CSE 3461: Introduction to Computer Networking and Internet Technologies

Spread Spectrum

Presentation J

Study: 9.1– 9.3

11-08-2012

Spread Spectrum: Basics

- Important encoding method for wireless communications
- Analog & digital data is encoded with analog signal
- Spreads data over wide bandwidth
- Makes jamming and interception harder
- Two approaches, both in use:
  - Frequency Hopping
  - Direct Sequence
- Advantages:
  - immunity from noise and multipath distortion
  - can hide / encrypt signals
  - several users can share same higher bandwidth with little interference, e.g. in CDMA mobile telephony

General Model of Spread Spectrum System

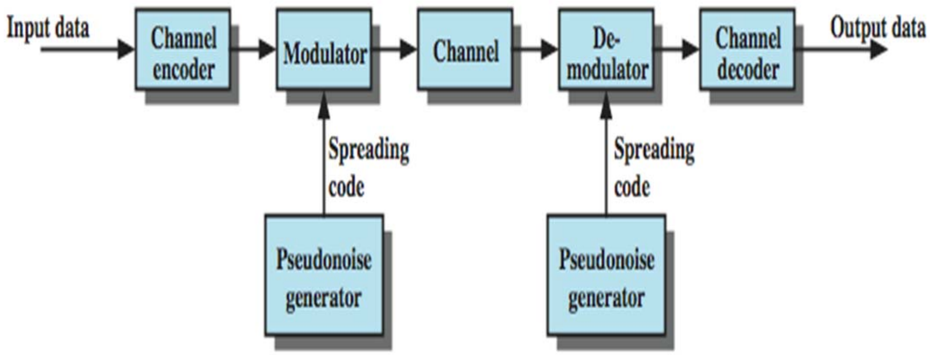


Figure 9.1

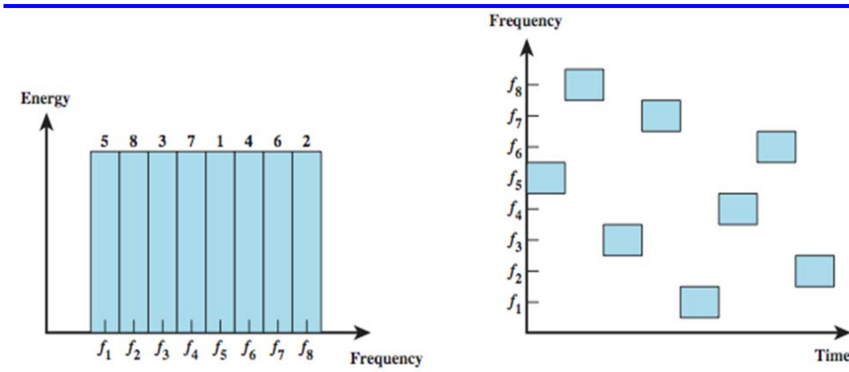
Pseudorandom Numbers

- Pseudorandom numbers are 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

FHSS - Frequency Hopping Spread Spectrum

- 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
- FHSS is commonly use multiple FSK (MFSK)
- Have frequency shifted every T_c seconds
- Duration of signal element is T_s seconds
- Slow and Fast FHSS
  —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

Frequency Hopping Spread Example



(a) Channel assignment (b) Channel use

Figure 9.2

- There are 2^k carrier frequencies forming 2^k channels. Here k=3.
- The spacing between carrier frequencies and the width of each channel usually corresponds to the bandwidth of the input signal.
- A spreading code dictates the sequence of channels used.

FHSS Transmitter

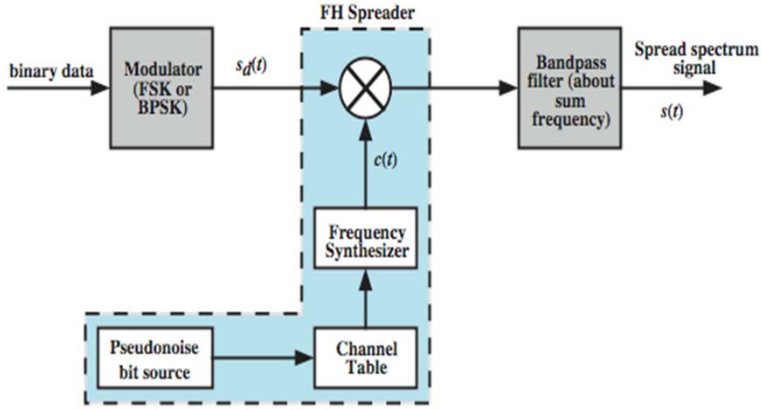


Figure 9.3a

FHSS Receiver

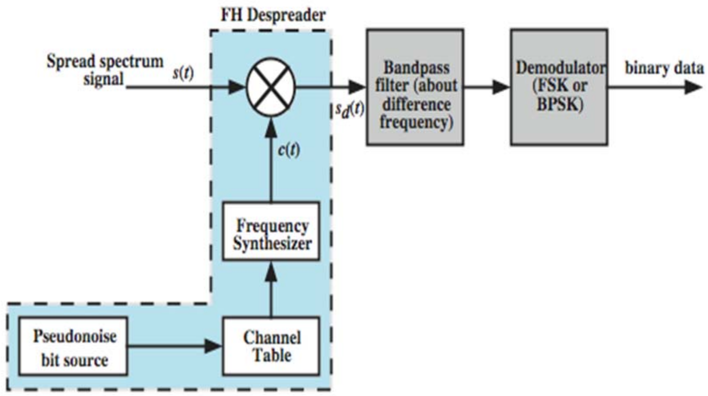


Figure 9.3b

Slow MFSK FHSS ($T_c \geq T_s$)

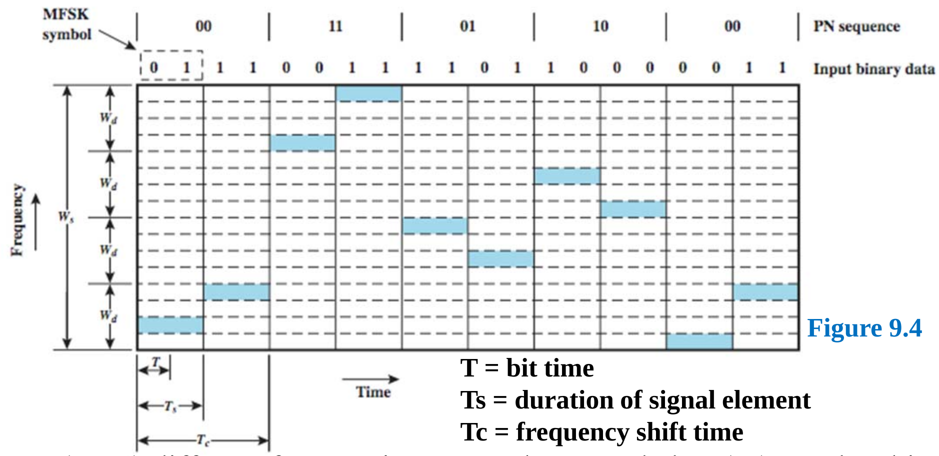


Figure 9.4

T = bit time
Ts = duration of signal element
Tc = frequency shift time

- M (M=4) different frequencies are used to encode $\log_2(M) = 2$ data bits
- Each channel has total bandwidth $W_d = M \times f_d$, f_d= difference frequency
- FHSS uses 2^k different channels (k = 2), total bandwidth $W_s = 2^k \times W_d$
- Each 2 bits of PN sequence is used to select one of the four channels

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Fast MFSK FHSS ($T_c < T_s$)

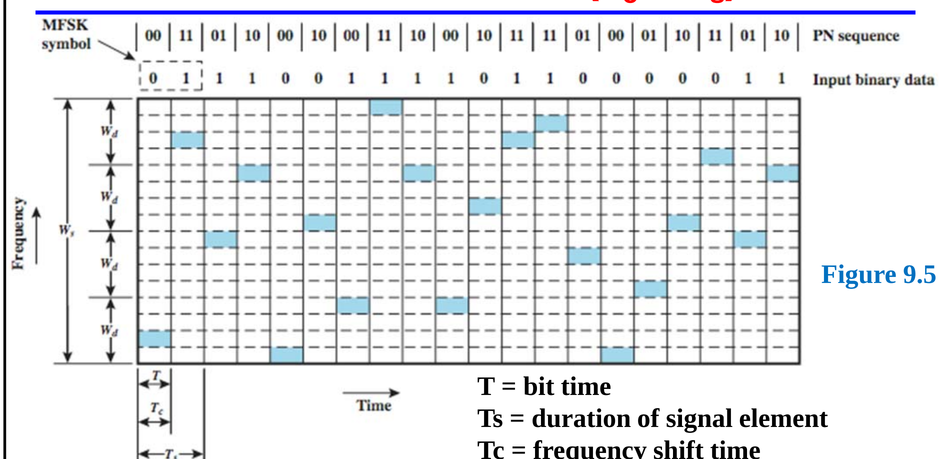

Figure 9.5

T = bit time
Ts = duration of signal element
Tc = frequency shift time

- Again, M=4 frequencies are used to encode $\log_2(M)$=2 data bits at time
- Again, FHSS uses 2^k channels (k = 2), $W_s = 2^k \times W_d$, $W_d = M \times f_d$
- In this case, each signal element is represented by two frequency tones and $Ts = 2T_c = 2T$

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DSSS - Direct Sequence Spread Spectrum

- Each bit is represented by multiple bits using a spreading code
- This spreads signal across a wider frequency band
- DSSS has performance similar to FHSS
- One technique with direct sequence spread spectrum is to combine the digital information stream with the spreading code bit stream using an exclusive-OR
- The combination bit stream has the data rate of the original spreading code sequence, so it has a wider bandwidth than the information stream.
- In the example on the next slide, the spreading code bit stream is clocked at four times the information rate.

Direct Sequence Spread Spectrum Example

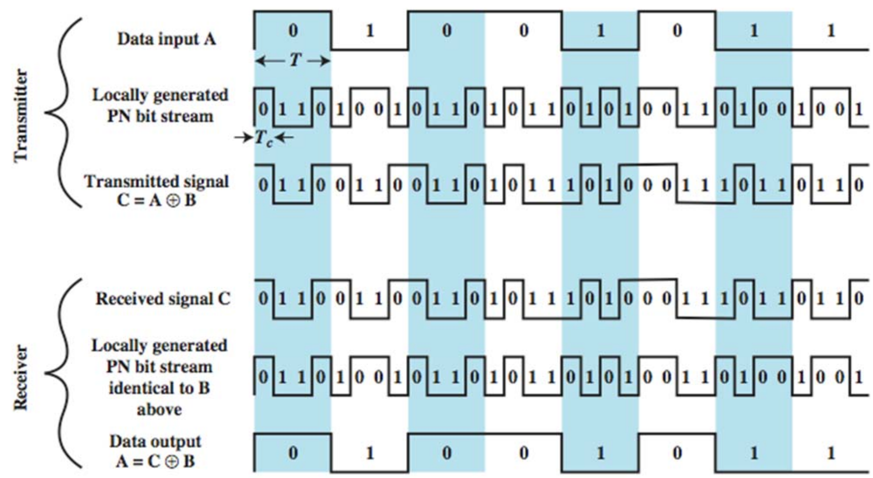


Figure 9.6

DSSS System Using BPSK Modulation

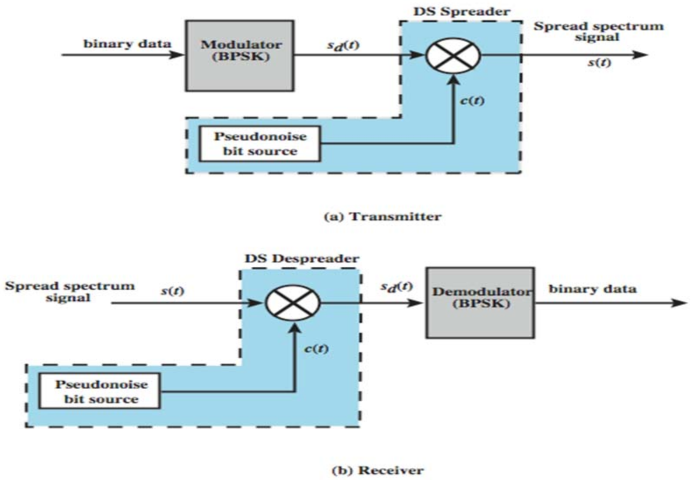


Figure 9.7

DSSS Example Using BPSK

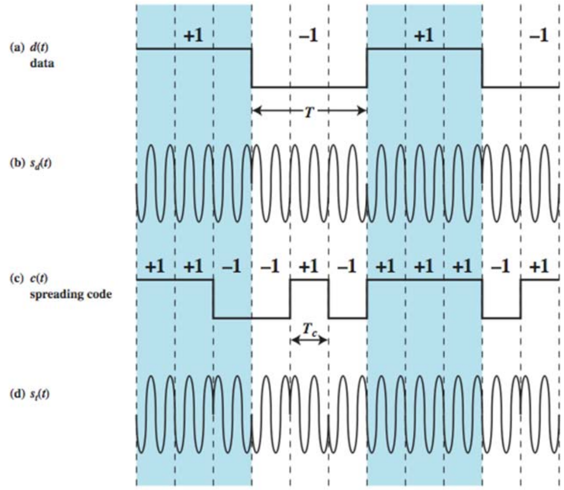
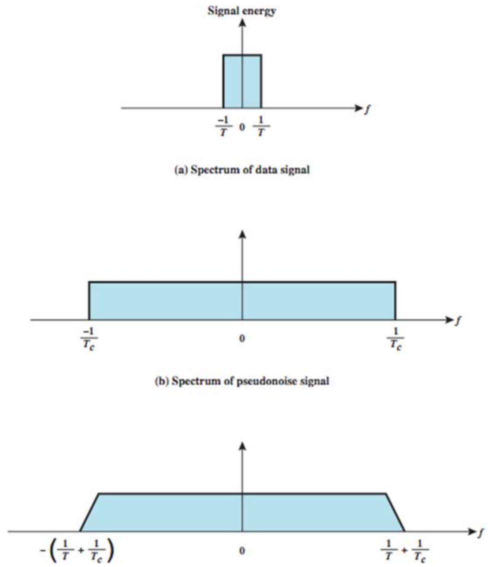


Figure 9.8

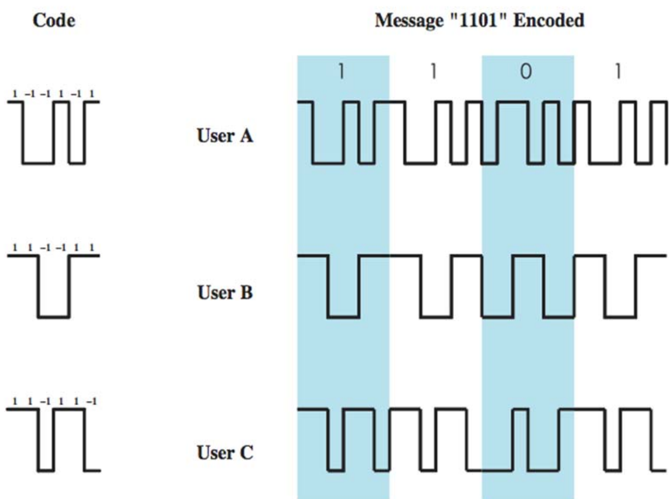
Approximate Spectrum of DSSS Signal



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



CDMA for DSSS