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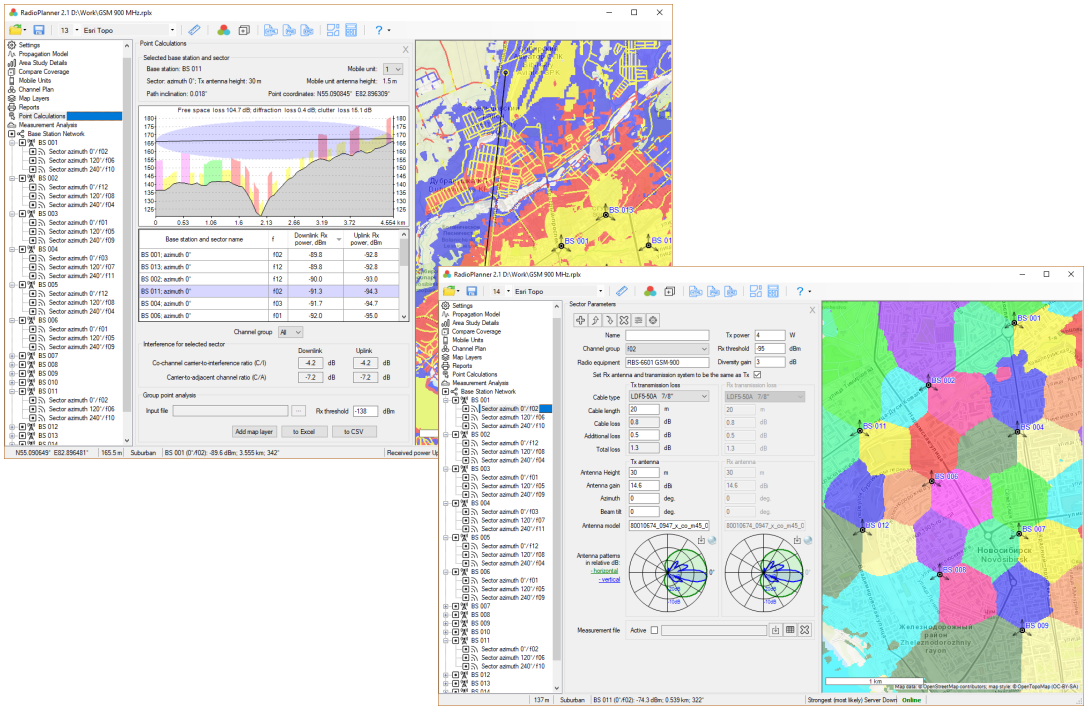
RadioPlanner 2.1

Mobile and Broadcast Network Planning

User Manual



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From the Developers

We've made every effort to create a user-friendly and intuitive application. However, we recommend that you spend some time reading this User Manual to get the most out of the RadioPlanner application.

RadioPlanner was created by engineers with more than 20 years of experience in designing radio communication and broadcasting networks and is a full-featured, yet simple and convenient planning tool.

Features

RadioPlanner 2.1 is a tool for planning:

- GSM / WCDMA / CDMA / UMTS / LTE / 5G mobile networks

- TETRA / P25 / DMR / dPMR / NXDN / GSM-R /McWiLL land mobile radio networks

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

- DVB-H / DVB-T / DVB-T2 / ISDB-T / DAB / DAB+ terrestrial radio and television broadcast networks

- Air-to-ground communication systems and radio navigation operating in the VHF, UHF, and microwave frequencies: UAV (Drone) Control, Air-to-ground radio, ADS-B, VOR, DME, etc.

RadioPlanner 2.1 uses the following propagation models:

- ITU-R P.1812-4 model
- Longley-Rice (ITM) model v 1.2.2
- ITU-R P.1546-6 model (for broadcasting only)
- Combined ITU-R P.528-3 + P.526-14 model (for aeronautical radio only)

RadioPlanner 2.1 performs various types of area studies for mobile networks:

- Received Power uplink/downlink
- Strongest Server (Best Server)
- C/I ratio
- Area with Signal above Both the Base and Mobile Thresholds
- Number of servers above uplink

Area studies for terrestrial radio and television broadcast transmitters:

- Field Strength at the Receiver Location
- Strongest Server (Best Server)
- FCC contours
- ITU-R P.1546-6 contours
- Calculation of the population in the coverage area based on the OpenStreetMap project database
- Generation of the list of localities covered by broadcasting

Area studies for air-to-ground communication systems:

- Received power Air-to-Ground link
- Received power Ground-to-Air link
- Strongest (most likely) Server Air-to-Ground link

RadioPlanner allows you to do:

- Frequency planning of radio networks considering co-channel and adjacent channels' interference
- Points calculation showing the profile of the path, losses, and levels of the signal and interference on co-channel and adjacent channels
- Calculation of uplink/downlink Rx levels for a set of IoT end-devices: LoRa, SigFox, and others, located in different conditions.
- Import the measurement results of the received signal power levels for comparison with calculated values and adjust propagation model parameters
- Compare two coverage study results
- Save the coverage prediction result as an interactive web page, a PNG image, a CSV file, a MIF file or as a KMZ file
- Flexible adjusting of the layers on the base map and show custom vector layers

GIS features:

- Terrain elevation data 30 m plane resolution (for more details on data sources see Appendix 3. Terrain Elevation Data)
- A clutter model with nine clutter types. The built-in clutter model was created from the OpenStreetMap (www.openstreetmap.org) and Global Forest Change (www.earthenginepartners.appspot.com) projects. If necessary, the simple and easy-to-use Clutter Editor will allow the user to prepare their own clutter model based on new satellite imagery.
- Any kind of base map—both common (such as OpenStreetMap, OpenTopoMap, US Topo, etc.) and custom ones.

Installation and Activation

RadioPlanner supports 64-bit Windows 7/8/8.1/10.

The minimum computer configuration is 64-bit Windows, Core i3 CPU, 4GB RAM, 200GB HDD, video card, and monitor with support for 1366x768, although the program can be installed on a less productive computer.

The recommended computer configuration is 64-bit Windows, Core i5 CPU, 16GB RAM, 256GB SSD, video card, and monitor with support for 1920x1080. To use all RadioPlanner features, the Microsoft Excel spreadsheet editor must be installed on the computer.

To use the full version of RadioPlanner, you should purchase a license.

Once you have successfully purchased RadioPlanner, you will receive an automated email within a few seconds containing a link to download the installation file and the Activation ID for the license.

Run the installation file and follow the instructions that appear on your screen. When the installation is complete, run the application, enter the Activation ID provided to you in the order email, and click Activate.

Once you have done that, you have activated the fully functional version.

Software Update

Periodically, we release free current updates in which we improve the functionality and stability of the software.

RadioPlanner supports both manual and automatic checking for updates. The software will check for available updates every time it starts. To check for updates manually, click "Help - Check for updates." If there is an available update, a window will open with information about the current and available versions. You can download the update from the link and install it manually. Exit the RadioPlanner software before installing the update.

User Interface

RadioPlanner has three different types of projects:

- Mobile Radio
- Radio or TV Broadcasting
- Air-to-Ground Communication

The configuration of the program menu and the set of input parameters will depend on the choice of project type, so before starting, the user must select the project type in the **Settings** menu (see the **Settings** section). The general procedure for working with the software is almost the same regardless of the type of project.

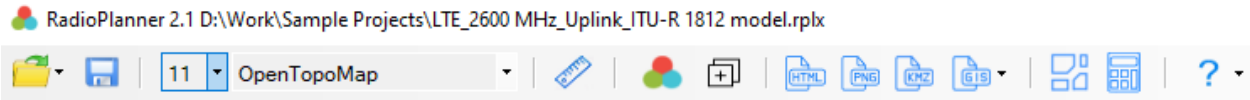
This manual is divided into four parts - first, a description of the work with those program functions that are independent of the type of project, then a description of work with Mobile communications projects, then with TV and radio broadcasting projects, and finally with air-to-ground communications projects.

After the program starts, the main panel will appear with the main menu on the left side and the base map on the right side. You can change the size of the panels as needed using the separator.

Different layers can be displayed on the base map — base stations, radio coverage, various additional vector layers, etc. You can choose to display one of the pre-installed base maps or customize your base map, as described in the Base map Settings section.

Navigation on the map is carried out using the mouse. Use the mouse wheel to zoom in on the map. You can also select the desired **zoom** from the drop-down list in the toolbar.

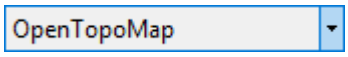
Toolbar and Main Menu



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

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

- The current zoom of the base map



- The current base map

- The tool "ruler," which allows measuring the distance and azimuth between any two points. To perform a measurement, click on the ruler, then click on any two points of the map and you will see the distance between the points and the azimuth from first to second. To exit, right-click anywhere on the map.

- Perform coverage calculation

- Add coverage to compare

- Save the coverage as a web page

- Save coverage as an image in *.png format

- Save coverage in *.kmz format

- Save the coverage in Text CSV file or Exchange file MapInfo (MIF + MID)

- Clutter Editor

- Calculator of the Noise-Adjusted Faded Performance Threshold

- Help

More information about each of the tools is described later in the relevant sections of the manual.

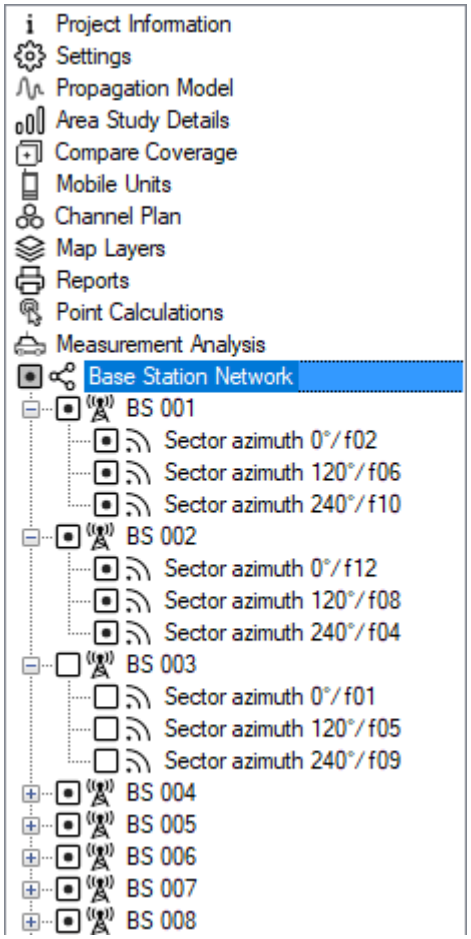


Figure 1. Tree View interface

Project Information

A new project is created automatically when RadioPlanner is launched.

There are standard buttons: New, Open, Save, Save As on the File menu, which allows performing standard file operations. A project file can be saved with the extension *.rplx. This file contains all of the information about the project.

You can specify the project's general information in the project information panel.

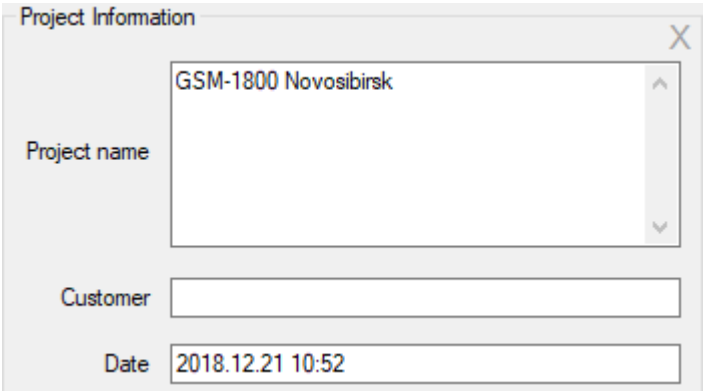


Figure 2. Project Information

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.

Settings

Before you start working with the software, you must configure the settings.

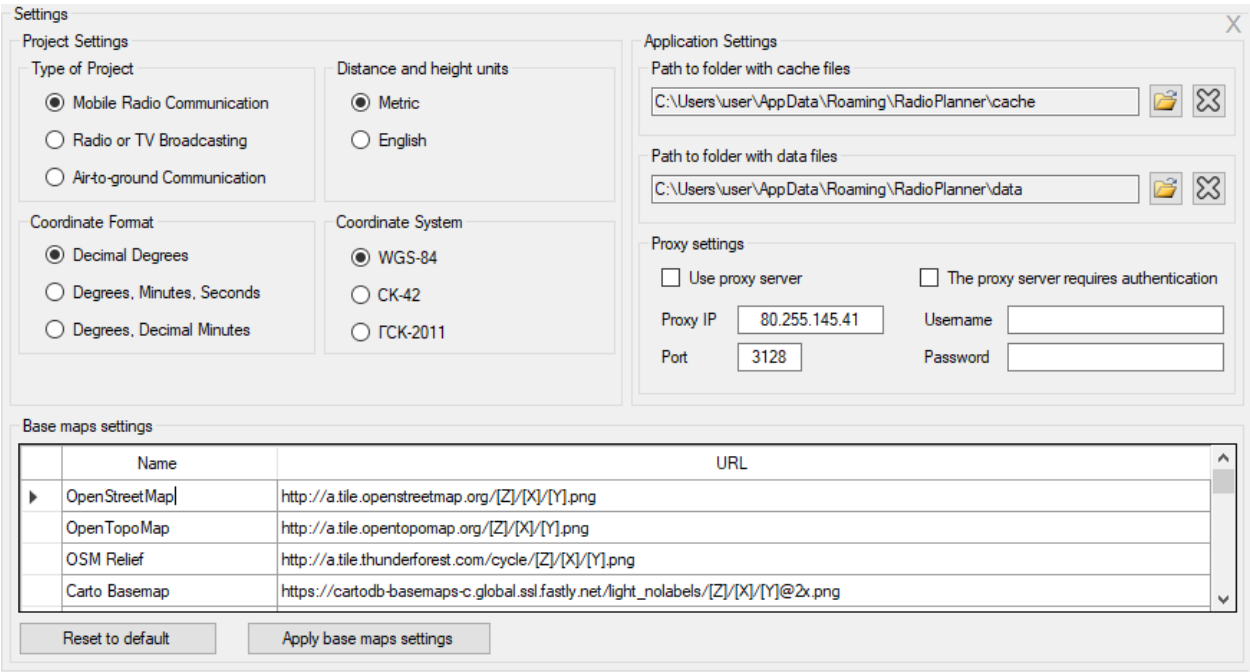


Figure 3. Settings

Project Settings	
Type of Project	- Mobile Radio Communication - Radio or TV Broadcasting - Air-to-Ground Communication Before changing the project type, save the current project, as the program will create a new project. The type of project will determine the configuration of the application menu.
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')
Coordinate System	- WGS-84 - SK-42 - GSK-2011
Application Settings	

Path to Folder with Cache Files	The path to the folder where downloaded base map tiles will be saved for quick access. This will speed up the application. The downloaded maps will remain on your computer, and you will be able to view them when you do not have an Internet connection. This folder is created automatically when the application is launched for the first time. You can change this folder.
Path to Folder with Data Files	The path to the folder where the downloaded SRTM and clutter files will be saved for quick access. This will speed up the application. Moreover, the downloaded files will remain on your computer and the application will be able to use them and create a terrain profile when you don't have an Internet connection. This folder is created automatically when the application is launched for the first time. You can change this folder.
Proxy Settings	If you are using a proxy server to access the Internet, enter its IP-address and port number. 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.

The prototype URL encapsulates a request format that is specific to the map provider and it varies from map provider to map provider. It consists of a text string that begins with http://, has a domain name and possible parameters, plus some symbols that RadioPlanner substitutes with real-time tile request information when actually contacting the server.

Below is a detailed explanation of how prototype URLs are constructed. The possible symbols that RadioPlanner accepts in the prototype URL are: [X], [Y], and [Z] coordinates and zoom.

To lookup map imagery in their database, most map providers use tile coordinates of x and y, plus zoom. As an example, the OpenStreetMap provides map imagery using x, y, and zoom. We can test-fetch a map tile of a portion of North America by typing 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. The OpenStreetMap fetches the map tile corresponding to x = 1, y = 2, and zoom = 3.

In order for RadioPlanner to properly fetch tiles from a map provider, a generalized prototype URL scheme must be furnished. This generalized URL scheme will be used by RadioPlanner to fetch any tile, at any coordinate, with any zoom. To accomplish this, the symbols "[X]," "[Y]," and "[Z]" (without the quotes) are inserted in the place of explicit coordinates.

For example, creating custom map types in RadioPlanner for OpenStreetMap can be accomplished by mixing the known specific URLs above with the symbols representing x, y, and zoom to form a custom map prototype URL (try these in the custom maps setup screen):

http://a.tile.openstreetmap.org/[Z]/[X]/[Y].png

When RadioPlanner needs a map tile fetched from a provider, it will replace the "[X]," "[Y]," and "[Z]" symbols with the actual coordinates and zoom for the tile required and then 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 required map. There are some examples listed below. Search online for local map providers' map servers' URLs.

Example:

OCM Transport:

http://a.tile2.opencyclemap.org/transport/[Z]/[X]/[Y].png

If the user has more relevant or more detailed cartographic data for the desired territory in the form of an image or vector map, he can create a tile server by himself in specialized GIS: MapInfo, QGIS, Global Mapper.

Map Layers

In the Map Layers menu, the user can control layers that are displayed on the map. The order of the layers in the menu corresponds to the order on the map (the base map is below all of the layers, sites are on top of all of the layers).

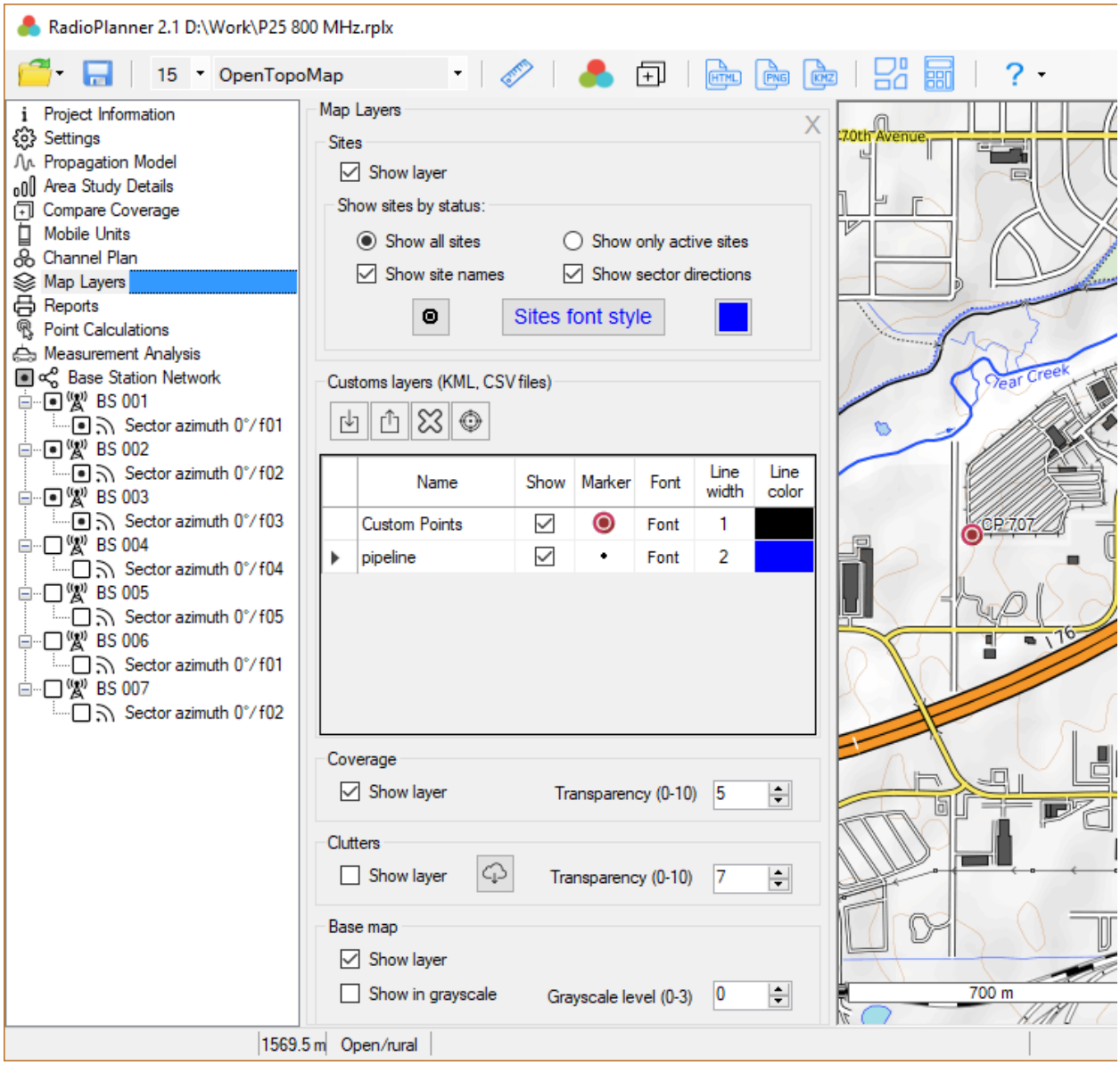


Figure 4. Map Layers

Sites

Sites are base stations or transmitters for TV and radio broadcasting, depending on the type of project.

Show layer	Show/hide site layer
Show all sites	Show all sites
Show only active sites	Show only active sites
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)

The user can load and display as a layer on the map any point or linear vector objects in KML format. This may be, for example, power lines, piping, and the results of measurements of signal levels.

Point objects can also be downloaded from a CSV file (text format, where the separator is a semicolon).

This is a universal format in which you can save a spreadsheet from any spreadsheet editor (Excel, LibreOffice Calc, and others), as well as databases.

The required fields for each point object are Parameter, Latitude, and Longitude. Format coordinates - HEMISPHERE degrees minutes seconds (N35 23.8 36) or HEMISPHERE decimal degrees (N12.34567). As a parameter, there can be any text that appears at the point with the specified coordinates. This may be, for example, the measurement result or the name of the object.

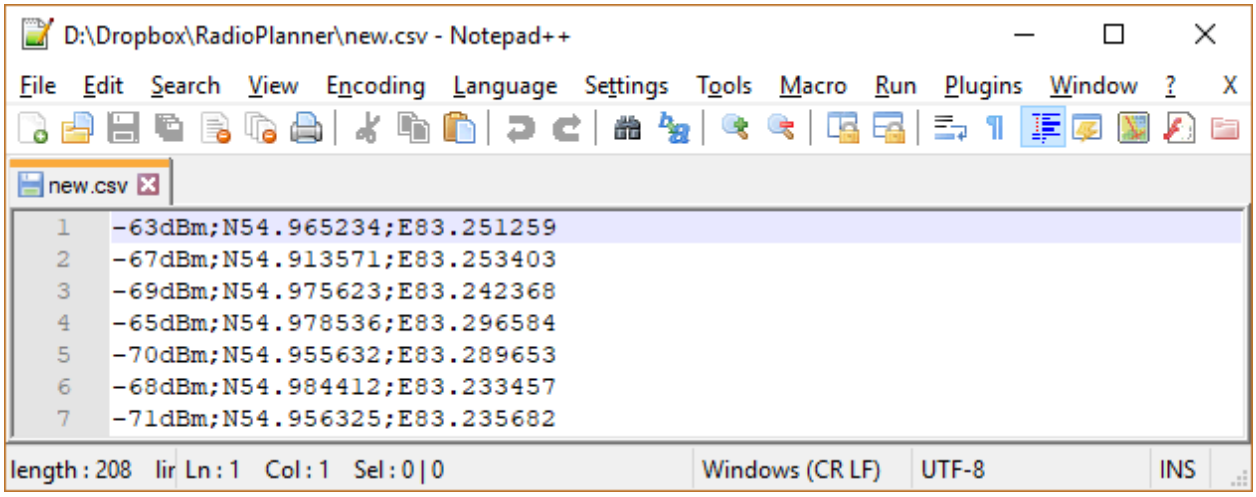


Figure 5. Sample CSV file with measurement results

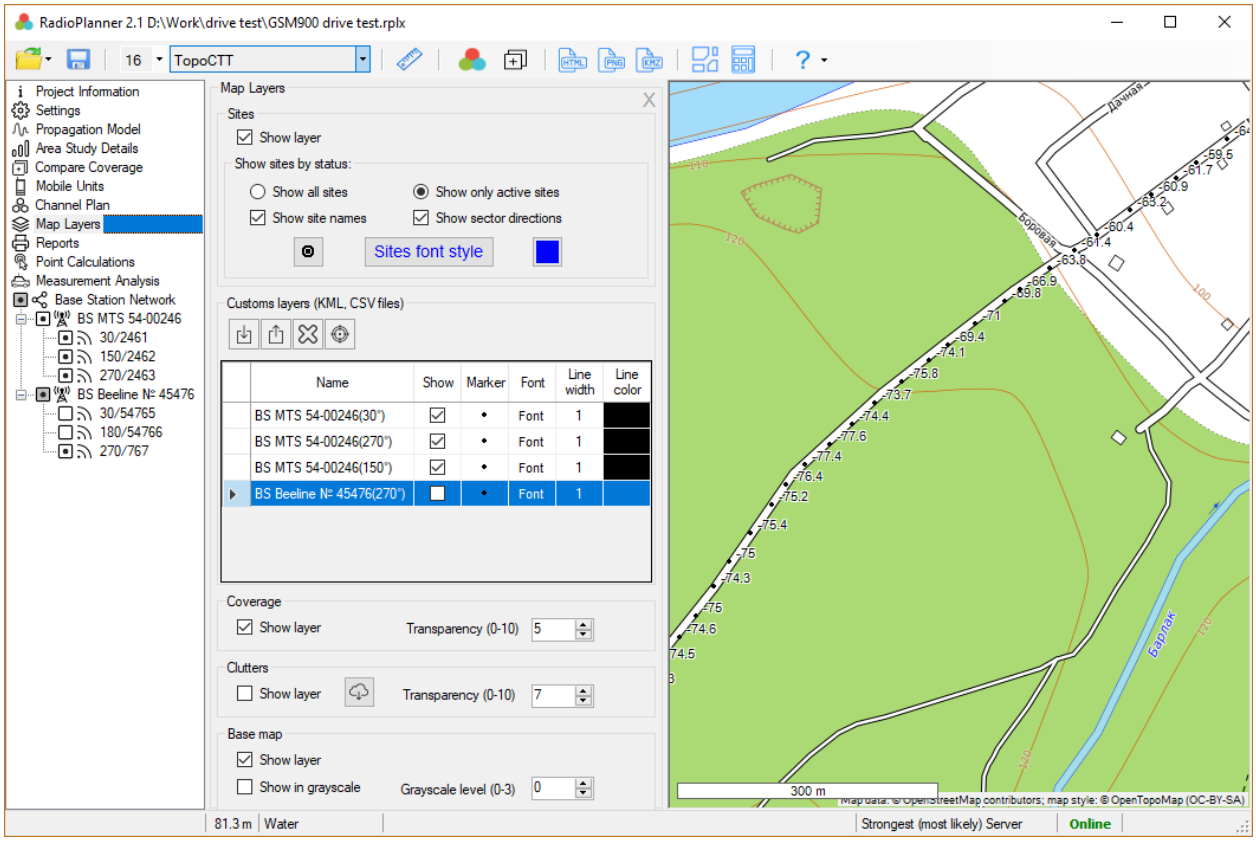


Figure 6. An example of the display of measurement results on the map

The user also can quickly create point objects on the map. To do this, right-click on the point location and in the context menu that appears, select "Add a new point to the 'Custom Points' layer," and then specify the point name. The point will appear on the map and it will also be added to the "Custom Points" layer, which will be automatically created when the user creates the first point object. The created point objects can also be deleted - to do this, right-click on the point and select "Delete the nearest point in the 'Custom Points' layer."

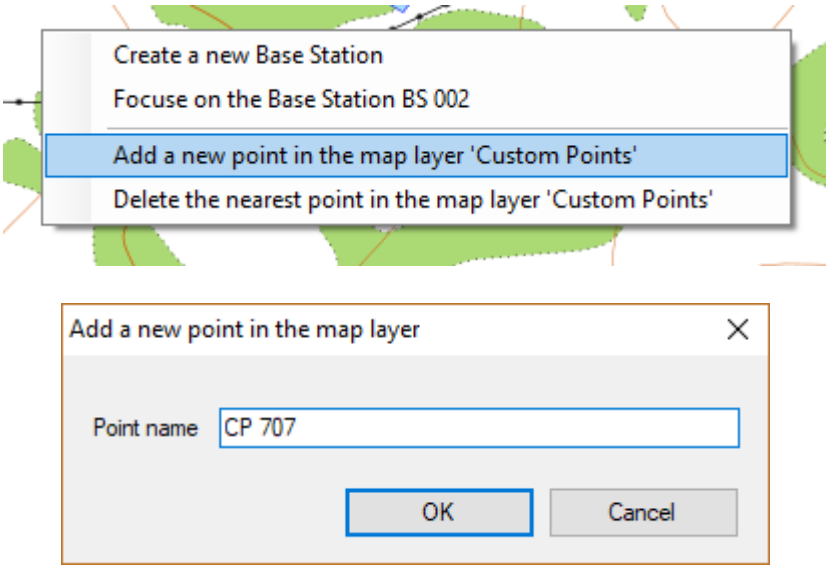


Figure 7. Adding a point feature to a map

Custom layers are saved in the project file.

	Load a custom layer (KML, CSV file)
	Delete selected custom layer
	Position the map on the first point of the selected layer
	Save points from the selected layer to a CSV file
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)

Coverage

Controlling the layer with the result of the coverage prediction.

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

Clutter

Control the clutter layer. The clutter layer is displayed starting with Zoom = 11.

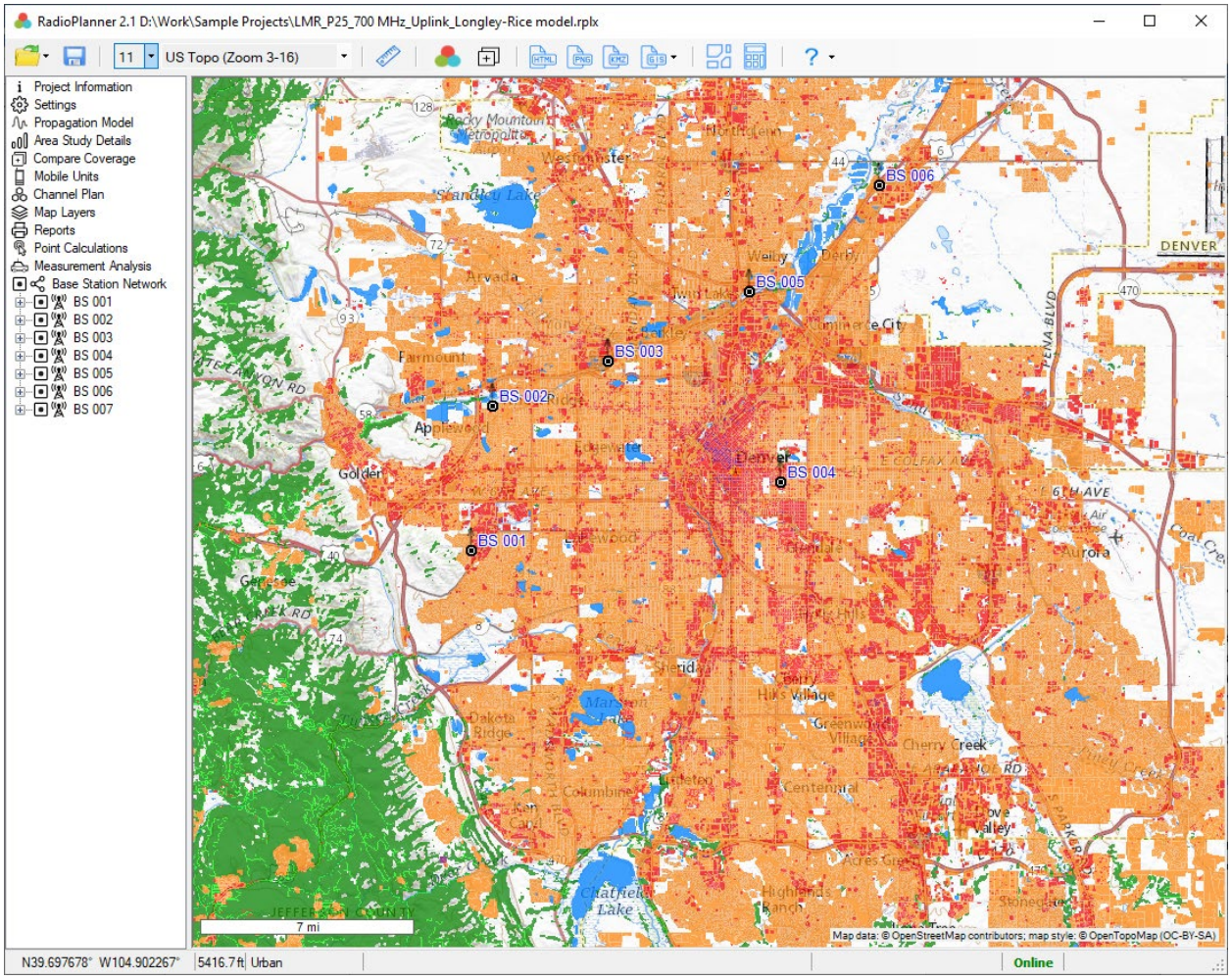


Figure 8. Clutter map

Colors that show clutter:

Open/rural
Water
Trees/forest
Suburban
Urban
Dense urban
Open areas in forest
Open areas in suburban
Open areas in urban

Show layer	Show/hide layer
	Download landcover within the screen area. This command will be required if the calculation of radio coverage in this area has not been performed yet.
Transparency	Layer opacity in the range from 0 (fully transparent) to 10 (not transparent)

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)

Saving the Coverage Calculation Result

Coverage prediction result can be saved as:

- Interactive web page in HTML format
- Image file in PNG format
- KMZ file
- 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 coverage as a webpage - Save the result of the calculation as an interactive webpage. The application allows the user to select the location and the name of the directory in which the result is saved. The index.html file (this is the page script), the bs.png file (base station icon), and the folder with the radio coverage tile pyramid {ZOOM} / {X} / {Y} will be saved to the specified directory. To open a web page, open the index.html file using your browser (Google Chrome, Mozilla Firefox, Internet Explorer, etc.). The specified folder with the script and the pyramid of tiles can be archived and forwarded to the customer.

Also, the resulting webpage can be placed on a web server for viewing in any browser and on any of the operating systems (Windows, Mac, IOS, Android, and Linux).

This webpage allows you to:

- Choose a base map from four different base maps
- Change zoom
- View basic data from the legend
- Display the scale and current coordinates of the cursor

For the operation of the web page, you'll need access to the Internet, since the base maps are downloaded from the corresponding resources.

A folder with a pyramid of tiles can be used for more than just this script. For example, it can be connected to any GIS that supports working with tiles, which will allow you to demonstrate the coverage as a layer on any GIS (QGIS, MapInfo, ArcGIS, SAS.Planet, and others).

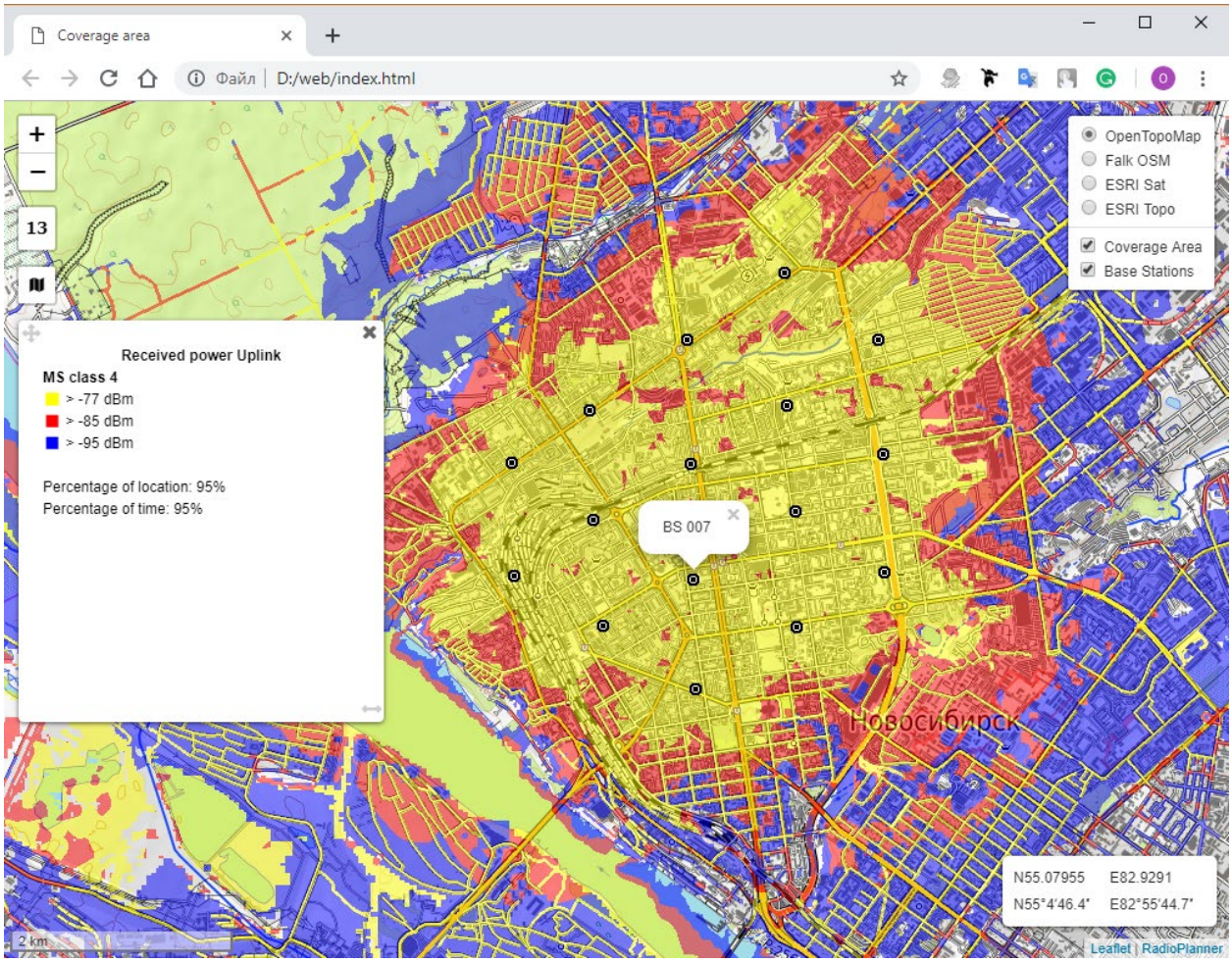


Figure 9. Example of the interactive web page

Save the coverage as an image - Save the result of coverage calculation as an image file in *.png format.

Before saving the image, the user can select the area of the saved coverage using the appearing frame (in this case, you can move both the border of the frame and the map itself).

When saving an image, the user also selects its resolution. Resolution may correspond with the current size or be two or four times larger. The better the resolution, the larger the size of the saved file. The maximum size of the bitmap image is approximately 5400x4400 pixels; the file size in the *.png format is about 10 MB.

Show map scale - a scale bar will appear in the lower left corner of the saved image.

Save coordinates (.txt file)* - saves a text file with the same name as the image file. The coordinates of the corners of the image are written into a text file (for uploading the result to the cartographic service

rtrs.ru).

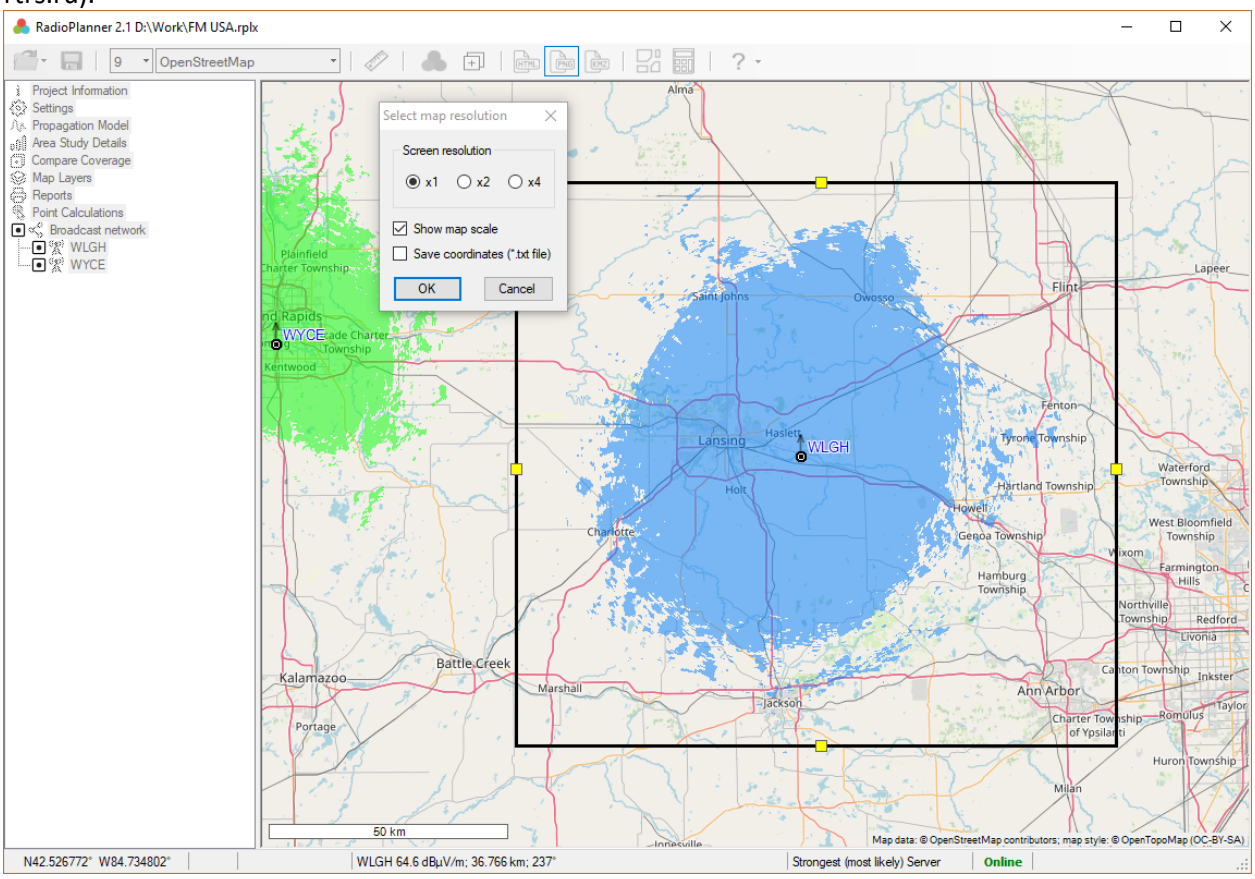


Figure 10. Selecting the area and resolution of the saved image

Save the coverage as a KMZ file - Save the calculation result as a KMZ file, which can be opened in Google Earth.

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.

The minimum signal level in the saved file will correspond to the minimum Rx power level (or field strength) that was specified in the Area Study Details menu.

CSV file format

Each line contains three parameters: geographical latitude; geographic longitude; strongest signal level (Rx power level for Mobile projects or field strength for Radio or TV projects); BS 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). See the example in Figure 11.

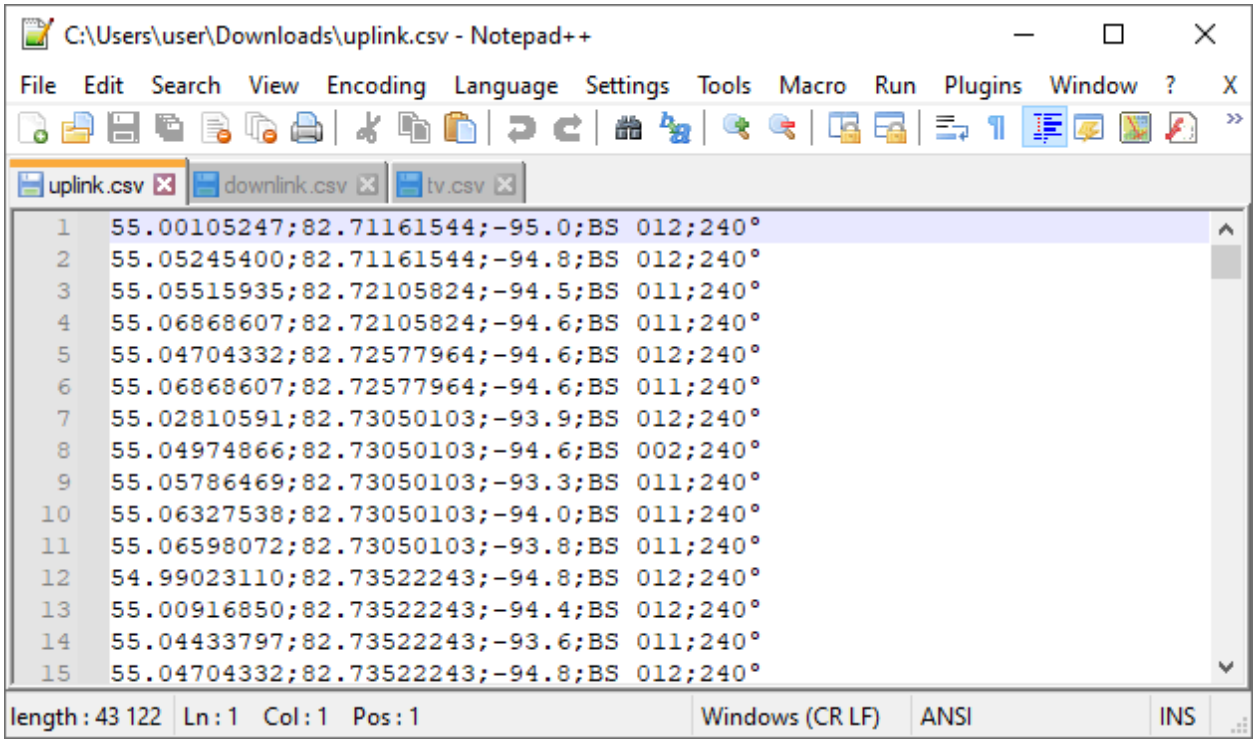


Figure 11. CSV file sample

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

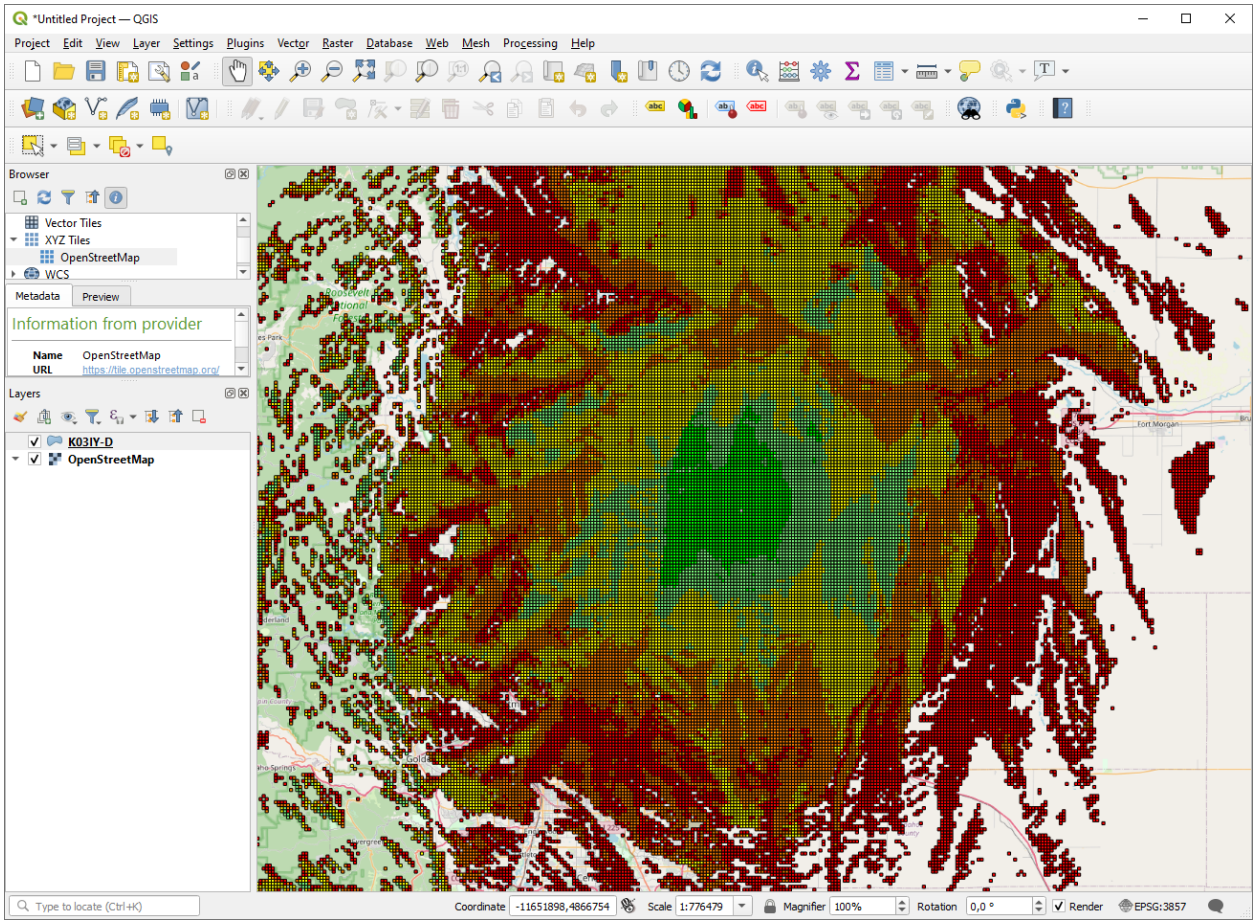
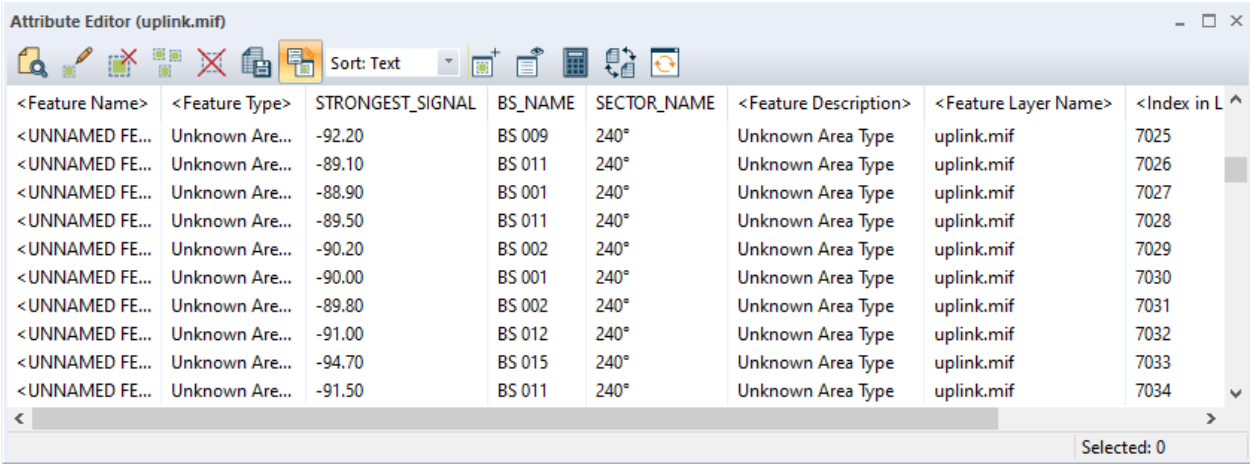


Figure 12. MIF Mapinfo Coverage file as a layer in QGIS



<Feature Name>	<Feature Type>	STRONGEST_SIGNAL	BS_NAME	SECTOR_NAME	<Feature Description>	<Feature Layer Name>	<Index in L
<UNNAMED FE...	Unknown Are...	-92.20	BS 009	240°	Unknown Area Type	uplink.mif	7025
<UNNAMED FE...	Unknown Are...	-89.10	BS 011	240°	Unknown Area Type	uplink.mif	7026
<UNNAMED FE...	Unknown Are...	-88.90	BS 001	240°	Unknown Area Type	uplink.mif	7027
<UNNAMED FE...	Unknown Are...	-89.50	BS 011	240°	Unknown Area Type	uplink.mif	7028
<UNNAMED FE...	Unknown Are...	-90.20	BS 002	240°	Unknown Area Type	uplink.mif	7029
<UNNAMED FE...	Unknown Are...	-90.00	BS 001	240°	Unknown Area Type	uplink.mif	7030
<UNNAMED FE...	Unknown Are...	-89.80	BS 002	240°	Unknown Area Type	uplink.mif	7031
<UNNAMED FE...	Unknown Are...	-91.00	BS 012	240°	Unknown Area Type	uplink.mif	7032
<UNNAMED FE...	Unknown Are...	-94.70	BS 015	240°	Unknown Area Type	uplink.mif	7033
<UNNAMED FE...	Unknown Are...	-91.50	BS 011	240°	Unknown Area Type	uplink.mif	7034

Figure 13. MIF Attribute Table

Two Coverage Calculation Comparison

RadioPlanner allows you to visually compare the results of the current coverage calculation with the calculation result previously added for such a comparison. Thus, it is possible to estimate the impact on the coverage due to changes in various parameters of the BS, the propagation model, etc.

To add the performed calculation to the comparison, click the **Add Coverage to Compare** button on the top toolbar. Now, when you go to the **Compare coverage** menu of the main toolbar, this calculation result will be located on the left side of the screen. Whereas on the right side of the screen, the result of the current coverage calculation will be displayed. Now, for example, you can change the height of the sector or sectors of active BSs, and after performing the coverage calculation, you can see how these changes were reflected in the result compared to the previous calculation.

Manage maps in the left and right panels (map shift and zoom) independently of each other. It is convenient to perform this operation with the mouse by dragging and rotating the wheel. By controlling the maps in this way, one can compare in small details the two results of coverage calculating.

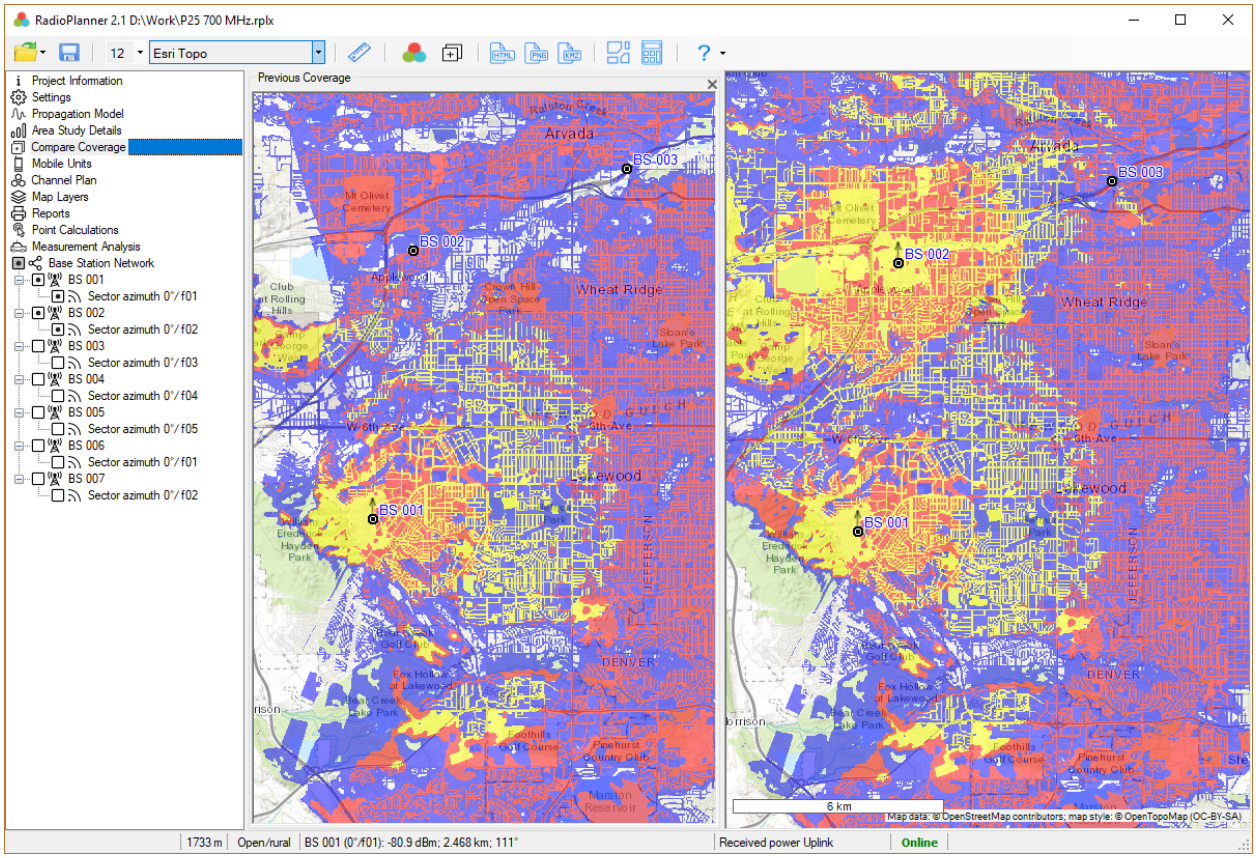


Figure 14. Two coverage calculation comparison

Reports

In the Report menu, you can create several types of equipment reports - short, complete, for all base stations, or for only active base stations.

The project report shows the results of calculating the coverage area in square kilometers for the corresponding Rx levels.

Using the toolbar, which is located above the report, you can print it as well as save it in PDF, Microsoft Word, or Excel formats.

1 of 1 100% Find | Next

29.09.2020 11:14:28 RadioPlanner 2.1 Page 1 of 1

Project name:	GSM-900 Novosibirsk
Customer:	
Data:	2018.12.21 10:52
Radio System Type:	Mobile Radio Communication
Frequency:	900 MHz
Propagation Model Type:	ITU-R P.1812-4
Percentage of time:	95%
Percentage of location:	95%
Margin:	0 dB
Mobile unit location:	Mobile unit with antenna below clutter height in urban or suburban environments
Clutter loss:	Yes
Area Study Type:	Received power Uplink
Co-channel interference:	No
Adjacent channel interference:	No

	Mobile Unit №1		Coverage area, km²
	> -77 dBm		10.9
	> -85 dBm		35.6
	> -95 dBm		198.3

Base Stations Parameters

№	Name	Latitude Longitude	Sector azimuth	Antenna model	Antenna height	Antenna beam tilt	Antenna gain, dBi	Tx power, W	Loss, dB
1	BS 001	N55.060233°	0°	80010674_0947_x_co_m45_06t	30 m	0°	14.6	4	1.3
		E82.913475°	120°	80010674_0947_x_co_m45_06t	30 m	0°	14.6	4	1.3
			240°	80010674_0947_x_co_m45_06t	30 m	0°	14.6	4	1.3

Mobile Units Parameters

Name	Tx power, W	Rx threshold, dBm	Cable and connectors loss, db	Antenna height	Antenna gain, dBi
MS class 4	2	-95	0	1.5 m	0
none	3	-100	0	3 m	3

Clutter loss

Clutter type	Mobile Unit №1 loss, dB	Mobile Unit №2 loss, dB	Clutter height, m
Open/rural:	0	0	0
Water:	0	0	0

Figure 15. Text report

Mobile networks

Frequency planning for a mobile network is a complex iterative process that is influenced by many factors. In practice, it is carried out by drawing up a frequency plan for the initial approximation network taking into account the requirements for coverage, number, and distribution of subscribers, communication quality, available frequency bands, features of the standard used, and other conditions. Then, the radio coverage of the network is calculated taking into account the co-channel, and adjacent channels' interference for the selected frequency plan and the optimization of the parameters of the base stations. The frequency plan is performed in order to reduce the influence of the interference on the network coverage.

The purpose of this user manual is not to educate users on the principles and features of frequency planning of mobile networks. A sufficient number of books have been published on this topic.

A general blog diagram of the mobile network planning algorithm is shown in the figure below.

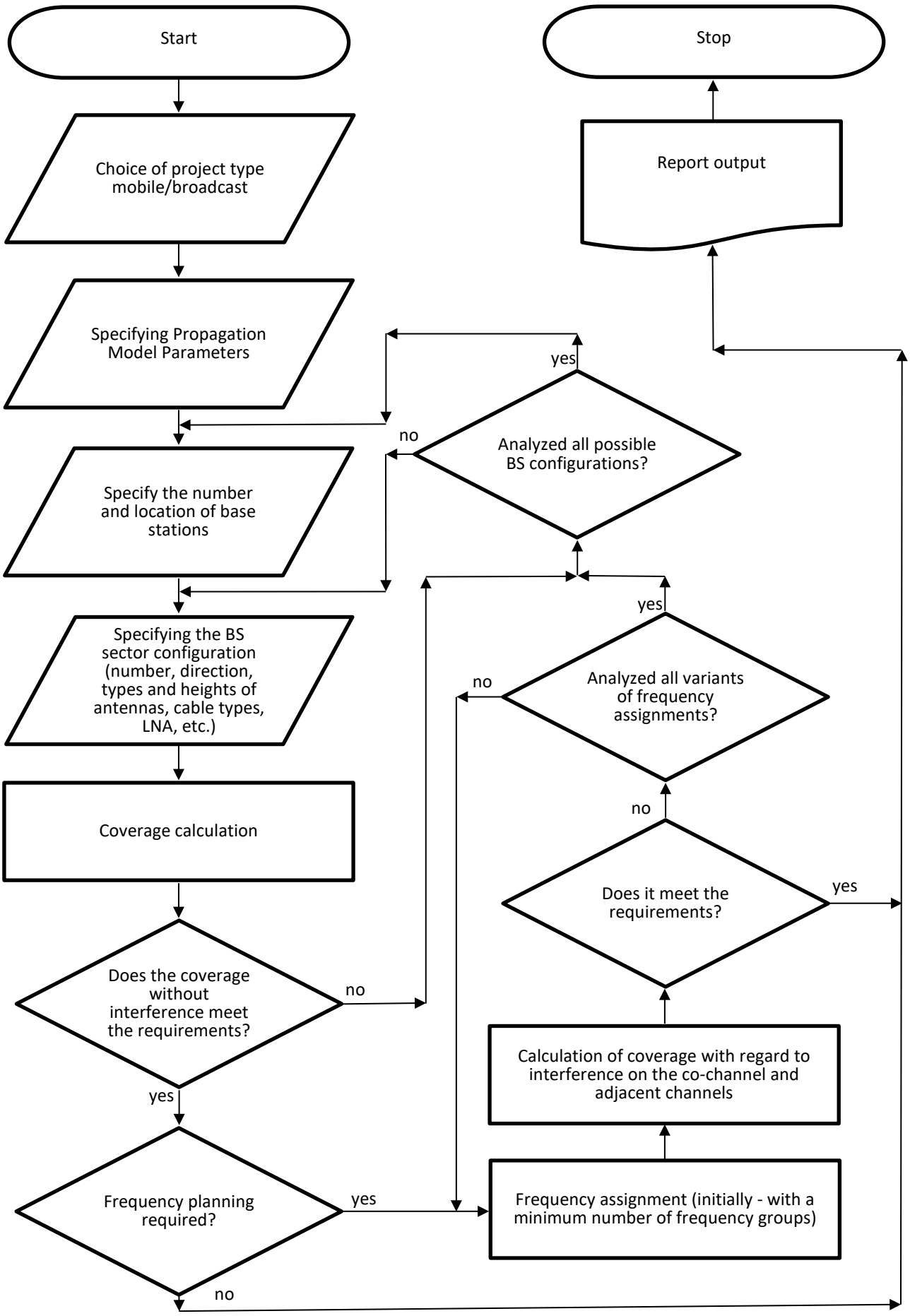


Figure 16. General algorithm for working with RadioPlanner

Mobile Units

The mobile units' characteristics in the Mobile Units menu.

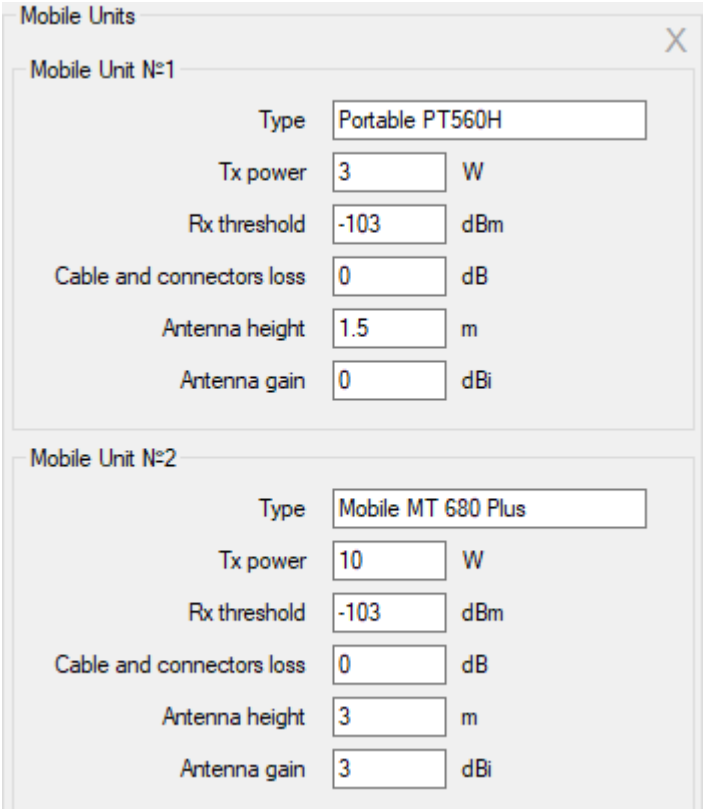


Figure 17. Mobile Units

Type	Name (model) of Mobile Unit, text field
Tx Power	Transmitter power, W
Rx Threshold	Receiver threshold sensitivity, dBm This parameter is taken into account when performing the calculation of the radio coverage "Areas with signal levels above both the base and mobile thresholds," as well as Point Calculations.
Cable and Connector Loss	Loss in cable and connectors, dB
Antenna Height	Antenna height relative to ground level, m
Antenna Gain	Antenna gain, dBi

The application allows calculating radio coverage for two types of mobile units, since, for example, in professional wireless networks portables and mobiles subscriber stations are often used, which differ in both energy characteristics and antenna height relative to ground level.

Base Stations

The characteristics of the radio equipment of the base stations in the Base Station Network menu. After creating a new project, the list of base stations is empty.

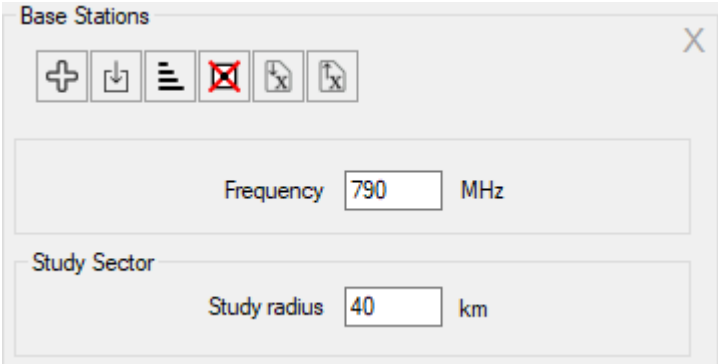


Figure 18. Base stations

Frequency	Center of frequency band, MHz
Study radius	Maximum radius of calculation from base stations, km. The larger the radius, the longer the calculation time.

- Create a new base station

- Import sites from *.csv file

- Sort base stations in alphabetical order

- Delete all active base stations

- Import base station parameters from Microsoft Excel document

- Export active base station to Microsoft Excel

Creating a Base Station

To create a new base station, click on Base Station Network in the Tree View interface, then click the button in the panel that opens, then select the template from which the new base station will be created. You can then create the template yourself.

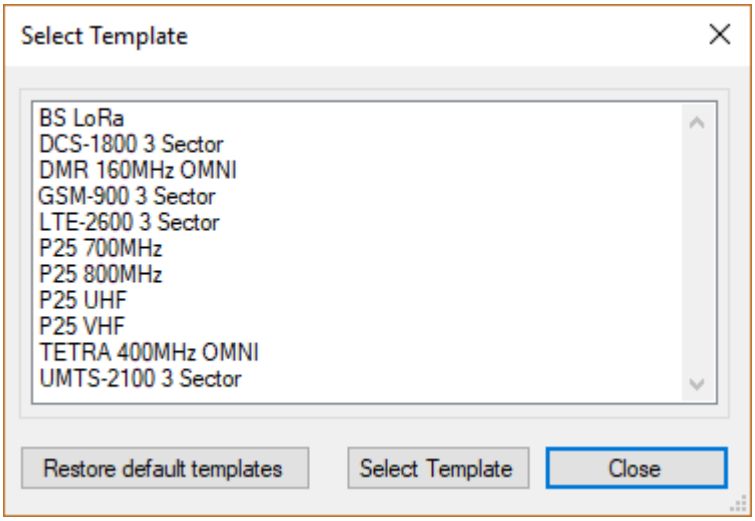


Figure 19. Creating a new BS using a template

Import sites from *.CSV file

You can also import sites from CSV files (text format, where the separator is a semicolon).

This is a universal format in which you can save a spreadsheet from any spreadsheet editor (Excel, LibreOffice Calc, and others), as well as databases.

The required fields for each point object are BS name, Latitude, and Longitude. Format coordinates - 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, then select a template from which new base stations will be created with coordinates of imported sites.

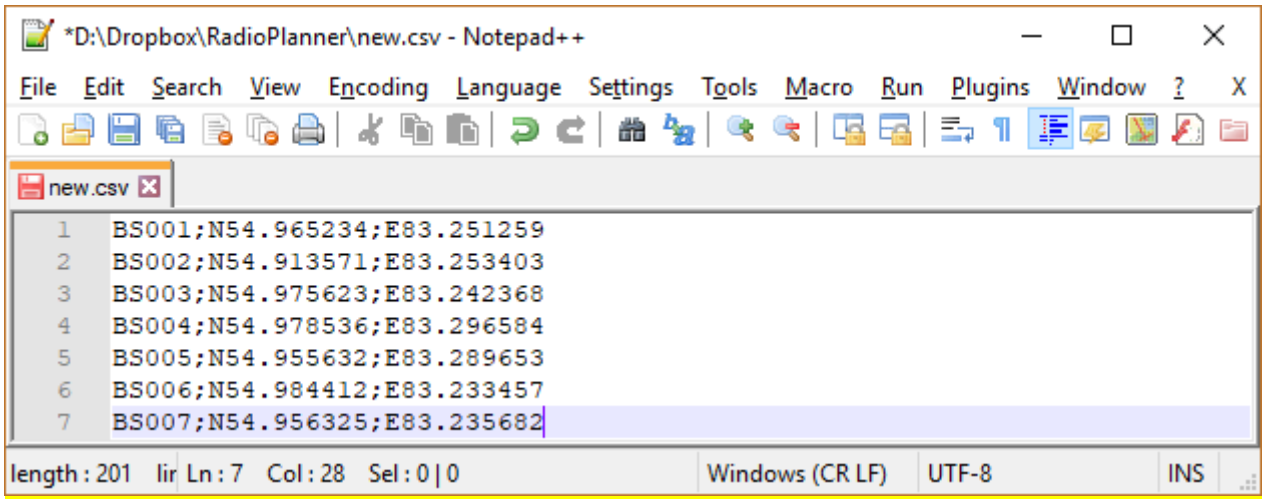
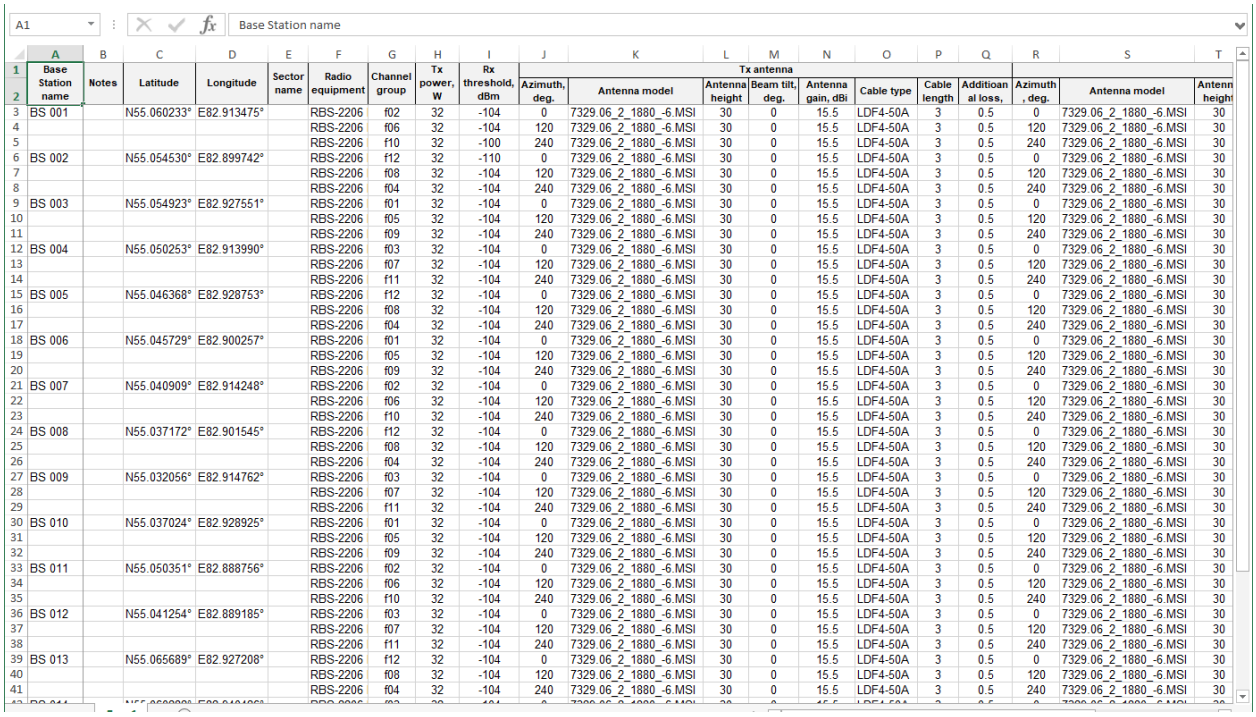


Figure 20. Example of a CSV file with the imported sites

Import/Export BS Parameters to Excel Spreadsheet

The program can export the parameters of the base stations to the Microsoft Excel spreadsheet, as well as import data from this spreadsheet. This function can accelerate the loading of source data for a network with a large number of base stations, as well as simplify the exchange of source data between the user and the customer. The format of the table can be found by exporting the parameters of base stations for one of the test examples.



A1 | Base Station name

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1										Tx antenna										
2	Base Station name	Notes	Latitude	Longitude	Sector name	Radio equipment	Channel group	Tx power, W	Rx threshold, dBm	Azimuth, deg.	Antenna model	Antenna height	Beam tilt, deg.	Antenna gain, dBi	Cable type	Cable length	Additional loss,	Azimuth, deg.	Antenna model	Antenna height
3	BS 001		N55.060233°	E82.913475°		RBS-2206	f02	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
4						RBS-2206	f06	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
5						RBS-2206	f10	32	-100	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
6	BS 002		N55.054530°	E82.899742°		RBS-2206	f12	32	-110	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
7						RBS-2206	f08	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
8						RBS-2206	f04	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
9	BS 003		N55.054923°	E82.927551°		RBS-2206	f01	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
10						RBS-2206	f05	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
11						RBS-2206	f09	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
12	BS 004		N55.050253°	E82.913990°		RBS-2206	f03	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
13						RBS-2206	f07	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
14						RBS-2206	f11	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
15	BS 005		N55.046368°	E82.928753°		RBS-2206	f12	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
16						RBS-2206	f08	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
17						RBS-2206	f04	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
18	BS 006		N55.045729°	E82.900257°		RBS-2206	f01	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
19						RBS-2206	f05	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
20						RBS-2206	f09	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
21	BS 007		N55.040909°	E82.914248°		RBS-2206	f02	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
22						RBS-2206	f06	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
23						RBS-2206	f10	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
24	BS 008		N55.037172°	E82.901545°		RBS-2206	f12	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
25						RBS-2206	f08	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
26						RBS-2206	f04	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
27	BS 009		N55.032056°	E82.914762°		RBS-2206	f03	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
28						RBS-2206	f07	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
29						RBS-2206	f11	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
30	BS 010		N55.037024°	E82.928925°		RBS-2206	f01	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
31						RBS-2206	f05	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
32						RBS-2206	f09	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
33	BS 011		N55.050351°	E82.888756°		RBS-2206	f02	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
34						RBS-2206	f06	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
35						RBS-2206	f10	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
36	BS 012		N55.041254°	E82.889185°		RBS-2206	f03	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
37						RBS-2206	f07	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
38						RBS-2206	f11	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30
39	BS 013		N55.065689°	E82.927208°		RBS-2206	f12	32	-104	0	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	0	7329.06_2_1880_-6.MSI	30
40						RBS-2206	f08	32	-104	120	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	120	7329.06_2_1880_-6.MSI	30
41						RBS-2206	f04	32	-104	240	7329.06_2_1880_-6.MSI	30	0	15.5	LDF4-50A	3	0.5	240	7329.06_2_1880_-6.MSI	30

Figure 21. Excel spreadsheet example

When importing/exporting a spreadsheet, the following should be considered:

1. Export to a spreadsheet is performed only for active base stations

2. When importing from a spreadsheet, the imported base stations will be added to the existing BS of the current project. That is, if you need to completely replace the information on base stations, then before performing the import, you should remove the existing base stations from the project.

3. When importing from a spreadsheet, the antenna pattern file must be in the folder with the Excel file.

4. If in the base station sector, the antenna-feeder transmission and reception path are the same, then when preparing the table, you can fill in the antenna-feeder path parameters for the transmit path only and do not fill in the receive path parameters - just leave the corresponding cells of the spreadsheet empty.

When clicking in the Tree View interface panel on the created base station, the **Base Station Details** panel will open, where you can edit the name, coordinates, specify additional text information about the base station, and find out the elevation of the base station relative to sea level.

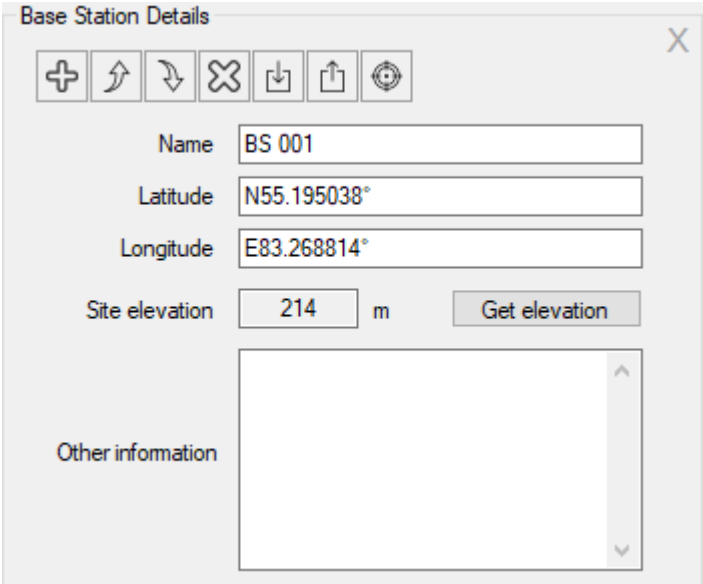


Figure 22. Base station parameters

Using the tools on the **Base Station Details** panel, you can do the following:

- Create a new base station as a copy of this base station

- Move this base station up or down

- Delete base station

- Load the base station parameters from the template

- Save the parameters of the base station (including the parameters of all its sectors) as a template

- Position the map with the base station at the center of the screen

Name	Base station name, text field
Latitude	The geographical latitude of the base station in the format specified by the user in **Settings**
Longitude	Geographical longitude of the base station in the format specified by the user in **Settings**
Site Elevation	Site elevation relative to sea level, m
Other Information	Text box for any additional base station information

When creating a base station, at least one sector of this base station is automatically created.

There is an activity icon in the Tree View interface panel next to each base station and sector. For the sector to be calculated, this sector must be marked as active (a dot in the center of the icon).

Clicking on the base station sector will open a panel with the parameters of this sector.

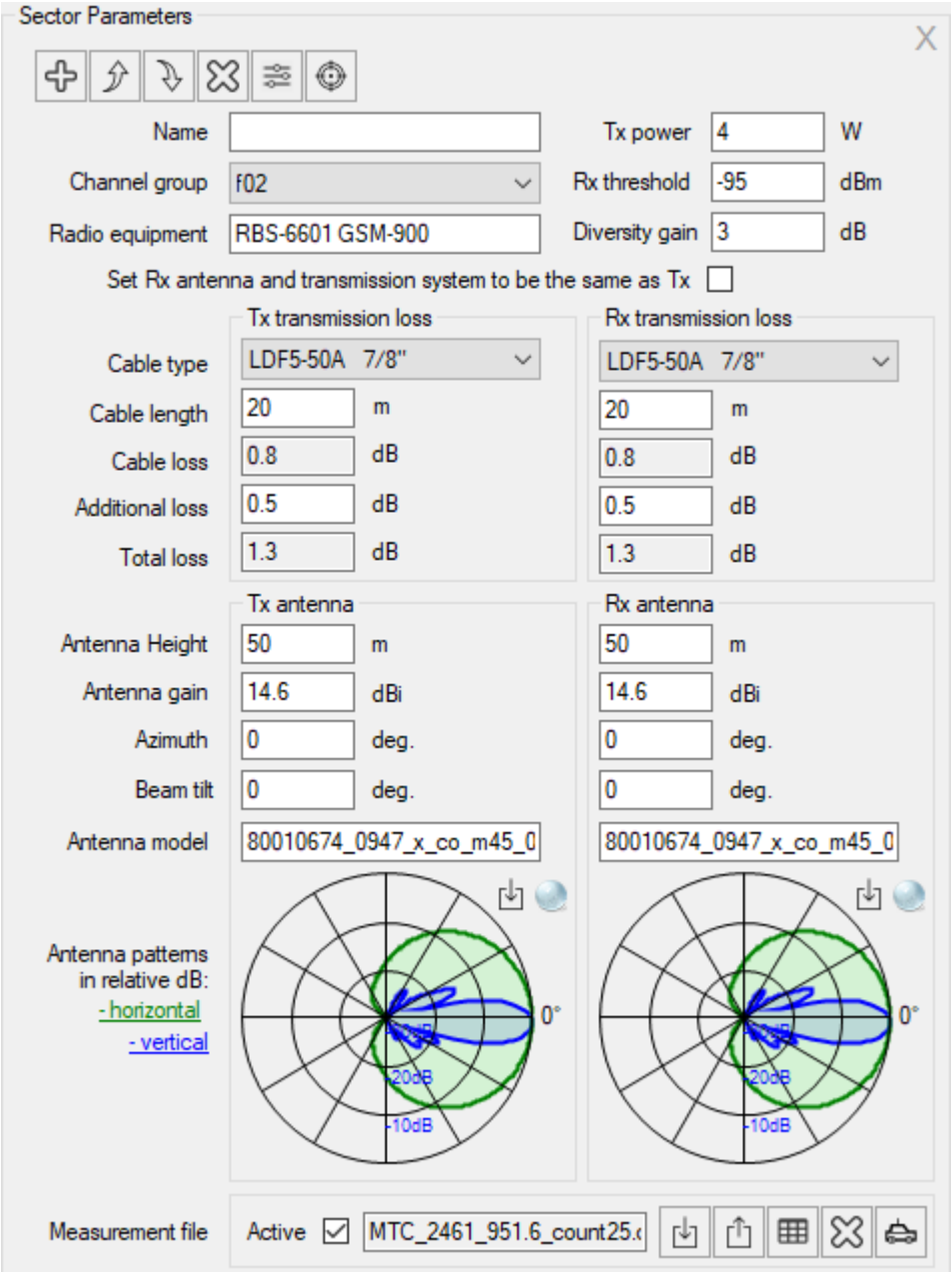


Figure 23. BS Sector parameters

Toolbar:

- Create a new sector as a copy of this sector

- Move this sector up or down

- Delete sector

- Group change of active sector parameters based on current sector parameters

- Position the map with the base station at the center of the screen

Name	The name of the sector, the text field. If this field is left blank, the name "Sector azimuth" with the azimuth value specified below in the sector parameters panel will be automatically displayed on the left in the tree view panel. If you specify the name in this field, it will be displayed in the tree view.
Channel Group	Frequency group to which this sector belongs, f01-f12
Radio Equipment	Name (model) of Radio equipment, text field
Tx Power	Transmitter power, W
Rx Threshold	Receiver threshold sensitivity, dBm
Diversity Gain	Gain due to the use of diversity reception, dB
Set Rx Antenna and Transmission System to be the Same as Tx	Copying parameters' antenna-feeder transmitter path to the receive path
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.
Measurement File	The file with the results of the measured signal downlink level in this BS sector and the toolbar for processing it. See more details in the "Import measurement results and adjustment of the propagation model" section.

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.

Group change of active sector parameters based on the parameters of the current sector is a useful feature that allows you to instantly change the parameters of any sectors following the parameters of the current sector.

The procedure for performing group parameter changes:

1. Mark sectors as active whose parameters need to be changed.

2. Set the required parameter values in the current sector.

3. Click the button , select in the list the parameters that need to be changed in the previously marked active sectors, and click the OK button.

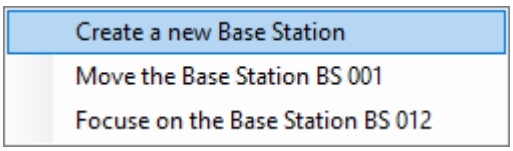
Context menu on the base map

When you right-click on the base map, the context menu appears, in which you can:

1. Create a new base station at this point

2. Change the location of the current (selected) base station

3. Open the parameters of the nearest base station (focus on ...)



Propagation models

RadioPlanner 2.1 uses the following propagation models:

- ITU-R P.1812-4 model
- Longley-Rice (ITM) model v 1.2.2
- ITU-R P.1546-6 model (for broadcasting only)
- Combined ITU-R P.528-3 + P.526-14 model (for aeronautical radio only)

ITU-R P.1812-4 model

This model is described in detail in the recommendation ITU-R P.1812-4 (07/2015) *A path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands.*

The following main factors which affect propagation are taken into account:

- Diffraction loss on the path profile obtained from the SRTM data
- The impact of local surrounding obstacles that exist in the landcover model
- Temporal and spatial instability of the received radio signal (slow and fast fading)

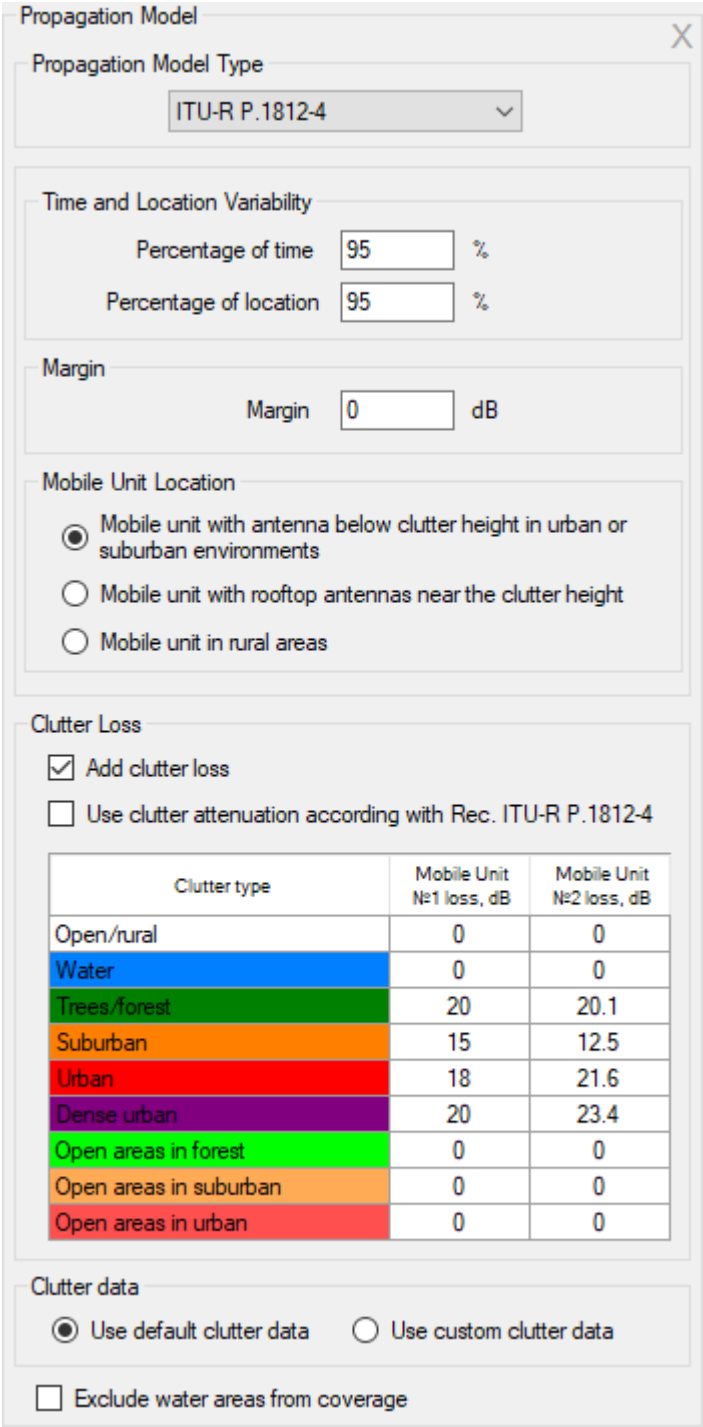


Figure 24. ITU-R P.1812-4 propagation model

Percentage of time (usually 90-95%). 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.

Percentage of location (usually 90-95%). The location percentage indicates that a given power level will be exceeded in at least that percentage of locations for similar propagation paths. The percentage of location can vary from 1% to 99%. The model is not valid for a percentage of locations less than 1% or more than 99%.

Margin 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 your signal level estimate is indeed above the specified signal level.

Specify the location of the Mobile units:

- Mobile units with antennas below clutter height in urban or suburban environments
- Mobile units with rooftop antennas near the clutter height
- Mobile units in rural areas

Clutter loss

RadioPlanner calculates the signal power loss on local obstacles surrounding the mobile unit using the clutter model with the different types of clutter.

The clutter model used in RadioPlanner since release 2.1_201202 has the following types of clutters:

- Open/rural

- Water

- Trees/forest

- Suburban

- Urban

- Dense urban

- Open areas in the forest (forest roads)

- Open areas in the suburban (highways, wide roads)

- Open areas in urban (highways, avenues, wide roads)

The clutter model was created based on OpenStreetMap (www.openstreetmap.org) and Global Forest Change (www.earthenginepartners.appspot.com) projects.

Losses are calculated following Recommendation ITU-R P.1812-4; they depend on the following parameters:

- Antenna height of the Mobile unit

- Width of the streets

- Average (typical) height of clutter

- Type of clutter

The frequency range is set in the **Base station Network** menu, the antenna height for each of the two types of Mobile units (usually portable and mobile) in the **Mobile Units** menu, the typical width of streets is 27m (in accordance with ITU-R P.1812-4), and the landcover model determines the type of obstacles at each point.

To determine the loss according to ITU-R P.1812-4, the user should select Calculate the loss in rec. ITU-R P.1812-4 and specify in the table the average height of the obstacles of each type based on local conditions. Default data in Rec. ITU-R P.1812-4:

Clutter type	Clutter height (m)
Water/sea	0
Open/rural	10
Tree/forest	15
Suburban	10
Urban	15
Dense urban	20

The user can also set clutter loss manually for each type of obstacle based on their own data - to do this, simply enter the losses into the table.

Clutter data

Use default clutter data or **Use custom clutter data** - The choice of the clutter data that will be used for calculations - the default clutter or the custom clutter. Custom clutter is created in the Clutter Editor (see the section Clutter Editor).

Longley-Rice (ITM) Model v 1.2.2

The Longley-Rice propagation model is also known as the Irregular Terrain Model (ITM). RadioPlanner 2.1 uses version 1.2.2 of the Irregular Terrain Model in PTP-mode. This propagation model is considered the industry standard for calculating radio coverage in North America.

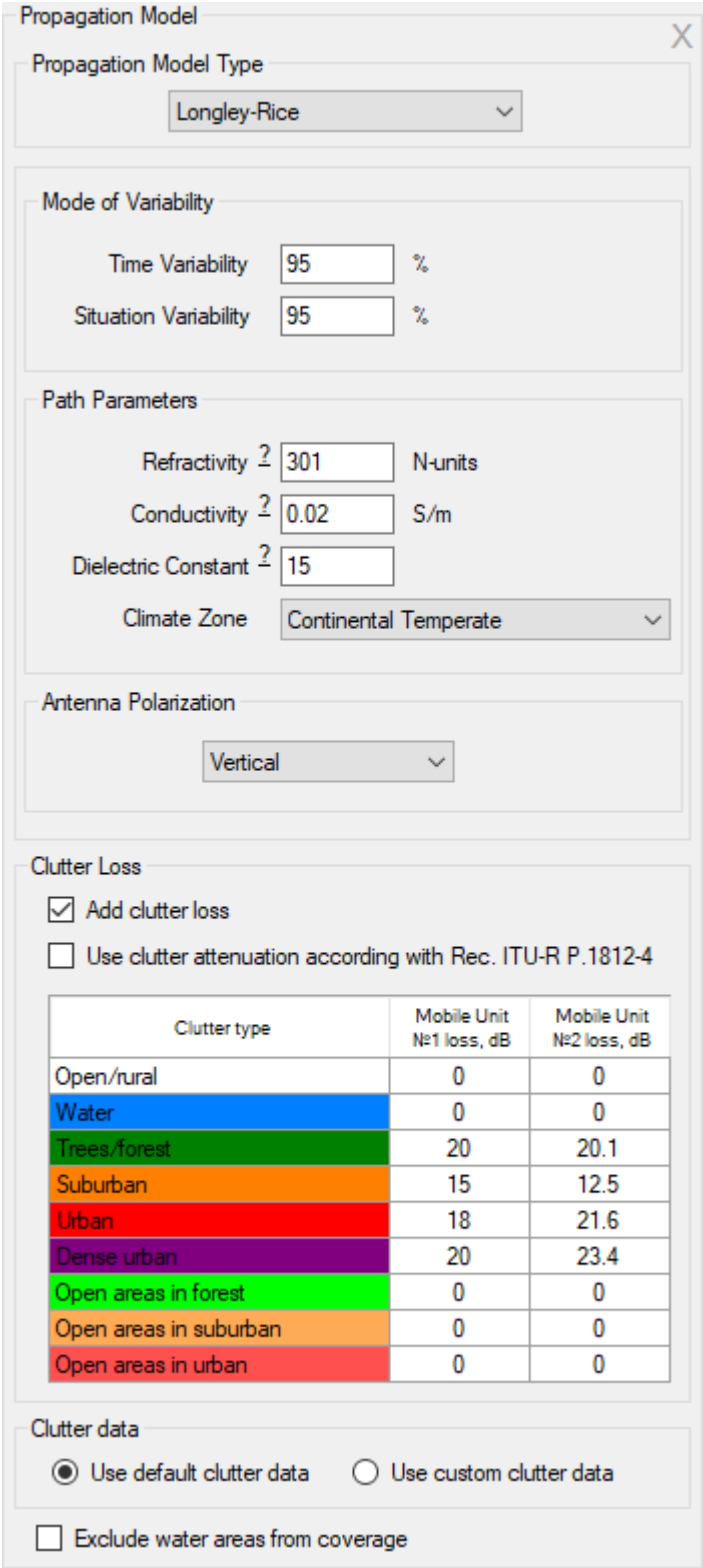


Figure 25. Longley-Rice propagation model parameters

Conductivity, S/m	Conductivity of the ground over which the signal propagates (Siemens per meter)
Dielectric Constant	The dielectric constant (relative ground permittivity)
Refractivity	Atmospheric refractivity, measured in N-Units

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
Time Variability, %	Time variability, %
Situation Variability, %	Situation variability, %

If necessary, the clutter losses calculation is performed in the same way as for model ITU-R P.1812-4 (see the previous section).

Area Study Details

In this panel, the user selects the type of calculation and sets its parameters.

For projects of the "Mobile Radio" type, you can select the following types of calculations:

- Received power Downlink
- Received power Uplink
- Areas with signal levels above both the base and mobile thresholds
- Strongest (most likely) Server Downlink
- C/I Downlink ratio using channel plan
- Number of servers above Uplink

Received power Downlink/Uplink

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

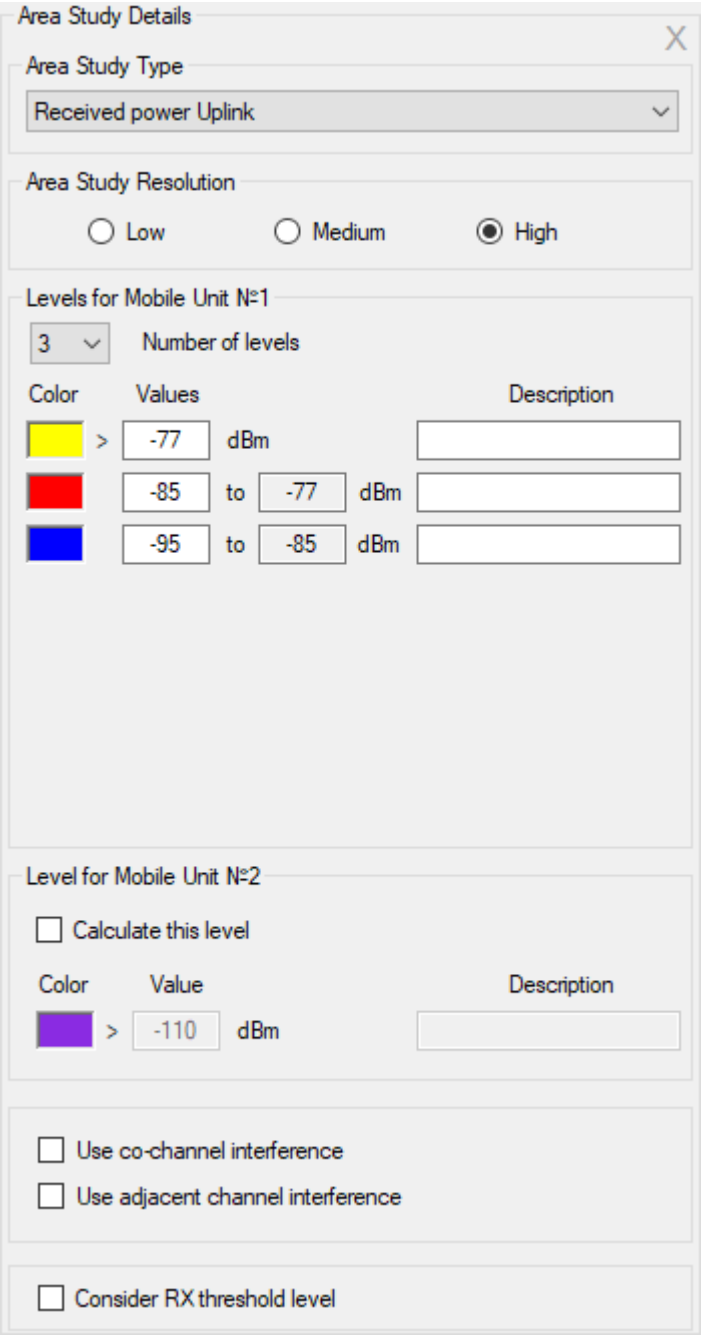


Figure 26. Area study type Received Power Uplink menu

Area Study Resolution	- Low - Medium - High It's the resolution of the result of the calculation. 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.
Number of Levels	The number of levels (1-8)

Color	Color level
Values	Received power level, dBm
Description	Text field to describe signal level
Consider RX threshold level	Exclude from coverage the areas with a level that is less than the threshold of mobile stations receivers for the downlink or threshold of base stations receivers for the uplink

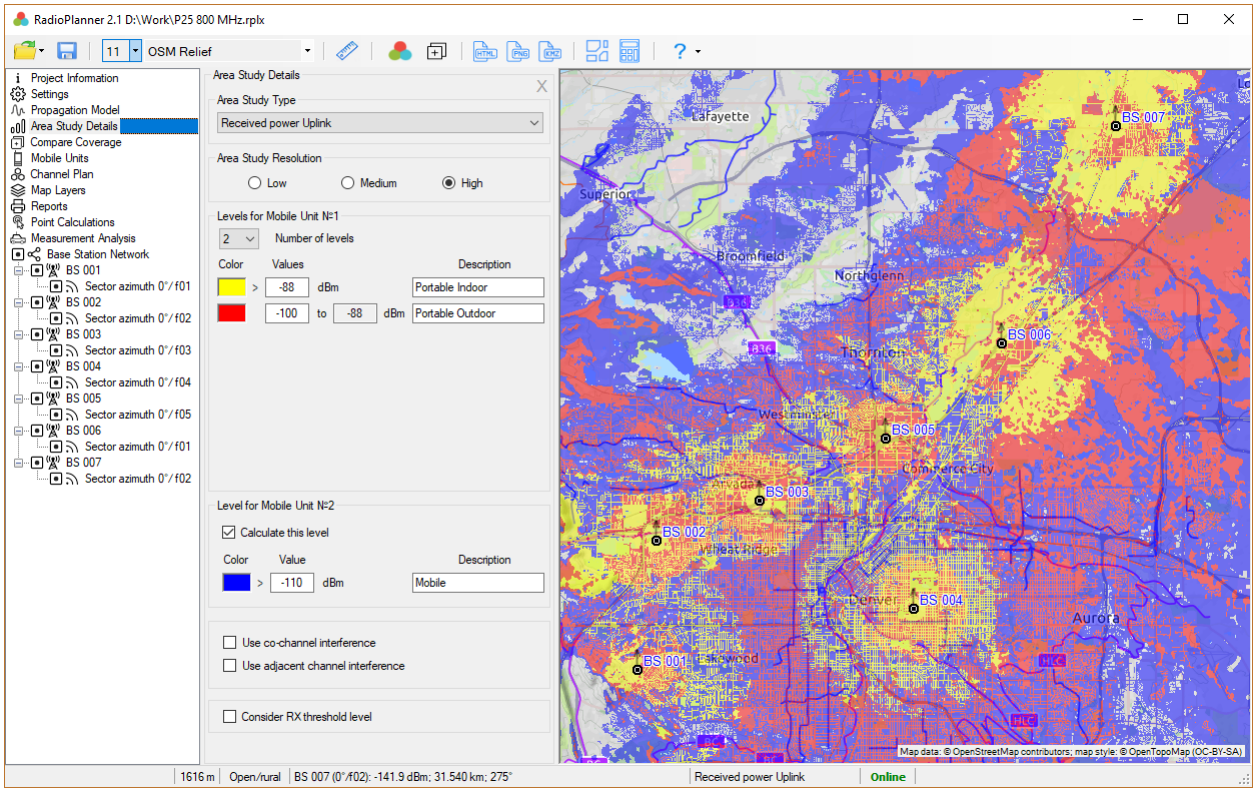


Figure 27. Received Power Uplink for P25 800 MHz network

For Mobile Unit No. 1 (portable), you can set from one to eight different levels of the received signal and thus simulate different reception conditions (for example, on the street, inside the car, indoors, etc.) or different data transfer rates.

For Mobile Unit No. 2, which is supposed to be a mobile subscriber station with an antenna on the roof of the car, only one signal level can be set.

In the calculations, you can also take into account interference on the co-channel and adjacent channels. For this, there are corresponding check-boxes at the bottom of the panel. In this case, the zones where the interference on the co-channel and/or adjacent channels exceeds the amount allowable, one will be excluded from the coverage area. A useful signal is a signal with the maximum level at a given point.

To take into account interference, it is necessary to specify the maximum permissible levels of interference on the co-channel (C/I) and adjacent (C/A) channels.

To calculate interference on adjacent channels, you must specify the channel bandwidth and the exact channel frequencies (these parameters are entered into the Channel Plan menu).

To calculate co-channel interference, it is sufficient to specify the frequency group in the sector parameters.

The calculation of interference is performed only for one type of subscriber station – Mobile Unit No. 1.

Areas with Signal Levels Above Both the Base and Mobile Thresholds

This area study type displays a map showing those grid locations where both the signal received by the mobile unit is above the remote receiver threshold and from where the signal received by the base station from the mobile is above the base threshold.

The calculations use the parameters of antennas, losses, transmitter power, and receiver sensitivity for the base and subscriber stations specified in the relevant menus.

This type of calculation can be performed for different conditions of use of Mobile Unit No. 1 (portable). For example, indoors, outdoors, and inside the car. Each condition of use has its own color and its own value of loss (margin) for signal penetration, which is indicated in this form.

For Mobile Unit No. 2, only outdoor calculations are performed.

Figure 28. Areas with Signal Levels Above Both the Base and Mobile Thresholds Menu

Number of Levels	The number of levels
Color	Color level
Penetration Loss	Penetration loss, dB
Description	Text field to describe condition of use
Consider RX threshold level	Exclude from coverage the areas with a level that is less than the threshold of mobile stations receivers for the downlink or threshold of base stations receivers for the uplink

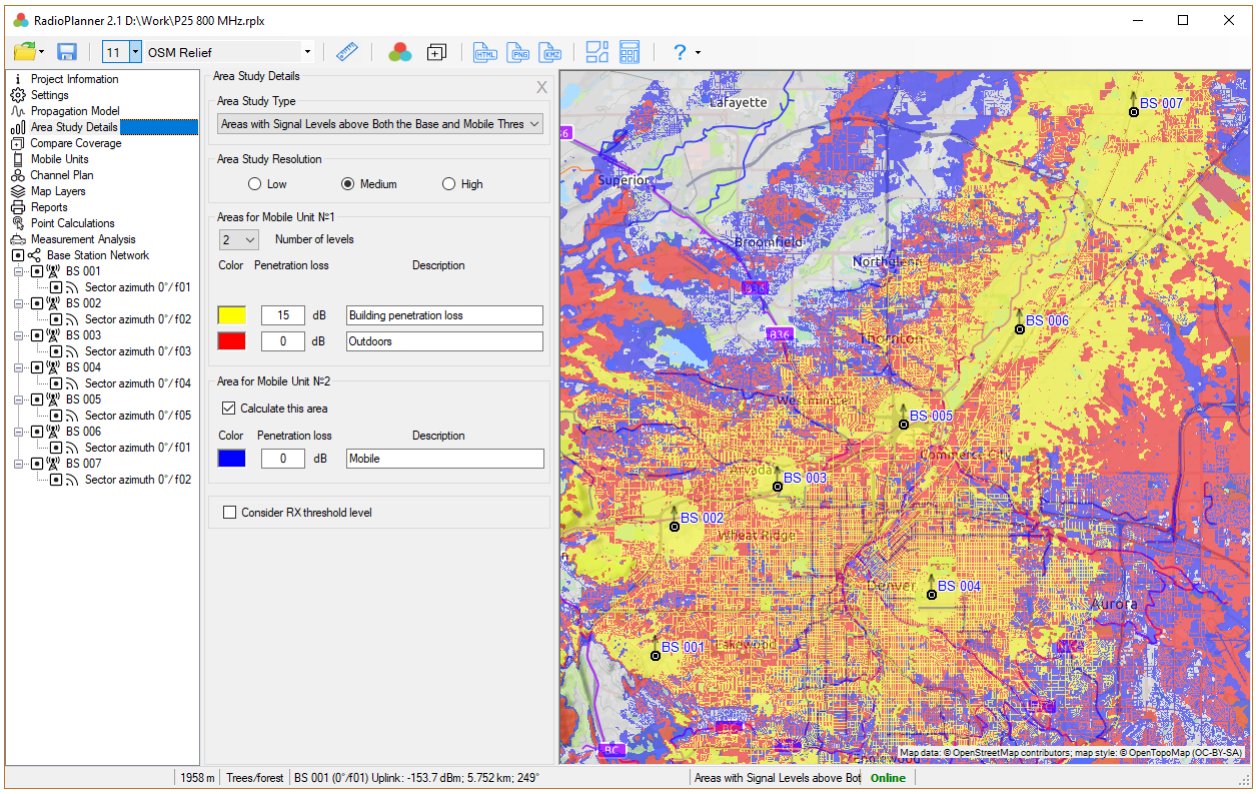


Figure 29. Areas with Signal Levels Above Both the Base and Mobile Thresholds for P25 800 MHz network

Strongest (Most Likely) Server Downlink

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

Sector colors can be assigned automatically or by the table of frequency groups.

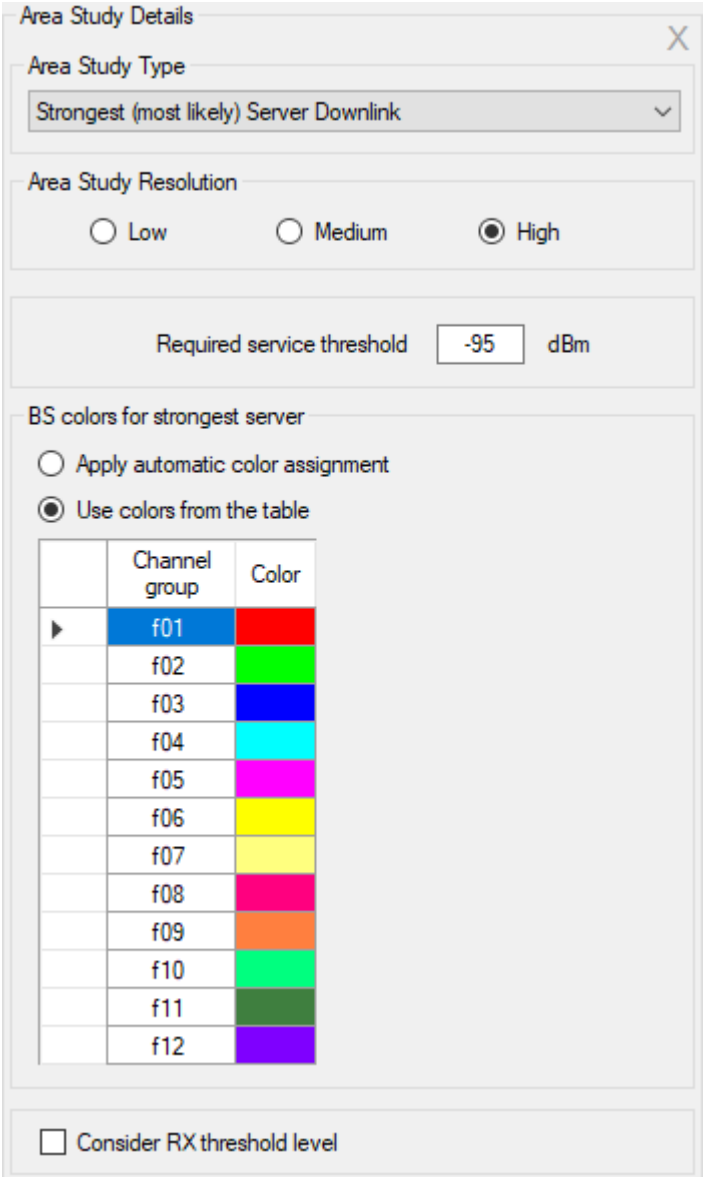


Figure 30. Strongest Server menu

Required Service Threshold	The minimum threshold level of the received signal to calculate Strongest (Most likely) Server, dBm
Apply Automatic Color Assignment	Assigning colors to BS sectors is performed automatically in random order.
Use Colors from the Table	Assigning colors to BS sectors is done from the table according to color frequency groups.
Consider RX threshold level	Exclude from coverage the areas with a level that is less than the threshold of mobile stations receiver

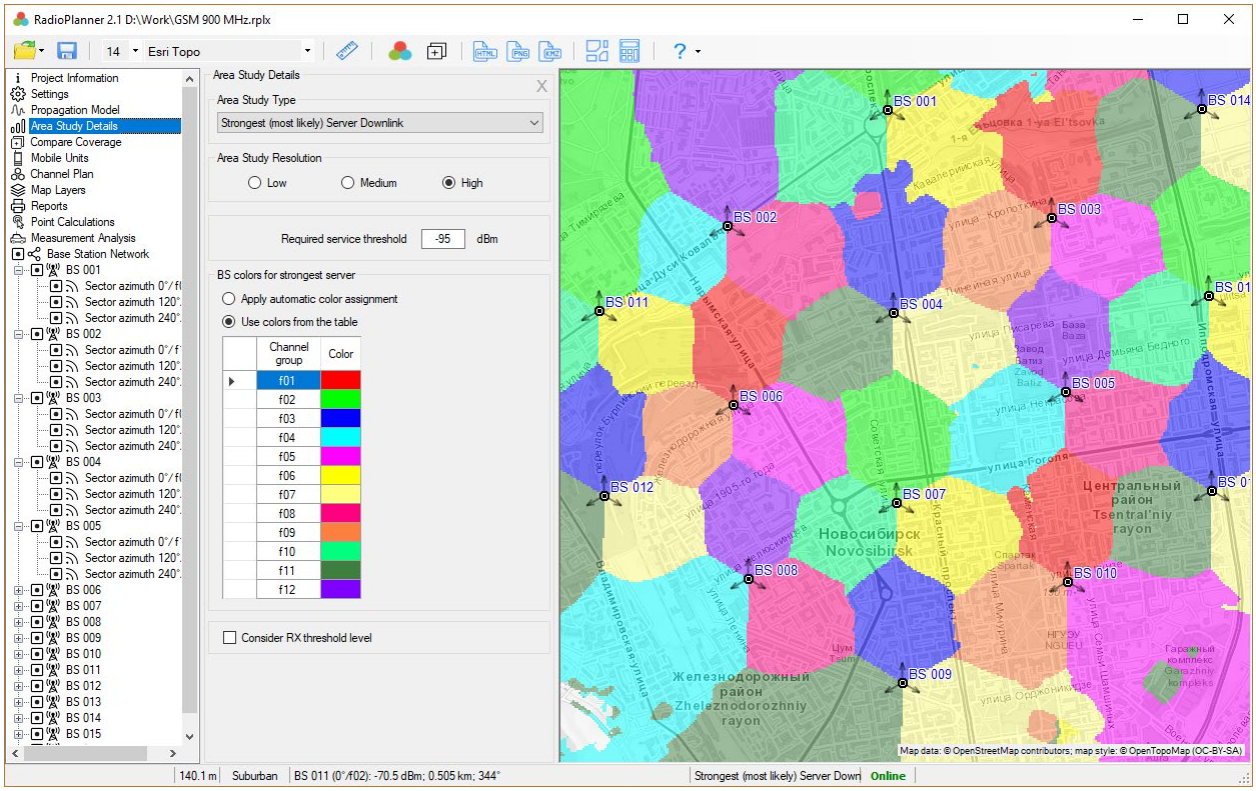


Figure 31. Strongest Server for GSM network

C/I Downlink Ratio Using Channel Plan

The carrier-to-interference ratio, C/I, is one of the essential quantities used in assessing system performance and affecting frequency planning.

RadioPlanner allows you to calculate and display areas with different C/I values for interference on co-channel and adjacent channels at the input of a mobile unit receiver.

Carrier-to-interference ratio is calculated by first finding the strongest received signal power from any BS sector at each location. Then it calculates the sum of the received signal powers from all other co-channel sectors and adjacent sectors (taking into account adjacent channel attenuation), which also have relevant signal levels at a location. After the sum of the interference is found, the carrier-to-interference ratio is calculated.

The calculation of adjacent channel interference can be turned off, in which case only co-channel interference will be taken into account.

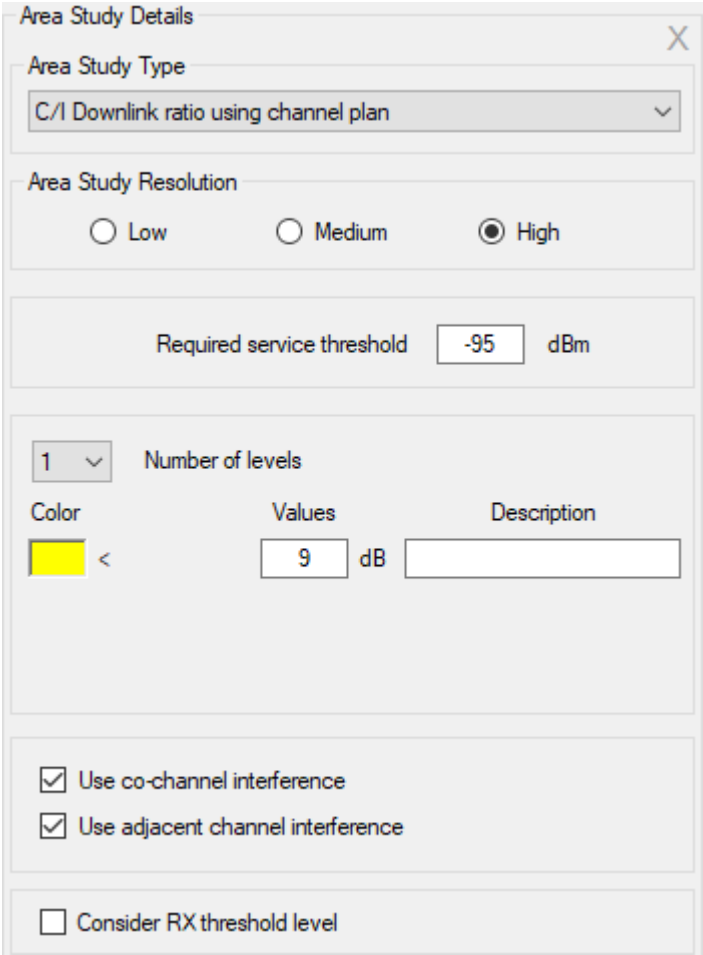


Figure 32. C/I Downlink ratio using channel plan menu

Required Service Threshold	The minimum threshold level of the received signal to calculate carrier-to-interference ratio, dBm
Number of Levels	The number of levels
Color	Color level
Value	Carrier-to-interference ratio C/I, dB
Description	Text field to describe carrier-to-interference ratio
Consider RX threshold level	Exclude from coverage the areas with a level that is less than the threshold of mobile stations receiver

To calculate co-channel interference, in the BS sector parameters, set the frequency group of the sector and set the C/I value. To calculate interference on adjacent channels, it is necessary to fill in the table of frequency groups with exact frequencies and set the channel bandwidth and C/A value (see section **Channel Plan**).

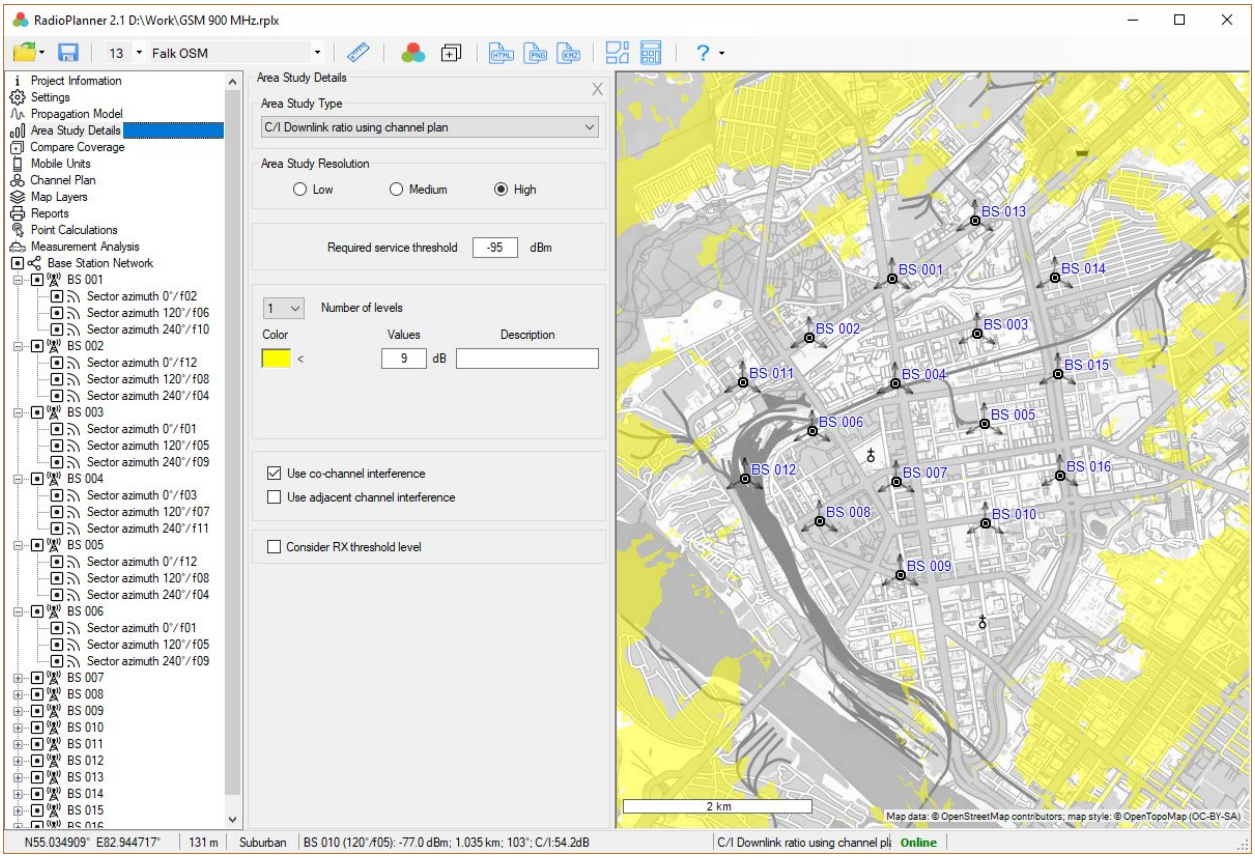


Figure 33. C/I Downlink ratio using channel plan for GSM-1800 network

Number of Servers Above Uplink

When performing this study, the base map displays the areas of possible location of subscriber stations with the number of BS sectors with a received power level above the threshold.

This study type is often required when planning networks based on wireless technologies IoT LPWAN – LoRa, and others.

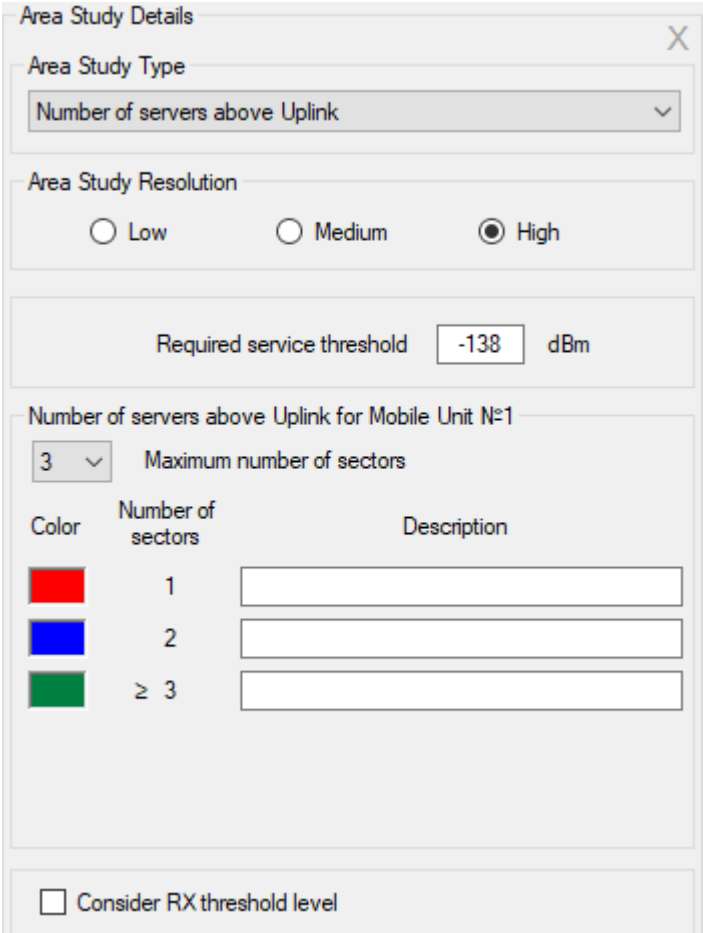


Figure 34. Number of servers above uplink

Area Study Resolution	- Low - Medium - High It's the resolution of the result of the calculation. 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.
Required Service Threshold	The minimum threshold level of the received signal, dBm
Maximum Number of Sectors	Maximum number of displayed servers above uplink
Color	Color indicating the appropriate number of sectors
Description	Text field
Consider RX threshold level	Exclude from coverage the areas with a level that is less than the threshold of BS Rx

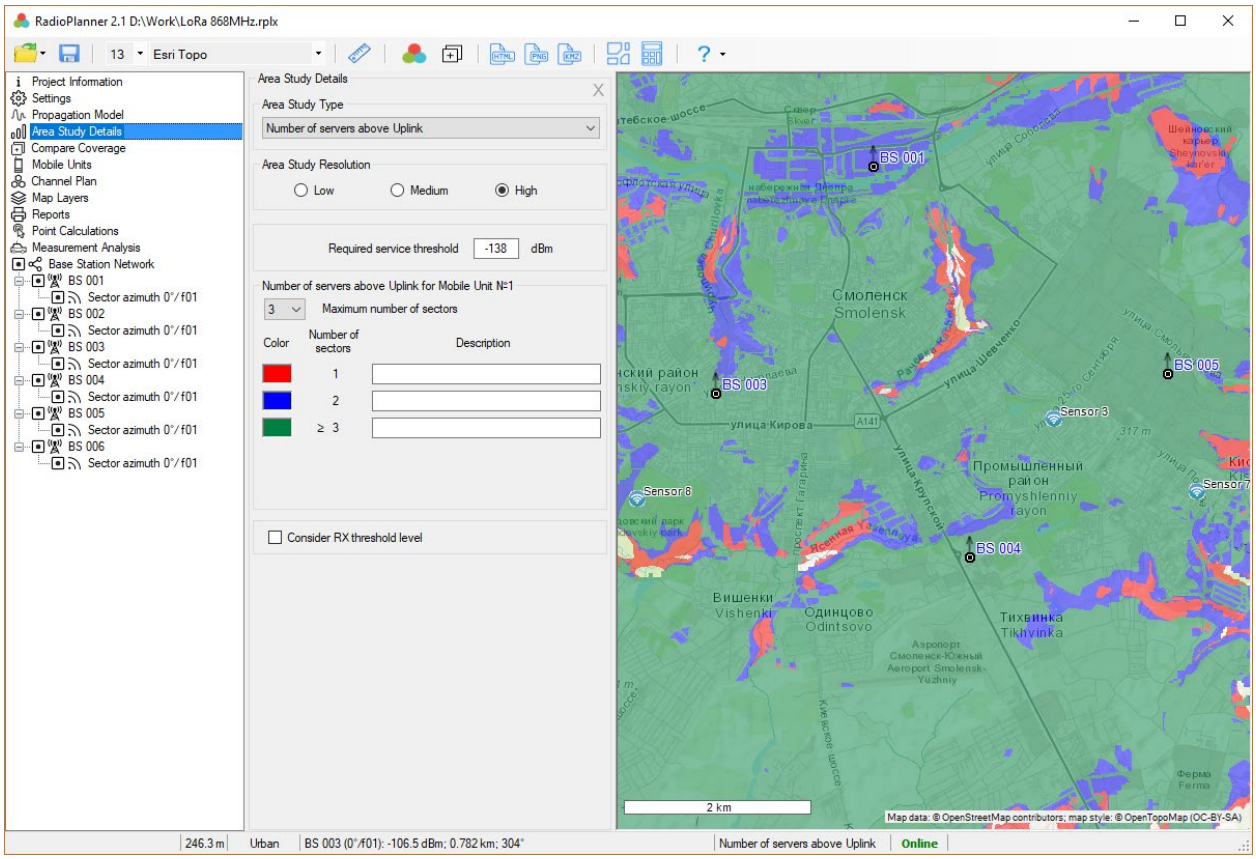
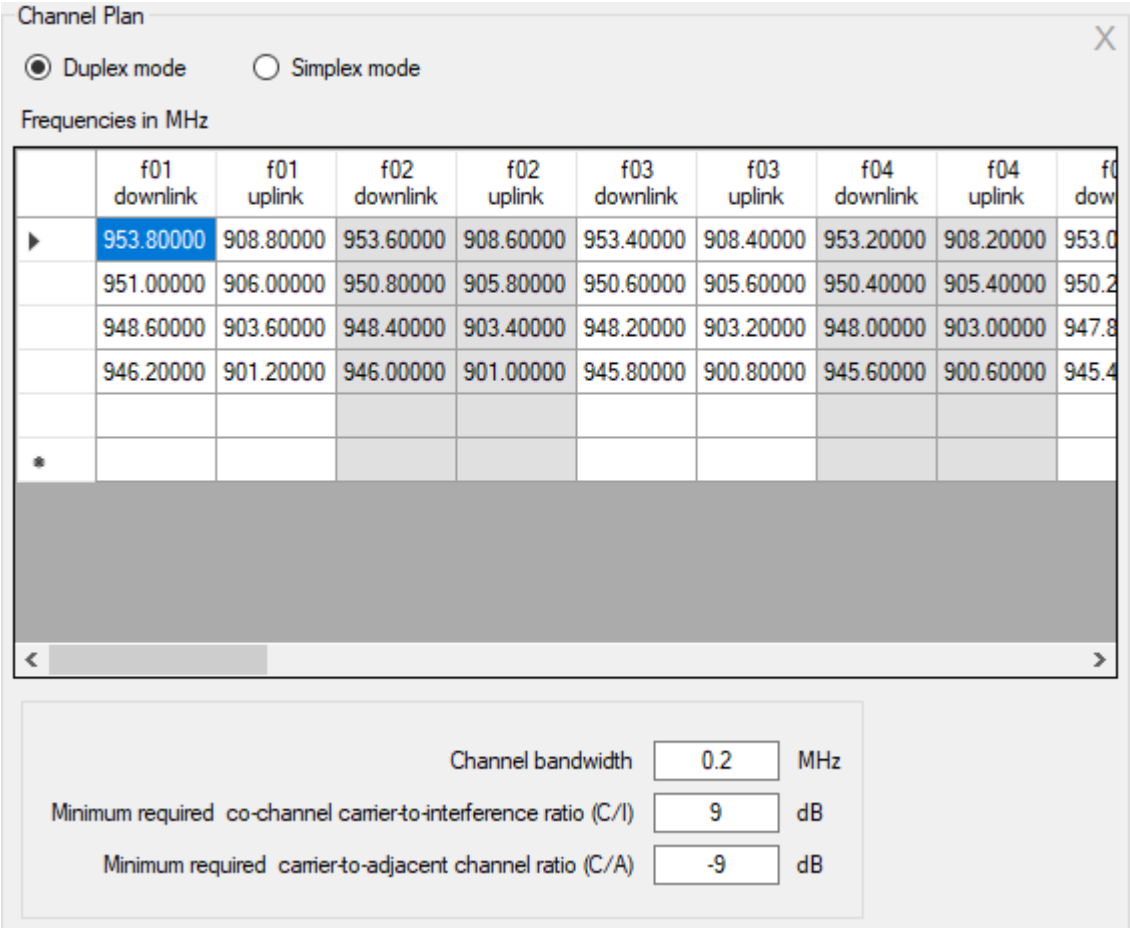


Figure 35. Number of servers above uplink for LoRa network

Channel Plan

In the Channel Plan menu, you can set frequencies for frequency groups. Also, there are several other parameters that affect interference.



f01 downlink	f01 uplink	f02 downlink	f02 uplink	f03 downlink	f03 uplink	f04 downlink	f04 uplink	f0 dow
953.80000	908.80000	953.60000	908.60000	953.40000	908.40000	953.20000	908.20000	953.0
951.00000	906.00000	950.80000	905.80000	950.60000	905.60000	950.40000	905.40000	950.2
948.60000	903.60000	948.40000	903.40000	948.20000	903.20000	948.00000	903.00000	947.8
946.20000	901.20000	946.00000	901.00000	945.80000	900.80000	945.60000	900.60000	945.4

Figure 36. Channel Plan (GSM-900)

Duplex Mode/ Simplex Mode	Radio channel type
Channel Bandwidth	Channel bandwidth, MHz The bandwidth of the radio channel is used to calculate which channels are adjacent. The channels will be adjacent if the modulus of the frequency difference is less than or equal to the bandwidth of the radio channel.
Minimum required co-channel carrier-to-interference ratio (C/I)	Minimum required co-channel carrier-to-interference ratio (C/I), dB
Minimum required carrier-to-adjacent channel ratio (C/A)	Minimum required carrier-to-adjacent channel ratio (C/A), dB

Typical C/I and C/A values for some wireless standards:

- GSM C/I=9 dB, C/A=-9dB
- TETRA (π/4-DQPSK modulation) C/I=19 dB, C/A=-40dB

Point Calculations

In this panel, the user can see detailed results of the calculation of the received signal power in the "down" and "up" directions at any point, as well as the levels of interference on the co-channel and adjacent channels.

You can change the current point on the map by clicking the mouse on the place you want. The path profile is a vertical section of the terrain between the base station and the mobile unit with information about land elevations, forests, and buildings. The colors that mark the various obstacles on the profile correspond to the colors of the landcover model.

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

The BS sector is selected on the left side of the panel in the general network Mobile Network. Find the BS sector you need and click on it with the mouse (don't be confused with the activity tag), after which information on this sector will appear above the path profile.

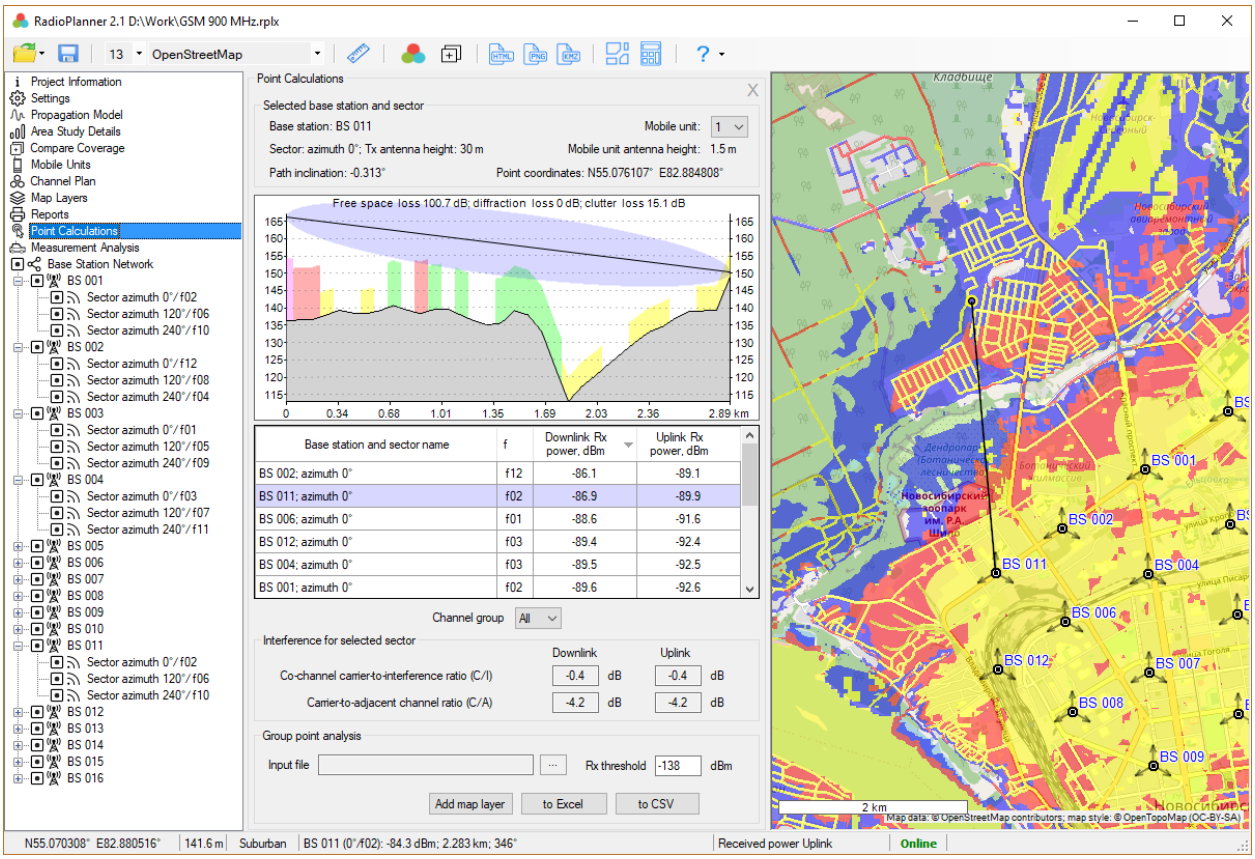


Figure 37. Point calculations

You can also select a mobile unit (No. 1 or No. 2), the parameters of which will be taken into account in the calculations.

Under the path profile, a table appears with the results of calculating the power levels "down" and "up" for the selected sector (it is highlighted in the table in color) and for sectors of other BS. Only sectors that are marked as active are accepted for calculation. In addition, in order for a sector to appear in the table, it is necessary for it to fulfill one of the following conditions: the threshold sensitivity level of the receiver of the selected type of mobile unit must be bigger than the "down" level or the threshold sensitivity level

of the BS sector receiver must be higher than the "up" level. Rows in the table can be sorted by frequency groups and received power levels "down" or "up." Also, using the drop-down list located below the table, you can display the results for only one frequency group.

The selected BS sector is considered to be a sector with a useful signal; signals from sectors with the same frequency group are considered to be co-channel interference and signals from sectors where there are frequencies adjacent to a selected sector are adjacent channel interference. Based on this, below are the calculated values of interference levels along the co-channel and adjacent channels for the "down" and "up" directions.

Group Point Analysis

RadioPlanner 2.1 allows you to calculate the RX uplink/downlink power for a group of points with a set of parameters. It is a useful tool for estimating the uplink/downlink when placing LoRa, SigFox, and other IoT end-devices in different conditions.

The end-devices parameters can be loaded into RadioPlanner as a spreadsheet in Microsoft Excel format or as a CSV text file. The calculation result can also be obtained in two versions - either in the form of a Microsoft Excel spreadsheet (to use this function, the Microsoft Excel spreadsheet editor must be installed on the computer) or in the form of a CSV file. It is more convenient to work with Excel tables, in addition, the results report in the form of a Microsoft Excel table is more visual (see the figure below). However, the work with the CSV file is much faster, and the format of the output CSV file is more convenient for further analysis of the result in various GIS.

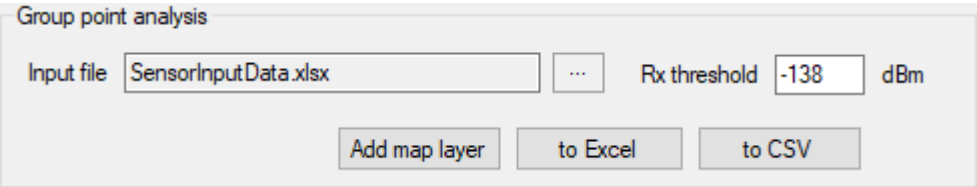


Figure 38. Group Point Analysis

Input file	File with data on points (end-devices) in Microsoft Excel or CSV format. Sample data set files SensorInputData.xlsx and SensorInputData.csv are located in the Sample Data folder
Rx threshold, dBm	The minimum threshold level that will be taken into account when filling out the table with the calculation results, dBm
Add map layer	Add end-devices from the source table as a customs point layer to the map
to Excel	Perform the calculation and open Microsoft Excel with the calculation result
to CSV	Calculate and save the result as a CSV file

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	A	B	C	D	E	F	G	H	I
1	Name	Lat	Lon	Type	Tx power, W	Ant. height, m	Ant. gain, dBi	Cable loss, dB	Penetration loss, dB
2	Sensor 1	54.81	31.96	Vega TD-11	0.025	2	0	0	0
3	Sensor 2	54.778	32.001565	Vega TD-11	0.025	9	0	0	20
4	Sensor 3	54.769603	32.08762	Vega TD-11	0.025	10	0	0	0
5	Sensor 4	54.803353	32.111449	Vega TD-11	0.025	10	0	0	20
6	Sensor 5	54.8206	32.05877	Vega TD-11	0.025	10	0	0	15
7	Sensor 6	54.72	32.06338	Vega TD-11	0.025	7	0	0	0
8	Sensor 7	54.762646	32.111406	Vega TD-11	0.025	10	0	0	20
9	Sensor 8	54.762	32.0187	Vega TD-11	0.025	3	0	0	0

Figure 39. Microsoft Excel spreadsheet with source data

Name	End-device name or ID
Lat	The geographic latitude of the terminal in any of the formats that RadioPlanner allows (see the Setup menu).
Lon	Geographic longitude of the terminal in any of the formats that RadioPlanner allows (see the Setup menu).
Type	Type (model) of end-device
Tx power, W	End-device transmitter power, W
Ant. height, m	End-device antenna height relative to ground level, m
Ant. gain, dBi	End-device antenna gain, dBi
Cable loss, dB	End-device cable loss, dB
Penetration loss, dB	Penetration loss into the building where the end-device is installed, dB

The calculation is carried out in accordance with the parameters set in the "Propagation model" menu. If the calculation takes into account clutter losses in accordance with Recommendation ITU-R P.1812-4, then the value of these losses is determined for each end-device, taking into account its antenna height above ground level. The calculation can additionally take into account the building penetration loss for each end-device. The output report for each end-device will show the uplink and downlink Rx powers for base stations that exceed the threshold set in this menu.

Q9

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Name	Lat	Lon	Type	Tx power, W	Ant. height, m	Ant. gain, dBi	Cable loss, dB	Penetration loss, dB	Clutter Type	Clutter loss, dB	BS Name	Distance, km	f	Downlink Rx power, dBm	Uplink Rx power, dBm
2	Sensor 1	N54.810000°	E31.960000°	Vega TD-11	0.025	2	0	0	0	Open/rural	0	BS 002 Azimuth 0°	2.819	f01	-120.3	-111.1
3												BS 003 Azimuth 0°	6.261	f01	-116.1	-106.9
4												BS 004 Azimuth 0°	9.439	f01	-121.3	-112.1
5												BS 005 Azimuth 0°	10.229	f01	-139.6	-130.4
6	Sensor 2	N54.778000°	E32.001565°	Vega TD-11	0.025	9	0	0	20	Urban	15.7	BS 002 Azimuth 0°	3.084	f01	-141.5	-132.3
7												BS 003 Azimuth 0°	2.028	f01	-139.4	-130.2
8	Sensor 3	N54.769603°	E32.087620°	Vega TD-11	0.025	10	0	0	0	Open/rural	0	BS 001 Azimuth 0°	3.261	f01	-138.3	-129.1
9												BS 002 Azimuth 0°	6.696	f01	-115.5	-106.2
10												BS 003 Azimuth 0°	3.615	f01	-107.1	-97.9
11												BS 004 Azimuth 0°	1.764	f01	-100.9	-91.7
12												BS 005 Azimuth 0°	1.323	f01	-98.4	-89.2
13												BS 006 Azimuth 0°	5.285	f01	-114.8	-105.6
14	Sensor 4	N54.803353°	E32.111449°	Vega TD-11	0.025	10	0	0	20	Suburban	0	BS 001 Azimuth 0°	3.614	f01	-127.1	-117.8
15												BS 005 Azimuth 0°	3.263	f01	-140.4	-131.2
16												BS 006 Azimuth 0°	1.85	f01	-127.5	-118.3
17	Sensor 5	N54.820600°	E32.058770°	Vega TD-11	0.025	10	0	0	15	Urban	14.2	BS 002 Azimuth 0°	3.877	f01	-138.7	-129.5
18												BS 003 Azimuth 0°	5.644	f01	-140.1	-130.9
19												BS 004 Azimuth 0°	7.234	f01	-144.5	-135.3
20												BS 005 Azimuth 0°	5.996	f01	-142	-132.8
21												BS 006 Azimuth 0°	2.29	f01	-132.3	-123.1
22	Sensor 6	N54.720000°	E32.063380°	Vega TD-11	0.025	7	0	0	0	Open/rural	0	BS 002 Azimuth 0°	10.221	f01	-131.4	-122.2
23												BS 003 Azimuth 0°	6.173	f01	-125.2	-115.9
24												BS 004 Azimuth 0°	4.058	f01	-113.8	-104.6
25												BS 005 Azimuth 0°	6.613	f01	-116.6	-107.4
26												BS 006 Azimuth 0°	11.011	f01	-133.3	-124.1
27	Sensor 7	N54.762646°	E32.111406°	Vega TD-11	0.025	10	0	0	20	Dense urbar	20	BS 004 Azimuth 0°	2.558	f01	-144.1	-134.8
28												BS 005 Azimuth 0°	1.323	f01	-138.4	-129.2
29	Sensor 8	N54.762000°	E32.018700°	Vega TD-11	0.025	3	0	0	0	Trees/forest	21.5	BS 002 Azimuth 0°	4.934	f01	-131.3	-122.1
30												BS 003 Azimuth 0°	1.411	f01	-120.5	-111.3
31												BS 004 Azimuth 0°	3.617	f01	-131.1	-121.9

Figure 40. Output Microsoft Excel spreadsheets

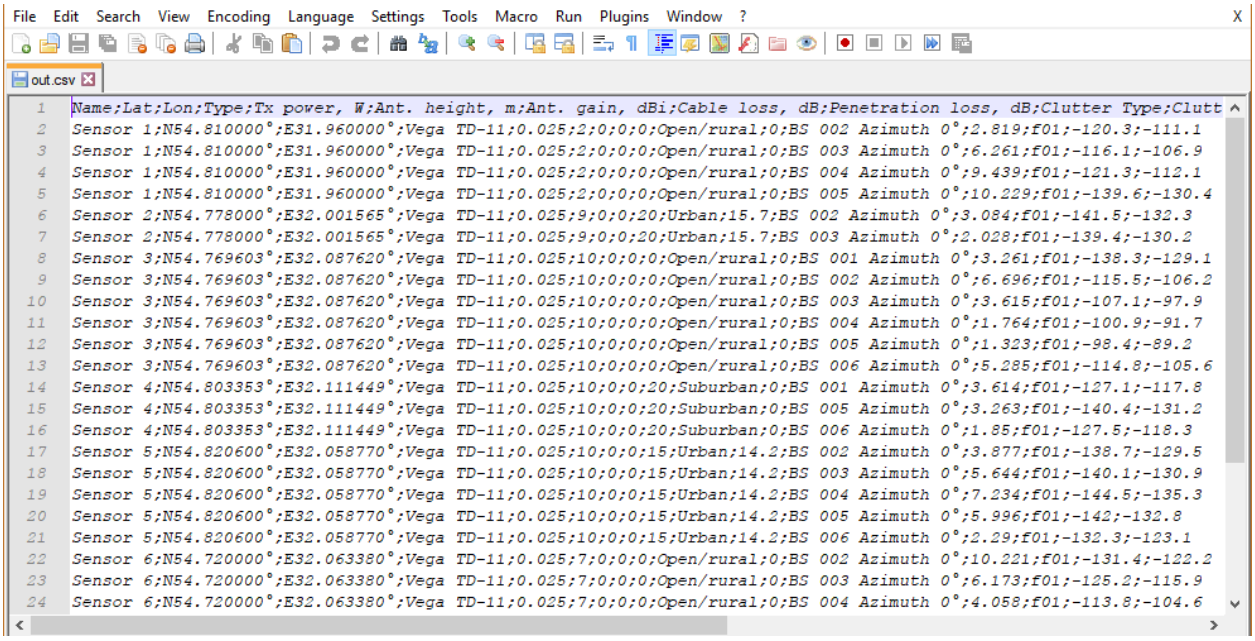


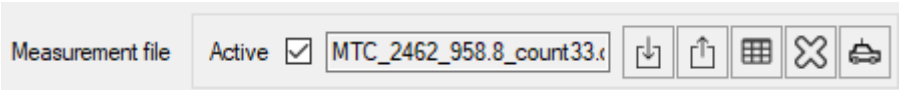
Figure 41. Output CSV file

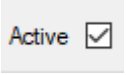
Import Measurement Results and Propagation Model Tuning

RadioPlanner allows you to determine the clutter loss for a propagation model by comparing measurements with the calculated values.

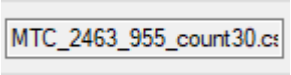
Loading, preprocessing and analysis of the measurement file for each BS sector is performed in the Sector parameters panel of the corresponding sector.

The toolbar is at the bottom :





- Active means that measurement data for this sector will be taken into account in the general analysis of measurements for a group of sectors



- File with measurement results

- Import of measurement data from a CSV file

- Export of measurement data to a CSV file

- Delete measurement data

- View and edit the measurement data

- Measurements analysis along the route

Operating procedure:

1. Prepare separate files of received power levels for each of the necessary base station sectors.

The measurement file is a CSV format file, each of the lines of which contains three parameters: the level of the measured signal from one BS sector 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).

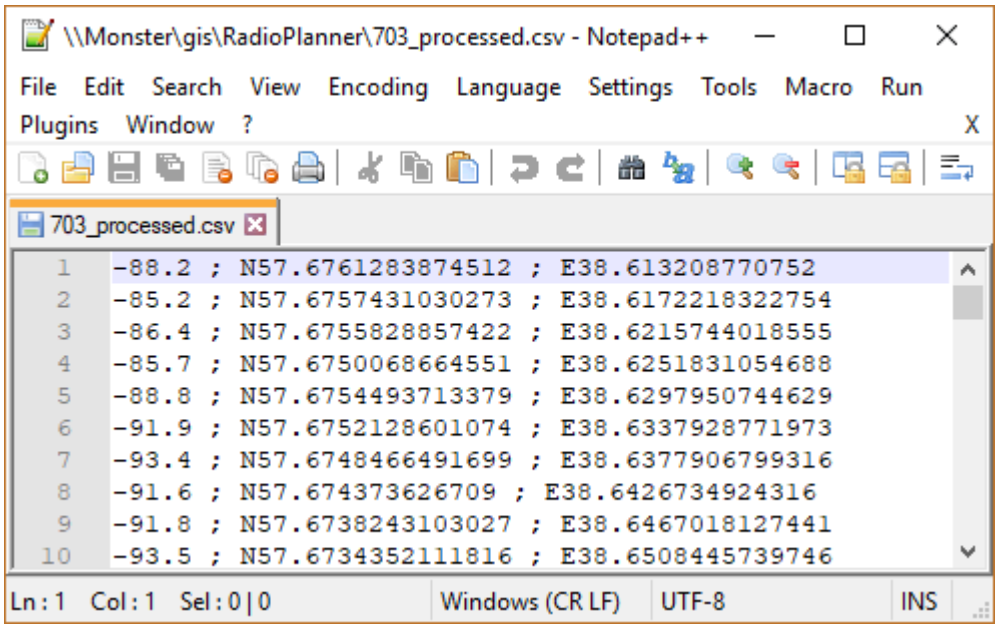


Figure 42. Sample measurement file

2. Upload measurement files to the appropriate BS sectors in "Mobile Network" - "Sector Settings."

Here, using the button, you can view the downloaded measurement data for the BS sector and, if necessary, perform the preliminary processing:

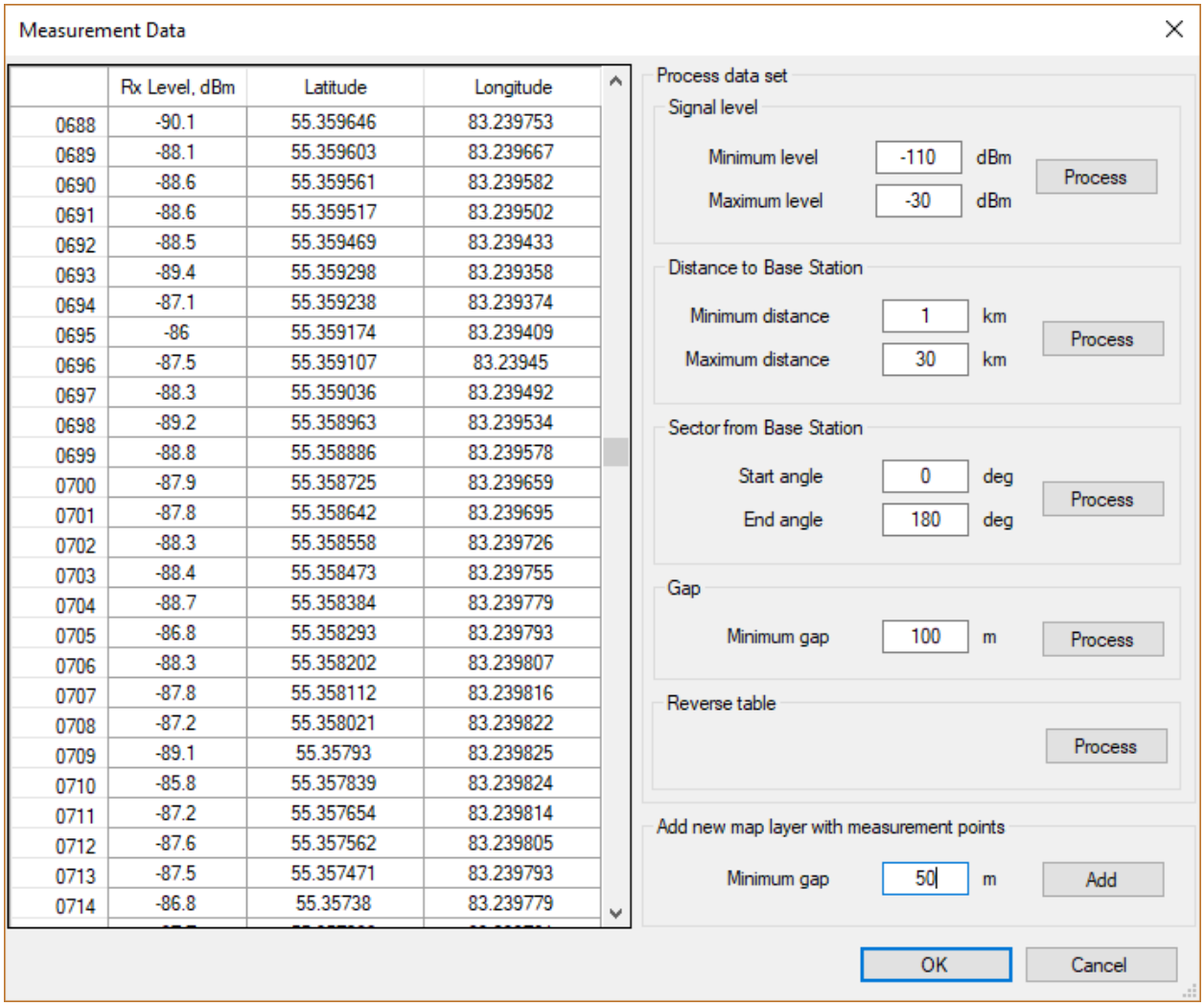
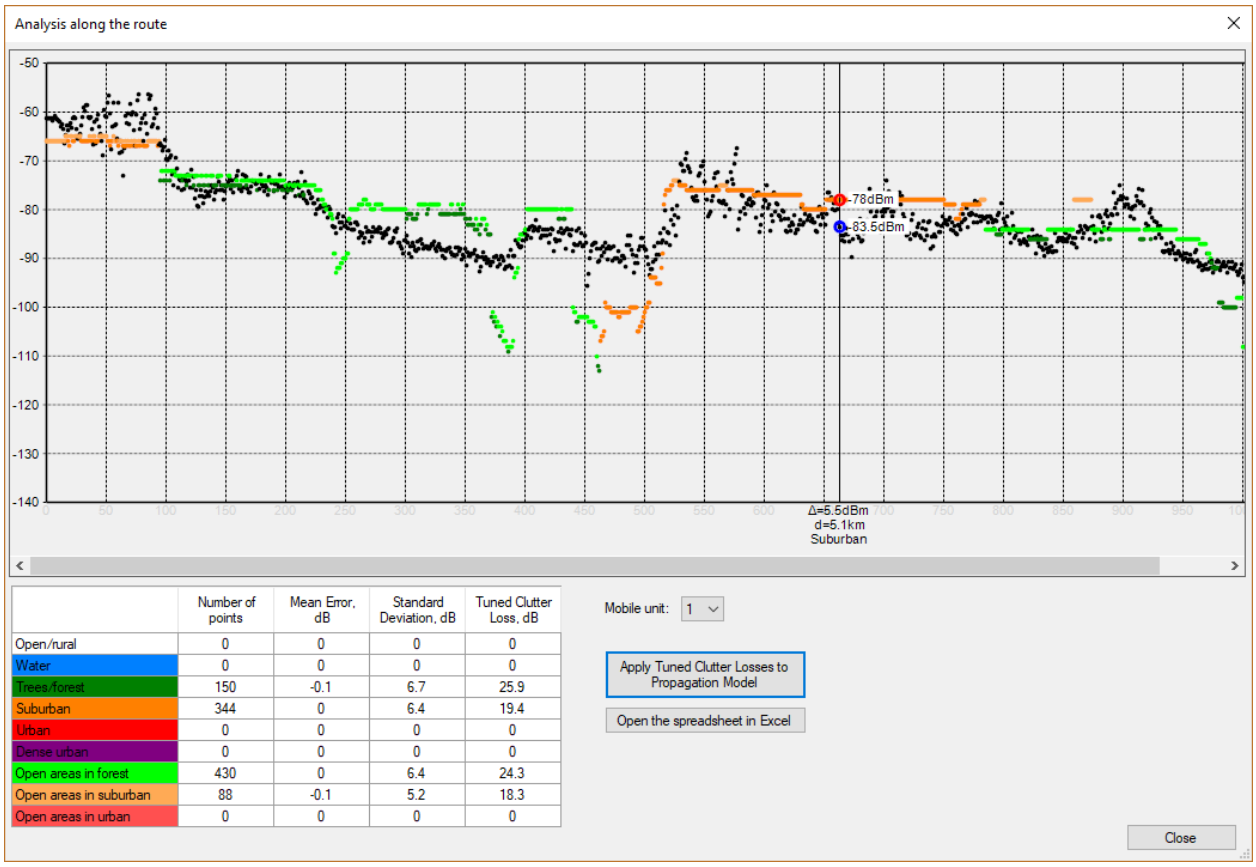


Figure 43. Pre-processing of measurement results in the BS sector

Signal level Minimum/Maximum Level	Limit the points that will be included in the comparison by received power level from the base station
Distance to Base Station Minimum/Maximum Distance	Limit the points that will be included in the comparison by distance from the base station
Sector from Base Station Minimum/Maximum Angle	Limit the points that will be included in the comparison by azimuth from the base station
Gap Minimum Gap	Perform averaging of the power level within a given segment
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 Minimum Gap	Add a custom measurement layer to the map with averaging within the specified minimum distance. The data in the table does not change. The resulting layer will appear among the user layers; the layer name will correspond to the BS name and sector direction.

3. Press the button “Analyze measurements along the route”, 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 graph displays the calculated and measured levels, the difference in levels, the distance to the base station in kilometers, and the clutter type.

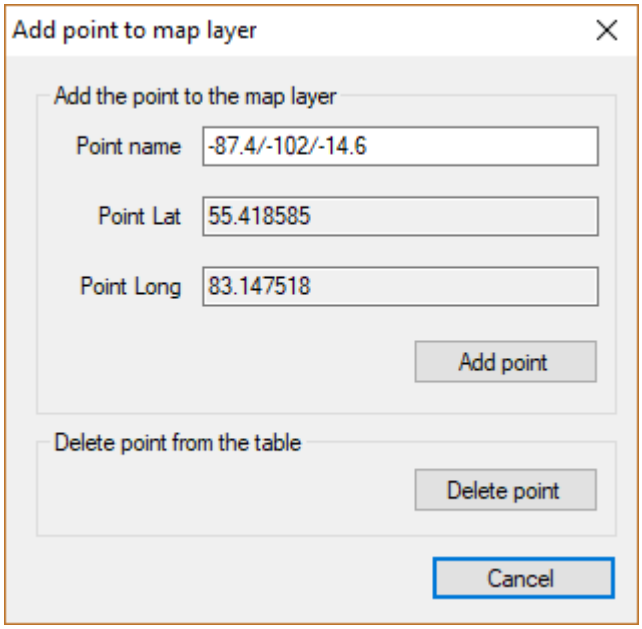
The table below the graph will indicate the number of points, the average error, the standard deviation of the error, as well as the recommended loss values for different clutter types, at which the average error will be zero. When you click on the button "Apply Tuned Clutter Losses to Propagation Model", the values for the points of the graph 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.



	Number of points	Mean Error, dB	Standard Deviation, dB	Tuned Clutter Loss, dB
Open/rural	0	0	0	0
Water	0	0	0	0
Trees/forest	150	-0.1	6.7	25.9
Suburban	344	0	6.4	19.4
Urban	0	0	0	0
Dense urban	0	0	0	0
Open areas in forest	430	0	6.4	24.3
Open areas in suburban	88	-0.1	5.2	18.3
Open areas in urban	0	0	0	0

Figure 44. Analysis measurements along the route

When you click on the graph, a context menu appears, in which you can delete a point with the measurement result or add it as a point object to the map:



4. General analysis of measurements for a group of sectors is performed in the "Measurement Analysis" panel of the main menu.

The results of the measured and calculated levels comparison for all sectors for which the measurement results have been loaded will appear here. Note that here the abscissa indicates the distance from the base station, not the route point number.

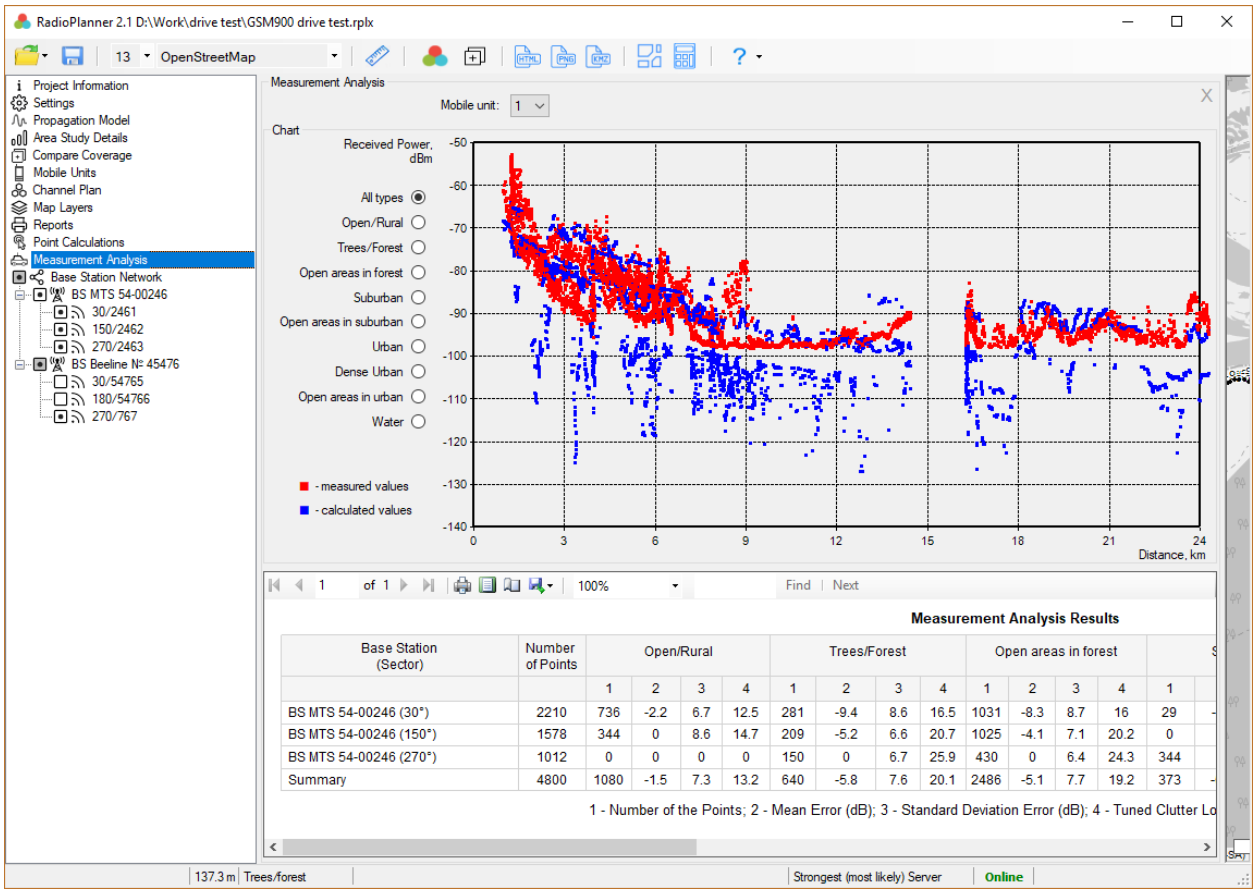


Figure 45. Measurement Analysis

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

Calculator of the Noise-Adjusted Faded Performance Threshold

The influence of man-made noise cannot be ignored in the frequency bands where most of the professional mobile radio communication systems operate (136-174 MHz and 403-470 MHz).

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)

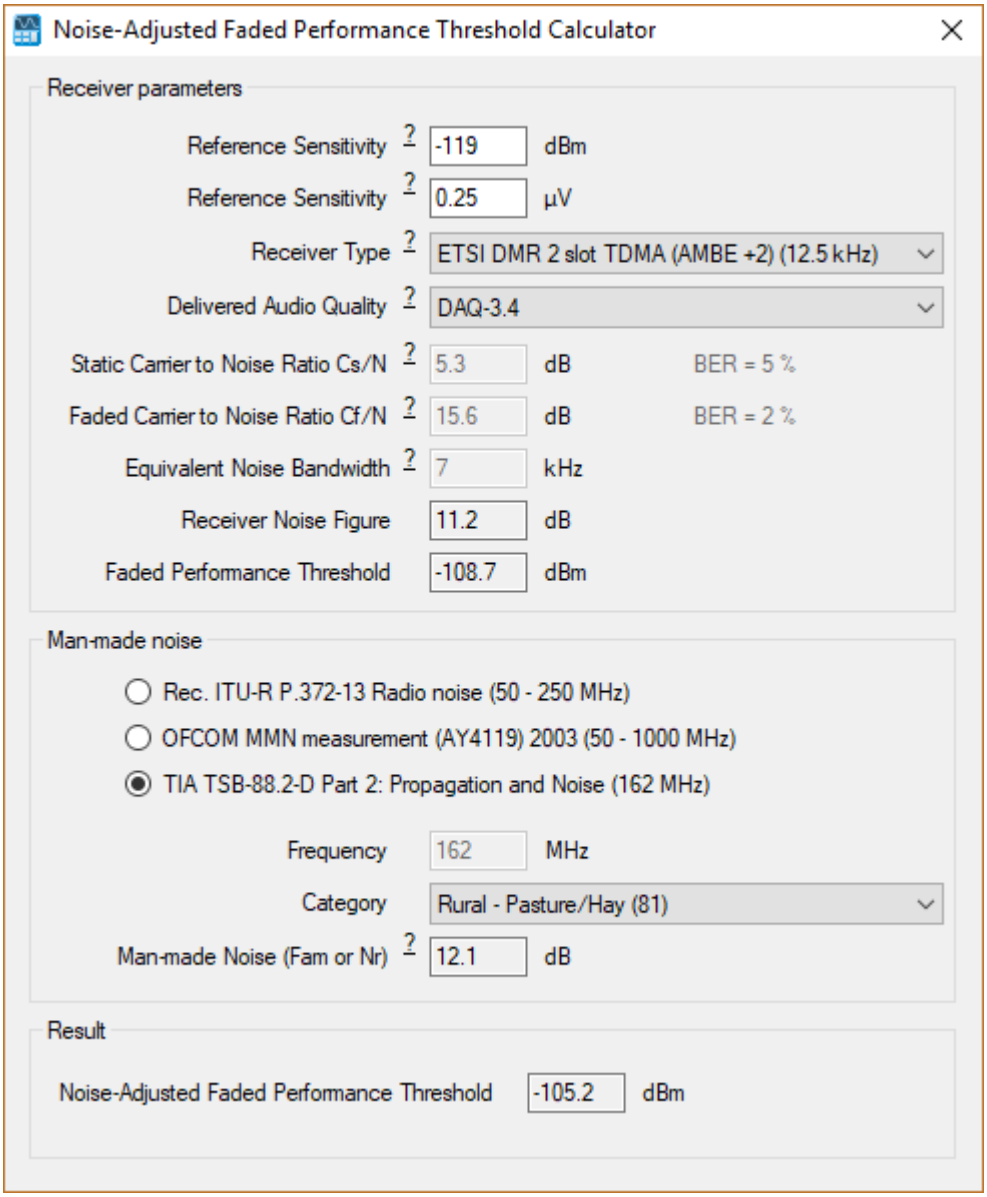


Figure 46. Man-made noise calculations

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 system

3. DAQ required, usually DAQ = 3.0 or 3.4

4. Select the research report on which the calculation will be based and the category of land cover.

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.

Radio and TV Broadcast

RadioPlanner 2.1 performs the coverage calculation for the transmitters of television and radio broadcast, as well as automatically determines the population in the coverage area based on the OpenStreetMap project base. Based on the results of the calculation, a list of localities covered by broadcasting is formed, indicating the population in each locality and the total population in the coverage area.

Broadcast Network

The characteristics of the radio equipment of the base stations are set in the Broadcasting Network menu. After creating a new project, the list of transmitters is empty.

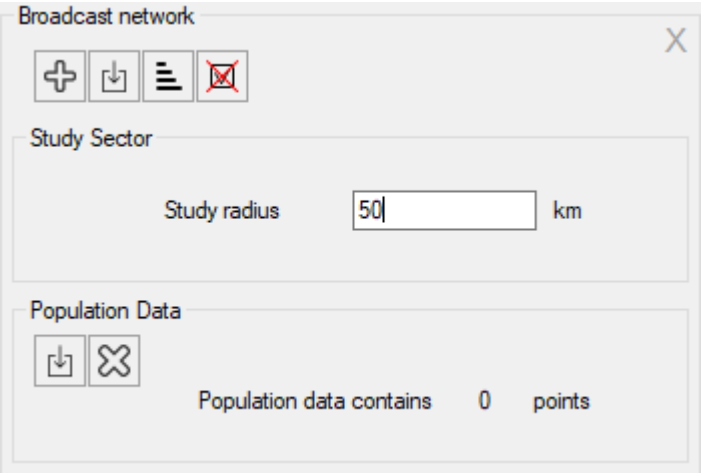


Figure 47. Broadcast network

Toolbar:

Broadcast network

- Create a new transmitter

- Import sites from *.csv file

- Sort transmitters in alphabetical order

- Delete all active transmitters

Study Radius	The maximum radius of calculation from transmitters, km. The larger the radius, the longer the calculation time.

Population Data

- Import population data from *.CSV

- Remove local population data from the project taken from the CSV file (then the data will be requested in the OpenStreetMap database)

To create a new transmitter, click on Broadcast Network in the Tree View interface, then click the button in the panel that opens, then select the template from which the new transmitter will be created.

You can also import sites from CSV files (text format, where the separator is a semicolon).

This is a universal format in which you can save a spreadsheet from any spreadsheet editor (Excel, LibreOffice Calc, and others), as well as databases.

The required fields for each point object are the transmitter name, the Latitude, and the Longitude. Format coordinates - 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, then select a template based on which new base stations will be created with coordinates of imported sites.

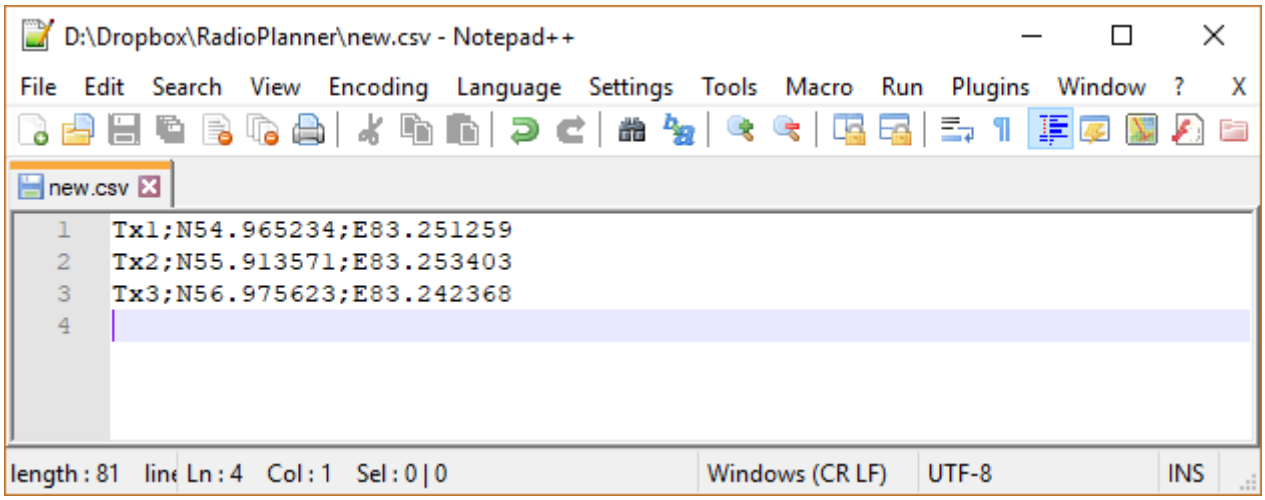


Figure 48. CSV file sample

When clicking in the Tree View interface panel on the created transmitter, the **Transmitter Details** panel will open, where you can edit the name, coordinates, specify additional text information about the transmitter, and find out the elevation of the transmitter relative to sea level.

Using the tools on the **Transmitter Details** panel, you can do the following:

- Create a new transmitter as a copy of this transmitter

- Move transmitter up or down

- Delete transmitter

- Load the transmitter parameters from a template

- Save the parameters of the transmitter as a template

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

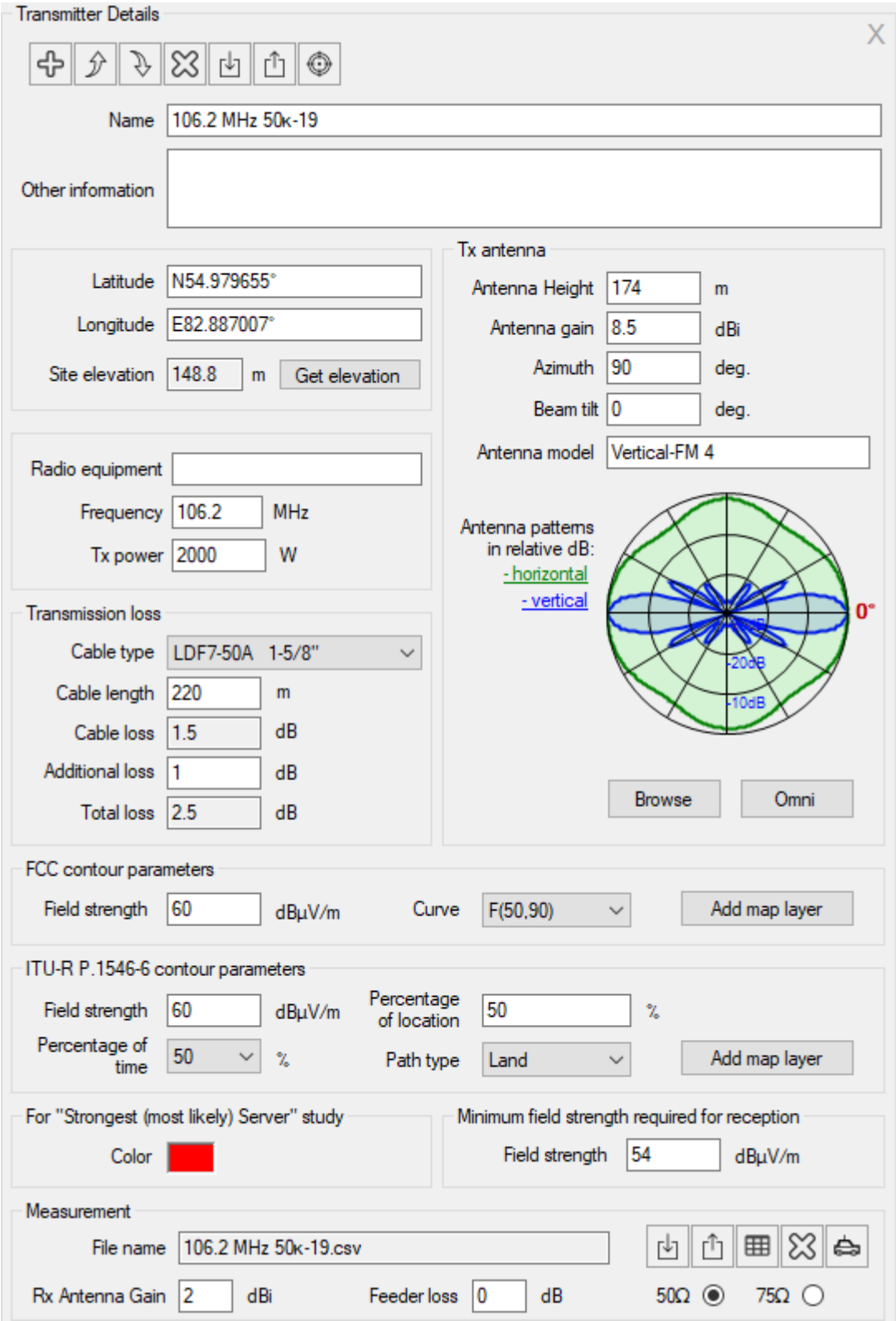


Figure 49. Transmitter Details

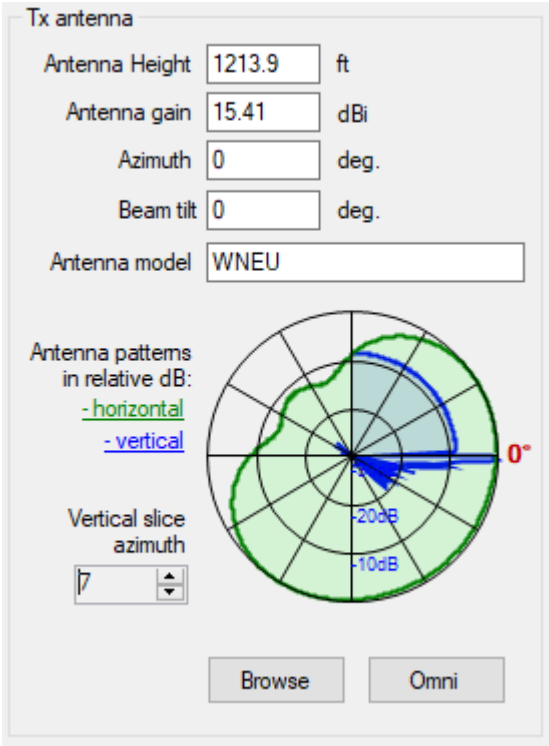
Name	Transmitter name, text field
Other Information	The text box for any additional transmitter information

Latitude	The geographical latitude of the base station in the format specified by the user in Settings
Longitude	Geographical longitude of the base station in the format specified by the user in Settings
Site Elevation	Site elevation relative to sea level, m
Radio Equipment	Type (model) of Radio equipment, text field
Frequency	Transmitter carrier frequency, MHz
Tx Power	Transmitter power, W
Cable Type	Main cable type. 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	Main cable loss, 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 height of the center of radiation of the antenna 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 of 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.
FCC contour parameters	
Field Strength, dBuV/m	The value of the field strength, dB(µV/m) for calculating the contours according to the FCC propagation curves. For more details, see the section **FCC contours**.
Curve	FCC curve from set F (50.50); F (50.10); F (50.90). For more details, see the section **FCC contours**.
Add Map Layer	Adding a contour with selected parameters to the map as a layer
ITU-R P.1546-6 contour parameters	
Field Strength, dBuV/m	The value of the field strength, dB(µV/m) for calculating the contours according to the ITU-R P.1546-6 propagation curves. For more details, 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
Color for Strongest (Most Likely) Server	The color that will be used to indicate the coverage for this transmitter when calculating the zones of maximum field strength at the receiving point (Strongest Server)
Minimum field strength required for reception, dBuV/m	Exclude from coverage for this transmitter area with a field strength less than the specified value. 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.
Measurement	The file with the results of the measured signal level in this Transmitter and the toolbar for processing it. See more details in the "Import measurement results and adjustment of the propagation model for TV- and radio broadcasting projects" section.

The 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.

In TV and radio broadcasting projects, you can also use full 3D antenna patterns in * .pat format from EDX Engineering https://help.edx.com/help/directional-antenna-pattern-file. This is relevant for complex broadcast antenna systems based on panels with different tilt angles in different azimuths. In the * .pat format, the vertical antenna patterns are presented as "slices" across multiple azimuths. When loading a file with such a radiation pattern in the transmitter parameters window, it will be possible to view all the antenna "slices":



Propagation Models for Radio and TV Broadcasting Projects

When working with TV and radio broadcasting projects, the user can choose from the following propagation models:

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

ITU-R P.1812-4 Model

This propagation model is described in detail in the Mobile Networks section. The model parameters for TV and broadcast projects are similar.

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 obstacles surrounding the receiver. These corrections are determined by the features of the terrain and obstacles in a particular territory.

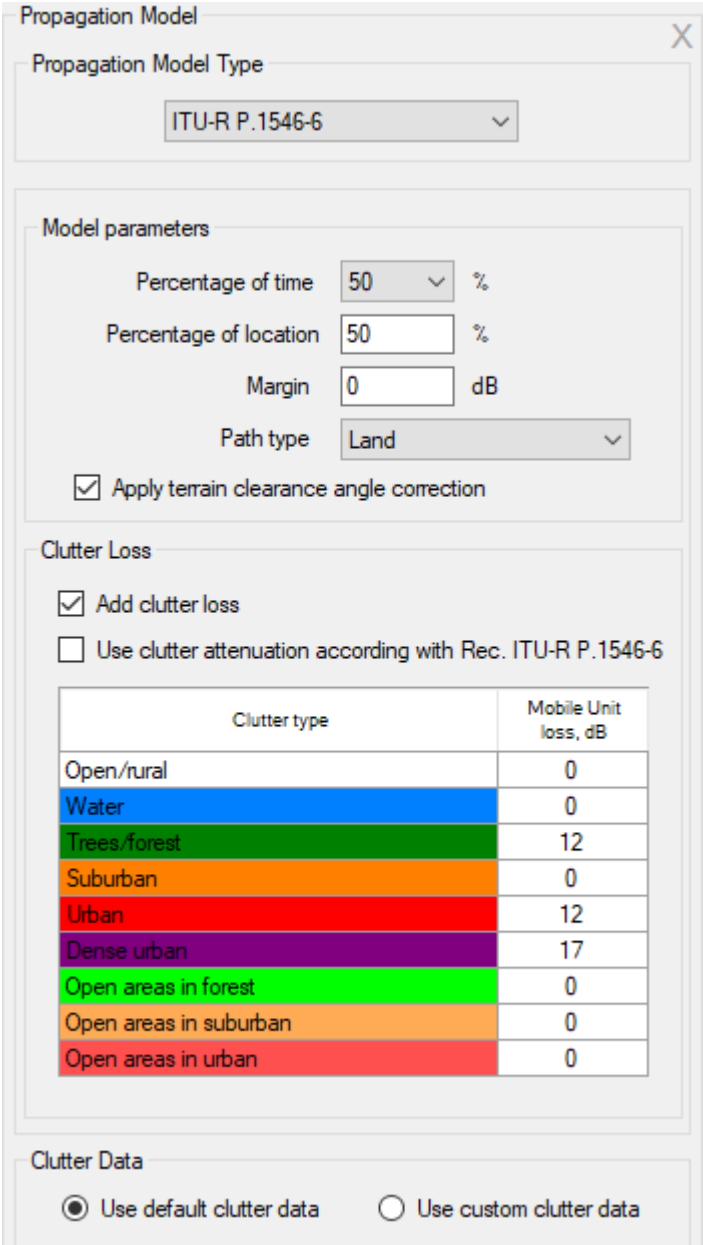


Figure 50. ITU-R P.1546-6 Propagation Model

Percentage of Time, %	The procedures deliver the field strength exceeded for this percentage of time. A value of 1% is used to calculate interference; 50% is used to calculate service areas.
Percentage of Location, %	The procedures deliver the field strength exceeded for this percentage of locations.
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 your signal level estimate is indeed above the specified signal level.
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	Take into account the clutter loss. The user can manually set the clutter loss for each type of clutter, based on third-party data on the amount of loss. For this, you need to specify **Add clutter loss** and enter the corresponding losses into the table.
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.
Clutter Data	Use default clutter data or Use custom clutter data - The choice of the clutter data that will be used for calculations - the default clutter or the custom clutter. Custom clutter is created in the Clutter Editor (see the section **Clutter Editor**).

Longley-Rice (ITM) Model v 1.2.2

This propagation model is described in detail in the Mobile Networks section. The model parameters for TV and broadcast projects are similar.

Area Study Details

In this panel, the user selects the type of calculation and sets its parameters.

For broadcast networks, the field strength (dBµV/m) of the radio signal at the receiving site is usually calculated.

For projects "radio or TV broadcasting," you can choose the following types of calculations:

- Field Strength at Remote;
- Strongest (Most Likely) Server

Field Strength at Remote

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

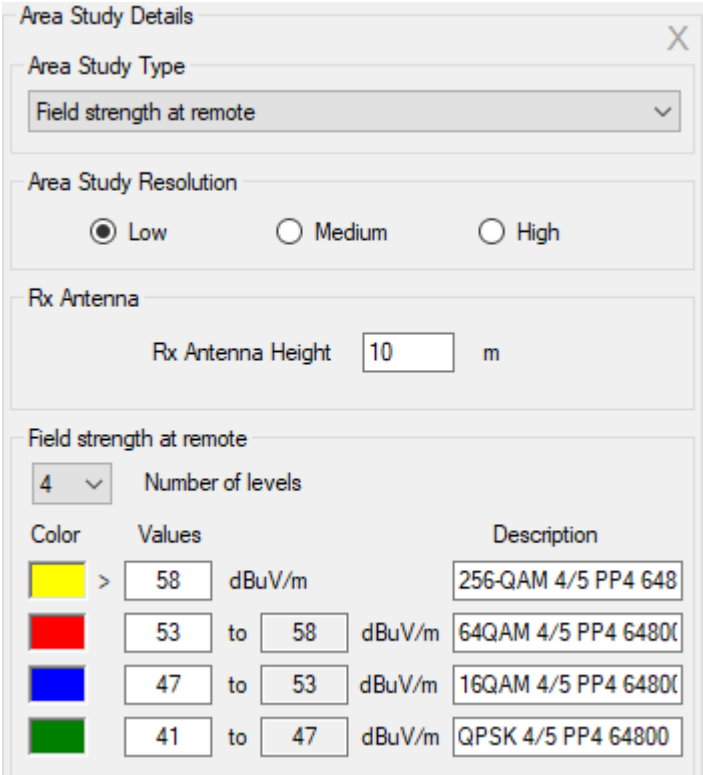


Figure 51. Field Strength at Remote menu

Area Study Resolution	- Low - Medium - High The resolution with which the result of the calculation will be presented. 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.
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
Rx Antenna Height	Rx antenna height relative to ground level, m

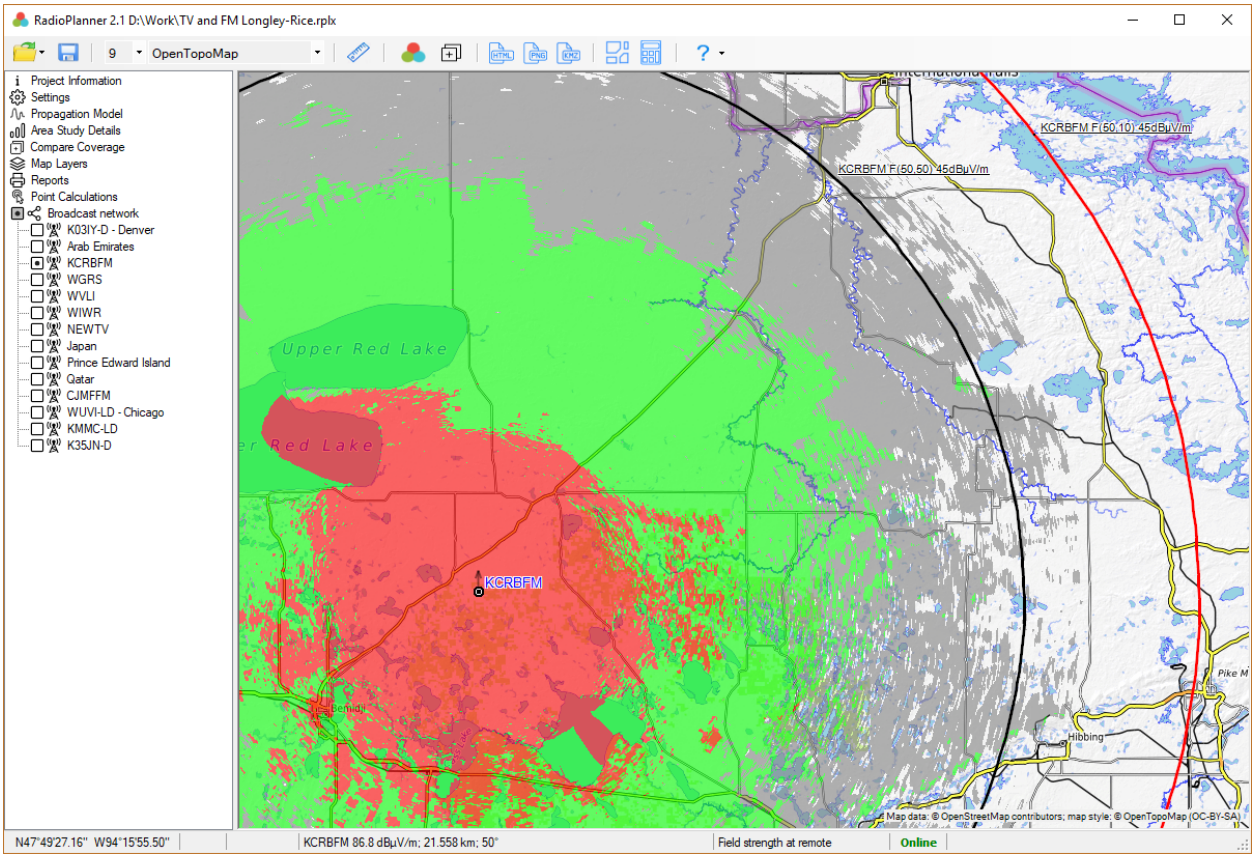


Figure 52. Field Strength at Remote for FM Transmitter

Strongest (Most Likely) Server

The strongest server map is a map showing the identity of the transmitter supplying the strongest received signal at each grid location. The colors that show coverage from different transmitters can be assigned to each transmitter or can correspond to a group of transmitters with the same frequencies.

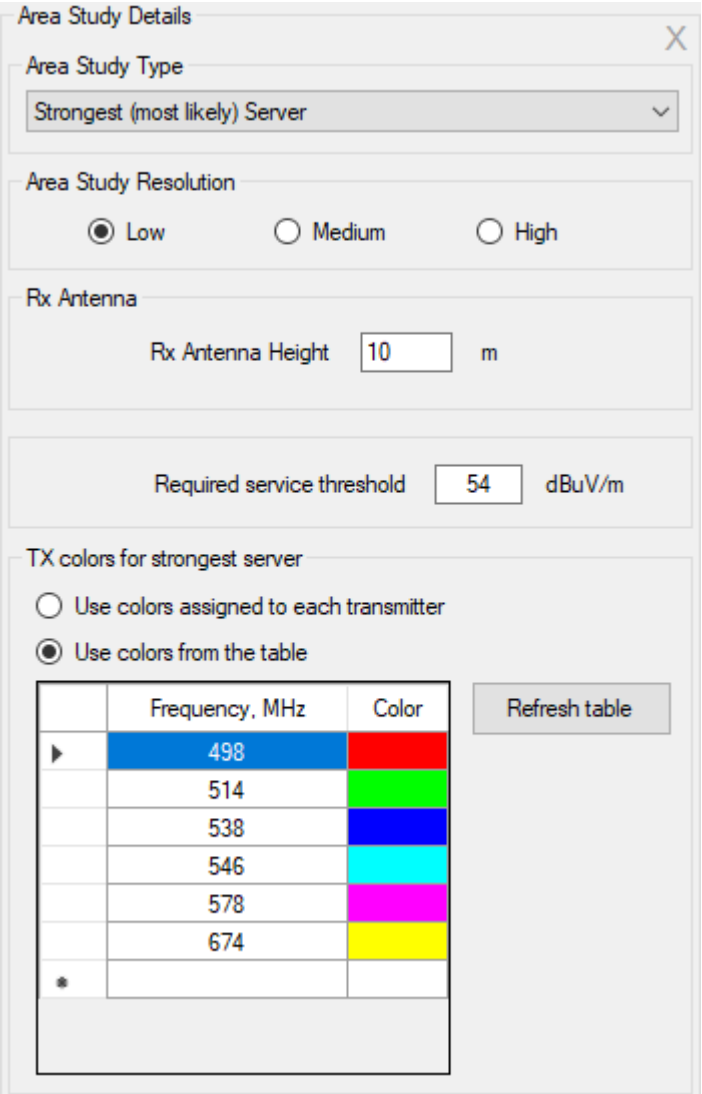


Figure 53. Strongest (Most Likely) Server menu

Area Study Resolution	- Low - Medium - High The resolution with which the result of the calculation will be presented. 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.
Rx Antenna Height	Rx antenna height relative to ground level, m
Required Service Threshold	Required service threshold for Strongest Server calculation, dBuV/m
Use Colors Assigned to each Transmitter	Color assignment to the transmitter is performed by the color specified in the "Transmitter Parameters" menu.
Use Colors from the Table	The color assignment will be performed according to the table depending on the frequency of the transmitter.

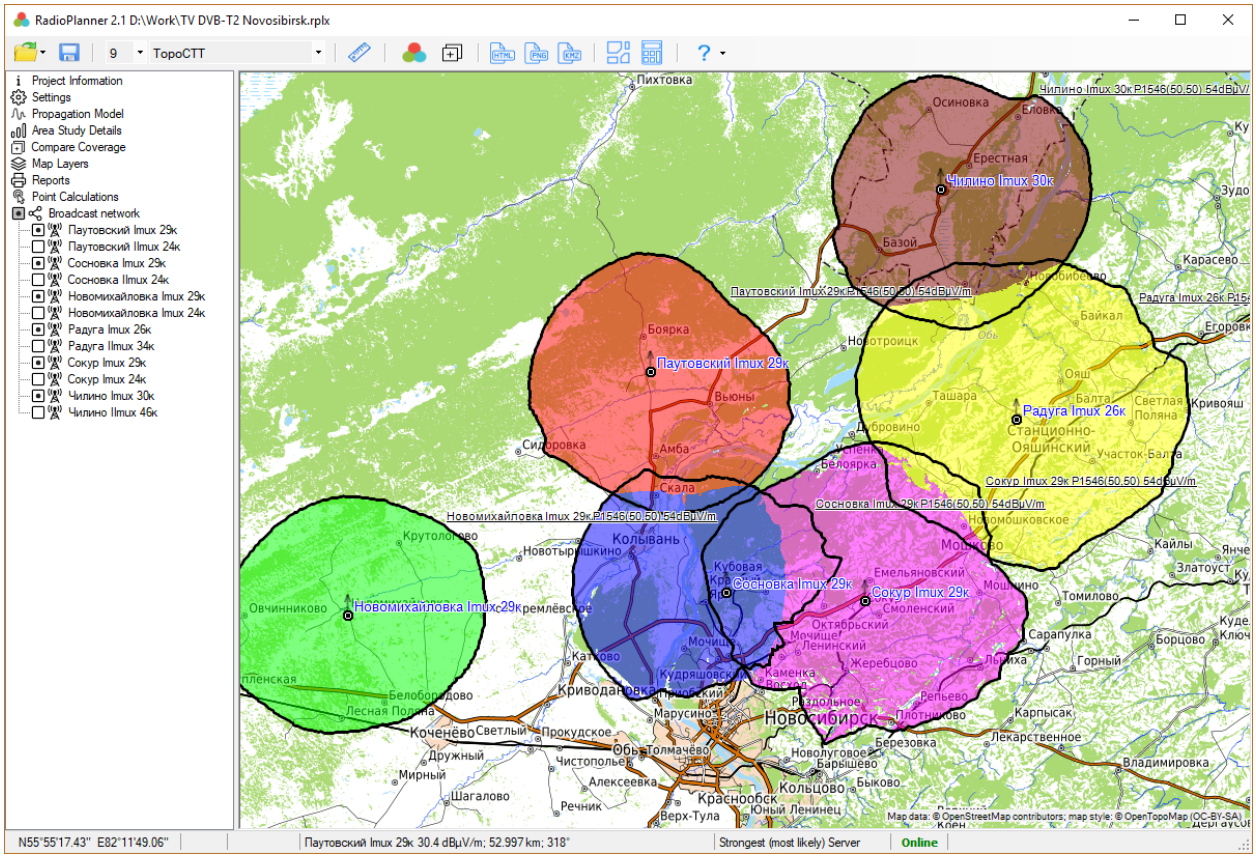


Figure 54. Strongest (Most Likely) Server for TV DVB-T2 broadcasting network

FCC Contours

RadioPlanner 2.1 allows you to calculate service and interference contours from FCC propagation curves. These contours are used in North America in accordance with FCC rules, as well as in some countries as a recommendation when planning television and FM broadcast stations.

FCC contour calculation is performed in the parameters menu of the transmitter for which the contour is calculated. Enter the required value of the electromagnetic field strength and also select the type of FCC propagation curve:

- F (50,50) - Curve of the service contour for FM broadcasting and analog television

- F (50,10) - Curve of the interference contour

- F (50,90) - Curve of the service contour for digital television

After clicking the **Add map layer** button, the FCC contour appears on the base map as a vector layer. The name of this layer displays information about the name of the transmitter, 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 you wish; working with it is no different from working with other vector layers on the map.

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.

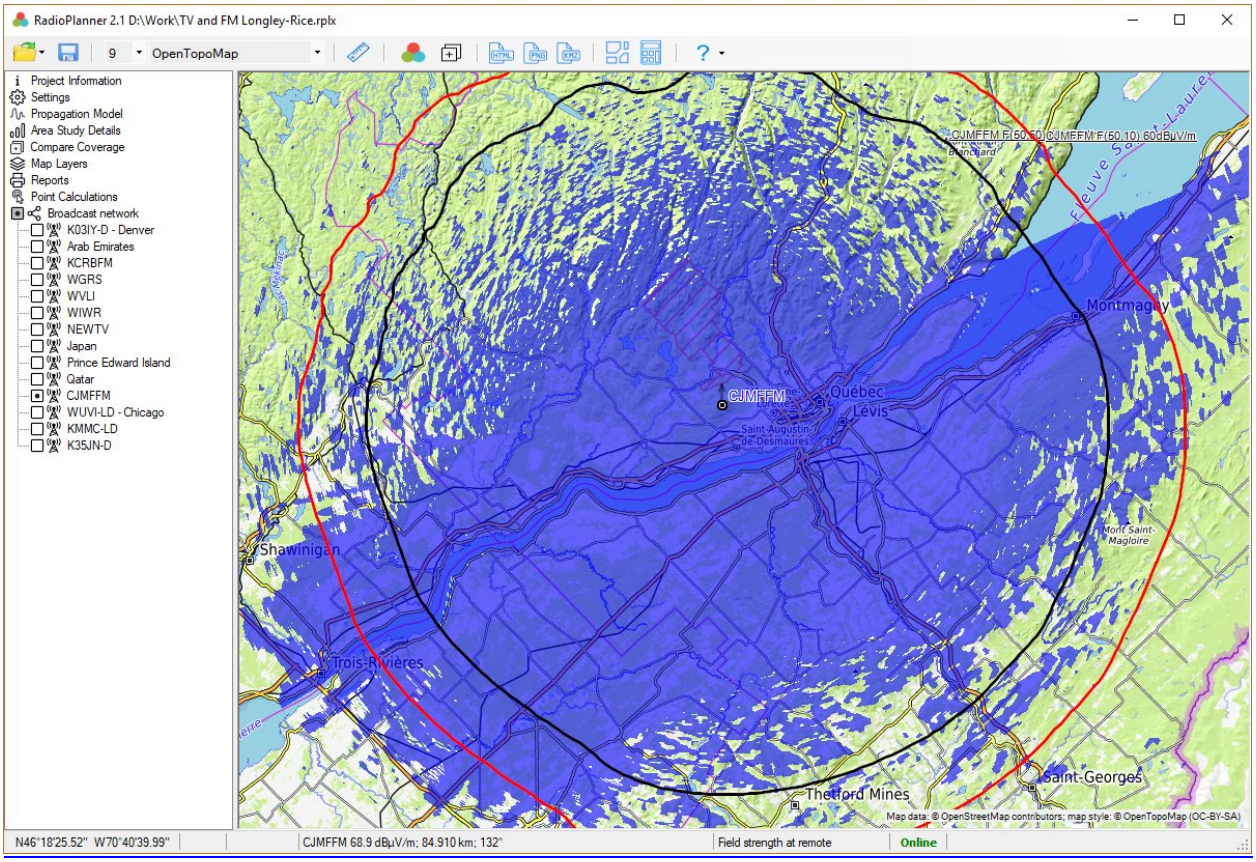


Figure 55. FCC Contours + Longley-Rice coverage

ITU-R P.1546-6 Contours

ITU-R P.1546-6 contour calculation is performed in the parameters menu of the transmitter for which the contour is calculated. To calculate, set the value of the electromagnetic field strength, the type of path, and the percentage of places and times for which the calculation will be made.

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

- (50.50) - service circuit 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 appears on the base map as a vector layer. The name of this layer displays information about the name of the transmitter, 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 you wish; working with it is no different from working with other vector layers on the map.

Point Calculations

The user can see results of the calculation of the field strength at any point in this panel.

You can change the current point on the map by clicking the mouse on the place you want. The path profile is a vertical section of the terrain between the transmitter and the receiver with information about land elevations, forests, and buildings. The colors that mark the various obstacles on the profile correspond to the colors of the landcover model.

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

The transmitter is selected on the left side of the panel in the general network Broadcast Network. Find the transmitter you need and click on it with the mouse (not to be confused with the activity tag), after which information on this sector will appear above the path profile.

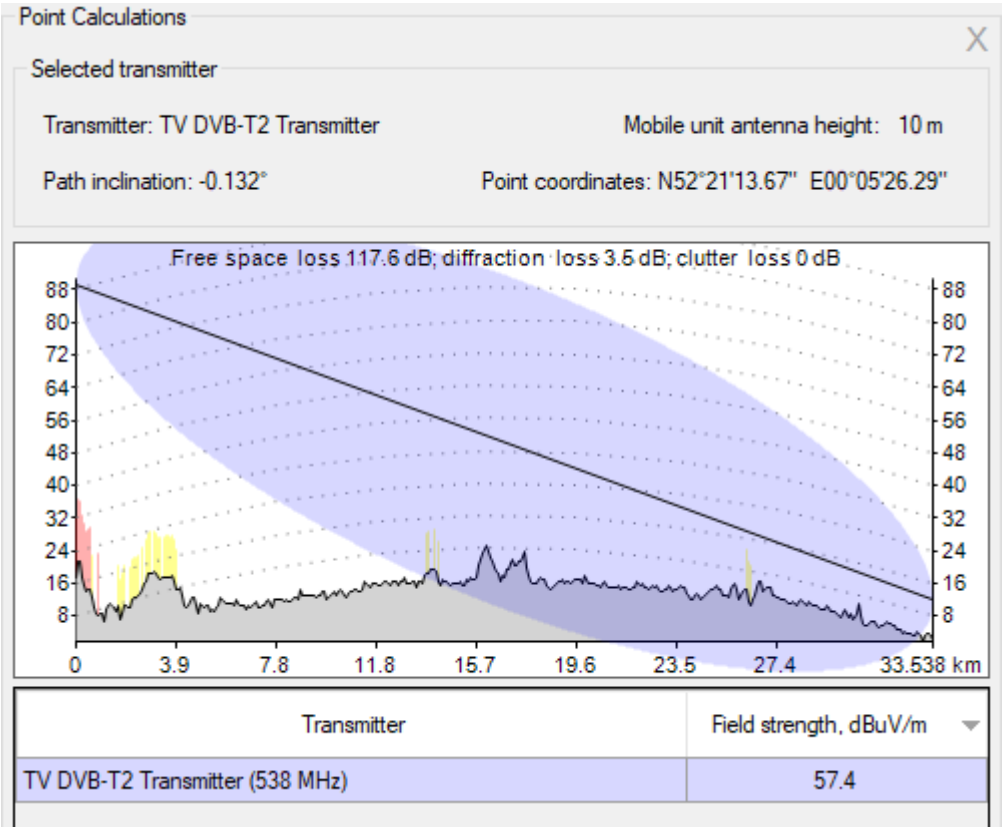


Figure 56. Point Calculations

Under the path profile, a table appears with the results of calculating the field strength.

Calculation of the Population Covered by Television and Radio Broadcasting

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

The population and list of localities covered by the broadcast can be obtained from a local dataset (CSV file) or from data from the OpenStreetMap project.

In both cases, the population covered by the broadcast 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. If a local dataset is used for the calculation, then the user must first prepare a CSV text file with the corresponding data.

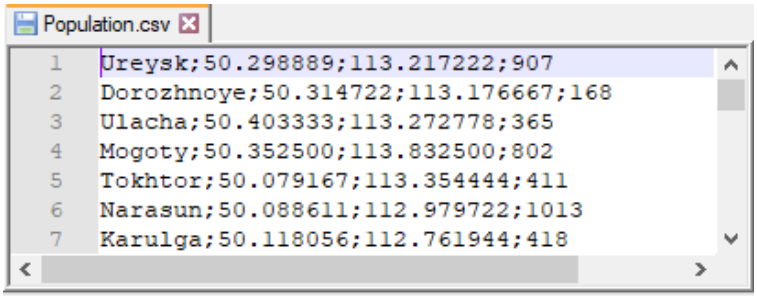


Figure 57. Sample text file with population data

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, in the Broadcasting network menu, click on the button (import data on population from a * .csv file) and select the appropriate file, after which the program will show the total number of settlements with data on the population.

If a CSV file with population data was not imported into the project, or it was imported, but then it was removed from the project, then data from OpenStreetMap will be requested to calculate the population.

To calculate the population, you first need to calculate the coverage area from the transmitter (or several transmitters). Calculation of the population will be performed for the very minimum field strength level from the **Area Study Details** menu. To display the calculation results, go to the **Report** menu and click on the **Population Coverage** button, after which a table will appear listing the settlements covered by the broadcast. The total area of coverage in square kilometers is indicated under the table, as well as the average coverage radius (only when calculating coverage from one transmitter).

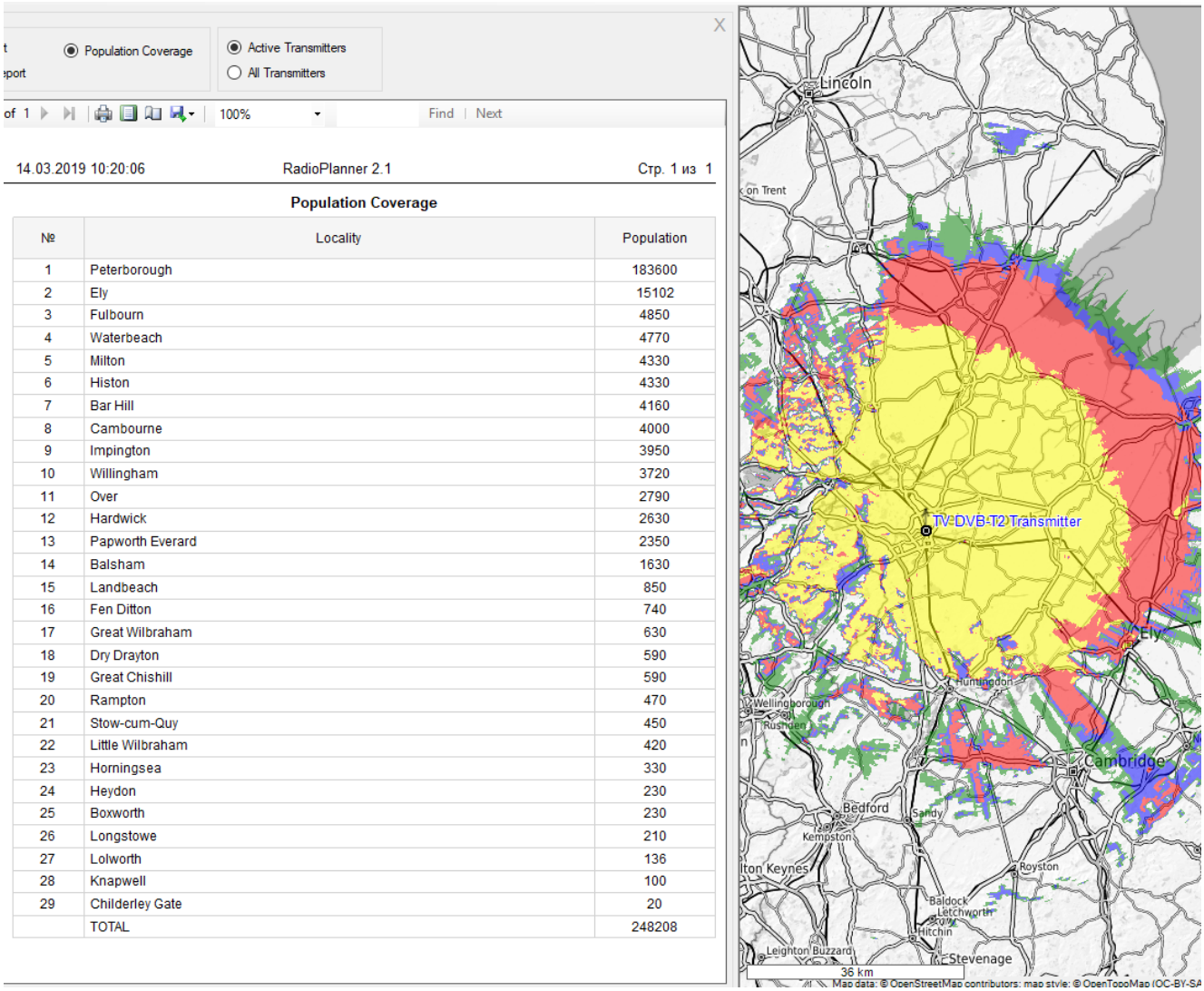


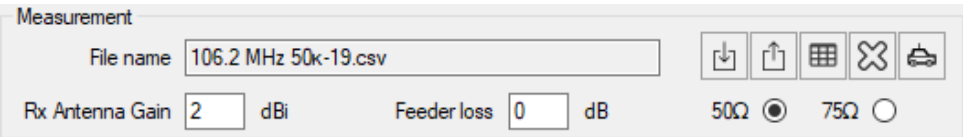
Figure 58. Population Coverage Report

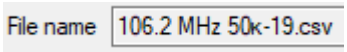
Import Measurement Results and Propagation Model Tuning for TV and Radio Broadcasting Projects

RadioPlanner allows you to determine the clutter loss for a propagation model by comparing measurements with the calculated values.

Loading, preprocessing and analysis of the measurement file is performed in the transmitter parameters panel.

The toolbar is at the bottom :





File with measurement results

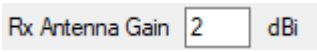
Import of measurement data from a CSV file

Export of measurement data to a CSV file

Delete measurement data

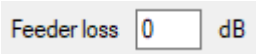
View and edit the measurement data

Measurements analysis along the route



Measurement receiver antenna gain, dBi

System type, ohm



Antenna cable loss, dB

The following measurement file formats are supported:

Universal 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).

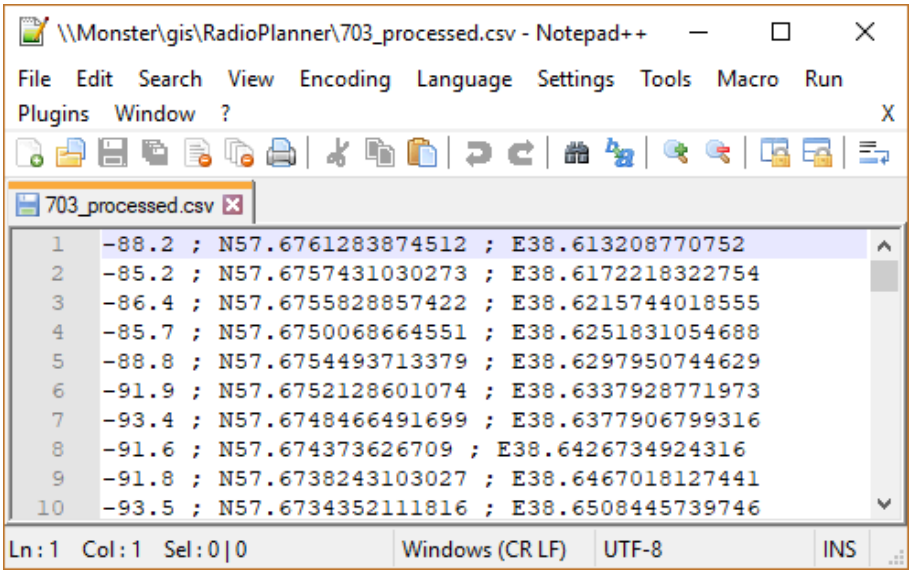


Figure 59. Universal measurement file in CSV format

Stream Labs FM PROBE Measurement File

It is also a text file in CSV format with several header lines and measurements of the received signal voltage in dBuV. The FM PROBE analyzer allows you to record signal levels for several transmitters at once in one file during measurements.

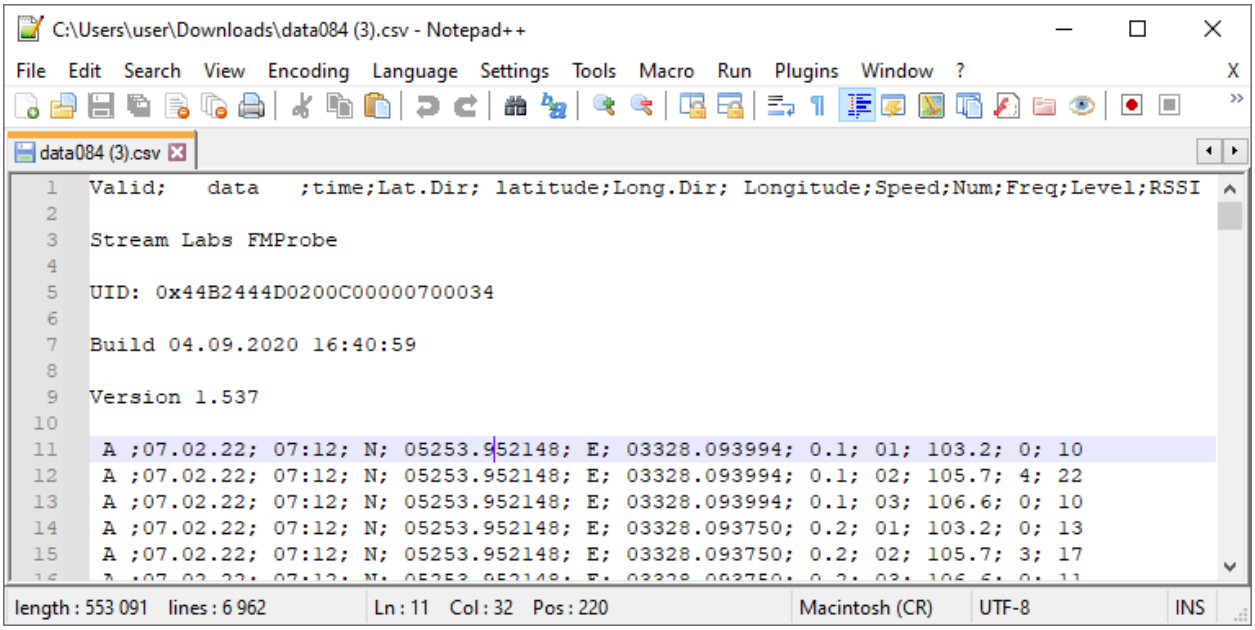


Figure 60. Stream Labs FM PROBE Measurement File

Since the file may contain measurement results for several transmitters, the user will be prompted to select the desired frequency during import.

When using an FM PROBE analyzer, its calibration factor KF at a given frequency must be taken into account in the antenna gain of the measuring receiver using the formula:

G=20log(f)-KF-29.8, dBi where f is frequency in MHz, cable loss should be set to 0 dB.

Operating procedure:

1. Based on the results of field measurements, prepare a file with the measurements results in one of the formats described above.

2. If the receiver was used to measure the signal power (dBmW) with the creation of a universal file in CSV format, then you should specify the antenna gain, cable loss and impedance for the measuring receiver path. If the measurements were performed with a calibrated FM PROBE measuring receiver from Stream Labs, then specify the antenna gain G=20log(f)-KF-29.8, dBi (f is the frequency in MHz, KF is the through calibration coefficient at the transmitter frequency), cable loss = 0 dB, impedance = 50 ohm.

Upload measurement files to the appropriate transmitter.

Here, using the button, you can view the downloaded measurement data for transmitter the and, if necessary, perform the preliminary processing:

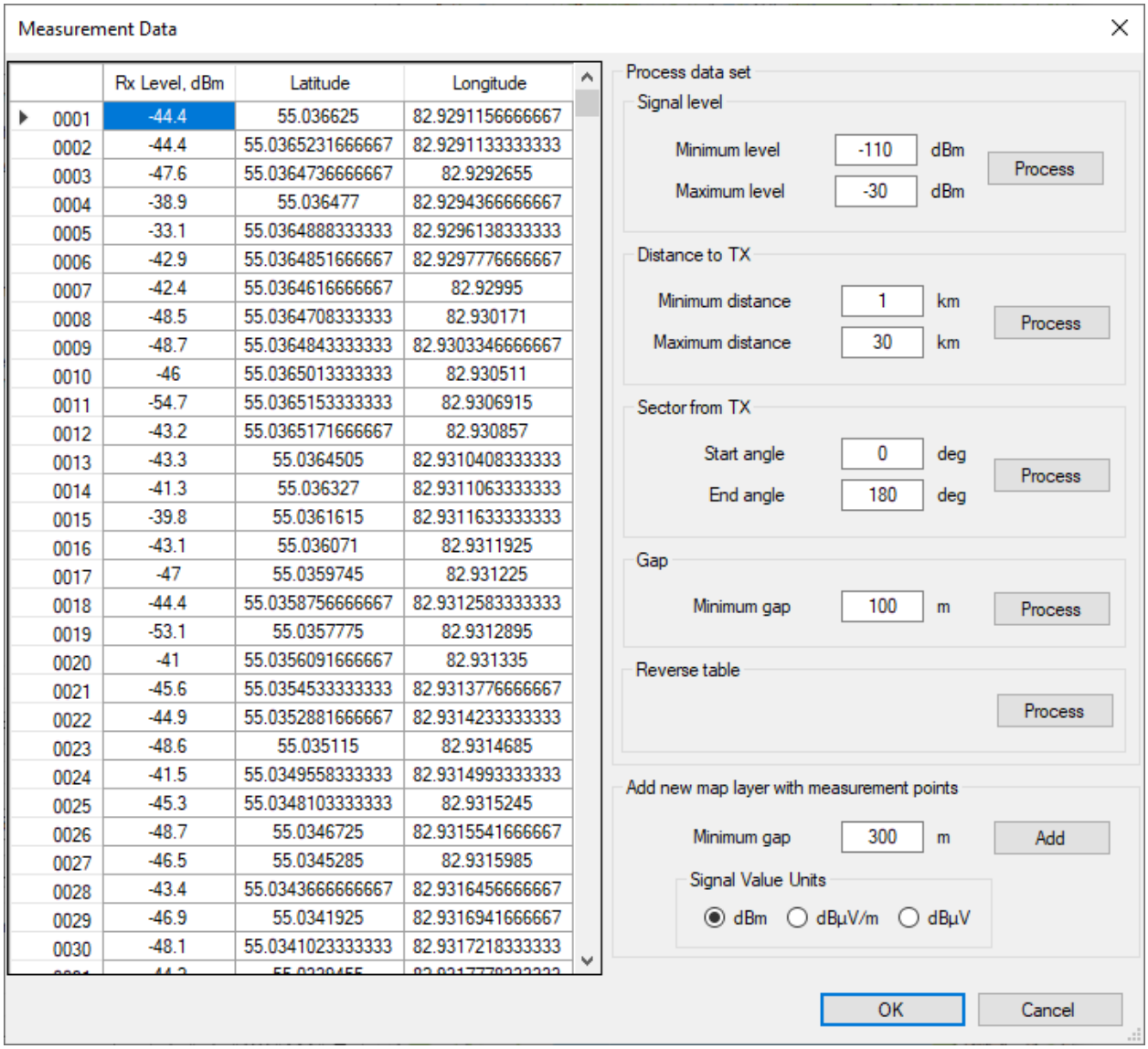


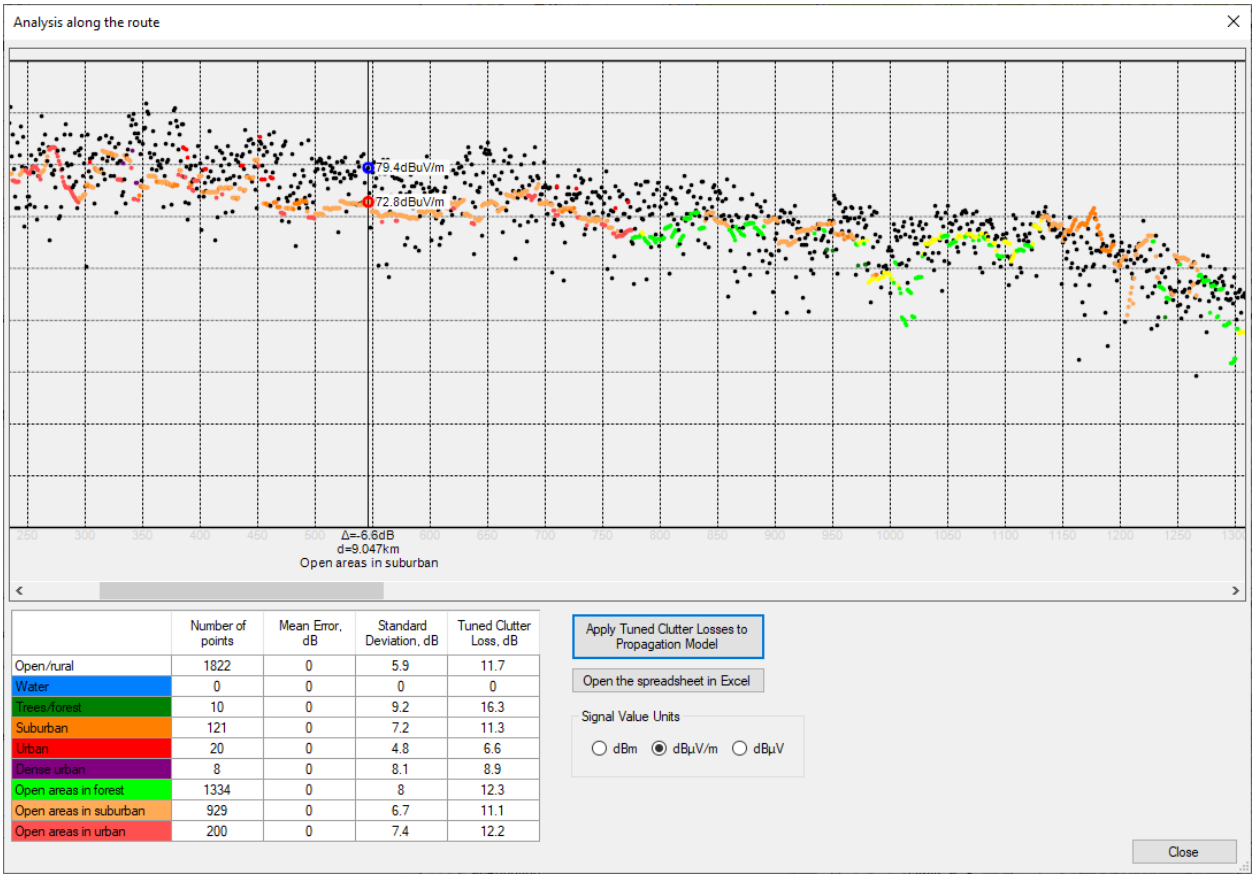
Figure 61. Pre-processing of measurement results

Signal level Minimum/Maximum Level	Limit the points that will be included in the comparison by received power level from the transmitter
Distance to Base Station Minimum/Maximum Distance	Limit the points that will be included in the comparison by distance from the transmitter
Sector from Base Station Minimum/Maximum Angle	Limit the points that will be included in the comparison by azimuth from the transmitter
Gap Minimum Gap	Perform averaging of the power level within a given segment
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 Minimum Gap	Add a custom measurement layer to the map with averaging within the specified minimum distance. The data in the table does not change. The resulting layer will appear among the user layers; the layer name will correspond to the transmitter and antenna direction. You can also select the signal value units to be displayed.

3. Press the button “Analyze measurements along the route”, 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 graph displays the calculated and measured levels, the difference in levels, the distance to the base station in kilometers, and the clutter type.

The table below the graph 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 graph 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.

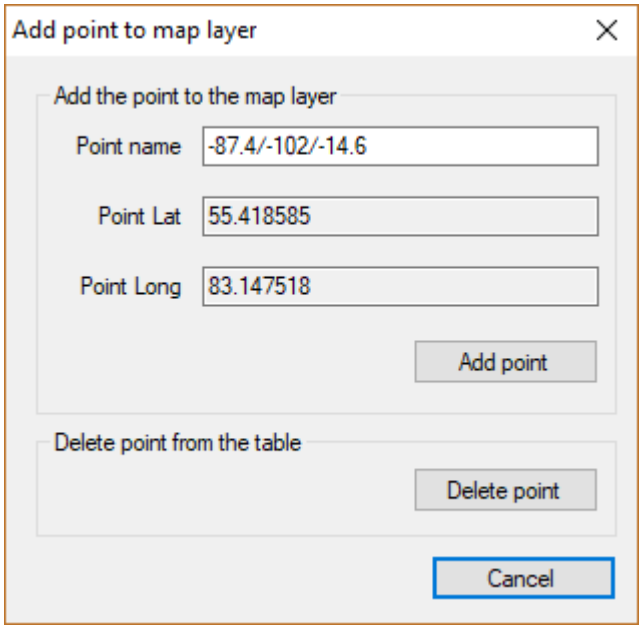
5. Now, based on the analysis of the results obtained for different clutter types and for different sectors, a decision is made regarding the need to tune the values of the previously used clutter losses in the propagation model.



	Number of points	Mean Error, dB	Standard Deviation, dB	Tuned Clutter Loss, dB
Open/rural	1822	0	5.9	11.7
Water	0	0	0	0
Trees/forest	10	0	9.2	16.3
Suburban	121	0	7.2	11.3
Urban	20	0	4.8	6.6
Dense urban	8	0	8.1	8.9
Open areas in forest	1334	0	8	12.3
Open areas in suburban	929	0	6.7	11.1
Open areas in urban	200	0	7.4	12.2

Figure 62. Analysis measurements along the route

When you click on the graph, a context menu appears, in which you can delete a point with the measurement result or add it as a point object to the map:


Add point to map layer
Add the point to the map layer
Point name
-87.4/-102/-14.6
Point Lat
55.418585
Point Long
83.147518
Add point
Delete point from the table
Delete point
Cancel

Air-to-Ground Communication

RadioPlanner 2.1 calculates coverage areas for ground-to-air and radio navigation aeronautical systems operating in the VHF, UHF, and microwave frequency bands.

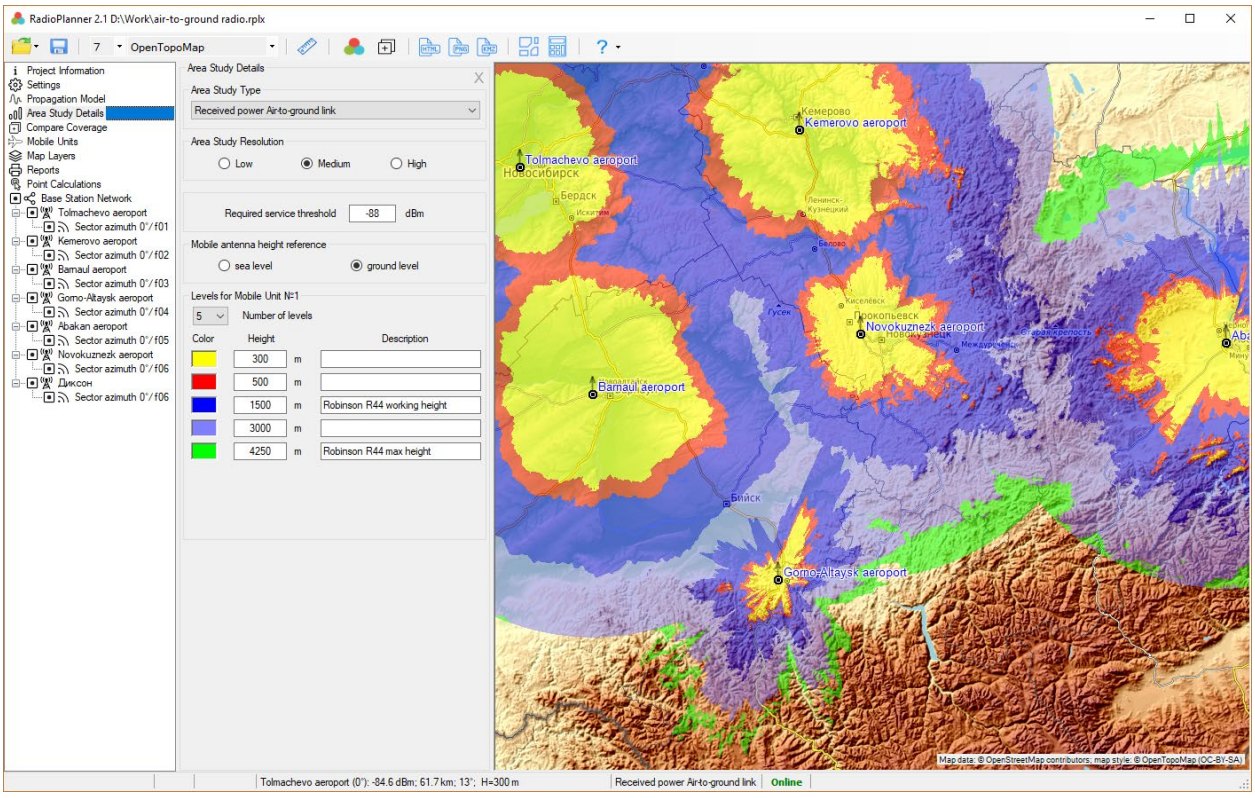


Figure 63. Air-to-Ground Communication coverage

Before starting work, you should select the project type "Air-to-Ground Communication" in the Settings menu (see the Settings section).

The set of parameters for the base station of the mobile aeronautical service is completely similar to that of the mobile communication network (See Section Mobile Networks - Base Stations).

The set of equipment parameters for the mobile aeronautical service station is similar to the set of parameters for the mobile communication network (See Section Mobile Networks - Mobile Stations), except for the antenna height, which is not specified here (the height of the mobile station for the mobile aeronautical service is used as a parameter in the menu "Area study details"). In addition, in the Air-to-Ground Communication projects, parameters are specified for only one type of subscriber station.

Propagation Model for Air-to-Ground Communication

The propagation model is a hybrid model based upon 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 applicable 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 digital elevation model SRTM
- Variation of the received radio signal due to multipath fading

In the used hybrid model, rain fading is not taken into account; therefore, the frequency range of its applicability is limited to 7000 MHz (100 MHz-7000 MHz).

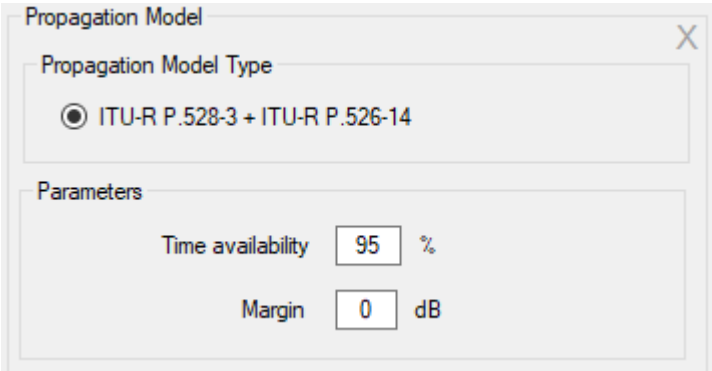


Figure 64. Propagation model for Air-to-Ground Communication

Time Availability, %	Percentage of time (usually 95%). 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
- Strongest (most likely) Server Air-to-Ground link

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

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

After the calculation is completed, the level of received power at the current point for different heights will also be displayed in the status bar.

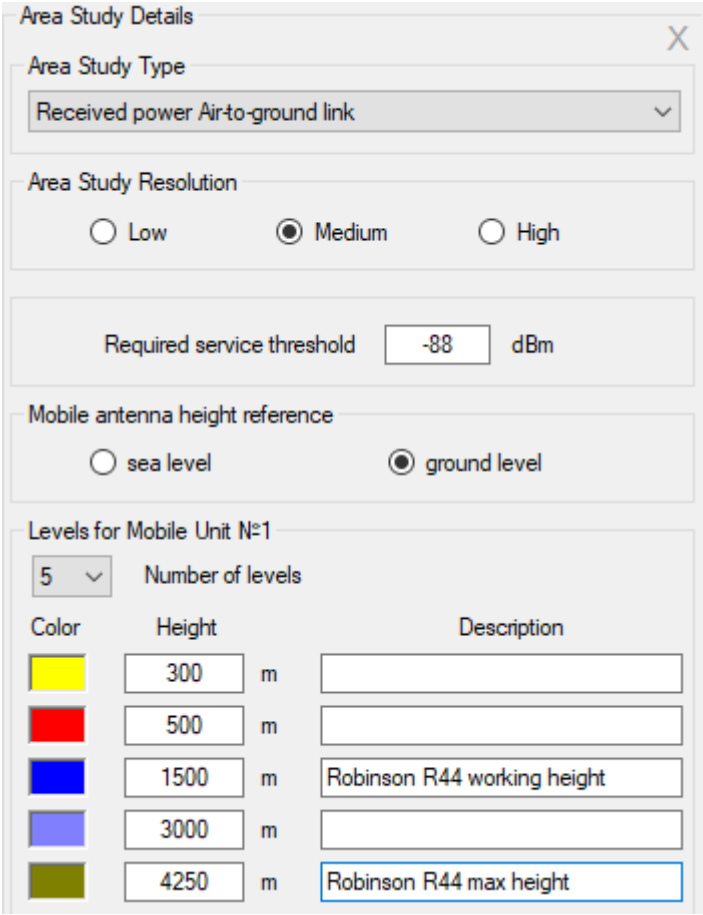


Figure 65. Received power Air-to-ground link

Area Study Resolution	- Low - Medium - High It's the resolution of the result of the calculation. The resolution corresponds to one pixel of the screen for zoom = 7 (low detail), zoom = 8 (medium), and zoom = 9 (high). For a geographic latitude of 55 degrees, this is approximately 720, 360, and 180 meters, respectively. The higher the resolution, the longer the calculation time.
Required Service Threshold	The minimum threshold level of the received signal, dBm
Mobile Antenna Height Reference	- Sea level - Ground level
Number of Levels	Number of altitude levels
Color	Color level
Height	The value of the level height of the mobile station for which the coverage area is displayed, m
Description	Text field

Strongest (Most Likely) Server Air-to-Ground Link

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

Sector colors can be assigned automatically or by the table of frequency groups.

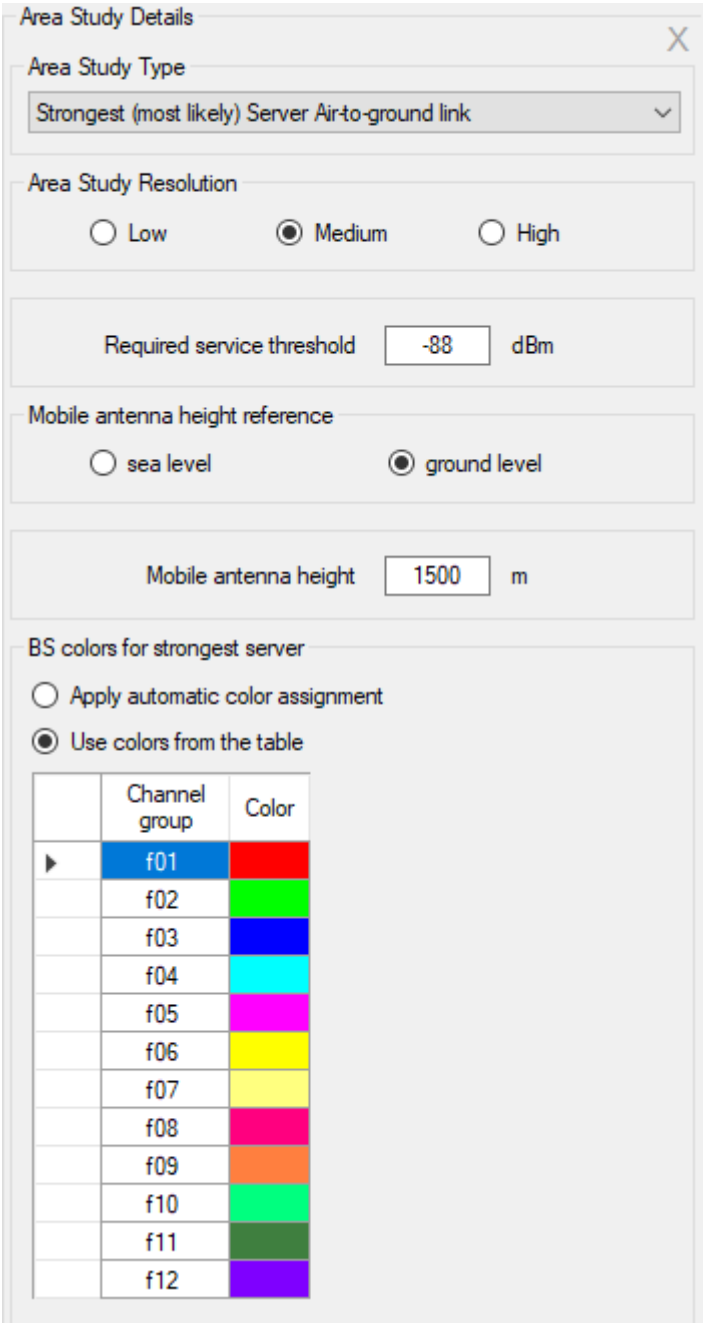


Figure 66. Strongest Server menu

Area Study Resolution	- Low - Medium - High

	It's the resolution of the result of the calculation. The resolution corresponds to one pixel of the screen for zoom = 7 (low detail), zoom = 8 (medium), and zoom = 9 (high). For a geographic latitude of 55 degrees, this is approximately 720, 360, and 180 meters, respectively. The higher the resolution, the longer the calculation time.
Required Service Threshold	The minimum threshold level of the received signal to calculate Strongest (Most likely) Server, dBm
Mobile Antenna Height Reference	- Sea level - Ground level
Apply automatic color assignment	Assigning colors to BS sectors is performed automatically in random order.
Use Colors from the Table	Assigning colors to BS sectors is done from the table according to color frequency groups.

Point Calculations for Air-to-Ground Communication

This menu displays the terrain profile from the selected base station to any point at the height of the mobile station. The current point on the map can be changed with a mouse click. The profile is a vertical section of the terrain between the base station and the mobile station with information about elevations.

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

The height of the mobile station 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 the *Area Study Details - Received Power Air-to-Ground link.*

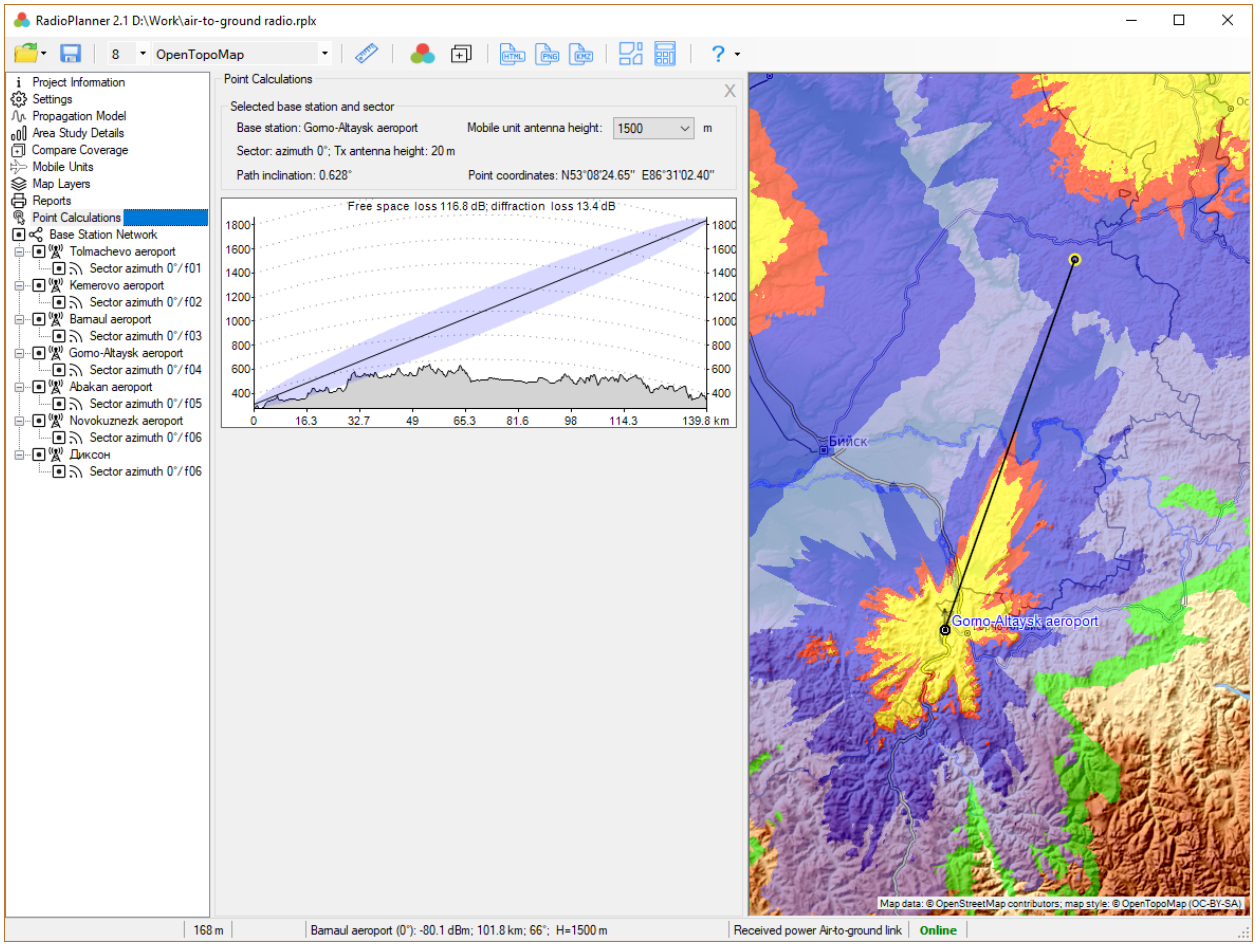


Figure 67. Point calculations for Air-to-Ground Communication

Some features of calculating coverage areas for aeronautical radio communications are given in Appendix 1.

Clutter Editor

RadioPlanner allows you to create custom clutters using the built-in Clutter Editor. The custom clutter model is formed by replacing the user-corrected areas in the default clutter model. A base map with actual satellite images is used as a data source for the custom clutter.

To start Clutter Editor, click the button on the main program panel.

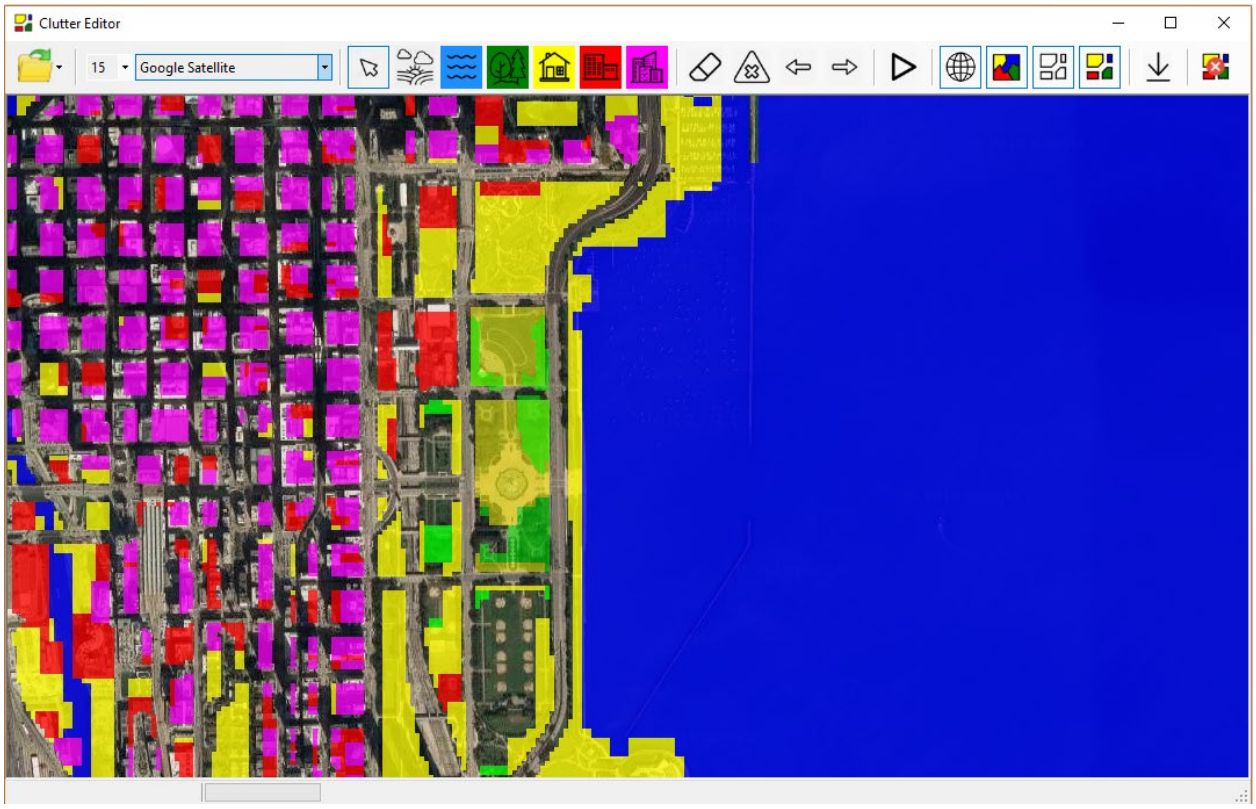


Figure 68. Clutter Editor

Menu commands are designed as a toolbar. When you hover over each of the icons, a hint appears.

- Standard tools for working with files of clutter polygons *.plg **Create, Open, Save**

- Base map zoom

- Base map

- Exit from polygon drawing mode

- Draw Open/Rural polygon

- Draw Water polygon

- Draw Trees/Forest polygon

- Draw Suburban polygon

- Draw Urban polygon

- Draw Dense Urban polygon

- Delete polygon. To delete a polygon, select this tool and then click with the mouse on the polygon (polygons) to be deleted.

- Delete all polygons; removes all user-drawn polygons. This action can be undone using the Undo button.

- Undo

- Redo

- Convert Polygons to a Custom Clutter

- Show Base map

- Show Default Clutter

- Show Custom Clutter Polygons

- Show Custom Clutter

- Download Default Clutter within the screen area

- Delete Custom Clutter within the screen area

The current map zoom can be changed by scrolling the mouse wheel. The display of the default and custom clutter on the map starts with a Zoom of at least 11. Navigation on the map is performed using the left mouse button while pressing the button. In polygon drawing mode, the map can be moved by clicking on the mouse wheel.

The procedure for preparing a custom clutter consists of two stages:

1. Drawing polygons for various clutter categories on the base map

In order to draw a clutter polygon of the desired category, click on the corresponding toolbar icon; the mouse pointer will change at the crosshairs. Click all vertices of the polygon with the mouse; to finish drawing the polygon, click on the right mouse button. Then you can proceed to draw the next polygon of the selected category. To change the clutter category - click on the desired icon on the toolbar. Using the toolbar, you can delete individual polygons or all polygons at once, as well as cancel or return up to ten actions in the editor.

When drawing polygons, their hierarchy should be taken into account, which is enhanced by looking at the category icons in the toolbar from left to right. For example, inside the Open/Rural polygon, you can draw any of the polygons and inside the Trees/Forest polygon, you can draw Urban polygons, etc. It is convenient to start the adjustment of the default clutter by drawing Open/Rural polygons, inside which others polygons are then drawn.

Polygons can be saved in a file with *.plg extension.

2. Conversion of polygons to the Custom Clutter

To convert drawn polygons into a Custom Clutter, click the button on the toolbar, after which the program converts polygons into a Custom Clutter matrix. Elements of the Custom Clutter matrix are stored in the cache along with the Default Clutter matrix.

You can choose a clutter model, Default or Custom, which will be taken into account in the calculations and displayed as a layer on the map, which is carried out in the "Propagation model" menu in RadioPlanner.

Using the corresponding buttons of the Clutter Editor toolbar, you can turn on/off the showing of the base map, drawn polygons, as well as the Default and Custom clutters.

When adjusting the clutter model, it should be noted that the ITU-R P.1812-4 propagation model used in the program assumes that the clutter model is detailed with a resolution of tens of meters. Accordingly, it makes no sense to outline the individual buildings and trees; it is enough to draw building blocks and forests.

Appendix 1. File formats

1.1 Cable attenuation file

A text file **feeders.txt** with information about frequency-dependent attenuation in cables is included in the folder where RadioPlanner is installed. The user can add information about the required cables to this file.

The feeders.txt file has a 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.

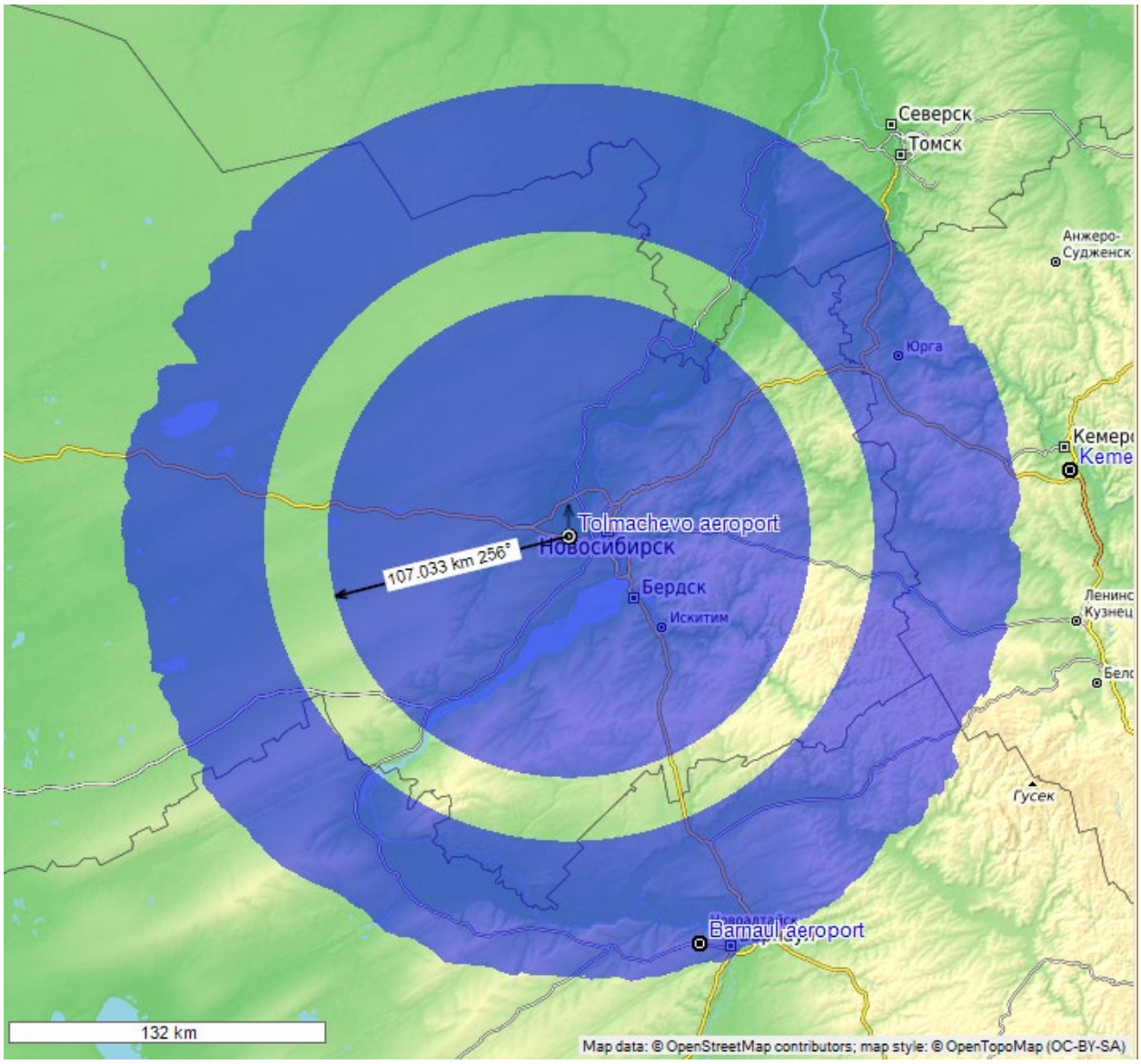
30 – frequency in MHz.

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

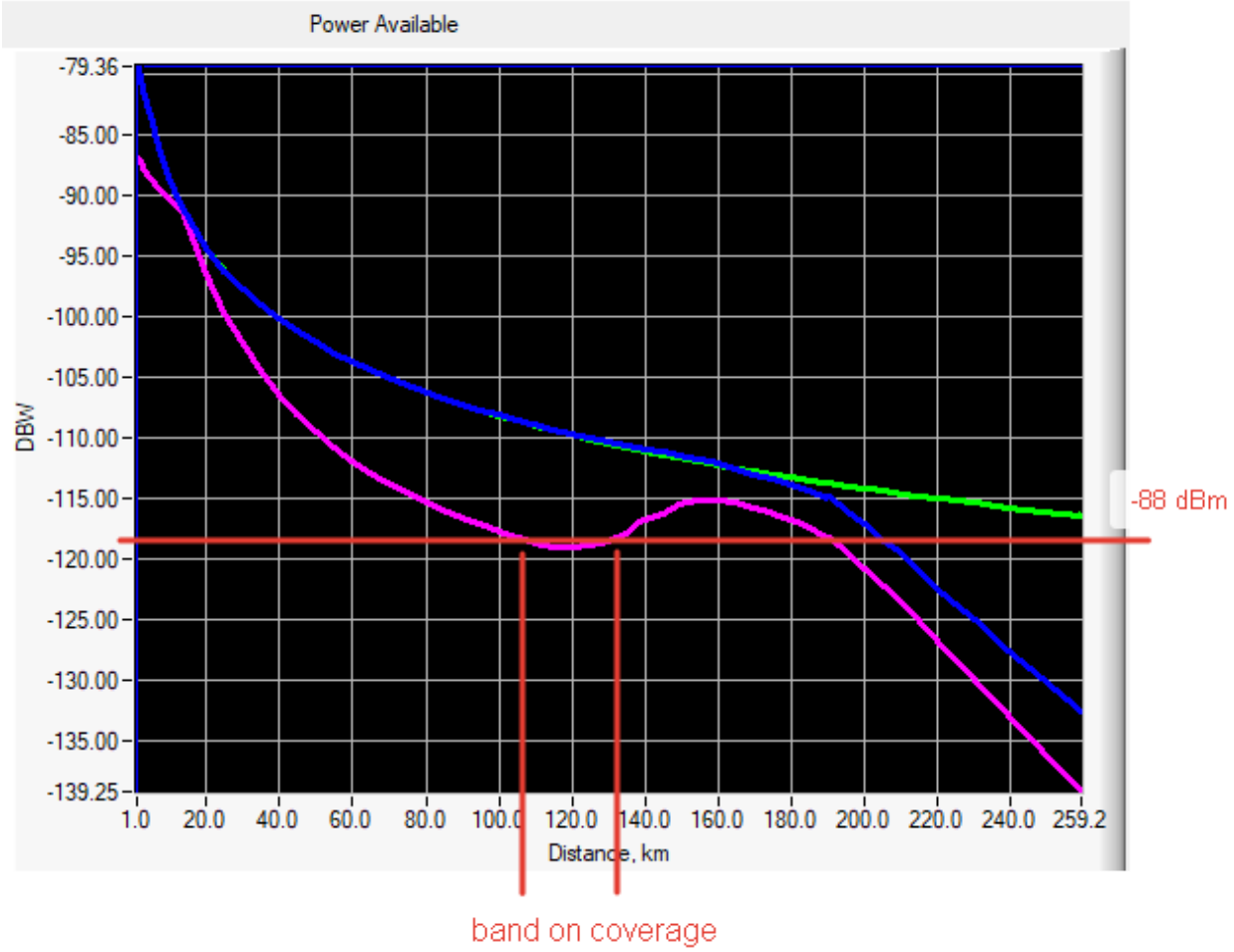
The number of frequency/attenuation pairs for each line need not be the same. TAB should be a separator between frequency and attenuation.

Appendix 2. Some Features of Coverage Calculating for Air-to-Ground Radio

For a certain combination of data (heights of the base and mobile stations, 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 BS).

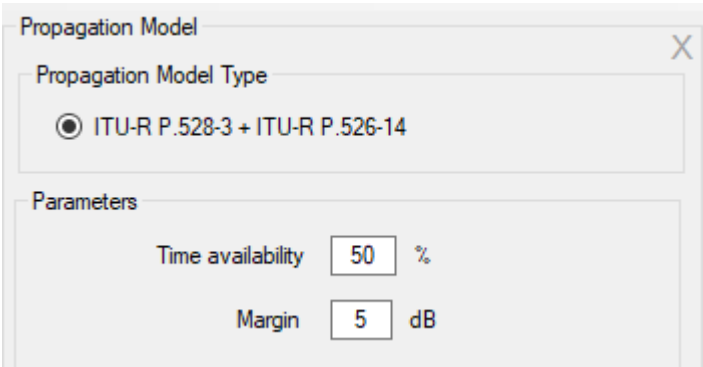


This means that in this zone, the mobile station (aircraft) will be in the area of the strong influence of multipath due to reflection from the Earth's surface and time availability will decrease. Model ITU-R P.528-3 (02/2012), which is based on the IF-77 Electromagnetic Wave Propagation Model by M.E. 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 the received power and the corresponding band in the coverage area.

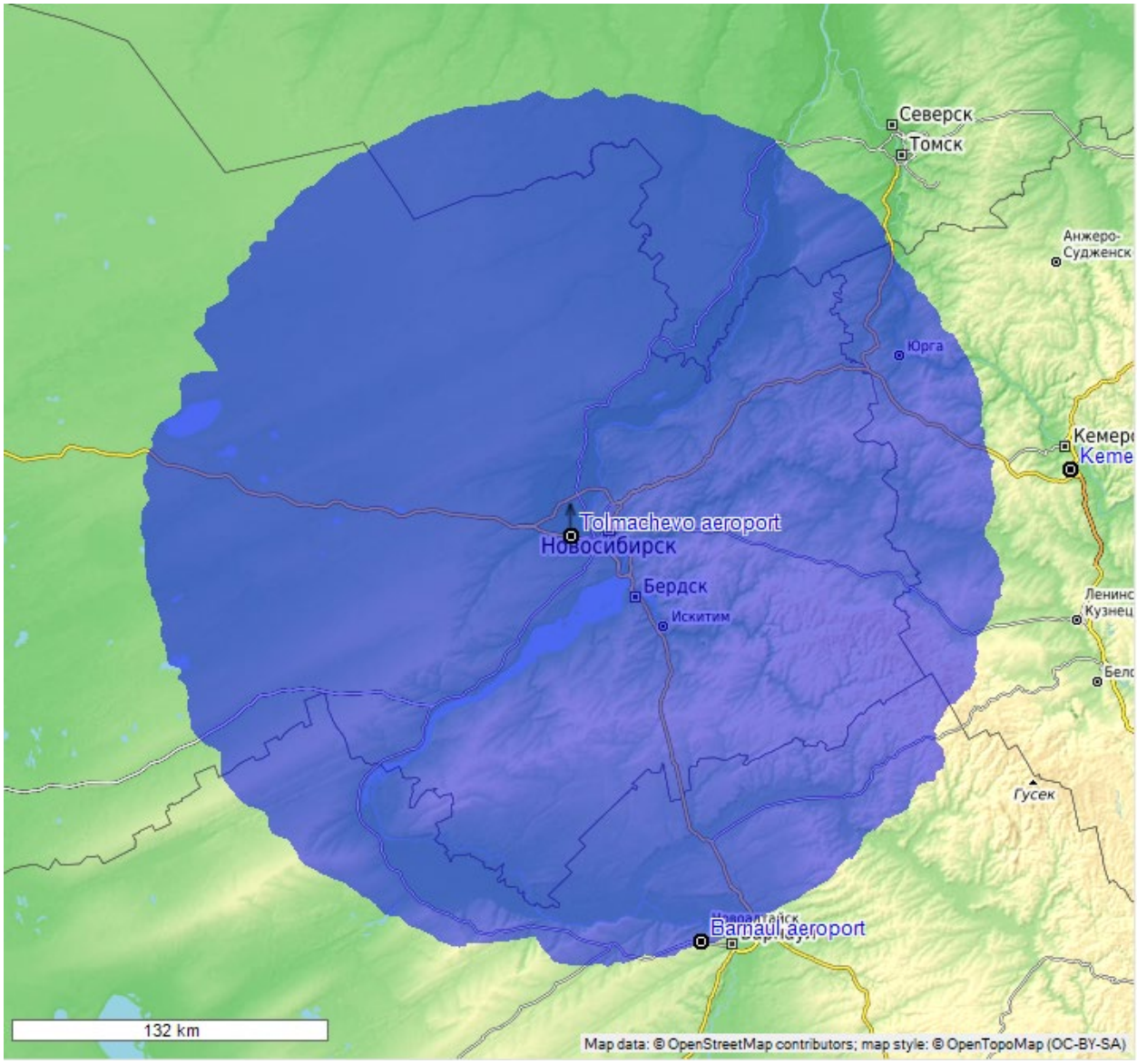


In fact, the appearance of such a band in the coverage area does not mean a significant, within 5-7 percent reduction, in time availability in this area. In practice, such a decrease in time availability in a small area within the coverage area can be considered acceptable.

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 the 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
Tolmachevo aeroport
Новосибирск
Бердск
Искитим
Гусек
Barnaul aeroport
132 km
Map data: © OpenStreetMap contributors; map style: © OpenTopoMap (OC-BY-SA)

Appendix 3. Terrain Elevation Data

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)
- Denmark (DTM 1.6 meters)
- Estonia (DTM 10 meters)
- Finland (DTM 10 meters)
- France (DTM 5-10 meters)
- Germany (DTM 2-25 meters)
- Iceland (DTM 10 meters)
- Italy (DTM 2-10 meters)
- Latvia (DTM 20 meters)
- Liechtenstein (DTM 10 meters)
- Luxembourg (DTM 5 meters)
- Netherlands (DTM 5 meters)
- Norway (DTM 10 meters)
- Slovakia (DTM 10 meters)
- 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, Czechia, Greece, Hungary, Kosovo, Lithuania, Malta, Montenegro, North Macedonia, Poland, Portugal, Romania, 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 4. Project Samples for Various Wireless Networks and Broadcasting Networks

There are several project samples for various wireless and broadcast networks in the software package.

These projects are entirely ready for calculation, and you just need to open the project and click on the "Calculate coverage" button.