Lecture 12 - EE 359: Wireless Communications - Winter 2020

Diversity: MGF, Generalized, Transmit Diversity. Intro to Adaptive Modulation. Adaptive MQAM.

Lecture Outline

- **MGF approach to MRC analysis**
- **Generalized Combining**
- **Transmit Diversity** *(not covered in lecture/HW/exams)*
- **Introduction to Adaptive Modulation**
- **Variable-Rate Variable-Power MQAM**

1. **MGF Approach to MRC Diversity Analysis**

   - Distribution of γ_Σ hard to obtain when fading is not Rayleigh or not identically distributed.
   - Can use alternate Q function representation to greatly simplify $\overline{P}_s$ calculation.
   - Using alternate representation and switching order of integration for modulations in AWGN with $P_s \approx \alpha Q(\sqrt{\beta\gamma_s})$ yields

   $$\overline{P}_s = \frac{\alpha}{\pi}\int_0^{\pi/2}\prod_{i=1}^{M}\mathcal{M}_{\gamma_i}\left(\frac{-.5\beta}{\sin^2\phi}\right)d\phi,$$

   where $\mathcal{M}_{\gamma_i}$ is the MGF for the distribution of the ith branch SNR γ_i.

2. **Generalized Combining**

   - For a diversity system with M branches, GC selects the L branches, $1 < L < M$ with the highest SNR.
   - These branches are combined with MRC or EGC.
   - GC has better performance than L-branch MRC/EGC but with higher complexity. It has worse performance than M-branch MRC/EGC but with lower complexity.
   - Performance analysis requires order statistics to characterize the L branches with the best SNR.
   - MGF approach with order statistics can be used to obtain the distribution of the output SNR, $\overline{P}_s$, and P_{out}.

3. **Transmit Diversity** *(not covered in lecture/HW/exams)*

   - 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.

4. **Introduction to Adaptive Modulation** chapter 9

- 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.

5. **Variable-Rate Variable-Power MQAM**

- Constellation size and power adapted to maximize average throughput given an instantaneous BER constraint.
- BER bound $\text{BER}(\gamma) = .2\exp[-1.5\gamma P(\gamma)/((M-1)\overline{P})]$ 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 $P[\gamma]$:

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

- 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 rate found by using this optimal $P(\gamma)$ in expression for $M(\gamma)$. Will see the problem formulation and solution is the same as in flat-fading capacity with a fixed power loss in $\overline{P}$ due to uncoded modulation.

Main Points

- Performance analysis of MRC greatly simplified using MGF approach.
- GC combines low-complexity benefits of SC with performance benefits of MRC (or EGC).
- Transmit diversity for known channel gains has same performance as receiver diversity.
- Adaptive modulation varies modulation parameters relative to fading to improve performance (throughput, BER, etc.).
- Optimizing adaptive MQAM by varying its instantaneous rate and power to maximize expected rate leads to the same problem formulation and solution as in flat-fading channel capacity with power loss due to uncoded modulation