EE359 – Lecture 19 Outline

- Announcements
  - HW due Fri; last HW posted, due Sunday 12/10 at 4 pm (no late HWs)
  - Last lecture Thu 12/7 10-11:50 (course review+advanced topics)
  - Final exam info on next slide
  - Final exam 12/13, 12:15pm-3:15pm in Thornton 102
  - Final projects must be posted 12/9 at midnight.
  - 25 bonus points for course evaluations (online)
- Random Access
- Cellular System Design
- Multiuser Detection
- Area spectral efficiency

Final Exam Announcements

- Final 12/13/2017, 12:15-3:15pm in Thornton 102 (here)
- Covers Chapters 9, 10, 12, 13.1-13.2, 13.4, 14.1-14.4, 15.1-15.4 (+ earlier chps)
- Similar format to MT, but longer: open book, notes.
  - If you need a book or calculator, let us know by 12/8 (Fri)
- Practice finals posted (10 bonus points)
  - Turn in for solns, by exam for bonus pts
- Course summary and bonus lecture on advanced topics Thursday 10-11:50am, here
- Final review and discussion section: Monday, 12/11, 2-4pm, Packard 364.

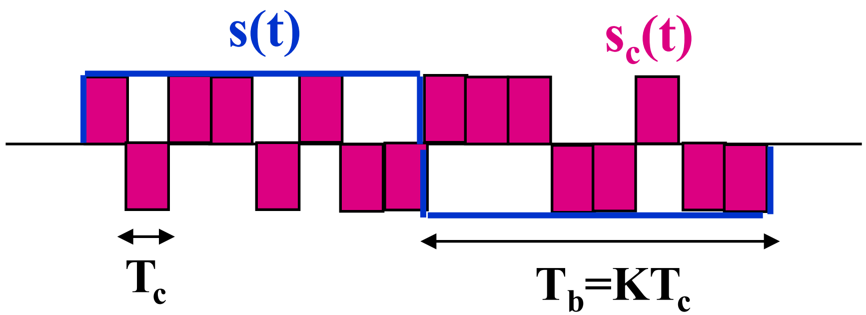
OHs leading up to final exam

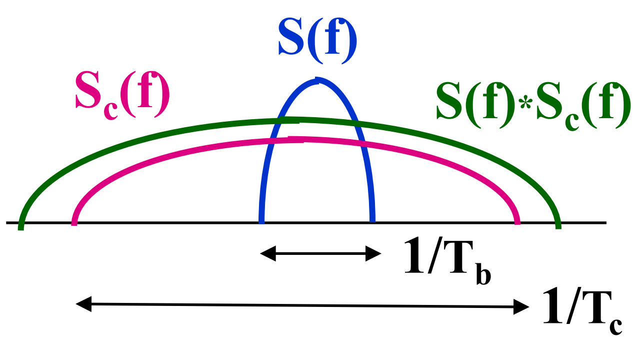
- Mine
  - This week: today and Thu after class, Fri 12-1pm & by appt.
  - Next week: Sun 12/10: 5-6pm, Tue 12/11 10:30-12 & by appt.
- TAs:
  - Wednesday, 12/6, 2-5pm Tom Email OH
  - Wednesday, 12/6, 5-6pm Discussion session
  - Thursday, 12/7, 5-6pm Milind OH
  - Thursday, 12/7, 6-7pm Milind Email OH
  - Saturday, 12/9, 2-4pm Tom OH (HW8 + Exam questions)
  - Monday, 12/11, 2-4pm Final review
  - Monday, 12/11, 4-6pm Tom OH
  - Tuesday. 12/12 2-4pm Milind OH
  - Wednesday, 12/13, 9:30am-11:30am, Tom OH

Review of Last Lecture

Direct Sequence Spread Spectrum

- Bit sequence modulated by chip sequence

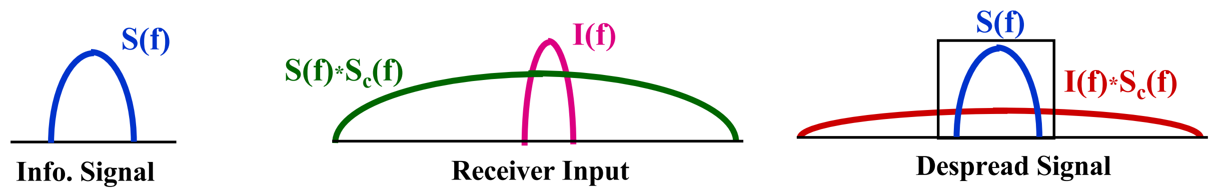




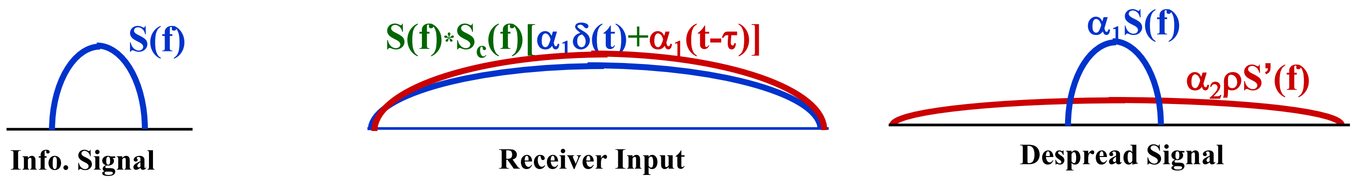
- Spreads bandwidth by large factor (G)
- Despread by multiplying by $s_c(t)$ again ($s_c^2(t)=1$)
- Mitigates ISI and narrowband interference

Review Continued
ISI/Interference Rejection and RAKE Receivers

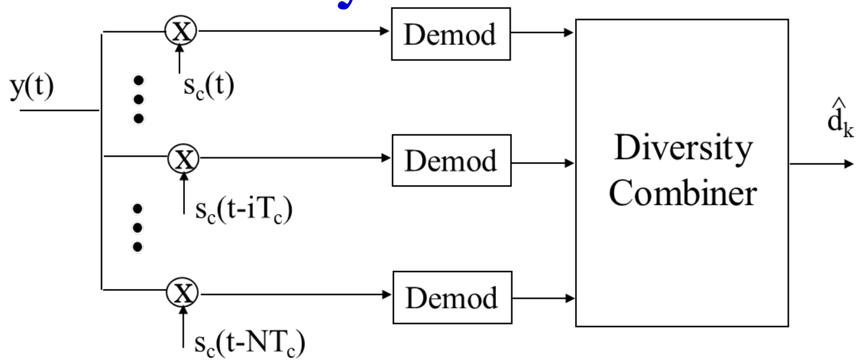
- Narrowband Interference Rejection (1/K)



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



- RAKE RX coherently combines multipath

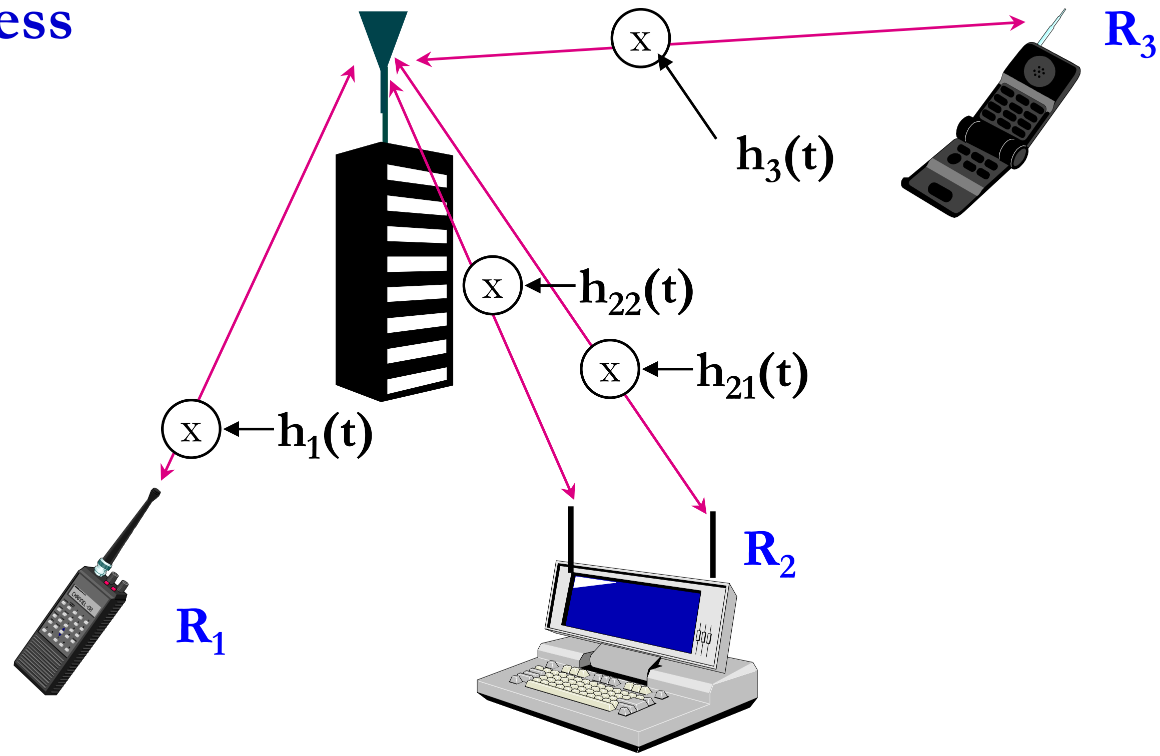


Review Continued

Multiuser Channels

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

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

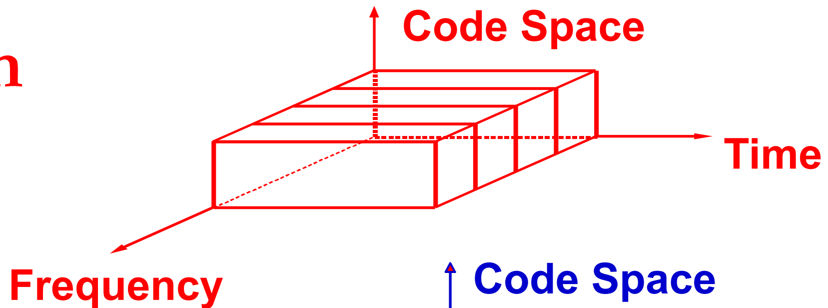


Uplink and Downlink typically duplexed in time or frequency

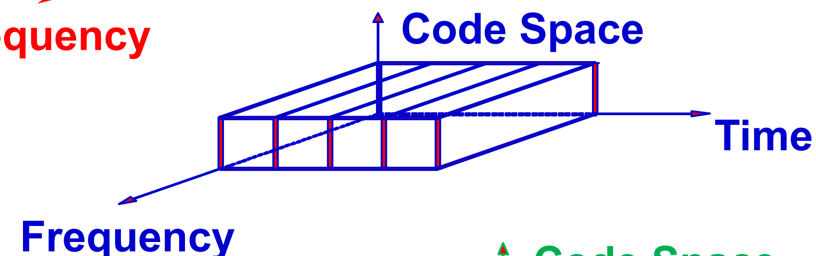
Full-duplex radios are being considered for 5G systems

Review Continued:
Bandwidth Sharing in Multiple Access

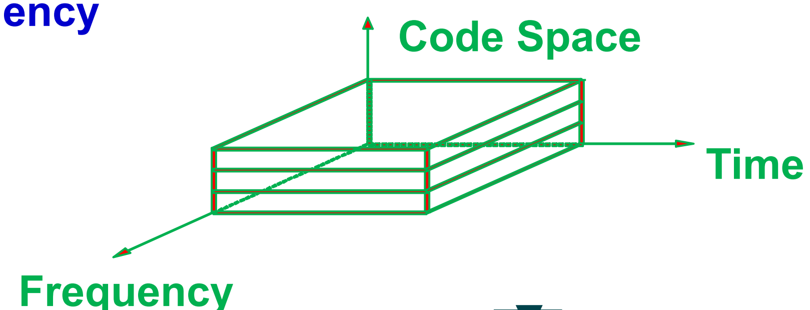
- Frequency Division
  - OFDMA



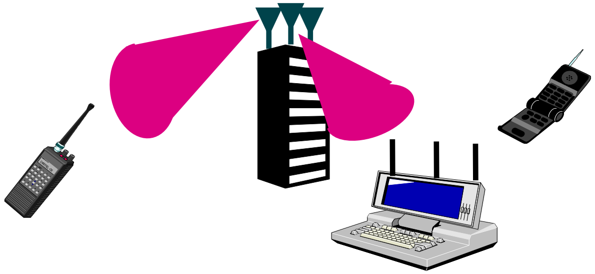
- Time Division



- Code Division
  - Code cross-correlation dictates interference
  - Multiuser Detection



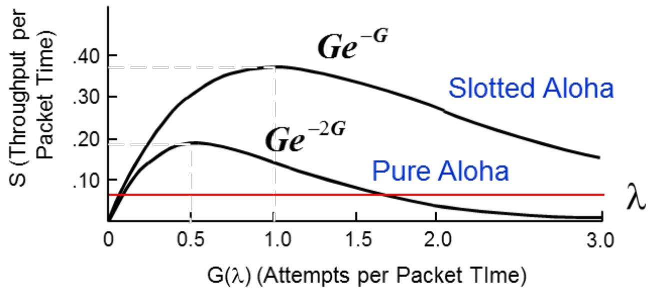
- Space Division (SDMA)
- Hybrid Schemes



Random 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

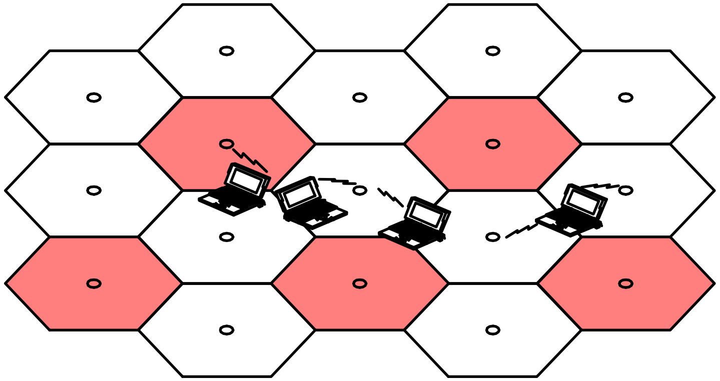
- ALOHA Schemes (not on exams/HW)
  - Data is packetized.
  - Packets occupy a given time interval



- 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.

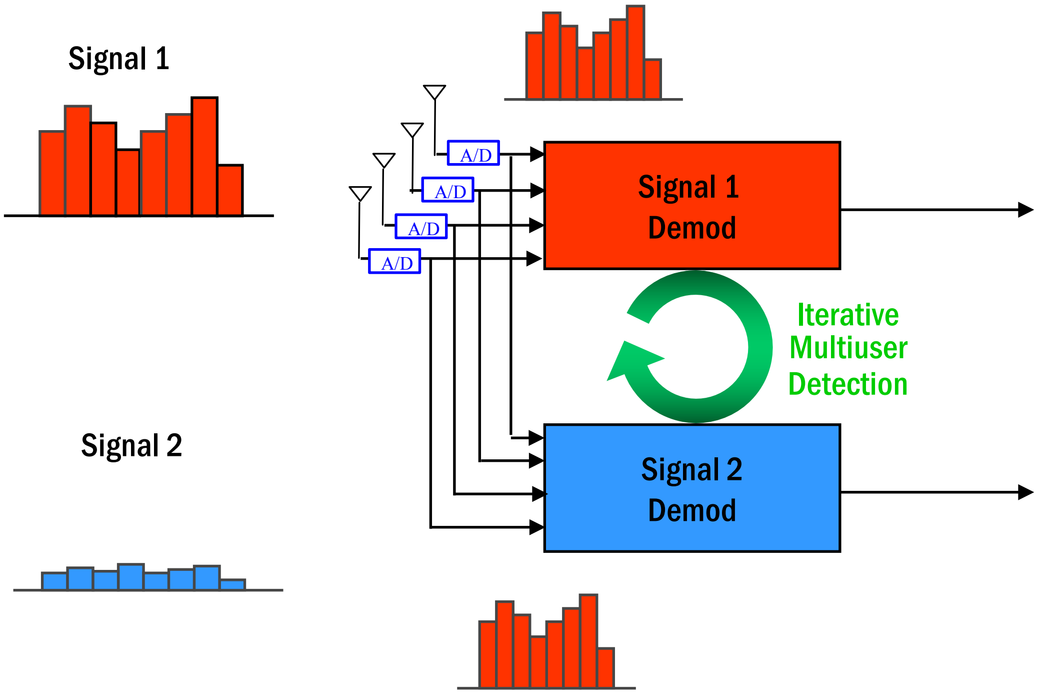
Cellular System Design



- Frequencies/time slots/codes reused at spatially-separated locations
  - Exploits power falloff with distance.
  - Best efficiency obtained with minimum reuse distance
- Base stations perform centralized control functions
  - Call setup, handoff, routing, etc.
- Ideally, interference results in SINR above desired target.
  - The SINR depends on base station locations, user locations, propagation conditions, and interference reduction techniques.
  - System capacity is interference-limited as SINR must be above target
  - MIMO introduces diversity-multiplexing-interference reduction tradeoff
  - Multiuser detection reduces inter/intracell interference: increases capacity

Multiuser Detection

- Multiuser detection (MUD) exploits the fact that the structure of the interference is known
  - Maximum likelihood: exponentially complex in number of users *N*
  - Successive interference cancellation (SIC)

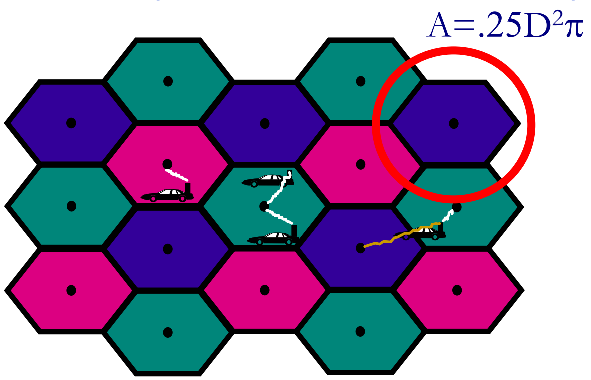


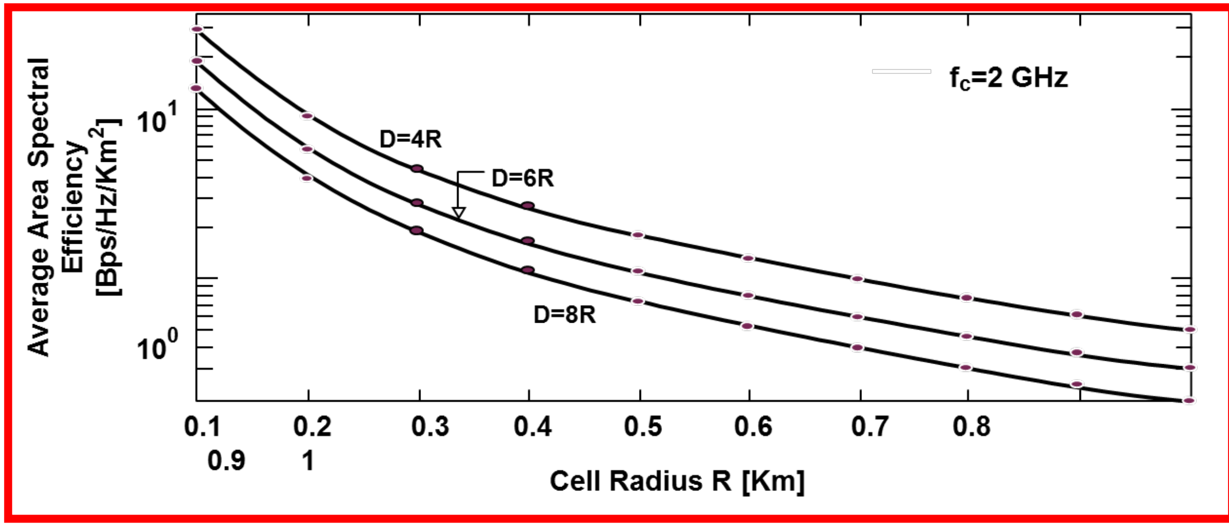
Why not ubiquitous today? Power, A/D Precision, Error propagation

Area Spectral Efficiency (ASE)

- **System capacity due to optimal cell size and/or reuse distance:** $A_e = \Sigma R_i / (.25D^2\pi)$ bps/Hz/Km^2.

Area Spectral Efficiency





- S/I increases with reuse distance (increases link capacity).
- Tradeoff between reuse distance and link spectral efficiency (bps/Hz).
- Capacity increases exponentially as cell size decreases
- Future cellular systems will be hierarchical
  - Large cells for coverage, small cells for capacity

Main Points

- Random access more efficient than multiple access for short/infrequent data transmission
- Cellular systems reuse time/freq/codes in space
  - Interference managed to meet SINR targets
  - Interference reduction increases capacity
  - MIMO trades diversity-multiplexing-interference reduction
- Multiuser detection mitigates interference through joint or successive detection
- Area spectral efficiency captures system capacity as a function of cell size and reuse distance
  - Small cells and reuse 1 distance typical of next-gen cellular