EE359 – Lecture 7 Outline

- Announcements:
  - Makeup lecture this Friday, 12-1:10, Hewlitt 102 (w/pizza)
  - I will have an extra OH Friday 2-3 and by appt.
  - Next HW posted today, due 10/14 5pm (ext. to 10/19 by rqst)
- Wideband Channels
- Scattering Functions
- Multipath Intensity Profile
- Doppler Power Spectrum

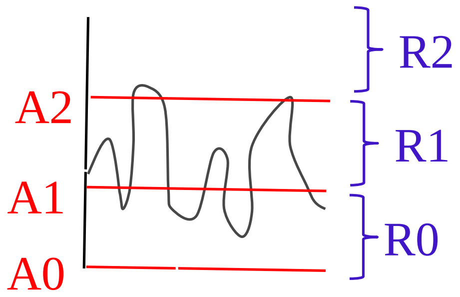
Review of Last Lecture

- Signal Envelope Distribution
  - LLN leads to Rayleigh distribution (exponential power)
  - Ricean distribution when LOS component present
  - Measurements support Nakagami distribution
    - Will be useful in later BER and diversity calculations
- How long signal stays below target R (SNR γ)
  - Derived from level crossing rate of fading process
  - For Rayleigh fading

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

Review Continued: Markov Models for Fading

- Model for fading dynamics
  - Simplifies performance analysis

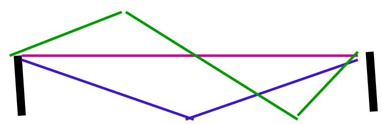


- Divides range of fading power into discrete regions $R_j=\{\gamma: A_j \leq \gamma < A_{j+1}\}$
  - A_j s and # of regions are functions of model
- Transition probabilities (L_j is LCR at A_j):

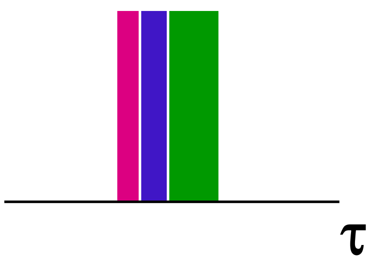
$$p_{j,j+1} = \frac{L_{j+1}T}{\pi_j},\ p_{j,j-1} = \frac{L_j T}{\pi_j},\ p_{j,j} = 1 - p_{j,j+1} - p_{j,j-1}$$

Wideband Channels

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

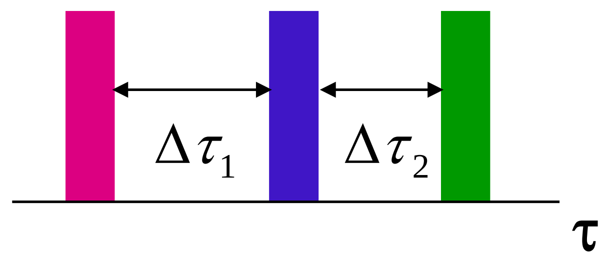


$$\Delta\tau << 1/\boldsymbol{B_u}$$



Narrowband

$$\Delta\tau >> 1/\boldsymbol{B_u}$$

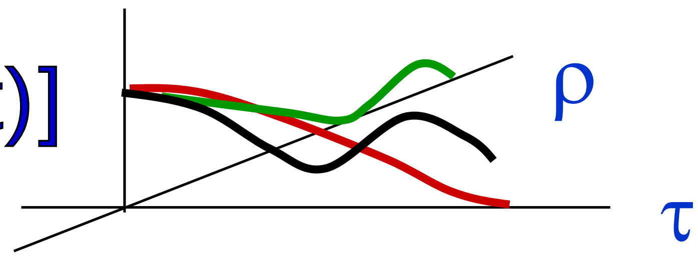


Wideband

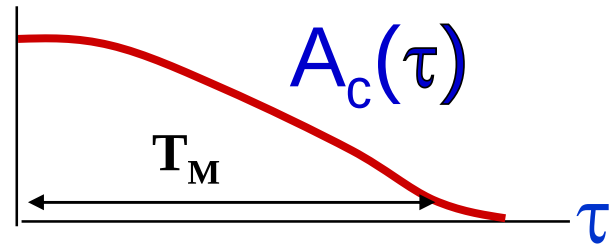
Scattering Function

- 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:

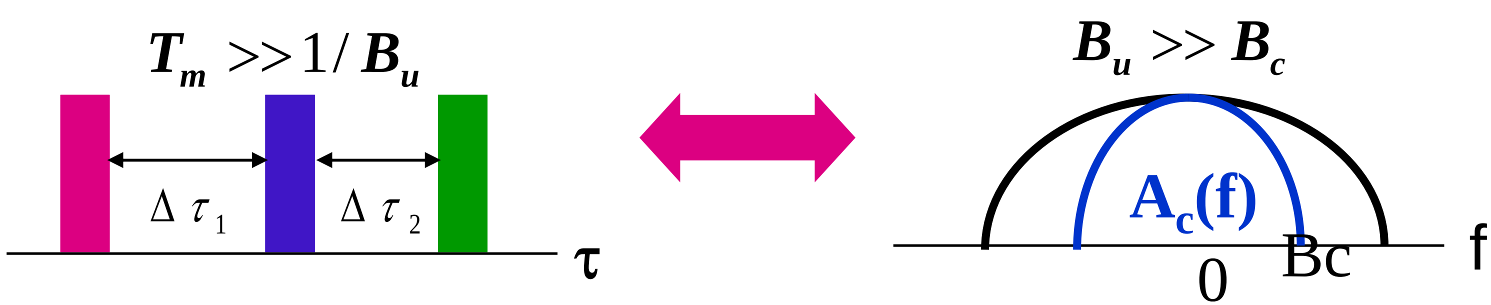
$$s(\tau,\rho)=F_{\Delta t}[A_c(\tau,\Delta t)]$$



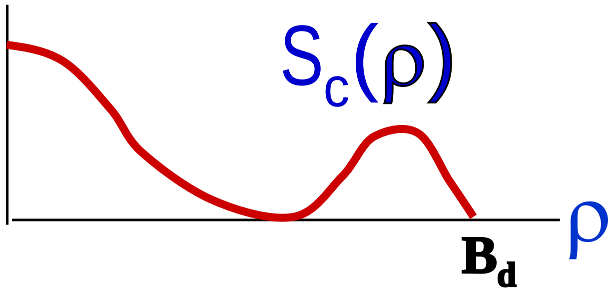
Multipath Intensity Profile



- 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

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 bandwidth of channel
- Doppler spread defines maximum nonzero doppler, its inverse is coherence time