UNIVERSITAS KOMPUTER INDONESIA

Chap 7– Spread Spectrum

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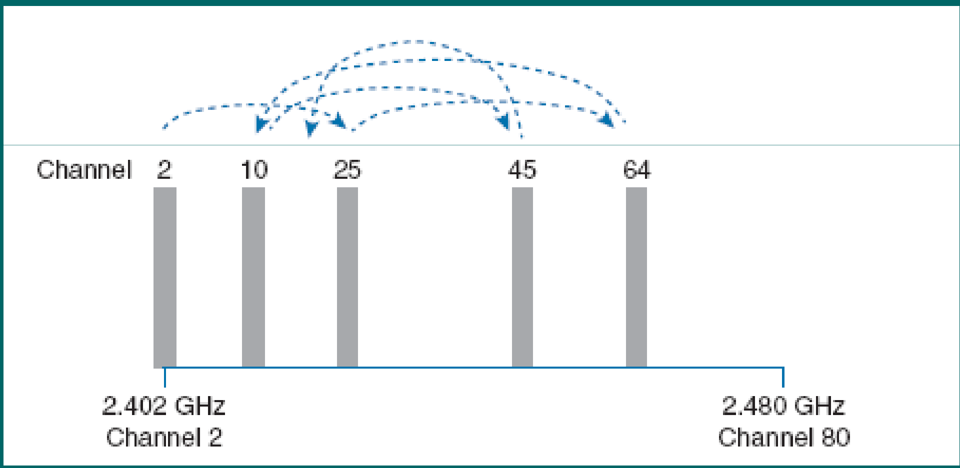
In contrast, wireless LANs must carry data at high bit rates, requiring more bandwidth for modulation. The end result is that the data being sent is spread out across a range of frequencies. This is known as *spread spectrum . At the physical layer, wireless LANs* can be broken down into the following three spread-spectrum categories, which are discussed
in subsequent sections:

- Frequency-hopping spread spectrum (FHSS)
- Direct-sequence spread spectrum (DSSS)
- Orthogonal frequency-division multiplexing (OFDM)

FHSS

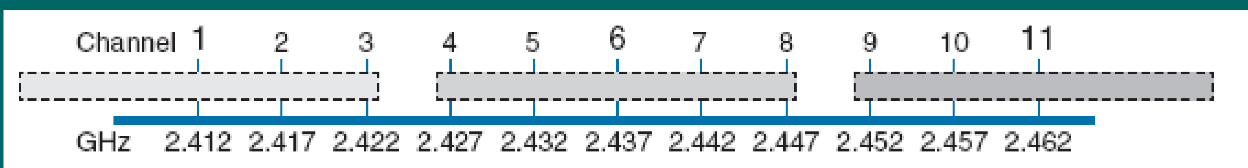


An Example FHSS Channel-Hopping Sequence.

Whatever advantage FHSS gained avoiding interference was lost because of the following limitations:

- Narrow 1-MHz channel bandwidth, limiting the data rate to 1 or 2 Mbps.
- Multiple transmitters in an area could eventually collide and interfere with each other on the same channels.

DSSS



Example Nonoverlapping Channels Used for DSSS.

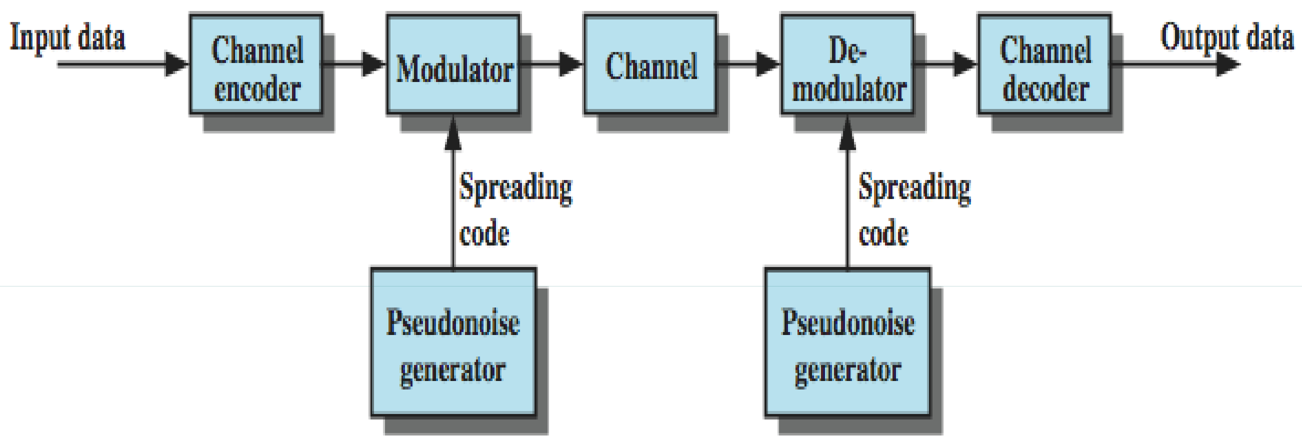
Spread Spectrum

- important encoding method for wireless communications
- analog & digital data with analog signal
- spreads data over wide bandwidth
- makes jamming and interception harder
- two approaches, both in use:
  - Frequency Hopping
  - Direct Sequence

Spread Spectrum Advantages

- immunity from noise and multipath distortion
- can hide / encrypt signals
- several users can share same higher bandwidth with little interference
  - CDM/CDMA Mobile telephones

General Model of Spread Spectrum System



Pseudorandom Numbers

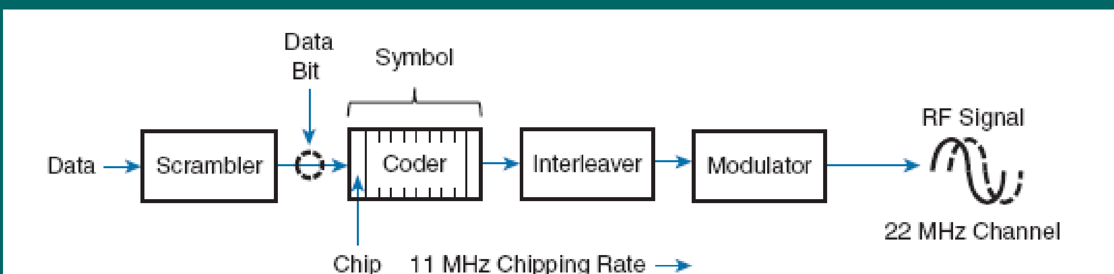
- generated by a deterministic algorithm
  - not actually random
  - but if algorithm good, results pass reasonable tests of randomness
- starting from an initial seed
- need to know algorithm and seed to predict sequence
- hence only receiver can decode signal

DSSS

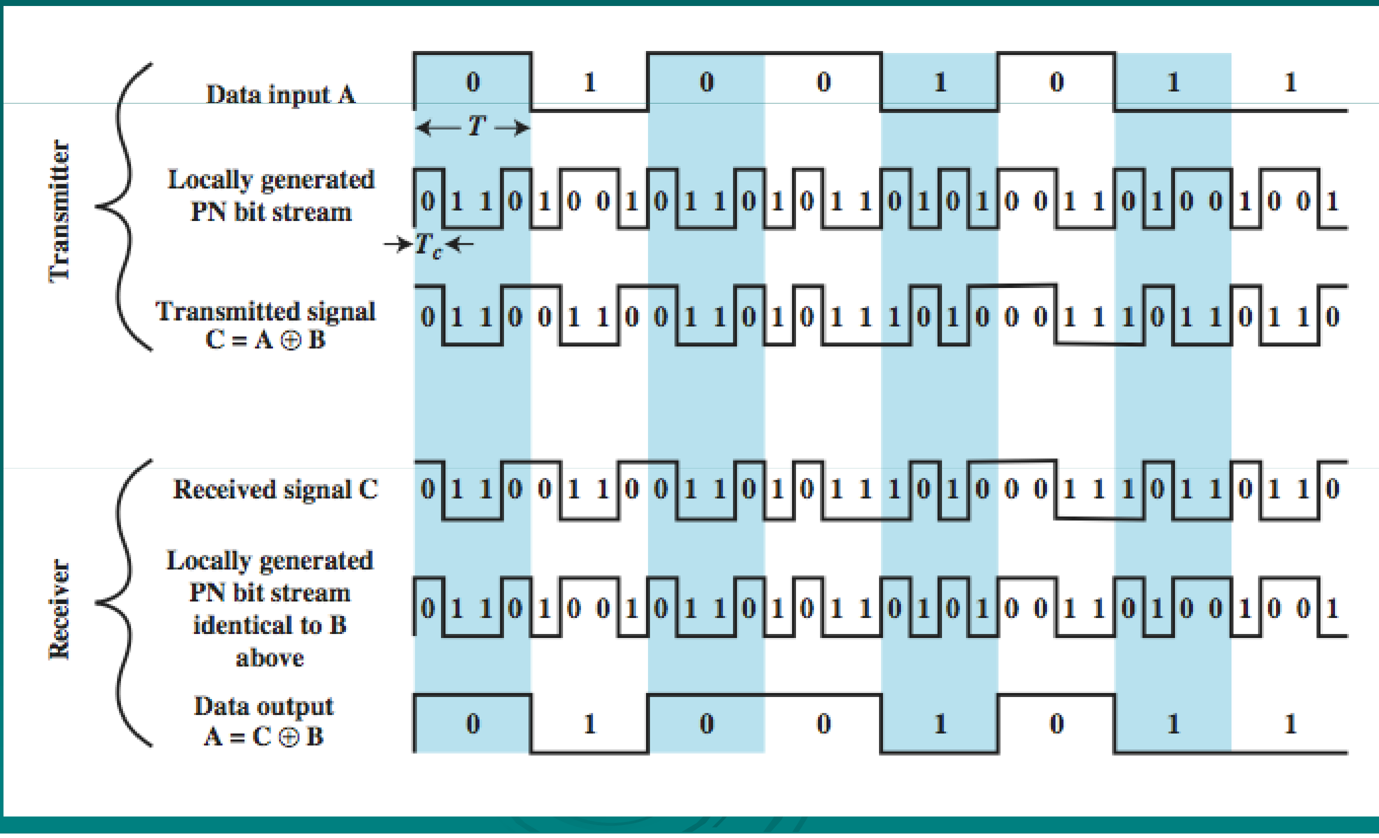
DSSS transmits data in a serial stream, where each data bit is prepared for transmission one at a time. It might seem like a simple matter to transmit the data bits in the order that they are stored or presented to the wireless transmitter; however, RF signals are often affected by external factors like noise or interference that can garble the data at the receiver. For that reason, a wireless transmitter performs several functions to make the data stream less susceptible to being degraded along the transmission path:

- **Scrambler**—The data waiting to be sent is first scrambled in a predetermined manner so that it becomes a randomized string of 0 and 1 bits rather than long sequences of 0 or 1 bits.
- **Coder**—Each data bit is converted into multiple bits of information that contain carefully crafted patterns that can be used to protect against errors due to noise or interference. Each of the new coded bits is called a *chip*. The complete group of chips representing a data bit is called a *symbol*. DSSS uses two encoding techniques: Barker codes and Complementary Code Keying (CCK).
- **Interleaver**—The coded data stream of symbols is spread out into separate blocks so that bursts of interference might affect one block, but not many.
- **Modulator**—The bits contained in each symbol are used to alter or modulate the phase of the carrier signal. This enables the RF signal to carry the binary data bit values.

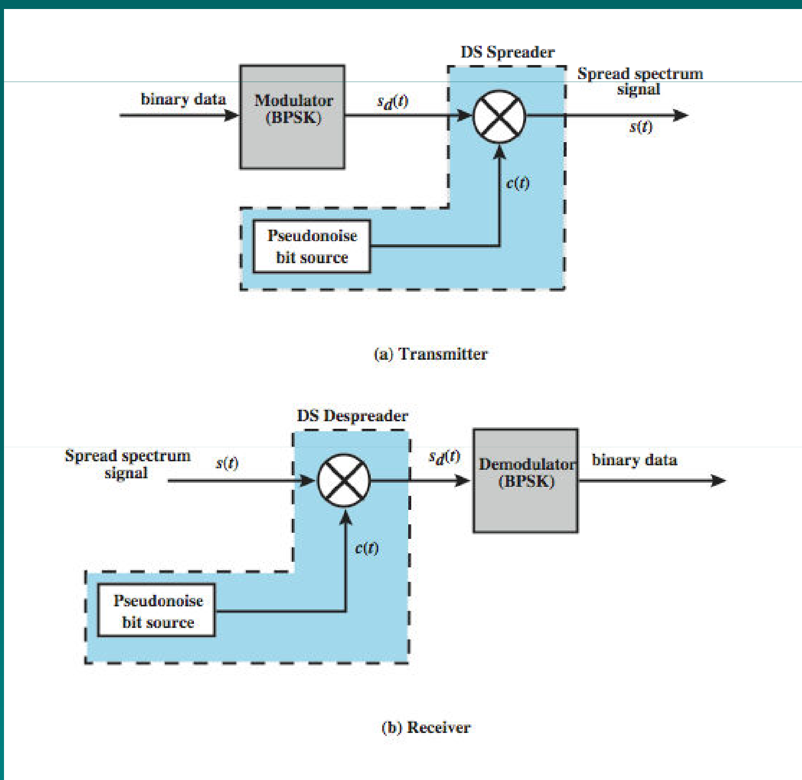
Functional Blocks Used in a DSSS Transmitter.



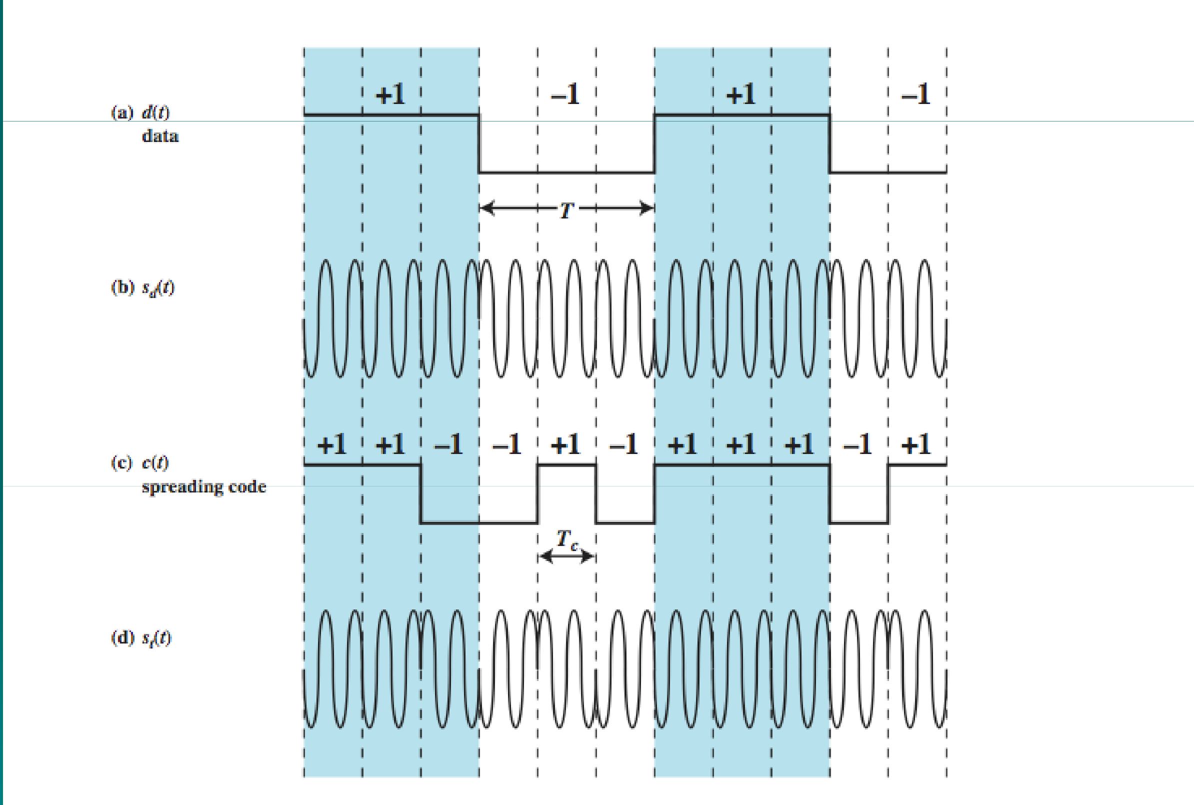
Direct Sequence Spread Spectrum Example



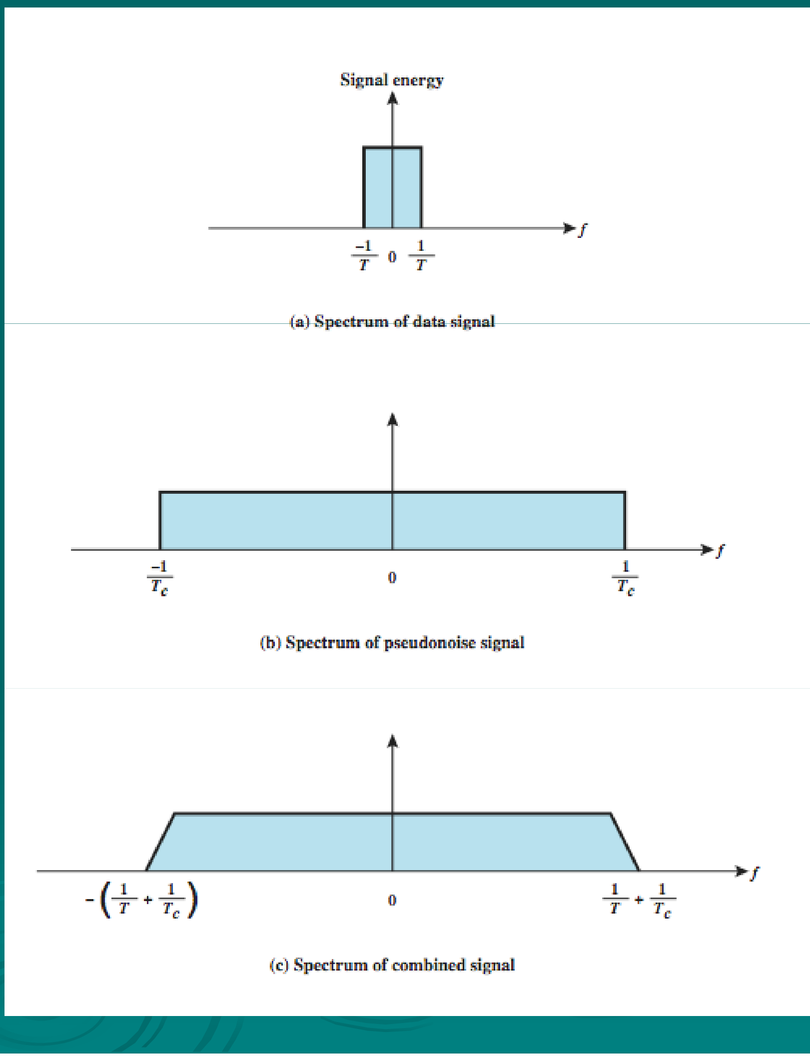
Direct Sequence Spread Spectrum System



DSSS Example Using BPSK



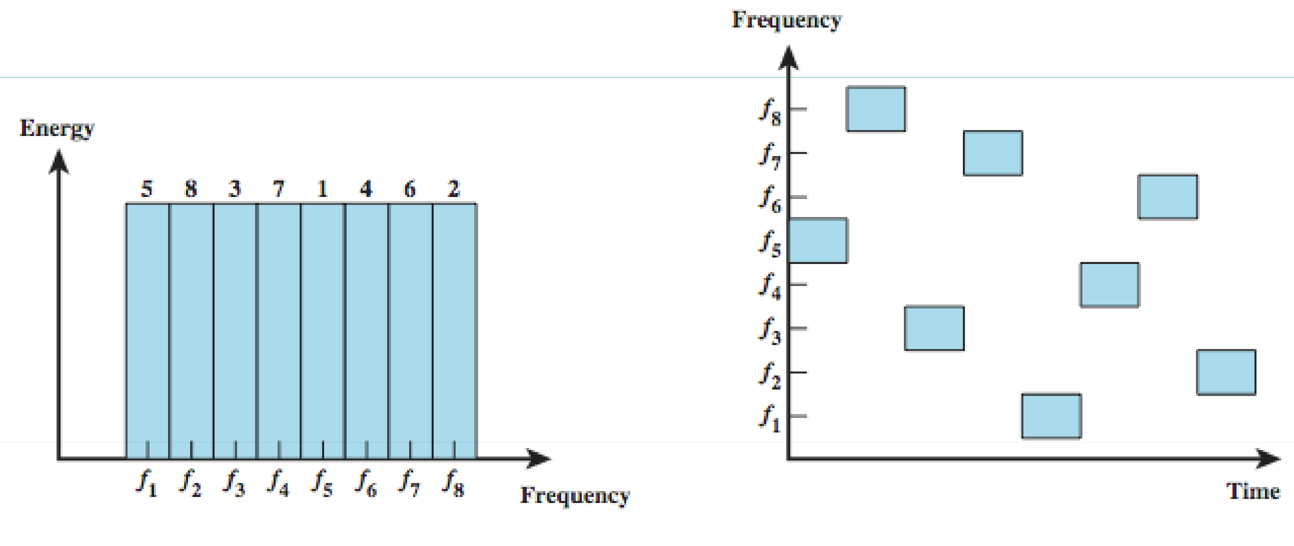
Approximate Spectrum of DSSS Signal



Frequency Hopping Spread Spectrum (FHSS)

- signal is broadcast over seemingly random series of frequencies
- receiver hops between frequencies in sync with transmitter
- eavesdroppers hear unintelligible blips
- jamming on one frequency affects only a few bits

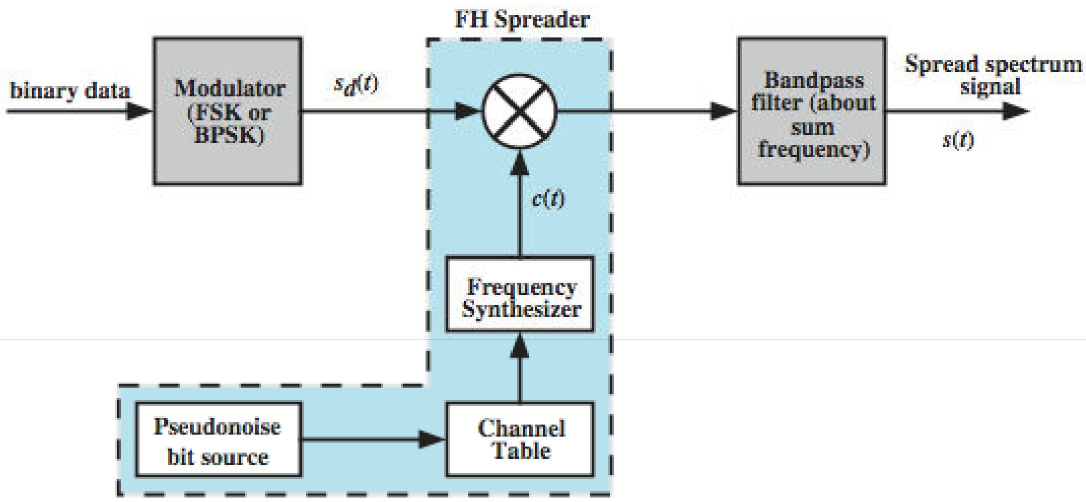
Frequency Hopping Example



(a) Channel assignment

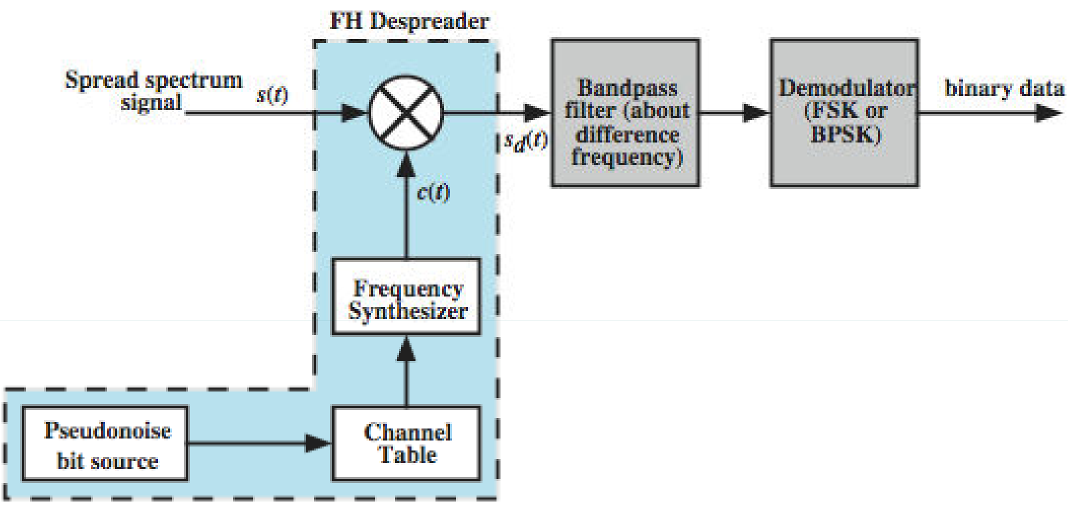
(b) Channel use

FHSS (Transmitter)



(a) Transmitter

Frequency Hopping Spread Spectrum System (Receiver)



(b) Receiver

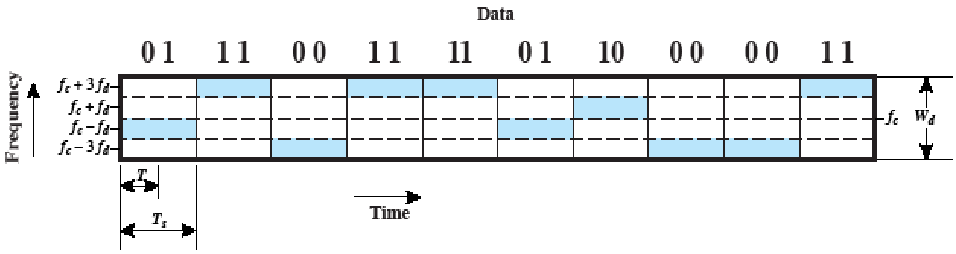
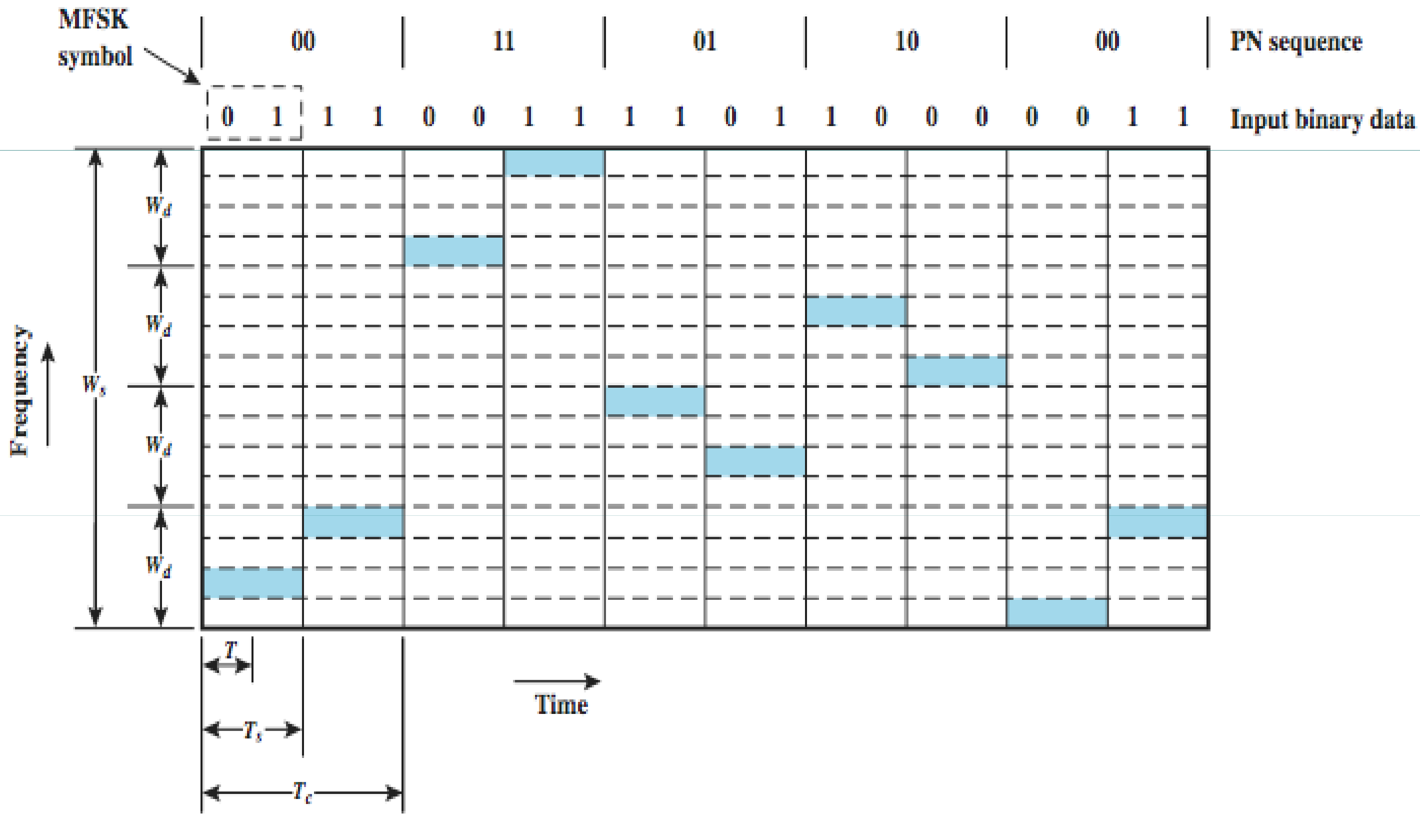


Figure 5.9 MFSK Frequency Use ($M = 4$)

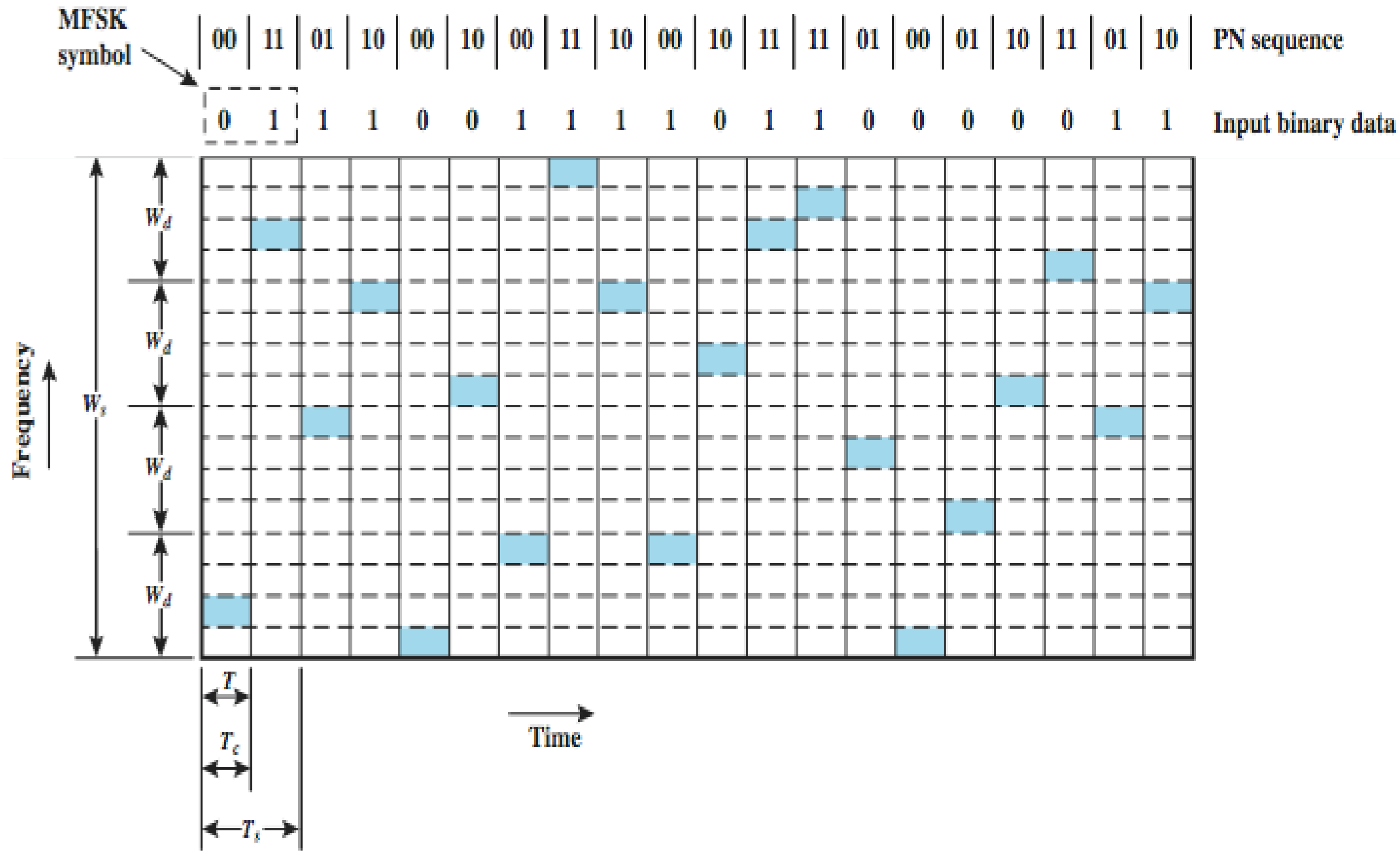
Slow and Fast FHSS

- commonly use multiple FSK (MFSK)
- have frequency shifted every T_c seconds
- duration of signal element is T_s seconds
- Slow FHSS has $T_c \geq T_s$
- Fast FHSS has $T_c < T_s$
- FHSS quite resistant to noise or jamming
  - with fast FHSS giving better performance

Slow MFSK FHSS



Fast MFSK FHSS



Code Division Multiple Access (CDMA)

- a multiplexing technique used with spread spectrum
- given a data signal rate D
- break each bit into *k* chips according to a fixed chipping code specific to each user
- resulting new channel has chip data rate *kD* chips per second
- can have multiple channels superimposed

CDMA Example

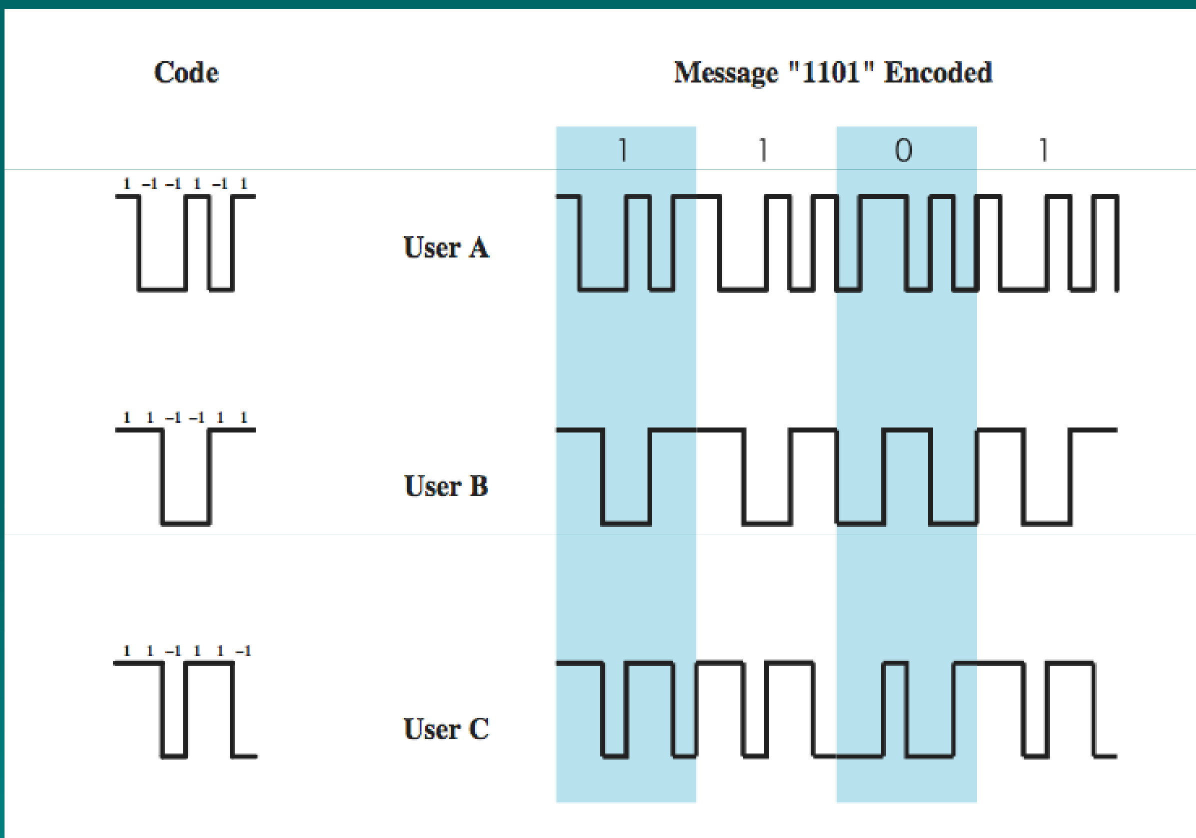


Table 9.1 CDMA Example

(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

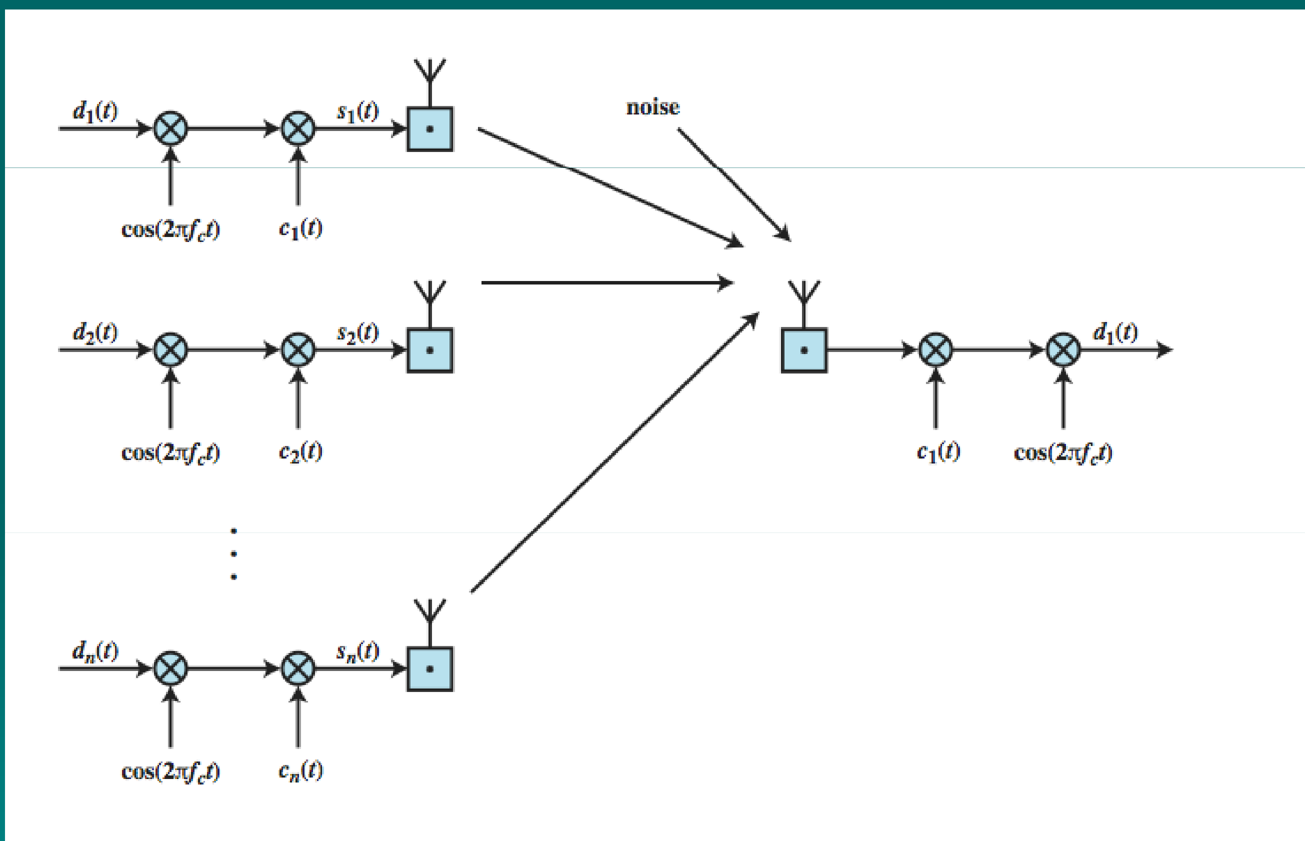
(d) Transmission from C, receiver attempts to recover B's transmission

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

CDMA for DSSS



Problem

 # Consider the seven-channel CDMA shown in the following figure. Enlist the user code for each channel. A positive sum is decoded (at the receiver) as ‘1’ and a negative sum is decoded as ‘0’. If all the channels are transmitting as shown, determine whether the receiver detects the correct bit of channel 1.

Problem

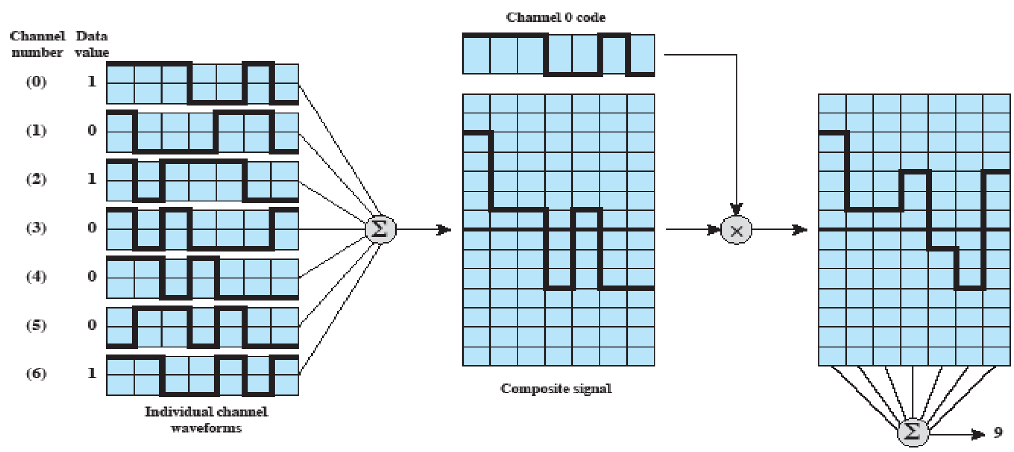


Figure 9.12 Example Seven-Channel CDMA Encoding and Decoding

Orthogonal Sequence

Sequence is generated by Walsh Table:

W1 = [+1]

W2 = W1 W1
W1 !W1

W4 = W2 W2
W2 !W2