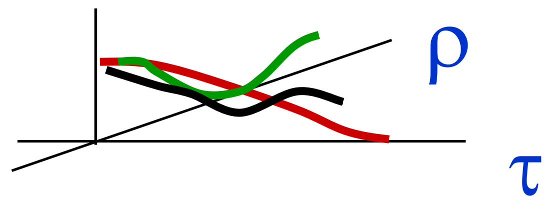
EE359 – Lecture 8 Outline

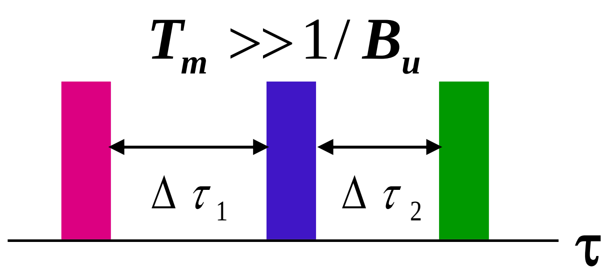
- Announcements:
  - Last makeup lecture; no class next week
  - HW posted, due next Th 5pm, extensions possible
  - Scheduling our midterm 11/2, 8:45-10:45, 4-6, 5-7, 6-8?
- Shannon Capacity
- Capacity of Flat-Fading Channels
  - Fading Statistics Known
  - Fading Known at RX
  - Fading Known at TX and RX
  - Optimal Rate and Power Adaptation
  - Channel Inversion with Fixed Rate
- Capacity of Freq.-Selective Fading Channels

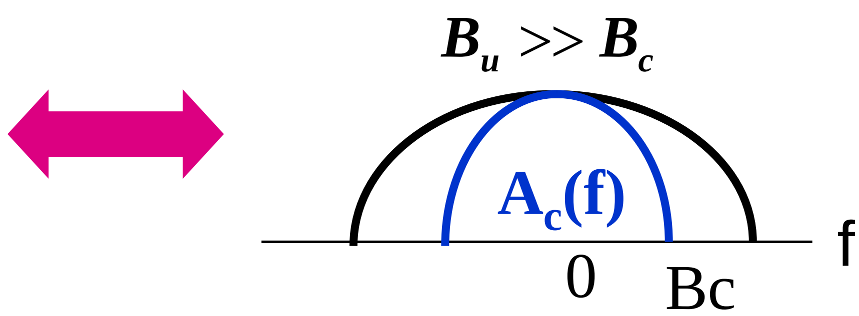
Review of Last Lecture

- Scattering Function: $s(\tau,\rho)=F_{\Delta t}[A_c(\tau,\Delta t)]$
  - Used to characterize $c(\tau,t)$ statistically



- Multipath Intensity Profile
  - Determines average (T_M) and rms (σ_τ) delay spread
  - Coherence bandwidth $B_c=1/T_M$





- Doppler Power Spectrum: $S_c(\rho)= F[A_c(\Delta t)]$
  - Power of multipath at given Doppler

Shannon Capacity

- Defined as the maximum MI of channel
- Maximum error-free data rate a channel can support.
- Theoretical limit (not achievable)
- Channel characteristic
  - Not dependent on design techniques

Capacity of Flat-Fading Channels

- Capacity defines theoretical rate limit
  - Maximum error free rate a channel can support
- Depends on what is known about channel
- Fading Statistics Known
  - Hard to find capacity
- Fading Known at Receiver Only

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

Fading Known at Transmitter and Receiver

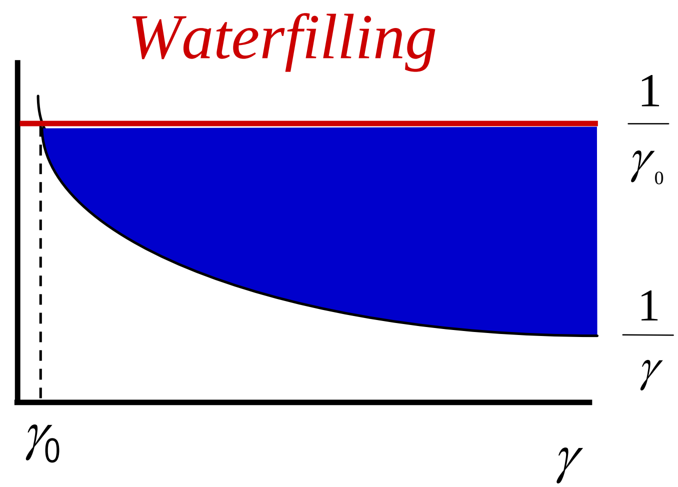
- For fixed transmit power, same as with only receiver knowledge of fading
- Transmit power S(γ) can also be adapted
- Leads to optimization problem

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

Optimal Adaptive Scheme

- Power Adaptation

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



- Capacity

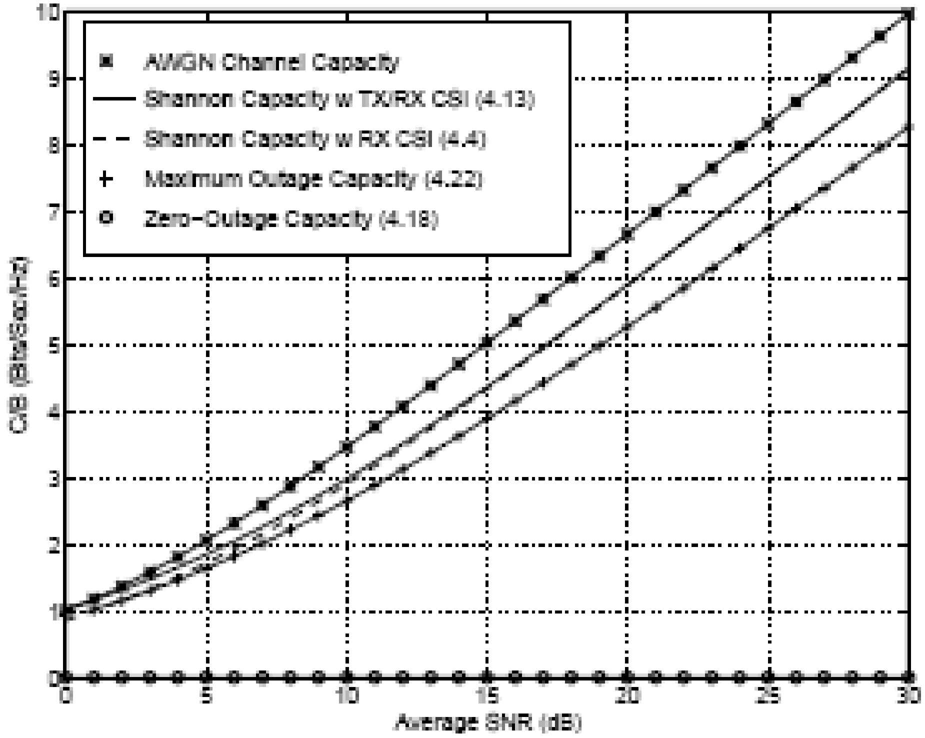
$$\frac{R}{B} = \int_{\gamma_0}^{\infty} \log_2\left(\frac{\gamma}{\gamma_0}\right) p(\gamma)\, d\gamma.$$

Channel Inversion

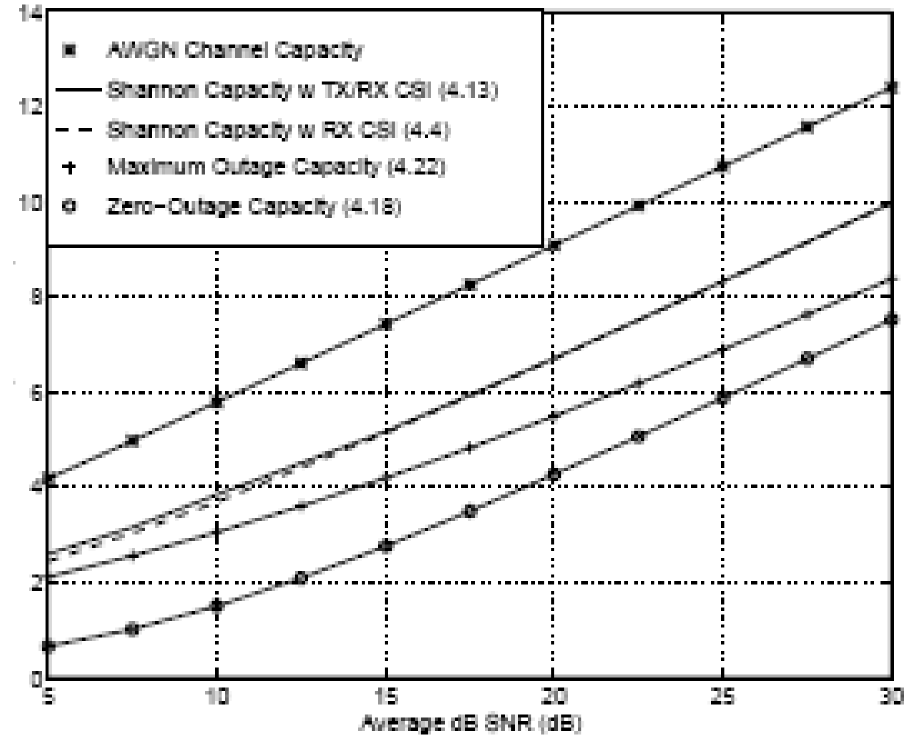
- Fading inverted to maintain constant SNR
- Simplifies design (fixed rate)
- Greatly reduces capacity
  - Capacity is zero in Rayleigh fading
- Truncated inversion
  - Invert channel above cutoff fade depth
  - Constant SNR (fixed rate) above cutoff
  - Cutoff greatly increases capacity
    - Close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

Capacity in Flat-Fading

Rayleigh

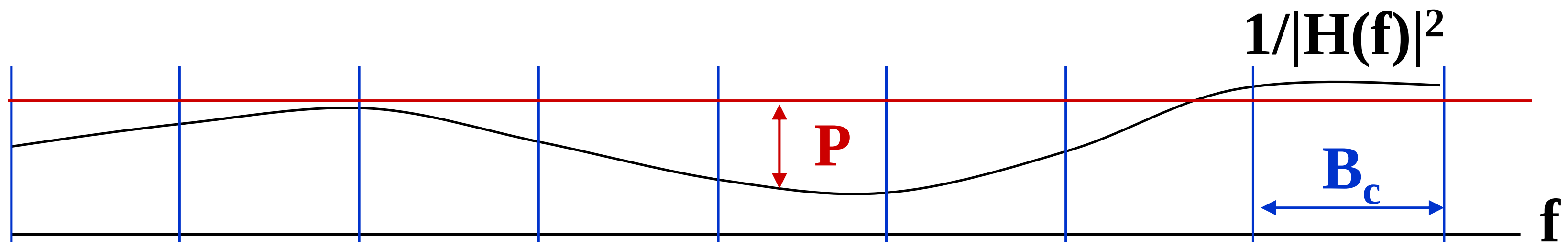


Log-Normal



Frequency Selective Fading Channels

- For TI 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).
  - Independent fading in each subband
  - Capacity is the sum of subband capacities



Main Points

- Fundamental capacity of flat-fading channels depends on what is known at TX and RX.
  - Capacity when only RX knows fading same as when TX and RX know fading but power fixed.
  - Capacity with TX/RX knowledge: variable-rate variable-power transmission (water filling) optimal
  - Almost same capacity as with RX knowledge only
  - Channel inversion practical, but should truncate
- Capacity of wideband channel obtained by breaking up channel into subbands
  - Similar to multicarrier modulation