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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

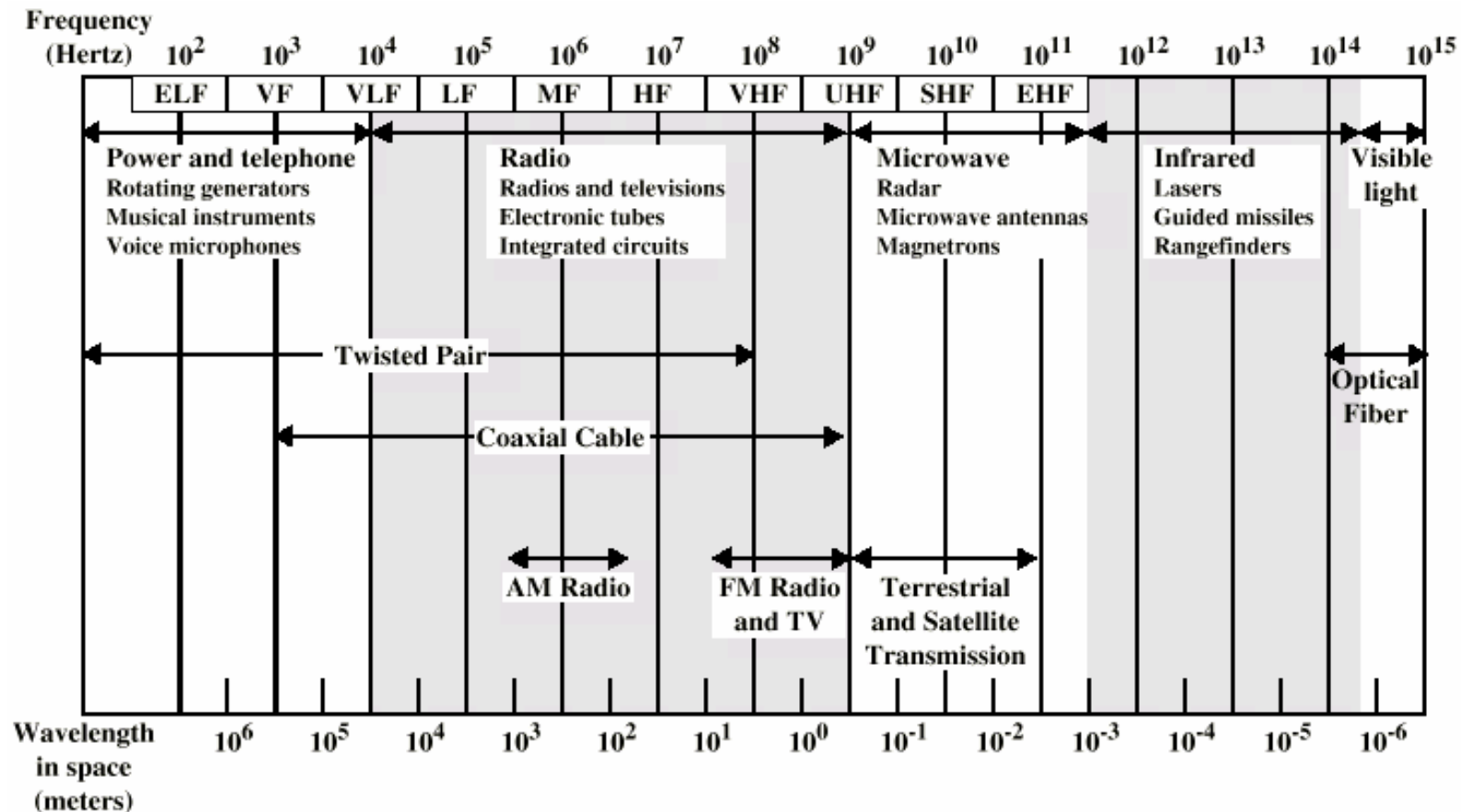
- ☑ Attenuation

⌘ Interference

⌘ Number of receivers

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

Electromagnetic Spectrum



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

Guided Transmission Media

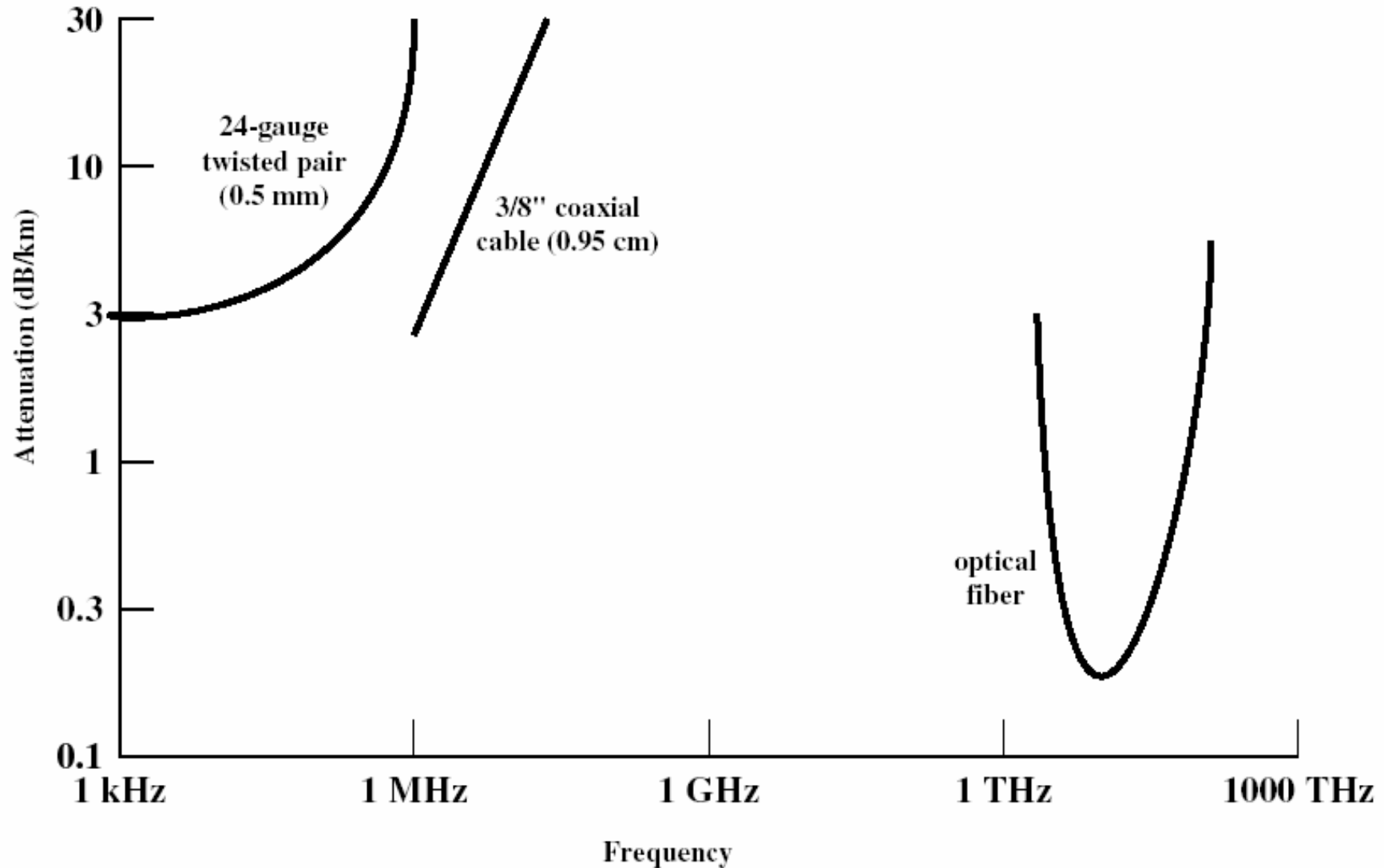
- ⌘ Twisted Pair
- ⌘ Coaxial cable
- ⌘ Optical fiber

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)

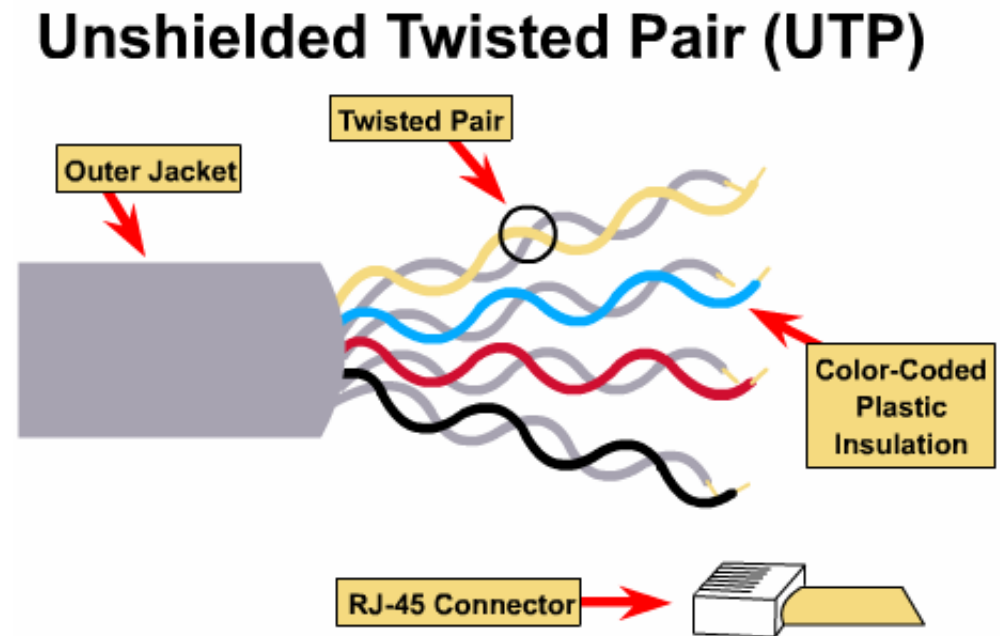
⌘ Limited data rate (100MHz)

⌘ 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



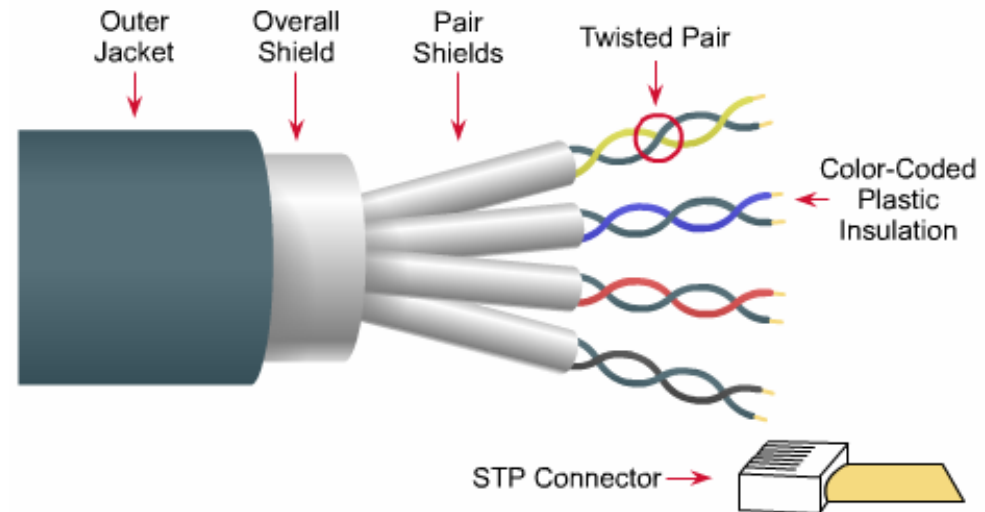
-
- ◆ Speed and throughput: 10 - 100 Mbps
 - ◆ Average \$ per node: Least Expensive
 - ◆ Media and connector size: Small
 - ◆ Maximum cable length: 100m (short)

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

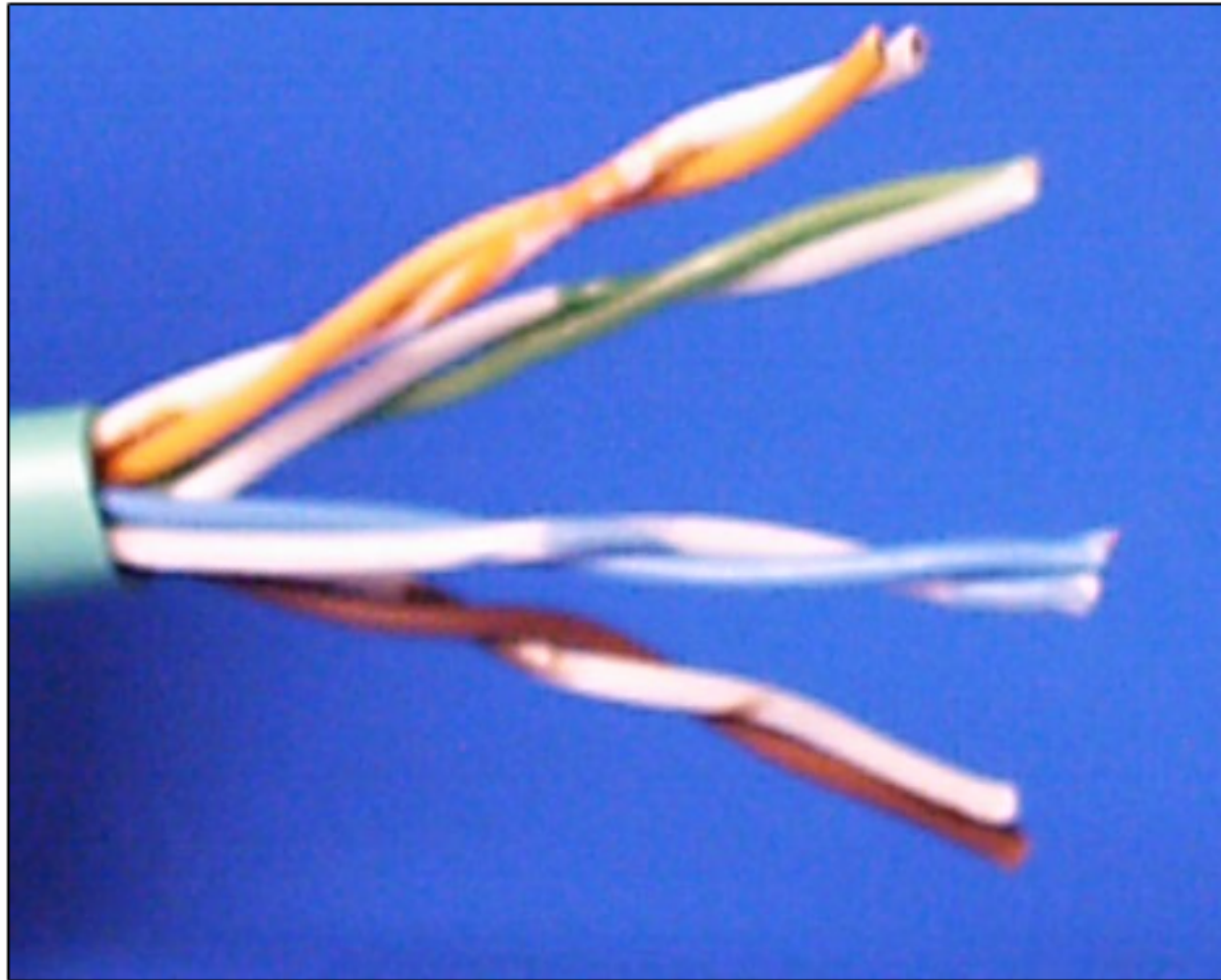
⌘ Cat 5

- ☑ 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

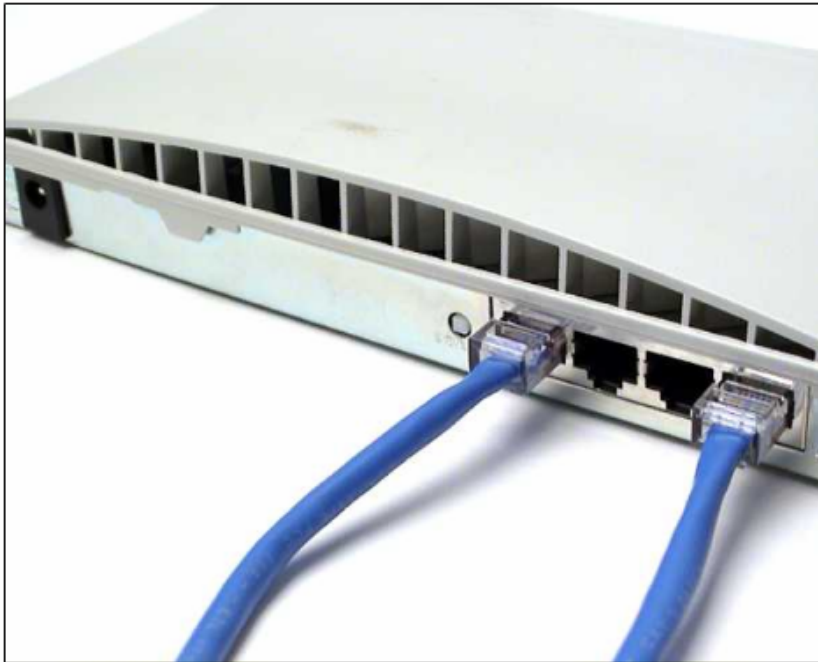
UTP Categories

CAT 5 Cable

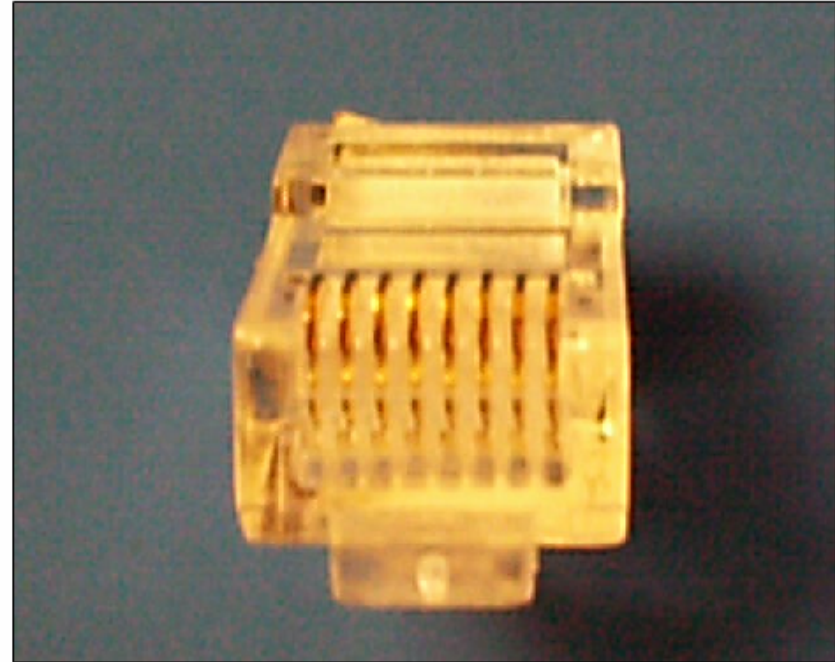


RJ-45 Connector

Multiport Repeaters (Hubs)



RJ-45 Front



Near End Crosstalk

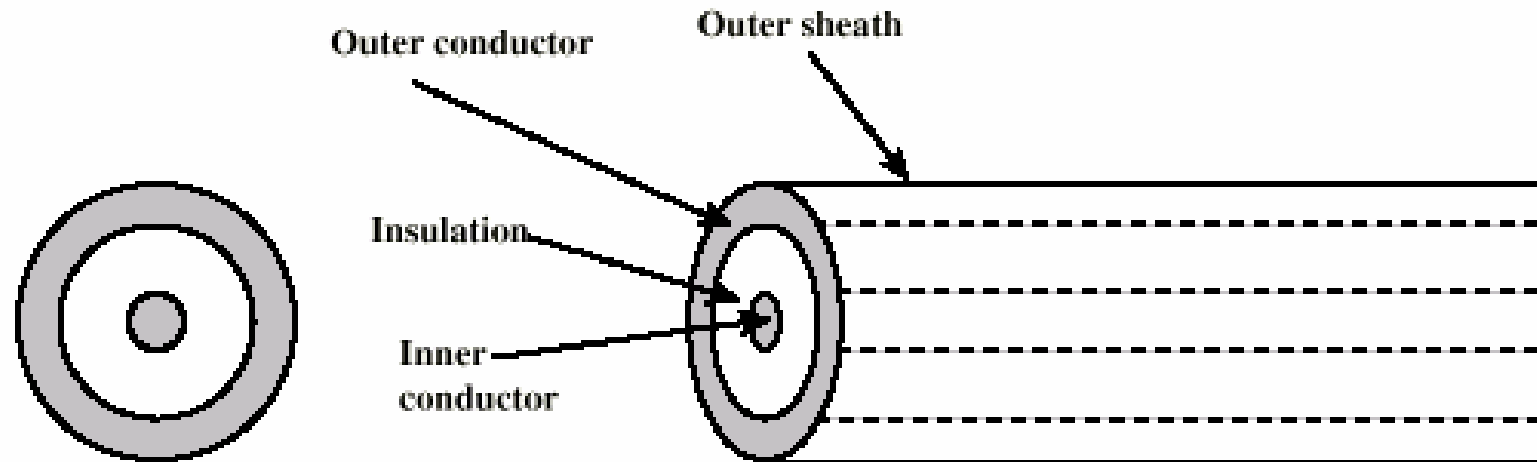
- ⌘ Coupling of signal from one pair to another
- ⌘ Coupling takes place when transmit signal entering the link couples back to receiving pair
- ⌘ i.e. near transmitted signal is picked up by near receiving pair

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

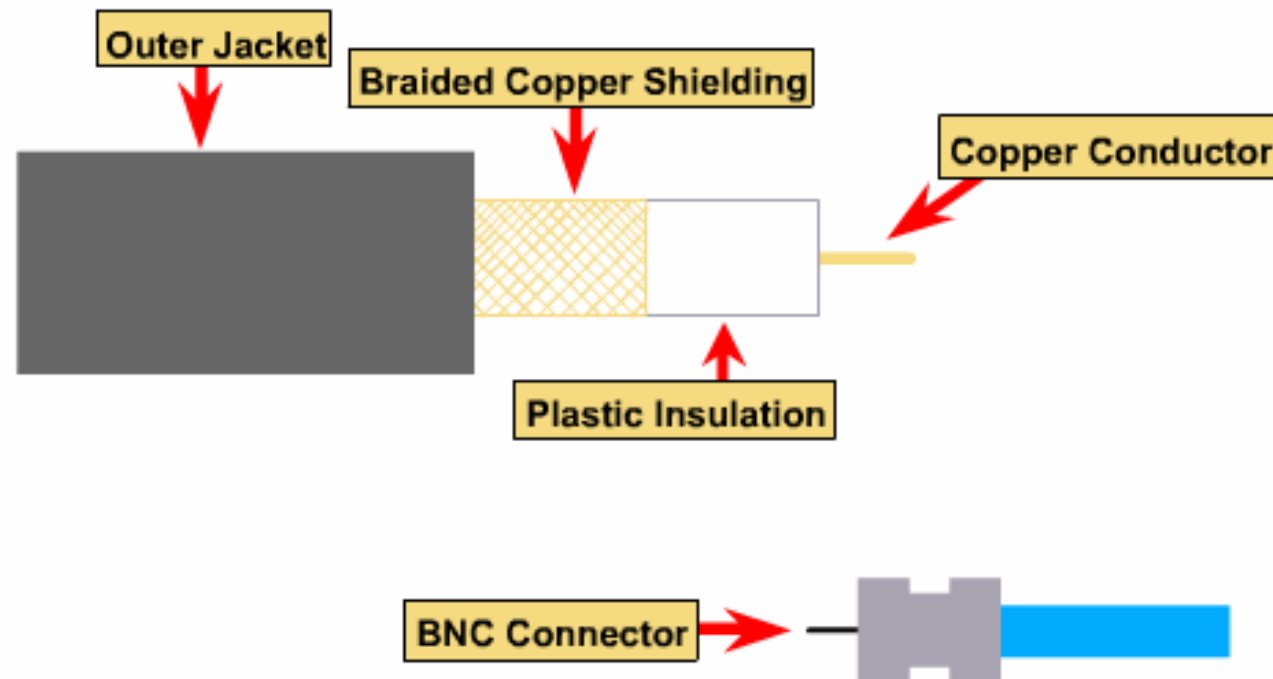


- Outer conductor is braided shield
- Inner conductor is solid metal
- Separated by insulating material
- Covered by padding

- 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

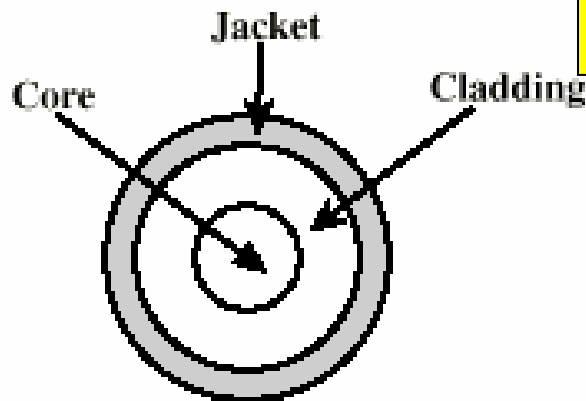
Coaxial Cable - Transmission Characteristics

10BASE2 50 Ohm Coax Cable

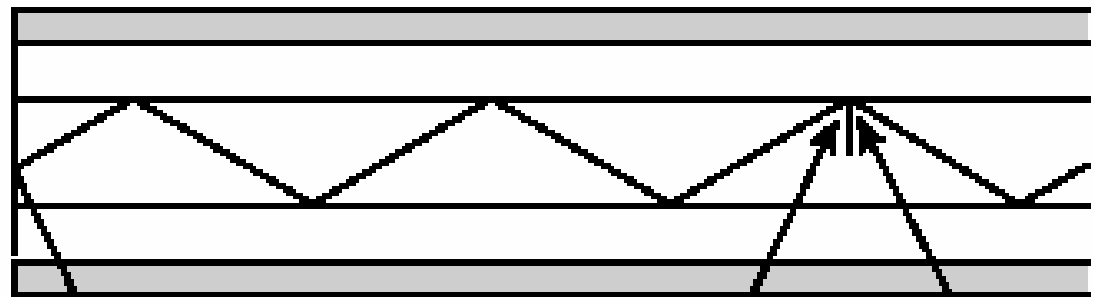


Optical Fiber

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



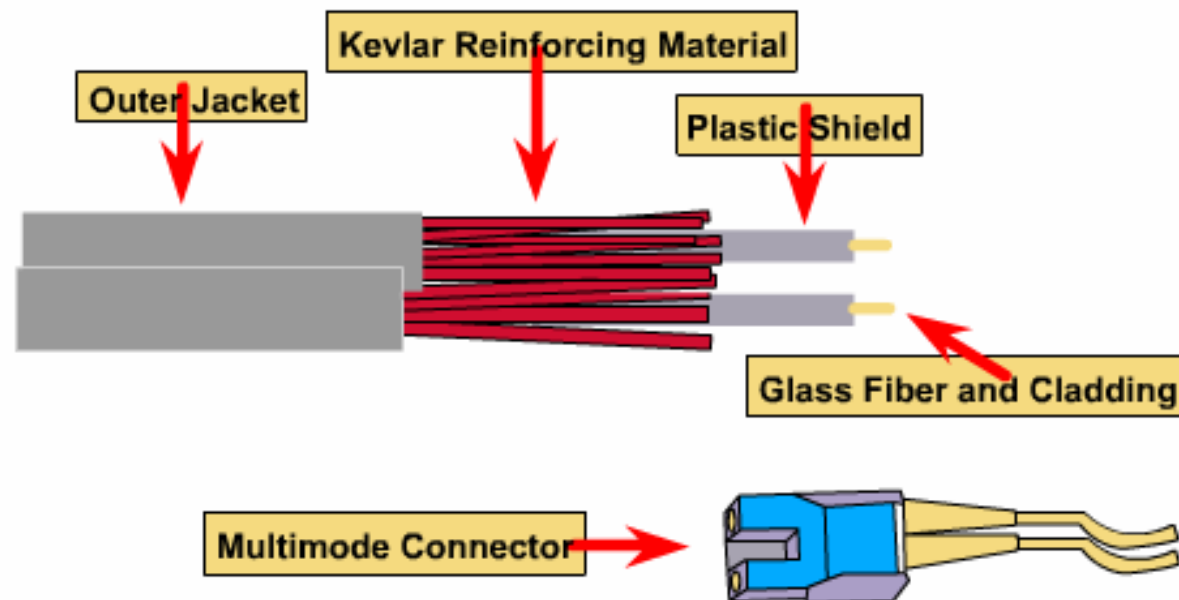
- Glass or plastic core
- Laser or light emitting diode
- Specially designed jacket
- Small size and weight



- 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)

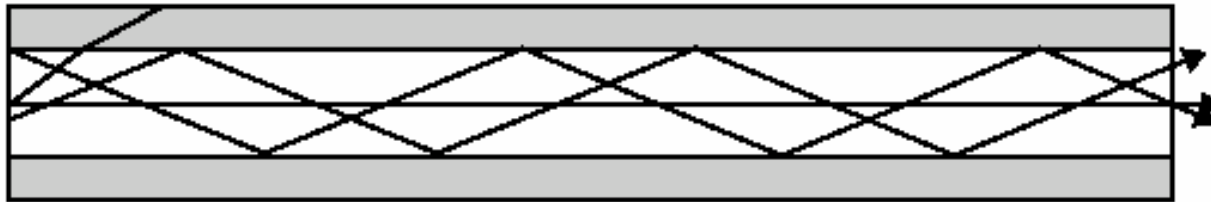
☑ More efficient

☑ Greater data rate

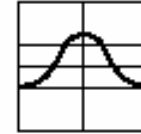
⌘ Wavelength Division Multiplexing

Optical Fiber Transmission Modes

Input pulse



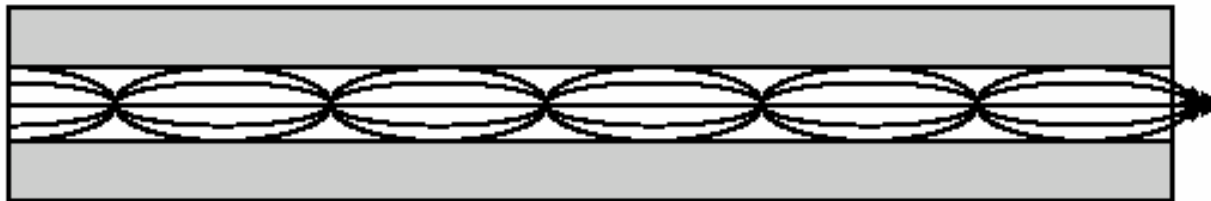
Output pulse



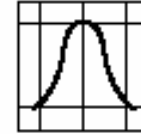
(a) Step-index multimode

More than one path for signal – distortion
Limits maximum data rate

Input pulse



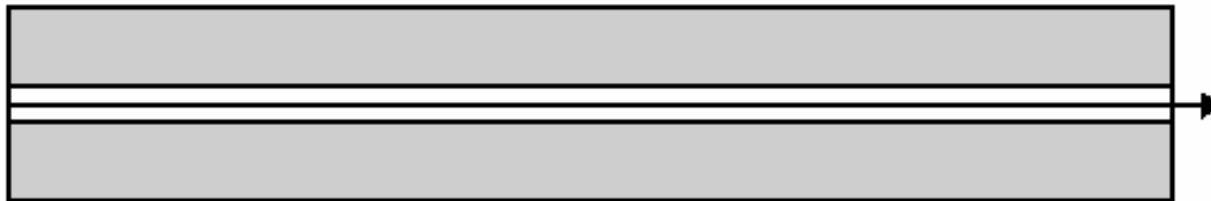
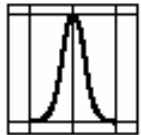
Output pulse



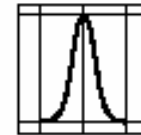
(b) Graded-index multimode

Intermediate mode

Input pulse



Output pulse

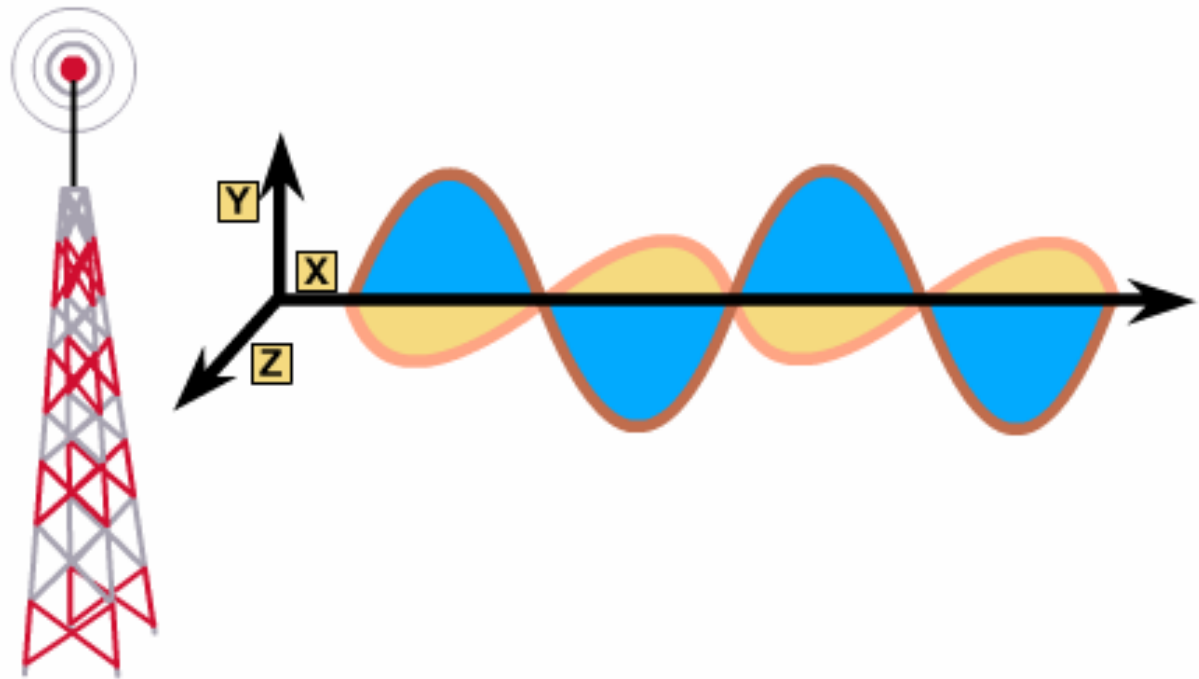


(c) Single mode

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