CS698T
Wireless Networks: Principles and Practice

Topic 03
RF Propagation, Path Loss

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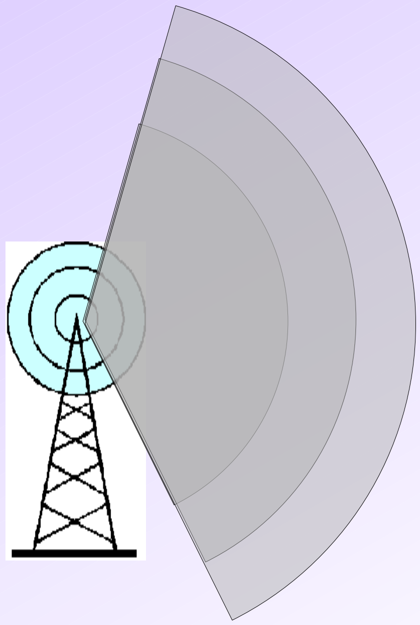
http://www.cse.iitk.ac.in/users/braman/courses/wless-spring2007/



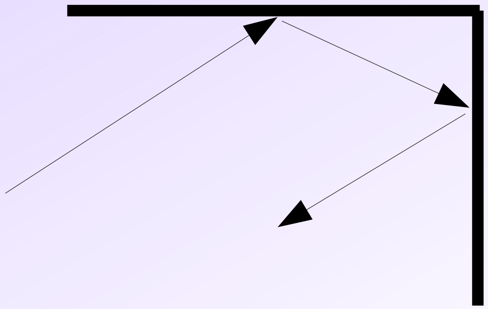
RF Propagation

Questions:
How does RF propagate with distance?
Behaviour under different environments
How to quantify these?

Goals:
Estimate coverage area, link performance

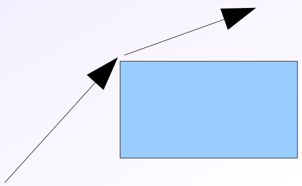
Use:
Determine network design parameters
- Locations of transmitters
- Transmit power
- Type of antenna

Three Basic Propagation Phenomena



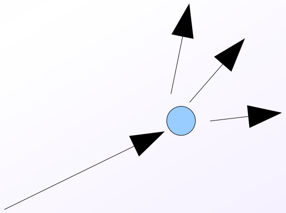
Reflection

$\lambda \ll D$



Diffraction

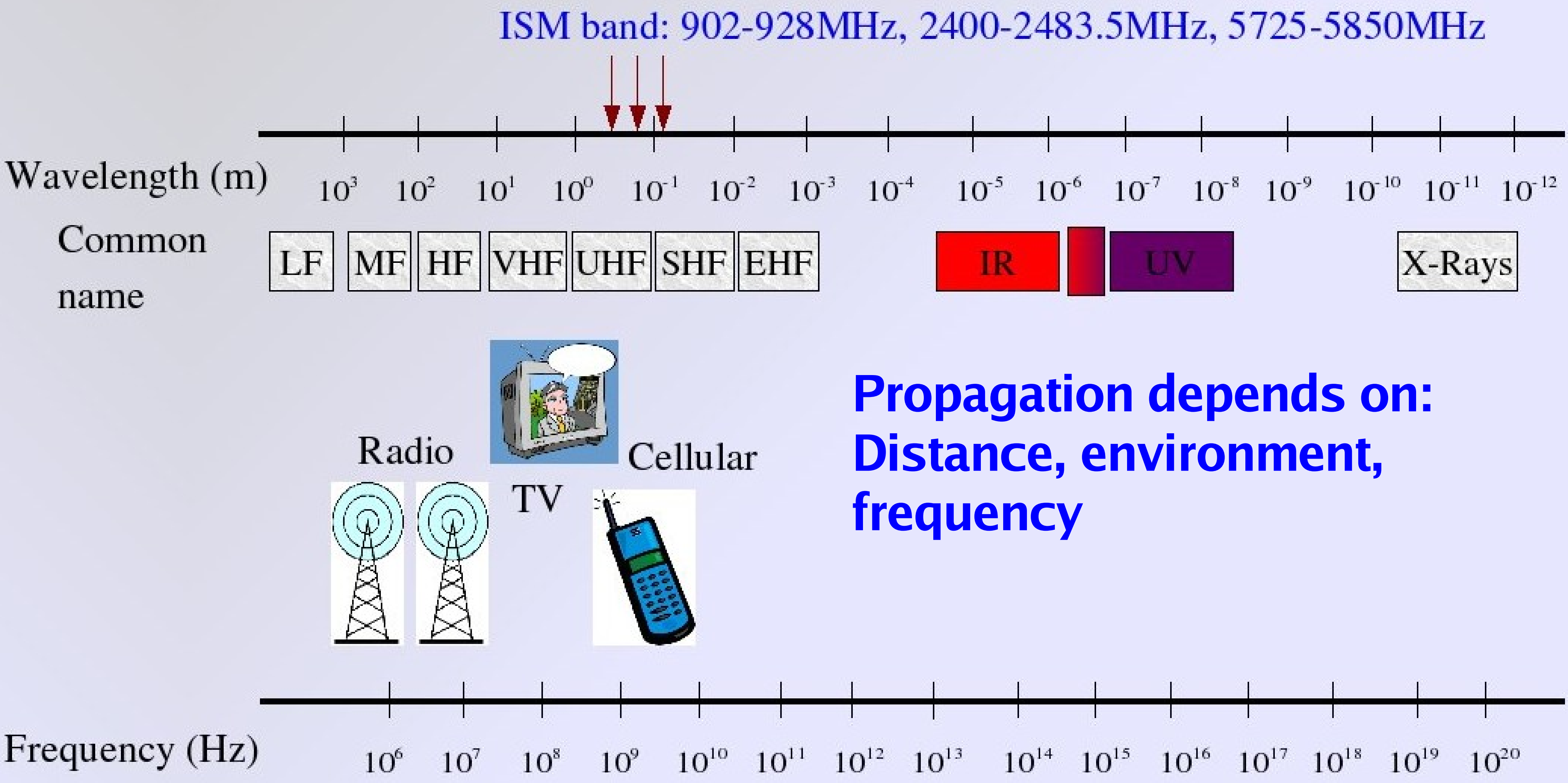
$\lambda \simeq D$



Scattering

$\lambda \gg D$

Electro-Magnetic Spectrum



Propagation depends on: Distance, environment, frequency

dB: Relative Measure (to measure propagtion)

Gravitational force on a mass *m* at distance *d/2*
4 timer more

← Gravitational force on a mass *m* at distance *d* →

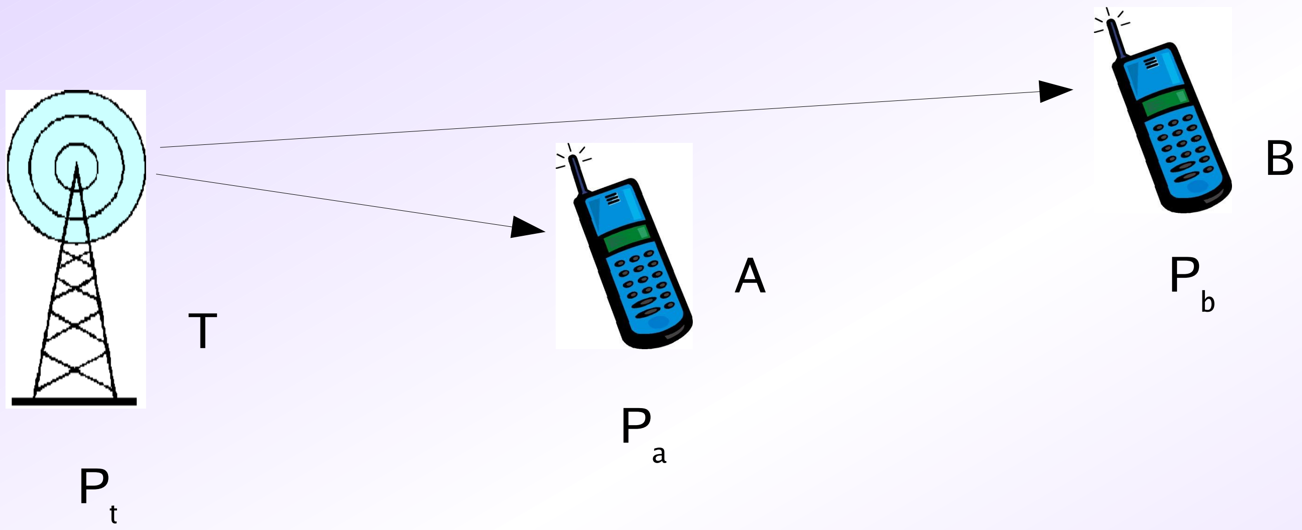
Gravitational force on a mass *m* at distance *10d*
100 times less

$$dB = 10 \times \log_{10}(ratio)$$

6dB more

20dB less

Measuring Path Loss in dB



$$Path\ loss\ at\ A = 10 \times \log_{10}\left(\frac{P_t}{P_a}\right)$$

$$Path\ loss\ at\ B = 10 \times \log_{10}\left(\frac{P_t}{P_b}\right)$$

Measuring Absolute Power in dBm

(Absolute power P) mW≡
(Relative power of P w.r.t. 1mW) dBm≡

$$10 \times \log_{10}\left(\frac{P}{1\text{mW}}\right)$$

Examples:

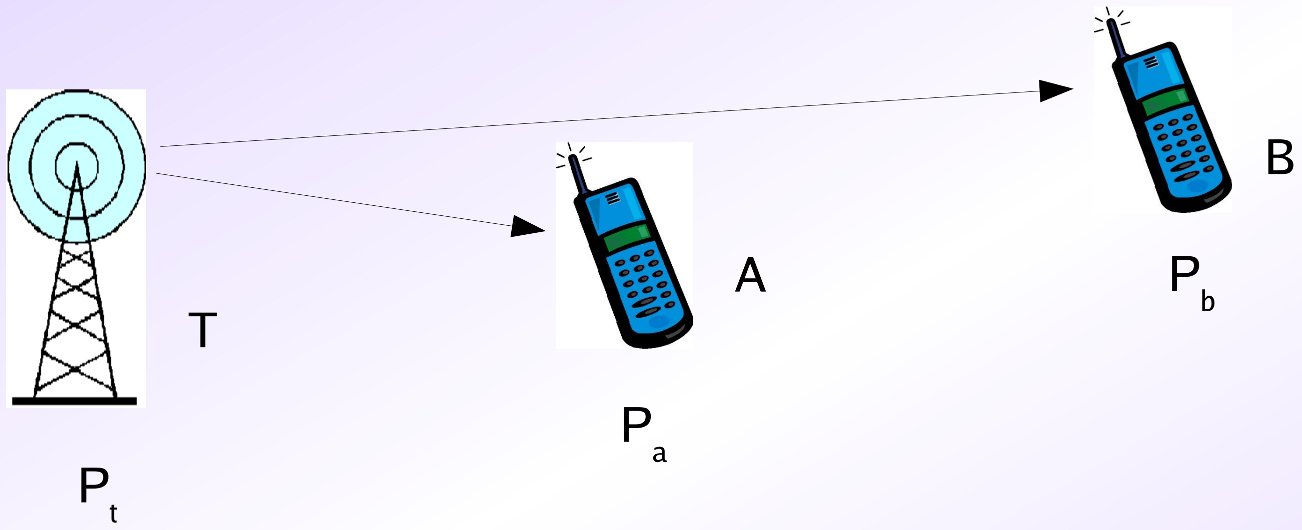
$1\text{mW} \equiv 0\text{dBm}$

$0.1\text{mW} \equiv -10\text{dBm}$

$10\text{mW} \equiv 10\text{dBm}$

$100\text{mW} \equiv 20\text{dBm}$

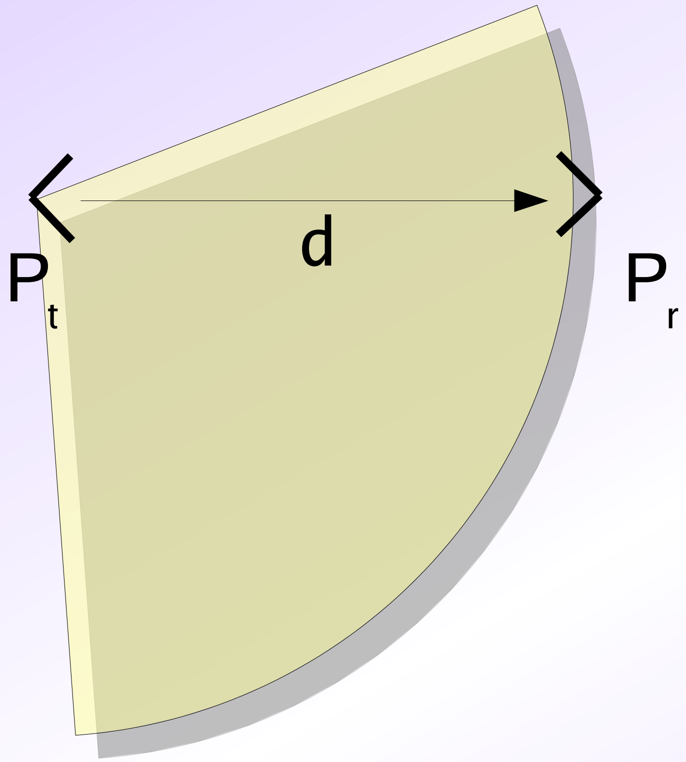
Putting Together dB and dBm



$$P_t = 20\text{dBm}, \; Path\ loss\ at\ A = 30\text{dB}, \; P_a = ?$$

$$P_a = P_t - (Path\ loss) = -10\text{dBm}$$

How to Estimate Path Loss?



$$Power\ density\ at\ receiver = PD = \frac{P_t}{4 \times \pi \times d^2}$$

$$P_r = PD \times A_{eff},$$
$$A_{eff}\ is\ the\ Effective\ Antenna\ Area$$

$$A_{eff} = \frac{\lambda^2}{4 \times \pi} \qquad P_r = P_t \times \left(\frac{\lambda}{4 \times \pi \times d}\right)^2$$

$$Path\ loss = \frac{P_r}{P_t} = \left(\frac{\lambda}{4 \times \pi \times d}\right)^2$$

The above calculations assume the use of **isotropic antennae**

Frii's Free-Space Formula

$$P_r = P_t \times \left(\frac{\lambda}{4 \times \pi \times d}\right)^2$$

Some more useful forms of the Frii's formula:

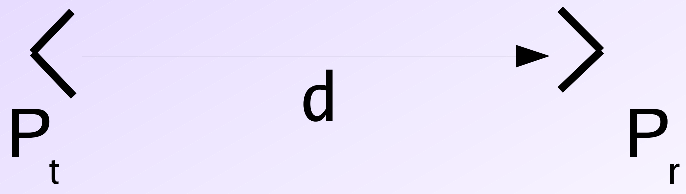
$$P_r = P_t \times \left(\frac{c}{4 \times \pi \times f \times d}\right)^2$$

Free-space path-loss

$$(P_r)_{dBm} = (P_t)_{dBm} - [32.5 + 20\log_{10}(f) + 20\log_{10}(d)]$$

where f is in MHz and d is in km

Path Loss Example



$$P_t = 50\text{mW}, 2.4\text{GHz}\ transmission, d = 2\text{km}, P_r = ?$$

$$PathLoss = 32.5 + 20\log_{10}(2400) + 20\log_{10}(2) \simeq 106\text{dB}$$

$$P_r = P_t - PathLoss = 17\text{dBm} - 106\text{dB} = -89\text{dBm}$$

Other Losses

- Cable loss:
  - Depends on the kind of cable, and its length
  - WBC400: 6dB/100ft

Path Loss Remarks

- Free space path loss is idealistic
- In reality, there is more path loss
  - Proportional to d^3 or higher
- Several path loss models are available
  - For indoor environments, outdoor metropolitan, etc.

Path Loss Models

- Ground reflection (two-ray) model
- Knife-edge diffraction model
- Outdoor propagation models
- Indoor propagation models (site-specific)
  - Partition losses (measured)
  - Depends on material
- Quick References:
  - Chapter-4: Theodore Rappaport
  - http://people.deas.harvard.edu/~jones/es151/prop_models/propagation.html