Chapter 5

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

Figure 5.1 *Digital-to-analog conversion*

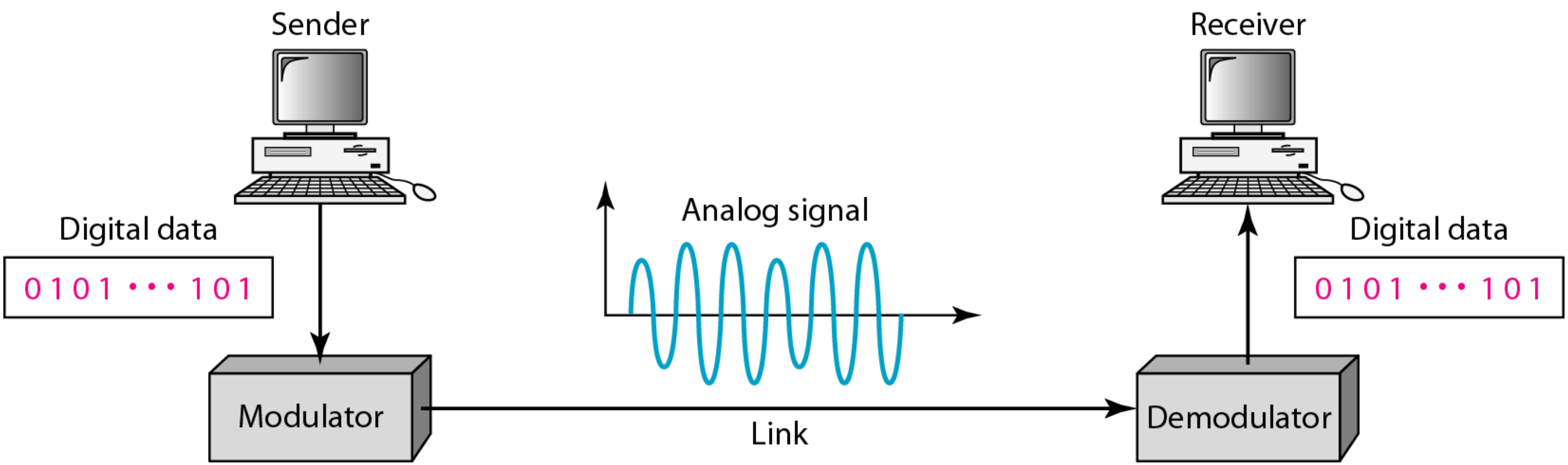
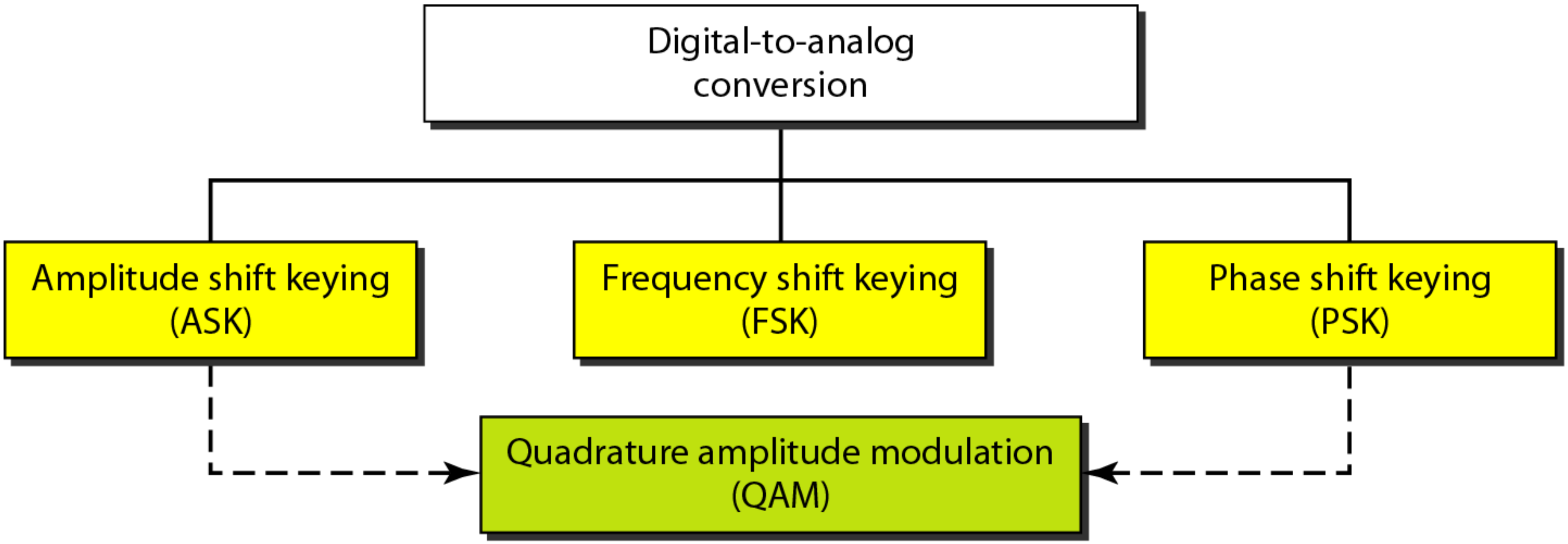


Figure 5.2 *Types of digital-to-analog conversion*



Note

**Bit rate is the number of bits per second. Baud rate is the number of signal
elements per second.**

In the analog transmission of digital data, the baud rate is less than or equal to the bit rate.

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

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

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.

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

$$r = \log_2 L \quad \Rightarrow \quad L = 2^r = 2^8 = 256$$

Figure 5.3 *Binary amplitude shift keying*

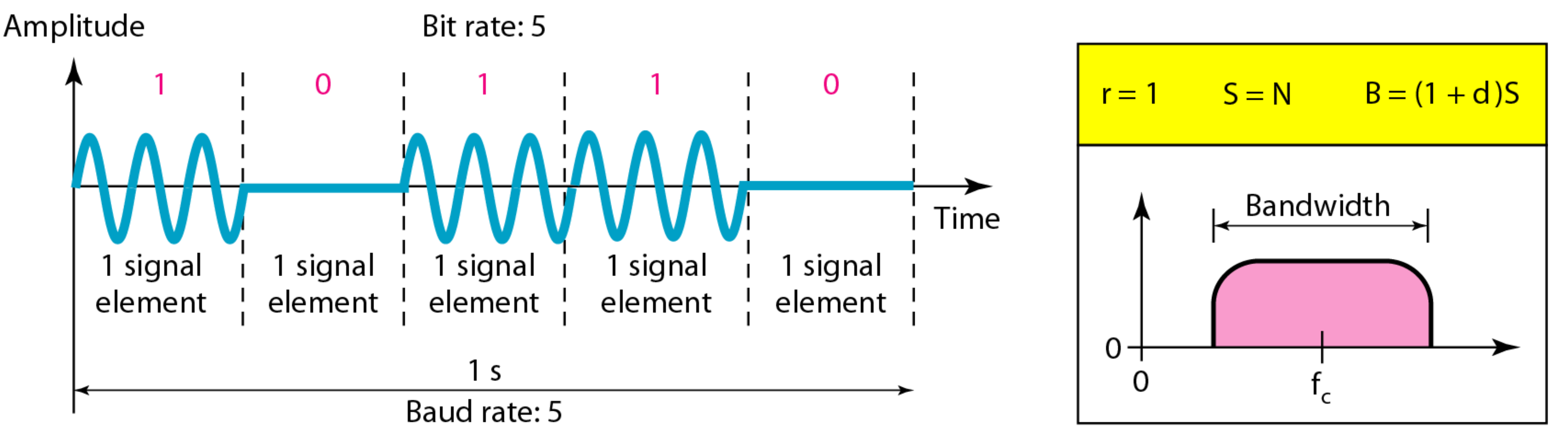
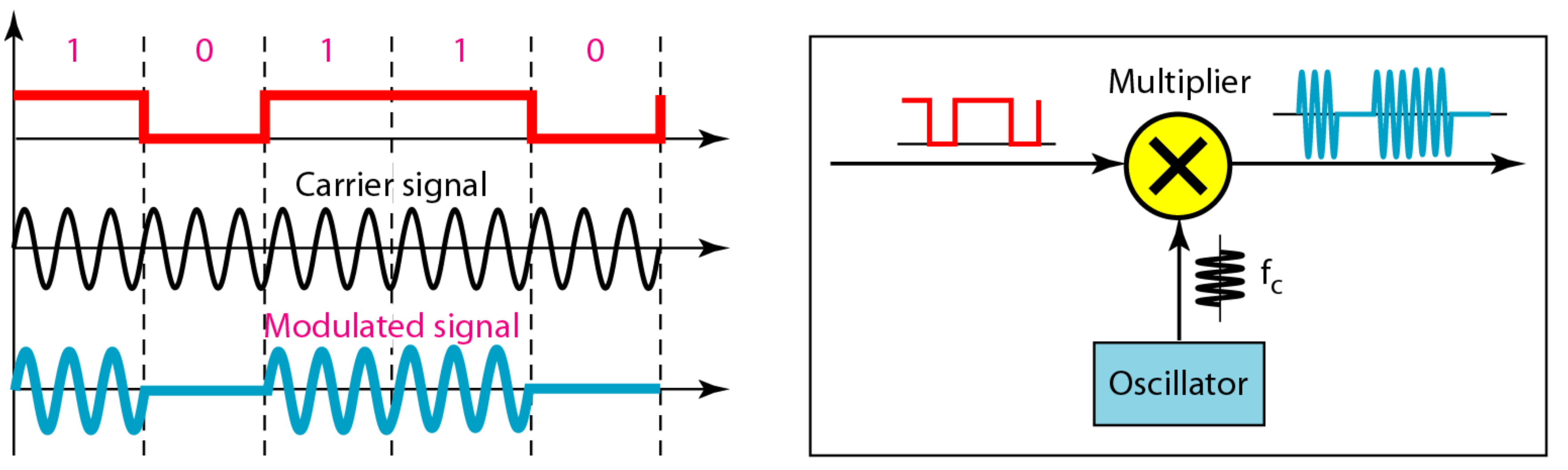


Figure 5.4 *Implementation of binary ASK*



Example 5.3

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?

Solution

The middle of the bandwidth is located at 250 kHz. This means that our carrier frequency can be at f_c = 250 kHz. We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

$$B = (1 + d) \times S = 2 \times N \times \frac{1}{r} = 2 \times N = 100 \text{ kHz} \rightarrow N = 50 \text{ kbps}$$

Figure 5.6 *Binary frequency shift keying*

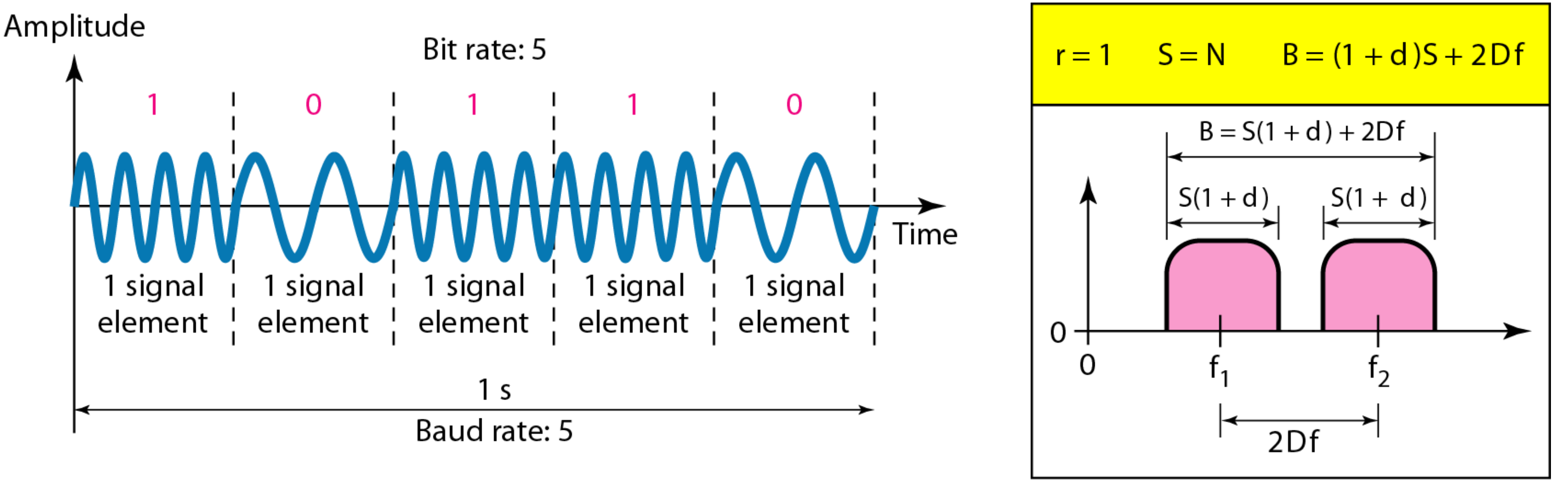
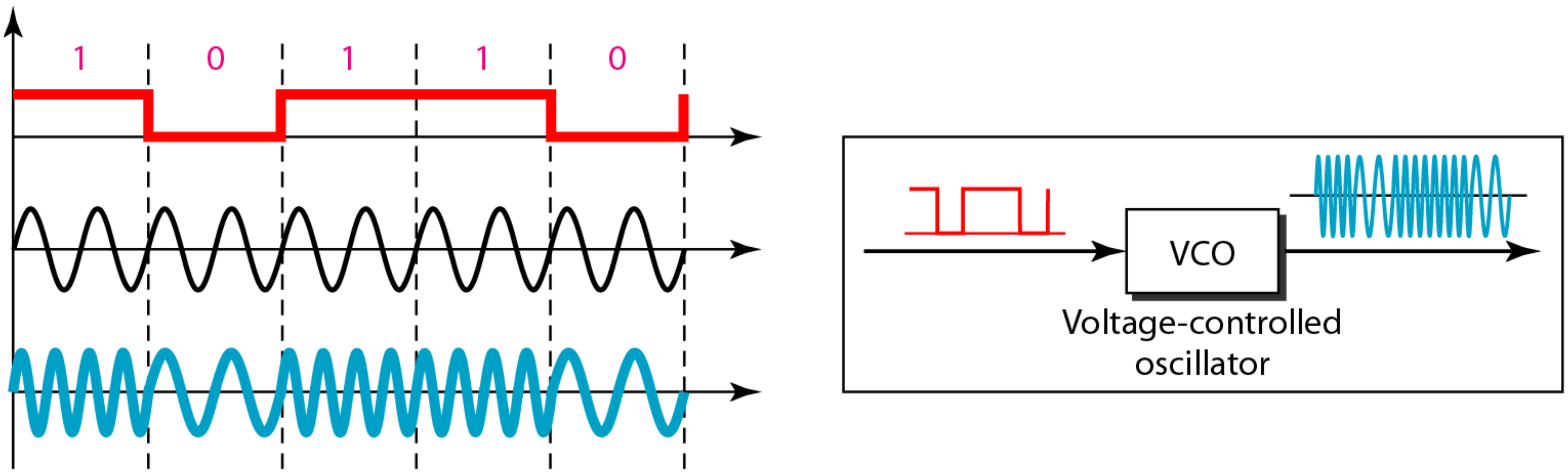


Figure 5.7 *Implementation of BFSK*



Example 5.6

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.

Solution

We can have $L = 2^3 = 8$. The baud rate is $S = 3$ Mbps/3 = 1 Mbaud. This means that the carrier frequencies must be 1 MHz apart ($2\Delta f = 1$ MHz). The bandwidth is $B = 8 \times 1$MHz = 8 MHz. Figure 5.8 shows the allocation of frequencies and bandwidth.

Figure 5.8 *Bandwidth of MFSK used in Example 5.6*

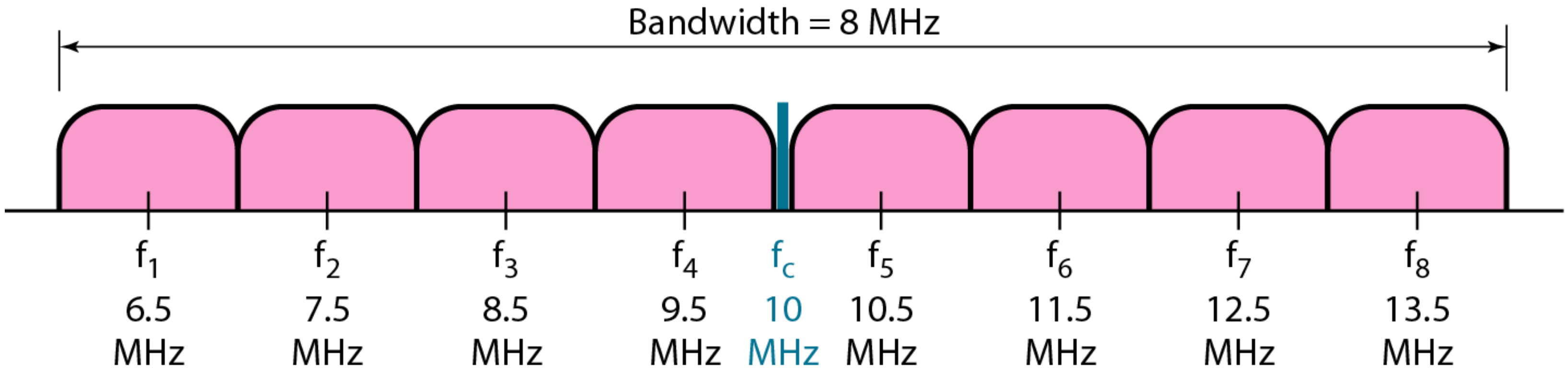


Figure 5.9 *Binary phase shift keying*

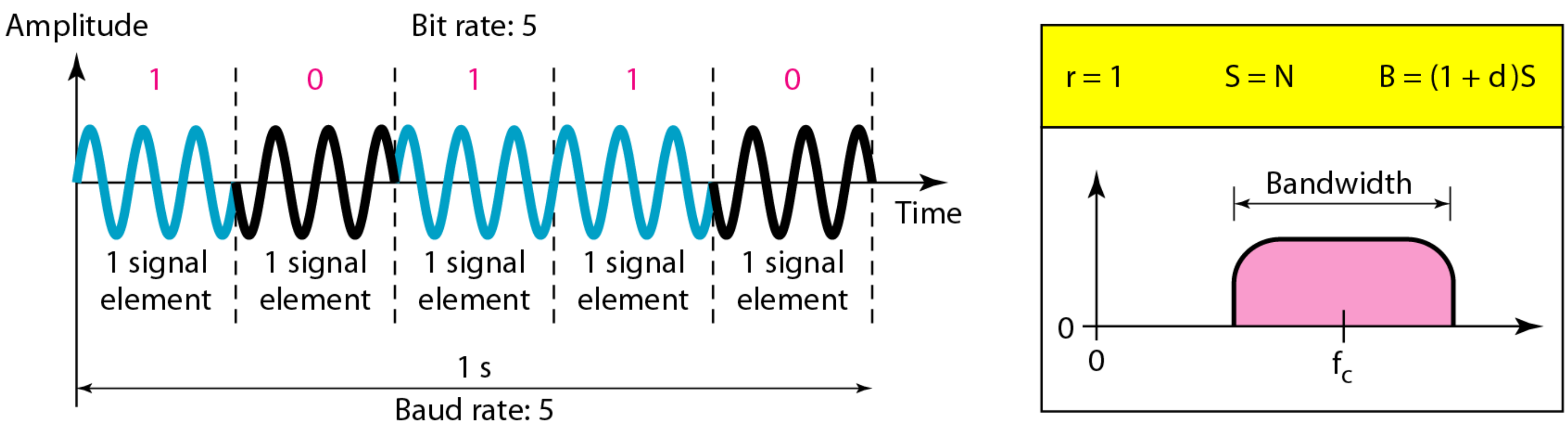


Figure 5.10 *Implementation of BPSK*

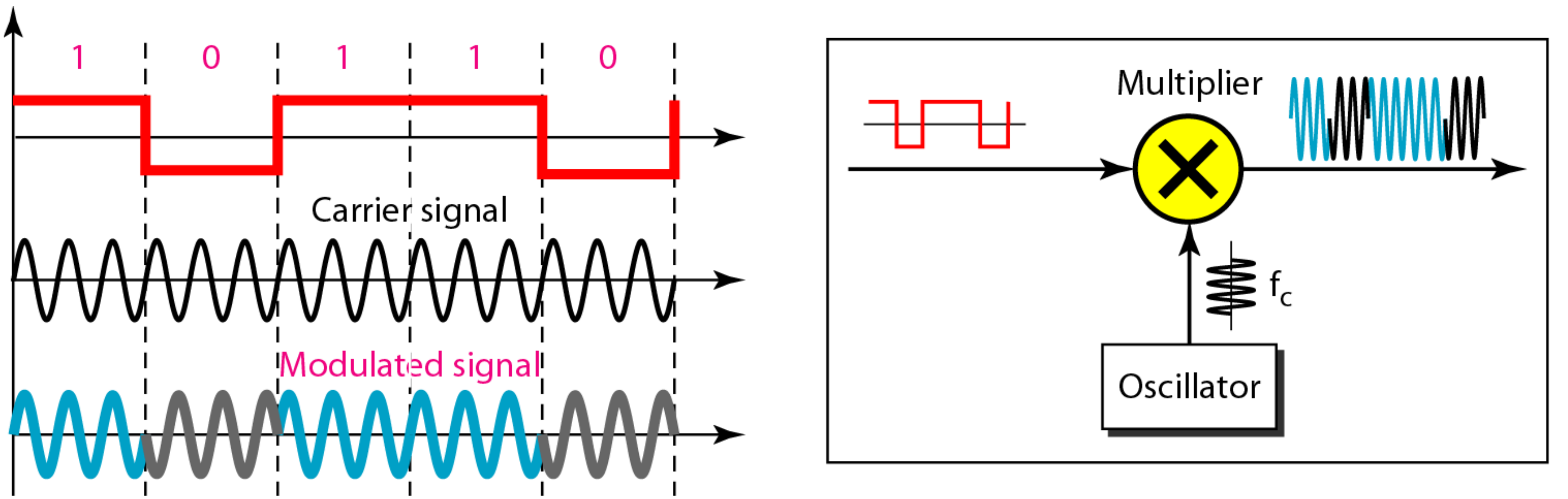


Figure 5.11 *QPSK and its implementation*

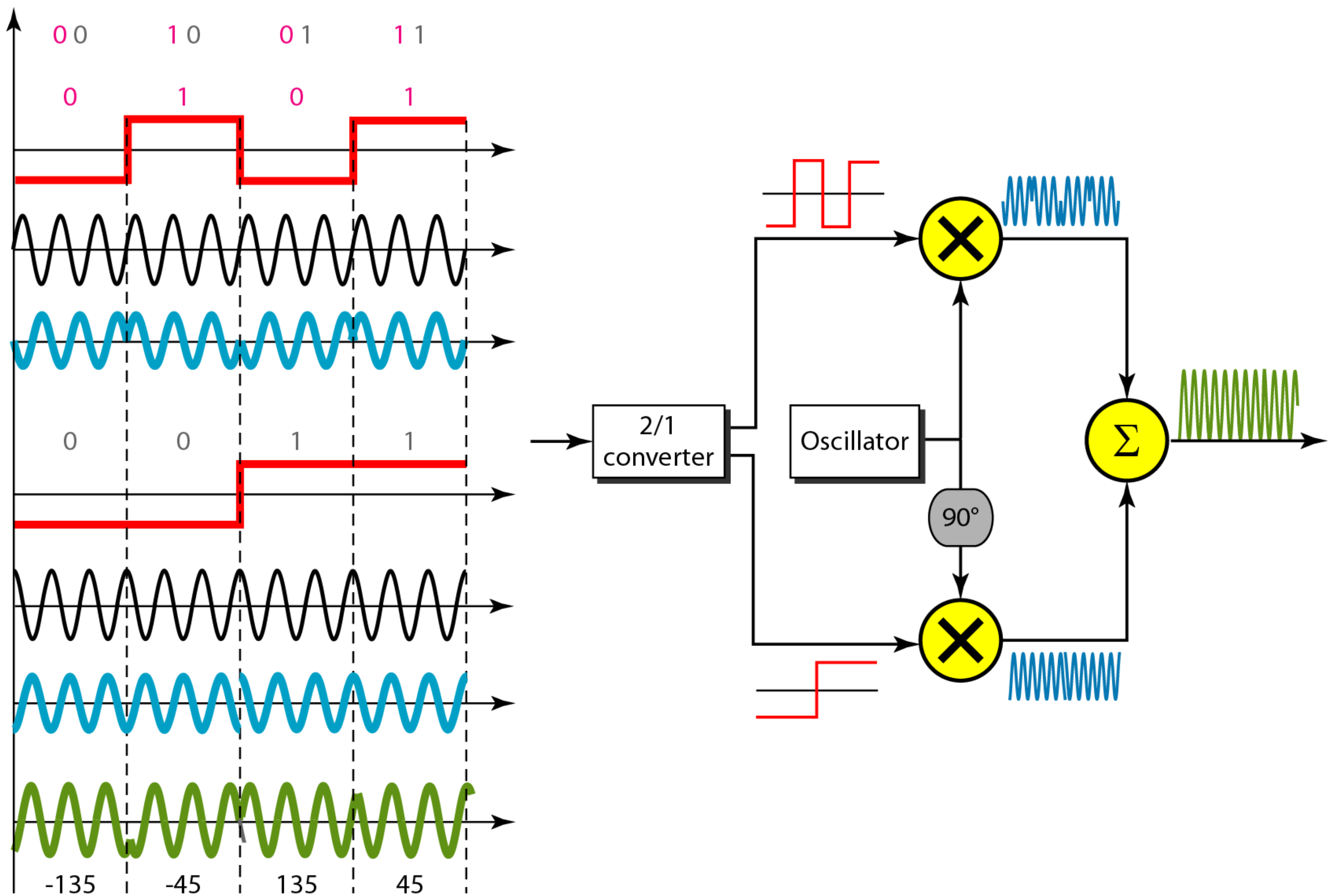
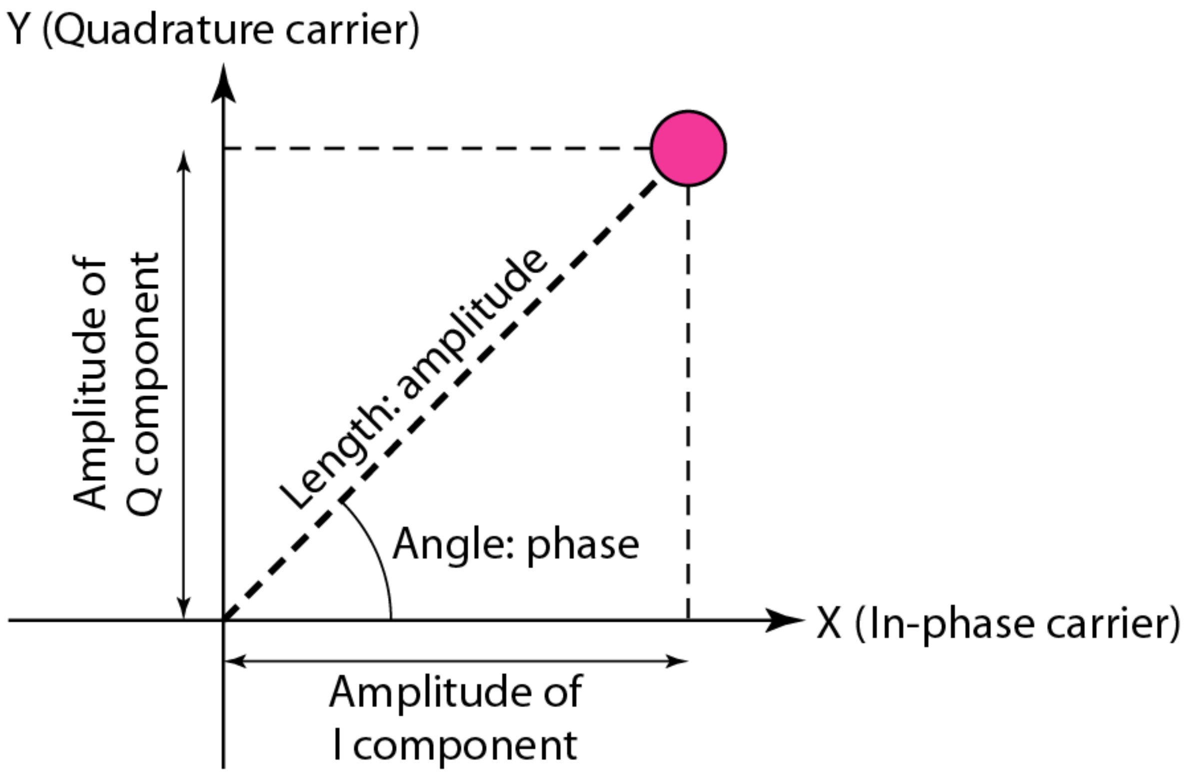


Figure 5.12 *Concept of a constellation diagram*



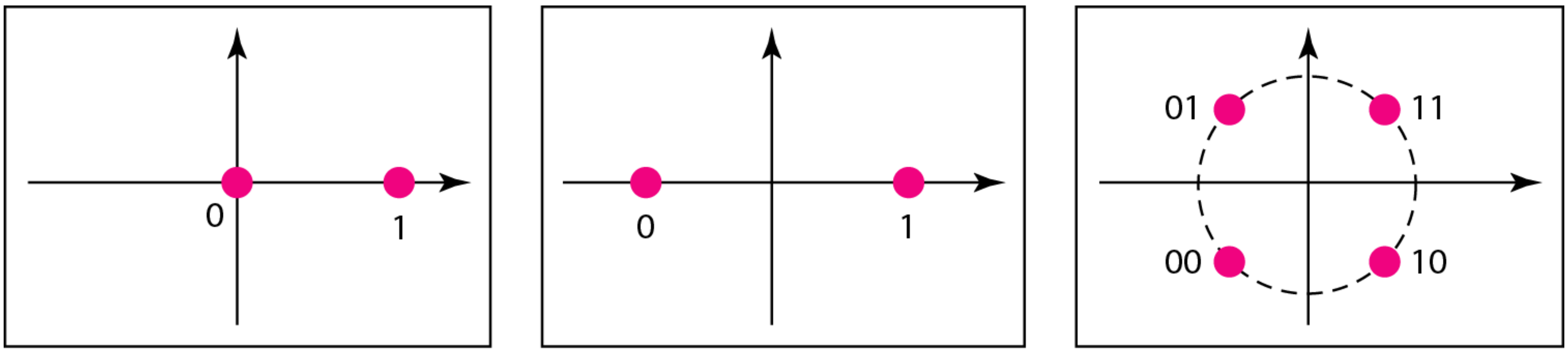
Example 5.8

Show the constellation diagrams for an ASK (OOK), BPSK, and QPSK signals.

Solution

Figure 5.13 shows the three constellation diagrams.

Figure 5.13 *Three constellation diagrams*

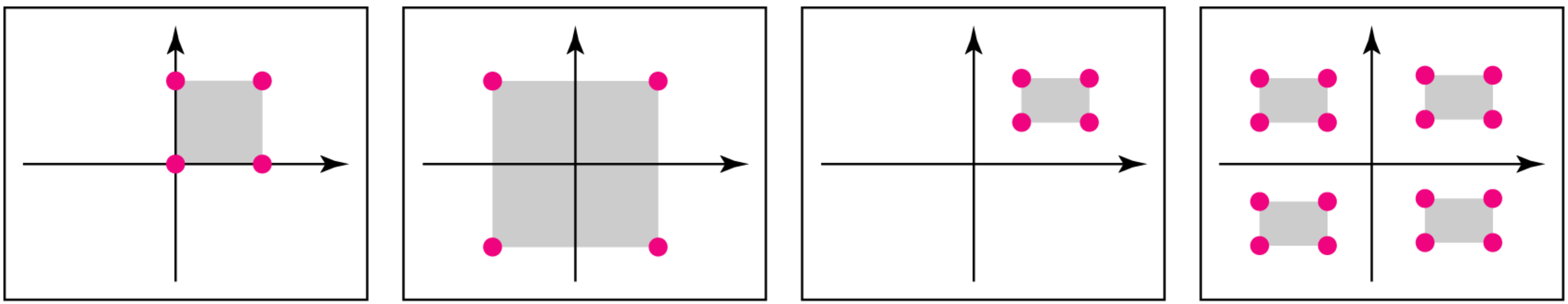


a. ASK (OOK)   b. BPSK   c. QPSK

Note

Quadrature amplitude modulation is a combination of ASK and PSK.

Figure 5.14 *Constellation diagrams for some QAMs*



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

5-2 ANALOG-TO-ANALOG CONVERSION

Analog-to-analog conversion is the representation of analog information by an analog signal. One may ask why we need to modulate an analog signal; it is already analog. Modulation is needed if the medium is bandpass in nature or if only a bandpass channel is available to us.

Topics discussed in this section:

Amplitude Modulation
Frequency Modulation
Phase Modulation

Figure 5.15 *Types of analog-to-analog modulation*

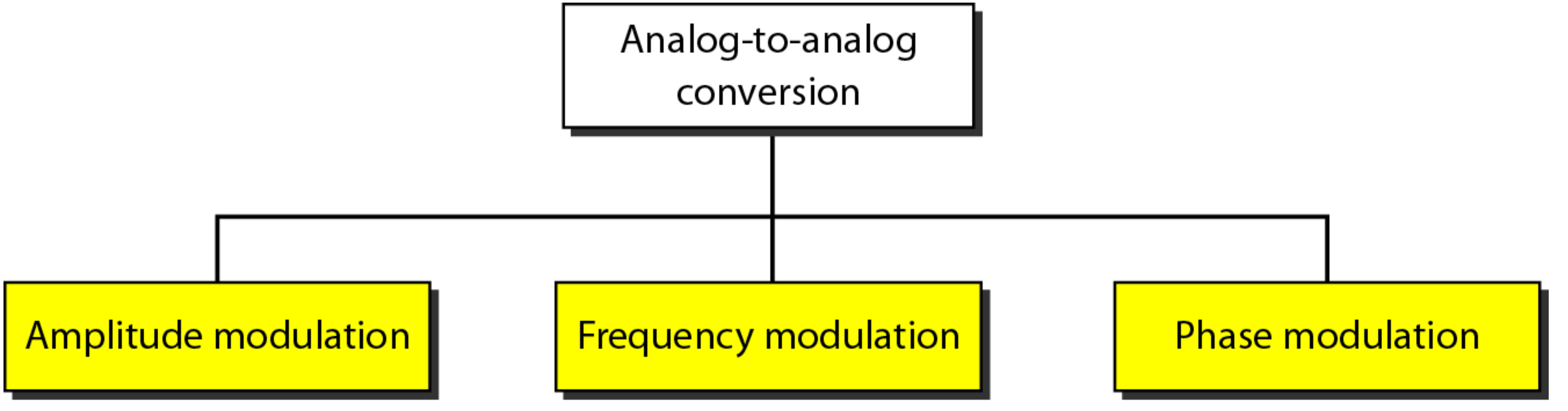
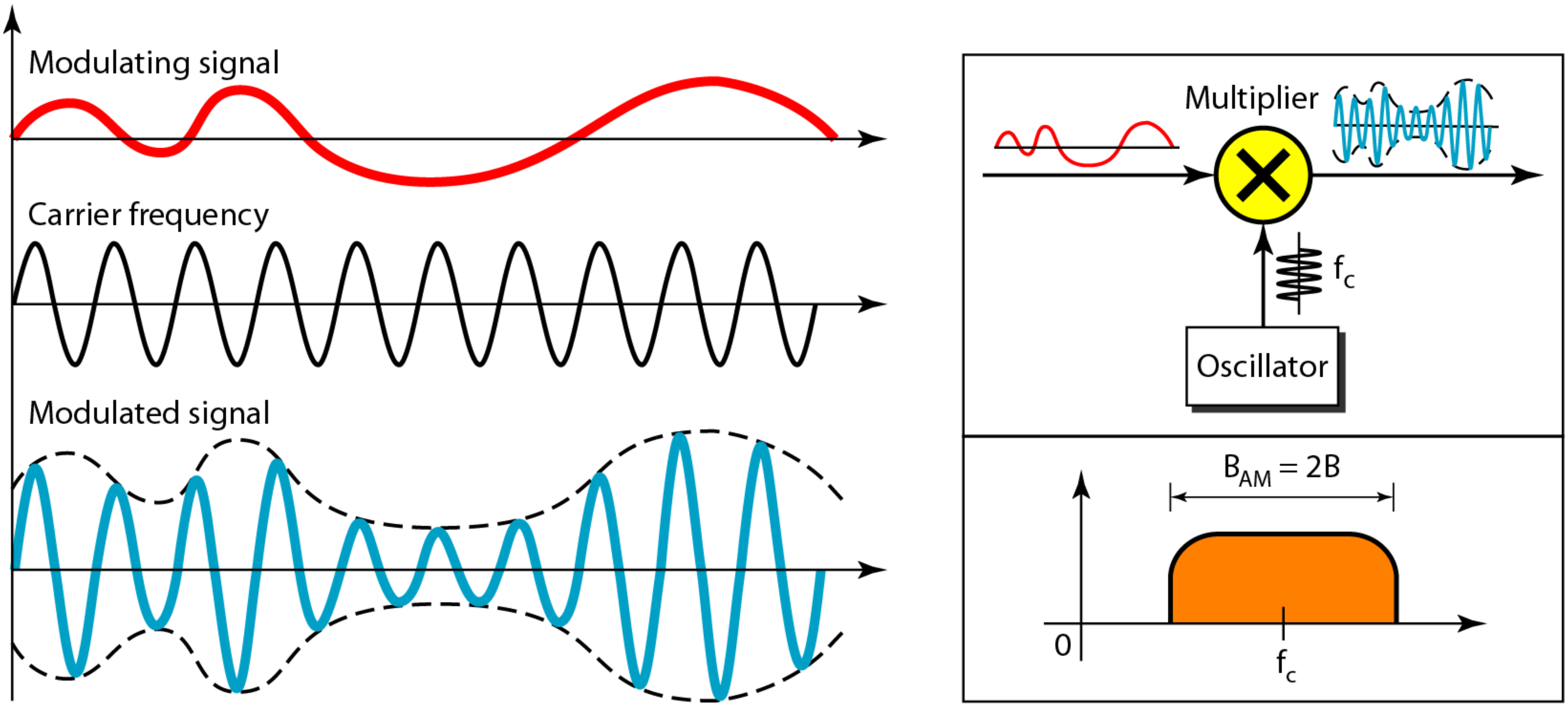


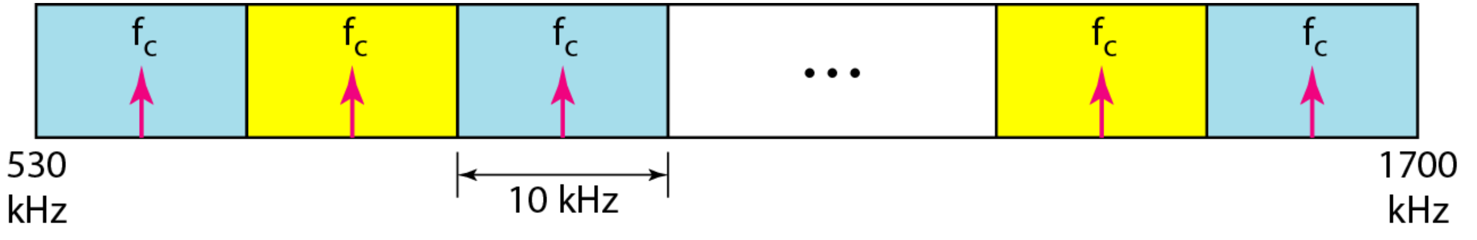
Figure 5.16 *Amplitude modulation*



Note

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

Figure 5.17 *AM band allocation*



Note

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

Figure 5.18 *Frequency modulation*

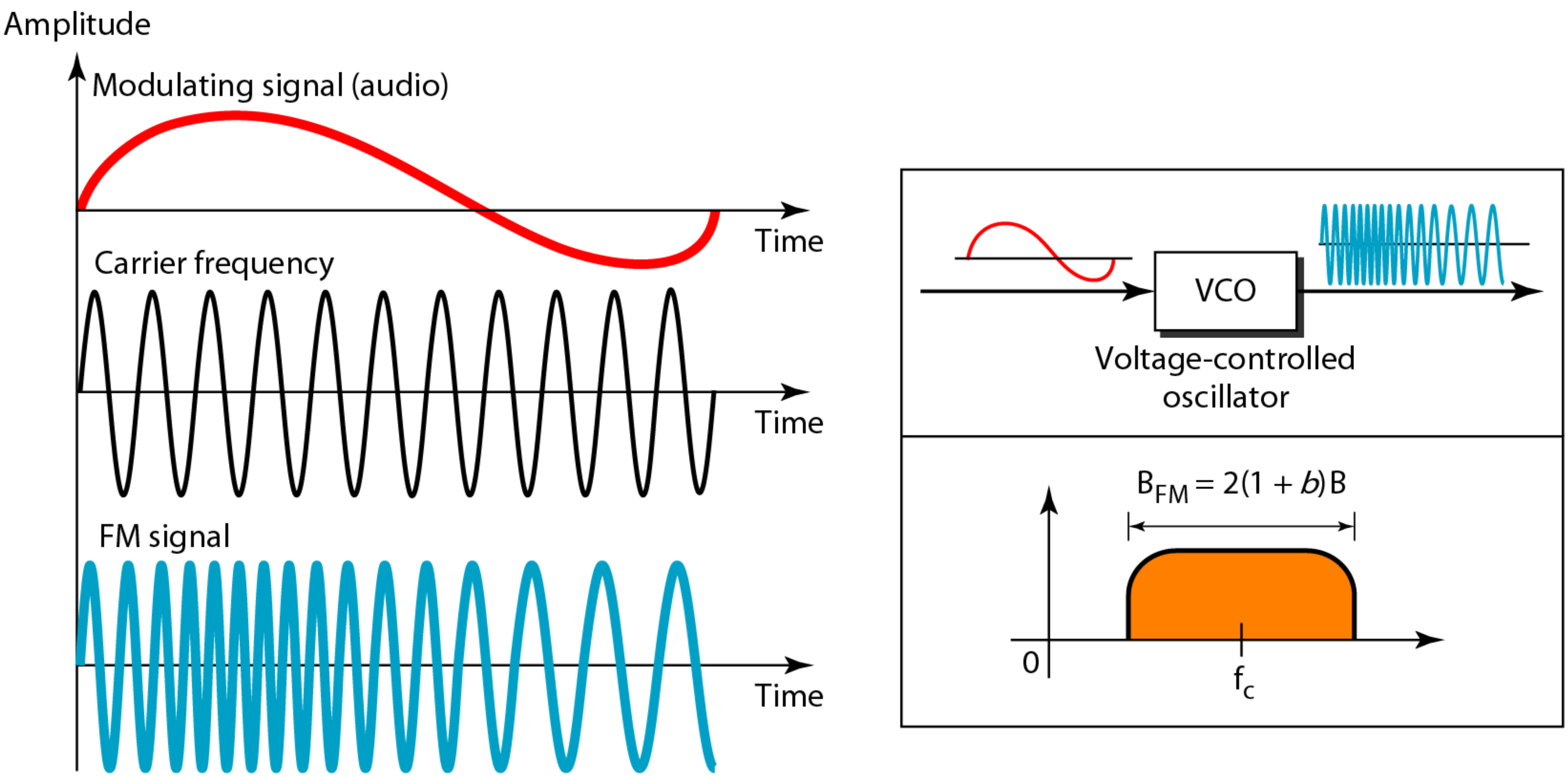


Figure 5.19 *FM band allocation*

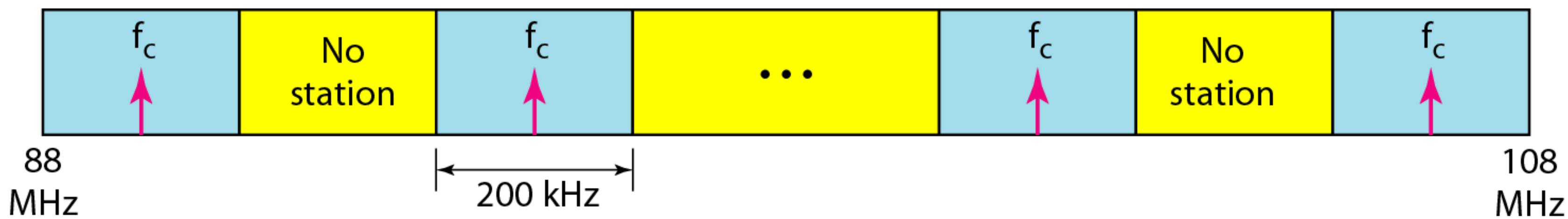
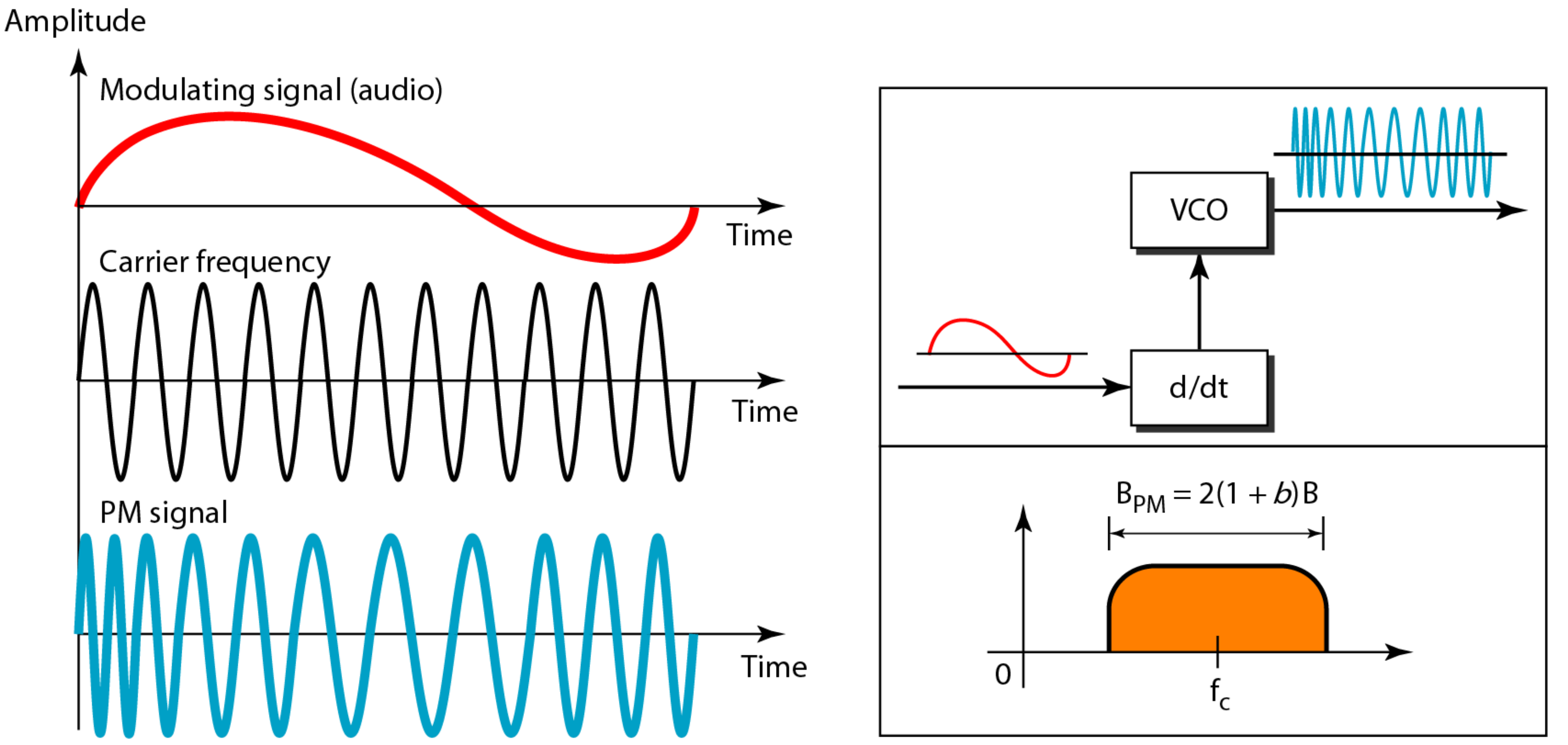


Figure 5.20 *Phase modulation*



Note

The total bandwidth required for PM can be determined from the bandwidth and maximum amplitude of the modulating signal:

$$B_{PM} = 2(1 + \beta)B.$$