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Data and Computer Communications

Chapter 4

Transmission Media

Overview

- ⌘ Guided - wire
- ⌘ Unguided - wireless
- ⌘ Characteristics and quality determined by medium and signal
- ⌘ For guided, the medium is more important
- ⌘ For unguided, the bandwidth produced by the antenna is more important
- ⌘ Key concerns are data rate and distance

Design Factors

⌘ Bandwidth

- ⊞ Higher bandwidth gives higher data rate

⌘ Transmission impairments

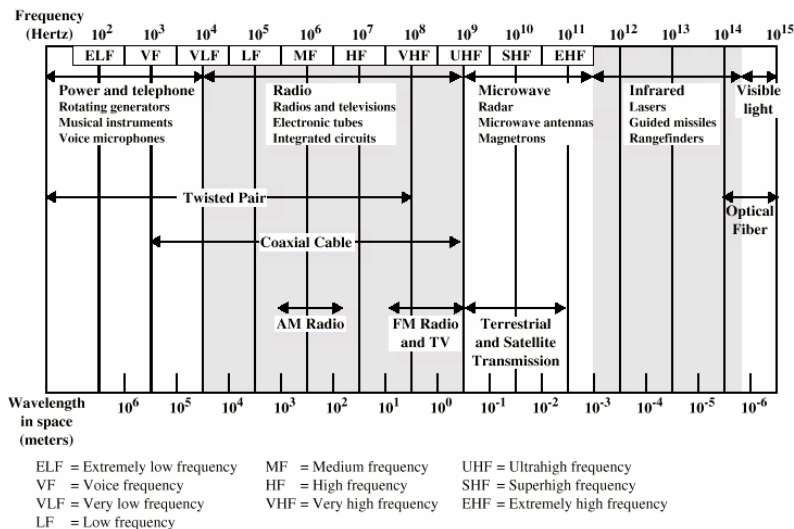
- ⊞ Attenuation

⌘ Interference

⌘ Number of receivers

- ⊞ In guided media
- ⊞ More receivers (multi-point) introduce more attenuation

Electromagnetic Spectrum



Guided Transmission Media

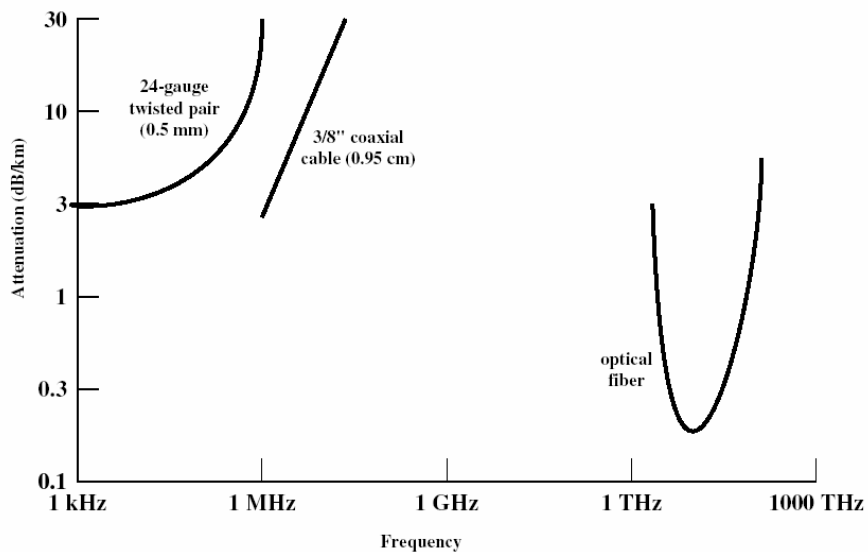
- ⌘ Twisted Pair
- ⌘ Coaxial cable
- ⌘ Optical fiber

Table 4.1 Point-to-Point Transmission Characteristics of Guided Media [GLOV98]

	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	3 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	180 to 370 THz	0.2 to 0.5 dB/km	5 μ s/km	40 km

THz = TeraHerz = 10^{12} Hz

Attenuation of Typical Guided Media



Twisted Pair

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



(a) Twisted pair

- Usually more than one pair bundled together
- Nearby pairs have different twist length to reduce crosstalk
- Twist length 5 cm to 15cm
- Wire thickness 0.4 to 0.9 mm

Twisted Pair - Applications

- ⌘ Most common medium
- ⌘ Telephone network
 - ☒ Between house and local exchange or end-office (subscriber loop)
- ⌘ Within buildings
 - ☒ To private branch exchange (PBX)
- ⌘ For local area networks (LAN)
 - ☒ 10Mbps or 100Mbps (for high rates – limited number of devices and distance)

Twisted Pair - Pros and Cons

- ⌘ Cheap
- ⌘ Easy to work with
- ⌘ Low data rate
- ⌘ Short range: repeaters required every few hundred meters

Twisted Pair - Transmission Characteristics

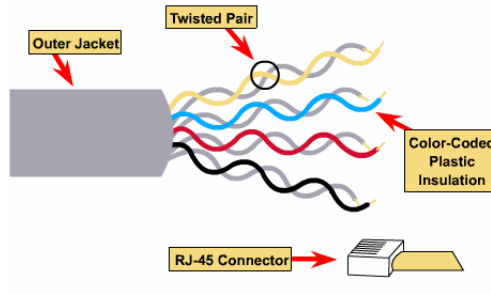
- ⌘ Analog
 - ☒ Amplifiers every 5km to 6km
- ⌘ Digital
 - ☒ Use either analog or digital signals
 - ☒ repeater every 2km or 3km (This may be wrong, few hundred meters is the answer)
- ⌘ Limited distance: highest attenuation relative to other guided media
- ⌘ Limited bandwidth (1MHz)
- ⌘ Limited data rate (100MHz)
- ⌘ Susceptible to interference and noise

Unshielded and Shielded TP

⌘ Unshielded Twisted Pair (UTP)

- ☒ Ordinary telephone wire
- ☒ Cheapest
- ☒ Easiest to install
- ☒ Suffers from external EM interference

Unshielded Twisted Pair (UTP)



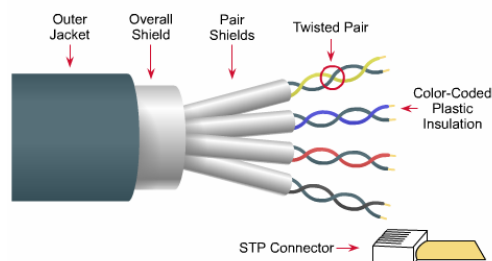
- ◆ Speed and throughput: 10 - 100 Mbps
- ◆ Average \$ per node: Least Expensive
- ◆ Media and connector size: Small
- ◆ Maximum cable length: 100m (short)

Unshielded and Shielded TP

⌘ Shielded Twisted Pair (STP)

- ☒ Metal braid or sheathing that reduces interference
- ☒ More expensive
- ☒ Harder to handle (thick, heavy)

STP (Shielded Twisted Pair)



- ◆ Speed and throughput: 10 - 100 Mbps
- ◆ Average \$ per node: Moderately Expensive
- ◆ Media and connector size: Medium to Large
- ◆ Maximum cable length: 100m (short)

UTP Categories (Recognized by EIA-568)

⌘ Cat 3

- ☒ up to 16MHz
- ☒ Voice grade found in most offices
- ☒ Twist length of 7.5 cm to 10 cm

⌘ Cat 4

- ☒ up to 20 MHz

⌘ Cat 5

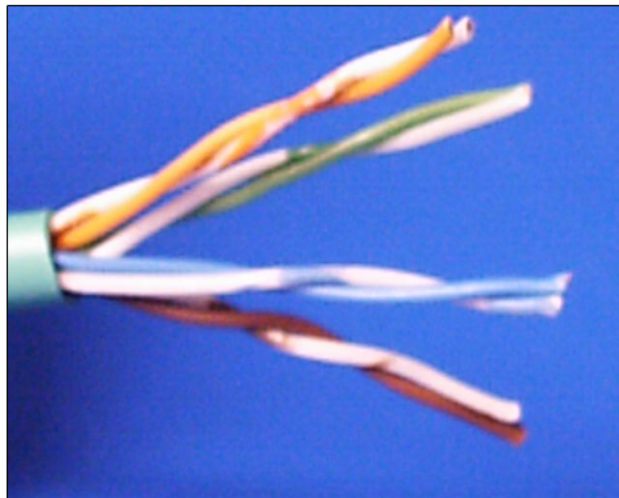
- ☒ up to 100MHz
- ☒ Commonly pre-installed in new office buildings
- ☒ Twist length 0.6 cm to 0.85 cm

Cat 3 and Cat 5 are ones mostly used for LAN applications:
- Differ in number of twists

EIA = Electronic Industries Association

UTP Categories

CAT 5 Cable

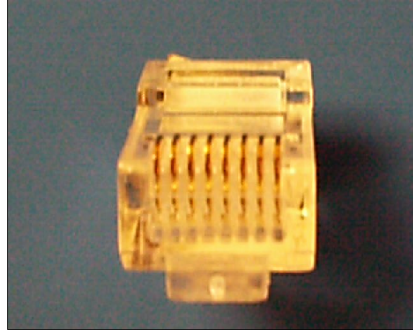


RJ-45 Connector

Multiport Repeaters (Hubs)



RJ-45 Front



Near End Crosstalk

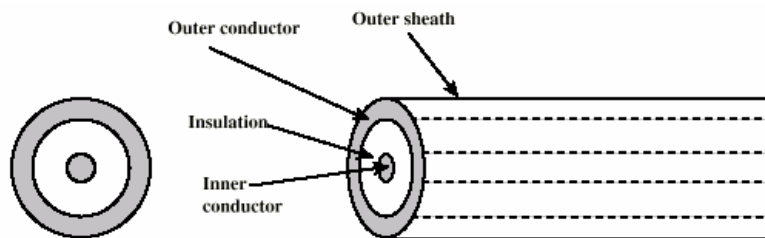
- ⌘ Coupling of signal from one pair to another
- ⌘ Coupling takes place when transmit signal entering the link couples back to receiving pair
- ⌘ i.e. near transmitted signal is picked up by near receiving pair

STP vs. UTP

Table 4.2 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

Coaxial Cable

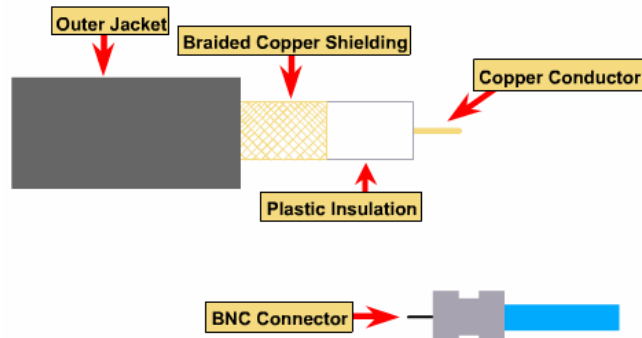


- Outer conductor is braided shield
- Inner conductor is solid metal
- Separated by insulating material
- Covered by padding

- To allow operation over wider range of frequencies
- Diameter of 1 to 2.5 cm
- Because of shielding, much less susceptible to interference and crosstalk

Coaxial Cable

Coaxial Cable



- ◆ Speed and throughput: 10 - 100 Mbps
- ◆ Average \$ per node: Inexpensive
- ◆ Media and connector size: Medium
- ◆ Maximum cable length: 500m (medium)

Coaxial Cable Applications

- ⌘ Most versatile medium
- ⌘ Television distribution
 - ☑ Ariel to TV
 - ☑ Cable TV
- ⌘ Long distance telephone transmission
 - ☑ Can carry 10,000 voice calls simultaneously (using FDM)
 - ☑ Being replaced by fiber optic
- ⌘ Short distance computer systems links
- ⌘ Local area networks

Coaxial Cable - Transmission Characteristics

⌘ Analog

- ☒ Amplifiers every few km
- ☒ Closer if higher frequency
- ☒ Up to 500MHz

⌘ Digital

- ☒ Repeater every 1km
- ☒ Closer for higher data rates

Performance limited by attenuation, thermal noise, and intermodulation noise

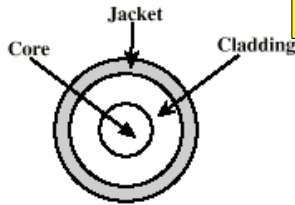
Coaxial Cable - Transmission Characteristics

10BASE2 50 Ohm Coax Cable

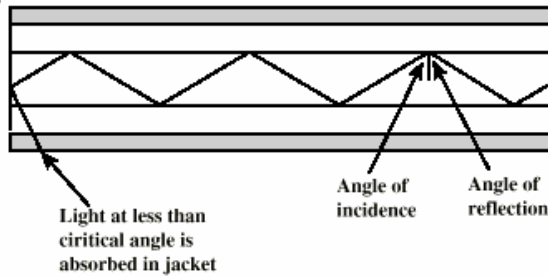


Optical Fiber

- Core: one or more thin strands or fibers (8 to 100 μ m)
- Cladding: glass or plastic coating with different optical properties than the core
- Core/Cladding interface: reflector – confine ray
- Jacket: protection against moisture, abrasion, crushing ...



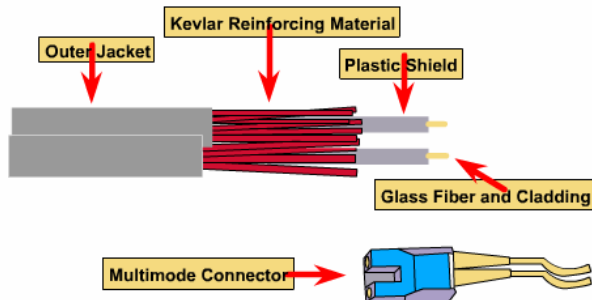
- Glass or plastic core
- Laser or light emitting diode
- Specially designed jacket
- Small size and weight



- Lowest losses using ultrapure fiber – difficult to manufacture
- Higher loss multicomponent glass fibers are more economical
- Plastic fiber is the cheapest – used for short-haul links

Optical Fiber

Fiber Optic Cable



- ◆ Speed and throughput: 100+ Mbps
- ◆ Average \$ per node: Most Expensive
- ◆ Media and connector size: Small
- ◆ Single mode, maximum cable length: Up to 3000m
- ◆ Multimode mode, maximum cable length: Up to 2000m
- ◆ Single mode: One stream of laser-generated light
- ◆ Multimode: Multiple streams of LED-generated light

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 - Applications

- ⌘ Long-haul trunks
- ⌘ Metropolitan trunks
- ⌘ Rural exchange trunks
- ⌘ Subscriber loops
- ⌘ LANs

Optical Fiber - Transmission Characteristics

⌘ Act as wave guide for 10^{14} to 10^{15} Hz

☒ Portions of infrared and visible spectrum

⌘ Light Emitting Diode (LED)

☒ Cheaper

☒ Wider operating temp range

☒ Last longer

LED – ILD: semiconductor devices that emit a beam when voltage is applied

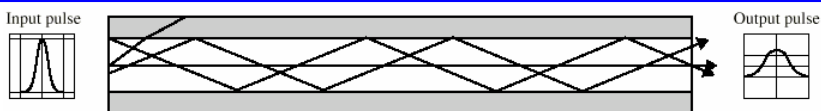
⌘ Injection Laser Diode (ILD)

☒ More efficient

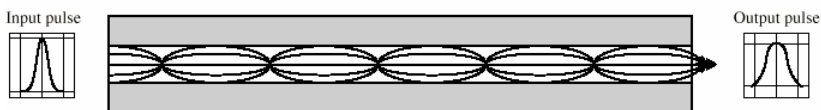
☒ Greater data rate

⌘ Wavelength Division Multiplexing

Optical Fiber Transmission Modes



(a) Step-index multimode More than one path for signal – distortion
Limits maximum data rate



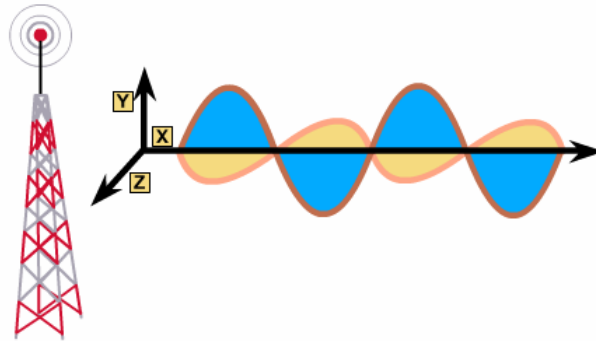
(b) Graded-index multimode Intermediate mode



(c) Single mode One path for signal – superior signal quality
- Used for long-haul telephone and TV comm

Wireless Transmission

Encoding Signals as Electromagnetic Waves



Wireless Transmission

- ⌘ Unguided media
- ⌘ Transmission and reception via antenna
- ⌘ Directional
 - ☑ Focused beam
 - ☑ Careful alignment required
- ⌘ Omnidirectional
 - ☑ Signal spreads in all directions
 - ☑ Can be received by many antennae

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

Terrestrial Microwave

⌘ Parabolic dish

⌘ Focused beam

⌘ Line of sight

⌘ Long haul telecommunications

⌘ Higher frequencies give higher data rates

Satellite Microwave

- ⌘ Satellite is relay station
- ⌘ Satellite receives on one frequency, amplifies or repeats signal and transmits on another frequency
- ⌘ Requires geo-stationary orbit
 - ☒ Height of 35,784km
- ⌘ Television
- ⌘ Long distance telephone
- ⌘ Private business networks

Broadcast Radio

- ⌘ Omnidirectional
- ⌘ FM radio
- ⌘ UHF and VHF television
- ⌘ Line of sight
- ⌘ Suffers from multipath interference
 - ☒ Reflections

Infrared

- ⌘ Modulate noncoherent infrared light
- ⌘ Line of sight (or reflection)
- ⌘ Blocked by walls
- ⌘ e.g. TV remote control, IRD port

Required Reading

- ⌘ Stallings Chapter 4