EE359 – Lecture 8 Outline

- Announcements
  - Schedule changes next week
    - No lecture next Tues 2/3.
    - Makeup class: Wed 2/5 11:30-12:50pm w/lunch in Gates B03
  - Project proposals due 2/7; I can provide early feedback
  - MT week of 2/17, 6-8pm (pizza after), poll this week; details soon
    - New version of Reader with Chapters 1-7 available next week
- Capacity of Fading channels
  - Recap Optimal Rate/Power Adaptation with TX/RX CSI
  - Channel Inversion with Fixed Rate
- Capacity of Freq. Selective Fading Channels
- Linear Digital Modulation Review
- Performance of Linear Modulation in AWGN

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Review of Last Lecture

- Channel Capacity
  - Maximum data rate that can be transmitted over a channel with arbitrarily small error
- Capacity of AWGN Channel: $B\log_2[1+\gamma]$ bps
  - $\gamma=P_r/(N_0B)$ is the receiver SNR
- Capacity of Flat-Fading Channels
  - Nothing known: capacity typically zero
  - Fading Statistics Known (few results)
  - Fading Known at RX (average capacity)

$$C=\int_0^\infty B\log_2(1+\gamma)p(\gamma)d\gamma \le B\log_2(1+\bar{\gamma})$$

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Review of Last Lecture (ctd)

- Capacity in Flat-Fading: γ known at TX/RX

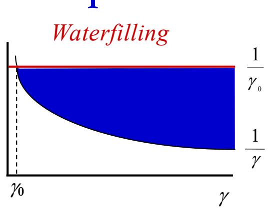
$$C=\max_{P(\gamma):E[P(\gamma)]\le \bar{P}} \int_0^\infty B\log_2\left(1+\frac{\gamma P(\gamma)}{\bar{P}}\right)p(\gamma)d\gamma$$

Same result with equality

- Optimal Rate and Power Adaptation

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

$$\frac{C}{B}=\int_{\gamma_0}^\infty \log_2\left(\frac{\gamma}{\gamma_0}\right)p(\gamma)d\gamma.$$



- The instantaneous power/rate only depend on $p(\gamma)$ through γ_0

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Channel Inversion

- Fading inverted to maintain constant SNR
- Simplifies design (fixed rate)
- Greatly reduces capacity
  - Capacity is zero in Rayleigh fading
- Truncated inversion
  - Invert channel above cutoff fade depth
  - Constant SNR (fixed rate) above cutoff
  - Cutoff greatly increases capacity
    - Close to optimal

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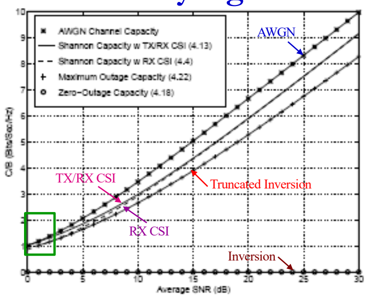
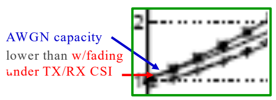
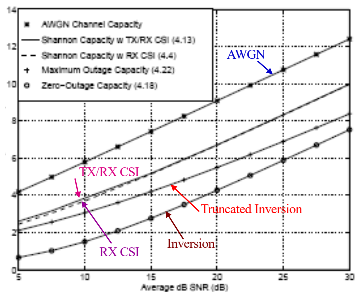
Capacity in Flat-Fading

Rayleigh





Log-Normal



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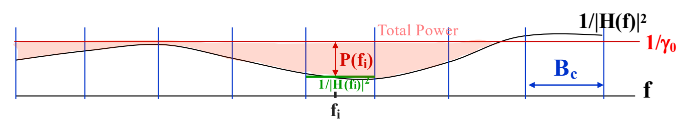
Frequency Selective Fading Channels

- For time-invariant channels, capacity achieved by water-filling in frequency
- Capacity of time-varying channel unknown
- Approximate by dividing into subbands
  - Each subband has width B_c (like MCM/OFDM).
  - Independent fading in each subband
  - Capacity is the sum of subband capacities



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Review of Linear Digital Modulation

- Signal over ith symbol period:

$$s(t) = s_{i1} g(t)\cos(2\pi f_c t + \phi_0) - s_{i2} g(t)\sin(2\pi f_c t + \phi_0)$$

  - Pulse shape g(t) typically Nyquist
  - Signal constellation defined by (s_{i1},s_{i2}) pairs
  - Can be differentially encoded
  - M values for $(s_{i1},s_{i2}) \Rightarrow \log_2 M$ bits per symbol
- P_s depends on
  - Minimum distance d_{min} *(depends on γ_s)*
  - # of nearest neighbors α_M
  - Approximate expression: $P_s \approx \alpha_M Q\left(\sqrt{\beta_M \gamma_s}\right)$
    - Standard/alternate Q function

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Main Points

- Channel inversion practical, but should truncate or get a large capacity loss
- Capacity of wideband channel obtained by breaking up channel into subbands
  - Similar to multicarrier modulation
- Linear modulation dominant in high-rate wireless systems due to its spectral efficiency
- Ps approximation in AWGN: $P_s \approx \alpha_M Q\left(\sqrt{\beta_M \gamma_s}\right)$
  - Alternate Q function useful in diversity analysis

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