Chapter 4

Transmission Media

Reading Materials

- **Data and Computer Communications**, William Stallings

Overview

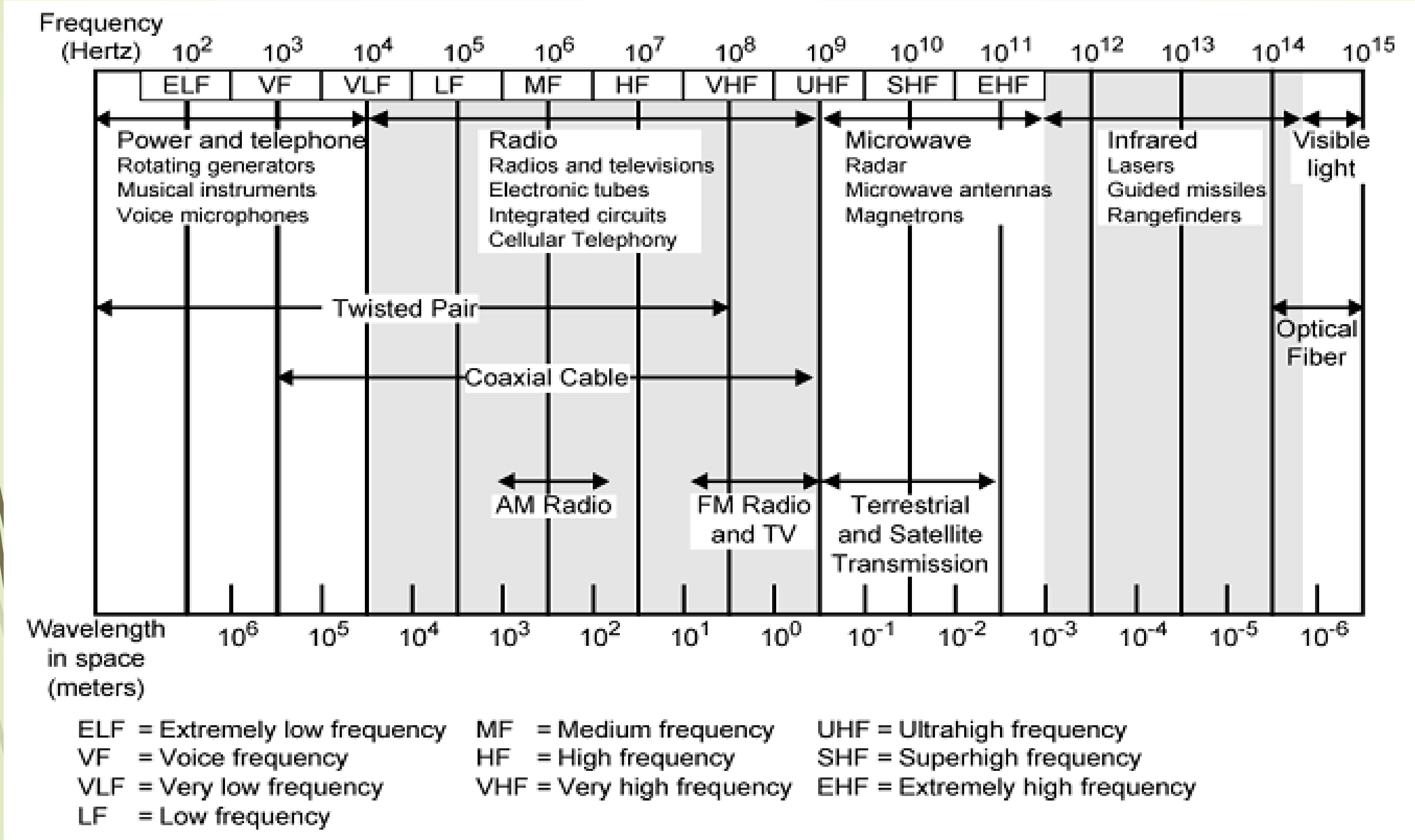
- Guided – wire
- Unguided – wireless
- Characteristics and quality determined by medium and signal
- Key concerns are data rate and distance

Design Factors

- Bandwidth
  – Higher bandwidth gives higher data rate
- Transmission impairments
  – e.g., Attenuation
- Interference
- Number of receivers
  – In guided media
  – More receivers (multi-point) introduce more attenuation

Electromagnetic Spectrum

$$\lambda f = c$$
$$c = 3 \times 10^8 m/s$$



Guided Transmission Media

- Twisted Pair
- Coaxial cable
- Optical fiber

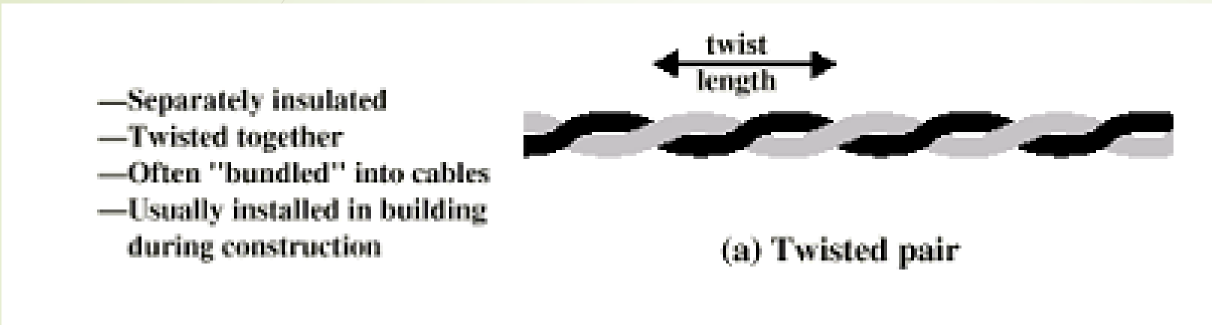
Transmission Characteristics of Guided Media

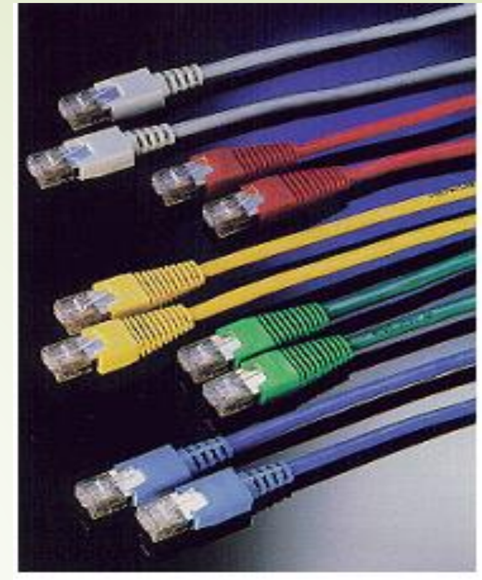
- For guided transmission media, the transmission capacity, in terms of either data rate or bandwidth, depends critically on the distance and on whether the medium is point-to-point or multipoint.

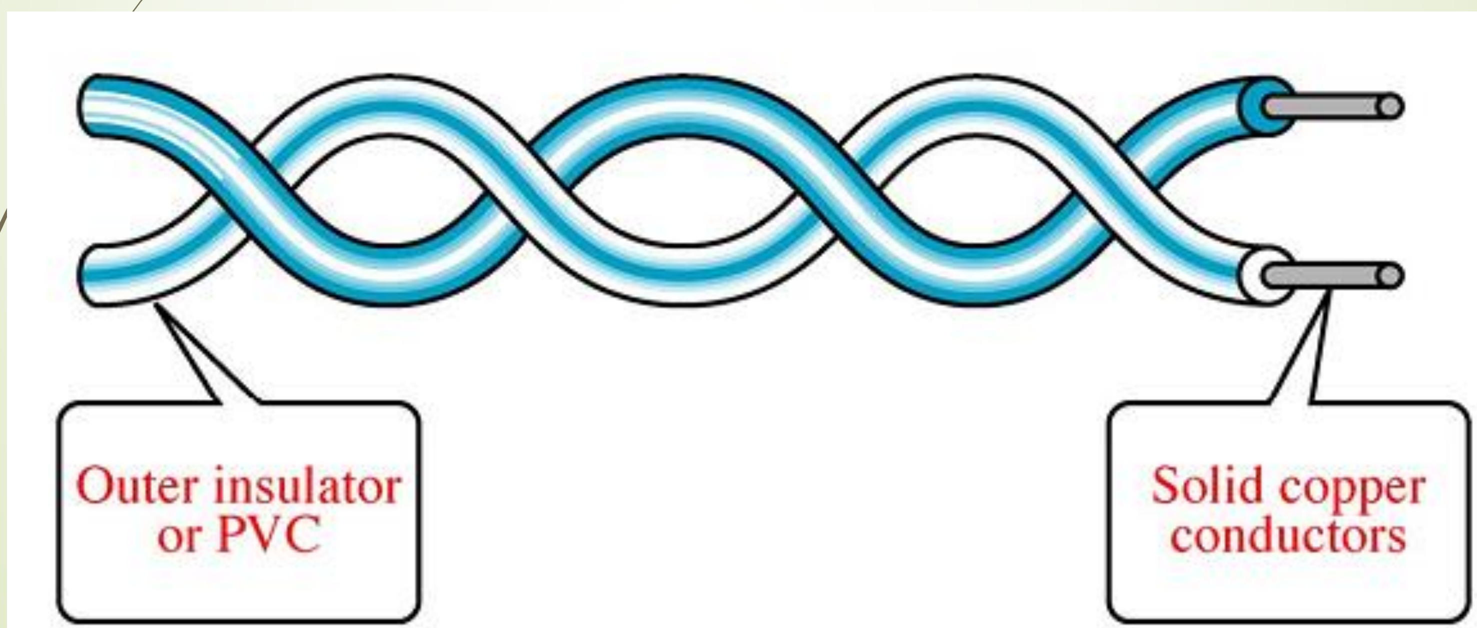
	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μs/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 μs/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μs/km	1 to 9 km
Optical fiber	186 to 370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

THz = TeraHerz = 10^{12} Hz

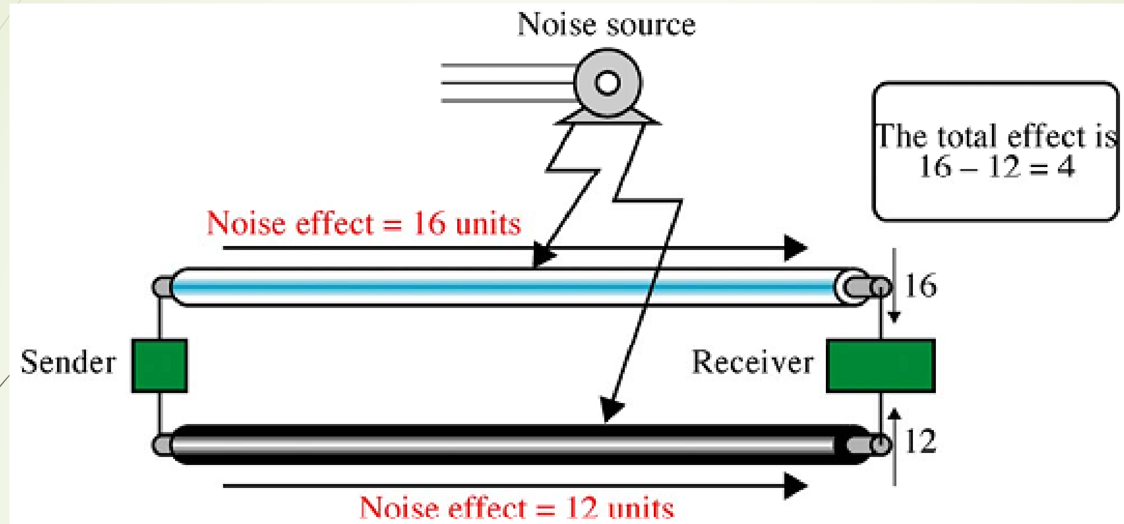
Twisted Pair

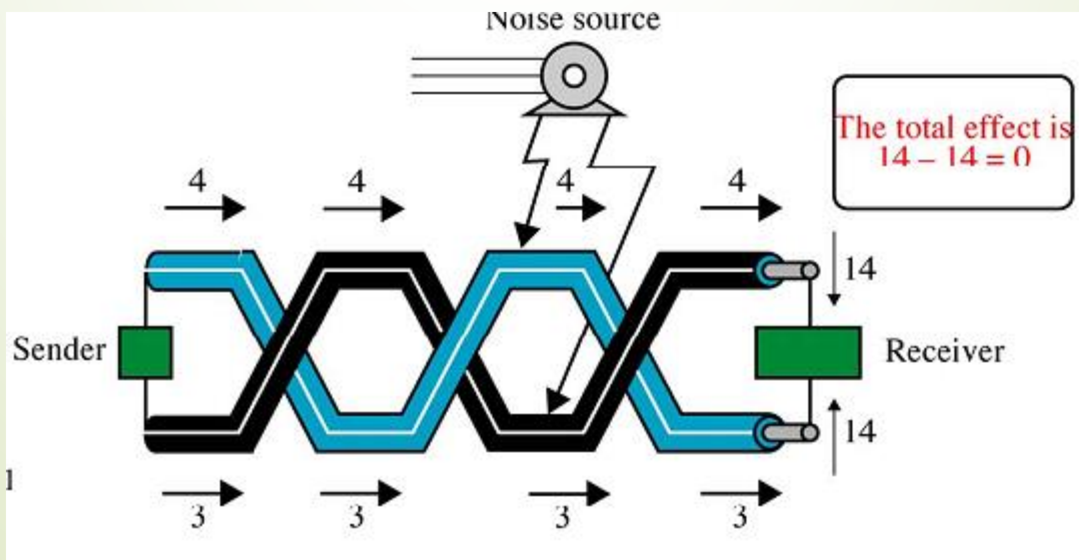




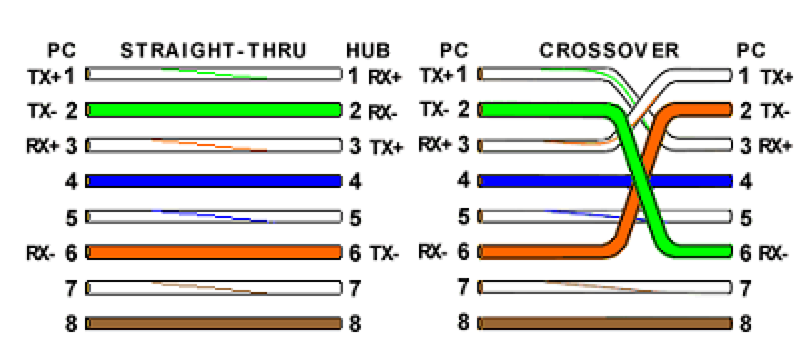


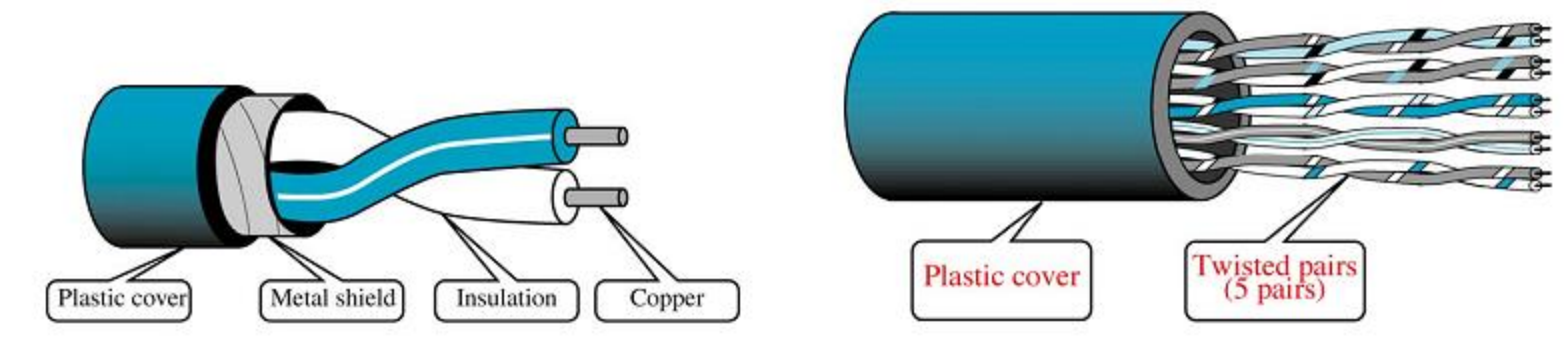
Twisted Pair (2)

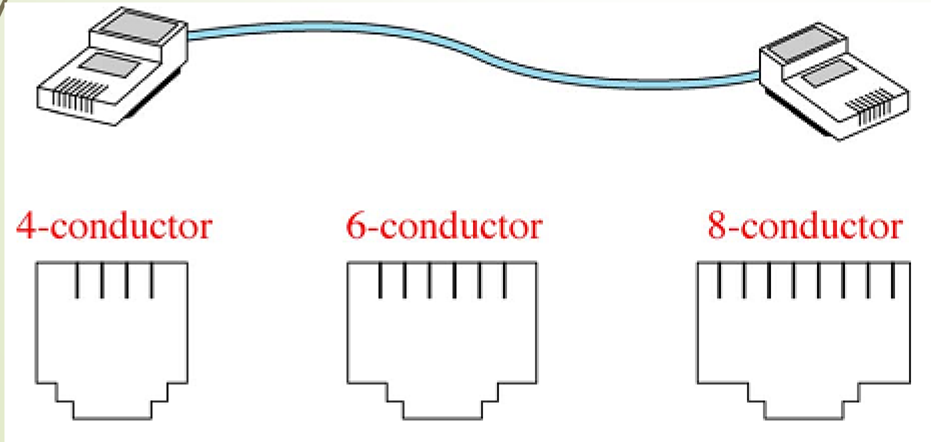




Twisted Pair (3)







RJ-45
is used for
10/100 BASE-T.
8 conductor.

Twisted Pair (4)

- Most common 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 or more
- Cheap
- Easy to work with
- Low data rate
  – 10 Mbps, 100 Mbps, 1Gbps
- Susceptible to interference and noise

Near End Crosstalk (NEXT)

- The unwanted coupling of the signal from an adjacent pair of conductors onto the subject pair at the transmit end. A familiar example of cross talk in general is when you hear a second conversation on the telephone while you are talking.

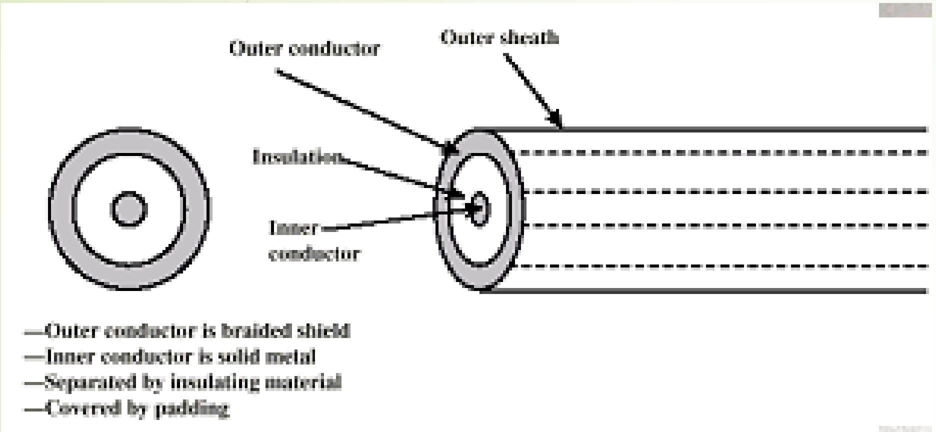
Unshielded and Shielded TP

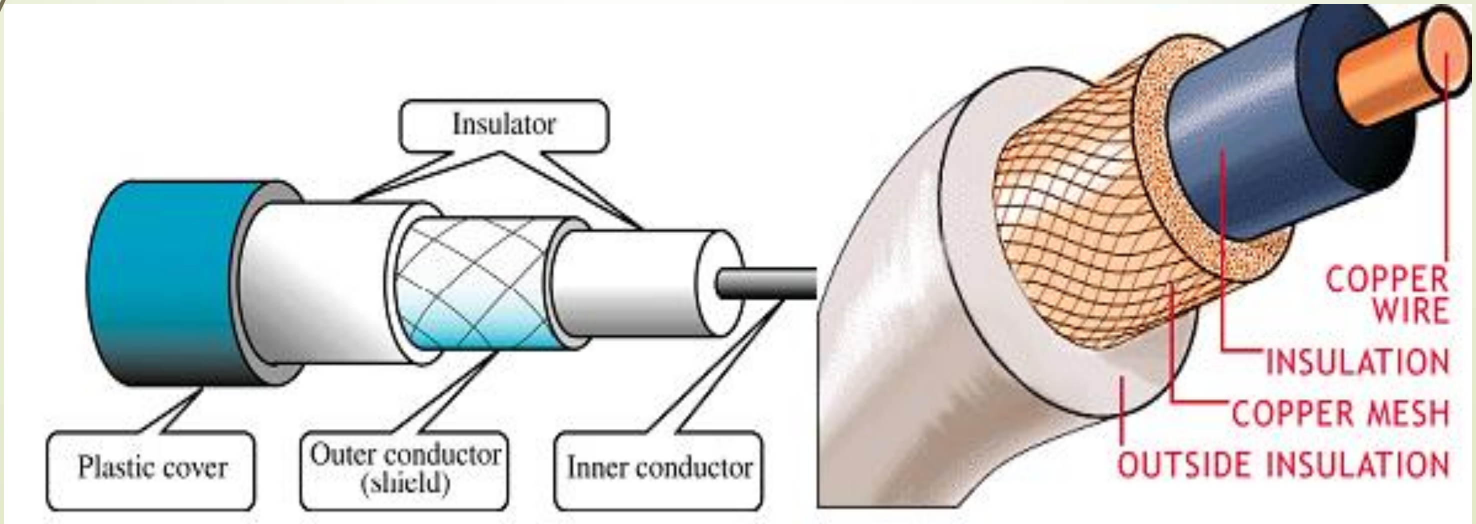
- Unshielded Twisted Pair (UTP)
  – Ordinary telephone wire
  – Cheapest
  – Easiest to install
  – Suffers from external EM interference
- Shielded Twisted Pair (STP)
  – Metal braid or sheathing that reduces interference
  – More expensive
  – Harder to handle (thick, heavy)

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)
- Cat 6
- Cat 7

Coaxial Cable





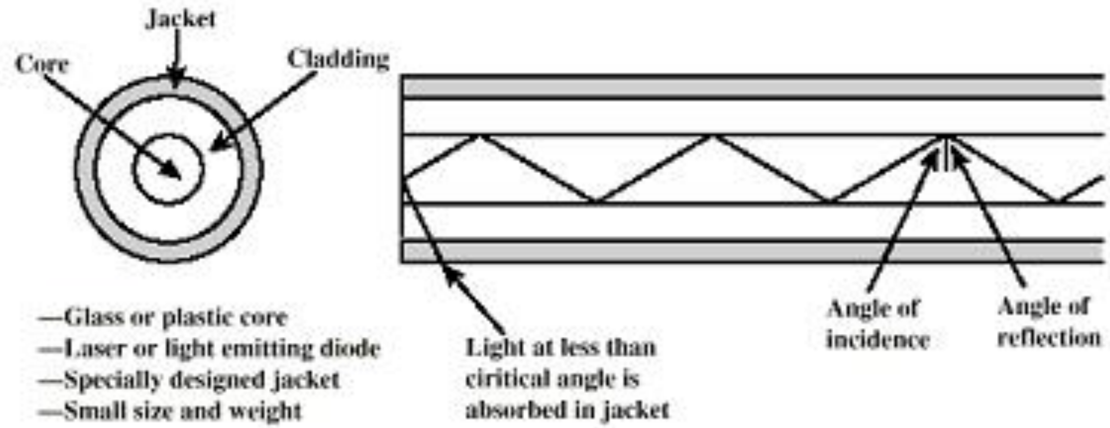
Coaxial Cable Applications

- Most versatile medium
- Television distribution
  – 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

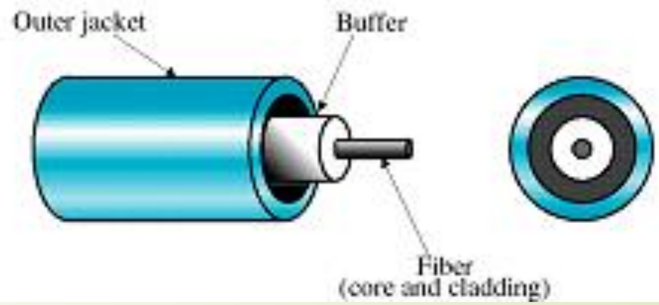
Coaxial Cable - Transmission Characteristics

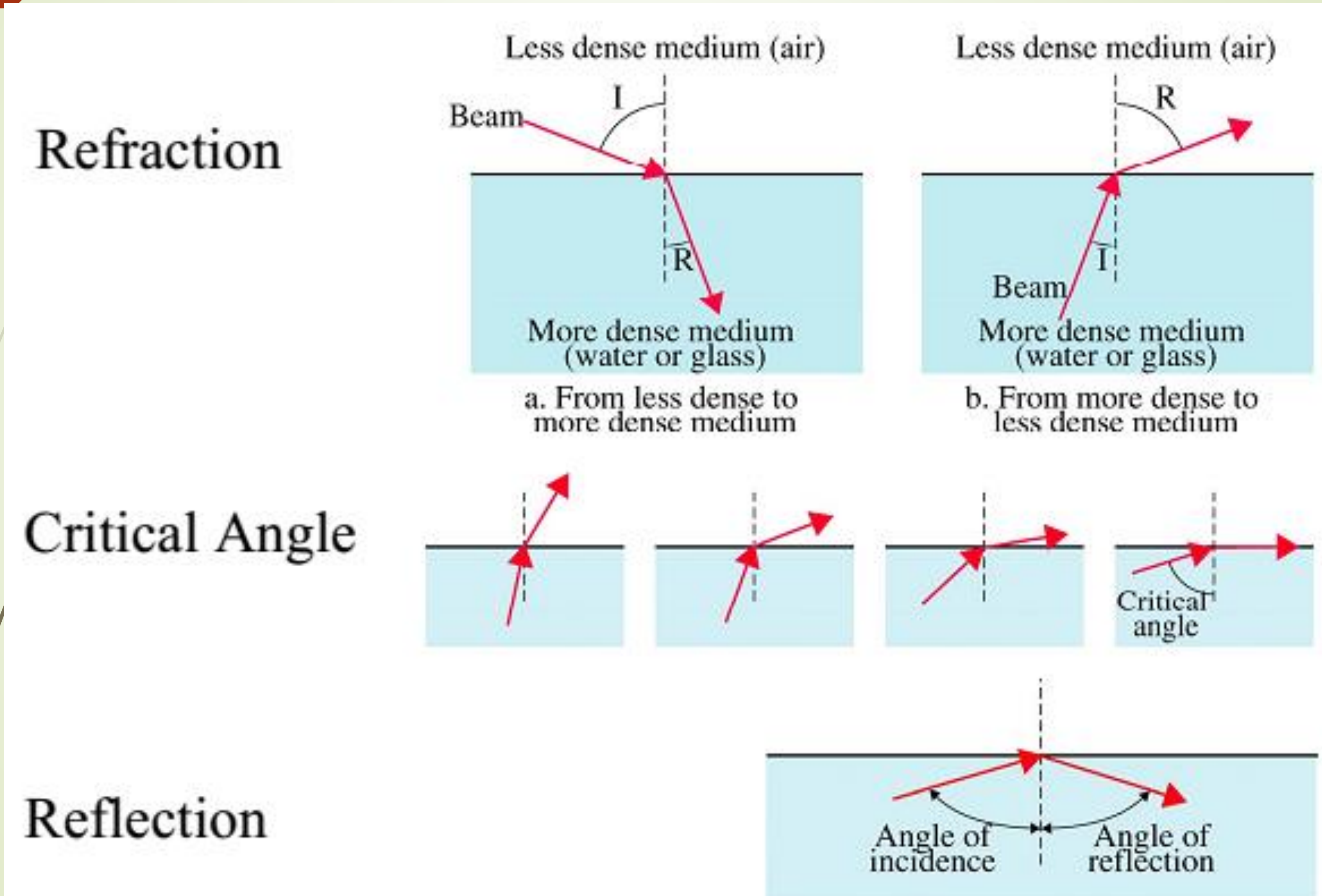
- Analog
  - – Amplifiers every few km
  - – Closer if higher frequency
  - – Up to 500 MHz
- Digital
  - – Repeater every 1 km
  - – Closer for higher data rates

Optical Fiber



A glass or plastic core is surrounded by a cladding of less dense glass or plastic.





Refraction
Less dense medium (air)
Less dense medium (air)
I
Beam
R
R
I
Beam
More dense medium
(water or glass)
More dense medium
(water or glass)
a. From less dense to
more dense medium
b. From more dense to
less dense medium
Critical Angle
Critical
angle
Reflection
Angle of
incidence
Angle of
reflection

Optical Fiber - Benefits

- Greater capacity
  – Data rates of hundreds of Gbps
- Smaller size & weight
- Lower attenuation
- Electromagnetic isolation
- Greater repeater spacing
  – 10s of km at least

Optical Fiber - Applications

- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- LANs

Optical Fiber - Transmission Characteristics

- Act as wave guide for 10^{14} to 10^{15} Hz
  – Portions of infrared and visible spectrum
- Light Emitting Diode (LED)
  – Cheaper
  – Wider operating temperature range
  – Last longer
- Injection Laser Diode (ILD)
  – More efficient
  – Greater data rate
- Wavelength Division Multiplexing

Wireless Transmission Frequencies

- 2GHz to 40GHz
  – Microwave
  – Highly directional
  – Point to point
  – Satellite
- 30 MHz to 1 GHz
  – Omni-directional
  – Broadcast radio
- 3×10^{11} to 2×10^{14} Hz
  – Infrared
  – Local point-to-point and multipoint applications within confined areas

Antennas

- Electrical conductor (or system of conductors) used to radiate electromagnetic energy or collect electromagnetic energy
- 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

Isotropic Antenna

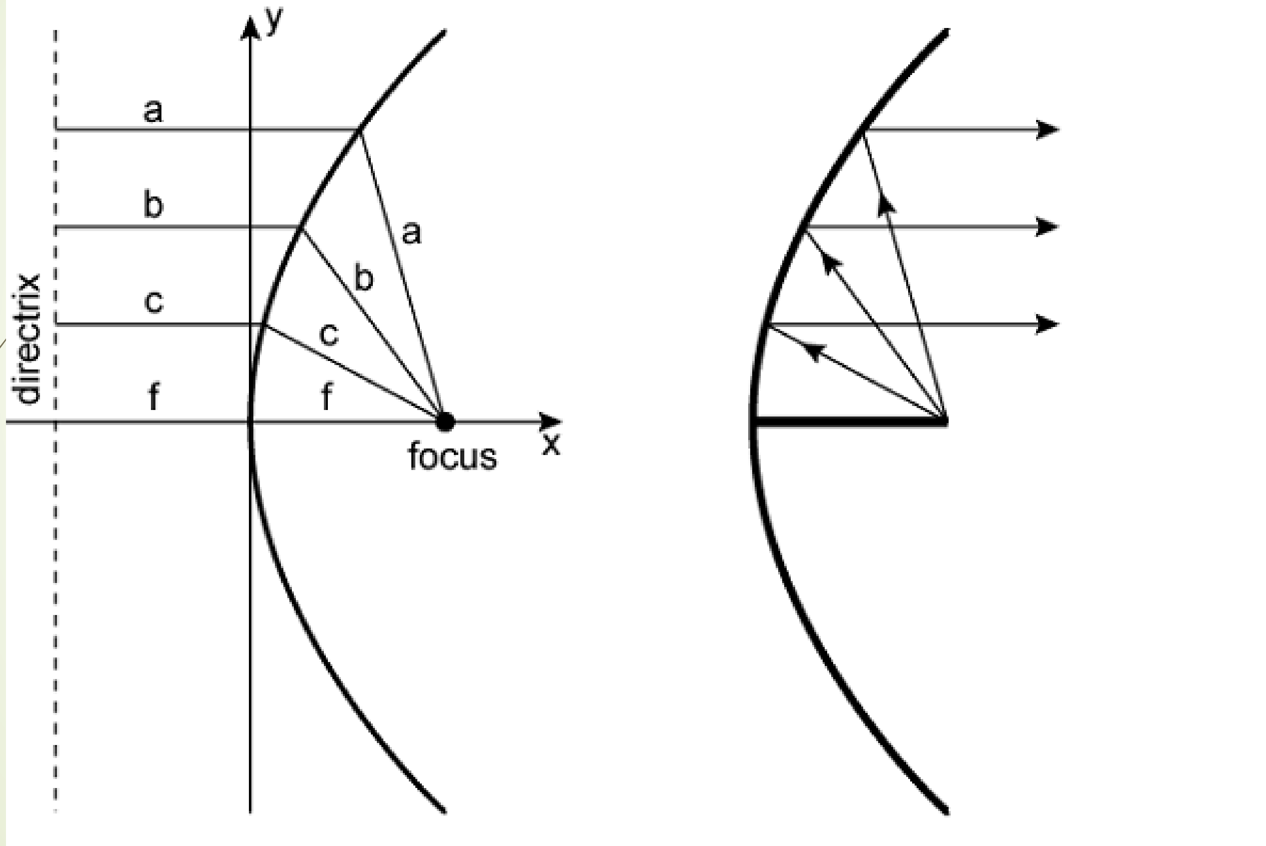
- Power radiated in all directions
- Not same performance in all directions
- Isotropic antenna is (**theoretical**) point in space
  – Radiates in all directions equally
  – Gives spherical radiation pattern

Parabolic Reflective Antenna

- Used for terrestrial and satellite microwave
- Parabola is locus of point equidistant from a line and a point not on that line
  – Fixed point is focus
  – Line is directrix

- Source placed at focus will produce wav[es] reflected from parabola in parallel to axis
  – Creates (theoretical) parallel beam of light/sound/radio
- On reception, signal is concentrated at focus, where detector is place

Parabolic Reflective Antenna (2)



(a) Parabola

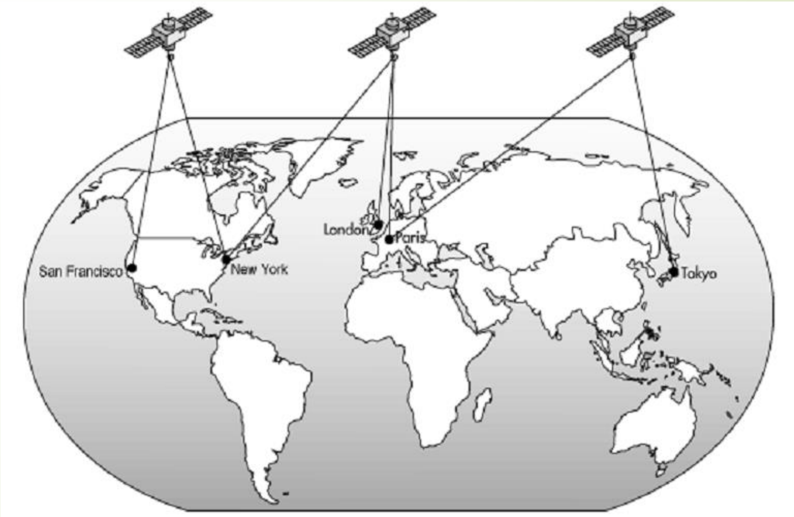
(b) Cross-section of parabolic antenna showing reflective property

Terrestrial Microwave

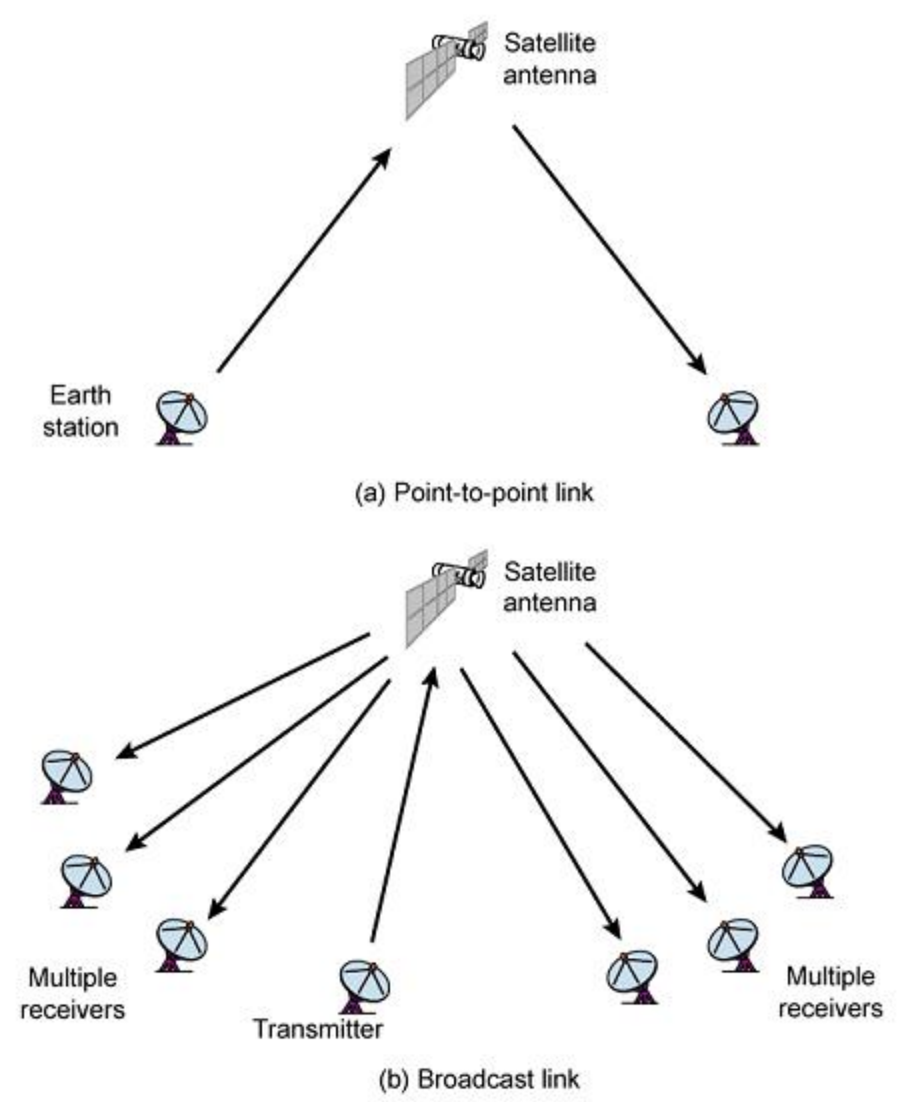
- Parabolic dish
- Focused beam
- Line of sight
- Long haul telecommunications
- Higher frequencies give higher data rates.
- The antennas are smaller and cheaper.

Satellite Microwave

- Satellite is relay station
- Satellite receives on one frequency (uplink), amplifies or repeats signal and transmits (downlink) on another frequency
- Requires geo-stationary orbit
  – Height of 35,784km
- Television
- Long distance telephone
- Private business networks



Satellite



(a) Point-to-point link

(b) Broadcast link

Broadcast Radio

- Omni-directional
- FM radio
- UHF and VHF television
- Suffers from multi-path interference
  – Reflections

Infrared

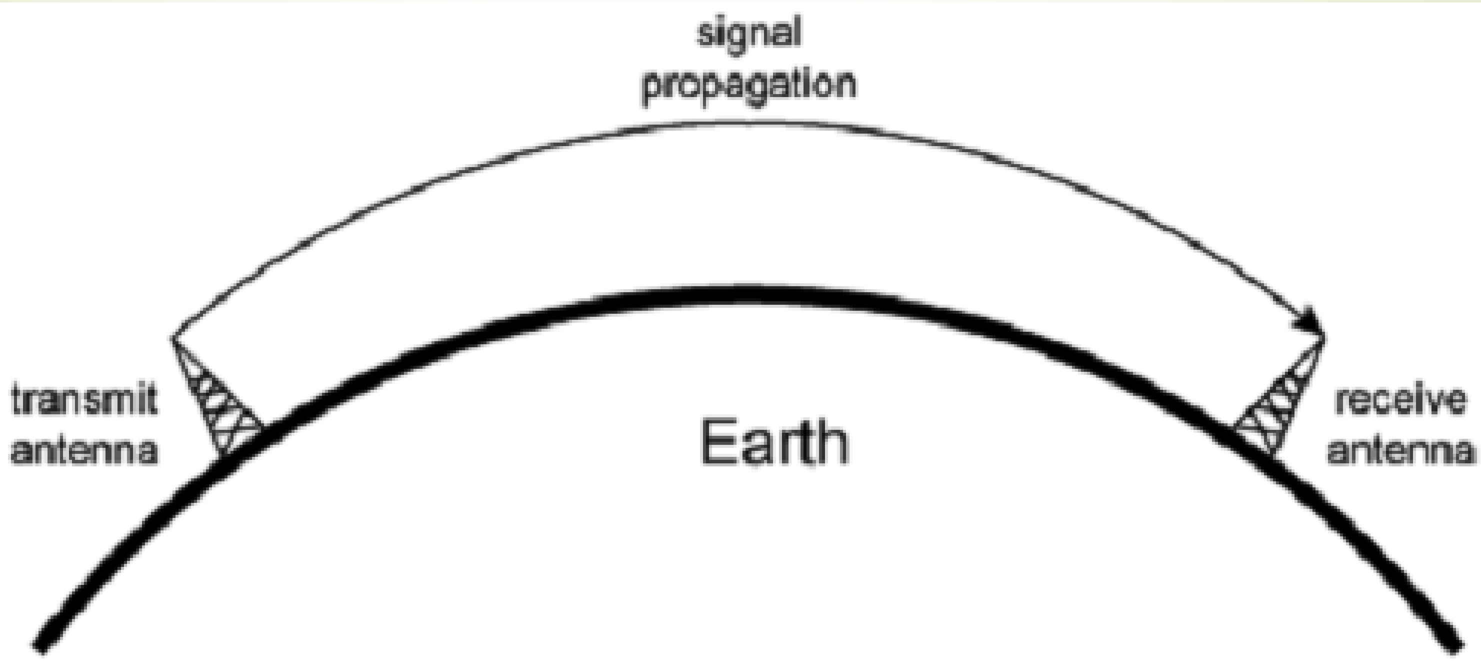
- Modulate non-coherent infrared light
- Line of sight (or reflection)
- Blocked by walls
  - e.g. TV remote control

Wireless Propagation

- Signal travels along three routes
  - Ground wave
  - Sky wave
  - Line of sight

Ground Wave Propagation

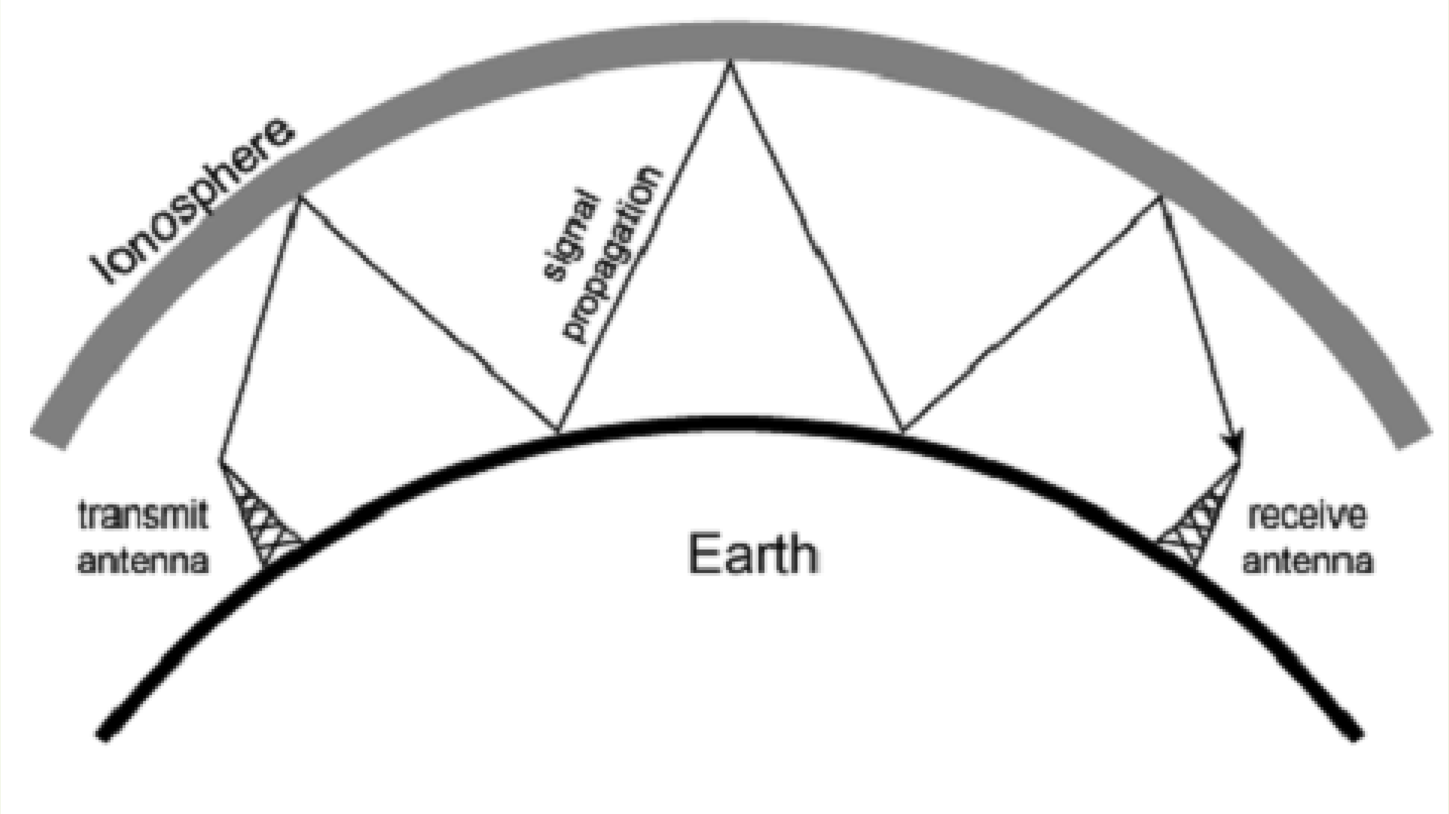
- Follows contour of earth
- Up to 2MHz
- AM radio



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

Sky Wave Propagation

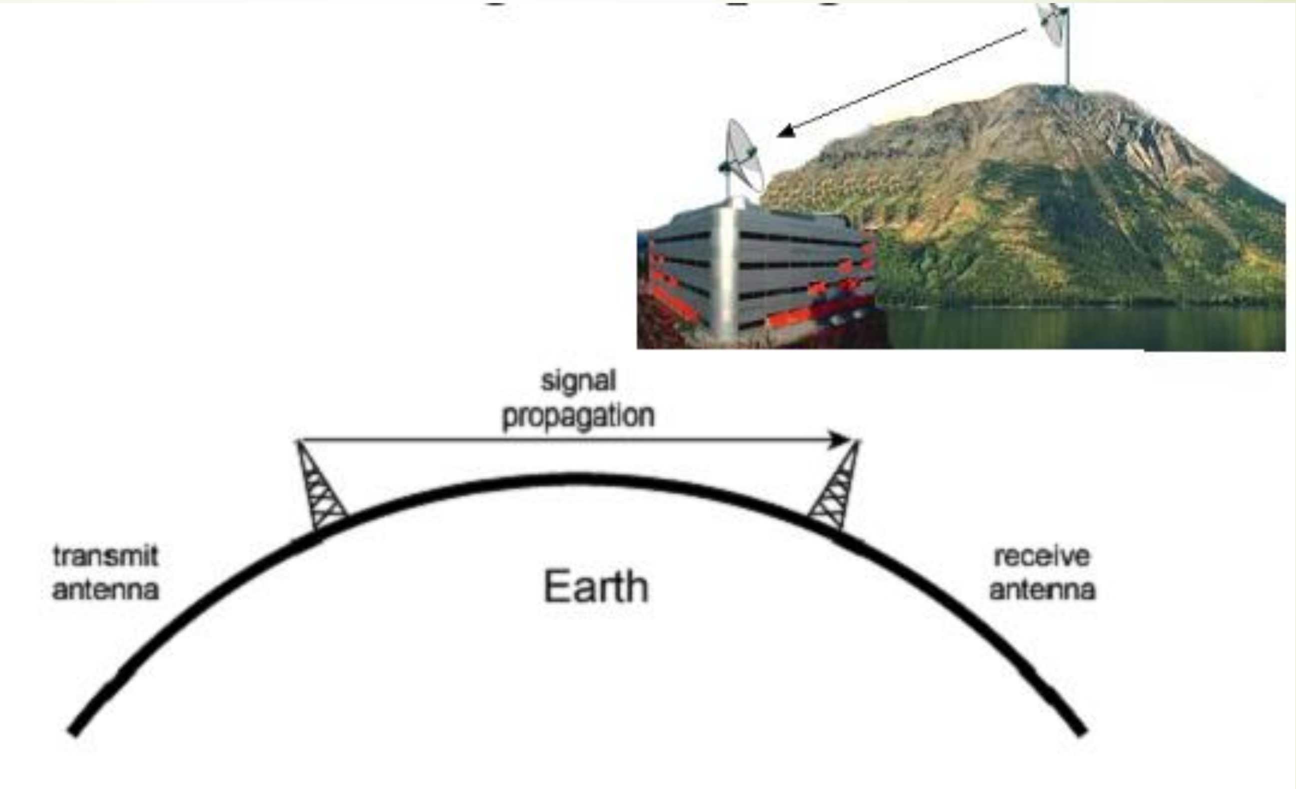
- Amateur radio, BBC world service, Voice of America
- Signal reflected from ionosphere layer of upper atmosphere



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

Line of Sight Propagation

- Above 30MHz
- May be further than optical line of sight due to refraction



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

☺

Courtesy

- Professor Jiying Zhao, University of Ottawa

Problems

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

G = antenna gain
A_e = effective area
f = carrier frequency
c = speed of light ($\approx 3 \times 10^8$ m/s)
λ = carrier wavelength

EXAMPLE 4.2 For a parabolic reflective antenna with a diameter of 2 m, operating at 12 GHz, what is the effective area and the antenna gain? We have an area of $A = \pi r^2 = \pi$ and an effective area of $A_e = 0.56\pi$. The wavelength is $\lambda = c/f = (3 \times 10^8)/(12 \times 10^9) = 0.025$ m. Then

$$G = (7A)/\lambda^2 = (7 \times \pi)/(0.025)^2 = 35{,}186$$
$$G_{dB} = 45.46 \text{ dB}$$

[10 marks] Given that the speed of light is 3×10^8 m/s. A satellite is at geosynchronous orbit. How long would it take for a signal to go from the earth station to the satellite (minimum time)? If the data rate is 64 Kbps, what is maximum frame size which can be accommodated so that the last bit leaves the earth station before the first bit reaches the satellite? Assume that the height of the satellite is 35,863 km.

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(35863*1000)/(3*10^8)=0.12 second
64000*0.12=7680 bits
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- How long it will take to transfer the data from USA to Bangladesh using Sky wave propagation model. Consider that the distance of USA to Bangladesh is 13,269 KM and satellite relay stations are placed in 4 degree distance in the longitude. 1 degree longitude 447 KM and data transfer from earth to the geo orbit uses both uplink and downlink.