Wave Propagation
inside and around Vehicles
in dynamic time variant Scenarios

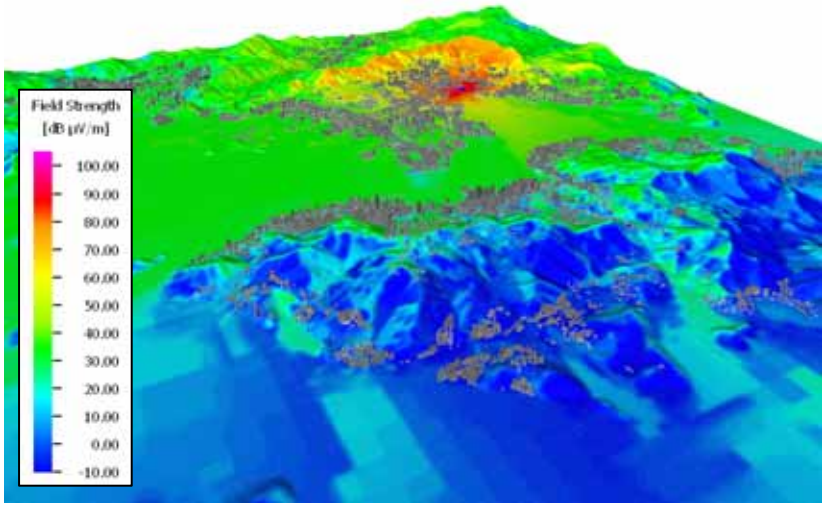
René Wahl, Gerd Wölfle

Outline

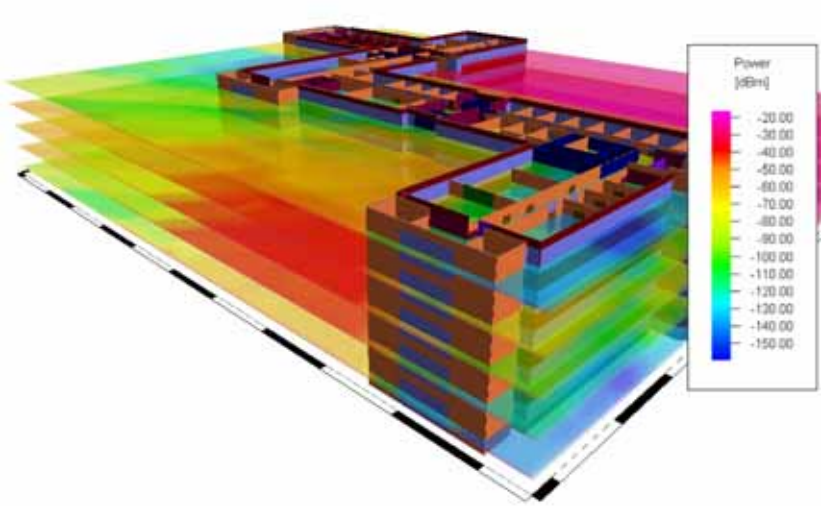
- Current Status
- Requirements to a Prediction Model for time variant Scenarios
- New Approach for time variant Scenarios
- Example Predictions
- Comparison to Measurements
- Conclusion

The current status:

- Sophisticated prediction models for static urban and indoor environments are available
- Moving elements in databases are not possible
- Time variant effects are not considered



Prediction of Hong Kong

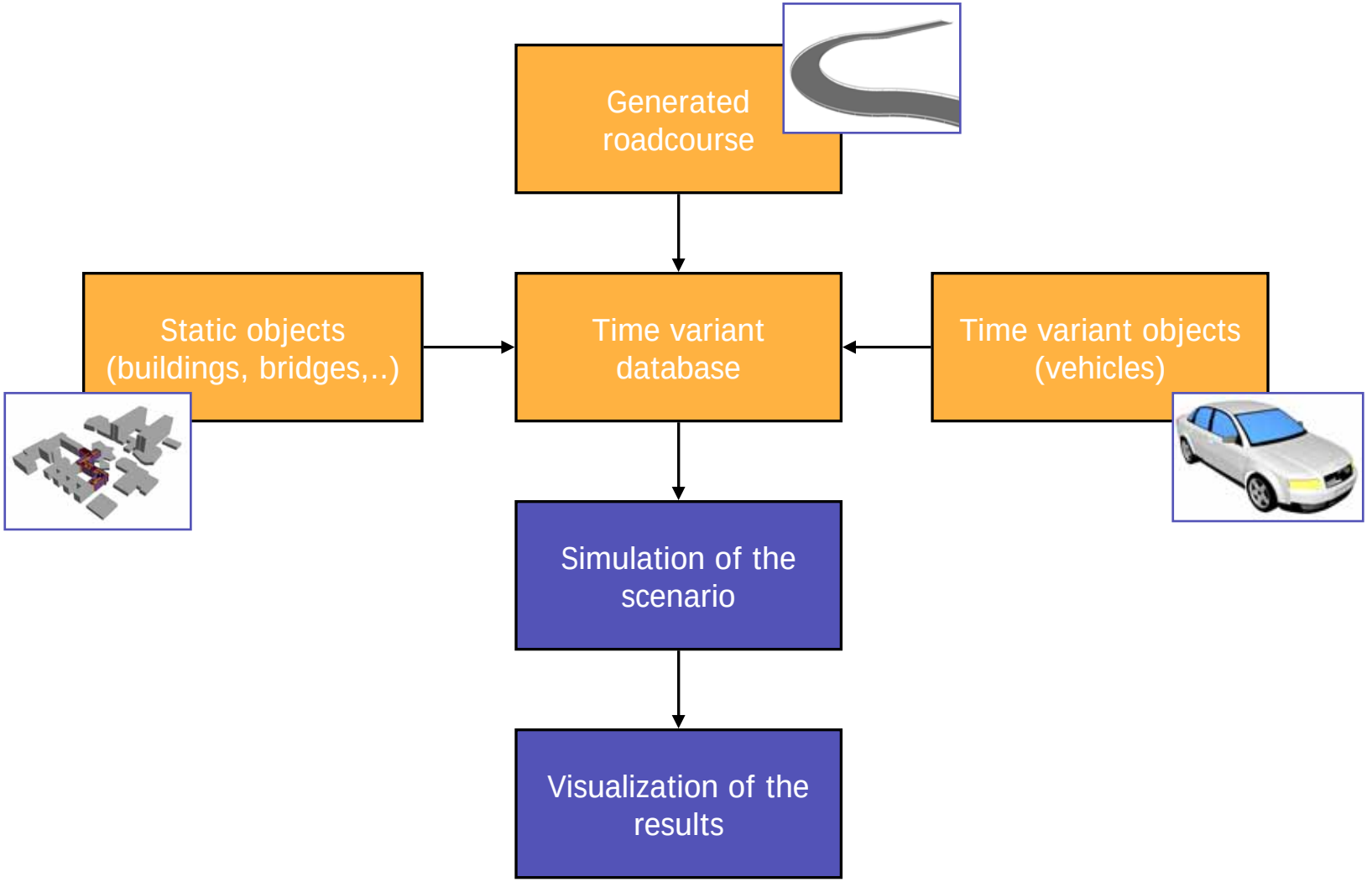


Prediction in a multifloor building

The Requirements to a new Prediction Model for Time Variant Scenarios:

- Consideration of transformation (translation, rotation) of objects in the database during prediction
- Consideration of the Doppler Shift
- Accurate ray optical prediction model
- Acceptable prediction times
- Suitable for urban and indoor scenarios and for enclosed spaces (inside vehicles, tunnels,..)

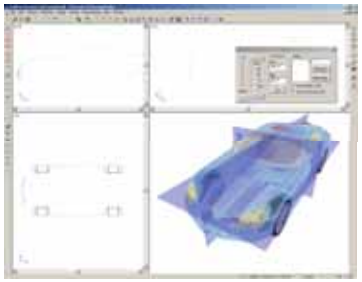
The process for a prediction in time variant scenarios:



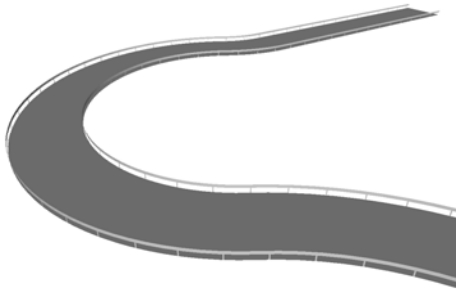
Definition of a scenario:

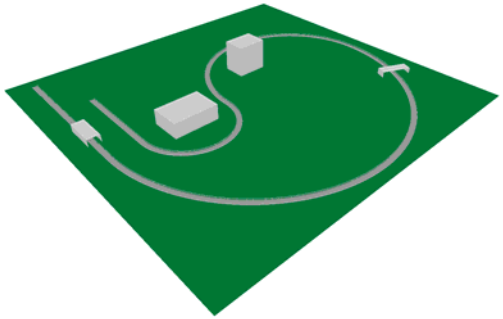
- Import of vehicle databases from common file formats or drawing of own simple vehicles

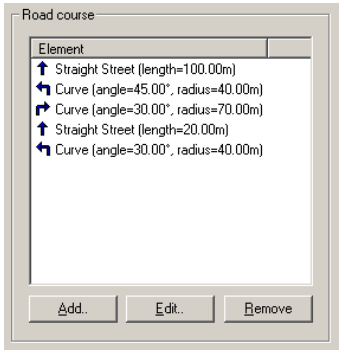
Import



- Automatic generation of arbitrary complex road courses





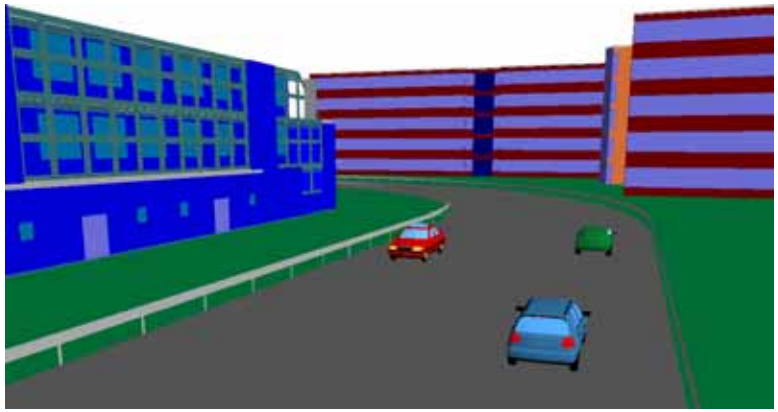


Definition of a scenario:

- Definition of transformation properties for each object

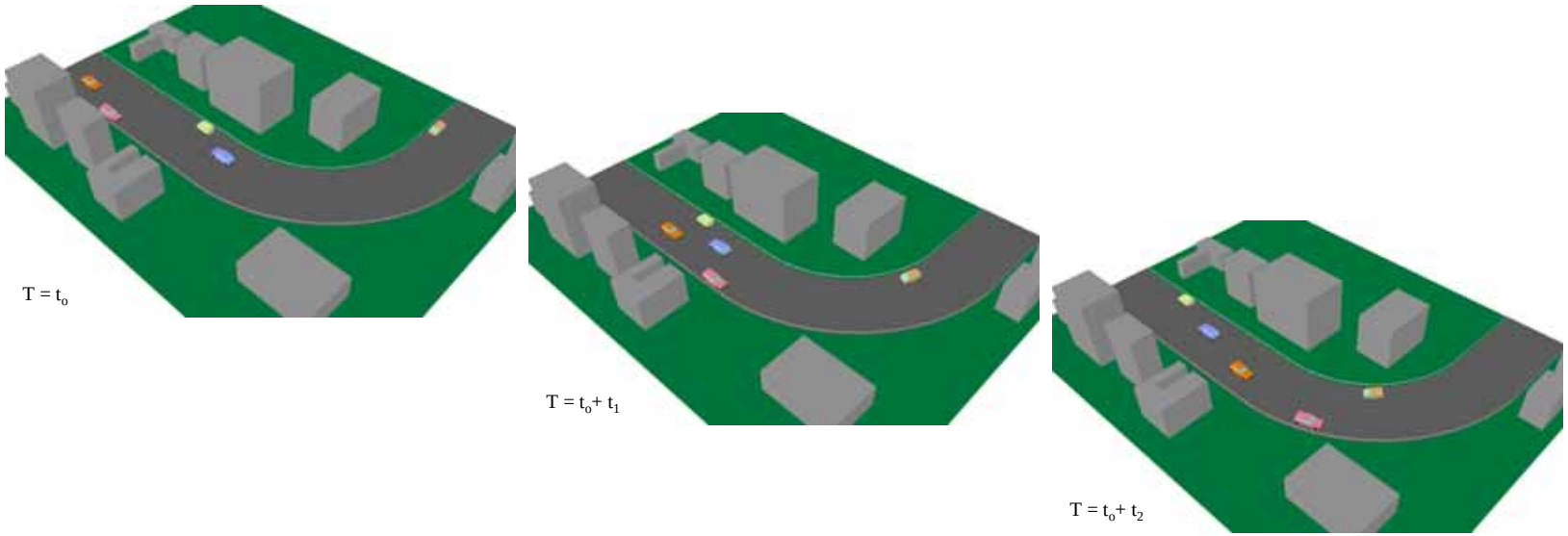
Translation	Rotation
Vector for translation Scalar value for velocity	Center of rotation Angle of rotation for each axis

- Combination of vehicles and road courses to a time variant database



Definition of a scenario:

- Example for a time variant behavior



New Approach for time variant Scenarios (5/6)

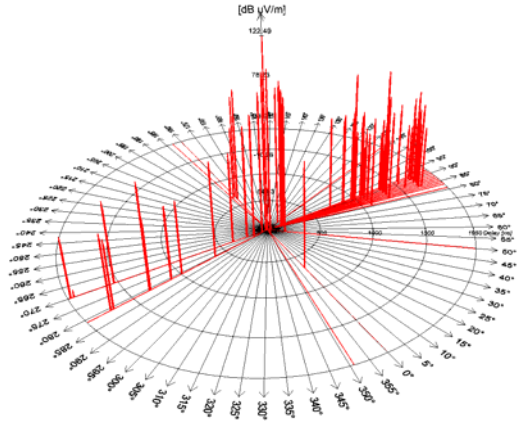
Ray Tracing approach:

- Fresnel Coefficients for reflections and GTD/UTD for diffractions
- Consideration of scattering by division of scatter objects into small tiles
- Suitable for urban and indoor scenarios and for enclosed spaces
- Consideration of Doppler Shift
- Consideration of individual material properties for each polygon/wall

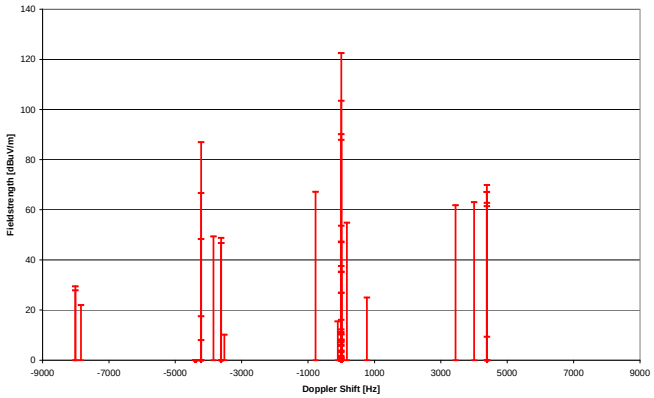
New Approach for time variant Scenarios (6/6)

Computed results:

- Directional Channel Impulse Response (CIR + DoA)
- Propagation paths for each receiver location
- Doppler Shift for each propagation path
- 3D View of scenario for all time stamps computed



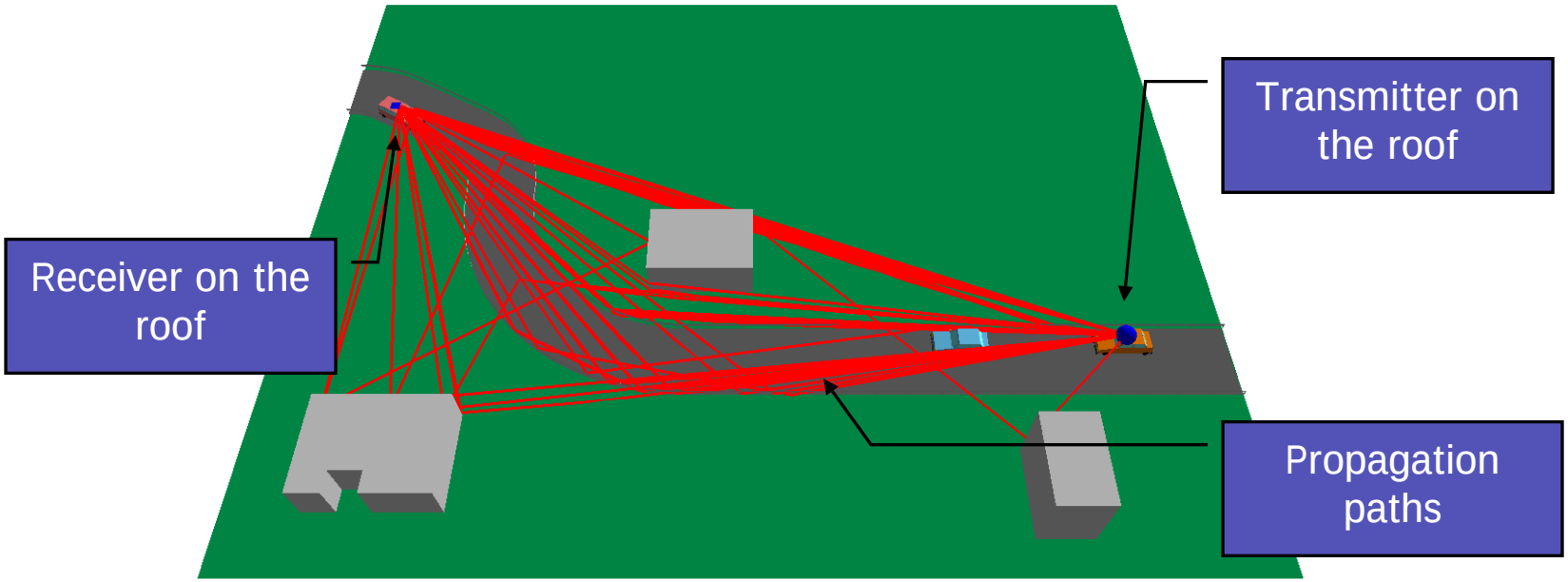
Example for directional CIR



Example for Doppler Shift

Car-2-Car Communication Scenario:

- Transmitter (3.4 GHz, 30 dBm) and receiver mounted at the roofs of vehicles
- Predictions for snapshots with constant time intervals
- All cars in motion



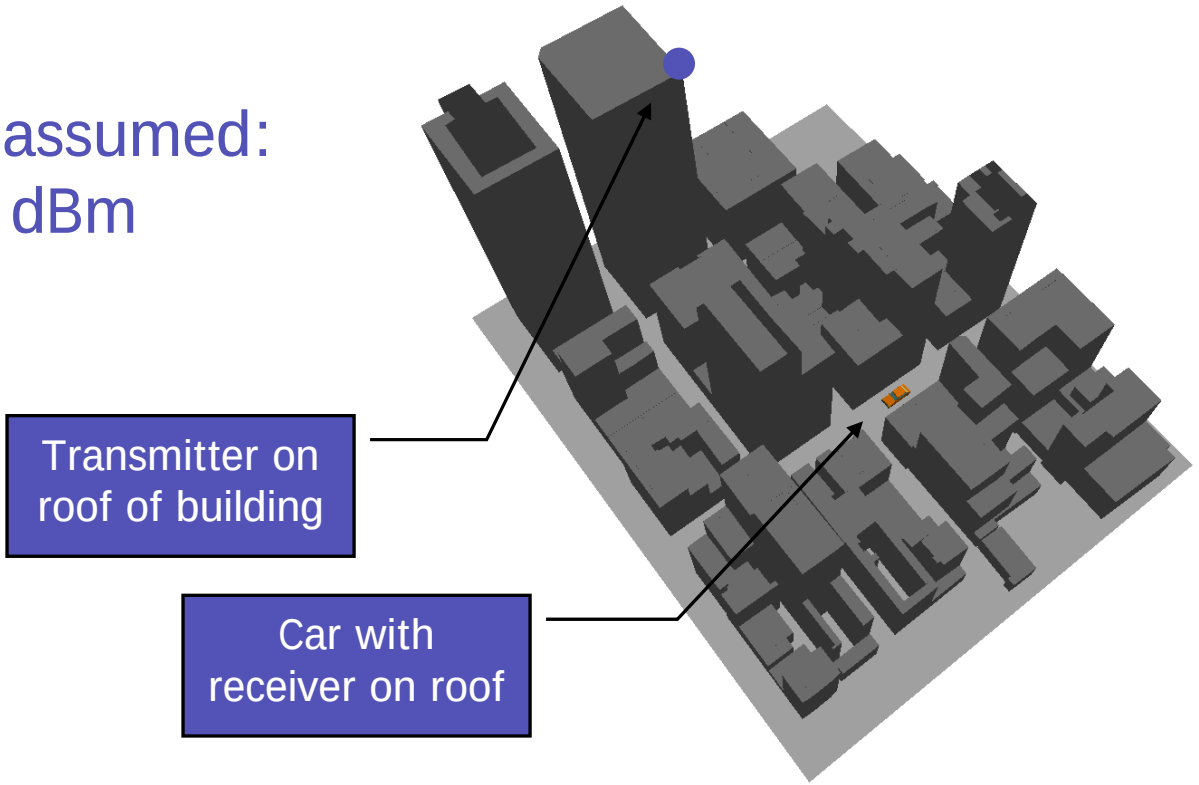
Car-2-Car Communication Scenario:

- Computed results:
  - CIR for a period of time
  - Doppler Shift for a period of time

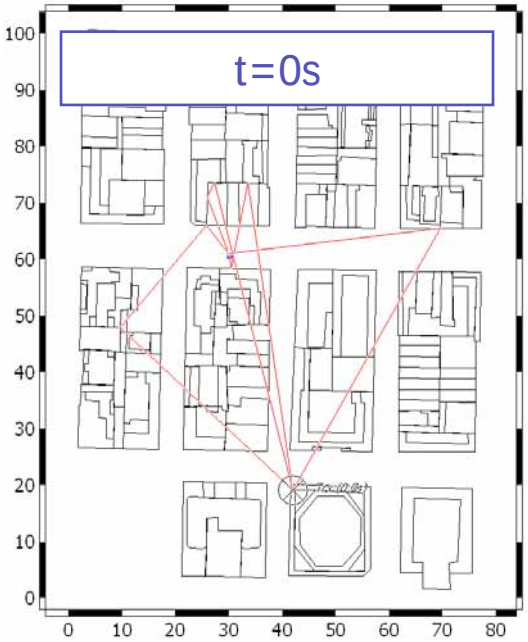
TODO

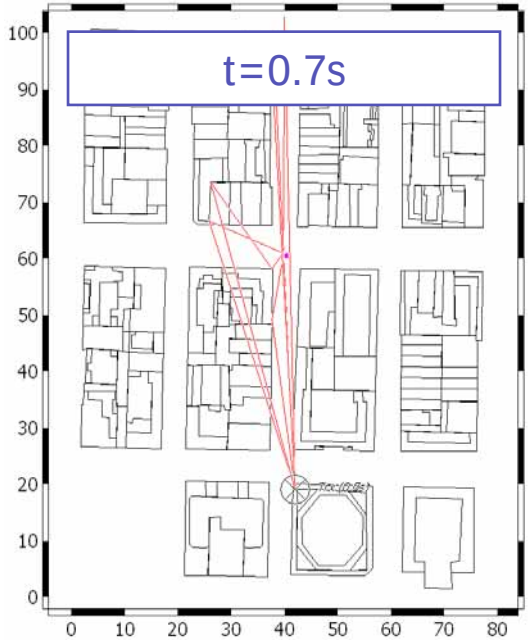
UMTS Communication Scenario:

- Transmitter mounted on a high building
- Receiver mounted at the roof of a car, driving on a wide street
- UMTS band assumed:
  2.2 GHz, 40 dBm



UMTS Communication Scenario:





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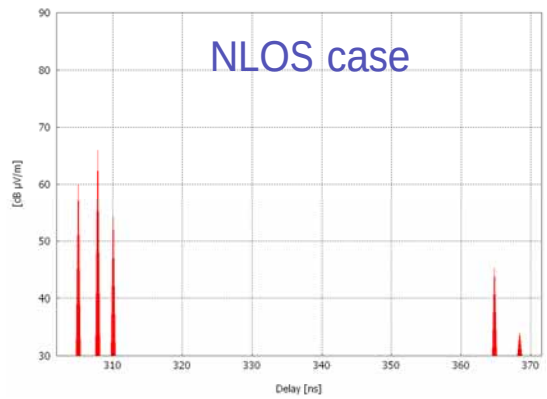
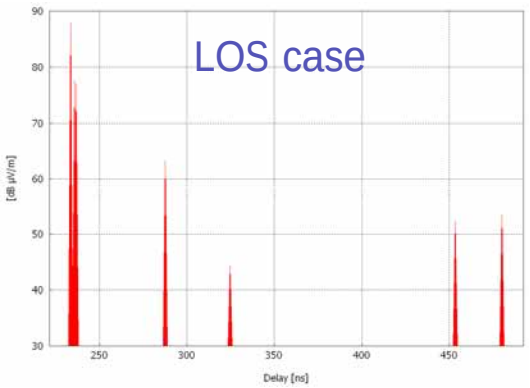
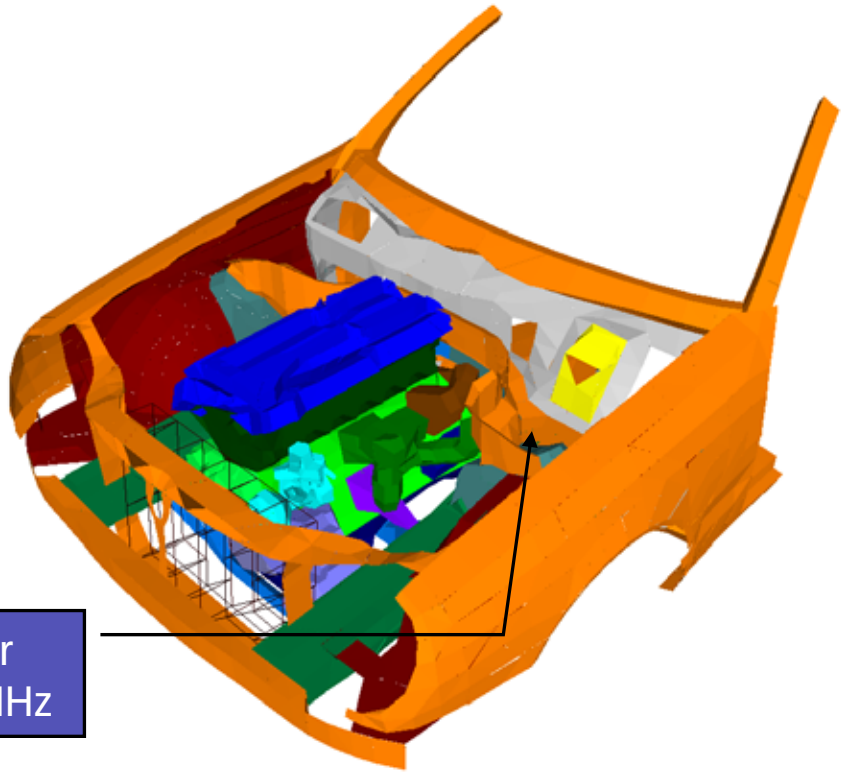


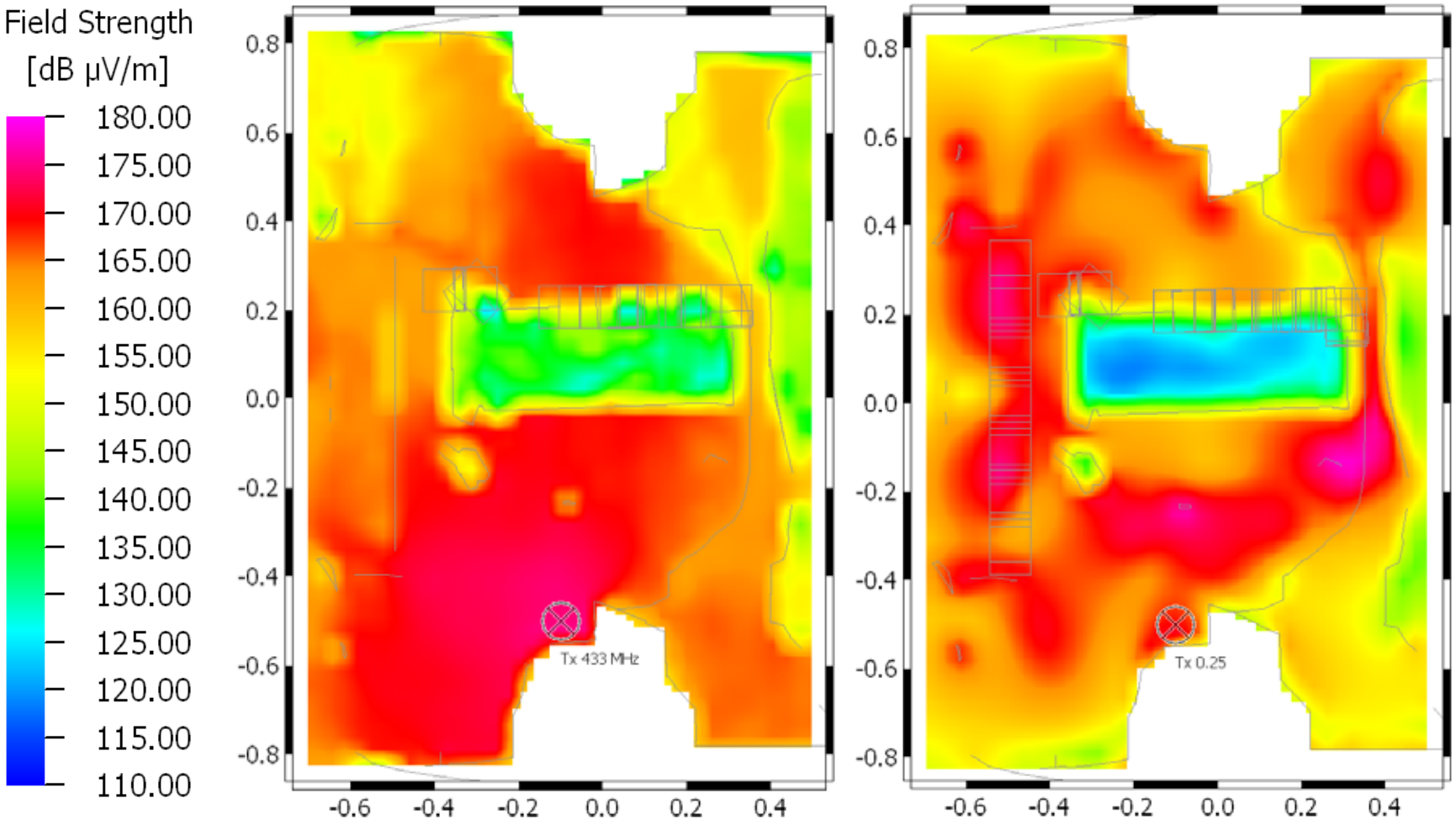


Communication Scenario inside a Vehicle:

- Computation inside engine compartment of a car
- Conditions for ray optical prediction models not completely fulfilled
- Comparison to prediction with MoM (Method of Moments) software tool FEKO



Communication Scenario inside a Vehicle:

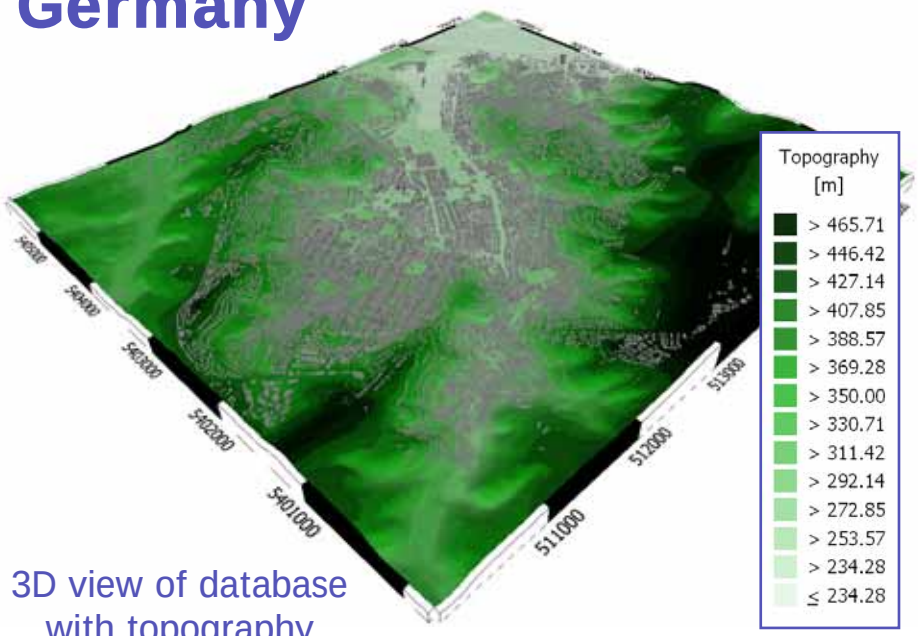


3D Ray Tracing Prediction

FEKO Prediction

Urban Scenario: Stuttgart, Germany

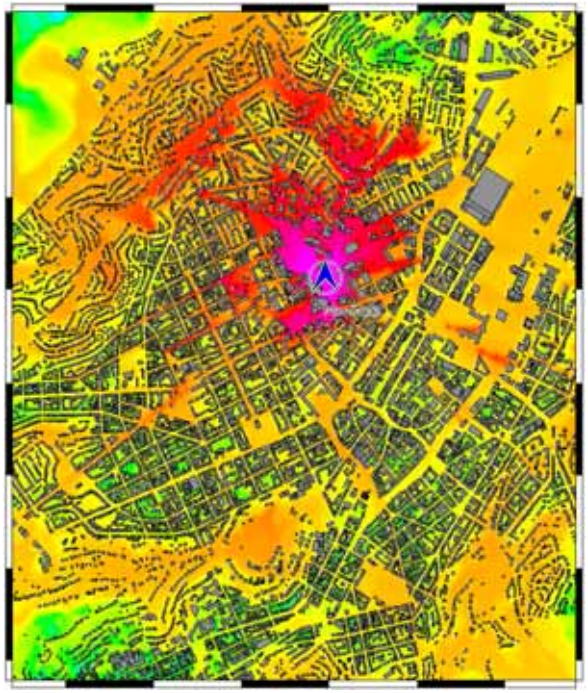
Scenario Information		
Number of buildings		19665
Topo. difference		363 m
Resolution		10 m
Transmitter	Site 1	51 m, 34 dBm, 3.5 GHz
	Site 2	31 m, 34 dBm, 3.5 GHz
	Site 3	48 m, 34 dBm, 3.5 GHz
Prediction height		2.1 m



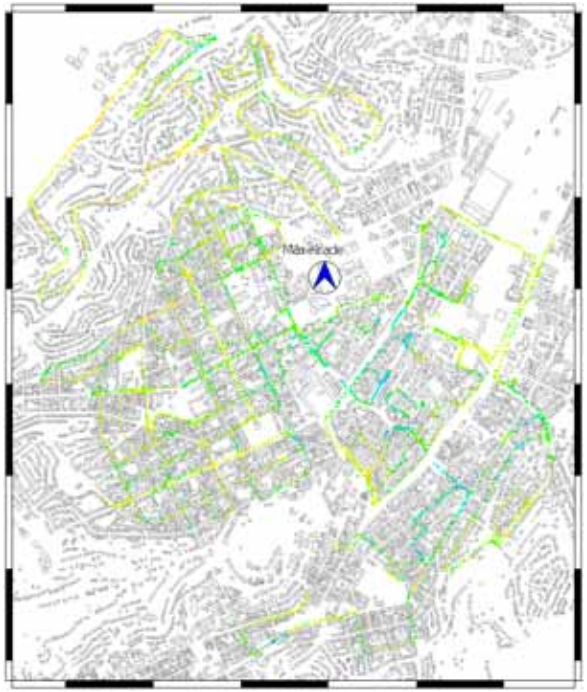
3D view of database with topography

Urban Scenario: Stuttgart, Germany

- Evaluation for transmitter location 1



Prediction with Ray Tracing



Difference of prediction with Ray Tracing and measurements

Tx	Difference	
	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
- ✓ Easy generation of roadcourses
- ✓ Computation of directional channel impulse response and Doppler Shift
- ✓ Successfull validation by comparing prediction results to measurements