

EE359 – Lecture 4 Outline

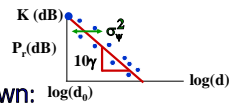
- Announcements:
 - 1st HW due tomorrow.
 - Makeup lecture Friday, 12pm-1:10, 102 Hewlitt, with pizza at 11:45 (also 10/9, these are makeups for Oct. 12-14)
 - Discussion T 4-4:50 in 380-380W (Math dept. basement)
- Review of Last Lecture
- Model Parameters from Empirical Data
- Random Multipath Model
- Time Varying Channel Impulse Response
- Narrowband Approximation for RX Signal
- In-phase and Quadrature RX Signal Components

Review of Last Lecture

- Log Normal Shadowing
- Combined Path Loss and Shadowing
- Cell Coverage Area

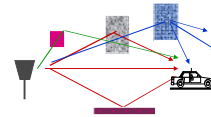
Model Parameters from Empirical Measurements

- Fit model to data
- Path loss (K, γ), d_0 known:
 - “Best fit” line through dB data
 - K obtained from measurements at d_0 .
 - Exponent is MMSE estimate based on data
 - Captures mean due to shadowing
- Shadowing variance
 - Variance of data relative to path loss model (straight line) with MMSE estimate for γ



Statistical Multipath Model

- Random # of multipath components, each with
 - Random amplitude
 - Random phase
 - Random Doppler shift
 - Random delay
- Random components change with time
- Leads to time-varying channel impulse response



Time Varying Impulse Response

- Response of channel at t to impulse at $t-\tau$:

$$c(\tau, t) = \sum_{n=1}^N \alpha_n(t) e^{-j\phi_n(t)} \delta(\tau - \tau_n(t))$$

- t is time when impulse response is observed
- $t-\tau$ is time when impulse put into the channel
- τ is how long ago impulse was put into the channel for the current observation
 - path delay for MP component currently observed

Received Signal Characteristics

- Received signal consists of many multipath components
- Amplitudes change slowly
- Phases change rapidly
 - Constructive and destructive addition of signal components
 - Amplitude fading of received signal (both wideband and narrowband signals)

Narrowband Model

- Assume delay spread $\max_{m,n} |\tau_n(t) - \tau_m(t)| \ll 1/B$
- Then $u(t) \approx u(t-\tau)$.
- Received signal given by

$$r(t) = \Re \left\{ u(t) e^{j2\pi f_c t} \left[\sum_{n=0}^{N(t)} \alpha_n(t) e^{j\phi_n(t)} \right] \right\}$$

- No signal distortion (spreading in time)
- Multipath affects complex scale factor in brackets.
- Characterize scale factor by setting $u(t) = \delta(t)$

In-Phase and Quadrature under CLT Approximation

- In phase and quadrature signal components:

$$r_I(t) = \sum_{n=0}^{N(t)} \alpha_n(t) e^{j\phi_n(t)} \cos(2\pi f_c t),$$
$$r_Q(t) = \sum_{n=0}^{N(t)} \alpha_n(t) e^{j\phi_n(t)} \sin(2\pi f_c t)$$

- For $N(t)$ large, $r_I(t)$ and $r_Q(t)$ jointly Gaussian (sum of large # of random vars).
- Received signal characterized by its mean, autocorrelation, and cross correlation.
- If $\phi_n(t)$ uniform, the in-phase/quad components are mean zero, indep., and stationary.

Main Points

- Statistical multipath model leads to a time-varying channel impulse response
- Received signal has random amplitude fluctuations
- Narrowband model and CLT lead to in-phase/quad components that are stationary Gaussian processes
 - Processes completely characterized by their mean, autocorrelation, and cross correlation.
- Assuming uniform phase offsets, process is zero mean with joint expectation also zero.