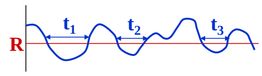
EE359 – Lecture 7 Outline

- Announcements:
  - HW this week due Friday 10/21@5pm
  - Project proposals due 10/28; I can provide early feedback
- Wideband Multipath Channels
- Scattering Function
- Multipath Intensity Profile
- Doppler Power Spectrum
- Shannon Capacity
- Capacity of Flat-Fading Channels
  - Fading Statistics Known
  - Fading Known at RX

Review of Last Lecture

- Signal envelope distributions:
  - CLT approx. → Rayleigh distribution (power exponential)
  - When LOS present, Ricean distribution used
  - Measurements support Nakagami distribution
- Average Fade Duration:
  - Rayleigh fading AFD

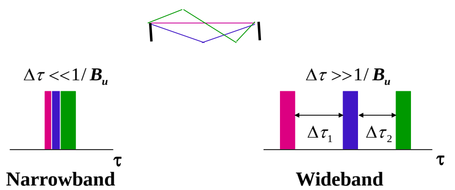
$\bar{t}_R = (e^{\rho^2} - 1)/(\rho f_D \sqrt{2\pi})$



- Markov Models:
  - Range of fading divided into discrete regions
  - Transition probabilities between regions depend on fading distribution and level crossing rate

Wideband Channels

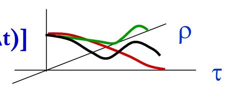
- Individual multipath components resolvable
- True when time difference between components exceeds signal bandwidth



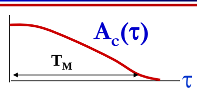
Scattering Function

- Fourier transform of $c(\tau,t)$ relative to t
- Typically characterize its statistics, since $c(\tau,t)$ is different in different environments
- Underlying process WSS and Gaussian, so only characterize mean (0) and correlation
- Autocorrelation is $A_c(\tau_1,\tau_2,\Delta t)=A_c(\tau,\Delta t)$
- Statistical scattering function:

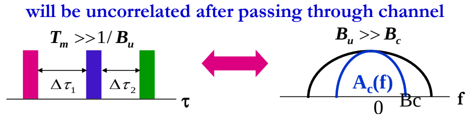
$s(\tau,\rho)=\mathcal{F}_{\Delta t}[A_c(\tau,\Delta t)]$



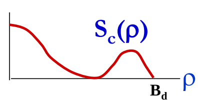
Multipath Intensity Profile



- Defined as $A_c(\tau,\Delta t=0)= A_c(\tau)$
  - Determines average (T_M) and rms (σ_τ) delay spread
  - Approximate max delay of significant m.p.
- Coherence bandwidth $B_c=1/T_M$
  - Maximum frequency over which $A_c(\Delta f)=F[A_c(\tau)]>0$
  - $A_c(\Delta f)=0$ implies signals separated in frequency by Δf will be uncorrelated after passing through channel



Doppler Power Spectrum



- $S_c(\rho)=F[A_c(\tau=0,\Delta t)]= F[A_c(\Delta t)]$
- Doppler spread B_d is maximum doppler for which $S_c(\rho)=>0$.
- Coherence time $T_c=1/B_d$
  - Maximum time over which $A_c(\Delta t)>0$
  - $A_c(\Delta t)=0$ implies signals separated in time by Δt will be uncorrelated after passing through channel

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

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

Main Points

- Scattering function characterizes rms delay and Doppler spread. Key parameters for system design.
- Delay spread defines maximum delay of significant multipath components. Inverse is coherence BW
- Doppler spread defines maximum nonzero doppler, its inverse is coherence time
- Fundamental channel capacity defines maximum data rate that can be supported on a channel
  - Capacity in fading depends what is known at TX & RX
- Capacity with RX CSI is average of AWGN capacity