

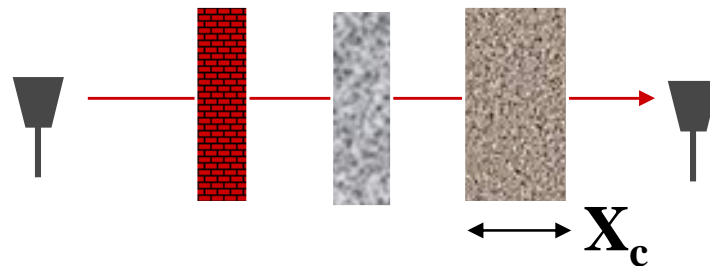
EE359 – Lecture 3 Outline

- **Announcements**
 - OHs today moved to Tuesday 3-4
 - First discussion section tomorrow.
 - HW posted, due Thursday at 5pm.
- Log Normal Shadowing
- Combined Path Loss and Shadowing
- Cell Coverage Area
- Models Parameters from Empirical Measurements

Lecture 2 Review

- Ray Tracing Models
- Free Space Model
 - Power falloff with distance proportional to d^{-2}
- Two Ray Model
 - Power falloff with distance proportional to d^{-4}
- General Ray Tracing
 - Used for site-specific models
- Empirical Models
- Simplified Model: $P_r = P_t K [d_0/d]^\gamma$, $2 \leq \gamma \leq 8$.
 - Captures main characteristics of path loss

Shadowing

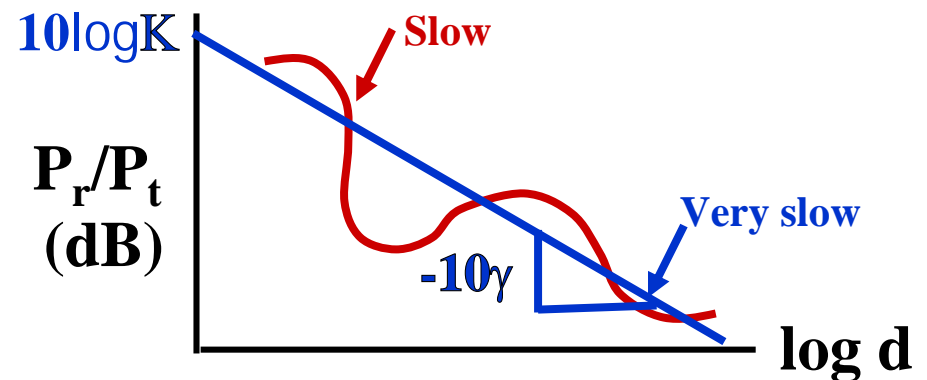


- Models attenuation from obstructions
- Random due to random # and type of obstructions
- Typically follows a log-normal distribution
 - dB value of power is normally distributed
 - $\mu=0$ (mean captured in path loss), $4 < \sigma^2 < 12$ (empirical)
 - LLN used to explain this model
 - Decorrelated over decorrelation distance X_c

Combined Path Loss and Shadowing

- Linear Model: ψ lognormal

$$\frac{P_r}{P_t} = K \left(\frac{d_0}{d} \right)^\gamma \psi$$



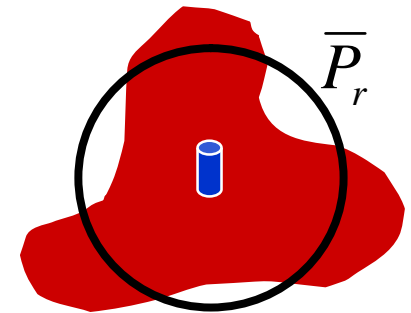
- dB Model

$$\frac{P_r}{P_t} (dB) = 10 \log_{10} K - 10 \gamma \log_{10} \left(\frac{d_0}{d} \right) + \psi_{dB},$$

$$\psi_{dB} \sim N(0, \sigma_\psi^2)$$

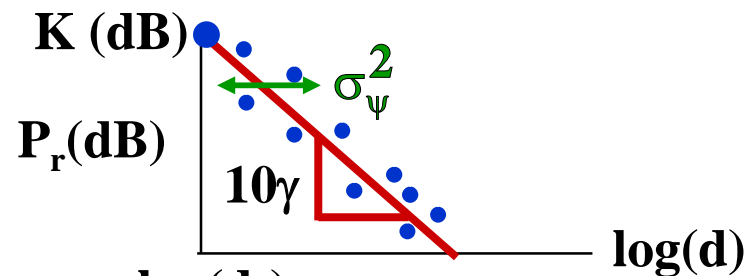
Outage Probability and Cell Coverage Area

- Path loss: circular cells
- Path loss+shadowing: amoeba cells
 - Tradeoff between coverage and interference
- Outage probability
 - Probability received power below given minimum
- Cell coverage area
 - % of cell locations at desired power
 - Increases as shadowing variance decreases
 - Large % indicates interference to other cells



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



Main Points

- Random attenuation due to shadowing modeled as log-normal (empirical parameters)
- Shadowing decorrelates over decorrelation distance
- Combined path loss and shadowing leads to outage and amoeba-like cell shapes
- Cellular coverage area dictates the percentage of locations within a cell that are not in outage
- Path loss and shadowing parameters are obtained from empirical measurements