Transmission Media

CHAPTER 4

TYPES OF TRANSMISSION MEDIA

- Guided transmission media
- Unguided (Wireless)transmission media

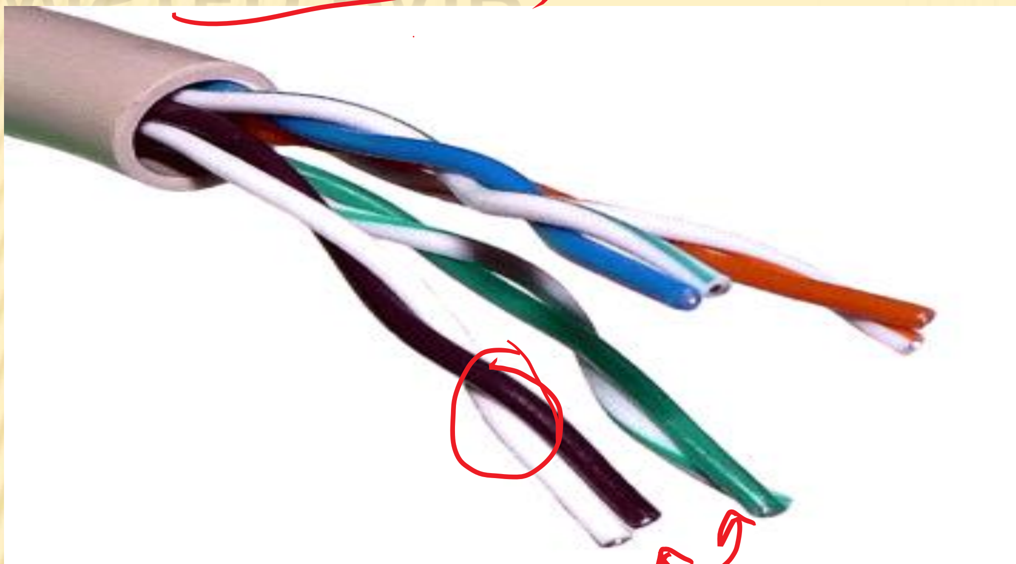
GUIDED TRANSMISSION MEDIA

- Twisted Pair
- Coaxial cable
- Optical Fiber

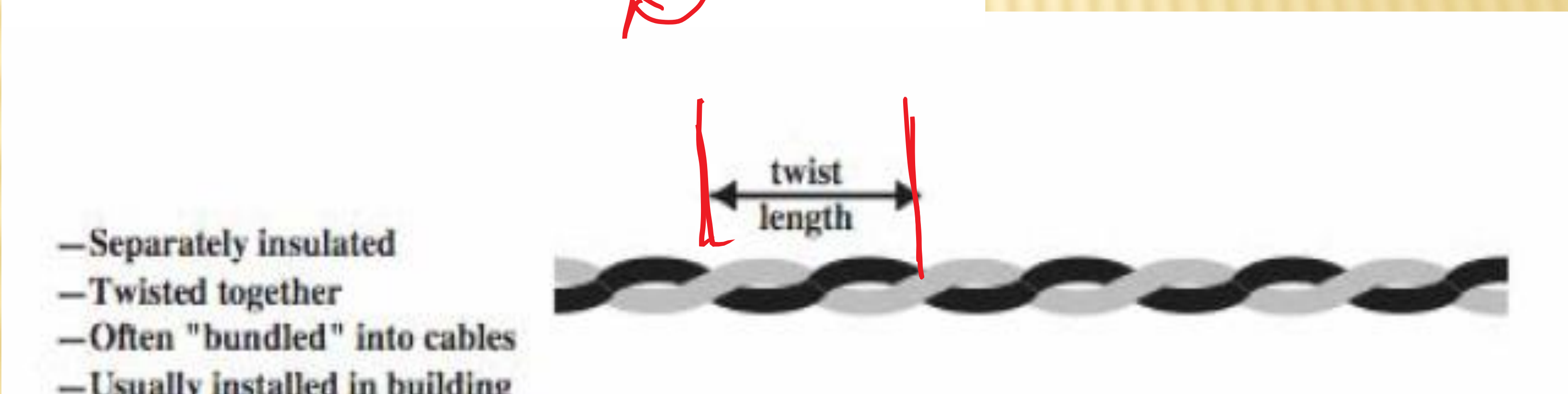
copper

glass & plastic

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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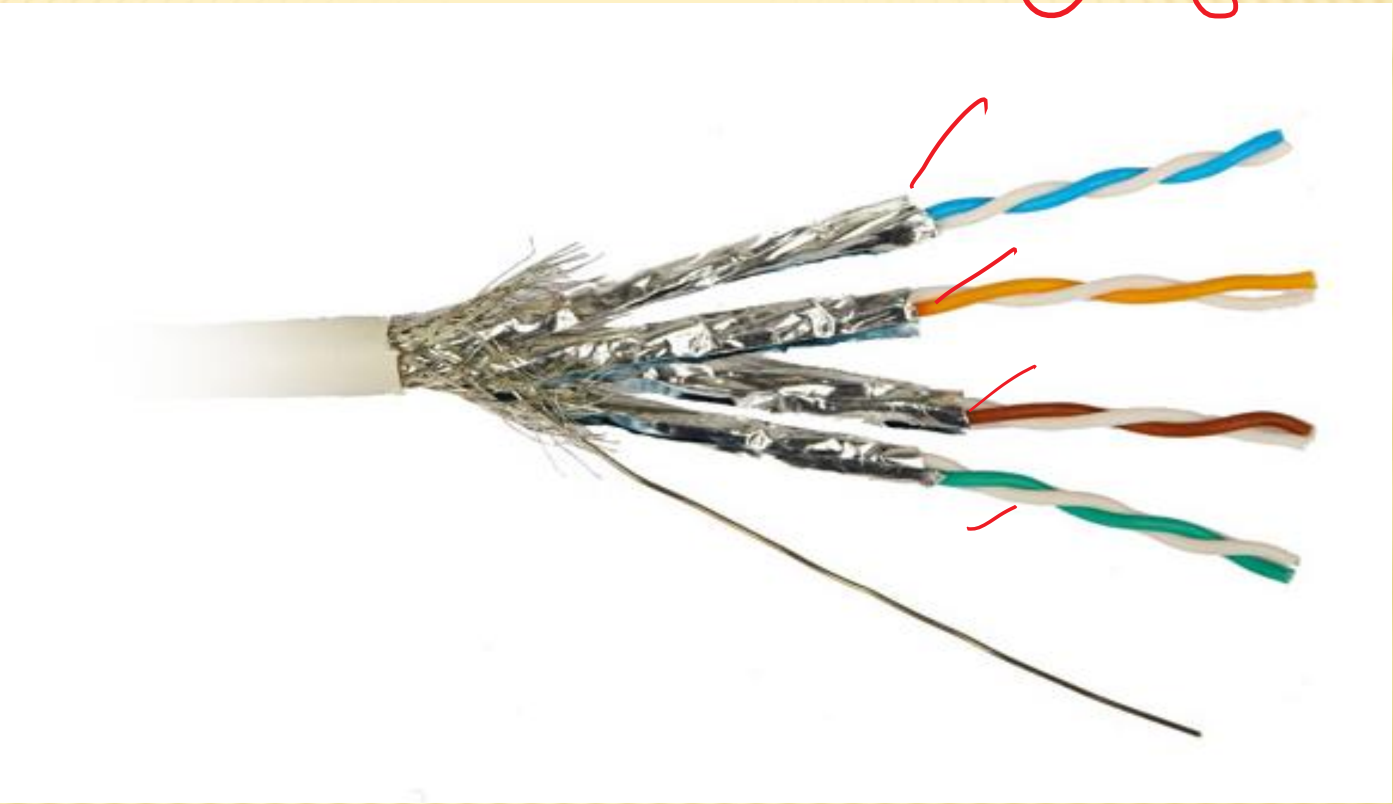
UTP :-

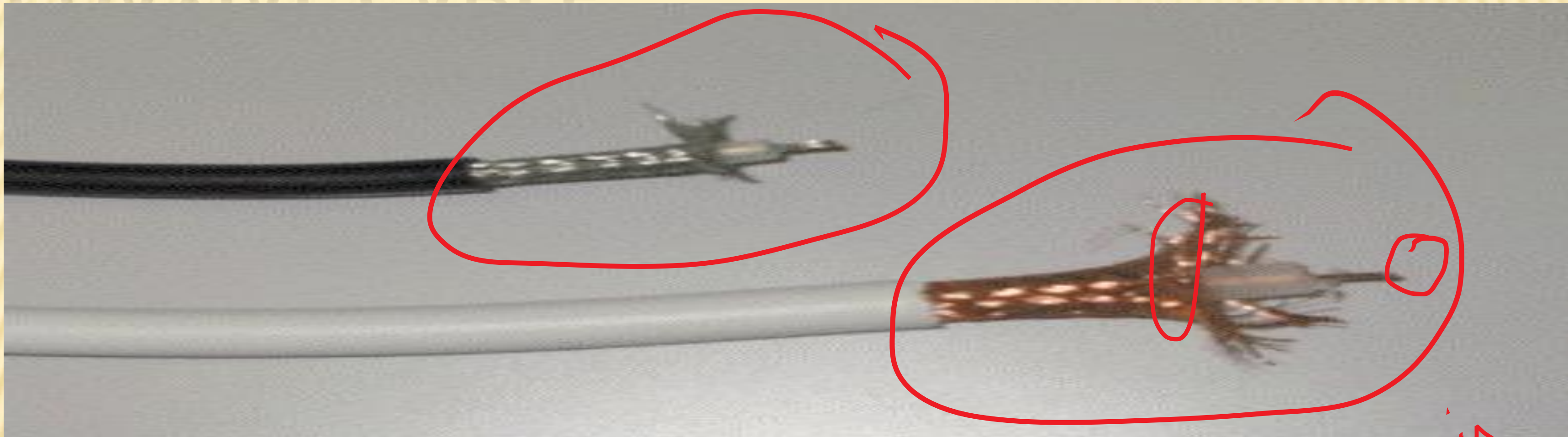
Category 3 → 16MHz

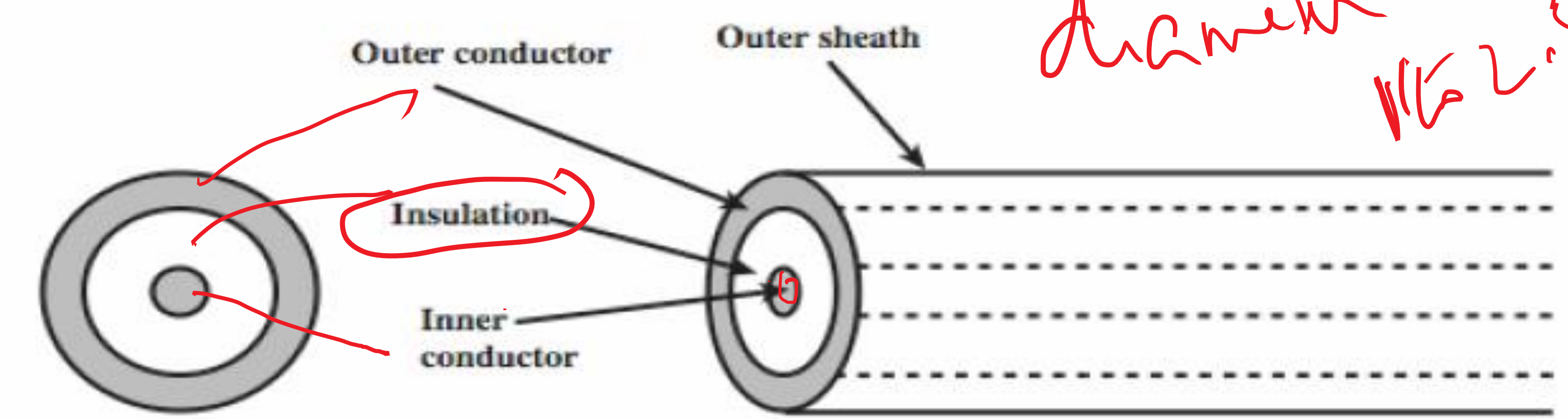
Category 4 → 20MHz

Category 5 → 100MHz



COAXIAL CABLE





diameter is 2.5 cm

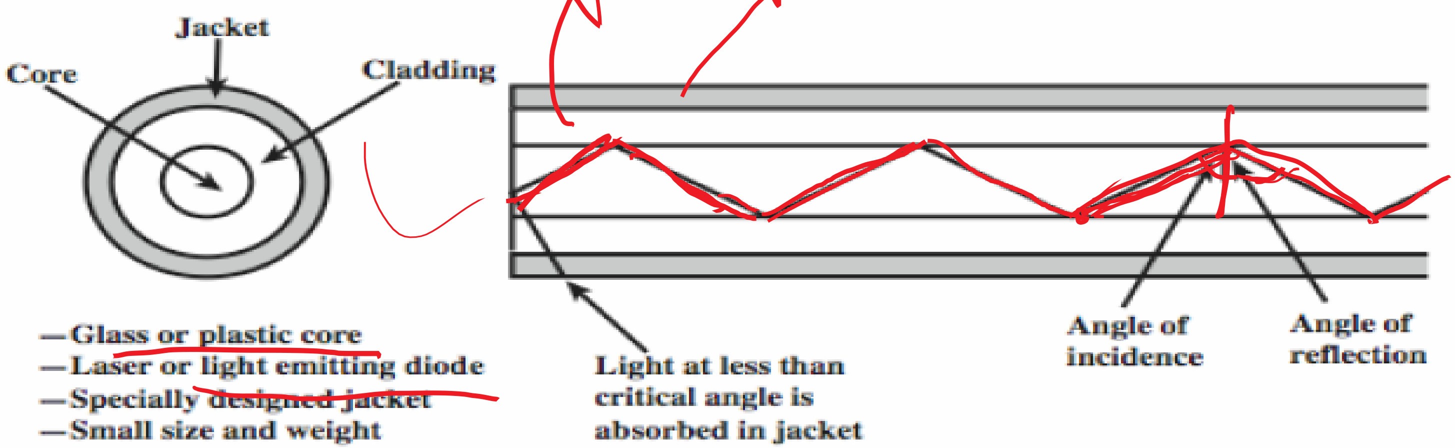
—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding

COAXIAL CABLE - TRANSMISSION CHARACTERISTICS

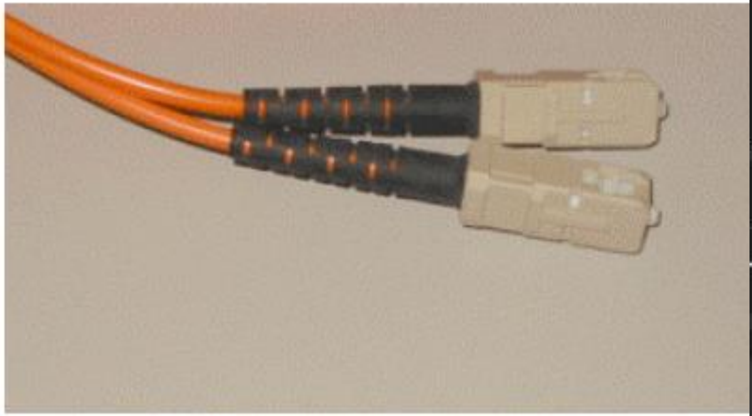
- superior frequency characteristics to TP
- performance limited by attenuation & noise
  - analog signals
    - amplifiers every few km
    - closer if higher frequency
    - up to 500MHz
  - digital signals
    - repeater every 1 to 9km
    - closer for higher data rates

1) Television
2) long distance telephone s/m
3) Computer s/m
4) Local Area network

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

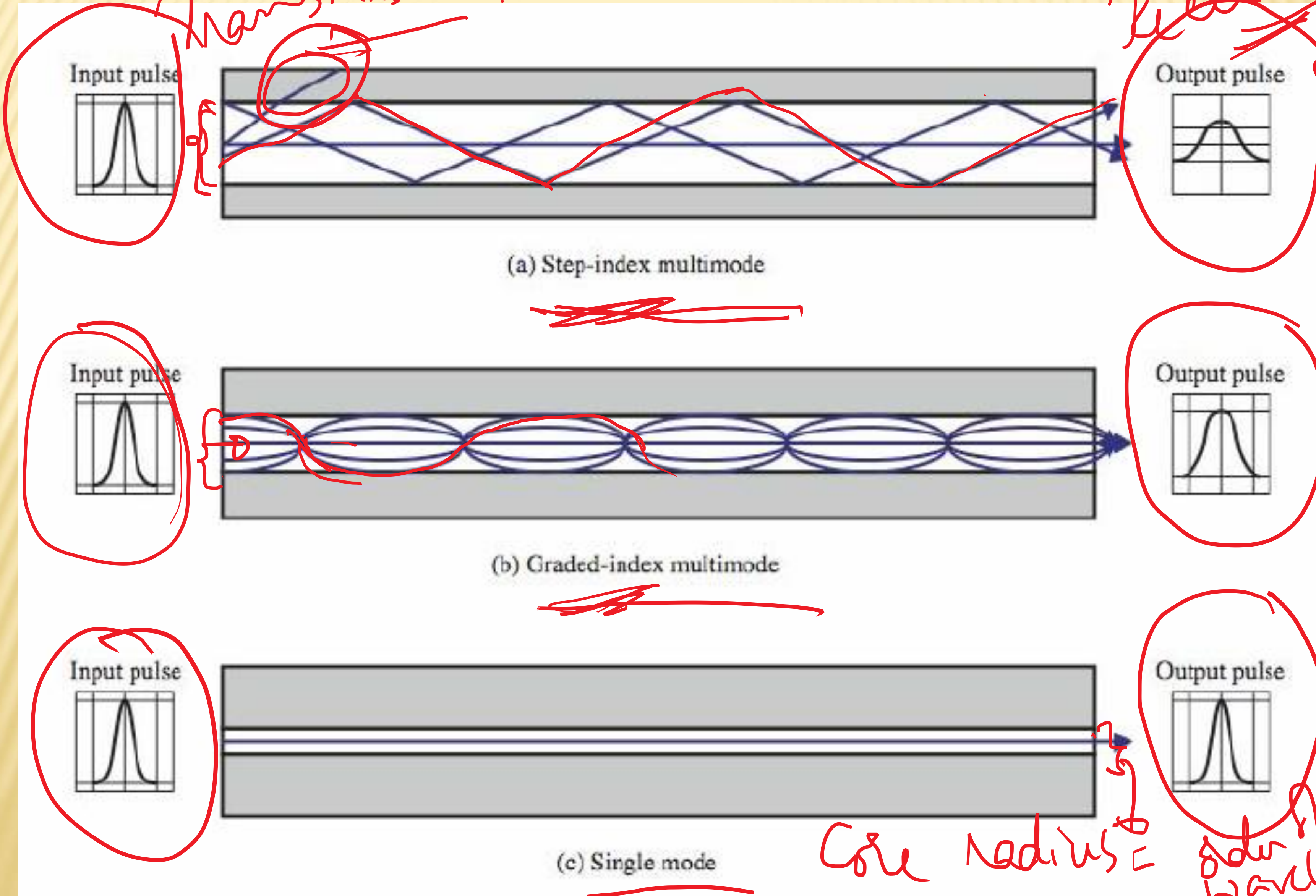
OPTICAL FIBER - TRANSMISSION CHARACTERISTICS

- 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

Transmitter

Receiver

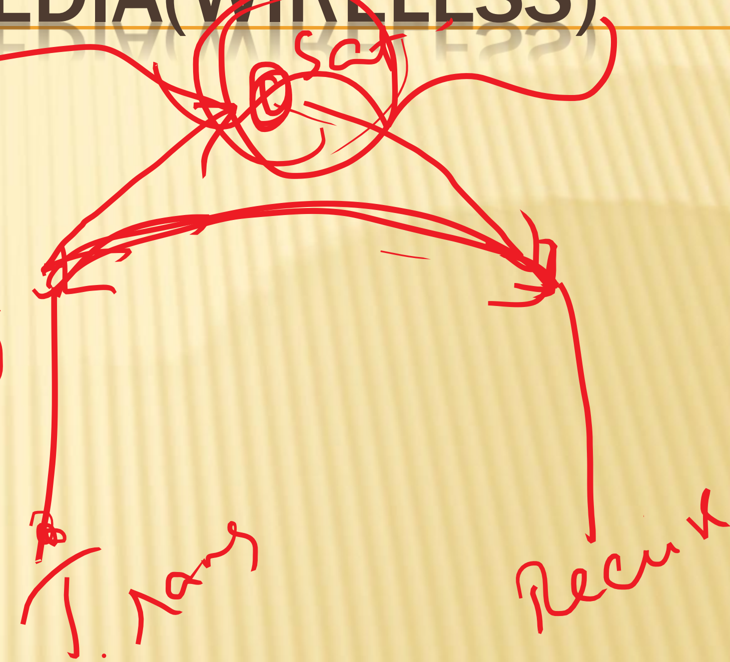


Core radius = order of wavelength

UNGUIDED TRANSMISSION MEDIA(WIRELESS)

Wireless Transmission Frequencies

- 2GHz to 40GHz: microwave
  - highly directional
  - point to point
  - satellite



- 30MHz to 1GHz :broadcast radio
  - omnidirectional

- 3×10^{11} to 2×10^{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

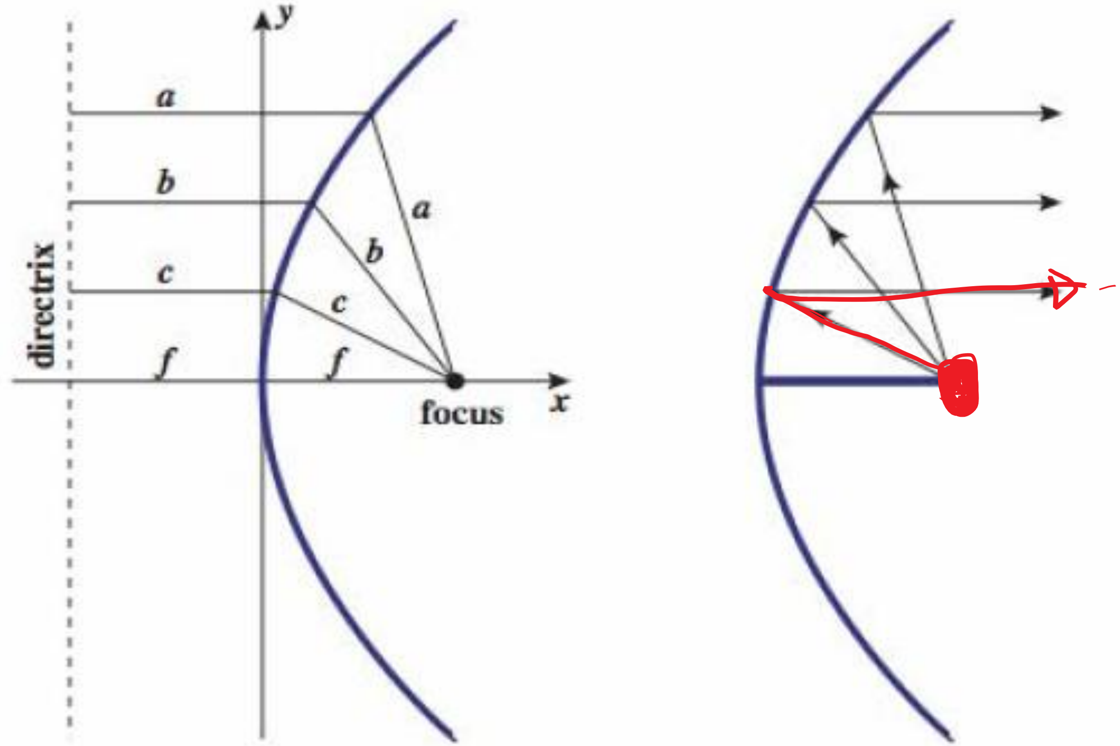
RADIATION PATTERN

- power radiated in all directions
- not same performance in all directions
- an isotropic antenna is a (theoretical) point in space

  Ideal antenna

  - 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:

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

3×10^8 m/s

$$G = antenna \ \ gain$$

$$A_e = effective \ \ area$$

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

$c \rightarrow$ speed of light

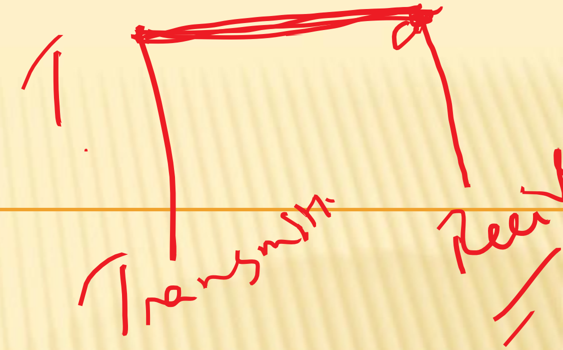
- Effective area of the isotropic antenna is $\dfrac{\lambda^2}{4\pi}$

And has a gain of 1=0dB

- Effective area of a parabolic antenna with a face area of A is $\boxed{A_e = 0.56A}$

$$\boxed{G = \frac{7A}{\lambda^2}}$$

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:

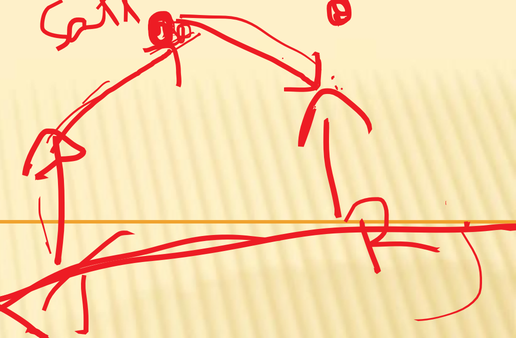
$$L_{dB} = 10\log_{10}\left(\frac{4\pi d}{\lambda}\right)^2 = 10\log_{10}\left(\frac{4\pi df}{c}\right)^2 \quad dB$$

d = distance

λ = wavelength

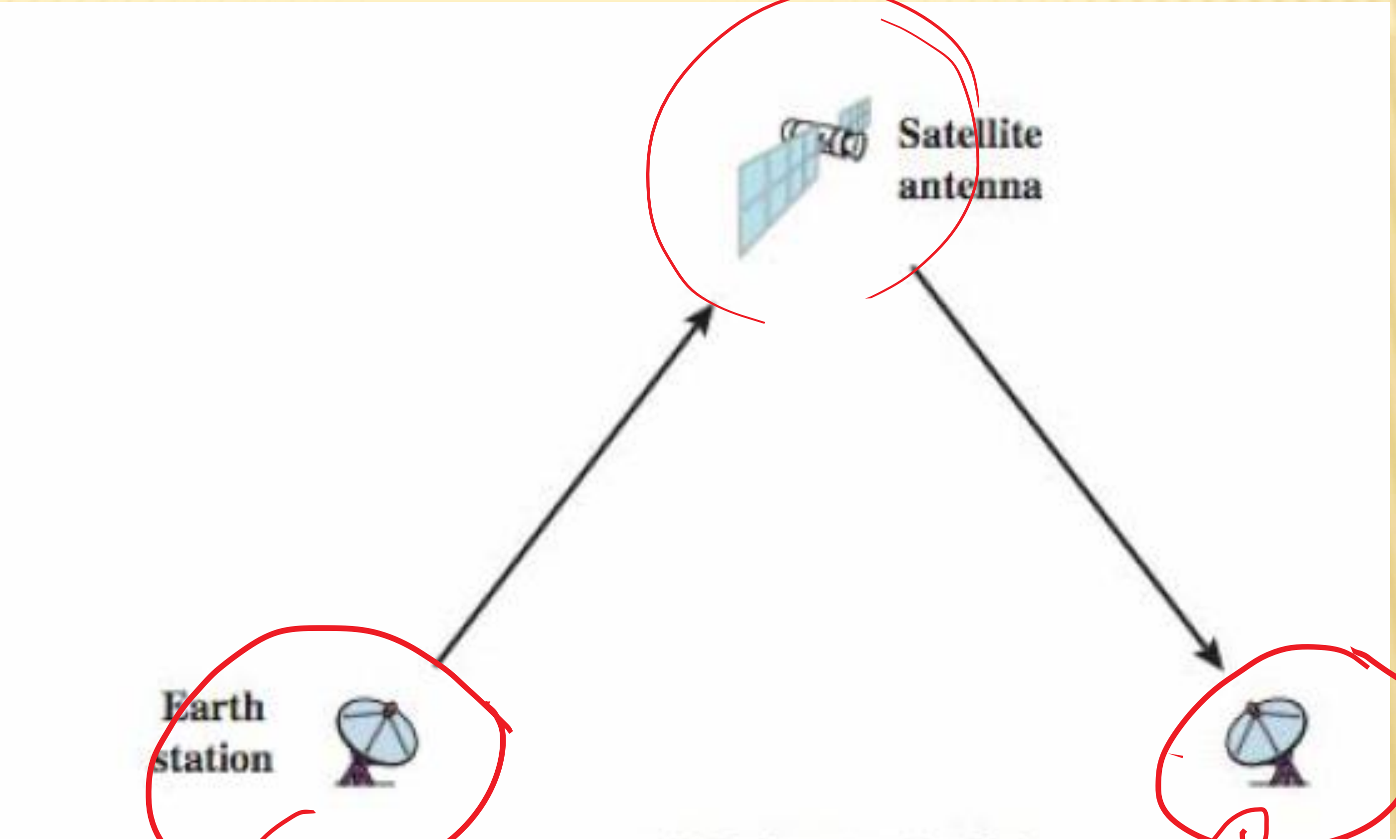
f = frequency

SATELLITE MICROWAVE



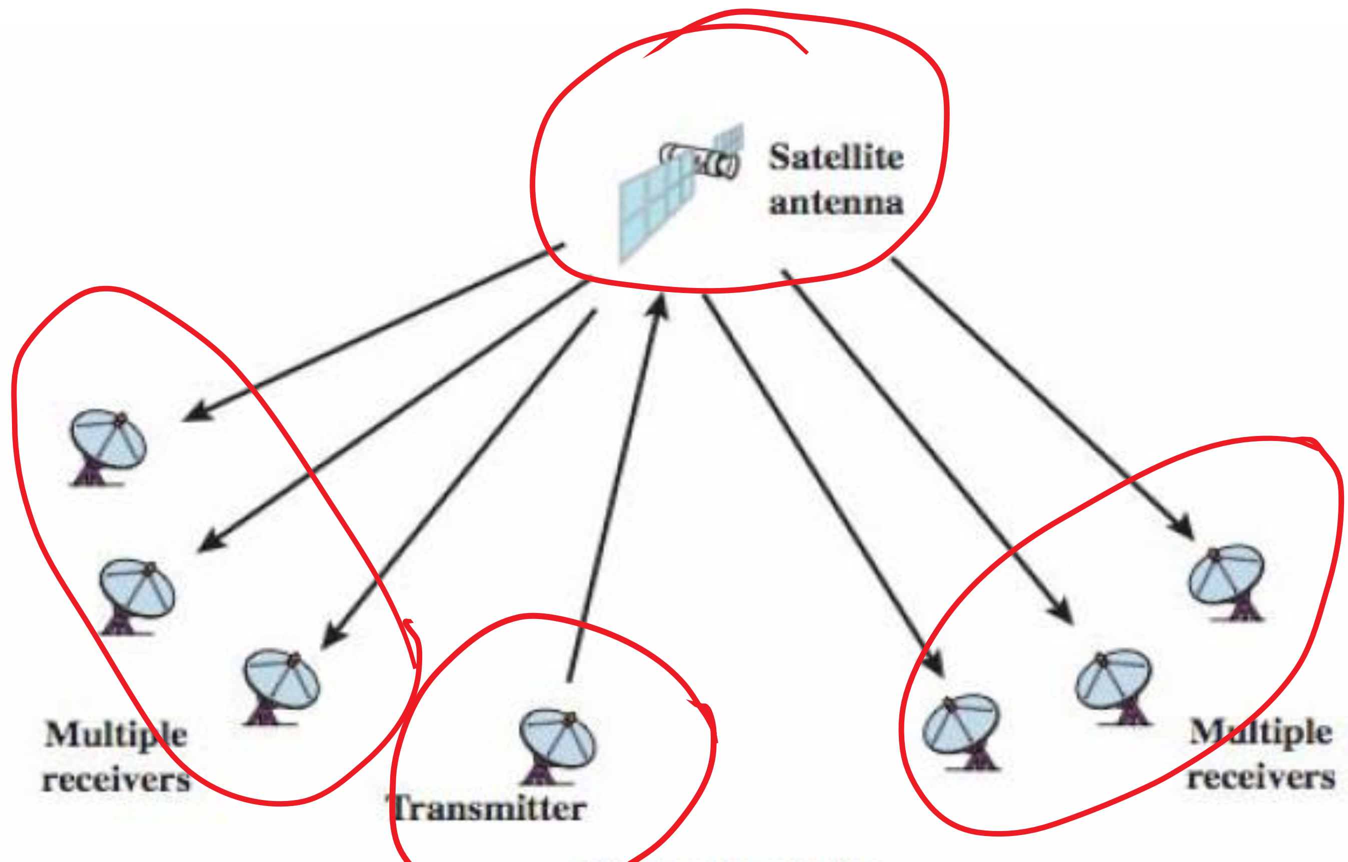
- To link two or more earth station.
- Satellite receives on one frequency(uplink), amplifies or repeats signal and transmits on another frequency(downlink).
  - eg. uplink 5.925-6.425 GHz & downlink 3.7-4.2 GHz
- typically requires geo-stationary orbit
  - height of 35,784km
  - spaced at least 3-4°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

SATELLITE POINT TO POINT LINK



(a) 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

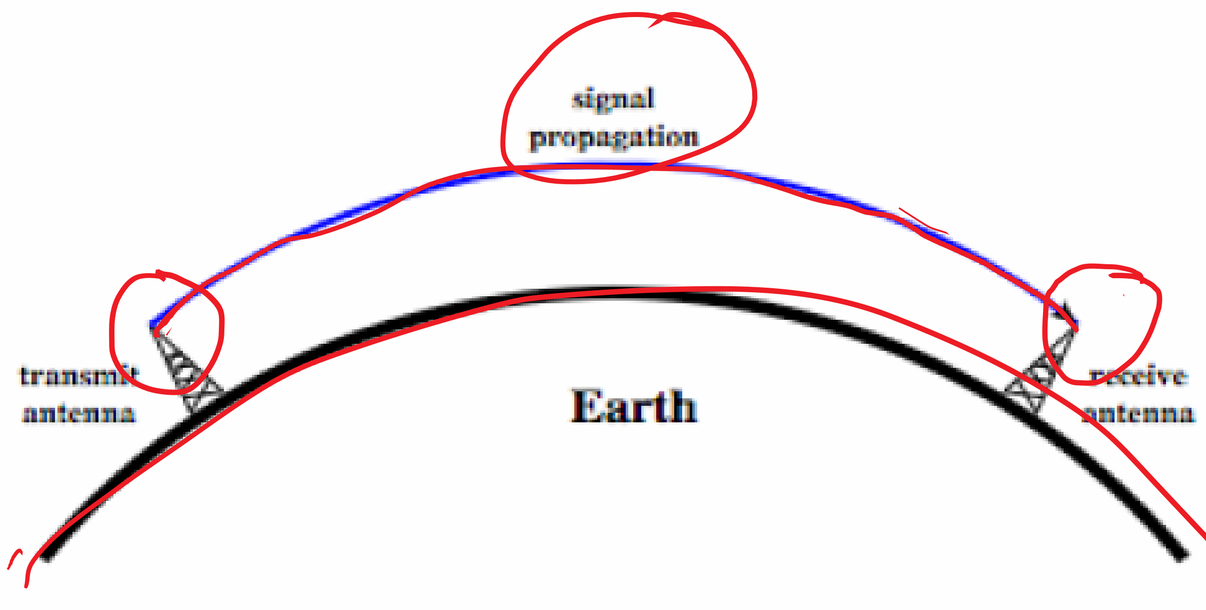
- need line of sight (or reflection)
- are blocked by walls
- no licenses required
- typical use
  - TV remote control

WIRELESS PROPAGATION

- Ground Wave
- Sky Wave
- Line of Sight

WIRELESS PROPAGATION GROUND WAVE

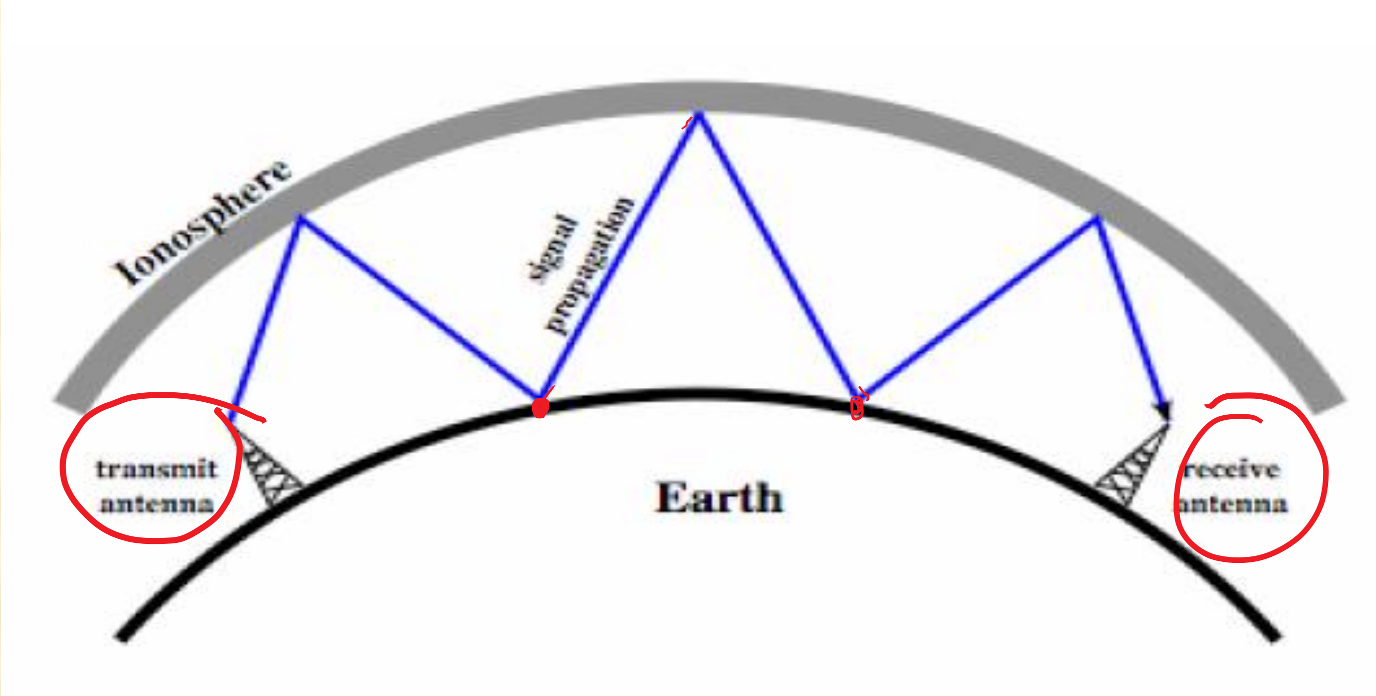
- Ground wave is found in frequencies up to 2MHz
- The best-known example of ground wave communication is AM radio



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

WIRELESS PROPAGATION SKY WAVE

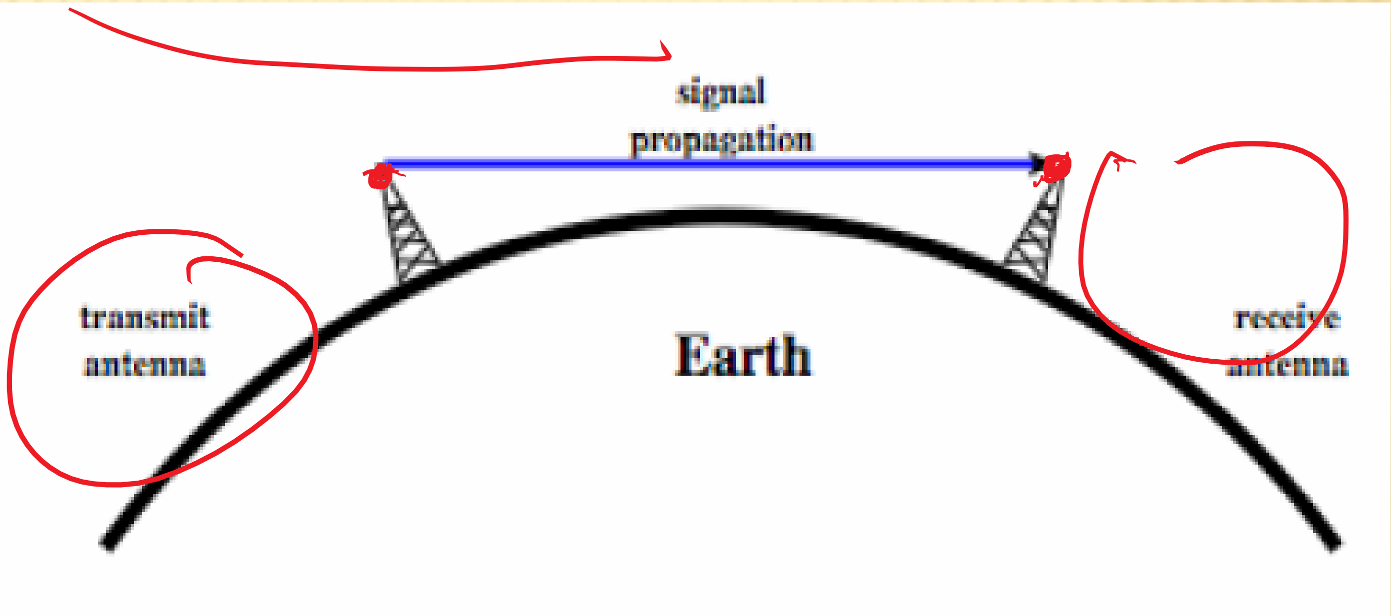
- Sky wave propagation is found in frequencies from 2MHz to 30MHz
- A sky wave signal bounces back and forth between the ionosphere and the earth surface



(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



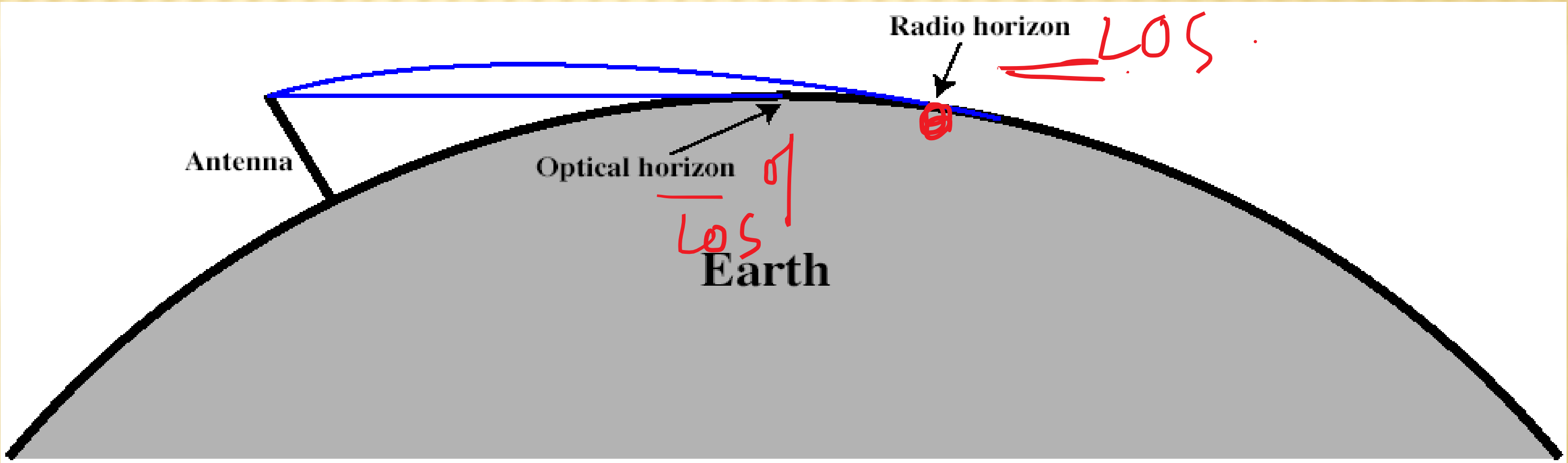
(c) Line-of-sight (LOS) propagation (above 30 MHz)

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:

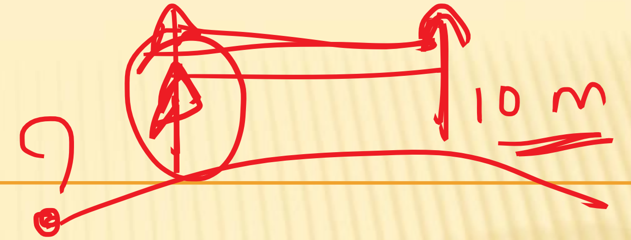
$$d = 3.57\sqrt{h}, \quad \text{where} \quad d: \text{ the distance between the antenna and the horizon in Kilometers}$$
$$h: \text{ the antenna height in meters}$$

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

$$d = 3.57\sqrt{Kh} \quad \text{where } K: \text{ adjustment factor to account for the refraction, usually } K = 4/3$$

- 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

Impairments.

- 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 $(3\times10^8 \text{ m/s})$

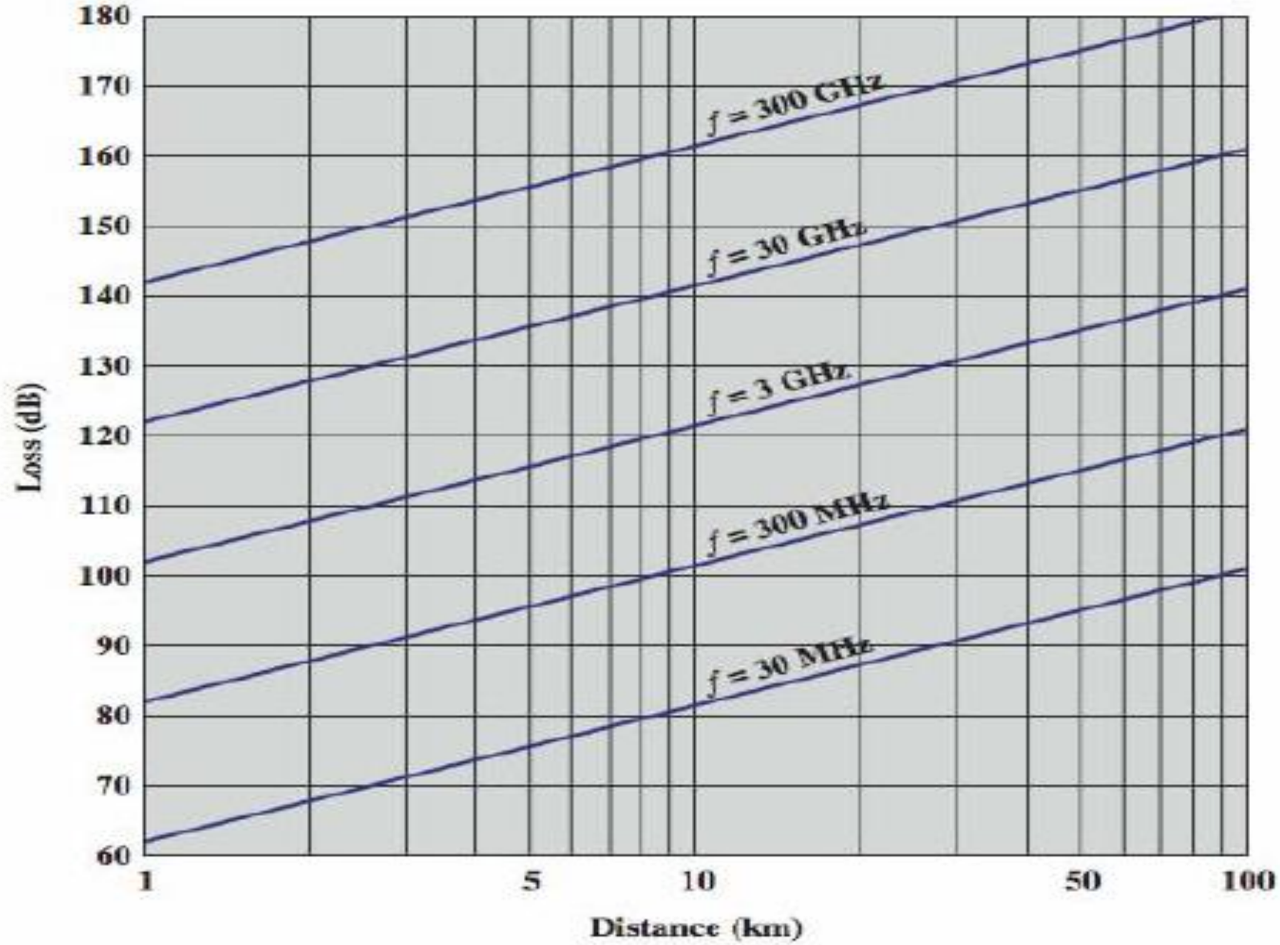
f, λ : carrier frequency and wavelength

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

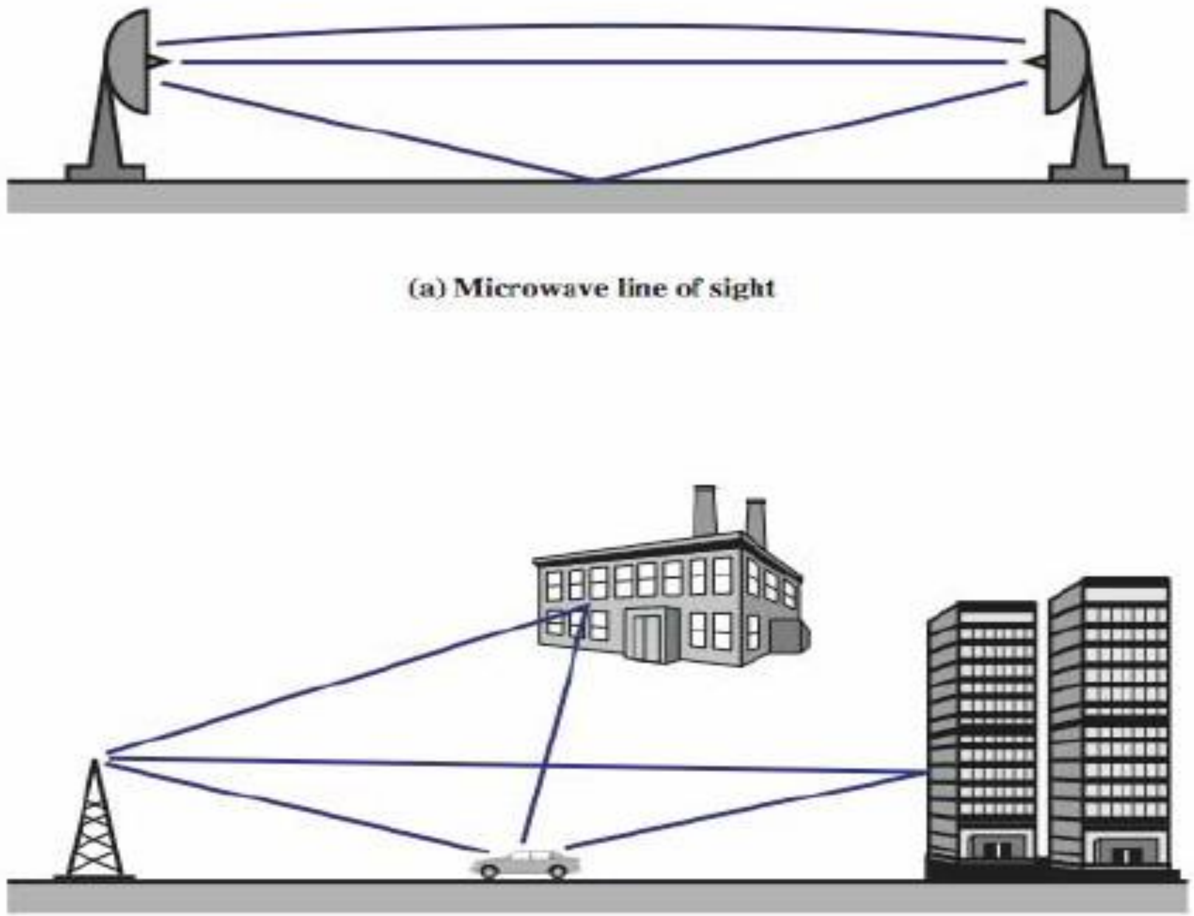
$$L_{dB} = 10\log_{10}\frac{P_t}{P_r} = 10\log_{10}\frac{(4\pi)^2 d^2}{G_t G_r \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

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