BLM6196 COMPUTER NETWORKS AND COMMUNICATION PROTOCOLS

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(13th Week)

5. Wireless Transmission Techniques

5.Outline

- MIMO Antennas
- OFDM, OFDMA, and SC –FDMA
- Spread Spectrum
- Direct Sequence Spread Spectrum
- Code-Division Multiple Access

MIMO Antennas

- Multiple-input-multiple-output
- Has become a key technology in evolving high-speed wireless networks
- Exploits the space dimension to improve wireless systems in terms of capacity, range, and reliability
- Cornerstone of emerging broadband wireless networks

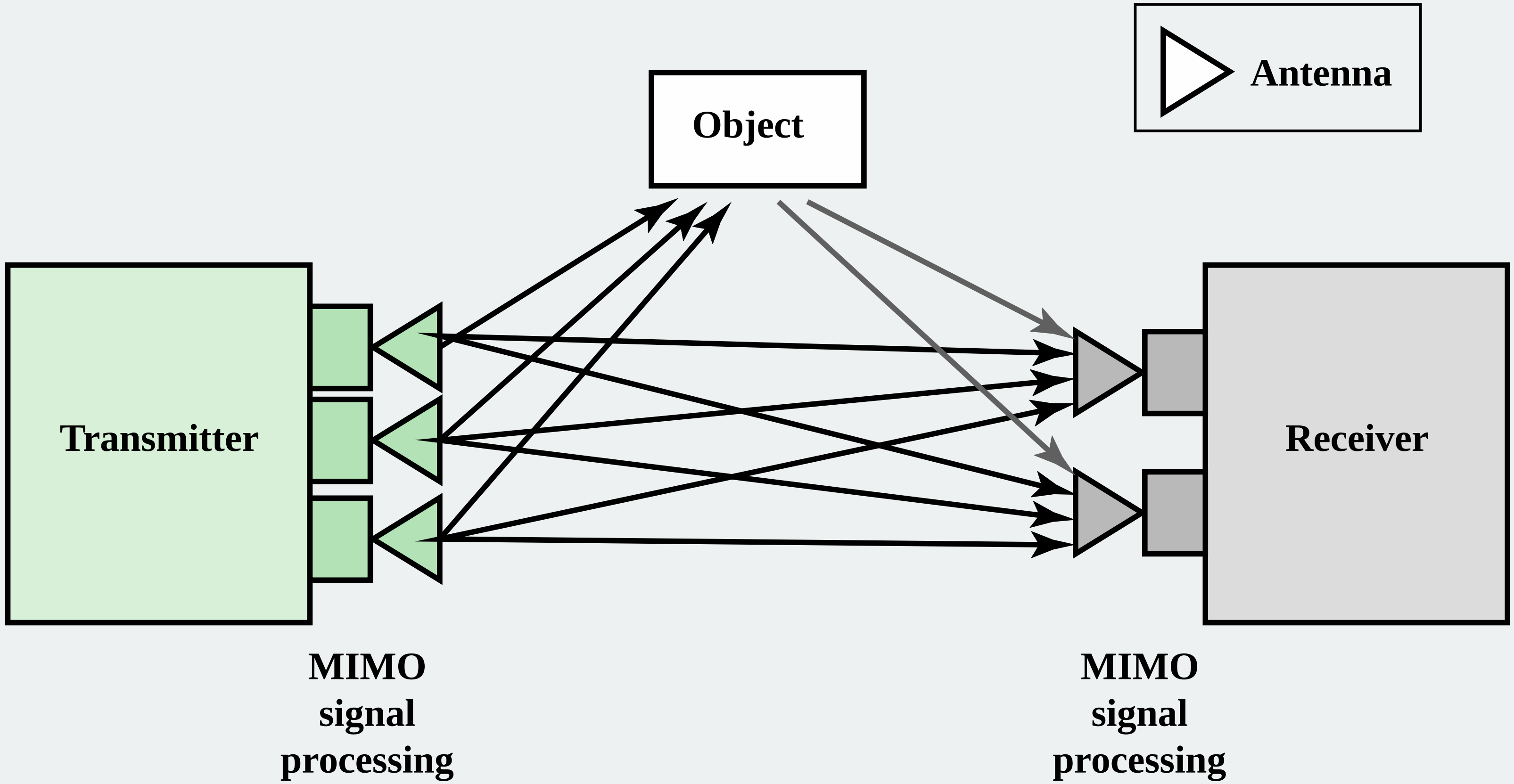


Figure 17.1 MIMO Scheme

MIMO Principles

- Two types of transmission schemes:

Spatial diversity

The same data is coded and transmitted through multiple antennas, which effectively increases the power in the channel proportional to the number of transmitting antennas

Improves SNR for cell edge performance

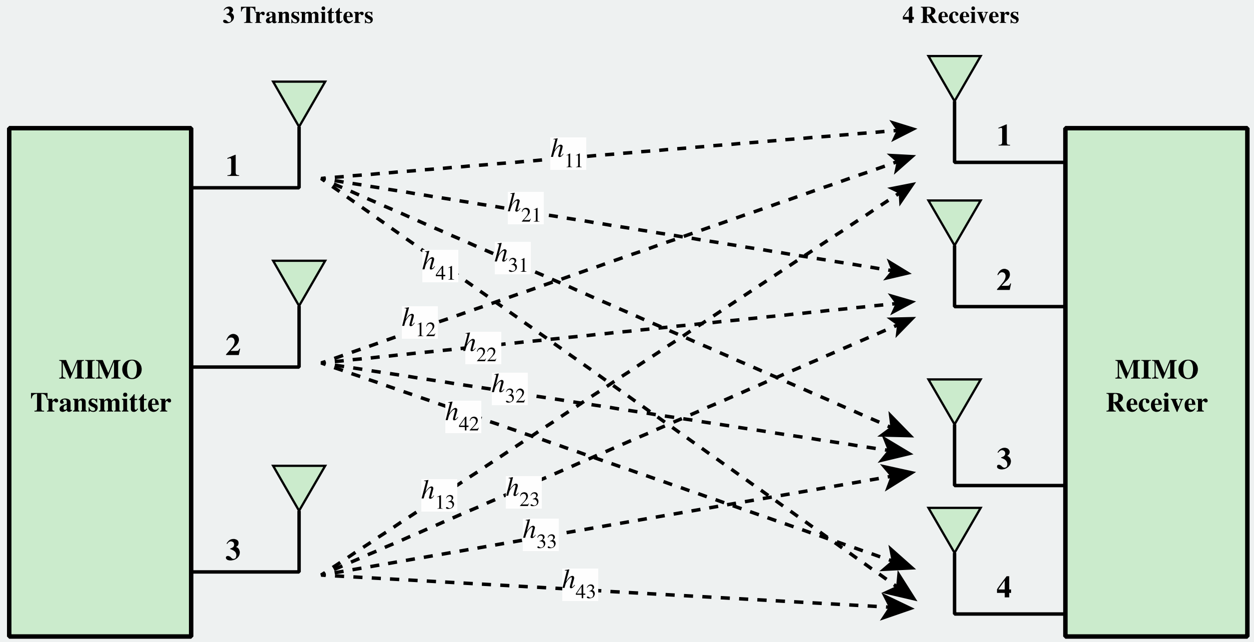
There is a high probability that if one antenna is suffering a high level of fading, another antenna has sufficient signal level

Spatial multiplexing

A source data stream is divided among the transmitting antennas

Gain in channel capacity is proportional to the available number of antennas at the transmitter or receiver, whichever is less

Can be used when transmitting conditions are favorable and for relatively short distances



$$\mathrm{H} = \left.\overbrace{\begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \\ h_{41} & h_{42} & h_{43} \end{bmatrix}}^{\textbf{3 transmit antennas}}\right\}\begin{array}{l}\textbf{4 receive} \\ \textbf{antennas}\end{array}$$

Figure 17.2 3×4 MIMO Scheme

Multiple-User MIMO

- MU-MIMO
- Extends the basic MIMO concept to multiple endpoints, each with multiple antennas
- Advantage is that the available capacity can be shared to meet time-varying demands
- Used in both Wi-Fi and 4G cellular networks

Applications of MU-MIMO

- Uplink – Multiple Access Channel, MAC
  - Multiple end users transmit simultaneously to a single base station
- Downlink – Broadcast Channel, BC
  - The base station transmits separate data streams to multiple independent users
- MIMO-MAC
  - Systems outperform point-to-point MIMO, particularly if the number of receiver antennas is greater than the number of transmit antennas at each user
  - A variety of multiuser detection techniques are used to separate the signals transmitted by the users
- MIMO-BC
  - Used to enable the base station to transmit different data streams to multiple users over the same frequency band
  - More challenging to implement
  - Techniques employed involve processing of the data symbols at the transmitter to minimize interuser interference

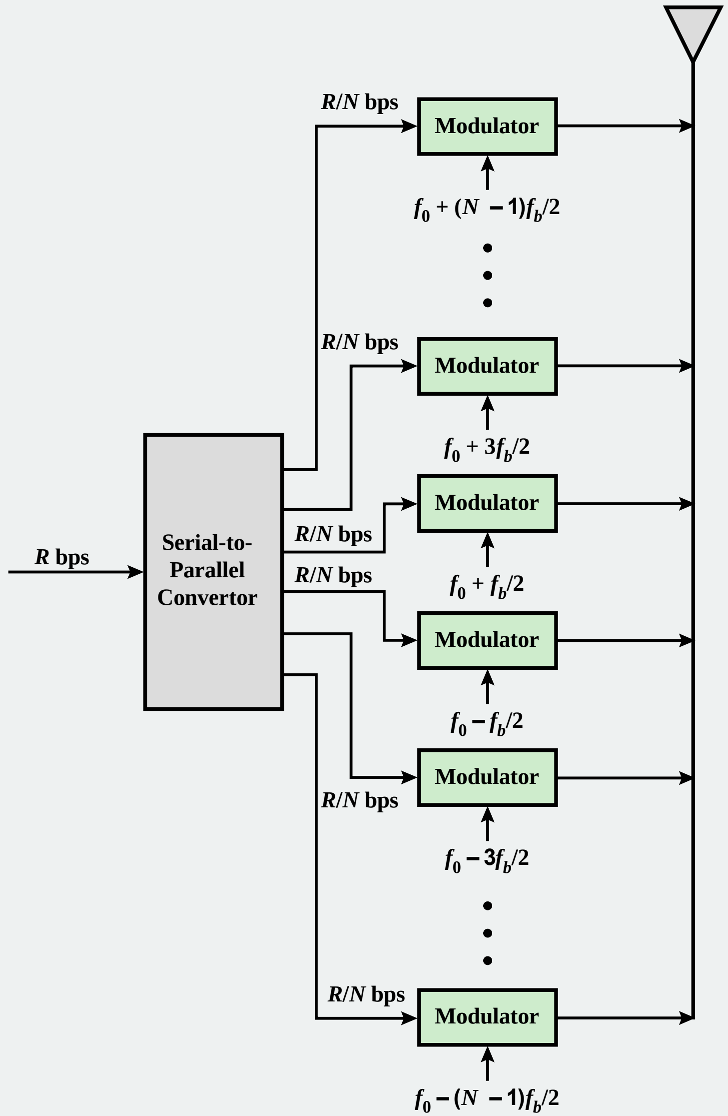


Figure 17.3 Orthogonal Frequency Division Multiplexing

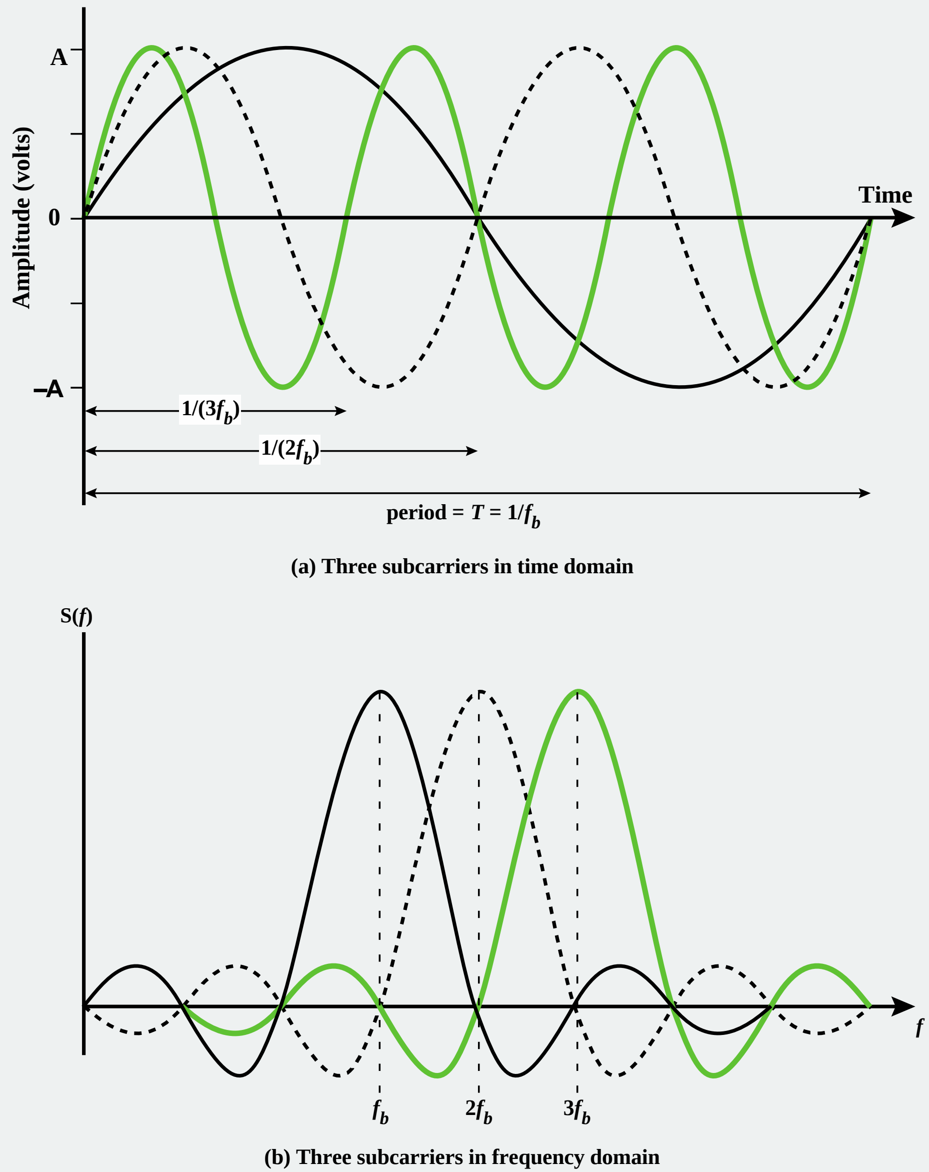
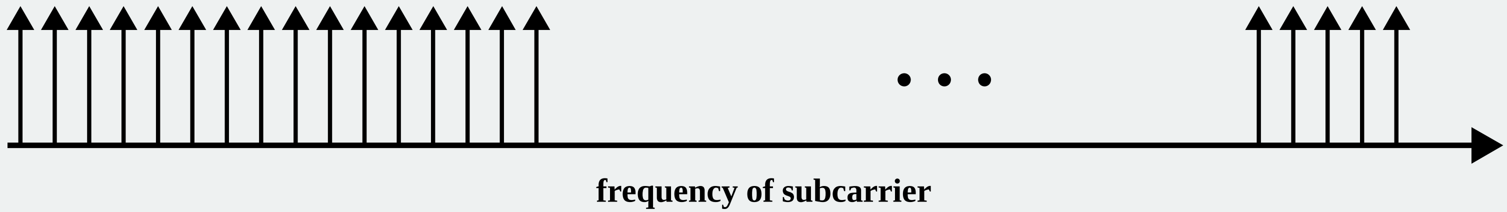


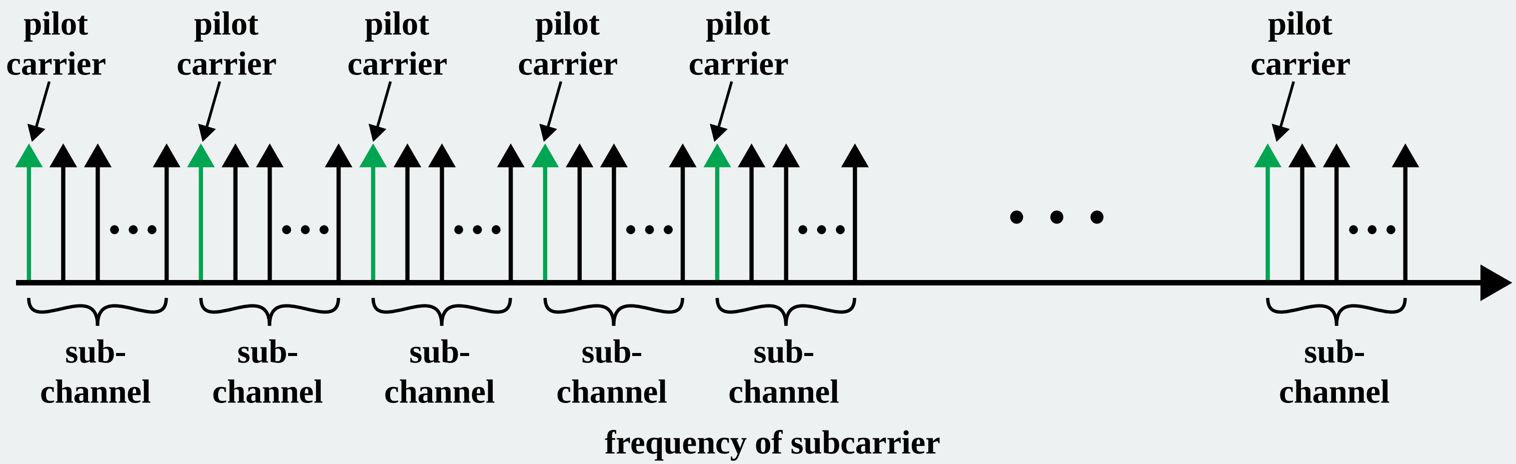
Figure 17.4 Illustration of Orthogonality of OFDM

OFDM Advantages

- If the data stream is protected by a forward error-correcting code frequency selective fading is easily handled
- Overcomes intersymbol interference (ISI) in a multipath environment
- QPSK is a common modulation scheme used with OFDM
- Signal processing involves two functions:
  - Fast Fourier transform (FFT)
    - Algorithm that converts a set of uniformly spaced data points from the time domain to the frequency domain
  - Inverse fast Fourier transform (IFFT)
    - Reverses the FFT operation
    - Has the effect of ensuring that the subcarriers do not interfere with each other

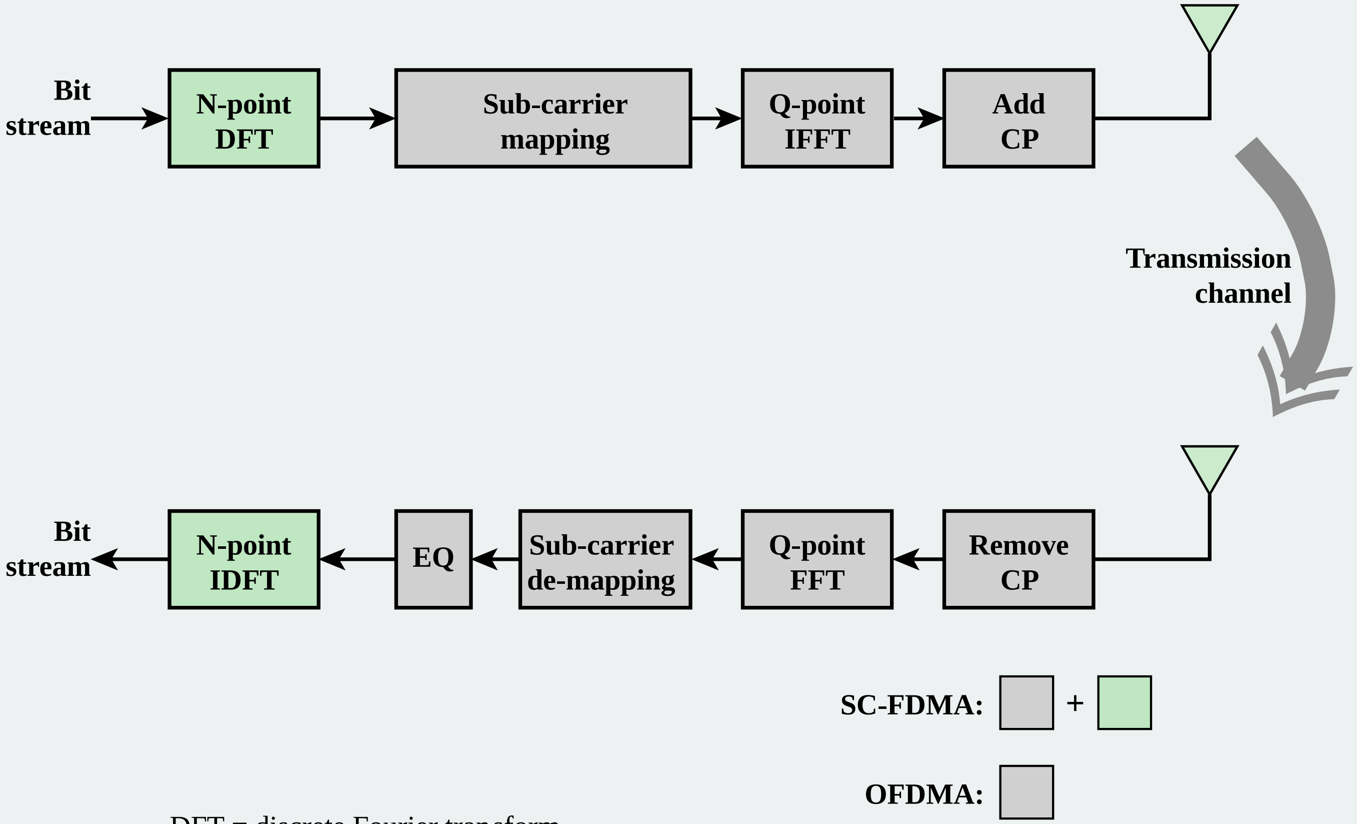


(a) OFDM



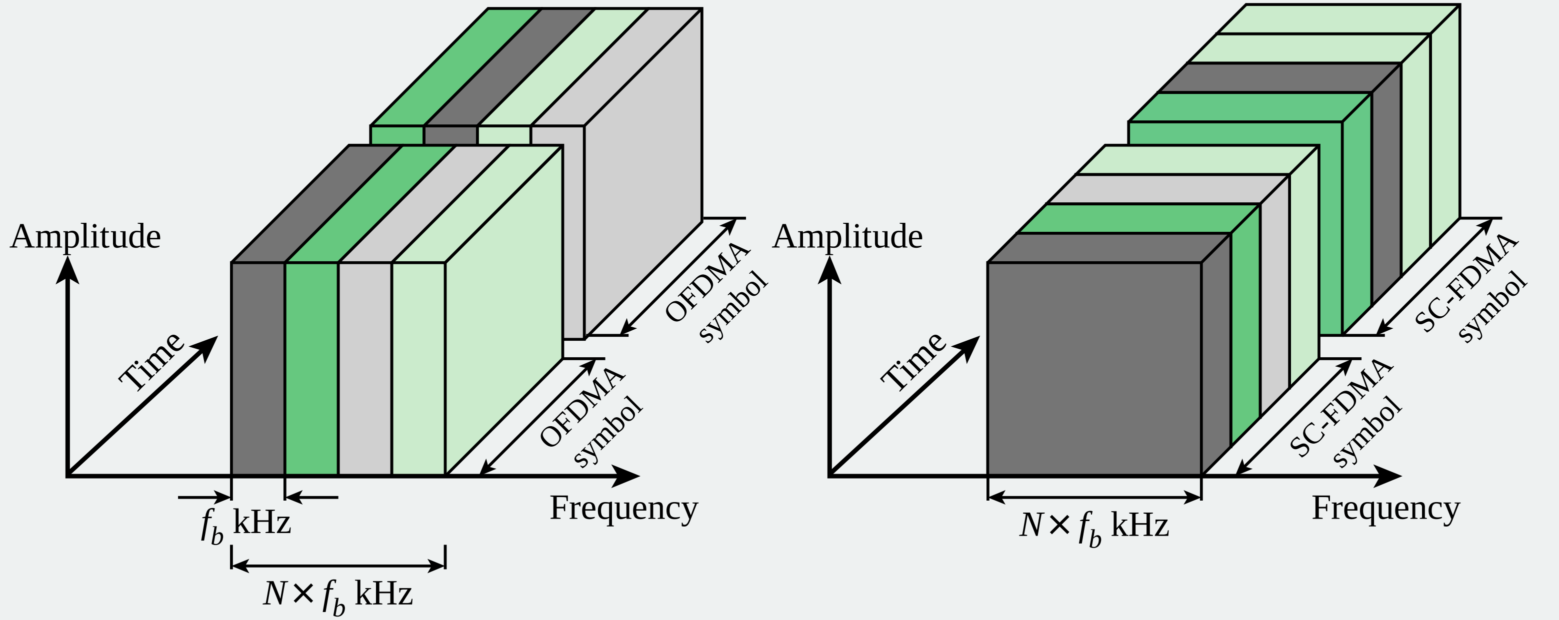
(b) OFDMA (adjacent subcarriers)

Figure 17.5 OFDM and OFDMA



DFT = discrete Fourier transform
IDFT = Inverse discrete Fourier transform
FFT = fast Fourier transform
IFFT = inverse fast Fourier transform
EQ = subcarrier equalization
CP = cyclic prefix

Figure 17.6 Simplified Block Diagram of OFDMA and SC-FDMA



(a) OFDM: Data symbols occupy f_b kHz for one OFDMA symbol period

(b) SC-FDMA: Data symbols occupy $N \times f_b$ kHz for $1/N$ SC-FDMA symbol period

Figure 17.7 Example of OFDMA and SC-FDMA

Spread Spectrum

- Form of encoding for wireless communications
- Can be used to transmit either analog or digital data, using an analog signal
- Was initially developed for military and intelligence requirements
- Essential idea is to spread the information signal over a wider bandwidth to make jamming and interception more difficult
  - Frequency hopping
  - Direct sequence

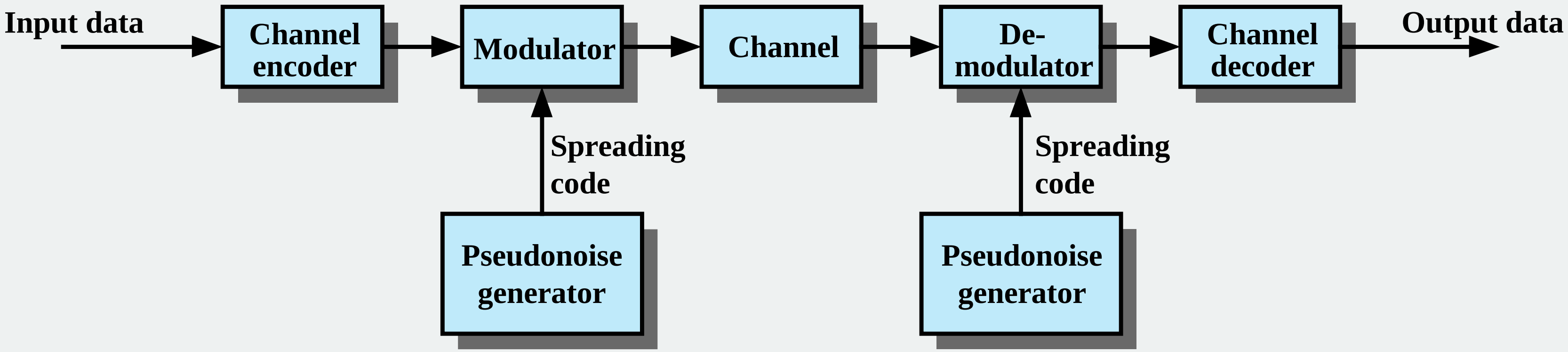


Figure 17.8 General Model of Spread Spectrum Digital Communication System

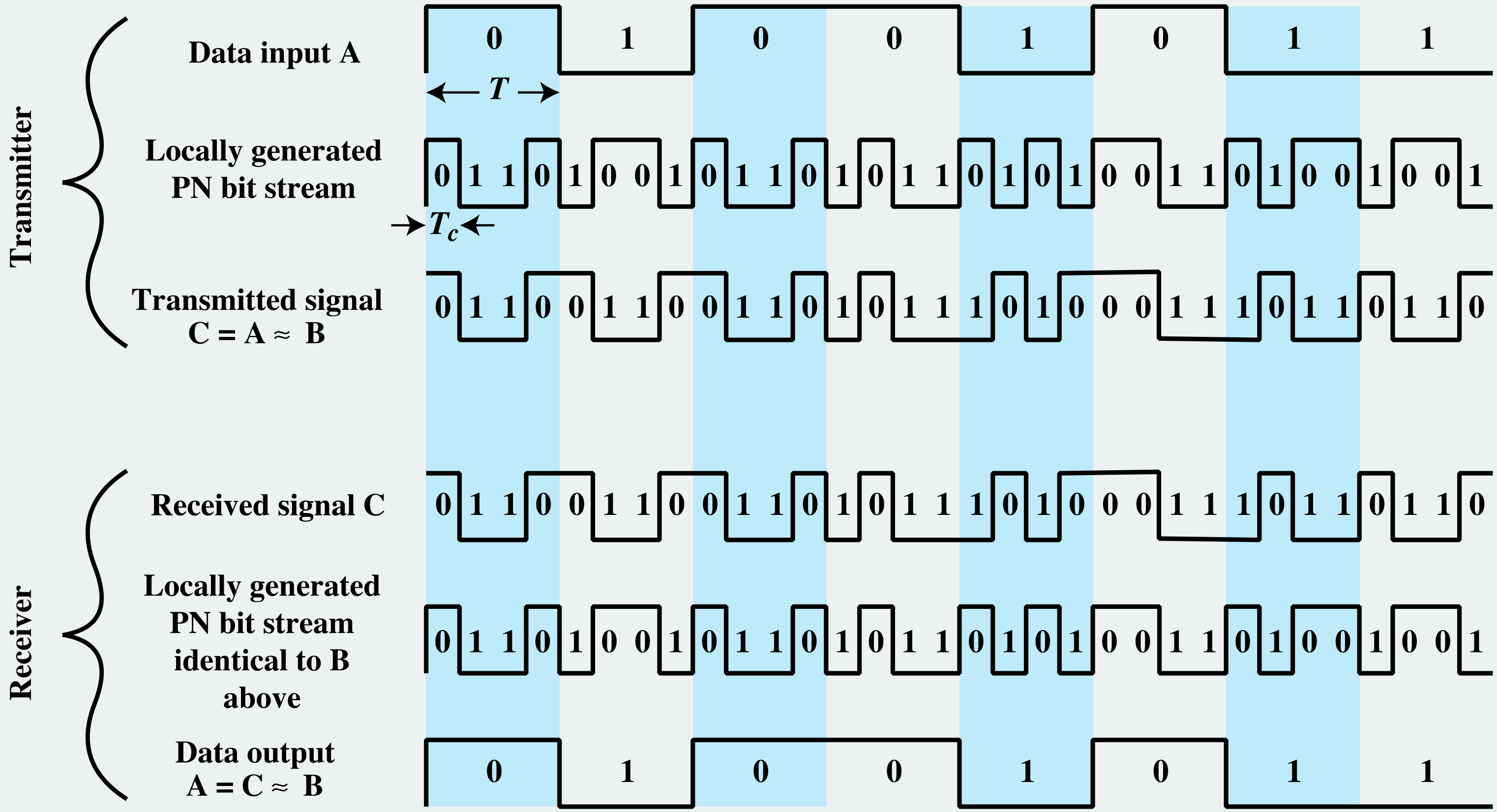
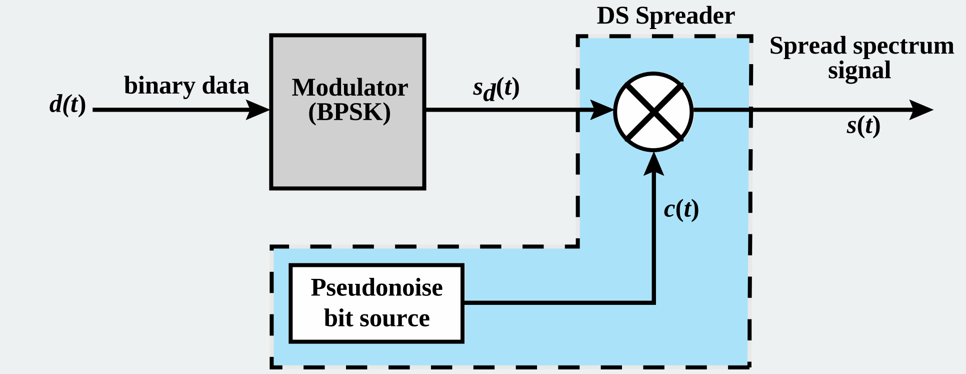
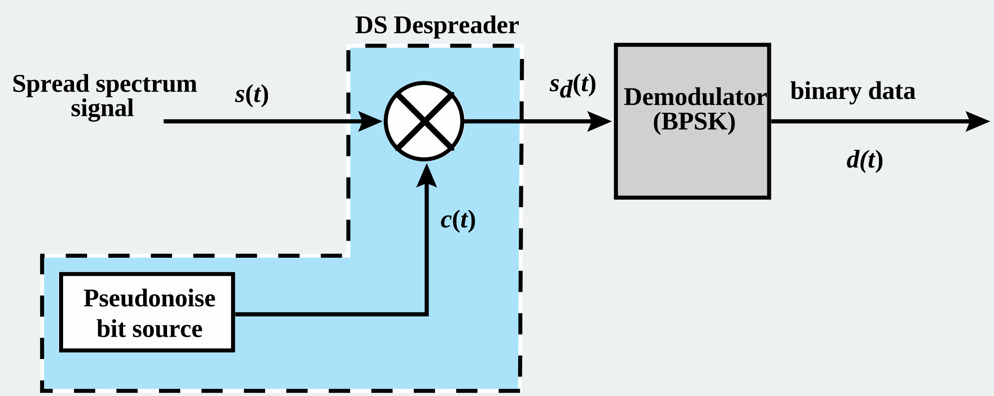


Figure 17.9 Example of Direct Sequence Spread Spectrum



(a) Transmitter



(b) Receiver

Figure 17.10 Direct Sequence Spread Spectrum System

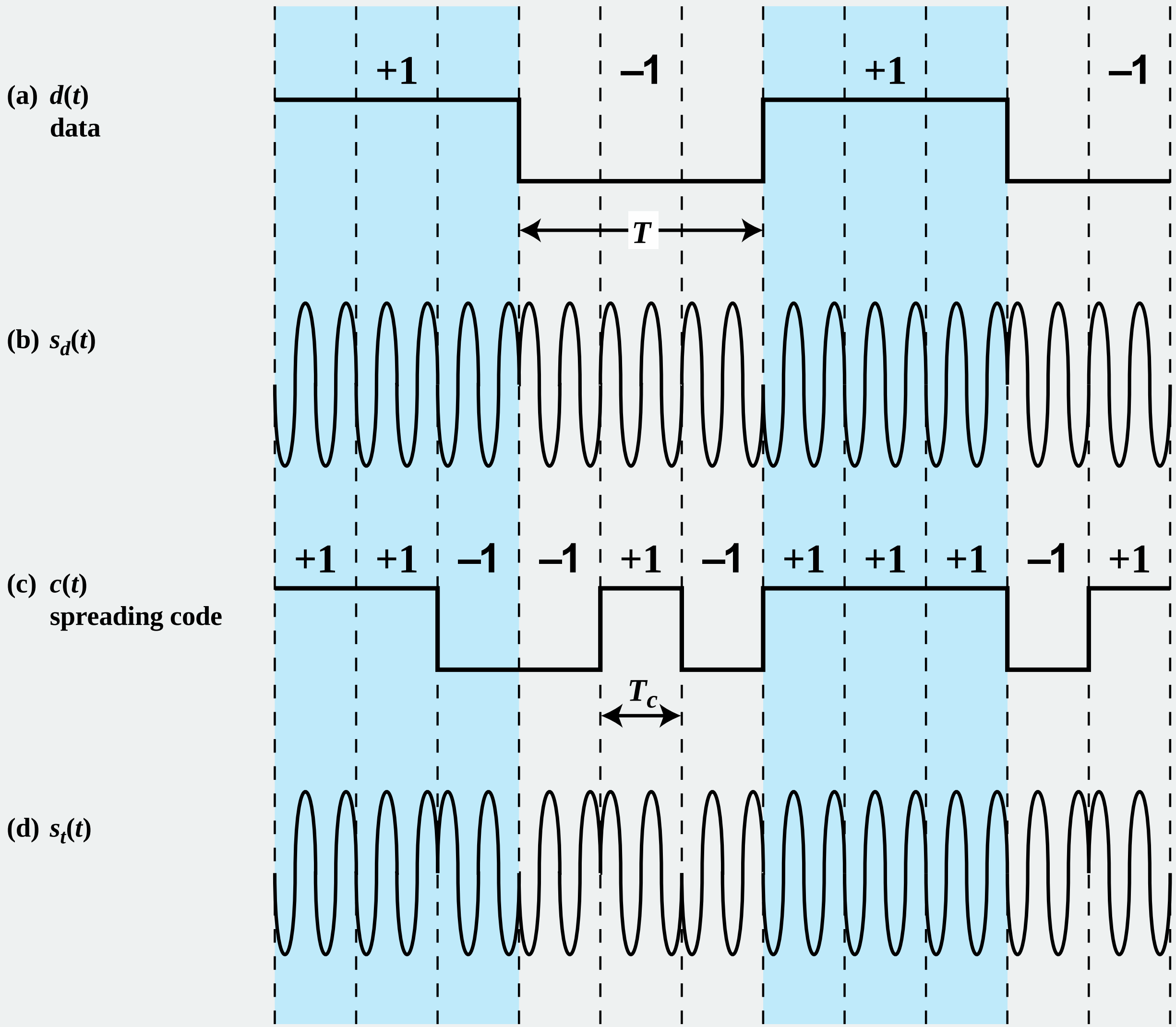


Figure 17.11 Example of Direct-Sequence Spread Spectrum Using BPSK

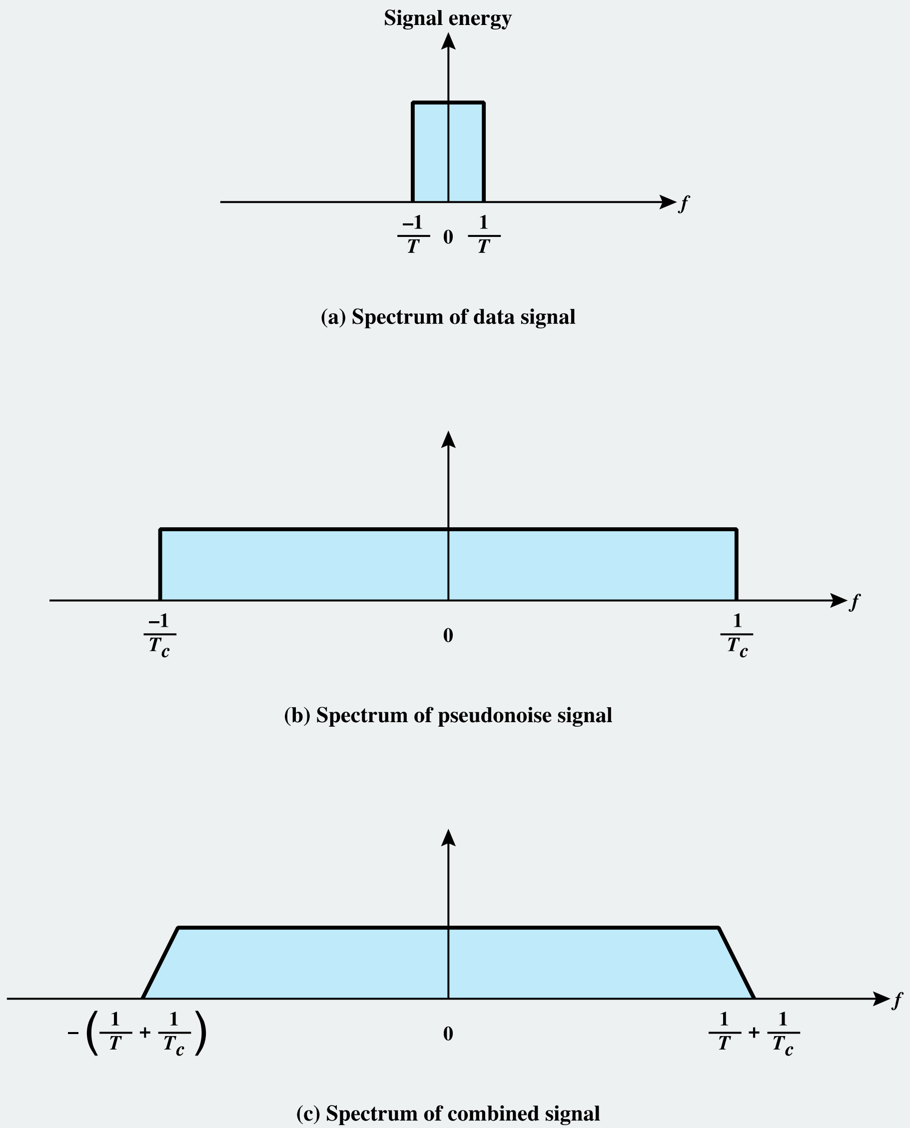


Figure 17.12 Spectrum of Direct-Sequence Spread Spectrum Signal

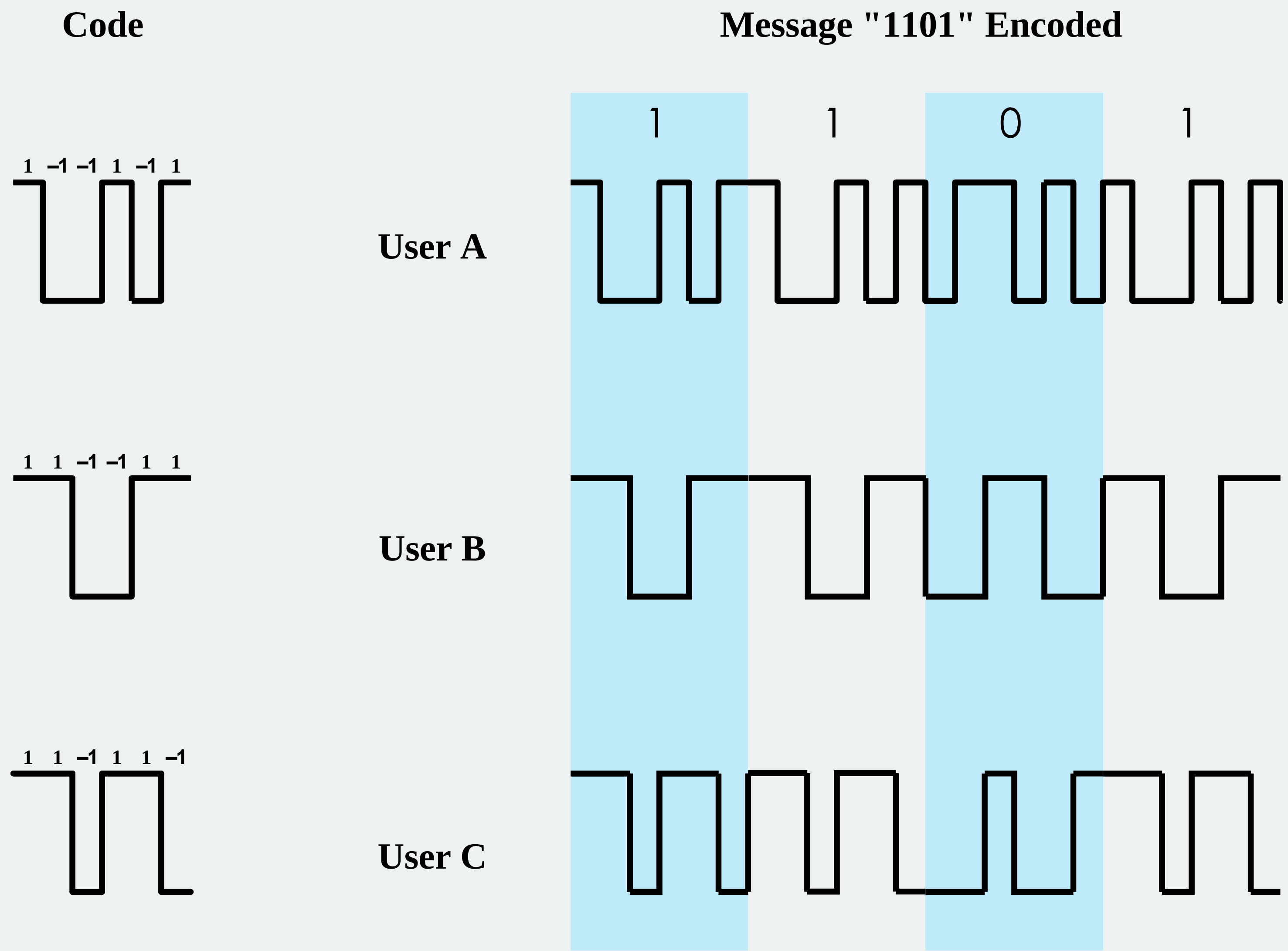


Figure 17.13 CDMA Example

CDMA Example

(a) User's codes

User A	1	–1	–1	1	–1	1
User B	1	1	–1	–1	1	1
User C	1	1	–1	1	1	–1

(b) Transmission from A

Transmit (data bit = 1)	1	–1	–1	1	–1	1	
Receiver codeword	1	–1	–1	1	–1	1	
Multiplication	1	1	1	1	1	1	= 6

Transmit (data bit = 0)	–1	1	1	–1	1	–1	
Receiver codeword	1	–1	–1	1	–1	1	
Multiplication	–1	–1	–1	–1	–1	–1	= –6

(c) Transmission from B, receiver attempts to recover A's transmission

Transmit (data bit = 1)	1	1	–1	–1	1	1	
Receiver codeword	1	–1	–1	1	–1	1	
Multiplication	1	–1	1	–1	–1	1	= 0

(d) Transmission from C, receiver attempts to recover B's transmission

Transmit (data bit = 1)	1	1	–1	1	1	–1	
Receiver codeword	1	1	–1	–1	1	1	
Multiplication	1	1	1	–1	1	–1	= 2

(e) Transmission from B and C, receiver attempts to recover B's transmission

B (data bit = 1)	1	1	–1	–1	1	1	
C (data bit = 1)	1	1	–1	1	1	–1	
Combined signal	2	2	–2	0	2	0	
Receiver codeword	1	1	–1	–1	1	1	
Multiplication	2	2	2	0	2	0	= 8

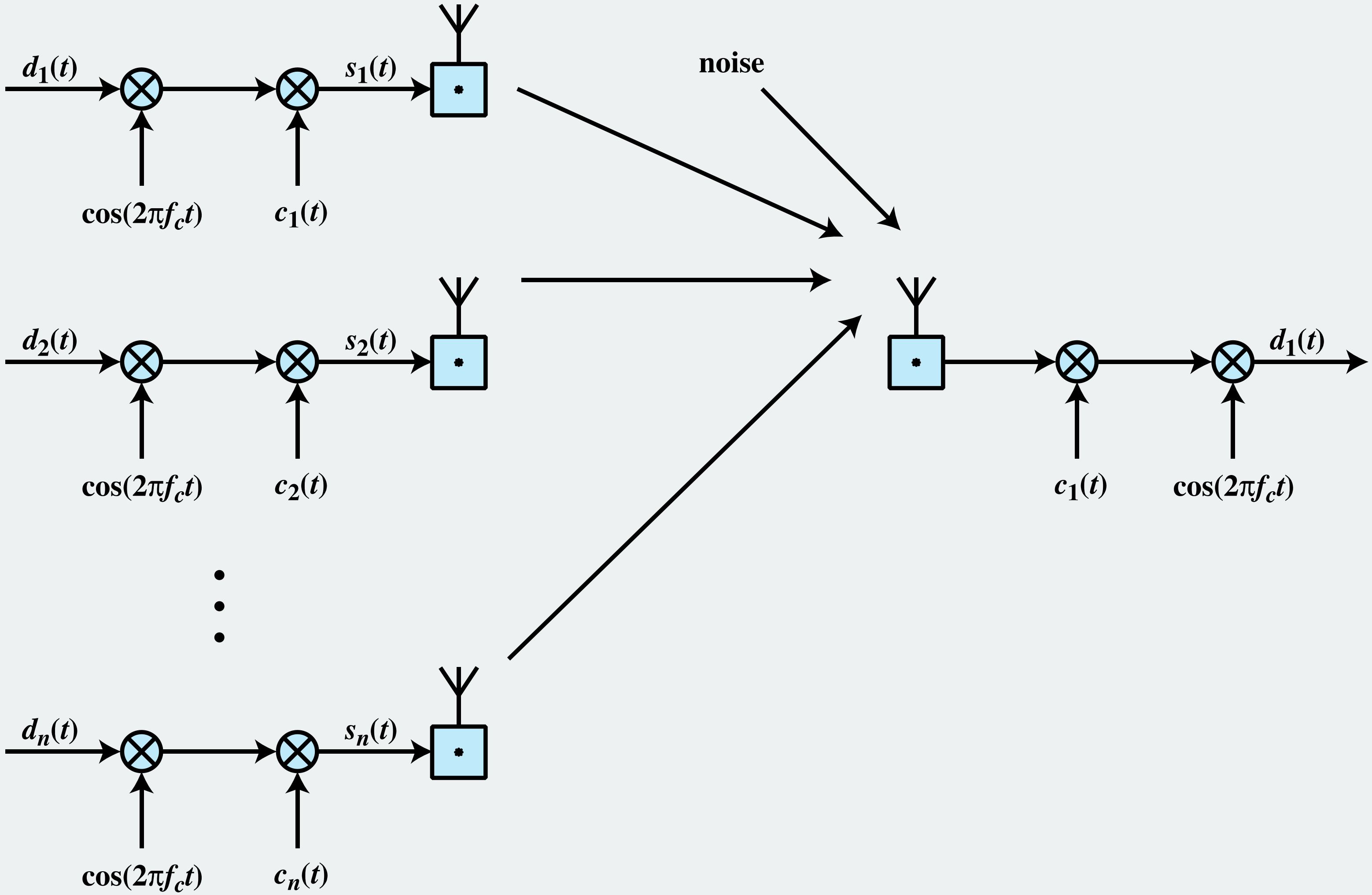


Figure 17.14 CDMA in a DSSS Environment for Receiving User 1