



# Lecture (03)

## Transmission Media (I)

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Dr. Ahmed ElShafee

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## Agenda

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- 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

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# Overview

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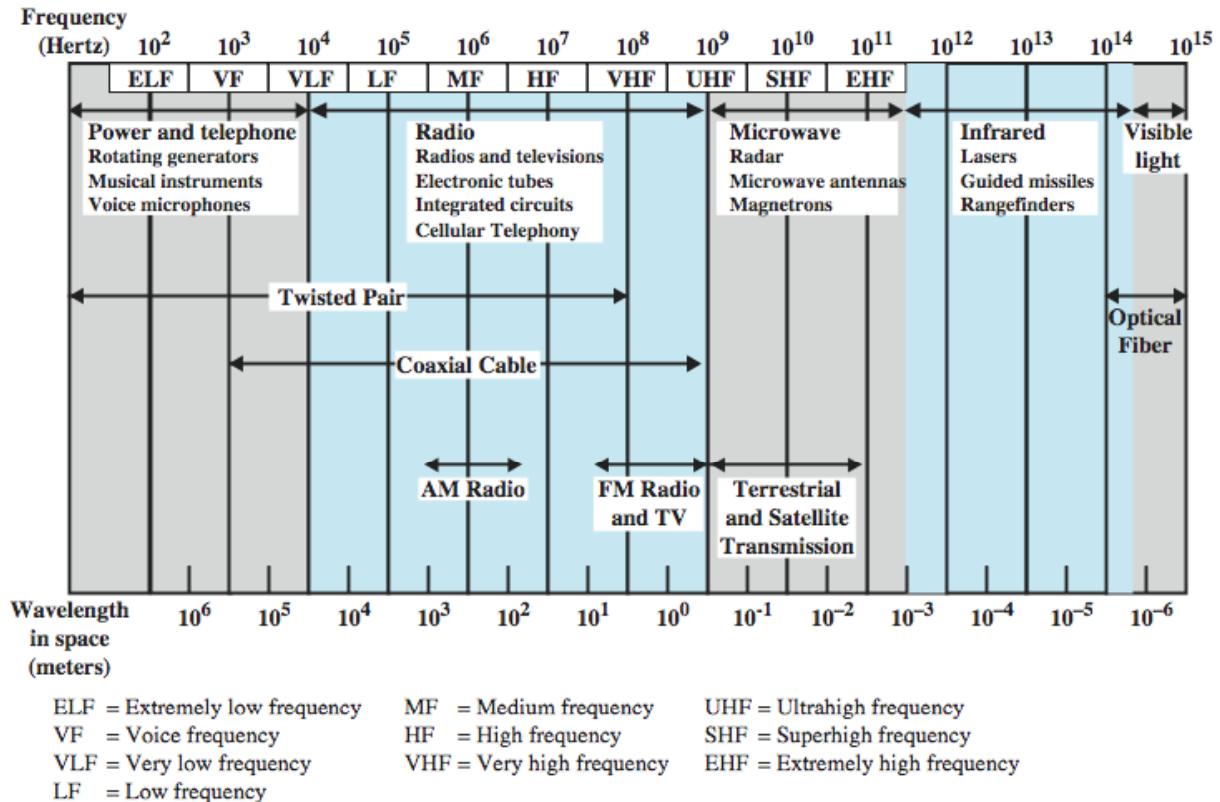
- The transmission media classified as guided or unguided.
- **Guided** media provide a physical path along which the signals are propagated; these include twisted pair, coaxial cable, and optical fiber.
- **Unguided** media employ an antenna for transmitting through air, vacuum, or water.
- The characteristics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

# Overview (cont,..)

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- 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,..)

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	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 $\mu$ s/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 $\mu$ s/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 $\mu$ s/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/km	5 $\mu$ s/km	40 km

# Transmission Characteristics of Un-Guided Media

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- 2GHz to 40GHz
  - microwave
  - Satellite
  - highly directional
  - point to point
- 30MHz to 1GHz
  - broadcast radio
  - omnidirectional
- $3 \times 10^{11}$  to  $2 \times 10^{14}$ 
  - infrared
  - Local Area Network
  - Directional (Pencil Beam)

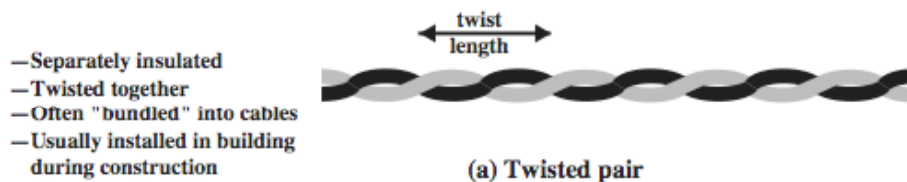
# Twisted pair

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- 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



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# Twisted pair (cont,..)

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## 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.

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## Twisted pair (cont,..)

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### 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,..)

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### 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,..)

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## 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

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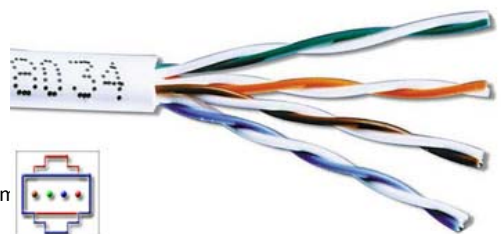
## Unshielded twisted pair (UTP)

- 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,..)

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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

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

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- 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,..)

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## 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,..)

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## STP & UTP comparison

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

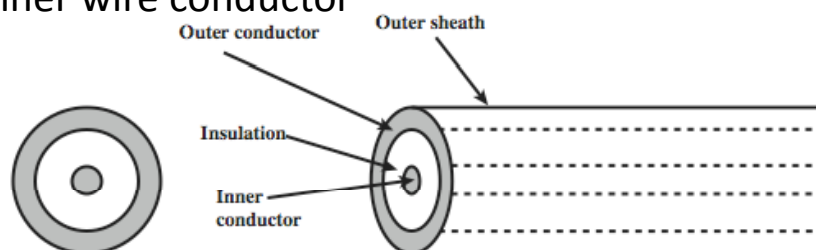
# Unshielded TP vs Shielded TP (cont,..)

- 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



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

## Coaxial cable (cont,..)

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- 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,..)

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### **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,..)

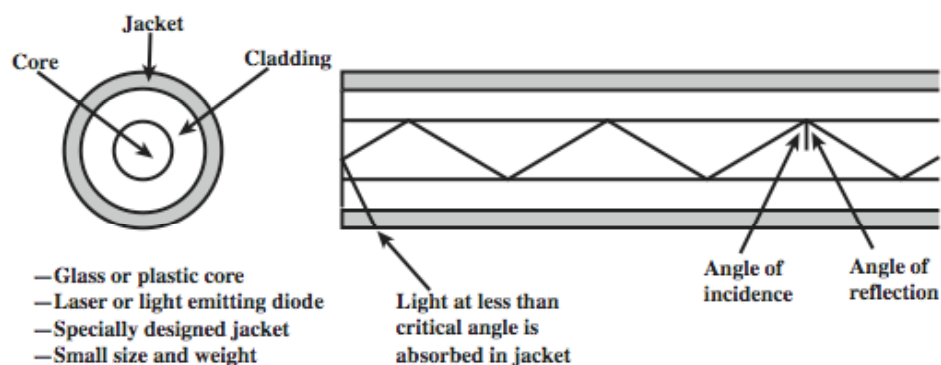
## Deployment

- 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  $\mu\text{m}$ ), 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,..)

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- 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  $\mu\text{m}$ .
- **cladding**, is a glass or plastic coating that has optical properties different from those of the core and a diameter of 125  $\mu\text{m}$ .
- The interface between the core and cladding acts as a reflector to confine light that would otherwise escape the core.

## Optical Fiber (cont,..)

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

# Optical Fiber (cont,..)

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## 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,..)

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## 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,..)

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- **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,..)

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### 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,..)

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- 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.

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## Optical Fiber (cont,..)

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### 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

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# Optical Fiber (cont,..)

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## 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.

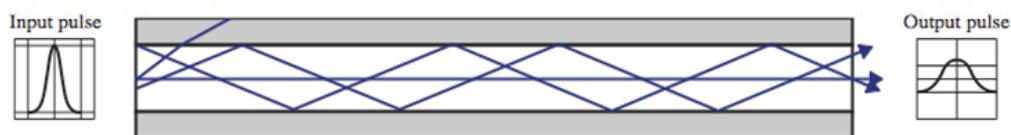
# Optical Fiber (cont,..)

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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,..)

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## 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

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# Optical Fiber (cont,..)

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## 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

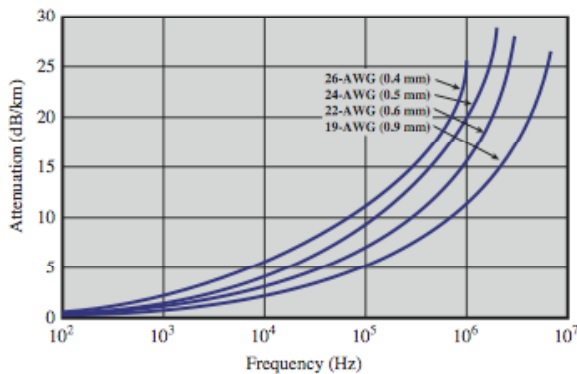
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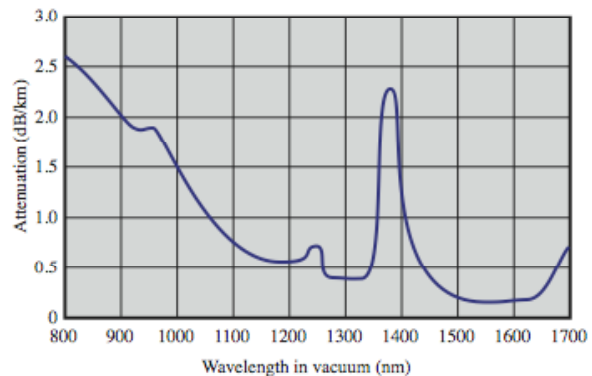
# Optical Fiber (cont,..)

- 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.

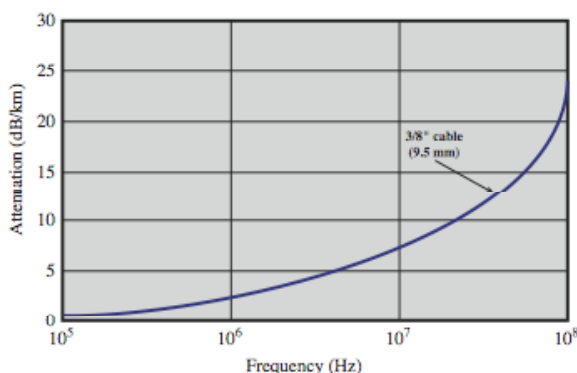
## Attenuation in Guided Media



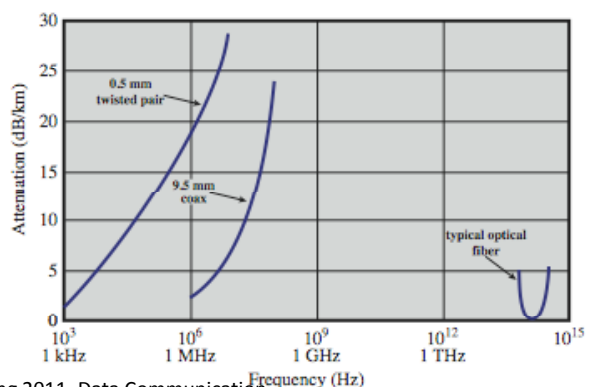
(a) Twisted pair (based on [REEV95])



(c) Optical fiber (based on [FREE02])



(b) Coaxial cable (based on [BELL90])



(d) Composite graph

# Attenuation in Guided Media (cont,..)

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- 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.

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Thanks,...