# Lecture (03)
# Transmission Media (I)

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## Agenda

- Overview
- Electromagnetic spectrum
- Transmission Characteristics of Guided Media
- Transmission Characteristics of Un-guided Media
- Twisted pair
- Unshielded TP vs. Shielded TP
- Coaxial cable
- Optical Fiber
- Attenuation in Guided Media



## Overview

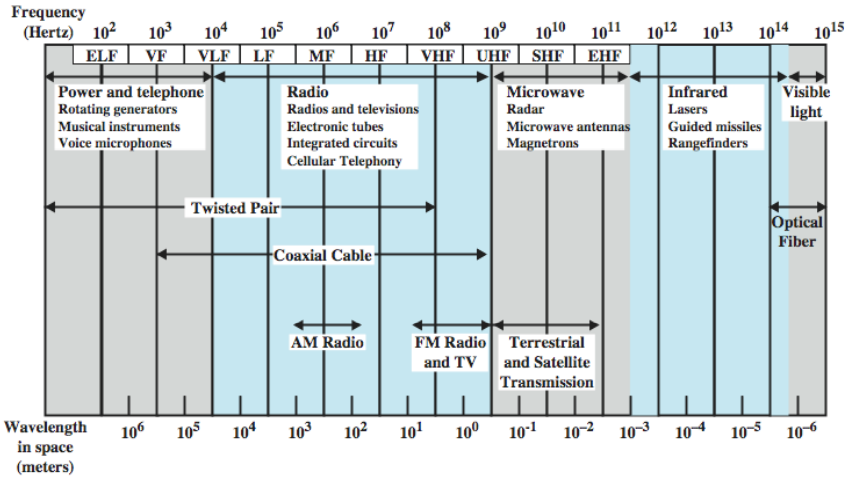
- The transmission media classified as guided or unguided.
- **Guided** media provide a physical path along which the signals are propagated; these include twisted pair, coaxial cable, and optical fiber.
- **Unguided** media employ an antenna for transmitting through air, vacuum, or water.
- The characteristics and quality of a data transmission are determined both by
  - the characteristics of the medium and
  - the characteristics of the signal.



## Overview (cont,..)

- For **guided media**, the medium itself is more important in determining the limitations of transmission.
- For **unguided media**, the
  - bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics.
  - One key property of signals transmitted by antenna is directionality.
    a. The lower frequencies are omnidirectional; that is, the signal propagates in all directions from the antenna.
    b. The higher frequencies are directional, it is possible to focus the signal into a directional beam.

# Electromagnetic spectrum




# Transmission Characteristics of Guided Media

- For guided transmission media, the transmission capacity, (data rate) or (bandwidth), depends on the
  - distance and on
  - whether the medium is point-to-point or multipoint.
- The three guided media commonly used for data transmission are
  - twisted pair,
  - coaxial cable, and
  - optical fiber
- Next table indicates the characteristics typical for the common guided media for long distance point-to-point applications;



# Transmission Characteristics of Guided Media (cont,..)

| | 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 (multi-pair cables) | 0 to 1 MHz | 0.7 dB/km @ 1 kHz | 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 |



# Transmission Characteristics of Un-Guided Media

- 2GHz to 40GHz
  - microwave
  - Satellite

  highly directional
  point to point
- 30MHz to 1GHz
  - broadcast radio

  omnidirectional
- 3 x $10^{11}$ to 2 x $10^{14}$
  - infrared
  - Local Area Network

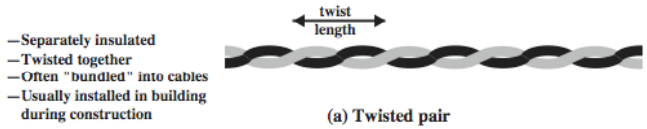
  Directional (Pencil Beam)

# Twisted pair

- the most common guided transmission medium for both analog and digital signals is twisted pair.

**Applications**

- Telephone network (linking residential telephones to the local telephone exchange, or office phones to a PBX)
- communications within buildings for LANs running at 10-100Mbps



(a) Twisted pair



# Twisted pair (cont,..)

**Structure & Characteristics**

- A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern.
- A wire pair acts as a single communication link.
- The twisting tends to decrease the crosstalk interference between adjacent pairs in a cable
- a number of these pairs are bundled together into a cable by wrapping them in a tough protective shield
- Neighboring pairs in a bundle typically have somewhat different twist lengths to reduce the crosstalk interference
- On long distance links, the twist length typically varies from 5 to 15 cm.
- The wires in a pair have thicknesses of from 0.4 to 0.9 mm.



# Twisted pair (cont,..)

**Deployment**

- Twisted pair may be used to transmit both analog and digital transmission.
- For analog signals, amplifiers are required about every 5 to 6 km.
- For digital transmission (using either analog or digital signals), repeaters are required every 2 or 3 km.



# Twisted pair (cont,..)

**Disadvantages**

- twisted pair is limited in distance, bandwidth, and data rate comparing to coaxial cable, optical fiber

  ***(uses repeaters or amplifiers)***
- The attenuation is a very strong function of frequency.

  ***(used for relatively low frequency)***
- The medium is quite susceptible to interference and noise because of its easy coupling with electromagnetic fields.

  ***(Shielding the wire with metallic shield)***

  ***(use of different twist lengths in adjacent pairs reduces crosstalk)***

# Twisted pair (cont,..)

**Bandwidth**

- For point-to-point analog signaling, a bandwidth of up to about 1 MHz is possible.
- For long-distance digital point-to-point signaling, data rates of up to a few (100) Mbps are possible;
- for very short distances, data rates of up to 10Gbps have been achieved in commercially available products.



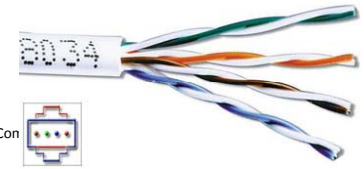
# Unshielded TP vs Shielded TP

**Unshielded twisted pair (UTP)**

- Is ordinary telephone wire.
- Used for telephone networks and local area networks
- least expensive of all the transmission media
- UTP is subject to external electromagnetic interference, including interference from nearby twisted pair and from noise generated in the environment.
- UTP is a 100-ohm cable commonly referred to as voice grade cable.

Shielded twisted pair (STP)

Unshielded twisted pair (UTP)







# Unshielded TP vs Shielded TP (cont,..)

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 |



# Unshielded TP vs Shielded TP (cont,..)

- Category 3: (voice grade cable) UTP cables and associated connecting hardware whose transmission characteristics are specified up to 16 MHz
- Category 4: UTP cables and associated connecting hardware whose transmission characteristics are specified up to 20 MHz
- Category 5: (data-grade cable) UTP cables and associated connecting hardware whose transmission characteristics are specified up to 100 MHz

# Unshielded TP vs Shielded TP (cont,..)

**Shielded Twisted Pair**

- A way to improve the characteristics of UTP is to shield the twisted pair with a metallic braid or sheathing that reduces interference
- (STP) provides better performance at higher data rates.
- it is more expensive and more difficult to work with than unshielded twisted pair.
- STP is 150 ohm cable



# Unshielded TP vs Shielded TP (cont,..)

STP & UTP comparison

| | 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 |



# Unshielded TP vs Shielded TP (cont,..)

- The first parameter used for comparison, **attenuation**
- The second parameter is **Near-end crosstalk** as it applies to twisted pair wiring systems is the coupling of the signal from one pair of conductors to another pair.
- Ex: the metal pins in a connector or wire pairs in a cable.
- The near end refers to coupling that takes place when the transmit signal entering the link couples back to the receive conductor pair at that same end of the link



# Coaxial cable

**Structure**

- Coaxial cable, like twisted pair, consists of two conductors, but is constructed differently to permit it to operate over a wider range of frequencies.
- It consists of outer cylindrical conductor that surrounds a single inner wire conductor

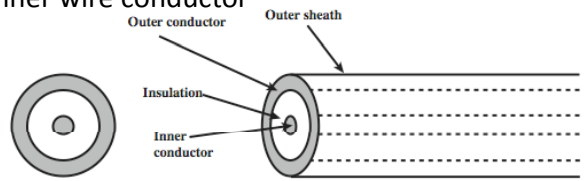



Fig. Coaxial cable

# Coaxial cable (cont,..)

- The inner conductor is held in place by either regularly spaced insulating rings or a solid dielectric material

**Characteristics**

- Coaxial cable can be used over longer distances
- support more stations on a shared line than twisted pair.
- used to transmit both analog and digital signals
- Used effectively at higher frequencies and data rates
- much less susceptible to interference and
- crosstalk than twisted pair.



# Coaxial cable (cont,..)

**Applications**

- Television distribution - aerial to TV & CATV systems
- Long-distance telephone transmission - traditionally used for inter-exchange links, now being replaced by optical fiber/microwave/satellite
- Short-run computer system links
- Local area networks



# Coaxial cable (cont,..)

**Deployment**

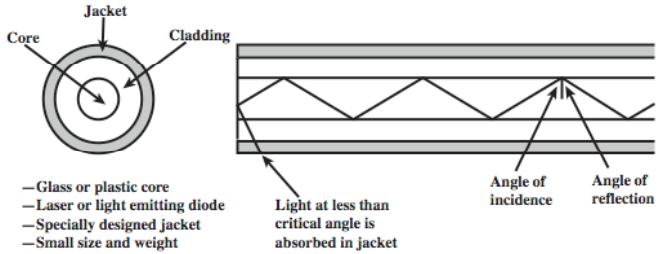
- For long-distance transmission of analog signals, amplifiers are needed every few kilometers, with closer spacing required if higher frequencies are used.
- The usable spectrum for analog signaling extends to about 500 MHz.
- For digital signaling, repeaters are needed every kilometer or so, with closer spacing needed for higher data rates.



# Optical Fiber

**Structure**

- An optical fiber is a thin (2 to 125 µm), flexible medium capable of guiding an optical ray.
- Various glasses and plastics can be used to make optical fibers.




(c) Optical fiber

# Optical Fiber (cont,..)

- An optical fiber cable has a cylindrical shape and consists of three concentric sections: the core, the cladding, and the jacket
- The **core** is the innermost section and consists of one or more very thin fiber, made of glass or plastic; has a diameter in the range of 8 to 50 µm.
- **cladding**, is a glass or plastic coating that has optical properties different from those of the core and a diameter of 125 µm.
- The interface between the core and cladding acts as a reflector to confine light that would otherwise escape the core.



# Optical Fiber (cont,..)

- **Jacket** is composed of plastic and other material layered to protect against moisture, abrasion, crushing, and other environmental dangers.



# Optical Fiber (cont,..)

**Usage & Application**

- Optical fiber used in long-distance telecommunications, and in military applications is growing.
- Five basic categories of application have become important for optical fiber:
  - Long-haul trunks,
  - Metropolitan trunks,
  - Rural exchange trunks,
  - Subscriber loops &
  - Local area networks.



# Optical Fiber (cont,..)

**Advantages**

- Greater capacity, data rates of hundreds of Gbps over tens of kilometers,
- **Smaller size and lighter weight**
- **Lower attenuation:** Attenuation is significantly lower for optical fiber than for coaxial cable or twisted pair, and is constant over a wide range.
- **Electromagnetic isolation:** Optical fiber systems are not affected by external electromagnetic fields.

  Thus the system is not vulnerable to interference, impulse noise, or crosstalk.

# Optical Fiber (cont,..)

- **Security,** there is little interference with other equipment and there is a high degree of security from eavesdropping. In addition, fiber is inherently difficult to tap.
- **Greater repeater spacing:** Fewer repeaters mean lower cost and fewer sources of error.



# Optical Fiber (cont,..)

**Theory of operation**

- Optical fiber transmits a signal-encoded beam of light by means of **total internal reflection.**
- Total internal reflection can occur in any transparent medium that has a higher index of refraction than the surrounding medium
- Optical fiber acts as a waveguide for frequencies in the range of about $10^{14}$ to $10^{15}$ Hertz;
- this covers portions of the infrared and visible spectra.



# Optical Fiber (cont,..)

- Two different types of light source are used in fiber optic systems:
  - the light-emitting diode (LED)
  - the injection laser diode (ILD).
- LED
  - is less costly,
  - operates over a greater temperature range,
  - has a longer operational life.
- ILD,
  - operates on the laser principle,
  - more efficient and can sustain greater data rates.



# Optical Fiber (cont,..)

**Mode of operation**

**Single mode:**

- Have a single transmission path,
- By reducing the radius of the core to the order of a wavelength, only a single angle or mode can pass: the axial ray.
- Single-mode is typically used for long-distance applications, including telephone and cable television.


(c) Single mode

# Optical Fiber (cont,..)

**Multimode**

- multiple propagation paths exist, each with a different path length and hence time to traverse the fiber.
- This causes signal elements (light pulses) to spread out in time, which limits the rate at which data can be accurately received.
- This type of fiber is best suited for transmission over very short distances.

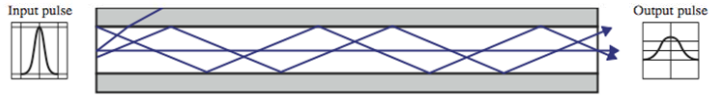


# Optical Fiber (cont,..)

There are two types of multimode;

**step-index multimode**

- Rays at shallow angles are reflected and propagated along the fiber; other rays are absorbed by the surrounding material.




(a) Step-index multimode



# Optical Fiber (cont,..)

**graded-index multimode**

- The core has varying the index of refraction.
- The higher refractive index (discussed subsequently) at the center makes the light rays moving down the axis advance more slowly than those near the cladding.
- Rather than zig-zagging off the cladding, light in the core curves helically because of the graded index reducing its travel distance The shortened path and higher speed index, distance.
- allows light at the periphery to arrive at a receiver at about the same time as the straight rays in the core axis.
- Graded-index fibers are often used in local area networks



# Optical Fiber (cont,..)

**Deployment**

| Wavelength (in vacuum) range (nm) | Frequency Range (THz) | BW (THz) | Band Label | Fiber Type | Application |
|---|---|---|---|---|---|
| 820 to 900 | 366 to 333 | 33 | | Multimode | LAN |
| 1280 to 1350 | 234 to 222 | 12 | S | Single mode | Various |
| 1528 to 1561 | 196 to 192 | 4 | C | Single mode | WDM |
| 1561 to 1620 | 192 to 185 | 7 | L | Single mode | WDM |

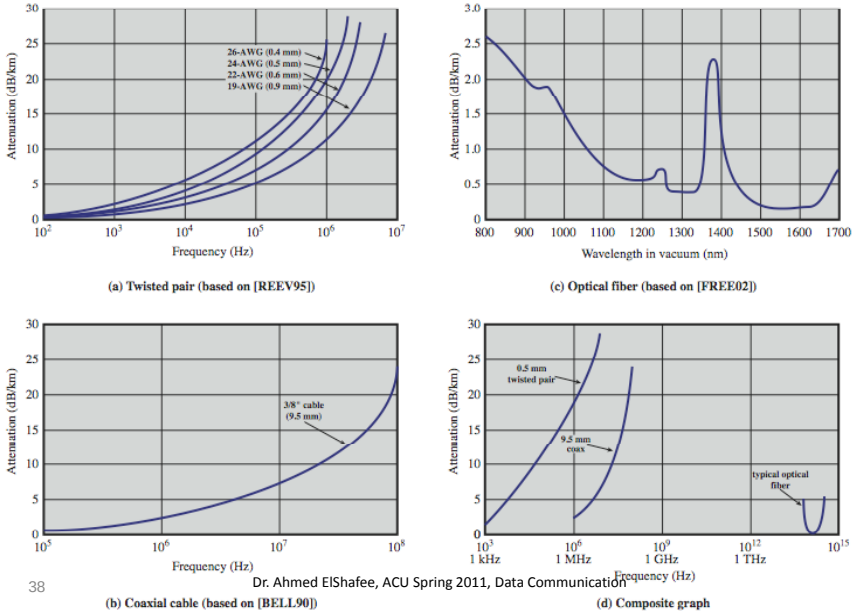
Note: WDM = wavelength division multiplexing

# Optical Fiber (cont,..)

- Many local applications today use 850-nm LED light sources.
- Although this combination is relatively inexpensive, it is generally limited to data rates under 100 Mbps and distances of a few kilometers.
- To achieve higher data rates and longer distances, a 1300-nm LED or laser source is needed.
- The highest data rates and longest distances require 1500-nm laser sources.



# Attenuation in Guided Media






# Attenuation in Guided Media (cont,..)

- attenuation for twisted pair is a very strong function of frequency.
- coaxial cable has frequency characteristics that are superior to those of twisted pair and can hence be used effectively at higher frequencies and data rates.
- For fiber, The unusual shape of the curve is due to the combination of a variety of factors that contribute to attenuation.
- The two most important of these are absorption and scattering, which is the change in direction of light rays after they strike small particles or impurities in the medium.



Thanks,…