Department of Computer science and Information Technology

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.

Figure 5.1 *Digital-to-analog conversion*

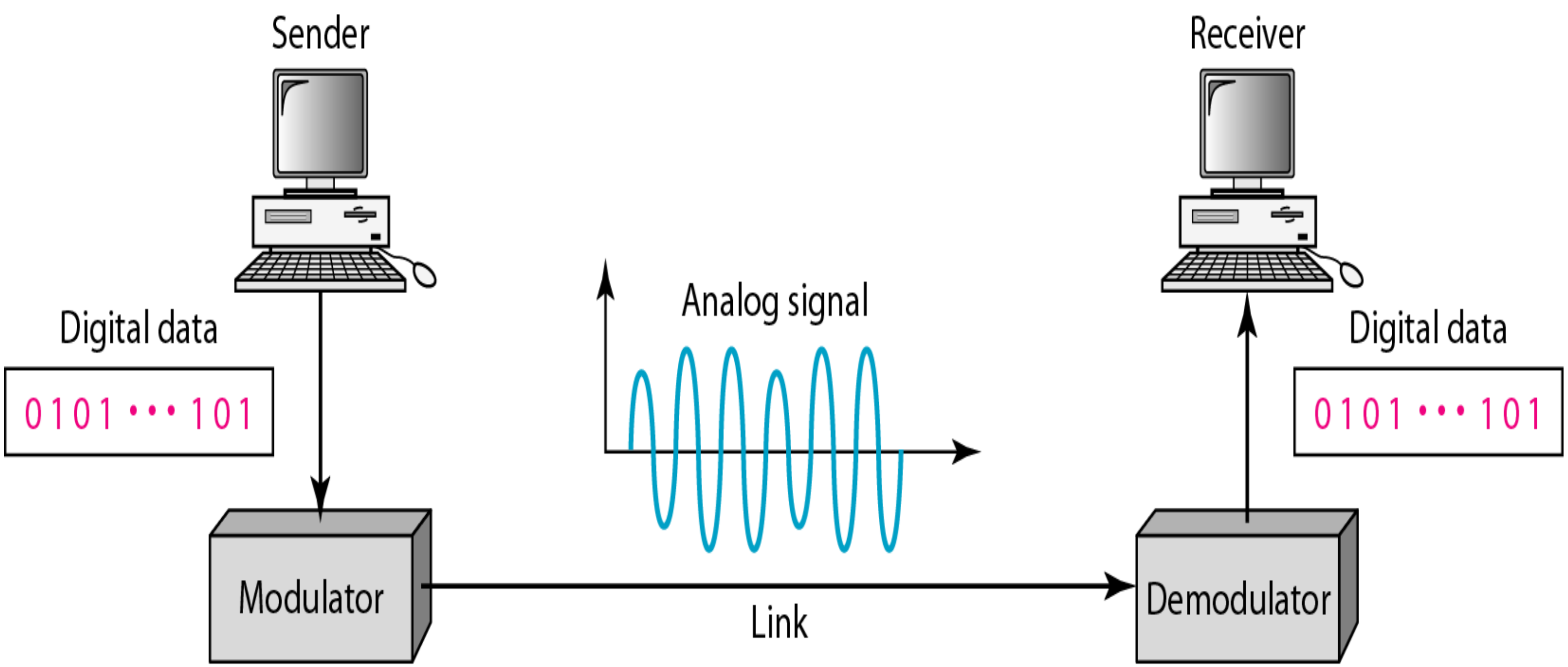
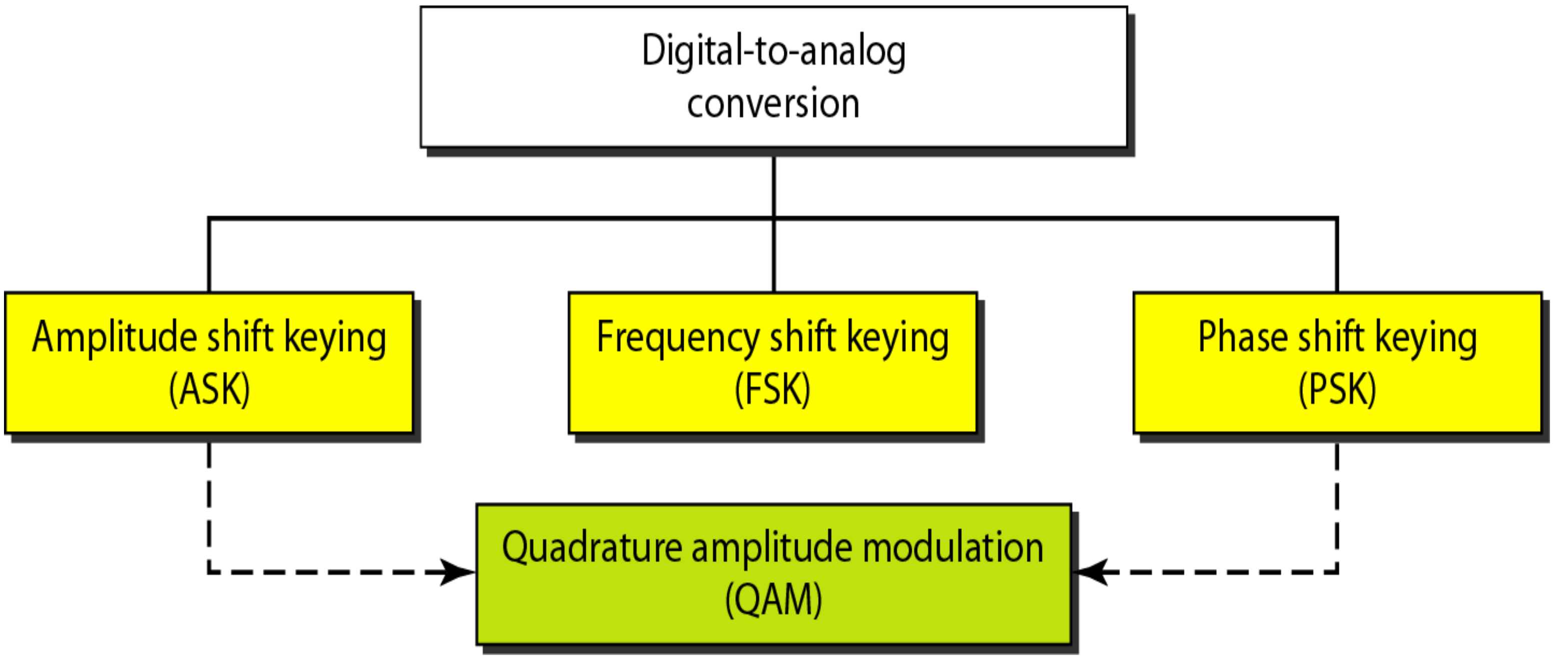


Figure 5.2 *Types of digital-to-analog conversion*



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.

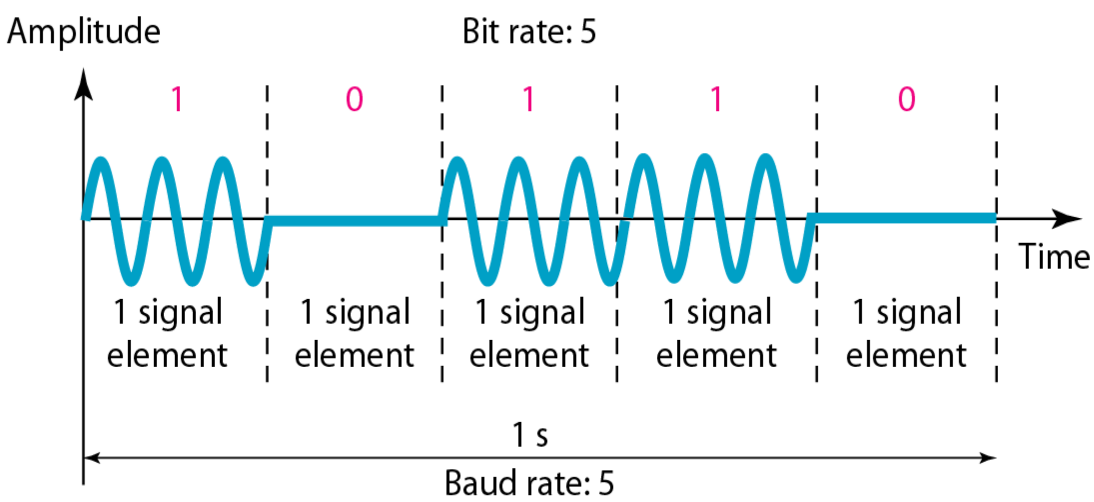
$$S = N \times \frac{1}{r} \rightarrow r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/baud}$$

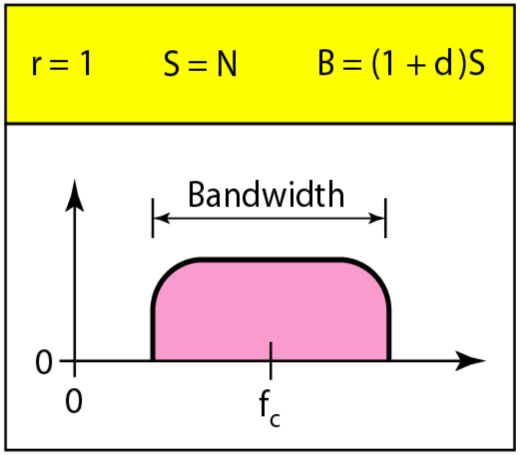
$$r = \log_2 L \rightarrow L = 2^r = 2^8 = 256$$

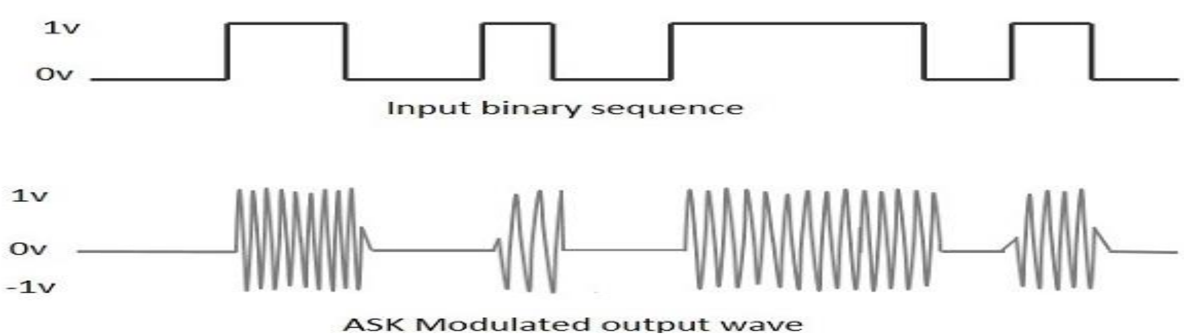
Binary amplitude shift keying

- Although we can have several levels (kinds) of signal elements, each with a different amplitude, ASK is normally implemented using only two levels. This is referred to as *binary amplitude shift keying* or *on-off keying* (OOK).
- The peak amplitude of one signal level is 0; the other is the same as the amplitude of the carrier frequency.

Figure 5.3 *Binary amplitude shift keying*



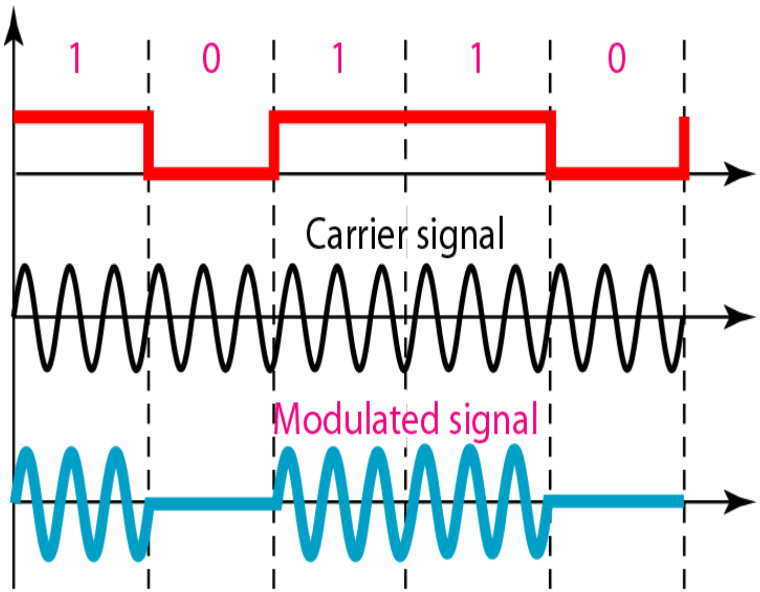


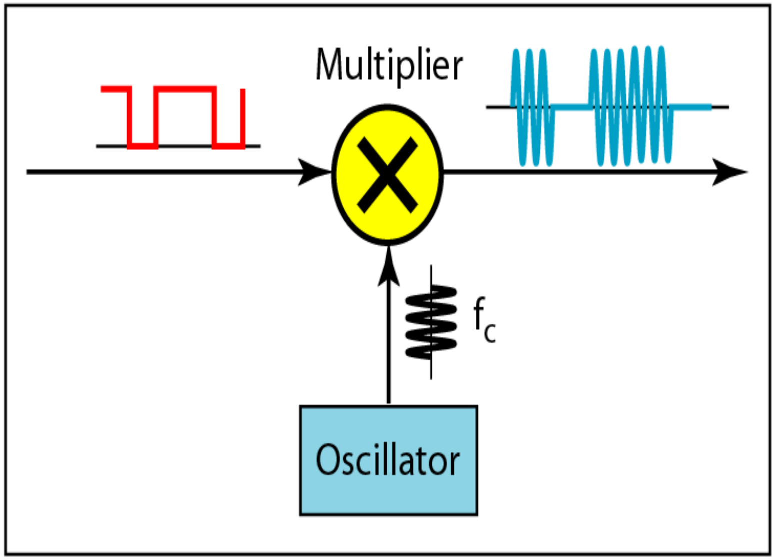


Bandwidth for ASK

- As we expect, the bandwidth is proportional to the signal rate (baud rate). However, there is normally another factor involved, called *d*, which depends on the modulation and filtering process. The value of *d* is between 0 and 1.
- $B = (1 + d) * S$

Figure 5.4 *Implementation of binary ASK*





Example 5.3

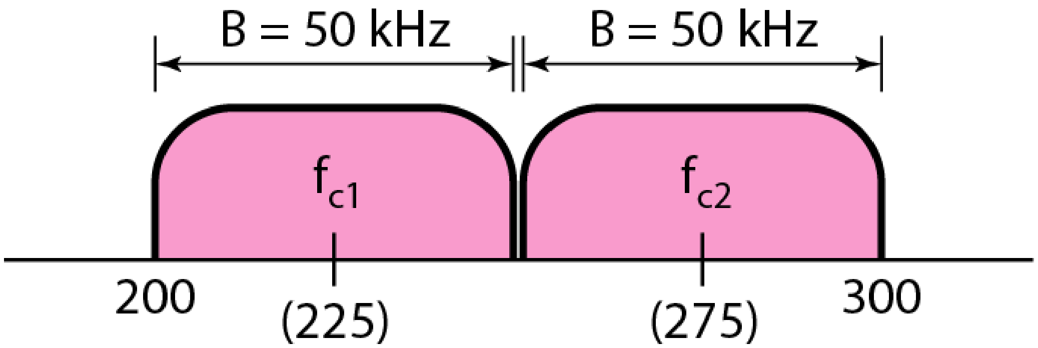
- We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate if we modulated our data by using ASK with d = 1?
- Solution
- The middle of the bandwidth is located at 250 kHz. This means that our carrier frequency can be at f_c = 250 kHz. We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

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

Example 5.4

- 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, as shown in Figure 5.5. The figure shows the positions of two carrier frequencies and the bandwidths. The available bandwidth for each direction is now 50 kHz, which leaves us with a data rate of 25 kbps in each direction.

Figure 5.5 *Bandwidth of full-duplex ASK used in Example 5.4*



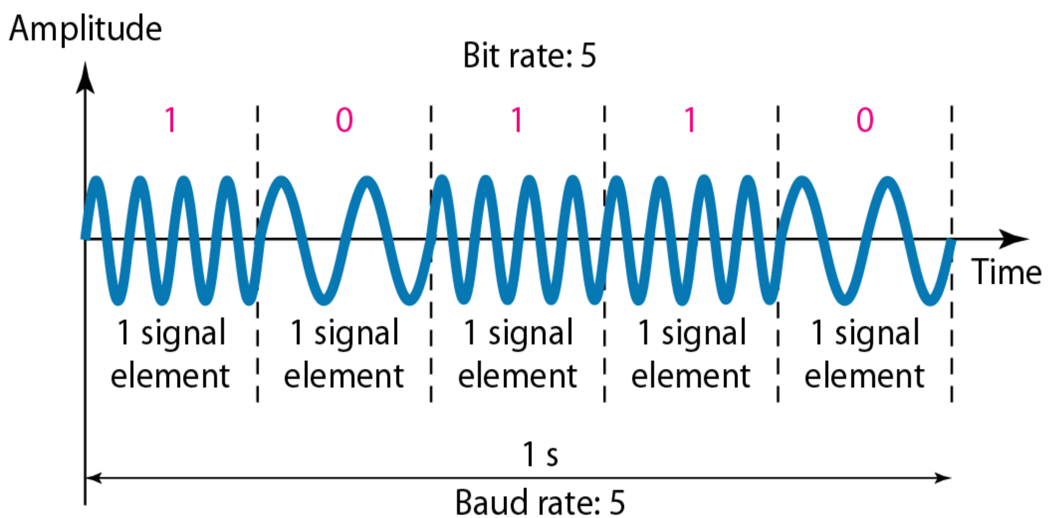
Frequency Shift Keying

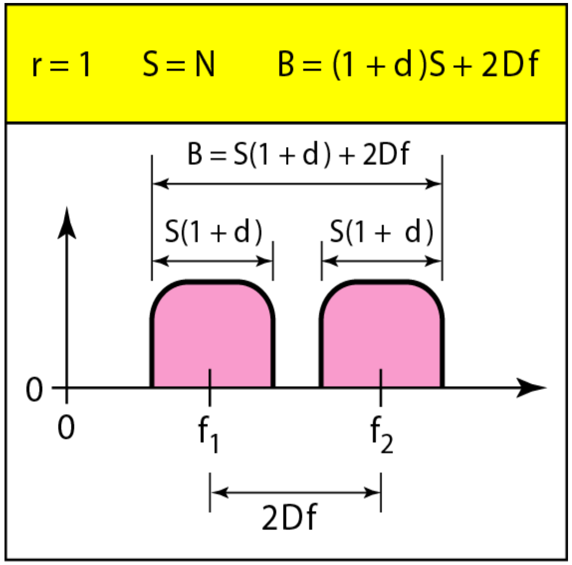
- In frequency shift keying, the frequency of the carrier signal is varied to represent data. The frequency of the modulated signal is constant for the duration of one signal element, but changes for the next signal element if the data element changes.

Binary FSK (BFSK)

- binary FSK (or BFSK) contains two carrier frequencies.

Figure 5.6 *Binary frequency shift keying*





Bandwidth for BFSK

- We can think of FSK as two ASK signals, each with its own carrier frequency ($f1$ or $f2$). If the difference between the two frequencies is $2\Delta f$, then the required bandwidth is
- $B = (1 + d) * S + 2\Delta\phi$

Example 5.5

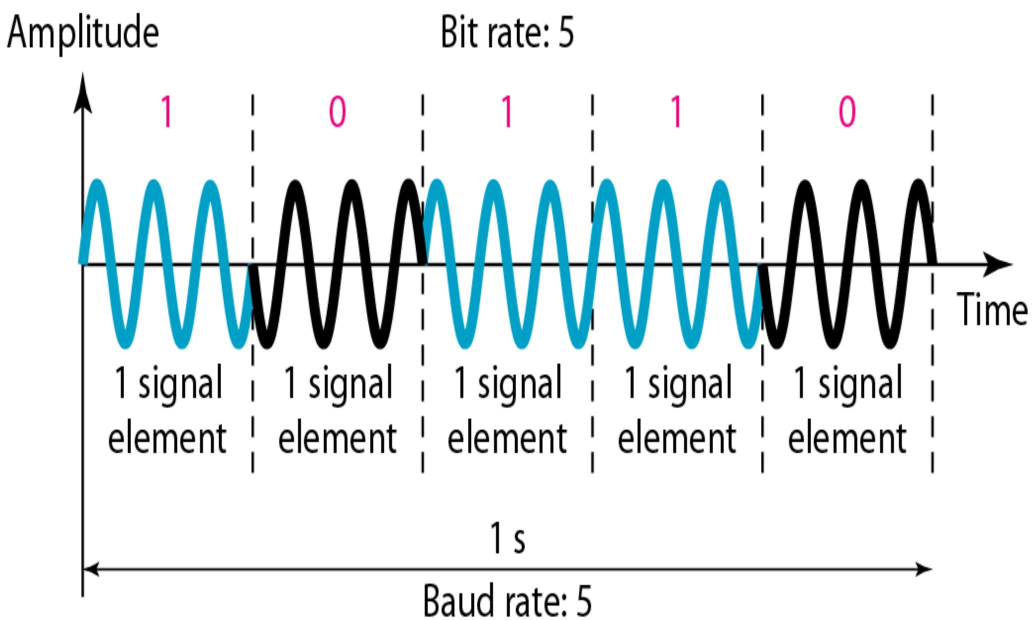
- We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?
- Solution
- This problem is similar to Example 5.3, but we are modulating by using FSK. The midpoint of the band is at 250 kHz. We choose 2Δf to be 50 kHz; this means

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

Phase Shift Keying

- In phase shift keying, 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 less susceptible to noise than ASK. PSK is superior to FSK because we do not need two carrier signals.

Figure 5.9 *Binary phase shift keying*



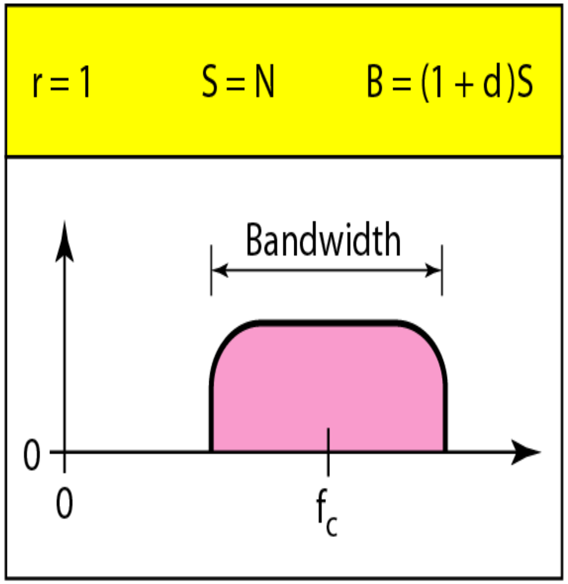


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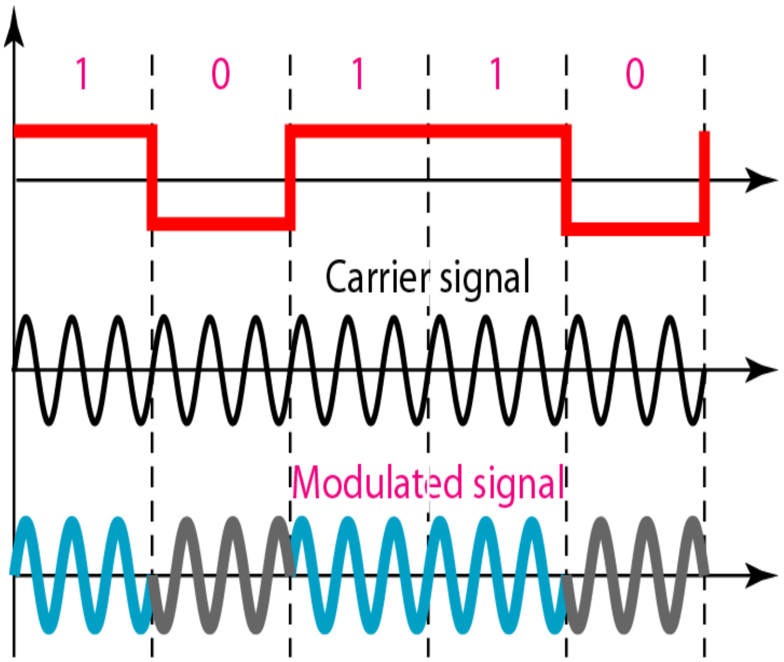
Figure 5.10 *Implementation of BASK*



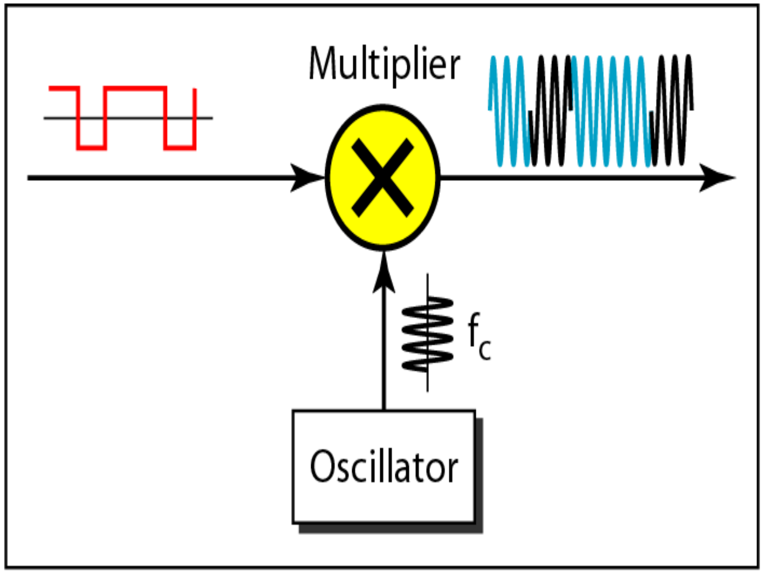
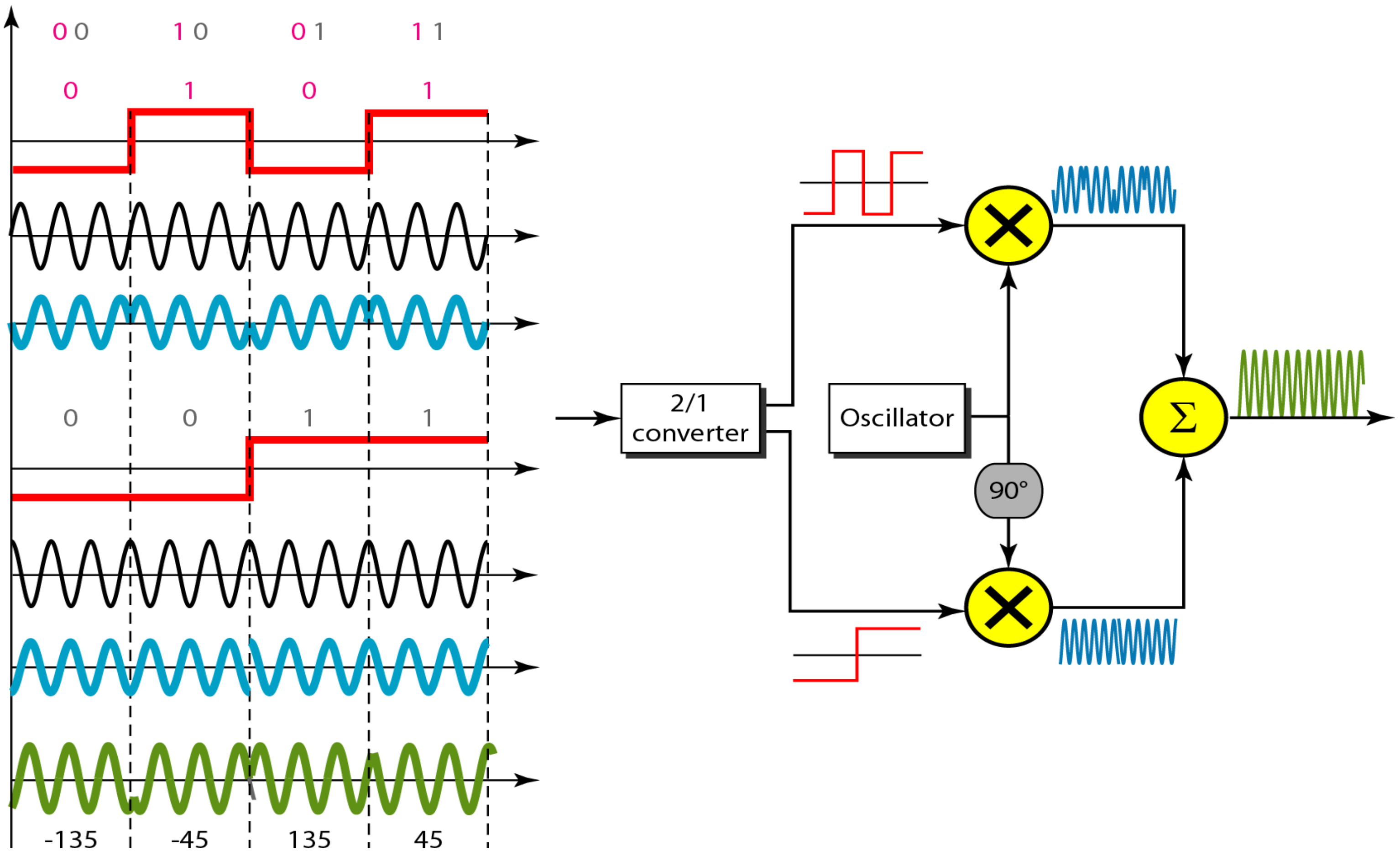


Figure 5.11 *QPSK and its implementation*



Example 5.7

- Find the bandwidth for a signal transmitting at 12 Mbps for QPSK. The value of d = 0.
- Solution
- For QPSK, 2 bits is carried by one signal element. This means that r = 2. So the signal rate (baud rate) is $S = N \times (1/r) = 6$ Mbaud. With a value of d = 0, we have B = S = 6 MHz.

5-2 ANALOG AND DIGITAL

- 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.

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

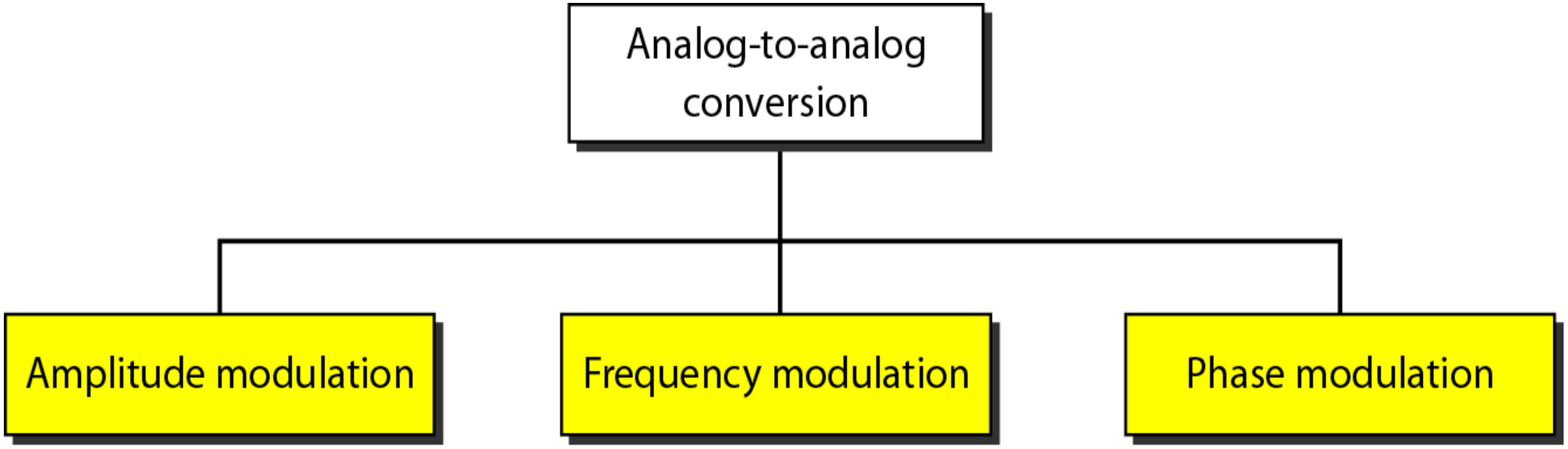


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Figure 5.16 *Amplitude modulation*

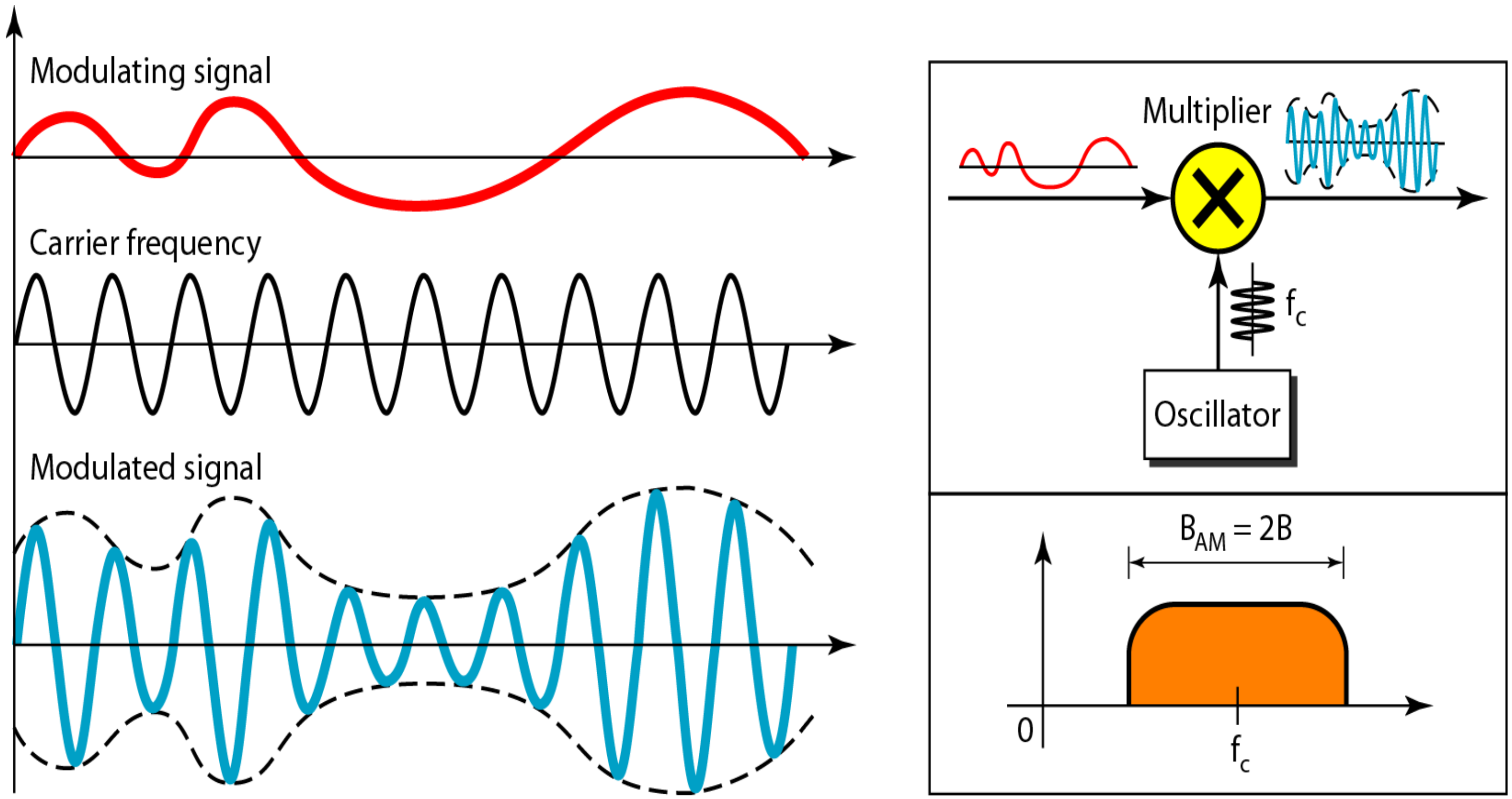
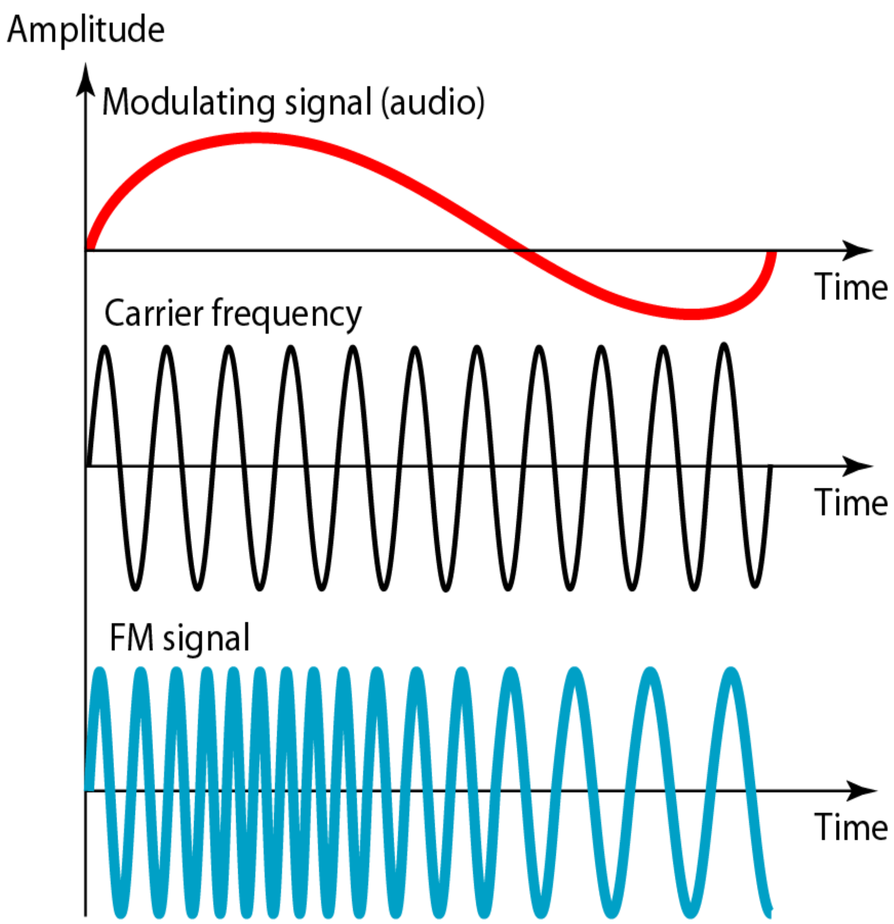


Figure 5.18 *Frequency modulation*



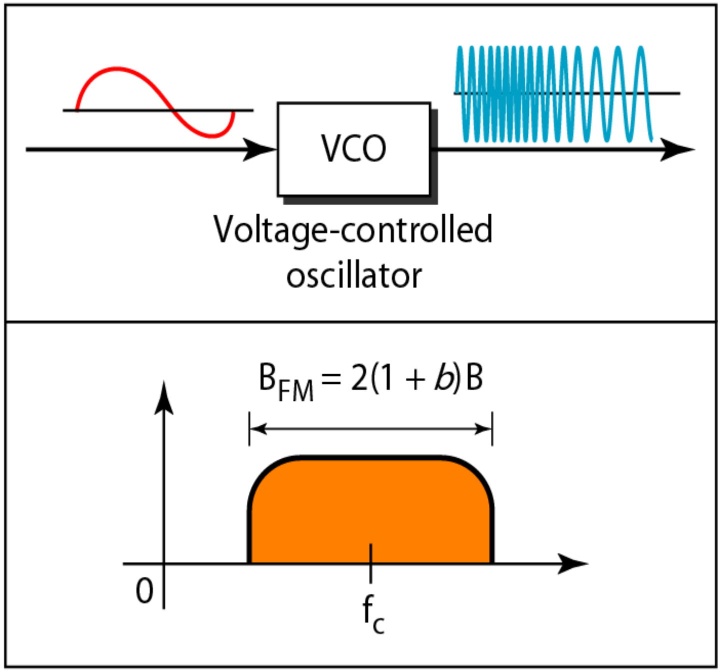


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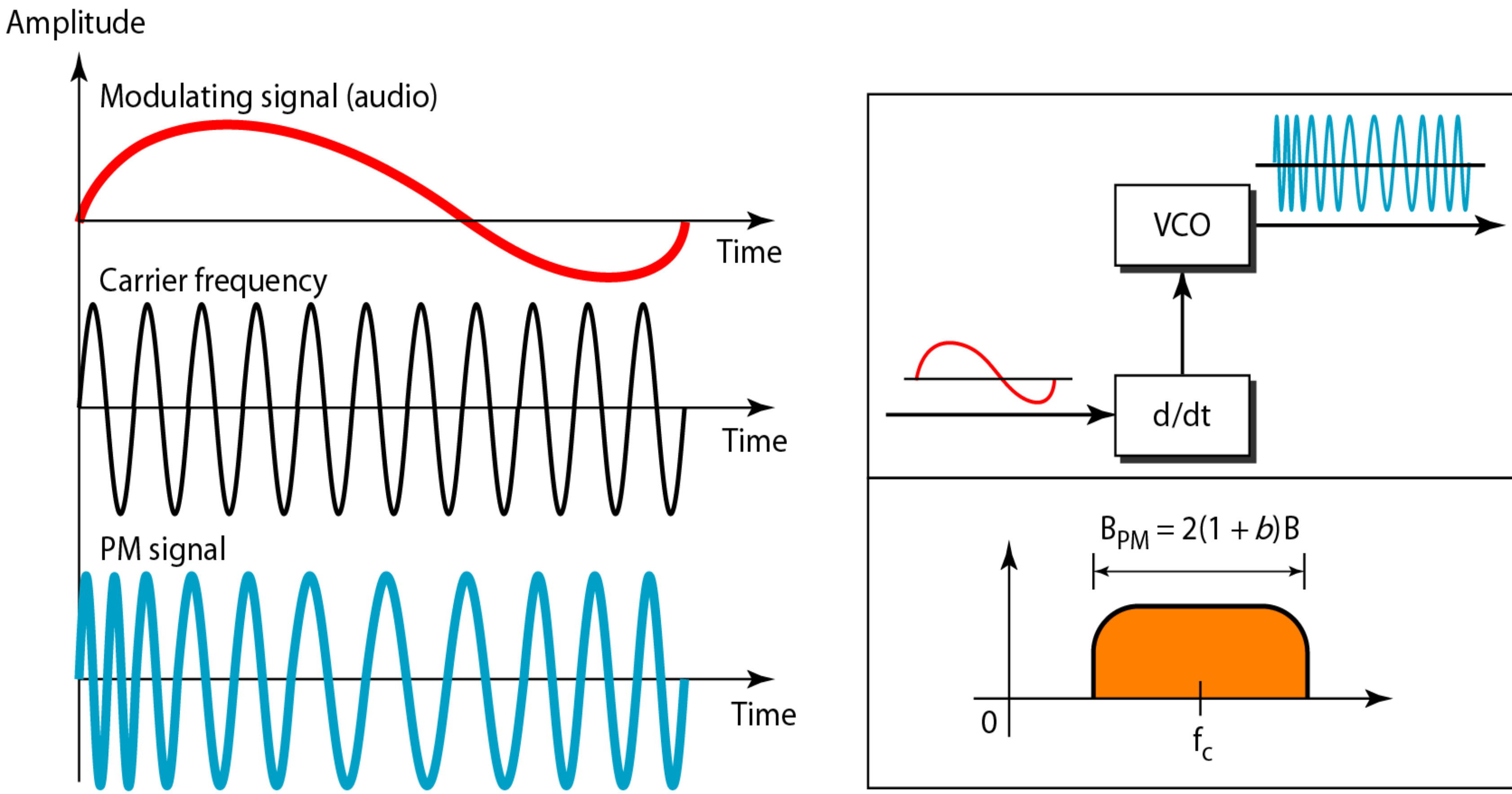
Figure 5.20 *Phase modulation*



Reference:

- Data Communications and Networking, Behrouz A. Forouzan, Fifth Edition, TMH, 2013.