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The HHI-Channel-Sounder and Measurements of the Radio Channel for Car-to-Car Communication.

Der HHI-Channel-Sounder und Messungen des Funkkanals für Fahrzeug-zu-Fahrzeug Kommunikation.

Supported by:
Federal Ministry of Economics and Technology
on the basis of a decision by the German Bundestag

Outline

- Introduction
- The HHI-Channel-Sounder
- Measurement of the vehicular channel
- Conclusions

Introduction

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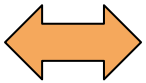
Cooperative Systems  Communication

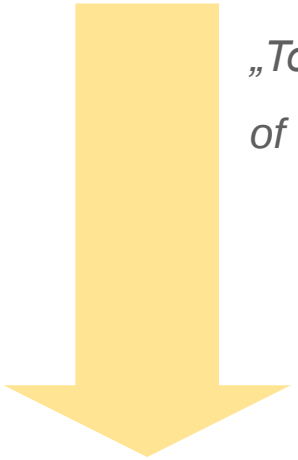
- Wireless communication in this vehicular context refers to Car2X (current standard IEEE 802.11p)

Focus

Goal:

Investigation and simulation of the Car-2-Car communication for cooperative safety systems.

- System Simulation
- Channel Modeling
- Channel Measurement
- Channel Sounder



„Top-Down“ analysis of the task

„Bottom-Up“ synthesis of the results

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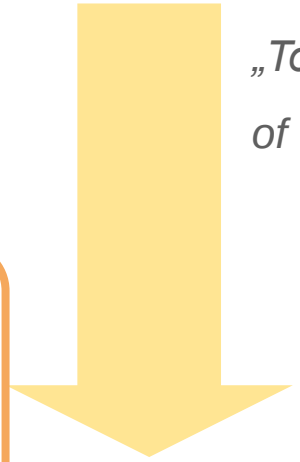


„Top-Down“ analysis of the task

„Bottom-Up“ synthesis of the results

Car2X Channel-Sounder

Efficient and effective communication system design requires sufficient and accurate channel knowledge.

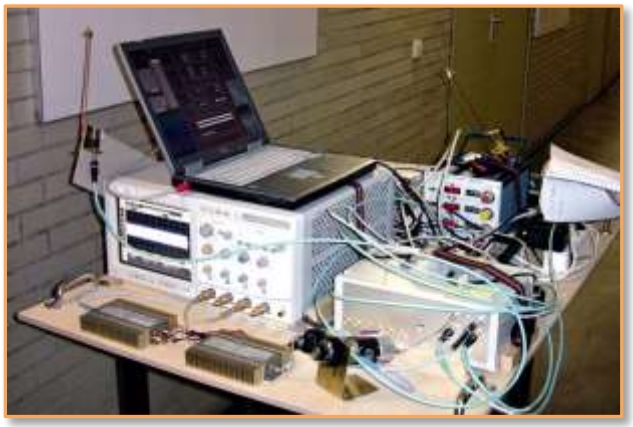
Experiments with communication systems can only yield statistical results on transmission success rates but cannot provide information about the reasons, thus cannot help to identify the potential in the channel.

Necessary properties of a Car2X channel sounder.

- High channel sampling rate
- High dynamic range
- Accurate synchronization
- Robustness and compact form factor

Before starting…

- High performance prototype:
  - 2x2 MIMO
  - High bandwidth
  - Accurate synchronization with „Synchronomat“-Box
- „Experimental“ setup
  - Labor equipment for signal generation, signal aquisition
  - Small data storage, time consuming data storing
  - Inefficient measurement flow
  - Inefficient battery usage
  - Fragile „ad hoc“ construction



Receiver of the HHI-Channel-Sounder before Ko-FAS

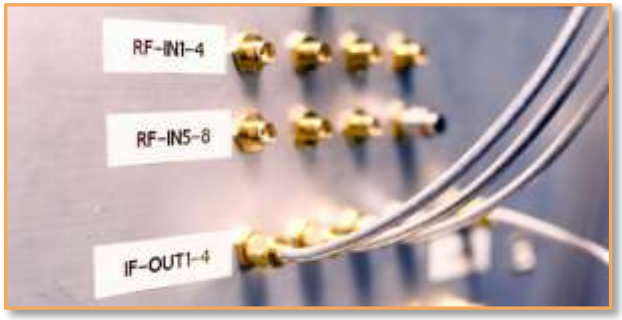
Transmitter of the HHI-Channel-Sounder before Ko-FAS

In Ko-FAS

- Completely new frontend design and modules
  - New modular frontent design
  - RF-Modules with increased performance and isolation
- Signal generation and acquisition
  - Specialized modules with very high performance
  - Practically unlimited data storage with HDD array, very low storing time
  - Efficient power usage (16x performance using only 50% more battery power)
- Robust casing and compact design
  - Measurements with conventional passenger vehicles
  - Optimized calibration procedures for efficient measurement flow

In Ko-FAS

- 2x4 true MIMO and 2x8 MIMO switched (TDM)
  - 2x4 parallel frontend chains for true MIMO
  - Separate gain control for each channel
  - High isolation switches for 2x8 MIMO (post-LNA switching)

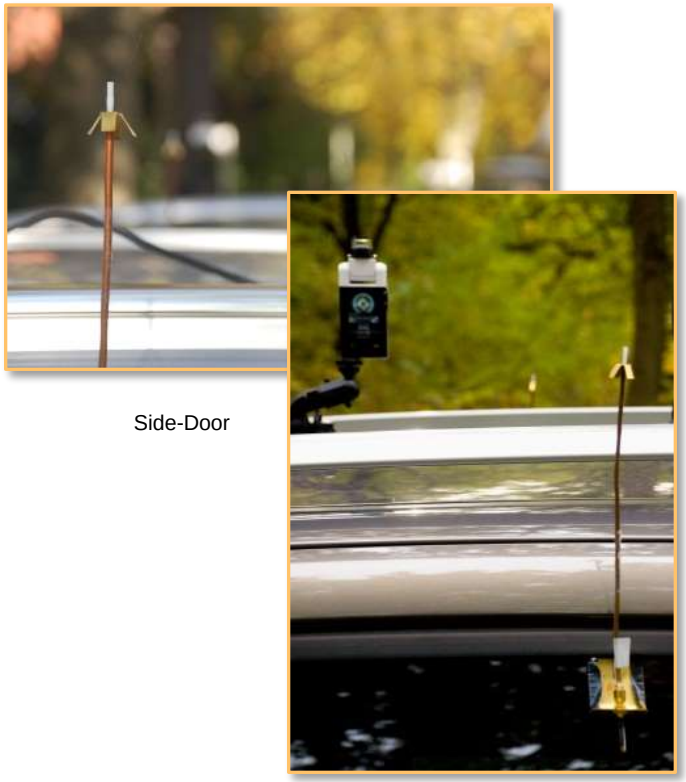


Enabling MIMO Measurements

- Antenna position (i.e. for space diversity techniques)
  - High channel isolation, (fading and shadowing in the vehicular environment can lead to more than 20 dB difference.
- Antenna array (directional measurements)
  - Calibration algorithm optimized for high bandwidth antenna array

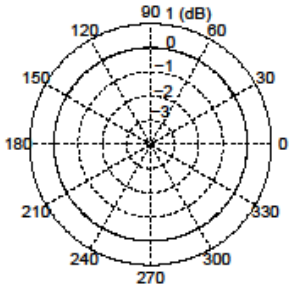
Antennas

Position of the antennas



Side-Door

In-cabin Mirror



Azimuth antenna diagramm

- The use of omnidirectional dipoles provides a neutral and flexible solution for most situations.

Documentation

Documentation of the surrounding conditions during the measurements is crucial.

Frontview-Video

ADMA In-Car Unit

GPS Antenna

GSM Antenna

360° Video

The ADMA Unit shown is a kind loan from Continental Safety and not a fix part of the HHI-Channel-Sounder

The HHI-Channel-Sounder

Within Ko-FAS, the HHI-Channel-Sounder has evolved from a high performance prototype to a robust and reliable high-end channel sounder.

In Action

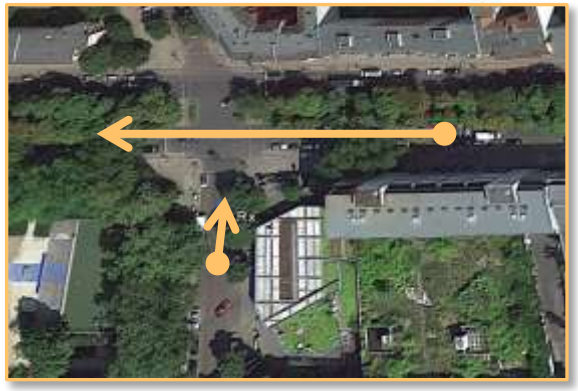
Car2X Channel Sounder

The HHI-Channel-Sounder was developed within the Ko-FAS projects Ko-KOMP and Ko-TAG.

Fraunhofer Heinrich Hertz Institute

Measurement of the channel

Measurement with the HHI-Channel-Sounder: Intersection



- The electromagnetic waves reflect on buildings and other objects, such as vehicles, road signs etc.
- Orientation, size and material of the reflecting surfaces are decisive.

Measurement of the channel

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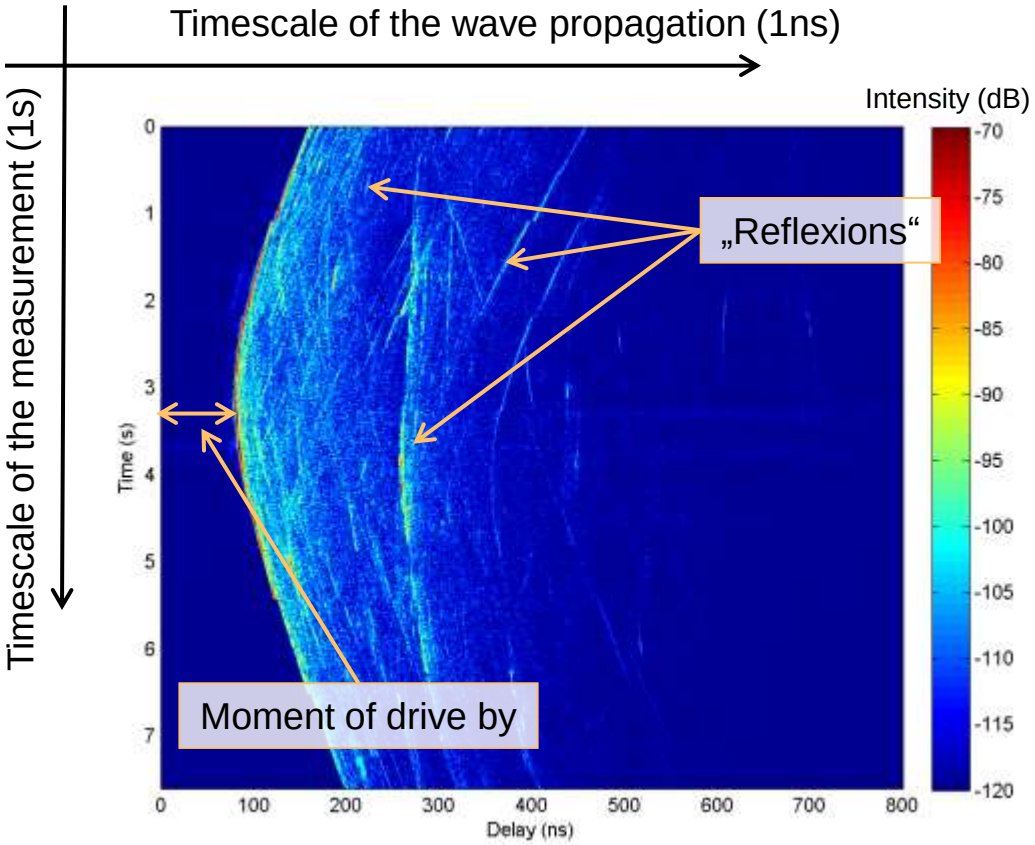

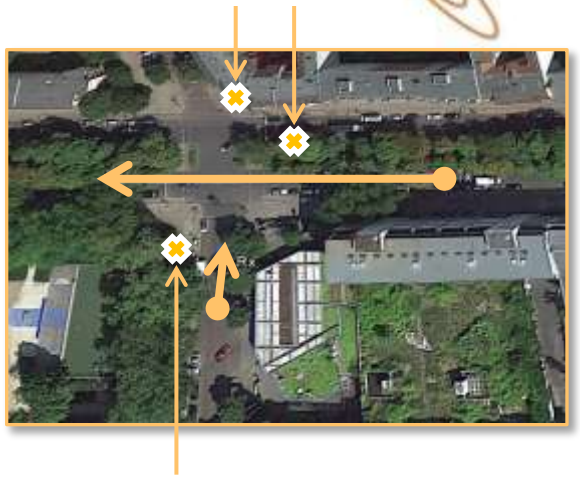

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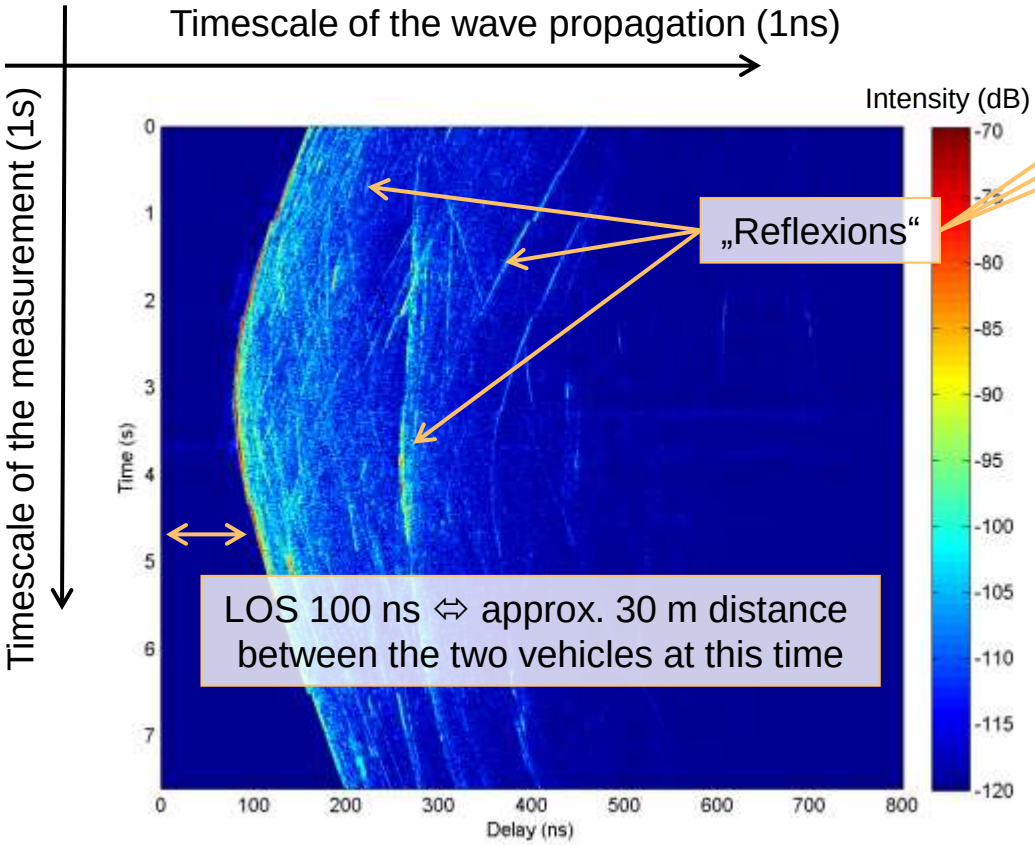
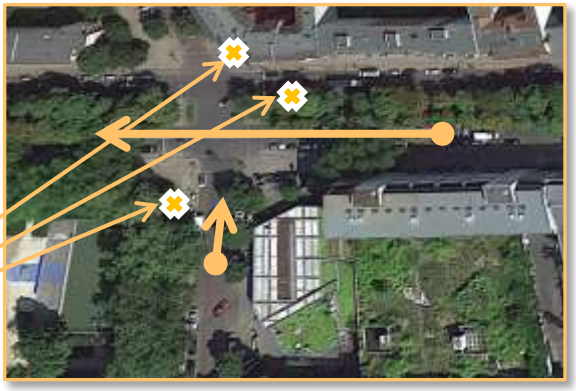
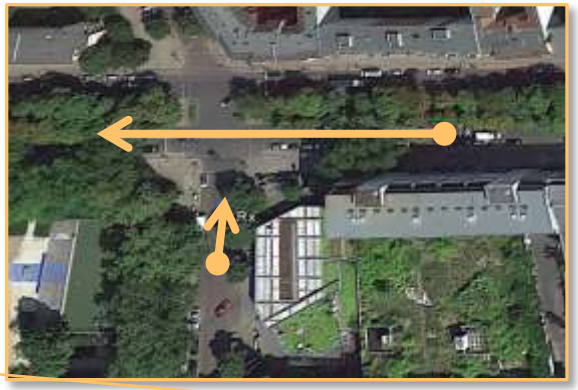


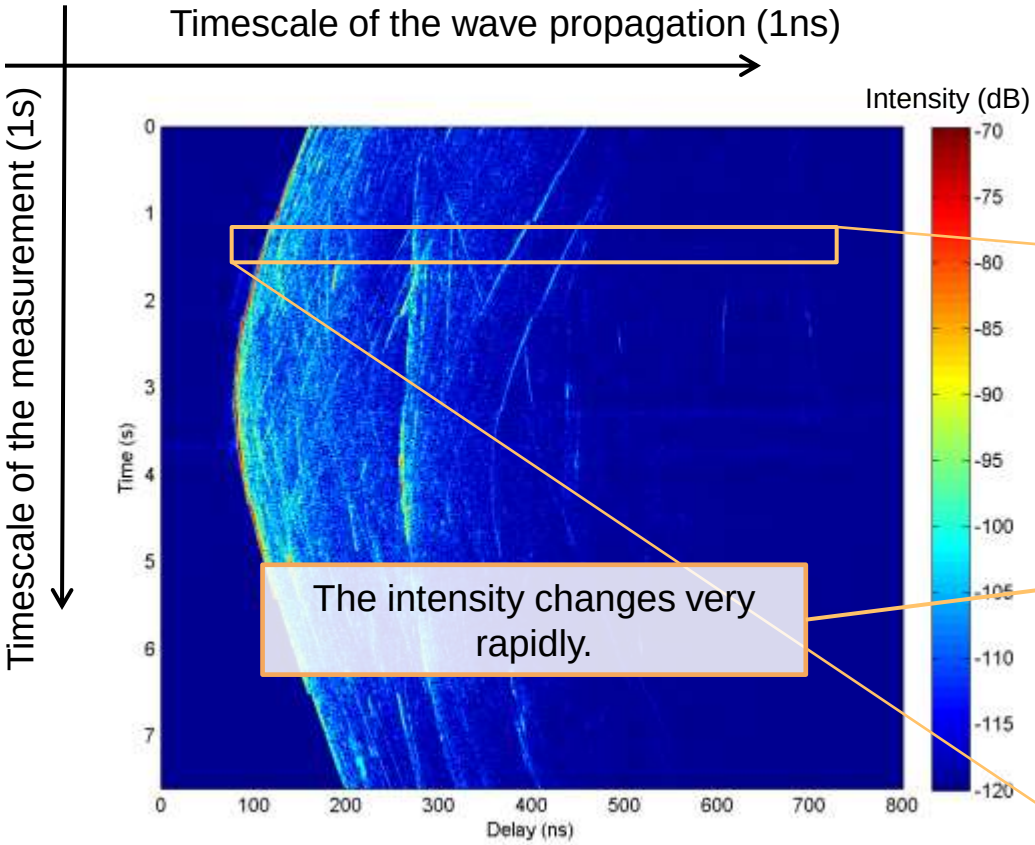


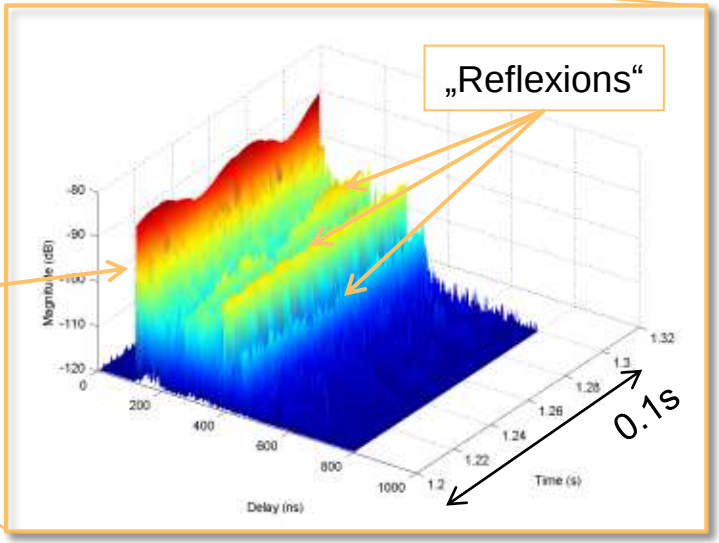
- Most significant objects can be identified if the documentation is systematic and solid.
- Accurate synchronization provides information about absolute distance.

Measurement of the channel

Measurement with the HHI-Channel-Sounder: Intersection

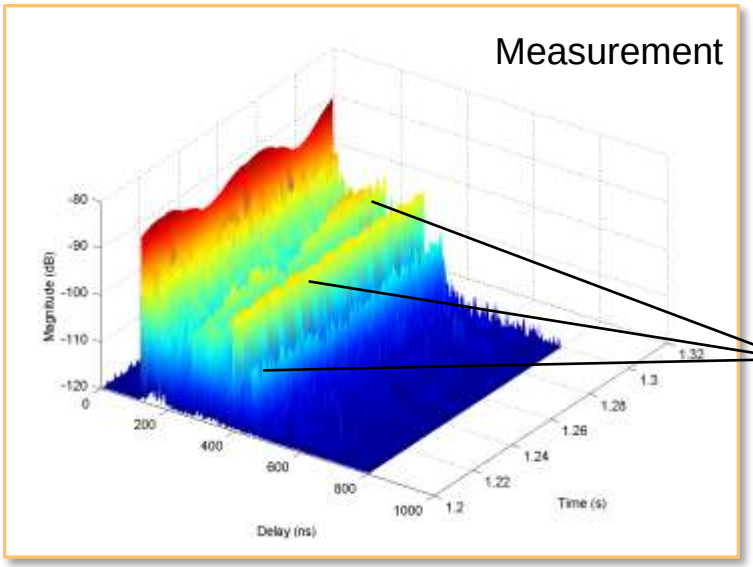


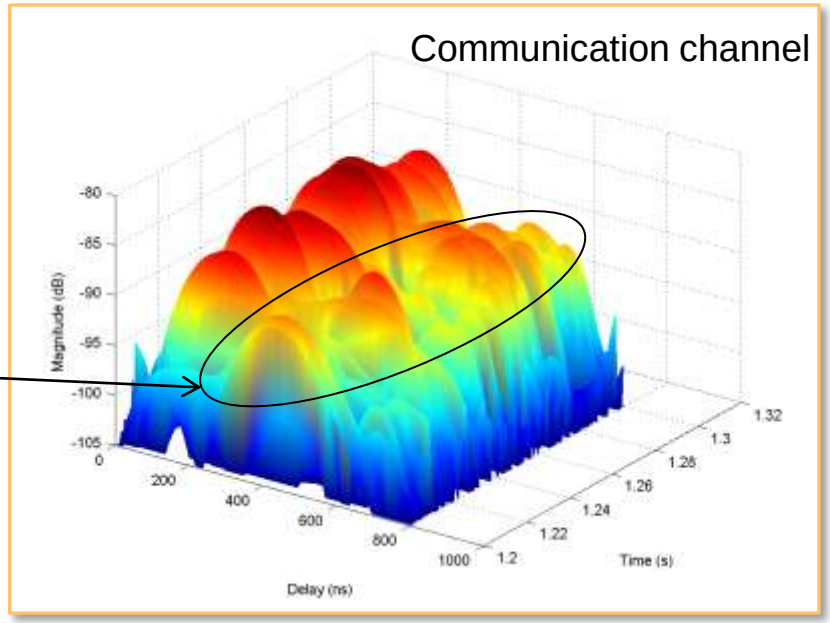




Measuring with high bandwidth

- Why did we use higher bandwidth than the communication system?





- High bandwidth provides high delay-time resolution.

✓ Most reflecting objects appear „resolved“ and can be identified via conversion of propagation time to distance and simple geometrical considerations.

- Using less bandwidth, less wave components can be resolved.

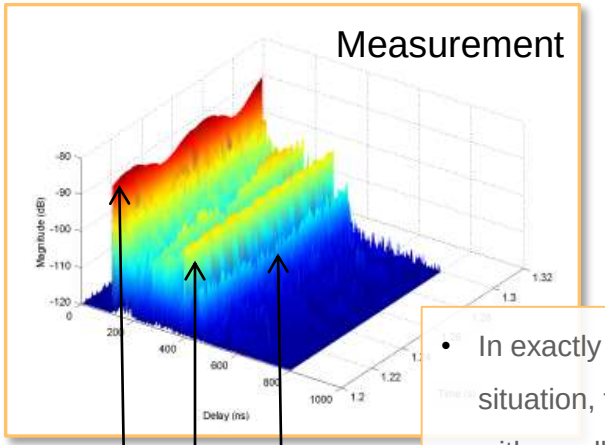
➢ The amplitude fades stronger and faster within shorter time intervals. It is more difficult to identify objects.

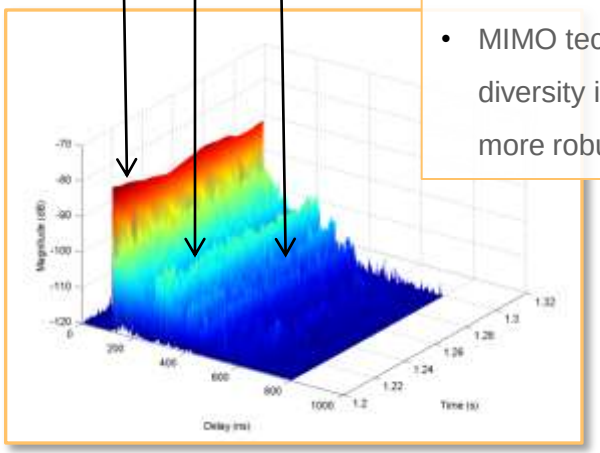
Focus on MIMO

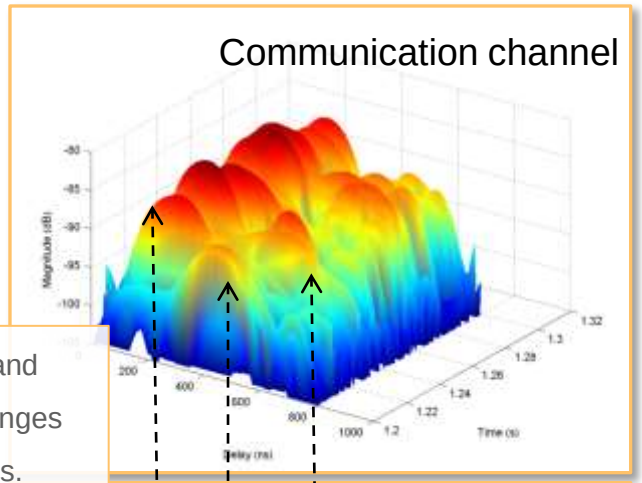
- Why measure different antenna positions and why investigate MIMO techniques?

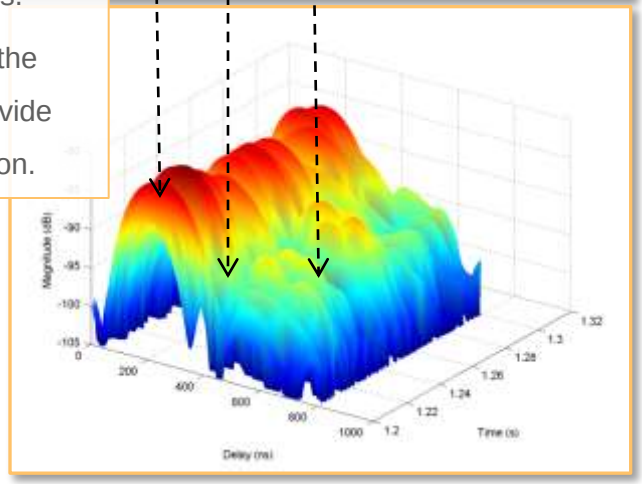
1. Antenna

2. Antenna









- In exactly the same time and situation, the channel changes with small space variations.
- MIMO techniques exploit the diversity in space and provide more robust communication.

Scenarios and categorization

Development of a categorization concept, for efficient measurement of the channel but also an exhausting „no-open questions“ investigation of the critical situations.

- Most important attributes are given by geometry and direction (fixed vehicle, antenna position)
  - Environment
    - Urban, Highway, Suburban etc…
    - Speed, traffic situation etc…
  - Vehicle constellation
    - Convoy, oncomming, crossing etc…
    - Typical road behaviour or route etc…
- Granularity for a scenario
  - Application
  - Important metrics (average throughput or garanteed performance)

Conclusions

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The vehicular channel is very challenging.

- The HHI-Channel-Sounder was developed to a **reliable high-end MIMO channel sounder** able to provide enlighting answers for vehicular applications.
  The focus was set on **versatility in investigating MIMO** aspects, since diversity concepts (space) can provide a decisive boost on connectivity and system reliability.

- Measuring the vehicular channel needs explicit attention on the **scenario selection and categorization**.
  Measurements based exclusively on applications or on traditional categorization are bound to be either inefficient or incomplete.

Thank you for your attention!

Fraunhofer
Heinrich Hertz Institute

Ko-KOMP – „Untersuchung und Simulation der Fahrzeug-zu-Fahrzeug Kommunikation für kooperative Sicherheitssysteme“

Ko-TAG – „Funkkanaluntersuchungen und Signalverarbeitung für kooperative Sensortechnologien“

Panagiotis Paschalidis, Kim Mahler, Mike Wisotzki, Andreas Kortke