# Propagation

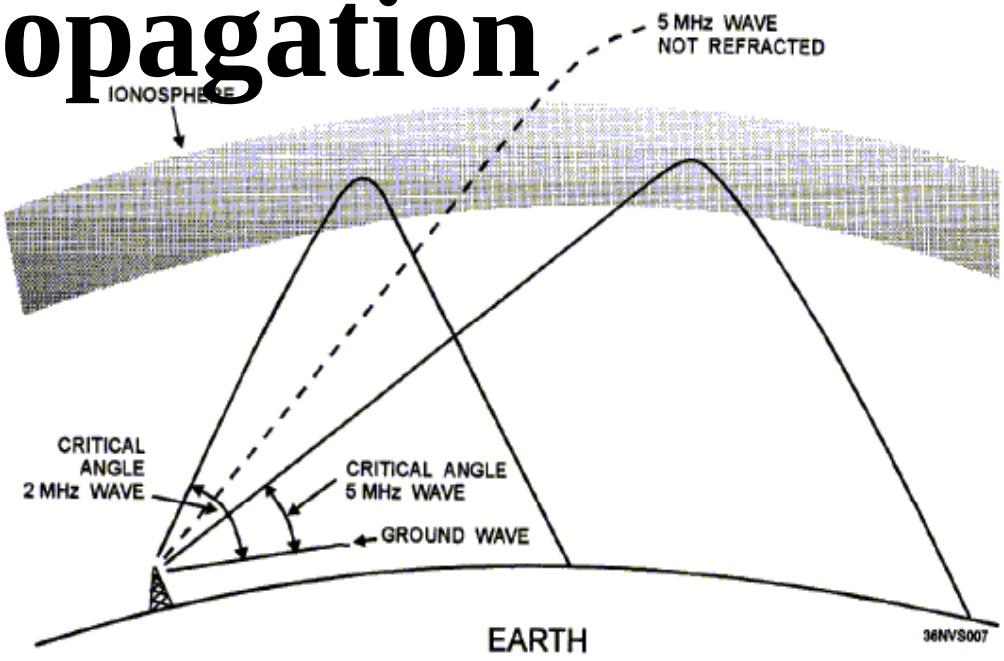



Figure 1-7.—Effect of frequency on the critical angle.

# Basic Propagation Mechanism



Wave length and frequency

$$\lambda = \frac{c}{f} = \frac{3\times 10^{8}\, m/\sec}{f}$$

$c$ : speed of light
$f$ : frequency

| $\lambda$ | $f$ | Example | |
|---|---|---|---|
| 1km | 300kHz | AM = 1000kHz | $\lambda_{AM}=300m$ |
| 1m | 300MHz | FM = 100MHz | $\lambda_{FM}=3m$ |
| | | Cellular = 900MHz | $\lambda_{cell}=30cm$ |
| | | PCS = 2GHz | $\lambda_{PCS}=12cm$ |
| 1mm | 300GHz | Satellite = 30GHz | $\lambda_{Sat}=10mm$ |

# Radio Wave Interaction



(General principle)

Radio wave only interacts with objects it can see

It can only see objects that are large relatively to its wave length

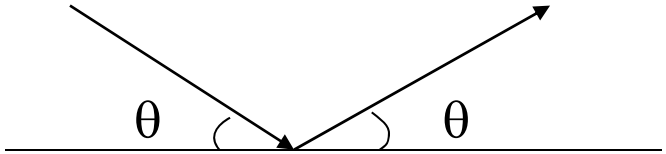
- $\lambda_{AM}$=300m: does not interact with a building
- $\lambda_{FM}$=3m: interacts with a building, but not with a stop sign
- $\lambda_{Cell}$=30cm: interacts with a building, and a stop sign

# How electromagnetic waves interact ?



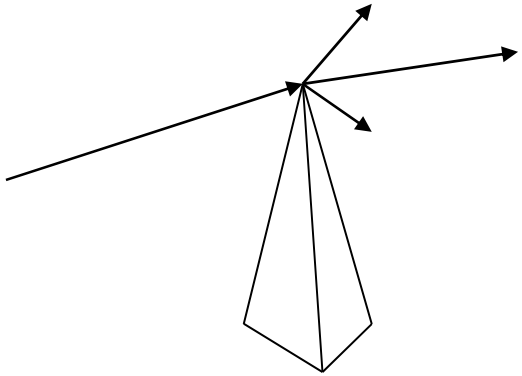
**Reflection**: size of object > λ

Due to flat and uniform surfaces




**Diffraction**: size of object > λ

Due to edges of objects



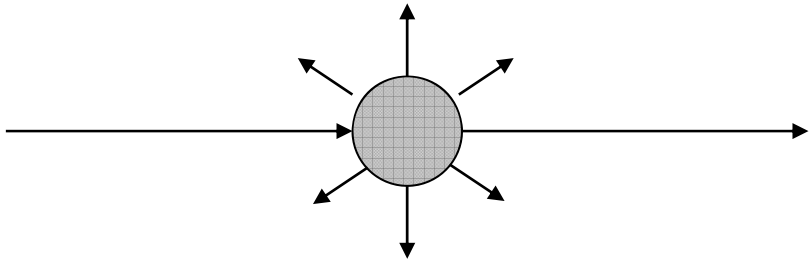
# How electromagnetic waves interact ?



**Scattering**: size of object < $\lambda$

Due to irregular and small objects

i.e., rain drops, leaves of a tree



The higher the frequency, the more the attenuation due to scattering

# How electromagnetic waves interact ?



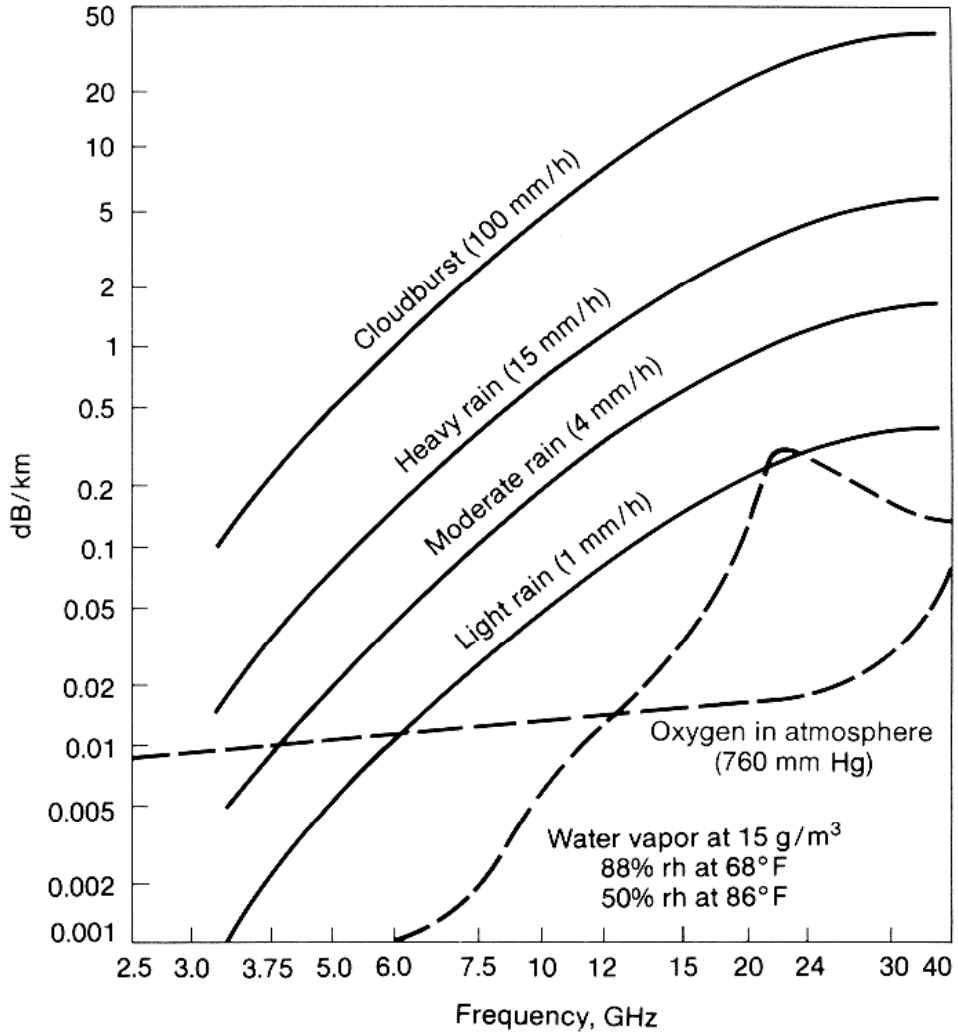



**Figure 12.11** Estimated atmospheric absorption. (*From Ref. 8, p. 443.*)

# How electromagnetic waves interact ?



Even in small wall, some waves reflect and some other waves scatter

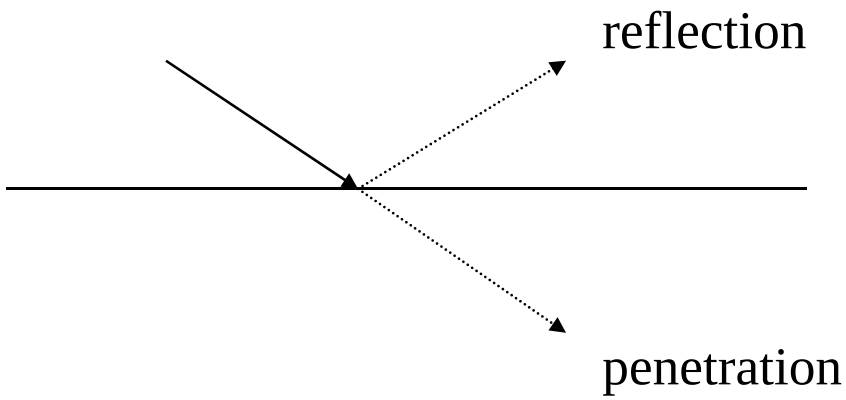
# How electromagnetic waves interact ?

## Penetration

If conductor, no penetration

Current flows on the surface of a conductor

Not perfect conductor, the wave penetrates



# Summary

High Frequency

- Almost everything looks rough surface in natural environment
- Scattering much
- Signal does not propagate much unless it has line of sight

Low Frequency $< 3GHz, \lambda \geq 10cm$

- Good reflection/Diffraction
- Signal fills up entire space (Good news)
- Many signal paths, multipath (Bad news)