

## EE359 – Lecture 18 Outline

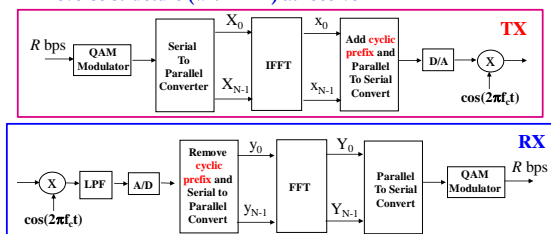
- **Announcements**
  - Today's lecture will end ~10 minutes early
  - Nima's OH Thur moved to Sun 10am, Packard 3<sup>rd</sup> floor
  - **HW due Sunday 5pm. No late HWs accepted**
  - Last HW will be assigned Friday, due 1+ week later
  - Bonus lecture info
  - Final info (coverage, review, extra OHs, etc) given 12/5
- **Review of Last Lecture**
- **Fading across subcarriers in multicarrier**
- **OFDM FFT Implementation**
- **OFDM Design Issues**

## Review of Last Lecture

- **Sphere Decoder (near ML):**
  - Only searches within a sphere of received symbol.
- **Other MIMO design issues**
  - Space-Time Codes, Adaptive techniques, Limited FB
- **ISI Countermeasures**
  - Equalization, multicarrier (OFDM), spread spectrum
- **Multicarrier Modulation**
  - Breaks data into N substreams such that  $B/N < B_c$
  - Substream modulated onto separate carriers
- **Overlapping substreams:  $\Delta f_i = 1/T_N$**

## FFT Implementation of OFDM

- Use IFFT at TX to modulate symbols on each subcarrier
- Cyclic prefix makes linear convolution of channel circular, so no interference between FFT blocks in RX processing
- Reverse structure (with FFT) at receiver



## Remainder of Course

- **Today: OFDM**
  - Lecture will end around 10:35am
- **Dec. 5: Spread spectrum**
- **Bonus lecture: Dec. 5 6-8pm, Hewlett 103**
  - Finish Spread Spectrum
  - Class summary
  - Advanced topics in wireless
- **Class Ends ☹**
  - Except for final Dec. 14 ☺
  - **No lecture Dec. 7**

## Fading Across Subcarriers

- **Leads to different BERS**
- **Compensation techniques**
  - Frequency equalization (noise enhancement)
  - Precoding
  - Coding across subcarriers
  - Adaptive loading (power and rate)

## OFDM Design Issues

- **Timing/frequency offset:**
  - Impacts subcarrier orthogonality; self-interference
- **Peak-to-Average Power Ratio (PAPR)**
  - Adding subcarrier signals creates large signal peaks
- **Different fading across subcarriers**
  - Same mitigation techniques as in MCM: Precoding to invert fading, coding across subcarriers, and adaptive loading over time most common
- **MIMO/OFDM**
  - Apply OFDM across each spatial dimension
  - Can adapt across space, time, and frequency

## Main Points

---

- Subcarrier fading degrades MCM performance
  - Compensate through precoding (channel inversion), coding across subcarriers, or adaptation
- OFDM efficiently implemented using IFFTs/FFTs
  - Block size depends on data rate relative to delay spread
- OFDM challenges:
  - PAPR; timing/frequency offset; fading across subcarriers
- 4G Cellular, Wimax, 802.11n all use OFDM+MIMO
  - Adapt across space, time, and frequency