Integrated Technical Education Cluster
At AlAmeeria

E-716-A
Mobile Communications Systems

Lecture #10
Effects of Mobile Radio Propagation (p1)

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Agenda

- Types of waves
- Propagation Mechanisms
- Path Loss

Speed, Wavelength, Frequency

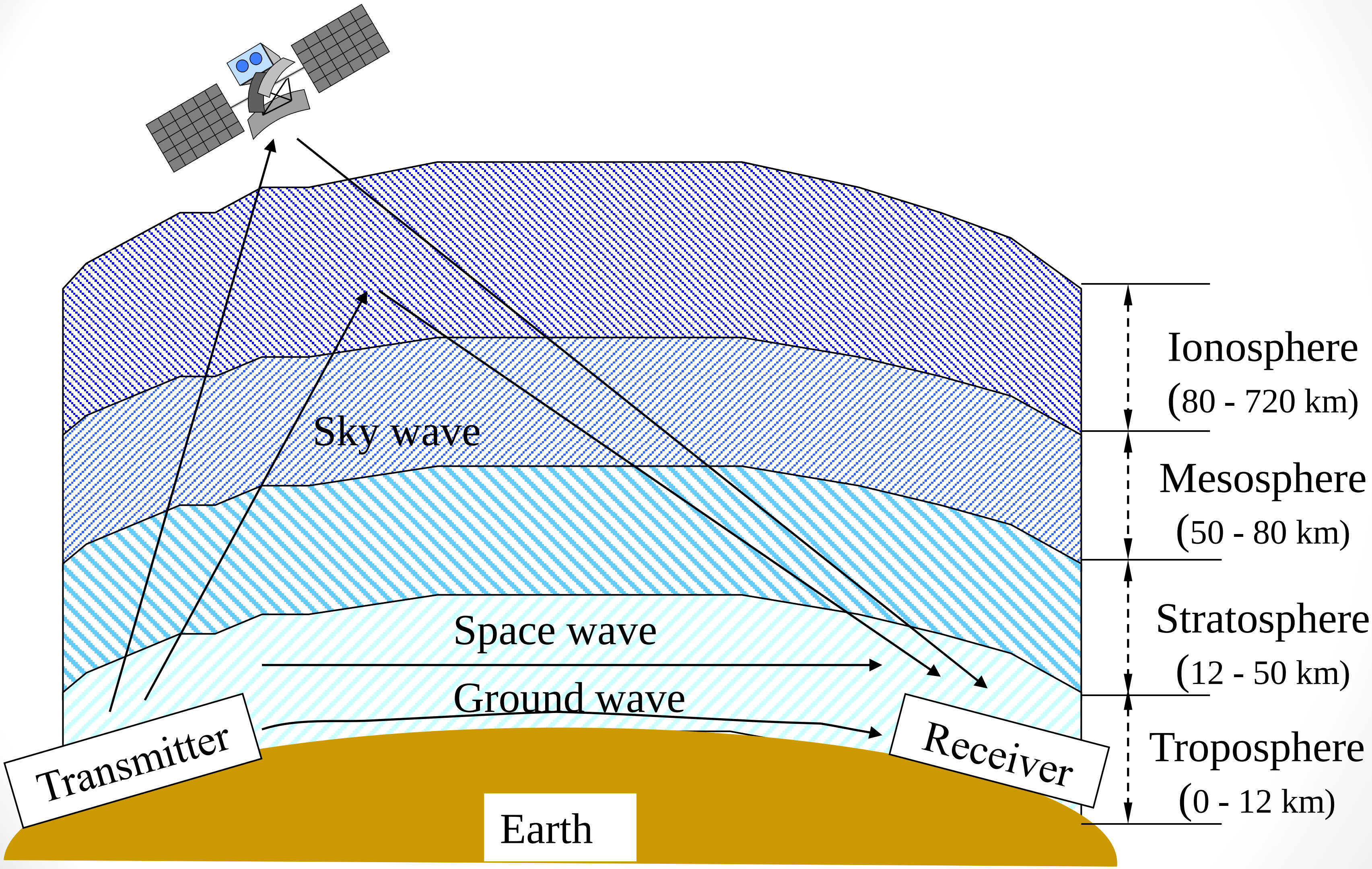
Light speed = Wavelength x Frequency

= 3×10^8 m/s = 300,000 km/s

System	Frequency	Wavelength
AC current	60 Hz	5,000 km
FM radio	100 MHz	3 m
Cellular	800 MHz	37.5 cm
Ka band satellite	20 GHz	15 mm
Ultraviolet light	10^{15} Hz	10^{-7} m

3

Types of Waves



Radio Frequency Bands

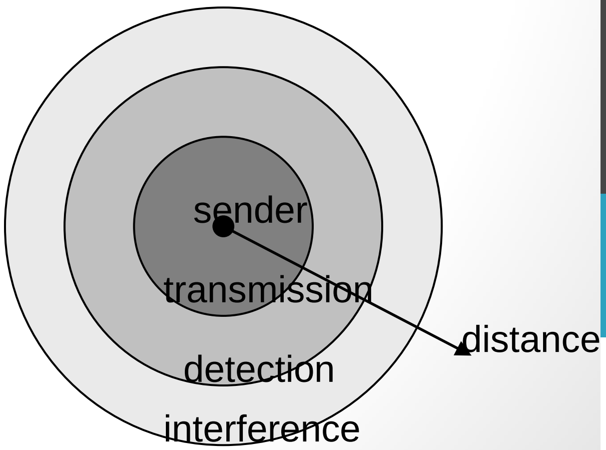
Classification Band	Initials	Frequency Range	Characteristics
Extremely low	ELF	< 300 Hz	Ground wave
Infra low	ILF	300 Hz - 3 kHz	
Very low	VLF	3 kHz - 30 kHz	
Low	LF	30 kHz - 300 kHz	
Medium	MF	300 kHz - 3 MHz	Ground/Sky wave
High	HF	3 MHz - 30 MHz	Sky wave
Very high	VHF	30 MHz - 300 MHz	Space wave
Ultra high	UHF	300 MHz - 3 GHz	
Super high	SHF	3 GHz - 30 GHz	
Extremely high	EHF	30 GHz - 300 GHz	
Tremendously high	THF	300 GHz - 3000 GHz	

Propagation Mechanisms

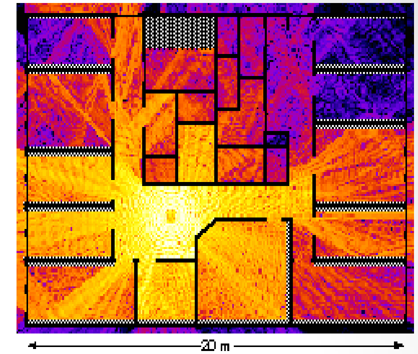
- Reflection
  - Propagation wave impinges on an object which is large as compared to wavelength

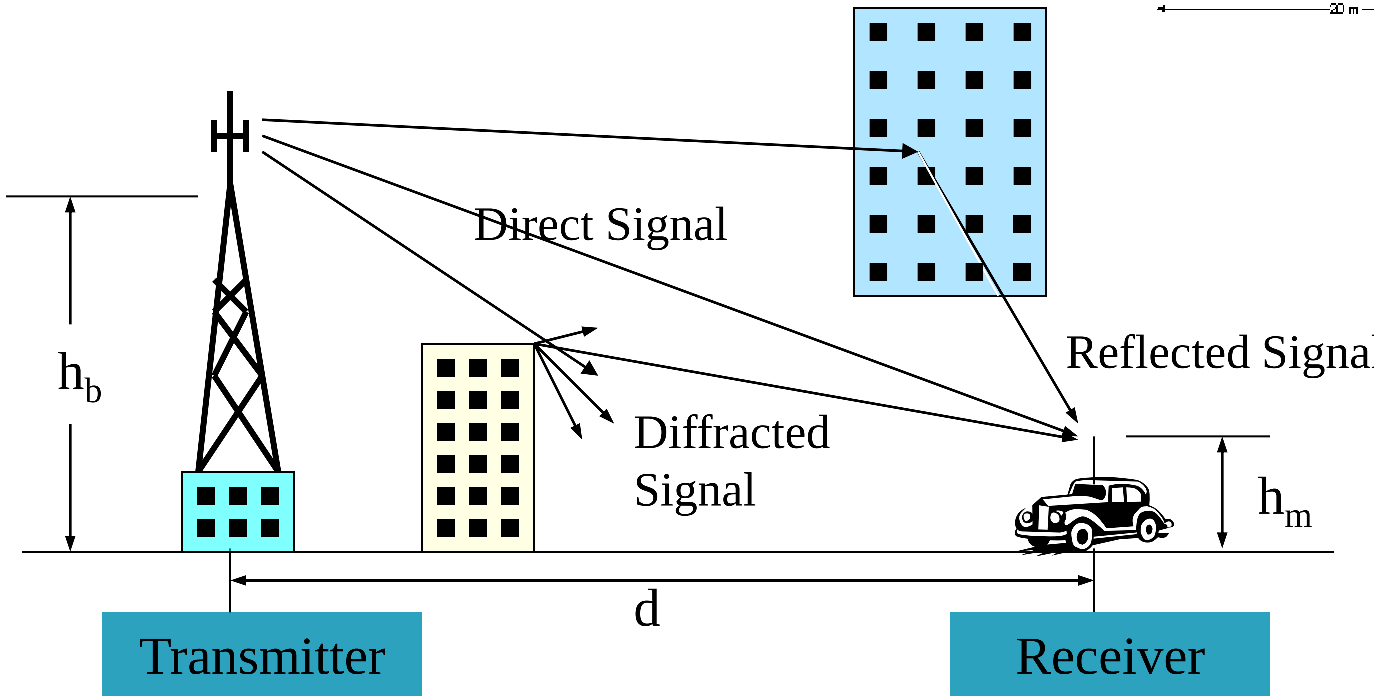
    - e.g., the surface of the Earth, buildings, walls, etc.
- Diffraction
  - Radio path between transmitter and receiver obstructed by surface with sharp irregular edges
  - Waves bend around the obstacle, even when LOS (line of sight) does not exist
- Scattering
  - Objects smaller than the wavelength of the propagation wave

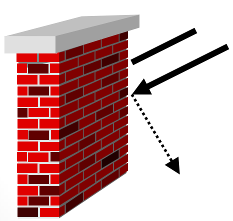
    - e.g. foliage, street signs, lamp posts
- Shadowing !



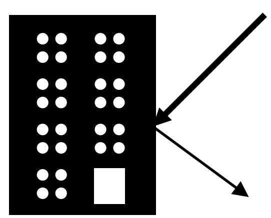
Radio Propagation Effects



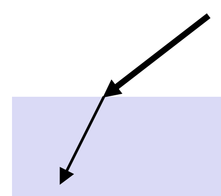




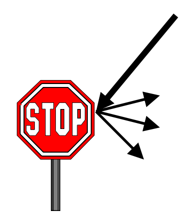
shadowing



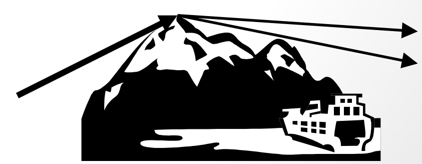
reflection



refraction

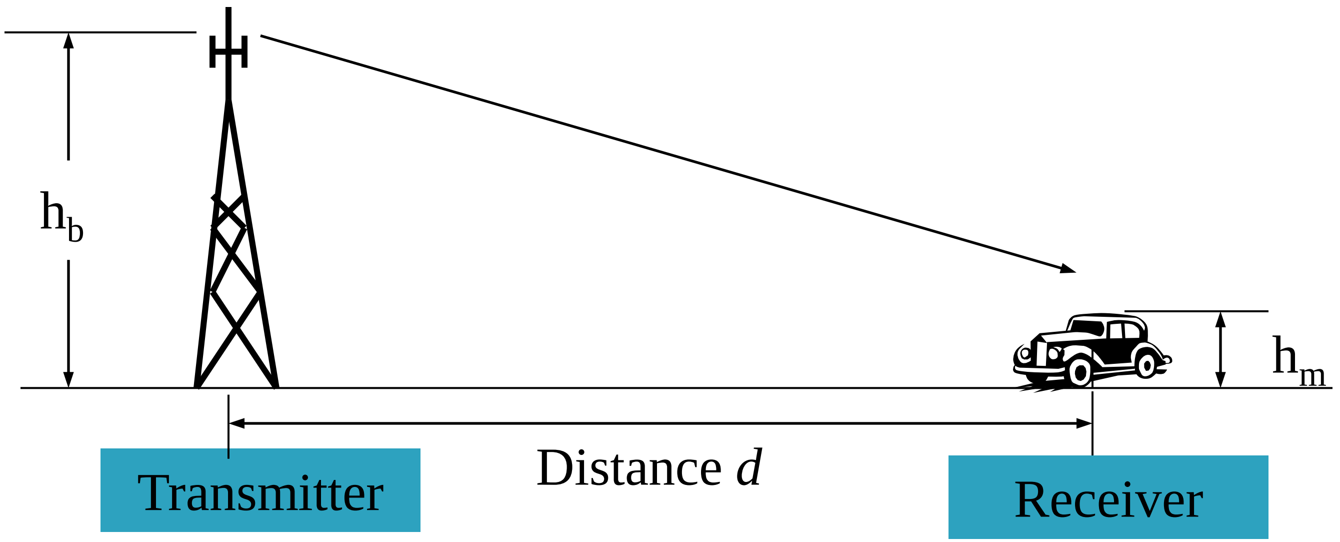


scattering



diffraction

Free-space Propagation



- The received signal power at distance *d*:

$$P_r = \frac{A_e G_t P_t}{4\pi d^2}$$

where P_t is transmitting power, A_e is effective area, and G_t is the transmitting antenna gain. Assuming that the radiated power is uniformly distributed over the surface of the sphere.

Antenna Gain

- For a circular reflector antenna

  Gain $G = \eta \, (\pi D / \lambda)^2$

  η = net efficiency (depends on the electric field distribution over the antenna aperture, losses, ohmic heating , typically 0.55)

  D = diameter

  thus, $G = \eta \, (\pi D f / c)^2$, $c = \lambda f$ (c is speed of light)

Example:

- Antenna with diameter = 2 m, frequency = 6 GHz, wavelength = 0.05 m

  G = 39.4 dB

- Frequency = 14 GHz, same diameter, wavelength = 0.021 m

  G = 46.9 dB

* Higher the frequency, higher the gain for the same size antenna

Land Propagation

- The received signal power:

$$P_r = \frac{G_t G_r P_t}{L}$$

where G_r is the receiver antenna gain,

L is the propagation loss in the channel, i.e.,

$$L = L_P \, L_S \, L_F$$

- L_F: Fast fading
- L_S: Slow fading
- L_P: Path loss

Path Loss (Free-space)

- Definition of path loss L_P:

$$L_P = \frac{P_t}{P_r},$$

Path Loss in Free-space:

$$L_{PF}(dB) = 32.45 + 20\log_{10} f_c(MHz) + 20\log_{10} d(km),$$

where f_c is the carrier frequency.

This shows greater the $f_{c\,,}$ more is the loss.

Path Loss (Land Propagation)

- Simplest Formula:

$$L_p = A\, d^{-\alpha}$$

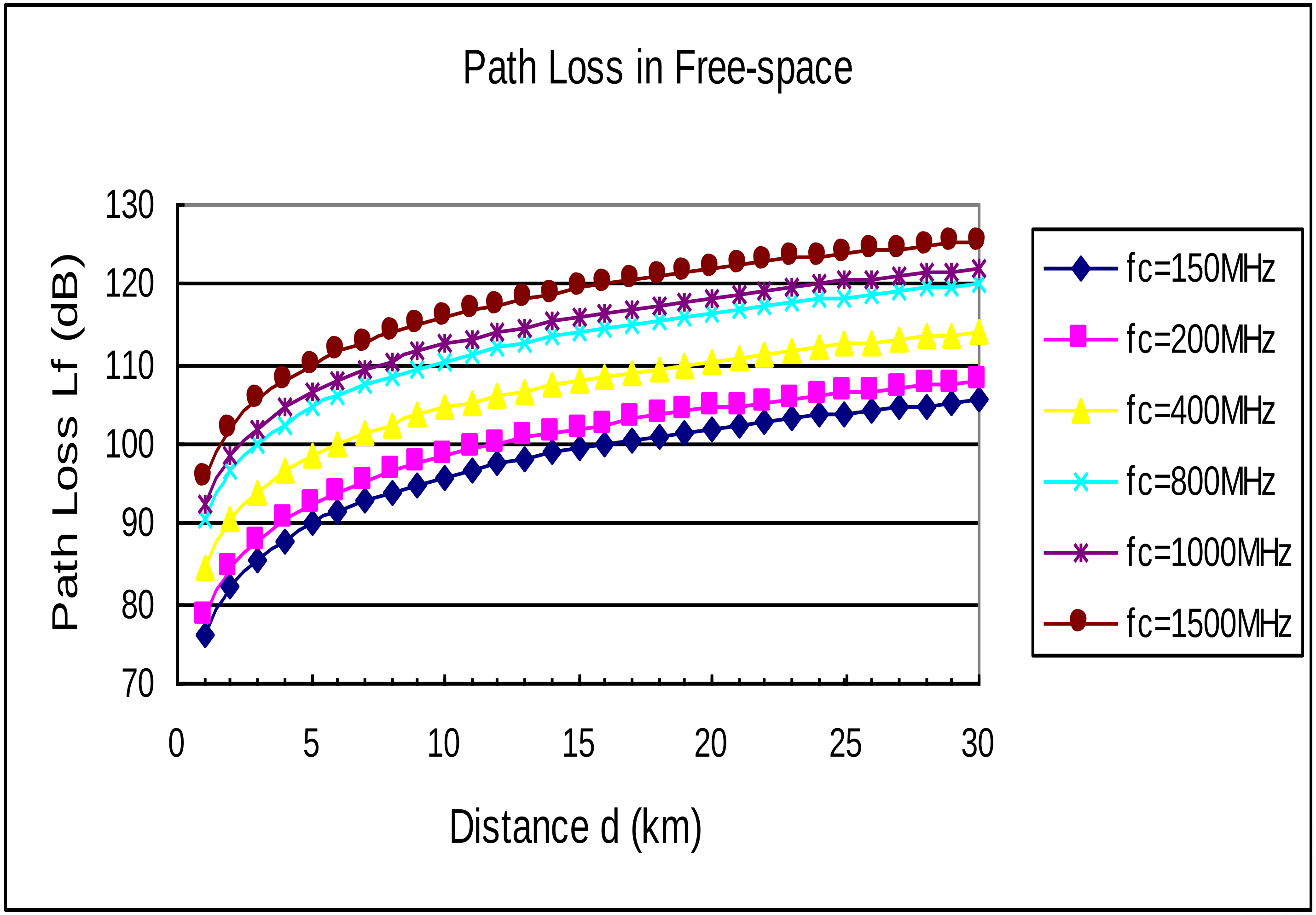
where

A and α: propagation constants

d : distance between transmitter and receiver

α : value of 3 ~ 4 in typical urban area

Example of Path Loss (Free-space)



Path Loss (Urban, Suburban and Open areas)

- Urban area:

$$L_{PU}(dB) = 69.55 + 26.16\log_{10} f_c(MHz) - 13.82\log_{10} h_b(m) - \alpha\left[h_m(m)\right] + \left[44.9 - 6.55\log_{10} h_b(m)\right]\log_{10} d(km)$$

where

$$\alpha\left[h_m(m)\right] = \begin{cases} \left[1.1\log_{10} f_c(MHz) - 0.7\right]h_m(m) - \left[1.56\log_{10} f_c(MHz) - 0.8\right], & for\ large\ city \\ \left.\begin{matrix} 8.29\left[\log_{10} 1.54 h_m(m)\right]^2 - 1.1, & for \quad f_c \le 200MHz \\ 3.2\left[\log_{10} 11.75 h_m(m)\right]^2 - 4.97, & for \quad f_c \ge 400MHz \end{matrix}\right\}, & for\ small\ \&\ medium\ city \end{cases}$$

- Suburban area:

$$L_{PS}(dB) = L_{PU}(dB) - 2\left[\log_{10}\frac{f_c(MHz)}{28}\right]^2 - 5.4$$

- Open area:

$$L_{PO}(dB) = L_{PU}(dB) - 4.78\left[\log_{10} f_c(MHz)\right]^2 + 18.33\log_{10} f_c(MHz) - 40.94$$

Path Loss

- Path loss in decreasing order:
  - Urban area (large city)
  - Urban area (medium and small city)
  - Suburban area
  - Open area

- For more details, refer to:
  - Chapter 2, A. Goldsmith, Wireless Communications, 2004.
- The lecture is available online at:
  - https://speakerdeck.com/ahmad_elbanna
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg