TECHNISCHE UNIVERSITÄT DRESDEN

IARIA iTVS DRESDEN concept

Prof. Dr.-Ing. Oliver Michler

Chair of Transport Systems Information Technology, Director Institute of Traffic Telematics
Faculty of Transportation and Traffic Sciences “Friedrich List” , Technical University of Dresden

Potentials of directional antennas for (Indoor Positioning) Systems in dense multipath environments

The Fifteenth International Conference on Advances in Satellite and Space Communications (SPACOMM) 2023
April 24-28, 2023 – Venice, Italy

Agenda

1) **CV, Chair and Topics of University Research**
2) Introduction - ICT-based Goal Formulation
3) Historical fundamental access - Antenna as a central element
4) Potentials of directional antennas – General remarks
5) Reseach Examples – Challenges in dense multipath environments
6) Conclusion and future outlook

1 CV Oliver Michler, University Full Professor

Scientific and Professional Positions (since 1993)

1993 - 1997	Scientific Staff and PhD-Research of TU Dresden, Faculty of Electrical and Computer Engineering
1997 – 2000	Scientific Project manager at Video-Audio-Design GmbH as a Telkom-Partner
2000 – 2005	Scientific Staff at Fraunhofer Institute for Transportation and Infrastructure Systems Dresden (FhG-IVI)
2005 – 2008	Professor at University of Applied Sciences Dresden in Signal Processing and Electronic Measurement Techniques
2010 – 2017	Head of department of TUD-Researchgroup at FhG-IVI
2008 –	Full Professor at TU Dresden in Systems Information Technology, Faculty of Transportation and Traffic Sciences
2019 -	Director of TU Dresden of Institute of Traffic Telematics
2017 -	Scientific advisory board member of MRK AG, Metirionic and ISCons GmbH as a knowledge transfer research

Research topics

data-driven and model-based approaches, wireless mobility systems over all traffic carriers and services, autonomous driving, intelligent vehicle, next generation technologies based of communication/localization/sensing, software defined radio

1 TU Dresden (TUD) ⇒ Campus Overview

- The Technische Universität Dresden dates back to the Technische Bildungsanstalt Dresden, founded in 1828 and, thus, ranks among the oldest technical-academic educational establishments in Germany.
- The TU Dresden has about 35.000 students and almost 5.000 permanent employees (excepting the Faculty of Medicine), about 400 professors among them, and, thus, is the largest university in Saxony, today.
- TU Dresden now is a multi-discipline university, also offering humanities and social sciences as well as medicine. There are only few universities in Germany which are able to match this broad scientific spectrum.

- Germany
- Saxony
- Dresden / Capital of Saxony: Dresden

1 University of Technology in Dresden (TUD)
The “Friedrich List” Faculty of Transport and Traffic Sciences

A unique, interdisciplinary competence center for transportation sciences

- Dresden Institute of Automobile Engineering
- Institute of Railway Vehicles and Railway Technology
- Institute of Railway Systems and Public Transport

- Institute of Logistics and Aviation
- Institute of Transport Planning and Road Traffic
- Institute of Traffic Telematics
- Institute of Transport and Economics

ITVS Informationstechnik für Verkehrssysteme

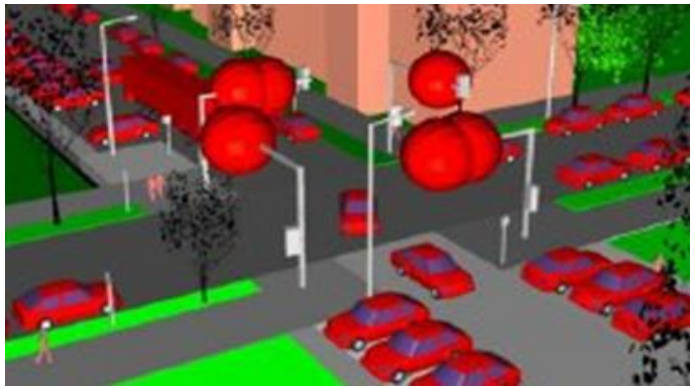
Technological and Market Progress in Transportation & Mobility

Changed Education in Transportation Economy and Transportation Engineering

1 Faculty of Transportation and Traffic Sciences „Friedrich List“
⇒ Selected laboratories at the faculty

- **Laboratories Traffic Control, Process Automation and ITS**

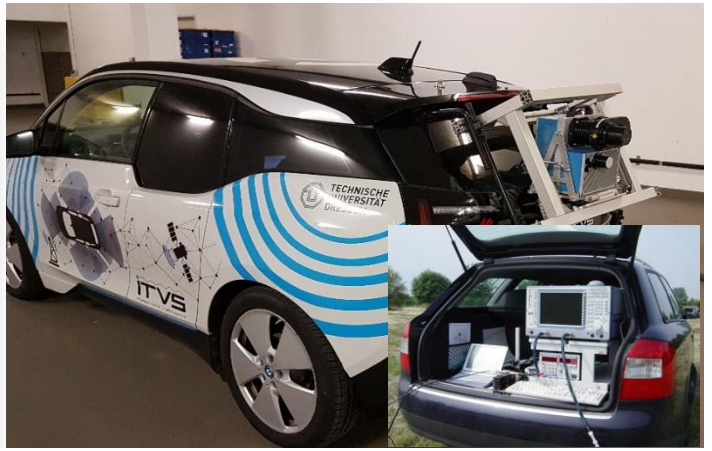
Traffic Control Center



Car2X-Wireless Simulation

Automatic Train Driving

Driving Simulation (Tram)

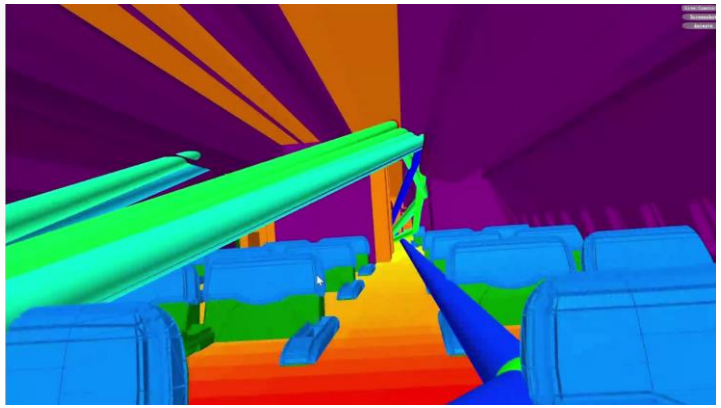


Test Cars

Automatic Car Driving

1 Faculty of Transportation and Traffic Sciences „Friedrich List“
⇒ Selected laboratories at the faculty

- **Aviation lab / Airbus 320 Simulator**



Application / operation purpose

- Research fields: Trajectory Management and Safety Assessment
- Integration in teaching fields Cockpit Technologies and Navigation
- Training and performance / Aircraft wireless ICT Cabin

1 Traffic ICT and Research fields of Chair competence

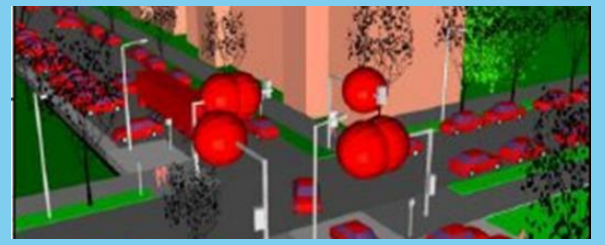
- **Overview:**

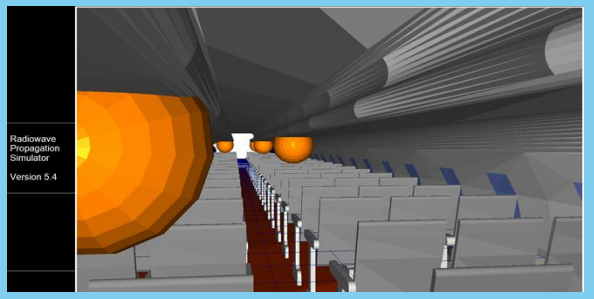
Simulation
Emulation
Radio planning

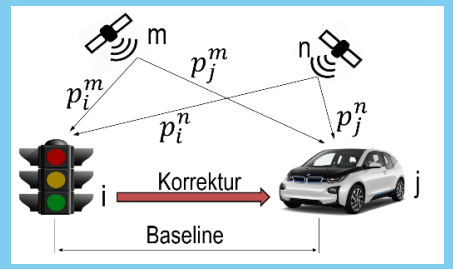
Networking
Localisation
Sensing

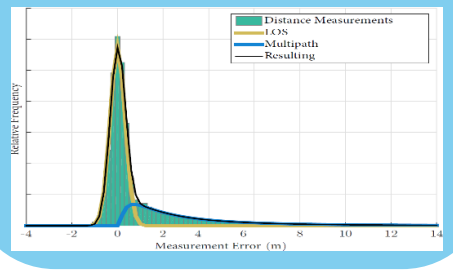
Lab Environment
Experimental -
Vehicles
Test fields

Big data
Statistics
Methodology
Procedures







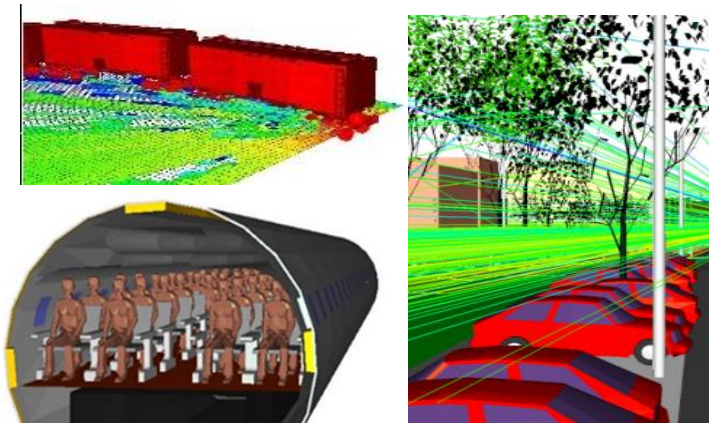


1 Research focus: Traffic carrier cross-modal vehicle environment signals

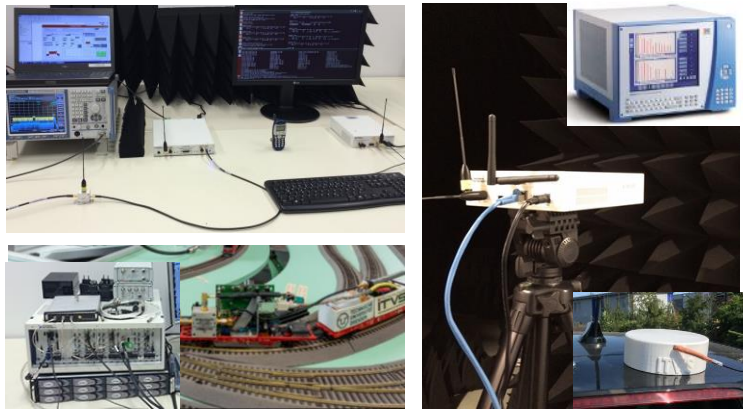
Telematics and IT - Platforms (RF, LF, Software, Protocols, Interfaces, HMI)

Modelling, Parametrisation | **Error analysis, Integrity**

Radio channel simulation (PC environment)



Signal environment generation (Lab environment)



Record/Playback Field measurements (Field-, long term tests)

Automotive ⇨ **Rail transport** ⇨ **Aviation / Aircraft cabin** ⇨ **Water transport**

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2 Introduction - ICT-based Goal Formulation

Everything moves and all is connected

2 Important Mobility Trends for the Next Decade


[1]

Use of personal data

Digitization

Real-time mobility marketplace

Decarbonization


[3]

E-Mobility

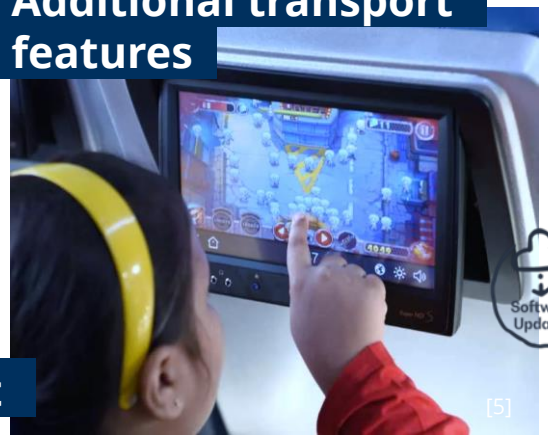
Integrated mobility concepts

[2]


[4]

Integrated and new forms of goods transport

Additional transport features


[5]

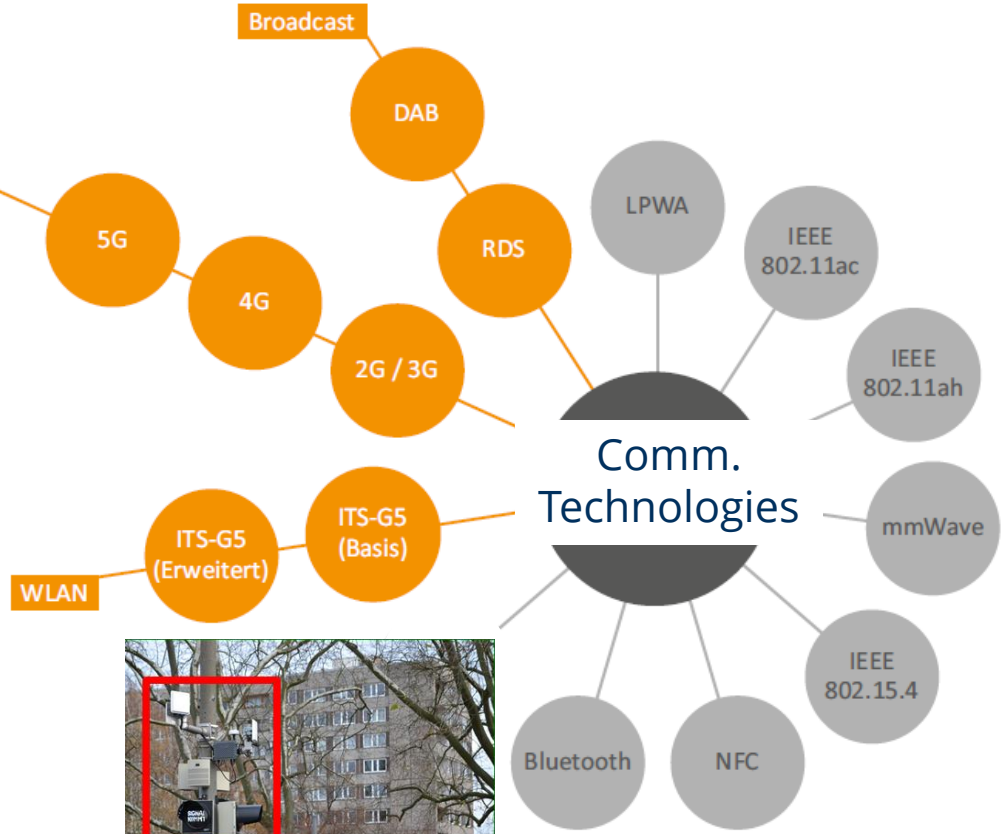
[6]

Addressing customer needs


[7]

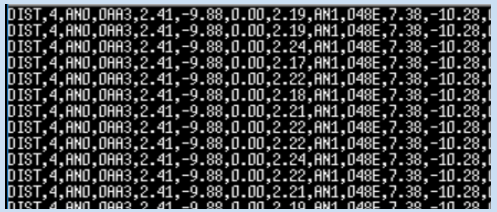
Autonomous driving

2 Variety of technologies and services

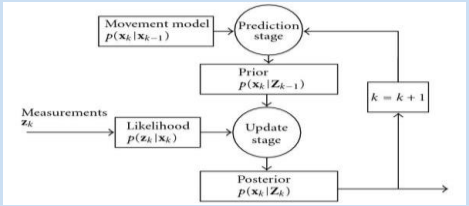


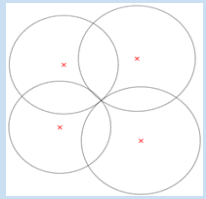
2 Information technology aspects and raw data (TUD-ITVS Framework)

Data input

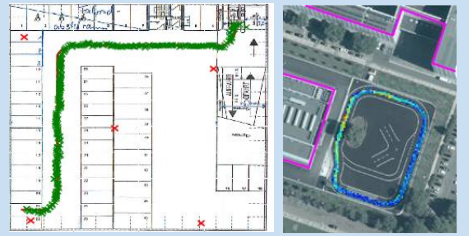


Communication / Positioning / Tracking / Sensing





Visualization

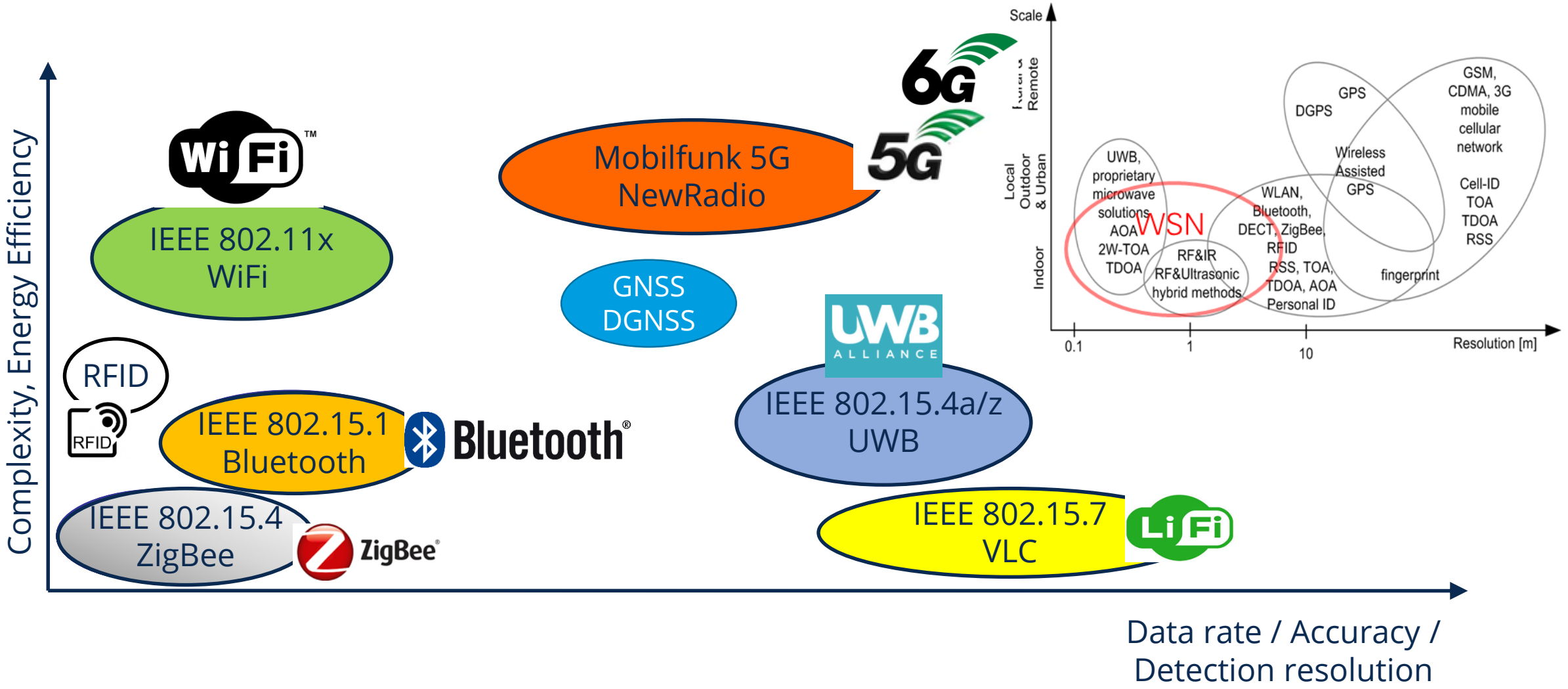


Client/Server -> Database Software

Technology Candidates:

IEEE 802.15.x (BLE, UWB, ZigBee, ...), IEEE 802.11.x (WiFi 2,4/5GHz); MobilComm (5G, 6G), IEEE 802.15.7 (LiFi)

2 IoT–Communication, Localization / Tracking and Sensing Cross Technolgies



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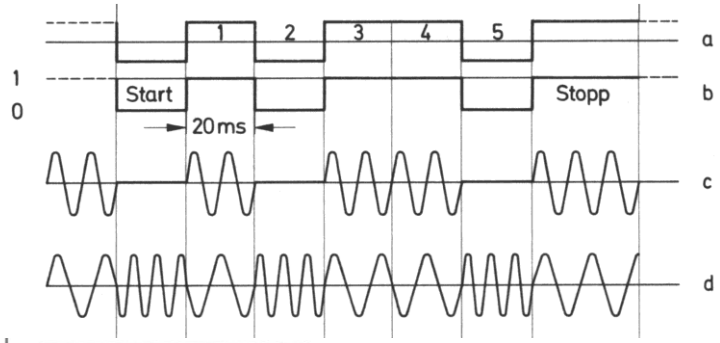
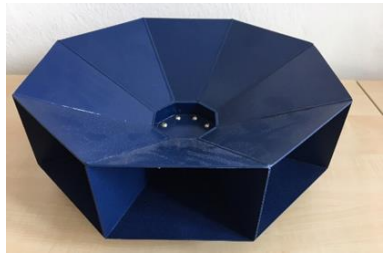
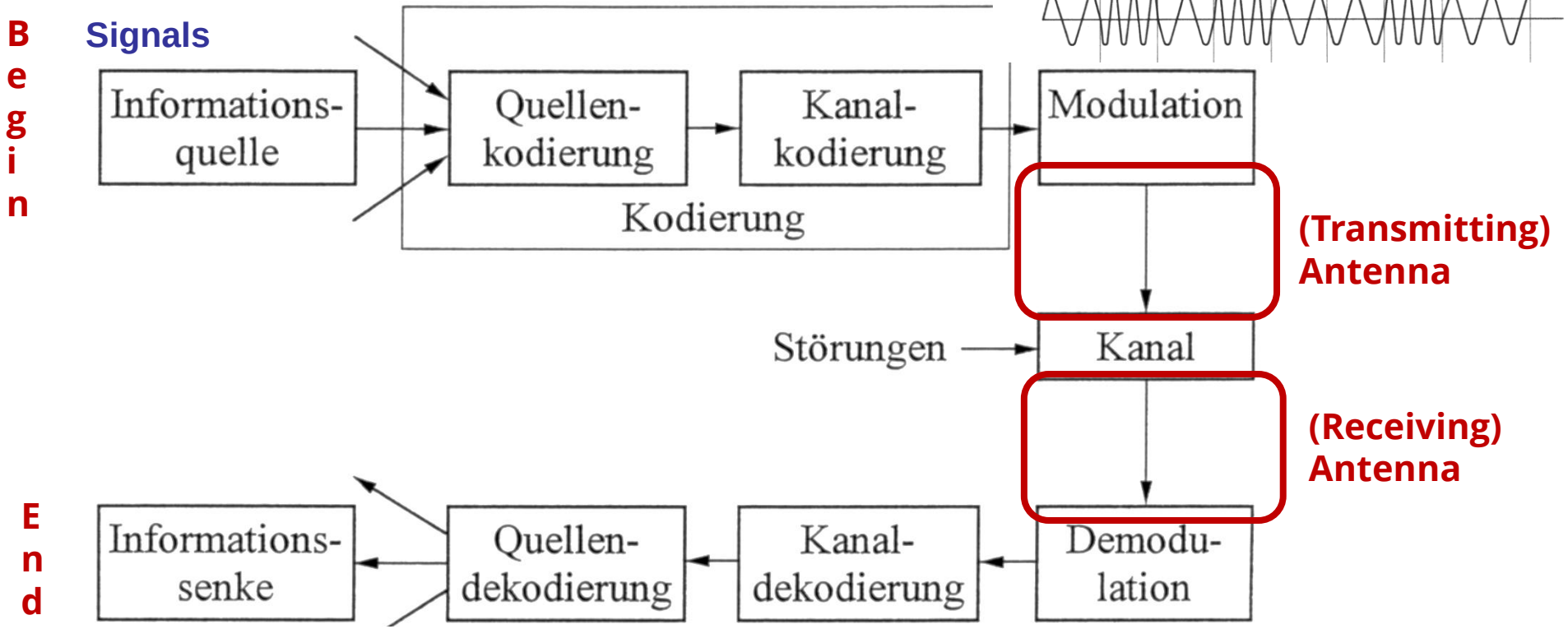
3 Historical fundamental access - Antenna as a central element



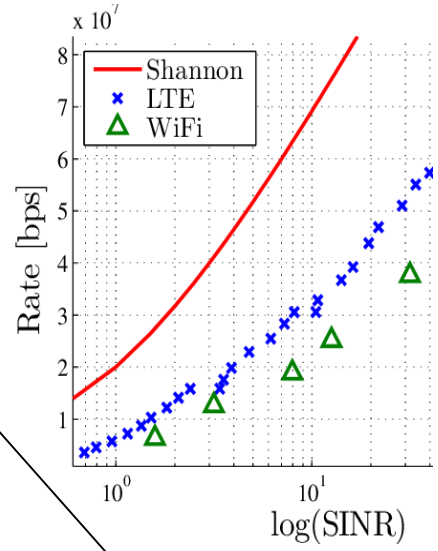




3 Timeless decision bases for communication and localization technologies

Shannon Channel Capacity Theorem

$$C \approx \frac{B}{3} \cdot \underbrace{SNR_{dB}}_{10 \cdot \lg\left(\frac{P_S}{P_N}\right)}$$

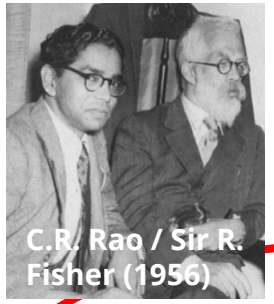


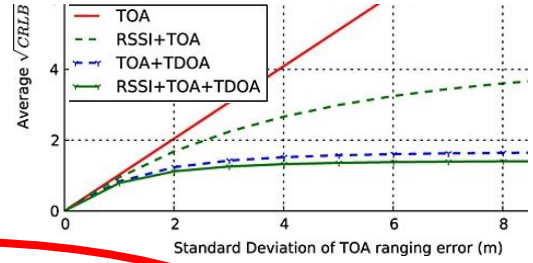
Channel capacity C max. Data rate [Mbit/s]

Bandwidth B / [MHz]

Signal-to-Noise Ratio SNR /[dB]

Cramer Rao Lower (Fisher) Bond





$$\sqrt{Var(d)} \geq \frac{c}{2\sqrt{2\pi}\sqrt{SNR\ B}}$$

Signal-to-Noise Ratio SNR

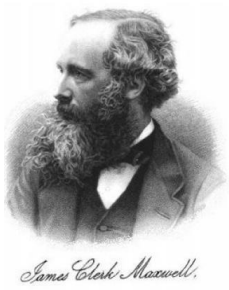
Bandwidth B

3 Antenna Basics - Description

- History

Faraday / Henry (1831) – first Experiments
Maxwell (1864) – Theory
Hertz (1886) – Experimental Proof
Marconi (1901) – Technical Proof

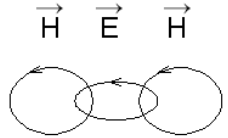
Source: https://de.wikipedia.org


James Clerk Maxwell

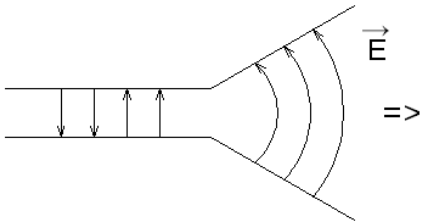

Heinrich Hertz


Guglielmo Marconi

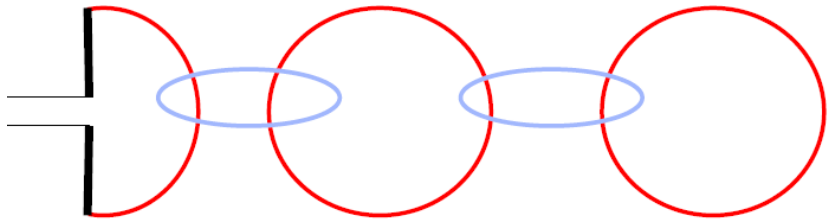
- Phenomenological description



Double swirl coupling



=> Shift current charge carrier
⇒ Electromagnetic wave

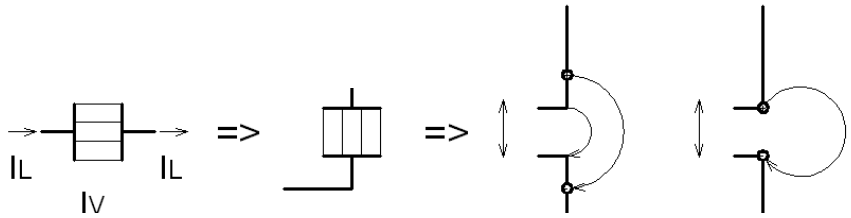


Magnetical field Magnetical field
Electrical field Electrical field Electrical field

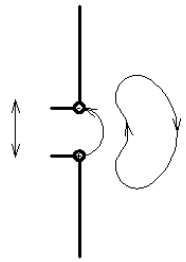
Leitungs-Welle

Wellentyp-wandler

Antenna

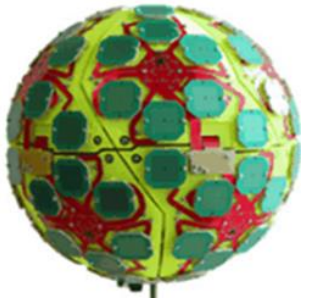


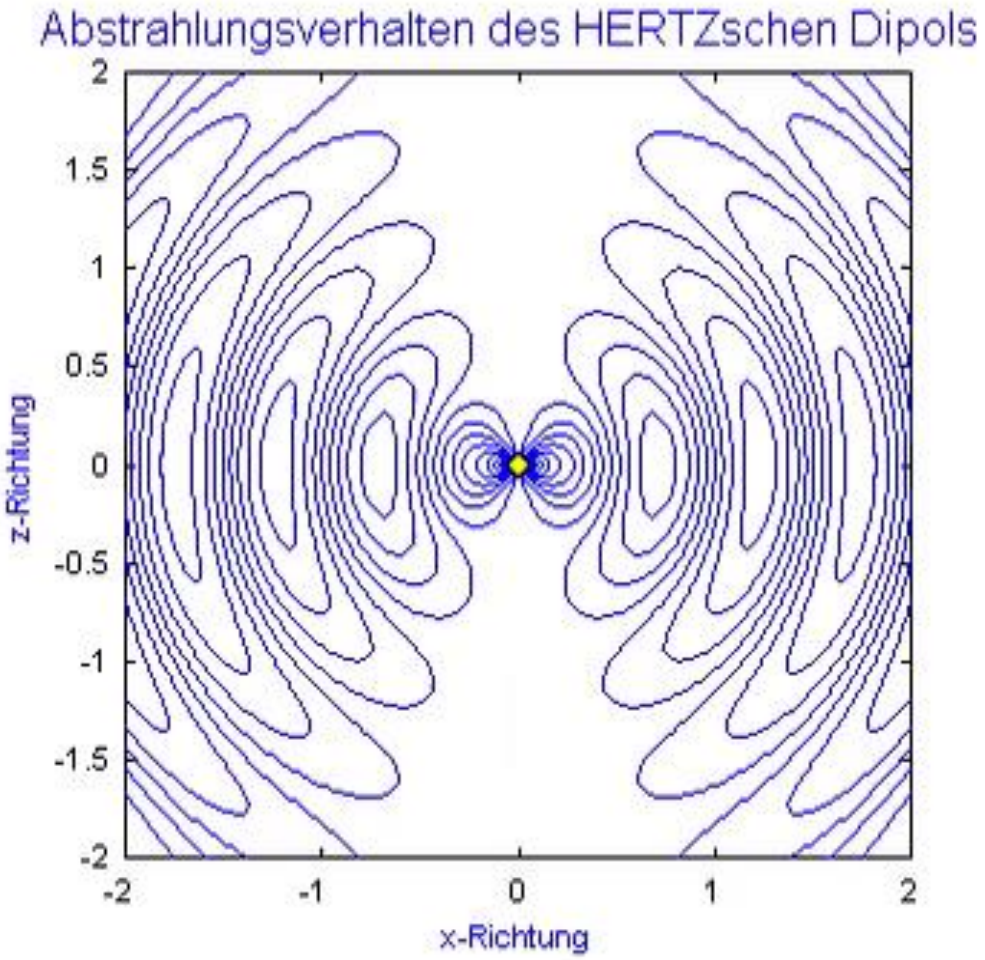
Capacitor (Shift current charge carrier)

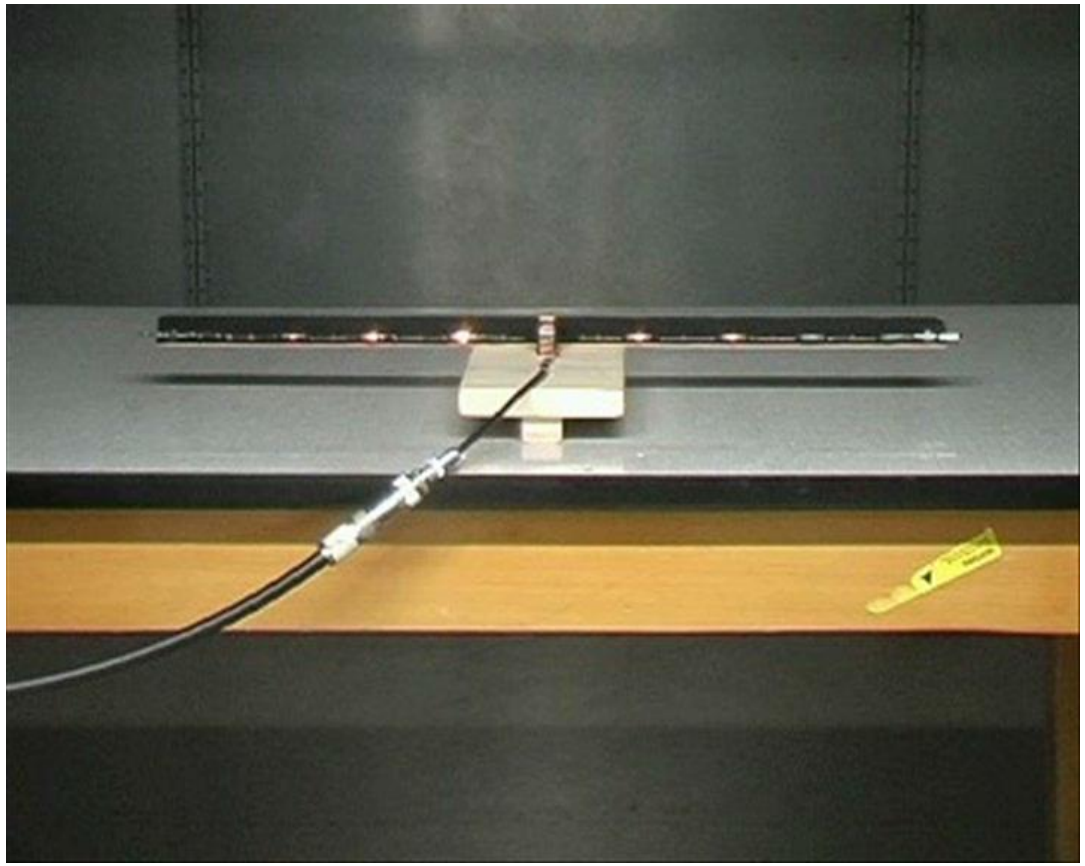


Hertzian dipole(1)

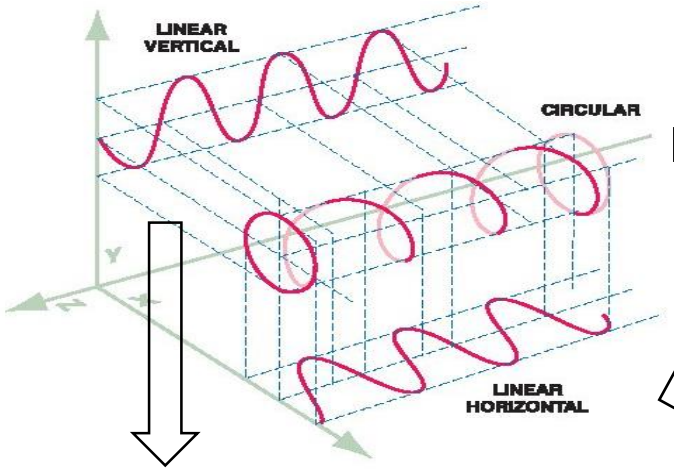
Hertzian dipole(2)




Abstrahlungsverhalten des HERTZschen Dipols
z-Richtung
x-Richtung
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1
0
1
2



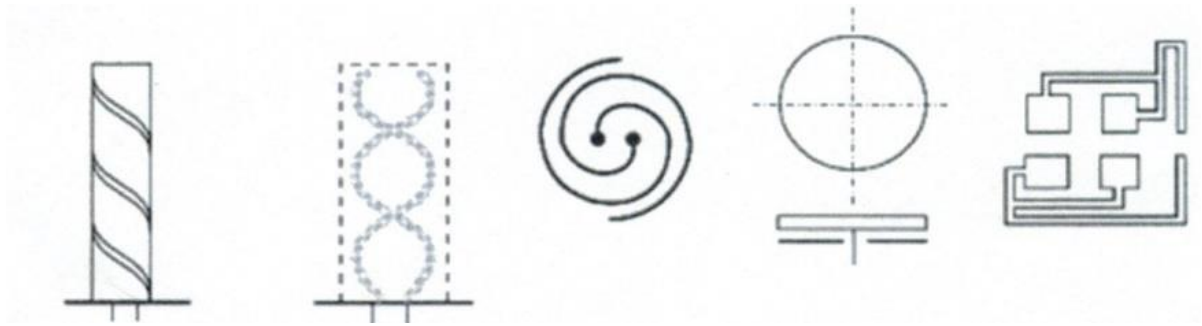
3 Antenna Basics - Polarisation



Vertical polarisation

Circular polarisation left- / right - rotation

Horizontal polarisation



Polarisation: patial orientation of the electric field strength vector

⇒ Decoupling possibilities

	Vertical ↑	Horizontal →	Circular Right ↷	Circular Left ↶
Vertical ↑	0 dB	∞	3 dB	3 dB
Horizontal →	∞	0 dB	3 dB	3 dB
Circular Right ↷	3 dB	3 dB	0 dB	∞
Circular left ↶	3 dB	3 dB	∞	0 dB

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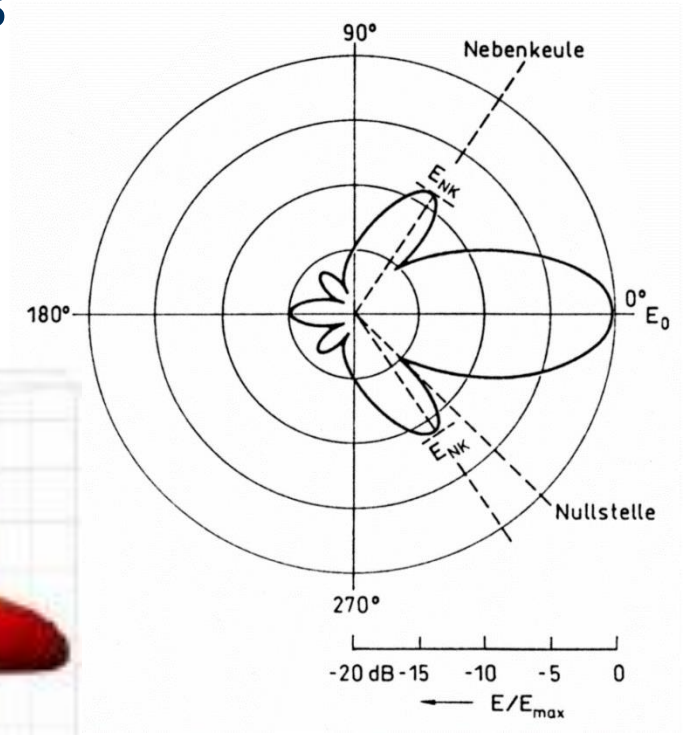
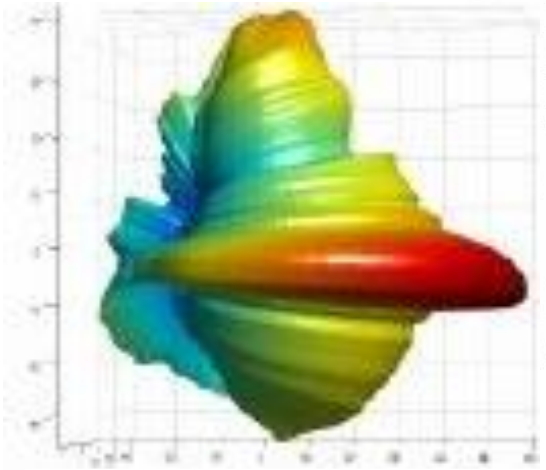
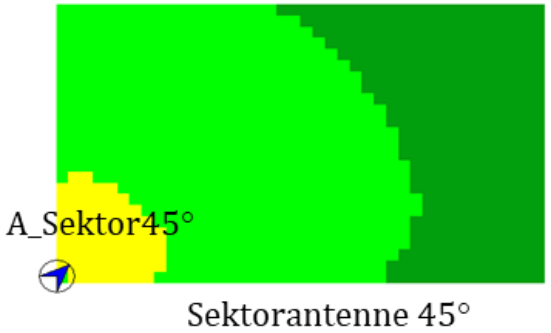
4 Potentials of directional antennas – General remarks

- Antenna characteristics (general)

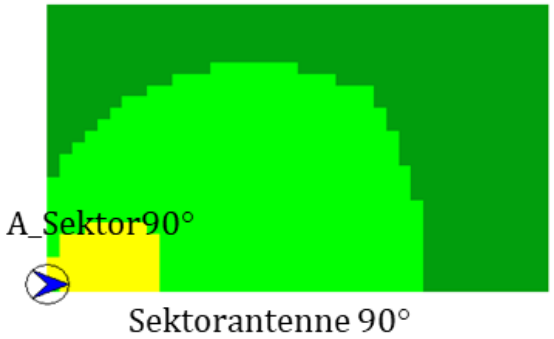
- Reciprocity: Identity of the characteristic in the transmit/receive casel
- Radiation characteristic: 3D field strength characteristiaraktistik
- Directional diagram: Cross-section through radiation pattern
- Gain: measure for directivity
- Half width: 3dB opening angle
- Forward/Backward ratio
- Side lobe damping





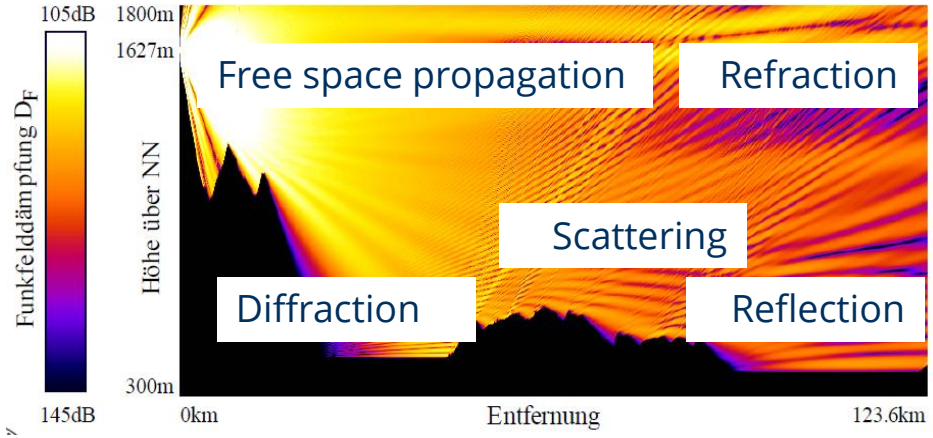


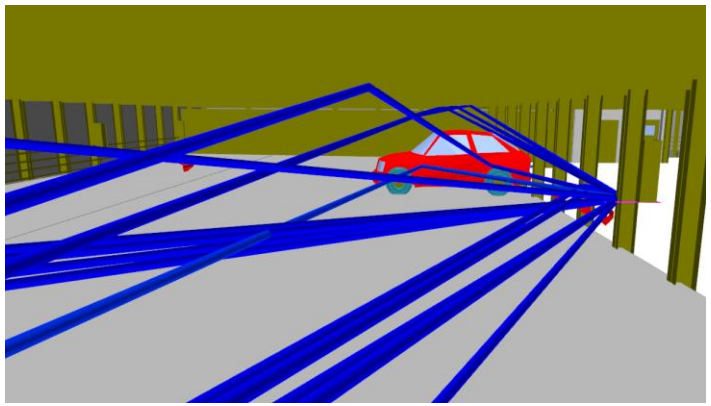
Sektorantenne 45°

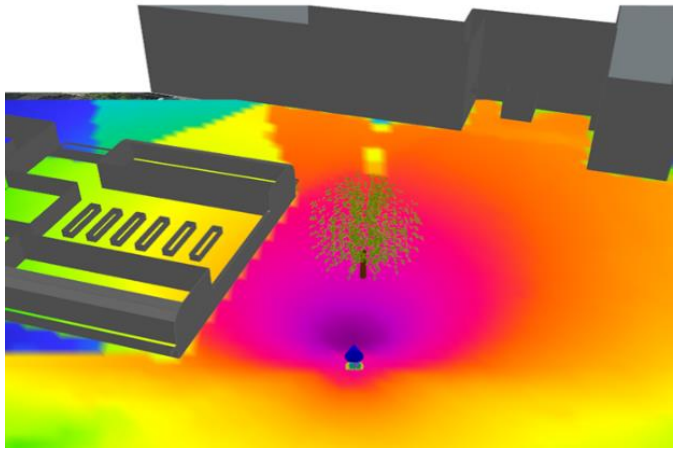


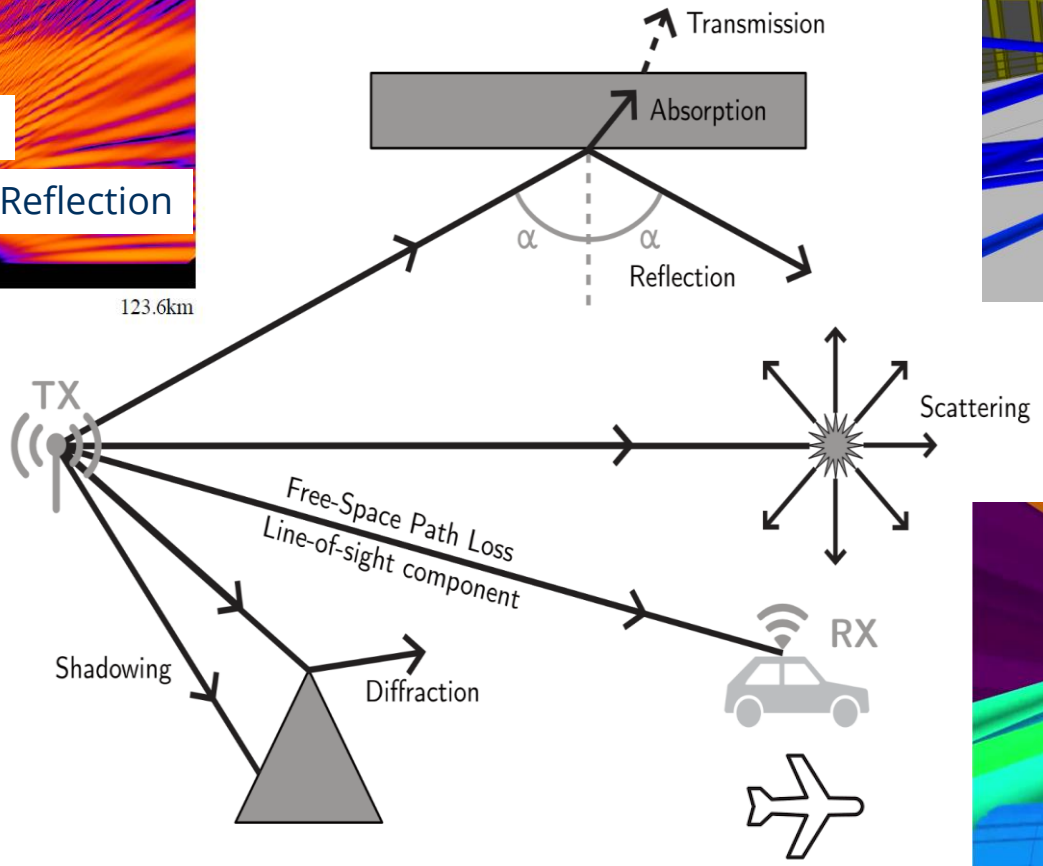
Sektorantenne 90°

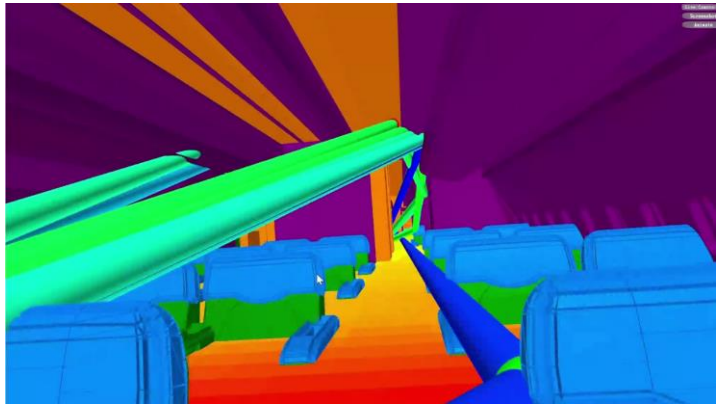
4 Potentials of directional antennas – Multipath aspects



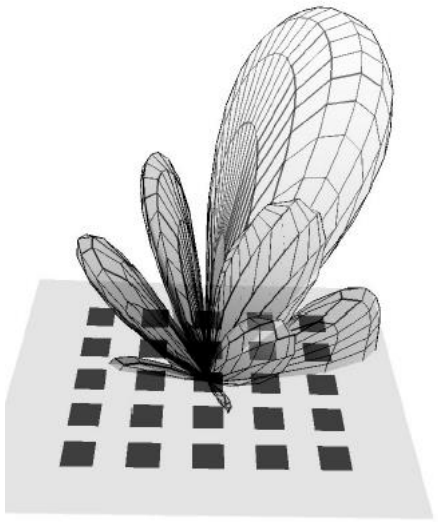








4 Potentials of directional antennas – Beamforming antennas

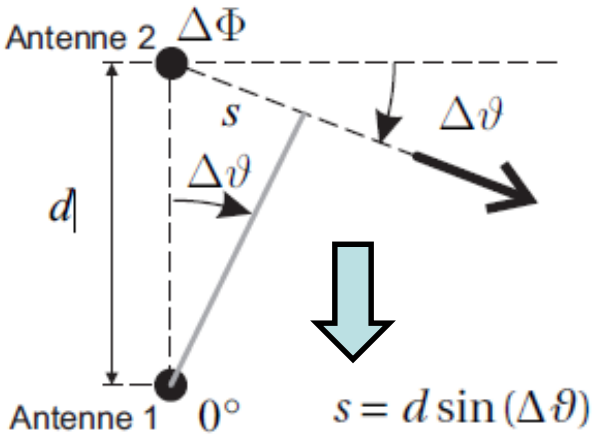


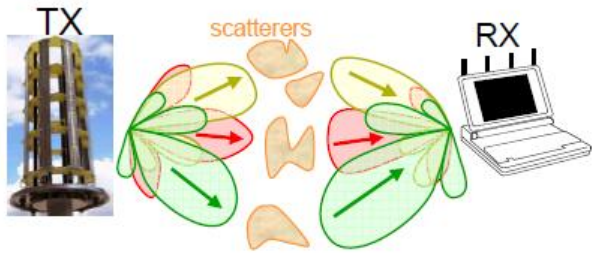
Beispiel einer Phasenbelegung der Elemente einer (5x5)-Patch-Antenne

	$m=0$	$m=1$	$m=2$	$m=3$	$m=4$
$n=4$	275,8°	333,5°	391,5°	449,3°	507,2°
$n=3$	206,8°	264,6°	322,6°	380,3°	438,3°
$n=2$	137,9°	195,7°	253,6°	311,4°	369,4°
$n=1$	68,9°	126,7°	191,2°	242,5°	300,4°
$n=0$	0,0°	57,9°	115,7°	173,6°	231,5°

Source: www.authorstream.com

⇒ Einsatz in Intelligenten Antennensystemen

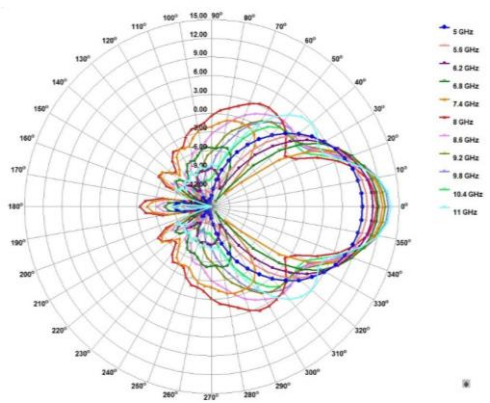


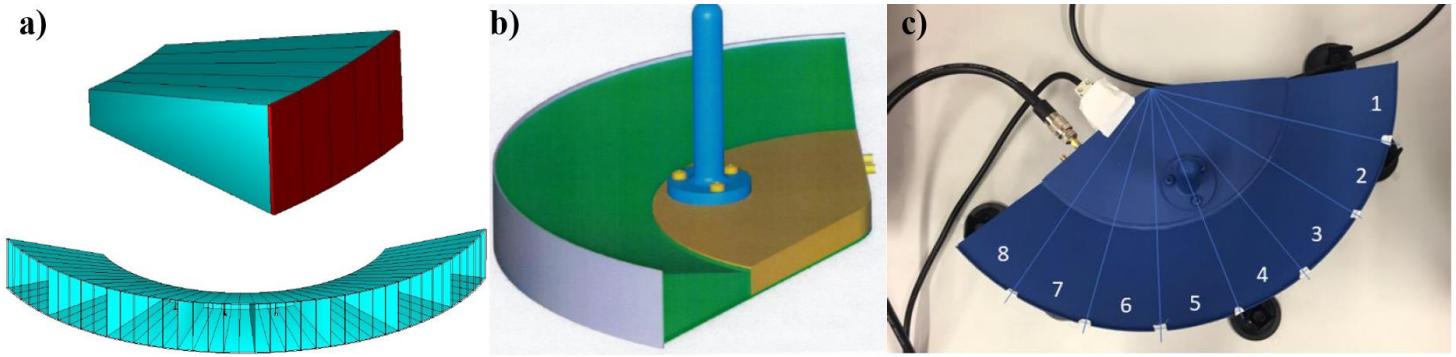


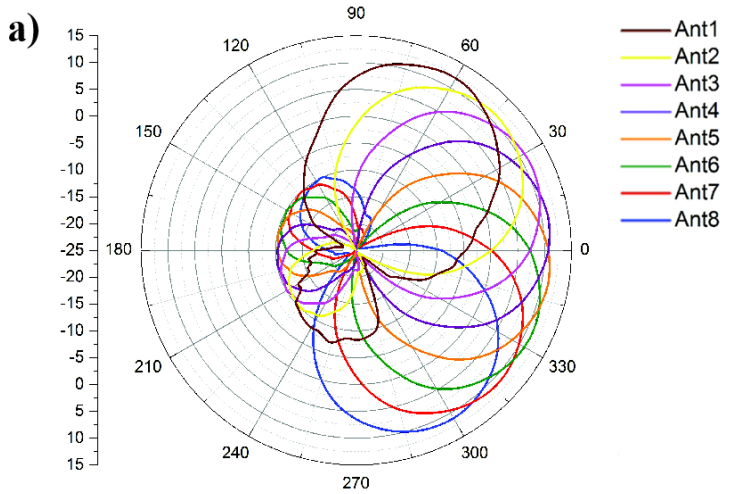
MIMO: Multiple Input Multiple Output

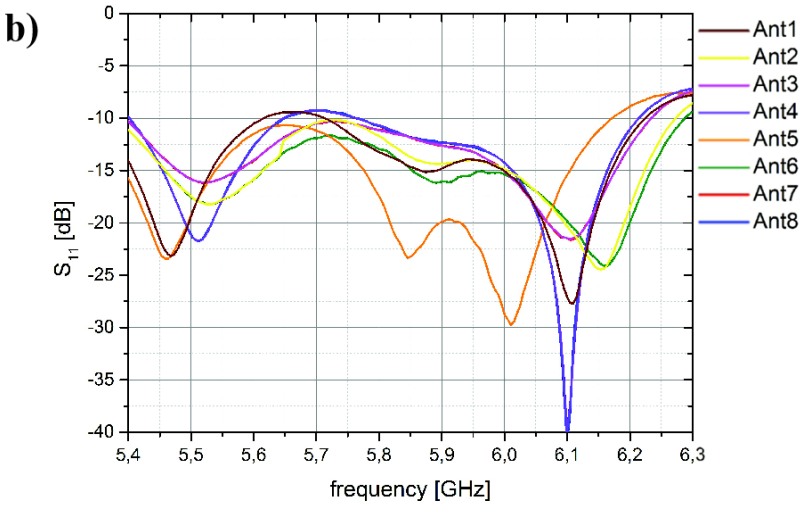
Quellen:
www.harticle.sapub.org

4 Potentials of directional antennas – Beamswitching antennas









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1) CV, Chair and Topics of University Research
2) Introduction - ICT-based Goal Formulation
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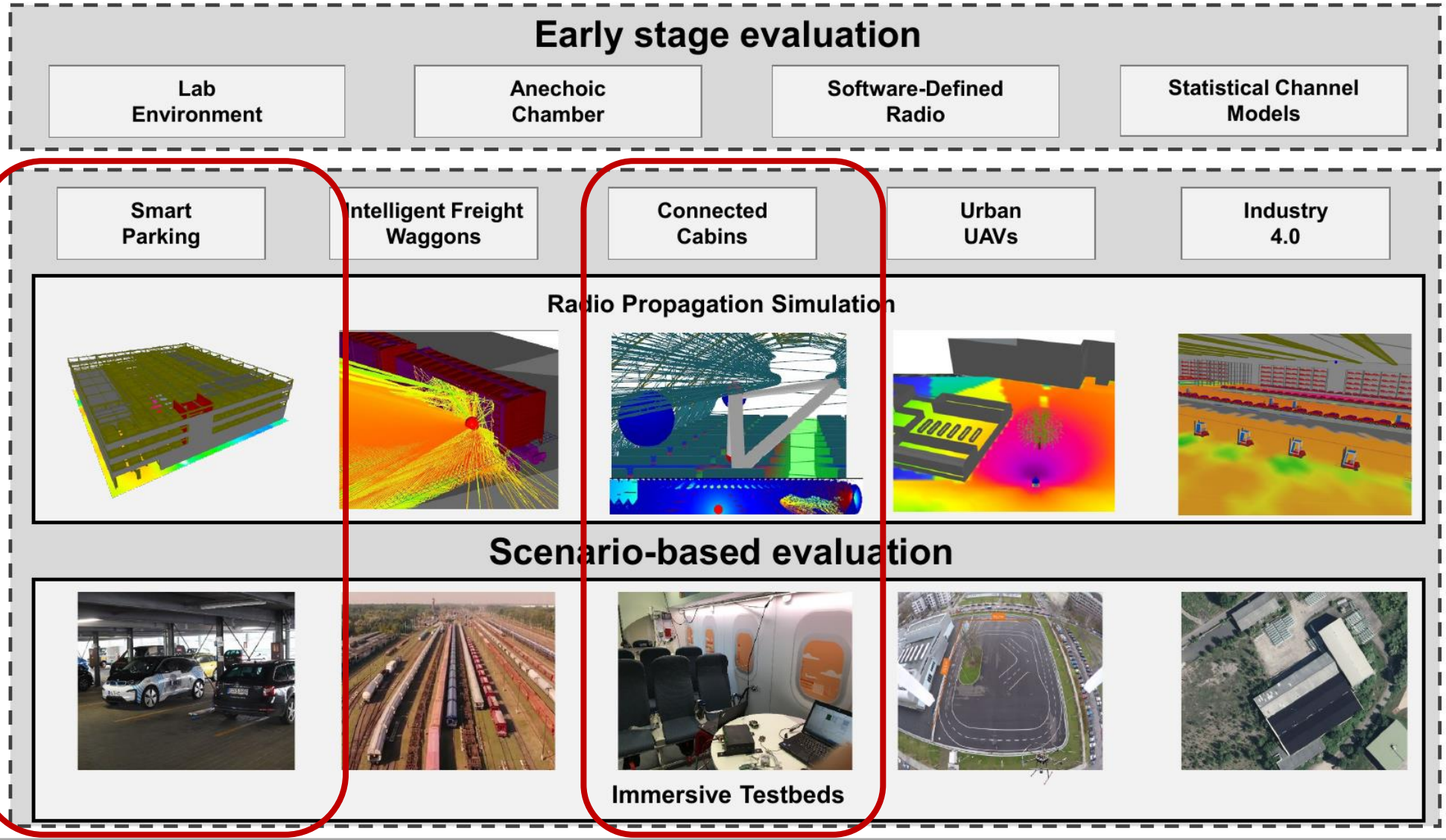
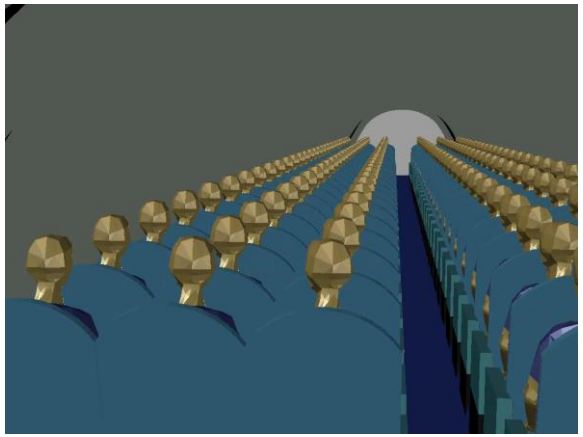
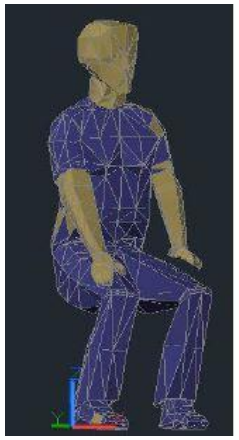
5) **Reseach Examples – Challenges in dense multipath environments**
6) Conclusion and future outlook

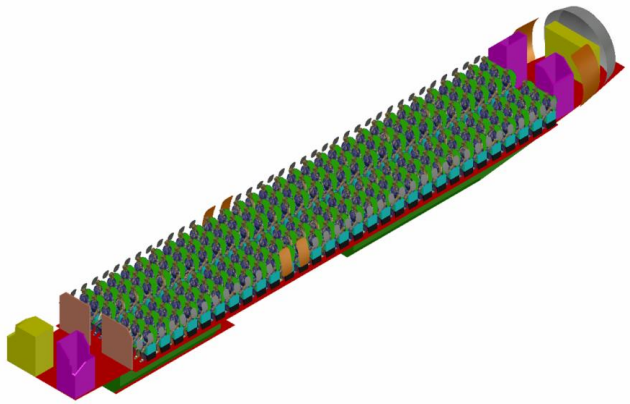
5 Reseach Examples – Challenges in dense multipath environments

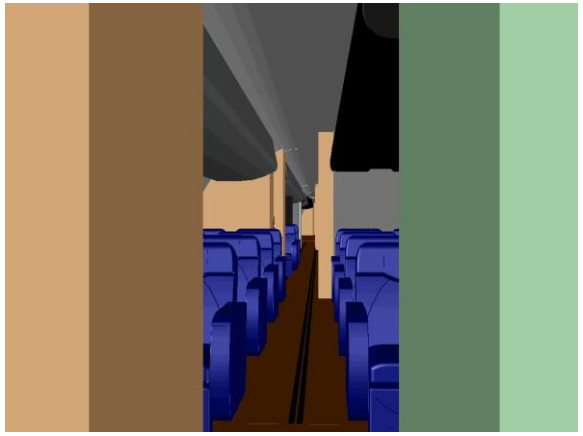


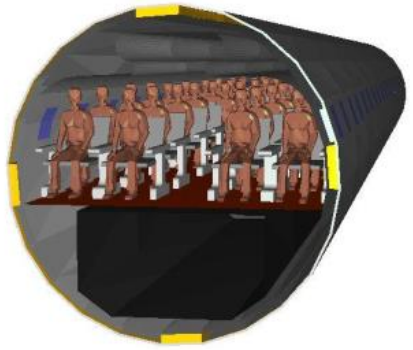
5 Current project activities (aviation and automotive)

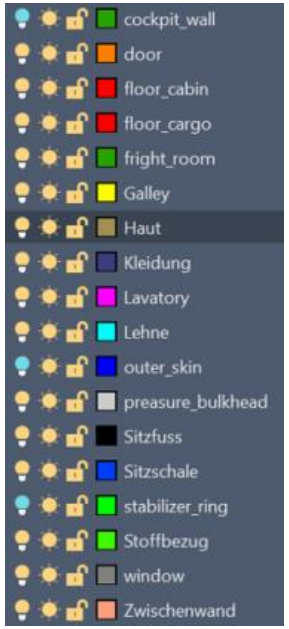


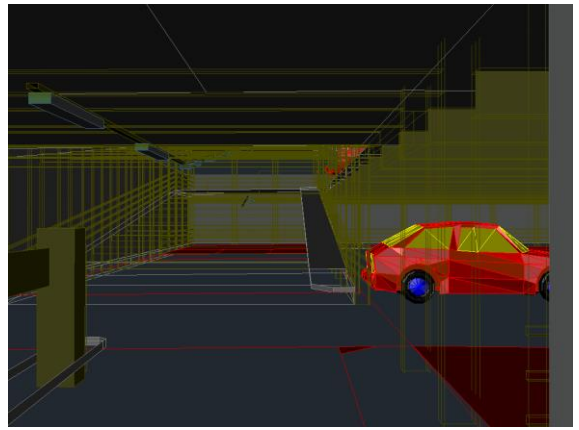




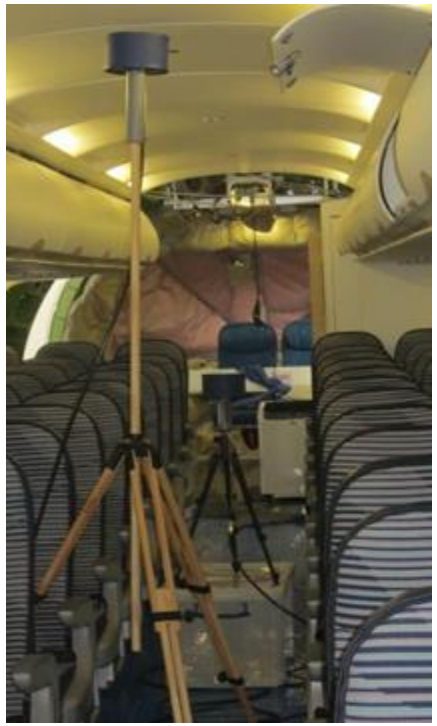




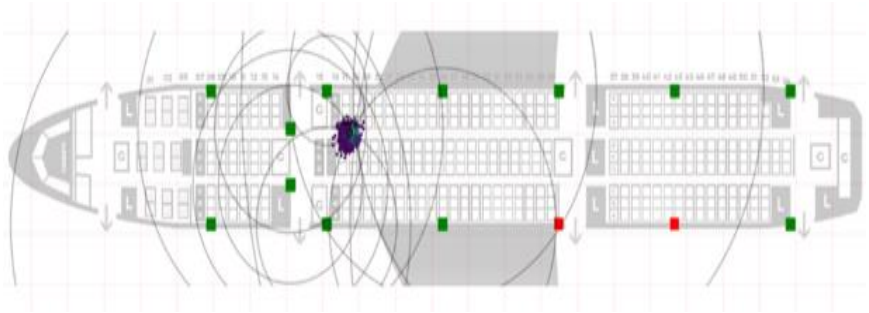


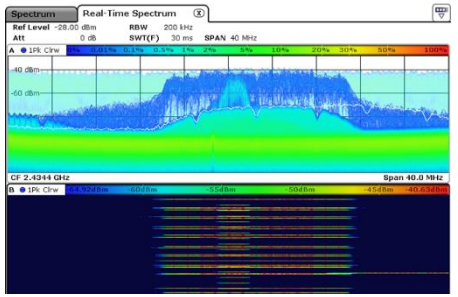


5 Current project activities (aviation)

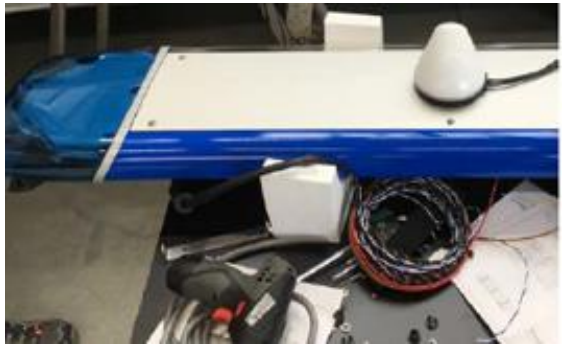


Innovative air traffic (Wirless Cabin)
CabiNET, CANARIA & ADKT





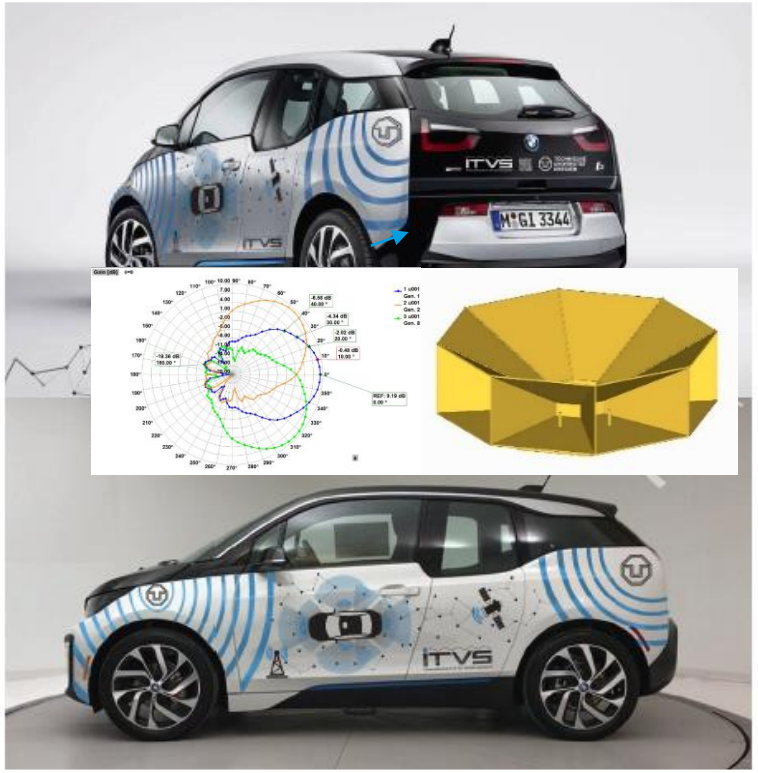
5 Current project activities (automotive)



Vehicle-2-X

eCall, GSM, UMTS

LTE zukünftig 5G

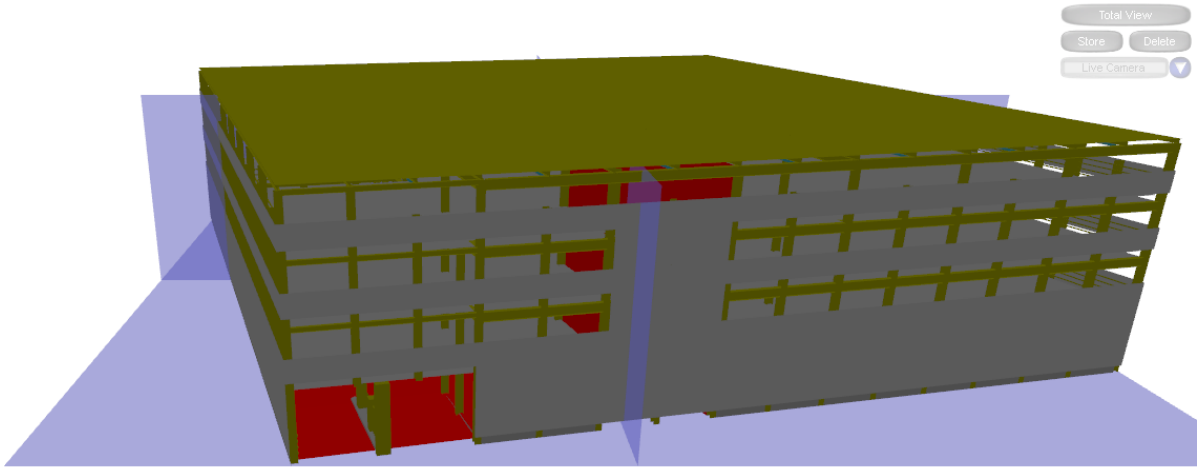


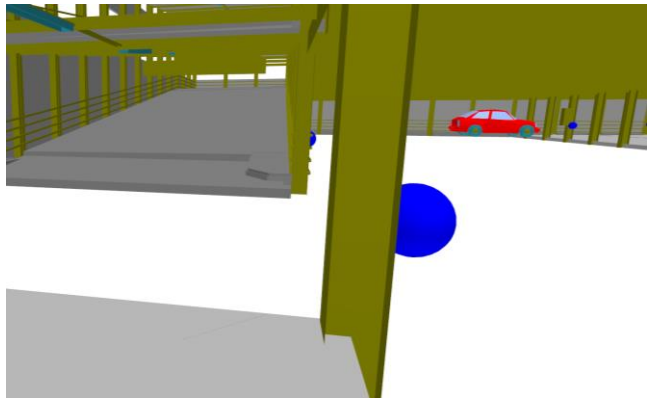
GPS, GLONASS, Galileo

FM, DAB+, TMC, TPEG

Connected and automated driving
IVS-AMP, IVS-LOK, Fast Sign, V2X4All

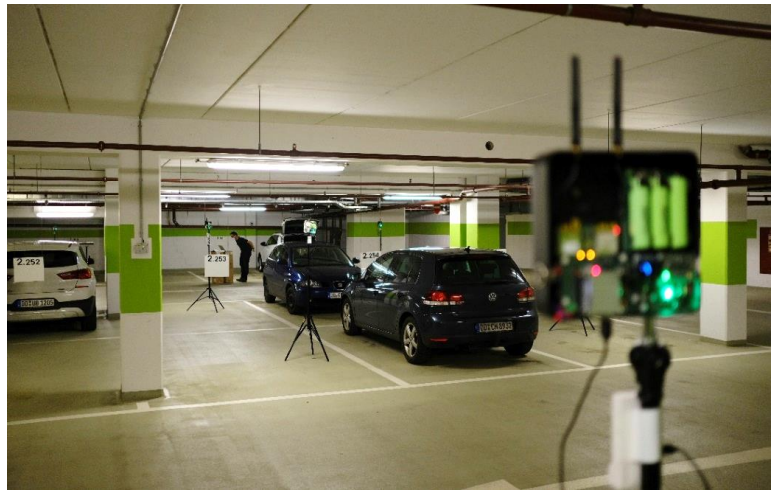
5 Selection: Evaluation using Inhouse parking scenario

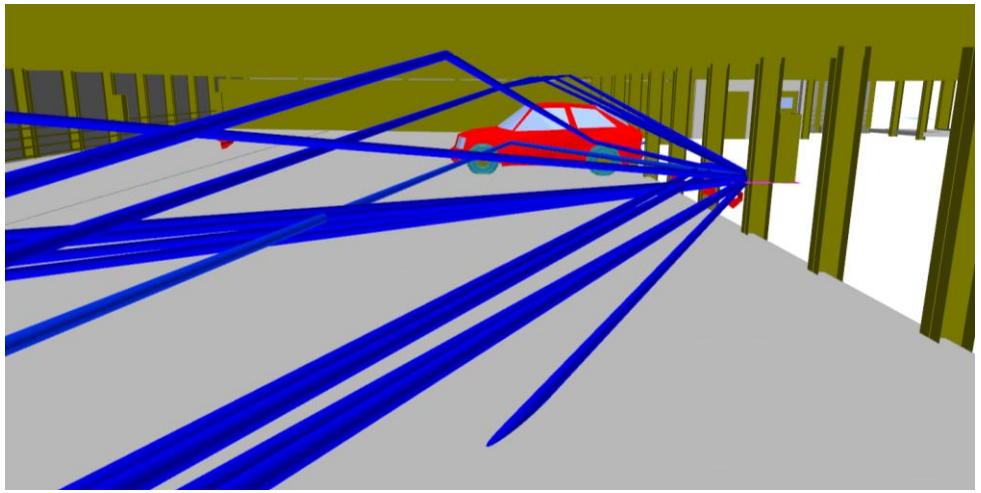


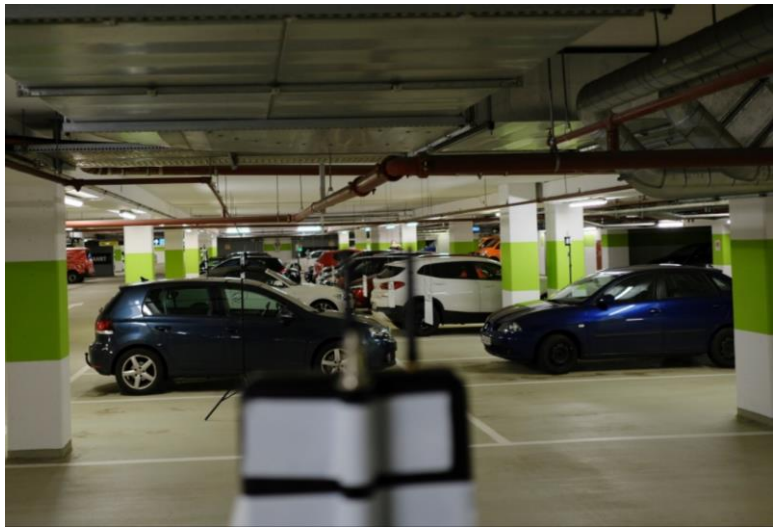


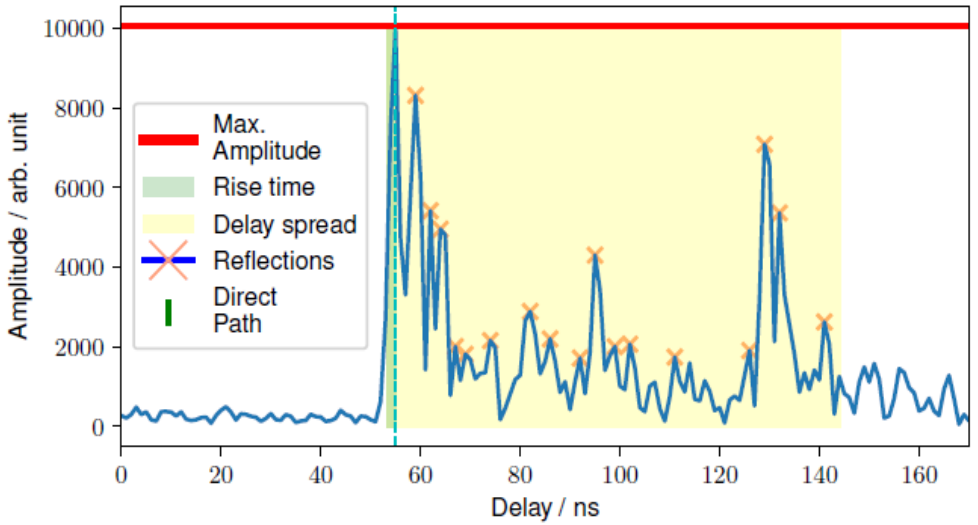

Chip Connection
00:09,85

5 Multipath effects in ITS- / JCS-scenarios (Parking area)

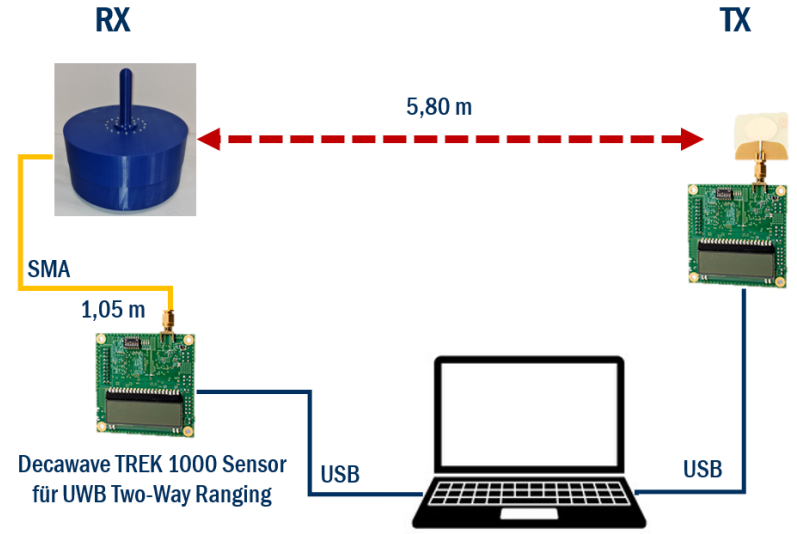


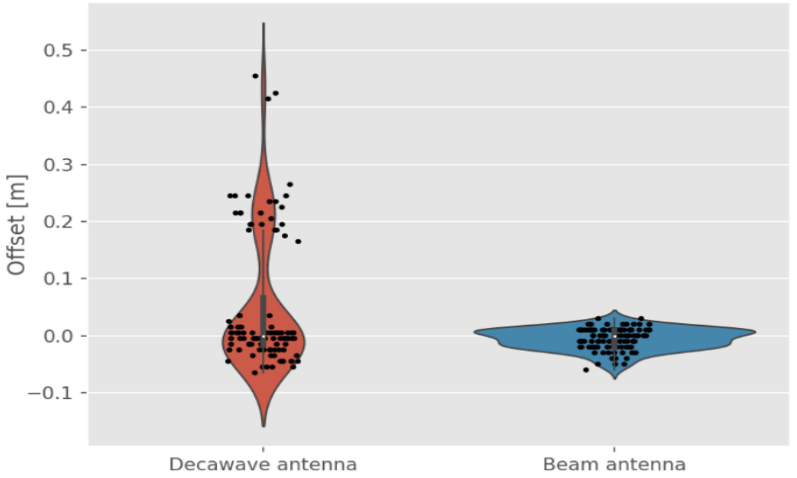




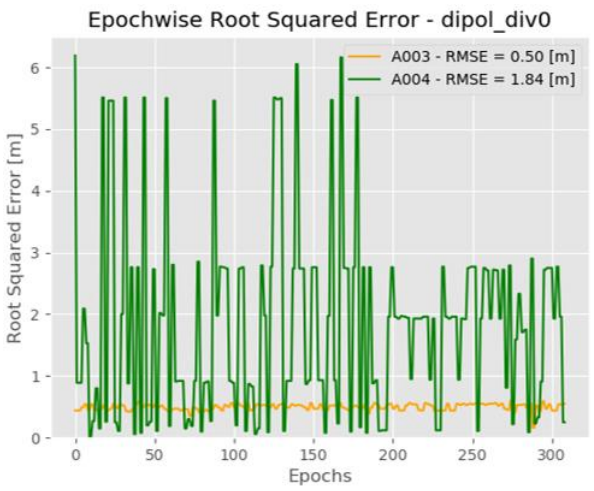


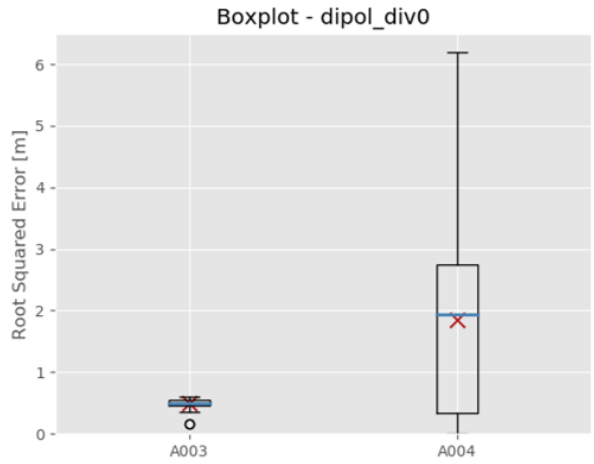
5 Measurement Area (Parking area)

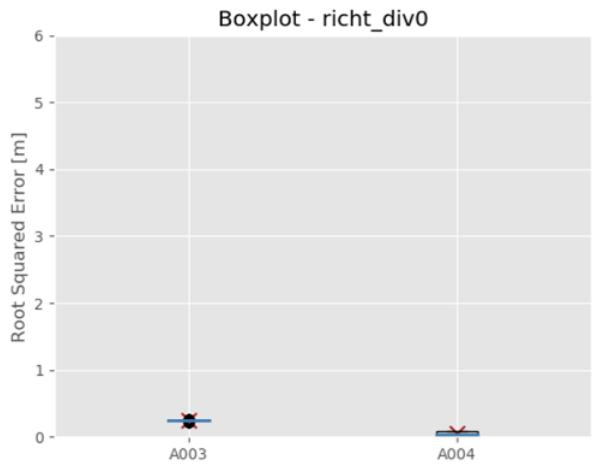




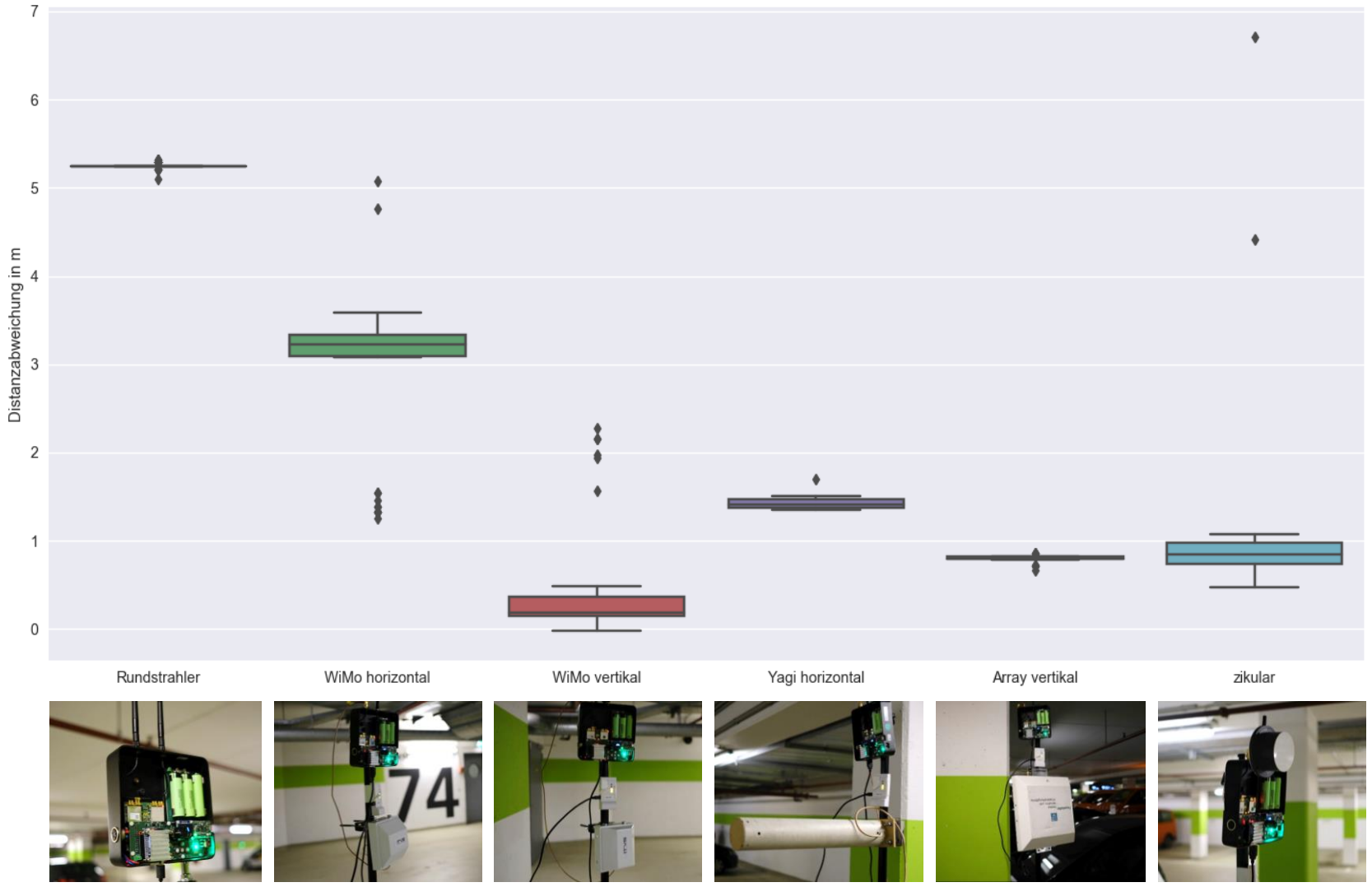
5 Directional antenna result (Parking area)



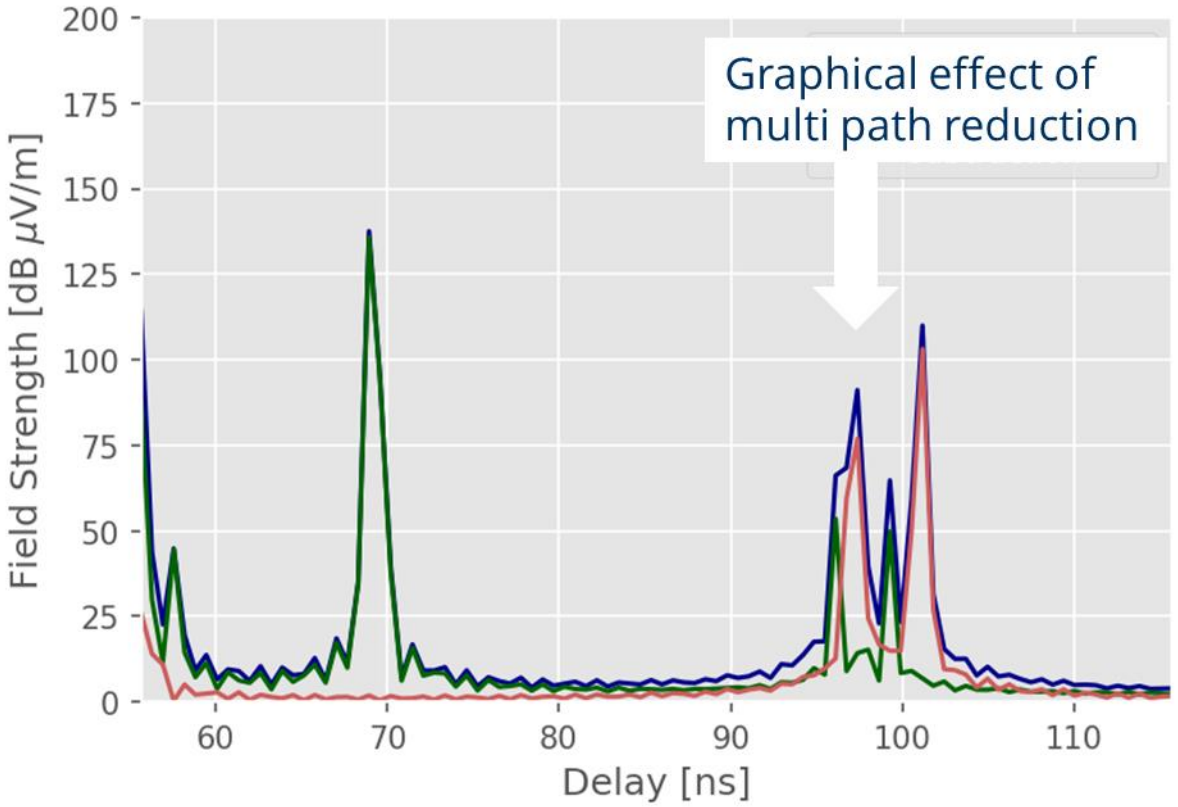




5 Different directional antenna results / Ranging (Parking area)



5 Beam-forming /-switching antenna results / RSSI + Delay (Parking area)



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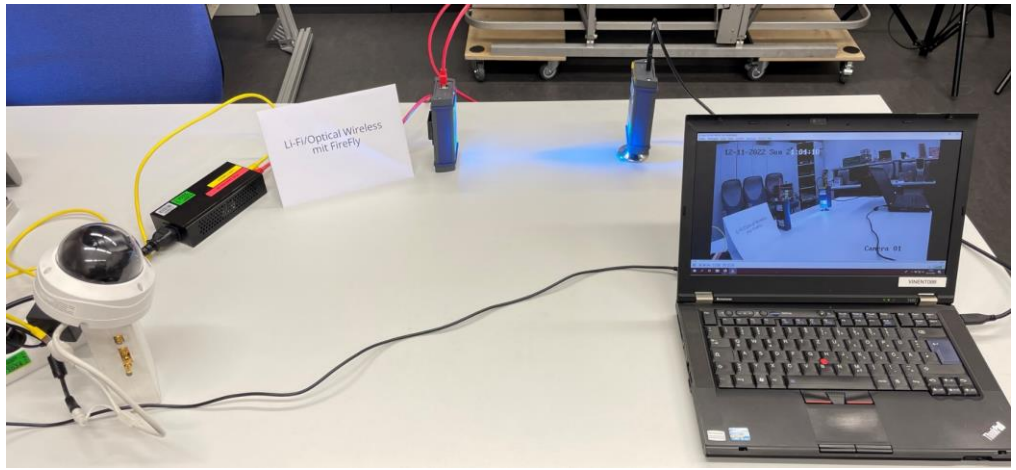
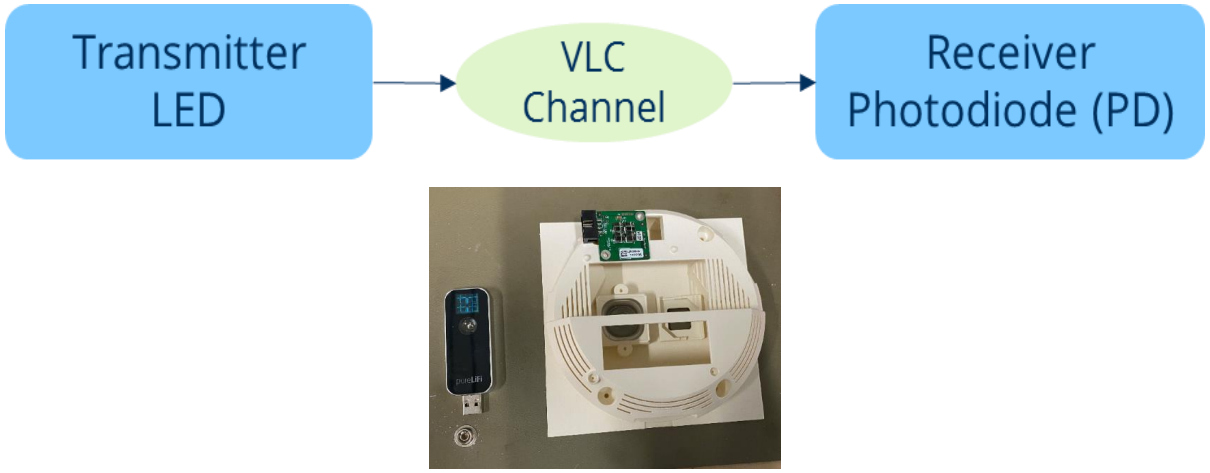
6 Conclusion and future outlook

- Modern and innovative antennas will continue to play a fundamental role in the next generations of radio-based communicatiRefractionon and positioning systems (e.g. 5G, 6G ++)
- The same principle will also apply to the optical free-space communication sector - Visible Lite Coimmunication (VLC) or LiFi / but here with so-called Directional Lense Antennas





Thank you very much for your attention

Contact:

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Institute of Traffic Telematics
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