

Data Communication



TRANSMISSION MEDIA

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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

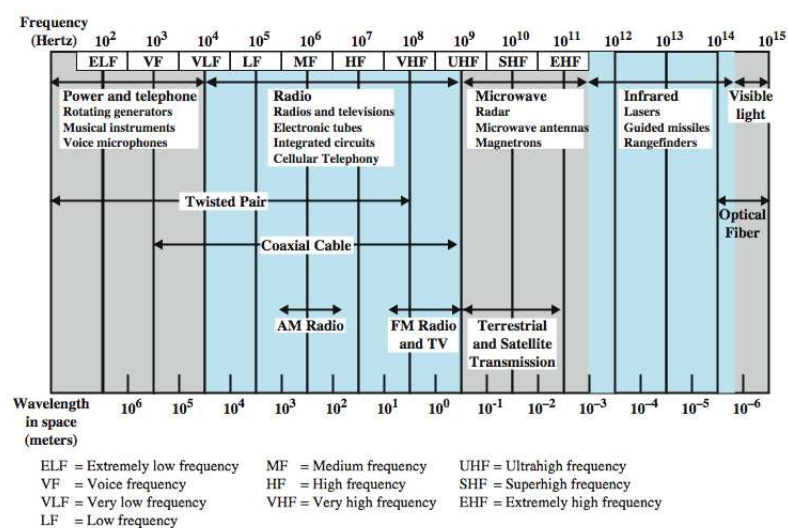
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Design Factors

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

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Electromagnetic Spectrum



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

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Twisted Pair

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



(a) Twisted pair

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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**

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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**

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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

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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

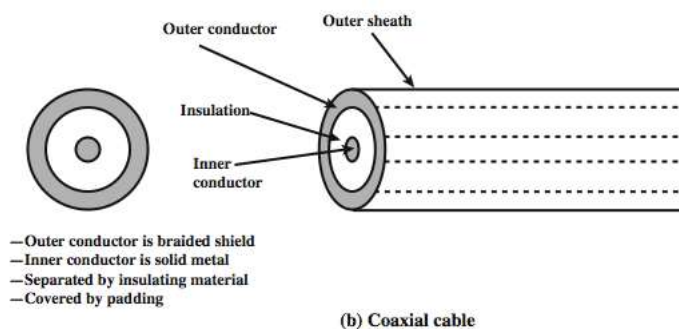
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Near End Crosstalk

- 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

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Coaxial Cable



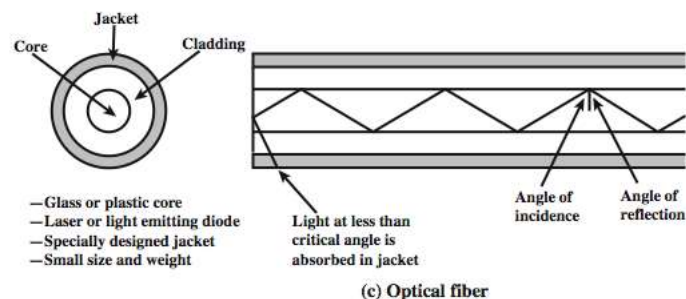
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Coaxial Cable - Transmission Characteristics

- 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

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Optical Fiber



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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

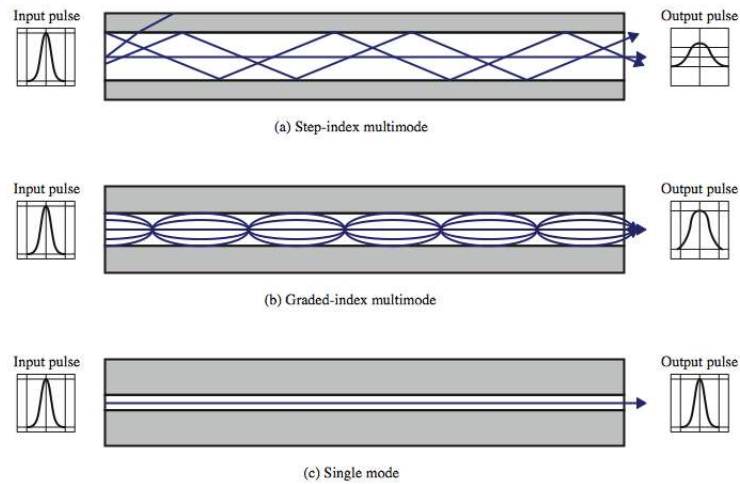
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Optical Fiber - Transmission Characteristics

- 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

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Optical Fiber Transmission Modes



Wireless Transmission Frequencies

- **2GHz to 40GHz**
 - microwave
 - highly directional
 - point to point
 - satellite
- **30MHz to 1GHz**
 - omnidirectional
 - broadcast radio
- **3×10^{11} to 2×10^{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

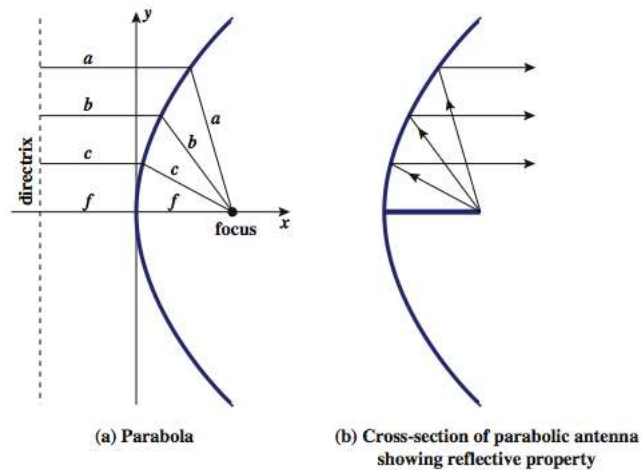
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Radiation Pattern

- 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

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Parabolic Reflective Antenna



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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

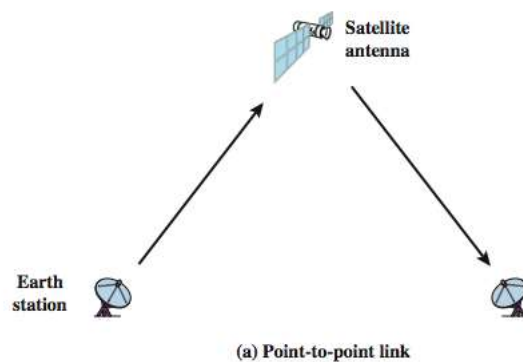
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Satellite Microwave

- 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

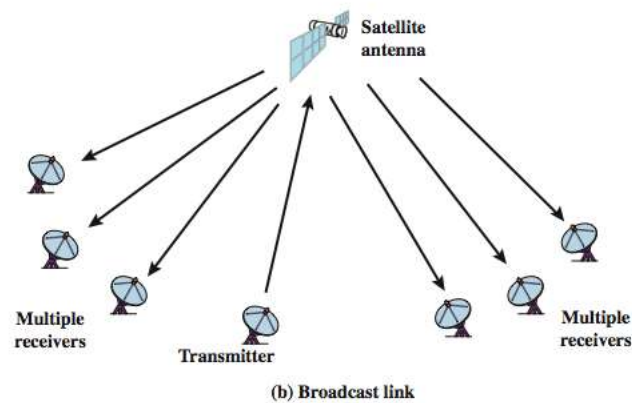
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Satellite Point to Point Link



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Satellite Broadcast Link



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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

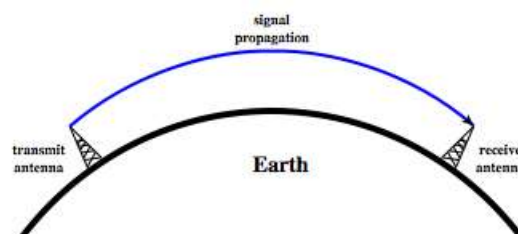
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Infrared

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

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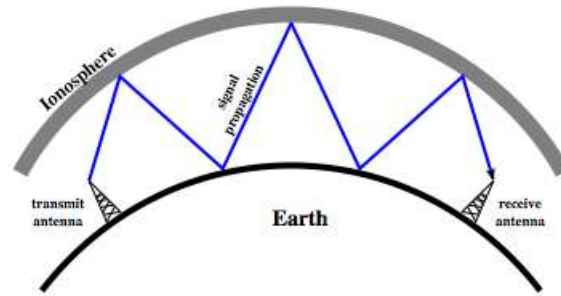
Wireless Propagation Ground Wave



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

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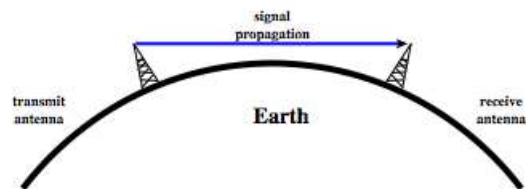
Wireless Propagation Sky Wave



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

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Wireless Propagation Line of Sight



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

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