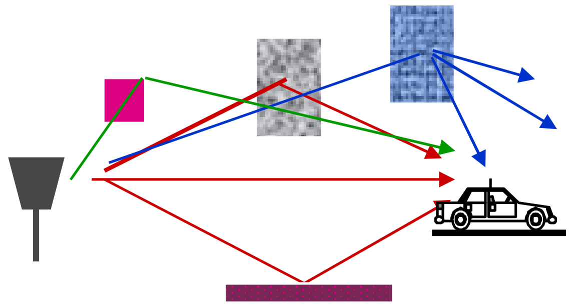
EE359 – Lecture 5 Outline

- Announcements:
  - No lectures Oct. 12-14, 1 more makeup next Fri.
- Review of Last Lecture
- Narrowband Fading Model
- In-Phase and Quad Signal Components
- Auto and Crosscorrelation
- Correlation and PSD in uniform scattering

Review of Last Lecture

- Model Parameters from Empirical Data
  - Obtain path loss model from MMSE curve fit
  - Obtain STD of data relative to path loss model
- Random Multipath Model



-Random (large) number of components
-Random delays/gains/doppler on each

- Time Varying Channel Impulse Response

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

Narrowband Model

- Assume delay spread $\max_{m,n} |\tau_n(t)-\tau_m(t)| << 1/B$
- 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 $u(t)=e^{j\phi_0}$

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

Auto and Cross Correlation

- Assume $\phi_n \sim U[0,2\pi]$
- Recall that θ_n is the multipath arrival angle
- Autocorrelation of inphase/quad signal is

$$A_{r_I}(\tau) = A_{r_Q}(\tau) = PE_{\theta_n}[\cos 2\pi f_{D_n}\tau], \quad f_{D_n} = v\cos\theta_n / \lambda$$

- Cross Correlation of inphase/quad signal is

$$A_{r_I,r_Q}(\tau) = PE_{\theta_n}[\sin 2\pi f_{D_n}\tau] = -A_{r_I,r_Q}(\tau)$$

- Autocorrelation of received signal is

$$A_r(\tau) = A_{r_I}(\tau)\cos(2\pi f_c\tau) - A_{r_I,r_Q}(\tau)\sin(2\pi f_c\tau)$$

Uniform AOAs

- Under uniform scattering, in phase and quad comps have no cross correlation and autocorrelation is

$$A_{r_I}(\tau) = A_{r_Q}(\tau) = PJ_0(2\pi f_D \tau)$$

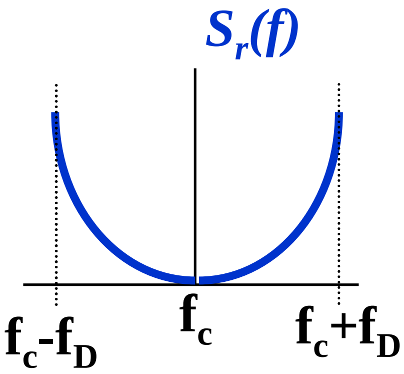
Decorrelates over roughly half a wavelength

- The PSD of received signal is

$$S_r(f) = .25[S_{r_I}(f - f_c) + S_{r_I}(f + f_c)]$$

$$S_{r_I}(f) = \mathcal{F}[PJ_0(2\pi f_D \tau)]$$

Used to generate simulation values



Main Points

- Narrowband model has in-phase and quad. comps that are zero-mean stationary Gaussian processes
  - Auto and cross correlation depends on AOAs of multipath
- Uniform scattering makes autocorrelation of inphase and quad follow Bessel function
  - Signal components decorrelate over half wavelength
  - Cross correlation is zero (in-phase/quadrature indep.)
- The power spectral density of the received signal has a bowel shape centered at carrier frequency
  - PSD useful in simulating fading channels