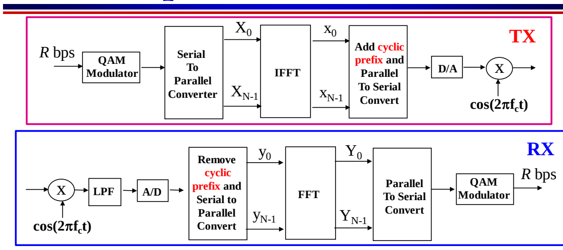
EE359 – Lecture 19 Outline

- Announcements
  - Final Exam Announcements
  - HW 8 (last HW) due Sunday 5pm (no late HWs)
  - Bonus lecture today 6-8pm (pizza/cake); Hewlett 103
  - 10 bonus points for course evaluations online
  - Projects due end of this week
- Introduction to Spread Spectrum
- Direct Sequence Spread Spectrum
- ISI and Inteference Rejection
- Spreading Codes and Maximal Linear Codes
- Synchronization
- RAKE Receivers
- Multiuser Spread Spectrum

Final Exam Announcements

- Final Wed., 12/14, 8:30-11:30, Gates B12 (here)
- Covers Chapters 9, 10, 12, 13.1-13.2 (+ earlier chps)
- Similar format to MT, but longer: open book, notes.
- Practice finals posted by Wed (10 bonus points)
  - Turn in to Pat or Nima for solns, by exam for bonus pts
- Bonus Lecture (Course review; advanced topics) today 6-8pm in Hewlett 103.
- Review Session: Thu, Fri, Sun, or Mon?
- Extra OHs in advance of the final
  - Me: 12/12 and 12/13 11:30-12:30 and by appt.
  - Nima: 12/12 and 12/13 5-6pm.

Review of Last Lecture FFT Implementation of OFDM



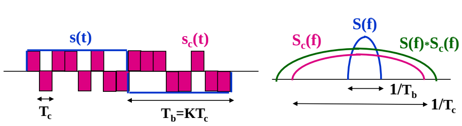
- Design Issues
  - PAPR, frequency offset, fading, complexity
  - MIMO-OFDM

Intro. to Spread Spectrum

- Modulation that increases signal BW
  - 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

Direct Sequence Spread Spectrum

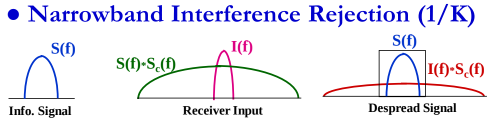
- Bit sequence modulated by chip sequence



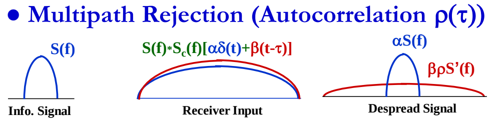
- Spreads bandwidth by large factor (G)
- Despread by multiplying by $s_c(t)$ again ($s_c^2(t)=1$)
- Mitigates ISI and narrowband interference

ISI and Interference Rejection

- Narrowband Interference Rejection (1/K)

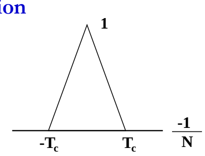


- Multipath Rejection (Autocorrelation $\rho(\tau)$)



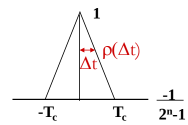
Maximal Linear Codes

- Autocorrelation determines ISI rejection
  - Ideally equals delta function
- Maximal Linear Codes
  - No DC component
  - Large period $(2^n-1)T_c$
  - Linear autocorrelation
  - Recorrelates every period
  - Short code for acquisition, longer for transmission
  - In SS receiver, autocorrelation taken over T_b
  - Poor cross correlation (bad for MAC)



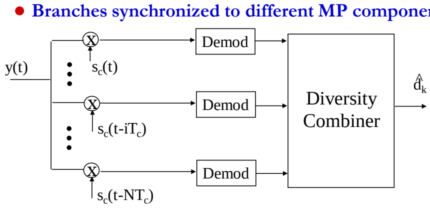
Synchronization

- Adjusts delay of $s_c(t-\tau)$ to hit peak value of autocorrelation.
  - Typically synchronize to LOS component
- Complicated by noise, interference, and MP
- Synchronization offset of Δt leads to signal attenuation by $\rho(\Delta t)$



RAKE Receiver

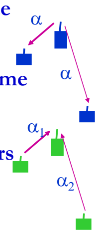
- Multibranch receiver
  - Branches synchronized to different MP components



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

Multiuser DSSS

- Each user assigned a unique spreading code; transmit simultaneously over same bandwidth
- Interference between users mitigated by code cross correlation
- In downlink, signal and interference have same received power
- In uplink, "close" users drown out "far" users ($\alpha_1 >> \alpha_2$: near-far problem)



Main Points

- Spread spectrum increases signal bandwidth above that required for information transmission
  - Benefits include ISI and interference rejection, multiuser technique
- DSSS rejects ISI by code autocorrelation
  - Maximal linear codes have good autocorrelation properties but poor cross correlation
- Synchronization depends on autocorrelation properties of spreading code.
- RAKE receivers combine energy of all MP
  - Use same diversity combining techniques as before