Transmission Media

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Transmission media

- A transmission medium is the physical path between transmitter and receiver
- For guided media, electromagnetic waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, and optical fiber.
- For unguided media, wireless transmission occurs through the atmosphere, outer space, or water.

Data transmission

- characteristics and quality of a data transmission are determined by
  - the characteristics of the medium
  - the characteristics of the signal
- Guided media: the medium is more important
- Unguided media: the bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics

Unguided media

- A key property of signals transmitted by antenna is directionality
- signals at lower frequencies are omni- directional
- At higher frequencies, it is possible to focus the signal into a directional beam

Key considerations in data transmission system design

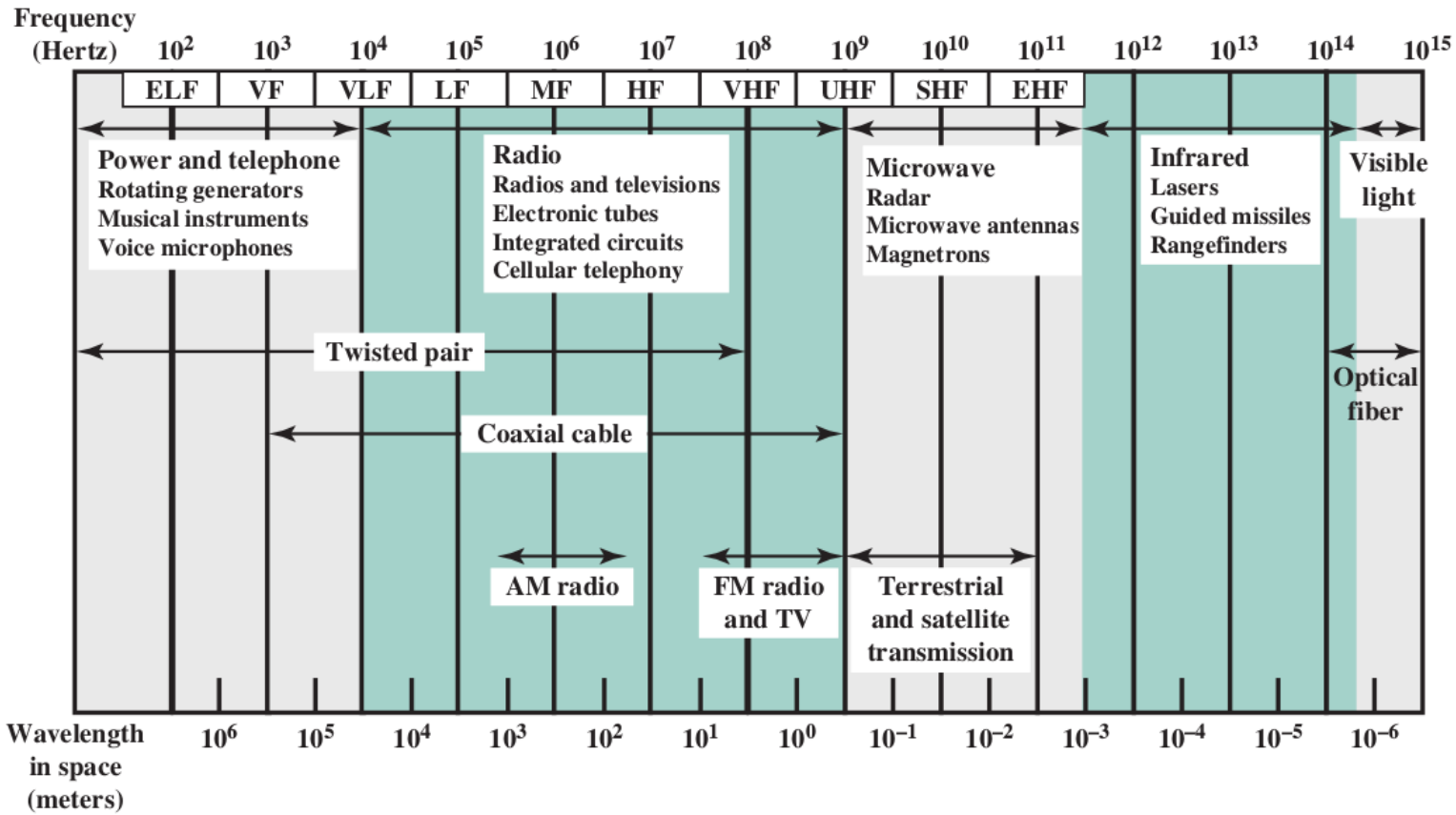
- Data rate
- Distance

Need to achieve the highest data rates over the longest distances

Factors determining data rates and distance

- Bandwidth: The greater the bandwidth, the _____ the data rate that can be achieved (greater/lesser)
- Transmission impairments: For guided media, from high impairments to low impairments — twisted pair, coaxial cable, optical fiber
- Interference: from competing signals in overlapping frequency bands can distort or cancel out a signal
  - For guided media, 1) alien crosstalk - interference due to nearby cables 2) internal crosstalk - adjacent conductors under the same cable sheath 3) electromagnetic coupling from unguided transmission
- Number of receivers: Shared link with multiple attachments - each attachment introduces some attenuation and distortion on the line, limiting distance and/or data rate

Electromagnetic Spectrum for Telecommunications



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

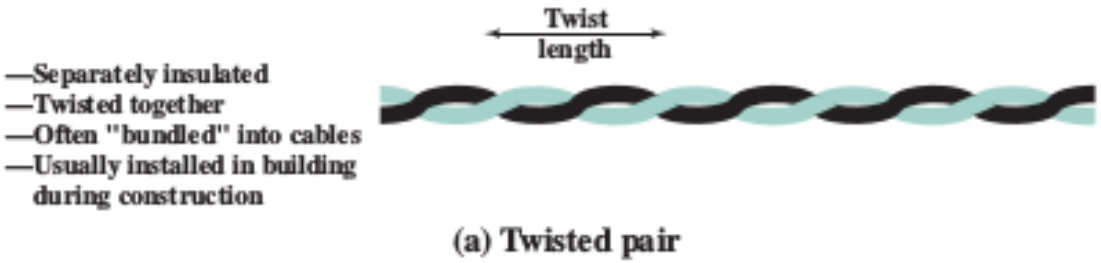
Guided Transmission media

	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 (multipair 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

THz = terahertz = 10^{12} Hz

- For guided transmission media, the transmission capacity, in terms of either data rate or bandwidth, depends on 1) the distance and 2) whether the medium is point-to-point or multipoint
- 3 commonly used guided transmission media: twisted pair, coaxial cable, optical fiber

Twisted pair



(a) Twisted pair

- Two insulated copper wires arranged in a regular spiral pattern
- A number of these pairs are bundled together into a cable by wrapping them in a tough protective sheath
- The twisting tends to decrease the crosstalk interference between adjacent pairs in a cable
- Neighboring pairs in a bundle - different twist lengths to reduce the crosstalk interference

Twisted pair: explanation

- The currents induced in each wire by an external source depends on the distance of the wire from the source
- Twisting ensures that both the wires are on an average at equal distance from the source
- Thus both the wires are affected equally
- It is the difference in voltage between the two wires that is amplified — since noise affects both the wires nearly equally, its effect is minimized

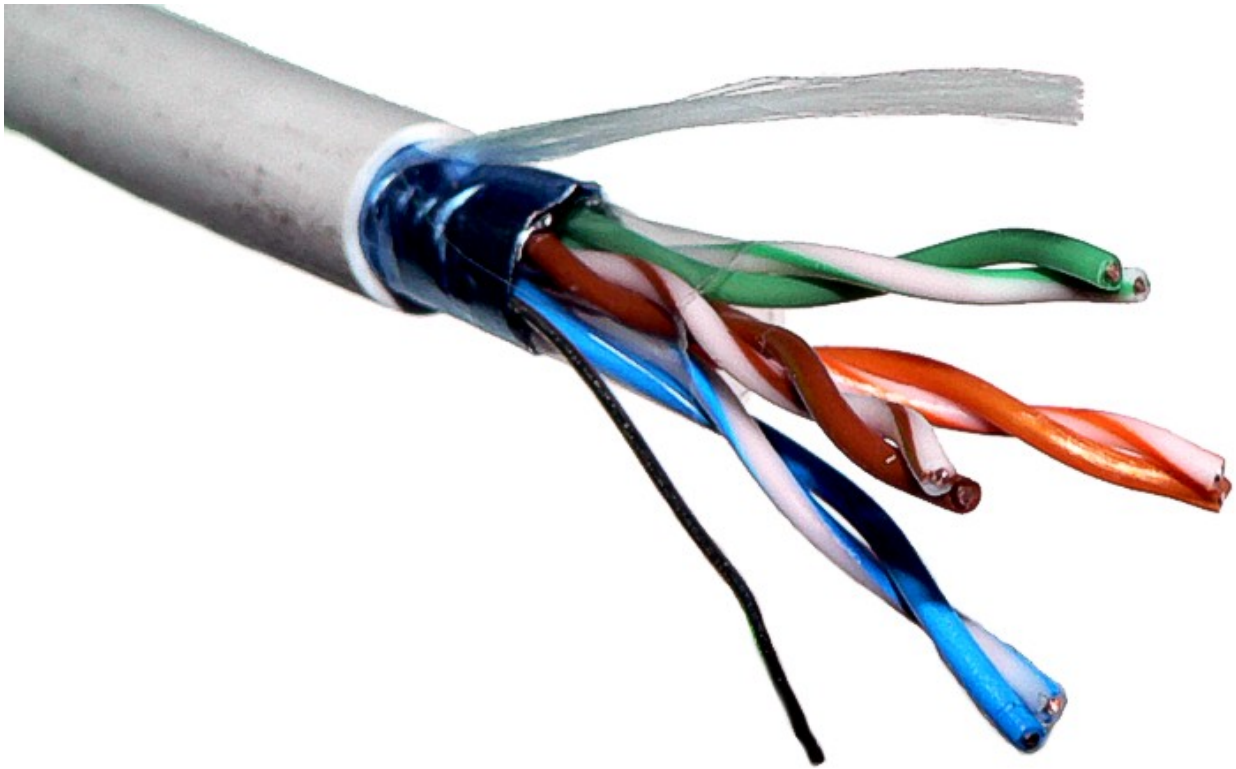
Twisted pair: applications

- The most common guided transmission medium for analog and digital singals
- Telephone network - individual residential telephones are connected to the local telephone exchange by a twisted-pair wire (subscriber loops)
- Individual office telephones are connected to a private branch exchange (PBX) through a twisted pair (64 kbps)
- Ethernet operates over twisted pair to connect PCs over a Local Area Network (100 Mbps to 1Gpbs)
- Long distance connections (more than 4 Mbps)

Twisted pair: transmission characteristics

- Amplifiers are required for every 5 to 6 km and repeaters every 2 to 3 km
- Attenuation is a strong function of frequency
- Susceptible to cross-talk
- Immune to interference from low frequencies (AC power transmitted at 60 Hz)
- Shielded twisted pair protects from high frequency disturbers (example: walkie-talkies at 30 Mhz) and supports higher data rates
- Shielding refers to electromagnetic shielding

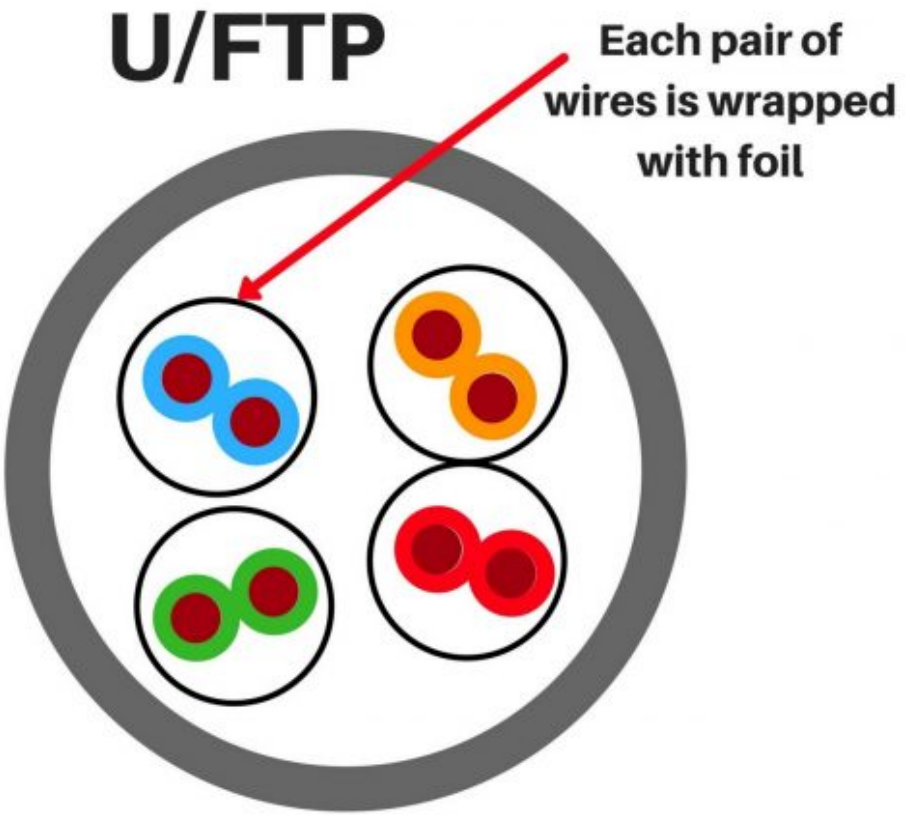
Foil / Unshielded Twisted Pair (F/UTP)



There is a foil or braid shield inside the jacket covering all wires (as a group). This configuration is sometimes designated as screened twisted pair

Figure source: Wikipedia

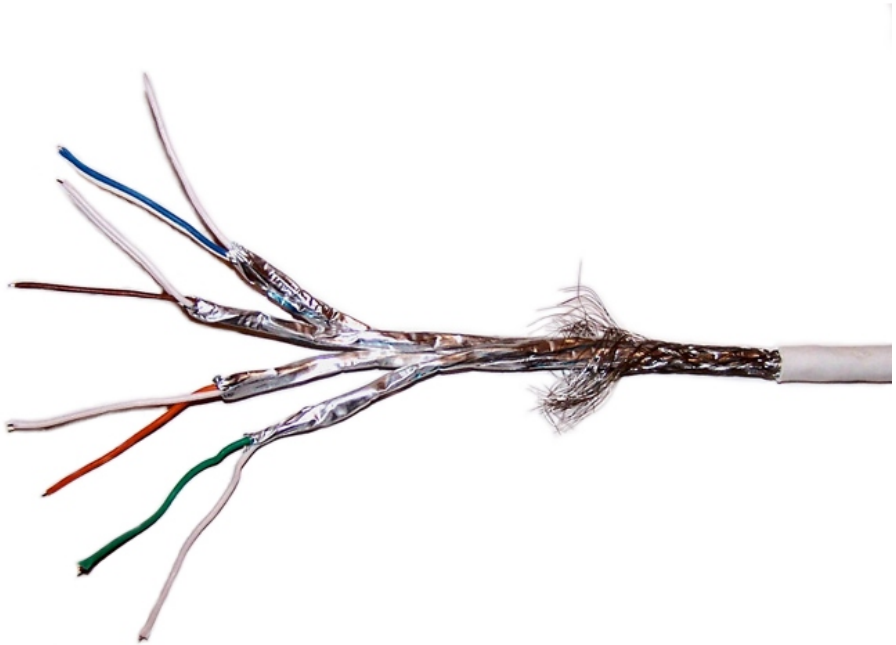
Unshielded Foil Twisted Pair (U/FTP)



Each pair of wires is individually shielded with metallic foil

Figure source:https://pactech-inc.com/difference-futp-vs-uftp-cat6a-cables/

Shielded Foil Twisted Pair (S/FTP)



There is a shield around each individual pair, as well as around the entire group of wires. This is referred to as fully shielded twisted pair or shielded/foil twisted pair

Figure source: Wikipedia

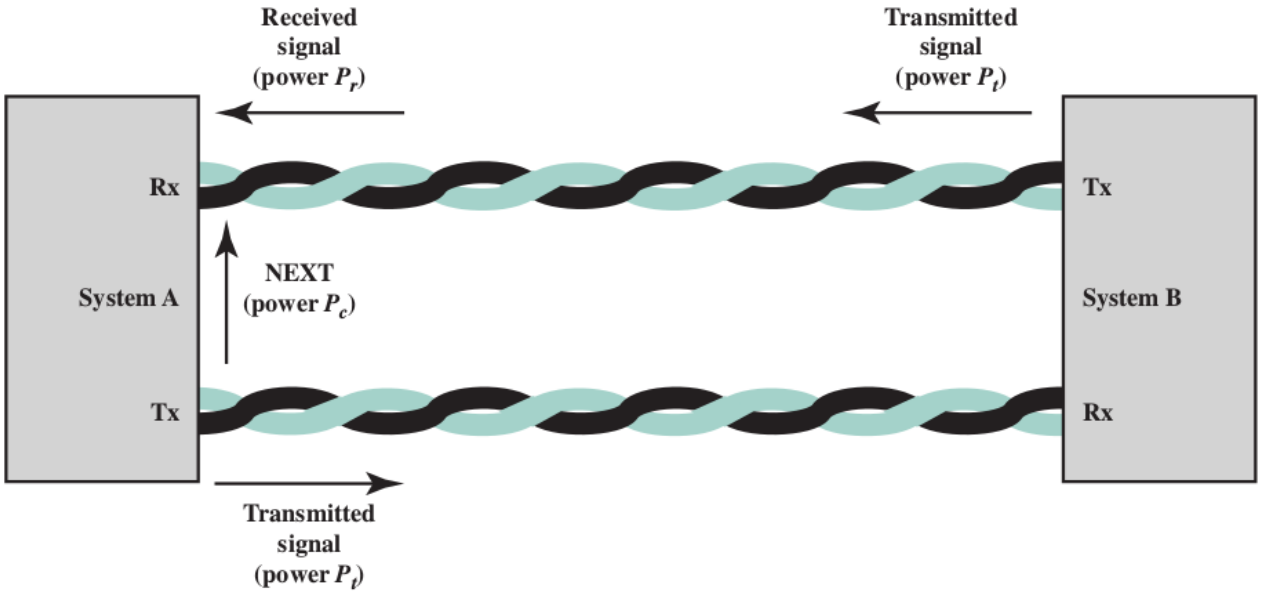
Twisted pair categories and classes

	Category 5e Class D	Category 6 Class E	Category 6A Class E_A	Category 7 Class F	Category 7_A Class F_A
Bandwidth	100 MHz	250 MHz	500 MHz	600 MHz	1,000 MHz
Cable type	UTP	UTP/FTP	UTP/FTP	S/FTP	S/FTP
Insertion loss (dB)	24	21.3	20.9	20.8	20.3
NEXT loss (dB)	30.1	39.9	39.9	62.9	65
ACR (dB)	6.1	18.6	19	42.1	44.1

UTP = Unshielded twisted pair
FTP = Foil twisted pair
S/FTP = Shielded/foil twisted pair

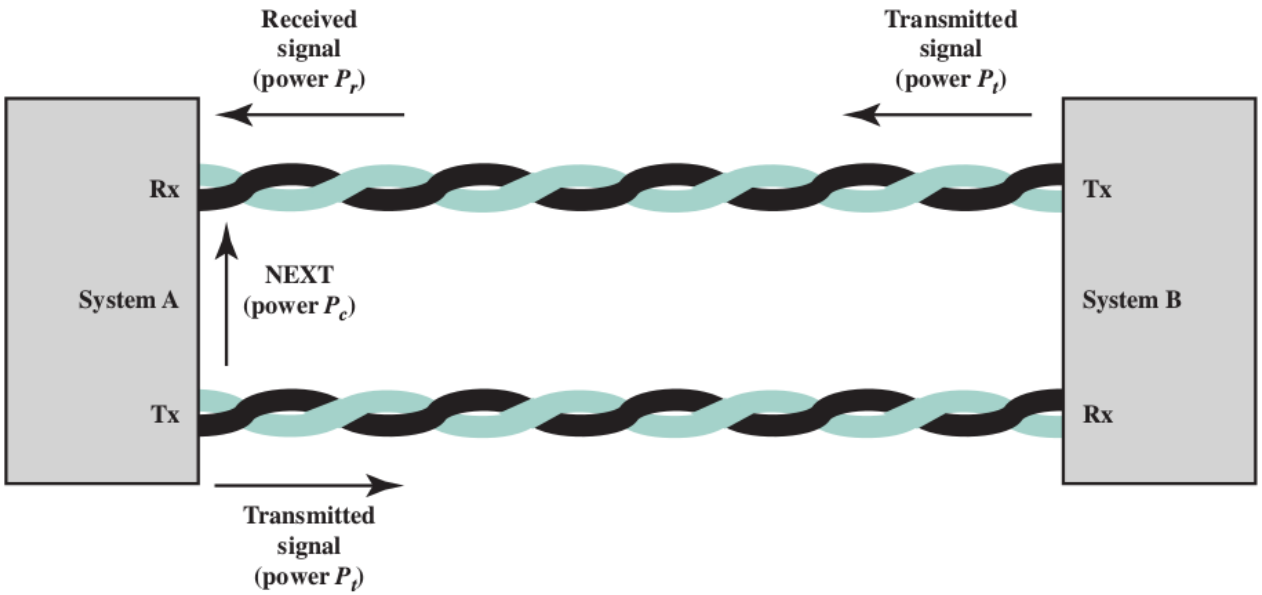
American National Standards Institute (ANSI) has come up with the above categories and classes.

Twisted pair categories and classes



- Insertion loss: the amount of attenuation across the link from the transmitting system to the receiving system
  - Attenuation in decibels is a linear function of distance
  - Attenuation is also a function of frequency

Twisted pair categories and classes



- Near-end crosstalk (NEXT) loss: the coupling of the signal from one pair of conductors to another pair
  - Near-end: 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
  - Higher dB values are better
  - NEXT loss is not a function of distance.
  - The higher the frequency, the higher the NEXT loss

Twisted pair: parameters

Insertion loss

$$A_{dB} = 10 \log_{10} \frac{P_t}{P_r}$$

NEXT loss

$$NEXT_{dB} = 10 \log_{10} \frac{P_t}{P_c}$$

Attenuation-to-crosstalk ratio (ACR)

$$ACR_{dB} = NEXT_{dB} - A_{dB}$$

ACR is a measure of how much larger the received signal strength is compared to the crosstalk on the same pair

Question

Smaller values of NEXT loss correspond to

(A) decreasing amount of crosstalk

(B) increasing amount of crosstalk

(C) neither of the above

Question

Which of the following is true of ACR?

(A) A positive value is required for successful operation

(B) A negative value is required for successful operation

Attenuation and crosstalk

$$10 \log_{10} \frac{P_t}{P_c} > 10 \log_{10} \frac{P_t}{P_r}$$

$$\log_{10} P_t - \log_{10} P_c > \log_{10} P_t - \log_{10} P_r$$

$$\log_{10} P_r > \log_{10} P_c$$

$$P_r > P_c$$

Received power $>$ Cross talk

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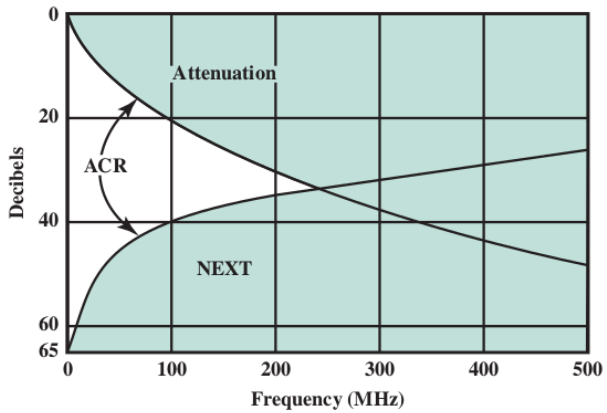
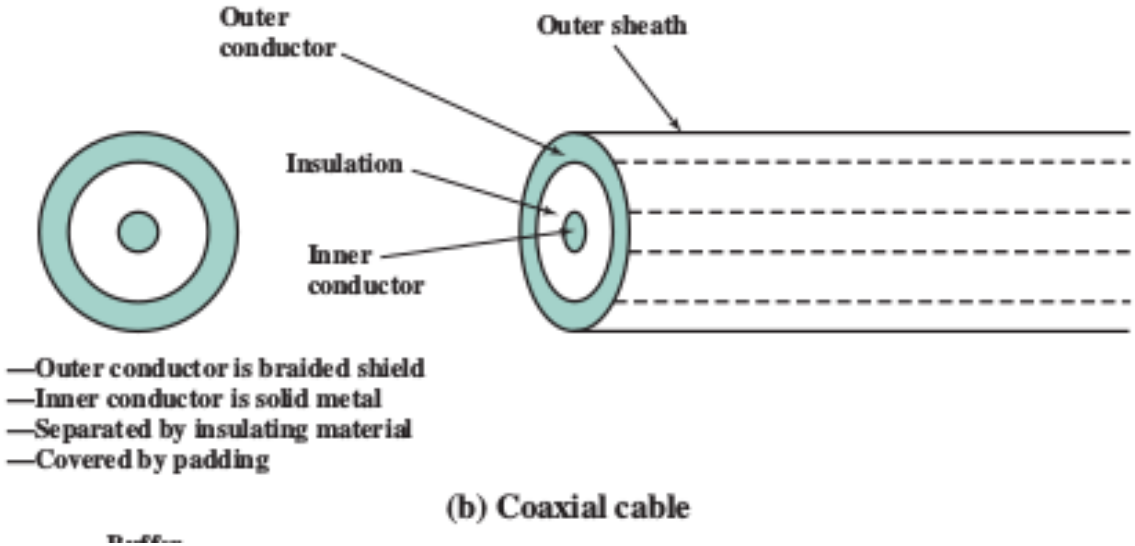


NEXT = near-end crosstalk
ACR = attenuation-to-crosstalk ratio

Communication is possible for frequencies greater than 250 MHz due to cross-talk cancellation.

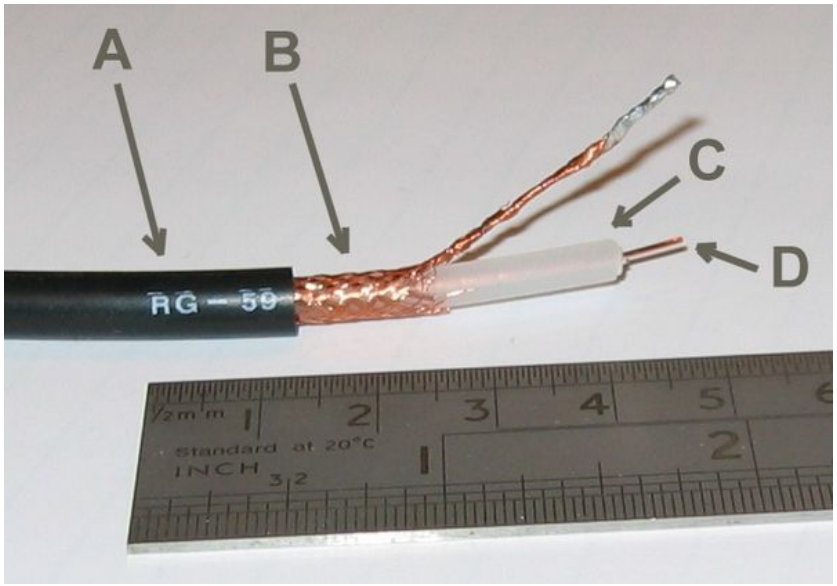
Coaxial cable



(b) Coaxial cable

- Diameter from 1 to 2.5 cm
- Can be used over longer distances and support more stations on a shared line than twisted pair

Coaxial cable - applications



- Television distribution (cable TV)
- Long-distance telephone transmission - using FDM, a coaxial cable can carry over 10,000 voice channels simultaneously
- Short-run computer system links
- Local area networks

Coaxial cable: transmission characteristics

- Used to transmit analog and digital signals
- Frequency characteristics are superior to those of twisted pair cables
- Less susceptible to interference and crosstalk than twisted pair - because of shielded concentric construction
- Constraints on performance : attenuation, thermal noise, and intermodulation noise (the last only when several channels are used, such as in FDM)
- Amplifiers are needed every few kilometers and repeaters every kilometer
- Spacing decreases if higher frequencies (analog) / higher data rates (digital) are used