Lecture 5

Spreading & FDMA&TDMA and CDMA

SPREAD SPECTRUM

In Multiplexing combines signals from several sources to achieve bandwidth efficiency; the available bandwidth of a link is divided between the sources.

In spread spectrum (SS), we combine signals from different sources to fit into a larger bandwidth, but our goals are to prevent eavesdropping and jamming. To achieve these goals, spread spectrum techniques add redundancy.

Spread spectrum is designed to be used in wireless applications (LANs and WANs)

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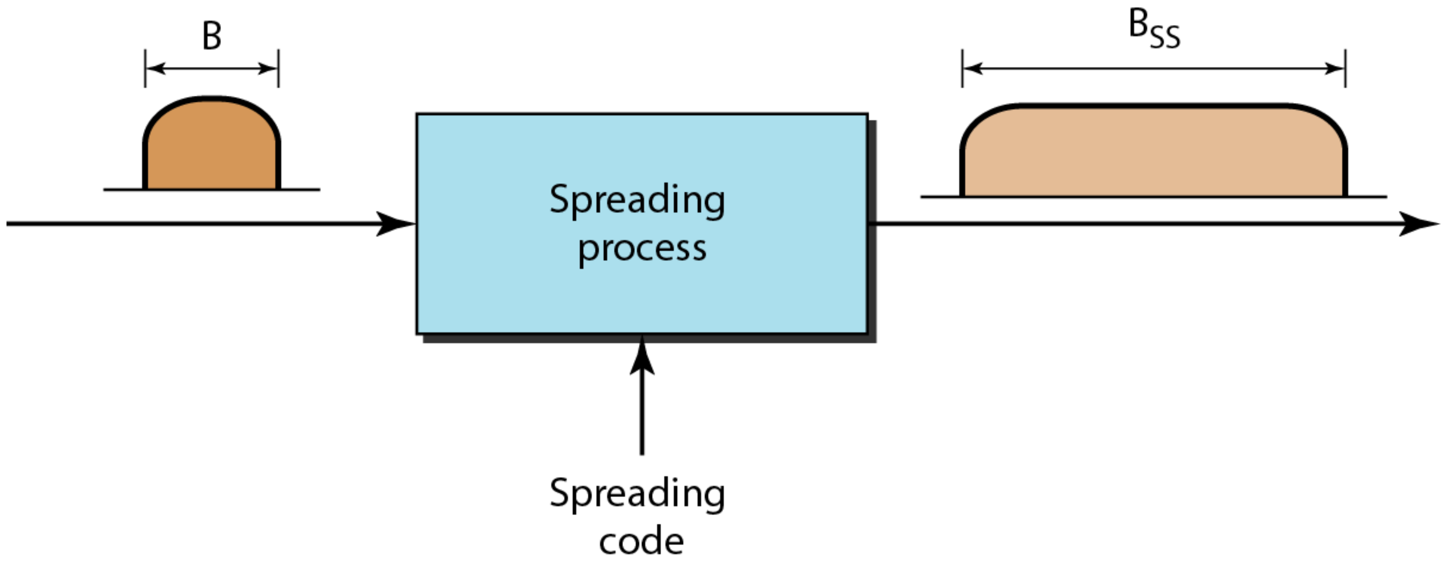
- A signal that occupies a bandwidth of B, is spread out to occupy a bandwidth of B_{ss}
- All signals are spread to occupy the same bandwidth B_{ss}
- Signals are spread with different codes so that they can be separated at the receivers.
- Signals can be spread in the frequency domain or in the time domain.

Figure 1 *Spread spectrum*



Frequency hopping spread spectrum (FHSS)

- The frequency hopping spread spectrum (FHSS) technique uses M different carrier frequencies that are modulated by the source signal. At one moment, the signal modulates one carrier frequency; at the next moment, the signal modulates another carrier frequency. Although the modulation is done using one carrier frequency at a time, M frequencies are used in the long run. The bandwidth occupied by a source after spreading is BpHSS »B.

- Suppose we have decided to have eight hopping frequencies. In this case, M is 8 and k is 3.
- The pseudorandom code generator will create eight different 3-bit patterns.
- These are mapped to eight different frequencies in the frequency table. As shown in figure 3.

Figure 2 *Frequency hopping spread spectrum (FHSS)*

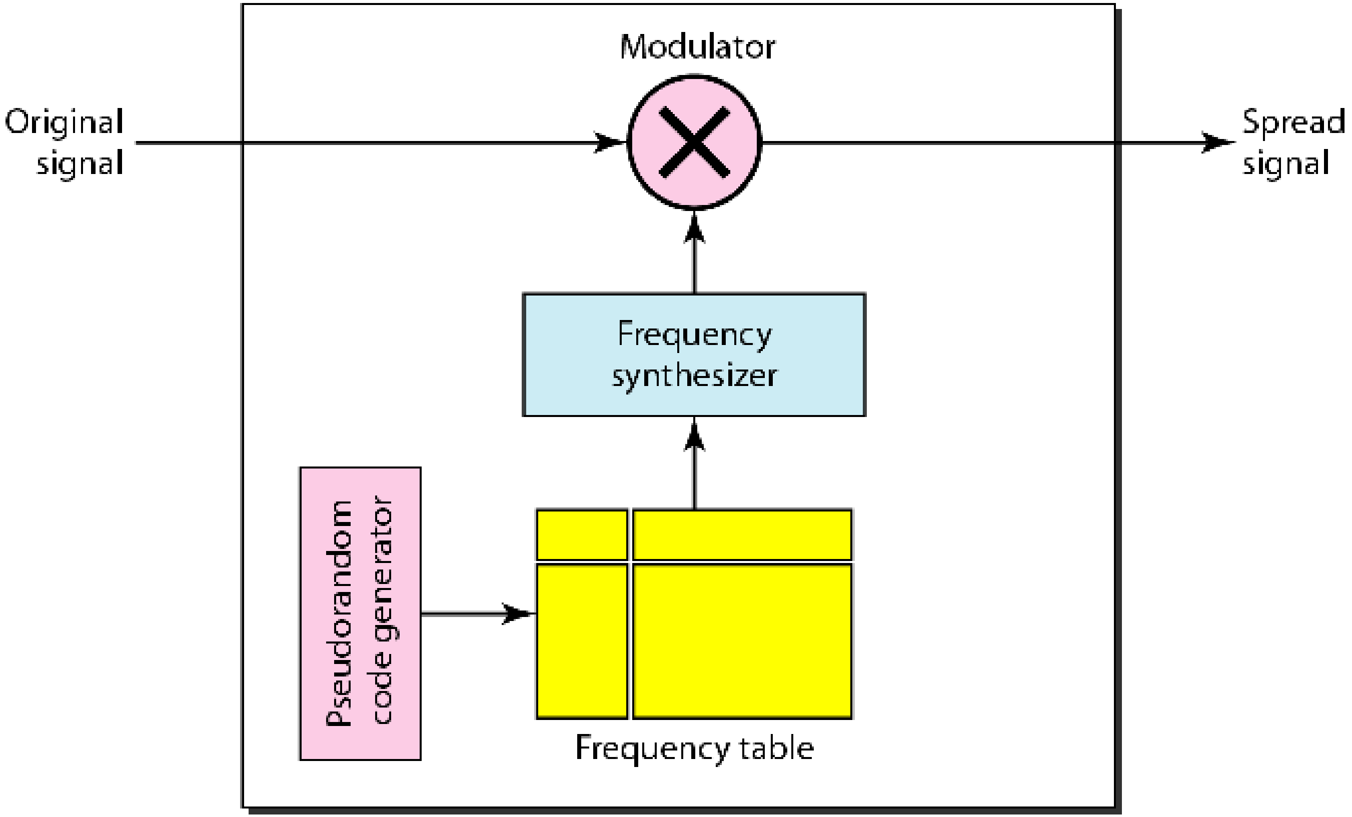
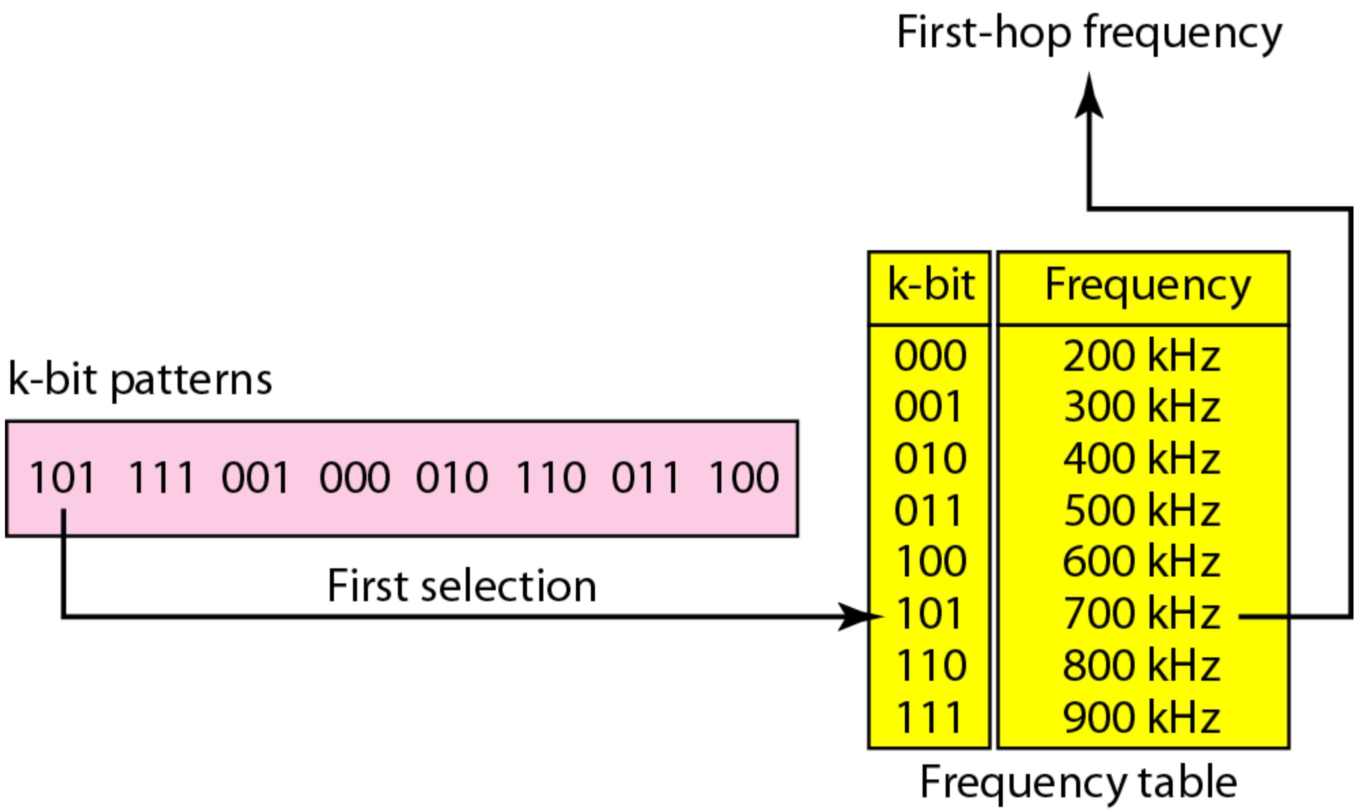


Figure 3 *Frequency selection in FHSS*



Bandwidth Sharing

- If the number of hopping frequencies is M, we can multiplex M channels into one by using the same Bss bandwidth. This is possible because a station uses just one frequency in each hopping period; M - 1 other frequencies can be used by other M - 1 stations.

- Figure 4 shows an example of four channels using FDM and four channels using FHSS,In FDM, each station has f ixed frequency; while in FHSS, each station uses changes frequency hop to other frequency hop.

Figure 4 *FHSS cycles*

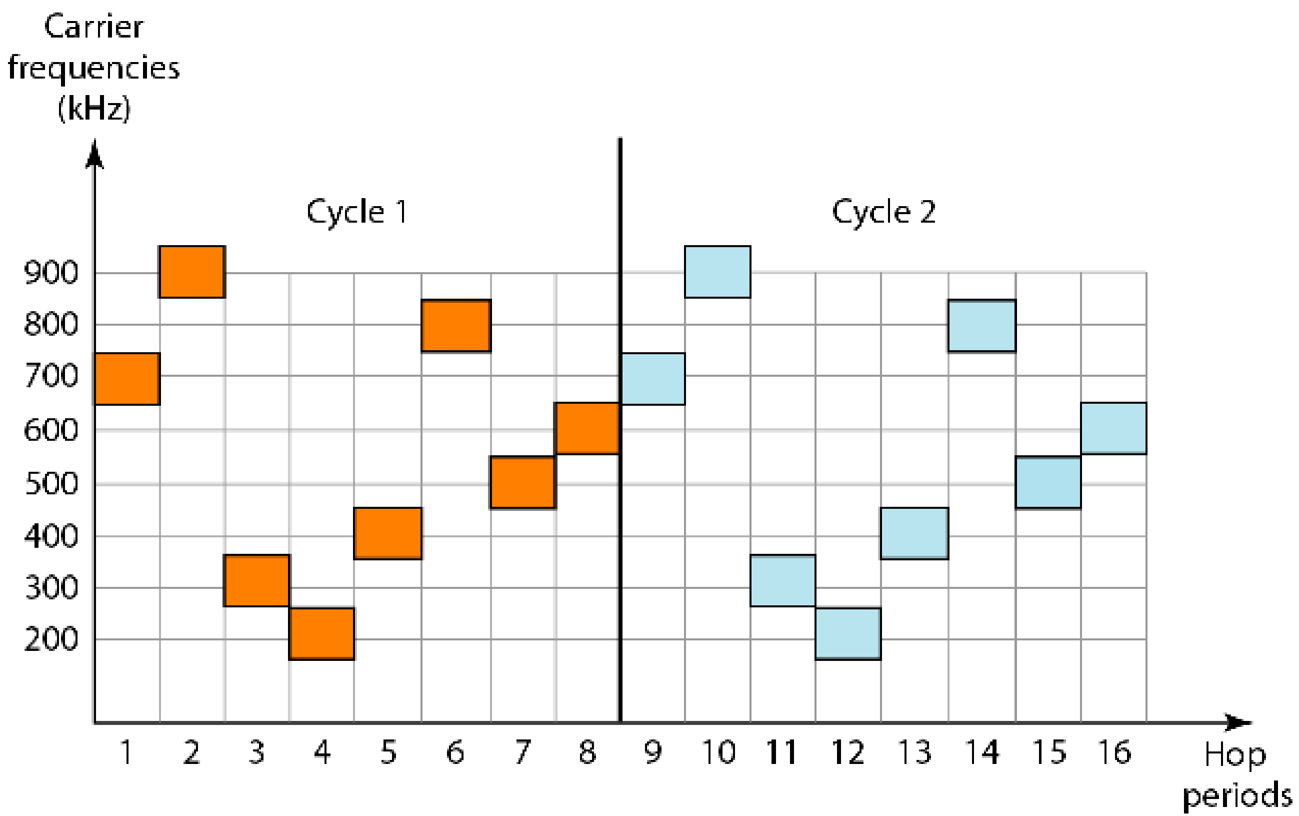
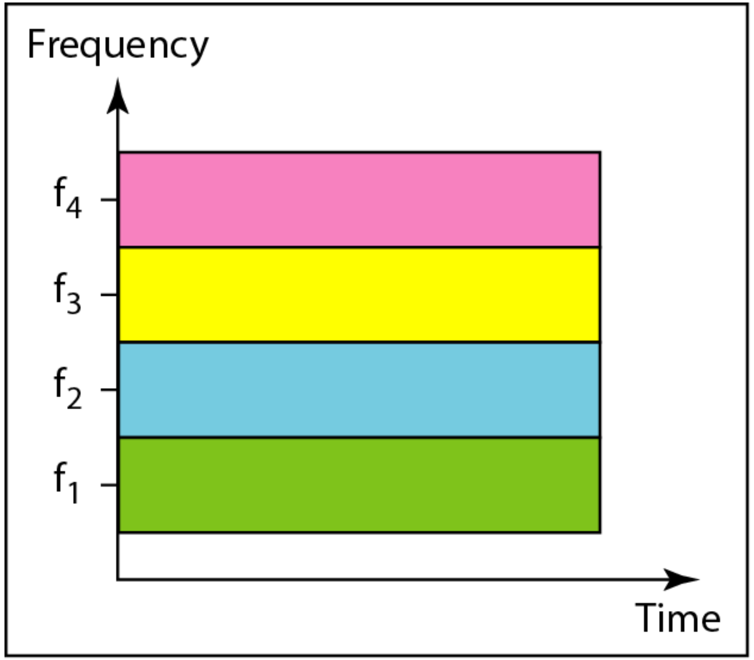
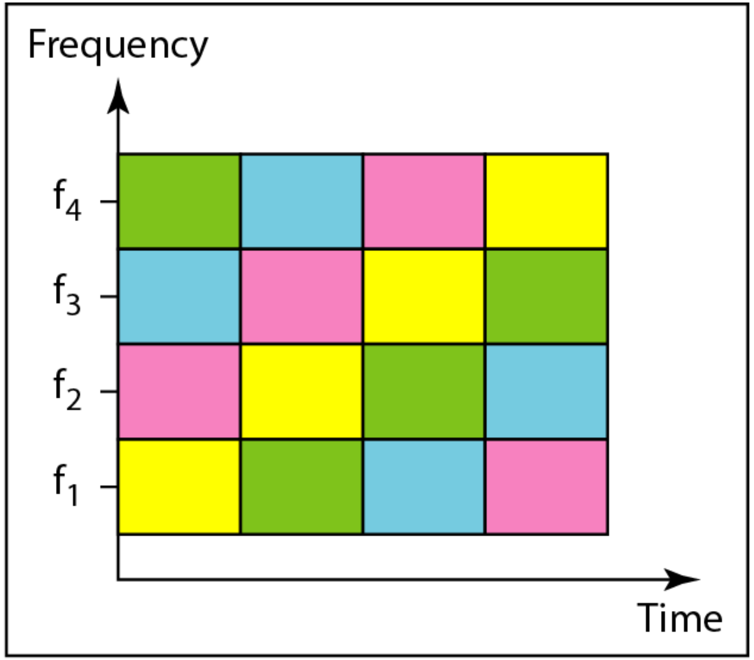


Figure 5 *Bandwidth sharing*



a. FDM

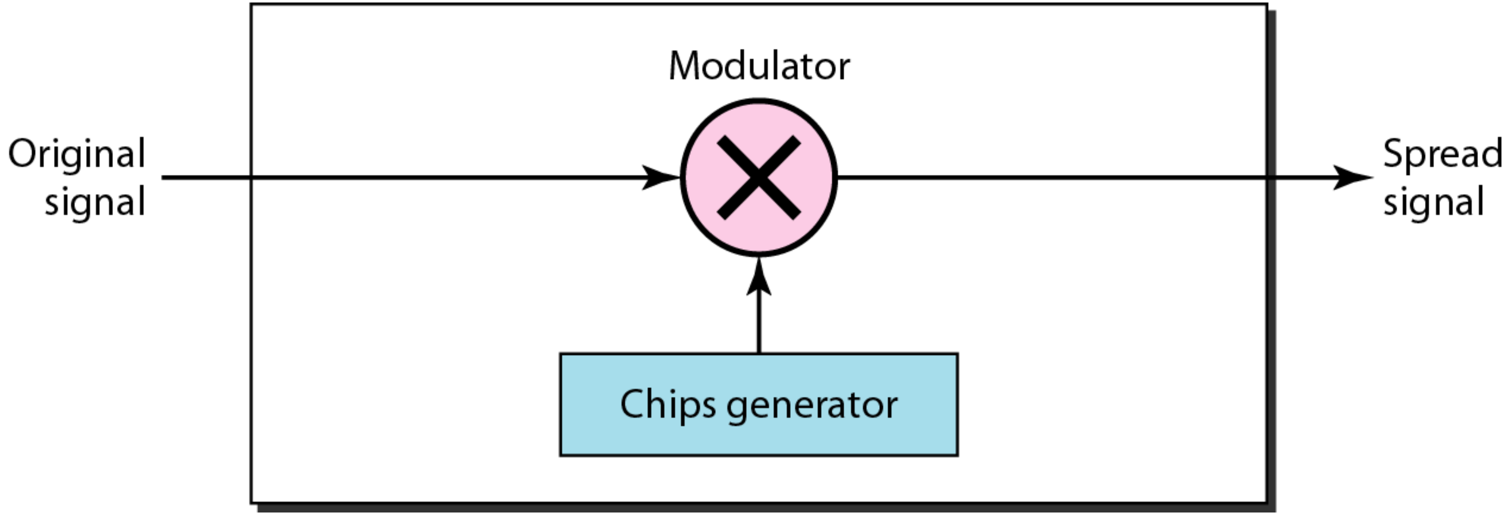


b. FHSS

Direct Sequence Spread Spectrum

- The direct sequence spread spectrum (DSSS) technique also expands the bandwidth of the original signal, but the process is different. In DSSS, we replace each data bit with n bits using a spreading code. In other words, each bit is assigned a code of n bits, called chips, where the chip rate is n times that of the data bit

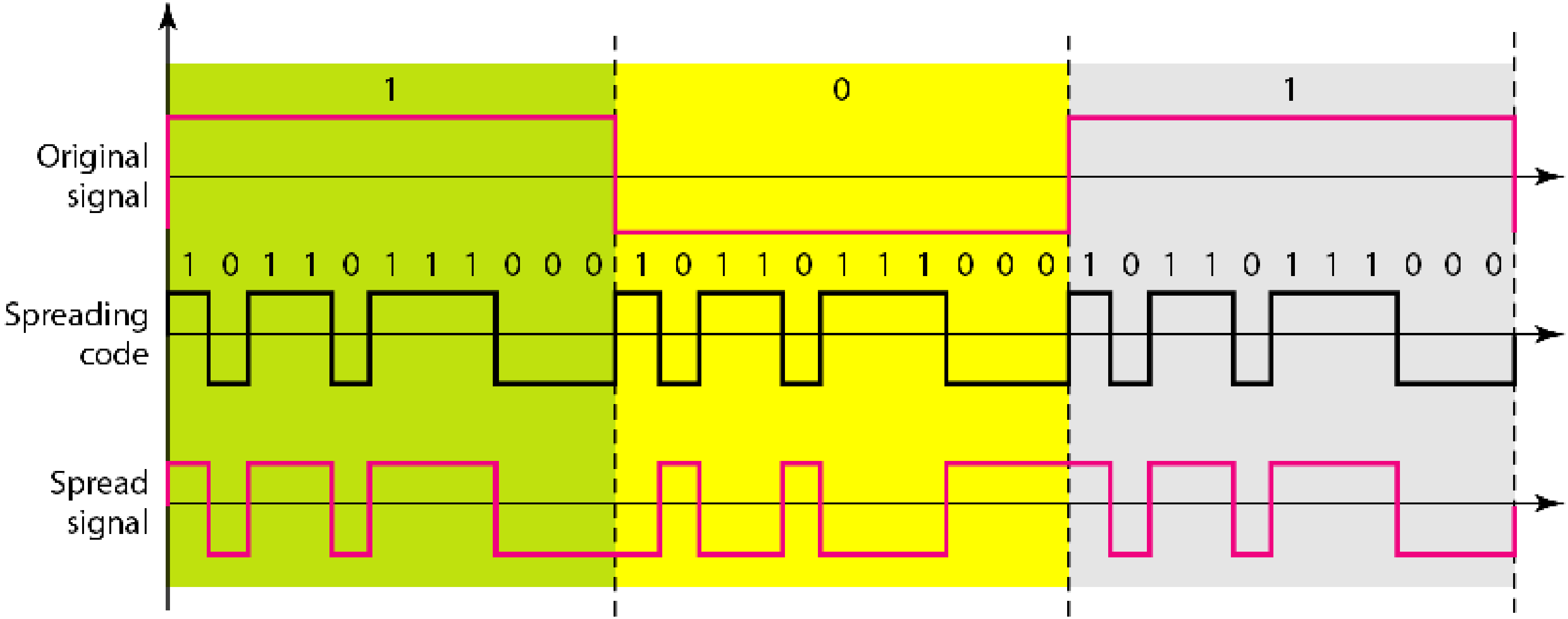
Figure6 *DSSS*



Cont..

- The direct sequence spread spectrum (DSSS) technique also expands the bandwidth of the original signal, but the process is different.
- In figure 7 , we replace each data bit with 11 bits using a spreading code.
- In other words, each bit is assigned a code of 11 bits, called chips, where the chip rate is 11 times that of the data bit.

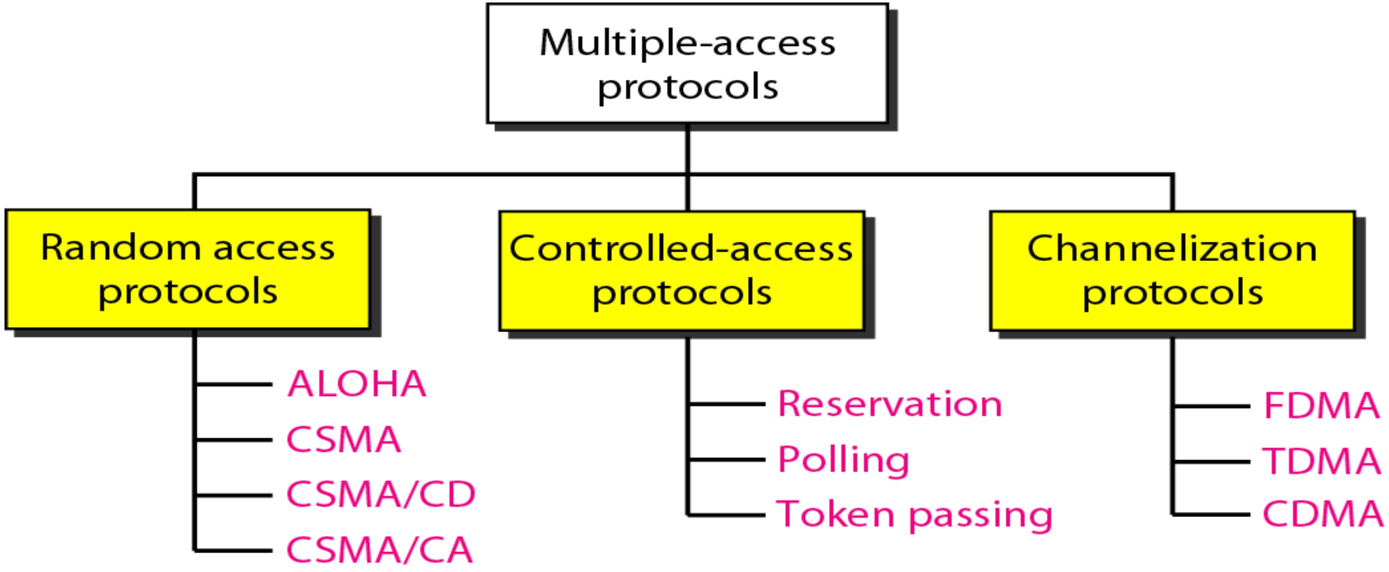
Figure 7 *DSSS example*



Introduction

- When nodes or stations are connected and use a common link, called a multipoint or broadcast link, we need a multiple-access protocol to coordinate access to the link. The problem of controlling the access to the medium is similar to the rules of speaking in an assembly. The procedures guarantee that the right to speak is upheld and ensure that two people do not speak at the same time. Many protocols have been devised to handle access to a shared link. All of these protocols belong to a sub layer in the data-link layer called media access control (MAC). We categorize them into three groups.

Taxonomy of multiple-access protocols



3 CHANNELIZATION

- Channelization is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols: FDMA, TDMA, and CDMA.

FDMA Frequency-Division Multiple Access (FDMA)

- In frequency-division multiple access (FDMA), the available bandwidth is divided into frequency bands. Each station is allocated a band to send its data.
- To prevent station interferences, the allocated bands are separated from one another by small guard bands.

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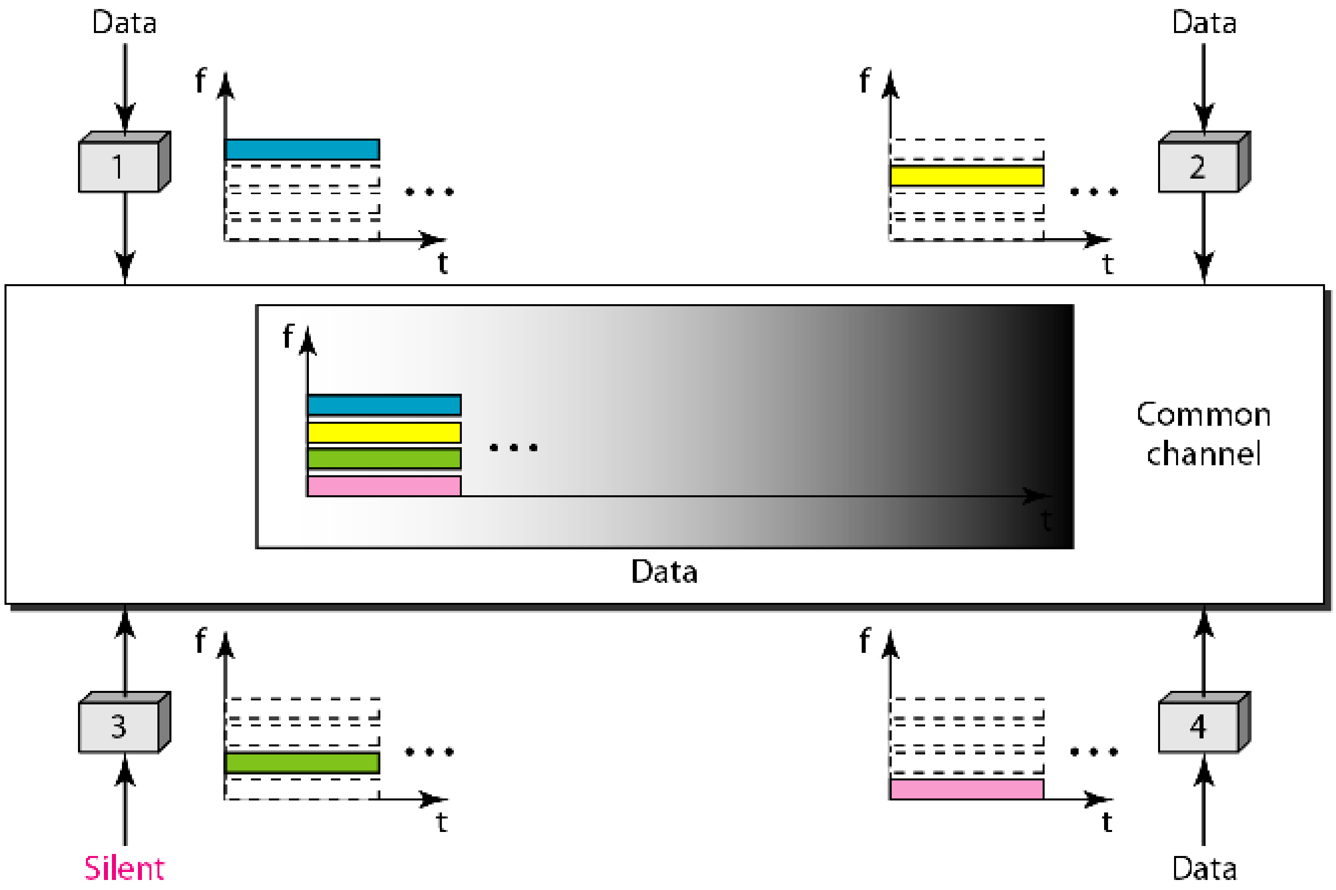
- Advantages:
- ❑ no dynamic coordination necessary
- ❑ works also for analog signals

- Disadvantages:
- ❑ waste of bandwidth if the traffic is distributed unevenly
- ❑ inflexible
- ❑ guard spaces

Figure 3.1 *Frequency-division multiple access (FDMA)*



Time-Division Multiple Access (TDMA)

- In time-division multiple access (TDMA), the stations share the bandwidth of the channel in time. Each station is allocated a time slot during which it can send data.
- Each station transmits its data in is assigned time slot.
- The main problem with TDMA lies in achieving synchronization between the different stations.
- Each station needs to know the beginning of its slot and the location of its slot. This may be difficult because of propagation delays introduced in the system if the stations are spread over a large area. To compensate for the delays, we can insert guard

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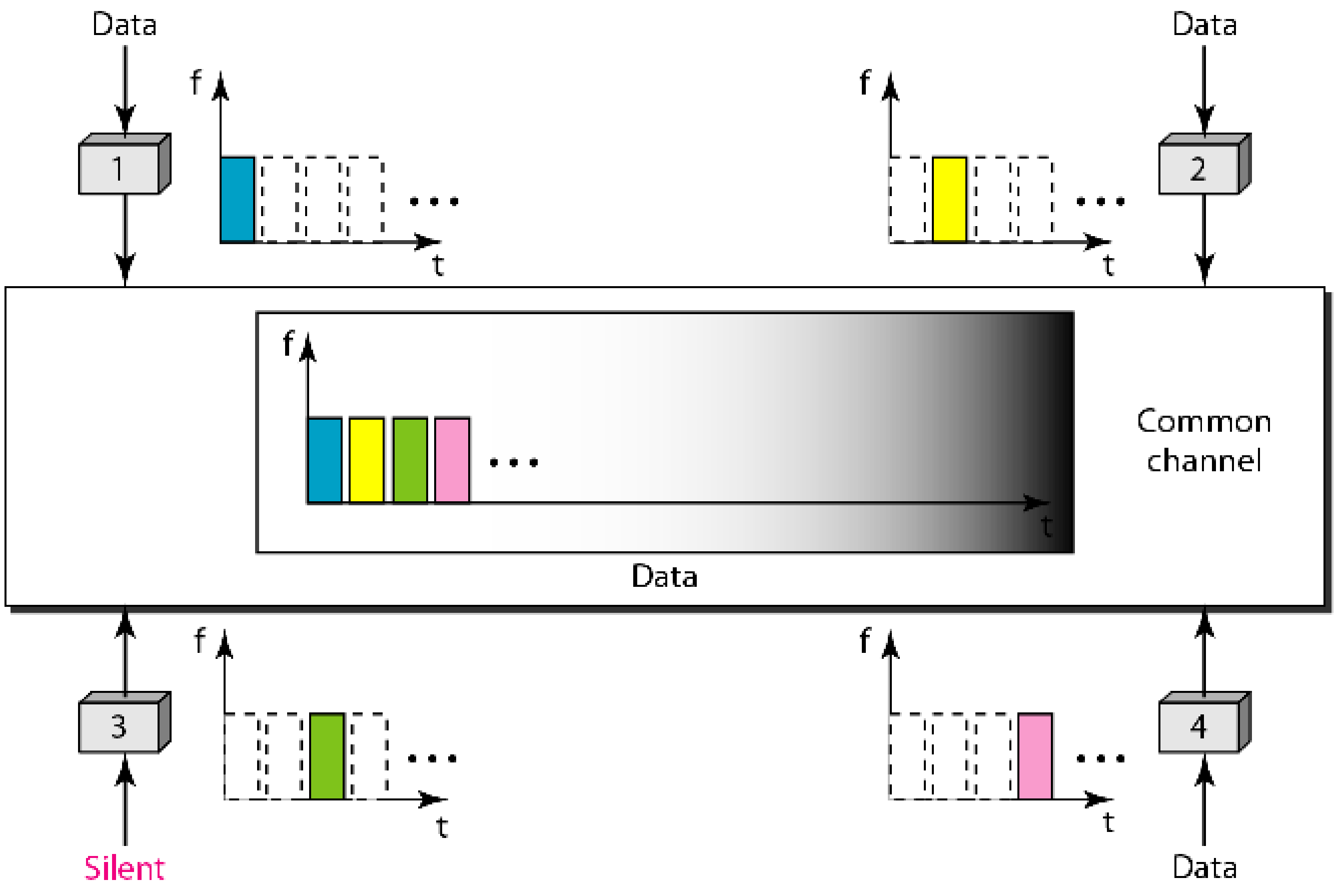
Advantage:

- No interference from simultaneous transmission.
- Share a single carrier frequency with multiple users.
- No frequency guard band required.
- Flexible bit rate.

Disadvantage

- Slot allocation is to be complex in TDMA.

Figure 3.2 *Time-division multiple access (TDMA)*



In TDMA, the bandwidth is just one channel that is timeshared between different stations.

CDMA (Code-Division Multiple Access)

- CDMA differs from FDMA because only one channel occupies the entire bandwidth of the link. It differs from TDMA because all stations can send data simultaneously; there is no timesharing.

Code multiplex

- Each channel has a unique code

- All channels use the same spectrum at the same time
- Advantages:
  - bandwidth efficient
  - no coordination and synchronization necessary
  - good protection against interference and tapping
- Disadvantages:
  - lower user data rates
  - more complex signal regeneration

Note

In CDMA, one channel carries all transmissions simultaneously.

Figure 3.3 *Data representation in CDMA*

Figure 3.3 *Simple idea of communication with code*

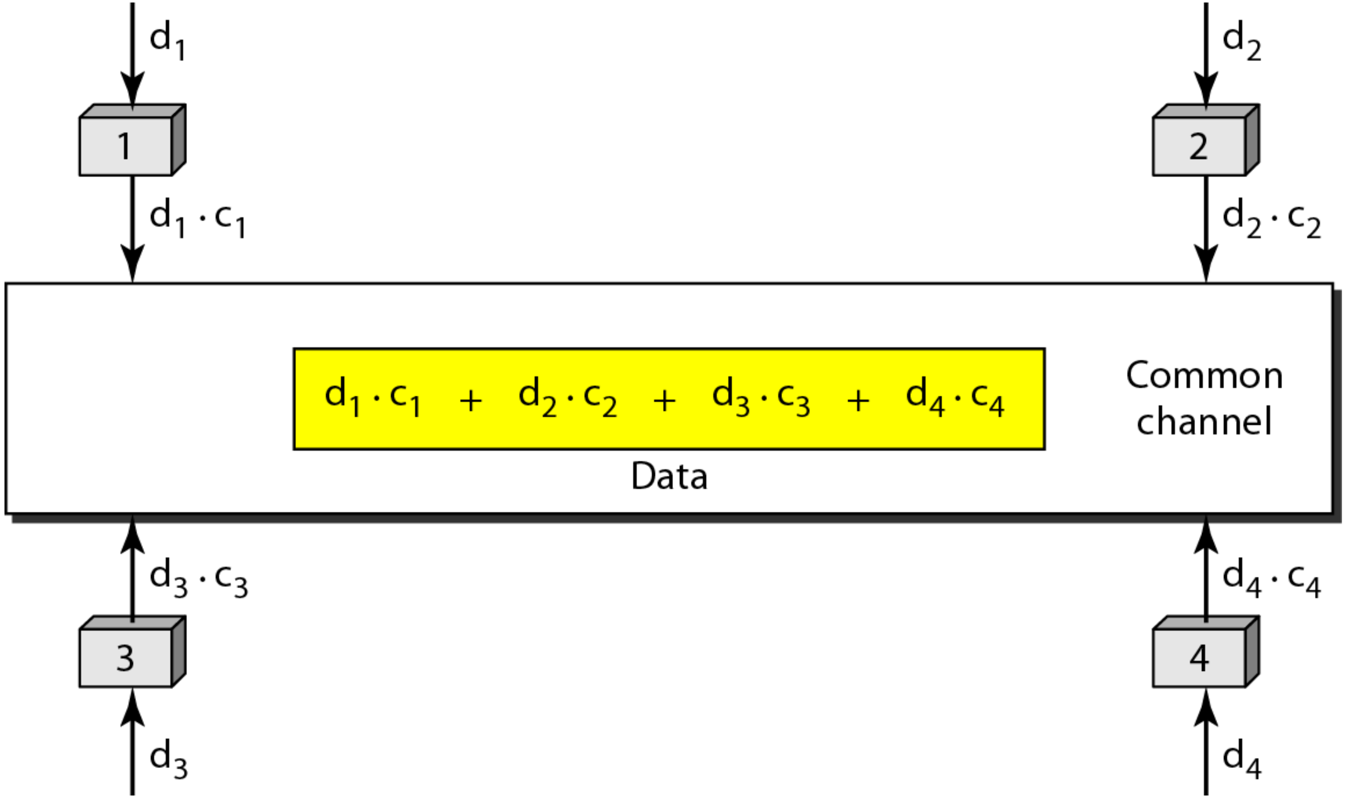


Figure 3.2 *Chip sequences*

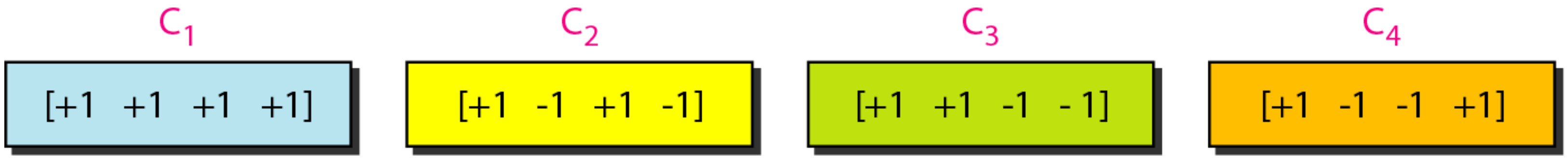


Figure 3.4 *Sharing channel in CDMA*

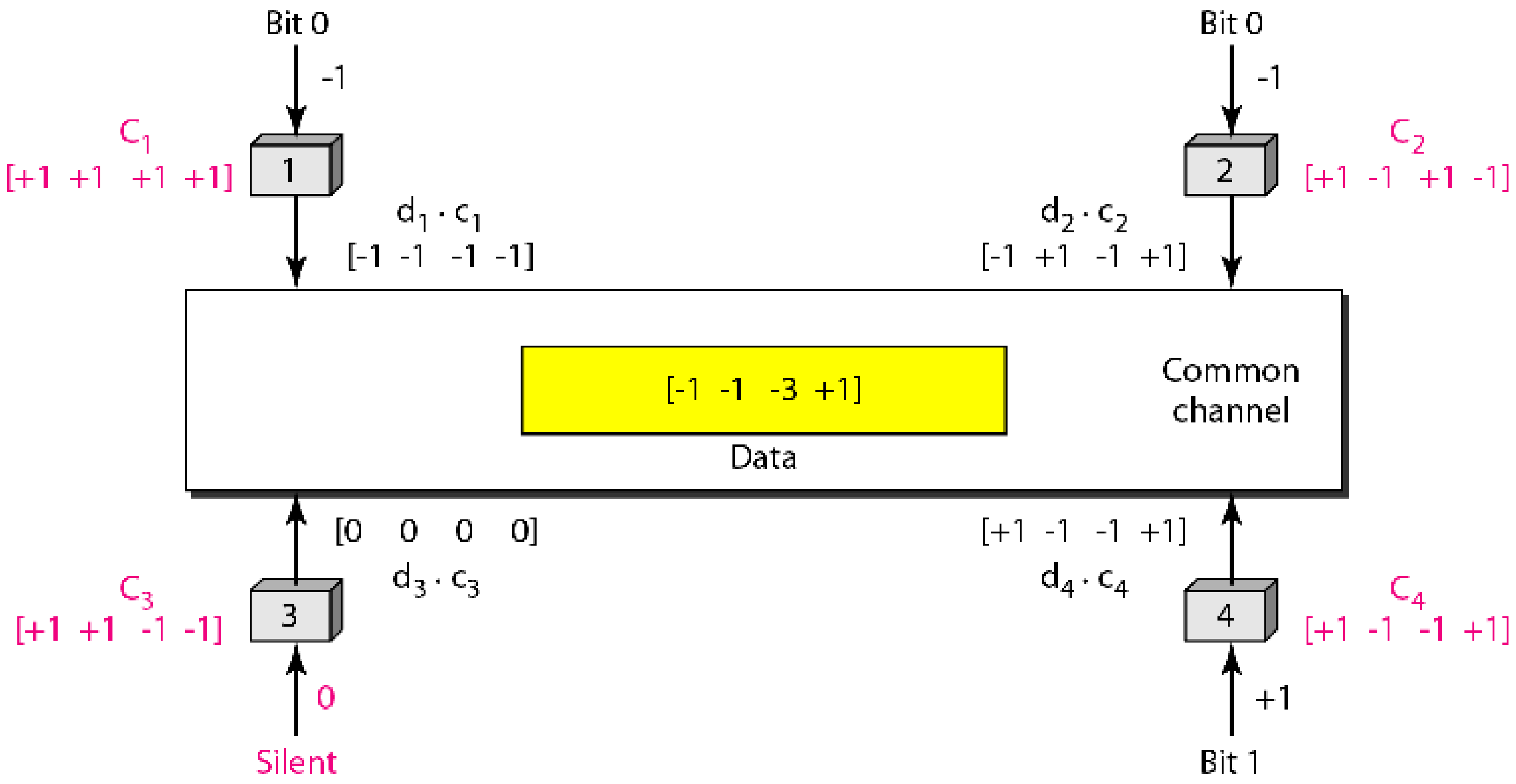


Figure 3.5 *Digital signal created by four stations in CDMA*

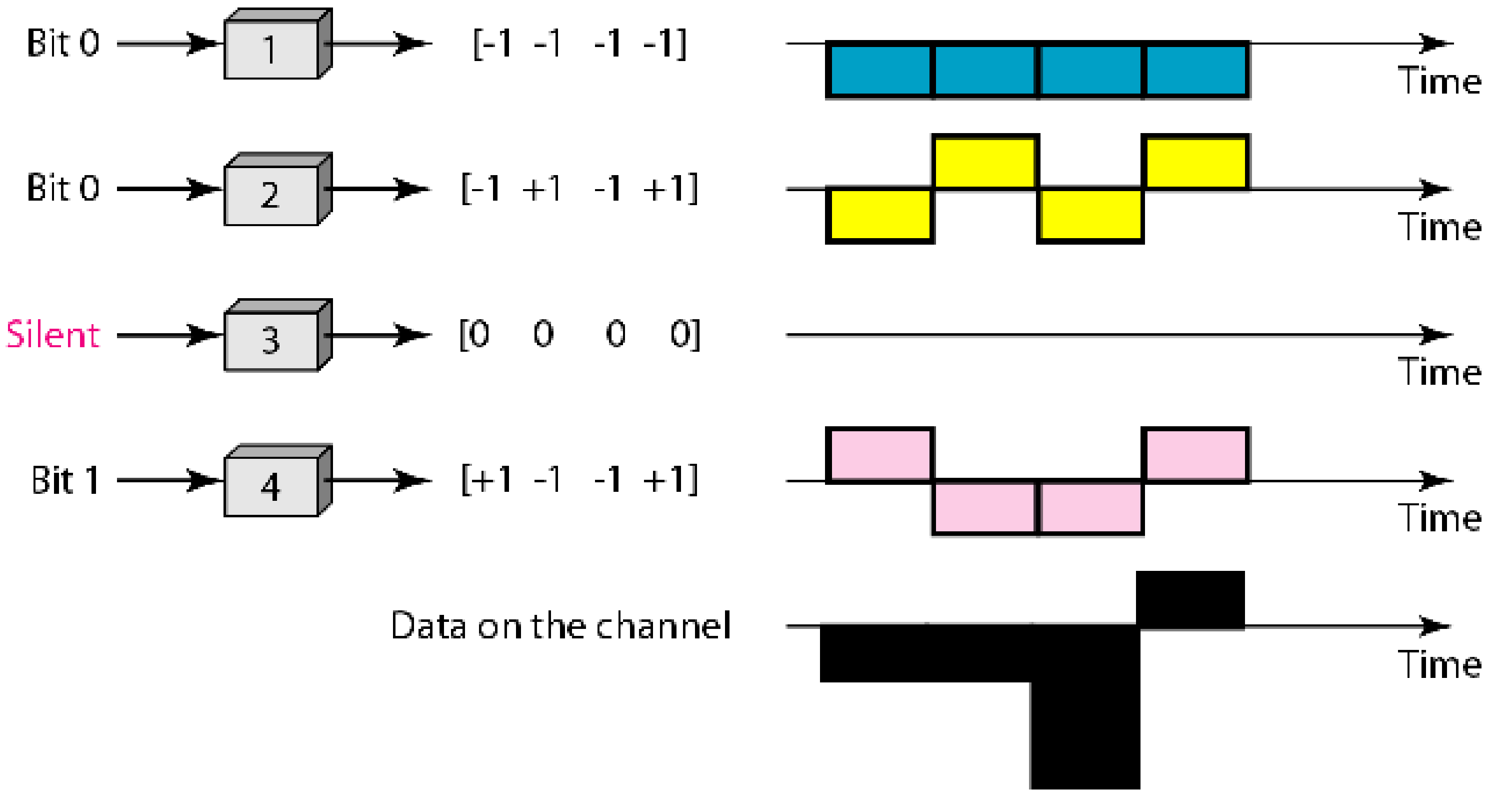


Figure 3.6 *Decoding of the composite signal for one in CDMA*

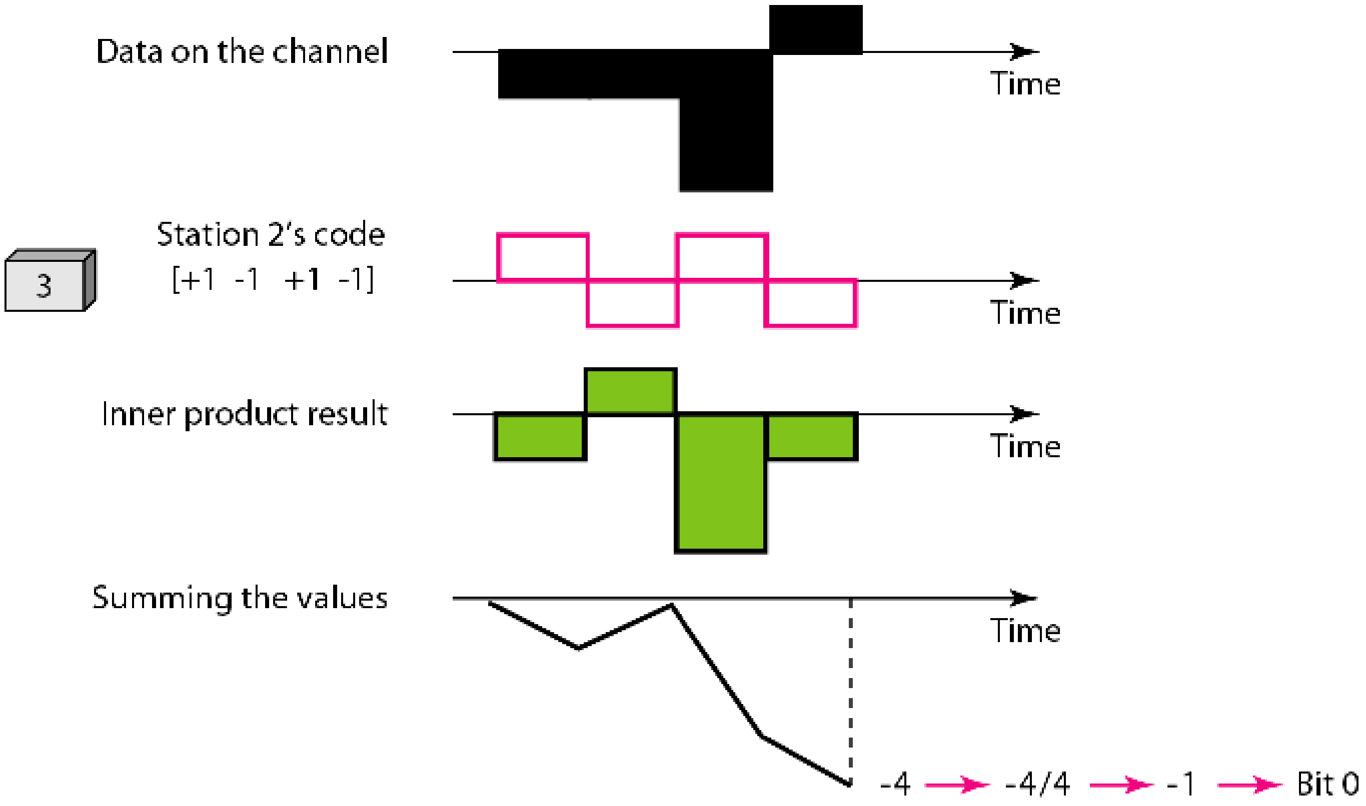


Figure 3.7 *General rule and examples of creating Walsh tables*

$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \qquad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

a. Two basic rules

$$W_1 = \begin{bmatrix} +1 \end{bmatrix}$$

$$W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} \qquad W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

b. Generation of W_1, W_2, and W_4

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e

The number of sequences in a Walsh table needs to be $N = 2^m$.

Where m is number of stations

Example 1

Find the chips for a network with

a. Two stations *b. Four stations*

Solution

We can use the rows of W_2 and W_4 in Figure 12.29:

a. For a two-station network, we have

[+1 +1] and [+1 −1].

b. For a four-station network we have

[+1 +1 +1 +1], [+1 −1 +1 −1],

[+1 +1 −1 −1], *and* [+1 −1 −1 +1].

Example 2

What is the number of sequences if we have 90 stations in our network?

Solution

The number of sequences needs to be 2^m. We need to choose m = 7 and N = 2^7 or 128. We can then use 90 of the sequences as the chips.

Example 3

Prove that a receiving station can get the data sent by a specific sender if it multiplies the entire data on the channel by the sender's chip code and then divides it by the number of stations.

Solution

Let us prove this for the first station, using our previous four-station example. We can say that the data on the channel

$$D = (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4).$$

The receiver which wants to get the data sent by station 1 multiplies these data by c_1.

Example 3 (continued)

$$\begin{aligned} D \cdot c_1 &= (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4) \cdot c_1 \\ &= d_1 \cdot c_1 \cdot c_1 + d_2 \cdot c_2 \cdot c_1 + d_3 \cdot c_3 \cdot c_1 + d_4 \cdot c_4 \cdot c_1 \\ &= d_1 \times N + d_2 \times 0 + d_3 \times 0 + d_4 \times 0 \\ &= d_1 \times N \end{aligned}$$

When we divide the result by N, we get d_1 .