Gemini Communication Ltd.

Innovation & Leadership

Basics of RF Technology

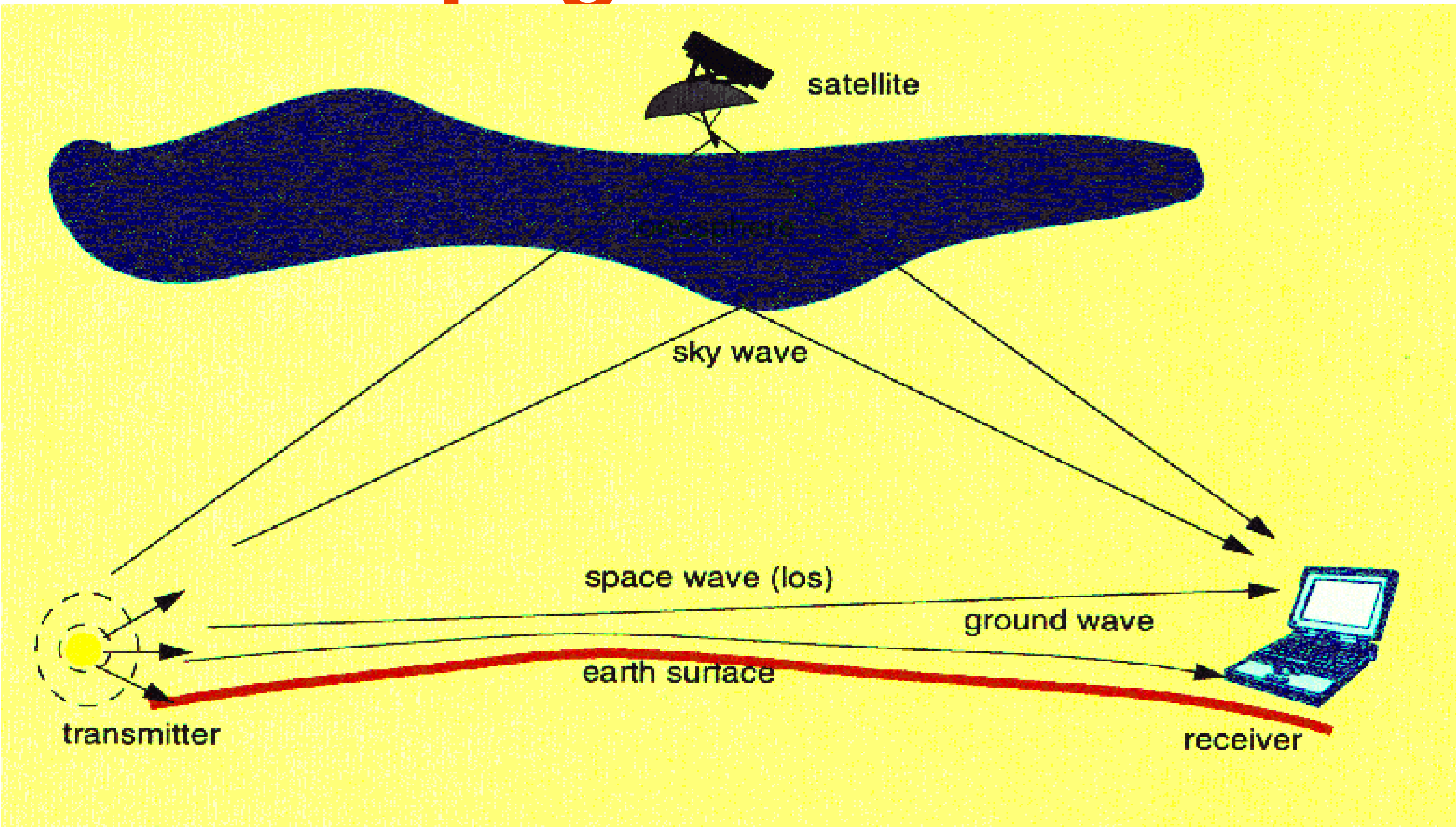
Ref. 1030001100

RF Propagation and Impairments

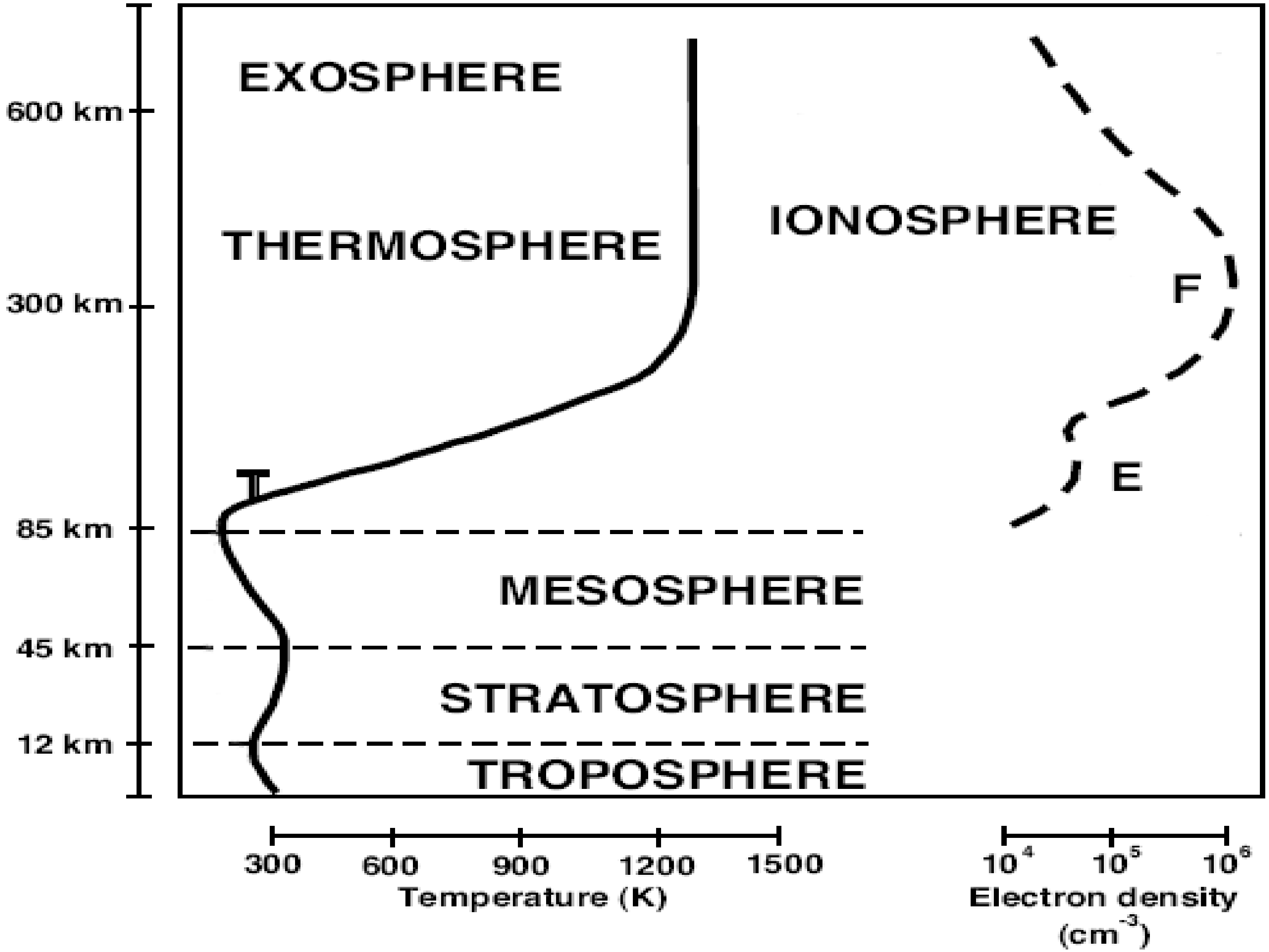
RF Propagation Methods

Radio Band		Frequency	Propagation Via
VLF	Very Low Frequency	3 - 30 kHz	Guided between earth and ionosphere
LF	Low Frequency	30 - 300 kHz	Guided between earth and ionosphere Ground Waves
MF	Medium Frequency	300 - 3000 kHz	Ground wave during the day E layer ionospheric reflection at night
HF	High Frequency (Short Wave)	3 - 30 MHz	E layer ionospheric reflection F layer ionospheric reflection
VHF	Very High Frequency	30 - 300 MHz	Line of Sight E layer ionospheric reflection
UHF	Ultra High Frequency	300 - 3000 MHz	Line of Sight

RF Propagation Methods

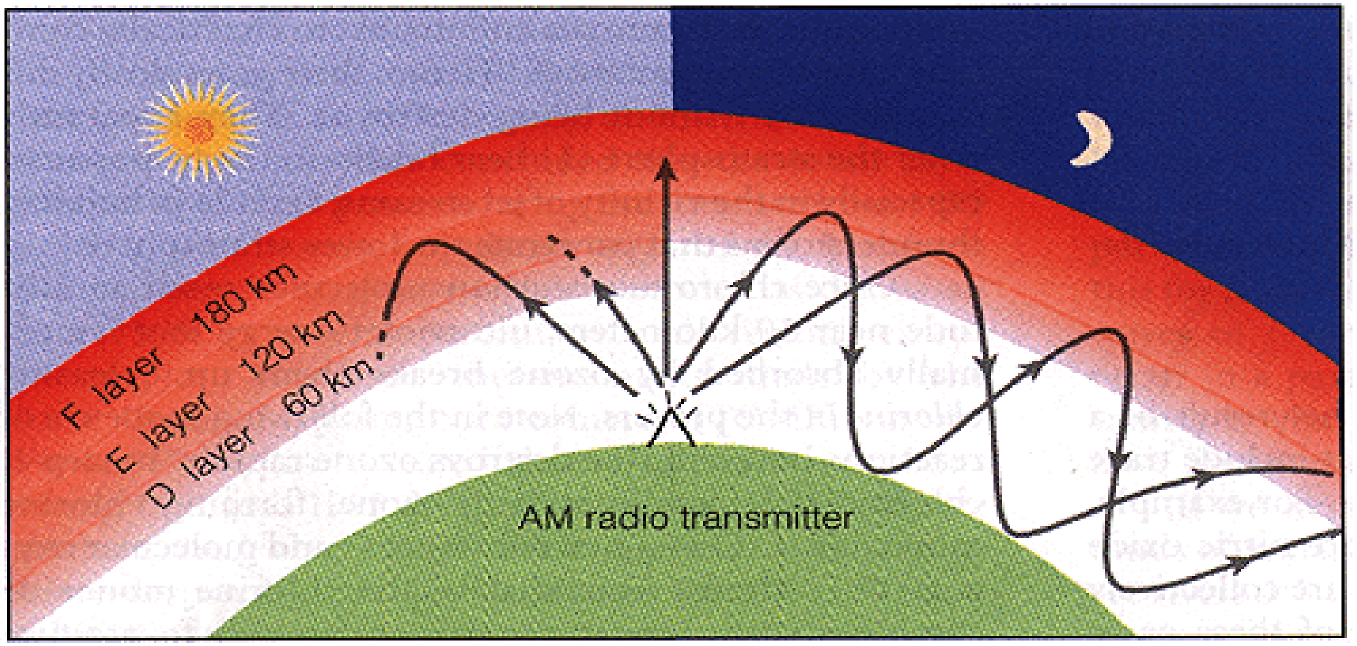


Atmosphere

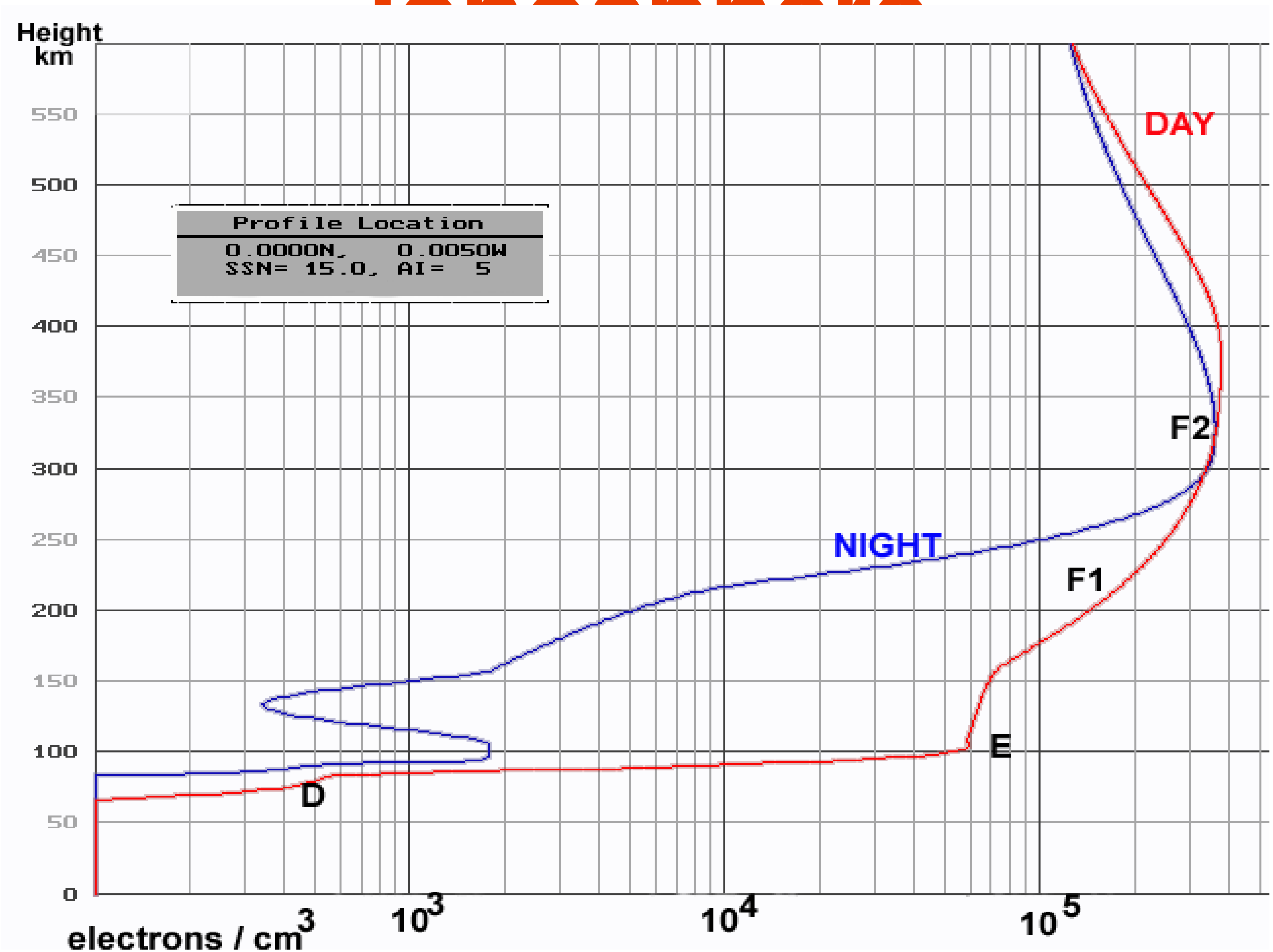

EXOSPHERE
THERMOSPHERE
IONOSPHERE
F
E
MESOSPHERE
STRATOSPHERE
TROPOSPHERE
600 km
300 km
85 km
45 km
12 km
300
600
900
1200
1500
Temperature (K)
10^4
10^5
10^6
Electron density
(cm^-3)

Ionosphere

- The **ionosphere** is the part of the atmosphere that is ionized by solar radiation
- It influences HF (3–30 MHz) radio propagation
- The ionization depends on the Sun and its activity

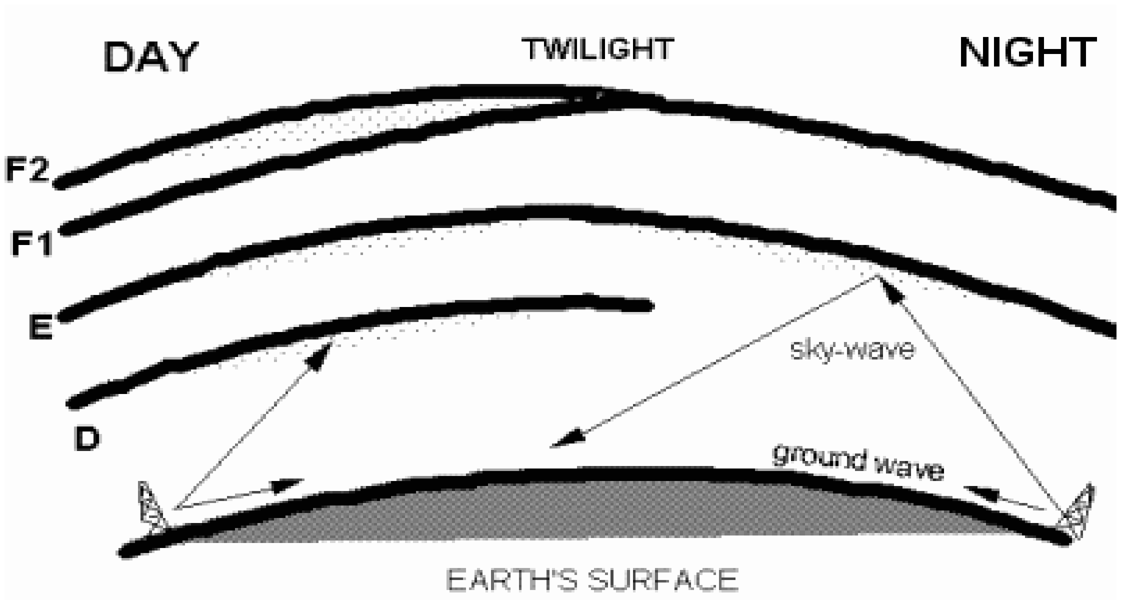


Ionosphere


Height
km
550
500
450
400
350
300
250
200
150
100
50
0
Profile Location
0.0000N, 0.0050W
SSN= 15.0, AI= 5
DAY
NIGHT
F2
F1
E
D
electrons / cm3
10^3
10^4
10^5

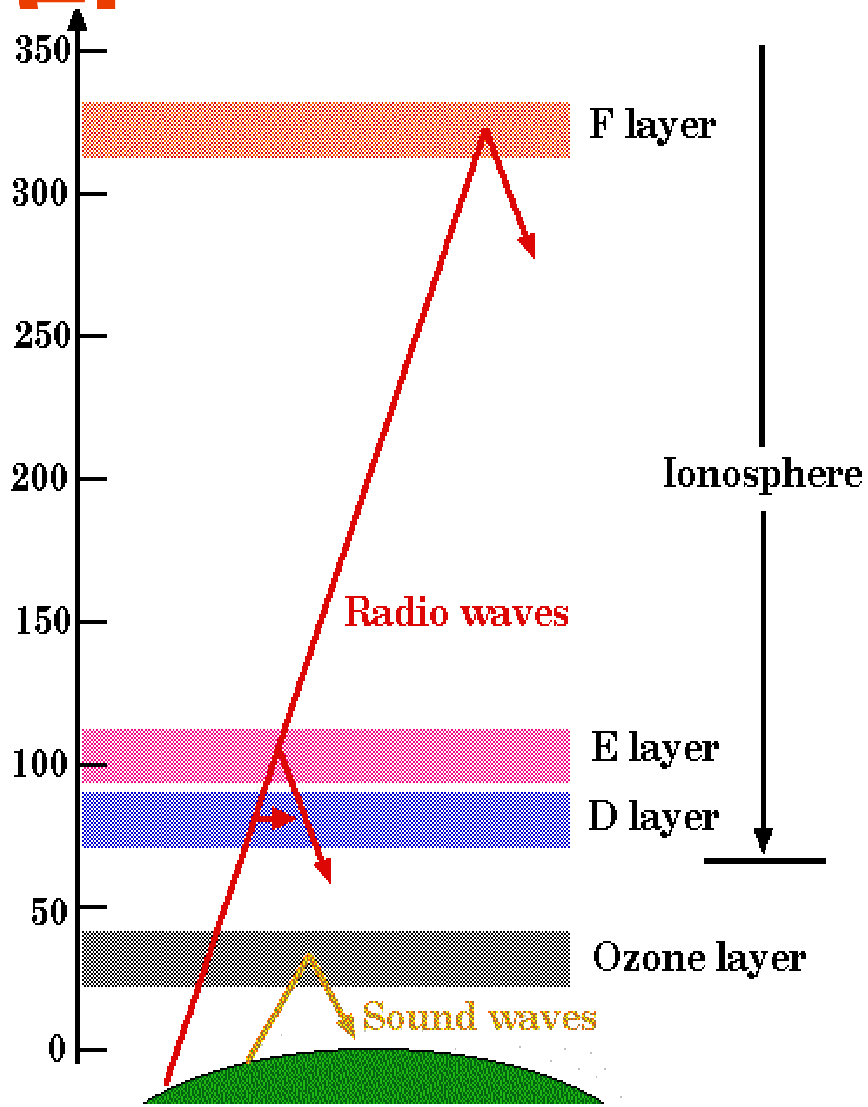
D Layer

- D layer is 50 km to 90 km above the earth surface
- Ionization is due to radiation, ionizing nitric oxide
- The ionization effect is low and the HF radio waves are not reflected by this layer
- This layer is mainly responsible for absorption of HF radio waves, particularly at 10 MHz and below



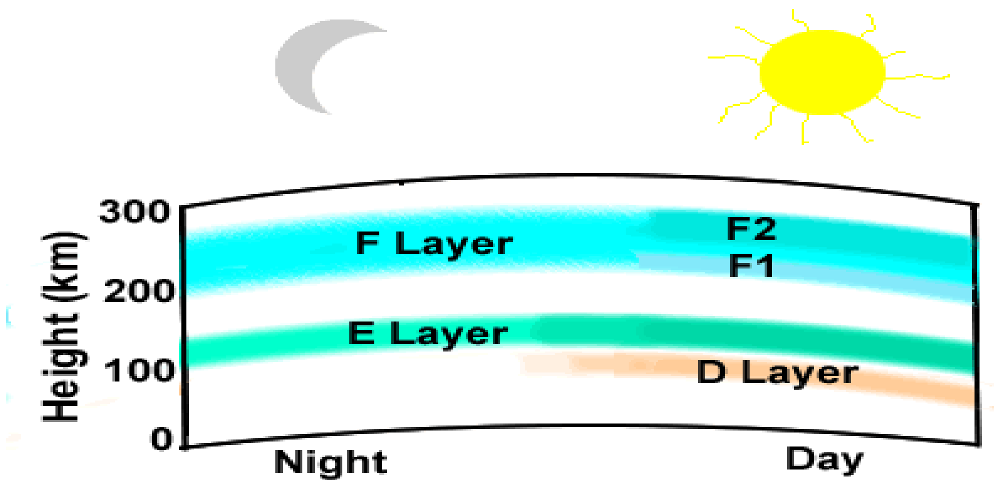
E Layer

- E layer is 90 km to 120 km above the earth surface
- Ionization is due to soft X ray and far ultraviolet solar radiation, ionizing oxygen
- This layer reflects frequencies less than 10 MHz



F Layer

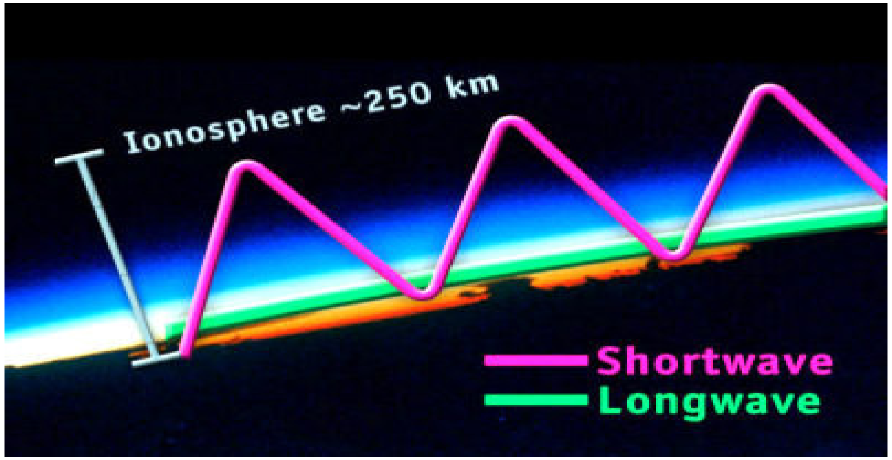
- F layer is 120 km to 400 km above the earth surface
- Extreme ultraviolet solar radiation ionizes oxygen
- The F layers combine into one layer at night
- During daytime, it divides into two layers, F1 and F2
- The F layers are responsible for sky wave propagation



Sky Wave Propagation

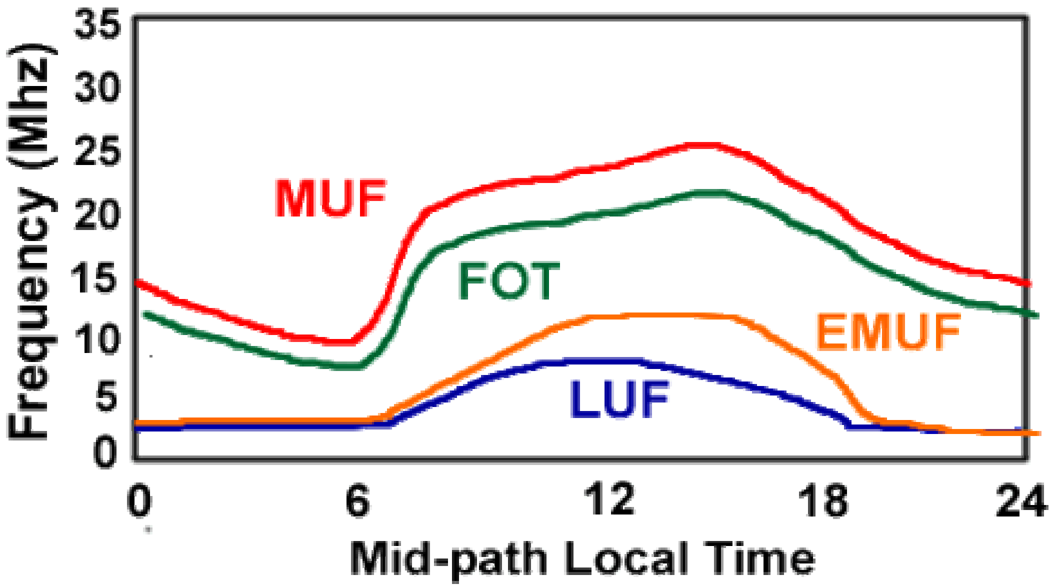
- For HF bands, the ionosphere is utilized to reflect the radio signal
- Radio waves hop between earth and ionosphere
- The critical frequency is the limiting frequency below which a radio wave is reflected by an ionospheric layer at vertical incidence
- Where, N = electron density per cc and $f_{critical}$ is in MHz

$$fcritical = 9 \times 10^{-3}\sqrt{N}$$



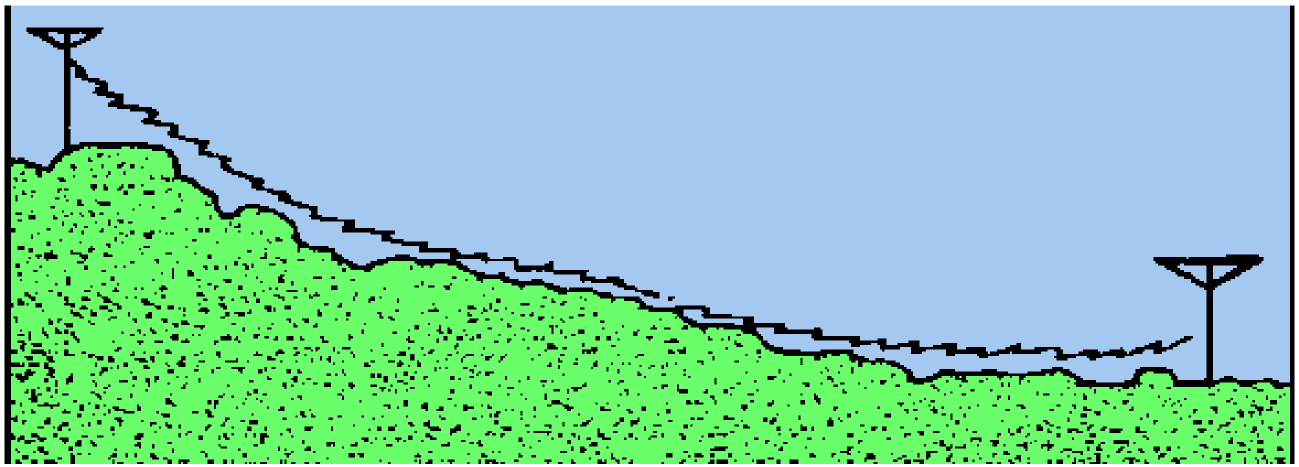
Sky Wave Propagation

- The Maximum Usable Frequency (MUF) is the upper frequency limit that can be used for t $fmuf = \frac{fcritical}{\sin(I)}$ en two points
- Where, I = angle of attack, the angle of the wave relative to the horizon
- The cutoff frequency is the frequency below which a radio wave fails to penetrate a layer



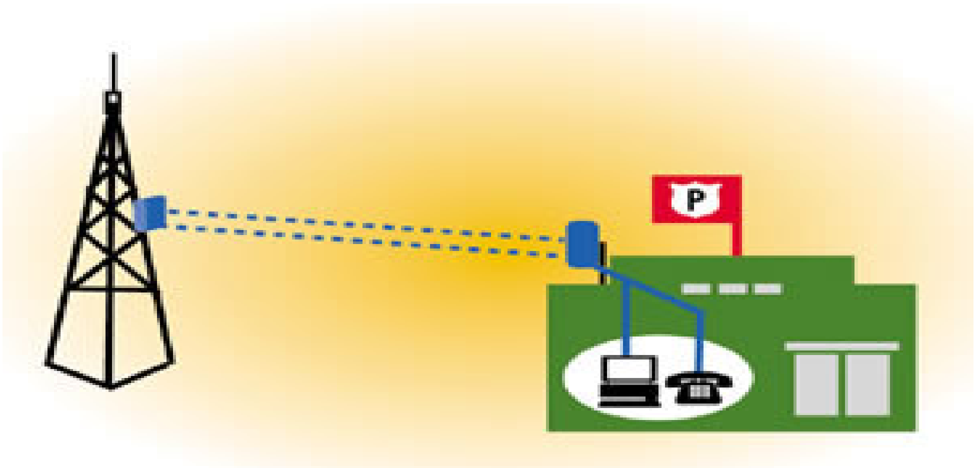
Ground Wave Propagation

- Progresses along curvature of the earth
- Gets attenuated as it follow the earth's surface
- At low frequencies, ground losses are low
- The VLF and LF frequencies are used by military
- Especially for ships and submarines communications



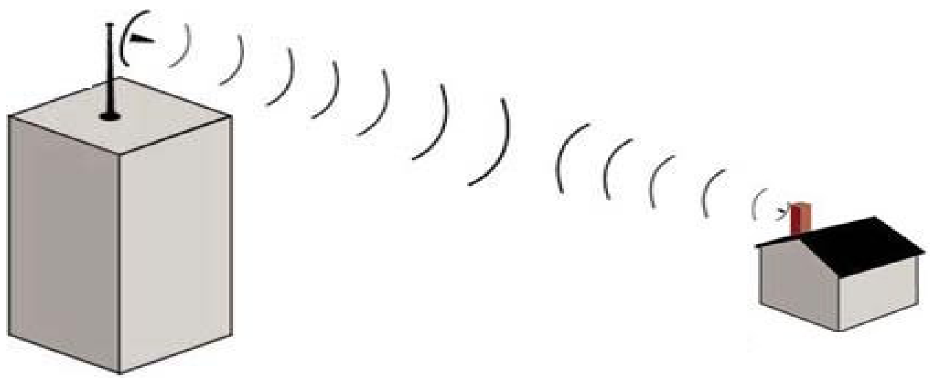
Line of Sight (LoS) Propagation

- Radio signals travel in straight lines
- At frequencies below 2 MHz diffraction effects allow them to follow the Earth's curvature
- Frequencies between 1 and 30 MHz, can be reflected by the ionosphere.
- But, at higher frequencies, neither of these effects applies



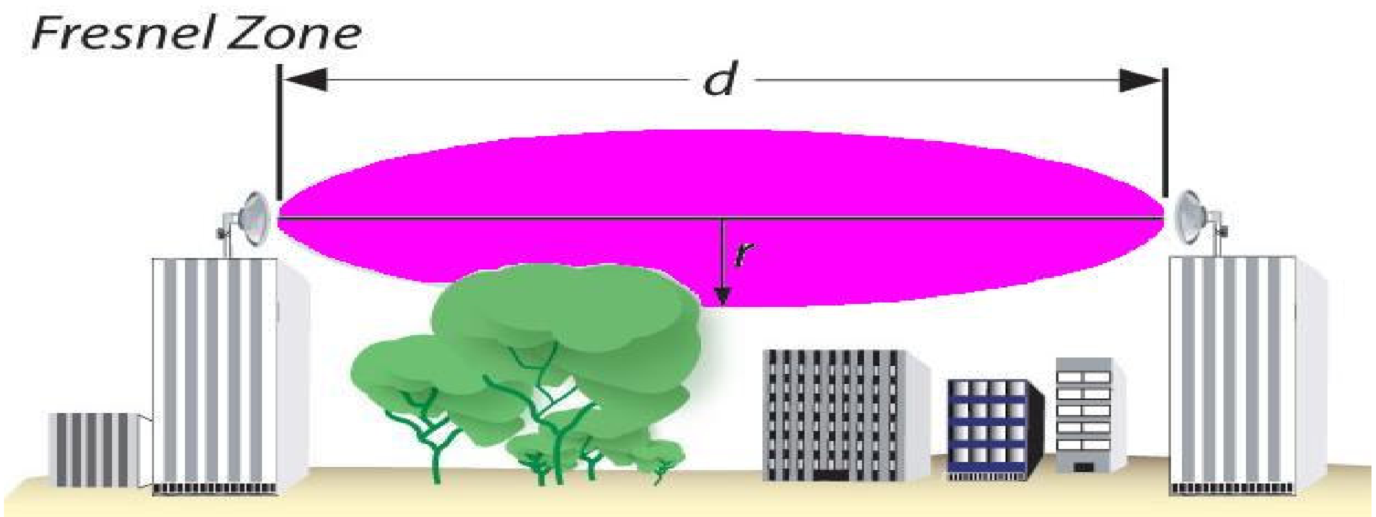
Line of Sight (LoS) Propagation

- Any obstruction between the transmitting and receiving and antenna will block the signal
- The ability to visually sight a transmitting antenna corresponds with the ability to receive a signal from it
- Hence, the propagation characteristic of HF radio is called line of sight
- The propagation characteristics depend on frequency and the strength of the transmitted signal



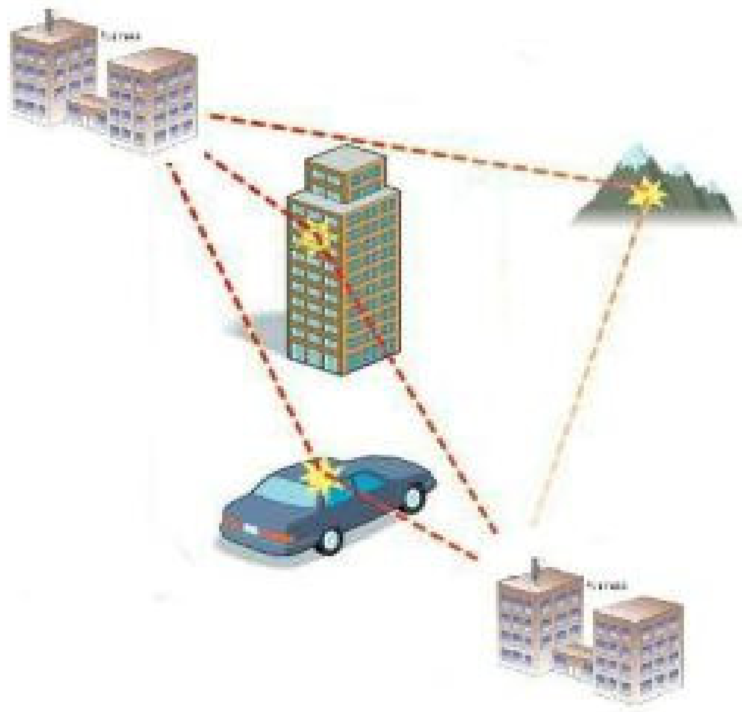
Impairments to LoS Propagation

- HF signal can be foiled by tree branches, heavy rain or snow
- The presence of objects not even in the direct visual line of sight can interfere with radio transmission
- A volume known as the first Fresnel zone should be kept free of obstructions
- Reflected radiation from the ground plane also acts to cancel out the direct signal



NLoS Propagation

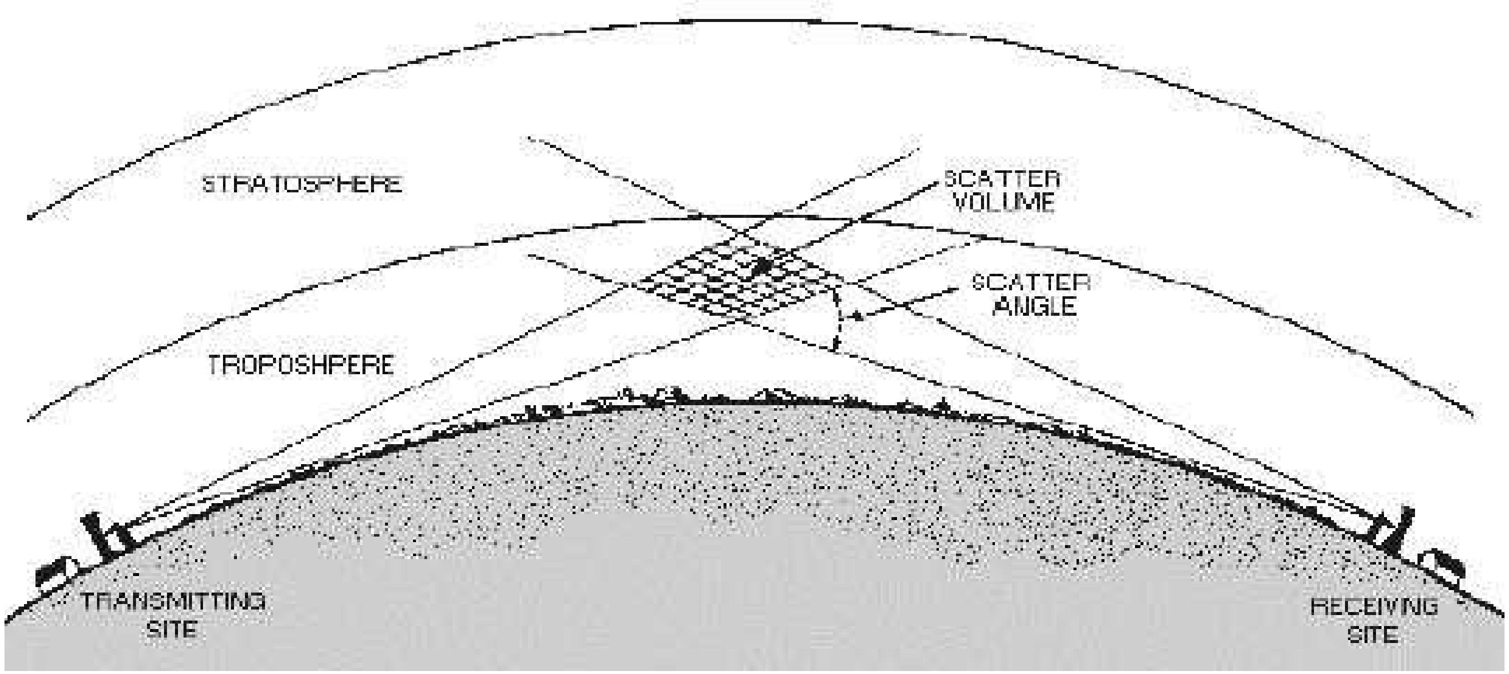
- **Near Line of Sight** or **Non Line of Sight**
- Radio transmission across a partially obstructed path
- Some of obstructions reflect certain signals, while some absorb the signals
- Effective NLoS networking is a major concern
- Most common method for dealing with NLoS conditions is to place relays at additional locations
- More advanced NLoS transmission schemes use multi-path signals



Tropospheric Scattering

- At VHF and higher, the atmosphere at a height of 10 km scatters some of the LoS signals back toward the ground

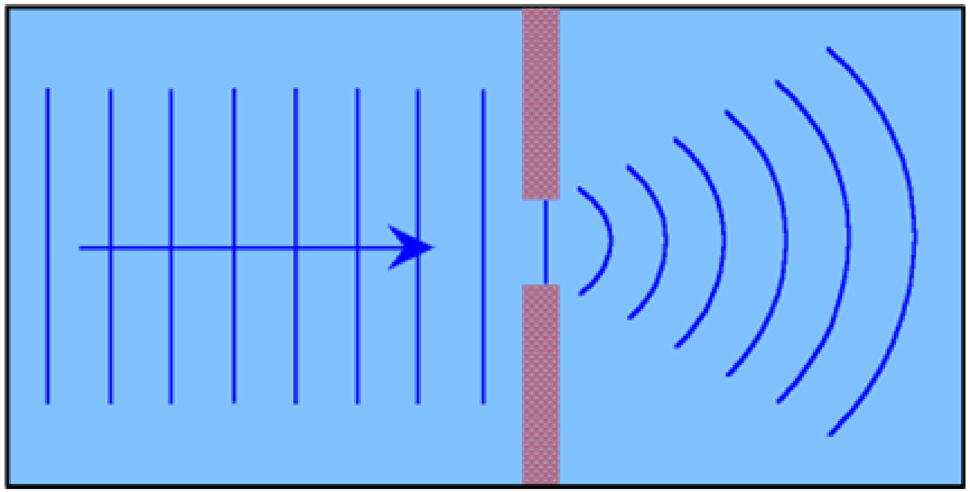
- This makes over the horizon communications possible

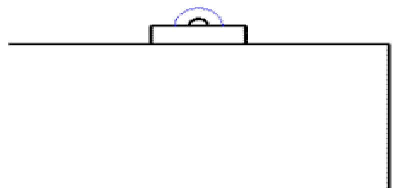


Diffraction

- **Diffraction** is the bending and spreading of waves when they meet an obstruction.
- Signals for urban cellular telephony are dominated by ground plane effects as they travel over the rooftops
- They diffract over roof
  edges into the street

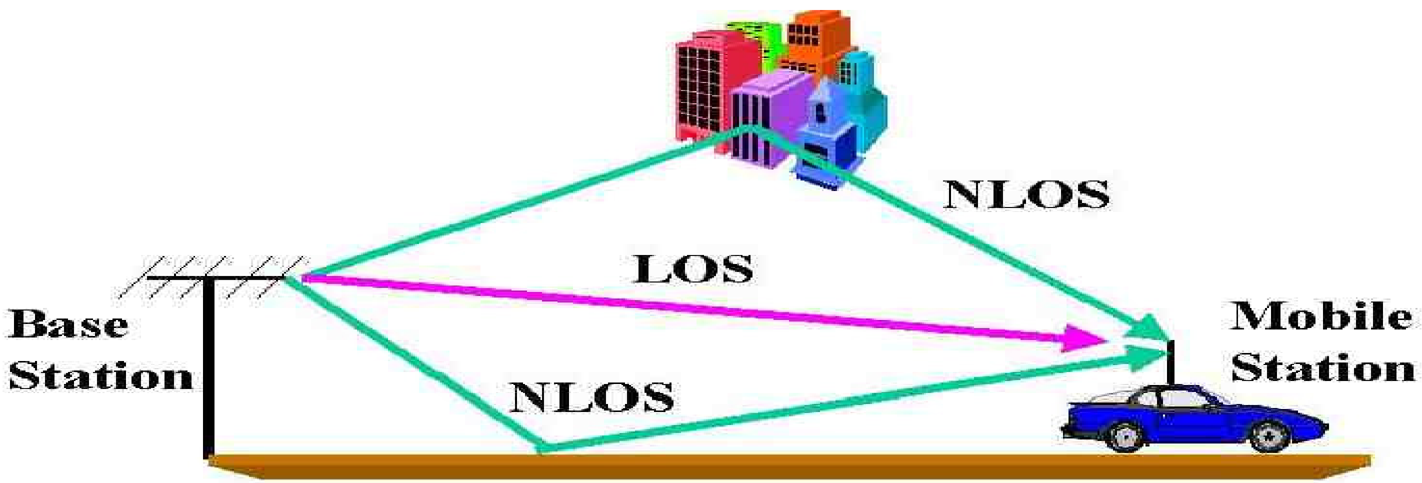
Note: diffraction from left edge of tweeter rim not shown





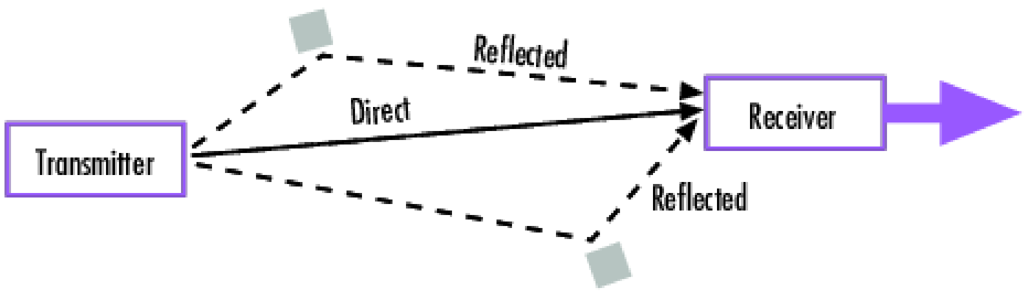
Multi-path Propagation

- RF signals may take two or more paths to reach the receiving antenna
- This results into constructive and destructive interference, and phase shifting of the signal
- This causes **Rayleigh fading**



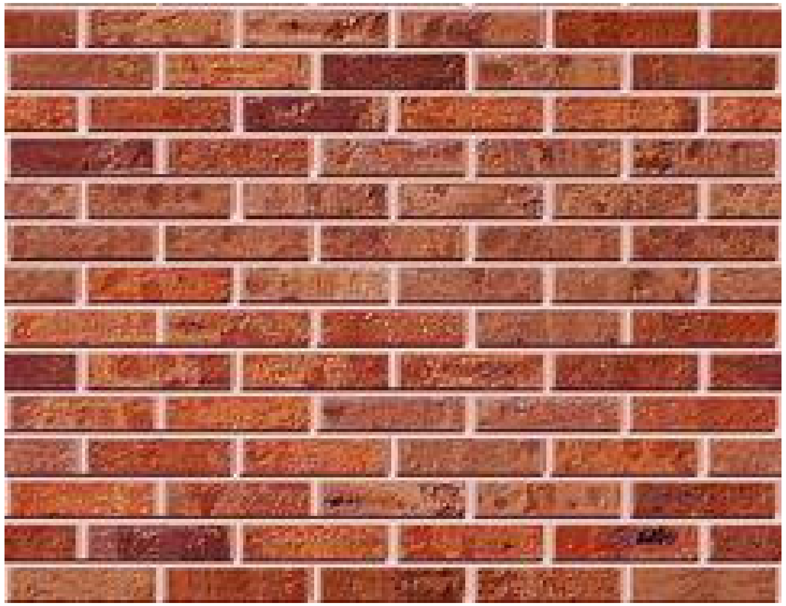
Multi-path Propagation

- In TV transmission, multi-path causes jitter and **ghosting**
- In digital radio communications such as GSM, multi-path can cause errors
- The errors are due to Inter Symbol Interference (ISI)
- Equalizers are often used to correct the ISI
- Alternatively, orthogonal frequency division modulation and Rake receivers may be used



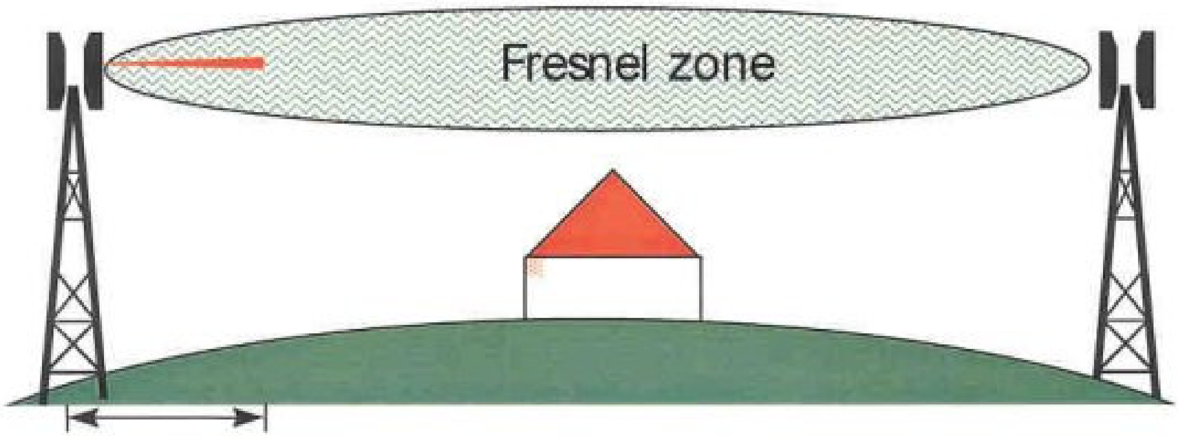
Absorption

- LF radio waves travel easily through brick and stone
- As the frequency rises, absorption effects become more significant
- Heavy rain and snow also present major challenges to microwave reception



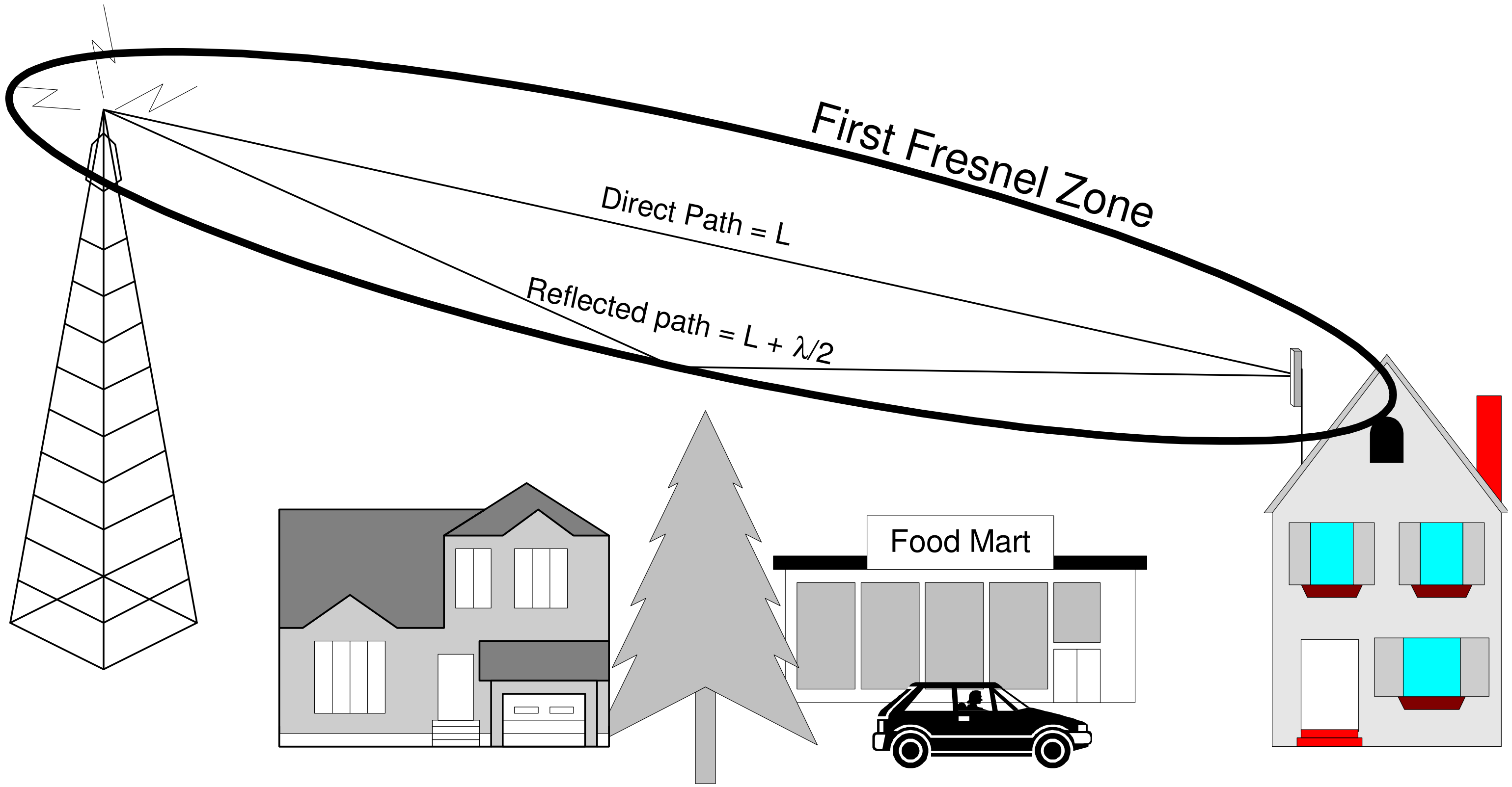
Fresnel Zone

- Obstructions between a transmitter and receiver reduce the communication range
- In order to maximize communication range, true RF LoS conditions must exist
- RF LoS is different from visual LoS
- RF LoS requires not only a visual sight line but an ellipsoid shaped area between the two antennas be free of obstructions
- Thi



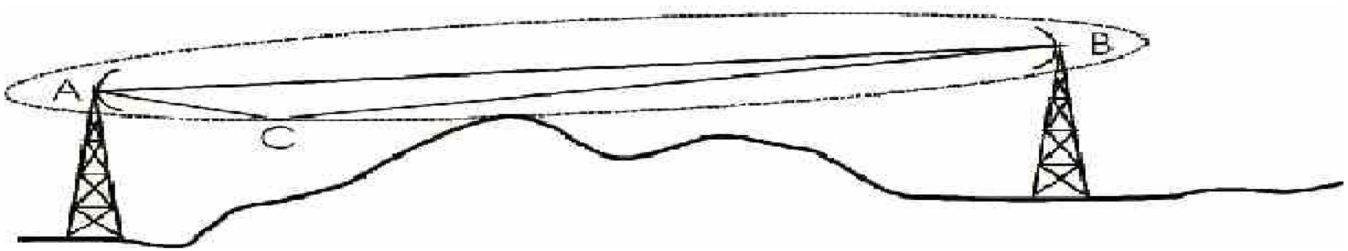
Fresnel Zone

- The fresnel zone is larger in diameter at the center and smaller at either end
- Greater the distance between the antennas, the larger the diameter of the fresnel zone in the center



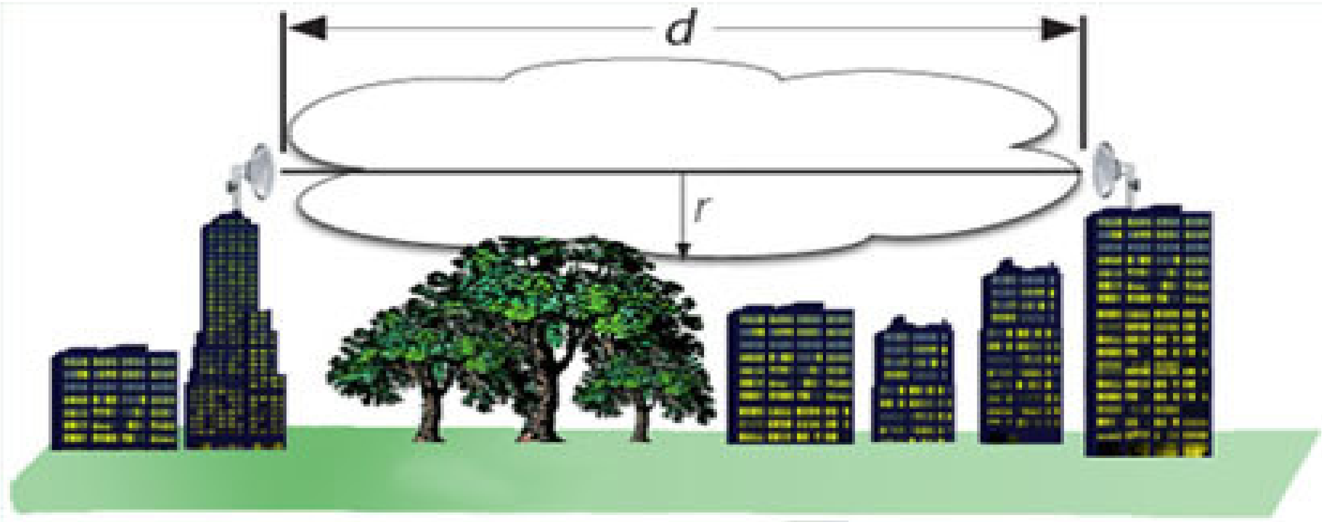
Fresnel Zone

- As the antennas get further apart and the diameter of the fresnel zone increases, the ground begins to obstruct the fresnel zone
- In order to keep the entire fresnel zone free of obstructions it is necessary to raise the antennas
- To keep the fresnel zone off the ground the heights of the antennas added together must be more than the diameter of the fresnel zone at the specific distance
- The diameter of the fresnel zone is a function of the frequency and the distance between the antennas



Fresnel Zone

- The cross section of the first Fresnel zone is circular
- The diameter of the first Fresnel zone is given by



$$r = 43.3 \times \sqrt{\frac{d}{4f}}$$

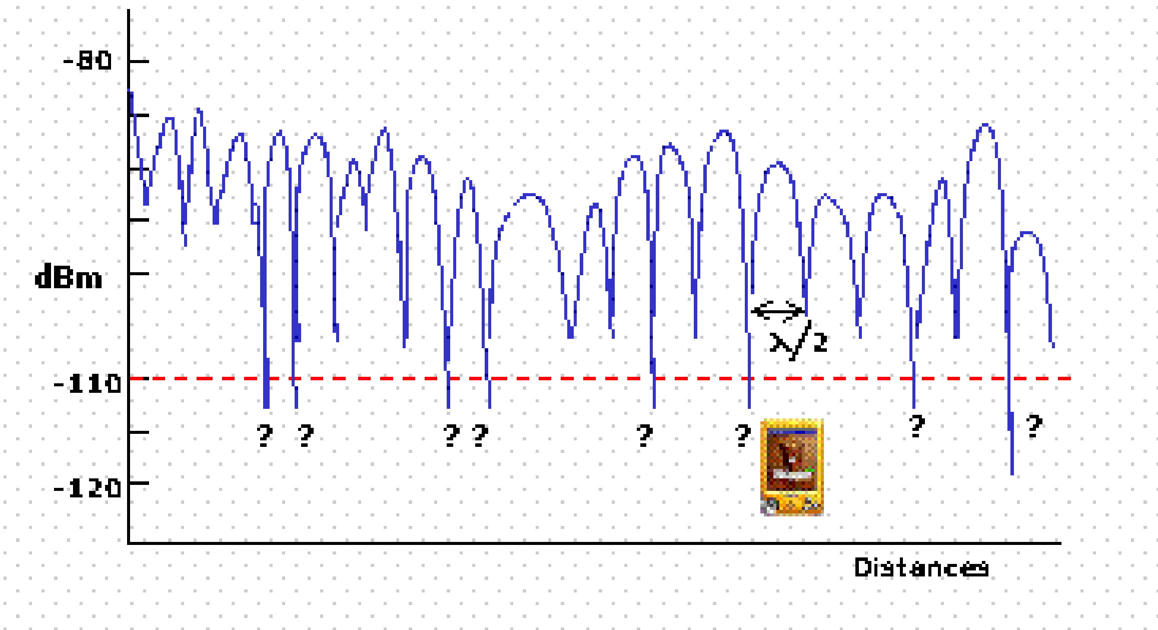
r **= radius in feet**

d **= distance in miles**

f **= frequency transmitted in gigahertz**

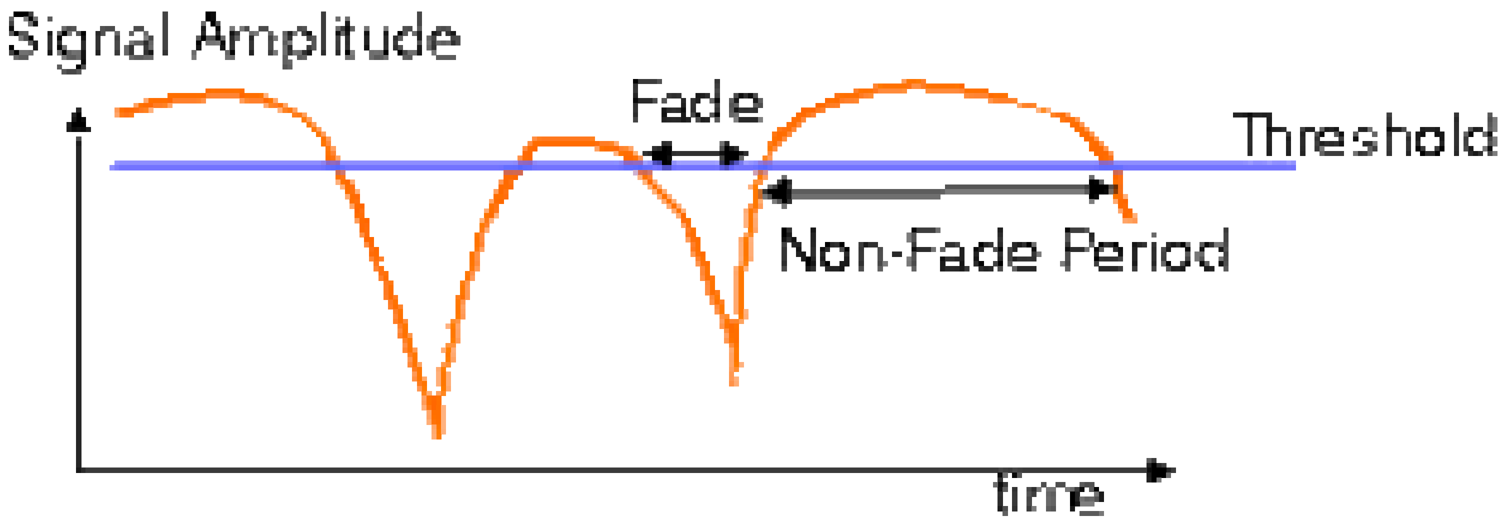
Fading

- The attenuation that a signal experiences temporarily
- This is due to destructive interference
- To combat fading, multiple versions of the same signal is transmitted, received, and coherently combined
- This is called diversity, and sometimes acquired through multiple antennas



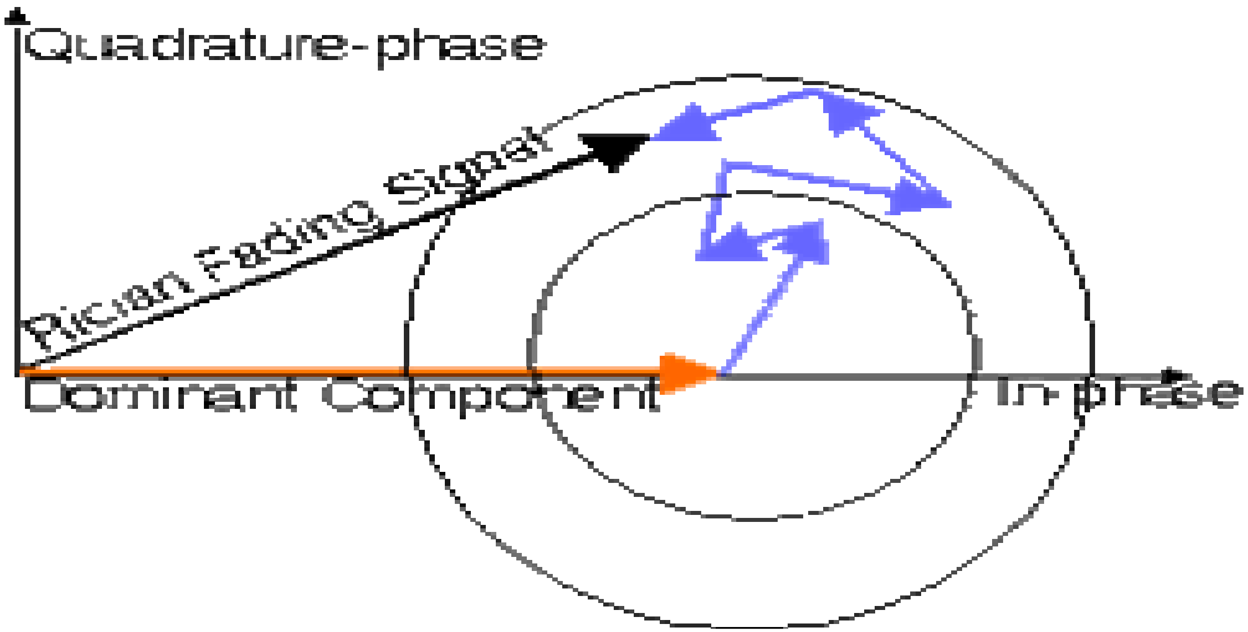
Fading

- In addition to the small scale fading, the signal can also undergo shadow fading, or shadowing
- This is due to the presence of obstacles between the transmitter and the receiver



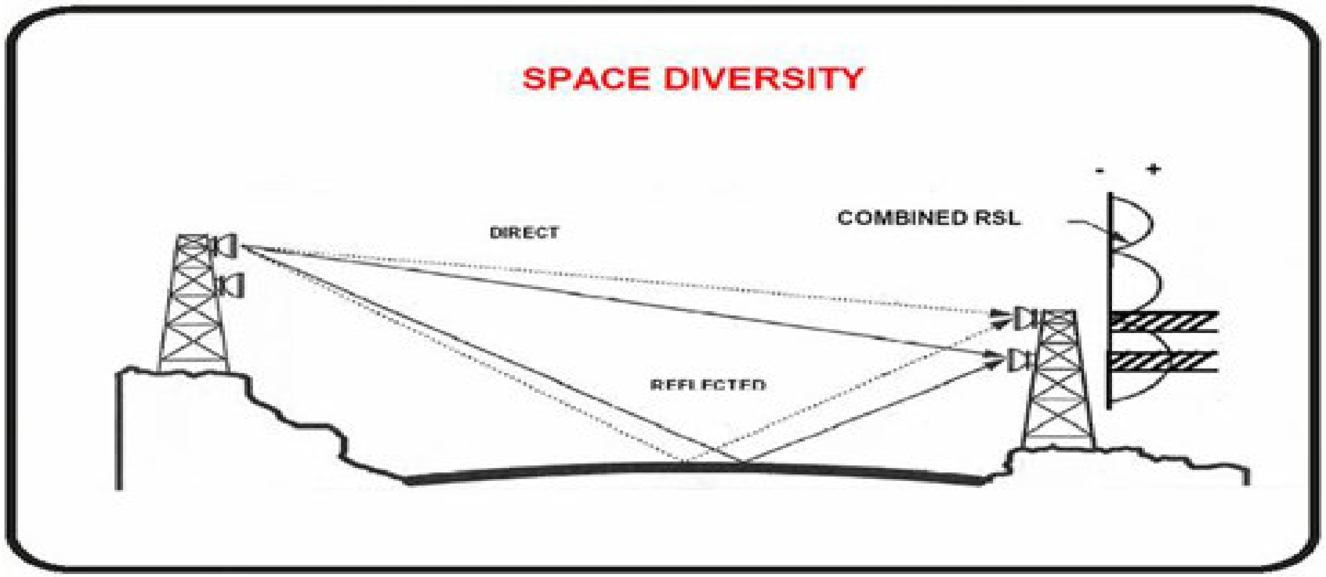
Rayleigh Fading

- The effects of multi-path are constructive and destructive interference, and phase shifting
- This causes **Rayleigh fading**
- Rayleigh fading with a strong LoS content is said to have a **Rician fading**



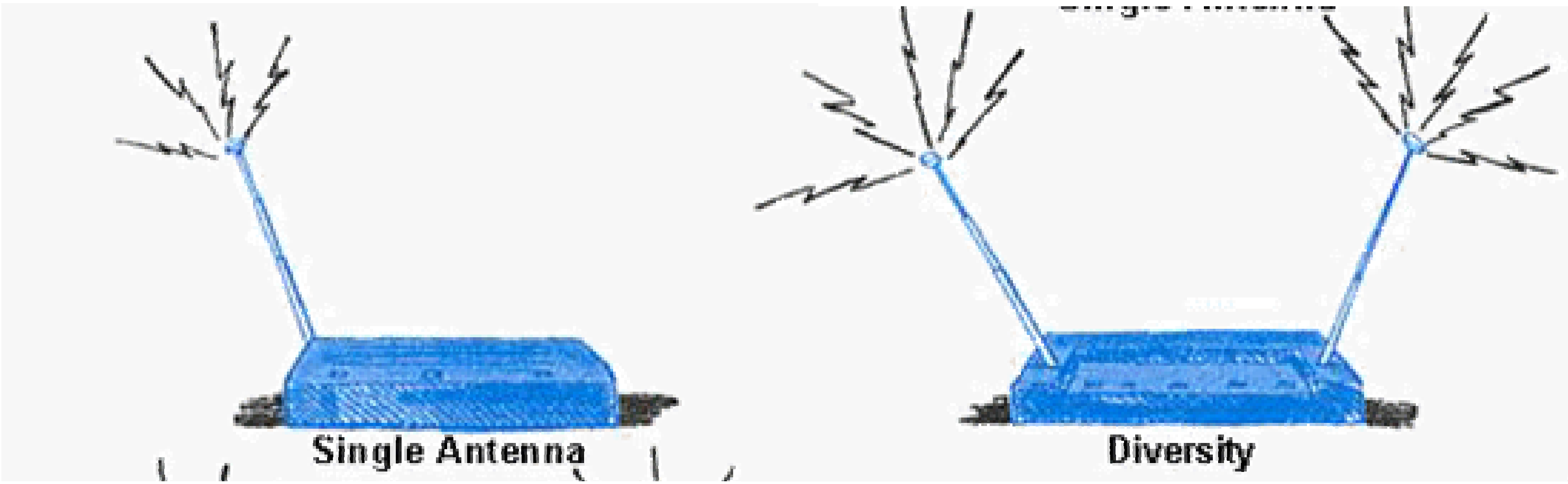
Diversity Reception

- Receiving multiple versions of the same signal
  - Space Diversity
  - Polarization Diversity
  - Time Diversity
  - Frequency Diversity
- After receiving the multiple versions of the signal, a diversity combining technique is applied



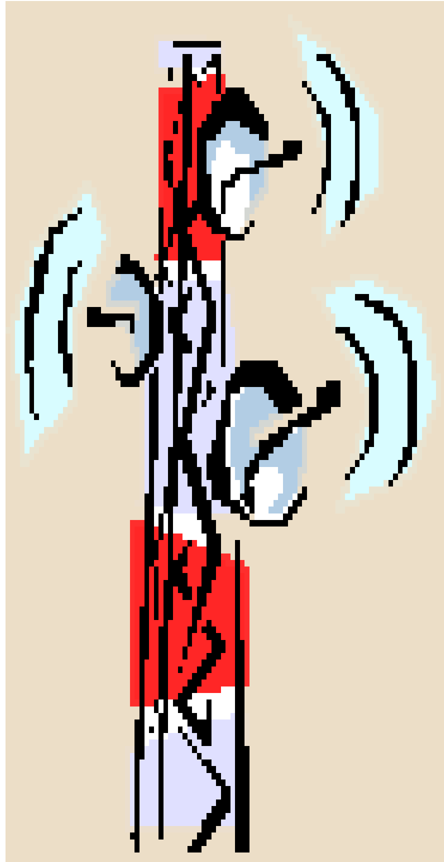
Antenna Diversity

- The signal is transmitted along different propagation paths
- Multiple receiving and / or transmitting antennas are used
- The antennas can be a quarter to one wavelength apart
- A diversity combining circuit combines the signals

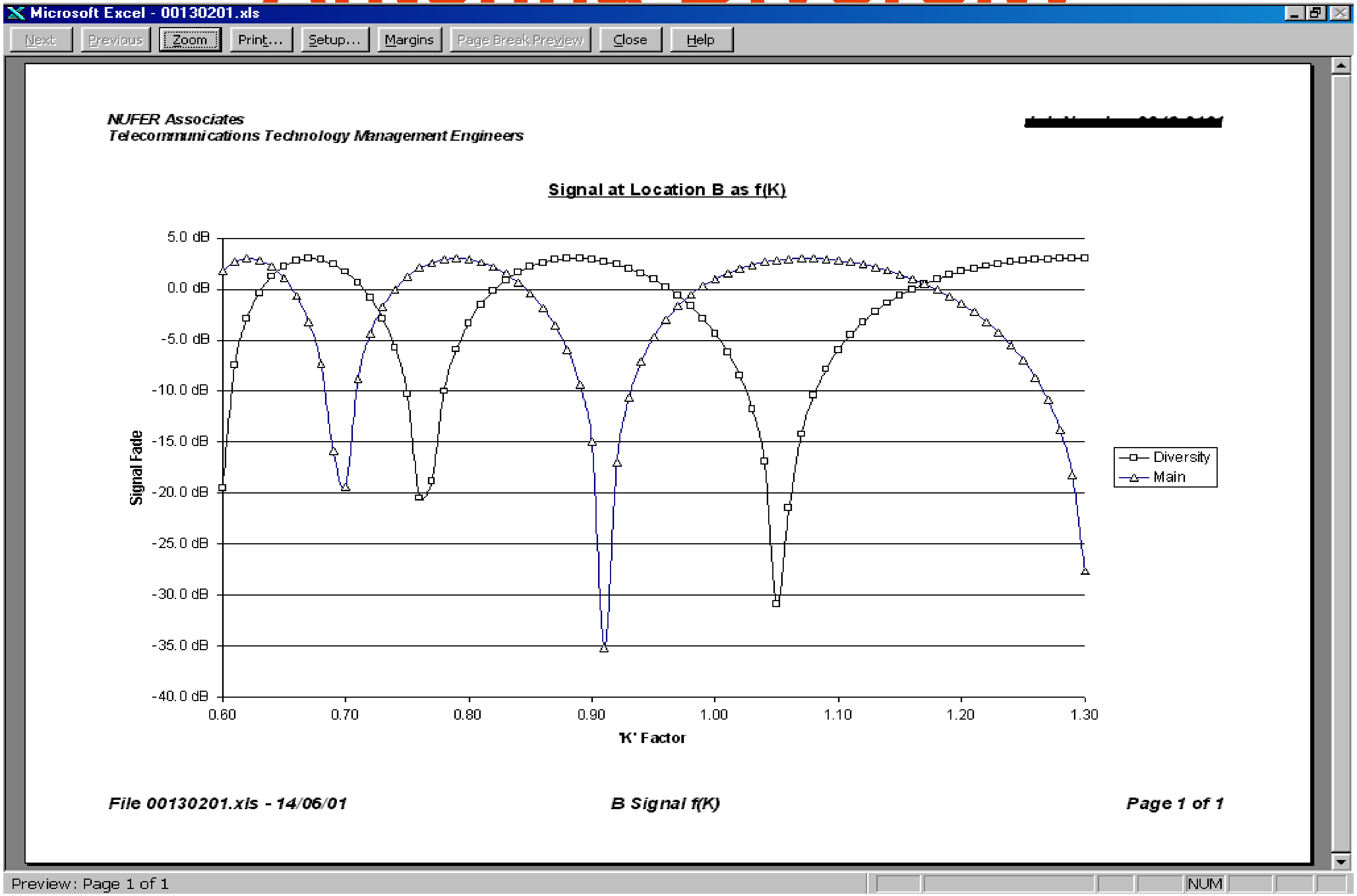


Antenna Diversity

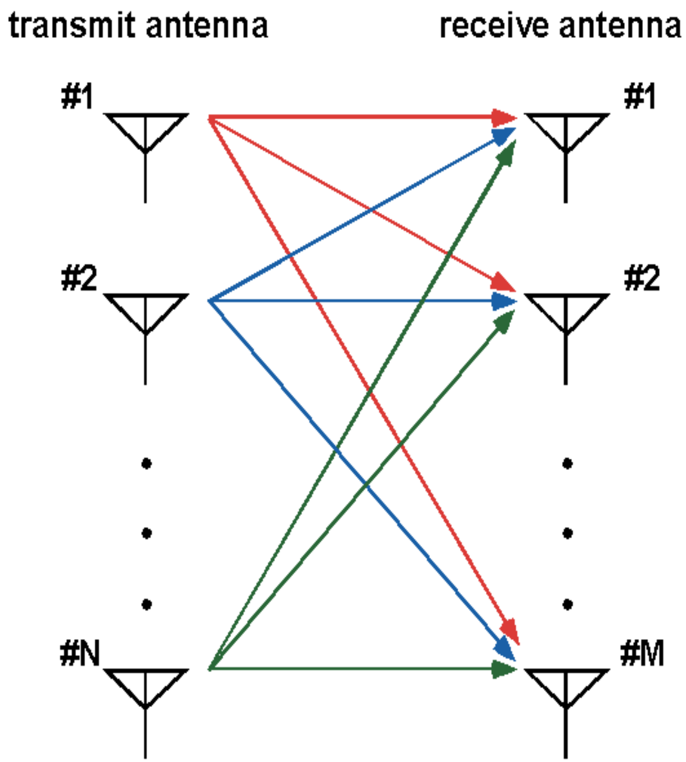
- A common usage is in WiFi networking
- This switches the reception to one of two antennas depending on which is currently receiving better
- Mobile phone towers also take advantage of diversity
- Each face of a tower has three antennas
- One is transmitting, while the other two are performing diversity reception
- The use of diversity techniques at both ends of the link is called space time coding



Antenna Diversity



Multiple Input Multiple Output (MIMO)

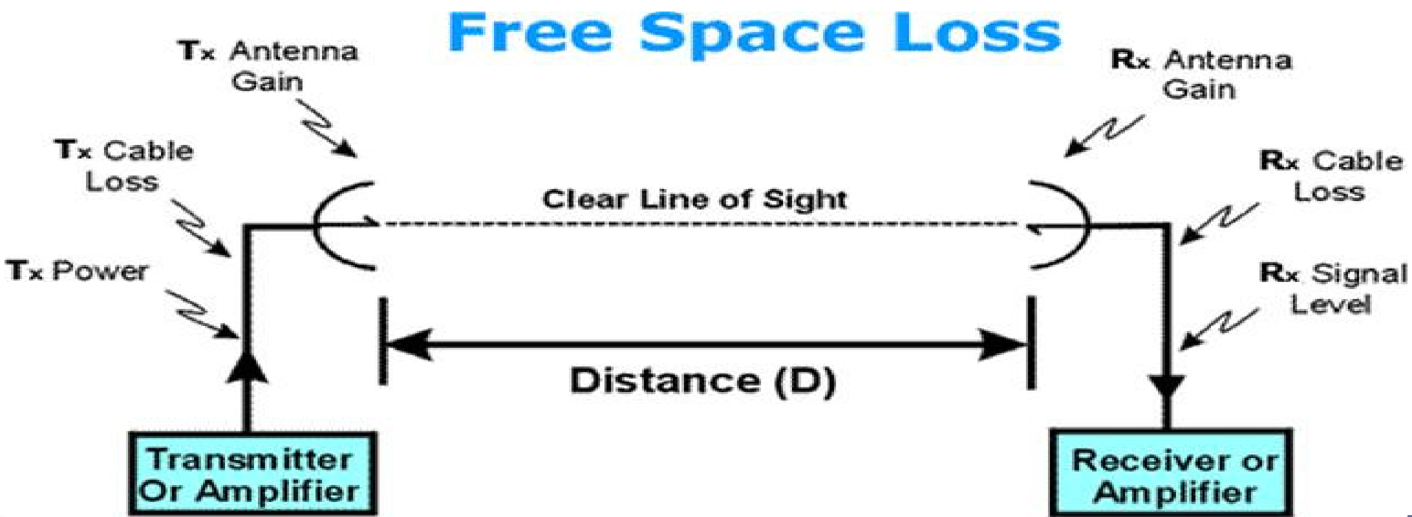


MIMO channel

- Uses multiple antennas at both transmit and receive ends
- Exploits multi-path propagation to increase throughput or to reduce bit error rates
- Can be used in conjunction with OFDM
- It is part of the IEEE 802.11 n standard
- It has been added to the latest draft version of Mobile WiMAX (IEEE 802.16 e)

Free Space Loss

- Proportional to the square of the distance between the transmitter and receiver
- Proportional to the square of the frequency of the signal
- FSL (dB) = 20.log(d) + 20.log(f) + K
  - **d is the distance, f is the frequency**
  - **K is a constant that depends on the units used and details of the radio link**
  - **If d is measured in meters, f in Hz, and the link uses isotropic antennas, K = – 147.5**



Thank You

Contact : info@gcl.in