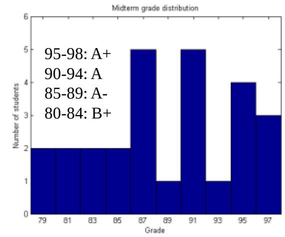
EE359 – Lecture 16 Outline

- **Announcements:**
  - HW due Friday
  - MT announcements
  - Rest of term announcements
- MIMO Diversity/Multiplexing Tradeoffs
- MIMO Receiver Design
  - Maximum-Likelihood, Decision Feedback, Sphere Decoder
  - Space-Time Processing
- Other MIMO Design Issues
  - Space/time Coding, Adaptive techniques, Limited feedback

Midterm Announcements



You guys ROCK

Will explain some common mistakes

Note: Bonus points count different from exam and homework points

Common MT Mistakes

- Q1b did not use the average fade duration stated in question
- Q1c did not write out the rate adaptation (just wrote power adaptation and capacity)
- Q1d did not use the maximum outage capacity definition in the text
- Q2 was well done in general
- Q3b/c assumed SC chooses the signal with highest average SNR, not instantaneous SNR

End of Quarter Announcements

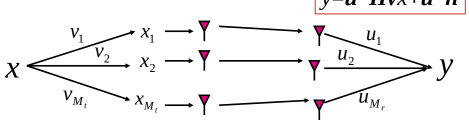
- Remaining lectures:
  - Today MIMO
  - Next week: Thanksgiving
  - Nov. 29 week: OFDM, Intro to SS
  - Dec. 5 week: SS, Summary, Advanced topics
- No lecture Dec 7
  - Can start class early on previous lecture (9am)
  - Can have a bonus lecture Dec. 5 and/or 6 to wrap up lecture material and do summary and advanced topics

Review of Last Lecture

- MIMO Channel Decomposition

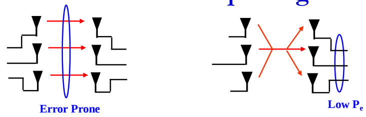
- MIMO Channel Capacity
  - Depends on what is known about H at TX/RX
- Beamforming

$$y = u^H H v x + u^H n$$



Diversity vs. Multiplexing

- Use antennas for multiplexing or diversity

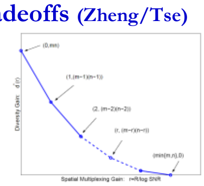


- Diversity/Multiplexing tradeoffs (Zheng/Tse)

$$\lim_{SNR\to\infty} \frac{\log P_e(SNR)}{\log SNR} = -d$$

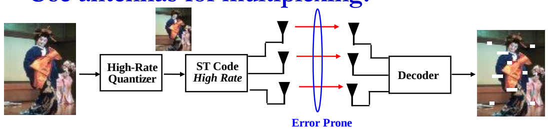
$$\lim_{SNR\to\infty} \frac{R(SNR)}{\log SNR} = r$$

$$d^*(r) = (M_t - r)(M_r - r)$$

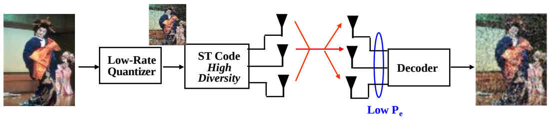


How should antenna be used?

- Use antennas for multiplexing:



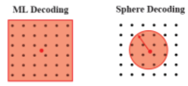
- Use antennas for diversity



Depends on end-to-end metric: *Solve by optimizing app. metric*

MIMO Receiver Design

- Optimal Receiver:
  - Maximum likelihood: finds input symbol most likely to have resulted in received vector
  - Exponentially complex # of streams and constellation size
- Decision-Feedback receiver
  - Uses triangular decomposition of channel matrix
  - Allows sequential detection of symbol at each received antenna, subtracting out previously detected symbols
- Sphere Decoder:
  - Only considers possibilities within a sphere of received symbol.



- Space-Time Processing: Encode/decode over time & space

Other MIMO Design Issues

- Space-time coding:
  - Map symbols to both space and time via space-time block and convolutional codes.
  - For OFDM systems, codes are also mapped over frequency tones.
- Adaptive techniques:
  - Fast and accurate channel estimation
  - Adapt the use of transmit/receive antennas
  - Adapting modulation and coding.
- Limited feedback:
  - Partial CSI introduces interference in parallel decomp: can use interference cancellation at RX
  - TX codebook design for quantized channel

Main Points

- MIMO introduces diversity/multiplexing tradeoff
  - Optimal use of antennas depends on application
- MIMO RX design trades complexity for performance
  - ML detector optimal; exponentially complex
  - DF receivers prone to error propagation
  - Sphere decoders allow performance tradeoff via radius
  - Space-time processing (i.e. coding) used in most systems
- Adaptation requires fast/accurate channel estimation
- Limited feedback introduces interference between streams: requires codebook design