WAVE PROPAGATION PARAMETERS

ELECTROMAGNETIC WAVES

- How strong?
- How far?
- How long?

PROPAGATION CONSTANT

- Maxwell's equations

- γ - Propagation constant (m):

$$\gamma = \alpha + j\beta$$

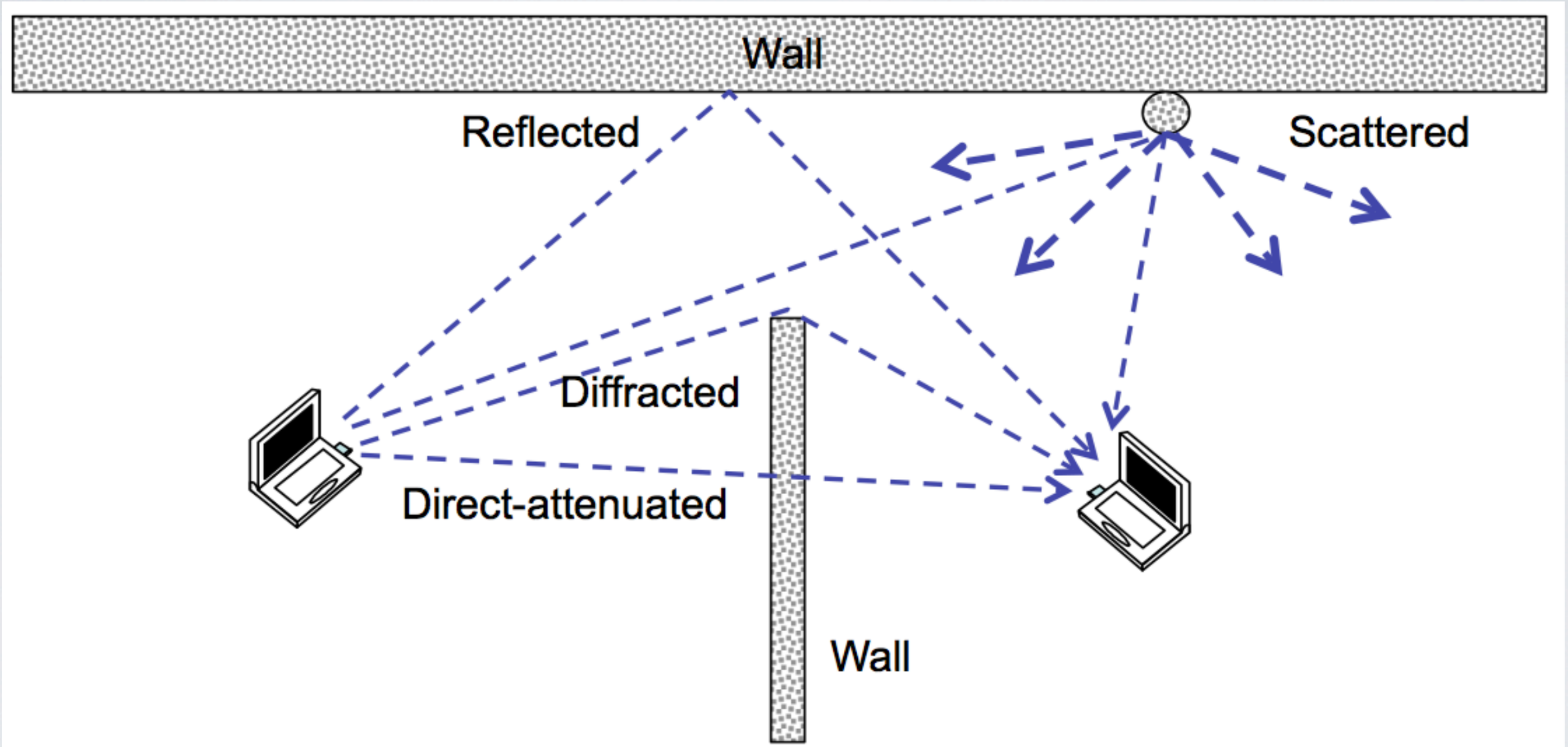
- α - Real part: attenuation constant (*Np/m*)

- β - Imaginary part: phase constant (*rad/m*)

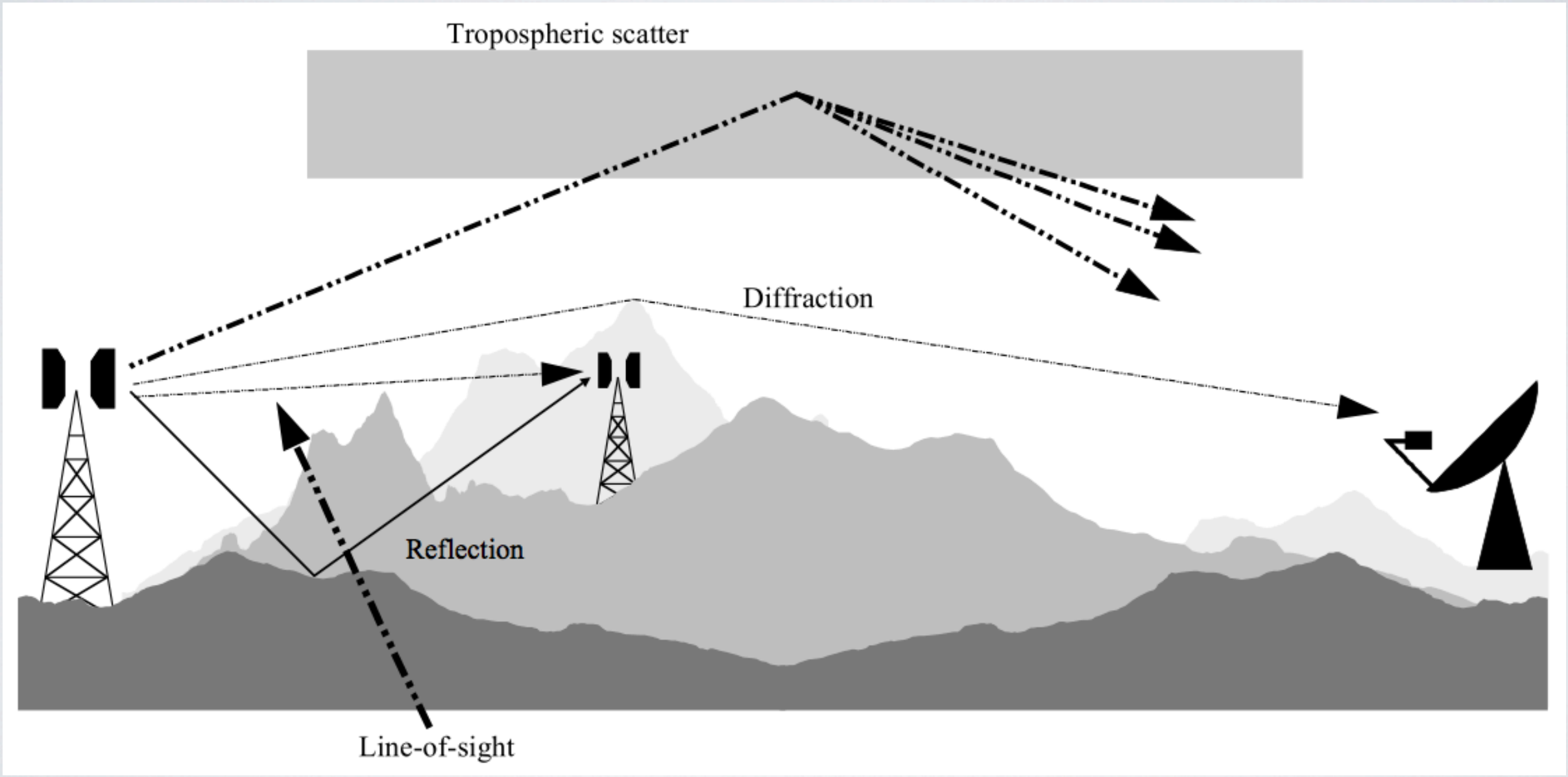
PROPAGATION EFFECTS

- Basic energy spreading
- Effects of obstructions (indoor & outdoor)
- Effects of the ground
- Tropospheric effects (outdoor)
- Ionospheric effects (outdoor)

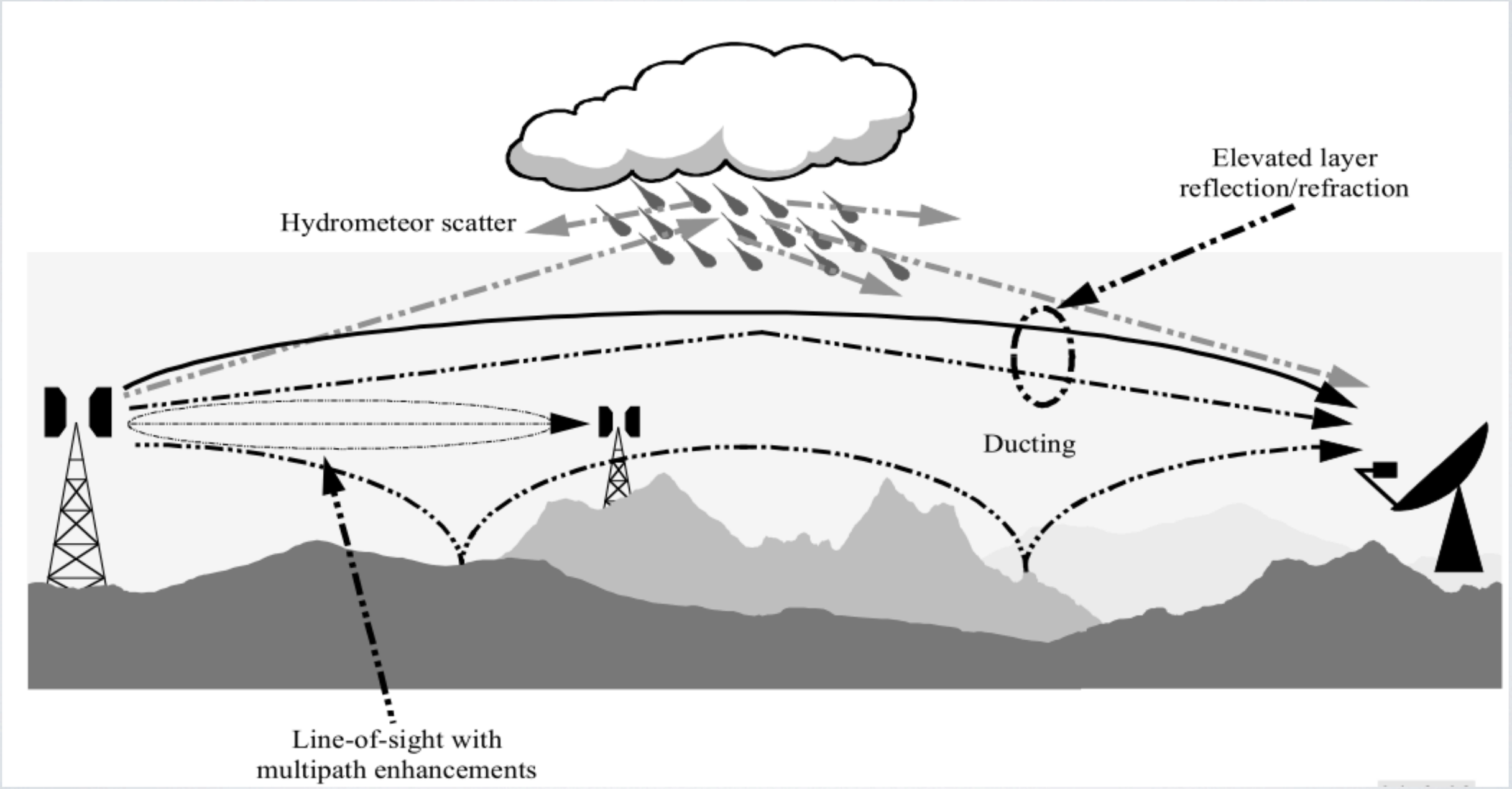
INDOOR PROPAGATION



OUTDOOR PROPAGATION



OUTDOOR PROPAGATION



PROPAGATION MECHANISMS

- Direct wave
- Attenuated wave
- Reflected wave
- Scattered wave
- Diffracted wave

GROUND WAVE

- Lower frequencies travel efficiently as ground waves
- Strong diffraction
- Earths curvature
- Ionospheric reflection

REFRACTION

- Change of direction, due to;
  - change in media (going from one media, to another)
  - passing through a medium that is a continuos function of position (graded-index fiber, earth atmosphere)
- Phase velocity changed, but frequency remains the same
- Snell's law

SUPER REFRACTION

- Also known as ducting, or "skip"
- Horizontal layer in the lower atmosphere
- Certain conditions (hot/warm air)
- Refractive index

PROPAGATION MODELS

Empirical mathematical formulation

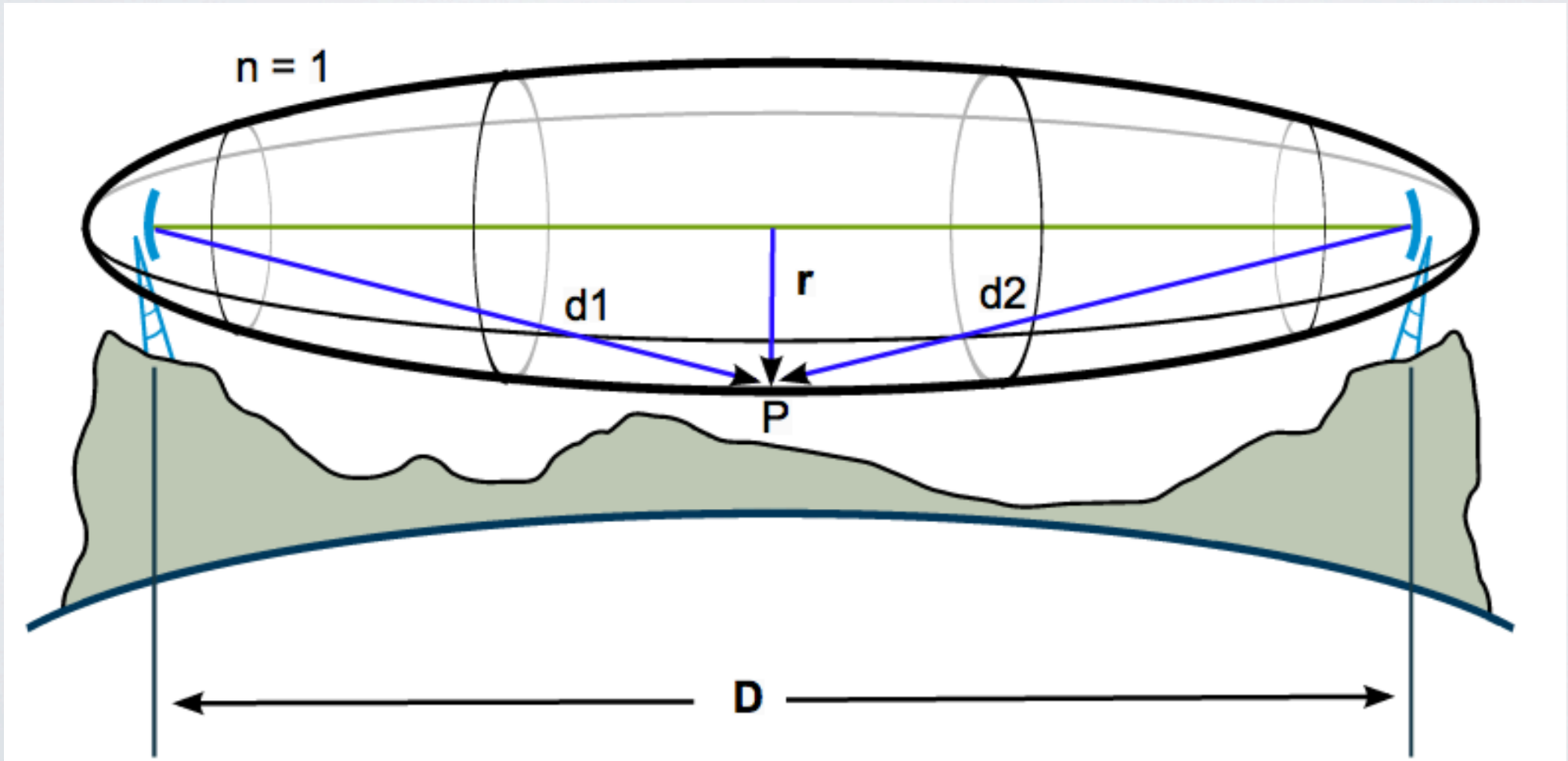
- Used to define wave propagation (path loss)
- A function of frequency, distance, and other conditions
- Usually one single model for propagation for all similar links under similar circumstances
- Many different models: various propagation mechanisms, different environments (indoor, outdoor, land, sea, space, etc), different applications, different frequencies, etc.

FREE-SPACE

- Simplest model of them all
- LOS
- No obstacles
- No hardware predictions (antenna gain, etc)

LOS

- Almost the same as free-space, if within first Fresnel zone, and has no reflections or other propagation effects



OKUMURA-HATA

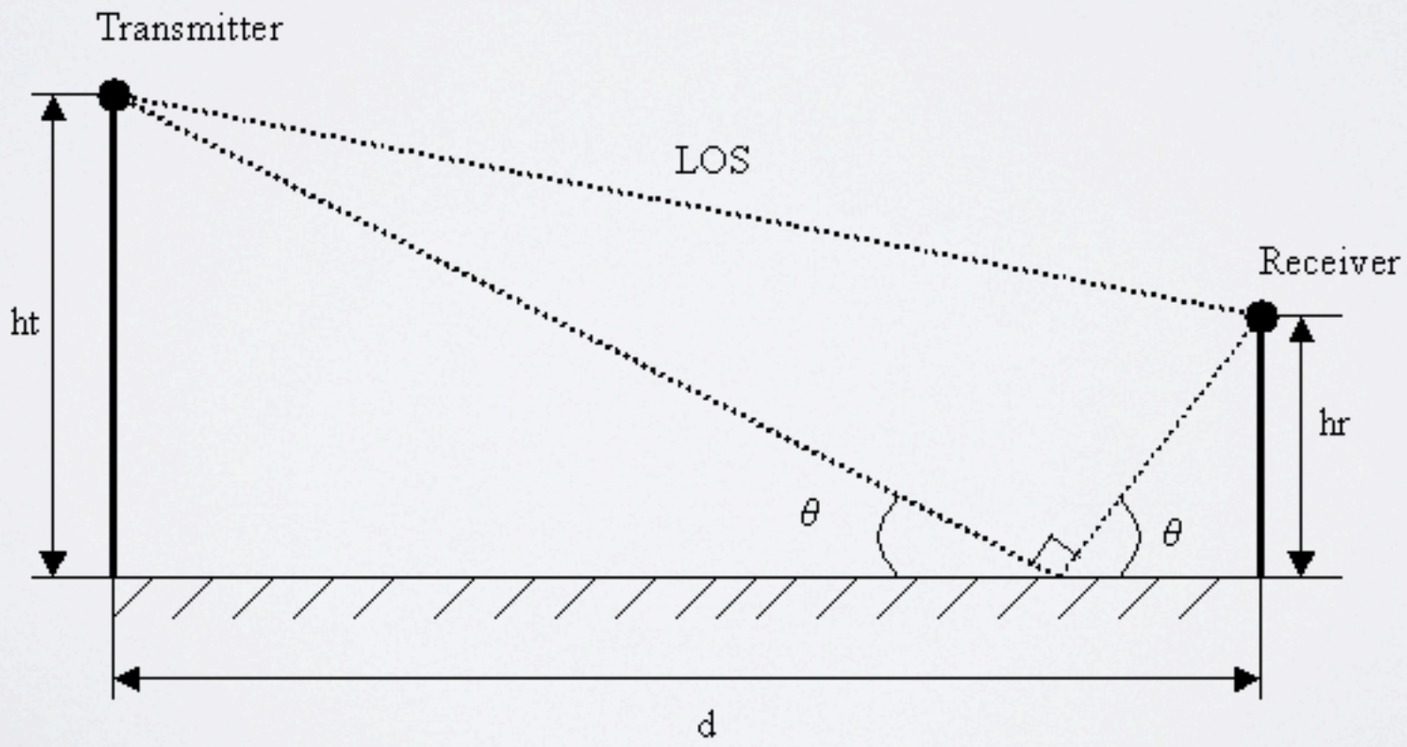
- One of the most widely used models for mobile communication systems
- Three varieties of it:
  - Urban areas
  - Suburban areas
  - Open areas

NON-LOS

- If the first Fresnel zone is obstructed
  - Obstacles not entering the first zone, can be ignored
- And/or if signal reaches the receiver due to reflection, refraction, diffraction, etc
- Obstructions can be located to either sides of the path, or above/below.

2-RAY MODEL

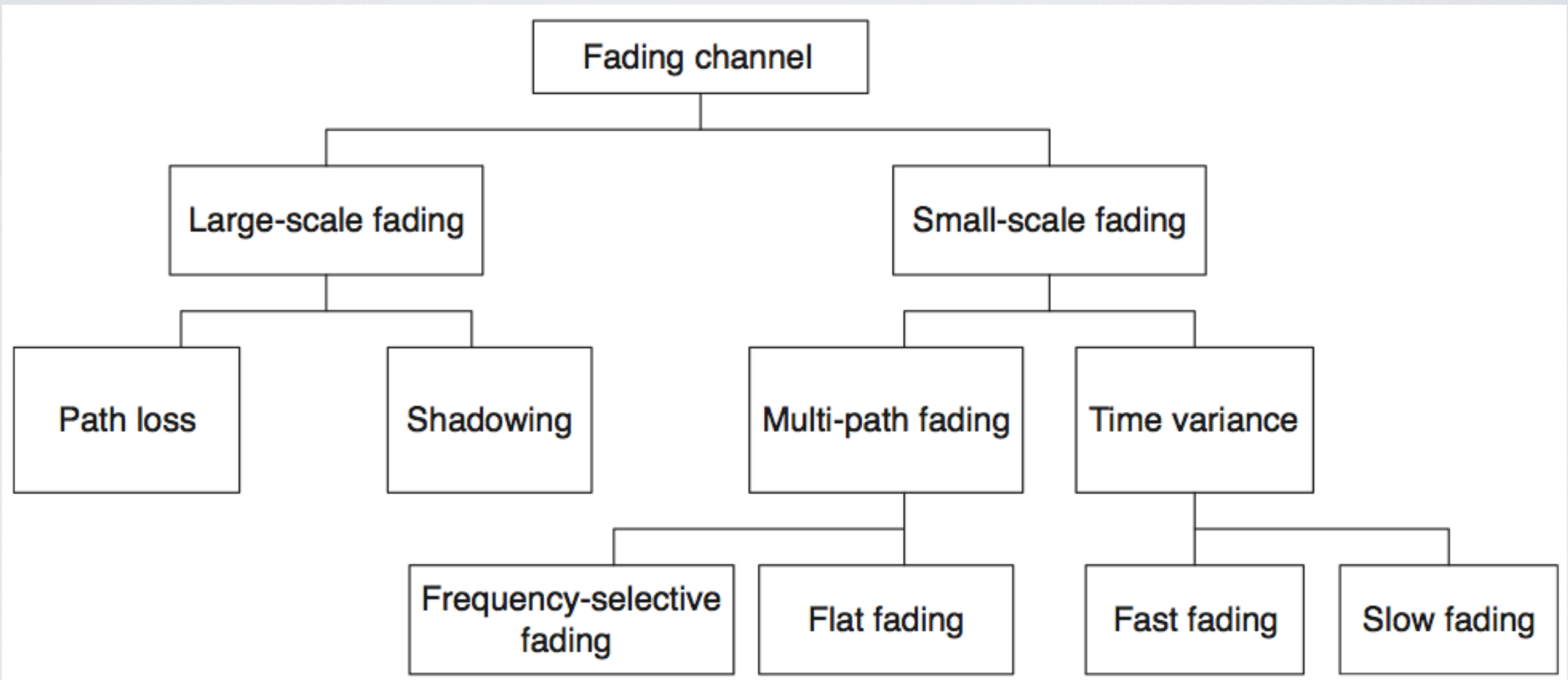
- Received and reflected waves differ
- Accurate for both short and long distances



FADING

- Random phenomena
- Variation of the signal amplitude over time and frequency
- Applies to mobile devices (mobile phones, radio, etc)
- Two main types:
  - Large-scale fading
  - Small-scale fading

FADING


Fading channel
Large-scale fading
Small-scale fading
Path loss
Shadowing
Multi-path fading
Time variance
Frequency-selective fading
Flat fading
Fast fading
Slow fading

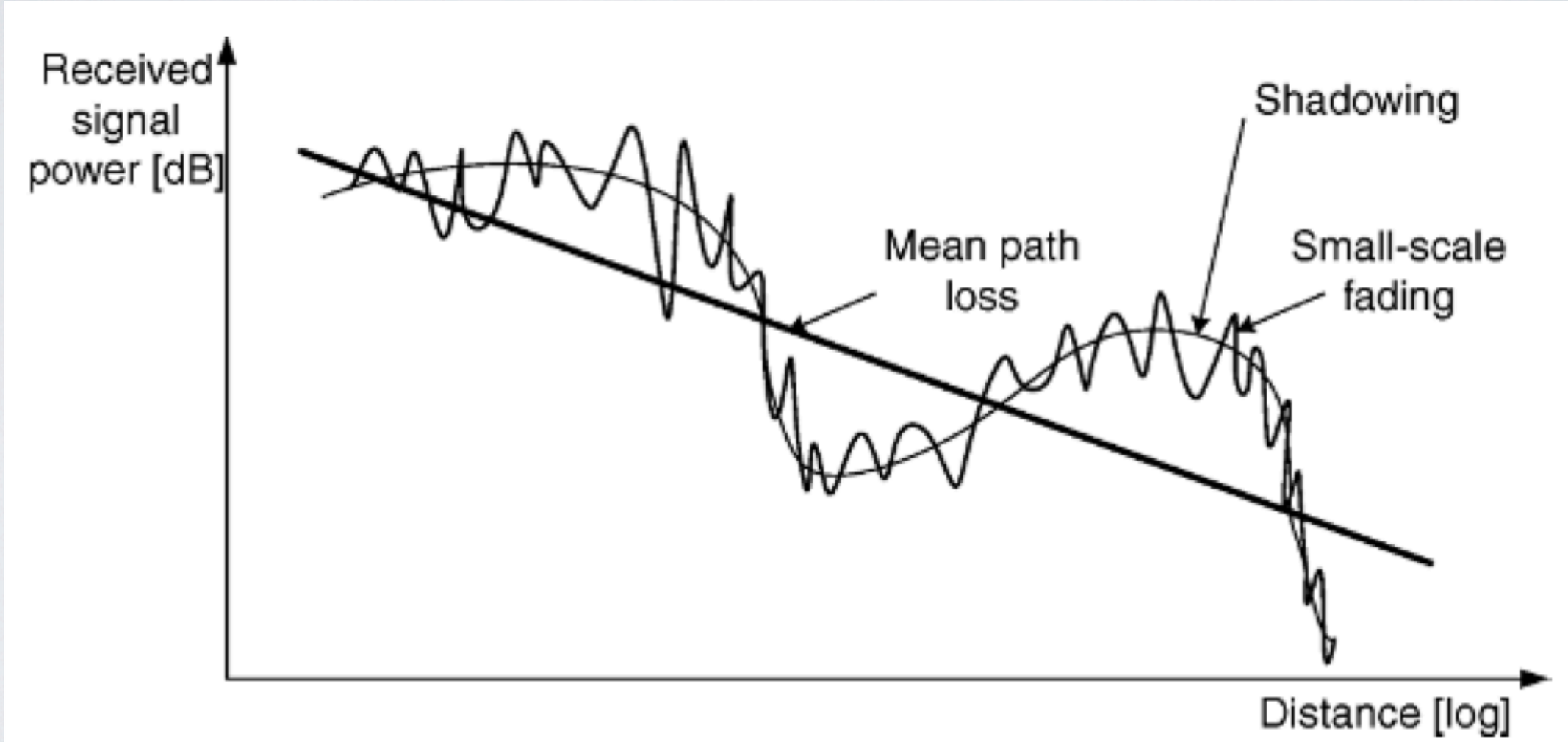
LARGE-SCALE FADING

- Occurs as the mobile moves through large distances
- Often a distance of the order of a cell size
- Mean path loss, that decreases with distance
- Shadowing that varies along the mean path loss

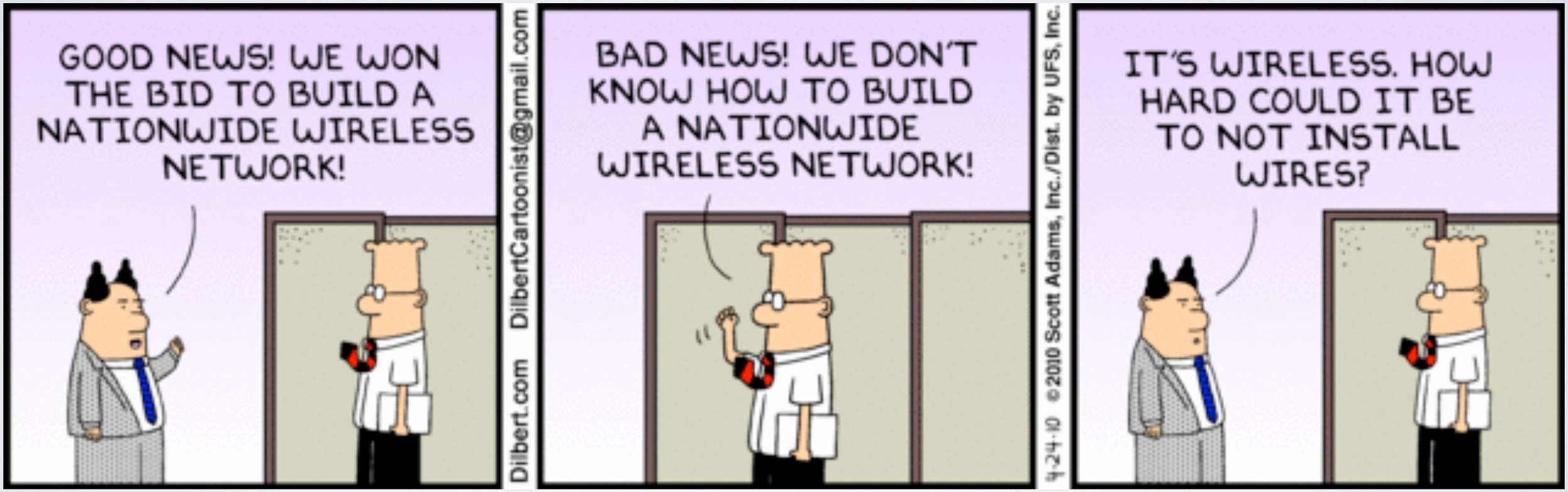
SMALL-SCALE FADING

- Occurs as the mobile moves through short distances
- Con- and destructive interference of multiple paths (also called multi-paths)
- Depending on the time variation, it can be classified as fast fading or slow fading.
- Doppler effect

LARGE- VS SMALL-SCALE



QUESTIONS?


GOOD NEWS! WE WON THE BID TO BUILD A NATIONWIDE WIRELESS NETWORK!
BAD NEWS! WE DON'T KNOW HOW TO BUILD A NATIONWIDE WIRELESS NETWORK!
IT'S WIRELESS. HOW HARD COULD IT BE TO NOT INSTALL WIRES?
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