EE359 – Lecture 18 Outline

- Announcements
  - My OHs today are 3:45-4:45. Tom has extra OHs by appointment
  - HW due Fri; last HW posted later this week
  - Lecture next Thu 3/12 1:30-3:30 (course review+advanced topics)
  - Final info (coverage, format, extra OHs, etc) given in 3/10 lecture
  - Final exam 3/17, 3:30pm-6:30pm here (Thornton 102)
  - Final projects must be posted 3/14 at midnight (hard deadline).
- Spread Spectrum
  - Direct sequence (DSSS)
  - ISI and Interference Rejection of DSSS
  - RAKE Receiver
- Multiuser Systems
  - Multiple access techniques
  - Random access techniques

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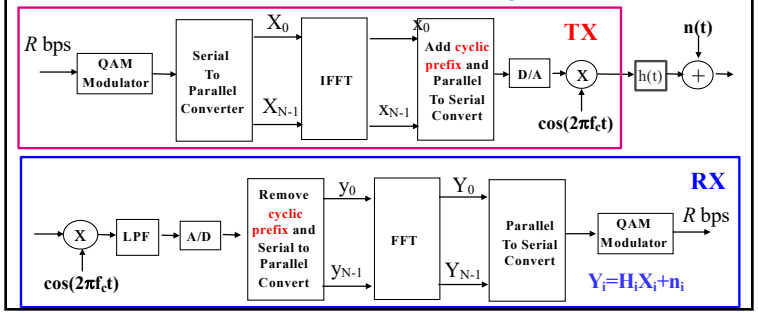
Review of Last Lecture

MCM, Overlapping Subcarriers and FFT Implementation (OFDM)

- MCM splits high rate data stream into lower rate flat-fading substreams
- Overlapping subcarriers reduces BW by factor of 2
- Modulate symbols with IFFT at TX, Reverse structure (with FFT) in RX
- Cyclic prefix makes linear convolution of channel circular, so no interference between FFT blocks in RX processing



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Review Continued
OFDM Design Issues

- Timing/frequency offset:
  - Impacts subcarrier orthogonality; self-interference
- Peak-to-Average Power Ratio (PAPR)
  - Adding subcarrier signals creates large signal peaks
  - Solve with clipping or PAPR-optimized coding
- Different fading across subcarriers
  - Mitigate by precoding (fading inversion), adaptive modulation over frequency, and coding across subcarriers
- MIMO-OFDM
  - Apply OFDM across each spatial dimension
  - Can adapt across space, time, and frequency
  - MIMO-OFDM represented by a matrix, extends matrix representation of OFDM alone (considered in HW)

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Intro. to Spread Spectrum

- Modulation that increases signal bandwidth
  - Spreads modulated signal over wider BW B~$1/T_s$ than needed for transmission ($R=\log_2(M)/T_s$)
  - Mitigates or coherently combines ISI
  - Mitigates narrowband interference/jamming
  - Hides signal below noise (DSSS) or makes it hard to track (FH)
  - Also used as a multiple access technique
- Two types
  - Frequency Hopping:
    - Narrowband signal hopped over wide bandwidth
  - Direction Sequence:
    - Modulated signal multiplied by faster chip sequence

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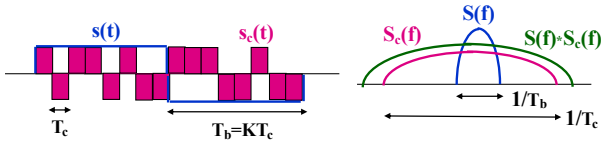
Direct Sequence Spread Spectrum

- Bit sequence modulated by chip sequence



- Spreads bandwidth by large factor (G)
- Despread by multiplying by $s_c(t)$ again ($s_c^2(t)=1$)
- Mitigates ISI and narrowband interference

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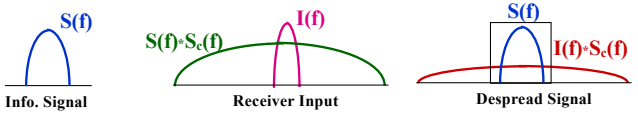
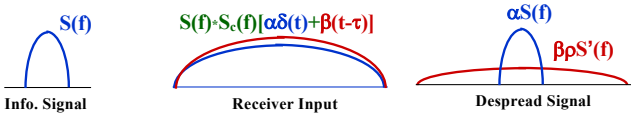
ISI and Interference Rejection

- Narrowband Interference Rejection (1/K)



- Multipath Rejection (Autocorrelation $\rho(\tau)$)



Can coherently combine all multipath components via a RAKE receiver

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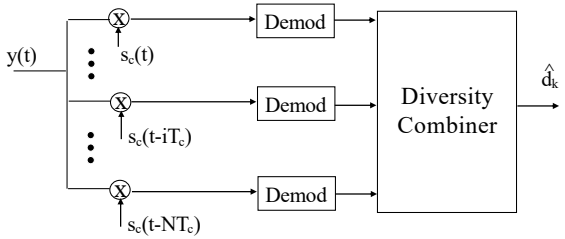
RAKE Receiver

- Multibranch receiver
  - Branches synchronized to different MP components



- These components can be coherently combined
  - Use SC, MRC, or EGC

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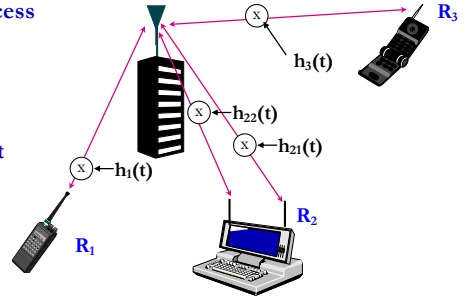
Multiuser Channels: Uplink and Downlink

Uplink (Multiple Access Channel or MAC):
Many Transmitters to One Receiver.

Downlink (Broadcast Channel or BC):
One Transmitter to Many Receivers.



Uplink and Downlink typically duplexed in time or frequency

Full-duplex radios are being considered for 5G systems

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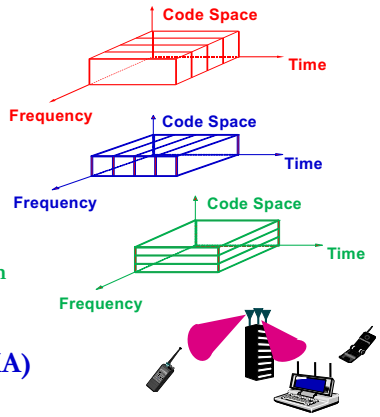
Bandwidth Sharing in Multiple Access

Channels assigned by central controller

- Frequency Division
  - OFDMA
  - Non-orthogonal FD
- Time Division
  - Non-orthogonal TD
- Code Division
  - Code cross-correlation dictates interference
  - Multiuser Detection
- Space Division (SDMA)
- Hybrid Schemes



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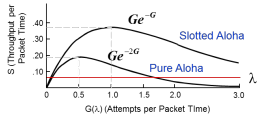
Random vs. Multiple Access

- In multiple access, channels are assigned by a centralized controller
  - Requires a central controller and control channel
  - Inefficient for short and/or infrequent data transmissions
- In random access, users access channel randomly when they have data to send
  - A simple random access scheme will be explored in homework
- ALOHA Schemes (not on exams/HW)
  - Data is packetized.
  - Packets occupy a given time interval



- Pure ALOHA
  - send packet whenever data is available
  - a collision occurs for any partial overlap of packets (nonorthogonal slots)
  - Packets received in error are retransmitted after random delay interval (avoids subsequent collisions).
- Slotted ALOHA
  - same as ALOHA but with packet slotting
  - packets sent during predefined timeslots
  - A collision occurs when packets overlap, but there is no partial overlap of packets
  - Packets received in error are retransmitted after random delay interval.

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Main Points

- Spread spectrum increases signal bandwidth above that required for information transmission
- Benefits of spread spectrum:
  - ISI/narrowband interference rejection by spreading gain
  - Also used as a multiuser/multiple access technique
- Multiple access: users can share the same spectrum via time/frequency/code/space division
- Random access more efficient than multiple access for short/infrequent data transmission

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