EE359 – Lecture 13 Outline

- Announcements
  - Midterm announcements
  - No HW this week
- Introduction to adaptive modulation
- Variable-rate variable-power MQAM
- Optimal power and rate adaptation
- Finite constellation sets

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Midterm Announcements

- Midterm: Friday (2/21), 2-4 pm in Hewlett 103
  - Food will be served after the exam!
- Review sessions
  - TA review (+OHs): Wednesday 2/19 from 4-6 pm in 364 Packard
- Midterm logistics:
  - Open book/notes; Bring reader/calculators.
  - Disconnected electronic devices OK. No Matlab.
  - Covers Chapters 1-7 (sections covered in lecture and/or HW)
- OHs this week:
  - Me: Tue 2/18: 3-4pm (or later), Thu 6-7pm (or later), Fri 10:30-11:30am, 371 Packard
  - Tom: Wed ~5-6pm, Thu 1:30-2:50pm, Fri 11:30-12:30pm
- No HW this week
- Midterms from past 3 MTs posted:
  - 10 bonus points for "taking" a practice exam
  - Solutions for all exams given when you turn in practice exam

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Adaptive Modulation

- Change modulation relative to fading
- Parameters to adapt:
  - Constellation size
  - Transmit power
  - Instantaneous BER
  - Symbol time
  - Coding rate/scheme

Only 1-2 degrees of freedom needed for good performance

- Optimization criterion:
  - Maximize throughput
  - Minimize average power
  - Minimize average BER

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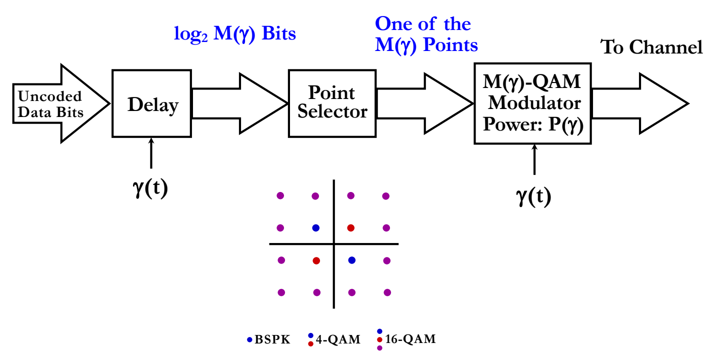
Variable-Rate Variable-Power MQAM



Goal: Optimize $P(\gamma)$ and $M(\gamma)$ to maximize $R=E\log[M(\gamma)]$

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Optimization Formulation

- Adaptive MQAM: Rate for fixed BER

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

- Rate and Power Optimization

$$\max_{P(\gamma)} E\log_2[M(\gamma)]=\max_{P(\gamma)} E\log_2\left[1+K\gamma\frac{P(\gamma)}{\overline{P}}\right]$$

Same maximization as for capacity, except for K=-1.5/ln(5BER).

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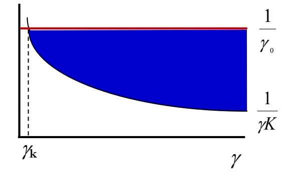
Optimal Adaptive Scheme

- Power Adaptation

$$\frac{P(\gamma)}{\overline{P}}=\begin{cases}\frac{1}{\gamma_0}-\frac{1}{\gamma K} & \gamma\geq\frac{\gamma_0}{K}=\gamma_K\\ 0 & \text{else}\end{cases}$$



- Spectral Efficiency

$$\frac{R}{B}=\int_{\gamma_K}^{\infty}\log_2\left(\frac{\gamma}{\gamma_K}\right)p(\gamma)d\gamma.$$

Equals capacity with effective power loss K=-1.5/ln(5BER).

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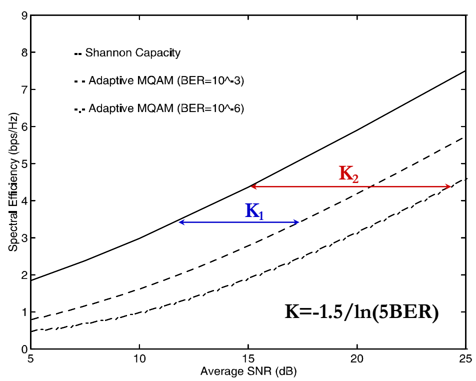
Spectral Efficiency



Can reduce gap by superimposing a trellis code

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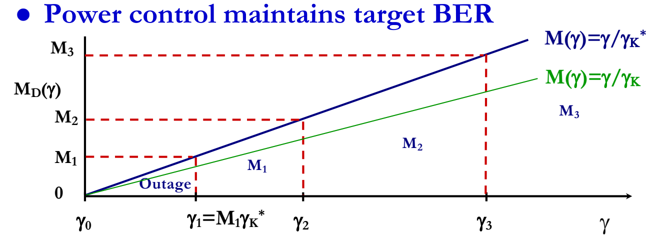
Constellation Restriction

- Restrict $M_D(\gamma)$ to $\{M_0=0,\ldots,M_N\}$.
- Let $M(\gamma)=\gamma/\gamma_K^*$, where γ_K^* is optimized for max rate
- Set $M_D(\gamma)$ to $\max_j M_j$: $M_j \leq M(\gamma)$ (conservative)
- Region boundaries are $\gamma_j=M_j\gamma_K^*$, j=0,…,N
- Power control maintains target BER



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Power Adaptation and Average Rate

- Power adaptation:
  - Fixed BER within each region
    - $E_s/N_0=(M_j-1)/K$
    - Channel inversion within a region
  - Requires power increase when increasing $M(\gamma)$

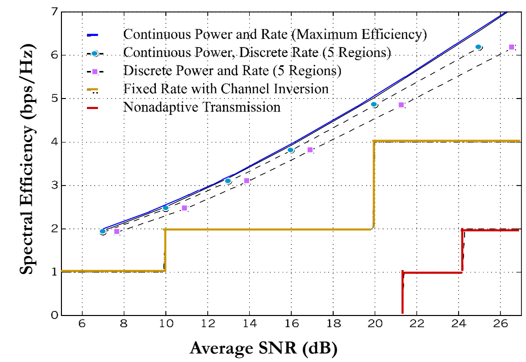
$$\frac{P_j(\gamma)}{P}=\begin{cases}(M_j-1)/(\gamma K) & \gamma_j \le \gamma < \gamma_{j+1}, j>0 \\ 0 & \gamma < \gamma_1\end{cases}$$

- Average Rate

$$\frac{R}{B}=\sum_{j=1}^{N}\log_2 M_j\, p(\gamma_j \le \gamma < \gamma_{j+1})$$

- Practical Considerations:
  - Update rate/estimation error and delay

Efficiency in Rayleigh Fading



Main Points

- Adaptive modulation leverages fast fading to improve performance (throughput, BER, etc.)
- Adaptive MQAM uses capacity-achieving power and rate adaptation, with power penalty K.
  - Comes within 5-6 dB of capacity
- Discretizing the constellation size results in negligible performance loss.
- Constellations cannot be updated faster than 10s to 100s of symbol times: OK for most dopplers.
- Estimation error/delay causes error floor