# CS311: Data Communication

# Unguided Transmission Media

by

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# Introduction

- Physical Path between transmitter and receiver in a data communication system

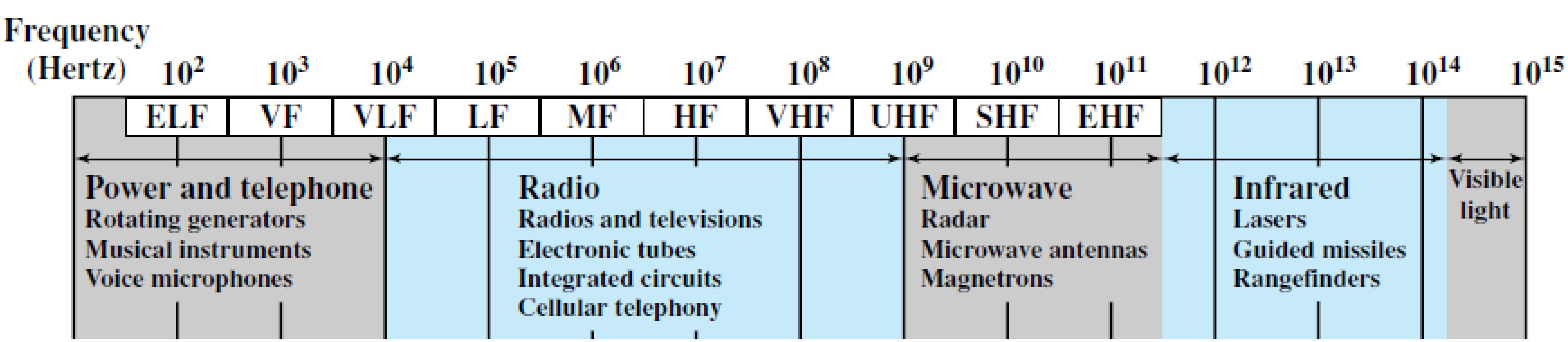
- Broadly classified into two types:

    - Guided:- Waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable or optical fibre.

    - Unguided:- Provides a means for transmitting electromagnetic signals through air but do not guide them.

# Wireless Communication

- Three general ranges of frequencies are of interest in our discussion of wireless transmission.
    - 1 - 40 GHz: microwave frequencies
        - highly directional beams are possible
        - quite suitable for point-to-point transmission
        - used for satellite communications
    - 30 MHz - 1 GHz: radio frequencies
        - suitable for omnidirectional applications
    - $3 \times 10^{11} – 2 \times 10^{14}$ Hz: infrared frequencies
        - useful to local point-to-point and multipoint applications within confined areas



# Antennas

- Transmission and reception are achieved by means of antennas
  - The antennas plays key role
  - An antenna can be defined as an electrical conductor or system of conductors used either for radiating or collecting electromagnetic energy.
  - For transmission, an antenna radiates electromagnetic radiation in the air
  - For reception, the antenna picks up electromagnetic waves from the surrounding medium.

# Cont…

- For transmission of a signal, radio-frequency electrical energy from the transmitter is converted into electromagnetic energy by the antenna and radiated into the surrounding environment (atmosphere, space, water).

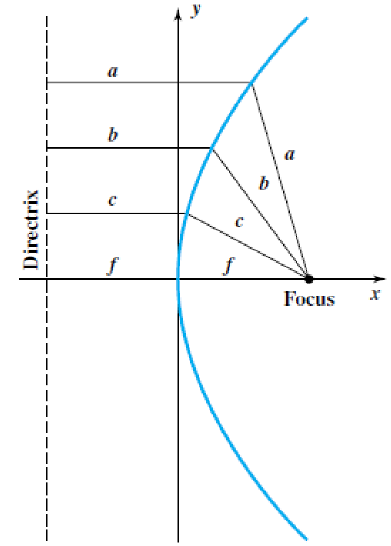
- For reception of a signal, electromagnetic energy impinging on the antenna is converted into radio-frequency electrical energy and fed into the receiver.

# Cont…

- Basically two types of configuration :
  - Transmitting antenna puts out a focused electromagnetic beam.
    - Transmitter & receiver must be carefully aligned.
    - Allows point-to-point communication.
  - Transmitted signal spreads in all directions.
    - can be received by many antennas
    - Allows broadcast communication

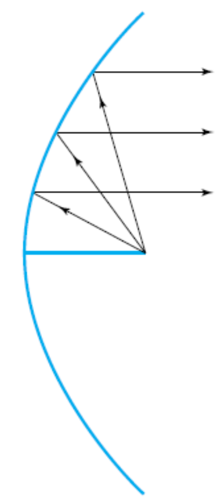
# Cont…

- Isotropic Antenna:
  - a point in space that radiates power in all directions equally.
  - The actual radiation pattern is a sphere with the antenna at the center.



(a) Parabola

- Parabolic Antenna:
  - used in terrestrial microwave and satellite applications
  - A parabola is the locus of all points equidistant from a fixed line and a fixed point not on the line.


(b) Cross section of parabolic antenna showing reflective property

# Antenna Gain

- Antenna gain is a measure of the directionality of an antenna (but not output power vs input power).
- It is defined as the power output, in a particular direction, compared to that produced in any direction by a perfect omnidirectional antenna (isotropic antenna)
- The effective area of an antenna is related to the physical size of the antenna
- The relationship between antenna gain and effective area

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$

$G$ = antenna gain

$A_e$ = effective area

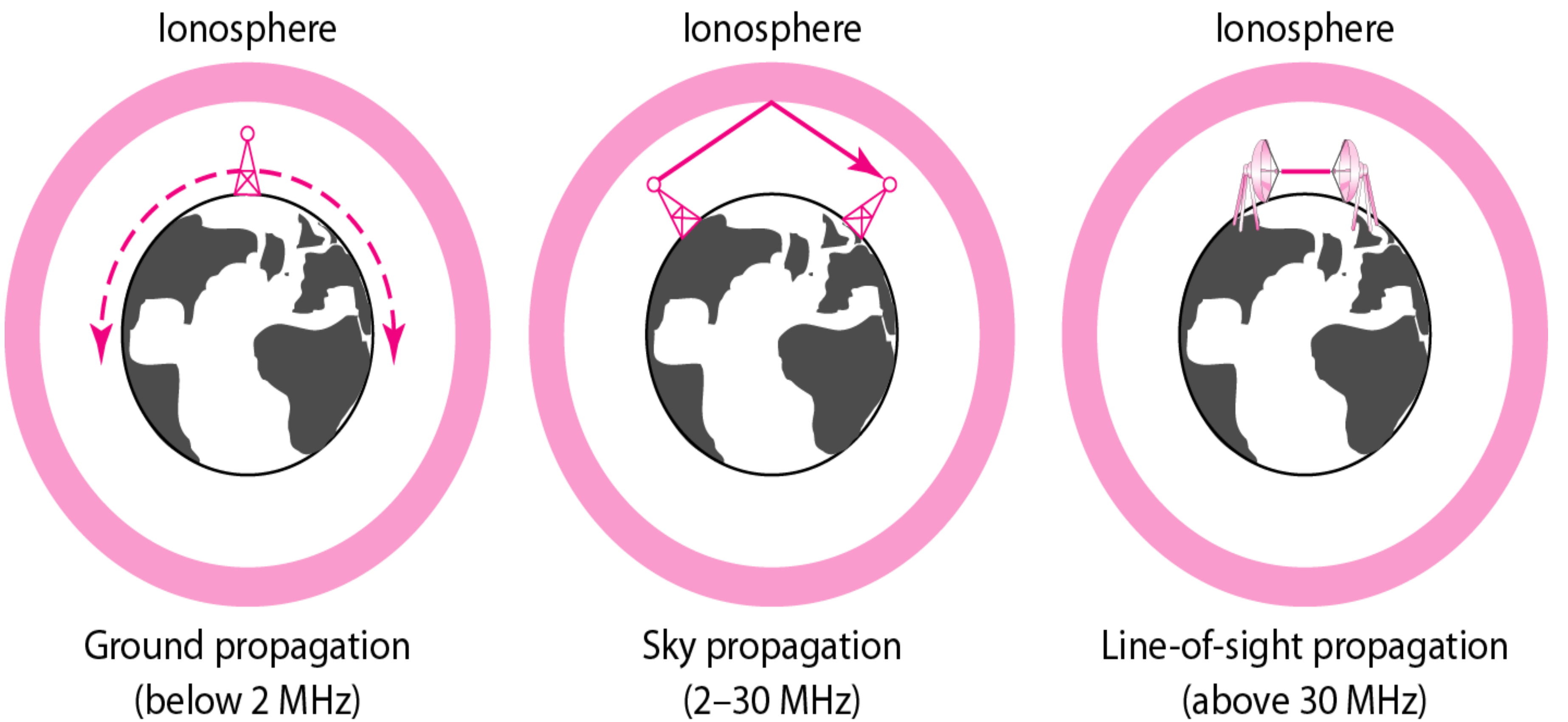
$f$ = carrier frequency

c = speed of light ($\approx 3 \times 10^8$ m/s)

$\lambda$ = carrier wavelength

# Propagation Modes

A signal radiated from an antenna travels along one of three routes



# Ground Wave Propagation

- Ground wave propagation
  - more or less follows the contour of the earth
  - can propagate considerable distances, well over the visual horizon
  - This effect is found in frequencies up to about 2 MHz.
  - Several factors account for such tendency
    - electromagnetic wave induces a current in the earth's surface, the result of which is to slow the wavefront near the earth, causing the wavefront to tilt downward and hence follow the earth's curvature
    - Electromagnetic wave experiences diffraction (slight bending of light as it passes around the edge of an object)

- Example: AM radio

# Sky Wave Propagation

- Sky wave propagation
  - A sky wave signal can travel through a number of hops, bouncing back and forth between the ionosphere and the earth's surface
  - This happens due to Refraction (change in direction of propagation of any wave as a result of its travelling at different speeds at different points along the wave front.)
  - a signal can be picked up thousands of kilometers from the transmitter

- Example: amateur radio, CB radio, and international broadcasts such as BBC and Voice of America

# Line-of-Sight Propagation

- LOS propagation
  - ➢ Generally works above 30 MHz
  - ➢ transmitted between an earth station and a satellite overhead that is not beyond the horizon.
  - ➢ the transmitting and receiving antennas must be within an effective line of sight of each other
  - ➢ Types:
    - Optical Line of Sight propagation
    - Radio Line of Sight propagation

# Cont…

- With no intervening obstacles, the optical line-of-sight can be expressed as $d = 3.57\sqrt{h}$

where, *d* is the distance between an antenna and the horizon in kilometers, and *h* is the antenna height in meters.

- radio line-of-sight to the horizon is expressed as $d = 3.57\sqrt{Kh}$

where *K* is an adjustment factor to account for the refraction.

- A good rule of thumb is *K*=4/3

- the maximum distance between two antennas for LOS propagation is $3.57(\sqrt{Kh_1} + \sqrt{Kh_2})$

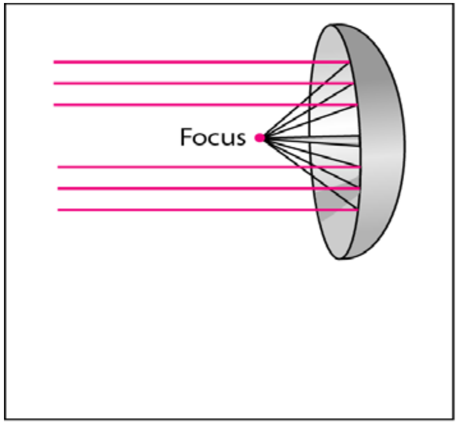
where $h_1$ and $h_2$ are the heights of the two antennas.

# Bands and Propagations

| *Band* | *Range* | *Propagation* | *Application* |
|---|---|---|---|
| VLF (very low frequency) | 3–30 kHz | Ground | Long-range radio navigation |
| LF (low frequency) | 30–300 kHz | Ground | Radio beacons and navigational locators |
| MF (middle frequency) | 300 kHz–3 MHz | Sky | AM radio |
| HF (high frequency) | 3–30 MHz | Sky | Citizens band (CB), ship/aircraft communication |
| VHF (very high frequency) | 30–300 MHz | Sky and line-of-sight | VHF TV, FM radio |
| UHF (ultrahigh frequency) | 300 MHz–3 GHz | Line-of-sight | UHF TV, cellular phones, paging, satellite |
| SHF (superhigh frequency) | 3–30 GHz | Line-of-sight | Satellite communication |
| EHF (extremely high frequency) | 30–300 GHz | Line-of-sight | Radar, satellite |

# Terrestrial Microwave

- requires fewer repeaters but line-of-sight
- The antenna is fixed rigidly
- use a parabolic "dish" to focus a narrow beam onto a receiver antenna
- usually located at substantial heights above ground level
- an alternative to coaxial cable or optical fiber



a. Dish antenna

- Applications:
  - In log-haul telecommunications (e.g. Military Comm.)
  - In short point-to-point links (e.g closed-circuit TV, data link between LANs)
  - In cellular systems

# Cont…

**Table 4.6** Typical Digital Microwave Performance

| Band (GHz) | Bandwidth (MHz) | Data Rate (Mbps) |
|---|---|---|
| 2 | 7 | 12 |
| 6 | 30 | 90 |
| 11 | 40 | 135 |
| 18 | 220 | 274 |

- The higher the frequency used, the higher the potential bandwidth and therefore the higher the potential data rate.
- Common frequencies used in the range 1 to 40 GHz.
- For microwave (and radio frequencies), the loss can be expressed as $$L = 10\log\left(\frac{4\pi d}{\lambda}\right)^2 \text{ dB}$$ where *d* is the distance and $\lambda$ is the wavelength
- higher microwave frequencies are less useful for longer distances because of increased attenuation

# Satellite Microwave

- Satellite is a microwave relay attention

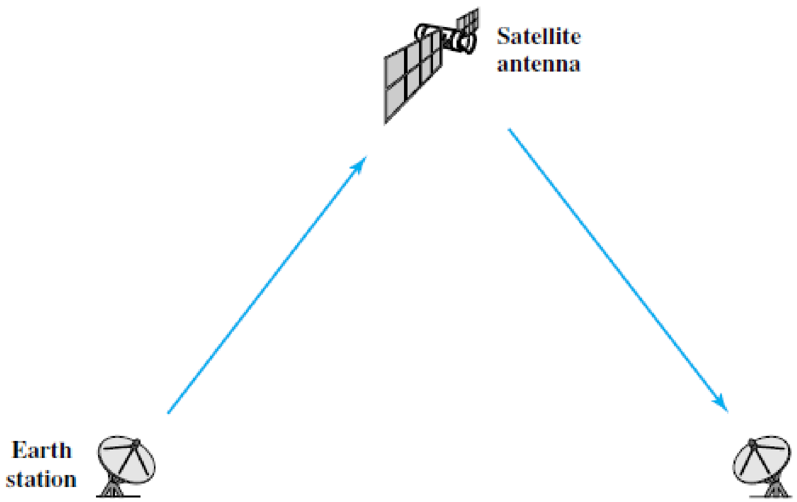
- The satellite receives transmissions on one frequency band (uplink), amplifies or repeats the signal, and transmits it on another frequency (downlink).

- Typically requires geo-stationary orbit
  - height of 35,863 km
  - spaced at least 3-4 degree apart (angular displacement as measured from the earth)

- Typical uses
  - television distribution
  - long distance telephone transmission
  - private business network
  - global positioning

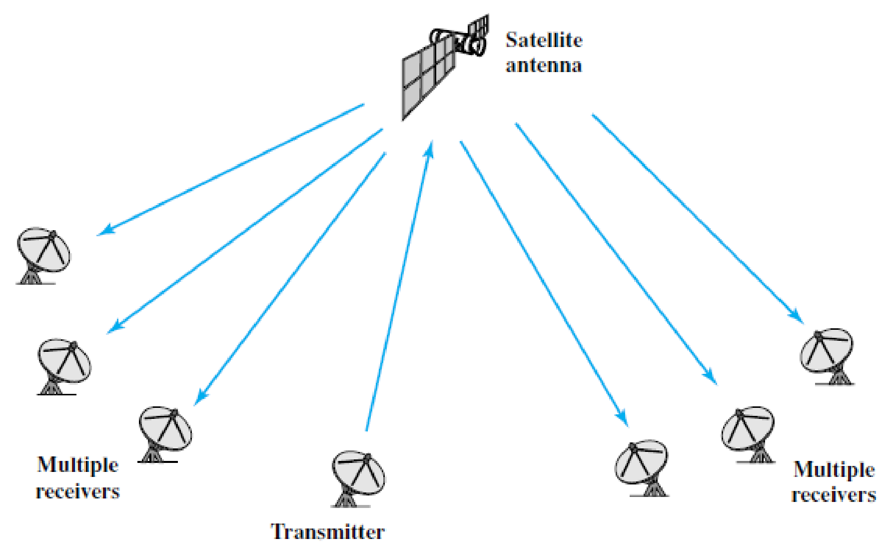
# Cont…

- A single orbiting satellite will operate on a number of frequency bands, called transponder channels




(a) Point-to-point link

The most recent application of satellite technology to television distribution is direct broadcast satellite (DBS), in which satellite video signals are transmitted directly to the home user.




(b) Broadcast link

It has huge business market.

# Cont…

- A recent development is the very small aperture terminal (VSAT) system, which provides a low-cost solution.
- Using some discipline, these stations share a satellite transmission capacity for transmission to a hub station.

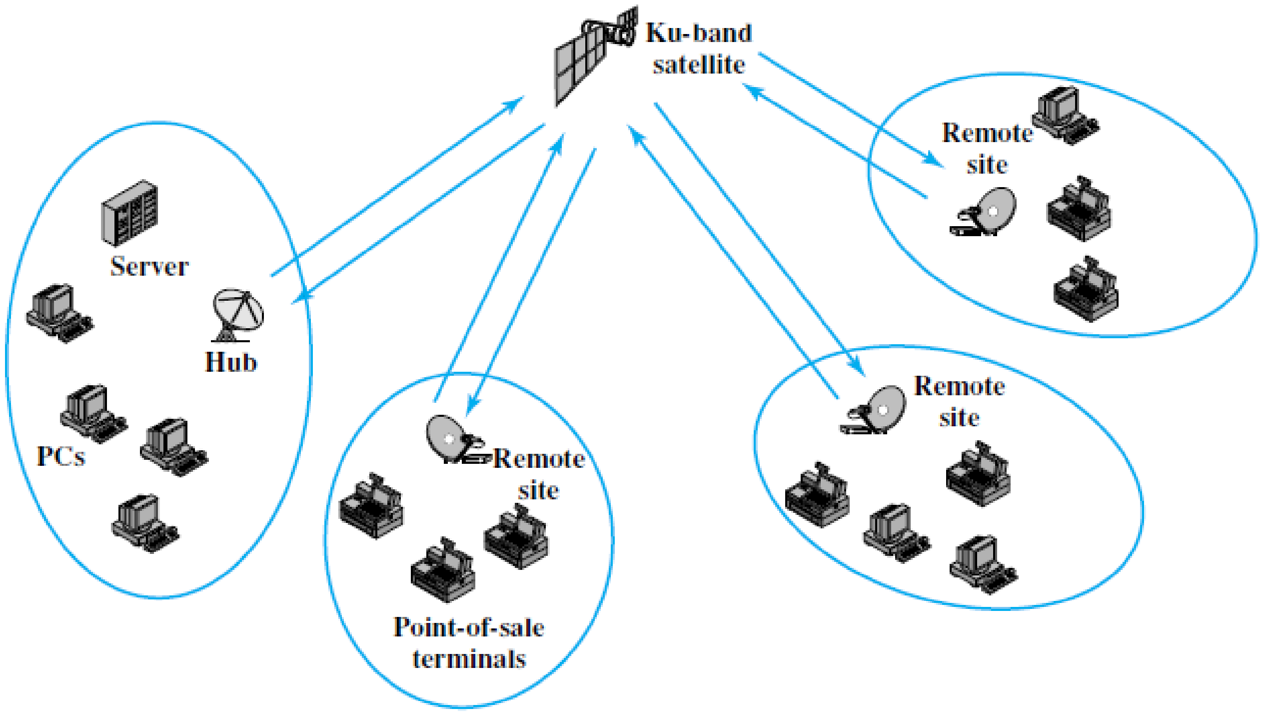



Figure 4.7 Typical VSAT Configuration

# Cont…

- A pervasive application is GPS (Navstar Global Positioning System)

- GPS consists of three segments:

  - A constellation of satellites (currently 32) orbiting about 20,180 km above the earth's surface.

  - A control segment which maintains GPS through a system of ground monitor stations and satellite upload facilities

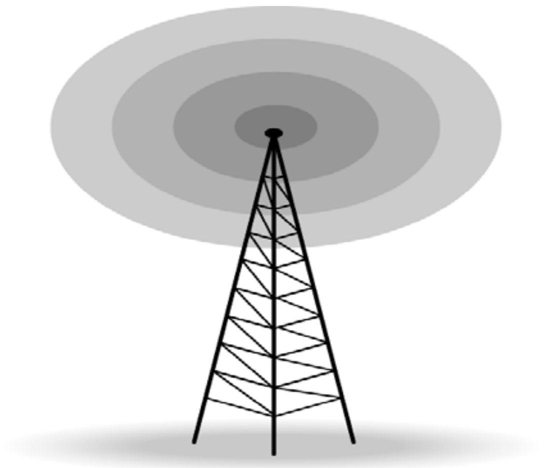
  - The user receivers -- both civil and military

- the GPS receiver can determine its latitude, longitude, and height while at the same time synchronizing its clock with the GPS time standard

# Broadcast Radio

- It does not require dish shaped antenna
- the antennas need not be rigidly mounted to a precise alignment
  - broadcast radio is omnidirectional
  - microwave is directional

- Radio frequency range 3 kHz – 300 GHz
- Use broadcast radio, 30 MHz – 1 GHz, for
  - FM Radio
  - UHF and VHF television



- Does not suffer much from rainfall
- Suffer from multipath interference
  - Reflections from land, water, other objects.

# Infrared

- Infrared communications is achieved using transmitters/receivers (transceivers) that modulate non-coherent infrared light.
  - (in coherent light, the electromagnetic waves maintain a fixed and predictable phase relationship with each other over a period of time.)

- Transceivers must be within the line-of-sight of each other either directly or via reflection

- Frequencies between 300 GHz to 400 THz.
- Can not penetrate walls.

- Used for short-range communication in a closed area using line-of-sight propagation.
- Typical uses
  - TV remote control
  - IRD port

# Comparision of Media

| Medium | Cost | Bandwidth, Data rate | Attenuation | EMI | Security |
|---|---|---|---|---|---|
| UTP | Low | 3 MHz, 4 Mbps | High, 2-10 Km | High | Low |
| Coaxial | Moderate | 356 MHz, 500 Mbps | Moderate, 1-10 Km | Moderate | Low |
| Optical Fiber | High | 2 GHz, 2 Gbps | Low, 10-100 Km | Low | High |
| Radio | Moderate | 1-10 Mbps | Low-High | High | Low |
| Microwave | High | 1 Mbps-10 Gbps | Variable | High | Moderate |
| Satelite | High | 1 Mbps - 10 Gbps | Variable | High | Moderate |
| Infrared | Low | 2.4 kbps - 4 Mbps | Low | Low | High |

# Impairments specific to LOS Transmission

- Atmospheric Absorption
  - from water vapor and oxygen absorption
  - Rain and fog cause scattering of radio waves
- Multipath
  - multiple interfering signals from reflections
- Refraction
  - only a fraction or no part of the line-of-sight wave reaches the receiving antenna.
- Free space loss
  - loss of signal with distance
  - bending signal away from receiver

# Cont…

- For the ideal isotropic antenna, free space loss is

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

where

$P_t$ = signal power at the transmitting antenna
$P_r$ = signal power at the receiving antenna
$\lambda$ = carrier wavelength
$d$ = propagation distance between antennas
c = speed of light ($3 \times 10^8$ m/s)

where $d$ and $\lambda$ are in the same units (e.g., meters).

- Loss in decibels: by taking 10 times the log of that ratio

# Cont…

- For other antennas, we must take into account antenna gain

- So, the free space loss is:

$$\frac{P_t}{P_r} = \frac{(4\pi)^2(d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

where

$G_t$ = gain of the transmitting antenna
$G_r$ = gain of the receiving antenna
$A_t$ = effective area of the transmitting antenna
$A_r$ = effective area of the receiving antenna

# Thanks!

Figure and slide materials are taken from the following sources:

1. W. Stallings, (2010), Data and Computer Communications
2. NPTL lecture on Data Communication, by Prof. A. K. Pal, IIT Kharagpur
3. B. A. Forouzan, (2013), Data Communication and Networking