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
General Model of Spread Spectrum System
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
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
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)
Frequency Hopping Spread Spectrum System (Receiver)

(b) Receiver
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
Direct Sequence Spread Spectrum (DSSS)

- each bit is represented by multiple bits using a spreading code
- this spreads signal across a wider frequency band
- has performance similar to FHSS
Direct Sequence Spread Spectrum Example

Transmitter:
- Data input A: 0 1 0 0 1 0 1 1 0 1 0 1 0 1 0 0 1 0 1 0 0 1 0 1 1 1 0 1 1 1
- Locally generated PN bit stream: 0 1 1 0 1 0 0 1 0 1 1 0 1 0 1 1 0 1 0 1 0 0 1 1 0 1 0 0 1 0 1 1
- Transmitted signal $C = A \oplus B$

Receiver:
- Received signal $C$:
- Locally generated PN bit stream identical to B above: 0 1 1 0 1 0 1 0 1 1 0 1 0 1 1 0 1 0 0 0 1 1 1 0 1 1 0 1 1 0 1 1 0
- Data output $A = C \oplus B$: 0 1 0 0 1 0 1 0 0 1 0 1 0 1 0 0 1 0 1 0 0 1 0 0 1 1
Direct Sequence Spread Spectrum System

(a) Transmitter

(b) Receiver
DSSS Example Using BPSK

(a) $d(t)$

(b) $s_d(t)$

(c) $c(t)$

(d) $s_i(t)$
Approximate Spectrum of DSSS Signal

(a) Spectrum of data signal

(b) Spectrum of pseudonoise signal

(c) Spectrum of combined 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

Code

Message "1101" Encoded

User A

User B

User C
CDMA

- code division multiple access
  - each station has a “station code”
  - each bit is encoded by station code
    - code 1 is mapped to 1

<table>
<thead>
<tr>
<th>Station codes</th>
<th>Transmissions</th>
<th>Decoding traffic of station:</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_A: 1 0 1 0</td>
<td>A: Bit 1 =&gt; -1 1 1</td>
<td>A: S<em>C_A=(-1 -1 3 -1)</em>(1 -1 1 -1)/4=1 =&gt; binary 1.</td>
</tr>
<tr>
<td>C_B: 1 0 0 1</td>
<td>B: Bit 0 =&gt; -1 1 1</td>
<td>B: S<em>C_B=(-1 -1 3 -1)</em>(1 -1 1 1)/4=-1 =&gt; binary 0.</td>
</tr>
<tr>
<td>C_C: 0 0 1 1</td>
<td>C: Bit 1 =&gt; -1 1 1</td>
<td>C: S<em>C_C=(-1 -1 3 -1)</em>(-1 -1 1 1)/4=1 =&gt; binary 1.</td>
</tr>
</tbody>
</table>

S = -1 -1 3 -1

Figure 2.33  CDMA operation
Summary

- looked at use of spread spectrum techniques:
  - FHSS
  - DSSS
  - DSSS
  - CDMA