CS-435
spring semester 2025

Network Technology & Programming Laboratory

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Computer Science Department

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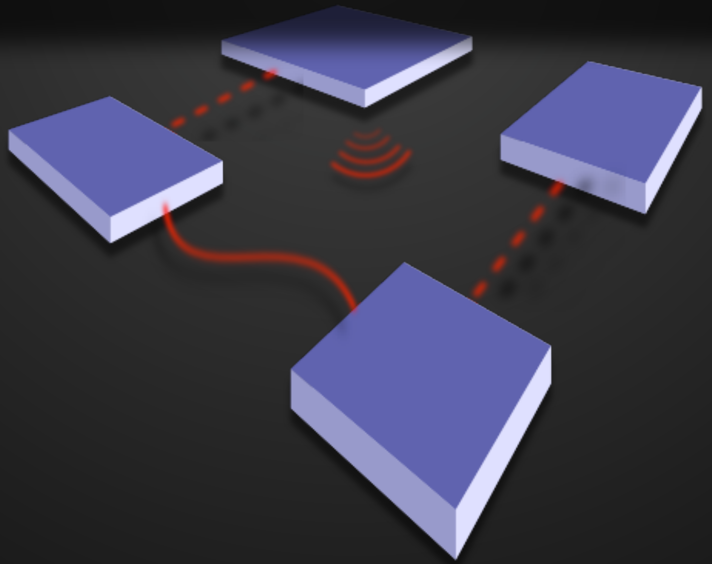
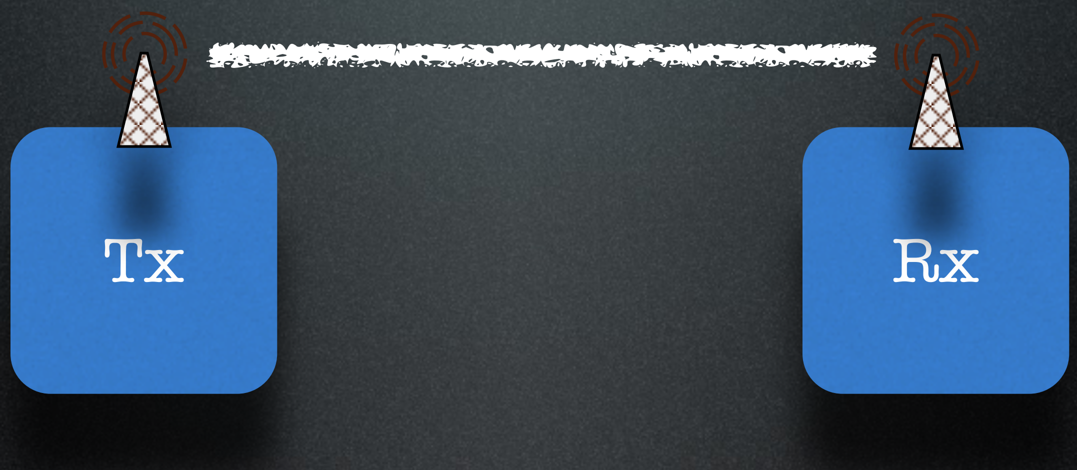


CS-435

Lecture #10 preview

- Wireless Networking
- Radio Communications Explored

two endpoints



SINR

- What is interference? I_{Rx}

- What is noise? $N = k_B T \Delta f$
  - noise floor
  - noise factor / noise figure

$$F = \frac{SNR_{in}}{SNR_{out}}$$

$$NF = 10log(\frac{SNR_{in}}{SNR_{out}})$$

- SNR / SINR / SIR

$$SNR = \frac{P_{Rx}}{N} \qquad SINR = \frac{P_{Rx}}{I_{Rx} + N}$$

Sensitivity

- SINR is not the only criterion for reception!
- The Received Signal power must be over a threshold
- Vendors usually provide only RSS thresholds, not SINR

RX SPECIFICATIONS			
	DataRate	Sensitivity	Tolerance
802.11b	1Mbps	-97 dBm	+/-1dB
	2Mbps	-96 dBm	+/-1dB
	5.5Mbps	-95 dBm	+/-1dB
	11Mbps	-92 dBm	+/-1dB
802.11g OFDM	6Mbps	-94 dBm	+/-1dB
	9Mbps	-93 dBm	+/-1dB
	12Mbps	-91 dBm	+/-1dB
	18Mbps	-90 dBm	+/-1dB
	24Mbps	-86 dBm	+/-1dB
	36Mbps	-83 dBm	+/-1dB
	48Mbps	-77 dBm	+/-1dB
	54Mbps	-74 dBm	+/-1dB

Sensitivity

$$\frac{P_{RX}}{I_{RX} + N} \geq \theta_{(Rate,BER)}$$

Threshold θ == minSNR
when I_{Rx} = 0

sensitivity = N + minSNR

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	24Mbps	-86 dBm	+/-1dB
	36Mbps	-83 dBm	+/-1dB
	48Mbps	-77 dBm	+/-1dB
	54Mbps	-74 dBm	+/-1dB

Rates vs Sensitivity/SNR

- Different modulation schemes have different constellations
- Denser constellations carry more bits/point
  - higher rate
  - increased BER
  - needs larger SNR

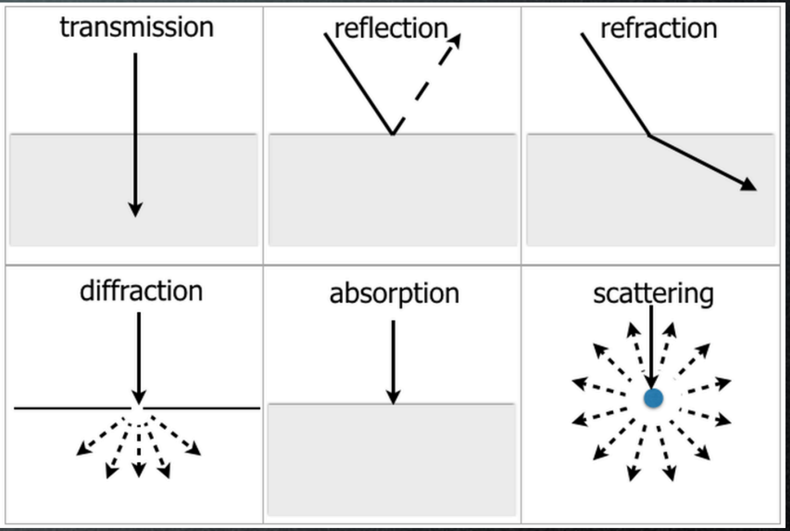
Path Loss

- Free Space propagation model $$PL = \frac{(4\pi d)^2}{\lambda^2}$$
- Two Ray model $$PL = \frac{d^4}{h_{Tx}^2 h_{Rx}^2}$$
- Log Distance model

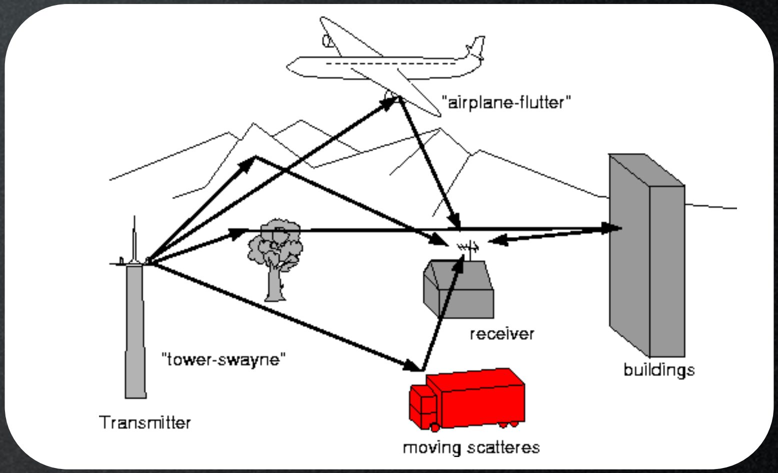
$$PL\,[\mathrm{dB}] = PL(d_0) + 10n\log\left(\frac{d}{d_0}\right) + X_\sigma$$

Signal Propagation

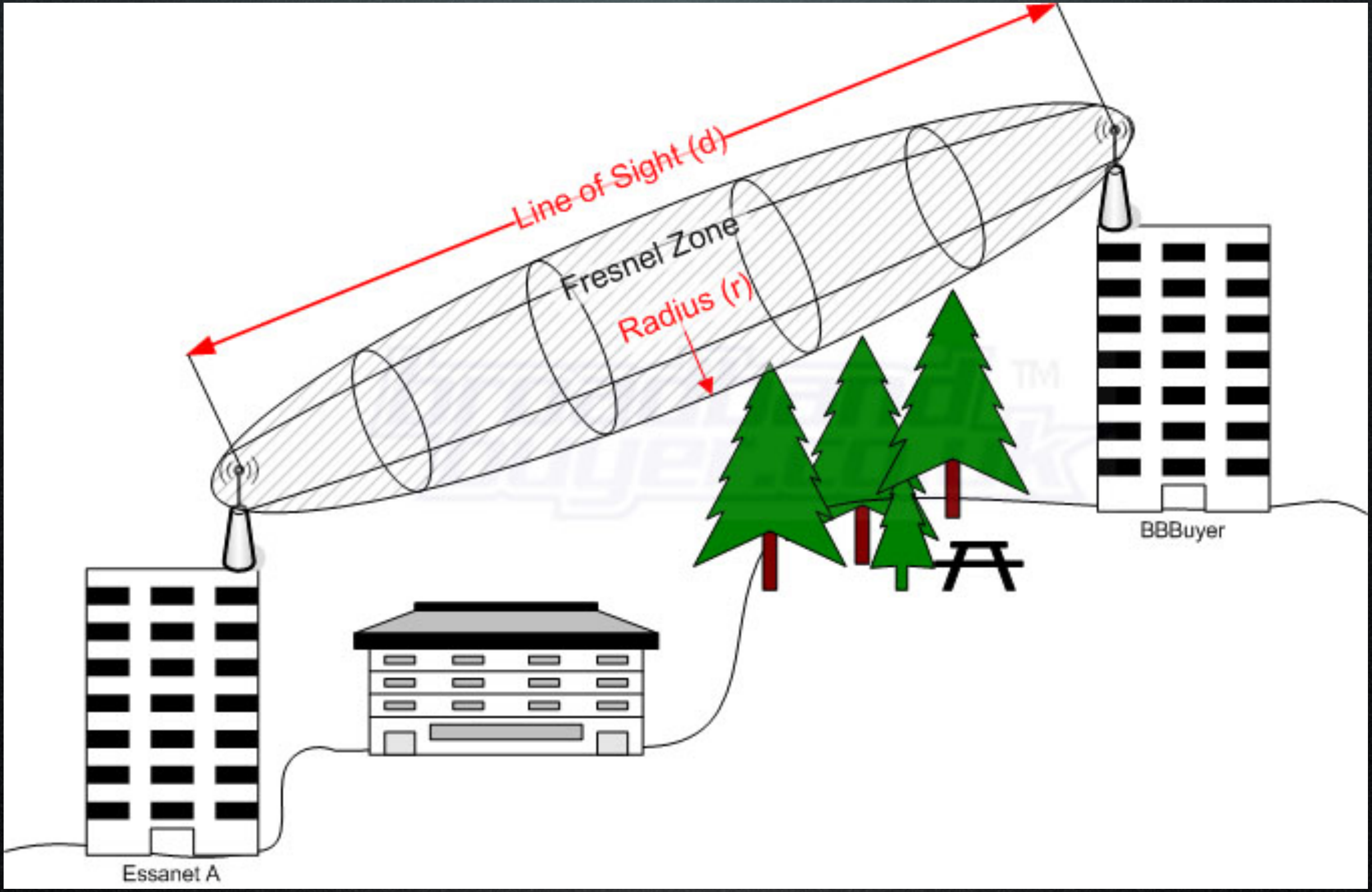
- Reflection
- Diffraction
- Scattering



- MultiPath
  - Fading
  - Shadow



Fresnel Zone



At the Receiver

- Signal of Interest
  - Account path loss + delayed reflections
- Interference
  - Transmissions in the same or neighboring channels/frequencies
- Noise
  - Thermal + System noise

Algebra

- When using Watt:
  - multiply, divide
- When using dB/dBm:
  - add, subtract

decibel

- Relative measurement unit: $10\,log_{10}(\frac{value}{1\;unit})$
- Examples
- Rule of thumb: +10dB <=> x10

$$1mW = 10\,log_{10}(\frac{1mW}{1mW}) = 0dBm$$

$$10mW = 10\,log_{10}(\frac{10mW}{1mW}) = 10dBm$$

$$100mW = 10\,log_{10}(\frac{100mW}{1mW}) = 10\,log_{10}(10^2) = 20dBm$$

decibel

- Rule of thumb: +3dB <=> x2

$$1mW = 10\,log_{10}(\frac{1mW}{1mW}) = 0dBm$$

$$2mW = 10\,log_{10}(\frac{2mW}{1mW}) = 10\,log_{10}(1) \cdot 10\,log_{10}(2) \simeq 3dBm$$

decibel

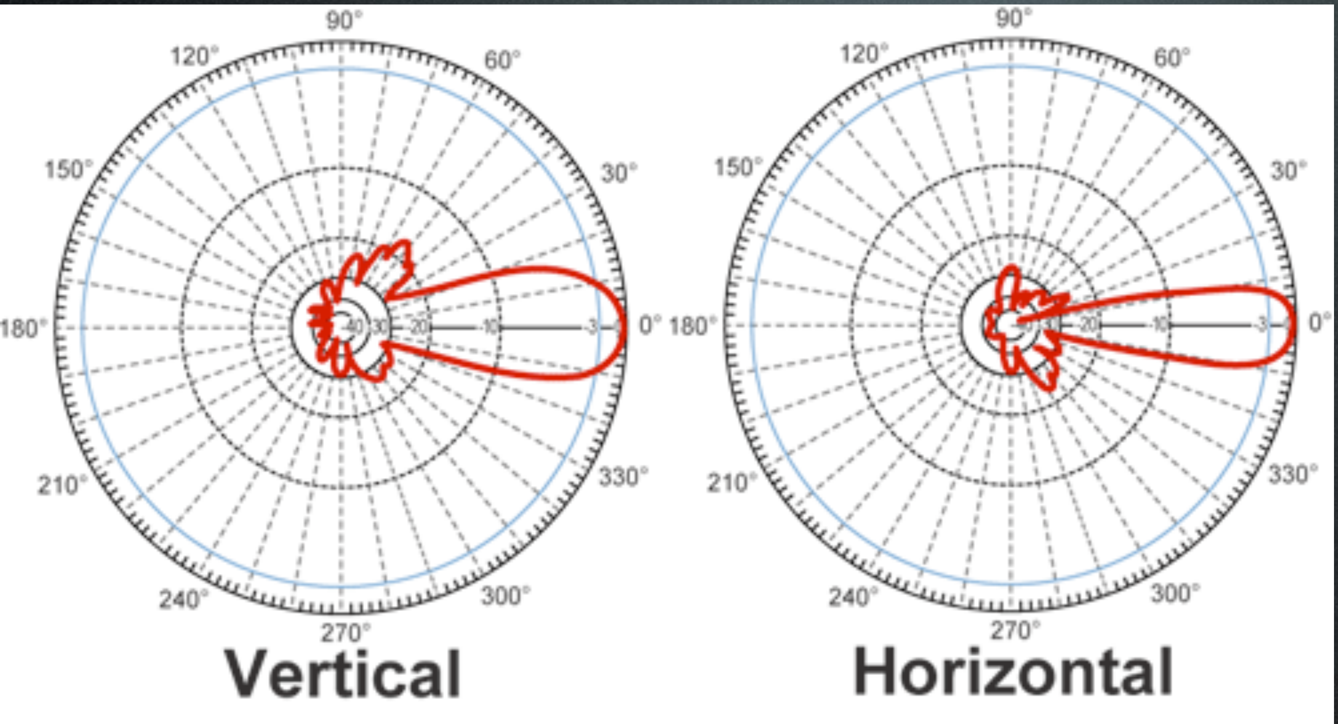
- From dB to units: $X\, dB_{unit} = 10^{\frac{X}{10}}\, unit$

$$
\begin{aligned}
15dBm &= 10^{1.5}mW = 31.62mW \\
1dBm &= 10^{0.1}mW = 1.26mW \\
17dBm &= (20-3)dBm \simeq \frac{100}{2}mW = 50mW
\end{aligned}
$$

antennas

- The antenna provides three fundamental properties
  - Gain
  - Direction
  - Polarization
- Gain: (pos/neg) increase in power
- Direction: transmission shape/pattern
- Polarization: electric field oscillation axis orientation

antennas



- Near/Far field
- Fraunhofer region

$$d_f = \frac{2D^2}{\lambda}$$

$$d_f \gg D$$

$$d_f \gg \lambda$$

Received Power

- Power at the receiver (Rx)

$$P_{Rx} \quad = \quad P_{Tx} + G_{Tx} + G_{Rx} - PL$$

- Effective Isotropic Radiated Power

$$E.I.R.P. = P_{Tx} + G_{Tx}$$

interference

- Everything on same channel
  - sum all powers
- On different channels
  - inter-channel power quotient

Link Budget

- Predict the wireless link
- Estimate the Received Power =>
  - Rate (based on sensitivity/SNR)
- Use dB (additions & subtractions)

Link Budget

- Example 1:
  - 802.11g , 54Mbps => -73dBm sens.
  - Tx Power 20dBm
  - EIRP 30dBm
  - distance covered?
- Example 2:
  - 802.11g
  - 2km distance
  - EIRP 20dBm
  - achievable rate?

Link Budget

$$
\begin{aligned}
P_{Rx} &= P_{Tx} + G_{Tx} + G_{Rx} - PL \\
P_{Rx} &= E.I.R.P. + G_{Rx} - PL \\
PL &= E.I.R.P. + G_{Rx} - P_{Rx}
\end{aligned}
$$