# Data Communication

## TRANSMISSION MEDIA

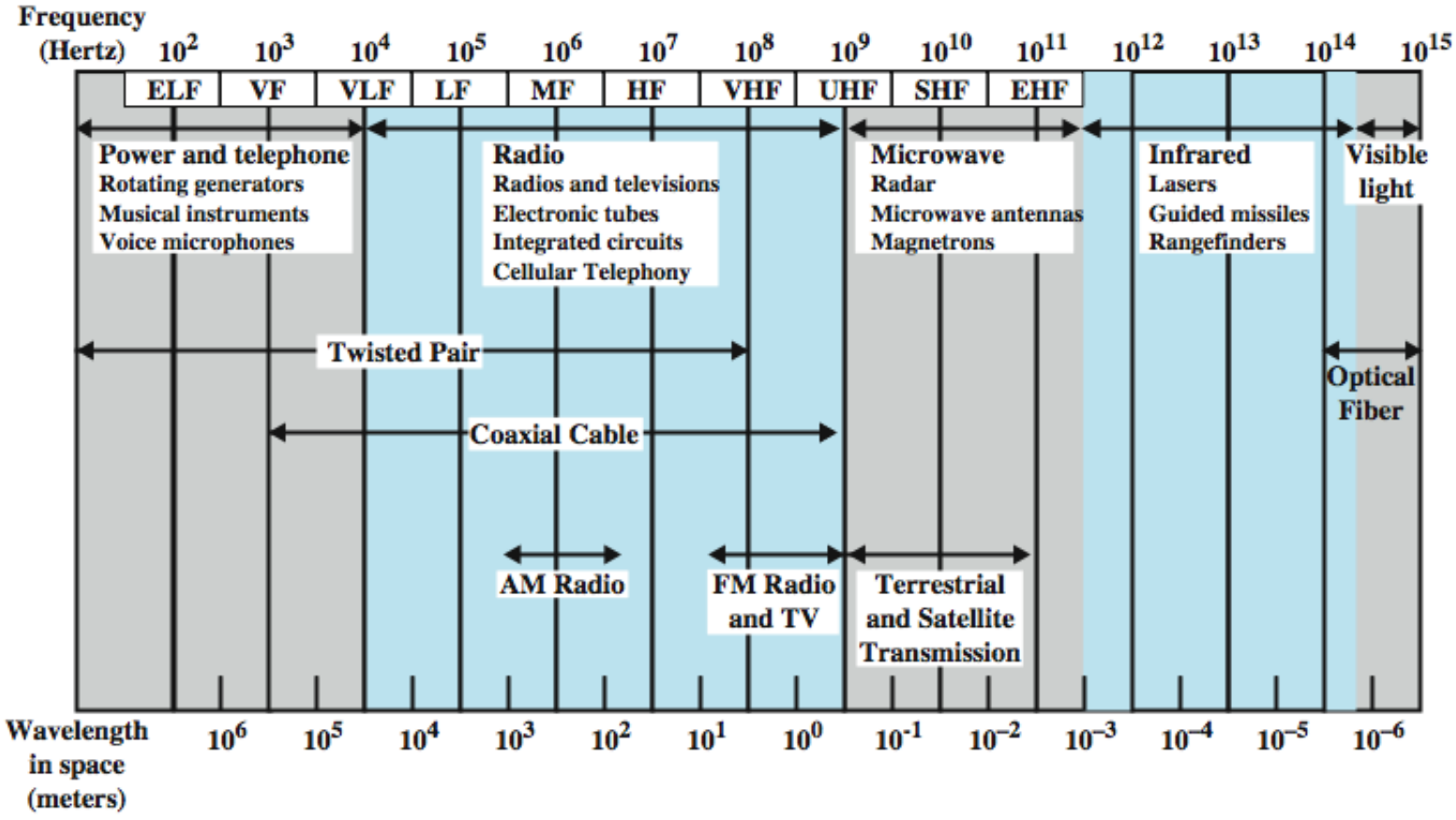
# Overview

- guided - wire / optical fibre
- unguided - wireless
- characteristics and quality determined by medium and signal
  - in unguided media - bandwidth produced by the antenna is more important
  - in guided media - medium is more important
- key concerns are data rate and distance

# Design Factors

- bandwidth
  - higher bandwidth gives higher data rate
- transmission impairments
  - eg. attenuation
- interference
- number of receivers in guided media
  - more receivers introduces more attenuation

# Electromagnetic Spectrum




ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

# 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 | 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 |

# Twisted Pair

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


(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)
- limited data rate (100MHz)
- susceptible to interference and noise

# Unshielded vs 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)
- in a variety of categories - see EIA-568

# UTP Categories

| | Category 3 Class C | Category 5 Class D | Category 5E | Category 6 Class E | Category 7 Class F |
|---|---|---|---|---|---|
| **Bandwidth** | 16 MHz | 100 MHz | 100 MHz | 200 MHz | 600 MHz |
| **Cable Type** | UTP | UTP/FTP | UTP/FTP | UTP/FTP | SSTP |
| **Link Cost (Cat 5 =1)** | 0.7 | 1 | 1.2 | 1.5 | 2.2 |

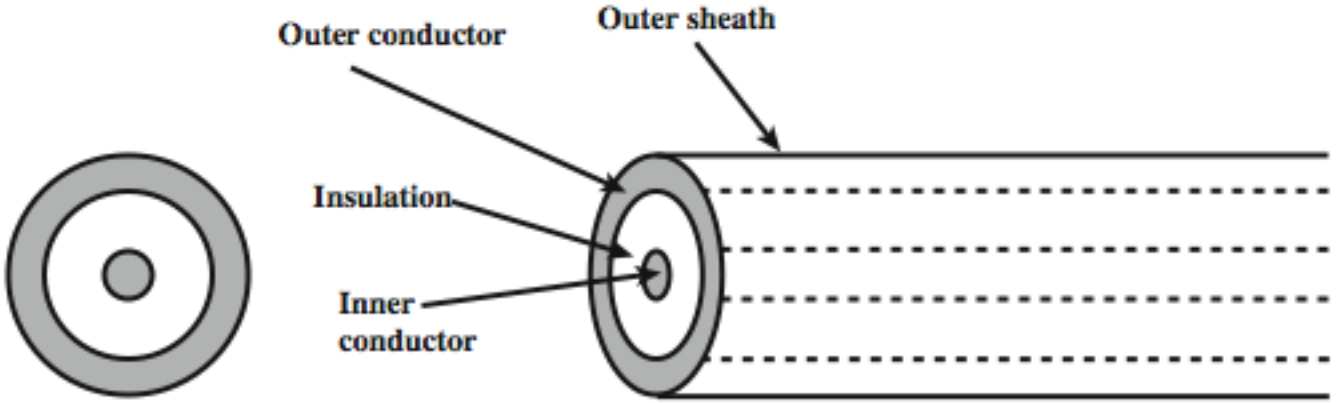
# Comparison of Shielded and Unshielded Twisted Pair

| | Attenuation (dB per 100 m) | | | Near-end Crosstalk (dB) | | |
|---|---|---|---|---|---|---|
| **Frequency (MHz)** | **Category 3 UTP** | **Category 5 UTP** | **150-ohm STP** | **Category 3 UTP** | **Category 5 UTP** | **150-ohm STP** |
| 1 | 2.6 | 2.0 | 1.1 | 41 | 62 | 58 |
| 4 | 5.6 | 4.1 | 2.2 | 32 | 53 | 58 |
| 16 | 13.1 | 8.2 | 4.4 | 23 | 44 | 50.4 |
| 25 | — | 10.4 | 6.2 | — | 41 | 47.5 |
| 100 | — | 22.0 | 12.3 | — | 32 | 38.5 |
| 300 | — | — | 21.4 | — | — | 31.3 |

# Near End Crosstalk

- coupling of signal from one pair to another
- occurs when transmit signal entering the link couples back to receiving pair
- ie. near transmitted signal is picked up by near receiving pair

# Coaxial Cable



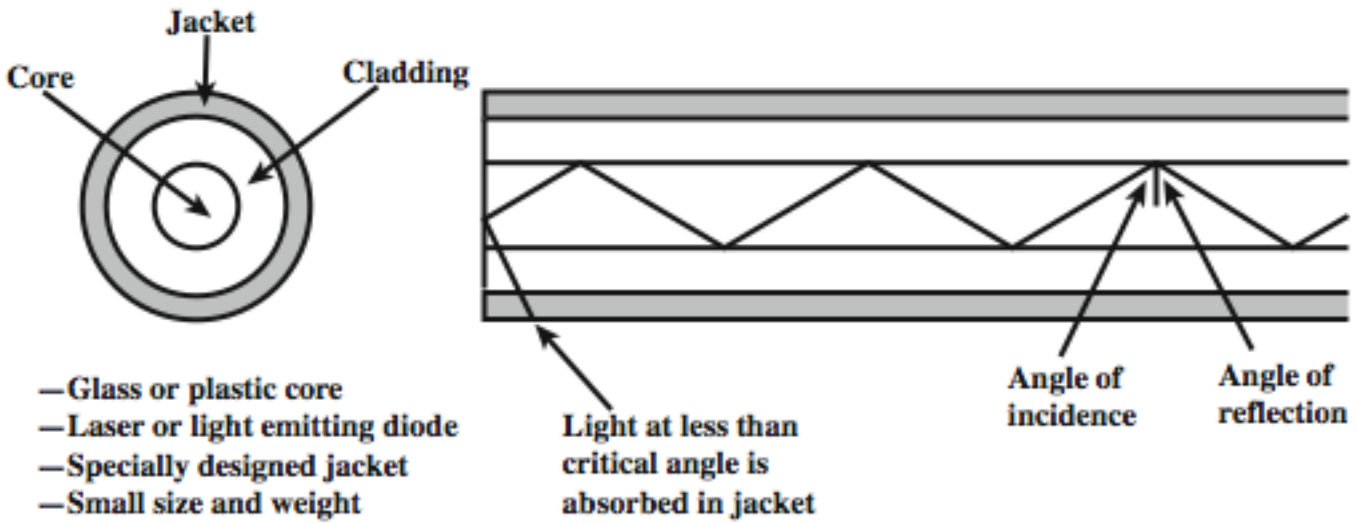

—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding

(b) 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 1km
  - closer for higher data rates

# Optical Fiber




(c) Optical fiber

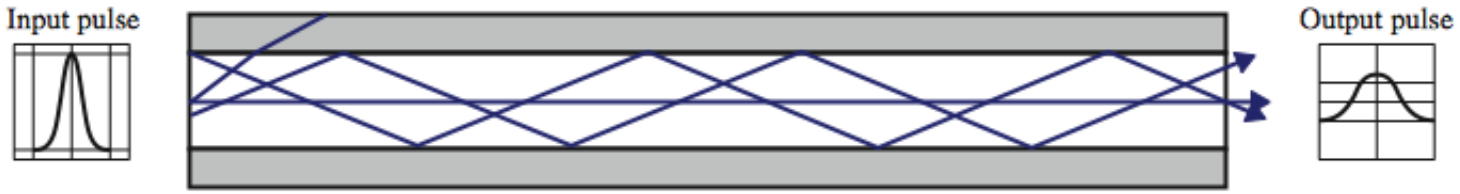
# Optical Fiber - Benefits

- greater capacity
  - data rates of hundreds of Gbps
- smaller size & weight
- lower attenuation
- electromagnetic isolation
- greater repeater spacing
  - 10s of km at least

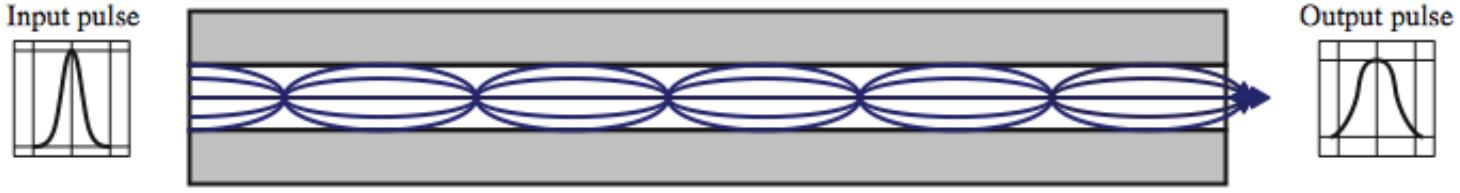
# Optical Fiber - Transmission Characteristics

- 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
- relation of wavelength, type & data rate

# Optical Fiber Transmission Modes




(a) Step-index multimode




(b) Graded-index multimode


(c) Single mode

# Wireless Transmission Frequencies

- 2GHz to 40GHz
  - microwave
  - highly directional
  - point to point
  - satellite
- 30MHz to 1GHz
  - omnidirectional
  - broadcast radio
- $3 \times 10^{11}$ to $2 \times 10^{14}$
  - infrared
  - local

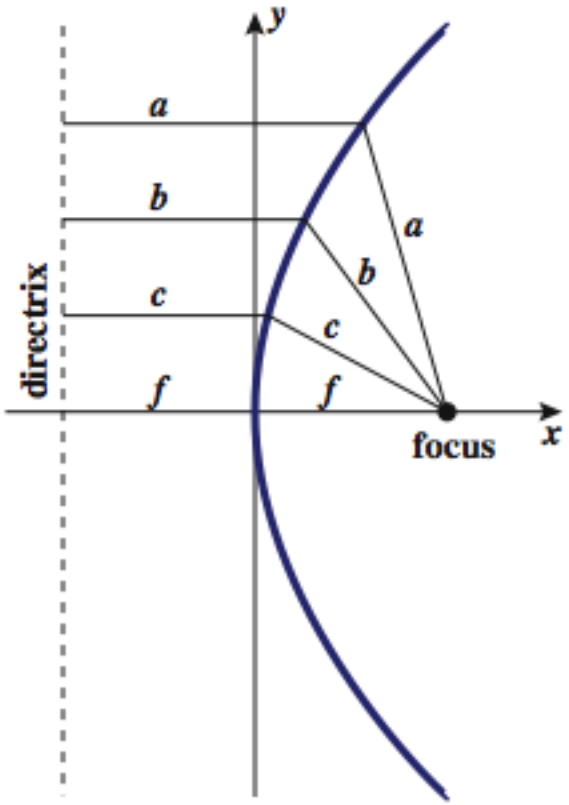
# Antennas

- electrical conductor used to radiate or collect electromagnetic energy
- transmission antenna
  - radio frequency energy from transmitter
  - converted to electromagnetic energy byy antenna
  - radiated into surrounding environment
- reception antenna
  - electromagnetic energy impinging on antenna
  - converted to radio frequency electrical energy
  - fed to receiver
- same antenna is often used for both purposes

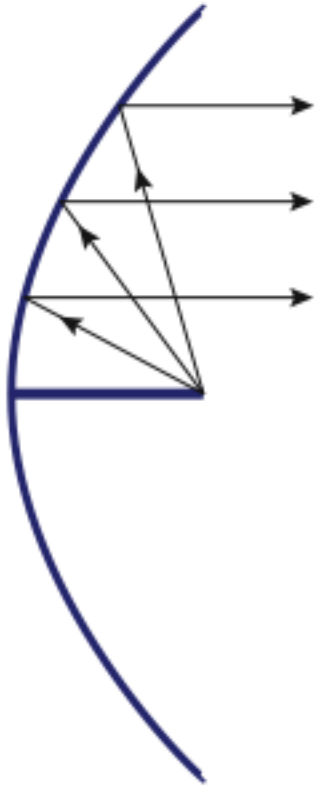
# Radiation Pattern

- power radiated in all directions
- not same performance in all directions
  - as seen in a radiation pattern diagram
- 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

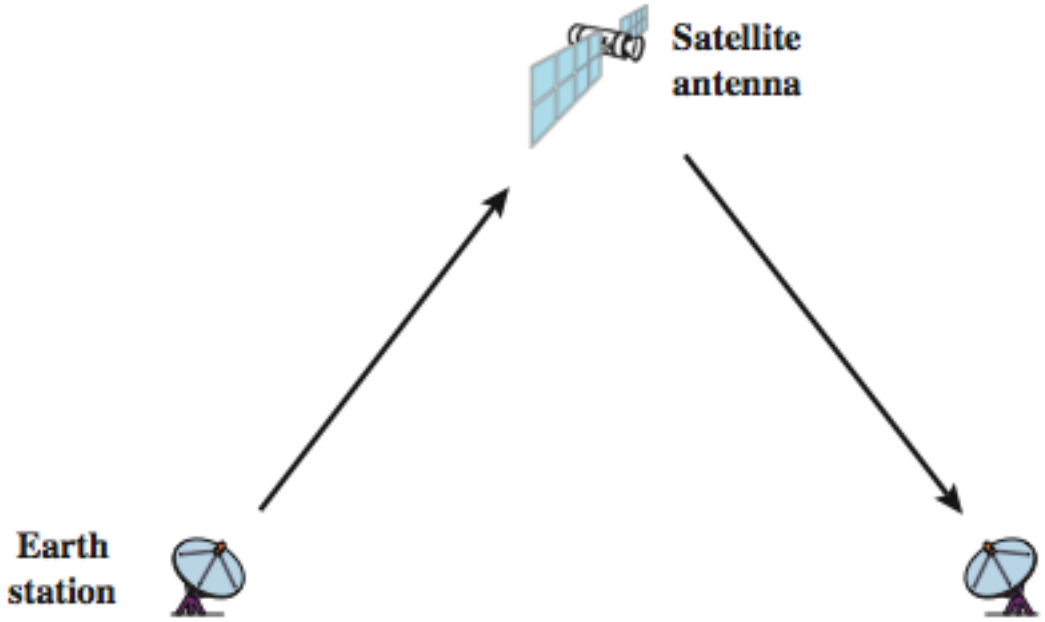
# Terrestrial Microwave

- used for long haul telecommunications
- and short point-to-point links
- requires fewer repeaters but line of sight
- use a parabolic dish to focus a narrow beam onto a receiver antenna
- 1-40GHz frequencies
- higher frequencies give higher data rates
- main source of loss is attenuation
  - distance, rainfall
- also interference

# Satellite Microwave

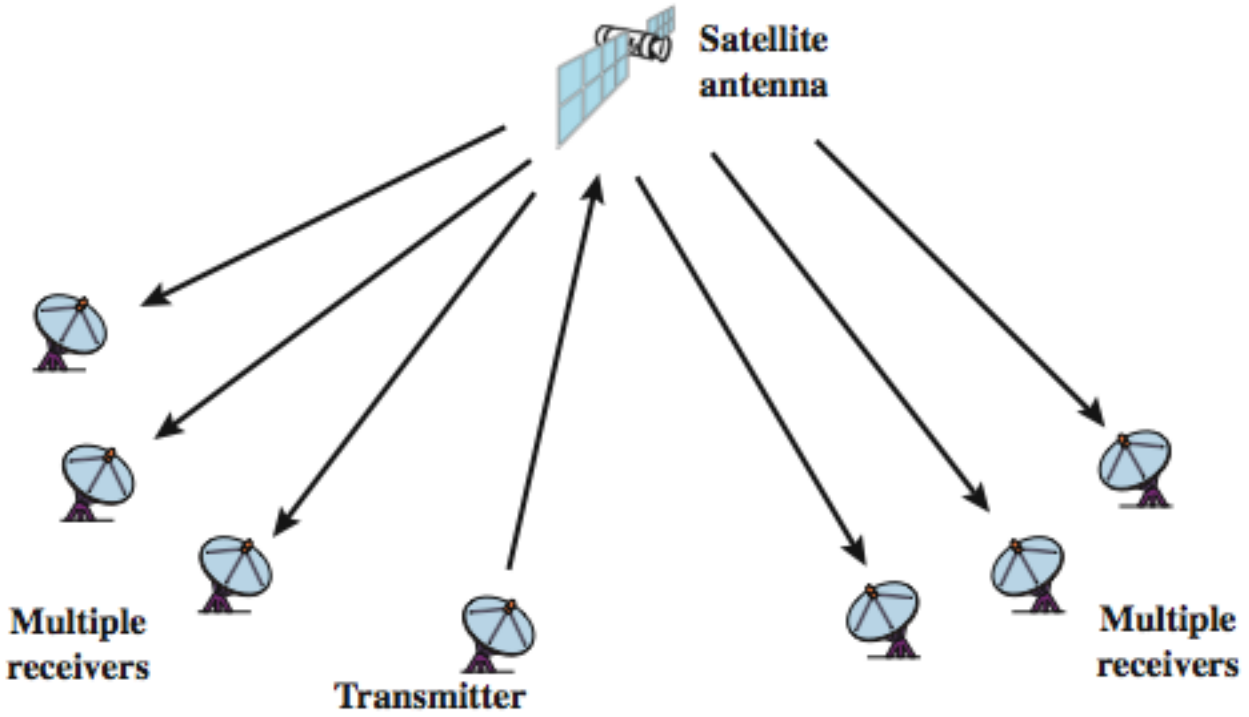
- satellite is relay station
- receives on one frequency, amplifies or repeats signal and transmits on another frequency
  - eg. uplink 5.925-6.425 GHz & downlink 3.7-4.2 GHz
- typically requires geo-stationary orbit
  - height of 35,784km
  - spaced at least 3-4° apart
- typical uses
  - television
  - long distance telephone
  - private business networks
  - global positioning

# Satellite Point to Point Link




(a) Point-to-point link

# Satellite Broadcast Link




(b) Broadcast link

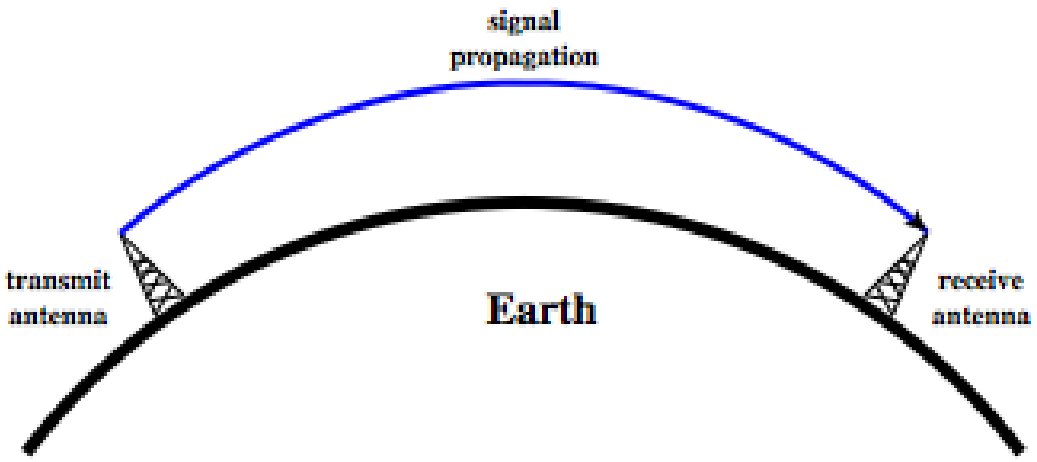
# Broadcast Radio

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

# Infrared

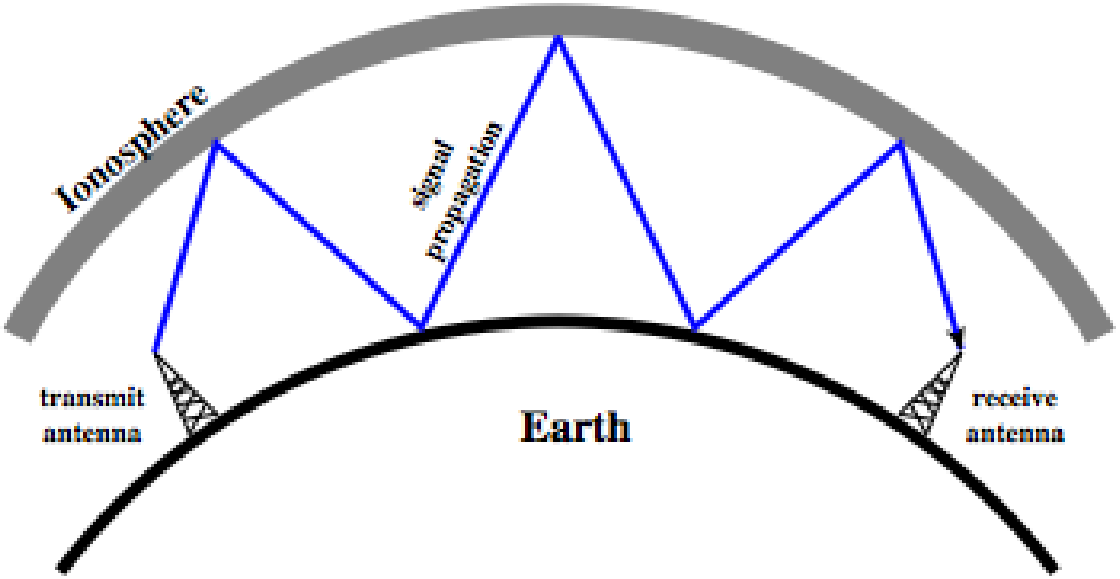
- end line of sight (or reflection)
- are blocked by walls
- no licenses required
- typical uses
  - TV remote control
  - IRD port

# Wireless Propagation
# Ground Wave



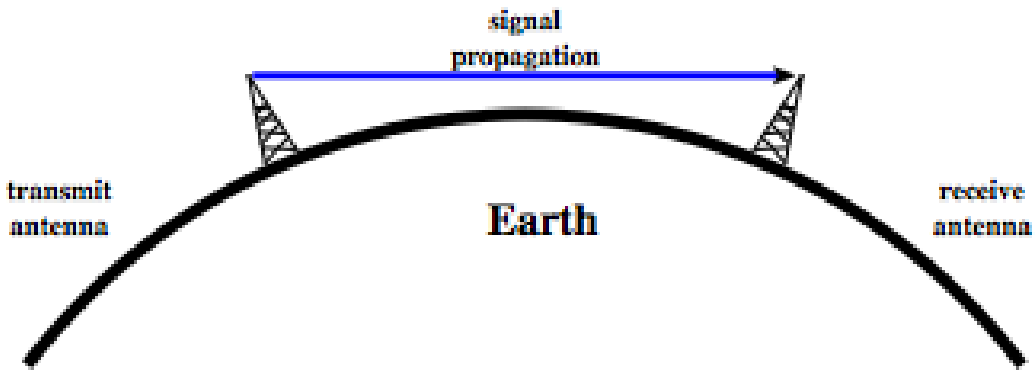

(a) Ground-wave propagation (below 2 MHz)

# Wireless Propagation
# Sky Wave




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

# Wireless Propagation
# Line of Sight




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