Transmission Media

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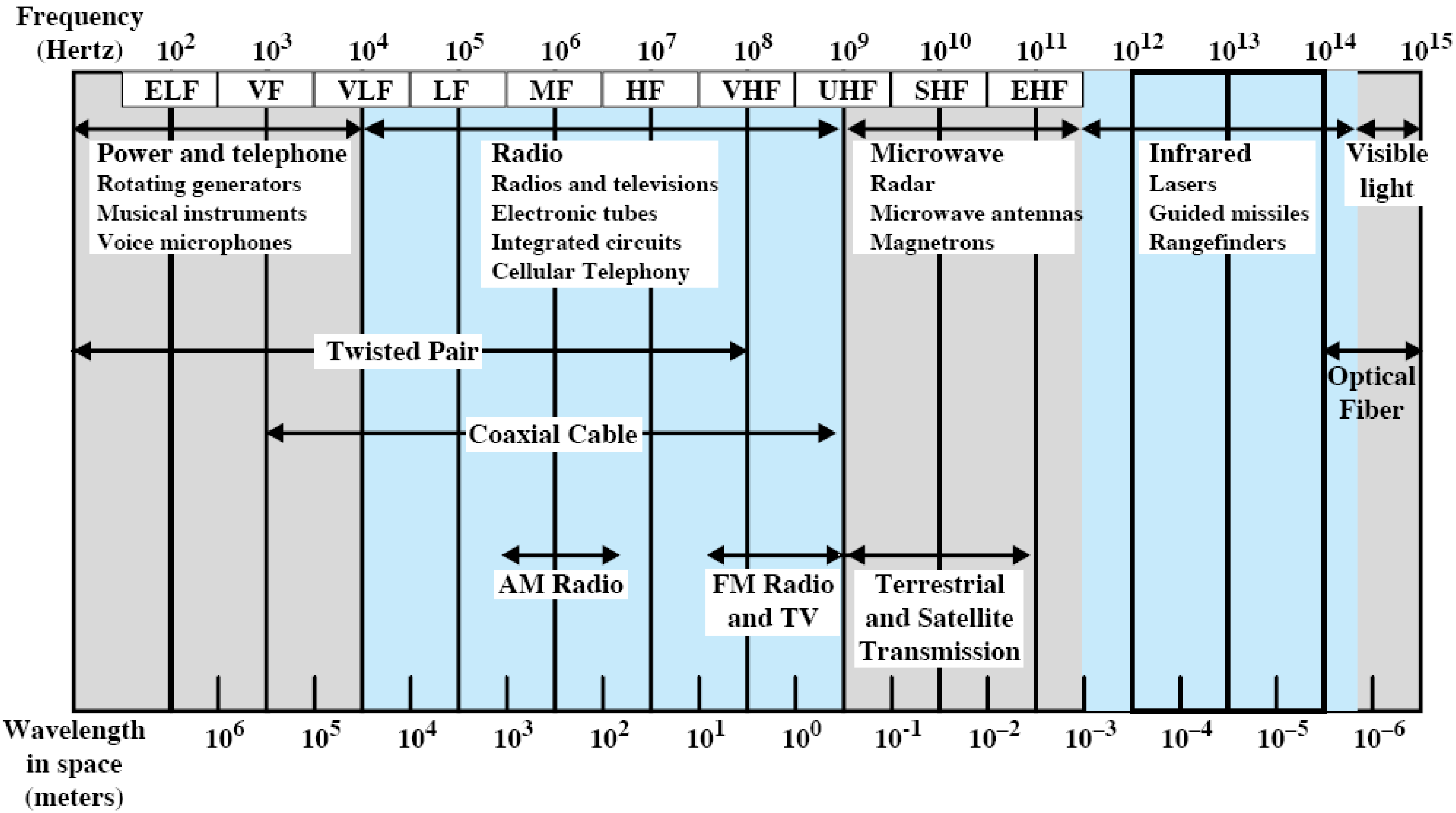
Design Factors

- Key concerns are data rate and distance
  - Generally, we want to transmit as fast as possible, for as far as possible
- Design factors that influence this are:
  - Bandwidth
    - Higher bandwidth gives higher data rate
  - Transmission impairments
    - E.g. Attenuation limits the distance
  - Interference
    - From competing signals, e.g. other cables or wireless systems
  - Number of receivers in guided media
    - More receivers introduces 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

Twisted Pair

- Two insulated copper wires arranged in spiral pattern to form one communications link
  - Often many pairs are bundled into one cable
- Most commonly used and least expensive medium
  - Used in telephone networks and in-building communications
  - Telephone networks designed for analog signalling
    - But support digital data using modem
  - Also used for digital signalling
  - Two varieties:
    - Unshielded Twisted Pair (UTP), subject to interference, cheaper and easy to use
      - Category 3 for Ethernet; Category 5 used for current 100Mb/s Fast Ethernet
    - Shielded Twisted Pair (STP), higher data rates, but expensive and harder to install

Coaxial Cable

- Two conductors, one inside the other
- Provide much more shielding from interference than twisted pair
  - Higher data rates, more stations on a shared line, longer distances
- Widely used for cable TV, as well as other audio/video cabling
- Used in long-distance telecommunications, although optical fibre is more relevant now

Optical Fiber

- Glass fibres are used to guide optical rays
- Used in long-distance telecommunications
  – Also becoming popular for telephone systems, local area networks, and city-wide networks
- Advantages over twisted pair and coaxial cable
  – Much higher capacity: 100’s of Gb/s
  – Small size, light weight: lowers cost of installation
  – Electromagnetic isolation: not vulnerable to interference from other systems or crosstalk
  – Larger distances: means greater spacing between repeaters, hence lower cost

Transmission Characteristics of Guided 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 (multi-pair 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

Wireless Transmission

- Common wireless systems for communications include:
  - Terrestrial microwave, e.g. television transmission
  - Satellite microwave, e.g. IPstar
  - Broadcast radio, e.g. IEEE 802.11 WiFi (wireless LAN)
  - Infrared, e.g. in-home communications
- Wireless transmission systems use antennas to radiate (send) and receive electromagnetic energy
  - Transmission can be omni-directional (everywhere) or directional (point-to-point)
    - Isotropic antenna propagates power in all directions equally
    - Directional antennas concentrate power in particular direction, and hence have a *gain* in power compared to isotropic

Antennas and Propagation

- Wireless signals disperse with distance
  - Received power is less than transmitted power
- Free-space loss determines amount of power loss:
  - $P_t/P_r = (4\pi d)^2 / (G_r G_t \lambda^2)$
    - P_t = power at transmitter
    - P_r = power at receiver
    - d = distance between transmitter and receiver
    - G_r = gain of receiving antenna
    - G_t = gain of transmitting antenna
    - λ = wavelength

$G = 4\pi A/\lambda^2$ where A is the effective area of the antenna

- In practice, other losses of power due to atmosphere, multiple paths, and refraction
- Typically, a receiver can only decode (or make sense) of a received signal if it is above a Received Power Threshold

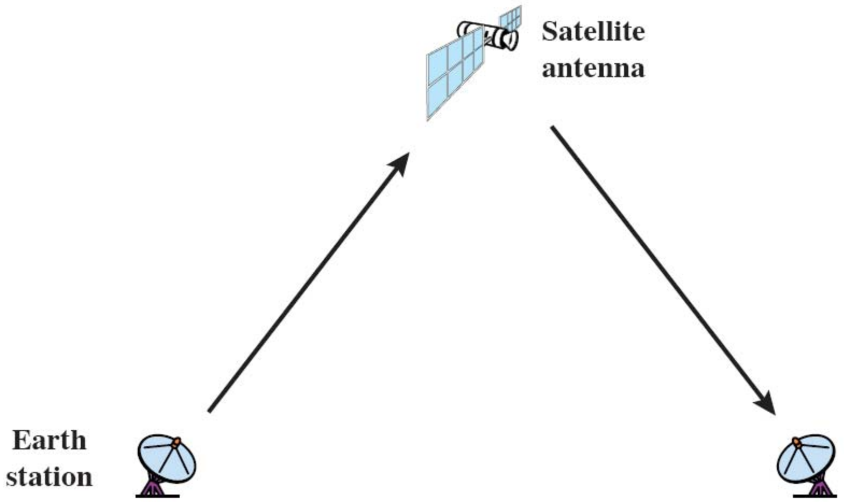
Terrestrial Microwave

- Parabolic antenna (usually 1-3 metres) used to transmit point-to-point to another antenna
  - Line-of-sight communications; often antennas are placed high (towers, buildings) to avoid obstacles
- Applications
  - Long-distance telecommunications (alternative to optical fibre, coaxial cable)
    - Voice and TV transmission
    - Less repeaters needed, but line-of-sight is needed
    - Only need access to tower sights (as opposed to digging holes in ground for cables)
  - Short communications between buildings (e.g. office buildings in city)
  - Mobile telephone systems (GSM, CDMA, 3G)

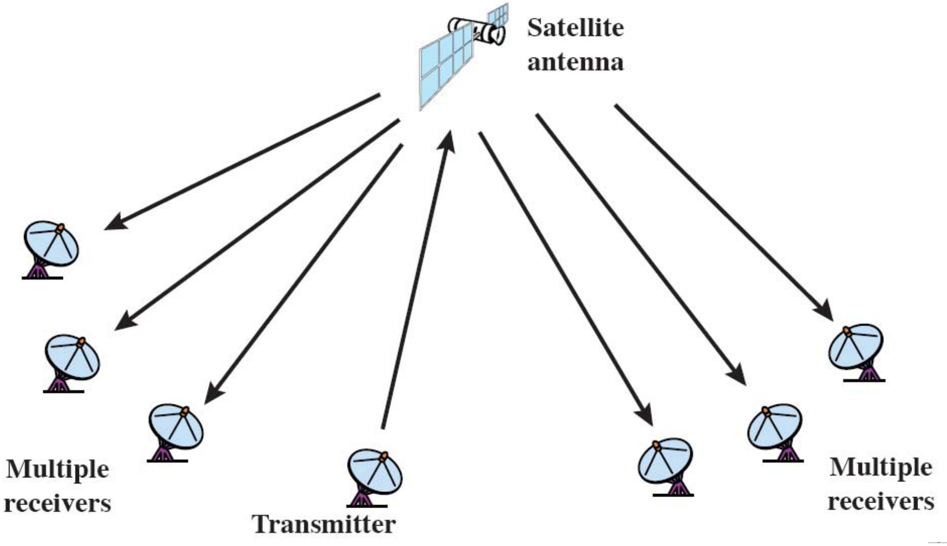
Satellite Microwave

- Communications satellite acts as microwave relay station
  - Links two or more ground/earth stations
  - Receives signal on one frequency (uplink), repeats or amplifies, and transmits on another frequency (downlink)

Point-to-point topology



Broadcast topology



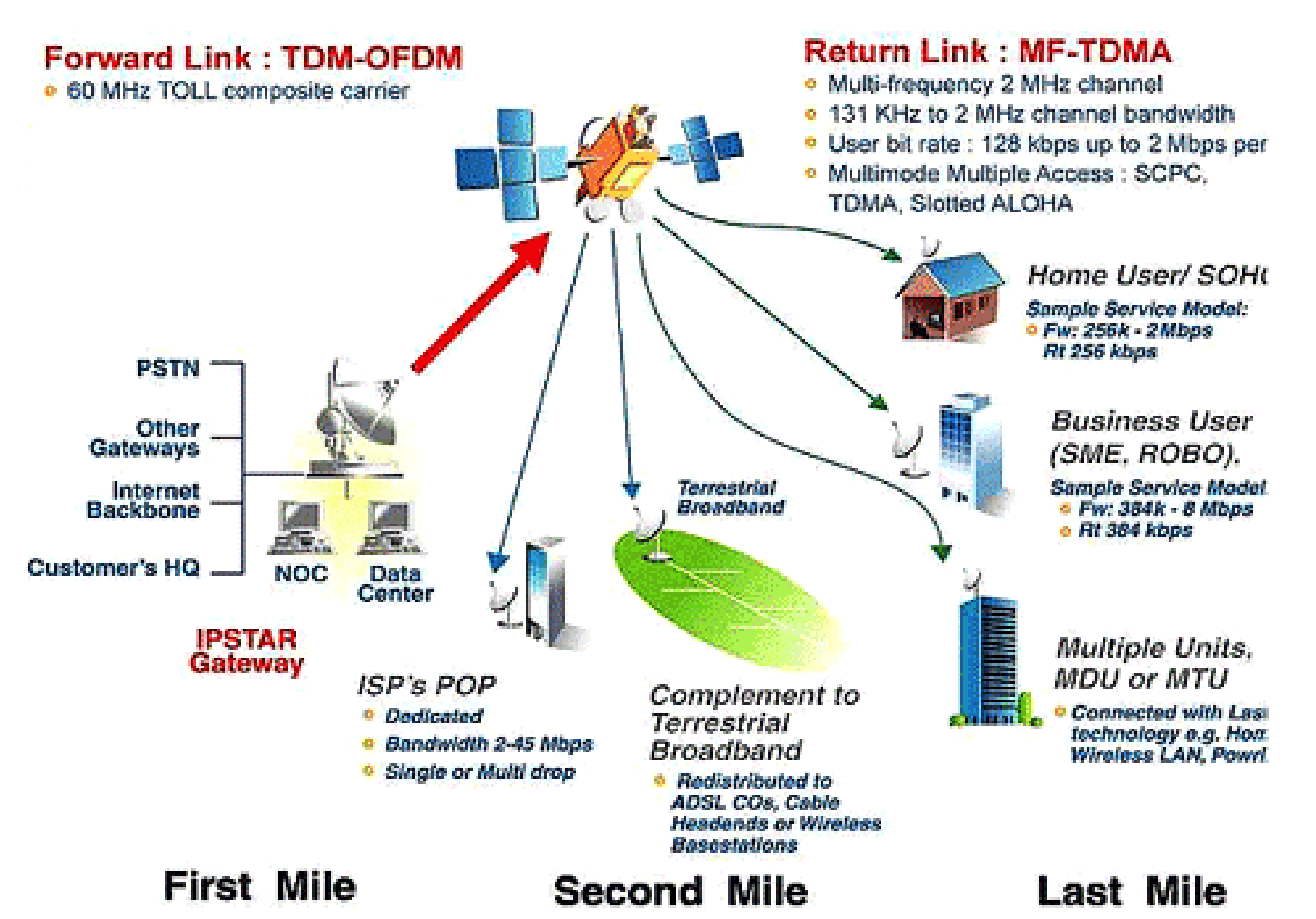
Satellite Microwave

- Applications
  - Television distribution: broadcast topology
  - Long-distance telephone transmission: national and international calls
  - Private business networks: Very Small Aperture Terminals (VSATs) allow for low cost earth stations at businesses/homes
  - Global Positioning System (GPS): provides longitude/latitude coordinates to receiver devices
- Features
  - High cost in deployment of satellites
  - Significant delay (0.5sec) for transmissions: problems for voice calls and flow/error control in data traffic
  - Broadcast – easy to send to many users
  - Avoids ground infrastructure – used by military and emergency services

Example: IPSTAR

- IPStar-1 (or Thaicom-4) satellite providing coverage over Asia
  - 84 individual spot beams in point-to-point topology
    - Additional larger regional spot beams
    - 14GHz Ku band
  - Provides broadband Internet service to users in Asia
    - E.g. 512kb/s down, 256kb/s up
    - Businesses: 1-2Mb/s down

Example: IPSTAR



Broadcast Radio

- Microwave is directional; Broadcast radio is omni-directional
  - Can use variety of antennas (not dish shaped) and do not need precise alignment of antennas
- Generally refers to 30MHz to 1GHz
- Applications
  - UHF/VHF TV
  - FM radio
  - Wireless data networking (wireless LAN)

Frequency Bands

Band	Frequency Range	Free-Space Wavelength Range	Propagation Characteristics	Typical Use
ELF (extremely low frequency)	30 to 300 Hz	10,000 to 1000 km	GW	Power line frequencies; used by some home control systems.
VF (voice frequency)	300 to 3000 Hz	1000 to 100 km	GW	Used by the telephone system for analog subscriber lines.
VLF (very low frequency)	3 to 30 kHz	100 to 10 km	GW; low attenuation day and night; high atmospheric noise level	Long-range navigation; submarine communication
LF (low frequency)	30 to 300 kHz	10 to 1 km	GW; slightly less reliable than VLF; absorption in daytime	Long-range navigation; marine communication radio beacons
MF (medium frequency)	300 to 3000 kHz	1,000 to 100 m	GW and night SW; attenuation low at night, high in day; atmospheric noise	Maritime radio; direction finding; AM broadcasting.
HF (high frequency)	3 to 30 MHz	100 to 10 m	SW; quality varies with time of day, season, and frequency.	Amateur radio; international broadcasting, military communication; long-distance aircraft and ship communication
VHF (very high frequency)	30 to 300 MHz	10 to 1 m	LOS; scattering because of temperature inversion; cosmic noise	VHF television; FM broadcast and two-way radio, AM aircraft communication; aircraft navigational aids
UHF (ultra high frequency)	300 to 3000 MHz	100 to 10 cm	LOS; cosmic noise	UHF television; cellular telephone; radar; microwave links; personal communications systems
SHF (super high frequency)	3 to 30 GHz	10 to 1 cm	LOS; rainfall attenuation above 10 GHz; atmospheric attenuation due to oxygen and water vapor	Satellite communication; radar; terrestrial microwave links; wireless local loop
EHF (extremely high frequency)	30 to 300 GHz	10 to 1 mm	LOS; atmospheric attenuation due to oxygen and water vapor	Experimental; wireless local loop
Infrared	300 GHz to 400 THz	1 mm to 770 nm	LOS	Infrared LANs; consumer electronic applications
Visible light	400 THz to 900 THz	770 nm to 330 nm	LOS	Optical communication

Propagation: LOS = Line of Sight; GW = Ground Wave (follows earths curvature) ;
SW = Sky Wave (reflects off ionosphere)