CHAPTER 2

Modulation, Encoding, and Decoding

In this chapter we review the basic properties of the modulated carriers involved in satellite systems. We will temporarily ignore the presence of the satellite here, and simply consider a transmitter generating the modulated carrier and a receiver processing this carrier. The discussion focuses the analysis on the basic components of any communication system, and the key elements of modulation theory and receiver performance are directly applicable. We consider specifically those modulation characteristics that are of particular interest to satellite systems.

In communication links, information is transmitted by modulating it onto electromagnetic carriers, which are then propagated to the receiver. At the receiver, the information is demodulated (extracted) from the carrier to complete the link. The objective of any communication system is to transmit the modulated carrier to the receiver as reliably as possible, so that the demodulated information can be recovered satisfactorily. In analog modulation systems, the information waveforms (voice, video, teletype, etc.) are modulated directly from the source onto the carrier. In digital communication systems, source information is first converted into sequences of digital symbols, which are then encoded into waveforms for carrier modulation. At the receiver, the demodulated waveforms are decoded into the digital sequence, from which the source information is then retrieved.

Early satellite systems primarily used analog modulation techniques, since their technology and hardware were fully developed for terrestrial microwave systems. Although modern satellite systems are still predominantly analog, the rapid development of high-speed digital circuitry is fostering a trend toward completely digital satellite communications. We here review the basic properties of modulation, encoding, and decoding associated with both these system formats.

2.1 ANALOG MODULATION

In analog communications, source waveforms are directly modulated onto carriers at the transmitter (Figure 2.1a) using some form of amplitude modulation (AM), frequency modulation (FM), or phase modulation (PM). The carrier can be at RF, or it can be at IF and then frequency-translated to RF, as we showed in Figure 1.4a. At the receiver (Figure 2.1b) the carrier is demodulated to recover directly the source waveforms. The performance of analog modulation systems is usually measured in terms of signal-to-noise ratio (SNR) of the demodulated information waveform relative to any interfering noise: the larger the demodulated SNR, the higher the quality of the communication link.

If $m(t)$ represents the information waveform to be transmitted, the modulated carriers (more specifically, the E-field component of the electromagnetic field) for each type of analog modulation take the following forms:

$$\text{AM:}\quad c(t) = A[1 + \Delta_a m(t)]\cos(\omega_c t + \psi) \tag{2.1.1a}$$

$$\text{FM:}\quad c(t) = A\cos\left(\omega_c t + 2\pi\Delta_f \int m(t)\,dt + \psi\right) \tag{2.1.1b}$$

$$\text{PM:}\quad c(t) = A\cos[\omega_c t + \Delta m(t) + \psi] \tag{2.1.1c}$$

Here A is the carrier amplitude, ω_c is the carrier frequency in rad/s, and ψ is the carrier phase angle. The coefficients Δ_a, Δ_f, and Δ are modulation coefficients determining the degree of modulation and are commonly called the *AM index*, the *frequency-deviation coefficient* (Hz/V), and the *phase-deviation coefficient* (rad/V), respectively. Note that frequency modulating with $m(t)$ is the same as phase modulating with the integral of $m(t)$. Thus, AM, FM and PM analog carriers are simply forms of modulated carriers in which the amplitude, the frequency, or the phase is modulated by the information waveform. Detailed description and analysis of the modulation and demodulation circuitry commonly used in modern com-