

# **Data and Computer Communications**

## **Chapter 4 –Transmission Media**

Eighth Edition  
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Lecture slides by Lawrie Brown

# Transmission Media

*Communication channels in the animal world include touch, sound, sight, and scent. Electric eels even use electric pulses. Ravens also are very expressive. By a combination voice, patterns of feather erection and body posture ravens communicate so clearly that an experienced observer can identify anger, affection, hunger, curiosity, playfulness, fright, boldness, and depression. —Mind of the Raven, Bernd Heinrich*

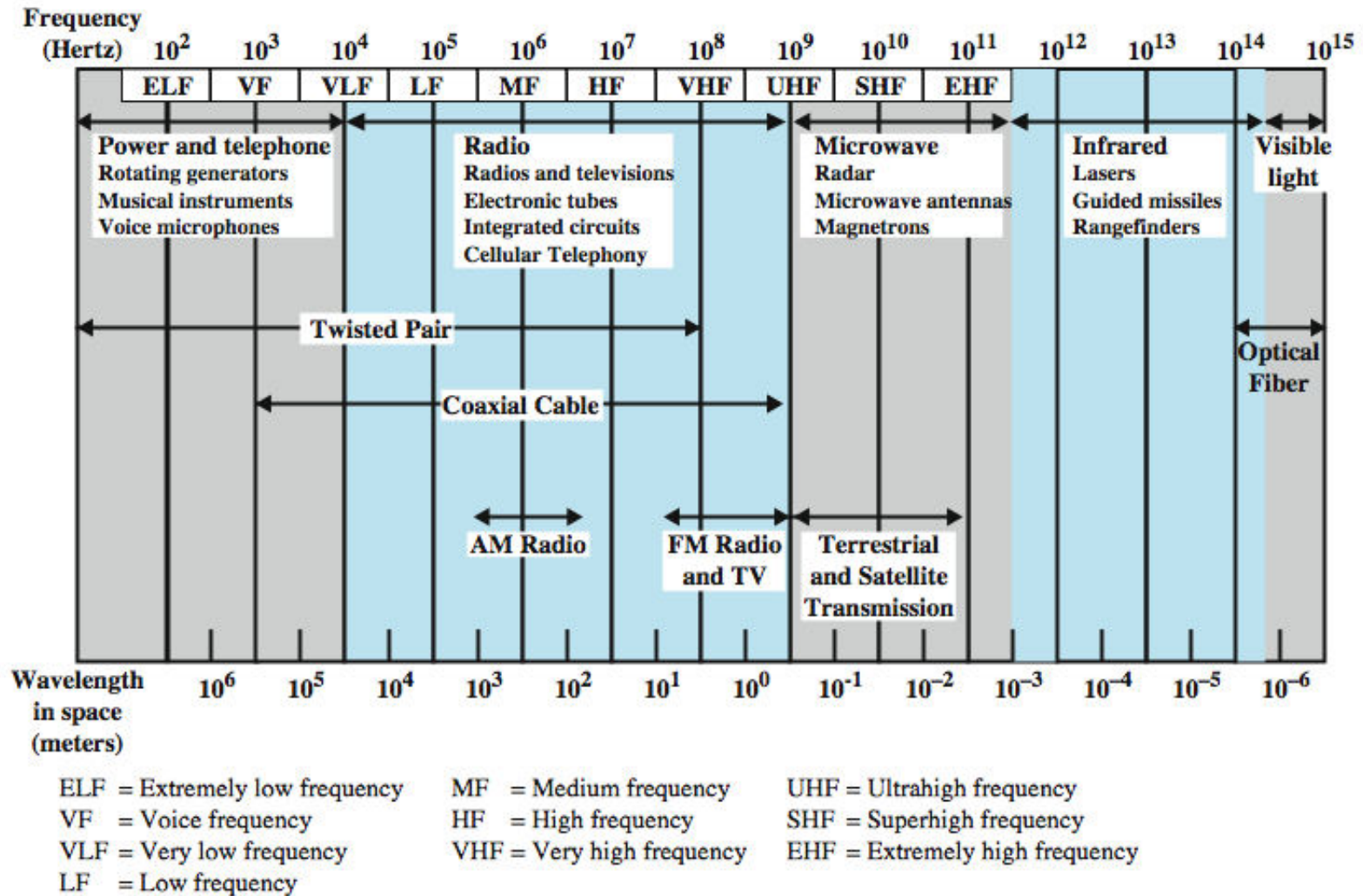
# Overview

- 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



# 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 $\mu$ s/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 $\mu$ s/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 $\mu$ s/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/km	5 $\mu$ s/km	40 km

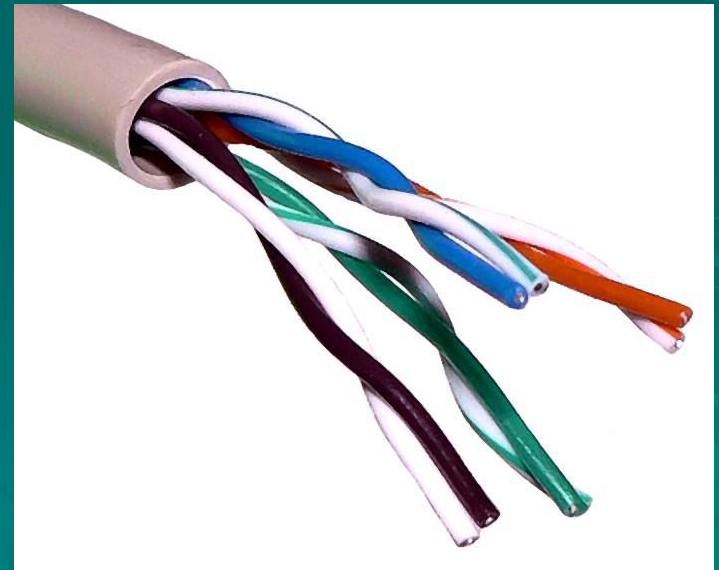
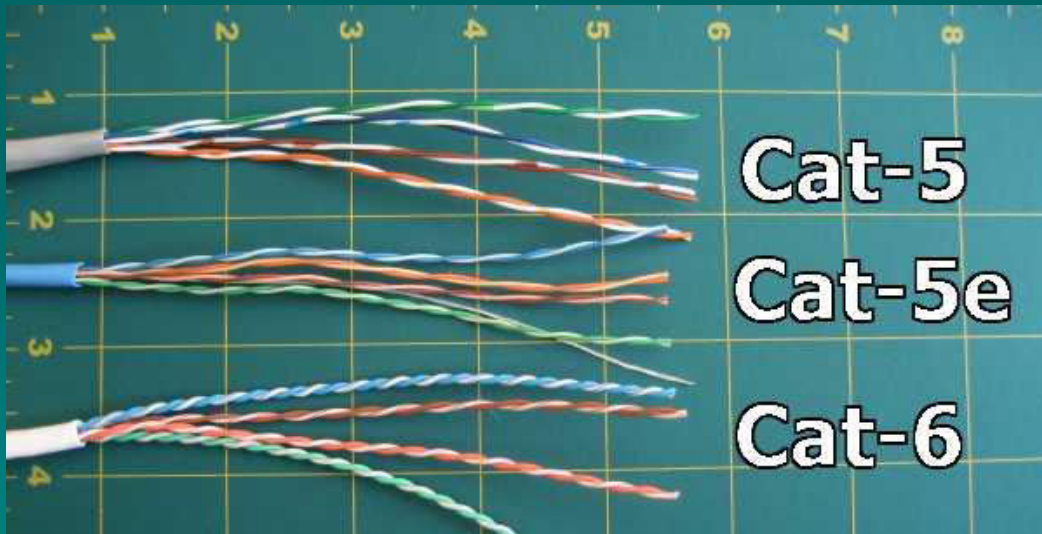
# Twisted Pair

## Reduce Electromagnetic Interference

- 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

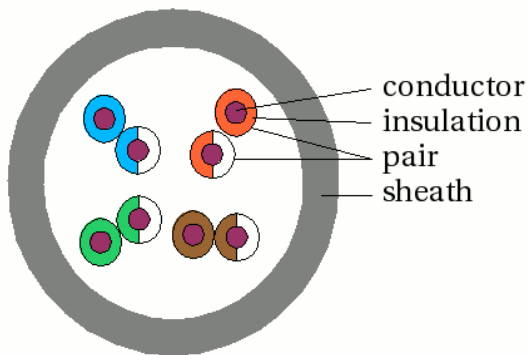
# UTP Categories

7.5~10 cm

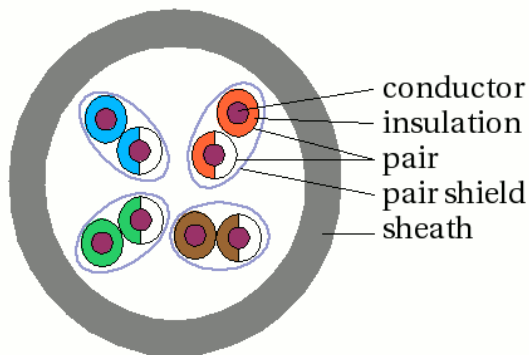
0.6~0.85cm

	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

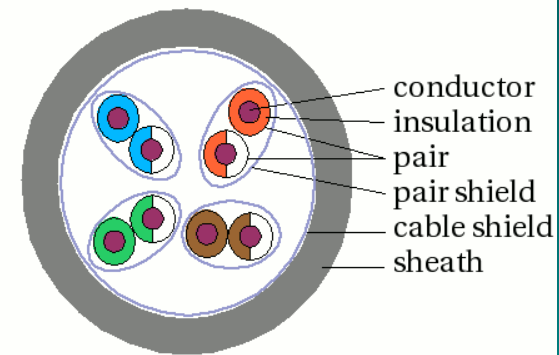
UTP



STP



S/STP



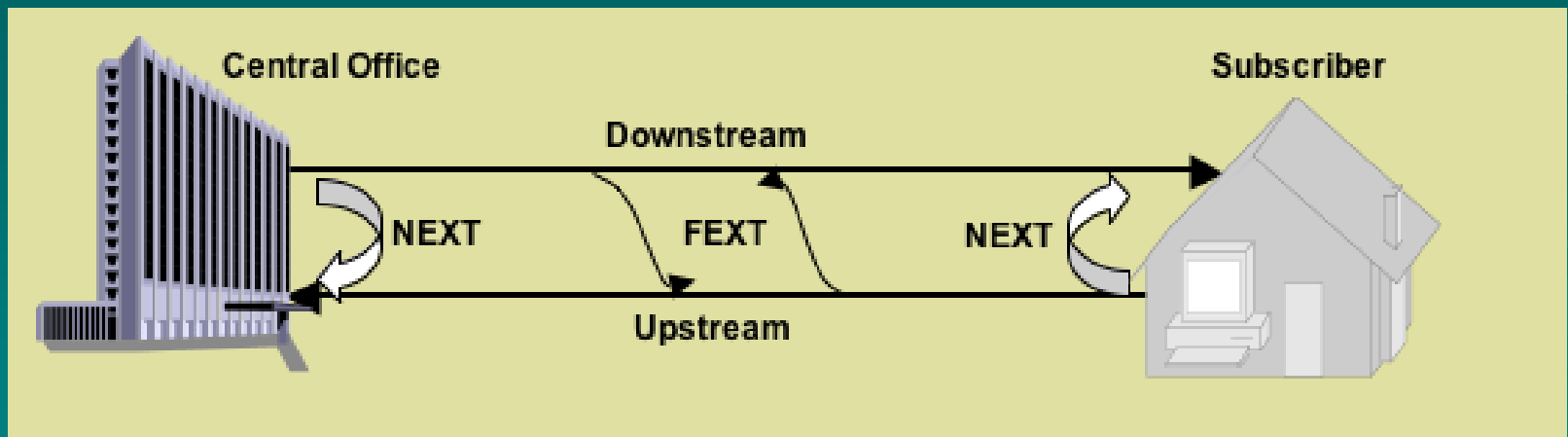
# Comparison of Shielded and Unshielded Twisted Pair

Frequency (MHz)	Attenuation (dB per 100 m)			Near-end Crosstalk (dB)		
	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

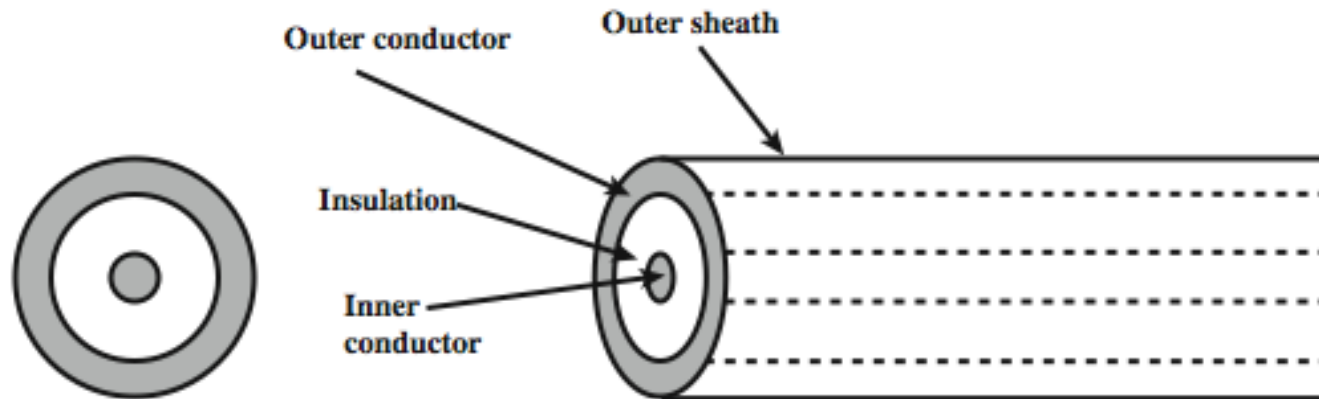


# Near End Crosstalk

- 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

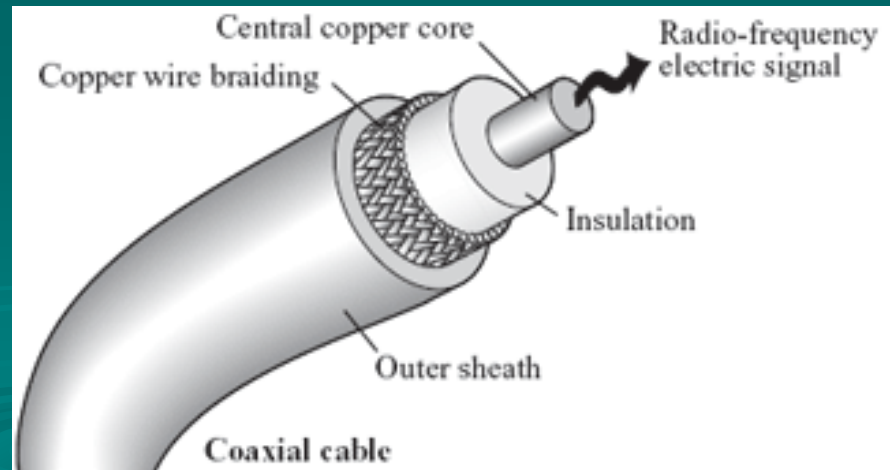
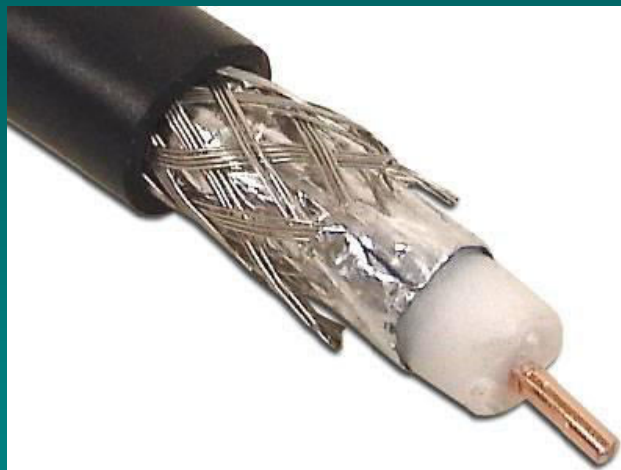


# Coaxial Cable



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

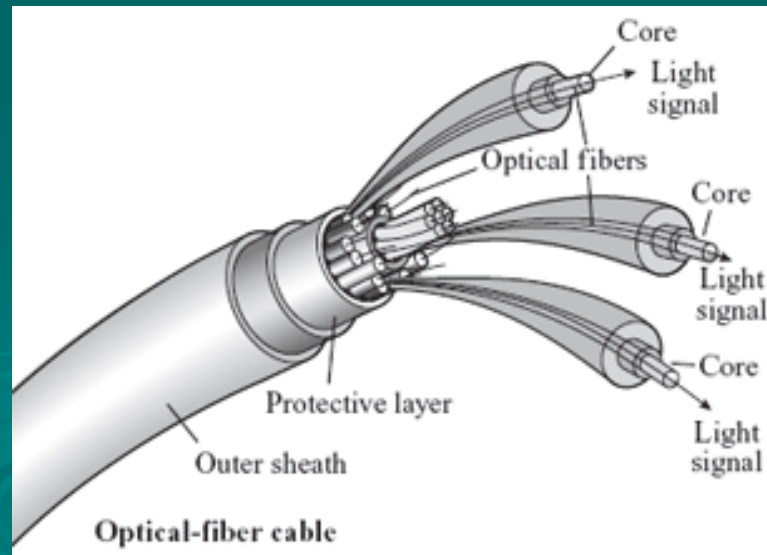
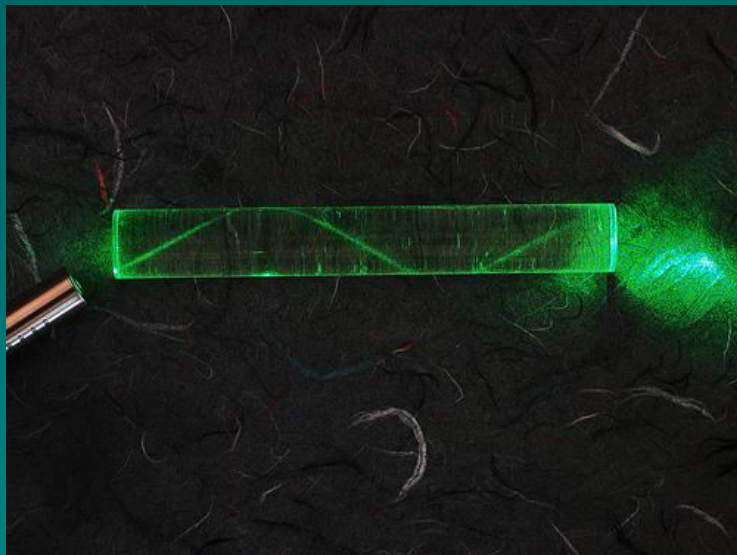
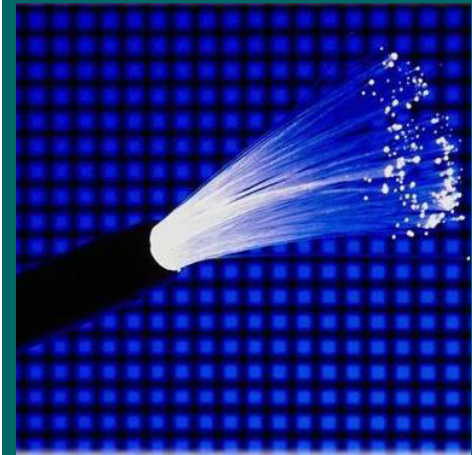
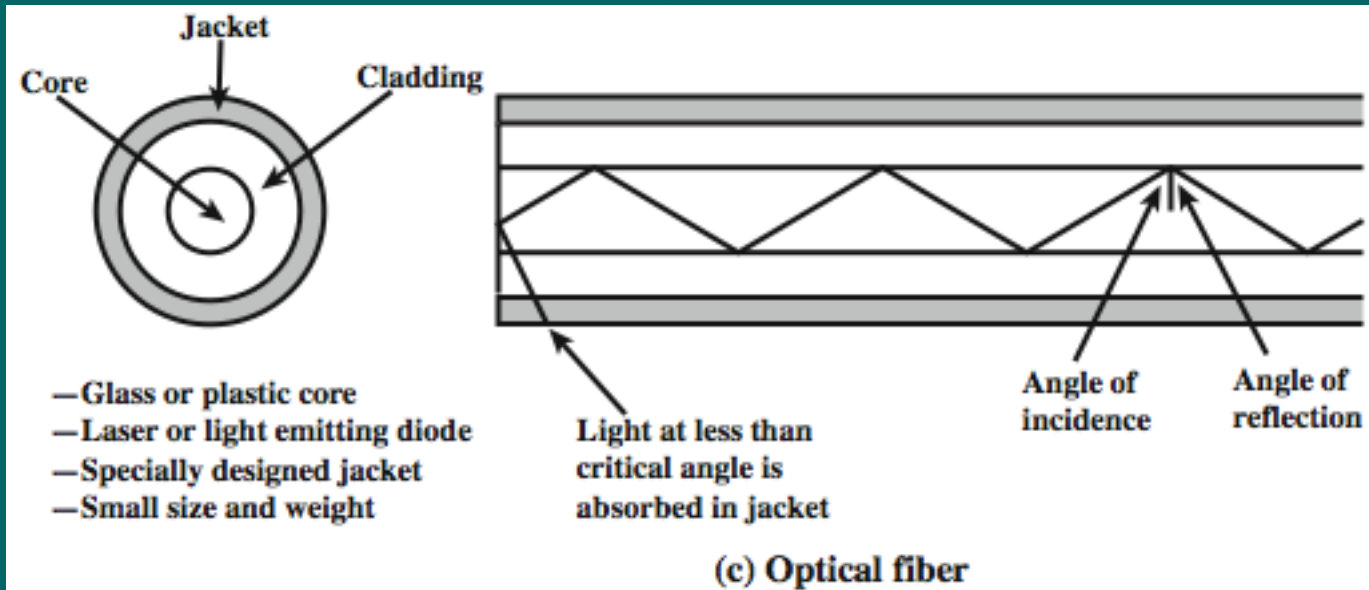
**(b) Coaxial cable**



# 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





# 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

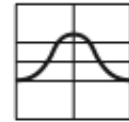
- uses total internal reflection to transmit light
  - effectively acts as wave guide for  $10^{14}$  to  $10^{15}$  Hz
- can use several different light sources
  - Light Emitting Diode (LED)
    - cheaper, wider operating temp range, lasts longer
  - Injection Laser Diode (ILD)
    - more efficient,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

# Optical Fiber Transmission Modes

Input pulse

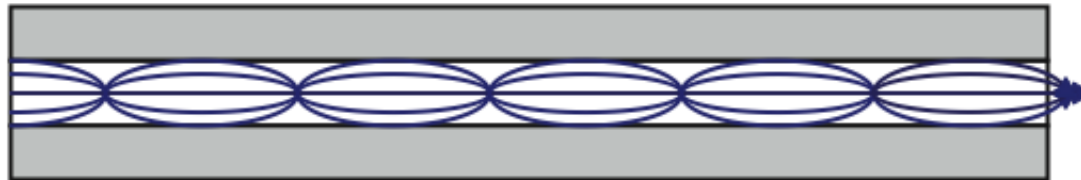


Output pulse

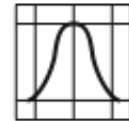


(a) Step-index multimode

Input pulse



Output pulse

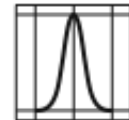


(b) Graded-index multimode

Input pulse



Output pulse

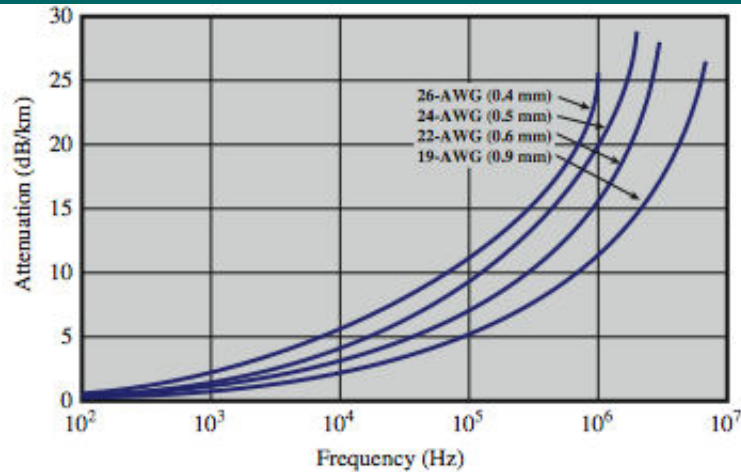


(c) Single mode

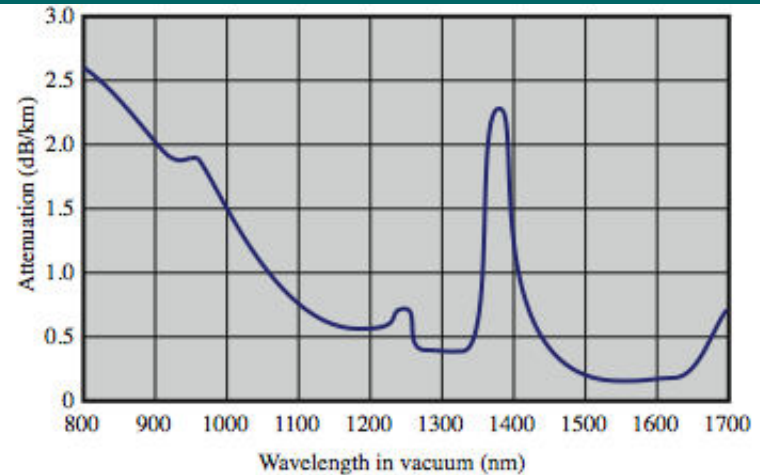
# Frequency Utilization for Fiber Applications

Wave length (in vacuum) range (nm)	Frequency Range (THz)	Band Label	Fiber Type	Appli cation
820 to 900	366 to 333		Multim ode	LAN
1280 to 1350	234 to 222	S	Single mode	Various
1528 to 1561	196 to 192	C	Single mode	WDM
1561 to 1620	192 to 185	L	Single mode	WDM

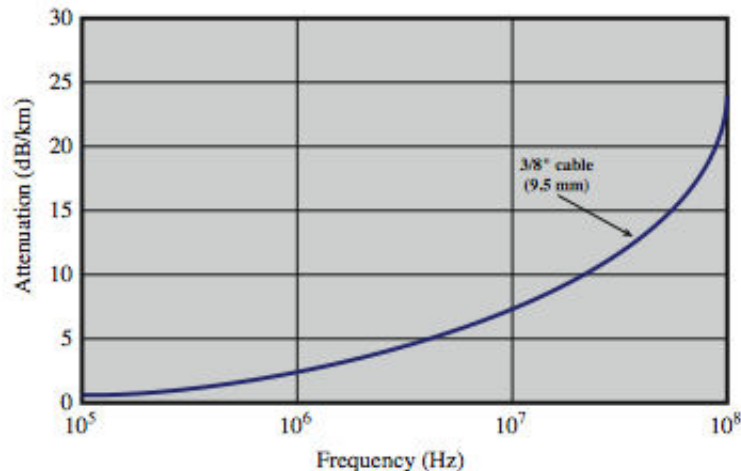
# Attenuation in Guided Media



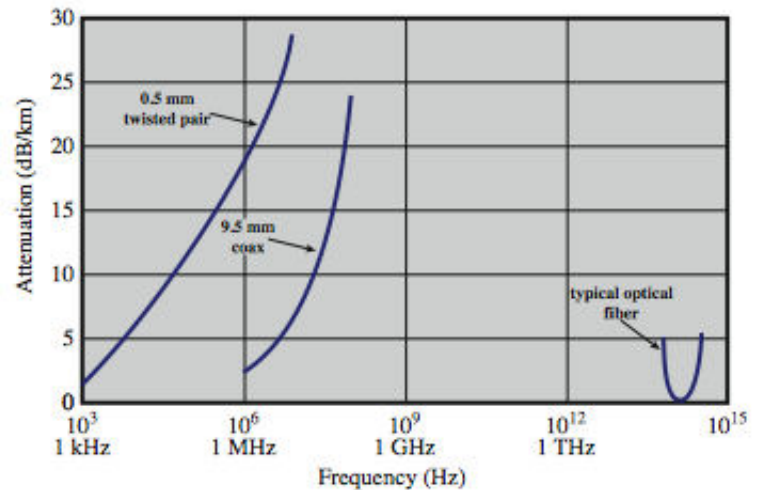
(a) Twisted pair (based on [REEV95])



(c) Optical fiber (based on [FREE02])



(b) Coaxial cable (based on [BELL90])



(d) Composite graph

# Wireless Transmission Frequencies

- 30MHz to 1GHz
  - Broadcast radio, omni-directional
- 2GHz to 40GHz
  - Microwave, highly directional
  - point to point
  - satellite
- $3 \times 10^{11}$  to  $2 \times 10^{14}$ 
  - infrared
  - local

# Antennas

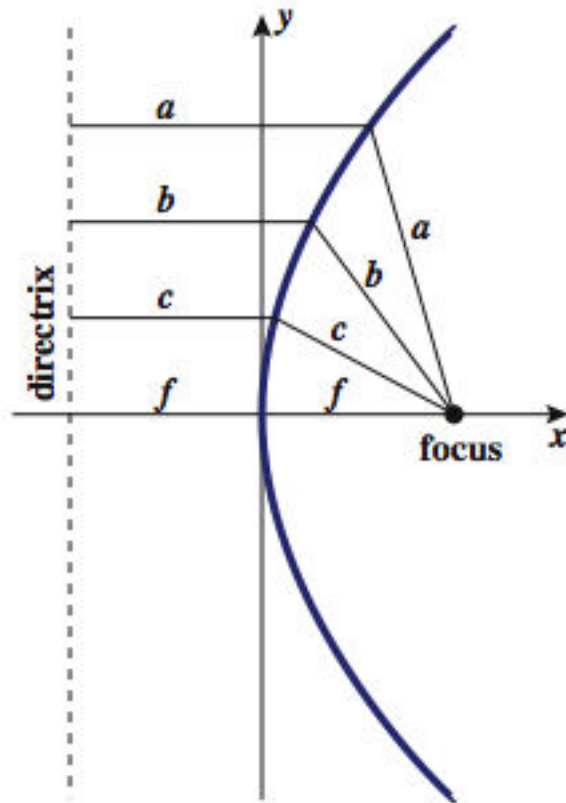
- electrical conductor used to radiate or collect electromagnetic energy
- transmission antenna
  - radio frequency energy from transmitter
  - converted to electromagnetic energy by antenna
  - radiated into surrounding environment
- reception antenna
  - electromagnetic energy impinging on antenna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



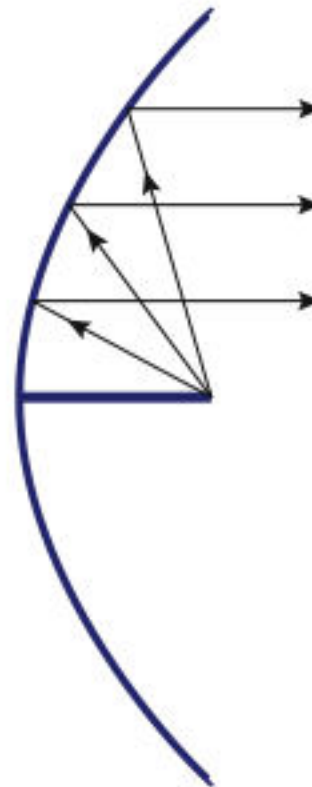
# Radiation Pattern

- 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

# 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
- effective area relates to size and shape
  - related to gain

# 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

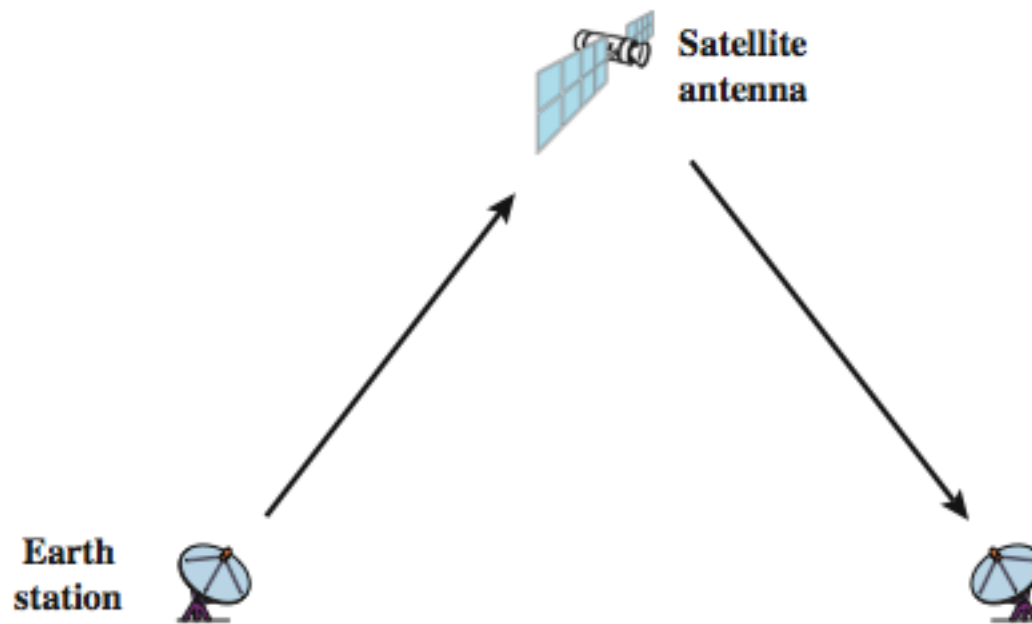
# Terrestrial Microwave

- 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

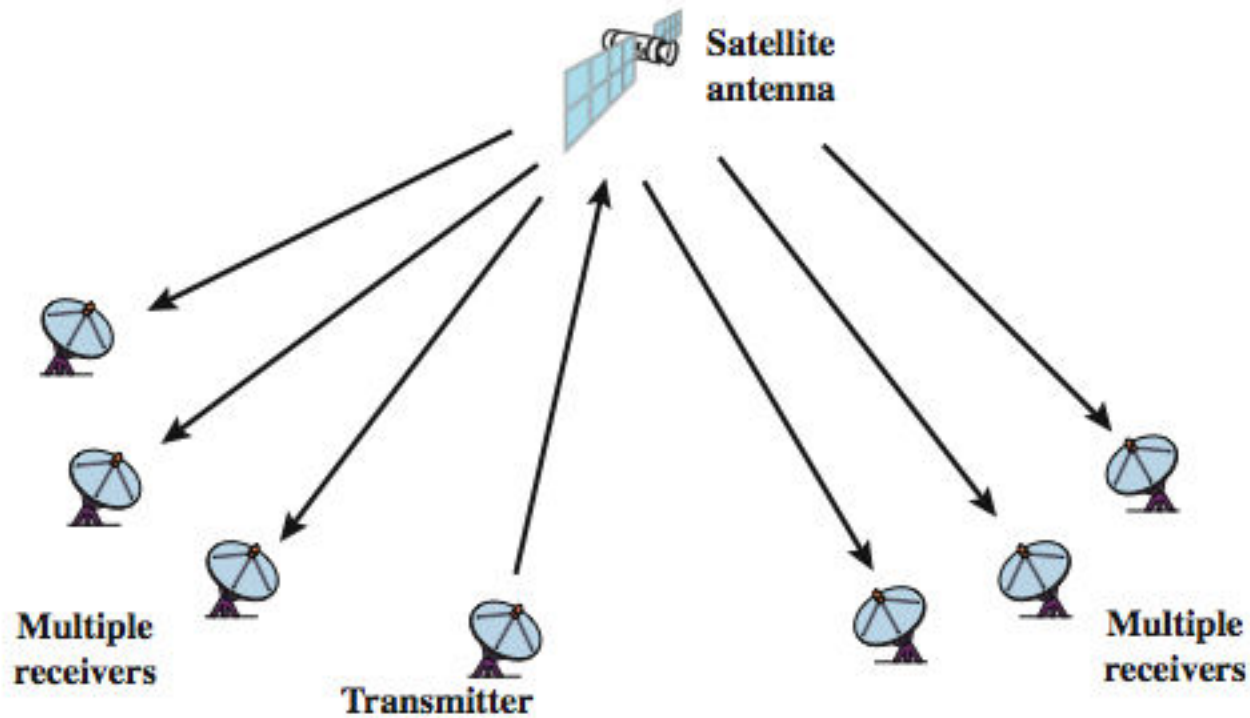
# Satellite Point to Point Link



(a) Point-to-point link



# Satellite Broadcast Link



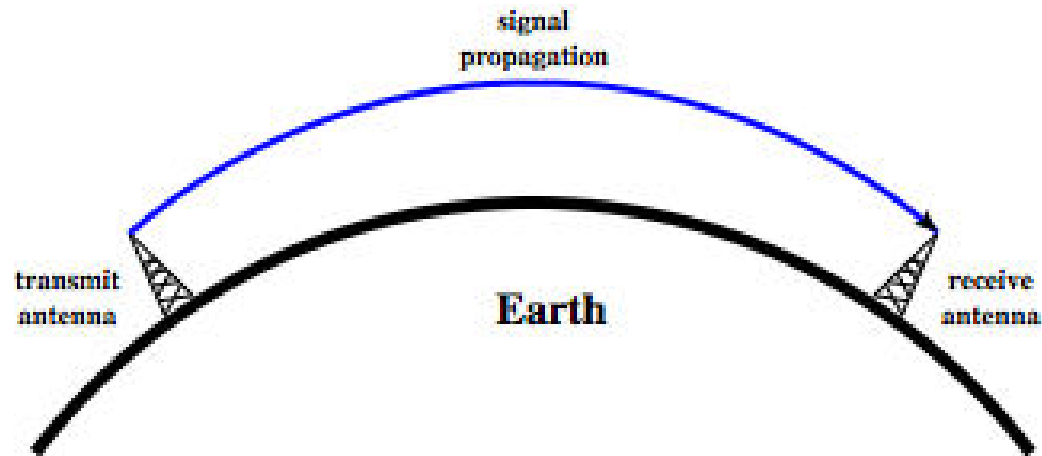
(b) Broadcast link

# Infrared

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

# Wireless Propagation

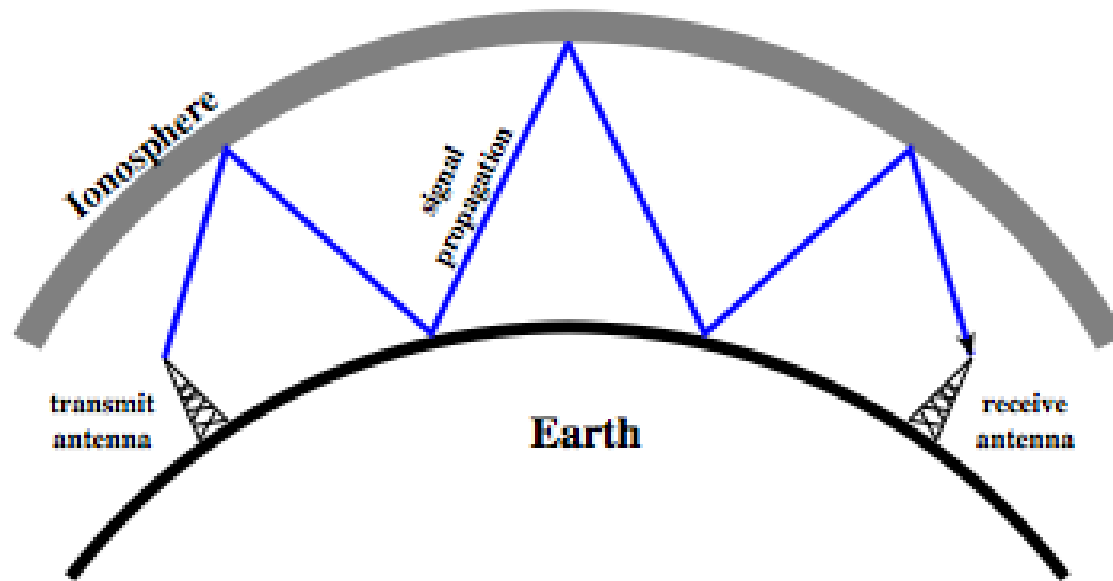
## Ground Wave



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

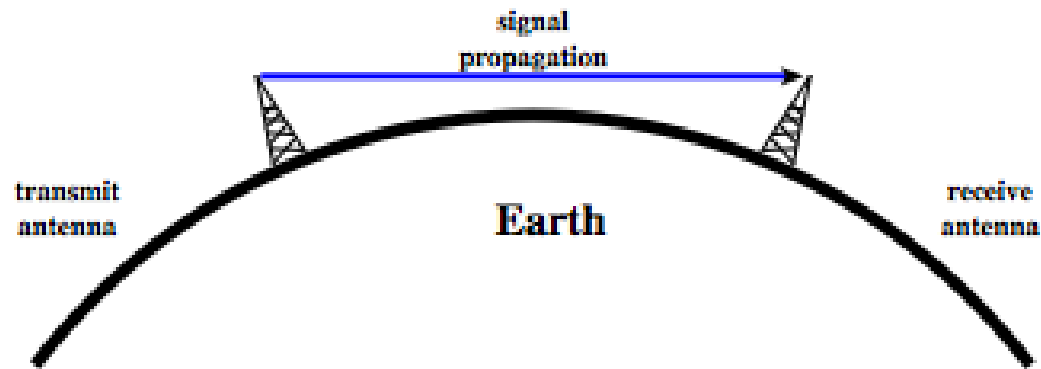
# Wireless Propagation

## Sky Wave



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

# Wireless Propagation Line of Sight



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

# Refraction

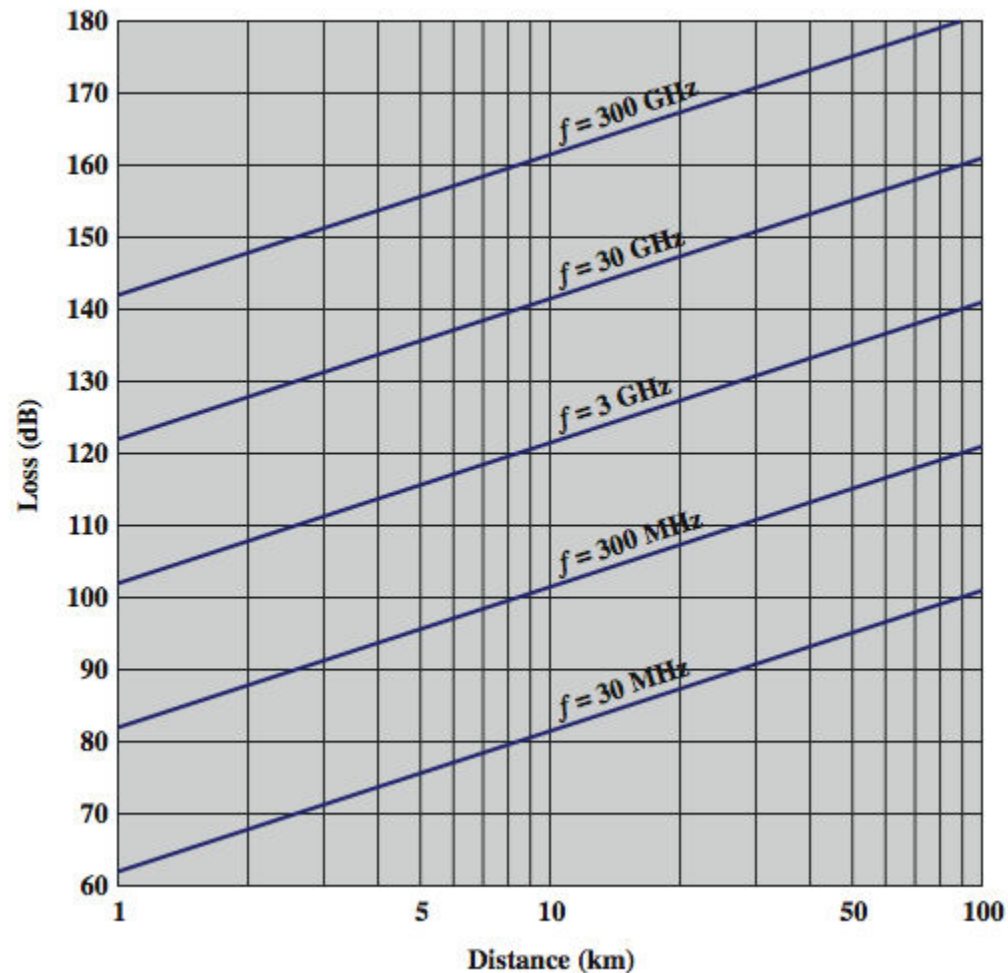
- velocity of electromagnetic wave is a function of density of material
  - $\sim 3 \times 10^8$  m/s in vacuum, less in anything else
- speed changes as move between media
- Index of refraction (refractive index) is
  - $\sin(\text{incidence})/\sin(\text{refraction})$
  - varies with wavelength
- have gradual bending if medium density varies
  - density of atmosphere decreases with height
  - results in bending towards earth of radio waves
  - hence optical and radio horizons differ

# Line of Sight Transmission

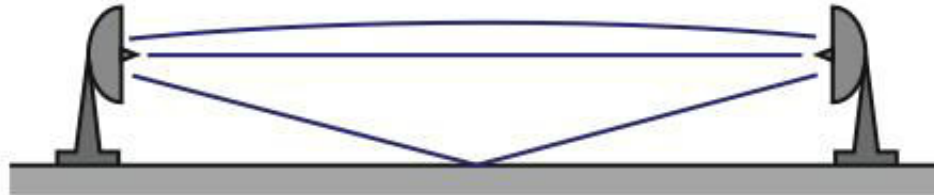
- Free space loss
  - loss of signal with distance
- Atmospheric Absorption
  - from water vapour and oxygen absorption
- Multipath
  - multiple interfering signals from reflections
- Refraction
  - bending signal away from receiver



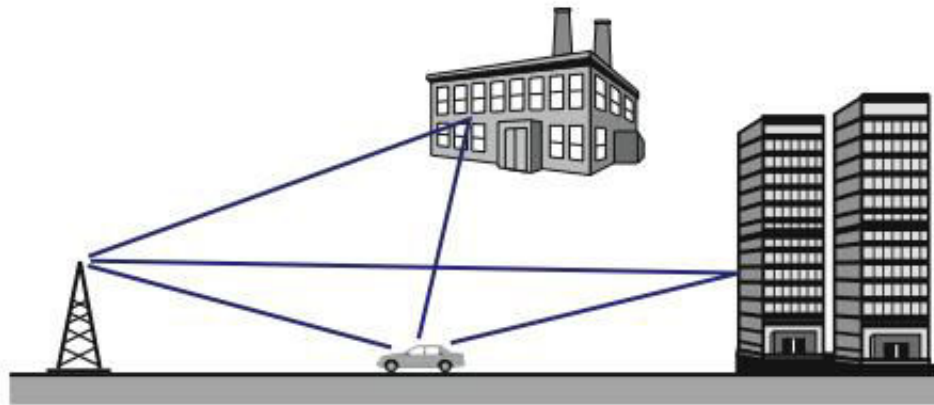
# Free Space Loss



# Multipath Interference



(a) Microwave line of sight



(b) Mobile radio

# Summary

- looked at data transmission issues
- frequency, spectrum & bandwidth
- analog vs digital signals
- transmission impairments