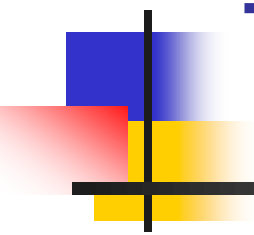

Transmission Media

รศ.ดร. อนันต์ ผลเพิ่ม

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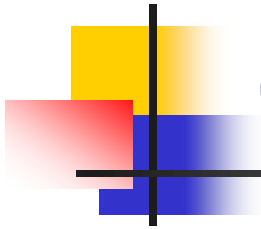
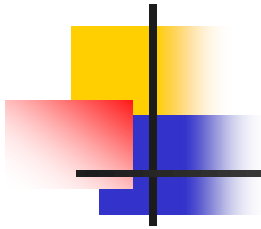


Outline

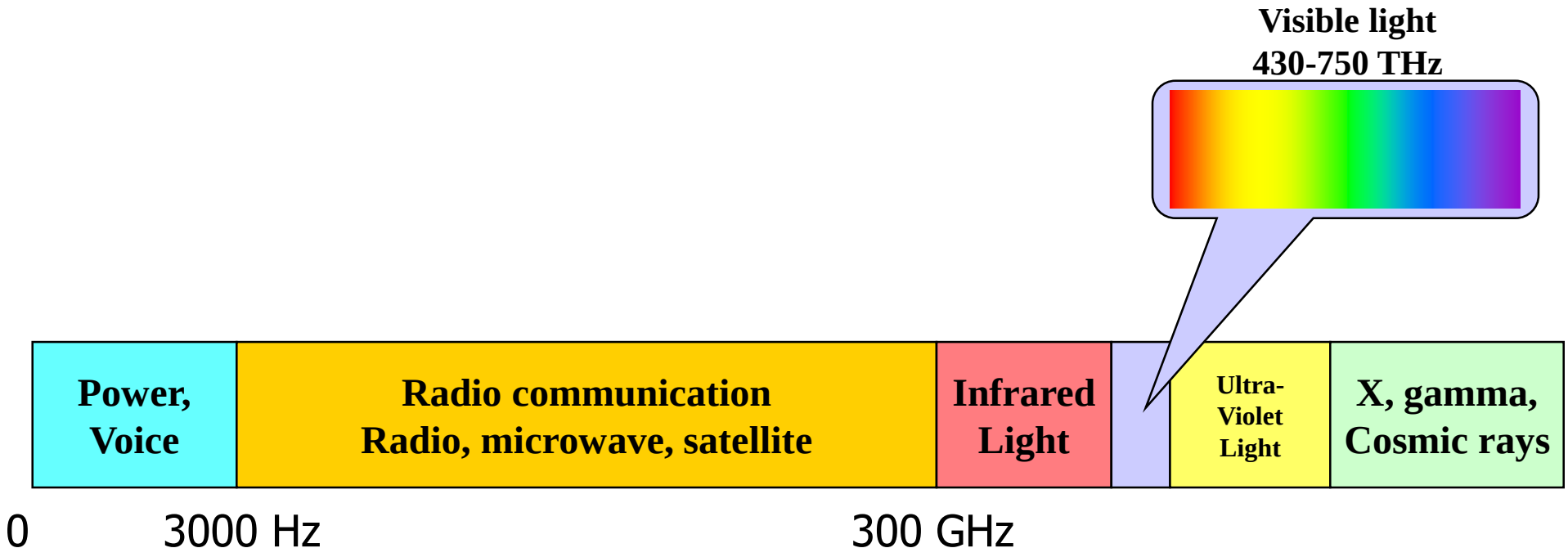
- Electromagnetic Energy
- Cable (Wire)
- Wireless
- Measuring Transmission Media

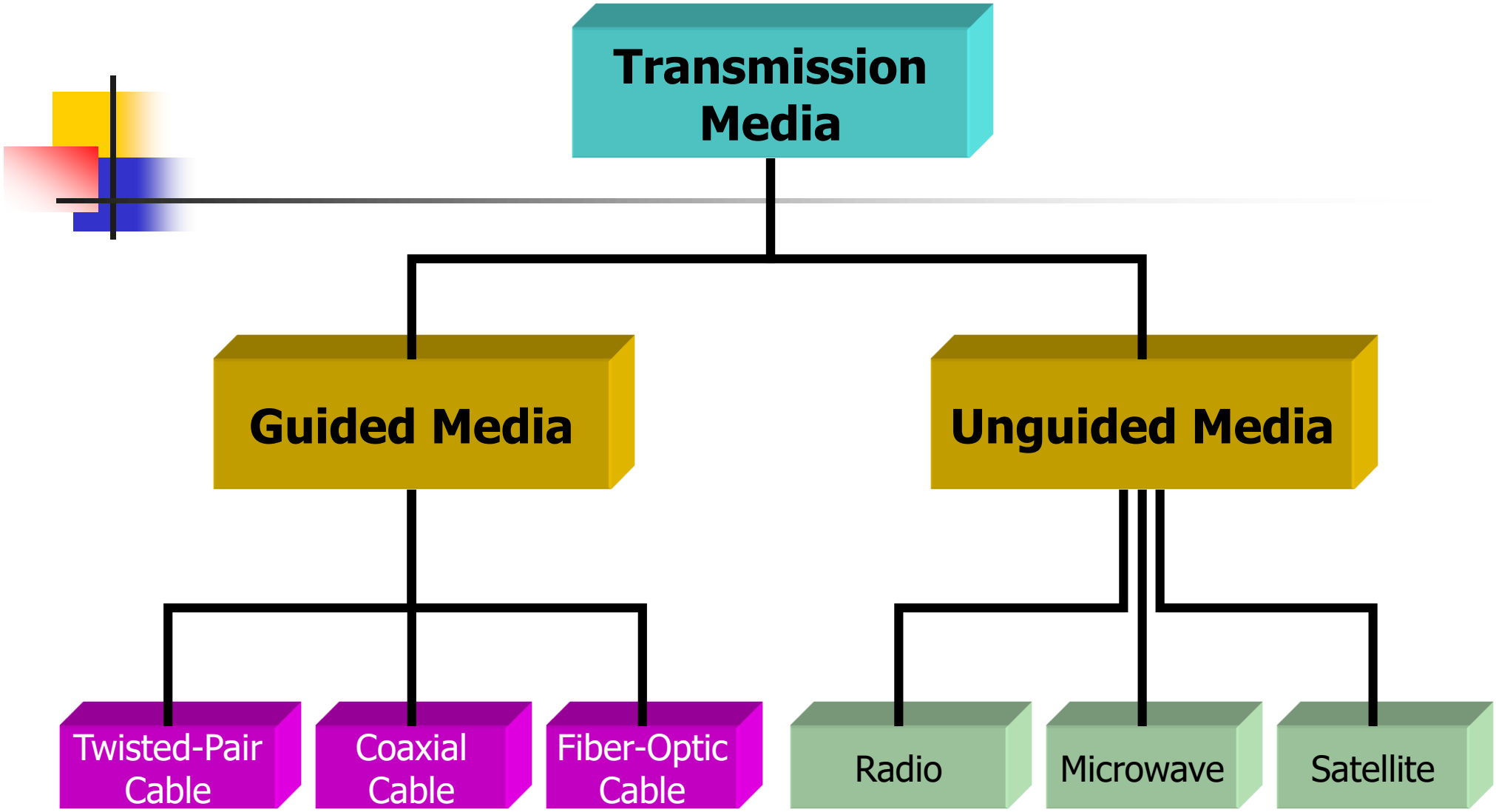


Electromagnetic Energy

- Signals are transmitted in form of electromagnetic energy
- Electromagnetic Energy:
  - a combination of electrical and magnetic fields vibration
  - Travel through a vacuum, air, or other transmission media
  - Some are used for communications

Electromagnetic Spectrum



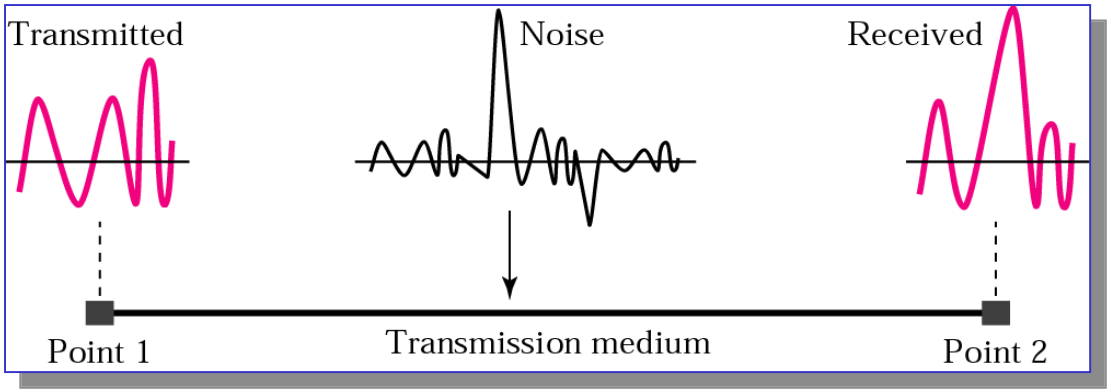

Transmission Media
Guided Media
Unguided Media
Twisted-Pair Cable
Coaxial Cable
Fiber-Optic Cable
Radio
Microwave
Satellite

Noise

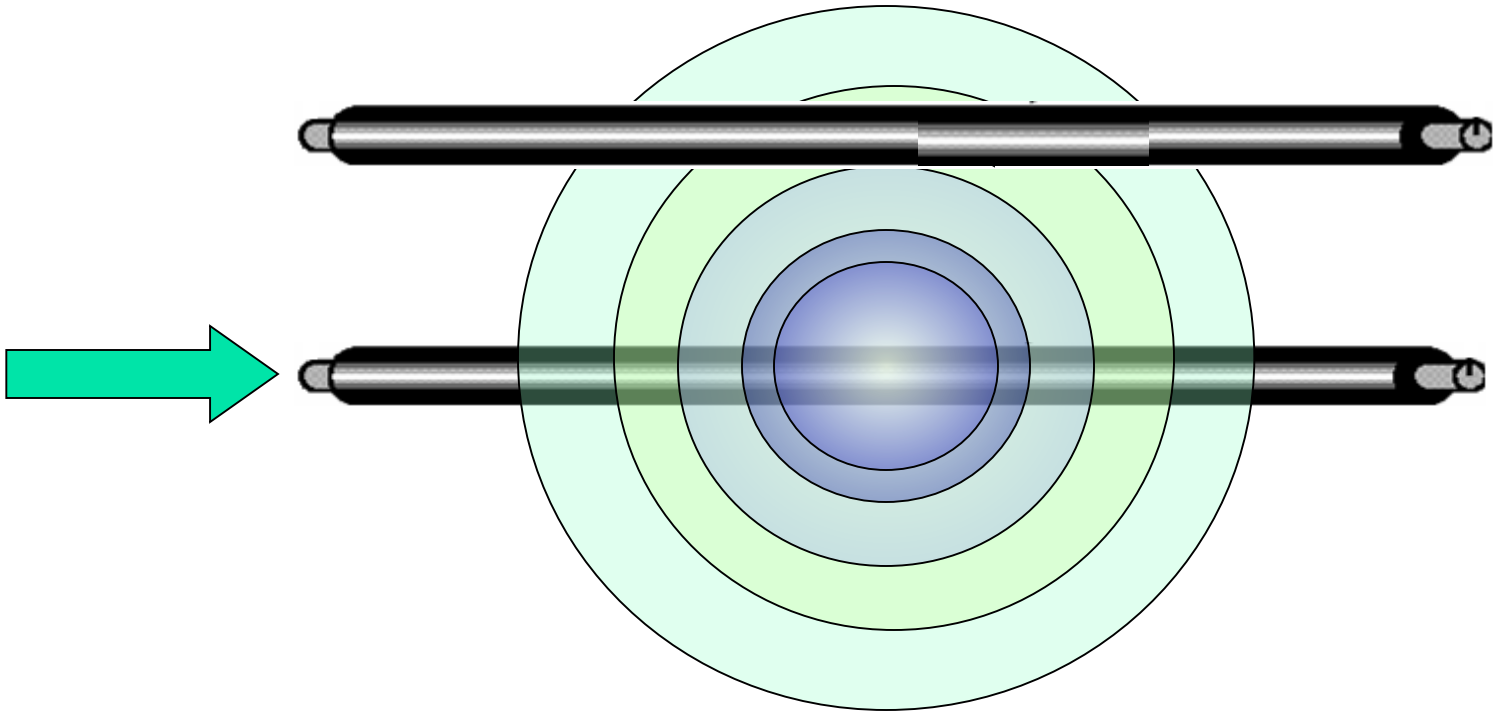
- Undesirable signals added between the transmitter and the receiver
- Noise sources:
  - Appliance

  →Heat in cables

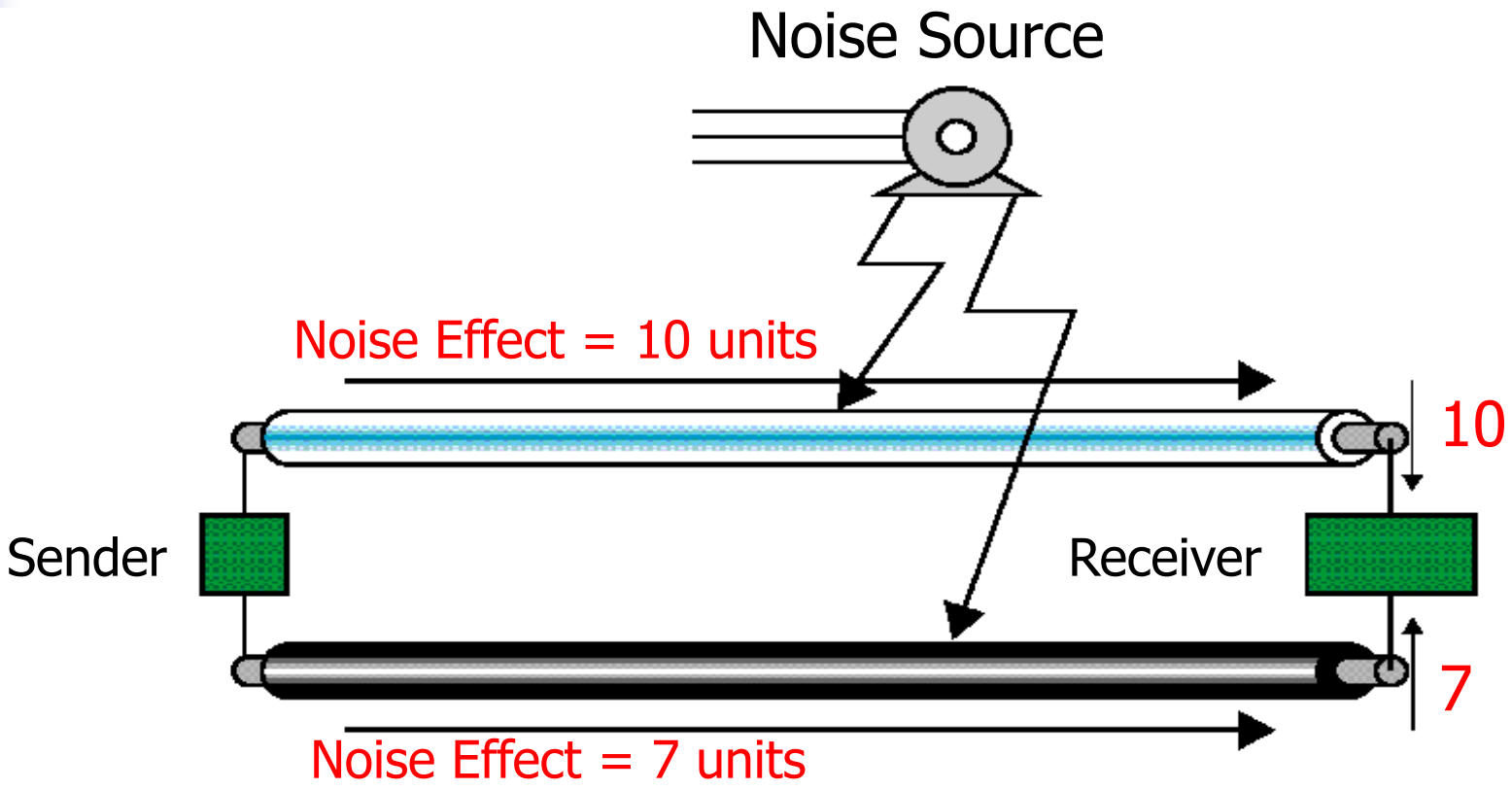
  →Electromagnetic radiation



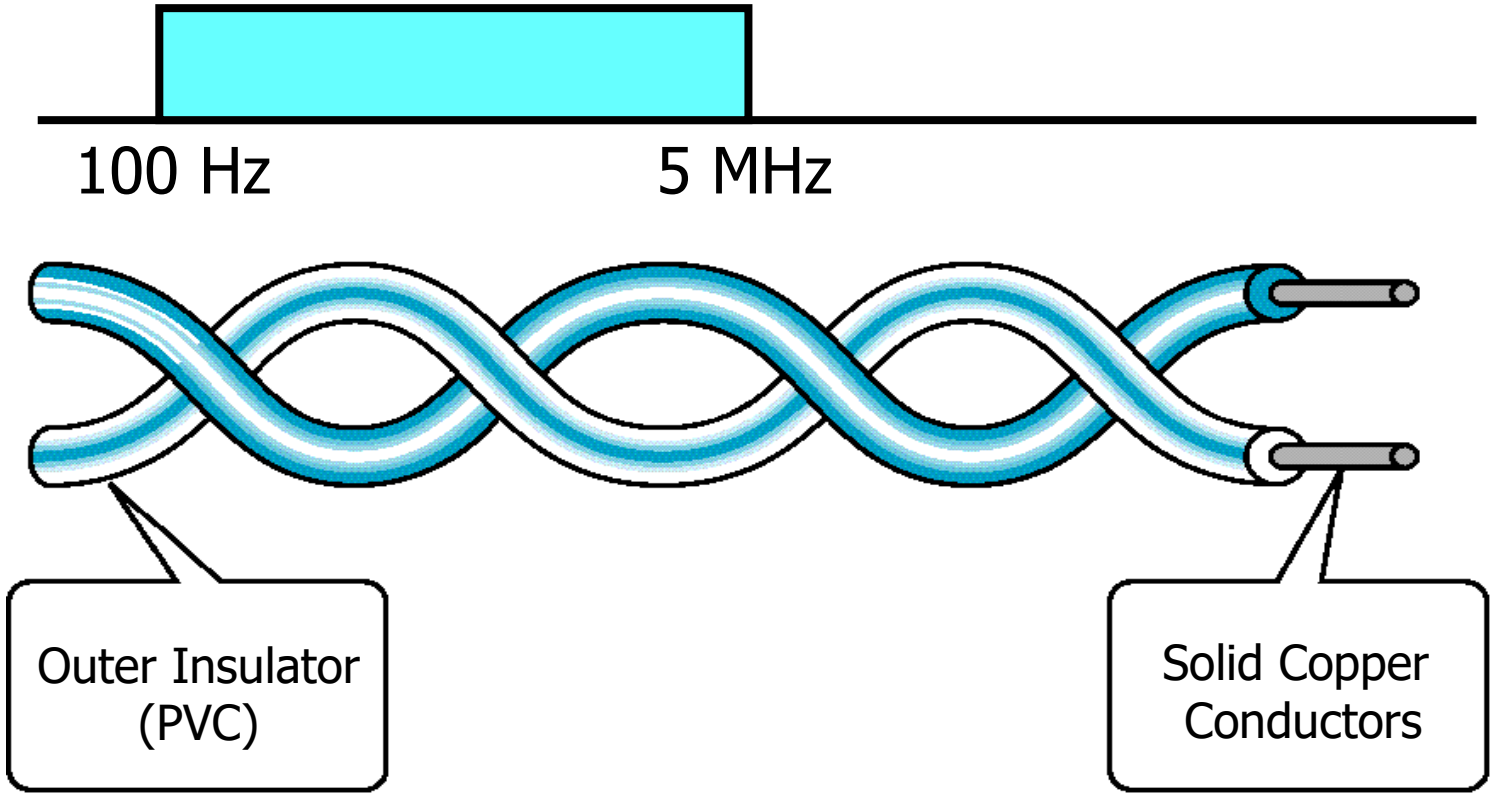
Interference from nearby cable



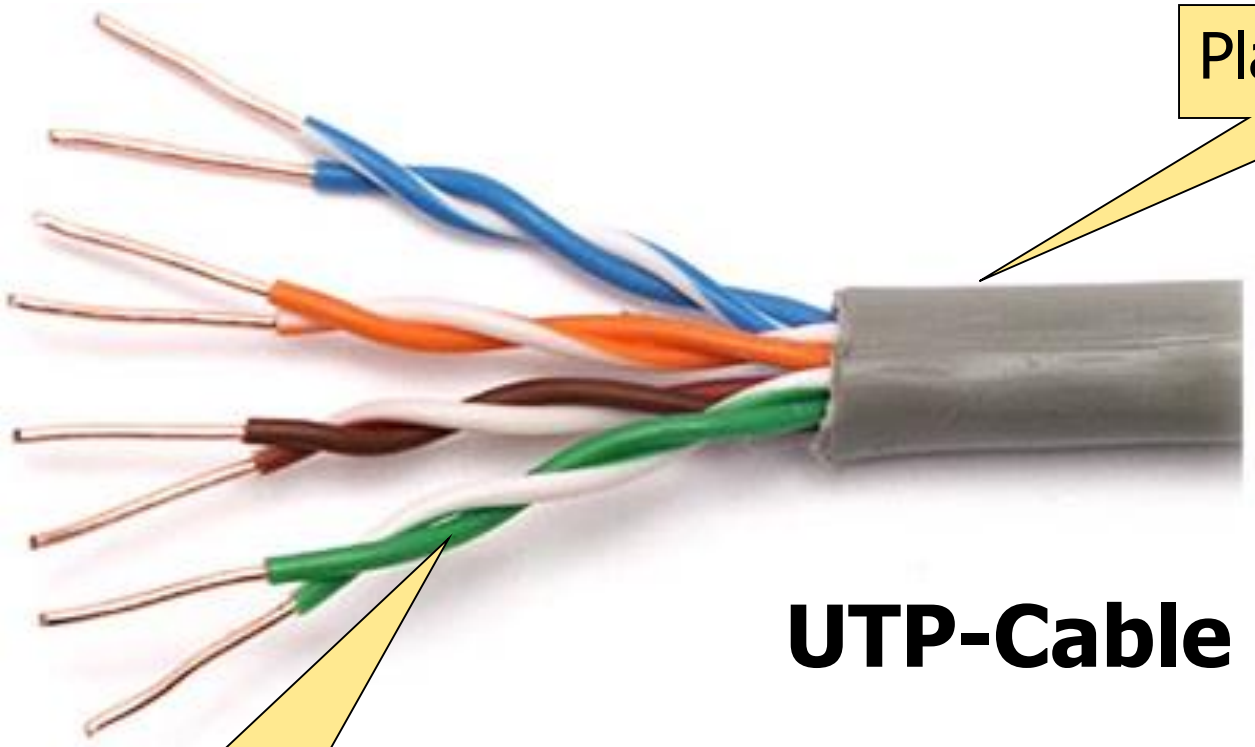
Interference from noise



Twisted Pair Cable

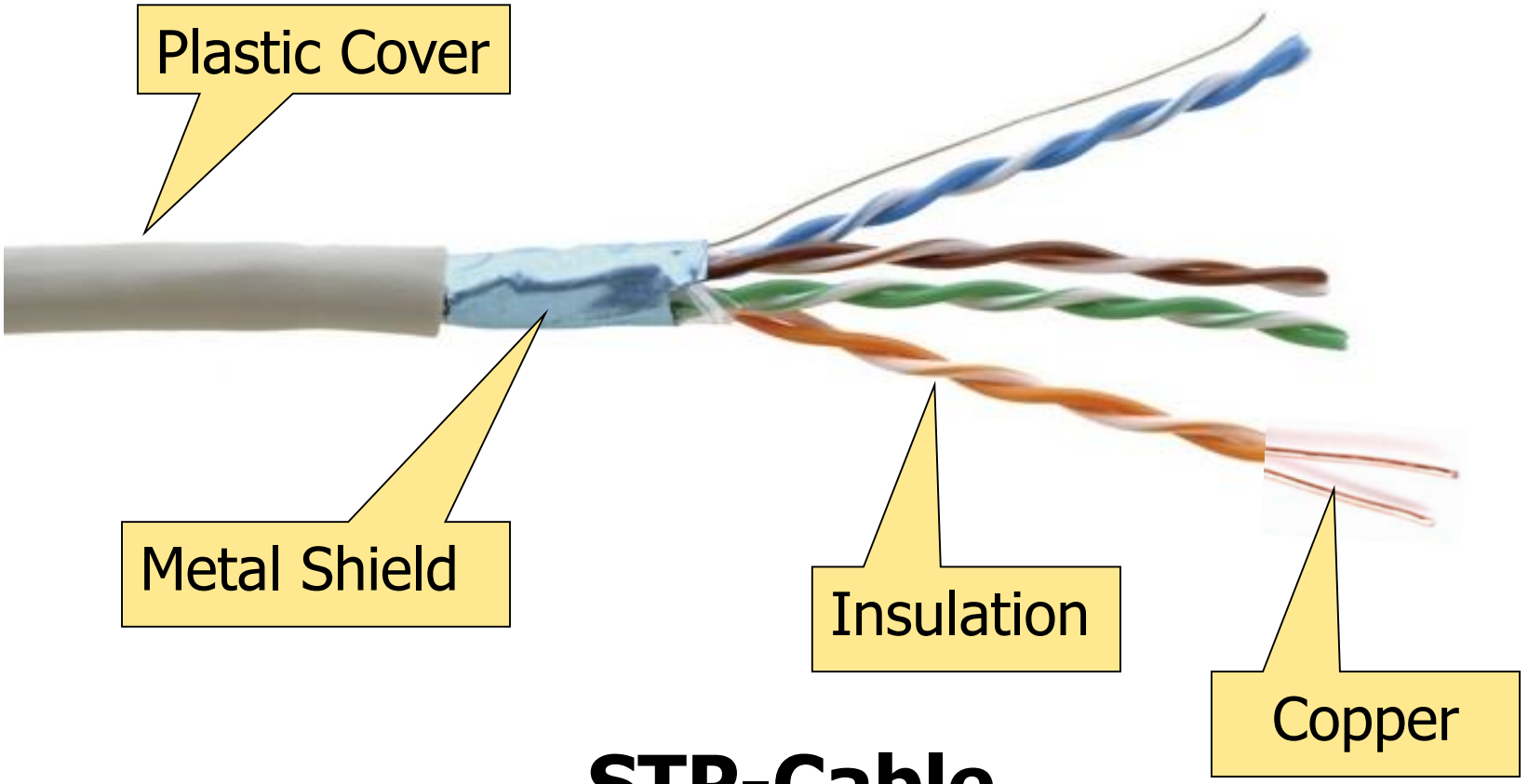


Unshielded Twisted Pair Cable



http://www.sattvengg.com/2013/09/an-easy-explanation-of-straighr-and.html

Shielded Twisted-Pair Cable



STP-Cable

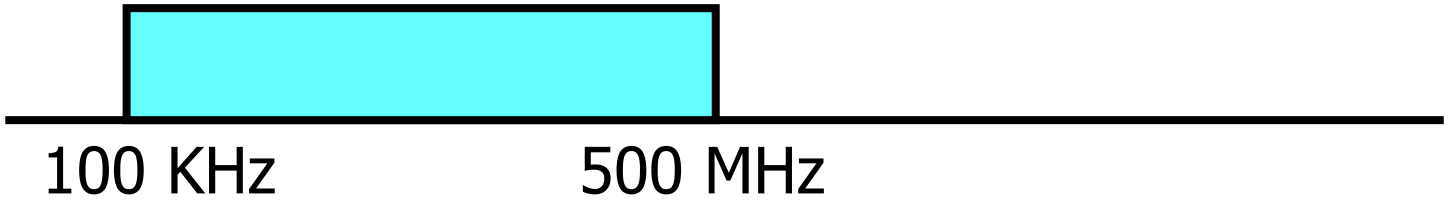
https://avprosupply.com/Kramer-BC-DGKat524-305M-24-AWG-STP-Cable-Optimized-for-Kramer-DVI--HDMI-Twisted-Pair-Products-BC-DGKat524-305M.html

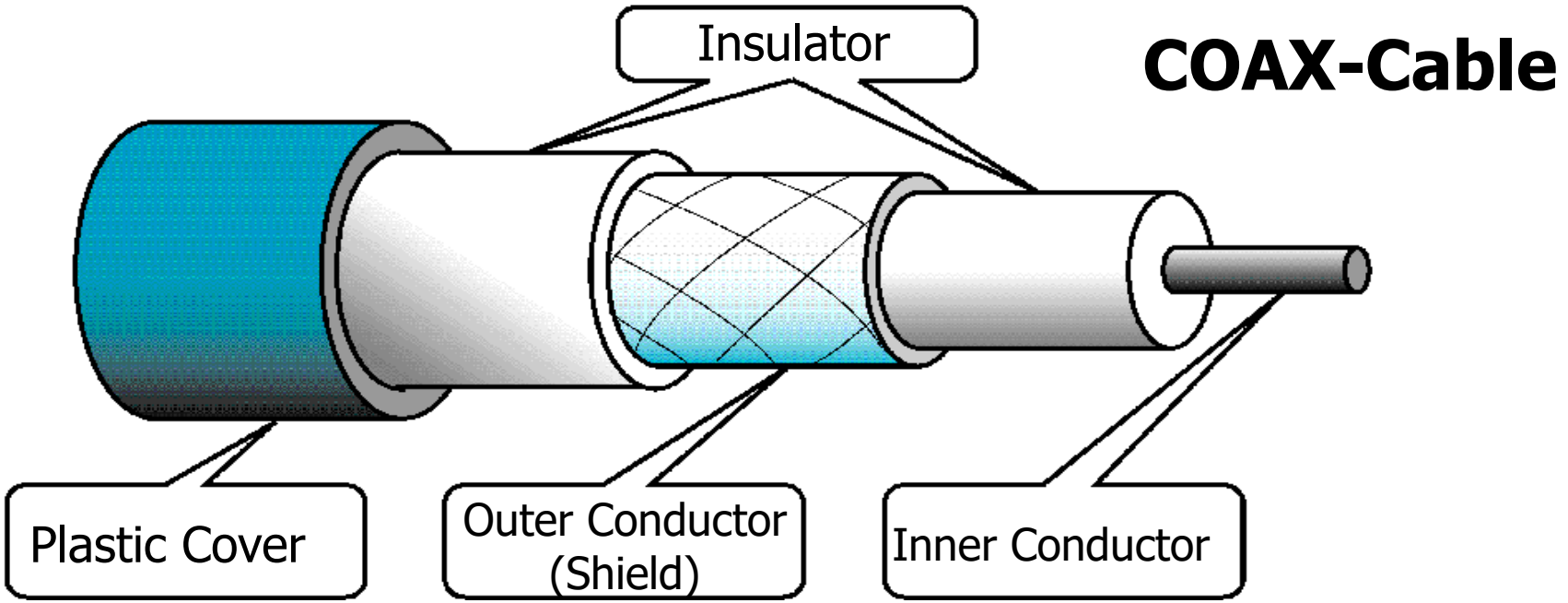
UTP cable standard

- EIA set the cable standards
- Categorized by the cable quality

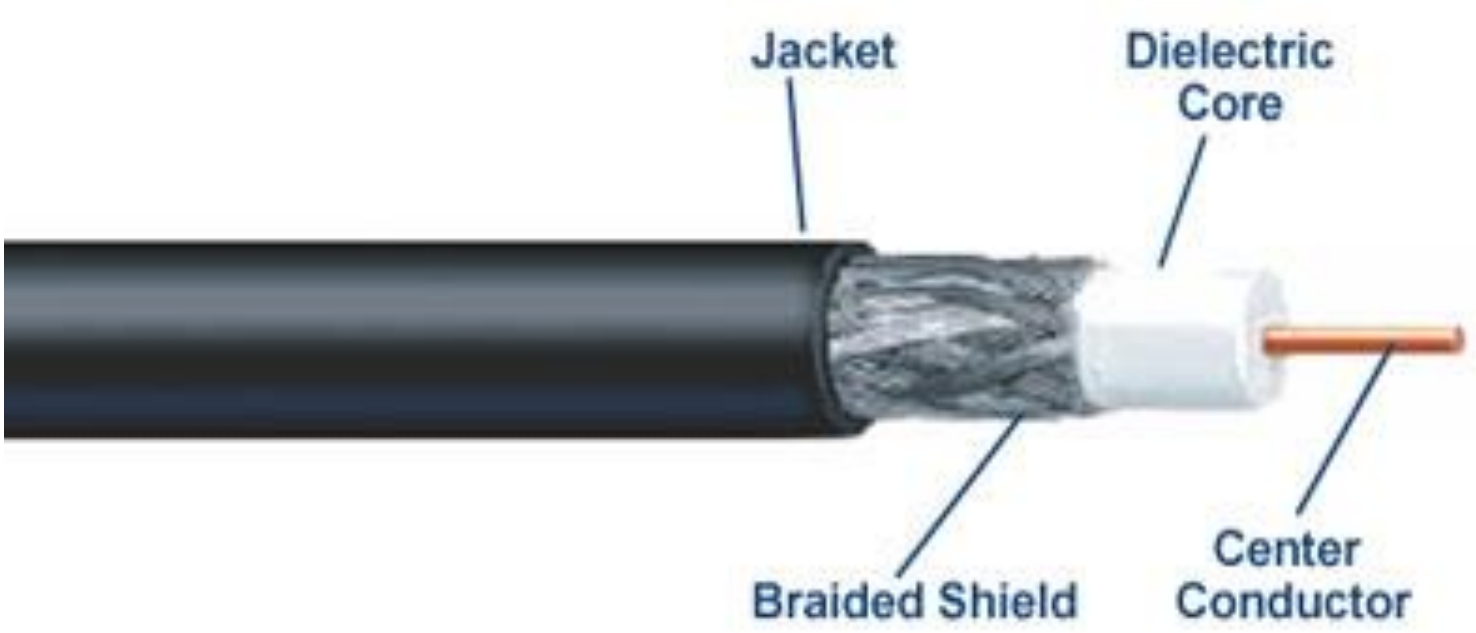
Category	Description	Data Rate (in Mbps)
CAT 1	Unshielded twisted pair used for telephones	< 0.1
CAT 2	Unshielded twisted pair used for T1 data	2
CAT 3	Improved CAT2 used for computer networks	10
CAT 4	Improved CAT3 used for Token Ring networks	20
CAT 5	Unshielded twisted pair used for networks	100
CAT 5E	Extended CAT5 for more noise immunity	125
CAT 6	Unshielded twisted pair tested for 200 Mbps	200
CAT 7	Shielded twisted pair with a foil shield around the entire cable plus a shield around each twisted pair	600

Coaxial cable

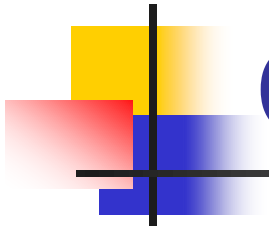




Coaxial cable

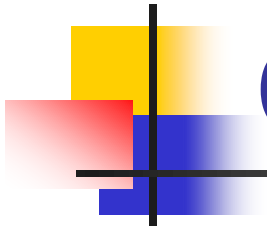


https://www.perfect-vision.com/PerfectVision/CoaxialCableGuide.aspx



Coaxial cable standard

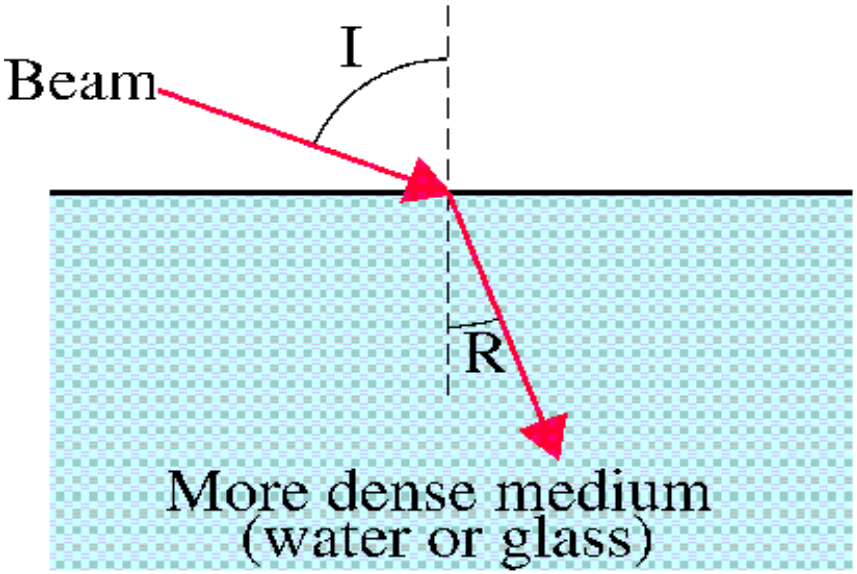
- Categorized by radio government (RG)
- Physical specification (wire gauge, conductor,…)
  - RG-8, RG-9, RG-11 : Thick Ethernet
  - RG-58 : Thin Ethernet
  - RG-59 : (older)TV → RG-6(triple/Quad shield)



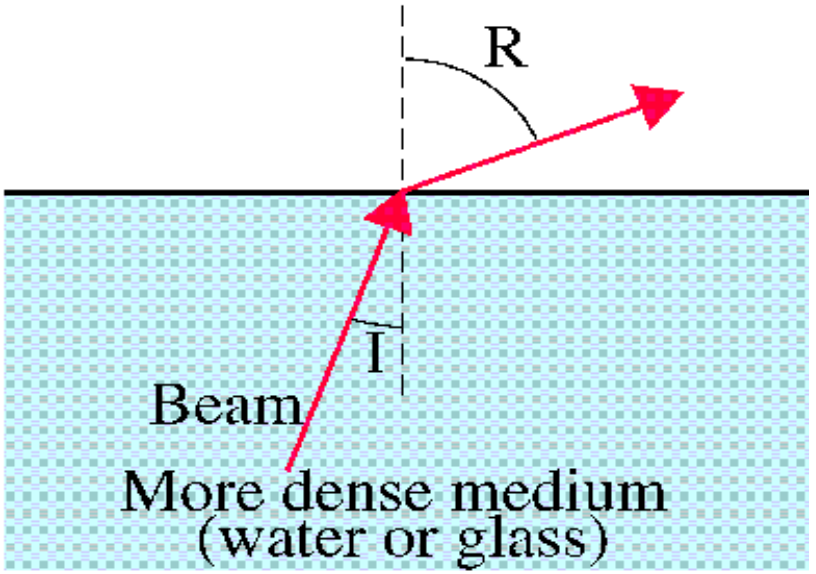
Optical Fiber

- Nature of light
  - In vacuum, $3x10^8$ m/s
  - Higher density, slower speed
  - Refraction
  - Reflection

Refraction

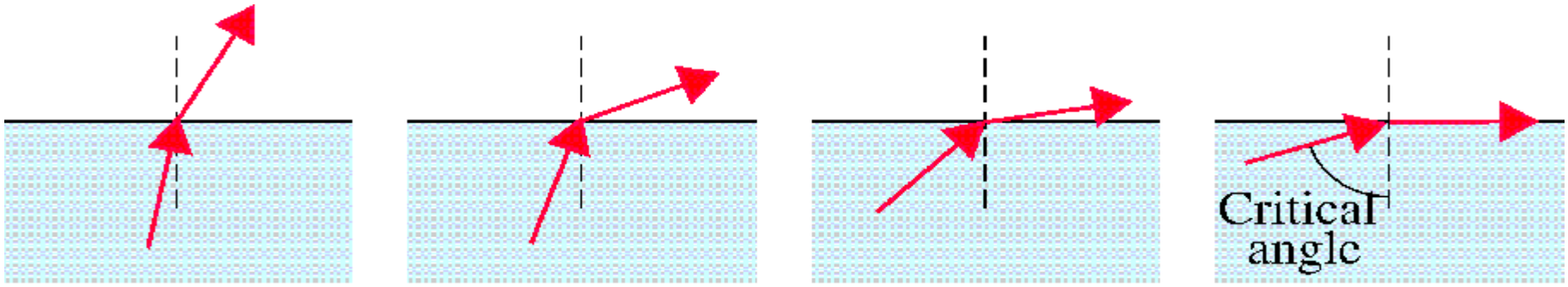


From less dense to more dense medium

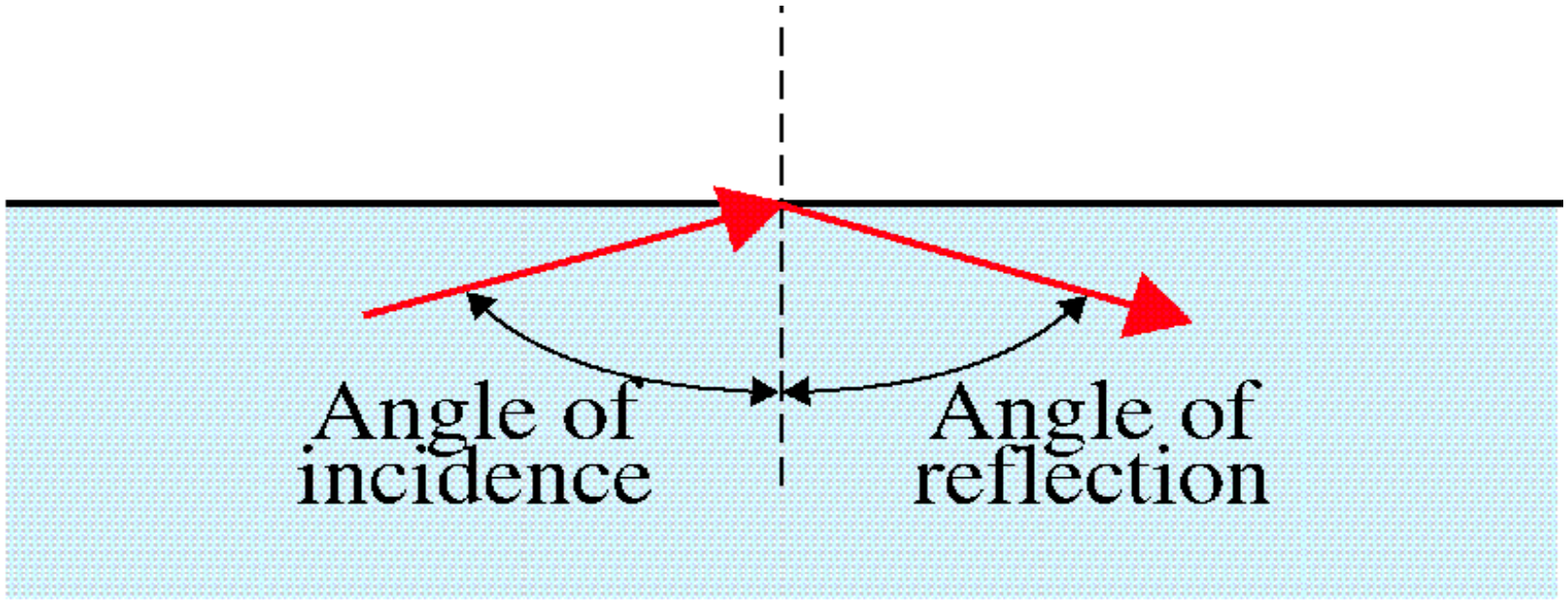


From more dense to less dense medium

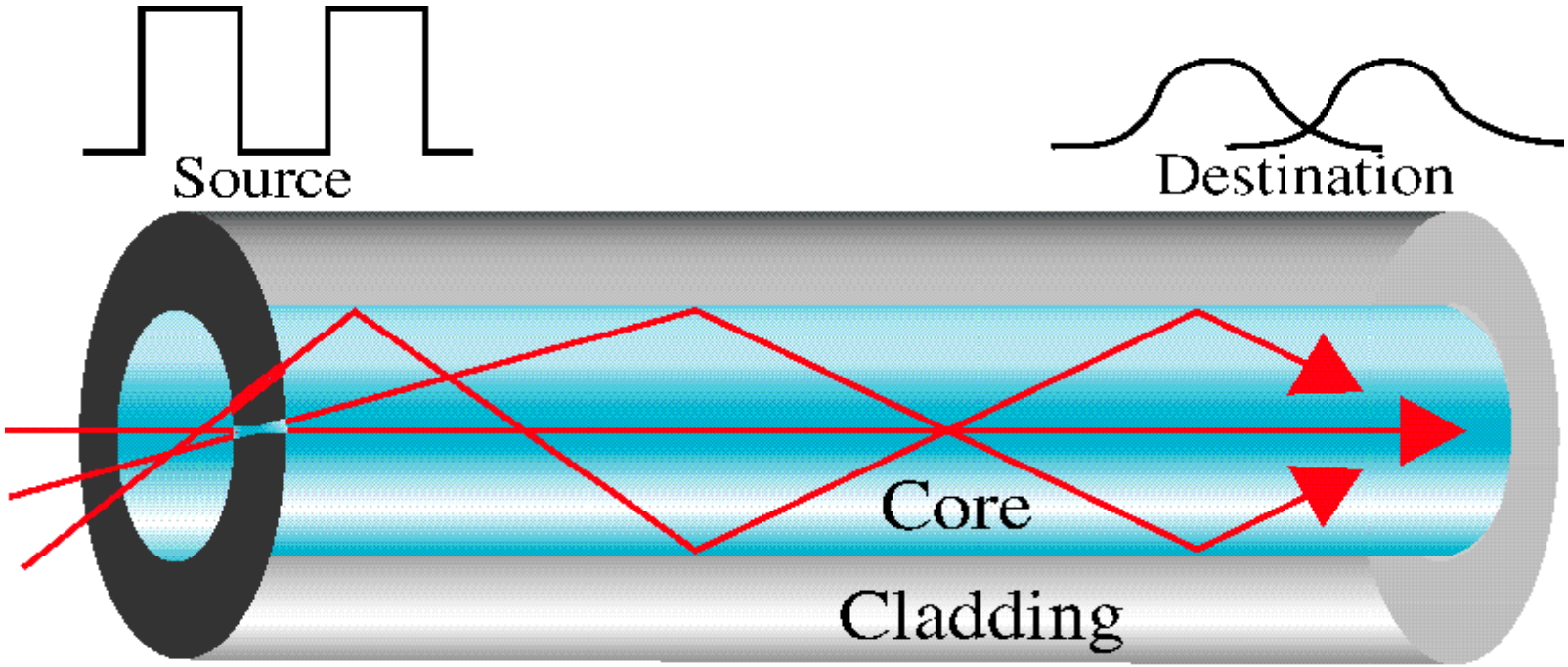
Critical Angle



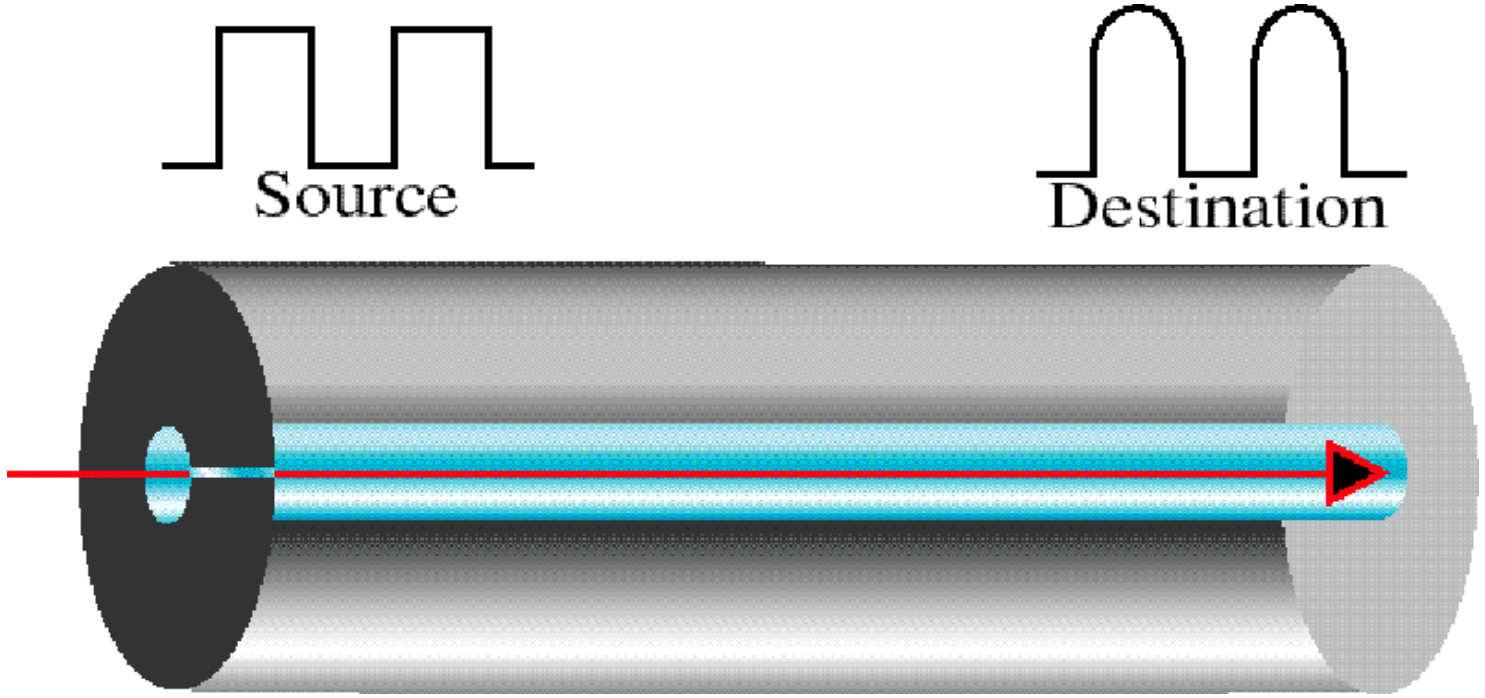
Reflection



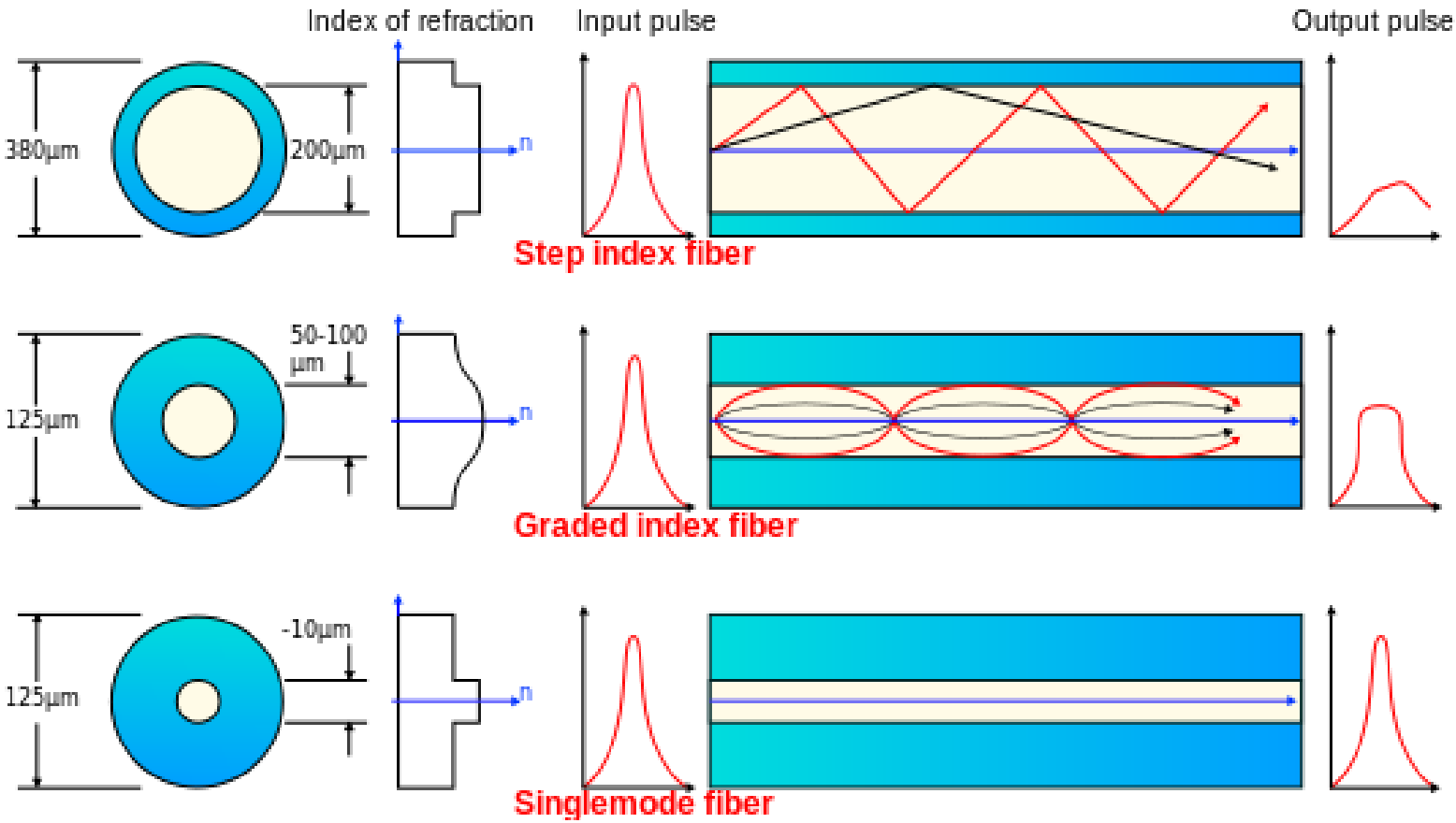
Multimode Step-Index



Single Mode

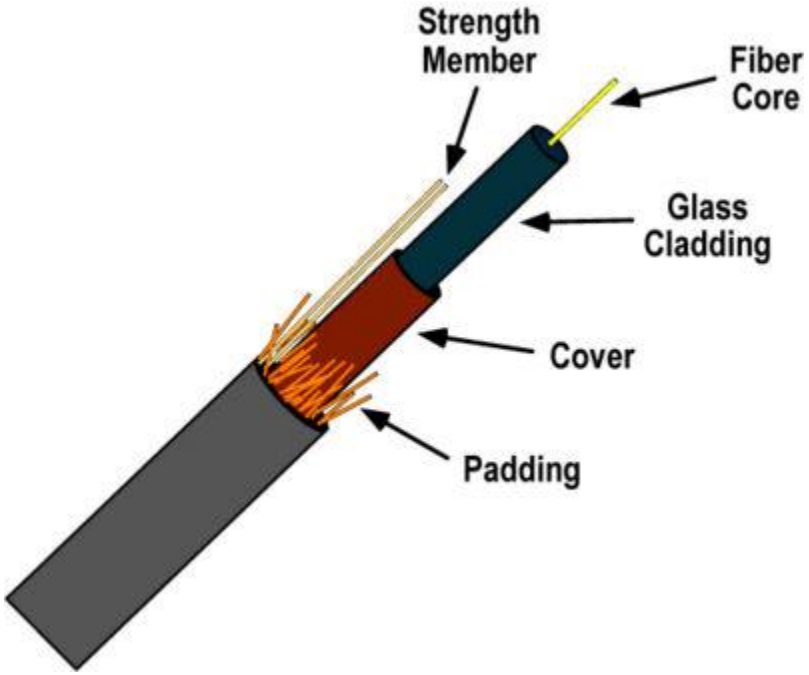


Optical Fiber Types



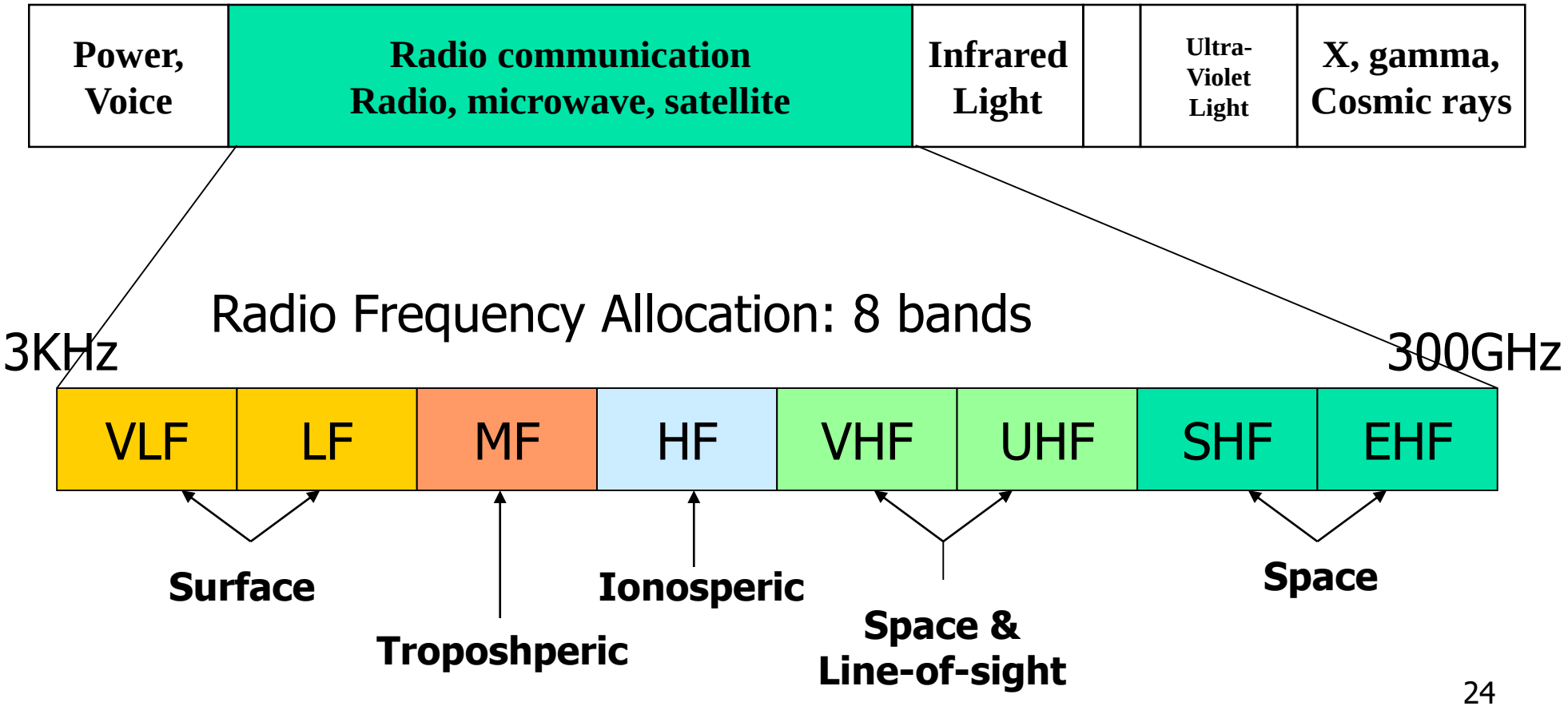
https://en.wikipedia.org/wiki/Optical_fiber#/media/File:Optical_fiber_types.svg

Optical Fiber Cable



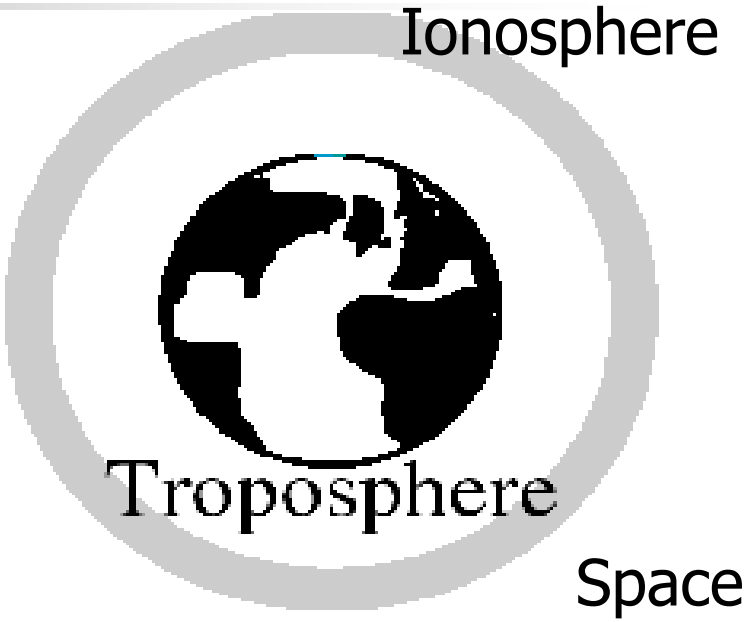
http://www.indiamart.com/solusys/optical-fiber.html

Electromagnetic Spectrum

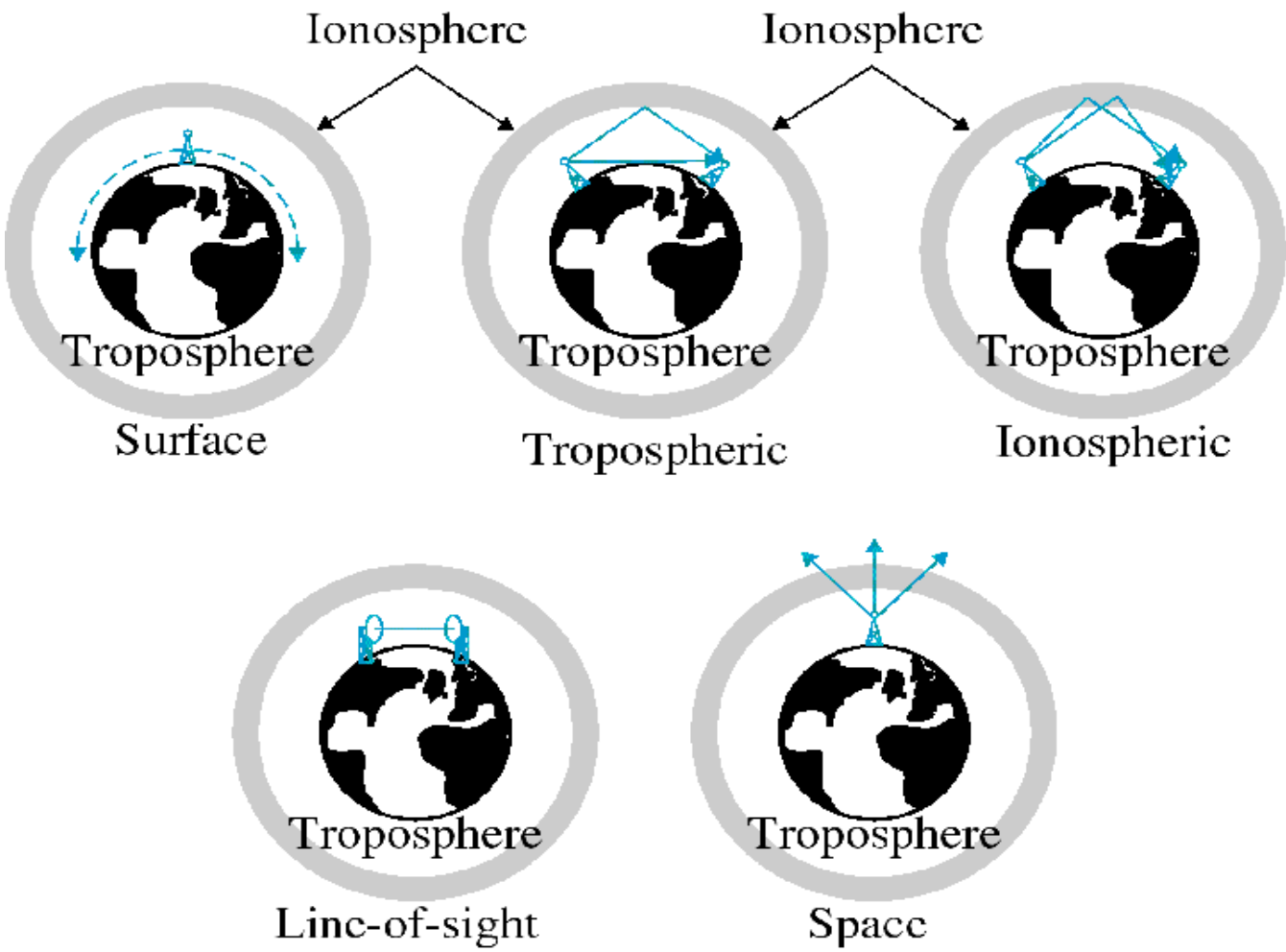


Earth atmosphere

- Troposphere
  - 30 miles from earth
  - Air
  - Clouds, wind, weather
  - Jet plane travel
- Ionosphere
  - Between Troposphere and space
  - Free electrically charged particles

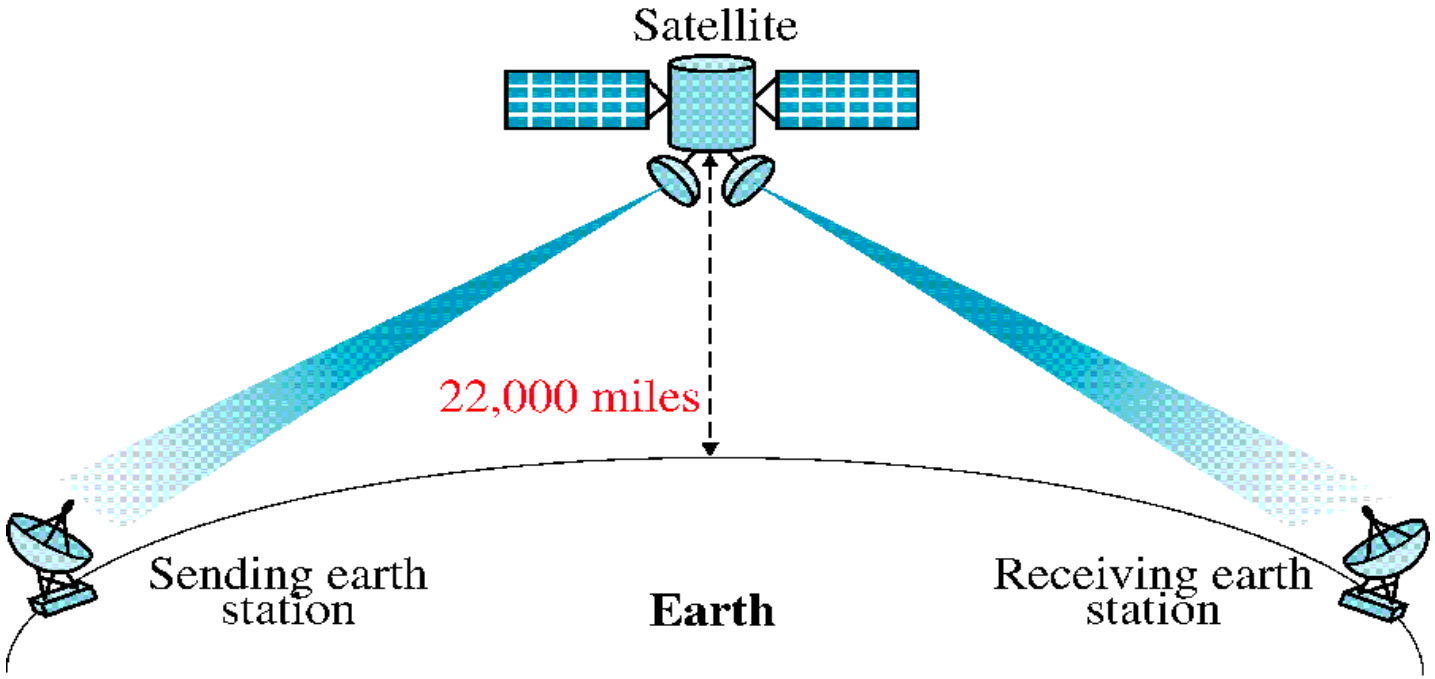


Type of propagation



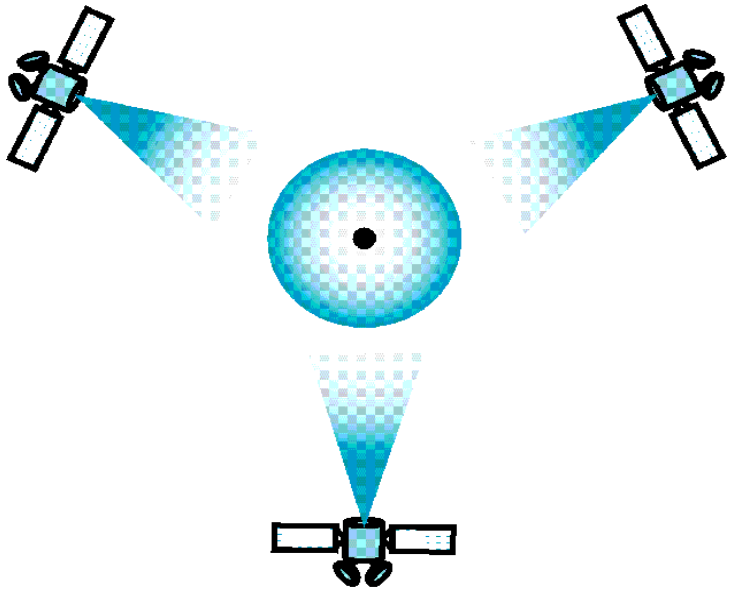
Satellite Communication

- Like microwave
- Supertall antenna & repeater

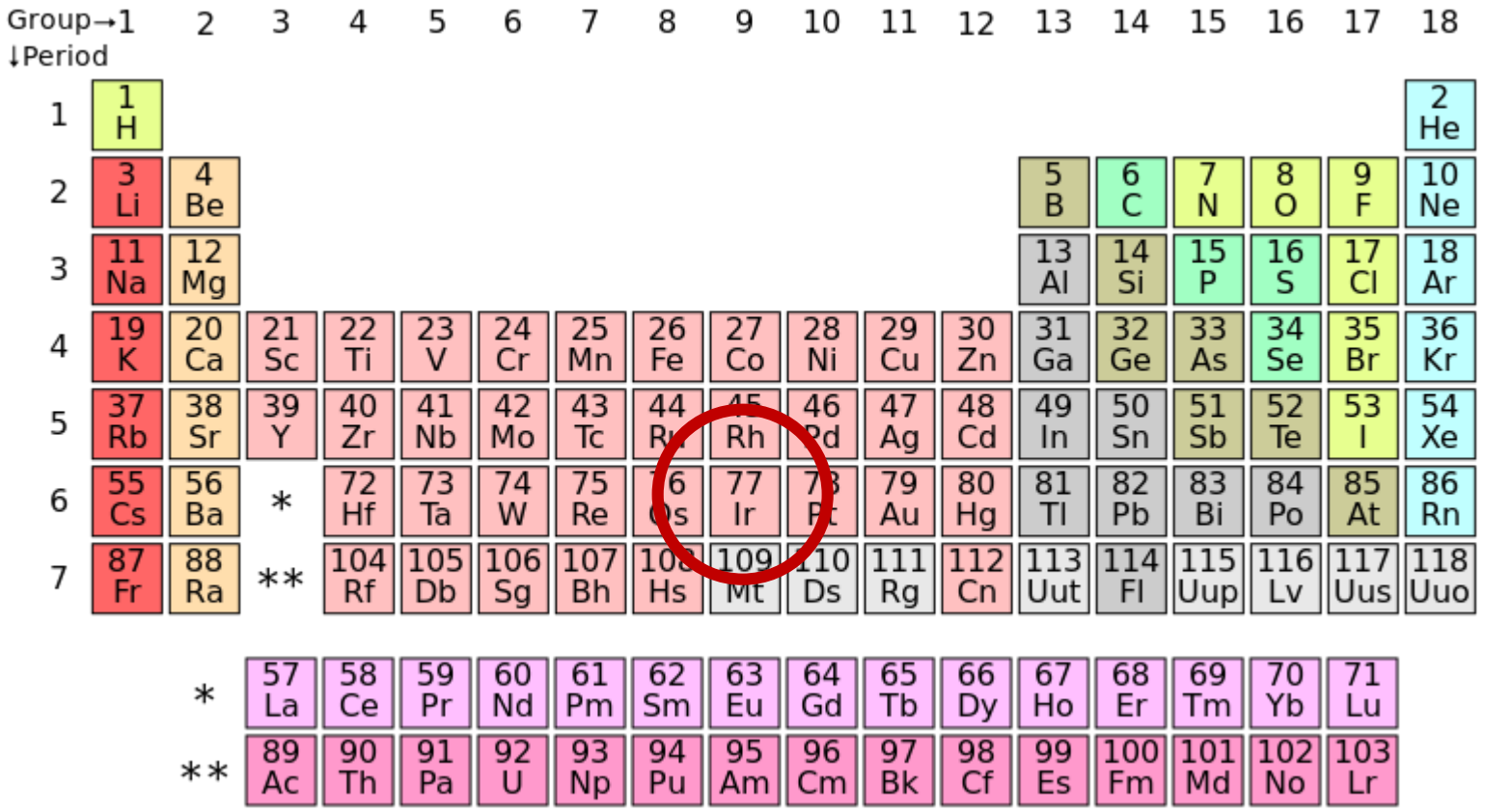


Geosynchronous Satellites

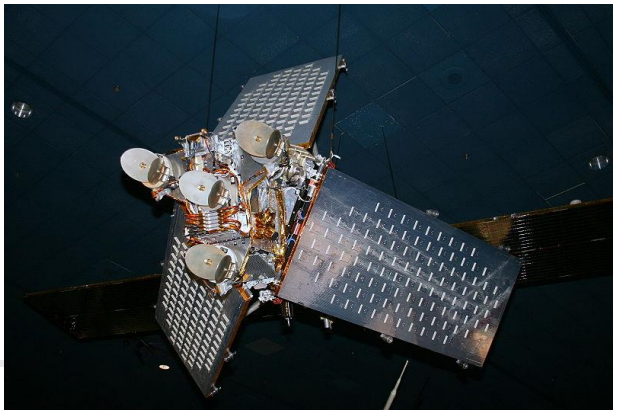
- Stationary antenna
- Satellite moves same speed as earth
- Only one orbit (22,000 miles)



Periodic table



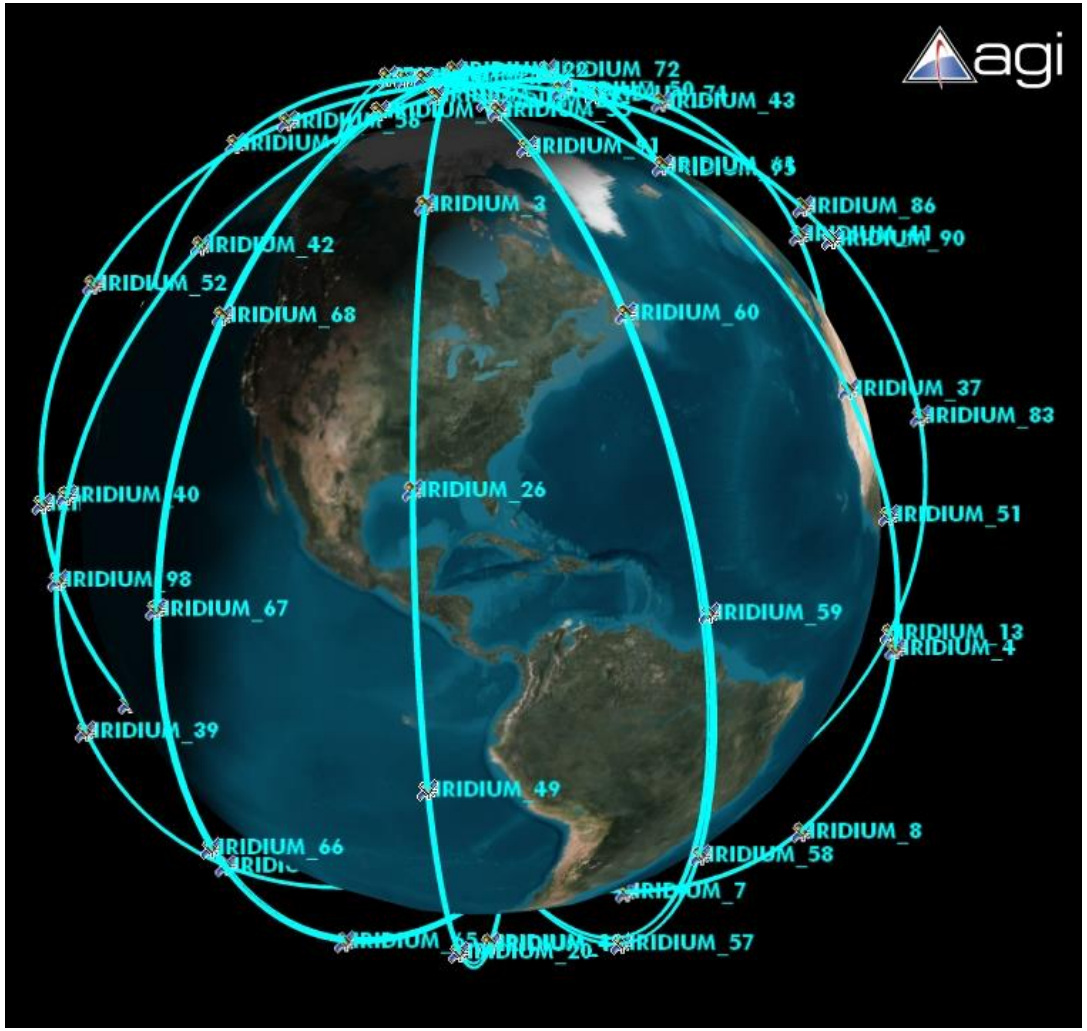
Iridium



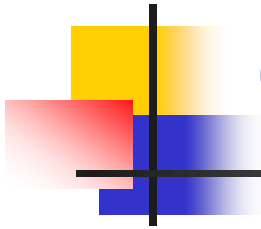
- Conceived, designed, and built by Motorola, the Iridium system provides wireless, mobile communications through a network of 66 satellites in polar, low-Earth orbits.
- Inaugurated in November 1998, under the auspices of Iridium LLC, this complex space system allowed callers using hand-held mobile phones and pagers to communicate anywhere in the world--a first in the history of telephony.
- The original concept was to have 77 satellites, which is where the name Iridium came from, being the element with the atomic number 77

https://en.wikipedia.org/wiki/Iridium_satellite_constellation#/media/File:Iridium_Satellite.jpg

Iridium

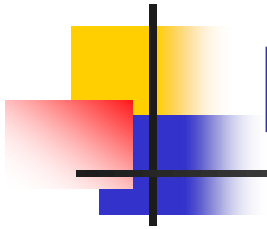

agi
IRIDIUM_72
IRIDIUM_43
IRIDIUM_3
IRIDIUM_86
IRIDIUM_42
IRIDIUM_52
IRIDIUM_68
IRIDIUM_60
IRIDIUM_37
IRIDIUM_83
IRIDIUM_40
IRIDIUM_26
IRIDIUM_51
IRIDIUM_98
IRIDIUM_67
IRIDIUM_59
IRIDIUM_13
IRIDIUM_4
IRIDIUM_39
IRIDIUM_49
IRIDIUM_8
IRIDIUM_66
IRIDIUM_58
IRIDIUM_7
IRIDIUM_57

Jurassic Park 3 (July 2001)



Other Wireless

- Satellite
  - Low Earth Orbit (LEO)
  - Low Earth Orbit Satellite Arrays
- Microwave
- Infrared



Measuring Transmission Media

- Two most important characteristics of a transmission medium are:
  - **Propagation delay**

    Time required for a signal to traverse the medium
  - **Channel capacity (bandwidth)**

    Maximum data rate that medium can support

Data Rate: Noiseless Channels

- *Nyquist Theorem*

$$D = 2B\log_2 K$$

  - *D* – Data rate in bps
  - *B* – Bandwidth in Hz
  - *K* – number of signal levels

Example

We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?

Solution

We can use the Nyquist formula as shown:

$$265{,}000 = 2 \times 20{,}000 \times \log_2 K$$
$$\log_2 K = 6.625 \quad K = 2^{6.625} = 98.7 \text{ levels}$$

Since this result is not a power of 2, we need to either increase the number of levels or reduce the bit rate. If we have 128 levels, the bit rate is 280 kbps. If we have 64 levels, the bit rate is 240 kbps.

Data Rate: Noisy Channels

- *Shannon Capacity*

$$C = B\log_2(1+SNR)$$

  - *C* – Capacity (maximum bit rate) in bps
  - *B* – Bandwidth of the channel in Hz
  - *SNR* – Signal-to-Noise Ratio

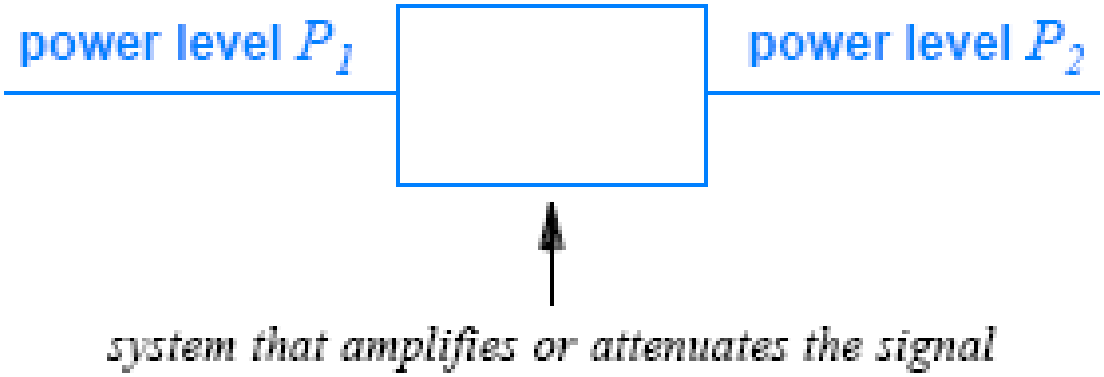
Example

A telephone line normally has a bandwidth of 3000. The signal-to-noise ratio is usually 3162. Calculate the theoretical highest bit rate of a regular telephone line.

$$C = B \log_2 (1 + \text{SNR}) = 3000 \log_2 (1 + 3162) = 3000 \log_2 3163$$
$$= 3000 \times 11.62 = 34{,}860 \text{ bps}$$

This means that the highest bit rate for a telephone line is 34.860 kbps. If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

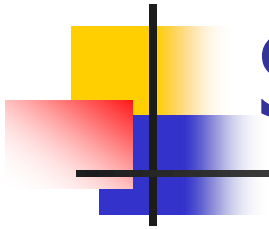
Measuring Power Levels



- Difference often measured in **decibel (dB)**

$$dB = 10 \log_{10}\left(\frac{P_2}{P_1}\right)$$

  - Negative dB → Signal power gets attenuated (reduced)
  - Positive dB → Signal power gets amplified



Summary

- Electromagnetic Energy
- Wire
  - Twisted Pair Cable
  - Coax Cable
  - Fiber Optic
  - Power cable (Powerline Networking)
- Wireless
  - Radio wave
  - Satellite
- Measuring Transmission Media