Introduction and technological Fundamentals
Basic Antenna Concepts

Content - Fundamentals - Basic Antenna Concepts

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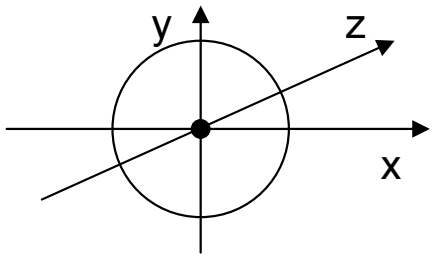
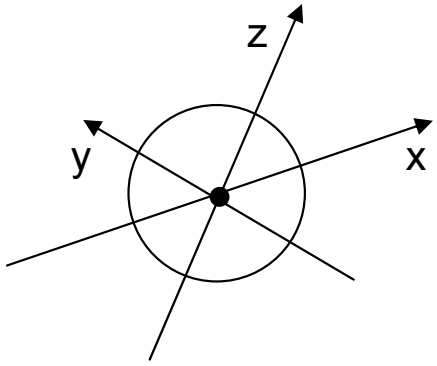
Isotropic Antennas (Point Radiators)

- Antennas are used to emitt and receive electromagnetic waves
- The antenna pattern is characterized by the directional diagram of the antenna (= antenna diagram); the directional diagram is determined by power measurements around the antenna
- An isotropic antenna is an ideal point antenna, which emitts power equally in all directions - it is used as a theoretical reference antenna
- Directional diagram of an ideal isotropic antenna:



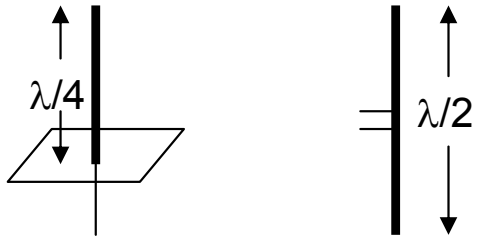


ideal isotropic antenna

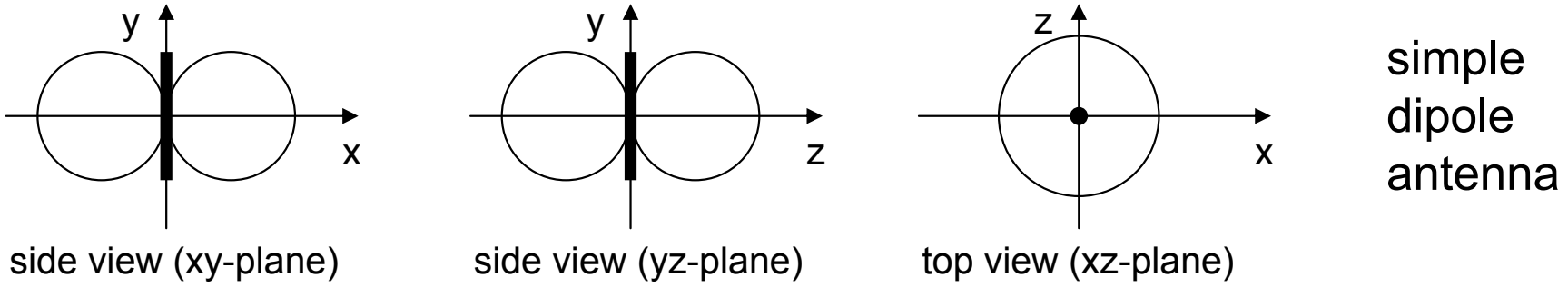
- Real antennas always have a vertical and/or horizontal directivity

Simple Dipole Antennas

- Real antennas are not isotropic radiators but e.g. λ/4 radiators (on a conductive surface, e.g. a car roof) or λ/2 dipoles; the size of a antenna is proportional to the wave length λ



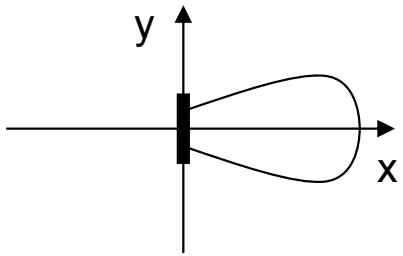
- Example: antenna diagram of a simple dipole antenna



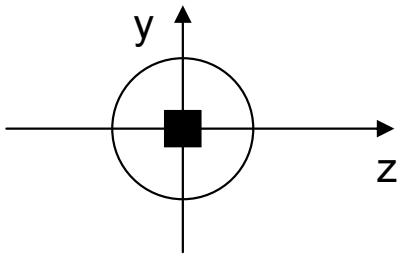
- Definition of the antenna gain: ratio of the transmit power density in the direction of the antenna main lobe and the transmit power density of a reference antenna (that transmits with equal mean power)

Directional Antennas and Sector Antennas

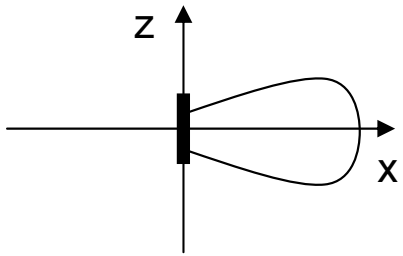
- These types of antennas are used frequently for point-to point microwave links and in cellular mobile systems
- Examples:



side view (xy-plane)

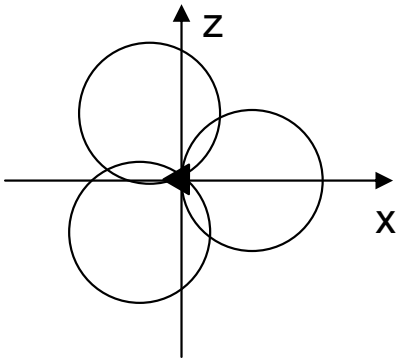


side view (yz-plane)

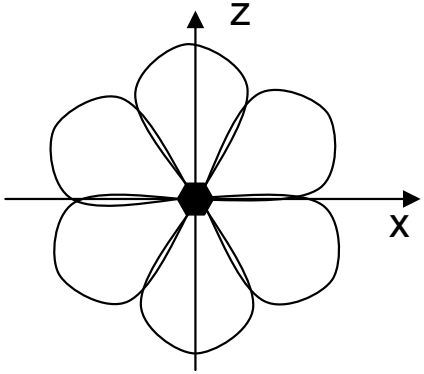


top view (xz-plane)

directional antenna



top view, 3 sectors

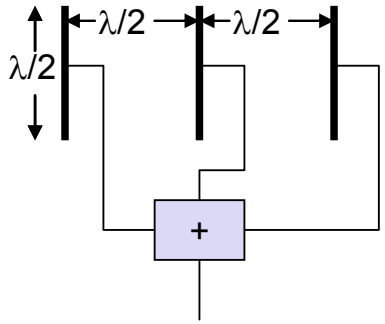


top view, 6 sectors

sector antenna

Antenna Arrays

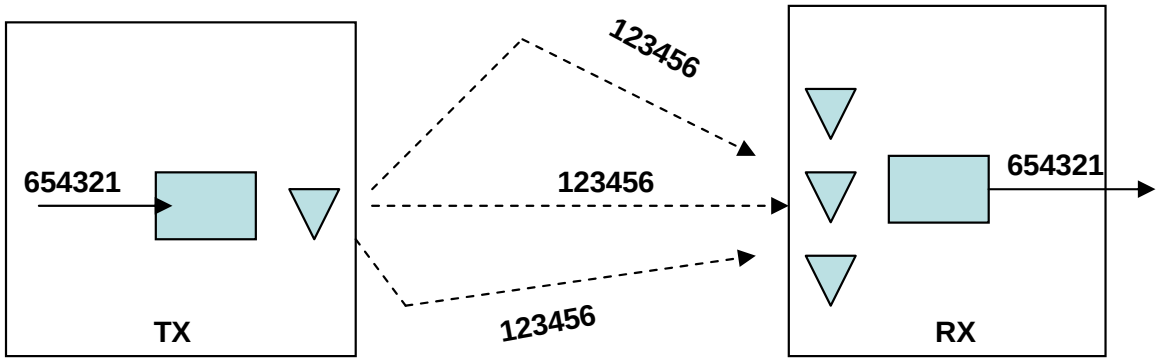
- Antenna arrays are build by grouping of two or more antennas
  - antenna placement in a circle → Circular Array
  - antenna placement in a plane → Linear Array



- Use cases for antenna arrays:
  - Transmit/Receive Diversity:
    - Receive Diversity: reception with multiple antennas and combination of the received signals
    - Transmit Diversity: parallel transmission of the same signal with multiple antennas
  - Spatial Multiplexing:
    - the original signal is transmitted with multiple antennas on different paths (inverse multiplexing in space)
  - Beamforming:
    - the same signal transmitted on all antennas but with an individual phase-shift → creation of directional antenna beams (SDMA)
  - Multi-User Detection / Interference Mitigation

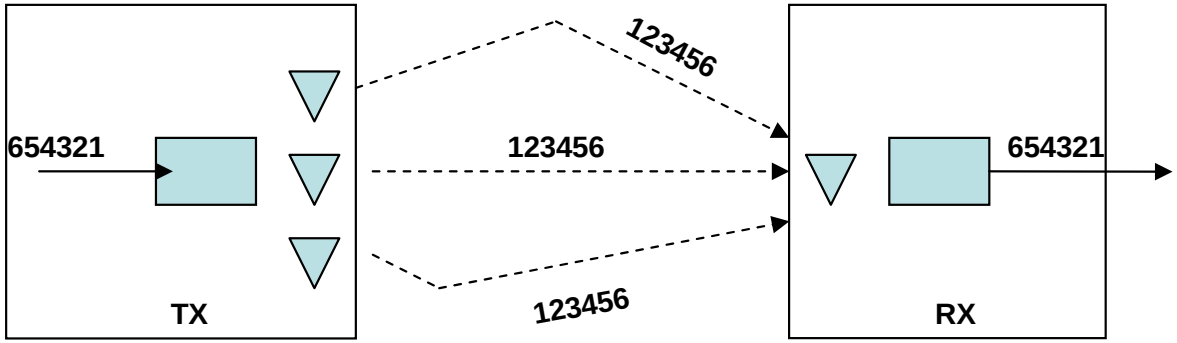
Antenna Arrays - Transmit/Receive Diversity

- Receive Diversity
  - reception with multiple antennas and combination of the received signals
  - combination schemes:
    - Selection Combining: switching/selecting of one antenna element - the antenna that receives the best signal is chosen
    - Maximum Ratio Combining: the signals of all antenna elements are used - weighted, coherent addition of the signals



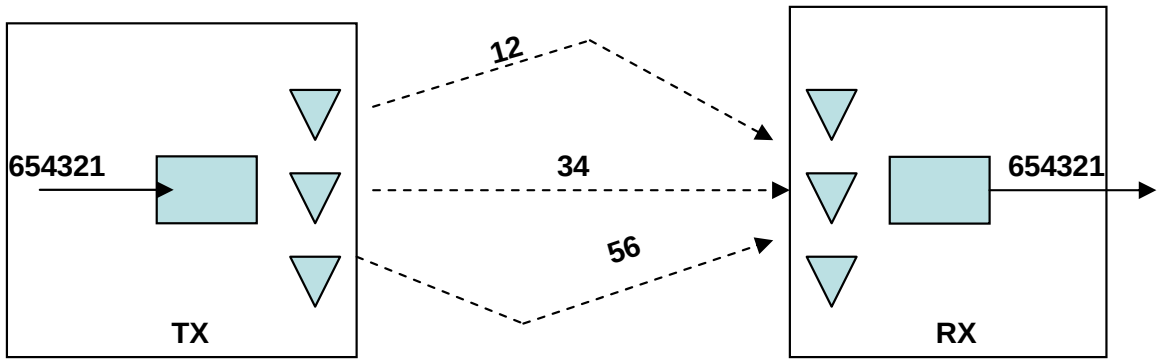
Antenna Arrays - Transmit/Receive Diversity

- Transmit Diversity
  - parallel transmission of the same signal with multiple antennas
  - variants: Open / Closed Loop Transmit Diversity
    - example for open loop transmit diversity: Space Time Block Coding (Alamouti scheme)



Antenna Arrays - Spatial Multiplexing

- Spatial Multiplexing:
  - the original signal is transmitted on different paths (inverse multiplexing in space); thus, each antenna transmits a individual (and different) signal
  - perquisite: the receiver also has an antenna array (**MIMO-Transmission**)
  - advantage: increasing the throughput in case of bad SNR by using multipath propagation (assuming that the fading on the paths occurs independently)



Antenna Arrays - Beamforming

- Beamforming:
  - Space Division Multiple Access (SDMA)
  - Beamforming variants:
    - fixed/switched-beam Beamforming:
      - fixed Beamforming: switching between pre-configured directional antennas
      - switched-beam Beamforming: switching between different pre-configured beam patterns of the antenna array
    - adaptive Beamforming: dynamic variation of the antenna characteristic
      - optimal Beamforming: steering beams according to an optimality criterion
      - Null-Steering Beamforming: blocking (nulling) interferers from certain directions