Spread Spectrum (SS) and CDMA Systems

We introduced spread spectrum techniques in Chapter 6. In this chapter, we present details of direct-sequence spread spectrum (DSSS) and frequency-hop spread spectrum (FHSS) systems [1,2,4]. We show how signal spreading and despreading is achieved with binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK) modulation in the DSSS [11,12]. We then address multipath issues in wireless communications and show how code division multiple access (CDMA) takes advantage of multipath in improving system performance with a Rake receiver [6,13]. We conclude the chapter by presenting a summary of the challenges in implementing a CDMA system and providing some highlights of the Telecommunication Industries Association (TIA) IS-95 CDMA system. Those who are not familiar with spreading codes should refer to Appendix D.

Concept of Spread Spectrum

In a wideband spread-spectrum (SS) system, the transmitted signal is spread over a frequency band that is much larger, in fact, than the maximum bandwidth required to transmit the information bearing (baseband) signal [3]. An SS system takes a baseband signal with a bandwidth of only a few kilohertz (kHz), and spreads it over a band that may be many megahertz (MHz) wide. In SS systems, an advantage in signal-to-noise ratio (SNR) is achieved by the modulation and demodulation process. The SS signal is generated from a data-modulated carrier. The data- modulated carrier is modulated a second time by using a wideband spreading signal. An SS signal has advantages in the areas of security, resistance to narrowband jamming, resistance to multipath fading, and supporting multiple-access techniques. The spreading modulation may be phase modulation or a rapid change of the carrier frequency, or it may be a combination of these two schemes. When spectrum spreading is performed by phase modulation, we call the resultant signal a *direct-sequence spread spectrum* (DSSS) signal (see Figure 11.1) [15]. When spectrum spreading is achieved by a rapid change of the carrier frequency, we refer to the resultant signal as a *frequency-hop spread spectrum* (FHSS) signal [14]. When both direct-sequence and frequency-hop techniques are employed, the resultant signal is called a hybrid DS-FH SS signal. Another way to also generate an SS signal is the *time-hop spread spectrum* (THSS) signal. In this case, the transmission time is divided into intervals called frames. Each frame is further divided into time slots. During each frame, one and only one time slot is modulated with a message (details of THSS are not given in this chapter). The DSSS is the averaging technique to reduce interference whereas FHSS and THSS are the avoiding techniques to minimize interference. The spreading signal is selected to have properties to facilitate demodulation of the transmitted signal by the intended receiver, and to make demodulation by an unintended receiver as diffi cult as possible. These same properties also make it possible for the intended receiver to differentiate between the communication signal and jamming. If the bandwidth of the spreading signal is large relative to the data bandwidth, the spread-spectrum transmission bandwidth is dominated by the spreading signal and is independent of the data signal bandwidth.

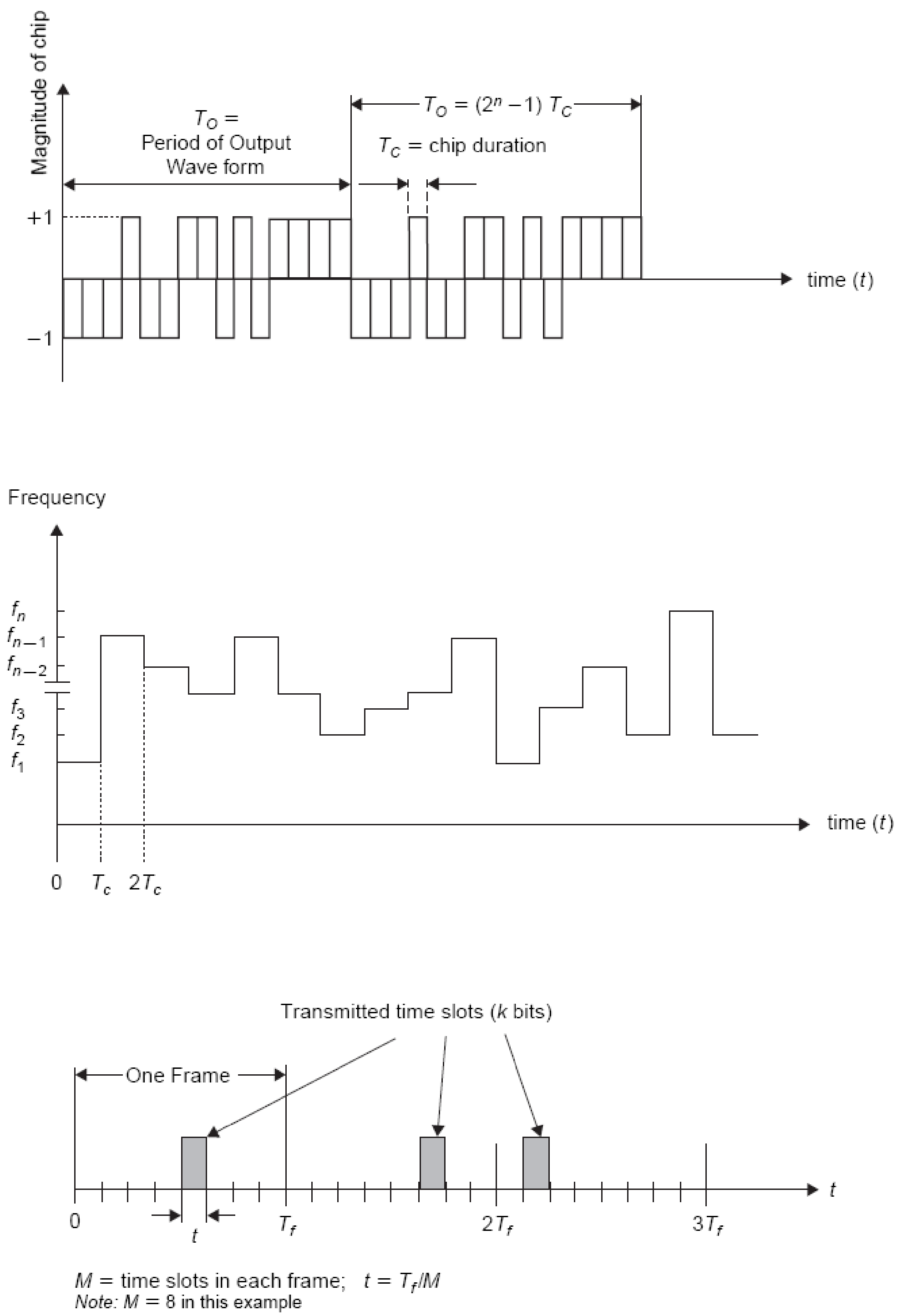

Figure 11.1 Spread spectrum techniques.

Quadrature Phase-Shift Keying DSSS

Sometimes it is advantageous to transmit simultaneously on two carriers which are in phase quadrature. The main reason for this is to save spectrum because, for the same total transmitted power, we can achieve the same bit error probability, P_e, using one-half the transmission bandwidth. The quadrature modulations are more diffi cult to detect in low probability of detection applications. Also, the quadrature modulations are less sensitive to some types of jamming. We refer to Figure 11.9 and write: hen the spreading codes are staggered one-half chip interval with respect to each other, the QPSK is called offset-QPSK (OQPSK). In OQPSK, the phase changes every one-half chip interval, but it does not change more than _90°. This limited phase change improves the uniformity of the signal envelope compared to BPSK and QPSK, since zero-crossings of the carrier envelope are avoided. Neither QPSK nor OQPSK modulation can be removed with a single stage of square-law detection. Two such detectors and the associated loss of signal-to-noise ratio are required. QPSK and OQPSK offer some low probability of detection advantages over the BPSK method.

Critical Challenges of CDMA

Code division multiple access (CDMA) is based on DSSS. CDMA is more complex than other multiple access technologies and as such poses several critical challenges. All users in a given cell transmit at the same time in the same frequency band. Can they be made not to interfere with each other? Will a user who is near the base station saturate the base station altogether so that it cannot receive users who are farther away (known as near-far problem)? CDMA uses a reuse factor of one. This means that the same frequency is used in adjacent cells. Can the codes provide suffi cient separation for this to work well in most situations? CDMA uses soft handoffs where a moving user can receive and combine signals from two or more base stations at the same time. What is the impact on base station traffi c handling ability?

Signal Strength:

signal strength refers to the magnitude of the electric field at a reference point that is a significant distance from the transmitting antenna. It may also be referred to as **received signal level** or **field strength**. Typically, it is expressed in voltage per length or signal power received by a reference antenna. High-powered transmissions, such as those used in broadcasting, are expressed in dB-millivolts per metre (dBmV/m). For very low-power systems, such as mobile phones, signal strength is usually expressed in dB-microvolts per metre (dBμV/m) or in decibels above a reference level of one milliwatt (dBm). In broadcasting terminology, 1 mV/m is 1000 μV/m or 60 dBμ (often written dBu).

Examples

- 100 dBμ or 100 mV/m: blanketing interference may occur on some receivers
- 60 dBμ or 1.0 mV/m: frequently considered the edge of a radio station's protected area in North America
- 40 dBμ or 0.1 mV/m: the minimum strength at which a station can be received with acceptable quality on most receivers

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