RF Signals in the Real World

This chapter covers the following topics

- ✓ **Interference**—This section describes several types of external interference that can adversely affect a wireless signal.
- ✓ **Free Space Path Loss**—This section explains why a radio frequency signal degrades as it travels through free space.
- ✓ **Effects of Physical Objects**—This section explores what happens when an RF signal meets various physical objects, resulting in effects such as reflection, absorption, refraction, and diffraction

1.Interference

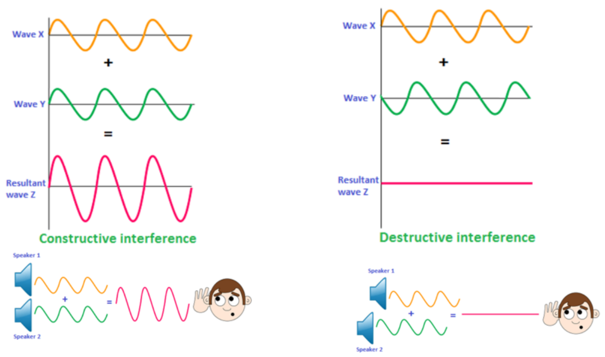
The idea behind WLAN modulation

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

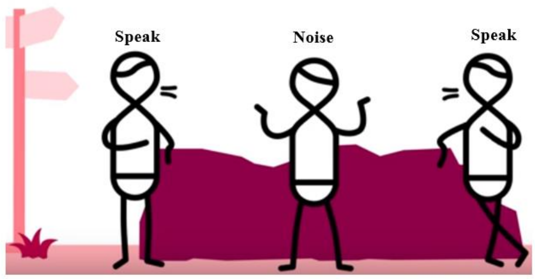
Radio frequency (RF) signals travel as electromagnetic waves. **Ideally**, the received signal is identical to the transmitted signal. **Practically**, many things affect RF signals during its propagation.

1.1 Interference phenomena

- Physicists: Interference concerned with the "behavior of waves".
- Telecommunications engineer: “... any noise that gets in the way”.



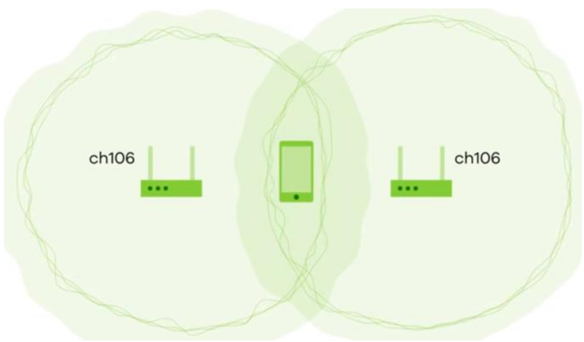
Physicists point of view

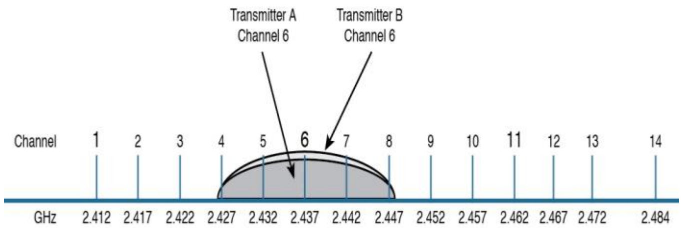


Telecommunications engineer point of view

1.2 Co-Channel Interference

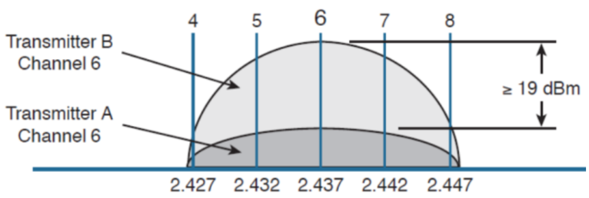
- Whenever one transmitter’s signal overlaps another on a frequency or channel, the signals interfere with each other.
- Co-channel interference occurs when two or more transmitters use the same channel.
- Co-channel interference might not be a problem if the transmitters are not sending data at the same time. Otherwise, the two signals begin to interfere and cause data corruption, which causes devices to retransmit lost data.



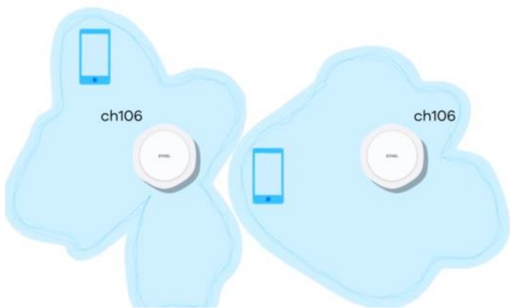


Solutions for co-channel interference

1) 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.
2) Maintaining signal power separation to minimize co-channel interference: Having at least 19-dB separation helps maintain a healthy signal-to-noise ratio (SNR) in the area surrounding the transmitter.
    - 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!
3) Smart Antennas



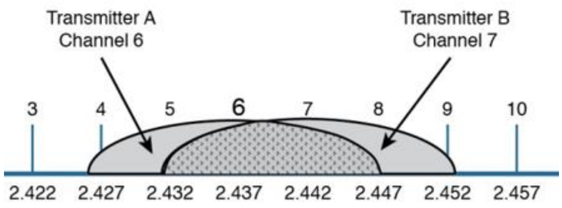
Maintaining Signal Separation to Minimize Co-Channel Interference



Smart Antenna

1.3 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.

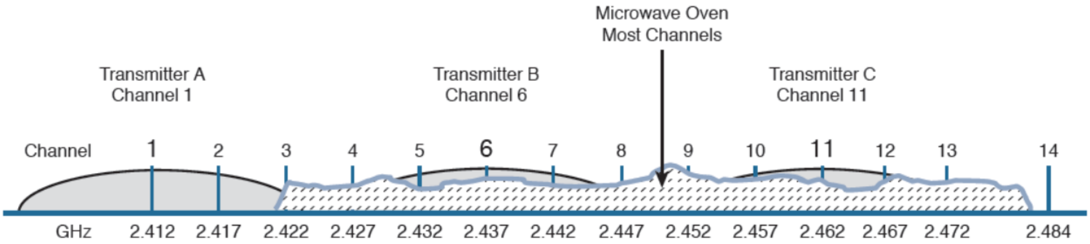


Tip Do you think of neighboring channels as having adjacent channel numbers? You are not alone; after all, channel numbers 1 and 2 are adjacent. Interference between neighboring channels is commonly called *adjacent channel interference*. Technically, this term is incorrect and is often misused. The 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.

1.4 Non IEEE802.11 devices Interference

Many non-802.11 devices do not sit on any one channel; they use frequency-hopping spread spectrum (FHSS) to hop around on a variety of channels at any given time.

Even worse, some devices do not adhere to any channel scheme at all.



Examples of non- IEEE802.11 devices that operate on the same 2.4 – 5 GHz unlicensed bands and impact the performance of IEEE802.11:

- Cordless phones
- Microwave ovens
- Bluetooth
- Zigbee

To mitigate interference from non-802.11 devices, you have to eliminate the source.

1) Leaky microwave ovens should be replaced with better models that have proper RF shielding.
2) Devices like 2.4-GHz FHSS cordless phones or wireless video cameras should be replaced with models that operate in a non-802.11 band.

2. 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.

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

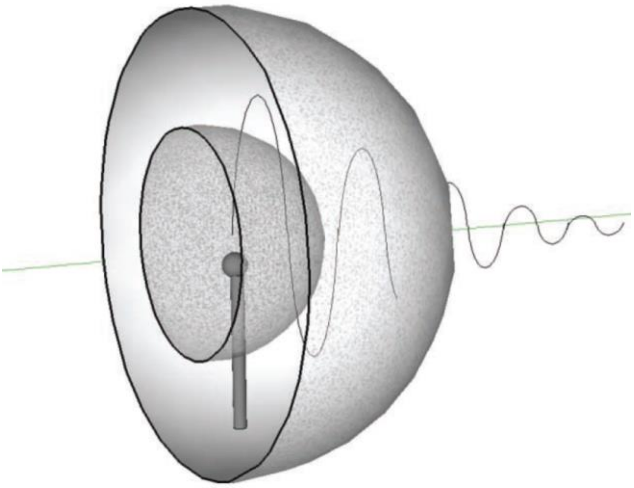
Where: k = constant and d = distance from the transmitter.

- The free space path loss can be expressed in terms of either the wavelength or the frequency:

$$\text{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2$$

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

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

- Free space path loss equation in deciBels

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

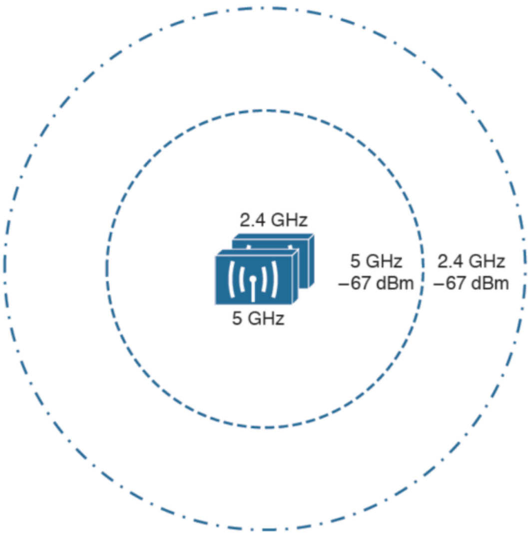
- The equation above does not include antenna gains and feeder losses. It is for two isotropic antennas, i.e. ones that radiate equally in all directions.
- It is possible to add the antenna gains into the equation

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

Where: G_{tx} = overall transmitter antenna gain including feeder losses

G_{rx} = 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.



Effective Range of 2.4-GHz and 5-GHz Transmitters

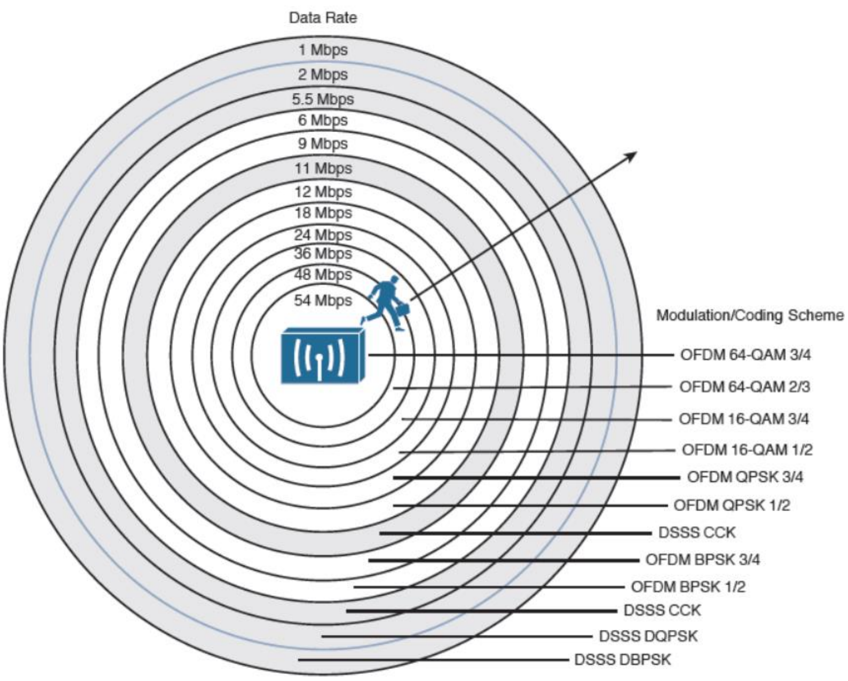
2.1 Mitigating the Effects of Free Space Path Loss

1) Increase the transmitter's output power.
2) Increasing the antenna gain can also boost the EIRP.

This approach might work fine for an isolated transmitter, but can cause interference problems when several transmitters are located in an area.

3) A more robust solution is to just cope (dealing) with the effects of free space path loss as follows:
    a. As a receiver gets closer to a transmitter, the RSSI (and SNR) increases. More complex modulation and coding schemes can be used to transport more data when the SNR is high.
    b. As a receiver gets farther away from a transmitter, the RSSI (and SNR) decreases. More basic modulation and coding schemes are needed there because of the increase in noise and the need to repeat more data.
4) 802.11 devices use the as dynamic rate shifting (DRS) scheme which select their modulation and coding schemes based on the current RSSI and SNR conditions.

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.



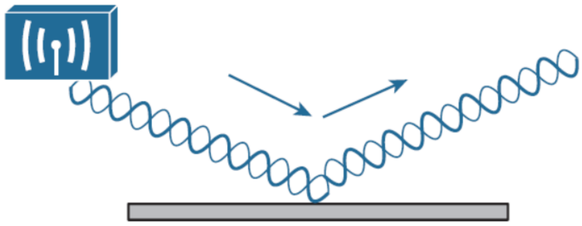
Dynamic Rate Shifting as a Function of Range

3. Effects of Physical Objects

As an RF signal propagates through free space, it might encounter physical objects in its path. Objects and materials can affect an RF signal in a variety of ways, mostly in a degrading or destructive fashion.

3.1 Reflection

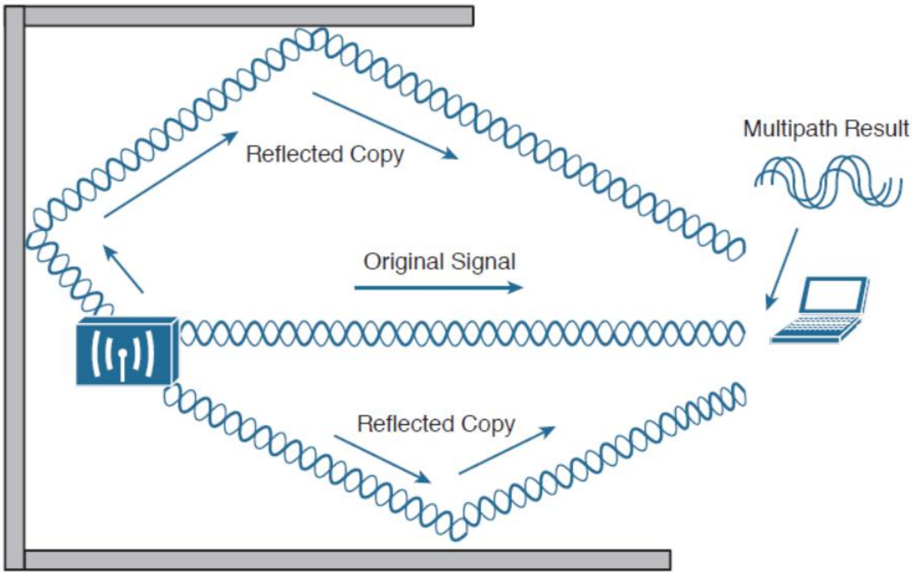
- If an RF signal traveling as a wave meets a **dense reflective material**, the signal can be reflected.



Reflection of an RF Signal

- **Indoor** objects such as metal furniture, filing cabinets, and metal doors can cause reflection.
- An **outdoor** wireless signal can be reflected by objects such as a body of water, reflective glass on a building, or the surface of the earth.
- A reflection is just a copy of the original signal. They can arrive out of phase with each other. This is because the reflection takes a different path than the original, causing it to arrive slightly later. This is known as **multipath.**

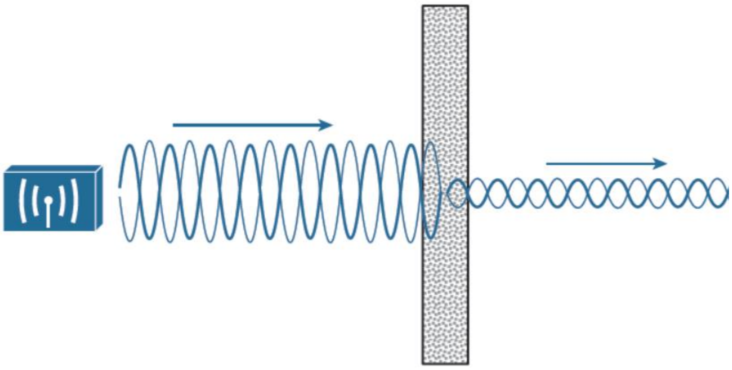
Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths



Multipath Transmissions

3.2 Absorption

If an RF signal passes into a material that can absorb some of its energy, the signal will be attenuated. The denser the material, the more the signal will be attenuated.



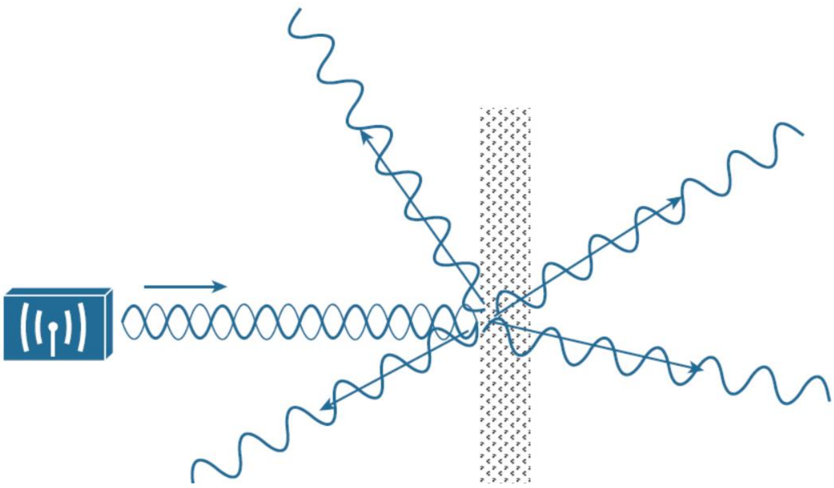
For examples:

- A wall constructed from gypsum or drywall might attenuate a signal by –4 dBm.
- A solid concrete wall might attenuate it by –12 dBm.
- Water in the form of rain, snow, hail, or fog.
- Human body, which is made up mostly of water.
- A hand covering a phone antenna can decrease a received signal by 6–8 dB;
- A person's head attenuate the signal received by a phone antenna by almost 30 dB.

3.3 Scattering

When an 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.

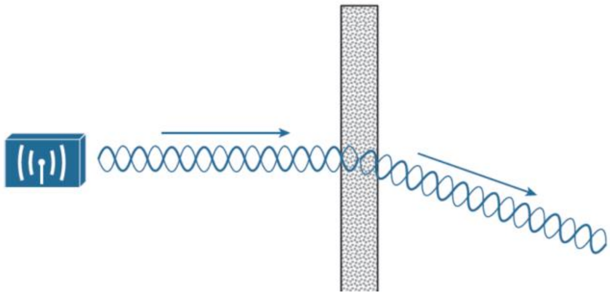
This is because the tiny irregular surfaces of the medium can reflect the signal. Scattering can occur when a wireless signal passes through a dusty or sandy environment.



3.4 Refraction

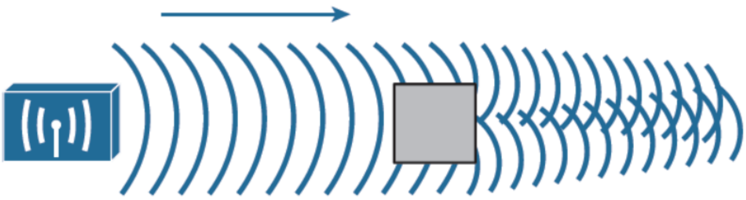
When an RF signal meets the boundary between media of two different densities, it can also be refracted. Think of reflection as bouncing off a surface and refraction as being bent while passing through a surface.

A refracted signal will have a different angle from the original. A signal can be refracted when it passes through layers of air having different densities or through building walls with different densities.



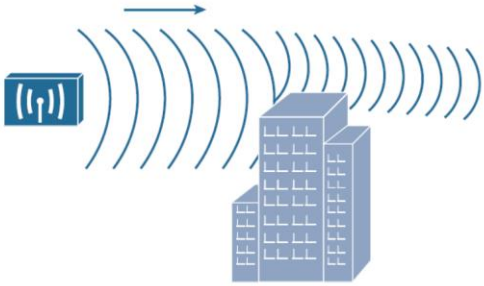
3.5 Diffraction

Diffraction has caused the signal to "heal" itself around an absorbing object. This makes reception possible even when a building stands between the transmitter and receiver. However, the signal is never quite like the original again, as it has been distorted by the diffraction.



3.6 Fresnel Zones

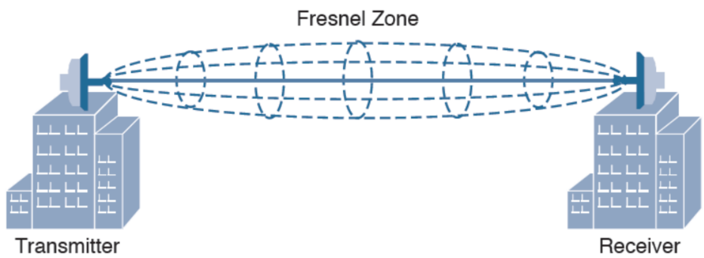
- If a standing object such as a building or a mountain obstructs the signal, the signal can be adversely affected in the vertical direction.
- Because of diffraction along the front and top of the building, the signal is bent and also attenuated.

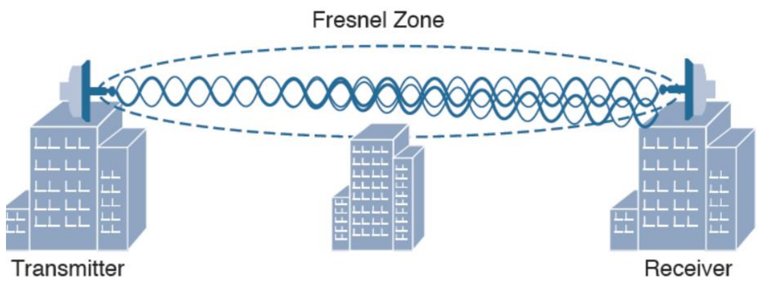


- For a line-of-sight path, the signal must be clear of any obstructions between the transmitter's antenna and the receiver's antenna.

- Paths between buildings or between cities commonly have other buildings, trees, or other objects that might block the signal.
- In those cases, the antennas must be raised higher than the obstructions to get a clear path.

- 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.



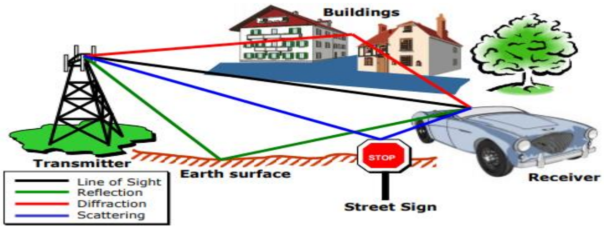


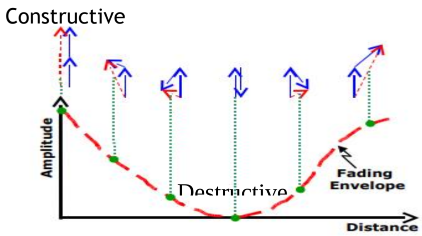
- The radius of the Fresnel zone can be calculated according to a complex formula.
- However, you should only be concerned with the idea that the Fresnel zone exists and should remain clear.
- The following Table gives some example values of the Fresnel zone radius at the midpoint of some line-of-sight path lengths for wireless frequencies in the 2.4-GHz band.

Path Length	Fresnel Zone Radius at Path Midpoint
0.5 mile	16 feet
1.0 mile	23 feet
2.0 miles	33 feet
5.0 miles	52 feet
10.0 miles	72 feet

3.7 Multipath effects

- When multipath transmissions occur, there can be two outcomes:
  1) A single radio chain: all of the arriving signals (original and reflected) are combined into one poor, error prone composite signal.
  2) Multiple chain (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 streams—making something good out of a bad situation.





Questions

1. An 802.11 transmitter is configured to send a signal on channel 11. Someone reports a problem receiving the signal, so you investigate and find a second transmitter broadcasting on channel 11. Which one of the following best describes the problem?

   a. Path interference

   b. Adjacent channel interference

   c. Co-channel interference

   d. Cross-channel interference

2. Suppose that you place a new 802.11n transmitter in a building, but notice that there are other signals already coming from transmitters in the same general area. To avoid interference problems, how much greater should your transmitter's signal be above all of the others to provide the best signal?

   a. 0 dB

   b. +3 dB

   c. +5 dB

   d. +10 dB

   e. +20 dB

3. An existing transmitter in your office sends its signal on 2.4-GHz channel 1. Suppose that someone in a neighboring office sets up a new wireless router. He notices your signal on channel 1, so he chooses channel 2 instead. Which one of the following might adversely affect the wireless operation?

a. Co-channel interference

b. Neighboring channel interference

c. Wideband interference

d. Excessive SNR

4. Which one of the following is the best strategy for avoiding interference between neighboring channels in the 2.4-GHz band?

a. Use any channel number that seems to be available

b. Leverage 802.11n for 40-MHz aggregated channels

c. Use only channels that are spaced four numbers apart, beginning with channel 1

d. Use only channels that are spaced five numbers apart, beginning with channel 1

5. Which one of the following is the primary cause of free space path loss?

a. Spreading

b. Absorption

c. Humidity levels

d. Magnetic field decay

6. Which one of the following has the shortest effective range in free space, assuming that the same transmit power level is used for each?

a. An 802.11g device

b. An 802.11a device

c. An 802.11b device

d. None of these answers

7. Suppose that an 802.11a device moves away from a transmitter. As the signal strength decreases, which one of the following might the device or the transmitter do to improve the signal quality along the way?

a. Aggregate more channels

b. Use more radio chains

c. Switch to a more complex modulation scheme

d. Switch to a less-complex modulation scheme

8. When RF signals are reflected by objects in a building, which one of the following best describes the result that might be experienced at a receiver?

a. Fresnel loss

b. Multipath

c. Cross-channel fading

d. Free space path loss

9. Which one of the following best describes the effect that a building material has as an RF signal passes through a wall?

a. Reflection

b. Refraction

c. Diffraction

d. Absorption

e. Multipath

10. Which one of the following best describes the first Fresnel zone?

a. The area covered by one transmitter on a channel

b. The area around a signal path that should be kept clear of any obstructions

c. The area around a signal path that is blocked by the earth's curvature

d. The area around a transmitter that represents the range of a signal