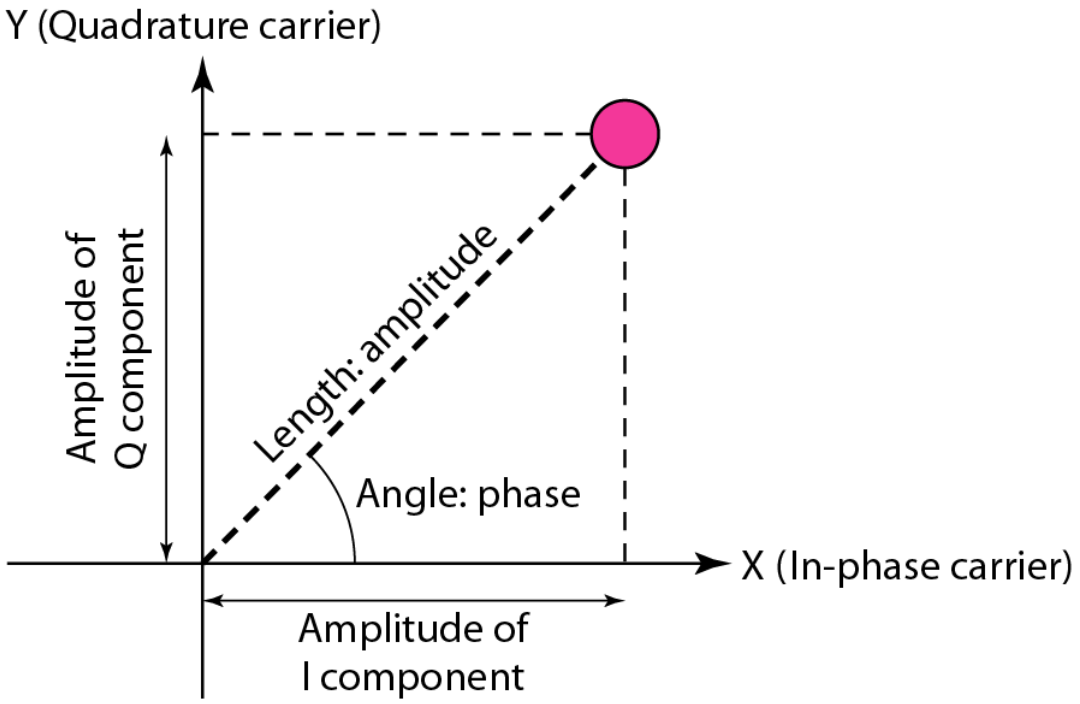
Quadrature PSK



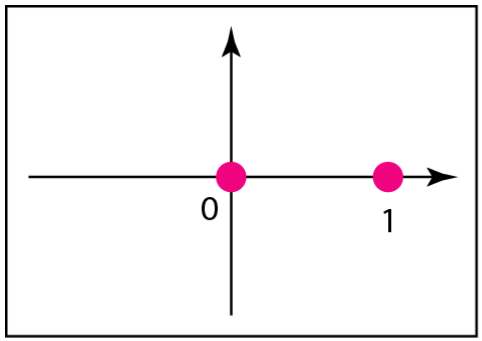


Constellation Diagram

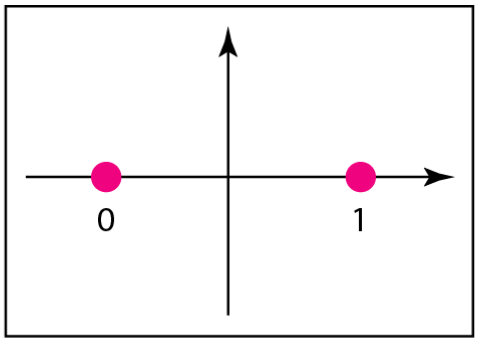
- Define the amplitude and phase of a signal element



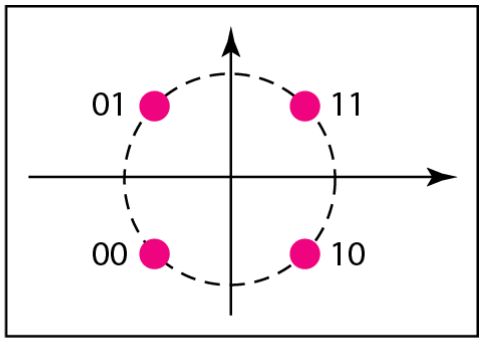
Constellation Diagram: Examples



a. ASK (OOK)



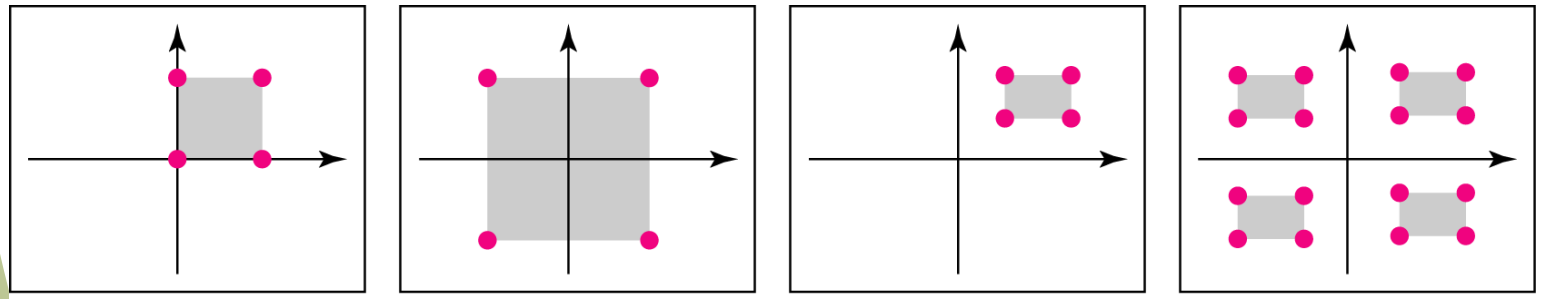
b. BPSK



c. QPSK

QAM

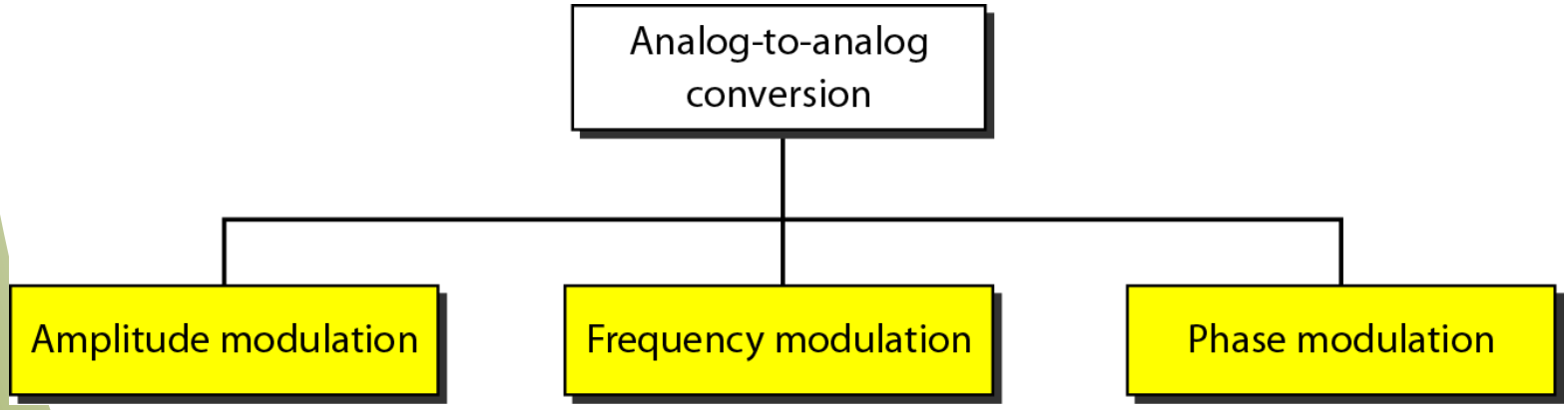
- Quadrature amplitude modulation
- Combination of ASK and PSK
- Bandwidth : the same as that required for ASK and PSK



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

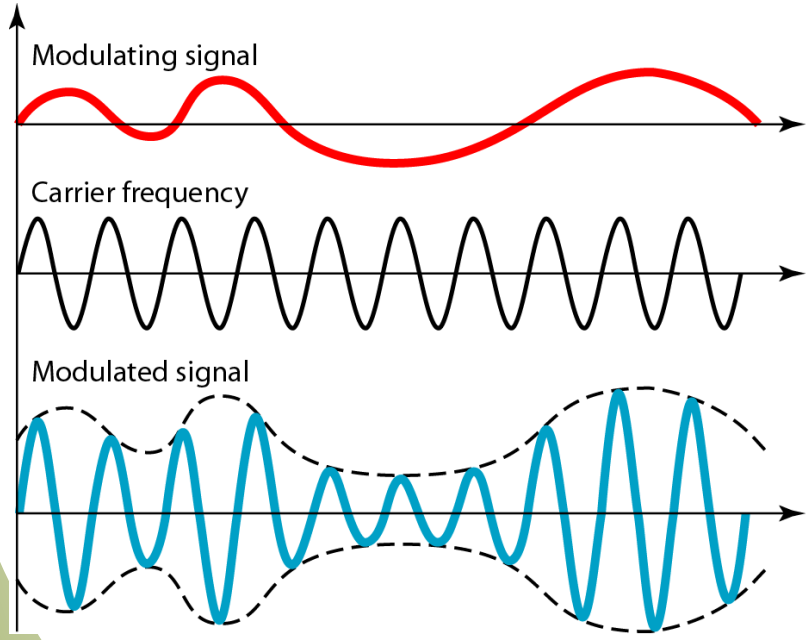
Analog-to-Analog Modulation

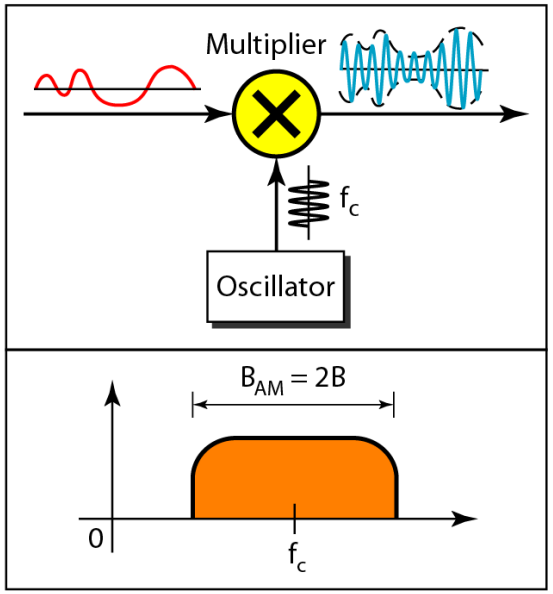
- Analog-to-analog conversion is the representation of analog information by an analog signal
- Modulation is needed if the medium is bandpass in nature or if only a bandpass channel is available to us



Amplitude Modulation

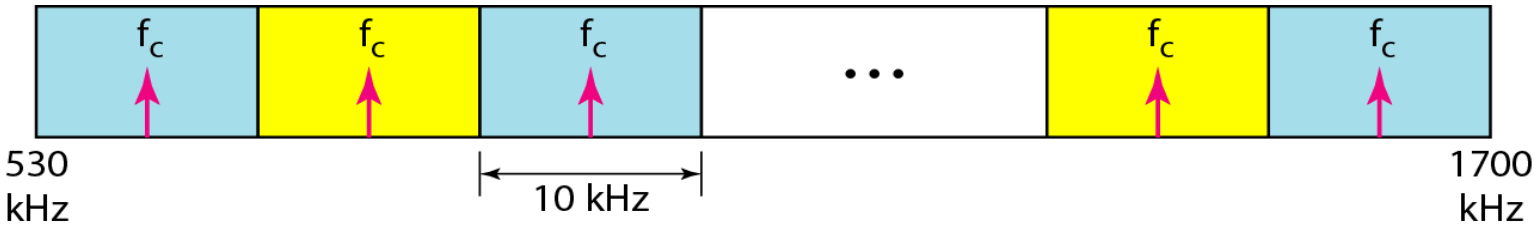
- The total bandwidth required for AM can be determined from the bandwidth of the audio signal: $B_{AM} = 2B$.





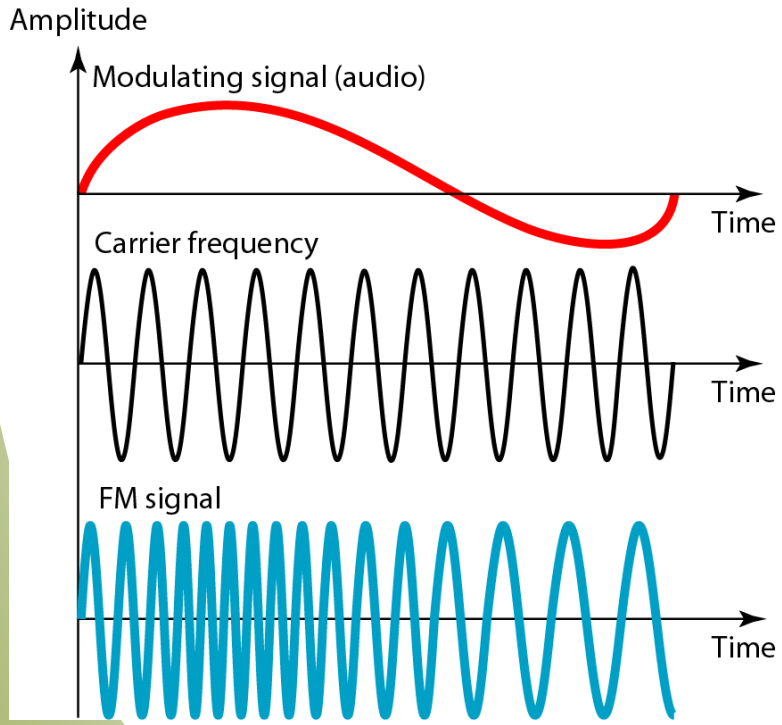
AM Band Allocation

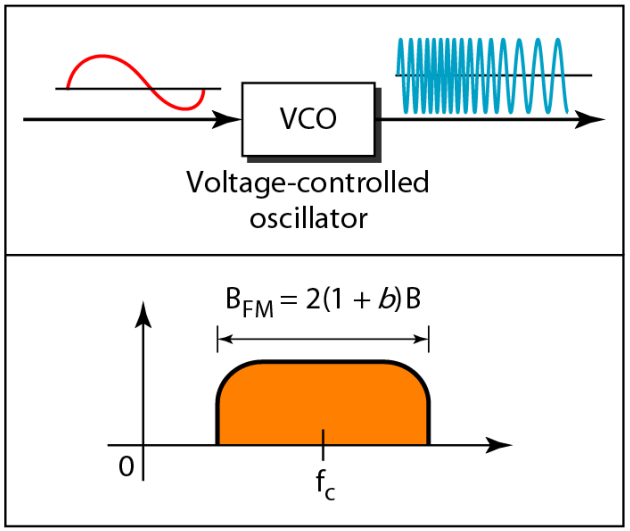
- Bandwidth of an audio signal (speech and music) is usually 5 kHz



Frequency Modulation

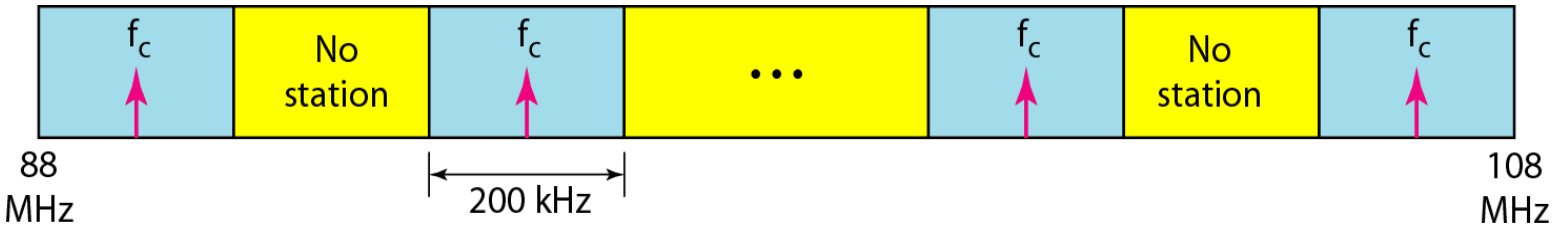
- The total bandwidth required for FM can be determined from the bandwidth of the audio signal: $B_{FM} = 2(1 + \beta)B$.





FM Band Allocation

- Bandwidth of an audio signal (speech and music) broadcast in stereo is almost 15 kH
- FCC allows 200 kHz for each station (β =4 with some extra guard band)
- Separated by at least 200 kHz



Phase Modulation

- The total bandwidth required for PM can be determined from the bandwidth and maximum amplitude of the modulating signal: $B_{PM} = 2(1 + \beta)B$.