جامعة الأهرام الكندية
AHRAM CANADIAN UNIVERSITY

Lecture (03)
WLAN RF Principles

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Agenda

- Characteristics of Wireless Networks
- Influences on Wireless Transmissions
  - Free Path Loss
  - Absorption
  - Reflection
  - Multipath fading
  - Scattering
  - Refraction
  - Line of Sight

Agenda (cont,..)

- Determining Signal Strength Influences
  - The Fresnel Zone
  - Received Signal Strength Indicator & Receive Channel Power Indicator
  - Signal-to-Noise Ratio
  - Link Budget

Characteristics of Wireless Networks

Review of Wavelength

- A *wavelength is the distance between successive crests of a wave.*
- Or distance between one point in the AC cycle to the next point in the AC cycle.
- the waveform takes on a form called a *sine wave.*
- The waveform starts as an AC signal that is generated by a transmitter inside an access point (AP) and is then sent to the antenna, where it is radiated as a sine wave.
- During this process, current changes the *electromagnetic field around the antenna, so it transmits* electric and magnetic signals.

Characteristics of Wireless Networks (cont,..)

- Examples of common signals wave length
  - AM radio waveforms are 400 to 500 meters long.
  - Wireless waveforms in wireless LANS are only a few centimeters.
  - Waveforms sent by satellites are approximately 1 mm long.

Characteristics of Wireless Networks (cont,..)

Review of Frequency

- It is the rate at which something occurs or is repeated over a particular period or in a given sample or period.
- Or it is the rate at which a vibration occurs that constitutes a wave in a second
- Because frequency refers to cycles

Characteristics of Wireless Networks (cont,..)

- some facts
  - 1 cycle = 1 Hz
  - Higher frequencies travel shorter distances
  - When a waveform is seen once in a second = 1 Hz
  - 10 times in a second = 10 Hz
  - 1 million times in a second = 1 MHz
  - 1 billion times in a second = 1 GHz

Characteristics of Wireless Networks (cont,..)

Review of Amplitude

- The vertical distance between crests in the wave is called *amplitude.*
- Amplitude is the quantity or amount of energy that is put into a signal.
- Folks like the FCC and European Telecommunications Standards Institute (ETSI) regulate the amplitude.

Characteristics of Wireless Networks (cont,..)

Review of Effective Isotropic Radiated Power

- When an access point sends energy to an antenna to be radiated, a cable might exist between the two.
- A certain degree of loss in energy is expected to occur in the cable.
- To calculate EIRP, use the following formula:
- EIRP = transmitter output power – cable loss + antenna gain

Influences on Wireless Transmissions

- Some influences can stop a wireless signal from propagating altogether, whereas others might simply shorten the transmission distance.
- These influences are
  - Free Path Loss model,
  - absorption,
  - reflection,
  - scattering,
  - multipath,
  - refraction, and
  - line of sight.

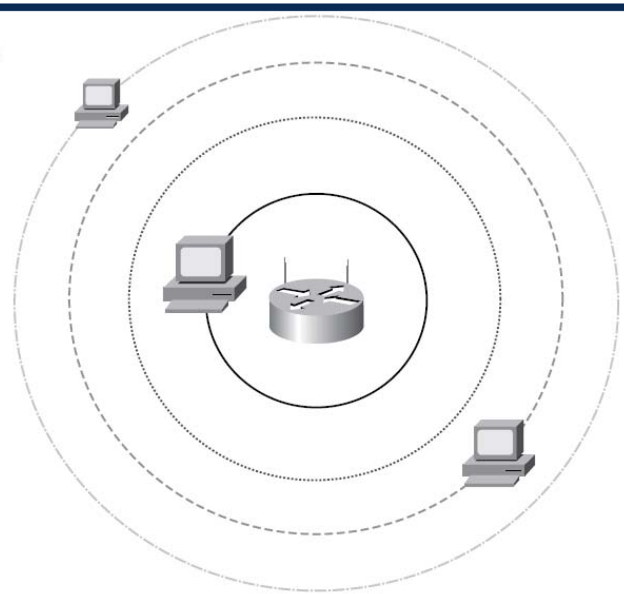
Free Path Loss

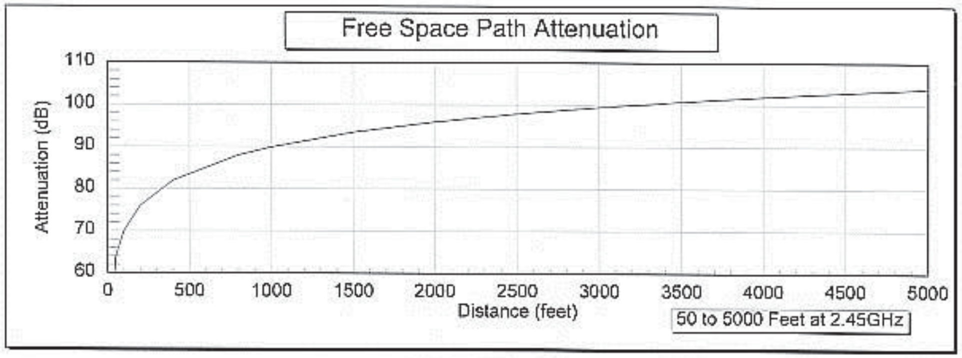
In telecommunication, free-space loss (FSL) is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space (usually air),

with no obstacles nearby to cause reflection or diffraction.

It does not include factors such as the gain of the antennas used at the transmitter and receiver, nor any loss associated with hardware imperfections.

Free Path Loss (cont,..)





Free Path Loss (cont,..)

- A device closer to the transmitter usually gets a more concentrated signal, and a receiver farther away might get only one dot.

- it is found that the signal decreases in a way that is inversely proportional to the square of the distance from the source of the radio signal.
- Free-space path loss is proportional to the square of the distance between the transmitter and receiver, and also proportional to the square of the frequency of the radio signal.

- The equation for FSPL is

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

- is the signal wavelength (in metres),
- is the signal frequency (in hertz),
- is the distance from the transmitter (in metres),
- is the speed of light in a vacuum, 2.99792458×10^8 metres per second.

- **Free-space path loss in decibels (generic)**

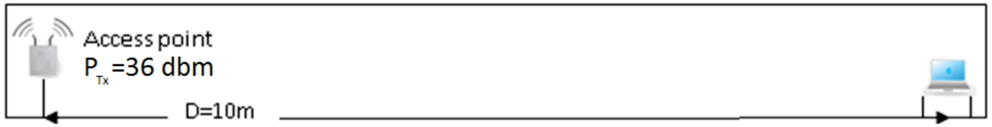
$$\mathrm{FSPL(dB)} = 10\log_{10}\left(\left(\frac{4\pi}{c}df\right)^2\right)$$
$$= 20\log_{10}\left(\frac{4\pi}{c}df\right)$$
$$= 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right)$$
$$= 20\log_{10}(d) + 20\log_{10}(f) - 147.55$$

- **d: distance in meters**
- **f: frequency in Hz**

- **Free-space path loss in decibels (WLAN)**

$$\mathrm{FSPL(dB)} = 10\log_{10}\left(\left(\frac{4\pi}{c}df\right)^2\right)$$
$$= 20\log_{10}\left(\frac{4\pi}{c}df * 10^9\right)$$
$$= 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c} * 10^9\right)$$
$$= 20\log_{10}(d) + 20\log_{10}(f) + 32.45$$

- **d: distance in meters**
- **f: frequency in GHz**



- Example, find received signal strength in mWatts, assuming that path between access point and laptop is clear path.

<u>ANS</u>

FSPL = 20 $\log_{10}(10)$ + 20 $\log_{10}(2.4)$ + 32.45 = 20 + 7.6 + 32.45 = 60.05 db

$P_{Rx(dbm)}$ = 36 – 60.05 = - 24.05 dbm

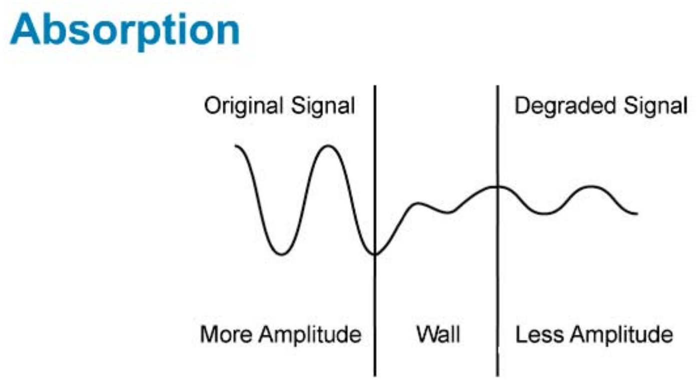
10 log $P_{Rx(mw)}$ = -24.05 → $P_{Rx(mw)}$ = 0.004 mw

Absorption

- An effect of absorption is heat. When something absorbs a wave, it creates heat in whatever absorbed the wave.
- This is seen in microwaves ovens. They create waves that are absorbed by your food, The result is hot food.
- Absorption reduces the amplitude of the signal, and reduces the travelling distance of that signal
- A problem you can encounter is that if a wave is entirely absorbed, it stops.
- Absorption does not change the wavelength or the frequency of the wave. These two values do not change as a wave is absorbed.

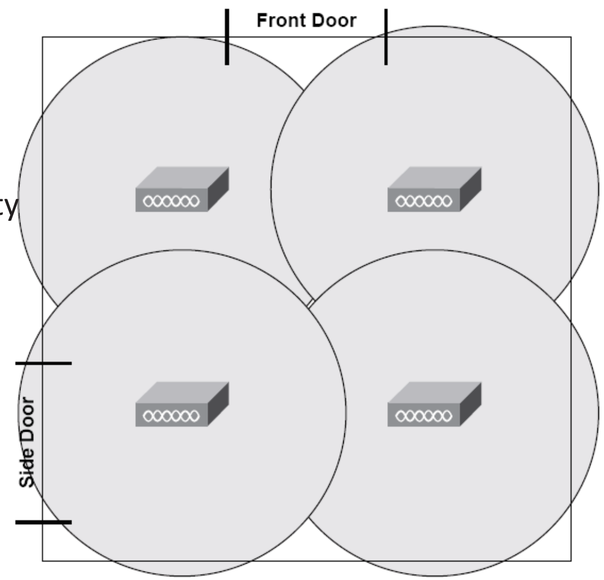
Absorption (cont,..)

- sources of absorption are; Walls, bodies, and carpet can absorb signals.



Absorption (cont,..)

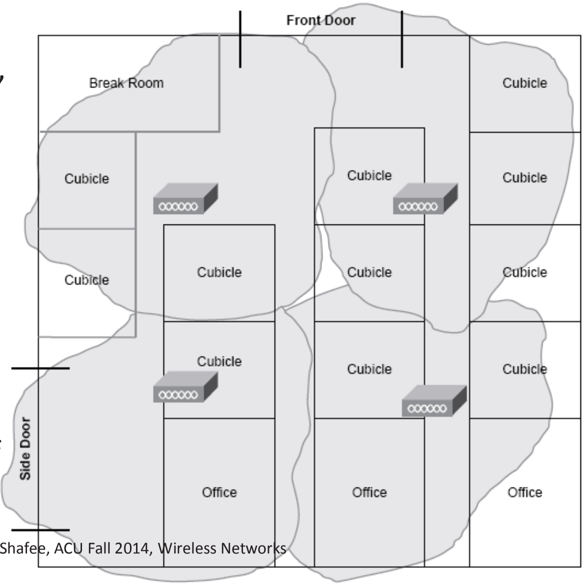
- Absorption and RF deployment:
- In the figure the four APs will provide plenty of coverage.
- This is because you cannot see absorption.
- Nothing causes the issue.

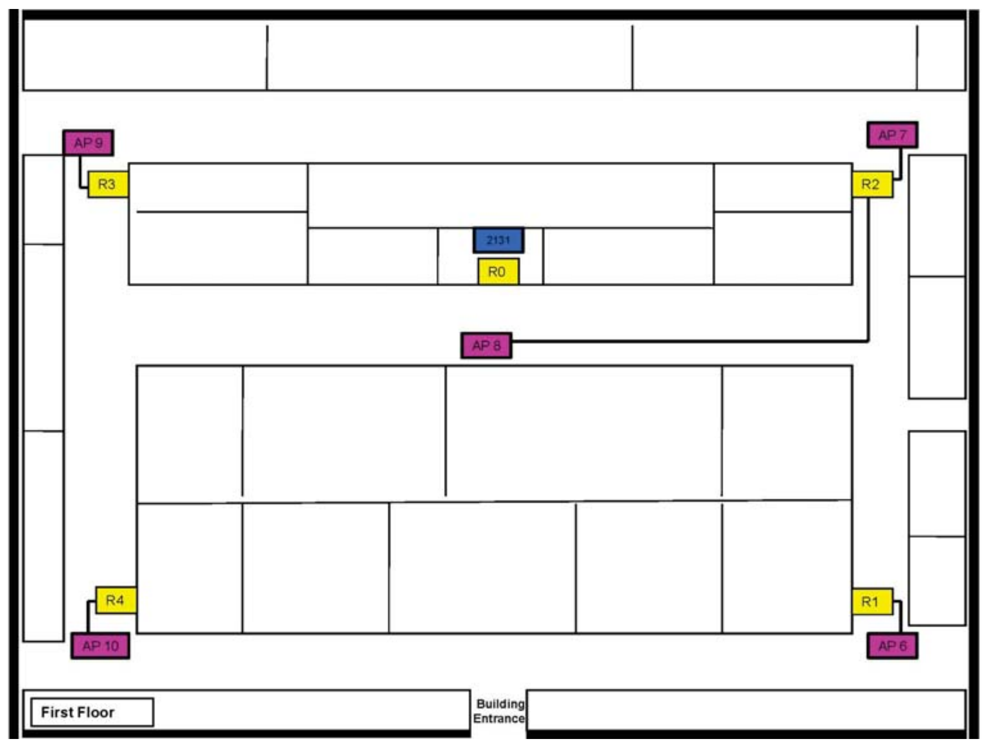


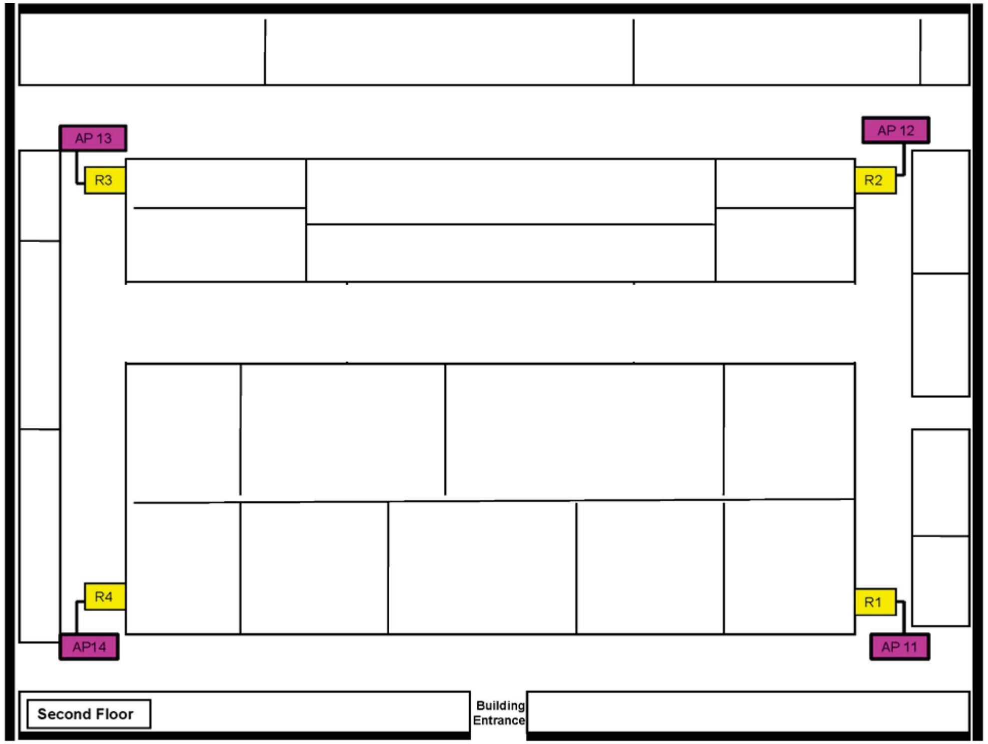
Absorption Before Office Move-In

Absorption (cont,..)

- Notice that with the furniture, cubicle walls, and other obstacles,
- the four APs that you originally thought would be sufficient no longer provide the proper coverage because of the signal being absorbed.
- This is an illustration of absorption.

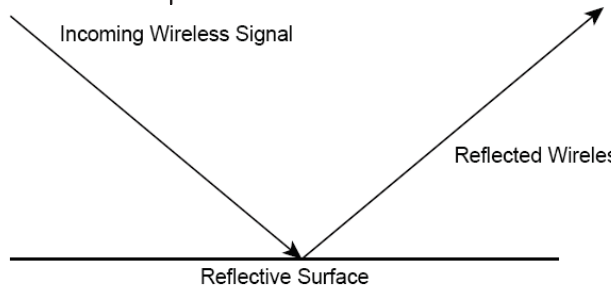






Reflection

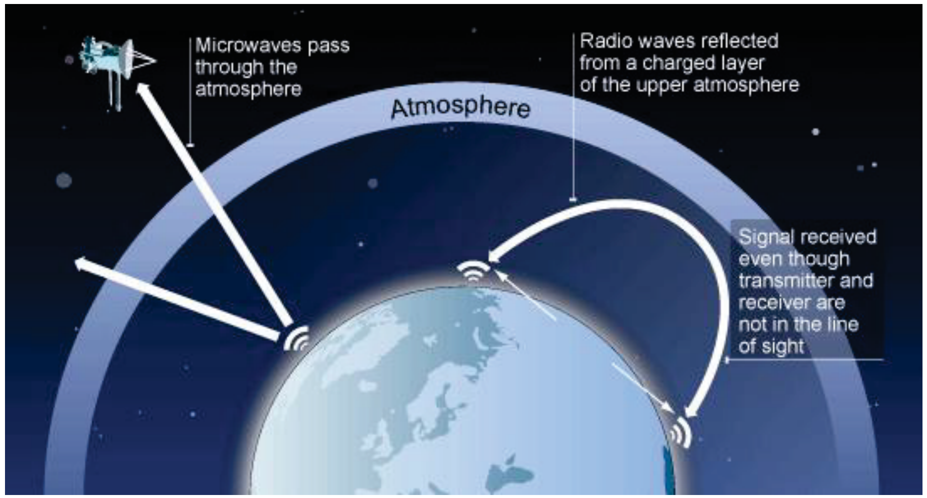
- Reflection happens when a signal bounces off of something and travels in a different direction.
- This can be illustrated by shining a flashlight on an angle at a mirror, which causes it to reflect on an opposite wall.
- The same concept is true with wireless waveforms.



The Reflection Issue

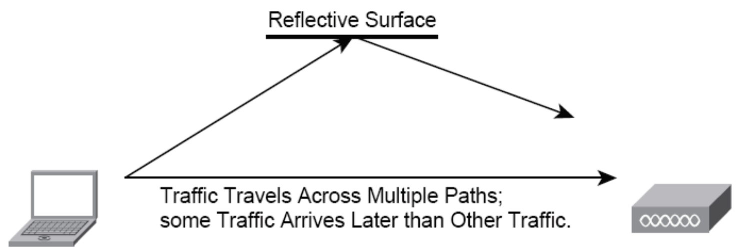
Reflection (cont,..)

- the reflection of the signal is reflected at the same angle that it hits the mirror.
- Reflection (reflected waves) considered to be a source of interference in an office environment.
- Offices do have objects with a reflective qualities (act as a reflector for electromagnetic waves basically metal or glassy objects), such as monitors and framed artwork with glass facing, metal art work.
- Reflection depends on the frequency.
- You will encounter some frequencies that are not affected as much as others.
- This is because objects that reflect some frequencies might not reflect others.



Multipath fading

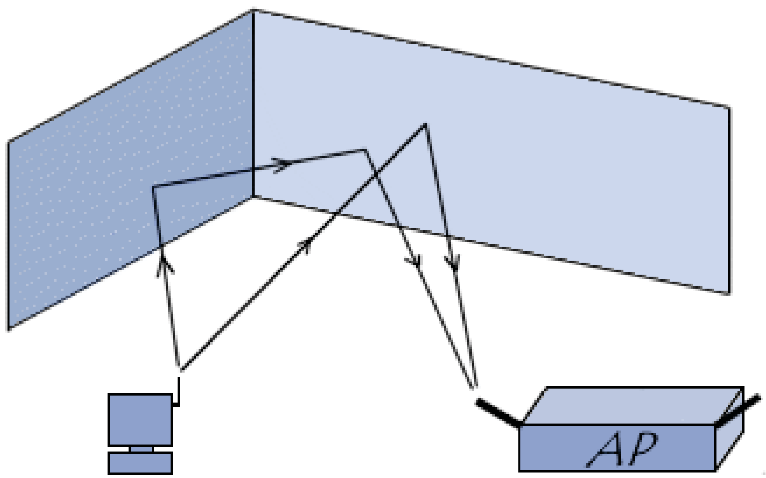
- *Multipath is what happens when portions of signals are reflected and then arrive out of* order at the receiver, as illustrated in Figure



The Multipath Issue

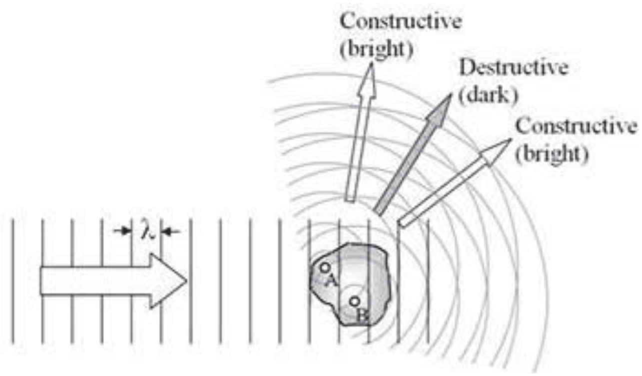
Multipath fading (cont,..)

- One characteristic of multipath is that a receiver might get the same signal several times over.
- This is dependent on the wavelength and the position of the receiver.
- Another characteristic of multipath is that it can cause the signal to become out of *phase.*
- *When you receive out-of-phase signals, they can cancel each other out, resulting* in a null signal.

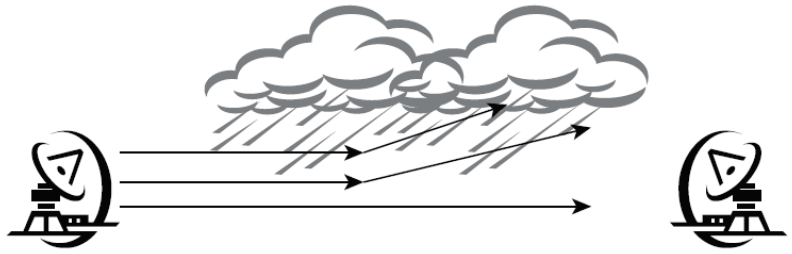


Scattering

- happens when the signal is sent in many different directions.
- This can be caused by some object that has reflective, yet jagged or rough edges, such as dust particles in the air and water.
- to illustrate the effects would be to consider shining a light onto a pile of broken glass.
- The light that is reflected shoots off in many different directions.
- The same is true with wireless, only the pile of glass is replaced with microparticles of dust or water.



Scattering (cont,..)



Wireless Signal Scattering

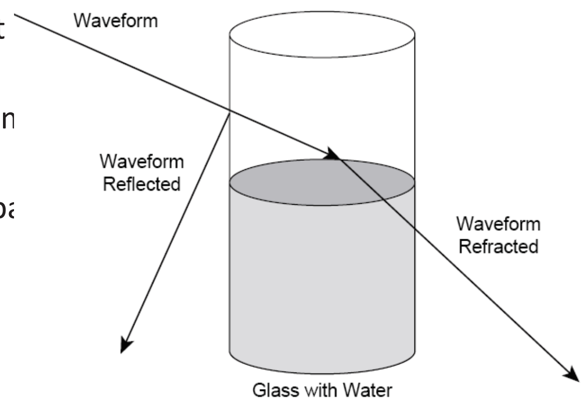
- On a large scale, imagine that it is raining.
- Large raindrops have reflective capabilities.
- When a waveform travels through those microparticles, it is reflected in many directions.
- This is *scattering.*

Scattering (cont,..)

- Scattering has more of an effect on shorter wavelengths, and the effect depends on frequency.
- The result is that the signal weakens.

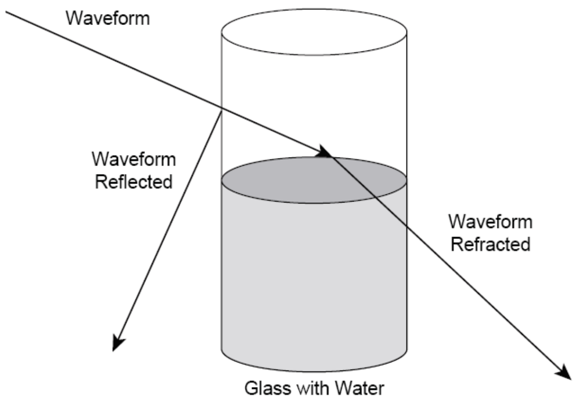
Refraction

- *Refraction is the change in direction of, or the bending of, a waveform as it pass*
through something that different density.
- This behavior causes son of the signal to
- be reflected away and pa to be bent through the object.



The Refraction Issue

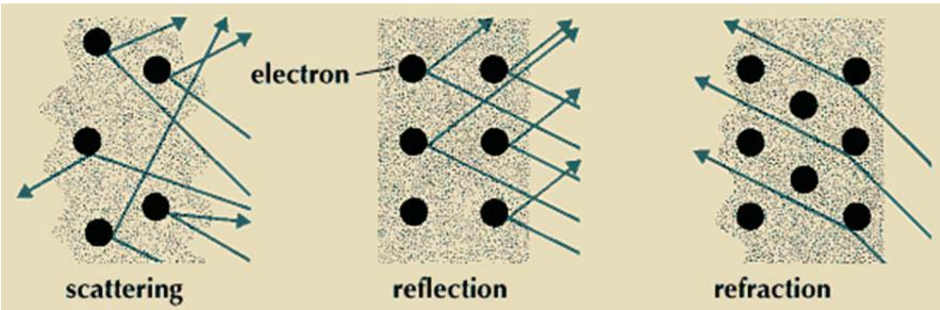
- To understand this consider A waveform is being passed through a glass of water.
- Notice that, because the glass is reflective, some of the light is reflected, yet some still passes through.
- The waveform that is passed through the glass is now at a different angle.



The Refraction Issue

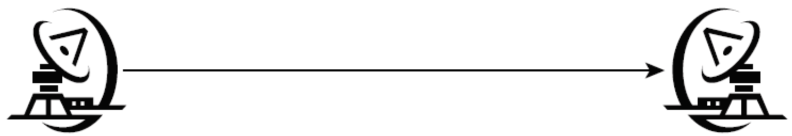
Refraction (cont,..)

- Because refraction usually has the most effect on outdoor signals,
  – dryness refracts away from the earth (as seen in dust particles),
  – and humidity refracts toward the earth.



Line of Sight

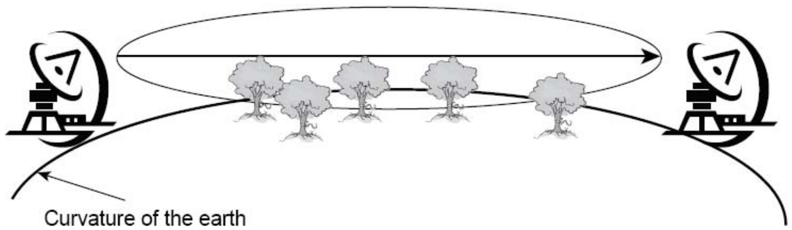
- As wireless signals travel farther distances, the signal widens near the midpoint and slims down nearer to the receiver.
- Figure below illustrates where two directional antennas are sending a signal between the two points.
- The fact that it appears to be a straight shot is called *visual line of sight (LOS).*



Directional Antennas and Line of Sight

Line of Sight (cont,..)

- Even though you see the other endpoint as a direct line, you must remember that the signal does not.

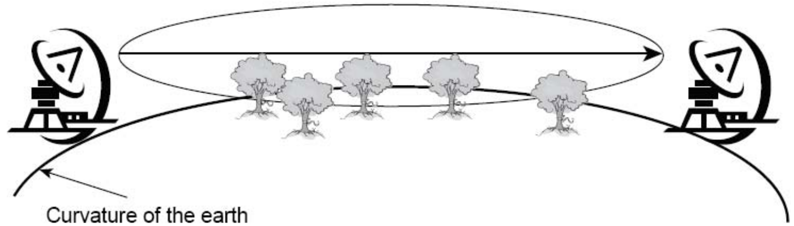


Directional Antennas and LOS with Obstructions

- the signal widens near the midpoint and slims down nearer to the receiver.

Line of Sight (cont,..)

- Although the path has no obvious obstacles, at greater distances the earth itself becomes an obstacle.
- This means that the curvature of the earth, as well as mountains, trees, and any other environmental obstacles, can actually interfere with the signal.



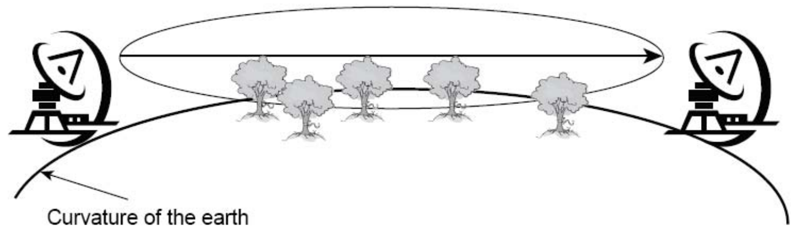
Directional Antennas and LOS with Obstructions

The Fresnel Zone

- Augustin-Jean Fresnel was a French physicist and civil engineer who lived from 1788 to 1827
- He correctly assumed that light moved in a wavelike motion transverse to the direction of propagation, and he was correct.
- Because of his work, a method for determining where reflections will be in phase and out of phase between sender and receiver is based on his name.
- This method determines what is called the *Fresnel zone.*

The Fresnel Zone (cont,..)

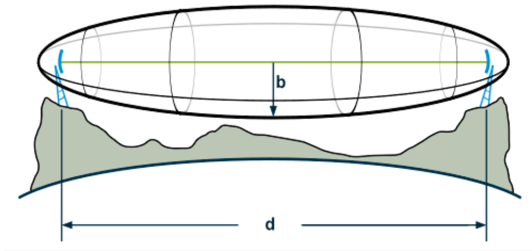
- First he divided the path into zones.
- The first zone should be at least 60 percent clear of obstructions.
- To visualize this, you can think of the shape of a ellipse, which is wider in the middle.



Directional Antennas and LOS with Obstructions

The Fresnel Zone (cont,..)

- However, with the Fresnel zone calculation, you use an equation to determine what the short diameter of the ellipse is at the middle.
- This helps to determine the width that a wave will be so you can make sure that no obstacles are in the path.



The Fresnel Zone (cont,..)

- The general equation for calculating the Fresnel zone radius at any point P in between the endpoints of the link is the following:

$$F_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}}$$

F_n = The n^{th} Fresnel Zone radius in metres

d_1 = The distance of P from one end in metres

d_2 = The distance of P from the other end in metres

λ = The wavelength of the transmitted signal in metres

The Fresnel Zone (cont,..)

- r = radius in metres
- D = total distance in kilometres
- f = frequency transmitted in gigahertz.

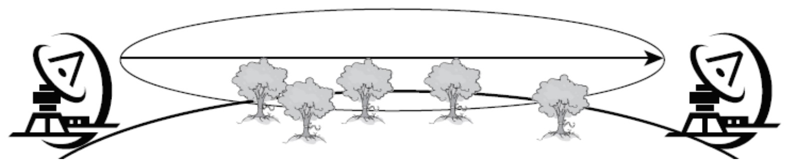
$$r = 8.657\sqrt{\frac{D}{f}}$$

The Fresnel Zone (cont,..)

- online Fresnel zone clearance calculator at *http://www.terabeam.com/support/calculations/fresnel-zone.php*

Example

- for a 2.4-GHz system, at 11 Km
- Short radius of 1st fresnel zone =18.5m
- You need 60% free of 1st freesenel zone = 11.1 m
- you need to have the antennas mounted at 12 meters.



The Fresnel Zone (cont,..)

Example

- for a 2.4-GHz system, at 10m
- Short radius of 1st fresnel zone =8.657 $(0.01/2.4)^{0.5}$= 0.56m
- You need 60% free of 1st freesenel zone 0.56 m
- you need to have the antennas mounted at 0.34 m for a plain ground surface
- Considering that person's average length is 1.8 m
- So you need to have the antennas mounted at 2.14 m to avoid effect of persons existence in WLAN path.

Received Signal Strength Indicator & Receive Channel Power Indicator

- The Received Signal Strength Indicator (RSSI) measurement uses vendor-specified values.
- Because of this, you cannot relay on it to compare different vendors.
- The scale is usually represented in dBm
- RSSI is acquired during the preamble stage of receiving an 802.11 frame
- Receive Channel Power Indicator (RCPI), which is a functional measurement covering the entire received frame with defined absolute levels of accuracy and resolution.

Signal-to-Noise Ratio

- *Signal-to-noise ratio (SNR) is the term used to describe how much stronger the signal is* compared to the surrounding noise that corrupts the signal
- To understand this, suppose you walk into a crowded park with many screaming kids and speak in a normal voice while on the phone.
- The odds are that the noise is going to be so loud that the person on the other end will not be able to distinguish your words from all the noise around you that is also being transmitted over the phone, "This is how the wireless network operates"

Signal-to-Noise Ratio (cont,..)

- If the outside influences are causing too much noise, the receivers cannot understand the transmissions.
- When the software that runs your wireless card reports this measurement, it is best to have a higher number, but this is also built on the RSSI value, so it is vendor determined.

Link Budget

- *Link budget is a value that accounts for all the gains and losses between sender and receiver,* including attenuation, antenna gain, and other miscellaneous losses that might occur.
- This can be useful in determining how much power is needed to transmit a signal that the receiving end can understand.
- The following is a simple equation to factor link budget:

Received Power (dBm) = Transmitted Power (dBm) + Gains (dB) – Losses (dB)

Thanks,

See you next Week, isA