EE359 – Lecture 2 Outline

- Announcements
  - 1st HW posted today, due next Thursday at 5pm.
  - Discussion section starts next week.
- Review of Last Lecture
- Signal Propagation Overview
- TX and RX Signal Models
  - Complex baseband models
- Path Loss Models
  - Free-space Path Loss
  - Ray Tracing Models
  - Simplified Path Loss Model
  - Empirical Models

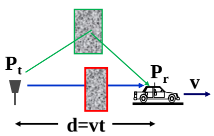
Lecture 1 Review

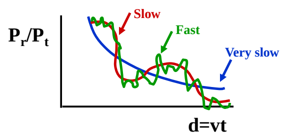
- Course Information
- Wireless Vision
- Technical Challenges
- Multimedia Requirements
- Current Wireless Systems
- Spectrum Regulation and Standards

Emerging systems will be covered in a bonus lecture later in the quarter

Propagation Characteristics

- Path Loss (includes average shadowing)
- Shadowing (due to obstructions)
- Multipath Fading

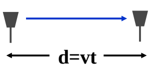




Path Loss Modeling

- Maxwell's equations
  - Complex and impractical
- Free space path loss model
  - Too simple
- Ray tracing models
  - Requires site-specific information
- Simplified power falloff models
  - Main characteristics: good for high-level analysis
- Empirical Models
  - Don't always generalize to other environments

Free Space (LOS) Model

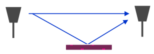


- Path loss for unobstructed LOS path
- Power falls off :
  - Proportional to $1/d^2$
  - Proportional to λ^2 (inversely proportional to f^2)

Ray Tracing Approximation

- Represent wavefronts as simple particles
- Geometry determines received signal from each signal component
- Typically includes reflected rays, can also include scattered and defracted rays.
- Requires site parameters
  - Geometry
  - Dielectric properties

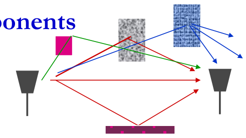
Two Path Model



- Path loss for one LOS path and 1 ground (or reflected) bounce
- Ground bounce approximately cancels LOS path above critical distance
- Power falls off
  - Proportional to d^2 (small d)
  - Proportional to d^4 ($d>d_c$)
  - Independent of λ (f)

General Ray Tracing

- Models all signal components
  - Reflections
  - Scattering
  - Diffraction



- Requires detailed geometry and dielectric properties of site
  - Similar to Maxwell, but easier math.
- Computer packages often used

Simplified Path Loss Model

- Used when path loss dominated by reflections.
- Most important parameter is the path loss exponent γ, determined empirically.

$$P_r = P_t K\left[\frac{d_0}{d}\right]^{\gamma}, \qquad 2 \le \gamma \le 8$$

Empirical Models

- Okumura model
  - Empirically based (site/freq specific)
  - Awkward (uses graphs)
- Hata model
  - Analytical approximation to Okumura model
- Cost 231 Model:
  - Extends Hata model to higher frequency (2 GHz)
- Walfish/Bertoni:
  - Cost 231 extension to include diffraction from rooftops

Commonly used in cellular system simulations

Main Points

- Path loss models simplify Maxwell's equations
- Models vary in complexity and accuracy
- Power falloff with distance is proportional to d^2 in free space, d^4 in two path model
- Main characteristics of path loss captured in simple model $P_r=P_tK[d_0/d]^{\gamma}$
- Empirical models used in simulations
  - Low accuracy (15-20 dB std)
  - Capture phenomena missing from formulas
  - Awkward to use in analysis