Mobile and Ubiquitous Computing

Wireless Signals

George Roussos

g.roussos@dcs.bbk.ac.uk

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Overview

- Signal characteristics
- Representing digital information with wireless
- Transmission and propagation
- Accessing the wireless medium

Signals

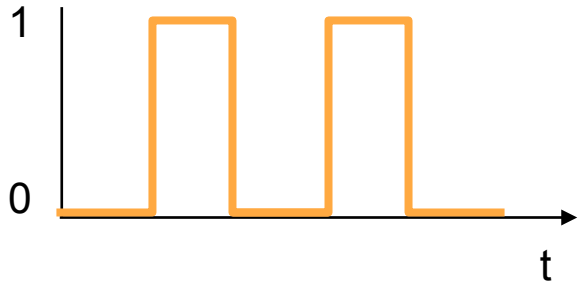
- physical representation of data
- function of time and location
- signal parameters: parameters representing the value of data
- classification
  - continuous time/discrete time
  - continuous values/discrete values
  - analog signal = continuous time and continuous values
  - digital signal = discrete time and discrete values

Signal parameters

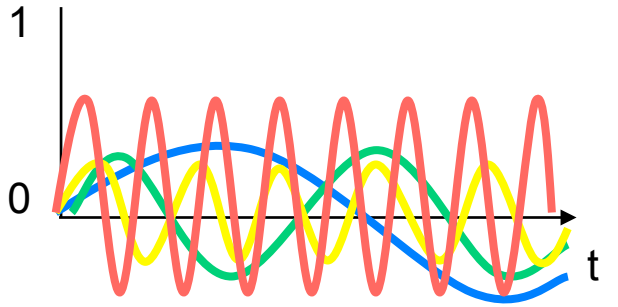
- signal parameters of periodic signals:
  - period T,
  - frequency f=1/T,
  - amplitude A,
  - phase shift φ
- Example: A sine wave as special periodic signal:

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

Fourier representation of signals



ideal periodic signal



real composition
(based on harmonics)

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

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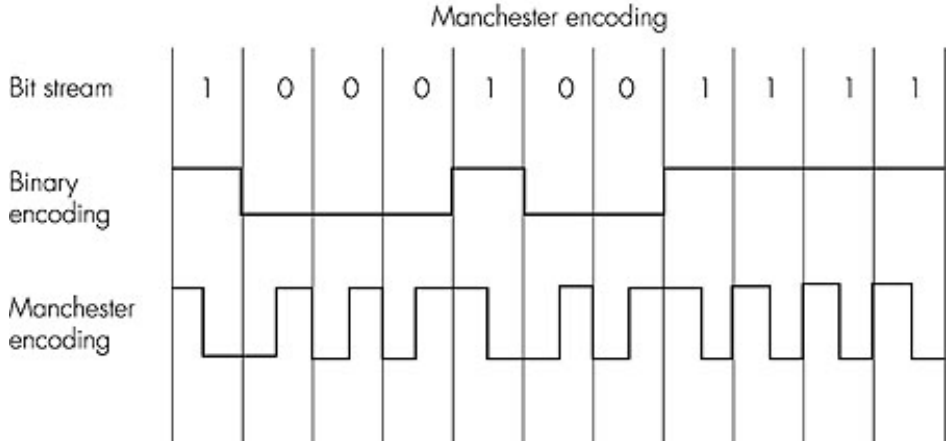
Modulation

- Digital modulation
  - digital data is translated into an analog signal
  - different ways to achieve this
    - sine waveforms whose parameters are shaped (modulated) by the sequence of bits that is transmitted
  - different alternatives have differences in spectral efficiency, power efficiency, robustness

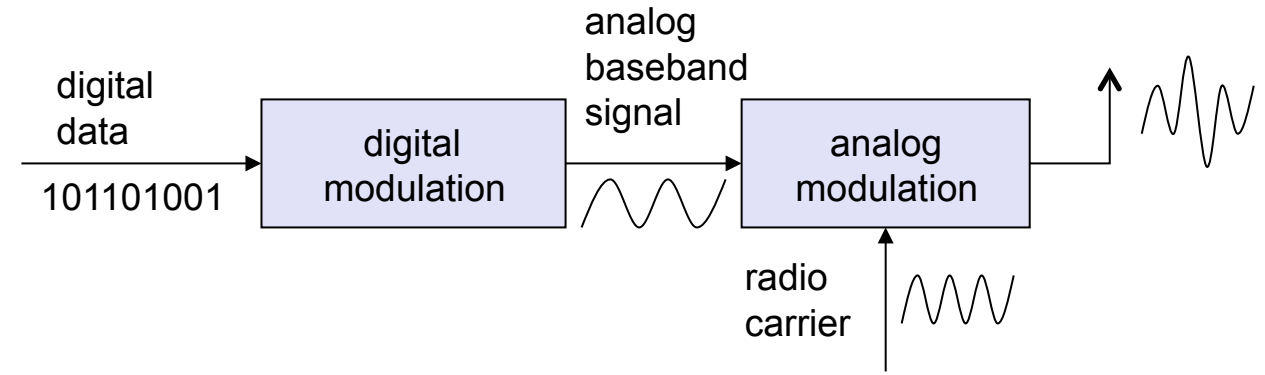
Encoding

- A set of rules according to which a sequence of bits is mapped to a signal
- Example: Manchester encoding

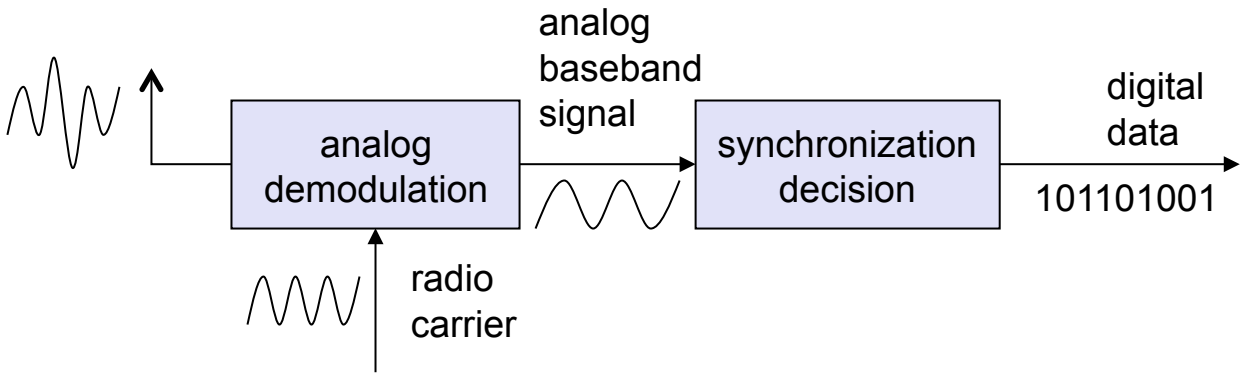


Source netlab.ulusofona.pt

Modulation and demodulation



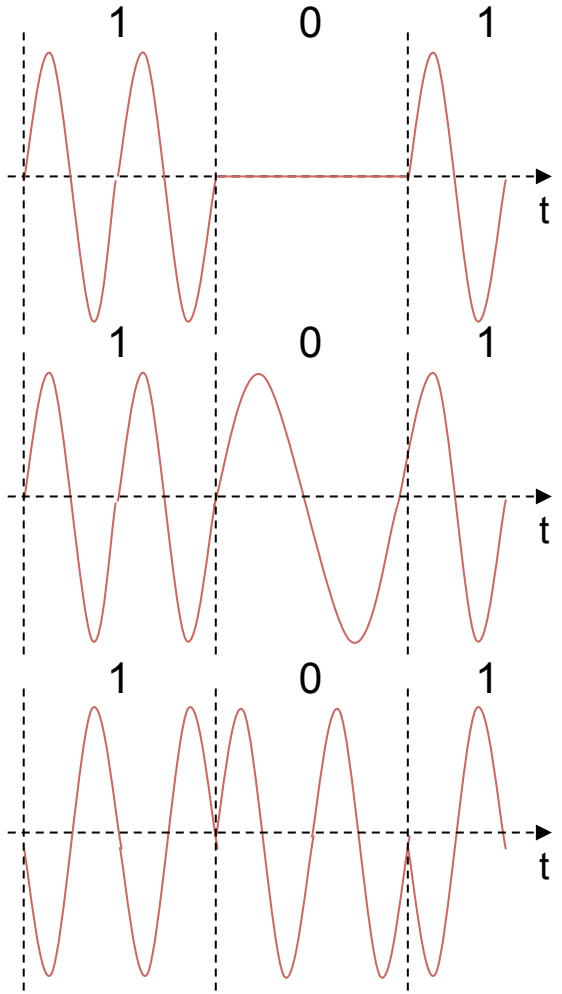
radio transmitter



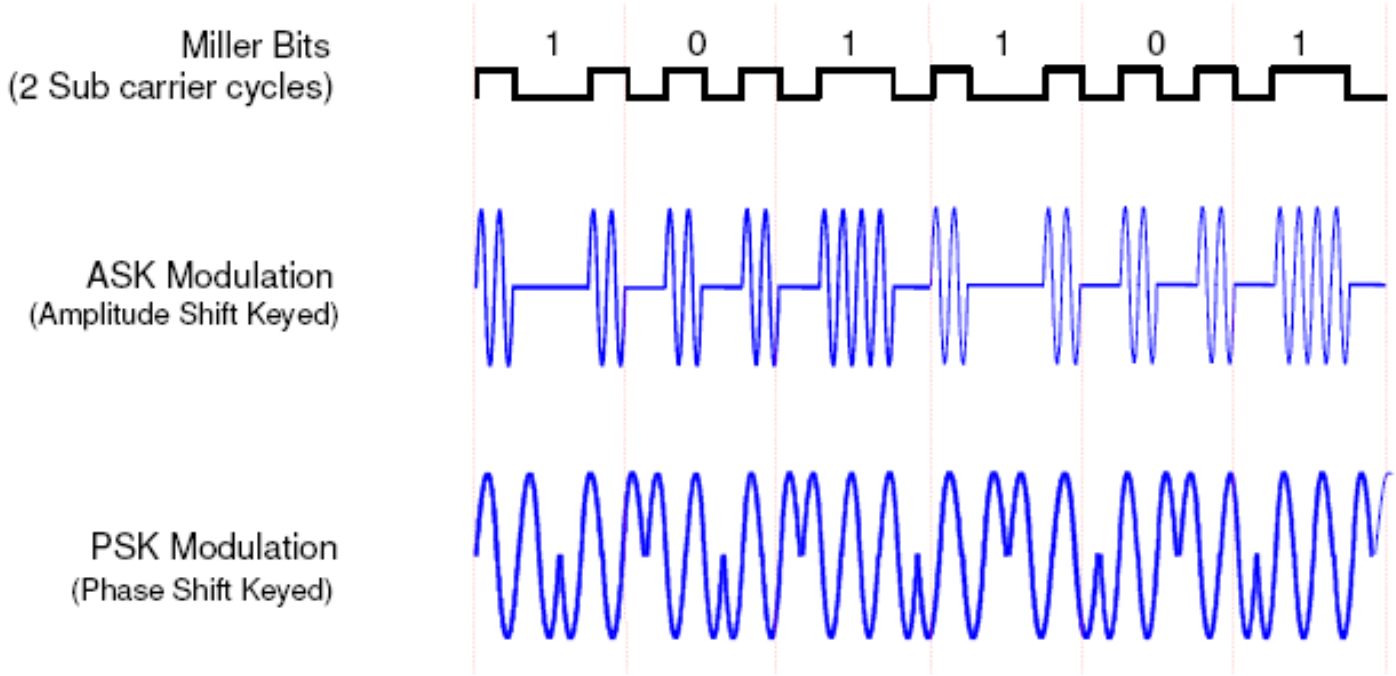
radio receiver

Digital modulation

- Modulation of digital signals known as Shift Keying
  - Amplitude Shift Keying (ASK)
  - Frequency Shift Keying (FSK)
  - Phase Shift Keying (PSK)

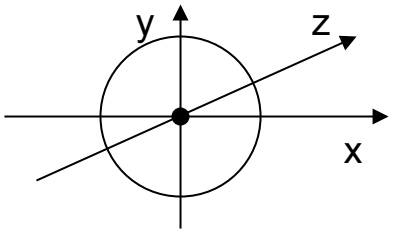


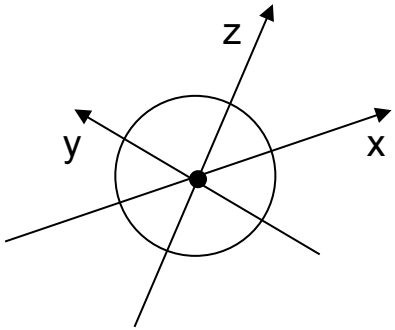
Example: EPC Gen2 RFID Example



Antennas: isotropic radiator

- Radiation and reception of electromagnetic waves, coupling of wires to space for radio transmission
- Isotropic radiator: equal radiation in all directions (three dimensional) - only a theoretical reference antenna

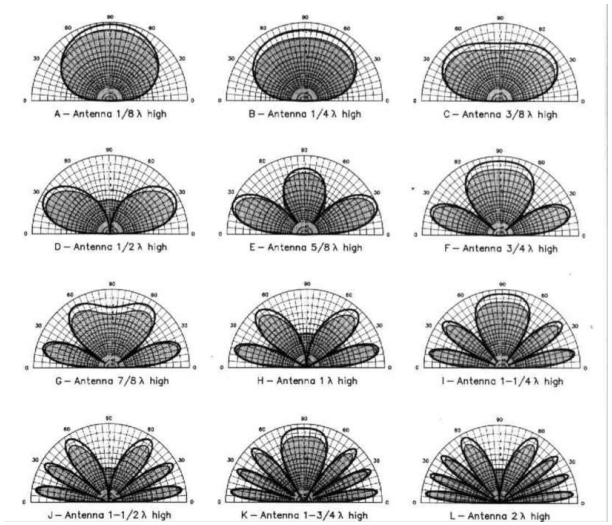


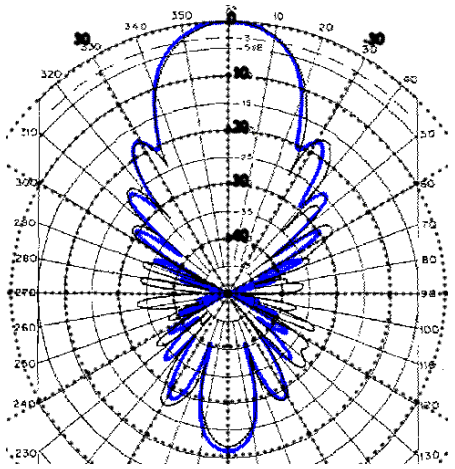


ideal isotropic radiator

Antennas: radiation pattern

- Real antennas always have directive effects (vertically and/or horizontally)
- Radiation pattern: measurement of radiation around an antenna





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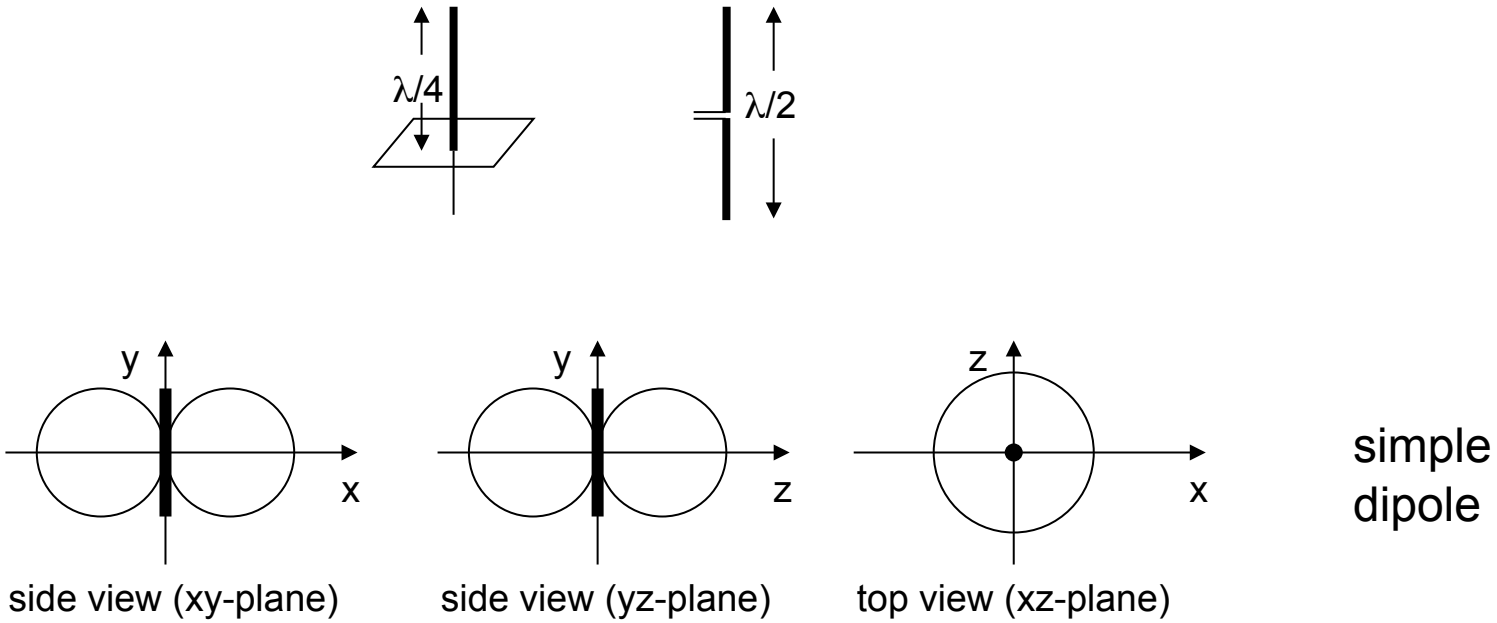
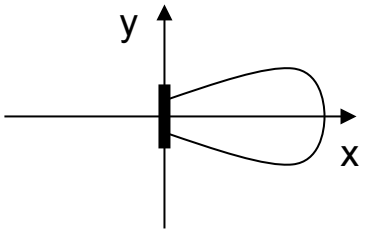
Antennas: simple dipoles

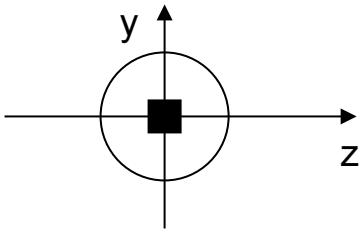


- Example: Radiation pattern of a simple dipole

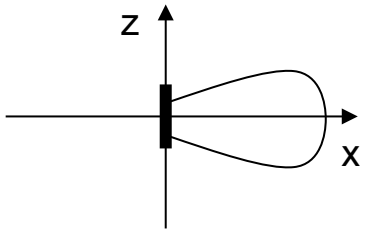
Antennas: directed and sectorized



side view (xy-plane)

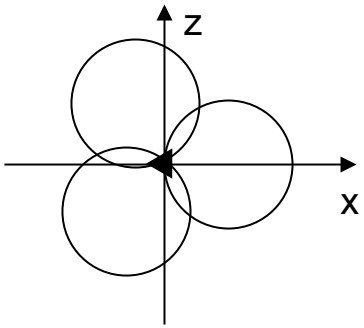


side view (yz-plane)

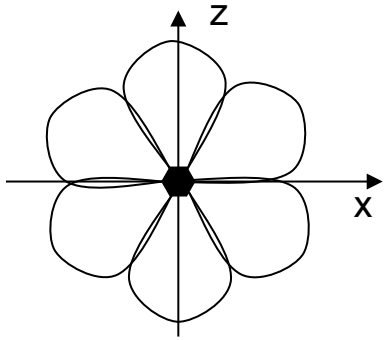


top view (xz-plane)

directed antenna



top view, 3 sector



top view, 6 sector

sectorized antenna

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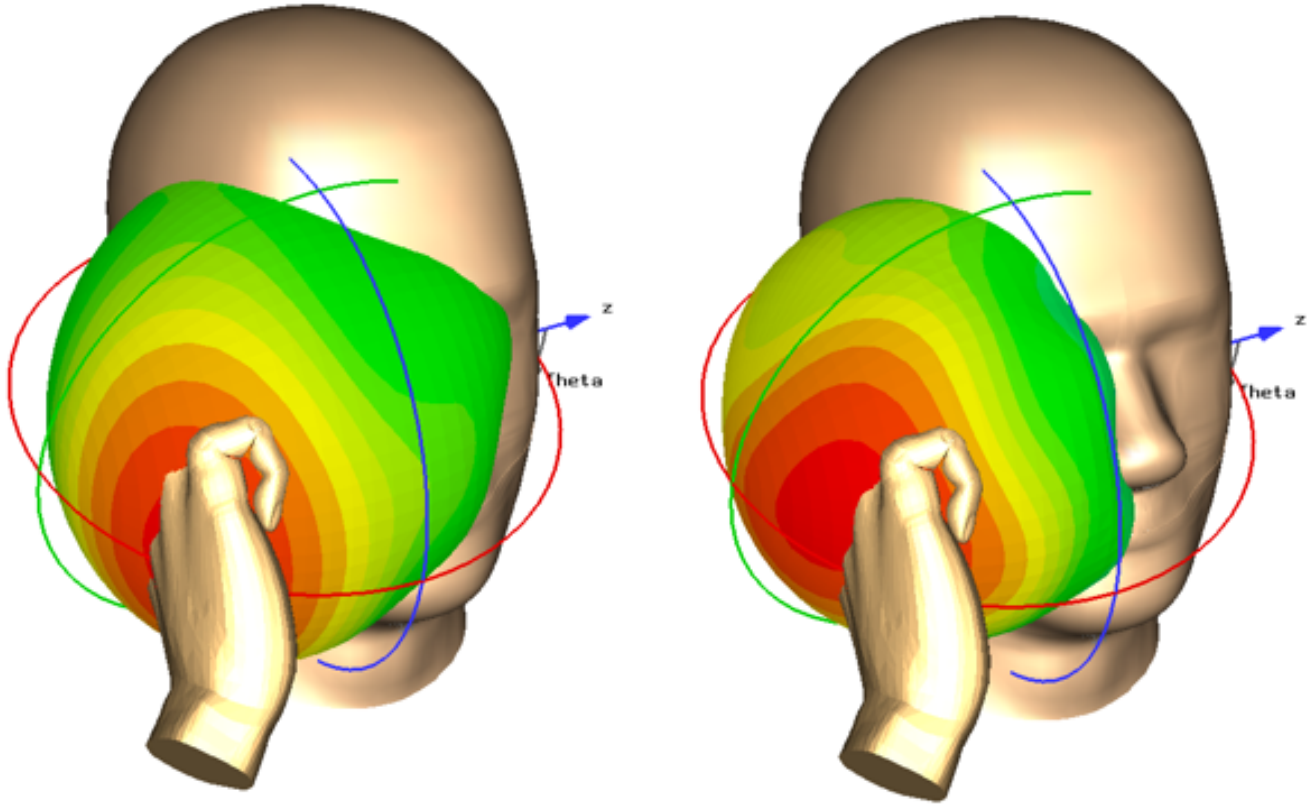
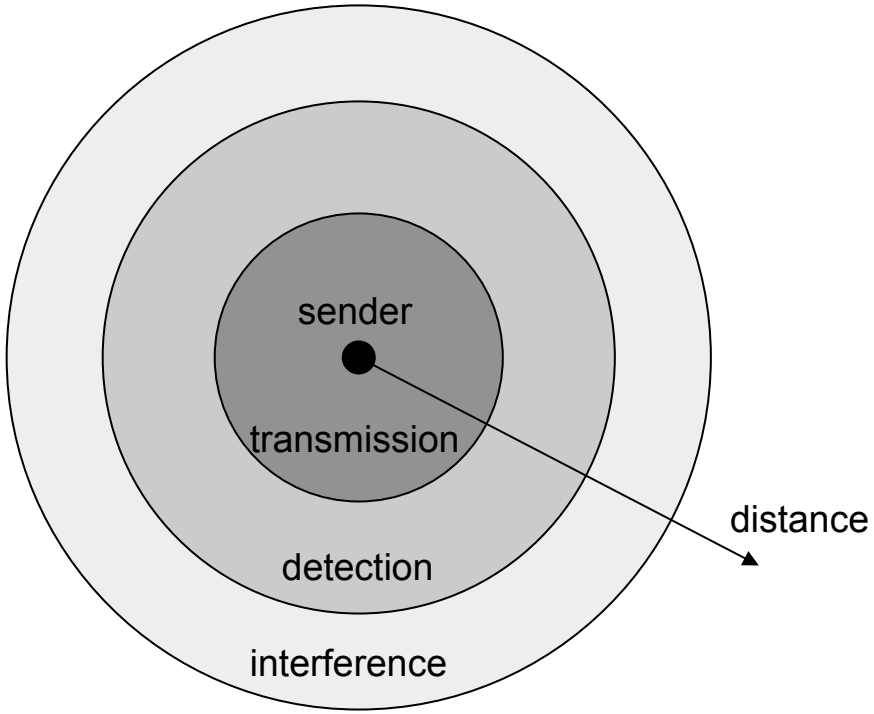
Example: Mobile phone antenna



Source: cst.com

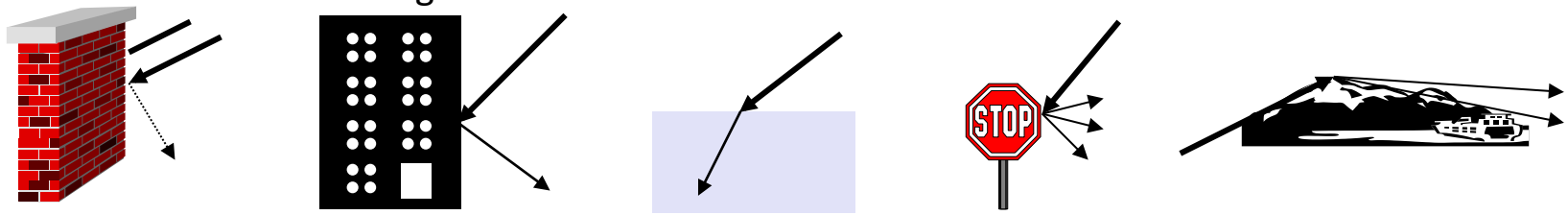
Signal propagation ranges

- Transmission range
  - communication possible
  - low error rate
- Detection range
  - detection of the signal possible
  - no communication possible
- Interference range
  - signal may not be detected
  - signal adds to the background noise



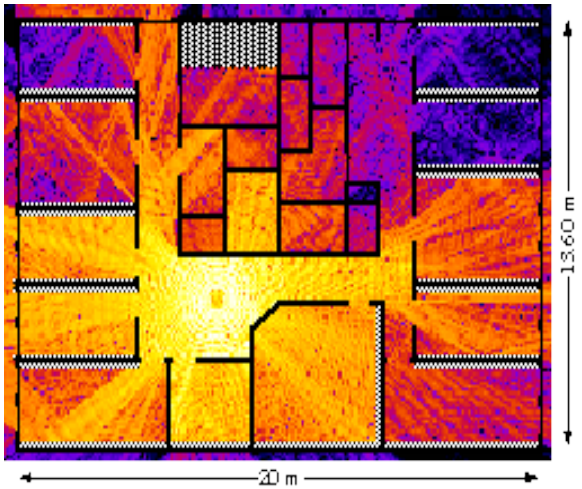
Signal propagation

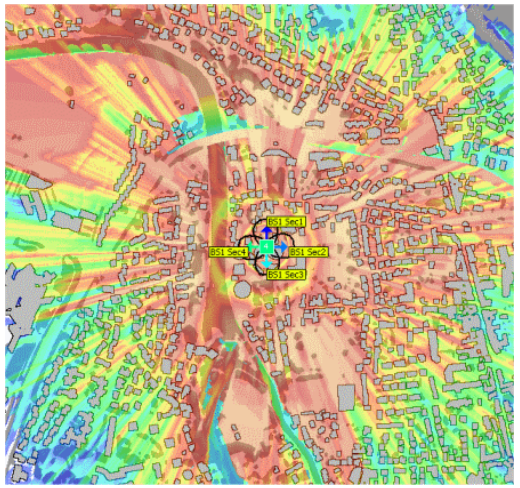
- Propagation in free space always like light (straight line)
- Receiving power proportional to $1/d^2$ in vacuum – much more in real environments (d = distance between sender and receiver)
- Receiving power additionally influenced by
  - fading (frequency dependent)
  - shadowing
  - reflection at large obstacles
  - refraction depending on the density of a medium
  - scattering at small obstacles
  - diffraction at edges

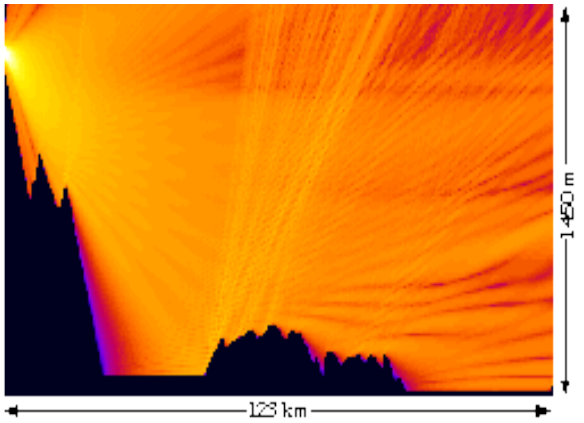


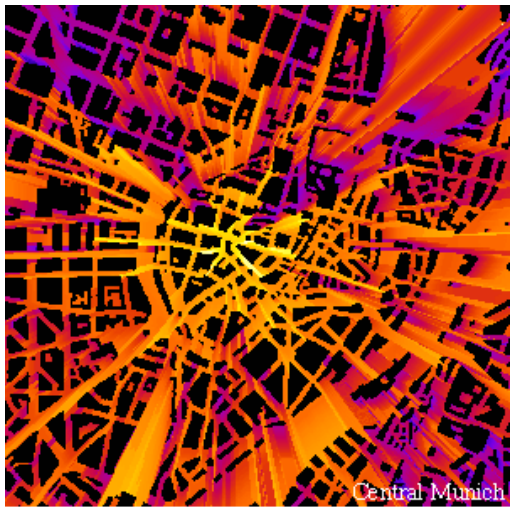
shadowing reflection refraction scattering diffraction

Real world examples









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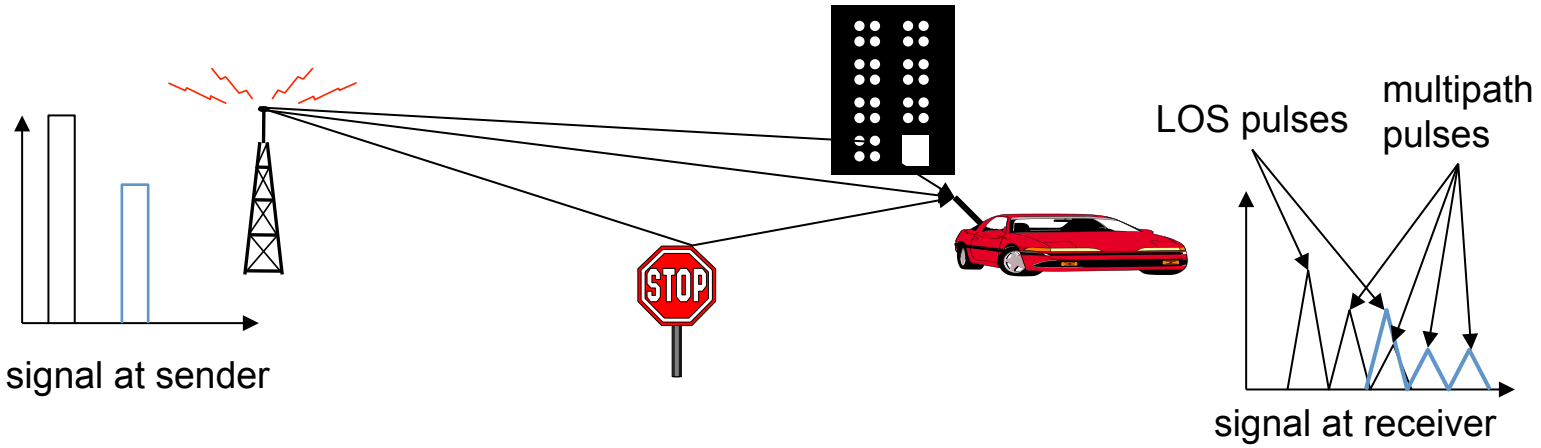
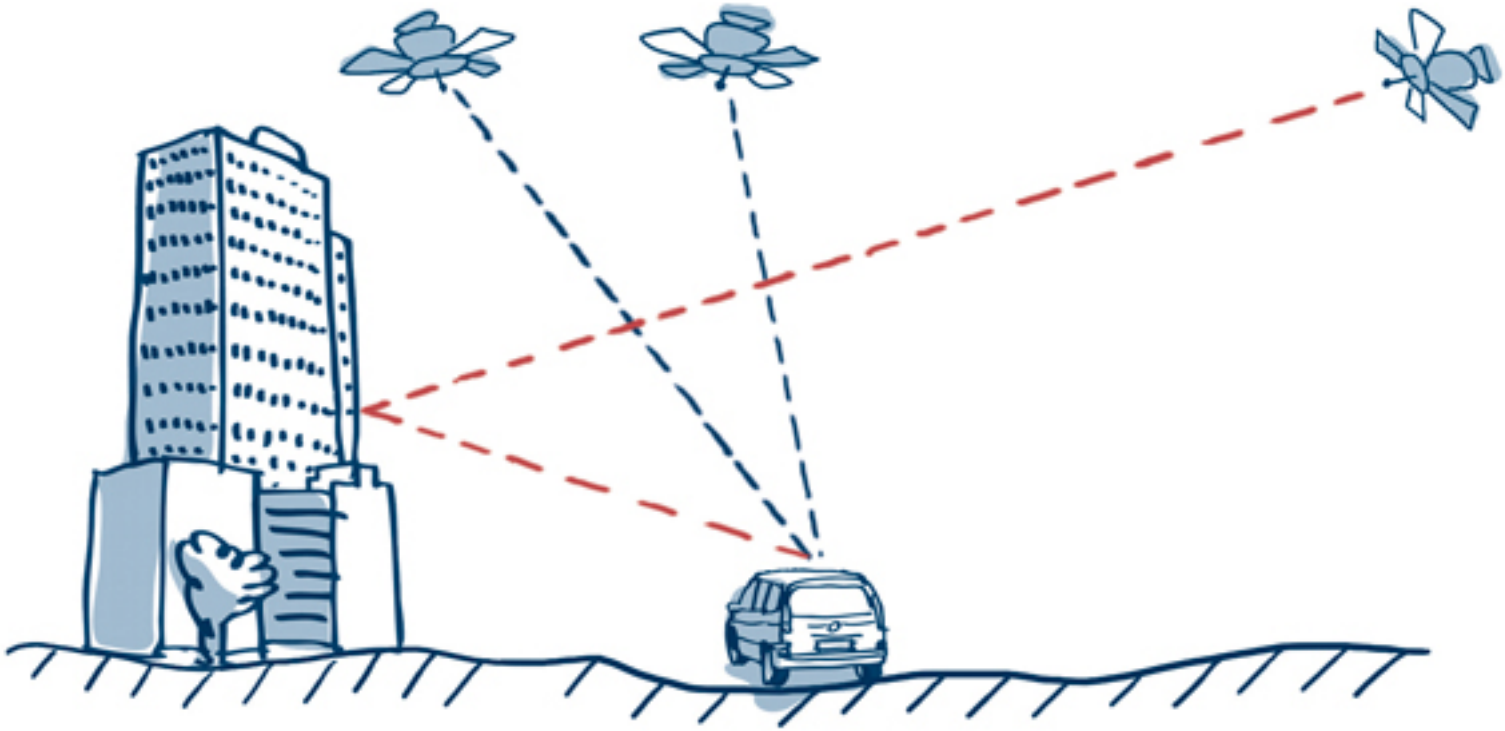
Multipath propagation



- Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction
- The signal reaches a receiver directly and phase shifted

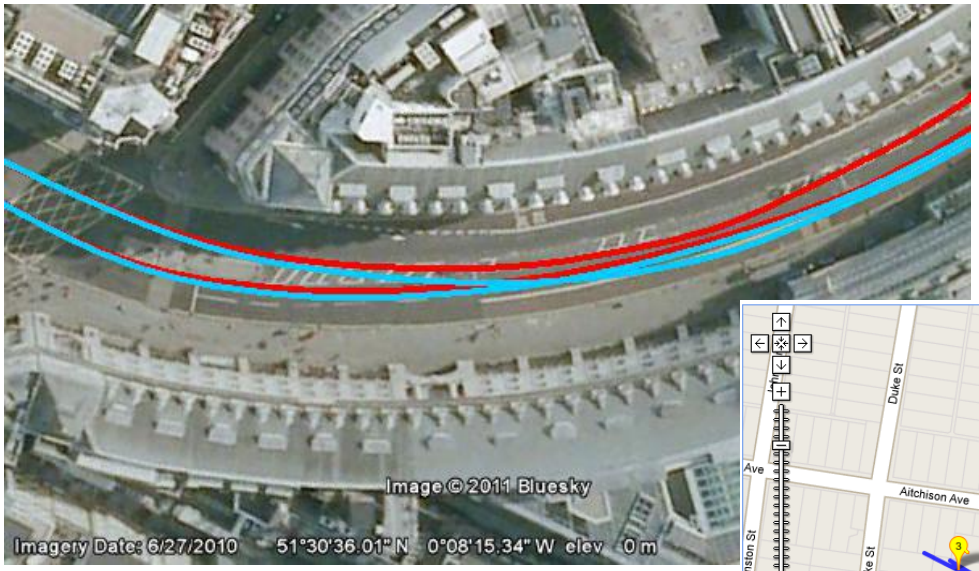
  ➔ signal distortion depending on the phases of the different parts

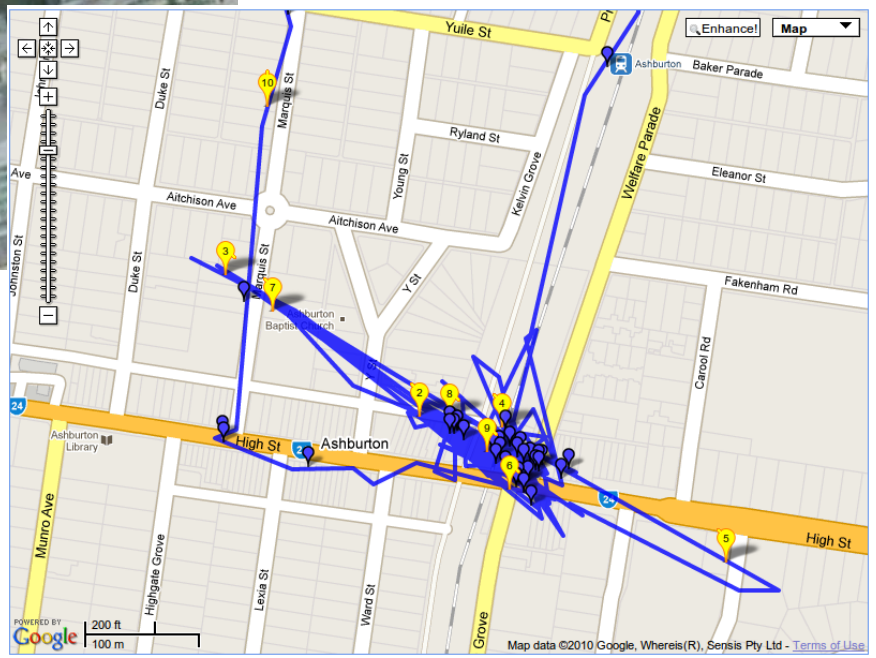
Example: Effect on GPS



Source: Bosch Sensortec

Observable error





Source: Oxford Technical Solutions oxts.com

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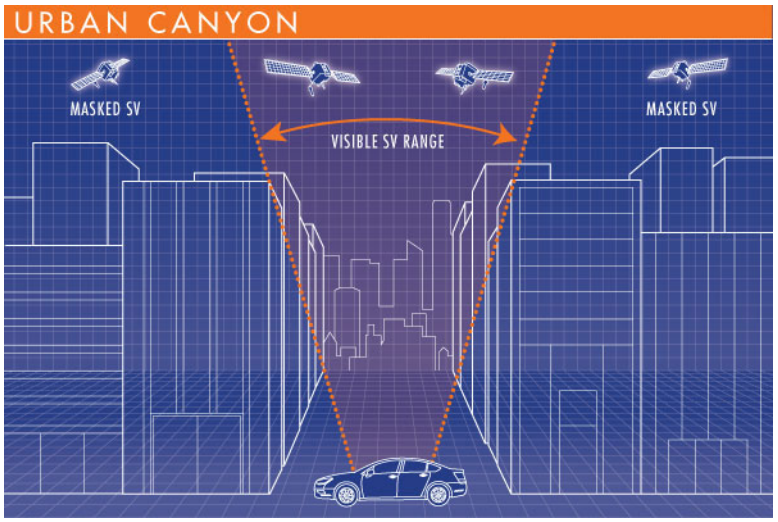
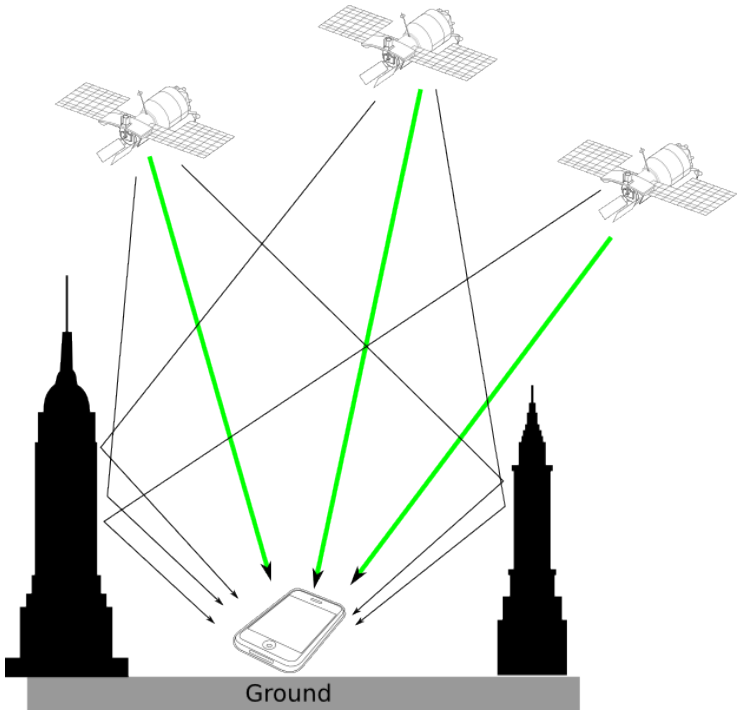
Urban Canyons

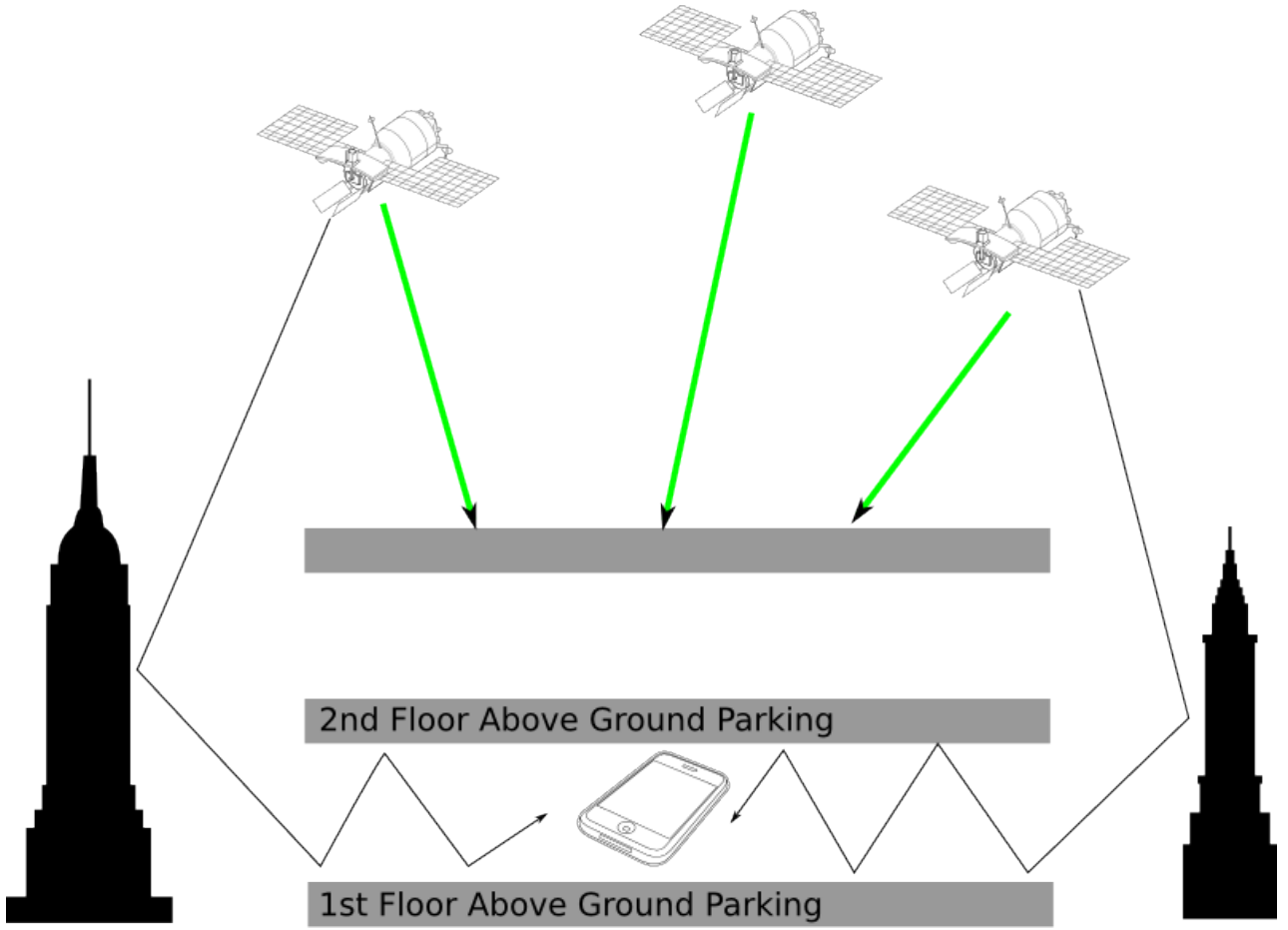
GPS in Urban Canyons





Source: fmcsmart.forumotion.com/

GPS in multi-storey car parks



Source: fmcsmart.forumotion.com/

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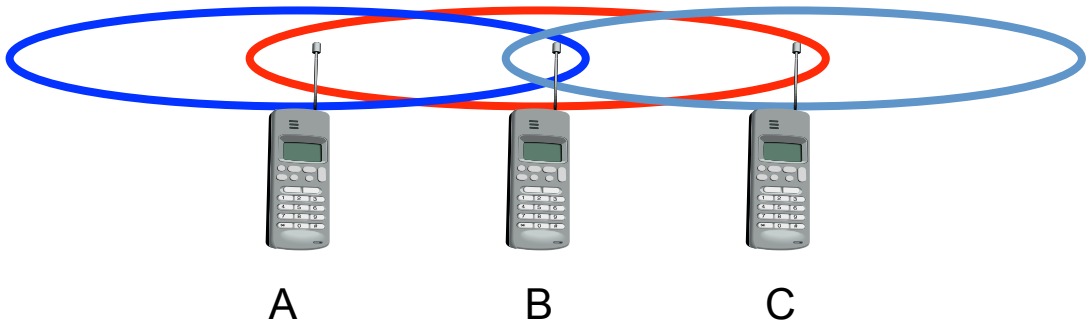
Media access

- Can we apply media access methods from fixed networks?

- Example CSMA/CD
  - **C**arrier **S**ense **M**ultiple **A**ccess with **C**ollision **D**etection
  - send as soon as the medium is free, listen into the medium if a collision occurs (original method in IEEE 802.3)
- Problems in wireless networks
  - signal strength decreases proportional to the square of the distance
  - the sender would apply CS and CD, but the collisions happen at the receiver
  - it might be the case that a sender cannot “hear” the collision, i.e., CD does not work
  - furthermore, CS might not work if, e.g., a terminal is “hidden”

Hidden and exposed terminals

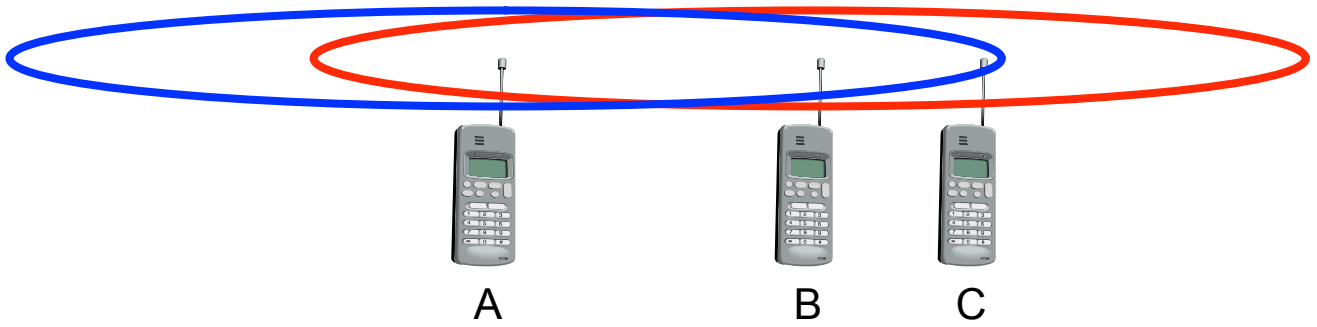
- Hidden terminals
  - A sends to B, C cannot receive A
  - C wants to send to B, C senses a “free” medium (CS fails)
  - collision at B, A cannot receive the collision (CD fails)
  - A is “hidden” for C



- Exposed terminals
  - B sends to A, C wants to send to another terminal (not A or B)
  - C has to wait, CS signals a medium in use
  - but A is outside the radio range of C, therefore waiting is not necessary
  - C is “exposed” to B

Motivation - near and far terminals

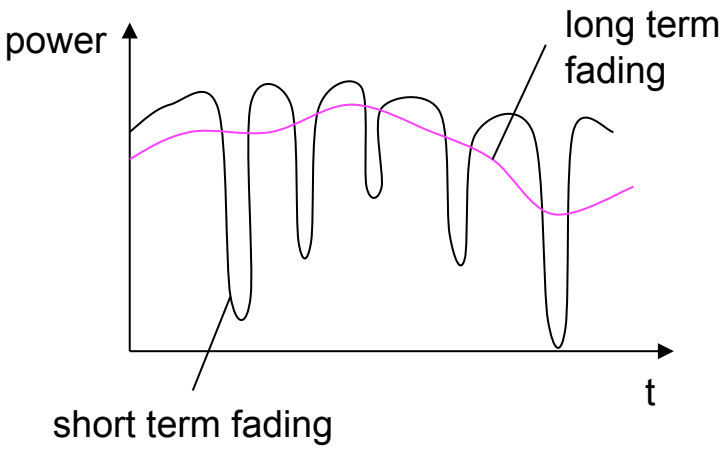
- Terminals A and B send, C receives
  - signal strength decreases proportional to the square of the distance
  - the signal of terminal B therefore drowns out A's signal
  - C cannot receive A



- If C for example was an arbiter for sending rights, terminal B would drown out terminal A already on the physical layer
- Also severe problem for CDMA-networks - precise power control needed!

Effects of mobility

- Channel characteristics change over time and location
  - signal paths change
  - different delay variations of different signal parts
  - different phases of signal parts
- ➔ quick changes in the power received (short term fading)
- Additional changes in
  - distance to sender
  - obstacles further away
- ➔ slow changes in the average power received (long term fading)



Summary

- Signal characteristics
- Signal modulation to represent information
- Signal processing pathway
- Role of antenna
- Propagation of wireless signals
- Wireless media access