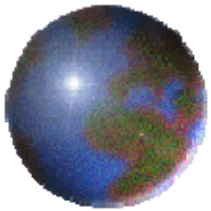
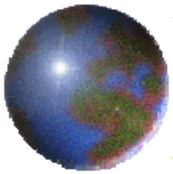


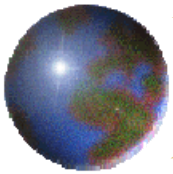
Data and Computer Communications

Transmission Media



Overview

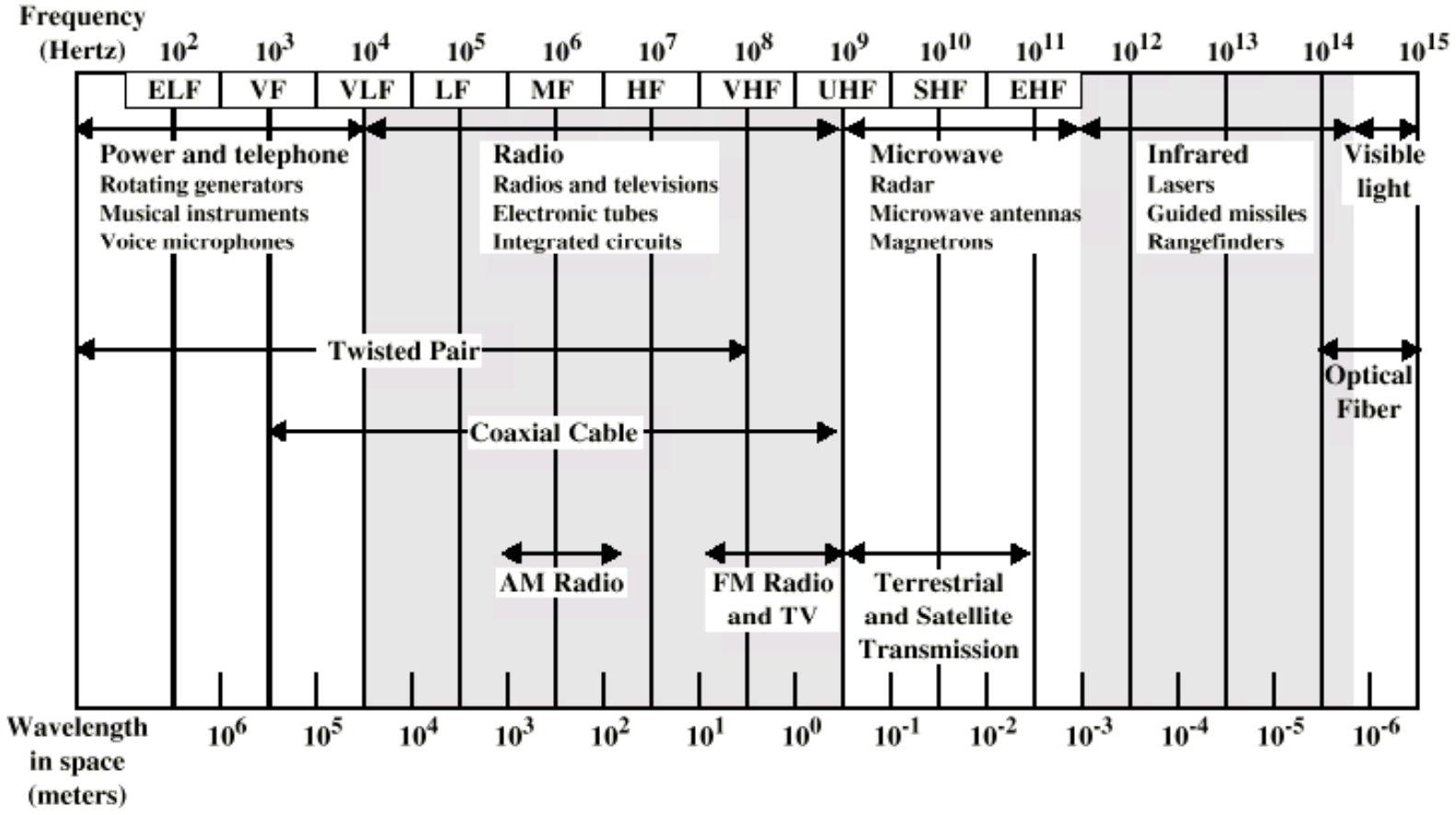
- Guided - wire
- Unguided - wireless
- Characteristics and quality determined by medium and signal
- For guided, the medium is more important
- For unguided, the bandwidth produced by the antenna is more important
- Key concerns are data rate and distance



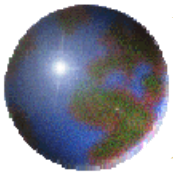
Design Factors

- Bandwidth
  - Higher bandwidth gives higher data rate
- Transmission impairments
  - Attenuation
- Interference
- Number of receivers
  - In guided media
  - More receivers (multi-point) introduce more attenuation

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 = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

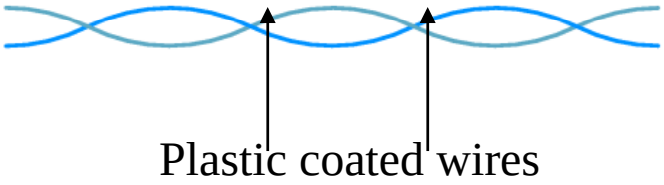


Guided Transmission Media

- Twisted pair
- Coaxial cable
- Optical fiber

Copper Wires

- Primary medium to connect computers because
  - Inexpensive & easy to install
  - Low resistance to electric current
- When wires placed close together in parallel, interference takes place
- To minimize interference, networks use:
  - Twisted pair

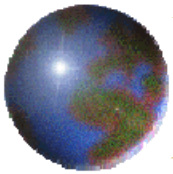


- Advantages
  - Limits electromagnetic energy emission
  - Prevents signals from other wires from interfering

Twisted Pair

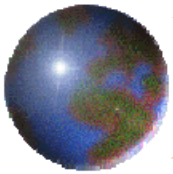
—Separately insulated
—Twisted together
—Often "bundled" into cables
—Usually installed in building during construction

(a) Twisted pair



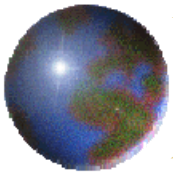
Twisted Pair - Applications

- Most common medium
- Telephone network
  - Between house and local exchange (subscriber loop)
- Within buildings
  - To private branch exchange (PBX)
- For local area networks (LAN)
  - 10Mbps or 100Mbps



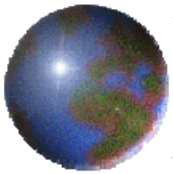
Twisted Pair - Pros and Cons

- Cheap
- Easy to work with
- Low data rate
- Short range



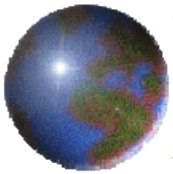
Twisted Pair - Transmission Characteristics

- Analog
  - Amplifiers every 5km to 6km
- Digital
  - Use either analog or digital signals
  - repeater every 2km or 3km
- Limited distance
- Limited bandwidth (1MHz)
- Limited data rate (100MHz)
- Susceptible to interference and noise



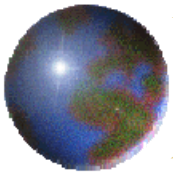
Unshielded and Shielded TP

- Unshielded Twisted Pair (UTP)
  - Ordinary telephone wire
  - Cheapest
  - Easiest to install
  - Suffers from external EM interference
- Shielded Twisted Pair (STP)
  - Metal braid or sheathing that reduces interference
  - More expensive
  - Harder to handle (thick, heavy)



UTP Categories

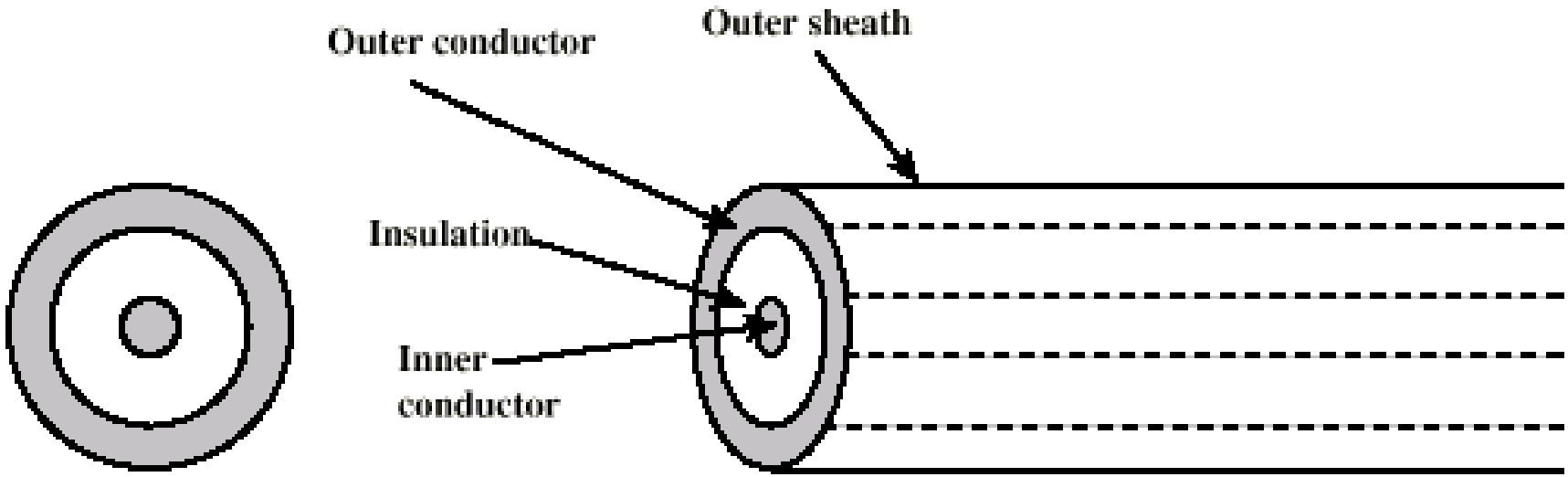
- Cat 3
  - up to 16MHz
  - Voice grade found in most offices
  - Twist length of 7.5 cm to 10 cm
- Cat 4
  - up to 20 MHz
- Cat 5
  - up to 100MHz
  - Commonly pre-installed in new office buildings
  - Twist length 0.6 cm to 0.85 cm



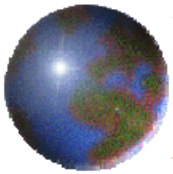
Near End Crosstalk

- Coupling of signal from one pair to another
- Coupling takes place when transmit signal entering the link couples back to receiving pair
- i.e. near transmitted signal is picked up by near receiving pair

Coaxial Cable



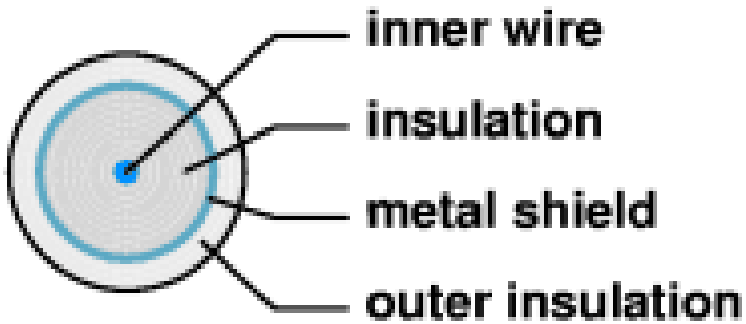
—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding



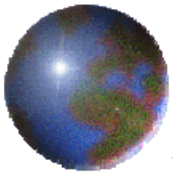
Coaxial Cable Applications

- Most versatile medium
- Television distribution
  - Ariel to TV
  - Cable TV
- Long distance telephone transmission
  - Can carry 10,000 voice calls simultaneously
  - Being replaced by fiber optic
- Short distance computer systems links
- Local area networks

Copper Wires

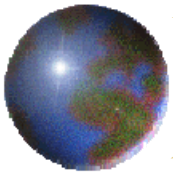


- Coaxial cable(coax)
  - Single wire surrounded by a heavier metal shield
  - Provides barrier to electromagnetic radiation
  - More protection than twisted pair
- Shielded twisted pair
  - A pair of wires surrounded by a metal shield



Coaxial Cable - Transmission Characteristics

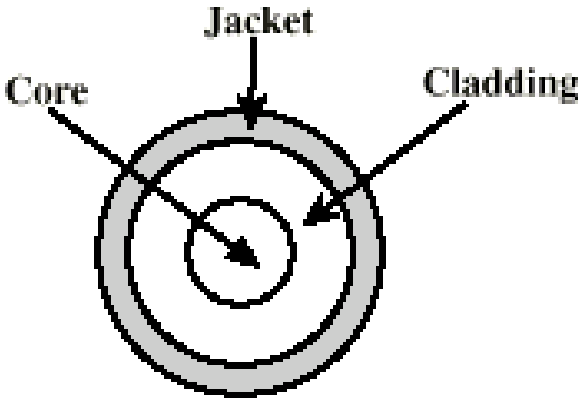
- Analog
  - Amplifiers every few km
  - Closer if higher frequency
  - Up to 500MHz
- Digital
  - Repeater every 1km
  - Closer for higher data rates



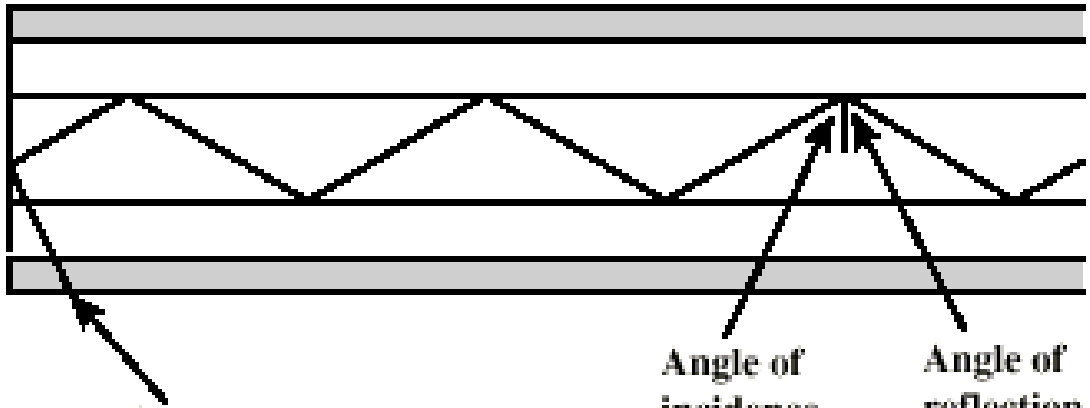
Glass Fibers

- Optical fibers uses light to transport data
- Advantages
  - Use of light eliminates interference
  - Carries of pulse of light much farther
  - Carries more information than wires
  - Requires only a single fiber
- Disadvantages
  - Installation requires special equipment
  - Difficult to locate a break in fiber
  - Difficult to repair a broken fiber

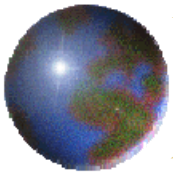
Optical Fiber



—Glass or plastic core
—Laser or light emitting diode
—Specially designed jacket
—Small size and weight

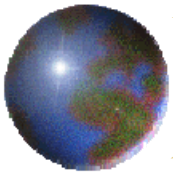


Light at less than ciritical angle is absorbed in jacket



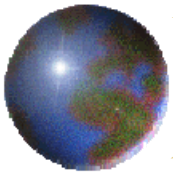
Optical Fiber - Benefits

- Greater capacity
  - Data rates of hundreds of Gbps
- Smaller size & weight
- Lower attenuation
- Electromagnetic isolation
- Greater repeater spacing
  - 10s of km at least



Optical Fiber - Applications

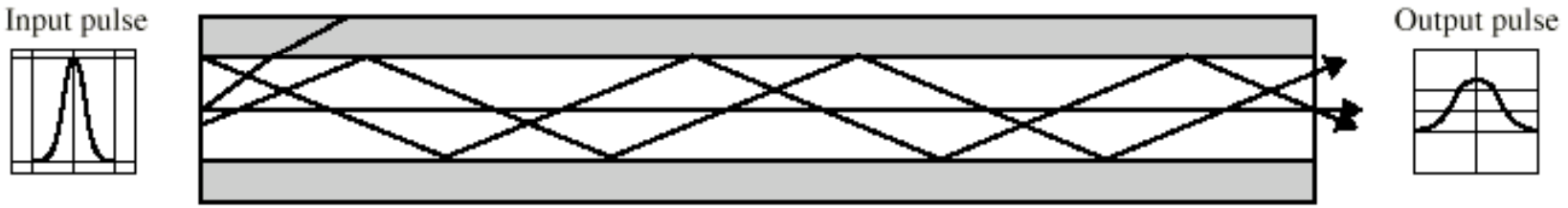
- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- LANs



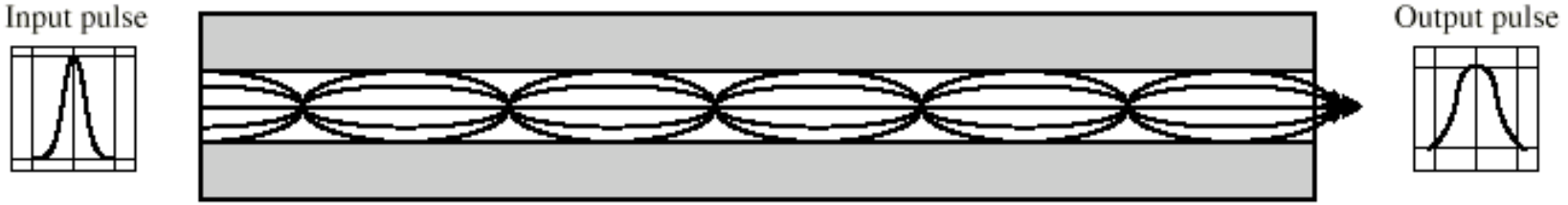
Optical Fiber - Transmission Characteristics

- Act as wave guide for 10^{14} to 10^{15} Hz
  - Portions of infrared and visible spectrum
- Light emitting diode (LED)
  - Cheaper
  - Wider operating temp range
  - Last longer
- Injection laser diode (ILD)
  - More efficient
  - Greater data rate
- Wavelength division multiplexing

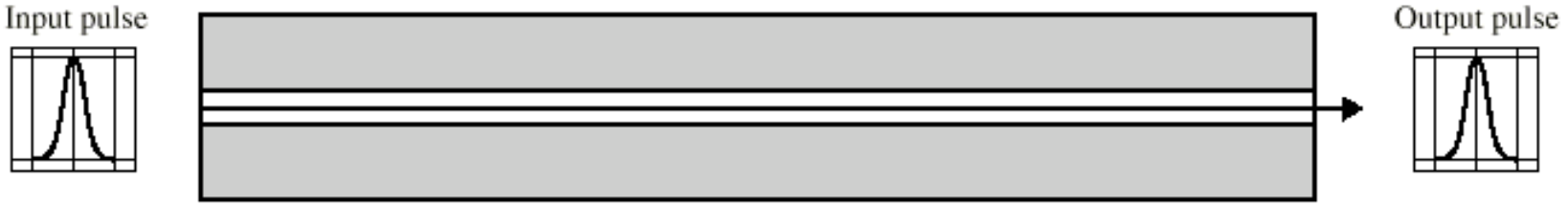
Optical Fiber Transmission Modes



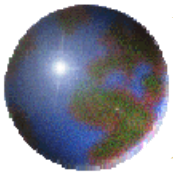
(a) Step-index multimode



(b) Graded-index multimode

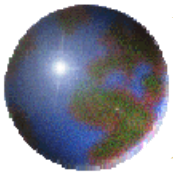


(c) Single mode



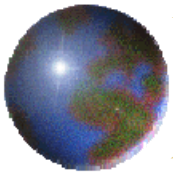
Wireless Transmission

- Unguided media
- Transmission and reception via antenna
- Directional
  - Focused beam
  - Careful alignment required
- Omni directional
  - Signal spreads in all directions
  - Can be received by many antennae



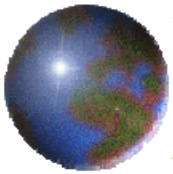
Frequencies

- 2GHz to 40GHz
  - Microwave
  - Highly directional
  - Point to point
  - Satellite
- 30MHz to 1GHz
  - Omni directional
  - Broadcast radio
- 3×10^{11} to 2×10^{14}
  - Infrared
  - Local



Terrestrial Microwave

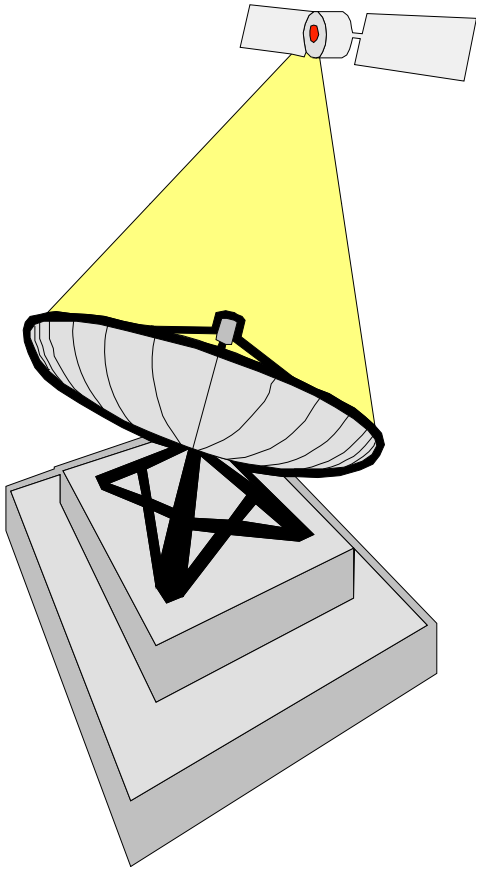
- Parabolic dish
- Focused beam
- Line of sight
- Long haul telecommunications
- Higher frequencies give higher data rates



Satellite Microwave

- Satellite is relay station
- Satellite receives on one frequency, amplifies or repeats signal and transmits on another frequency
- Requires geo-stationary orbit
  - Height of 35,784km
- Television
- Long distance telephone
- Private business networks

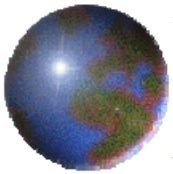
Satellites



- Combined with RF technology to provide communication across longer distances
- Satellite contains a *transponder* which
  - Accepts incoming radio transmission
  - Amplifies it, and
  - Transmits the amplified signal
- Contains multiple transponders operating independently at different frequency

Geosynchronous Satellites

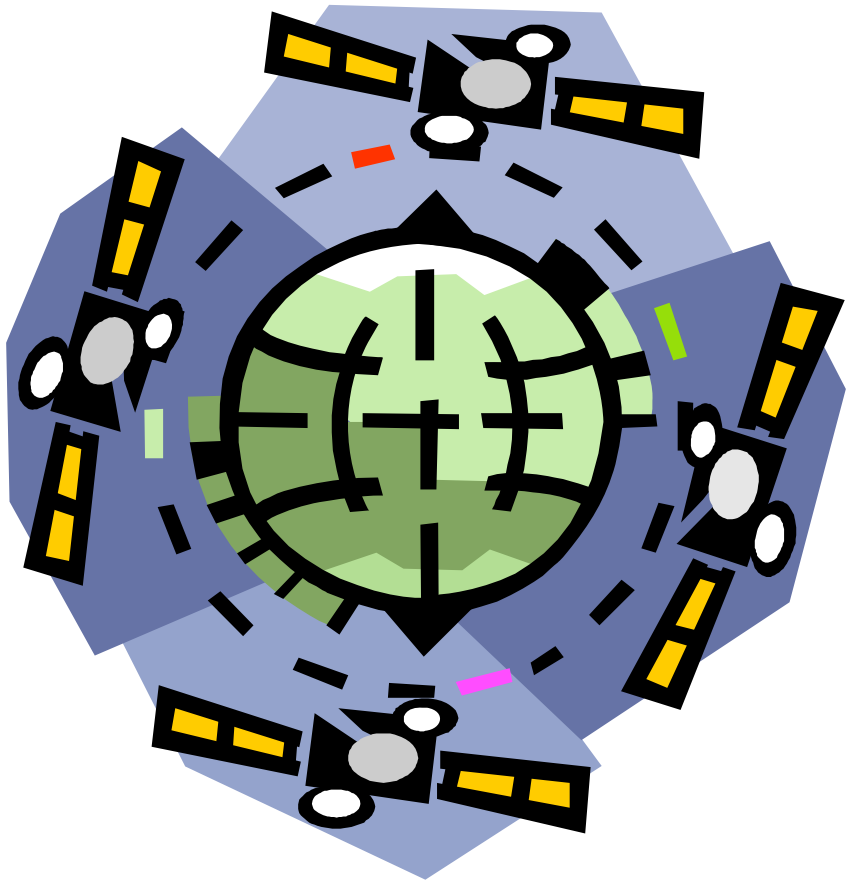
- Placed in an orbit exactly synchronized with the rotation of the earth
- Appears at exactly the same spot at all times
- Ex: A satellite above equator over Atlantic ocean



Low Earth Orbit Satellites

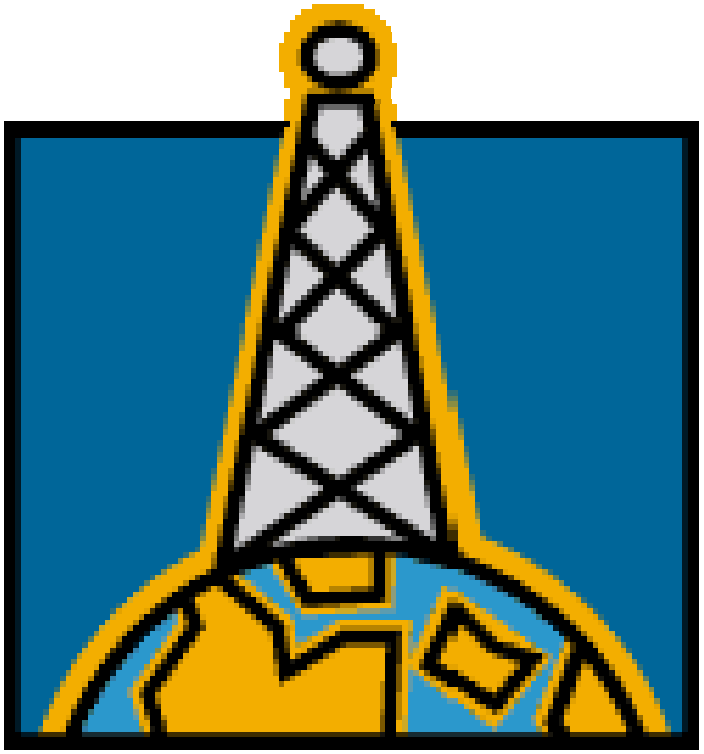
- They orbit a few hundred miles above the earth(typically 200-400 miles)
- Disadvantages
  - Rate at which satellite must travel
  - Can only be used during the time its orbit passes between two ground stations
  - Maximal utilization requires complex control systems

Low Earth Orbits Satellite Arrays

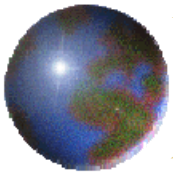


- Satellite arrays
  - Launching a set of satellites into low earth orbits
  - Each point in ground has at least one satellite overhead
- Satellites in an array communicate with one another

Radio

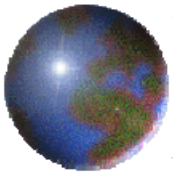


- Uses electromagnetic radiation to transmit data
- Operates at radio frequency
- Transmissions referred to as RF transmissions
- Does not require a direct physical connection between computers



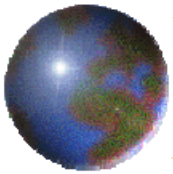
Broadcast Radio

- Omni directional
- FM radio
- UHF and VHF television
- Line of sight
- Suffers from multipath interference
  - Reflections



Infrared

- Modulate noncoherent infrared light
- Line of sight (or reflection)
- Blocked by walls
- E.G. TV remote control, IRD port

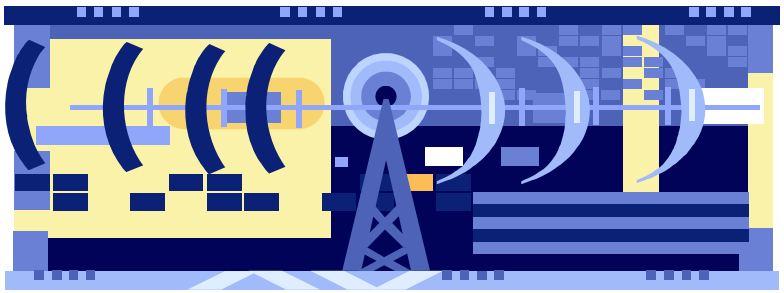


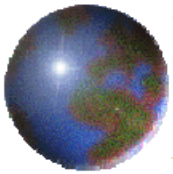
Infrared

- Infrared technology can be used for data communication
- Limited to a small area
- Especially convenient for small, portable computers
- Advantages of wireless communication
- Light from a laser can be used to carry data

Microwave

- A higher frequency version of radiowaves
- Can be aimed in a single direction
- Can carry more information than lower frequency RF transmissions
- Cannot penetrate metal structures





Comparison of Cable Media

Cable type	Cost	Installation	Capacity	Range	EMI
Coaxial Thinnet	<STP	Inexpensive/ easy	10 Mbps typical	185 m	<sensitive than UTP
Coaxial Thicknet	>STP <fiber	Easy	10 Mbps typical	500 m	<sensitive than UTP
Shielded Twisted-Pair	>UTP <Thicknet	Fairly easy	16 Mbps typical, up to 500 Mbps	100 m typical	<sensitive than UTP
Unshielded Twisted-Pair	Lowest	Inexpensive/ /easy	10 Mbps typical, up to 100 Mbps	100 m typical	Most sensitive
Fiber optic	Highest	Expensive/ difficult	100 Mbps typical	10s of kilometer	insensitive