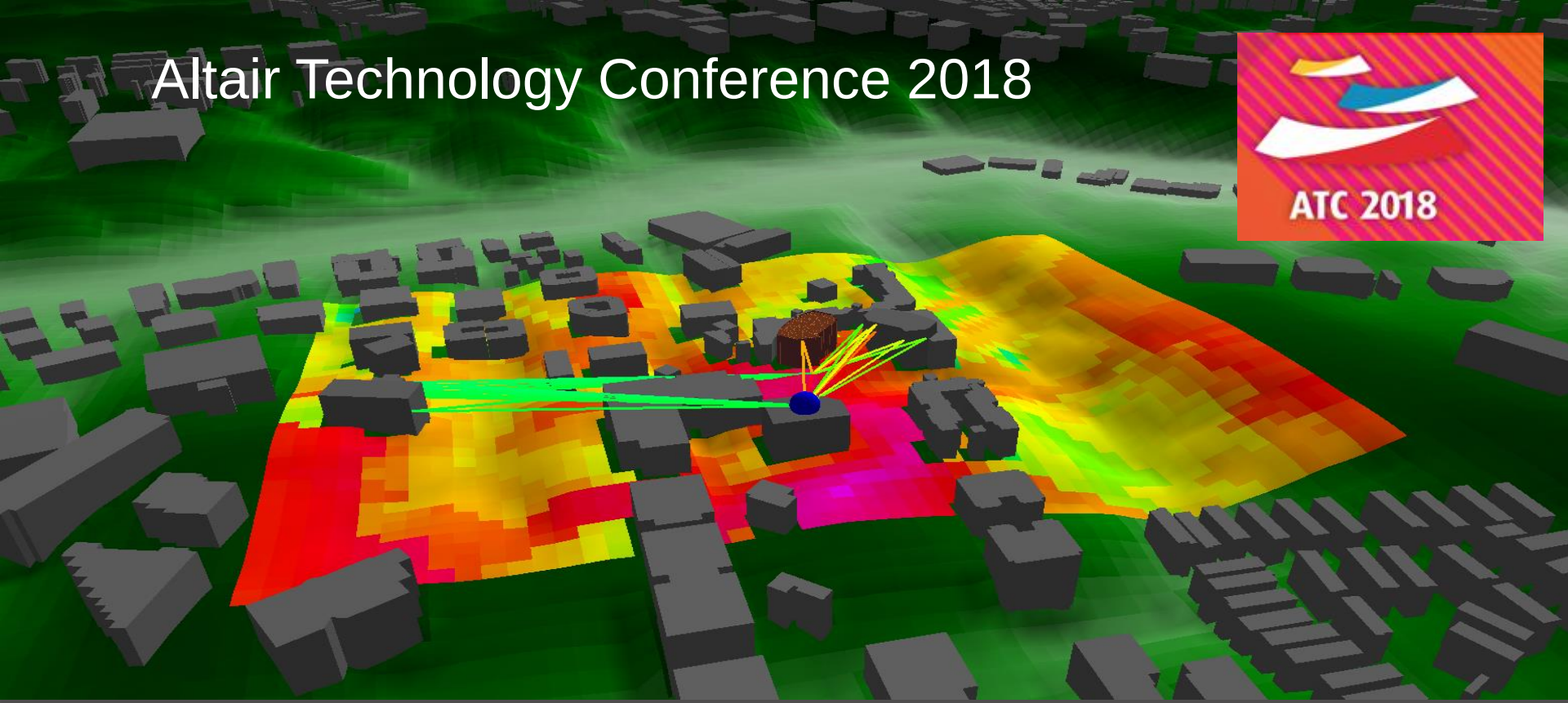

WinProp Radio Channel Simulations for Automotive, Aerospace, Defense, Railway, Telecom

Altair

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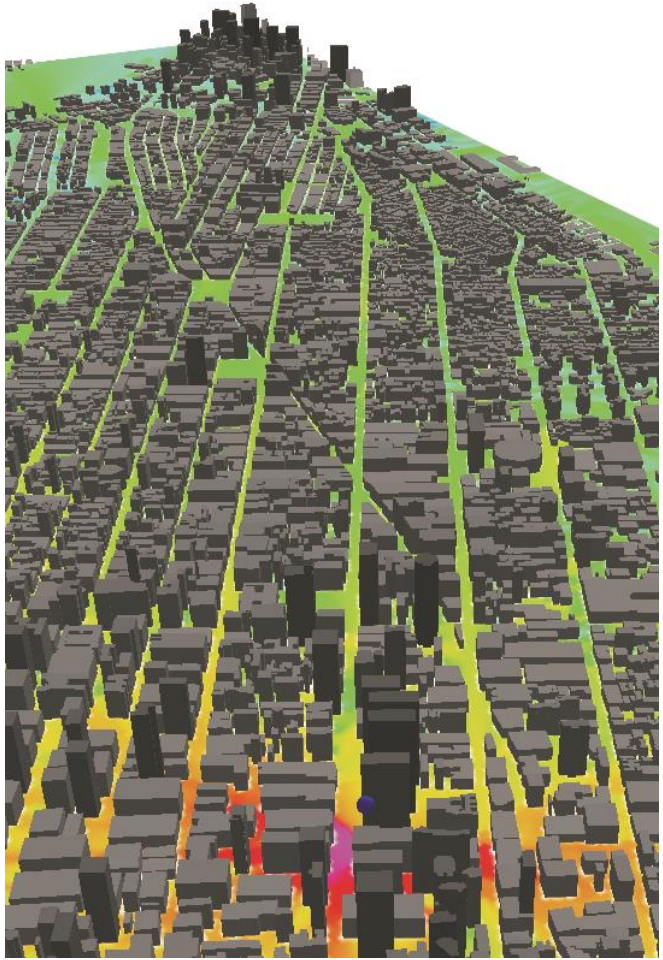
OUTLINE

- WinProp Overview
- Automotive use cases
- Aerospace applications
- Defense use cases
- Railway applications
- Telecom use cases



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WINPROP OVERVIEW

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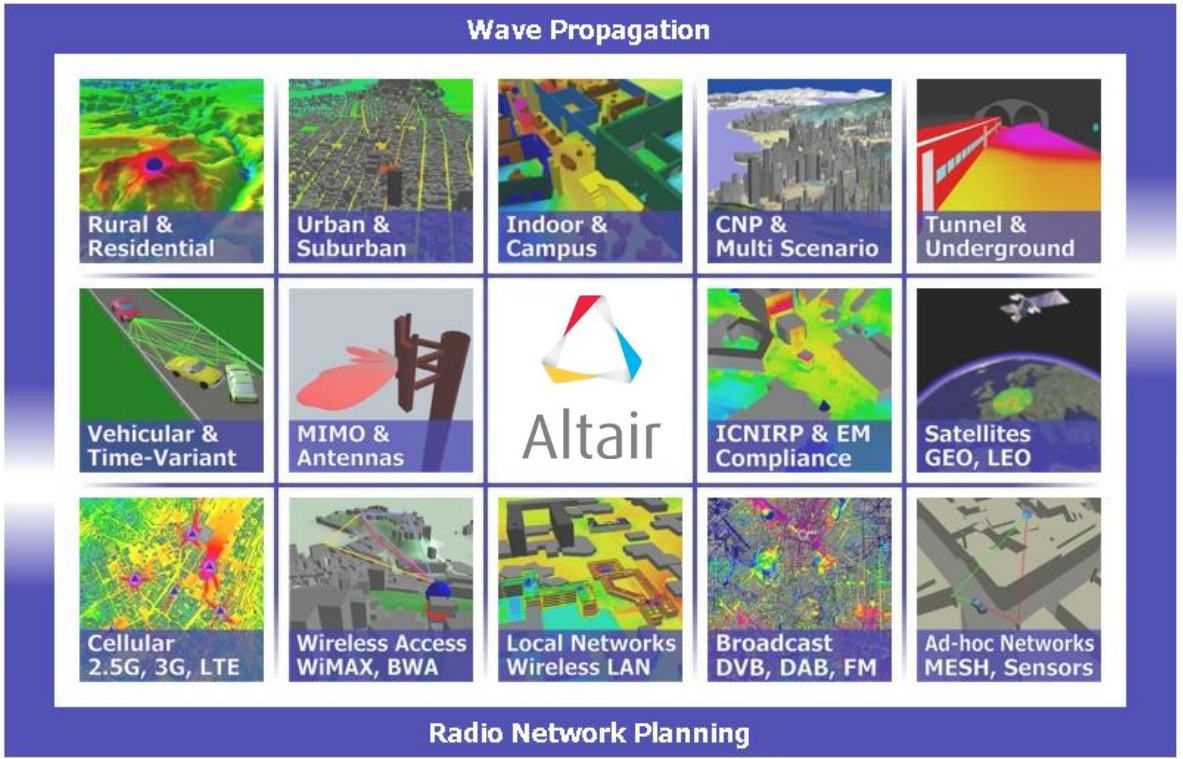
WINPROP OVERVIEW

WinProp Radio Planning Tool

- Wave propagation models for various scenarios:
  - Rural, urban, indoor, tunnel, …
  - Ray tracing & dominant path models
  - Highly accurate and fast
- Radio planning for various systems
  - Mobile cellular
  - WiFi
  - Broadcasting
- Separate tools for 3D vector data incl. materials and antenna handling
- WinProp API allows integration into other software tools



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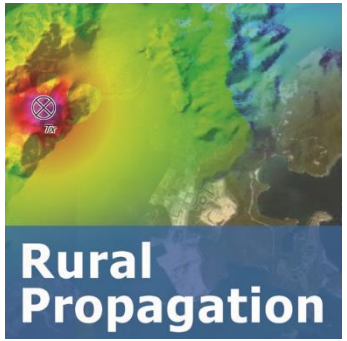
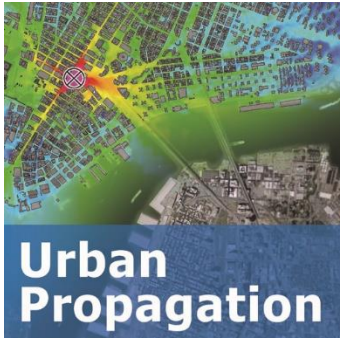
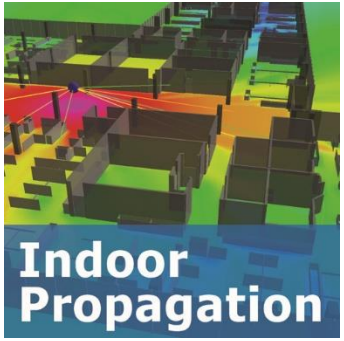
INDIVIDUAL PROPAGATION MODELS FOR VARIOUS SCENARIOS

			
Databases	Topography pixel data	2.5D building vector data	3D vector data
Optional Data	Clutter losses / heights Ground properties	Material properties Topography pixel data Vegetation objects	Material properties Subdivisions, furniture
Propagation Models	Empirical models (Hata, ITU,…) Vertical plane models **Dominant path model** ***3D Standard Ray Tracing (SRT)***	Vertical plane models (WI) **Dominant path model** ***3D Intelligent Ray Tracing (IRT)***	Direct ray models (Multi-Wall) **Dominant path model** ***3D Ray Tracing SRT/IRT***

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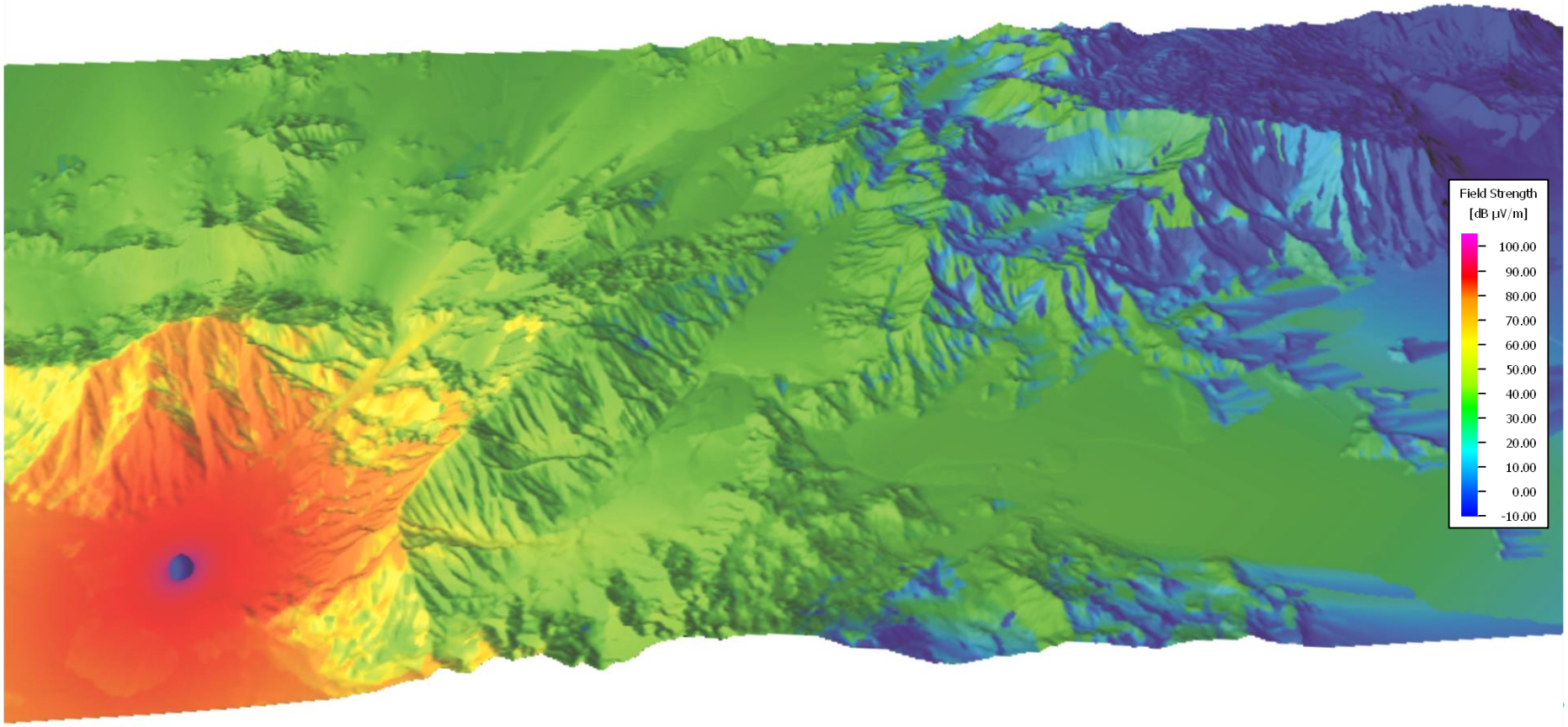
RURAL PROPAGATION MODELS



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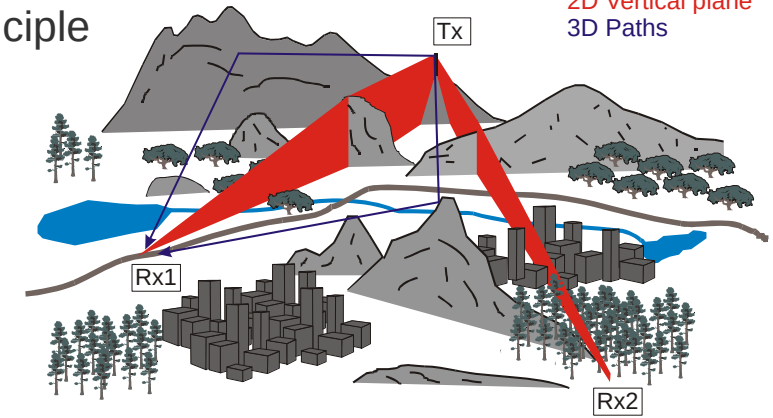
RURAL SCENARIOS – WAVE PROPAGATION MODELS

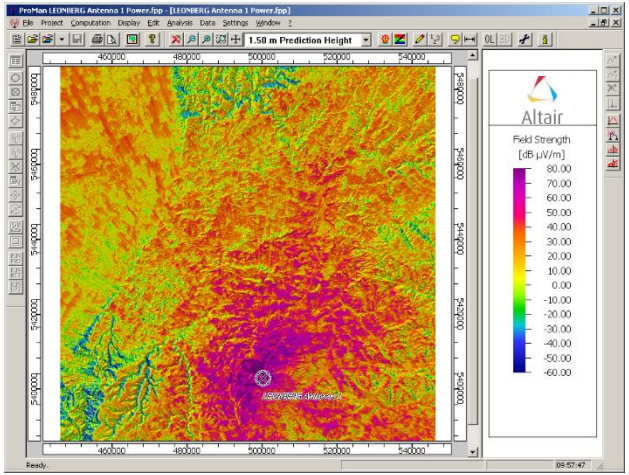
Propagation models for rural:

- Hata-Okumura, Longley-Rice, ITU, Two ray models
- 2D vertical plane model for topographical impact

Principle

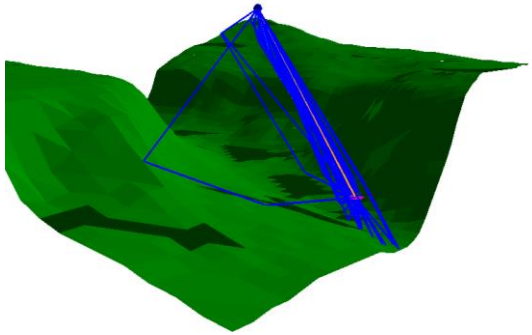


Example of DAB transmitter



Propagation phenomena to be considered:

- Distance dependency
- Multiple diffractions in vertical plane
- Frequency dependent diffraction loss due to clutter
- Scattering and/or reflections at topography



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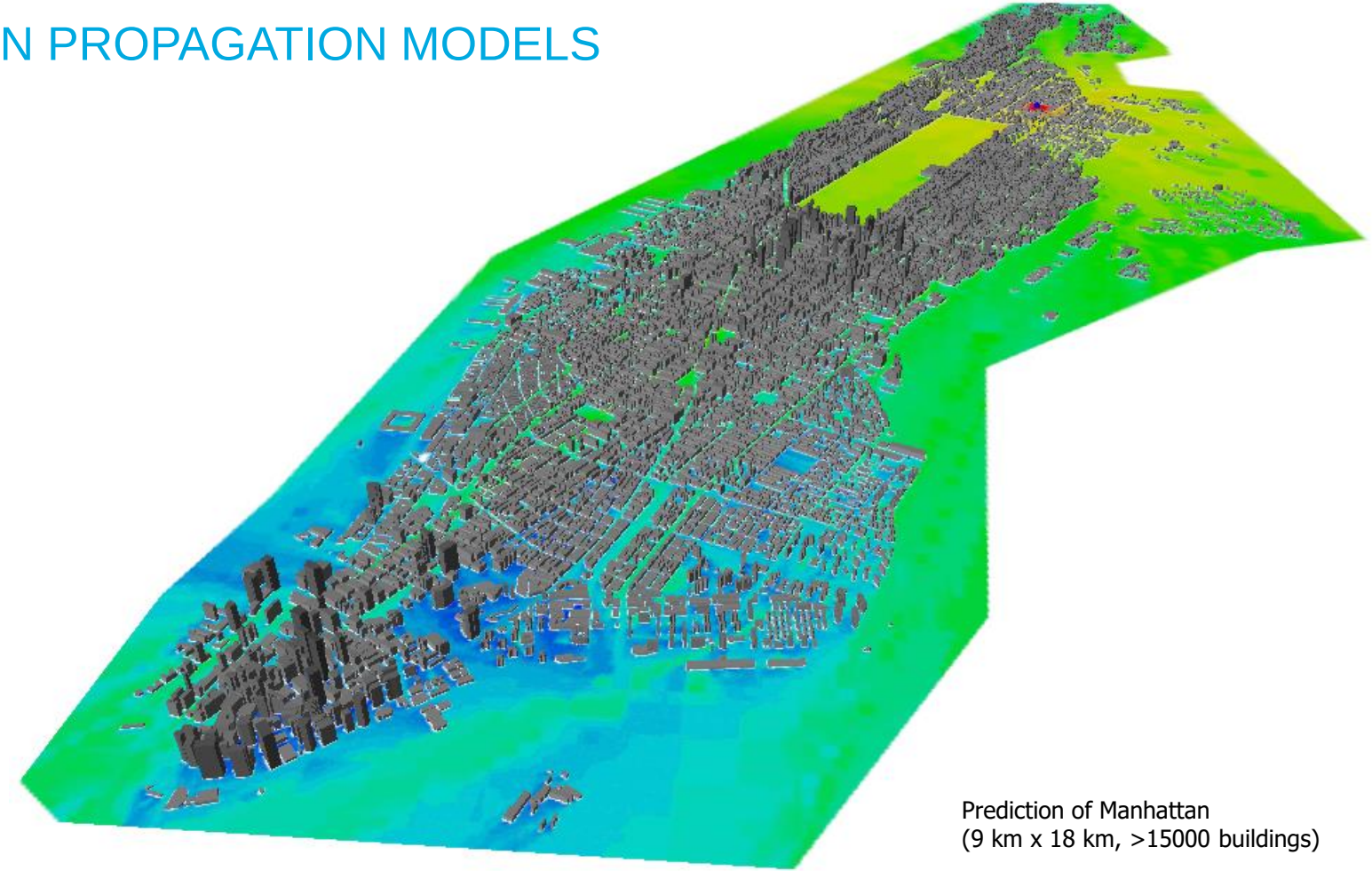
URBAN PROPAGATION MODELS



Prediction of Manhattan
(9 km x 18 km, >15000 buildings)

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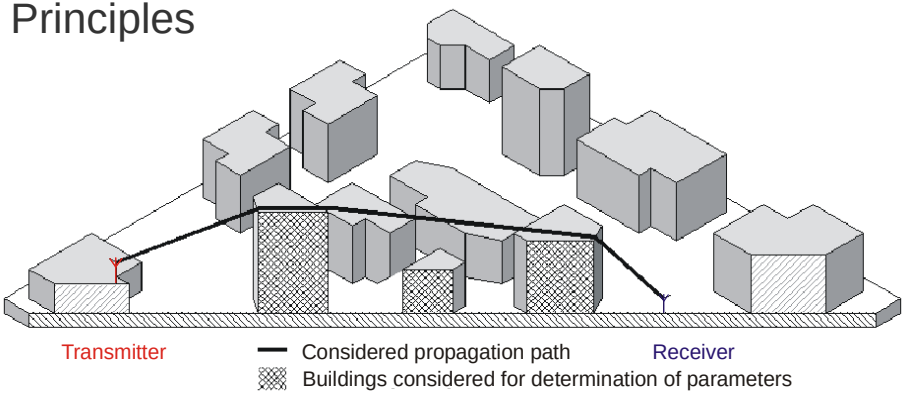
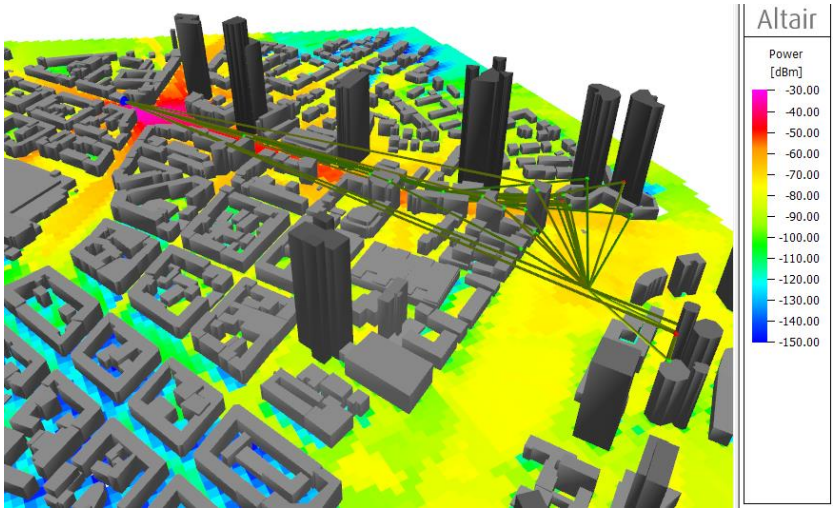
URBAN SCENARIOS – WAVE PROPAGATION MODELS

Propagation models for urban:

2D vertical plane or Full 3D WinProp Ray Tracing/DPM

Principles





Propagation phenomena to be considered:

- Distance dependency
- Multiple reflections at walls
- Multiple diffractions at vertical and horizontal wedges
- Loss due to paths inside vegetation objects

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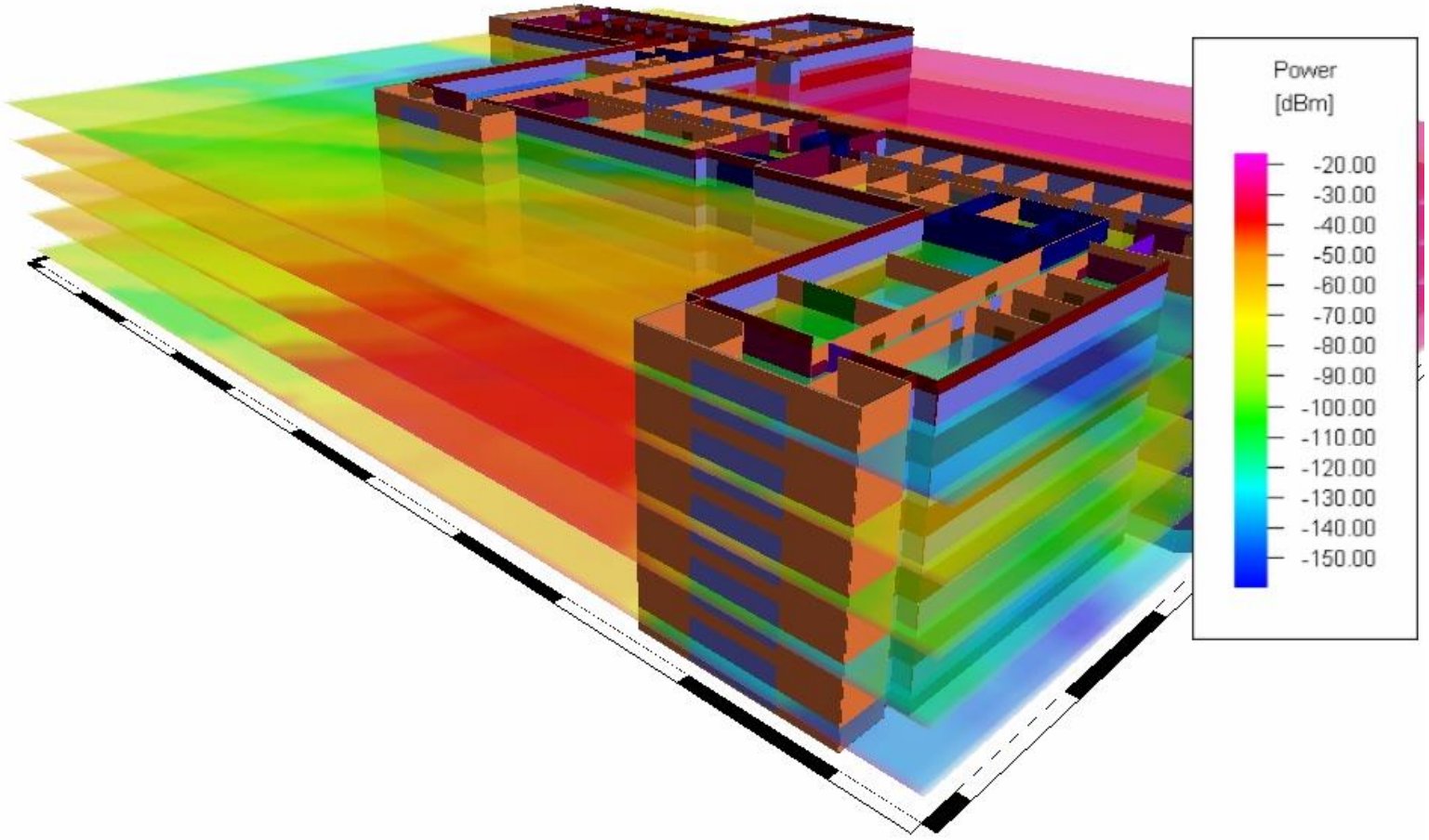
INDOOR PROPAGATION MODELS



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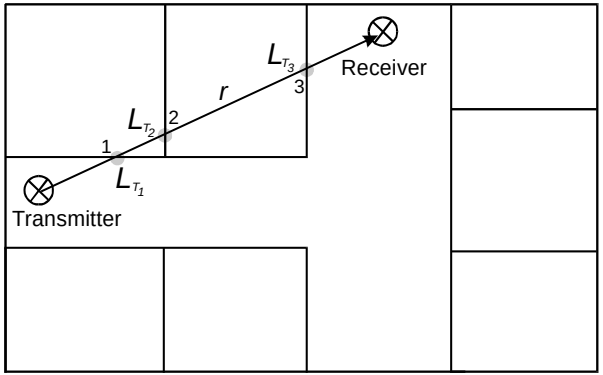
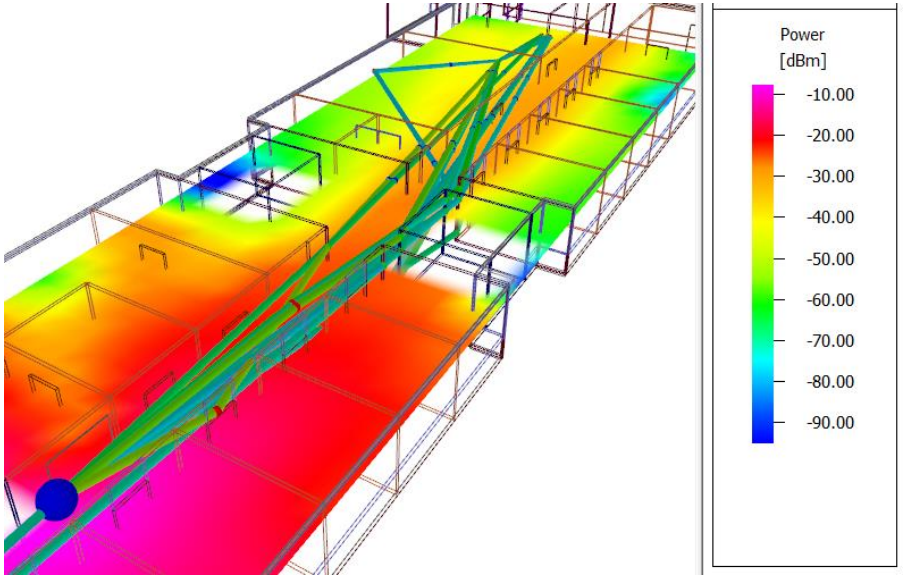
INDOOR SCENARIOS – WAVE PROPAGATION MODELS

Propagation models for indoor:

Direct Ray or Full 3D WinProp Ray Tracing / DPM

Principles





Propagation phenomena to be considered:

- Distance dependency
- Transmission (penetration) through walls
- Multiple reflections
- Multiple diffractions
- Scattering

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AUTOMOTIVE USE CASES

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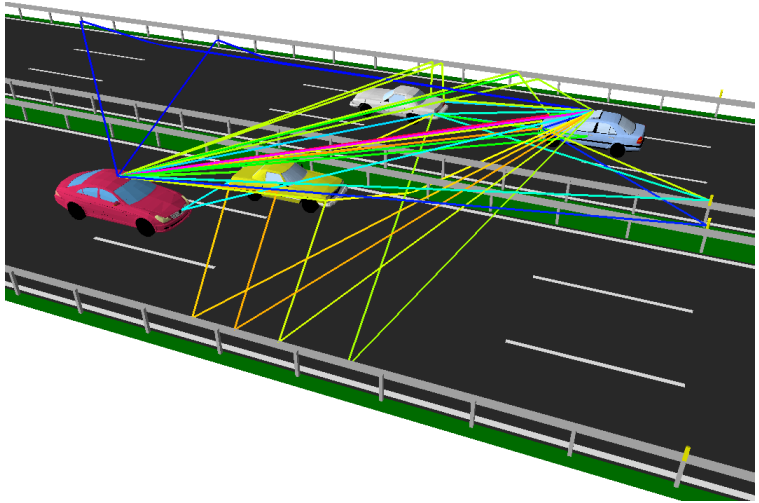
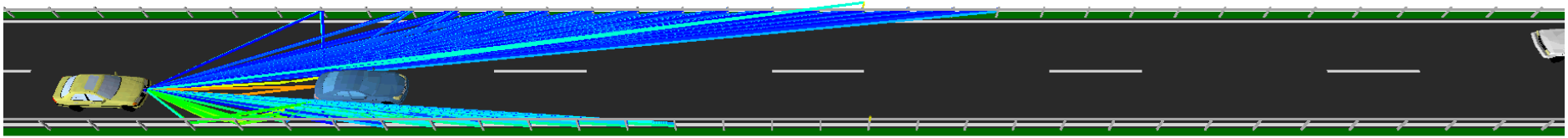
AUTOMOTIVE USE CASES

Relevant Scenarios

- Car-2-Car Communication
- Car-2-Infrastructure Communication



- Radar channel (e.g. collision avoidance)



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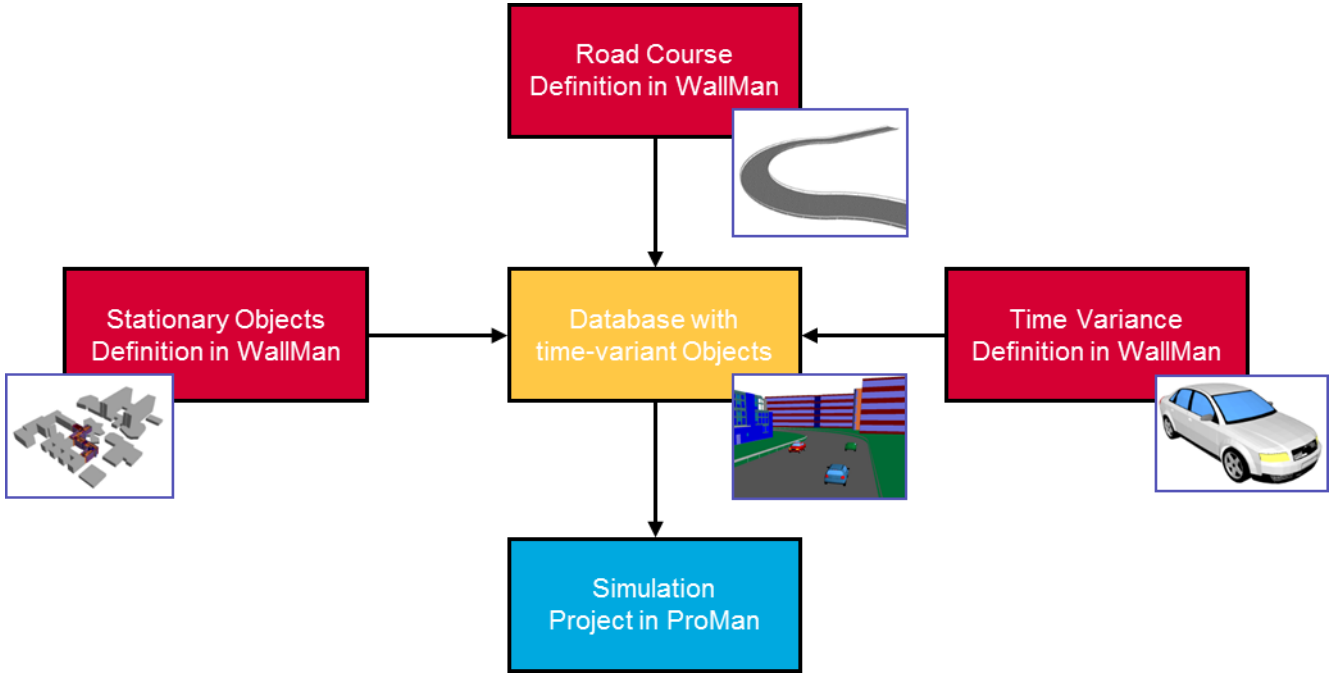
AUTOMOTIVE VIRTUAL-DRIVE TESTS

Definition of Scenarios



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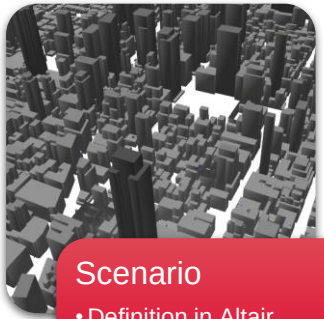
AUTOMOTIVE VIRTUAL-DRIVE TESTS

Car-2-Infrastructure: LTE Car Antenna Evaluation by Virtual-drive Tests

- Definition of scenario (highway, urban, … possibly with cars, real test route)
- Selection of air interface, definition of cell load for interference
- Computation of radio waves impinging on car antenna along trajectory
- Superposition of 3D car antenna patterns (computed with FEKO)
- Evaluation of possible antenna configurations based on performance indicators



Scenario

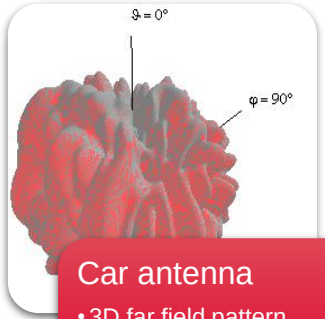
- Definition in Altair WinProp Tool WallMan
- Buildings, topography, optionally cars
- Conversion from different formats
- Superposition of different layers

Air interface

- Selection in Altair WinProp Tool ProMan
- Car-2-Car
- Car-2-X
- Transmission modes
- Cell load for interference consideration

3D Ray Tracing

- Simulation in Altair WinProp ProMan
- Computation of receiving situation at car antenna along trajectory
- File with computed ray paths
- Per frequency band



Car antenna

- 3D far field pattern
- Computed with FEKO
- Superposition in WinProp Tool ProMan based on file with ray path data
- Evaluation performance
- Antenna combinations

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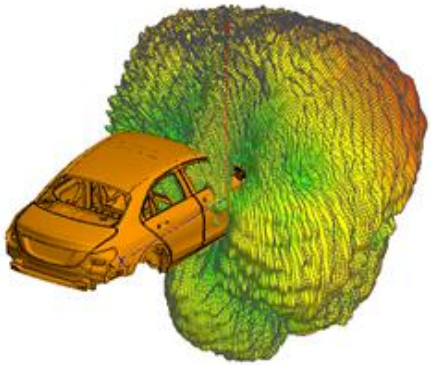
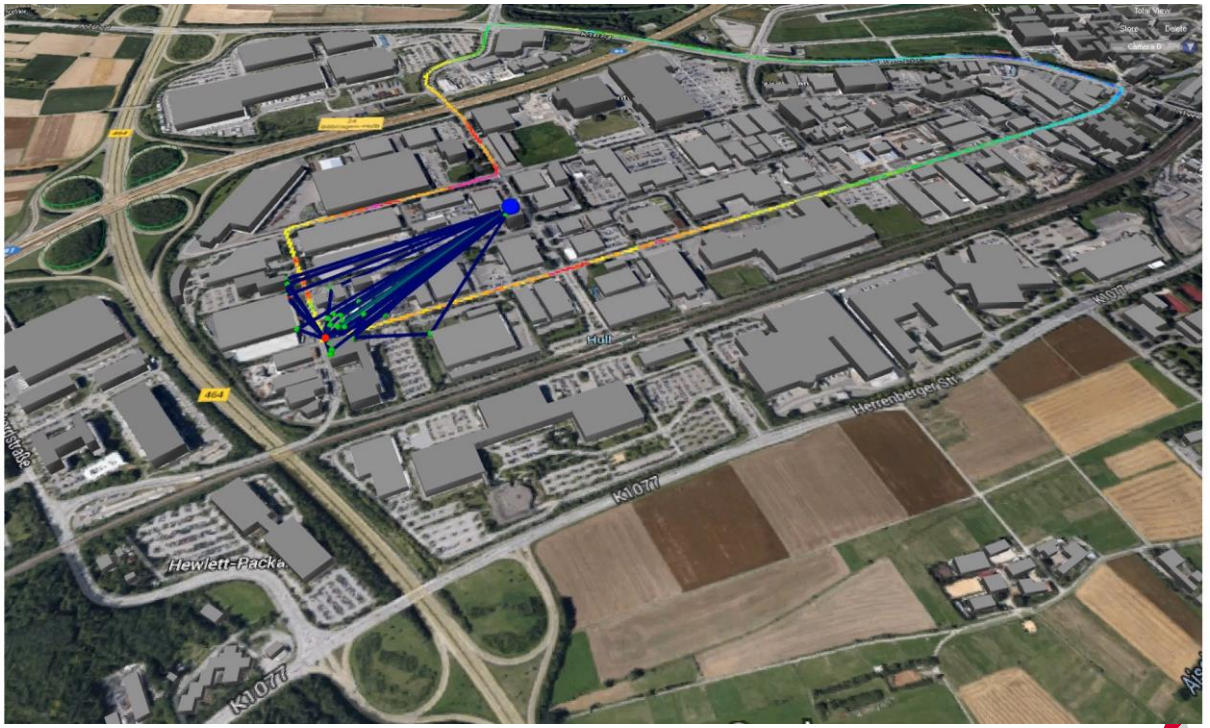
AUTOMOTIVE VIRTUAL-DRIVE TESTS

Car-2-Infrastructure: LTE Car Antenna Evaluation by Virtual-drive Tests

- Test drive in suburban scenario with about 5 km length around LTE base station
- Evaluation of different car antenna configurations regarding Rx power and MIMO throughput





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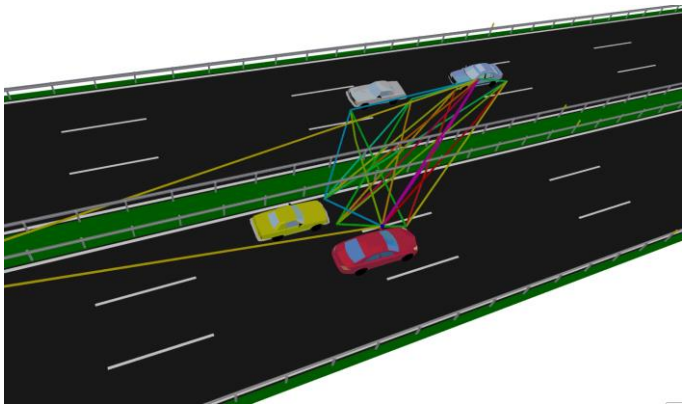
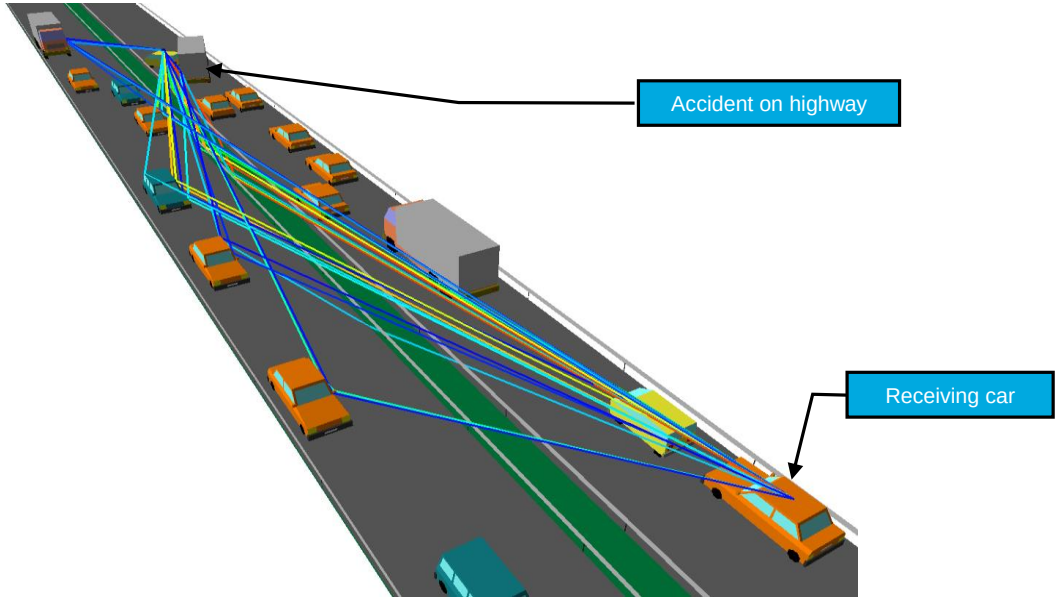
AUTOMOTIVE VIRTUAL-DRIVE TESTS

Car-2-Car Communication I

- E.g. automatic hazard warning
- Transmission of messages from one car to another based on IEEE 802.11p
- Receiving car indicates imminent hazard to driver
- Autonomous action of car possible





Car-2-Car Communication II

- Analysis of connectivity and coverage in Car-2-Car network
- Evaluation of antenna performance

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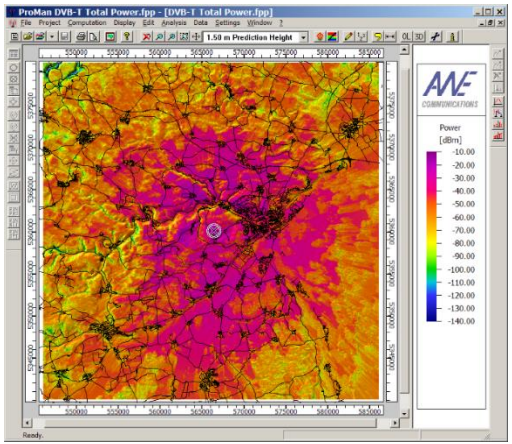
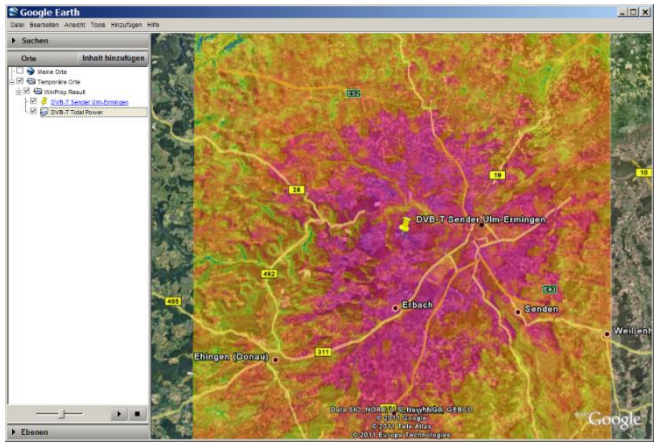
AUTOMOTIVE VIRTUAL-DRIVE TESTS

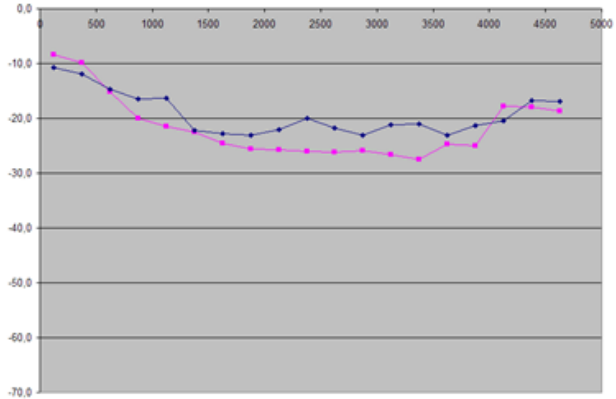
Broadcasting

- Prediction of signal levels for broadcasting transmitters
- Broadcasting channels between 482 and 650 MHz
- Rural scenarios described by topographical and clutter data





Comparison: Rx power [dBm] over distance [m]
simulation in red / measurement in blue



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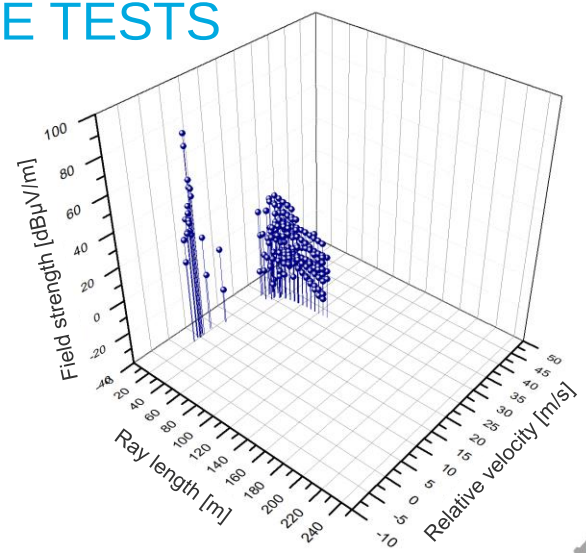
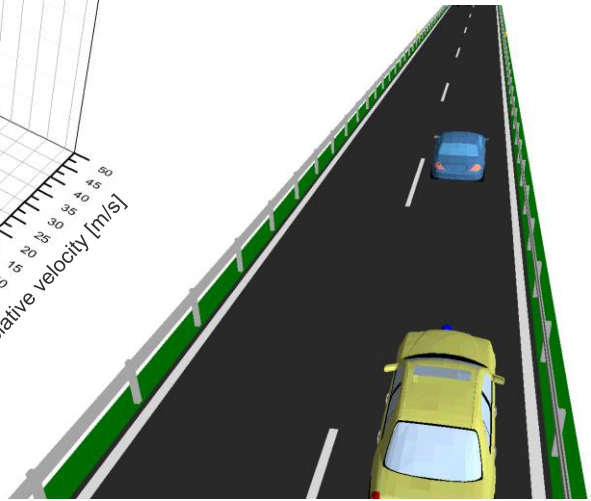
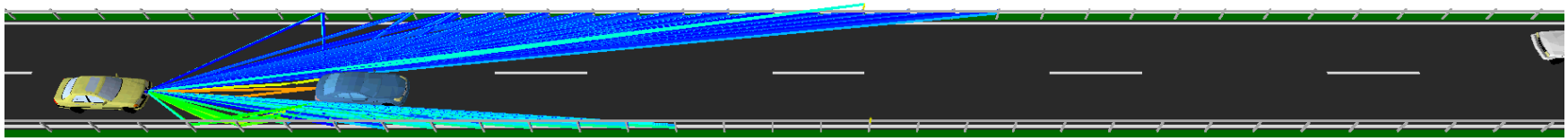
AUTOMOTIVE VIRTUAL-DRIVE TESTS

Radar for Adaptive Cruise Control (ACC)

- Adaptive cruise control (ACC) systems allow the detection of obstacles in front of the car
- Yellow car overtakes although another car approaches
- Computation of field strength, delay and Doppler shift for each ray
- Analysis of received ACC signal for detection of oncoming car
- Evaluation of results for duration of 3.5 seconds







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AEROSPACE APPLICATIONS

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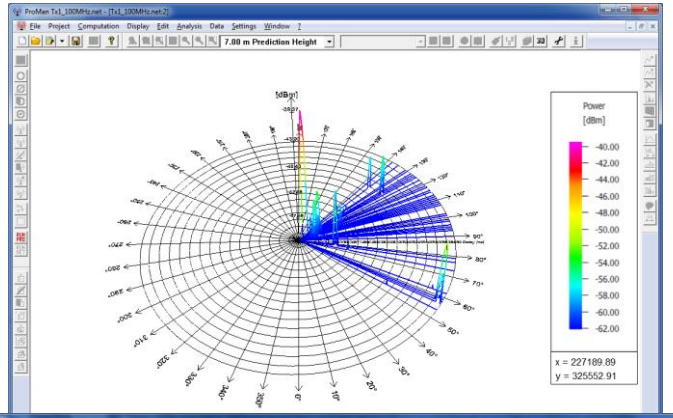
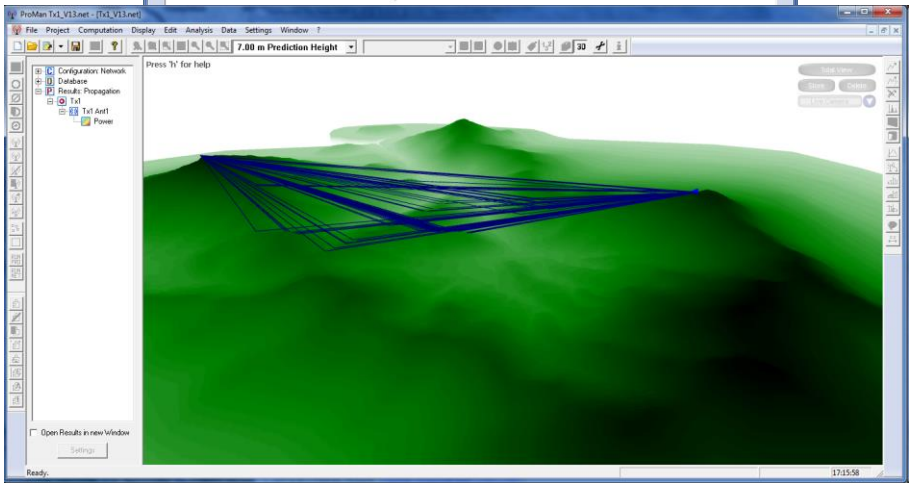
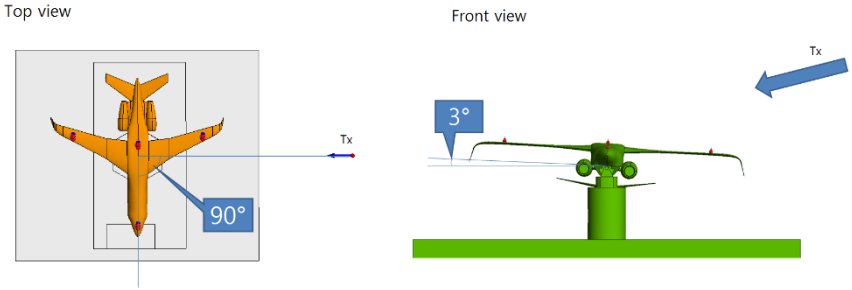
AEROSPACE APPLICATIONS

Installed Antenna Performance

- Radio channel over topographical/clutter scenario (or scenarios with buildings, aircrafts, …)
- Usage of 3D ray tracing model including scattering
- Provision of 3D radio channel properties including antenna effect
- Evaluate different antenna placement strategies
- Wide frequency range (30 MHz up to 100 GHz)







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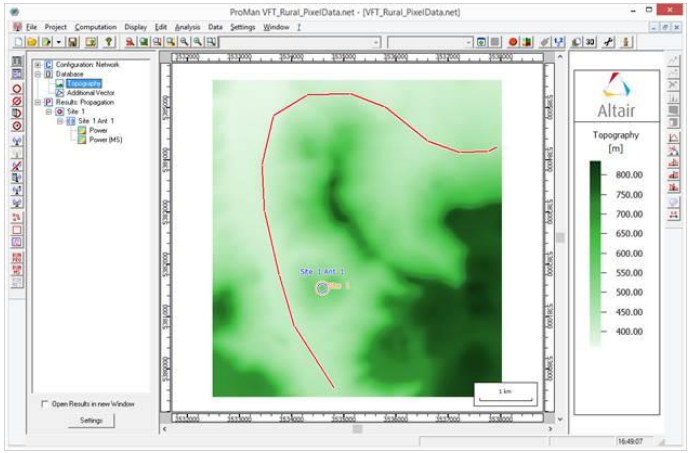
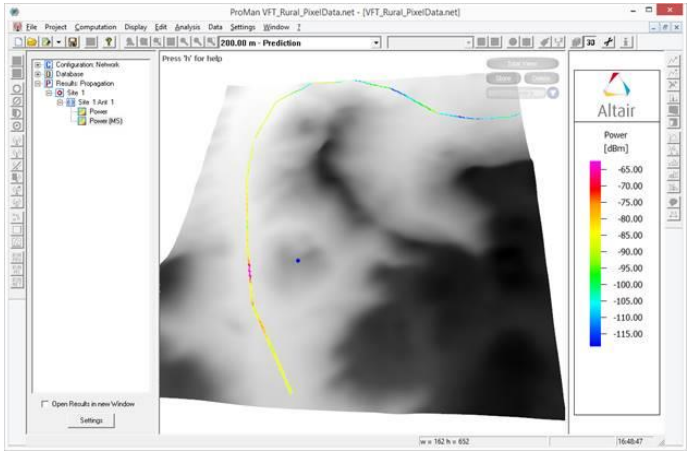
AEROSPACE APPLICATIONS

Installed Antenna Performance

- Virtual flight / drive test in topographical/clutter scenario (or scenarios with buildings, …)
- Define trajectory (so far with constant height above ground only)
- Evaluate received power levels and coverage range along trajectory
- Usage of ray tracing or single path propagation model (e.g. DPM)





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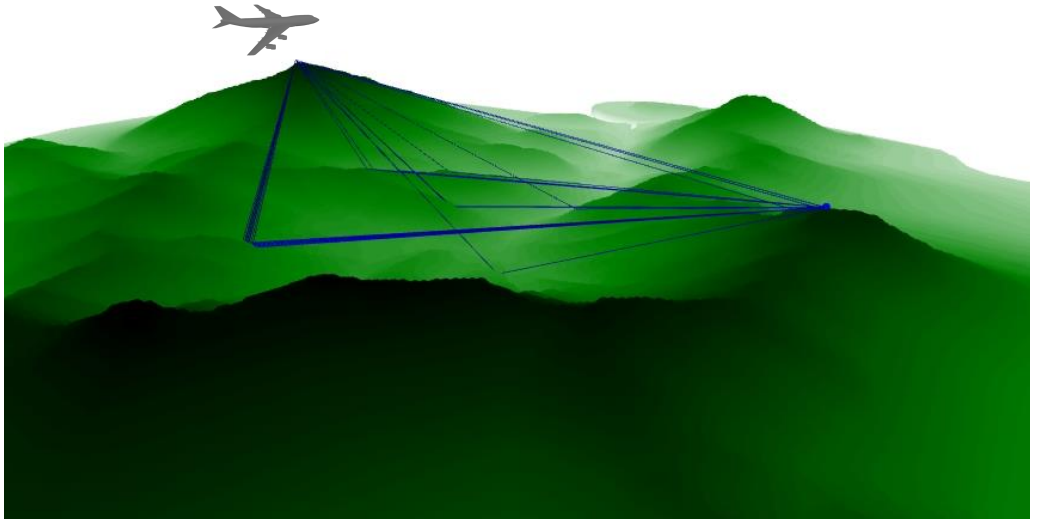
AEROSPACE APPLICATIONS

Multipath Impairments for Navigation Systems

- Radio channel over topographical/clutter scenario
- For different technologies:
  - DME – Distance Measurement Equipment
  - VOR/DVOR – (Doppler) VHF Omni Radio Range
- Impact due to topography, wind turbines, nearby buildings, etc.
- Usage of 3D ray tracing model including scattering at ground
- Provision of 3D radio channel properties with amplitude, delay/phase per contribution including antenna effect
- Evaluate different deployment strategies



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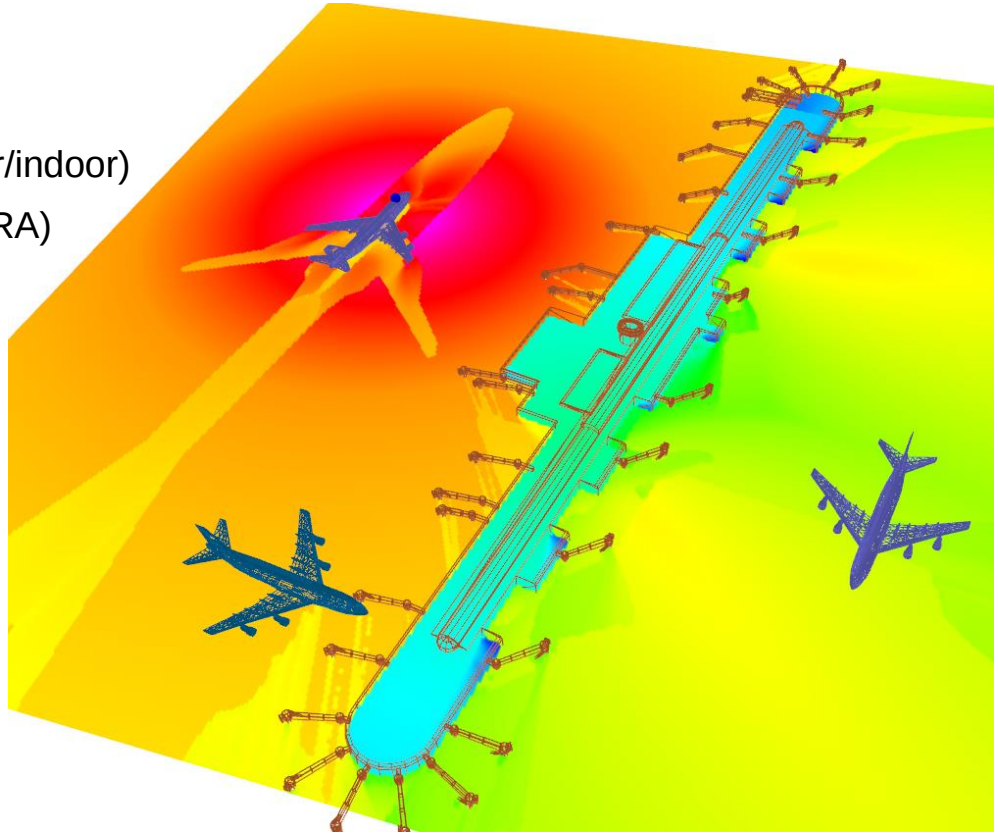
AEROSPACE APPLICATIONS

Aerospace Scenarios

- Radio coverage within airport, terminals (outdoor/indoor)
- For different kinds of radio networks (PMR, TETRA)
- Consideration of complex scenarios feasible (with buildings, aircrafts, vehicles, …)
- Evaluate different deployment strategies
- Analyze interference between different radio systems (co-existence studies)
- Wide frequency range (30 MHz up to 100 GHz)
- Material catalogue with properties for typical construction materials



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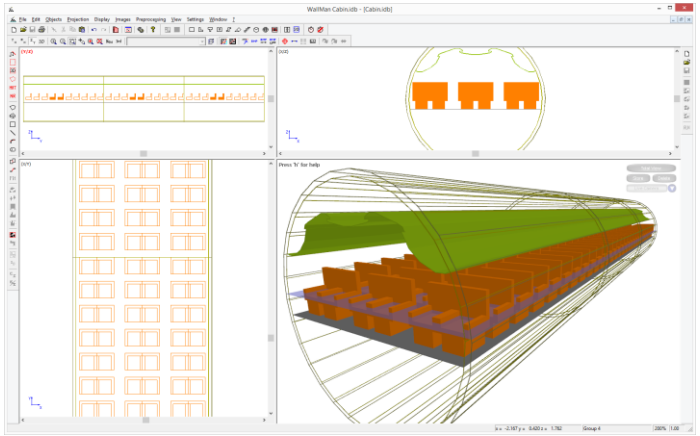
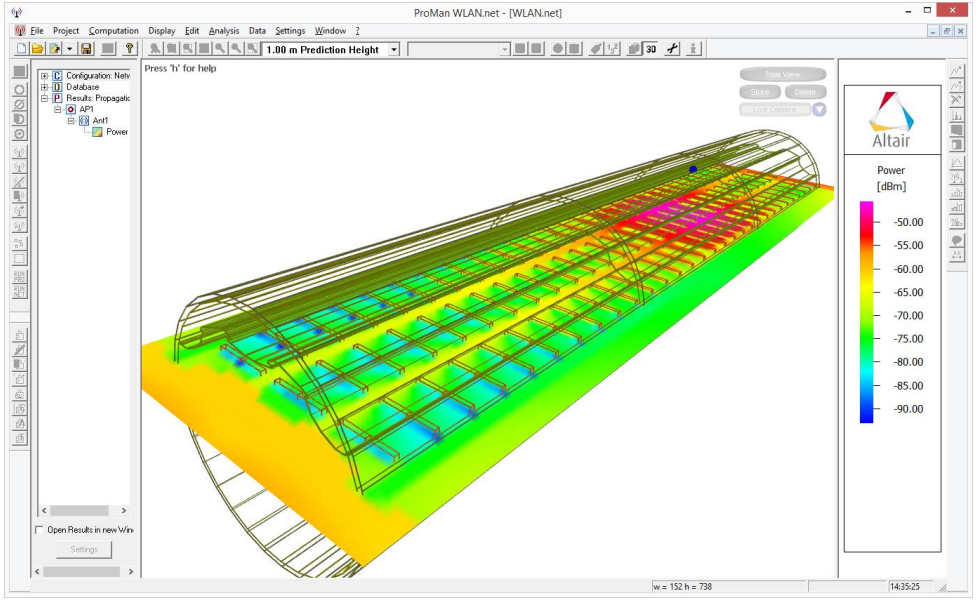
AEROSPACE APPLICATIONS

In-Cabin Radio Coverage

- Aircraft in-cabin scenario with seating area
- Evaluation of different transmitter deployments and configurations (e.g. for WiFi)
- Possible consideration of persons impact





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DEFENSE USE CASES

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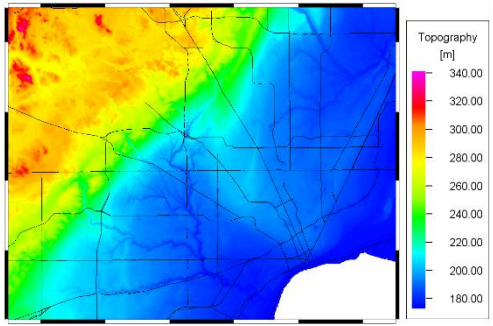
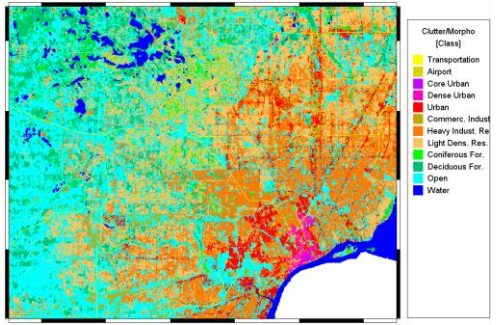
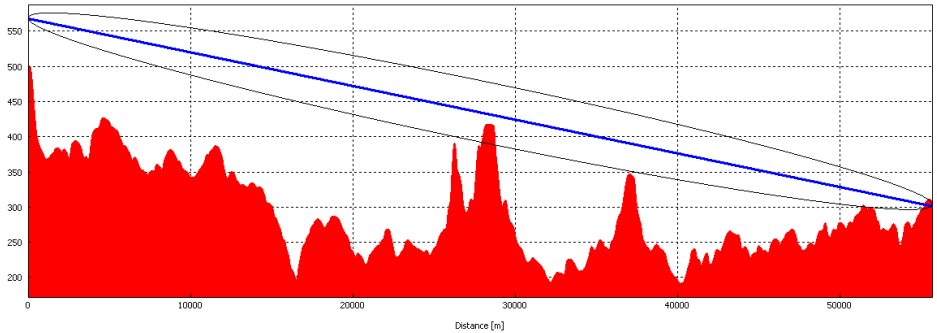
DEFENSE USE CASES

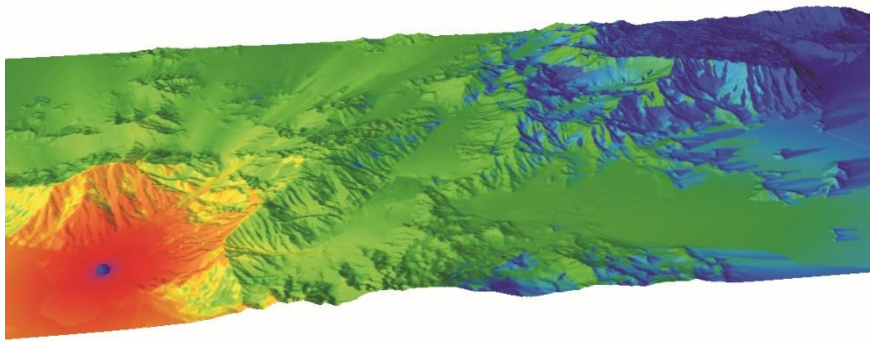
Military Radio Planning

- Radio coverage planning for portable devices
- Impact due to topography and clutter
- Usage of WinProp wave propagation models for rural scenarios (vertical plane and full 3D)
- Evaluate different transmitter positions/configurations
- Wide frequency range (30 MHz up to 100 GHz)









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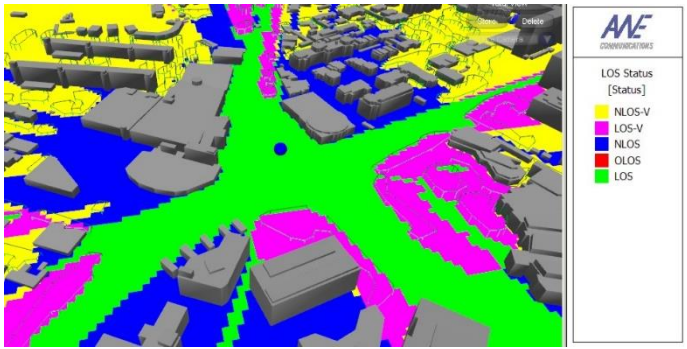
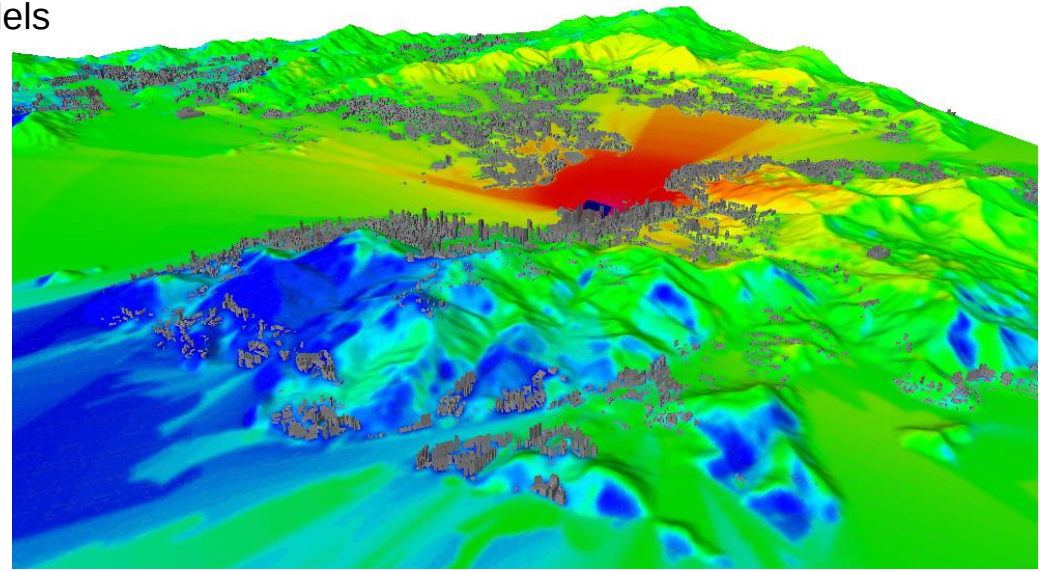
DEFENSE USE CASES

Military Radio Planning

- Radio coverage planning for portable devices
- Impact due to buildings, topography and further objects (e.g. vegetation)
- Usage of WinProp wave propagation models for urban scenarios (3D ray tracing)
- Prediction of field strength, pathloss and LOS/NLOS areas





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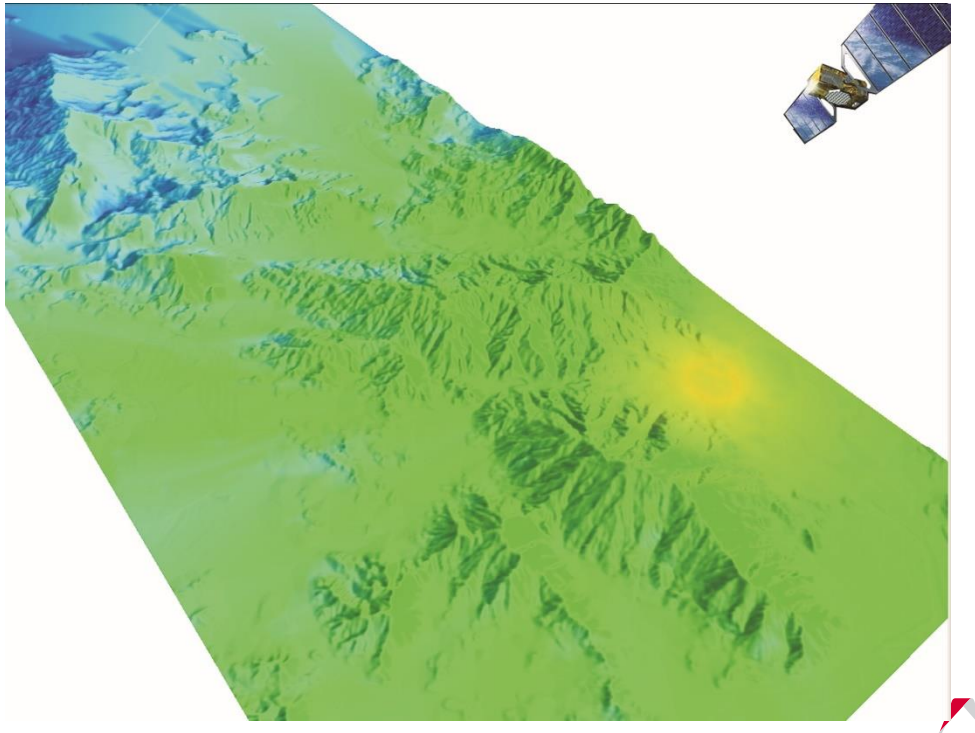
DEFENSE USE CASES

Areas of Visibility from Satellite or Airplane/Helicopter

- Determination of line-of-sight (LOS) areas and areas where the direct ray is blocked (NLOS)
- Impact due to topography and earth curvature
- Usage of ray-optical model based on topographical and clutter maps



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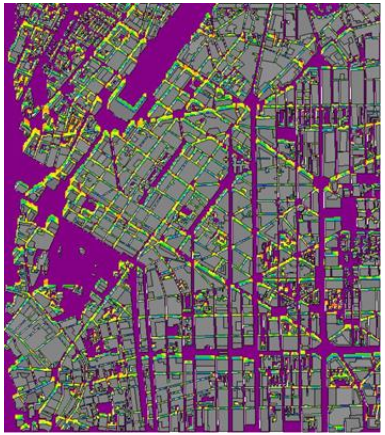
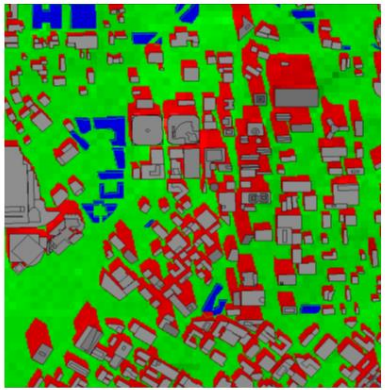
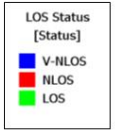
DEFENSE USE CASES

Satellite Radio Coverage

- Radio planning for satellite coverage
- Wide range from low earth orbit to GEO type satellites
- Possibility to define hybrid infrastructures with satellites and terrestrial repeaters
- Various kinds of map data including topography and clutter maps
- Satellite coverage in urban scenarios based on 3D building vector data
- Impairments for satellite navigation systems
  - Blocking due to buildings, terrain or foliage
  - Number of visible satellites and received power per satellite
  - Multipath errors







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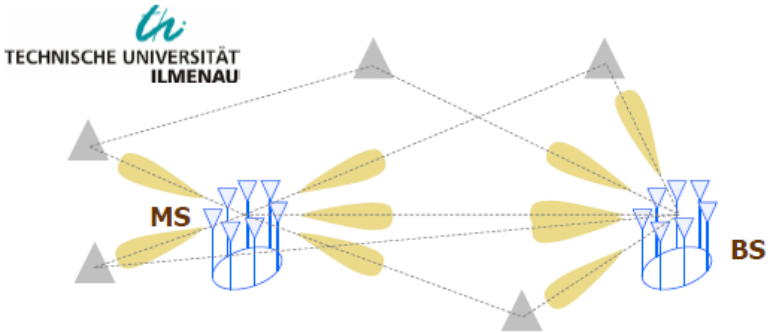
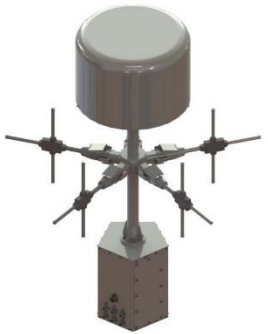
DEFENSE USE CASES

Emitter Localization in Multipath Scenario

- Direction-finding (DF) and localization is affected enormously by multi-path propagation
- Multi-path propagation is a very complex physical problem which can be simulated
- Ray-tracing can reproduce the multi-path propagation in various environments
  ➔ limitations about accuracy (3D environment data, frequencies, bandwidth)
- High resolution channel parameter estimation are useful for DoA estimation
- Polarization information offers an opportunity to improve DF algorithms (cross-polarization discrimination)





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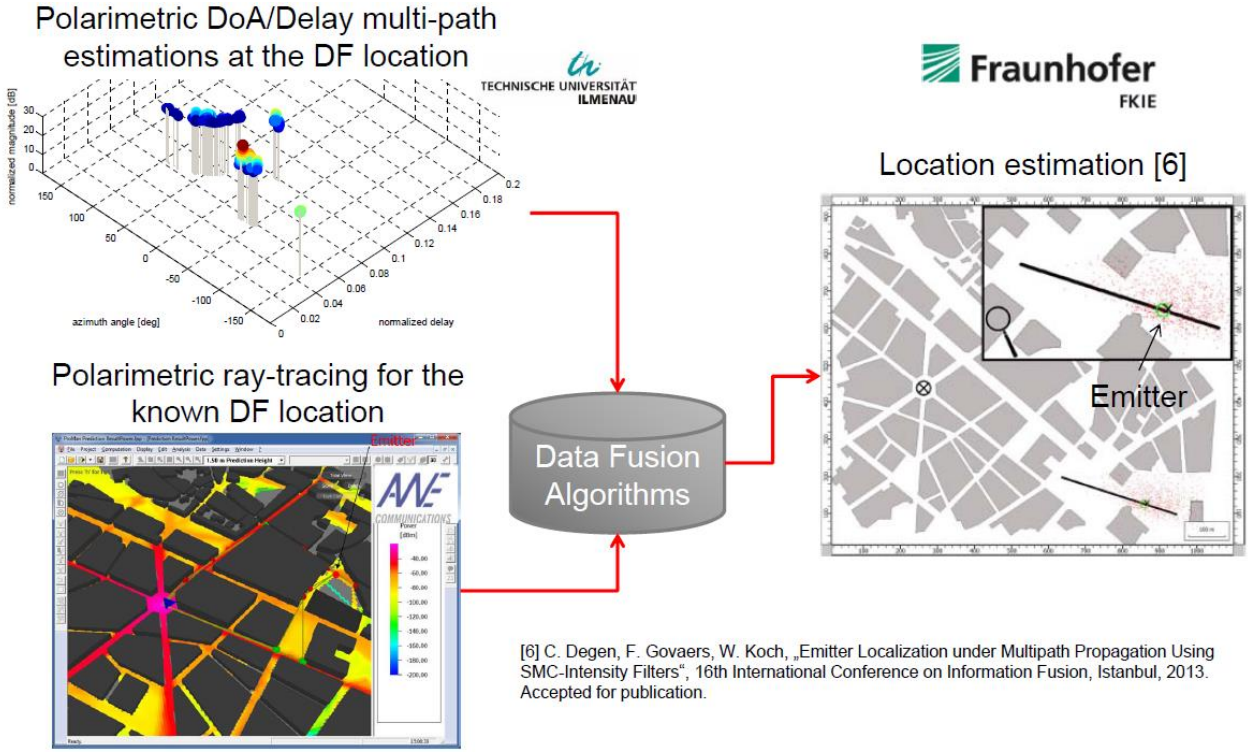
DEFENSE USE CASES

Emitter Localization in Multipath Scenario I

- Data fusion for emitter localization under multipath
- In DF both the transmitted signal and the radio channel are unknown
- Comparison between measured and pre-simulated radio channel allows to get the location information
- Data fusion of high-resolution polarimetric-DF and ray tracing allows single-sensor DF localization system



[6] C. Degen, F. Govaers, W. Koch, „Emitter Localization under Multipath Propagation Using SMC-Intensity Filters“, 16th International Conference on Information Fusion, Istanbul, 2013. Accepted for publication.

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RAILWAY APPLICATIONS

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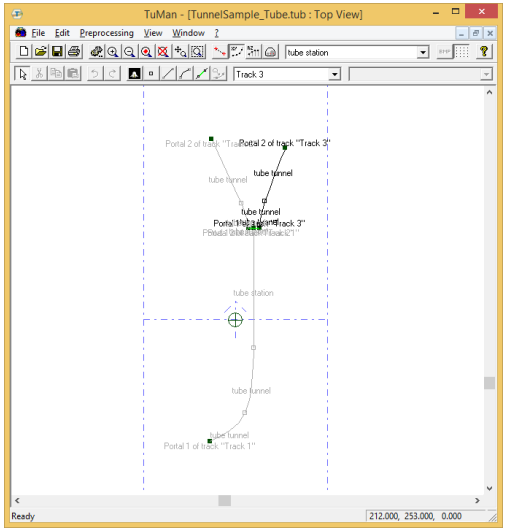
RAILWAY APPLICATIONS

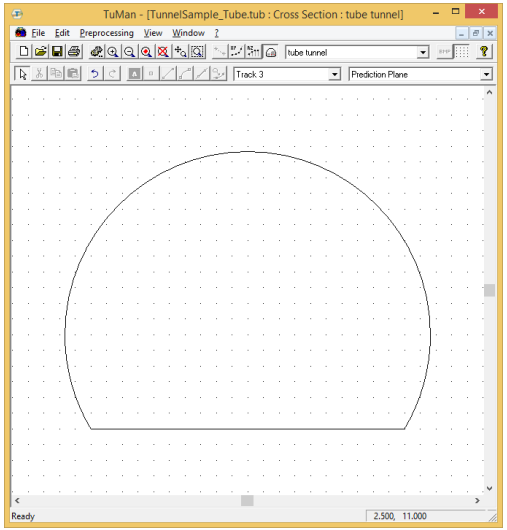
Definition of Tunnel and Station Geometry in TuMan

- Define separate cross sections for tunnel tubes and stations
- Define tunnel track using line and spline elements and assign each segment a cross section
- Export the 3D geometry into the WinProp vector format

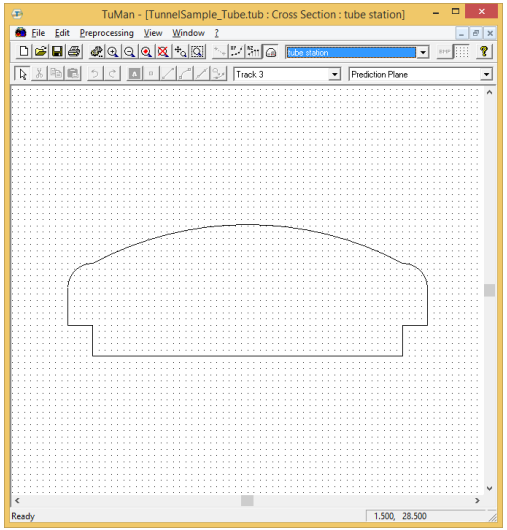
Tunnel track



Tunnel cross section



Station cross section



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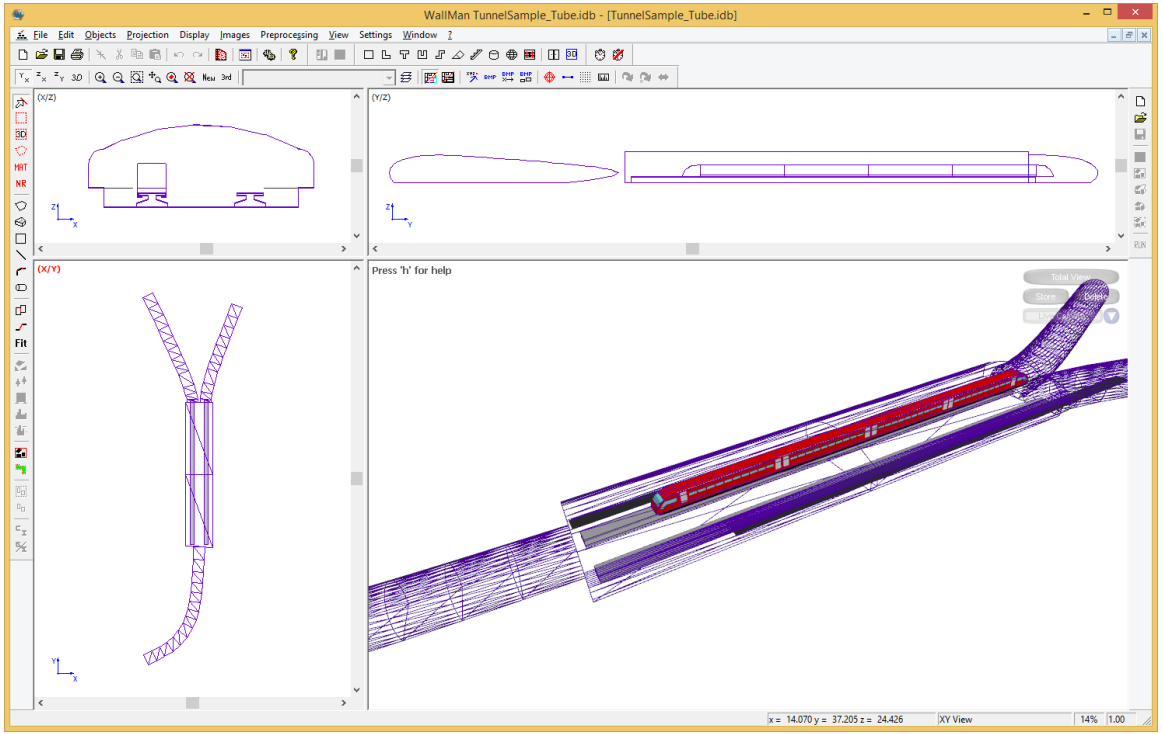
RAILWAY APPLICATIONS

Addition of Objects in WallMan

- Load geometry defined in TuMan
- Addition of objects like station building, train, …
- Configuration of the material properties for the involved categories
- Catalogue with default properties for typical construction materials available
- Time-variance can be added to consider different train positions (also worst case with two trains on the same section)
- Save the database in the WinProp vector format



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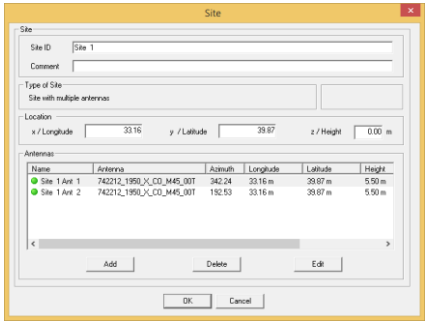
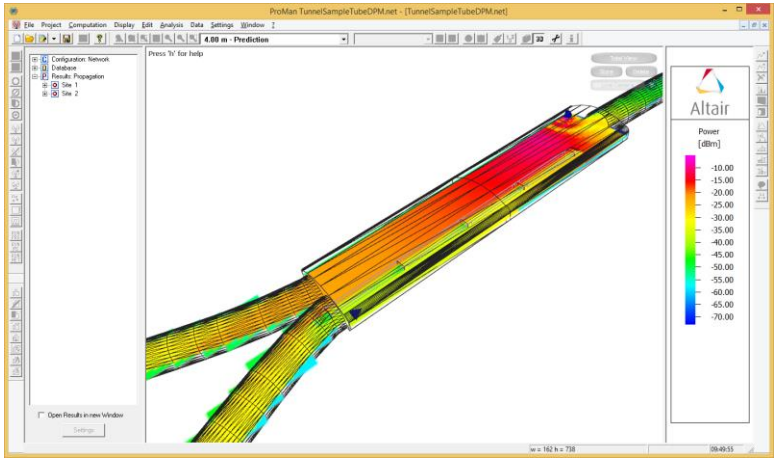
RAILWAY APPLICATIONS

Project Definition and Simulation in ProMan



- Definition of network planning projects based on defined scenario and wst files (e.g. for LTE, WiFi and TETRA)
- Deploy Distributed Antenna System (DAS) in station building:
  - DAS amplifiers (remote units) connected via coax cables to Tx antennas
  - Tx power (EIRP) of 30 dBm for each antenna
  - Omnidirectional antennas in large halls, with multi floors and stairs
  - Directional antennas on long platforms (at opposite ends)
  - For tunnels radiating cables (leaky feeders) can be added
- Usage of dominant path model for the wave propagation analysis
- Coverage to be achieved:
  - For cellular over 95% coverage in station & tunnels (RSRP target of -95 dBm)
  - For TETRA 100% coverage in station & tunnels (Rx power target of -95 dBm)
  - For WiFi over 95% coverage in station (Rx power target of -75 dBm)



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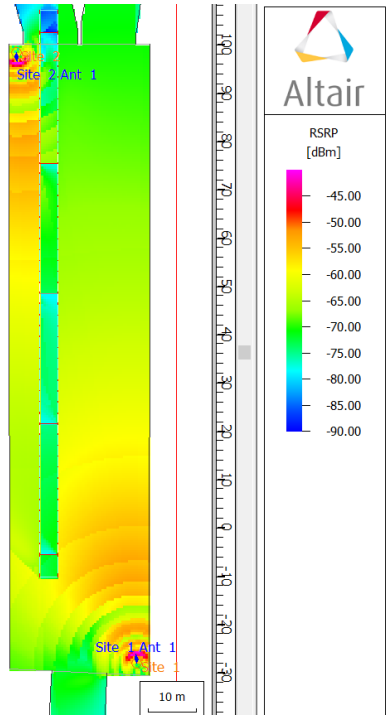
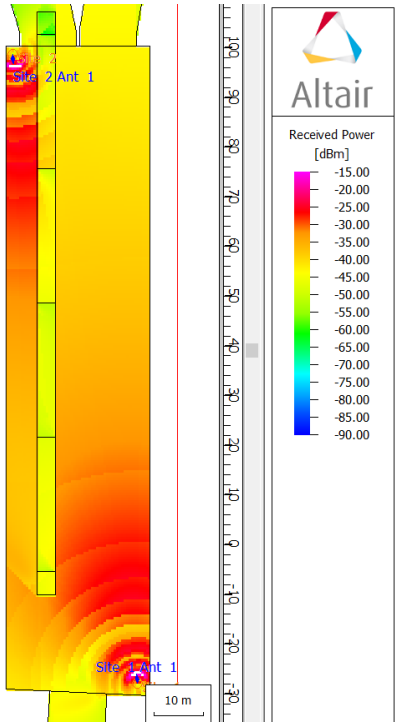
RAILWAY APPLICATIONS

Analysis of Network Planning Results in Station

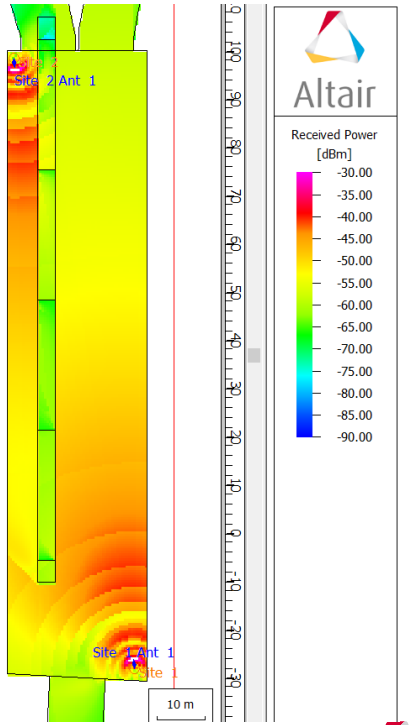
LTE



TETRA



WiFi



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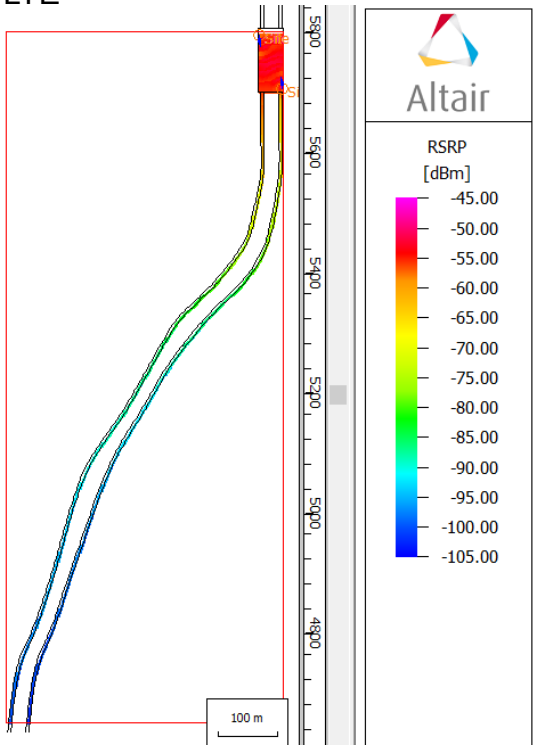
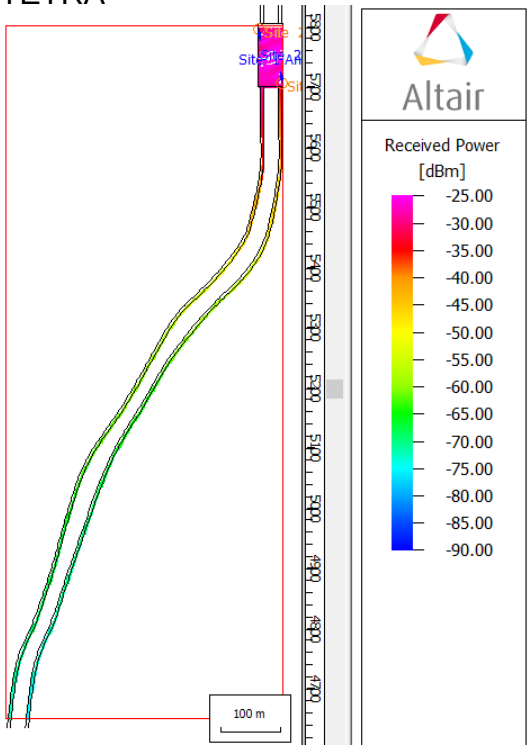
RAILWAY APPLICATIONS

Analysis of Network Planning Results in Tunnels

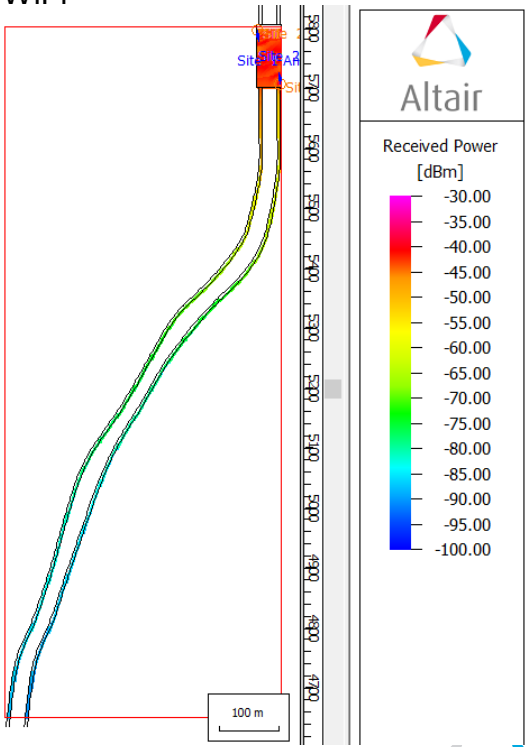
LTE



TETRA



WiFi



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RAILWAY APPLICATIONS

Tunnel & Station Radio Coverage - Conclusions

- Comparison of different deployment options using key performance indicators
- Omni and/or directional Tx antennas for stations and tunnels
- Optional usage of leaky feeder cables for tunnels (especially for TETRA in worst case scenario)
- Transmitter deployment and radio planning simulation in ProMan
- Evaluation of simulation results using the statistic features (CDF/PDF) in ProMan for the different air interfaces (LTE, TETRA, WiFi) and scenarios (station and tunnel)

Radio coverage	Station	Tunnel
Wireless cellular service LTE	100% above -95 dBm	80% above -95 dBm
Emergency service TETRA	100% above -95 dBm	98% above -95 dBm
WiFi 802.11ac	99% above -75 dBm	61% above -75 dBm

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TELECOM USE CASES

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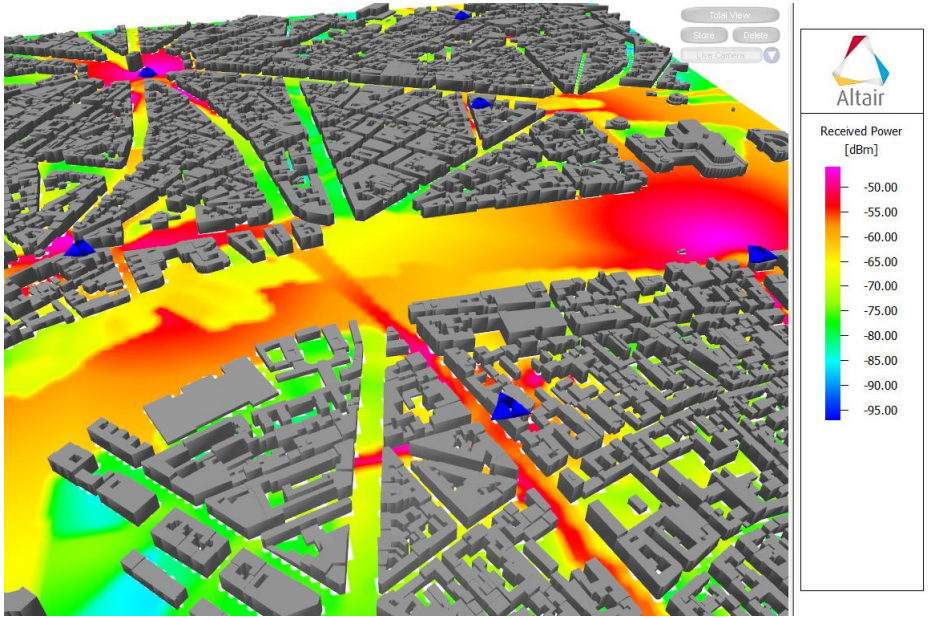
TELECOM USE CASES

Radio Network Planning for Urban Scenarios

- Processing 3D building vector data (with optionally vegetation objects) superposed to terrain layer
- Highly accurate wave propagation models for macro-cells and micro-cells
- Dominant path model (DPM) offers short computation time
- DPM won the benchmark from large operator
- Initial radio coverage planning for network roll-out
- Optimization of radio network for further evolution
- Different air interfaces of interest (e.g. LTE)
- WinProp propagation models available under API for integration into other radio planning tool



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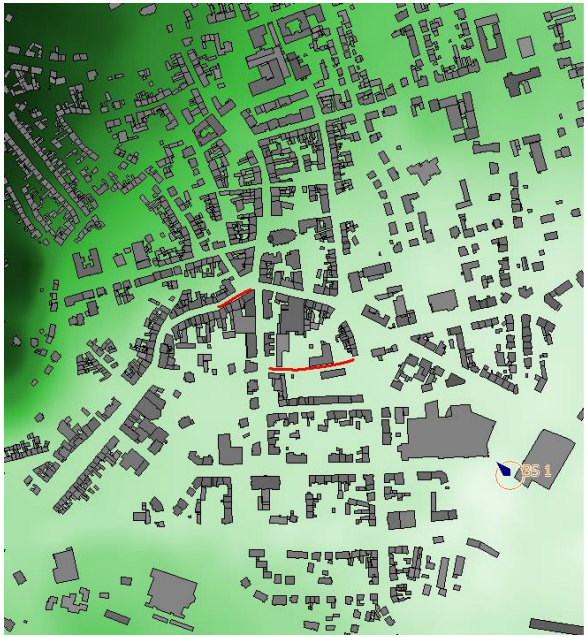
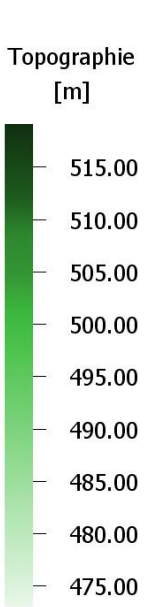
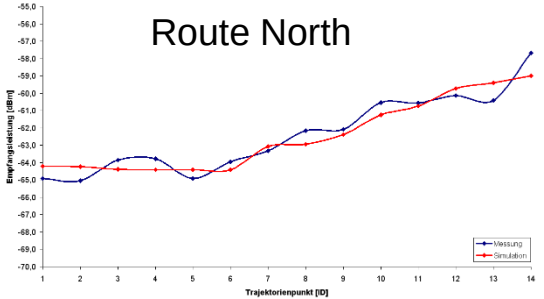
TELECOM USE CASES

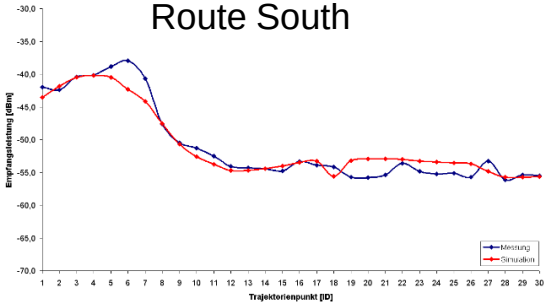
Verification of Model Accuracy in Urban Scenario

- Measurements with high resolution 3D channel sounder in urban macro cell reference scenario
- Tx height: 26.5 m
- Tx frequency: 2.53 GHz
- Tx power: 46 dBm
- Rx height: 1.9 m









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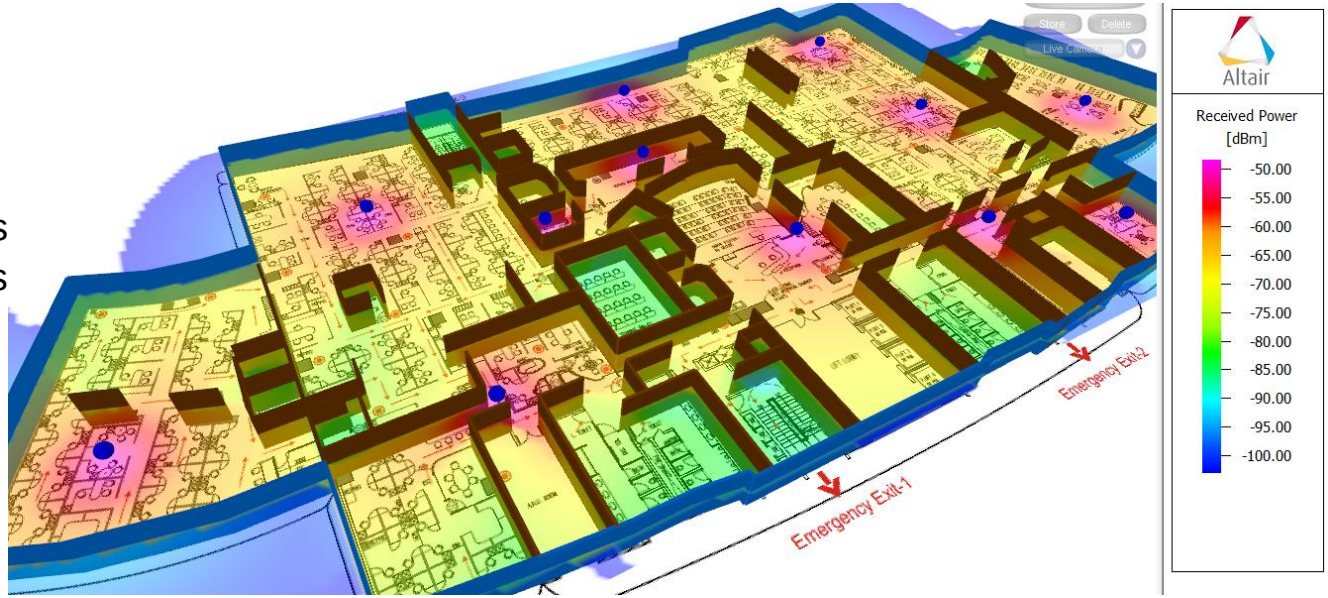
TELECOM USE CASES

Indoor Radio Network Planning

- Processing 3D building vector data with outer and inner walls including subdivisions like doors/windows
- Conversion of CAD data or definition based on imported bitmap
- Material catalogue with typical construction materials and their electrical properties
- Computation of Rx coverage and throughput (data rate)
- For WiFi / DECT planning
- For planning of indoor sites of cellular network



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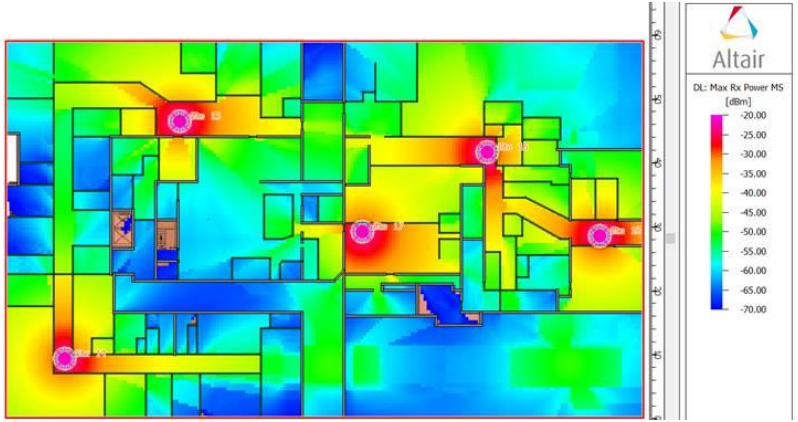
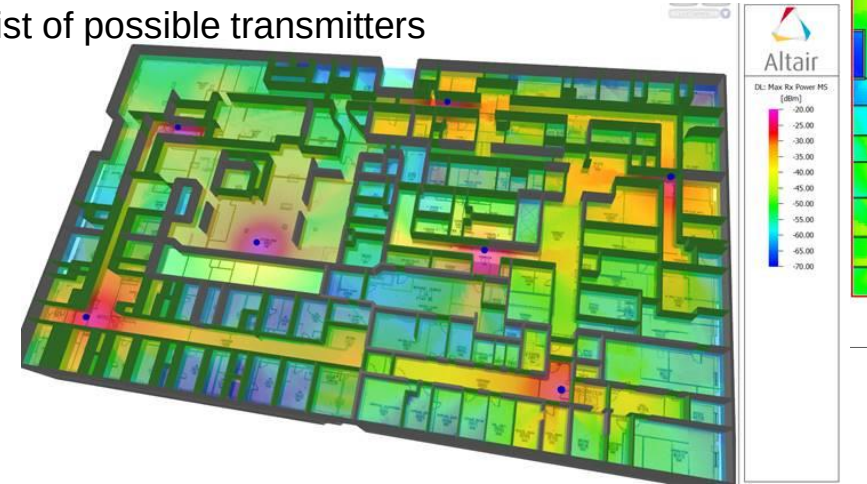
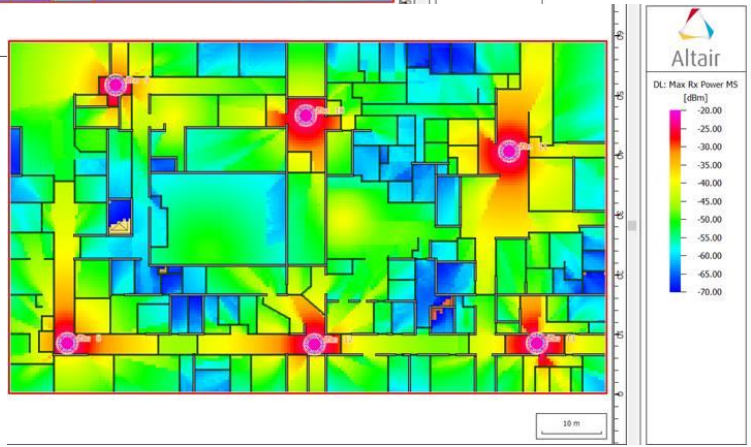
TELECOM USE CASES

Planning of Required Access Points per Floor

- Define multi-floor database with different material types in WallMan
- Run radio coverage per transmitter
- Network planning computes the superposed coverage per floor
- OptMan allows to derive required subset out of predefined list of possible transmitters







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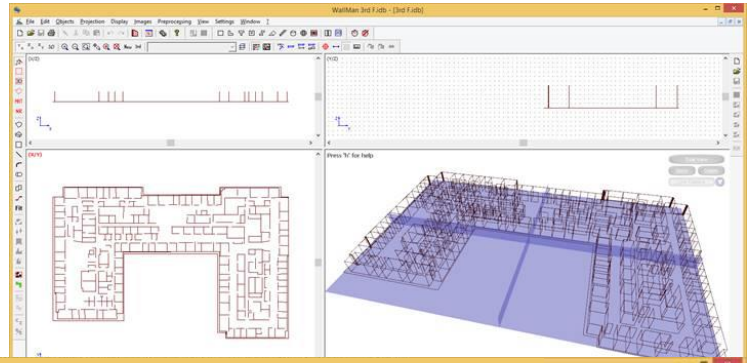
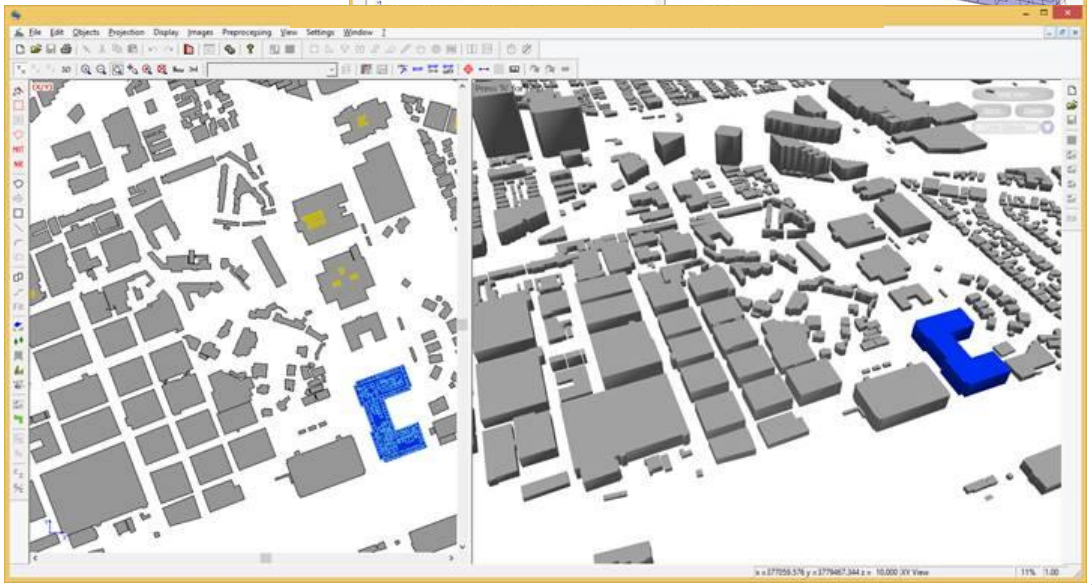
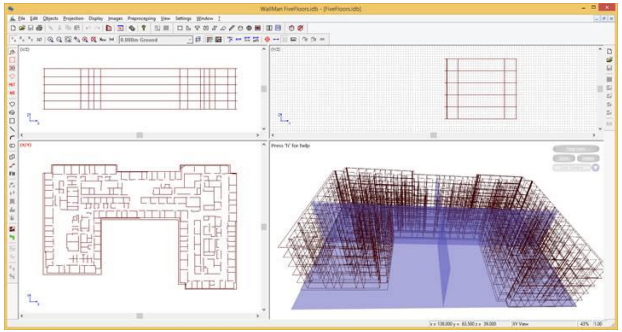
TELECOM USE CASES



Heterogeneous Networks

- Combine urban and indoor building data in WallMan
- Create multi-floor building
- Import multi-floor building in urban scenario
- Use cases:
  - Detailed indoor coverage analysis
  - Are indoor repeaters required
  - Analysis of interference from indoor cells to surrounding cellular network





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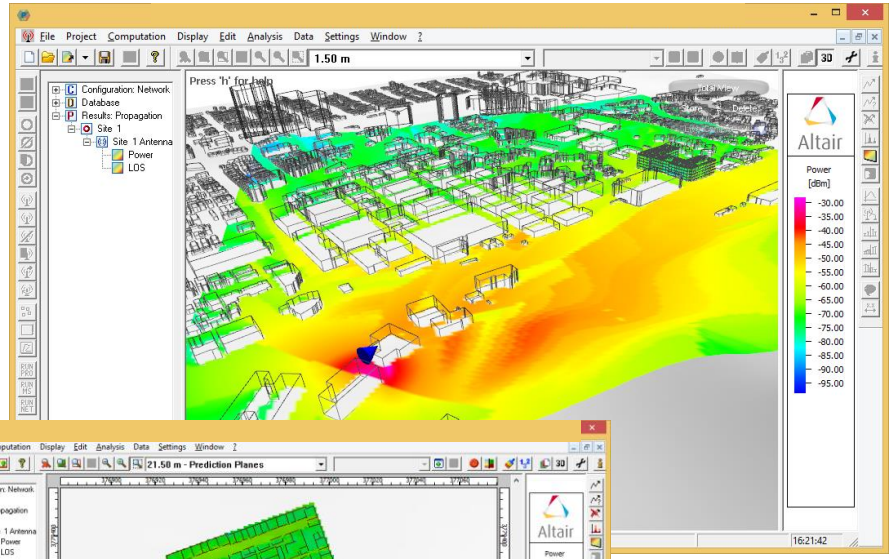
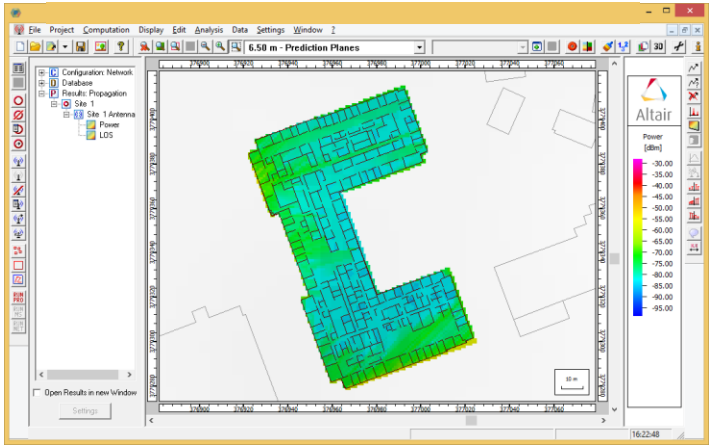
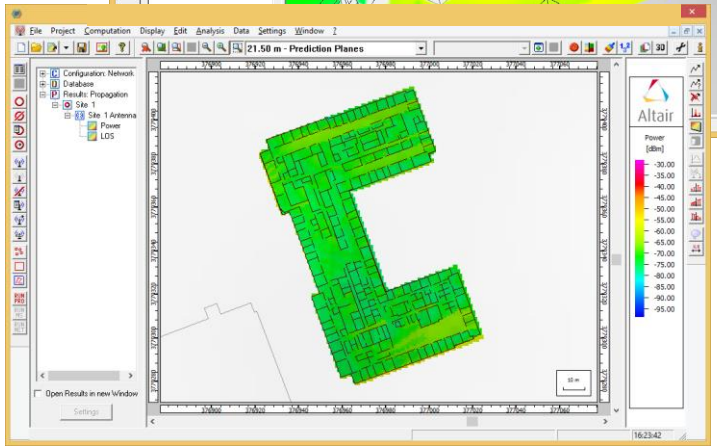
TELECOM USE CASES

Heterogeneous Networks

- Deploy transmitter network (outdoor and indoor sites)
- Predict outdoor plus indoor coverage on several floors
- Use cases:
  - Detailed indoor coverage analysis
  - Are indoor repeaters required
  - Analysis of interference from indoor cells to surrounding cellular network







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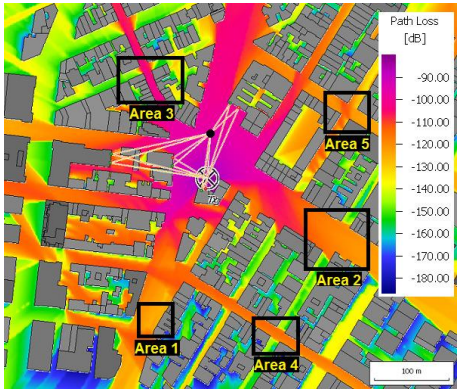
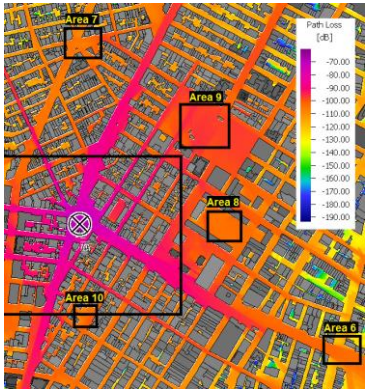
TELECOM USE CASES

5G Radio Channel Analysis I

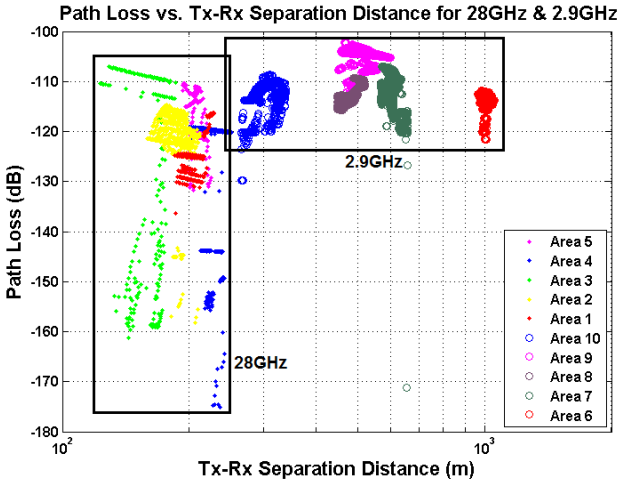
- Comparison of simulated path loss at 28 GHz



and 2.9 GHz



  - New York city scenario
  - WinProp 3D ray tracing model
  - BS at street intersections
  - 3 different BS locations analyzed
  - Areas marked in black rectangles evaluated in below diagram
  - Path loss over BS ➔ MS distance gives much smaller range for 2.9 GHz
  - Wide range of path loss for same/similar distances at 28 GHz
  - Hence simple path loss model not sufficient
    but 3D ray-optical model required
  - Alternative to measurements is the usage of 3D ray tracing engine



Source: Qualcomm Z. Zhang et al.: Coverage and Channel Characteristics of Millimeter Wave Band Using Ray Tracing, IEEE ICC 2015

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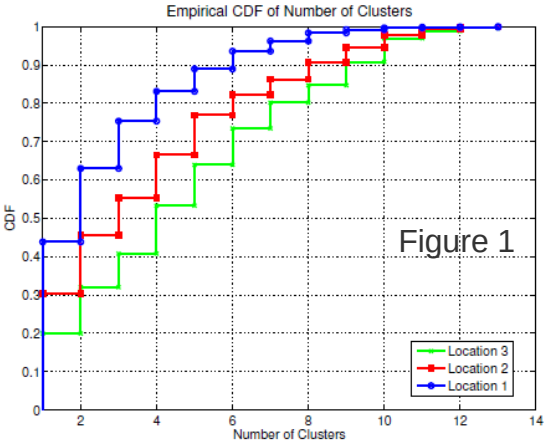
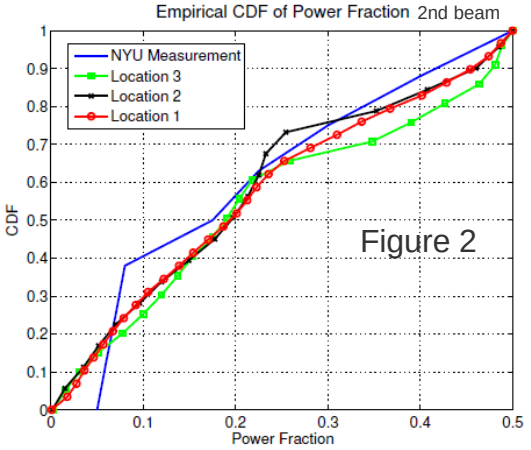
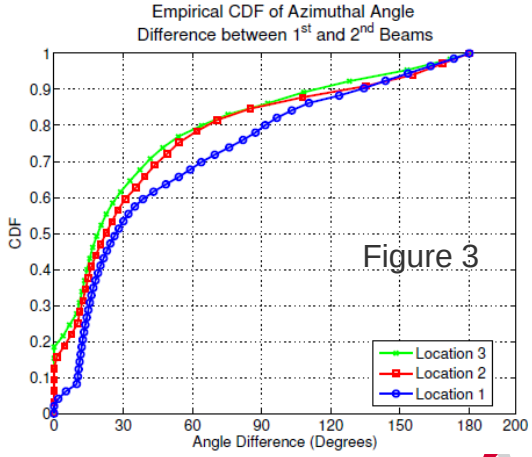
TELECOM USE CASES

5G Radio Channel Analysis II

- Beam diversity at 28 GHz
  - New York city scenario
  - WinProp 3D ray tracing model
  - BS at street intersections
  - 3 different BS locations analyzed
  - Statistics on number of paths between BS and MS
    ➔ on median there are 2-4 clusters (see figure 1)
  - If dominant direction is blocked alternative path required
  - Power fraction of the second strongest path
    (at least 10° away) ➔ on average 7 dB weaker (see figure 2)
  - Azimuthal separation between two strongest paths on average about 20° (see fig. 3)
  - WinProp simulation results in agreement to NYU measurements







Source: Qualcomm Z. Zhang et al.: Coverage and Channel Characteristics of Millimeter Wave Band Using Ray Tracing, IEEE ICC 2015

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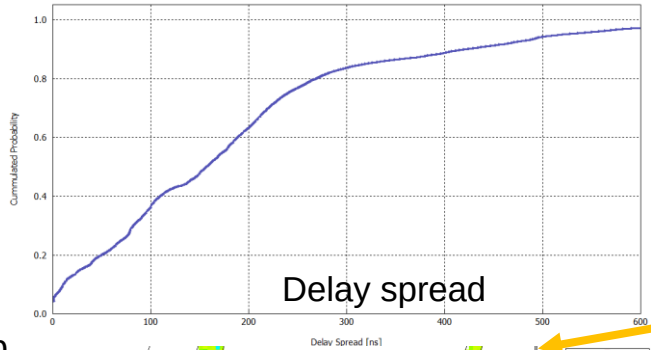
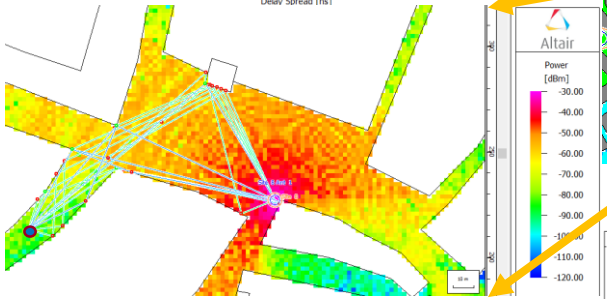
TELECOM USE CASES

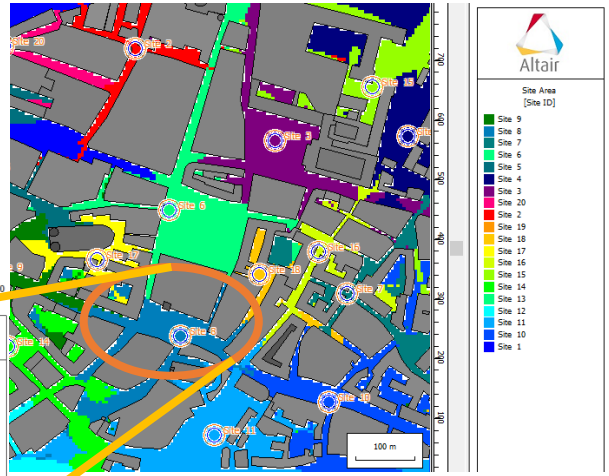
5G Radio Channel Statistics

- Computed for individual cells
- Consideration of omni BS antenna
- Cell areas given by best server map
- Delay spread at 26 GHz
- Azimuth angular spreads at 26 GHz

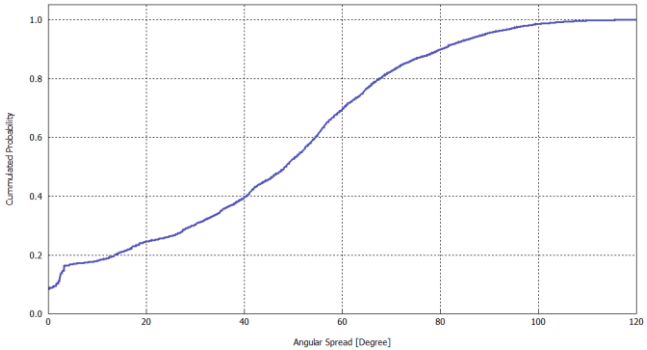


Delay spread

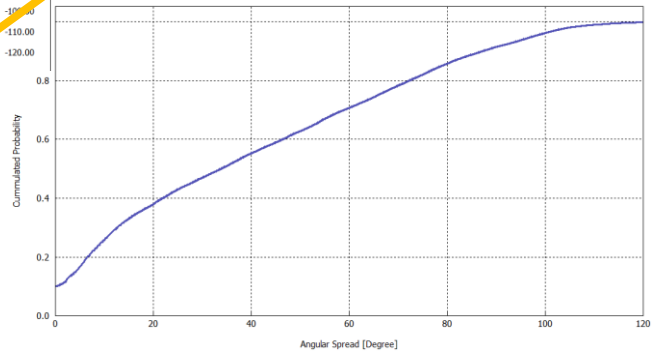




Angular spread BS



Angular spread MS



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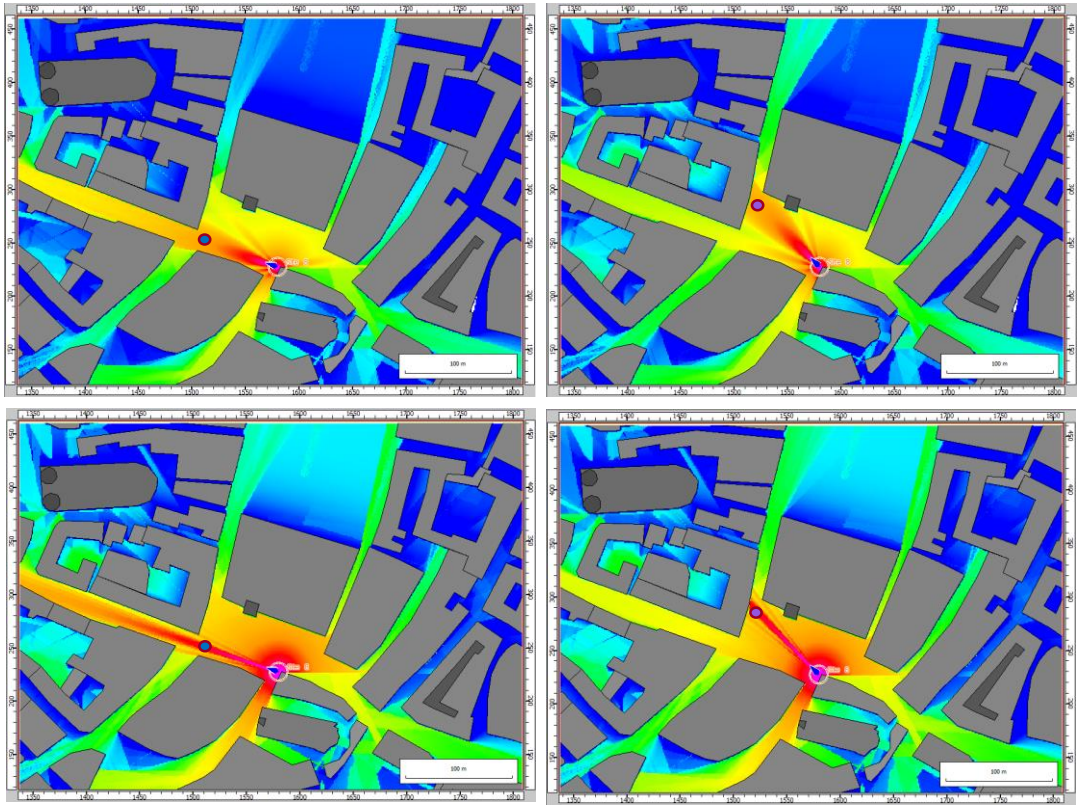
TELECOM USE CASES

5G Beamforming

- Massive MIMO antenna arrays used to
  - Transmit different signals to different users simultaneously in same frequency band
  - Increase Rx power levels and SNIR for dedicated user
  - Reduce interference for others
- Example shows separation of two different users
  - 4x4 antenna elements on BS side (upper figures)
  - 16x16 antenna elements on BS side (lower figures)
- Trade-off between beam width and MIMO spatial multiplexing within beam



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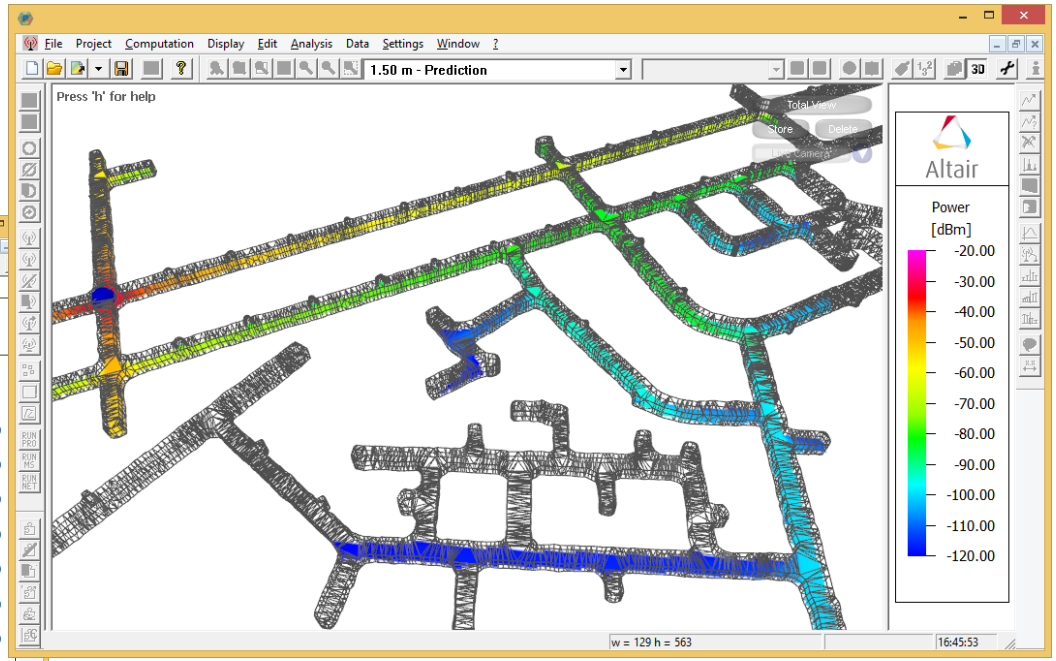
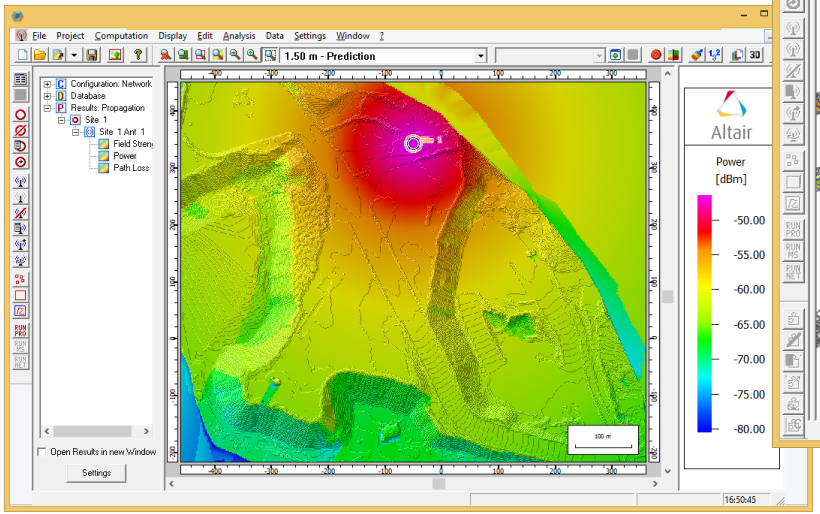
TELECOM USE CASES

Open / Underground Mining Scenarios

- Convert map data (topography / tunnels / obstacles)
- Usage of dominant path model (DPM)
- Use cases:
  - Radio coverage analysis
  - Planning of repeaters





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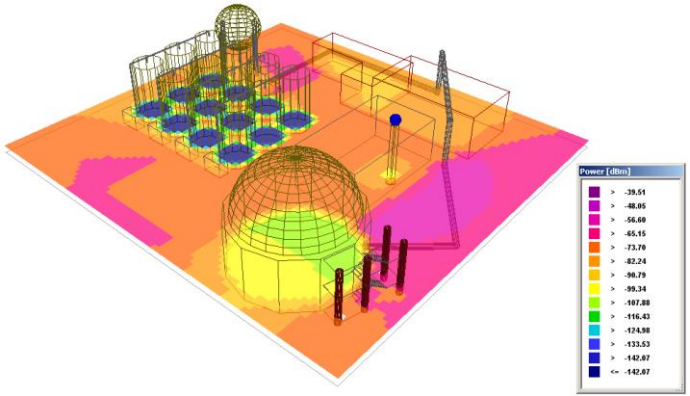
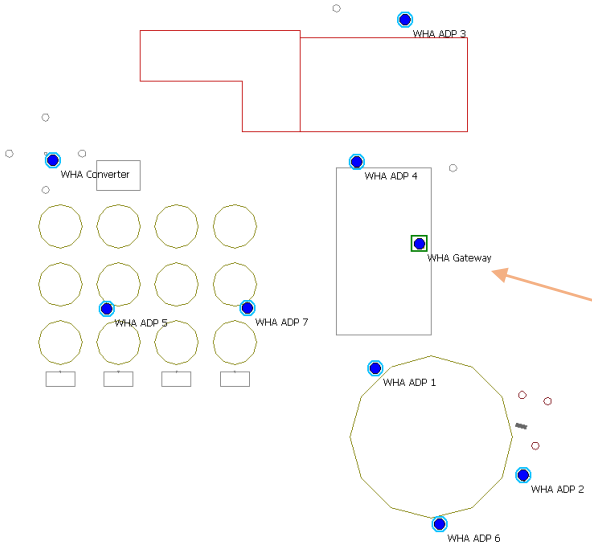
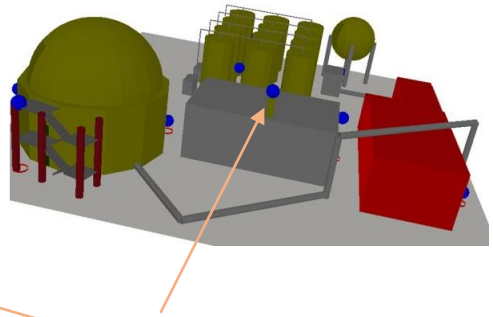
TELECOM USE CASES

Planning of Wireless Sensor Networks in Industrial Scenarios

- Monitoring of processes and constructions (assembly lines, industrial automation, environment, …)
- Distribution or placement of sensor nodes
- Path loss computation between nodes depending on scenario (rural / urban / indoor)
- Connectivity analysis
- WirelessHart, ZigBee, LoRa







Gateway

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CONCLUSIONS

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WINPROP SOFTWARE SUITE

Radio Planning Tool

- Wave propagation models for various scenarios
  - Rural/Suburban
  - Urban
  - Indoor/Tunnel
- Radio network planning of various systems
  - Mobile cellular
  - WiFi
  - Broadcasting
  - Mesh/sensor networks
- Applications
  - Radio channel analysis
  - Radio network planning

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Thank you!