Wireless Network and Mobile Computing

This chapter covers the following topics

01 **Interference** — Several types of external interference that can adversely affect a wireless signal are described.

02 **Free Space Path Loss** — Why a radio frequency signal degrades as it travels through free space?.

03 **Effects of Physical Objects** —This section explores what happens when an RF signal meets various physical objects. (reflection, absorption, refraction, and diffraction)

01

Interference — Several types of external interference that can adversely affect a wireless signal are described.

Exam topics:

- ✓ Describe the propagation of radio waves.
- ✓ Absorption, reflection, diffraction, scattering, refraction, fading, free space path loss, multipath.
- ✓ Interpret RF signal measurements
- ✓ Differentiate interference vs. noise

RF Signals in the Real World

❖ The idea behind WLAN modulation

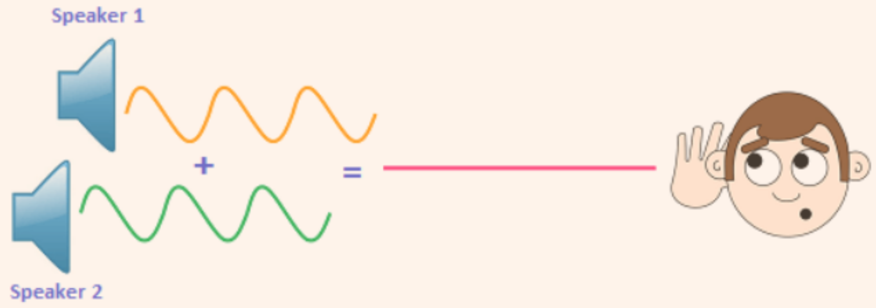
- Pack as much data as possible into the wireless signal.
- Minimize the amount of data that might be lost due to interference or noise.

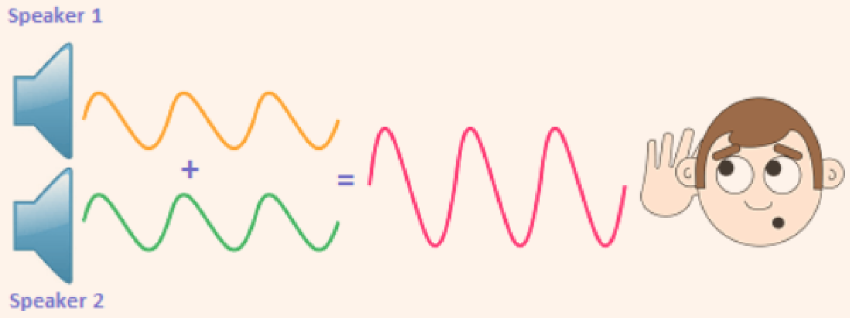
❖ Radio frequency (RF) signals travel as electromagnetic waves. Ideally, the received signal is identical to the transmitted signal.

❖ Practically, many things affect RF signals during its propagation.

❑ Interference phenomena

❖ Physicists: Interference concerned with the "behaviour of waves".





❑ Interference phenomena

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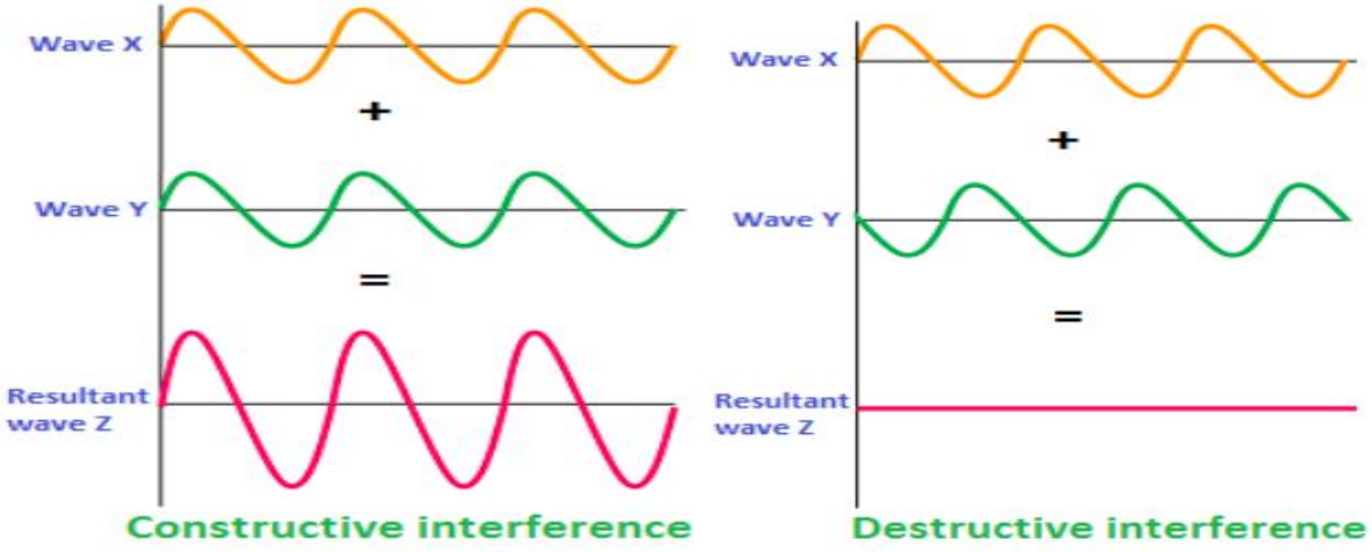


Example 1: The way that antennas are arranged in what are called beamforming arrays, in order to give maximum constructive interference in a certain directions, and destructive interference (no signal) in other directions.

Example 2: Let we have three antennas - and we don't want antenna 3 to pick up signal from antenna 1 and 2. You would then place antenna 3 at a position where the signals from antennas 1 and 2 canel each other out.

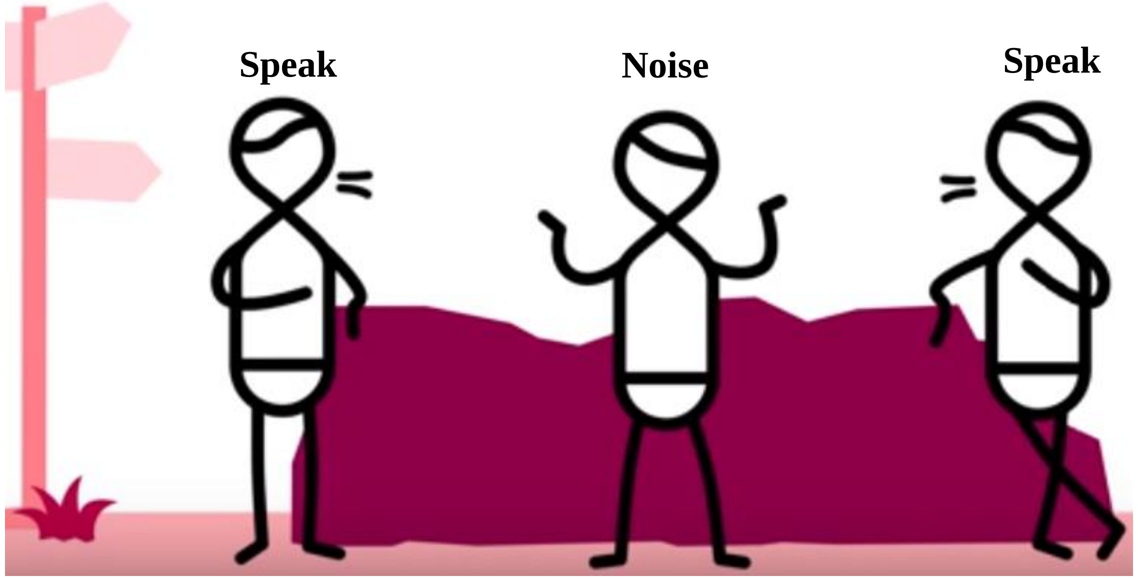
For demo: visit:

https://www.desmos.com/calculator/m2tmszn

RF Signals in the Real World

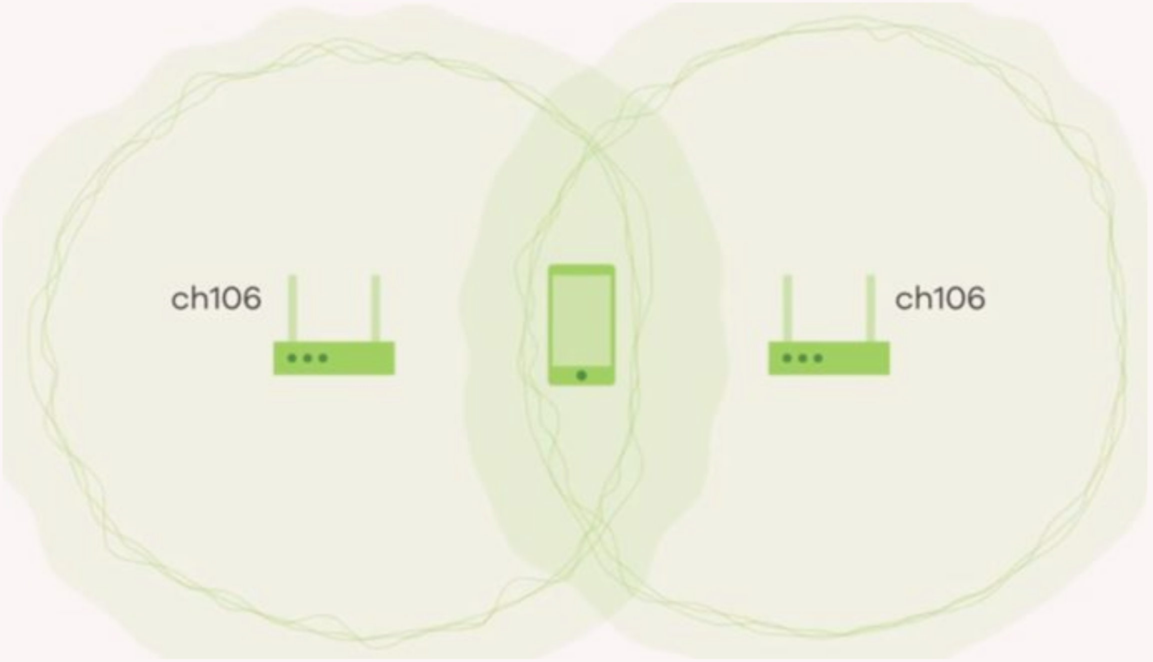
❑ Interference phenomena

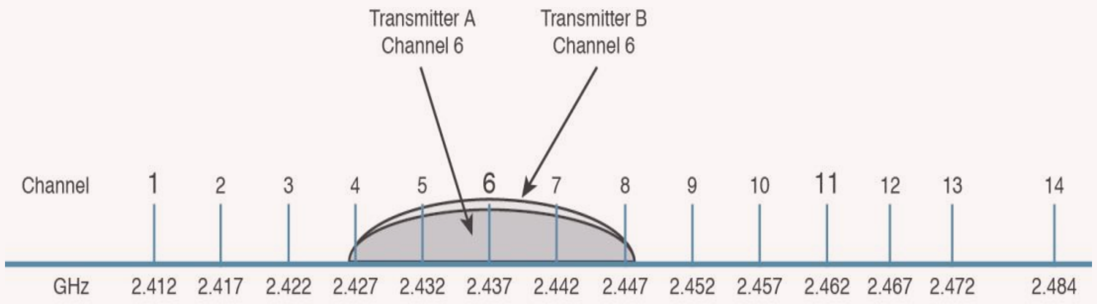
❖ Telecommunications engineer: "… any noise that gets in the way".



❖ Co-Channel Interference

- Whenever one transmitter's signal overlaps another on a frequency or channel, the signals interfere with each other.
- Co-channel interference occurs when two or more transmitters use the same channel.





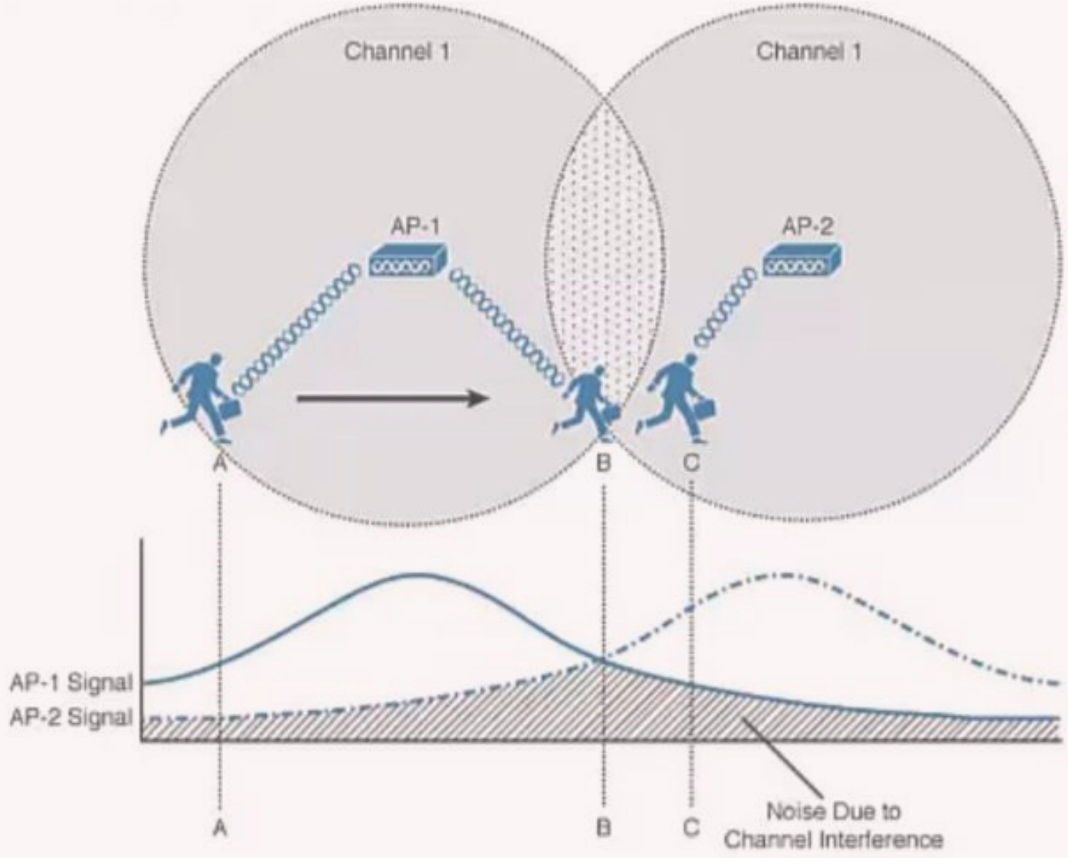
Two 802.11 transmitters are using the same channel

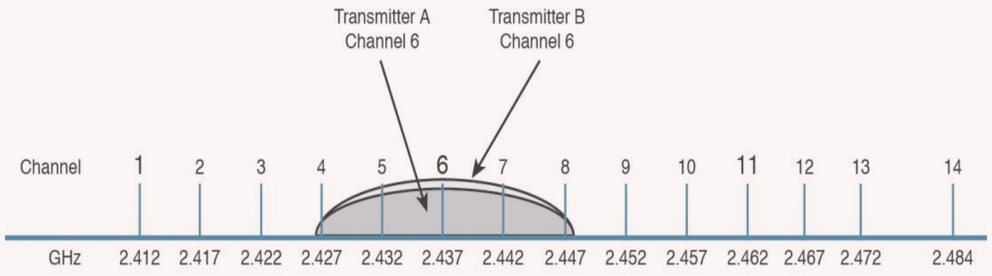
RF Signals in the Real World

❑ **Interference phenomena**

❖ Co-Channel Interference

- Co-channel interference might not be a problem if the transmitters are not sending data at the same time .
- When both transmitters are busy sending data, the channel can become very congested.
- The two signals begin to interfere and cause data corruption, which causes devices to retransmit lost data.



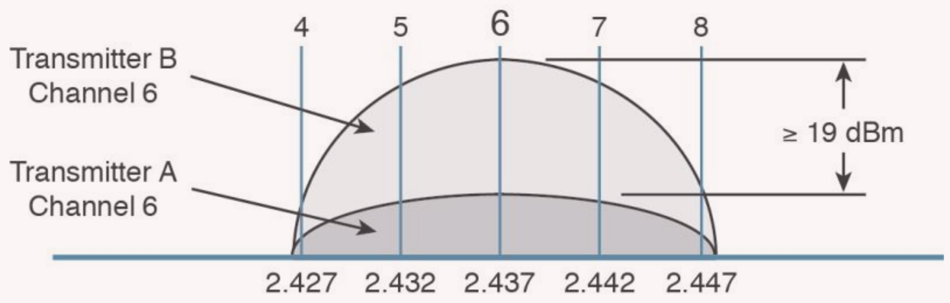


RF Signals in the Real World

❑ Interference phenomena

❖ Solutions

1) Since the 2.4-GHz band offers only three non-overlapping channels, bound the transmission can be used by IEEE802.11.
2) Use careful planning when you select the channel for each transmitter. For instance, in IEEE802.11, two nearby transmitters should never be placed on the same channel because their strong signals would be more likely to interfere.
3) Maintaining signal separation to minimize co-channel interference:
   - BPSK modulation needs less than 10 dB.
   - 19 dB may be enough to support 64-QAM modulation (54 Mbps) for 802.11g or 802.11a.
   - The 256-QAM modulation used in 802.11ac requires from 31 to 50 dB!
4) Smart antenna.



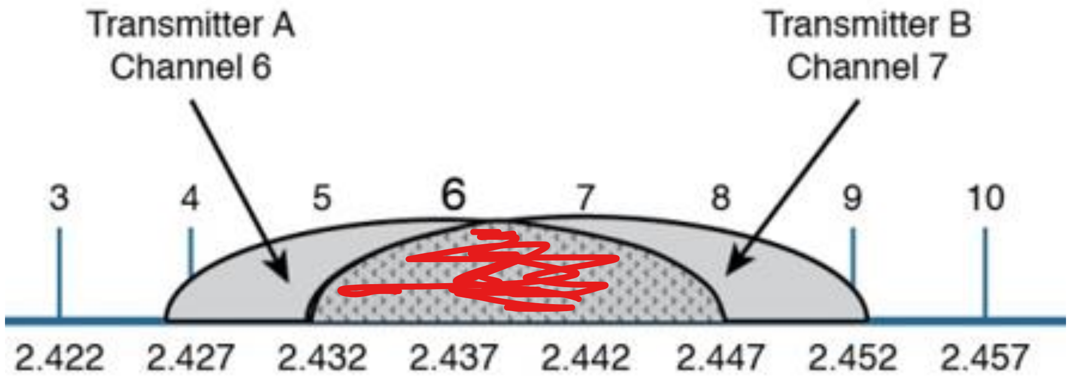
Signal power separation

Smart Antenna

❑ Interference phenomena

❖ Neighboring Channel Interference

- Using two slightly different channel numbers.
- The neighboring channels in the 2.4-GHz band overlap because a portion of one signal overlaps a portion of another signal.



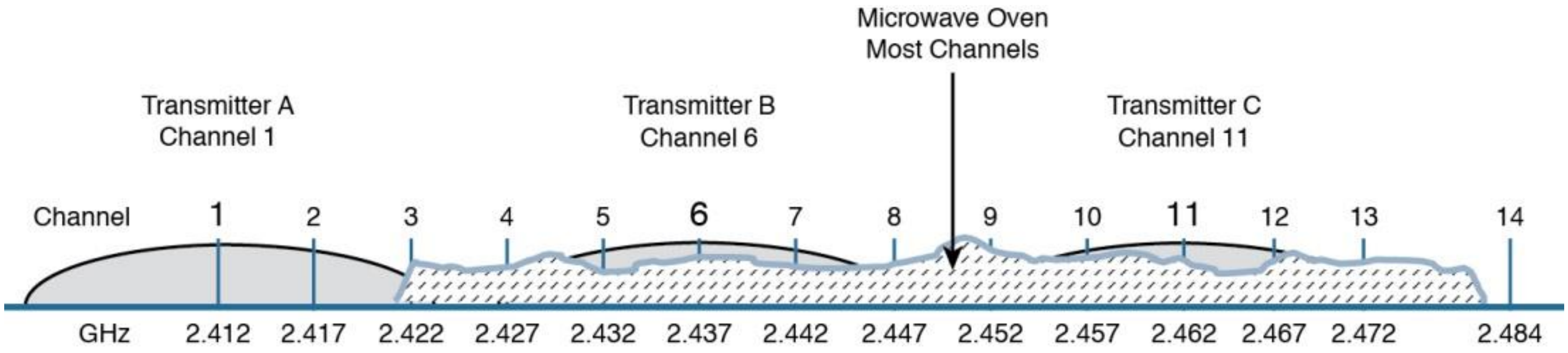
Tip Do you think of neighboring channels as having adjacent channel numbers? You are not alone; after all, channel numbers 1 and 2 are adjacent. Interference between neighboring channels is commonly called *adjacent channel interference*. Technically, this term is incorrect and is often misused. The 802.11 standard defines adjacent channels as non-overlapping channels. Therefore, by definition, it is impossible for adjacent channels to overlap and interfere. Be aware that the CCNA Wireless exam strictly uses the terminology found in the 802.11 standard. *Adjacent* channels cannot overlap, but *neighboring* channels can.

[Non-802.11 Interference from a Microwave Oven]

❑ Interference phenomena

❖ Non IEEE802.11 devices Interference

- Other RF sources that operate on the same 2.4 – 5 GHz unlicensed bands impact the performance of IEEE802.11, such as:
  - ➢ Cordless phones
  - ➢ Microwave ovens
  - ➢ Bluetooth
  - ➢ Zigbee.



Non-802.11 Interference from a Microwave Oven

02

Free Space Path Loss — Why a radio frequency signal degrades as it travels through free space?.

RF Signals in the Real World

❖ Free Space Path Loss

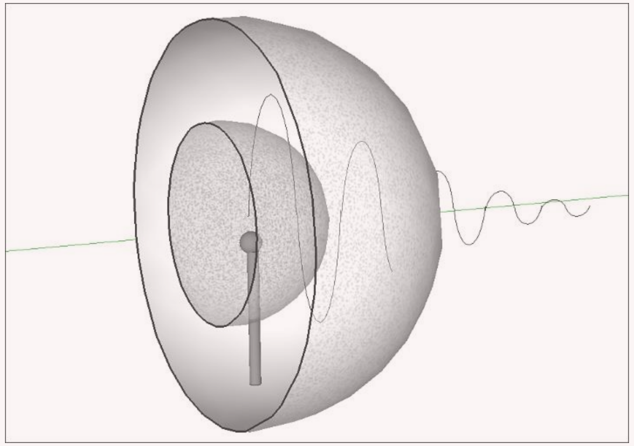
- The free space path loss is the loss in signal strength as it travels through free space.
- In isotropic antenna, the RF energy travels in every direction.
- The amount of energy coming out is spread over a sphere in free space.
- That energy gets weaker as the distance from the antenna increases.

$$\text{Signal level} = \frac{\mathrm{k}}{d^2}$$

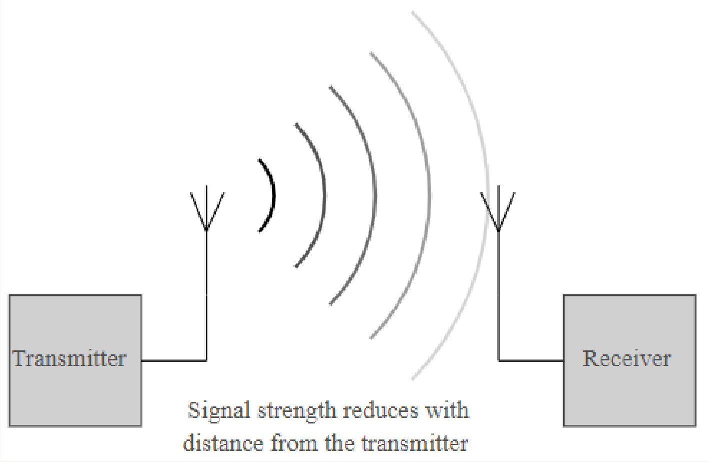
- Where: k = constant and d = distance from the transmitter.
- The free space path loss can be expressed in terms of either the wavelength or the frequency:

$$\mathrm{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 \qquad \mathrm{FSPL} = \left(\frac{4\pi d f}{c}\right)^2$$

- Where: **FSPL** = Free space path loss, **d** = distance from the transmitter to the receiver (metres), **λ** = signal wavelength (metres), ***f*** = signal frequency (Hz), **c** = speed of light (metres per second) and **λf=c**



Free Space Loss Due to Wave Spreading



RF Signals in the Real World

❖ Free Space Path Loss

- Free space path loss equation in deciBels

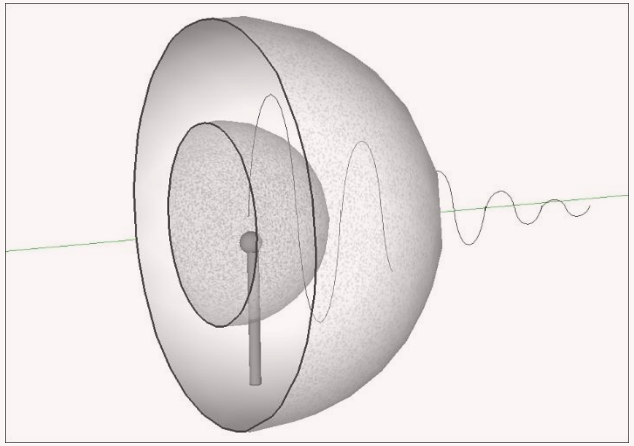
$$\mathrm{FSPL(dB)} = 20\log(d) + 20\log(f) + 32.44$$

- The equation above does not include antenna gains and feeder losses.
- It is for two isotropic antennas, i.e. ones that radiate equally in all directions.
- It is possible to add the antenna gains into the equation

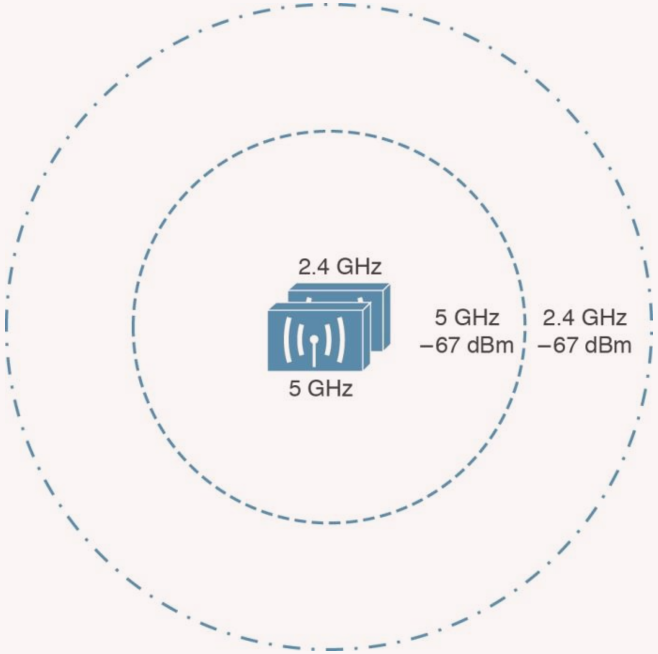
$$F = 20\log(d) + 20\log(f) + 32.44 - Gtx - Grx$$

- Where: Gtx = overall transmitter antenna gain including feeder losses

  Grx = overall receiver antenna gain including feeder losses
- The free space path loss is greater in the 5-GHz band than it is in the 2.4-GHz band.
- This means that 802.11b/g/n devices (2.4 GHz) have a greater effective range than 802.11a/n (5 GHz) devices, assuming an equal transmitted signal strength.



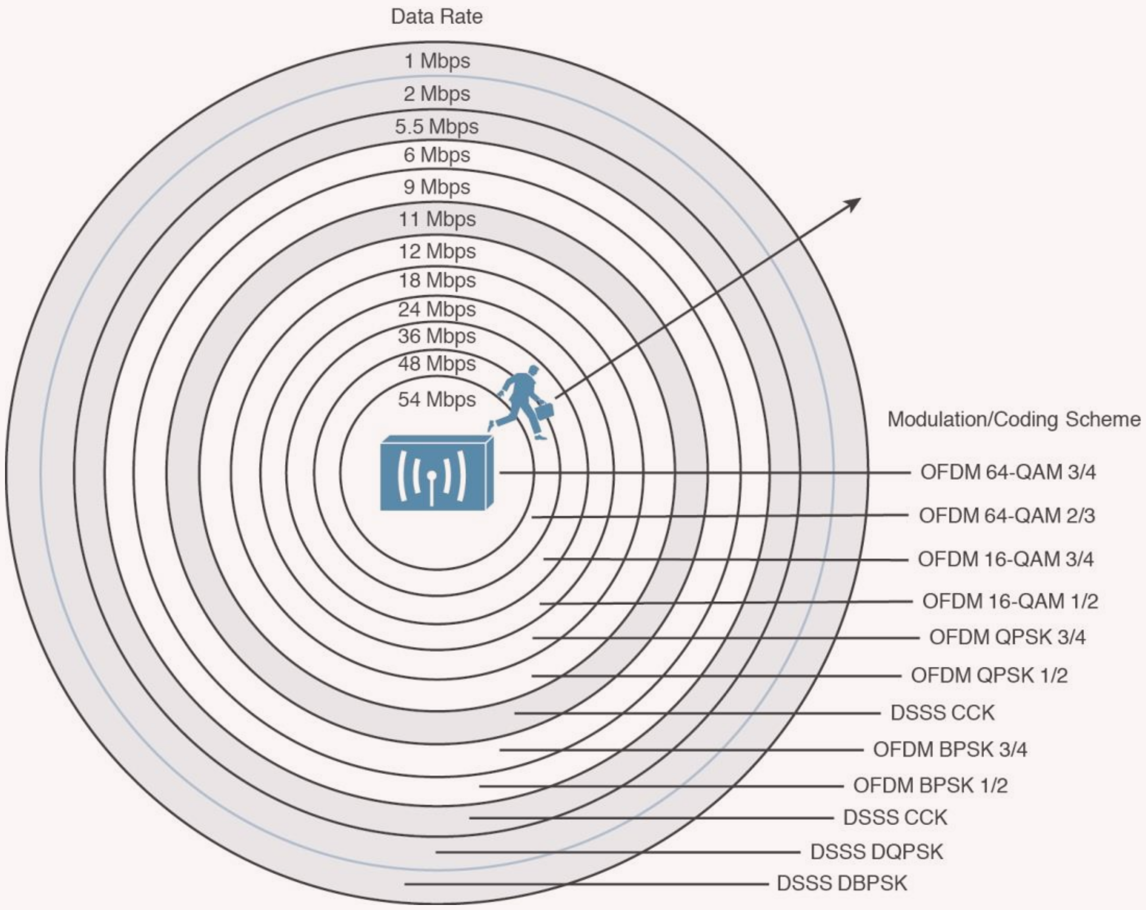
Free Space Loss Due to Wave Spreading



Effective Range of 2.4-GHz and 5-GHz Transmitters

❖ Mitigating the Effects of Free Space Path Loss

1) Increasing the transmitter's output power.
2) Increasing the antenna gain can also boost the effective isotropic radiated power (EIRP).
    1) **Problem**:
        - A greater signal strength translates to a greater received signal strength indicator (RSSI) value at a distant receiver.
        - This works fine for an isolated transmitter, but can cause interference when several transmitters are located in an area.
3) IEEE802.11 devices use a dynamic rate shifting (DRS) approach:
    - When the RSSI increases, the SNR value increases also, so more complex modulation and coding schemes can be used to transport more data.
    - When RSSI and SNR decrease, more basic modulation and coding schemes are needed there because of the increase in noise and the need to repeat more data.



Dynamic Rate Shifting as a Function of Range

Tip Although DRS is inherently used in 802.11 devices, it is not defined in the 802.11 standard. Each manufacturer can have its own approach to DRS; so all devices don't necessarily select the same scheme at the same location. DRS is also known by many alternative names, such as *link adaptation*, *adaptive modulation and coding* (AMC), *rate adaptation*, and so on.

03

Effects of Physical Objects —This section explores what happens when an RF signal meets various physical objects:

- ✓ Reflection
- ✓ Multipath
- ✓ Absorption
- ✓ Refraction
- ✓ Diffraction

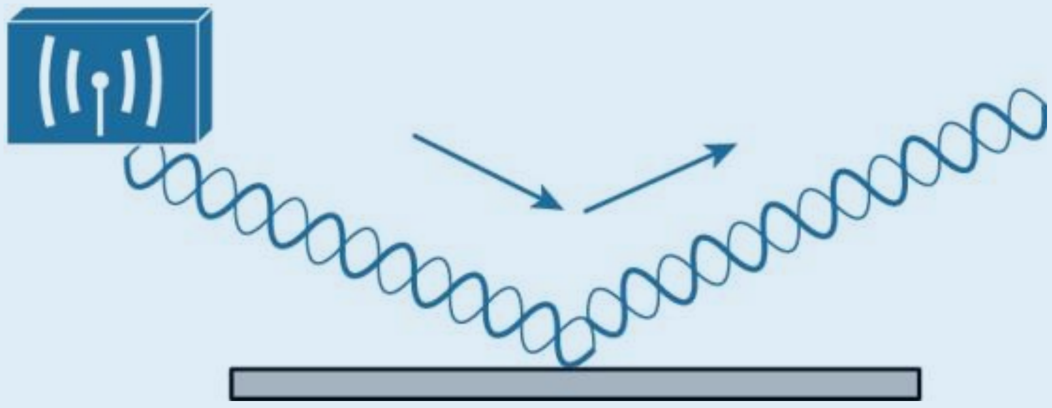
❖ Effects of Physical Objects

❑ Reflection

- ❖ When a wave hits a smooth object that is larger than the wave itself, depending on the media, the wave may bounce in another direction.
- ❖ As a wave radiates from an antenna, it broadens and disperses. If portions of the wave are reflected, new wave fronts appear from the reflection points.
- ❖ Causes:
  - Outdoor:
    - ✓ Buildings, Roads, Bodies of water
    - ✓ Earth's surface
  - Indoor:
    - ✓ Doors, Walls
    - ✓ File Cabinets
    - ✓ Metal objects, Glass
    - ✓ Concrete

❖ **Impact**:

- ✓ Creates multipath, which can degrade the strength and quality of the received signal as well as cause data corruption or cancel signals.



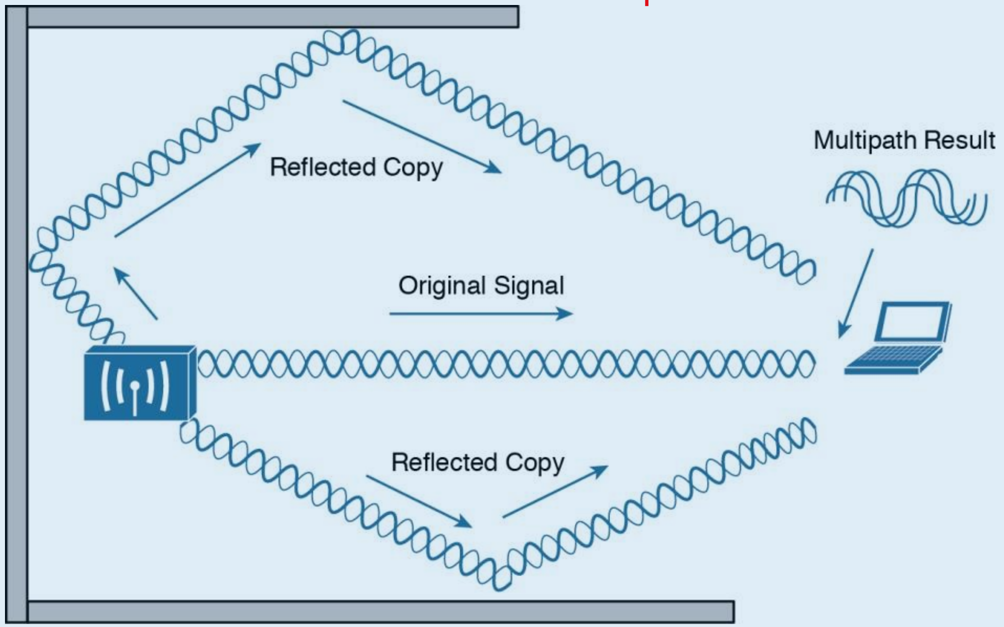
Reflection of an RF Signal

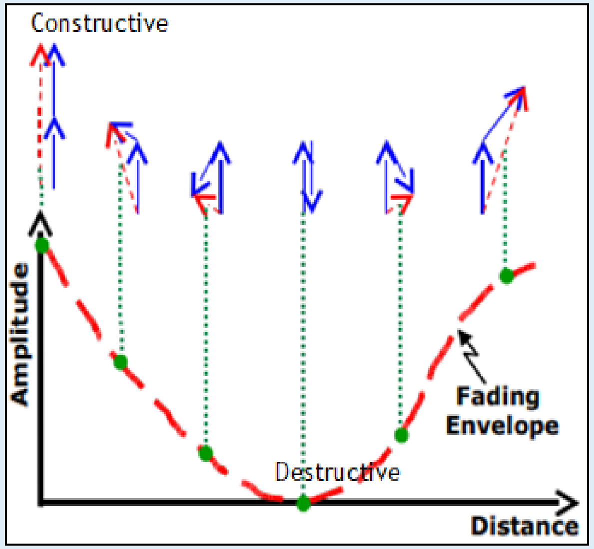
❖ Effects of Physical Objects

❑ Multipath

- A signal propagates over multiple paths between the transmitter and the receiver.
- Multiple copies of signal combines with random **phase** resulting in random **amplitude** attenuation and **phase variation.**
- The different components of the same signal can be added at the receiver constructively of destructively
- **I**n MIMO, each arriving signal will be received on each of the different antennas and radios.
- Further processing can improve the signal quality to extract the multiple data stream making something good out of a bad situation.

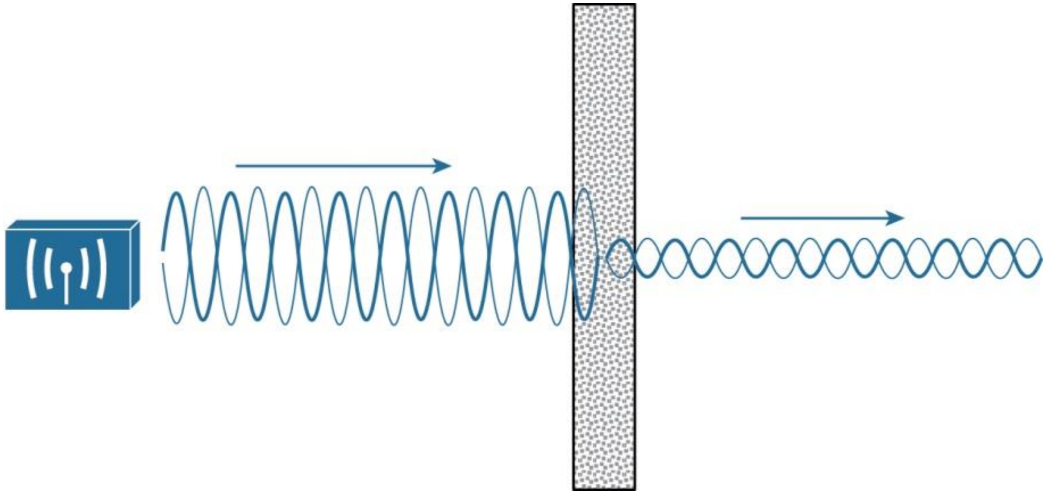
Multipath Transmissions





❖ Effects of Physical Objects

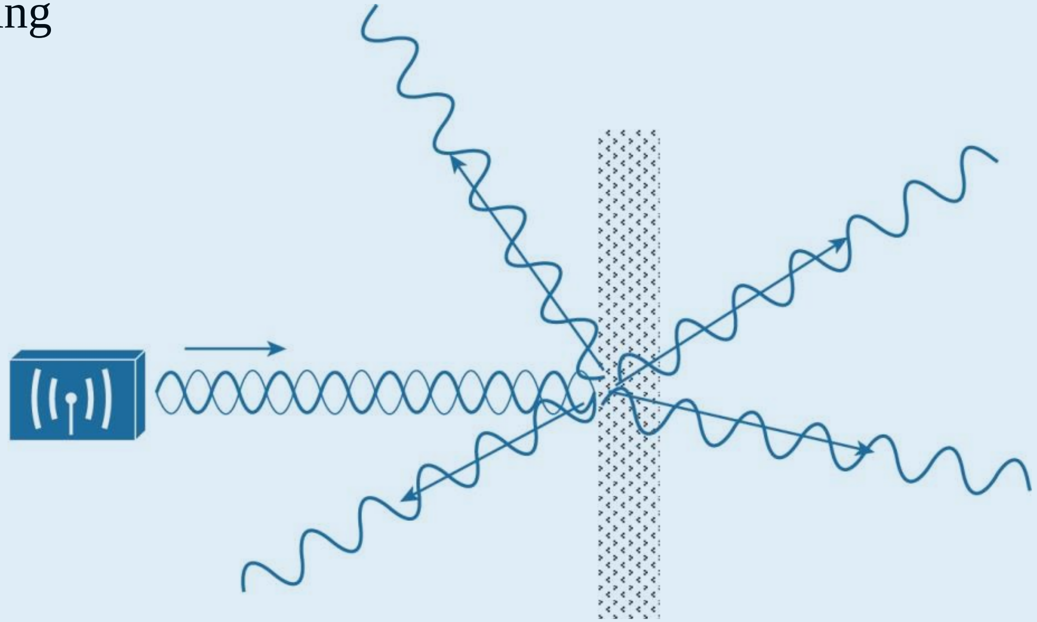
❑ Absorption



- The absorption attenuates the RF signal that passes into a material.
- Drywall might attenuate a signal by –4 dBm.
- A solid concrete wall might attenuate it by –12 dBm.
- In outdoor :
  - ➢ The water contained in tree leaves, rain, snow, hail, or fog.
  - ➢ Human body, which is made up mostly of water.

Tip To gain perspective, a quick experiment revealed that a human body attenuated a 2.4-GHz signal by –5 dBm.

❑ Scattering

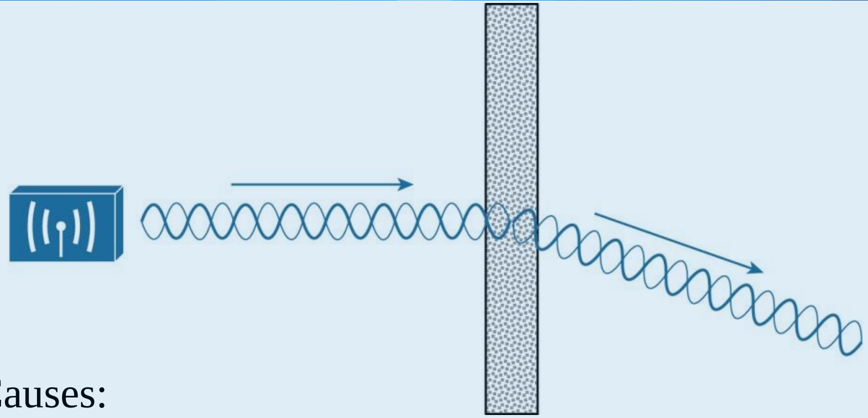


- When a RF signal passes into a medium that is rough, uneven, or made up of very small particles, the signal can be scattered into many different directions.
- As shown in the above Figure, scattering can occur when a wireless signal passes through a dusty or sandy environment

❖ Effects of Physical Objects

❑ Refracting

- ❖ When an RF signal meets the boundary between media of two different densities, it can also be refracted.
- ❖ The speed of the wave can also be affected as it passes through the different materials.
- ❖ A signal can be refracted when it passes through layers of air having different densities or through building walls with different densities
- ❖ Refraction is measured based on the k-factor. A k-factor is simply a value to represent the bend that is occurring.
  - o k-factor 1 = No bending
  - o k-factor <1 = Signal bending away from the earth
  - o k-factor >1 = Signal bending toward the earth
  - o k-factor 4/3 = Normal atmospheric conditions. Signal slightly bending toward the earth



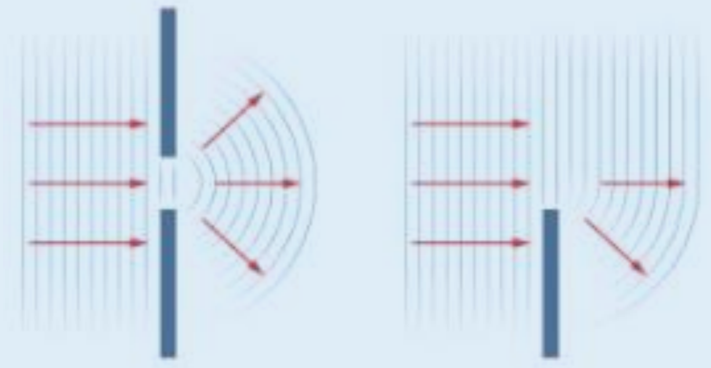
- ❖ Causes:
  - ✓ Outdoor:
    - o Water vapor
    - o Changes in air temperature
    - o Changes in air pressure
  - ✓ Indoor:
    - o Certain types of glass
    - o Passing through various materials
- ❖ Impact:
  - o May cause lower data rates, re-transmissions and lead to reduced capacity.

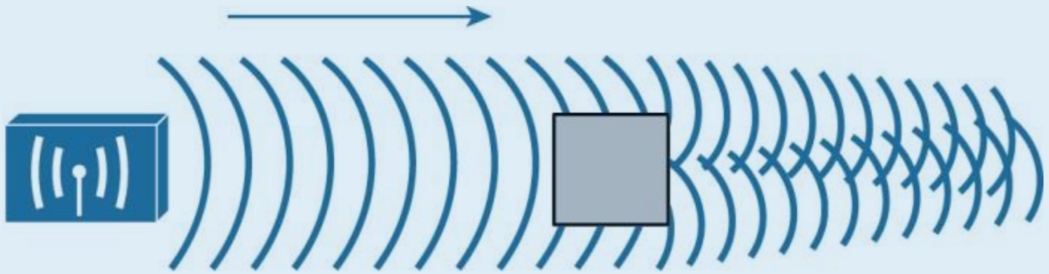
RF Signals in the Real World

❖ Effects of Physical Objects

❑ Diffraction

- ❖ Diffraction is the bending and spreading around of an RF signal when it encounters an obstruction
- ❖ The waves that encounter the object bend around the object, taking a longer and different path.
- ❖ The waves that do not encounter the object do not bend and maintain a shorter and original path.
- ❖ **Causes:**
  - ➢ Conditions that must be met for diffraction to occur.
    - ✓ Characteristics of the obstructing object:
      - o Shape
      - o Size
      - o Material
    - ✓ Characteristics of the RF signal:
      - o Polarization
      - o Phase
      - o Amplitude



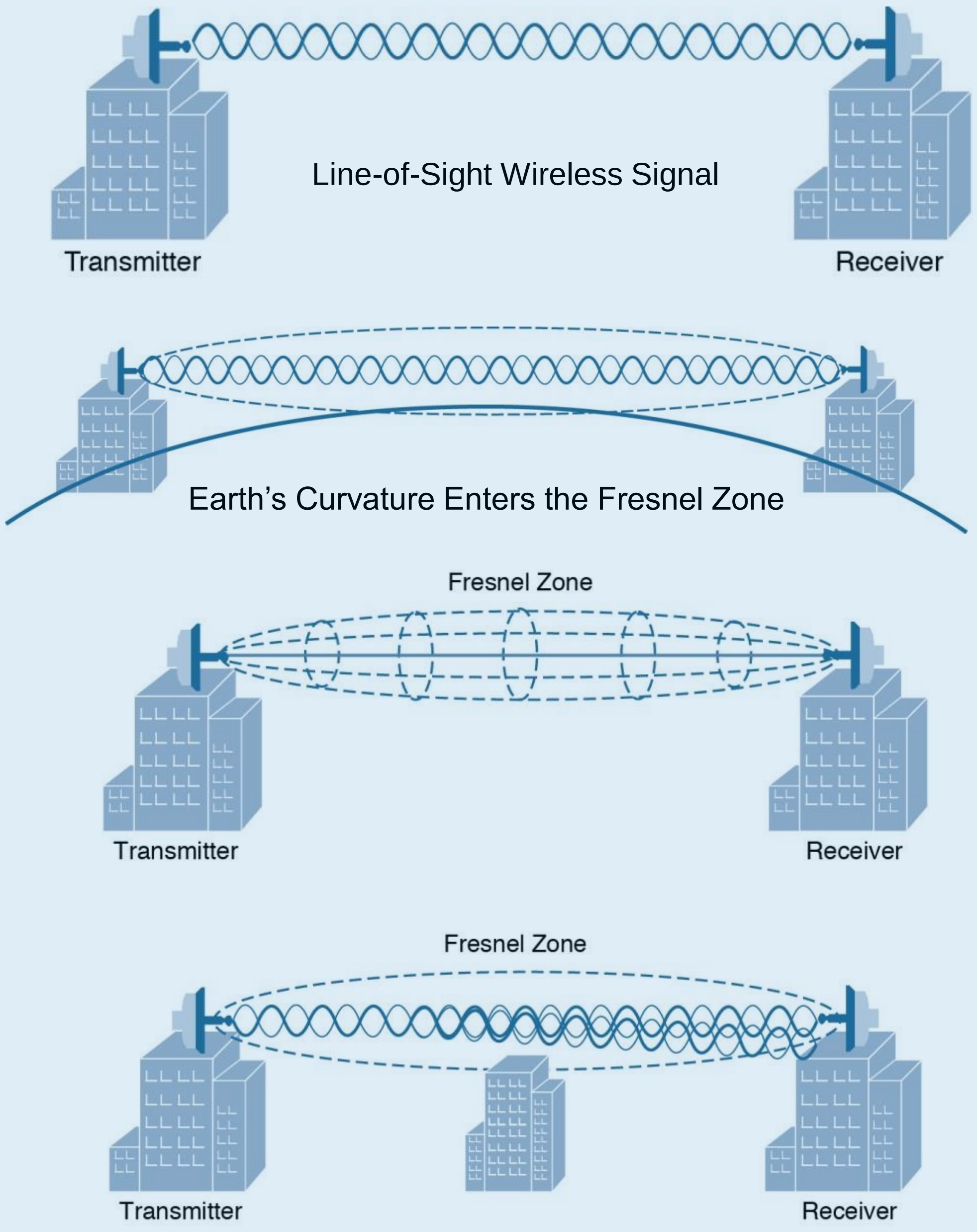


- ❖ Diffraction is caused by some sort of partial blockage such as a small hill or building that is between a transmitting radio and receiver.
- ❖ **Impact**:
  - o RF shadow can occur causing dead coverage zones or receive degraded signals.

❖ Effects of Physical Objects

❑ Fresnel Zones

- ❖ In point to point wireless communications, the line of sight (LOS) must be clear of any obstructions between the Tx's and the Rx's antennas.
- ❖ If the LOS paths have obstructions like trees, terrain, vegetation, buildings, wind farms and a host of other obstructions the antennas must be raised higher than the obstructions to get a clear path.
- ❖ Over a very long distance (beyond a distance of about two miles) , the curvature of the earth actually becomes an obstacle that can affect the signal.
- ❖ LOS can be affected by diffraction, even if an object does not directly block the signal.



RF Signals in the Real World

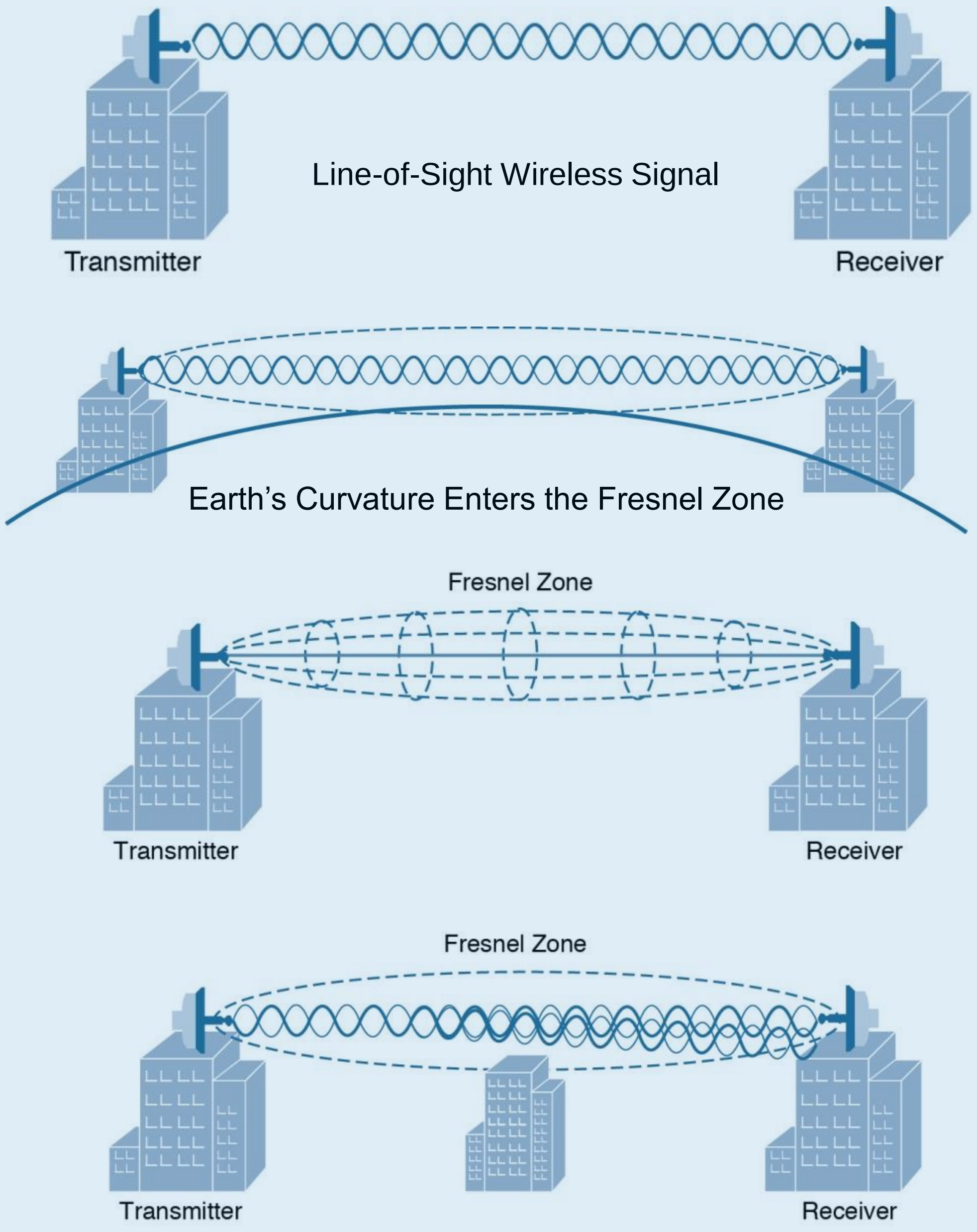
❖ **Effects of Physical Objects**

❑ Fresnel Zones

❖ There is an elliptical-shaped volume around the line of sight that must also remain free of obstructions.

❖ This is called the Fresnel zone.

❖ If an object penetrates the Fresnel zone anywhere along the path, some portion of the RF signal can be diffracted by it.

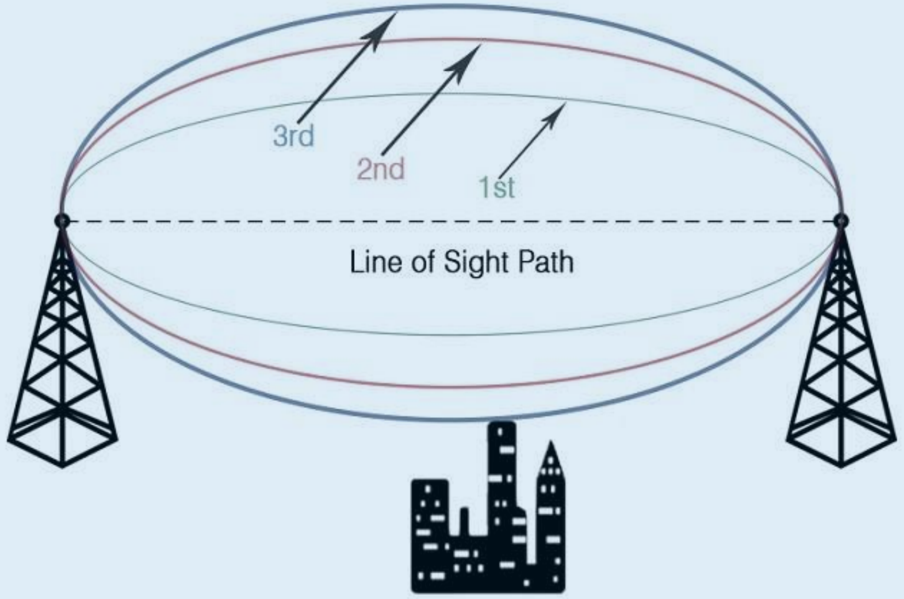


❖ Effects of Physical Objects

❑ Fresnel Zones

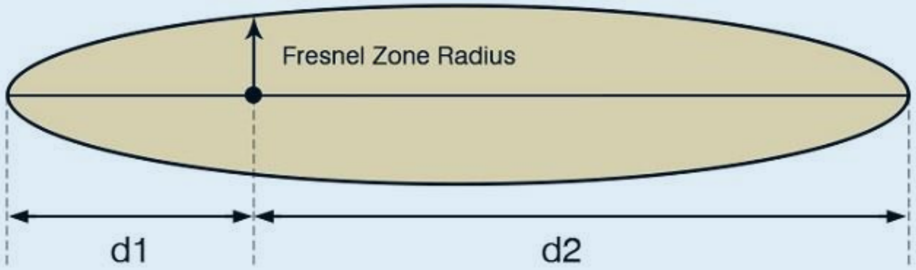
- ❖ The Fresnel zone is made up of multiple zones, with zone 1 having the strongest signal and following zones (Zone 2, and Zone 3) having weaker signals.
- ❖ If ***n***>0 is the number of zones and ***f*** is frequency, then the radius ***R*** of the Fresnel zone can be calculated according to a complex formula. (https://www.everythingrf.com/rf-calculators/fresnel-zone-calculator)

$$R = \sqrt{\frac{n d_1 d_2 f}{d_1 + d_2}}$$



Some example values of the Fresnel zone radius at the midpoint of Some LOS path lengths in the 2.4-GHz band.

Path Length	Fresnel Zone Radius at Path Midpoint
0.5	16
1	23
2	33
5	52
10	72



Calculate Fresnel zone radius

- $r = 17.31 \times \text{sqrt}(N(d1 \times d2)/(f \times d))$

$= 17.31 \times \sqrt{\frac{d=2}{4f}}$

- Example:

The distance between to building is 20 km
The freqency is 2.437 Ghz
The height of the building is 10 m

1. Calculate the Fresnel zone radius?
2. What is the maximum allowed height of obstruction in the path between transmitter and receiver

$r = 17.31 \text{ sqrt}(1 \times (1000 \times 1000) / (2437 \times 2000))$
$r = 17.31 \text{ sqrt}(1000000 / 4874000)$
$r = 7.84$ meters
the maximum allowed height of obstruction in the path between transmitter and receiver is $10-7.84= 2.16$ m

Wireless

RF Signals in the Real World

❖ If we need to maintain 60% of the Fresnel zone from interference, then we just multiply by 0.6 under the square root

Calculate Fresnel zone radius

- r = 17·31 sqrt(1 x 0·6 x(1000 * 1000) / (2437 x 2000))
- r = 17·31 sqrt(600000 / 4874000)
- r = 6·07 meters

$= 17.31 \times \sqrt{\frac{0.6 \times d}{4f}}$

the maximum allowed height of obstruction in the path between transmitter and receiver is 10-6·07= 3·93 m

Fresnel Zone