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UNIVERSITÄT FREIBURG

Algorithms for Radio Networks

Smart Antennas and MIMO

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Smart Antennas

► Alternative terms

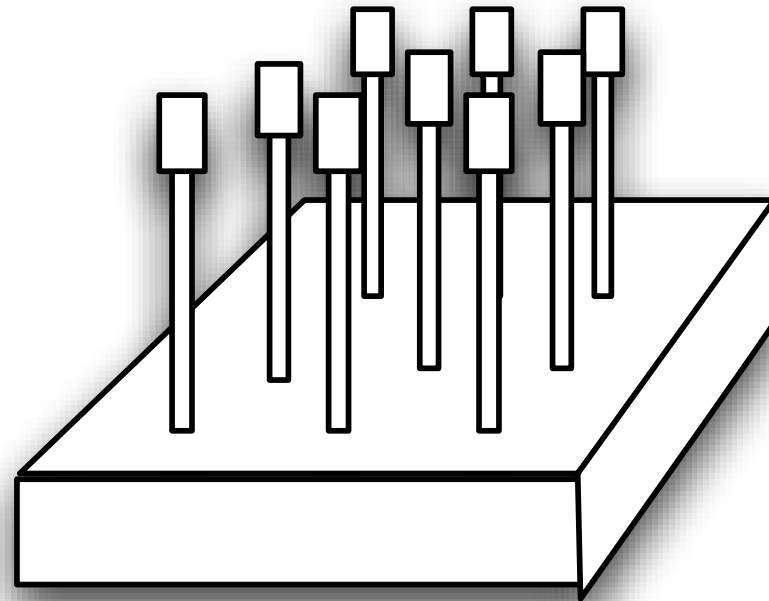
- Adaptive Array Antennas
- Multiple Input Multiple Output (MIMO)

► Prinzip

- Multiple antennas are coordinated manner
 - used to improve reception or transmission of behavior
 - to allow additional features

► Features

- Directional receivers
- Directional senders
 - better path loss exponent
 - spatial multiplexing
 - MIMO communication



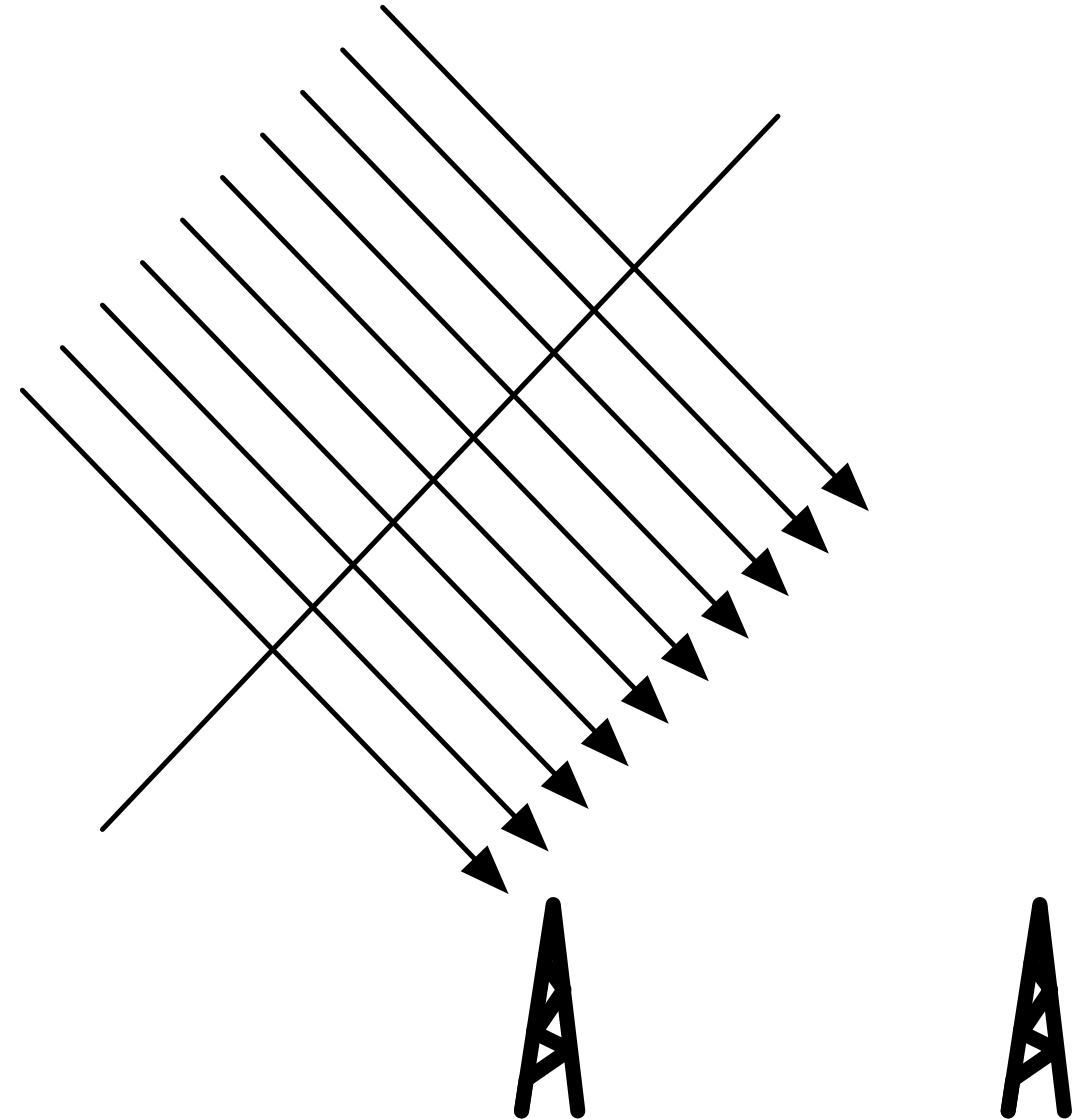
DOA Estimation

► **With two antennas, one can determine the receive direction (DOA)**

- Paulraj, Roy, Kailath, Estimation of Signal Parameters via Rotational Invariance Techniques- ESPRIT, Nineteenth Asilomar Conference on Circuits, Systems and Computers, 1985, 83- 89

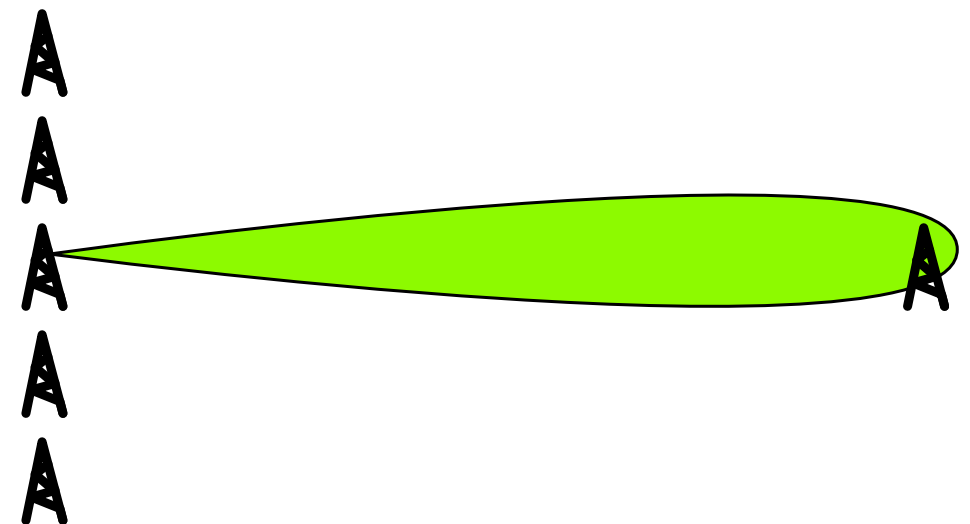
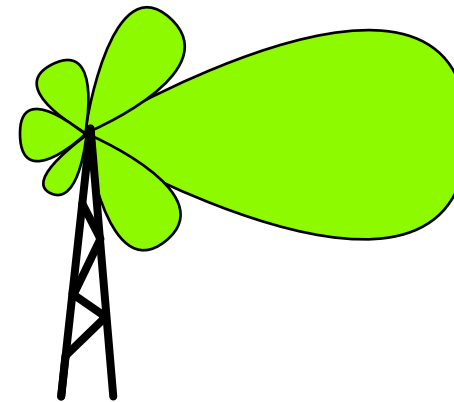
► **Idea:**

- The signals arrive at different times to the antennas. By parallel testing of overlays can be candidates for the angle of incidence findenn



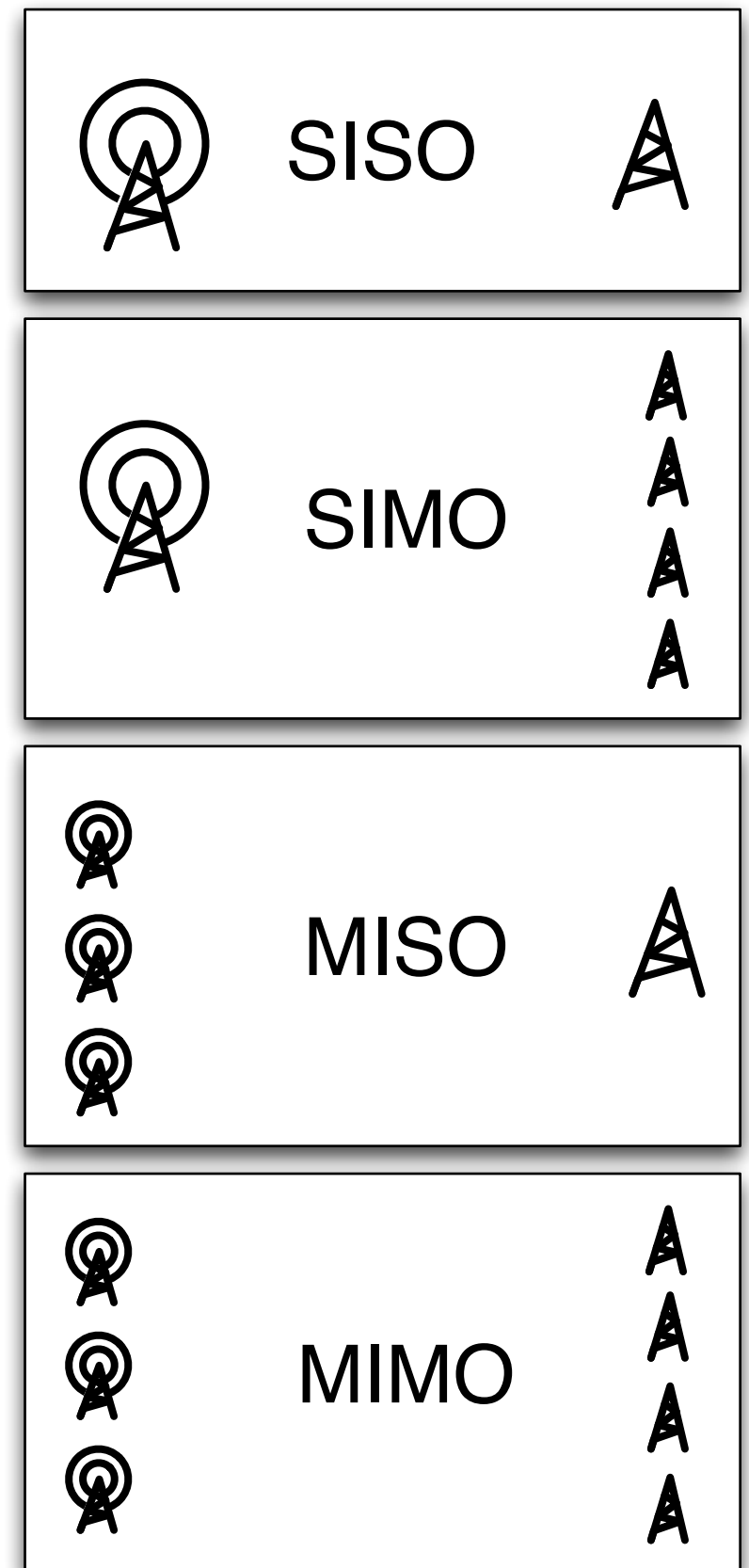
Beam forming

- ▶ **Simulation of receiving or transmitting antenna behavior of any of Smart Antennas**
- ▶ **Active**
 - By suitably chosen time shift, receipt of signals at the antennas will transmit the desired direction preference
 - Other directions only increase only background noise
 - Applications: radar, mobile communications, MIMO
- ▶ **Passive**
 - As with the DOA-detection, the signals are delayed and superimposed
 - Applications: Microphones, MIMO



Smart Antennas Combinations

- **SISO (Single Input Single Output)**
 - Classic radio model
- **SIMO (Single Input Multiple Output)**
 - Classical transmitter with an antenna
 - Antenna array at the receiver
 - Different channels can be received in parallel from different angles
- **MISO (Multiple Input Single Output)**
 - Antenna array as a transmitter
 - Individual recipients (groups) can be individually reached
- **MIMO (Multiple Input Multiple Output)**
 - Directed (and parallel) communication between the transmitter and receiver possible
 - Efficient utilization of the medium



MIMO-Klassifikationen

- ▶ **Single User (since 1996)**
 - Only a point to point connection can be made
 - More connections via multiplexing possible
- ▶ **Multi User (since 2004)**
 - Parallel communication between various partners
 - on the same carrier wave, at the same time
 - as long as angles differ

Theoretical Potential of MIMO

- ▶ **Gerard J. Foschini and Michael. J. Gans**
 - "On limits of wireless communications in a fading environment when using multiple antennas". Wireless Personal Communications 6 (3): 311–335, 1998
- ▶ **Shannon's theorem does not apply to antenna arrays**
 - Transmission rate can increase arbitrarily for large numbers of antennae

Pros and Cons

► Pro

- Shannon's law repealed
- SNR is improved
- more bandwidth, more parallel connections
- spatial localization possible
- beam forming

► Contra

- complex structure
- rotations must be compensated
- motion tracking necessary



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