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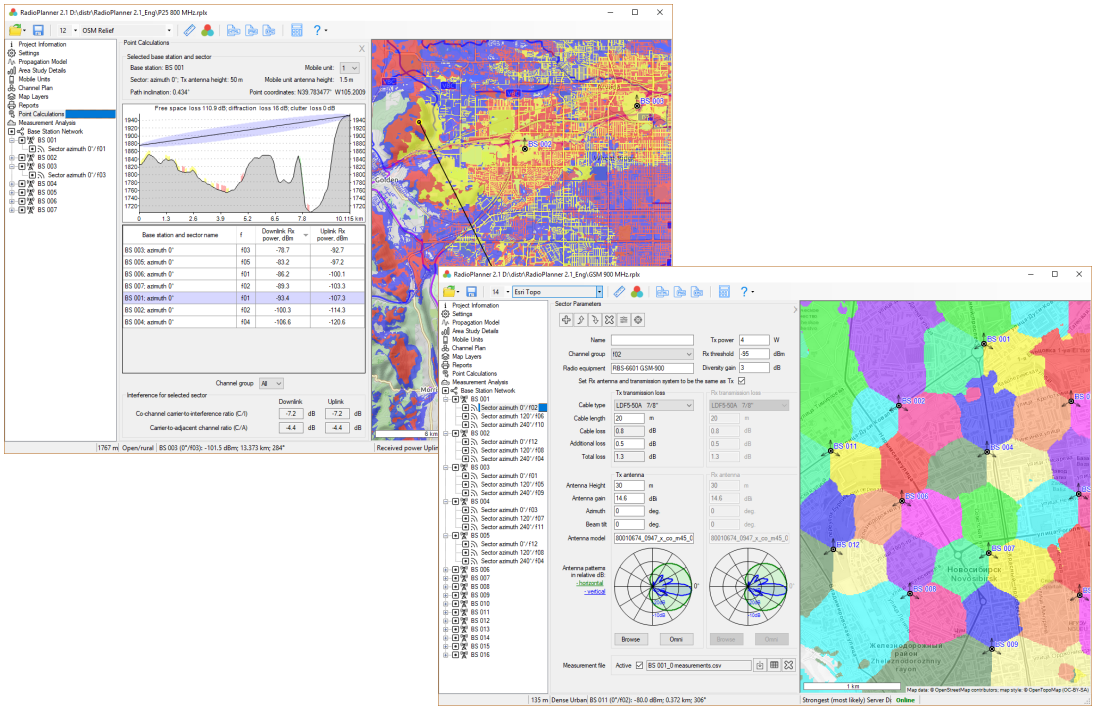
RadioPlanner 2.1

Mobile and Broadcast Networks Planning

User Manual



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From the Developers

We made every effort to create a user-friendly and intuitive application. However, we recommend 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 mobile networks

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

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

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

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

RadioPlanner 2.1 uses the following propagation models:

- ITU-R P.1812-4 model (for mobile and broadcasting)
- Longley-Rice (ITM) model v 1.2.2 (for broadcasting only, for mobile coming soon)
- 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;
- 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;
- Import the measurement results of the received signal power levels for comparison with calculated values and adjust propagation model parameters;
- Save the result of the coverage calculation as an interactive web page, as a raster image or KMZ file;
- Flexibly adjust the layers on the base map, show custom vector layers.

GIS features

- SRTM-3 dataset is used as a digital terrain model. Data sources: USGS EarthExplorer site https://earthexplorer.usgs.gov;
- Landcover model with the different types of clutter (dense urban, urban, suburban, open land, water, and trees/forest). The landcover model was created based on OpenStreetMap (www.openstreetmap.org) и Global Forest Change (www.earthenginepartners.appspot.com) projects; Built-in RadioPlanner a simple and easy to use Clutter Editor will allow the user to prepare their own clutter model based on new satellite imagery.
- Any kinds of basemaps—both common (such as OpenStreetMap, OpenTopoMap, etc.) and custom ones.

Installation, Activation, and Registration

RadioPlanner supports Windows 7/8/8.1/10.

The minimum computer configuration is 32-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, 8GB RAM, 256GB SSD, video card and monitor with support for 1920x1080.

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 and 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 two different types of project:

- 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.

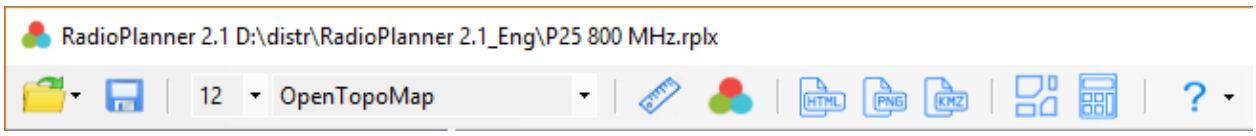
This manual is divided into four parts - first, a description of the work with those program functions that are independent of the type of project, then a description of work with Mobile communications projects, then with TV and radio broadcasting projects, and finally with air-to-ground communications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

After the 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 basemaps or customize your basemap, as described in the Basemap Settings section.

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

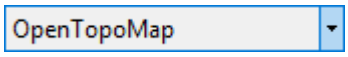
Toolbar and Main Menu



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;

 - Save the coverage as a web page;

 - Save radio coverage as an image in *.png format;

 - Save radio coverage in *.kmz format;

 - 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.

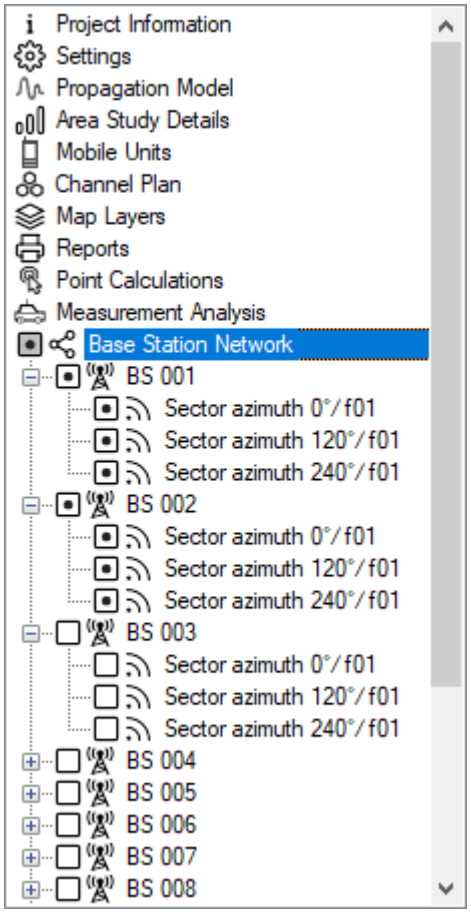


Figure 1. Tree View interface

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 the information about the project.

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

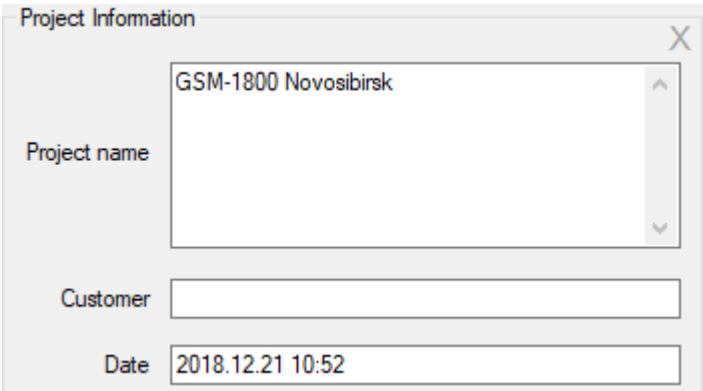


Figure 2. Project Information

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.

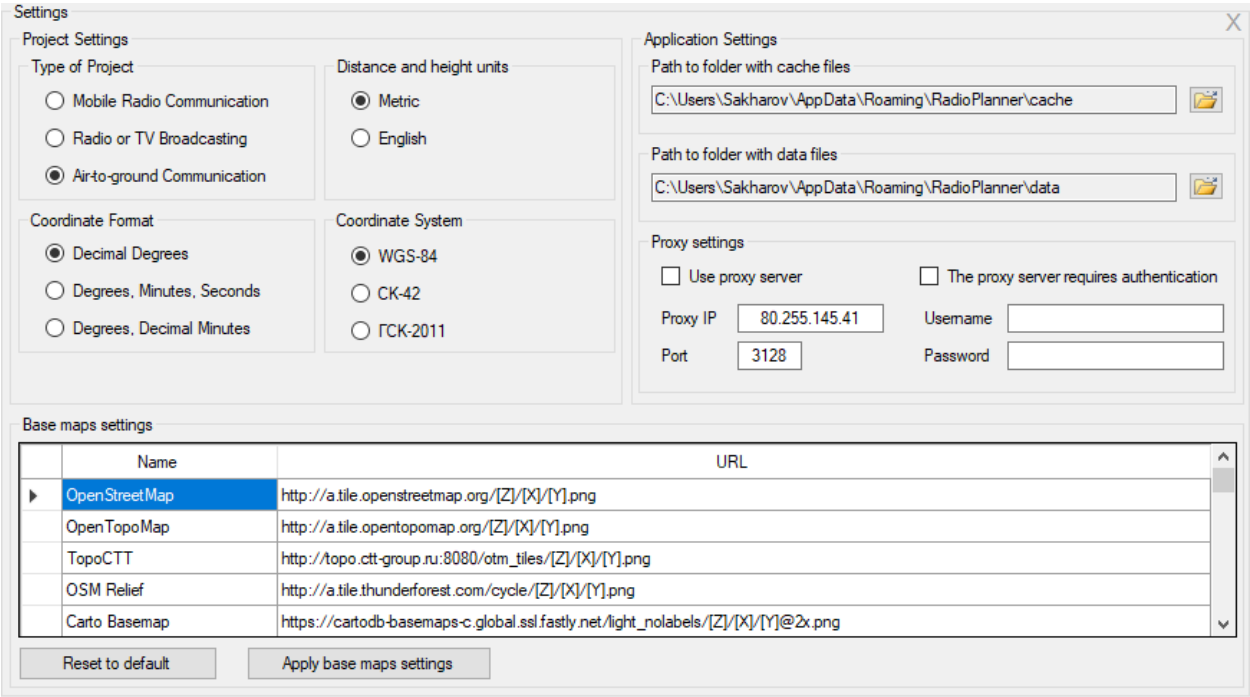


Figure 3. Settings

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 basemap 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

Basemap Settings

You can configure your own custom basemap 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) is 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 in MLinkPlanner):

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 Servers 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

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 correspond to the order on the map (the base map is below all the layers, sites are on top of all the layers).

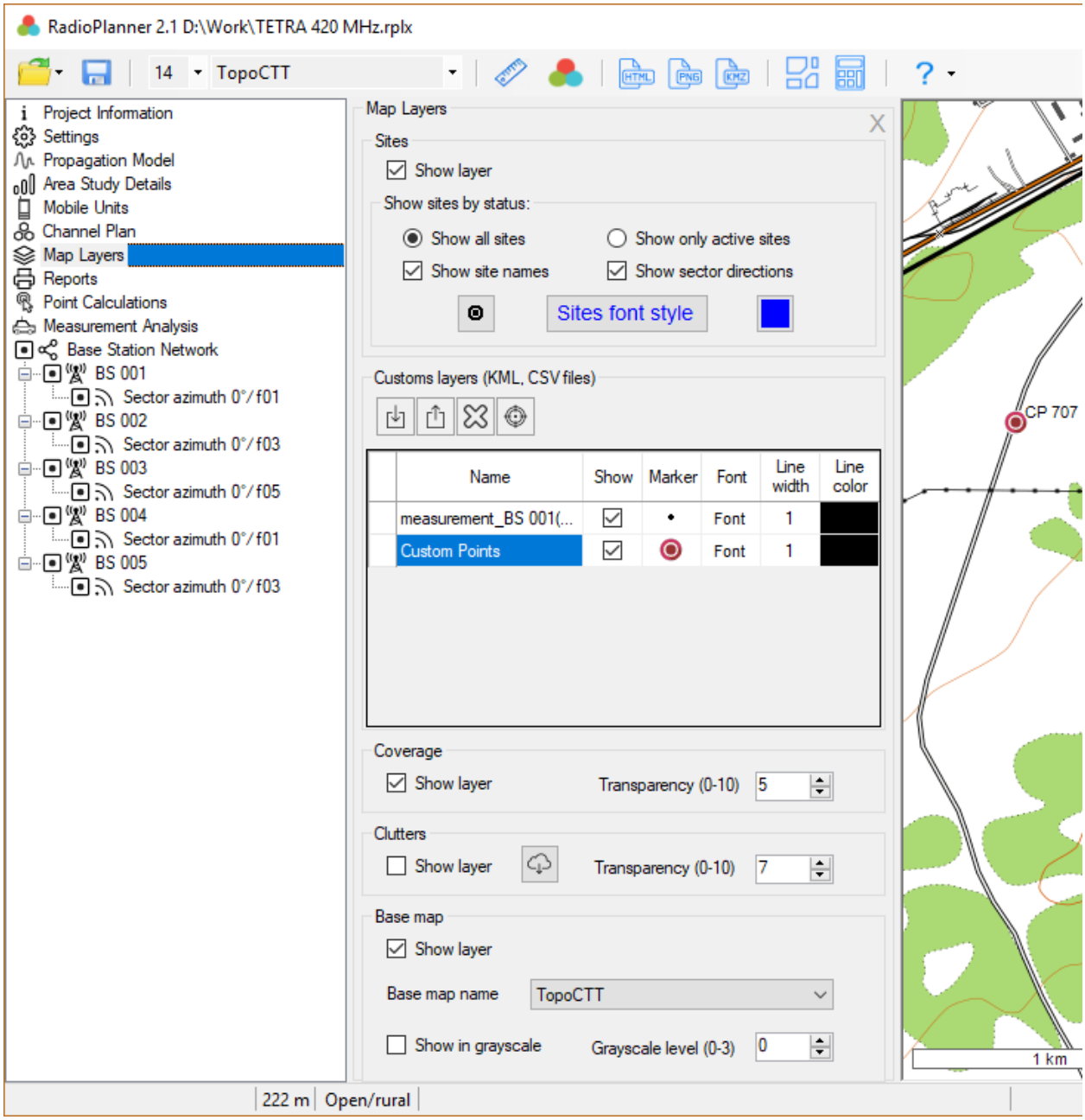


Figure 4. Map Layers

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
Sites marker	Choose marker for sites
Sites 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, Longitude. Formats 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.

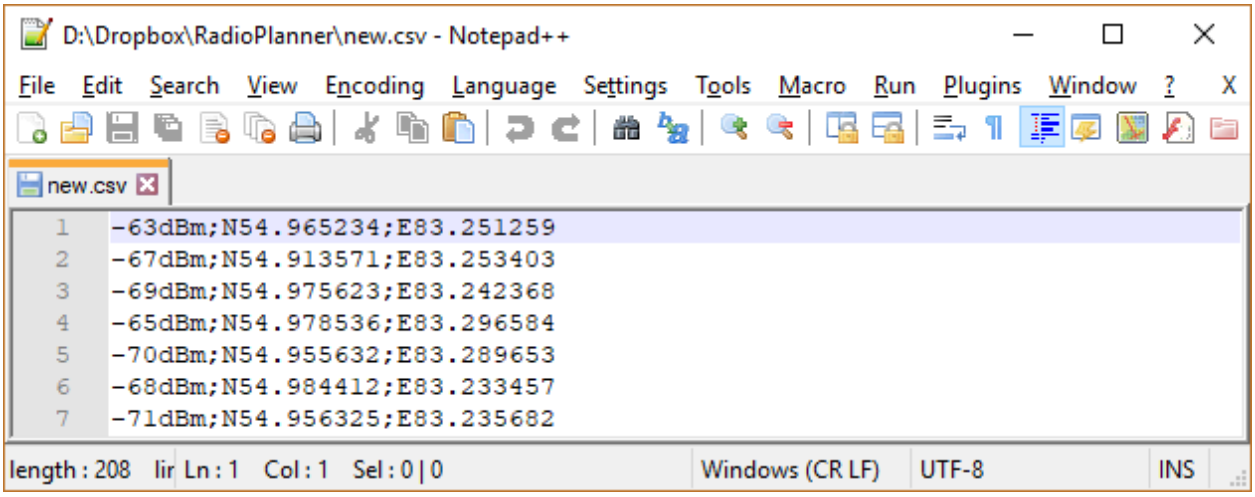


Figure 5. Sample CSV file with measurement results

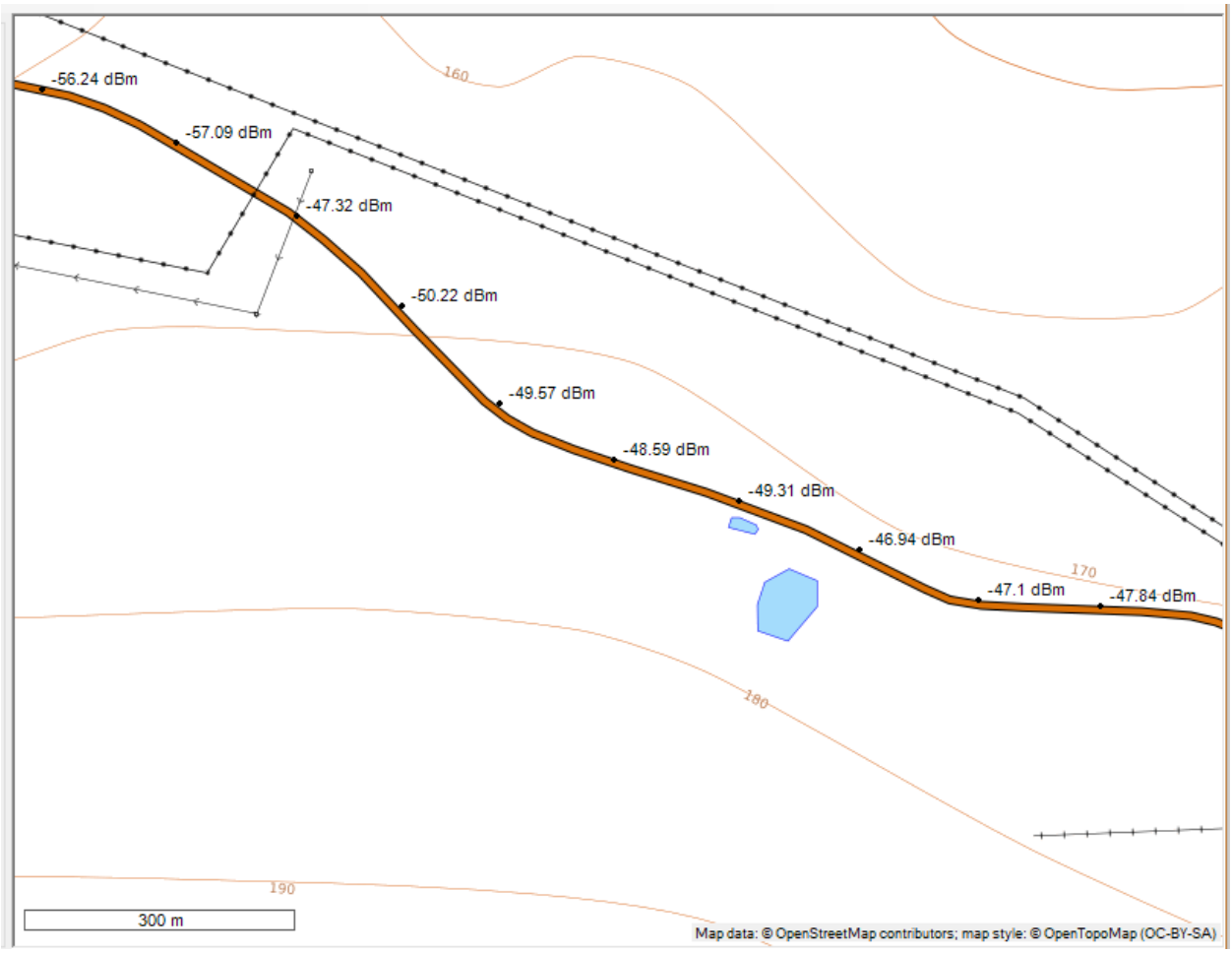
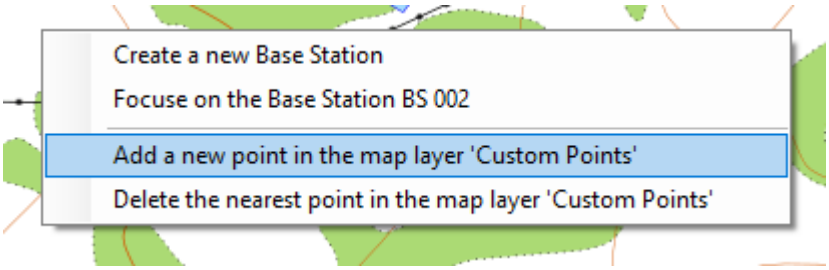


Figure 6. An example of the display of measurement results on the map

The user also can quickly create point objects on the map. To do this, right-click on the point location, 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.



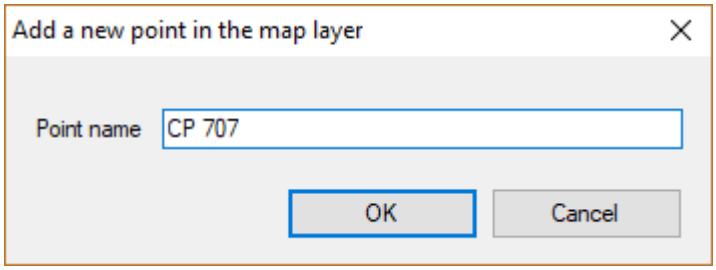


Figure 7. Adding a point feature to a map

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 calculation of the radio coverage.

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

Clutter

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

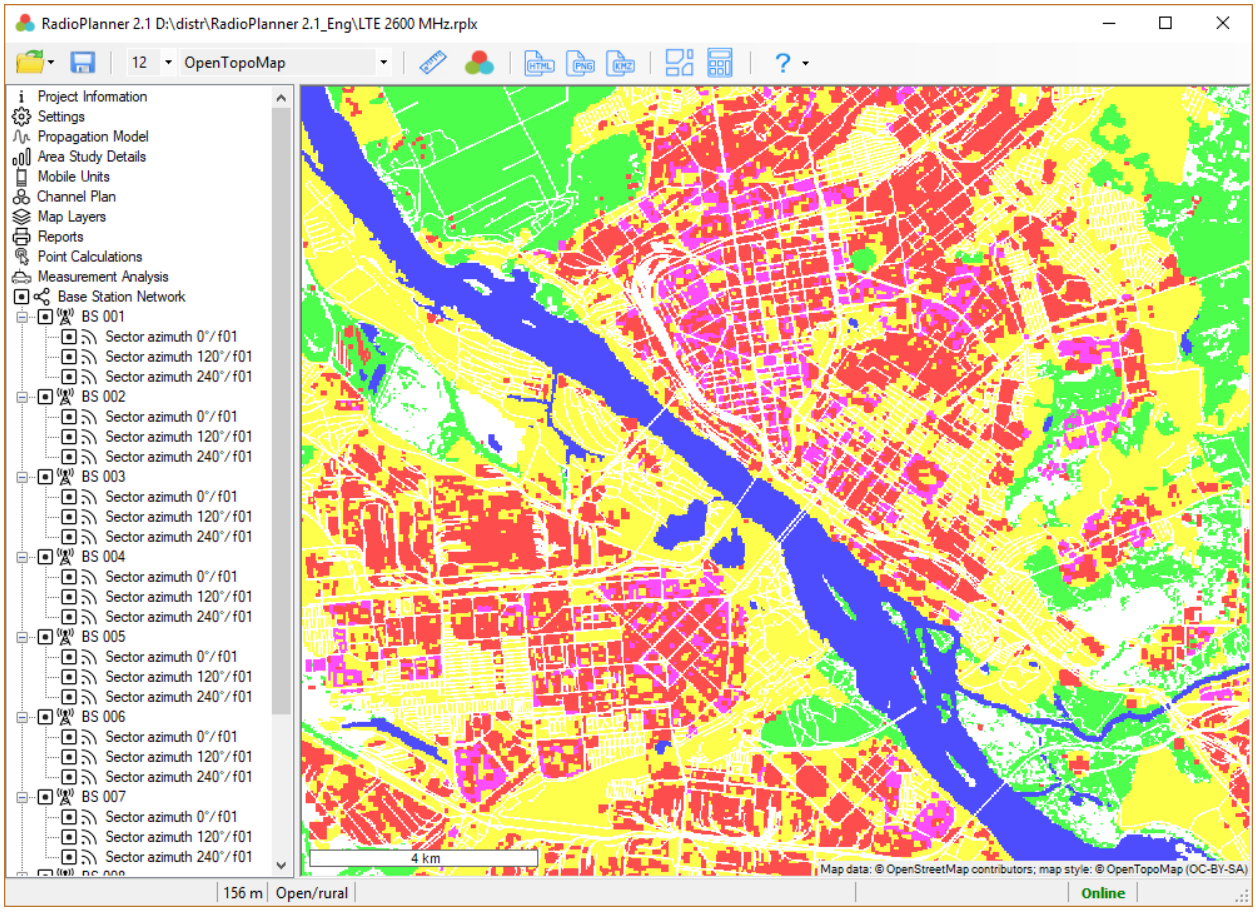


Figure 8. Clutter map example

Colors that show clutter:

No color	Open land
	Water
	Trees/Forest
	Suburban
	Urban
	Dense 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)

Basemap

Basemap layer control.

Show layer	Show/hide the layer

Base map name	Choose a basemap from a set of maps. Basemap names and addresses of tile servers are specified in the Settings menu.
Show in grayscale	Show basemap in grayscale
Grayscale level	Brightness from the range 0 (darker) - 3 (lighter)

Saving the Result of Coverage Calculation

The result of the calculation of any type of radio coverage can be saved as an interactive web page, an image file, or KMZ file.

Save the coverage as a webpage - save the result of the calculation as an interactive webpage. The application offers 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 4 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 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 not only with this script - for example, it can be connected to any GIS that supports working with tiles, which will allow you to demonstrate the result of the calculation of radio coverage as a layer on any GIS (QGIS, MapInfo, ArcGIS, SAS.Planet and others).

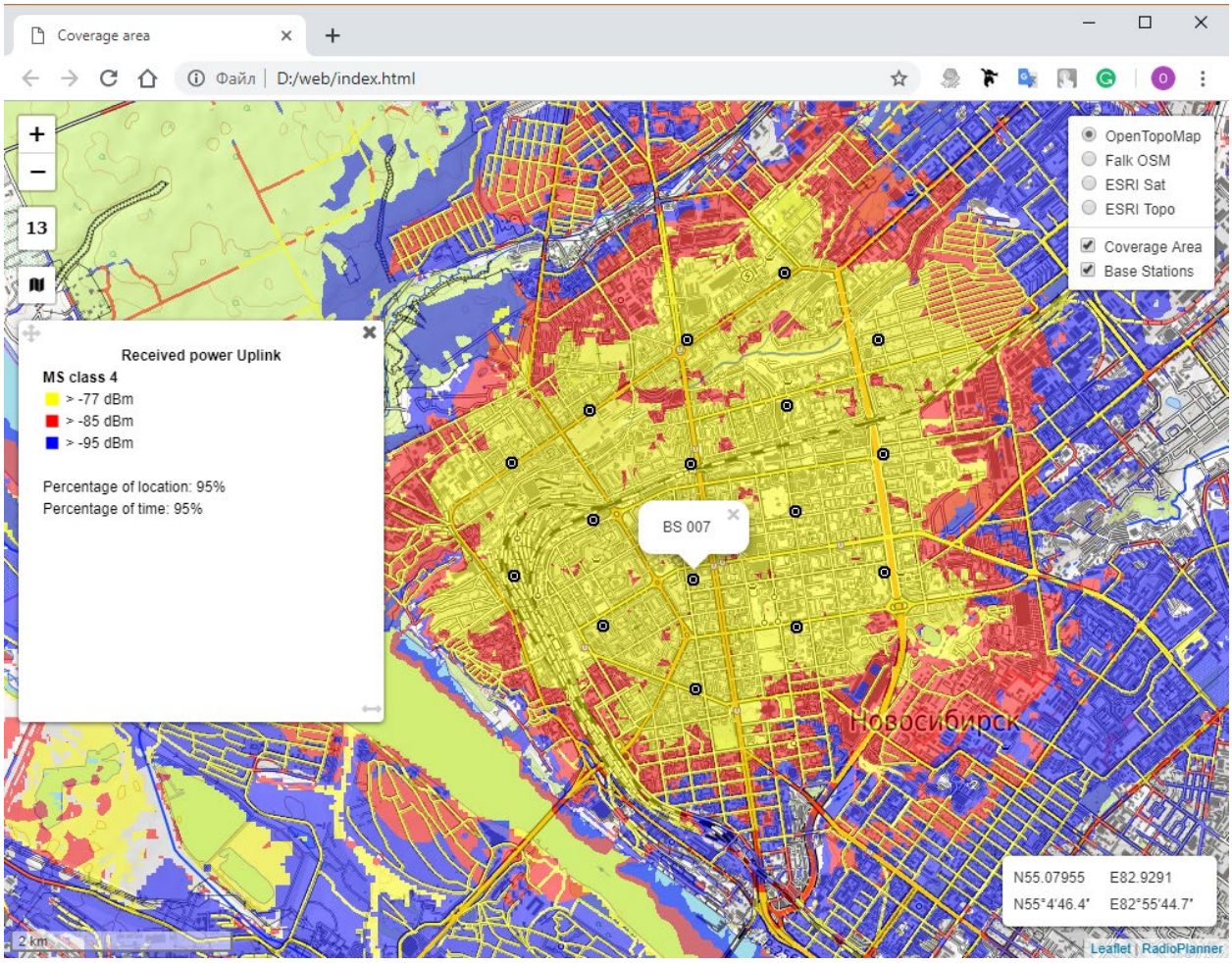


Figure 9. Example of the interactive web page

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 to the current or be 2 or 4 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.

A scale bar appears in the lower-left corner of the saved image.

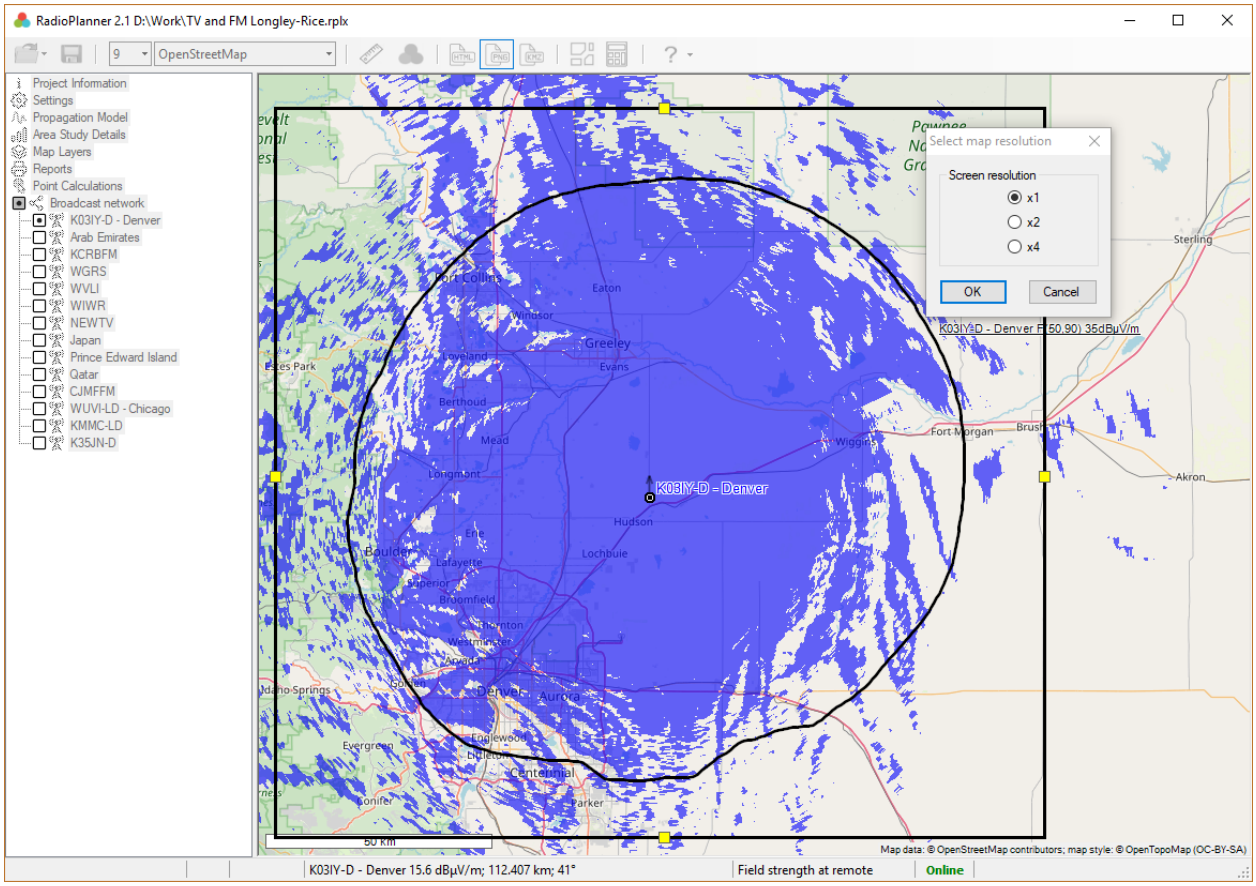


Figure 10. Selecting the area and resolution of the saved image

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

Reports

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

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

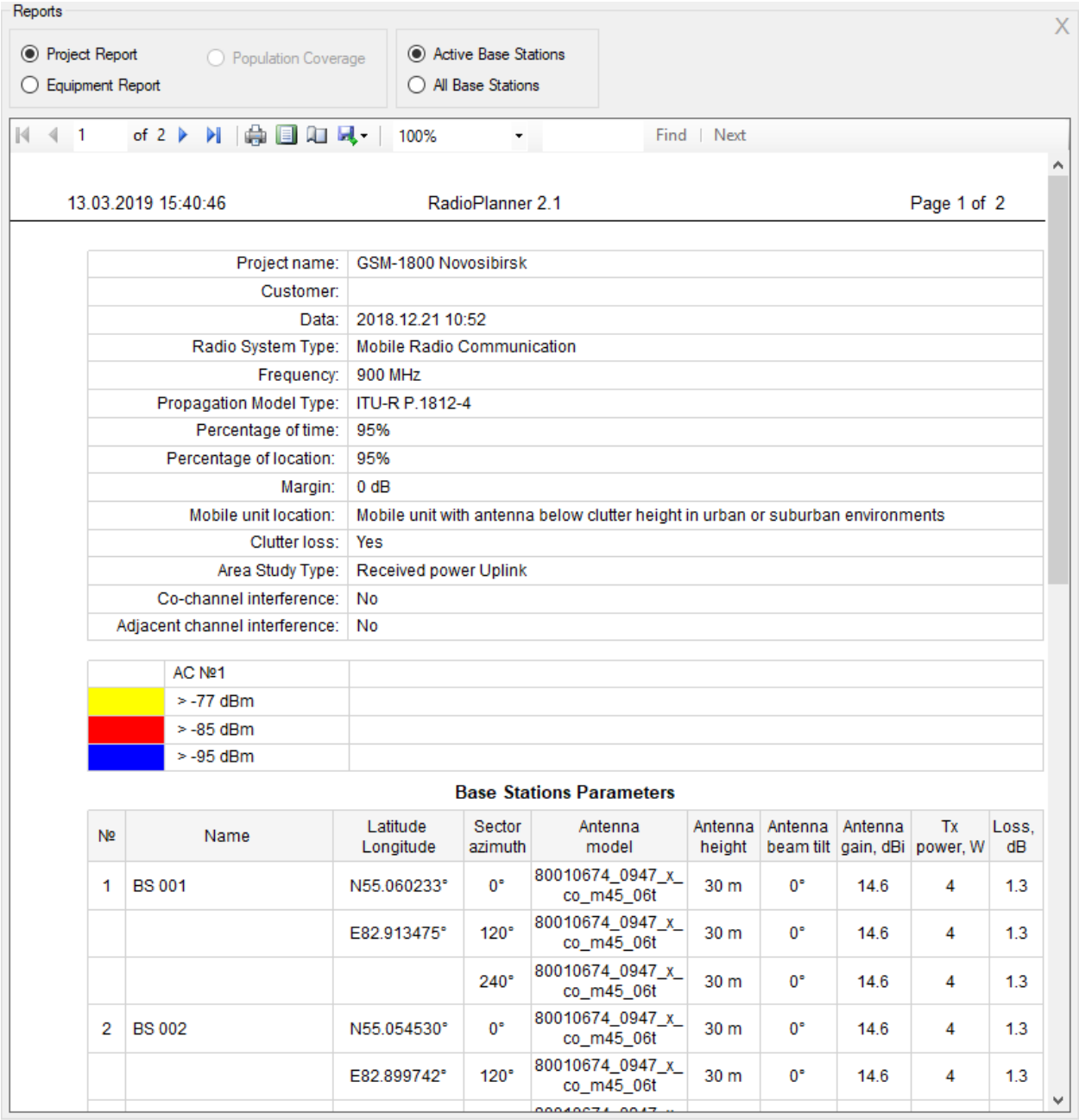


Figure 11. Text report example

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 and 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 Figure 12.

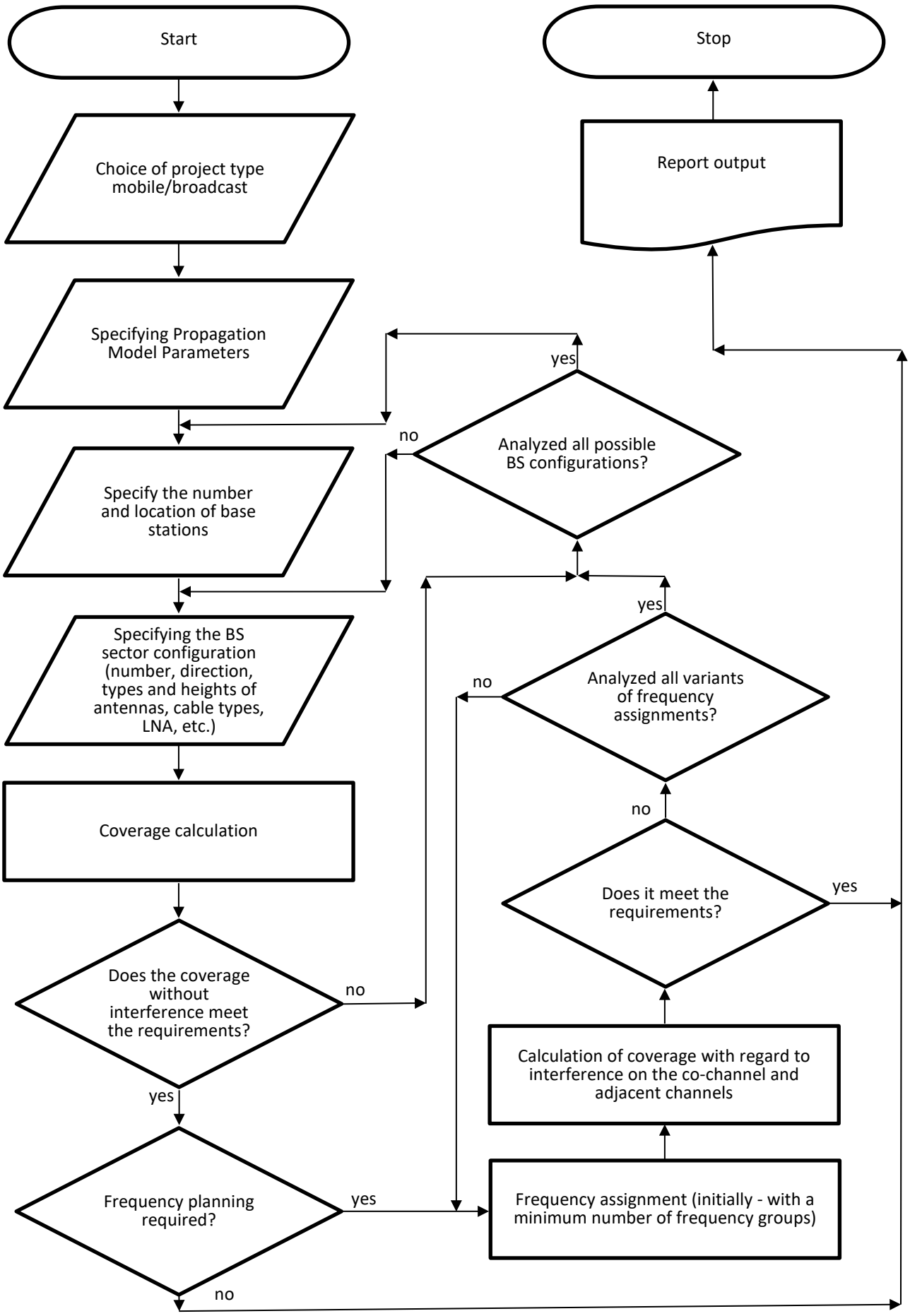


Figure 12. General algorithm for working with RadioPlanner

Mobile Units

The mobile units' characteristics in the Mobile Units menu.

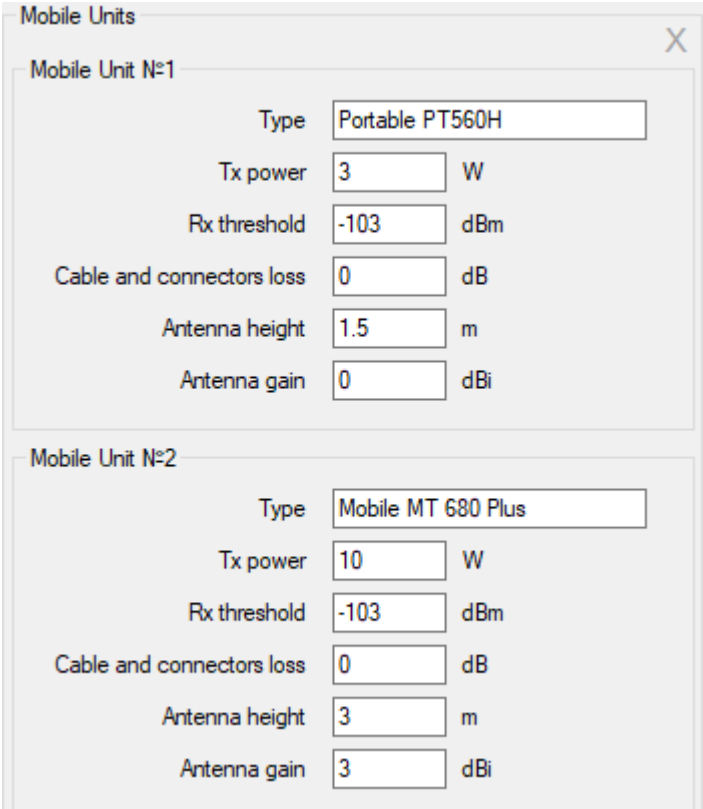


Figure 13. Mobile Units

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 connectors 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.

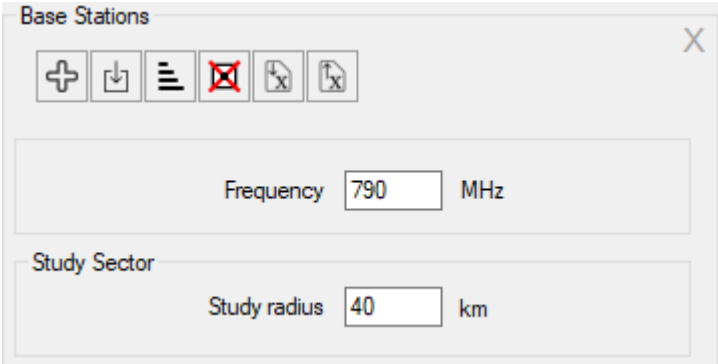


Figure 14. Base stations

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 settings 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 on which the new base station will be created.

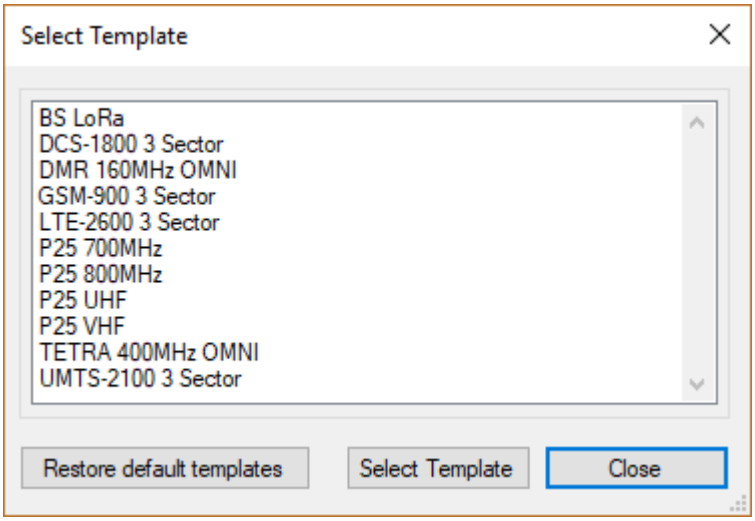


Figure 15. Template selection for a new BS

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, Longitude. Formats 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.

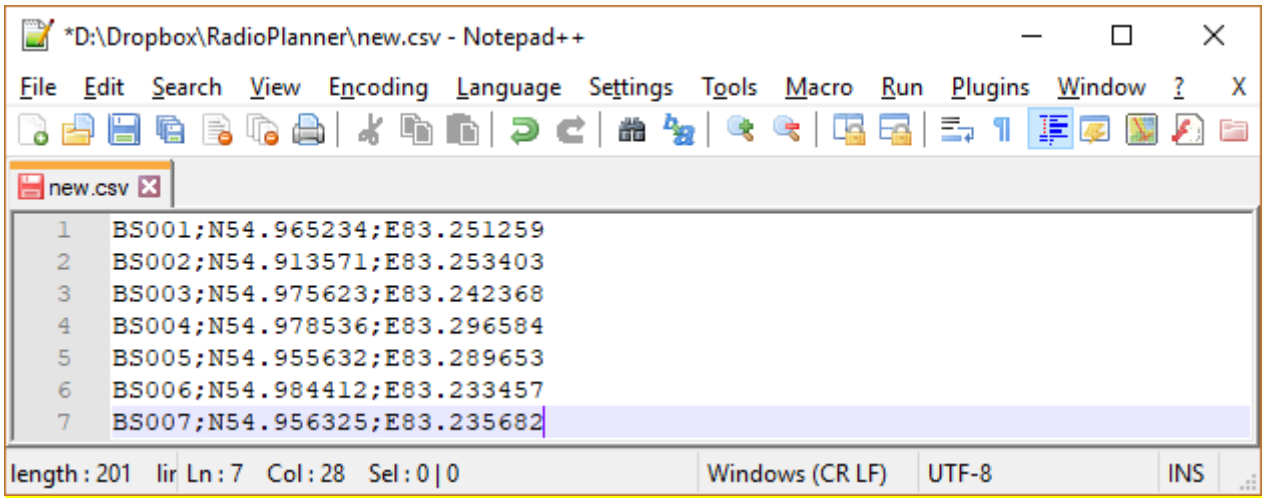
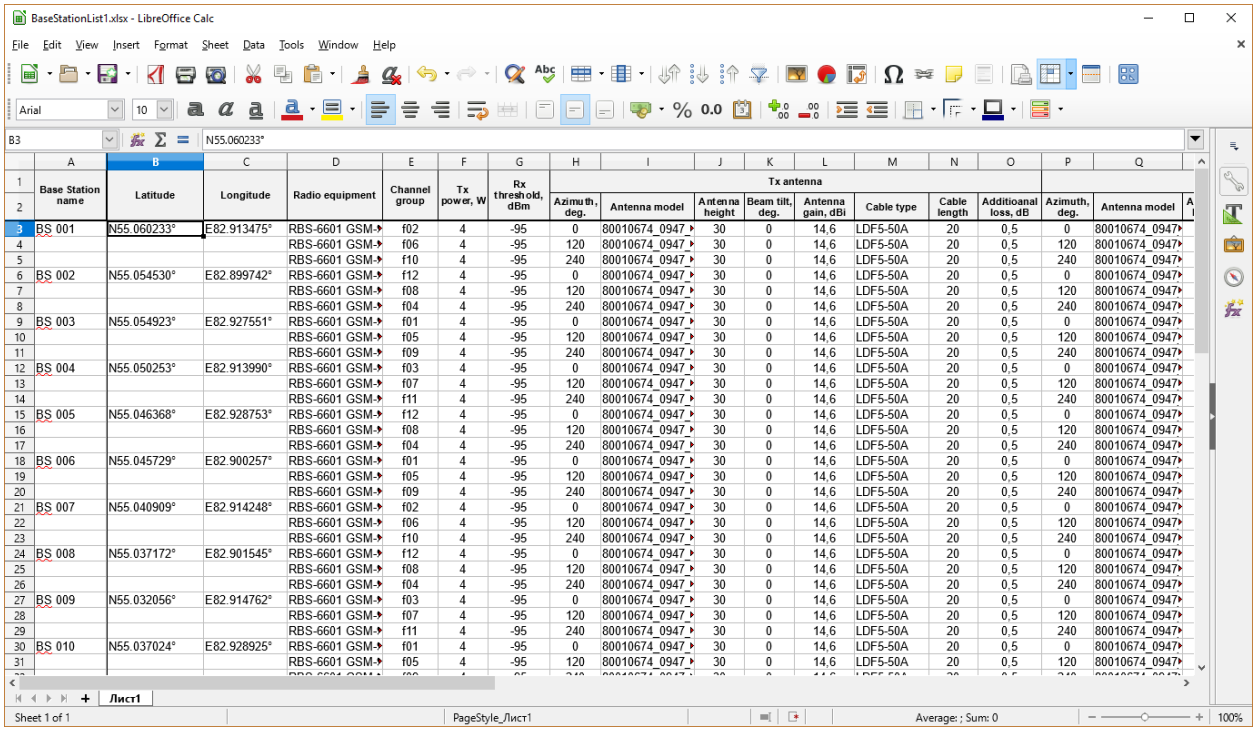


Figure 16. Example of a CSV file with the imported sites

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.



Base Station name	Latitude	Longitude	Radio equipment	Channel group	Tx power, W	Rx threshold, dBm	Tx antenna									
							Azimuth, deg.	Antenna model	Antenna height	Beam tilt, deg.	Antenna gain, dBi	Cable type	Cable length	Additioanal loss, dB	Azimuth, deg.	Antenna model
BS 001	N55.060233°	E82.913475°	RBS-6601 GSM-	f02	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f06	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f10	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 002	N55.054530°	E82.899742°	RBS-6601 GSM-	f12	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f08	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f04	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 003	N55.054923°	E82.927551°	RBS-6601 GSM-	f01	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f05	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f09	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 004	N55.050253°	E82.913990°	RBS-6601 GSM-	f03	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f07	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f11	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 005	N55.046368°	E82.928753°	RBS-6601 GSM-	f12	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f08	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f04	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 006	N55.045729°	E82.900257°	RBS-6601 GSM-	f01	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f05	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f09	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 007	N55.040909°	E82.914248°	RBS-6601 GSM-	f02	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f06	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f10	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 008	N55.037172°	E82.901545°	RBS-6601 GSM-	f12	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f08	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f04	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 009	N55.032056°	E82.914762°	RBS-6601 GSM-	f03	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f07	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947
			RBS-6601 GSM-	f11	4	-95	240	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	240	80010674_0947
BS 010	N55.037024°	E82.928925°	RBS-6601 GSM-	f01	4	-95	0	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	0	80010674_0947
			RBS-6601 GSM-	f05	4	-95	120	80010674_0947	30	0	14,6	LDF5-50A	20	0,5	120	80010674_0947

Figure 17. Example of spreadsheet

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. Since the antenna patterns in the table are not saved, when importing, all radiation patterns are replaced with OMNI, the antenna name is taken from the spreadsheet. The radiation patterns can then be easily replaced with group parameter changes.

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 the antenna-feeder path parameters for the transmit path only, and do not fill 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.

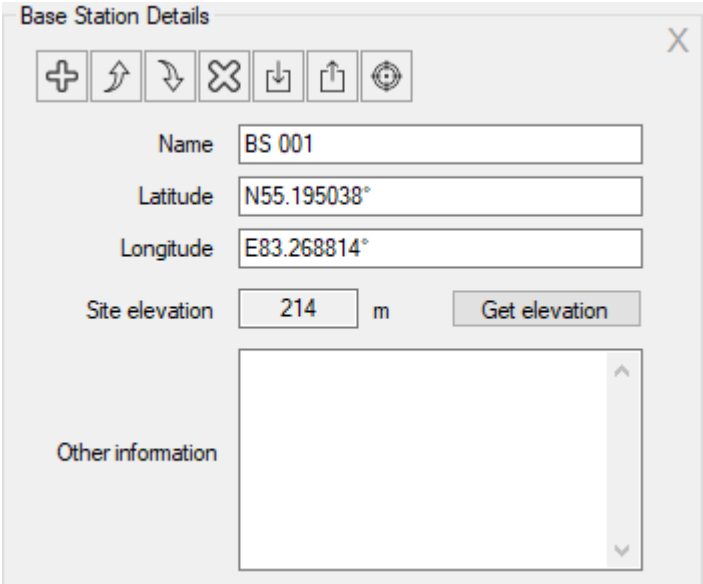


Figure 18. Base station parameters

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.

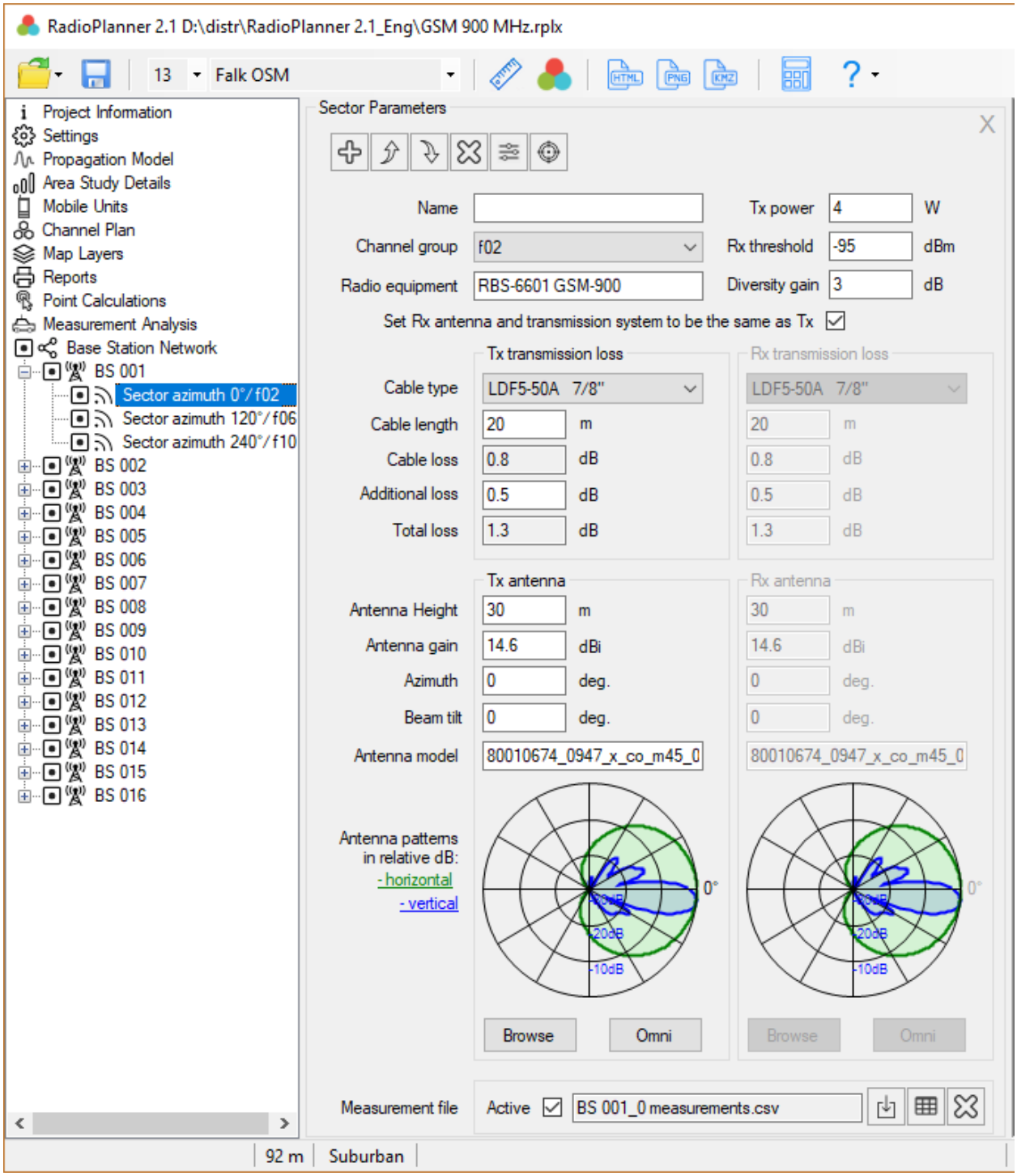


Figure 19. Sector parameters

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 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.
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 transmit path to the receive path.
Cable type	Type of main cable for transmission or reception path
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 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 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. 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 ...)

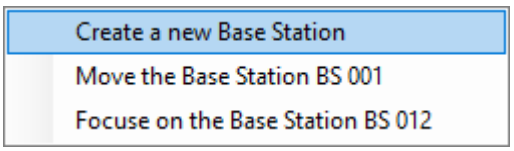


Figure 20. Context menu

Propagation models

RadioPlanner 2.1 uses the following propagation models:

- ITU-R P.1812-4 model (for mobile and broadcasting)
- Longley-Rice (ITM) model v 1.2.2 (for broadcasting only, for mobile coming soon)
- 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)

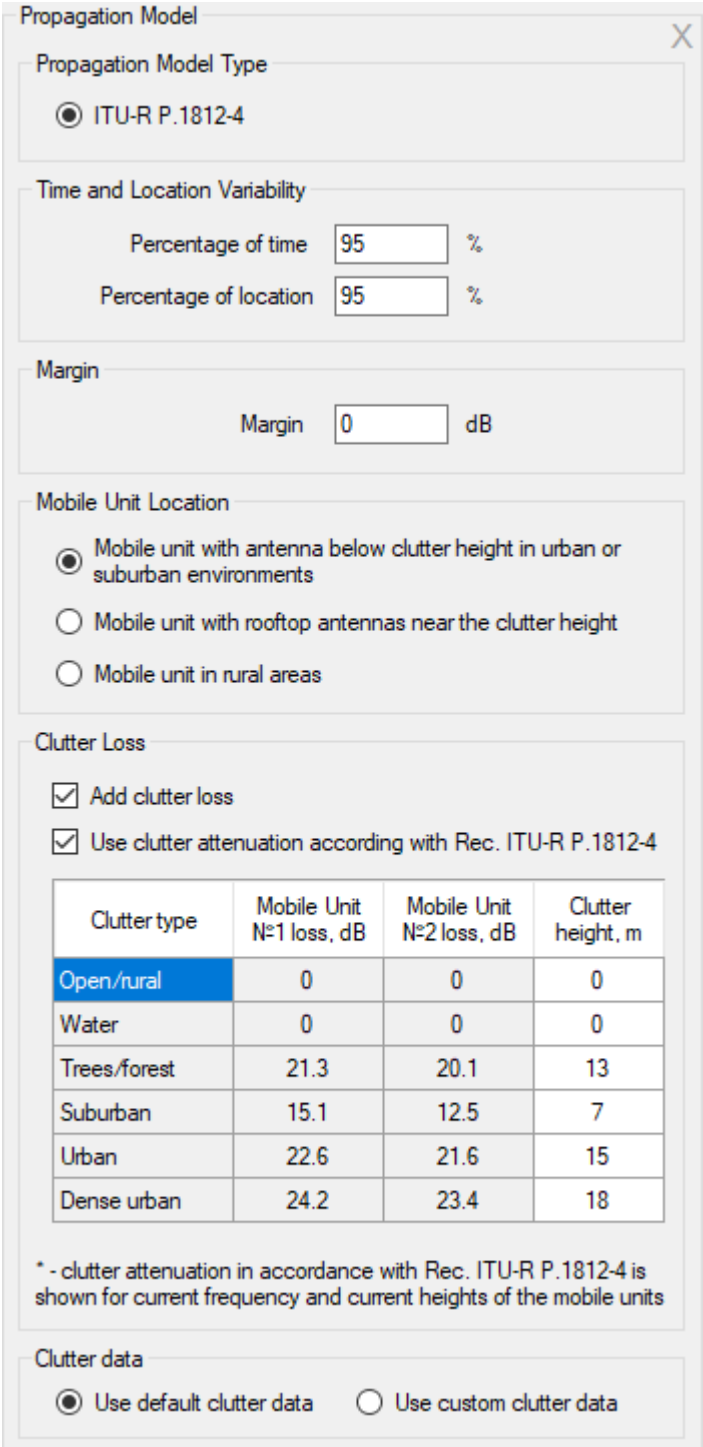


Figure 21. ITU-R P.1812-4 propagation model

You may select three parameters that determine the time, location, and prediction confidence margin of the calculation results:

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 landcover model with the different types of clutter (dense urban, urban, suburban, open land, water, and trees/forest). Landcover model was created based on OpenStreetMap (www.openstreetmap.org) и 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), the landcover model determines the type of obstacles at each point.

To determine the loss according to ITU-R P.1812-4 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 obstacles, based on their own data - to do this, simply enter the losses in 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).

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.

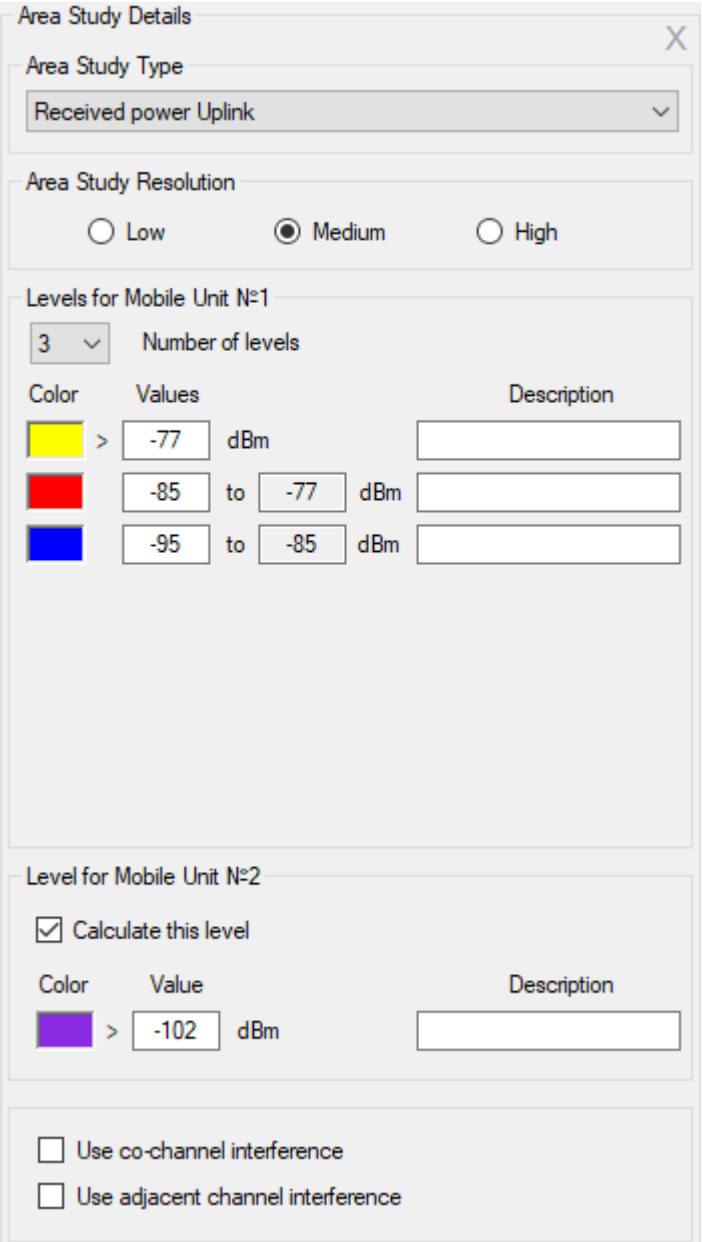


Figure 22. Area study type Received Power Uplink menu

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

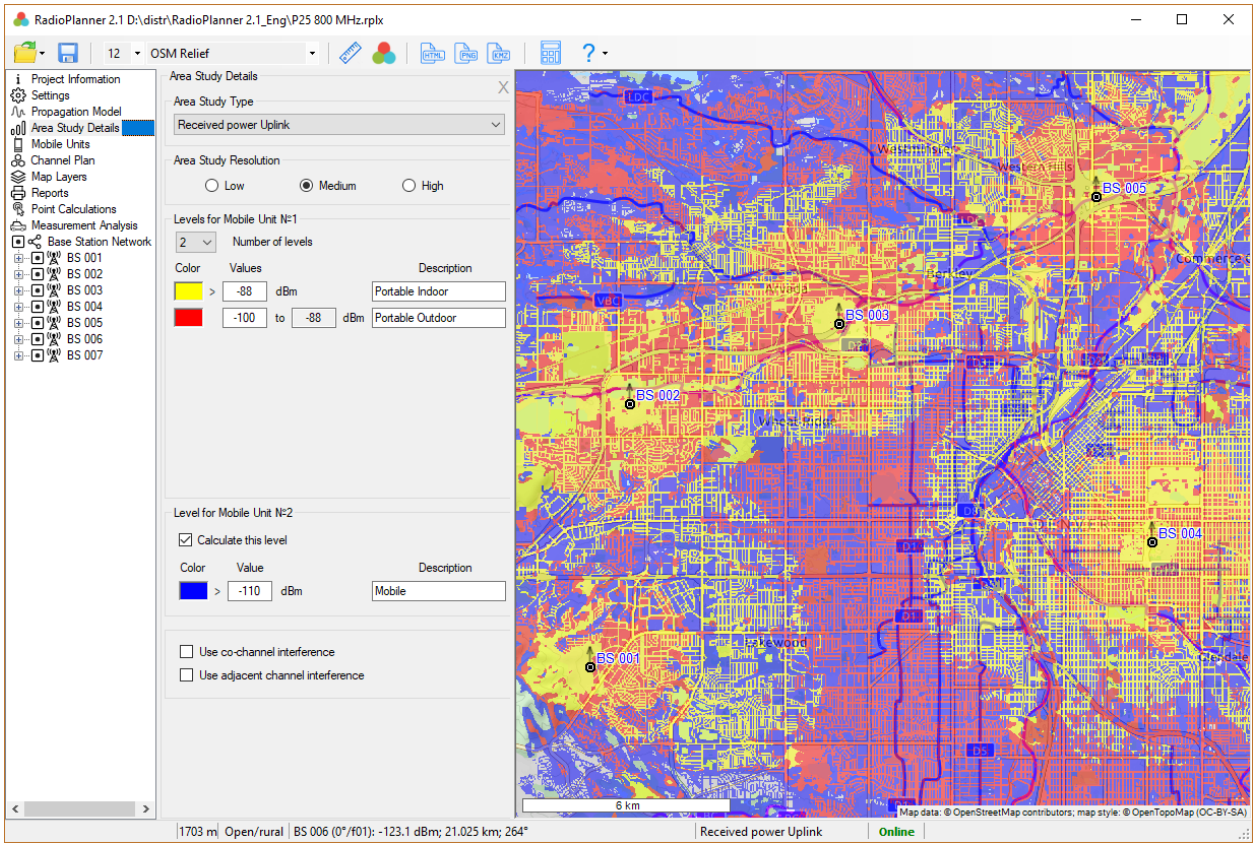


Figure 23. Received Power Uplink for P25 800 MHz network

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 in the bottom of the panel. In this case, the zones where the interference on the co-channel and/or adjacent channels exceeds the 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 in 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 a 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.

Number of levels	The number of levels
Color	Color level
Penetration loss	Penetration loss, dB
Description	Text field to describe condition of use

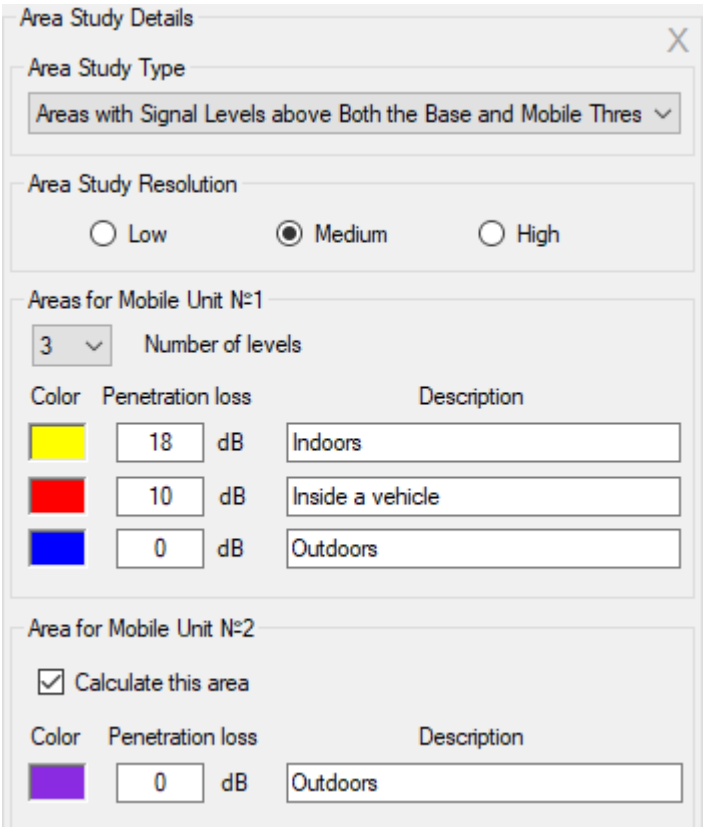


Figure 24. Areas with Signal Levels above Both the Base a Mobile Thresholds Menu

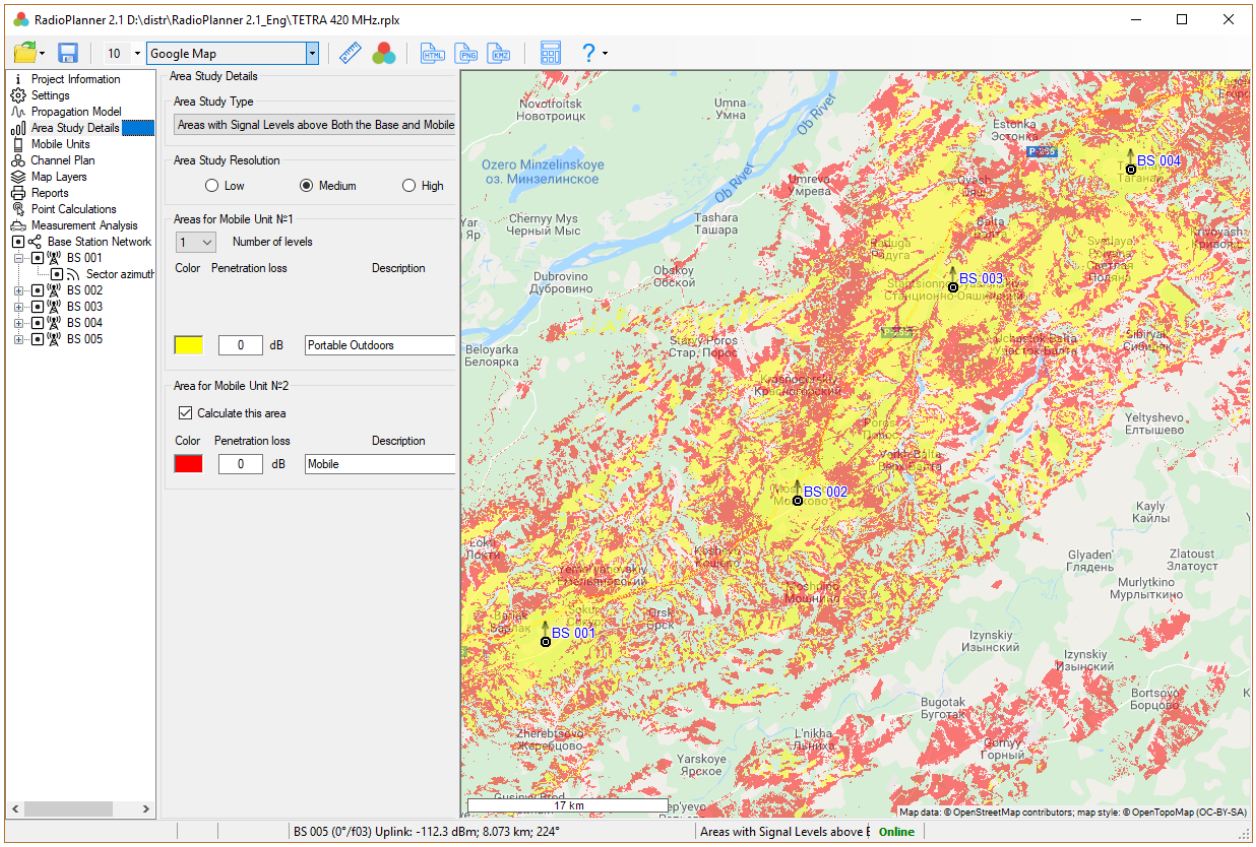


Figure 25. Areas with Signal Levels above Both the Base a Mobile Thresholds for TETRA network

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.

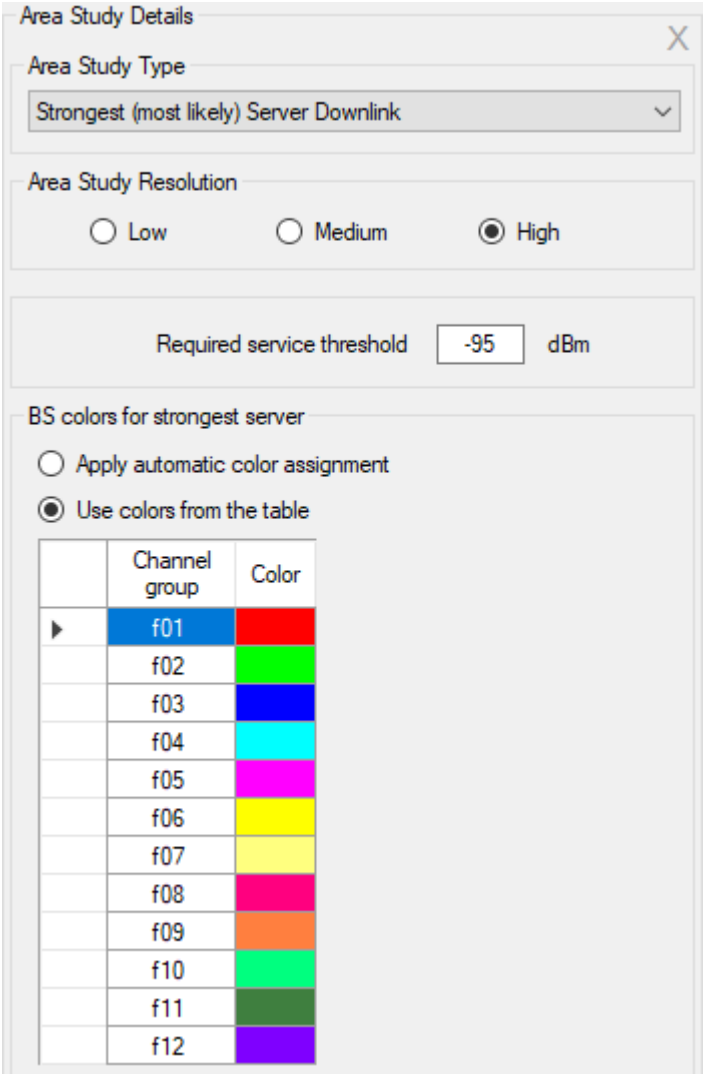


Figure 26. Strongest Server menu

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 BS sector is made from the table according to colors frequency groups

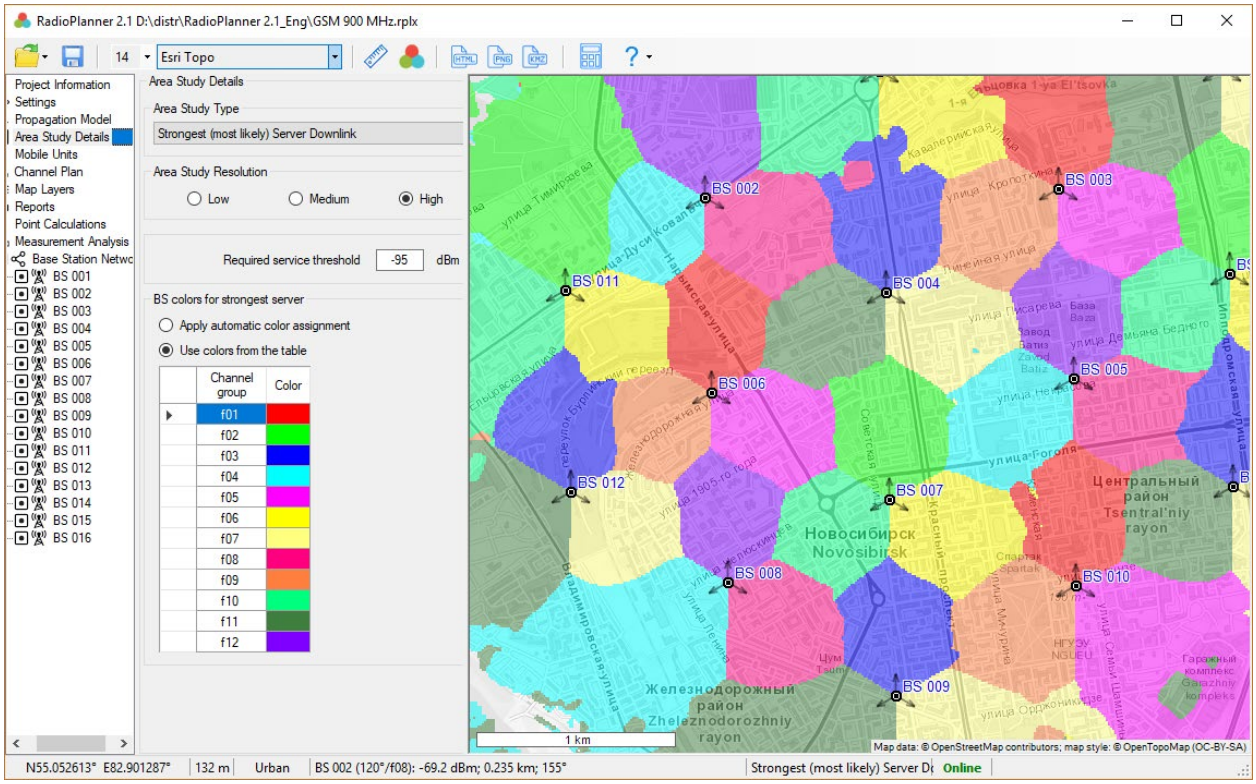


Figure 27. Strongest Server for GSM network

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 receive signal powers from all the 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.

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

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, set the channel bandwidth and C/A value (see section **Channel Plan**).

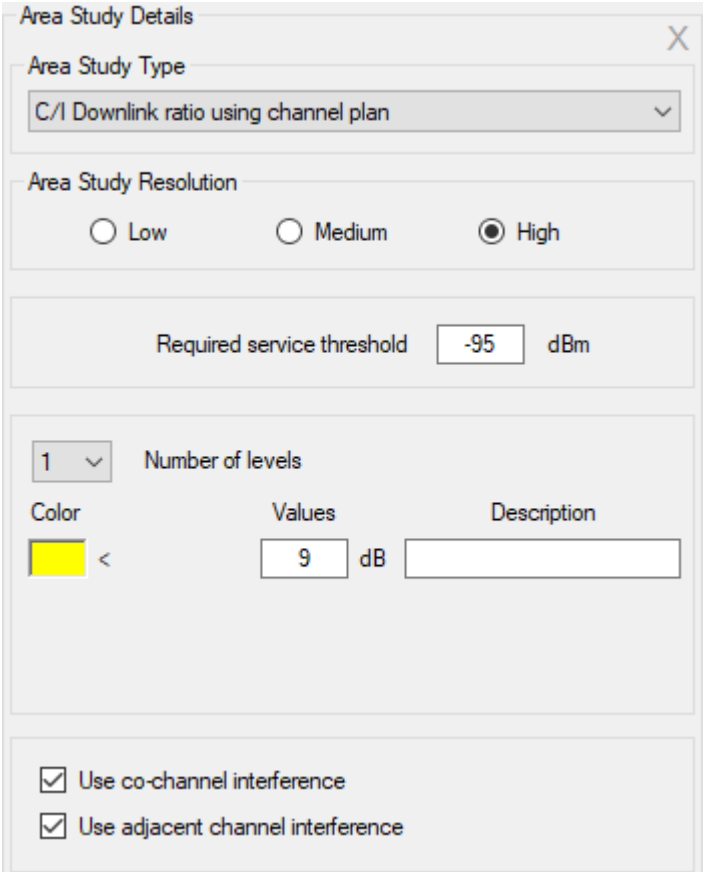


Figure 28. C/I Downlink ratio using channel plan menu

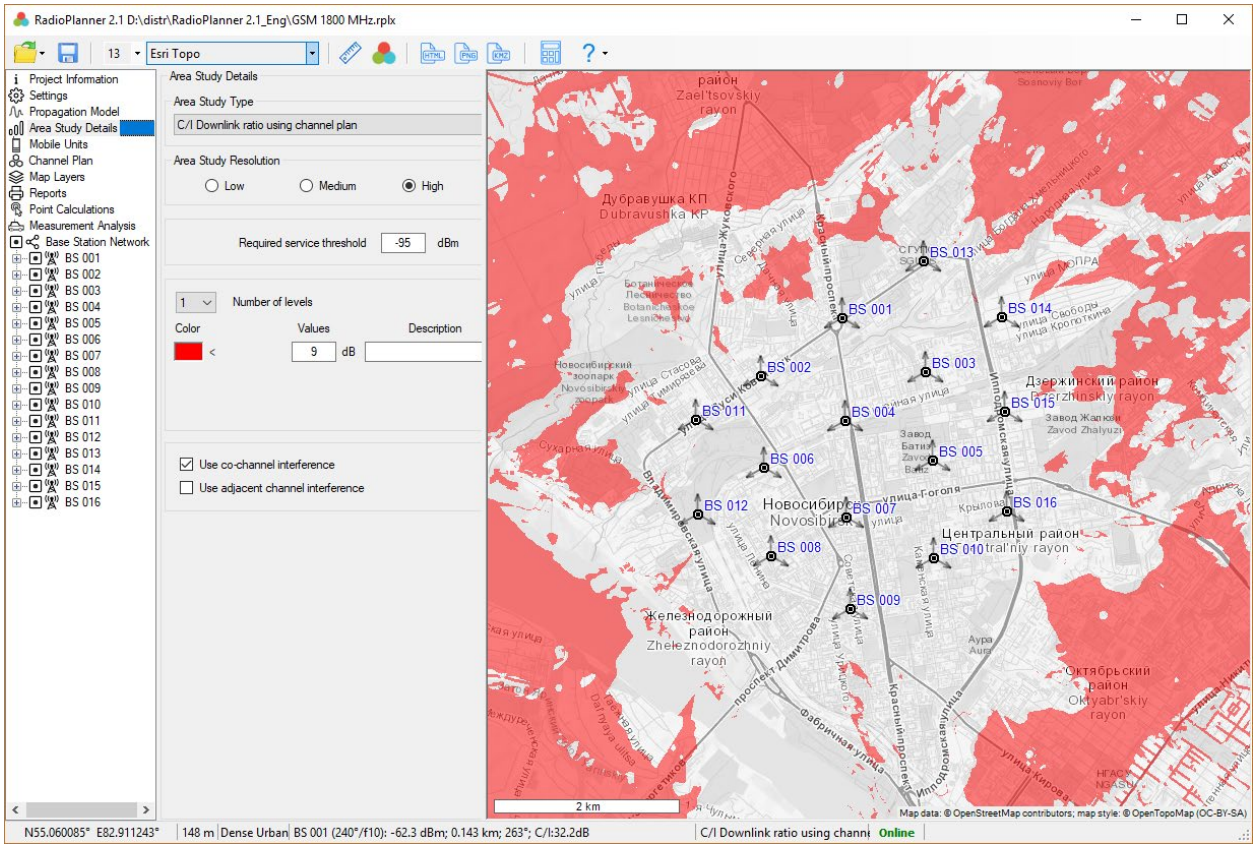


Figure 29. C/I Downlink ratio using channel plan for GSM-1800 network

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.

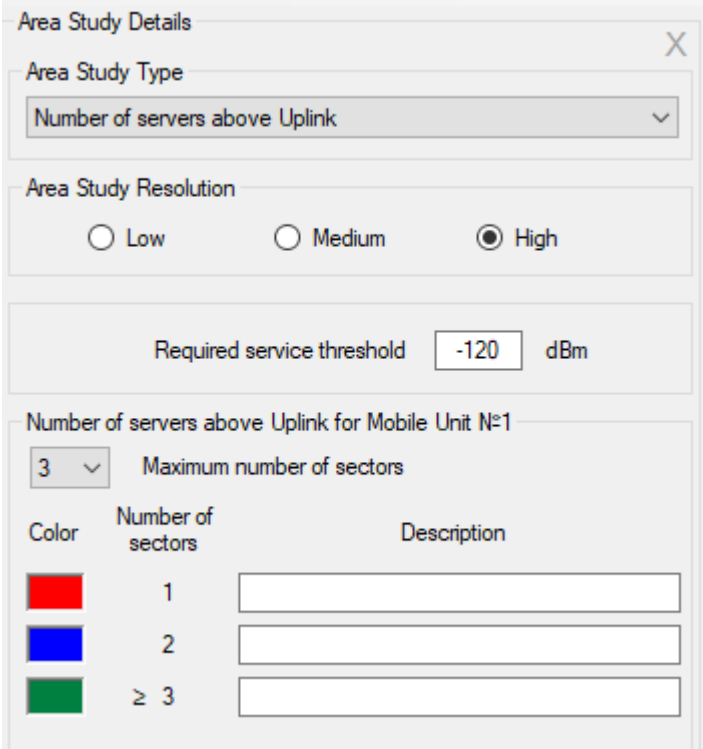


Figure 30. Number of servers above uplink

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

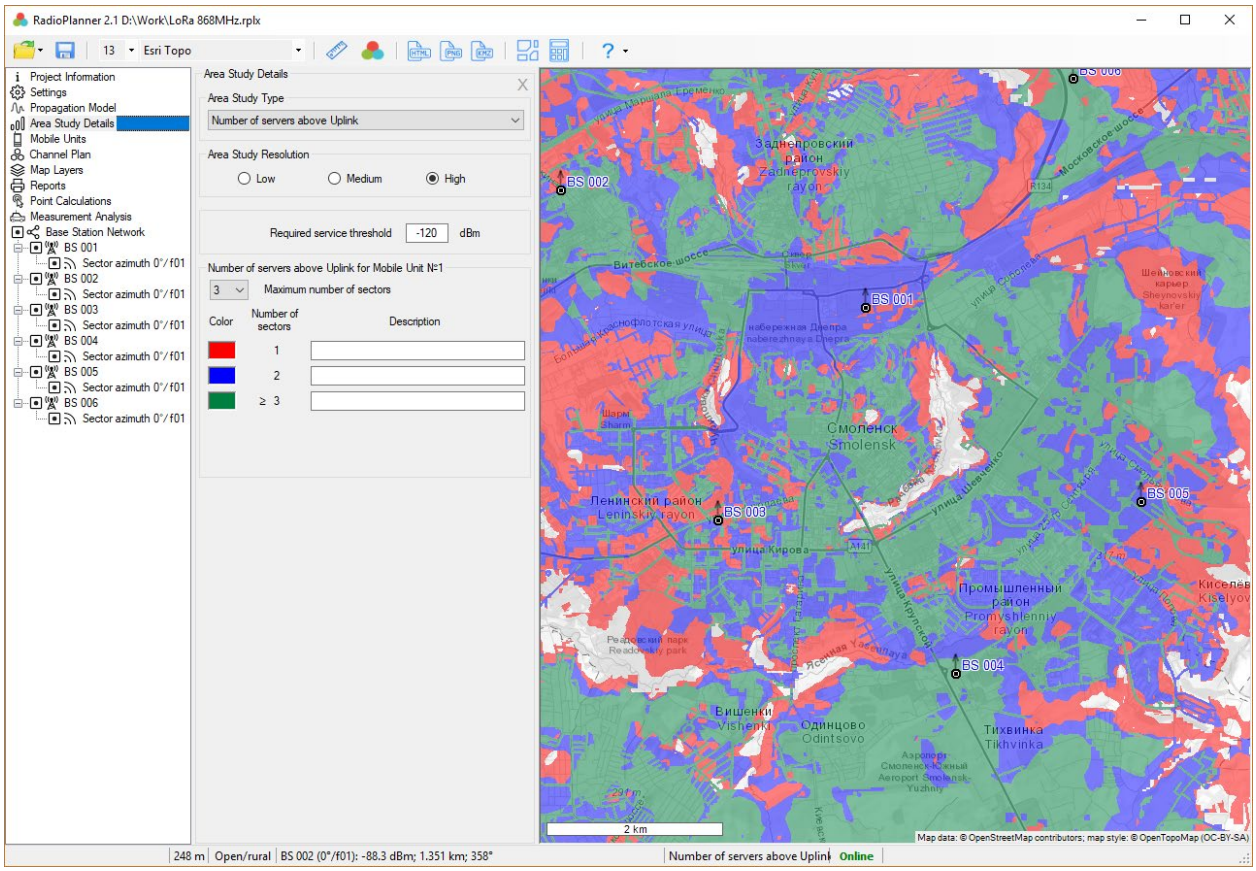
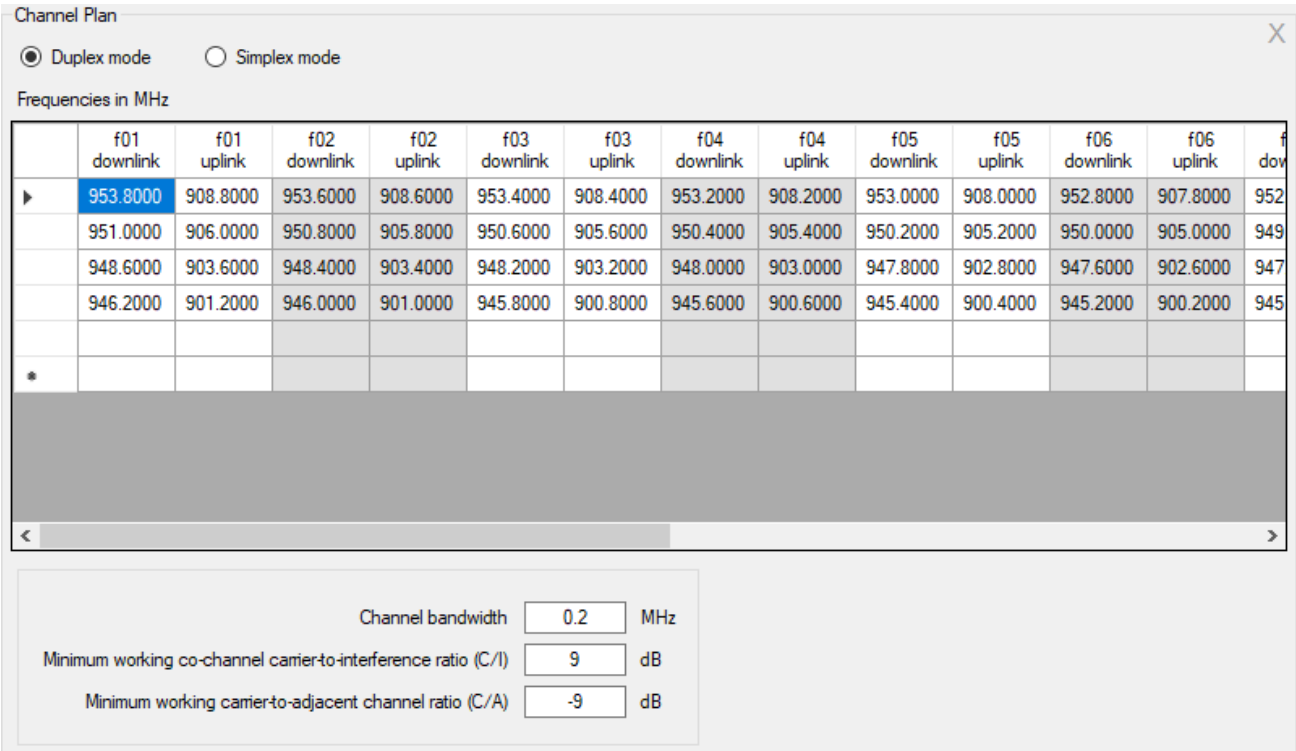


Figure 31. Number of servers above uplink example for LoRa network

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	f05 downlink	f05 uplink	f06 downlink	f06 uplink	f dow
953.8000	908.8000	953.6000	908.6000	953.4000	908.4000	953.2000	908.2000	953.0000	908.0000	952.8000	907.8000	952
951.0000	906.0000	950.8000	905.8000	950.6000	905.6000	950.4000	905.4000	950.2000	905.2000	950.0000	905.0000	949
948.6000	903.6000	948.4000	903.4000	948.2000	903.2000	948.0000	903.0000	947.8000	902.8000	947.6000	902.6000	947
946.2000	901.2000	946.0000	901.0000	945.8000	900.8000	945.6000	900.6000	945.4000	900.4000	945.2000	900.2000	945

Figure 32. 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 working co-channel carrier-to-interference ratio (C/I)	Minimum working co-channel carrier-to-interference ratio (C/I), dB
Minimum working co-channel carrier-to-adjacent channel ratio (C/A)	Minimum working co-channel 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 corresponding to the colors of the landcover model.

The path profile shows the heights 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.

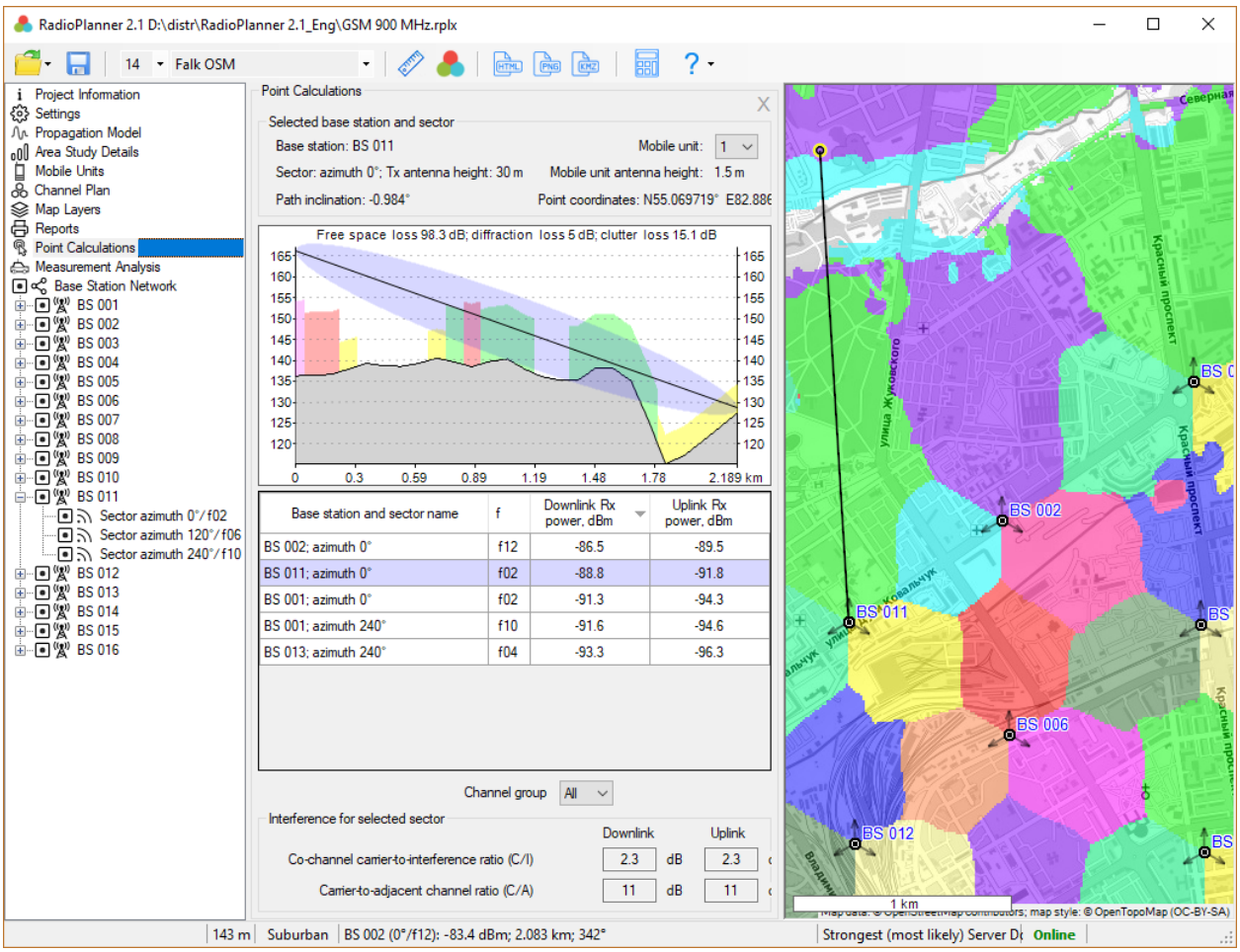


Figure 33. Point calculations

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.

Import Measurement Results and Propagation Model Tuning

The user can import the results of measurements of the received signal power levels and compare with the calculated values, and then adjust the parameters of the propagation model.

Operating procedure:

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

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).

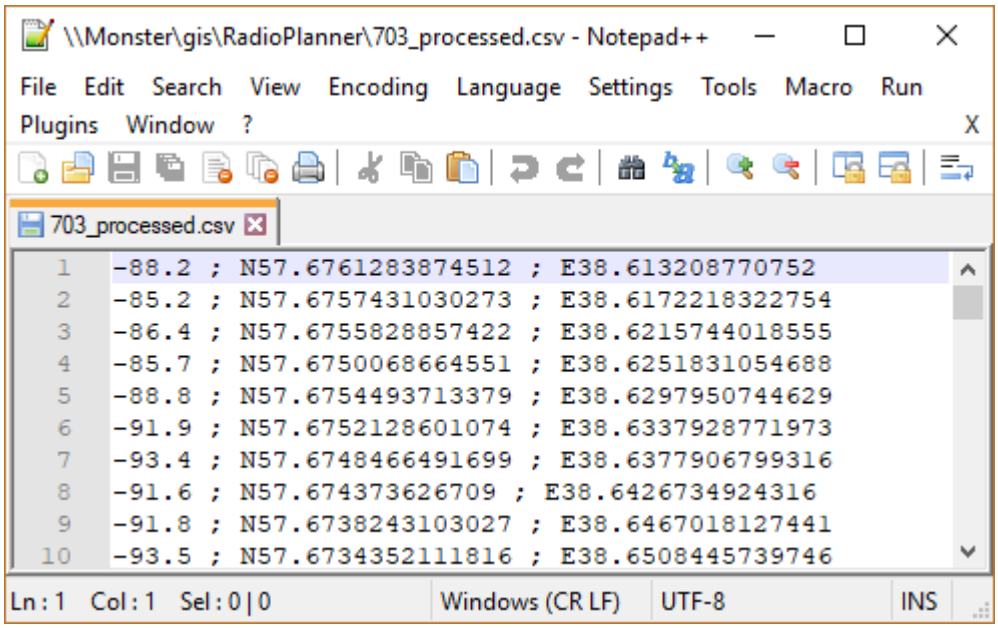


Figure 34. Sample measurement file

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 their preliminary processing:

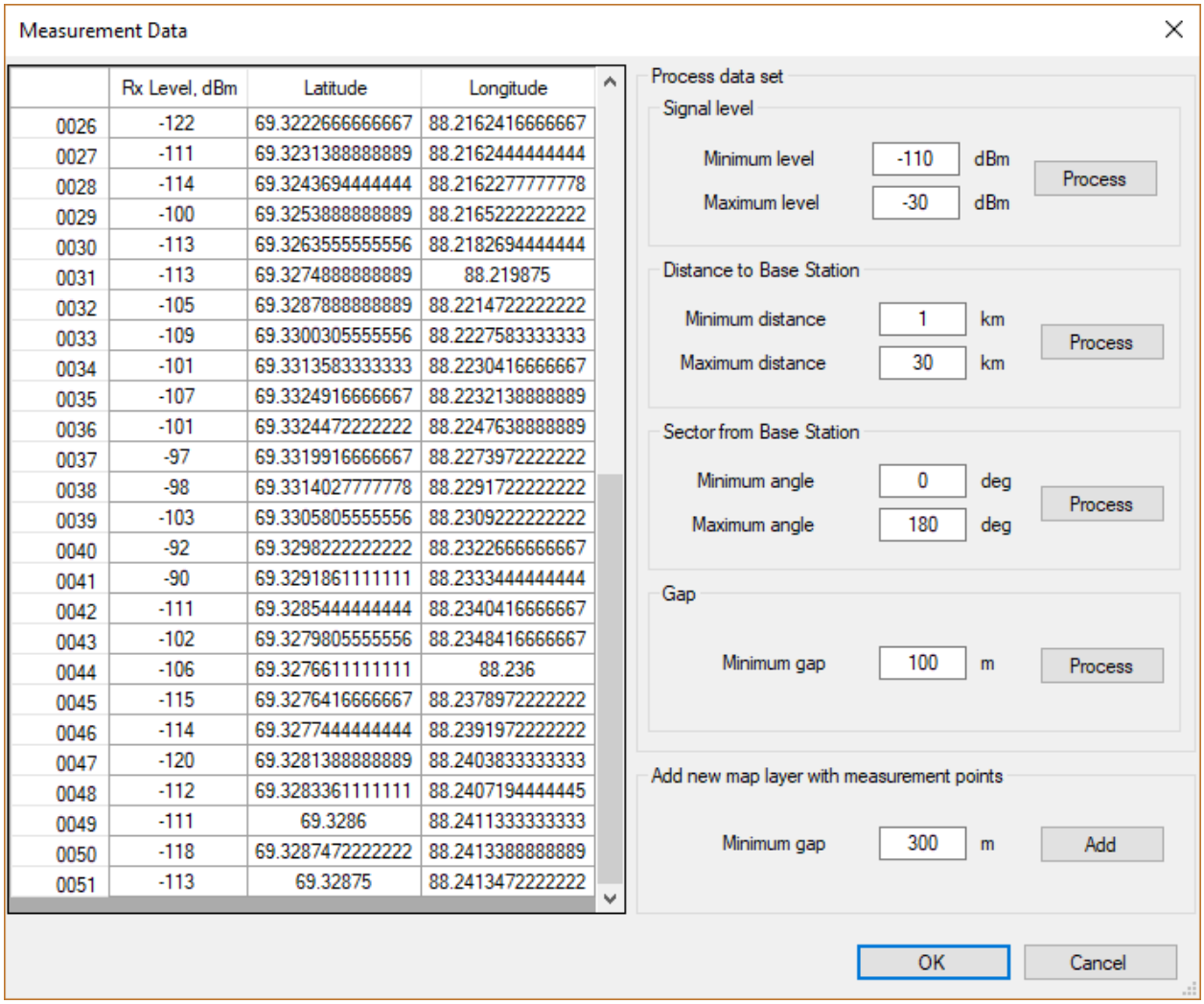


Figure 35. Pre-processing of measurement results in the BS sector

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
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. In the “Measurement Analysis” menu, the results of the comparison of the measured and calculated levels for each of the sectors for different clutter types will appear - the average error and the standard deviation of the error. Also, the recommended loss values for different clutter types, for which the average error will be zero, will also be indicated. On the graph, you can see the distribution of measured and calculated signal level values for different clutter types.

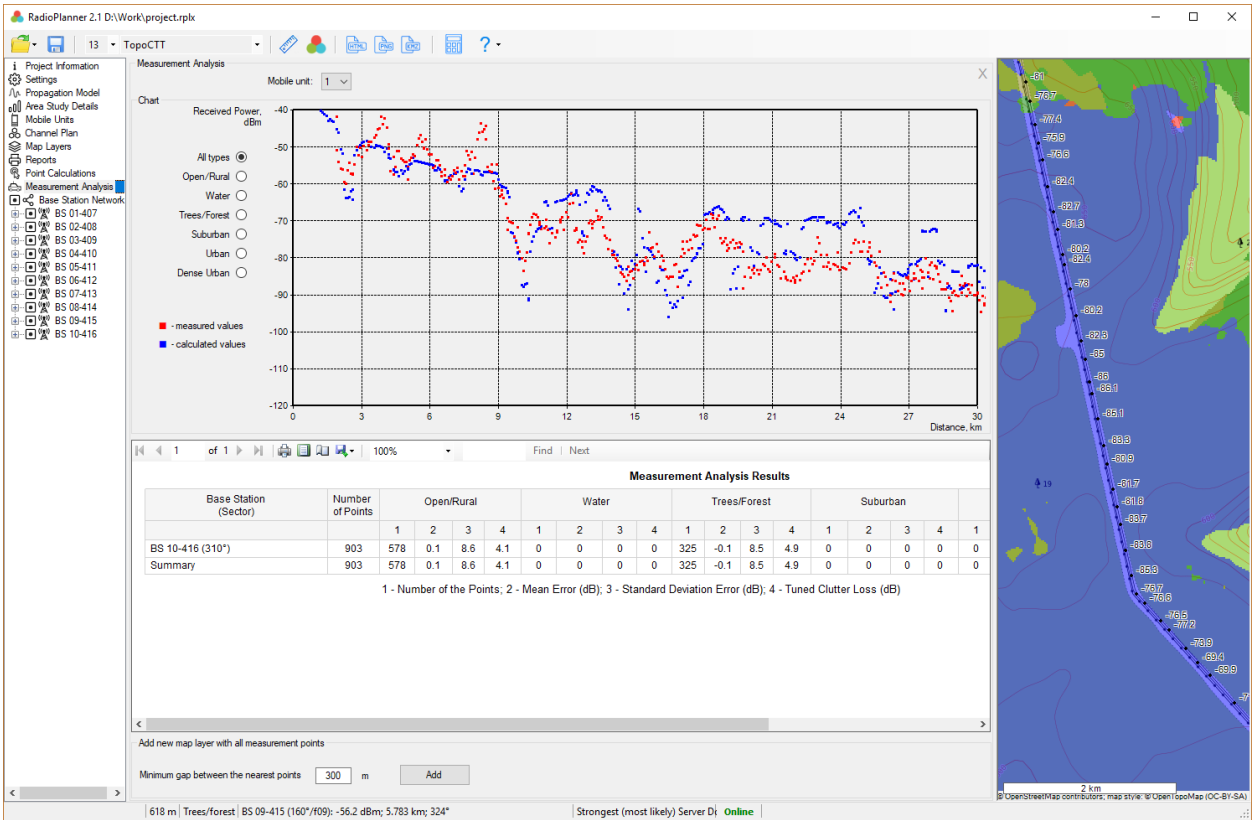


Figure 34. Measurement Analysis

4. Now, based on the analysis of the results obtained for different clutter types, 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 are 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).

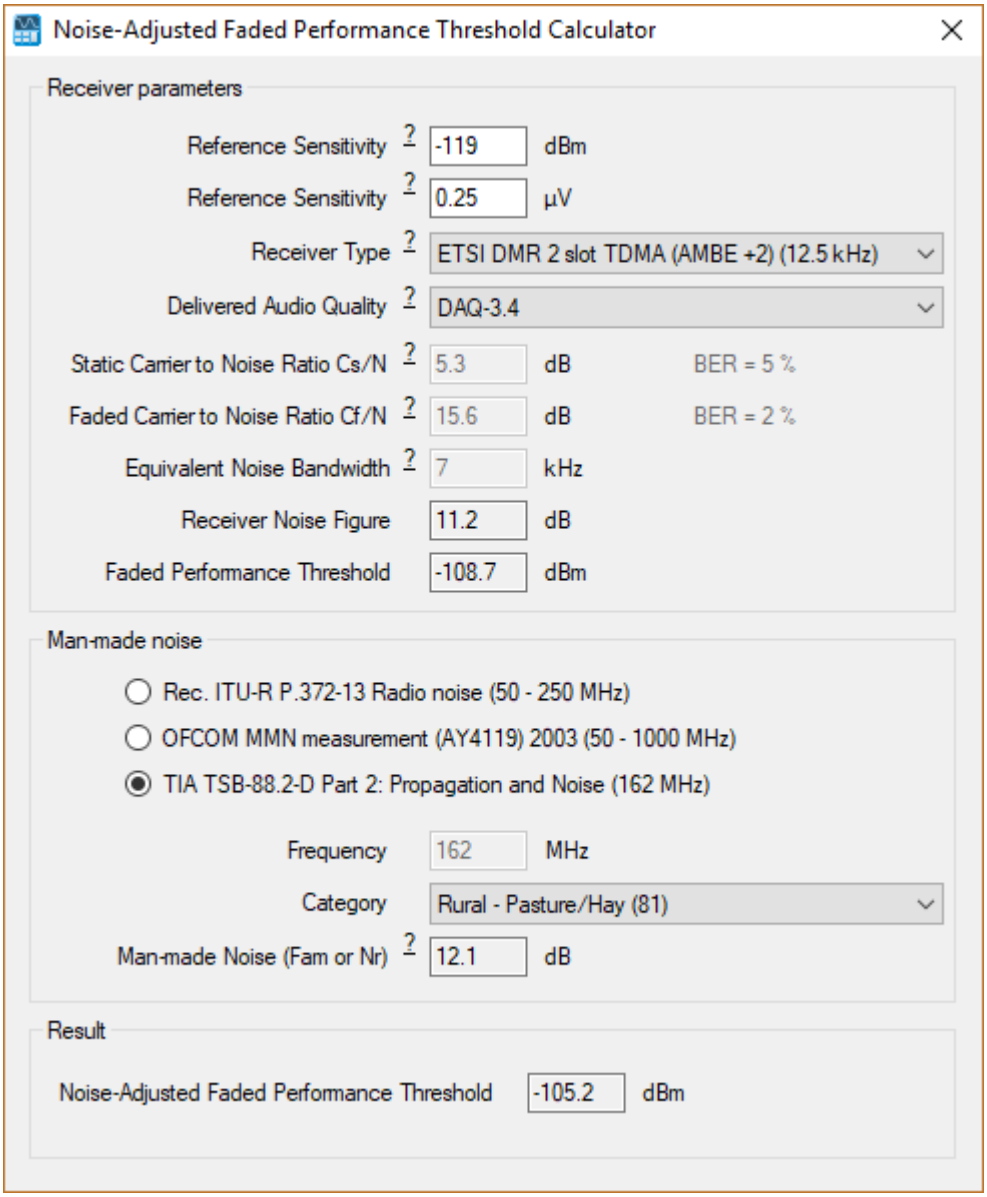


Figure 35. Man-made noise calculations

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

1. Reference receiver sensitivity in dBm or µV - it 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 perform the coverage calculation for the transmitters of television and radio broadcast, as well as automatically determine 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.

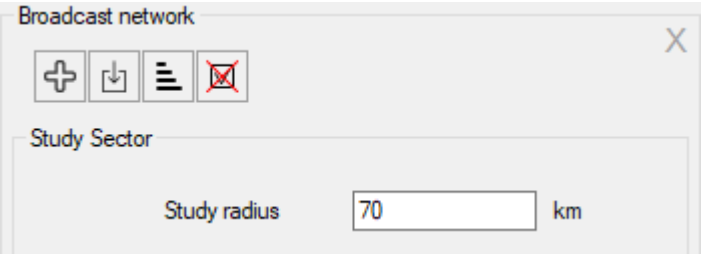


Figure 36. Broadcast network

Toolbar:

- 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.

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 on 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, the Longitude. Formats 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.

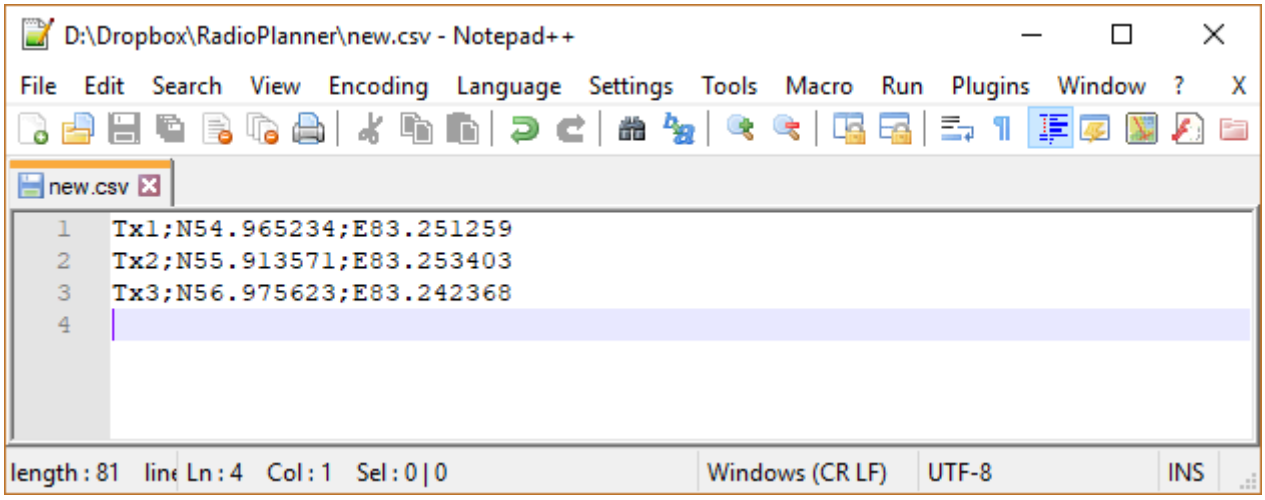


Figure 37. CSV file sample

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 the template;
- save the parameters of the transmitter as a template;
- Position the map with the transmitter at the center of the screen.

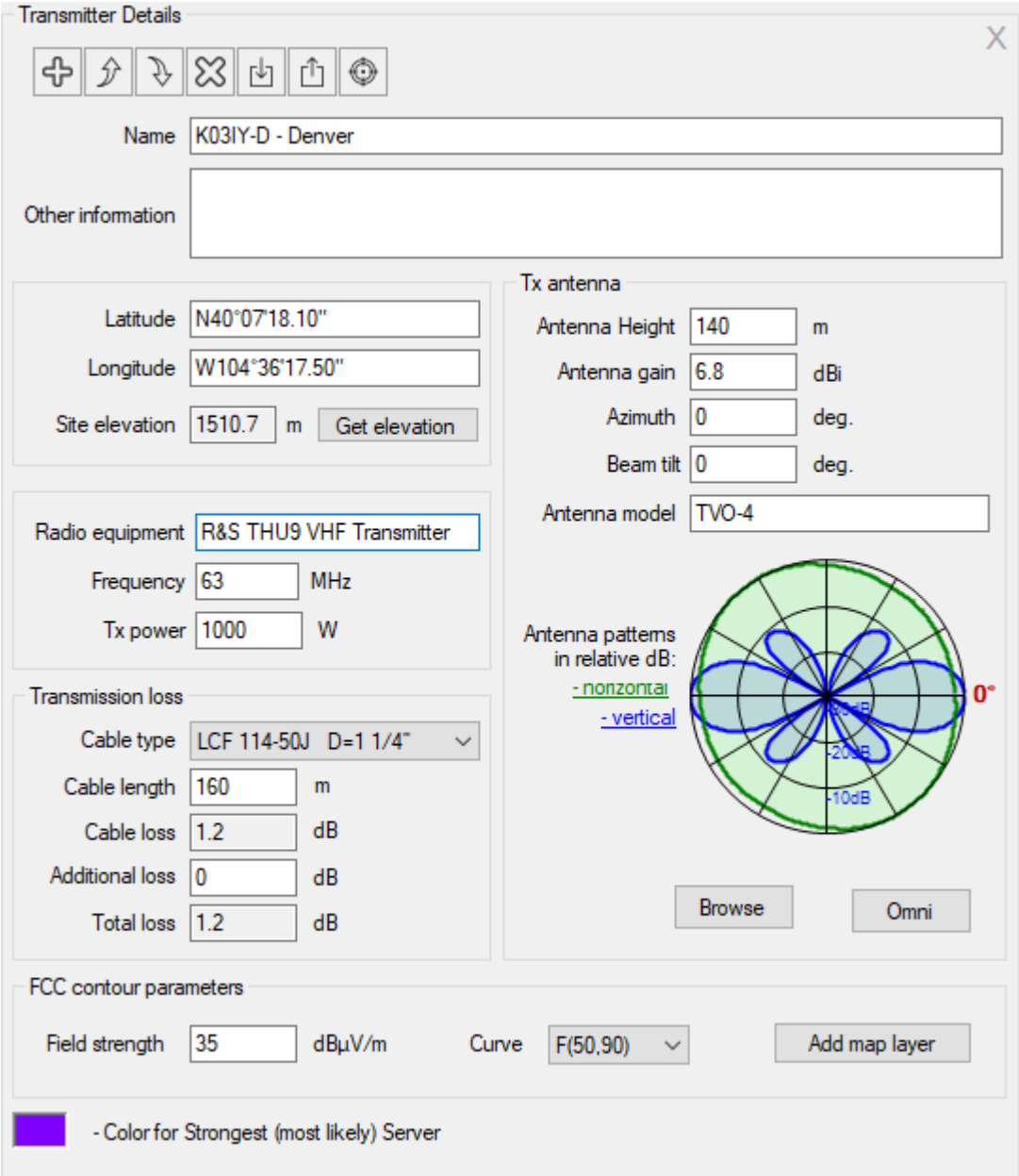


Figure 38. Transmitter Details

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	Name (model) of Radio equipment, text field
Frequency	Transmitter carrier frequency, MHz
Tx power	Transmitter power, W
Cable type	Type of main cable for transmission or reception path
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 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 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.
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
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)

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.

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.

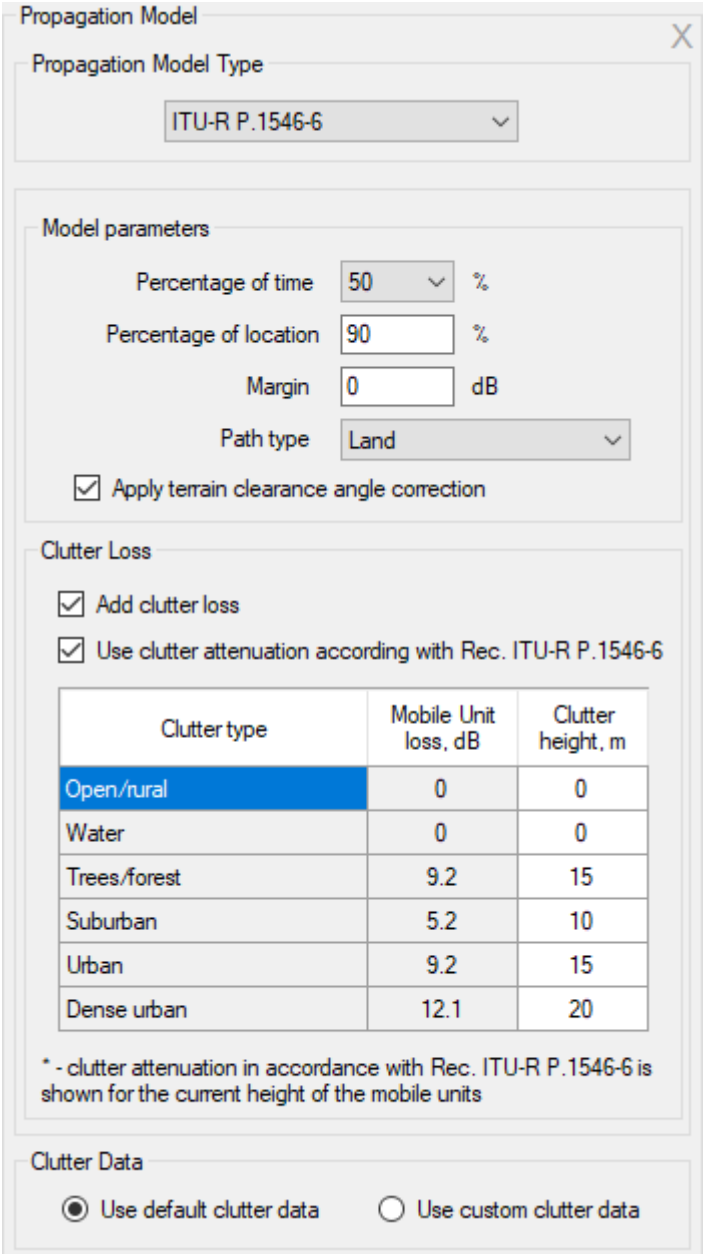


Figure 39. ITU-R P.1546-6 Propagation Model

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 in the table.
Use clutter attenuation according with 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

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.

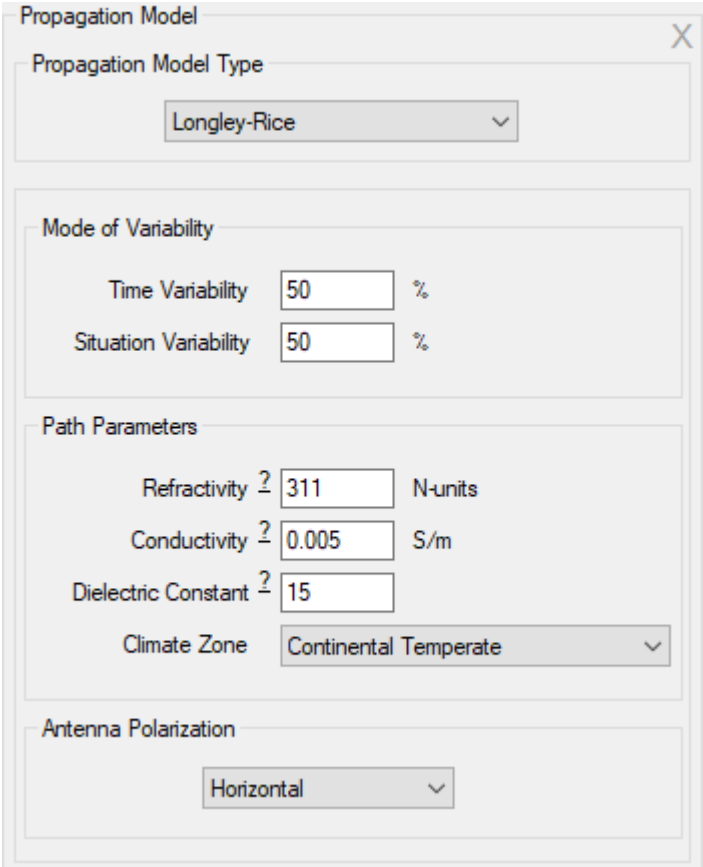


Figure 40. Longley-Rice propagation model parameters

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, %

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.

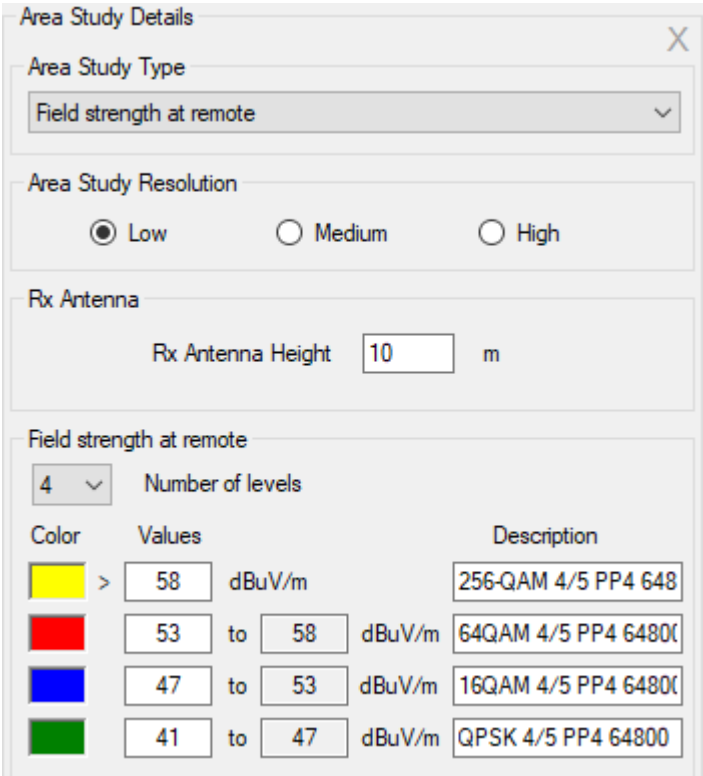


Figure 41. Field Strength at Remote menu

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

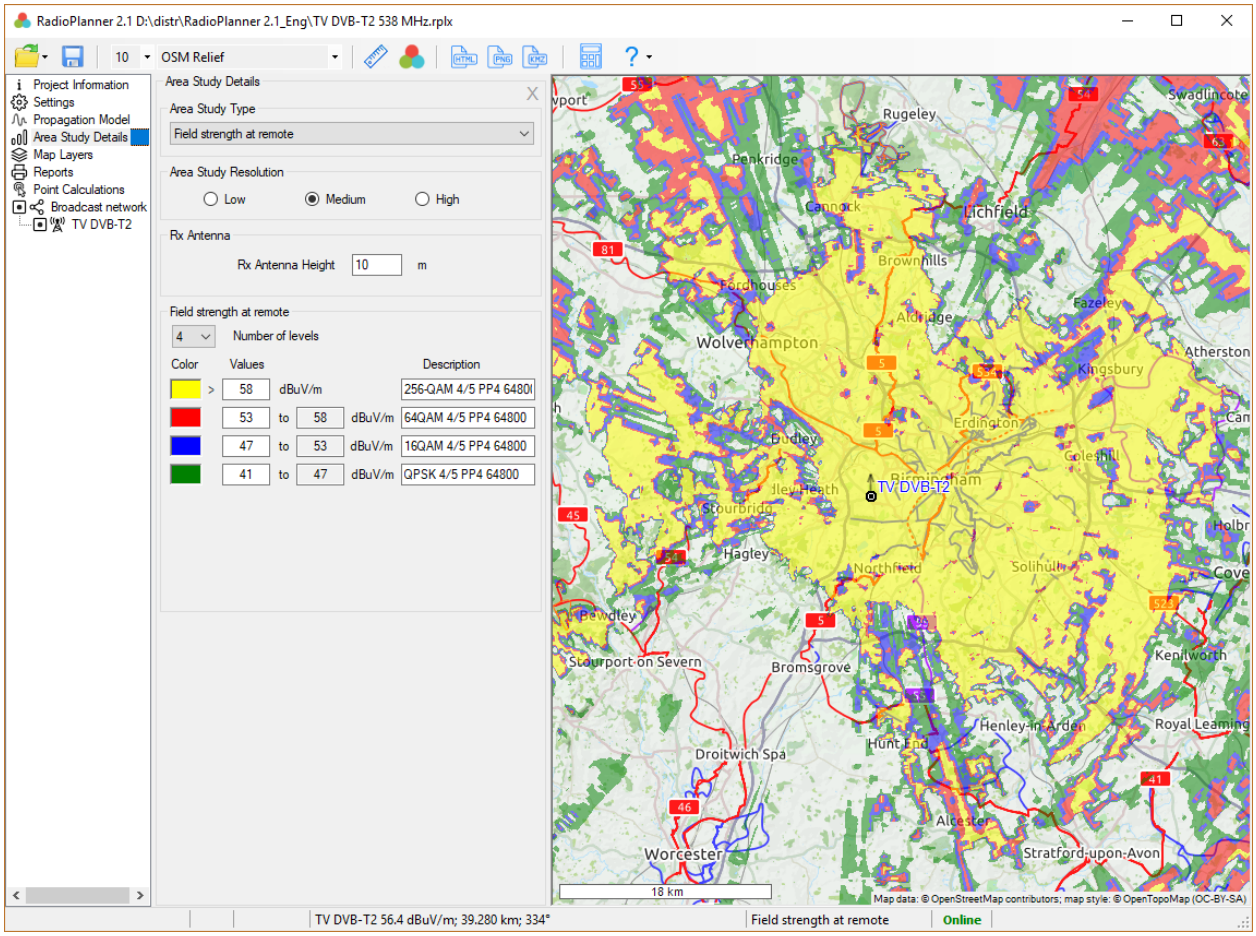


Figure 42. Field Strength at Remote for TV DVB-T2 Transmitter

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 correspond to a group of transmitters with the same frequencies.

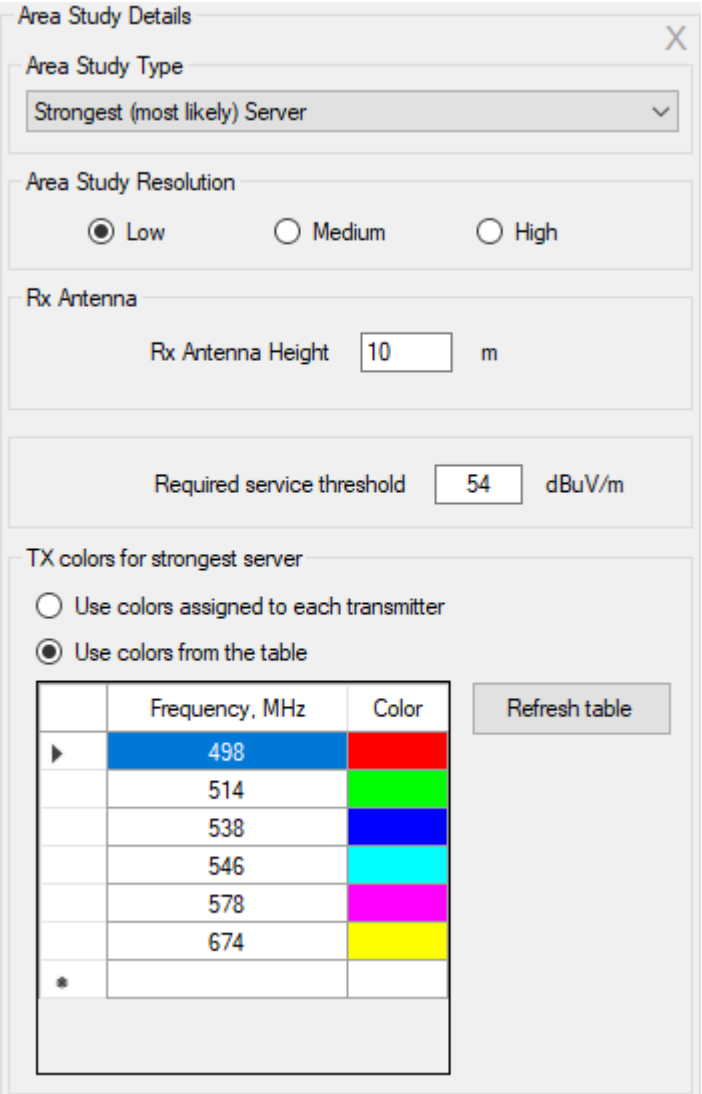


Figure 43. Strongest (Most Likely) Server menu

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

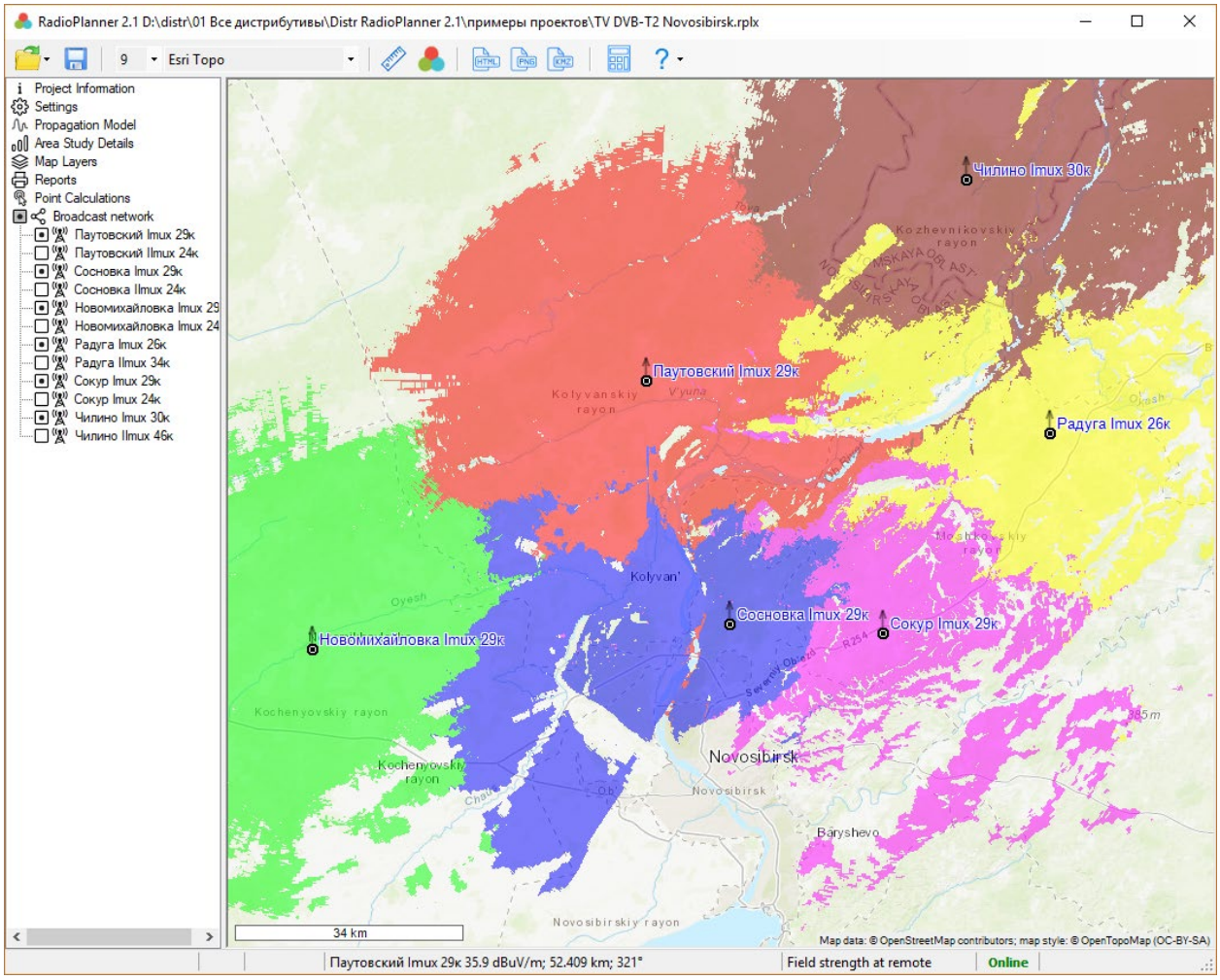


Figure 44. Strongest (Most Likely) Server for TV DVB-T2 broadcasting network

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, 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

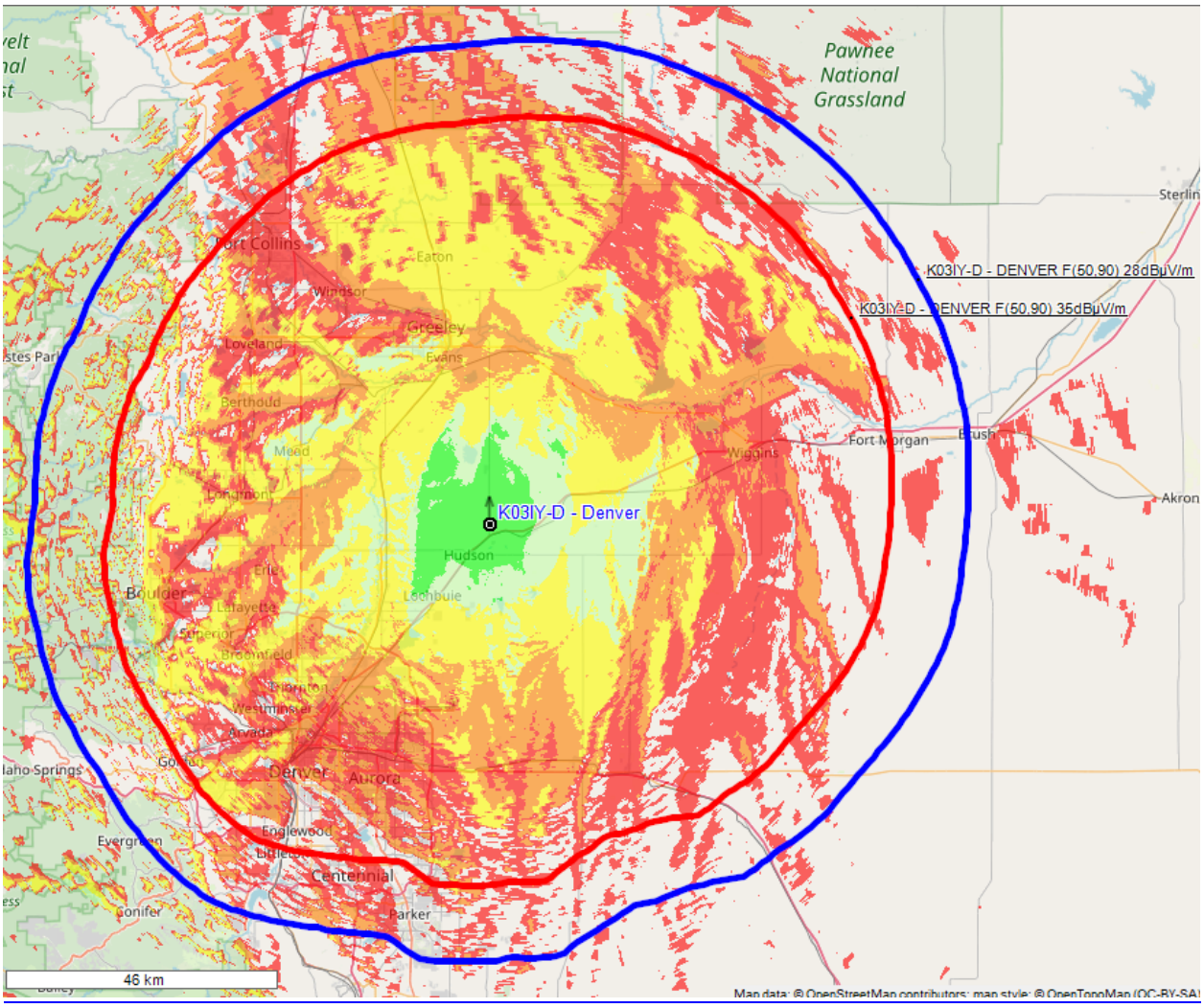


Figure 45. FCC Contours + Longley-Rice coverage

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 corresponding 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.

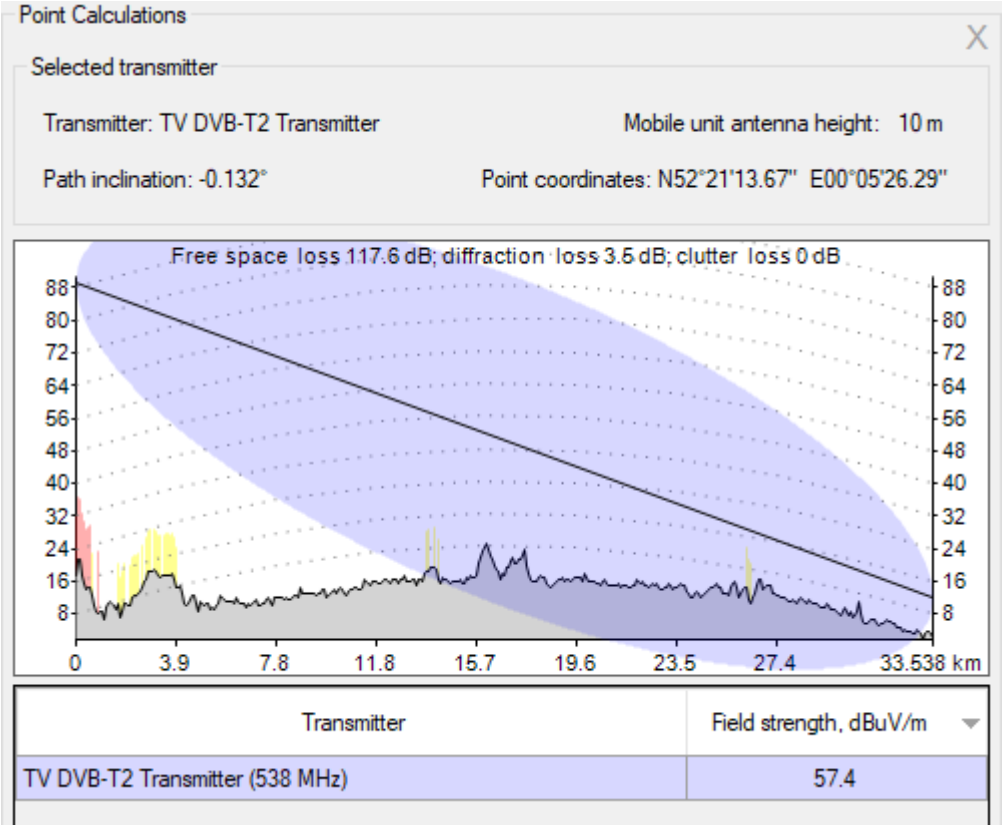


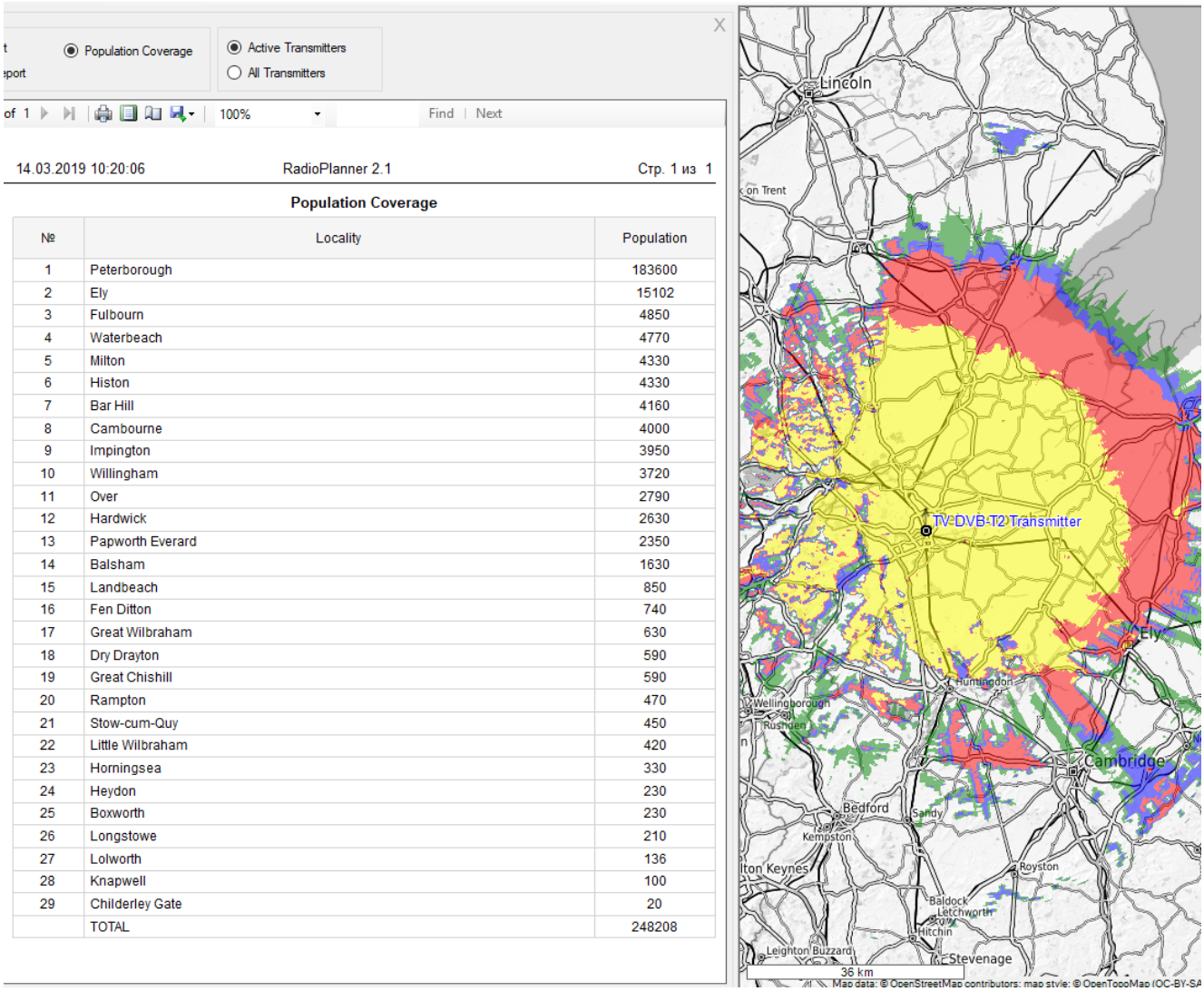
Figure 46. Point Calculations

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 2.1 allows automatically determine 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.

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).



Population Coverage

№	Locality	Population
1	Peterborough	183600
2	Ely	15102
3	Fulbourn	4850
4	Waterbeach	4770
5	Milton	4330
6	Histon	4330
7	Bar Hill	4160
8	Cambourne	4000
9	Impington	3950
10	Willingham	3720
11	Over	2790
12	Hardwick	2630
13	Papworth Everard	2350
14	Balsham	1630
15	Landbeach	850
16	Fen Ditton	740
17	Great Wilbraham	630
18	Dry Drayton	590
19	Great Chishill	590
20	Rampton	470
21	Stow-cum-Quy	450
22	Little Wilbraham	420
23	Horningsea	330
24	Heydon	230
25	Boxworth	230
26	Longstowe	210
27	Lolworth	136
28	Knapwell	100
29	Childerley Gate	20
	TOTAL	248208

Figure 47. Population Coverage Report

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.

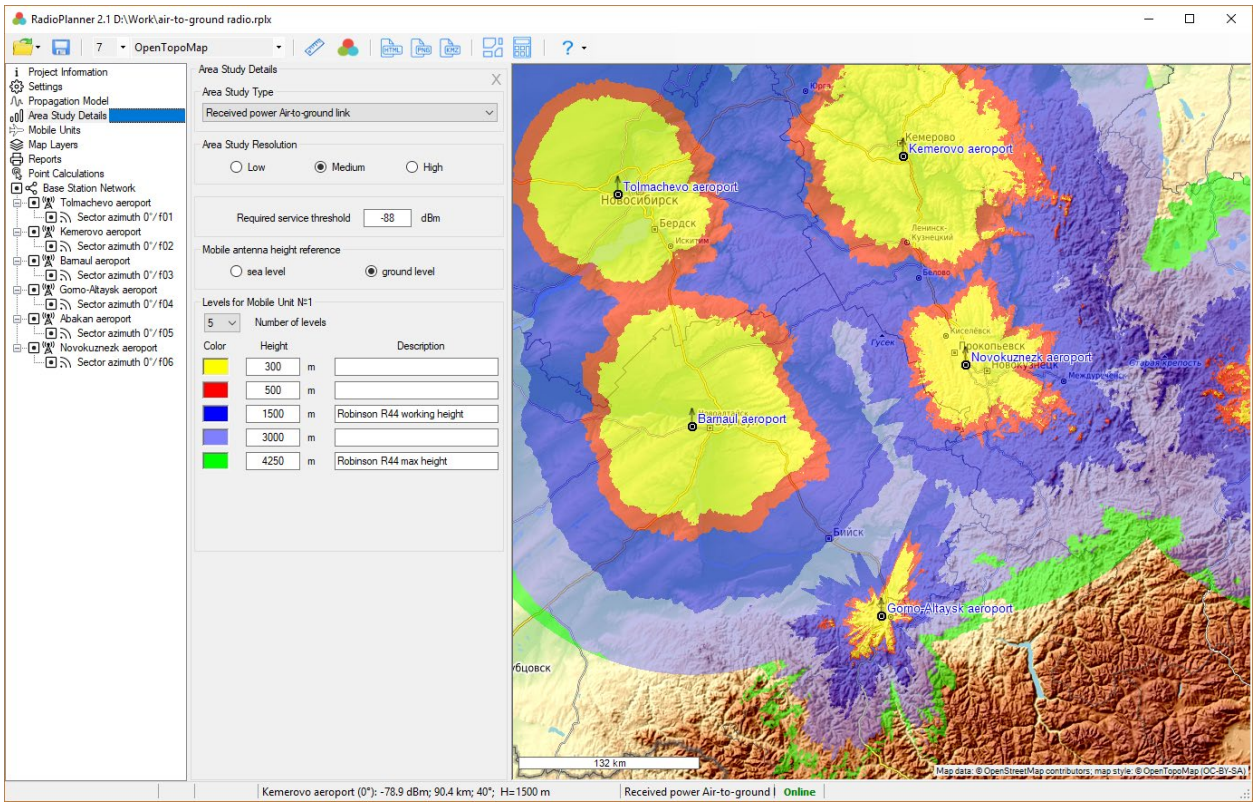


Figure 48. Air-to-Ground Communication calculation example

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 for 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 radionavigation 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).

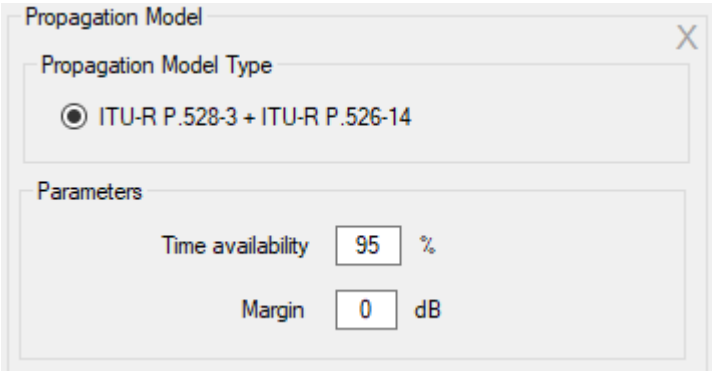


Figure 49. Propagation model for Air-to-Ground Communication

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 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 calculation, the map displays different colors of the coverage area for different heights 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.

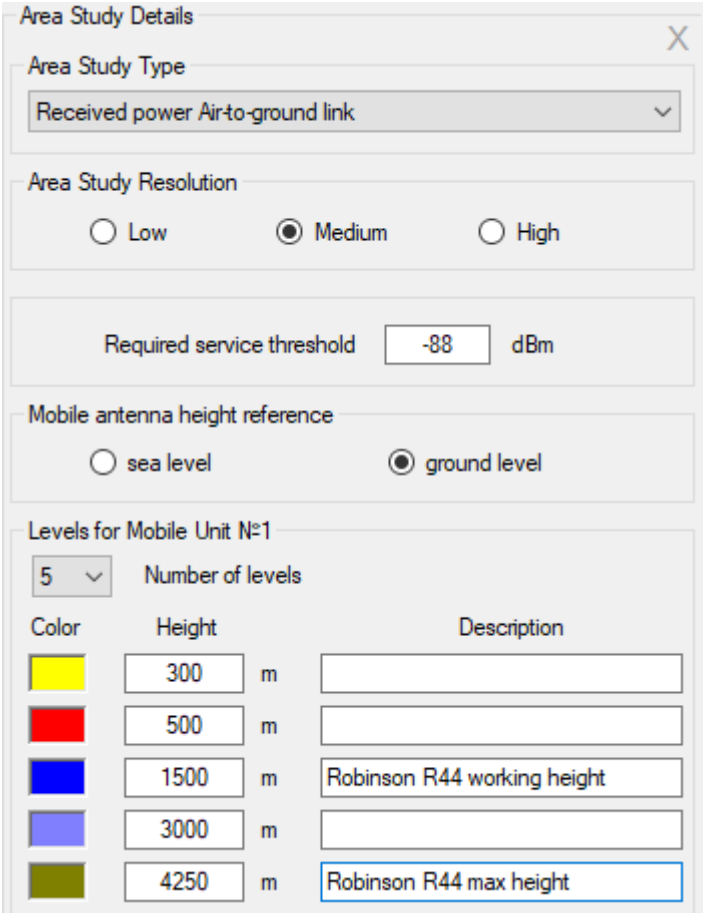


Figure 50. Received power Air-to-ground link

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.

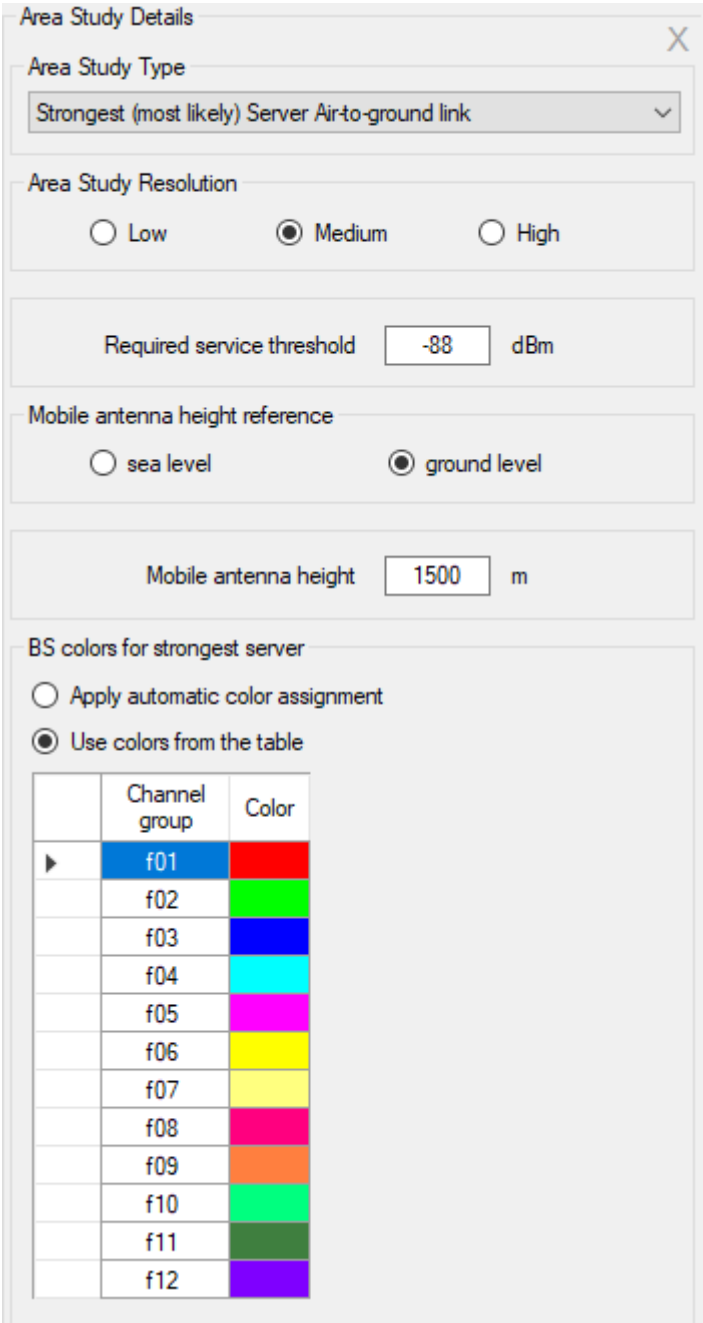


Figure 51. Strongest Server menu

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 BS sector is made from the table according to colors 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.*

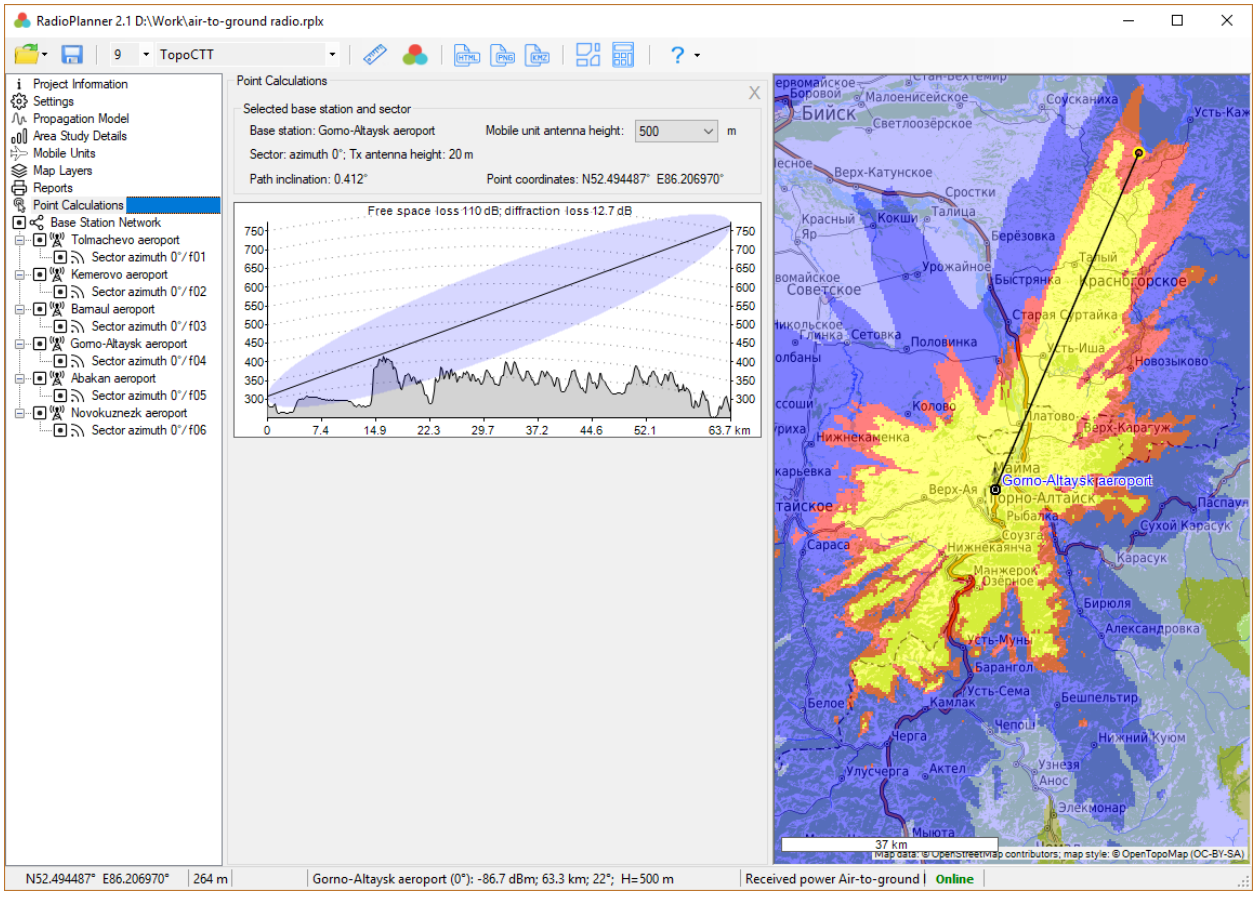


Figure 52. Point calculations for Air-to-Ground Communication example

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 basemap 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.

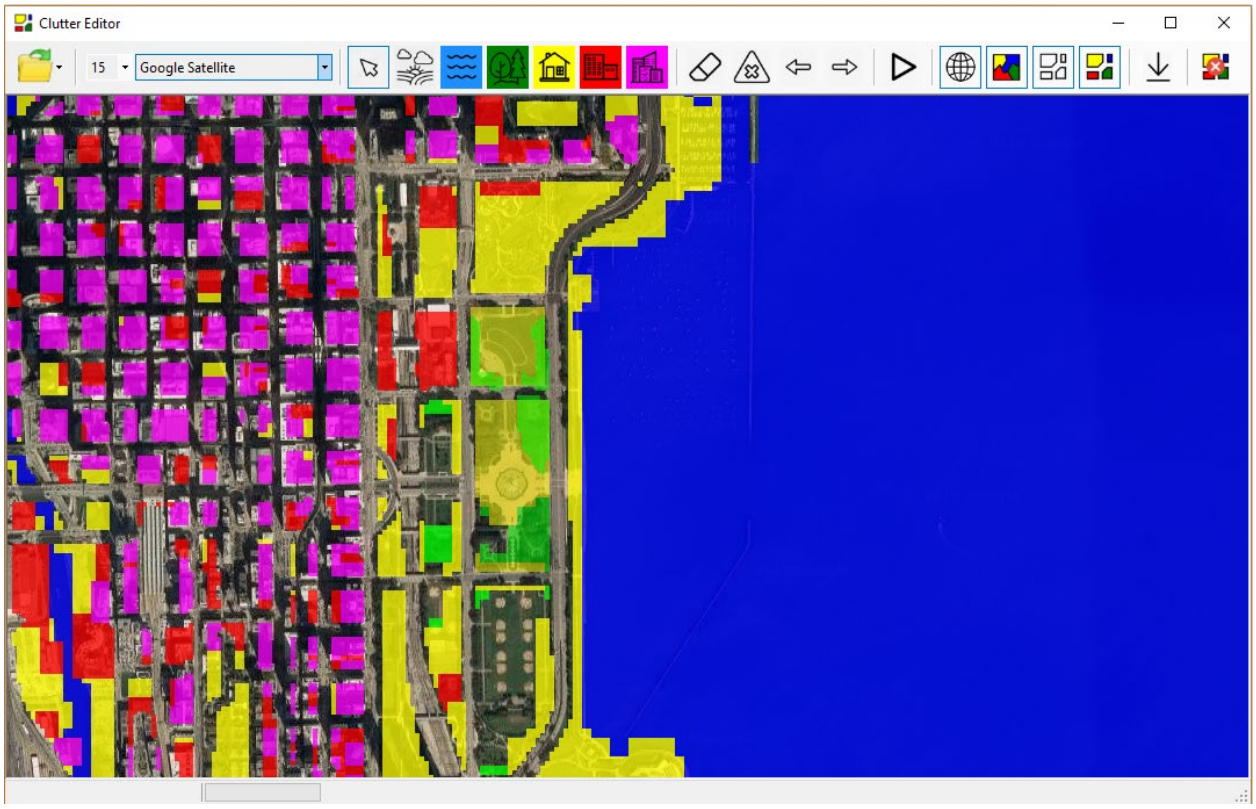


Figure 53. Clutter Editor

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**

- Basemap zoom

- Basemap;

 - 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 Basemap;

 - 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  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 basemap;

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 10 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  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.

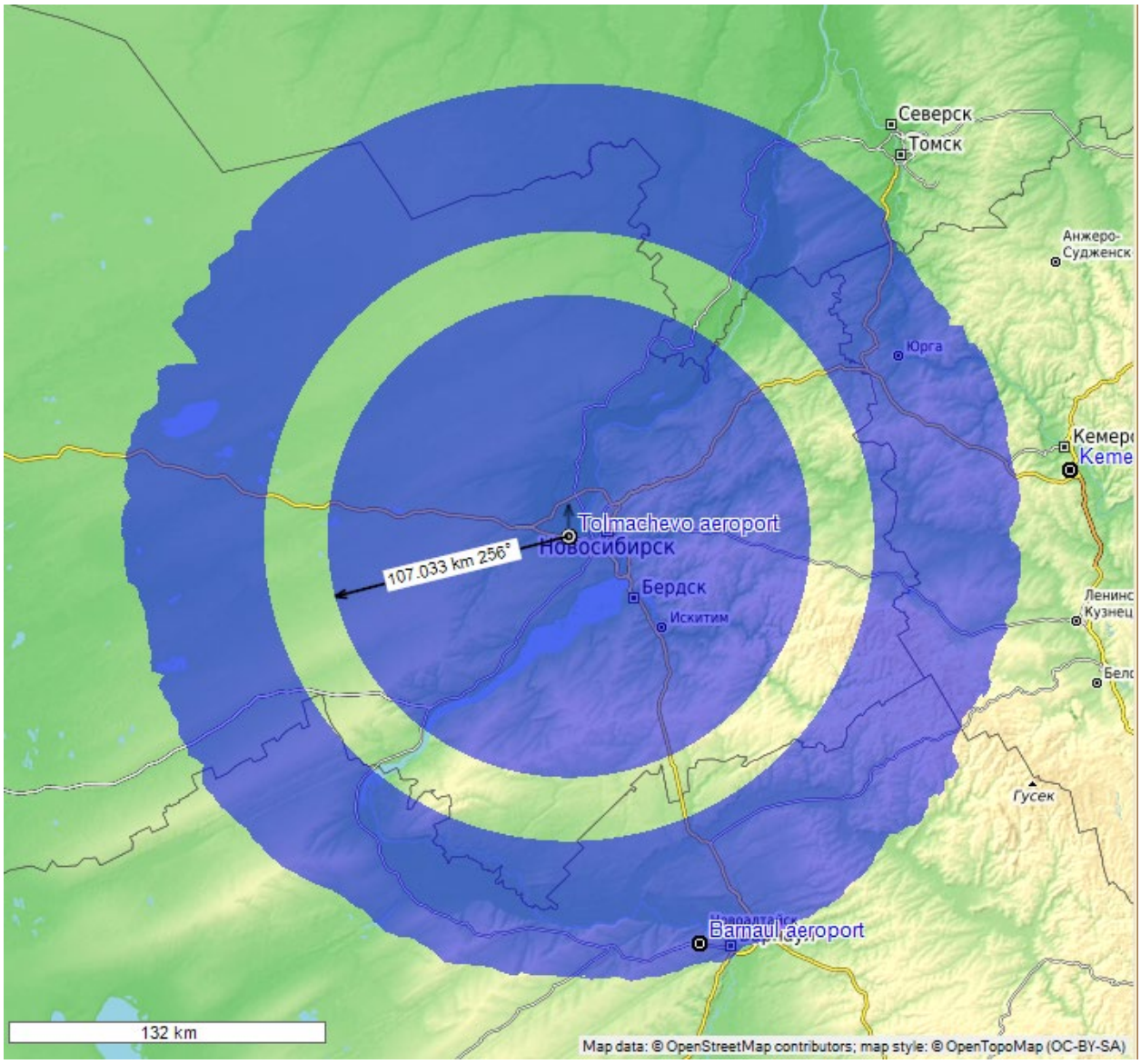
You can choose a clutter model the Default or Custom one, which will be taken into account in the calculations and displayed as a layer on the map is carried out in the “Propagation model” menu in RadioPlanner.

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

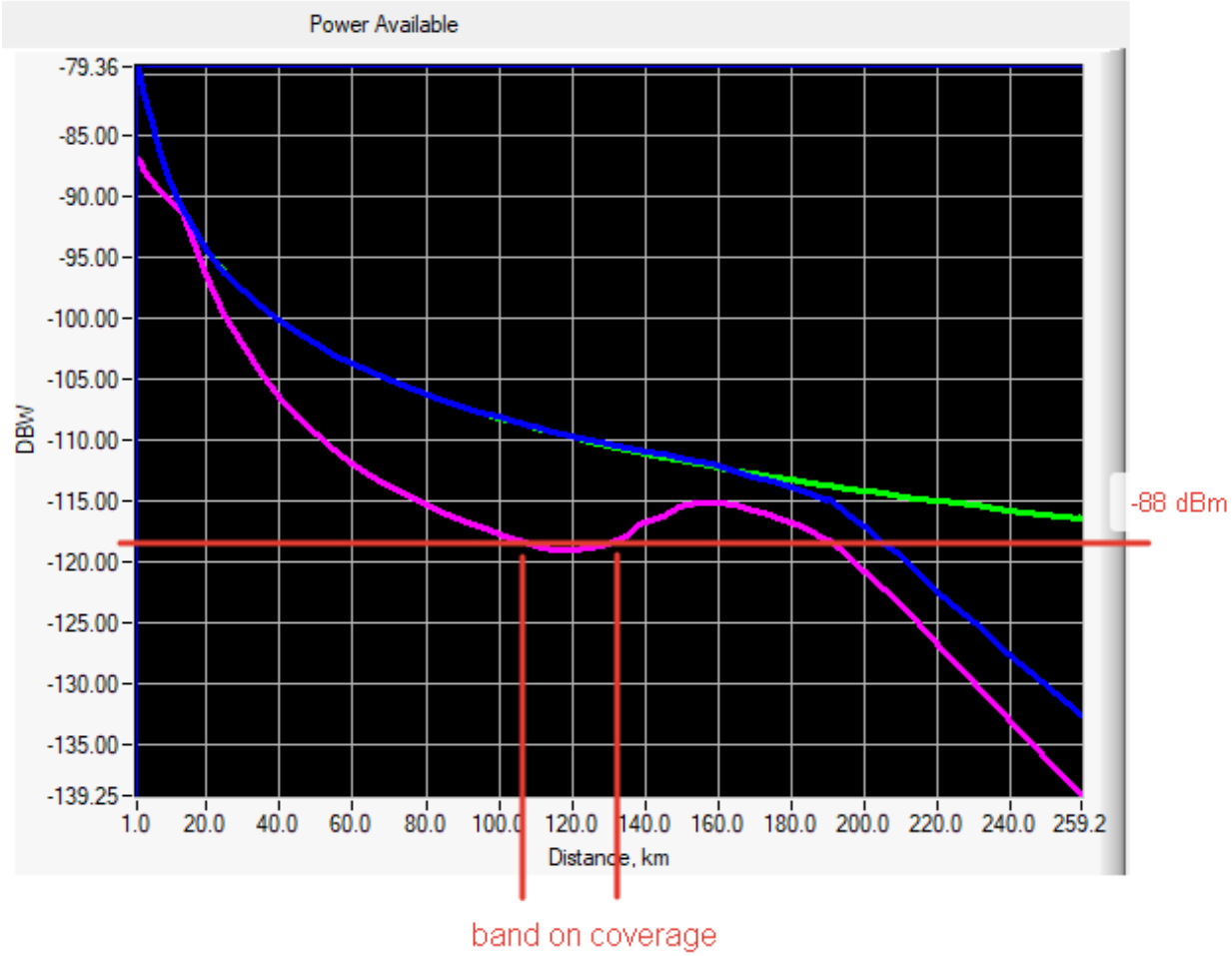
When adjusting the clutter model, it should be noted that the ITU-R P.1812-4 propagation model used in the program assumes that the clutter model is detailed with a resolution of tens of meters. Accordingly, it makes no sense to outline the individual buildings and trees - it is enough to draw building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

Appendix 1. 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, and service threshold, 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).

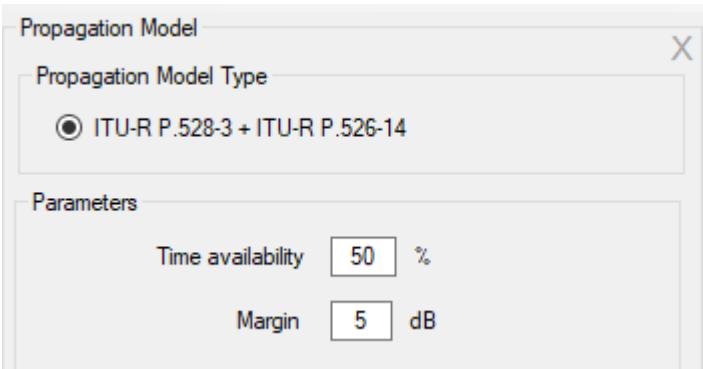


This means that in this zone the mobile station (aircraft) will be in the area of the strong influence of multipath due to reflection from the earth's surface, and time availability will decrease. Model ITU-R P.528-3 (02/2012), which is based on The IF-77 Electromagnetic Wave Propagation Model by M.E.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

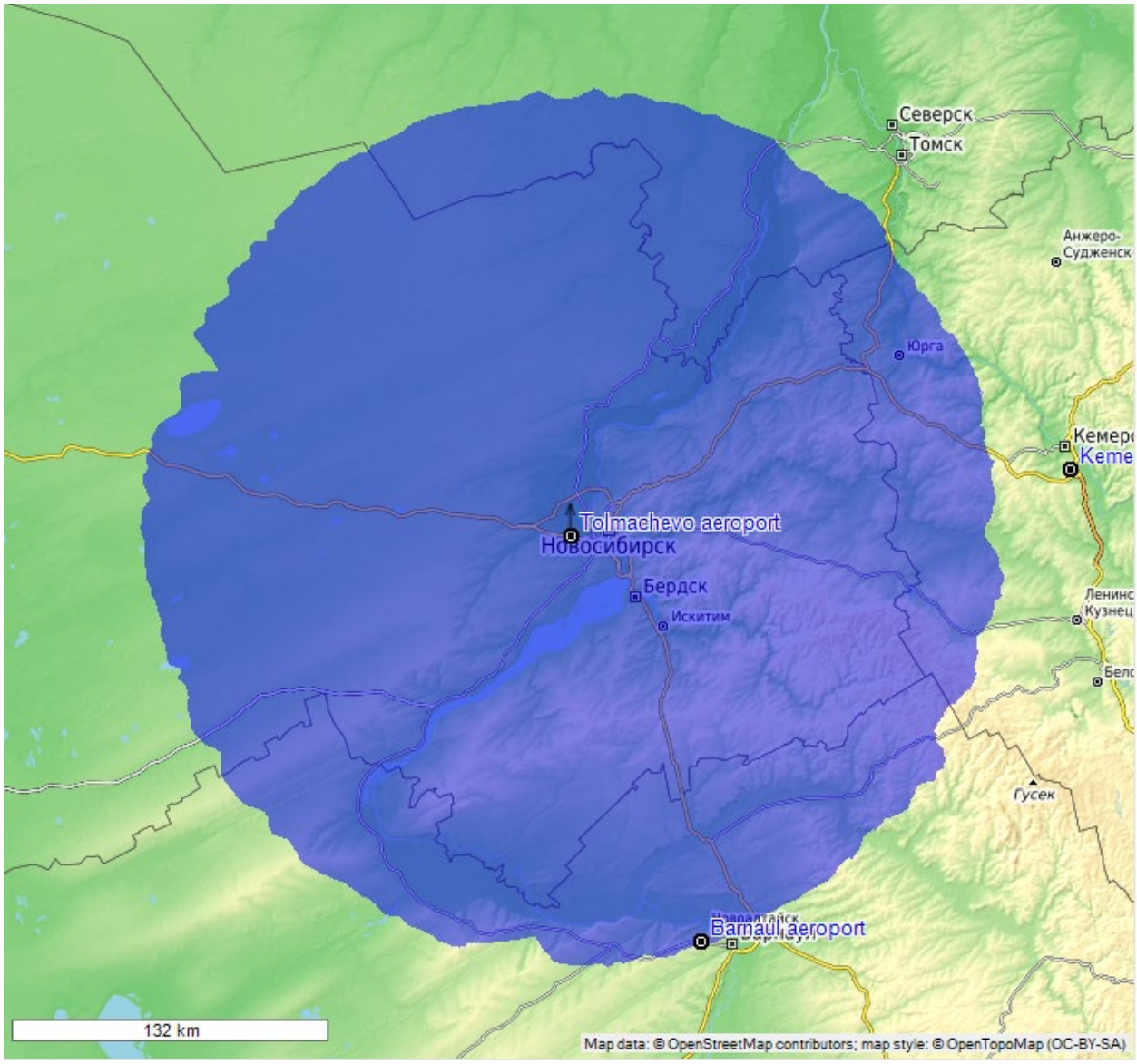


In fact, the appearance of such a band in the coverage area does not mean a significant, within 5-7 percent reduction in time availability in this area. In practice, such a decrease in time availability in a small area within the coverage area can be considered acceptable.

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

Appendix 2. Examples of calculations for various wireless networks and broadcasting networks

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