Forschungsinitiative

Ko-FAS

Transponder Based Ranging

Transponderbasierte Abstandsmessung

Gerrit Kalverkamp, Bernhard Schaffer
Technische Universität München

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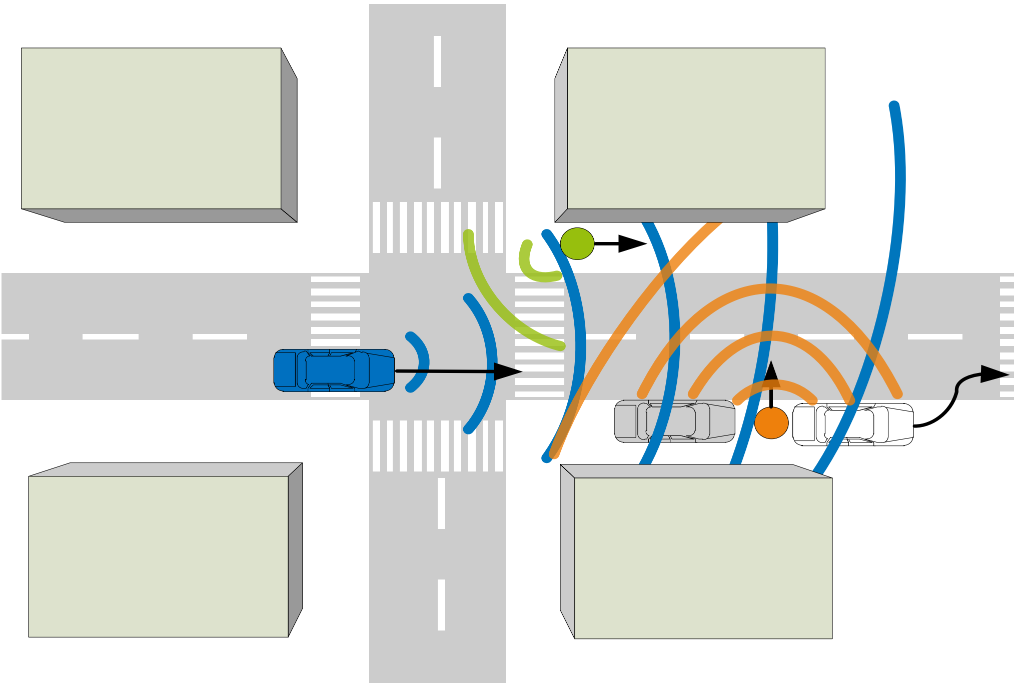
Outline

- Secondary radar principle
- Looking around corners: Diffraction of radio waves
- Roundtrip time of flight: Measurement principle and signals
- Comparison of modulations and estimation methods

- SafeTAG prototype hardware
- System performance
- Comparing SafeTAG to other technologies
- Conclusion

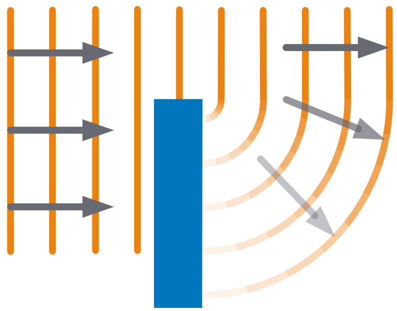
Secondary Radar Principle

- Higher received signal power
- Detection and ranging in non-line of sight situations
- Unambiguous target classification
- No phantom targets
  by passive reflections
- Multi-user capability
- Data link from transponders
  allows additional information
  (e.g. inertial sensor data)

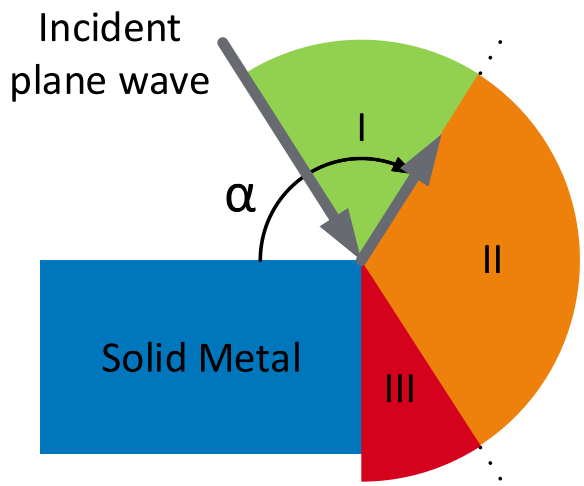


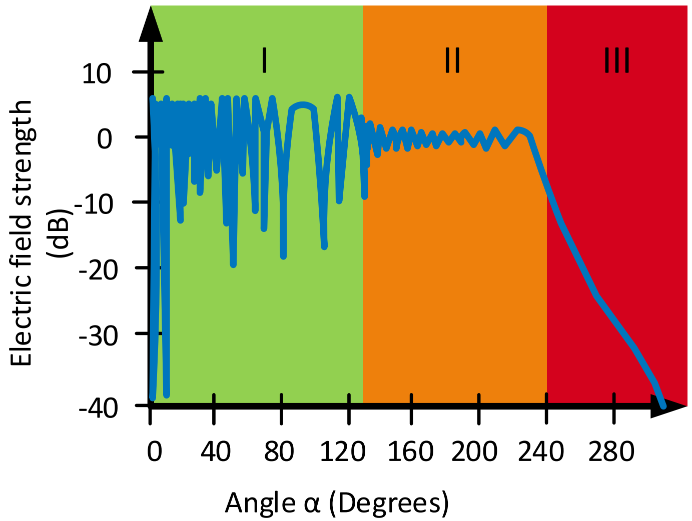
Looking around corners: Diffraction of radio waves

Reception even in optically occluded regions



Example: Diffraction at a corner:





Source: McNamara, D. A.; Pistorius, C. W. I.; Malherbe, J. A. G.: Introduction to the Uniform Geometrical theory of diffraction, Artech House 1990

Roundtrip Time of Flight: Measurement Principle

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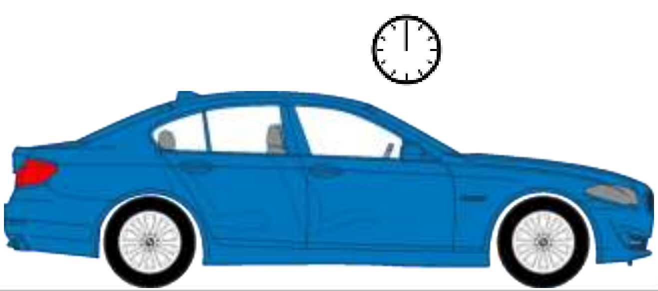
Onboard unit sends out ranging signal

Road users with transponders receive the signal

Transponders send code back after a defined waiting time

Onboard unit calculates roundtrip time of flight and distance

In risk situations: Warning or autonomous maneuvers



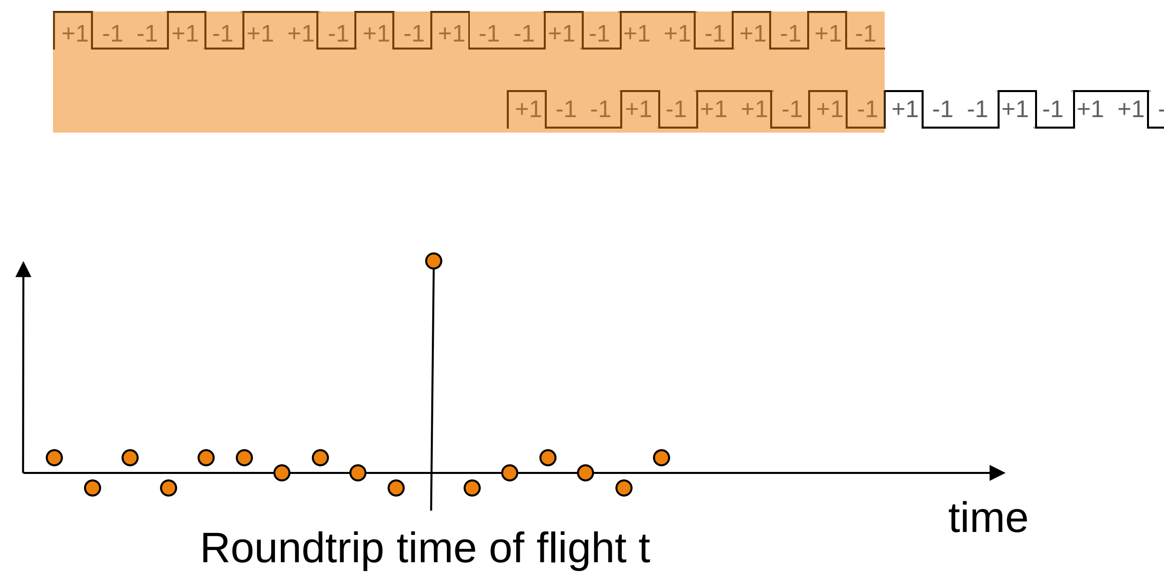
Roundtrip Time of Flight: Measurement Principle

Measuring the distance by correlation:

Transmitted ranging signal:

Received response from tag:

Correlation result:

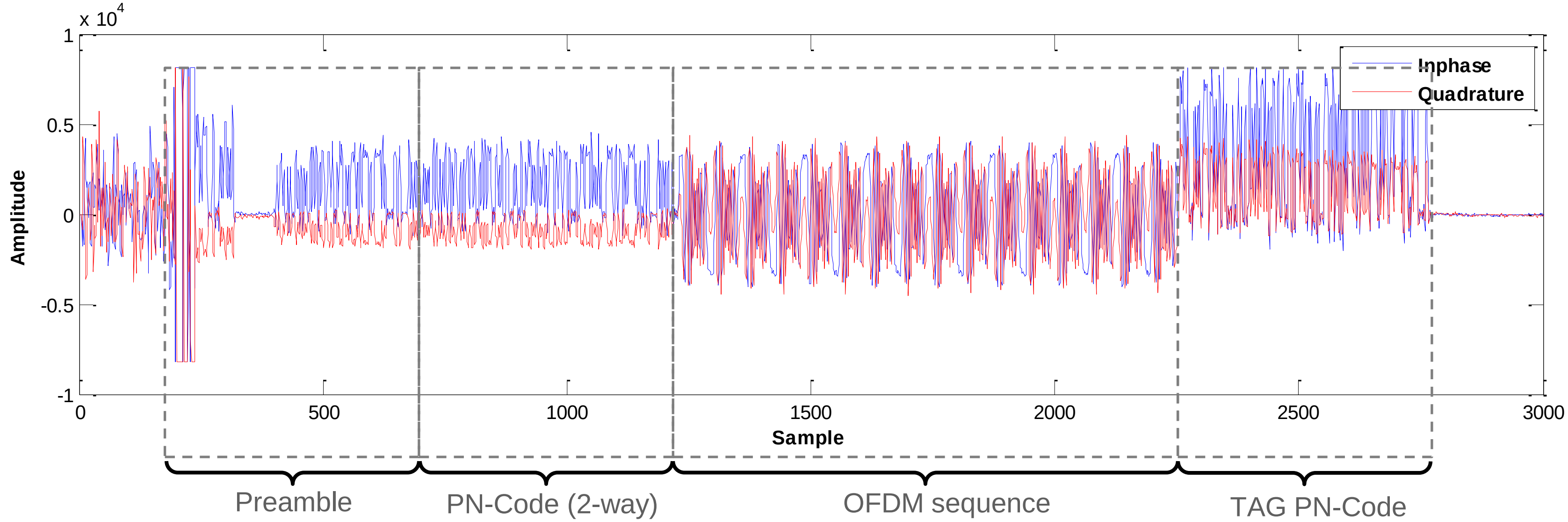


Distance to transponder:

$$\text{Distance} = \frac{1}{2} \cdot (\text{Roundtrip time of flight} - \text{Waiting time}) \cdot \text{speed of light}$$

Roundtrip Time of Flight: Signals

- Ranging signal:

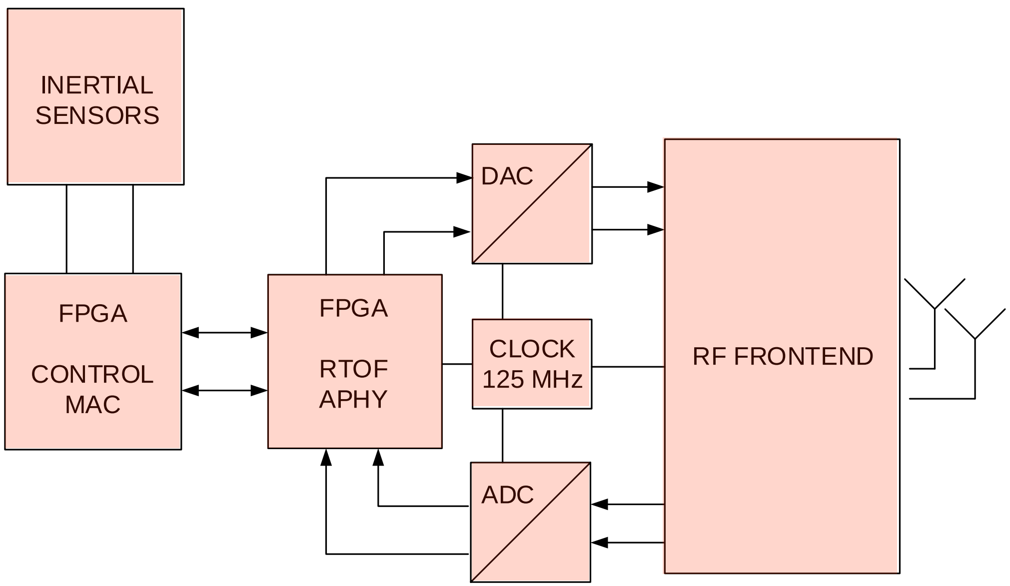


Pulse compression:	255 bit m-sequence; 4.08 µs
Carrier frequency:	5.8 GHz
Transmit power:	~18 dBm
Receiver bandwidth:	54 MHz (IF SAW Filter)

Comparison of Modulations and Estimation Methods

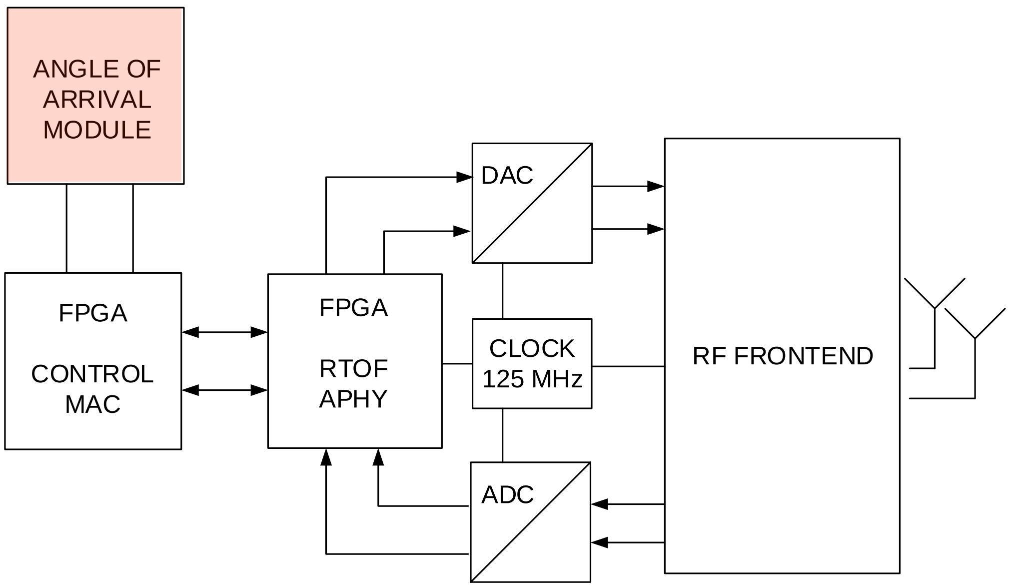
- Research topics:
  - Application of parametric algorithms for increased resolution
  - Multicarrier waveforms for spectral flexibility and agility
  - Methods for simultaneous communication and ranging

SafeTAG 2.0 Prototype Platform Transponder



- Modular, flexible prototype
- Identical hardware for transponder and OBU
- Size and power consumption can be drastically reduced in future implementations

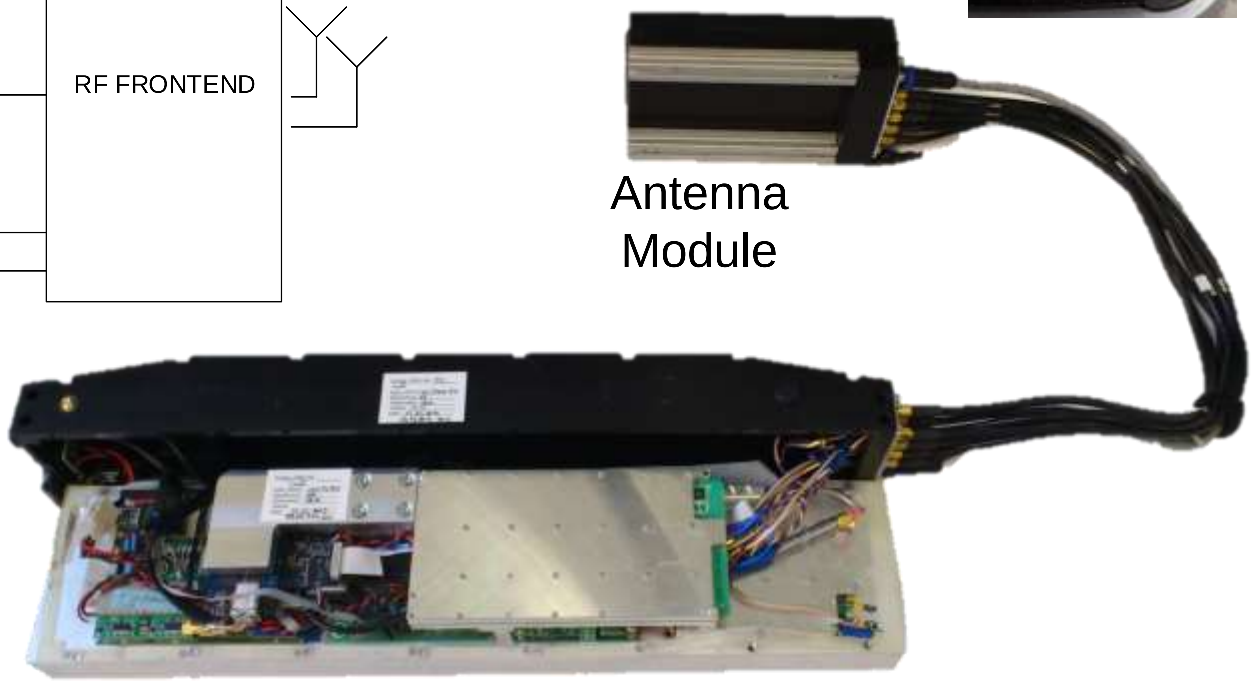
SafeTAG 2.0 Prototype Platform Onboard Unit



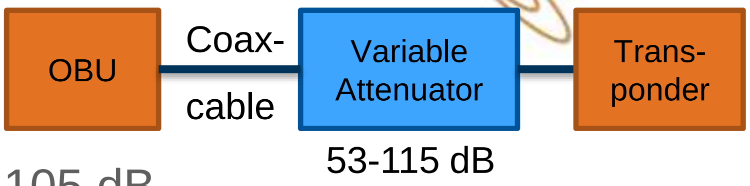
Antenna array mounting position

Antenna Module

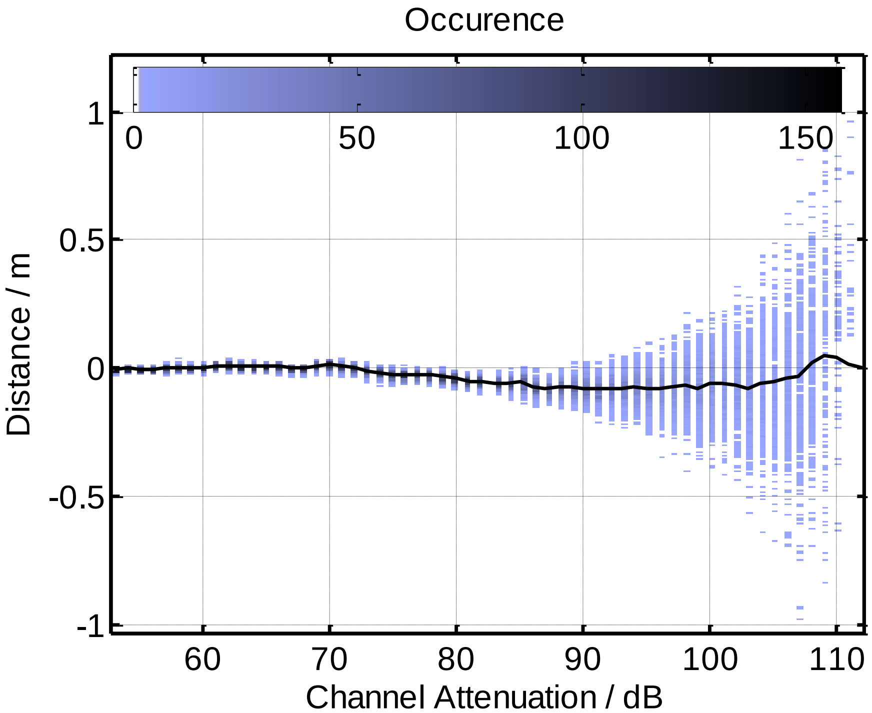
Onboard Unit

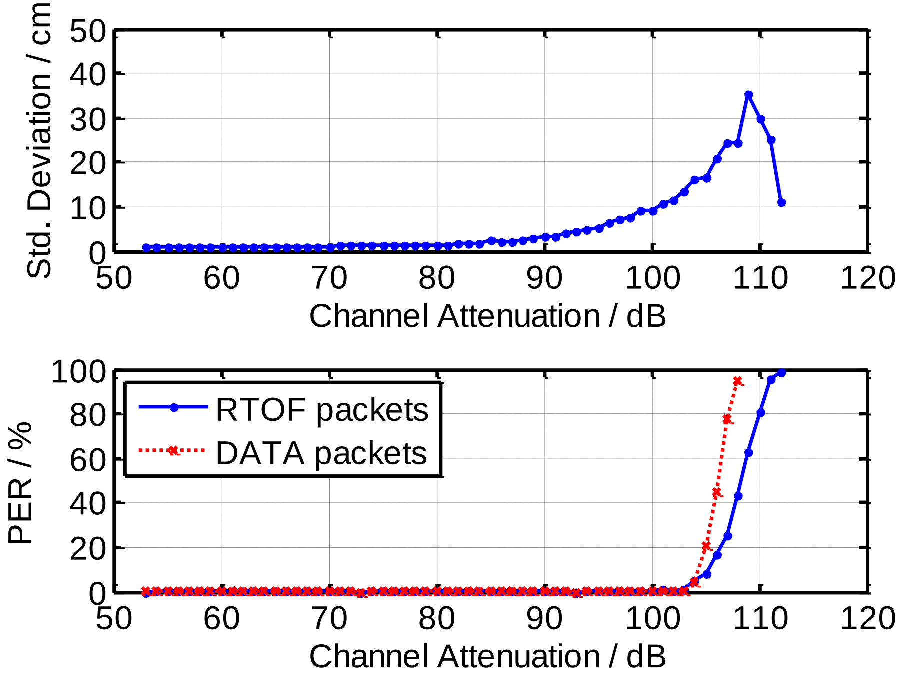


Performance: Laboratory Measurements



- Distance standard deviation:
  σ = ~7 mm at 60 dB, 10 cm at 100 dB
- Distance packet error rate: < 10 % up to 105 dB
- Data packet error rate: < 10 % up to 104 dB (→ Sensitivity: -86 dBm)





Performance: Outdoors, Line of Sight

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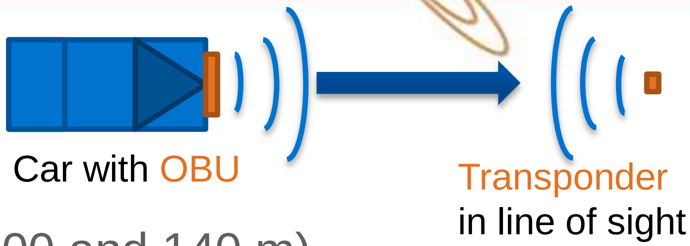
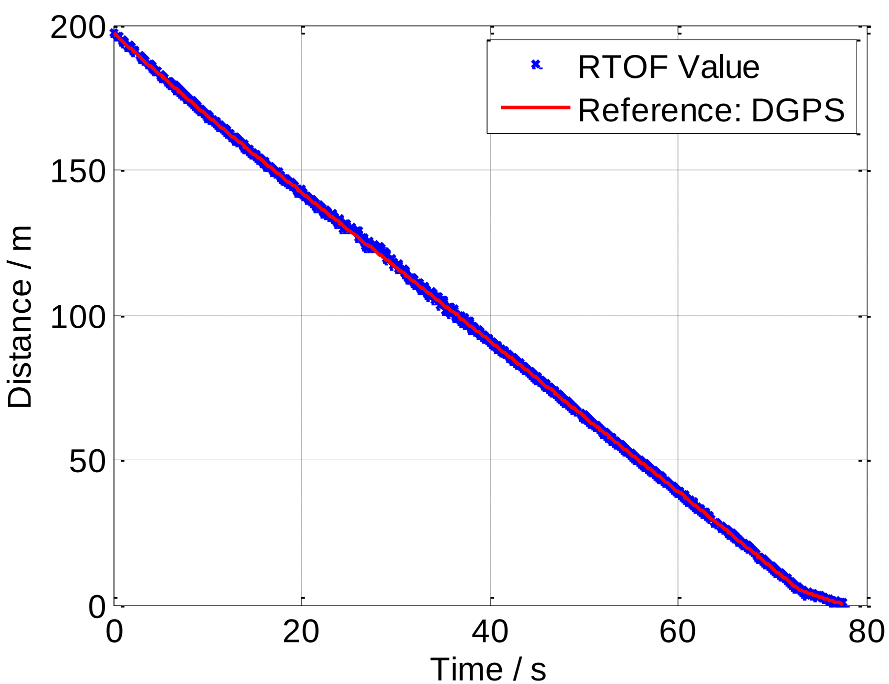
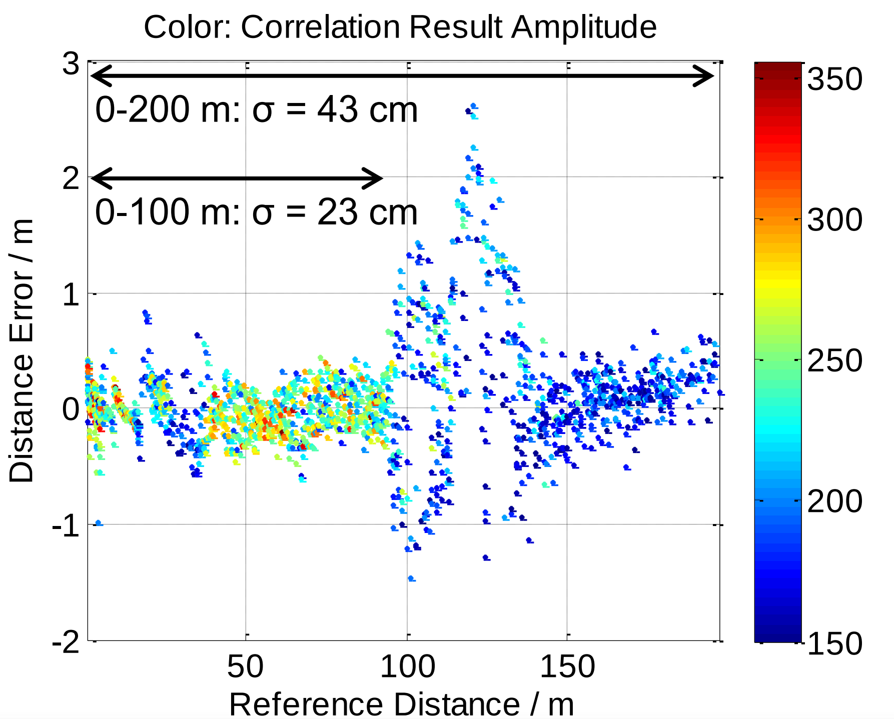
- Range > 200 m
- Std. deviation of error: 23 cm
  unfiltered, untracked raw data!
- Multipath distortions can occur (here: between 100 and 140 m)
- Multipath resolution: theoretical: c/B = 5.5 m, measured: > 6.8 m

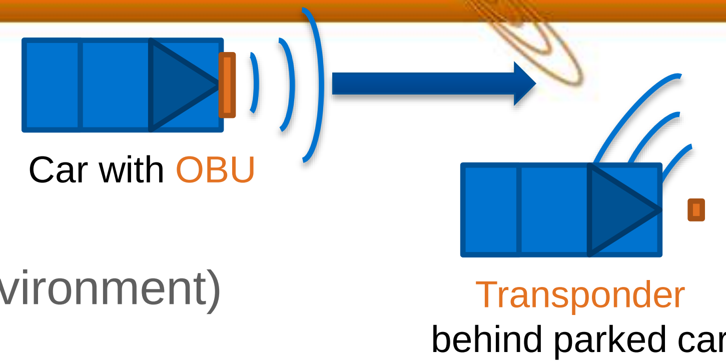


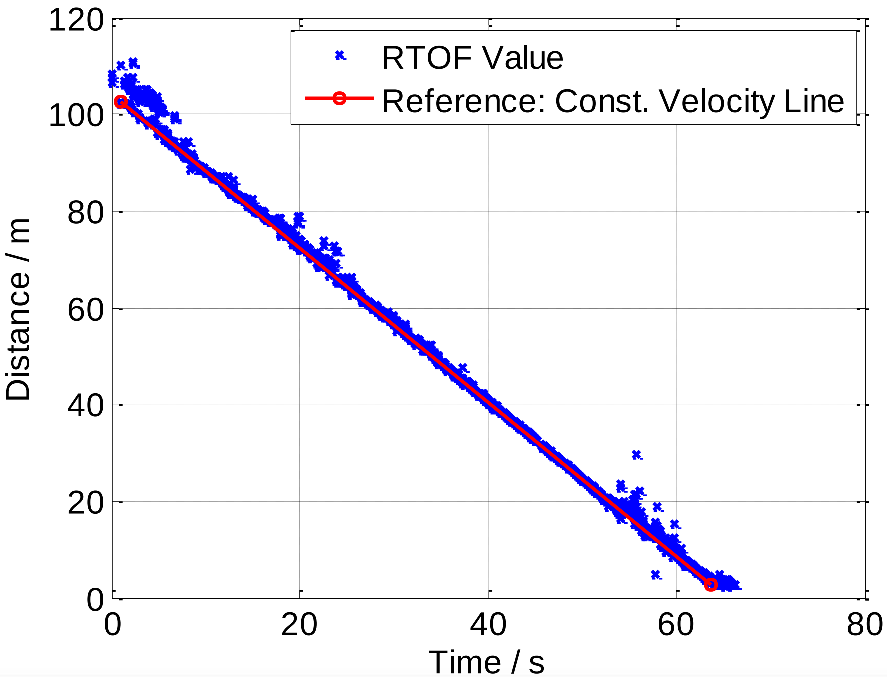


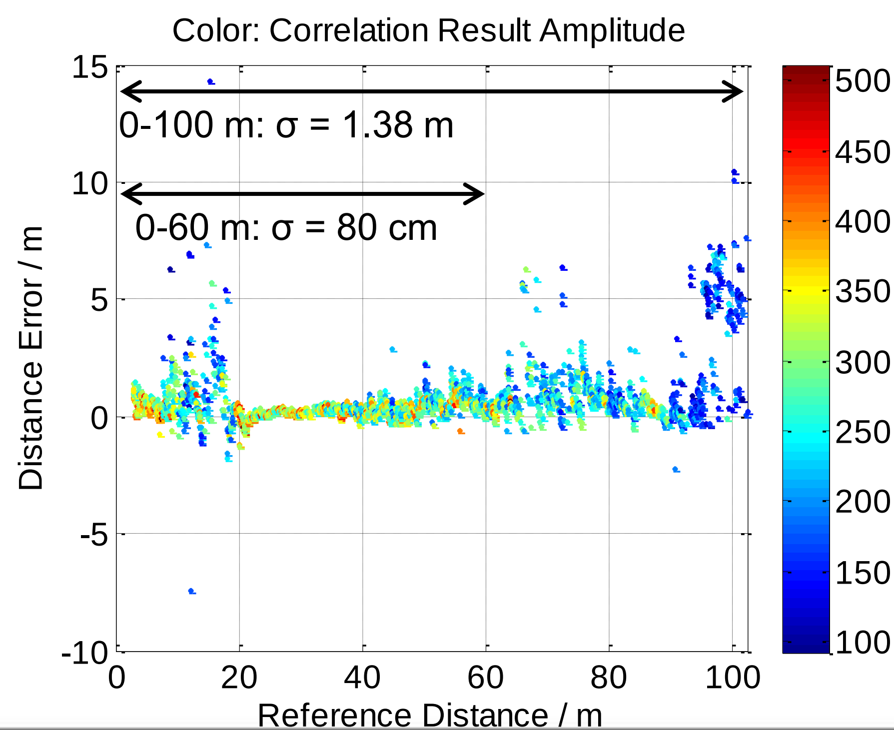


Performance: Outdoors, Non-Line of sight

- Range > 100 m
- Distortions due to diffraction, reflection and multipath
- Typical distance error 1-2 m (depends on environment)
- Unfiltered, untracked raw data!







Comparing SafeTAG to Other Sensors

	SafeTAG	Camera	Radar	Lidar
Target response	active	passive		
Target resolution	very good	computationally expensive	~ bandwidth	good
Accuracy	high	low	high	
Field of view	even in NLOS	similar to driver		
Phantom Targets	none	some	many	
Influence of weather	low	strong	strong	strong
Range	> 200m	< 50 m	< 200 m	< 200 m

Conclusion

- Cooperative transponder system for traffic safety applications
  - High precision detection and ranging
  - Even in non-line of sight situations
  - Distance accuracy considerably higher than camera and GPS
  - Very low false alarm rate
  - Unambiguous classification (car / pedestrian / roadside unit)
- Design and implementation of prototype hardware
- Evaluation of performance in laboratory and field tests
- Further applications:
  - Self-localization
  - High precision reference positioning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for your attention!
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