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Mobile and Ubiquitous Computing

Wireless Transmission and Mobility

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Mobile Computing in More Depth

- Wireless communication
  - Disconnection
  - Low bandwidth
  - High bandwidth variability
  - Heterogeneous networks
  - Security
- Mobility
  - Addressing and routing
  - Location based information
  - Migration
- Portability
  - Low power
  - Small interface
  - Restricted storage
  - Security

Signals I

- 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

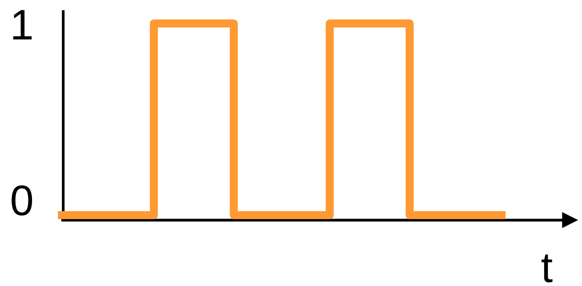
Signals II

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

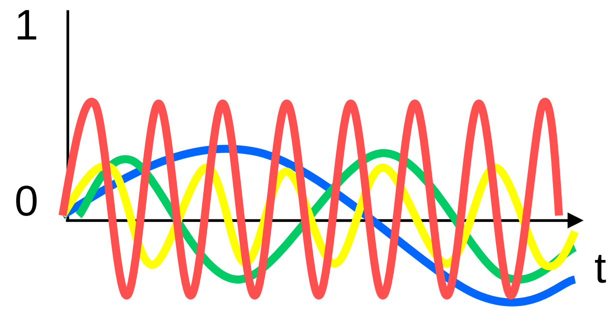
$$s(t) = A_t \sin(2 \pi f_t t + \varphi_t)$$

Fourier representation of periodic signals

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

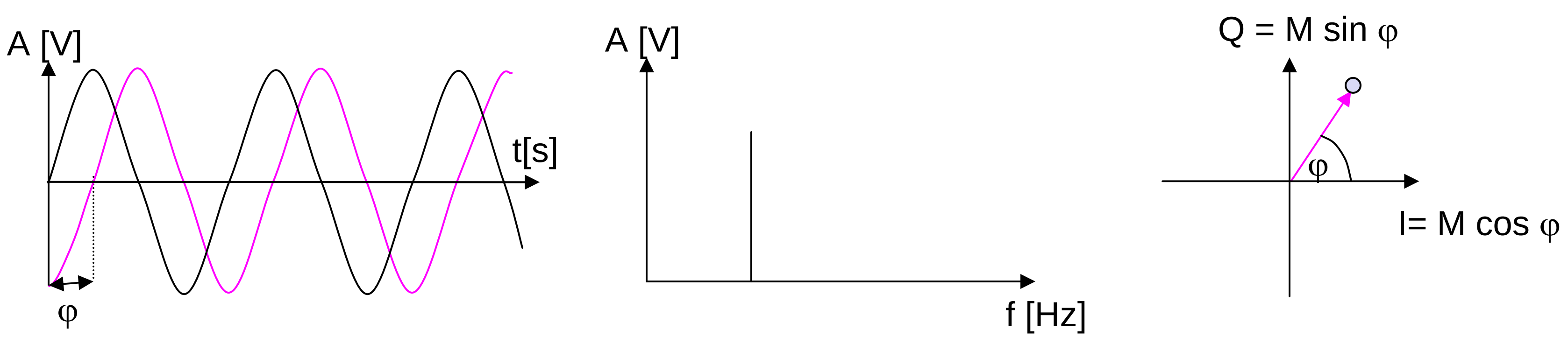


ideal periodic signal



real composition
(based on harmonics)

Signals III

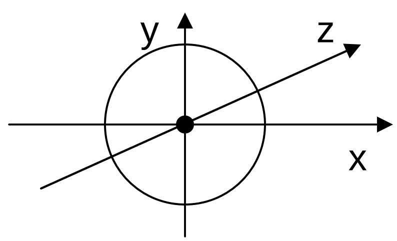


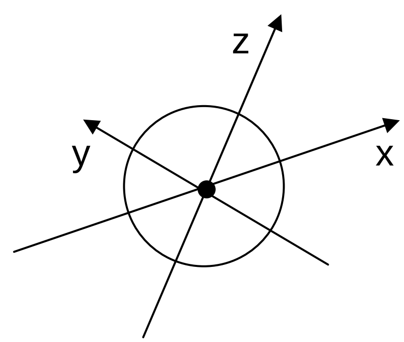
Different representations of signals

- amplitude (amplitude domain)
- frequency spectrum (frequency domain)
- phase state diagram (amplitude M and phase φ in polar coordinates)

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

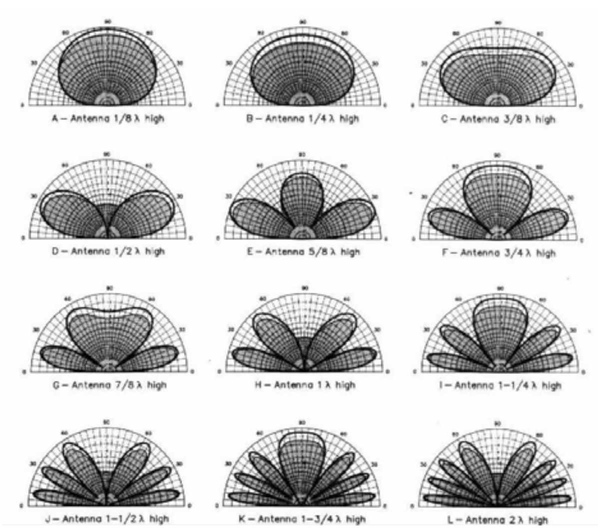


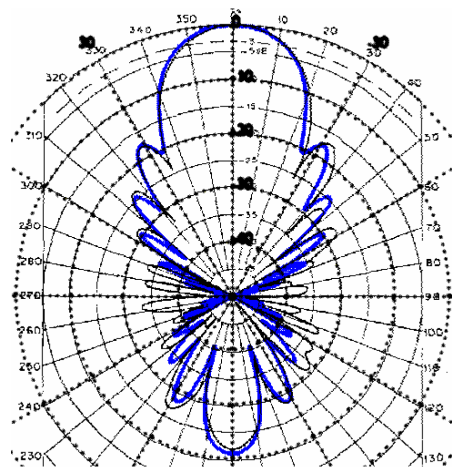


ideal
isotropic
radiator

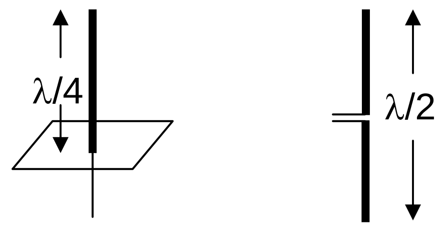
Antennas: radiation pattern

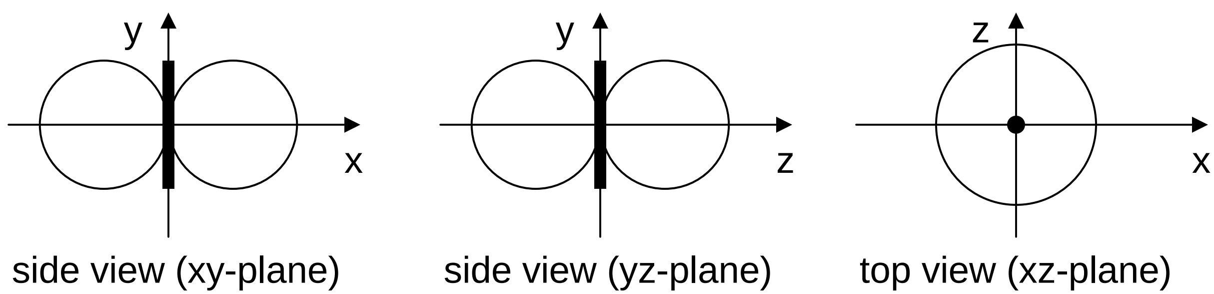
- Real antennas always have directive effects (vertically and/or horizontally)
- Radiation pattern: measurement of radiation around an antenna





Antennas: simple dipoles

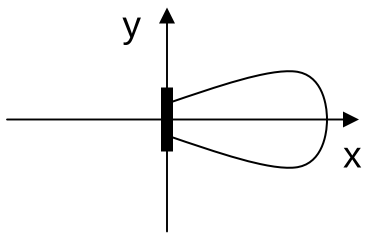




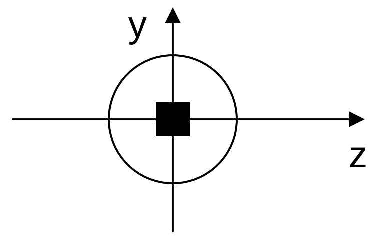
simple
dipole

- Example: Radiation pattern of a simple dipole

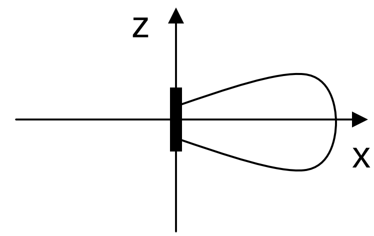
Antennas: directed and sectorized



side view (xy-plane)

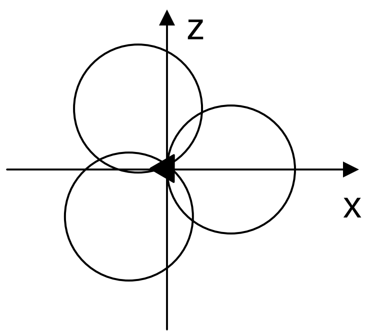


side view (yz-plane)

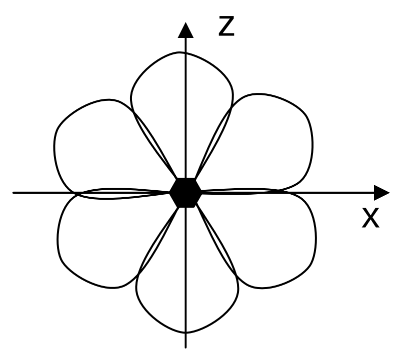


top view (xz-plane)

directed antenna



top view, 3 sector

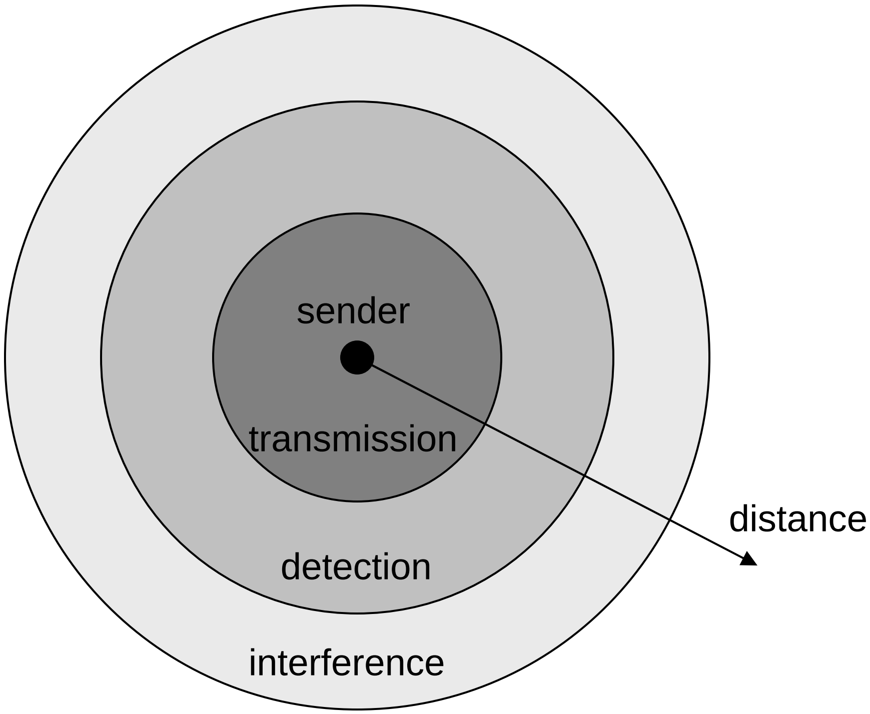


top view, 6 sector

sectorized antenna

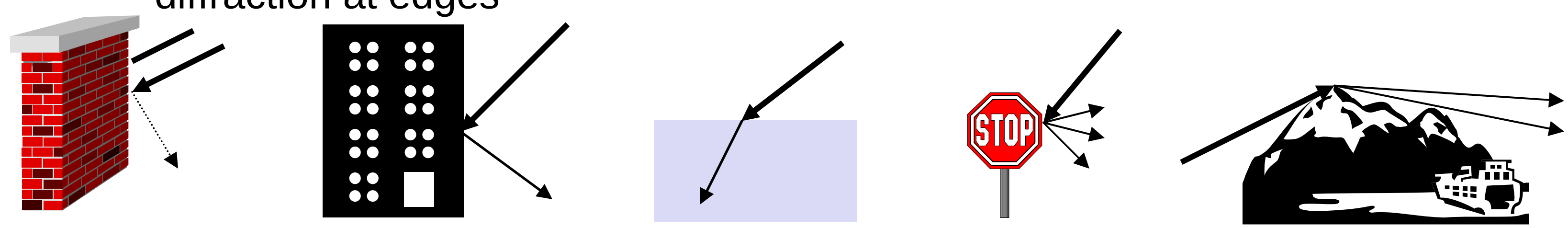
Signal propagation ranges

- 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



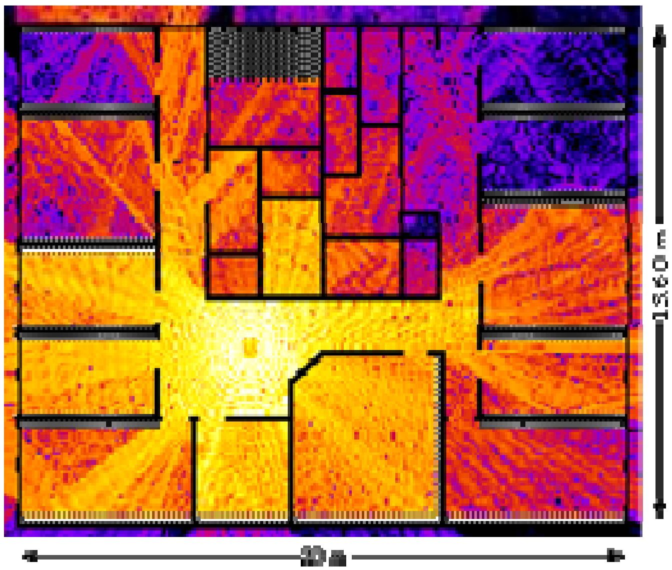
Signal propagation

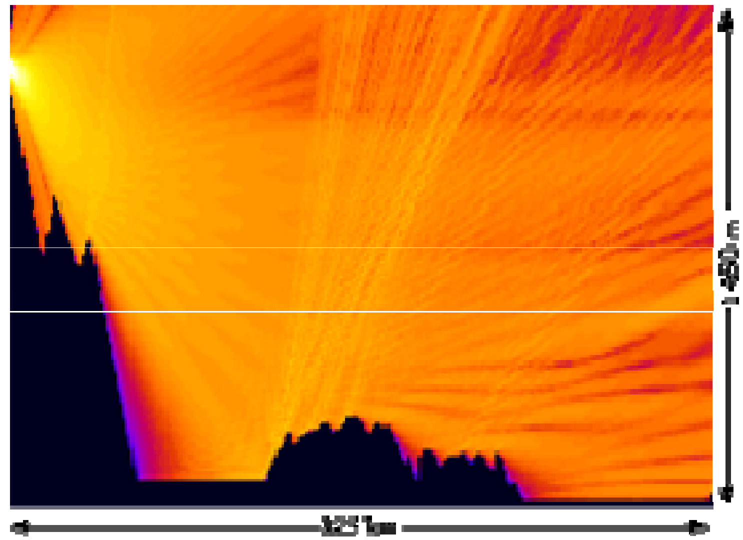
- Propagation in free space always like light (straight line)
- Receiving power proportional to $1/d^2$ in vacuum – much more in real environments (d = distance between sender and receiver)
- Receiving power additionally influenced by
  - fading (frequency dependent)
  - shadowing
  - reflection at large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

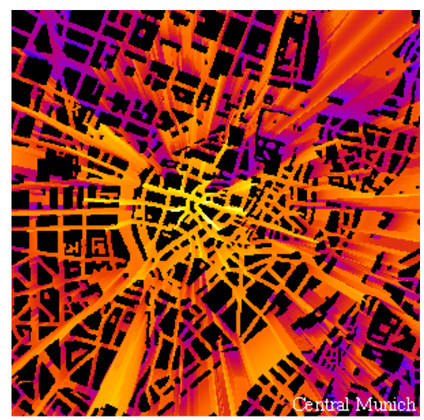


shadowing reflection refraction scattering diffraction

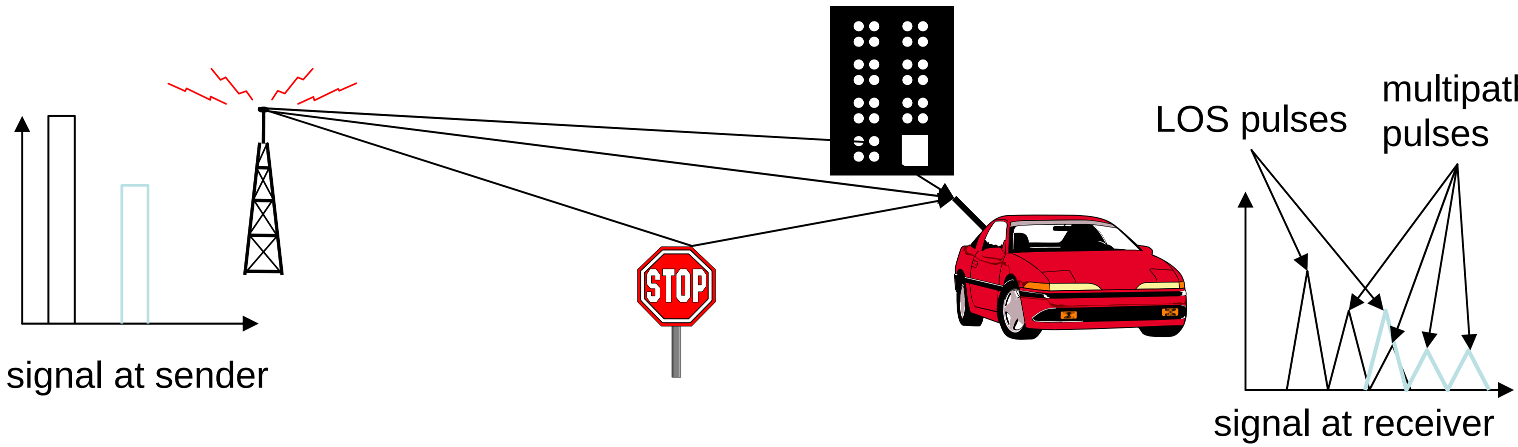
Real world example







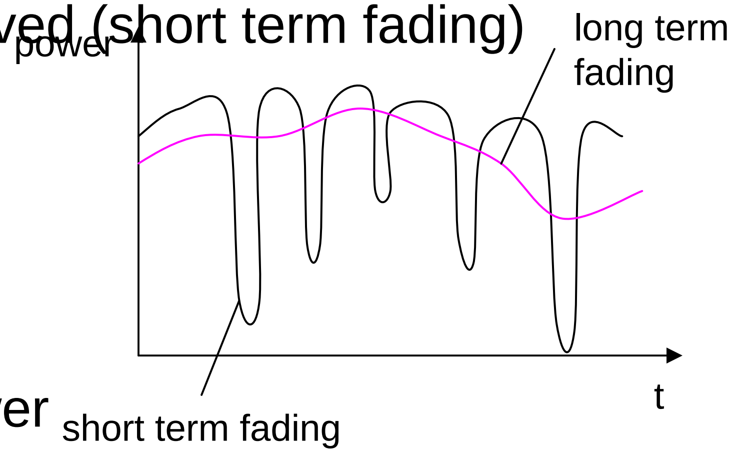
Multipath propagation



- Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction
- The signal reaches a receiver directly and phase shifted
- ➔ distorted signal depending on the phases of the different parts

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)



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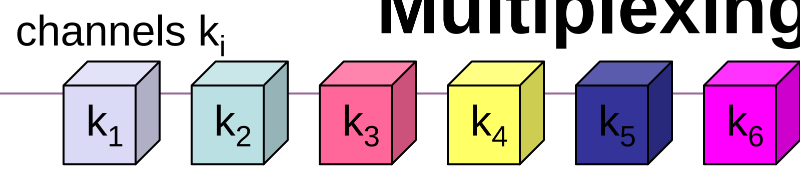
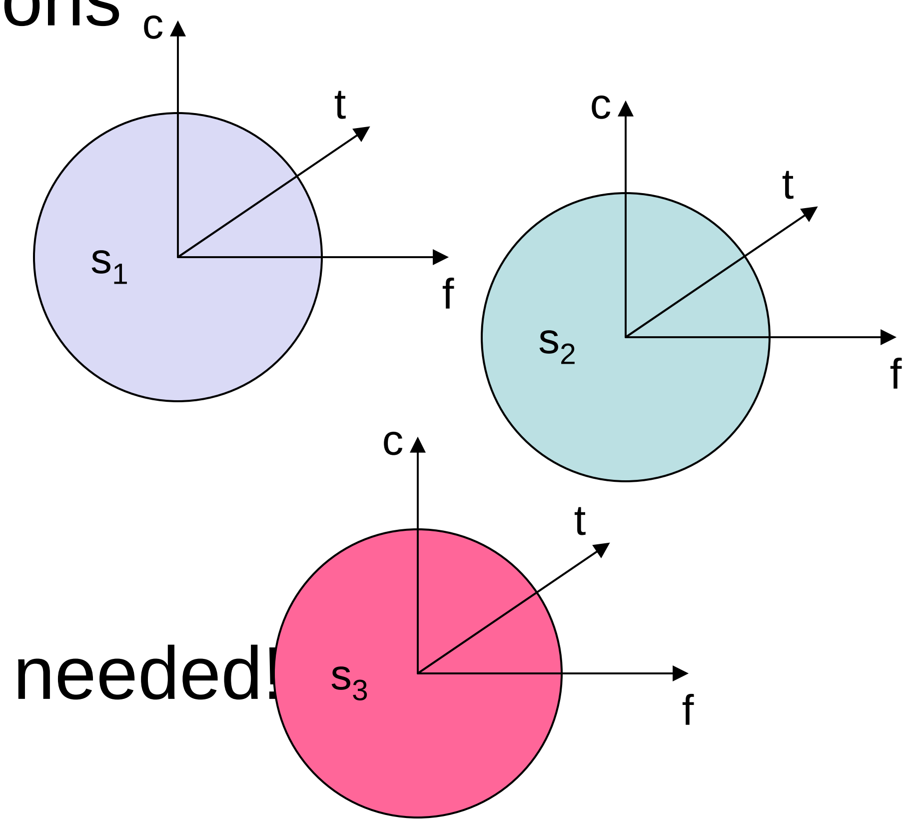
Multiplexing



- Multiplexing in 4 dimensions
  - space (s_i)
  - time (t)
  - frequency (f)
  - code (c)
- Goal: multiple use of a shared medium
- Important: guard spaces needed!

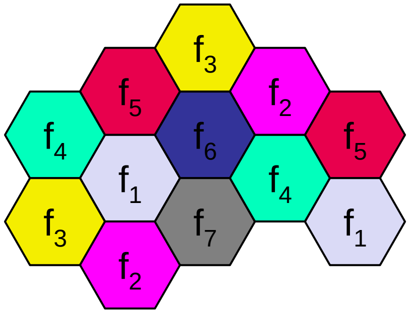


Cell structure

- Implements space division multiplex: base station covers a certain transmission area (cell)
- Mobile stations communicate only via the base station
- Advantages of cell structures:
  – higher capacity, higher number of users
  – less transmission power needed
  – more robust, decentralized
  – base station deals with interference, transmission area etc. locally
- Problems:
  – fixed network needed for the base stations
  – handover (changing from one cell to another) necessary
  – interference with other cells
- Cell sizes from some 100 m in cities to, e.g., 35 km on the country side (GSM) - even less for higher frequencies

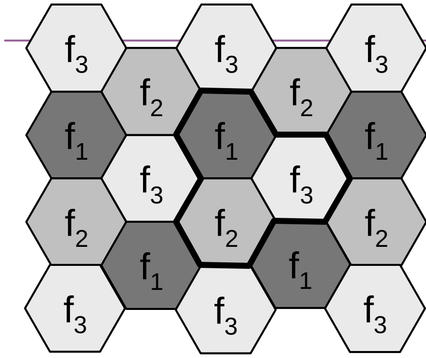
Frequency planning I

- Frequency reuse only with a certain distance between the base stations
- Standard model using 7 frequencies:

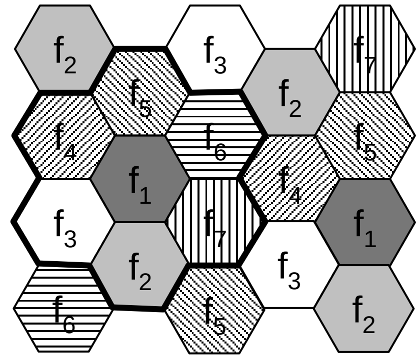


- Fixed frequency assignment:
  - certain frequencies are assigned to a certain cell
  - problem: different traffic load in different cells
- Dynamic frequency assignment:
  - base station chooses frequencies depending on the frequencies already used in neighbor cells
  - more capacity in cells with more traffic
  - assignment can also be based on interference measurements

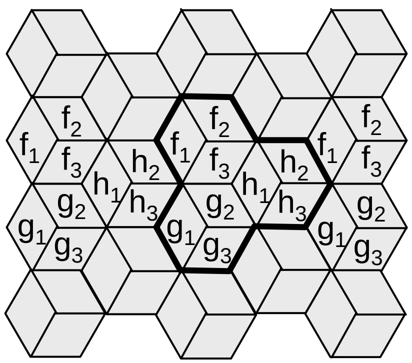
Frequency planning II



3 cell cluster



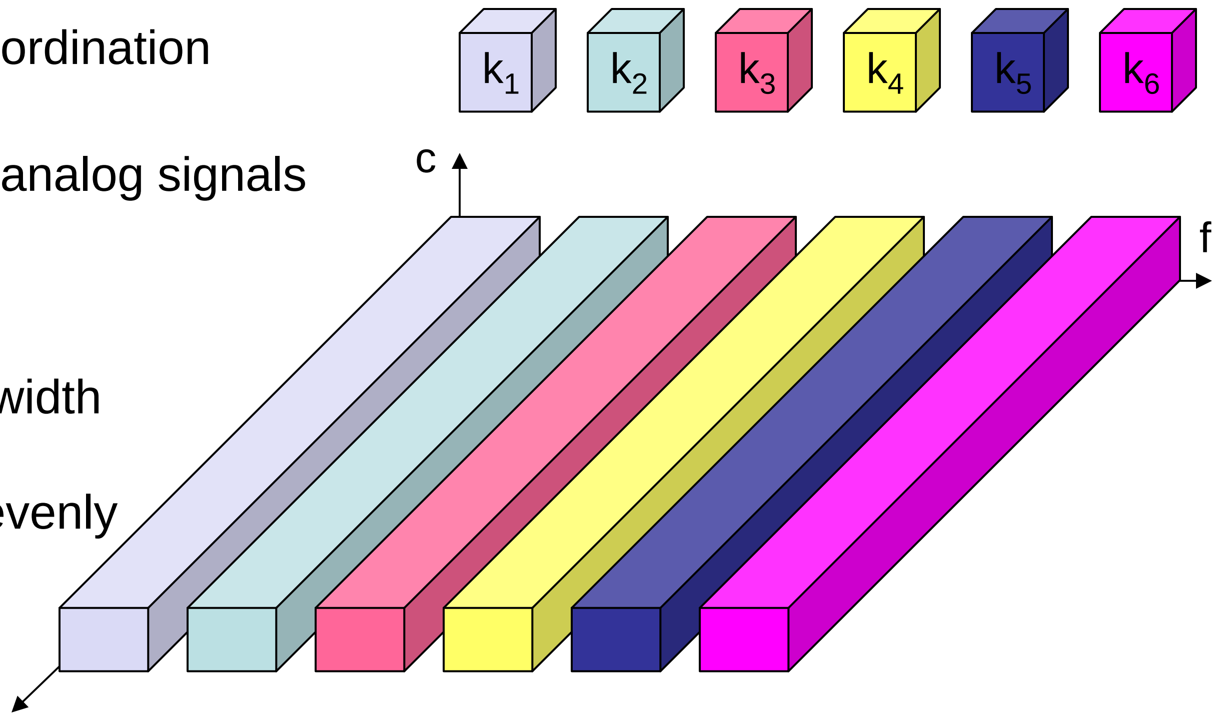
7 cell cluster



3 cell cluster
with 3 sector antennas

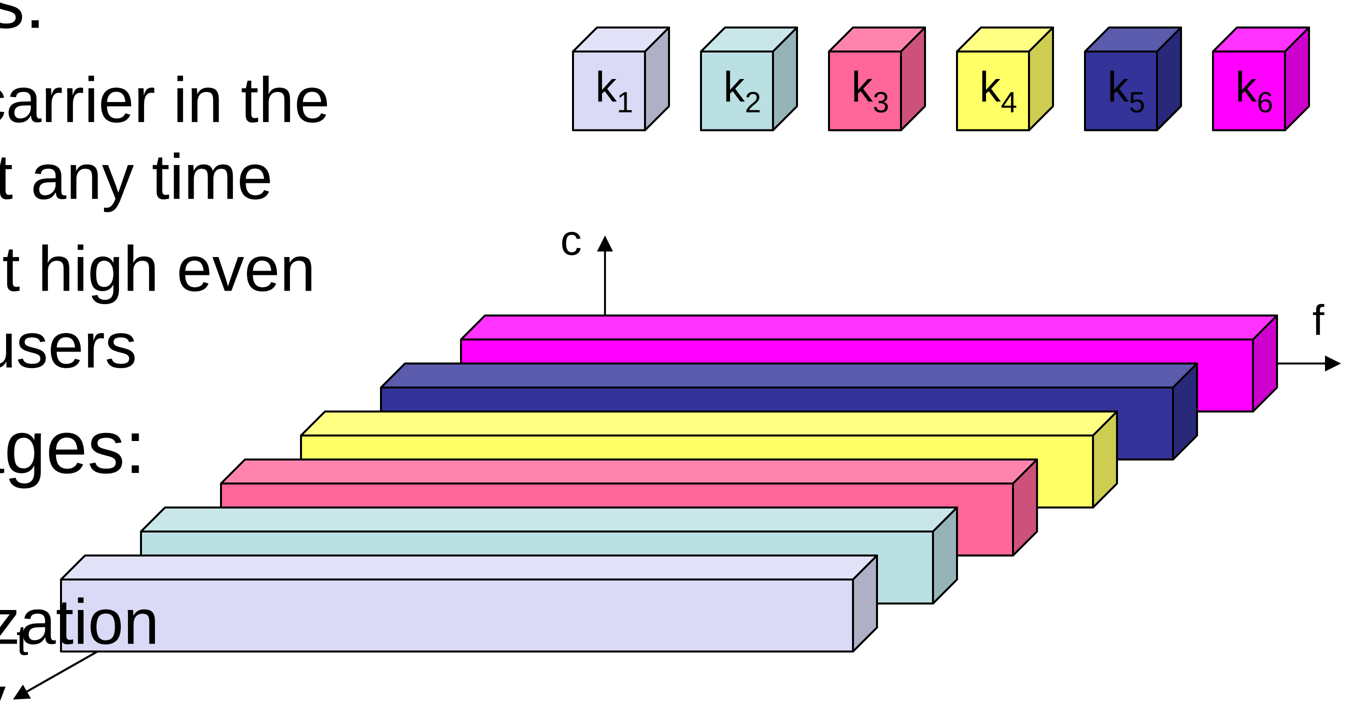
Frequency multiplex

- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- Advantages:
  - no dynamic coordination necessary
  - works also for analog signals
- Disadvantages:
  - waste of bandwidth if the traffic is distributed unevenly
  - inflexible
  - guard spaces



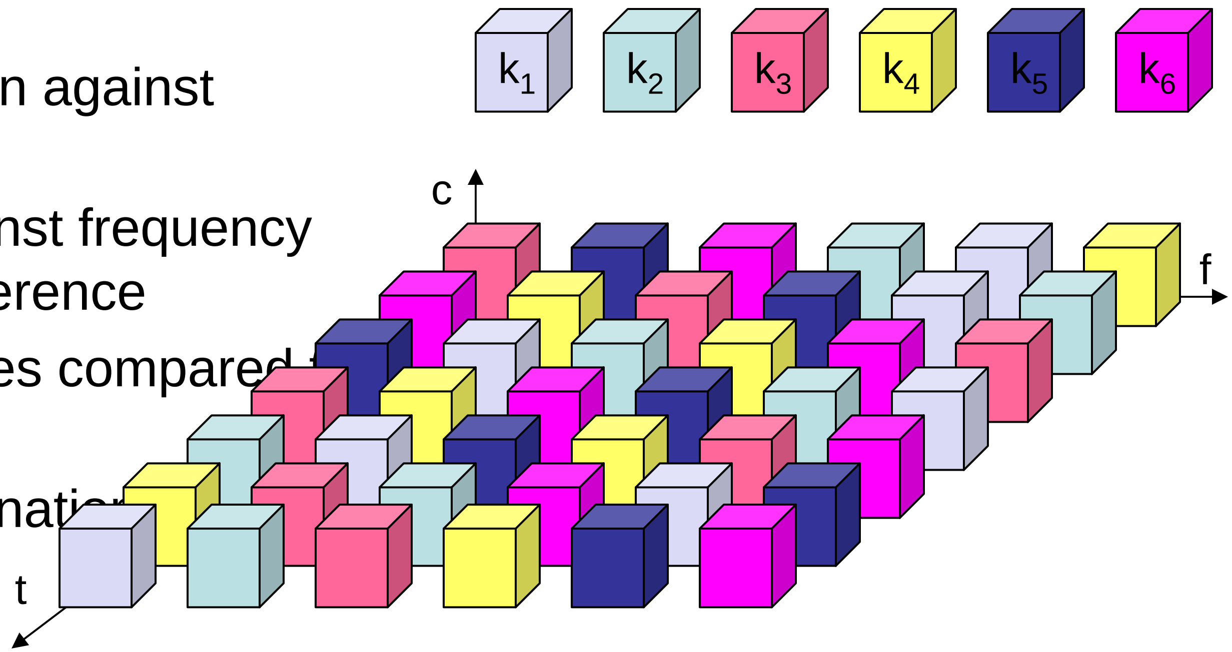
Time multiplex

- A channel gets the whole spectrum for a certain amount of time
- Advantages:
  - only one carrier in the medium at any time
  - throughput high even for many users
- Disadvantages:
  - precise synchronization necessary



Time and frequency multiplex

- Combination of both methods
- A channel gets a certain frequency band for a certain amount of time
- Example: GSM
- Advantages:
  - better protection against tapping
  - protection against frequency selective interference
  - higher data rates compared to code multiplex
- but: precise coordination required



Code multiplex

- Each channel has a unique code
- All channels use the same spectrum at the same time
- Advantages:
  - bandwidth efficient
  - no coordination and synchronization necessary
  - good protection against interference and tapping
- Disadvantages:
  - lower user data rates
  - more complex signal regeneration
- Implemented using spread spectrum technology