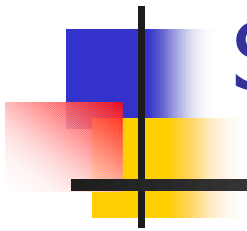
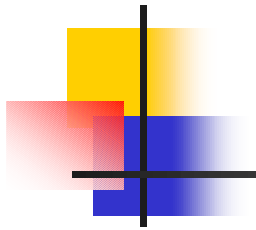


S-72.423 Telecommunication Systems

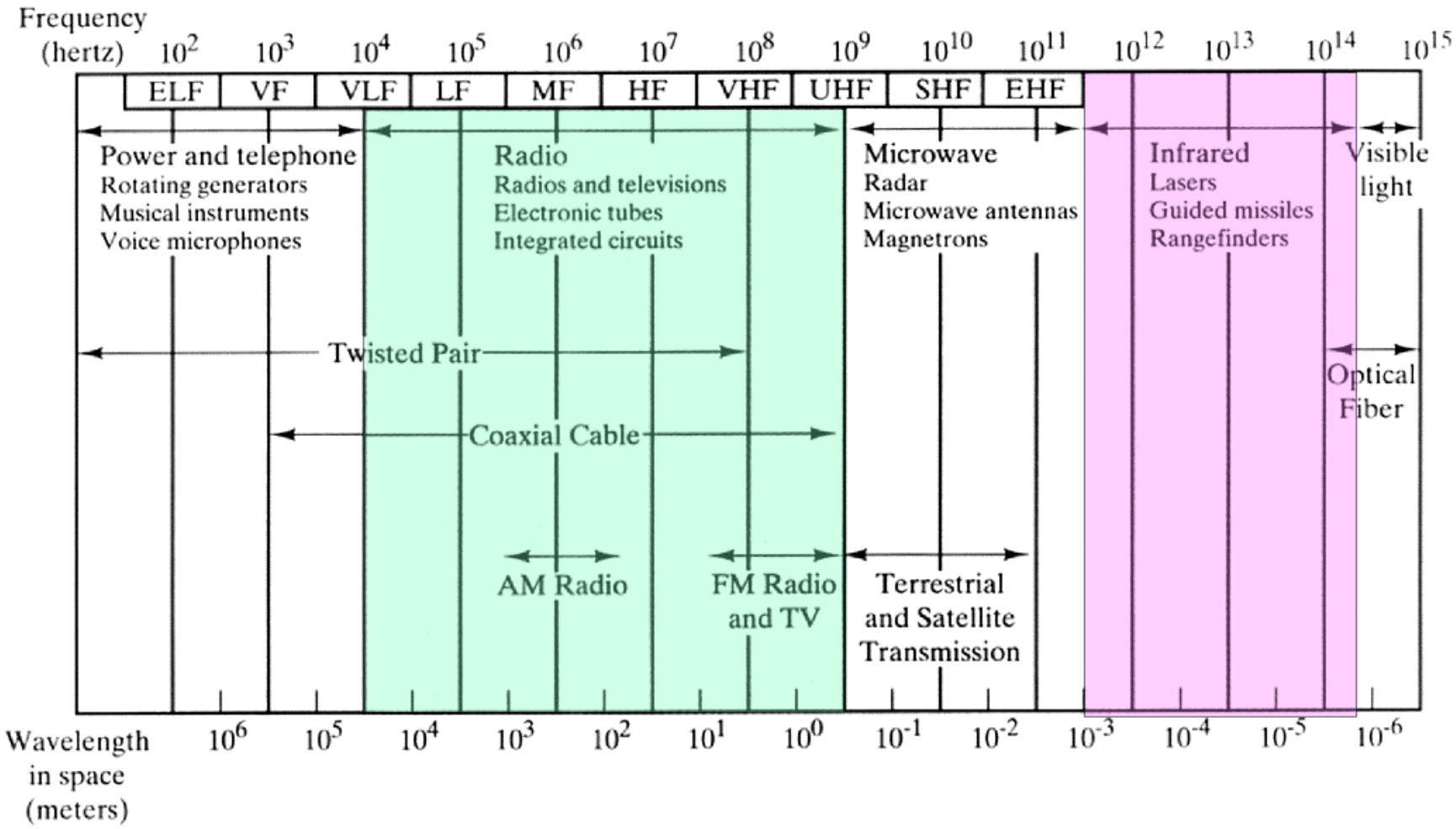
Transmission Media



Selecting the media

- What is **amount** of traffic to be distributed?
- What is the **cost** we can afford?
- What is the **interference** environment?
- Is mechanical **robustness** adequate?
- Point-to-point or **networking** usage?
- Capability to transfer **power** (for instance for repeaters)?
- Often the first selection is done between
  - Wired
  - Wireless
- Often one should consider if **digital** or **analog** message is transmitted: as analog PSTN takes 300-3400 kHz, but digital PCM 64 kHz, but digital GSM speech only 13 kbit/s

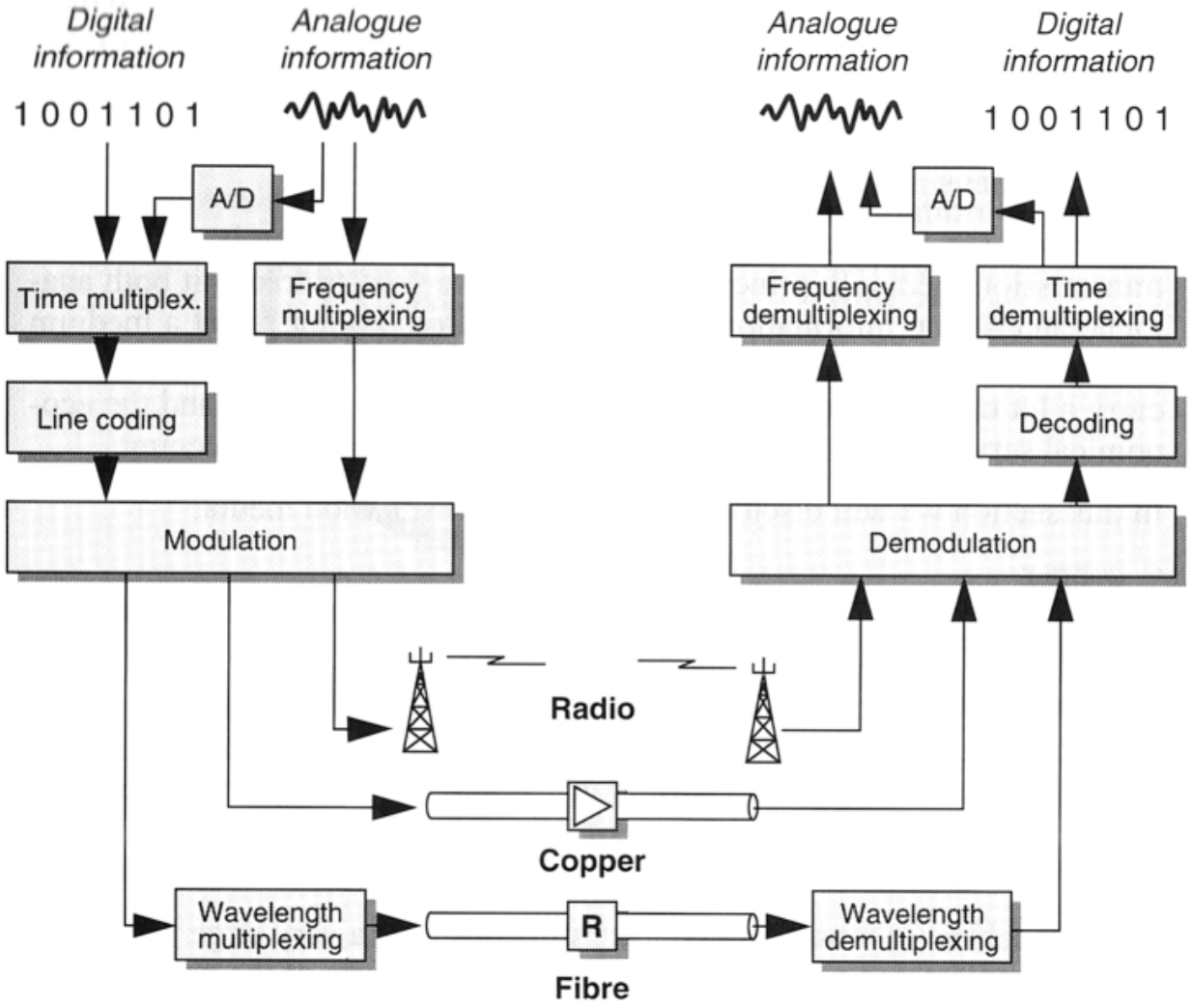
Electromagnetic spectrum



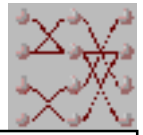
Characteristics of unguided communications bands

Frequency band	Name	Analog data		Digital data		Principal applications
		Modulation	Bandwidth	Modulation	Data rate	
30–300 kHz	LF (low frequency)	Generally not practical		ASK, FSK, MSK	0.1–100 bps	Navigation
300–3000 kHz	MF (medium frequency)	AM	To 4 kHz	ASK, FSK, MSK	10–1000 bps	Commercial AM radio
3–30 MHz	HF (high frequency)	AM, SSB	To 4 kHz	ASK, FSK, MSK	10–3000 bps	Shortwave radio CB radio
30–300 MHz	VHF (very high frequency)	AM, SSB; FM	5 kHz to 5 MHz	FSK, PSK	To 100 kbps	VHF television FM radio
300–3000 MHz	UHF (ultra high frequency)	FM, SSB	To 20 MHz	PSK	To 10 Mbps	UHF television Terrestrial microwave
3–30 GHz	SHF (super high frequency)	FM	To 500 MHz	PSK	To 100 Mbps	Terrestrial microwave Satellite microwave
30–300 GHz	EHF (extremely high frequency)	FM	To 1 GHz	PSK	To 750 Mbps	Experimental short point-to-point

Transmission methods: an overview*



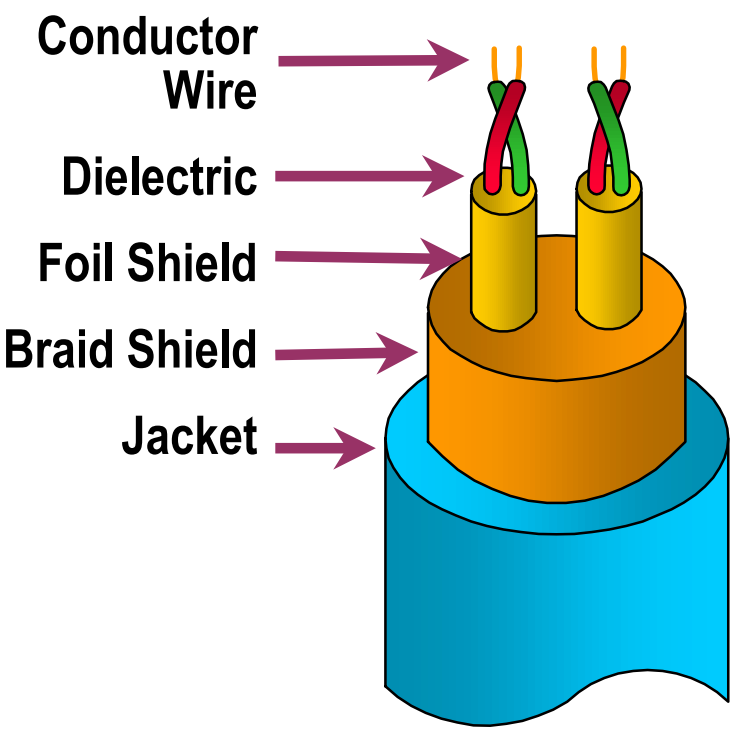
*Telia, Ericsson: Understanding Telecommunications, Part I



Types of Transmission Media

- **Conductive metal:** (twisted pair, coaxial cable) Conductive metal such as copper transmits data using electric current.
- **Glass or plastic:** (fiber optic) A transparent glass or plastic such as fiber optic cable transmits data using light waves.
- **Wireless:** (microwave, satellite) Wireless transmission requires no physical media but relies on electromagnetic waves such as those found in television and radio broadcasts. This type of media is such as microwave and satellite transmission.

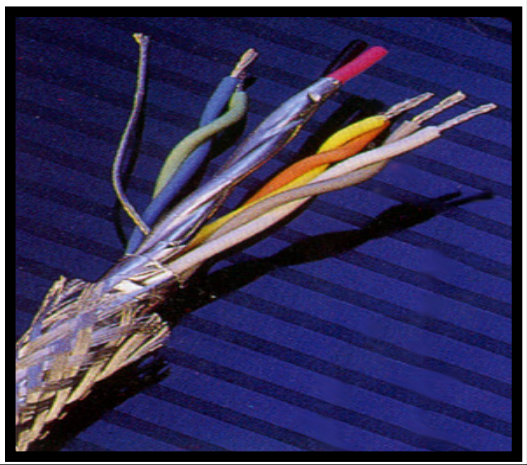
Twisted Pair



- Connect low rate date and especially PSTN local loop. Packaged in two or more pairs since some locations require multiple connections (e.g. add another line for modem use).
- Since straight copper wires tend to act as antennas and pick up erroneous signals. The twisting helps reduce the amount of interference and also reduce migration.
- Twisted pairs (send and receive) often are bundled together and wrapped in a protective coating.
- Each pair has twist length (2-16 in), reducing the interference between them (crosstalk or electromagnetic induction).

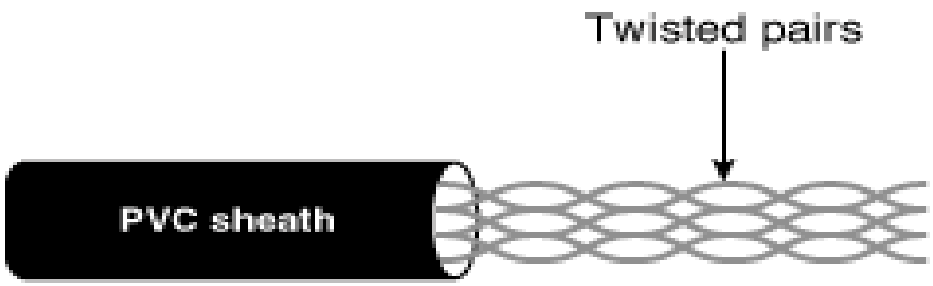
Shielded Twisted-Pair Cable (STP)

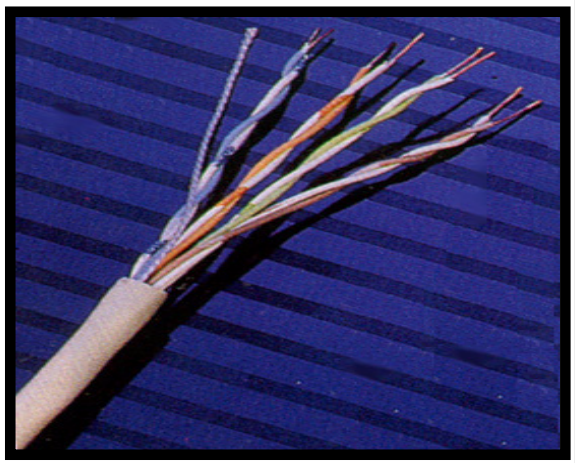
- Used in some business locations TP is covered with a foil shield that functions as a ground to reduce interference and crosstalk. Though the shield increase *attenuation* (decrease in signal strength from one point to another on the network) and may cause loss of data in itself (due to change in resistance, capacitance and inductance).
- STP can handle high-speed transmissions. Cable itself is relatively expensive, can be quite bulky and heavy.
- STP is used Token Ring networks.

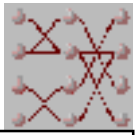


Unshield Twisted-Pair (UTP)

- Least expensive. Ordinary wire to the home (telephone) usually does not include any extra shielding around the wire pairs (UTP). Easy to work with and simple to install.
- Because it lacks shielding, UTP isn't as good at blocking noise and interference as STP.
- UTP is the primary choice for a 10BaseT Ethernet network that uses UTP cabling at 10 Mbps.







UTP Categories

- 5 major categories:
  - Category 1: mainly used to **carry voice** (telephone wiring prior to 1980). Not certified to carry data of any type.
  - Category 2: used to carry data at rates up to **4Mbps.** Popular for older Token-based networks utilising 4Mbps specs. Rated 1Mhz.
  - Category 3: known as voice grade. Used primarily in older **Ethernet 10base-T LANs.** Certified to carry **10Mbps** data. 16Mhz. 3-4 twists/feet.
  - Category 4: primarily used for token-based or 10Base-T**.** 20MHz.
  - Category5: most popular Ethernet cabling category. Capable of carrying data at rates up to **100 Mbps (Fast Ethernet)** and used for 100base-T and 10base-T networks. Rated to 100MHz. 3-4 twists/inch.

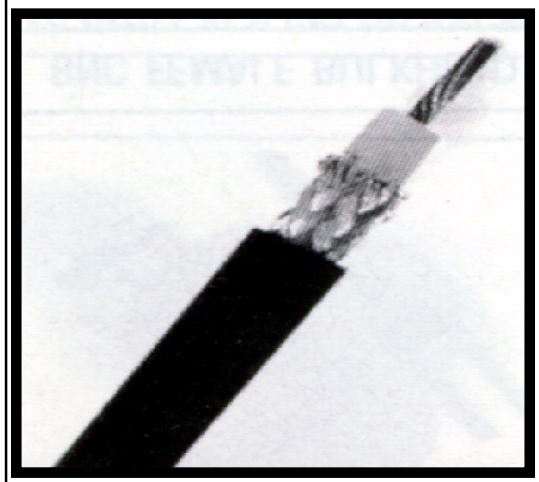
Unshielded and shielded twisted pairs attenuation compared

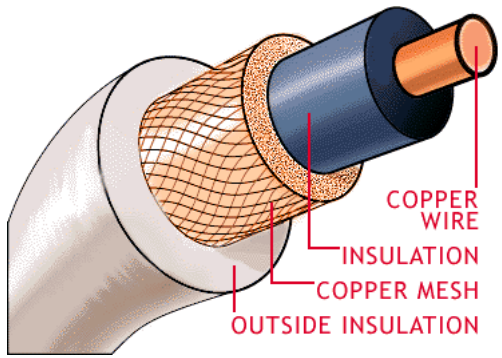
- Electronic Industries Association has specified in EIA-568-A twisted pairs for different applications.

	Attenuation (dB per 100 m)			Near-end crosstalk (dB)		
Frequency (MHz)	Category 3 UTP	Category 5 UTP	150 Ω STP	Category 3 UTP	Category 5 UTP	150 Ω 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	—	32	47.5
100	—	22.0	12.3	—	—	38.5
300	—	—	21.4	—	—	31.3

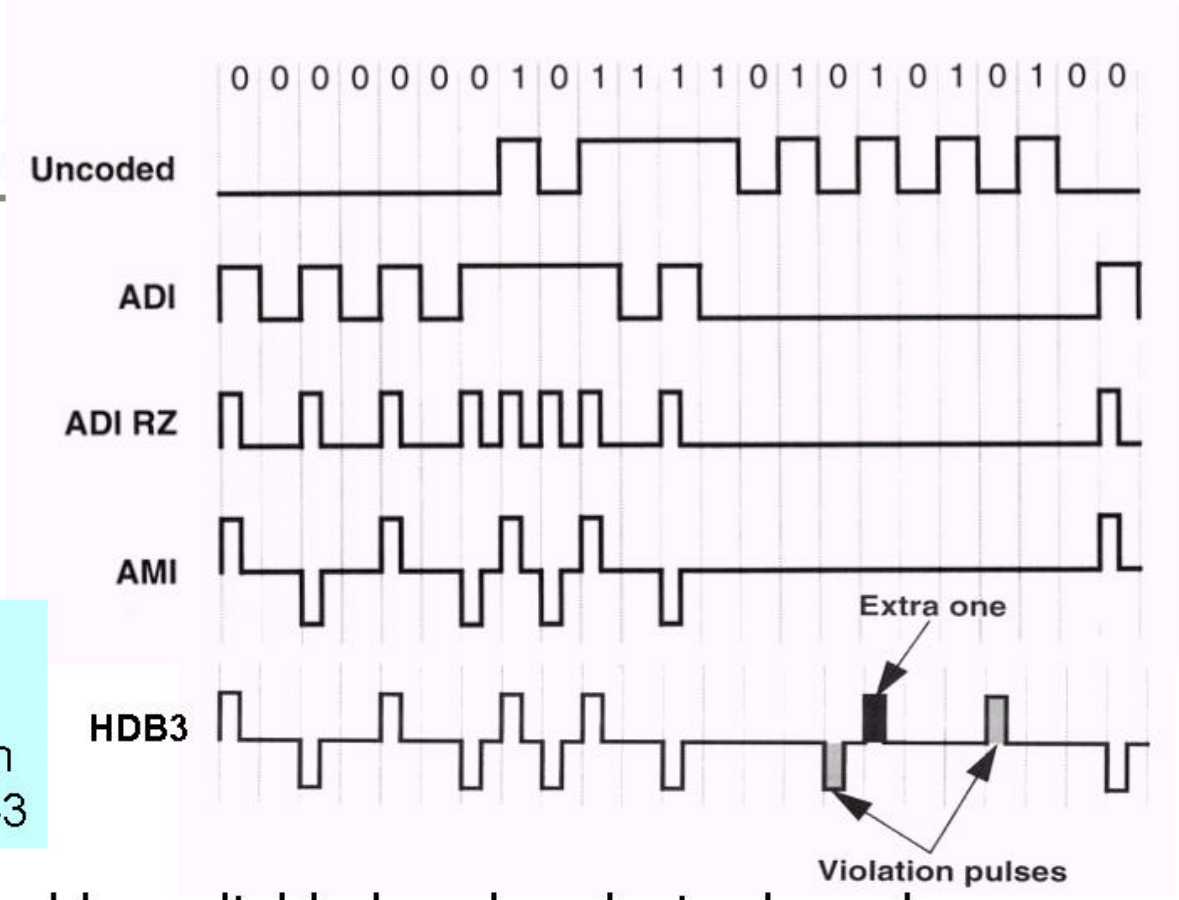
Coaxial cable

- Called coaxial because it includes one physical channel surrounded (after a layer of insulation) by another concentric physical channel, both running along the same axis and separated by a dielectric material. 2 sizes (1/2”, 3/8”).
- With repeaters, can carry information for a longer distance than Twisted Pair.
- Popular for cable television transmissions and for LANs because it has better **noise immunity.**
- Functionally grouped into
  - **baseband (10BASE-2, 10BASE-5)**
    - **cable is dedicate for only one channel**
  - **broadband**
    - **cable can carry several analog signals (at different frequencies) simultaneously**





Line coding

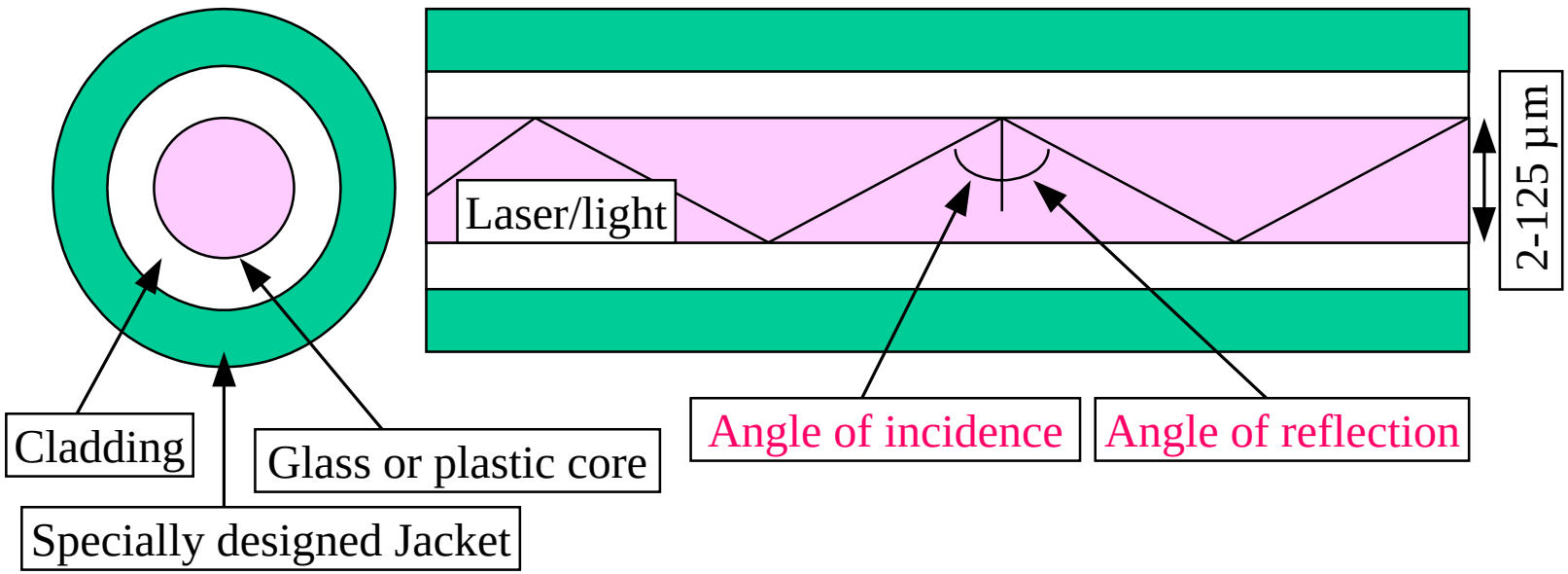


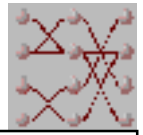
ADI: Alternate digit Inversion
RZ: Return to zero
AMI: Alternate mark inversion
HDB3: High Density Bipolar -3

- Line coding enables reliable baseband wire-based transmission by
  - being spectral efficient
  - giving strong enough peak in power spectral density for clock synchronization (repeaters and end-RX)
  - has no DC components

Optical Fiber

- Light at less than **critical angle** is absorbed in the jacket.
- Each fiber is surrounded by its own cladding, a glass or plastic coating that has different optical properties than the core.
- The jacket is composed of plastic and other material layered to protect from moisture, abrasion, crushing and other environment dangers.



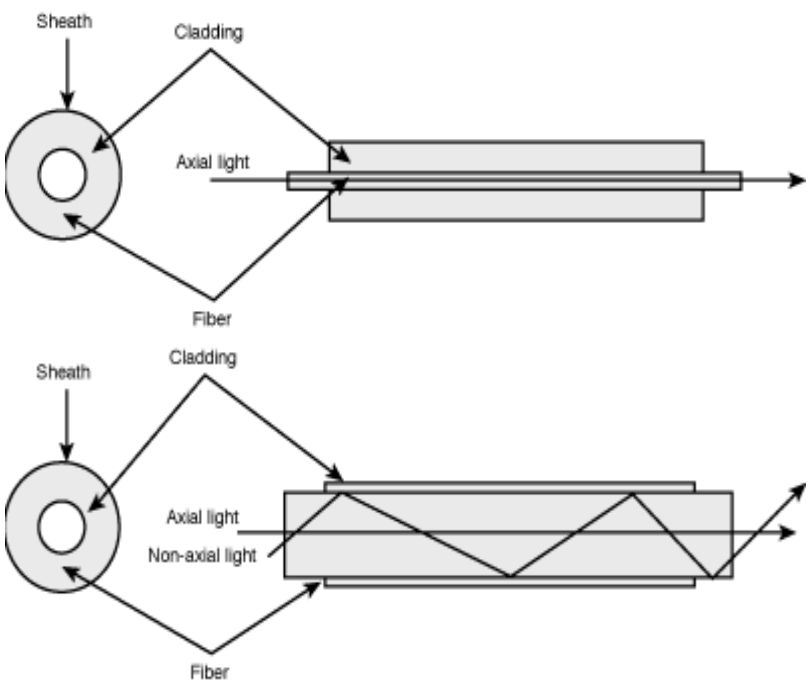


Optical Fiber (BASE-F)

- Fiber-optic cable or optical fiber provides a thin glass wire/cable medium using light waves rather than electricity, totally non-conductive. The most **expensive** of all but **secure**/most **reliable.**
- Light waves/pulses provide superior electrical **isolation** for equipment and are immune to electromagnetic interference and crosstalk. Usually preserved for connections between backbone routers in large networks. Also **in demanding environments**.
- Optical fiber can be used for much **longer distances** before the signal must be amplified. Data rates of 4Gbps over 500 kms have been demonstrated. However as distance ↑ bandwidth ↓.
- Data transmission using optical fiber is many times **faster** than with electrical methods and can handle rates up tenths of Gbps.

Single vs Multimode Fiber

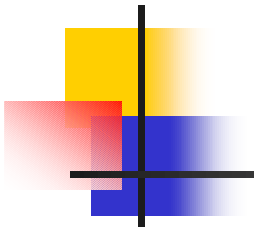
- Single (Axial): light travels along the axis of a thin wire. Power is extremely guided, Fast
- Multimode (Non-Axial): some of the light waves enter a thick pipe at different angles and travel non-axially bouncing from wall to wall. Waves travel for greater distances than single mode causing the light to arrive at the terminating point at different times. This is known as **modal dispersion**. Number of modes of light ↑→ bandwidth ↓



At 100 m, multi-mode reaches about 1600MHz at 850nm. Single mode reaches 888HHz For same 100 m run.

Characteristics of optical fibers

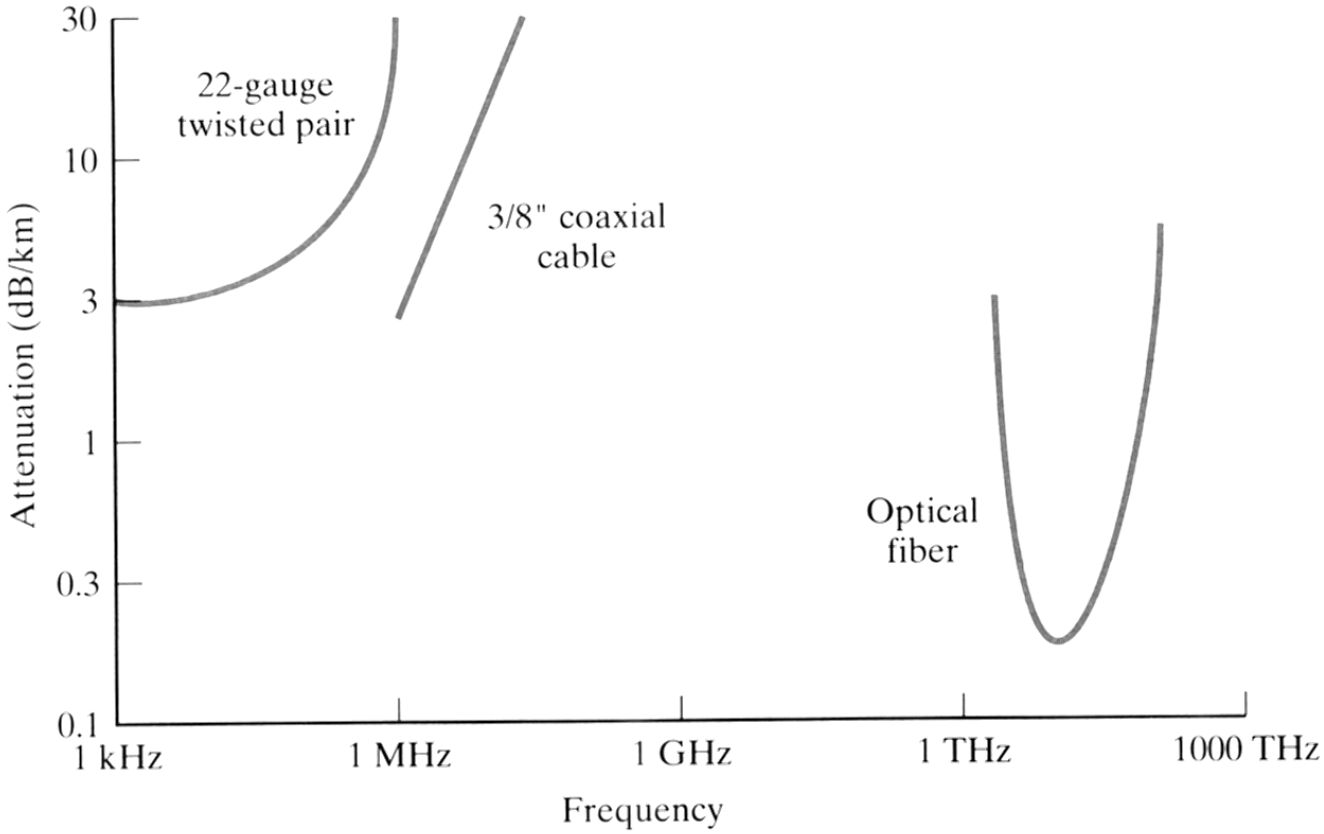
Fiber type	Core diameter (μm)	Cladding diameter (μm)	Attenuation (dB/km) (Max)			Bandwidth (MHz/km) (Max)
			850 nm	1300 nm	1500 nm	
Single Mode	5.0 8.1	85 or 125 125	2.3	0.5	0.25	5000 @ 850 nm
Graded-index	50	125	2.4	0.6	0.5	600 @ 850 nm 1500 @ 1300 nm
	62.5	125	3.0	0.7	0.3	200 @ 850 nm 1000 @ 1300 nm
	100	140	3.5	1.5	0.9	300 @ 850 nm 500 @ 1300 nm
Step-index	200 or 300	380 or 440	6.0			6

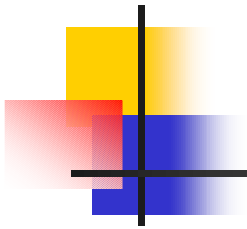


Wavelength Division Multiplexing (WDM)

- Optical variant of FDM
- Used for bit rates exceeding 10 Gbit/s
- Combined with TDM
- Use multiple lasers or LEDs
- Single channel rate up 25 Gb/s
- In Course WDM wavelength spacing 2-10 channels with spacing of 5-20 nm
- In Dense up to 400 wavelength having spacing order of 0.1 nm
- Both 1.3 μm and 1.55 μm windows can be used simultaneously -> capacity increase

Guided media attenuation characteristics compared



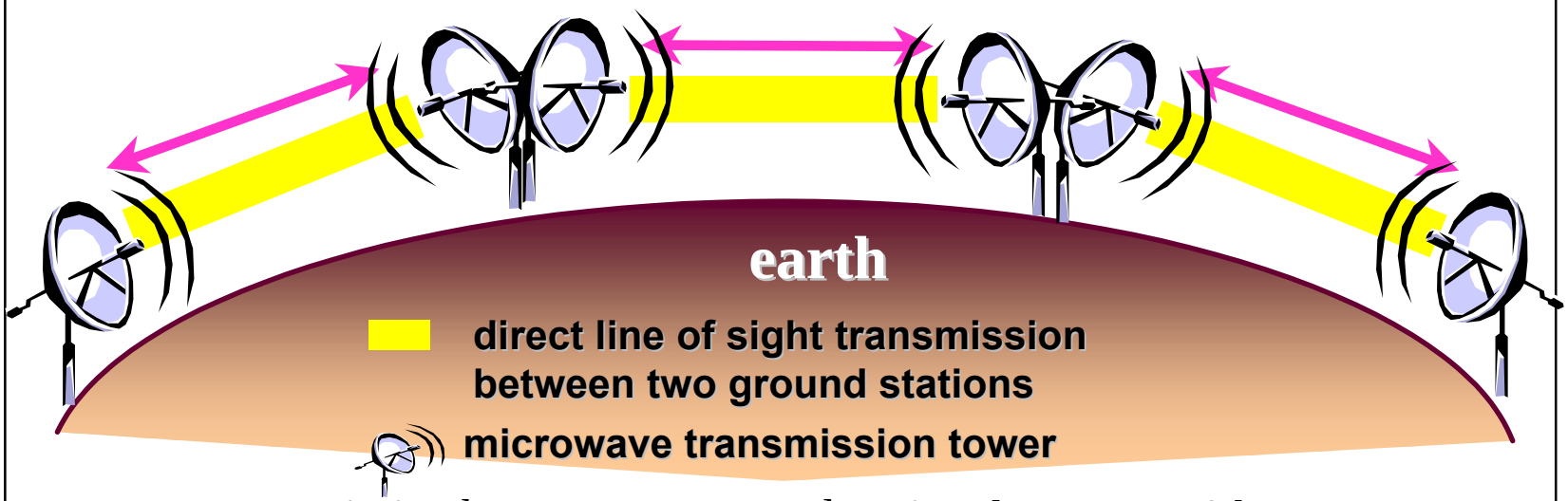


Comparing media in point-to-point transmission

- Twisted pair:
  total rate: 4 Mbps, BW=3 MHz, rep.sp=2 … 10 km
- Coaxial cable:
  total rate: 500 Mbps, BW=350 MHz, rep.sp=1 … 10 km
- Optical fiber:
  total rate: 2 Gbps, BW=2 GHz, rep.sp=10 … 100 km

Microwave

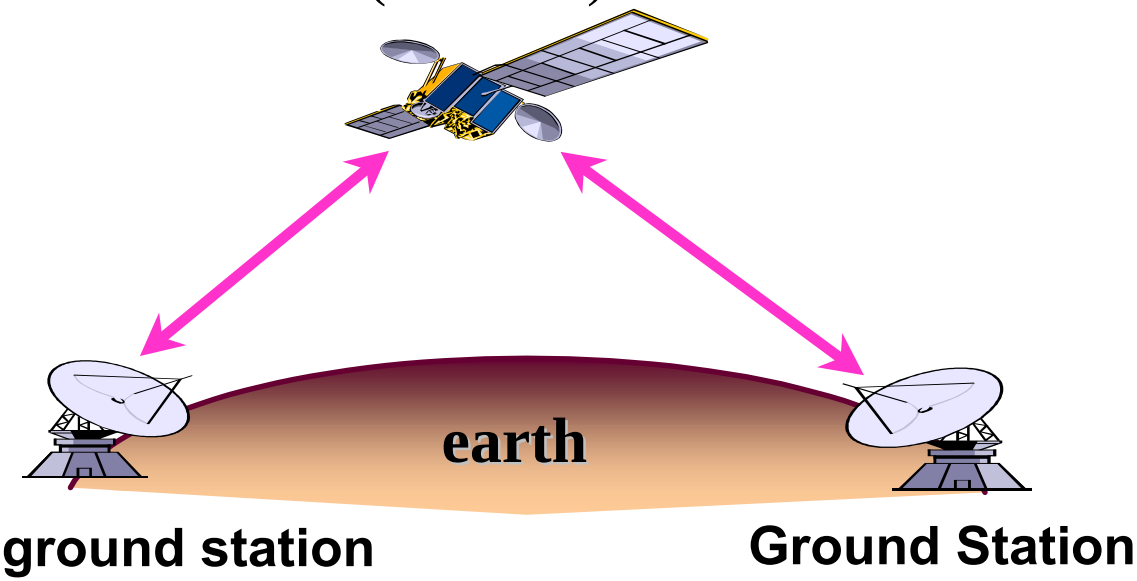
- Microwave links are widely used to provide communication links when it is **impractical** or too **expensive** to install physical media. Two properties of microwave transmission place restrictions on its use.
  - microwaves travel **in straight lines** and do not follow the earth's curvature.
  - **atmospheric conditions and solid objects** interfere with microwaves. For example, the cannot travel through buildings.



transmission between two ground station distance ≈ 50 km

Satellites

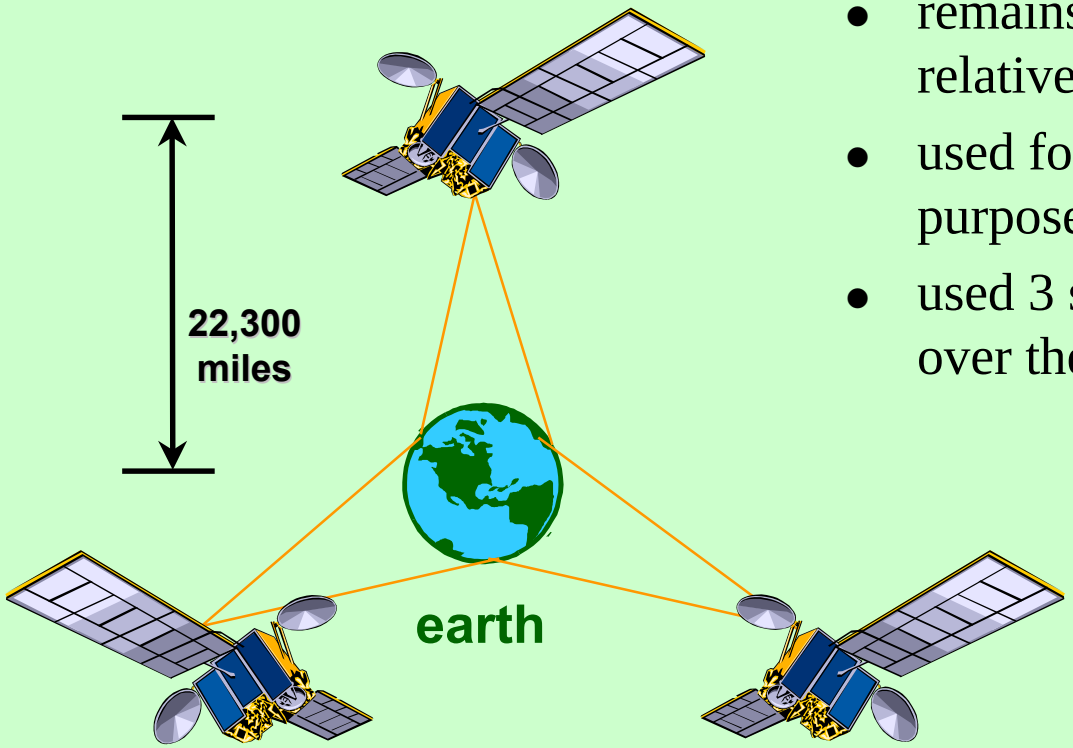
- Satellite transmission is microwave transmission in which one of the stations is a satellite orbiting the earth.
- A microwave beam is sent from the ground and satellite retransmits (relayed) to destination. Receiver and transmitter is called **transponder.**
- Upward transmission (uplink) 6 GHz (C band, 14 in KU band).
- Downward transmission (downlink) 4 GHz.



Satellite band

- The optimum frequency range for satellite transmission is in the range 1 to 10 GHz. Below 1 GHz, there is significant noise from natural sources, atmospheric noise, and noise from electronic devices. Above 10 GHz, the signal is attenuated by atmospheric absorption.
  C band 4/6 GHz
  5.925 - 6.425 GHz uplink
  3.7 - 4.2 GHz downlink
- The KU band systems require higher uplink and downlink radiate **power** and greater transponder receiver **sensitivity.**
  KU band 12/14 GHz
  14 - 14.5 GHz uplink
  11.7 - 12.2 GHz downlink

Geostationary Satellite



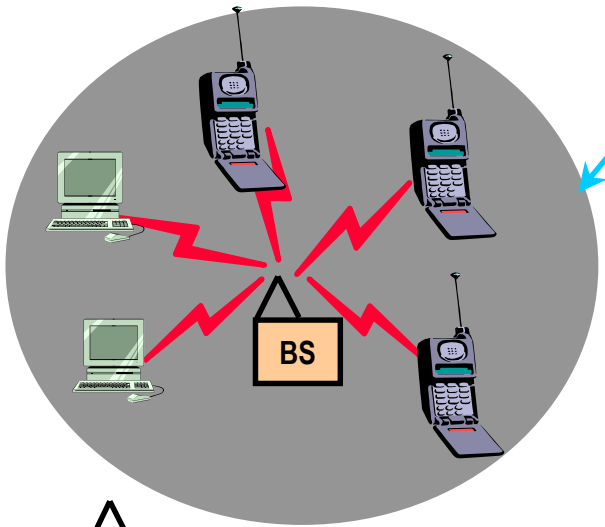
- remains in a fixed position relative to ground station.
- used for communication purposed.
- used 3 satellites to cover all over the earth.

Geostationary Satellite

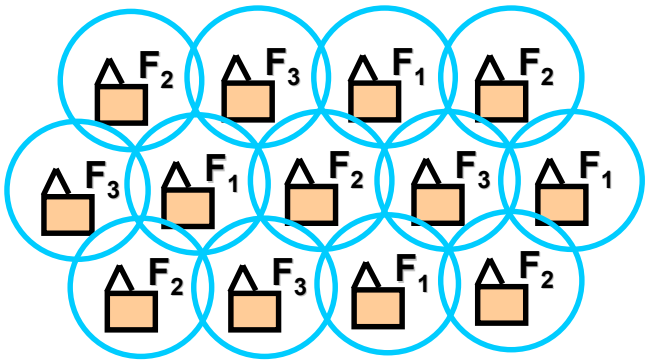
- Satellites moves across the sky, communication is possible for only a short time. As at dropped below the horizon, communication ceased until it later appeared above the other horizon. To always provide communications :
  - 1. A series of satellites would be arranged so that when one disappeared, another would appear to take it place.
  - 2. Arrange satellite's velocity synchronous with the earth's rotation, This is called "geostationary orbit". Kepler's third law
    - $P^2 = K \times D^3$
    - P = times to rotate = 24 hrs, K = constant, D = distance between satellite and earth's center (22,300 miles above the equator).

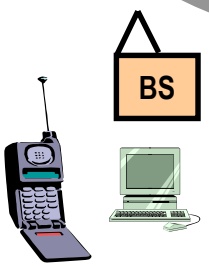
Radio (GSM)

- **Wireless link** between fixed terminal point (base station) and terminal.
- Coverage area is restricted by **limiting its power** to support total load.
- Wider coverage can be achieved by arraying **multiple base stations.** This allows using a frequency band of one station in others.



Radio field of coverage of base station

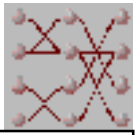




= Base station

= User computer/terminal

F_1, F_2, F_3 = Frequencies used in cell

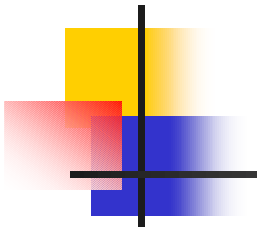


Factor to Select Media Type

- **Cost:** Media and devices they attach to have different costs.
- **Data rate & bandwidth:** Various media can support different data rate & bandwidth. Choose a media type according to your rate need.
- **Distance:** How long a media can run should be taken into account.
- **QoS:** Interference and nonlinear distortion.

Point-to-point transmission characteristics of guided media compared

- Twisted pair (used in PSTN local loop)
  - can achieve data rate up to 60 Mb/s but the usual value is up to 2Mb/s in ADSL usage.
  - least expensive
  - most common media for both analog and digital signals
  - Analog usage repeaters every 5-6 km, digital usage repeaters every 2-3 km
- Coaxial cable that is used in CATV systems achieve up to tenths of Gb/s depending on cable quality. Provides also relatively good electrical shielding but is more expensive than twisted pair
- Optical cable can potentially accommodate up to 20 000 Gb/s but nowadays used commercially only about to 20 Gb/s per channel. Optical fiber does not feel external electrical fields but can be sensitive to mechanical stress. The most expensive media-type that often compeats with microwave links



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