MODULATION AND MULTIPLE ACCESS TECHNIQUES

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Outlines

- Introduction
- Digital Transmission
- Digital Modulation
- Digital Transmission of Analog Signal
- Time Division Multiplexing
- Multiple Access Techniques

Introduction (1960s – 1970s)

- Communication satellites are used to carry telephone, video, and data signals, and can use both analog and digital modulation techniques. When GEO satellites were first used for communications in the 1960s and 1970s, the signals were almost exclusively analog.

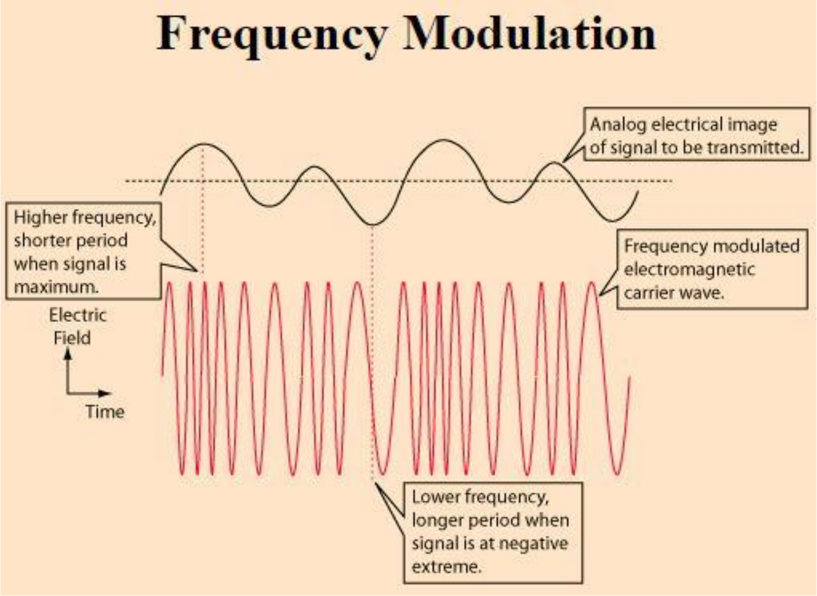
- The modulation and multiplexing techniques that were used at this time were analog, adapted from the technology developed for microwave links in the previous two decades.

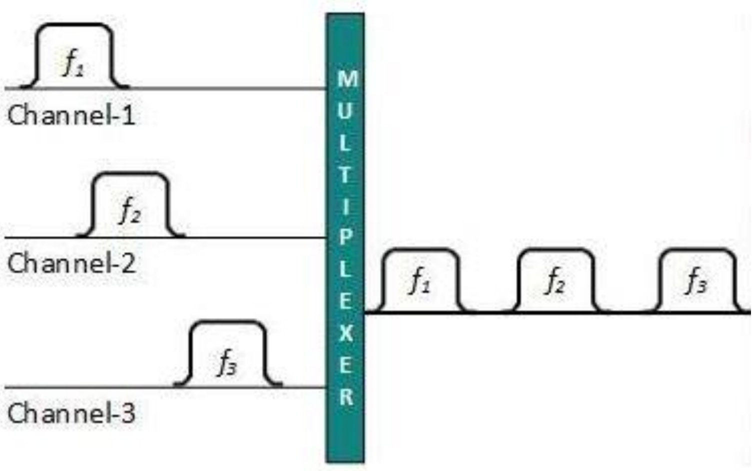
- **Frequency Modulation (FM)** was the modulation of choice and **Frequency Division Multiplexing (FDM)** was used to combine hundreds or thousands of telephone channels onto a single microwave carrier.

Introduction

Frequency Modulation

Frequency Division Multiplexing





Digital Transmission

Digital Transmission

- Digital modulation is the obvious choice for satellite transmission of signals that originate in digital form and that are used by digital devices.

- Virtually all signals sent via satellites are now digital. Example: data transmission using Internet, digital telephony, and TV signals in digital form, such as HDTV and DBS-TV.

- All digital links are designed in much the same way, using a specific symbol rate, and specific filters that minimize Intersymbol interference (ISI).

- In a satellite link, a symbol is almost always a phase state (BPSK and QPSK) or a phase and amplitude state (QAM). Symbol rates are given in ***bound*** or in symbols per second, abbreviated to ***sps***.

Digital Transmission

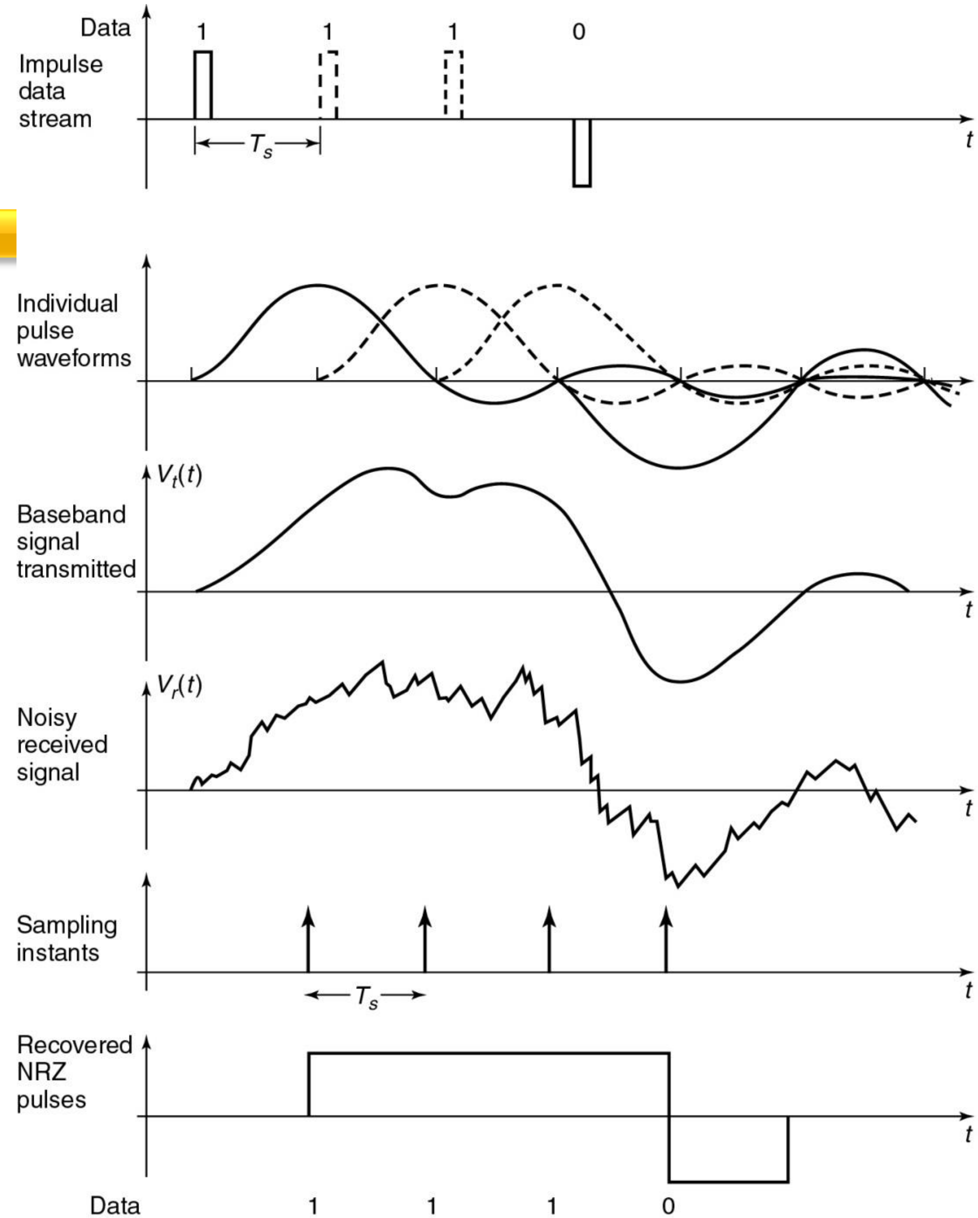
- In any digital communication system, a symbol is defined by the rate at which information is sent over a link, in the form of pulses at baseband, or changes in phase angle of a carrier, for example, in a PSK system.

- Popular modulations that transmit more than one bit per symbol are QPSK (two bits/symbol) and QAM (up to 10 bits/symbol).

- QPSK is widely used on satellite links, including direct broadcast satellite television.

- High-speed modems designed for telephone lines use QAM to send a high bit rate in a small bandwidth (e. g., 28.8 kbps in 4kHz bandwidth).

Figure 5.5 (p. 175) Transmission and reception of baseband zero-ISI pulses.

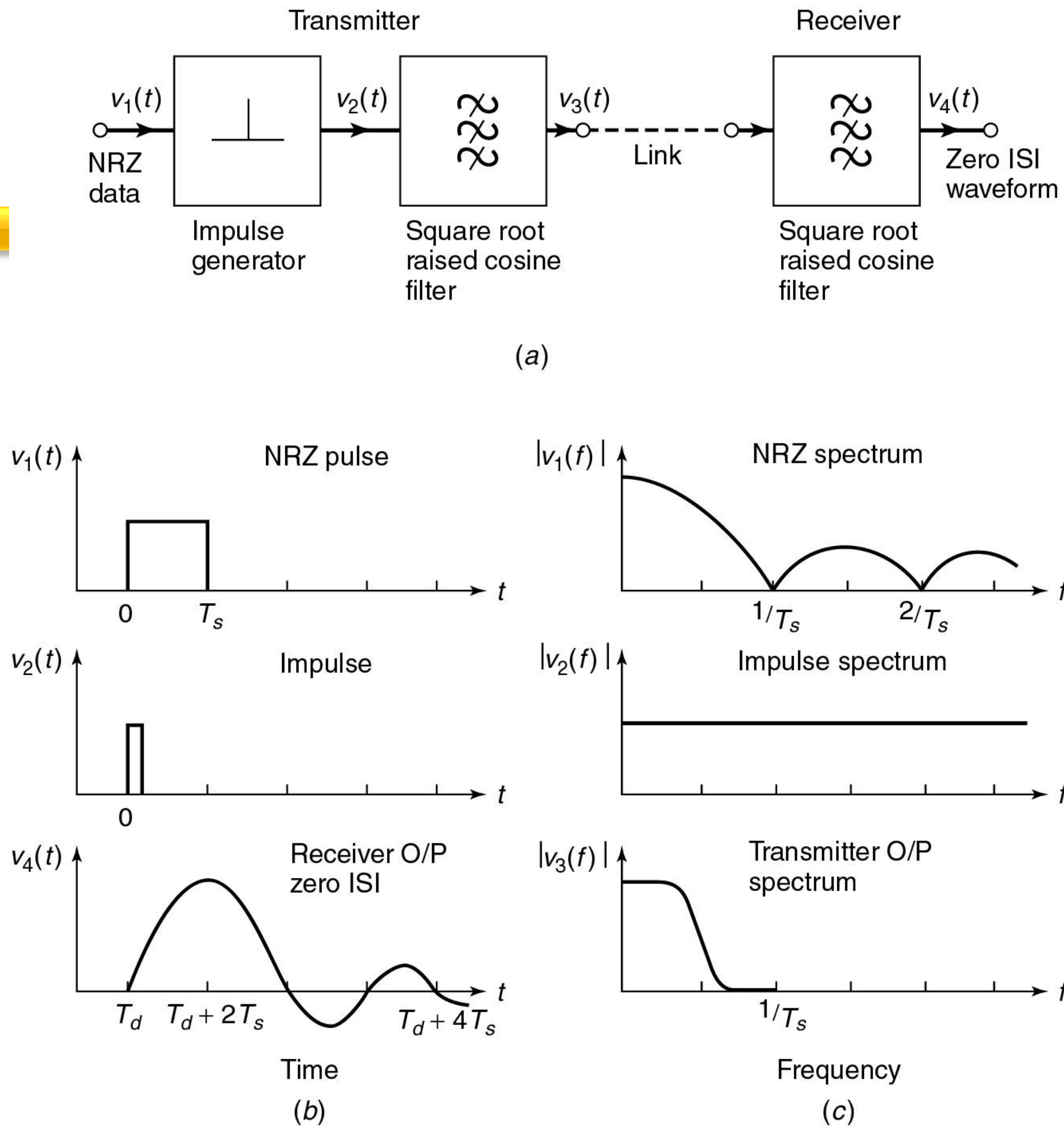


Satellite Communications, 2/E by Timothy Pratt, Charles Bostian, & Jeremy Allnutt

Figure 5.7 (p. 178)

Waveforms and spectra in a baseband data system with raised cosine filters. (*a*) System block diagram.

(*b*) Waveforms. (*c*) Spectra.



Digital Modulation

- While any parameter of a carrier waveform- amplitude, frequency, or phase- may be digitally modulated, phase modulation is almost universally used for satellite.
- For historical reasons, digital phase modulation is called **Phase Shift Keying**, abbreviated PSK.
- An m-phase PSK modulator puts the phase of a carrier into one of m states according to the value of a modulating voltage.

- Two states or biphase PSK is usually called **BPSK**, and four-state or quadriphase PSK is termed **QPSK**.
- **Note:**
  - Other numbers of states and some combinations of amplitude and phase modulation are possible and are employed in terrestrial links, but historically, satellite users have been reluctant to adopt anything besides BPSK or QPSK. **WHY?**

BPSK

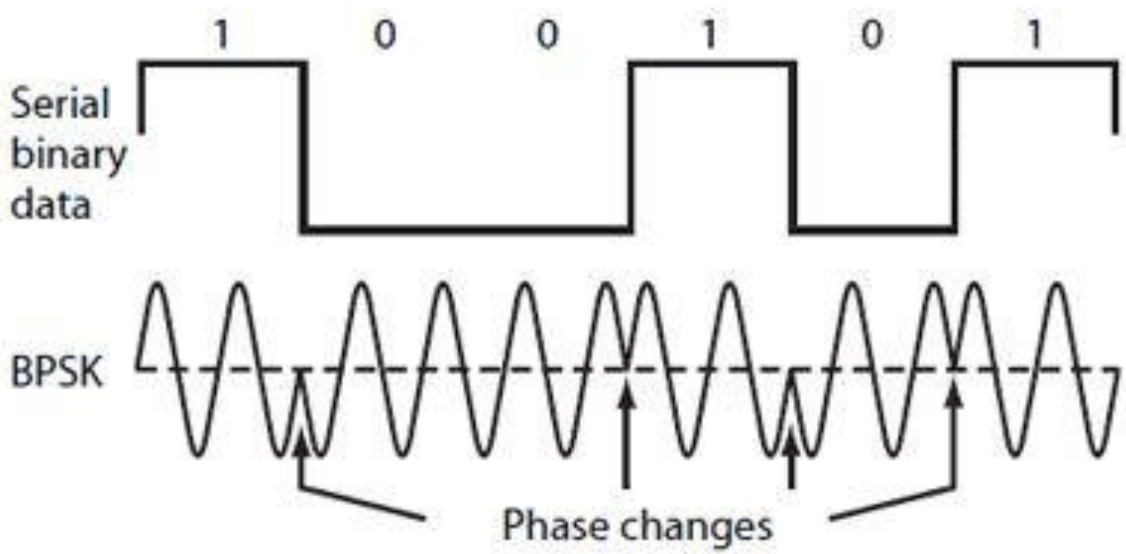
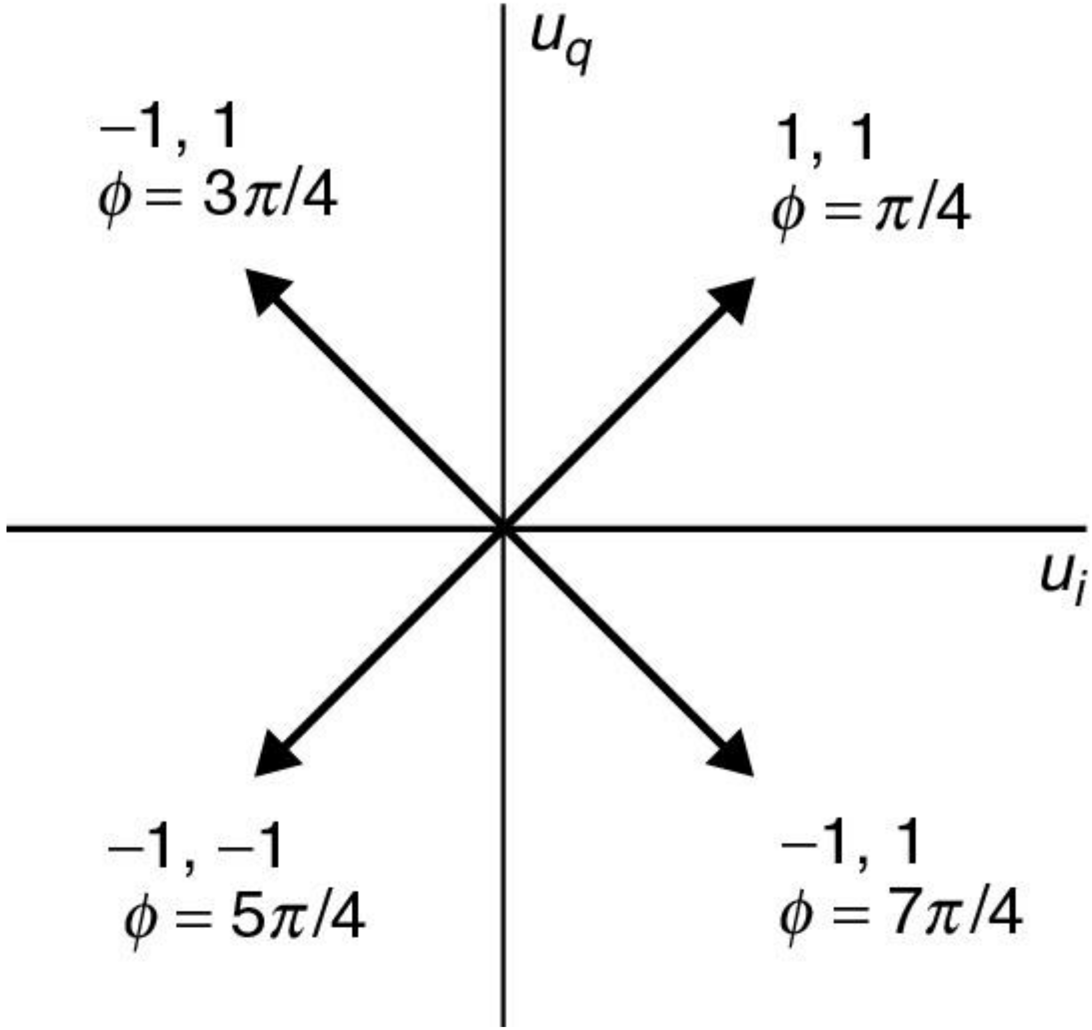
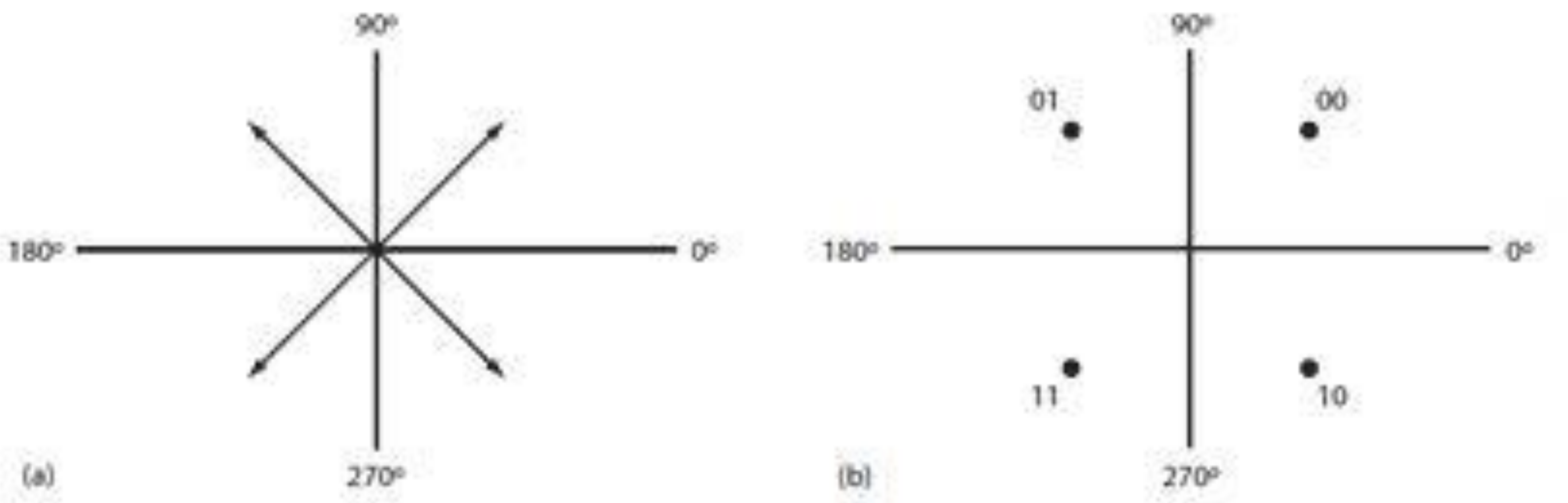


Figure 5.14 (p. 199)

Phasor diagram showing the phase of a QPSK waveform modulated with all possible pair combinations of the bits (u_i, u_q). Each phasor is formed by summing a u_i and a u_q signal.



QPSK



Bit pairs	Phase (degrees)
0 0	45
0 1	135
1 1	225
1 0	315

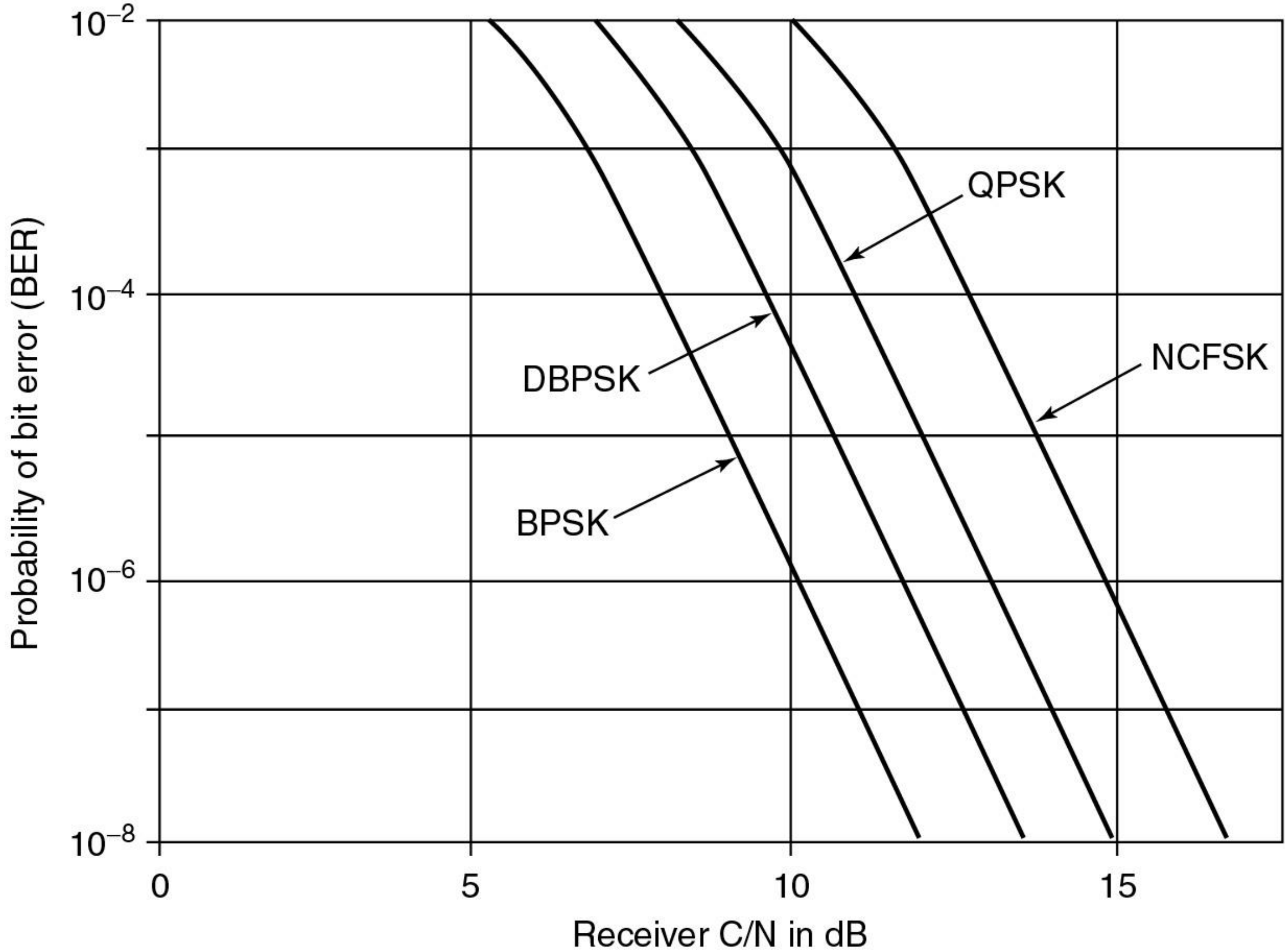
BPSK, and QPSK Bit Error Rate

- When BER is considered as a function of C/N ratio, BPSK and QPSK do not have the same BER. It takes twice as much transmitter power to deliver two BPSK data streams as to deliver one.

- Therefore, QPSK requires 3 dB more C/N ratio than BPSK to achieve the same error rate when transmitting at twice the bit rate in the same channel bandwidth.

Figure 5.13 (p. 196)

Bit error rate as a function of C/N for a link with ideal RRC filters and no intersymbol interference or timing jitter. The curves shown are for BPSK and QPSK with coherent detection (BPSK, QPSK), differential BPSK (DBPSK), and noncoherent FSK (NCFSK). The implementation margin in each case is 0 dB.



Digital Transmission of Analog Signal

Digital Transmission of Analog Signal

- The basic process in digital transmission of analog information are sampling, quantizing, and encoding.

- The principles underlying sampling are routinely presented in beginning courses in communications theory.

- The sampling theorem states that a signal may be reconstructed without error from regularly spaced samples taken at a rate $f, {}^{\text{samples}}/_{\text{second}}$ which is at least twice the maximum frequency f_{max} present in the signal.

Digital Transmission of Analog Signal

- The samples to which the sampling theorem refers are analog pulses whose amplitudes are equal to that of the original waveform at the time of sampling.

- The original waveform may be reconstructed without error by passing the sample through an ideal low pass filter whose transfer function is appropriate to the sampling pulse shape.

Digital Transmission of Analog Signal

- Each sample is converted into a digital word that represents the quantization value closest to the original analog sample. Quantization may be uniform or nonuniform depending on whether or not the quantized voltage levels are uniformly or nonuniformly spaced.

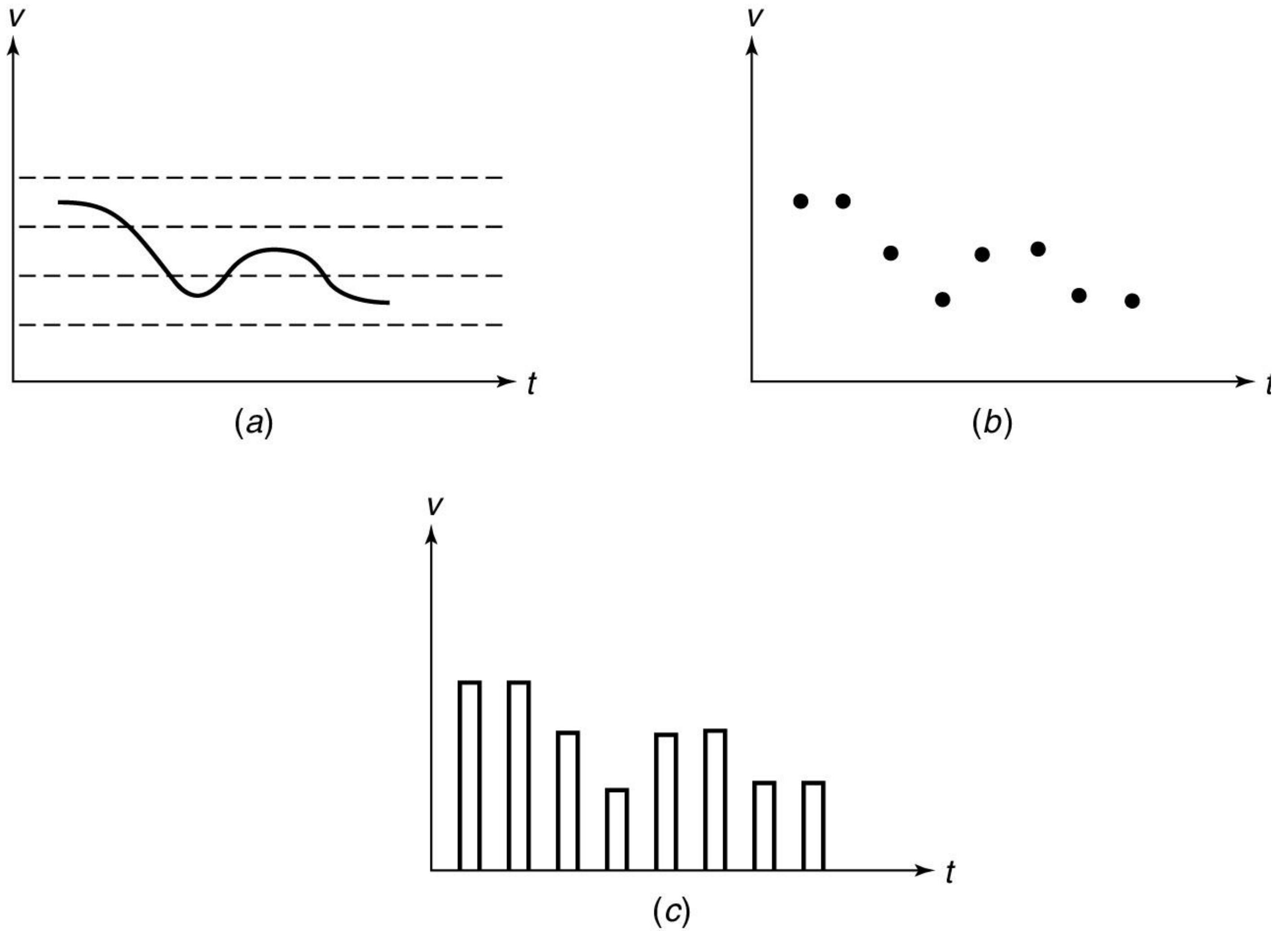
- At the receiver a digital-to-analog (D/A) converter converts each incoming digital word back into an analog sample; these analog samples are filtered and the original input waveform is reconstructed.

Digital Transmission of Analog Signal

- A communications system that transmits digitally encoded quantized value is called a *pulse code modulation* (**PCM**)system, when the PCM process is applied to voice and TV signals, they are often referred to simply as digital voice and digital TV.

Figure 5.18 (p. 203)

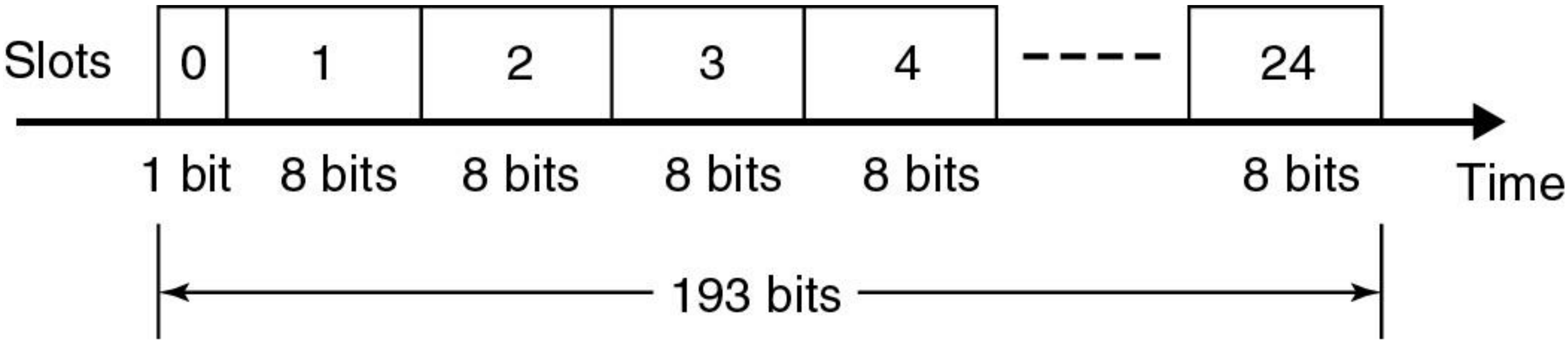
The quantizing process. (*a*) The input waveform and the quantization levels. (*b*) Quantized samples. (*c*) Quantized pulses. The pulse amplitude is encoded digitally for PCM transmission.



Time Division Multiplexing

Time Division Multiplexing

- Digital signals from different channels are interleaved for transmission through time division multiplexing (TDM). Data, or digitized samples of analog signals from each channel, are transmitted in turn.



Time Division Multiplexing

- The time interval in which one sample or word from each channel is sent is called a frame. Channels are identified by their position in the frame and individual frames are identified by the presence of synchronization bits that repeat with a known pattern.
- **Home Work:**
  - Talk about the important TDM standards!

Multiple Access Techniques

Multiple Access Techniques

- The ability of the satellite to carry many signals at the same time is known as multiple access.

- Multiple access allows the communication capacity of the satellite to be shared among a large number of earth stations, and to accommodate the different mixes of communication traffic that are transmitted by the earth station.

Multiple Access Techniques

- The basic form of multiple access employed by all communications satellites is the use of many transponders. A large GEO satellite may have a communication bandwidth of over 2000 MHz within an allocated spectrum of 500 MHz. through frequency reuse with multiple beams and orthogonal polarization, the spectrum can be reused several times over – as many as seven times in the case of INTELSAT IX satellites.

Multiple Access Techniques

- The frequency spectrum used by the satellite is divided into smaller bandwidth which are allocated to transponders, allowing separate communication links to be established via the satellite on the basis of transmit frequency.

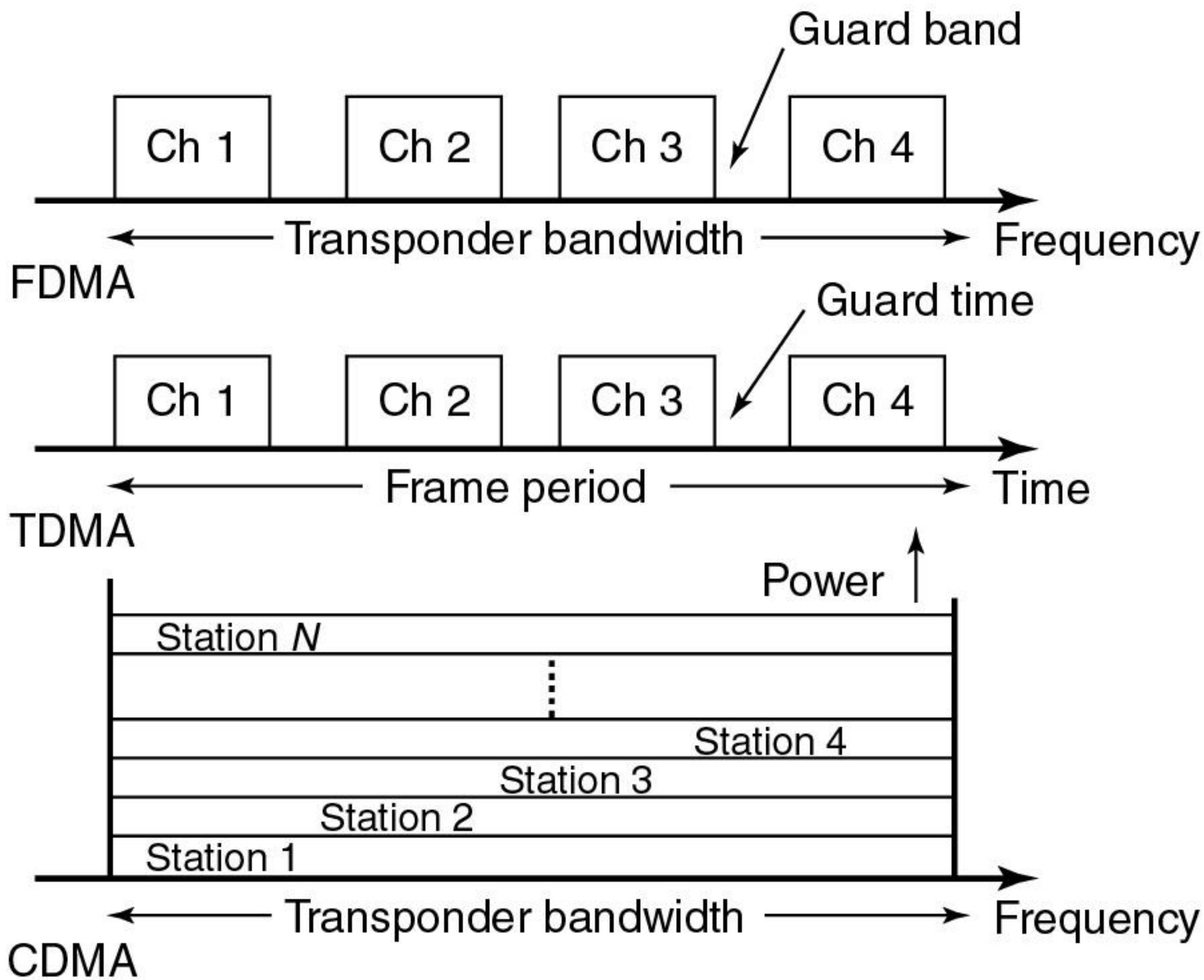
- Transponder bandwidths of 36, 54, and 72 MHz have been commonly employed on GEO satellites.

Multiple Access Techniques

- In each of the multiple access techniques, some unique property of the signal (frequency, time, or code) is used to label the transmission such that the wanted signal can be recovered at the receiving terminal in the presence of all other signals.
- **Home Work?**
  - Explain the difference between Multiplexing and Multiple Access?

Figure 6.1 (p. 222)

Multiple access techniques: FDMA, TDMA, and CDMA. Note that in the direct sequence form of CDMA shown here, all the channels overlap in both time and frequency.



FDMA

- In Frequency Division Multiple Access (FDMA) all users share the satellite at the same time, but each user transmits at a unique allocated frequency. Each radio station is allocated a frequency and a bandwidth, and transmits its signal within that piece of the frequency spectrum.

- FDMA can be used by analog or digital signals.

- First technique used in satellite communication systems.

FDMA

- The main advantage of FDMA is that filters can be used to separate signals. Filter technology was well understood when satellite communications began, and microwave filter were used in earth stations to separate the FDMA signals within a given transponder.

Figure 6.2 (p. 224)

Frequency plan for two C-band transponders using FDMA. The triangles are symbols representing the bandwidth occupied by the signals, not power spectral densities. The places and figures within the triangles are the transmitting station location and carrier RF bandwidth. Frequencies shown are for the downlink from the satellite.

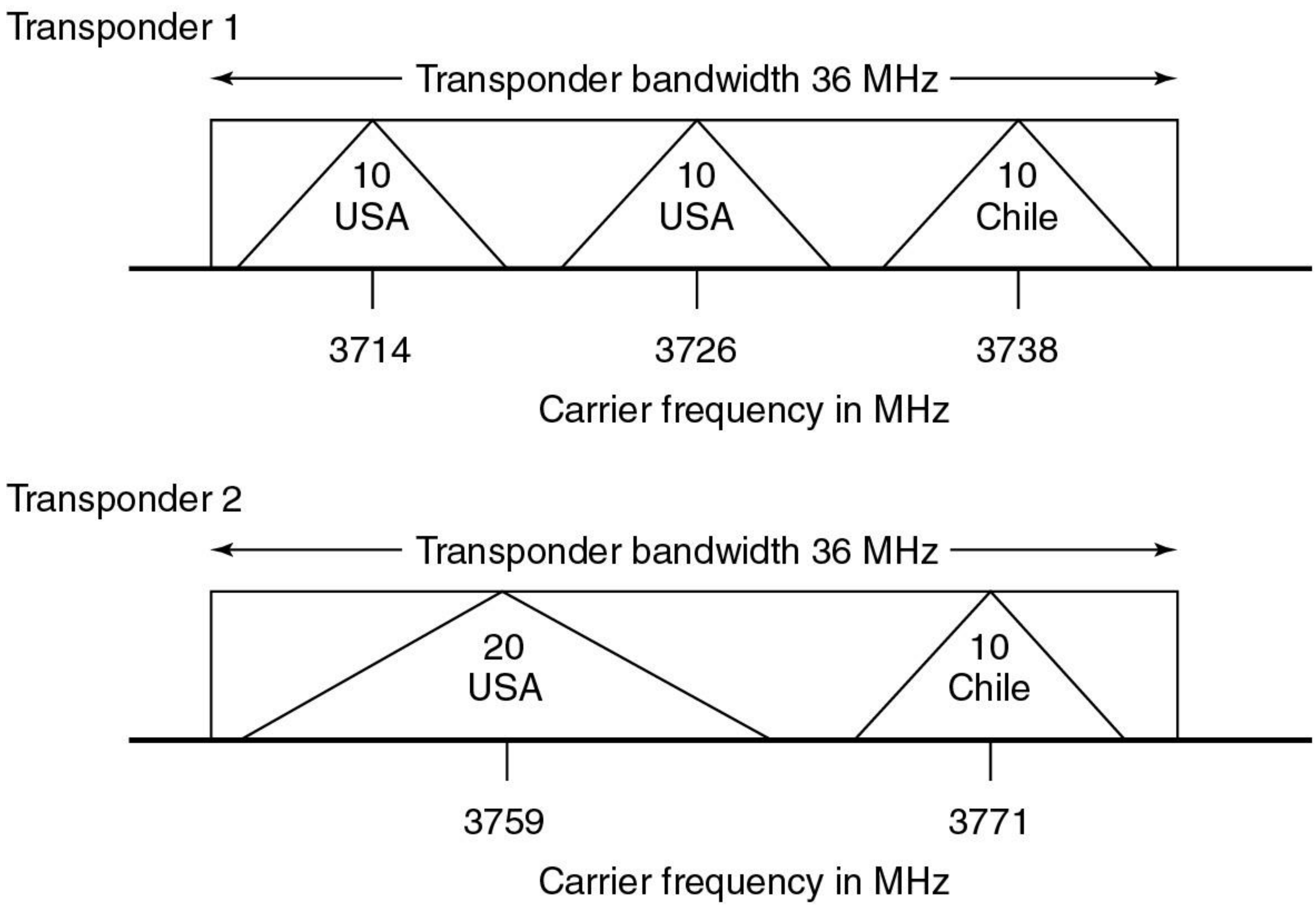
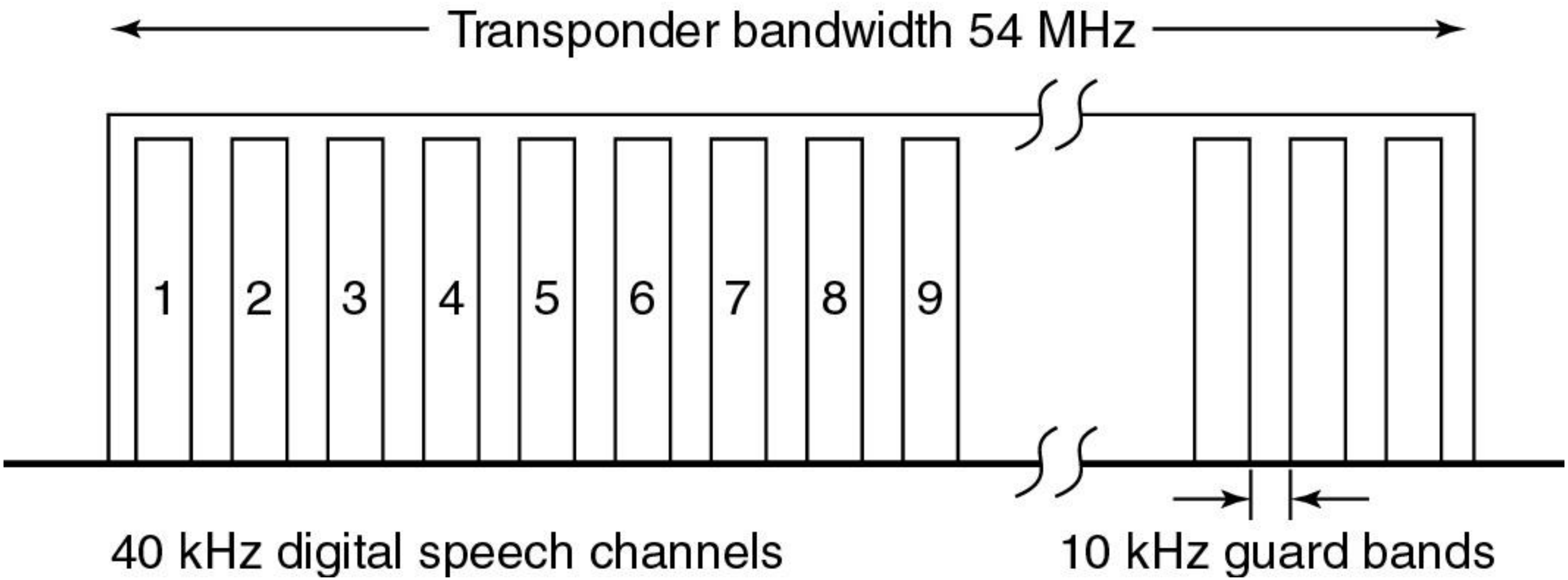


Figure 6.3 (p. 225)

Illustration of a Ku-band transponder bandwidth filled with a large number of FDMA-SCPC digital speech channels.
RF bandwidth of each channel is 40 kHz with 10 kHz guard bands between channels.



TDMA

- In Time Division Multiple access (TDMA)each user is allocated a unique time slot at the satellite so that signals pass through the transponder sequentially.

- Because TDMA causes delays in transmission, it is used only with digital signals.

- Because the signals are digital and can be divided by time, are easily reconfigured for changing traffic demands, are resistant to noise and interference, and can readily handle mixed voice, video, and data traffic.

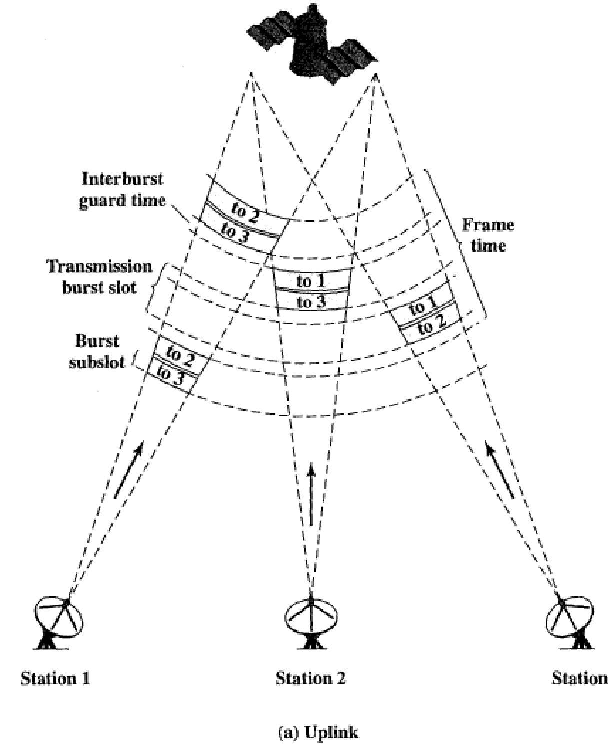
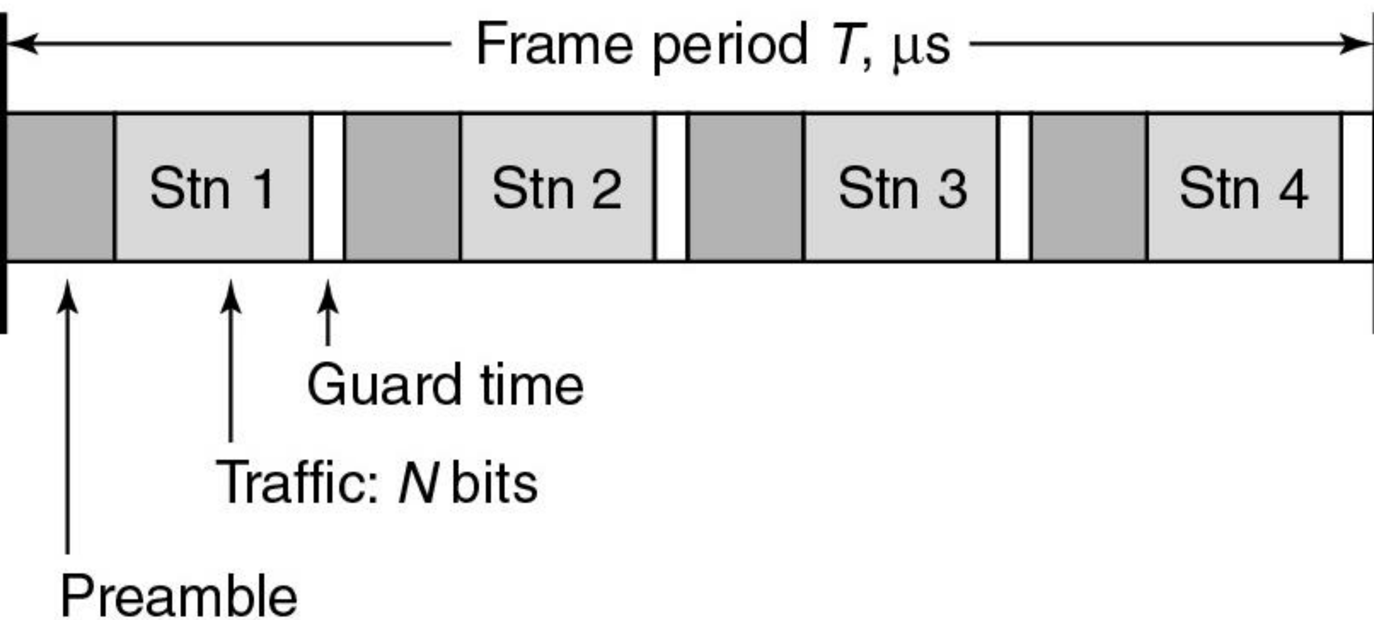


Figure 6.8 (p. 235)

TDMA frame with four transmitting earth stations.



CDMA

- In Code Division Multiple Access (CDMA) all users transmit to the satellite on the same frequency and at the same time. The earth stations transmit orthogonally coded spread spectrum signals that can be separated at the receiving earth station by correlation with the transmitted code.

- CDMA is inherently a digital technique.

- Stations with traffic can access a transponder on demand without coordinating their frequency (as in FDMA) or their time of transmission (as in TDMA)

CDMA

- Each receiving station is allocated a CDMA code; any transmitting station that wants to send data to the earth station must use the correct code.

- CDMA codes are typically 16 bits to many thousands of bits in length, and the bits of a CDMA code are called chips to distinguish them from the message bits of a data transmission.

- CDMA is also known as a spread spectrum. Direct sequence spread spectrum (DSSS) is the only type currently used in satellite communication.

- **Home Work?**
  - **CDMA is not widely adopted by satellite communications?**

Figure 6.16 (p. 258)

The basic principle of a direct sequence spread spectrum (CDMA) system. Each incoming message data bit is multiplied by the same PN sequence. In this example the message sequence is –1 + 1 and the PN sequence is + 1 + 1 + 1–1 +1 –1 –1.

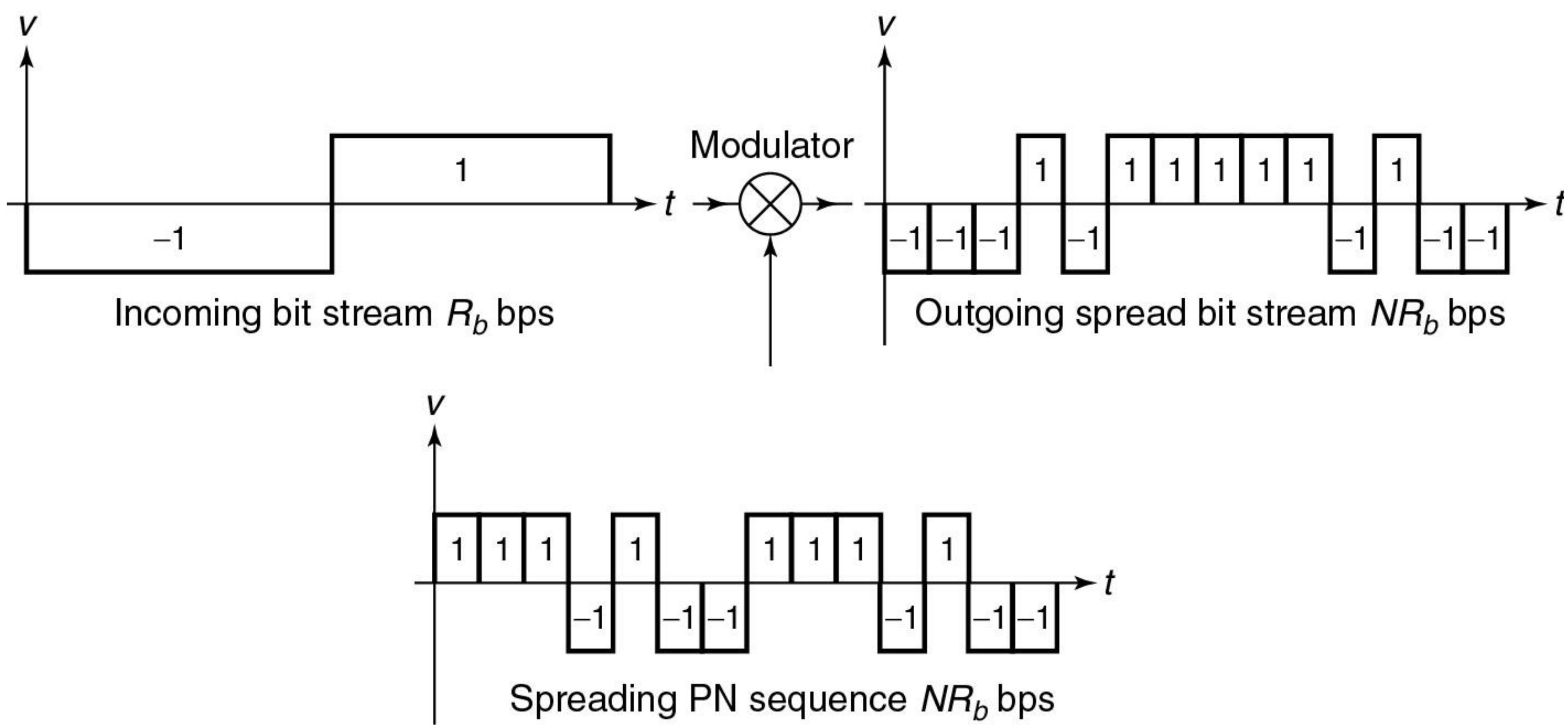


Figure 6.17 (p. 259) Data bit recovery using an IF correlator (matched filter). In this example the PN sequence is seven bits long for illustration. The CDMA chips from the receiver are clocked into the shift register serially and the shift register contents passed through phase shifters and added. The phase shifters convert –1 chips to + 1 when the correct code is in the shift register such that all the voltages add to a maximum when the received sequence is correct. This figure shows the shift register contents and adder output for the chip sequence in Figure 6.16. Note that a high spurious output of 5 occurs at the third clock step, indicating that the seven bit sequence used here for illustration has poor autocorrelation properties.

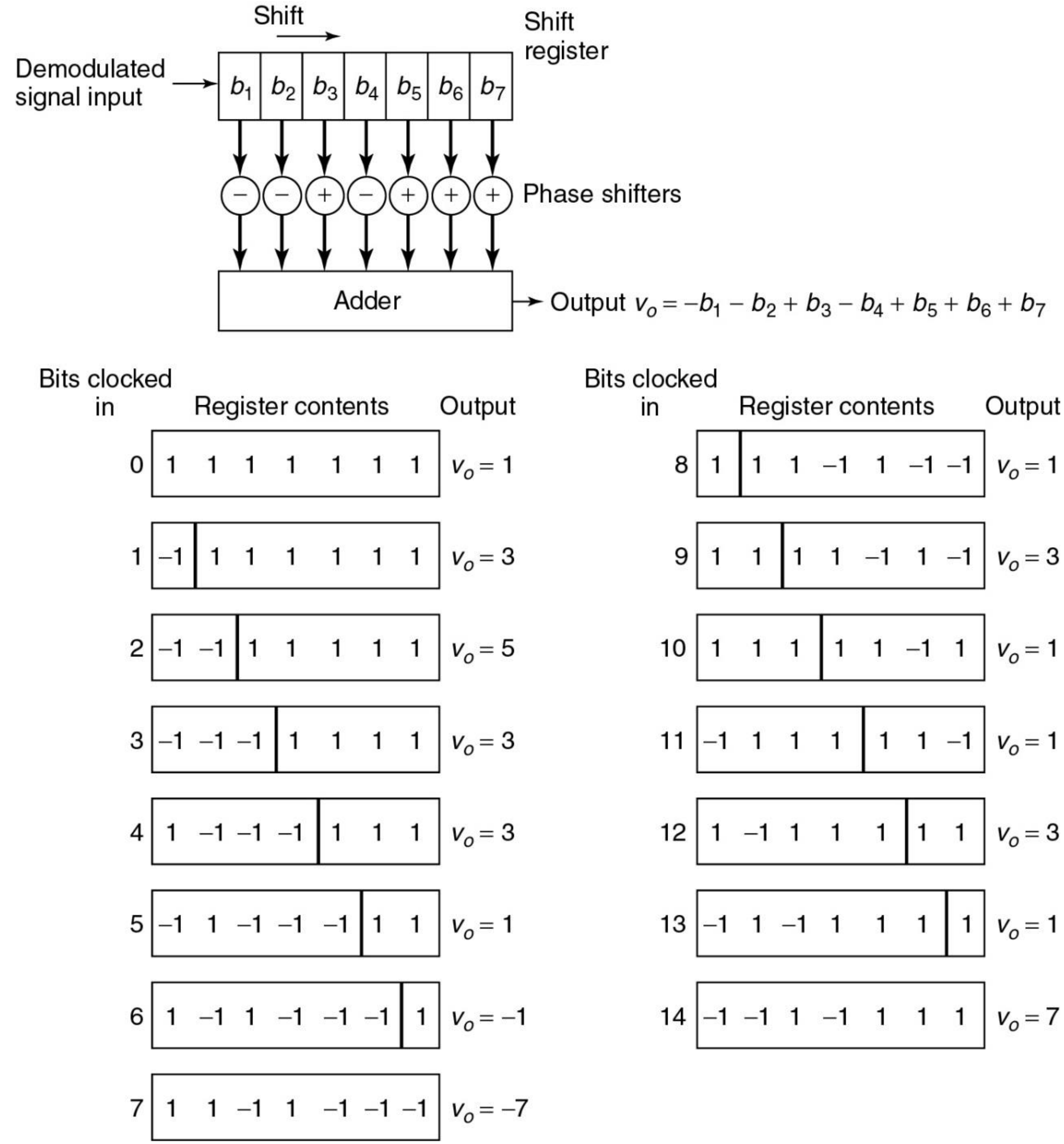
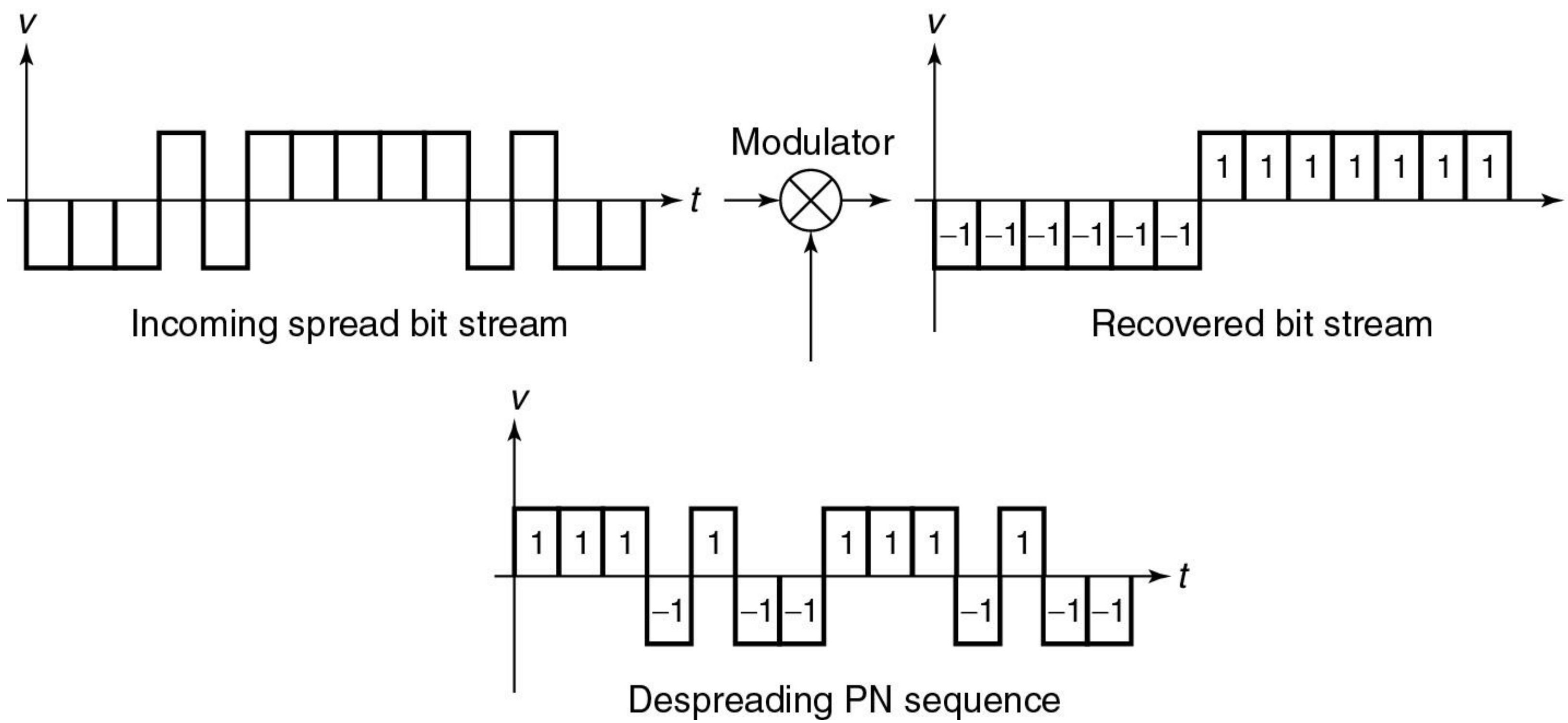


Figure 6.18 (p. 260)

A baseband correlator for dispreading CDMA signals. The original bit stream is recovered by multiplying the received signal by a synchronized copy of the PN sequence that was used in the transmitter.



Q & A