CS311: Data Communication

Guided Transmission Media

by

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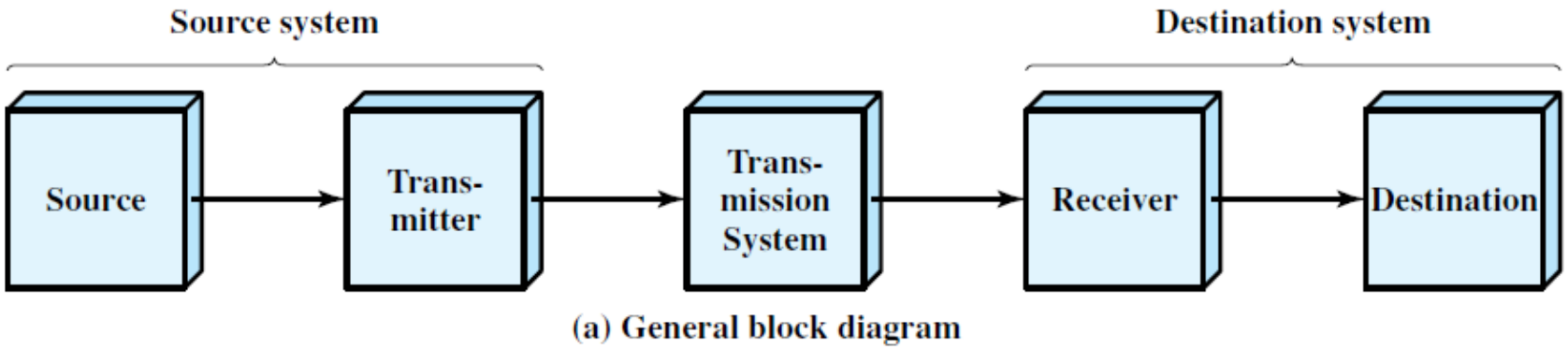
Outline of the Lecture

- Transmission Media Classification
- Introduction to Guided Transmission
- Characteristics and Applications of
  - Twisted-Pair Cable
  - Coaxial Cable
  - Optical Fibre Cable

Transmission Medium



(a) General block diagram

- Physical path between transmitter and the receiver in a data communication system is called the Transmission medium.

Classification of Transmission Media

Types of Transmission Media:

- Guided Media: Electromagnetic waves are guided along a solid medium such as copper twisted pair, copper coaxial cable or an optical fiber.

- Unguided Media: Provides a means for transmitting electromagnetic signals through the atmosphere or outer space. Can also be termed as Wireless Communication.

Quality of Transmission

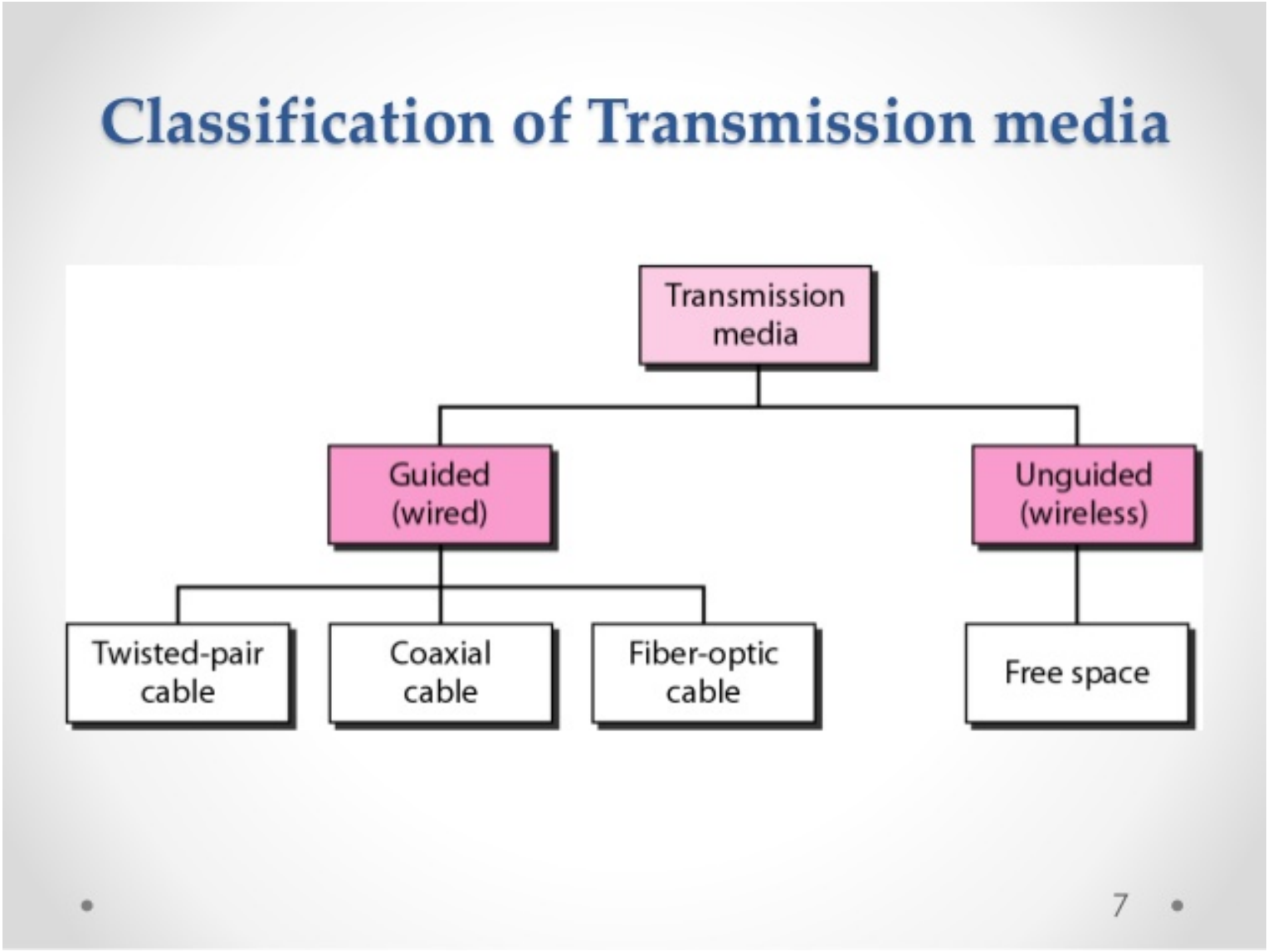
- Characteristics and quality of data transmission are determined by medium and signal characteristics.
- For guided media, the medium is more important in determining the limitations of transmission.
- For unguided media, the bandwidth of the signal produced by the transmitting antenna is more important than the medium.
- In general, signals at lower frequencies are omnidirectional.
- At higher frequencies, it is possible to focus the signal into a directional beam.

Cont…

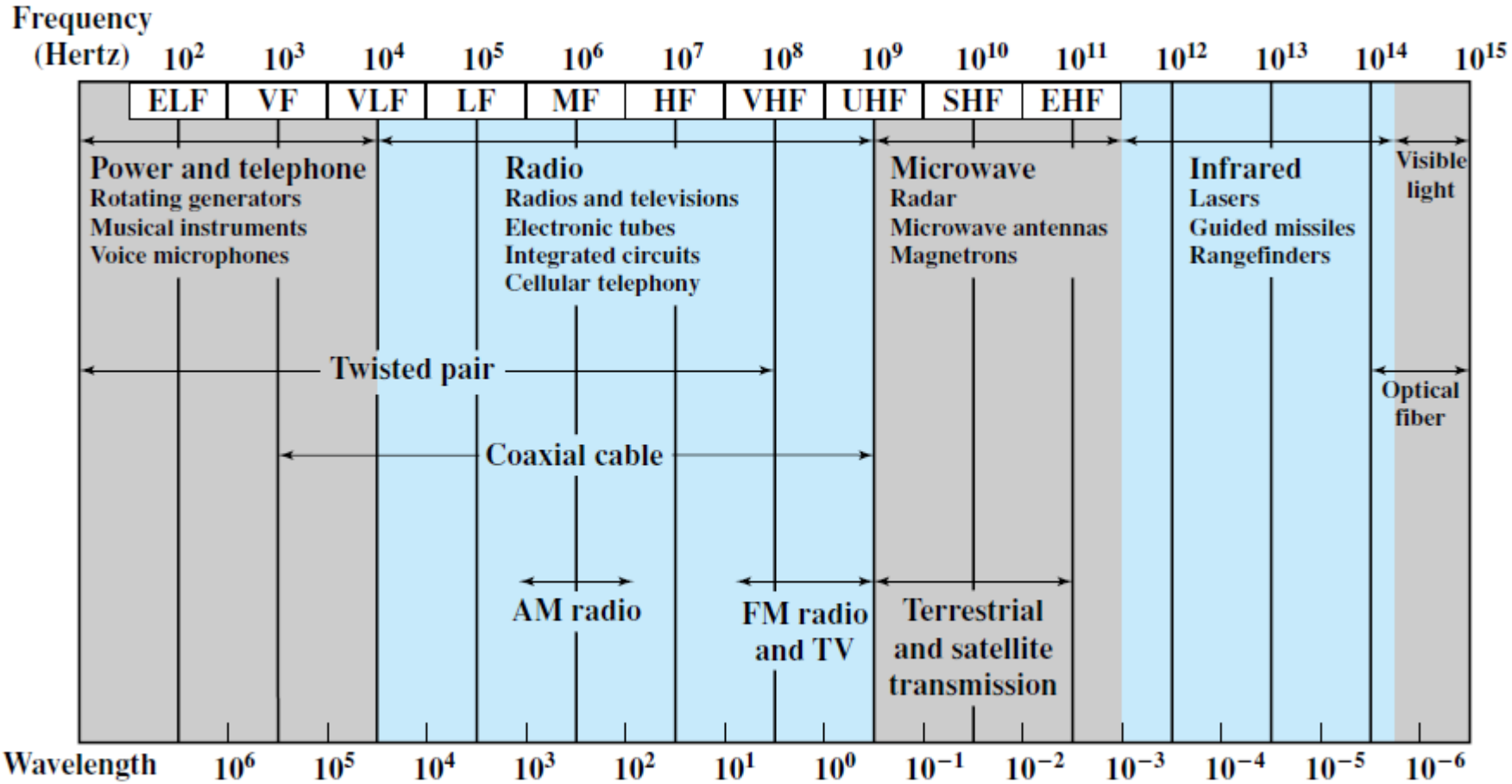
- Key concerns for data transmission system
  - Data rate & Distance

- Design factors which determine the data rate and distance
  - Bandwidth
    - Greater the bandwidth of a signal, the higher the data rate
  - Transmission Impairments
    - attenuation limits the distance
    - Attenuation varies in different medium
    - Twisted pair > coaxial cable > optical fiber
  - Interference
    - Cause of distortion in received signal
    - More problematic in unguided media
  - Number of receivers
    - Signal receiving point introduces some attenuation and distortion

Different Media



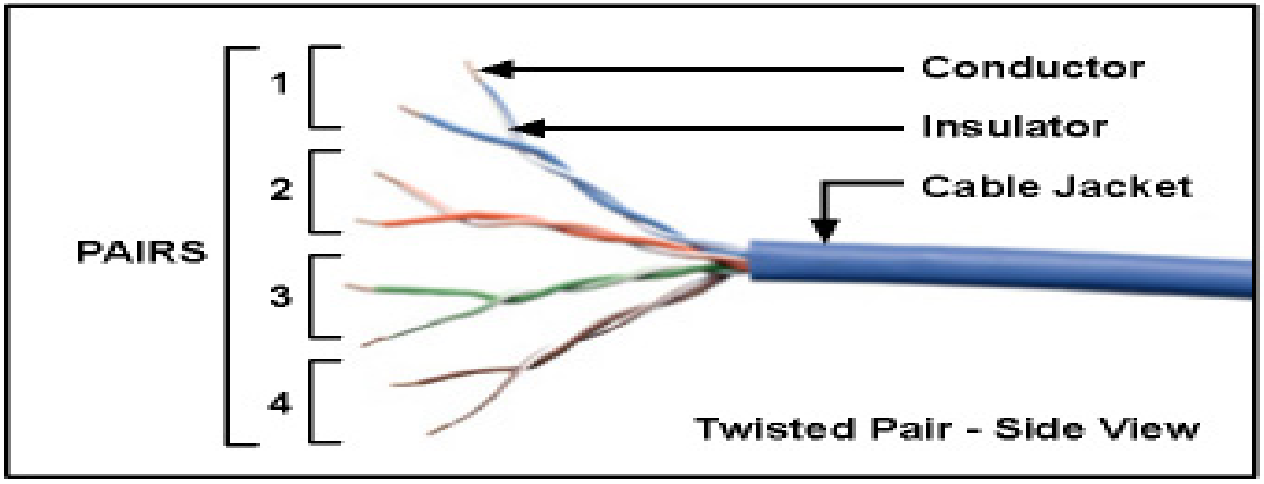
Electromagnetic Spectrum



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 = Ultra high frequency
SHF = Super high frequency
EHF = Extremely high frequency

Twisted Pair Cable

- A twisted pair cable consists of two insulated copper wires arranged in a regular spiral pattern.
- Typically, a number of pairs are bundled together into a cable by wrapping them in a tough protective sheath.
- Least expensive and most widely used



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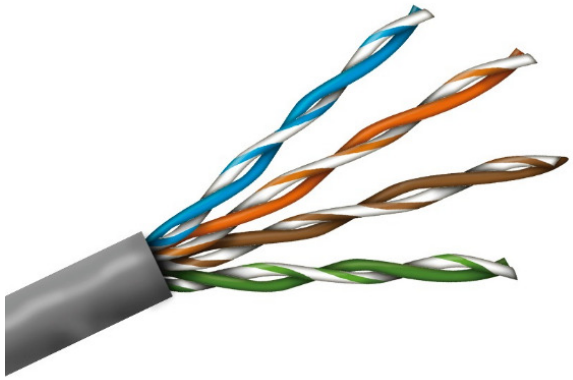
Why Twisting?

- Twisting decreases the crosstalk interference between adjacent pairs in a cable.
- Tighter twisting provides much better performance but also increases the cost.
- Neighbouring pairs in a bundle typically have somewhat different twist lengths to reduce the crosstalk interference.



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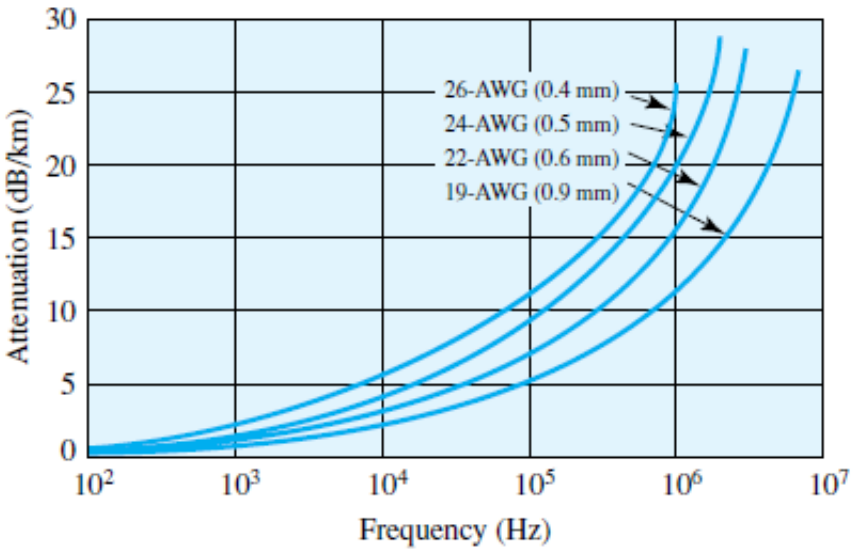
- Transmission characteristics:
  - used to transmit both analog and digital transmission
  - attenuation for twisted pair is a very strong function of frequency



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

  - The medium is quite susceptible to interference and noise because of its easy coupling with electromagnetic fields
  - Impulse noise (e.g. lightening, electric spark) also easily intrudes into twisted pair

Types of Twisted Pair

- Two common types of twisted pair cables are
  - Unshielded Twisted pair (UTP)
    - E.g., ordinary telephone wire; local ethernet cable
  - Shielded Twisted pair (STP)
    - E.g., voice and data grade cables

Cont…

UTP Categories - Copper Cable				
UTP Category	**Data Rate**	**Max. Length**	**Cable Type**	**Application**
CAT1	Up to 1Mbps	-	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	-	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Rink & 10BASE-T Ethernet
CAT4	Up to 16Mbps	100m	Twisted Pair	Token Ring Networks
CAT5	Up to 100Mbps	100m	Twisted Pair	Ethernet, FastEthernet, Token Ring
CAT5e	Up to 1 Gbps	100m	Twisted Pair	Ethernet, FastEthernet, Gigabit Ethernet
CAT6	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT6a	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT7	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (100 meters)

- These are different categories of UTP / STP.

Applications of Twisted Pair

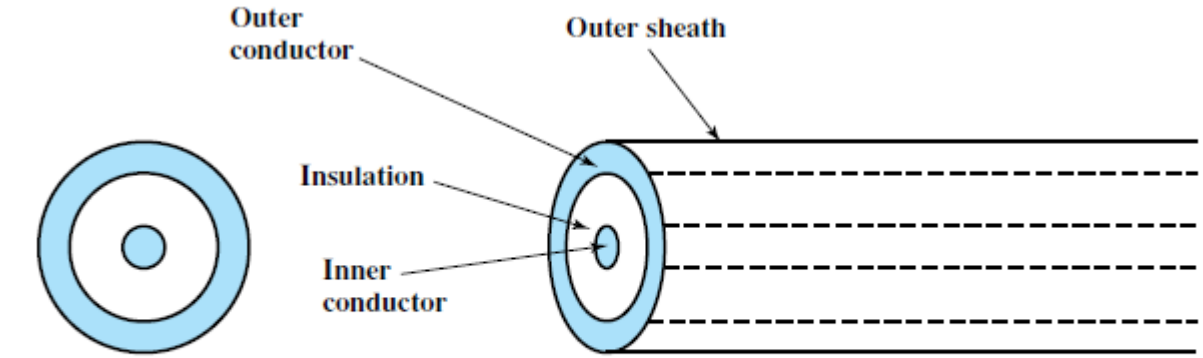
Some common applications of Twisted Pair Cable:

- As local loop / subscriber loop in telephone lines
  - individual residential telephone sets are connected to the local telephone exchange
  - It supports voice traffic using analog signaling
- Digital Subscriber Lie (DSL)
  - It can handle digital data traffic at modest data rates
- Local Area Networks (10BaseT, 100BaseT)
  - For creating local networks
- Connector Used – RJ45 (8-Lines)
  - For connecting personal computers

Coaxial Cable

- Consists of two conductors
  - a hollow outer cylindrical conductor that surrounds a single inner wire conductor.
  - The inner conductor is held in place by either regularly spaced insulating rings or a solid dielectric material.

- The outer conductor is covered with a jacket or a shield.
- A single coaxial cable has a diameter of from 1 to 2.5 cm.



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

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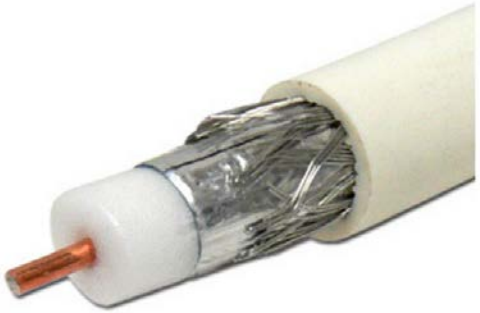
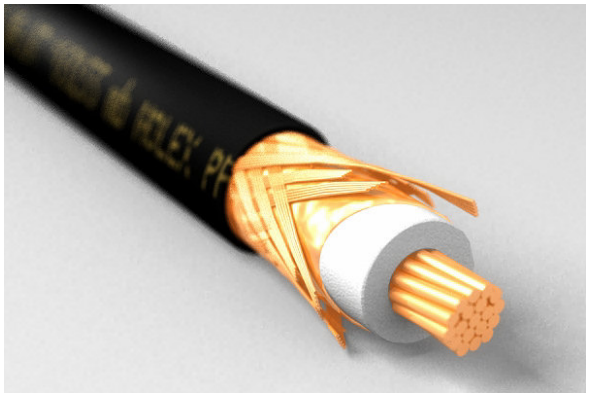
- Due to its shielding, coaxial cables are much less susceptible to interference or crosstalk than twisted pair.





Applications of Coaxial Cable

Some common applications:

- Television distribution (Cable TV)
- Long distance telephone transmission (10,000 voice channels per cable)
- Local Area Networks
- Short-run computer system links (for high-speed I/O)

- Common Types:

  RG-6, RG-7, RG-8

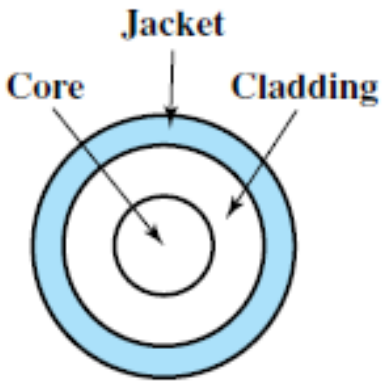
  The RG designation stands for Radio Guide.

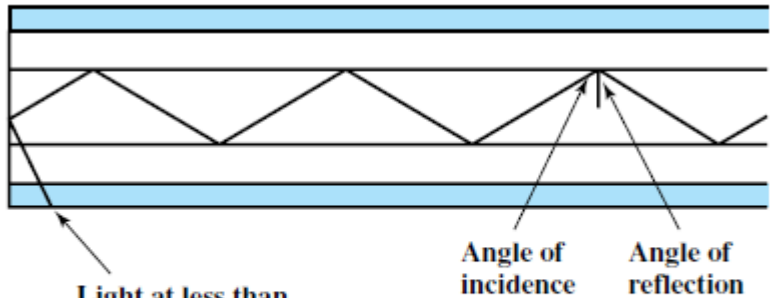
Optical Fiber

- 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 fiber.
- Made of ultrapure fused silica, glass fiber or even plastic.

- It has a cylindrical shape and consists of three concentric sections:
  - the ***Core***
  - the ***Cladding***
  - the ***Jacket***





(c) Optical fiber

Cont…

- The Core is the innermost section;
- it consists of one or more very thin strands, or fibers, made of glass or plastic;
- the core has a diameter in the range of 8 to 50 µm.

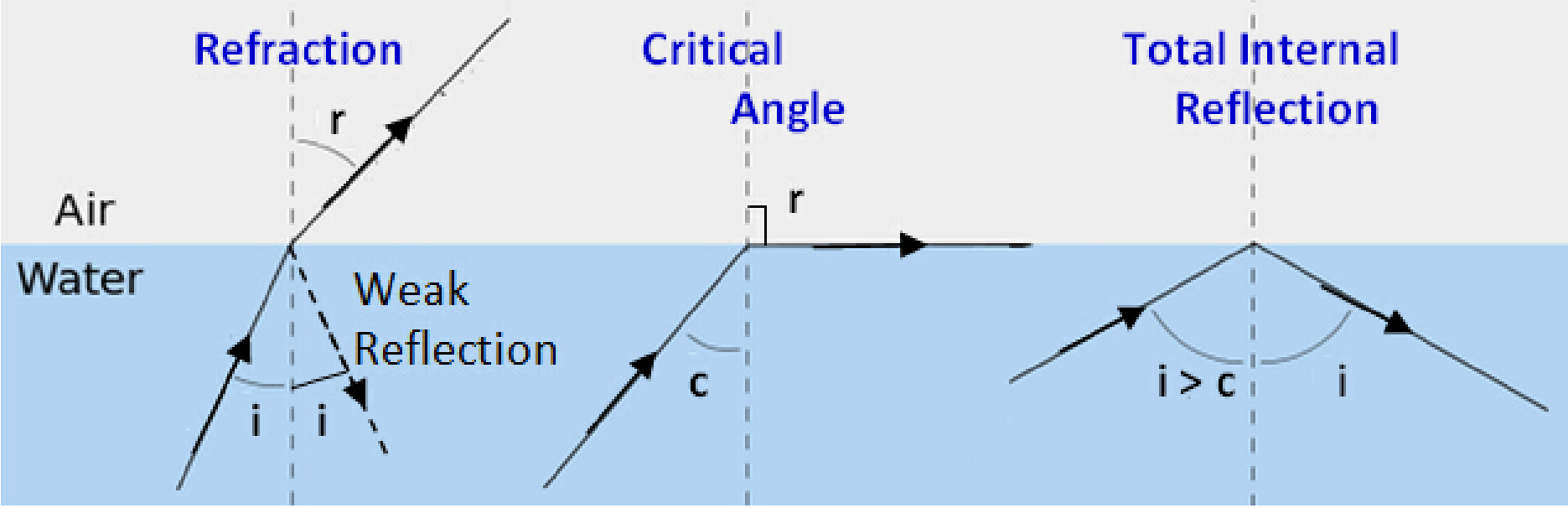
- The *Cladding* is a glass or plastic coating that has optical properties different from that of *Core;*
- each fiber is surrounded by its own cladding;
- its diameter is 125 µm

- The *Jacket* surrounds one or a bundle of cladded fibers;
- composed of plastic and other material layered to protect against moisture, abrasion, crushing, and other environmental dangers.

Cont…

- Distinguishing characteristics:
  - Greater capacity
    - data rates of hundreds of Gbps over tens of kilo-meters
  - Smaller size and lighter weight
    - thinner than coaxial cable or bundled twisted-pair cable
  - Lower attenuation
    - Attenuation is significantly lower for optical fiber than for coaxial cable or twisted pair
  - Electromagnetic isolation
    - the system is not vulnerable to external interference, impulse noise, or crosstalk.
  - Greater repeater spacing
    - Repeater spacing in the tens of kilometers for optical fiber is common; Coaxial and twisted-pair systems generally have repeaters every few kilometers.

How Optical Fiber Works?



Refraction is the change in direction of wave propagation due to a change in its transmission medium.

Cont…

- Optical fiber transmits a signal-encoded beam of light by means of total internal reflection.

- the optical fiber acts as a waveguide for frequencies in the range of about 10^{14} to 10^{15} Hertz

- High demand for communicating all types of information (voice, data, image, video)

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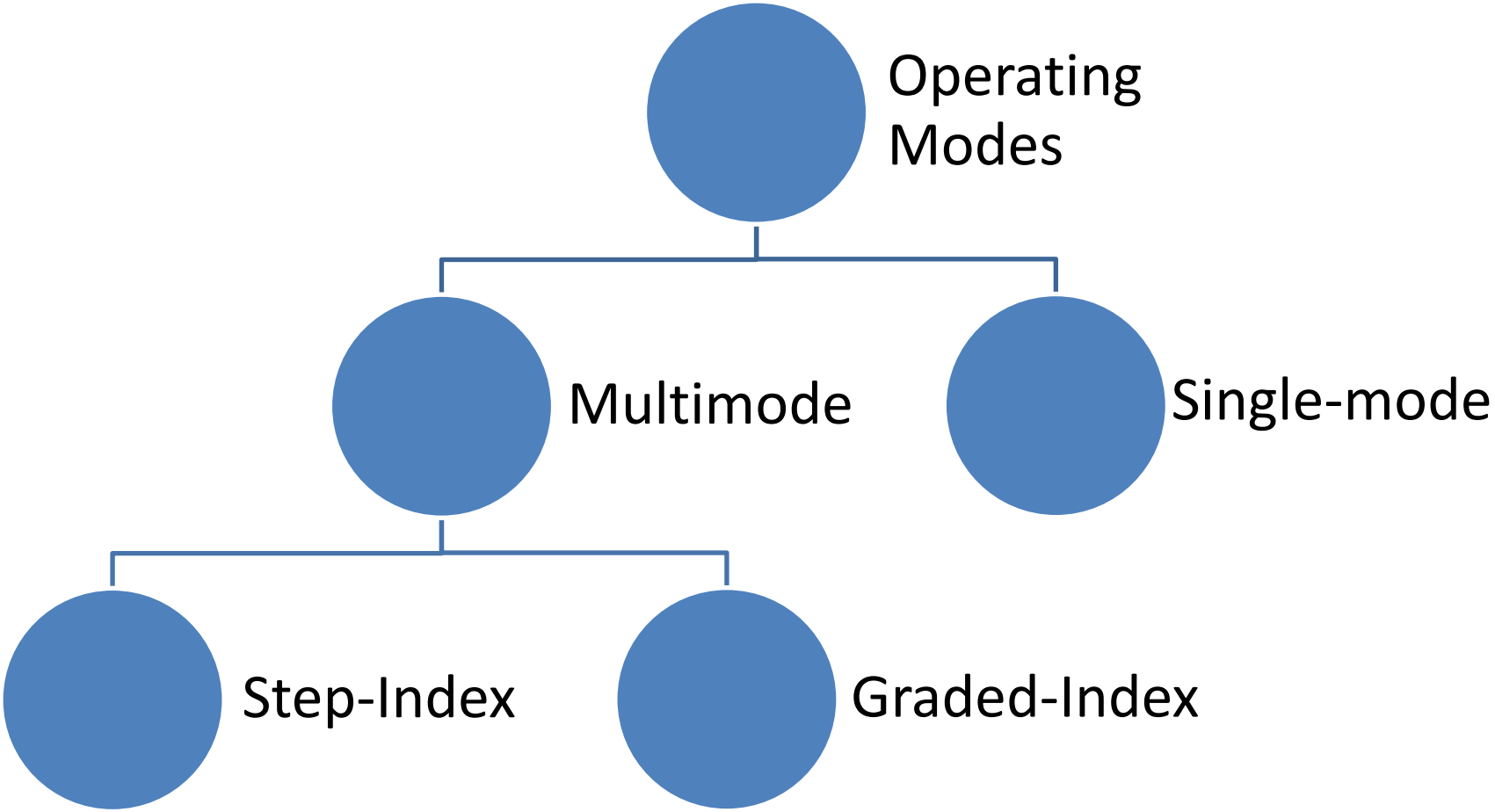

Operating Modes
Multimode
Single-mode
Step-Index
Graded-Index

Step-index Multimode Transmission

- Light from a source enters the cylindrical glass or plastic core.
- Rays at shallow angles are reflected and propagated along the fiber;
- other rays are absorbed by the surrounding material.

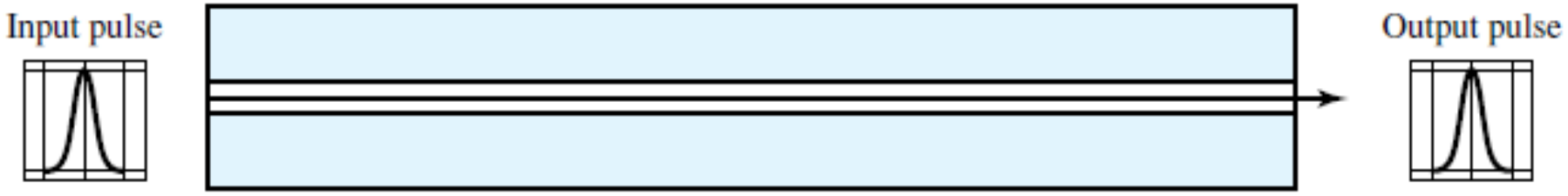
- This form of propagation is called step-index multimode, referring to the variety of angles that will reflect.

(a) Step-index multimode

Single-mode Transmission

- When the fiber core radius is reduced, fewer angles will reflect.
- By reducing the radius of the core to the order of a wavelength, only a single angle or mode can pass: the axial ray.

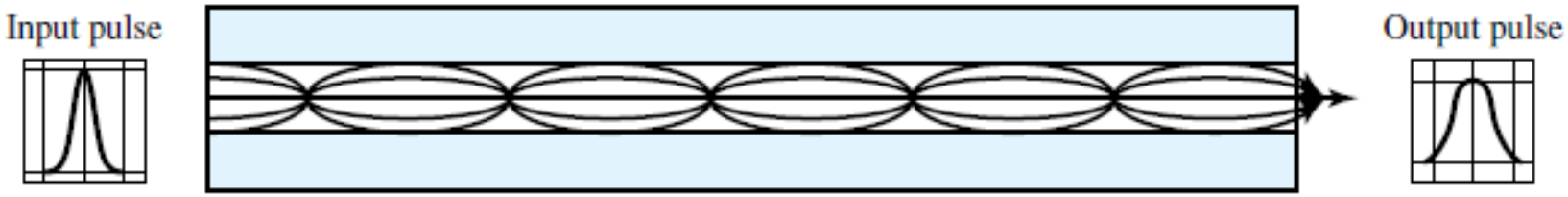
- This single-mode propagation provides superior performance because the distortion found in multimode cannot occur.



(c) Single mode

Graded-index Multimode Transmission

- by varying the index of refraction of the core graded-index multimode transmission is possible.
- The higher refractive index 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 allows light at the periphery to arrive at a receiver at about the same time as the straight rays in the core axis.



(b) Graded-index multimode

Light Sources and Detectors

- Light Emitting Diode (LED)
  - Cheaper
  - Greater Temperature Range
  - Longer Life
  - Shorter distance
  - Power coupled: 25 µW (50 µW)
- Injection Laser Diode (ILD)
  - Costlier
  - More efficient
  - Allows longer distance
  - Power coupled: 1.0 mW (Monomode)
- Detectors:
  - PIN Photo Detector
  - Avalanche Photo Diode (APD)

Comparison

Medium	Cost	Bandwidth, Data Rate	Attenuation	Electro-magnetic interference	Security
UTP	Low	3 MHz, 4 Mbps	High, 2-10 Km	High	Low
Coaxial	Moderate	350 MHz, 500 Mbps	Moderate, 1-10 Km	Moderate	Low
Optical Fiber	High	2 GHz, 2 Gbps	Low, 10-100 Km	Low	High

Thanks!

Figure and slide materials are taken from the following sources:

1. W. Stallings, (2010), Data and Computer Communications
2. NPTL lecture on Data Communication, by Prof. A. K. Pal, IIT Kharagpur
3. B. A. Forouzan, (2013), Data Communication and Networking