EE359 – Lecture 13 Outline

- Annoucements
  - Midterm announcements
  - No HW due this week (will be usual HW next week)
- Adaptive MQAM: optimal power and rate
- Finite Constellation Sets
- Update rate
- Estimation error
- Estimation delay

Midterm Announcements

- Midterm Wed Nov. 4, 8:45-10:45a in this rm.
  - Open book/notes (bring textbook/calculators)
  - Covers Chapters 1-7 (through today's lecture)
- Review Session notes posted
- Extra OHs
  - Me: Monday, Tuesday 2-3pm,
  - Yao: Tues, 4-5pm in 380-380w
- Midterms from past 3 MTs posted
  - 10 bonus points for "taking" a practice exam (due at MT)
  - Solns for all exams given when you turn in practice exam

Review of Last Lecture

- Combining Techniques
- Selection Combining and its Performance
- Maximal Ratio Combining

$$\overline{P}_b = \int P_b(\gamma_\Sigma) p(\gamma_\Sigma) d\gamma_\Sigma = \int\int \ldots \int P_b(\gamma_\Sigma) p(\gamma_1) * p(\gamma_2) * \ldots * p(\gamma_M) d\gamma_1 d\gamma_2 \ldots d\gamma_M$$

- MGF Approach for Performance of MRC

$$\overline{P}_b = \frac{1}{\pi} \int_0^{.5\pi} \prod_{i=1}^{M} \mathrm{M}_i \left[\frac{-g}{\sin^2\varphi}; \gamma_i \right] d\varphi$$

- EGC and Transmit Diversity

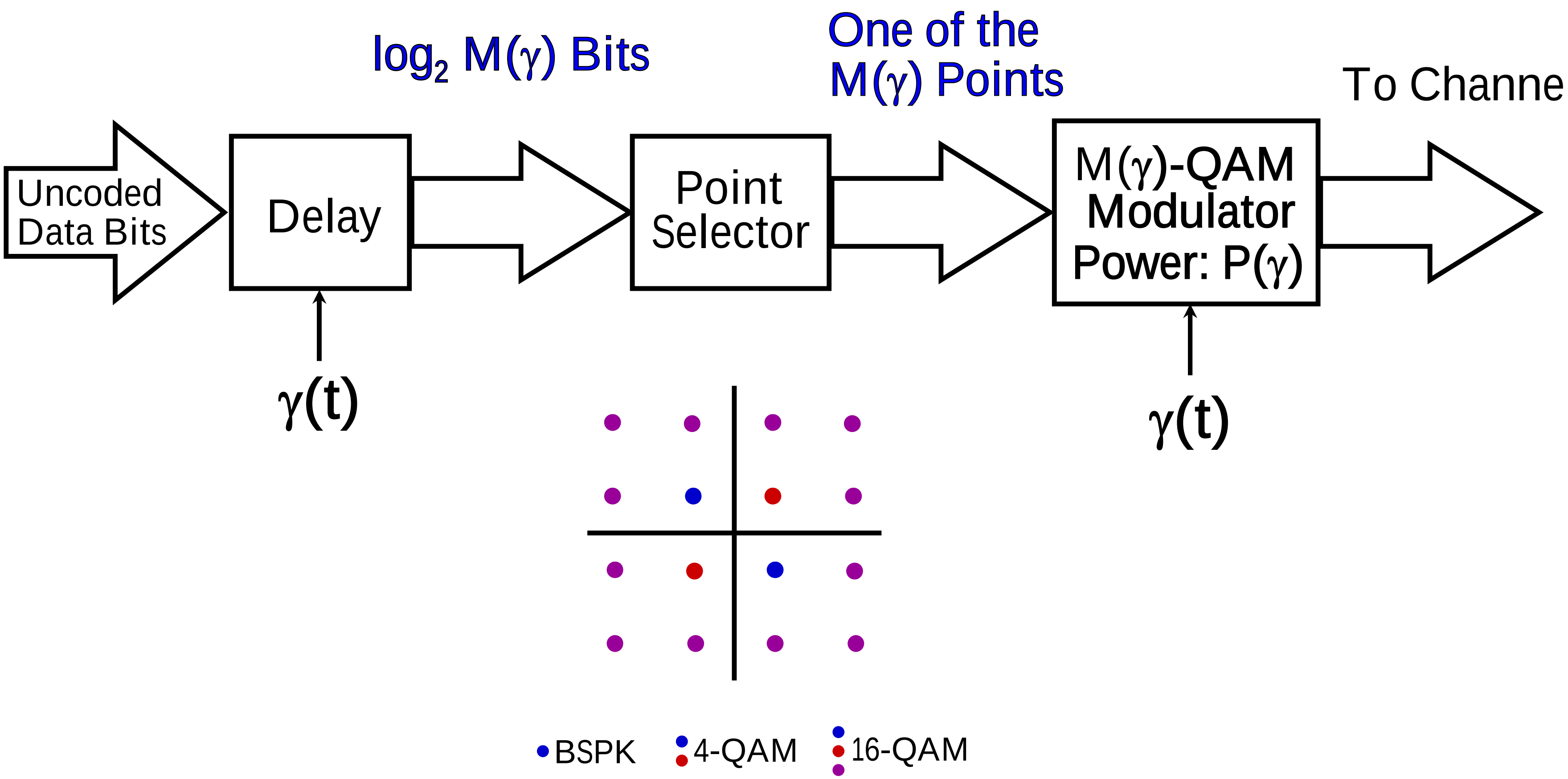
Adaptive Modulation

- 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

Variable-Rate Variable-Power MQAM



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

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

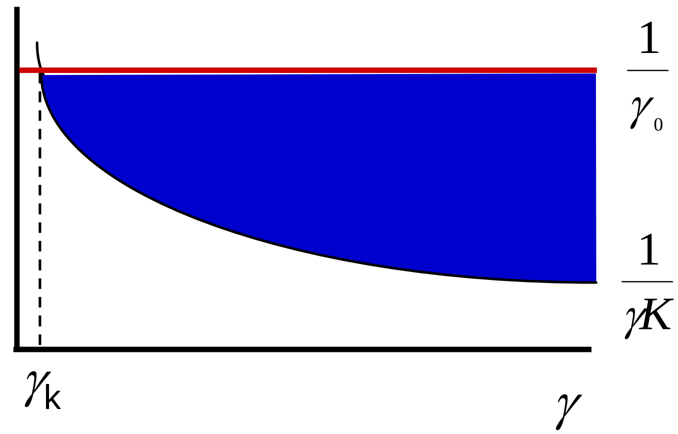
$$\max_{P(\gamma)} E \log_2[M(\gamma)] = \max_{P(\gamma)} E \log_2\left[1 + K\gamma \frac{P(\gamma)}{\overline{P}}\right]$$

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

Optimal Adaptive Scheme

- Power Adaptation

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

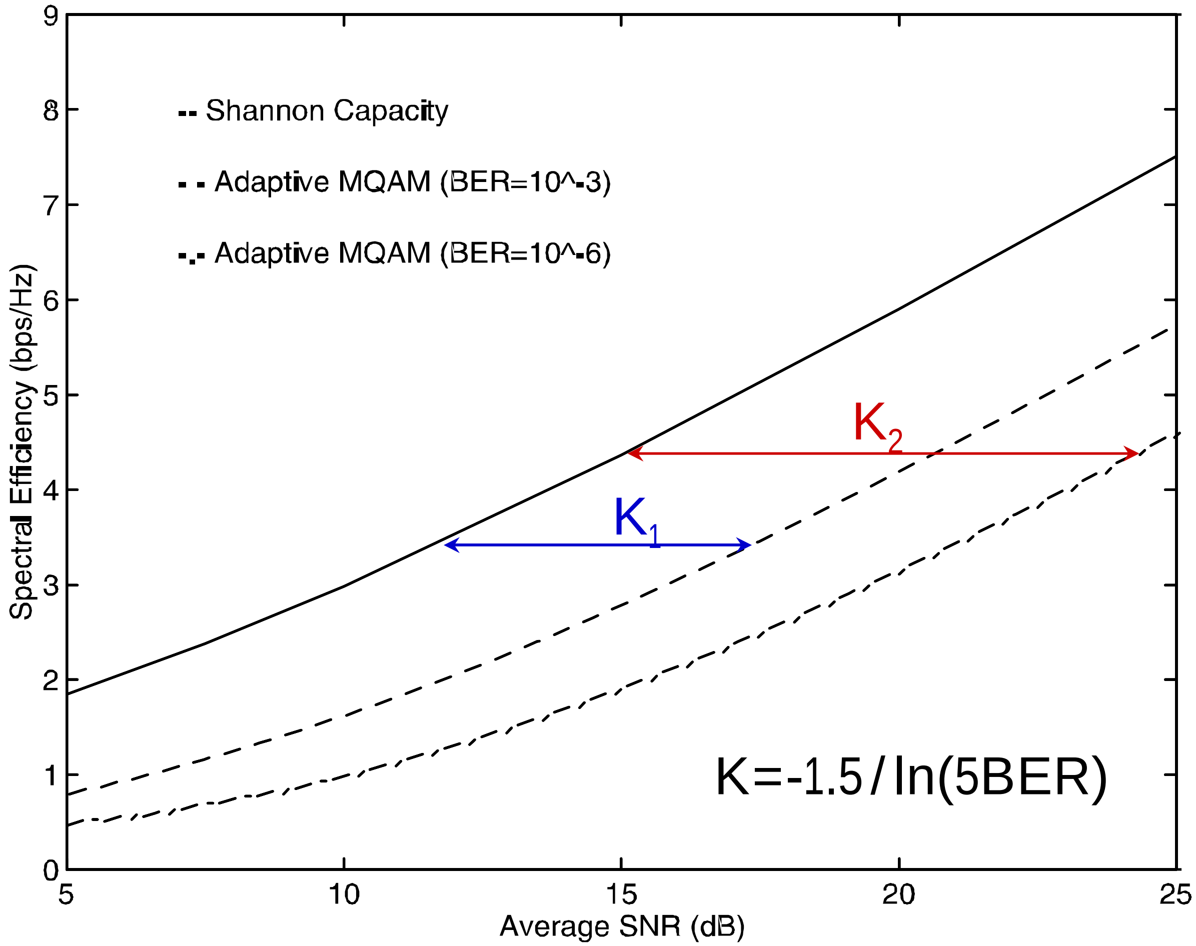


- Spectral Efficiency

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

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

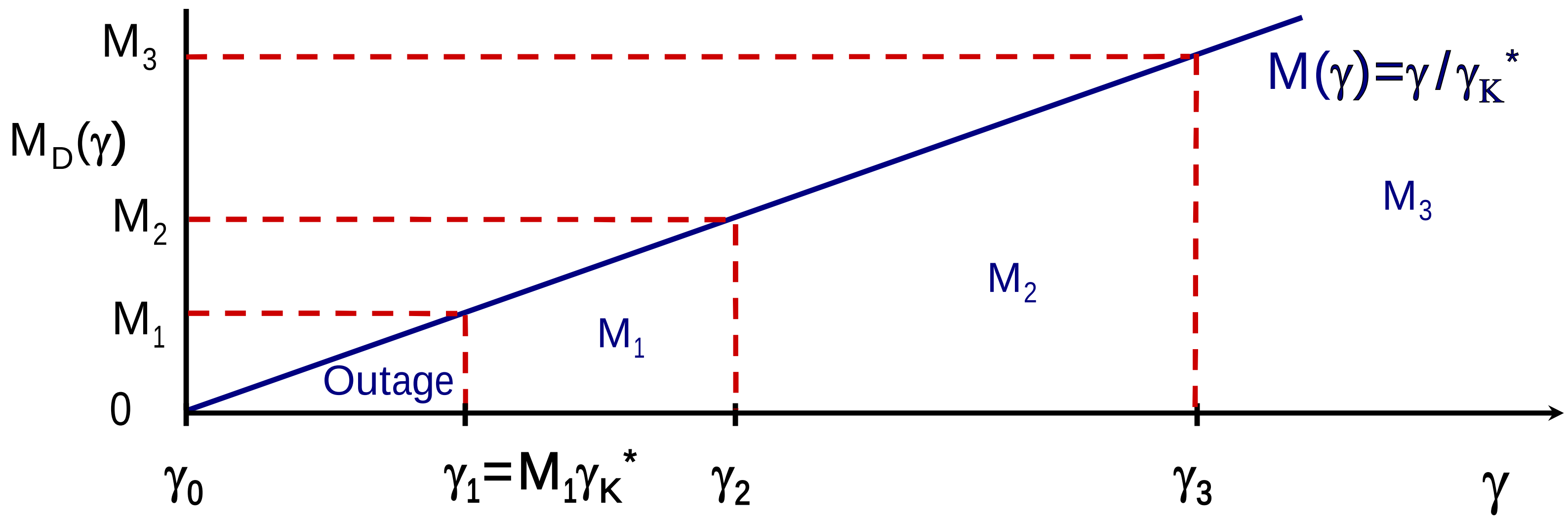
Spectral Efficiency



Can reduce gap by superimposing a trellis code

Constellation Restriction

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



Power Adaptation and Average Rate

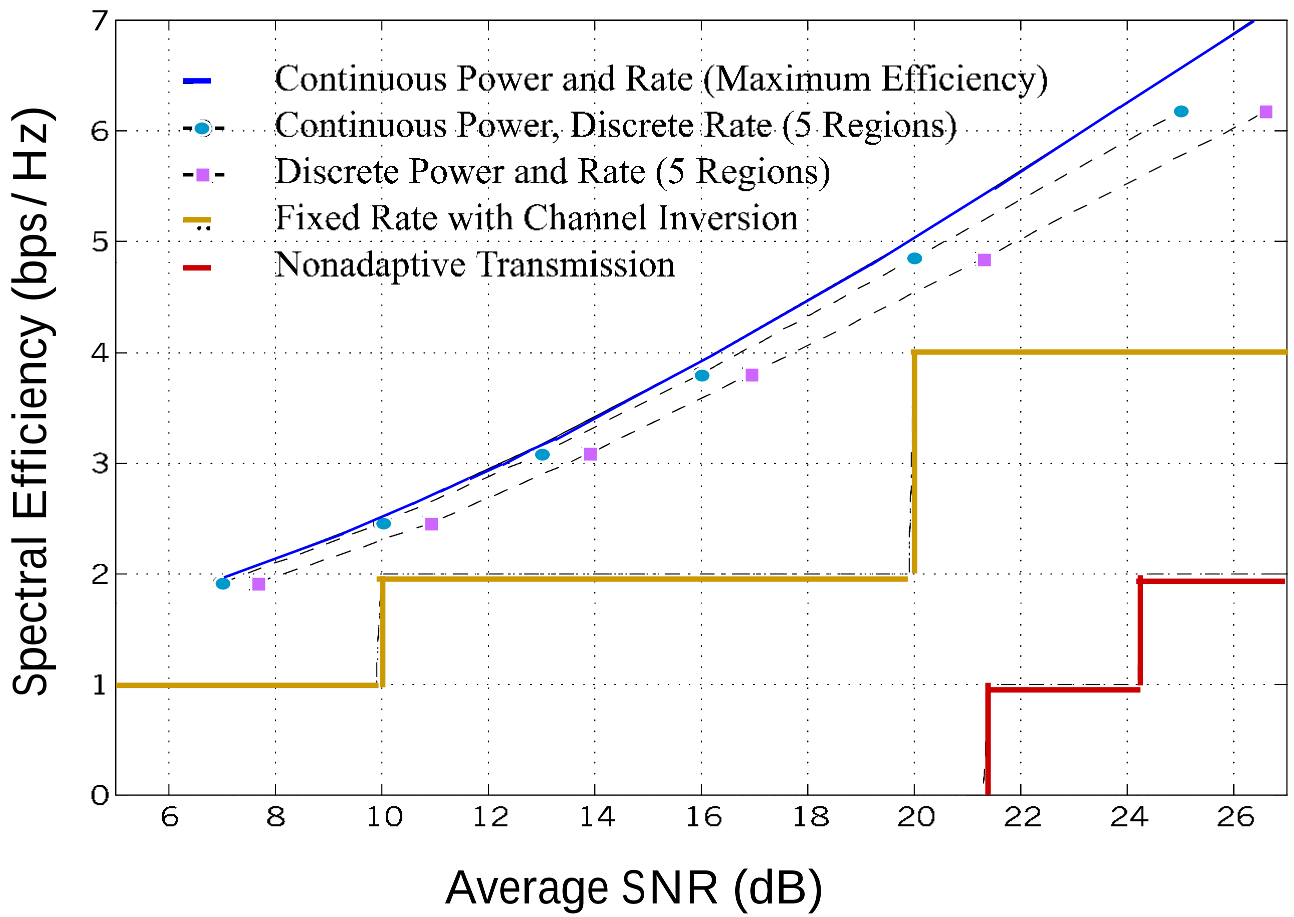
- Power adaptation:
  - Fixed BER within each region
    - $E_s / N_0 = (M_j - 1) / K$
    - Channel inversion within a region
  - Requires power increase when increasing $M(\gamma)$

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

- Average Rate

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

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.