Class 4 ((Communication and Computer Networks))

Lesson 5... SIGNAL ENCODING TECHNIQUES

Abstract

Both analog and digital information can be encoded as either analog or digital signals. The particular encoding that is chosen depends on the specific requirements to be met and the media and communications facilities available. This lesson will focus on signal encoding techniques used in the communication system.

Introduction

For digital signaling, a data source g(t), which may be either digital or analog, is encoded into a digital signal x(t).The actual form of x(t) depends on the encoding technique and is chosen to optimize use of the transmission medium.

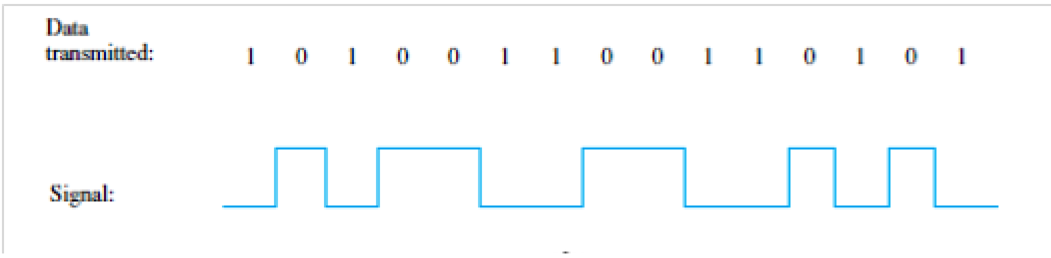
The basis for analog signaling is a continuous constant-frequency signal known as the **carrier signal**. The frequency of the carrier signal is chosen to be compatible with the transmission medium being used. Data may be transmitted using a carrier signal by modulation. **Modulation** is the process of encoding source data onto a carrier signal with frequency f_c .All modulation techniques involve operation on one or more of the three fundamental frequency domain parameters: **amplitude, frequency, and phase**.

The input signal m(t) may be analog or digital and is called the **modulating** signal or baseband signal. The result of modulating the carrier signal is called the **modulated signal** s(t). Next we going to examine the techniques involved in each of these four combinations.

DIGITAL DATA, DIGITAL SIGNALS

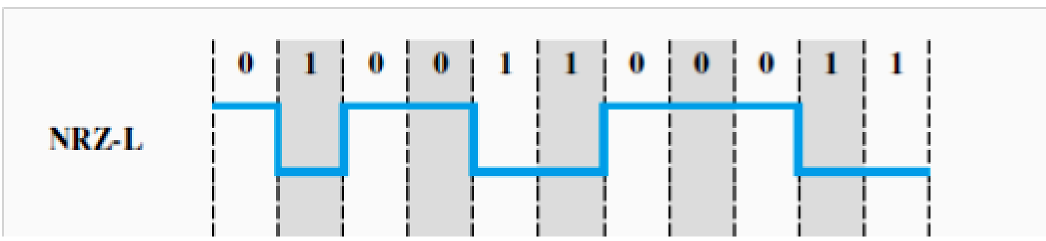
A digital signal is a sequence of discrete, discontinuous voltage pulses. Each pulse is a signal element. **Binary data** are transmitted by encoding each data bit into **signal elements**. In the simplest case, there is a one-to-one correspondence between bits and signal elements. An example is shown in Figure below, in which binary 1 is represented by a lower voltage level and binary 0 by a higher voltage level.

We will show in this section there is a variety of other encoding schemes are also used, these are:



Nonreturn to Zero (NRZ)

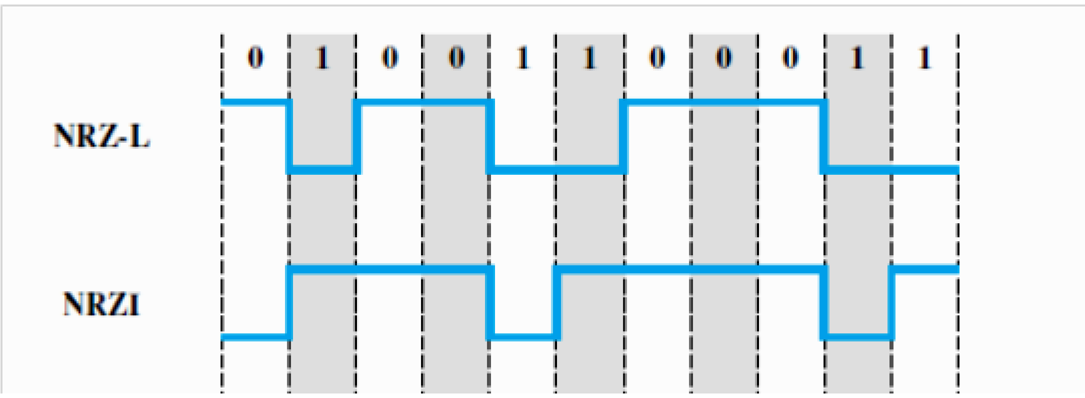
The most common, and easiest, way to transmit digital signals is to use two different voltage levels for the two binary digits. Codes that follow this strategy share the property that the voltage level is constant during a bit interval; there is no transition (no return to a zero voltage level). For example, the absence of voltage can be used to represent binary 1, with a constant positive voltage used to represent binary 0.



A variation of NRZ is known as NRZI (Nonreturn to Zero, invert on ones).

As with NRZ-L, NRZI maintains a constant voltage pulse for the duration of a bit time. The data themselves are encoded as the presence or absence of a signal transition at the beginning of the bit time. A transition (low to high or high to low) at the beginning of a bit time denotes a binary 1 for that bit time; no transition indicates a binary 0.

NRZI is an example of differential encoding. In differential encoding, the information to be transmitted is represented in terms of the changes between successive signal elements rather than the signal elements themselves.



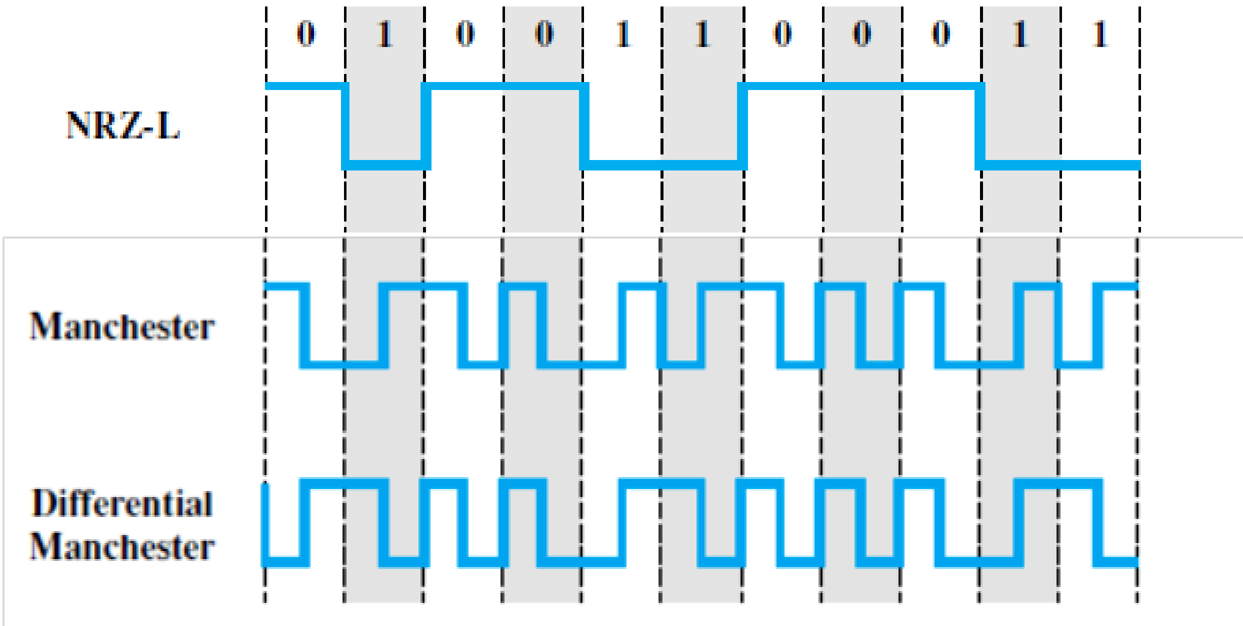
The main limitations of NRZ signals are the presence of a dc component and the lack of synchronization capability. To picture the latter problem, consider that with a long string of 1s or 0s for NRZ-L or a long string of 0s for NRZI, the output is a constant voltage over a long period of time. Under these circumstances, any drift between the clocks of transmitter and receiver will result in loss of synchronization between the two.

Manchester code (Biphase)

There is another set of coding techniques, grouped under the term ***biphase***, that overcomes the limitations of NRZ codes. Two of these techniques, **Manchester** and **differential Manchester**, are in common use.

In the **Manchester code**, there is a transition at the middle of each bit period. The midbit transition serves as a clocking mechanism and also as data: a **low-to-high transition** represents 1, and a high-to-low transition represents 0.

In **differential Manchester**, the midbit transition is used only to provide clocking.The encoding of 0 is represented by the presence of a transition at the beginning of a bit period, and a 1 is represented by the absence of a transition at the beginning of a bit period. Differential Manchester has the added advantage of employing differential encoding.



DIGITAL DATA, ANALOG SIGNALS

The most familiar use of this transformation is for transmitting digital data through the public telephone network. The telephone network was designed to receive, switch, and transmit analog signals in the voice-frequency range of about 300 to 3400 Hz.

The digital devices are attached to the network via a modem (modulator-demodulator), which converts digital data to analog signals, and vice versa.

We mentioned that modulation involves operation on one or more of the three characteristics of a carrier signal: amplitude, frequency, and phase. Accordingly, there are three basic encoding or modulation techniques for transforming digital data into analog signals, as illustrated in Figure below: **amplitude shift keying** (ASK), **frequency shift keying** (FSK), and **phase shift keying** (PSK).

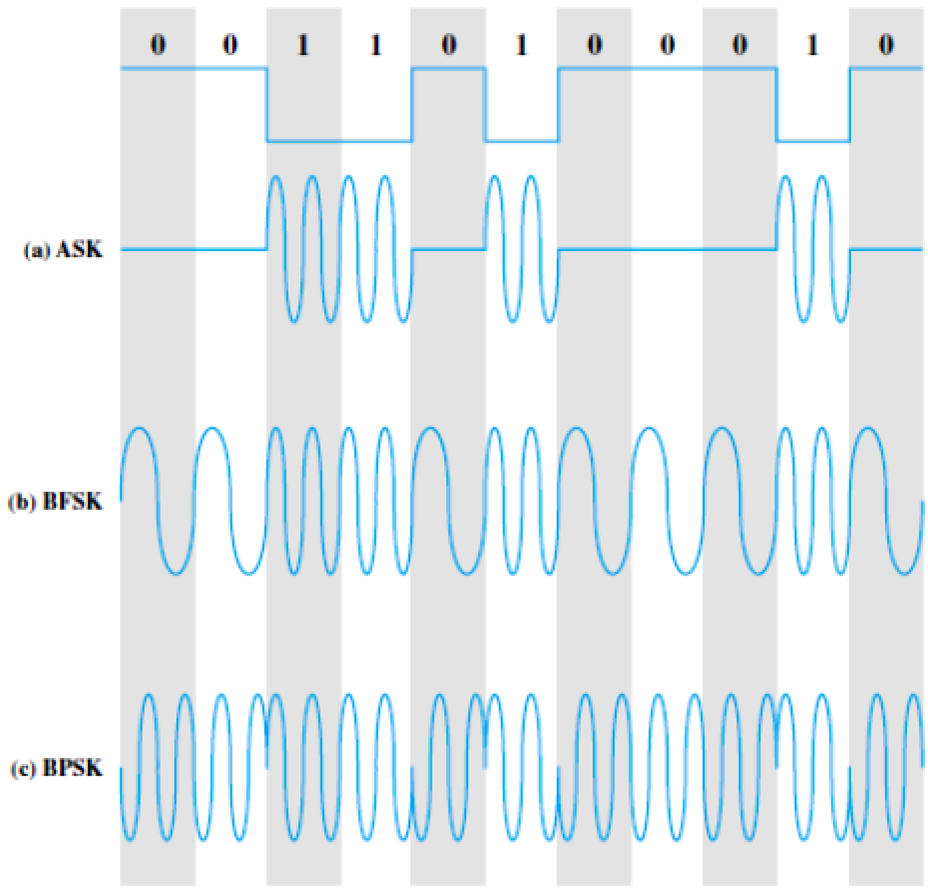


Figure 5.7 Modulation of Analog Signals for Digital Data

Amplitude Shift Keying

In ASK, the two binary values are represented by two **different amplitudes** of the carrier frequency. Commonly, one of the amplitudes is zero; that is, one binary digit is represented by the presence, at constant amplitude, of the carrier, the other by the absence of the carrier (Figure 5.7a).

ASK is susceptible to sudden gain changes and is a rather inefficient modulation technique.

$$\textbf{ASK} \qquad s(t) = \begin{cases} A\cos(2\pi f_c t) & \text{binary 1} \\ 0 & \text{binary 0} \end{cases}$$

Frequency Shift Keying

The most common form of FSK is binary FSK (BFSK), in which the two binary values are represented by two different frequencies near the carrier frequency (Figure 5.7b).The resulting transmitted signal for one bit time is

$$\textbf{BFSK} \qquad s(t) = \begin{cases} A\cos(2\pi f_1 t) & \text{binary 1} \\ A\cos(2\pi f_2 t) & \text{binary 0} \end{cases}$$

Where f_1 and f_2 are typically offset from the carrier frequency by equal but opposite amounts.

Phase Shift Keying

The simplest scheme uses two phases to represent the two binary digits (Figure 5.7c) and is known as binary phase shift keying. The resulting transmitted signal for one bit time is

$$\textbf{BPSK} \qquad s(t) = \begin{cases} A\cos(2\pi f_c t) \\ A\cos(2\pi f_c t + \pi) \end{cases}$$

ANALOG DATA, DIGITAL SIGNALS

The device used for converting analog data into digital form for transmission, and subsequently recovering the original analog data from the digital, is known as a codec (coder-decoder). In this section we examine the two principal techniques used in codecs, pulse code modulation and delta modulation

Pulse Code Modulation (PCM)

Pulse-code modulation (PCM) is a method used to digitally represent sampled analog signals. It starts with a continuous-time, continuous-amplitude (analog) signal, from which a digital signal is produced.

PCM is the standard form of digital audio in computers, Compact Discs, digital telephony and other digital audio applications. In a PCM stream, the amplitude of the analog signal is **sampled** regularly at uniform intervals (these analog samples, called pulse amplitude modulation (PAM) samples) , and each sample is **quantized** to the nearest value within a range of digital steps.

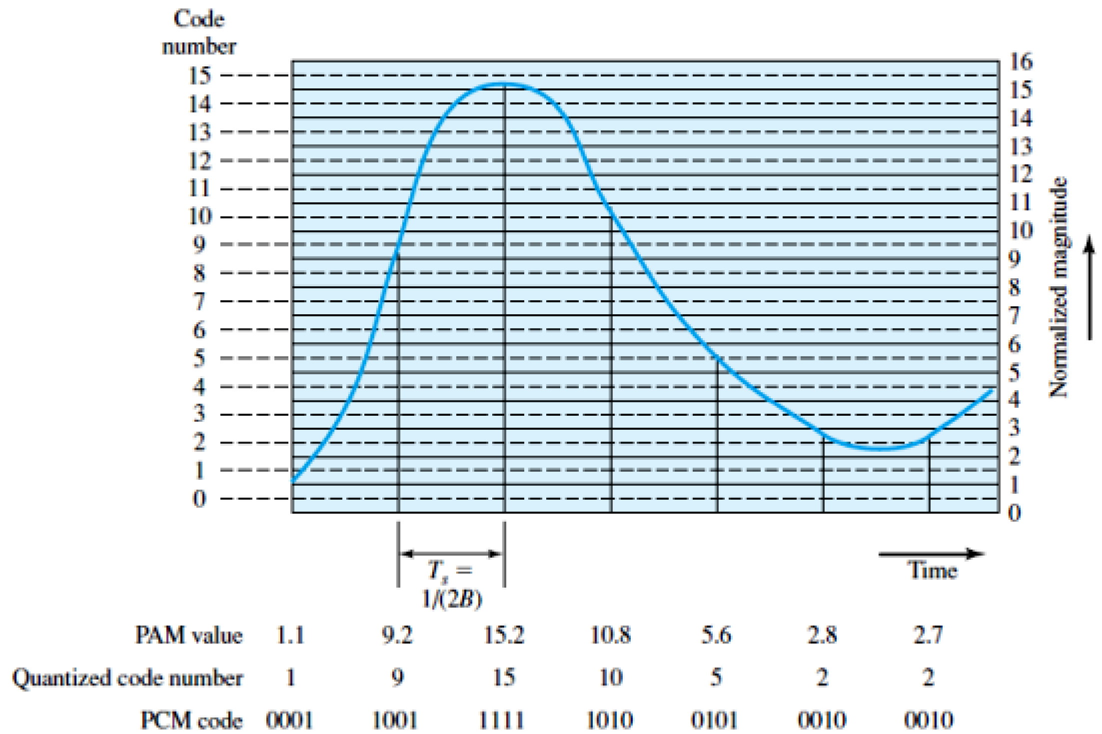


Figure 5.16 Pulse Code Modulation Example

In general, PCM encoder has three processes, as shown below

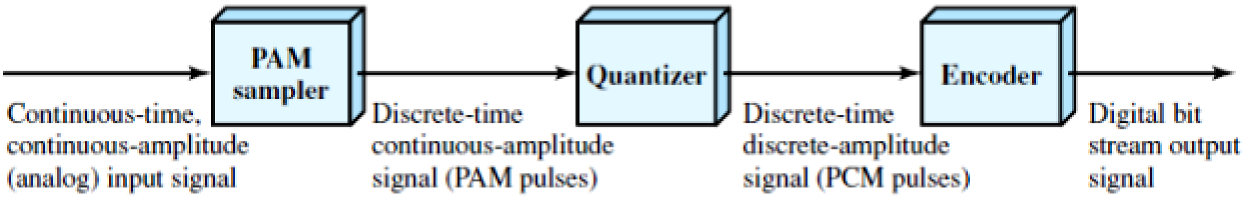


Figure 5.17 PCM Block Diagram

1. The analog signal is sampled.
2. The sampled signal is quantized.
3. The quantized values are encoded as streams of bits.

Sampling: Is the process in which the magnitude of the analog signal is sampled regularly at uniform intervals.

Quantization: is the process of converting the obtained samples into discrete values.

Encoding : After each sample is quantized and the number of bits per sample is decided, each sample can be changed to an 1 or 0-bit code word. A quantization code of 2 is encoded as 010; 5 is encoded as 101; and so on.

Delta Modulation (DM)

One of the most popular alternatives to PCM is delta modulation (DM). With delta modulation, an analog input is approximated by a staircase function that moves up or down by one quantization level at each sampling interval An example is shown in Figure 5.20, where the staircase function is overlaid on the original analog waveform. The important characteristic of this staircase function is that its behavior is binary: At each sampling time, the function moves up or down a constant amount Thus, the output of the delta modulation process can be represented as a single binary digit for each sample.

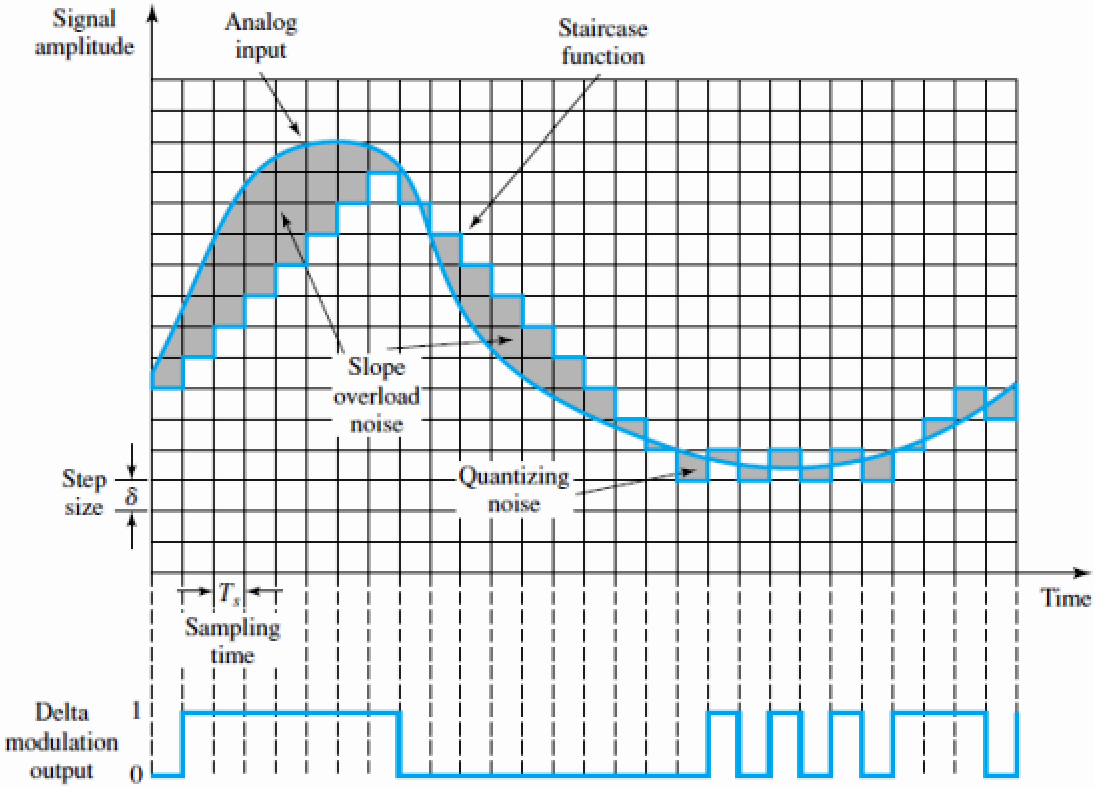


Figure 5.20 Example of Delta Modulation

ANALOG DATA, ANALOG SIGNALS

Modulation has been defined as the process of combining an input signal m(t) and a carrier at frequency (fc) to produce a signal s(t) whose bandwidth is (usually) centered on (fc).

The principal techniques **for** modulation using analog data: amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM).As before, the three basic characteristics of a signal are used for modulation.

Amplitude Modulation

Amplitude modulation (AM) is the simplest form of modulation and is depicted in Figure 5.22. Mathematically, the process can be expressed as

$$\textbf{AM} \qquad s(t) = [1 + n_a x(t)]\cos 2\pi f_c t$$

The parameter n_a known as the **modulation index**, is the ratio of the amplitude of the input signal to the carrier.

Angle Modulation

Frequency modulation (FM) and phase modulation (PM) are special cases of angle modulation.The modulated signal is expressed as

$$\textbf{Angle Modulation} \qquad s(t) = A_c \cos[2\pi f_c t + \phi(t)]$$

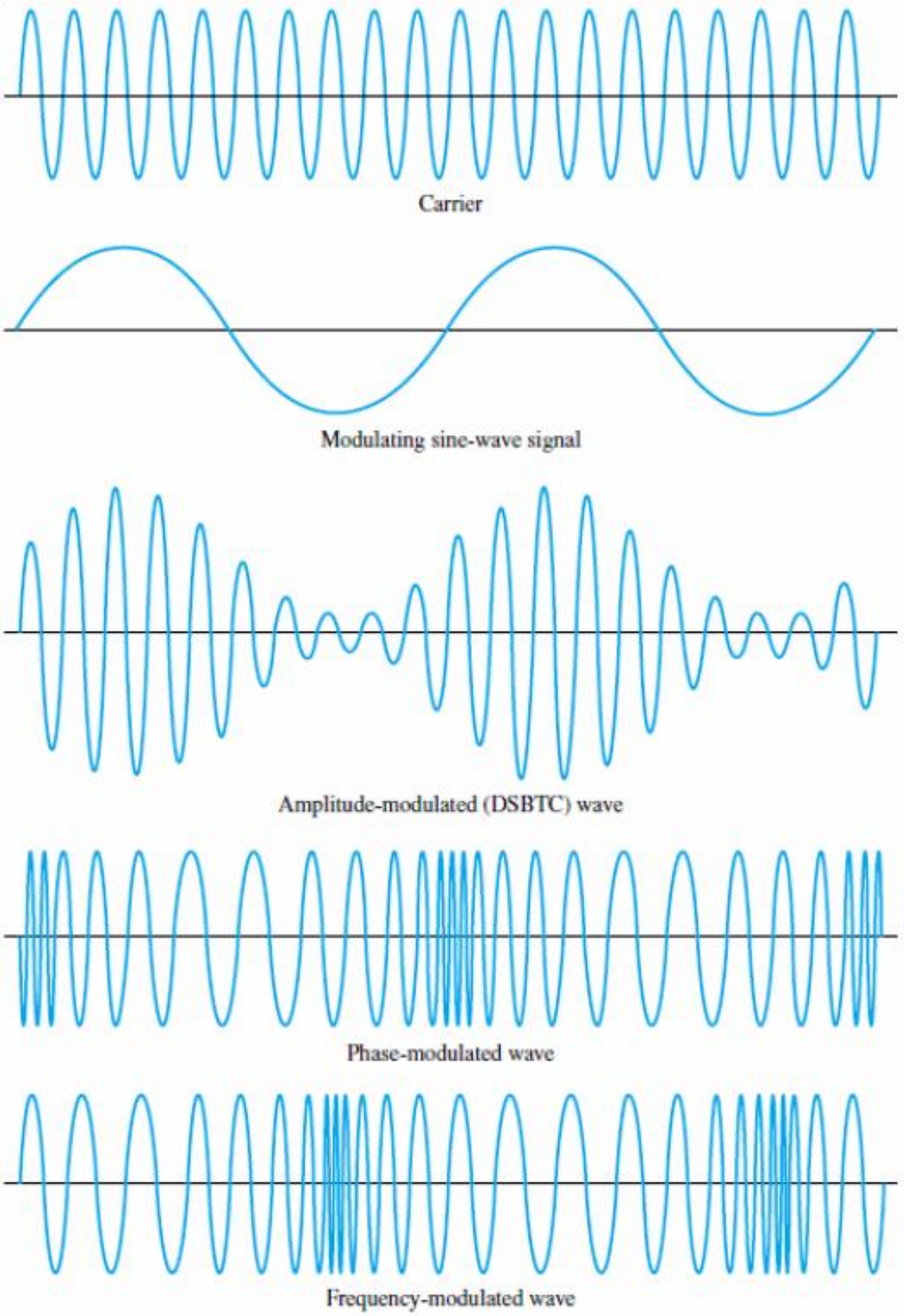


Figure 5.24 Amplitude, Phase, and Frequency Modulation of a Sine-Wave Carrier by a Sine-Wave Signal