Wave Propagation
Inside and Around Vehicles
in Dynamic Time Variant Scenarios

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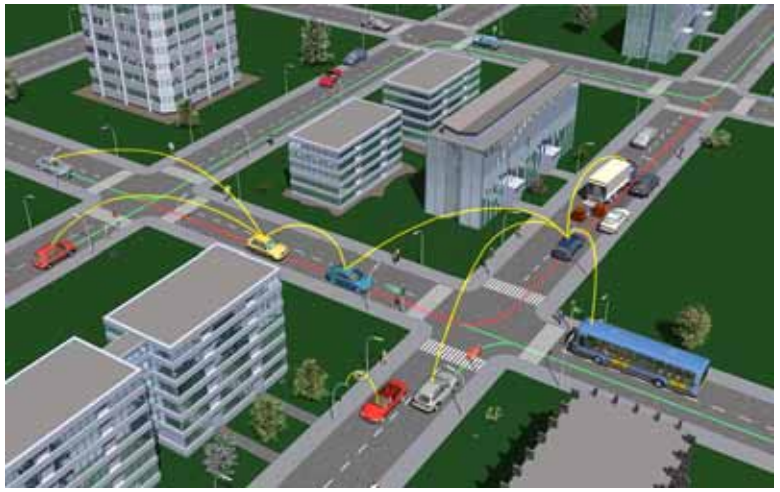
Outline

- Motivation
- Current Status
- Requirements to a New Prediction Model for Time Variant Scenarios
- New Approach for Time Variant Scenarios
- Example Predictions
- Comparison to Measurements
- Conclusion

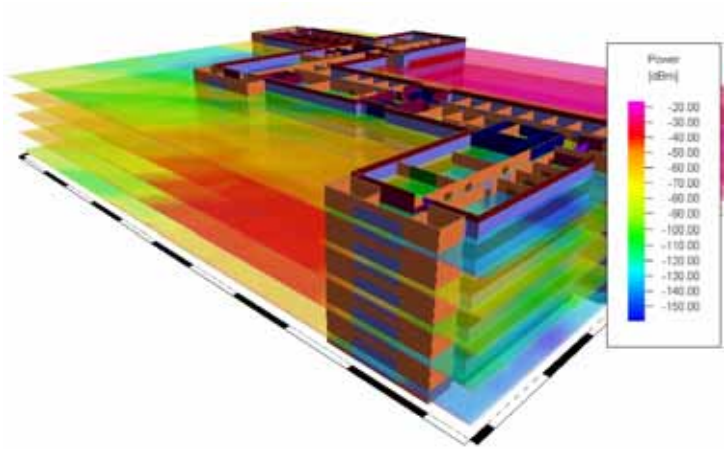
Well known Time Variant Applications

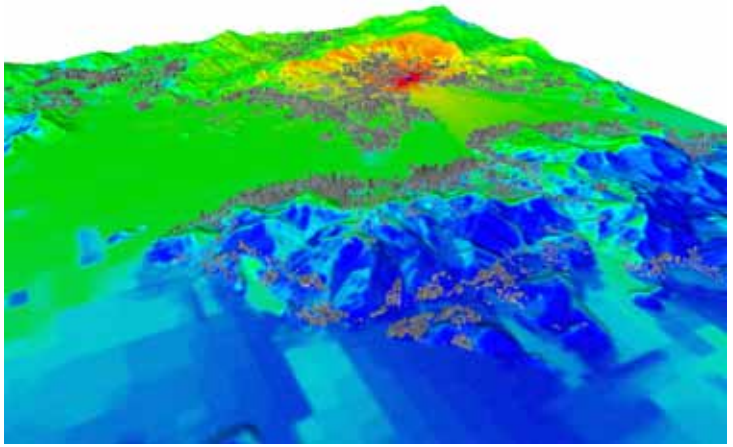
- Wireless Multimedia Applications in Cars, Trains, Aircrafts
- Radio Controlled Transportation Systems in Industrial Halls
- Car-to-Car Communication
- Automotive Radar Systems



Current Status

- Sophisticated Ray Optical Prediction Models for static urban and indoor Environments are available
- Definition of moving Objects in Scenario Databases not possible
- Time Variant Effects are not considered



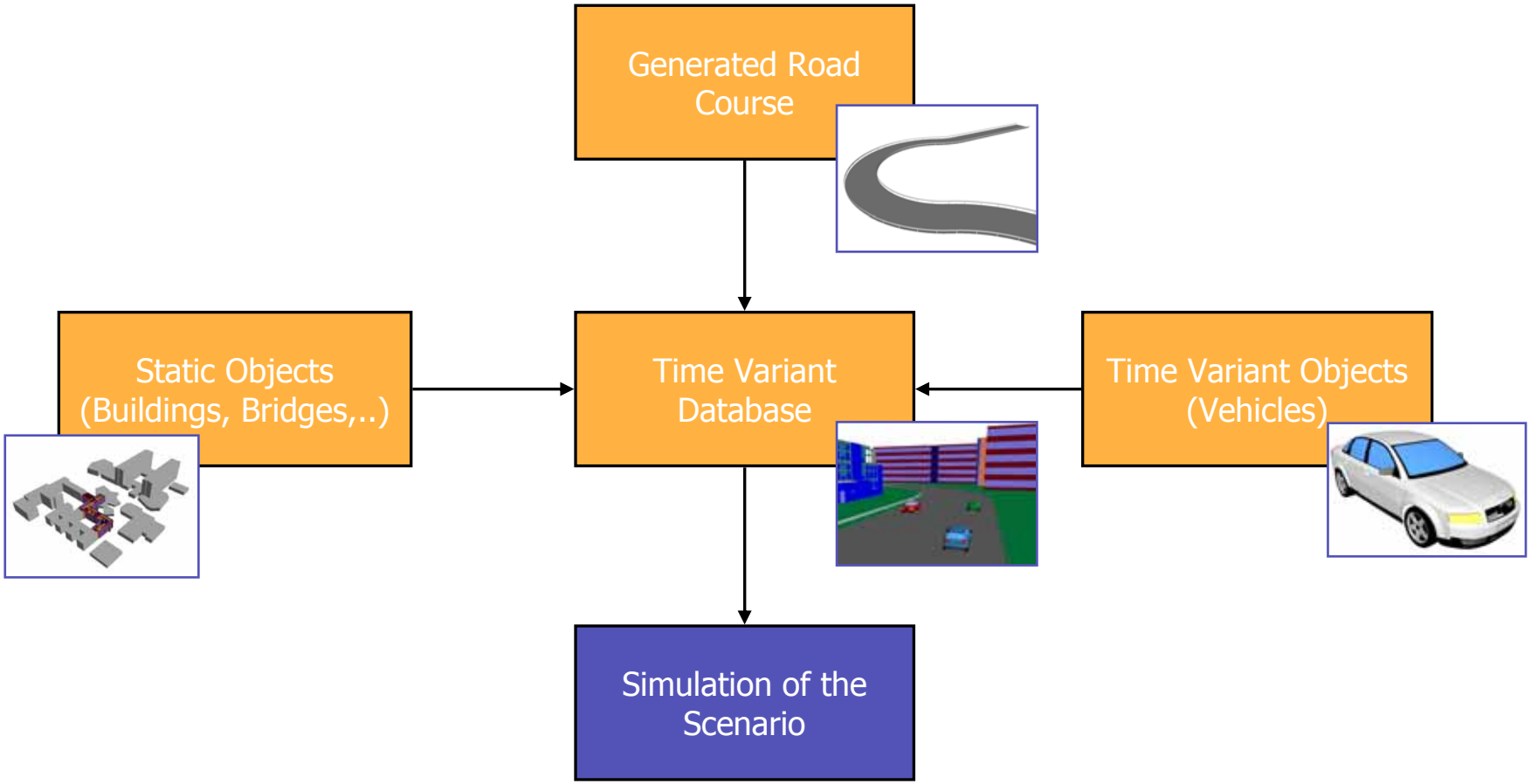


Requirements to a New Prediction Model

- Handling of Time Variant Databases possible
- Consideration of Time Variant Effects: Doppler Shift and Slow Fading
- Accurate Ray Optical Prediction Model (Ray Tracing)
- Acceptable Prediction Times
- Suitable for urban and indoor Scenarios and for enclosed Spaces (inside Vehicles, Tunnels,..)

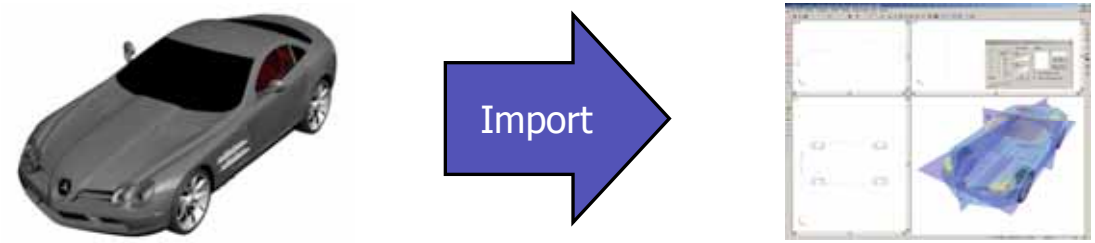
New Approach (1/6)

Process for Predictions in Time Variant Scenarios



Modeling of Vehicles

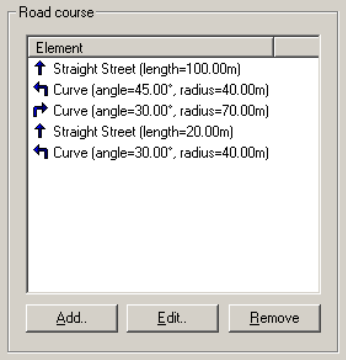
- Import of Vector Vehicle Databases from common File Formats or Drawing of own simple Vehicles



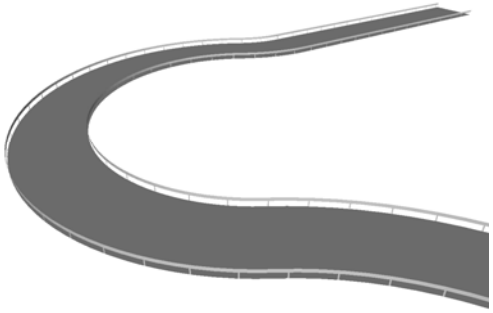
- Usage of Radar Cross Section (RCS) Data to substitute polygonal Models
  - Definition of a Relation between incident and scattered Rays
  - Acceleration of Prediction
  - Only valid in larger Distances from Transmitter/Receiver

Modeling of Scenarios

- Simple and automatic Generation of arbitrary complex Road Courses



Definition of Road Course



Part of a Road Course

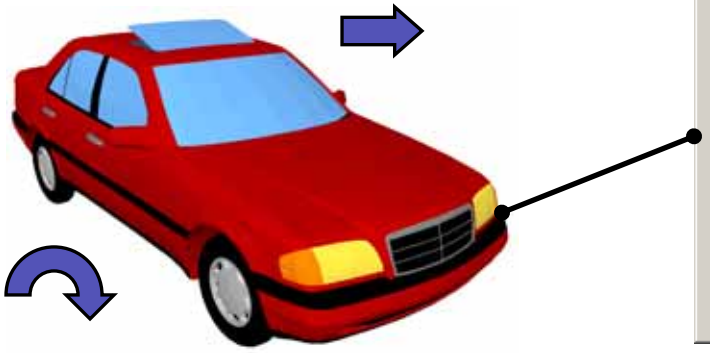
Buildings, Road Course and Vehicles

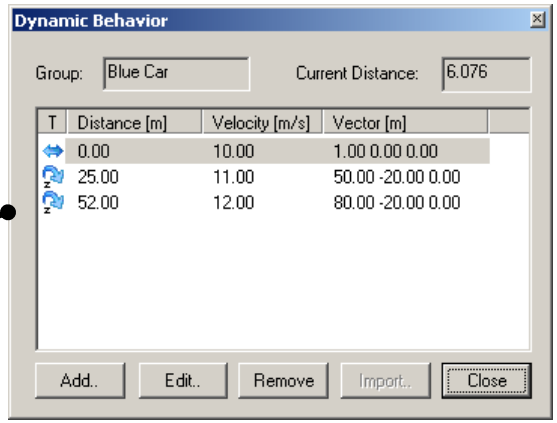
Adding Time Variant Behavior

- Definition of Time Variant Behavior for each Object

Translation	Rotation
Vector for Direction Scalar Value for Velocity	Center of Rotation Velocity of Rotation for each Axis

- Definition of motion Data depending on covered Distance





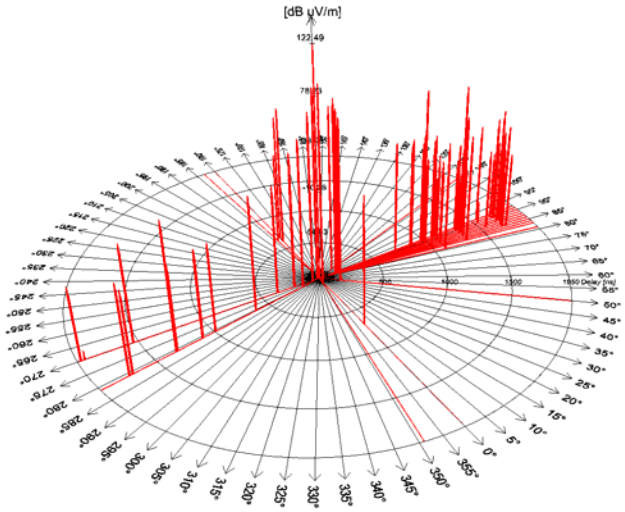
New Approach (5/6)

3D Ray Tracing Approach

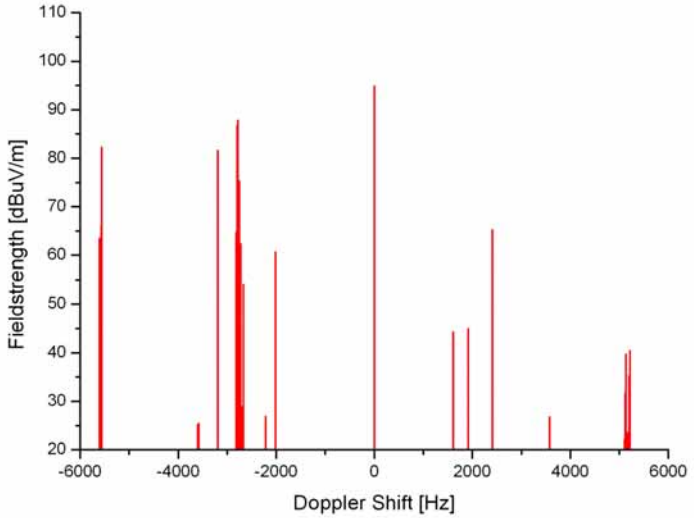
- Multiple Reflections (Fresnel Coefficients)
- Multiple Diffractions (Uniform Geometrical Theory of Diffraction – UTD)
- Scattering on rough Surfaces (Lambertian Source)
- Suitable for urban & indoor Scenarios and for enclosed Spaces
- Consideration of Doppler Shift and Slow Fading
- Individual Material Properties (Conductance, Permittivity, Permeability) for each Polygon/Wall
- Support of Radar Cross Section Data

Computed Results

- Directional Channel Impulse Response (CIR + DoA) with Path Length, Phase Shift and Doppler Shift



Example for Directional CIR

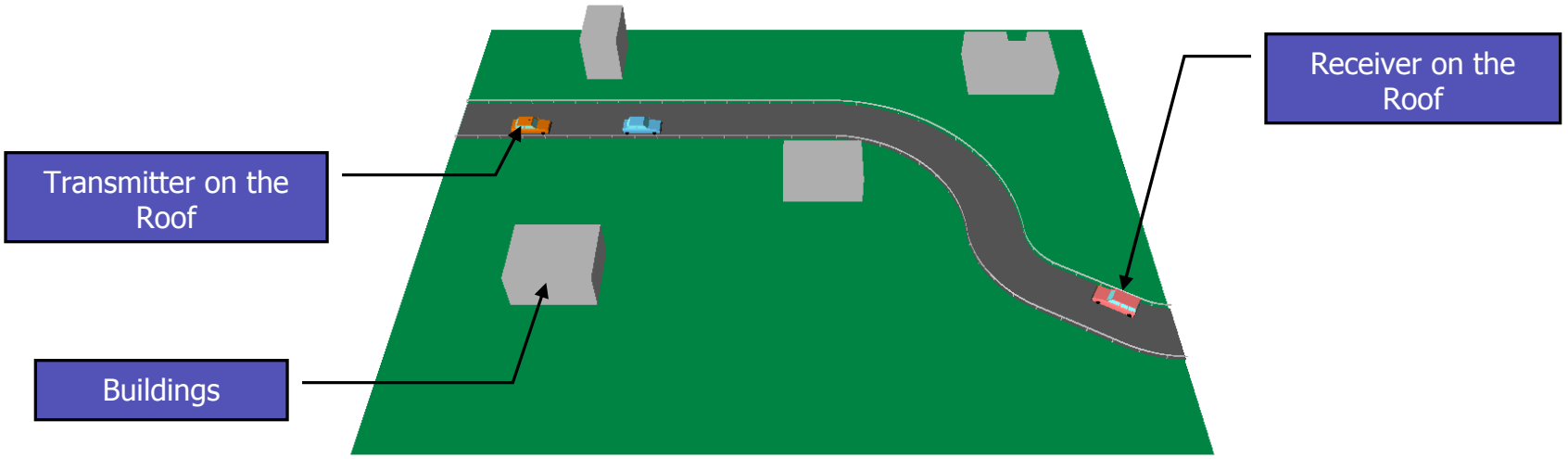


Example for Doppler Shift

Examples (1/6)

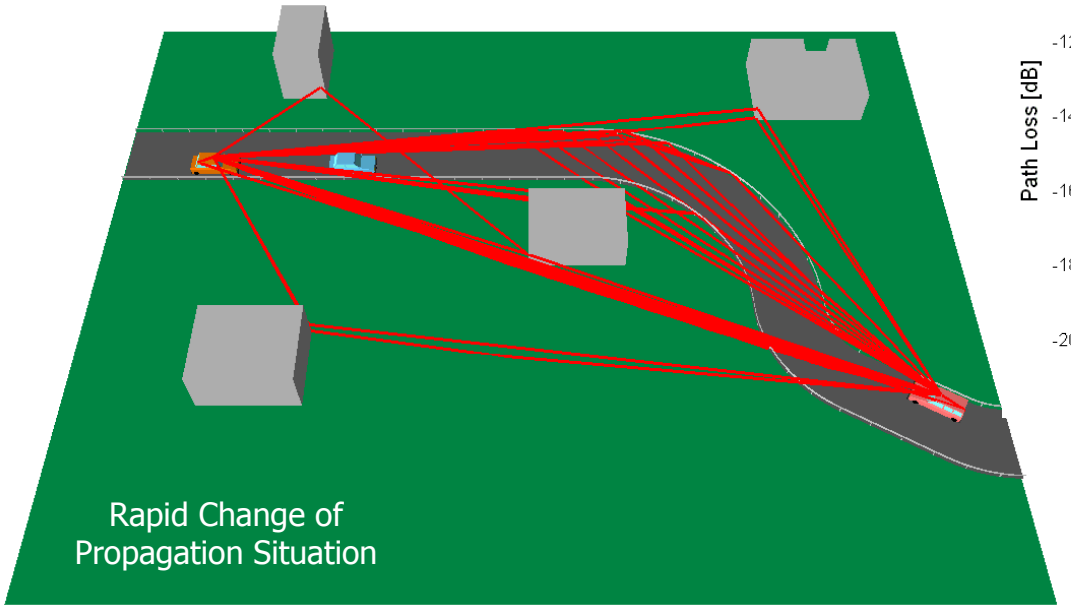
Car-to-Car Communication Scenario

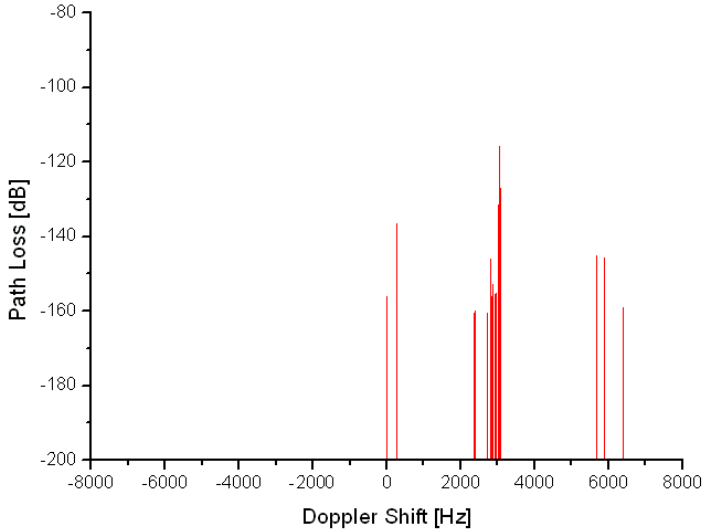
- Transmitter (3.4 GHz, 30 dBm) and Receiver mounted at the Roofs of Vehicles
- 130 Snapshots with constant Time Intervals computed
- 2 Interactions per Ray Path computed



Car-to-Car Communication Scenario

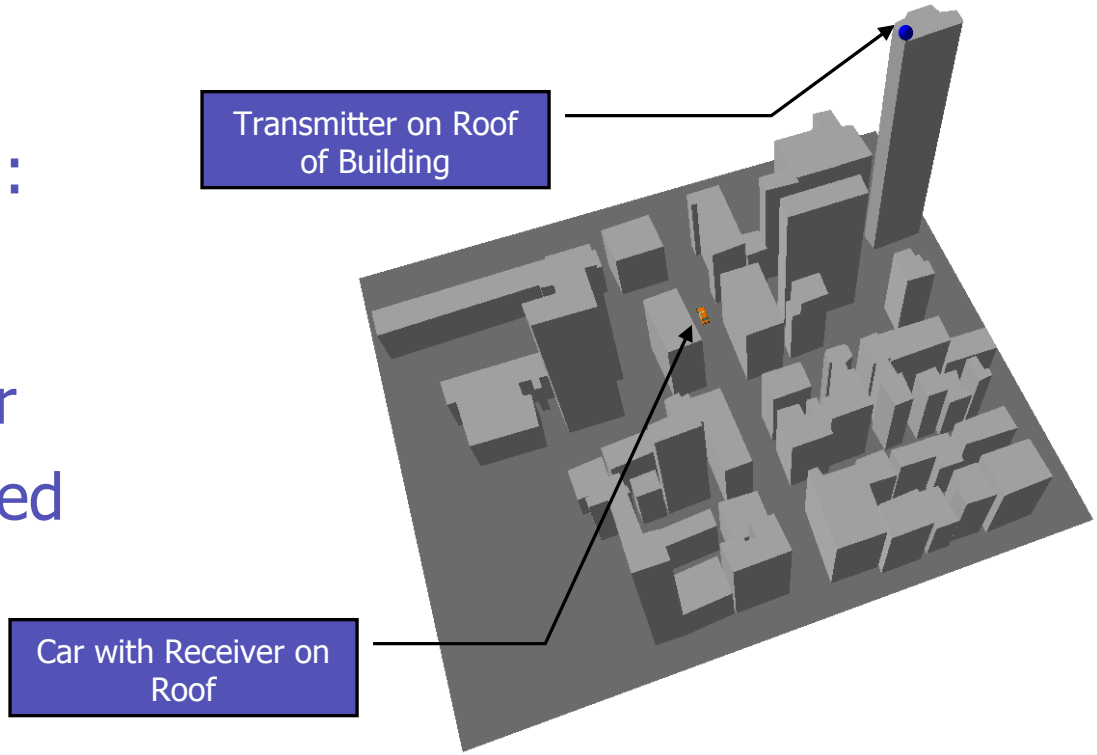
- The most relevant Propagation Paths within a Range of 60 dB and the Doppler Shift for all Snapshots





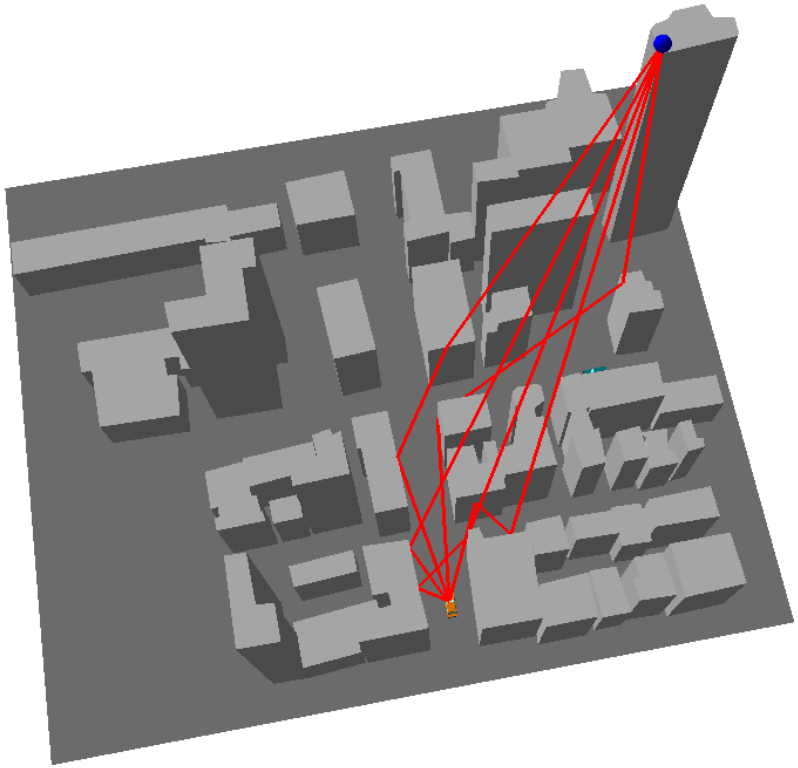
Infrastructure-to-Car Communication Scenario

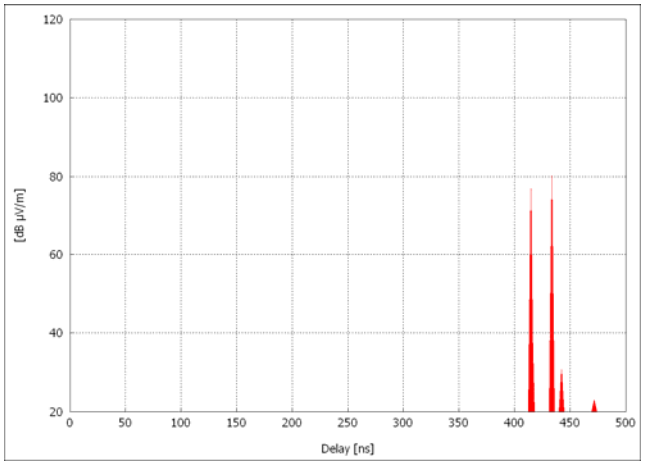
- Transmitter mounted on a tall Building
- Receiver mounted at the Roof of a Car, driving on a wide Street
- Trx Configuration:
  2.4 GHz, 35 dBm
- 2 Interactions per
  Ray Path computed



Infrastructure-to-Car Communication Scenario

- The most relevant Propagation Paths within a Range of 65 dB and the Channel Impulse Response



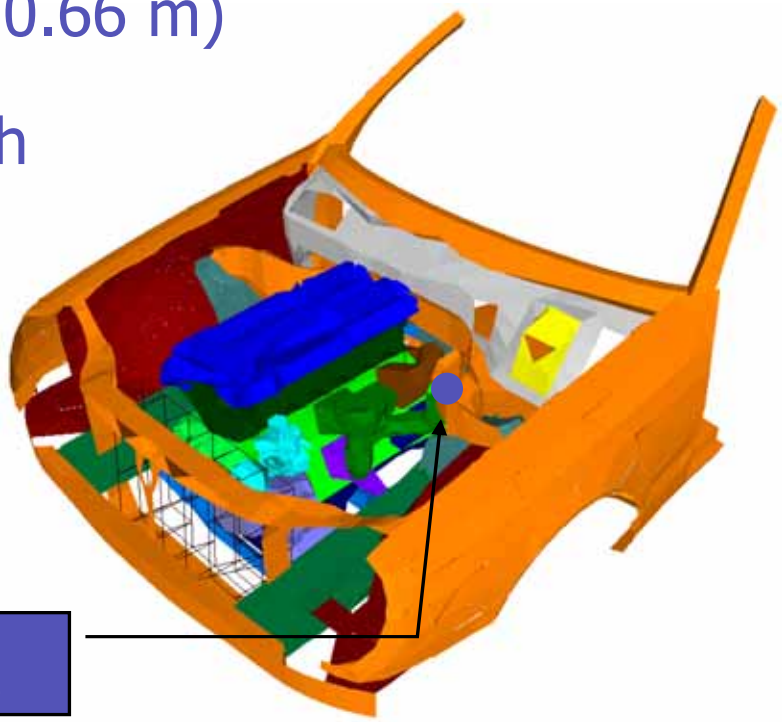


Rapid Change of Propagation Situation

Examples (5/6)

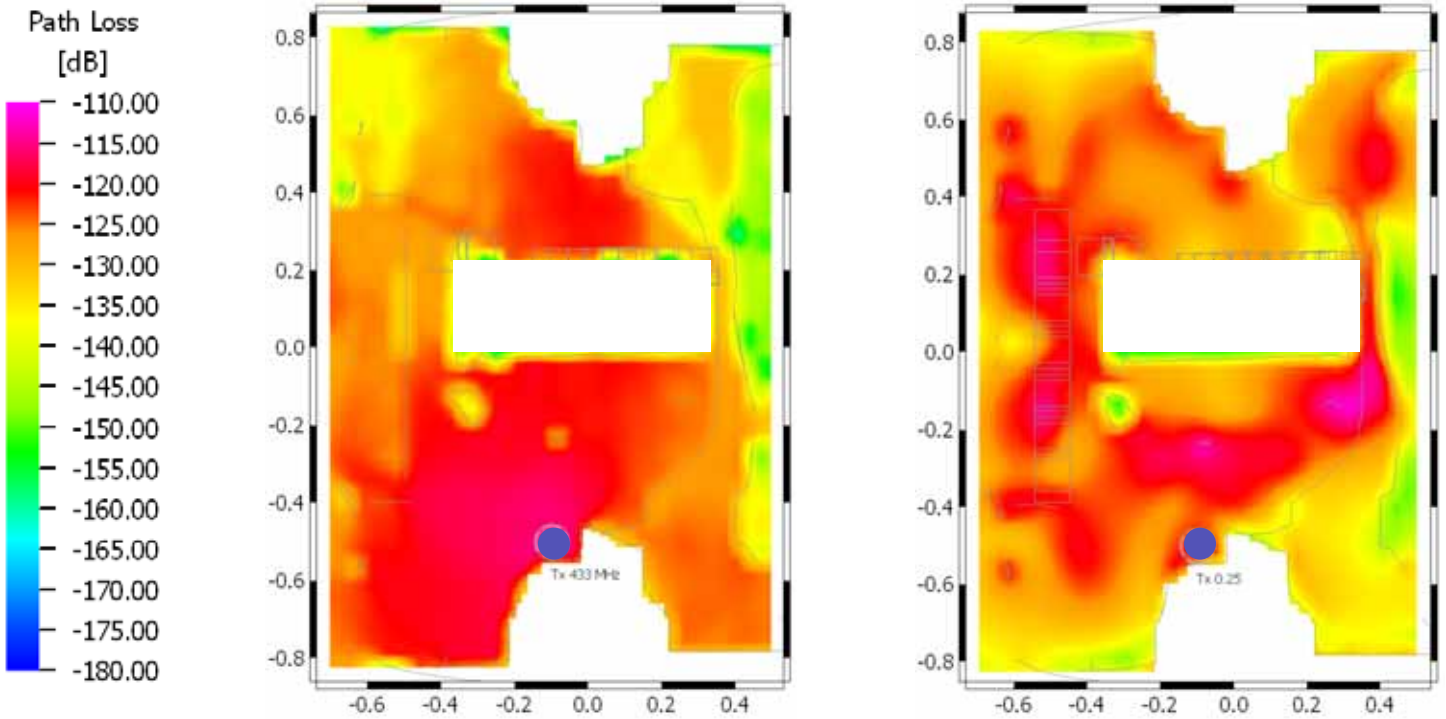
Wireless Incar Sensor Network

- Computation inside Engine Compartment of a Car
- Conditions for Ray Optical Prediction Models not completely fulfilled (here: λ=0.66 m)
- Comparison to Prediction with MoM (Method of Moments)
- 3 Interactions per Ray Path computed



Wireless Incar Sensor Network

- Comparison of both Predictions



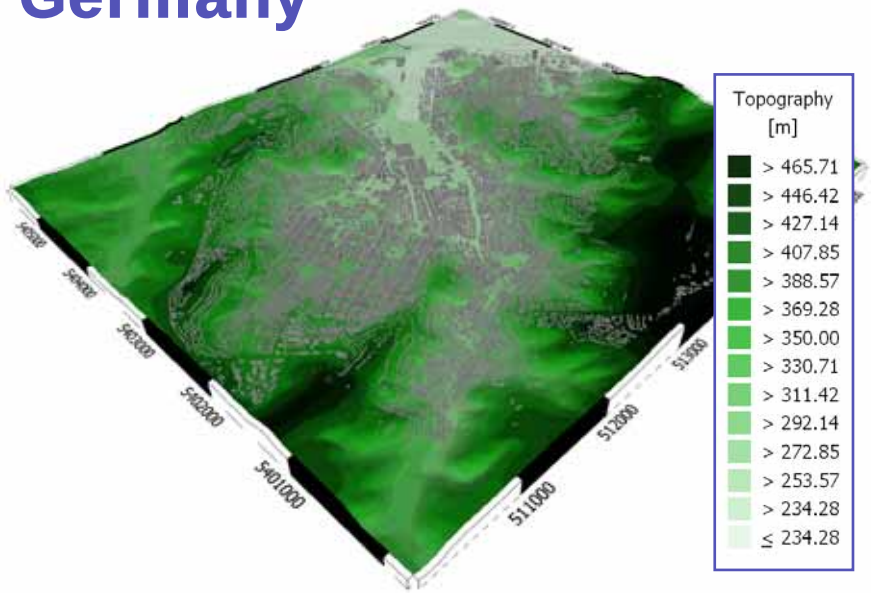
3D Ray Tracing Prediction

MoM Prediction

Comparison to Measurements (1/2)

Urban Scenario: Stuttgart, Germany

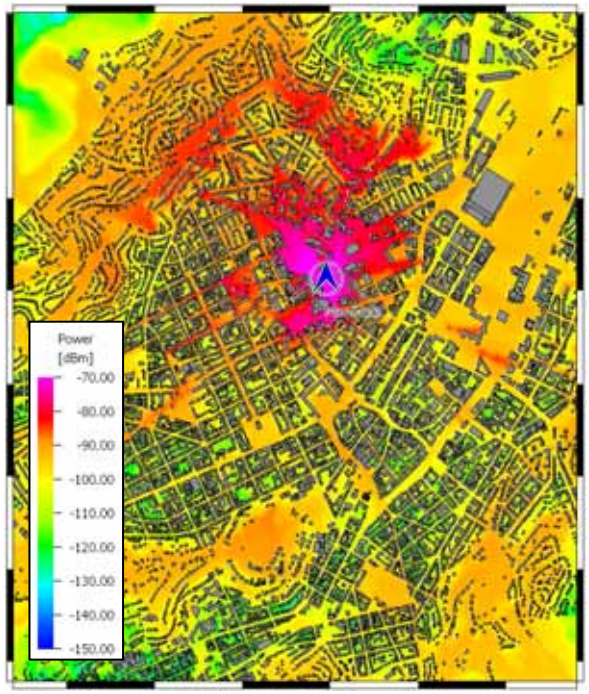
Scenario Information		
Number of buildings		19665
Topo. difference		363 m
Resolution		10 m
Transmitter	Site 1	51 m, 34 dBm, 3.5 GHz
	Site 2	31 m, 34 dBm, 3.5 GHz
Prediction height		2.1 m



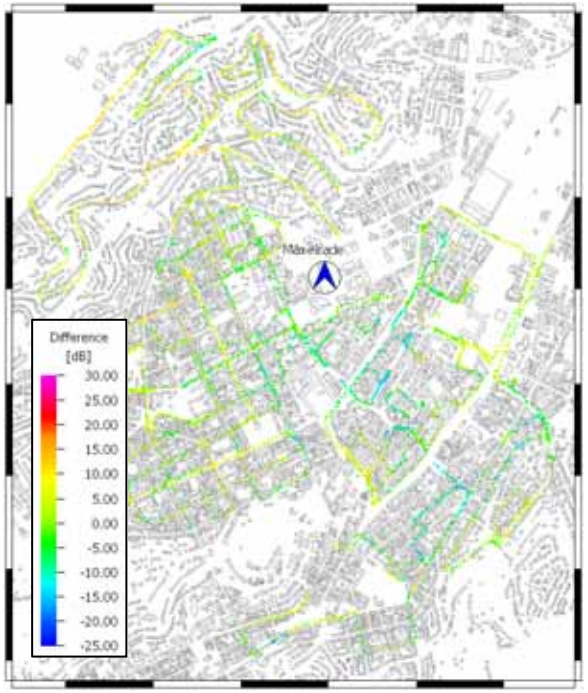
Comparison to Measurements (2/2)

Urban Scenario: Stuttgart, Germany

- Evaluation for Transmitter Location 1



Prediction with Ray Tracing



Difference of Prediction with Ray Tracing and Measurements

Tx	Statistical Evaluation	
	Mean Value [dB]	*Std. Dev. [dB]*
1	1.30	5.02
2	0.82	5.08

Conclusion

- New Approach allows Predictions in Time Variant Scenarios
- Simple Generation of Road Courses and Time Variant Databases possible
- Computation of Directional Channel Impulse Response and Doppler Shift
- Successful Validation by Comparing Prediction Results to Measurements