Signals, Antennas and Propagation

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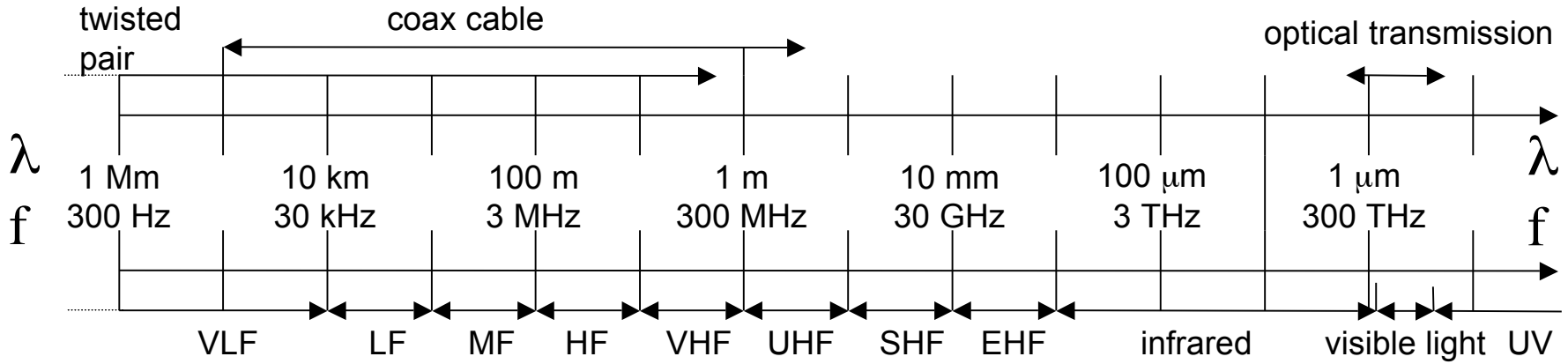
Radio frequency spectrum



$\lambda = c / f$ ($c = 3\ 10^8$ m/s)

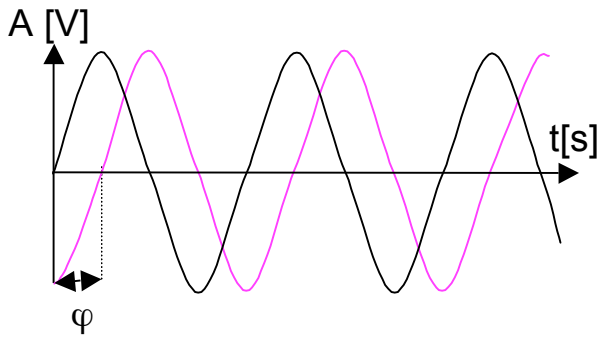
- VHF/UHF for mobile radio
  - GSM uses 900/1800/1900 MHz
- UHF to SHF used for Wireless LAN
  - 802.11 (Wi-Fi) uses 2.4 GHz, WiMAX 10-66 GHz
  - Limitations due to water/oxygen caused fading
- SHF and higher for satellite communications
  - Small directed antennas
  - Large bandwidth available

Regulations

- Radio frequencies are scarce resources
- International Telecommunications Union (ITU) responsible for worldwide regulations
- ITU Radiocommunication sector (ITU-R) handles standardisation in wireless communications
- ITU-R splits the world in three regions, within them national agencies are responsible for further regulations
- In Europe the European Telecommunications Standards Institute (ETSI) is responsible for standardisation
- ITU-R periodically holds the World Radio Conference to try achieve worldwide harmonisation of radio frequency regulations

Signals

- Physical representations of data
- Signal parameters represent data values
- Continuous/discrete in time and value
- Parameters of periodic signals
  - Frequency (f)
    - Period (T = 1 / f)
  - Amplitude (A)
  - Phase shift (φ)

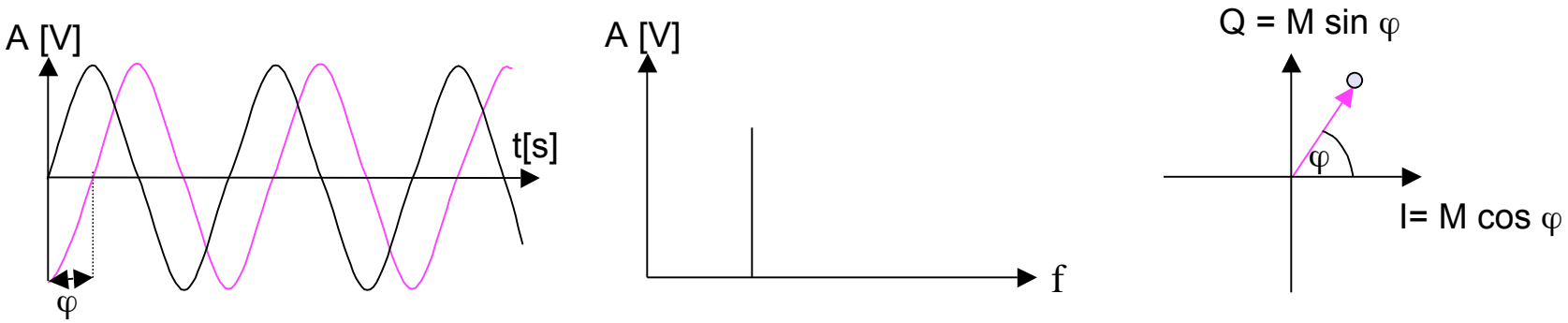


- Sine wave, special periodic signal:

$$s(t) = A_t \sin(2 \pi f_t t + \varphi_t)$$

Signal representations

- Time domain
- Frequency domain
- Phase domain



- Fourier transformation to go from time domain to frequency domain

Fourier representation of periodic signals

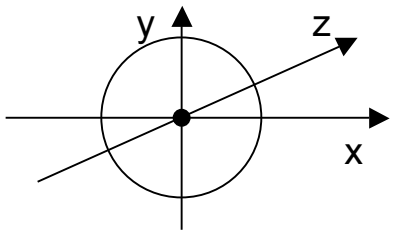
- Possible to reconstruct any periodic signal using sine and cosine functions:

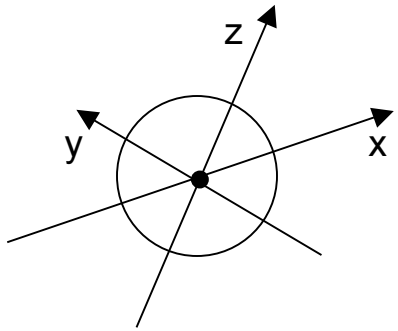
$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

- Perfect representations require an infinite number of sine/cosine functions
- In practice, a limited number of functions is enough, as real world mediums have limited bandwidth

Antennas: isotropic radiator

- Theoretical reference antenna
- Point in space radiating equally in three dimensions
- Real antennas always have directive effects
- Radiation pattern: measurement of radiation around antenna

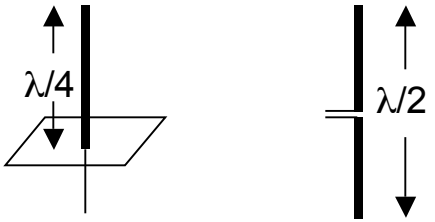




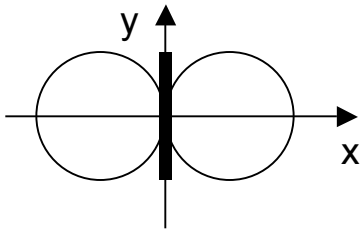
Ideal Isotropic radiator

Dipole antennas

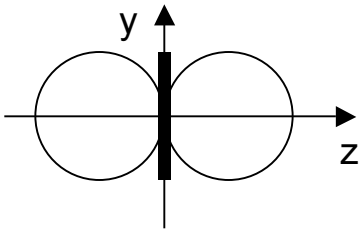
- Shape of antenna proportional to wavelength
  - Half-wave dipole (Hertzian dipole)
  - Quarter-wave dipole (Marconi dipole)



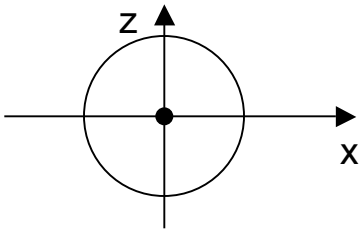
  - Radiation pattern of a Hertzian dipole:



side view (xy-plane)



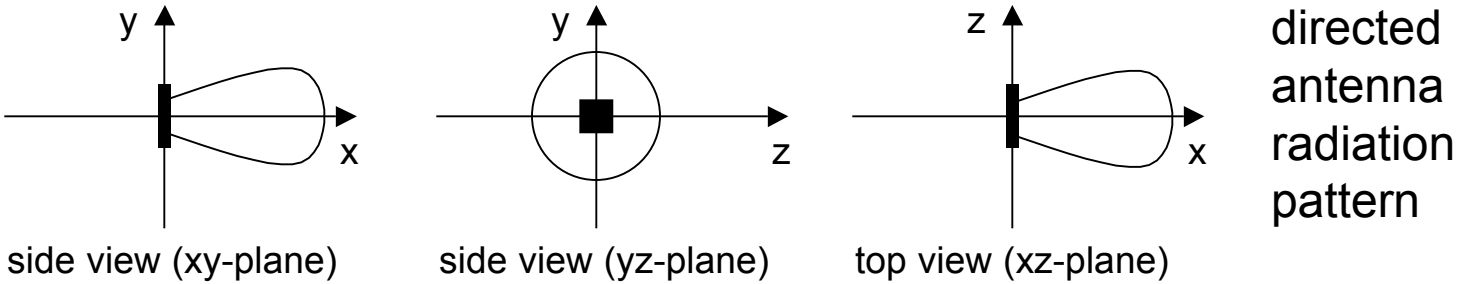
side view (yz-plane)



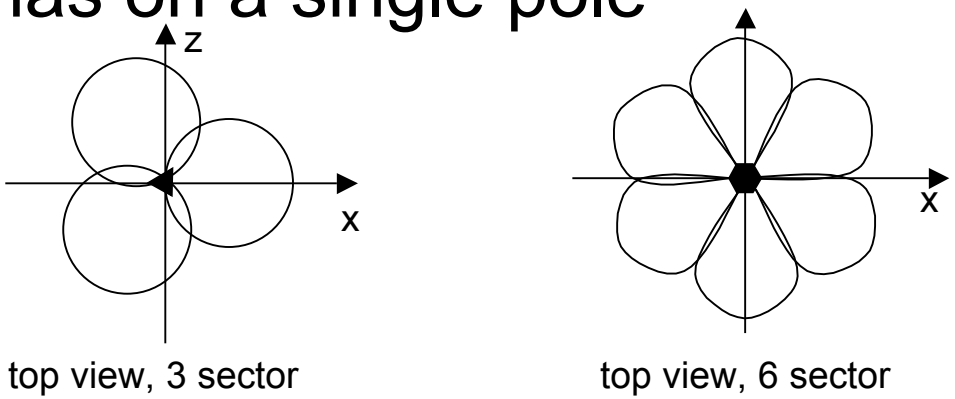
top view (xz-plane)

Directed and sectorised antennas

- Used for microwave connections or mobile phone base stations
  - Radio coverage of a valley or between buildings

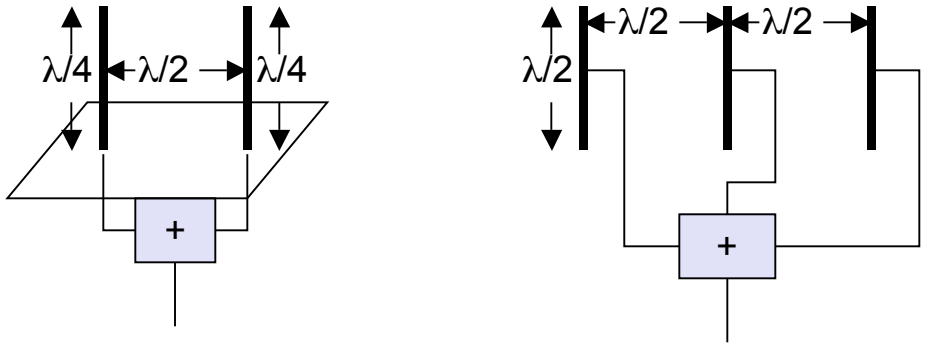


  - Sectorised antenna: combination of directed antennas on a single pole



Multi-element antenna arrays

- Antenna group to improve reception
- Switched/selection diversity: receiver chooses antenna with largest output
- Diversity combining: combine output of all antennas to produce gain
  - Phase correction(cophasing) to avoid cancellation

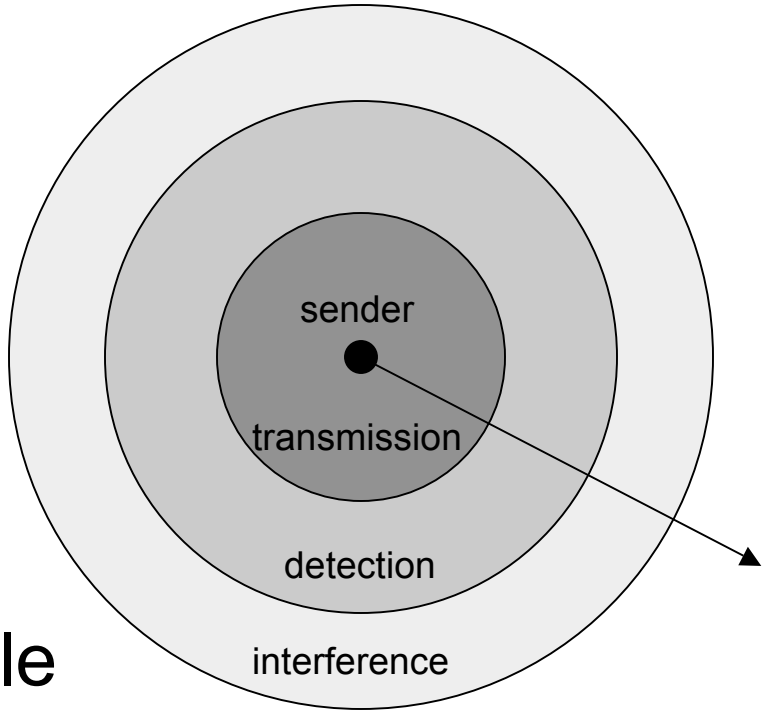


Signal propagation

- Propagation in free space like light
- Path loss or attenuation
  - Receiving power in vacuum proportional to $1 / d^2$
  - d = distance, much more in a real environment
  - Long distance transmissions affected by atmosphere (satellite)
  - Rain absorbs energy
  - The lower the frequency the better the penetration
    - Long waves cross sea, high freq. stopped by a tree
  - The higher the frequency the behaviour is more similar to light

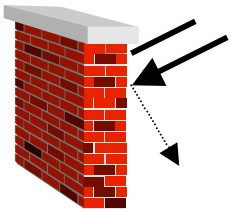
Signal propagation ranges

- Transmission range
  - Communication possible
  - Low error rate
- Detection range
  - Signal detection possible
  - No communication possible
- Interference range
  - Signal may not be detected
  - Signal adds to background noise

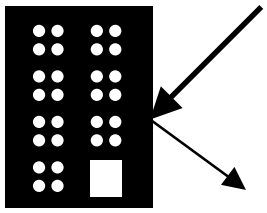


Signal propagation effects

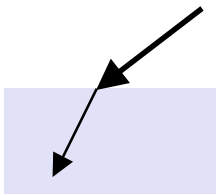
- Propagation effects that affect the receiving power
  - Frequency dependent fading
  - Blocking or shadowing
  - Reflection: at large objects
  - Refraction: depends on density of medium
  - Scattering at small objects
  - Diffraction at edges



shadowing



reflection



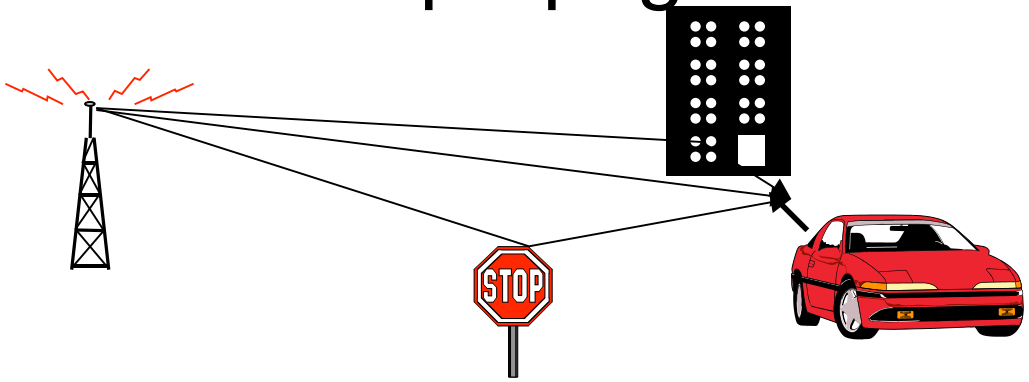
refraction

scattering

diffraction

Multipath propagation

- Signal can take different paths to arrive to sender due to propagation effects



- Time dispersion / delay spread
  - Signal dispersed over time
- Inter symbol interference (ISI)
  - Symbols in signal interfere with their "neighbour" symbols due to delay spread

Effects of mobility

- Channel characteristics change over time
  - Different signal paths
  - Different delays of signal parts
  - Different phases of signal parts
- Short term fading: quick changes on receiver power
- Long term fading
  - Slow change on average power
  - Due to distance to sender or obstacles further away