

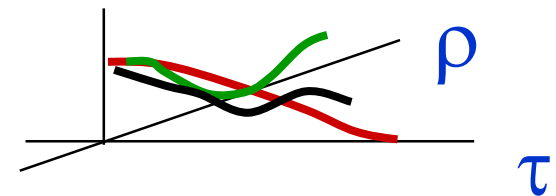
EE359 – Lecture 8 Outline

- 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

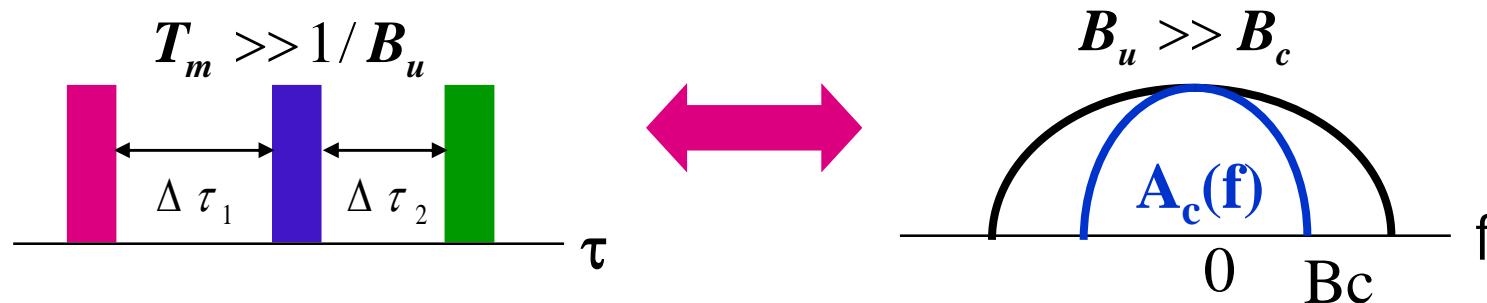
- Scattering Function: $s(\tau, \rho) = F_{\Delta t}[A_c(\tau, \Delta t)]$

- 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

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

Fading Known at Transmitter and Receiver

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

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

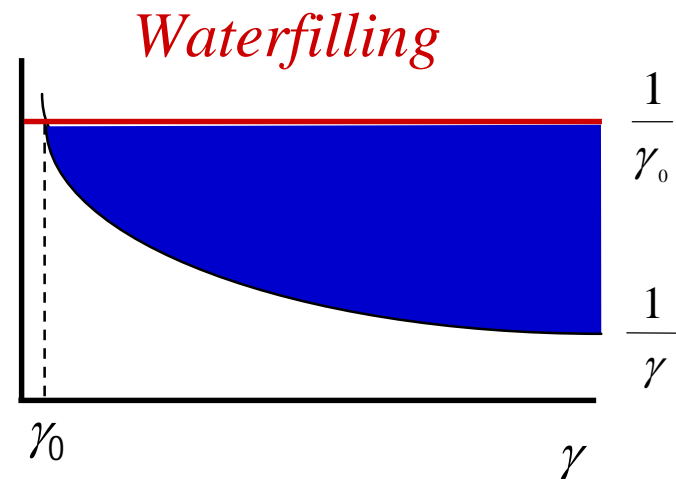
Optimal Adaptive Scheme

- Power Adaptation

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

- Capacity

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

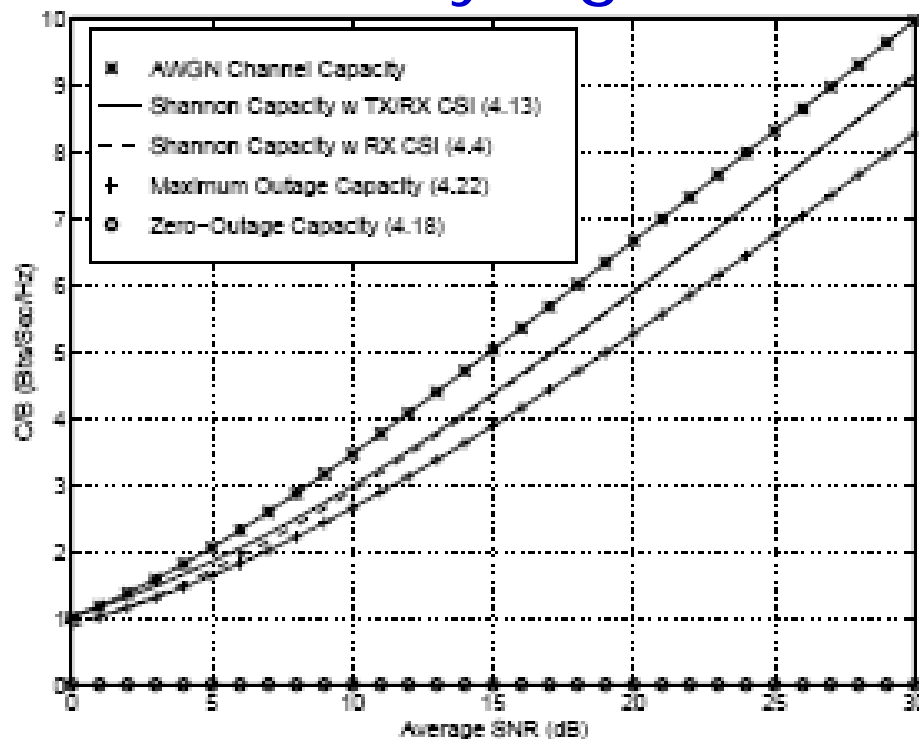


Channel Inversion

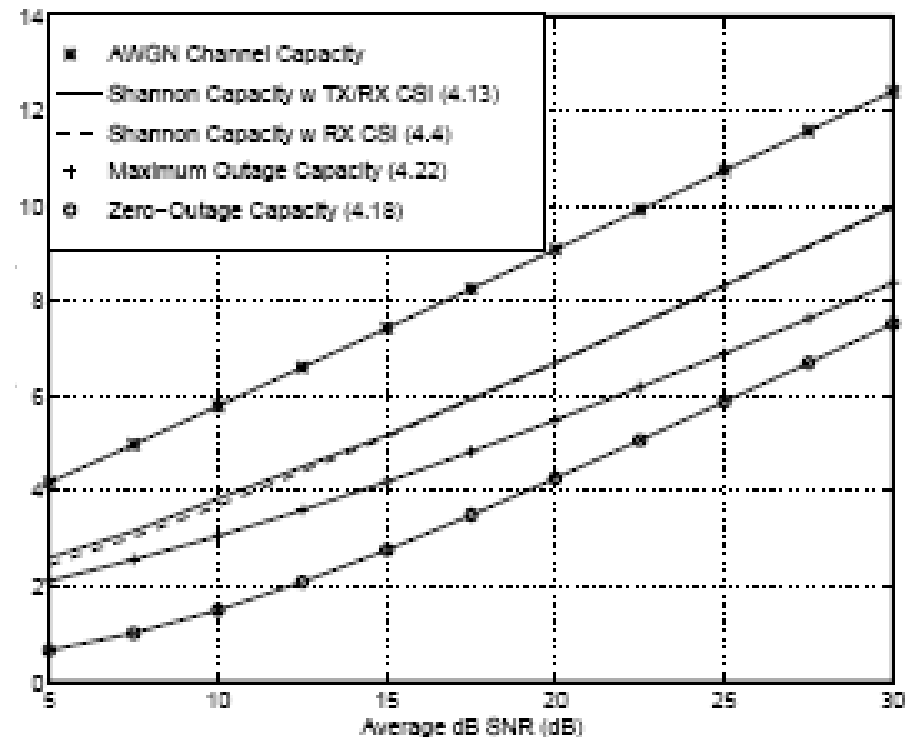
- Fading inverted to maintain constant SNR
- Simplifies design (fixed rate)
- Greatly reduces capacity
 - Capacity is zero in Rayleigh fading
- Truncated inversion
 - Invert channel above cutoff fade depth
 - Constant SNR (fixed rate) above cutoff
 - Cutoff greatly increases capacity
 - Close to optimal

Capacity in Flat-Fading

Rayleigh

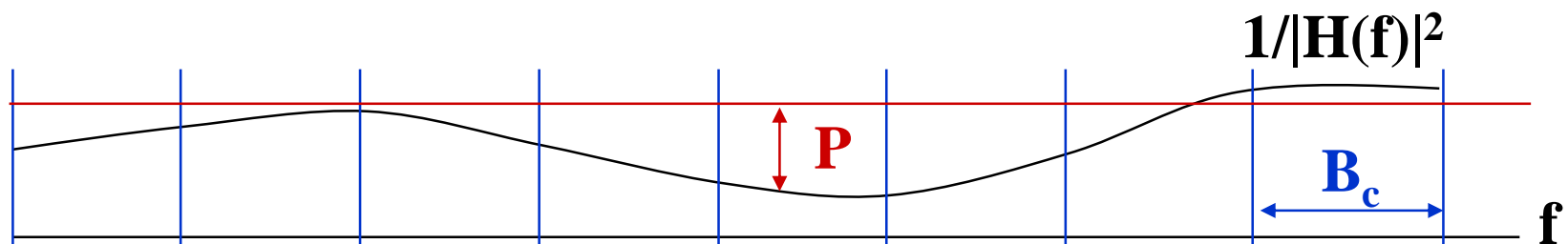


Log-Normal



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