RadioTracer

Demonstration

Manual Version 1.8

mobile **connect** GmbH
Universität des Saarlandes
D-66123 Saarbrücken

URL: http://www.mobile-connect.de
Email: info@mobile-connect.de

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Contents

1 Installation **5**
1.1 Linux . . . 5
1.2 Windows . . . 6

2 Demonstration Version **7**

3 Customized Version **8**

4 General Remarks to the User-Interface **9**
4.1 Command Line Execution . . . 9
4.2 Startup File . . . 9
4.3 Script Files . . . 9
4.4 Non-Interactive Mode . . . 10
4.5 Interactive Mode . . . 10
4.6 Input with Mouse Buttons . . . 10
4.7 Attached Menus . . . 10
4.8 Mouse Cursor Shapes . . . 11
4.9 Input with Dialog Boxes . . . 11
4.10 Input with Shortcut Keys . . . 12
4.11 Subwindows . . . 14

5 Educational Version **15**

6 User-Interface Reference Manual **16**
6.1 File . . . 16
6.1.1 About . . . 16
6.1.2 Load Environment . . . 16
6.1.3 Load Configuration . . . 17
6.1.4 Load Material . . . 17
6.1.5 Store Configuration . . . 17
6.1.6 Store Custom Data . . . 18
6.1.7 Point-to-Point . . . 18
6.1.8 Point-to-Multi . . . 18
6.1.9 Multi-to-Multi . . . 19
6.1.10 Edit . . . 20
6.1.11 Exit . . . 20
6.2 View . . . 20
6.2.1 Point-to-Point . . . 20
6.2.2 Point-to-Multi . . . 21
6.2.3 Multi-to-Multi . . . 22
6.2.4 Vrml . . . 22
6.3 Window . . . 22
6.3.1 Zoom . . . 23
6.3.2 Redraw . . . 24
6.3.3 Draw Quadtree . . . 24
6.3.4 Close All . . . 24
6.4 Set . . . 24
6.4.1 Interactions . . . 24
6.4.2 Transmitter . . . 26

6.4.3 Receiver . . . 29
6.4.4 Antenna Setup Dialog . . . 33
6.4.5 Preferences . . . 36
6.4.6 Tolerances . . . 37
6.4.7 Thresholds . . . 37
6.4.8 Colors . . . 38
6.4.9 Advanced . . . 40
6.4.10 Custom . . . 41
6.5 Select . . . 41
6.5.1 Transmitter . . . 41
6.5.2 Receiver . . . 41
6.5.3 by Index . . . 42
6.5.4 Height . . . 42
6.5.5 Material . . . 42
6.6 Run . . . 42
6.6.1 Ray-Paths . . . 42
6.6.2 Field . . . 43
6.6.3 Power . . . 43
6.6.4 LOS M-Coverage . . . 44
6.6.5 DOP Coverage . . . 44
6.6.6 DOP Optimization . . . 45
6.6.7 Fresnel Clearance . . . 46
6.6.8 Script . . . 47
6.6.9 Custom . . . 47
6.7 RadioTracer . . . 47
6.8 Exit . . . 47

7 Common Dialog Boxes **48**
7.1 File Select Dialog . . . 48
7.2 Plot Setup Dialog . . . 48
7.3 PostScript Setup Dialog . . . 49

8 Output Data Visualization **51**
8.1 Power Delay Profile . . . 51
8.2 Direction of Arrival . . . 51
8.3 Power Variation . . . 52
8.4 Power Sum Variation . . . 53
8.5 Fast Variation . . . 54
8.6 Phase Variation . . . 54
8.7 Power Coverage . . . 55
8.8 Power Sum Coverage . . . 56
8.9 LOS M-Coverage . . . 57
8.10 DOP Coverage . . . 57
8.11 Fresnel Clearance Coverage . . . 58

9 RadioTracer Files **60**
9.1 General Remarks to the Format Description . . . 60
9.2 Format of Configuration Files . . . 61
9.3 Format of Environment Data Files . . . 64
9.4 Format of DOP Coverage Files . . . 66
9.5 Format of Field Files . . . 67

9.6 Format of LOS Multi-Coverage Files 67
9.7 Format of Fresnel-Coverage Files 68
9.8 Format of Material Files 68
9.9 Format of Ray-Path Files 69
9.10 Format of Script Files 69
9.11 Format of Voltage Files 70
9.12 Format of VRML Files 70
9.13 Common Non-Terminal Symbols 70
9.13.1 Antenna 71
9.13.2 Receiver 71
9.13.3 Transmitter 72
9.13.4 Miscellaneous 73
9.14 Key Words 74
9.15 Temporary Files 74

10 Hardware and Software Requirements **75**

11 Change Log **76**
11.1 Changes from v3.4.x to v3.5.0 76

12 Bugs and Features **77**

13 Copyright Information **78**
13.1 License Agreement 78
13.2 Trademarks 78

1 Installation

This section describes briefly how the **RadioTracer** demonstration version can be installed on different platforms.

1.1 Linux

Copy the compressed tar-archive file, i.e., `rtdemo_linux.tgz` to a directory of your choice. Unpacking the compressed tar-archive file with the command

```
gtar zxf rtdemo_linux.tgz
```

or

```
gunzip rtdemo_linux.tgz ; tar xf rtdemo_linux.tar
```

will produce the following directory and file structure within the chosen directory:

```
rt/rt_demo
   rt_startup.cnf
   vigo.dat
   vigo.cnf
   vigo.rts
   data.mtr
   copyright.txt
  /manual/index.html
         ...
```

You can now savely remove the archive file, it is no longer needed.
Please note the following remarks:

1. The binary executable `rt_demo` can be executed on an Intel Pentium based platform. It may be convenient for you to copy the file to some other location on your system. Possibly, you want to include the path towards **RadioTracer** into your default path list of your executables. Please consider the license file which regulates clearly under which conditions and restrictions you are allowed to use **RadioTracer**.

2. The startup configuration file `rt_startup.cnf` reflect the default values. (See startup configuration (Section 4.2) for a detailed description.)

3. `vigo.dat` is an example environment file (Section 6.1.2) .

4. `vigo.rts` is an example script file (Section 4.3) .

5. `vigo.cnf` is an example configuration file (Section 6.1.3) with some transmitter and receiver locations.

6. `data.mtr` is an example material file (Section 6.1.4) .

7. `copyright.txt` contains the license agreement.

8. `manual/index.html` is the entry point for the on-line manual in HTML-format. Please, use your favorite browser to navigate through the manual sections.

1.2 Windows

Copy the compressed archive file, i.e., `rtdemo_windows.tgz` to a directory of your choice. Unpack the compressed archive file with a program of your choice, that is able to handle this standard archive format.
The following directory and file structure will be produced:

```
rt/rt_demo.exe
   rt_startup.cnf
   vigo.dat
   vigo.cnf
   vigo.rts
   data.mtr
   copyright.txt
  /manual/index.html
         ...
```

You can now savely remove the archive file, it is no longer needed.
Please note the following remarks:

1. The binary executable `rt_demo` can be executed on an Intel Pentium based platform. It may be convenient for you to copy the file to some other location on your system. Please consider the license file which regulates clearly under which conditions and restrictions you are allowed to use **RadioTracer**.

2. The startup configuration file `rt_startup.cnf` reflect the default values. (See startup configuration (Section 4.2) for a detailed description.)

3. `vigo.dat` is an example environment file (Section 6.1.2) .

4. `vigo.rts` is an example script file (Section 4.3) .

5. `vigo.cnf` is an example configuration file (Section 6.1.3) with some transmitter and receiver locations.

6. `data.mtr` is an example material file (Section 6.1.4) .

7. `copyright.txt` contains the license agreement.

8. `manual/index.html` is the entry point for the on-line manual in HTML-format. Please, use your favorite browser to navigate through the manual sections.

2 Demonstration Version

The demonstration version of **RadioTracer** is a fully implemented version with all features enabled.
The only restrictions is: the demonstration version works *only* with the accompanying environment data file `vigo.dat`.
The demonstration version of **RadioTracer** can be downloaded for various operating systems from the web-site

`http://www.mobile-connect.de`

3 Customized Version

The on-going manual describes all features of **RadioTracer**.
Usually, **RadioTracer** is delivered as a customized version.
You would find additional information for your customized version here.

4 General Remarks to the User-Interface

RadioTracer can be run interactively (Section 4.5) and non-interactively (Section 4.4).
In the interactive mode, a graphical user interface permits user input and the different types of output data are visualized graphically. Section 6 contains a detailed description of the graphical user interface.
In non-interactive mode, the tasks to be performed by **RadioTracer** are controlled by a script file (Section 4.3), which contains the commands to guide the simulations. All output data are written to files.

4.1 Command Line Execution

The command line to execute **RadioTracer** is as follows:

```
radiotracer [OPTIONS]

  OPTIONS:  -c <file>       configuration file
            -h              this message
            -r              run non-interactively
            -s <file>       script to run
```

Possibly, the real name of your executable might vary, e.g., the demonstration version is usually distributed with the name `rt_demo`.
On a Unix platform **RadioTracer** may output certain status information to the controlling shell until the graphical user interface has been launched. No input is read from this shell. **RadioTracer** forks a new process, so the controlling shell looses control over the job.

4.2 Startup File

RadioTracer looks at startup time for a configuration file named `rt_startup.cnf` in the directory from which the program was launched. The content of this configuration file is used to overwrite the default settings. See the configuration file format (Section 9.2) for a formal description of the configuration file content. A further configuration file can be specified on the command line (Section 4.1).

4.3 Script Files

Script files are used to guide the execution of simulations without any further user interaction. They are particularly useful in non-interactive mode (Section 4.4).
Usually, a script file contains some commands to load data and afterwards some commands to run simulations. A script file is a simple ASCII text file. See the script file format (Section 9.10) for a formal description of the script file content. Note that

- a script file again may run another script file, where the nesting of script files is confined by a constant (currently 10 (ten)), exceeding this constant is an error; and
- a script file may run *any* Unix command using the syntax

  ```
  run system "command"
  ```

4.4 Non-Interactive Mode

In non-interactive mode (with command line option `-r`) no windows are opened. The program is exited after the last command in the script file (Section 4.3) has been executed or if an error occurred during execution of a command in the script file (Section 4.3). The name of the script file is provided with command line option `-s <file>`. If no such file is given, **RadioTracer** exits after initialization.

4.5 Interactive Mode

In interactive mode, **RadioTracer** presents the graphical user interface and waits for further input by the user.
Starting **RadioTracer** in interactive mode, allows for a script file to be specified as well. In that case, prior to any user interaction the script file is run. After the last instruction of the script has been executed, the simulator presents the graphical user interface. The last configuration as well as the last environment are presented to the user. Depending on the script file, possibly, some output data are available to be presented to the user.

4.6 Input with Mouse Buttons

- The *left* mouse button is used to enter two-dimensional points (x- and y-coordinates). The corresponding height (z-coordinate) for the specific input is taken from the appropriate parameter settings.
- Rectangular areas are entered by clicking with the *left* mouse button two opposite corners in any order.
- A set of points, e.g., as required for trajectories, polygons or lists, is entered by consecutive *left* mouse button clicks.
- The *right* mouse button is used either to abort input or to finish input.
- An input can always be aborted *before* the first point is entered pressing the *right* mouse button. In some cases—for instance, while entering a rectangular area—the input can be aborted after the first point has been entered already.
- Multi-point input, e.g., entering a trajectory or list, is *finished* with a *right* mouse button click.

4.7 Attached Menus

If a mouse button is pressed within the main window an attached menu is opened at the cursor position:

Left button:	Set Menu (Section 6.4)
Left button with shift:	Zoom Menu (Section 6.3.1)
Middle button:	Window Menu (Section 6.3)
Right button:	File Menu (Section 6.1)

4.8 Mouse Cursor Shapes

The shape of the mouse cursor indicates which type of input is required:

Arrow: Menu or Dialog input is requested.

Target: Input of a point, of an element of a list of points, or a selection of an item is requested using the left mouse button. The operation can be aborted or is finished with a right mouse button click.

Dotted Box: Input of a rectangular area is requested. Two opposite corners should be selected with the left mouse button. The operation can be aborted with a right mouse button click.

Watch: No input is possible, **RadioTracer** is busy.

Additionally, a status line at the very bottom of the main window indicates which type of input is expected. Generally, right mouse button click sets the state to menu mode (cursor shape arrow) aborting or finishing any other operation.

4.9 Input with Dialog Boxes

A dialog box is either presented within an already opened window or it may appear as a new window. Usually, all other menus are disabled until the dialog box has been exited.
All input is checked after the dialog box has been exited through the **[Ok]** button. In some dialog boxes the exit buttons are labeled differently, e.g., **[Load]**, **[Store]**, or **[Apply]** etc. If an invalid entry is detected, the dialog box is reopened and the user is requested to correct the entry. Exiting a dialog box through the **[Cancel]** button restores all values to the settings prior to opening the dialog besides those confirmed through an exit button in an subordinary dialog box.
Note that depending on the current window layout, certain dialog boxes may appear hidden behind other windows. This is especially true for requests-for-confirmation which are usually displayed within the main window.

4.10 Input with Shortcut Keys

Certain menu functions are directly accessible through shortcut keys. The following table summarizes the assigned keys in alphabetical order.

Ctrl-A	About Menu	(Section 6.1.1)
Ctrl-D	Run DOP Coverage	(Section 6.6.5)
Ctrl-C	Exits **RadioTracer** immediately.	(Section 6.1.11)
Ctrl-E	Run Field	(Section 6.6.2)
Ctrl-F	Run Fresnel Clearance	(Section 6.6.7)
Ctrl-G	Grab current window	(Section 4.11)
Ctrl-L	Run LOS M-Coverage	(Section 6.6.4)
Ctrl-O	Run DOP Optimization	(Section 6.6.6)
Ctrl-P	Run Power	(Section 6.6.3)
Ctrl-R	Run Ray-Paths	(Section 6.6.1)
Ctrl-S	Run Script	(Section 6.6.8)
A	About Menu	(Section 6.1.1)
C	Load Configuration	(Section 6.1.3)
E	Load Environment	(Section 6.1.2)
M	Load Material	(Section 6.1.4)
R	Store Receiver Configuration	(Section 6.1.5)
S	Store Configuration	(Section 6.1.5)
T	Store Transmitter Configuration	(Section 6.1.5)
Z	Zoom Reset	(Section 6.3.1)
a	Receiver Area	(Section 6.4.3)
b	Select Material	(Section 6.5.5)
c	Set Colors Environment	(Section 6.4.8)
h	Select Height	(Section 6.5.4)
i	Interactions	(Section 6.4.1)
l	Zoom List	(Section 6.3.1)
m	Receiver Modify	(Section 6.4.3)
n	New Center	(Section 6.3.1)
p	Receiver Parameters	(Section 6.4.3)
q	Close All	(Section 6.3.4)
r	Receiver Region	(Section 6.4.3)
s	Select Transmitter	(Section 6.5.1)
t	Receiver Trajectory	(Section 6.4.3)
u	Redraw	(Section 6.3.2)
z	Zoom Area	(Section 6.3.1)
1	Transmitter Point	(Section 6.4.2)
2	Transmitter Area	(Section 6.4.2)
3	Transmitter List	(Section 6.4.2)
4	Transmitter Point to List	(Section 6.4.2)
5	Transmitter Area to List	(Section 6.4.2)
6	Transmitter Modify	(Section 6.4.2)
7	Transmitter Parameters	(Section 6.4.2)
8	Transmitter Set	(Section 6.4.2)
.	Receiver Point	(Section 6.4.3)
+	Zoom In	(Section 6.3.1)
-	Zoom Out	(Section 6.3.1)
Cur-Up	scroll upwards	
Cur-Down	scroll downwards	
Cur-Left	scroll to the left	
Cur-Right	scroll to the right	

4.11 Subwindows

RadioTracer displays the output data of the simulations in various subwindows. These subwindows have a menu bar with the following buttons:

About Displays Copyright Information (Section 13) and License Agreement (Section 13.1) in a new window.

Update Displays a dialog box with additional information about the data presented in the subwindow. Certain parameters of the display can be changed through this dialog box. All input to **RadioTracer** is blocked until the dialog has been exited. The dialog box or subsequent dialog boxes available through additional buttons are used to modify the visualization mode of the subwindow, to export the content of the subwindow into a file, or to set certain parameters.

Close (Not available on Windows platforms.) The subwindow is closed. The main menu entry Close All (Section 6.3.4) closes all subwindows.

Note that while a dialog box disabling the menus is open, no subwindow can be closed.
The content of any window can be grabbed and stored into a file. There is no menu entry for grabbing. Whenever the shortcut key `Ctrl-G` is pressed, the window content of the window containing the cursor is stored into a file with name `grabNNN.ppm` in ppm-format, where the number `NNN` is automatically incremented each time a window content is grabbed. Note that grabbing works directly on the screen, i.e., if another window is partially overlapping the active window, the overlap is stored into the file.

5 Educational Version

The educational version of **RadioTracer** implements almost all features. However, certain restrictions concerning the sizes of the simulations that can be worked with are introduced:

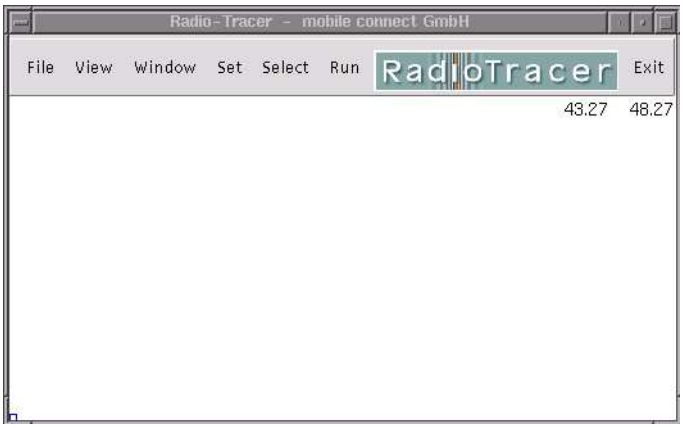
- The number of transmitters is confined to 4, respectively 8 for DOP and LOS-M-coverage maps.
- A receiver of type trajectory is confined to straight lines. If a polyline is entered, only its first segment is used.
- A receiver of type trajectory is confined to have at most 40 samples. Longer trajectories are cut.
- A receiver of type area or region is confined to have at most 10 times 10 samples.
- The number of building blocks is confined to 30.
- Only some theoretical antenna radiation patterns can be selected.

Note that in a full version of **RadioTracer** none of the above restrictions apply, the sizes of the simulations are only limited by the memory available on the simulation platform (see the hardware requirements (Section 10) for more detailed information).
Moreover, in the educational version the following restrictions concerning the user interface apply:

- The script files (Section 4.3) cannot be nested.
- The binary file formats are not available.

6 User-Interface Reference Manual

This section describes the menu structure of **RadioTracer** in left-to-right and top-to-bottom order.



6.1 File

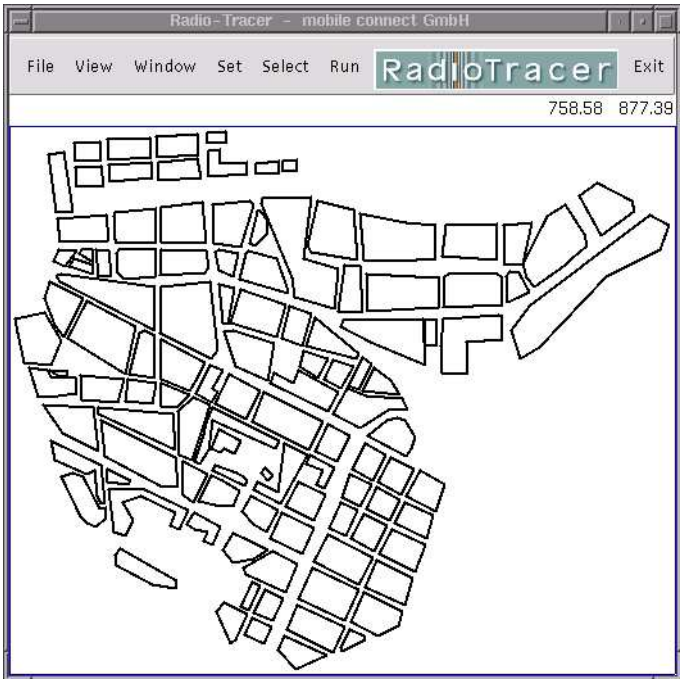
The file menu is used to access data in files, e.g., to load or store configurations or environments, or to visualize data from files.

6.1.1 About

(Shortcut key: A). Displays Copyright Information (Section 13) and License Agreement (Section 13.1) in a new window.

6.1.2 Load Environment

(Shortcut key: E). Loads an environment, i.e., the geometric data, from a file (extension `.dat`). The current environment is replaced by the new environment. The current configuration is not changed. See the environment file format (Section 9.3) for a formal description of the environment file content.
The file name is entered through the file select dialog (Section 7.1). The selected file name is maintained and will be presented in a subsequent load or store command as initial dialog value. The file name is part of a complete configuration file.
After having loaded the environment, the building blocks are displayed in the main window in a two-dimensional top-view. In the upper right corner of the window the position in world coordinates of the current cursor position is displayed. The heights of the entities can be inspected through the height menu (Section 6.5.4).



6.1.3 Load Configuration

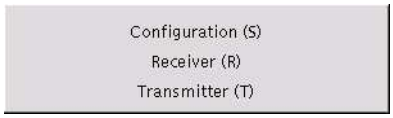
(Shortcut key: C). Loads a configuration from a file (extension `.cnf`). The file may contain only a partial configuration, e.g., only a transmitter specification. The current environment is not changed. If the configuration file has not the correct format or the entries are invalid, only the erroneous entries are discarded, the correctly found entries in the file will have effect. In such a case, a warning message is shown to the user. See the configuration file format (Section 9.2) for a formal description of the configuration file content.
The file name is entered through the file select dialog (Section 7.1). The selected file name is maintained and will be presented in a subsequent load or store command as initial dialog value. The file name is part of a complete configuration file.

6.1.4 Load Material

(Shortcut key: M). Loads the material properties from a file (extension `.mtr`).
The file name is entered through the file select dialog (Section 7.1). The selected file name is maintained and will be presented in a subsequent load command as initial dialog value. The file name is part of a complete configuration file.

6.1.5 Store Configuration

A configuration file is an ASCII file that can be edited with a text editor (Section 6.1.10). A configuration file need not to be complete. See the configuration file format (Section 9.2) for a formal description of the configuration file content.



Configuration (Shortcut key: S). Stores the complete configuration to a file (extension `.cnf`). The file name is entered through the file select dialog (Section 7.1). The selected file name is maintained and will be presented in a subsequent load or store command as initial dialog value. The file name is part of a complete configuration file.

Receiver (Shortcut key: R). Stores only the configuration of the receiver data to a file (extension `.cnf`). The file name is entered through the file select dialog (Section 7.1). The selected file name is maintained and will be presented in a subsequent load or store command as initial dialog value. The file name is part of a complete configuration file.

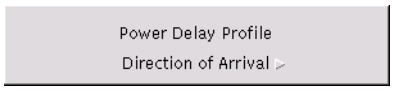
Transmitter (Shortcut key: T). Stores only the configuration of the transmitter data to a file (extension `.cnf`). The file name is entered through the file select dialog (Section 7.1). The selected file name is maintained and will be presented in a subsequent load or store command as initial dialog value. The file name is part of a complete configuration file.

6.1.6 Store Custom Data

Depending on the version of **RadioTracer**, certain data can be stored customized data format. See the description of the customized version (Section 3).

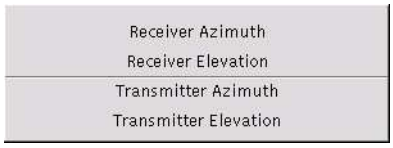
6.1.7 Point-to-Point

Point-to-Point means that electromagnetic data between *one* transmitter and *one* receiver is visualized. The indices of the transmitter and the receiver to be used must be selected previously through the Select Menu (Section 6.5).



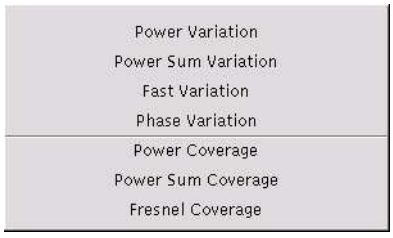
Power Delay Profile See view power delay profile (Section 6.2.1) for a more detailed description of this menu entry. The only difference to the view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. The file name is entered through the file select dialog (Section 7.1).

Direction of Arrival



See view direction of arrival (Section 6.2.1) for a more detailed description of these menu entries. The only difference to a view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. A file name is entered through the file select dialog (Section 7.1).

6.1.8 Point-to-Multi



Power Variation See view power variation (Section 6.2.2) for a more detailed description of this menu entry. The only difference to the view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. The file name is entered through the file select dialog (Section 7.1).

Power Sum Variation See view power sum variation (Section 6.2.2) for a more detailed description of this menu entry. The only difference to the view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. The file name is entered through the file select dialog (Section 7.1).

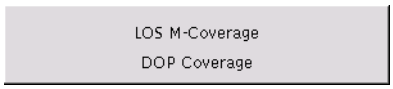
Fast Variation See view fast variation (Section 6.2.2) for a more detailed description of this menu entry. The only difference to the view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. The file name is entered through the file select dialog (Section 7.1).

Phase Variation See view phase variation (Section 6.2.2) for a more detailed description of this menu entry. The only difference to the view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. The file name is entered through the file select dialog (Section 7.1).

Power Coverage See view power coverage (Section 6.2.2) for a more detailed description of this menu entry. The only difference to the view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. The file name is entered through the file select dialog (Section 7.1).

Power Sum Coverage See view power sum coverage (Section 6.2.2) for a more detailed description of this menu entry. The only difference to the view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. The file name is entered through the file select dialog (Section 7.1).

6.1.9 Multi-to-Multi



LOS M-Coverage See view LOS M-coverage (Section 6.2.3) for a more detailed description of this menu entry. The only difference to a view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. A file name is entered through the file select dialog (Section 7.1).

DOP Coverage See view DOP coverage (Section 6.2.3) for a more detailed description of this menu entry. The only difference to a view menu entry is that rather than the data available from the last simulation run the data taken from a file is visualized. A file name is entered through the file select dialog (Section 7.1).

6.1.10 Edit

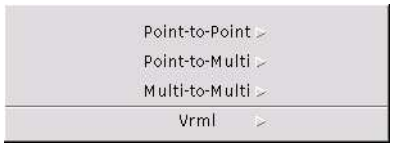
The edit menu is used to launch a text editor which allows to manipulate the ASCII data files of **RadioTracer**. The command line to start the editor is set in the advanced settings (Section 6.4.9). The file name is entered through the file select dialog (Section 7.1).
If a text file is changed, the modifications *do not* have immediate effect. Rather, the file has to be *re-loaded* through the appropriate menu entry.

6.1.11 Exit

Exits **RadioTracer** immediately.

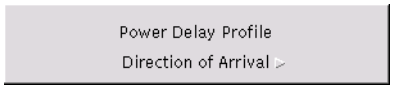
6.2 View

The view menu is used to directly visualize data from simulation runs (Section 6.6). A simulation stores its output data in temporary files (Section 9.15) which are held until the next simulation run or until the program is terminated. If a necessary temporary file is not available (for instance, because the simulation run has not been performed) or if the receiver type does not match, an error message is shown.
The menu groups the entries according to the number of transmitters and receivers that are invoked to produce the output. The output is presented for the currently selected (see Section 6.5) transmitters and receivers.



6.2.1 Point-to-Point

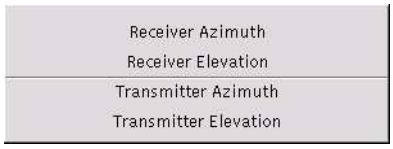
Point-to-Point means that electromagnetic data between *one* transmitter and *one* receiver is visualized. The indices of the transmitter and the receiver to be used must be selected previously through the Select Menu (Section 6.5).



Power Delay Profile The power delay profile plot shows the arrival times in [ns] (nanoseconds) of the different ray-paths versus its received power in [dBm] between the selected transmitter and the selected receiver as being computed by the last Run Field (Section 6.6.2) command. The times are given relative to the arrival time of the line-of-sight, i.e., if the line-of-sight path exists, its arrival time is 0.0. A more detailed description is given in Section 8.1.

Direction of Arrival The direction-of-arrival plot shows the arrival angles in [deg] of the different ray-paths between the selected transmitter and the selected receiver as being computed by the last Run Field (Section 6.6.2) command. The arrival angles can be inspected both in azimuth and elevation plane. Additionally, its contribution to the received power in [dBm] is

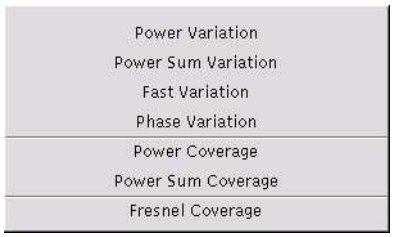
indicated. If the line-of-sight path exists, its arrival component is highlighted. A more detailed description is given in Section 8.2.



- Receiver Azimuth
- Receiver Elevation
- Transmitter Azimuth
- Transmitter Elevation

6.2.2 Point-to-Multi

Point-to-Multi means that electromagnetic data between *one* transmitter and *a set of* receivers, i.e., a trajectory, an area, or a region is visualized. The index of the transmitter to be used must be selected previously through the Select Menu (Section 6.5).



Power Variation Displays in a new window the power variation plot which shows the received power in [dBm] obtained as the sum of the received powers of the individual ray-paths along the trajectory for the selected transmitter as being computed by the last Run Power (Section 6.6.3) command. A more detailed description is given in Section 8.3. The receiver must be of type trajectory.

Power Sum Variation Displays in a new window the power sum variation plot which shows the received power in [dBm] obtained as the complex sum of the received powers of the individual ray-paths for each sampling point along the trajectory for the selected transmitter as being computed by the last Run Power (Section 6.6.3) command. A more detailed description is given in Section 8.4. The receiver must be of type trajectory.

Fast Variation Displays in a new window the fast variation plot which shows the difference in [dBm] between the power variation and the power sum variation along the trajectory for the selected transmitter as being computed by the last Run Power (Section 6.6.3) command. A more detailed description is given in Section 8.5. The receiver must be of type trajectory.

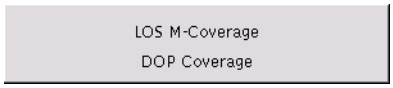
Phase Variation Displays in a new window the phase variation plot which shows the phase in [rad] along the trajectory for the selected transmitter as being computed by the last Run Power (Section 6.6.3) command. A more detailed description is given in Section 8.6. The receiver must be of type trajectory.

Power Coverage Displays in a new window the coverage map of the received power (complex sum) in [dBm] for the selected transmitter as being computed by the last Run Power (Section 6.6.3) command. If the currently loaded environment coincides with the one used to compute the coverage map, the environment is drawn into the map. A more detailed description is given in Section 8.7. The receiver must be of type area or region.

Power Sum Coverage Displays in a new window the coverage map of the received power (power sum) in [dBm] for the selected transmitter as being computed by the last Run Power (Section 6.6.3) command. If the currently loaded environment coincides with the one used to compute the coverage map, the environment is drawn into the map. A more detailed description is given in Section 8.8. The receiver must be of type area or region.

6.2.3 Multi-to-Multi

Multi-to-Multi means that electromagnetic data between *a set of* transmitters and *a set of* receivers, i.e., an area or a region, is visualized.



LOS M-Coverage Displays in a new window the line-of-sight multi-coverage map as being computed by the last execution of the Run LOS M-Coverage (Section 6.6.4) command. A more detailed description is given in Section 8.9.

DOP Coverage Displays in a new window the DOP (dilution-of-precision) coverage map as being computed by the last execution of the Run DOP Coverage (Section 6.6.5) command. A more detailed description is given in Section 8.10.

6.2.4 Vrml

This menu is only available with the VRML-package of **RadioTracer**.

- **Without Rays**

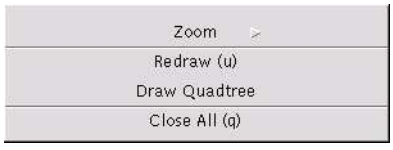
  Starts the VRML-Viewer with the current environment.

- **With Rays**

  Starts the VRML-Viewer with the current environment including the ray-paths as computed by the last Ray Path Computation (Section 6.6.1).

6.3 Window

The window menu is used to change the visualization mode within the main window of **RadioTracer** (e.g., perform a zoom) and to manipulate other windows having been opened during the interactive session.



6.3.1 Zoom

Zoom Reset **(Shortcut key: Z).** If there is a zooming area (see below in Section 6.3.1) with label `reset` defined, the environment (buildings, transmitters and receivers) is displayed in such a way that the zooming area is entirely visible in the center of the window. If there is no such zooming area defined the environment is displayed such that it fits completely into the window.

Zoom Out **(Shortcut key: -).** Zooms out according to the Zoom Factor (see advanced settings in Section 6.4.5).

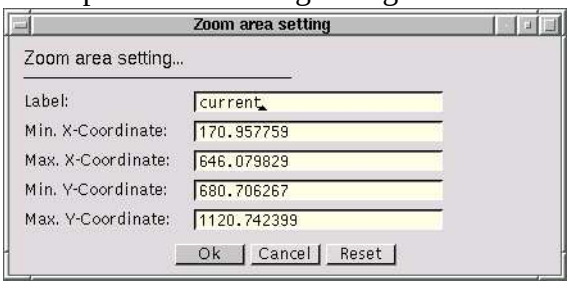
Zoom In **(Shortcut key: +).** Zooms in according to Zoom Factor (see advanced settings in Section 6.4.5).

Zoom Area **(Shortcut key: z).** Zooms into a rectangular area selected by specifying the two corners with left mouse button clicks. The operation can be aborted with a right mouse button click.

Zoom List **(Shortcut key: l).** Allows to manage an ordered list of rectangles as zooming areas. Each rectangle has a user definable label. The labels are used to sort the list. If the aspect of the current window does not match the aspect of a zooming area, the zooming takes place in such a way that the entire zooming area is visible and justified in the center of the window.

Zoom: Zooms to the selected zooming area.

Edit: With the help of the following dialog



the label and the coordinates of the selected zooming area can be edited.

Current: Edits the current zooming area, note that the label has to be changed to a string different from `current`.

Delete: Deletes the selected zooming area from the list.

Clear: Clears the entire zoom list.

Cancel: Leaves the dialog without changing the current view of the window. However, all changes in the zoom list have taken place.

Two labels have a special meaning: the label `reset` defines the zooming area which is used in the Zoom Reset (see above in Section 6.3.1) command; the label `current` is automatically used for the currently visible area within the window, the label `current` cannot be used to label a zooming area.

The zoom list is part of a complete configuration file. If a configuration file containing a zoom list is loaded, the zooming areas are added to the current zoom list.

New Center **(Shortcut key: n).** Moves the center of the display to the point selected with left mouse button click. The old center is marked by a red coordinate system. The operation can be aborted with a right mouse button click.

6.3.2 Redraw

(Shortcut key: u). Redraws the main window.

6.3.3 Draw Quadtree

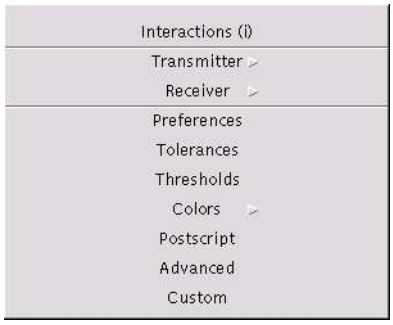
Visualizes the quadtree of the current environment. The default color is green, see Color Menu (Section 6.4.8) for possible user settings.

6.3.4 Close All

(Shortcut key: q). Closes all subwindows currently opened. Note that all local settings of these windows get lost.

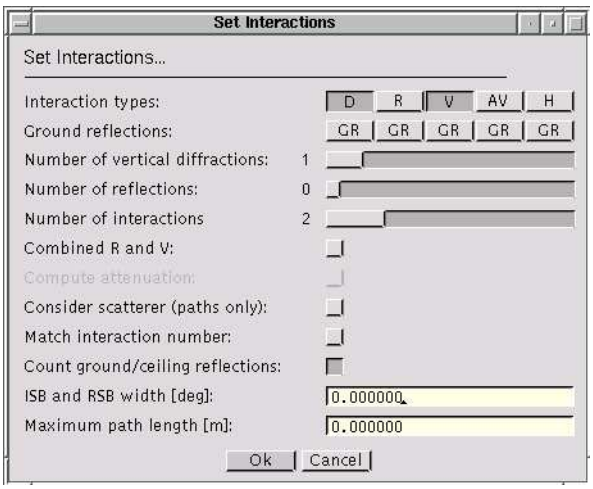
6.4 Set

The menu set is used to configure all settings of **RadioTracer** during an interactive session. The actual configuration can be stored completely or partially through the Store Configuration (Section 6.1.5) command. Instead of setting the parameters interactively, configuration files can be loaded through the Load Configuration (Section 6.1.3) command.



6.4.1 Interactions

(Shortcut key: i). The interactions dialog allows to set all relevant data for the ray-path search algorithm, i.e., which types of ray-paths an to which length the ray-paths are search for.



- **Interaction types and Ground reflections:**

  D Search for line-of-sight ray-paths.

  R Search for ray-paths with reflections.

  V Search for ray-paths with vertical diffraction.

  AV Search for ray-paths with adjacent vertical diffraction.
  (Only first order adjacent vertical diffraction is considered, i.e., ray-paths with diffraction on adjacent vertical edges where the one is directly visible by the transmitter and the other one is directly visible by the receiver, or vice versa.)

  H Search for ray-paths with horizontal diffraction.
  (Only first order horizontal diffraction is considered, i.e., ray-paths with diffraction on horizontal edges directly visible by transmitter or receiver, respectively.)

  AH Search for ray-paths with adjacent horizontal diffraction.
  (Only first order adjacent horizontal diffraction is considered, i.e., ray-paths with diffraction on adjacent horizontal edges where one is directly visible by the transmitter and the other one is directly visible by the receiver, or vice versa.)

  GR Search for ray-paths with reflection on the ground (and on the ceiling in case of indoor environment).

- **Number of vertical diffractions:**

  Search for ray-paths with at most that many vertical diffractions. Note, that actually the minimum of **Number of Vertical Diffractions** and **Number of Interactions** is used to determine the maximum ray-path length. The value must be positive.

- **Number of reflections:**

  Search for ray-paths with at most that many reflections. Note, that actually the minimum of **Number of Reflections** and **Number of Interactions** is used to determine the maximum ray-path length. The value must be positive.

- **Number of interactions:**

  Search for ray-paths with at most that many interactions. This is especially useful to confine the ray-path length when combined reflection and diffraction is set. The value must be positive.

- **Combined R and V:**

  The flag specifies whether to search for ray-paths with both reflections and vertical diffractions. The ray-path length is limited by the **Number of Interactions**.

- **Compute attenuation:**

  The flag specifies whether to compute the distances the ray-paths passes through attenuating media (e.g., trees).

- **Consider scatterer:**

  The flag specifies whether to search for ray-paths towards scatterer (e.g., trees). Only first order effects are considered.

- **Match interaction number:**

  The flag specifies whether to search only for ray-paths that match exactly the given **Number of Interactions**. If this flag is not set, all ray-paths up to the maximum length as given in **Number of Interactions** are searched for.

- **Count ground/ceiling reflections:**

  The flag specifies whether ground or ceiling reflections are counted as interaction while determining the length of the ray-path. This flag is only used when matching the interaction number is enabled.

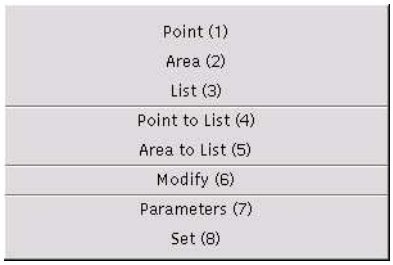
- **ISB and RSB width:**

  Specifies the maximum width of the ISB (incident shadow boundary) and the RSB (reflection shadow boundary) after a vertical diffraction that should be considered during the ray-path search. A value of 0.0 means no limitation of the boundary, i.e., all ray-paths are searched for. The value must be positive, the angle is entered in [deg].

- **Maximum path length:**

  Specifies the maximum length of a ray-paths that should be considered during the ray-path search. A value of 0.0 means no limitation of the length, i.e., all ray-paths are searched for. The value must be positive, the length is entered in [m].

6.4.2 Transmitter



- **Point**

  (Shortcut key: 1). Allows to sets a single transmitter as a point. The height of the transmitter is set to the value as specified in the Parameter Settings (see below). The operation can be aborted with a right mouse button click.

- **Area**

  (Shortcut key: 2). Allows to sets a single transmitter as a rectangular area. The actual location of the transmitter is computed as the center of the area. The height of the transmitter is set to the value as specified in the Parameter Settings (see below). The operation can be aborted with a right mouse button click.

- **List**

  (Shortcut key: 3). Allows to set a list of transmitters. The transmitters are entered as the corners of a polyline. The polyline is displayed during the interaction. The height of the transmitters is set to the value as specified in the Parameter Settings (see below). The input is finished with a right mouse button click or the operation can be aborted with a right mouse button click before the first point is entered.

- **Point to List**

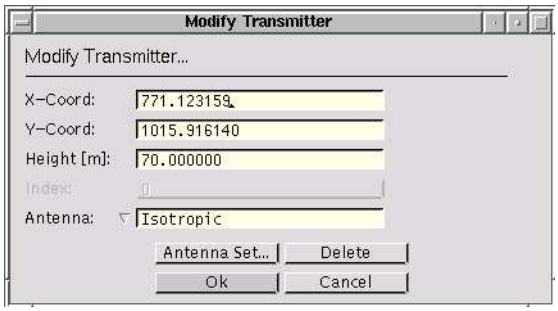
  (Shortcut key: 4). Allows to add a single transmitter as a point to the list of transmitters. The operation can be aborted with a right mouse button click.

- **Area to List**

  (Shortcut key: 5). Allows to add a single transmitter as a rectangular area to the list of transmitters. The operation can be aborted with a right mouse button click.

- **Modify**

  (Shortcut key: 6). Allows to modify or to delete the selected transmitter. If currently no transmitter is selected, a selection is requested. In that case, the operation can be aborted with a right mouse button click.



  – X-Coord:

  – Y-Coord:

    Sets the new location of the transmitter in coordinates of the environment.

  – X-Min:

  – Y-Max:

  – X-Min:

  – Y-Max:

    Sets the new rectangular area of the transmitter in coordinates of the environment. These entries are only available if the selected transmitter is of type area. Note that it is not forbidden to place the actual location of the transmitter outside the area.

  – Height [m]:

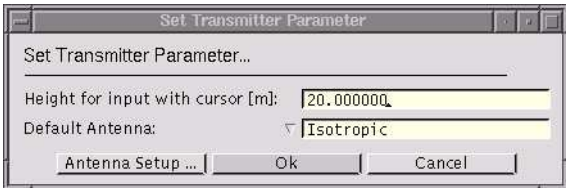
    Sets the new height of the transmitter. The height must be larger than 0.0, the value is entered in [m].

– Antenna:

Allows to change the antenna. The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings. Note that once the antenna has been changed through the antenna setup dialog, the modification is valid even if the dialog is left through the **[Cancel]** button.

- **Parameters**

(Shortcut key: 7). Sets the default parameters used during placement of the transmitter with mouse cursor input.



– Height for input with cursor [m]:

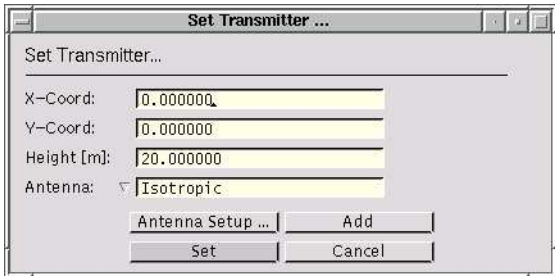
Sets the height in for interactive placement of the transmitter. The height must be larger than 0.0, the value is entered in [m].

– Default Antenna:

Allows to select the default antenna for interactive placement of the transmitter. The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings.

- **Set**

(Shortcut key: 8). Allows to set a single transmitter or to add the transmitter to the list of transmitters.



– X-Coord:

– Y-Coord:

Specifies the location of the transmitter in coordinates of the environment.

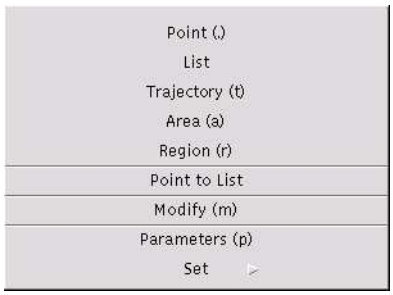
– Height [m]:

Sets the height of the transmitter position. The height must be larger than 0.0, the value is entered in [m].

– Antenna:

Allows to select the antenna for the transmitter. The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings.

6.4.3 Receiver



- **Point**

  (Shortcut key: .). Allows to set a single receiver as a point. The height of the receiver is set to the value as specified in the Parameter Settings (see below). The operation can be aborted with a right mouse button click.

- **Trajectory**

  (Shortcut key: t). Allows to set the receiver as a trajectory (polyline). The height of the receiver points along the trajectory and the sampling rate for the trajectory are set to the values as specified in the Parameter Settings (see below). The input is finished with a right mouse button click. The operation can be aborted with a right mouse button click before the second input point is entered.

- **Area**

  (Shortcut key: a). Allows to set the receiver as a rectangular area by specifying two opposite corners. The operation can be aborted with a right mouse button click before the second input point or in the subsequent dialog box.

  In the subsequently displayed dialog box the additional parameters are set (see Modify below).

- **Region**

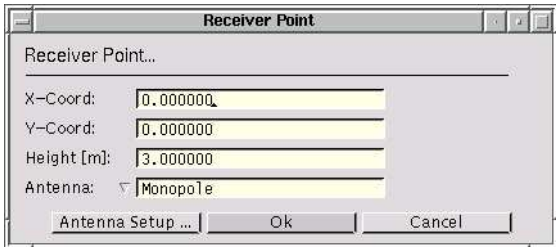
  (Shortcut key: r). Allows to set the receiver as a region defined as a *simple* polygon. If the entered polygon is not simple, no receiver samples are taken. The operation can be aborted with a right mouse button click before the second input point or in the subsequent dialog box.

  In the subsequently displayed dialog box the additional parameters are set (see Modify below).

- **Modify**

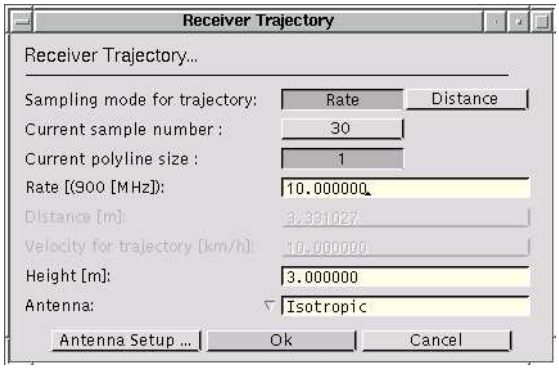
  (Shortcut key: m). Depending on the current receiver type one of the following dialog boxes is presented which allows to modify the receiver parameters.

  – **Point:**



* X-Coord:
* Y-Coord:
  Specifies the location of the receiver in coordinates of the environment.
* Height [m]:
  Sets the height of the receiver position. The height must be larger than 0.0, the value is entered in [m].
* Antenna:
  Allows to select the antenna for the receiver. The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings.

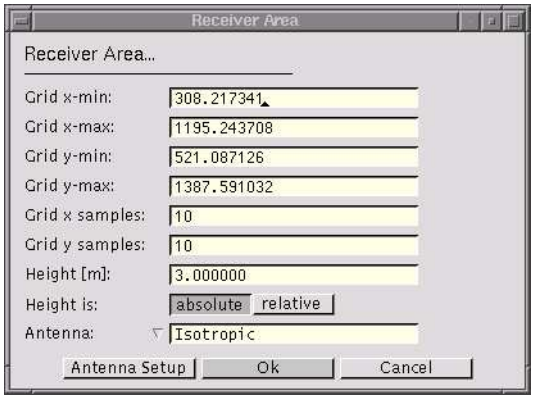
– **Trajectory:**



* Sample mode for trajectory:
  Allows to choose between different sampling modes for interactive placement of the receiver. The trajectory can either be sampled according to the frequency of the default transmitter (Section 6.4.2), or according to a specified distance. Depending on the current selection, the corresponding entries to enter the values are enabled or disabled, respectively. On opening the dialog box, the rate value and the distance value represent the same sampling of the trajectory.
* Current sample number:
  Shows the number of samples on the current trajectory. No value can be entered.
* Current polyline size:
  Shows the number of segments of the polyline of the current trajectory. No value can be entered.
* Rate (freq [MHz]):
  Sets the sampling rate in wavelengths of the frequency of the default transmitter (Section 6.4.2). The current frequency is shown within the parentheses. The sampling rate must be larger than 0.0.
* Distance [m]:
  Sets the sampling distance in [m]. The sampling distance must be larger than 0.0.
* Velocity for trajectory [km/h]:
  Sets the velocity the receiver moves along the trajectory. The velocity must be different from 0.0, the value is entered in [km/h].
* Height [m]:
  Sets the height of the trajectory. The height must be larger than 0.0, the value is entered in [m].
* Antenna:

Allows to select the antenna for the receiver. The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings.

– **Area:**



∗ Grid x-min:

∗ Grid x-max:

∗ Grid y-min:

∗ Grid y-max:
Sets the minimum and maximum bounds of the area.

∗ Grid x samples:
Sets the number of sampling points in x-direction for the area or region.

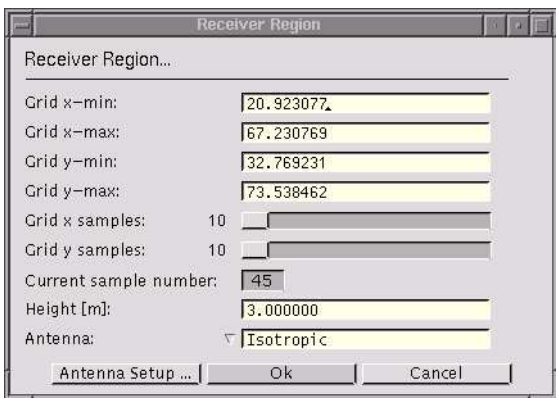
∗ Grid y samples:
Sets the number of sampling points in y-direction for the area or region.

∗ Height [m]:
Sets the height for the receivers in the area or region. The height must be larger than 0.0, the value is entered in [m].

∗ Height is:
Specifies whether the height of a receiver point is taken as an absolute value or as a relative value which is added to the current height of the environment at the position of the point.

∗ Antenna:
Allows to select the antenna for the receiver. The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings.

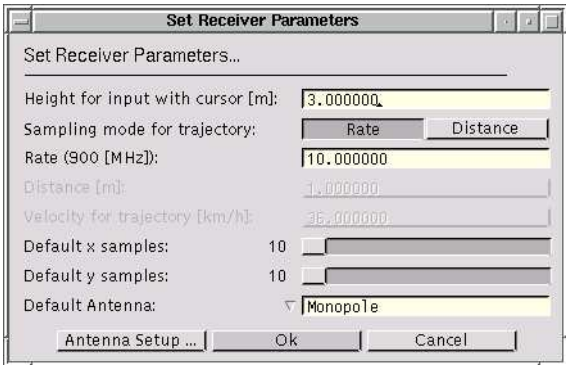
– **Region:**



- Grid x-min:
- Grid x-max:
- Grid y-min:
- Grid y-max:
  Sets the minimum and maximum bounds of the region. All samples that fall outside of the polygon are not considered as valid receiver points.
- Grid x samples:
  Sets the number of sampling points in x-direction for the region.
- Grid y samples:
  Sets the number of sampling points in y-direction for the region.
- Current sample number:
  Shows the number of sampling points of the grid that fall into the region.
- Height:
  Sets the height for the receivers in the area or region. The height must be larger than 0.0, the value is entered in [m].
- Antenna:
  Allows to select the antenna for the receiver. The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings.

- **Parameters**

  (Shortcut key: p). The dialog box is used to set certain parameters which are taken as default values for interactive receiver placement.



  – Height for input with cursor [m]:
    Sets the height for interactive placement of the receiver. The height must be larger than 0.0, the value is entered in [m].
  – Sample mode for trajectory:
    Allows to choose between different sampling modes for interactive placement of the receiver. The trajectory can either be sampled according to the frequency of the default transmitter (Section 6.4.2), or according to a specified distance. Depending on the current selection, the corresponding entries to enter the values are enabled or disabled, respectively. On opening the dialog box, the rate value and the distance value represent the same sampling of the trajectory.
  – Rate (freq [MHz]):
    Sets the sampling rate in wavelengths of the frequency of the default transmitter (Section 6.4.2). The current frequency is shown within the parentheses. The sampling rate must be larger than 0.0.

- Distance [m]:

  Sets the sampling distance in [m]. The sampling distance must be larger than 0.0.

- Velocity for trajectory [km/h]:

  Sets the velocity the receiver moves along the trajectory. The velocity must be different from 0.0, the value is entered in [km/h].

- Default x samples:

  Sets the default number of sample points in x-direction to be used for interactive placement of the receiver as a grid, region, or area.

- Default y samples:

  Sets the default number of sample points in y-direction to be used for interactive placement of the receiver as a grid, region, or area.

- Default Antenna:

  Allows to select the default antenna for interactive placement of the receiver. The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings.

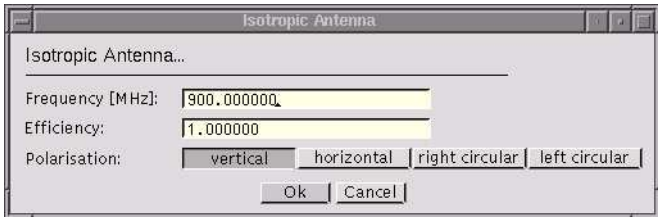
- **Set**

  Allows to set a receiver directly through a dialog box, which is similar to the one presented in the modify dialog box (see Section 6.4.3).

6.4.4 Antenna Setup Dialog

The antenna setup dialog is not directly accessible in the set menu. However, an antenna can be set in various places, so the dialog is described only once in this section.
Several theoretical antenna radiation patterns or measured antenna patterns, which are loaded from a file, can be selected. Setting receiver antennae do not require to set the power. However, the frequency must be set for a receiver antenna as well, because it is needed to determine some geometric parameters of a certain antenna types. The description below refers to setting transmitter antennae. In the case of receiver antennae, certain parameters as indicated below may not be present in the dialog box.

Isotropic Antenna



- **Frequency [MHz]:**

  Sets the frequency of the antenna in [MHz].

- **Power [W]:**

  Sets the input power of the antenna in [W]. The radiated power is calculated as the product of the input power and the efficiency.

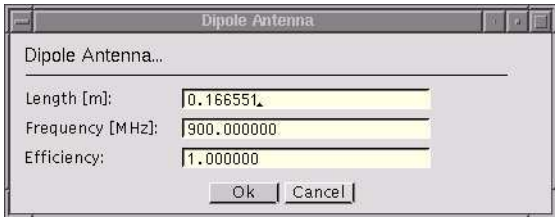
- **Efficiency:**

  Sets the efficiency of the antenna. The value is entered dimensionless. The radiated power is calculated as the product of the input power and the efficiency. (In case of a receiver antenna, the output power is calculated as the product of the received power and the efficiency.)

- **Polarisation:**

  The isotropic antenna can be polarised either as vertical, or as horizontal, or as left circular, or as right circular.

Dipole Antenna



- **Length [m]:**

  Sets the length of the dipole in [m].

- **Frequency [MHz]:**

  Sets the frequency of the antenna in [MHz].

- **Power [W]:**

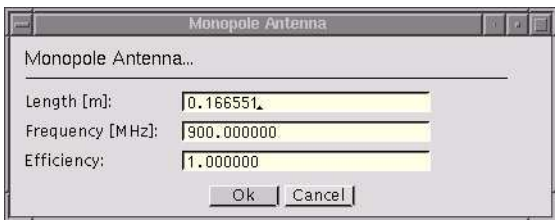
  Sets the input power of the antenna in [W]. The radiated power is calculated as the product of the input power and the efficiency.

- **Efficiency:**

  Sets the efficiency of the antenna. The value is entered dimensionless. The radiated power is calculated as the product of the input power and the efficiency. (In case of a receiver antenna, the output power is calculated as the product of the received power and the efficiency.)

- The polarisation of a dipole antenna is assumed to be vertical.

Monopole Antenna



- **Length [m]:**

  Sets the length of the monopole in [m].

- **Frequency [MHz]:**

  Sets the frequency of the antenna in [MHz].

- **Power [W]:**

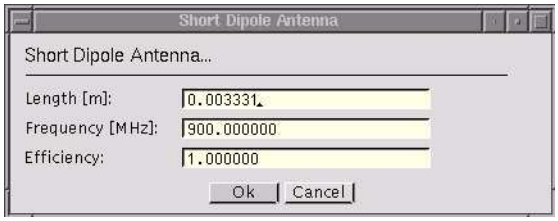
  Sets the input power of the antenna in [W]. The radiated power is calculated as the product of the input power and the efficiency.

- **Efficiency:**

  Sets the efficiency of the antenna. The value is entered dimensionless. The radiated power is calculated as the product of the input power and the efficiency. (In case of a receiver antenna, the output power is calculated as the product of the received power and the efficiency.)

- The polarisation of a monopole antenna is assumed to be vertical.

Short Dipole Antenna



- **Length [m]:**

  Sets the length of the short dipole in [m].

- **Frequency [MHz]:**

  Sets the frequency of the antenna in [MHz].

- **Power [W]:**

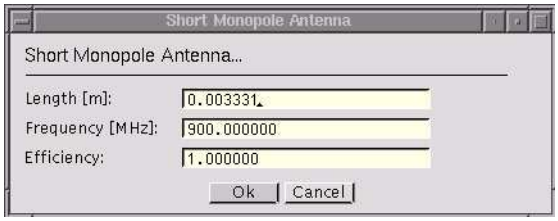
  Sets the input power of the antenna in [W]. The radiated power is calculated as the product of the input power and the efficiency.

- **Efficiency:**

  Sets the efficiency of the antenna. The value is entered dimensionless. The radiated power is calculated as the product of the input power and the efficiency. (In case of a receiver antenna, the output power is calculated as the product of the received power and the efficiency.)

- The polarisation of a short dipole antenna is assumed to be vertical.

Short Monopole Antenna



- **Length [m]:**

  Sets the length of the short monopole in [m].

- **Frequency [MHz]:**

  Sets the frequency of the antenna in [MHz].

- **Power [W]:**

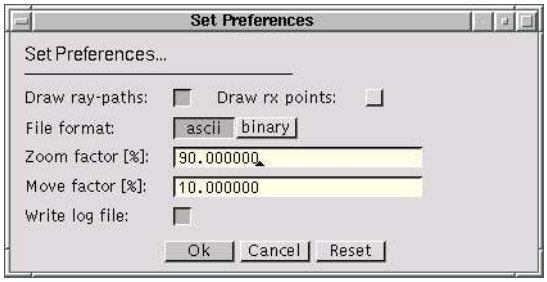
  Sets the input power of the antenna in [W]. The radiated power is calculated as the product of the input power and the efficiency.

- **Efficiency:**

  Sets the efficiency of the antenna. The value is entered dimensionless. The radiated power is calculated as the product of the input power and the efficiency. (In case of a receiver antenna, the output power is calculated as the product of the received power and the efficiency.)

- The polarisation of a short monopole antenna is assumed to be vertical.

6.4.5 Preferences



- **Draw ray-paths:**

  Specifies whether the ray-paths should be drawn during the simulation.

- **Draw rx points:**

  Specifies whether complex receivers should be drawn as set of points of as geometric shapes (polylines or polygons). Note that the currently selected receiver is only marked if the receiver locations are drawn as points.

- **File format:**

  Specifies whether the output files should be written in BINARY or in ASCII format. Configuration files, script files and material data files are *always* stored in ASCII format.

- **Zoom factor:**

  Specifies the zoom factor to be used while zooming in or out in the main window. The value must be in the range [1.0 .. 100.0].

- **Move factor:**

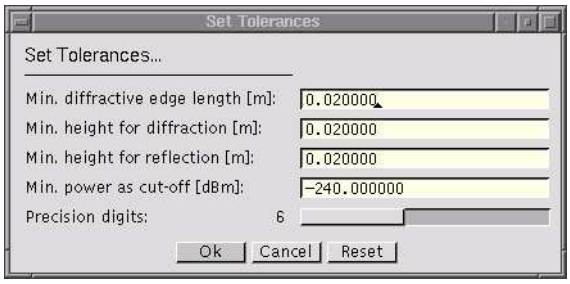
  Specifies the factor to be used while moving the content of the main window with cursor keys (scrolling). The value must be in the range [0.0 .. 100.0].

- **Write log file:**

  Sets whether a log file should be written. Such a log file contains certain error and warning messages that are not presented interactively to the user. The file name is entered through the file select dialog (Section 7.1). **RadioTracer** does not overwrite an existing log file. If the file already exists, the new output is appended. Note that the first and the last entry written to the log file indicate when the log file was opened or closed respectively.

6.4.6 Tolerances

Sets certain tolerances which are used in the computational parts of **RadioTracer**. The tolerance settings are part of a complete configuration file.



- **Min. diffractive edge length [m]:**

  Sets the minimum length of an edge in the environment such that the edge is considered in the ray-path search. The length must not be negative, the value is entered in [m].

- **Min. height for diffraction [m]:**

  Sets the minimum height a diffraction point must have such that the point is considered in the ray-path search. The height must not be negative, the value is entered in [m].

- **Min. height for reflections [m]:**

  Sets the minimum height a reflection point must have such that the point is considered in the ray-path search. The height must not be negative, the value is entered in [m].

- **Min. power as cut-off [dBm]:**

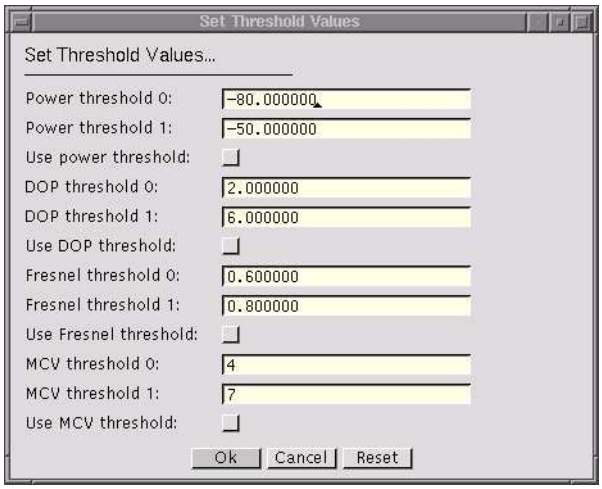
  Sets the minimum power a receiver must receive. Any value below the threshold will be clamped to this value. The value is merely used in the plots and maps to avoid practically unrealistic received power values. The value is entered in [dBm].

- **Precision digits:**

  Sets the number of decimal digits used to write floating point values in ASCII output files.

6.4.7 Thresholds

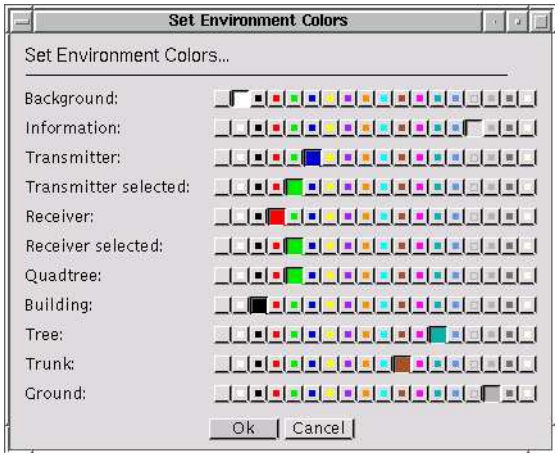
Sets the threshold values which are used as default values during the visualization of coverage maps of **RadioTracer**. The thresholds settings are part of a complete configuration file.



6.4.8 Colors

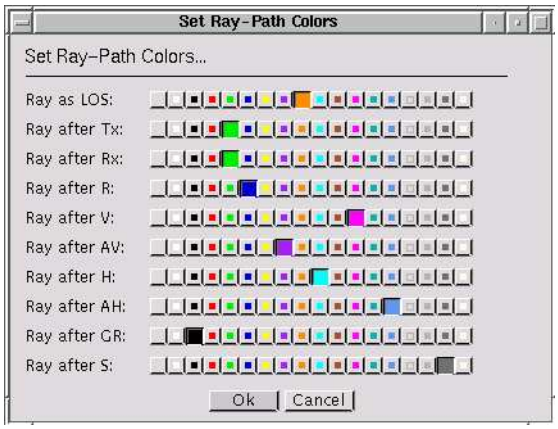
Sets the colors to be used in the drawings. The color settings are part of a complete configuration file. Note that the first entry specifies the transparent color, i.e., the object is drawn *invisible*.

Environment



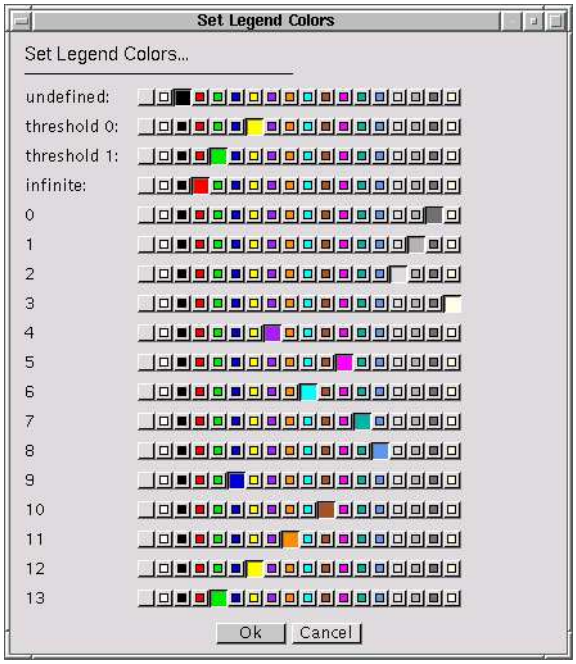
(Shortcut key: c). Sets the different colors for drawings of the environment. Note that the chosen colors will have effect in all windows as well as in the PostScript files.

Ray-Paths



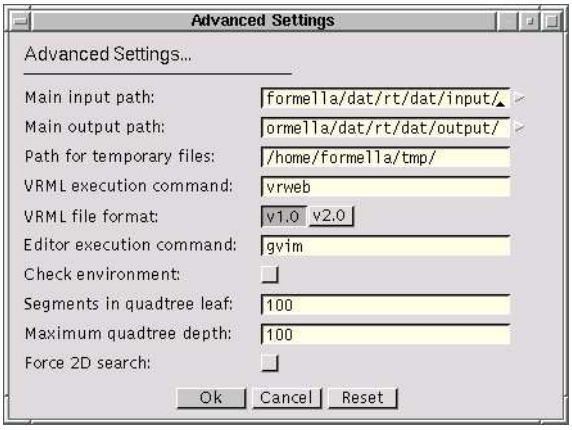
Sets the different colors for drawings of the ray-paths if this drawing mode is enabled (see set preferences (Section 6.4.5)).

Legends



Sets the different colors of the legends used in the maps. The leftmost color representing the smallest value is always the one labelled *undefined*, the rightmost color representing the largest value is always the one labelled *infinite*. Note that the chosen colors will have effect in all windows as well as in the PostScript files.

6.4.9 Advanced



- **Main input path:**

  Specifies the directory from where the input files, i.e., the environment, the configuration, the material, and the scripts are taken by default. Only a name of a directory that exists is accepted.

- **Main output path:**

  Specifies the directory to where the output files, e.g., the ray-paths, the electromagnetic data, etc. are written by default. Only a name of a directory that exists is accepted.

- **Path for temporary files:**

  Specifies the directory to where the temporary files are written. Only a name of a directory that exists is accepted.

- **VRML execution command:**

  Specifies the command line to be used to start the VRML viewer. The viewer visualizes the environment and the ray-paths in three-dimensional mode. (The option is only available with the VRML-package of **RadioTracer**.)

- **VRML file format:**

  Selects the VRML format to be standard version 1.0 or standard version 2.0. (The option is only available with the VRML-package of **RadioTracer**.)

- **Editor execution command:**

  Specifies the command line to be used to start the text editor which will be used for editing text files (Section 6.1.10).

  Examples for a possible command line within a Unix environment are

  ```
  gvim
  xterm -e vi
  ```

- **Check environment:**

  Specifies whether a consistency check of the geometric data in the environment is to be performed each time a new environment is loaded. Once a file has been checked, it is convenient to switch-off the possibly time-consuming check whenever the same file is loaded again. The check environment flag is *not* stored into the configuration file.

If the check finds touching buildings, warning messages are printed to the controlling shell including the points where the buildings touch. If the check finds crossing segments (partially overlapping buildings), a warning message indicating the first intersection point encountered is printed to the controlling shell. The environment will not be loaded if two buildings partially overlap and the check is enabled.

- **Segments in quadtree leaf:**

  Sets the maximum number of segments that should be contained in a leaf of the quadtree. The value must be at least 4. Note that the construction of the quadtree is terminated as well when the maximum depth has been reached. The setting becomes effective for the *next* environment to be loaded.

- **Maximum quadtree depth:**

  Sets the maximum depths of the quadtree. The value must be positive. A value of 0 means that no quadtree is built. The setting becomes effective for the *next* environment to be loaded.

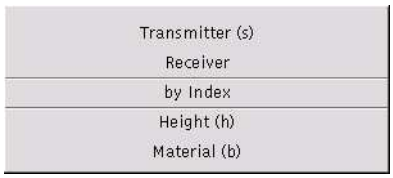
- **Force 2D search:**

  Specifies whether the ray-path search should be performed only two-dimensional, i.e., ray-paths over building blocks will not be detected. This mode is especially useful for micro-cell simulations where all building blocks close to the transmitter and the receiver are higher than the antennae heights. **RadioTracer** switches automatically to the two-dimensional search mode when *all* building blocks are higher than both the receiver and the transmitter antenna.

6.4.10 Custom

Depending on the version of **RadioTracer**, certain parameters can be set here. See the description of the customized version (Section 3) for more details.

6.5 Select



6.5.1 Transmitter

(Shortcut key: s). Allows to select a transmitter with a left mouse button click. Automatically, the transmitter closest to the location where the mouse button click takes place is chosen. The currently selected transmitter is highlighted. The default index is 0. The default highlight color is green, see Color Menu (Section 6.4.8) for possible user settings. The operation can be aborted with a right mouse button click.

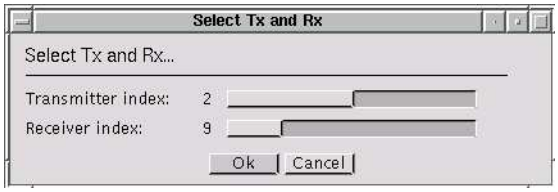
6.5.2 Receiver

Allows to select a receiver with a left mouse button click. Automatically, the receiver closest to the location where the mouse button click takes place is chosen. The currently selected receiver is highlighted. The default index is 0. The default highlight color is green, see Color Menu

(Section 6.4.8) for possible user settings. The operation can be aborted with a right mouse button click.

6.5.3 by Index

Allows to select a transmitter and a receiver with a dialog box. The currently selected transmitter and receiver are used as initial values.



It depends on the number of actual available transmitter respectively receiver points whether a scroll bar or a number field is used for the input. In the case that currently no transmitter or receiver is specified, no selection can be performed. The currently selected transmitter and receiver are highlighted. The default highlight color is green, see Color Menu (Section 6.4.8) for possible user settings.

6.5.4 Height

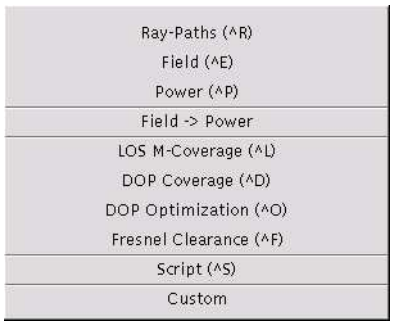
(Shortcut key: h). Until the operation is aborted, the height of the selected entity below the cursor is printed at the cursor position. The block is selected with a left mouse button click. The operation can be aborted with a right mouse button click. Any subsequent redraw of the window will erase all annotations.

6.5.5 Material

(Shortcut key: b). Displays the material properties of a building block. The block is selected with a left mouse button click. The operation can be aborted with a right mouse button click.

6.6 Run

The run menu is used to perform simulation or optimization runs. The computed data can be visualized through the view menu (Section 6.2).

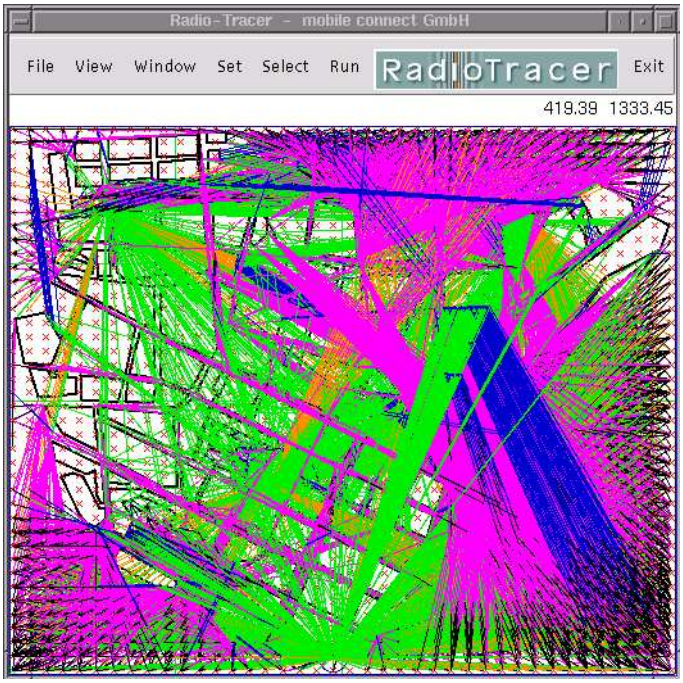


Depending on the command performed, certain temporary files (Section 9.15) are generated and stored into the temporary directory path, which is specified in the advanced settings (Section 6.4.9).

6.6.1 Ray-Paths

(Shortcut key: Crtl-R). Computes all ray-paths (Fermat paths) according to the settings in the interaction dialog (Section 6.4.1). Previously, the environment, the transmitter(s) (Section

6.4.2), and the receiver(s) (Section 6.4.3) must be specified. Drawing of ray-paths can be enabled via the set preferences (Section 6.4.5) dialog (see the Color Menu (Section 6.4.8) for possible user settings of the colors).
Example of a ray-paths drawing:



6.6.2 Field

(Shortcut key: Crtl-E). Computes the complex field of all ray-paths (Fermat paths) according to the settings in the interaction dialog (Section 6.4.1). Previously, the environment, the transmitter(s) (Section 6.4.2), and the receiver(s) (Section 6.4.3) including their antenna parameters must be specified. Drawing of ray-paths can be enabled via the set preferences (Section 6.4.5) dialog (see the Color Menu (Section 6.4.8) for possible user settings of the colors).
The output data of the field simulation run can be visualized directly through the point-to-point view menu (Section 6.2.1) or the data is used as input data for the Run Power (Section 6.6.3) command.

6.6.3 Power

(Shortcut key: Crtl-P). Computes the received power at the receiver locations provided a field simulation run (Section 6.6.2) has been performed previously. The following dialog box allows to change the receiver antenna parameters for the power calculation.

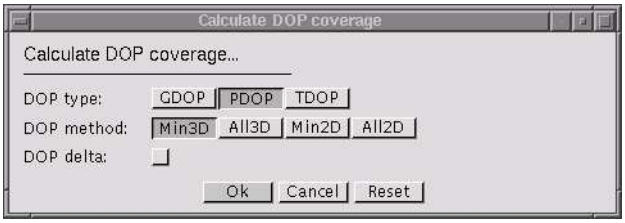
The type of antenna can be chosen from the list and its parameters with a subsequent dialog through the **[Antenna Setup]** button. See the antenna setup dialog (Section 6.4.4) for a general description of the antenna settings.
The output data of the power calculation run can be visualized directly through the point-to-multi view menu (Section 6.2.2).

6.6.4 LOS M-Coverage

(Shortcut key: Crtl-L). Computes a multi-line-of-sight coverage map, i.e, for each receiver the number of transmitters visible with direct line-of-sight is computed. A more detailed description is given in Section 8.9.. Previously, the environment, the transmitter(s) (Section 6.4.2), and the receiver(s) (Section 6.4.3) must be specified. The receiver must be of type area or region, respectively.
Drawing of ray-paths can be enabled via the set preferences (Section 6.4.5) dialog (see the Color Menu (Section 6.4.8) for possible user settings of the colors). The LOS M-Coverage map can be visualized with the View LOS M-Coverage (Section 6.2.3) command.

6.6.5 DOP Coverage

(Shortcut key: Crtl-D). Computes a DOP (dilution-of-precision) coverage map, i.e, for each receiver the DOP value corresponding to the direction vectors towards the directly visible transmitters—depending on the method—is computed. A more detailed description is given in Section 8.10.. Previously, the environment, the transmitter(s) (Section 6.4.2), and the receiver(s) (Section 6.4.3) must be specified. The receiver must be of type area or region, respectively.



- **DOP type:**

  Specifies the type of DOP to be computed:

  - GDOP: geometric DOP;
  - PDOP: positional DOP;
  - TDOP: time DOP.

- **DOP method:**

  Specifies the method how the directional vectors are to be selected:

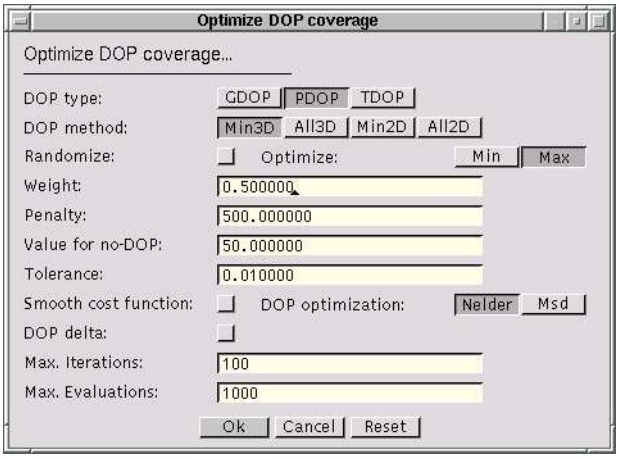
  - Min 3: minimum value out of all possible sets of three-dimensional vectors, i.e., best 3D DOP;
  - All 3: value using all available three-dimensional vectors, i.e., 3D DOP;
  - Min 2: minimum value out of all possible sets of two-dimensional vectors i.e., best 2D DOP (not considering height);
  - All 2: value using all available two-dimensional vectors, i.e., 2D DOP (not considering height).

- **DOP delta:** Specifies whether delta-DOP or normal DOP should be computed. If delta-DOP is enabled, setting TDOP makes no sense.

Drawing of ray-paths can be enabled via the set preferences (Section 6.4.5) dialog (see the Color Menu (Section 6.4.8) for possible user settings of the colors). The DOP Coverage map can be visualized with the View DOP Coverage (Section 6.2.3) command.

6.6.6 DOP Optimization

(Shortcut key: Crtl-O). Computes an optimized DOP (dilution-of-precision) coverage map optimizing the locations of the transmitters that are of type area. A more detailed description is given in Section 8.10. Previously, the environment (Section 6.1.2), the transmitter(s) (Section 6.4.2), and the receiver(s) (Section 6.4.3) must be specified. The receiver must be of type area or region, respectively. At least one transmitter must be of type area.



- **DOP type:**

  Specifies the type of DOP to be computed:

  - GDOP: geometric DOP;
  - PDOP: positional DOP;
  - TDOP: time DOP.

- **DOP method:**

  Specifies the method how the directional vectors are to be selected:

  - Min 3: minimum value out of all possible sets of three-dimensional vectors, i.e., best 3D DOP;
  - All 3: value using all available three-dimensional vectors, i.e., 3D DOP;
  - Min 2: minimum value out of all possible sets of two-dimensional vectors i.e., best 2D DOP (not considering height);
  - All 2: value using all available two-dimensional vectors, i.e., 2D DOP (not considering height).

- **Randomize:**

  Specifies whether the optimization is started with random transmitter locations. If the flag is not set, two consecutive optimization runs performed with the same initial values of the environment, the receivers, and the transmitters will yield the same final result.

- **Optimize:**

  Specifies whether the minimum DOP value or the maximum DOP value should be minimized.

- **Weight:**

  Specifies the weight w used in the cost function in the optimization procedure. The value must be in the range [0.0 .. 1.0].

- **Penalty:**

  Specifies the penalty p used in the cost function in the optimization procedure. The value must be positive.

- **Value for no-DOP:**

  Specifies the value to be used for receiver locations where no DOP value can be calculated. If the value is negative, for these points the maximum DOP value of all receiver location is used.

- **Tolerance:**

  Specifies the tolerance used to determine whether the optimization procedure has been terminated. The value must be positive.

- **Smooth cost function:**

  Specifies whether the cost function is smoothed applying a logarithm. A smoother cost function might result in a better convergence of the optimization procedure.

- **DOP optimization:**

  Selects the optimization method: NelderMead or MSD.

- **DOP delta:**

  Specifies whether delta-DOP or normal DOP should be computed. If delta-DOP is enabled, setting TDOP makes no sense.

- **Max. Iterations:**

  Specifies how many iterations are to be performed at most.

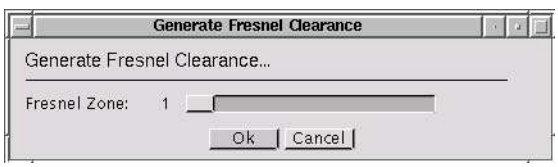
- **Max. Evaluations:**

  Specifies how many evaluations of the cost function (i.e., computations of DOP coverage maps) are to be performed at most.

Drawing of ray-paths can be enabled via the set preferences (Section 6.4.5) dialog (see the Color Menu (Section 6.4.8) for possible user settings of the colors). The resulting optimized DOP coverage map can be visualized with the View DOP Coverage (Section 6.2.3) command.

6.6.7 Fresnel Clearance

(Shortcut key: F). Computes a Fresnel clearance coverage map, i.e, for each receiver the clearance percentage of the n-th Fresnel-zone towards the directly visible transmitters is computed. A more detailed description is given in Section 8.11.. Previously, the environment, the transmitter(s) (Section 6.4.2), and the receiver(s) (Section 6.4.3) must be specified. The receiver must be of type area.



- **Zone:**

  Specifies the number of the Fresnel-zone for which the coverage should be calculated.

6.6.8 Script

(Shortcut key: Crtl-S). Runs a script file. First, the file is checked syntactically. Incorrect script files are rejected. See the script file format (Section 9.10) for a formal description of the script file content. If a command in the script file fails (e.g., a configuration file could not be loaded), processing of the script is terminated. Note that commands being executed earlier to the failing one will have effect.
The file name is entered through the file select dialog (Section 7.1). The selected file name is maintained and will be presented in a subsequent script command as initial dialog value.

6.6.9 Custom

Depending on the version of **RadioTracer**, certain simulation runs can be executed. See the description of the customized version (Section 3).

6.7 RadioTracer

Displays Copyright Information (Section 13) and License Agreement (Section 13.1) in a new window.

6.8 Exit

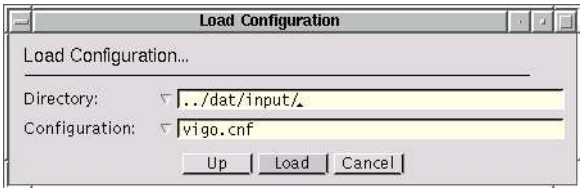
Exits **RadioTracer** immediately.
Note that **RadioTracer** (in its Unix-Version) can be terminated with the common **Crtl-C** input either while the focus is on a **RadioTracer**-window or while it is on the controlling shell.

7 Common Dialog Boxes

The common dialog boxes are presented to the user in various occasions. Besides small variations, they always appear much the same to the ones described in this section, which are the file select dialog (Section 7.1), the plot setup dialog (Section 7.2), and the PostScript setup dialog (Section 7.3).

7.1 File Select Dialog

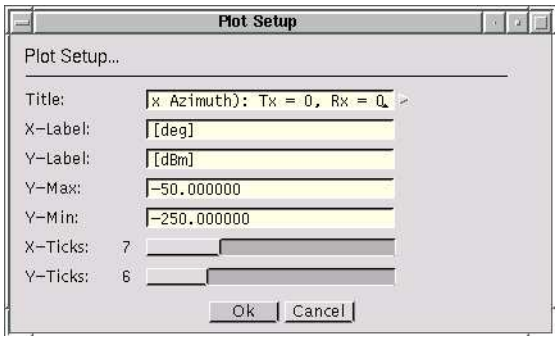
To select a file—either for reading or for writing—**RadioTracer** uses, e.g., the following dialog box (under Windows as well an input line to select the drive):



Clicking on the small triangle beside the drive, directory, or file entry visualizes a list (possibly with a scroll bar on the right side) from which an entry may be selected. The button **[up]** ascends the directory entry one level. If the entry contains a relative path name, the name is converted into an absolute path name.
The drive list contains all available one character drive identifier; the drive `A:` is always present. A drive must be specified with the terminating colon.
The directory list contains all directories down the path to the displayed directory and all directories within the displayed directory. The file list always contains all files in the displayed directory matching the required file type.
However, an arbitrary directory name or file name may be entered in the editable lines. **RadioTracer** accepts only file names built with the following character set: alpha numeric characters `0..9`, `a..z`, `A..Z`, the eight characters `$ % @ . # _ / \` and the blank.
Note, that a directory name must be terminated by the delimiter / (slash) in Unix or \ (backslash) in Windows, in which case the file list will be updated. If the entered directory is not available, the file list will be empty.
After closing the dialog, the selected file name is the concatenation of the directory entry and the file entry with one exception: if the file name is entered as an absolute name, i.e., starting with a slash or backslash or with a drive specification under Windows, the directory name is not prepended.
Usually, the file name which was selected last remains memorized for the next selection. Leaving the advanced settings (Section 6.4.9) dialog with **[ok]** will change automatically all directory and drive entries for subsequent file selections.

7.2 Plot Setup Dialog

The plot setup dialog is used to configure a specific plot:



- **Title:**

  An arbitrary title for the specific plot can be entered. The default title names the type of the plot and the indices of the transmitter and the receiver, whenever appropriate.

- **X-Label:**

- **Y-Label:**

  An arbitrary label for the x- and y-axis for the specific plot can be entered. The default labels indicate the units on the axis for the plot.

- **Y-Max:**

- **Y-Min:**

  The range for the y-values of the specific plot can be entered. The default range is computed automatically such that all data points can be represented. If zero appears within the range, it is marked through a horizontal dashed line in the plot.

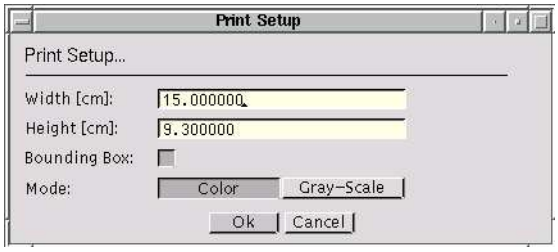
- **X-Ticks:**

- **Y-Ticks:**

  The number of ticks to be used on the axis for the specific plot can be entered. The default ticks are set to 6.

7.3 PostScript Setup Dialog

The PostScript setup dialog is used to configure a specific plot to be output as a PostScript file or to set the default values for all plots:



- **Width [cm]:**

  Specifies the width in [cm] for the plot on paper. The width must be positive.

- **Height [cm]:**

  Specifies the height in [cm] for the plot on paper. The height must be positive.

- **Font scaling:**

  Specifies a scaling factor for the fonts used in the PostScript file. The factor must be larger than 0.0.

- **Bounding Box:**

  Specifies whether a bounding box should be drawn around the plot on paper.

- **Mode:**

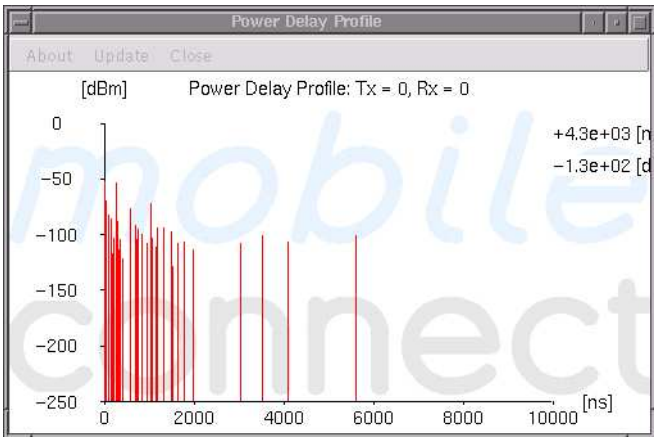
  Specifies whether the output should be in color or gray-scale mode.

8 Output Data Visualization

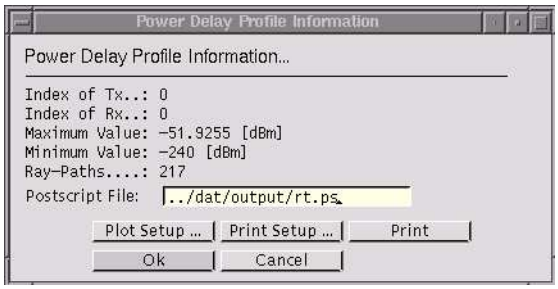
RadioTracer visualizes various sets of output data in different subwindows, either as one-dimensional plots or as two-dimensional maps. The output format can be modified to a certain extent through an update dialog box which is accessible via a menu button (see subwindow handling in Section 4.11).
The coordinate system used for the two-dimensional maps within the subwindows is always the same as currently visible in the main window, i.e., any redraw operation of a subwindow adjusts the visible area of the subwindow to the area currently visible in the main window.
Usually, while moving the mouse cursor over the data, the corresponding value under the cursor is printed at some location in the subwindow.

8.1 Power Delay Profile

The power delay profile plot shows the arrival times in [ns] of the different ray-paths versus its received power in [dBm] between the selected transmitter and the selected receiver. The times are given relative to the arrival time of the line-of-sight, i.e., if the line-of-sight path exists, its arrival time is 0.0. Example of a power delay profile plot:



More information and the possibility to update or export the plot can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:

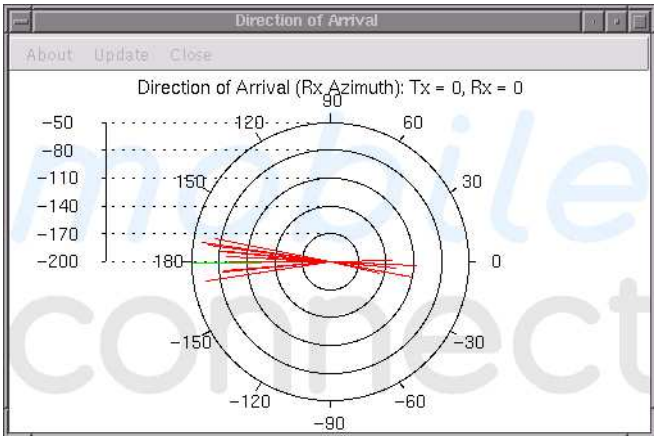


See the plot setup dialog (Section 7.2) for a general description of the settings available through the **[Plot Setup]** button. See the PostScript setup (Section 7.3) for a general description of the settings available through the **[PostScript Setup]** button.

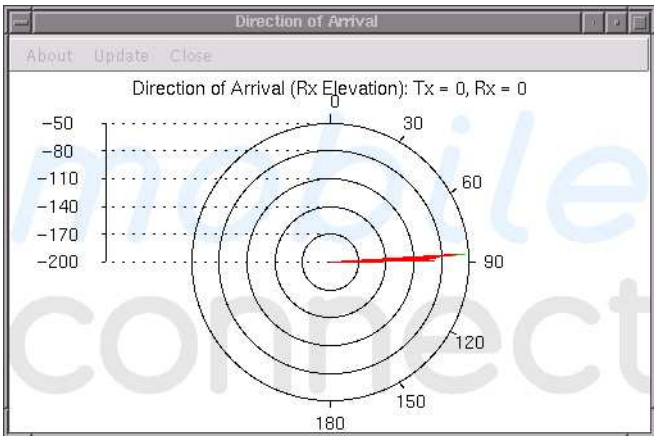
8.2 Direction of Arrival

The direction-of-arrival plot shows the arrival angles of the different ray-paths including their contributions to the received power in [dBm] between the selected transmitter and the selected receiver. The direction-of-arrival plot can be presented either in the azimuth or in the elevation plane for either the receiver or the transmitter location. If the line-of-sight path exists, its arrival component is highlighted.

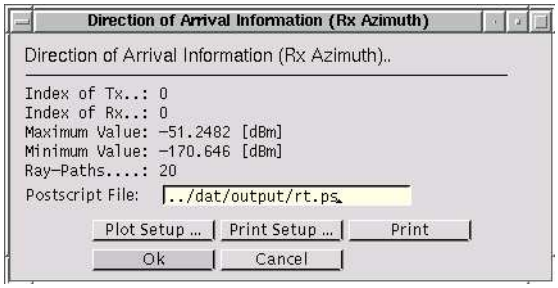
Example of a direction-of-arrival plot in azimuth plane:



Example of a direction-of-arrival plot in elevation plane:



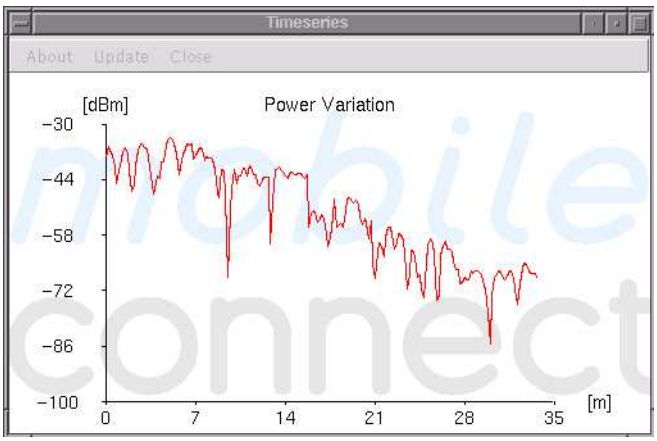
More information and the possibility to update or export the plot can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:



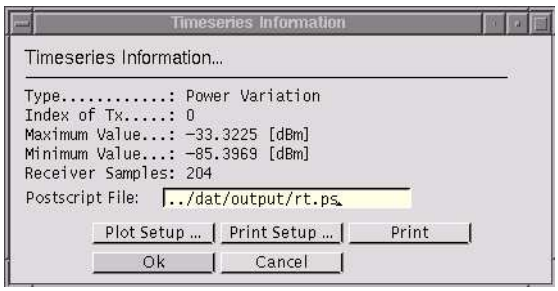
See the plot setup (Section 7.2) for a general description of the settings available through the **[Plot Setup]** button. See the PostScript setup (Section 7.3) for a general description of the settings available through the **[PostScript Setup]** button.

8.3 Power Variation

The power variation plot shows the received power in [dBm] as the complex sum, i.e., taking the phase shift into account, of the contributions of the different ray-paths along the receiver trajectory for the selected transmitter. Example of a power variation plot:



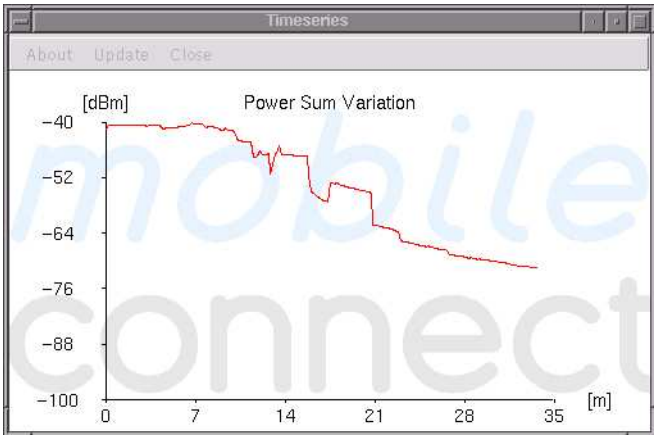
More information and the possibility to update or export the plot can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:



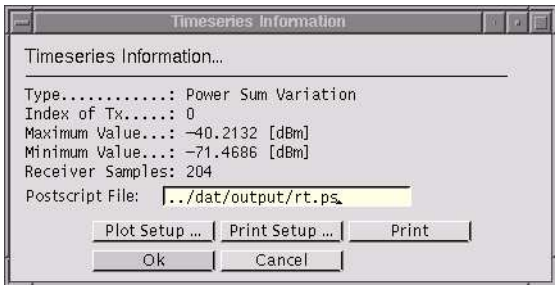
For a receiver of type area or region, the power variation can be visualized as a coverage map (Section 8.7).

8.4 Power Sum Variation

The power sum variation plot shows the received power in [dBm] as the sum, i.e., not taking the phase shift into account, of the contributions of the different ray-paths along the receiver trajectory for the selected transmitter. Example of a power sum variation plot:

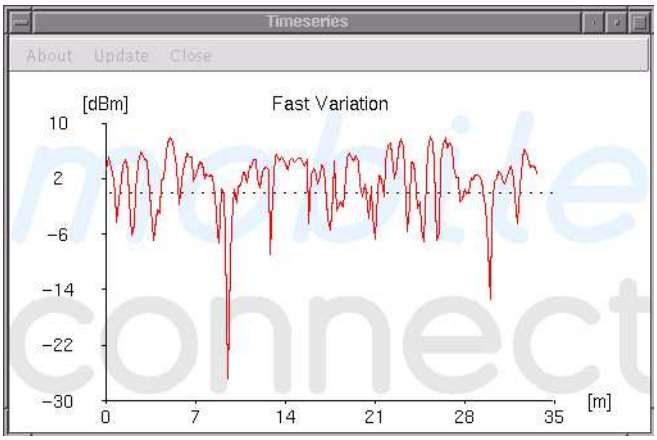


More information and the possibility to update or export the plot can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:

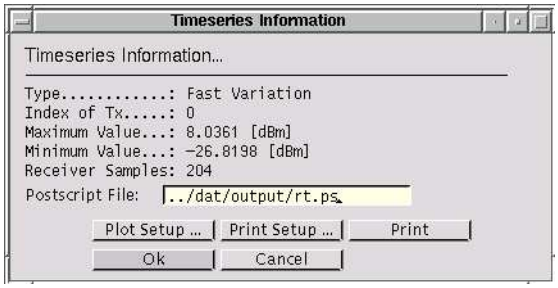


8.5 Fast Variation

The fast variation plot shows the difference in [dBm] between the power variation and the power sum variation of the different ray-paths along the receiver trajectory for the selected transmitter. Example of a fast variation plot:

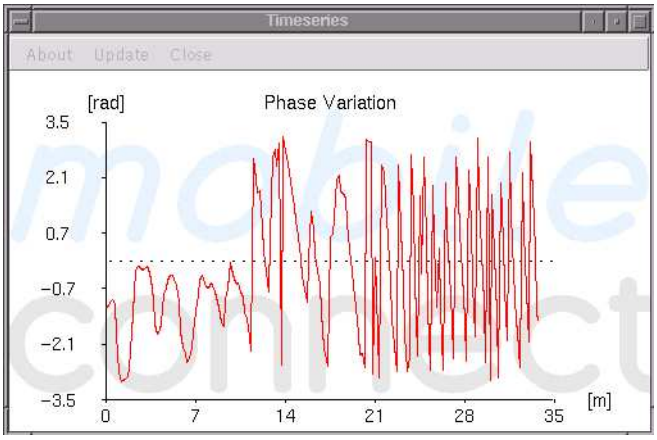


More information and the possibility to update or export the plot can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:

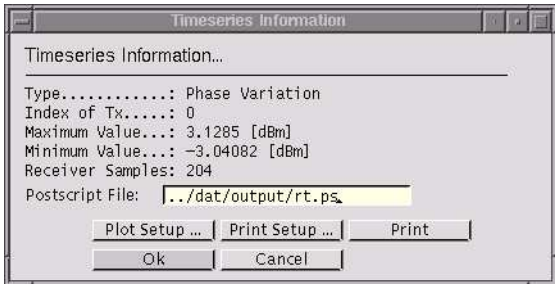


8.6 Phase Variation

The phase variation plot shows the phase of the received field in [rad] of the different ray-paths along the receiver trajectory for the selected transmitter. Example of a phase variation plot:

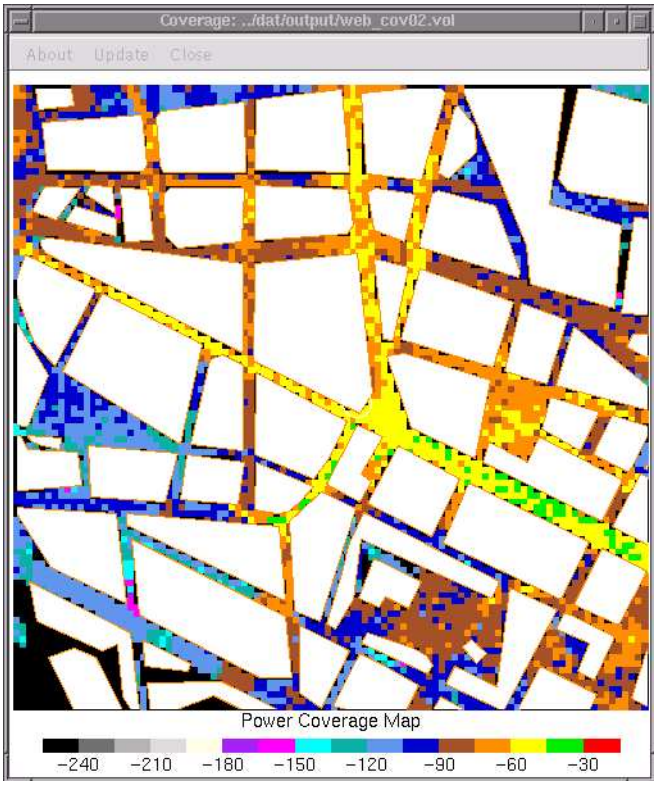


More information and the possibility to update or export the plot can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:

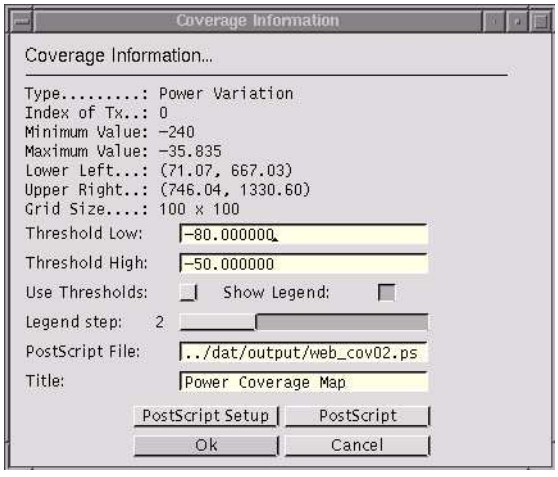


8.7 Power Coverage

The power coverage map shows the received power in [dBm] as the complex sum, i.e., taking the phase shift into account, of the different ray-paths for all receivers within the area or region and for the selected transmitter. Example of a power coverage map (without thresholds):



More information and the possibility to update or export the map can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:

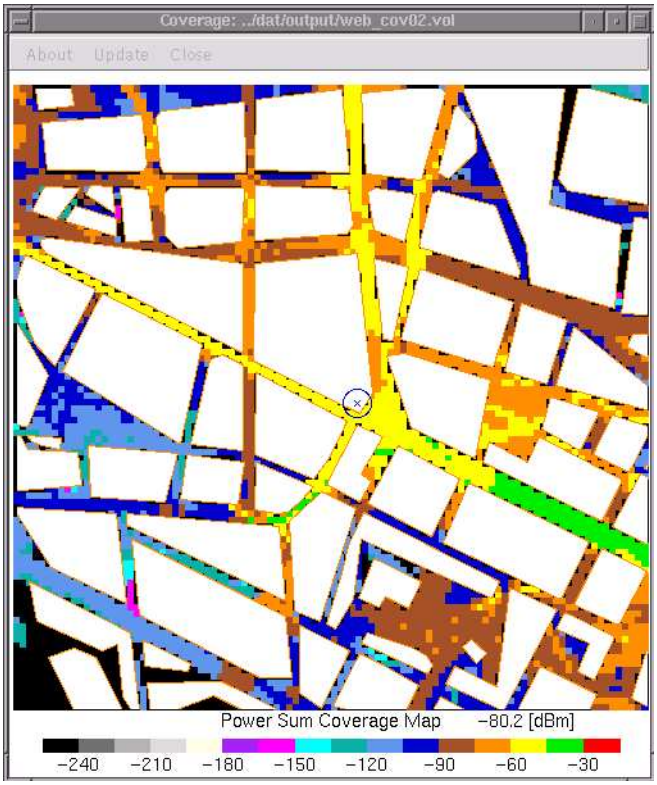


The threshold values provide a mean to color the map with only four colors, where the actual color depends whether a certain receiver point reaches at most the threshold as power value.

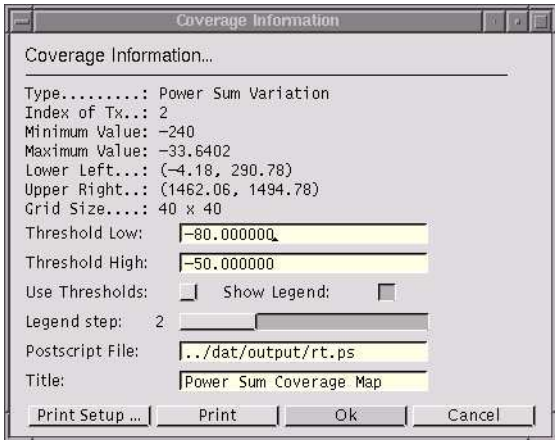
For a receiver of type trajectory, the power can be visualized as a power variation (Section 8.3).

8.8 Power Sum Coverage

The power sum coverage map shows the received power in [dBm] as sum, i.e., not taking the phase shift into account, of the contributions of the different ray-paths for all receivers within the area or region and for the selected transmitter. Example of a power sum coverage map (without thresholds):



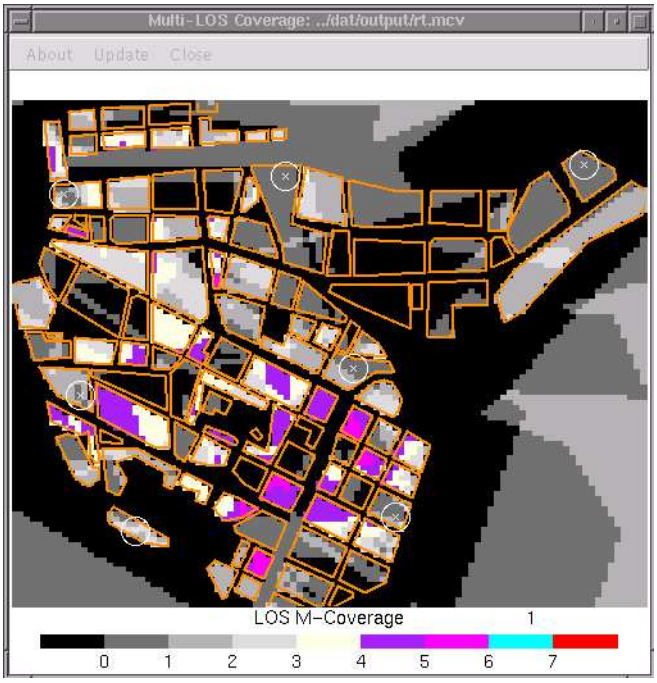
More information and the possibility to update or export the map can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:



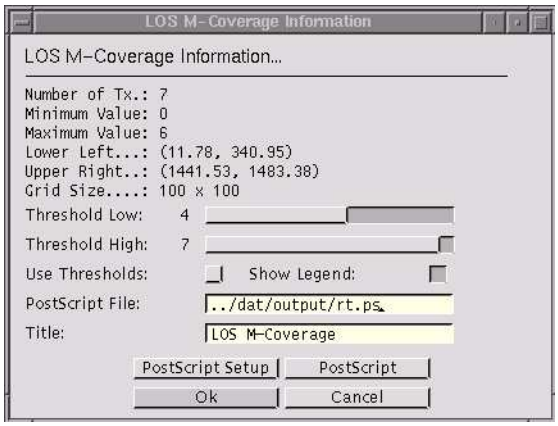
The threshold values provide a mean to color the map with only four colors, where the actual color depends whether a certain receiver point reaches at most the threshold as power value.
For a receiver of type trajectory, the power sum can be visualized as a power sum variation (Section 8.4).

8.9 LOS M-Coverage

The LOS M-coverage (line-of-sight multi-coverage) map shows for all receivers within the area or region to how many transmitters the line-of-sight is not obstructed. Example of a LOS M-coverage map (without thresholds) where the receivers have been located with relative height, i.e., they are placed above the building blocks:



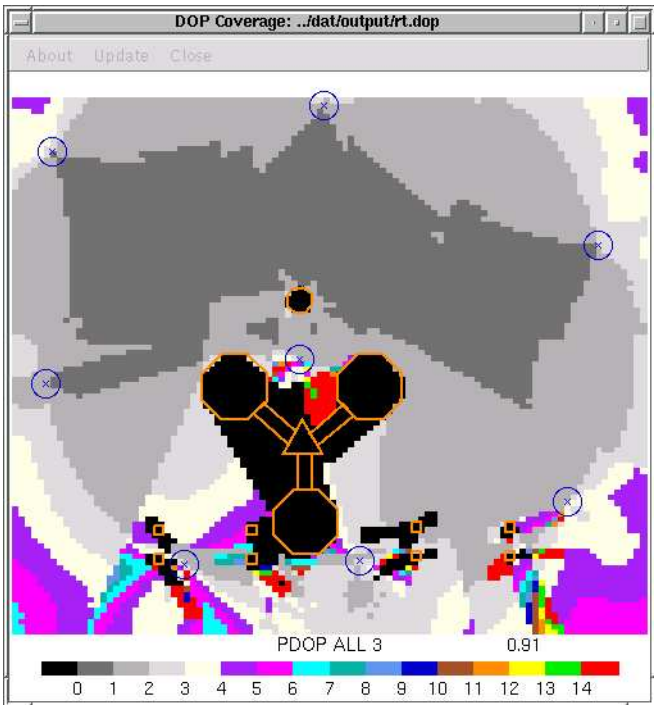
More information and the possibility to update or export the map can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:



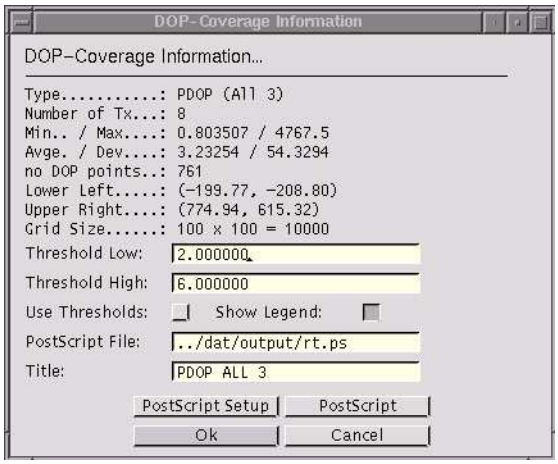
The threshold values provide a mean to color the map with only four colors, where the actual color depends whether a certain receiver point *sees* at least that many transmitters.

8.10 DOP Coverage

The DOP (dilution-of-precision) coverage map shows the dimensionless DOP value for all receivers within the area or region. Example of a DOP coverage map (without thresholds):



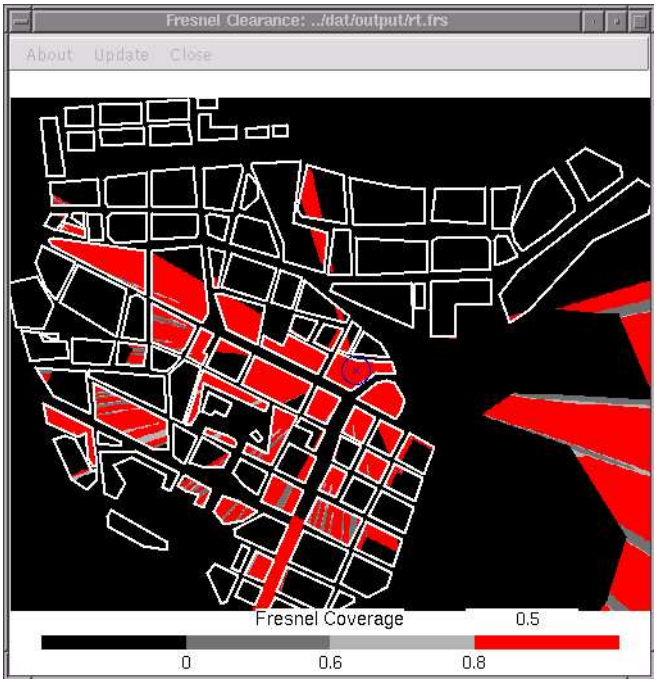
More information and the possibility to update or export the map can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:



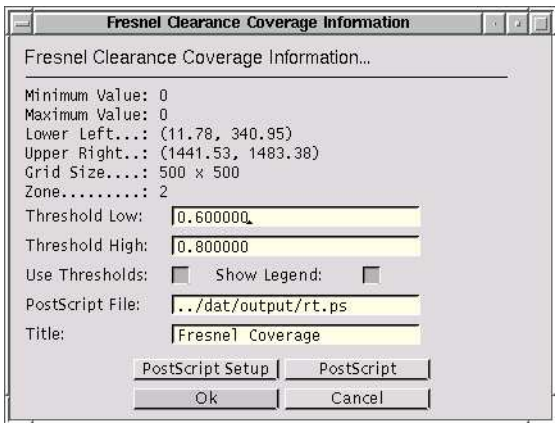
The threshold values provide a mean to color the map with only four colors, where the actual color depends whether a certain receiver point reaches at most the threshold as DOP value.

8.11 Fresnel Clearance Coverage

The Fresnel-coverage map shows for all receivers within the area the clearance percentage of the n-th Fresnel-zone.
Example of a Fresnel-coverage map (with thresholds) where the receivers have been located with relative height of 1 meter, i.e., they are placed above the building blocks:



The transmitting frequency was set to 20 GHz. More information and the possibility to update or export the map can be accessed through the **[Update]** menu entry of the window, which presents, for instance, a dialog like:



The threshold values provide a mean to color the map with only four colors, where the actual color depends whether a certain receiver point *has* at least that clearance percentage.

9 RadioTracer Files

RadioTracer reads and writes the following proprietary file formats:

extension	description	format	(Section)
.cnf	configuration	ASCII	9.2
.dat	environment	binary and ASCII	9.3
.dop	DOP map	binary and ASCII	9.4
.em	field	binary and ASCII	9.5
.frs	fresnel	binary and ASCII	9.7
.mcv	LOS M-map	binary and ASCII	9.6
.mtr	materials	ASCII	9.8
.pth	ray-paths	binary and ASCII	9.9
.rrl	VRML ray paths	ASCII	9.12
.rts	script	ASCII	9.10
.vol	voltage	binary and ASCII	9.11
.wrl	VRML environment	ASCII	9.12

9.1 General Remarks to the Format Description

The general structure of a **RadioTracer** output file is:

ASCII-header + the rest

where the header defines whether the rest will be in ASCII or in binary.
Throughout this section, the following meta symbols are used for the formal description of the formats (modified Backus-Naur-Notation):

//	comments follow
( )	group of symbols
{ }	optional group of symbols
|	exclusive OR
&	any order allowed within group
[ ]	non-terminal symbol
< >	terminal symbol (token), where
	<lower case> means required
	<UPPER CASE> means optional
	<{> <}> means optional
	(but must be used in pairs correctly!)
	case insensitive within file
" "	input defined terminal symbol
	(but must be double quoted in file too!)
	case sensitive within file
$ $	number representation
$type == x$	means value must be equal to x
:n	width in bits for number representation in binary files

The accepted delimiters to separate tokens in ASCII files are:

blank	ASCII character code 32	(0x20 hexadecimal)
tabulator	ASCII character code 9	(0x09 hexadecimal)
carriage return	ASCII character code 13	(0x0D hexadecimal)
line feed	ASCII character code 11	(0x0A hexadecimal)

Please note the following remarks:

- Except for user defined tokens (such tokens are double quoted), the reading of the tokens in an ASCII file is *case insensitive*.
- A user defined token cannot contain a double quote (").
- The maximal length of a token including user defined ones is 128 characters.
- The maximal length of a line in an ASCII file is 512 characters including the carriage return and/or line feed.
- Comments in **RadioTracer** files are line oriented.
- Comments are only allowed in ASCII files, they start with the comment symbol, and they continue for the rest of the line.
- The default comment symbol is `*`.
- The comment symbol can be changed at the very beginning of the file, i.e., before the usual header, with `comment <symbol>`. For instance, if a **RadioTracer** file begins with `comment #`, comments start with the symbol #.
- Sequences of bits in binary files are always padded to multiples of 32 bits.

The following short-cut notation is used for iteration:

```
[list] = [item] | [list]
```

9.2 Format of Configuration Files

Only ASCII configuration files are supported. The default extension for the name of a configuration file is `.cnf`.
The order of the different entries does not matter. If some entry occurs more than once, the last entry found in the file is taken as the final value. All key words can be abbreviated with a prefix. If the prefix is not unique, the key word that would occur first in a dictionary is taken. See the **RadioTracer** key words (Section 9.14) for a complete (ordered) list.
Example of a configuration file:

```
* (c) 2000, mobile connect GmbH
*     Universitaet des Saarlandes, Starterzentrum
*     D-66123 Saarbruecken, Germany
*     Tel. : +49 681 831 8858
*     http ://www.mobile-connect.de
*     email: info@mobile-connect.de
*     RadioTracer demo-version
radiotracer version 2 configuration ascii
file name scene "../input/vigo.dat"
file name configuration "../input/rt_startup.cnf"
file name dop "../output/rt.dop"
file name field "../output/rt.em"
file name material "../input/data.mtr"
file name mcv "../output/rt.mcv"
file name path "../output/rt.pth"
file name voltage "../output/rt.vol"
file name script "../input/rt.rts"
```

```
file name log "../output/rt.log"

path name in "../input/"
path name out "../output/"
path name tmp "~/tmp/"
window {
  1.709578e+02   6.460798e+02   6.807063e+02   1.120742e+03   }
window "center" {
  1.709578e+02   6.460798e+02   6.807063e+02   1.120742e+03   }
window "reset" {
  -1.102094e+01   1.471157e+03   2.816584e+02   1.654383e+03   }

command name vrml "vrweb "
command name editor "gvim  "

color background 0
color info 13
color transmitter 4
color transmitter select 3
color receiver 2
color receiver select 3
color quadtree 3
color building 1
color tree 11
color trunk 9
color ground 14
color path los 7
color path transmitter 3
color path receiver 3
color path reflection 4
color path vertical diffraction 10
color path adjacent vertical diffraction 6
color path horizontal diffraction 8
color path adjacent horizontal diffraction 12
color path ground 1
color path scatterer 15
color threshold 1 5 3 2
color legend number 14 15 14 13 16 6 10 8 11 12 4 9
7 5 3

threshold power 0 -8.000000e+01
threshold power 1 -5.000000e+01
use threshold power off
threshold dop 0 2.000000e+00
threshold dop 1 6.000000e+00
use threshold dop off
threshold fresnel 0 6.000000e-01
threshold fresnel 1 8.000000e-01
use threshold fresnel off
threshold mcv 0 4
threshold mcv 1 7
use threshold mcv off

format vrml 1
```

```
format file ascii
zoom 9.000000e+01

postscript width 1.500000e+01
postscript height 2.300000e+01
postscript scale 1.000000e+00
postscript mode color
postscript box on

draw path on
write log on
leafsegments 100
depth 100

dop type pdop
dop method minimum 3
dop optimize neldermead
dop delta off
dop weight 5.000000e-01
dop penalty 5.000000e+02
dop nodop 5.000000e+01
dop tolerance 1.000000e-02
dop evaluation 1000
dop iteration 100
dop maximum
dop random off
dop smooth off

fresnel zone 1
maxreflections 0
maxvdiffractions 1
maxinteractions 2
los on
ground los off
diffraction vertical on
ground diffraction vertical off
diffraction horizontal off
ground diffraction horizontal off
reflection off
ground reflection off
diffraction reflection off
diffraction horizontal adjacent off
ground diffraction horizontal adjacent off
diffraction vertical adjacent off
ground diffraction vertical adjacent off
attenuation off
scatterer off
shadowboundary 0.000000e+00
path length 0.000000e+00

tolerance minimum diffraction height 2.000000e-02
tolerance minimum diffraction length 2.000000e-02
tolerance minimum reflection height 2.000000e-02
tolerance minimum power -2.400000e+02
```

```
precision 6

transmitter default height 2.000000e+01
transmitter default antenna isotropic polarisation vertical
frequency 9.000000e+02 power 1.000000e+00 end

receiver default height 3.000000e+00
receiver default samplingrate 1.000000e+01
receiver default antenna isotropic polarisation vertical
frequency 9.000000e+02 end

end
```

9.3 Format of Environment Data Files

The default extension for the name of an environment file is `.dat`.

```
[environment file] =

    [header]  { [rest environment]  } <end>
```

The type in `[header]` of the file must be `scene`.

```
[rest environment] =

    [outdoor]  | [indoor]

[indoor] =

    <indoor> <NUMBER> $int$:16 [indoor entity list]

[outdoor] =

    <NUMBER> $int$:16 [outdoor entity list]
```

The value for `<NUMBER>` specifying the number of entities in the file is only informative. The entities are read until the end-of-file is reached.

```
[indoor entity list] =

    [indoor entity list item]  | [indoor entity list]

[indoor entity list item] =

    [exterior]  | [interior]  | [info]

[outdoor entity list] =

    [outdoor entity list item]  | [outdoor entity list]

[outdoor entity list item] =

    [flattop]  | [tree]  | [trunk]  | [trunktree]  | [ground]  |
    [info]
```

There is at most one `[ground]` object allowed.
The following entities are allowed within an outdoor scenario

```
[interior] =

    <interior> { "name" } <{> <NUMBER> $int$:16 [corner list]
    [height]  [material index]  <}>
```

```
[exterior] =

    <exterior> { "name" } <{> <NUMBER> $int$:16 [corner list]
    [height]  [material index]  <}>
```

Note that the height of the indoor environment is automatically taken as the largest height of the objects in the file.

```
[flattop] =

    <flattop> { "name" } <{> <NUMBER> $int$:16 [corner list]
    [height]  { [ground height]  } [material index]  <}>

[corner list] =

    [corner list item]  | [corner list]

[corner list item] =

    [point]  { ( <nodiff> | <diff> $float$:32 ) } { <stealth> }
```

The `[corner list]` must have as many items as the value of `<NUMBER>` indicates. Marking a corner with `<nodiff>` means that the corner is not considered for diffraction, marking it with `<diff>` and a height value means that a diffraction points must lie at least at that height. Marking a corner with `<stealth>` means that the wall from this corner to the next corner in the list is not considered for reflections.

```
[ground] =

    <ground> <{> ( [height field]  | [mesh]  ) [material index]
    <}>

[mesh] =

    <mesh> <POINT> <NUMBER> $int$:16 [point list]  <TRIANGLE>
    <NUMBER> $int$:16 [index list]
```

The number of items in the `[index list]` must be equal to three times the value of the `<TRIANGLE> <NUMBER>`. An index must not exceed the number of points. Counting starts at zero.

```
[point list] =

    [point list item]  | [point list]

[point list item] =

    [point]  [height]

[index list] =

    [index list item]  | [index list]

[index list item] =

    $int$:16

[tree] =

    <tree> <{> [point]  [radius]  [height]  { [ground height]  }
    [material index]  <}>

[trunk] =
```

```
    <trunk> <{> [point]  [radius]  [height]  { [ground height]
    } [material index]  <}>

[trunktree] =

    <trunktree> <{> [point]  [radius]  [height]  [radius]  {
    [ground height]  } [material index]  <}>

[info] =

    <info> <{> <NUMBER> $int$:16 [points]  <}>
```

The `[points]` list must have as many items as the value of `<NUMBER>` indicates.

9.4 Format of DOP Coverage Files

The default extension for the name of a DOP file is `.dop`.

```
[dop file] =

    [header]  [rest dop]  <end>
```

The type of the file must be `dop`.

```
[rest dop] =

    <ENVIRONMENT> $int$:32 [dop type]  [dop method]
    [transmitter geo list]  <RECEIVER> [receiver grid]  [dop
    values]
```

The environment value represents the check sum of the environment file for which the DOP file has been computed. There must be number of receiver points (size of the grid) times number of transmitters many DOP values present.

```
[dop method] =

    ( <all> | <min> ) ( <2> | <3> )

[dop type] =

    <gdop> | <pdop> | <tdop>

[dop values] =

    [dop value]  | [dop values]

[dop value] =

    $float$:32 $int$:8 $int$:8 $int$:8 $int$:8
```

A negative DOP value indicates that no dop value could be computed for the corresponding receiver location. The four integer numbers indicate the indices towards the four respectively three transmitters which produce the minimal DOP value provided the `[dop method]` is `min`. Note that if more than 256 transmitters are present the field width for the indices is increased to 32 bits in binary files.

9.5 Format of Field Files

The default extension for the name of a field file is `.em`.

```
[field file] =

    [header]  { [rest field]  } <end>
```

The type of the file must be `field`.

```
[rest field] =

    { <environment> $int$:32 } [transmitter]  [receiver]  [field
    values]
```

The environment value represents the check sum of the environment file for which the field file has been computed.

```
[field values] =

    [field value]  | [field values]

[field value] =

    <PATH> <RECEIVER> <INDEX> $int$:16 <TRANSMITTER> <INDEX>
    $int$:16 <{> <FIELD> <THETA> $float$:32 $float$:32 <FIELD>
    <PHI> $float$:32 $float$:32 <DELAY> $float$:32 <PHI>
    $float$:32 <THETA> $float$:32 <PHI> $float$:32 <THETA>
    $float$:32 <}>
```

The indices correspond to the list of receivers and transmitters. The complex field is given for the receiving point according to the coordinate system of the last incoming ray whose angles theta and phi are given as the first pair of values after the delay. The second pair gives the angles of the first ray existing the transmitter antenna. Multiplying the delay with the speed of light computes the length of the ray path.

9.6 Format of LOS Multi-Coverage Files

The default extension for the name of a multi-coverage file is `.mcv`.

```
[mcv file] =

    [header]  [rest mcv]  <end>
```

The type of the file must be `mcv`.

```
[rest mcv] =

    <ENVIRONMENT> $int$:32 [transmitter geo list]  <RECEIVER>
    [receiver grid]  [mcv values]
```

The environment value represents the check sum of the environment file for which the LOS multi-coverage file has been computed. A value of 0 indicates that the check sum should be ignored (avoids possible warning messages). There must be number of receiver points (size of the grid) times number of transmitters many mcv values present.

```
[mcv values] =

    [mcv value]  | [mcv values]

[mcv value] =

    $int$:1
```

A value different from zero means that corresponding LOS exits.

9.7 Format of Fresnel-Coverage Files

The default extension for the name of a Fresnel-coverage file is `.frs`.

```
[fresnel file] =

    [header]  [rest fresnel]  <end>
```

The type of the file must be `fresnel`.

```
[rest fresnel] =

    { <environment> $int$:32 } { <zone> $int$:16 } [transmitter]
    [receiver]  [fresnel values]
```

The environment value represents the check sum of the environment file for which the fresnel file has been computed.

```
[fresnel values] =

    [fresnel value]  | [fresnel values]

[fresnel value] =

    <TRANSMITTER> <INDEX> $int$:32 <RECEIVER> <INDEX> $int$:32
    <FRESNEL> $float$:32
```

The fresnel value indicates the percentage of clearance of the fresnel zone between the receiver and transmitter point.

9.8 Format of Material Files

Only ASCII material files are supported. The default extension for the name of a material file is `.mtr`. Three main types of materials are supported: conductors, dielectrics, and scatterer.

```
[material file] =

    [header]  { [rest material]  } <end>
```

The type of the file must be `material`. An empty material file, i.e., no `[rest material]` is contained, is allowed and can be used to reset all materials to the default material (perfect conductor).

```
[rest material] =

    [materials]

[materials] =

    [material]  | [materials]

[material] =

    [conductor]  | [dielectric]  | [scatterer]

[conductor] =

    <conductor> | <conductor> "material name"
```

Indicates a perfect conductor.

```
[dielectric] =

    ( <dielectric> | <dielectric> "material name" ) <{>
    <EPSILON> $float$:64 <COND> $float$:64 <RMS> $float$:64 <}>
```

The value for <EPSILON> is the relative dielectricity, the value for <COND> is the conductivity in [S], and the value for <RMS> the root mean square roughness in [m].

```
[scatterer] =

    ( <scatterer> | <scatterer> "material name" ) <{> <RCS>
    $float$:64 <}>
```

The value for <RCS> is the radar cross section.
The "material name" may be any name not containing newlines nor the character ", however, blanks and tabulators are allowed. Implicitly, the materials in the file get indexed according to the order they appear in the file.
Example of a material file:

```
radiotracer version 1 material ascii
conductor  "conductor"
dielectric "code_21" { epsilon 3 cond 0.2 rms 0 }
scatterer  "tree" { rcs 40 }
scatterer  "pine" { rcs 30 }
end
```

9.9 Format of Ray-Path Files

The default extension for the name of a ray-path file is .pth.

```
[ray path file] =

    [header]  { [rest ray path]  } <end>
```

The type of the file must be path.
The detailed decription of a ray-path file is not available.

9.10 Format of Script Files

Only ASCII script files are supported. Note that script files can contain commands to run other script files. The maximum nesting level is 10.

```
[script file] =

    [header]  { [rest script]  } <end>
```

The type of the file must be script.

```
[rest script] =

    [commands]

[commands] =

    [command]  | [commands]

[command] =

    <load> [load command]  | <run> [run command]  | <store>
    [store command]

[load command] =

    <config> "file name" | <environment> "file name" |
    <material> "file name"

[run command] =
```

```
    <path> | <field> | <fresnel> | <power> | <mcv> | <dop> |
    <dop> <optimize> | <script> "file name" | <system> "command"

[store command] =

    <timeseries> "file name"
```

Example of a script file:

```
radiotracer version 2 script ascii
load environment "../dat/input/vigo.dat"
load config "../dat/input/vigo.cnf"
run dop
run system "cp ../dat/output/rt.dop /home/someone/dop_files/nice.dop"
end
```

9.11 Format of Voltage Files

The default extension for the name of a voltage file is `.vol`.

```
[voltage file] =

    [header]  [rest voltage]  <end>
```

The type of the file must be `voltage`.

```
[rest voltage] =

    { <environment> $int$:32 } <transmitter> [transmitter
    simple]  [receiver]  [voltage values]
```

The environment value represents the check sum of the environment file for which the voltage file has been computed.

```
[voltage values] =

    [voltage value]  | [voltage values]

[voltage value] =

    $float$:32 $float$:32 $float$:32
```

9.12 Format of VRML Files

The VRML-files generated by **RadioTracer** are either written in VRML 1.0 or in VRML 2.0 standard depending on the settings in the advanced settings (Section 6.4.9) . The files are placed into the temporary directory (Section 9.15) to be accessed by an external VRML-visualization program (Section 6.4.9) .

9.13 Common Non-Terminal Symbols

The following common non-terminal symbols appear in more than one file described in the previous sections. They are classified in different sub-sections and within the sub-section they are given in alphabetic order.

9.13.1 Antenna

```
[antenna] =

    <antenna> ( [antenna isotropic]  | [antenna dipole]  |
    [antenna short dipole]  | [antenna monopole]  | [antenna
    short monopole]  ) <FREQUENCY> $float$:32 <POWER> $float$:32
    <end>
```

Note that for a receiver antennae the power must not be specified.

```
[antenna dipole] =

    <dipole> [antenna genpole]

[antenna genpole] =

    <LENGTH> $float$:32

[antenna isotropic] =

    <isotropic> <POLARISATION> ( <vertical> | <horizontal> |
    <lhcp> | <rhcp> )

[antenna monopole] =

    <monopole> [antenna genpole]

[antenna short dipole] =

    <shortdipole> [antenna genpole]

[antenna short monopole] =

    <shortmonopole> [antenna genpole]
```

9.13.2 Receiver

```
[receiver] =

    <receiver> ( [receiver grid]  | [receiver list]  | [receiver
    region]  | [receiver simple]  | [receiver trajectory]  ) {
    [antenna]  } <end>
```

If no antenna is present, an isotropic default antenna is used.

```
[receiver grid] =

    <grid> <SIZE> $int$:16 $int$:16 <XMIN> $float$:32 <XMAX>
    $float$:32 <YMIN> $float$:32 <YMAX> $float$:32 [height]

[receiver list] =

    <list> <NUMBER> $int$:16 [receiver list items]
```

There must be as many list entries given as indicated by the value of <NUMBER>.

```
[receiver list items] =

    [point]  [height]  | [receiver list items]

[receiver region] =
```

```
    <region> [receiver grid]  <REGION> <POLYGON> <NUMBER>
    $int$:16 [points]
```

The <grid> token after <region> is optional. There must be as many points given as indicated by the value of <NUMBER>.

```
[receiver simple] =

    <simple> <INDEX> $int$:16 [point]  [height]

[receiver trajectory] =

    <trajectory> <DELTA> $float$:32 <NUMBER> $int$:16 [receiver
    list items]
```

There must be as many list entries given as indicated by the value of <NUMBER>.

9.13.3 Transmitter

```
[transmitter] =

    <transmitter> ( [transmitter simple]  | [transmitter list]
    ) <end>

[transmitter area] =

    <area> $float$:32 $float$:32 $float$:32 $float$:32
    [transmitter point]

[transmitter geo list] =

    <TRANSMITTER> <NUMBER> $int$:16 [transmitter geo list items]

[transmitter geo list items] =

    [transmitter point]  | [transmitter geo list items]

[transmitter list] =

    <list> <NUMBER> $int$:16 [transmitter list items]
```

There must be as many list entries given as indicated by the value of <NUMBER>.

```
[transmitter list items] =

    ( [transmitter simple]  | [transmitter area]  ) |
    [transmitter list items]

[transmitter point] =

    [point]  [height]

[transmitter simple] =

    ( <simple> <INDEX> $int$:16 ( [transmitter point]  |
    [transmitter area]  ) { [antenna]  }
```

If no [antenna] is present, an isotropic default antenna is used.

9.13.4 Miscellaneous

```
[comment symbol] =

    any printable character, besides:  0-9 a-z A-Z $ .  , - + {
    } "

[data format] =

    <ascii> | <bin>

[ground height] =

    <ground> $float$:32

[header] =

    { <comment> [comment symbol]  } <radiotracer> <version>
    $int$ [type]  [data format]  <newline>

[height] =

    <HEIGHT> $float$:32

[index] =

    <INDEX> $int$:16

[normal index] =

    <NORMAL> [index]

[on-off] =

    ( <on> | <off> ) | $int$:32
```

A value different from 0 means on.

```
[point] =

    <POINT> $float$:32 $float$:32

[point index] =

    <POINT> [index]

[points] =

    [point]  | [points]

[radius] =

    <RADIUS> $float$:32

[type] =

    ( <config> | <dop> | <field> | <fresnel> | <material> |
    <mcv> | <normal> | <path> | <point> | <scene> | <script> |
    <voltage> )

[values] =

    $float$:32 | [values]
```

9.14 Key Words

RadioTracer does not distinguish between lower and upper case letters within key words.

absolute adjacent all antenna aperture area ascii attenuation azimuth
background biconic bin box building
cl color combined command comment conductivity conductor configuration connect cosn cylinder
default delay delta depth dielectric diffraction dipole direction distance dop draw
edge editor elevation end environment epsilon evaluation exterior
factor field file flattop format frequency fresnel
gdop gr grid ground
hd height horizontal
igloo in info index indoor interior isotropic iteration
leafsegments legend length lhcp list load los
material maximum maxinteractions maxreflections maxvdiffractions mcv measured mesh method minimum mobile mode mono monocir monopole move msd
name neldermead node nodiffraction nodop none normal normals2d normals3d number
off on optimize out
path pdop penalty phi point polarisation polygon position postscript power precision
quadtree
r radiotracer radius random rcs receiver rectangular reflection region relative rhcp rms roof roofheight rooftop run
s samples samplingrate satellite scale scatterer scene screen script select shadowboundary shortdipole shortmonopole simple single sinn size smooth span sphere stealth store system
t tau tdop theta threshold timeseries tmp tolerance trajectory transdis transmitter transmode tree triangle trunk trunktree type
use
vd version vertical vgraph voltage vrml
wave weight width window write
xmax xmin
ymax ymin
zone zoom

9.15 Temporary Files

RadioTracer generates during execution certain temporary files. Such files are placed either in the temporary directory or in the output directory both specified in the advanced settings (Section 6.4.9). All temporary files are named `rt` and have extensions according to the file summary in Section 9.

RadioTracer *does not* remove such temporary files once the program is finished. So they remain available for later usage. However, the files are overwritten in subsequent executions whenever the appropriate command is run.

Note that temporary files might be quite large.

10 Hardware and Software Requirements

RadioTracer is developed to run on any Unix or Windows platform. To install and run **RadioTracer** you need

- at least 8 MBytes of free memory for simple examples; depending on your simulation needs certainly more memory is needed
- approximately 25 MBytes of free disk space for installation, documentation, and simple examples; depending on your simulation needs certaily more disk space is needed.

The software and hardware requirements are:

- Linux-operating system
  - Linux kernel 2.2.x or higher
  - X-windows environment with window manager
  - Intel processor 586 or higher
  - at least 16 color graphics with resolution of 800x600; however, 256 colors and a resolution of 1024x768 is recommended
- Solaris-operating system
- Windows-operating systems
  - Windows95, Windows98, WindowsNT, Windows2000
  - Intel pentium processor
  - at least 16 color graphics with resolution of 800x600; however, 256 colors and a resolution of 1024x768 is recommended

11 Change Log

Starting with version 1.8 of the manual and version 3.5.0 of the program, this sections describes the mayor changes made in **RadioTracer** from version to version.

11.1 Changes from v3.4.x to v3.5.0

- Certain items between Advanced settings (Section 6.4.9) and Preferences (Section 6.4.5) interchanged.
- Number of receiver points within regions changed to inlimited.
- Plots use degrees instead of radians.
- Scrolling of main window with cursor keys added, amount of scroll can be set in preferences (Section 6.4.5).
- File format of LOS multi-coverage and DOP coverage slightly changed to allow for a better binary representation. Floating point precision for DOP values in binary files set to single precision.
- User can select whether complex receivers are drawn as points or as geometric shapes (e.g., rectangles, polylines, polygons) (see Preferences (Section 6.4.5)).
- **Bugfix:** Iteration over trajectory of receiver could have caused memory corruption if number of points was a multiple of 32.
- The RayTracing kernel is slightly faster.

12 Bugs and Features

The following behavior of **RadioTracer** may be considered “peculiar” (certainly, the on-going development will remove some of the short-comings):

1. The non-interactive mode needs a running X-Environment.
2. If memory is exhausted, **RadioTracer** exits with an error message.
3. If disk space is exhausted, simulations will not be interrupted. However, every write attempt results in an error message.
4. A running simulation cannot be interrupted. Please, use the possibility to store configuration files oftenly, so after a hard-break (Ctrl-C), the situation before having started the simulation can be restored.
5. **RadioTracer** does not automatically remove temporary files.
6. If you use a table driven color representation with few colors, other running programs may occupy the color space, this may result in color warnings on the controlling shell and/or rendering of black instead of the desired color.
7. The gray-scale images in PostScript-format do not use increasing gray level steps as one might expect.
8. **RadioTracer** does not ask whether you really want to exit the program.
9. The cursor shapes may be different in Windows as described in this manual.
10. The shortcut keys as control characters and the **(Shortcut key: Z).** do not work in Windows.
11. Message boxes containing file names, use always the slash / as path separator independently from the operating system used.

13 Copyright Information

mobile **connect** retains all Intellectual Property Rights in the **RadioTracer** Software and Documentation.

13.1 License Agreement

RadioTracer may be used only in accordance with the written license agreement which is also delivered together with the program (see file *copyright.txt* and the menu entry About (Section 6.1.1)):

```
This is the demonstration version of the
RadioTracer software.  The software can be
freely copied and distributed.  It is
forbidden to manipulate the software.  The
software comes as is without any warranty
whatsoever.  The simulations can be
performed only with the accompanying data
file vigo.dat.

If you like to obtain more information
or a more functional version,
feel free to contact mobile connect GmbH
(phone: +49 (0) 681 831 8858,
email: info@mobile-connect.de)
```

Any further usage is forbidden.

RadioTracer is not fault-tolerant and is not designed, manufactured or intended for use in on-line control equipment, in hazardous environments requiring fail-safe performance, such as in the operation of nuclear facilities, aircraft navigation or communication systems, air traffic control, direct life support machines, or weapons systems, in which the failure of **RadioTracer** could lead directly to death, personal injury, or severe physical or environmental damage ("High Risk Activities"). ***mobile*** **connect** specifically disclaims any express or implied warranty of fitness for High Risk Activities.

13.2 Trademarks

Linux is a trademark of Linus Torvalds.

PostScript is a trademark of Adobe System, Inc.

Solaris is a trademark of Sun Microsystems.

Unix is used as a generic term, however, in a specific context the term may be owned by a trademark holder.

Windows, Windows95, Windows98, WindowsNT, Windows2000 are trademarks of Microsoft Corporation.