IT 4505
Section 1.0

Fundamentals of Digital Communications

1.1.7 Transmission Media

- In a data transmission system, the **transmission medium is the physical path** between transmitter and receiver.
- guided – Copper wire / optical fibre

  For guided media, electromagnetic waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, and optical fibre.
- unguided – Free space wireless

  For **unguided media, wireless transmission** occurs through the atmosphere, outer space, or water.

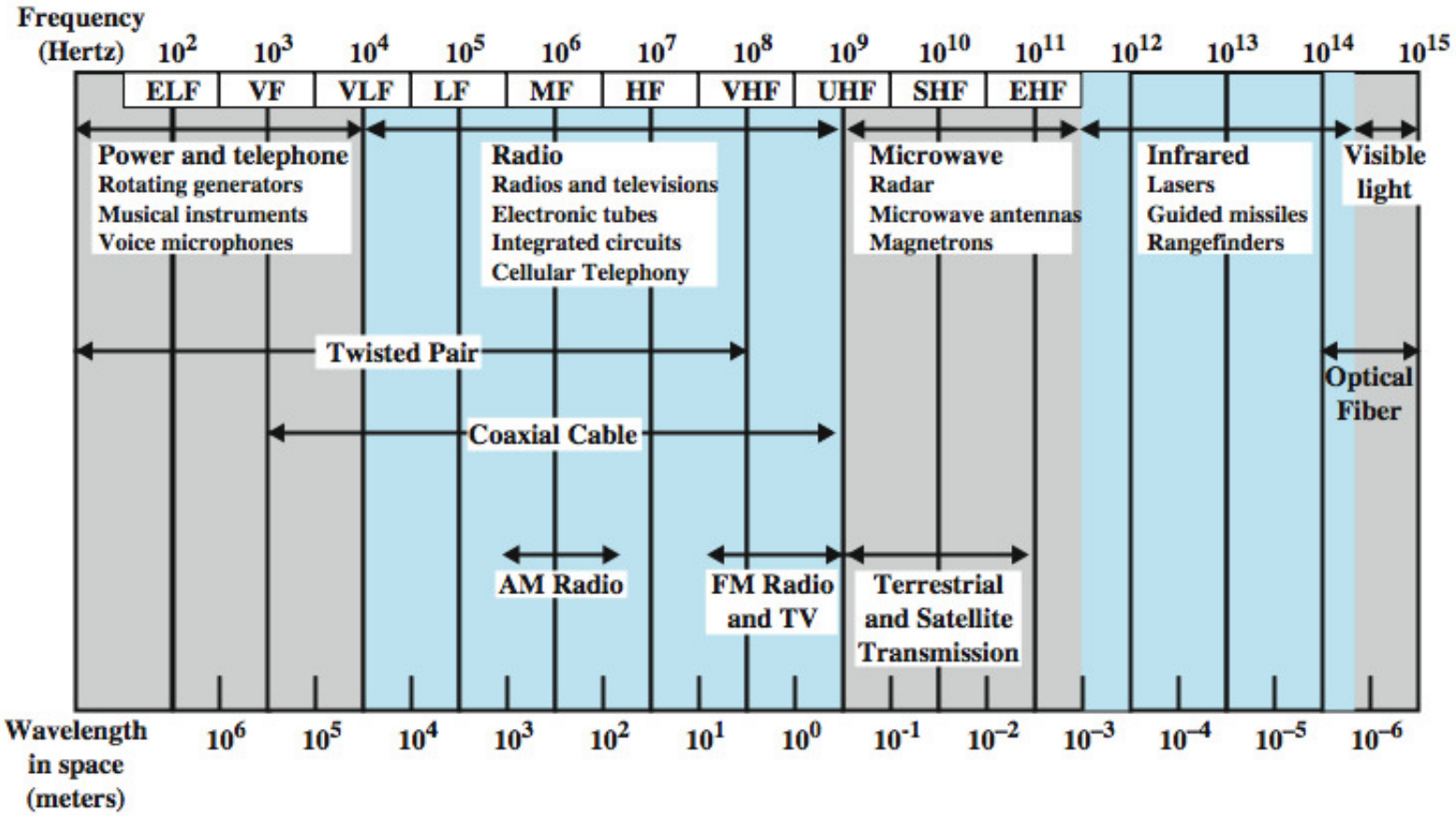
- key concerns are data rate, distance and susceptibility to noise.

Design Factors

- Bandwidth
  - Higher the channel bandwidth, higher the data rate supported.
- Transmission impairments
  - Eg. Attenuation distortion, delay distortion
- Interference

- Interference from competing signals in overlapping frequency bands can distort or wipe out a signal.

Electromagnetic Spectrum



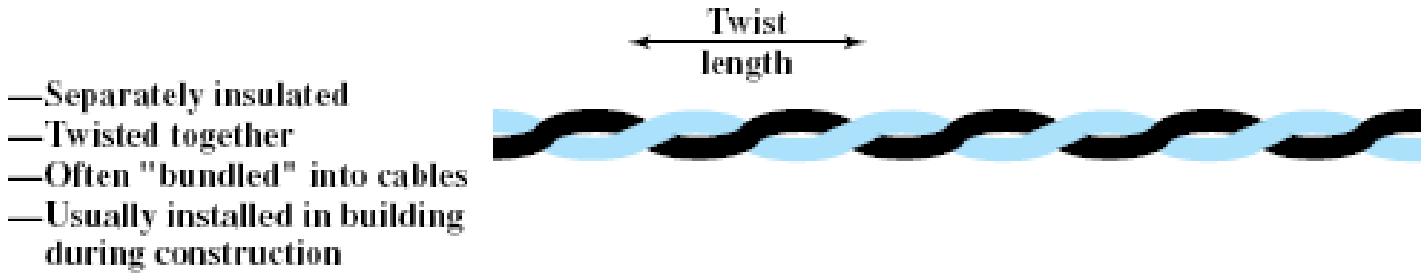
ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

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 (multipair cables)	0 to 1 MHz	0.7 dB/km @ 1 MHz	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

1.1.8 Twisted Pair Cables

A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern. A wire pair acts as a single communication link.



Twisted Pair - Transmission Characteristics

- analogue
  - needs amplifiers every 5km to 6km
- digital
  - can support either analogue or digital signals
  - needs a regenerator every 2-3km
- limited distance
- limited bandwidth (1MHz)
- limited data rate (100Mbps)
- 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

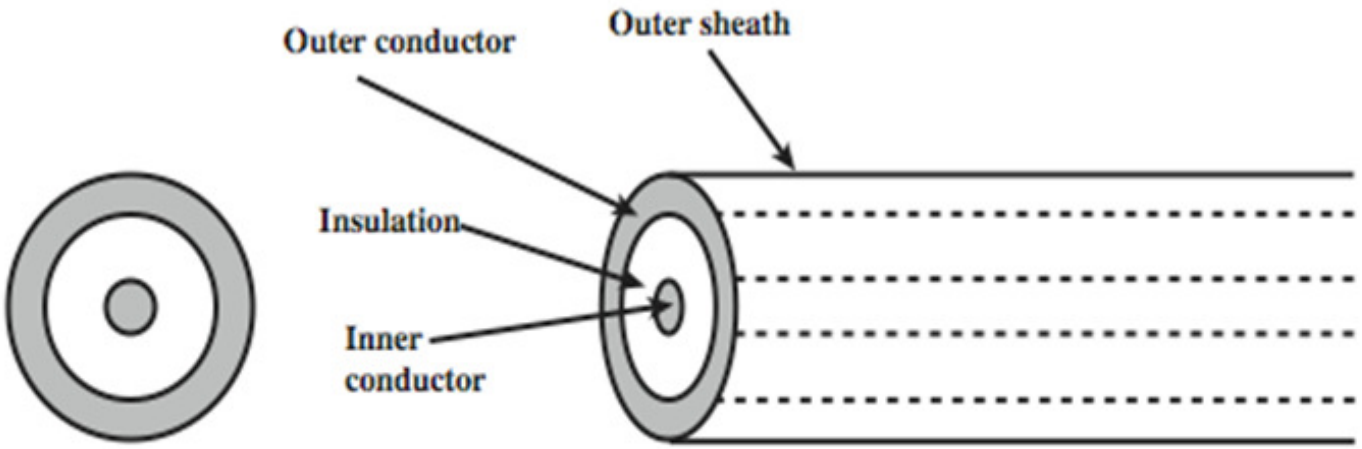
	Category 3 Class C	Category 5 Class D	Category 5E	Category 6 Class E	Category 7 Class F
Bandwidth	16 MHz	100 MHz	100 MHz	200 MHz	600 MHz
Cable Type	UTP	UTP/FTP	UTP/FTP	UTP/FTP	SSTP
Link Cost (Cat 5=1)	0.7	1	1.2	1.5	2.2
Max data rate	16 Mbps	100Mbps	100Mbps		

UTP: Unshielded twisted pair
SSTP: Screened Shielded Twisted Pair

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

1.1.9 Coaxial Cable

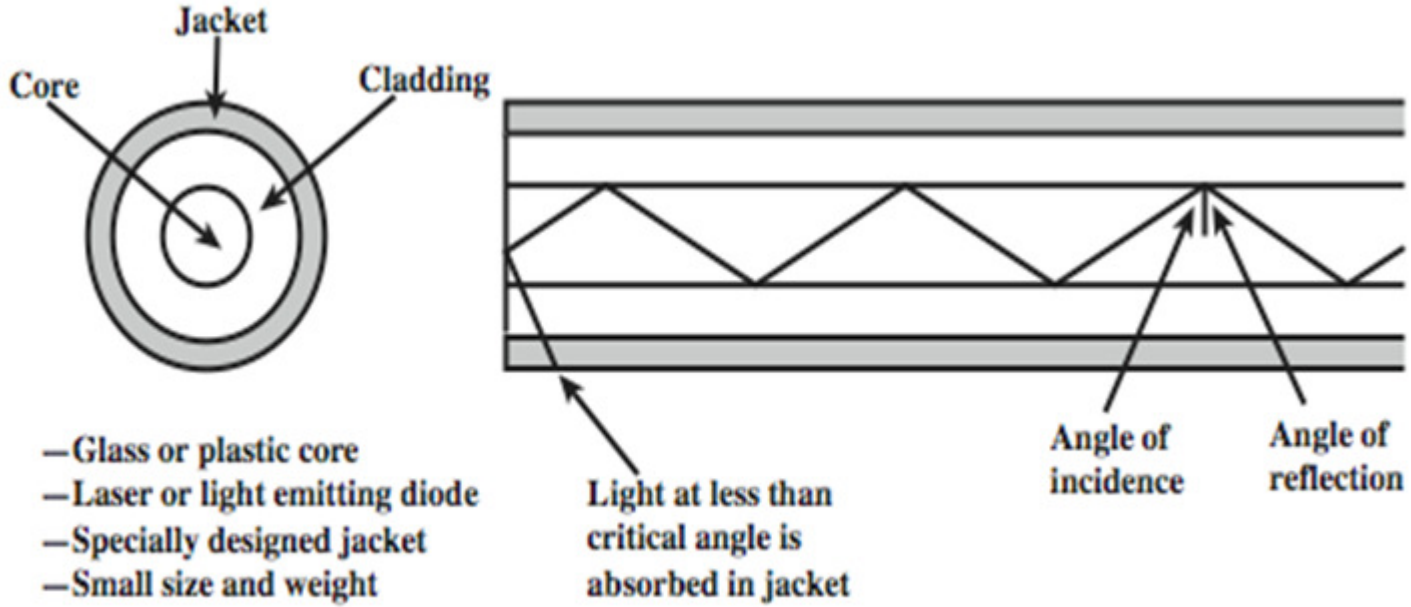


—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding

Coaxial Cable - Transmission Characteristics

- superior frequency characteristics compare to Twisted pair.
- performance limited by attenuation & noise.
- analog signals
  - Amplifiers required every few km
  - closer if higher frequency
  - up to 500MHz
- digital signals
  - repeater every 1km
  - closer for higher data rates

1.1.10 Fibre Optic Cables



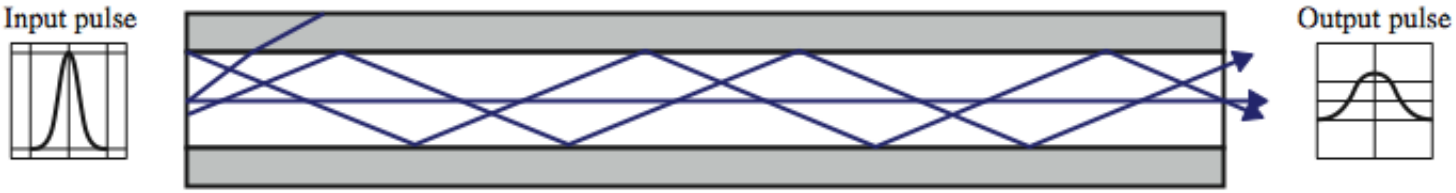
Optical Fiber - Benefits

- greater capacity
  - data rates of hundreds of Gbps possible.
- smaller size & weight
- lower attenuation per Km
- electromagnetic isolation
- greater regenerator spacing
  - 10s of km at least

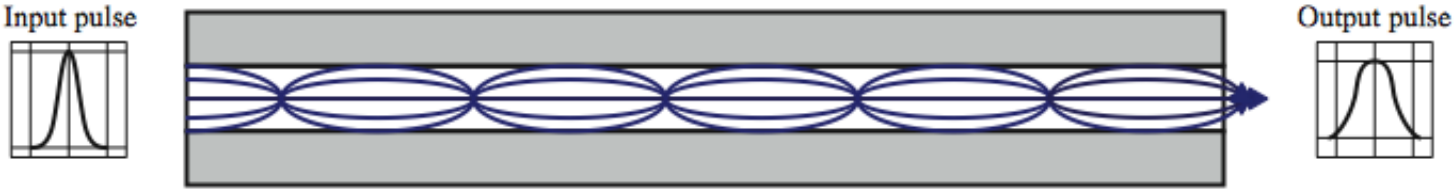
Optical Fiber - Transmission Characteristics

- uses total internal reflection to transmit light
  - effectively acts as wave guide for 10^{14} to 10^{15} GHz
- 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



(a) Step-index multimode



(b) Graded-index multimode

(c) Single mode

Frequency Utilization for Fiber Applications

Wave length (in vacuum) range (nm)	Frequency Range (THz)	Band Label	Fiber Type	Application
820 to 900	366 to 333		Multi mode	LAN
1280to 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

LAN : Local Area networks
WDM : wavelength division multiplexing

1.1.11 Wireless Media

Wireless Transmission Frequency Ranges

- 3GHz to 30GHz
  - Microwave frequencies
  - highly directional beams are possible
  - suitable for point-to-point transmission
  - also used for satellite communications

- 30MHz to 1GHz
  - suitable for omnidirectional applications
  - Radio range

- 3×10^{11} Hz to 2×10^{14} Hz
  - Infrared range
  - useful to local point-to-point and multipoint applications

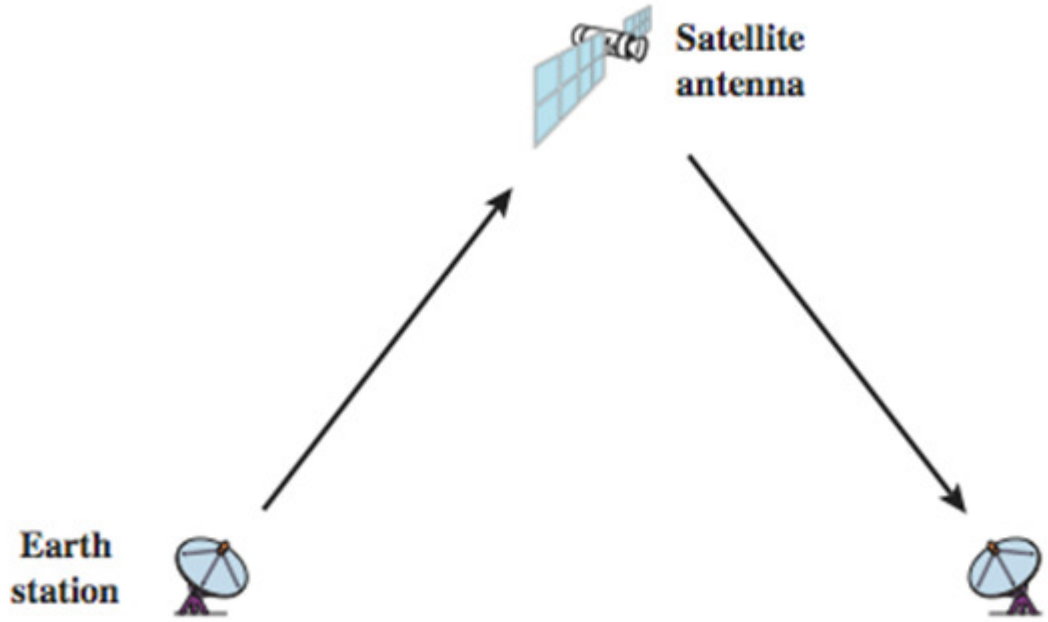
Terrestrial Microwave

- long haul telecommunications
- short point-to-point links
- requires fewer repeaters but should be line of sight
- uses 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 atmosphere attenuation
- Interference from similar sources.

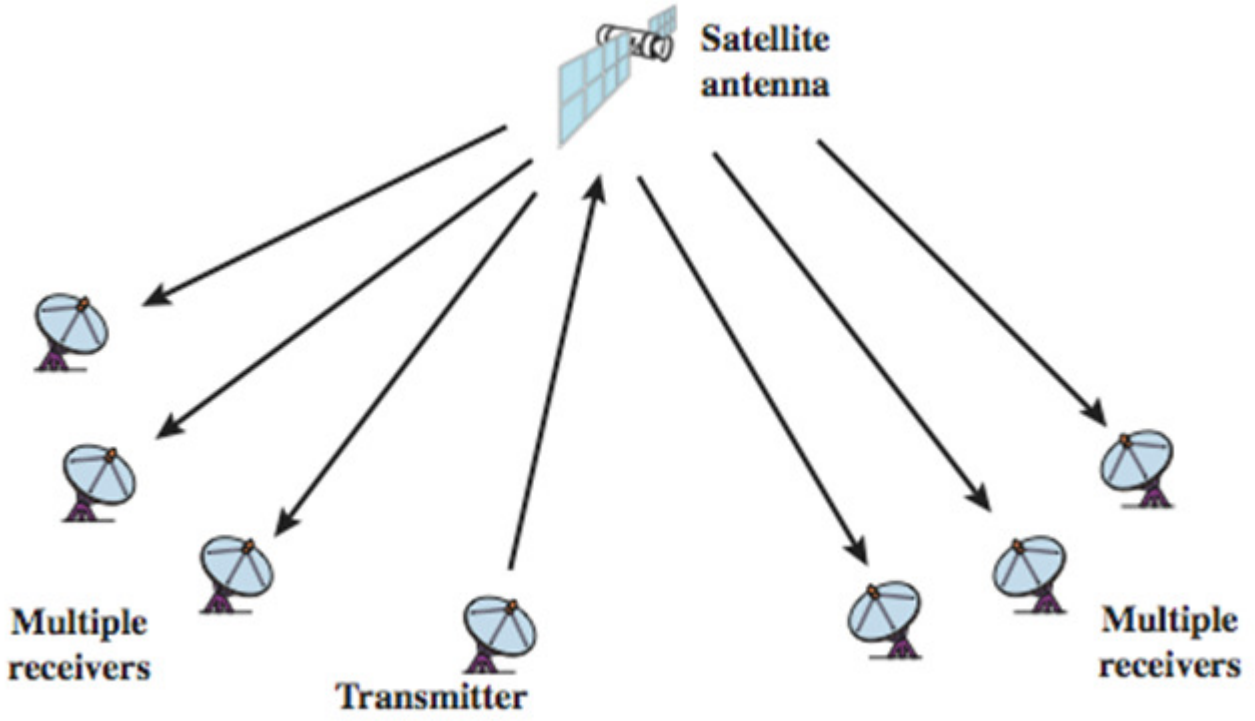
Satellite Microwave

- A satellite is a 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



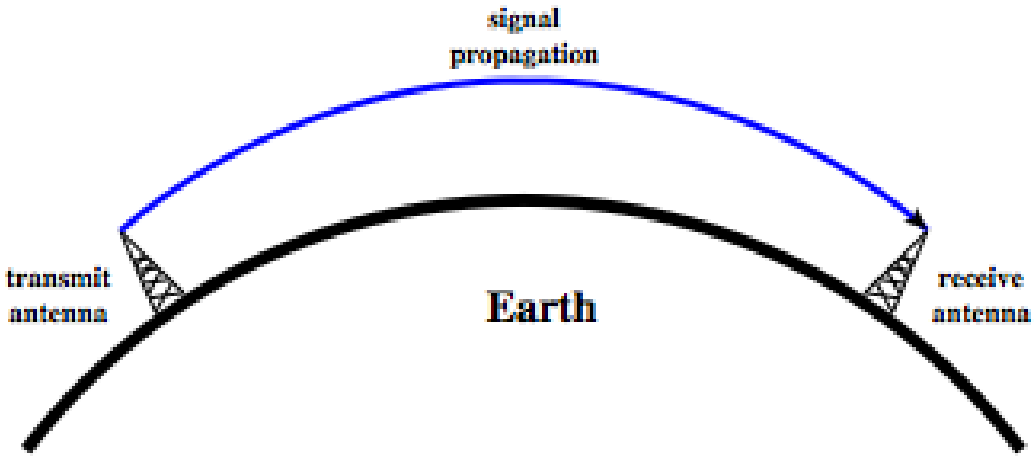
Satellite Broadcast Link



Broadcast Radio

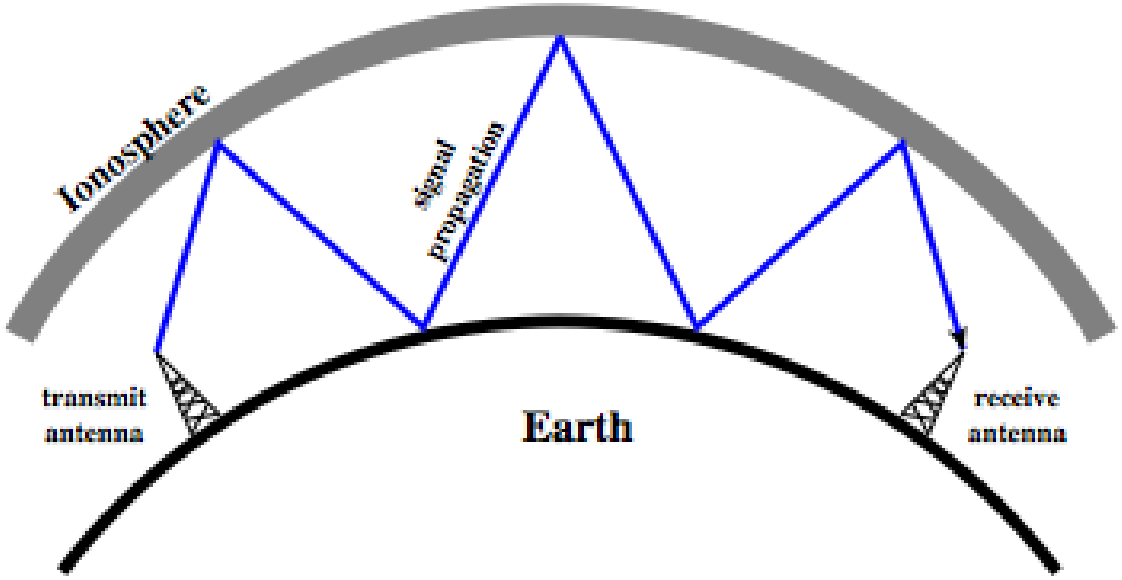
- radio spectrum is 3kHz to 300GHz
- use broadcast radio, 30MHz - 1GHz, for:
  - FM radio
  - UHF and VHF television
- is omnidirectional
- suffers from multipath interference as frequency increases.
  - reflections from land, water, other objects

Wireless Propagation
Ground Wave



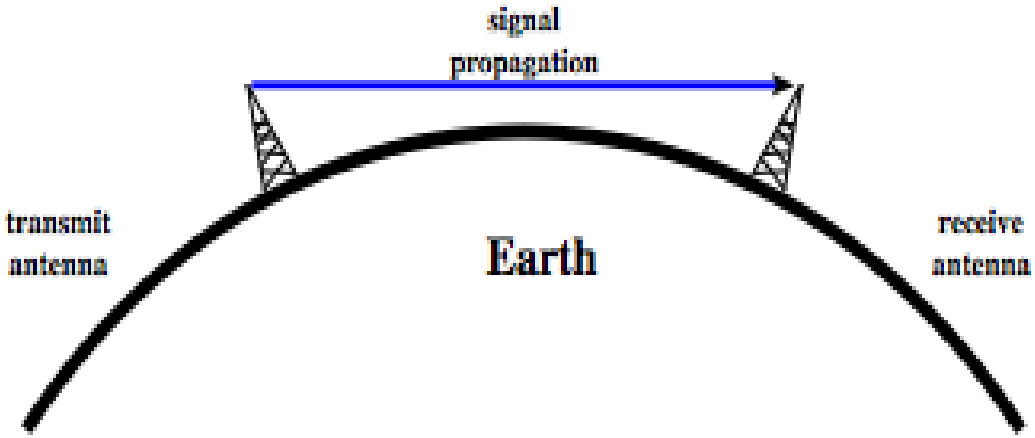
(a) Ground-wave propagation (below 2 MHz)

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)

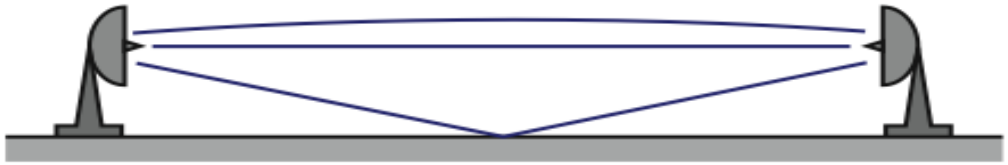
Refraction

- velocity of electromagnetic wave is a function of density of material
  - ~3 x 10^8 m/s in vacuum, less in any other media
- velocity changes as signal moves between media
- Index of refraction (refractive index) is
  - sin(incidence)/sin(refraction)
  - varies with wavelength
- have gradual bending if medium density varies
  - density of atmosphere decreases with height
  - results in bending towards earth for radio waves
  - hence optical and radio horizons differ

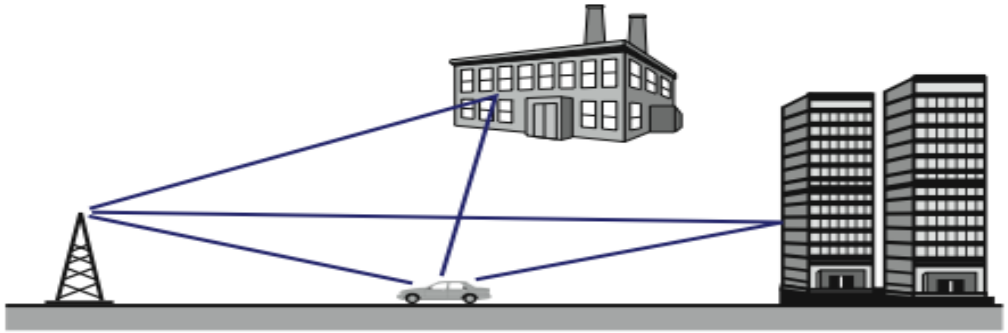
Line of Sight Transmission

- 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

Multipath Interference



(a) Microwave line of sight



(b) Mobile radio