William Stallings Data and Computer Communications 7th Edition

Chapter 4

Transmission Media

Overview

- **Characteristics and quality determined by:**
  - Medium
  - Signal
- **Medium**
  - Guided - wire
  - Unguided - wireless
- **For Guided Medium**
  - The medium is more important
- **For Unguided**
  - The bandwidth produced by the antenna is more important
- **Key concerns are data rate and distance**

Design Factors

- **Bandwidth**
  - ***Higher bandwidth gives higher data rate***
- **Transmission impairments**
  - *Attenuation*
- **Interference**
  - ***Issue especially in case of unguided medium***
- **Number of receivers**
  - ***Unicast (one sender, one receiver)***
  - ***Multicast (multiple receivers can introduce more errors)***

Guided Transmission Media

- **Twisted Pair**
- **Coaxial Cable**
- **Optical Fiber**

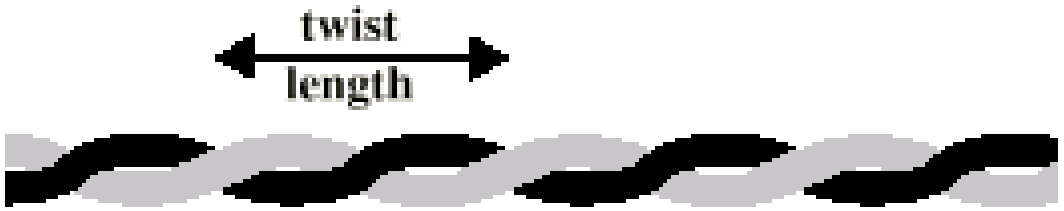
Transmission Characteristics of Guided Media

	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μs/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	50 μs/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μs/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/km	5 μs/km	40 km

Twisted Pair

Twisted Pair ➔ Architecture

—Separately insulated
—Twisted together
—Often "bundled" into cables
—Usually installed in building during construction



(a) Twisted pair

Two Insulated copper wires

Issues:

(1) Interference due to unwanted electrical coupling of two copper

(2) Interference due to unwanted electrical coupling between the neighboring twisted pairs

Twisted Pair ➔ Applications

- Most commonly used medium
- **Telephone network**
  - —***Between house and local exchange (subscriber loop)***
- **Within buildings**
  - —***To private branch exchange (PBX)***
- For local area networks (LAN)
  - —10Mbps or 100Mbps

Twisted Pair - Pros and Cons

- **Advantages**
  - Less expensive
  - Easy to work with
- **Disadvantages**
  - Low data rate
  - Short range

Twisted Pair (TP) ➔Characteristics

- **Analog transmission**
  - Amplifiers every 5km to 6km
- **Digital transmission**
  - Use either *analog* or *digital* signals
  - repeater every 2km or 3km

- **TP is Limited**
  - Distance
  - Bandwidth
  - Data rate

- **Susceptible to interference and noise**
  - **Easy coupling of electromagnetic fields**

Unshielded and Shielded TP

- **Unshielded Twisted Pair (UTP)**
  - —Ordinary telephone wire
  - —Less expensive
  - —Weak immunity against noise and interference
  - —Suffers from external EM interference

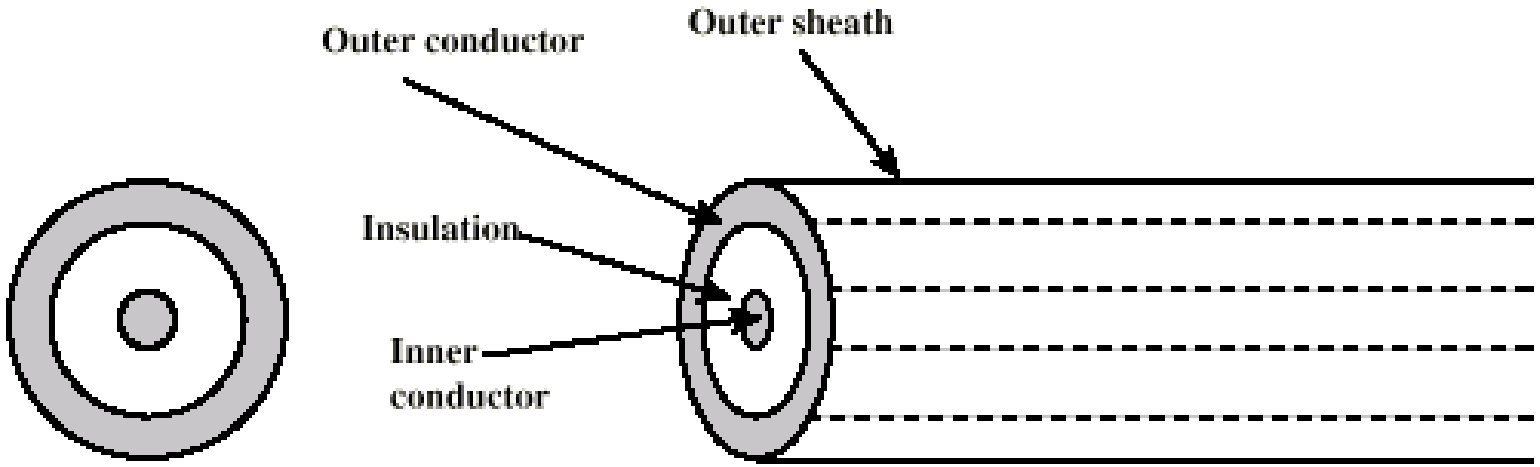
- **Shielded Twisted Pair (STP)**
  - —An extra metallic sheath on each pair
  - —Relatively more expensive
  - —Provide better performance than UTP
    - Increased Data rate
    - Increased Bandwidth

UTP Categories

- **Cat 3**
  - up to 16MHz
  - Voice grade found in most offices
  - Twist length of 7.5 cm to 10 cm
- Cat 4
  - up to 20 MHz
- **Cat 5**
  - up to 100MHz
  - Commonly pre-installed in new office buildings
  - Twist length 0.6 cm to 0.85 cm
- Cat 5E (Enhanced) –see tables
- Cat 6
- Cat 7

Coaxial Cable

Coaxial Cable ➔ Architecture



—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding

Coaxial Cable ➔Applications

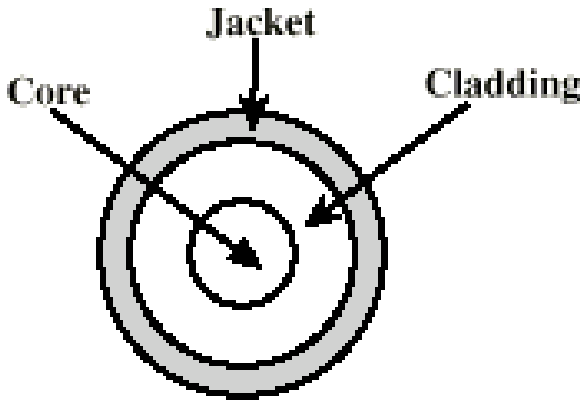
- **Television (TV) signals distribution**
  - —*Ariel to TV*
  - —*Cable TV*
- **Long distance telephone transmission**
  - —*Can carry 10,000 voice calls simultaneously*
  - —*Being replaced by fiber optic*
- **Short distance computer systems links**
  - —*Local area networks (LAN)*
  - —*Metropolitan area network (MAN)*

Coaxial Cable ➔Characteristics

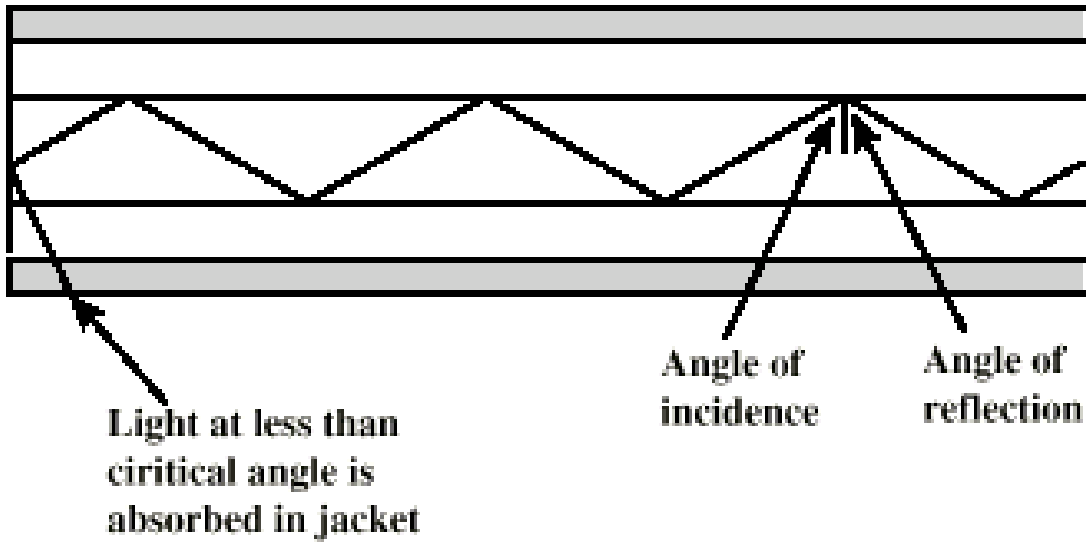
- **Analog**
  - —Amplifiers every few km
  - —Closer if higher frequency
  - —Up to 500MHz
- **Digital**
  - —Repeater every 1km
  - —Closer for higher data rates
- **Problem**
  - —Inter-modulation noise
  - —Thermal noise

Optical Fiber

Optical Fiber ➔ Architecture



—Glass or plastic core
—Laser or light emitting diode
—Specially designed jacket
—Small size and weight



Optical Fiber ➔ Benefits

- **Greater capacity**
  - —***Data rates of hundreds of Gbps***
- **Smaller size & weight**
  - —***Made up of extremely thin fibers***
- **Lower attenuation**
  - —***Electromagnetic isolation***
- **Greater repeater spacing**
  - —***10s of km at least***

Optical Fiber - Transmission Characteristics

- **Operational range**
  - 10^{14} to 10^{15} Hz
- **Light source**
  - **Light Emitting Diode (LED)**
    - ***Cheaper***
    - ***Wider operating temperature range***
    - ***Last longer***
  - **Injection Laser Diode (ILD)**
    - ***Operates on laser principle***
    - ***More efficient***
    - ***Greater data rate***
- **Wavelength Division Multiplexing (WDM)**

Wireless Transmission

Wireless Transmission Frequencies

- **2GHz to 40GHz *(Microwave Frequency)***
  - —Highly directional
  - —Point to point devices
  - —Microwave communications
- **30MHz to 1GHz *(Radio Frequency)***
  - —Omnidirectional
  - —Broadcast radio
- **3×10^{11} to 2×10^{14} *(Local Frequency)***
  - —For Local applications

Antennas

- **By definition**
  - Is a electrical device
- **Transmission**
  - Radio frequency energy from transmitter
  - Converted to electromagnetic energy
  - By antenna
  - Radiated into surrounding environment
- **Reception**
  - Electromagnetic energy impinging on antenna
  - Converted to radio frequency electrical energy
  - Fed to receiver
- **Same antenna often used for both**

Radiation Pattern

- **Antenna might radiate power in all direction**
- **Not same performance in all directions**

- **How can we determine the performance of an antenna?**
  - **Solution is "*Radiation Pattern*"**
    - **Graphical representation of the radiated power**

- **Isotropic antenna is an ideal antenna**
  - **Radiates in all directions equally**
  - **Use as a reference to characterize the power**

Antenna Gain

- **Measure of directionality of antenna**
- **Power output in particular direction compared with that produced by isotropic antenna**
- **Measured in decibels (dB)**
- **Gain could be +ve or -ve**

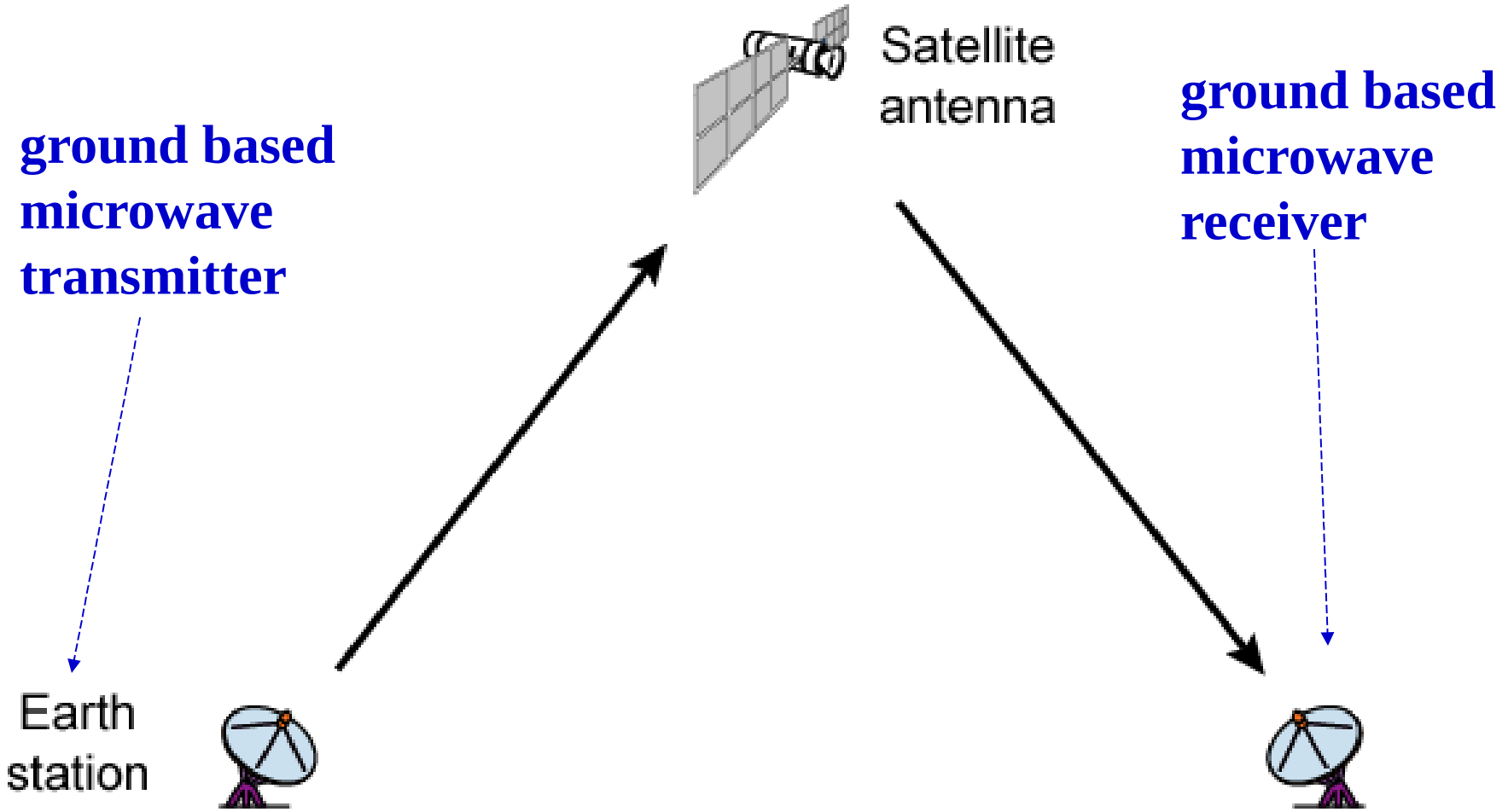
Terrestrial Microwave (TMW)

1. Parabolic antenna
2. Small beam
3. Line of sight
4. Use especially for P2P applications
5. Usually use for long distance communications

Satellite Microwave (SM)

1. Satellite is relay station
2. Satellite
   - receives on one frequency
   - amplifies or repeats signal
   - transmits on another frequency
3. Requires geo-stationary orbit
   - Height of 35,784km
4. Applications
   - Television
   - Long distance telephone
   - Private business networks

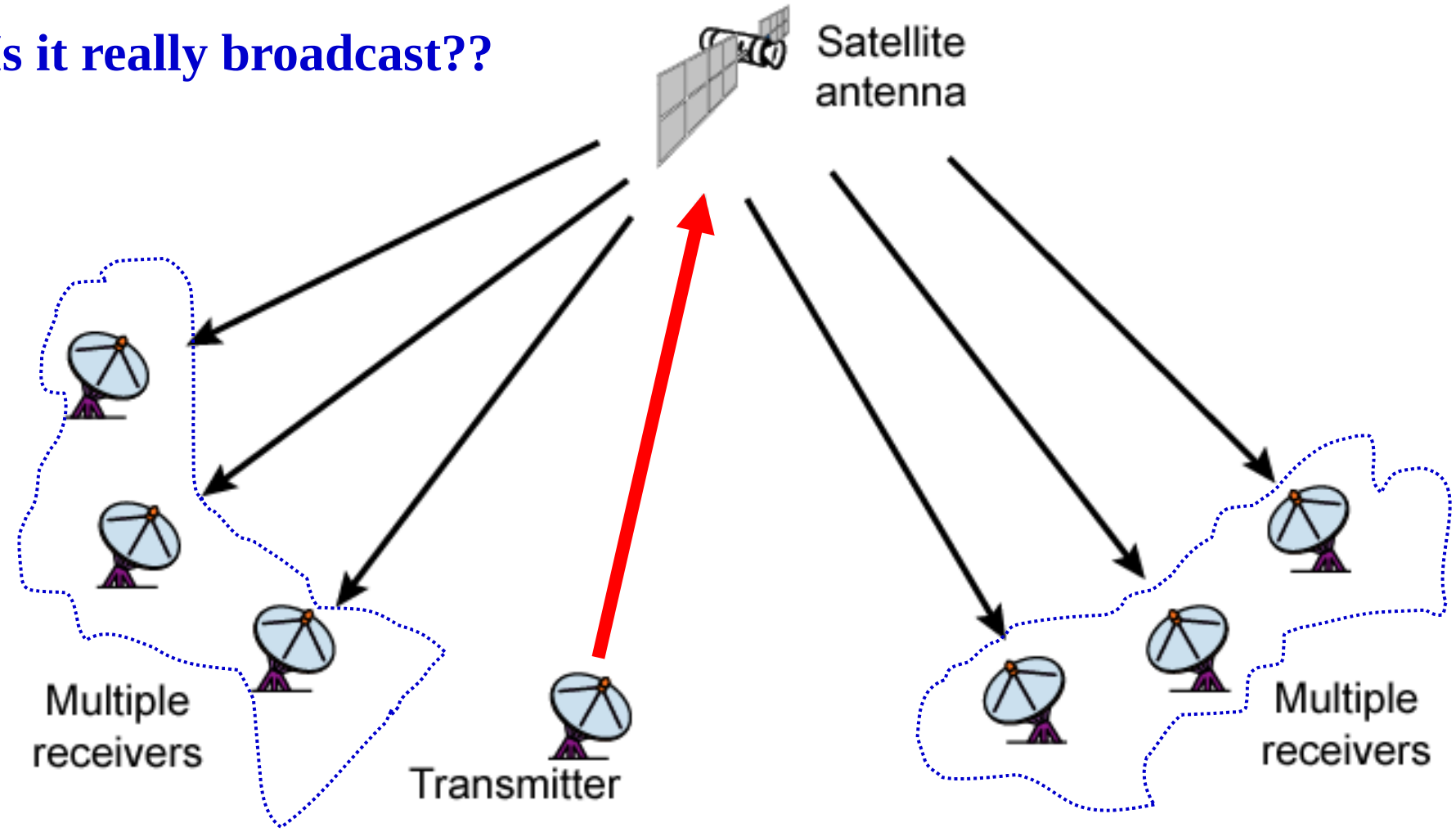
Satellite Point to Point Link



(a) Point-to-point link

Satellite Broadcast Link

Is it really broadcast??



(b) Broadcast link

Broadcast Radio

1. **Omnidirectional** (*travel in all directions*)
2. **Line of sight is over**
3. **Doesn’t need parabolic antenna**
4. **Example**→ FM radio

Wireless Propagation

- Signal travels along three routes

1. Ground wave

- *Follows contour of earth*
- *Up to 2MHz*
- *AM radio*

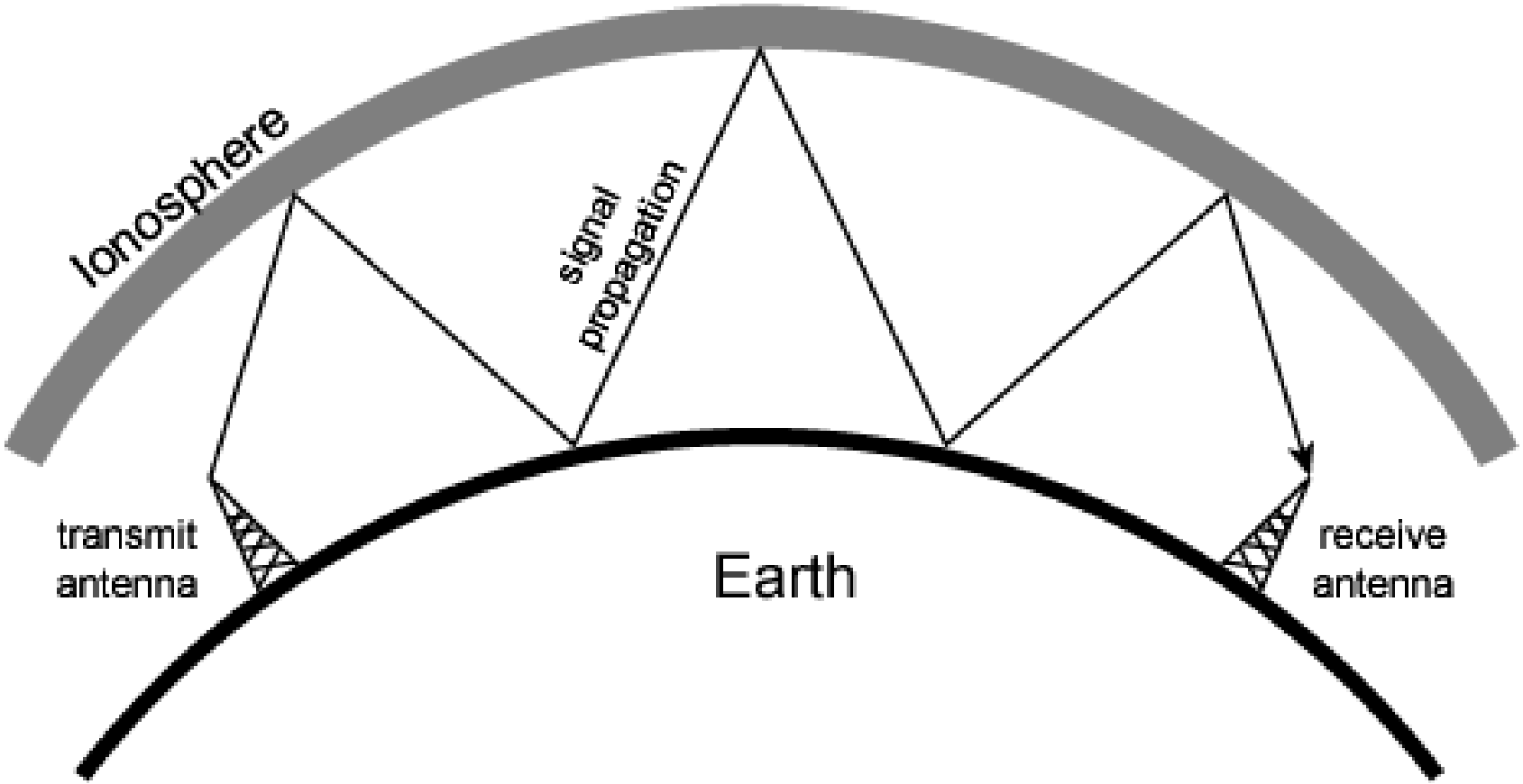
2. Sky wave

- *Signal reflected from ionize layer of upper atmosphere*
- *BBC world service, Voice of America*

3. Line of sight

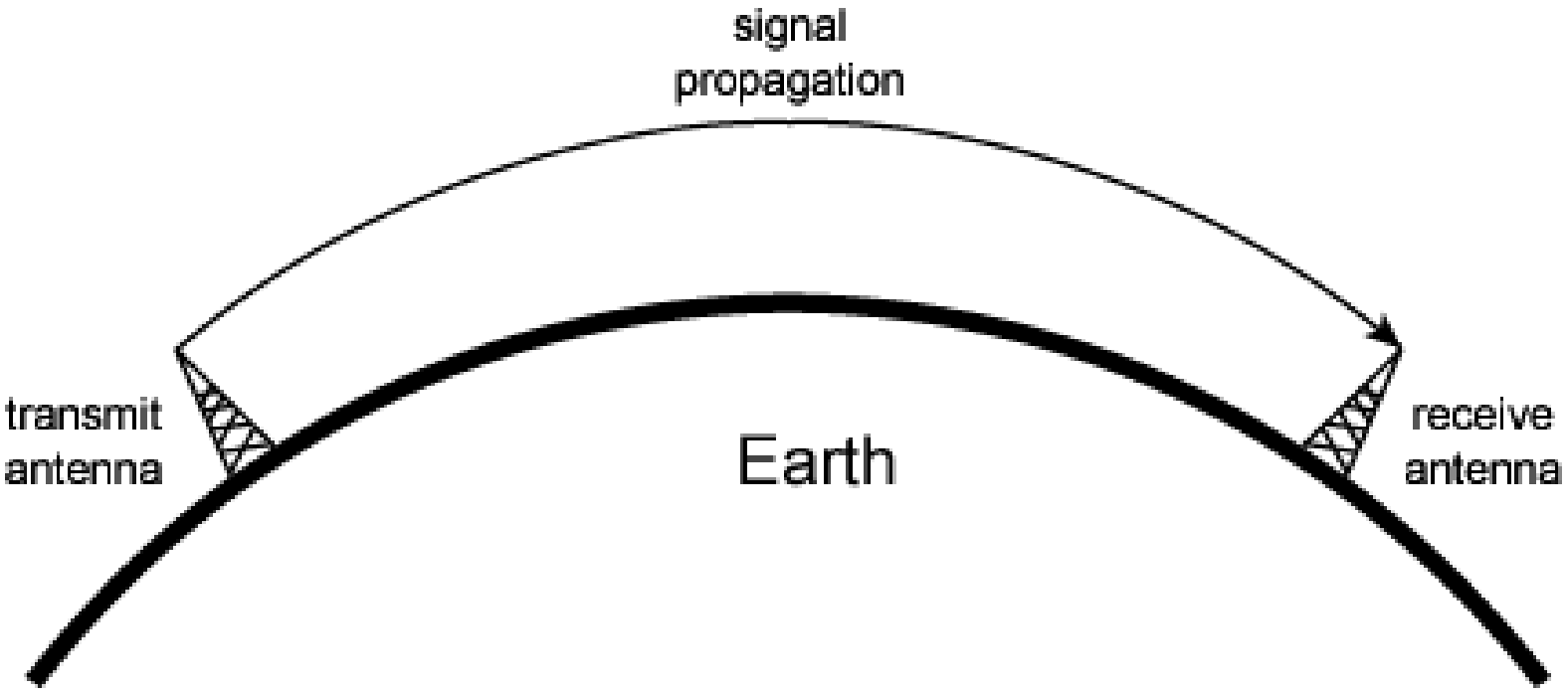
- *Above 30Mhz*
- *Antennas must be physically aligned*
- *Atmosphere can reflect the microwave signal*

Sky Wave Propagation



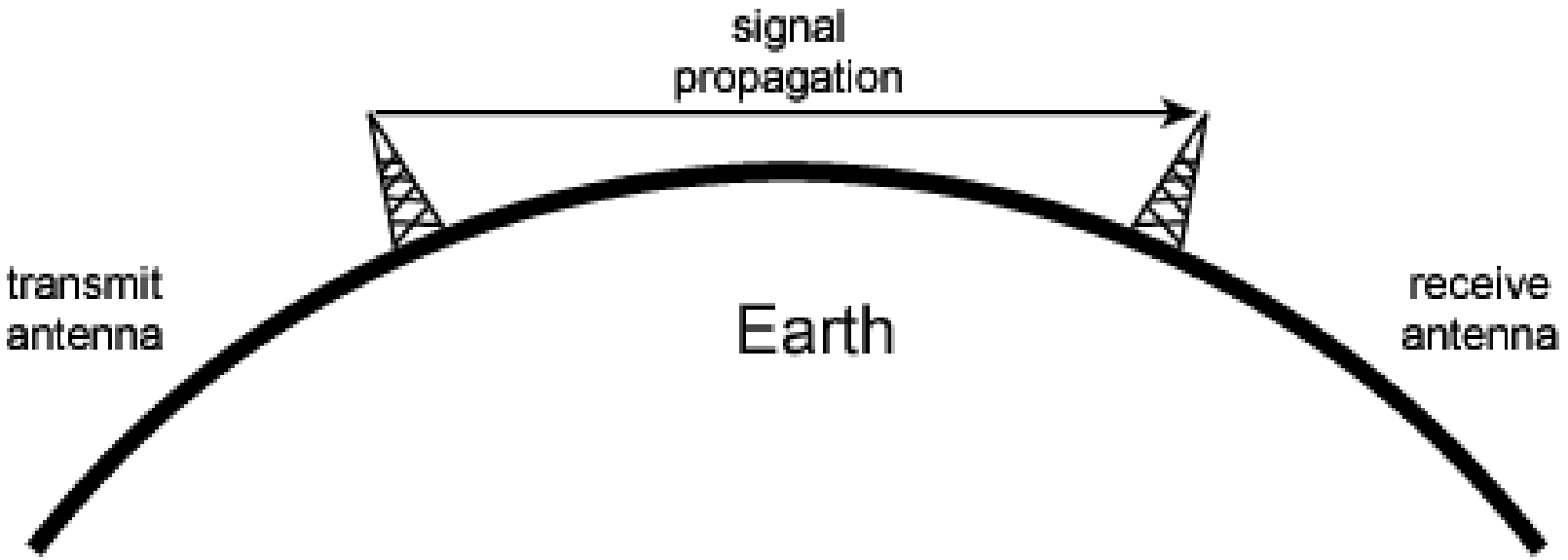
(b) Sky-wave propagation (2 to 30 MHz)

Ground Wave Propagation



(a) Ground-wave propagation (below 2 MHz)

Line of Sight Propagation



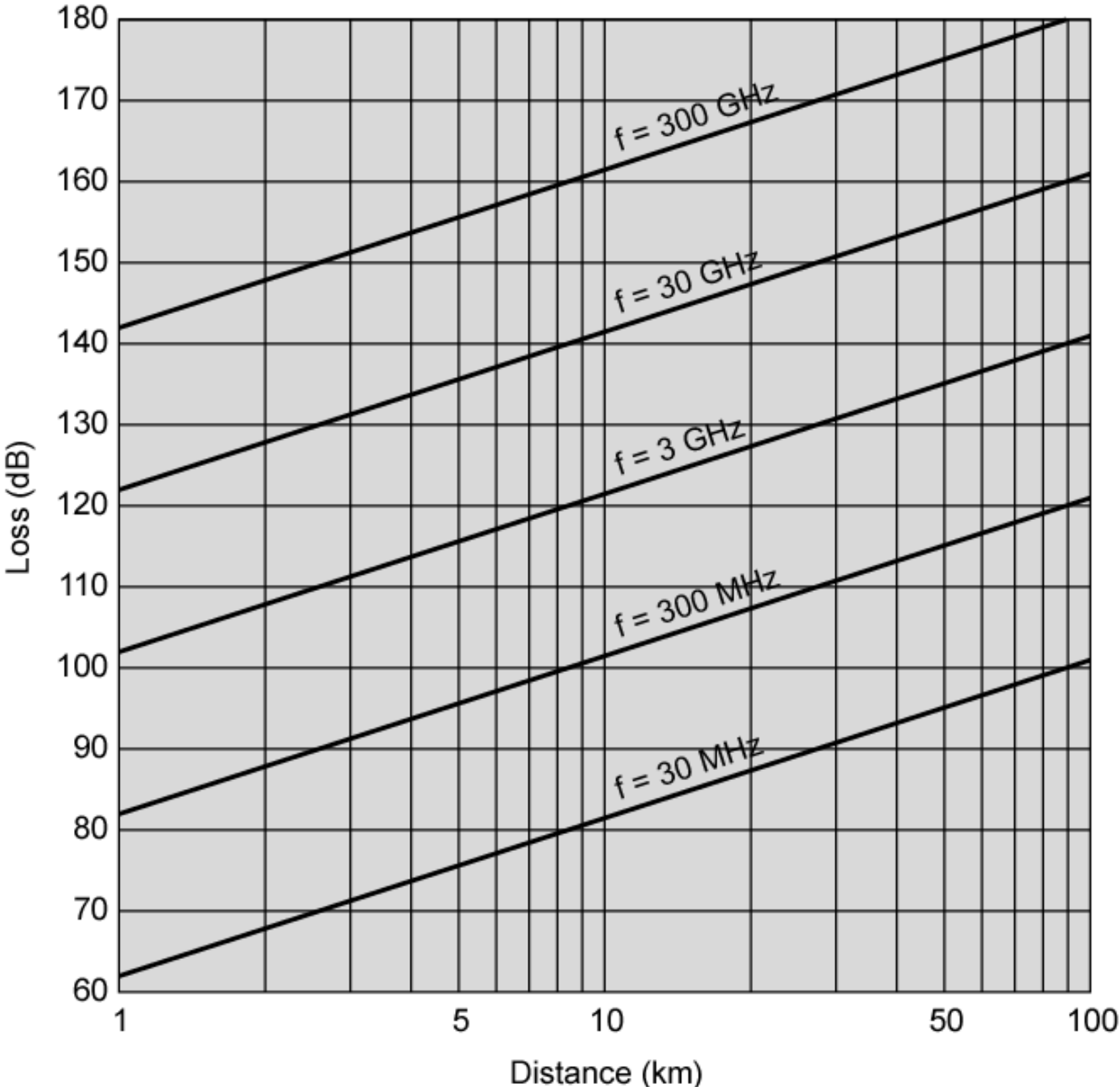
(c) Line-of-sight (LOS) propagation (above 30 MHz)

Transmission Impairments in Wireless Transmission

- **Free Space Loss**
  1. **Signal dispersion is a function of distance**
  2. **Ratio between *power-radiated* to *power-received***
  3. **Greater for lower wavelength**
  4. **Antenna gain can be used to compensate the losses**
  5. **Also known as near far problem**

- **Refraction**
  1. ***Each wireless medium has its own density***
  2. ***Propagation speed is a function of density of the medium***
  3. ***When medium changes, the result is refraction***
  4. ***Refraction means change of direction***

Free Space Loss



Required Reading

- Review Examples 4.1 to 4.4
- **HW#2: Problems 4.1 and 4.2**
  - **Due Date: Tuesday, September 25 (in class timing)**
  - **Need hard copy (typed or in hand writing)**
- **OpNet Lab 2 and 3**
  - **(Due Date: Thursday, September 27 before 2:30 Pm)**
  - **3 Students (maximum) per group**
  - **One submission per group**