Transmit Diversity. Intro to Adaptive Modulation. Adaptive MQAM.

Lecture Outline

- **Transmit Diversity**
- **Introduction to Adaptive Modulation**
- **Variable-Rate Variable-Power MQAM**
- **Optimal Rate and Power Adaptation**

1. **Transmit Diversity**
   - When channel known at transmitter, similar to receiver diversity. Get same array and diversity gain.
   - When channel unknown at transmitter, for 2 TX antennas can use the Alamouti scheme over two symbol times to obtain full diversity gain, but no array gain. This scheme is part of various wireless standards but is hard to generalize to more than 2 antennas. Alamouti not covered on homeworks or exams.

2. **Introduction to Adaptive Modulation**
   - Basic idea: adapt at transmitter relative to channel fade level (borrows from capacity ideas).
   - Parameters to adapt (degrees of freedom) include constellation size, transmit power, instantaneous BER, symbol time, coding rate/scheme, and combinations.
   - Optimization criterion for adaptation is typically maximizing average rate, minimizing average power, or minimizing average BER.
   - Few degrees of freedom need be exploited for near-optimal performance.

3. **Variable-Rate Variable-Power MQAM**
   - Constellation size and power adapted to maximize average throughput given an instantaneous BER constraint.
   - BER bound $\text{BER}(\gamma) = .2\exp[-1.5\gamma P(\gamma)/((M-1)\overline{S})]$ inverted to get adaptive constellation size $M[\gamma]$ below with $K = -1.5/ln(5\cdot\text{BER})$ that meets the BER constraint for any adaptive power policy $P[\gamma]$:

$$M[\gamma] = 1 + \frac{-1.5\gamma)}{-ln(5\cdot\text{BER})}\frac{P(\gamma)}{\overline{P}} = 1 + K\gamma P(\gamma)/\overline{P}.$$

4. **Optimal Rate and Power Adaptation for Maximum Throughput**
   - Optimal power adaptation $P(\gamma)$ found by maximizing average throughput $\text{E}[\log_2(M[\gamma])] = \text{E}[\log_2(1 + K\gamma P(\gamma)/\overline{P})$ relative to $P(\gamma)$.
   - Optimal power adaptation is the same waterfilling as the capacity-achieving strategy with an effective power loss K.

- Optimal rate adapation found by substituting optimal power adaptation into $M(\gamma)$, yielding $R(\gamma) = \log_2(\gamma/\gamma_K), \gamma > \gamma_K$, where γ_K is cutoff value for the water-filling power policy.
- Same optimal power and rate adaptation as the capacity-acheiving strategies with an effective power reduction $K = -1.5/\ln(5 \cdot \text{BER})$. Throughput is within 5-6 dB of channel capacity.
- Different modulations and BER bounds result in different adaptive policies.

Main Points

- Transmit diversity for known channel gains at transmitter has same performance as receiver diversity.
- Adaptive modulation varies modulation parameters relative to fading to improve performance (throughput, BER, etc.).
- Optimizing adaptive MQAM leads to the same variable-rate and power policy that achieves channel capacity, with an effective power loss K. Comes within 5-6 dB of capacity, and this gap can be bridged through coding.