QRap Help

www.QRap.org.za

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1) Introduction

Q-Rap is an Open Source Radio Planning software package, which can be used by cellular operator, radio amateurs, people installing any form radio based technology, to do radio coverage analysis and link planning.

The core origin of this package was developed specifically for the South African Police Services' Radio Technical Services which paid for the initial development and specified that the software be release as Open Source to enable the continued development and maintenance thereof. This original project was done via/by Business Enterprises at the University of Pretoria (BE@UP) and executed mainly by Magdaleen Ballot from the Department for Electictrical, Electronic and Computer Engineering at the University of Pretoria. The copyright belongs to the University of Pretoria. The core propagation prediction algorithms originates from the GISRAP tool developed by the Meraka Institute, then Mikomtek at the CSIR. The copyright these classes re-used from the GISRAP code hence belongs to the Meraka Institute. Meraka also paid for the further development of a multi-link identification tool, while the Department of Science and Technology sponsored the development of the Spectral Analysis tool for the Square Kilometer Array project. The South African Police Services(SAPS), the University of Pretoria and the Meraka Institute has all agreed to release the code under the General Public License.

The core properties of this package are:

- It is based on an Open Source Geographic Information System (QGIS), which enables easy integration with all GIS functionalities.
- It has an fairly flexible open database structure, that allows easy changes and translations. It is based on Open Source PostgreSQL.
- The use of Open Source Postgis enables a number of spatial queries on the data.
- The use of the open source package GDAL allows the use of almost any Digital Elevation Model format.
- Most package choices (e.g. open source Qt for interface development) were made to allow it to be Operating System independent.
- The database structure and design choices were made to allow for various and multiple wireless technologies.
- Data that is visible can be filtered based on location, technology, project and other criteria.
- The core propagation prediction model is based on free-space loss calculations and the multiple knife-edge diffraction losses done according to the Deygout method. It includes addition losses for rounded hills.
- The effective earth model is used. The k-Factor, i.e. the ratio of the real earth radius to the effective earth radius, reflects the gradient of the refractiveness of the lower earth, and hence the curvature of the path of the radio waves. This model originates from the Mikomtek, CSIR, now the Meraka Institute.
- Easy to use, particularly when compared to other free mobile planning tools.
- Amble use of tool-tips to ease use.

The following functionalities are currently included:

- Link Analysis including Fresnel Zone clearance.
- Coverage prediction that calculates the received signal strength at all points for one or many radio installations,
- Primary Server calculations that indicates the actual 'cell' area of each radio installation,
- Number of server calculations, with which coverage overlap can be determined.
- Interference calculations based on frequency assignments in the database.
- Loading of small area of the Digital Terrain Data
- Spectral Interference analysis for inter-system interference analysis
- Automatic tool for the identification of visible links among a set of sites.

For help on QGIS functionalities please refer to the QGIS manual.

2) Getting Started

2.1) Installing Ubuntu

The instructions on how to obtain Ubuntu and install it, can be found on the following pages
http://www.ubuntu.com/getubuntu/download
http://www.ubuntu.com/
The CD/DVD image could also be downloaded from:
ftp://ftp.up.ac.za/mirrors/ubuntu/ubuntu-cdimage/releases/

2.2) Downloading the required software

In Ubuntu the tool Synaptic Package Manager is used to download and install the software. First use the Ubuntu Software Centre to search for and install Synaptic.

Once you open Synaptic you need to set-up the necessary "repositories", where the software is kept. This can be done within Synaptic, under Settings->Repositories. You will need to add at least one location under "Other Software", (which is the second tab). After clicking *Add* you will be required to enter the apt line:

deb http://qgis.org/debian precise main
deb-src http://qgis.org/debian precise main

to be able to install QGis, which is the open source geographic information tool on which Q-Rap is built. For more information see http://www.qgis.org/en/download.html. It is important to use QGis version 1.8 or later. Synaptics might want to you to activate the authorisation key, which is available under the Technical details on the download page. This is however not critical.

If you live in South Africa you might want to add the following repositories as well:
deb ftp://ftp.up.ac.za/ubuntu *precise* main universe multiverse restricted
deb ftp://ftp.up.ac.za/ubuntu precise-security main universe multiverse restricted
deb ftp://ftp.up.ac.za/ubuntu *precise*-backports main universe multiverse restricted
deb ftp://ftp.up.ac.za/ubuntu *precise*-updates main universe multiverse restricted
deb ftp://ftp.up.ac.za/ubuntu *precise*-proposed main universe multiverse restricted

You must *Reload* the repositories before continuing ...

Using the *Search* (not Quick Search) you must find and mark the following packages for installation:

- qgis
- libqgis-dev

(make sure all older versions of qgis and the development files are removed completely)

- gdal

(once again ensure that you have only one version installed)

- g++
- cpp
- gpp
- cmake
- subversion
- flex
- bison
- libpoco-dev
- qt4-designer
- qt4-dev-tools
- libqt4-core
- libqt4-dev

- libqt4-sql-psql
- libqwt5-qt4-dev
- libpqxx-dev
- postgresql
- postgresql-server-dev-9.1 (or latest)
- postgis
- postgresql-9.1-postgis (or latest)
- libeigen3-dev

The following packages are optional:

- postgresql-doc
- tora (database interface tool)
- xiphos

Now, might also be a good time to *Mark All Upgrades* to ensure that you have the latest software installed. Downloading and installation might take a while, so take a break once you hit the *Apply*-button. Go to the gym, home, lunch, meeting …

3) Installing Q-Rap on Ubuntu

3.1) Compiling from source

The first releases of Q-Rap will need to be compiled from source. To obtain the source you must enter the following on the command line (a terminal interface is available under Applications->Accessories ->Terminal):

svn checkout https://svn.code.sf.net/p/qrap/code/ qrap

this points Subversion to the server that currently contains Q-Rap. Once it has been downloaded (enough time for a cuppa coffee) you can compile Q-Rap. The source code will be provided in the directory '/qrap/'. On the command line, go to the /qrap/ directory. You can use

- *pwd* to determine your **p**resent **w**orking **d**irectory
- *cd ..* to go one directory up and
- *ls –l* to view the content of the current directory and
- *cd qrap* to go to the qrap directory

In this directory run

cmake ./

to configure the makefile. Take note of any dependencies that might still not be resolved and download these packages. Then to compile the package run:

make

(Time to refill the coffee mug.)
and to install run

sudo make install

you will be asked for the password of the main user.
Q-Rap should now exist but alas you will first need a database.

3.2) Creating the Database

Change the password of the **postgres** user

sudo passwd postgres

change it to *postqrap* to make life simple at first
Still in the command line, log-on as user **postgres**

su postgres

Go to the /qrap/DataBase/ directory by typing

cd DataBase

Run the script CreateDB.sh.
./CreateDB.sh

If you have problems with the scripts you can try the following:

- *Confirm the permissions of the **qrap** directory and **DataBase** and **Prediction** subdirectories:*
  - Using the file browser right click **each** (sub)directory. Select **Permissions**. Make sure that all users have create, delete, read and write permissions to all the files.
  - If this does not work enter
    exit
    goto the /qrap/ base directory
    and then
    sudo postgres chown <subdirectory> for the DataBase and Prediction subdirectories respectively.

  Try the above again.
- *Make CreateDB.sh executable:*
  - In the file browser right click on the file, go to **Permissions** and tick the "*Allow executing file as program*" tick-box.
- *Make sure you are using the correct PostGIS script directory*
  - Open the **CreateDB.sh** file for editing, and change the **PostGISDir** variable to the directory on your machine containing **postgis.sql** file. A easy way to determine this is by looking at the location of the "installed files" in Synaptic for your particular version of postgres-v.v-postgis.
- Another problem might be that the default port **5432** is not applicable to / available on your machine, then you need to change the file qrap/DataBase/settings.xml, and change the port to for example **5433**.

3.3) Loading the demo database (Optional)

If you just quickly want to get an feel for what this tool can do, this is really recommended.
However the demo database does not exist yet:
We must write a script that will load all the data including the height data that you will be able to use.

3.4) Setting up Q-Rap

3.4.1)Activate the Q-Rap-plugin

To get most feedback it is best to run QGIS from the command line. Simply type:
qgis

Activate the Q-Rap plug-in:
On the tool-bar of QGIS, select command **Plugins**, and **Plugin Manager** and select at least **Q-Rap** and **SPIT**, but you may want to try out some of the other plug-ins as well.
On closing the **QGIS Plugin Manager**, the **Login Dialog** box will appear:

All you need to do is fill in the password, which should be postqrap, unless you changed the CreateDB.sh script. The port setting might also be different: e.g. 5433 and the host might simply be referred to as **localhost**.

The Q-Rap tool-bar should now appear on the QGIS interface. It might be necessary to rearrange the Tool-bars a bit to make it visible.

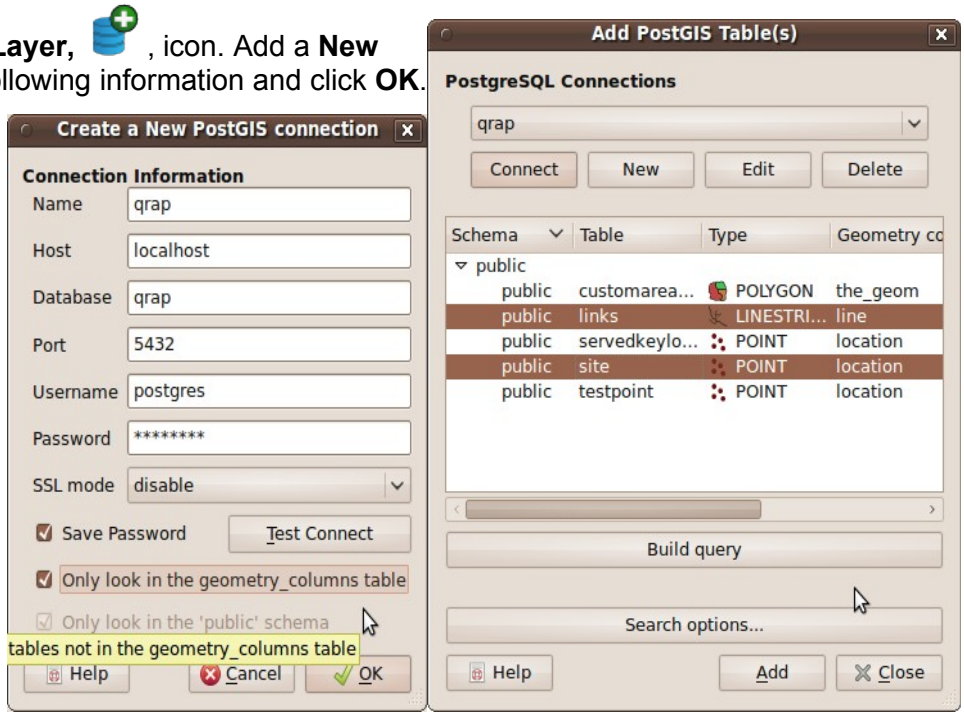
3.4.2) Set up a map in QGIS

You can refer to the QGIS help for more information on how to go about adding layers. To provide some form of visual reference on the map you can add a vector layer by clicking on the **Add a Vector Layer** icon, , and finding a normal shape file to add. Some examples are available in /qrap/Data/Shapefiles/.

3.4.3) Make the Q-Rap spatial information visible

Click on the **Add a PostGIS Layer,** , icon. Add a **New** database and complete the following information and click **OK**.

Connect to the database and **Add** the selected **Site** and **Link** information to be displayed.
On the QGIS tool-bar **Save Project**. This will allow you to avoid all this setting up next time you start.
You can additional layers to the postgis-layer of the qrap-database using the SPIT tool (look for the blue elephant). It might be for example be a good idea to add the provincial boundaries. These boundaries could later be used as a why to filter for different sites.



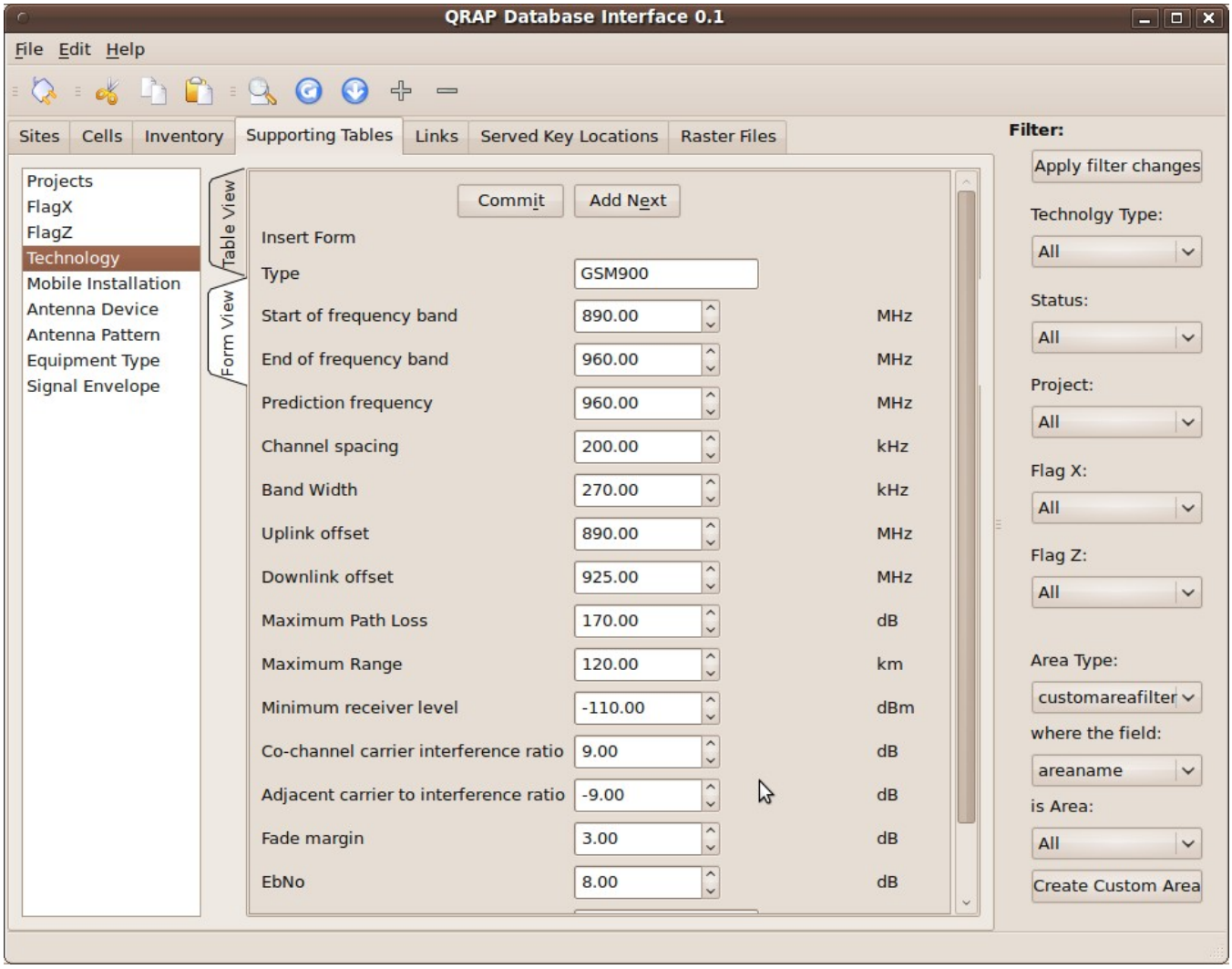
3.4.4) Setting up the Q-Rap-database

In this section we will only briefly go through all the steps that are required to get going using Primary GSM as an example technology. For a complete discussion of each step you will have to refer to the latter sections of the manual.

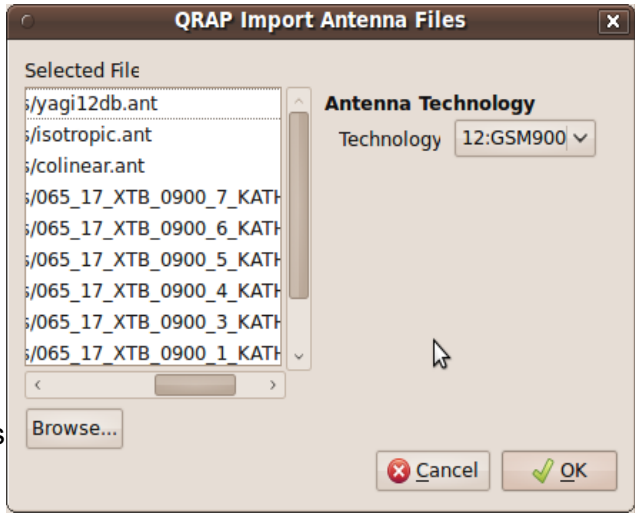
The first step is to open up the database interface: Click on the Q-Rap Database Interface icon, .

3.4.4.1) Set up a Technology

Select the **Supporting Tables** tab, and the **Technology Form View** to complete the following and **Commit** it to the database:



3.4.4.2) *Import a few antenna pattern files*



Q-Rap imports any antenna file that is in “planet” format. Some antenna suppliers make files in this format available. A few samples files are available in /qrap/Data/AntennaFiles/.

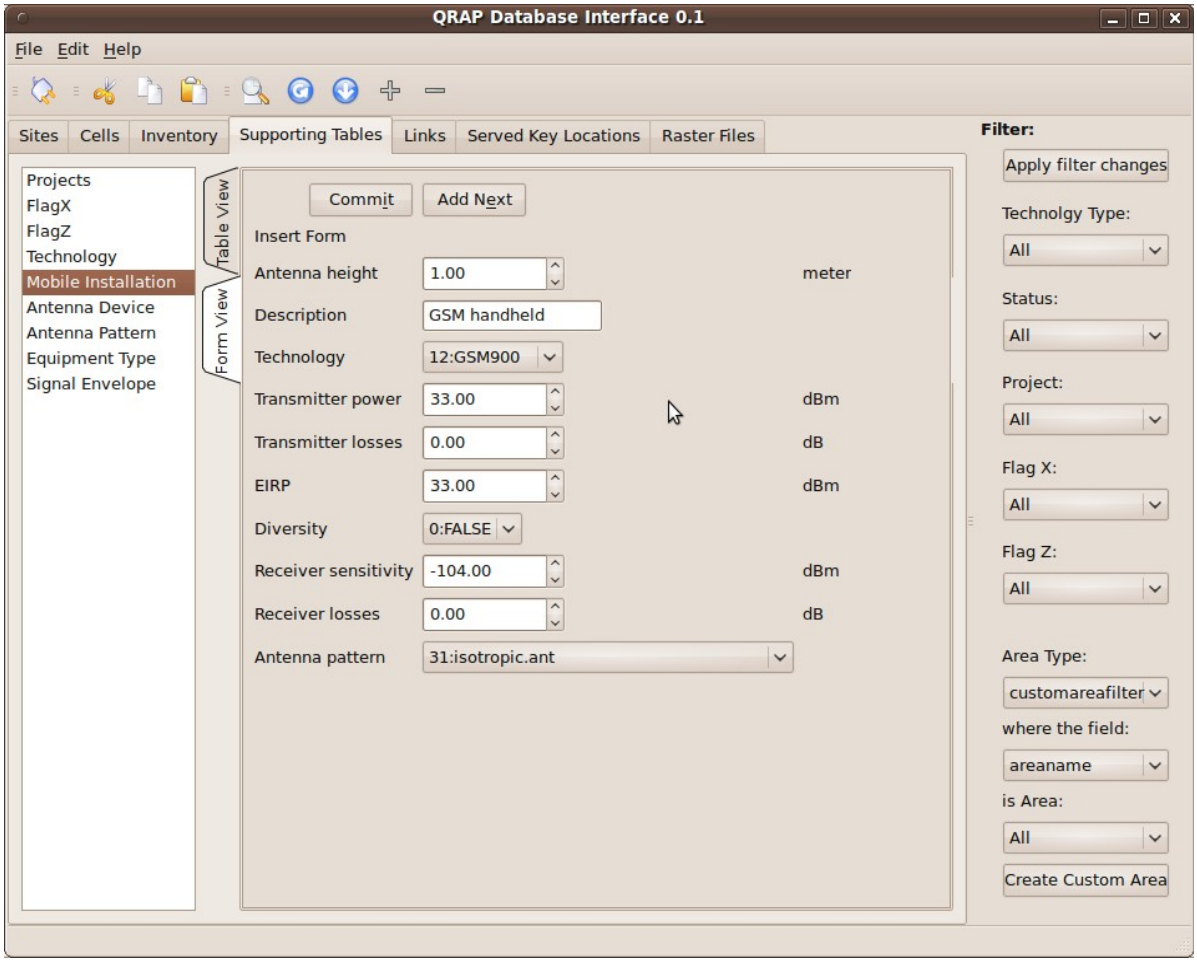
On the toolbar of the database user interface select
File,
Import,

Antenna Files.
Select the Technology that will be served with these antennas patterns. Browse for and select the antennas you would like to import. Select OK.

Alternatively, the Antenna Device and Antenna Pattern Form Views could be used to enter your first antenna pattern in the database.

3.4.4.3) *Create a Mobile installation*

The mobile installations are used to represent the subscribers units when doing coverage predictions.



3.4.4.4) Generate default entries

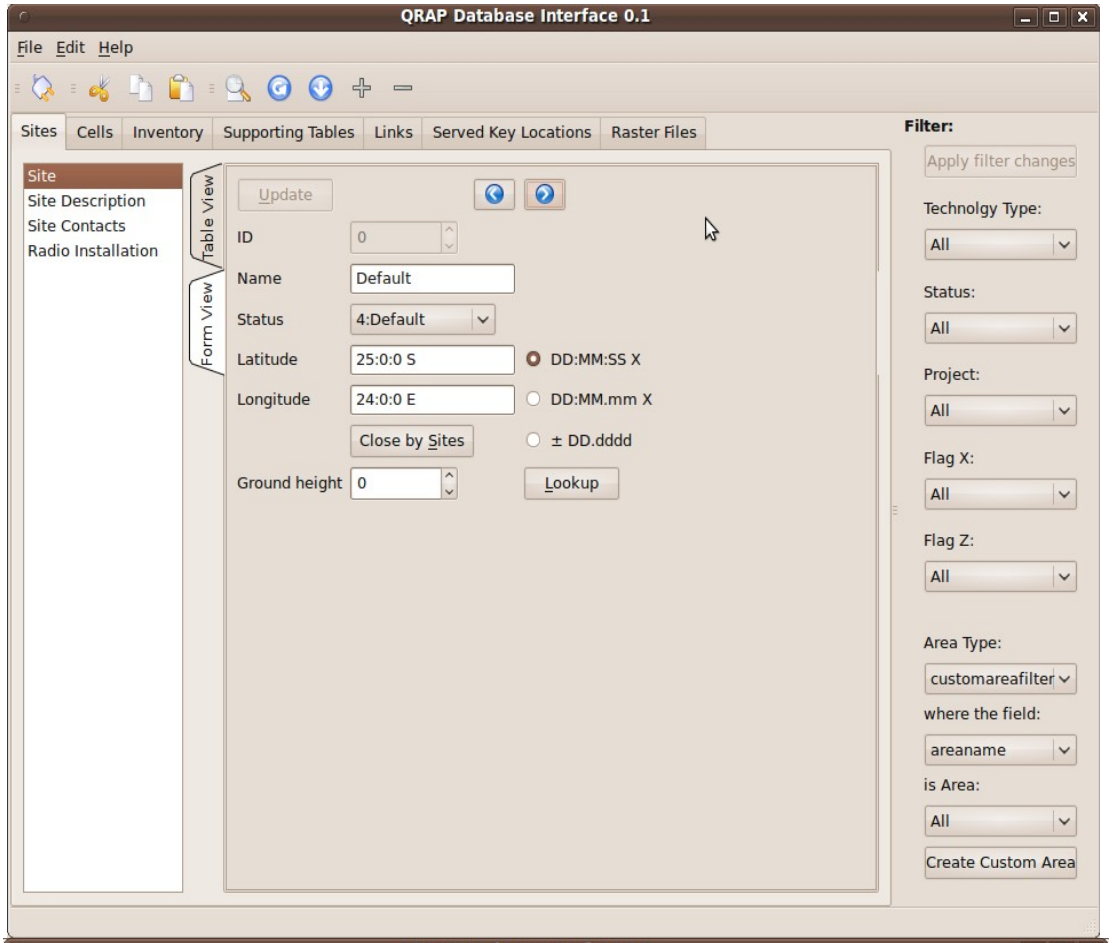
The first entry of a table (with primary key 0) will generally be used to set the default entries into any given table. Select the Preference icon,  , or select

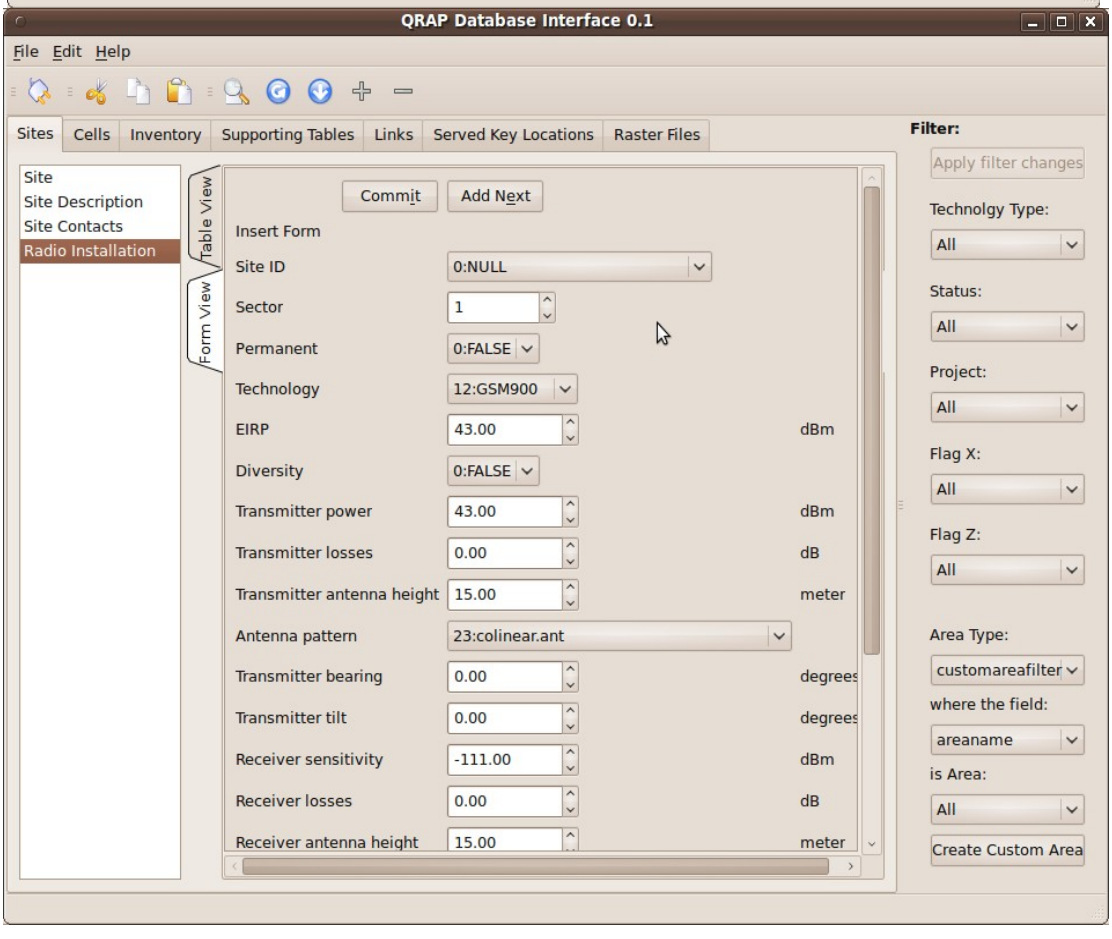
Edit,
Preferences

on the QRap Database Interface tool-bar.
Select

RAP
Defaults

and select the **Edit Defaults** radio button.
Now you can proceed to enter all the tables you would like to with default entries in each field. It might be a particularly good idea to at least provide defaults for the Radio Installation table with sensible default entries. First you need to add the default site:

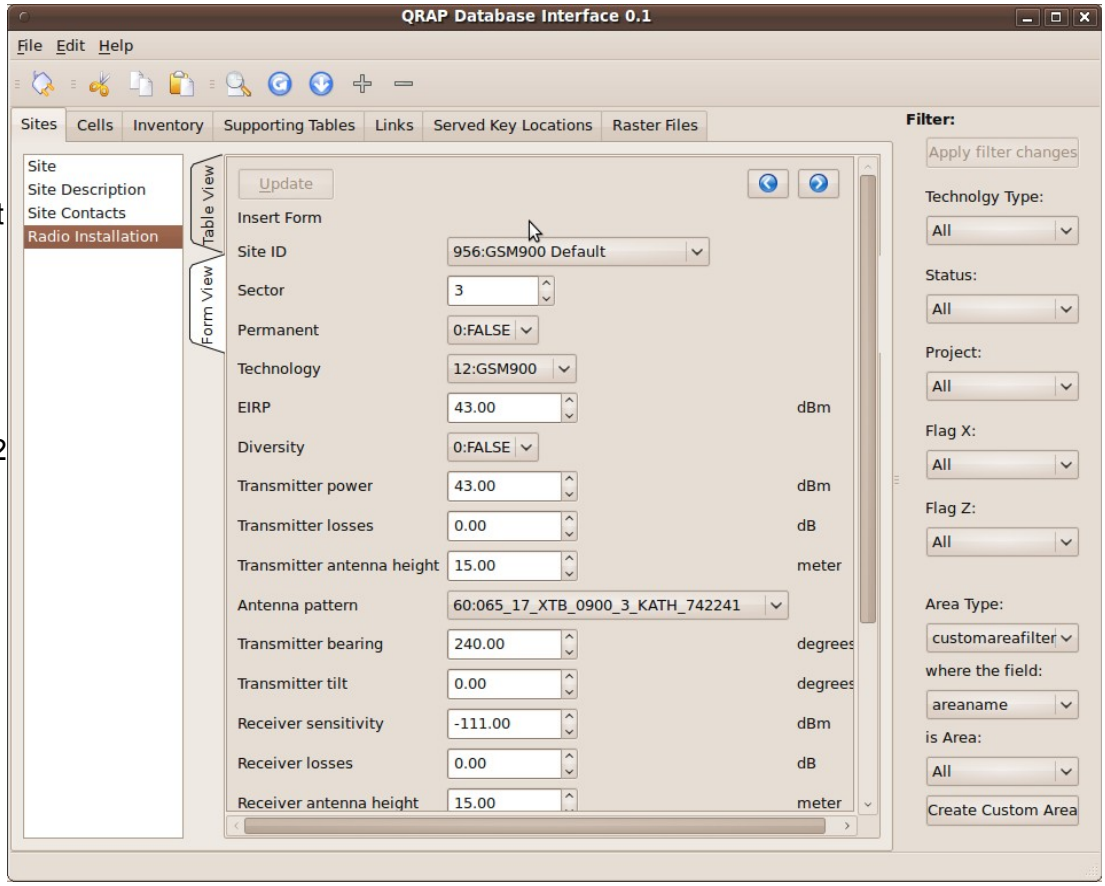

QRAP Database Interface 0.1
File Edit Help
Sites Cells Inventory Supporting Tables Links Served Key Locations Raster Files
Site
Site Description
Site Contacts
Radio Installation
Table View
Form View
Update
ID 0
Name Default
Status 4:Default
Latitude 25:0:0 S
DD:MM:SS X
Longitude 24:0:0 E
DD:MM.mm X
Close by Sites
± DD.dddd
Ground height 0
Lookup
Filter:
Apply filter changes
Technolgy Type: All
Status: All
Project: All
Flag X: All
Flag Z: All
Area Type: customareafilter
where the field: areaname
is Area: All
Create Custom Area


QRAP Database Interface 0.1
File Edit Help
Sites Cells Inventory Supporting Tables Links Served Key Locations Raster Files
Site
Site Description
Site Contacts
Radio Installation
Table View
Form View
Commit
Add Next
Insert Form
Site ID 0:NULL
Sector 1
Permanent 0:FALSE
Technology 12:GSM900
EIRP 43.00 dBm
Diversity 0:FALSE
Transmitter power 43.00 dBm
Transmitter losses 0.00 dB
Transmitter antenna height 15.00 meter
Antenna pattern 23:colinear.ant
Transmitter bearing 0.00 degrees
Transmitter tilt 0.00 degrees
Receiver sensitivity -111.00 dBm
Receiver losses 0.00 dB
Receiver antenna height 15.00 meter
Filter:
Apply filter changes
Technolgy Type: All
Status: All
Project: All
Flag X: All
Flag Z: All
Area Type: customareafilter
where the field: areaname
is Area: All
Create Custom Area

3.4.4.5) Default Entries per Technology

You can also create a default configuration, e.g. a 3 sectored site, for each technology:

First change the **Defaults** radio button back **Edit Normally.**

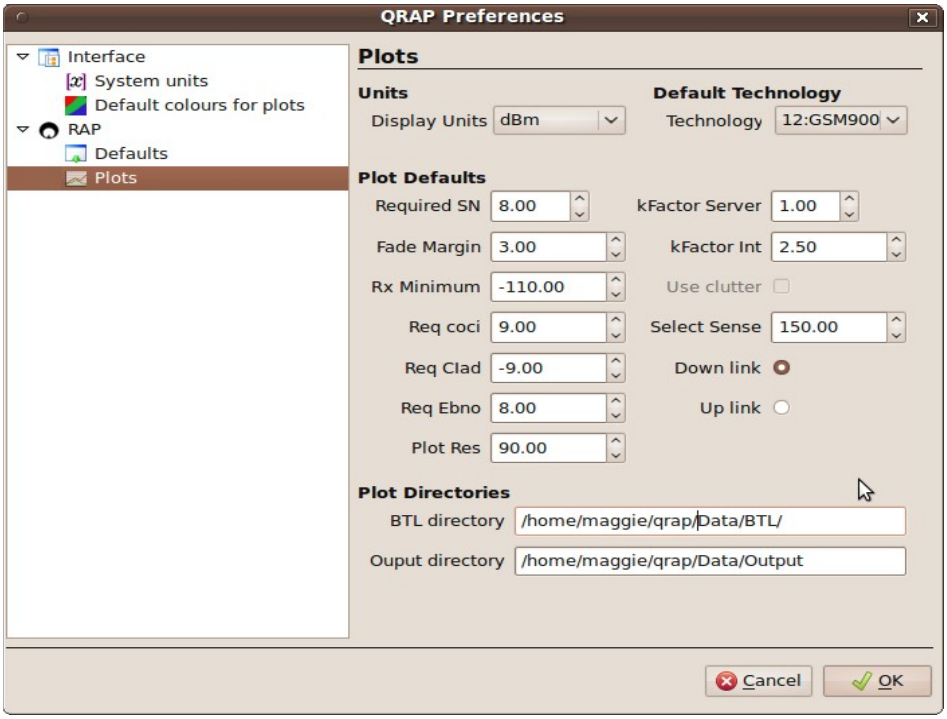


Add a new site, making the position lets say 00:00:00 N and 00:00:00 E to ensure that it is not confused with an actual site. Set its status flag as **Default**
Add 3 Radio Installations with sector numbers 1,2 and 3 and Transmitter and Receiver Azimuths as 0, 120 and 240 degrees respectively.
Select the site created above in SiteID and e.g. GSM900 as Technology.

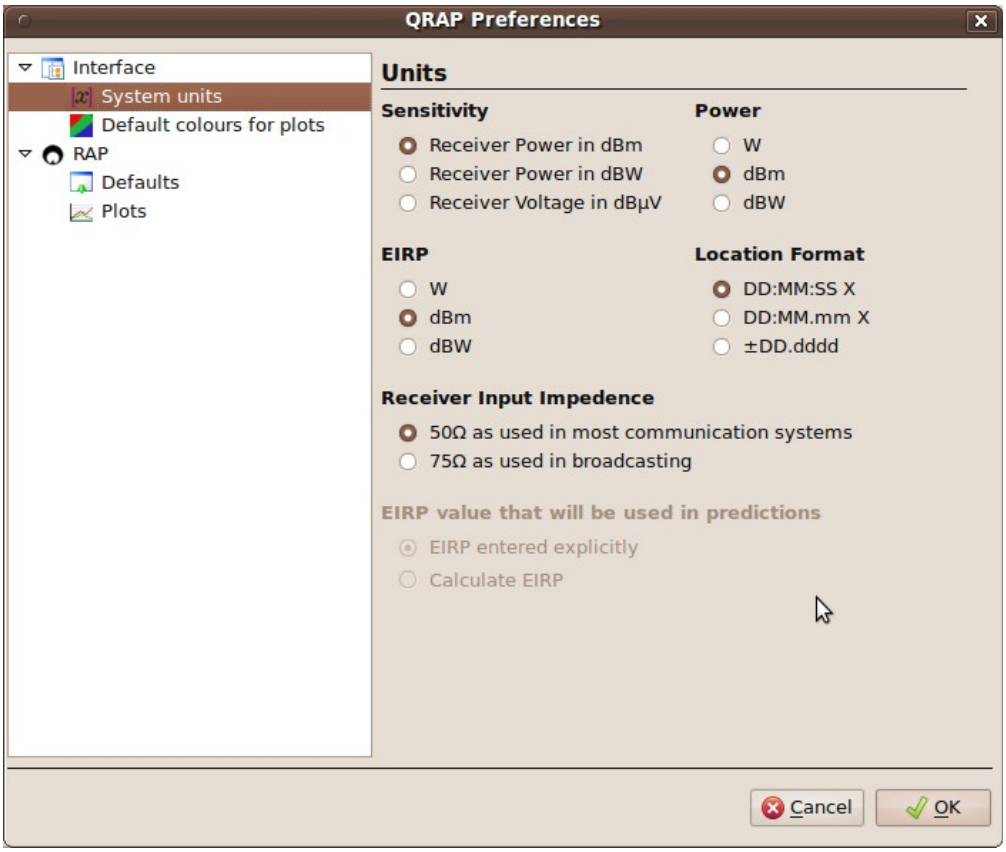
Edit the Technology to have the Default Site (at the bottom of the Technology form) reference the site created above. This will be the configuration added when one selects to add a default site.

3.4.4.6) Setup Plot defaults.

The Preferences could be accessed either by selecting **Edit**, and **Preferences** on the Database Interface, or clicking on the **Preferences** icon,  . The Plots preferences or defaults is used when doing plots, but also to setup a few other defaults. When completing this form be sure to select a Default Technology and that the directory where Basic Transmission Loss files are stored, **BTL directory** and **Output directory** exist and is writable for the user(s).

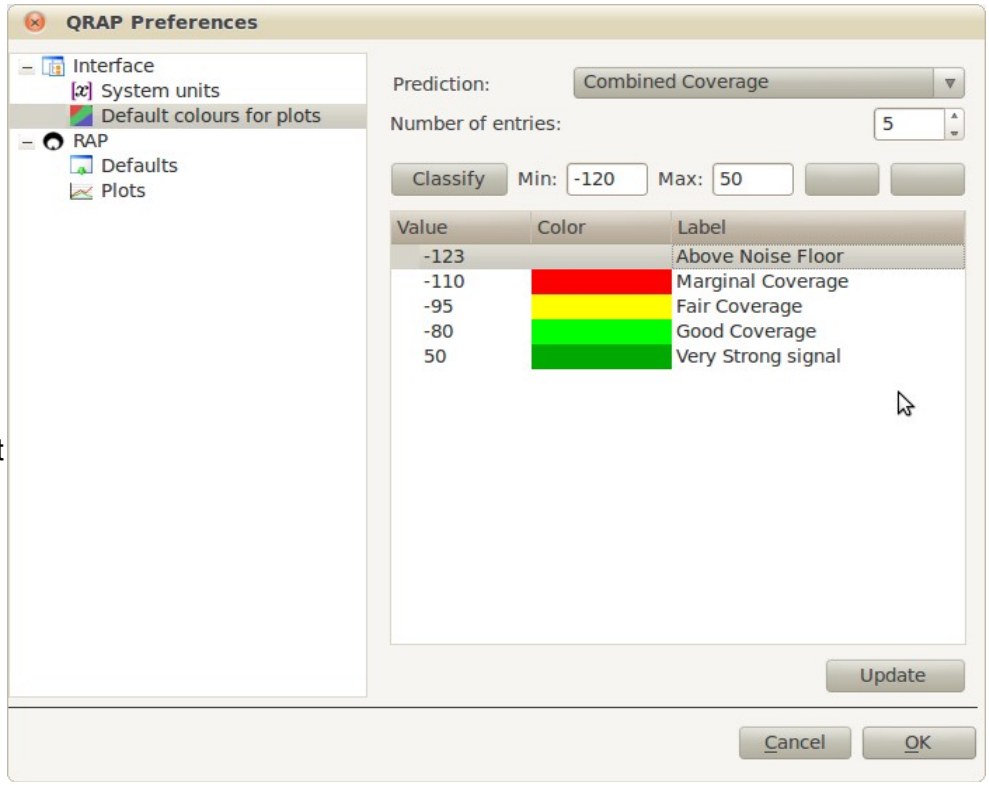


Now might also be a good idea to confirm that your preferences for the input formats are selected:



3.4.4.7) Set-up Colours for the Maps

Defaults colours for the different kind of maps could be setup using Preferences Dialogue box. First enter the number of bands and the minimum and maximum values you expect, then click on **Classify** which will render default starting values, that can be edited by clicking on each entry.

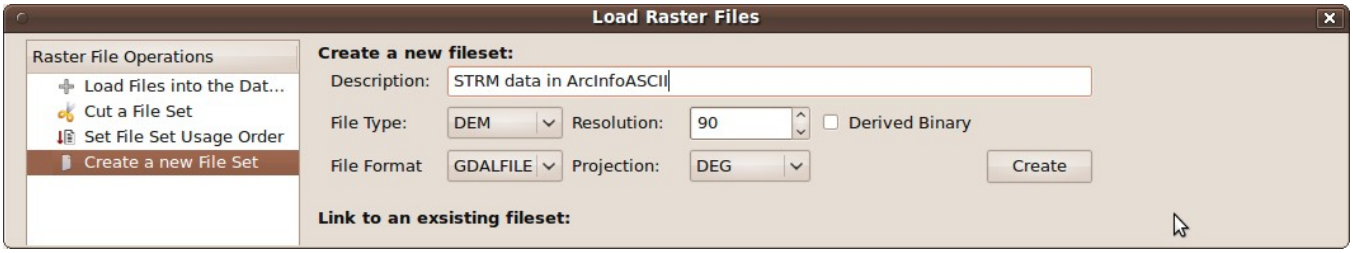


3.4.4.8) Add DEM and Clutter raster files

To “import” the raster files select **File**, **Import** and then **Raster Files** on Q-Rap Database Interface.

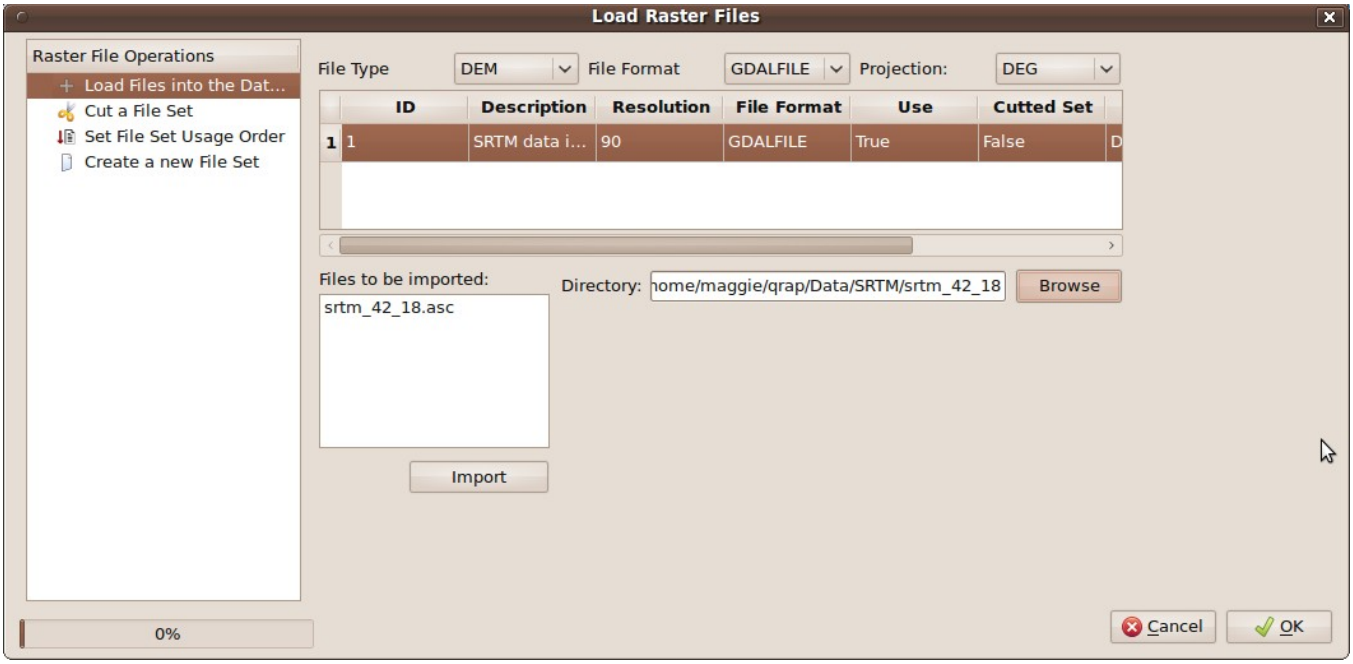
Here we will only present an example. More detailed information is available in a later section.

First create a new File Set to which the files could be added. In this example we will add the SRTM data that is available from http://srtm.csi.cgiar.org/ or you can directly go to http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp. ArcInfoASCII (or GeoTiff) format can be used. The gdal libraries (http://www.gdal.org/) is used to load these files, so most files could be loaded selecting the **File Format** “GDALFILE”. The files could be loaded as either **DEM** (**D**igital **E**levation **M**odel) for the local ground height data or **Clutter** for land cover type data.

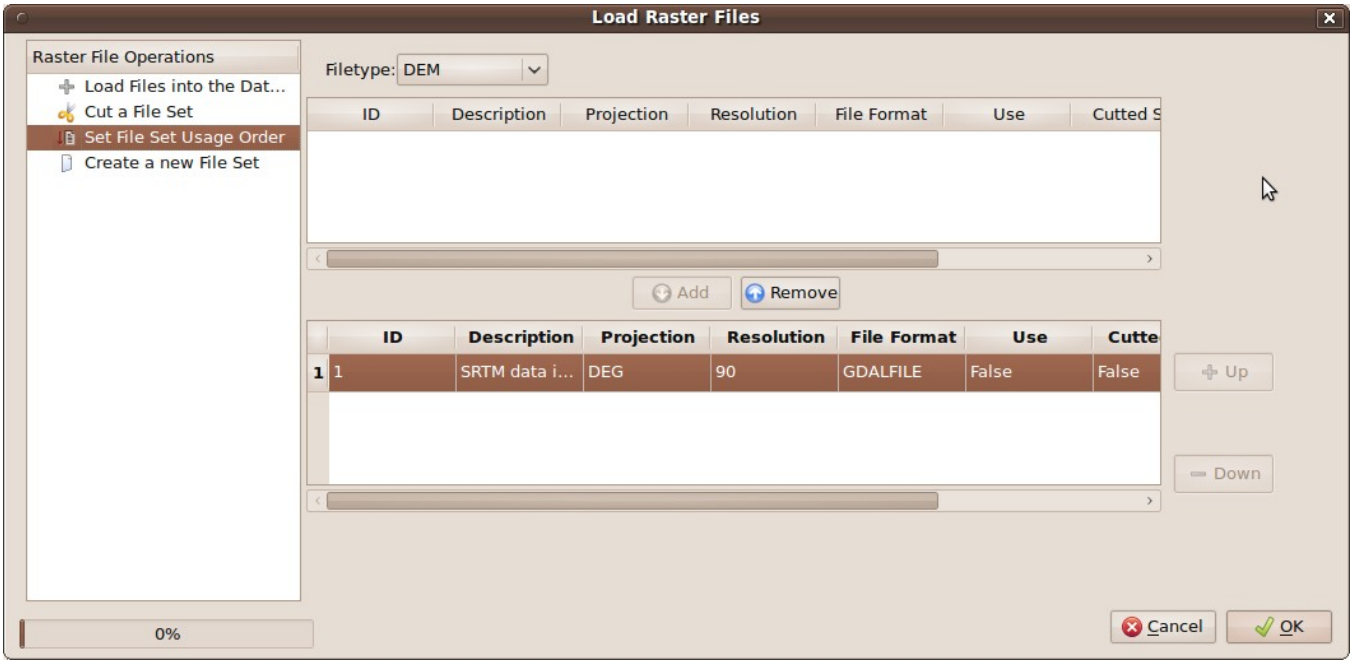


Next one needs to add the references to these files in the database. Select the newly created File Set, and **Browse** for, select and **Open** the files. To **Import** the files might take a while … you are probably in need of a break.

When the files are completely installed the **Files to be imported** list, will be clear.



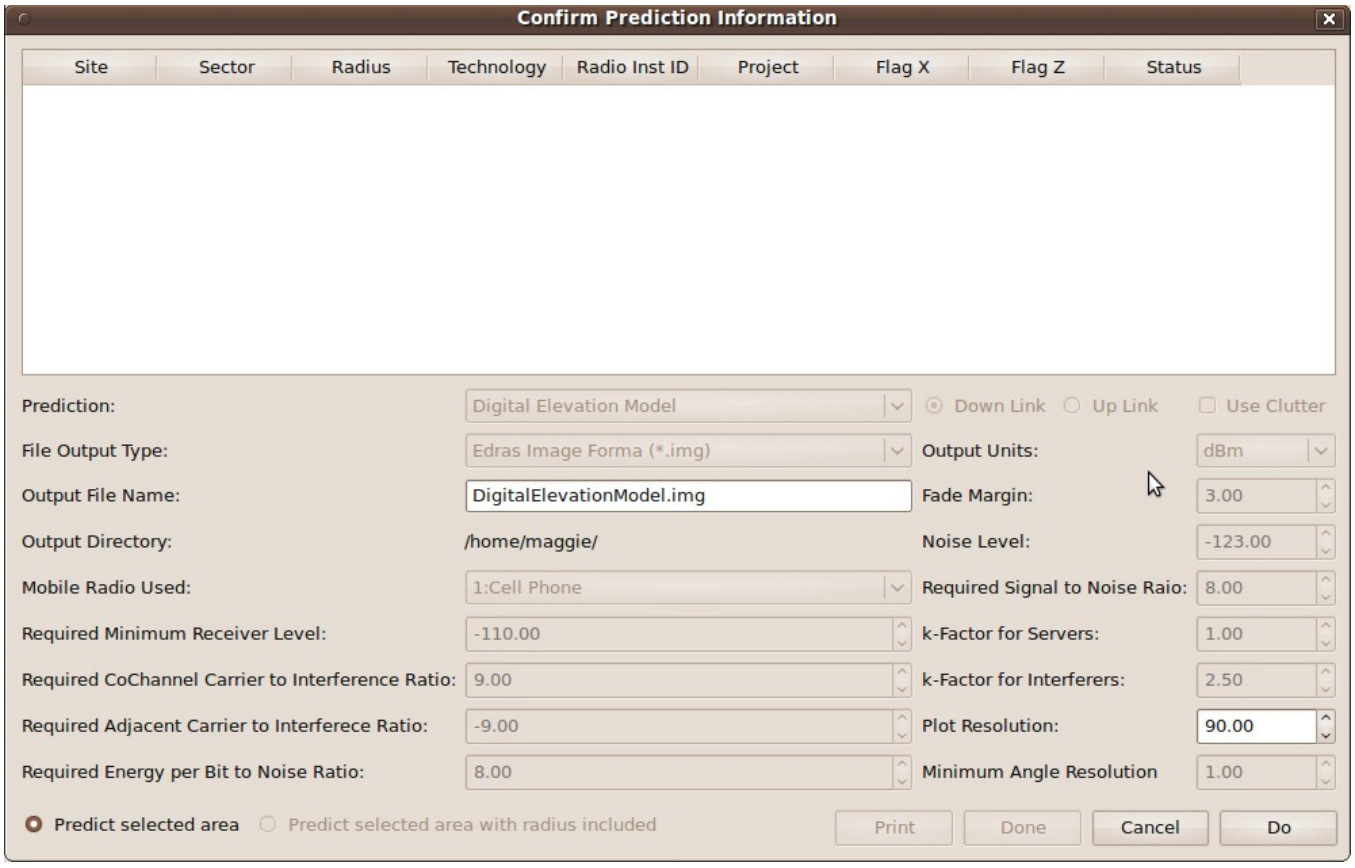
It is important to **Set the File Set Usage Order** (Raster File Operation on the left hand of the dialog box). **Add** the newly created FileSet to the list for the DEM **FileType.**



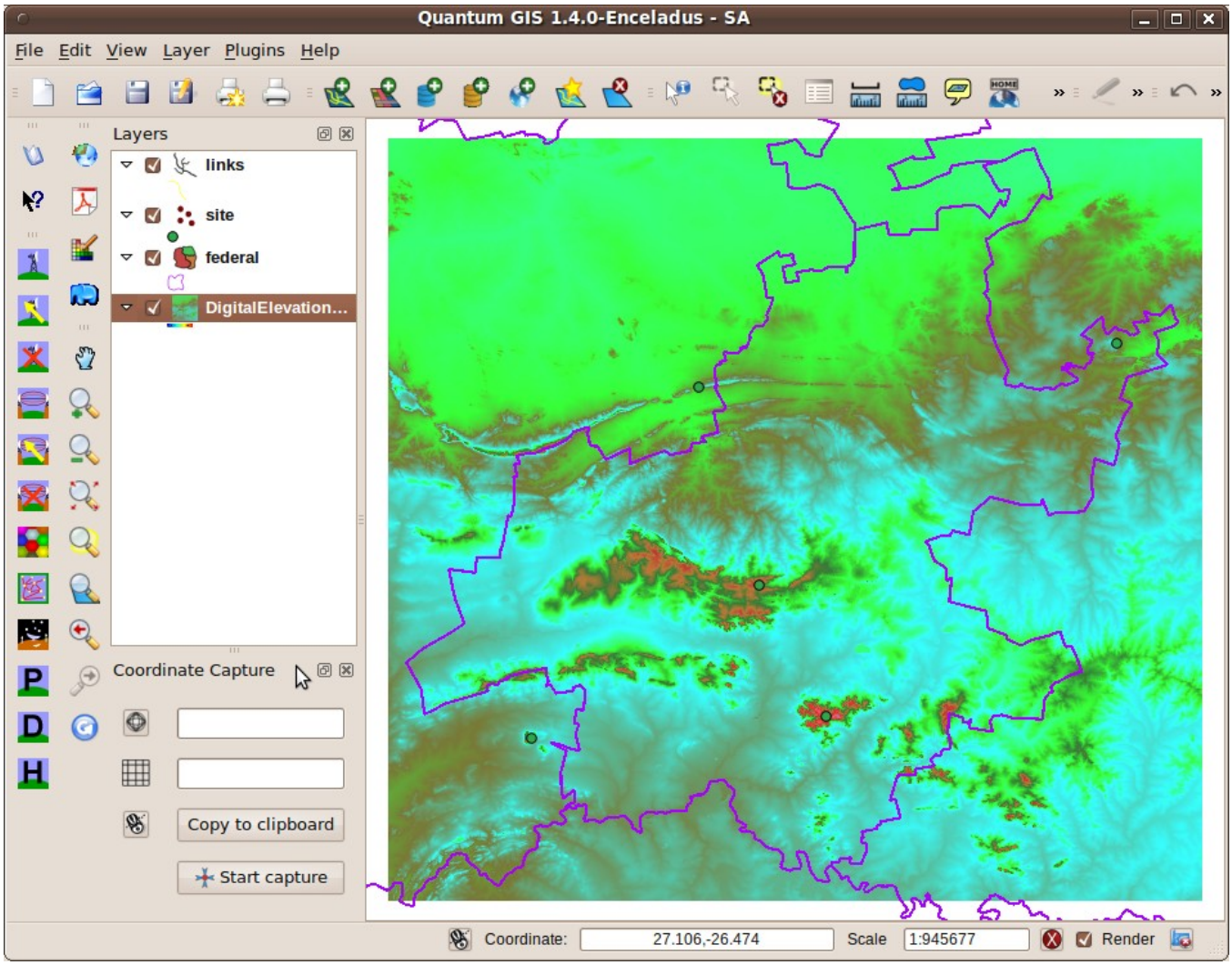
4) A Few First Examples

4.1) Loading Digital Elevation Model

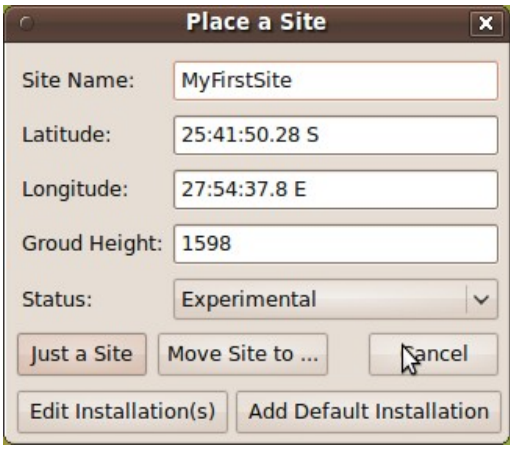
Click on the **Perform a Prediction** icon,  , and with the mouse's left button select an area for which you would like view the Digital Elevation Model data, ending the selection with a right button click. If the area does not include any site, a information or warning message will appear. Upon closing this message box, The Prediction Dialog box will appear. The Digital Elevation Model is the last option



available under Prediction. Click on **Do.** When the height data has been loaded the **Done** can be used to close the Dialog Box. An example of such a DEM is shown below.



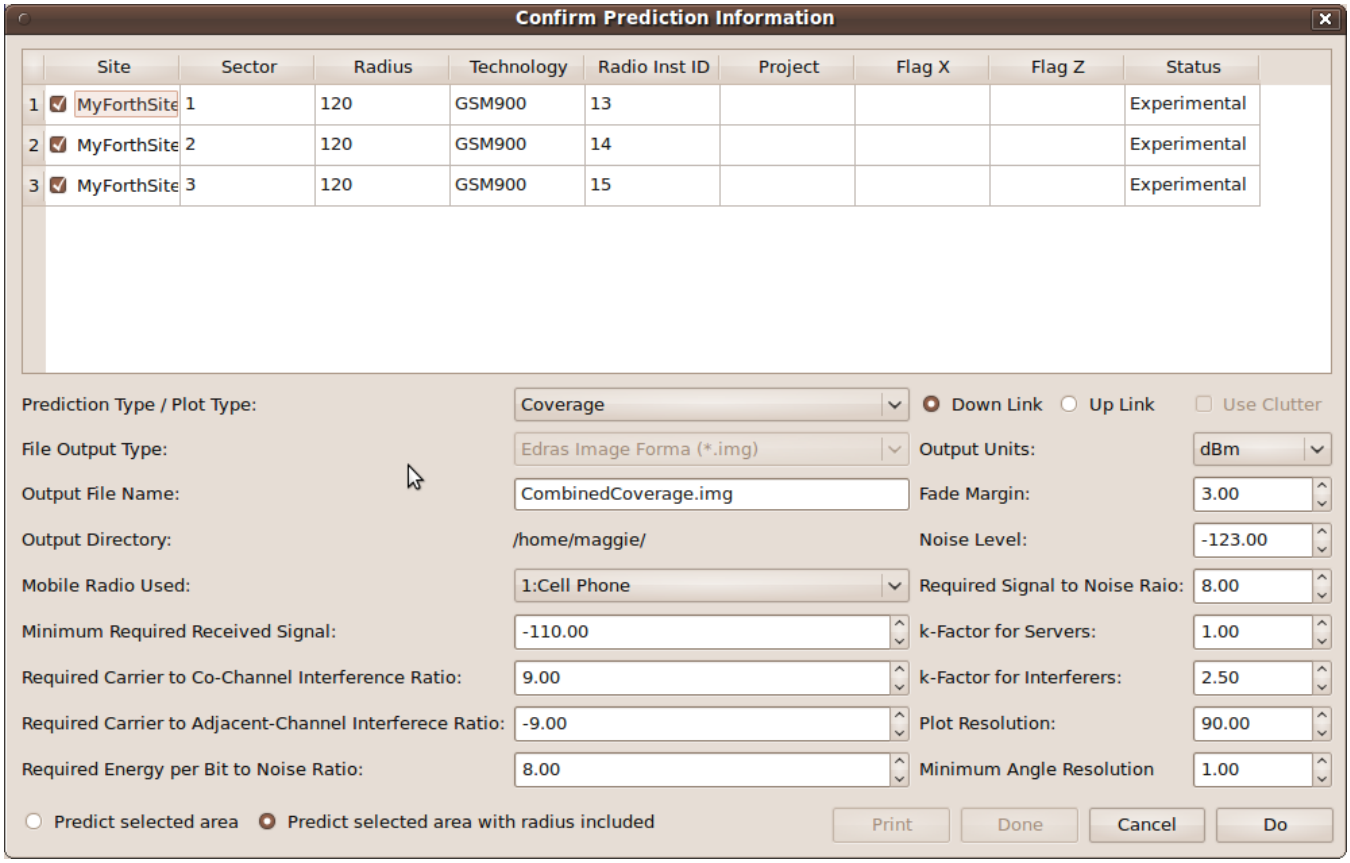
4.2) Creating a site.



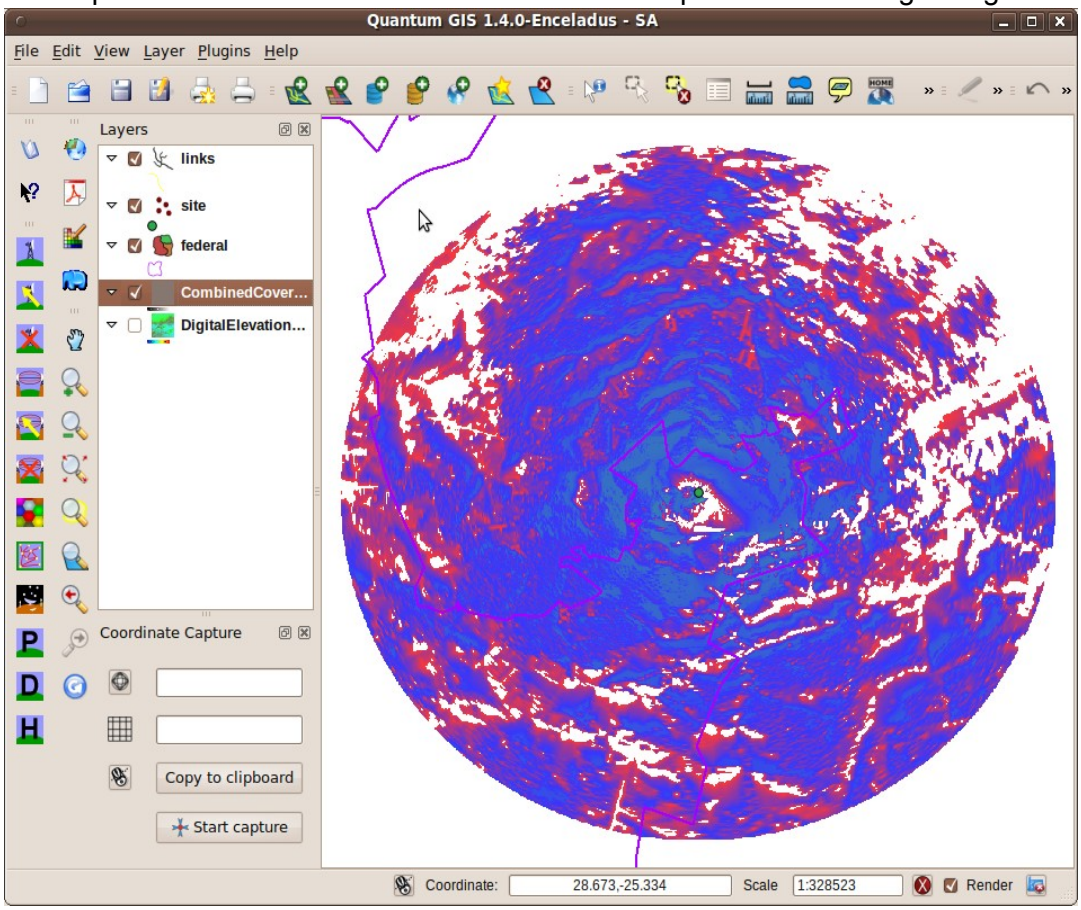
Click on the **Place a Site** icon,  , point the cursor to the location where you would like to place a site and click on the left mouse button. First you are informed that to obtain the height data at the point might take a while. Click on **OK** and wait for the dialog box to appear. To add a set of installations like those edited in paragraph 3.4.4.4 click on **Add Default Installation.**

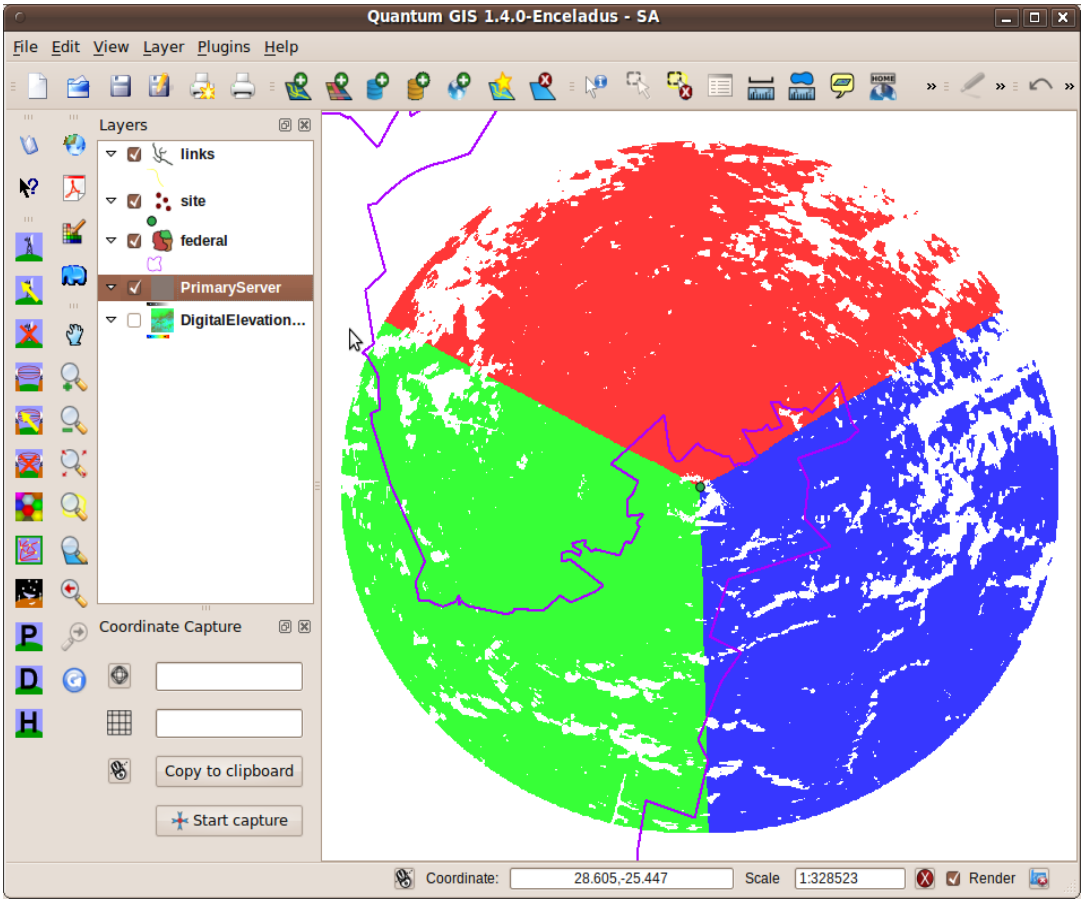
4.3) Do a Coverage Prediction

Once again by clicking on the **Perform a Prediction** icon,  , and selecting an area that includes all the sites for which you would like to include in the prediction, ending with a right click will bring the Prediction dialog box up. Click **Do** to start the prediction. This might take a while. The **Radius** determine the maximum distance from the site for which the prediction will be done.



Many prediction options are available. They will be discussed in later sections. Two examples are a Coverage plot that indicates the receivable signal strength at different locations and the other a Primary Server plot that indicates which radio installation will provide the strongest signal.

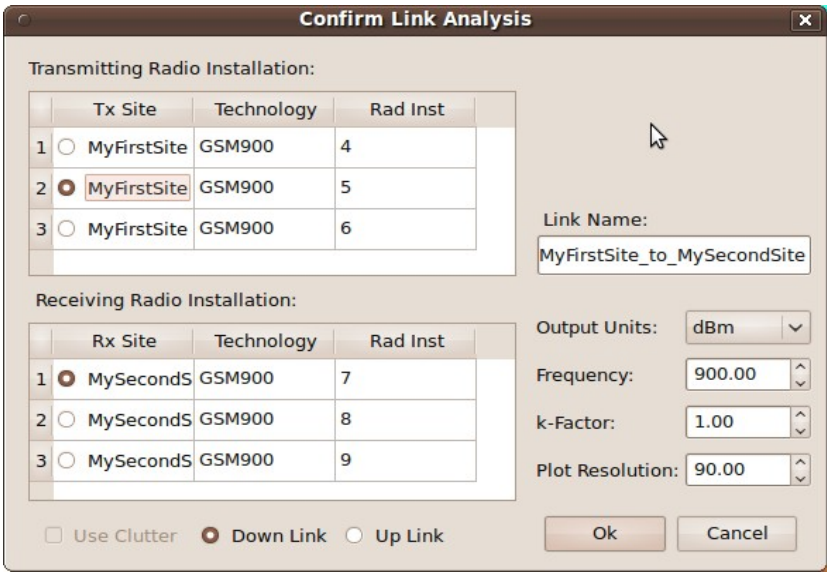




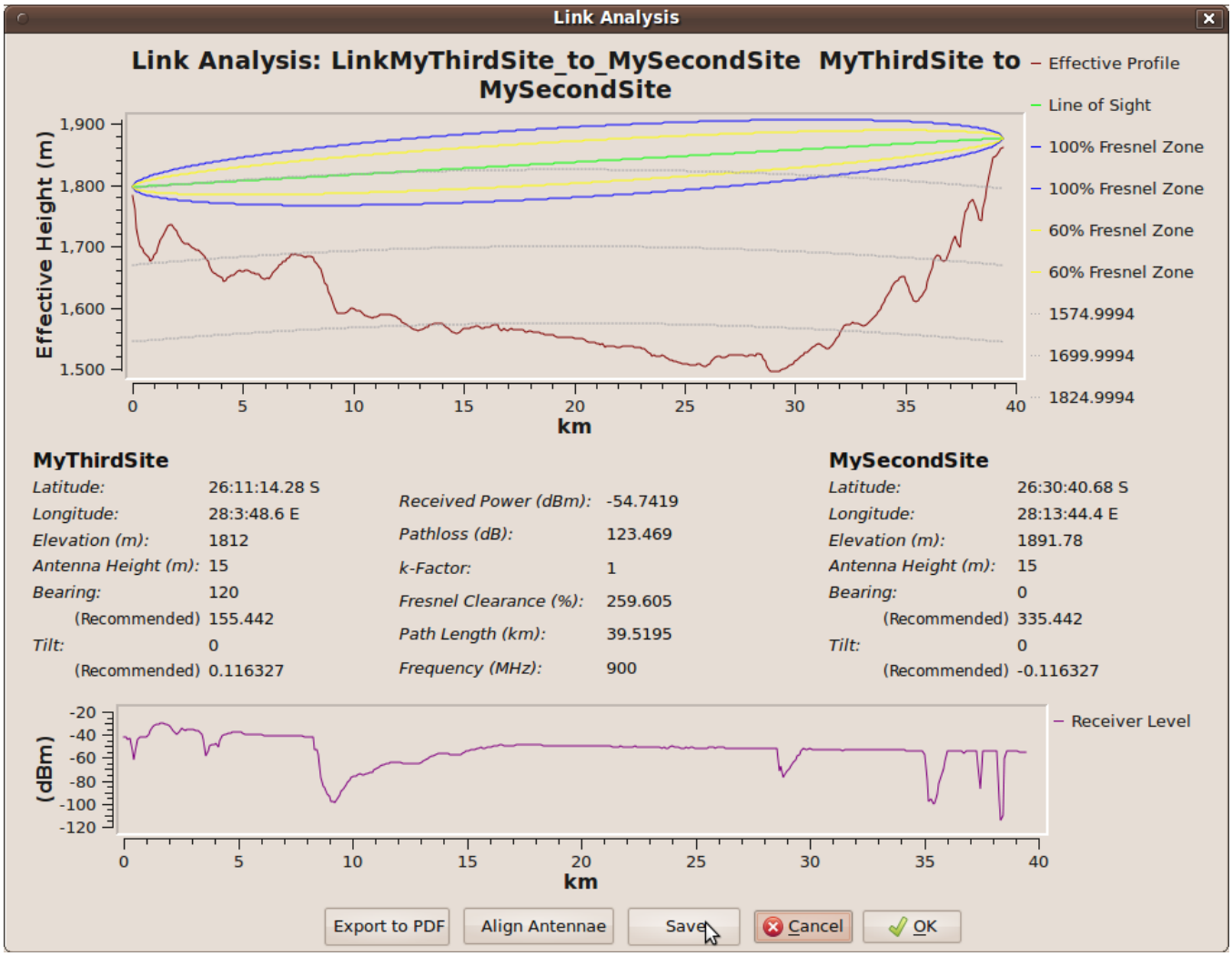
4.4) Perform a link analysis

Create another site, in a similar manner described in 4.2. Note that both sites need to have a radio installation attached.

Click on the **Link Analysis** icon,  , then on the first site, and then on the second. The link request dialog box should appear. After selecting the radio installation between which you would like to do the link analysis click on **Ok**.



Below is the resultant Link Analysis. Saving the link stores it in the database. Clicking on the **Align Antennae** will result in changing the radio installations in the database to point to one another. It also analyses the link again.

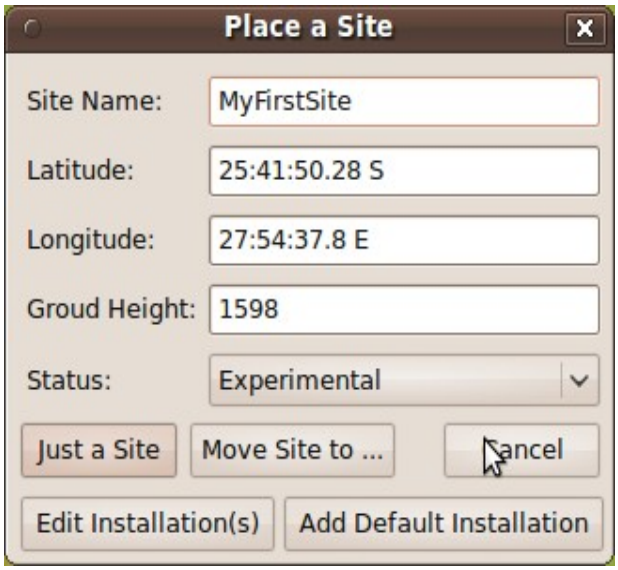


5) Description of User Interface Functionalities

5.1)  **Place Site** button

This button is a way to create a site via the QGIS user interface.

- Click on the button,
- move the mouse cross-point to the location where you would like to place the site.
- Left click again.
- A information dialog box will appear requesting you to wait a while, close it by clicking on **Ok.**
- Wait until the Site Dialog box appears:



5.2) **Place Site** dialog box

5.2.1) Move Site to … button

This buttons allows one to again use the QGIS user interface to move the site position:

- Click on the button,
- move the cross-hair mouse position to the the position where you would like to place the site,
- Left click.

- The coordinates of the new position will appear in the dialog box. The position shown will not move until one of the three accepting buttons are clicked:

*5.2.2) **Just a Site** button*

If you just want to add a site, but do not want to place any radio installation on the site, clicking on this button will store the site in the database and close the dialog box.

*5.2.3)**Add Default Installation** button*

Clicking on this button will save the site and add copies of all the radio installations connected to the default site (3.4.4.5) of the current default technology as selected in Plot Preferences (3.4.4.6). It results in the dialog box being closed.

*5.2.4)**Edit Installation** button*

Clicking on this button will save the site in the Database, close the dialog box and take you to the Database User Interface where you will be able to edit, and commit (a) radio installation(s) that is connected to this site.

*5.2.5)**Cancel** button*

This button will close the dialog box WITHOUT saving the site information in database.

5.3)  **Select a Site** button

To edit a site click on this button. The same Dialog Box as above will appear, and the functionalities will be exactly the same as in (5.1) except:

*5.3.1) **Update** button*

This will save any changes you made to the information in the dialog box in the database can close the dialog box.

*5.3.2) **Edit Installation** button*

After closing the dialog box clicking on this button will take you to the information of any existing radio installations on the site and allow you to edit it via the Database User Interface.

5.4)  **Delete a Site** button

Clicking on this button will bring up a confirmation dialog box. On clicking **Delete**, the site and any radio installation and or any other information linked to that site will be removed from the database.

5.5)  **Link Analysis** button

To create a site-to-site radio link between two sites that already have radio installation installed:

- Click on this button.
- Move the mouse to the site that you would like to serve as transmitter.
- Left click.
- Move mouse to site that were the receiving radio installation will be.
- Left click.

The Link Analysis dialog box (4.4)will appear.

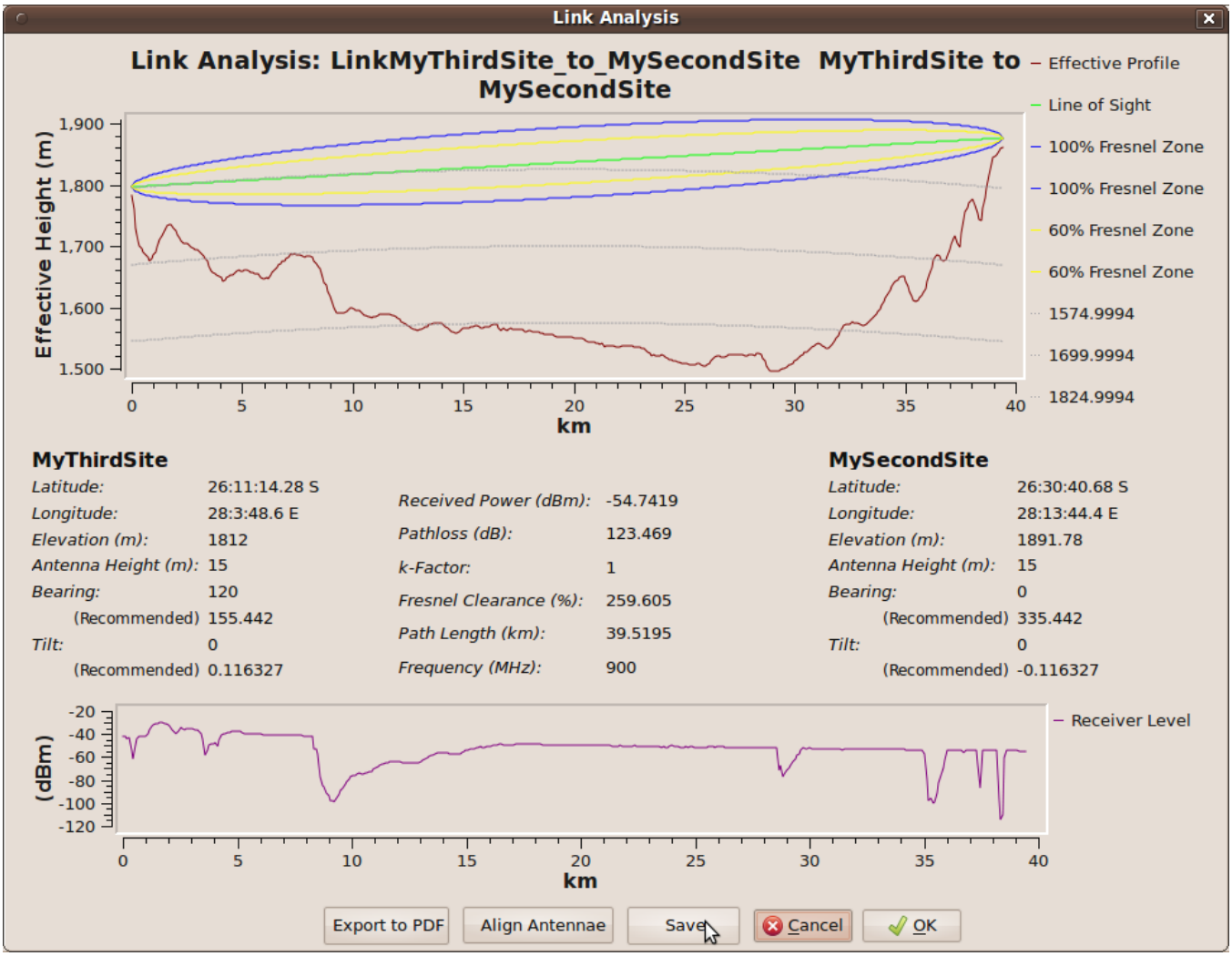
5.6) **Confirm Link Analysis** dialog box (4.4)

- Use the radio buttons select the radio installation you would like to use for the transmitter and receiver respectively.
- The radio button on the bottom allows you to an analysis using the Tx radio installation as the actual transmitter (Downlink) or the Rx radio installations transmitting part (Uplink).

- The **Link Name** may be any recognisable name and duplicates may occur.

For help on the remaining parameters see Section 6.
Click **Ok** and wait a bit. The Link Analysis Display will appear:

5.7) Link Analysis Display



*5.7.1) **Export to PDF** button*

This allows one to save the information of the link on a *.pdf file of your choice. It does not save it in the database.

*5.7.2) **Align Antennae** button*

This alters the radio installations involved to point to one another, which means the actual azimuth and tilt of the antennae will change to the recommended values. This change is save in the database. The link is however not saved in the database.

*5.7.3) **Save** button*

Clicking on this button will result in the Link being saved in the database. When an existing link was selected (5.8), this will result in the link being updated in the database.

*5.7.4) **Ok** button*

To close the display click on this button.

*5.7.5) **Cancel** button*

This button also make the Link Display button disappear.

5.8)  **Select Link** button

To view the Link Analysis of a Link in the database,

- click on this button,
- move the mouse pointer to anywhere on the line representing the link.
- Left click.

The Confirm Link Analysis dialog box (5.6) will appear with the actual values of the link in the dialog box. You may now edit these values and press **Ok**, to view the Link Analysis Display (5.7). Pressing the **Save** button will now result in updating the link in the database.

5.9)  **Delete Link** button

To delete a link from the database

- click on this button,
- move the mouse pointer to any point on the line representing the link.
- Left click.

A confirmation dialog box will appear.
Press **Ok** to delete the link. The radio installations on either side of the link will also be removed from the database. (The sites with any other radio-installation on it will remain).

5.10)  **Perform Area Prediction** button

This button enables one to perform any of a number of possible area analyses. These are described in detail in Section 7. To perform any of these analysis.

- Left click on this button
- Using the left mouse button mark a polygon on the QGIS user interface that includes all the sites that you would like to include in the analysis.
- End the selection with the right mouse button.

The Confirm Prediction Information Dialog Box should appear.

5.11) **Confirm Prediction Information** dialog box

The Prediction Information that can be edited are:

5.11.1)Radio Installation Selection Table

This table contains a row for each Radio Installation in the selected area.

- The tick boxes allow for these installations to be included(ticked) or excluded (unselected) in the prediction analysis.
- The only other entry that really makes sense to edit is the **Radius**. It is the maximum radius from the site for which the prediction will be done. The default value supplied here originates from the setting in the Technology table (3.4.4.1)for the Technology of that site, if it was specified, otherwise the default value will be that supplied in the Plot Preferences (3.4.4.6).

The remaining columns are there to ease the identification of the Radio Installations.

5.11.2)Prediction Type

In this combo box one can select the type of plot you would like to have generated. In Section (7) you will find a complete description of each of these options.

5.11.3)Output File Name

The default output filename corresponds to the Prediction Type or Plot Type. This could be changed to anything. At this stage the file extension needs to remain *.img.

5.11.4)Output Directory

This is actually more informational. This is the directory where the output file is saved. It can be altered under Plot Preferences (3.4.4.6). Make sure that the current user has write access to this directory.

5.11.5)Mobile Radio Used

This is a selection from the Mobile table (3.4.4.3) entries. This is to represent any mobile, cellphone or handhold unit for which the coverage is to be planned.

5.11.6)Minimum Required Received Signal Level (dBm?)

This determines the minimum level that will be displayed on the plot. Signal levels below this level will not be displayed as coverage at all (a value of -9999 is assigned, which will be transparent). The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on how to chose this parameter will be found in Section 6

5.11.7)Required Carrier to Co-channel Interference Ratio (dB)

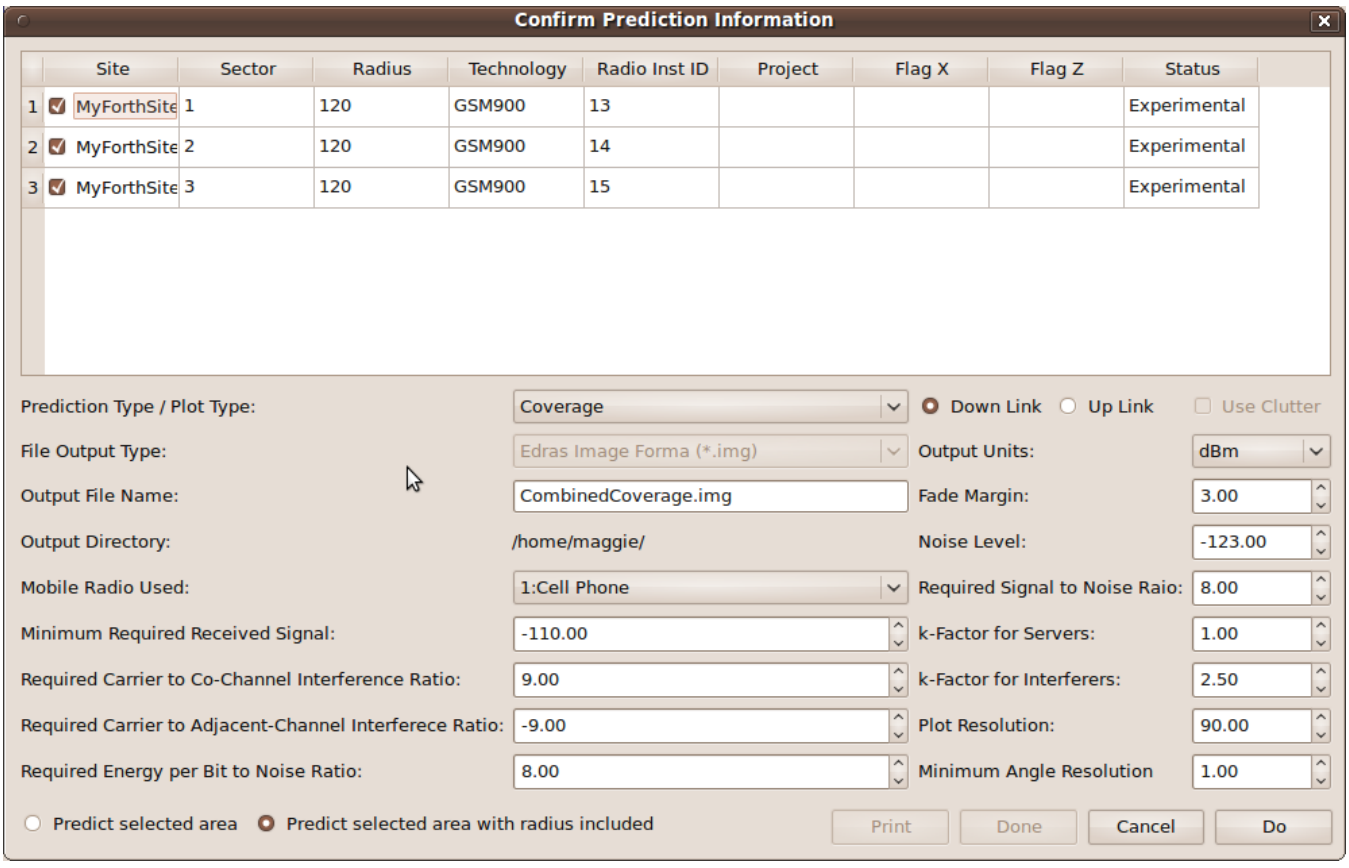
This value will be used in the interference related plots as criteria when interference should be displayed. The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on this parameter will be found in Section (6).

5.11.8)Required Carrier to Adjacent-channel Interference Ratio (dB)

This value will be used in the interference related plots as criteria when interference should be displayed. The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on this parameter will be found in Section (6).

5.11.9)Required energy per Bit to Noise Ratio (dB)

This value will be of particular importance CDMA based systems. Currently it is not incorporated in any plot. The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on this parameter will be found in Section (6).



5.11.10)Down-link or Up-link *Radio button*

Normally when doing area predictions the prediction is done on the down-link, i.e. with the fixed installation or base station as the transmitter and the mobile unit as the receiver. It is however often useful to present the value that would be received by the base-station from a mobile transmitter at the point in the area. The default is determined by the values set in the Plot Preferences (3.4.4.6).

5.11.11)Output Units

This determines the units in which particularly the Coverage Plot will be presented. The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on the meaning of different output units will be found in Section (6).

5.11.12)Fade Margin (dB)

This represent a margin that is introduced to ensure that a certain percentage of the signal will be above the required level in a fading environment. Currently it is not incorporated in any plot. The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on how to chose this parameter will be found in Section 6

5.11.13)Noise Level (dBm)

This is the noise level or noise floor. The value is used in the signal to noise ratio plot. This level is determined by the bandwidth of the technology and the environmental noise sources present. More detail on how to chose this parameter will be found in Section 6 (In future versions this will be set as the power spectral density in e.g. dBm/Hz)

5.11.14)Required Signal to Noise Ratio (dB)

The value is used in the signal to noise ratio plot. This value is mostly determined by the technology and the quality of the equipment. The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on this parameter will be found in Section 6

5.11.15)k-Factor for Servers

This parameter is used in the effective earth model. It depends on the gradient of the refractiveness of air just above the surface of the earth. The value for servers will be used for the serving calculations in Coverage Plots and Interference-Plots. Values between 0.96 and 1.33 are typical. The smaller the value the more likely it is that hills and mountain will obstruct the wave. The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on this parameter will be found in Section (6).

5.11.16)k-Factor for Interference

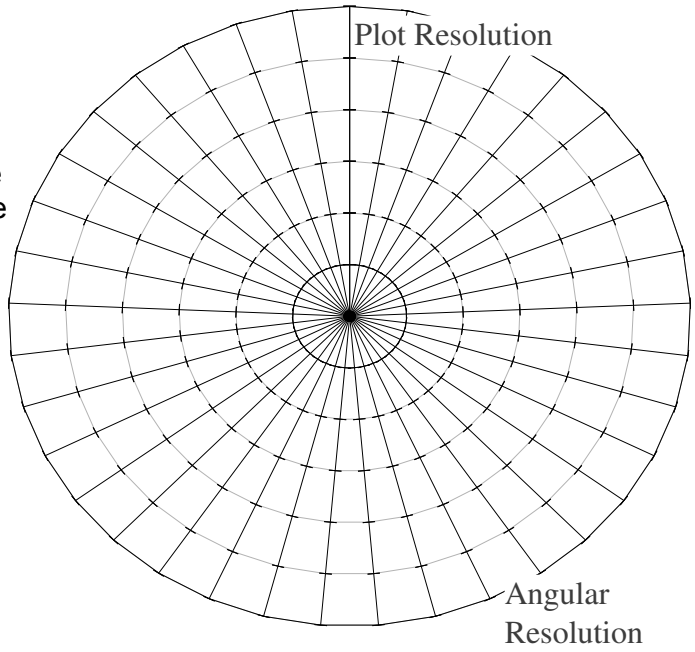
This parameter is used in the effective earth model. It depends on the gradient of the refractiveness of air just above the surface of the earth. The value for servers will be used for the serving calculations in Coverage Plots and Interference-Plots. Values between 1.33 and 6.8 are typical. The bigger the value the more likely is that the interfering signal will overshoot obstacle to cause interference. The default value is determined by the values set in the Plot Preferences (3.4.4.6). More detail on this parameter will be found in Section (6).

5.11.17)Predict selected area (with radius included) *radio button*

The default value is **Predict selected area with radius included** for most plots which means that the area for which the coverage will be calculated is all the sites selected plus the extent of the prediction radius of the sites so that the entire coverage of all sites will be shown. For a Digital Elevation Model plot (DEM), only a square around the selected polygon will be shown.

5.11.18)Plot Resolution (meter)

This value determines the resolution at which points along a path profile will be sampled from the raster files. The recommended value for the plot resolution is the lowest resolution or the resolution of the first file of the loaded raster files that is in the list of the File Set Order (3.4.4.8). The default value is determined by the values set in the Plot Preferences (3.4.4.6).



5.11.19)Minimum Angular Resolution (degrees)

This value determines the difference in angle of different path profiles that will be extracted. The lower the value the longer it will take but the better the result will pick up any changes. The smallest recommended value is the Plot Resolution divided by the Radius (5.11.1) (converted to meters) multiplied by 180/π.

5.12)  **Multi-link identification** button

This button provides access to a utility that will perform all link analysis between a set of sites, and store the links that adhere to certain criteria. For this utility the sites may be without any radio-installation, however it is necessary that a default site with one radio installation is defined for the technology (3.4.4.5) that will be used on the links. This radio installation will be automatically installed for each site of each link that works and the links that works will be automatically saved in the database. To use this functionality:

- Left click on this button
- Using the left mouse button mark a polygon on the QGIS user interface that includes all the sites that you would like to include in the analysis.
- End the selection with the right mouse button.

The Multi-Link Identification Dialog Box should appear:

5.13) **Multi-Link Identification** Dialog Box

5.13.1)Site Selection Table

This table contains a row for each Site in the selected area.

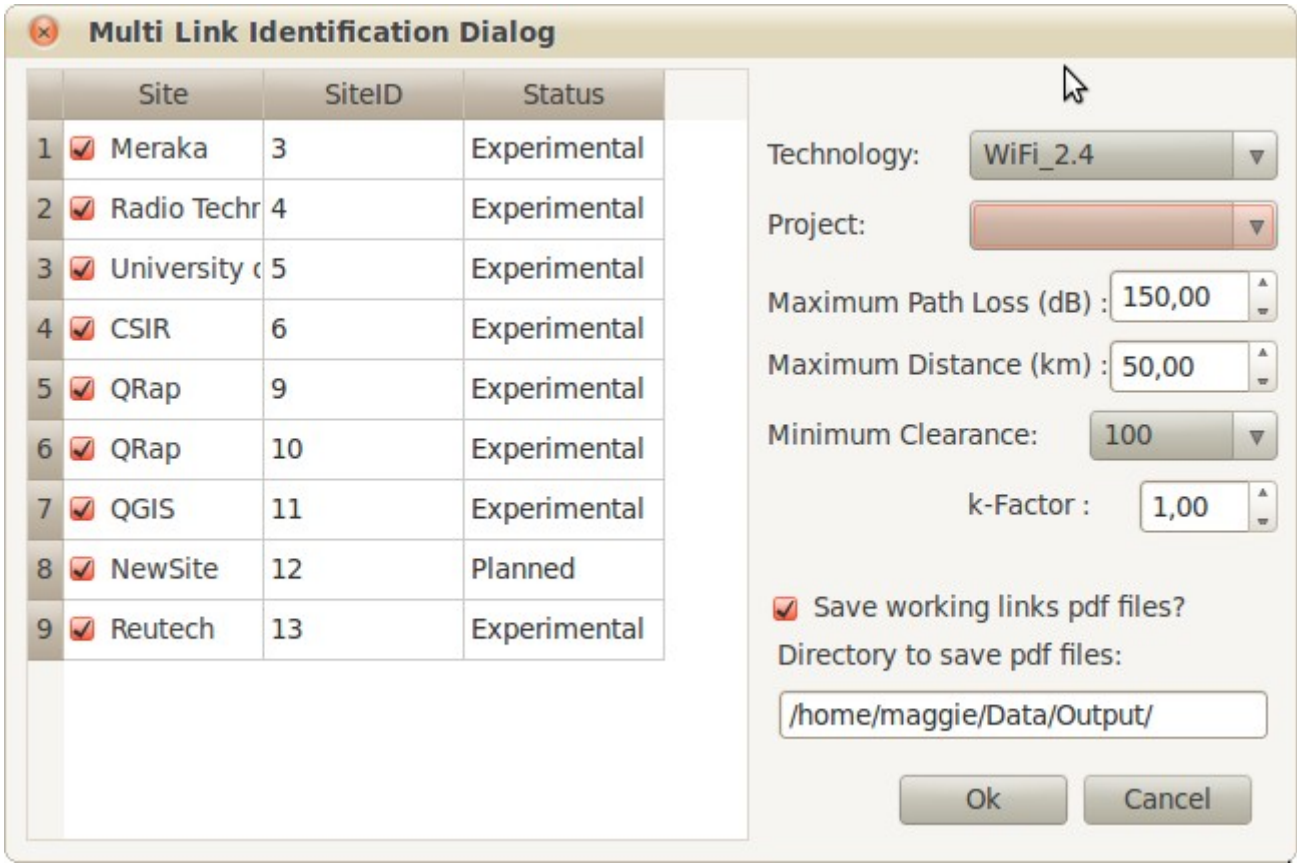
- The tick boxes allow for these sites to be included(ticked) or excluded (unselected) in the multi-link identification process.

5.13.2)Technology

This is a very important input parameter. You must ensure that the technology that you specify have a default site with an installation attached. (3.4.4.5). This radio installation will be automatically added at each end of each successful link and the azimuth of the transmitter and receiver antennas will be pointed to the other side of the link.

5.13.3) Project

It is not crucial that you enter a project, but this is the project value that will be assigned to each radio installation added.



5.13.4) Maximum Path Loss (dB)

This is the maximum path loss in decibel, for which you believe the link will still work. Links with a path loss less than this value and adhere to the other criteria below will be saved. See section 6 for guidelines on how to calculate it.

5.13.5) Maximum Distance (km)

This is the maximum distance in kilometer for which the link should still work. There are a number of criteria that needs to be considered here. These are discussed in section (6)

5.13.6)Minimum Clearance (%)

This value indicates the Fresnel zone clearance that the saved links need to have. If the entire first Fresnel zone needs to be clean 'n 100% clearance should be selected. This would be a prudent value. To ensure at least 60% of the first Fresnel zone is clean is highly recommended, while for lower frequencies it might suffice to have Line-of-Site (use the value 0). The value to choose will also be influenced by the k-Factor you choose to use.

5.13.7)k-Factor

This parameter is used in the effective earth model. The k-Factor is the ratio of the effective earth radius to the real earth radius. It represent the effect that the gradient of the refractive-index in the lower troposphere have of the path the rays/waves travel. A value between 0.95 (very conservative) and 1.33(often used when no other information in available) is typical. See section (6) for more detail.

5.14)  **Spectral Interference Calculation** button

This button provides access to the inter-system interference analysis tool. The interference received at a particular receiver will be calculated using all the information from the other sites. The interference is shown as a function of the frequency spectrum. Here it is important that all sites involved in the calculation has a defined technology with a defined signal envelope (see Database interface under Supporting Tables.) The power transmitted from each of the radio-installations, the path loss between

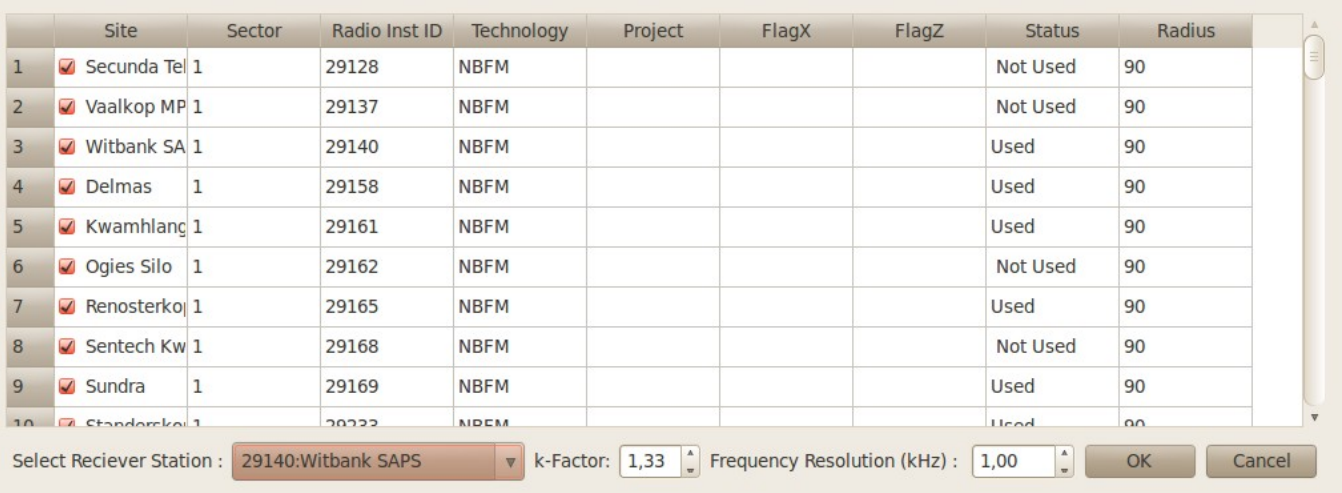
these transmitters and the receiving installation and the signal envelope is used in estimating the interference that will be experienced at each frequency in the spectrum.

To use this feature:

- Left click on this button.
- Using the left mouse button mark a polygon on the QGIS user interface that includes all the sites that you would like to include in the analysis.
- End the selection with the right mouse button.

The Spectral Interference Analysis Dialog Box should appear:

5.15) **Spectral Interference Analysis** Dialog Box



5.15.1)Radio Installation Selection Table

This table contains a row for each Radio Installation in the selected area.

- The tick boxes allow for these installations to be included(ticked) or excluded (unselected) in the Spectral Interference Analysis as transmitting radio installations.

The remaining columns are there to ease the identification of the Radio Installations.

5.15.2)Receiver Station:

Here one select the receiving station at which the interference analysis needs to be done. In the case of Radio Astronomy, this will be the radio telescope, while the transmitting sites in 5.15.1 would be the radio-installation in the vicinity that could negatively impact on the radio-telescope.

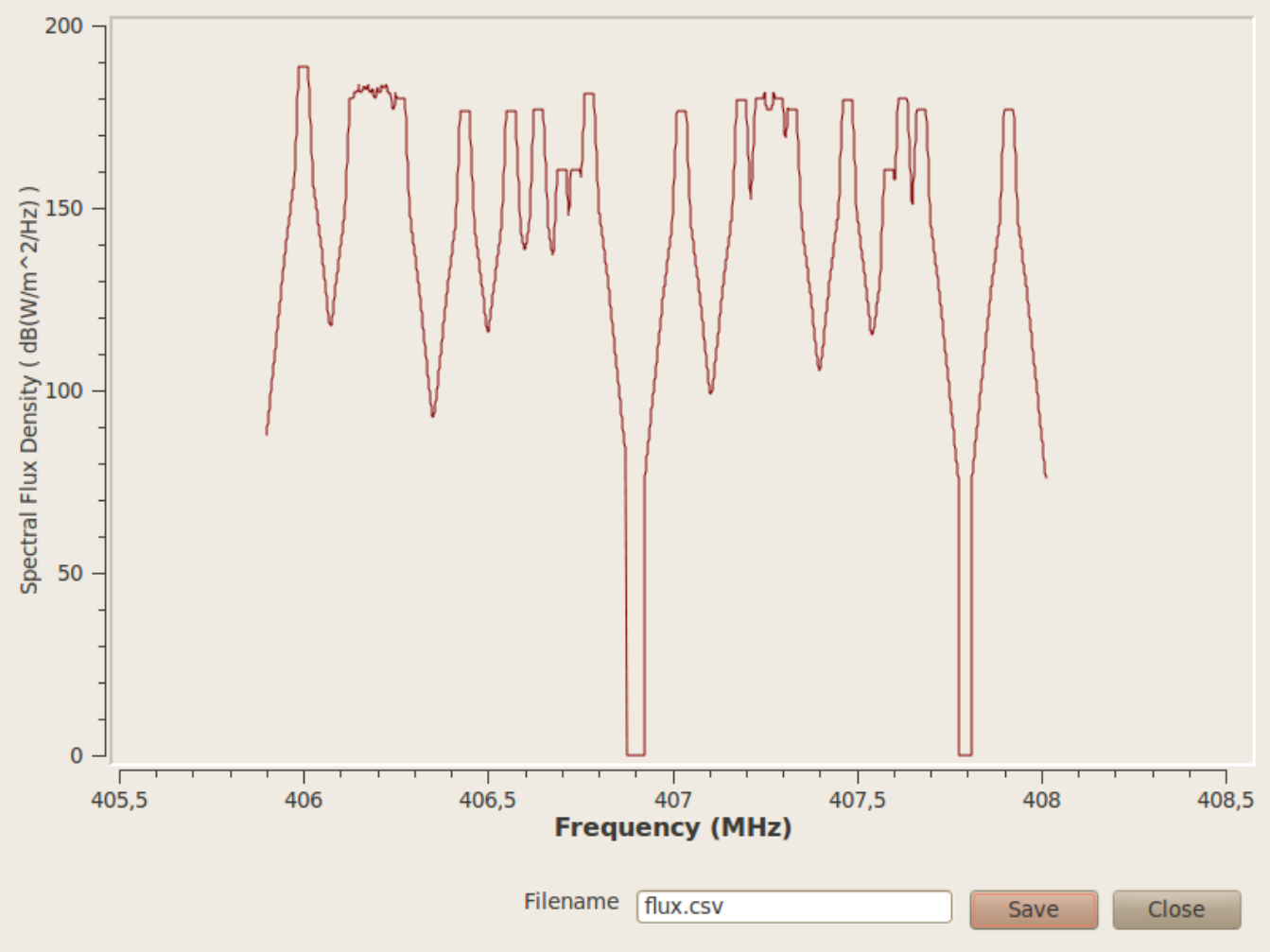
5.15.3)k-Factor

This parameter is used in the effective earth model. It depends on the gradient of the refractiveness of air just above the surface of the earth. Because this is an interference analysis values between 1.33 and 6.8 are typical. The bigger the value the more likely is that the interfering signal will overshoot obstacle to cause interference, hence choosing a higher k-Factor is a more conservative approach. More detail on this parameter will be found in Section (6).

5.15.4)Frequency Resolution (kHz)

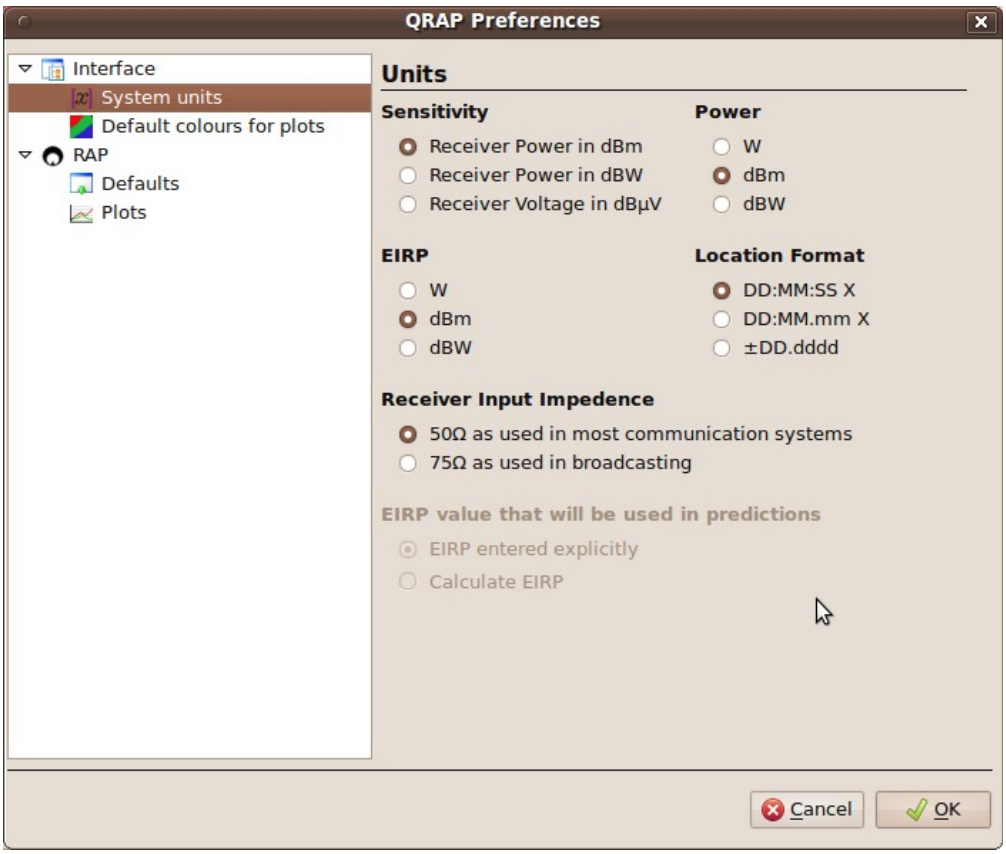
This is the resolution in which the spectral flux density (in dBW/m^2/Hz) will be calculated and displayed.

Pressing the OK-button will result in the interference analysis showing the resultant spectral flux density. The results can be saved in a csv file for later analysis.



5.16) Preferences Button

Pressing the Preferences Button will up the Q-Rap Preferences dialog box.



5.16.1)Q-Rap Preferences dialog box.

5.16.1.1) System Units

The first set of preferences relate to the Units in which the data will be entered particularly in the Database Interface (5.17). More information will be provided in sections 5.17 and (6).

5.17)  Database Interface

6) Parameters

W
dBW
dBm
dBµV
dBµV/m
dBW/m^2
dBW/m^2/Hz

Power

EIRP

Sensitivity

Required Signal to Noise Ratio
(Required SN)

Fade Margin

Minimum Required Signal Strength
(Rx Min)

Required Co-channel Carrier to Interference Ratio
(Req CoCI)

Required Adjacent-channel Carrier to Interference Ratio
(Req CIad)

Required Energy per Bit to Noise Ratio
(Req EbNo)

Plot Resolution

Location format

Select Sensitivity

Frequency
operating/centre frequency

Uplink vs. Downlink

Maximum path loss

Maximum Distance

kFactor

kFactor Server

kFactor Interference

Fresnel clearance

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7) Analysis Functionalities

8) Design and Planning Assistance Functionalities