ATDI

Critical communications in rail environment

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About Us

CRITICAL COMMUNICATIONS NETWORK PLANNING AND MODELLING SOFTWARE SOLUTIONS FOR BOTH INDOOR AND OUTDOOR

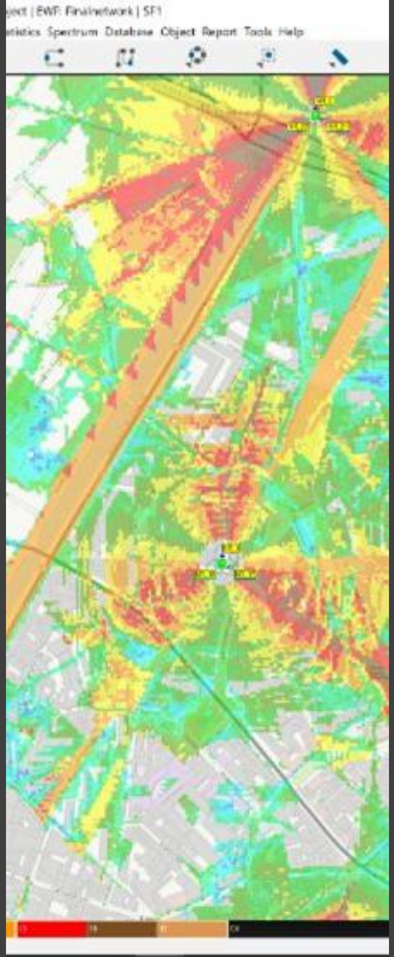
OUR FOCUS IS TO SUCCEED AT EVERY LEVEL OF OPERATIONS IN ELECTROMAGNETIC SPECTRUM OPERATIONS

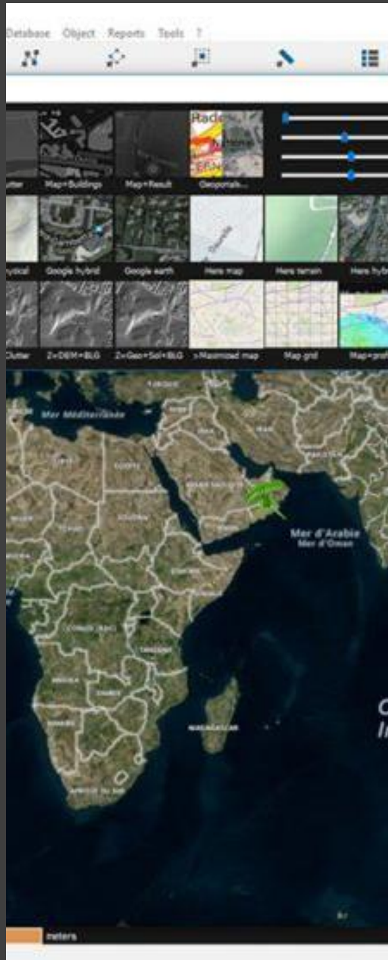
ATDI are global leaders in the development and implementation of automated spectrum management solutions.

For over three decades, we have backed over 2,000 civil and defence spectrum agencies, operators and vendors. Our solutions continue to evolve to meet the growing needs of the critical communications industries.

We provide a unique and global solutions for:

- **Radio planning and optimisation:** activities for all communication and transmission systems used by the Ground/Air/Sea/Space forces;
- **Frequency management (FM)**
- **Spectrum management solution (SMS):** for planning, coordinating, and managing joint use of the EMS through operational, engineering and administrative procedures;
- **Electronic Warfare (EW)** management / interception and intelligence





Our Offices
Global Footprint

- Allows us to leverage different time zones
- Provide support around the clock
- Fast response times
- Draw resources from across the group to support larger projects ensuring we offer the very best services to our end users
- Shared experiences – combining many man-years experience across the group. At every stage of the project (from project outset to going live) we aim to learn and improve our services. To do that we carry out regular internal project reviews and a group review at handover.

Our **Services**

Training

Customised training service online or onsite.

Support

24/7 global technical support via phone, email and web-conference

System Customisation

Business analysis, system design, architecture, customisation, integration, and configuration.

Spectrum consulting

Provide professional consulting services in spectrum engineering and management to solve any spectrum issues.

Cartographic data

Medium to High resolution DTM and Clutter library.
Cloud base digital map image streaming and cache support.

System Deployment & Maintenance

Support on Go-Live, Testing, and bug fixing.
On-going maintenance support with software updates.

Key References in Rail Industry

- *Boldyn Communications, UK*
- *TGV (INEO SUEZ), FRANCE*
- *PKP POLISH RAILWAY LINES S.A, Poland*
- *Sydney Trains, Australia*
- *Public Transportation Authority of WA, Australia*
- *Queensland Rail (Parsons Brinckerhoff consulting), Australia*
- *Tasmania Rail, Australia*
- *Victrack, Australia*
- *Vodafone International, Australia*
- *Huawei Australia*
- *KORAIL, S. Korea*
- *Gimpo GoldLine, S. Korea*
- *GYPROTRANSSIGNALSVYAZ (GTSS SPB), Russia*
- *INDRA, SPAIN*
- *Ingeniería y Economía del Transporte S.A. (Ineco), SPAIN*

- *WSP, UK*
- *ATKINS RAIL, UK*
- *WHP, UK*
- *INTRACOM, GREECE*
- *GLOBAL NOVICOM, KAZAKHSTAN*
- *AECOM FOR CROATIA RAILWAY LINE, Croatia*
- *SEPURA, Malaysia*
- *ST Engineering, Singapore*
- *DAMM Cellular Systems India Pvt Ltd, India*
- *Kontron Transport GmbH, Austria*
- *United Group Infrastructure, Australia*
- *HMF Smart Solutions GmbH, Germany*
- *Stadler Rail, Switzerland*

All-in-One
RF engineering solution
for Rail Network Design

HTZ Communications

HTZ Communications SUPPORTS ALL TECHNOLOGIES & FUNCTIONS BETWEEN 8 kHz upto 1 THZ:

Radio cellular technologies: GSM/GSM-R, GPRS, EDGE, EDGE Evolution PMR, Trunked Radio Systems (TETRA, TETRAPOL, APCO-25, MPT 1327), GSM-R, DCS, CDMA EVDO GPRS, Wi-Fi (802.11a/b/g/ac), WiMax (802.16 a/d/e), UMTS, R99, HSDPA, HSUPA, HSPA+, DB-HSDPA, DC-HSDPA, CDMA 2000 1x, CDMA 200 EV-DO, DCS, LTE Advanced (latest 3GPP release), MBSFN-LTE, NB-IoT (3GPP), IoT/LoRA/SigFox, WiFi, Ingenu, LoWPAN, RPMA, Zigbee, Enocean, ISA 100, LTE-M, LTE-R (TDD/FDD), PS-LTE, ZWave, Mesh network, Smart Grid, CISCO smart grid technology, 5G-NR (FDD/TDD), SCADA, FRMCS, etc.

Satellite/Earth station

Microwave-links & Point to Multi-Points

Aeronautical & UAVs : Communications (Ground To Ground/Ground To Air), Radio Navigation (GP, markers, Loc, MLAT, DME, TACAN, NDB, Markers, GBAS RX, MLS AZ, etc.) and Surveillance systems, counter-drones

Radio-localisation: (DF/Sensors/MLAT, Telemetry, TDOA, RSSI, etc.)

Broadcast : Radio analog and digital (FM, AM, LF/MF, TDAB, etc.), TV analog and digital (DVB, DVB-T2, ISDB-T, DMR, DVB-S, DVBS2, etc.)

Subscribers and User Equipment

Supporting
Multi-Technology Capability

It is critical to support technology evolution for any current and future network migration. HTZ supports any technologies between 8 kHz and 1 THz. Some of the common radio systems in Rail Communications are supported.

- GSM-R/LTE-R & 5G
- FRMCS
- Microwave-links & Point to Multi-Points
- Leaky Feeder
- TETRA
- WiFi
- Mesh network
- And more

Supporting
the entire life cycle of the network planning

i) Site acquisition: Site database management (technical and administrative data), rank of potential candidates sites (backhaul availability, site cost, planning coverage targets….

ii) Best site selection: automatic network planning of;

- Automatic site candidates selection according to the coverage and traffic targets
- Automatic Cell Planning (ACP)
- Automatic Site Placement (ASP)

iii) DL/UL coverage calculation and analysis:

- Automatic link budget calculator (DL/UL) taking into account % of reliability at the cell edge
- Composite, best server (1st, 2nd, …), overlapping, number of servers, etc.
- Coverage analysis (surface, population, vectors, points…)

iv) Traffic analysis:

- Import of traffic map (user profiles with traffic demand, subscribers database, density of users…)
- Automatic traffic dimensioning (Erlang and data)
- Network traffic congestion analysis

Supporting
the entire life cycle of the network planning

v) Interference and Automatic frequency assignment:

- Interference analysis (Co-channel, adjacent, N+2,…)
- Spurious interference analysis (intermod , dezensification, coexistence analysis…
- Automatic Frequency Planning (AFP)

vi) Automatic optimization:

- Automatic site optimization in order to improve the coverage inside a polygon or along a vector line
- Automatic site optimization in order to reduce the interference
- Automatic site optimization to increase the number of connected subscribers (calculation done according to the subscriber distribu
- Automatic search of repeaters/gap filler to improve the existing coverage and to solve the gap of coverage.

vii) Handover and neighbour analysis :

- Handover maps
- Automatic Neighbor list

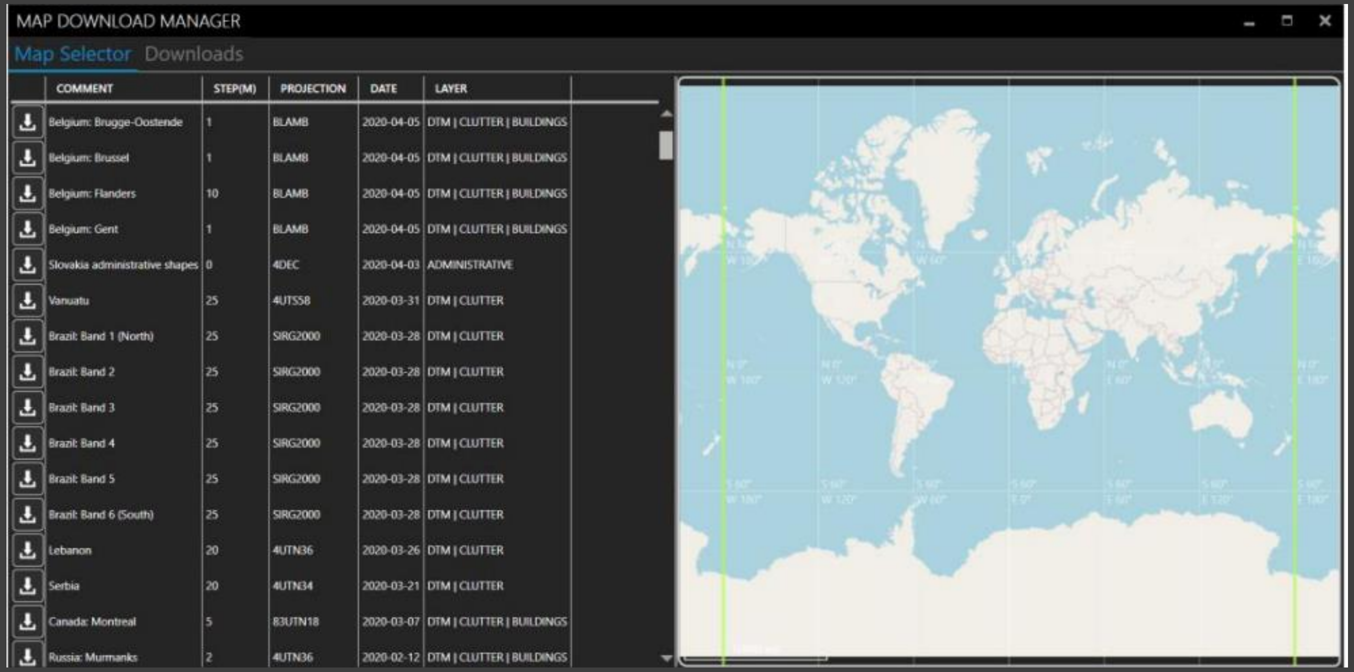
Viii) Drive test analysis and correlation with prediction:

- Comparison of the measurement data (drive tests, punctual measurements…) and the prediction.
- Automatic tuning propagation model
- KPI analysis with statistics charts

Worldwide Cartographic Data Library

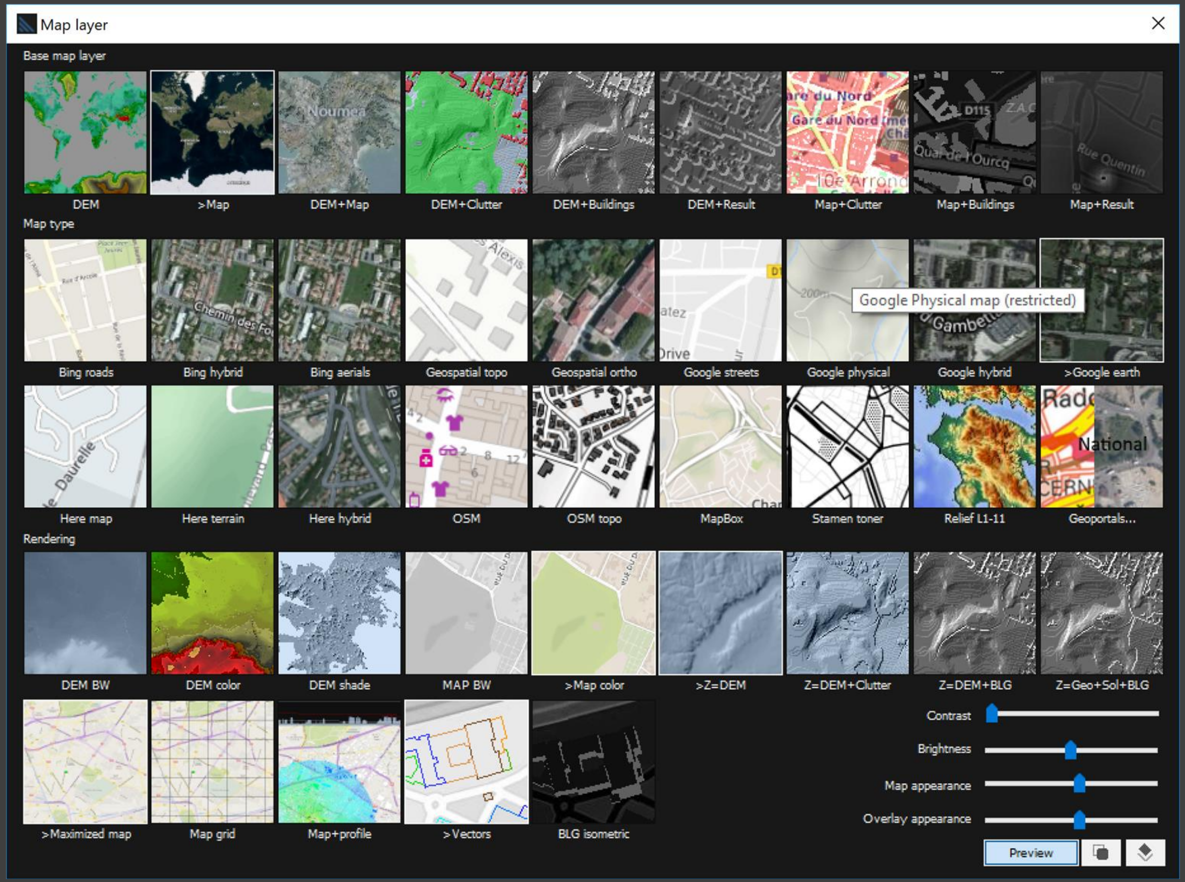
ATDI offers a worldwide cartographic data library for all HTZ software license users. The data is developed using the open-source maps from national government agencies for GIS and land survey (e.g Norwegian maps authority/geonorge.no)

The quality of maps vary between 1 m (DTM, clutters and 3D building) and 25 m (DTM and clutters), depending on the source resolution,

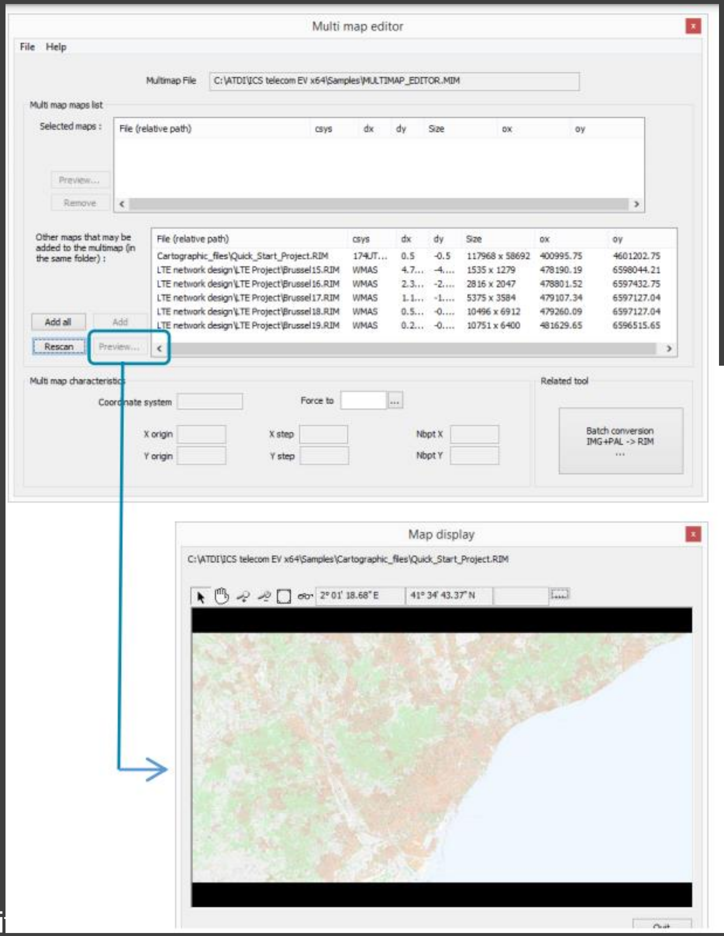


Integration with Web-Map Services

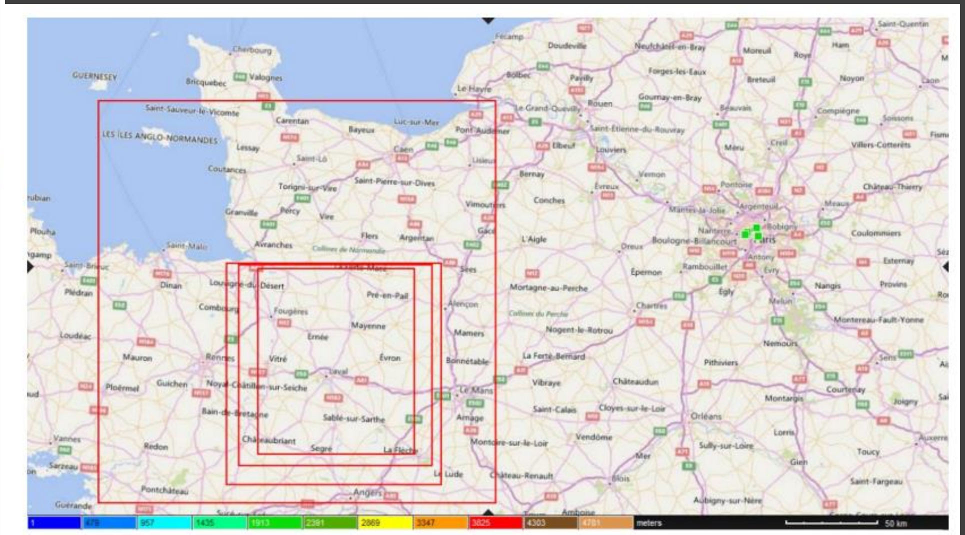
HTZ utilizes web-serviced map images such as Google Maps, Bing Maps, Here, and so on, or specific cartographic collection from Geoportals which is available in some countries (Poland, France, Spain, United States, etc.)



Managing GIS Data; Multi-Map



HTZ enables to use and manage different maps (DTM, clutter, images…) using different resolutions (e.g 2m, 10m, 50m, 100m...) and allows the users to use and switch between maps in a single scenario. As long as multiple raster resolution topographic maps are loaded, the software will supportt the multimap display depending on the zoom levels.

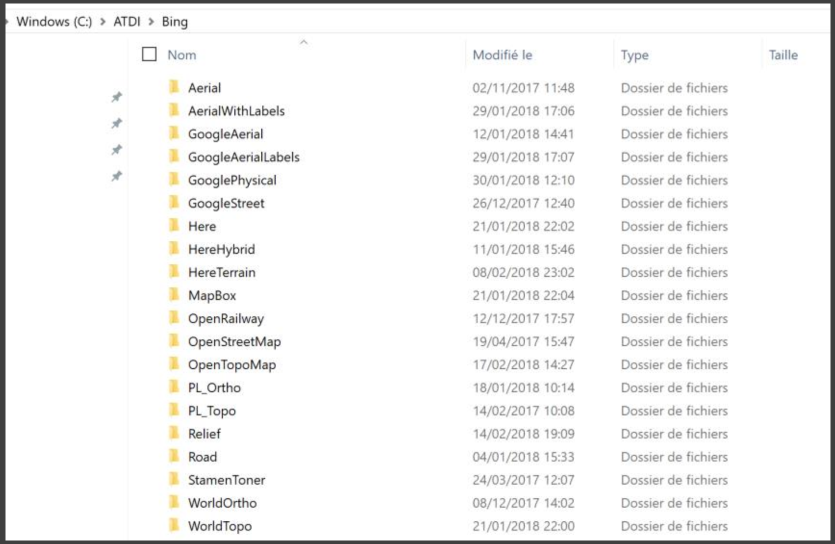


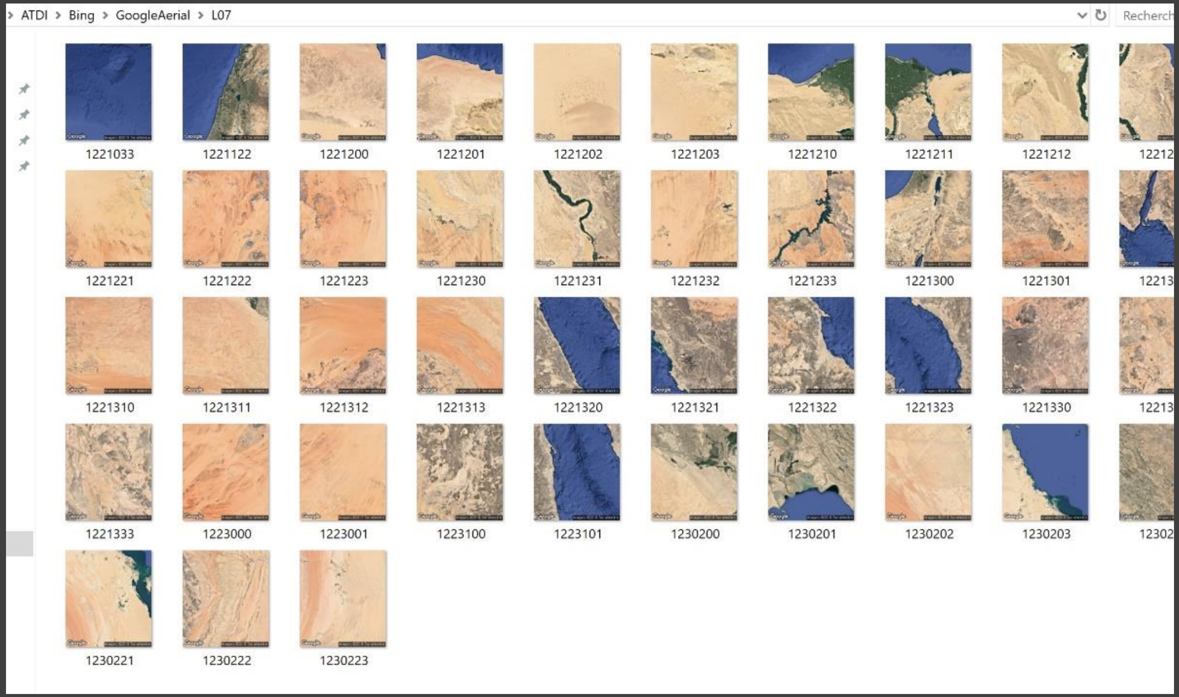
Covered zones in Multimap file

Managing GIS Data; Multi-Map Offline Cache

If the customer provides the sources (offline), it is simply to set up the multi-map. If no sources are available, ATDI can provide offline cache images obtained from Google Maps, MS Bing, etc.

Example,

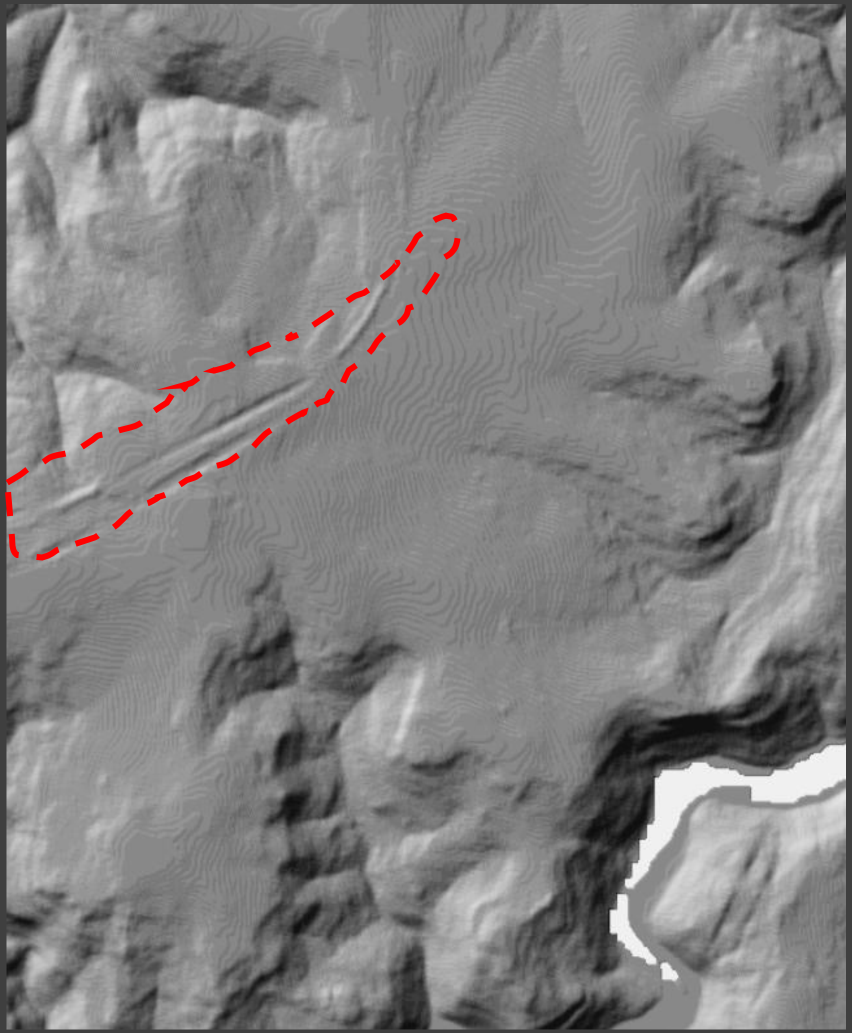




Supporting
Robust GIS Data Manipulation

RF planning tool should have a capabilities to interpolate such dynamic structures and environments in DTM/DEM along the rail corridors as it's the main inputs for propagation modelling accuracy. HTZ supports rail centerline importation in vector formats.

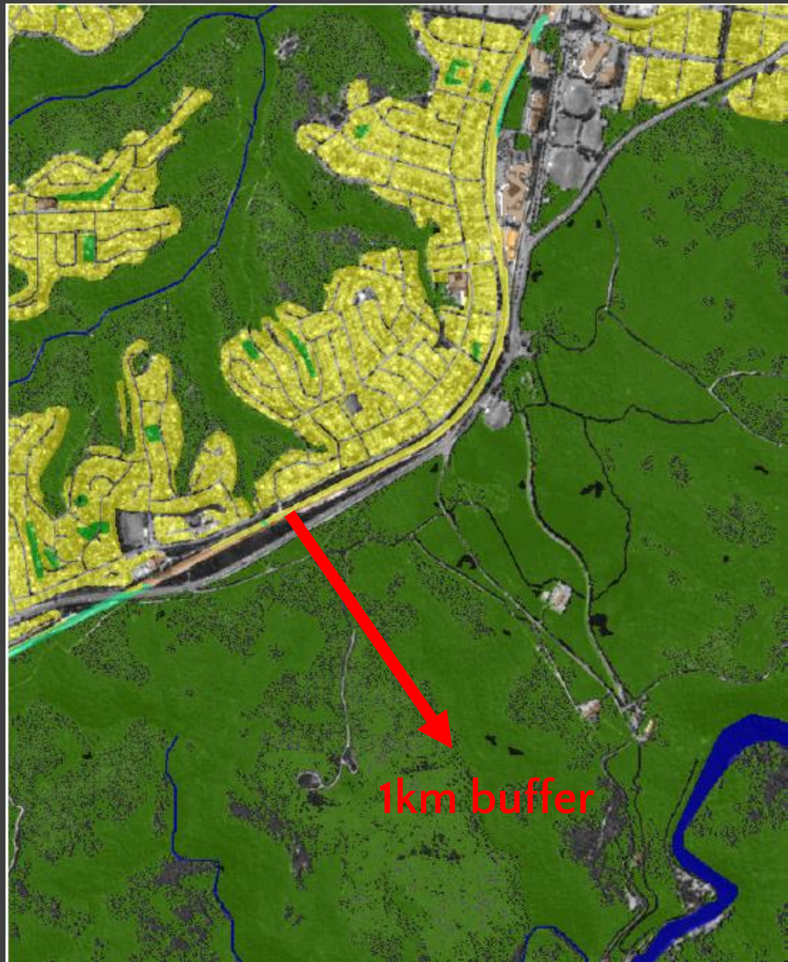
- Cuttings through mountains
- Tunnels
- Rail Corridor elevations
- Footbridges
- Platforms and Stations



Supporting
Robust GIS Data Manipulation

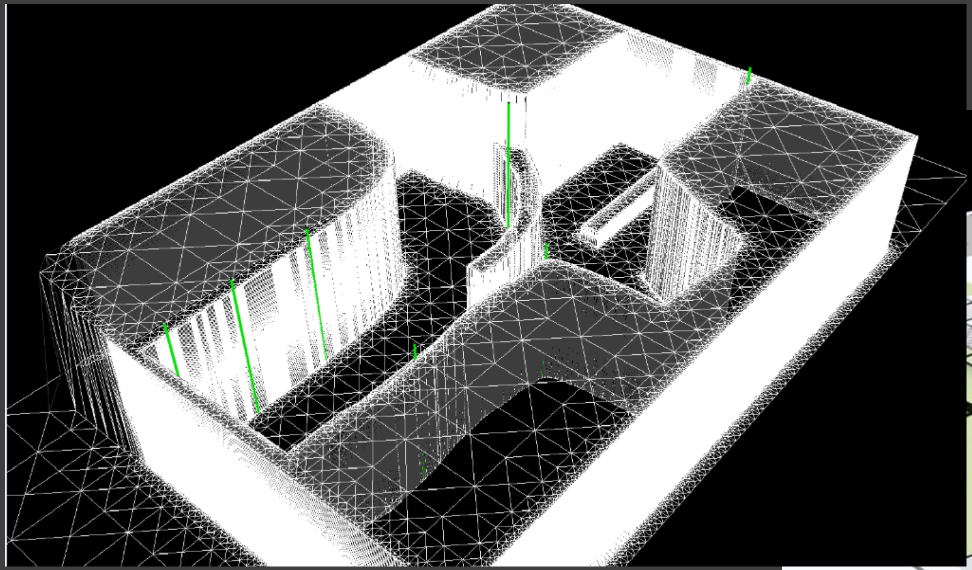
Creating multiple rail clutters depending on environment to provide higher flexibility to tune environment models which also impacting the accuracy of the propagation modelling

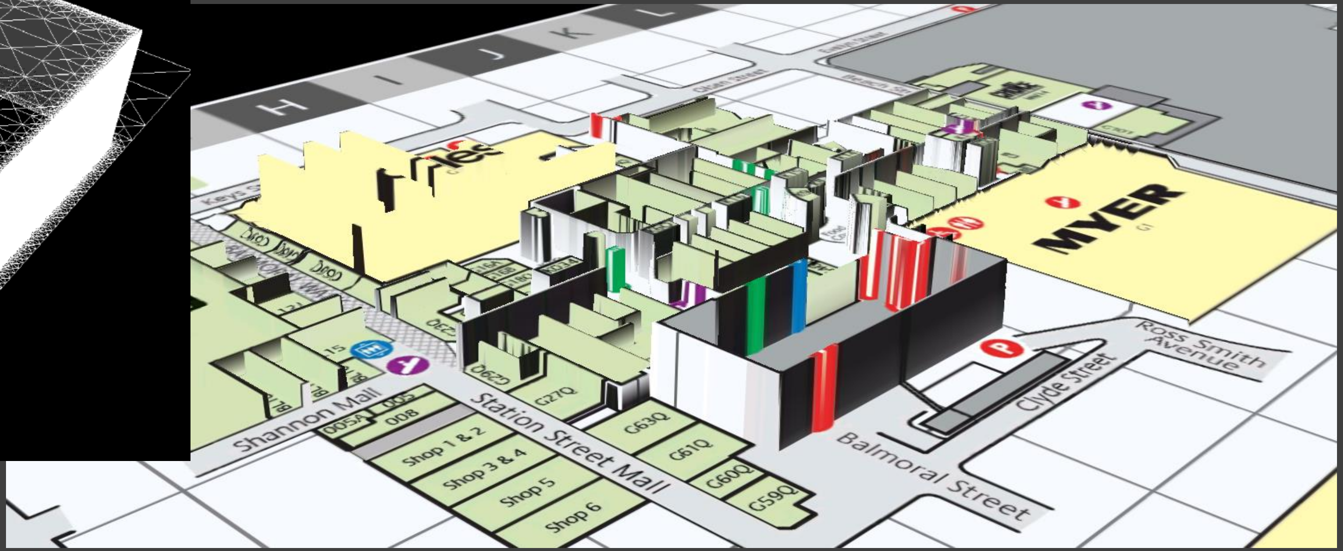
0	Open/Open in Uurban
1	Water
2	Mean Suburban
3	Dense Suburban
4	Mean Urban
5	Dense Urban
6	Skyscrapers
7	Village
8	Industrial
9	Forest
10	Park
11	Railcorp Building
12	Tunnel
13	Rail in Open
14	Rail in Suburban
15	Rail in Urban
16	Rail in Village
17	Rail in Industrial
18	Rail in Forest
19	Bridge over rail



Supporting
Robust GIS Data Manipulation

Tunnels and stations/platforms, HTZ imports ESRI (.shp), AutoCAD (.dxf), or laser scans (LiDAR in LAS or LAZ) in very high resolution to create the indoor models.



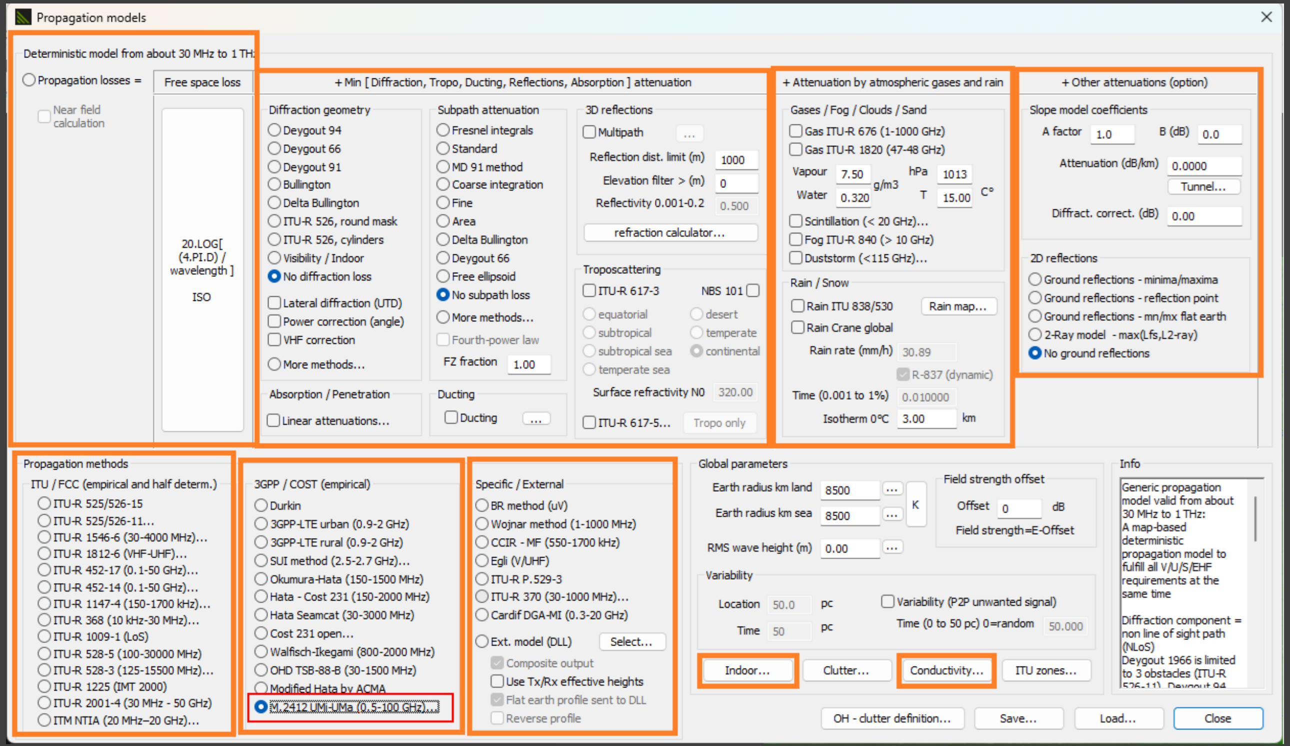


Supporting multiple frequencies and technologies

Propagation models

HTZ has a complete propagation model library including all ITU-R recommendations and industry standards such as 3GPP, COST models. It supports 3D ray-tracing in various modes and atmospheric effects also can be simulated. If one has a customised propagation model, it can be imported in .dll.

1. Free Space model
2. Diffraction models
3. Tropo-scattering models
4. Deterministic ITU Recommendations
5. Industry standard models including aeronautical models
6. Specific/external & custom-built models
7. HF conductivity model

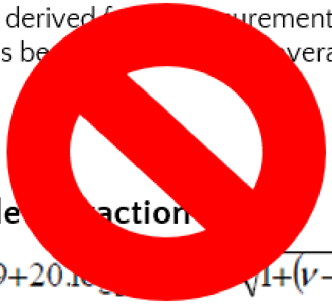


Full-Deterministic Propagation models using **customised GIS data** inputs

Full-Deterministic Propagation models

Deterministic modelling:
- Path specific,
- Superior accuracy,
- Dependent on terrain and clutter height
- Calculates free-space, diffraction and reflections
- Example: ITU-R P.525/526 Deygout-94 method

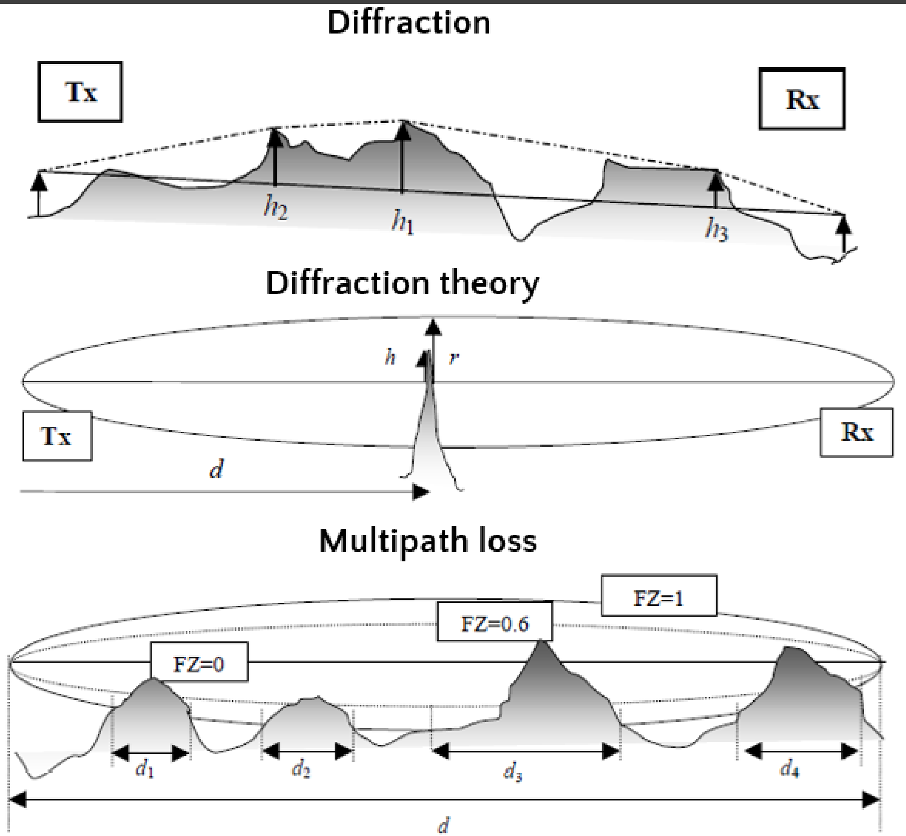
Empirical modelling: the calculation of the signal loss is based upon propagation formulas
that have been derived f… …urements (Okumura Hata, COST231…). Has be… …verage



Simple … action

$Ld = 6.9 + 20.l\ldots \sqrt{1+(v-0.1)^2}\,]$

where $v=\sqrt{\frac{h}{r}}$



Comparison between SPM & Deterministic models

SPM model	Deterministic model
SPM model is fundamentally a curve fitting approach to measured data in order to model the path loss. It also includes a correction term to account for attenuations caused by diffractions from local obstacles. Therefore, the SPM model fundamentally consists of a curve with local corrections provided by the diffraction term. The K2 and K5 parameters control the slope of the curve (and hence the path loss exponent), and other K factors control the Y Intercept. As field measurements are highly correlated with the characteristics of the environment in which they are carried out, the K values would have to be tuned in order to adapt the SPM model to local environment. This implies re-using K values from one project to another project will introduce inaccuracies and error to the path loss predictions. Another source of complication with the SPM model is its dependence on the Transmitter and Receiver heights. Once K values are tuned for a given Tx and Rx heights, changing these heights could compromise the accuracy of the SPM model, as it will affect the Y intercept of the fitted curve.	The general form of the deterministic model is *Path Loss = Free Space Path Loss + Diffraction attenuation + Sub-Path attenuation.* Since all components of the model are deterministic and terrain height is the only height of interest (i.e. no clutter height is considered and hence no need for clutter height tuning), there's no requirement for curve fitting to adapt the model to rail services environment.

Comparison between SPM & Deterministic models

Difference in Path Loss Correction Term

SPM and Deterministic models make use of Diffraction to provide compensation to path loss calculations. The accuracy of diffraction calculations depends on the number of edges that the given method considers in its calculations. While the maximum number of diffracting objects that are considered in SPM are 3 (ITUR 526-5), there are no limits in other models such as Deygout 94 method

Comparison between SPM & Deterministic models

Line of Sight Conditions

Environment	Full deterministic	SPM Model
LOS	ITU P.525, function of frequency and distance	Hata model, function of tuneable K factors as well as Tx & Rx antenna heights
nLOS	Standard Sup-Path model, function of terrain profile, Tx & Rx antenna heights	
NLOS	Deygout 94 model, considers unlimited obstacles, function of terrain profile as well as Tx & Rx antenna heights	Diffraction models such as Deygout 66, considers Max. of 3 obstacles, function of terrain profile as well as Tx & Rx antenna heights

Comparison between SPM & Deterministic models

Correlation comparison samples

	Full-Deterministic Model			SPM Model		
Site	Std. Dev	Mean error	Cor. Factor	Std. Dev	Mean error	Cor. Factor
Site_1	5.73	-2.68	0.86	9.1	7.7	0.58
Site_2	5.92	-5.27	0.85	8.74	-0.33	0.53
Site_3	2.7	0.03	0.96	7.45	9.1	0.6
Site_4	3.26	-0.79	0.95	7.15	3.21	0.69
Site_5	3.07	-0.81	0.95	5.9	-0.05	0.63

Indoor & Outdoor Network Design

(3G, 4G & 5G)

Link Budget Calculation (1/2)

HTZ provides an in-built link budget calculator

to calculate them based on different input parameters:

- RSRP threshold for best server and RS coverage display and during SNIR calculations

- Coverage threshold for the minimum field strength (or power received) on the UE from the eNodeB/gNodeB. It is set in the Threshold parameters box as the Global threshold, or Cov. threshold in station parameters (if mode “Threshold from stations” is set in Threshold parameters box). It is an unbalanced threshold and is calculated from:

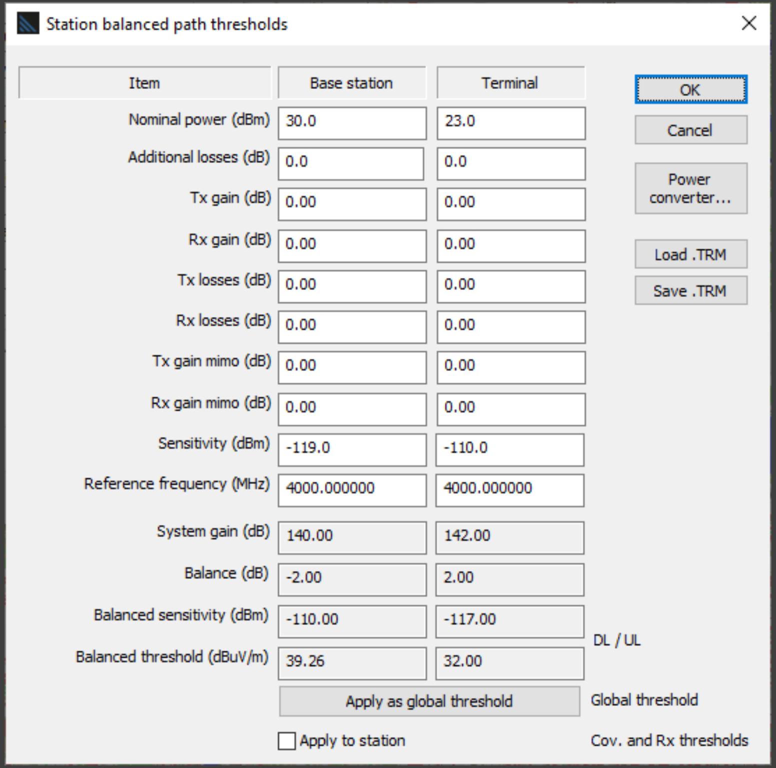
✓ Network parameters (Bandwidth, Probability to achieve, Standard deviation);

✓ Downlink parameters: SNIR required for throughput, Noise figure.

- Rx threshold for the minimum field strength (or power received) on the eNodeB/gNodeB from the UE. It is an unbalanced threshold and is calculated from:

✓ Network parameters (Bandwidth, Probability to achieve, Standard deviation);

✓ Uplink parameters: SNIR required for throughput, Noise figure.



Link Budget Calculation (2/2)

HTZ provides an in-built link budget calculator

to calculate them based on different input parameters:

- Maximum permissible path loss (dB) downlink for the Radio link budget for downlink. It is calculated from:

o eNodeB/gNodeB parameters (power, Tx gain including MIMO gain and losses) and UE parameters (Rx gain including MIMO gain and losses);

✓ Network parameters (Bandwidth, Probability to achieve, Standard deviation);

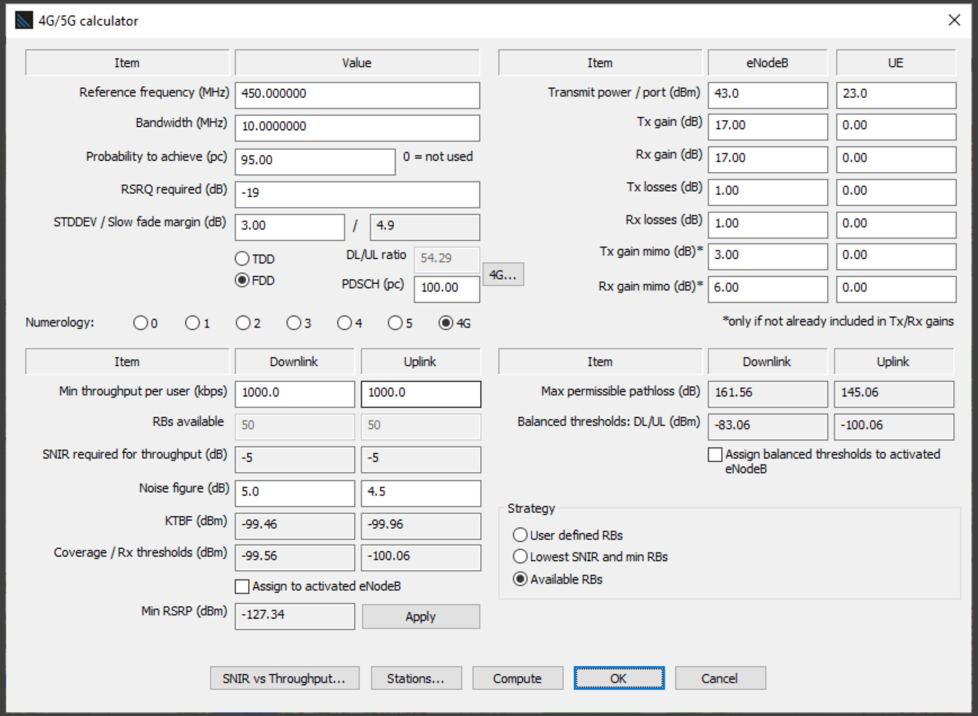
✓ Downlink parameters: SNIR required for throughput, Noise figure.

- Maximum permissible path loss (dB) uplink for the Radio link budget for uplink. It is calculated from:

o eNodeB/gNodeB parameters (Rx gain including MIMO gain and losses) and UE parameters (Power, Tx gain including MIMO gain and losses);

✓ Network parameters (Bandwidth, Probability to achieve, Standard deviation);

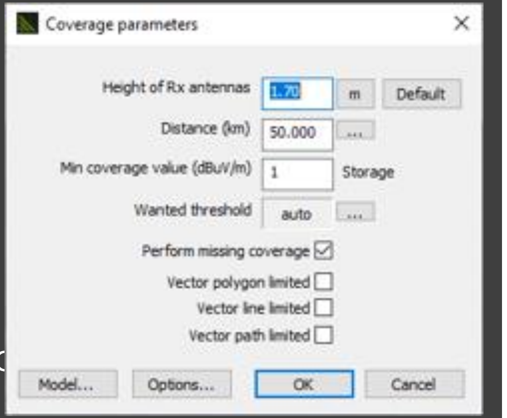
✓ Uplink parameters: SNIR required for throughput, Noise figure.

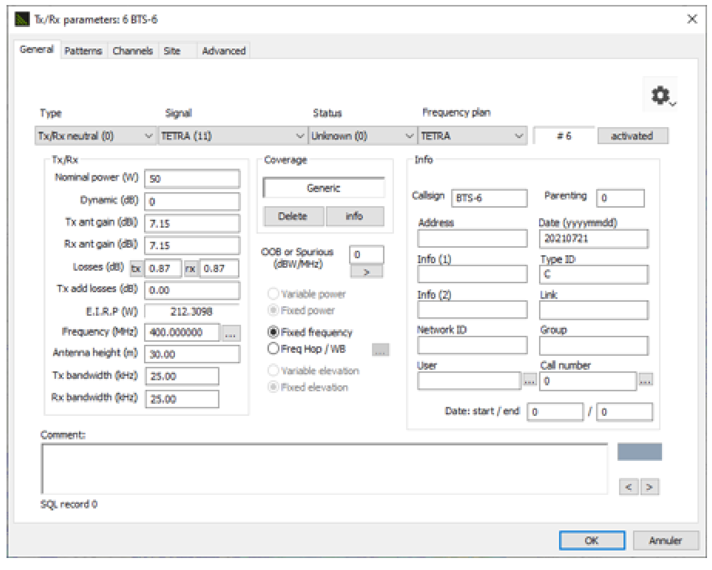


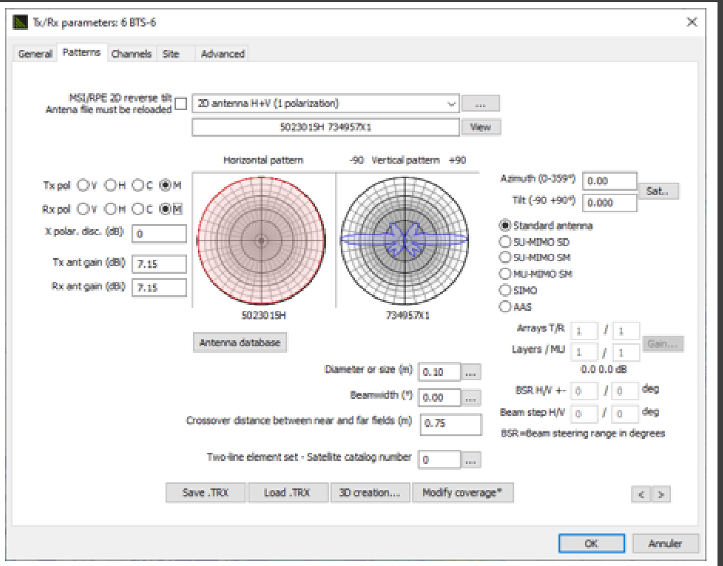
Managing Technical Parameters

HTZ provides a comprehensive technical parameter setup for both transmitters and receivers. In addition, database can be used to select equipment (Tx/Rx) and antennas or predefined station/mobile settings.

Once the coverage of each station has been performed, it will be automatically attached to the stations. So, when saving the network (either to a Network file .EWFx) or a station database (Internal or SQL), the coverage will be saved along with the station locations and parameters. No need to perform the coverage again and can be used for further calculations (Composite coverage, Best server, SNIR maps, Throughput maps, ...).







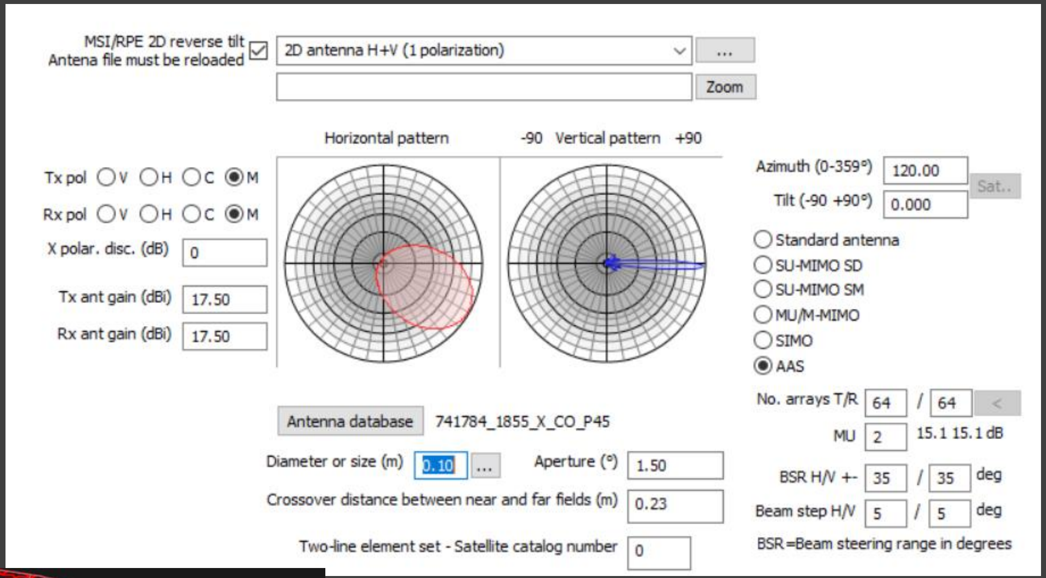
Massive MiMO Beamforming (1/3)

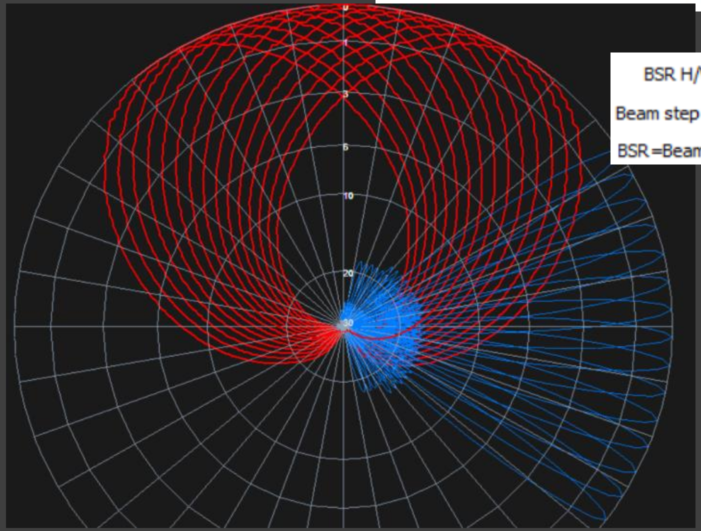
Key capabilities
- Multi-port
- Beam-forming
- Multi-user MIMO (massive MIMO)

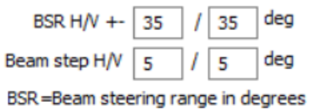
Antenna database
- Managing multiple vendors

Smart antenna – auto switch
- Transmission diversity (SD-MIMO)
- Spatial multiplexing (SM-MIMO)
- Multi-user (MU-MIMO)
- Mixed (all above)
- Auto switch to achieve best throughput

NR adaptive (SMART) – Beamforming
- Specify min/max limits
- V and H planes
- Specify steering steps



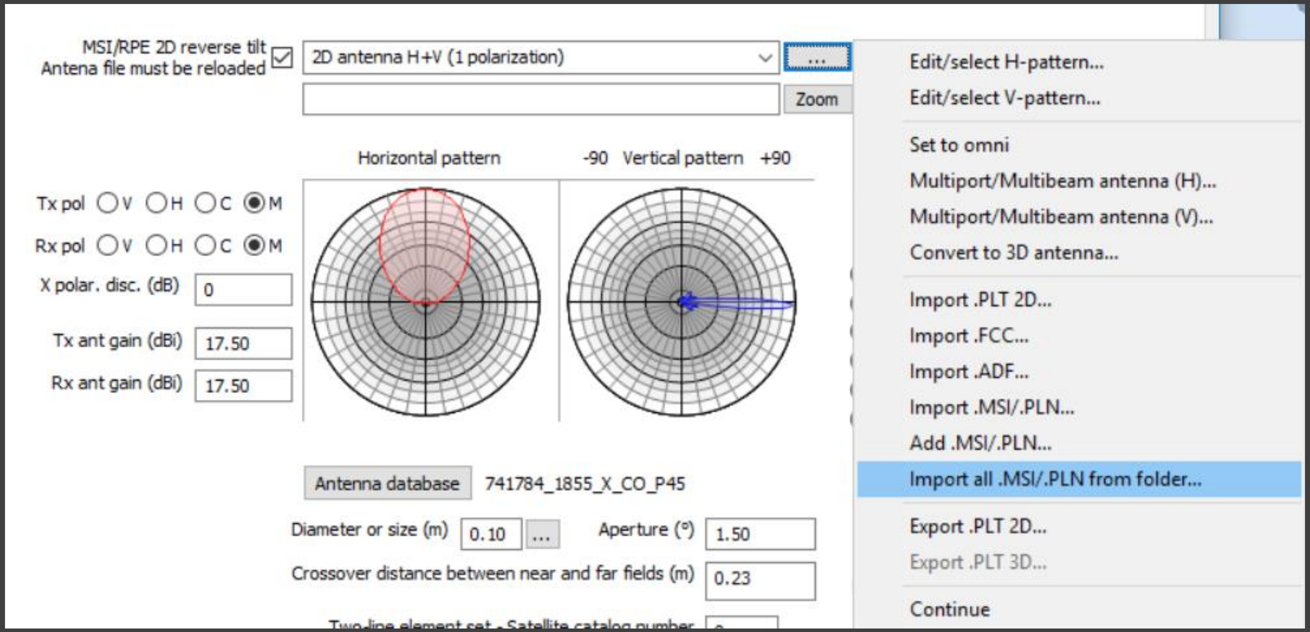




Massive MiMO & Beamforming (2/3)

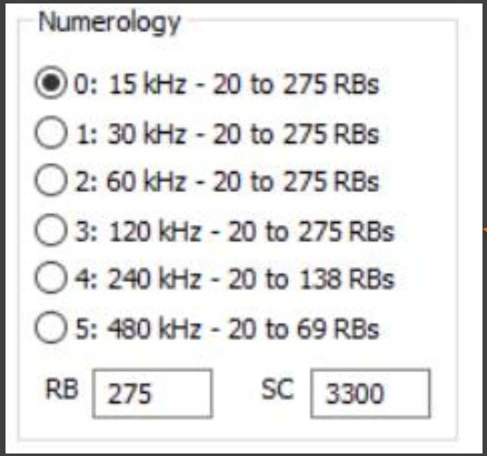
NR adaptive (SMART) – batch import of beam patterns

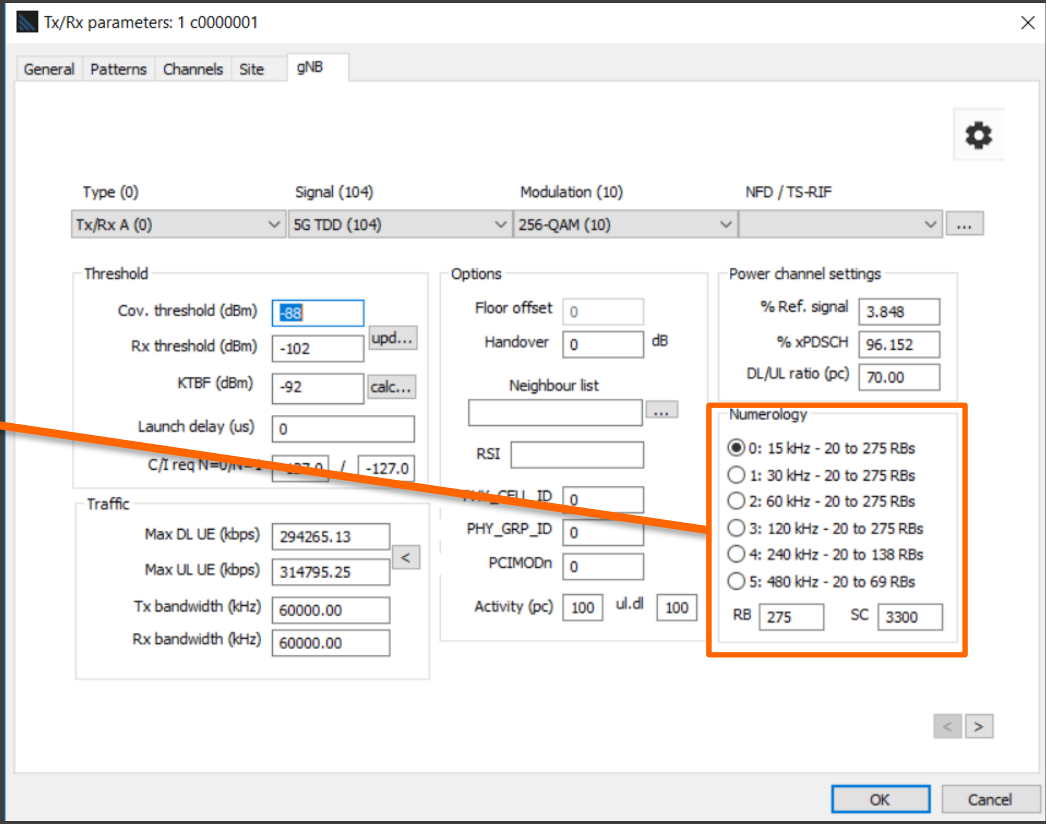
Support broadcast and service beams: Batch importation and combination of multiple beams



Massive MiMO & Beamforming (3/3)

Flexible 5G numerology modelling approach





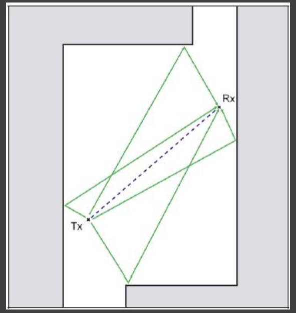
Reflections in tunnel – Multi-Path (3D reflection)

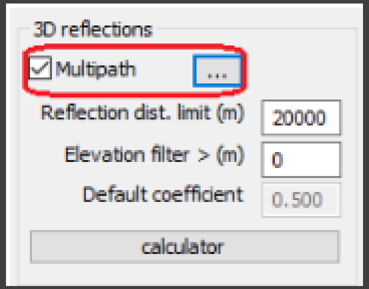
Using the full-deterministic propagation models, HTZ supports 3D ray tracing which calculates reflectivity of tunnel walls, ceiling and ground.

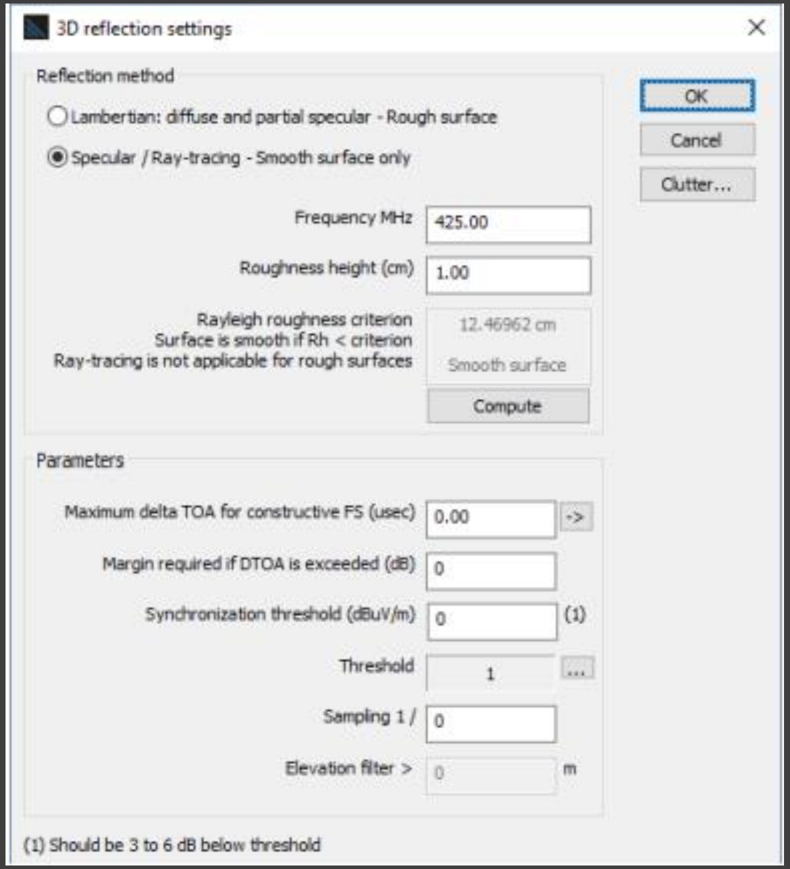
It includes the Specular / Ray tracing (Smooth surface only) mode which is applicable for smooth surface reflection calculation such as tunnels. Only one reflected ray is considered for each reflection point, where Reflection angle = Incident angle.

* Lambertian: diffuse and partial specular for Rough surface computing the field strength received on all points of the simulation area considering the reflected signals contributions.

Multi-path reflections







Coverage analysis (1/2)

HTZ provides coverage simulations and other network analyses such as:

- Tx/Rx UL/DL coverage
- 3D coverage
- Composite coverage
- Best server and best activated server coverage
- Site overlapping
- Simultaneous server and channels map
- Differences between sites

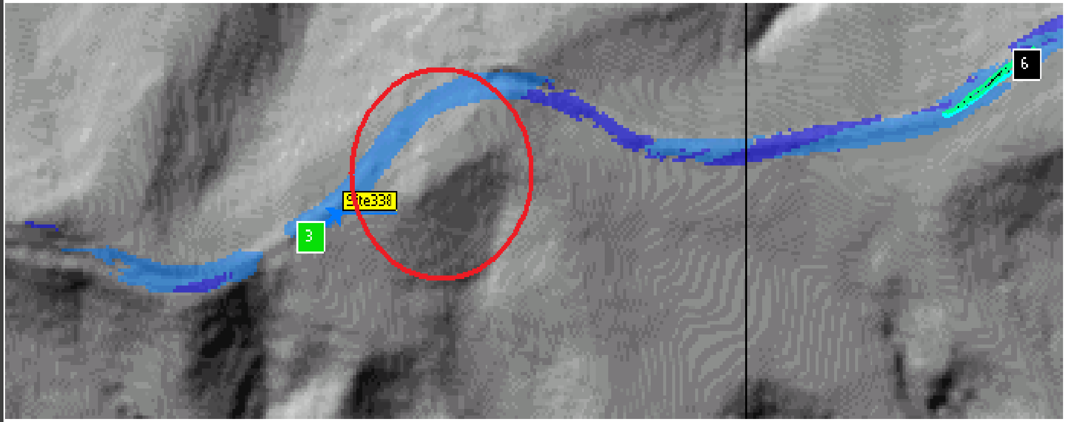


Figure 126, best server, terrain obstruction from site 338

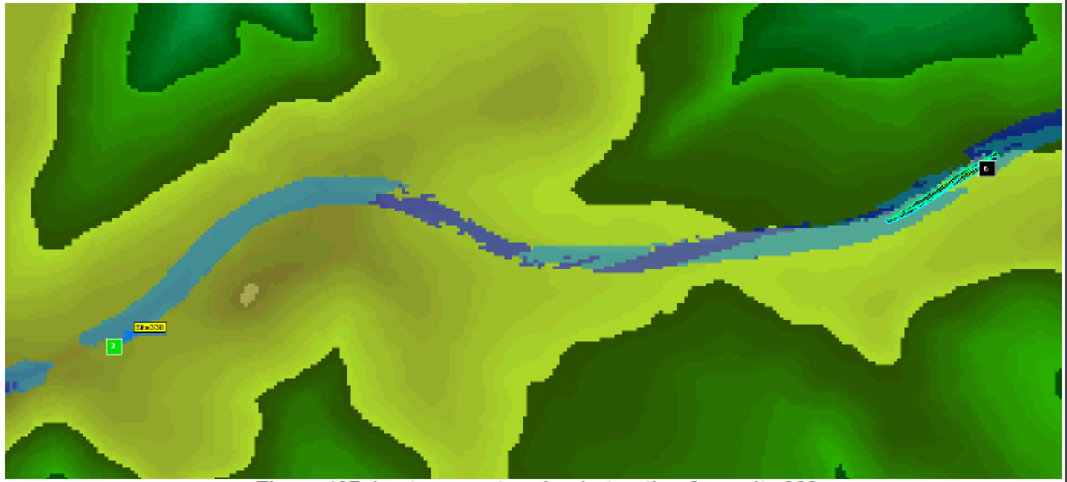


Figure 127, best server, terrain obstruction from site 338

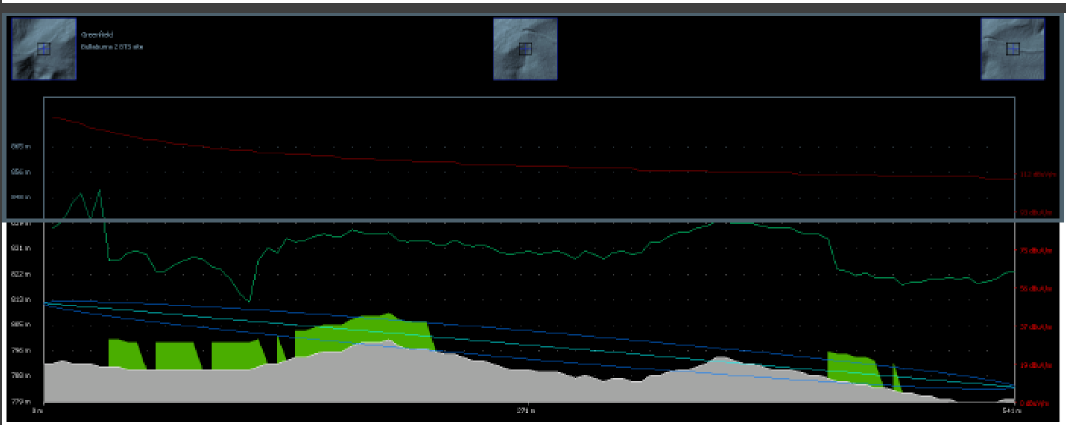
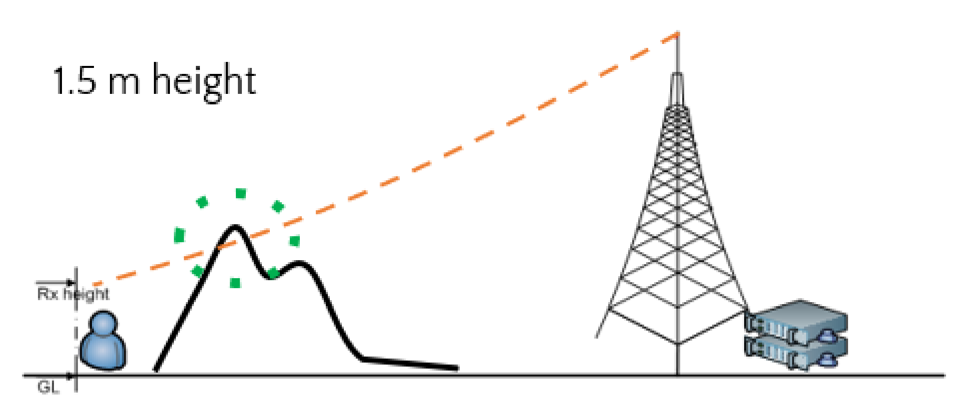
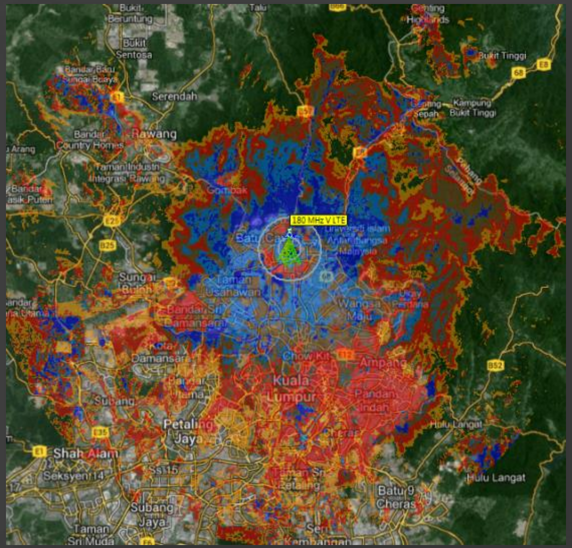


Figure 128, profile from site 338 to pixels with low coverage

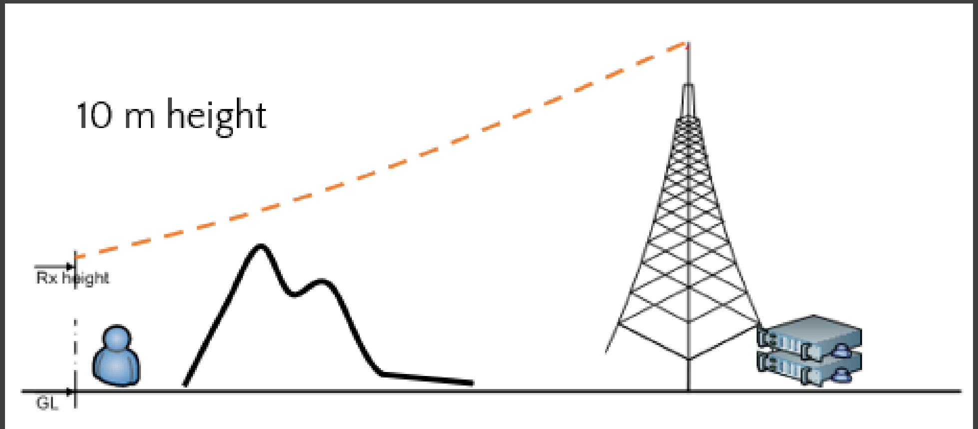
Coverage analysis (2/2)

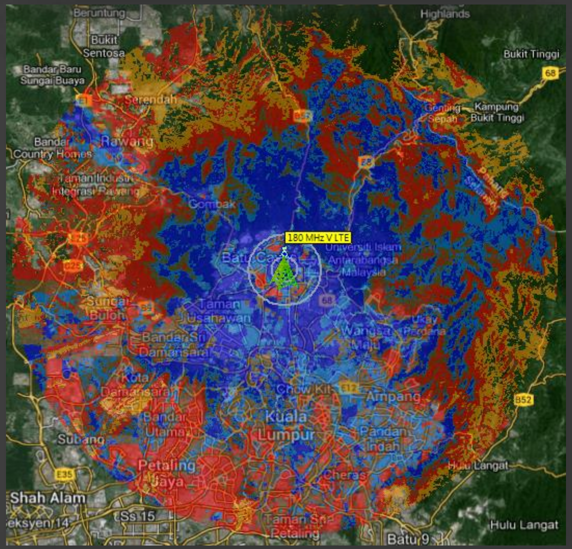
Example: Notion of deterministic predictions RX antenna height





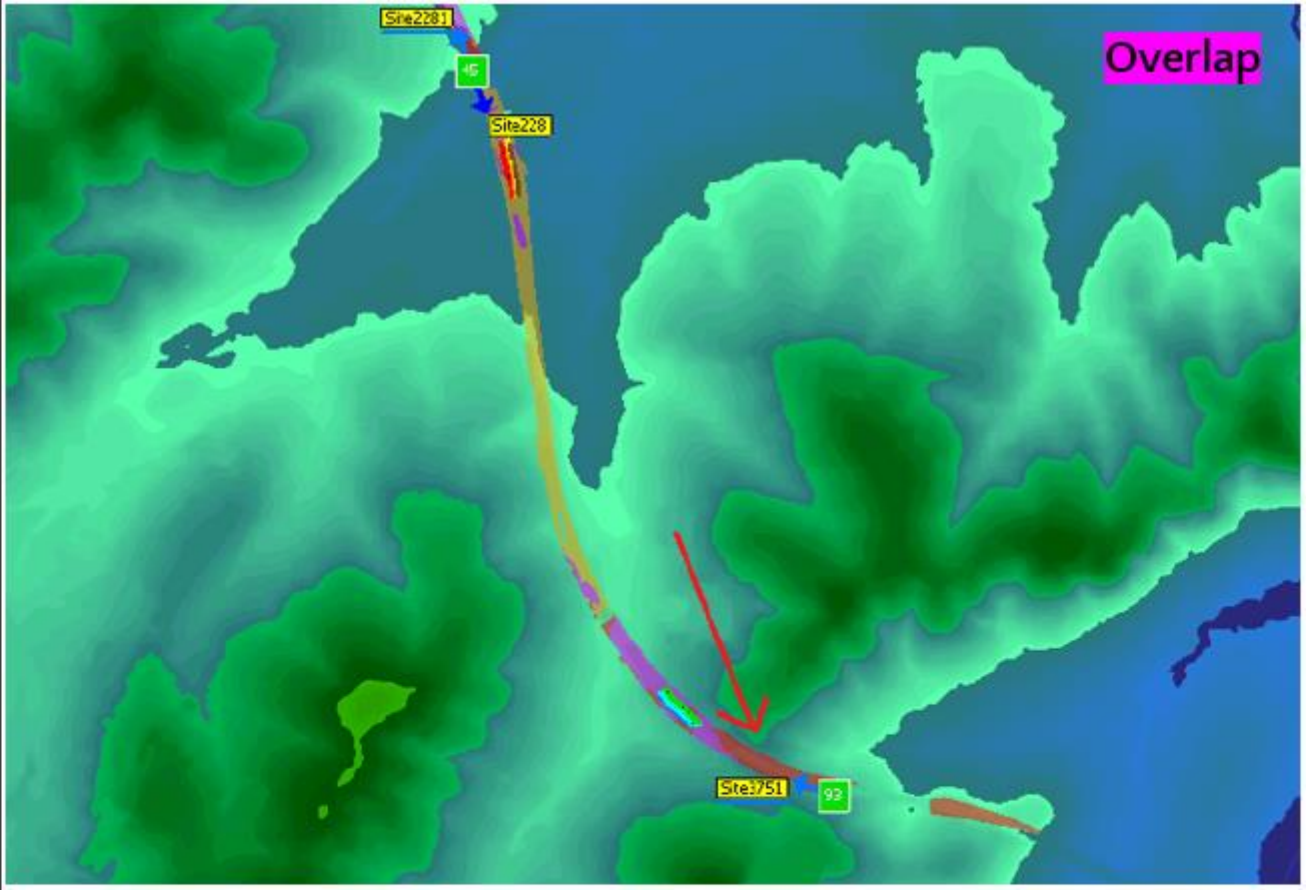
1.5 m height
826.14 KM²





10 m height
1119.6 KM²

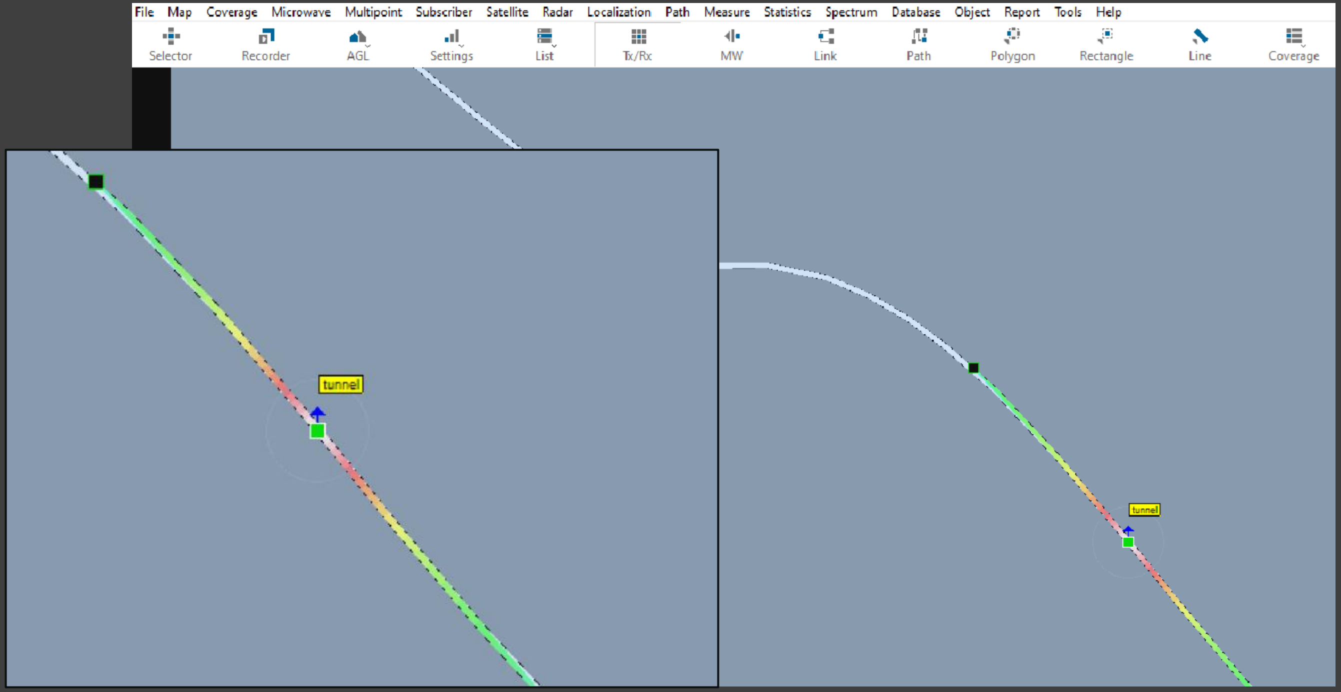
Coverage Overlap Analysis



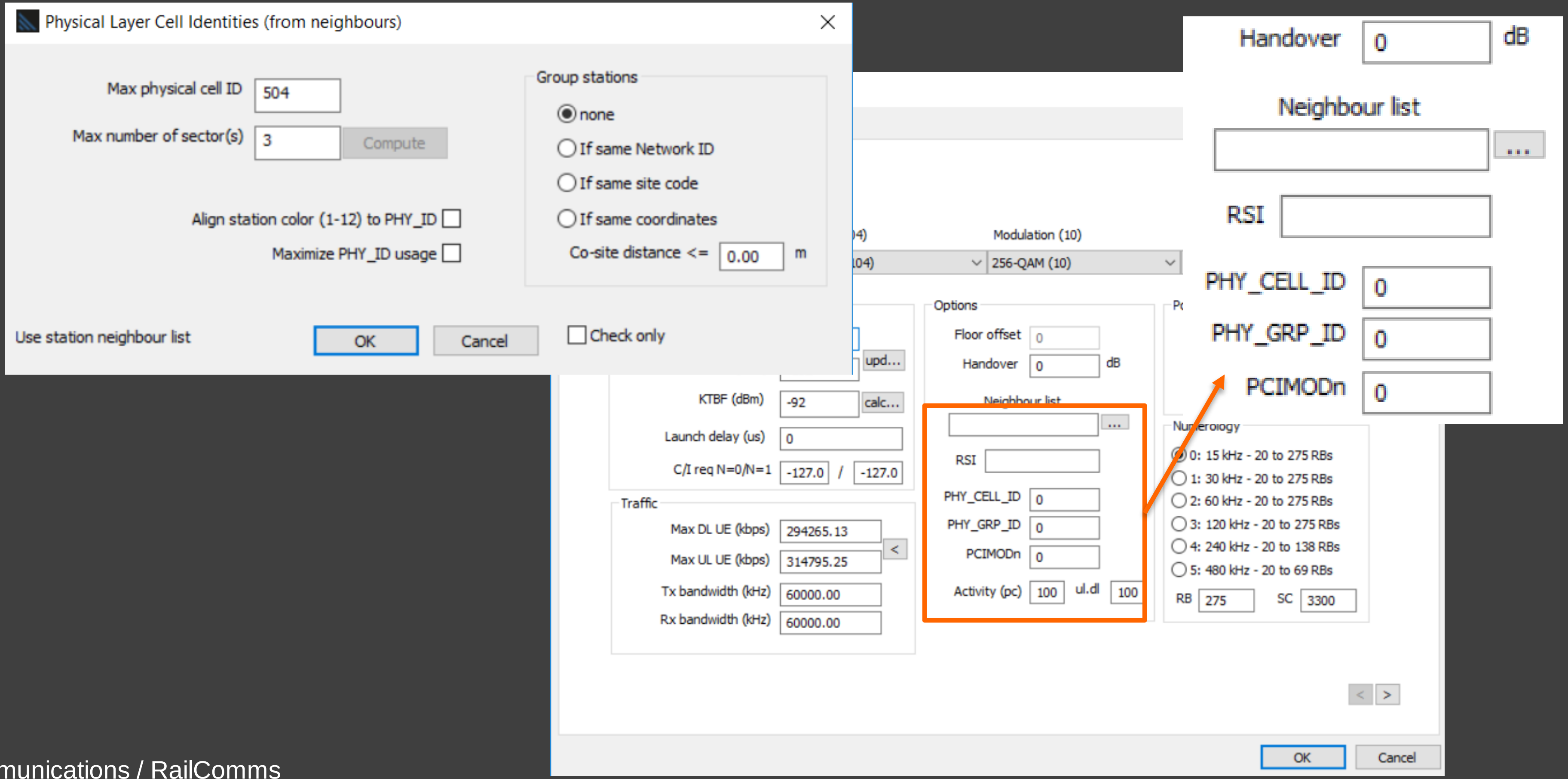
Indoor Tunnel Coverage

Tunnel (Pure indoor) – engraving

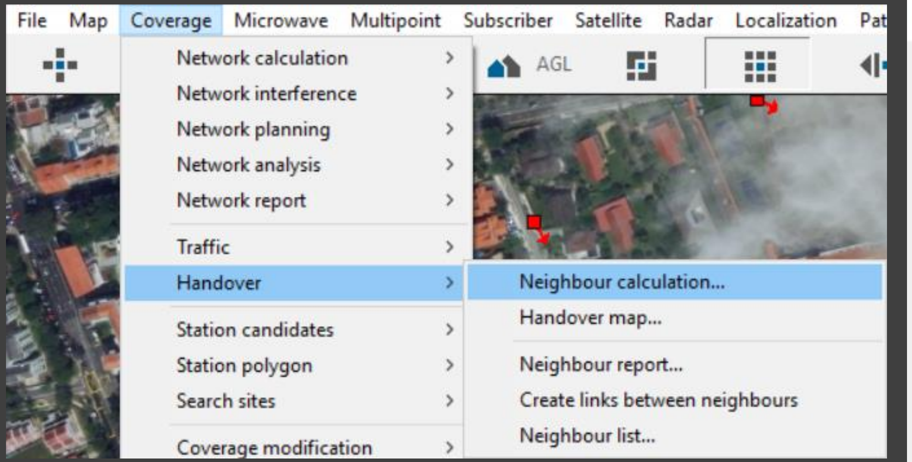
The walls of the tunnel are modelling; reflections calculated as well. The entire tunnel coverage can be attached to one object (e.g base station or repeater) and loaded in outdoor model.

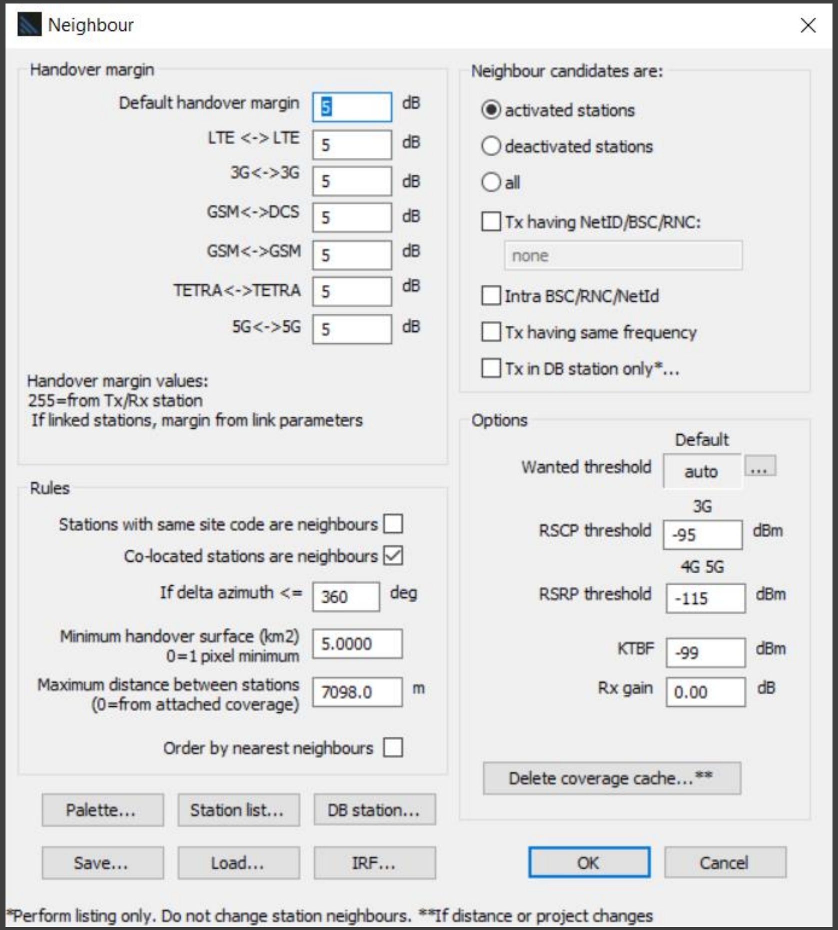


Auto Cell ID and neighbour planning (1/2)

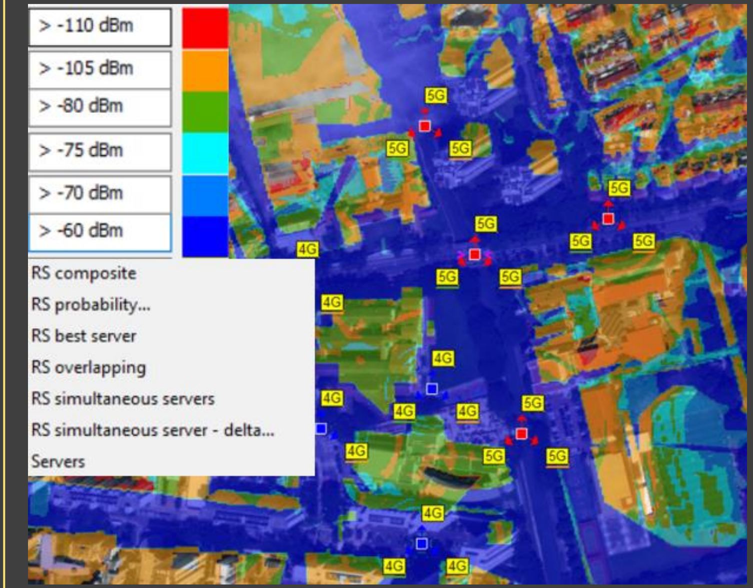
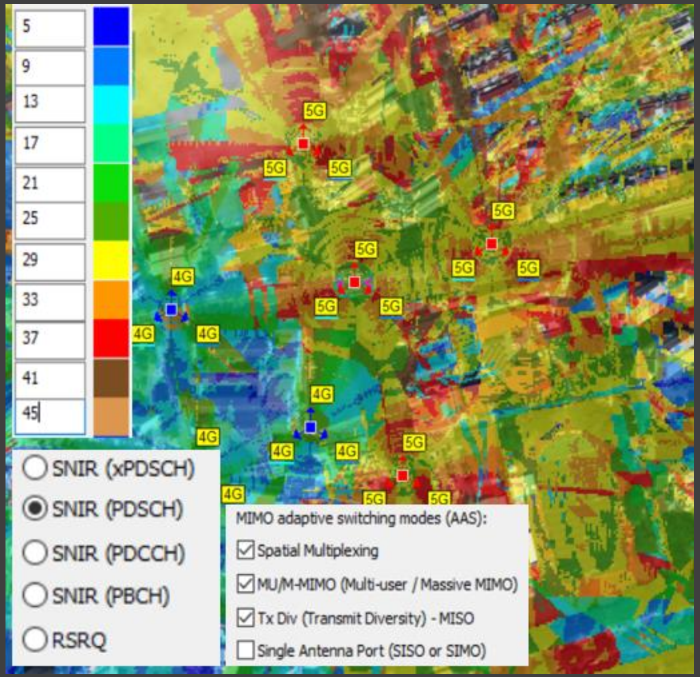
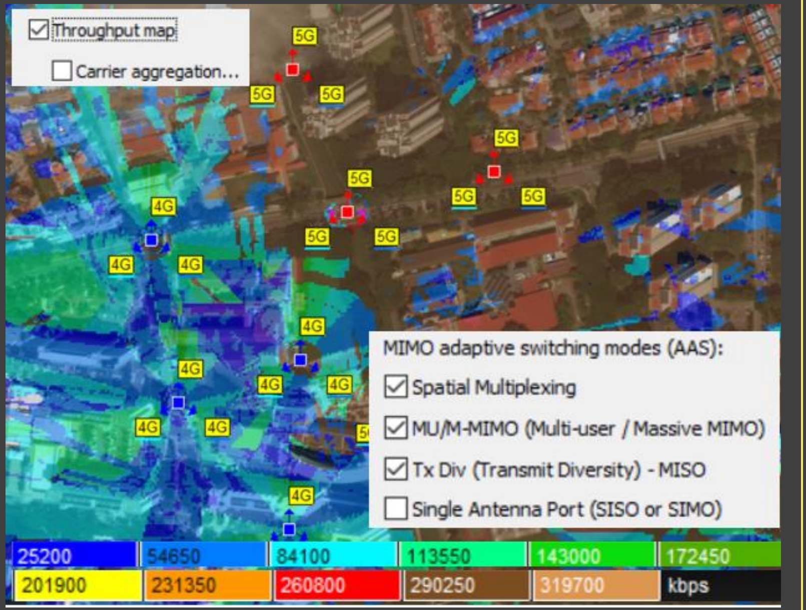


Auto Cell ID and neighbour planning (2/2)



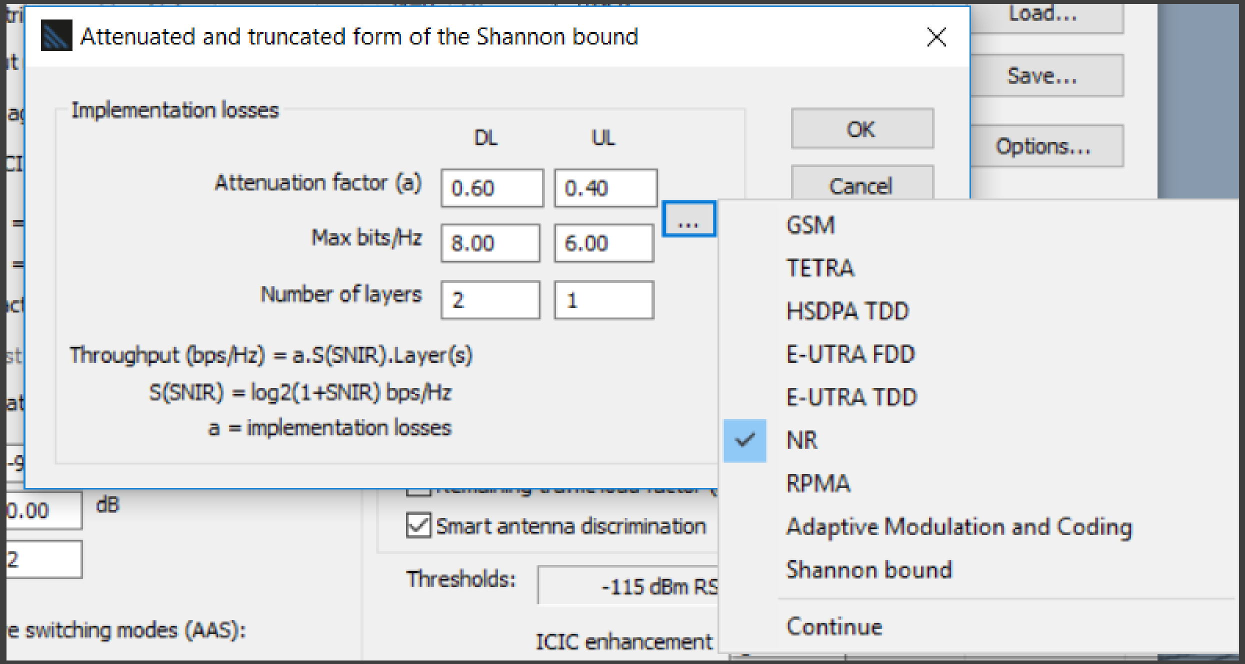


RSRP/SINR/Throughput analysis (1/2)

RSRP	SINR	Throughput Carrier aggregation
		

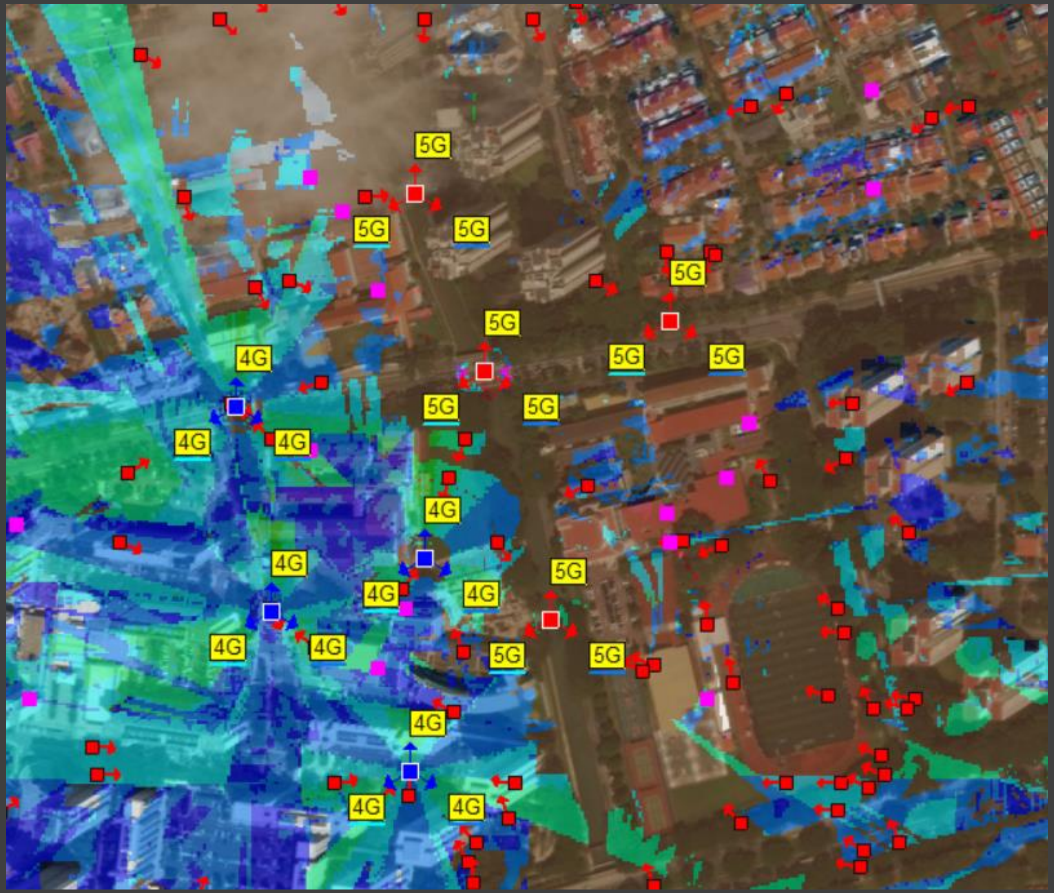
RSRP/SINR/Throughput analysis (2/2)

- Vendor independent approach to throughput calculations
- 3GPP compliant throughput assessment
- Support for TDD/FDD, LTE & NR



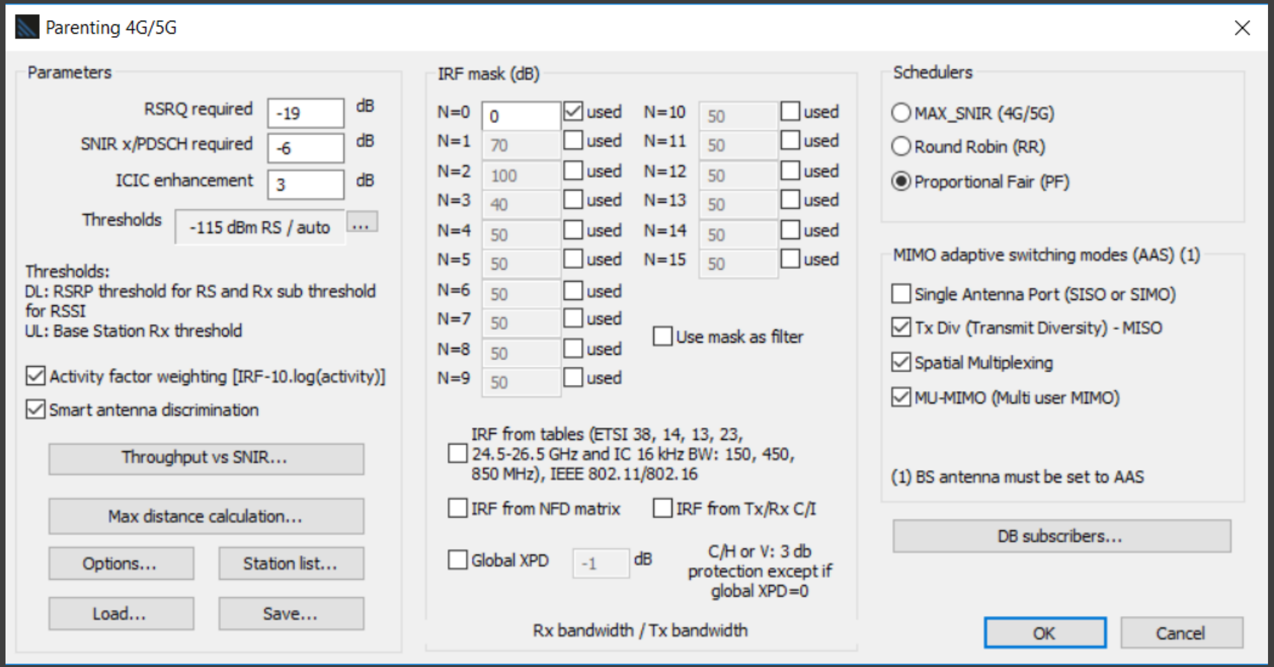
Subscriber modelling and traffic analysis

- Generate traffic scenarios
- Generate subscribers or import existing subscriber database
- Assign traffic profiles (handsets)



Traffic and QoS prediction simulation (1/2)

- Support for multiple scheduler configurations
- Model base station load
- Model smart UE antenna
- Support for AAS BTS antenna



Traffic and QoS prediction reports (2/2)

Report listing

Record	Subscriber #	Address	info1	Info2	Station #	Callsign	Group code	Wanted Power (dBm)	RSSI (dBm)	RSRP (dBm)	PUSCH (dBm)	RSRQ (dB)	SNIR PDSCH (dB)	Gain (dB)
1	1	adr1			7	c000...		-40.3	-39.8	-75.5	-68.1	-11.3	11.9	18.1
2	2	adr2			7	c000...		-22.2	-22.1	-57.4	-50.0	-10.9	18.6	18.1
3	3	adr3			10	c000...		-48.5	-48.1	-83.6	-76.2	-11.1	14.2	18.1
4	4	adr4			7	c000...		-42.1	-41.3	-77.3	-69.9	-11.6	9.7	18.1
5	5	adr5			7	c000...		-20.7	-20.7	-55.9	-48.5	-10.8	24.0	3.0
6	6	adr6			10	c000...		-46.2	-45.9	-81.4	-74.0	-11.2	13.5	18.1
					9	c000...		-49.9	-48.5	-85.1	-77.7	-12.2	7.3	18.1
					10	c000...		-58.5	-57.9	-93.7	-119.6	-11.4	11.4	18.1
					10	c000...		-43.9	-43.1	-79.1	-71.7	-11.6	10.0	18.1
					8	c000...		-50.3	-49.2	-85.5	-78.1	-12.0	8.0	18.1
					8	c000...		-38.3	-37.9	-73.5	-84.7	-11.2	13.6	18.1
					10	c000...		-60.9	-58.9	-96.1	-88.6	-12.7	5.5	21.1
					19	c000...		-56.8	-53.8	-87.6	-81.5	-13.7	3.2	6.0
					9	c000...		-53.5	-52.8	-88.7	-119.9	-11.5	10.7	18.1
					10	c000...		-71.2	-70.0	-106.4	-122.9	-12.0	8.0	18.1
					4	c000...		-48.1	-47.6	-78.9	-72.8	-11.3	12.3	6.0
					9	c000...		-7.8	-7.8	-43.0	-35.6	-10.8	33.6	3.0
					9	c000...		-51.2	-51.2	-86.4	-115.4	-10.8	33.0	3.0
					4	c000...		-55.1	-52.0	-85.9	-79.8	-13.9	2.8	6.0
					11	c000...		-32.1	-30.5	-67.2	-85.4	-12.4	6.5	18.1
					10	c000...		-38.3	-38.0	-73.4	-66.0	-11.1	14.8	18.1
					10	c000...		-25.0	-24.9	-60.1	-52.7	-10.8	27.5	3.0
					10	c000...		-43.5	-43.2	-78.7	-71.2	-11.0	15.3	18.1
					3	c000...		-47.0	-44.9	-82.2	-74.8	-12.9	5.0	21.1
					12	c000...		-13.1	-11.4	-48.3	-40.9	-12.5	6.1	18.1
					16	c000...		-38.9	-38.2	-69.7	-63.7	-11.6	10.1	6.0

Listing... Close

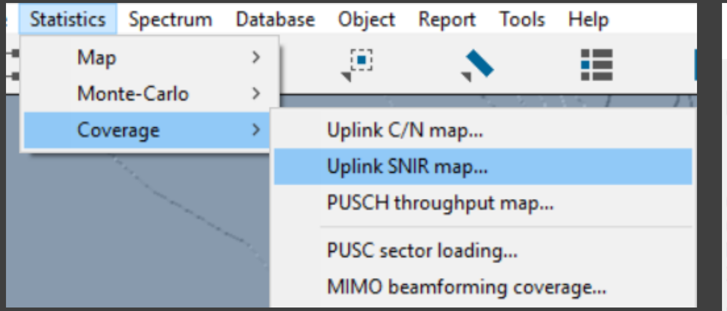
SUBSCRIBER PROPORTIONAL FAIR

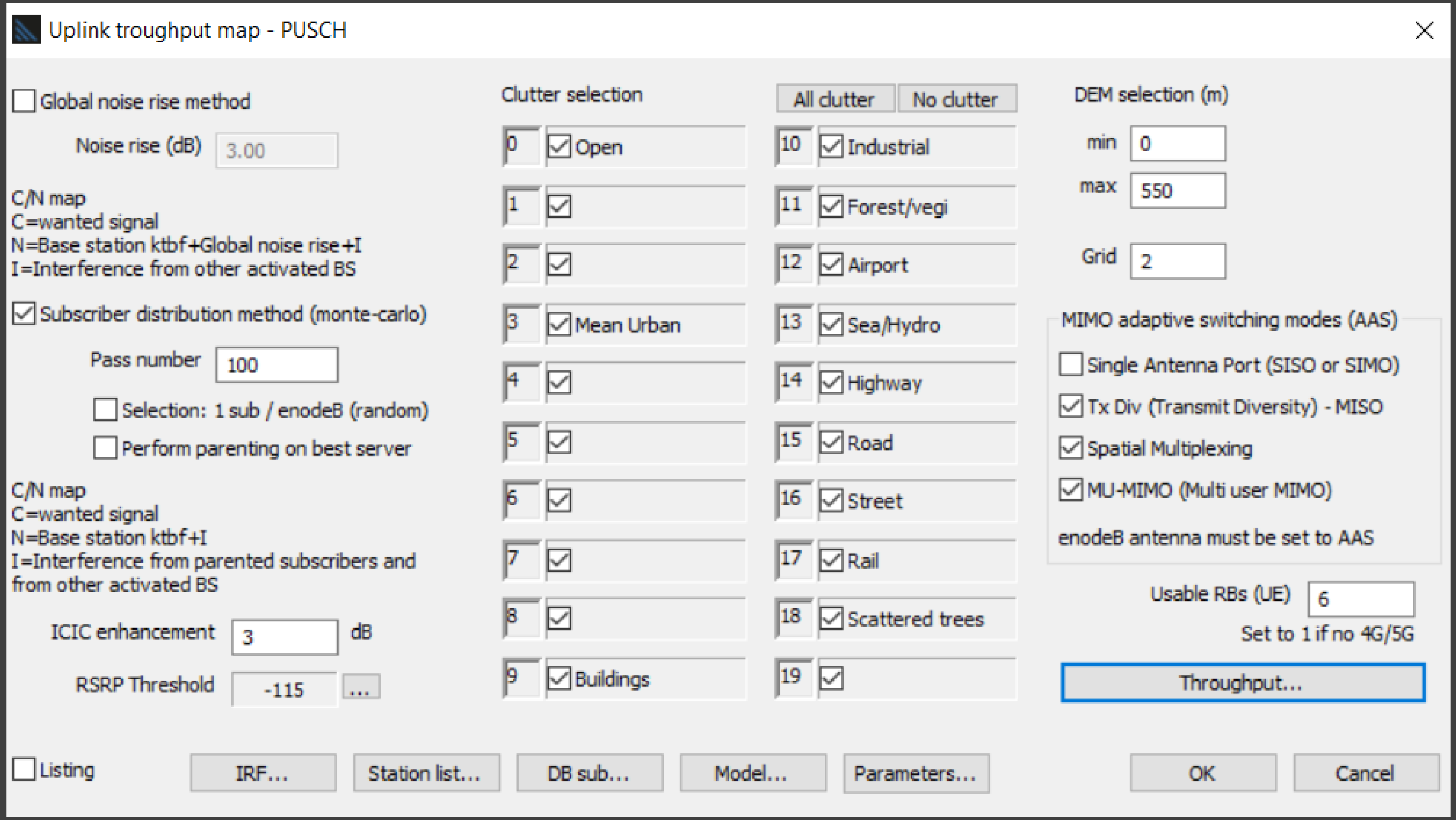
BST #	Callsign	RB/slot	Offered RB	Connected	Offered (kbps)	QoS (pc)
1	c0000001	185	0	0	0.0	0.00
2	c0000002	185	58	1	100224.0	100.22
3	c0000003	185	116	2	200448.0	100.22
4	c0000004	85	225	2	200174.6	100.09
5	c0000005	85	254	3	301477.2	100.49
6	c0000006	85	371	4	401656.5	100.41
7	c0000007	185	232	4	400896.0	100.22
8	c0000008	185	116	2	200448.0	100.22
9	c0000009	185	116	2	200448.0	100.22
10	c0000010	185	406	7	701568.1	100.22
11	c0000011	185	407	7	701992.1	100.28
12	c0000012	185	58	1	100224.0	100.22
13	c0000013	185	58	1	100224.0	100.22
14	c0000014	185	754	13	1302912.1	100.22
15	c0000015	185	0	0	0.0	0.00
16	c0000016	85	202	3	300674.6	100.22
17	c0000017	85	650	6	603017.7	100.50
18	c0000018	85	182	2	201049.7	100.52
19	c0000019	85	202	2	200426.8	100.21
20	c0000020	85	181	2	201081.9	100.54
21	c0000021	85	402	4	402666.4	100.67
22	c0000022	85	0	0	0.0	0.00
23	c0000023	85	589	7	703318.9	100.47
24	c0000024	85	609	8	803326.1	100.42

QoS network (pc): 100.34

Connected vs Connectable: 83 / 83

Uplink SINR/Throughput – Monte-Carlo simulation





Handover Analysis

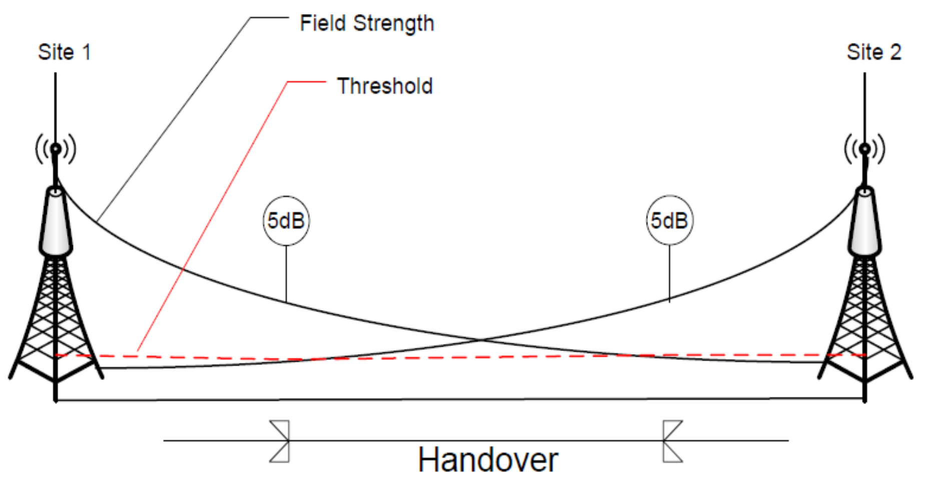


Figure 143, Concept of handover map in ICS telecom
5 dB is set as handover margin, ratio between RXLEV1 and RXLEV2

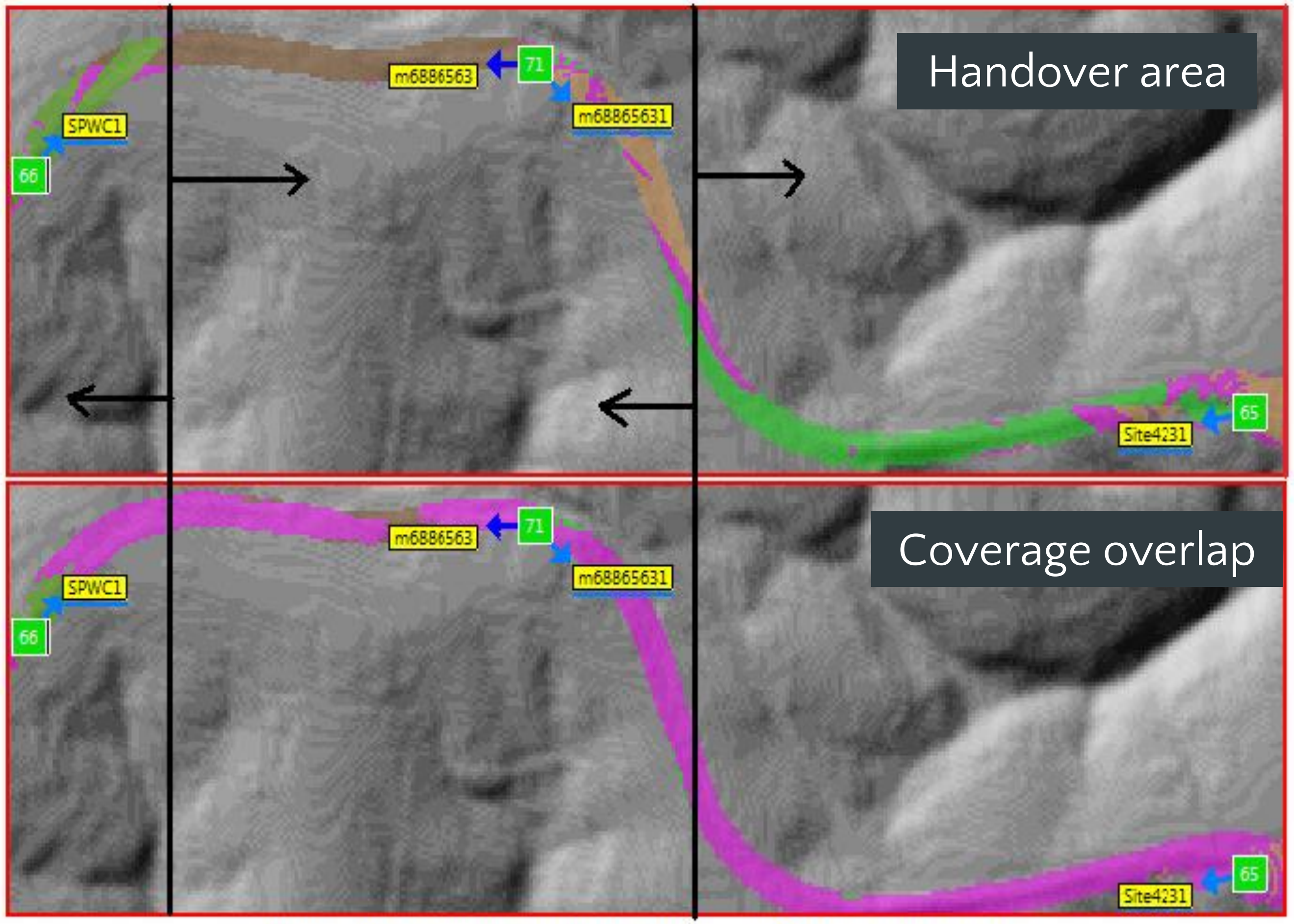
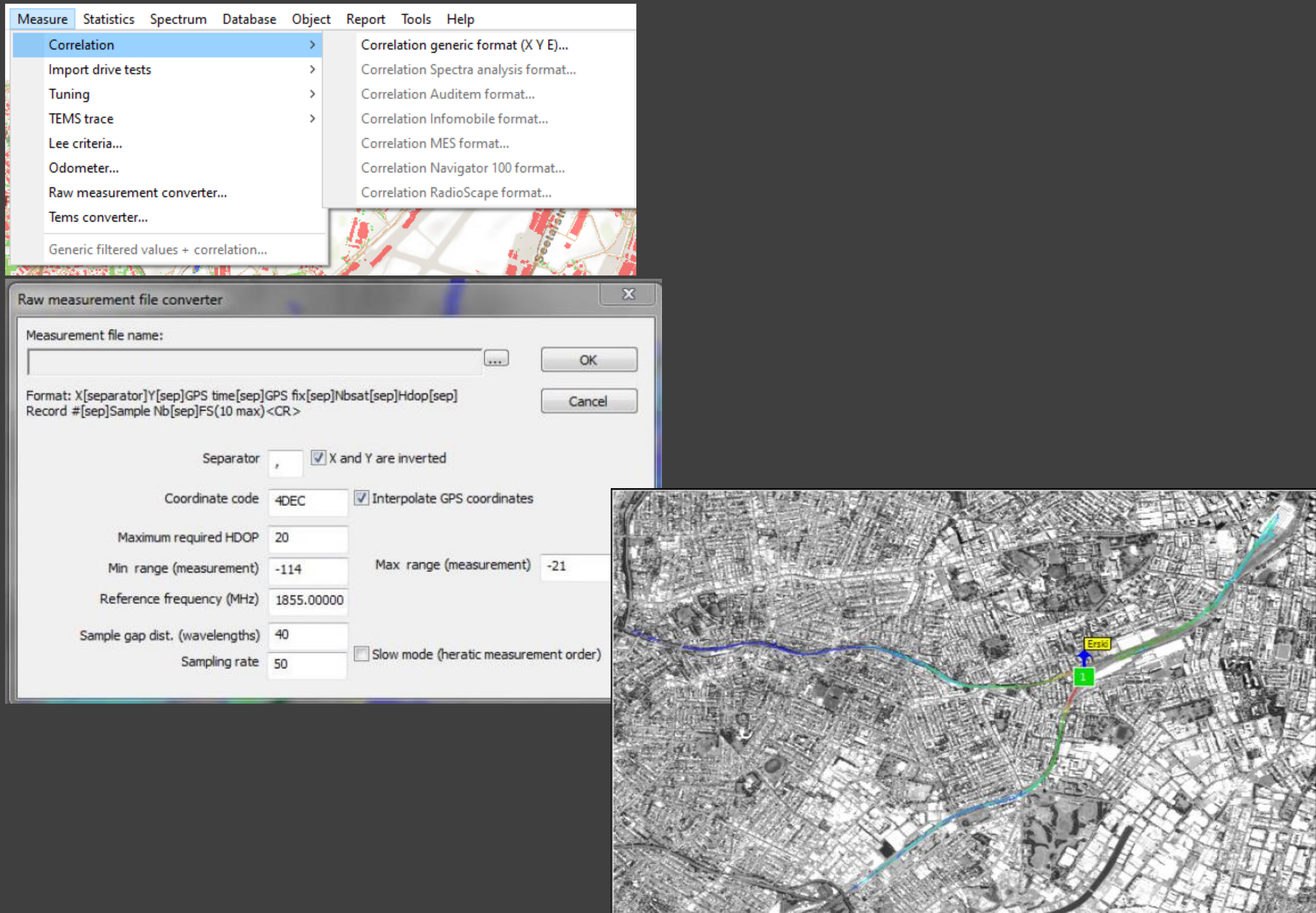


Figure 178, handover analysis for sites SPWC, m6886563& 423

Correlations and Model tuning

Importing measurement data

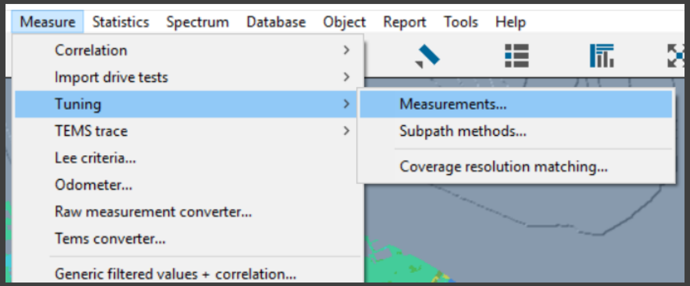
- Auto apply of Lee criteria to extract slow faded signal
- Lee criteria
  - ✓ 50 samples over 40 lambda
  - ✓ Extract slow faded signal
  - ✓ Increase confidence

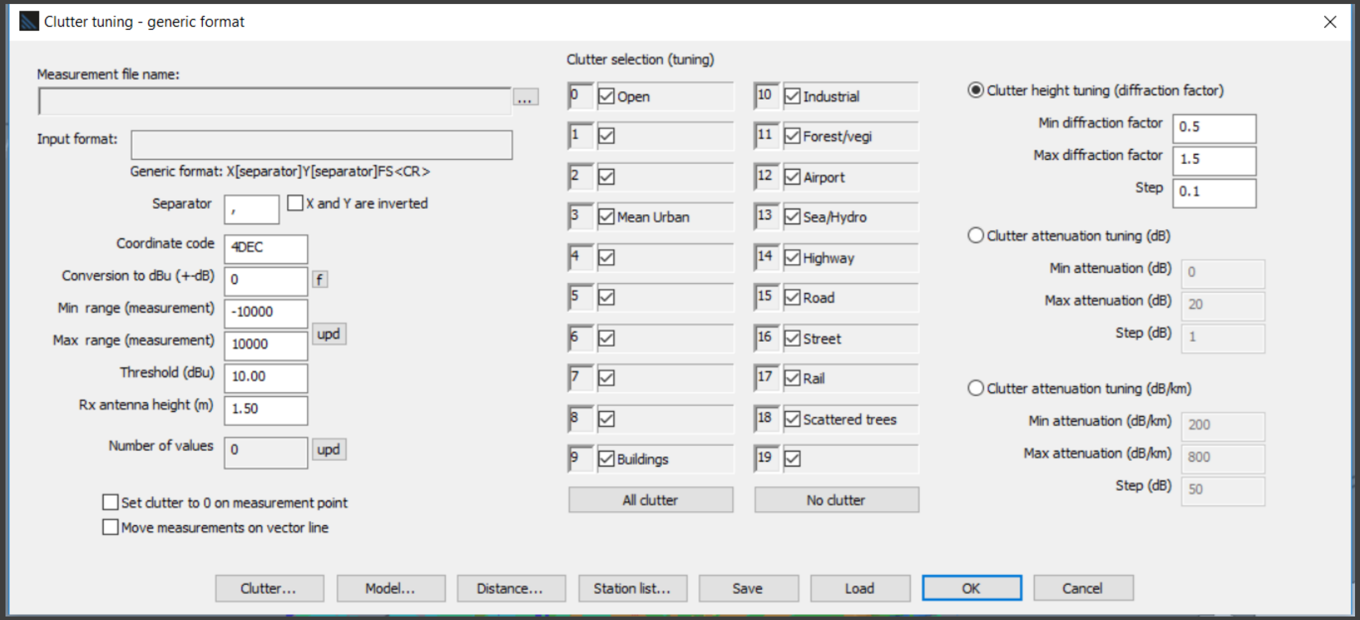


Correlations and Model tuning

Auto model tuning and calibration functions

- Correlation analysis between measurements and prediction
- Tune signal absorption per environment
- Tune signal penetration per environment
- Benchmark multiple propagation theories

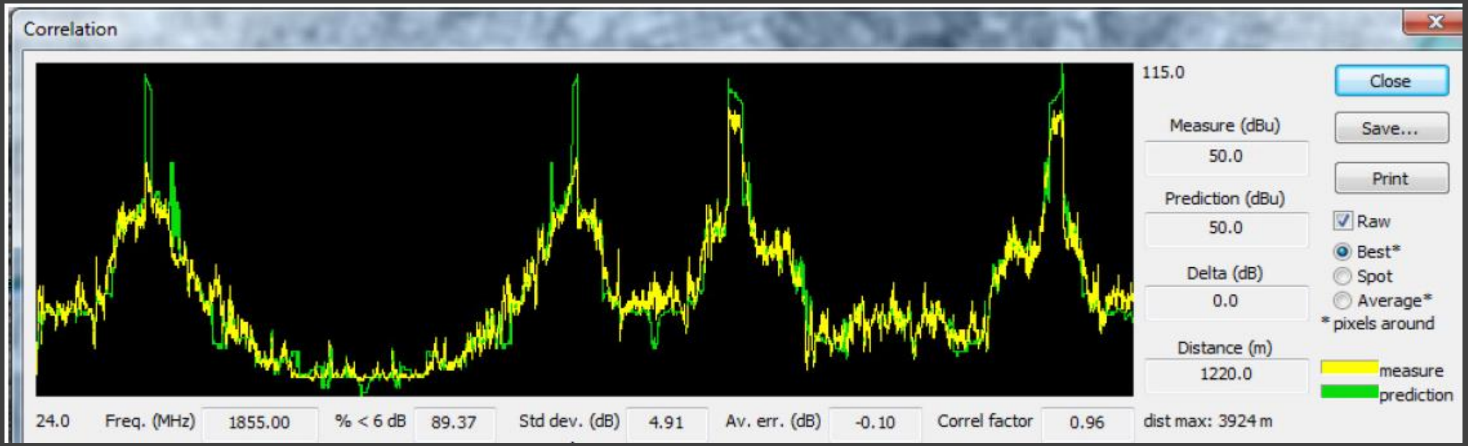




Correlations and Model tuning

Sample correlation result (before tuning)

Prediction vs measurements: **Standard deviation of error: 4.9 dB, 89% within 6dB & 96% correlation factor**

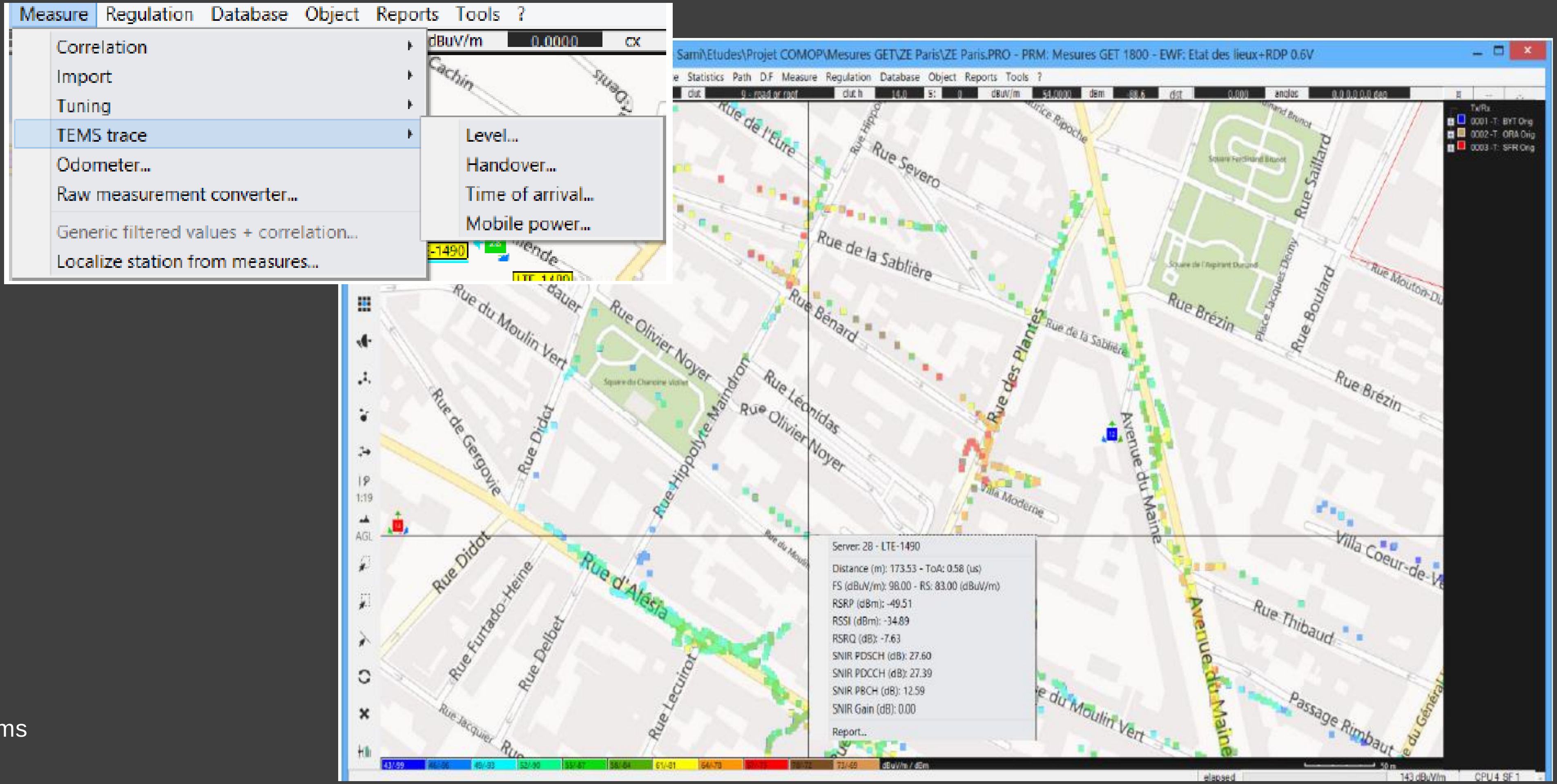


Site	% < 6 dB	STD (dB)	Average error (dB)	Correlation factor
Erskineville	86.26	4.19	-0.45	0.96
Strathfield	89.7	3.83	-0.04	0.97
Lidcombe	85.71	5.48	-0.13	0.94
Seven Hills St	Not used for tuning see next section			
Mortdale	93.86	3.04	-0.1	0.98
Sutherland	87.3	4.31	0.27	0.97
Gooma	88.1	4.47	0.02	0.96
Wollstonecraft	80.1	5.64	-0.29	0.73
Turramura	95.39	2.95	0.27	0.99
Berowra	80.09	5.2	0.02	0.92
Woy Woy	84.78	4.57	0.49	0.96
Hornsby	90.23	4.18	-0.01	0.96
West Ryde	Not used for tuning see next section			

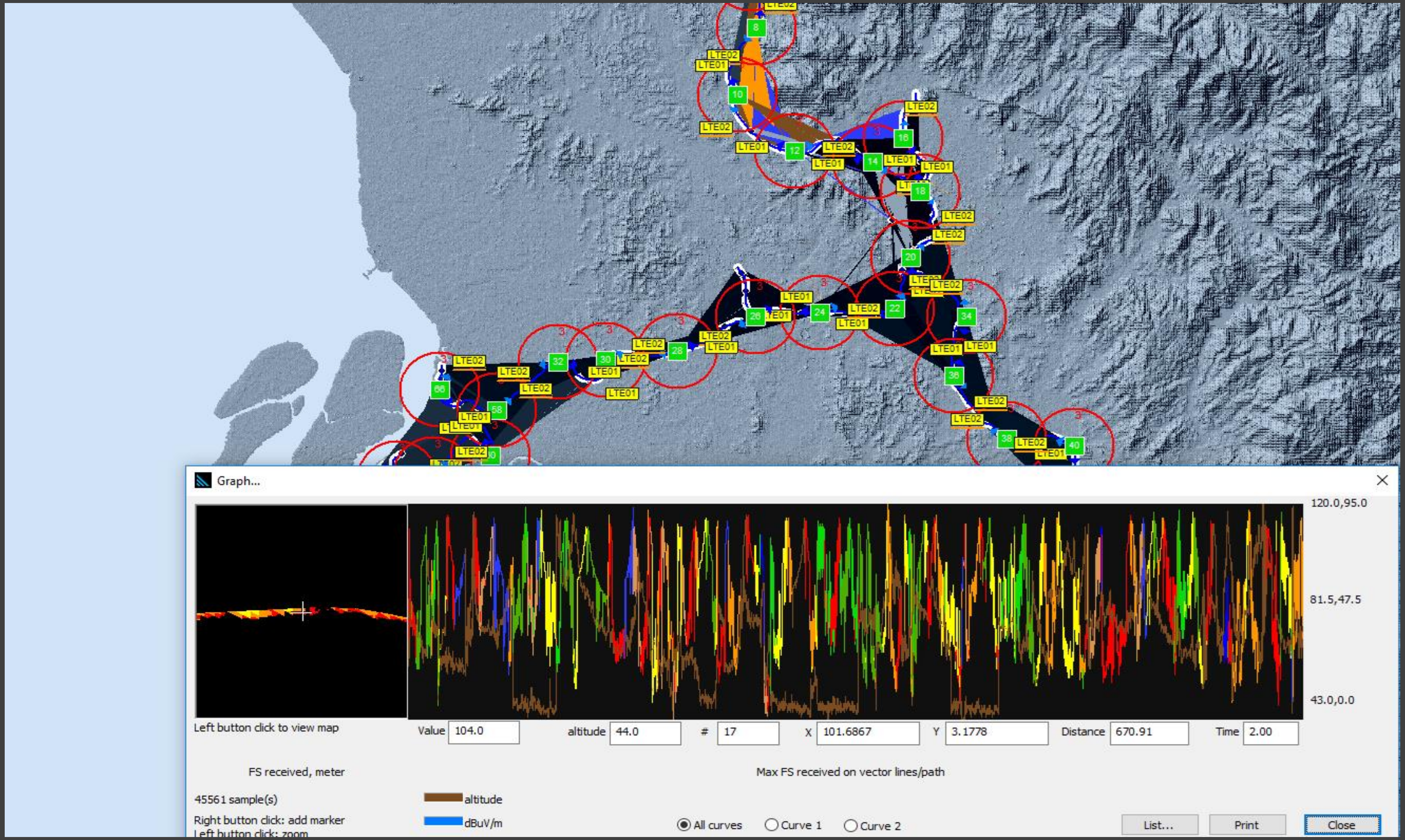
Table 11, correlation results for the test sites

Correlations and Model tuning

TEMS Trace



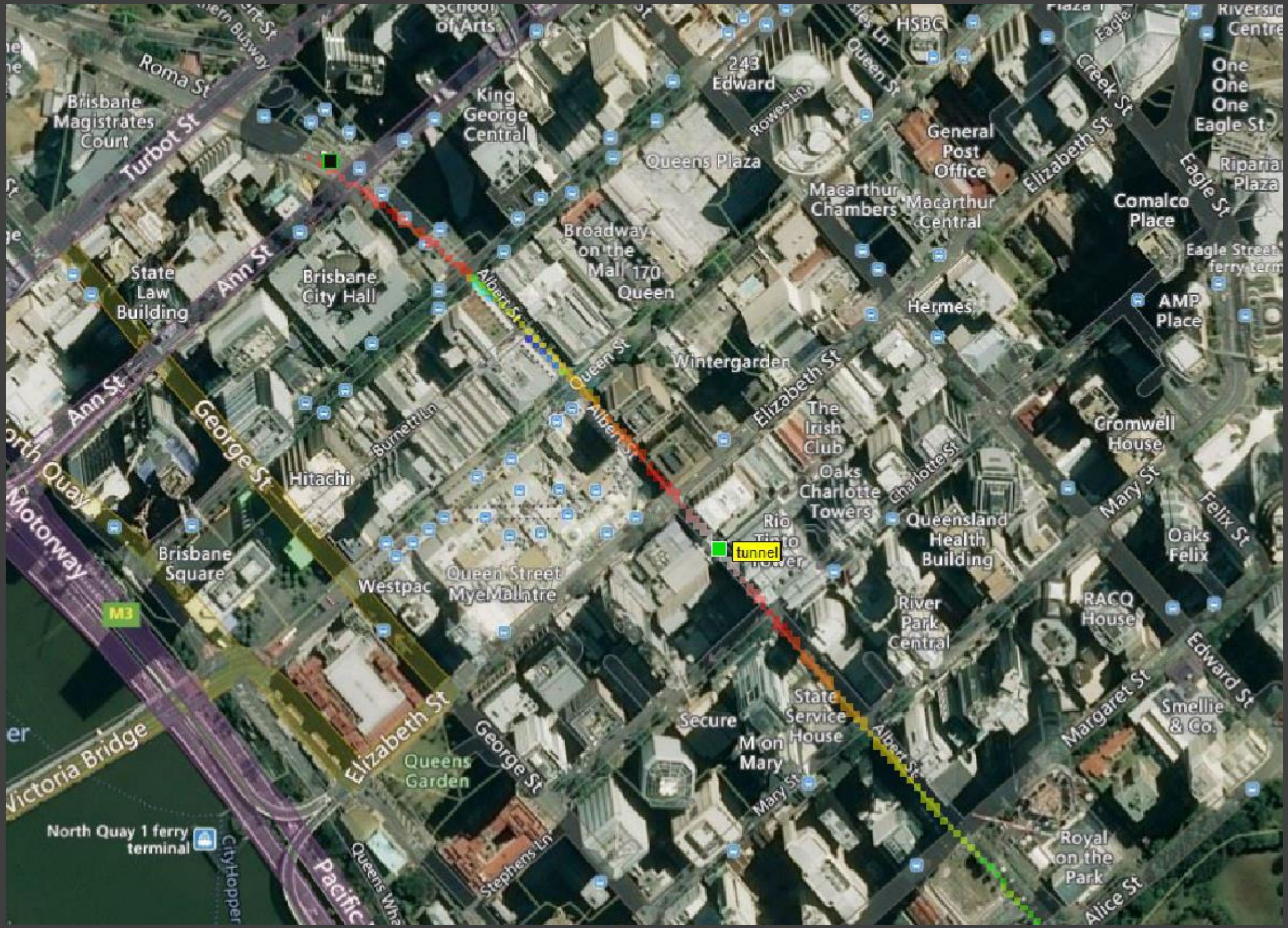
Train path analysis



Composite coverage of outdoor & indoor (1/4)

Tunnel (Pure indoor) – prediction

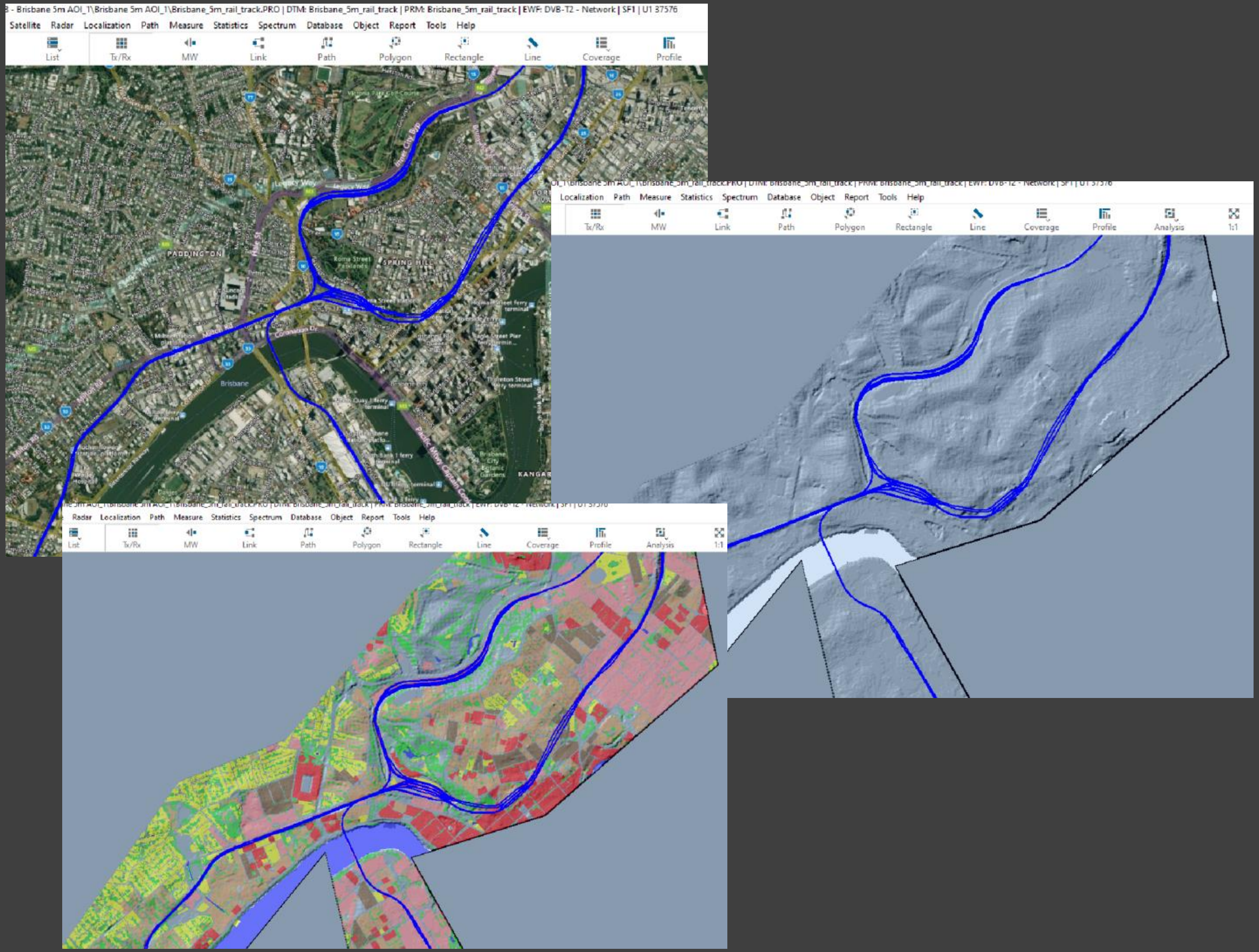
HTZ calculates the indoor coverage plotted above ground but the correct location (X/Y) from either leaky feeder or Tz/Rx stations, which can be either 3G, 4G or 5G. That allows exchange with indoor project and outdoor project.



Composite coverage of outdoor & indoor (2/4)

Tunnel (Pure outdoor)

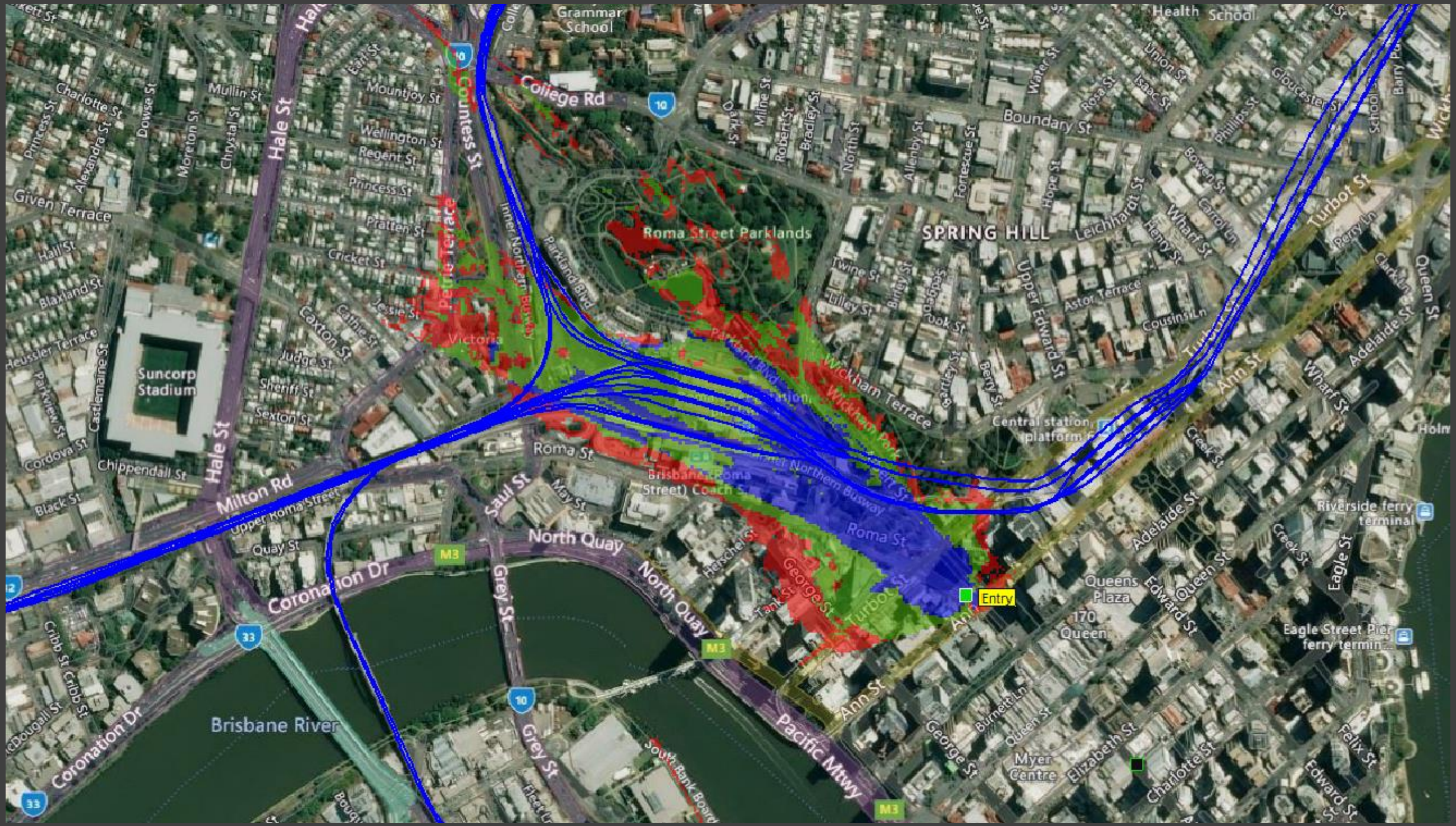
HTZ imports the tunnel vector files in the outdoor projects.



Composite coverage of outdoor & indoor (3/4)

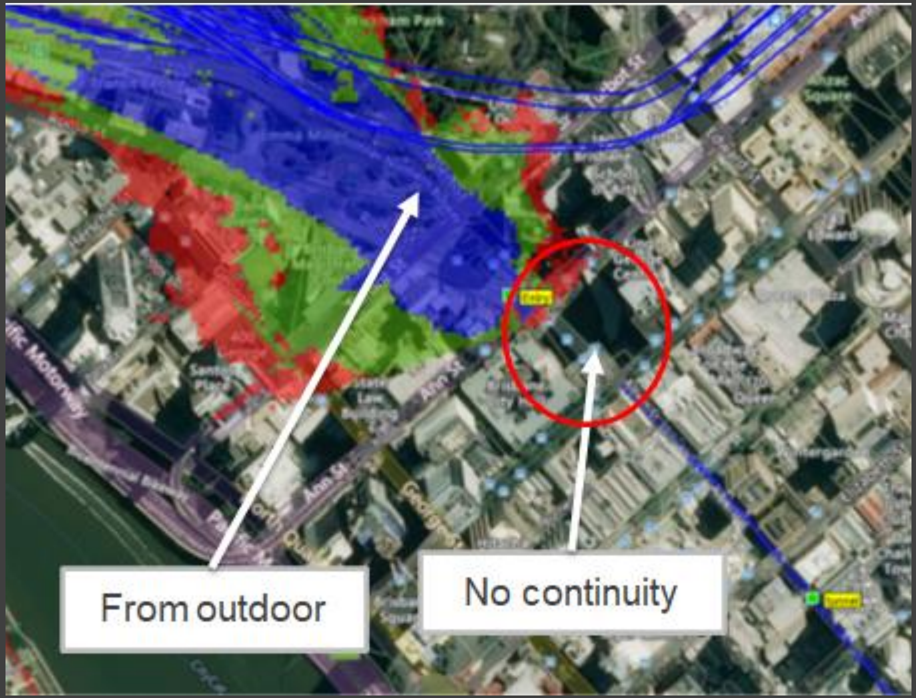
Outdoor coverage over the tunnel areas

The coverage for a Yagi antenna positioned at the entry of the portal pointing outside the tunnel. Very often the indoor and outdoor antennas are on the same RF layer to ensure continuity of coverage.

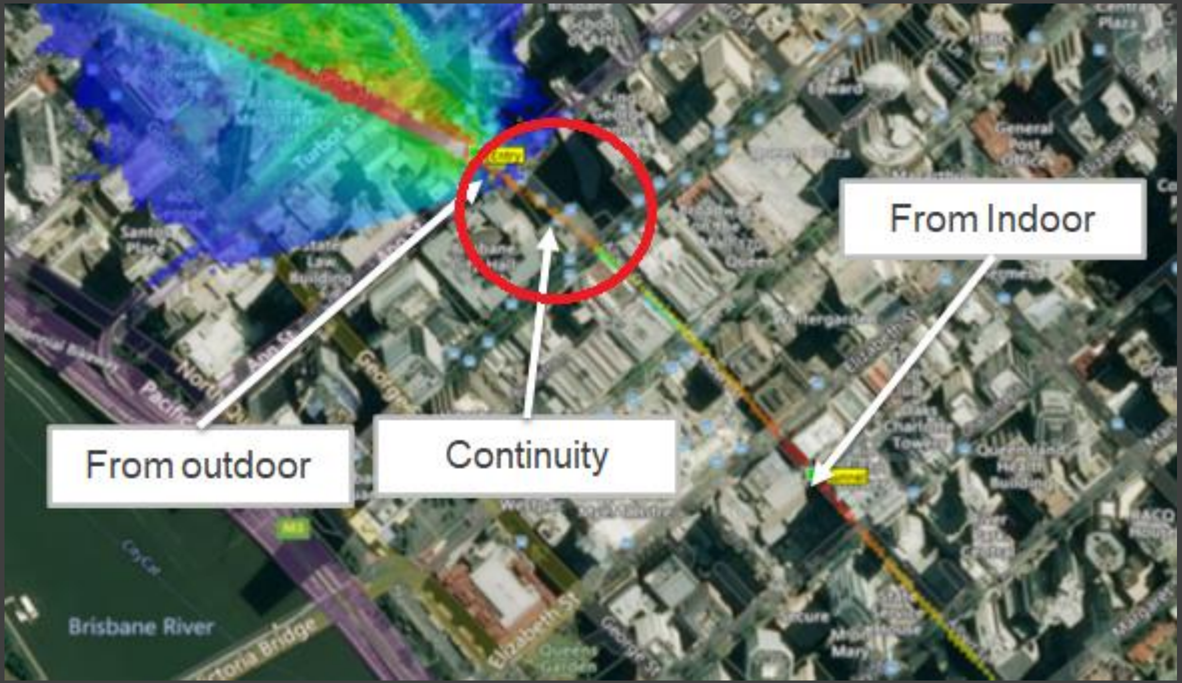


Composite coverage of outdoor & indoor (4/4)

Outdoor coverage displayed over the tunnel without the coverage from the tunnel



Composite coverage between outdoor and indoor (tunnel) coverage which creates the coverage continuity



Study to quantify signal losses due to LOS obstruction (1/7)

e.g. leaky feeder & cab antenna in a tunnel

Study background

- ✓ Leaky feeder and train radio antenna are typically installed to deliver Line-of-Sight conditions
- ✓ Leaky feeder is typically characterized by Linear and Coupling losses with the later one being measured and estimated by the manufacturer in LOS conditions. Departing from LOS conditions means there is additional scope of further attenuations which may or may not be tolerable in the current link budget.
- ✓ With measurements not readily available for such conditions – hence Unity Alliance is seeking a consultation to derive these additional figures by constructing a computer model and through simulations.
- ✓ ATDI supplies radio network planning tools to manage every part of the network lifecycle from the initial radio network plans to optimizing coverage and reducing interference.
- ✓ ATDI is trusted by governments, operators, emergency services, and armed forces, we deliver professional services from expert engineers. Our greatest resource is the knowledge gained from over three decades working in the industry and an in-depth understanding of how the growing demands for spectrum affect radio users.

Study to quantify signal losses due to LOS obstruction (2/7)

e.g. leaky feeder & cab antenna in a tunnel

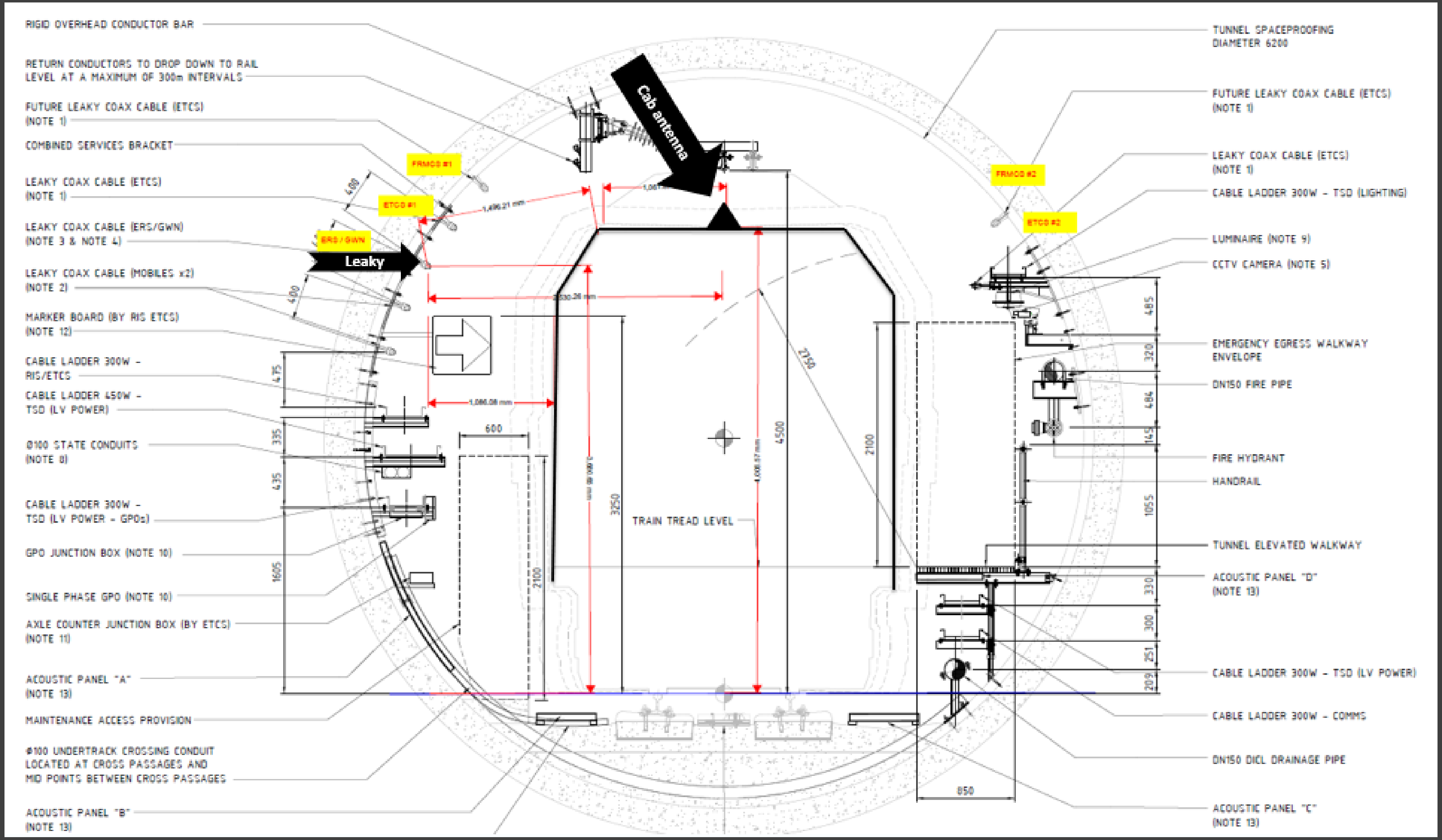
Scope of Study

- ✓ To compute additional propagation losses experienced due to obstructions of LOS including. Image below depicts the setup current being simulated using “HTZ communications”.
- ✓ Estimate signal diffraction on the shoulder of the train between the Leaky cable and the Cab radio antenna.
- ✓ Estimate signal losses due to cab antenna discrimination as a result of signal angle-of-arrival due to the geometry of the setup and diffraction angle.

Study to quantify signal losses due to LOS obstruction (3/7)

e.g. leaky feeder & cab antenna in a tunnel

Setup



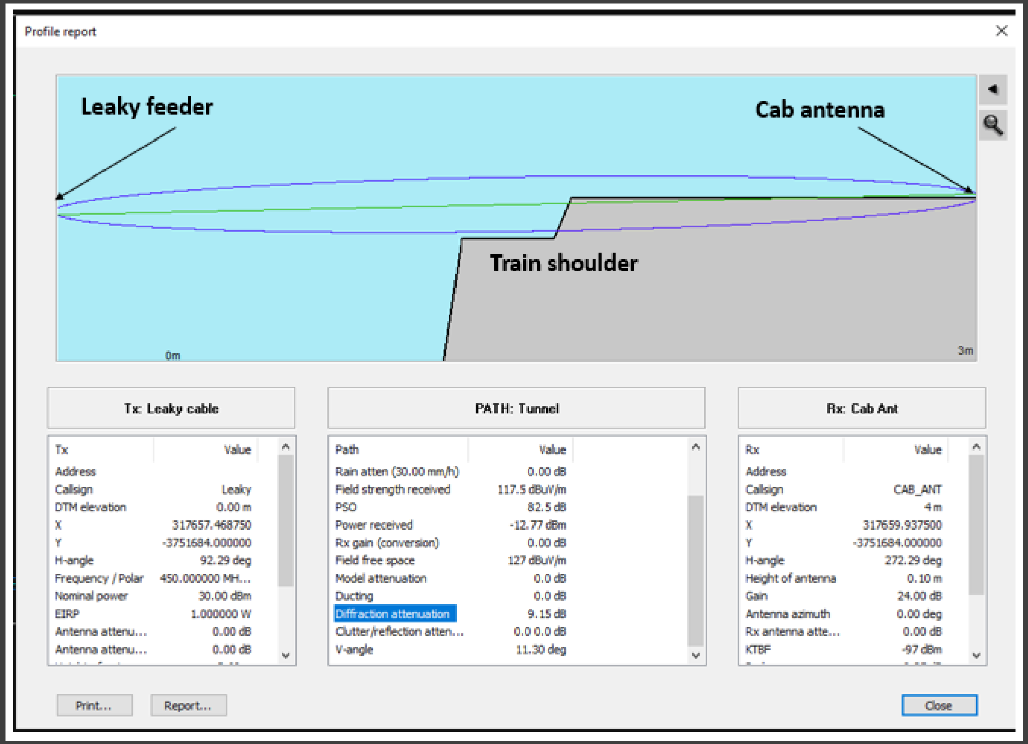
Study to quantify signal losses due to LOS obstruction (4/7)

e.g. leaky feeder & cab antenna in a tunnel

Diffraction Modelling

- ✓ Diffraction is simulated using a number of mathematical models. See table below.
- ✓ The level of diffraction varies between 8.7 and 16.4 dB with Deygout94 method being around 9.6 dB.
- ✓ Deygout94 method is considered a reliable method for sharp edges.

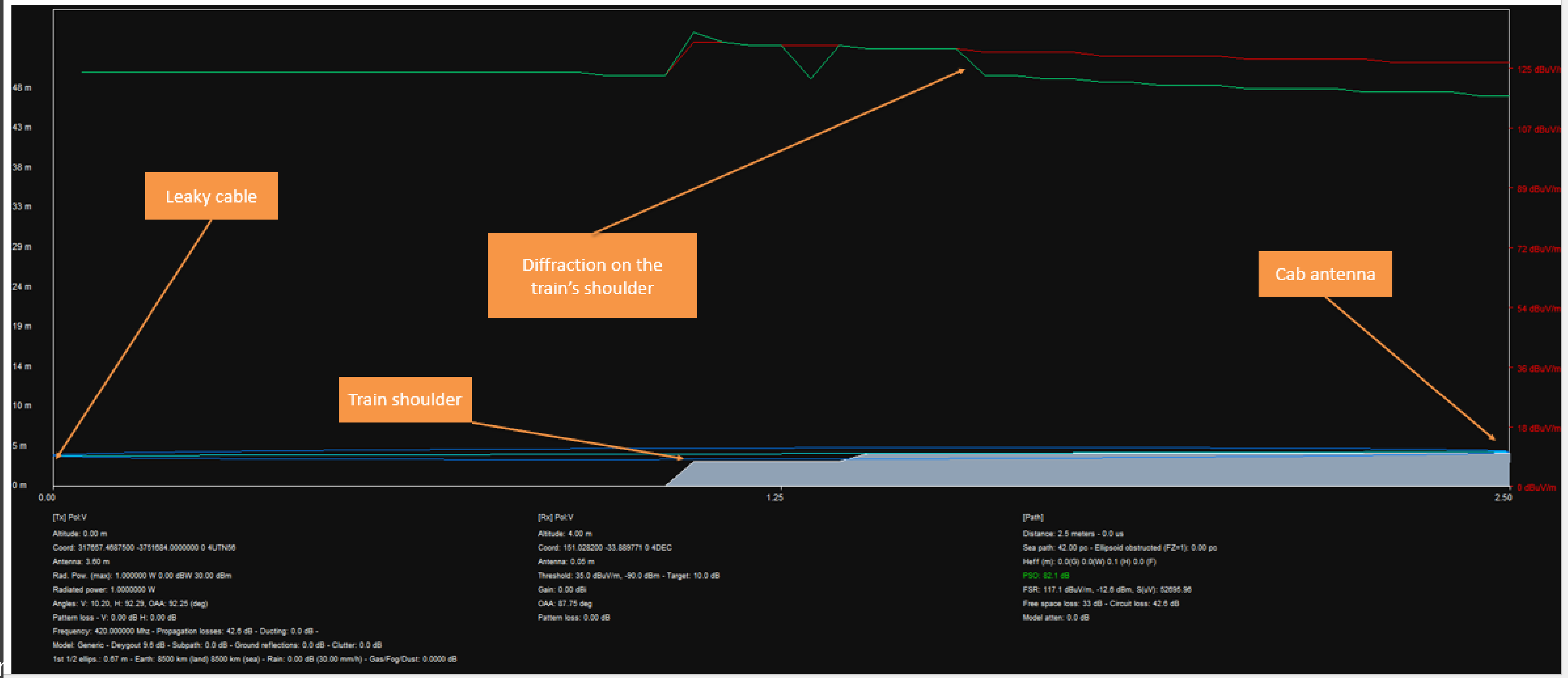
Diffraction method	Predicted value
Deygout94	9.6 dB
Deygout 66	14.6 dB
Bullington	8.7 dB
Delta Bullington	16.4 dB
ITU-R P.526 Round mask	8.9 dB
ITU-R P.526 Cylinders	8.8 dB



Study to quantify signal losses due to LOS obstruction (5/7)

e.g. leaky feeder & cab antenna in a tunnel

Diffraction loss (Deygout 94)

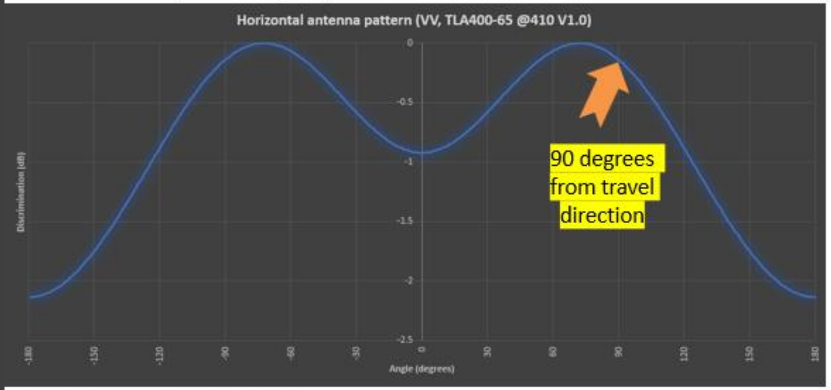


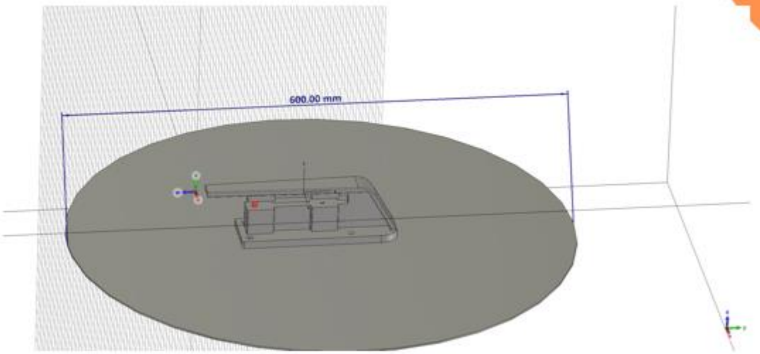
Study to quantify signal losses due to LOS obstruction (6/7)

e.g. leaky feeder & cab antenna in a tunnel

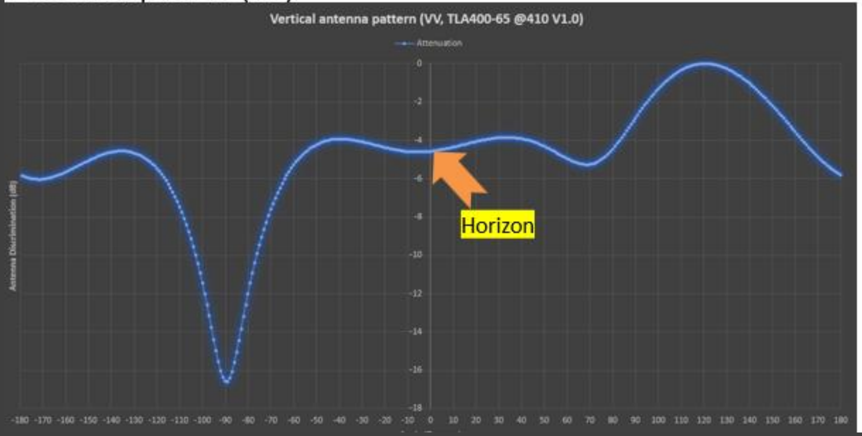
Cab Antenna Discrimination

❑ Horizontal pattern (VV)





❑ Vertical pattern (VV)



Source: TLA400-65 @410 V1.0.adf
Frequency: ~410 MHz

- Marked positions are angles for which we expect the diffracted signal to come through.
- Horizontal attenuation is not significant, ranging from 0 to 1 dB with attenuation being around 0.2 dB at +/- 90 degrees (signals coming from each shoulder)
- Vertical attenuation is ranging between 0 and 16.5 dB. With value being around 4.5 dB discrimination for signals coming from the horizon (0 degrees).

Study to quantify signal losses due to LOS obstruction (7/7)

e.g. leaky feeder & cab antenna in a tunnel

Summary

- Signal propagates by many concurrent mechanisms
  - ✓ Reflections: Deliver signal beyond LOS, can enhance or degrade the signal and result in low-scale signal fluctuations. Modelling requires very advanced knowledge of the materials and their structure.
  - ✓ Diffraction: Deliver signal beyond LOS, degrades the signal depending on frequency and level of obstruction
  - ✓ Conductivity – especially for very low frequencies
- While all above is happening all the time, it would be sufficient to consider the mechanism delivering the highest signal level.
- This study is focused on propagation by diffraction since the Leaky cable's specifications already account for other propagation anomalies in a tunnel environment except for diffraction.
- The study estimated diffraction loss to 9.6 dB due to obstruction of LOS between the leaky cable and the Cab radio antenna.
- The study estimated the antenna discrimination loss to 4.5 dB for VV scenario. Assuming both the cable and the cab antenna are of the same polarization (V). And assuming the polarization is maintained.
- Total additional loss (on the top of Linear and Coupling loss) is estimated to 14.1 dB

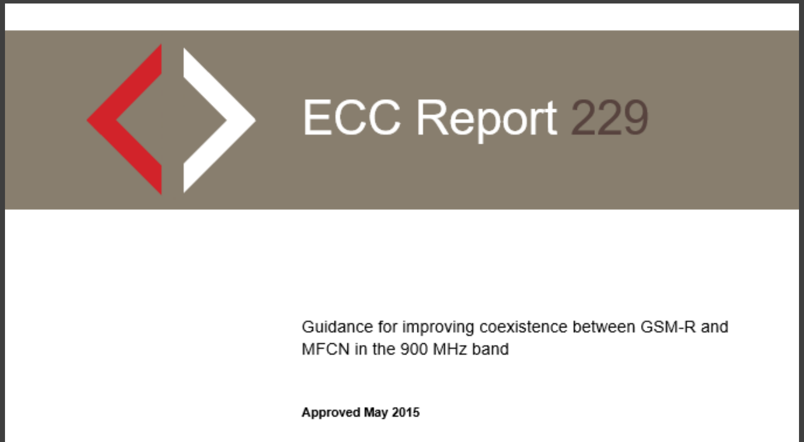
Supporting
Frequency coordination & intermodulation

National Coordination procedures to improve coexistence between MFCN and GSM-R

Why coordination procedures to improve coexistence between MFCN and GSM-R is required ?
-> Measurement campaigns performed during 2013-2014 concluded that current GSM-R receivers are affected by intermodulation products generated from a wideband signal such as UMTS/LTE, two narrowband signals such as GSM, or a combination of wideband and narrowband signals. Wideband signals can impact the whole GSM-R downlink frequency range. UMTS, LTE/5MHz and LTE/10MHz have similar interference potential

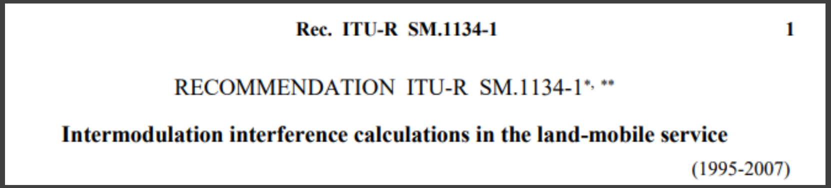
Methodologies and methods:
-> ECC Report 229 provides a calculation method that gives the maximum MFCN OOB level below 924.9 MHz and anywhere at 4m above the rail tracks, which should trigger the proactive coordination process.

-> ITU-R SM1134.1 recommendation provides guidance for intermodulation interference calculations in the land mobile service


ECC Report 229

Guidance for improving coexistence between GSM-R and MFCN in the 900 MHz band

Approved May 2015


Rec. ITU-R SM.1134-1 1

RECOMMENDATION ITU-R SM.1134-1*, **

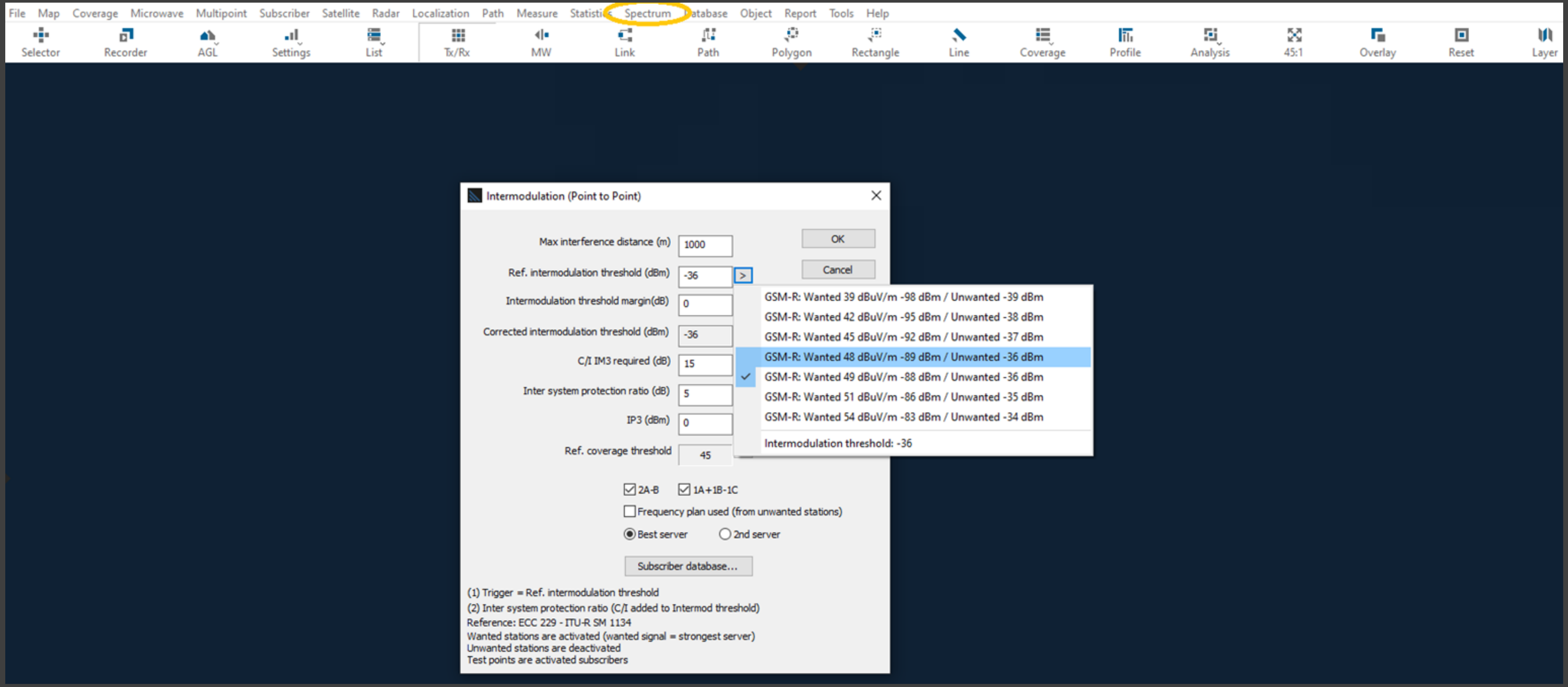
Intermodulation interference calculations in the land-mobile service

(1995-2007)

Supporting

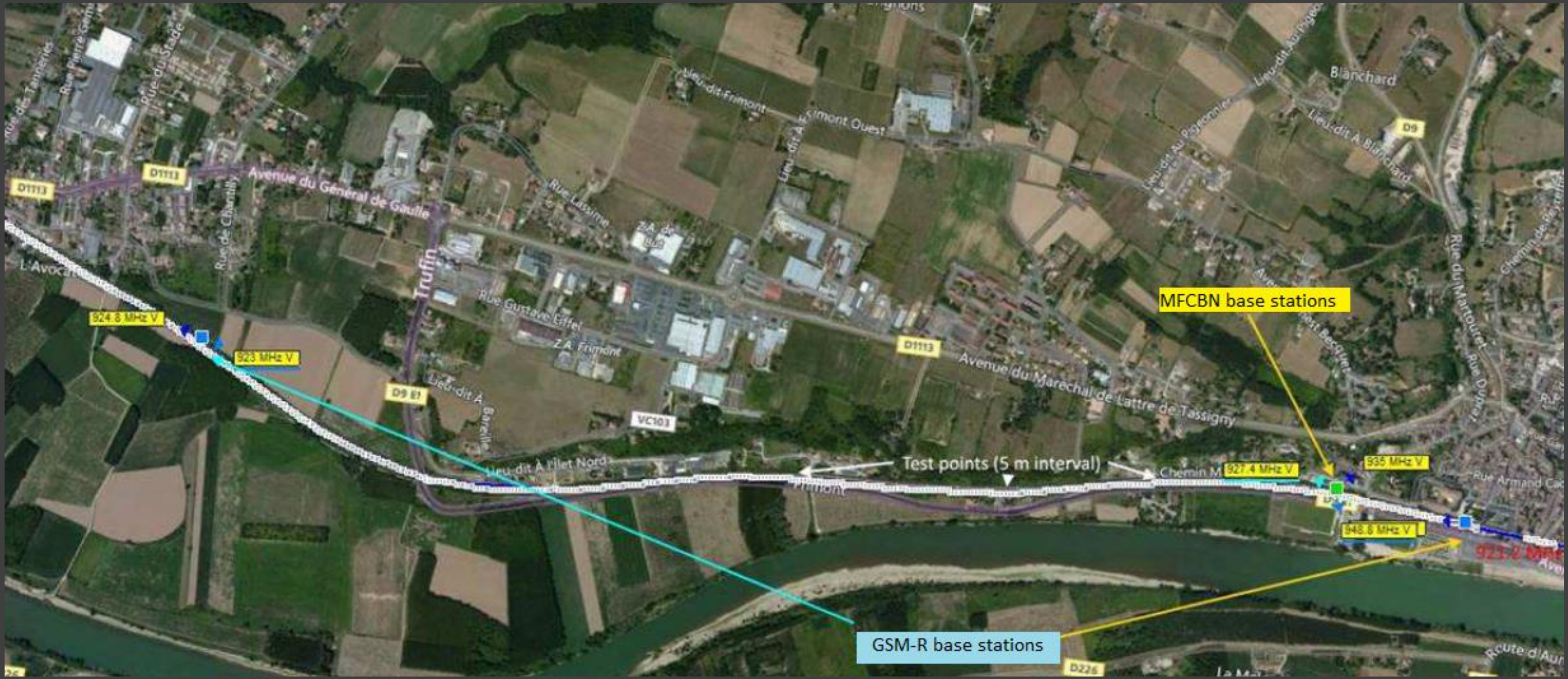
Frequency coordination & intermodulation

National Coordination procedures to improve coexistence between MFCN and GSM-R



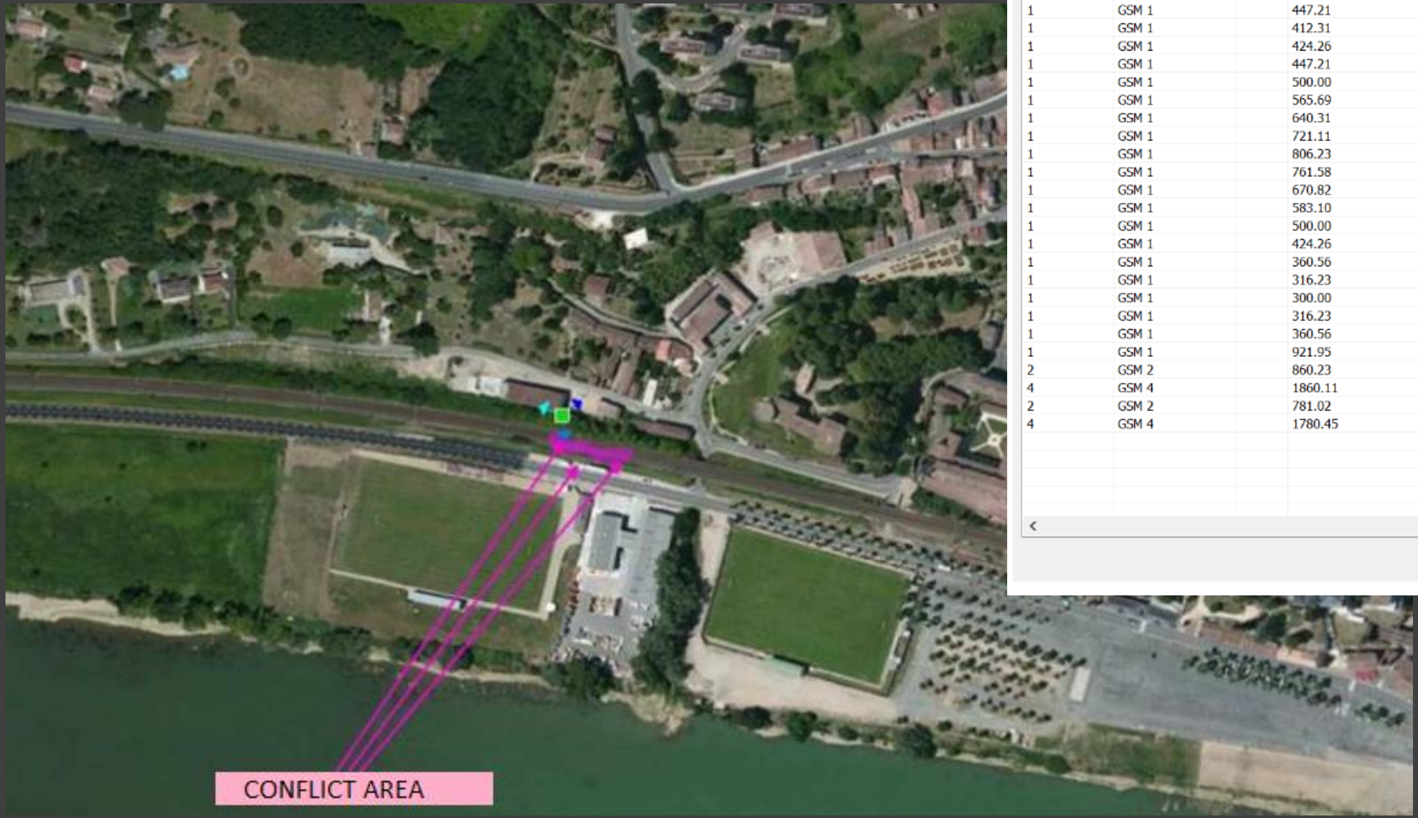
Supporting

Frequency coordination & intermodulation



Supporting

Frequency coordination & intermodulation



Report listing

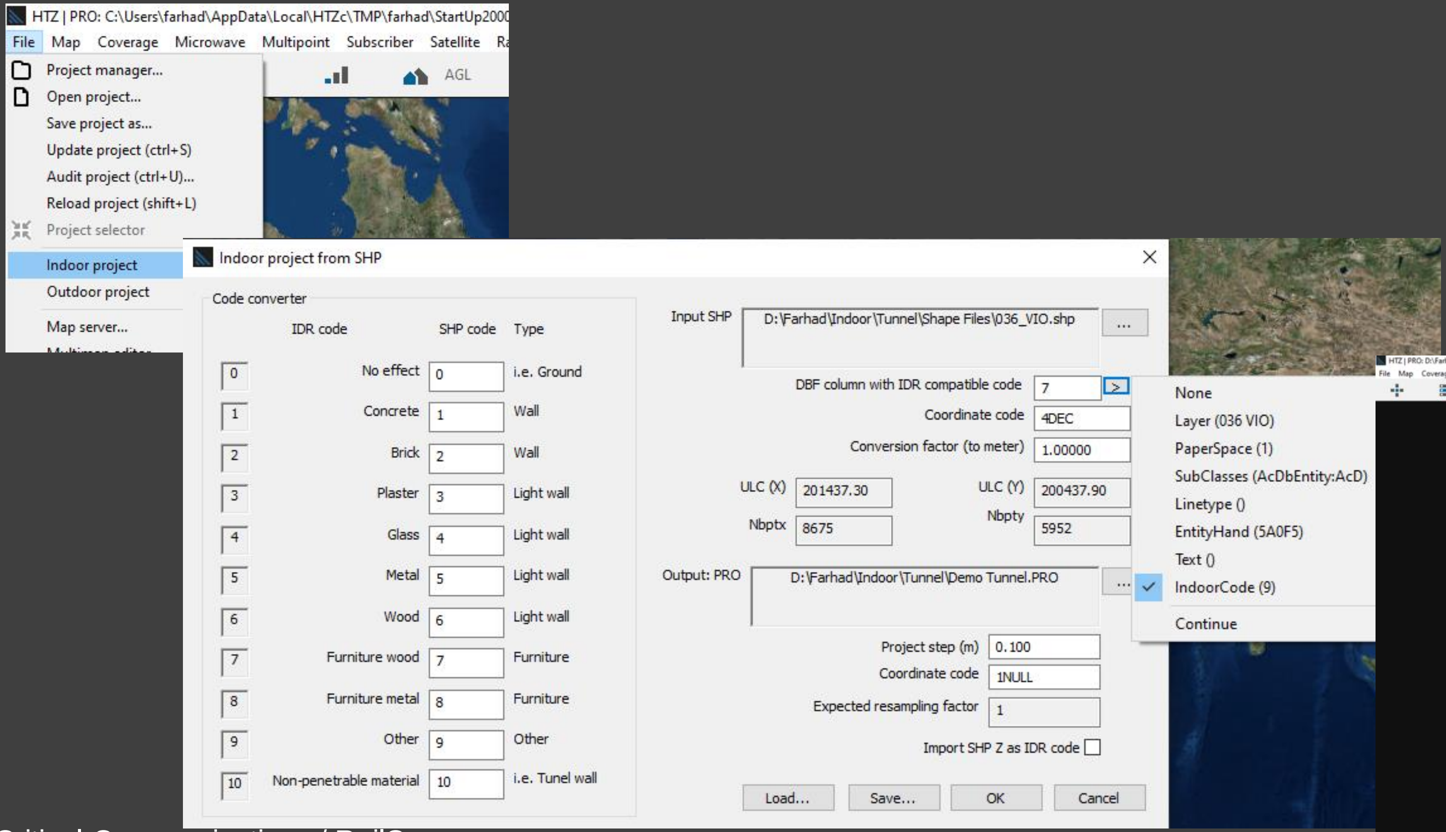
Unwanted A #	Unwanted A callsign	GroupA	Distance A->Wanted (m)	FA MHz	PrA dBm	Unwanted B #	Unwanted B callsign	GroupB	Distance B->Wanted (m)	FB MHz	PrB dBm
1	GSM 1		447.21	920.400000	-4.8	5	GSM 5		538.52	930.500000	-6.2
1	GSM 1		412.31	920.400000	-3.4	5	GSM 5		583.10	930.500000	-18.3
1	GSM 1		424.26	920.400000	0.4	5	GSM 5		608.28	930.500000	-3.1
1	GSM 1		447.21	920.400000	-0.8	5	GSM 5		700.00	930.500000	-5.1
1	GSM 1		500.00	920.400000	-5.7	5	GSM 5		860.23	930.500000	-11.4
1	GSM 1		565.69	920.400000	-7.1	5	GSM 5		943.40	930.500000	-12.5
1	GSM 1		640.31	920.400000	-11.4	5	GSM 5		1029.56	930.500000	-30.1
1	GSM 1		721.11	920.400000	-9.6	5	GSM 5		1118.03	930.500000	-27.8
1	GSM 1		806.23	920.400000	-13.8	5	GSM 5		1208.30	930.500000	-31.5
1	GSM 1		761.58	920.400000	-12.1	5	GSM 5		670.82	930.500000	-5.7
1	GSM 1		670.82	920.400000	-9.0	5	GSM 5		632.46	930.500000	-4.9
1	GSM 1		583.10	920.400000	-5.7	5	GSM 5		608.28	930.500000	-4.1
1	GSM 1		500.00	920.400000	-2.1	5	GSM 5		600.00	930.500000	-3.5
1	GSM 1		424.26	920.400000	0.4	5	GSM 5		608.28	930.500000	-3.1
1	GSM 1		360.56	920.400000	2.8	5	GSM 5		632.46	930.500000	-2.9
1	GSM 1		316.23	920.400000	4.6	5	GSM 5		670.82	930.500000	-14.1
1	GSM 1		300.00	920.400000	5.4	5	GSM 5		721.11	930.500000	-19.7
1	GSM 1		316.23	920.400000	-0.2	5	GSM 5		781.02	930.500000	-17.0
1	GSM 1		360.56	920.400000	-1.6	5	GSM 5		848.53	930.500000	-10.8
1	GSM 1		921.95	920.400000	-13.4	5	GSM 5		860.23	930.500000	-8.7
2	GSM 2		860.23	924.300000	-6.2	4	GSM 4		1860.11	921.400000	-27.6
4	GSM 4		1860.11	921.400000	-27.6	2	GSM 2		860.23	924.300000	-6.2
2	GSM 2		781.02	924.300000	-5.6	4	GSM 4		1780.45	921.400000	-27.6
4	GSM 4		1780.45	921.400000	-27.6	2	GSM 2		781.02	924.300000	-5.6

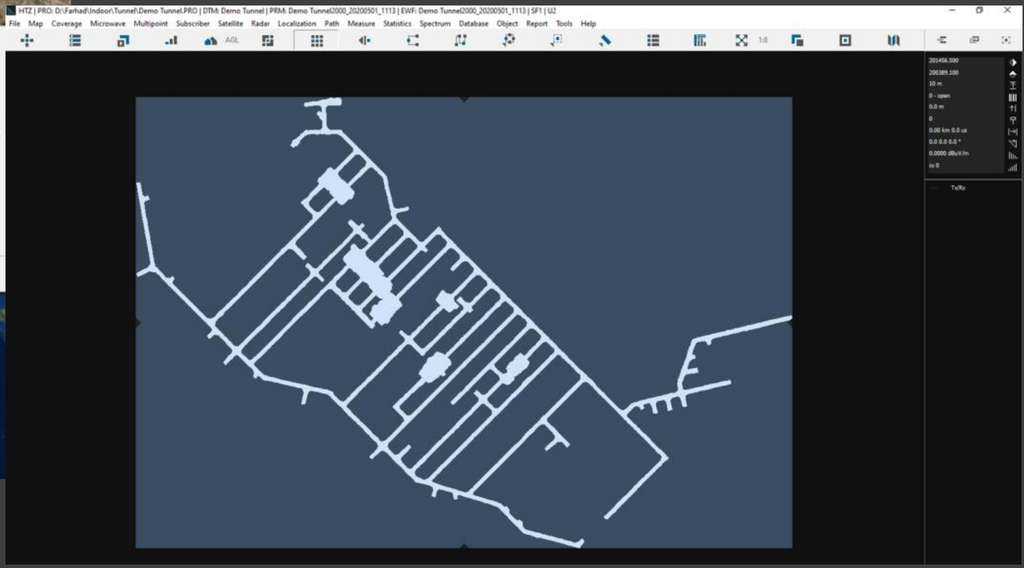
Listing... Close

Tunnel Modelling

Tunnel model GIS conversion

Source data formats for rail corridors/centre lines in x, y and z: ESRI (.shp), AutoCAD (.dxf), LiDAR sensors (.LAZ or .LAS)



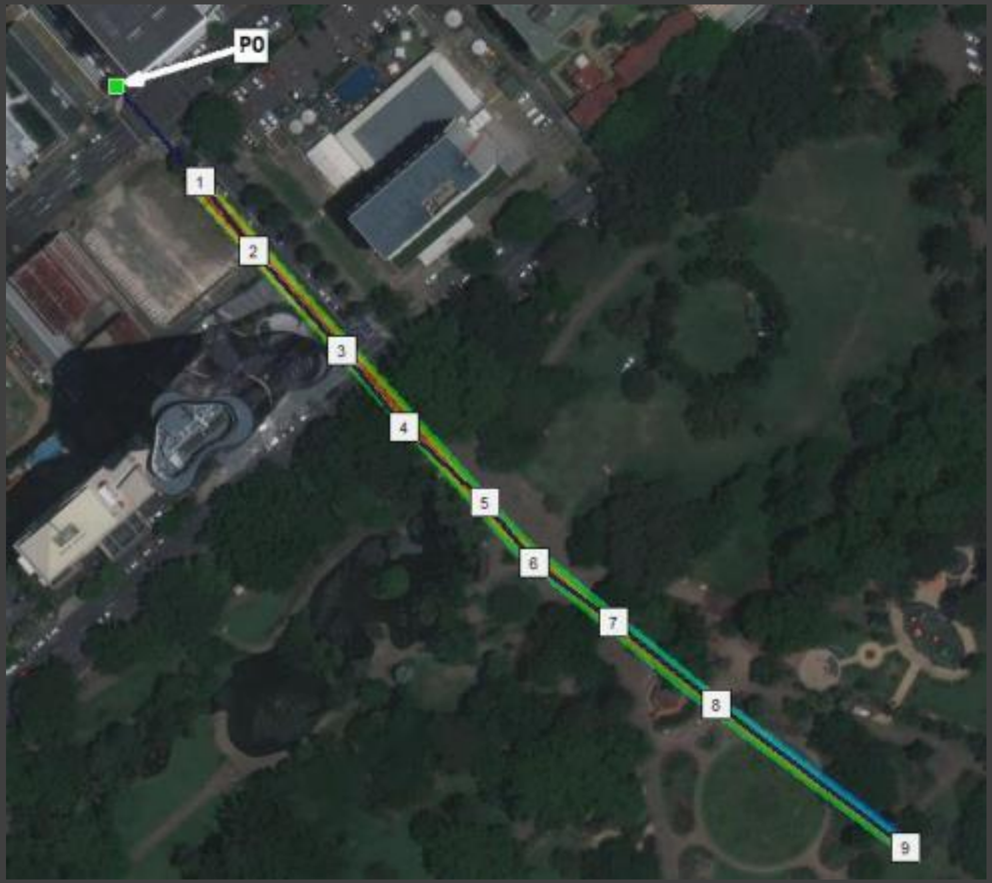


Leaky Feeder Simulation

Leaky feeder coverage analysis (1/3)

HTZ simulates a leaky feeder in an indoor environment such as tunnels to model the following aspects:

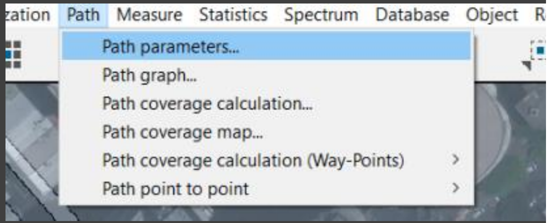
- ✓ Signal source
- ✓ Cable RF properties
- ✓ Propagation losses inside and outside the cable
- ✓ Receiver's signal level requirements

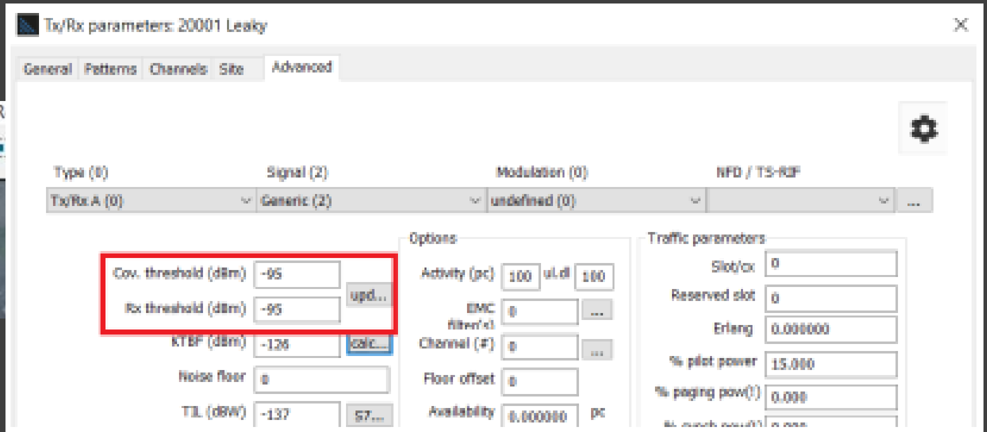


Leaky feeder coverage analysis (2/3)

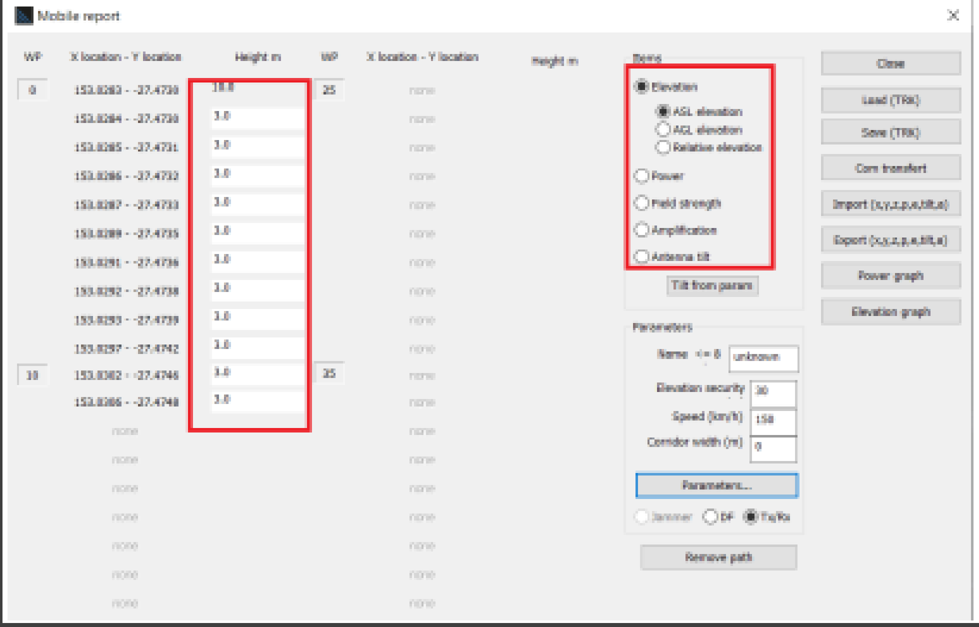
Leaky feeder parameters set up in HTZ:

- ✓ Cable height from the ground
- ✓ Ingress power to the leaky feeder
- ✓ Radiation pattern (typically equally distributed)
- ✓ Connectors/splitters/combiners loss

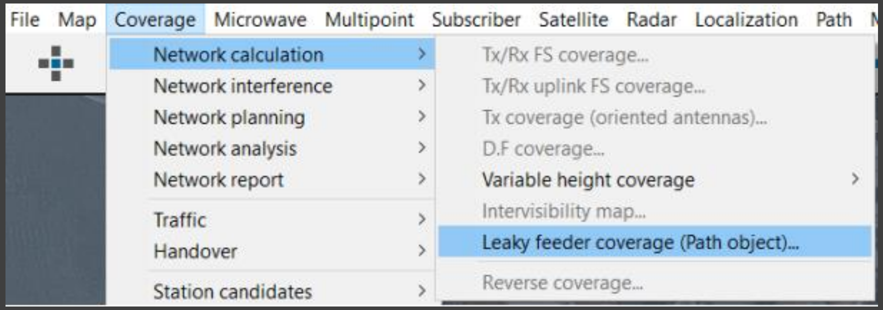


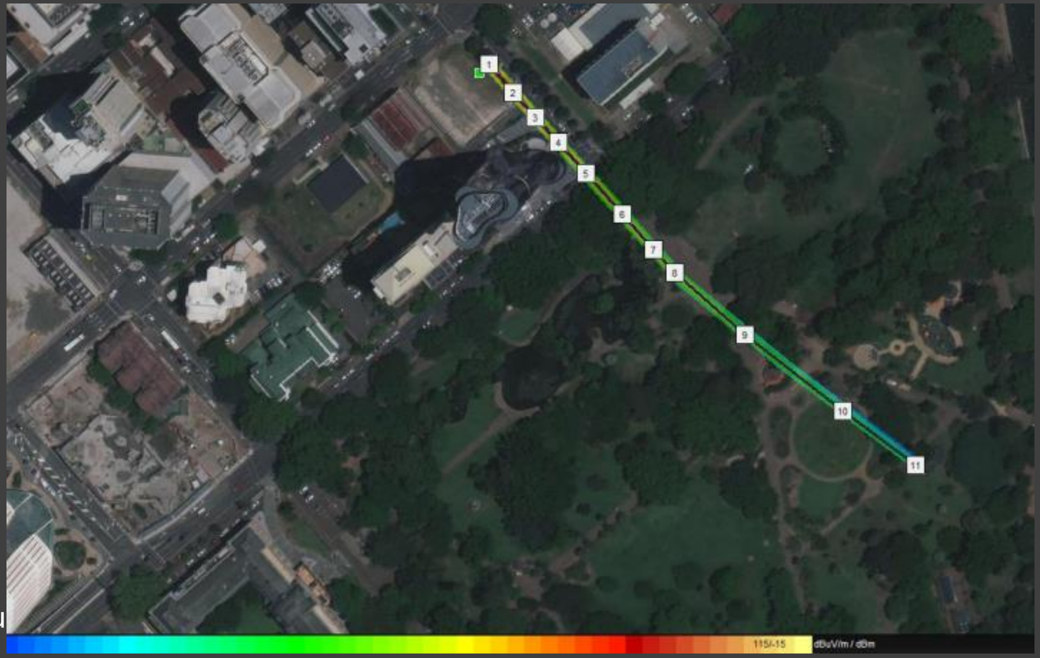


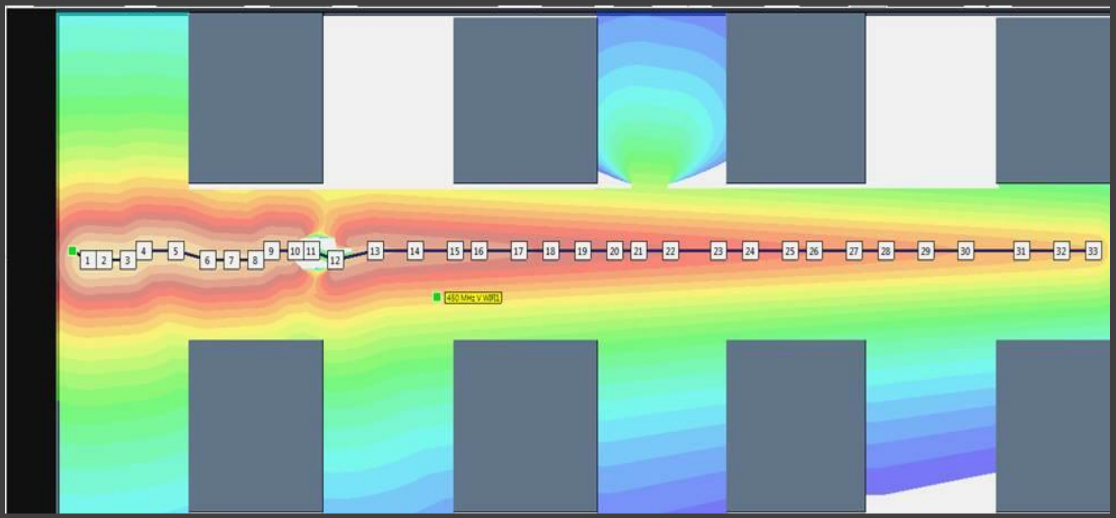
User can check the path parameters:



Leaky feeder coverage analysis (3/3)



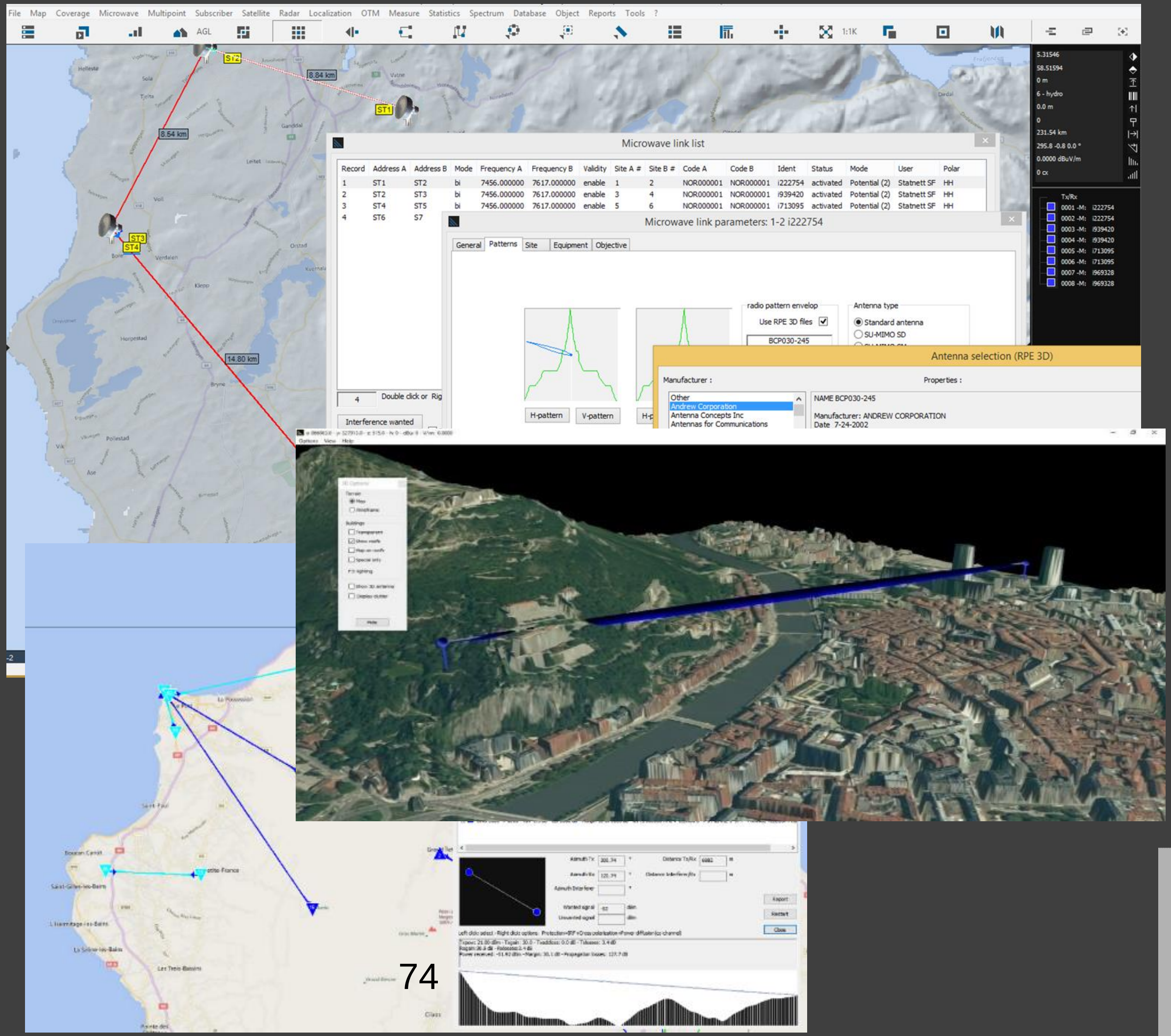




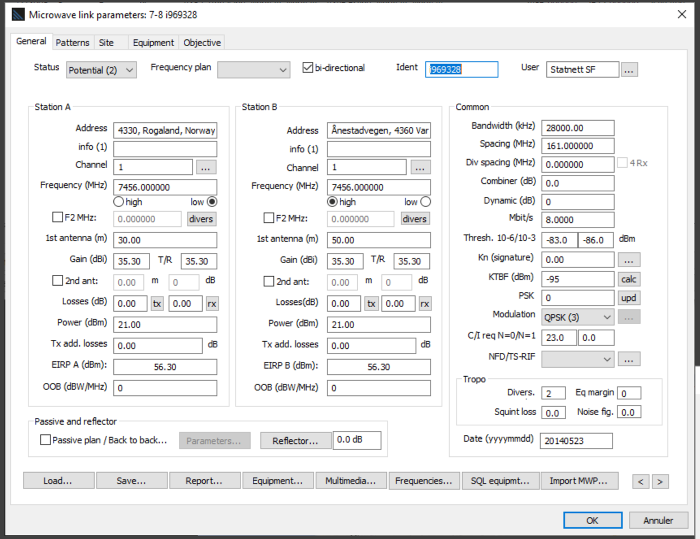
Microwave link, P2MP, Backhaul, mmW bands

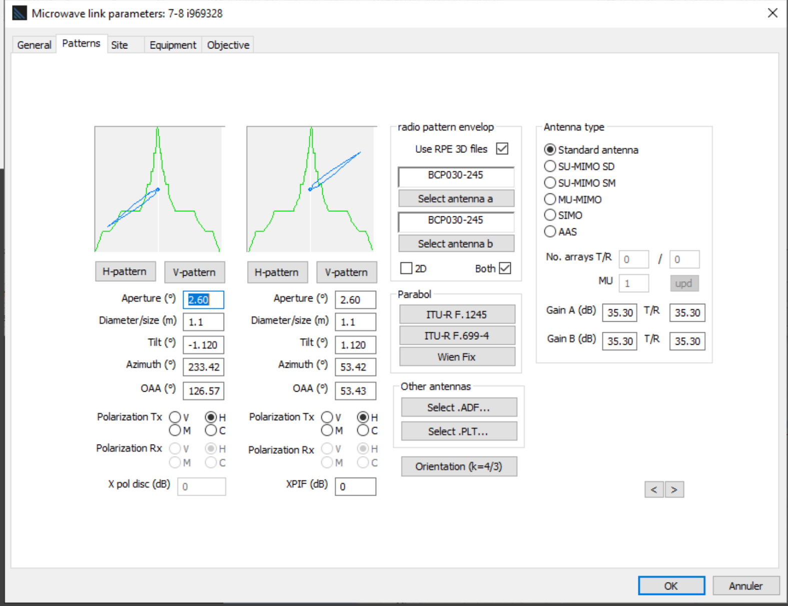
MW, P2MP, Backhaul & mmWave

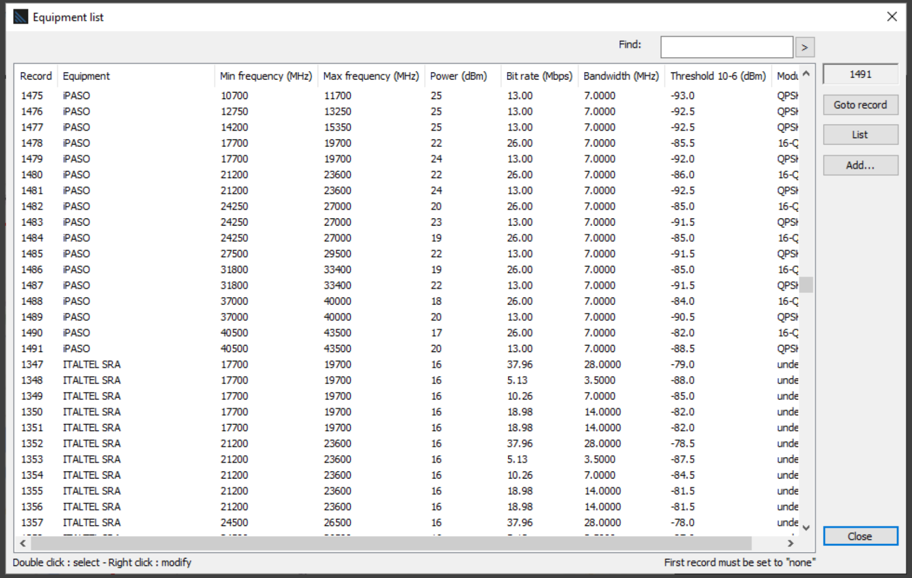
- Profile budget calculations
- Antenna and equipment database
- Frequency and space diversity
- Multi-K factor calculations
- Climate and rain parameters
- Reliability calculations
- Automatic antenna orientation
- Link optimization
- Automated frequency planning
- Interference calculations
- Quality objectives calculations (ITU-R F. 1703 and ITU-T G.827
- MIMO Antenna systems
- M2M, D2D, SCADA, CDMA 450, MMDS, WiMAX, LMDS, etc.

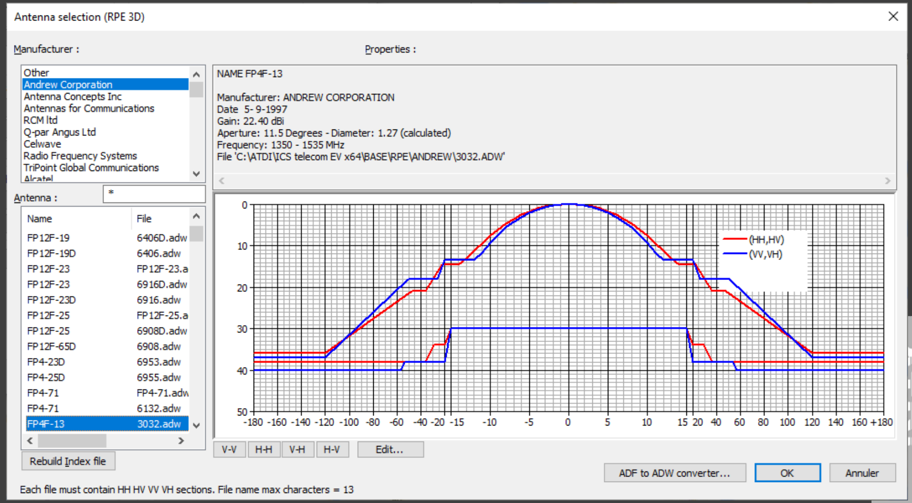


MW, P2MP, Backhaul & mmWave

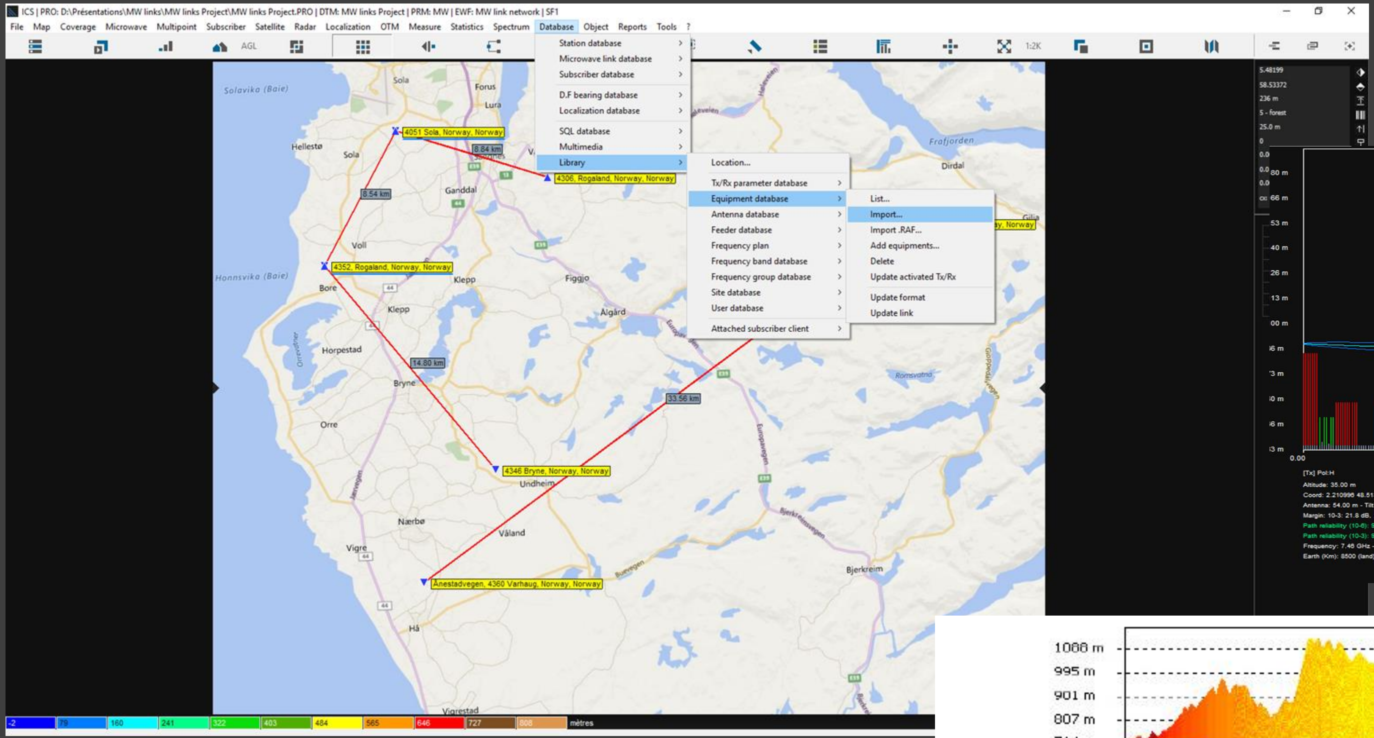


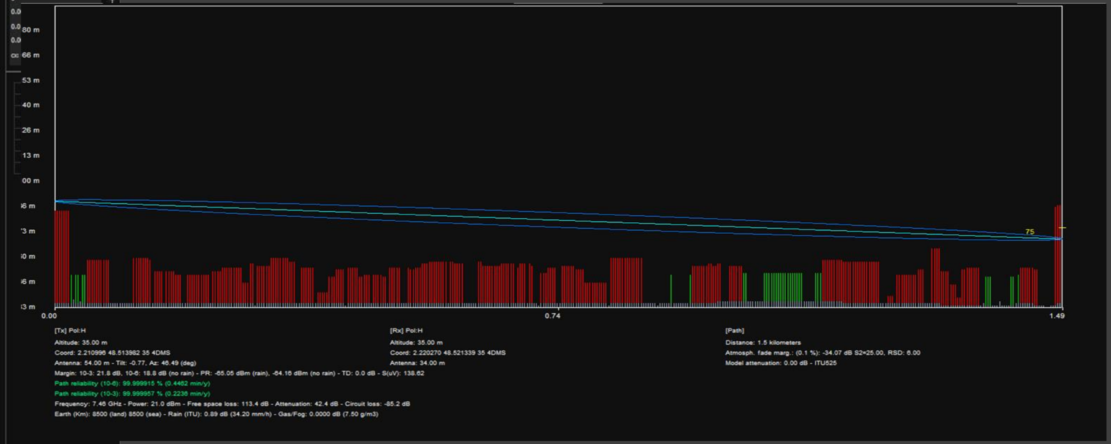


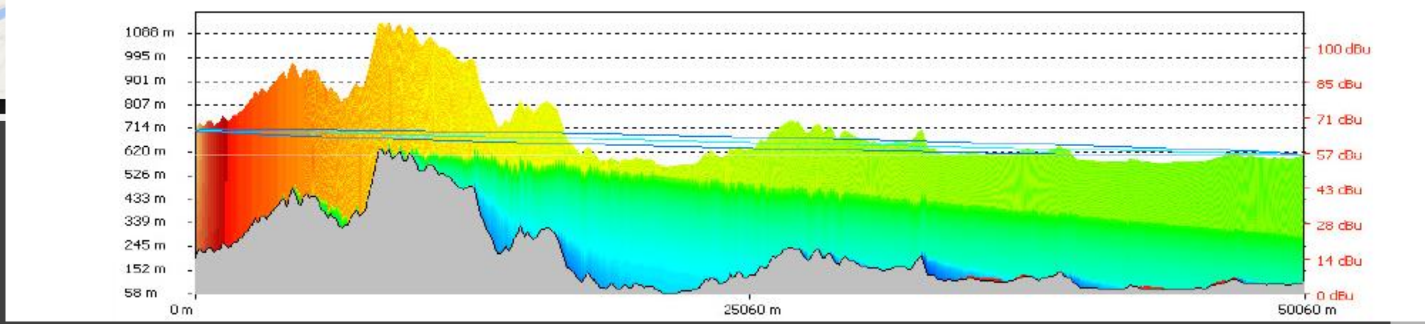




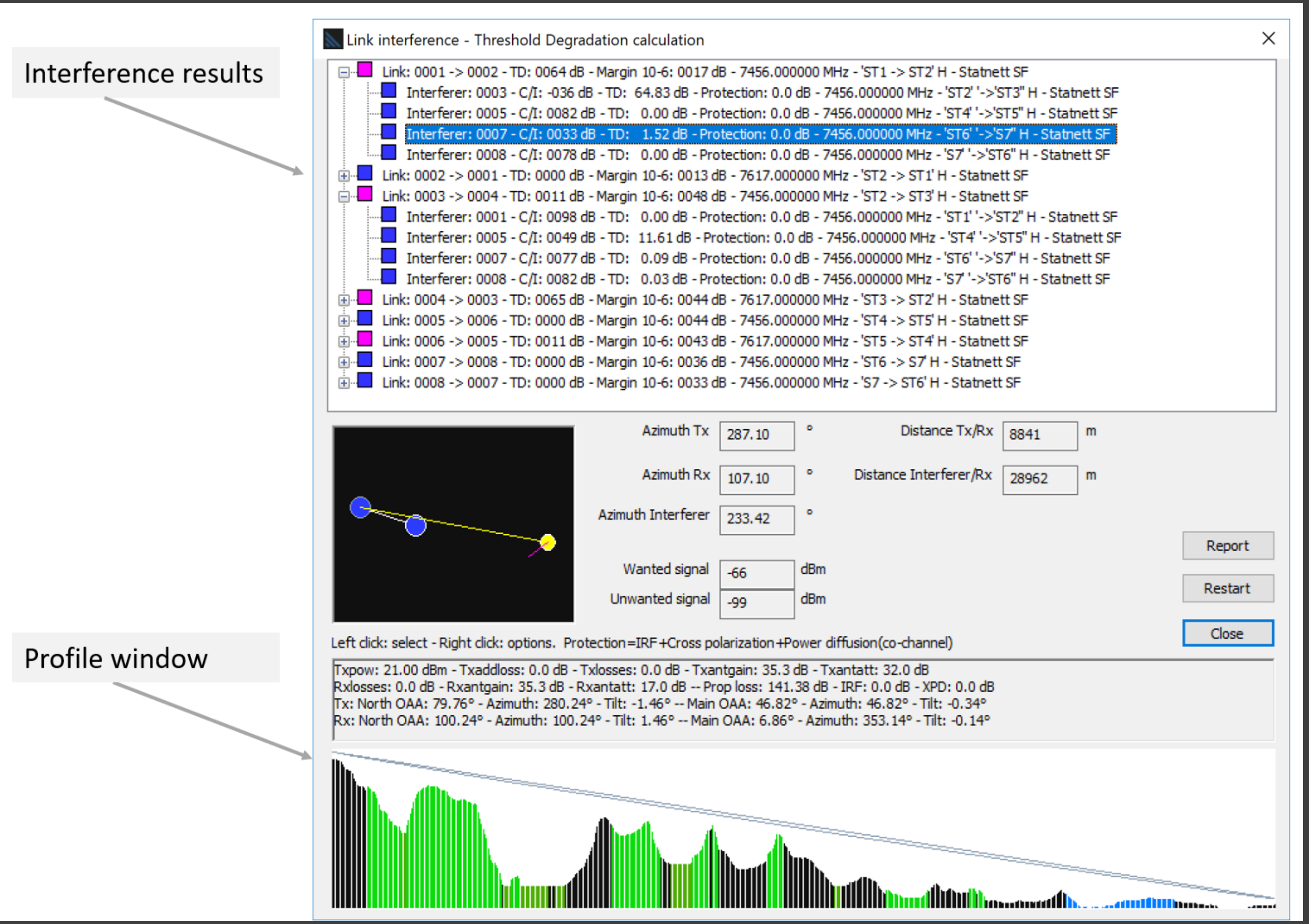
MW, P2MP, Backhaul & mmWave







MW, P2MP, Backhaul & mmWave



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