## **Analog Transmission**

#### 5-1 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.

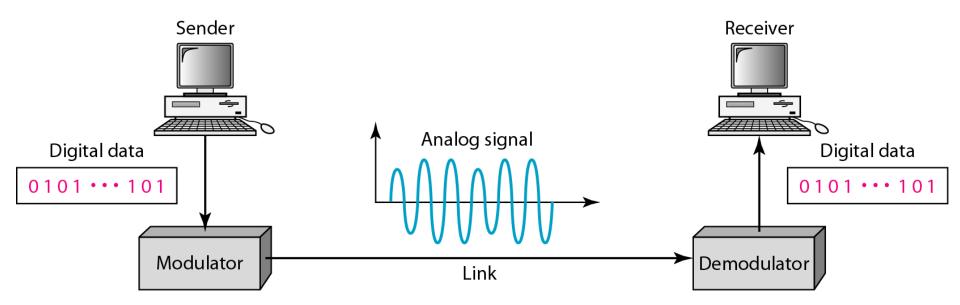
#### Topics discussed in this section:

- Aspects of Digital-to-Analog Conversion
- Amplitude Shift Keying
- Frequency Shift Keying
- Phase Shift Keying
- Quadrature Amplitude Modulation

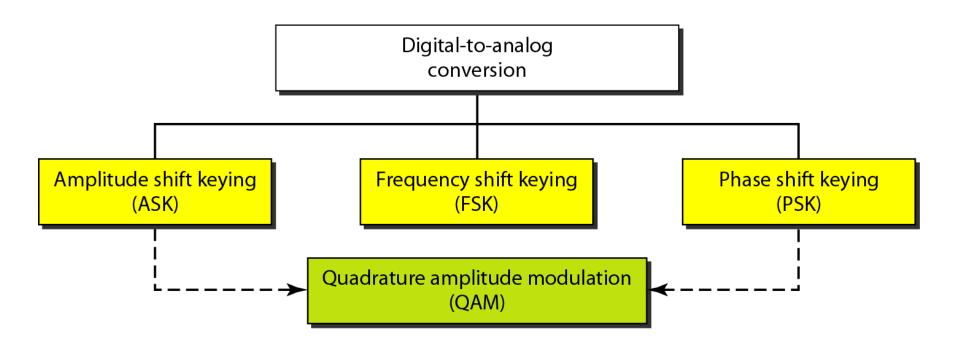
# Digital to Analog Conversion

- Digital data needs to be carried on an analog signal.
- A carrier signal (frequency f<sub>c</sub>) performs the function of transporting the digital data in an analog waveform.
- The analog carrier signal is manipulated to uniquely identify the digital data being carried.

#### Figure 5.1 Digital-to-analog conversion



#### Figure 5.2 Types of digital-to-analog conversion





Bit rate, N, is the number of bits per second (bps). Baud rate is the number of signal elements per second (bauds). In the analog transmission of digital data, the signal or baud rate is less than or equal to the bit rate. S=Nx1/r bauds Where r is the number of data bits per signal element.

### Example 5.1

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

#### Solution

In this case, r = 4, S = 1000, and N is unknown. We can find the value of N from

$$S = N \times \frac{1}{r}$$
 or  $N = S \times r = 1000 \times 4 = 4000 \text{ bps}$ 

### Example 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**

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

$$S = N \times \frac{1}{r}$$
  $\longrightarrow$   $r = \frac{N}{S} = \frac{8000}{1000} = 8$  bits/baud  
 $r = \log_2 L$   $\longrightarrow$   $L = 2^r = 2^8 = 256$ 

# Amplitude Shift Keying (ASK)

- ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal.
- For example: a digital "1" could not affect the signal, whereas a digital "0" would, by making it zero.
- The line encoding will determine the values of the analog waveform to reflect the digital data being carried.

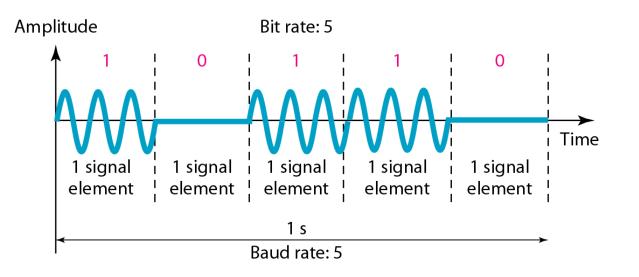
### Bandwidth of ASK

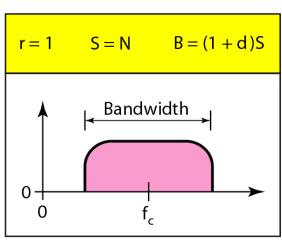
 The bandwidth B of ASK is proportional to the signal rate S.

$$B = (1+d)S$$

"d" is due to modulation and filtering, lies between 0 and 1.

#### Figure 5.3 Binary amplitude shift keying

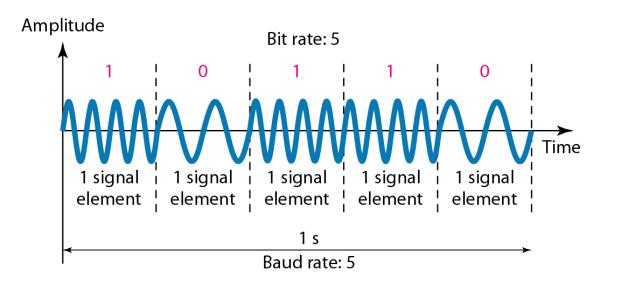


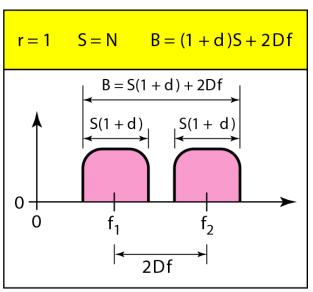


# Frequency Shift Keying

- The digital data stream changes the frequency of the carrier signal, f<sub>c</sub>.
- For example, a "1" could be represented by  $f_1=f_c+\Delta f$ , and a "0" could be represented by  $f_2=f_c-\Delta f$ .

#### Figure 5.6 Binary frequency shift keying





### Bandwidth of FSK

If the difference between the two frequencies ( $f_1$  and  $f_2$ ) is 2∆f, then the required BW B will be:

$$B = (1+d)xS + 2\Delta f$$

### Example 5.5

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?

#### Solution

This problem is similar to Example 5.3, but we are modulating by using FSK. The midpoint of the band is at 250 kHz. We choose  $2\Delta f$  to be 50 kHz; this means

 $B = (1+d) \times S + 2\Delta f = 100$   $\longrightarrow$  2S = 50 kHz S = 25 kbaud N = 25 kbps

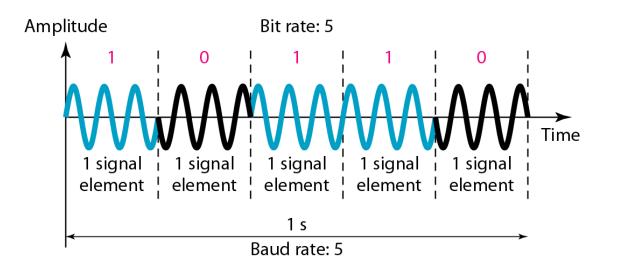
# Phase Shift Keyeing

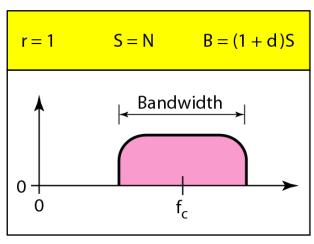
- We vary the phase shift of the carrier signal to represent digital data.
- The bandwidth requirement, B is:

$$B = (1+d)xS$$

PSK is much more robust than ASK as it is not that vulnerable to noise, which changes amplitude of the signal.

#### Figure 5.9 Binary phase shift keying

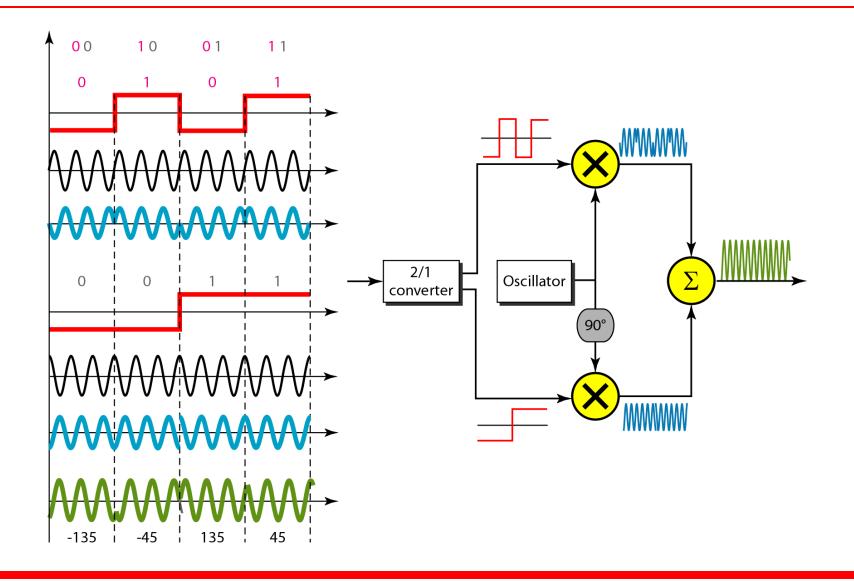




# Quadrature PSK

- To increase the bit rate, we can code 2 or more bits onto one signal element.
- In QPSK, we parallelize the bit stream so that every two incoming bits are split up and PSK a carrier frequency. One carrier frequency is phase shifted 90° from the other - in quadrature.
- The two PSKed signals are then added to produce one of 4 signal elements. L = 4 here.

#### Figure 5.11 QPSK and its implementation



Note

# Quadrature amplitude modulation is a combination of ASK and PSK.