Optimal Power Control for Discrete-Rate Link Adaptation Schemes with Capacity-Approaching Coding

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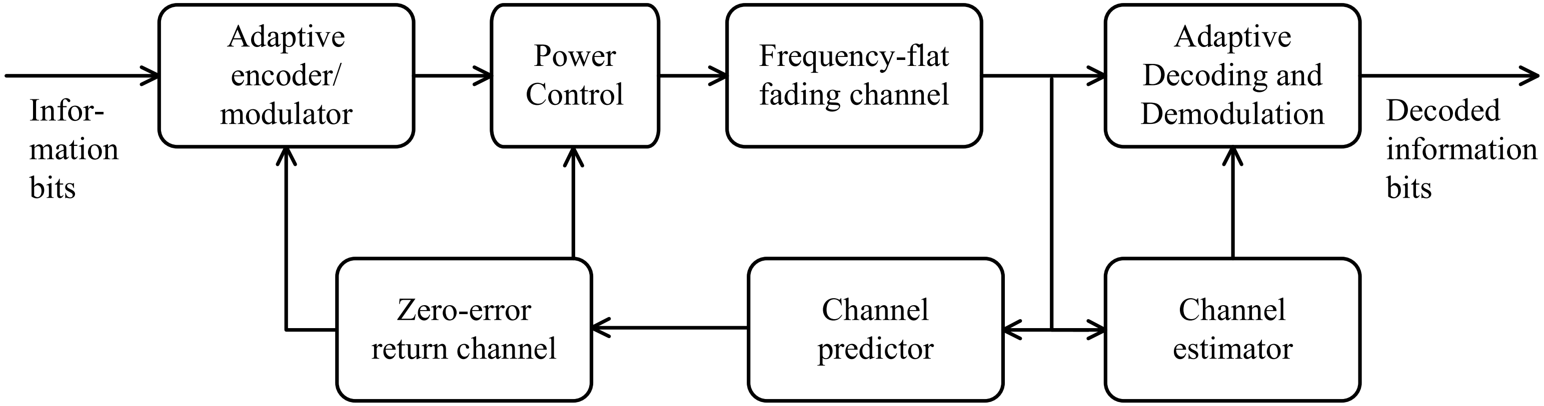
System Model



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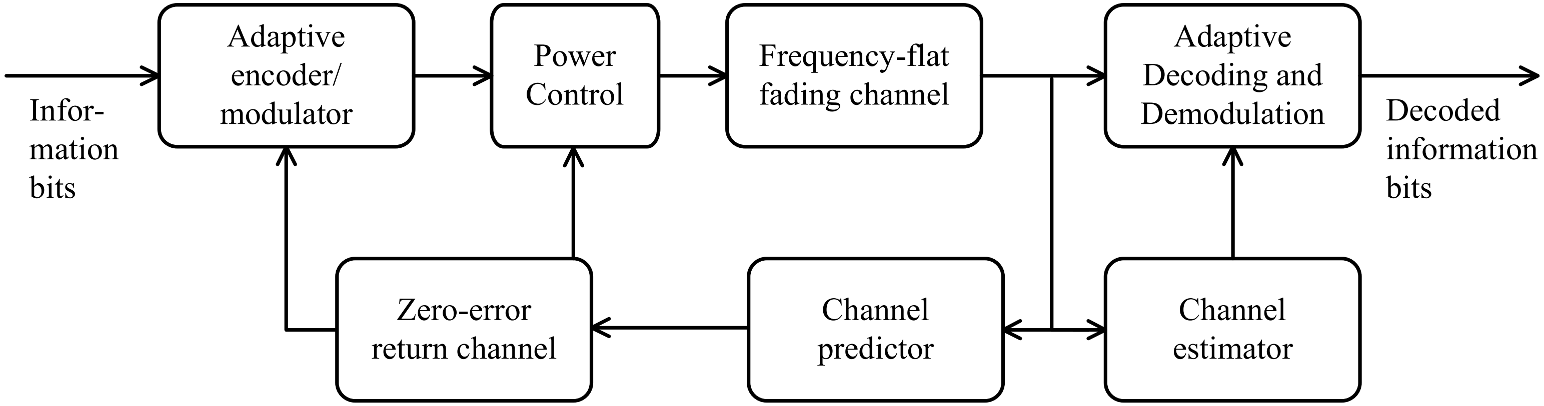

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  - Frequency flat fading

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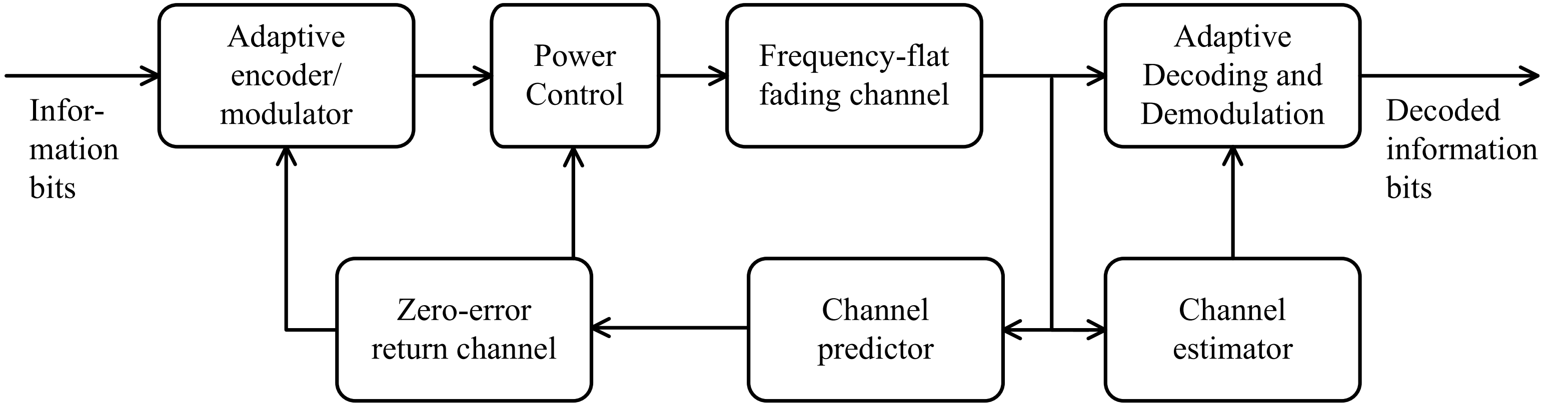

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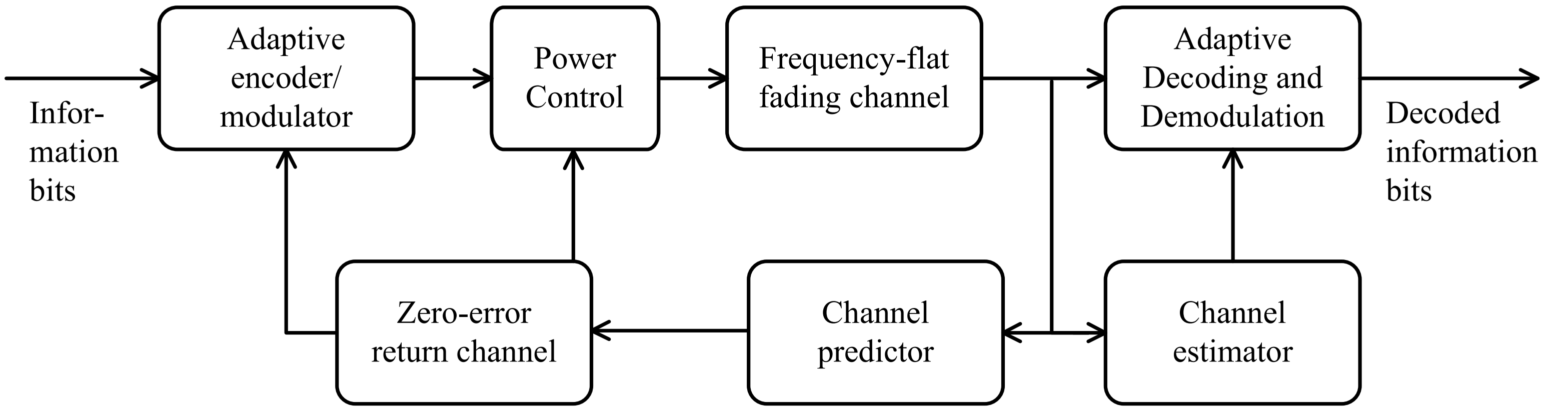

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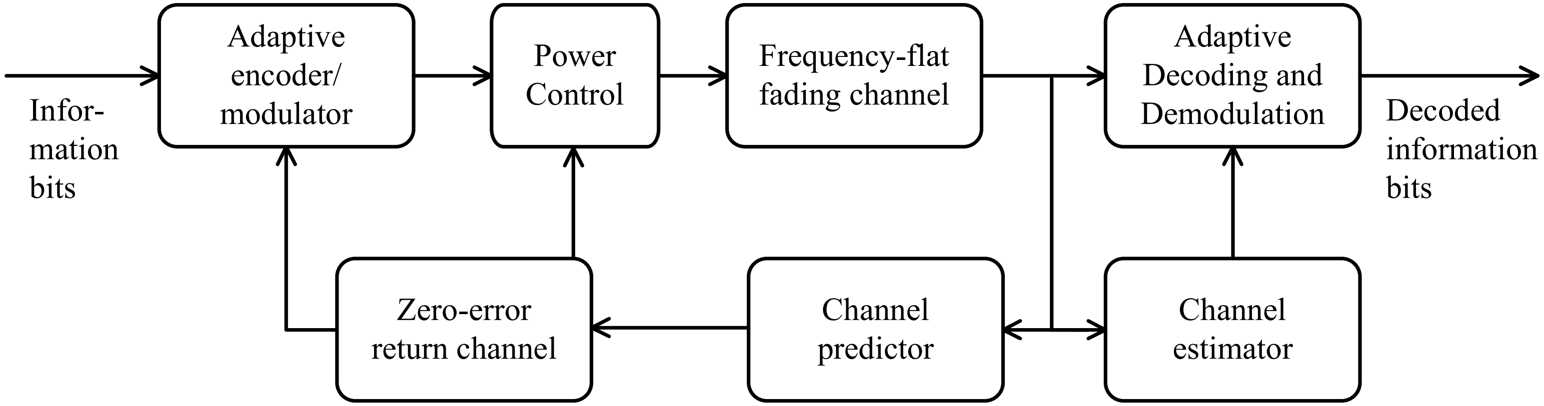
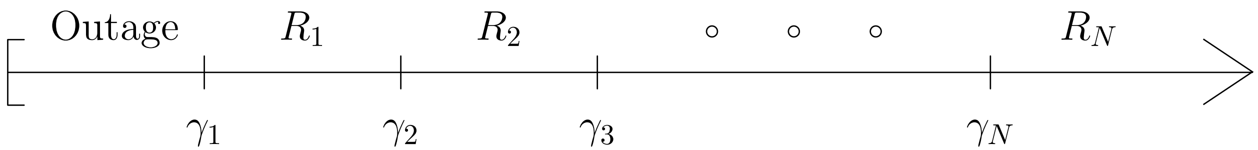


- Assumptions:
  - Frequency flat fading
  - Slow fading, i.e., coherence time larger than signal duration
  - Channel is AWGN within each codeword
  - Perfect channel predictions sent over a zero-error zero-delay feedback channel

Problem Formulation

We consider systems where the number of rates is *finite*:



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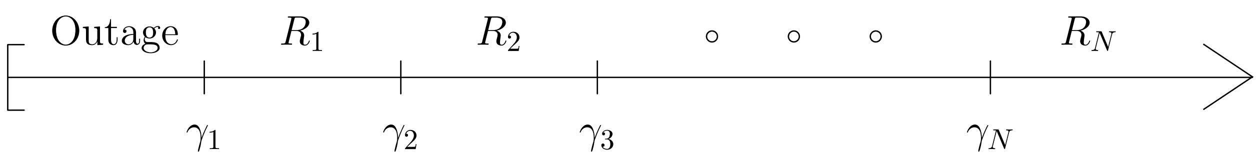

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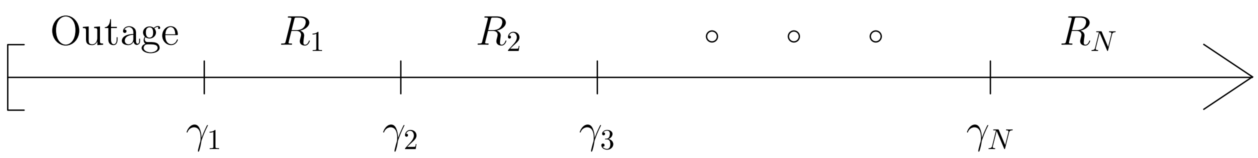

- Problems
  - How do we find $\{\gamma_n\}_{n=1}^{N}$?
  - If power adaptation is allowed, what is the optimal power scheme?

Related work

- Goldsmith & Chua: “Variable-Rate Variable-Power M-QAM for Fading Channels”
  - Solves the problem for M-QAM
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- Holm et.al: "Maximizing the Average Spectral Efficiency of Adaptive Coded Modulation"
  - Finds the optimal switching thresholds for a *constant power* scheme

Related work, cont'd

- Caire & Shamai: "On the Capacity of Some Channels with Channel State Information"
  - Shows that if the coherence time is significantly smaller than the codeword length the capacity can be reached using *a single codebook with dynamic power allocation*.

MASA Analysis

- Average Spectral Efficiency (ASE):

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  - P_n is the probability that code n is employed
- The Maximum Average Spectral Efficiency for Adaptive Coded Modulation (MASA):

$$\text{MASA} = \sum_{n=1}^{N} C_n P_n$$

  - C_n is the AWGN channel capacity

MASA Analysis cont'd

- Constant transmit power, Received SNR: γ

$$\text{MASA} = \sum_{n=1}^{N} \log_2(1+\gamma_n) \int_{\gamma_n}^{\gamma_{n+1}} f_\gamma(\gamma) d\gamma$$

MASA Analysis cont'd

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- Power adaptation, Received SNR: $\frac{S(\gamma)}{\bar{S}}\gamma$

$$\text{MASA}_{\text{Power}} = \sum_{n=1}^{N} \log_2\left(1+\frac{S(\gamma_n)}{\bar{S}}\gamma_n\right) \int_{\gamma_n}^{\gamma_{n+1}} f_\gamma(\gamma) d\gamma$$

Power Adaptation

The *rate is constant* within each region, so intuitively:

Also keep the *received SNR constant*.

$$\frac{S(\gamma)}{\bar{S}} = \begin{cases} \frac{\beta_n \gamma_n}{\gamma}, & \text{for } \gamma_n \leq \gamma < \gamma_{n+1} \\ 0, & \text{for } \gamma < \gamma_1, \end{cases}$$

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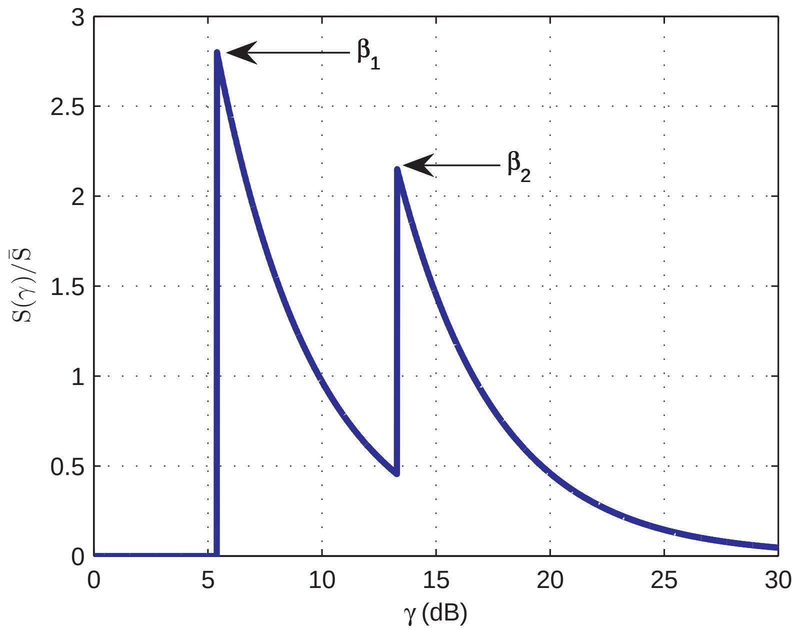


Power Adaptation cont'd

Using the proposed power adaptation scheme:

$$\text{MASA}_{\text{Power}} = \sum_{n=1}^{N} \log_2(1 + \beta_n \gamma_n) \int_{\gamma_n}^{\gamma_{n+1}} f_\gamma(\gamma) d\gamma \qquad (1)$$

Optimization problem

Maximize (1) subject to:

$$\sum_{n=1}^{N} \beta_n \gamma_n \int_{\gamma_n}^{\gamma_{n+1}} \frac{1}{\gamma} f_\gamma(\gamma) d\gamma = 1 \qquad \text{(2a)}$$

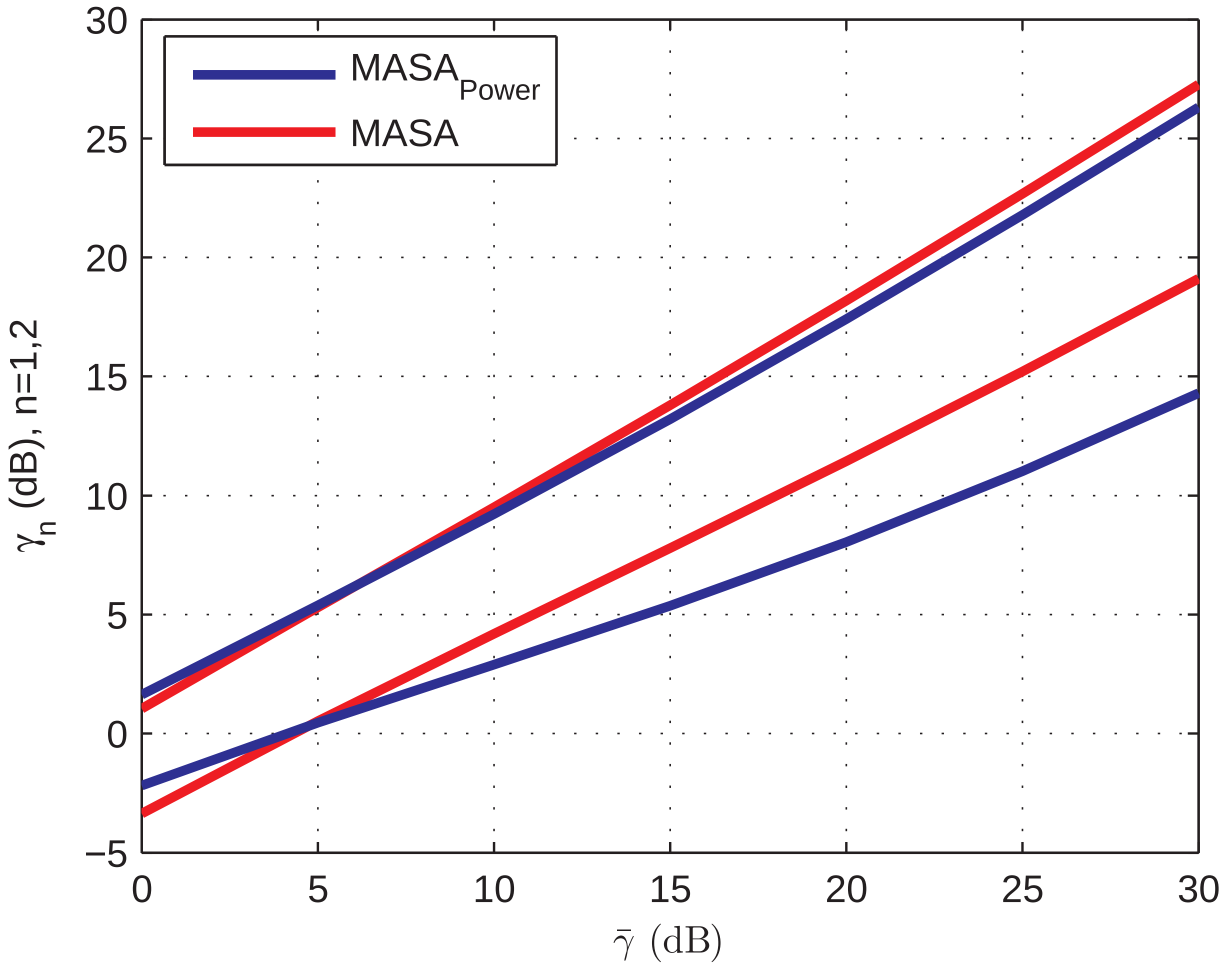
$$\beta_1, \beta_2, \cdots, \beta_N \geq 0 \qquad \text{(2b)}$$

$$0 \leq \gamma_1 \leq \gamma_2 \leq \cdots \leq \gamma_N \qquad \text{(2c)}$$

Numerical results

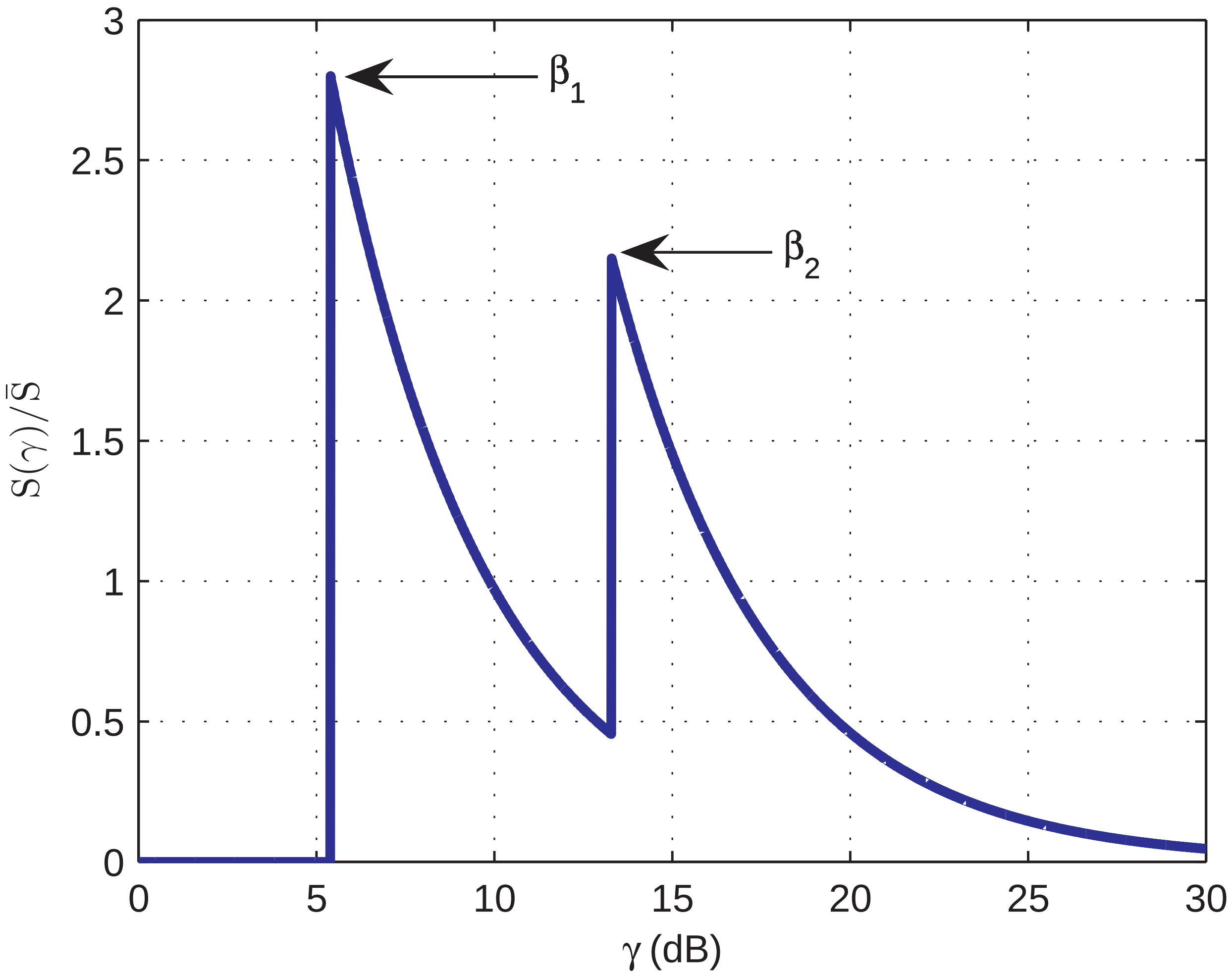
For the following results Rayleigh fading is assumed.

Optimized parameters



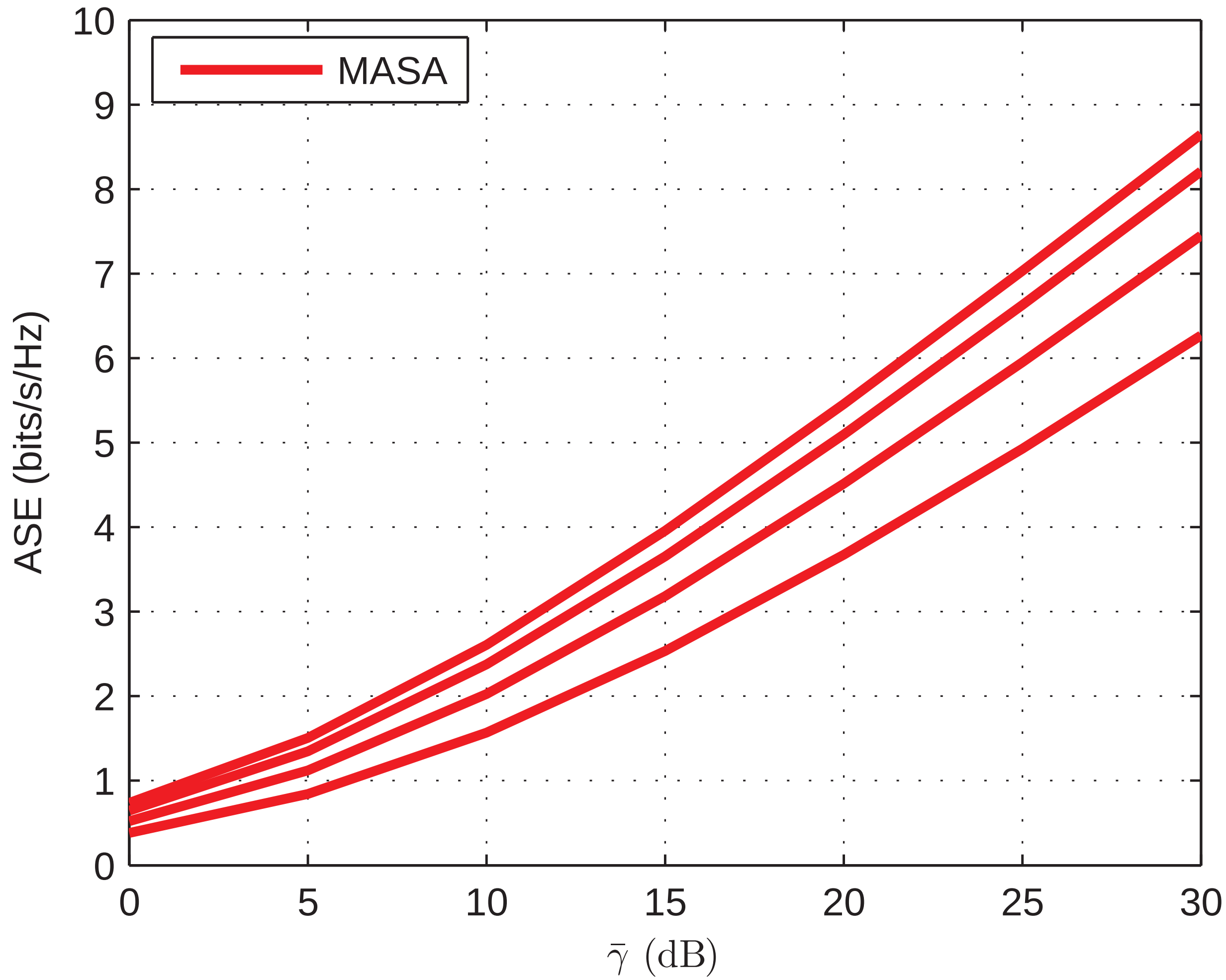
Switching levels for $N = 2$.

Optimized parameters, cont'd

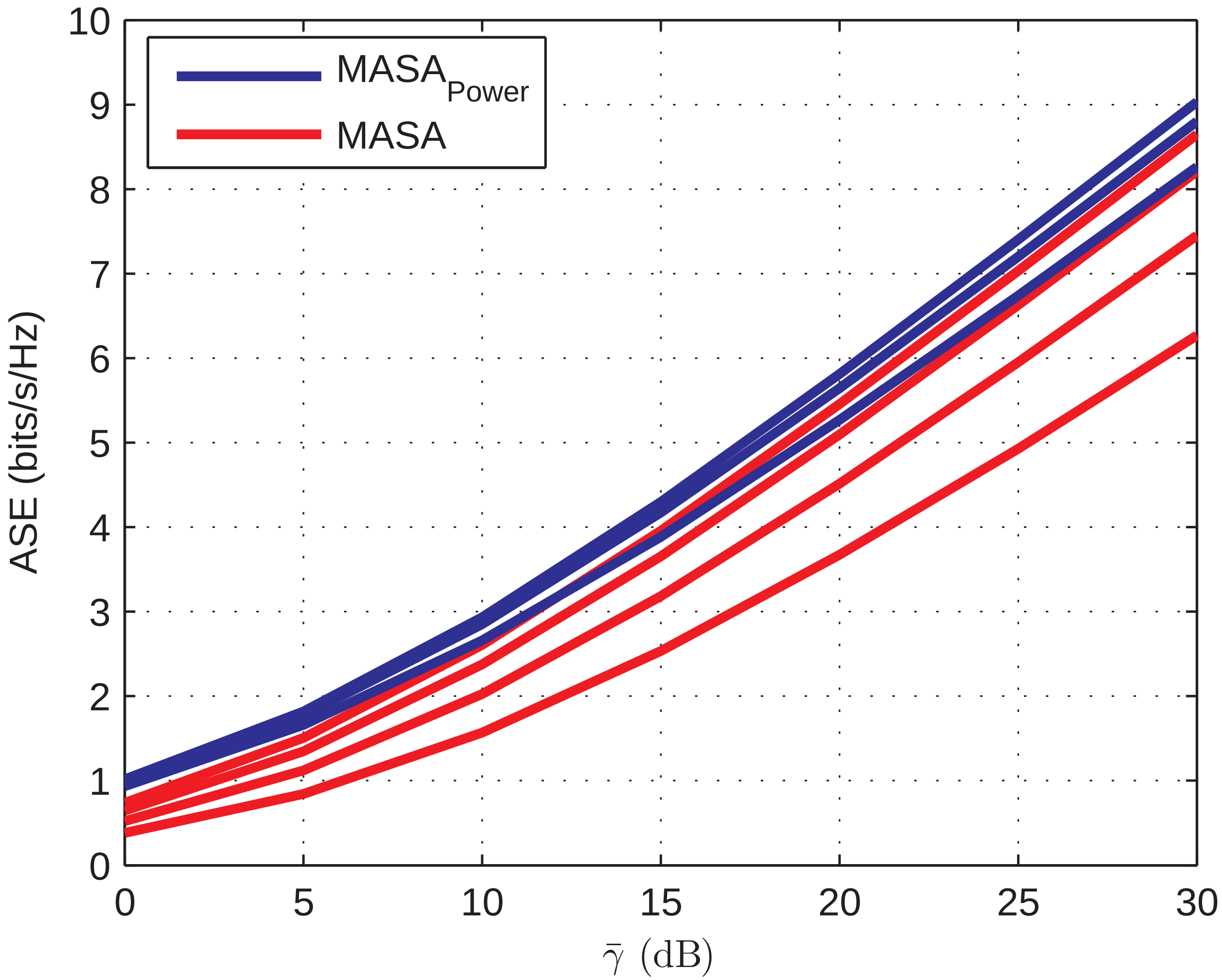


Power scheme for $\bar{\gamma} = 15$ dB.

MASA and $\text{MASA}_{\text{Power}}$



MASA and MASA$_{Power}$



MASA and Shannon Capacities

- MASA and $\text{MASA}_{\text{Power}}$, C_{OPRA} as a reference,

$$C_{\text{OPRA}} = \log_2(e)\left(\frac{e^{\frac{-\gamma_c}{\bar{\gamma}}}}{\frac{\gamma_c}{\bar{\gamma}}} - \bar{\gamma}\right)$$

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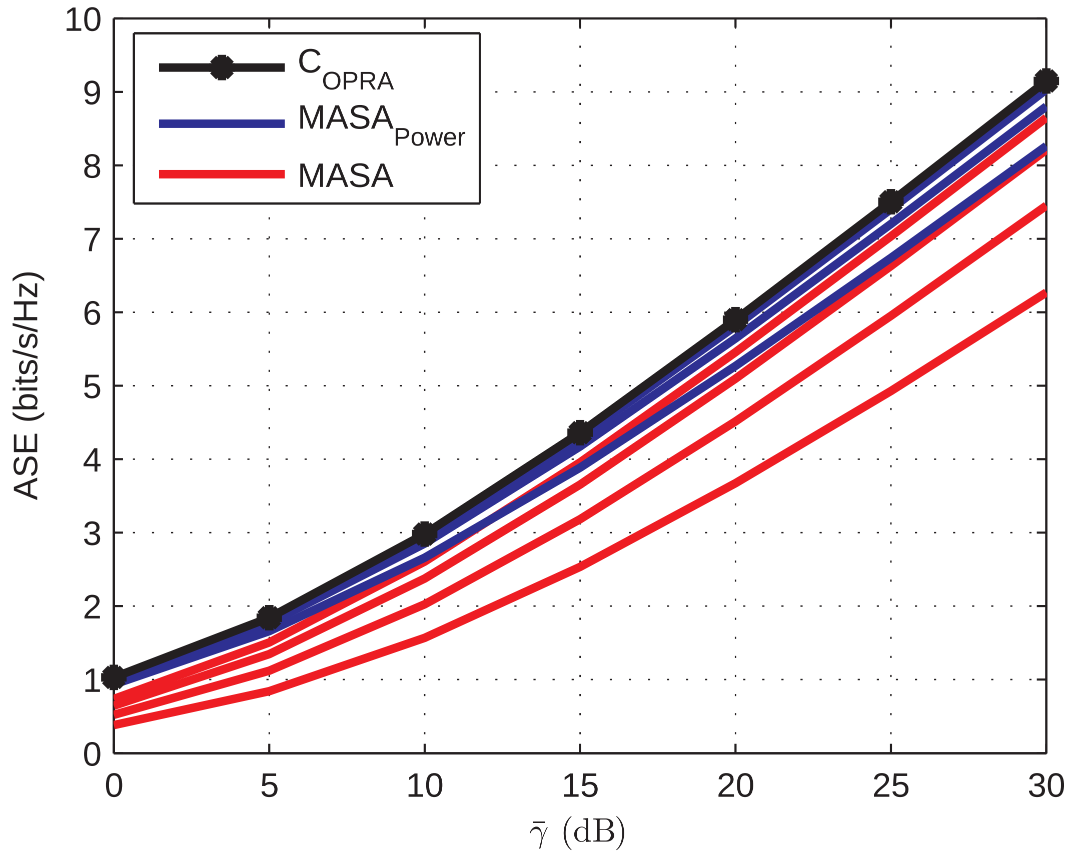

Conclusions

- Introducing power adaptation for MASA has a significant ASE gain over the constant power MASA scheme.
- Power adapted MASA scheme using just four different rates achieves a spectral efficiency within 0.15 bits/s/Hz of C_{OPRA}.

References

- A. Goldsmith and S. Chua, “Variable-rate variable-power MQAM for fading channels,” *IEEE Trans. Commun., vol. 45, pp. 1218-1230, Oct. 1997.*
- H. Holm, G. E. Øien, M.-S. Alouini, F. Bøhagen, D. Gesbert, and K. J. Hole, “Maximizing the average spectral efficiency of adaptive coded modulation,” *Submitted to IEEE Transactions on ..., 2004*
- G. Caire and S. Shamai (Shitz), “On the Capacity of Some Channels with Channel State Information,” *IEEE Trans. Inform. Theory, vol. 45, pp. 2007-2019, Sept. 1999.*