Transmission Media

CHAPTER 4

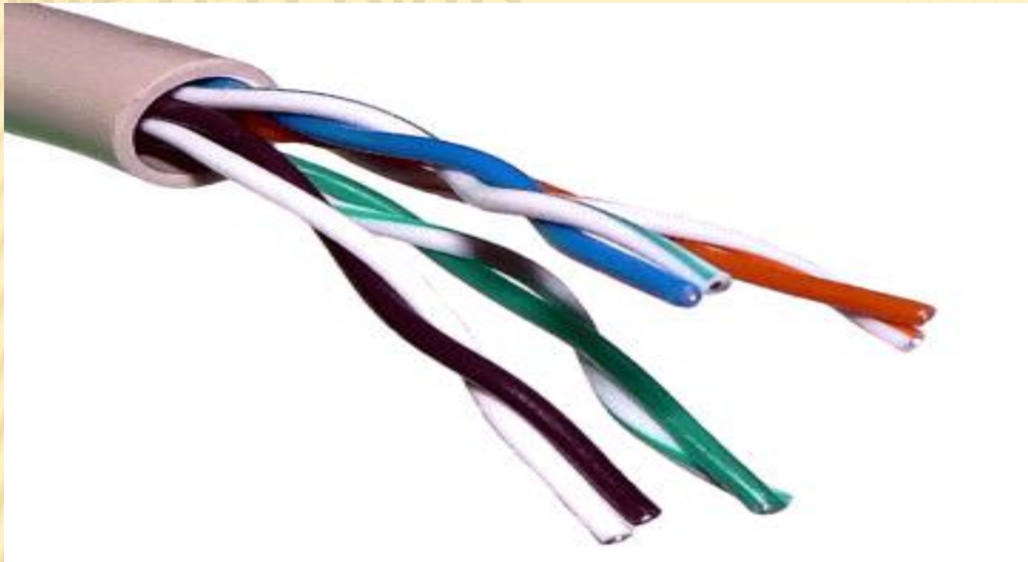
TYPES OF TRANSMISSION MEDIA

- Guided transmission media
- Unguided (Wireless)transmission media

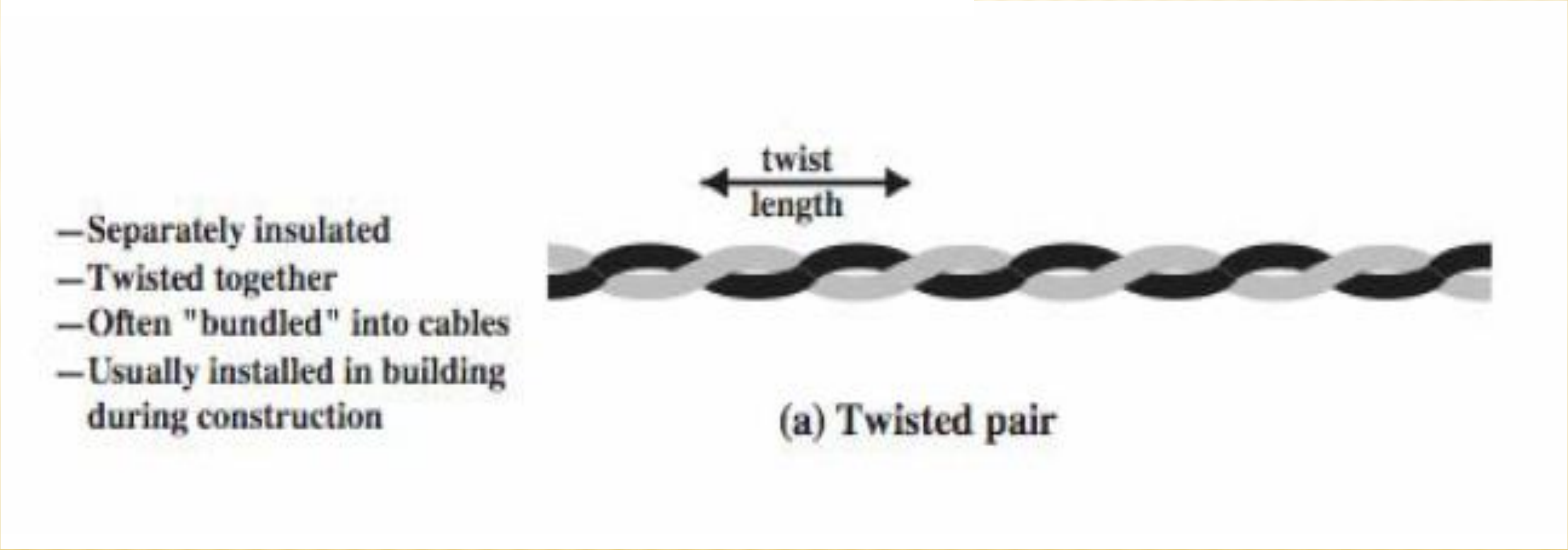
GUIDED TRANSMISSION MEDIA

- Twisted Pair
- Coaxial cable
- Optical Fiber

TWISTED PAIR



- Twisting tends to decrease cross talk.
- Neighbouring pairs will have different twist length to reduce cross talk.



(a) Twisted pair

TWISTED PAIR - TRANSMISSION CHARACTERISTICS

- analog
  - needs amplifiers every 5km to 6km
- Digital
  - can use either analog or digital signals
  - needs a repeater every 2-3km
- limited distance
- limited bandwidth (1MHz)
- For long distance- limited data rate (100Mbps)
- For short distance(10Gbps)
- Less expensive

VARIETIES OF TWISTED PAIRS

- unshielded Twisted Pair (UTP)
  - ordinary telephone wire
  - cheapest
  - easiest to install
  - suffers from external EM interference from nearby twisted pair.
  - Commonly used for local area networks.
- shielded Twisted Pair (STP)
  - metal braid or sheathing that reduces interference
  - Better performance at higher data rates.
  - more expensive
  - harder to handle (thick, heavy)

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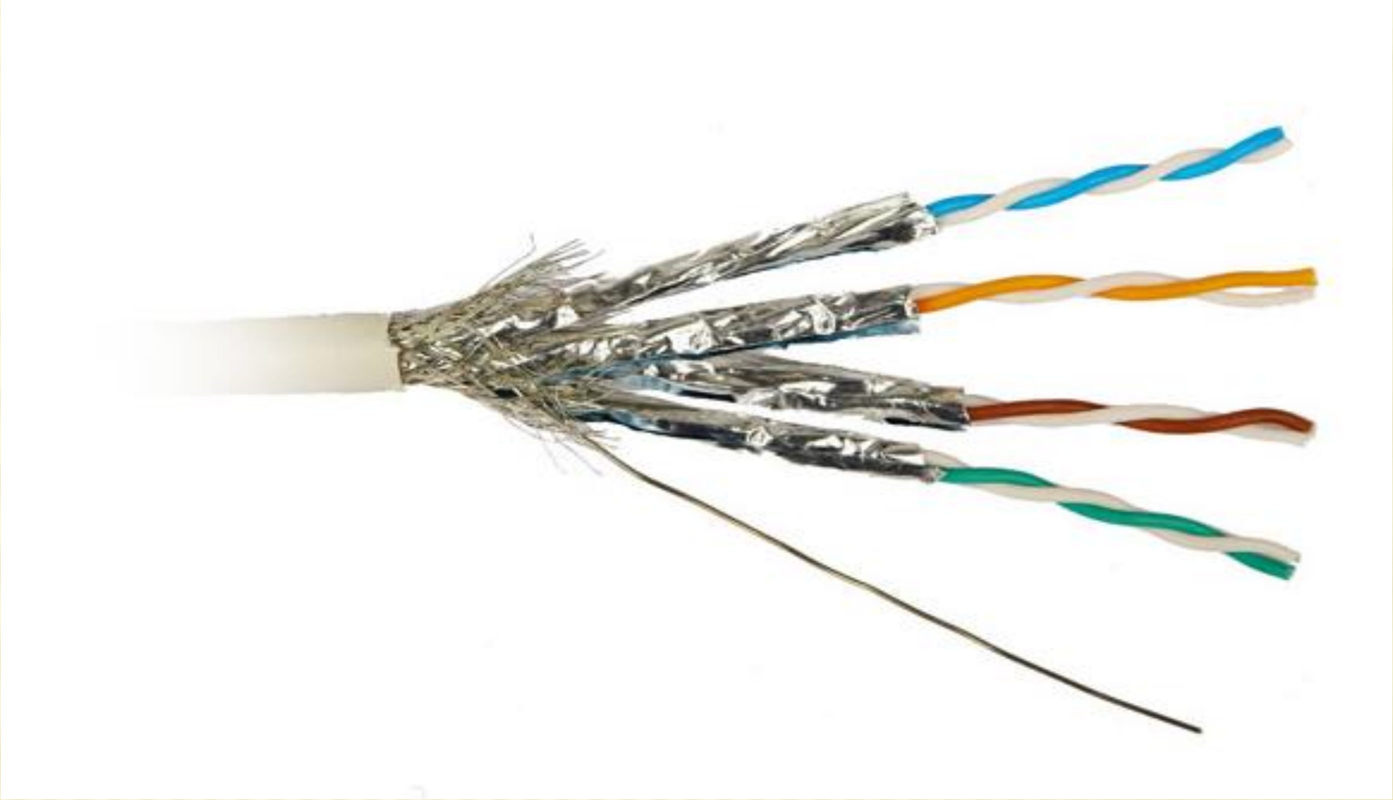
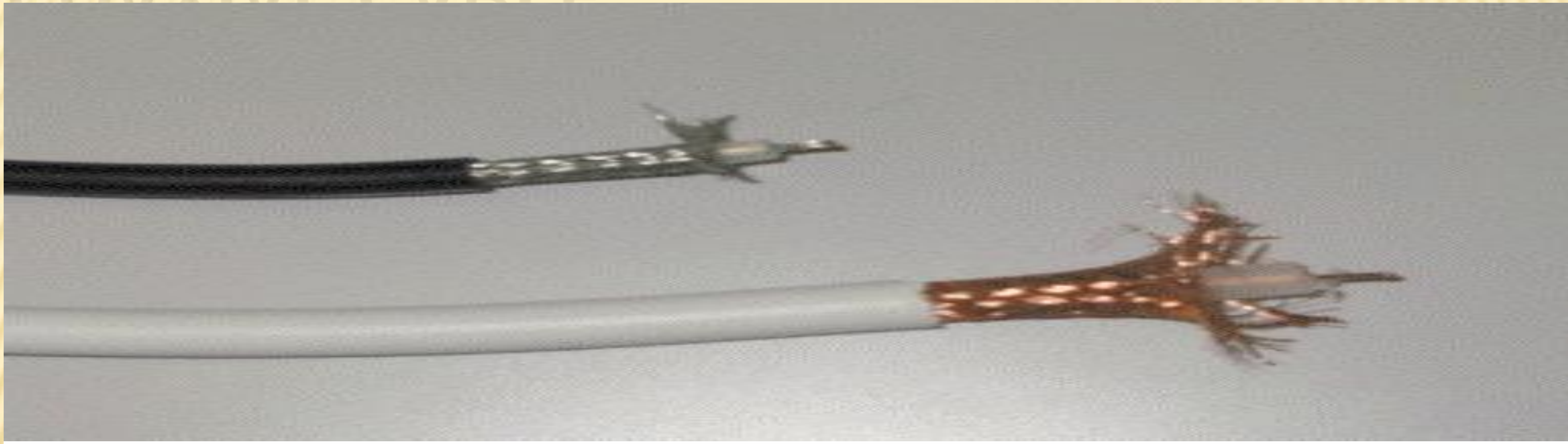
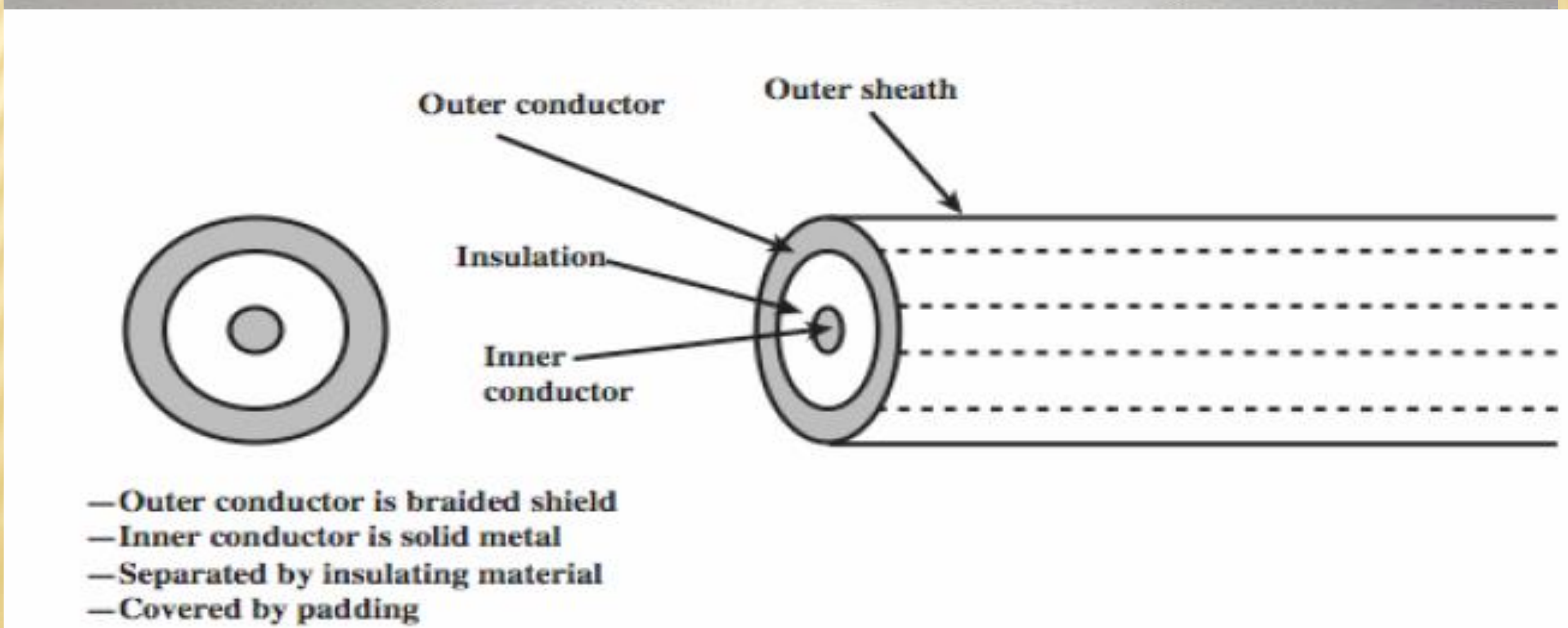


COAXIAL CABLE

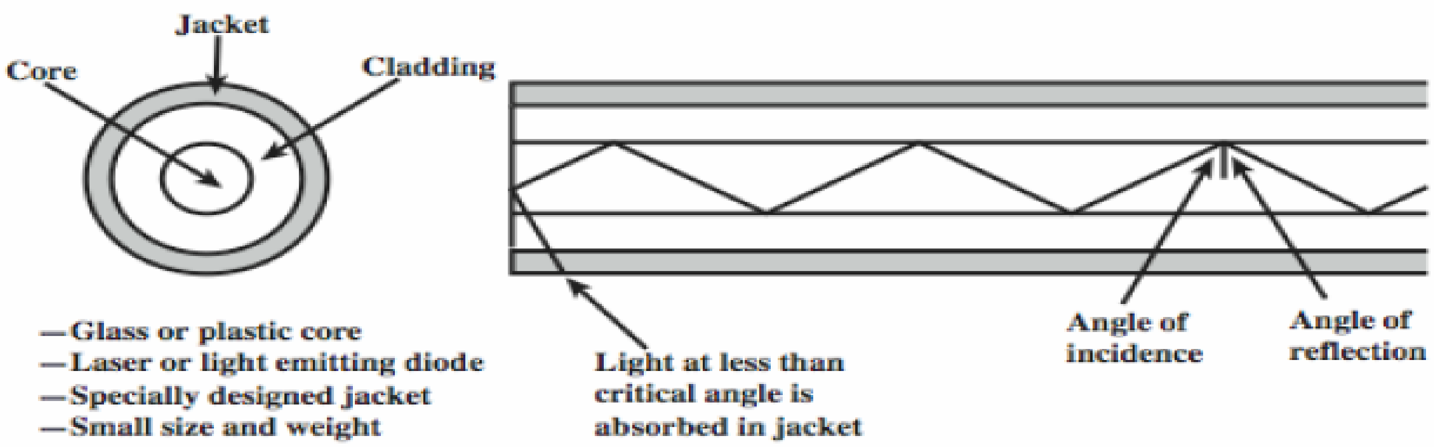




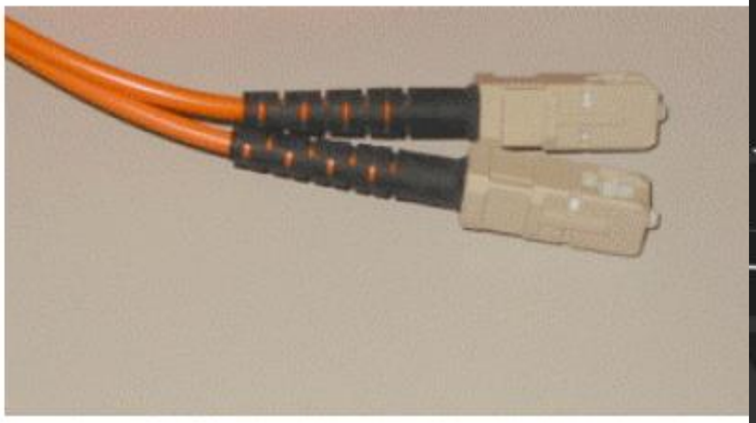
COAXIAL CABLE - TRANSMISSION CHARACTERISTICS

- superior frequency characteristics to TP
- performance limited by attenuation & noise
  - analog signals
    - amplifiers every few km
    - closer if higher frequency
    - up to 500MHz
  - digital signals
    - repeater every 1 to 9km
    - closer for higher data rates

OPTICAL FIBER



(c) Optical fiber



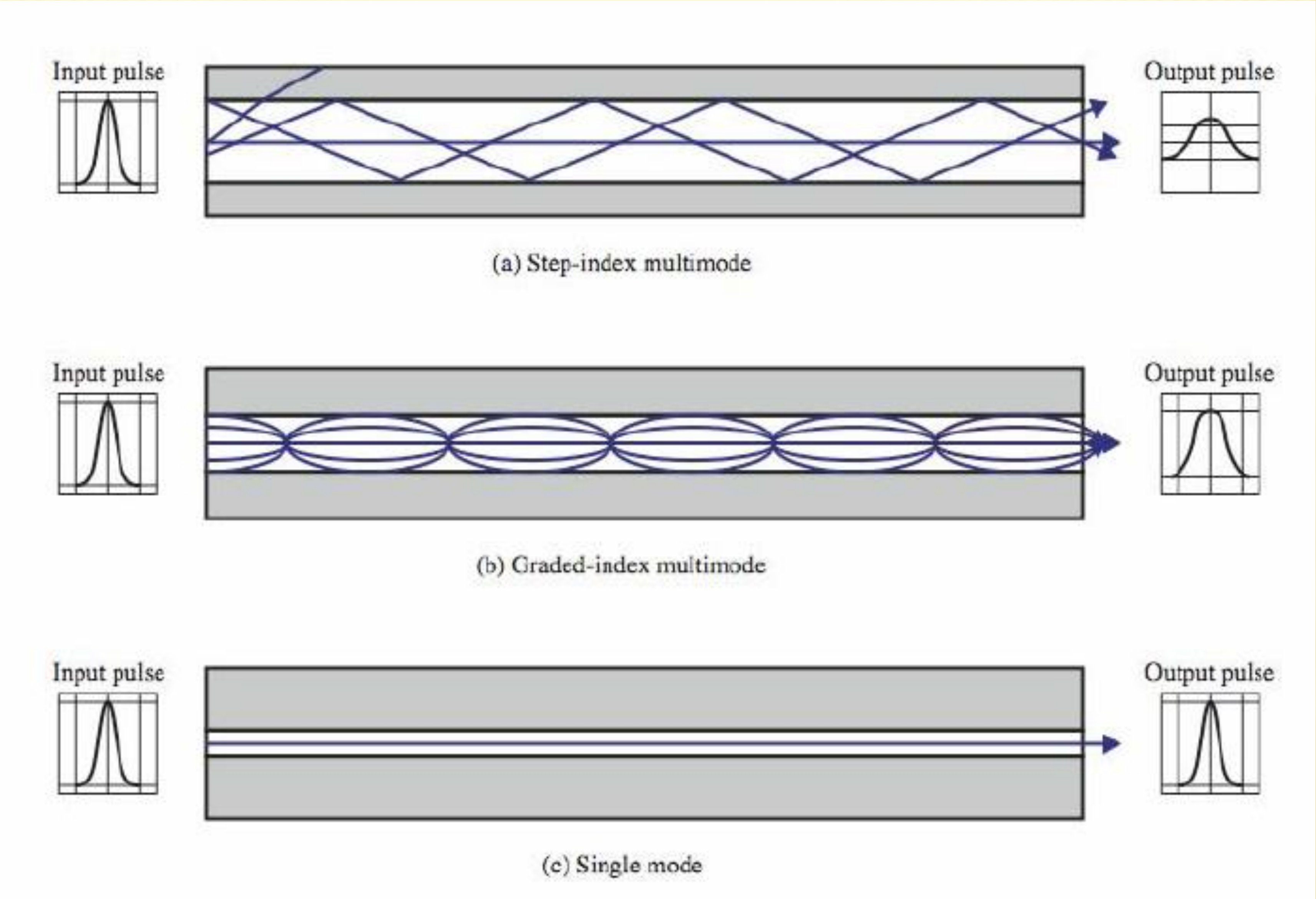
OPTICAL FIBER - BENEFITS

- Bandwidth of 370THz
- greater capacity
  - data rates of hundreds of Gbps
- smaller size & weight
- lower attenuation
- Greater repeater spacing: 10s of km.
- electromagnetic isolation
  - greater repeater spacing10s of km at least

OPTICAL FIBER - TRANSMISSION CHARACTERISTICS

- uses total internal reflection to transmit light effectively.
- acts as wave guide for 10^{14} to 10^{15} Hz
- can use several different light sources
  - Light Emitting Diode (LED)
    - cheaper, wider operating temp range, lasts longer
  - Injection Laser Diode (ILD)
    - more efficient, has greater data rate

OPTICAL FIBER TRANSMISSION MODES



UNGUIDED TRANSMISSION MEDIA(WIRELESS)

Wireless Transmission Frequencies

- 2GHz to 40GHz: microwave
  - highly directional
  - point to point
  - satellite
- 30MHz to 1GHz :broadcast radio
  - omnidirectional
- 3 x 10^{11} to 2 x 10^{14} Hz: infrared
  - Local point to point

ANTENNAS

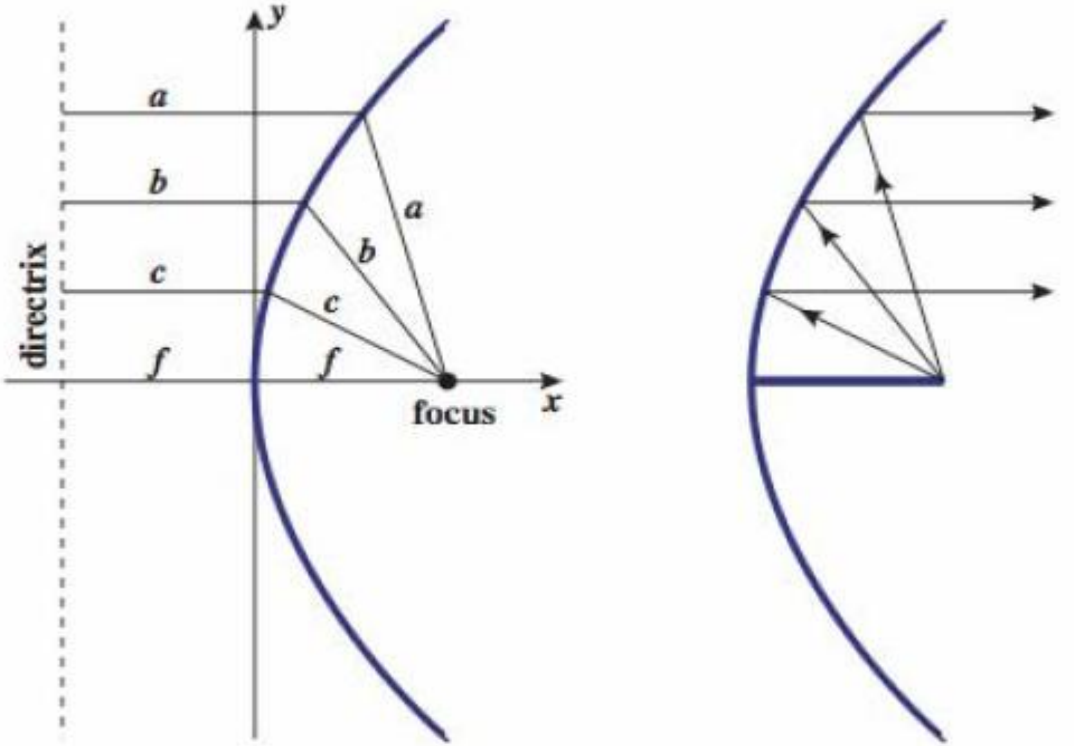
Electrical conductor used to radiate or collect electromagnetic energy

- transmission antenna
  - electrical energy from transmitter converted to electromagnetic energy by antenna radiated into surrounding environment
- reception antenna
  - electromagnetic energy impinging on antenna converted to electrical energy fed to receiver
- same antenna is often used for both purposes

RADIATION PATTERN

- power radiated in all directions
- not same performance in all directions
- an isotropic antenna is a (theoretical) point in space
  - radiates in all directions equally
  - with a spherical radiation pattern

PARABOLIC REFLECTIVE ANTENNA



(a) Parabola

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

ANTENNA GAIN

- measure of directionality of antenna
- power output in particular direction verses that produced by an isotropic antenna
- measured in decibels (dB)
- results in loss in power in another direction
- The antenna gain is related to the effective area of an antenna:

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

$G = antenna\ \ gain$

$A_e = effective\ \ area$

$\lambda = \frac{c}{f} = carrier\ \ wavelength$

- Effective area of the isotropic antenna is $\dfrac{\lambda^2}{4\pi}$

And has a gain of 1=0dB

- Effective area of a parabolic antenna with a face area of A is

TERRESTRIAL MICROWAVE

- Typical size is about 3m in diameter.
- used for long haul telecommunications(4GHz to 6GHz).
  - 12GHz band: Cable TV Systems.
- and short point-to-point links
- requires fewer repeaters at about 10-100km.
- line of sight
- use a parabolic dish to focus a narrow beam onto a receiver antenna
- 1-40GHz transmission frequencies
- higher frequencies give higher data rates
- main source of loss is attenuation
  - distance, rainfall
- interference

- Loss can be expressed as:

$$L_{dB} = 10\log_{10}\left(\frac{4\pi d}{\lambda}\right)^2 = 10\log_{10}\left(\frac{4\pi df}{c}\right)^2 \quad dB$$

d = distance

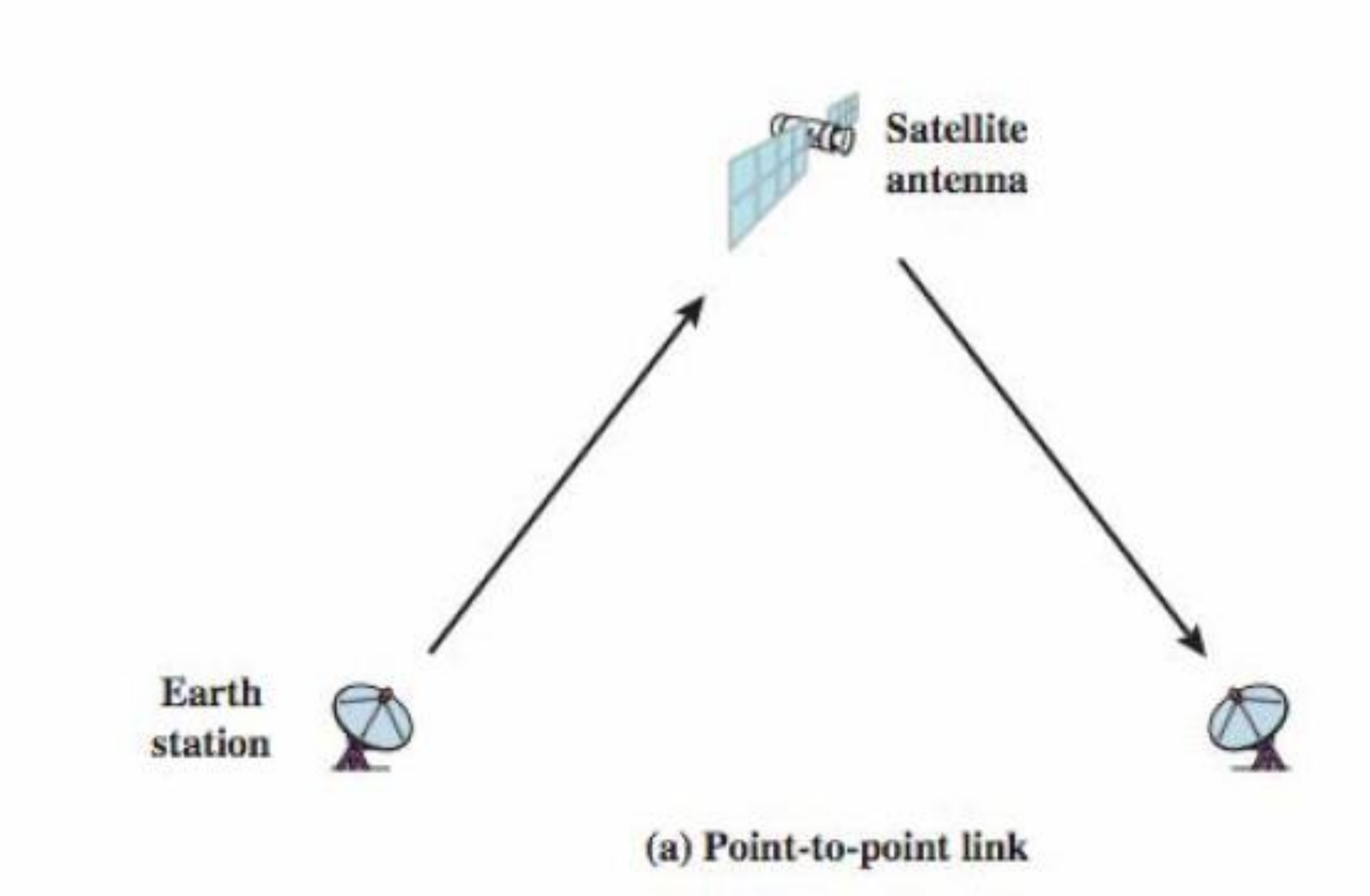
λ = wavelength

f = frequency

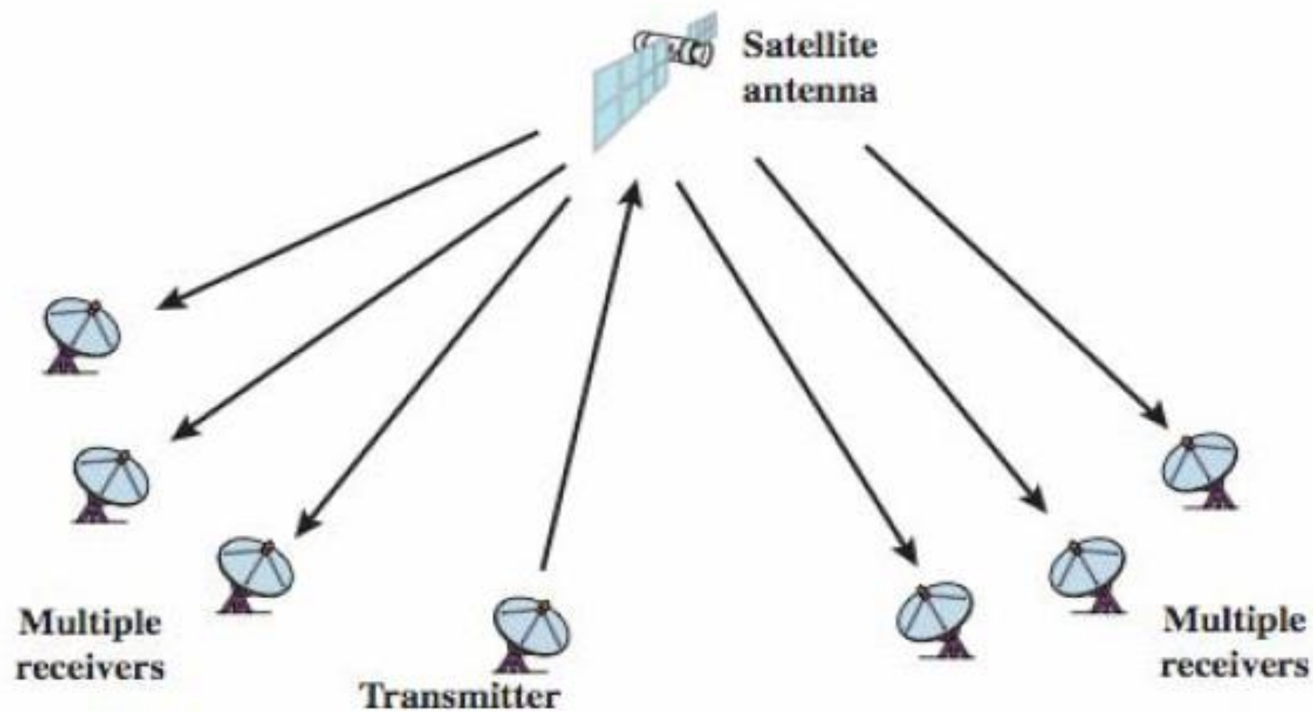
SATELLITE MICROWAVE

- To link two or more earth station.
- Satellite receives on one frequency(uplink), amplifies or repeats signal and transmits on another frequency(downlink).
  - eg. uplink 5.925-6.425 GHz & downlink 3.7-4.2 GHz
- typically requires geo-stationary orbit
  - height of 35,784km
  - spaced at least 3-4° apart (to minimize interference from other satellites)
- typical uses
  - television
  - long distance telephone
  - private business networks
  - global positioning

SATELLITE POINT TO POINT LINK



SATELLITE BROADCAST LINK



(b) Broadcast link

BROADCAST RADIO

- radio is 3kHz to 300GHz
- use broadcast radio, 30MHz - 1GHz, for : FM radio
- is omnidirectional
- still need line of sight
- suffers from multipath interference
  - reflections from land, water, other objects

INFRARED

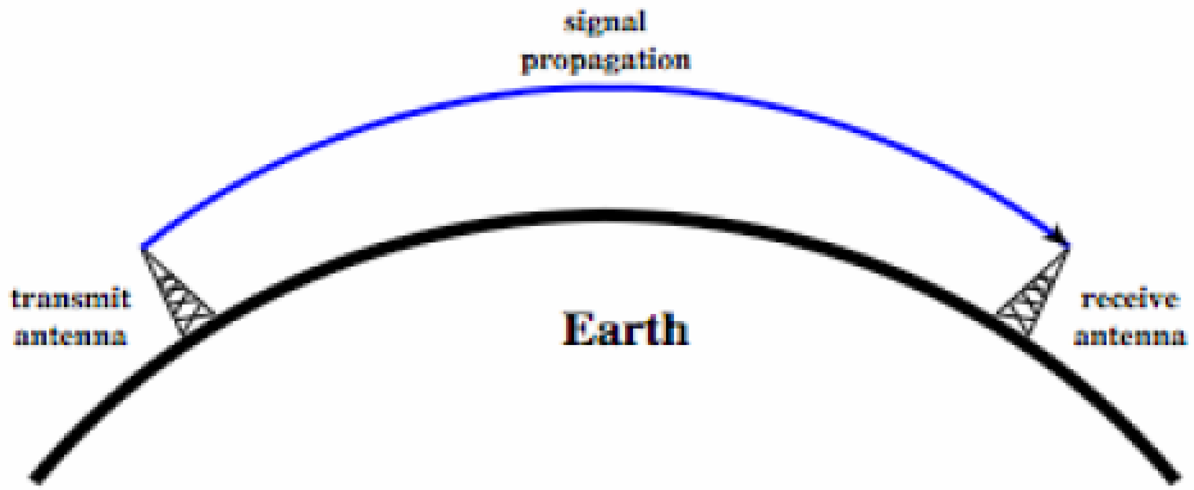
- need line of sight (or reflection)
- are blocked by walls
- no licenses required
- typical use
  - TV remote control

WIRELESS PROPAGATION

- Ground Wave
- Sky Wave
- Line of Sight

WIRELESS PROPAGATION GROUND WAVE

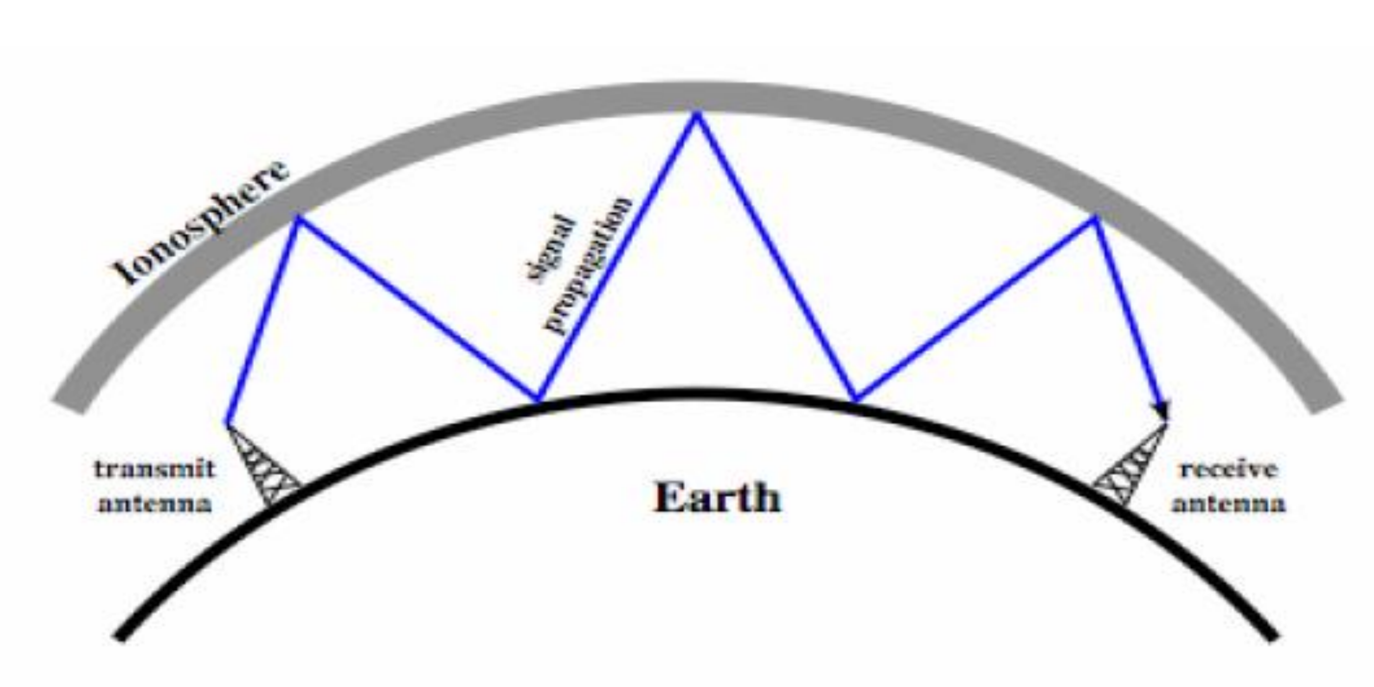
- Ground wave is found in frequencies up to 2MHz
- The best-known example of ground wave communication is AM radio



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

WIRELESS PROPAGATION SKY WAVE

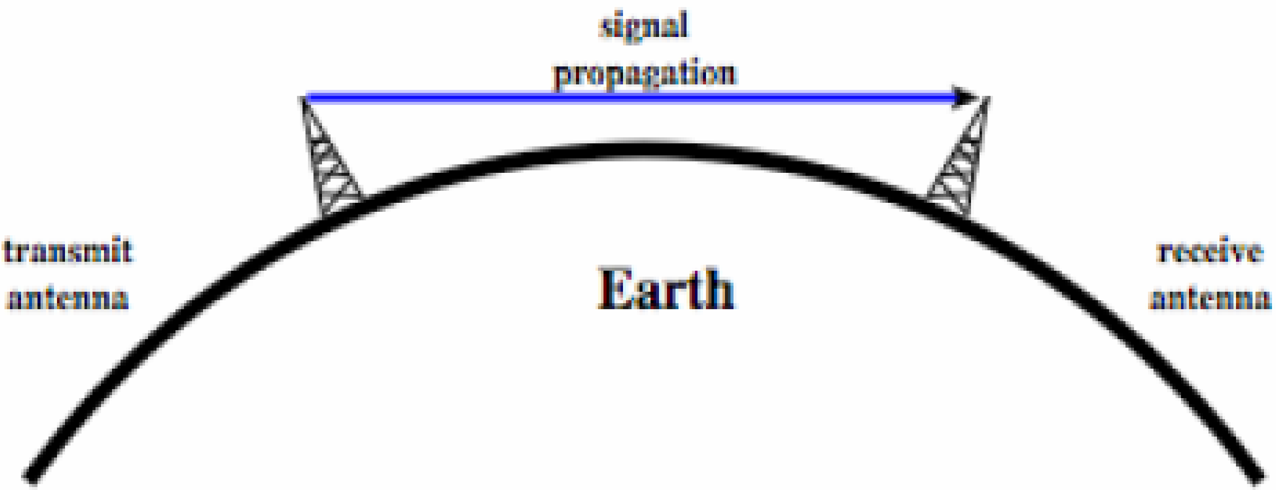
- Sky wave propagation is found in frequencies from 2MHz to 30MHz
- A sky wave signal bounces back and forth between the ionosphere and the earth surface



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

WIRELESS PROPAGATION LINE OF SIGHT

- LOS propagation is found in frequencies above 30MHz
- the transmitting and receiving antennas must be within a line of sight of each other



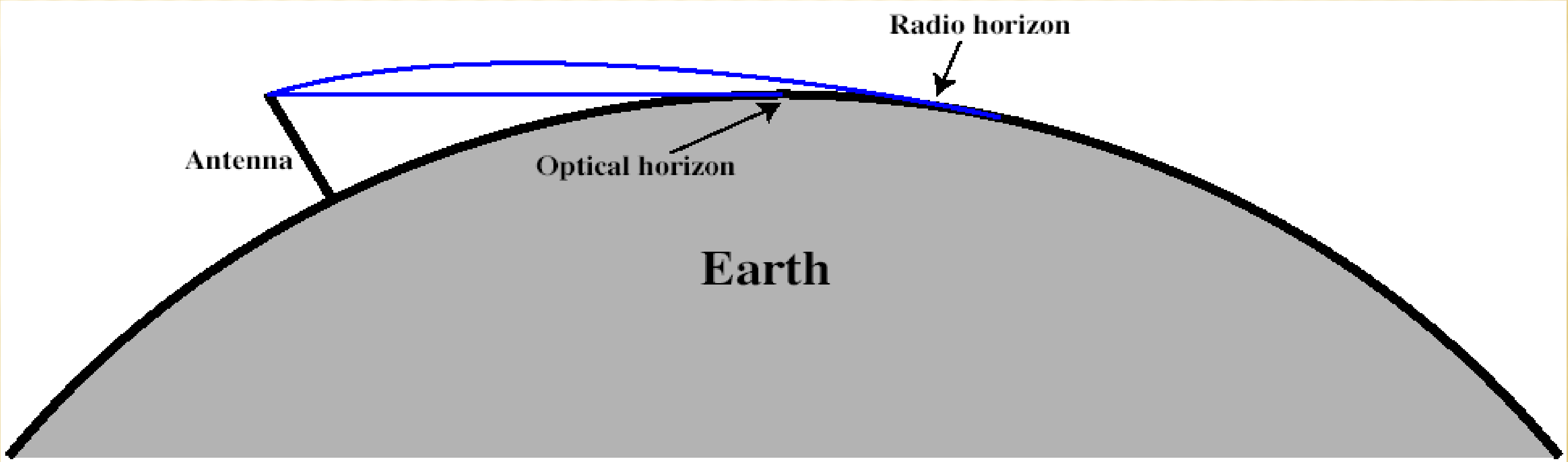
(c) Line-of-sight (LOS) propagation (above 30 MHz)

REFRACTION

- Occurs because of velocity of electromagnetic wave is function of material density. 3 x 10^8 m/s in vacuum.
- Index of refraction is given as:

$$n = \sin(\theta_1) / \sin(\theta_2)$$

- have gradual bending if medium density varies
  - density of atmosphere decreases with height
  - results in bending of radio waves towards earth
  - hence optical LOS horizon and radio LOS horizon are not the same



OPTICAL AND RADIO LOS

- The optical LOS to the horizon can be expressed as:

$$d = 3.57\sqrt{h}, \quad \text{where} \quad d: \text{ the distance between the antenna and the horizon in Kilometers}$$

$$h: \text{ the antenna height in meters}$$

- The radio LOS to the horizon can be expressed as:

$$d = 3.57\sqrt{Kh} \quad \text{where K: adjustment factor to account for the refraction,}$$

$$\text{usually K} = 4/3$$

- The max. distance between two antennas for LOS propagation:

$$d = 3.57\left(\sqrt{Kh_1} + \sqrt{Kh_2}\right) \quad \text{where } h_1 \text{ and } h_2 \text{ are the height of the two antennas}$$

EXAMPLE 4.3 The maximum distance between two antennas for LOS transmission if one antenna is 100 m high and the other is at ground level is

$$d = 3.57\sqrt{Kh} = 3.57\sqrt{133} = 41 \text{ km}$$

Now suppose that the receiving antenna is 10 m high. To achieve the same distance, how high must the transmitting antenna be? The result is

$$41 = 3.57\left(\sqrt{Kh_1} + \sqrt{13.3}\right)$$

$$\sqrt{Kh_1} = \frac{41}{3.57} - \sqrt{13.3} = 7.84$$

$$h_1 = 7.84^2/1.33 = 46.2 \text{ m}$$

This is a savings of over 50 m in the height of the transmitting antenna. This example illustrates the benefit of raising receiving antennas above ground level to reduce the necessary height of the transmitter.

LINE OF SIGHT TRANSMISSION

- Free space loss
  - loss of signal with distance
- Atmospheric Absorption
  - from water vapour and oxygen absorption
- Multipath
  - multiple interfering signals from reflections
- Refraction
  - Speed of signal increases with altitude causing radio waves to bend downwards.

FREE SPACE LOSS

The free space loss for ideal isotropic antenna is:

$$L_{dB} = 10\log_{10}\frac{P_t}{P_r} = 10\log_{10}\left(\frac{4\pi d}{\lambda}\right)^2 = -20\log_{10}\lambda + 20\log_{10}d + 21.98dB$$

$$= 10\log_{10}\left(\frac{4\pi df}{c}\right)^2 = 20\log_{10}f + 20\log_{10}d - 147.56dB$$

where

P_t, P_r : signal power at the transmitting and receiving antennas

c : speed of light $(3\times10^8\,\text{m/s})$

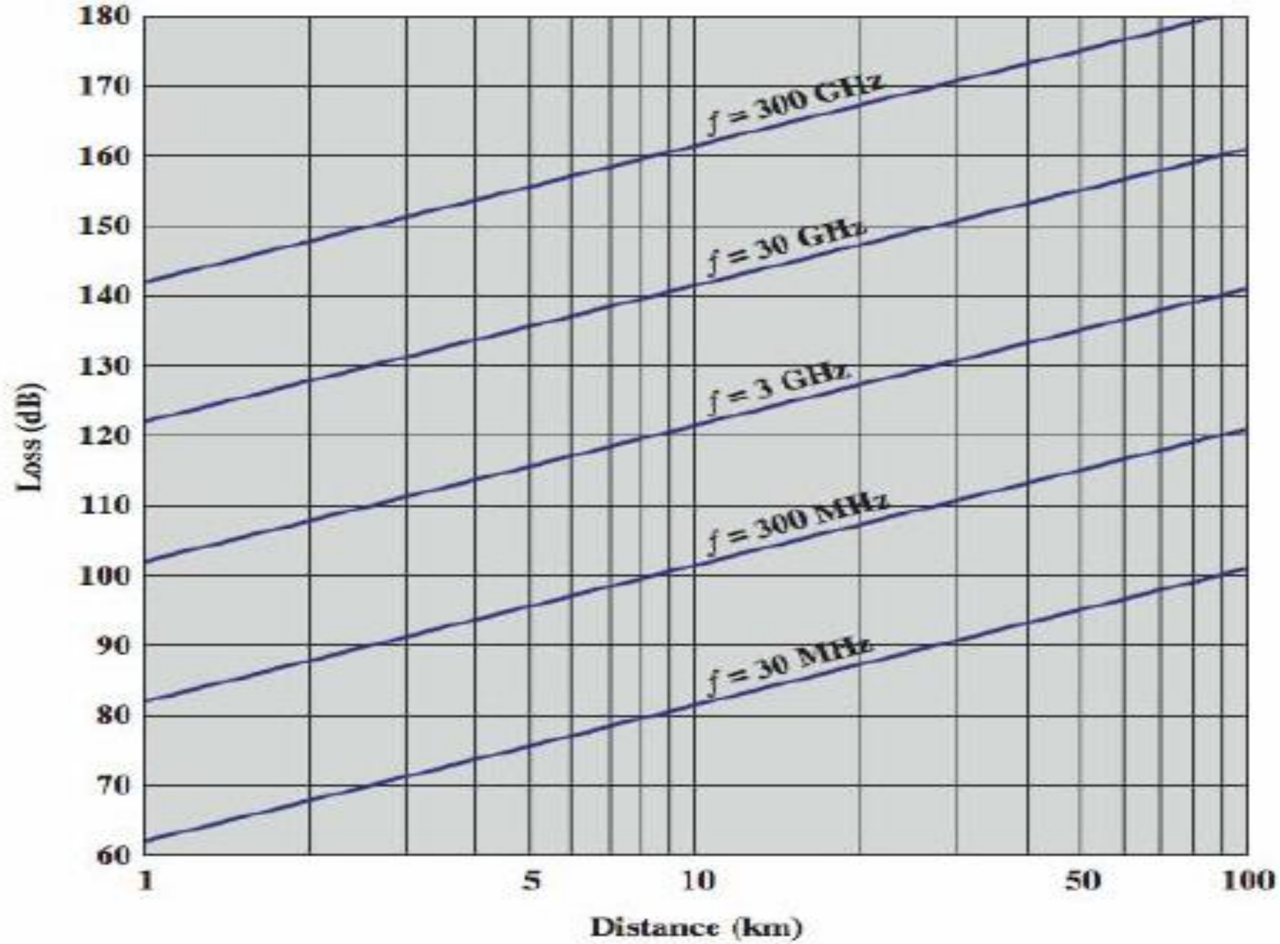
f, λ : carrier frequency and wavelength

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

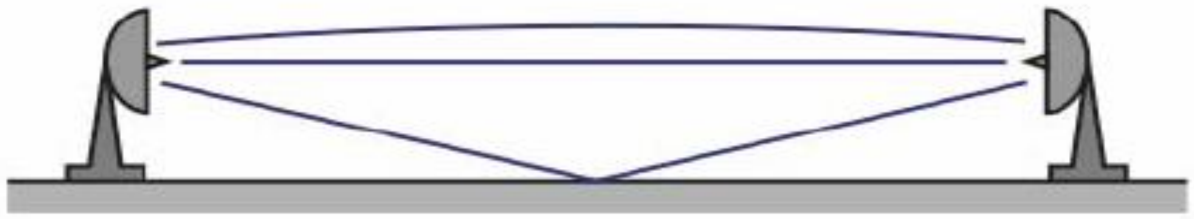
$$L_{dB} = 10\log_{10}\frac{P_t}{P_r} = 10\log_{10}\frac{(4\pi)^2 d^2}{G_t G_r \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

where G_t and G_r are the gains of the transmitting and receiving antennas

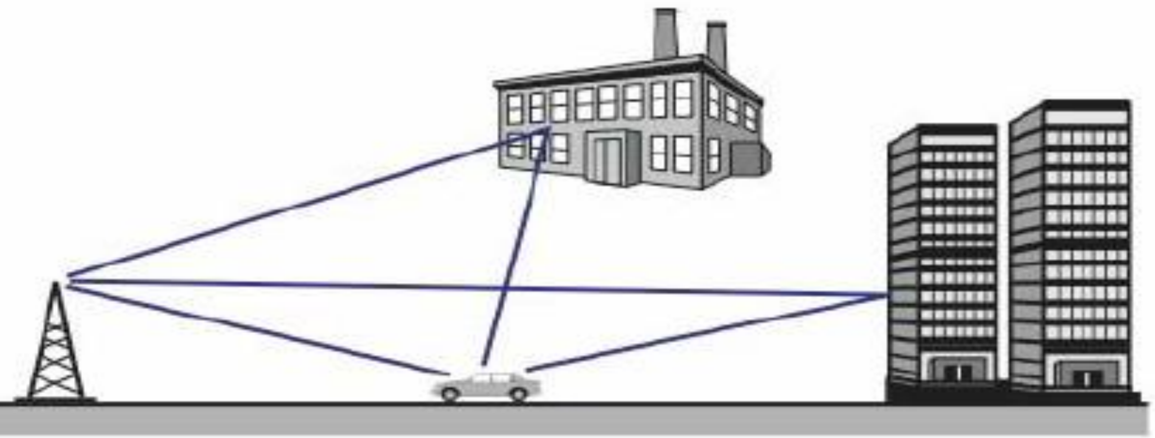
FREE SPACE LOSS



MULTIPATH INTERFERENCE



(a) Microwave line of sight



(b) Mobile radio