EE359 – Lecture 18 Outline

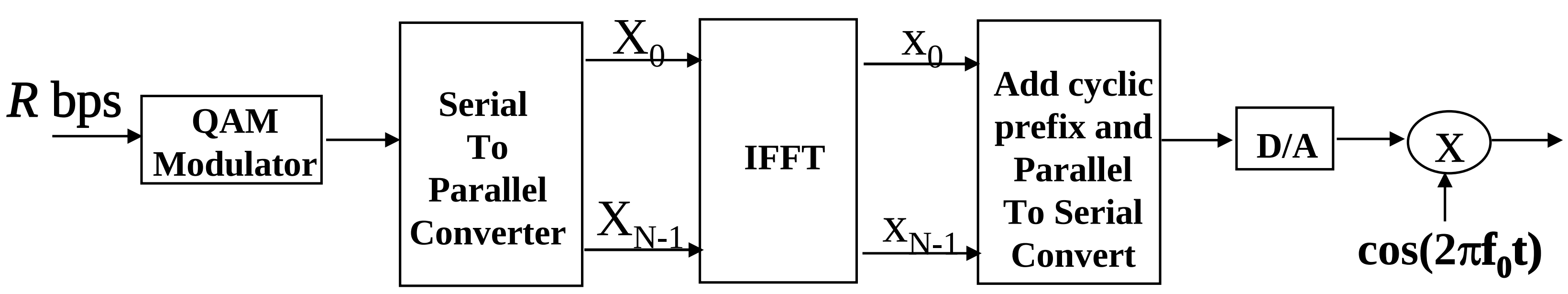
- Announcements
  - No Wed. OHs this week; Yao moved to Tue 8:10pm, mine to Thu 1:30.
  - HW 8 (last HW) due Thur. 5pm (no late HWs after Fri.)
  - Bonus lecture today 5:15-7:15 (pizza) in Packard 204
  - 10 bonus points for course evals online
  - Final next Wednesday, 12/9, 8:30-11:30, in this room
- Review of Last Lecture
- Introduction to Spread Spectrum
- Direct Sequence Spread Spectrum
- Speading codes and autocorrelation
- RAKE Receivers

Final Exam Announcements

- Final 12/9, 8:30-11:30, this room
- Review Session: next Saturday or Sunday afternoon
- Open book/notes
- Covers Chapters 7, 9, 10, 12, 13.1-13.2 (+ earlier chps)
- Similar format to first exam
- Practice finals posted soon (10 bonus points)
- Extra OHs in advance of the final
  - Me: F 12/4 11-12, M 12/7 1-2, T 12/8 11-12 and by appt.
  - Yao: Monday 12/7 4-5pm and Tues 12/8 7-8pm (Pack 107), Tuesday 12/8 4-5pm in Math 380/380W (review session rm)

Review of Last Lecture

- Overlapping substreams in OFDM: Dfi=1/TN
- Compensation for fading across subcarriers:
  - Coding or adaptive loading
- FFT Implementation of OFDM
  - Challenges: PAPR, offset, fading across subcarriers

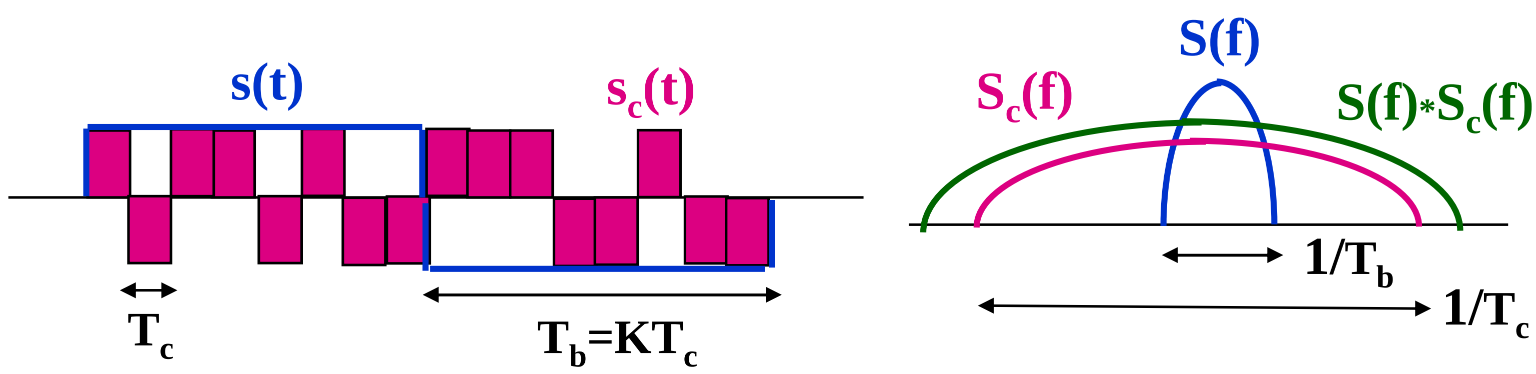


Introduction to Spread Spectrum

- 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

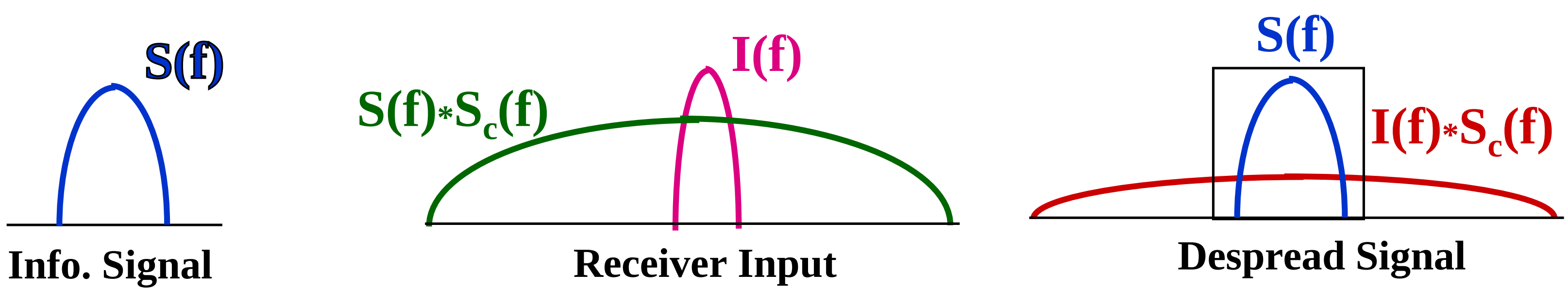
- Bit sequence modulated by chip sequence



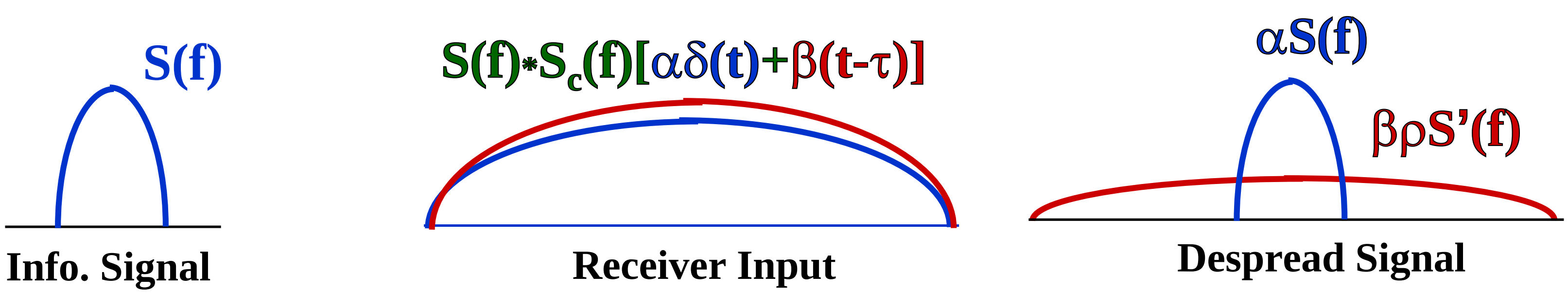
- Spreads bandwidth by large factor (K)
- Despread by multiplying by $s_c(t)$ again ($s_c^2(t)=1$)
- Mitigates ISI and narrowband interference

ISI and Interference Rejection

- Narrowband Interference Rejection (1/K)

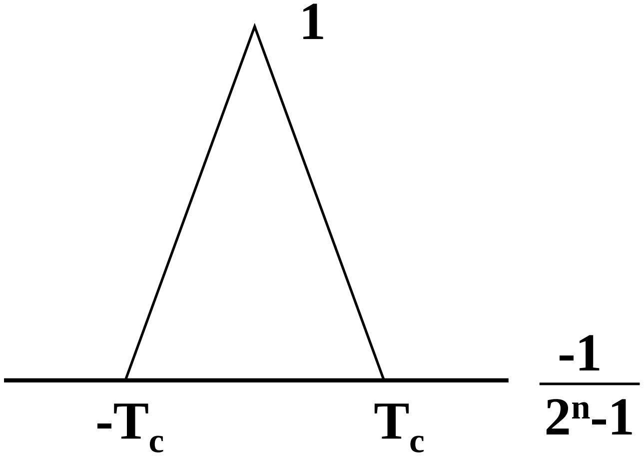


- Multipath Rejection (Autocorrelation $\rho(\tau)$)



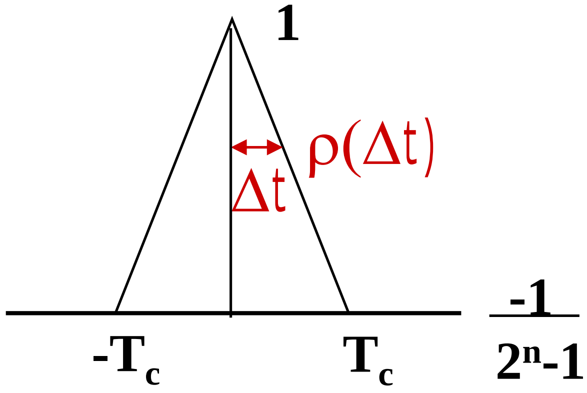
Pseudorandom Sequences

- 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)



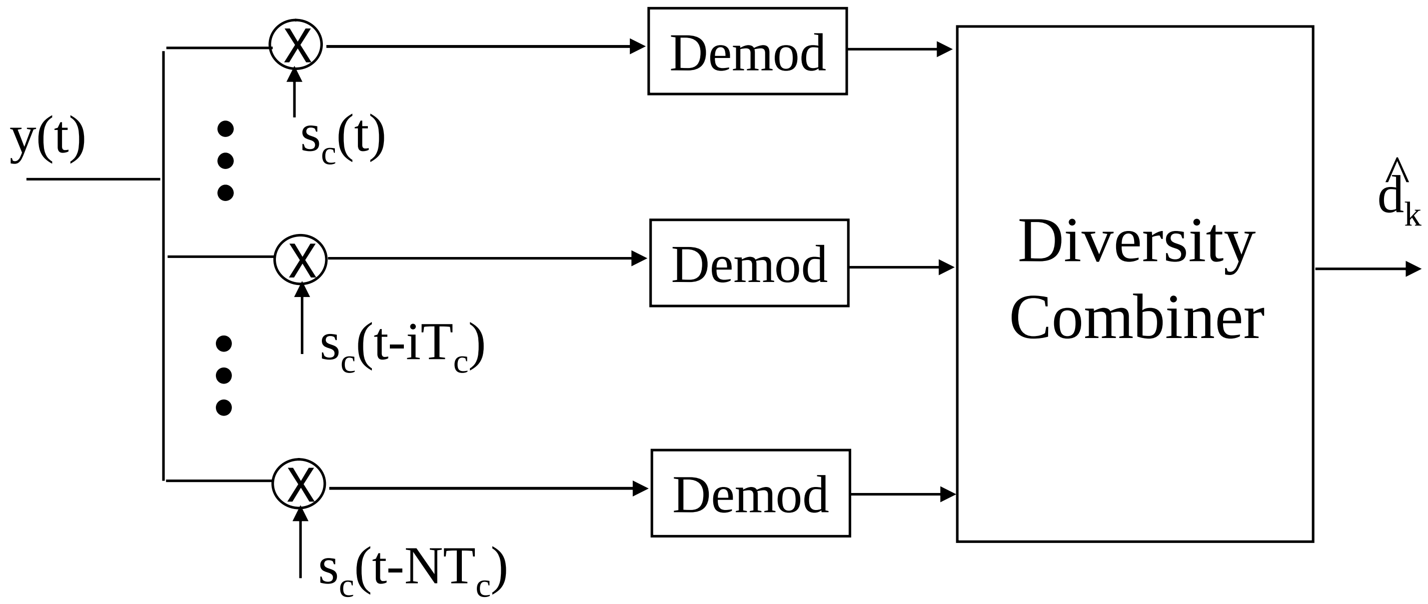
Synchronization

- 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

SS Multiuser Systems

- Spread spectrum codes can also be used as a multiple access technique.
  - modulate user signals with orthogonal / semi-orthogonal codes.
  - signals can be separated at receiver using code properties.
- Interference between users determined by cross correlation properties of the codes.
- Most spread spectrum codes are semi-orthogonal.
- Orthogonal codes ‘‘channelize’’ the system
  - Similar to TD or FD
  - In downlink (BC) all signals received with the same power.
  - In uplink (MAC) channels signals are received with power that depends on channle gain of each user (near-far problem).

Main Points

- DSSS rejects interference by spreading gain
- 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
- SS can also be used in multiuser systems to separate out users