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RadioPlanner 3.0

Mobile and Broadcast Network Planning

User Manual

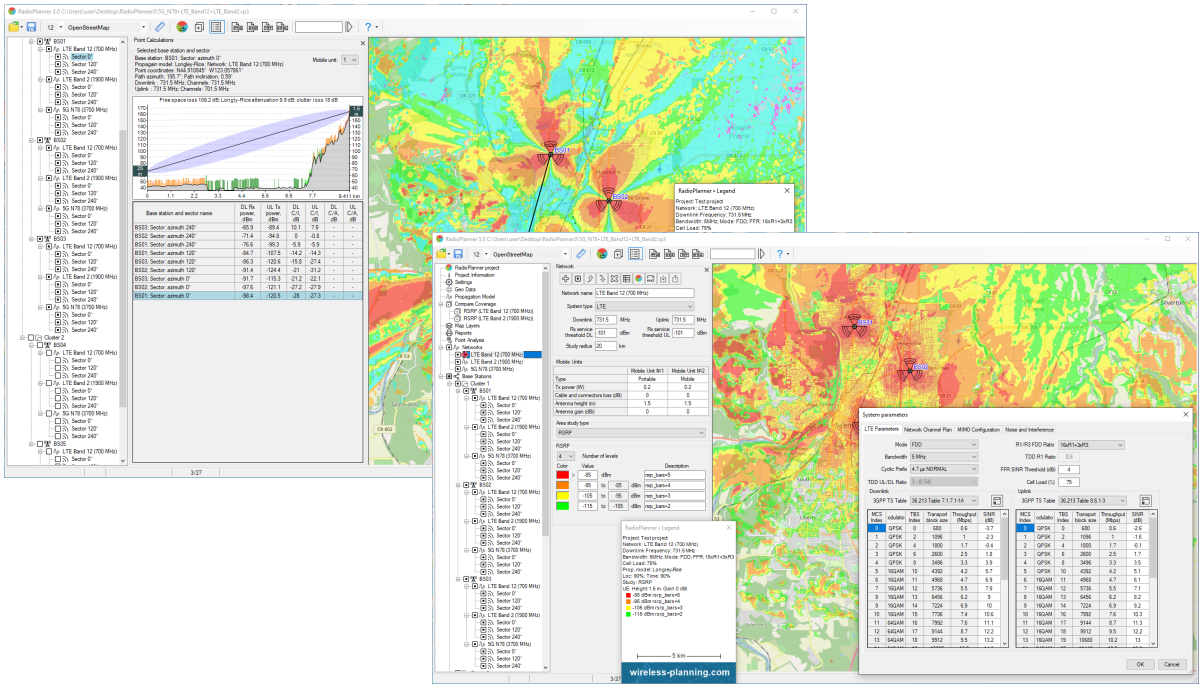


Table of Contents

From the Developers

We have made every effort to create a user-friendly and intuitive application. However, we recommend taking some time to read this User Manual to fully utilize RadioPlanner's capabilities. Created by engineers with over 25 years of experience in designing radio communication and broadcasting networks, RadioPlanner is a full-featured yet simple and convenient planning tool.

Features

RadioPlanner 3.0 is a planning tool for various types of networks, including:

- Mobile networks: 5G (NR), LTE, UMTS, GSM, GSM-R, WCDMA
- Public safety land mobile networks: P25, TETRA, DMR, dPMR, NXDN
- Wireless IoT LPWAN networks: LoRa, SigFox
- Precision agriculture systems
- Terrestrial radio and television broadcast networks: ATSC, DVB-T, DVB-T2, ISDB-T, DTMB, DAB, DAB+
- Air-to-ground communication and radio navigation systems operating in VHF, UHF, and microwave frequencies: UAV (Drone) Control, Air-to-ground radio, ADS-B, VOR, DME

RadioPlanner 3.0 uses propagation models:

- ITU-R P.1812-6
- ITU-R P.1546-6
- Longley-Rice (ITM) v1.2.2
- Okumura-Hata
- 3GPP TR 38.901
- Combined ITU-R P.528-3 + P.526-14 (for Ground-to-Air Radio only)

RadioPlanner 3.0 performs various types of area studies for mobile networks:

- Received Power
- Best Server (Strongest Server)
- C/(I+N) Ratio
- Maximum Throughput
- Maximum aggregated Throughput
- Area with Signal above Both Base and Mobile Thresholds
- Number of Servers
- Coverage Probability
- Reference Signal Received Power (RSRP) for 5G and LTE
- Energy Per Resource Element (EPRE) for 5G and LTE
- Reference Signal Received Quality (RSRQ) for 5G and LTE
- Simulcast Delay Spread
- Received Power with Simulcast Interference
- TalckOut and TalckBack
- Field Strength

Area studies for terrestrial radio and television broadcast transmitters include:

- Field Strength at Receiver Location
- Best Server
- Simulcast Delay Spread

- FCC contours
- ITU-R P.1546-6 contours
- Population coverage
- Generation of list of localities covered by broadcasting

Area studies for Air-to-Ground radio communication systems include:

- Received power Air-to-Ground link
- Received power Ground-to-Air link
- Best Server Air-to-Ground link

RadioPlanner offers the following features:

- Work with multiple networks within a single project and view aggregate coverage predictions for maximum throughput and number of servers.
- Plan radio network frequencies while considering co-channel and adjacent channel interference.
- Display of path profiles with path losses and levels of carrier and interference on the co-channel and adjacent channels.
- Perform multipoint study of a group of CPE or IoT sensors (end devices), each with their individual parameters (antenna height, antenna gain, transmitter power, cable loss, and penetration loss) under varying deployment conditions.
- Import measured signal power level results for comparison with calculated values and adjust propagation model parameters.
- Compare multiple coverage prediction results.
- Save coverage prediction results as an interactive web page, KMZ file, PNG image, GeoTiff file, CSV file or as MIF file.
- Flexibly adjust base map layers and display custom vector layers.

GIS features:

- Default digital terrain model (DTM) with 30m plane resolution, automatically loaded worldwide (see Appendix 2 for data source details).
- Option to use custom DTM in GeoTiff format.
- Default clutter model with nine clutter types, automatically loaded worldwide. Created from OpenStreetMap (www.openstreetmap.org) and Global Forest Change projects.
- Option to use custom clutter in GeoTiff format.
- Common (e.g., OpenStreetMap, OpenTopoMap, US Topo) and custom base maps.

Installation and Activation

RadioPlanner is compatible with 64-bit Windows 10/11. The minimum computer requirements include a 64-bit Windows operating system, Core i3 CPU, 4GB RAM, 200GB HDD, video card, and monitor with support for 1366x768 resolution. For optimal performance, it is recommended to use a computer with a 64-bit Windows operating system, Core i5 CPU, 16GB RAM, 256GB SSD, video card, and monitor with support for 1920x1080 resolution. Additionally, Microsoft Excel must be installed on the computer to use all RadioPlanner features.

To access the full version of RadioPlanner, a license must be purchased. After successful purchase, an email will be sent containing a link to download the full version installation file and an Activation ID for

the license. Follow the instructions in the installation file and enter the Activation ID when prompted to activate the fully functional version of RadioPlanner.

Software Update

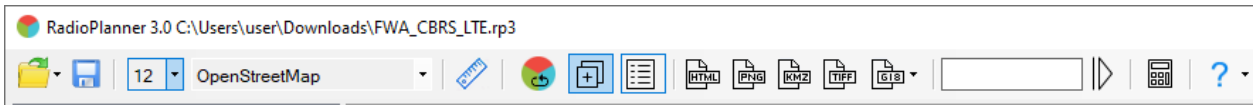
We periodically release free updates to improve the functionality and stability of RadioPlanner. The software supports both manual and automatic checking for updates and will check for available updates every time it starts. To check for updates manually, click “Help - Check for updates.” If an update is available, a window will open with information about the current and available versions. You can download the update from the provided link and install it manually. Be sure to exit RadioPlanner before installing the update.

User Interface

After starting the program, the main panel will appear with the main menu on the left side and the base map on the right side. The size of the panels can be adjusted using the separator. The base map can display various layers, including sites, coverage, terrain and clutter layers, base map, and additional vector layers. You can choose to display one of the pre-installed base maps or customize your own base map as described in the Base map Settings section.

Navigation on the map is done using the mouse, with the mouse wheel used to zoom in and out. You can also select the desired zoom level from the drop-down list in the toolbar.

Toolbar and Main Menu

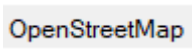


When you hover over each of the icons, a hint appears.

Standard tools for working with files: Create, Open, Save

Save project

The zoom of the base map



The base map

The “ruler” tool allows you to measure the distance and azimuth between any two points on the map. To use this tool, click on the ruler icon and then click on any two points on the map. The distance between the points and the azimuth from the first to the second point will be displayed. To exit the tool, right-click anywhere on the map.

Repeat previous coverage prediction

Add the coverage to compare

Show / Hide Legend

Save the map as WEB page

Save the map as an image in PNG format

Save the map as KMZ file

Save the map as GeoTiff file

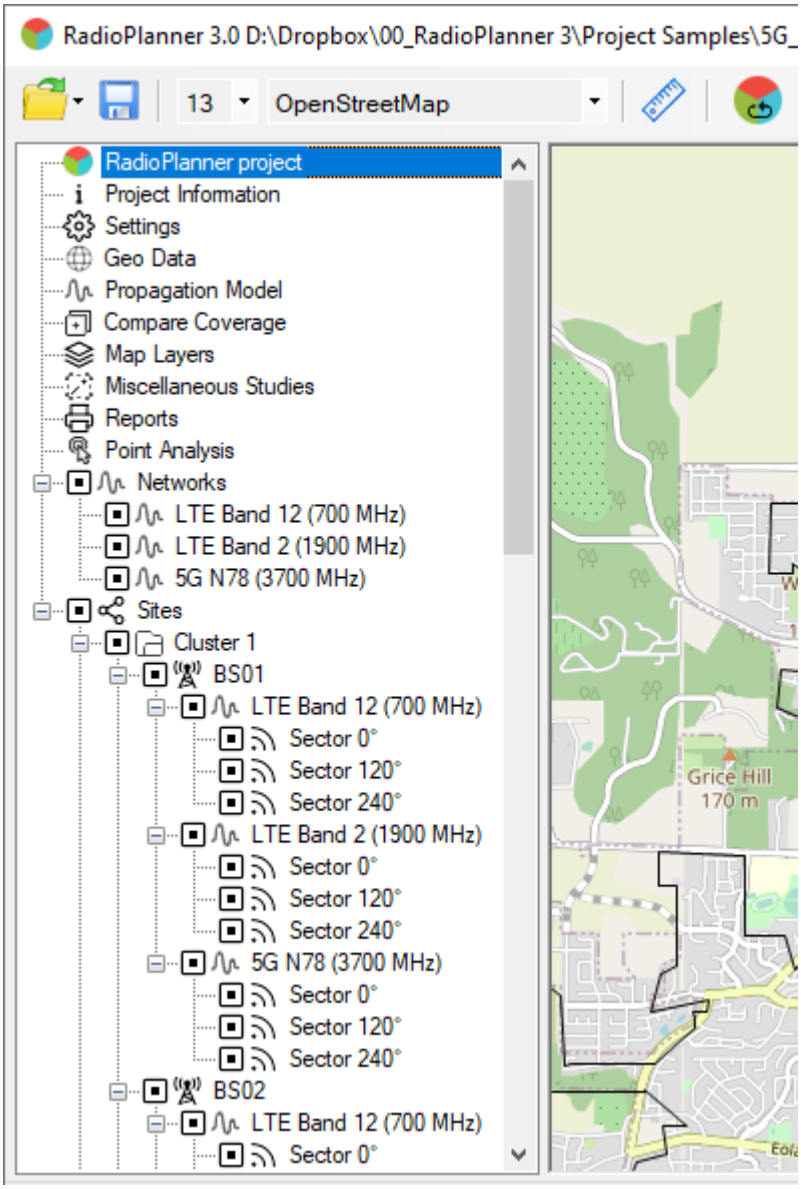
Save coverage in GIS format

Searh sites by the name

Run Noise-Adjusted Faded Performance Threshold Calculator

Help

For more detailed information about each tool, please refer to the corresponding sections in the User Manual.

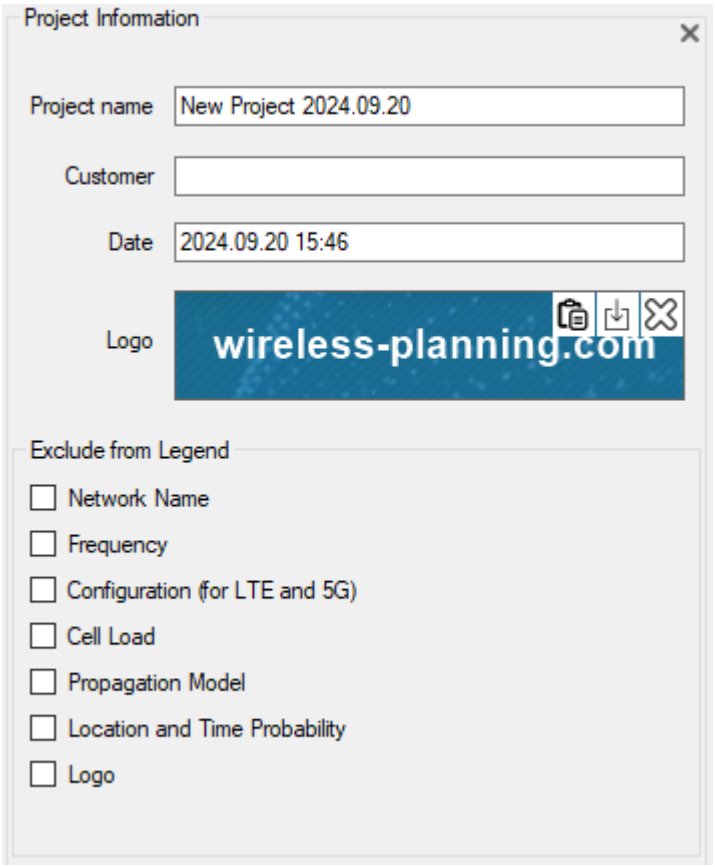


Tree View interface

Project Information

A new project is automatically created when RadioPlanner is launched. The File menu contains standard buttons (New, Open, Save, Save As) for performing standard file operations. Project files can be saved with the *.rp3 extension and contain all information about the project.

General information about the project can be specified in the project information panel.

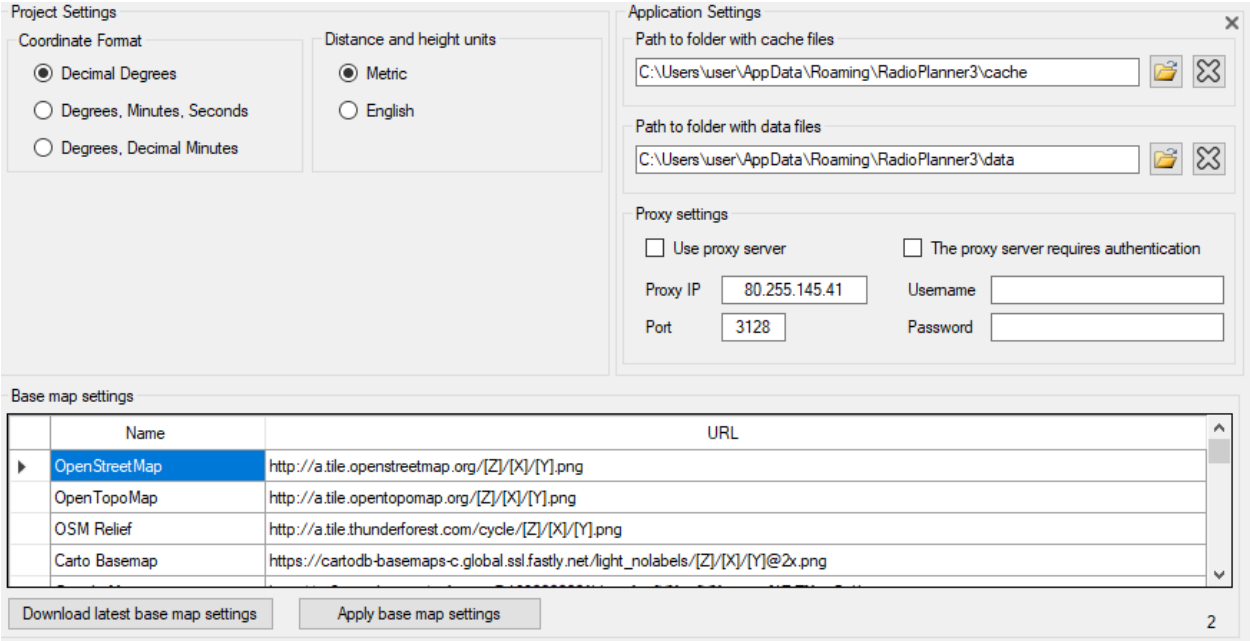


Project Information

Project name	Text field
Customer	Text field
Data	Text field - When creating a new project, it records the date and time of the project creation.
Logo	Your company logo. The recommended resolution is approximately 270 by 60 pixels.
Exclude from Legend	Exclude corresponding lines from Legend

Settings

Before starting to work with the software, it is necessary to configure the settings.



Settings

Project Settings	
Distance and Height Units	- Metric - English
Coordinate Format	- Decimal Degrees (N44.345678 W134.567893) - Degrees, Minutes, Seconds (N44° 34' 23.7" W134° 29' 23,4") - Degrees, Decimal Minutes (N44°34.2356' W134° 29.2354')
Application Settings	
Path to Folder with Cache Files	The path to the folder where downloaded base map tiles will be saved for quick access can be specified in the settings. This folder is created automatically when the application is launched for the first time and can be changed if desired. The downloaded maps will remain on your computer and can be viewed even when you do not have an Internet connection.
Path to Folder with Data Files	The path to the folder where downloaded default Digital Terrain Model (DTM) and default clutter model files will be saved for quick access can be specified in the settings. This folder is created automatically when the application is launched for the first time and can be changed if desired. The downloaded files will remain on your computer and can be used by the application to create a terrain profile even when you do not have an Internet connection.
Proxy Settings	If you are using a proxy server to access the Internet, enter its IP address and port number in the Proxy Settings section. If the proxy server requires authentication, enter the username and password.

Base Map Settings

You can configure your own custom base map by specifying a tile server URL. This URL encapsulates a request format specific to the map provider and consists of a text string that begins with http:// and includes a domain name, possible parameters, and symbols that RadioPlanner substitutes with real-time tile request information when contacting the server.

The symbols that RadioPlanner accepts in the prototype URL are [X], [Y], and [Z] coordinates and zoom. Most map providers use tile coordinates of x and y, plus zoom to lookup map imagery in their database. For example, OpenStreetMap provides map imagery using x, y, and zoom. To fetch a map tile of a portion of North America, you can enter the following URL into a web browser: http://a.tile.openstreetmap.org/3/1/2.png. The numbers at the end of the URL represent zoom, x, and y respectively.

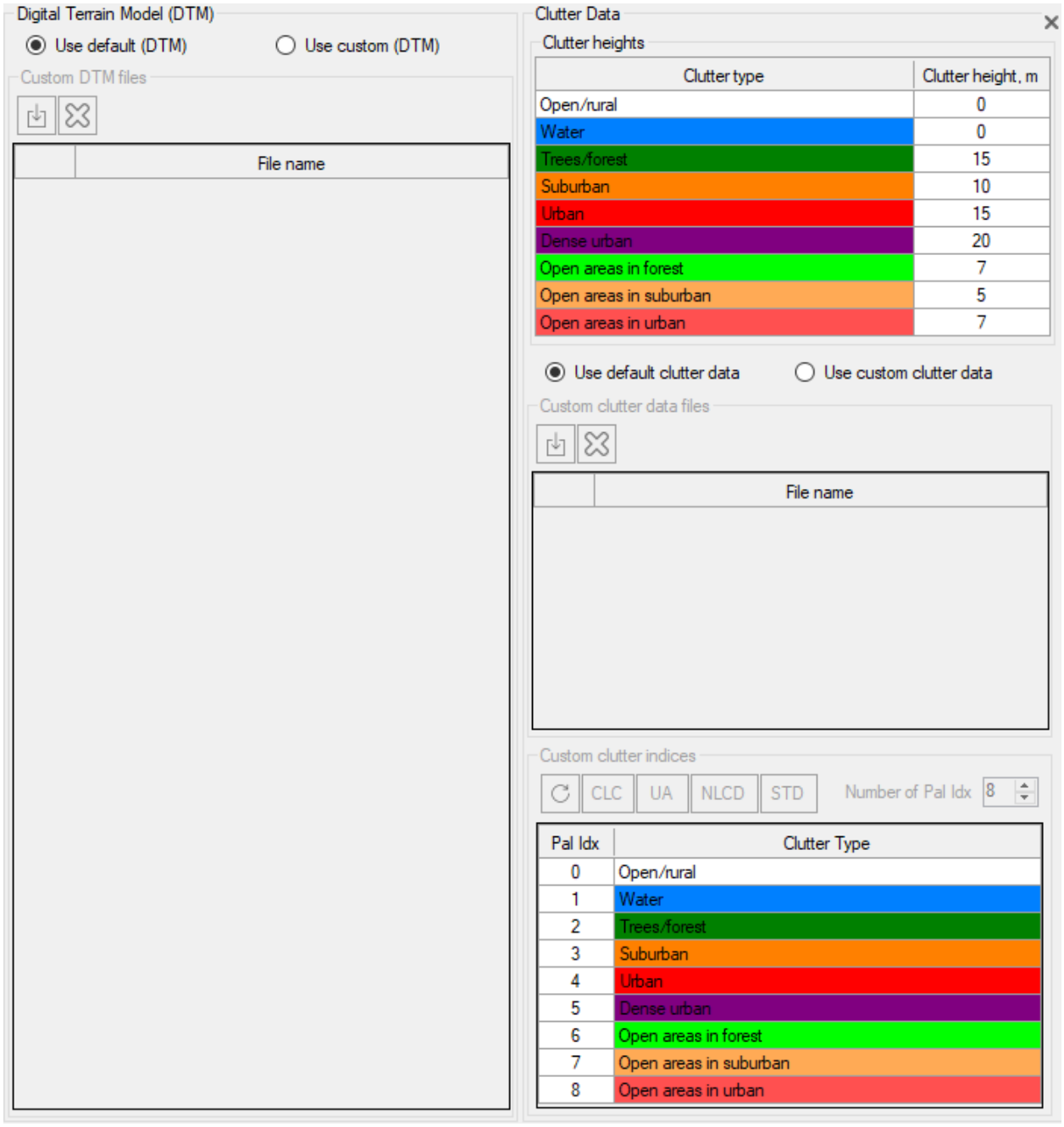
To create custom map types in RadioPlanner for OpenStreetMap, you can mix the known specific URLs with the symbols representing x, y, and zoom to form a custom map prototype URL. For example: http://a.tile.openstreetmap.org/[Z]/[X]/[Y].png. When RadioPlanner needs to fetch a map tile from a provider, it will replace the [X], [Y], and [Z] symbols with the actual coordinates and zoom for the required tile and use the resulting URL to contact the map provider's server to fetch the map tile.

To use custom maps, enter the Map Server's URL of the desired map. You can search online for local map providers' map servers' URLs. If you have more relevant or detailed cartographic data for the desired territory in the form of an image or vector map, you can create your own tile server using specialized GIS software such as MapInfo, QGIS or Global Mapper.

Download latest base map settings	Update basemap settings from our server. User tile server addresses will be removed.
Apply base map settings	Apply basemap settings after entering custom tile server address

Geo Data

This menu allows you to specify the geodata (DTM and clutters) that will be used in calculations.



Geo Data Parameters

Digital Terrain Model (DTM)

The Digital Terrain Model (DTM) is a geographic data file (or files) representing the elevation of the ground above sea level. In RadioPlanner 3, you can use the default DTM that is automatically downloaded from our server when predicting coverage. This DTM is compiled from open geodata sources and is available worldwide. It is sufficient for most use cases.

Alternatively, you can use custom DTMs in GeoTiff format. GeoTIFF is an open format that can be used to convert elevation data from a LiDAR survey or any other DTM. This conversion can be performed using specialized GIS applications such as QGIS, Global Mapper, ArcGis, MapInfo, and others.

Use default DTM	Use default DTM
Use custom DTM	Use custom elevation DTM. Import the DTM file(s) in Geotiff format.

Custom DTM GeoTIFF files(s) must have the following format:

File Type: Int16 (Sixteen-bit signed integer)

Compression: No/LZW/Deflate (ZIP)

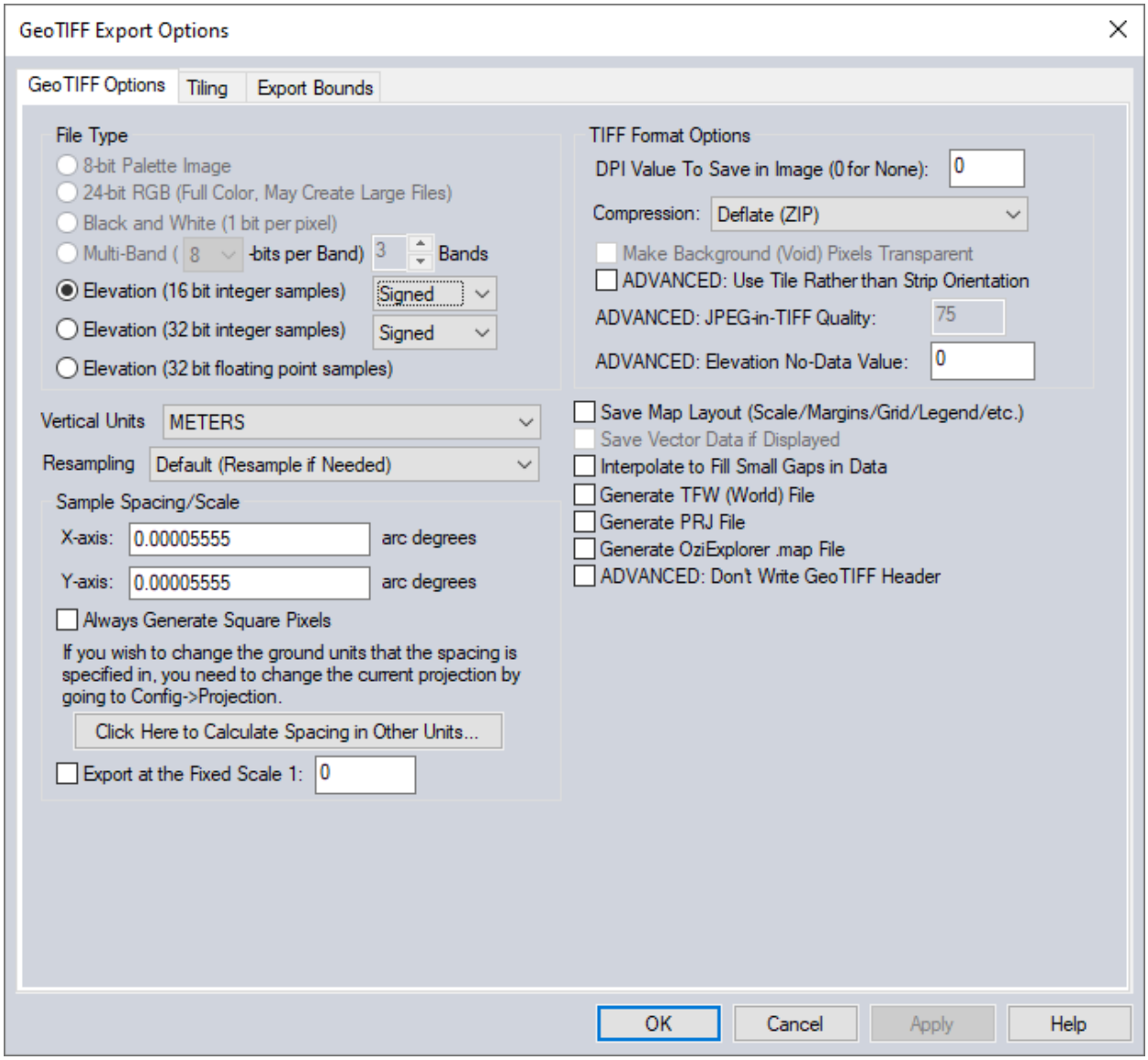
Projection: Geographic (Latitude/Longitude)

Datum: WGS84

Planar Units: ARC Degrees

Vertical Units: Meters

An example of exporting to a DEM Geo TIFF file in the Global Mapper with a resolution of 1/5 arc second (0.00005555 arc degree):

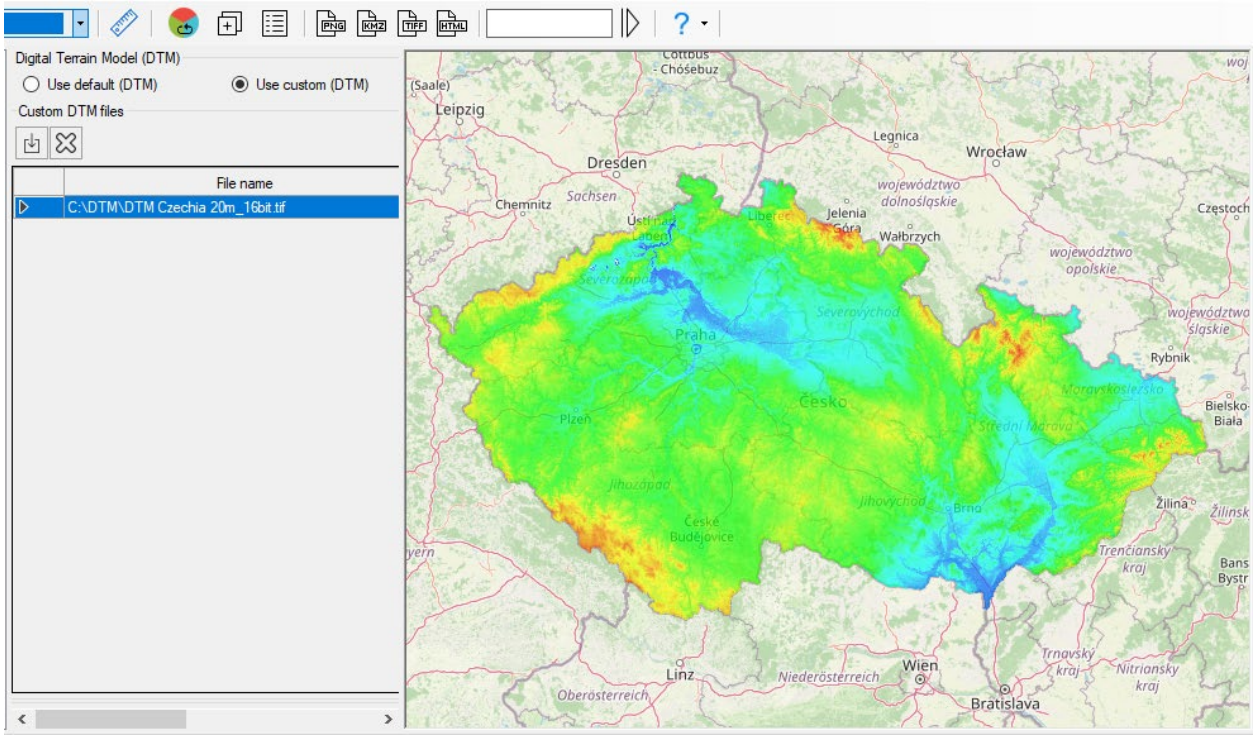


An example of configuring DTM export settings to Geotiff

Max Width x Height: 100 000 x 100 000 points (for 64 GB RAM and powerful CPU). For comfortable work on a computer of average performance, we do not recommend making the DEM size larger than 50,000 by 50,000 points.

Some custom DTM samples in GeoTIFF format can be found in the installation folder.

On our YouTube channel, we have posted a video on preparing custom DTM:
https://youtu.be/yS2dQreh3Cs



Custom DTM

Clutter Data

The clutter data describes land cover or land use and is used by RadioPlanner to calculate signal power loss on local obstacles surrounding the mobile unit.

In RadioPlanner 3, you can use the default clutter data that is automatically downloaded from our server when predicting coverage. This data is compiled from open geodata sources (OpenStreetMap and Global Forest Change projects) and is available worldwide. It is sufficient for most use cases.

The clutter model used in RadioPlanner has 9 types of clutters:

	Clutter Type	Color	Description
1	Open / Rural		Open and rural area
2	Water		Water area
3	Trees / Forest		Forest area
4	Suburban		Suburban area
5	Urban		Urban area
6	Dense urban		Dense urban area
7	Open areas in forest		Forest roads
8	Open areas in suburban		Highways, wide roads
9	Open areas in urban		Highways, avenues, wide roads

For each clutter type, you can specify an average height (used to calculate clutter loss in the ITU-R P. 1812-6 propagation model) or directly enter the loss value (see the Propagation Model menu).

Clutter heights	The typical clutter height. This value is used in the ITU-R P.1812 and ITU-R P.1546 recommendations to calculate clutter loss.

Use default clutter data	Use default clutter
Use custom clutter data	Import the clutter file(s) in Geotiff format.

You can also use custom clutter data in GeoTiff 8-bit Palette Image file format. Each pixel of this file can contain up to 256 possible clutter classes (commonly used up to 30), representing specific types of land use or landcover. Custom clutter files can be prepared from a land use database (e.g., NLCD, CORINE, ESA Global Land Cover) using specialized software (Global Mapper, QGIS, MapInfo, etc.).

Custom clutter indices	Clutter file palette indices to clutter type correspondence table CLC - CORINE Land Cover https://land.copernicus.eu/pan-european/corine-land-cover UA – CORINE Urban Atlas https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018 NLCD - National Land Cover Database https://www.usgs.gov/centers/eros/science/national-land-cover-database Default - Deafaul clutter indices (0,1,2,3,4,5,6,7,8)
Number of Pal Idx	Number of indexes in custom palette

After importing a custom clutter file into RadioPlanner, it is necessary to establish a correspondence between its palette indexes and the 9 clutter types used in the program. We have made lookup table presets for some standard land cover types (NLCD, CORINE Land Cover, CORINE Urban Atlas). To use these presets correctly, you need to use a special standard (for NLCD and CORINE Land Cover) or custom (for CORINE Urban Atlas) palette when exporting to GeoTiff. Some custom clutter data file samples in GeoTiff format can be found in the installation folder.

On our YouTube channel, we have posted a video on preparing custom clutter from several common landcover types:

https://youtu.be/5QWYYGhGEdY How to make custom clutter from National Land Cover Database (NLCD)

https://youtu.be/pmY6YNy3eIo How to make custom clutter from CORINE Land Cover

https://youtu.be/DwBRa2g2VIA How to make custom clutter from Urban Atlas

Custom clutter GeoTIFF file(s) must have the following format:

File Type: 8-bit Pallete Image

Compression: No/LZW/Deflate (ZIP)

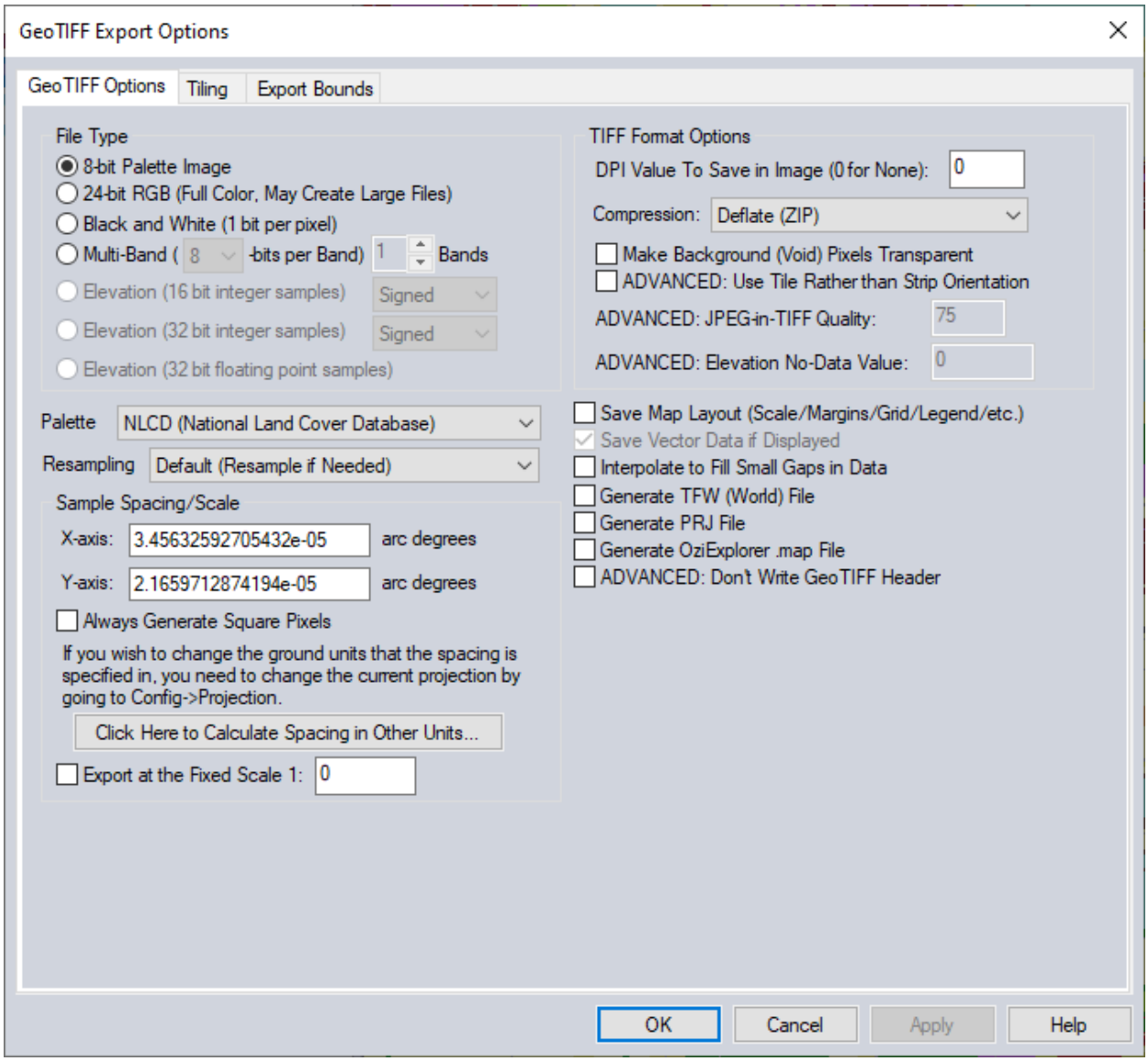
Projection: Geographic (Latitude/Longitude)

Datum: WGS84

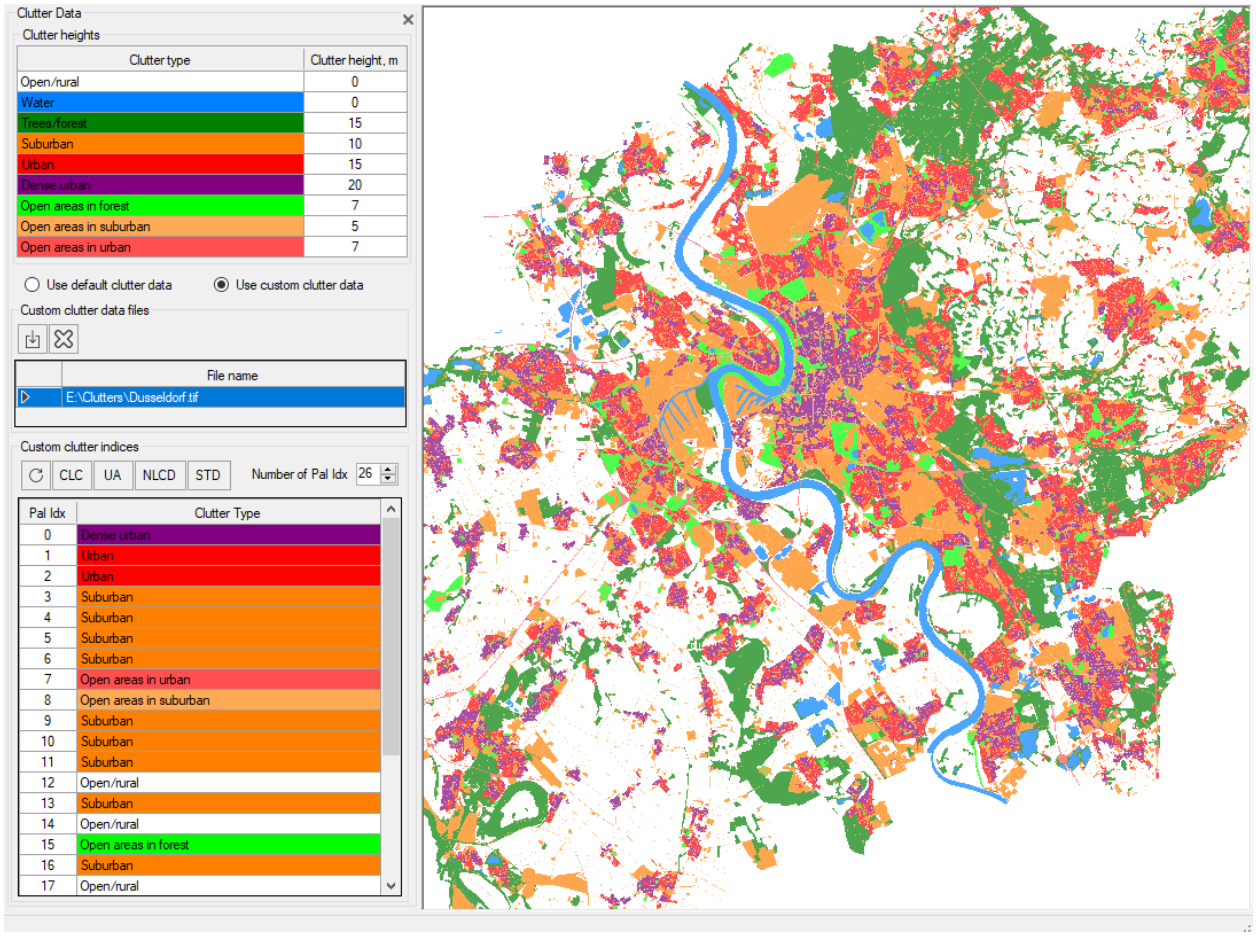
Planar Units: ARC Degrees

Max Width x Height: 100 000 x 100 000 points (for 64 GB RAM and powerful CPU). For comfortable work on a computer of average performance, we do not recommend making the clutter size larger than 50,000 by 50,000 points.

An example of exporting to a clutter Geo TIFF file in the Global Mapper:



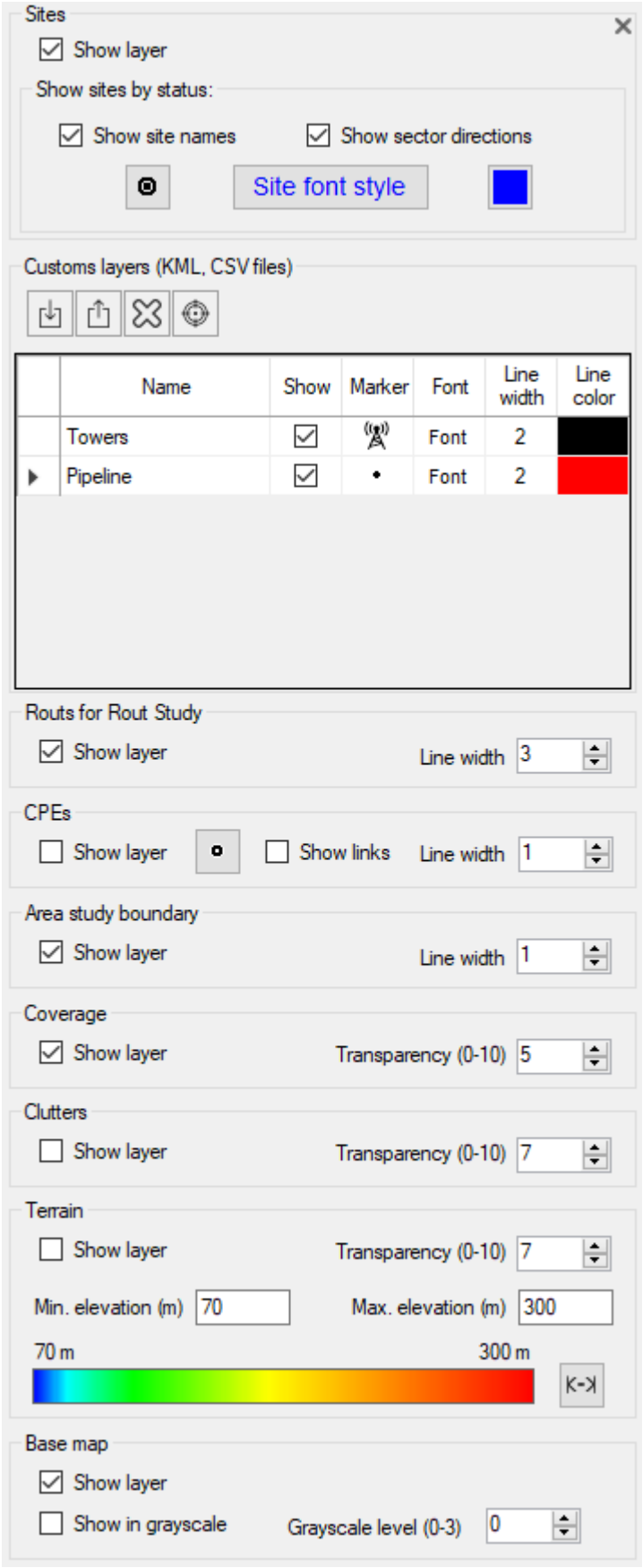
An example of configuring clutter export settings to Geotiff



Custom clutter

Map Layers

In the Map Layers menu, you can control which layers are displayed on the map. The order of the layers in the menu corresponds to their order on the map, with the base map at the bottom and sites at the top of all layers.


Sites
Show layer
Show sites by status:
Show site names
Show sector directions
Site font style
Customs layers (KML, CSV files)
Name
Show
Marker
Font
Line width
Line color
Towers
Font
2
Pipeline
Font
2
Routs for Rout Study
Show layer
Line width
3
CPEs
Show layer
Show links
Line width
1
Area study boundary
Show layer
Line width
1
Coverage
Show layer
Transparency (0-10)
5
Clutters
Show layer
Transparency (0-10)
7
Terrain
Show layer
Transparency (0-10)
7
Min. elevation (m)
70
Max. elevation (m)
300
70 m
300 m
K->I
Base map
Show layer
Show in grayscale
Grayscale level (0-3)
0

Map Layers

Sites

Sites are Base Stations or transmitters for TV and radio broadcasting.

Show layer	Show/hide site layer
Show site names	Show site names
Show sector directions	Show sector direction according to antenna azimuth
Site marker	Choose marker for sites
Site font style	Change font type for sites

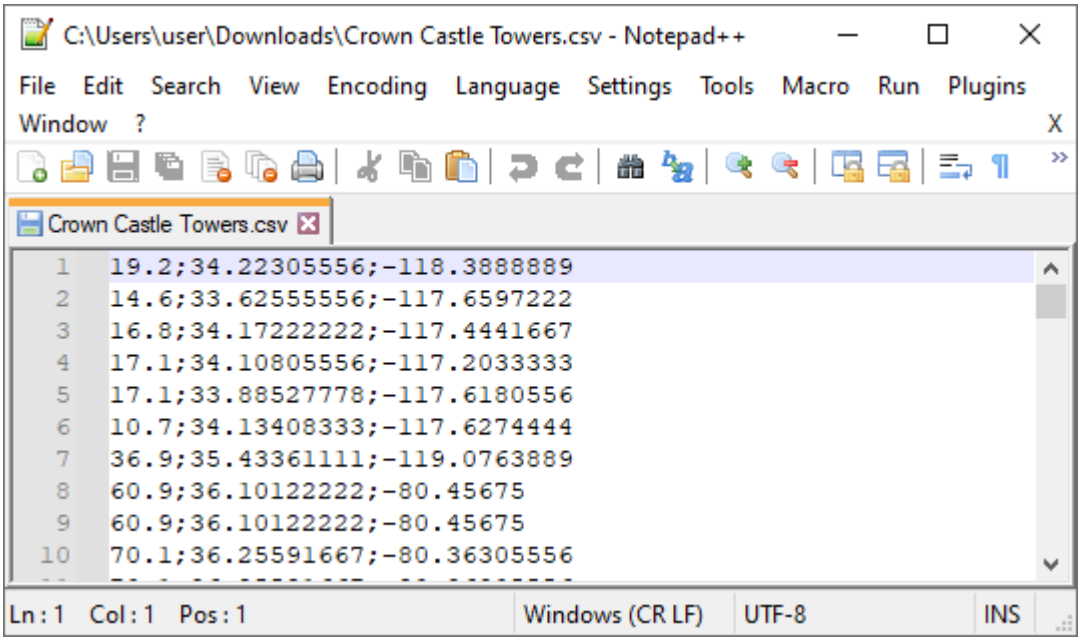
Custom Layers (KML, CSV)

You can load and display point or linear vector objects in KML format as a layer on the map. This can include objects such as power lines, piping, and etc. Custom layers are saved in the project file.

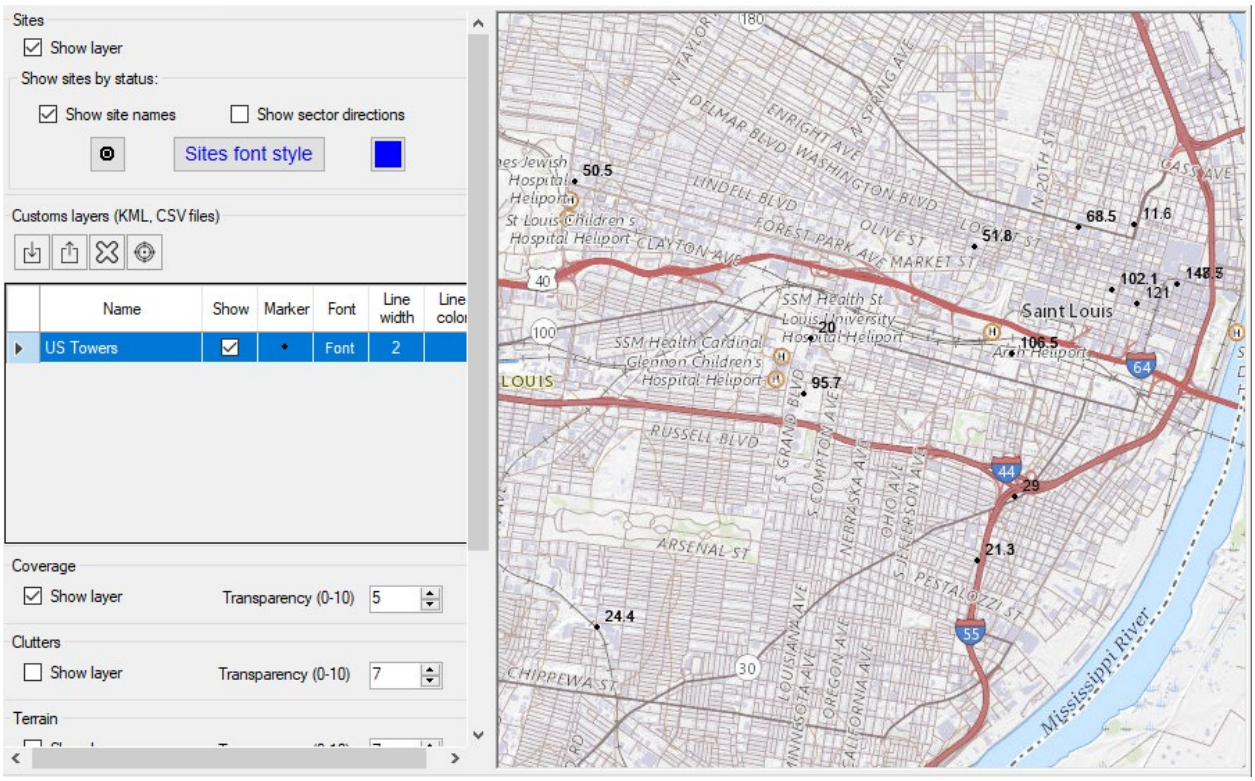
	Load a custom layer (KML, CSV file)
	Save points from the selected layer to a CSV file
	Delete selected custom layer
	Position the map on the first point of the selected layer
Name	The name of the user layer. Initially corresponds to the file name, but can be changed.
Show	Show/hide custom map layer
Marker	Select a marker for the item (only for point objects)
Line width	Specify the line width in pixels (only for line)
Line color	Specify line color (only for line)

Point objects can also be downloaded from a CSV file (text format with a semicolon separator).

Each point object must have the required fields of Parameter, Latitude, and Longitude. Coordinates can be formatted as HEMISPHERE degrees minutes seconds (N35 23.8 36) or HEMISPHERE decimal degrees (N12.34567). The parameter can be any text that appears at the specified coordinates, such as a measurement result or the name of an object.

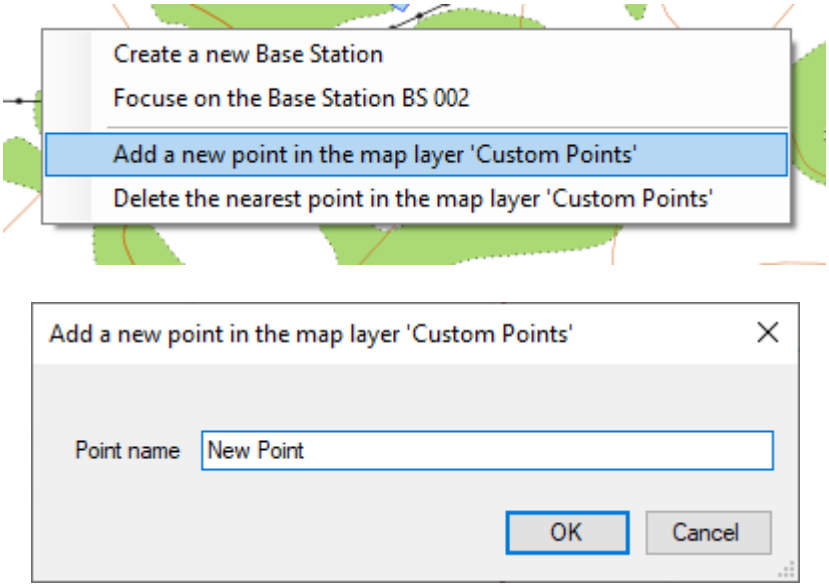


Sample CSV file with Antenna Towers



Custom Layer on the map

You can also quickly create point objects directly on the map. To do this, right-click on the desired location and select “Add a new point to the ‘Custom Points’ layer” from the context menu. Then specify the point name and it will appear on the map and be added to the “Custom Points” layer, which is automatically created when you create the first point object. You can also delete created point objects by right-clicking on the point and selecting “Delete the nearest point in the ‘Custom Points’ layer” from the context menu.



Adding a point feature to a map

Routs for Route Study

Routs layer control. For more details, see the section on Miscellaneous Studies - Route Study.

Show layer	Show/hide Routs layer
Line width	Line width

CPEs

CPE map layer control. CPE is customer premises equipment for fixed wireless access (FWA) applications or Sensors for IoT networks such as LoRaWAN, SigFox and others.

Show layer	Show/hide CPE layer
Select marker	Choose marker for CPEs
Show links	Show link to the assigned BS sector
Line width	Line width

Area Study Boundary

The area study boundary map layer control.

Show layer	Show/hide layer
Line width	Line width

Coverage

The coverage prediction map layer control.

Show layer	Show/hide layer
Transparency	Set layer opacity in the range from 0 (fully transparent) to 10 (not transparent)

Clutter

The clutter map layer control.

Show Layer	Show / Hide the clutter map layer. **The default clutter is shown only for zoom 11 and higher. A custom clutter is shown for any zoom.**
Transparency	Set layer opacity in the range of 0 (fully transparent) to 10 (not transparent)

Terrain

The Terrain map layer control.

Show Layer	Show / Hide the terrain map layer. **The default terrain is shown only for zoom 9 and higher. A custom terrain is shown for any zoom.**
Transparency	Set layer opacity in the range of 0 (fully transparent) to 10 (not transparent)
Min (Max) Elevation	Elevation legend range. All heights below the minimum (including the minimum) will be fully transparent. All heights above the maximum will be in maroon.
	Set the minimum and maximum height on the screen. Sets the height range within the minimum and maximum heights found within the screen.

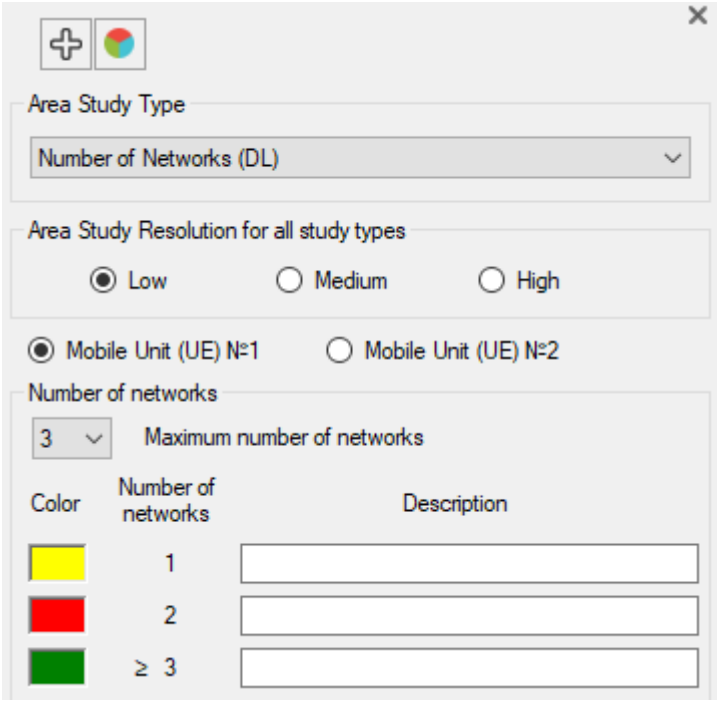
Base Map

Base map layer control

Show layer	Show/hide the layer
Show in grayscale	Show base map in grayscale
Grayscale level	Brightness from the range 0 (darker) - 3 (lighter)

RF Planning for Mobile Networks

RadioPlanner 3.0 allows you to work with multiple networks in one project. When creating a new project, the first network is created by default.



Networks menu

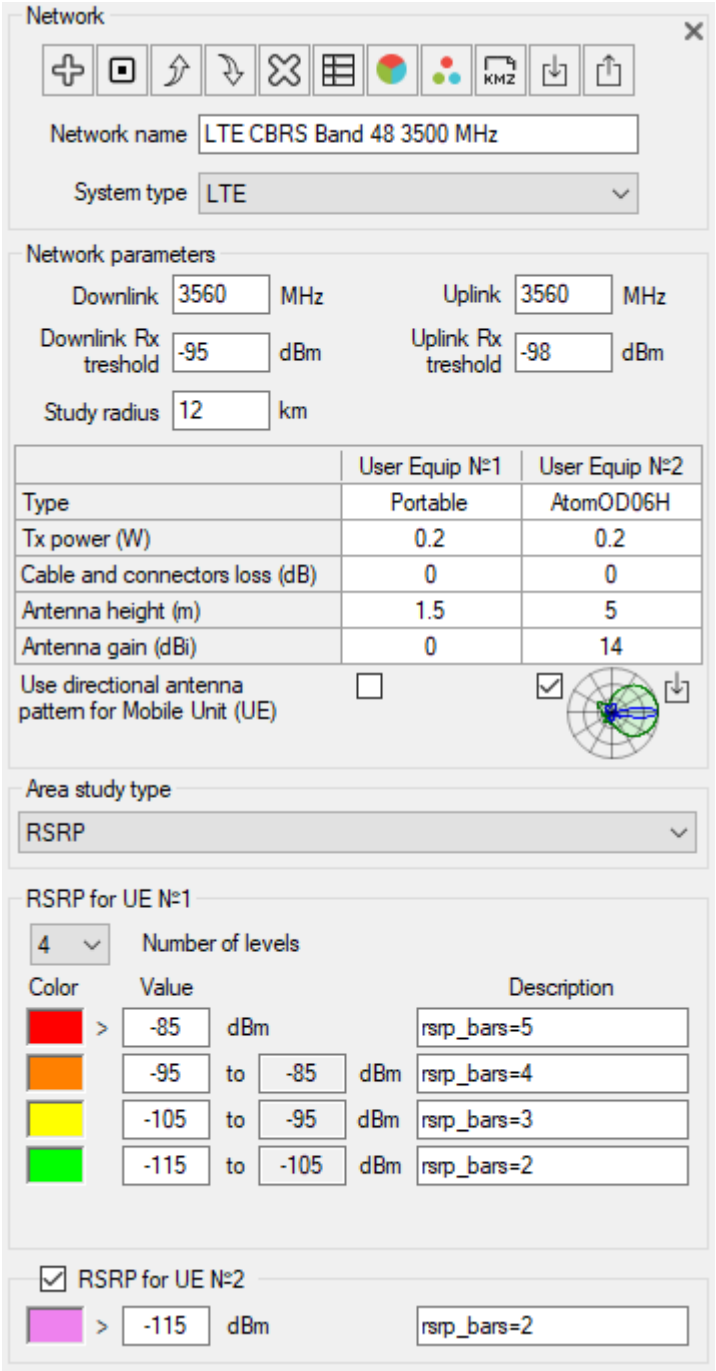
Add a new network

Calculate Coverage (See Coverage predictions for multiple networks section)

Area Study Type	Coverage predictions for multiple networks: - Number of Networks (DL) - Number of Networks (UL) - Maximum Aggregated (DL) Throughput - Maximum Aggregated (UL) Throughput See Coverage predictions for multiple networks section
Area Study Resolution for all study types	Coverage prediction resolution. Specifies the details of both aggregated calculations and calculations for each of the networks. - Low - Medium - High The resolution corresponds to one pixel of the screen for zoom = 11 (low detail), zoom = 12 (medium), and zoom = 13 (high). For a geographic latitude of 55 degrees, this is approximately 40, 20, and 10 meters, respectively. The higher the resolution, the longer the calculation time.
Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made

Network

The “Network” menu is used to set all parameters for the selected network, including mobile station parameters and calculation parameters. You can also perform calculations for the network using this menu.



Network menu

Add a new network with the same parameters (copy the network)

Check/Uncheck all sectors for current network

Move the Network up


Move the Network down


Delete the network


System parameters


Calculate Coverage


Calculate FWA Coverage taking into account the parameters of each CPE. See section "Fixed Wireless Access network"

Calculate coverage for each active sector and save the map as a KMZ file


Load network parameters from a template


Save network parameters as a template

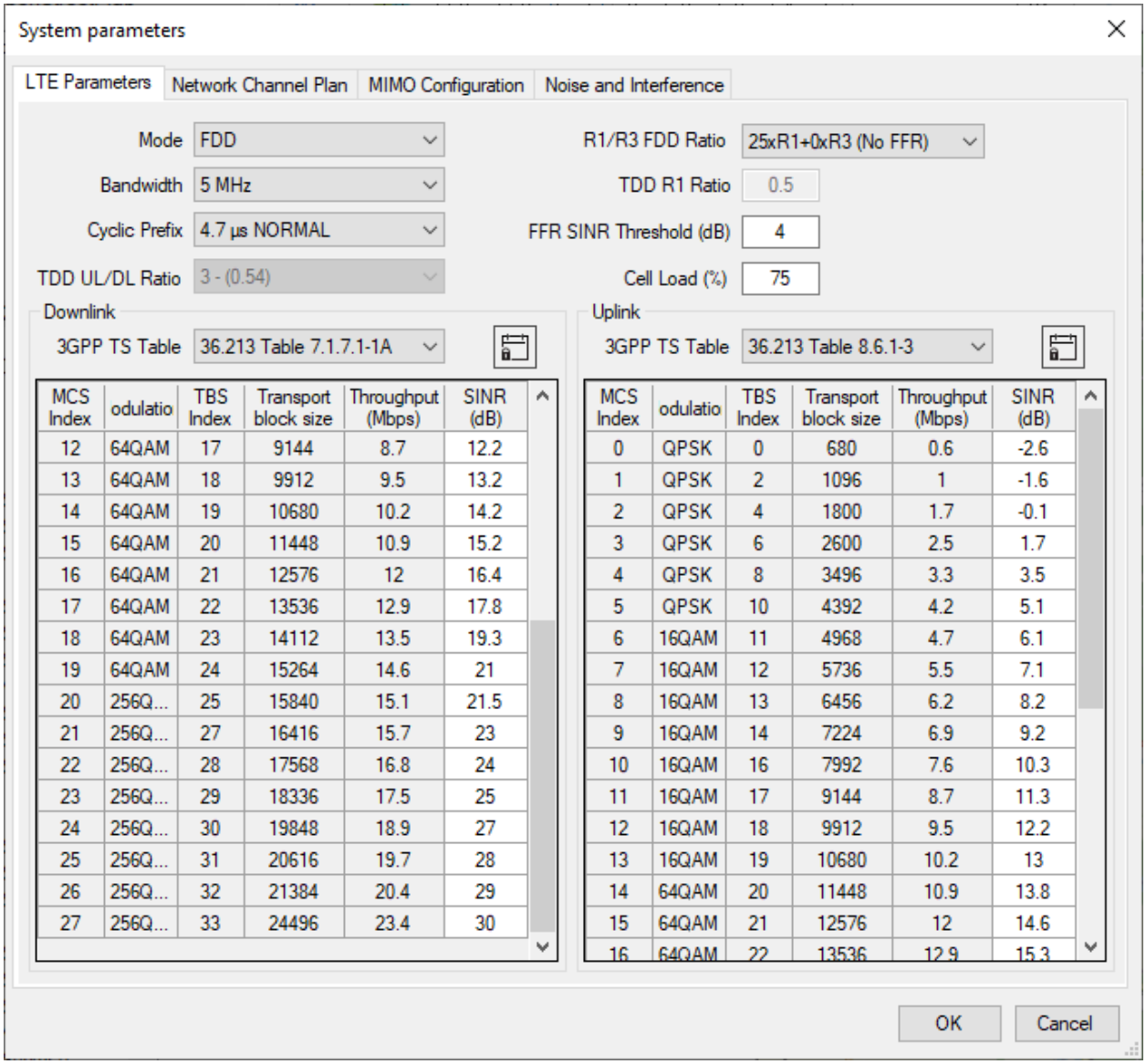
Network name	Name of network, text field
System type	System type options: - Generic TRX - LTE - 5G - Terrestrial Broadcasting - Air-to-Ground Radio The selected system type will determine the set of additional system parameters, as well as the types of coverage predictions available.
Downlink	Average downlink frequency, MHz
Uplink	Average uplink frequency, MHz
Downlink Rx threshold	This threshold value will limit the coverage prediction display based on whether the signal received at the mobile unit from the base station is above or below this threshold, dBm
Uplink Rx threshold	This threshold value will limit the coverage prediction display based on whether the signal received at the base station from the mobile unit is above or below this threshold, dBm
Study radius	Maximum study radius, km The larger the radius, the longer the computation time. Do not set an unnecessarily large calculation radius.

Mobile Units

Type	Name (model) of Mobile Unit, text field
Tx Power	Transmitter power, W
Cable and Connector Loss	Loss in cable and connectors, dB
Antenna Height	Antenna height relative to ground level, m
Antenna Gain	Antenna gain, dBi
Use directional antenna pattern for Mobile Unit (UE)	By default, the mobile units' (UE) antenna pattern is assumed to be isotropic. If you are designing a fixed wireless access (FWA) network with directional CPE antennas, you should download the antenna pattern in MSI format. It is assumed that the CPE antennas are aimed at the BS sector with the strongest signal at the CPE location. The use of directional antennas on the CPE significantly reduces interference from neighboring cells and, as a result, increases CPE throughput.

RadioPlanner allows you to predict coverage for two types of mobile devices. This is used in professional mobile radio networks, where portable and mobile stations are often used, since they differ in both power characteristics and antenna height relative to ground level. Also, coverage prediction for several types of mobile devices with different antenna heights is often necessary in fixed wireless access (FWA) networks.

LTE System Parameters



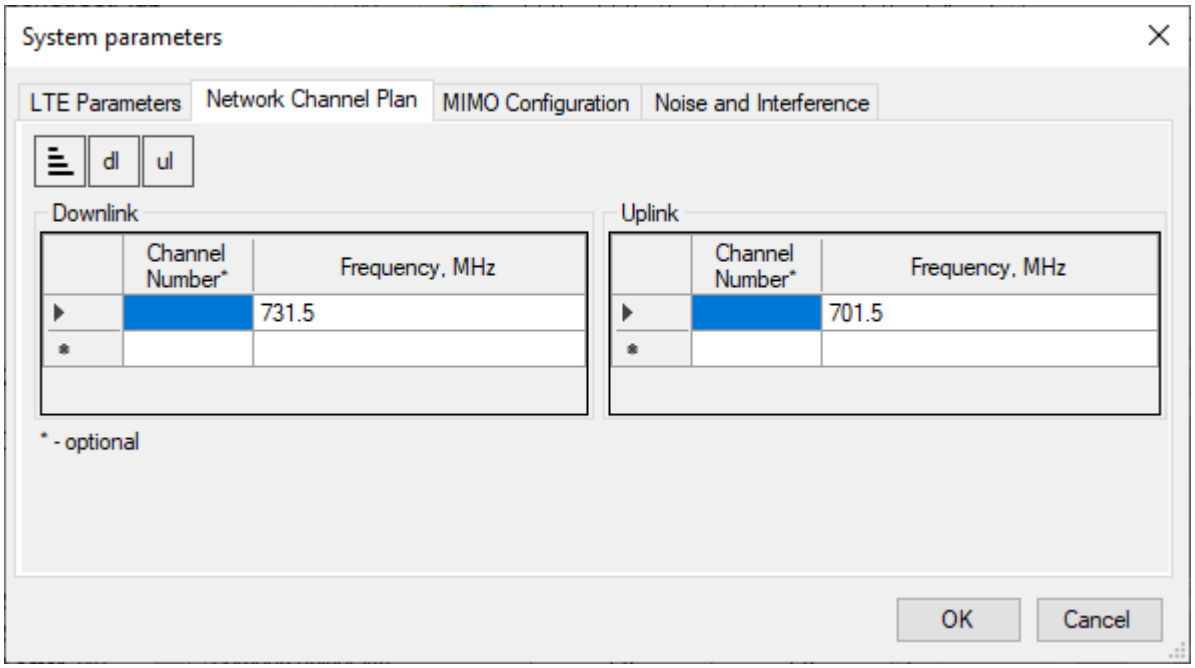
LTE System Parameters

Mode	LTE duplex mode: - FDD - TDD
Bandwidth	LTE bandwidth: 1.4 MHz; 3 MHz; 5 MHz; 10MHz; 15 MHz; 20 MHz
Cyclic Prefix	LTE Cyclic Prefix: - 4.7 µs (Normal) - 16.7 µs (Extended)
TDD UL/DL Ratio	TDD configurations in 3GPP LTE specification:

	TDD Configuration # UL/total ratio DL/total ratio 0 0.7 0.3 1 0.5 0.5 2 0.3 0.7 3 0.35 0.65 4 0.25 0.75 5 0.15 0.85 6 0.6 0.4
R1/R3 FDD Ratio	Type of Fractional Frequency Reuse (FFR) plan that is being used in LTE project in the R1/R3 zone Resource Blocks drop-down list
TDD R1 Ratio	Part (from 0.1 to 1) the R1 zone subcarriers of physical resource blocks (PRB) for TDD
FFR SINR Threshold	SINR threshold for switching between R1 and R3 zones in FFR, dB
Cell Load	Cell Load, 0-100 % Cell Loading is considered uniform. The possibility of different cell loading by sectors and the use of subscriber density maps will be added in the future.
Downlink and Uplink 3GPP Tables	These tables contain the MCS Index, modulation type, and transport block size (TBS) specified in the tables of 3GPP TS 36.213. Minimum C/(I+N) values for 1% SER (dB) can be specified separately for both uplink and downlink. The theoretical defaults shown in this table are from published MATLAB simulations of LTE radio link performance. The throughput for each modulation index is determined from the 3GPP tables, taking into account the transport block size. This throughput does not take into account the MIMO multiplier.

Network Channel Plan

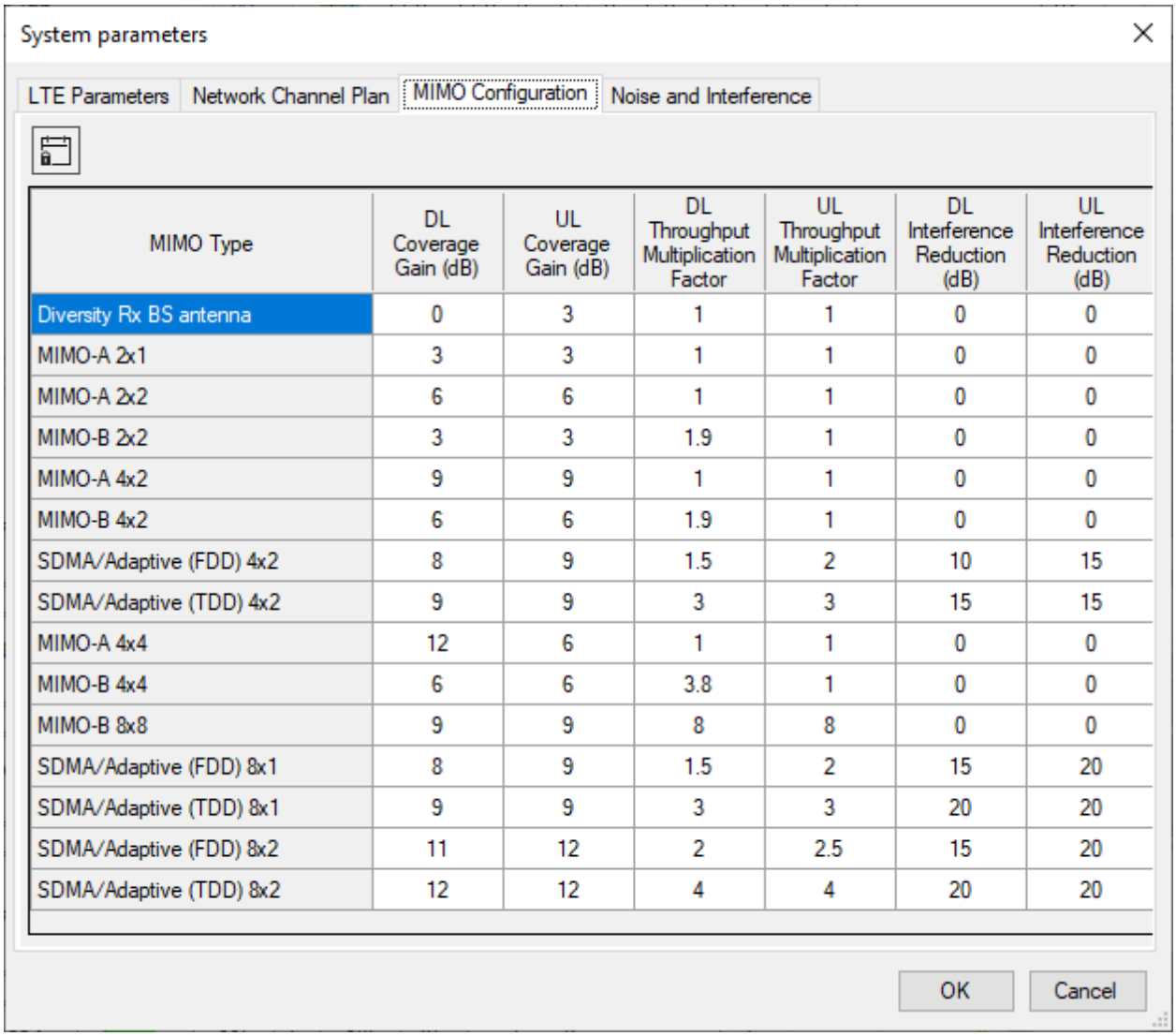
In the channel table, specify all possible uplink and downlink frequencies (channels) that will be used in the network. For TDD, enter the same frequency. If the network operates on a single channel, then the frequencies in the Network Channel Plan may not be specified.



LTE Network Channel Plan

MIMO Configuration

The MIMO table is fully configurable for all downlink and uplink scenarios.

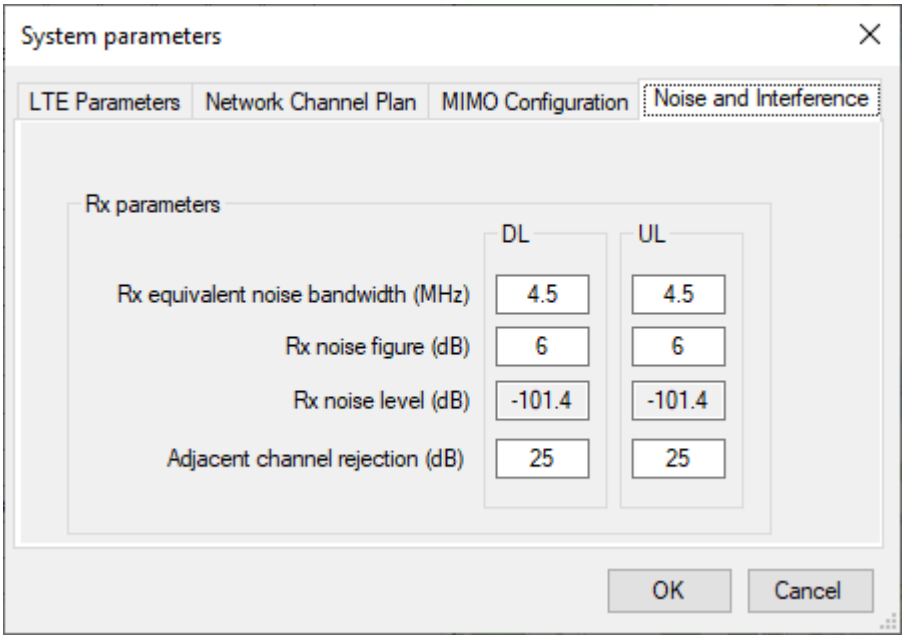


MIMO Type	DL Coverage Gain (dB)	UL Coverage Gain (dB)	DL Throughput Multiplication Factor	UL Throughput Multiplication Factor	DL Interference Reduction (dB)	UL Interference Reduction (dB)
Diversity Rx BS antenna	0	3	1	1	0	0
MIMO-A 2x1	3	3	1	1	0	0
MIMO-A 2x2	6	6	1	1	0	0
MIMO-B 2x2	3	3	1.9	1	0	0
MIMO-A 4x2	9	9	1	1	0	0
MIMO-B 4x2	6	6	1.9	1	0	0
SDMA/Adaptive (FDD) 4x2	8	9	1.5	2	10	15
SDMA/Adaptive (TDD) 4x2	9	9	3	3	15	15
MIMO-A 4x4	12	6	1	1	0	0
MIMO-B 4x4	6	6	3.8	1	0	0
MIMO-B 8x8	9	9	8	8	0	0
SDMA/Adaptive (FDD) 8x1	8	9	1.5	2	15	20
SDMA/Adaptive (TDD) 8x1	9	9	3	3	20	20
SDMA/Adaptive (FDD) 8x2	11	12	2	2.5	15	20
SDMA/Adaptive (TDD) 8x2	12	12	4	4	20	20

LTE MIMO Configuration

Noise and Interference

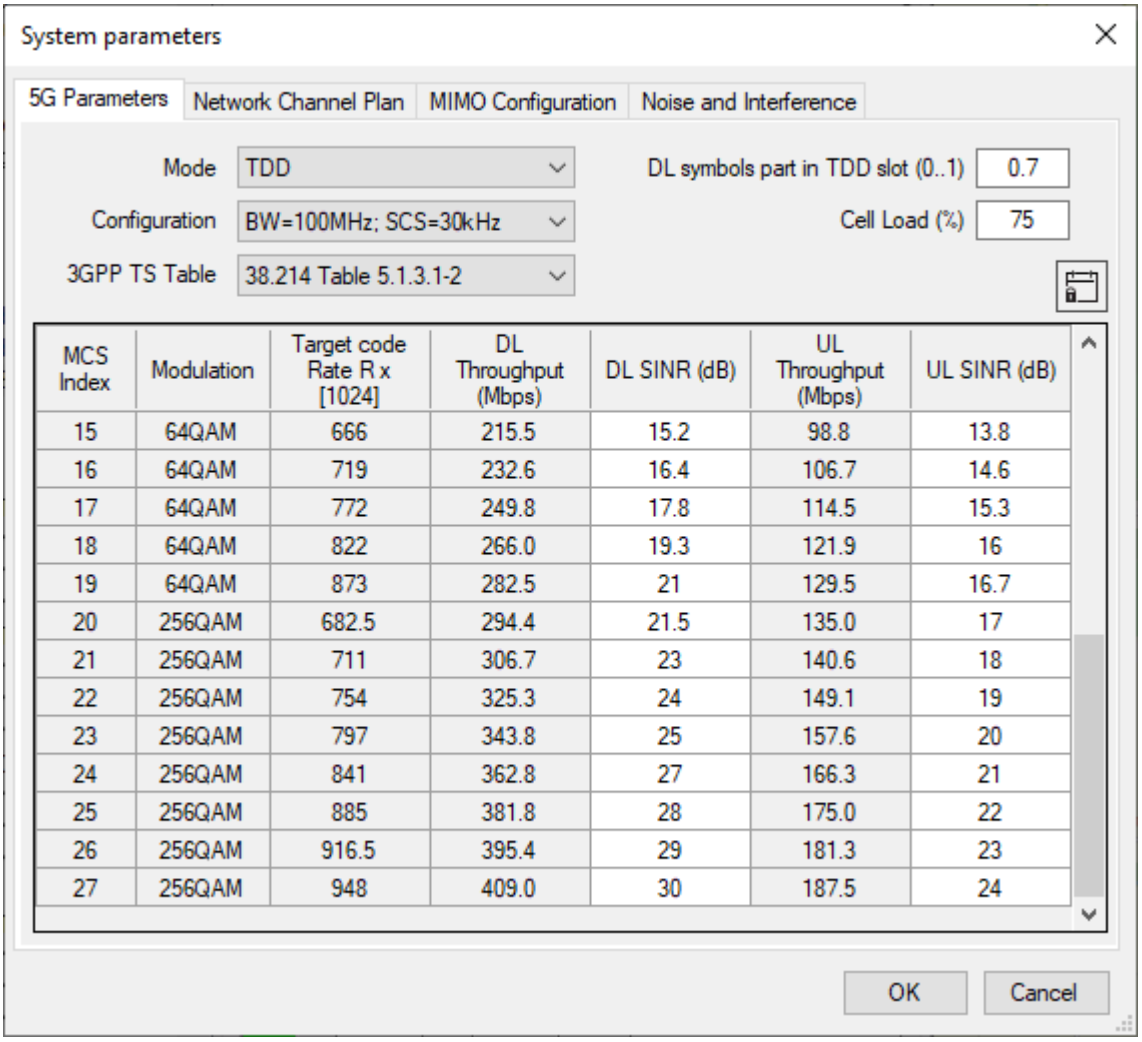
The receiver parameters in this tab are used for noise and interference calculations.



LTE Noise and Interference

Rx equivalent noise bandwidth	Receiver Equivalent Noise Bandwidth, MHz In LTE systems, when using all resource blocks, the following noise bandwidths are obtained: 1.08 MHz (1.4 MHz Bandwidth) 2.7 MHz (3 MHz Bandwidth) 4.5 MHz (5 MHz Bandwidth) 9 MHz (10 MHz Bandwidth) 13.5 MHz (15 MHz Bandwidth) 18 MHz (20 MHz Bandwidth)
Rx noise figure	Receiver noise figure, dB Typically 3-4 dB for eNodB and 6 dB for UE
Rx noise level	Receiver noise level, dB This value is used to estimate the noise on the receiving path when calculating all types of interference.
Adjacent channel rejection	Adjacent channel rejection, dB It is assumed that the receiver has a rectangular “brick wall” bandpass shape with a width equal to the equivalent noise bandwidth. Under these conditions, you can set the amount of attenuation on adjacent channels (one bandwidth above and below the desired bandwidth) by entering a value here for adjacent channel rejection.

5G (NR) System Parameters



MCS Index	Modulation	Target code Rate R x [1024]	DL Throughput (Mbps)	DL SINR (dB)	UL Throughput (Mbps)	UL SINR (dB)
15	64QAM	666	215.5	15.2	98.8	13.8
16	64QAM	719	232.6	16.4	106.7	14.6
17	64QAM	772	249.8	17.8	114.5	15.3
18	64QAM	822	266.0	19.3	121.9	16
19	64QAM	873	282.5	21	129.5	16.7
20	256QAM	682.5	294.4	21.5	135.0	17
21	256QAM	711	306.7	23	140.6	18
22	256QAM	754	325.3	24	149.1	19
23	256QAM	797	343.8	25	157.6	20
24	256QAM	841	362.8	27	166.3	21
25	256QAM	885	381.8	28	175.0	22
26	256QAM	916.5	395.4	29	181.3	23
27	256QAM	948	409.0	30	187.5	24

5G Parameters

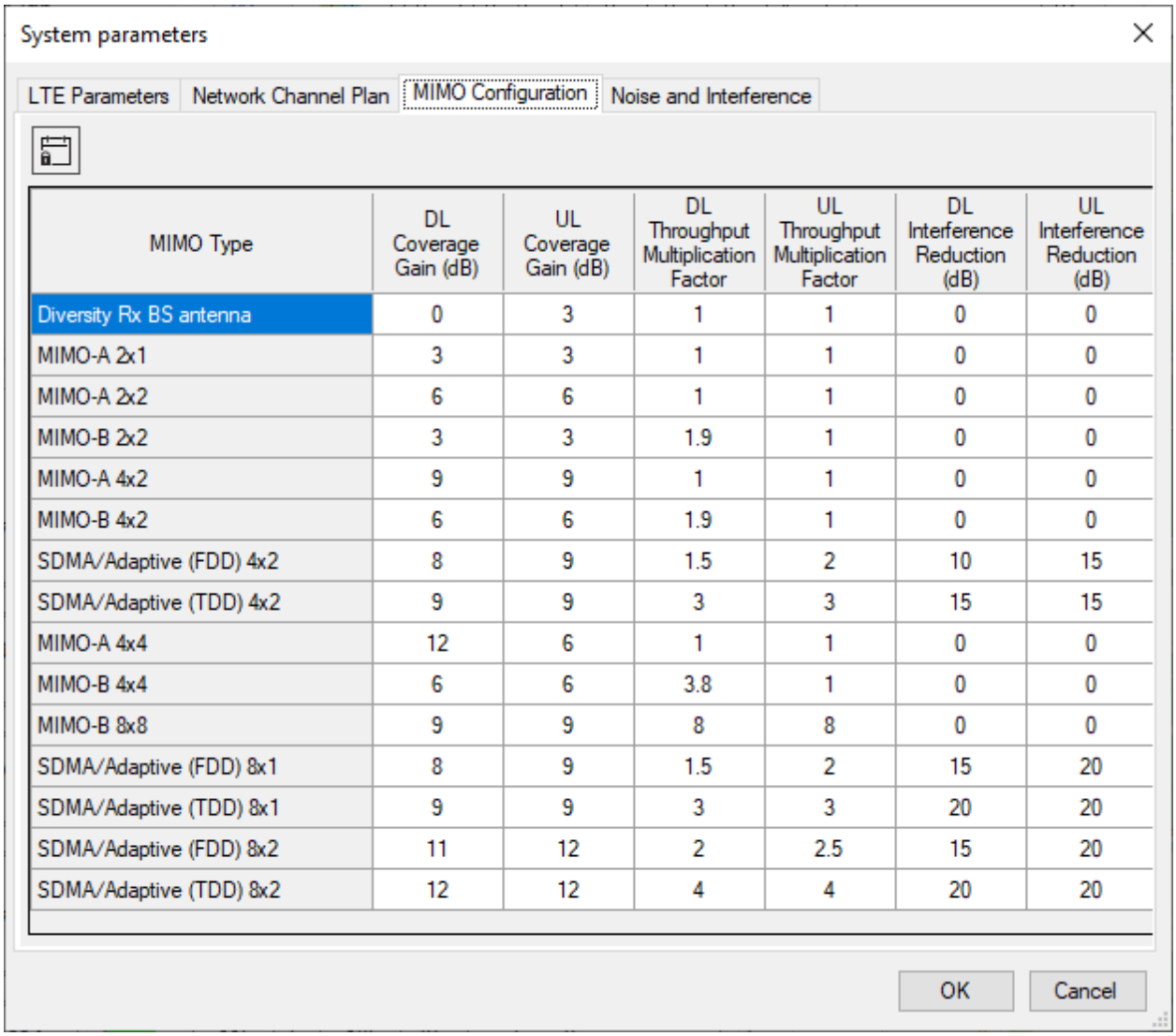
Mode	Duplex mode: - FDD - TDD
Configuration	Choice from bandwidth (BW) and Subcarrier Spacing (SCS) configurations.
Downlink and Uplink 3GPP Tables	These tables contain the MCS Index, modulation type, and Target code rate specified in the tables of 3GPP TS 36.214. Minimum C/(I+N) values for 1% SER (dB) can be specified separately for both uplink and downlink. The theoretical defaults shown in this table are from published MATLAB simulations of 5G radio link performance. The throughput for each modulation index is determined from the 3GPP tables. This throughput does not take into account the MIMO multiplier.
DL symbols part in TDD slot (0..1)	Part of the TDD resource that is intended for downlink
Cell Load	Cell Load, 0-100 % Cell Loading is considered uniform. The possibility of different cell loading by sectors and the use of subscriber density maps will be added in the future.

Network Channel Plan

In the channel table, specify all possible uplink and downlink frequencies (channels) that will be used in the network. For TDD, enter the same frequency. If the network operates on a single channel, then the frequencies in the Network Channel Plan may not be specified.

MIMO Configuration

The MIMO table is fully configurable for all downlink and uplink scenarios.

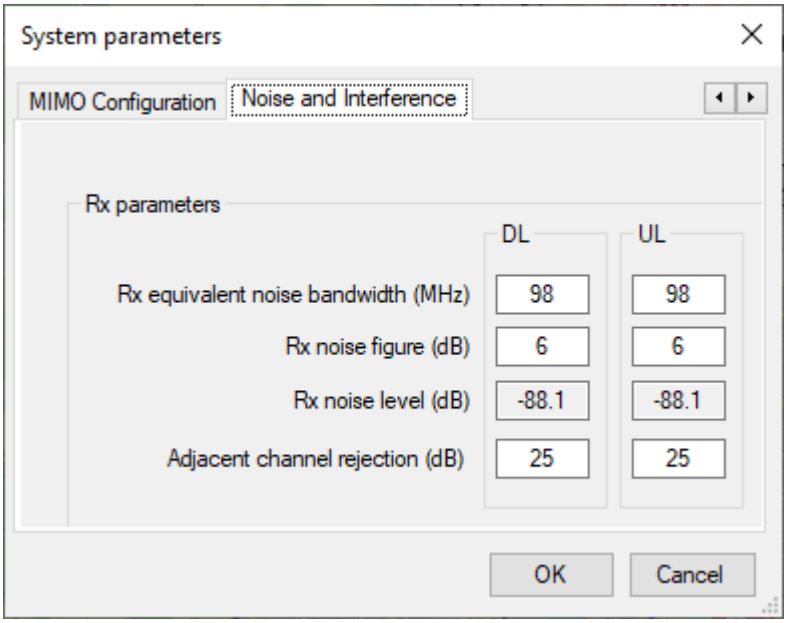


MIMO Type	DL Coverage Gain (dB)	UL Coverage Gain (dB)	DL Throughput Multiplication Factor	UL Throughput Multiplication Factor	DL Interference Reduction (dB)	UL Interference Reduction (dB)
Diversity Rx BS antenna	0	3	1	1	0	0
MIMO-A 2x1	3	3	1	1	0	0
MIMO-A 2x2	6	6	1	1	0	0
MIMO-B 2x2	3	3	1.9	1	0	0
MIMO-A 4x2	9	9	1	1	0	0
MIMO-B 4x2	6	6	1.9	1	0	0
SDMA/Adaptive (FDD) 4x2	8	9	1.5	2	10	15
SDMA/Adaptive (TDD) 4x2	9	9	3	3	15	15
MIMO-A 4x4	12	6	1	1	0	0
MIMO-B 4x4	6	6	3.8	1	0	0
MIMO-B 8x8	9	9	8	8	0	0
SDMA/Adaptive (FDD) 8x1	8	9	1.5	2	15	20
SDMA/Adaptive (TDD) 8x1	9	9	3	3	20	20
SDMA/Adaptive (FDD) 8x2	11	12	2	2.5	15	20
SDMA/Adaptive (TDD) 8x2	12	12	4	4	20	20

5G MIMO Configuration

Noise and Interference

The receiver parameters in this tab are used for noise and interference calculations.



5G Noise and Interference

Rx equivalent noise bandwidth	Receiver Equivalent Noise Bandwidth, MHz In 5G, the noise band can be obtained from the formula: Rx equivalent noise BW= 12*SCS*Resource Blocks. For example, for BW=100 MHz, SCS=30 kHz Rx equivalent noise BW=12*0.03*273=98.28 MHz
Rx noise figure	Receiver noise figure, dB Typically 3-4 dB for gNodeB and 6 dB for UE
Rx noise level	Receiver noise level, dB This value is used to estimate the noise on the receiving path when calculating all types of interference.
Adjacent channel rejection	Adjacent channel rejection, dB It is assumed that the receiver has a rectangular “brick wall” bandpass shape with a width equal to the equivalent noise bandwidth. Under these conditions, you can set the amount of attenuation on adjacent channels (one bandwidth above and below the desired bandwidth) by entering a value here for adjacent channel rejection.

Generic TRX System Parameters

Generic TRX in RadioPlanner includes all mobile communication systems except for LTE and 5G:

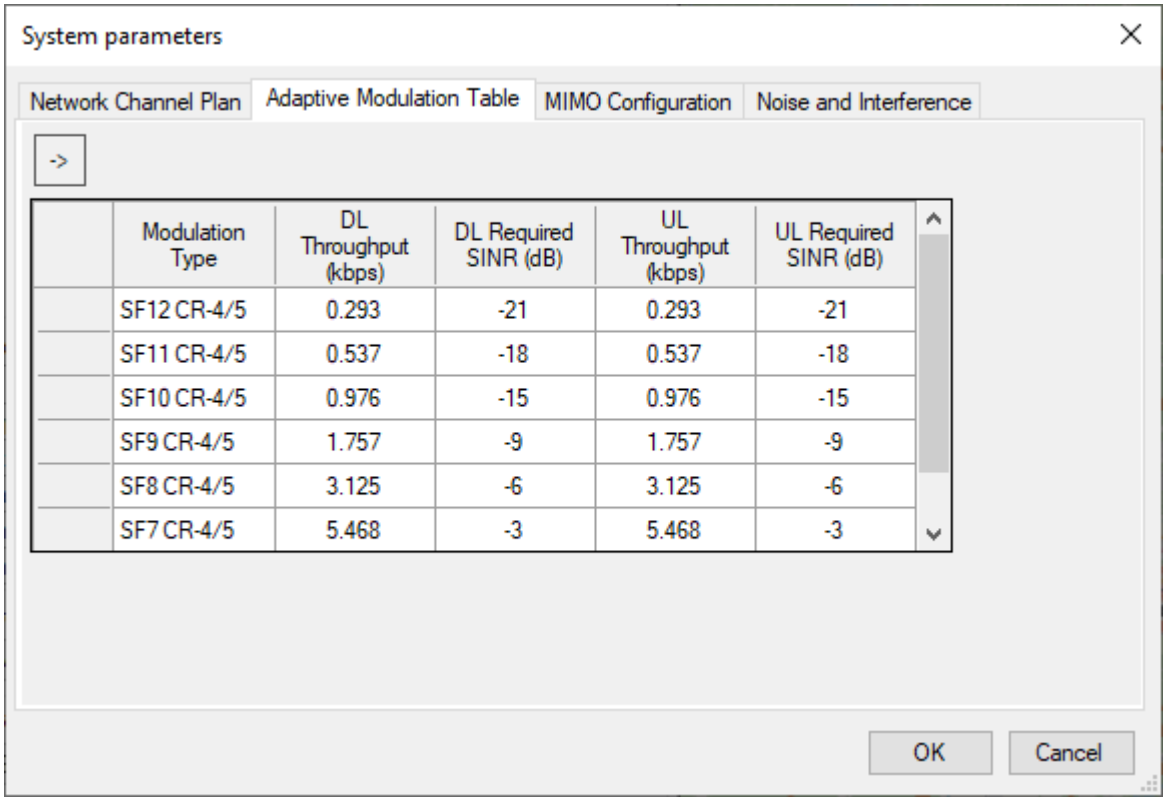
- UMTS / GSM / GSM-R / WCDMA mobile networks

- P25 / TETRA / DMR / dPMR / NXDN land mobile radio networks

- Networks based on wireless IoT LPWAN technologies: LoRa, SigFox, and others

Adaptive Modulation Table

The adaptive modulation table is filled with SINR values and their respective throughput. This table is used to predict downlink and uplink throughput in Generic TRX. Note that LTE and 5G have separate adaptive modulation tables tied to 3GPP specifications.

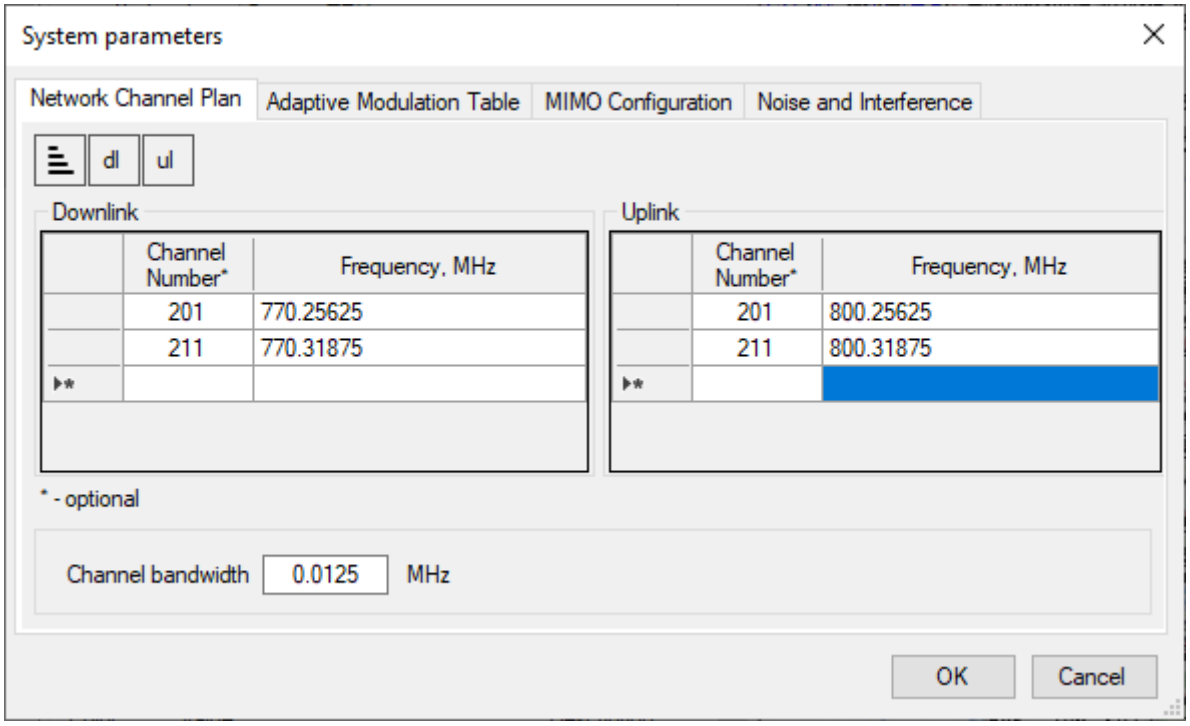


LoRaWAN Adaptive Modulation Table

Modulation Type	Modulation Type (text field)
DL Throughput (kbps)	Downlink Throughput, kbps
DL SINR (dB)	Downlink SINR,dB
UL Throughput (kbps)	Uplink Throughput, kbps
UL SINR (dB)	Uplink SINR,dB

Network Channel Plan

In the channel table, specify all possible uplink and downlink frequencies (channels) that will be used in the network. For TDD, enter the same frequency. If the network operates on a single channel, then the frequencies in the Network Channel Plan may not be specified.



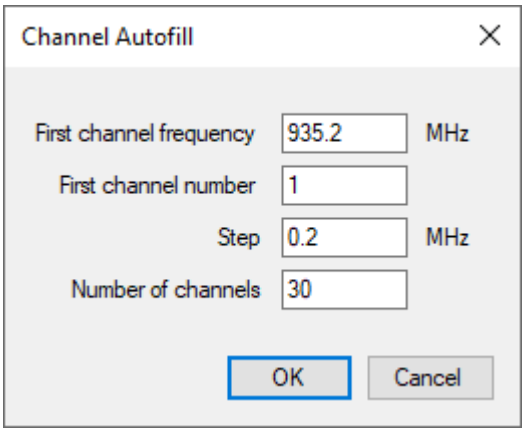
Generic TRX Network Channel Plan

Sort frequencies in ascending order

Autofill downlink frequencies

Autofill uplink frequencies

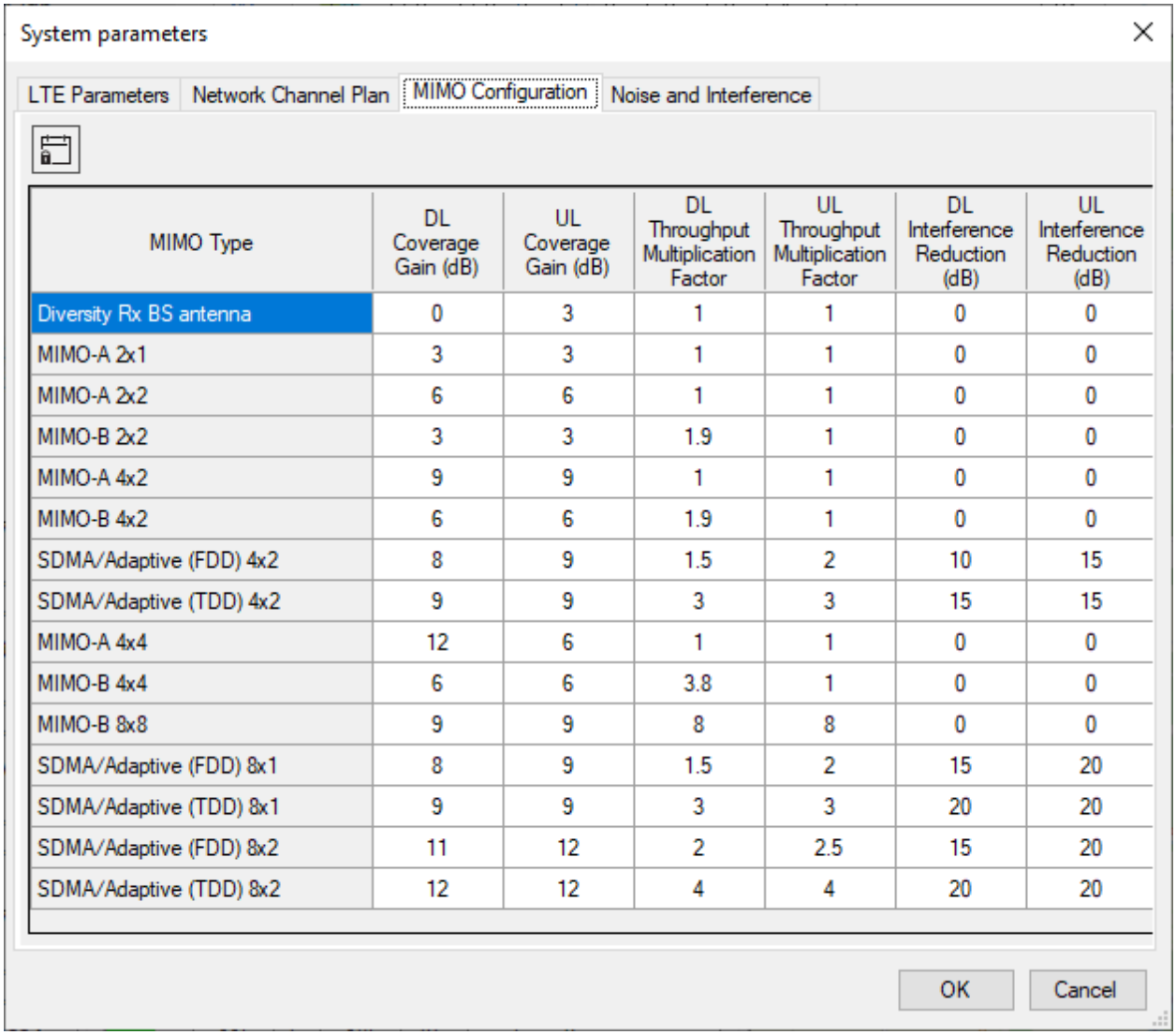
If your network has a large frequency grid, then you can use the autofill feature:



Channel Autofill

MIMO Configuration

The MIMO table is fully configurable for all downlink and uplink scenarios.

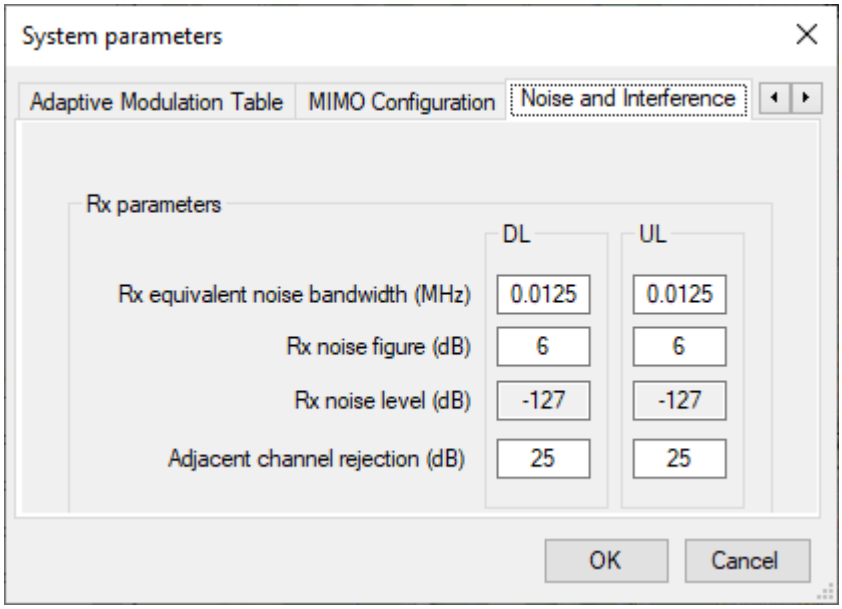


MIMO Type	DL Coverage Gain (dB)	UL Coverage Gain (dB)	DL Throughput Multiplication Factor	UL Throughput Multiplication Factor	DL Interference Reduction (dB)	UL Interference Reduction (dB)
Diversity Rx BS antenna	0	3	1	1	0	0
MIMO-A 2x1	3	3	1	1	0	0
MIMO-A 2x2	6	6	1	1	0	0
MIMO-B 2x2	3	3	1.9	1	0	0
MIMO-A 4x2	9	9	1	1	0	0
MIMO-B 4x2	6	6	1.9	1	0	0
SDMA/Adaptive (FDD) 4x2	8	9	1.5	2	10	15
SDMA/Adaptive (TDD) 4x2	9	9	3	3	15	15
MIMO-A 4x4	12	6	1	1	0	0
MIMO-B 4x4	6	6	3.8	1	0	0
MIMO-B 8x8	9	9	8	8	0	0
SDMA/Adaptive (FDD) 8x1	8	9	1.5	2	15	20
SDMA/Adaptive (TDD) 8x1	9	9	3	3	20	20
SDMA/Adaptive (FDD) 8x2	11	12	2	2.5	15	20
SDMA/Adaptive (TDD) 8x2	12	12	4	4	20	20

Generic TRX MIMO Configuration

Noise and Interference

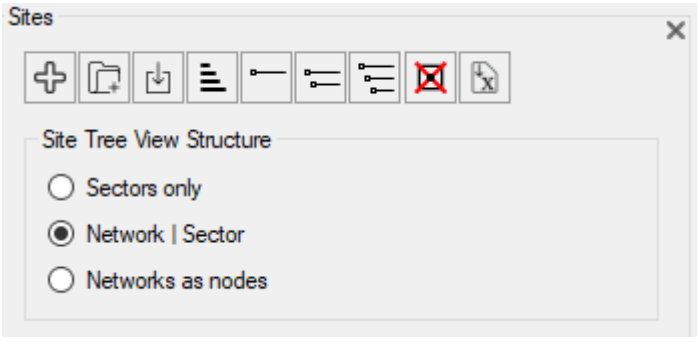
The receiver parameters in this tab are used for noise and interference calculations.



Generic TRX Noise and Interference

Rx equivalent noise bandwidth	Receiver Equivalent Noise Bandwidth, MHz
Rx noise figure	Receiver noise figure, dB Typically 3-4 dB for base station sector and 6 dB for Mobile Unit
Rx noise level	Receiver noise level, dB This value is used to estimate the noise on the receiving path when calculating all types of interference.
Adjacent channel rejection	Adjacent channel rejection, dB It is assumed that the receiver has a rectangular “brick wall” bandpass shape with a width equal to the equivalent noise bandwidth. Under these conditions, you can set the amount of attenuation on adjacent channels (one bandwidth above and below the desired bandwidth) by entering a value here for adjacent channel rejection.

Sites



Sites


Add a new site


Add a new site group


Import a site list from *.csv file


Sort sites in alphabetical order


Collapse of site nodes


Collapse all network nodes


Epand all site nodes


Delete all selected sites

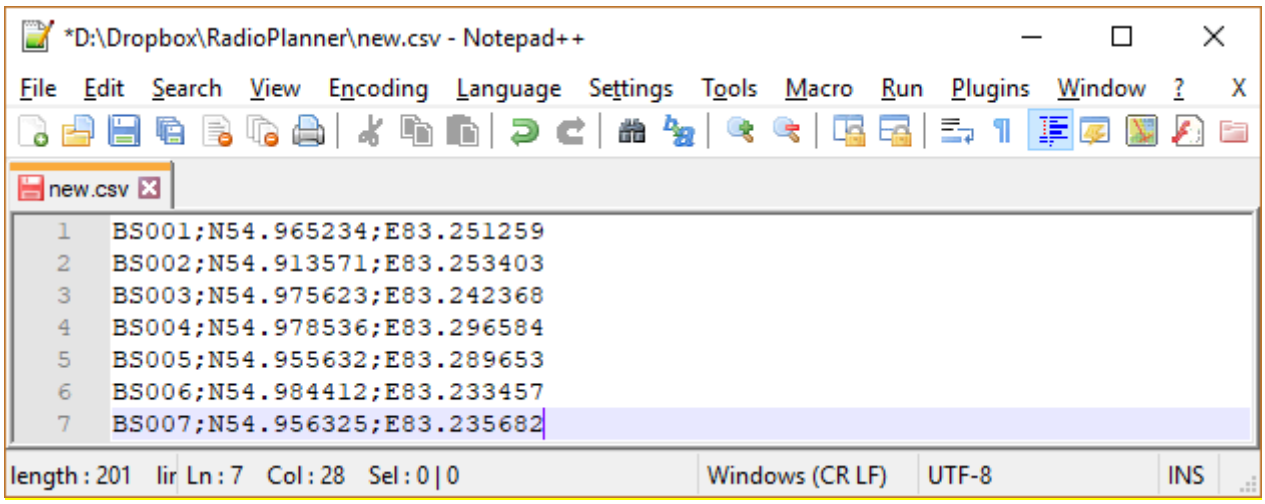

Import site parameters from Microsoft Excel spreadsheet

To create a new site, click on Sites in the Tree View interface, then click the  button in the panel that opens.

Import sites from *.CSV file

You can also import sites from CSV files (text format with a semicolon separator). This is a universal format that can be used to save a spreadsheet from any spreadsheet editor (Excel, LibreOffice Calc, etc.) or database. Each point object must have required fields including site name, Latitude, and Longitude. Coordinates can be formatted as HEMISPHERE degrees minutes seconds (N35 23.8 36) or HEMISPHERE decimal degrees (N12.34567).

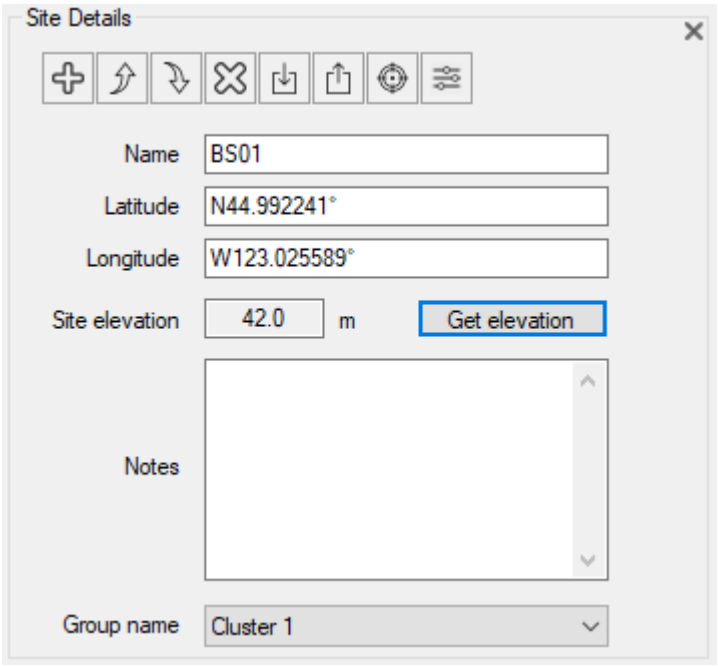
To import sites, click on the button  (import sites from *.CSV) and select a CSV file.



Example of a CSV file with the imported sites

Site Details

When clicking on a created site in the Tree View interface panel, the Site Details panel will open where you can edit details such as name, coordinates and additional text information about the site and view elevation relative to sea level.



Site Details

 Add a new site as a copy of this site

 Move this site up or down

 Delete the site

 Load sectors of the selected network from a template

 Save the sectors of the selected network as a template

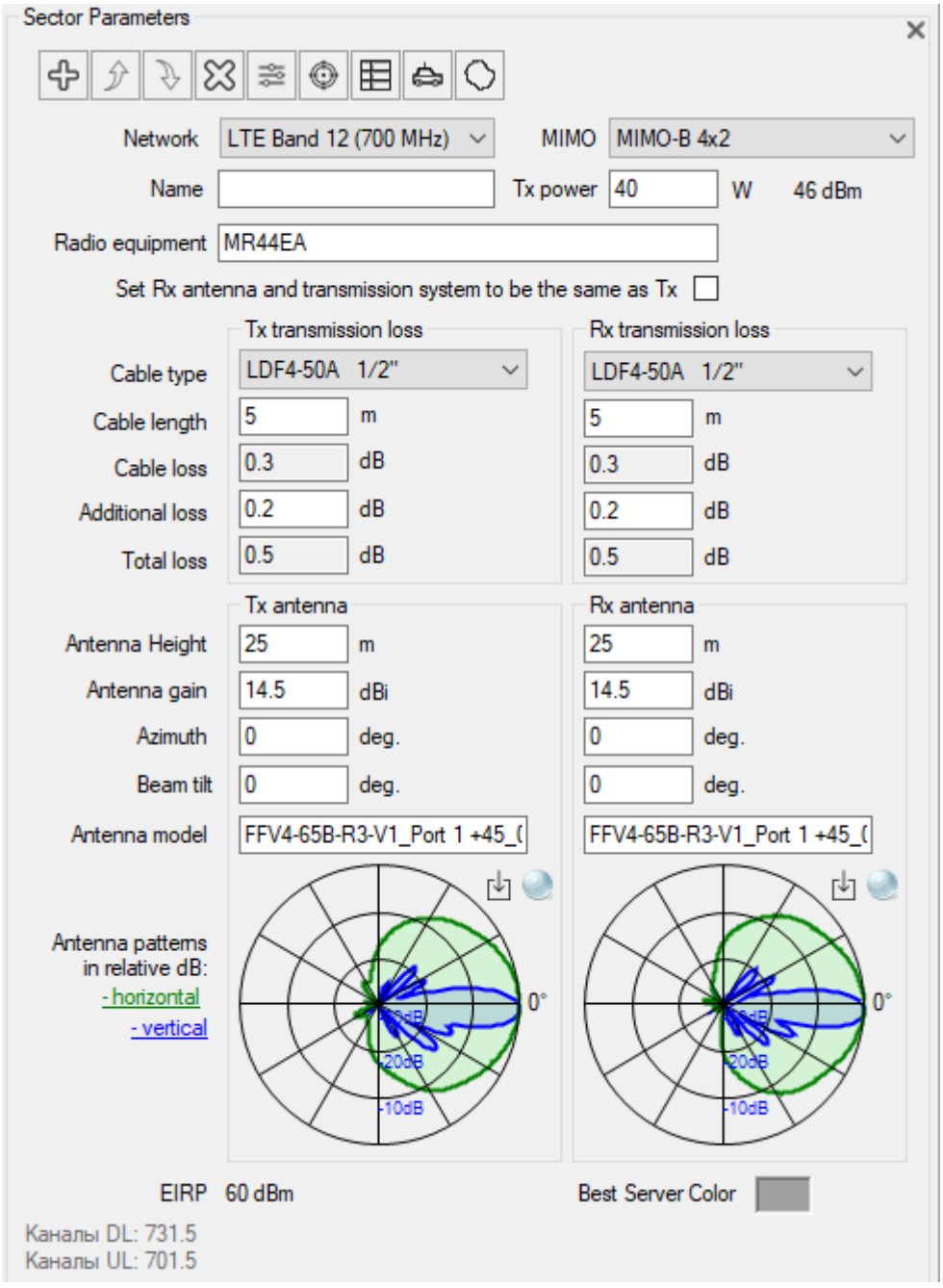
 Position the map with the site at the center of the screen

 Copy Site Parameters to all active sites

Name	Site name, text field
Latitude	The geographical latitude of the site in the format specified by the user in **Settings**
Longitude	Geographical longitude of the site in the format specified by the user in Settings
Site Elevation	Site elevation relative to sea level, m
Notes	Text box for any additional site information
Group name	Select site group. Sites can be combined into groups (clusters), allowing you to quickly include/exclude large site groups of from calculations.

Sector Parameters

When creating a site, at least one sector of this site is automatically created. There is an activity icon next to each site and sector in the Tree View interface panel. For a sector to be calculated, it must be marked as active (a dot in the center). Clicking on the site sector will open a panel with the sector parameters.



Sector Parameters

Toolbar:

Add a new sector with the same parameters

Move the sector up or down. These buttons are active for site Tree view structures "Sectors Only" and "Network | Sector"

Delete the sector

Global Active Sector parameters change. You can replace the selected parameters for all active sectors as the current sector.

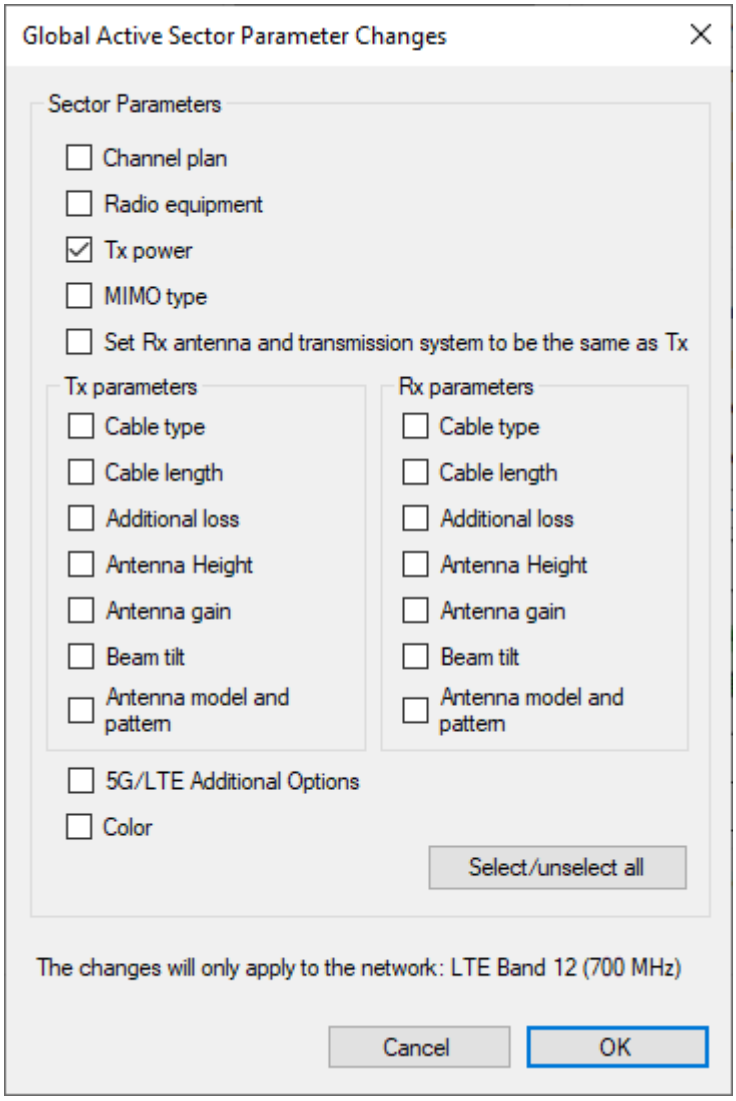
Position the map with the site at the center of the screen

Advanced sector parameters

Analysis of measurements along the route. See more details in the "Measurement Results Analysis and Propagation Model Tuning" section.

Calculation of service and interference contours using FCC and ITU-R propagation curves. For more details, see the TV and Radio Broadcast Networks.

Network	The network to which the sector belongs, select from the drop-down list of networks.
MIMO	MIMO type for the sector, selection from a drop-down list of all possible MIMO configurations specified in the system parameters of this network.
Name	The name of the sector, the text field. You can specify the name of the sector in the text field. If left blank, the name “Sector azimuth” with the azimuth value specified in the sector parameters panel will be automatically displayed in the tree view panel on the left. If you specify a name in this field, it will be displayed in the tree view.
Radio Equipment	Name (model) of Radio equipment, text field
Set Rx Antenna and Transmission System to be the Same as Tx	Copying parameters' antenna-feeder transmitter path to the receive path
Tx Power	Transmitter power, W. Same value in dBm for control
Cable Type	Type of the main cable for transmission or reception path. If the required cable is not in the list, then the user can add it himself - see Appendix 1.1
Cable Length	Main cable length, m
Cable Loss	Loss in cable, dB. Calculated value
Additional Loss	Additional losses, dB - combining losses, losses in jumpers, and connectors. Any additional losses.
Total Loss	Total loss, dB. The calculated value.
Antenna Height	The antenna radiation center height relative to ground level, m
Antenna Gain	Antenna gain relative to isotropic radiator, dB
Azimuth	The azimuth of the antenna in degrees
Beam Tilt	Tilt the antenna in degrees. Down is negative; up is positive.
Antenna Model	Antenna name, text field. Automatically filled with the antenna pattern file name when selecting a pattern.
	Load MSI antenna pattern file. An antenna pattern file is a standard MSI file that can be downloaded from the antenna manufacturer's website. Antenna patterns are integrated into the project file.



Global Active Sector parameters change

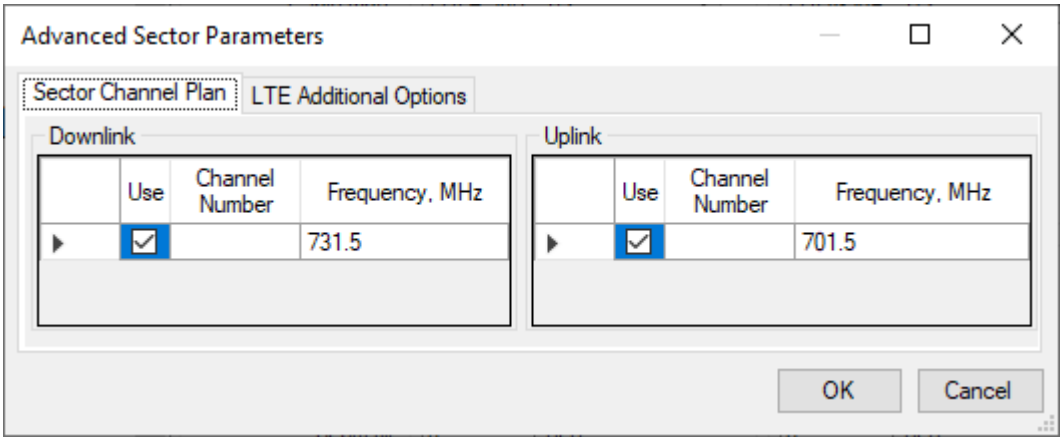
Global Active Sector parameters change is a feature that allows you to instantly change the parameters of any active sectors to match those of the current sector. To perform group parameter changes, mark the sectors whose parameters need to be changed as active, set the required parameter values in the current sector, click on the button  , select the parameters that need to be changed in the previously marked active sectors from the list, and click on the OK button.

Advanced Sector Parameters

Advanced Sector Parameters include the channel plan and other parameters that differ for different types of systems.

Sector Channel Plan

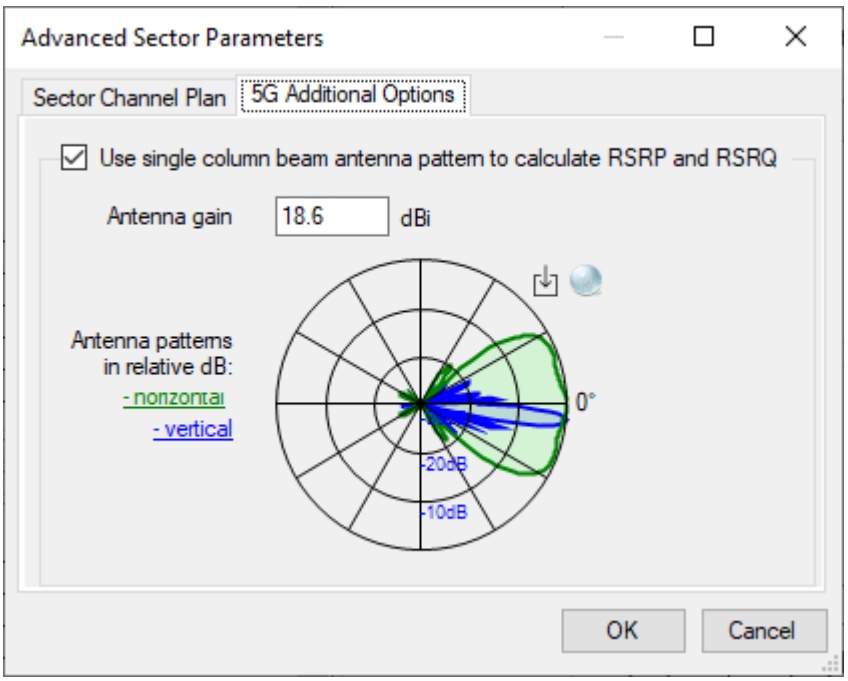
In the Sector Channel Plan, you can select specific frequencies (or channel numbers) from the entire frequency grid specified in the System Parameters of this network.



Sector Channel Plan

LTE/5G Additional Options

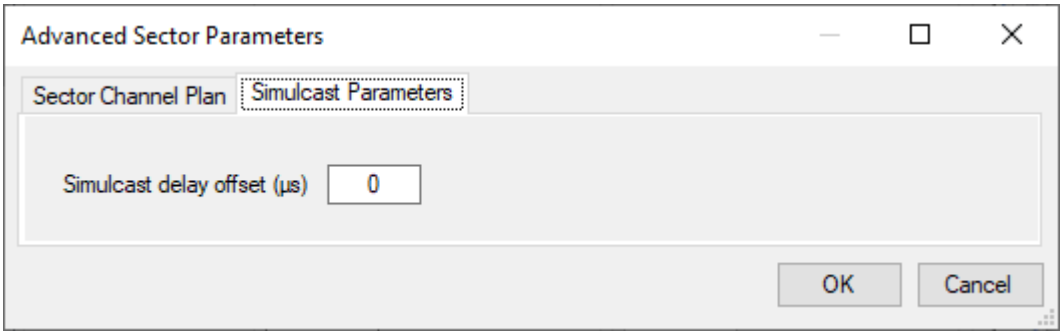
Additional options for LTE and 5G networks include using a special antenna pattern (single column antenna pattern beam) for calculating RSRP and RSRQ.



LTE/5G Additional Options

Generic TRX Additional Options (Simulcast parameters)

Advanced parameters for Generic TRX include only entering the Sector simulcast delay offset, which applies only to simulcast systems where multiple transmitters share the same frequency.

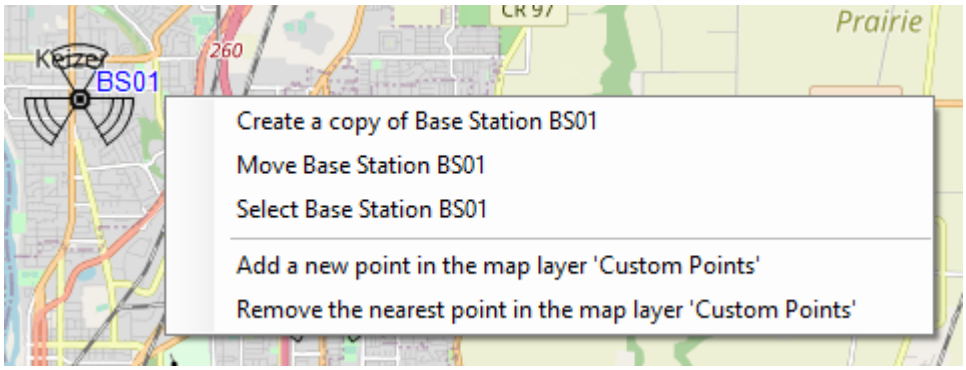


Sector Simulcast Parameters

Simulcast delay offset (µs)	Sector simulcast delay offset, µs

Context menu on the base map

When right-clicking on the base map, a context menu appears with options to create a new site at that point, move a selected site, or open the parameters of the nearest site by selecting “Select Site.”



Context menu on the base map

Import Sita Data from MS Excel Spreadsheet

In the Sites menu of RadioPlanner 3.0 there is an option to import sites with a full configuration from an Excel table. This table has the same format as the exported table in the Reports Menu - Base Stations/Transmitters Report. That is, to get a table in the required format for further filling at your discretion, you should first export it from the project with the system you need from the Reports Menu - Base Stations/Transmitters Report.

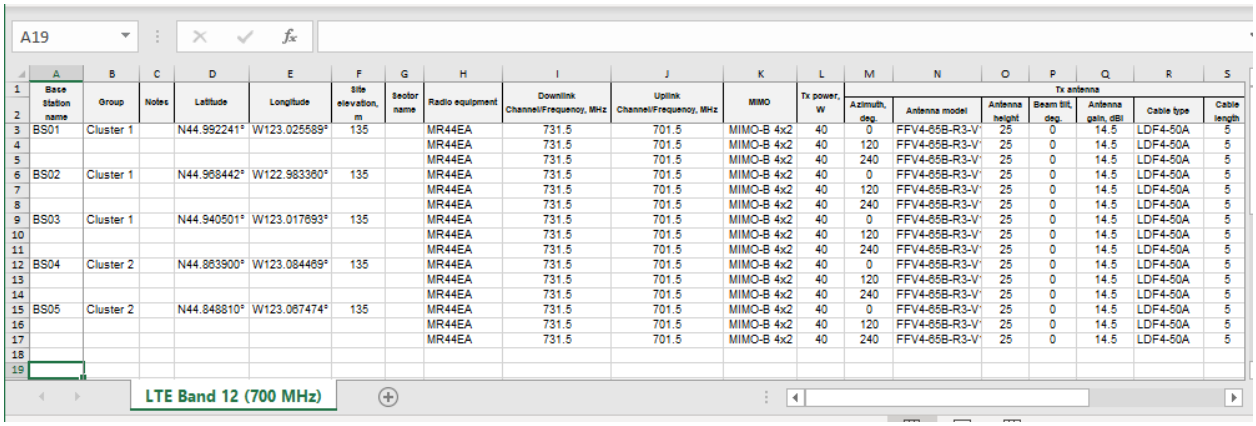
Rules for importing sites from an Excel table:

1. If a site with such a name already exists in the project, then new imported sectors will be added to this site, otherwise a new site will be created.

2. If a group is specified for the site and if the project already has a group with such a name, then the site will be added to this group. If there is no group, then this group will be created.

3. If the group of sites is not specified, then the site will be created outside the groups.

4. If the folder with the Excel document contains an antenna pattern file *.msi with a name that matches the name of the antenna of the imported sector, then the antenna pattern from this file will be loaded, otherwise the antenna pattern will remain OMNI.



Base station name	Group	Notes	Latitude	Longitude	Site elevation, m	Sector name	Radio equipment	Downlink Channel/Frequency, MHz	Uplink Channel/Frequency, MHz	MIMO	Tx power, W	Tx antenna					
												Azimuth, deg.	Antenna model	Antenna height	Beam tilt, deg.	Antenna gain, dBi	Cable type	Cable length
BS01	Cluster 1		N44.992241°	W123.025589°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
BS02	Cluster 1		N44.968442°	W122.983360°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
BS03	Cluster 1		N44.940501°	W123.017693°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
BS04	Cluster 2		N44.863900°	W123.084469°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
BS05	Cluster 2		N44.848810°	W123.067474°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5

Excel spreadsheet with site parameters

Propagation models

In RadioPlanner 3.0, you can select from several propagation models to perform coverage predictions. You can also specify time and location variability statistics and prediction confidence margin for most models.

Available propagation models:

- ITU-R P.1812 model
- Longley-Rice (ITM) model v 1.2.2
- Okumura-Hata
- 3GPP TR 38.901
- ITU-R P.1546-6 model
- Combined ITU-R P.528-3 + P.526-14 model (for air-to-ground radio only)

The main parameters for each of the propagation models are shown in the table below.

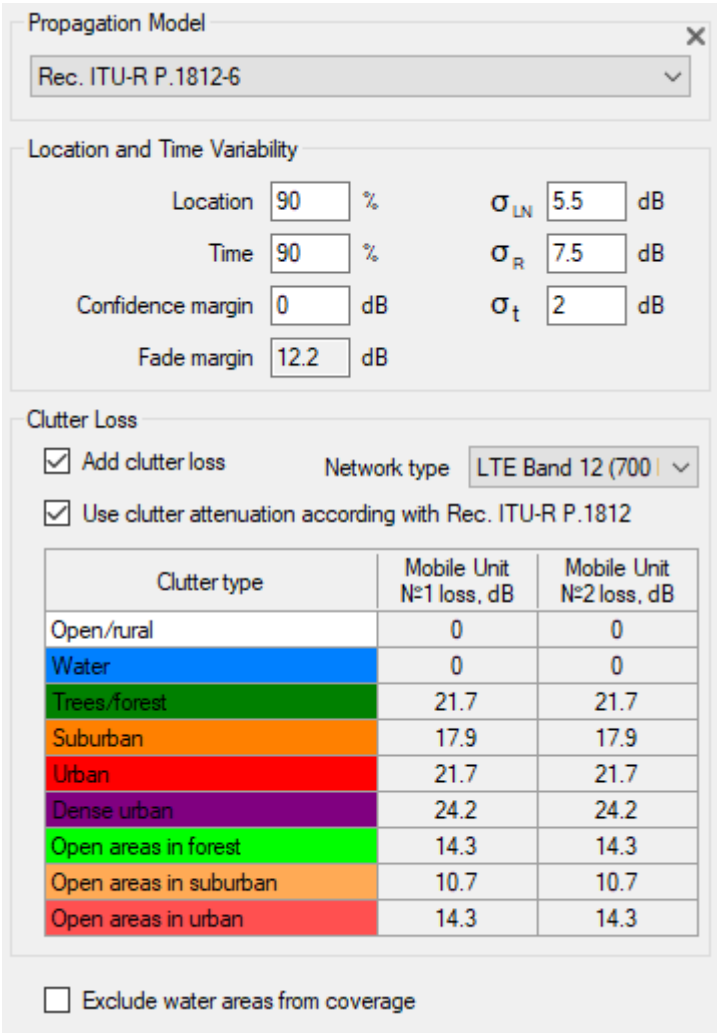
Propagation model	Frequency Range	Use DTM	Use Clutter
ITU-R P.1812-6	30 MHz to 6 GHz	+	+
Longley-Rice (ITM) v 1.2.2	20 MHz to 20 GHz	+	+
Okumura-Hata	100 MHz to 1.5 GHz	-	+
3GPP TR 38.901	500 MHz to 100 GHz	+[1]	-
ITU-R P.1546-6	30 MHz to 3 GHz	+	+
ITU-R P.528-3 + P.526-14	125 MHz to 15.5 GHz	+	+

[1]Used to determine LOS/NLOS path status only

ITU-R P.1812-6 Propagation Model

The ITU-R P.1812-6 Propagation Model is described in detail in Recommendation ITU-R P.1812-6 (09/2021) “A path-specific propagation prediction method for point-to-area terrestrial services in the frequency range 30 MHz to 6 000 MHz.”

This model takes into account factors such as diffraction loss on path profile obtained from DTM data; impact of local surrounding obstacles determined by clutter model; and local and time variability of received radio signal.



ITU-R P.1812-6 Propagation Model

Location, %	Location percentage (50%-99%, typically 50%, 90% or 95%) indicates that a given power level will be exceeded in at least that percentage of locations for similar propagation paths. Set 50% if you want to completely exclude the influence of Location variability.
Time, %	By choosing a time percentage (50%-99%, typically 50%, 90% or 95%), the calculated received power values are the power levels that will be exceeded at least that percentage of time. Set 50% if you want to completely exclude the influence of Time variability.
Confidence margin, dB	Since the received power level calculations are estimates, the prediction margin lets you specify a safety margin in dB so that you can be more confident your signal level estimate is indeed above the specified signal level.

σ_{LN}, dB	Lognormal large-scale (shadow) fading standard deviation, dB. This value depends on the digital terrain model (DTM) resolution and carrier frequency. Typical value 2-5 dB for modern DTMs.
σ_R, dB	Small-scale fading (Rayleigh) standard deviation, dB. Typically 7.5 dB
σ_t, dB	Time variability standard deviation, dB. At distances up to 50 km, the σ_t usually varies for between 2-3 dB (Land), and up to 9 dB for the Sea. See Table 3 in Recommendation ITU-R P.1406-2 *"Propagation effects relating to terrestrial land mobile and broadcasting services in the VHF and UHF bands"*
Fade margin, dB	Fade margin, dB. Calculated total fade margin depending on location and time variability, as well as the confidence margin.

Clutter loss

Clutter loss is calculated according to Recommendation ITU-R P.1812-6 and depends on factors such as antenna height of the mobile unit, frequency, typical width of streets, average height of clutter, and clutter type.

The frequency and antenna height for each of the two types of mobile units (portable and mobile) are set in the Network menu. The typical width of streets is 27m (in accordance with ITU-R P.1812-6). The clutter model determines the type of obstacles at each point.

Add clutter loss	Add clutter loss to path loss
Network type	Select the network for which the clutter loss applies
Use clutter attenuation according whith Rec. ITU-R P.1812	Calculate losses in clutter using Rec. ITU-R P.1812-6 formulas

Average heights for different types of clutter are set in the Geo Data menu. The default clutter height in Rec. ITU-R P.1812-6:

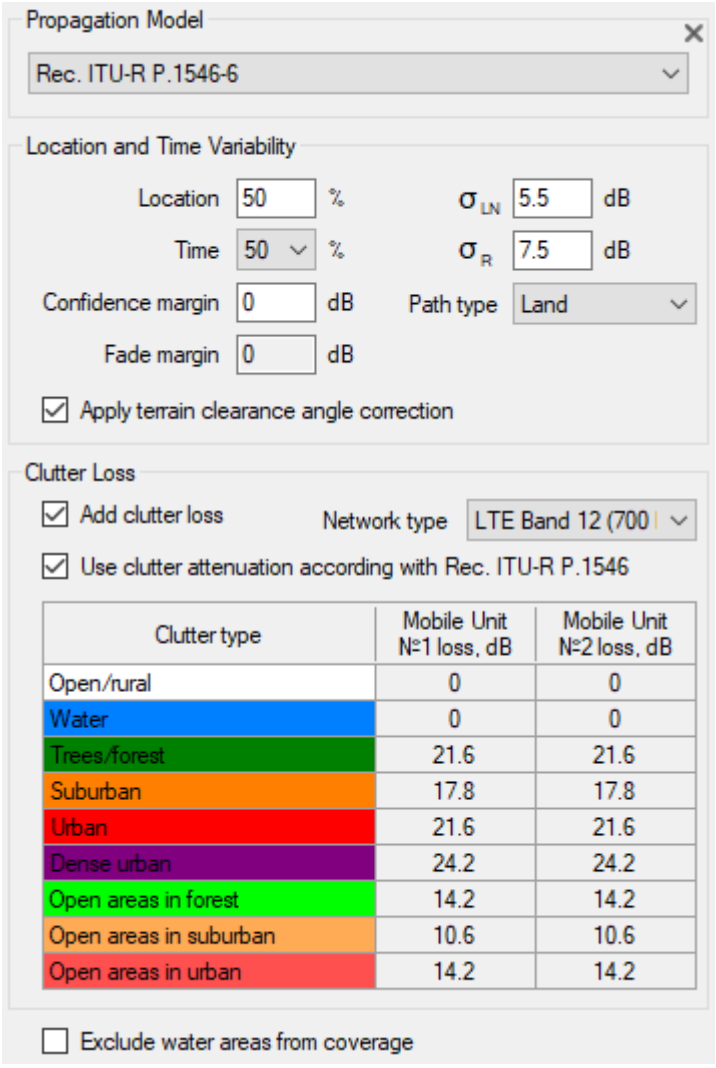
	Clutter Type	Color	Clutter height (m)
1	Open / Rural		7
2	Water		0
3	Trees / Forest		15
4	Suburban		10
5	Urban		15
6	Dense urban		20
7	Open areas in forest		7
8	Open areas in suburban		5
9	Open areas in urban		7

You can also manually set clutter loss for each clutter type based on your own data by entering the losses into the table.

ITU-R P.1546-6 Model

The model is based on recommendation ITU-R P.1546-6 (08/2019): "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 4000 MHz"

Model ITU-R P.1546-6 is empirical because it is based on experimentally obtained field strength curves versus distance for different frequencies, antenna heights, path types, and time probability. In Recommendation ITU-R P.1546-6, in addition to these curves, losses are also determined by the terrain clearance angle correction from the receiver side and the correction for the height of the clutter surrounding the receiver.



ITU-R P.1546-6 Propagation Model

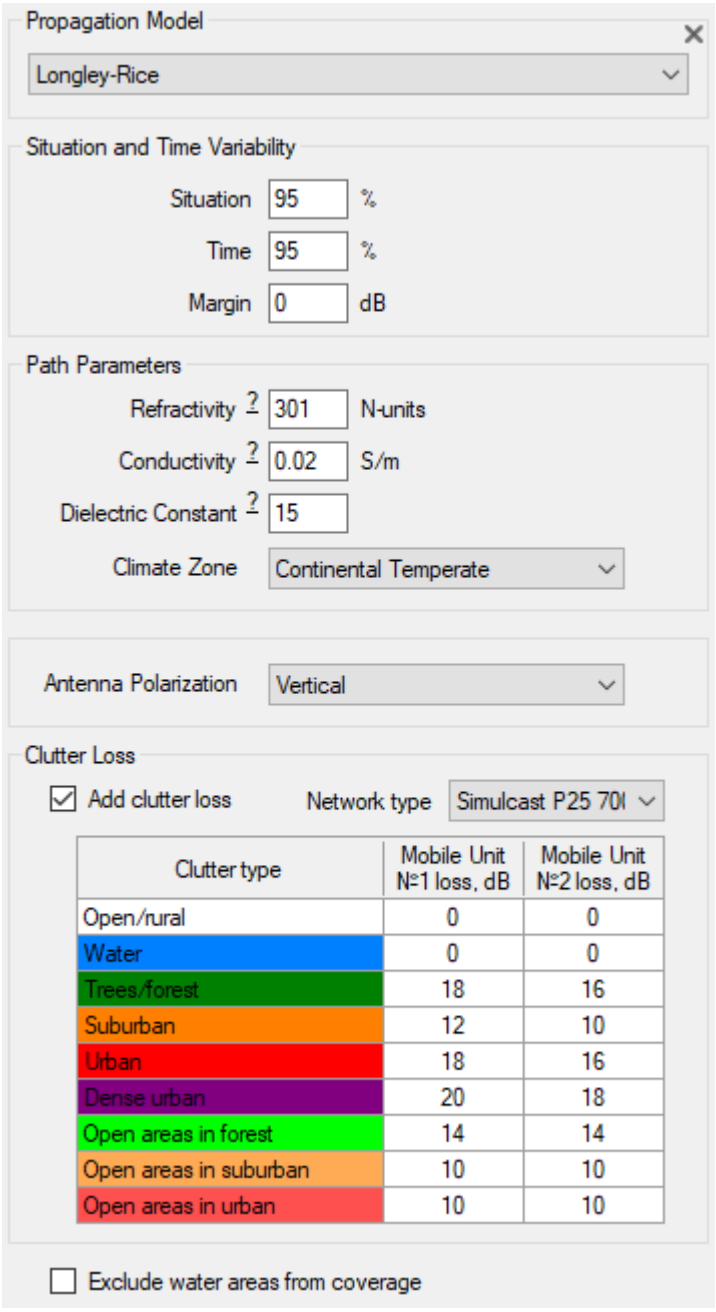
The approach to fade margin calculation, taking into account location and time variability as well as large/small-scale and time fading standard deviations, is the same as described in the ITU-R P.1812 Propagation Model.

Path Type	- Land - Cold Sea - Warm Sea
Apply Terrain Clearance Angle Correction	This uses the terrain profile to adjust the field strength at the receive point for terrain blockage on non-line-of-sight paths.

Add Clutter Loss	Add clutter loss to path loss
Use Clutter Attenuation According to Rec. ITU-R P.1546-6	Calculation of clutter losses in accordance with Rec. ITU-R P.1546-6, depending on the height of clutter. You can also manually set clutter loss for each clutter type based on your own data by entering the losses into the table.

Longley-Rice (ITM) Propagation Model v 1.2.2

The Longley-Rice propagation model, also known as the Irregular Terrain Model (ITM), is considered the industry standard for coverage prediction in North America. RadioPlanner 3.0 uses version 1.2.2 of the Irregular Terrain Model in PTP-mode.



Longley-Rice Propagation Model Parameters

Situation, %	Situation (location) percentage, (50%-99%, typically 50%, 90% or 95%) indicates that a given power level will be exceeded in at least that percentage of locations for similar propagation paths. Set 50% if you want to completely exclude the influence of Situation variability.
Time, %	Time percentage, %. By choosing a time percentage (50%-99%, typically 50%, 90% or 95%), the calculated received power values are the power levels that will be exceeded at least that percentage of time. Set 50% if you want to completely exclude the influence of Time variability.
Margin	Confidence margin. Since the received power level calculations are estimates, the prediction margin lets you specify a safety margin in dB so that you can be more confident your signal level estimate is indeed above the specified signal level.
Refractivity	Atmospheric refractivity, measured in N-Units
Conductivity (S/m)	Conductivity of the ground over which the signal propagates (Siemens per meter)
Dielectric Constant	The dielectric constant (relative ground permittivity)
Climate Zone	The following Radio Climates can be selected: - Equatorial (Congo) - Continental Subtropical (Sudan) - Maritime Subtropical (West Coast of Africa) - Desert (Sahara) - Continental Temperate, common to large landmasses in the Temperate Zone - Maritime Temperate, over Land (United Kingdom and Continental West Coasts) - Maritime Temperate, over Sea
Antenna Polarization	Antenna Polarization: Horizontal / Vertical

Clutter Loss

In the Longley-Rice propagation model, clutter loss for are entered manually directly into the table for each network.

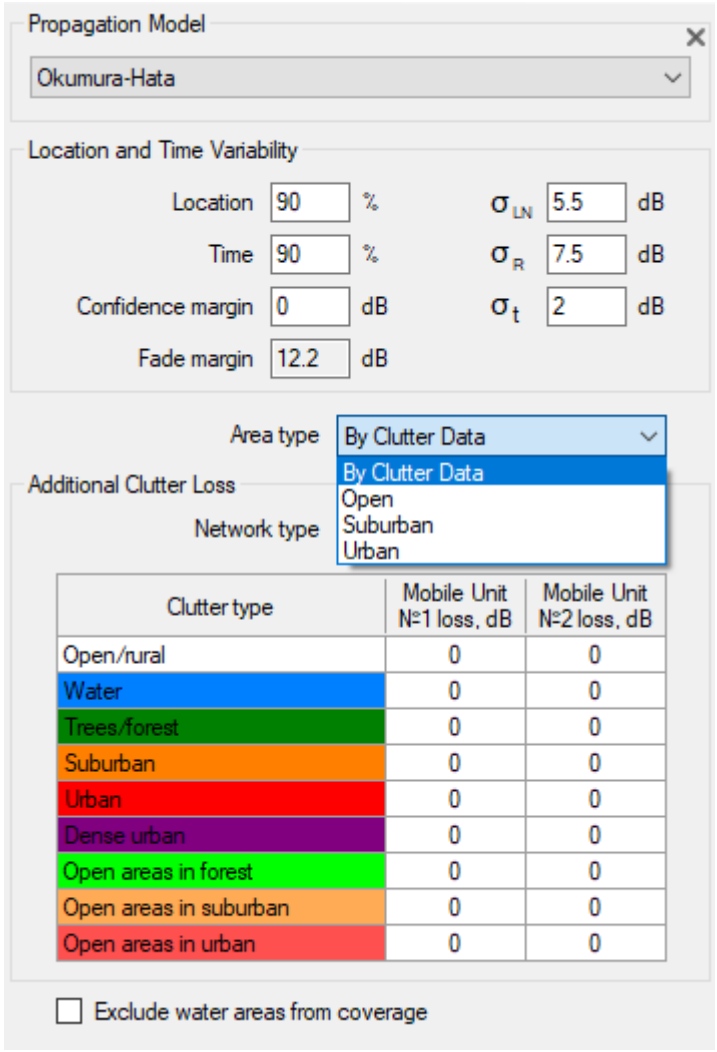
Add clutter loss	Add clutter loss to path loss
Network type	Select the network for which the clutter loss applies

Okumura-Hata Propagation Model

This empirical model was developed by Hata and is based on Okumura's experimental data taken in the Tokyo urban and suburban area. When calculating coverage using this model, you must determine which category the site location area belongs to: Urban Area, Suburban Area, or Open Area. Path loss is calculated using different formulas depending on the type of area.

- **Urban Area:** Built up city or large town including buildings and houses with two or more stories, or large villages and tall trees, green lands.
- **Suburban Area:** Small town, village or highway scattered with trees and houses, some obstacles near the mobile set but not very congested and scattered industrial plants.
- **Open Area:** No tall trees or buildings in the radiowaves path, open fields, land cleared for 300–400m ahead, very low congested area, no factories such as farm lands and rice fields.

Path loss is calculated using different formulas, depending on the type of area.



Okumura-Hata Propagation Model

The approach to fade margin calculation, taking into account location and time variability as well as large/small-scale and time fading standard deviations, is the same as described in the ITU-R P.1812-6 Propagation Model.

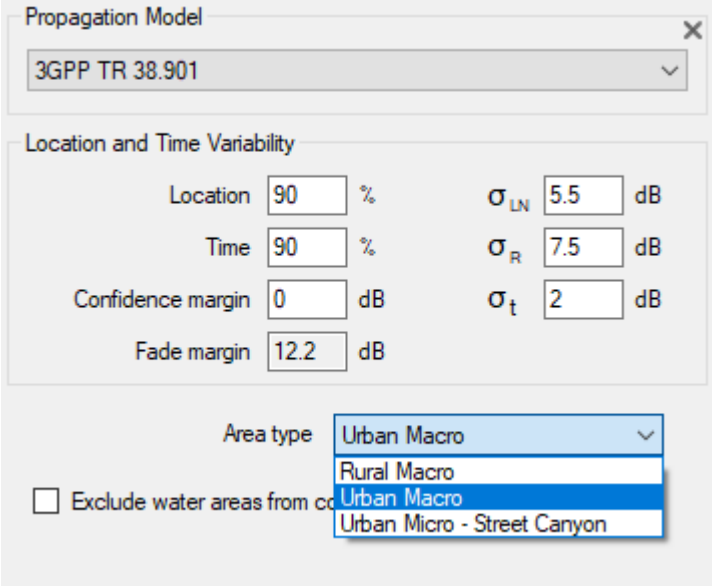
Area Type	Select the area type: - By Clutter Data - Open - Suburban - Urban
Network type	Select the network for which the additional clutter loss applies

In RadioPlanner 3.0, you can select one of these standard Okumura-Hata area types or choose “By Clutter Data” for automatic detection of Okumura-Hata area type based on clutter type. The correspondence table between clutter type and Okumura-Hata area type is shown below. When choosing this option, you can also use additional attenuation for different types of clutter.

	RadioPlanner Clutter Type	Color	Okumura-Hata Area Type
1	Open / Rural		Open
2	Water		Open
3	Trees / Forest		Open
4	Suburban		Suburban
5	Urban		Urban
6	Dense urban		Urban
7	Open areas in forest		Open
8	Open areas in suburban		Suburban
9	Open areas in urban		Urban

3GPP TR 38.901 Propagation Model

This model is described in detail in 3GPP Tecnical Report 5G; Study on channel model for frequencies from 0.5 to 100 GHz (3GPP TR 38.901 version 17.0.0 Release 17; 2022-04)



3GPP TR 38.901 Propagation Model

The approach to fade margin calculation, taking into account location and time variability also large/small-scale and time fading standard deviations, the same as described in the ITU-R P.1812 Propagation Model.

Area Type	Select the area type: - Rural Macro - Urban Macro - Urban Micro-Street Canyon

Area Study (Coverage Prediction) types

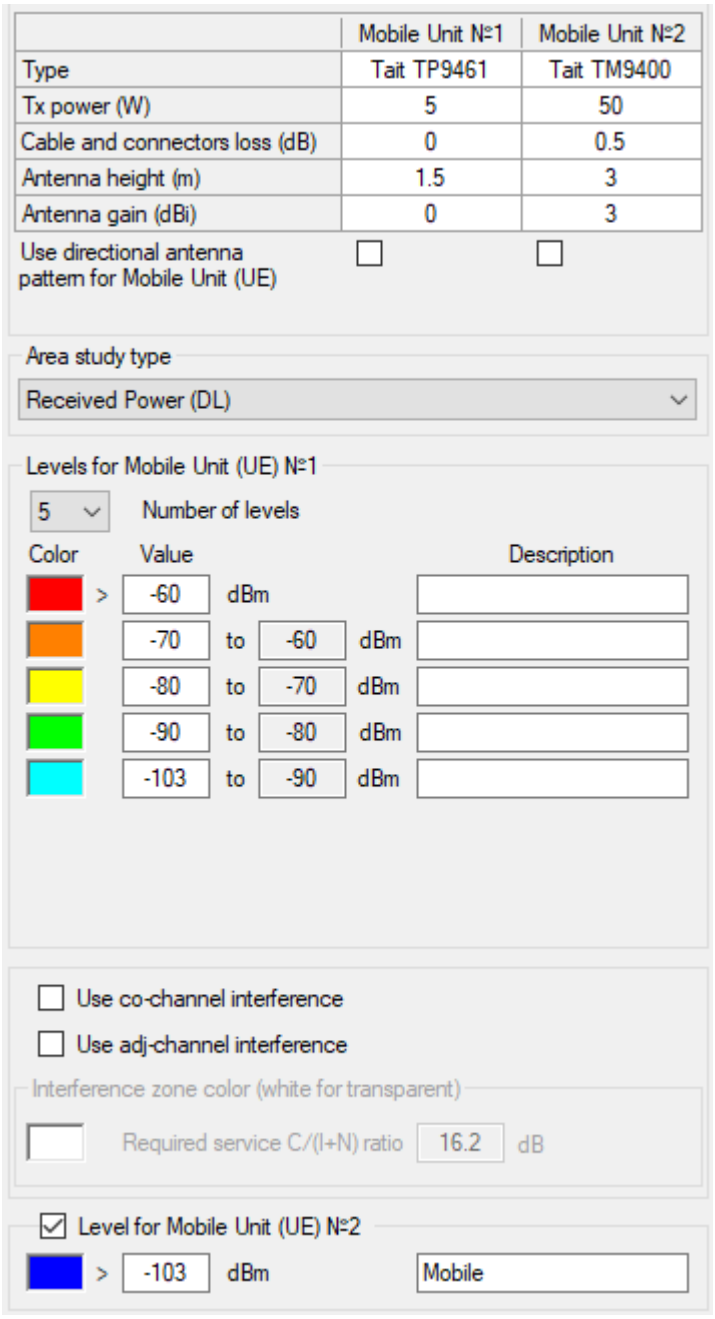
RadioPlanner 3.0 performs various types of area studies:

- Received Power Uplink/Downlink
- Best Server Uplink/Downlink
- Area with Signal above Both the Base and Mobile Thresholds
- C/(I+N) Ratio Uplink/Downlink
- Maximum Throughput Uplink/Downlink
- Maximum aggregated Throughput Downlink
- Number of Servers Uplink/Downlink
- Coverage Probability Uplink/Downlink
- RSRP for LTE and 5G
- RSRQ for LTE and 5G
- Simulcast Delay Spread
- Received Power with Simulcast Interference
- Field Strength Downlink

The availability of a particular area study type is determined by the type of system chosen.

Received power Downlink/Uplink

Received power maps show those areas where a given signal power level is present at the receiver.



Received Power Downlink Study Type Parameters

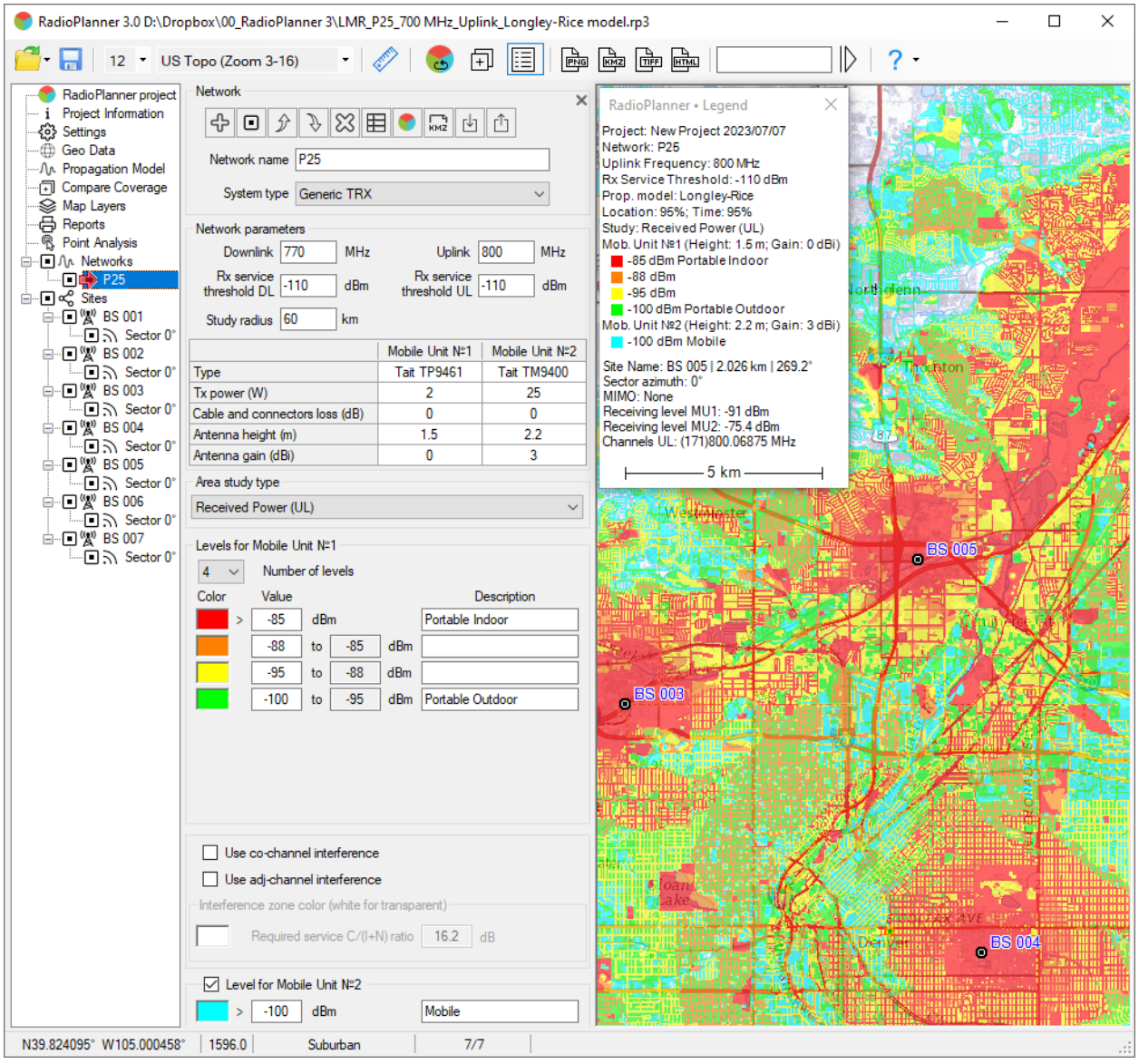
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Received power level, dBm
Description	Text field to describe signal level
Use co-channel interference	Perform coverage calculation taking into account co-channel interference using frequency assignments for each sector.
Use adj-channel interference	Perform coverage calculation taking into account adjacent channel interference using parameters in network settings (Channel bandwidth and Adjacent Channel rejection) as well as frequency assignments for each sector.
Required Service C/(I+N) Ratio	Requred service C/(I+N) ratio, dB This is the minimum acceptable C/(I+N) ratio required by the receiver for “acceptable” performance.

	"Acceptable" can mean a variety of things in terms of subjective signal quality, so this number can be adjusted to represent systems of varying quality or marginal quality. An area with a C/(I+N) below the Required Service C/(I+N) ratio will be shown on the map as an interference zone.

For Mobile Unit No. 1 (portable), you can set from one to eight different levels of received signal to simulate different reception conditions (e.g., on street, inside a car, indoors).

For Mobile Unit No. 2 (mobile radio with an antenna on the roof of a car), only one signal level can be set.

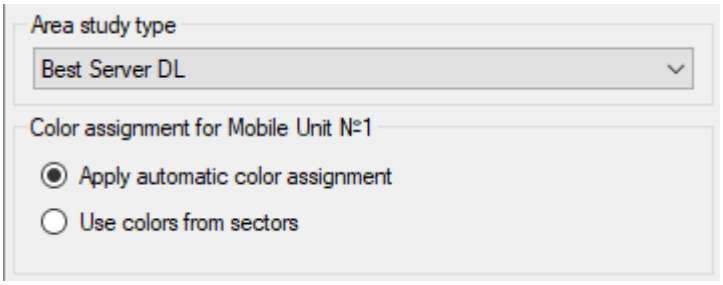
The interference calculation always takes into account the noise component, which depends on the noise bandwidth and receiver noise figure. These settings are entered in Noise and Interference in the Network system settings.



Uplink Received Power Coverage Prediction for P25 700 MHz Network

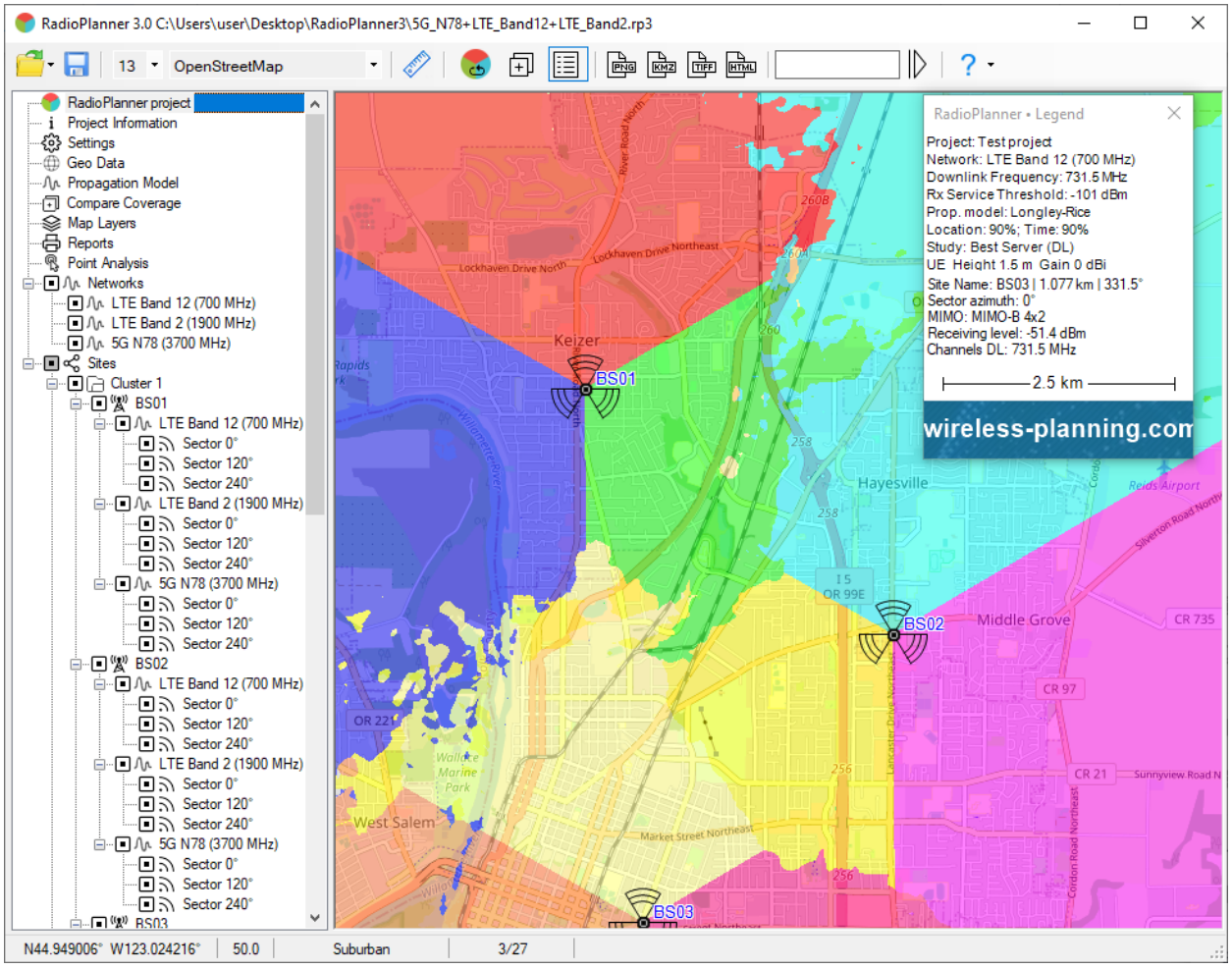
Best Server Uplink/Downlink

The Best Server map shows the identity of the sector supplying the strongest received signal at each location. The minimum received signal level for calculating the Best Server is downlink/uplink Rx threshold. The sector color is defined in the sector parameters or can be assigned automatically.



Best Server Study Type Parameters

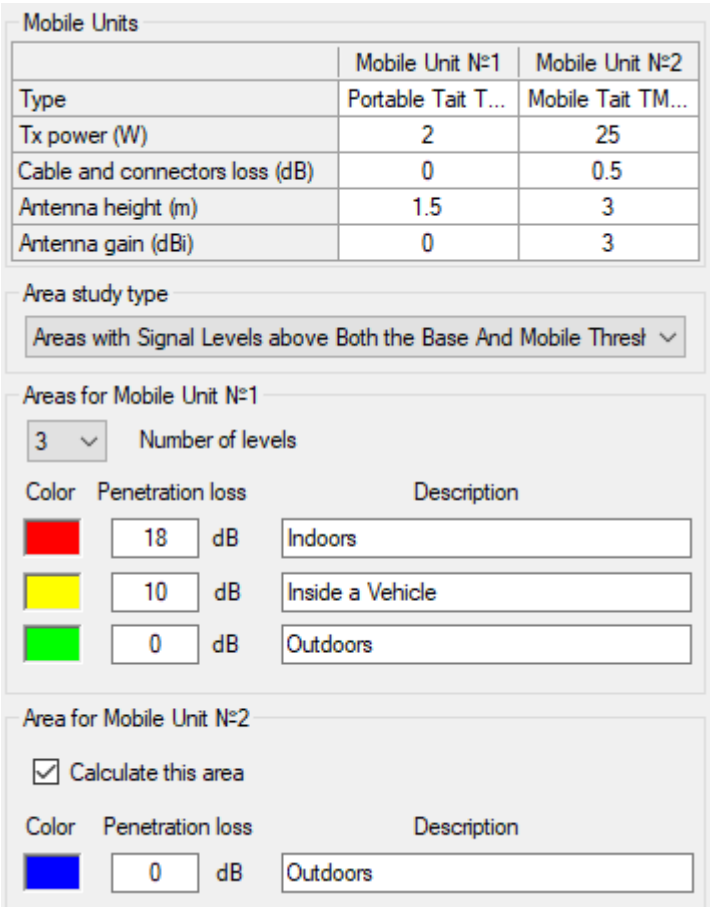
Apply Automatic Color Assignment	Assign colors to sectors in random order
Use Colors from sectors	Assigning colors to sectors from the sector parameters



Best Server

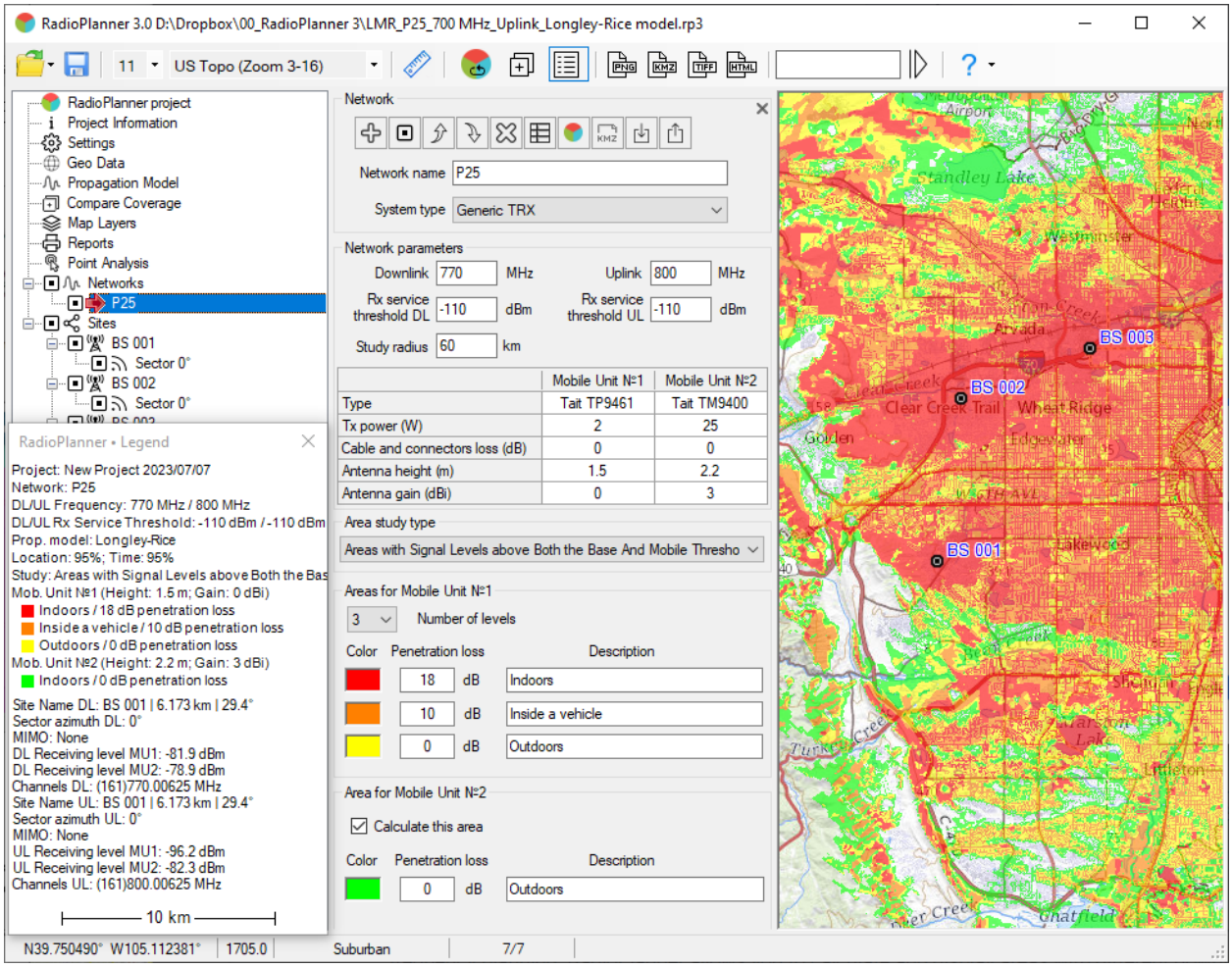
Areas with Signal Levels Above Both the Base and Mobile Thresholds

This area study type displays a map showing locations where both the signal received by the mobile unit is above the downlink Rx threshold and where the signal received by the base station sector from the mobile is above the uplink Rx threshold. This calculation can be performed for different conditions of use of Mobile Unit No. 1 (portable radio or UE), such as indoors, outdoors, and inside a car. Each condition of use has its own color and value of loss (margin) for signal penetration indicated in this form. For Mobile Unit No. 2, only outdoor calculation is performed.



Areas with Signal Levels Above Both the Base and Mobile Thresholds Study Type Parameters

Number of Levels	The number of levels
Color	Color level
Penetration Loss	Penetration loss, dB
Description	Text field



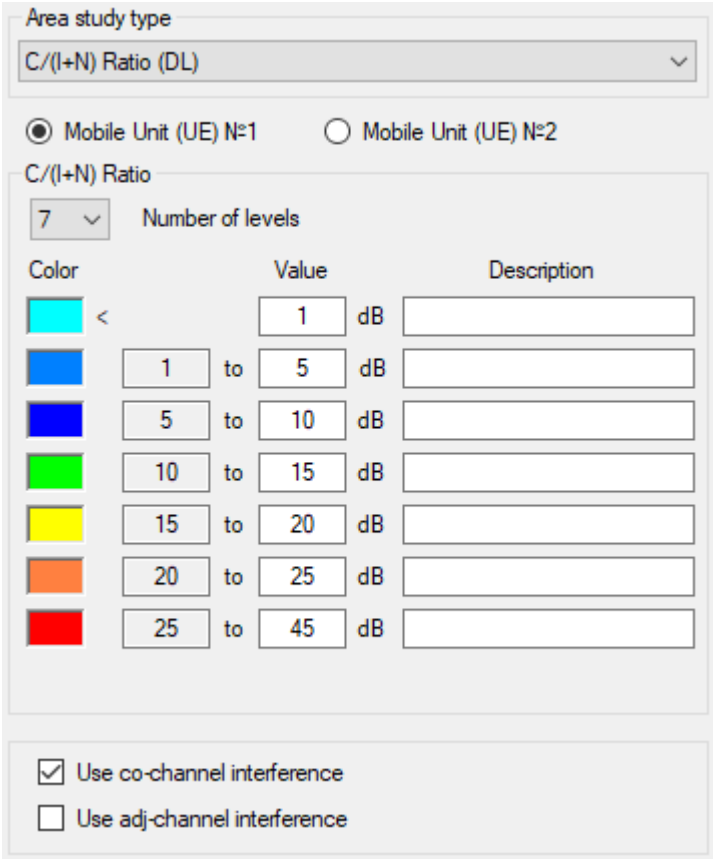
Areas with Signal Levels Above Both the Base and Mobile Thresholds for P25 700 MHz network

C/(I+N) Ratio Downlink/Uplink

The carrier-to-interference+noise ratio (C/(I+N)) is an essential quantity used in assessing system performance and affecting frequency planning. RadioPlanner allows you to calculate and display areas with different downlink/uplink C/(I+N) values for interference on co-channel and adjacent channels.

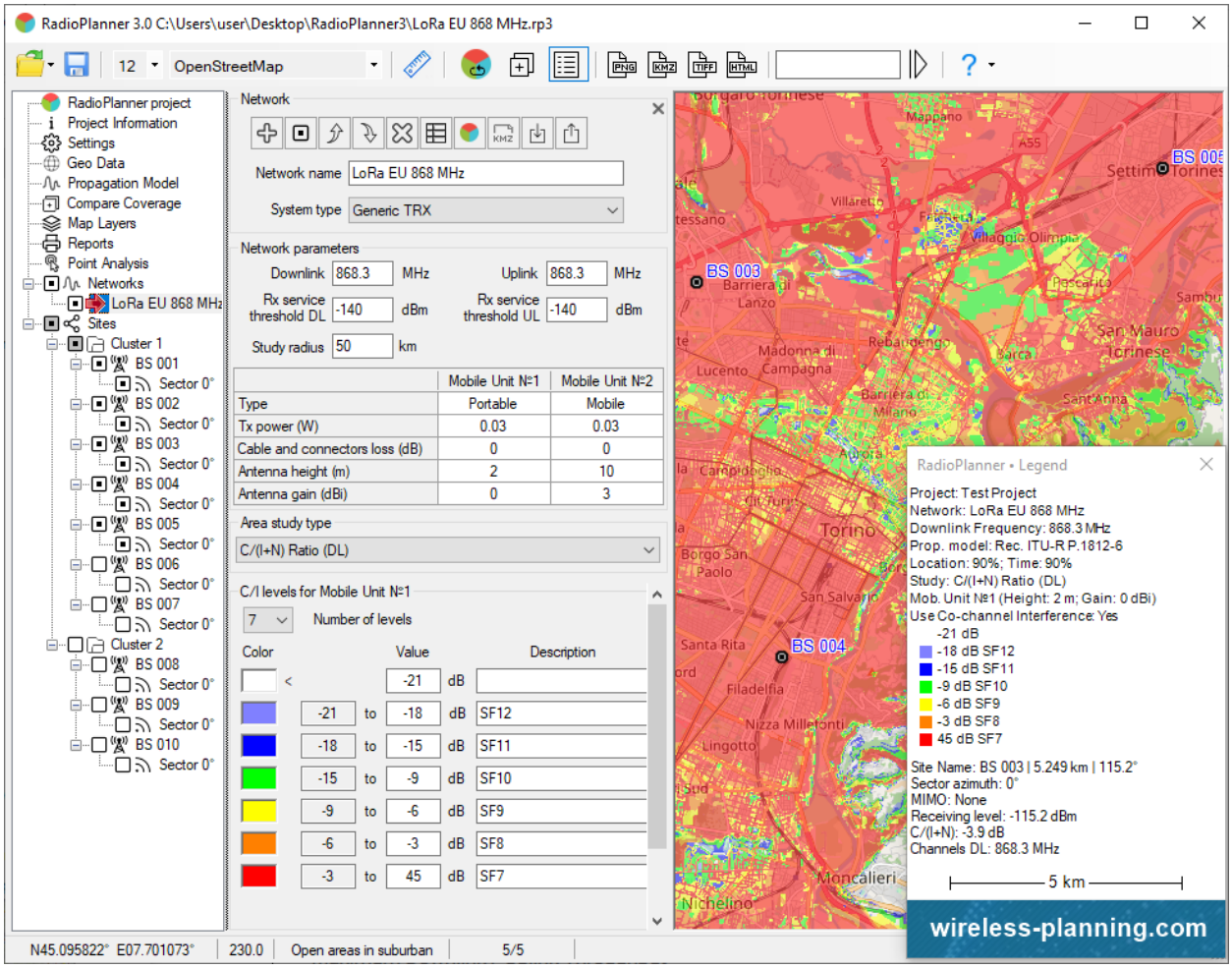
Carrier-to-interference+noise ratio is calculated by first finding the strongest received signal power at each location, then calculating the sum of received signal powers from all other co-channel and adjacent sectors (taking into account adjacent channel rejection) that also have relevant signal levels at that location. After finding the sum of interference, the carrier-to-interference+noise ratio is calculated.

The interference calculation always takes into account the noise component, which depends on noise bandwidth and receiver noise figure entered in Noise and Interference in Network system settings. The calculation of adjacent channel interference can be disabled to only take into account co-channel interference.



C/(I+N) Downlink Ratio Study Type Parameters

Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Number of Levels	The number of levels
Color	Color level
Value	Carrier-to-interference+noise ratio C/(I+N), dB
Description	Text field



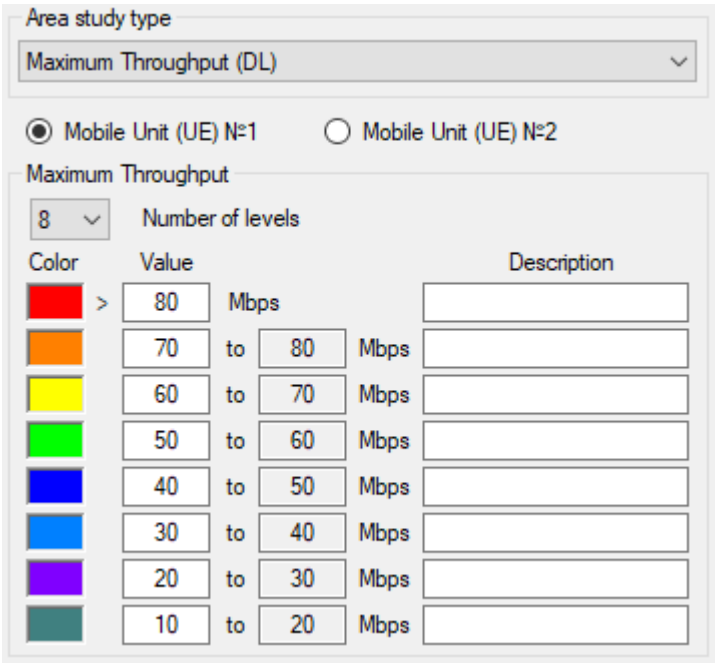
C/(I+N) Downlink ratio for LoRaWAN network

Maximum Downlink / Uplink Throughput

This prediction type shows maximum cell throughput.

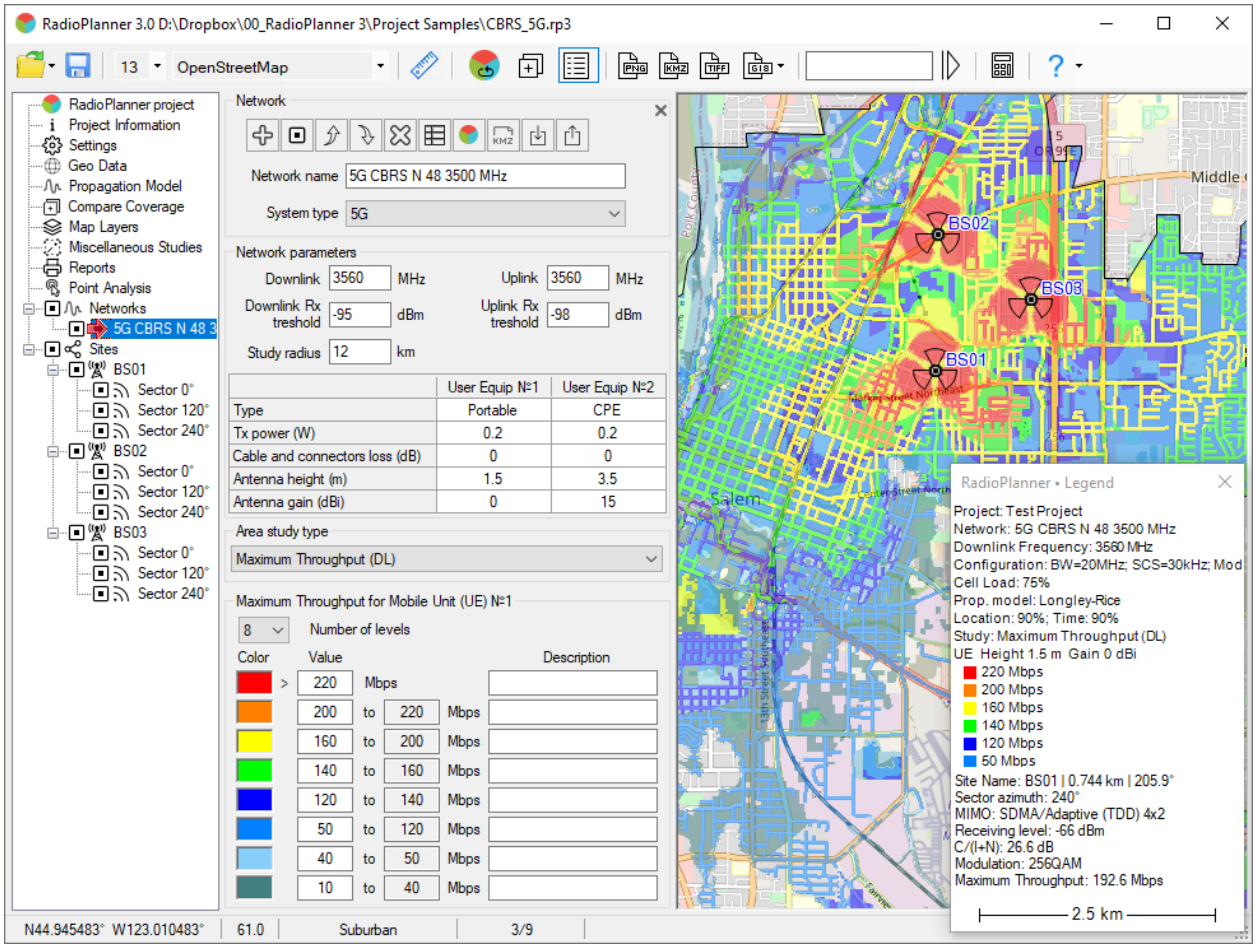
For LTE/5G System Types, this study calculates MCS Index for each point based on predicted C/(I+N) from LTE/5G system parameters tab of Network. Throughput associated with MCS is determined using 3GPP specified formulas and tables.

For Generic TRX System Type, this study calculates Throughput for each point based on predicted C/(I+N) from Adaptive Modulation Table in system parameters tab of Network.



Maximum Downlink Throughput Study Type Parameters

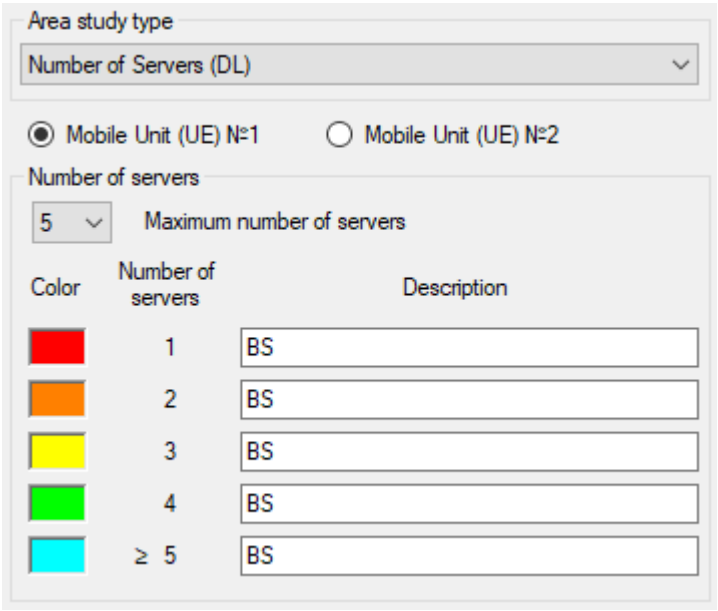
Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Maximum Throughput, Mbps
Description	Text field



Maximum Downlink Throughput Coverage Prediction for 5G CBRS N48 (3500 MHz) Network

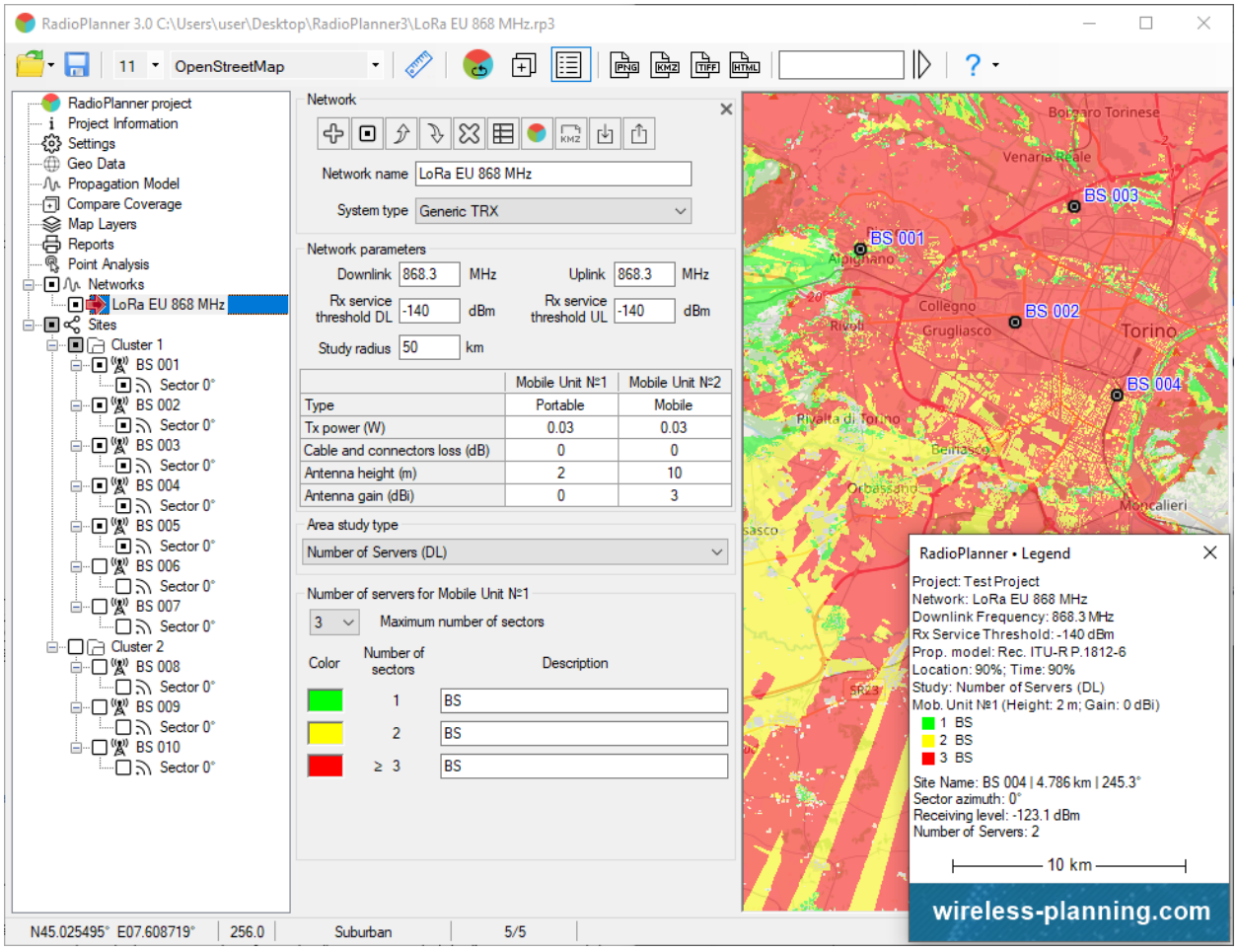
Number of Servers Uplink/Downlink

This study indicates total number of sectors that provide a signal above Rx threshold at each location. This study type is often required when planning networks based on wireless IoT technologies such as LoRaWAN.



Number of Servers Above Downlink Study Type Parameters

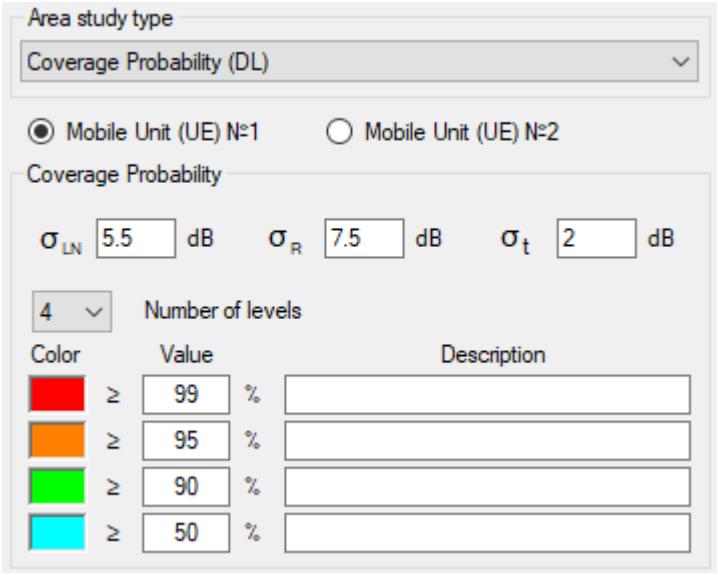
Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Maximum Number of Sectors	Maximum number of displayed servers above uplink
Color	Color indicating the appropriate number of sectors
Description	Text field



Number of Servers Above Downlink for LoraWAN Network

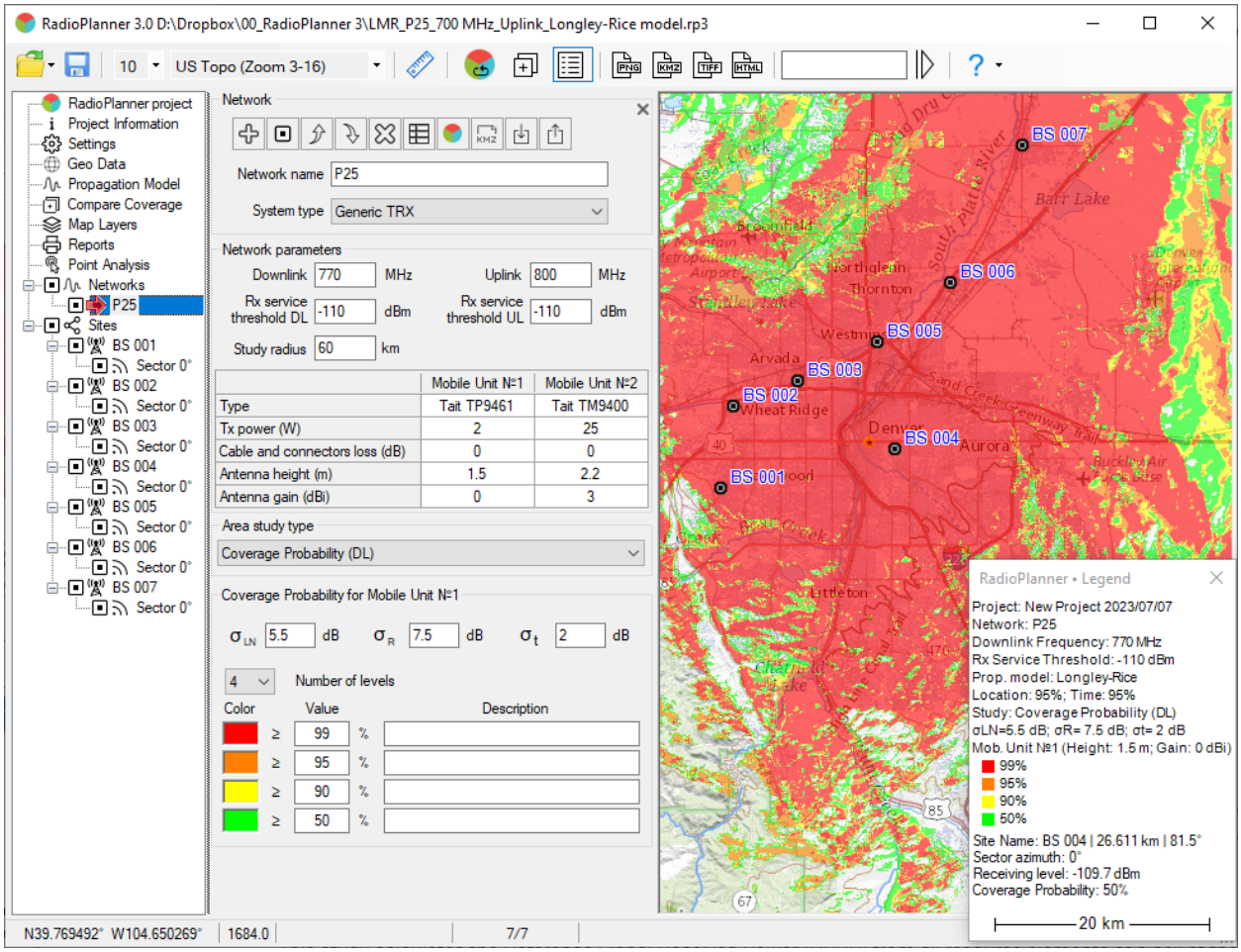
Coverage Probability Uplink/Downlink

This area study shows the availability of service based on a Gaussian (“normal”) distribution in dB. The calculation determines the “fade margin” at each study location based on the received signal strength with respect to a receiver threshold. The percent reliability is then a lognormal distribution of the fade margin in dB. Interference and noise are not taken into account in the calculation. The values of standard deviations in the calculation are taken from the “Coverage Probability” parameters, while standard deviation values in propagation model parameters are ignored.



Coverage Probability Study Type Parameters

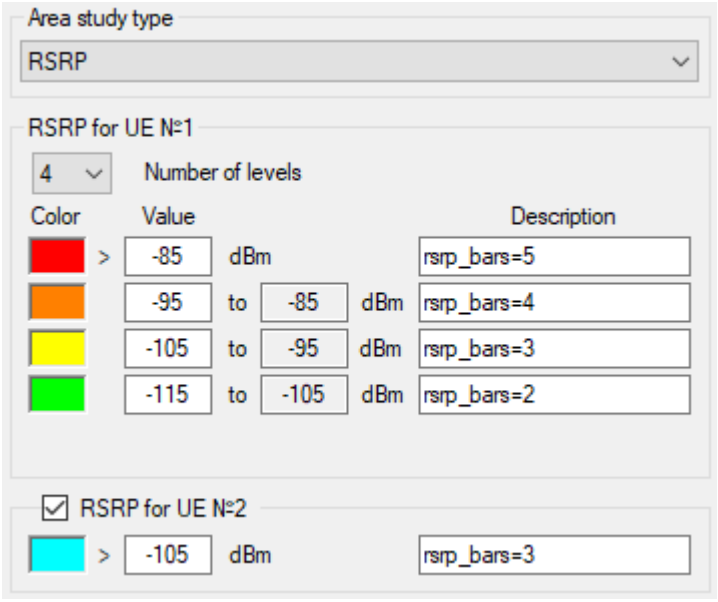
Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
σ_{LN}, dB	Lognormal large-scale (shadow) fading standard deviation, dB. This value depends on the digital terrain model (DTM) resolution and carrier frequency. Typical value 2-5 dB for modern DTMs.
σ_R, dB	Small-scale fading (Rayleigh) standard deviation, dB. Typically 7.5 dB
σ_t, dB	Time variability standard deviation, dB. At distances up to 50 km, the σ_t usually varies for between 2-3 dB (Land), and up to 9 dB for the Sea. See Table 3 in Recommendation ITU-R P.1406-2 *"Propagation effects relating to terrestrial land mobile and broadcasting services in the VHF and UHF bands"*
Number of Levels	The number of levels
Color	Color level
Value	Probability, %
Description	Text field



Coverage Probability Coverage Prediction for P25 700 MHz Network

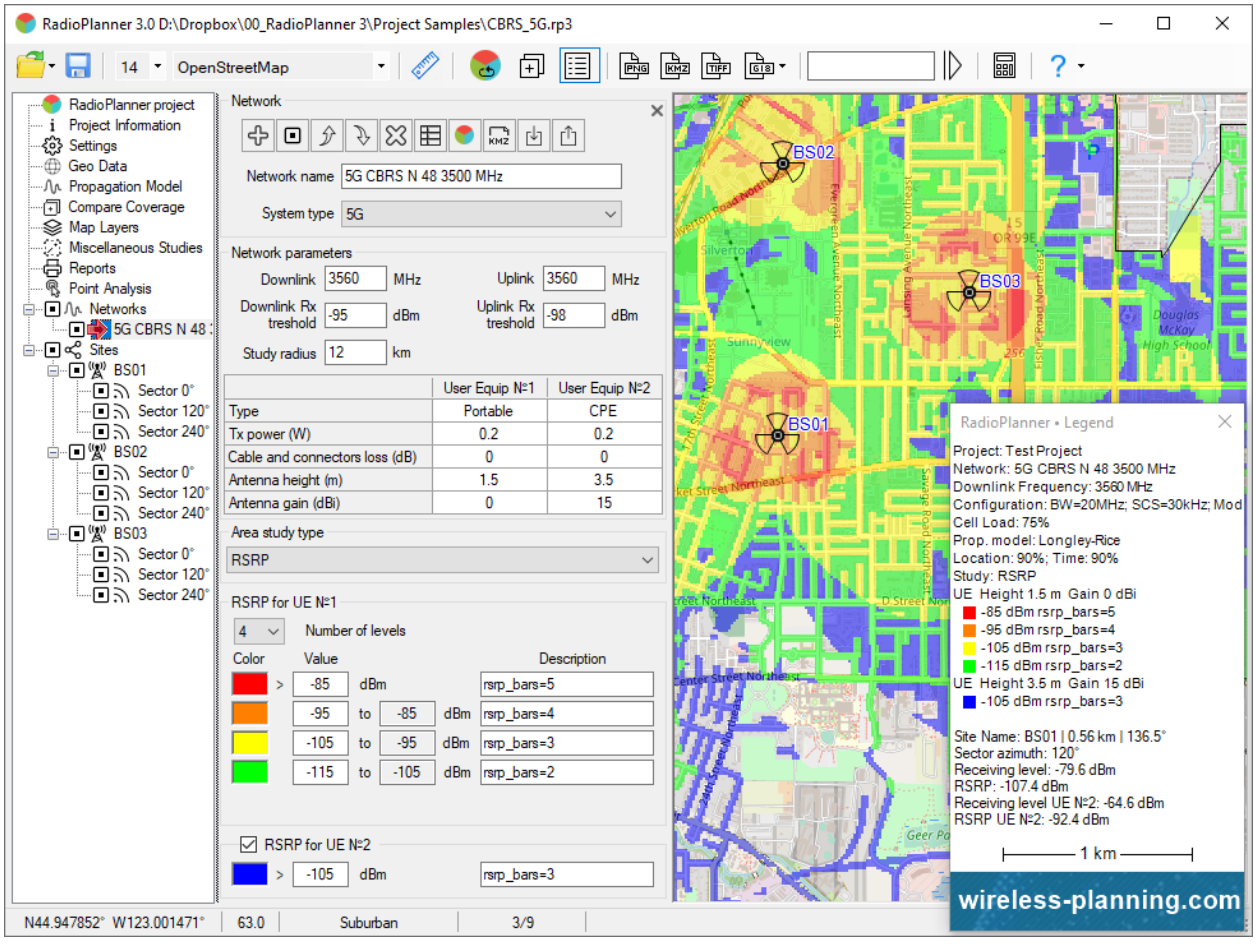
Reference Signal Received Power (RSRP)

This study calculates the Reference Signal Received Power (RSRP) from all resource elements of a cell at the remote UE receiver using system parameters of LTE and 5G networks (bandwidth, subcarrier spacing). The calculation can use a single-column antenna pattern for a sector if selected in LTE/5G sector Additional Options.



RSRP Study Type Parameters

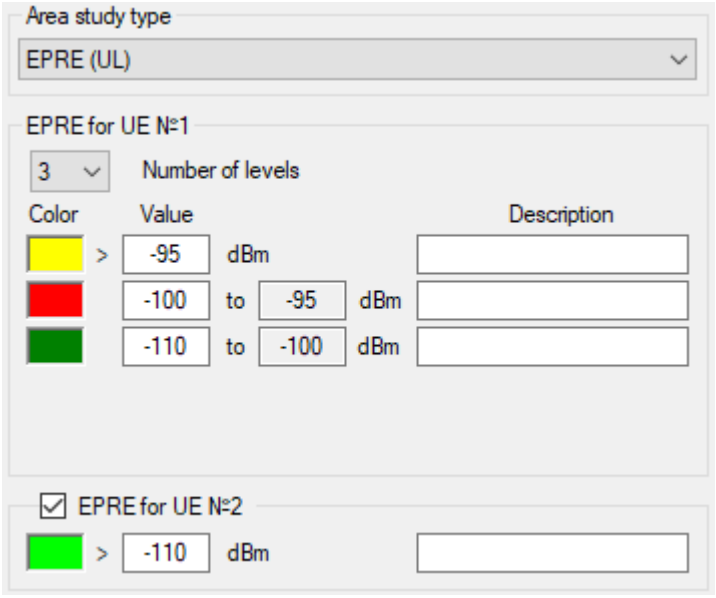
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Reference Signal Received Power (RSRP), dBm
Description	Text field to describe RSRP level



RSRP coverage prediction for 5G CBRS N48 (3500 MHz) Network

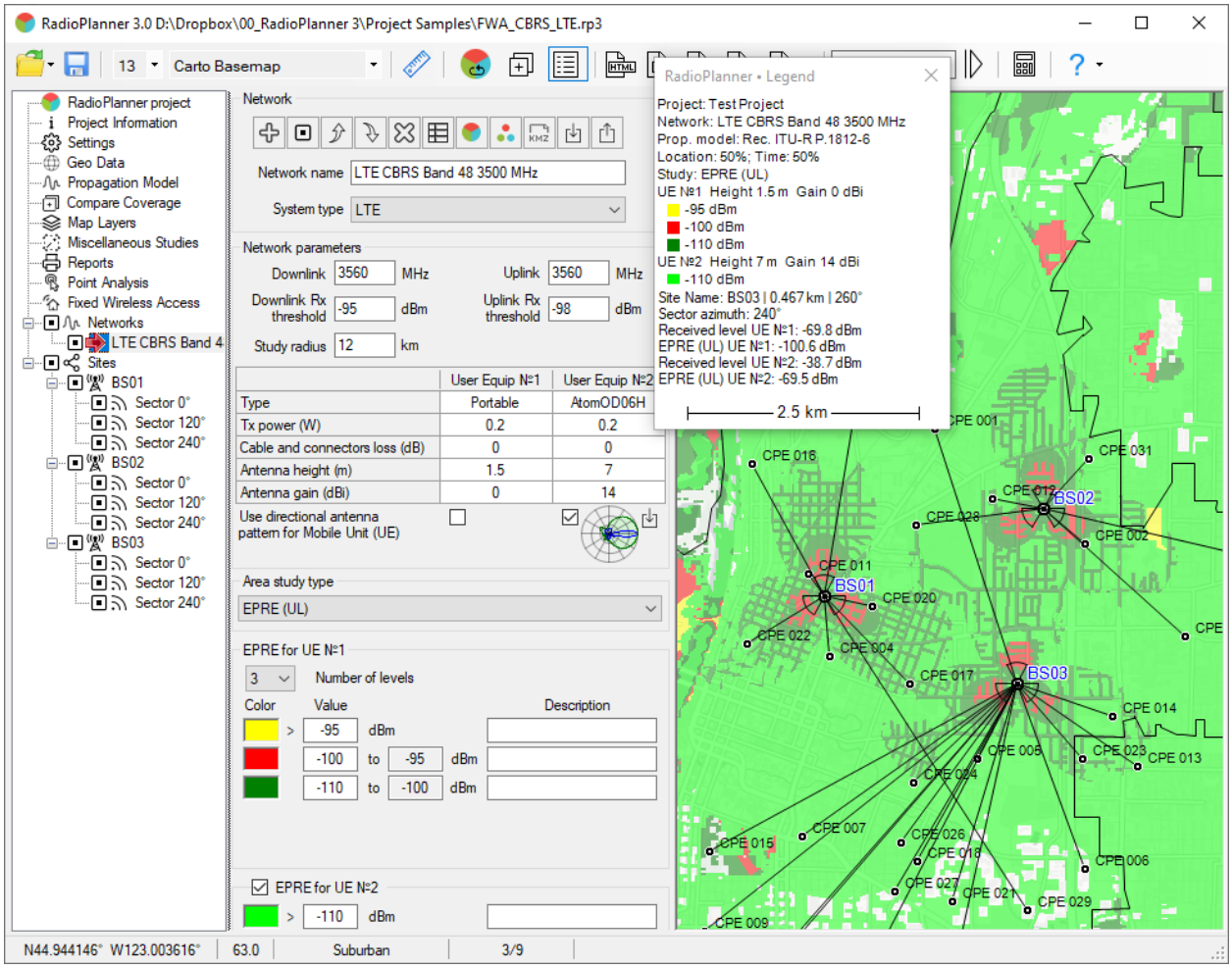
Energy Per Resource Element (EPRE)

This study calculates the average resource element power (uplink only) using system parameters of LTE and 5G networks.



EPRE Study Type Parameters

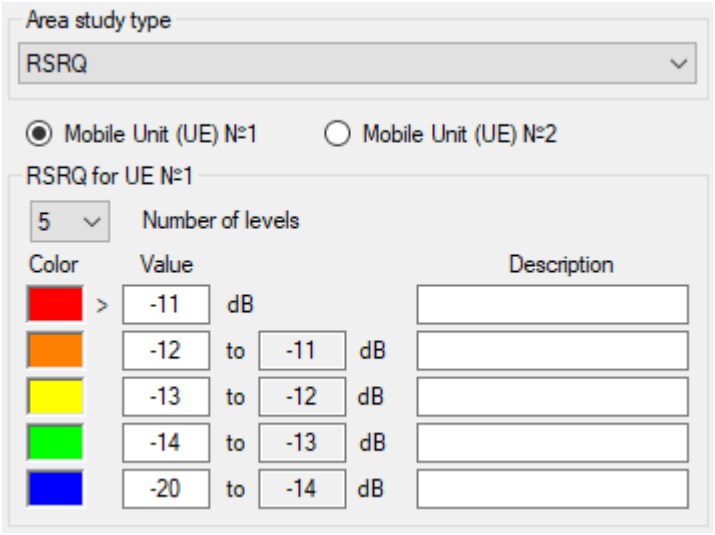
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Energy Per Resource Element (EPRE), dBm
Description	Text field to describe EPRE level



EPRE coverage prediction for 5G CBRS N48 (3500 MHz) Network

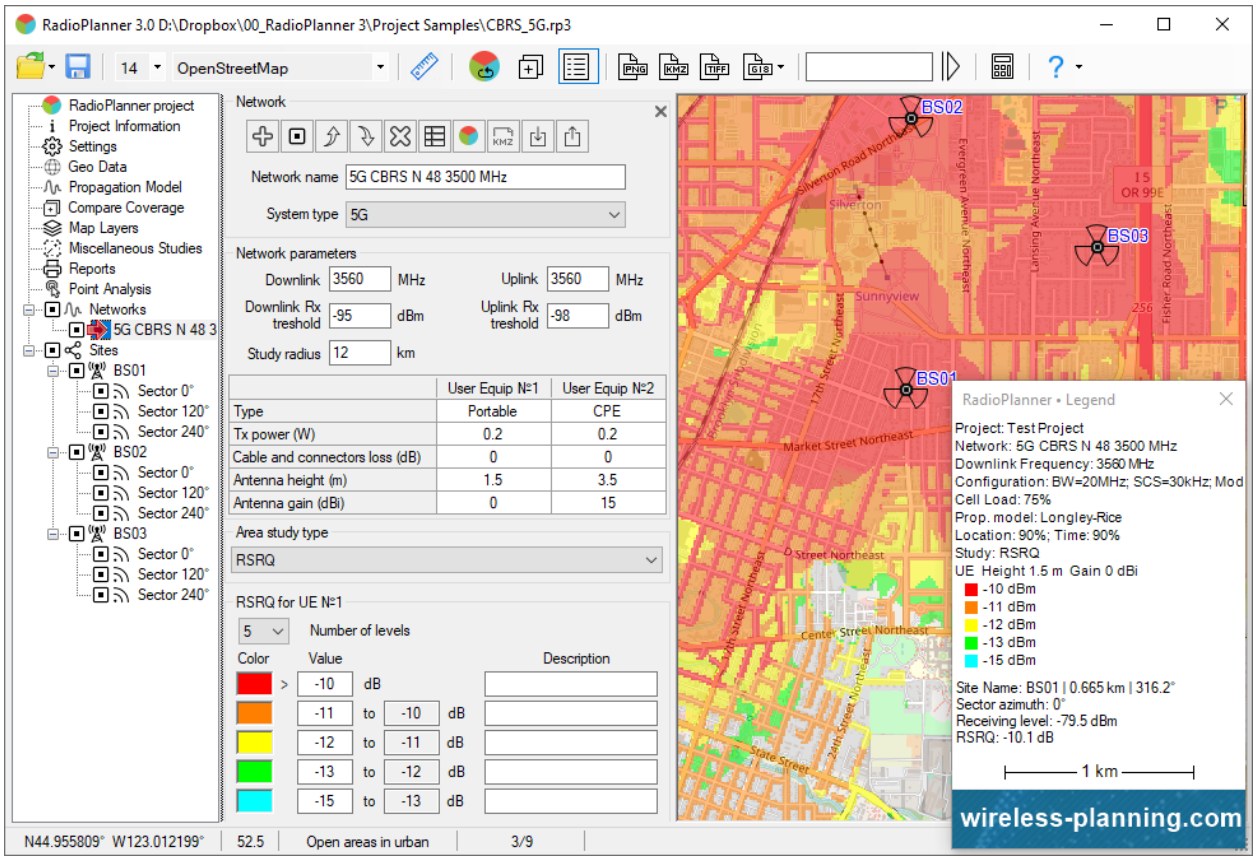
Reference Signal Received Quality (RSRQ)

This study calculates the Reference Signal Received Quality (RSRQ) from all resource elements at the remote UE receiver using system parameters of LTE and 5G networks (bandwidth, subcarrier spacing, cell load, and C/(I+N) ratio). The calculation can use a single-column antenna pattern for a sector if selected in LTE/5G sector Additional Options.



RSRQ Study Type Parameters

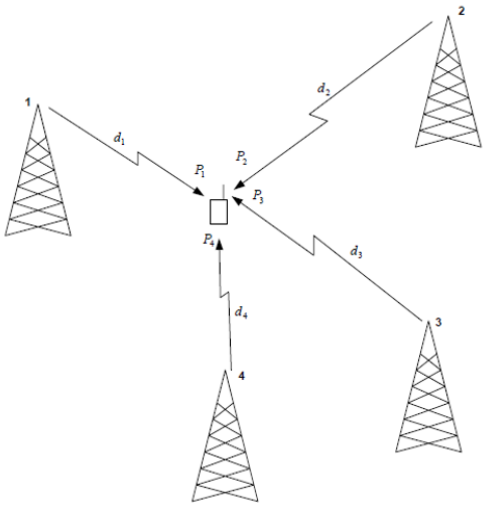
Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Reference Signal Received Quality (RSRQ), dB
Description	Text field to describe RSRQ level



RSRQ coverage prediction for 5G CBRS N48 (3500 MHz) Network

Simulcast Delay Spread

This prediction is used for simulcast systems that transmit signals from multiple locations simultaneously on the same channel. Interference in the receiver will occur under certain conditions related to delay time between signals arriving at a given location and their relative power. The simulcast delay spread is calculated as follows:



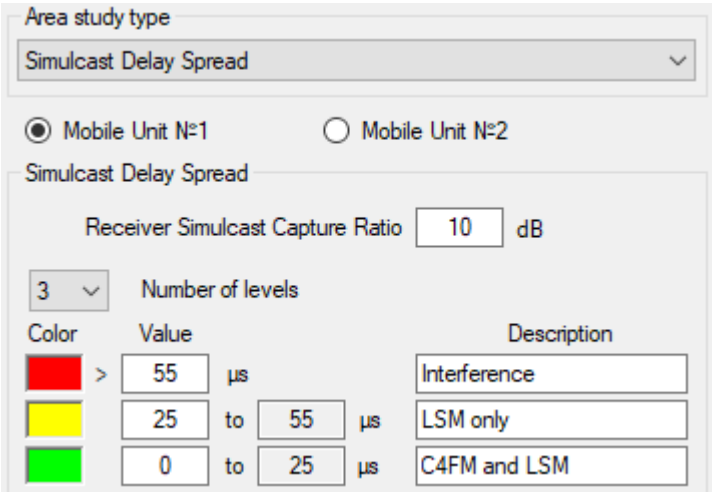
$$T_m = 2\sqrt{\frac{\sum_{i=1}^{N} P_i d_i^2}{\sum_{i=1}^{N} P_i} - \frac{\left(\sum_{i=1}^{N} P_i d_i\right)^2}{\left(\sum_{i=1}^{N} P_i\right)^2}}$$

T_m Multipath Spread (twice the RMS delay spread)

P_i Power arriving at a terminal antenna from transmitter i

d_i Time of flight from transmitter i to antenna terminal

The simulcast delay spread is calculated by considering only the six strongest signals at any grid analysis location. The results of the calculation are displayed in µs on the map.

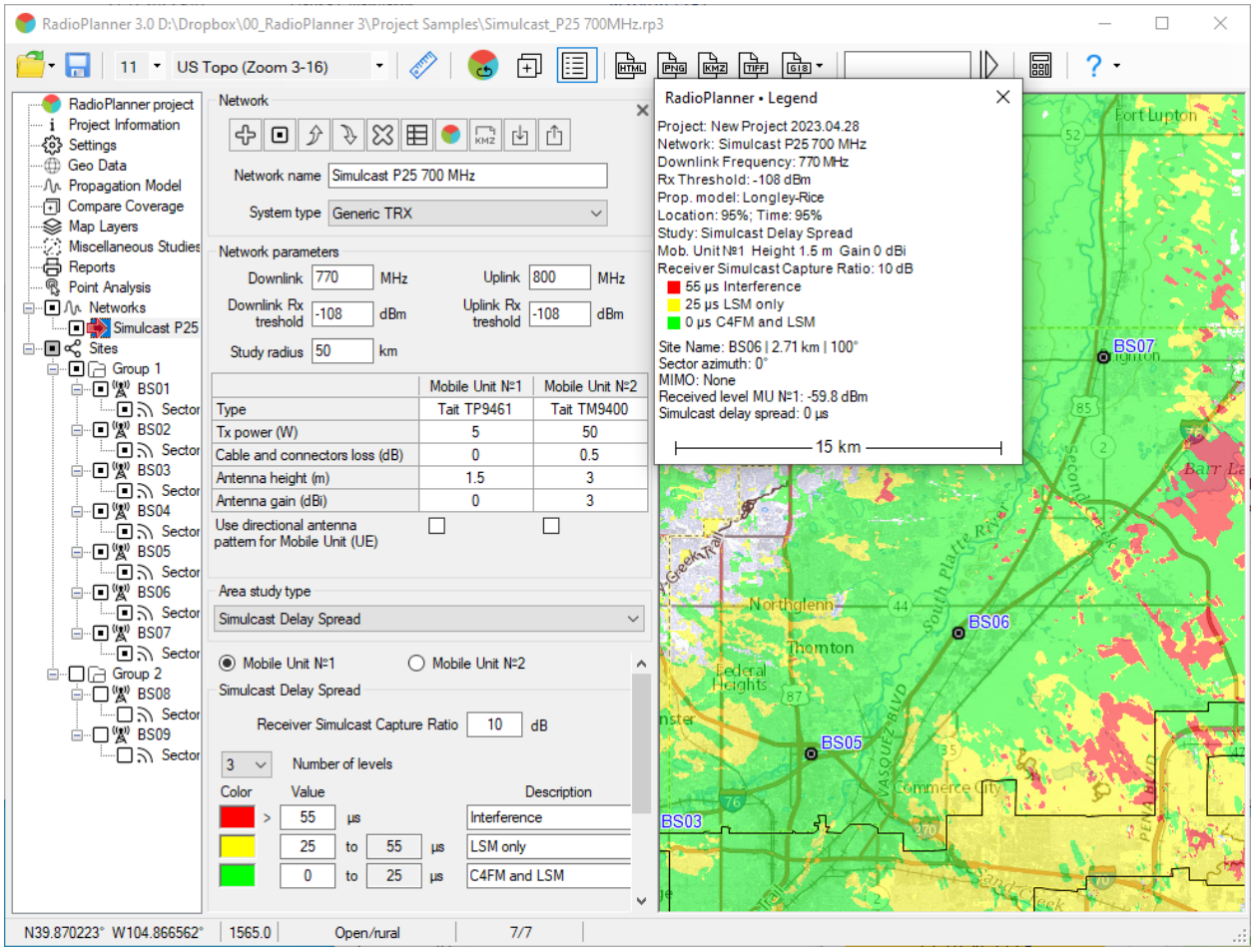


Simulcast Delay Spread Study Type Parameters

Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Receiver Simulcast Capture Ratio	For delay spread studies, the delay is calculated and displayed only when the power of the strongest received signal and the power of the second strongest received signal are within the capture ratio of each other. Typical value 7-15 dB.
Number of Levels	The number of levels (1-8)
Color	Color level

Values	Simulcast Delay Spread, µs
Description	Text field to describe Simulcast Delay Spread value

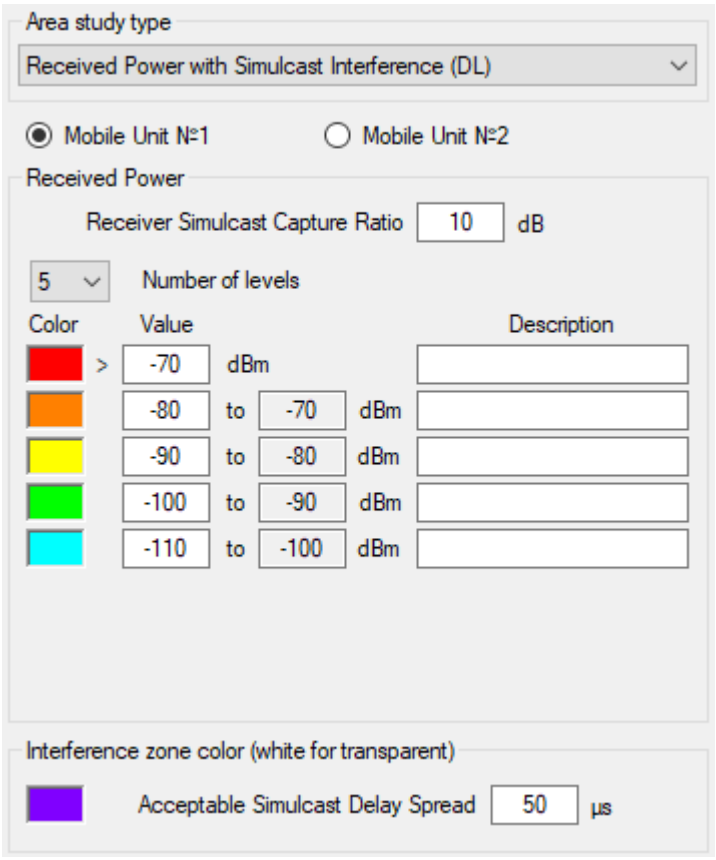
To reduce interference between simulcast transmitters, it can be useful to artificially delay the signal transmitted from a given location using Simultaneous Delay Offset entered in Advanced Sector Parameters. By carefully assigning offsets to different sectors, some control can be exercised over where interference occurs in simulcast system.



Simulcast Delay Spread Prediction for P25 700 MHz Simulcast Network

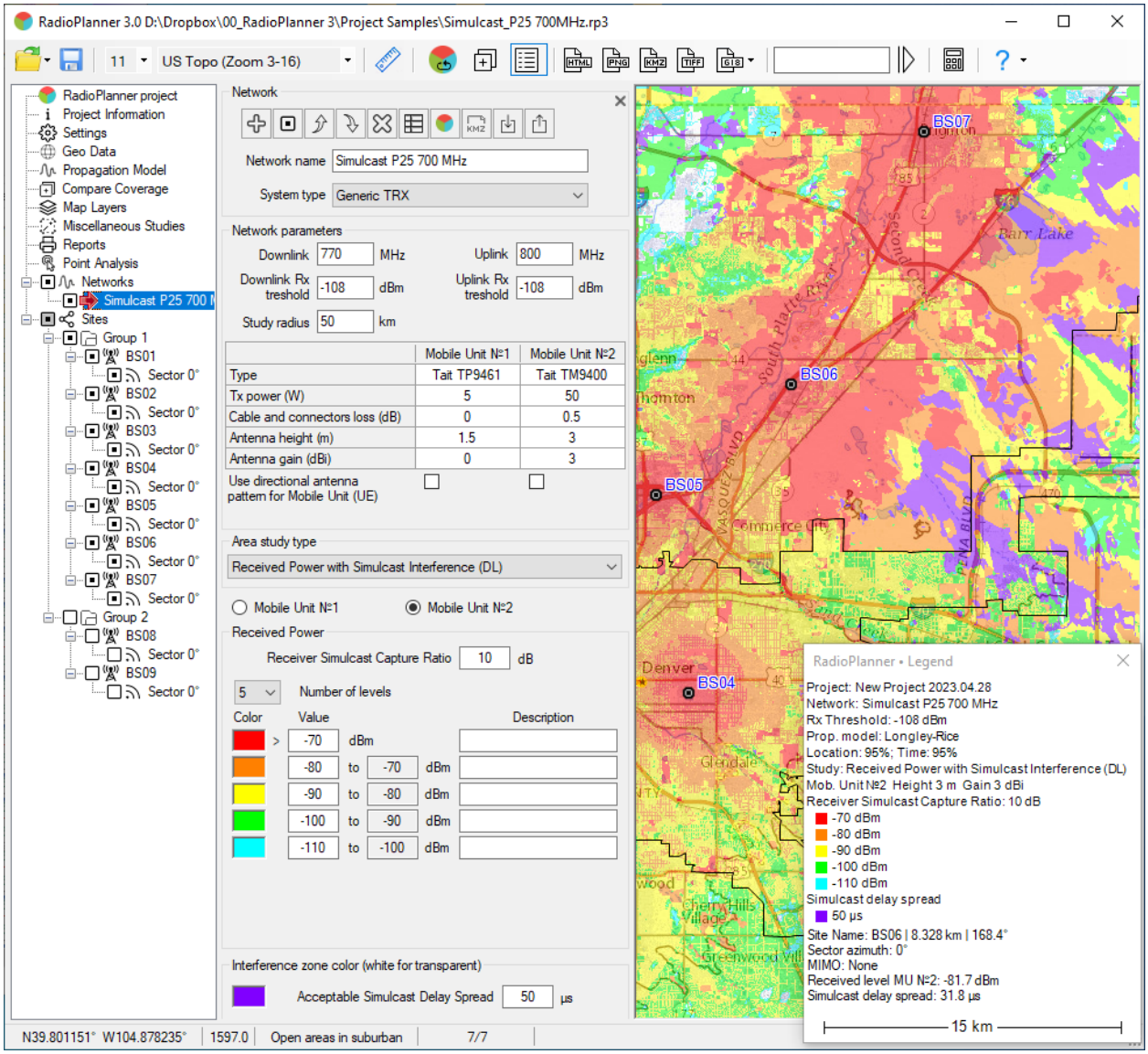
Received Power Downlink with Simulcast Interference

Received power maps show areas where a given signal power level is present at mobile unit receiver. This prediction also takes into account interference due to simulcast.



Received Power with Simulcast Interference Downlink Study Type Parameters

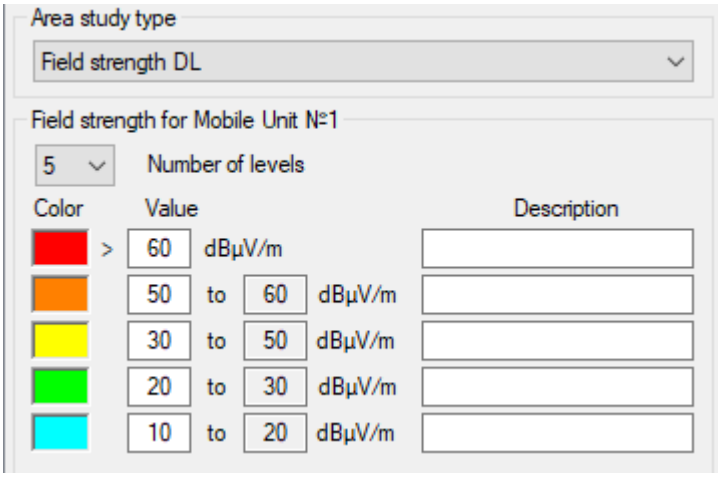
Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Receiver Simulcast Capture Ratio	For delay spread studies, the delay is calculated and displayed only when the power of the strongest received signal and the power of the second strongest received signal are within the capture ratio of each other. Typical value 7-15 dB.
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Received power level, dBm
Acceptable Simulcast Delay Spread, µs	An area with a Simulcast Delay Spread higher of the acceptable one will be shown on the map as an interference zone. The interference zone can be painted with any color on the map, or made transparent by selecting white for it.
Description	Text field



Received Power with Simulcast Interference Prediction for P25 700 MHz Simulcast Network

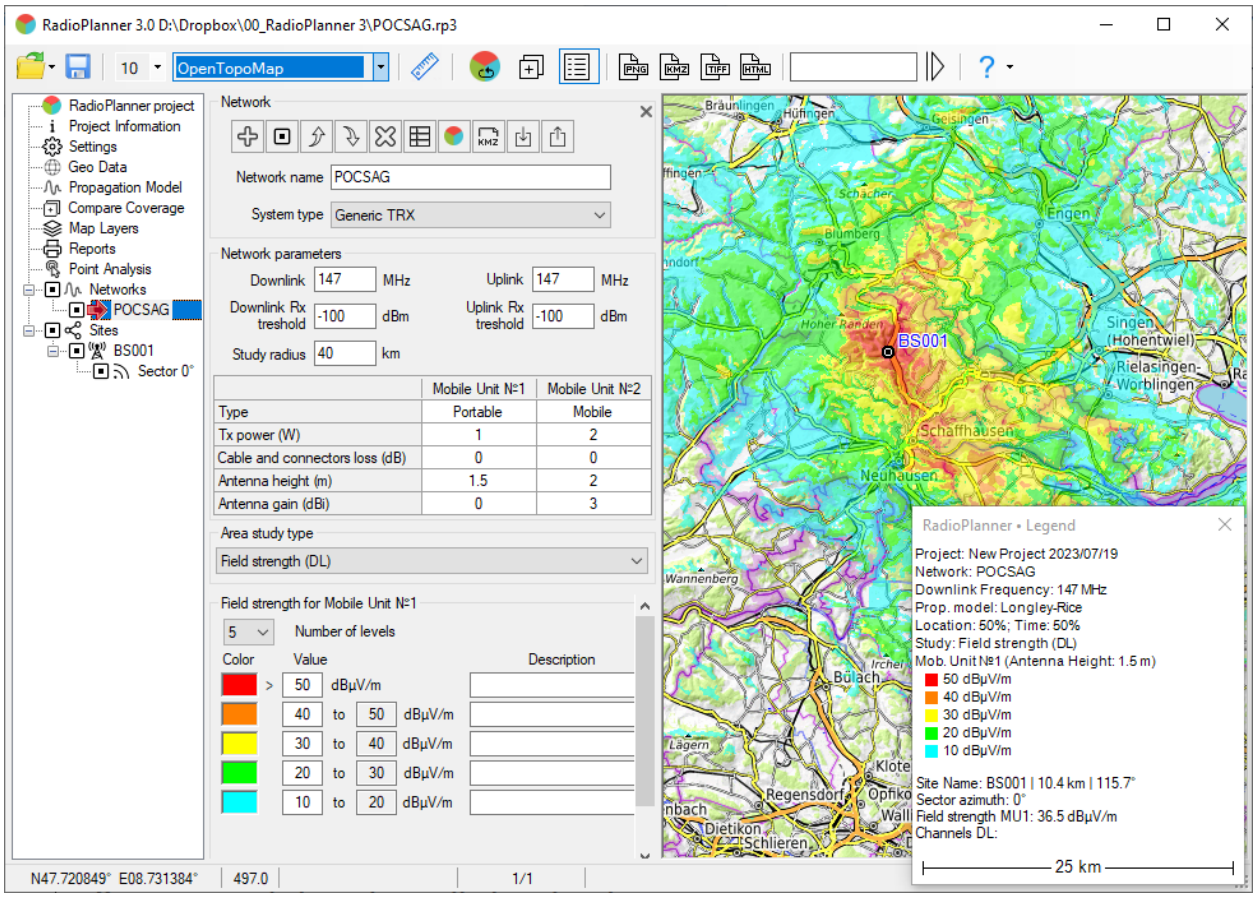
Field Strength Downlink

Field Strength maps show areas where a given field strength level is present at receiver point. Note that field strength is not a function of receive antenna parameters.



Field Strength Study Type Parameters

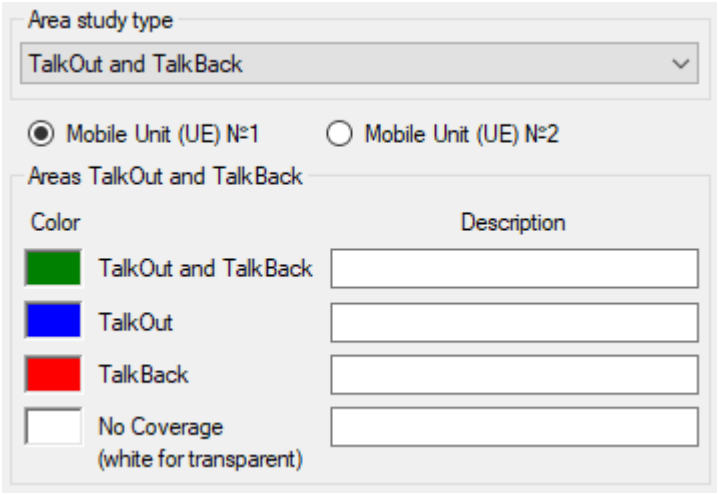
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Downlink Received Field Strength, dBµV/m
Description	Text field



Field Strength Prediction for POCSAG Pager Network

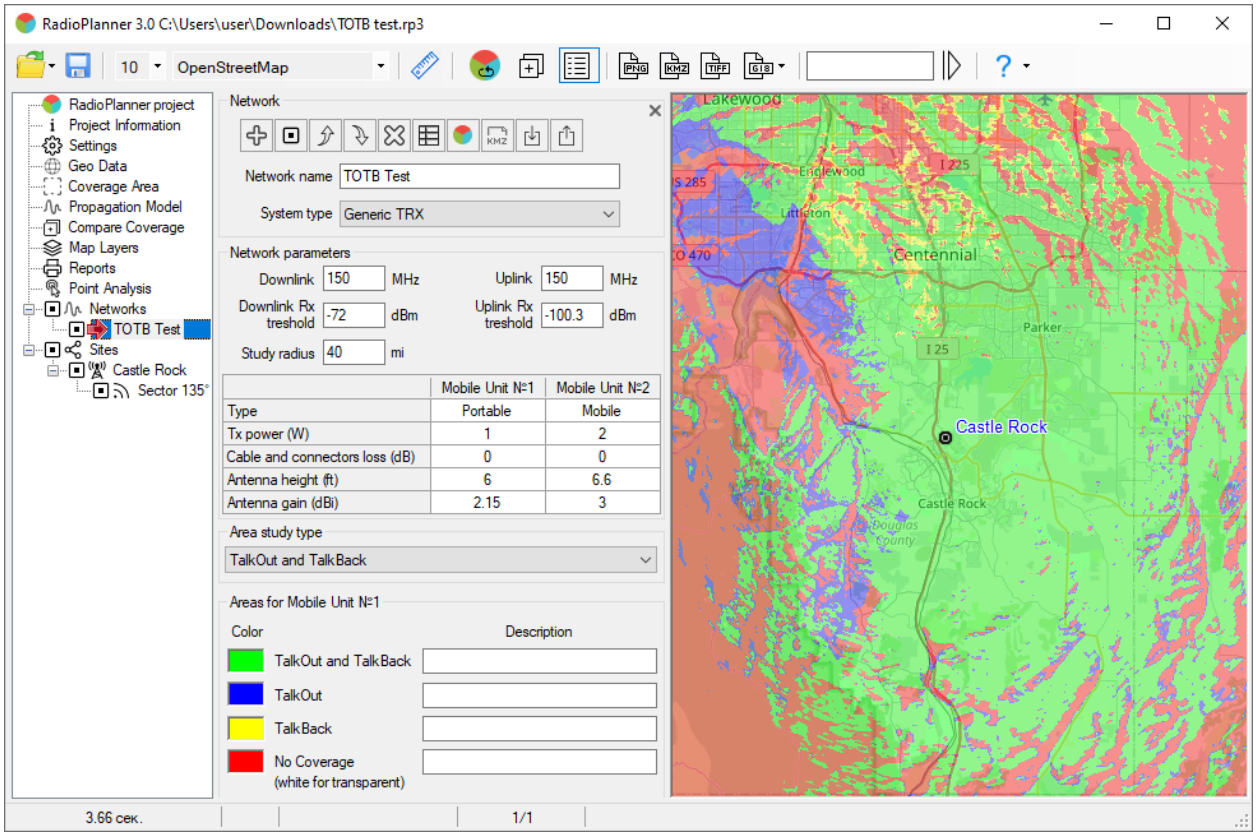
TalckOut and TalckBack

This area study type displays a map with the talk-out and talck-back (two-way) locations, talk-out only (downlink), talk-back only (uplink), and no coverage locations for mobile unit №1.



TalckOut and TalckBack Study Type Parameters

Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Color	Color
TalkOut and TalckBack	Downlink and uplink coverage
TalkOut	Downlink coverage only
TalckBack	Uplink coverage only
No Coverage	No Coverage (white color for transparent)
Description	Text field

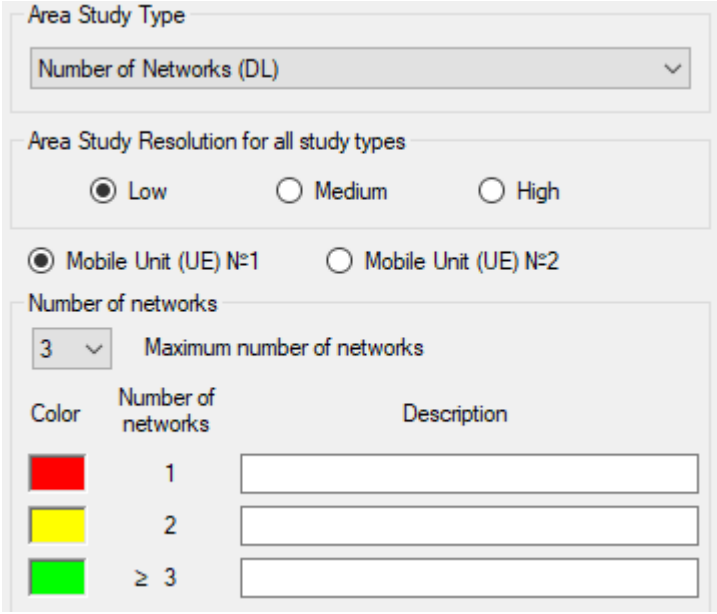


TalckOut and TalckBack Coverage Prediction

Coverage predictions for multiple networks

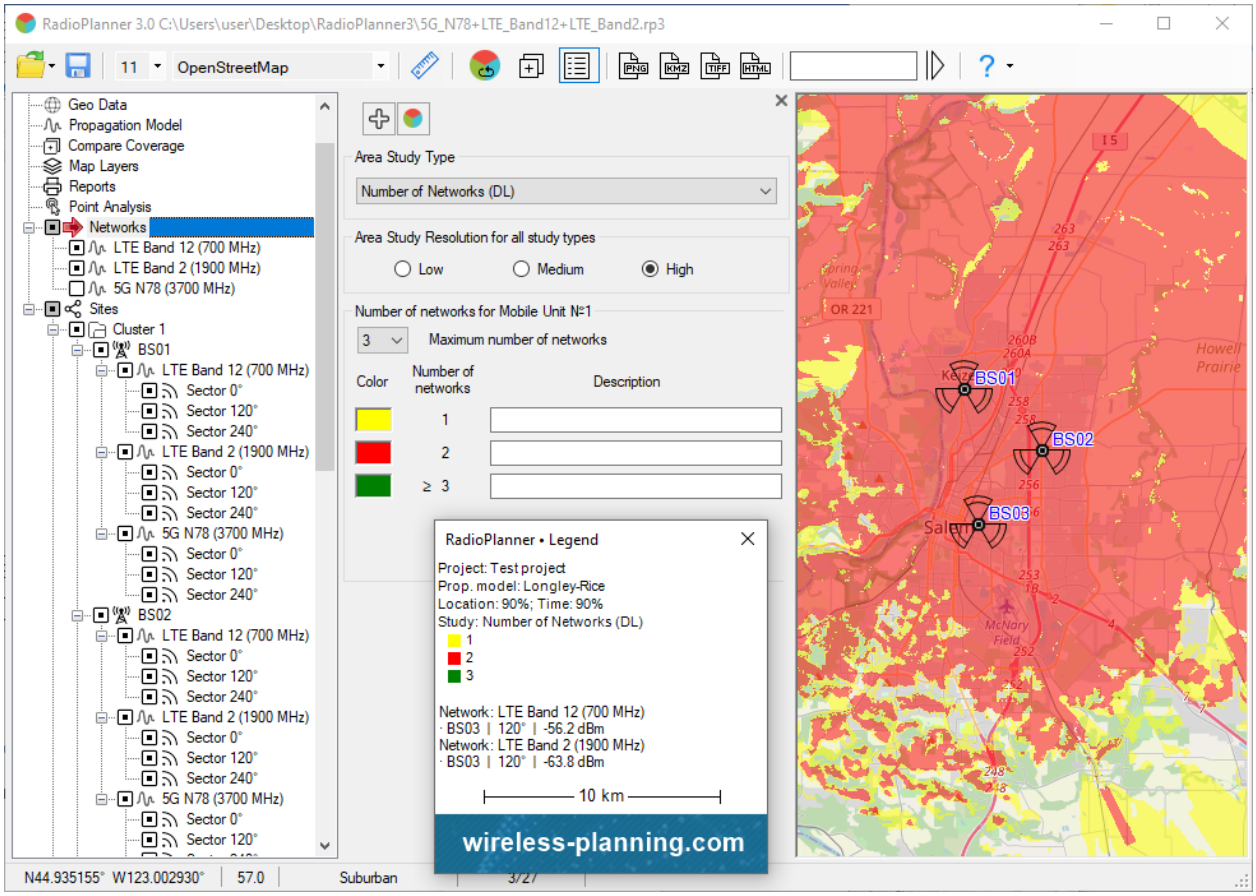
Number of Networks Downlink / Uplink

This prediction shows number of networks providing service at each calculation point for downlink or uplink. Calculation is performed for respective thresholds Rx of each network taken into account in calculation.



Number of Networks Downlink Study Type Parameters

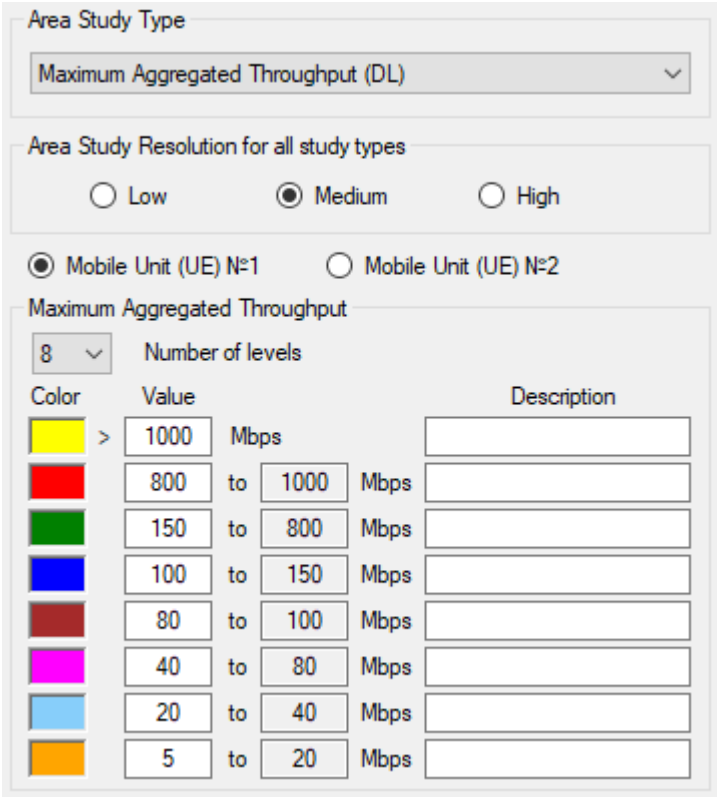
Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Maximum Number of Networks	Maximum number networks
Color	Color indicating the number of networks
Description	Text field



Number of Networks Downlink Coverage Prediction for LTE Band 12 and Band 2

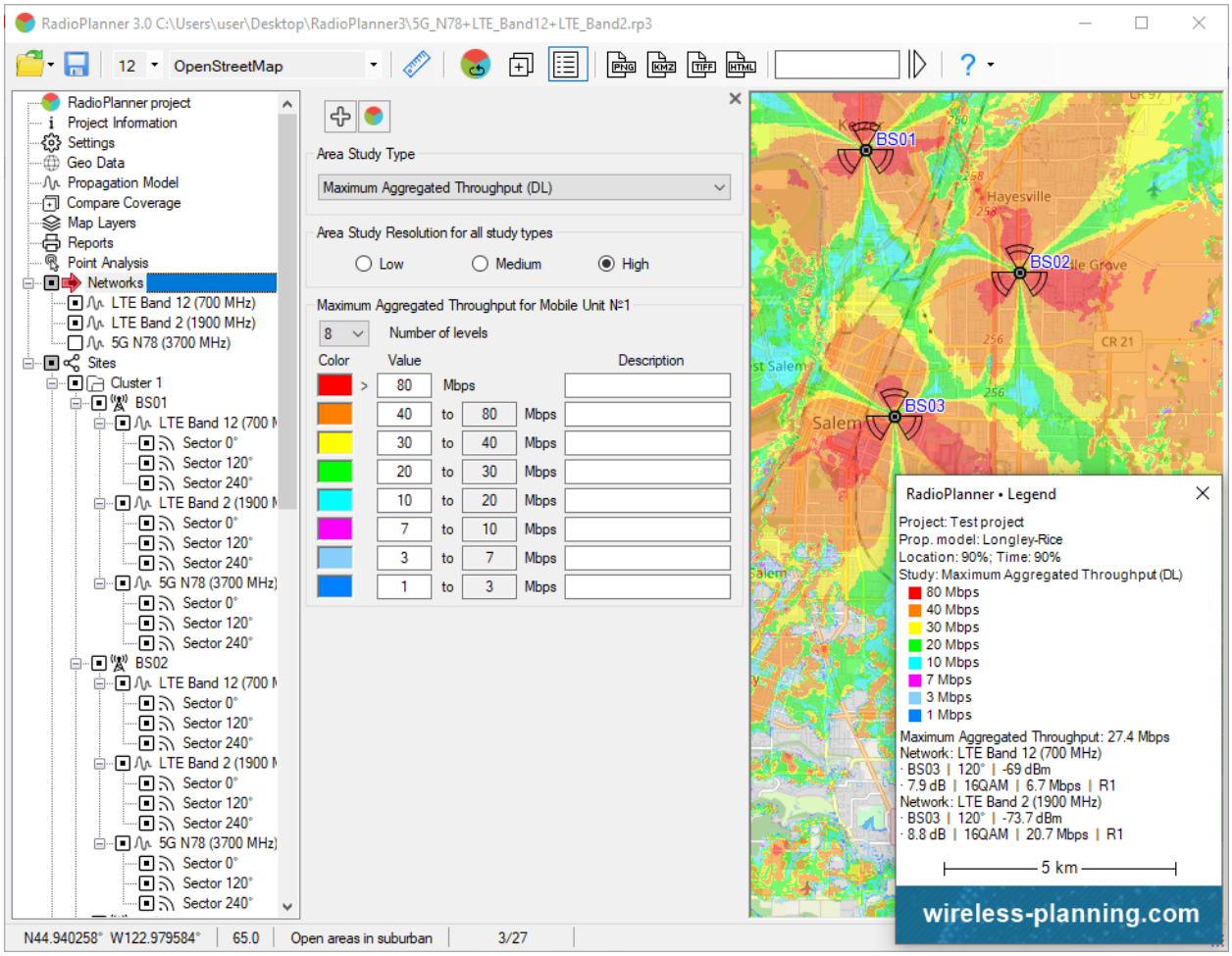
Maximum Aggregated Downlink / Uplink Throughput

This prediction type shows the total throughput at each point for all networks involved in the calculation.



Maximum Aggregated Downlink Throughput Study Type Parameters

Mobile Unit (UE) №1/№2	Select the mobile device for which the calculation will be made
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Maximum Aggregated Throughput, Mbps
Description	Text field



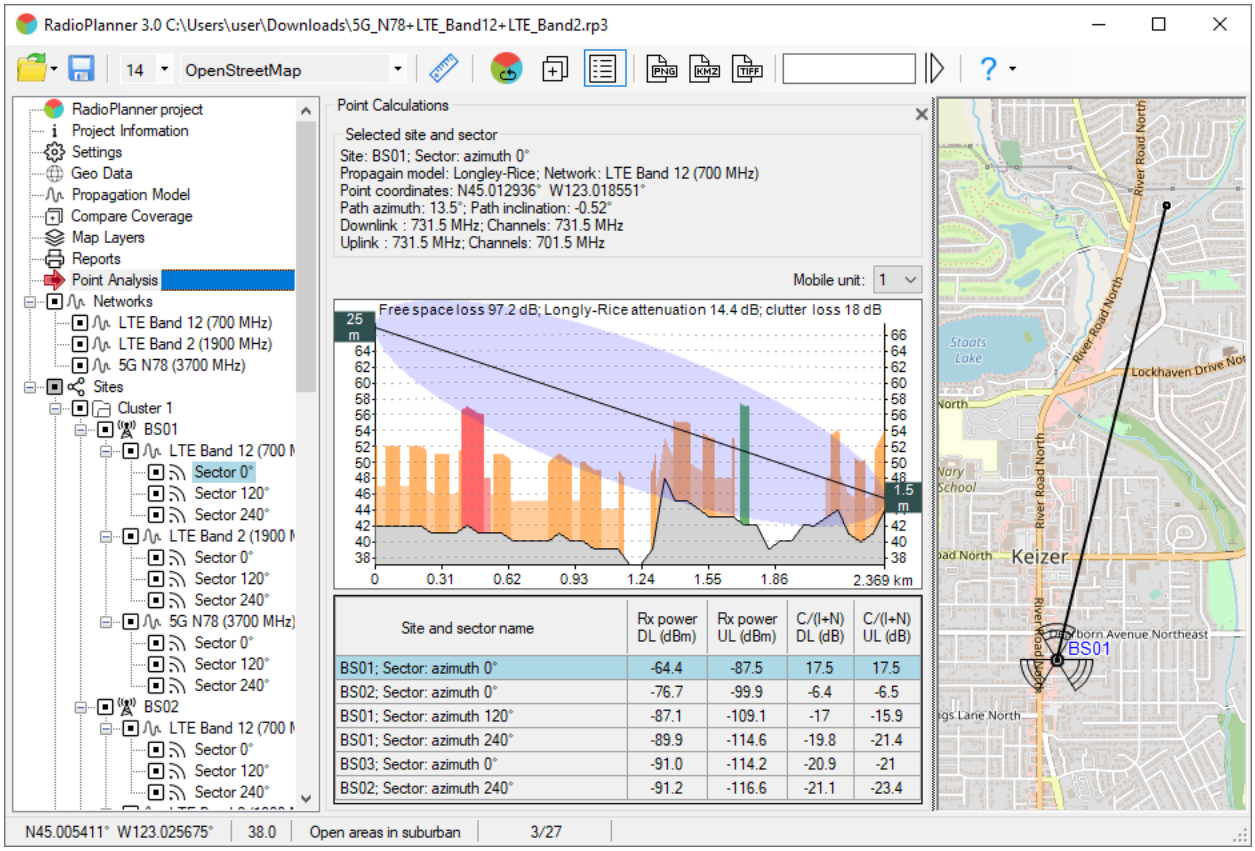
Maximum Aggregated Downlink Throughput Coverage Prediction for LTE Band 12 and Band 2

Point Analysis

In this panel, you can see detailed results of received signal power downlink and uplink calculation at any point as well as interference levels on co-channel and adjacent channels. The path profile is a vertical section of terrain between site and mobile unit with elevations and clutter information. Clutter height in path profile is determined by height for each clutter type set in Geo Data menu.

Click on “Point Analysis” and then find the required sector in the interface tree and click on it (do not confuse it with the activity tag). A path profile from the sector to the current point on the map will appear. You can change the current point on the map by clicking on the desired location.

The path profile shows the height of the antenna radiation center of the selected sector and mobile unit, as well as the Fresnel zone for the radio beam, loss in free space, diffraction loss due to terrain, and loss on clutter surrounding mobile unit.



Point Analysis

You can select a mobile unit (No. 1 or No. 2) whose parameters will be taken into account in calculations.

Under the path profile, a table appears with results of calculating power levels of downlink and uplink channels for selected sector (highlighted in color in table) and other sectors. Only sectors marked as active are included in calculation. For a sector to appear in table, received signal level must be greater than corresponding downlink or uplink Rx Threshold (see Network menu). Values in table can be sorted in ascending or descending order by clicking on corresponding field in table header.

The selected sector is considered to have a useful signal; signals from sectors with same frequency are considered co-channel interference, and signals from sectors whose frequencies are adjacent to selected sector are considered interference from adjacent channels. With this in mind, the table shows the calculated values of the interference level, taking into account noise and interference in the co-channel and adjacent channel.

Fixed Wireless Access

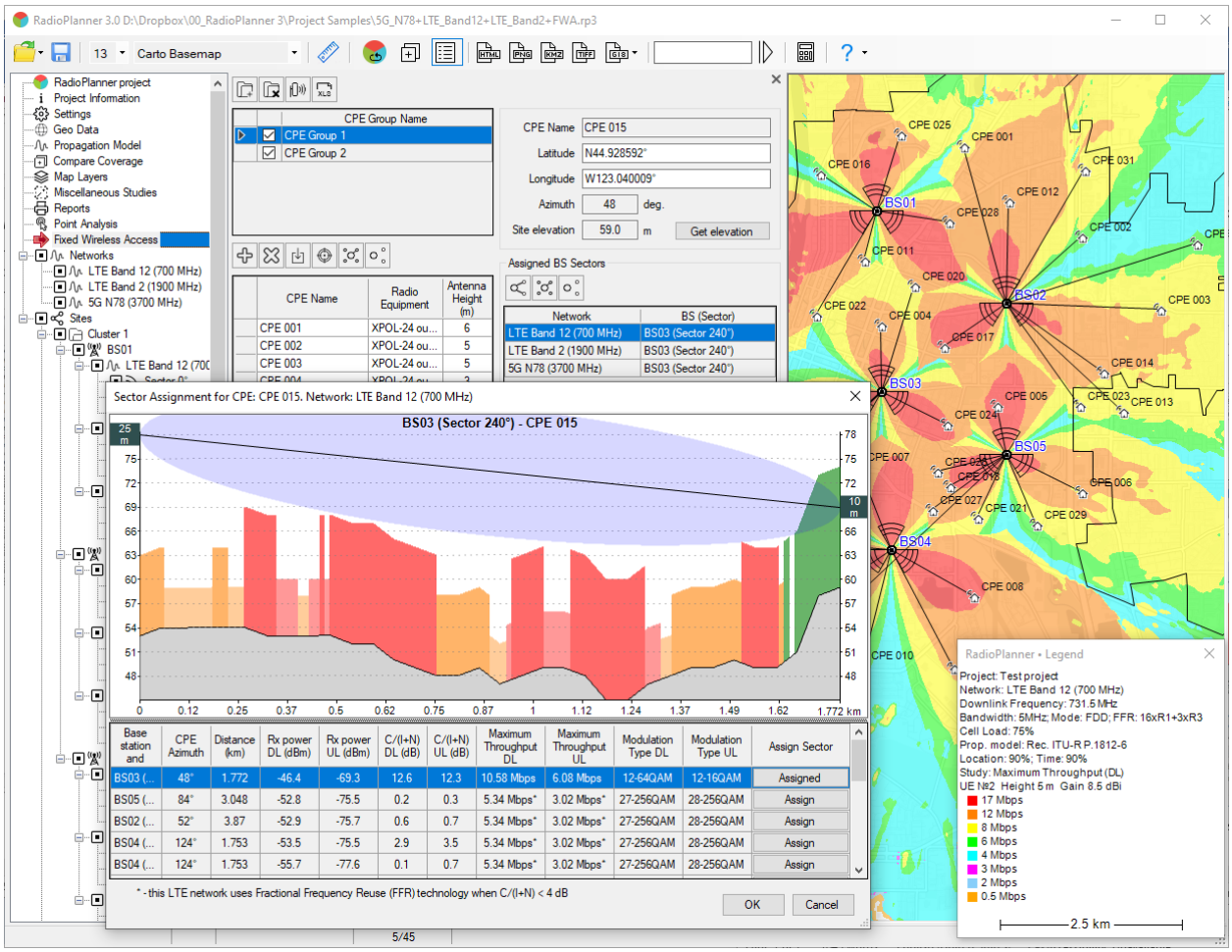
RadioPlanner 3.0 allows you to plan Fixed Wireless Access (FWA) and Internet of Things (IoT) networks such as LoRa, SigFox, and others.

Users can perform calculations for multiple Customer Premises Equipment (CPEs) or IoT sensors, each with their own individual parameters (antenna height, antenna gain, antenna pattern, transmitter power, cable loss, and penetration loss). For ease of use and display on the screen, users can create separate CPE groups.

In the Fixed Wireless Access panel, users can:

1. Import CPEs/Sensors from a CSV file or manually create new CPEs/Sensors on the map.
2. Use multiple types of CPE/Sensor equipment.
3. Adjust the antenna height for an individual CPE/Sensor or multiple CPEs in the table.
4. Manually or automatically assign CPEs/Sensors to Base Station (BS) sectors based on various criteria.
5. View path profiles from the selected CPEs/Sensors to nearby base stations.
6. Generate a single network report or an aggregate throughput summary report for CPEs/Sensors in Excel.

To display the CPE and the link to the assigned BS on the base map, a separate layer has been created in 'Map Layers'. Here, users can modify the CPE icon and line width. This layer can be saved in HTML, PNG, and KMZ coverage files.



Fixed Wireless Access panel

		Add a new CPE group
		Delete current CPE group
		Edit CPE Equipment
		Excel reports: - Full report on the selected network in Excel - Aggregate Bandwidth Summary Report in Excel (LTE/5G only)
		Add a CPE site as a copy of selected one

	Remove selected CPE site (full row has to be selected)
	Import a list of CPE sites from CSV file
	Position the map with CPE site at the center of the screen
	Automatic BS assignment for all CPEs. The selection criterion is defined in the lower right part of the panel.
CPE Name	CPE (End-device) name or ID
Latitude	CPE latitude in any of the formats that RadioPlanner allows (see the Setup menu)
Longitude	CPE longitude in any of the formats that RadioPlanner allows (see the Setup menu)
Azimuth	CPE antenna direction azimuth
Site elevation	Site elevation

CSV file format with CPE input data:

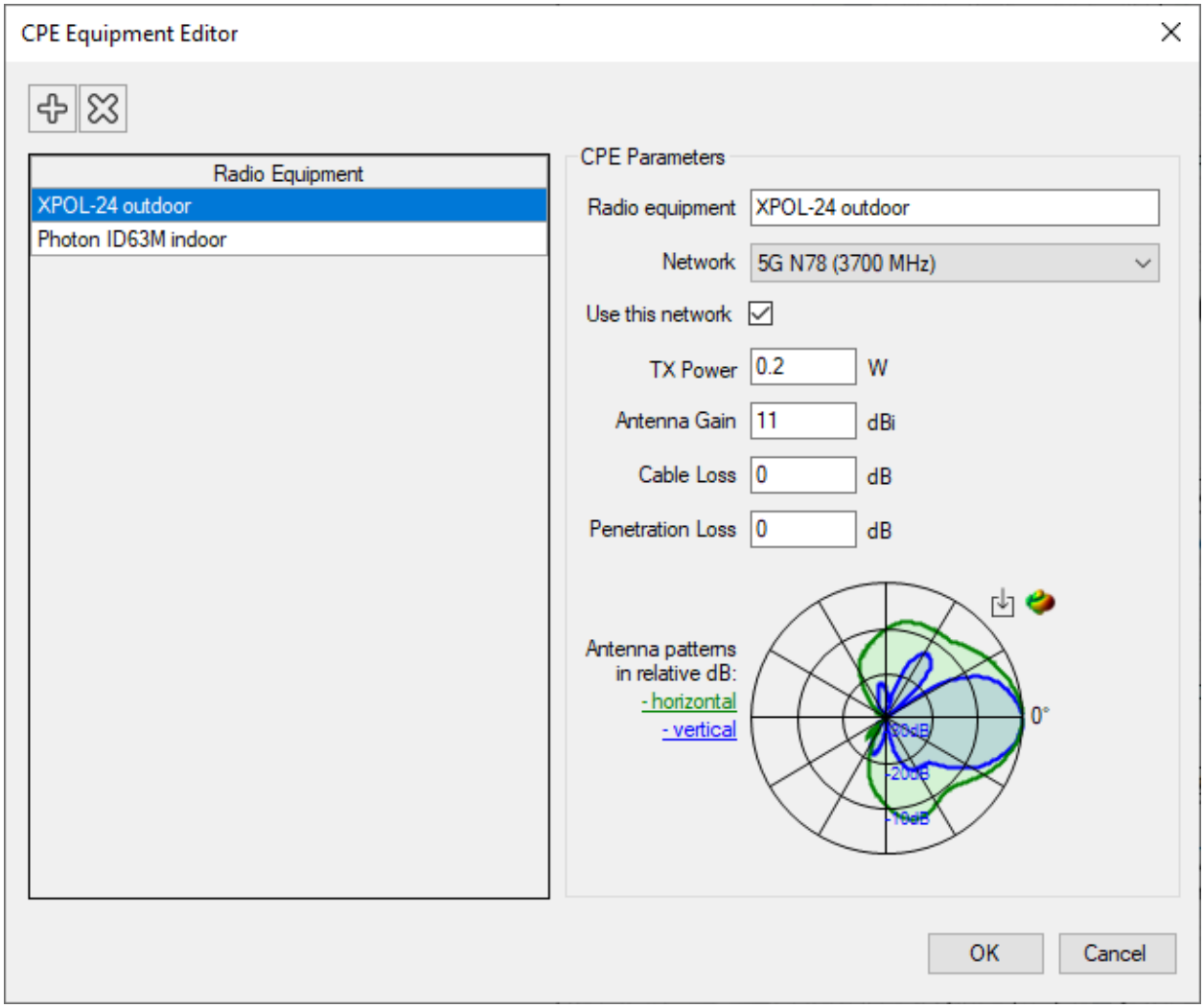
CPE/Sensor;Lat;Lon; Ant. height, m

for example:

CPE 001;44.96965602;-123.0091095;1.5

.....

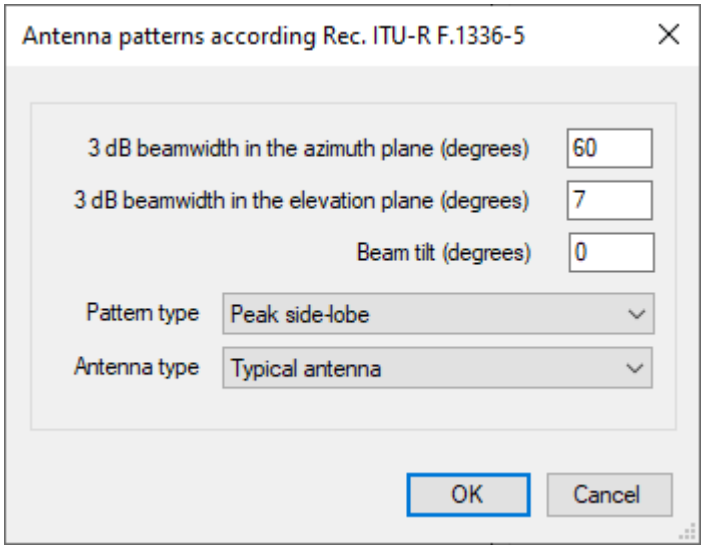
CPE 007;44.93005057;-123.0273056;3



CPE Equipment Editor

	Add a new CPE type with the same parameters as selected CPE
	Remove the CPE
Radio equipment	CPE Type (model)
Network	Network
Use this network	Select the checkbox if the CPE supports the selected network
Tx power, W	CPE transmitter power, W
Ant. gain, dBi	CPE antenna gain, dBi
Cable loss, dB	CPE cable loss, dB
Penetration loss, dB	Penetration loss into the building where the CPE is installed, dB
	Load MSI antenna pattern file
	Create antenna pattern using a reference model in accordance with Rec. ITU-R F.1336-5

The CPE equipment editor allows you to synthesize an antenna pattern using a reference model in accordance with Rec. ITU-R F.1336-5.



Creation of antenna pattern using a reference model in accordance with Rec. ITU-R F.1336-5

3 dB beamwidth in the azimuth plane (degree)	3 dB beamwidth in the azimuth plane (degree)
3 dB beamwidth in the elevation plane (degree)	3 dB beamwidth in the elevation plane (degree)
Beam tilt (degree)	Beam tilt (degree)
Pattern Type: - Peak side-lobe - Average side-lobe	Type of antenna pattern approximation: - on the peaks (maximums) of the side lobes - the average level of the side lobes
Antenna Type - Typical antenna - Improved side-lobe performance antenna	Antenna Type - Typical antenna - Improved side-lobe performance antenna

	Assign BS sector manually
	Automatic BS assignment for selected CPE in below selected network. The selection criterion is defined in the lower right part of the panel.
	Reset sector assignments
Assignment BS sectors by Best Server	Assignment of BS sectors according to the Best Server criterion
Assignment BS sectors by best SINR	Assignment of BS sectors based on the best SINR criterion

The calculation of CPE - BS links is carried out according to the parameters specified in the “Propagation Model” menu.

If you use the ITU-R P.1812/1546 propagation model for FWA calculations, then the **clutter loss will always take into account the clutter height**; these losses are determined for each end device taking into account the height of its antenna above ground level.

The calculation can also take into account building penetration losses for each CPE/end device. The output report for each CPE or end device will display the received downlink/uplink power, C/(I+N) ratio, modulation type, maximum throughput, and other parameters.

General Procedure for Working in the Fixed Wireless Access Menu:

1. Load a list of CPEs from a CSV file or create a CPE manually using the right mouse button in the context menu. The CSV file format is described above. If you already have CPEs in your table, then when importing from a CSV file, new ones will appear at the end of the table.

2. Create one or more types of CPE equipment in the "Edit CPE Equipment" menu. Please note that for one type of CPE equipment, parameters for different networks can be specified.

3. Specify the type of equipment for each CPE in the table. To do this, point to the desired cell with the equipment and select the required equipment from the list that appears. You can select several cells in the table at once and set one type of equipment for them.

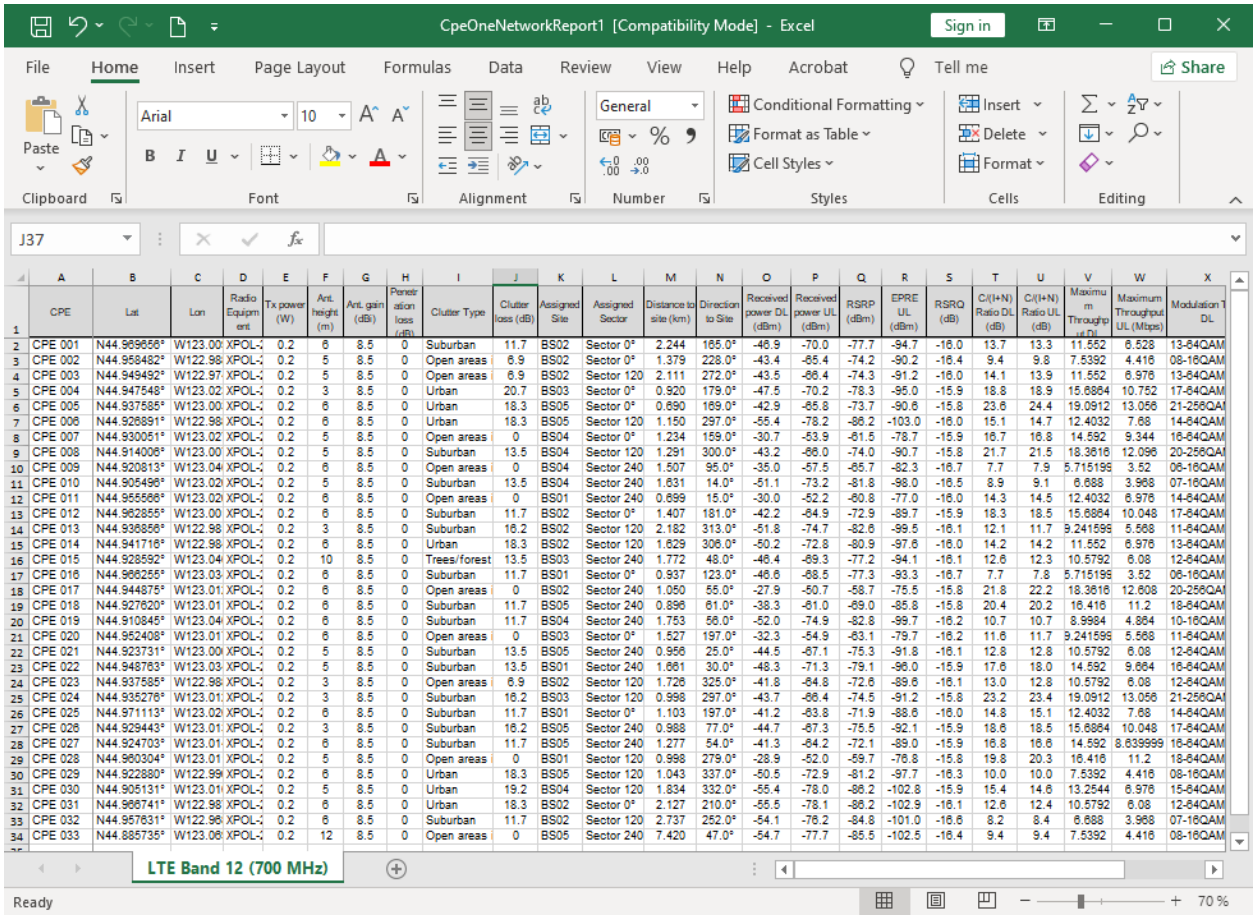
4. If your CSV file did not include data on antenna heights, or you created the CPE manually on the map, then indicate the antenna heights in the appropriate cells of the table. Here, it is also possible to select several cells at once and enter the same height for these cells.

5. If you want to assign BS sectors for all CPEs at once automatically, then select the criterion by which the assignment will be made - best server or best SINR - and click on the "Assign BS sectors for all CPE" button. After this, you will be asked to select a network for which the calculation and assignment of BS sectors will be carried out, and then automatic assignment will be performed. If there is only one network in the project, then automatic assignment will occur immediately. Please note that even if the CPE operates in different networks, it can be assigned and directed only to one BS site (the sectors are, of course, different). CPEs that do not have an assigned BS sector are displayed in the table in faded font.

6. If you want to view the path profile from the CPE to the BS sector or manually assign/reassign the BS sector, then first select the CPE you need in the main table, then select the desired network on the right and click on the "Assign BS Sector Manually" tool. In the window that opens with the path profile, you can select the sector you need, view the main calculation results, and assign/reassign the selected BS sector.

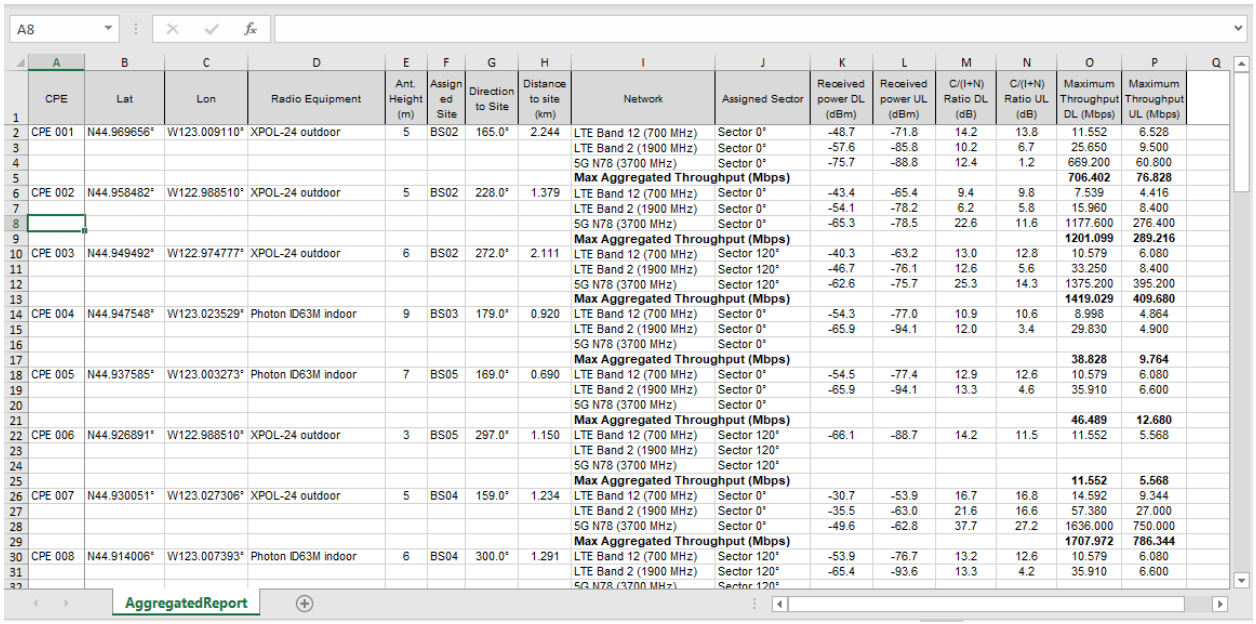
7. After the sector assignments have been completed for all CPEs, you can obtain the calculation results in Excel "*Full report on the selected network in Excel*" for one network or for several networks *"Aggregate Bandwidth Summary Report in Excel (LTE/5G only)*" . Only those networks that are marked in the main left menu “Networks” will be taken into account.

8. If the calculation results do not satisfy you, then change the parameters of the CPE (antenna height, equipment type, etc.) and perform the calculation again, and so on, until you get the desired result.



CPE	Lat	Lon	Radio Equipment	Tx power (W)	Ant. height (m)	Ant. gain (dBi)	Penetration loss (dB)	Clutter Type	Clutter loss (dB)	Assigned Site	Assigned Sector	Distance to site (km)	Direction to Site	Received power DL (dBm)	Received power UL (dBm)	RSRP (dBm)	EPRE UL (dBm)	RSRQ (dB)	C/(I+N) Ratio DL (dB)	C/(I+N) Ratio UL (dB)	Maximum Throughput DL	Maximum Throughput UL (Mbps)	Modulation DL
CPE 001	N44.969656°	W123.00	XPOL-2	0.2	6	8.5	0	Suburban	11.7	BS02	Sector 0°	2.244	165.0°	-46.9	-70.0	-77.7	-94.7	-16.0	13.7	13.3	11.552	6.528	13-64QAM
CPE 002	N44.958482°	W122.98	XPOL-2	0.2	5	8.5	0	Open areas	6.9	BS02	Sector 0°	1.379	228.0°	-43.4	-65.4	-74.2	-90.2	-16.4	9.4	9.8	7.5392	4.416	08-16QAM
CPE 003	N44.949492°	W122.97	XPOL-2	0.2	5	8.5	0	Open areas	6.9	BS02	Sector 120	2.111	272.0°	-43.5	-66.4	-74.3	-91.2	-16.0	14.1	13.9	11.552	6.976	13-64QAM
CPE 004	N44.947548°	W123.02	XPOL-2	0.2	3	8.5	0	Urban	20.7	BS03	Sector 0°	0.920	179.0°	-47.5	-70.2	-78.3	-95.0	-15.9	18.8	18.9	15.6864	10.752	17-64QAM
CPE 005	N44.937585°	W123.00	XPOL-2	0.2	6	8.5	0	Urban	18.3	BS05	Sector 0°	0.690	169.0°	-42.9	-65.8	-73.7	-90.6	-15.8	23.6	24.4	19.0912	13.056	21-256QAM
CPE 006	N44.926891°	W122.98	XPOL-2	0.2	6	8.5	0	Urban	18.3	BS05	Sector 120	1.150	297.0°	-55.4	-78.2	-86.2	-103.0	-16.0	15.1	14.7	12.4032	7.68	14-64QAM
CPE 007	N44.930051°	W123.02	XPOL-2	0.2	5	8.5	0	Open areas	0	BS04	Sector 0°	1.234	159.0°	-30.7	-53.9	-61.5	-78.7	-15.9	16.7	16.8	14.592	9.344	16-64QAM
CPE 008	N44.914006°	W123.00	XPOL-2	0.2	5	8.5	0	Suburban	13.5	BS04	Sector 120	1.291	300.0°	-43.2	-66.0	-74.0	-90.7	-15.8	21.7	21.5	18.3616	12.096	20-256QAM
CPE 009	N44.920813°	W123.04	XPOL-2	0.2	6	8.5	0	Open areas	0	BS04	Sector 240	1.507	95.0°	-35.0	-57.5	-65.7	-82.3	-16.7	7.7	7.9	5.715199	3.52	06-16QAM
CPE 010	N44.905496°	W123.02	XPOL-2	0.2	5	8.5	0	Suburban	13.5	BS04	Sector 240	1.631	14.0°	-51.1	-73.2	-81.8	-98.0	-16.5	8.9	9.1	6.688	3.968	07-16QAM
CPE 011	N44.955566°	W123.02	XPOL-2	0.2	6	8.5	0	Open areas	0	BS01	Sector 240	0.699	15.0°	-30.0	-52.2	-60.8	-77.0	-16.0	14.3	14.5	12.4032	6.976	14-64QAM
CPE 012	N44.962855°	W123.00	XPOL-2	0.2	6	8.5	0	Suburban	11.7	BS02	Sector 0°	1.407	181.0°	-42.2	-64.9	-72.9	-89.7	-15.9	18.3	18.5	15.6864	10.048	17-64QAM
CPE 013	N44.936856°	W122.98	XPOL-2	0.2	3	8.5	0	Suburban	16.2	BS02	Sector 120	2.182	313.0°	-51.8	-74.7	-82.6	-99.5	-16.1	12.1	11.7	9.241599	5.568	11-64QAM
CPE 014	N44.941716°	W122.98	XPOL-2	0.2	6	8.5	0	Urban	18.3	BS02	Sector 120	1.629	306.0°	-50.2	-72.8	-80.9	-97.6	-16.0	14.2	14.2	11.552	6.976	13-64QAM
CPE 015	N44.928592°	W123.04	XPOL-2	0.2	10	8.5	0	Trees/forest	13.5	BS03	Sector 240	1.772	48.0°	-46.4	-69.3	-77.2	-94.1	-16.1	12.6	12.3	10.5792	6.08	12-64QAM
CPE 016	N44.966255°	W123.03	XPOL-2	0.2	6	8.5	0	Suburban	11.7	BS01	Sector 0°	0.937	123.0°	-46.6	-68.5	-77.3	-93.3	-16.7	7.7	7.8	5.715199	3.52	06-16QAM
CPE 017	N44.944875°	W123.01	XPOL-2	0.2	6	8.5	0	Open areas	0	BS02	Sector 240	1.050	55.0°	-27.9	-50.7	-58.7	-75.5	-15.8	21.8	22.2	18.3616	12.608	20-256QAM
CPE 018	N44.927620°	W123.01	XPOL-2	0.2	6	8.5	0	Suburban	11.7	BS05	Sector 240	0.896	61.0°	-38.3	-61.0	-69.0	-85.8	-15.8	20.4	20.2	16.416	11.2	18-64QAM
CPE 019	N44.910845°	W123.04	XPOL-2	0.2	6	8.5	0	Suburban	11.7	BS04	Sector 240	1.753	56.0°	-52.0	-74.9	-82.8	-99.7	-16.2	10.7	10.7	8.9984	4.864	10-16QAM
CPE 020	N44.952408°	W123.01	XPOL-2	0.2	6	8.5	0	Open areas	0	BS03	Sector 0°	1.527	197.0°	-32.3	-54.9	-63.1	-79.7	-16.2	11.6	11.7	9.241599	5.568	11-64QAM
CPE 021	N44.923731°	W123.00	XPOL-2	0.2	5	8.5	0	Suburban	13.5	BS05	Sector 240	0.956	25.0°	-44.5	-67.1	-75.3	-91.8	-16.1	12.8	12.8	10.5792	6.08	12-64QAM
CPE 022	N44.948763°	W123.03	XPOL-2	0.2	5	8.5	0	Suburban	13.5	BS01	Sector 240	1.661	30.0°	-48.3	-71.3	-79.1	-96.0	-15.9	17.6	18.0	14.592	9.664	16-64QAM
CPE 023	N44.937585°	W122.98	XPOL-2	0.2	3	8.5	0	Open areas	6.9	BS02	Sector 120	1.726	325.0°	-41.8	-64.8	-72.6	-89.6	-16.1	13.0	12.8	10.5792	6.08	12-64QAM
CPE 024	N44.935276°	W123.01	XPOL-2	0.2	3	8.5	0	Suburban	16.2	BS03	Sector 120	0.998	297.0°	-43.7	-66.4	-74.5	-91.2	-15.8	23.2	23.4	19.0912	13.056	21-256QAM
CPE 025	N44.971113°	W123.02	XPOL-2	0.2	6	8.5	0	Suburban	11.7	BS01	Sector 0°	1.103	197.0°	-41.2	-63.8	-71.9	-88.6	-16.0	14.8	15.1	12.4032	7.68	14-64QAM
CPE 026	N44.929443°	W123.01	XPOL-2	0.2	3	8.5	0	Suburban	16.2	BS05	Sector 240	0.988	77.0°	-44.7	-67.3	-75.5	-92.1	-15.9	18.6	18.5	15.6864	10.048	17-64QAM
CPE 027	N44.924703°	W123.01	XPOL-2	0.2	6	8.5	0	Suburban	11.7	BS05	Sector 240	1.277	54.0°	-41.3	-64.2	-72.1	-89.0	-15.9	16.8	16.6	14.592	8.639999	16-64QAM
CPE 028	N44.960304°	W123.01	XPOL-2	0.2	5	8.5	0	Open areas	0	BS01	Sector 120	0.998	279.0°	-28.9	-52.0	-59.7	-76.8	-15.8	19.8	20.3	16.416	11.2	18-64QAM
CPE 029	N44.922880°	W122.99	XPOL-2	0.2	6	8.5	0	Urban	18.3	BS05	Sector 120	1.043	337.0°	-50.5	-72.9	-81.2	-97.7	-16.3	10.0	10.0	7.5392	4.416	08-16QAM
CPE 030	N44.905131°	W123.01	XPOL-2	0.2	5	8.5	0	Urban	19.2	BS04	Sector 120	1.834	332.0°	-55.4	-78.0	-86.2	-102.8	-15.9	15.4	14.6	13.2544	6.976	15-64QAM
CPE 031	N44.966741°	W122.98	XPOL-2	0.2	6	8.5	0	Urban	18.3	BS02	Sector 0°	2.127	210.0°	-55.5	-78.1	-86.2	-102.9	-16.1	12.6	12.4	10.5792	6.08	12-64QAM
CPE 032	N44.957631°	W122.96	XPOL-2	0.2	6	8.5	0	Suburban	11.7	BS02	Sector 120	2.737	252.0°	-54.1	-76.2	-84.8	-101.0	-16.6	8.2	8.4	6.688	3.968	07-16QAM
CPE 033	N44.885735°	W123.06	XPOL-2	0.2	12	8.5	0	Open areas	0	BS05	Sector 240	7.420	47.0°	-54.7	-77.7	-85.5	-102.5	-16.4	9.4	9.4	7.5392	4.416	08-16QAM

Full report on the selected network in Excel



CPE	Lat	Lon	Radio Equipment	Ant. Height (m)	Assigned Site	Direction to Site	Distance to site (km)	Network	Assigned Sector	Received power DL (dBm)	Received power UL (dBm)	C/(I+N) Ratio DL (dB)	C/(I+N) Ratio UL (dB)	Maximum Throughput DL (Mbps)	Maximum Throughput UL (Mbps)
CPE 001	N44.969656°	W123.009110°	XPOL-24 outdoor	5	BS02	165.0°	2.244	LTE Band 12 (700 MHz)	Sector 0°	-48.7	-71.8	14.2	13.8	11.552	6.528
								LTE Band 2 (1900 MHz)	Sector 0°	-57.6	-85.8	10.2	6.7	25.650	9.500
								5G N78 (3700 MHz)	Sector 0°	-75.7	-88.8	12.4	1.2	669.200	60.800
								Max Aggregated Throughput (Mbps)						**706.402**	**76.828**
CPE 002	N44.958482°	W122.988510°	XPOL-24 outdoor	5	BS02	228.0°	1.379	LTE Band 12 (700 MHz)	Sector 0°	-43.4	-65.4	9.4	9.8	7.539	4.416
								LTE Band 2 (1900 MHz)	Sector 0°	-54.1	-78.2	6.2	5.8	15.960	8.400
								5G N78 (3700 MHz)	Sector 0°	-65.3	-78.5	22.6	11.6	1177.600	276.400
								Max Aggregated Throughput (Mbps)						**1201.099**	**289.216**
CPE 003	N44.949492°	W122.974777°	XPOL-24 outdoor	6	BS02	272.0°	2.111	LTE Band 12 (700 MHz)	Sector 120°	-40.3	-63.2	13.0	12.8	10.579	6.080
								LTE Band 2 (1900 MHz)	Sector 120°	-46.7	-76.1	12.6	5.6	33.250	8.400
								5G N78 (3700 MHz)	Sector 120°	-62.6	-75.7	25.3	14.3	1375.200	395.200
								Max Aggregated Throughput (Mbps)						**1419.029**	**409.680**
CPE 004	N44.947548°	W123.023529°	Photon ID63M indoor	9	BS03	179.0°	0.920	LTE Band 12 (700 MHz)	Sector 0°	-54.3	-77.0	10.9	10.6	8.998	4.864
								LTE Band 2 (1900 MHz)	Sector 0°	-65.9	-94.1	12.0	3.4	29.830	4.900
								5G N78 (3700 MHz)	Sector 0°						
								Max Aggregated Throughput (Mbps)						**38.828**	**9.764**
CPE 005	N44.937585°	W123.003273°	Photon ID63M indoor	7	BS05	169.0°	0.690	LTE Band 12 (700 MHz)	Sector 0°	-54.5	-77.4	12.9	12.6	10.579	6.080
								LTE Band 2 (1900 MHz)	Sector 0°	-65.9	-94.1	13.3	4.6	35.910	6.600
								5G N78 (3700 MHz)	Sector 0°						
								Max Aggregated Throughput (Mbps)						**46.489**	**12.680**
CPE 006	N44.926891°	W122.988510°	XPOL-24 outdoor	3	BS05	297.0°	1.150	LTE Band 12 (700 MHz)	Sector 120°	-66.1	-88.7	14.2	11.5	11.552	5.568
								LTE Band 2 (1900 MHz)	Sector 120°						
								5G N78 (3700 MHz)	Sector 120°						
								Max Aggregated Throughput (Mbps)						**11.552**	**5.568**
CPE 007	N44.930051°	W123.027306°	XPOL-24 outdoor	5	BS04	159.0°	1.234	LTE Band 12 (700 MHz)	Sector 0°	-30.7	-53.9	16.7	16.8	14.592	9.344
								LTE Band 2 (1900 MHz)	Sector 0°	-35.5	-63.0	21.6	16.6	57.380	27.000
								5G N78 (3700 MHz)	Sector 0°	-49.6	-62.8	37.7	27.2	1636.000	750.000
								Max Aggregated Throughput (Mbps)						**1707.972**	**786.344**
CPE 008	N44.914006°	W123.007393°	Photon ID63M indoor	6	BS04	300.0°	1.291	LTE Band 12 (700 MHz)	Sector 120°	-53.9	-76.7	13.2	12.6	10.579	6.080
								LTE Band 2 (1900 MHz)	Sector 120°	-65.4	-93.6	13.3	4.2	35.910	6.600
								5G N78 (3700 MHz)	Sector 120°						

Aggregate Bandwidth Summary Report in Excel (LTE/5G only)

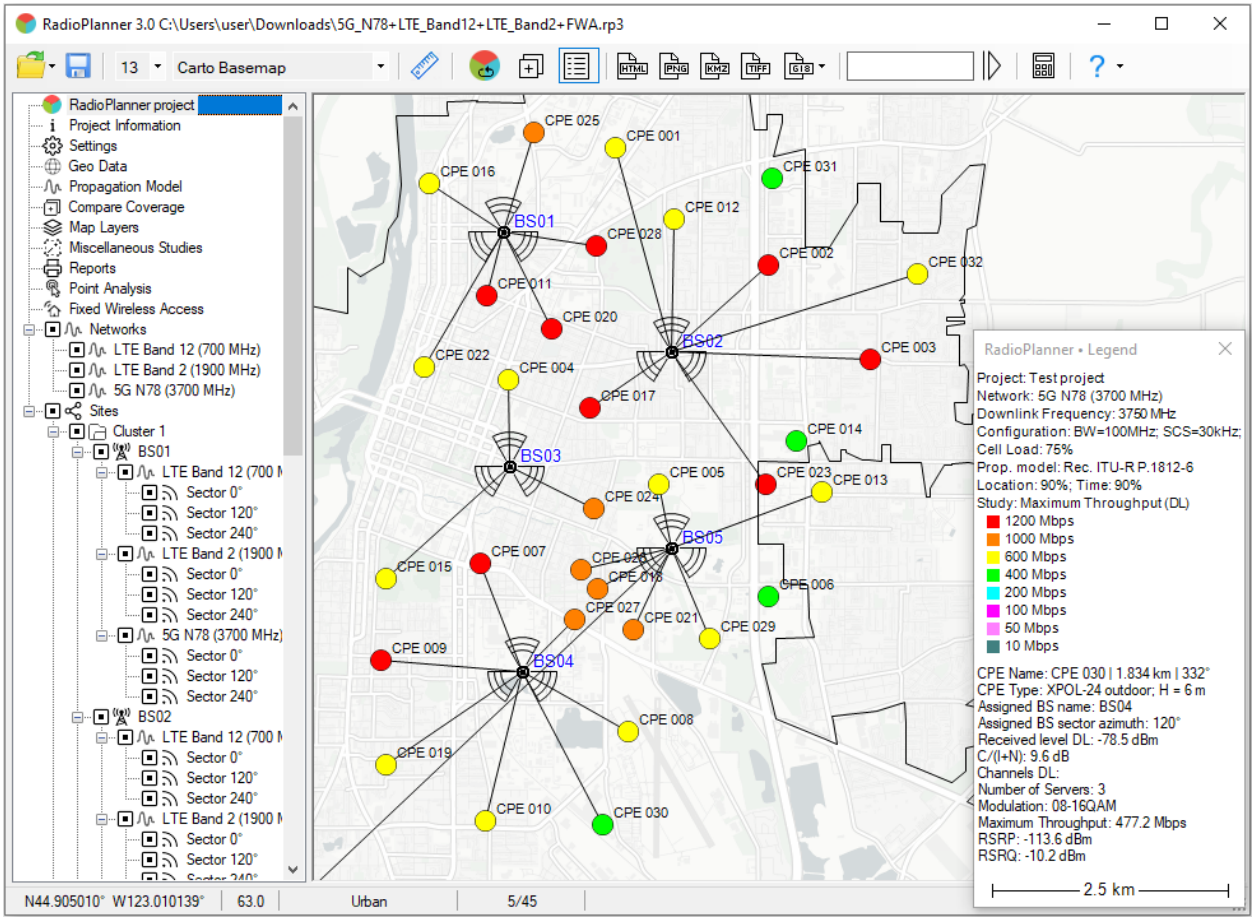
Coverage prediction for Fixed Wireless Access network

RadioPlanner 3.0 enables the display of coverage predictions for a Fixed Wireless Access (FWA) network or an IoT network (such as LoRaWAN) on a map. The algorithm used to calculate coverage for CPEs or IoT sensors differs from the one used for mobile units. This difference stems from the fact that while calculating mobile network coverage, the characteristics of one of two typical mobile units (UE1 or UE2) are considered. However, when calculating FWA coverage, the individual characteristics of each CPE or sensor are taken into account. These include antenna height, antenna gain, antenna pattern, transmitter power, losses in the cable, and building penetration losses. As a result, coverage prediction results are more accurate.

Upon calculation, a small circle will appear at the location of each CPE or sensor. The color of this circle will correspond to the result of the selected study type. The study type can be chosen from the menu of the corresponding network, and the calculation can be initiated there using a special tool 'Calculate FWA Coverage'.

If a CPE/Sensor has an assigned BS sector, then the coverage calculation will be performed for this BS sector. If the CPE/Sensor does not have an assigned BS sector, then the coverage calculation will be performed for the sector with the best power at the receiver (Best Server).

When you hover your mouse over the CPE circle, the equipment parameters and calculation results will be displayed on the Legend.



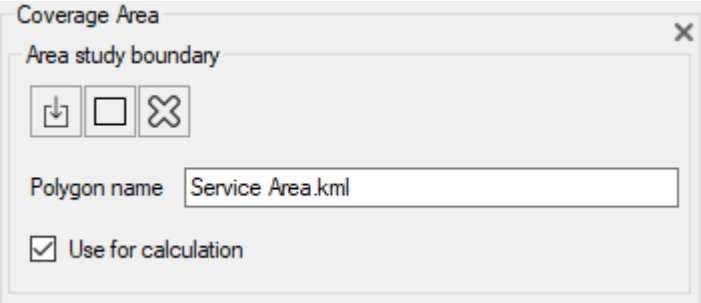
Coverage prediction for Fixed Wireless Access network

Miscellaneous Studies

Area study boundary

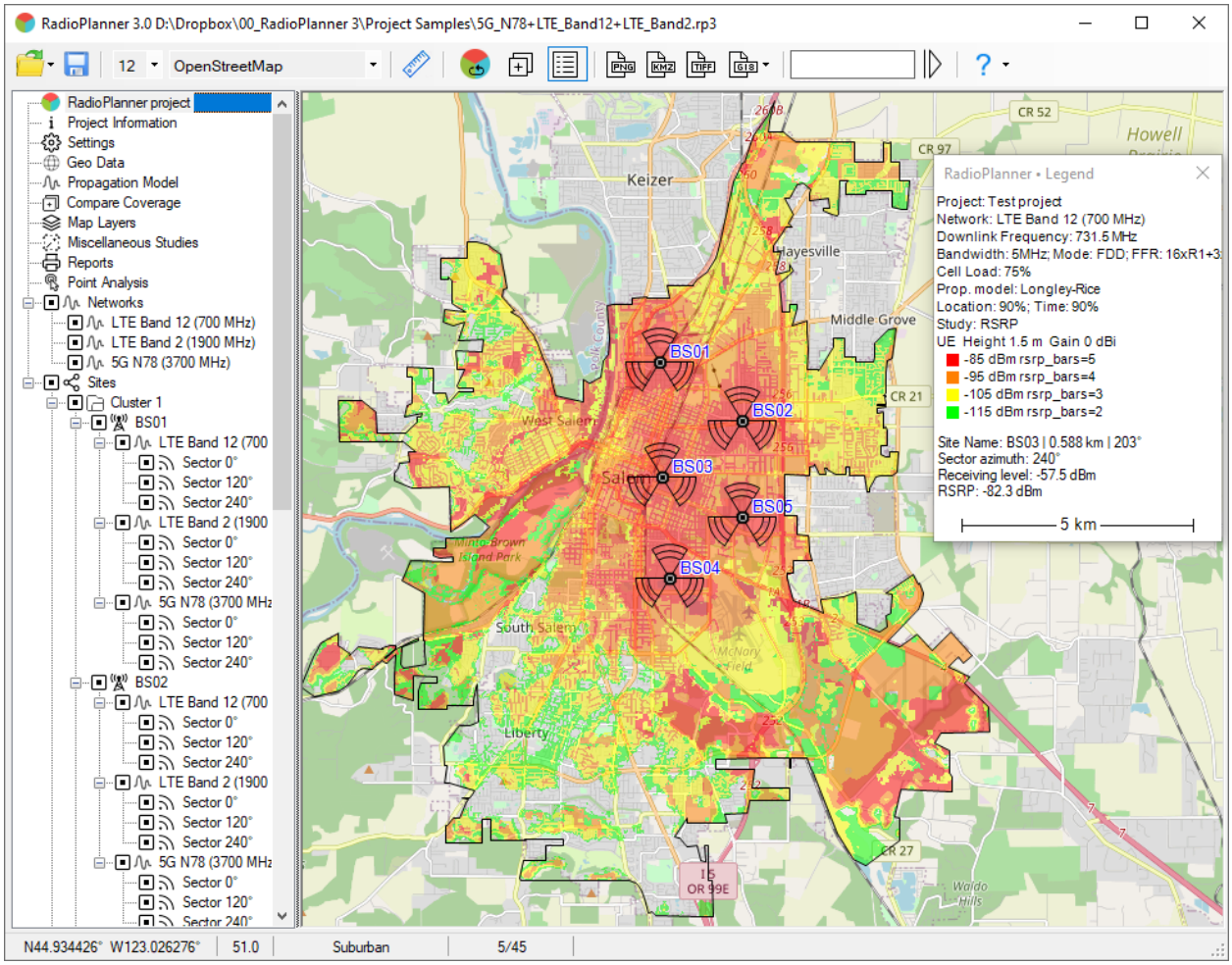
You can specify the area on which the coverage area will be cropped. The boundaries of a rectangular area can be set manually, or you can upload an arbitrary area in KML format.

U.S. community and county boundary in KML format is available on FCC website
https://www.fcc.gov/media/radio/us-community-boundary-overlays-kml



Area study boundary

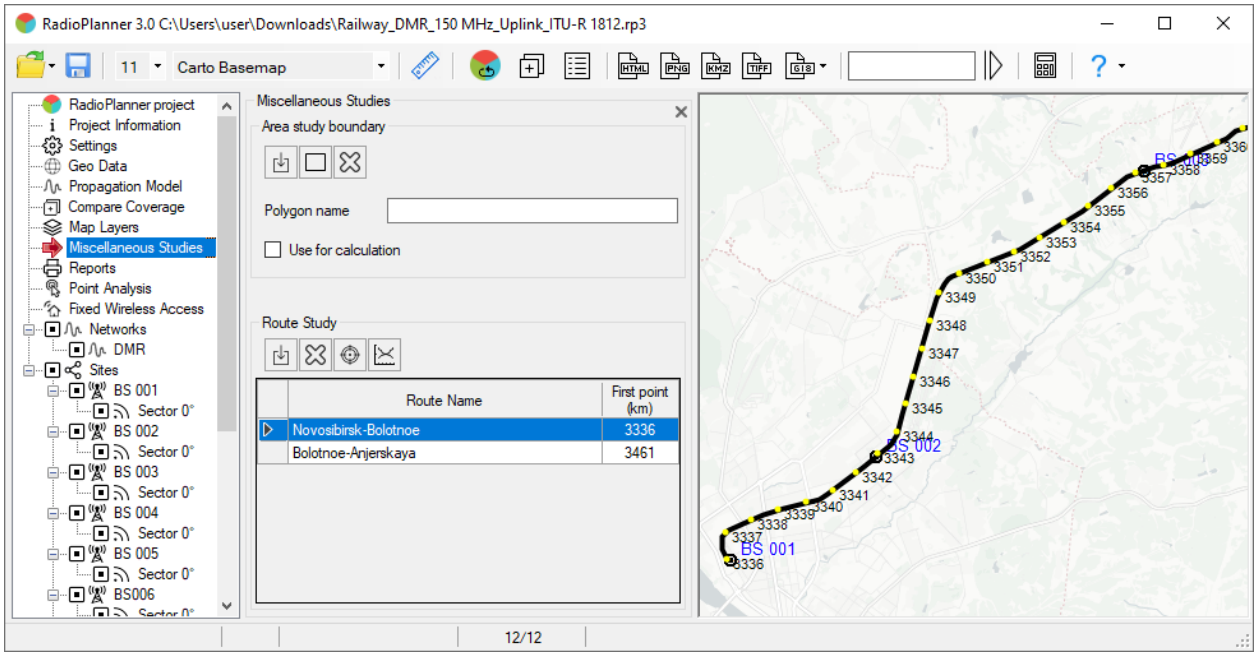
	Import polygon from KML file
	Define area as a rectangle
	Delete polygon
Use for calculation	Crop the coverage at the area boundary



Coverage prediction based on area study boundaries

Route Study

The Route Study feature allows you to construct graphs of received power levels, C/(I+N), or a throughput graph along any extended object such as a pipeline, railway, or highway, etc.



Route Study menu

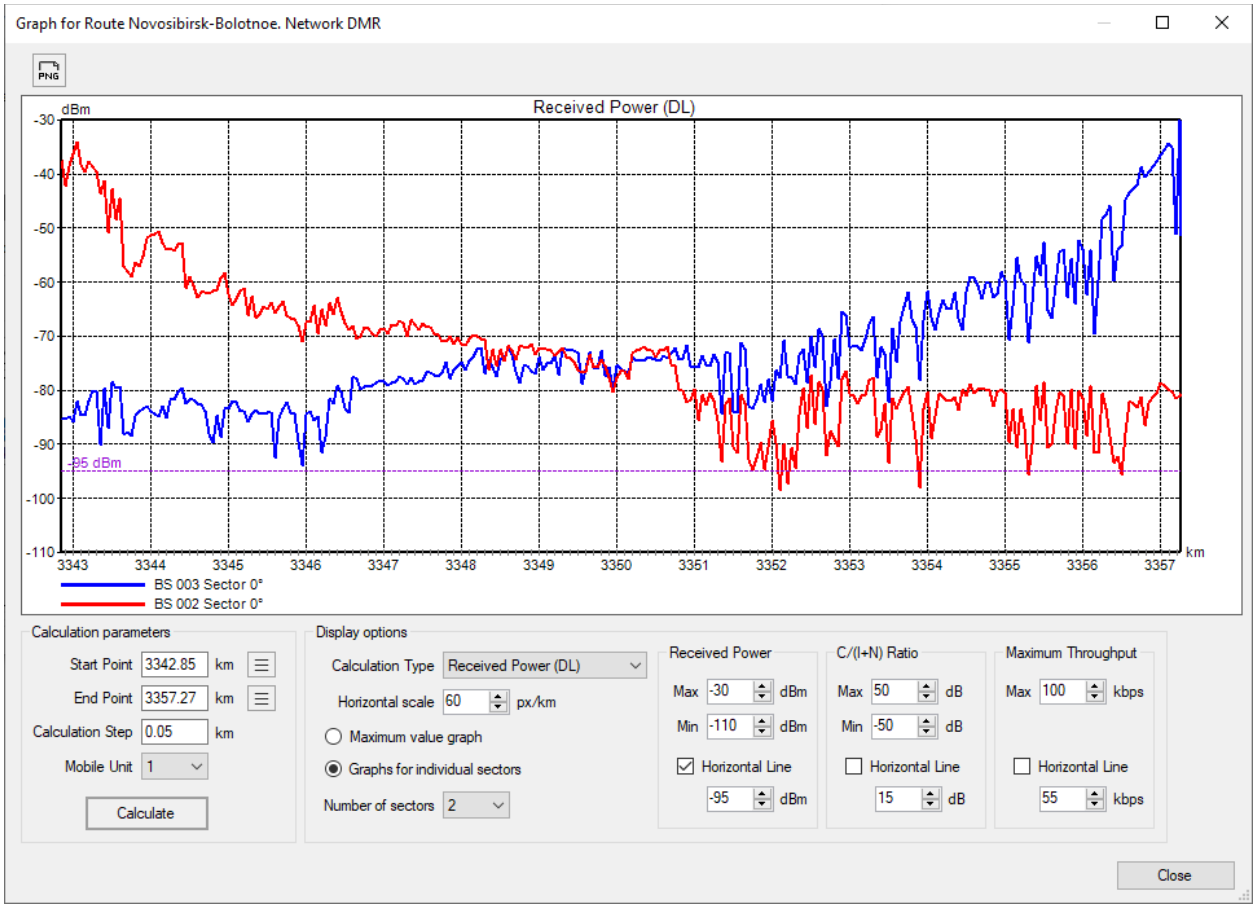
Import route from KML file

Delete Route

Position the map with the route first point at the center of the screen

Display Route Graph

The route for which the calculation will be performed is loaded from a KML file. This file can be prepared in any third-party software, for example, Google Earth. There can be multiple routes. You can specify any desired value as the marker for the first point of a linear section. The remaining kilometer markers will be placed on the map along the route automatically. To construct graphs, double-click on the desired route or use the 'Display Route Graph' tool.



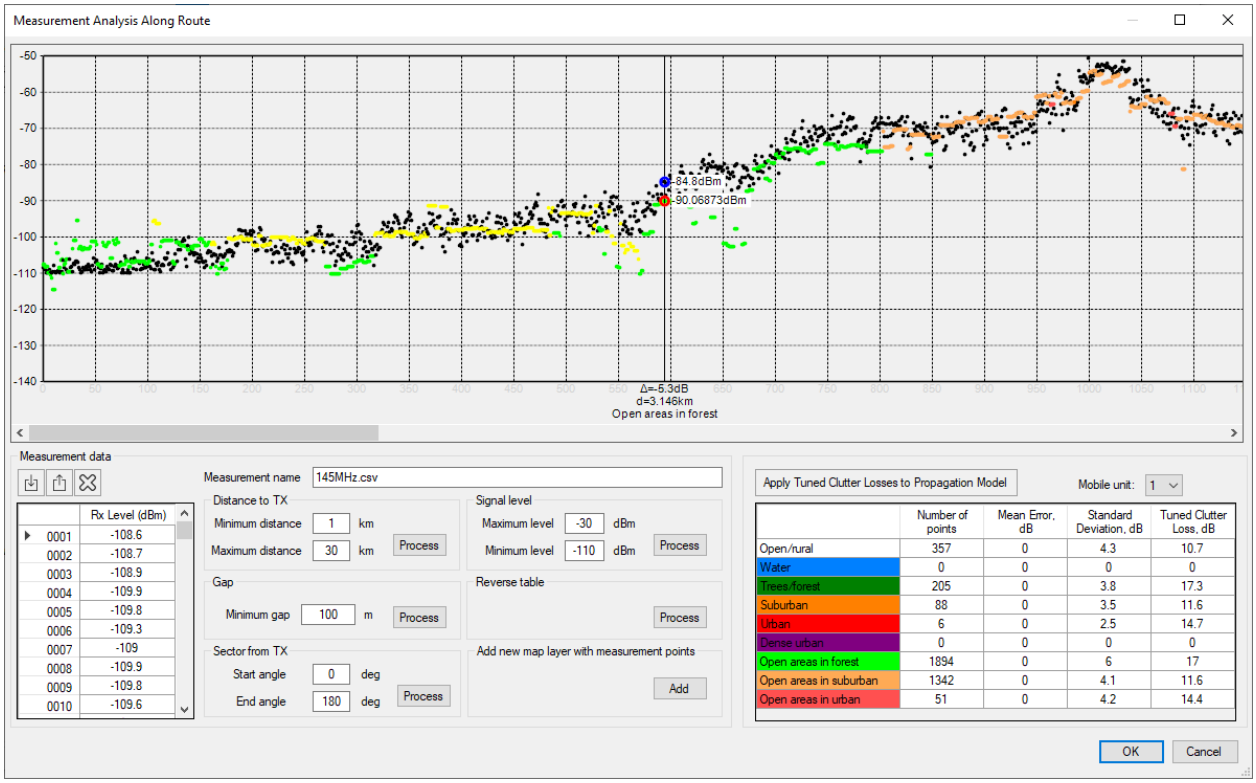
Route Graph

PNG	Save the graph in PNG format. The original size will remain
Start Point	Starting point of the graph
End Point	End point of the graph
☰	Determine the point with the minimum distance from the selected BS to the route
Calculation Step	Calculation step. Minimum step 20m.
Mobile unit	Mobile unit (UE)
Calculate	Perform calculation
Calculation Type	Calculation Type

Horizontal scale	Horizontal scale of the graph in pixels per kilometer
Maximum value graph	Maximum value graph
Graphs for individual sectors	Display a graph for individual sectors. This feature allows you to display a graph for individual sectors. The sectors displayed on the graph are determined automatically based on the maximum level of the integral reception Rx power on a given section of the route. If the algorithm for automatically determining sectors does not function (which happens very rarely), it is recommended to manually select the necessary BS sectors for calculation in the main left menu.
Number of sectors	Number of displayed sectors. Maximum 5 BS sectors.
Received Power	Set the maximum and minimum reception level values on the graph
C/(I+N) Ratio	Set the maximum and minimum values of C/(I+N) on the graph
Maximum Throughhput	Set maximum and minimum throughput values on the graph
Horizontal Line	Display a horizontal line with the specified value on the graph

Measurement Results Analysis and Propagation Model Tuning

RadioPlanner 3.0 allows you to tune clutter loss for a propagation model by comparing measurements with predicted Rx power values. Loading, preprocessing and analysis of measurement file for each sector is performed in Sector parameters panel.



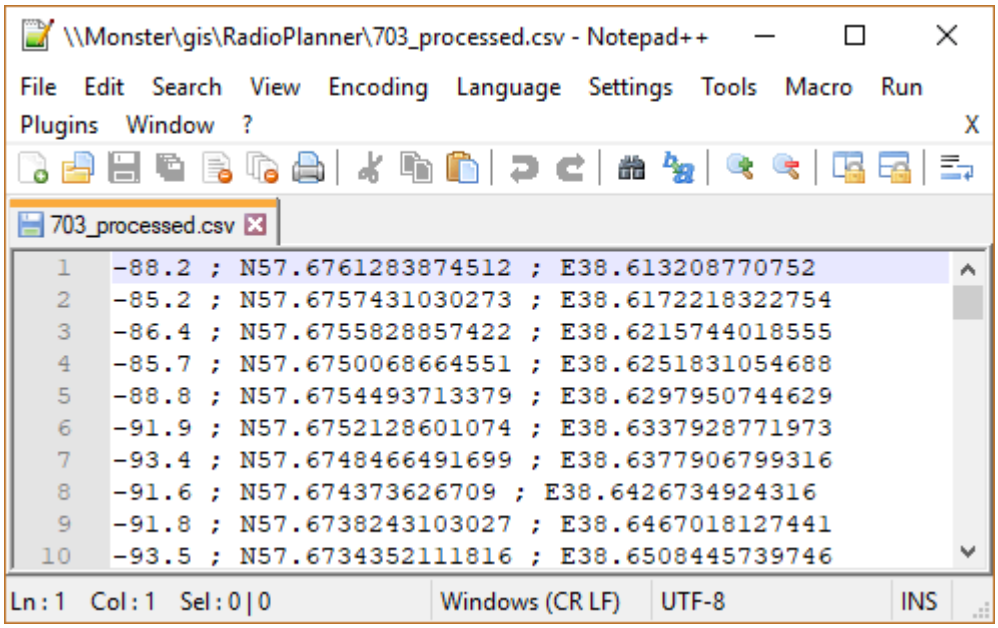
Measurement Analysis Along Route

Import of measurement data from a CSV file

Export of measurement data to a CSV file

Delete all measurement points

First prepare a file of received power levels for required site sector. The measurement file is a CSV format file with each line containing three parameters: level of measured signal from one sector in dBm; geographical latitude; geographic longitude. The separator of parameter values is semicolon. Formats for representation of geographic coordinates are Hemisphere Degrees SECOND MINUTES (N35 36 23.8) or HEM DECIMAL DEGREES (N12.34567).



Sample Measurement File

Upload measurement file to appropriate sector and perform preliminary processing if necessary:

Signal level Minimum/Maximum Level	Limit the measurement points by received power level from the site
Distance to TX Minimum/Maximum Distance	Limit the measurement points by distance from the site
Sector from Site Minimum/Maximum Angle	Limit the measurement points by azimuth from the site
Gap Minimum Gap	Perform measurement points power level averaging within a given distance
Reverse table	Change the order of measurement points in the route (the last point becomes the first, the penultimate point becomes the second, and so on)
Add New Layer with Measurement Points	Add a custom measurement layer to the map. The resulting layer will appear among the user layers; the layer name will determinate to the site name and sector direction.

On the results scatter-plot, measurement levels are indicated in black, while predicted values are indicated in a color corresponding to the clutter type at a given point (e.g., yellow for open space). The x-axis displays the waypoint numbers. When hovering the cursor over the graph, calculated and measured

levels, level difference, distance to the site (in kilometers), and clutter type are displayed. When you click on the plot, a context menu appears, in which you can delete a point with the measurement result.

Below the plot is a table that displays the number of points, mean error, standard deviation of error, and recommended loss values for different clutter types that will result in an average error of zero. Clicking the “Apply Tuned Clutter Losses to Propagation Model” button changes the clutter loss values in the “Propagation Model” menu and recalculates the plot point values based on the tuned loss values. To assess the impact of the new clutter loss values on coverage calculation results, coverage must be recalculated.

A decision is made regarding the need to tune previously used clutter loss values in the propagation model based on an analysis of results obtained for different clutter types and sectors.

Saving the Coverage Calculation Result

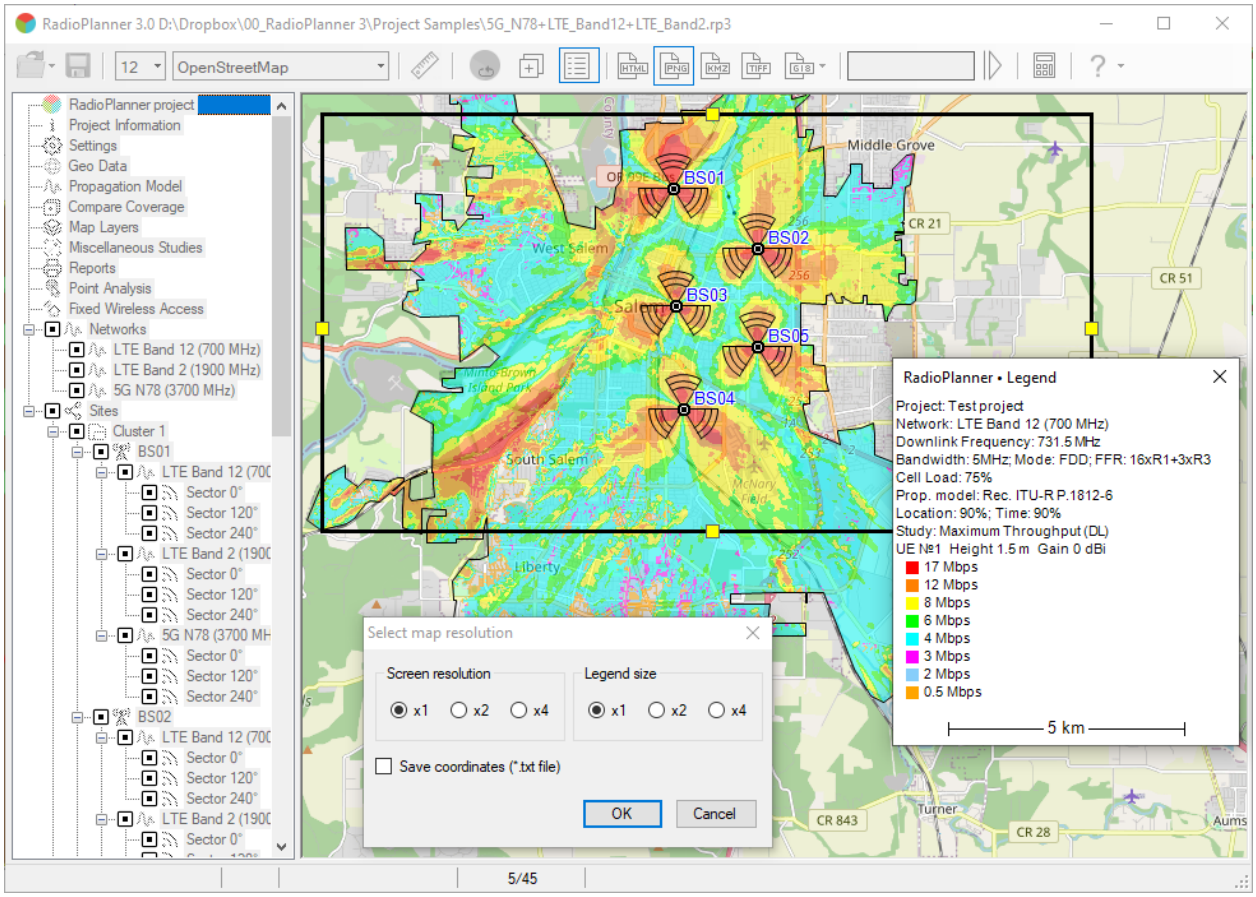
Coverage prediction result can be saved as:

- Image file in PNG format
- Interactive web page in HTML format
- KMZ file
- Image file in GeoTiff format
- Text CSV file - a set of points with coordinates and a received power / a field strength
- Exchange file MapInfo (MIF + MID) - a set of squares with the attribute as received power / a field strength

Save the map as a PNG image - Save result of coverage calculation as image file in *.png format. Before saving image, you can select area of saved coverage using frame (you can move both border of frame and map itself). When saving image, you also select its resolution. Resolution may correspond with current size or be two or four times larger. The better resolution, larger size of saved file.

Maximum size of bitmap image is approximately 5400x4400 pixels; file size in *.png format is about 10 MB. If Legend is active, it will appear in upper left corner of saved image. Save coordinates (*.txt file): Saves text file with same name as image file. Coordinates of corners of image are written into text file.

In the exported PNG image, the Legend will be relative to the coverage in the same place as on the screen. In addition, when exporting to a PNG file, you can change the size of the Legend.

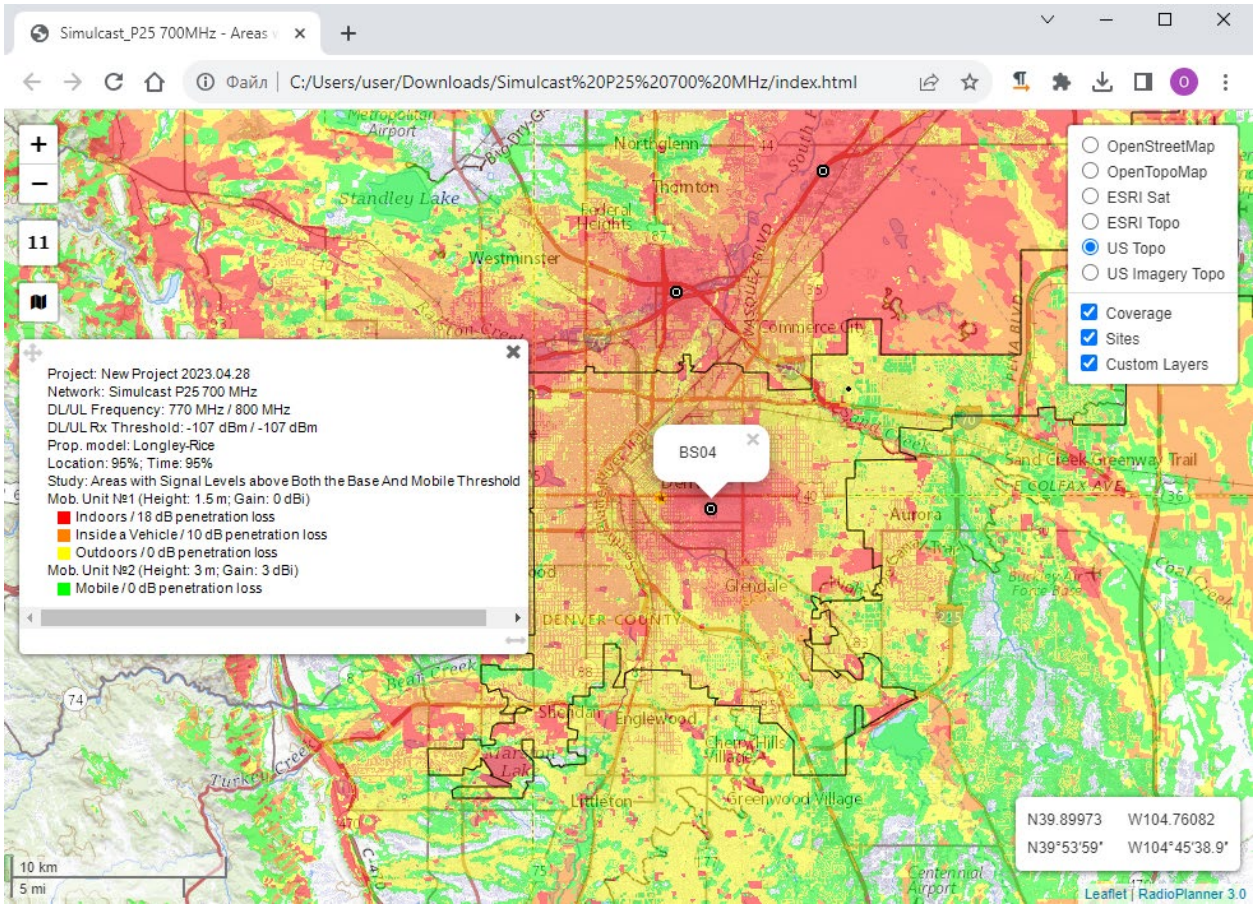


Selecting the area and resolution of the saved image

Save the map as a WEB page - Save result of calculation as interactive webpage. Application allows user to select location and name of directory where result is saved. The index.html file (page script), bs.png file (site icon), and folder with radio coverage tile pyramid {ZOOM}/{X}/{Y} will be saved to specified directory. To open webpage, open index.html file using browser (Google Chrome, Mozilla Firefox, Internet Explorer, etc.). Specified folder with script and tile pyramid can be archived and forwarded to customer.

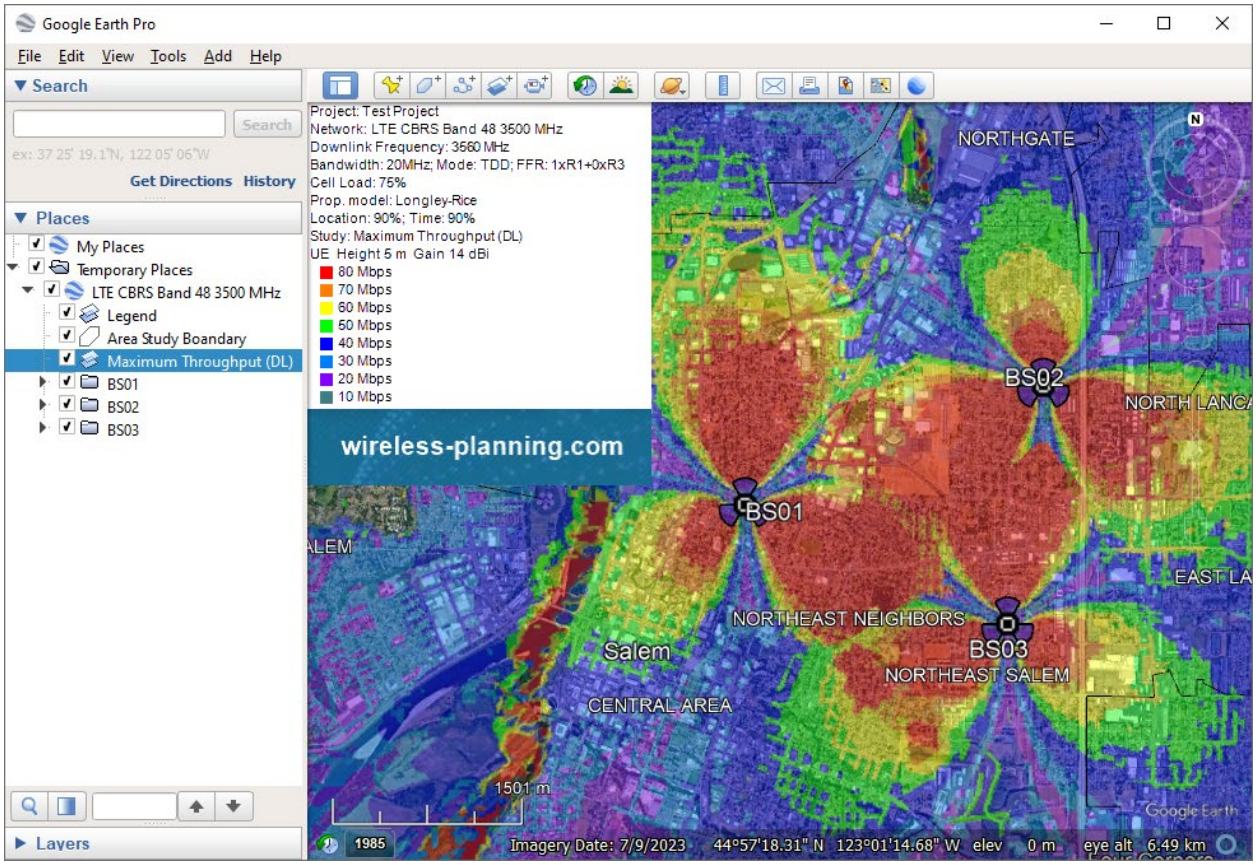
Resulting webpage can also be placed on web server for viewing in any browser and operating system (Windows, Mac, IOS, Android, Linux). This webpage allows you to choose base map from different base maps; change zoom; view basic data from legend; display scale and current coordinates of cursor.

For the webpage to function, you'll need access to the internet as base maps are downloaded from corresponding resources. A folder with a tiles pyramid can be connected to any GIS that supports working with tiles, allowing you to demonstrate coverage as a layer on any GIS (QGIS, MapInfo, ArcGIS, SAS.Planet, etc.).



Calculation result in the form of HTML page

Save the map as a KMZ file - Save calculation result as structured KMZ file for Google Earth. If Legend is active, it will appear in upper left corner of Google Earth.



Calculation result in the form of KMZ

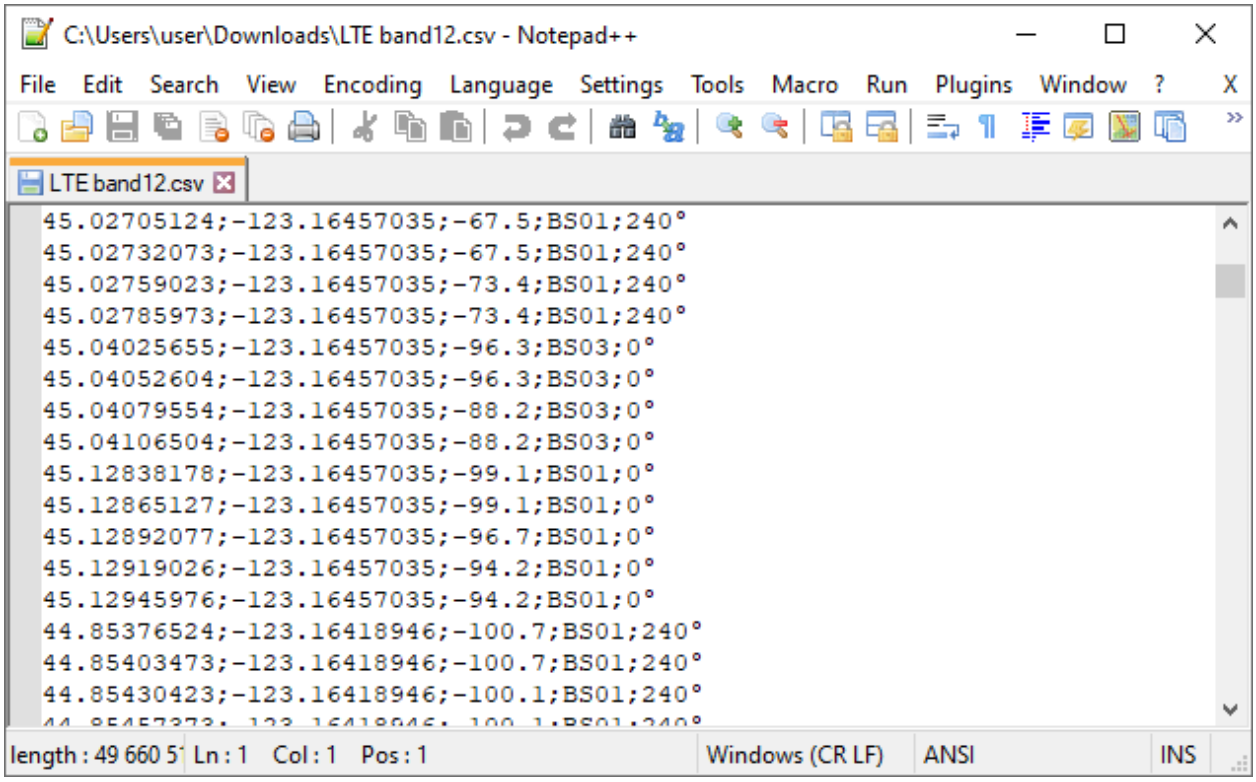
Save the map as a GeoTIFF file - Save calculation result without a base map as a georeferenced file in geotiff format

Save the coverage in GIS format – Save the coverage in Text CSV file or Exchange file MapInfo (MIF + MID). Coverage export to these vector formats is necessary for those users who use the coverage for further analysis in various GIS applications.

When saving the file, you will need to specify the space grid with which the result will be saved.

CSV file format

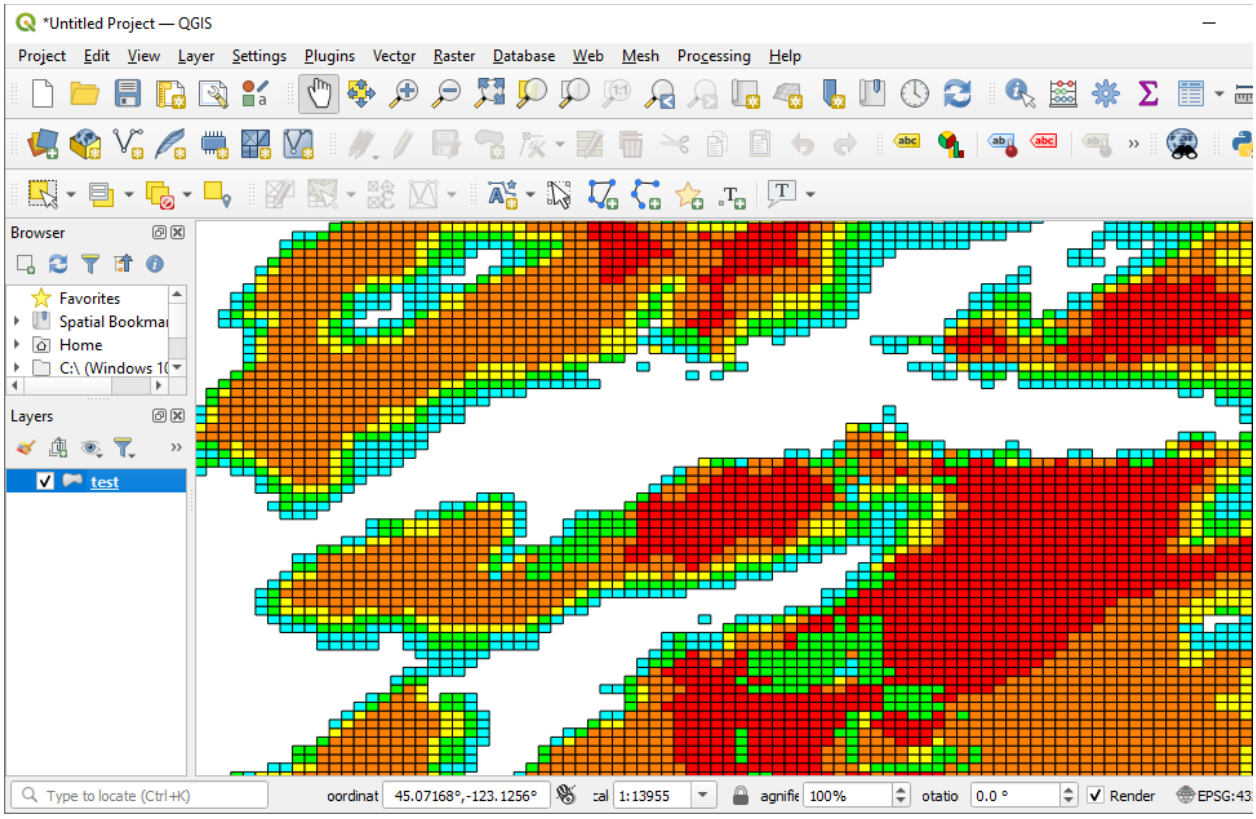
Each line contains three parameters: geographical latitude; geographic longitude; strongest signal level (Rx power level or field strength); site name; sector azimuth. The separator of parameter values is a semicolon. Formats for geographic coordinates: Degrees Minutes Second (35 36 23.8) or Decimal Degrees (12.34567).



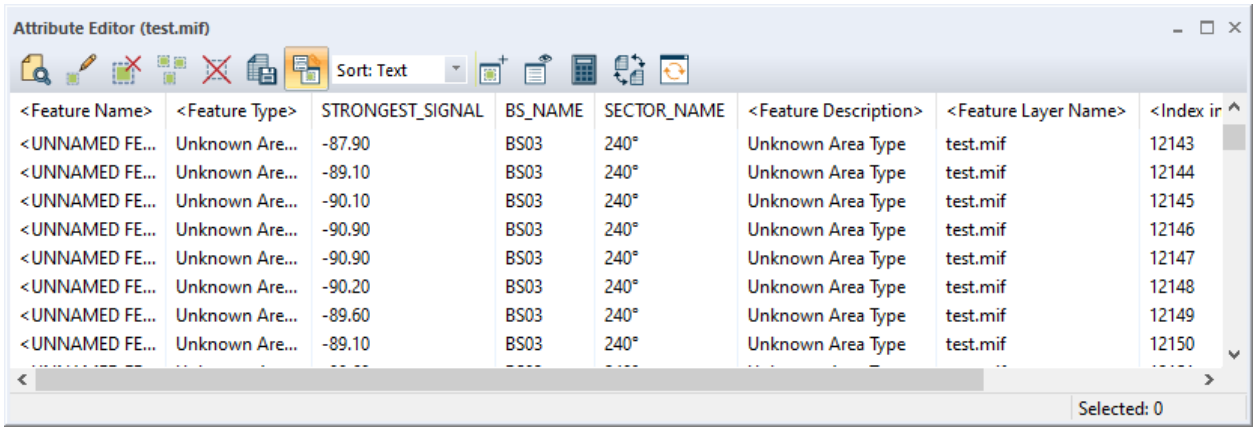
CSV file sample

MIF MapInfo file

MIF coverage file is a standard MapInfo exchange file that can be opened in any GIS application.



MIF Mapinfo Coverage file as a layer in QGIS

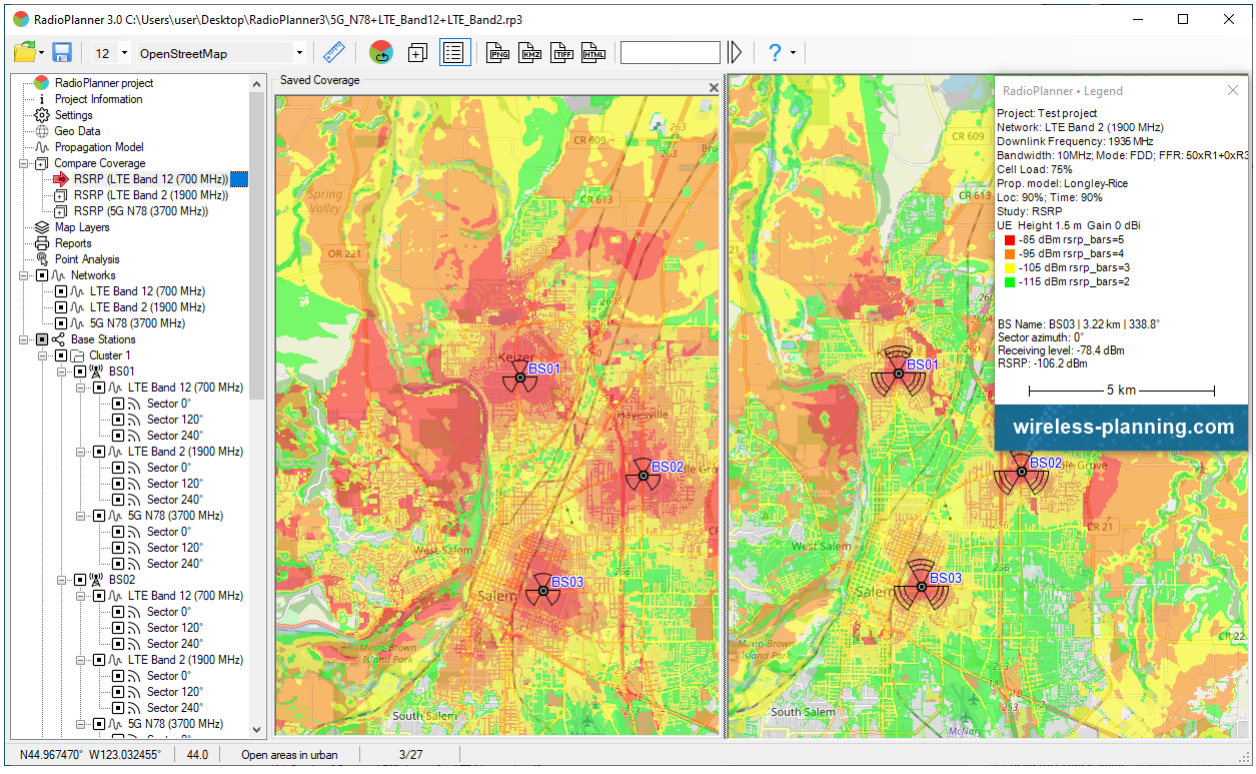


MIF Attribute Table

Coverage Prediction Comparison

RadioPlanner 3.0 allows you to compare results of current coverage prediction with previously performed predictions. This allows you to evaluate the impact on coverage by changing various site parameters, propagation model, etc.

To add a performed calculation to comparison, click on the  **Add Coverage to Compare button** on top toolbar. When you go to Compare Coverage menu of main toolbar, this calculation result will be located on left side of screen while result of current coverage calculation will be displayed on right side. If Legend is enabled, it will display calculation parameters that mouse pointer is currently over.



Coverage Prediction Comparison

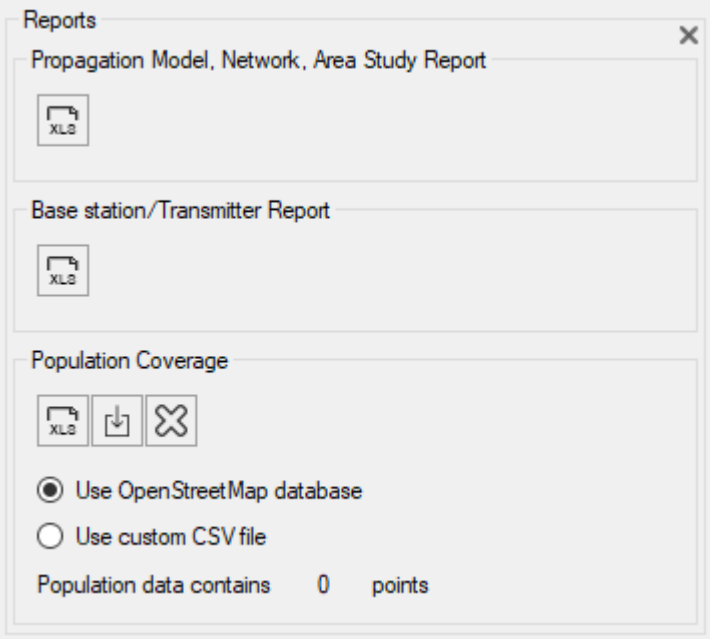
You can add multiple calculations to comparison and their names will appear in tree-view interface under Compare Coverage. When adding a calculation to comparison, RadioPlanner saves all calculation matrices so for large calculations it can take a long time and take up a lot of hard disk space. Manage maps in left and right panels (map shift and zoom) independently of each other. This allows you to compare two results of coverage calculation in detail. To rename a calculation in tree-view interface, double-click on it and rename it. To delete an unnecessary calculation, click on it and press Delete button on keyboard. When closing RadioPlanner, calculations added to comparison are not saved.

Reports

In the "Reports" menu, you can create different types of project reports - network configuration report, propagation model report, area survey type, and active sites configuration report.

You can also create a report on population coverage (currently only for broadcasting - see the corresponding section of this User Manual).

All types of reports open directly in Excel.



Reports menu

Propagation Model, Network, Area Study Report

Open report in Microsoft Excel

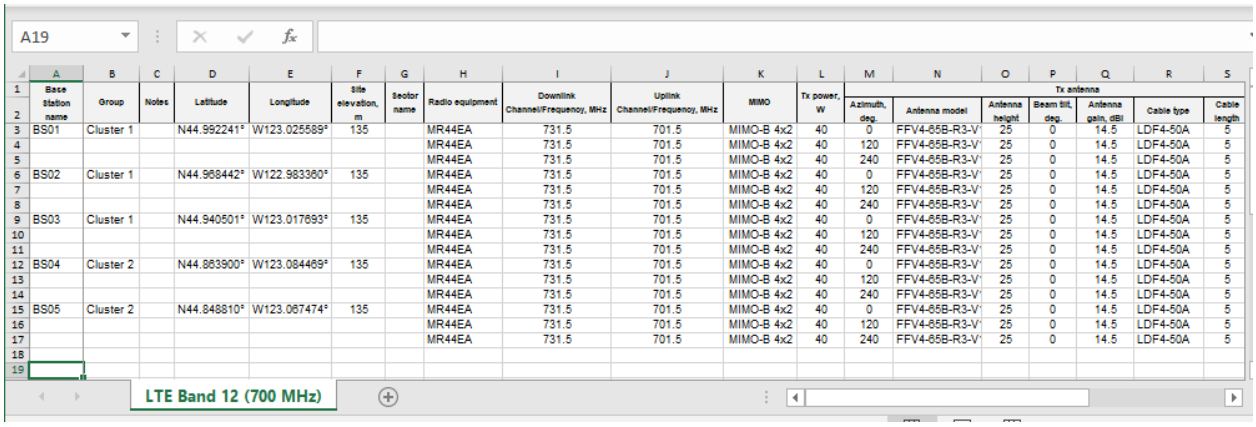
	A	B	C	D	E	F	G	H
4	Project Name	Test project						
5	Customer							
6	Data							
7								
8	**Network**							
9	Name	LTE Band 12 (700 MHz)						
10	System Type	LTE						
11	Downlink	731.5 MHz						
12	Uplink	701.5 MHz						
13	Downlink Rx treshold	-101 dBm						
14	Uplink Rx treshold	-103 dBm						
15	Study radius	20 km						
16								
17	**User Equipment (UE)**							
18		UE №1	UE №2					
19	Type	Portable	Mobile					
20	Tx Power	0.2 W	0.2 W					
21	Cable and connector loss	0 dB	0 dB					
22	Antenna height	1.5m	1.5m					
23	Antena gain	0 dBi	0 dBi					
24								
25	**Propagation Model**							
26	Type	Longley-Rice						
27	Situation	90%						
28	Time	90%						
29	Margin	0 dB						
30	Refractivity	301 N-units						
31	Conductivity	0.02 S/m						
32	Dielectric Constant	15						
33	Climate Zone	Continental Temperate						
34	Antenna Polarization	Vertical						
35	Add Clutter Loss	Yes						
36								
37	**Area Study**							
38	Type	RSRP						
39	UE №1		Description					
40		-85 dBm	rsrp_bars=5					
41		-95 dBm	rsrp_bars=4					
42		-105 dBm	rsrp_bars=3					
43		-115 dBm	rsrp_bars=2					

LTE Band 12 (700 MHz)

Report in Microsoft Excel

Base station/Transmitter report

Open active site configuration in Microsoft Excel



Base station name	Group	Notes	Latitude	Longitude	Site elevation, m	Sector name	Radio equipment	Downlink Channel/Frequency, MHz	Uplink Channel/Frequency, MHz	MIMO	Tx power, W	Tx antenna					
												Azimuth, deg.	Antenna model	Antenna height	Beam tilt, deg.	Antenna gain, dBi	Cable type	Cable length
BS01	Cluster 1		N44.992241°	W123.025589°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
BS02	Cluster 1		N44.968442°	W122.983360°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
BS03	Cluster 1		N44.940501°	W123.017693°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
BS04	Cluster 2		N44.863900°	W123.084469°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
BS05	Cluster 2		N44.848810°	W123.067474°	135		MR44EA	731.5	701.5	MIMO-B 4x2	40	0	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	120	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5
							MR44EA	731.5	701.5	MIMO-B 4x2	40	240	FFV4-65B-R3-V	25	0	14.5	LDF4-50A	5

Sites report sample in Microsoft Excel

Population Coverage

Open population coverage report in Microsoft Excel

Import population data from CSV file

Delete population data

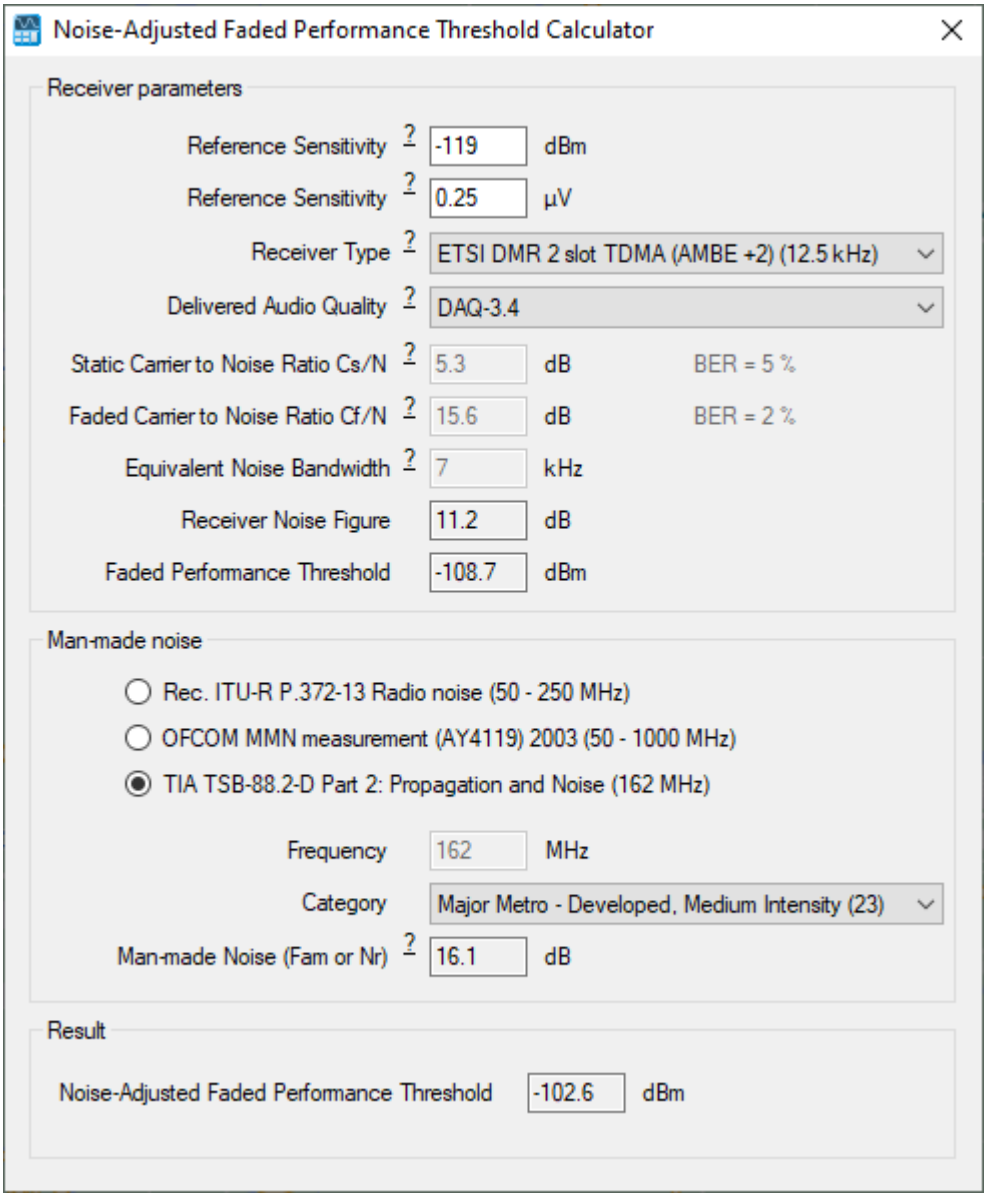
Noise-Adjusted Faded Performance Threshold Calculator

The influence of man-made noise cannot be ignored in the VHF and UHF frequency bands where most professional mobile radio communication systems operate.

The calculator built into the software determines the Noise-Adjusted Faded Performance Threshold for various environmental conditions and frequencies.

The calculations take into account Delivered Audio Quality (DAQ) according to the methodology described in the TIA TSB-88.1 recommendation. The typical parameters of the receiver-demodulator of all land mobile radio systems are built into the calculator - data is taken from Table A1 “Projected VCPC Parameters for Different DAQs” TIA TSB-88.1-D. Next, a Noise-Adjusted Faded Performance Threshold is calculated, taking into account one of the three research reports for different categories of land cover:

1. Recommendation ITU-R P.372-13 "Radio noise" (50-250 MHz)
2. OFCOM MMN measurement (AY4119) 2003 (50-1000 MHz)
3. Data from TIA TSB-88.2-D Part 2: Propagation and Noise (162 MHz)



Noise-Adjusted Faded Performance Threshold Calculation

To calculate the Noise-Adjusted Faded Performance Threshold, the user must specify:

1. Reference receiver sensitivity in dBm or µV - This is usually given in the technical specification as receiver sensitivity with 12 dB SINAD for analog systems or with BER = 5% for digital systems.

2. Type of land mobile radio

3. DAQ required, usually DAQ = 3.0 or 3.4

4. Select the research report on which the calculation will be based and the environmental category

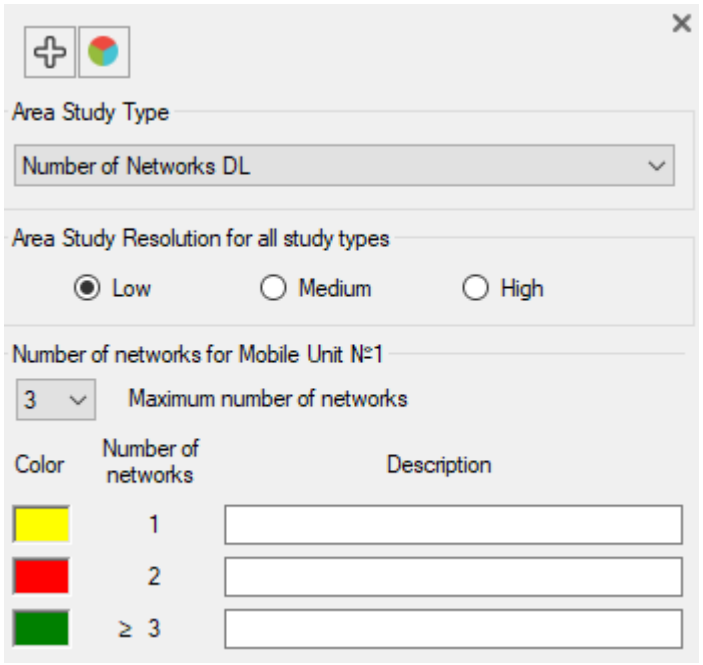
5. Specify the carrier frequency.

After changing any field of source data, the calculation is performed automatically. If an empty field appears as a result of the calculation, this means that incorrect data has been entered on receiving equipment (not physically feasible) or man-made noise graphs are beyond the frequencies at which the studies were performed.

TV and Radio Broadcast Networks Planning

RadioPlanner 3.0 performs broadcast coverage prediction and determines the population in the coverage area based on the OpenStreetMap project database or user data in CSV format. Based on the results of the prediction, a list of settlements covered by broadcasting is formed, indicating the population in each settlement and the total population in the coverage area.

RadioPlanner 3.0 allows you to work with multiple TV or Radio networks in one project. When creating a new project, the first network is created by default.



Networks menu

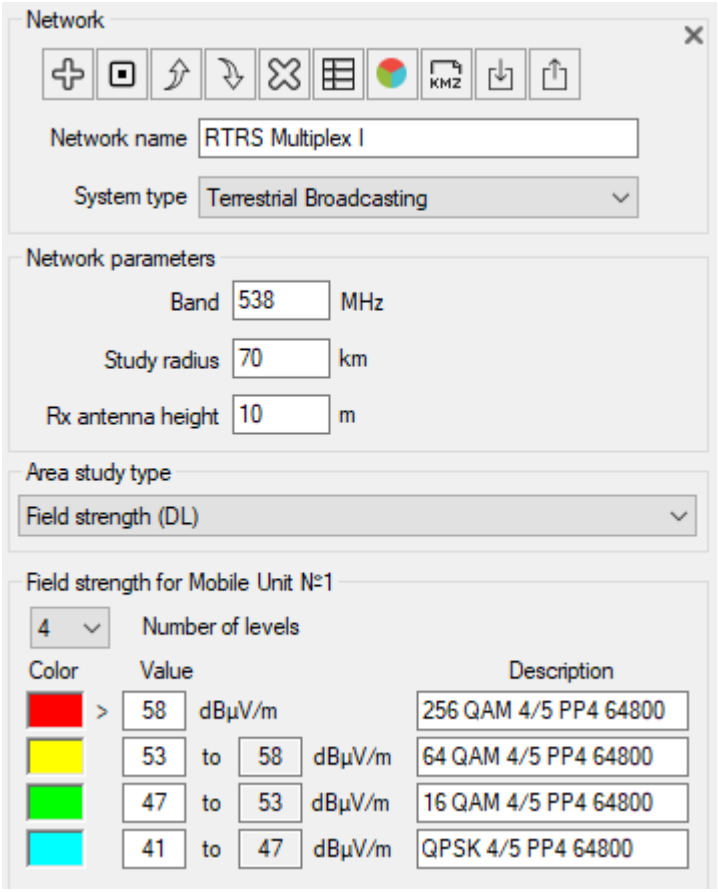
Add a new network

Calculate Coverage (See Coverage predictions for multiple networks section)

Area Study Type	Coverage predictions for multiple networks: - Number of Networks (DL) See Coverage predictions for multiple networks section
Area Study Resolution for all study types	Coverage prediction resolution. Specifies the details of both aggregated calculations and calculations for each of the networks. - Low - Medium - High The resolution corresponds to one pixel of the screen for zoom = 11 (low detail), zoom = 12 (medium), and zoom = 13 (high). For a geographic latitude of 55 degrees, this is approximately 40, 20, and 10 meters, respectively. The higher the resolution, the longer the calculation time.

Network

The “Network” menu is used to set all parameters for the selected network and calculation parameters. To design television and radio broadcasting networks, you must select the system type "Terrestrial Broadcasting".



Network menu

Add a new network with the same parameters (copy the network)

Check/Uncheck all sectors for current network

Move the Network up

Move the Network down

Delete the network

Calculate Coverage

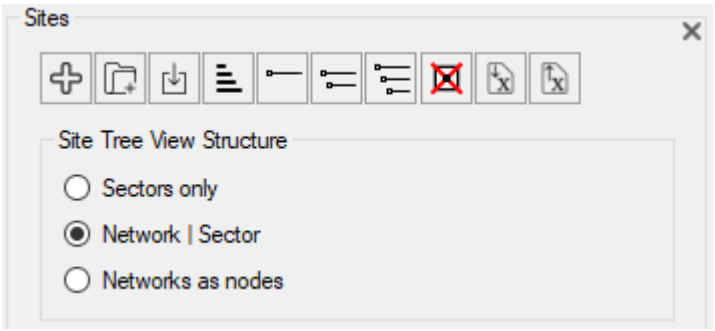
Calculate coverage for each active transmitter and save the map as a KMZ file

Load network parameters from a template

Save network parameters as a template

Network name	Name of network, text field
System type	System type options: - Generic TRX - LTE - 5G - Terrestrial Broadcasting - Air-to-Ground Radio The selected system type will determine the set of additional system parameters, as well as the types of coverage predictions available.
Band	Average network frequency, MHz Used only to calculate clutter loss in the ITU-R P.1812 and ITU-R P.1546 propagation models
Rx antenna height	Rx antenna height, m
Study radius	Maximum study radius, km The larger the radius, the longer the computation time. Do not set an unnecessarily large calculation radius.

Sites



Sites

 Add a new site

 Add a new site group

 Import a site list from *.csv file

 Sort sites in alphabetical order

 Collapse of site nodes

 Collapse all network nodes

 Epand all site nodes

 Delete all selected sites

 Import sites parameters from Microsoft Excel document

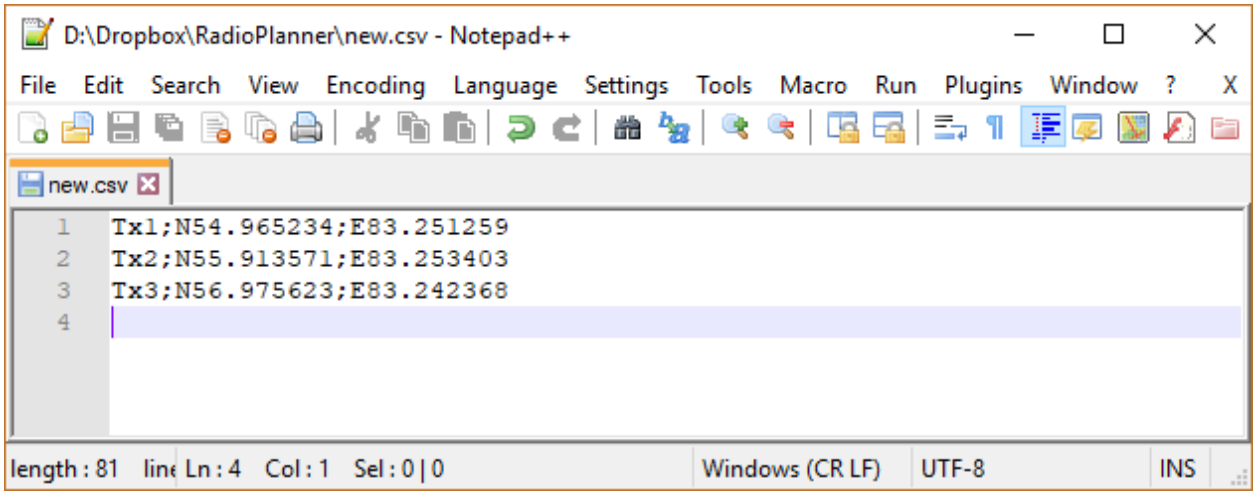
 Export active sites to Microsoft Excel

To create a new site, click on Sites in the Tree View interface, then click the  button in the panel that opens.

Import sites from *.CSV file

You can also import sites from CSV files (text format with a semicolon separator). This is a universal format that can be used to save a spreadsheet from any spreadsheet editor (Excel, LibreOffice Calc, etc.) or database. Each point object must have required fields including site name, Latitude, and Longitude. Coordinates can be formatted as HEMISPHERE degrees minutes seconds (N35 23.8 36) or HEMISPHERE decimal degrees (N12.34567).

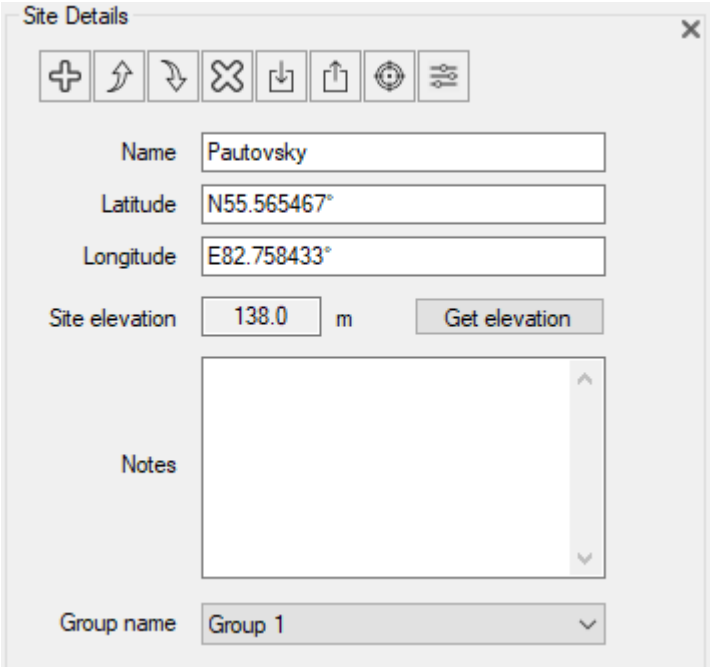
To import sites, click on the button  (import sites from *.CSV) and select a CSV file.



CSV file sample

Site Details

When clicking on a created site in the Tree View interface panel, the Site Details panel will open where you can edit details such as name, coordinates and additional text information about the site and view elevation relative to sea level.



Site Details

 Add a new site as a copy of this site

 Move this site up or down

 Delete the site

 Load site sectors of the selected netwirk from a template

 Save the sectors of the selected netwirk as a template

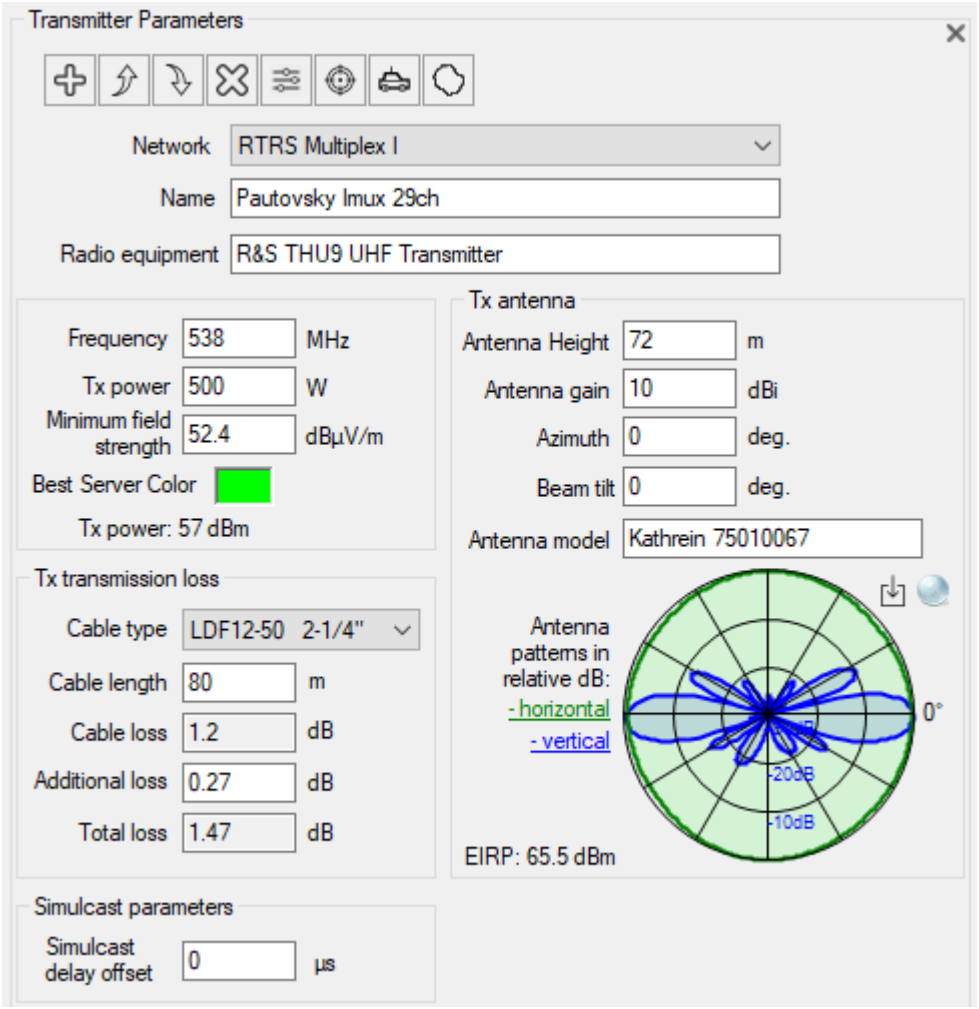
 Position the map with the site at the center of the screen

 Copy Site Parameters to all active Sites

Name	Site name, text field
Latitude	The geographical latitude of the site in the format specified by the user in Settings
Longitude	Geographical longitude of the site in the format specified by the user in Settings
Site Elevation	Site elevation relative to sea level, m
Notes	Text box for any additional site information
Group name	Select site group. Sites can be combined into groups (clusters), allowing you to quickly include/exclude large groups of site from calculations.

Transmitter Parameters

When creating a site, one transmitter of this site is automatically created. There is an activity icon next to each site and sector in the Tree View interface panel. For a transmitter to be calculated, it must be marked as active (a dot in the center). Clicking on the transmitter will open a panel with its parameters.



Transmitter Parameters

Add a new transmitter with te same parameters to selected site

Move the transmitter up or down

Delete the transmitter

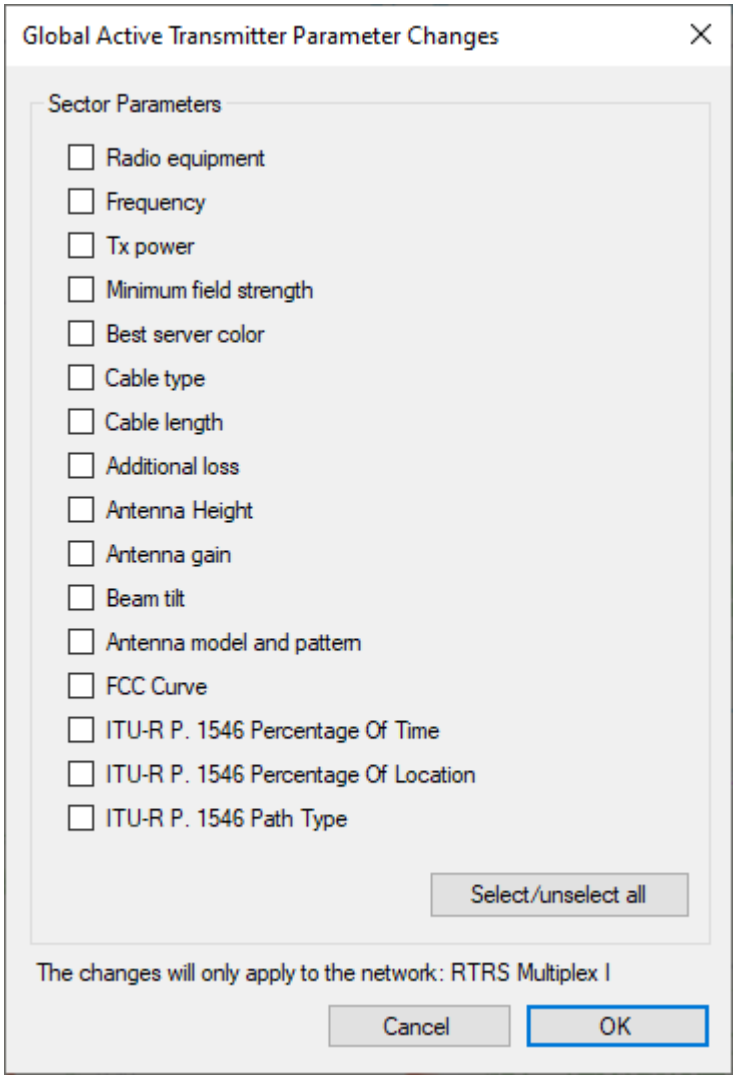
Global Active Transmitter parameters change. You can replace the selected parameters for all active transmitters as the current transmitter.

Position the map with the transmitter at the center of the screen

Analysis of measurements along the route. See more details in the " Import Measurement Results and Propagation Model Tuning for TV and Radio Broadcasting Projects" section.

Calculation of service and interference contours using FCC and ITU-R propagation curves.

Network	The network to which the transmitter belongs, select from the drop-down list of networks.
Name	The name of the transmitter, the text field. If left blank, the name “Sector azimuth” with the azimuth value specified in the transmitter parameters panel will be automatically displayed in the tree view panel on the left. If you specify a name in this field, it will be displayed in the tree view.
Radio Equipment	Name (model) of Radio equipment, text field
Frequency	Transmitter carrier frequency, MHz
Tx Power	Transmitter power, W. Same value in dBm for control
Min. field strength, dBuV/m	Minimum field strength required for reception, dBuV/m. An area with a field strength less than the specified value will be excluded from transmitter coverage. This feature is useful for displaying the total coverage area for a network of transmitters operating in different frequency bands or with different modulation levels. Since such transmitters have different minimum field strength required for reliable reception. This value is also used in FCC and ITU-R 1546 contours calculations.
Best Server Color	The color that will be used to indicate the coverage for this transmitter when calculating the Best Server coverage prediction
Cable Length	Main cable length, m
Cable Loss	Loss in cable, dB. Calculated value
Additional Loss	Additional losses, dB - combining losses, losses in jumpers, and connectors. Any additional losses.
Total Loss	Total loss, dB. The calculated value.
Antenna Height	The antenna radiation center height relative to ground level, m
Antenna Gain	Antenna gain relative to isotropic radiator, dBi
Azimuth	The azimuth of the antenna in degrees
Beam Tilt	Tilt the antenna in degrees. Down is negative; up is positive.
Antenna Model	Antenna name, text field. Automatically filled with the antenna pattern file name when selecting a pattern.
	Load MSI antenna pattern file. An antenna pattern file is a standard MSI file that can be downloaded from the antenna manufacturer's website. Antenna patterns are integrated into the project file.
Simulcast delay offset (µs)	Transmitter simulcast delay offset, µs



Global Active Transmitter Parameter Changes

Global Active Transmitter parameters change is a feature that allows you to instantly change the parameters of any active transmitters to match those of the current transmitter. To perform group parameter changes, mark the transmitters whose parameters need to be changed as active, set the required parameter values in the current transmitter, click on the button, select the parameters that need to be changed in the previously marked active transmitters from the list, and click on the OK button.

Propagation Models for Radio and TV Broadcasting

When working with television and radio broadcasting projects, one of the following propagation models is usually used:

- ITU-R P.1812-4
- ITU-R P.1546-6
- Longley-Rice (ITM) v 1.2.2

For more information about these models, see the Propagation Models for mobile section.

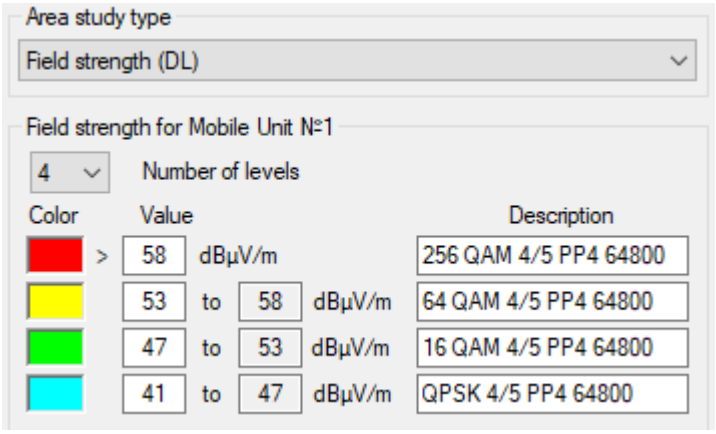
Area Study Types

For terrestrial broadcasting systems, you can choose the following types of coverage prediction:

- Field Strength
- Best Server

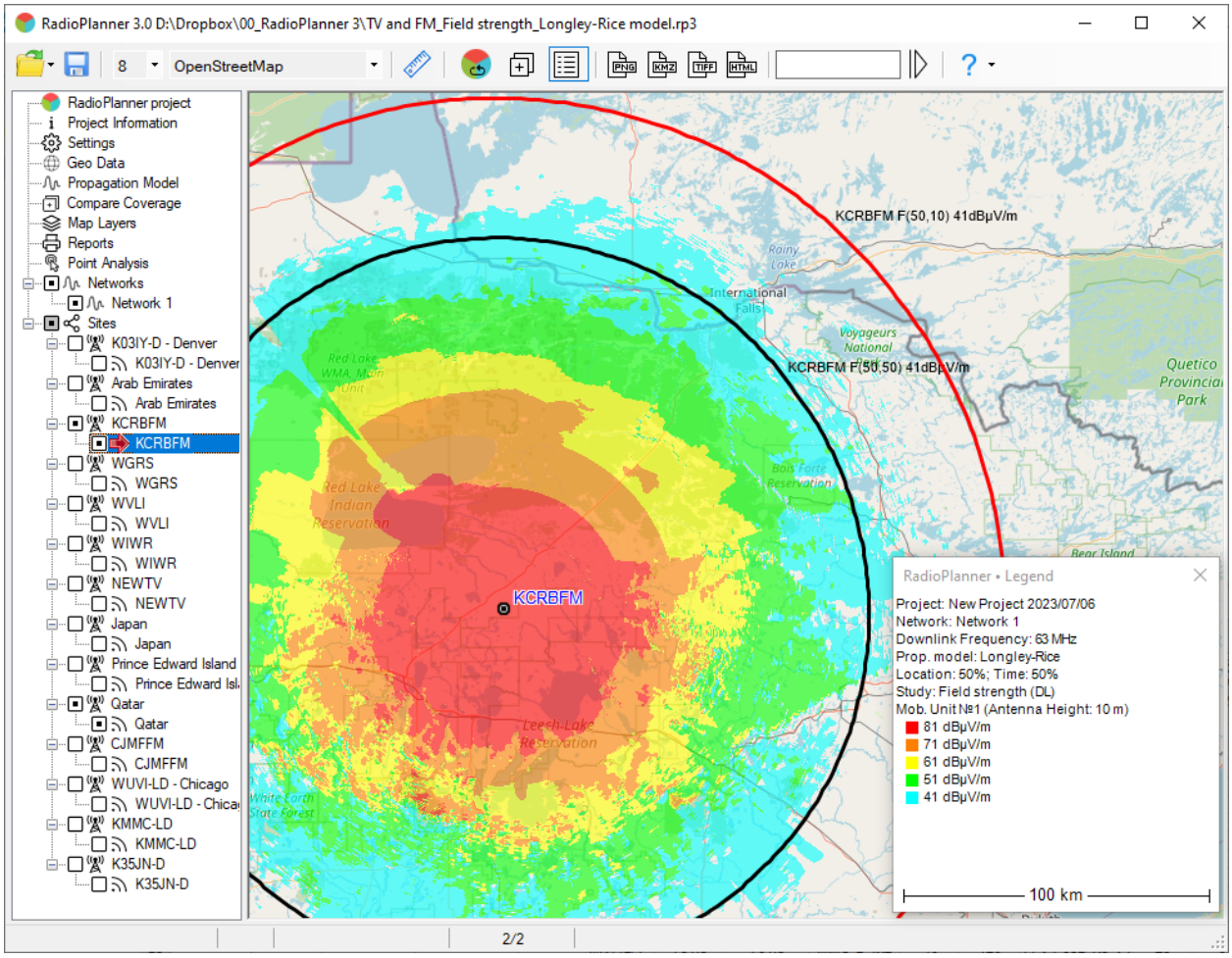
Field Strength (DL)

The base map displays areas with different colors, where the corresponding level of radio signal strength is present at the reception point.



Field Strength (DL) menu

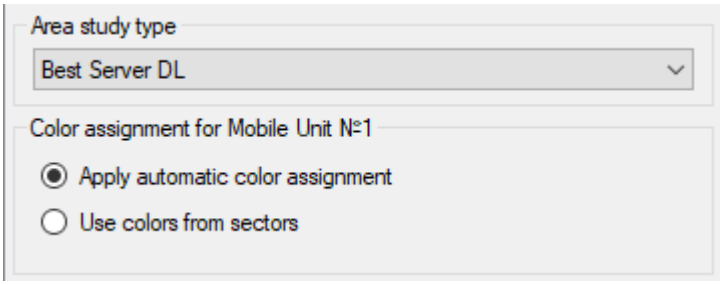
Number of Levels	The number of field strength levels (1-8)
Color	Color level
Values	Field strength, dBµV/m
Description	Text field to describe signal level



FM Transmitter Field Strength Coverage

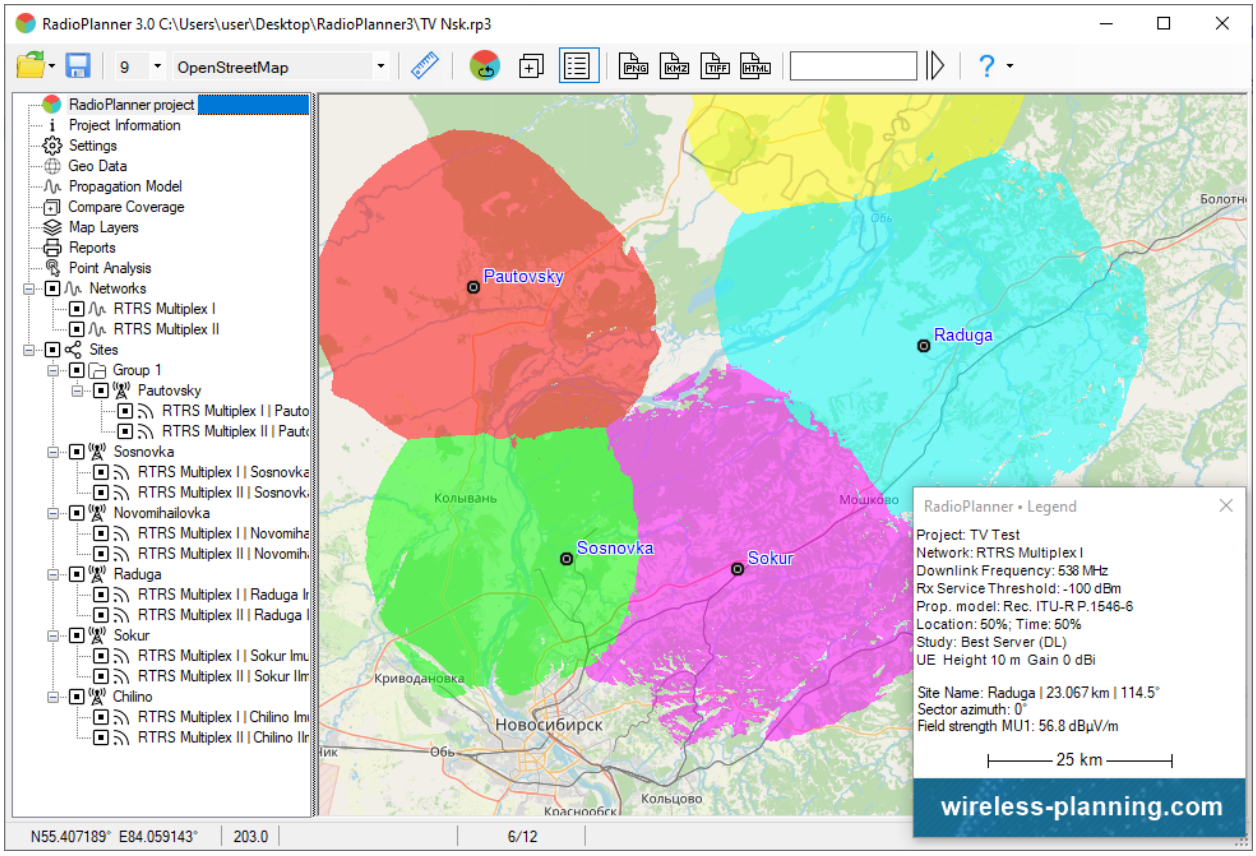
Best Server (DL)

The Best Server map shows the identity of the transmitter supplying the strongest received signal at each location. The required service threshold for calculating the Best Server is Min. field strength, dBuV/m.



Best Server Study Type Parameters

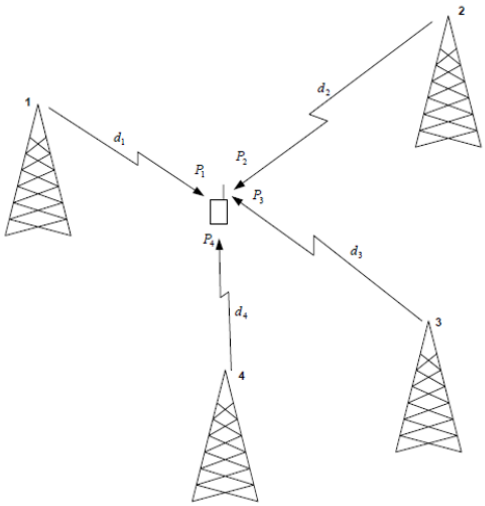
Apply Automatic Color Assignment	Assign colors to transmitters in random order
Use Colors from sectors	Assigning colors from the transmitters parameters



Best Server for TV DVB-T2 network

Simulcast Delay Spread

This prediction is used for single-frequency network (SFN). Inter symbol interference in the receiver will occur under certain conditions related to delay time between signals arriving at a given location and their relative power. The simulcast delay spread is calculated as follows:



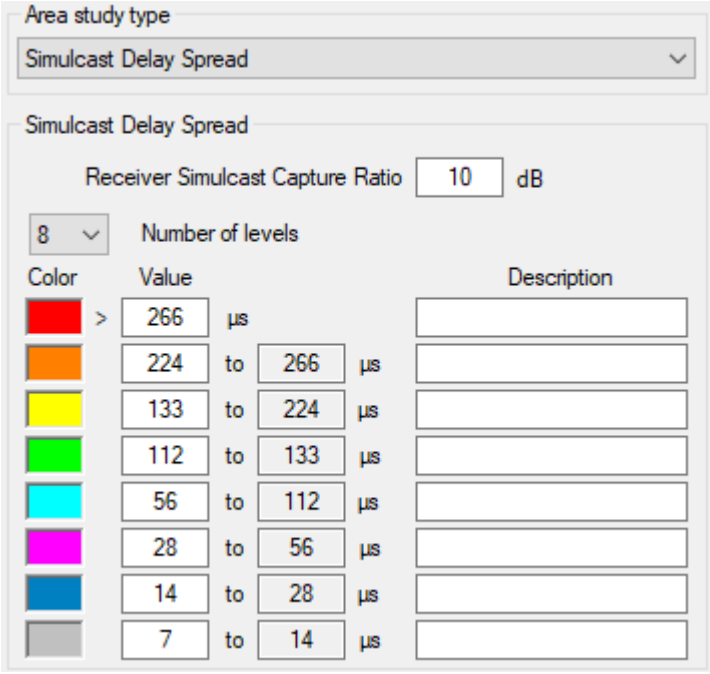
$$T_m = 2\sqrt{\frac{\sum_{i=1}^{N} P_i d_i^2}{\sum_{i=1}^{N} P_i} - \frac{\left(\sum_{i=1}^{N} P_i d_i\right)^2}{\left(\sum_{i=1}^{N} P_i\right)^2}}$$

T_m Multipath Spread (twice the RMS delay spread)

P_i Power arriving at a terminal antenna from transmitter i

d_i Time of flight from transmitter i to antenna terminal

The simulcast delay spread is calculated by considering only the six strongest signals at any grid analysis location. The results of the calculation are displayed in µs on the map.



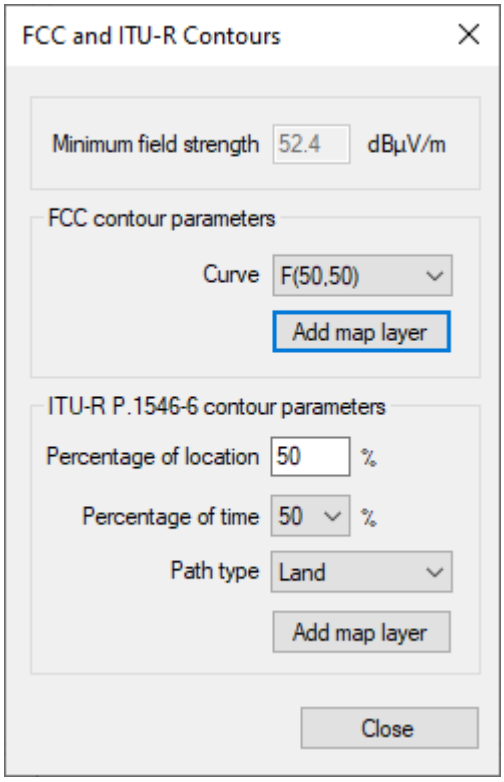
Simulcast Delay Spread Parameters

Receiver Simulcast Capture Ratio	For delay spread studies, the delay is calculated and displayed only when the power of the strongest received signal and the power of the second strongest received signal are within the capture ratio of each other.
Number of Levels	The number of levels (1-8)
Color	Color level
Values	Simulcast Delay Spread, µs
Description	Text field to describe Simulcast Delay Spread value

To reduce interference between simulcast transmitters, it can be useful to artificially delay the signal transmitted from a given location using Simultaneous Delay Offset entered in Transmitter Parameters. By carefully assigning offsets to different transmitters, some control can be exercised over where interference occurs.

FCC Contours

RadioPlanner 3.0 allows you to calculate service and interference contours using FCC propagation curves. These contours are used in North America in accordance with FCC rules and are also recommended for use when planning television and FM broadcast stations in some countries.



FCC and ITU-R Contours

FCC contour parameters	See the section FCC contours
Curve	FCC curve from set F (50.50); F (50.10); F (50.90).
Add Map Layer	Adding a contour with selected parameters to the map as a layer
ITU-R P.1546-6 contour parameters	See the section ITU-R P.1546-6 Contours
Percentage of time	Percentage of time for which the contour will be calculated (50%, 10% or 1%)
Percentage of location	Percentage of location (receivers) for which the contour will be calculated (50% -99%)
Path type	Land, Cold sea or Warm sea
Add Map Layer	Adding a contour with selected parameters to the map as a layer

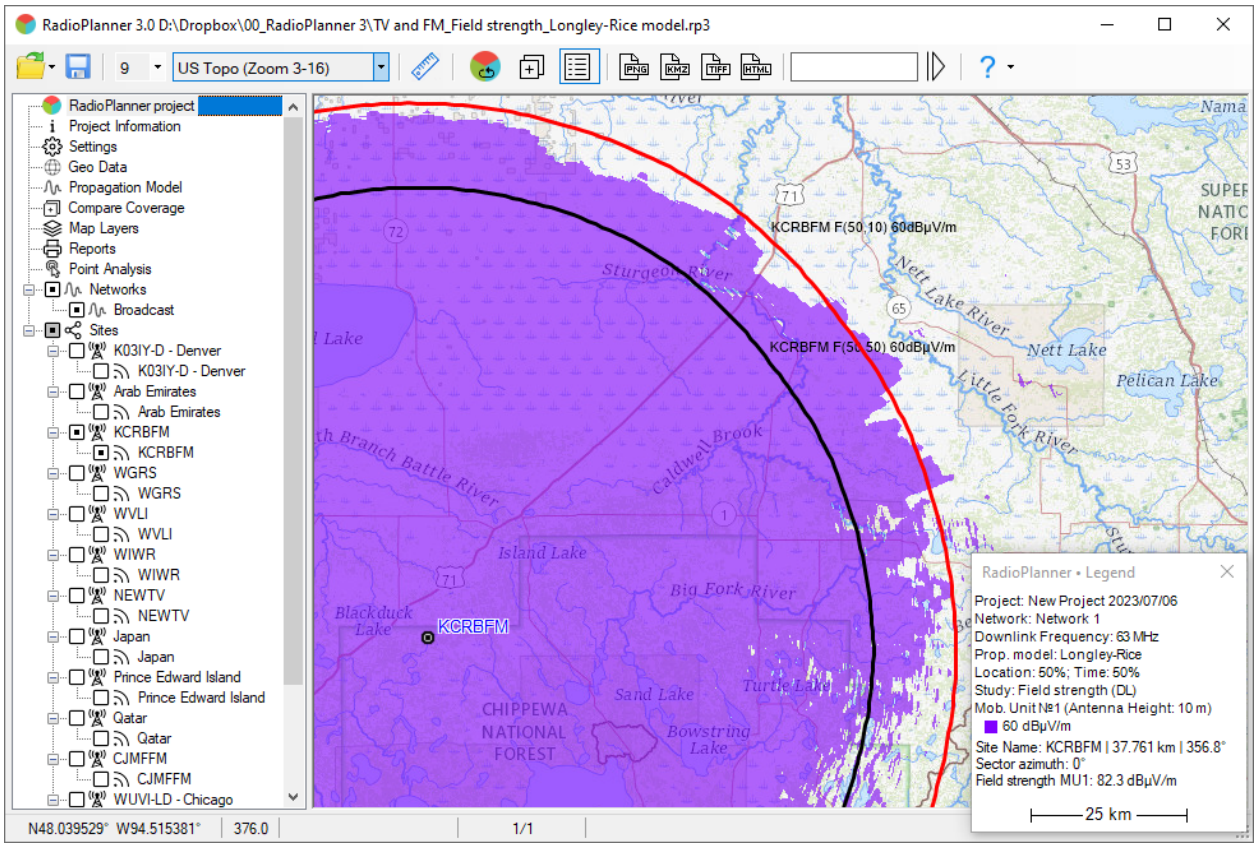
To calculate an FCC contour, go to the parameters menu of the transmitter for which you want to calculate the contour. Enter the required value for the electromagnetic field strength (Minimum field strength) and select the type of FCC propagation curve:

- F (50,50) - Service contour curve for FM broadcasting and analog television
- F (50,10) - Interference contour curve
- F (50,90) - Service contour curve for digital television

After clicking the “Add map layer” button, the FCC contour will appear on the base map as a vector layer. The name of this layer displays information about the transmitter’s name, the type of curve, and the field strength level. By default, service contours are displayed in black and interference contours in red. You can change the display settings of this layer as desired; working with it is no different from working with other vector layers on the map.

The calculation uses the frequency specified in the “Band” item in the “Network” menu.

For more information on designing broadcast stations using FCC curves, see https://recnet.com/faq-contours or https://www.fcc.gov/media/radio/fm-and-tv-propagation-curves-graphs.



FCC Contours + Longley-Rice coverage

ITU-R P.1546-6 Contours

To calculate an ITU-R P.1546-6 contour, go to the parameters menu of the transmitter for which you want to calculate the contour. Set the value of the electromagnetic field strength (Minimum field strength), select the type of path, and enter the percentage of locations and times for which you want to perform the calculation.

The following contours are commonly used (percentage of locations, percentage of time):

- (50.50) - Service contour for FM broadcasting and television
- (50.10) and (50.1) - Interference contours

After clicking the “Add map layer” button, the ITU-R P.1546-6 contour will appear on the base map as a vector layer. The name of this layer displays information about the transmitter’s name, the type of curve, and the field strength level. By default, all contours are displayed in black. You can change the display settings of this layer as desired; working with it is no different from working with other vector layers on the map.

Point Analysis in Terrestrial Broadcasting

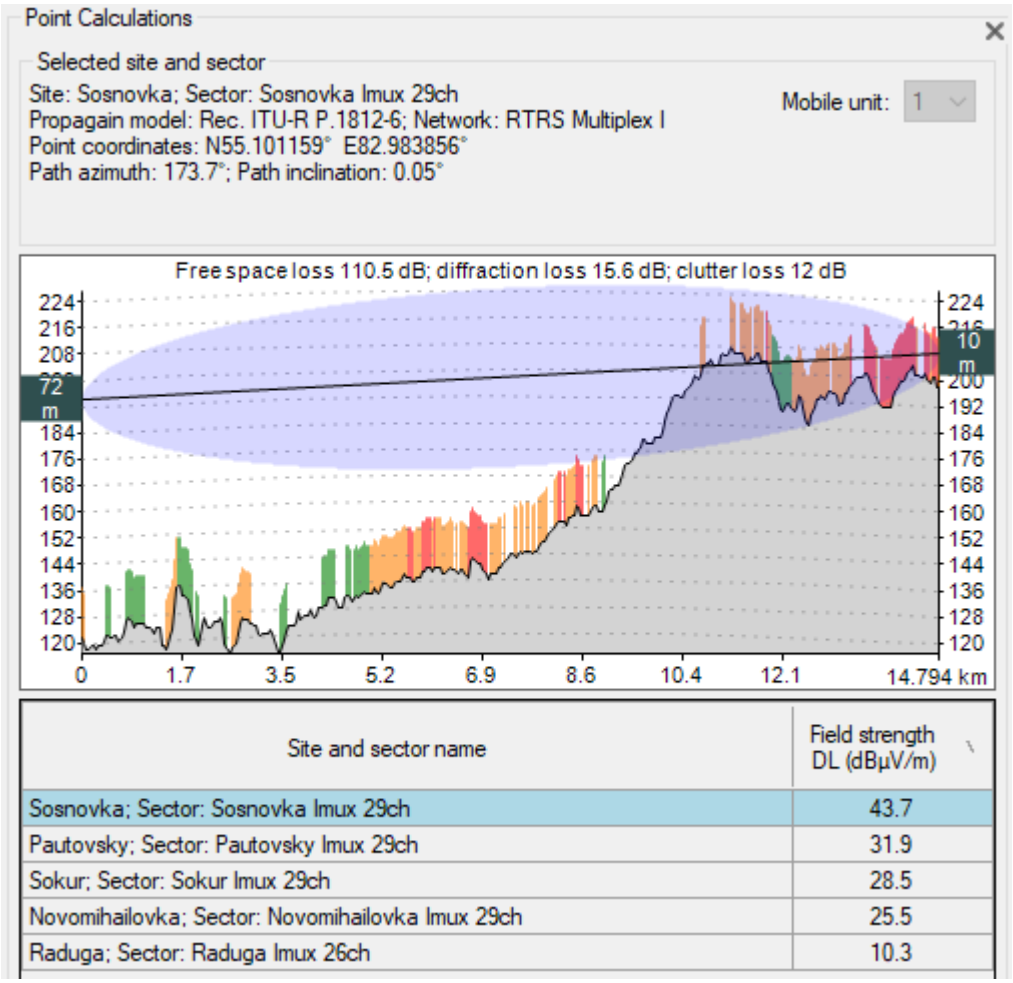
In this panel, you can see results of field strength calculations at any point on the map.

You can change the current point on the map by clicking on a new location with your mouse. The path profile is a vertical section of terrain between transmitter and receiver that shows information about elevations and clutter. The colors that mark various obstacles on the profile correspond to those used in the clutter model.

The path profile shows antenna radiation center heights for both transmitter and receiver as well as Fresnel zone for radio beam, free space loss, diffraction loss due to terrain and clutter surrounding the receiver.

Find the required transmitter and click on it with your mouse (not to be confused with activity tag). Information about selected sector will appear above path profile.

Below path profile is a table displaying results of field strength calculations.



Point Analysis

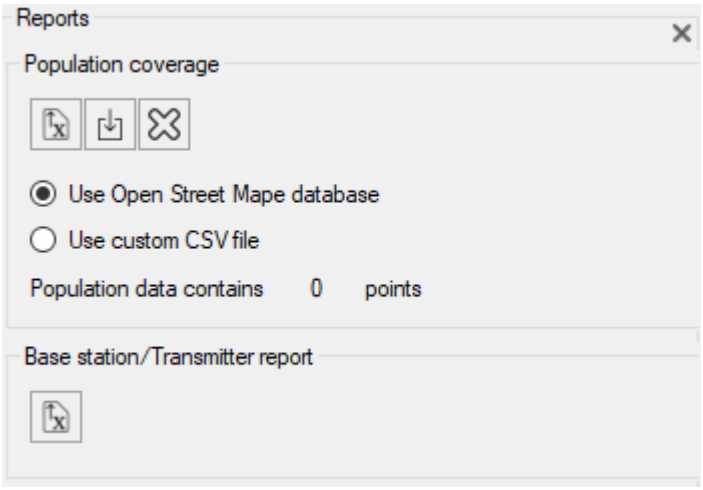
Calculation of the Population Covered by Television and Radio Broadcasting

RadioPlanner allows you to determine the population in the coverage area. Based on the calculation results, a list of localities covered by broadcasting is formed, indicating the population in each locality and the total population in the coverage area.

To calculate population covered, you first need to calculate the downlink field strength coverage for the transmitter (or several transmitters). The population covered will be made for the lowest field strength level used in the calculation.

The population and list of localities covered by the broadcast can be obtained from the OpenStreetMap project data or a local dataset (CSV file). In both cases, the population covered is counted according to the following algorithm. In the center of each settlement, there is a point, the entry of which into the coverage area with a given field strength is the basis for including the entire population of this settlement into the coverage area. If the OpenStreetMap database is used for the calculation (in this case, a copy of the database located on our server is accessed), then these points are point objects - settlements with the tag place = city; town; village; hamlet, and the corresponding population tag.

To calculate the population covered, go to the "Report" menu and select the calculation method - using OpenStreetMap database or a custom CSV file. If you have selected the OpenStreetMap database, then click on the "Open Report" tool and a spreadsheet will appear with the population and the list of settlements covered by the broadcast. This spreadsheet will also show the total area of coverage in square kilometers, as well as the average coverage radius (only when calculating coverage from a single transmitter).

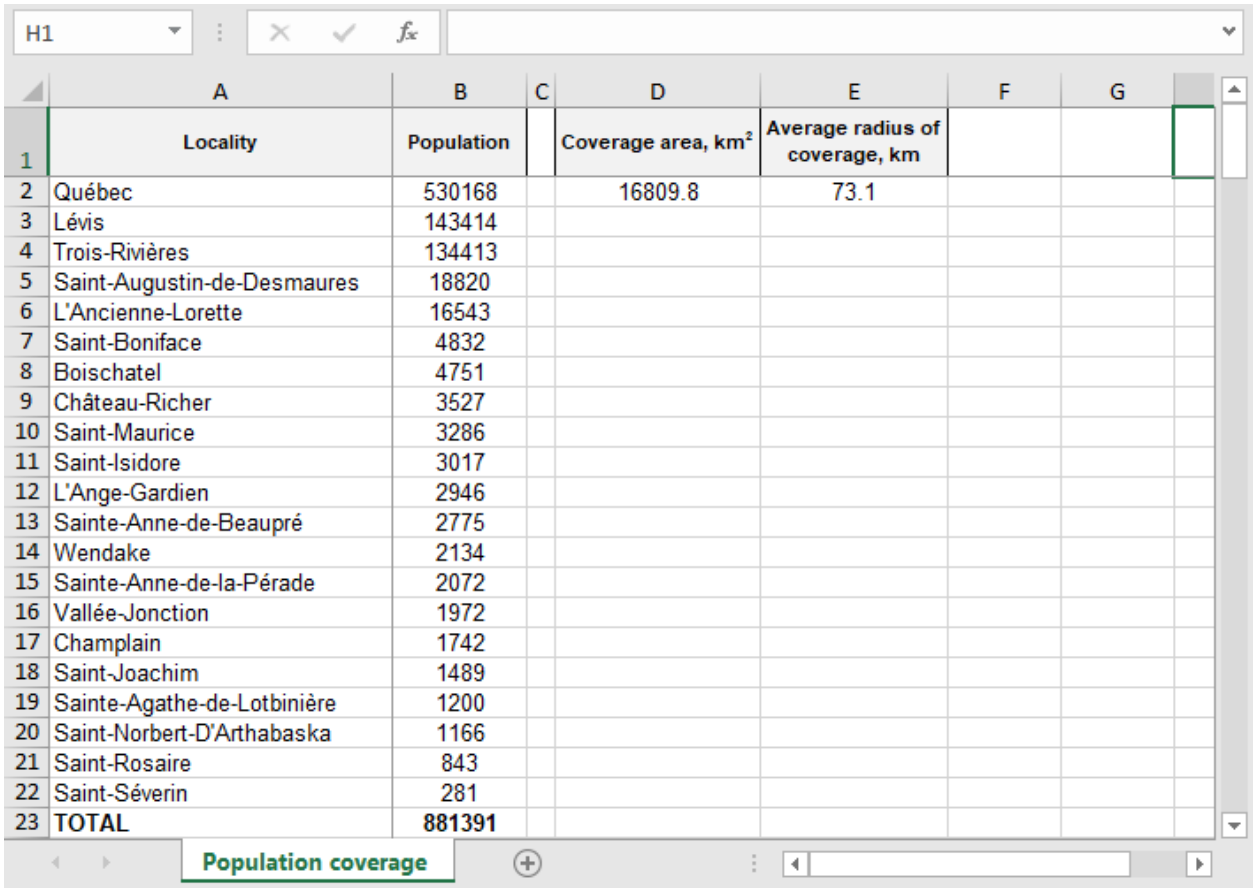


Reports panel

 Open population coverage report in Microsoft Excel

 Import population data from CSV file

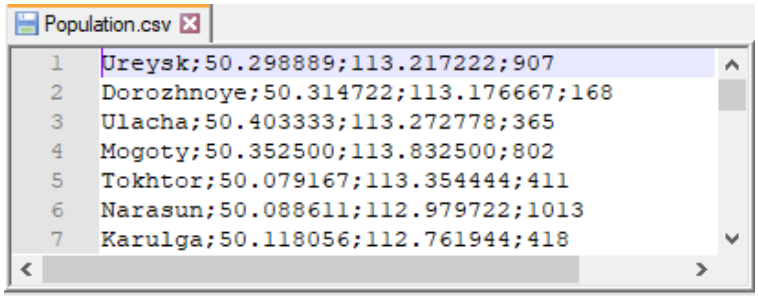
 Delete population data



	Locality	Population		Coverage area, km²	Average radius of coverage, km
2	Québec	530168		16809.8	73.1
3	Lévis	143414			
4	Trois-Rivières	134413			
5	Saint-Augustin-de-Desmaures	18820			
6	L'Ancienne-Lorette	16543			
7	Saint-Boniface	4832			
8	Boischatel	4751			
9	Château-Richer	3527			
10	Saint-Maurice	3286			
11	Saint-Isidore	3017			
12	L'Ange-Gardien	2946			
13	Sainte-Anne-de-Beaupré	2775			
14	Wendake	2134			
15	Sainte-Anne-de-la-Pérade	2072			
16	Vallée-Jonction	1972			
17	Champlain	1742			
18	Saint-Joachim	1489			
19	Sainte-Agathe-de-Lotbinière	1200			
20	Saint-Norbert-D'Arthabaska	1166			
21	Saint-Rosaire	843			
22	Saint-Séverin	281			
23	**TOTAL**	**881391**			

Population Coverage Report

If you want to use custom population data to calculate population coverage, prepare a text CSV file in the format described below.



```
Ureysk;50.298889;113.217222;907
Dorozhnoye;50.314722;113.176667;168
Ulacha;50.403333;113.272778;365
Mogoty;50.352500;113.832500;802
Tokhtor;50.079167;113.354444;411
Narasun;50.088611;112.979722;1013
Karulga;50.118056;112.761944;418
```

Sample CSV text file with population data

Required data for each locality: The name of the settlement; Latitude; Longitude; Population

The data separator is the semicolon character.

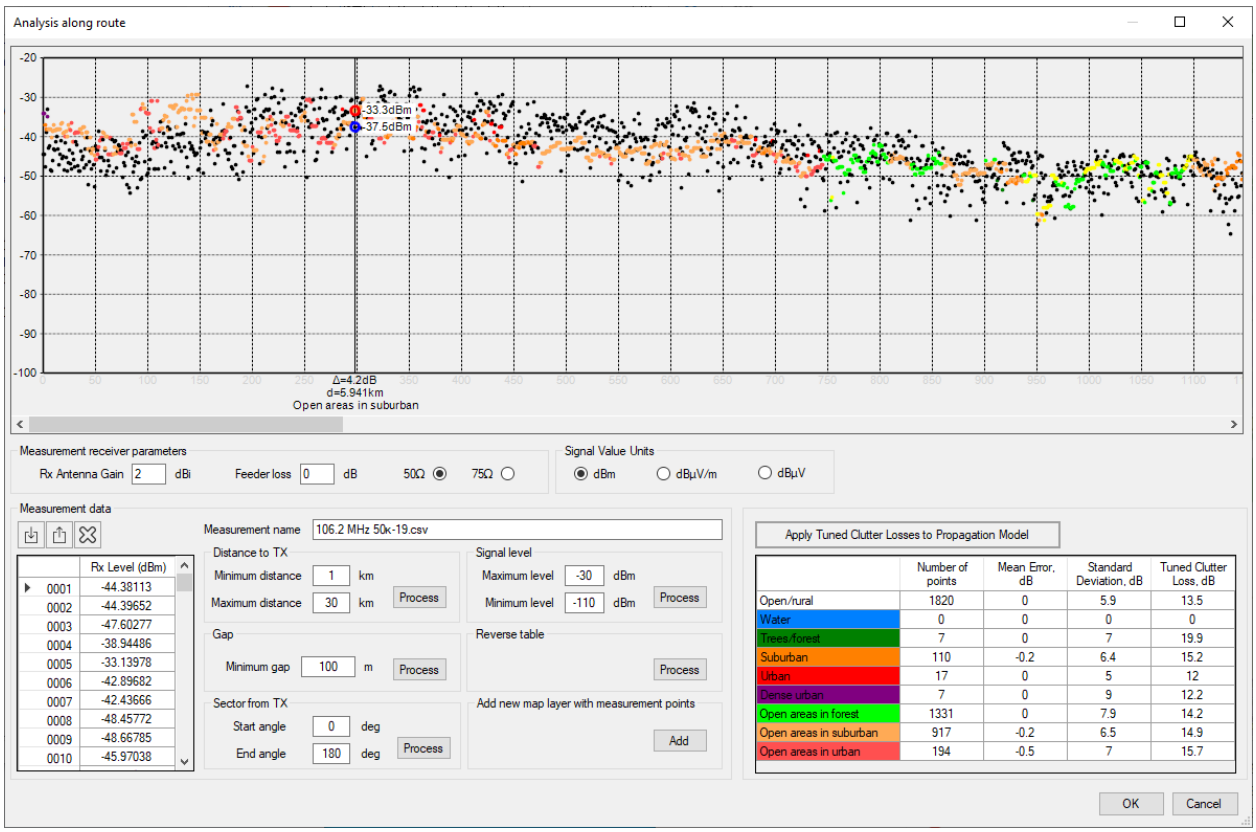
Coordinate presentation formats - HEMISPHERE DEGREES MINUTES SECOND (N35 36 23.8) or HEMISPHERE DECimal DEGREES (N12.34567).

To import data on population from a CSV file, click on the button "Import population data from CSV file" and select file, after which the program will show the total number of settlements with data on the

population. Click on the "Open Report" tool and a spreadsheet will appear with the population and the list of settlements covered by the broadcast.

Import Measurement Results and Propagation Model Tuning for TV and Radio Broadcasting Projects

RadioPlanner 3.0 allows you to tune clutter loss for a propagation model by comparing measurements with predicted Rx power values. Loading, preprocessing and analysis of measurement file is performed in transmitter panel.

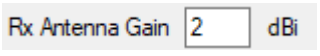


Measurement Analysis Along Route for FM

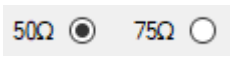
Import of measurement data from a CSV file

Export of measurement data to a CSV file

Delete measurement data

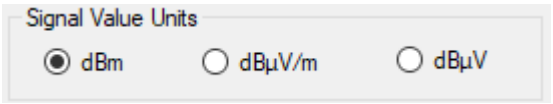


Measurement receiver antenna gain, dBi



System type, Ohm

Antenna cable loss, dB



Select signal units to display

Tools for preliminary processing:

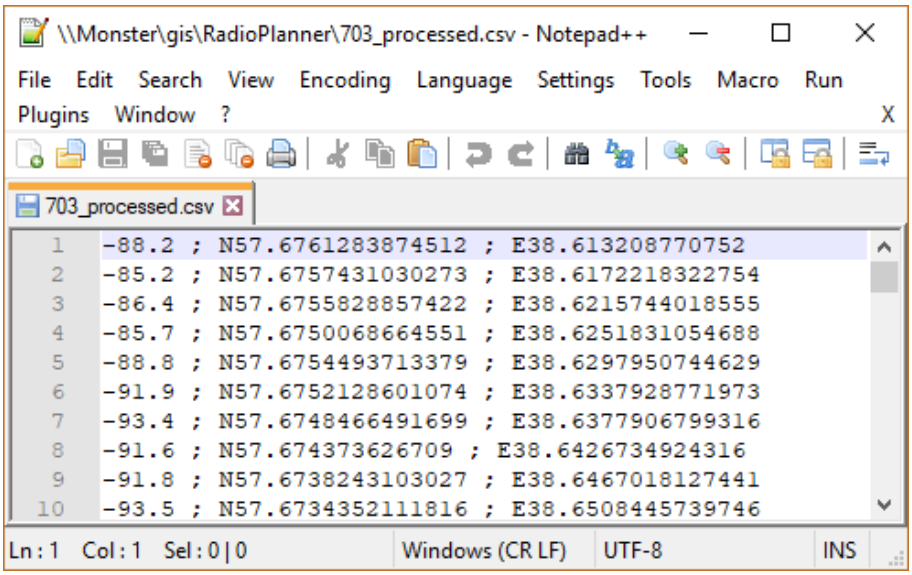
Distance to TX Minimum/Maximum Distance	Limit the points that will be included in the comparison by distance from the transmitter
Signal level Minimum/Maximum Level	Limit the points that will be included in the comparison by received power level from the transmitter
Gap Minimum Gap	Perform averaging of the power level within a given segment
Sector from TX Minimum/Maximum Angle	Limit the points that will be included in the comparison by azimuth from the transmitter
Reverse table	Change the order of points in the route (the last point becomes the first, the penultimate point becomes the second, and so on)
Add New Layer with Measurement Points	Add a custom measurement layer to the map. The resulting layer will appear among the user layers; the layer name will correspond to the transmitter and antenna direction.

Measurement file in CSV format

Each of the lines in this file contains three parameters: the level of the measured signal from transmitter in dBm; geographical latitude; geographic longitude

The separator of parameter values is a semicolon.

Formats for the representation of geographic coordinates are Hemisphere Degrees SECOND MINUTES (N35 36 23.8) or HEM DECIMAL DEGREES (N12.34567).



Measurement file in CSV format

Operating procedure:

1. Based on the results of field measurements, prepare a file with the measurements results.

2. Specify the antenna gain, cable loss and impedance for the measuring receiver path. The height of the receiving antenna is set in the network parameters.

3. Upload measurement files to the transmitter. The results of the measured and calculated receiving levels along the route will appear. Measurement levels are indicated in black, calculated levels - in a color that corresponds to the clutter type at a given point (yellow - open space). The abscissa shows the route point numbers. Hovering over the plot displays the calculated and measured levels, the difference in levels, the distance to the site in kilometers, and the clutter type. If necessary, perform the preliminary processing. When you click on the plot, a context menu appears, in which you can delete a point with the measurement result.

The table below the plot will indicate the number of points, the average error, the standard deviation of the error, as well as the recommended loss values for different clutter types, at which the average error will be zero. When you click on the button "Apply Tuned Clutter Losses to Propagation Model", the values for the points of the plot will be recalculated taking into account the tuned values, as well as the loss values in the "Propagation Model" menu will be changed. To assess how the new obstacle loss values will affect the coverage calculation result, you need to re-calculate the coverage.

4. Now, based on the analysis of the results obtained for different clutter types and for different transmitters, a decision is made regarding the need to tune the values of the previously used clutter losses in the propagation model.

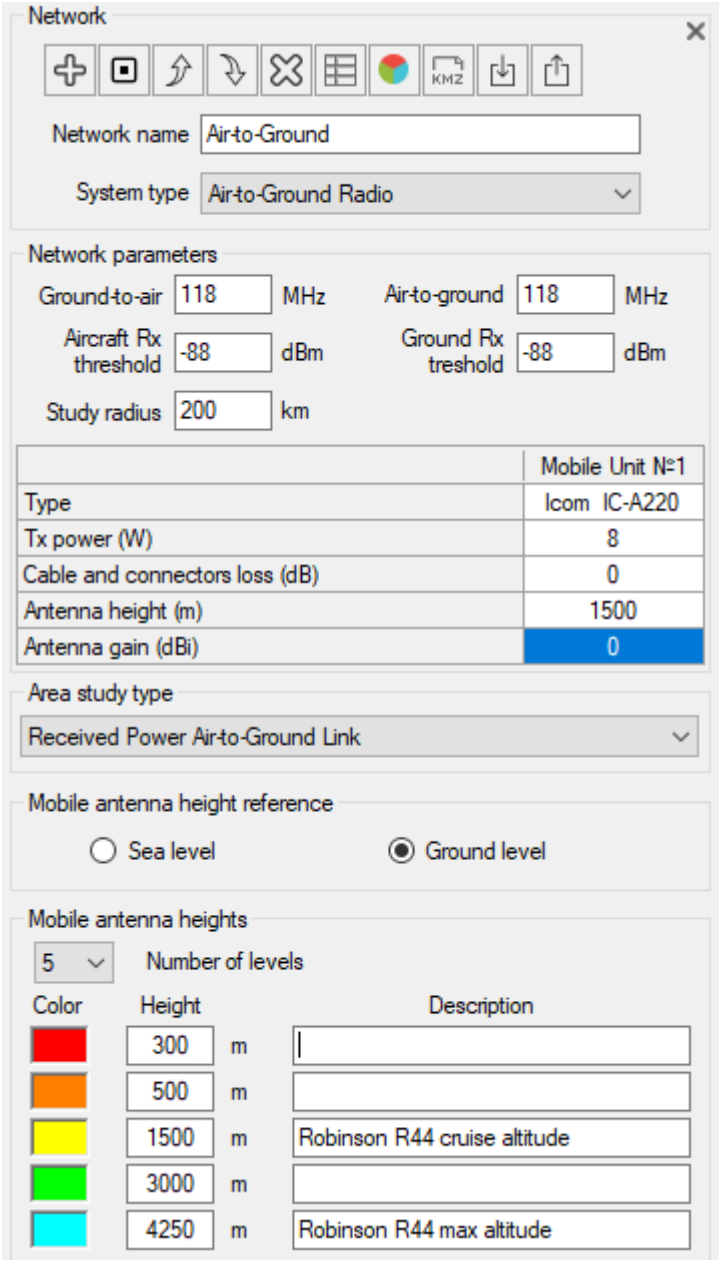
Air-to-Ground Communication Coverage Prediction

RadioPlanner 3.0 can predict coverage for Air-to-ground communication and radio navigation systems operating in VHF, UHF, and microwave frequencies: UAV (Drone) Control, Air-to-ground radio, ADS-B, VOR, DME.

The system type must be set to Air-to-Ground Radio. The set of parameters for the Site and Mobile Unit is similar to that of the mobile communication network.

Network

The “Network” menu is used to set all parameters for the selected network, including mobile station parameters and calculation parameters. You can also perform calculations for the network using this menu.



Network menu for Air-to-Ground Radio

Add a new network with the same parameters (copy the network)

Check/Uncheck all sectors for current network

Move the Network up

Move the Network down

Delete the network

System parameters

Calculate Coverage

Calculate coverage for each active sector and save the map as a KMZ file

Load network parameters from a template

Save network parameters as a template

Network name	Name of network, text field
System type	System type options: - Generic TRX - LTE - 5G - Terrestrial Broadcasting - Air-to-Ground Radio The selected system type will determine the set of additional system parameters, as well as the types of coverage predictions available.
Ground-to-Air	Carrier frequency towards aircraft, MHz
Air-to-Ground	Carrier frequency to ground, MHz
Aircraft Rx threshold	This threshold value will limit the coverage prediction display based on whether the signal received at the aircraft from the ground base station is above or below this threshold, dBm
Ground Rx threshold	This threshold value will limit the coverage prediction display based on whether the signal received at the ground base station from the aircraft is above or below this threshold, dBm
Study radius	Maximum study radius, km The larger the radius, the longer the computation time. Do not set an unnecessarily large calculation radius.

Mobile Units

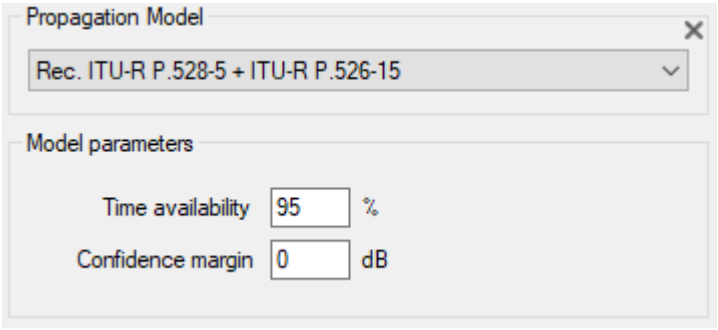
Type	Name (model) of Mobile Unit, text field
Tx Power	Transmitter power, W
Cable and Connector Loss	Loss in cable and connectors, dB
Antenna Height	Antenna height relative to ground level, m
Antenna Gain	Antenna gain, dBi

Propagation Model for Air-to-Ground Radio

The propagation model is a combined model based on the recommendation ITU-R P.528-3 (02/2012), “Propagation curves for aeronautical mobile and radio navigation services using the VHF, UHF, and SHF bands” and the recommendation ITU-R P. 526-14 “Propagation by Diffraction.”

The hybrid model takes into account the following factors affecting the propagation of radio waves along the air-to-ground path:

- Free space loss
- Diffraction loss along the path taking into account the curvature of the Earth and the terrain profile extracted from the DTM
- Variation of the received radio signal due to multipath fading



Propagation model for Air-to-Ground Communication

Time Availability, %	By choosing a particular time percentage, the calculated received power values are the power levels that will be exceeded at least that percentage of time.
Margin, dB	Prediction confidence margin. Since the received power level calculations are estimates, the prediction margin lets you specify a safety margin in dB so that you can be more confident that your signal level estimate is indeed above the specified signal level.

Area Study Types for Air-to-Ground Communication

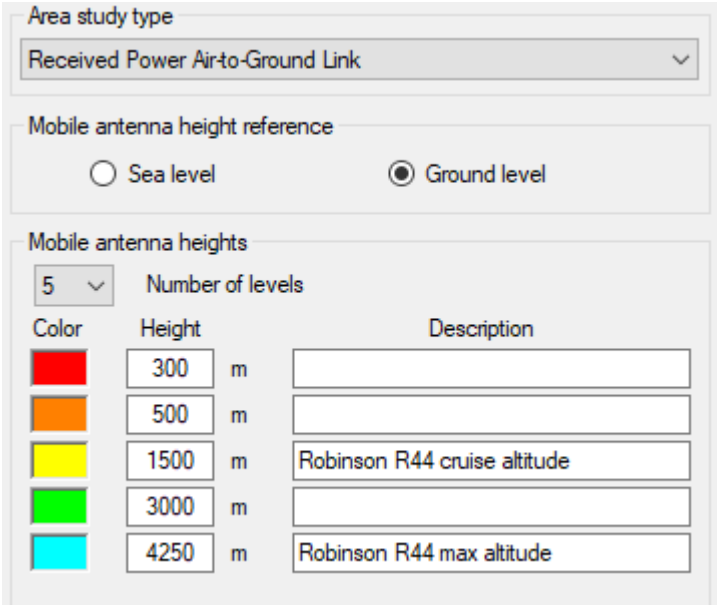
For the Air-to-Ground Communication project, you can choose one of the following area study types:

- Received power Air-to-Ground link
- Received power Ground-to-Air link
- Best Server Air-to-Ground link

The area study resolution for air-to-ground calculations corresponds to one screen pixel for magnification = 7 (Low), magnification = 8 (Medium), and magnification = 9 (High). For a geographic latitude of 55 degrees, this is approximately 720, 360 and 180 meters, respectively. The higher the resolution, the longer it takes to calculate.

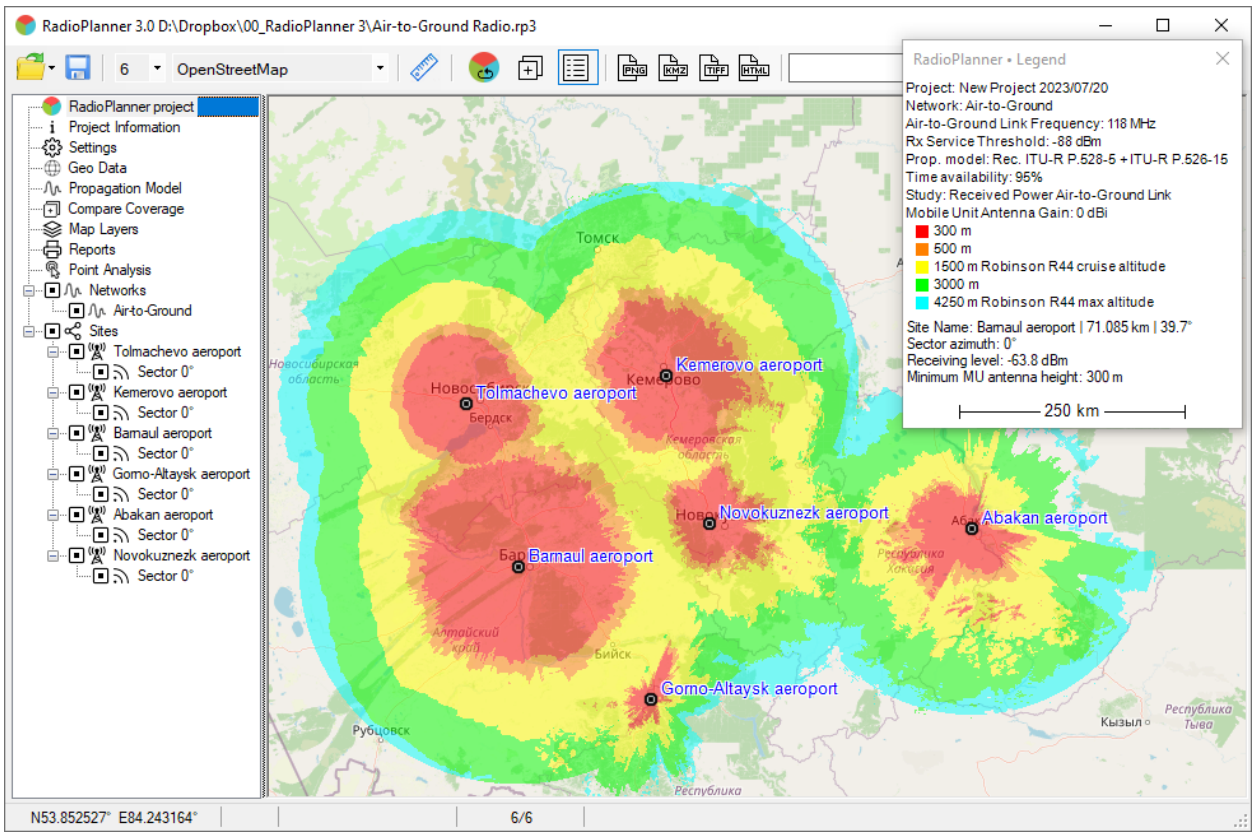
Received Power Air-to-Ground/Ground-to-Air Link

In these types of calculations, the map displays different colors of coverage areas for different heights of the Mobile Unit (aircraft). You can set from one to eight different altitude levels.



Received power Air-to-ground link

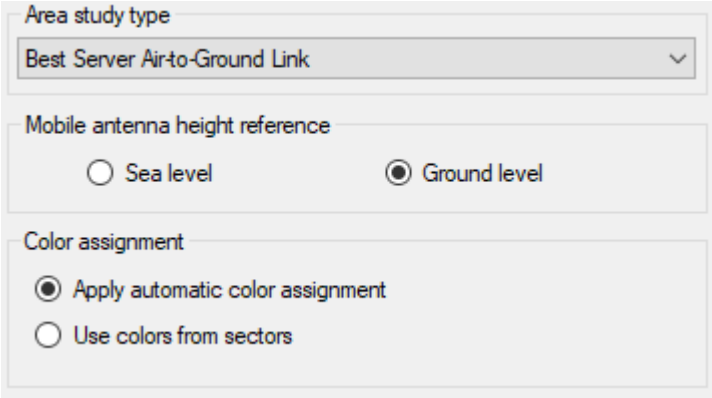
Mobile Antenna Height Reference	- Sea level - Ground level
Number of Levels	Number of altitude levels
Color	Color level
Height	The value of the height of the mobile unit for which coverage area is displayed in meters.
Description	Text field



Air-to-Ground Radio Coverage

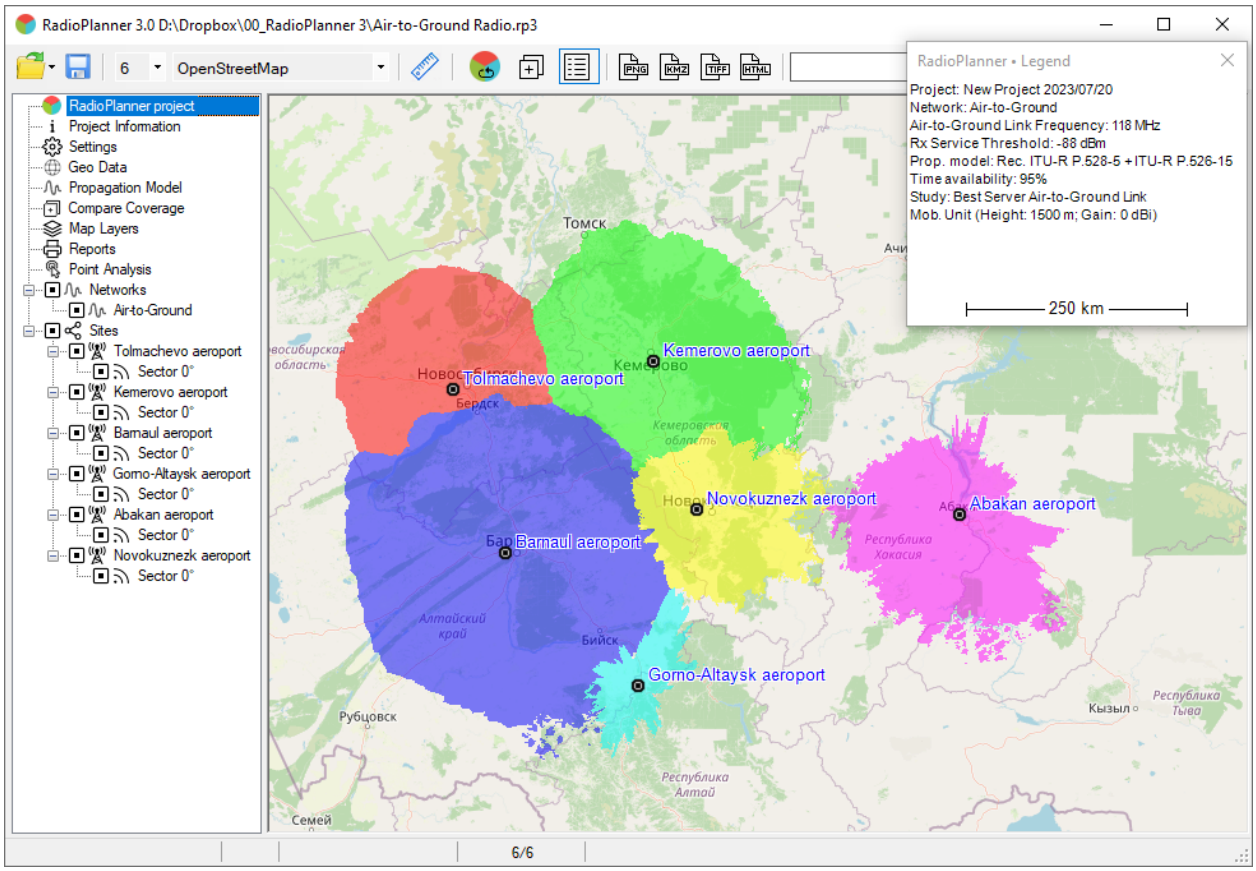
Best Server Air-to-Ground Link

The Best Server map is a map showing the identity of the sector supplying the strongest received signal at each grid location.



Best Server menu

Mobile Antenna Height Reference	- Sea level - Ground level
Apply Automatic Color Assignment	Assign colors to sectors in random order
Use Colors from sectors	Assigning colors to sectors from the sector parameters



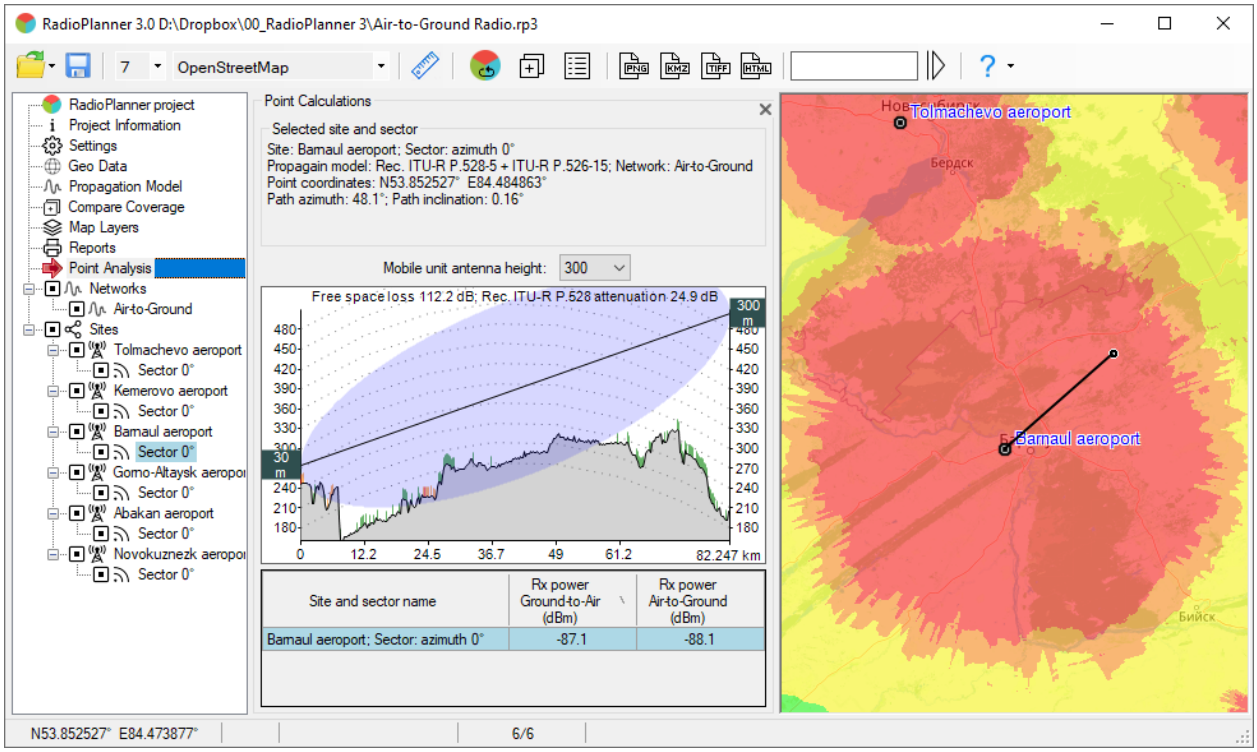
Best Server Air-to-Ground Radio Coverage

Point Analysis for Air-to-Ground Communication

This menu displays the terrain profile from the selected site to any point at the height of the mobile unit. The current point on the map can be changed with a mouse click.

The terrain profile shows the heights of the radiation centers of the antennas of the site and mobile unit, as well as the 60% Fresnel zone for the radio beam, free space loss, and diffraction loss due to the terrain. The site for which the profile will be shown is selected in the left part of the panel in the general sites tree. Click on the required site sector (not to be confused with the activity icon), after which information on this sector will appear above the terrain profile.

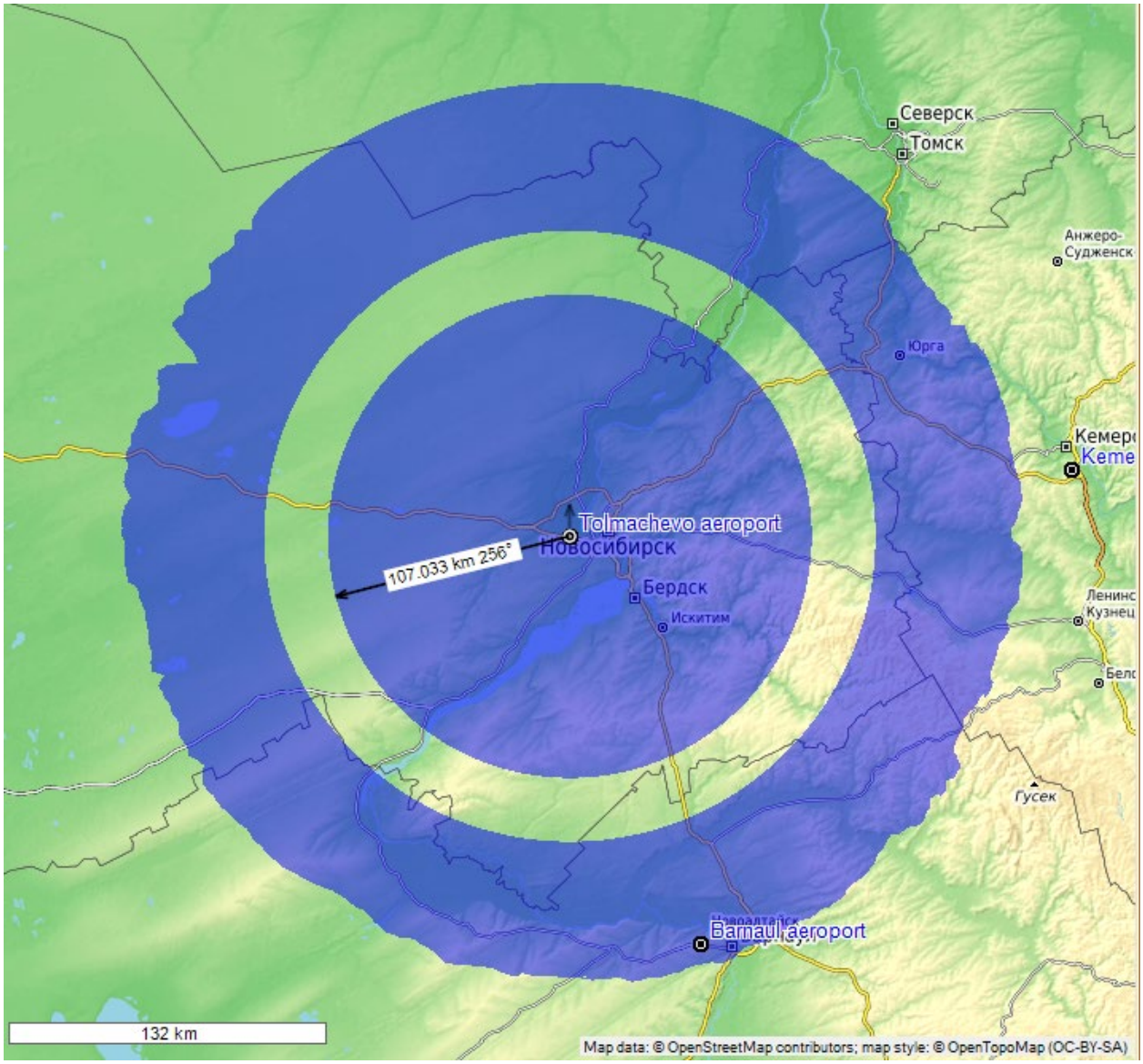
The height of the mobile unit is selected in the drop-down list on the right above the terrain profile from the set of heights specified for calculating coverage areas in Area Study Details - Received Power Air-to-Ground link. The maximum path profile length is limited by the Study Radius parameter in the Network menu.



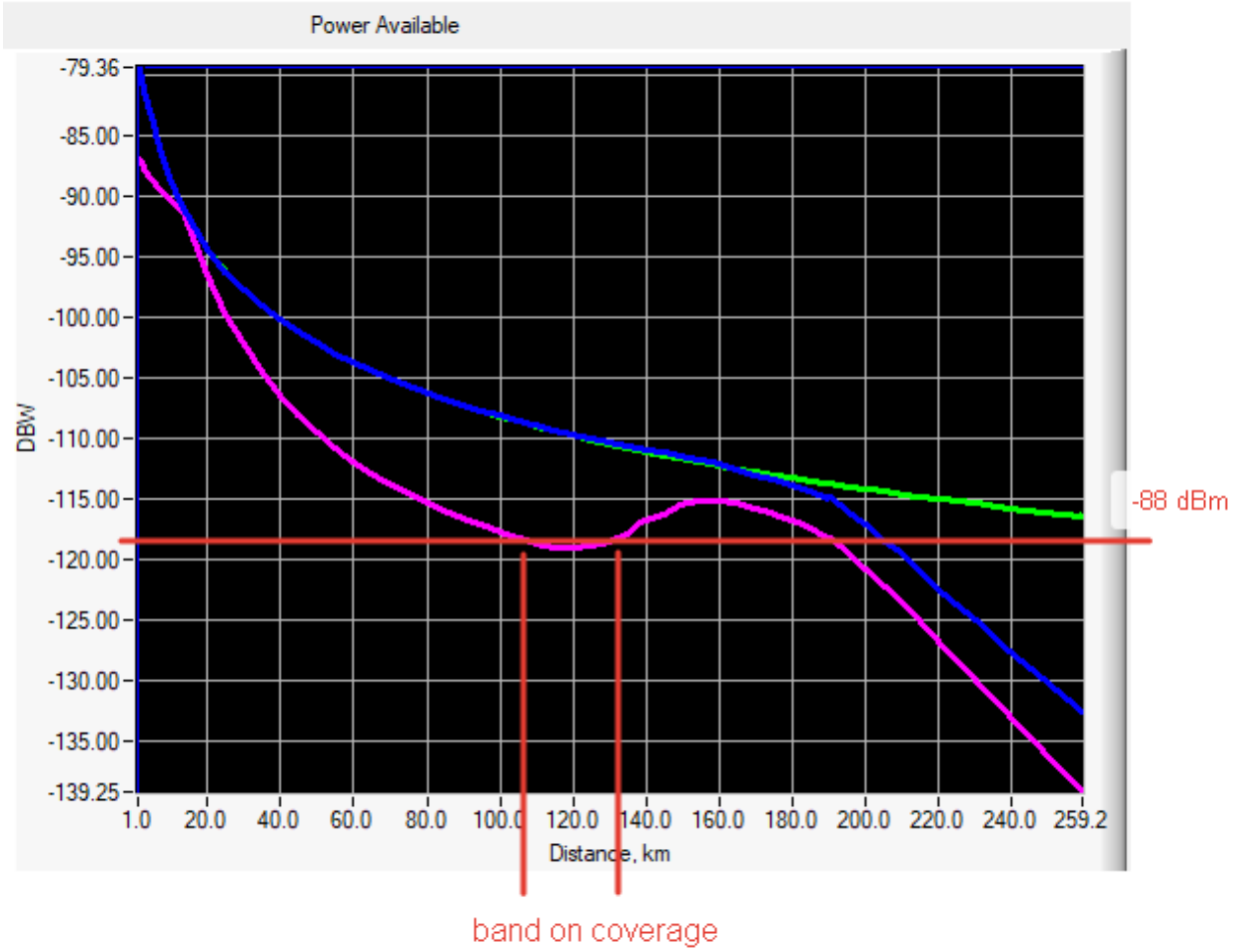
Point Analysis

Some Features of Coverage Calculating for Air-to-Ground Radio

For a certain combination of data (heights of the site and mobile unit, frequency, power, service threshold, and time availability), a band may appear on the radio coverage area indicating lack of communication (in the example below, such a band is present at a distance of 107-134 km in the radial direction from the base station).

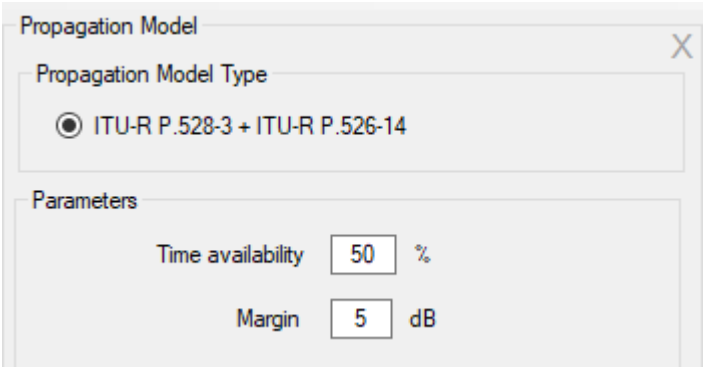


This means that in this zone, the mobile unit (aircraft) will be in the area of strong influence of multipath due to reflection from the Earth's surface and time availability will decrease. Model ITU-R P.528-3 (02/2012), which is based on the IF-77 Electromagnetic Wave Propagation Model by M.E. Johnson and G.D. Gierhart, specially designed for aeronautical radio communications, takes this effect into account. A plot of received power versus distance for the example in question is shown below. It shows that at a time availability of 95% for the level of -88 dBm (-118 dBW), the curve has a bend, which determines the dip in received power and the corresponding band in the coverage area.

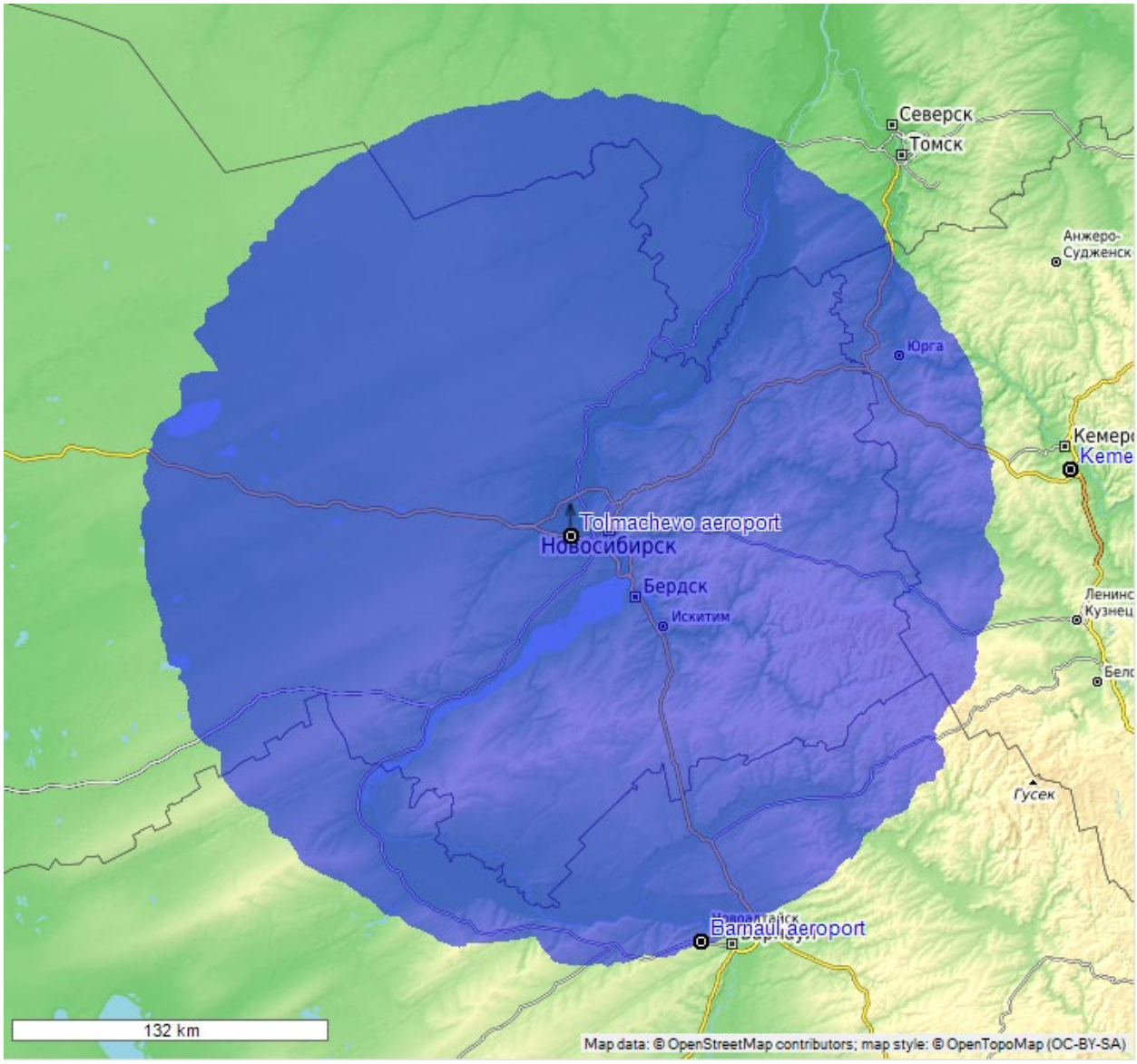


In fact, the appearance of such a band in the coverage area does not mean a significant reduction (within 5-7 percent) in time availability in this area. In practice, such a decrease in time availability in a small area within the coverage area can be considered acceptable.

In order to take this assumption into account, a calculation should be made for the average power of the received signal (time availability 50%), taking into account an additional margin for fading within 5-7 dB.



After which, the calculation result for the example considered above will look like this:


Северск
Томск
Анжеро-
Судженск
Юрга
Кемер
Keme
Tolmachevo aeroport
Новосибирск
Бердск
Искитим
Ленинс
Кузнец
Бело
Гусек
Barnaul aeroport
132 km
Map data: © OpenStreetMap contributors; map style: © OpenTopoMap (OC-BY-SA)

Appendix 1. File formats

1.1 Cable attenuation file

A text file named **feeders.txt**, containing information about frequency-dependent attenuation in cables, is included in the RadioPlanner installation folder. Users can add information about required cables to this file.

The **feeders.txt** file has the simple format:

```
-
FSJ1-50A   1/4"
30      3.22
100     5.94
450     12.9
1000    19.7
2000    28.6
6000    53.2
10000   71.5
-
LCF12-50J   D=1/2”
0.5     0.15
100     2.16
200     3.1
300     3.8
450     4.71
900     6.8
1500    8.97
1800    9.91
2300    11.35
3000    13.2
4000    15.5
8800    24.6
```

where:

FSJ1-50A 1/4" – the cable name that will appear in the cable list box.

30 – frequency in MHz.

3.22 – attenuation in dB per 100 meters at this frequency.

The number of frequency/attenuation pairs for each line in the feeders.txt file does not need to be the same. A TAB character should be used as a separator between frequency and attenuation values.

Appendix 2. Default Digital Terrain Model (DTM)

North America
1 Arc-second Digital Elevation Model USGS National Map 3DEP
Coverage: USA, Canada, Mexico.
Source: https://data.usgs.gov/datacatalog/data/USGS:35f9c4d4-b113-4c8d-8691-47c428c29a5b

Europe
We use open digital terrain models (DTM) from national geoservices for the following European countries:

- Austria (DTM 5-10 meters)
- Belgium (DTM 5-10 meters)
- Czech (DTM 1 meter)
- Denmark (DTM 2 meter)
- Estonia (DTM 10 meters)
- Finland (DTM 10 meters)
- France (DTM 5-10 meters)
- Germany (DTM 2-10 meters)
- Iceland (DTM 10 meters)
- Ireland (DTM 2 meter)
- Italy (DTM 2-10 meters)
- Latvia (DTM 20 meters)
- Lithuania (DTM 5 meters)
- Liechtenstein (DTM 10 meters)
- Luxembourg (DTM 0.5 meter)
- Netherlands (DTM 5 meters)
- Norway (DTM 10 meters)
- Poland (DTM 1 meters)
- Portugal (DTM 0.5-10 meters)
- Romania (DTM 1 meter)
- Slovakia (DTM 1 meter)
- Slovenia (DTM 1 meters)
- Spain (DTM 2-5 meters)
- Sweden (DTM 50 meters)
- Switzerland (DTM 2 meters)
- United Kingdom (DTM 2 meters)

For the rest of Europe, we use the *European Digital Elevation Model (EU-DEM), version 1.1*.
Coverage: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus , Greece, Hungary, Kosovo, Malta, Montenegro, North Macedonia, Serbia, Turkey.
Source: https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1?tab=metadata

Australia
SRTM-derived 1 Second Digital Elevation Models Version 1.0 (DEM-S).
Coverage: Australia
Source: https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/72759

New Zealand
New Zealand National Digital Elevation Model a 25-meter resolution.
Coverage: New Zealand
Source: https://lris.scinfo.org.nz/layer/48131-nzdem-north-island-25-metre/

South America, Africa, Asia, Middle and Far East regions
ALOS World 3D - 30m (AW3D30) by the Japan Aerospace Exploration Agency's (JAXA).
Source: https://www.eorc.jaxa.jp/ALOS/en/aw3d30/

https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLIII-B4-2020/183/2020/isprs-archives-XLIII-B4-2020-183-2020.pdf

Appendix 3. Project Samples for Various Wireless Networks and Broadcasting Networks

The software package includes several project samples for various wireless and broadcast networks. These projects are fully prepared for calculation; simply open the project and click the “Calculate coverage” button.