# Transmission Media

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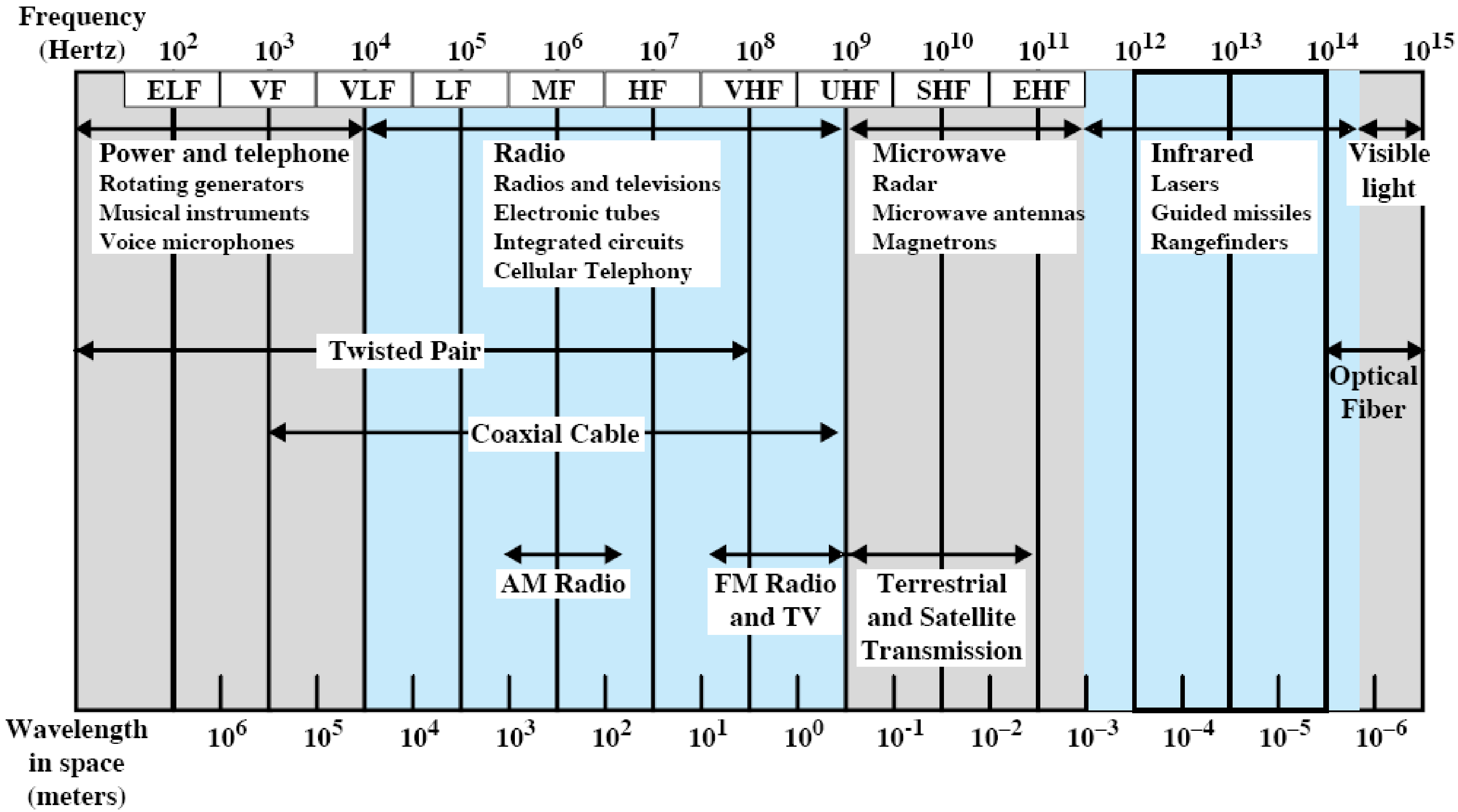
# Design Factors

- 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

# 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)

Radio Frequency (RF): 3Hz to 300GHz

# Guided Media

Electrical Cables: Twisted Pair, Coaxial Cable

Optical Cables: Optical Fibre

# Electrical Cables

- Transmit electrical signals on a conductor
  - Copper is one of the most commonly used metals in network cables
- A cable carrying electrical current radiates energy, and can pick-up energy from other sources
  - Can cause interference on other cables
  - Other sources can cause interference on the cable
    - E.g. two wires next to each other can cause ‘cross-talk’ interference
  - Interference results in poor quality signals being received
- To minimise interference:
  - Keep the cable lengths short
  - Keep the cables away from other sources
  - Design the cables to minimise radiation and pick-up
    - Use materials to shield from interference
    - Organise multiple wires so they don’t interfere with each other

# Twisted Pair

- Two insulated copper wires arranged in spiral pattern to form one communications link
  - Often many pairs are bundled into one cable
  - E.g. LAN cables commonly use 4 twisted pairs per 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 of twisted pair:
  - 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
  - Arranged to minimise interference from each other and other sources
- Provide much more shielding from interference than twisted pair
  - Higher data rates
  - More devices 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 Cables and Fibre

- Light (optical rays) is guided within glass or plastic fibres
- Used in long-distance telecommunications
  - Also becoming popular for telephone systems, local area networks, and city-wide networks
- Advantages of optical fibre over electrical cables (twisted pair and coaxial cable)
  - Optical fibre has much lower loss: can transfer much larger distances with a single cable
  - Optical fibre has much higher bandwidth: a single fibre is equivalent to 10’s or 100’s of electrical cables
    - Small size, light weight: lowers cost of installation
  - Electromagnetic isolation: not vulnerable to interference from other systems or crosstalk

# Comparison of Guided Media

- Electrical Cables
  - Moderate data rates: 1Gb/s
  - Maximum distance: 2km (twisted pair); 10km (coaxial cable)
  - Cheapest for low data rates
  - UTP: easy to install, susceptible to interference
  - STP, Coaxial Cable: rigid, protection against interference
- Optical Cables
  - Very high data rates: 100Gb/s+
  - Maximum distance: 40km
  - Expensive equipment, but cost effective for high data rates
  - Difficult to install

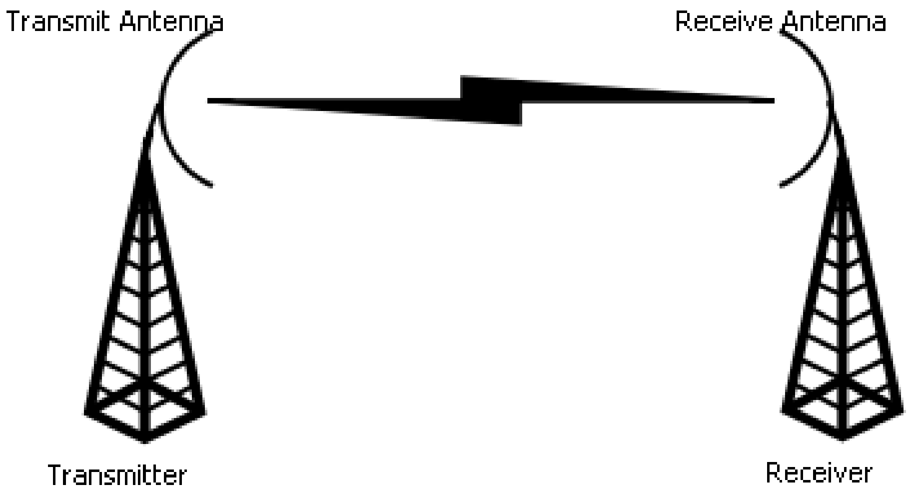
# Unguided Media

Antennas and Propagation

Terrestrial Microwave
Satellite Microwave
Broadcast Radio

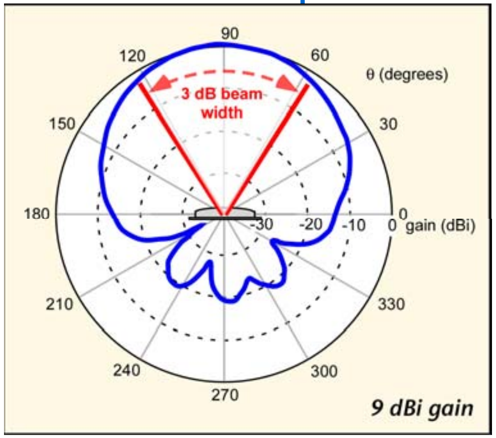
# Wireless Transmission

- 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



# Antennas

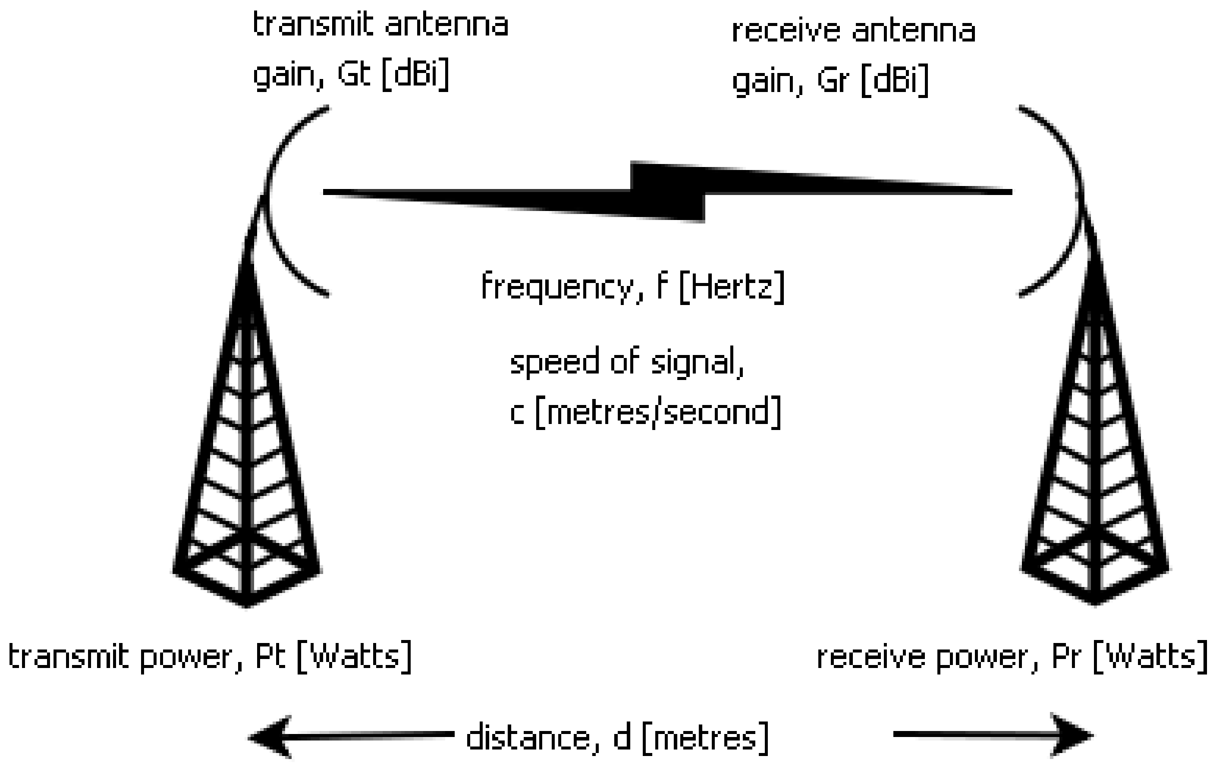
- An antenna converts between electrical current and electromagnetic waves (the ‘wireless signal’)
  - Waves are within the RF band (3Hz to 300GHz)
  - Direction and propagation of a wave depends on the antenna shape
  - Wireless signal is transmitted with a power level $P_t$
  - Power of received signal depends on: antennas, frequency, distance and obstacles between transmitter/receiver
- Isotropic Antenna
  - Power propagates in all directions equally (*omni-directional*)
  - Theoretical concept; perfect isotropic antenna cannot be built in practice
- Directional Antenna
  - Concentrates power in a particular direction
  - Increase of receive power (compared to isotropic antenna) due to directionality is the *antenna gain*



# Propagation of Wireless Signals

- Wireless signals disperse with distance
  - Received power is less than transmitted power
- If we now the smallest powered signal a receiver can successful decode, then what is the maximum distance between transmitter and receiver?
- Propagation Models
  - Mathematical models of the amount of power lost between transmitter and receiver
  - Examples:
    - Friis free space propagation model (ideal conditions)
    - Okumura-Hata models for urban, suburban and open areas
    - Longley-Rice model suitable for TV broadcast links
    - Log-distance model for indoor environments

# Propagation of Wireless Signals



# Free Space Propagation Loss

- Ideal model to determine amount of power loss between transmitter and receiver:

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_r G_t \lambda^2}$$

- For a parabolic antenna with radius $r$ and effective area $A = \pi r^2$:

$$G = \frac{4\pi A}{\lambda^2}$$

- (Ideal model: assumes no obstacles, operating in a vacuum (free-space), and perfect antennas)

# Decibels and Power

- Power is measured in Watts (or milliwatts …)
- Decibel (dB) is a measure of a ratio between two signals
  - For transmission systems, often referred to as a gain or loss
  - Example: loss of a system with $P_t$ = 100W and $P_r$ = 10W
    - $Loss_{dB} = 10 \log_{10} (P_t/P_r) = 10$ dB => $Gain_{dB} = -10$dB
- Decibel can be also given relative to some value :
  - dBi: ratio relative to an isotropic antenna (e.g. 6dBi)
  - dBW: ratio relative to 1W
    - $P_t$ = 100W = 20dBW
  - dBmW (or dBm): ratio relative to 1mW
    - $P_t$ = 30mW = 14.77 dBm = -15.23 dBW
- Free space propagation model uses standard units (Watts, metres, seconds)
  - You may need to convert from dB-based units to standard units

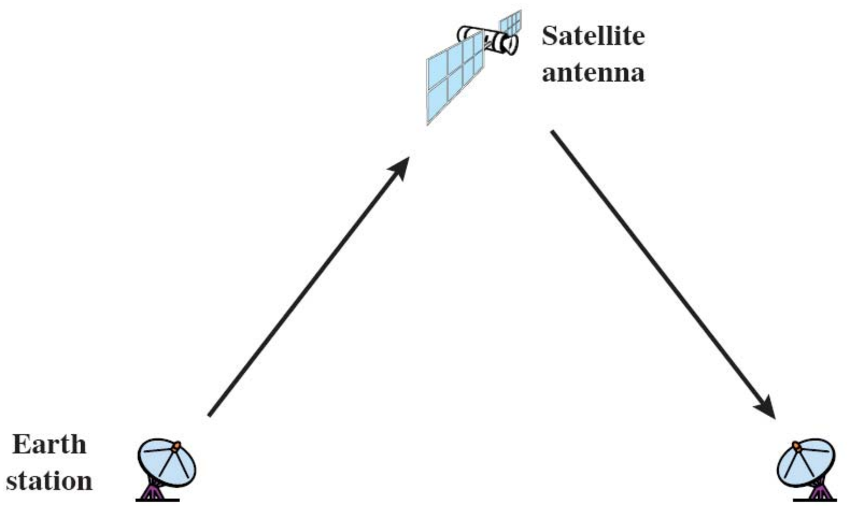
# Terrestrial Microwave

- 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)

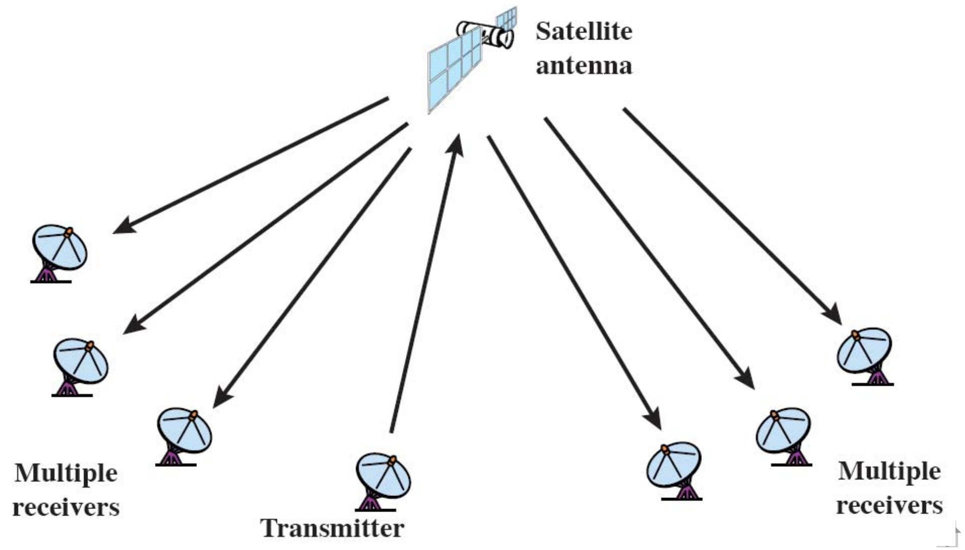
# Satellite Microwave

- 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



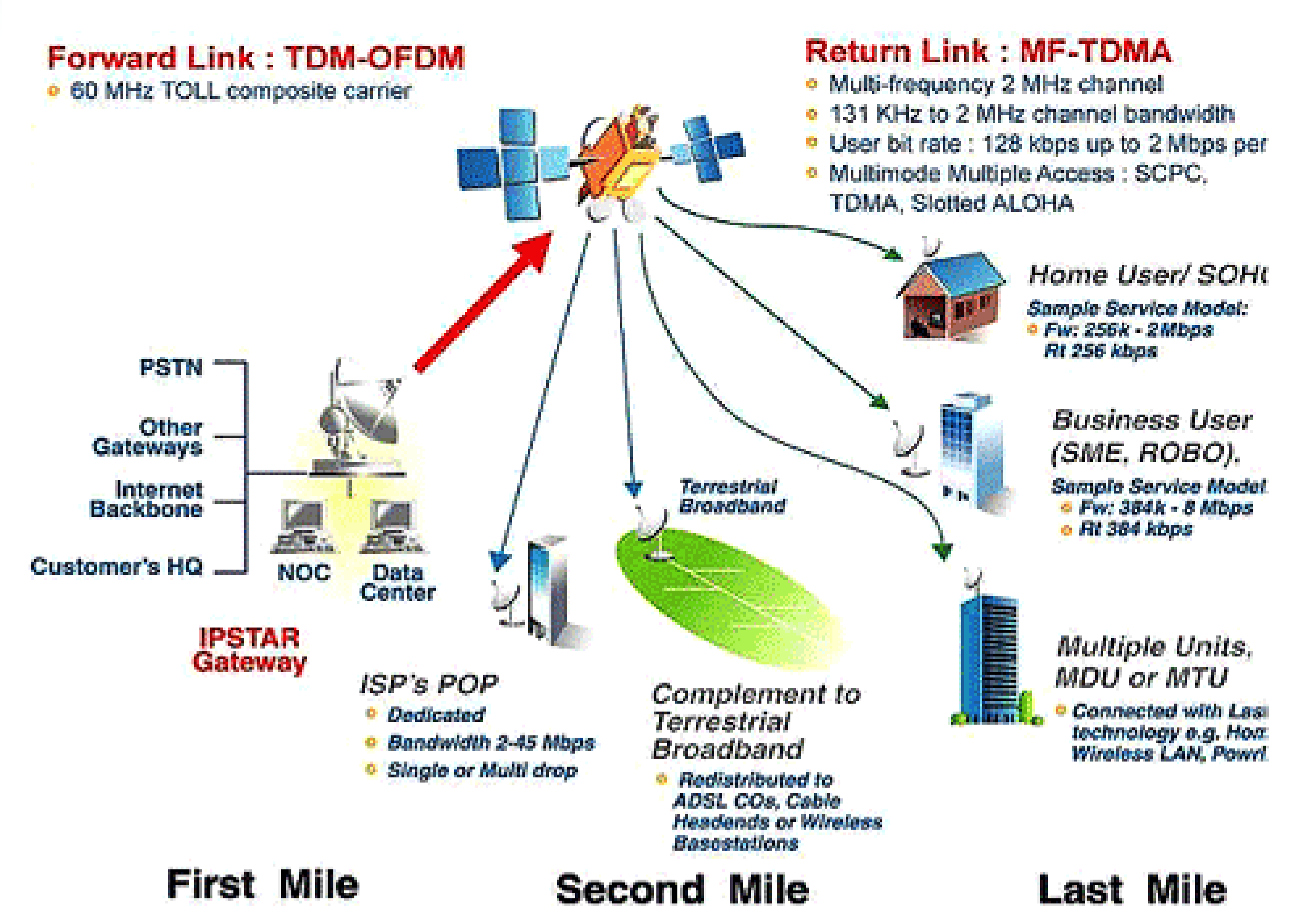
# Satellite Microwave

- 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)