HY-330

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Introduction to telecommunication systems theory

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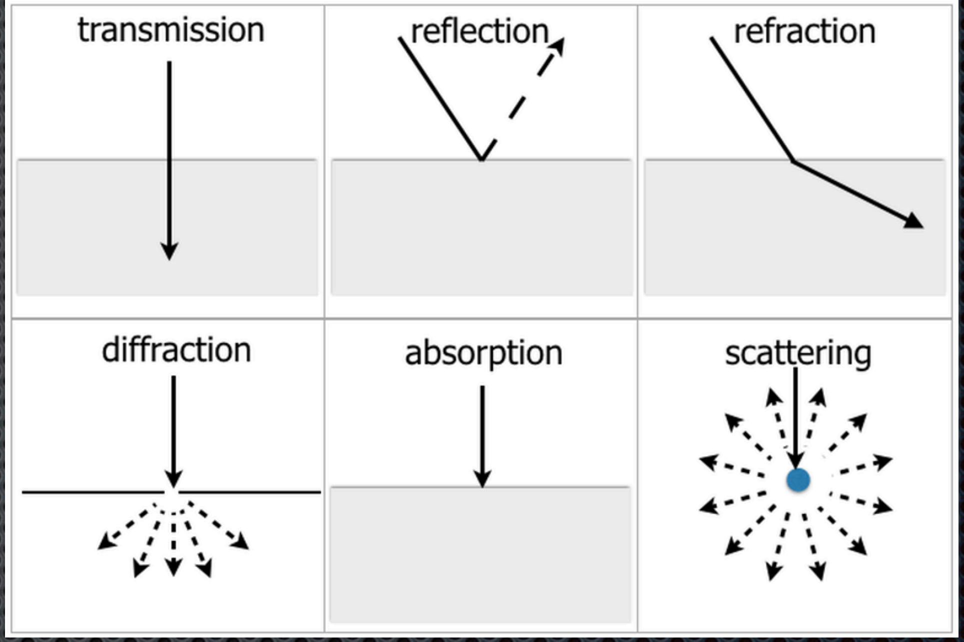
Propagation

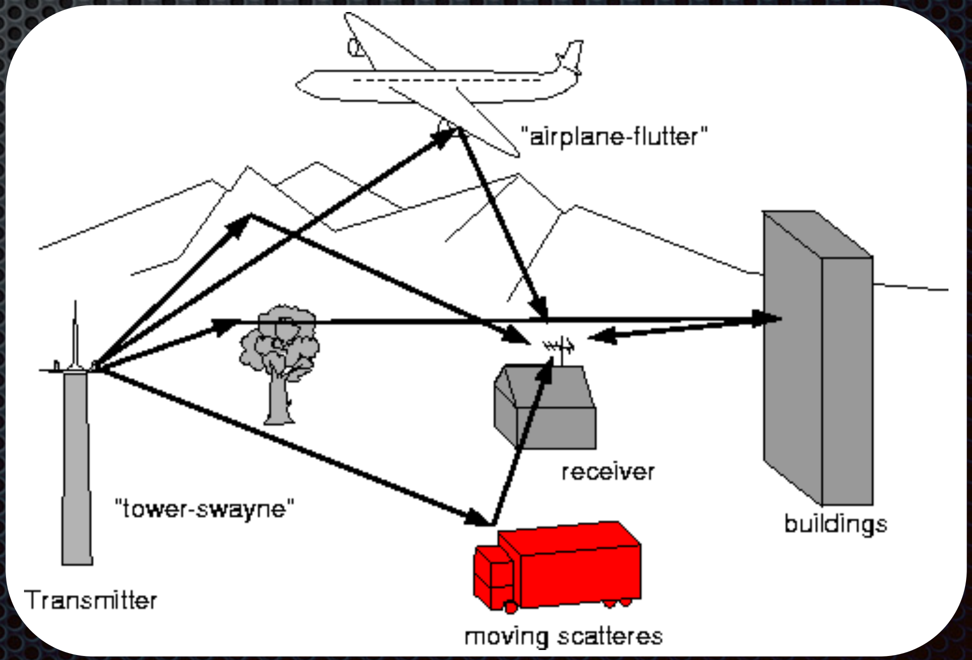
- ElectroMagnetic Waves
- Path Loss
- dB
- Examples

Signal Propagation

- Reflection
- Diffraction
- Refraction
- Scattering
- Absorbtion

- Multipath
    - Fading
    - Shadowing





Radio Propagation Model

- An empirical mathematical formulation for the:
  - characterization of radio wave propagation as a function of :
    - frequency, distance and other conditions
- A single model developed to
  - predict the behavior of propagation for similar links under similar constraints
  - formalize the way radio waves are propagated from one place to another
- Goal: predict the path loss along a link or the effective coverage area of a transmitter.

Propagation Modes

- Ground-wave propagation
- Sky-wave propagation
- Line-of-sight propagation
- Waveguides

Fresnel Zone

- The area around the visual line-of-sight that radio waves spread out into after they leave the antenna.
- This area must be clear or else signal strength will weaken.
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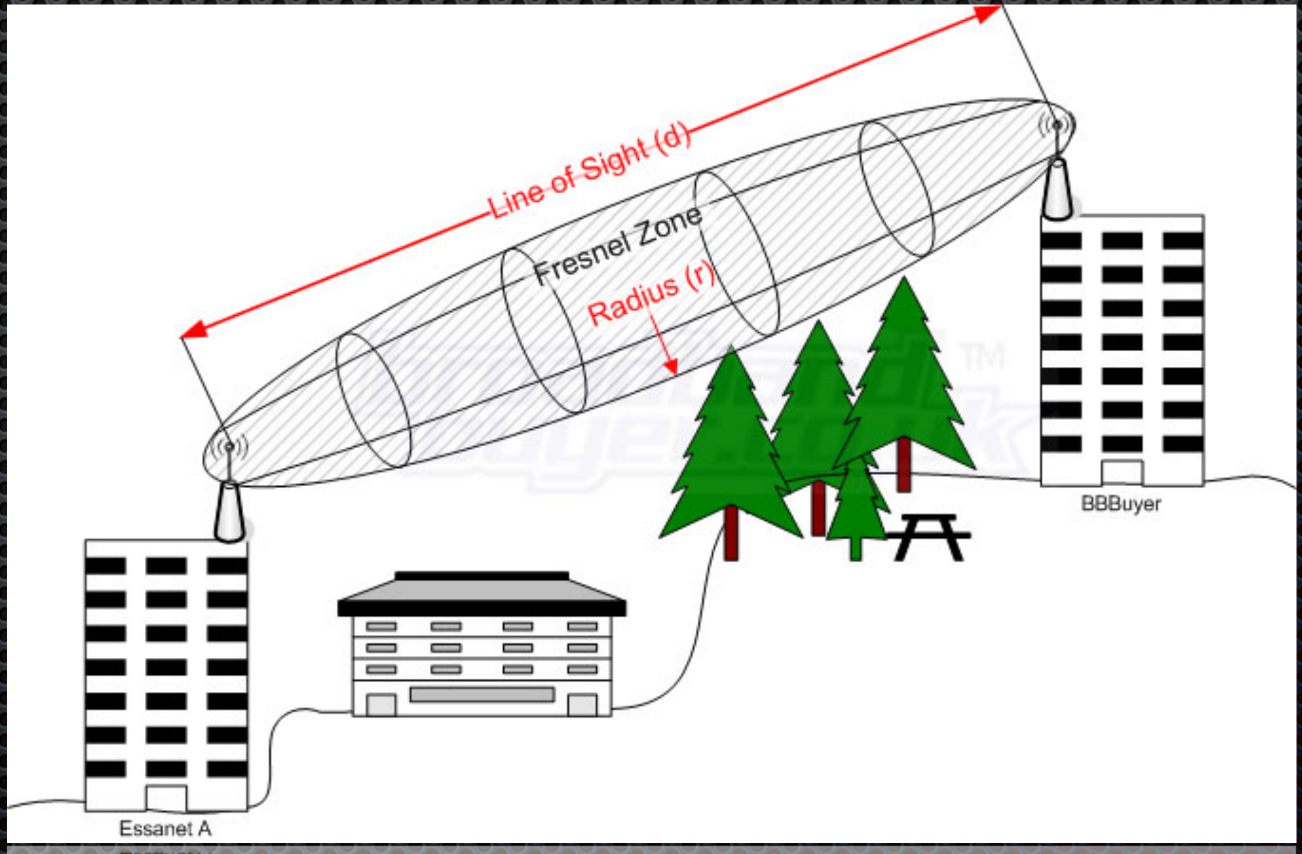
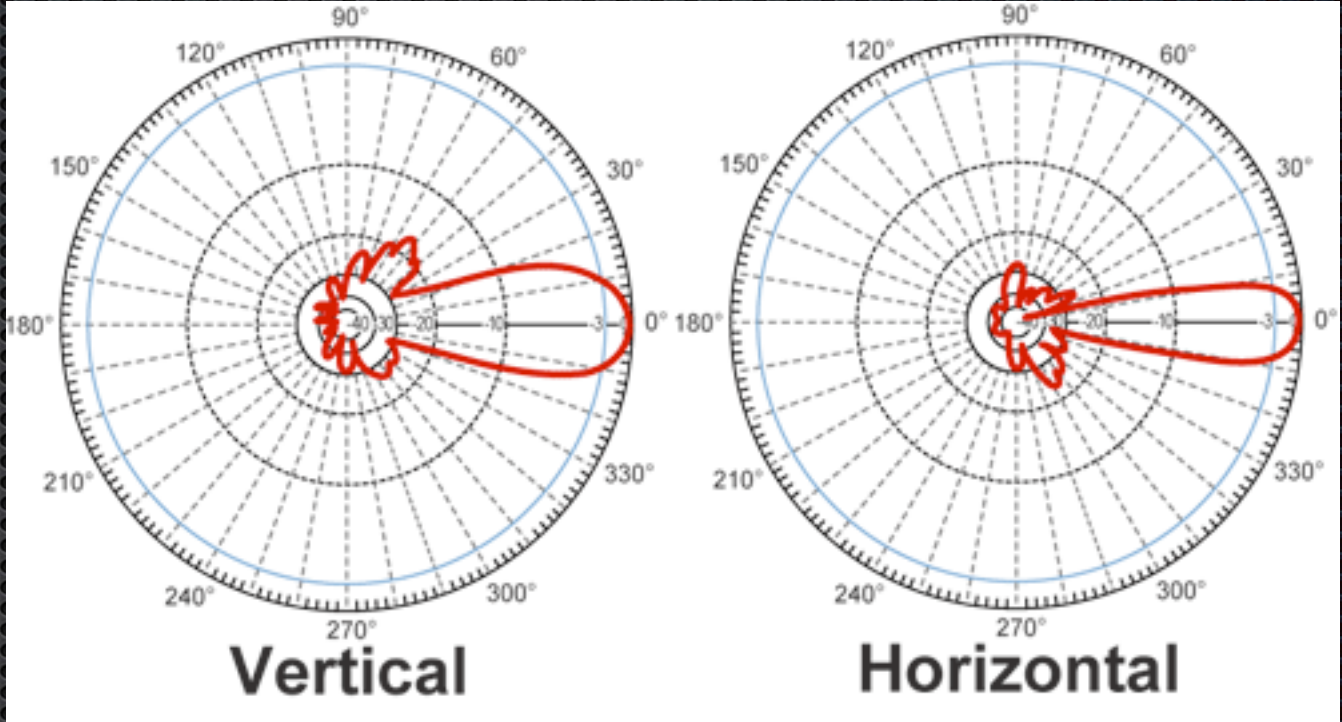


Antennas

- Three fundamental properties
  - gain
  - directivity
  - polarization



- Gain: (pos/neg) increase in power
- Directivity: transmission shape/pattern
- Polarization: electric field oscillation axis orientation

Path Loss

- Free Space 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 $$PL[dB] = PL(d_0) + 10n \log \frac{d}{d_0} + X_\sigma$$

At the Receiver

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

Link Budget

- Predict the wireless link
- Estimate the Received Power
- Use dB (additions & subtractions)

Losses

- Noise
  - noise floor
  - noise factor / noise figure
- SNR / SINR / SIR:

$$N = k_B T B = k_B T \Delta f$$

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

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

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

Received Power

- Received Power

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

- Effective Isotropic Radiated Power (EIRP)

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

- SNR

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

Decibel

- Relative measurement unit: $$10\log_{10}(\frac{value}{1unit})$$
- Examples:
  - Rule of thumb: +10dB <=> x10
-
$$\begin{aligned}
1mW &= 10\log_{10}(\frac{1mW}{1mW}) &= 0dBm\\
10mW &= 10\log_{10}(\frac{10mW}{1mW}) &= 10dBm\\
100mW &= 10\log_{10}(\frac{100mW}{1mW}) &= 20dBm
\end{aligned}$$

Decibel

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

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

$$2mW = 10\log_{10}(\frac{2mW}{1mW}) \approx 3dBm$$

- 10 mW + 3 dB = 20 mW
- 100 mW - 3dB = 50 mW
- 10 mW + 10 dB = 100 mW
- 300 mW - 10 dB = 30 mW

Decibel

- From dB to units:

$$XdB_{unit} = 10^{\frac{X}{10}} unit$$

- -3dB = half the power in mW
- +3dB = double the power in mW
- -10dB = one tenth the power in mW
- +10dB = ten times the power in mW

Algebra

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

- The decibel (dB) is a logarithmic unit that indicates the ratio of a physical quantity (usually power or intensity) relative to a specified or implied reference level
- Decibel suffix:
- dBm: indicates that the reference quantity is one milliwatt
- dBi : dB(isotropic) – the forward gain of an antenna compared with the hypothetical isotropic antenna, which uniformly distributes energy in all directions.

Algebra

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