ROHDE&SCHWARZ
Test and Measurement Division

User Manual

RFEX

System Software for EMF Measurements

Version 3.2.0

1140.7984.03

Contents

Introduction

RFEX (**R**adio **F**requency **EX**posure software), the System Software for EMF measurements by Rohde & Schwarz, is a dedicated solution for the measurement and evaluation of electromagnetic fields (EMF). It is implemented as a standard Windows application, and has been developed to support the operation of the following R&S measurement systems:

- Portable System for EMF Measurements **TS-EMF**, Ident. No. 1158.9295
- EMF Measurement System (with ESPI and an antenna array), Ident. No. 1158.9037

When used with one of these systems, RFEX takes care the remote control of the measurement instrument and the antenna switching, of integrating and correcting the raw measurement data, of saving the results and, if possible, of generating measurement reports. All these features can be accessed and parameterised by the user from a standard Windows-style user interface.

The present manual first describes the requirements for the use of the software. Chapter 2 gives a brief introduction to first time users in order to get familiar with RFEX. A full reference of the user interface can be found in chapter 3, whereas chapter 4 explains in detail which data files are required and generated by RFEX at run time. Chapter 5 deals with the details of the measurement process.

Throughout this manual, there will be many details which apply to the portable EMF measurement system TS-EMF alone. These will be marked by the following special formatting:

* ***TS-EMF***	*Hints formatted like this are applicable to the portable EMF measurement system TS-EMF only.*

1 Installation and Requirements

1.1 System requirements

The System Software for EMF measurements RFEX has to be installed on a computer running with Windows® Operating Systems. Its functionality is tested and guaranteed on Windows 2000 and Windows XP.

There are no particular requirements on the computer system except that it should have enough resources to run the operating system.

The resolution of the graphic interface card should be minimum 800 x 600 pixel.

A minimum of 10 MBytes of hard disc memory is required for the installation. For the measurement data enough hard disc memory should be foreseen, too. Long-time measurements running for 24 hours have shown the following amount of data to be recorded:

- The final results data file for a long-time measurement contains about 12 kBytes per measurement packet.
- The raw data files (saved optionally!) make up to 50 MBytes.
- The measurement log file (saved optionally!) has a size of up to 1 MByte.

For the automatic report generation, Microsoft Excel has to be installed.

1.2 Copy Protection

In order to protect RFEX from being illegally copied and used, the software is delivered with and protected by a hardlock. It is allowed to install RFEX on as many computers as you like, but only if a valid hardlock is connected to the computer, the possibility to do measurements is enabled.

Installing the software without hardlock allows to generate or modify measurement setups (packets) and to print out reports. However, if you try to start a measurement on such an installation, the following message will appear and the measurement is aborted:

Additionally, specially coded hardlocks will enable additional options. For example, the measurements on UMTS base stations with channel decoding can only be done with such a specially coded hardlock.

1.3 Required Hardware Interfaces

Depending on the configuration of the measurement system, the computer must be equipped with the following interfaces:

TS-EMF (Portable System for EMF Measurements)

- A ***serial interface (COMx)*** must be available for remote control of the spectrum analyzer FSH3. If the computer is equipped with USB interfaces only, a standard commercially available USB to RS232 converter can be used.
- A ***USB port*** must be available for controlling the switching of the tri-axis isotropic probe.
- A second ***USB port*** is required for connecting the hardlock for copy protection. A two-port USB extender is delivered by standard with the TS-EMF system in order to support notebooks with one single USB port.
- Optionally, a second ***serial interface (COMx)*** must be available if a GPS receiver shall be supported for accurate geographic detection.
- Optionally, a ***IEEE 1394 (Firewire)*** port or plug-in card is required for measurements on UMTS base stations with channel decoding using a R&S TSMU. A suitable OEM card (different types for desktop computers and notebooks) can be purchased from R&S.

EMF Measurement System with ESPI and an antenna array

- A ***GPIB (IEEE bus) plug-in card*** must be available for remote control of the ESPI. The recommended card is the National Instruments PCI-GPIB (for desktop computers) or PCMCIA-GPIB (for notebooks); both interface cards can be purchased from R&S. The Windows software driver to be installed shall be version 1.60 or upper.
- Alternatively, the ESPI can be remotely controlled by network. For this purpose, a ***LAN connection*** with the Microsoft Windows Network TCP/IP driver must be available. In this case, the GPIB interface card is not required.
- A ***serial interface (COMx)*** must be available for remote control of the antenna switching unit.
- A ***USB port*** is required for connecting the hardlock for copy protection.
- Optionally, a second ***serial interface (COMx)*** must be available if a GPS receiver shall be supported for accurate geographic detection.
- Optionally, a ***IEEE 1394 (Firewire)*** port or plug-in card is required for measurements on UMTS base stations with channel decoding using a R&S TSMU. A suitable OEM card (different types for desktop computers and notebooks) can be purchased from R&S.

1.4 Installation

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Important Note !

If any other version of RFEX is installed on the computer, this older version must be uninstalled before installing a new version!

For uninstalling RFEX click on

Start à Settings à Control Panel à Add or Remove Programs

select Rohde & Schwarz RFEX from the list of installed programs and click on

Remove

For installing RFEX, please start the ***Setup.Exe*** program on the delivered CD-ROM. Do so by selecting ***Start à Run…*** and typing ***D:\Setup.exe*** into the command line, assuming that the CD-ROM drive on your computer is configured as drive ***D:***. Click on ***OK*** to start the installation. If the Autostart feature is enabled for your CD-ROM drive, the setup program will be launched automatically when loading the CD-ROM.

The installation consists in starting, one after another, two independent utilities. The first one installs the Windows system driver for the iKey hardlock, which is delivered for protecting the software against unwanted copying. The second one is the RFEX installation utility.

Installation should be self-explaining. The only user interaction required is to define the path where to copy the RFEX to. Default path is ***C:\Program Files\Rfex***.

In addition to the application software RFEX itself, the available manuals and an example data set are copied to the hard disk, so that RFEX is ready to start measurements from the beginning. All these additional files can also be found on the CD-ROM.

*

TS-EMF

*The calibration data for the delivered tri-axis probe are available on the CD-ROM in the folder **CalDataAntenna**. Please make sure to copy them by hand after software installation.*

For systems newly delivered with RFEX V3.2.0, the probe calibration data are burnt onto the hardlock as well, and can directly be imported from the user interface, see section 3.2.

Two additional hardware components used with TS-EMF require special Windows drivers to be installed as well:

- The 3-axis probe is switched by means of a signal converter connected to one of the PC's USB ports. When first connecting this converter to the PC, the Operating System will try to find a driver. Please select the directory ***\UsbIODriver*** on the CD-ROM as source directory fort his driver.
- If option TSEMF-US2 for UMTS measurements with channel decoding based on the R&S Radio Network Analyzer TSMU is used, the special Windows driver for the IEEE1394 interface developed for supporting the TSMU must be installed. For this purpose, an entry is added to the Windows Start menu: Please click on ***Start à Programme à Rohde & Schwarz RFEX à Ohci1394 Driver Installation*** for installing this driver. Alternatively, the installation utility can be found on the CD-ROM, directory ***\TsmuOhciDriver***. See also te TSMU manual for details.

2 First Steps

This chapter describes the basic steps to configure the system software RFEX, to perform measurements and to generate reports.

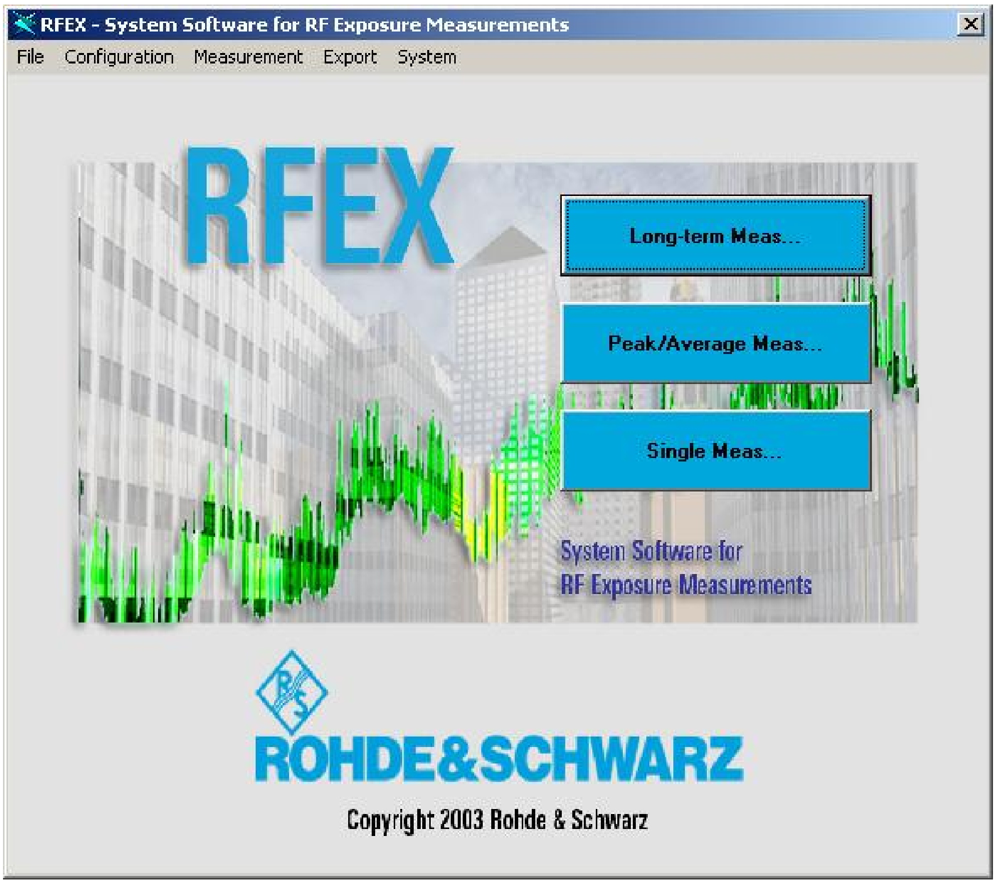
Before starting to work with RFEX according to the following example, please make sure that the following requirements are matched:

- The tables containing the cable loss of the used cables and the antenna factor of the used antenna must be available. These tables give the associated correction factors depending on the frequency. Section 3.3 shows how to edit such tables.
- The instruments making up the system must have been configured to RFEX software. Refer to section 3.4 for information on how to configure the available hardware.

TS-EMF *The software dialogs shown throughout this chapter apply to the use of RFEX with the TS-EMF system. For the use with other systems, the Measurement Packet configuration dialog (section 2.2) will be slightly different.*

2.1 Step 1: Starting RFEX

Start the System Software RFEX by clicking on ***Start à Programs à Rohde & Schwarz RFEX à RFEX V3.2.0.*** The main screen of RFEX will appear. Most of the configuration and measurement actions start from this point. A complete reference of the interface is given in chapter 3.

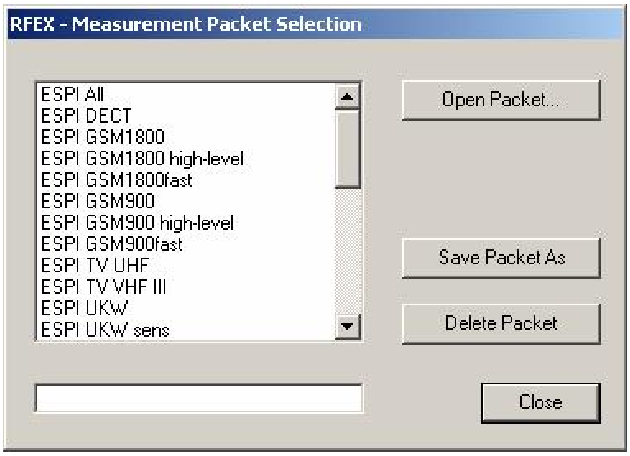


2.2 Step 2: Configuring a Measurement Packet

Measurement configuration is done in two steps. Since each measurement can be made up by a sequence of partial measurements each one defined by a separate measurement setup ("***Measurement Packet***"), the first configuration step consists in defining the necessary measurement packets. In the second step, these measurement packets will be combined to a complete measurement configuration.

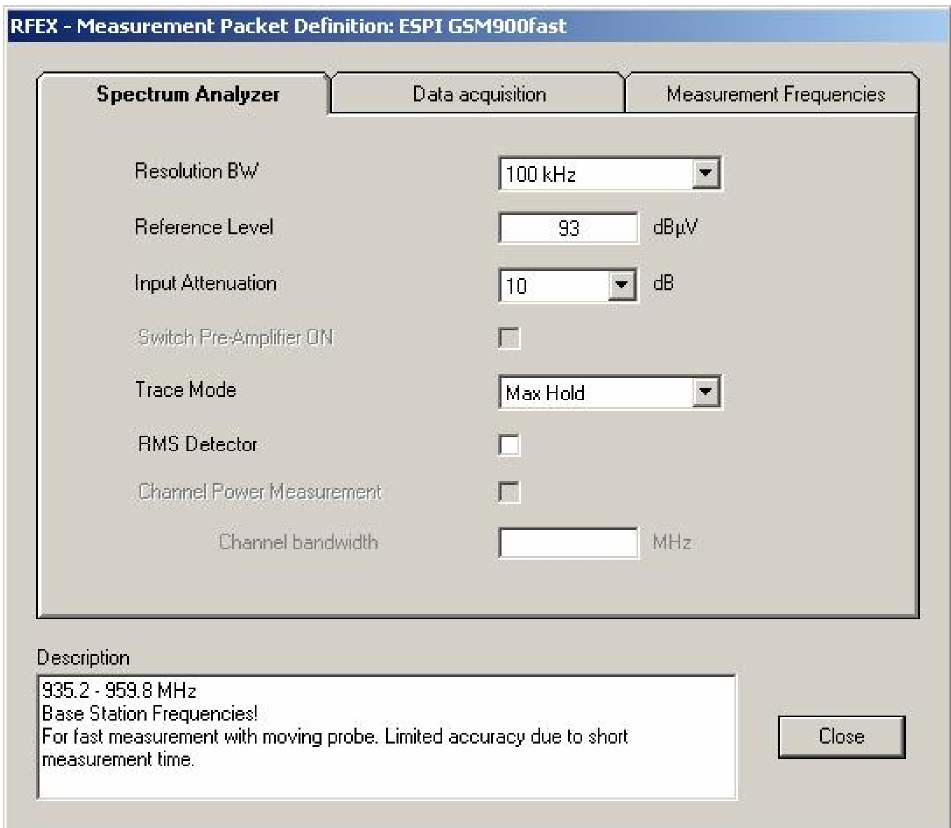
The need for defining different measurement packets arises from the fact that the total EMF to be evaluated is generated from several separate sources of electromagnetic radiation. Each of these contributions (e.g. TV and radio broadcasting, mobile phone base stations) must eventually be measured with different settings of the analyzing instrument (e.g. different bandwidths, signal detectors, sweep times, frequency ranges). Each measurement packet defines how to operate the system for evaluating the EMF contribution of one radiation source in a certain frequency range.

Click on ***Configuration à Packet...***. The following dialog for selecting a packet will be opened:



To create a new packet, type the name of the packet (for example "My first packet") in the field for packet names at the bottom and click on ***Open Packet...***.

The configuration dialog for measurement packets will be opened:

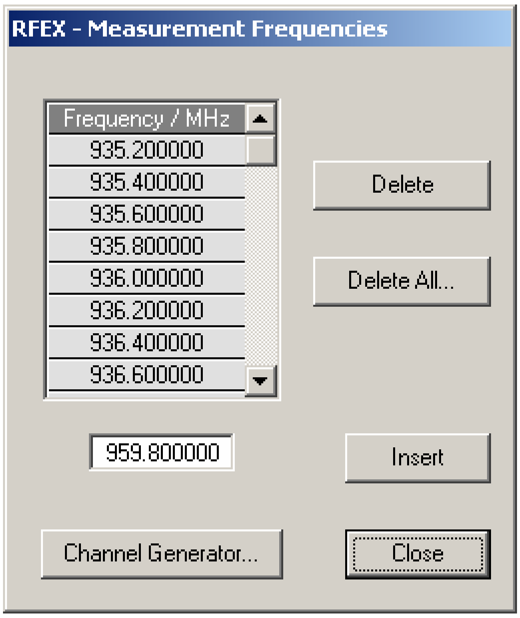


This dialog allows to define different parameters for

- the setup of the spectrum analyzer,
- the data acquisition procedure, and
- the measurement frequencies for this particular setup.

Section 3.5 gives a complete reference of all control elements in this dialog.

For setting up the measurement frequencies at which to evaluate the electromagnetic radiation level, select the ***Measurement Frequencies*** tab and click on the ***Frequency list...*** button to open the dialog for the definition of the measurement frequencies.



This dialog allows to enter new frequencies into the table or to delete frequencies from it.

In many cases, it is required to perform the measurement on a series of frequency points with the same step width (equidistant channel spacing). To make the editing of such tables easier, RFEX contains a so called channel generator to be accessed via the ***Channel Generator...*** button in the measurement frequencies dialog. This channel generator adds (or deletes!) any number of entries in the frequency list; the amount of entries is defined by giving suitable values for the start and the stop frequencies and for the required frequency step width.

Leave the Measurement Frequency Dialog and the Measurement Packet Editor by pressing the button ***Close***. The measurement setup definition generated this way is automatically checked for consistency and stored. Details about data storage are given in chapter 4.

Creating a completely new package

In most cases, the standard packages delivered and installed with RFEX will be adequate for the required measurements. Only small adaptations may be needed depending on specific conditions of the measurement site. These adaptations can be performed with the help of the RFEX routines for packet testing (see next section).

However, if a completely new packet needs to be set up, e.g. for measuring the EMF contribution of a signal source not taken into account by any standard packet, setting the following parameters to correct values is critical for getting reasonable measurement results without neglecting or underestimating major contributors to the EMF:

- **Spectrum Analyzer section**
  - The resolution bandwidth shall match the bandwidth of the expected RF signal. If the signal's bandwidth is bigger than the broadest bandwidth available on the analyzer, consider using the channel power measurement utility (only for FSH3).
  - The input attenuation shall be enough to protect the analyzer's input from overload or even damage by too high fields. Only if the measured signal is very low (find out by testing the package) an attenuation of 0 dB shall be set.
  - Use RMS detector whenever pulsed signals are to be measured.

- **Data Acquisition section**
  - Use a short dwell time if the signal to be measured is expected to be constant in amplitude (e.g. an FM modulated carrier signal). Use longer dwell times (with Max Hold trace mode on the analyzer) when the signal's amplitude varies with time but the carrier signal is permanent. Use long dwell times (several thousands of milliseconds) if the signal is a pulsed (keyed) carrier signal.

    Consider setting this long time as analyzer sweep time if you want to force the analyzer to sweep slowly in order to measure on each frequency during a time long enough to make sure any keyed signal on this frequency is going to be detected.

    Have a look at the delivered standard packets for measurements on GSM base stations in order to get an additional understanding of these hints.
  - Always perform a threshold calibration run (see next section) before working with your new packet. This will automatically calculate a suitable value for the acceptance threshold depending on the locally available fields and the noise floor of your analyzer.
  - Use an extrapolation factor for correcting measured values which you know to be too low, e.g. when the bandwidth of the signal to be measured exceeds the highest bandwidth of the analyzer, but no channel power measurement option is available.

    The extrapolation factor should reflect how much of the signal strength is lost during measurement due to too small a bandwidth being used. It is recommended to do some experiments comparing levels measured with TS-EMF and with instruments specifically suited to measuring such broadband signals, in order to determine reasonable extrapolation factors.

- **Measurement Frequencies section**
  - For measuring the EMF of signal sources emitting with a known fixed channel pattern, use the known channel pattern mode with a frequency list, eventually generated with the channel generator utility as shown above.
  - For signal sources emitting at frequencies with no known distribution pattern, use the sweep with peak search mode.

In any case, some knowledge about the nature and characteristics of the signals to be evaluated must be gathered before starting to evaluate them with RFEX.

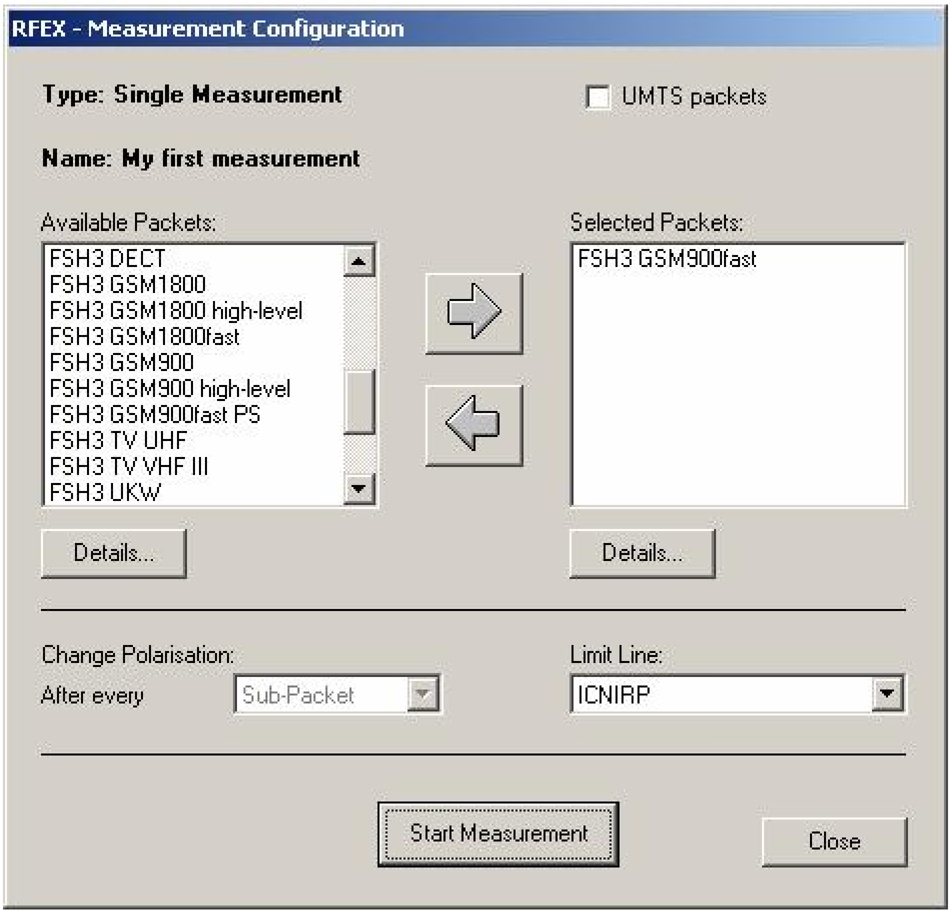
2.3 Step 3: Testing the Packets

Before starting a real long-term EMF measurement, the measurement packet configured just before should be tested. This ensures that all parameters are selected correctly.

To test the measurement packet, RFEX features two test procedures: the Single Measurement mode and the Threshold Calibration. Both of these combine set of measurements packets to a sequence and run this sequence once. This allows to test all the steps which are used during a later long-time measurement because the same sequences are used.

Single Measurement

Click on ***Measurement à Single Meas...*** and the measurement selection dialog is opened. This is similar to the dialog for selecting a measurement packet shown in the previous step. Type in the name for the measurement (for example "*My first Measurement*") and click on ***New Measurement...***. The Measurement Configuration dialog appears:



The main task of this dialog is to configure the list of measurement packets in the correct sequence. Select one or several packets in the list ***Available Packets*** and shift it to the list ***Selected Packets*** by pressing the upper button showing the arrow to the right. Clicking on the ***Close*** button will save the configuration. The Single Measurement configuration is now available for a later measurement.

To start a test run immediately, click on the ***Start Measurement*** button. The dialog will be closed and the measurement will start immediately. A display box occupying the main part of the RFEX main window is opened, showing a measurement log which allows to follow step by step how the measurement is proceeding.

Threshold Calibration

An additional refinement is available for fine-tuning the packet definition: the ***Threshold Calibration*** utility. One of the most critical parameters in a measurement packet is the ***Acceptance threshold*** parameter in the ***Data Acquisition*** tab. This value defines a radiation level below which any measured field level will be ignored. It is very important to set this parameter in a way that it is neither too high (would lead to too low an EMF value being measured) nor too low (would lead to the analyzer's noise floor to be evaluated as radiation). A suitable value can automatically be determined with the threshold calibration procedure.

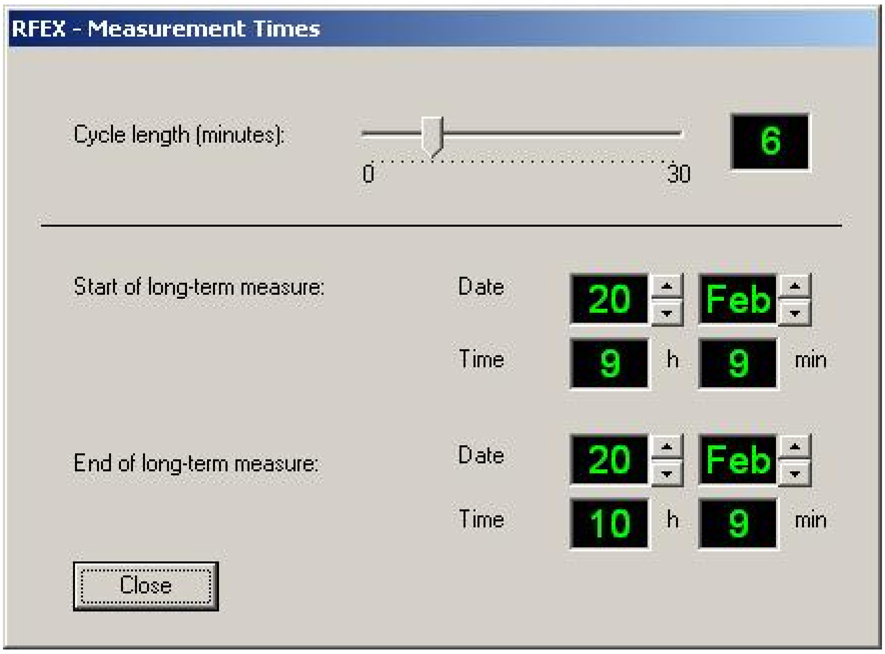
Click on ***Measurement à Threshold Calibration…*** The same Measurement Configuration dialog as above with only some little differences will be opened. Select the packets to be tested and click on ***Start Measurement***. Again, one test run will be performed. At the end, the acceptance threshold value of each packet will automatically be adapted to a value representing a good compromise between the requirements of not including the analyzer's noise floor in the measurement result, but not loosing too much of the signal to be measured in the result compression process.

2.4 Step 4: Executing a Long-term Measurement

Once the measurement configuration has been edited and tested, a long-term measurement of the electromagnetic field can be performed. This measurement is the main task of the system.

For starting a long-term measurement, click on ***Measurement à Long-term Meas...***. The dialog for the measurement selection appears showing all existing long-term measurement configurations. For a new measurement, type in the name of the measurement, for example “*My first Long-term meas.*" and click on ***New Measurement...***.

Next, the dialog for configuring a measurement appears, which is the same as for configuring a Single Measurement, except that an additional button ***Measurement Times...*** is available. Click on this button to define the measurement time.



A long-term measurement starts at a certain moment in time and ends at another moment. The overall duration can be defined at will. During such a long-term measurement the list of selected measurement packets is executed cyclically in sequence. For each frequency, the average value of the measured field is accumulated and the peak value for each frequency is determined. This accumulation is done for a selectable cycle length (in minutes), after which these accumulated values are compressed so that for each measurement packet only one average value and one peak value are left. The overall resulting field strength will be determined, too.

To generate the final result, all measurement data are reduced to three values per measurement packet and per cycle length (in minutes).

Details about data recording and compression are given in chapter 5.

2.5 Step 5: Generating a Report

After completing a measurement, a report may be created. Basically, there are two possibilities:

- The measurement result which is available as file in ASCII format can be printed directly or be post-processed by any other tool (see chapter 4 for information on data format and data storage)
- The measurement result may also be used to automatically generate an EXCEL® spreadsheet from RFEX.

For generating this spreadsheet, select ***Export à Long-term Meas...***. A measurement selection dialog similar to the one for selecting the measurement will appear. Select the measurement for which a report shall be generated and click on ***Create Meas. Report***. Depending on the amount of data recorded, it may take some time to generate the report as a total of three Excel files. When this operation is complete, the files can be found in the directory ***Reports***.

Eventually, no report will be generated at all. This may be the case if no signals could be measured or the signal level was so low that it fell below the acceptance threshold and hence was ignored during result compression. In this case, a warning will inform the user about this.

Similarly, the spreadsheets generated from a long-term measurement may contain empty cells, which arise from no signal above acceptance threshold having been measured, during the associated time lapse and for the corresponding measurement packet.

2.6 Step 6: Backing Up Measurement Data

RFEX creates setup and result files as well as Excel worksheets. All these files are not further managed or saved by the RFEX. If you want to keep a secure backup of these files on hard-disc or any network drive, this backup procedure must be handled from outside of RFEX, for example via the Windows-Explorer.

Details on the type and location of the files generated by RFEX are given in chapter 4.

3 Reference of the User Interface

3.1 Main Menu

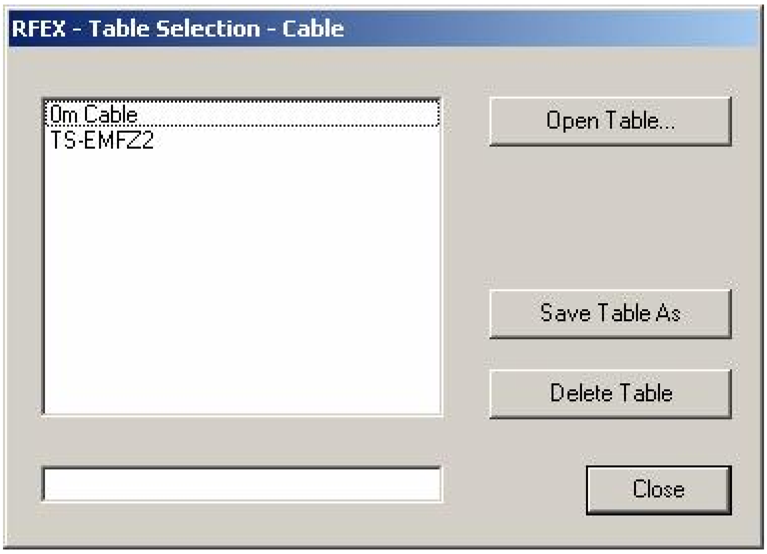
The main menu of System Software RFEX contains the following entries (menu entries in Italics and marked with * are not available for the ***TS-EMF*** system):

Menu		**Function**	Refer to section
File			
	Antenna	Open the editor for antenna factor tables	3.2, 3,.3
	Cable	Open the editor for cable loss tables	3.2, 3,.3
	Limit Line	Open the editor for limit line tables	3.2, 3,.3
	Exit	Exit RFEX	
Configuration			
	Packet	Open the editor for the measurement packets	3.2, 3.5
	Umts-Packet	Open the editor for UMTS measurement packets	3.7
	Hardware	Open the hardware configuration dialog	3.4
Measurement			
	Overview-Sweep *	Execute an overview sweep	5.2
	Single Meas	Configure and execute a single measurement	3.2, 3.6, 5.1
	Peak/Average Meas	Configure and execute a Peak / Average measurement (cycle in minutes)	3.2, 3.6, 5.1
	Long-term Meas	Configure and execute a long-term measurement	3.2, 3.6, 5.1
	Threshold Calibration	Configure and execute a threshold calibration	5.2
	Cable Calibration *	Record the frequency dependent attenuation loss of a cable	5.2
Export			
	Single Meas	Generate a report for a single measurement	4.4
	Peak/Average Meas	Generate a report for a Peak / Average measurement	4.4
	Long-term Meas	Generate a report for a long-term measurement	4.4
System			
	Options	Optional settings to parameterise RFEX run time operation	3.8
	Change Language	Changing the interface language	
	Info	Opens the system information dialog	

RFEX can run its user interface displaying all strings in different languages. Currently, English, German, Spanish and, on Windows versions enabling Chinese user interface, Chinese are supported. Default language after installation is English. The language can be changed from the main menu entry ***System à Change Language.*** RFEX must be restarted to activate the new language.

3.2 Selection Dialogs

Several functions of the software RFEX require the selection of certain files. All the dialogs for the selecting a file have the same layout. Additionally, the dialogs offer the possibility to delete the files or to save them with another name.



Description of the control elements

List with file names

Shows the names of the existing files of the selected type. Selecting one name (single click) copies the name into the lower field. A double click on a name will open this file.

Field for editing a new file name

Prior to edit a new file, the file name must be typed in. This is done into the lower field. Every time an existing file is selected (single click), the name will be copied into this field.

Button ***Open Table...***

Opens the editor for the file selected. A file name of an existing file must be selected. For a non-existing file first the name has to be typed-in.

Button ***Copy from hardlock***

From V3.2.0 on, the calibration data for the tri-axis isotropic probes of the TS-EMF system are not only delivered on the RFEX CD-ROM, but are also written on the software protection hardlock. This button will be displayed whenever a hardlock containing antenna data is found to be connected to the PC.

Clicking on this button will copy the antenna calibration tables from the hardlock and store them on the PC's hard disk.

Button ***Delete Table***

The selected file will be deleted. Prior to deletion an additional confirmation is required.

Button ***Save Table as***

The selected file will be copied and saved with different name. Proceed as follows:

- First select from the list the file to be copied.
- Type-in a new name for the file in the lower field.
- Select the above button

If no file is selected or if the new name is missing, or if both file names are equal, then an error message will be shown and the operation will be aborted.

Button ***Close***

Exits the dialog.

Additional control elements in other selection dialogs

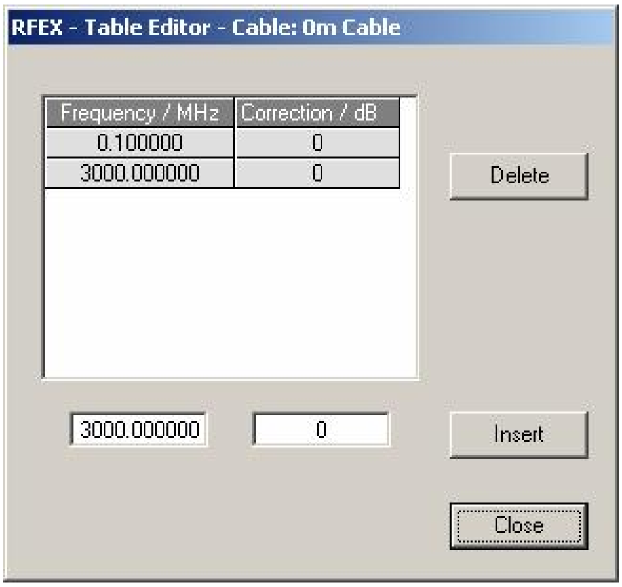
Depending on the dialog, the buttons have slightly different meanings. The selection dialog for measurement packet shows ***Measurement Packet*** instead of ***Table***, and selection dialog for measurements shows ***Measurement*** instead of ***Table***.

The selection dialog for measurements shows the button ***New Measurement*** instead of ***Open Measurement***. Pressing this button generates a new data file with the specified name. If the file already exists, an error message will appear.

To repeat a measurement, the button ***Repeat Measurement...*** is available. Before starting the measurement an additional confirmation is necessary to repeat the measurement, since in that case all the existing data will be overwritten. In case of a Long-term measurement the button is labelled ***Repeat Measurement...***. During Long-term measurements the existing data are not deleted but the new measurement data are attached to the existing data.

3.3 Table Editor

The purpose of the table editor is to create, display or change data tables. The editor is started by pressing the button ***Open Table...*** in the selection dialog for tables.



Data are presented in a table with two columns. The left column always shows the frequency in MHz. The right column depends on the type of table.

Together with the software RFEX three different types of tables are available: antennas, cables and limit lines.

- ***Antenna*** describes the antenna factor of the antennas used. The right column shows the antenna factor in dB/m. The measurement results of the spectrum analyzer are corrected by the antenna factor.

  The serial number code of the antenna to which the file belongs is displayed on top of the data table if the file contains this information. This allows a fast check whether the table corresponds to the real probe being used with the system.
- ***Cable*** describes the attenuation caused by the cabling from spectrum analyzer to the antenna. The data in the right column are shown in dB and the attenuation is expressed in positive values. The measurement results of the spectrum analyzer are corrected by the cable loss; the raw data already include the cable loss.
- ***Limit Line*** describes the maximum field strength allowed. Refer to the national regulations of each country. The limit line is expressed in V/m. The limit line table is used during final data compression to calculate the relation of the measured field strength to the limit line (shown as parts per thousand).

Tables of type Antenna and Limit Line are to be generated manually from within RFEX using the table editor. Tables of type Cable can alternatively be generated with the cable calibration utility (see section 5.2.3). But this requires a tracking generator option to be installed in the spectrum analyzer.

Editing a table only can be done line by line. The line is selected clicking on it with the mouse, and the content of the selected line is transferred to the lower two input fields for editing.

<u>Button ***Delete***</u>

To delete a line from the table, the line is selected by clicking on it with the mouse, and then this button is selected. A table at least must contain one line; therefore the last line never can be deleted.

<u>Button ***Insert***</u>

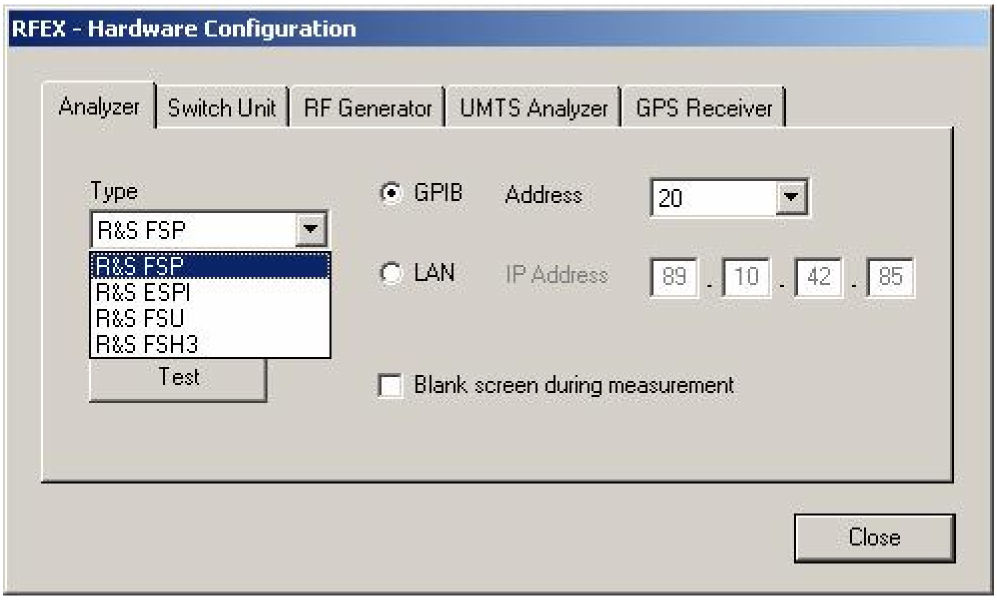
To add a new line to the table, first the values to be added are to be typed in the two input fields at the bottom of the dialog. Then the button ***Insert*** has to be selected. The table is automatically sorted out with increasing frequency.

3.4 Hardware Configuration

This dialog allows to configure the hardware to be controlled by RFEX. Normally, it will be enough to set up the configuration once after RFEX installation. The dialog is opened from the main menu by clicking on ***Configuration à Hardware...***. It contains one tab for each device which can eventually be supported by RFEX.

3.4.1 Spectrum Analyzer

The spectrum analyzer is the basic instrument to perform any measurements and data acquisition.



Selection box ***Type***

Select the device to be used. The following devices are supported:

- Spectrum Analyzer FSP from Rohde & Schwarz
- EMITest Receiver ESPI from Rohde & Schwarz
- Spectrum Analyzer FSU from Rohde & Schwarz
- Spectrum Analyzer FSH3 from Rohde & Schwarz

Availability of the other control elements depends on which instrument is selected.

Option ***GPIB***

This option is available only if an analyzer with GPIB interface has been selected, i.e. the FSP, the FSU or the ESPI. If this option is checked, the selection box ***Address*** is enabled for configuring the analyzer's GPIB address.

Option ***LAN***

This option is available only if an analyzer with TCP/IP interface has been selected, i.e. the FSP, the FSU or the ESPI. If this option is checked, four fields are enabled for configuring the analyzer's ***IP Address***.

Selection Box ***Interface***

This selection box is available only if the FSH3 is selected as analyzer. The serial port to which the analyzer is connected shall be selected here.

Selection Box ***Baud Rate***

This selection box is available only if the FSH3 is selected as analyzer.

Please choose the baud rate set at the FSH3 via its setup menu. Only with the correct baud rate information, RFEX will be able to set up a communication with the FSH3.

When operating the FSH3 without mains power supply, each time the device is switched off, it will return to the default baud rate setting of 19200 baud, RFEX will by default try to find the FSH3 testing this baud rate. If the FSH3 can be found with 19200 baud and the Baud Rate selection box contains a different value, the FSH3 will be programmed by remote control to use this new baud rate.

Check box ***Blank screen during measurement***

If this box is checked, trace display on the analyzer's screen is turned off during the measurement.

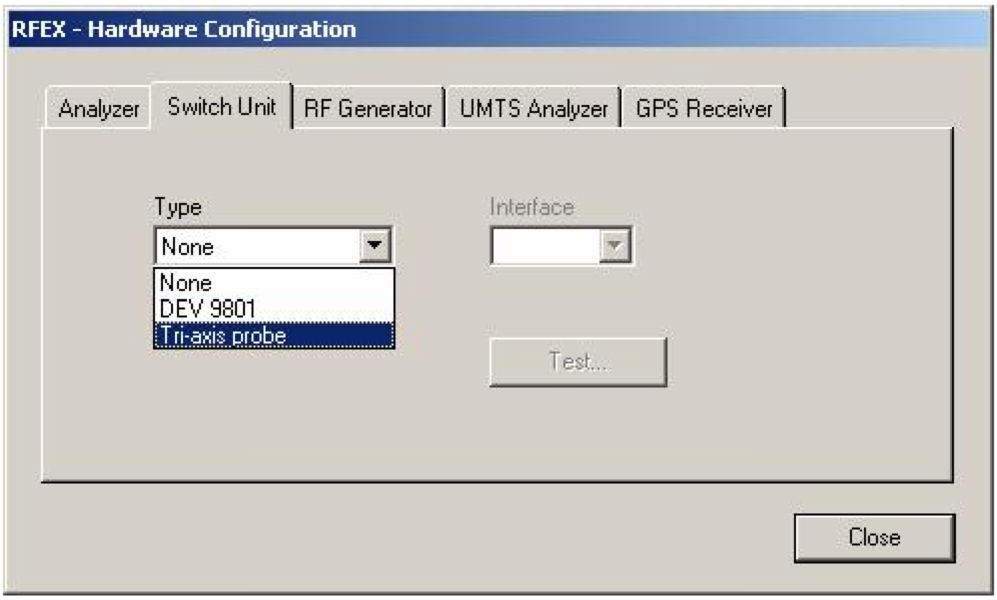
This selection is only available if one of the devices FSP, FSU or ESPI is selected. The FSH3 does not enable turning off screen display by remote control.

Button ***Test***

Clicking on this button will make RFEX try to establish communication with the analyzer. The device's identification will be queried and it will be reset to default state. If the analyzer can not be addressed, an error message will be displayed. This gives a fast way of testing whether the parameters of the remote interface have been set correctly to RFEX.

3.4.2 Switch Unit

A remotely controlled switch unit is used to sequentially connect the different antennas of a EMF measurement system or the different axes of the TS-EMF isotropic probe, to the input of the spectrum analyzer during a measurement run.



<u>Selection box ***Type***</u>

The following devices can be selected as switch unit:

- None. In this case, antenna polarisation must be changed by hand. The user will be prompted to do so if polarisation is due to change during the measurement.
- Automatic Antenna Switch Unit, Type DEV 9801
- Tri-Axis Probe (only for ***TS-EMF***; is used to switch the three axis of the sensor)

Availability of the other control elements depends on which instrument is selected.

<u>Selection box ***Interface***</u>

This selection is only active for the device DEV 9801 and allows to select the serial interface port to be used (COM1 to COM4).

*

TS-EMF

The TS-EMF tri-axis probe is switched via a USB interface. Therefore, no address selection is required.

<u>Button ***Test…***</u>

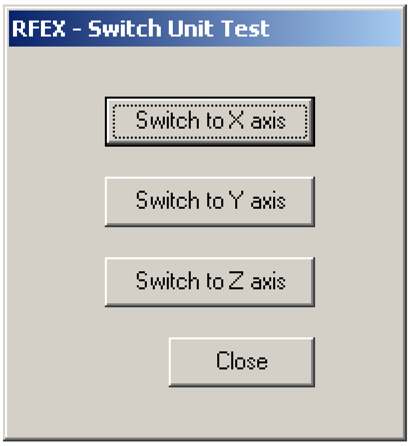
This button allows to open a dialog for further configuring and for testing the switch unit's operation.

The device DEV 9801 can be configured for seven different switch positions. A logical name can be assigned to each of the positions and this name will be used later on for switching. RFEX requires the logical names „*Position 1*" to „*Position 7*" for correct switching. For each switch position a button ***Test*** is available which allows to check correct switching functionality.

*

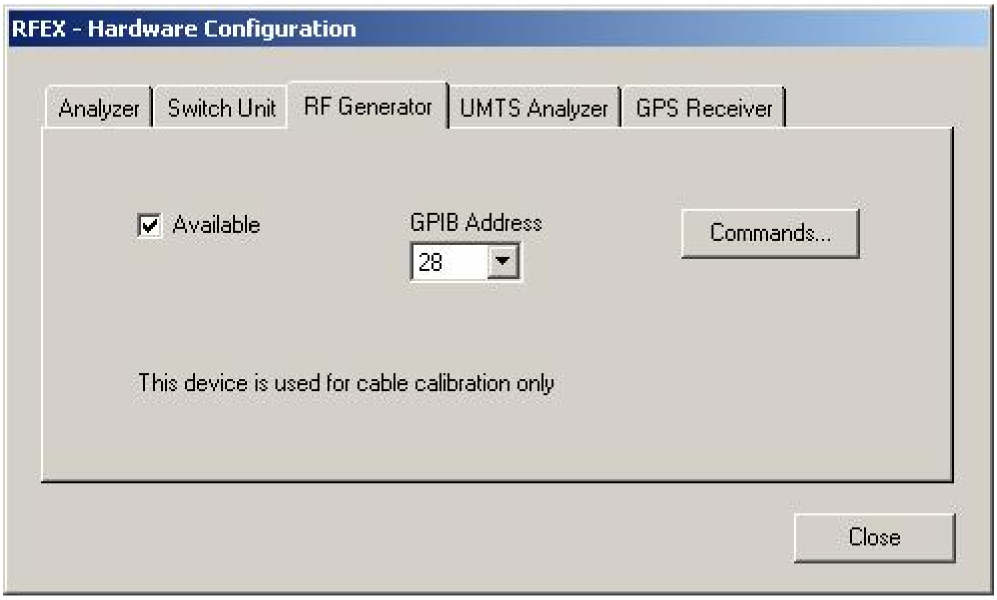
TS-EMF

For the TS-EMF tri-axis probe, the switch positions are pre-configured and cannot be changed. This button can be used to check the correct switching functionality.



3.4.3 RF Generator

To perform EMF measurements, a RF generator is not mandatory. But it can be used to record the cable loss in a cable calibration measurement (see section 5.2.3). Without signal generator no cable calibration will be possible.



Any suitable RF generator with a GPIB interface can be used. The optionally available tracking generator of a GPIB controlled spectrum analyzer (FSP, FSU or ESPI) can be used as well.

*

TS-EMF

The TS-EMF system is delivered with standard cables calibrated from factory. Although the FSH3 may be equipped with a tracking generator option, driving this option is not supported by RFEX.

*Therefore, the **RF Generator** tab will not be displayed if FSH3 is chosen as analyzer instrument in the **Analyzer** tab.*

Check box ***Available***

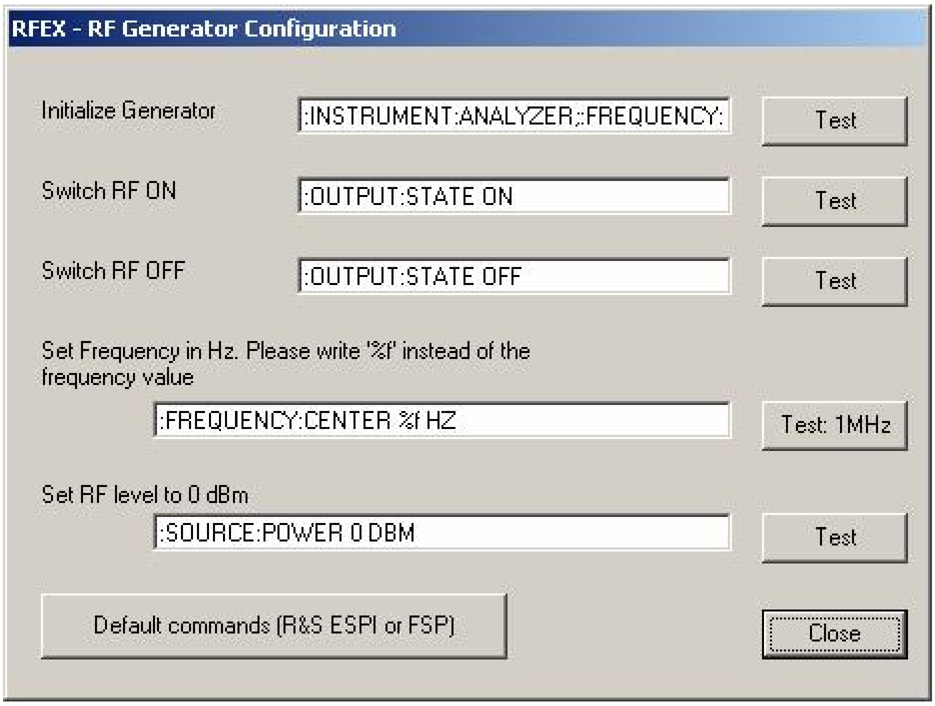
If this box is checked, the presence of a signal generator is assumed and the other control elements on this tab are enabled.

Selection box ***GPIB Addr.***

This selection box is used to select the signal generator's GPIB address. In case of an analyzer's tracking generator, the address is the same as for the analyzer's.

Button ***Commands...***

Since the exact type and manufacturer of the RF generator cannot be selected, it is necessary to specify the GPIB commands for the operation of the generator. Clicking on this button opens the following dialog for configuring the generator's remote control commands:



Text fields for entering the GPIB commands

In total, five text fields are available to enter the GPIB commands for the RF generator. Three of them are optional:

- Initialize Generator (Reset)
- Switch RF ON
- Switch RF OFF

The other two command lines have to be edited in any case; empty text fields will lead to an error message when trying to save this setup.

- Set frequency in Hz: The command has to be entered in a way that the signal frequency is transferred with unit Hz; the value of the frequency is replaced by the string %f .
- Set RF level to 0 dBm: Cable calibration is done with a generator level of 0 dBm. The corresponding command has to be entered in this text field.

G **Attention !**

During cable calibration the commands are used exactly as entered in this dialog. Make sure that the correct syntax is used!

Buttons ***Test***

For each command line, a button ***Test*** is available. Clicking on this button will send the command to the device as written in the text field. This allows to check if the command has been entered correctly.

Button ***Default commands***

Clicking on this button will enter the commands applicable to the R&S devices ESPI and FSP in all input fields.

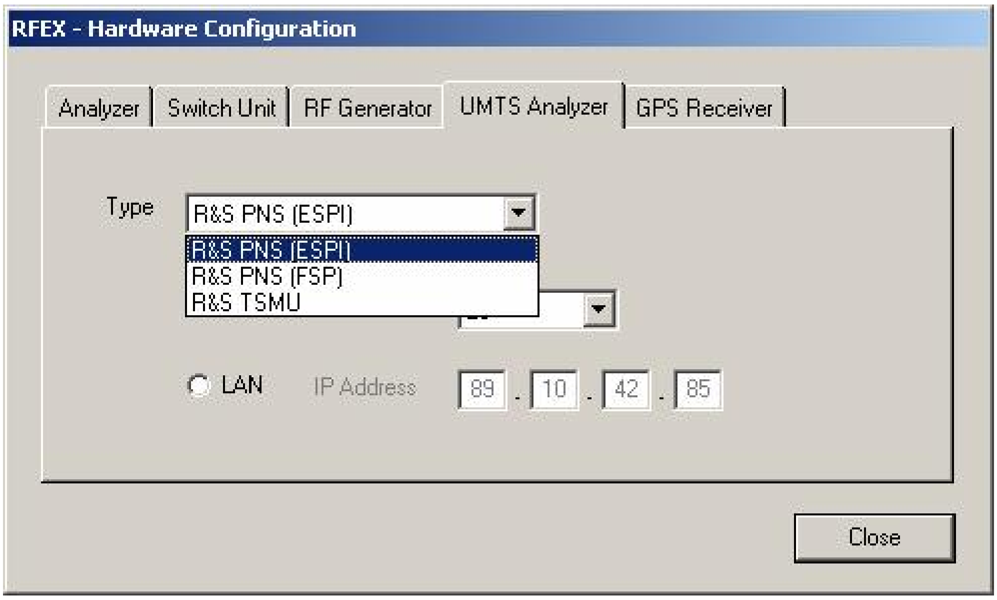
Button ***Close***

Clicking on this button will save all configured commands and will close the dialog. If no command is specified to set the frequency or the level of the signal generator, an error message will appear.

3.4.4 UMTS Analyzer

Options TSEMF-US1 and TSEMF-US2 extend RFEX by software modules able to decode the W-CDMA signals of UMTS base stations and directly measure the channel power of the identified primary channels (C-PICH). Option TSEMF-US1 includes such measurements based on the R&S PN Scanner with an FSP or an ESPI or based on the R&S TSMU Radio Network Analyzer. Option TSEMF-US2 includes only the measurements with the TSMU, it is a subset of option TSEMF-US1.

In the same way as the application itself, these options are protected from being illegally copied and used by a special encryption version of the RFEX hardlock. If one of these options is enabled with a suitable hardlock, the tab for selecting and configuring an instrument for UMTS measurements will be displayed in the Hardware Configuration dialog.



<u>Selection box ***Type***</u>

Select the device to be used. The following devices are supported for UMTS measurements:

- R&S Spectrum Analyzer FSP (only with option TSEMF-US1)
- R&S EMI Test Receiver ESPI (only with option TSEMF-US1)
- R&S Radio Network Analyzer TSMU (with both options TSEMF-US1 and TSEMF-US2)

Availability of the other control elements depends on which instrument is selected.

<u>Option ***GPIB***</u>

This option is available only if an analyzer with GPIB interface has been selected, i.e. the FSP or the ESPI. If this option is checked, the selection box ***Address*** is enabled for configuring the analyzer's GPIB address.

<u>Option ***LAN***</u>

This option is available only if an analyzer with TCP/IP interface has been selected, i.e. the FSP or the ESPI. If this option is checked, four fields are enabled for configuring the analyzer's ***IP Address***.

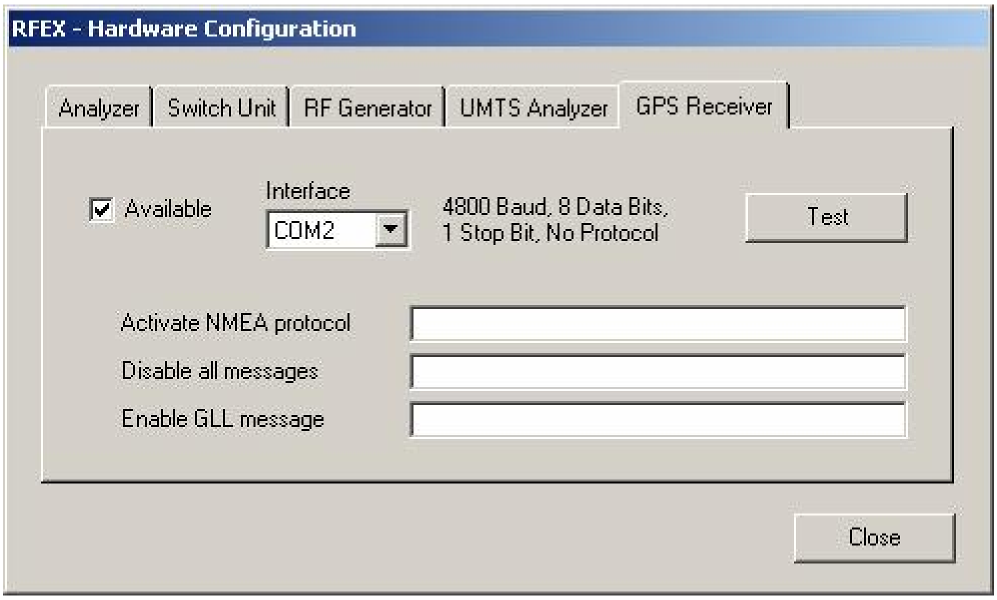
No additional control element is displayed if R&S TSMU is selected as UMTS Analyzer. The instrument is driven via a IEEE 3194 (Firewire) interface which needs no further configuration.

3.4.5 GPS Receiver

As the TS-EMF system is conceived to be used as hand-held mobile utility, it can be useful to record the position where a measurement is performed as precisely as possible, and not relying only on descriptive indications of the measurement location. For this purpose, RFEX implements a simple interface for reading out the geographical position from GPS receivers. The interface relies on the GPS receiver device being able to send the $GPGLL message as defined in the well-known NMEA message protocol. Only this $GPGLL message is interpreted, and the current geographical position is extracted from this message.

There are lots of different GPS receivers available on the market, and many different approaches for configuring the output interface. Before using a GPS receiver with RFEX please make sure that it supports the NMEA protocol and consult the device's manual on how to configure the device for activating output messages according to NMEA.

The feature has been tested with the Garmin GPS III+ receiver. No guarantee can be given for a general compatibility to any device.



Check box ***Available***

If this box is checked, the presence of a GPS receiver is assumed and the other control elements on this tab are enabled.

Selection box ***Interface***

This selection box is used to select the serial port (COMx) to which the receiver is connected. According to NMEA specifications, the port is configured to be operated with 4800 baud, 8 data bits, one stop bit and no handshake.

Button ***Test***

Clicking on this button activates the COM port. If any of the possible command strings is not empty, it is sent to the device. Then, the port input is scanned. If a valid $GPGLL message is received, the position decoded from it is displayed in a message box.

The timeout for receiving a valid position is 30 seconds. Hence set up your GPS receiver and make sure it is able to locate its position before testing the communication.

Text fields for entering the NMEA configuration messages

For some types of GPS receivers it may be necessary (or possible) to explicitly activate NMEA protocol and to configure which messages will be output to RFEX.

G

Attention !

Whether such commands are defined and/or mandatory depends on the used GPS receiver. This information and the exact syntax for the commands must be found in the receiver's manual and supplied to RFEX by the user.

If such commands are defined, they can be entered in these text fields and will be sent ***as typed here*** to the serial port. Three different commands are supported:

- Activate NMEA protocol: The command entered in this field shall be used to switch the receiver's output syntax to NMEA if the default protocol after switching it on is a different one.
- Disable all messages: This command can be used for turning off NMEA output, and should be used together with the next one. The purpose is to avoid output of messages which are not interpreted by RFEX.
- Enable GLL message: Once all NMEA messages are disabled, the GLL message must be enabled again in order to allow position interpretation by RFEX.

The Garmin GPS III+ device used for testing does not define such commands. Instead, NMEA output must be enabled manually from the devices user interface. In this case, for example, all three fields should remain empty.

3.5 Editor for Measurement Packets

This editor is used to define the measurement packets. A measurement packet specifies how to record measurement data in a particular frequency range.

There are several reasons why it is necessary and recommendable to split the total frequency range to be evaluated for EMF into different sub-ranges:

- On the one hand, the total EMF to be evaluated is generated by several separate sources of electromagnetic radiation. Each of these contributions (e.g. TV and radio broadcasting, mobile phone base stations) must eventually be measured with different settings of the analyzing instrument (e.g. different bandwidths, signal detectors, sweep times, frequency ranges). Hence, each measurement packet defines how to operate the system for evaluating the EMF contribution of one source of radiation.
- On the other hand, the overall frequency range which a full EMF system with an array of different antennas is able to evaluate, must be split up into several sub-ranges because the complete range can not be covered by one antenna. Therefore at least one measurement packet is to be defined for each antenna.
- Finally, it is recommendable to define several frequency sub-ranges in order to separate the contributions to the total EMF of different services (e.g. GSM base stations, FM broadcast, etc.) to be monitored in the final result tables. Since during the measurement process the acquired data are compressed to one resulting figure for each measurement packet, defining logically separate packets allows an easy identification of their contributions to the total EMF.

The Editor for the Measurement Packet is opened via the selection dialog for Measurement Packet (main menu entry ***Configuration à Packet...***). The settings to be entered in order to define system operation are organized in four different tabs which will be described in the following.

* ***TS-EMF***	*For the TS-EMF system, only three of these tabs will be displayed, as the available measurement axes are defined and there is no need for defining axis-dependent measurement parameters. Differences will be explicitly noted throughout the following description.*

Additionally, two general elements are contained in this dialog:

Text field ***Description***

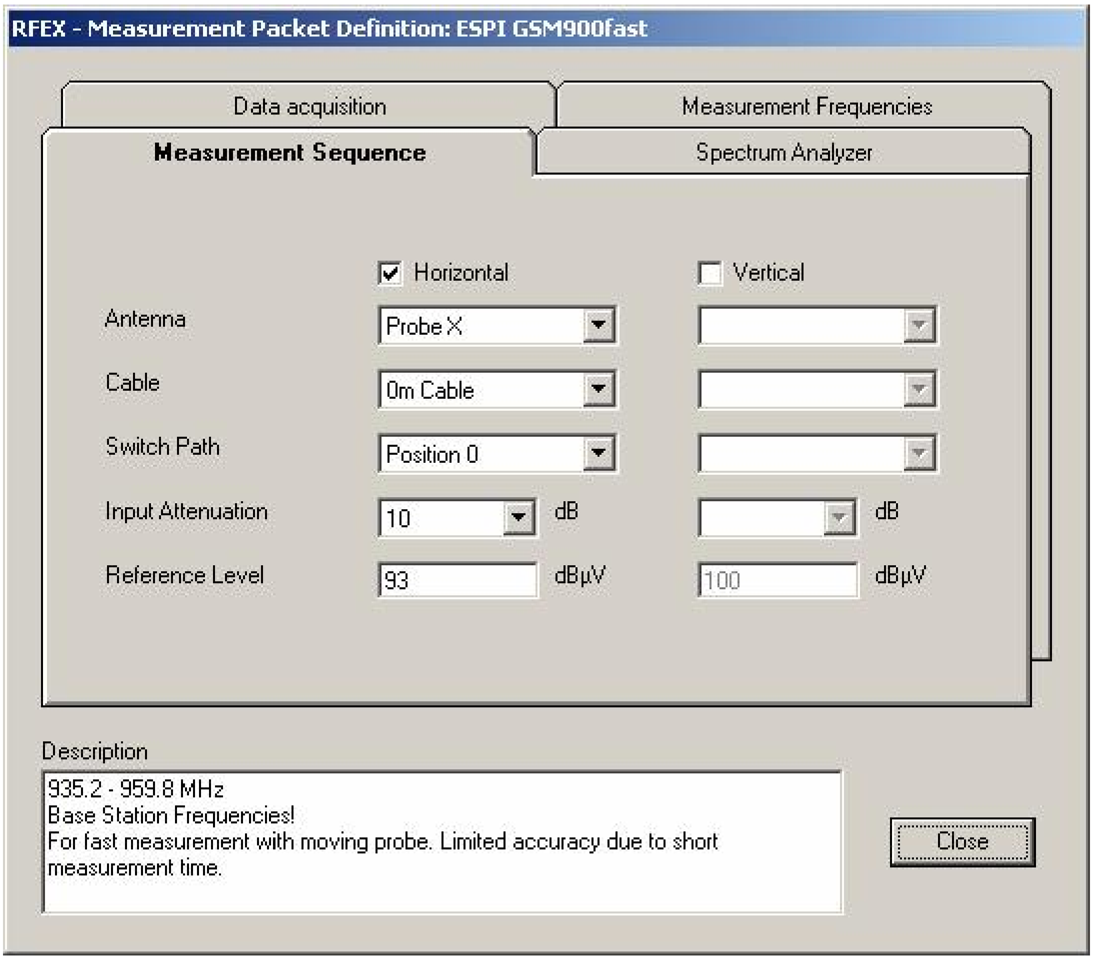
This text field allows to enter any description of the measurement packet. This description is considered as a comment but is useful for a later identification and explanation.

Button ***Close***

Clicking on this button causes all the setups to be stored and the dialog will be closed. Before saving the data, they are checked for consistency. Among others, the measurement frequency range is tested to be covered in full extent by the selected correction tables (antenna and cable). In case any inconsistency is detected, an error message will be displayed and the dialog can not be closed until all mismatches are corrected.

3.5.1 Measurement Sequence Tab

This tab will not be displayed for the TS-EMF system. Instead, the three parameters ***Cable***, ***Reference Level*** and ***Input Attenuation*** will be included only once for all measurement axes in other tabs of this dialog.



<u>Check boxes ***Horizontal*** and ***Vertical***</u>

The state of these boxes defines whether the system is to perform measurements in horizontal and vertical polarisations. Only if the corresponding box is checked, the associated selection boxes (for antenna, cable etc.) can be accessed.

For the TS-EMF system, these boxes are not needed as the three axes of the isotropic probe will always be measured in sequence.

<u>Selection boxes ***Antenna***</u>

These selection boxes are used to choose the antennas which shall be used during the measurement. All available files of type ***Antenna*** are listed. The antenna factors contained in the selected file will be used for correcting the spectrum analyzer's reading (raw data).

For the TS-EMF system, these boxes are not needed, as the single antenna factor tables for the tri-axis probe are defined internally to have the fixed names ***Probe X***, ***Probe Y*** and ***Probe Z.***

Selection boxes ***Cable***

These selection boxes are used to choose the tables containing the cable loss of the measurement setup. All available files of type ***Cable*** are listed. The cable loss contained in the selected file will be used for correcting the spectrum analyzer's reading (raw data).

For the TS-EMF system only one box is needed as the three axes of the isotropic probe are connected to the analyzer's input through the same cable. The box is included in the Data Acquisition parameter tab. Only two pre-defined cables are available in this case:

- ***0m Cable:*** no cable, the probe cable is included in the antenna factor.
- ***TS-EMFZ2***: 8m extension cable, available as option TS-EMFZ2.

Selection boxes ***Switch Path***

These boxes are used to select the switch path to be set at the switch unit in order to connect a specific the antenna to the input of the spectrum analyzer. All switch paths defined in the switch unit section of the hardware configuration dialog (see section 3.4.2) are listed.

For the TS-EMF system, these boxes are not needed as the three axes of the isotropic probe are switched through a USB port and no additional configuration information is needed for this.

Selection boxes ***Input Attenuation***

These boxes are used to define the input attenuation to be set at the spectrum analyzer. This parameter can be individually selected for horizontal and vertical polarisation, because the different nature of the signals to be measured as well as the influence of the antenna and of the measurement environment can lead to significantly different levels for different polarisations.

For the TS-EMF system, only one box is needed as the voltages induced in the three axes of the isotropic probe are measured with identical analyzer settings. The box is included in the Spectrum Analyzer settings tab.

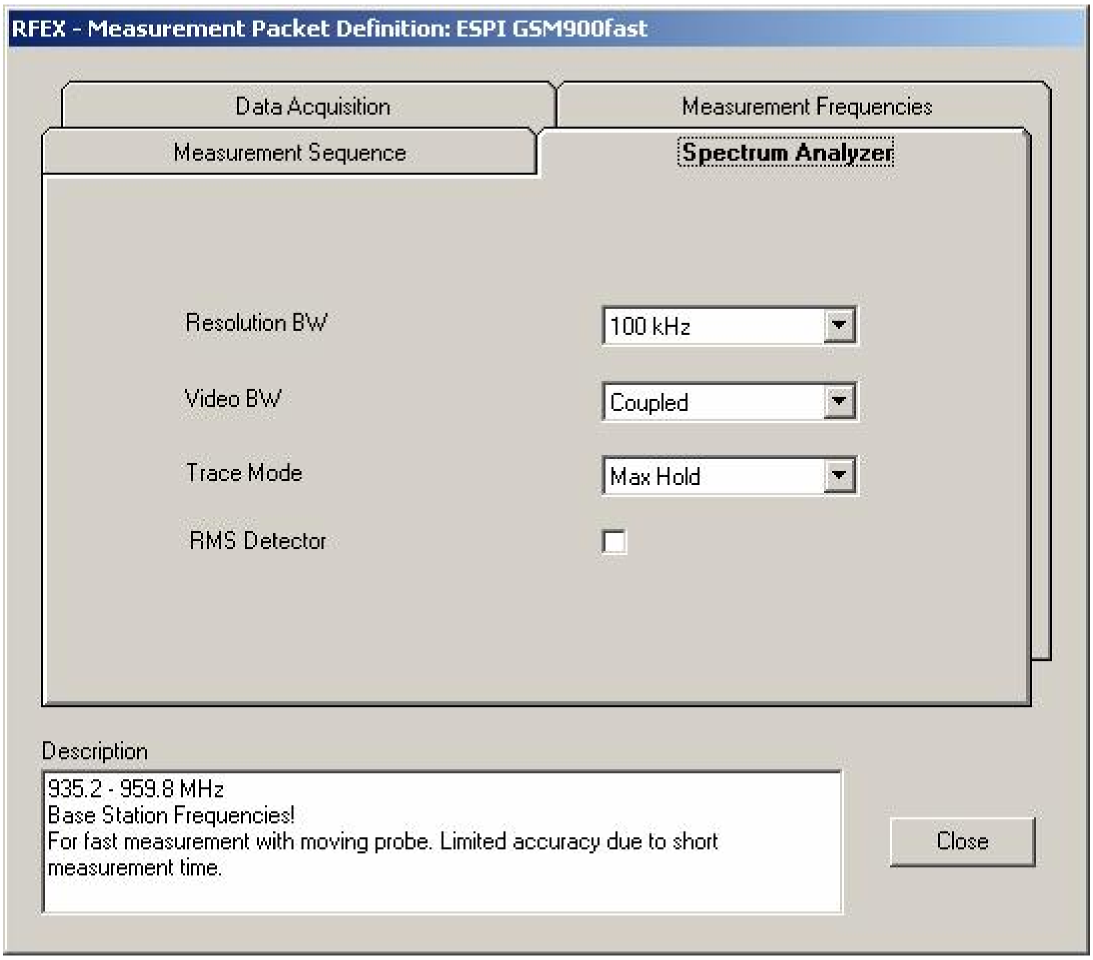
Text fields ***Reference Level***

These text fields are used to enter the reference level in dBµV to be set at the spectrum analyzer. A suitable value can be determined by a manual test or with the help of RFEX Overview Sweep utility.

If the so called Learning Phase (see section 5.1.4) is activated, the values specified for Input Attenuation and Reference Level are taken as start values for this learning phase. The actual settings for both parameters are automatically evaluated during the learning phase.

For the TS-EMF system, only one of these fields is needed as the voltages induced in the three axes of the isotropic probe are measured with identical analyzer settings. The field is included in the Spectrum Analyzer settings tab.

3.5.2 Spectrum Analyzer Tab



Selection box ***Resolution BW***

This box is used to select the resolution bandwidth of the spectrum analyzer. This is an important parameter since it strongly influences measurement speed and measurement resolution.

The standard resolution bandwidths from 3 kHz to 1 MHz are available. Additionally, a special bandwidth of 200 kHz can be selected, but can only be set on the FSH3 from firmware version 5.0 on and if firmware option FSH-K1 is installed. For all analyzers except the FSH3, the bandwidths 5 MHz and 10 MHz are available, too. The 5 MHz bandwidth is implemented as a Channel Filter; if it is not available at the instrument, 10 MHz will be set.

Selection box ***Video BW***

This box is used to specify the video bandwidth to be set at the spectrum analyzer. Since this parameter only serves to smoothen the display of the measured spectrum, it is recommended to select the mode ***Coupled***. Then the video bandwidth will be automatically set in relation to the resolution bandwidth.

This parameter is not included for the TS-EMF system, video bandwidth will always be coupled to resolution bandwidth.

<u>Selection box ***Trace Mode***</u>

This box is used to define which trace mode is set at the spectrum analyzer.

- ***MaxHold*** means, that the spectrum analyzer, when performing several sweeps, shows the maximum level evaluated at each frequency point.
- ***Average*** means that the spectrum analyzer displays the average value for all frequency points.
- ***ClearWrite*** means that for each sweep the previous data are deleted and only the measurement of the actual sweep shown.

When performing a Peak/Average measurement or a long-term measurement, frequency sweeps are done several times and the peak (*MaxHold*) and average values are determined by RFEX. Therefore, it is recommended to use the *ClearWrite* setting for the analyzer. Especially when measuring digitally modulated signals (pulsed signals), it is recommended to use the *MaxHold* function for fast measurements (only one sweep performed with dwell time set to zero). This may result in a kind of overrated value but ensures that the pulsed signal is reliably detected. If the dwell time is selected as a multiple of the sweep time then the *Average* function can be used. This way the average value of a pulsed signal is shown.

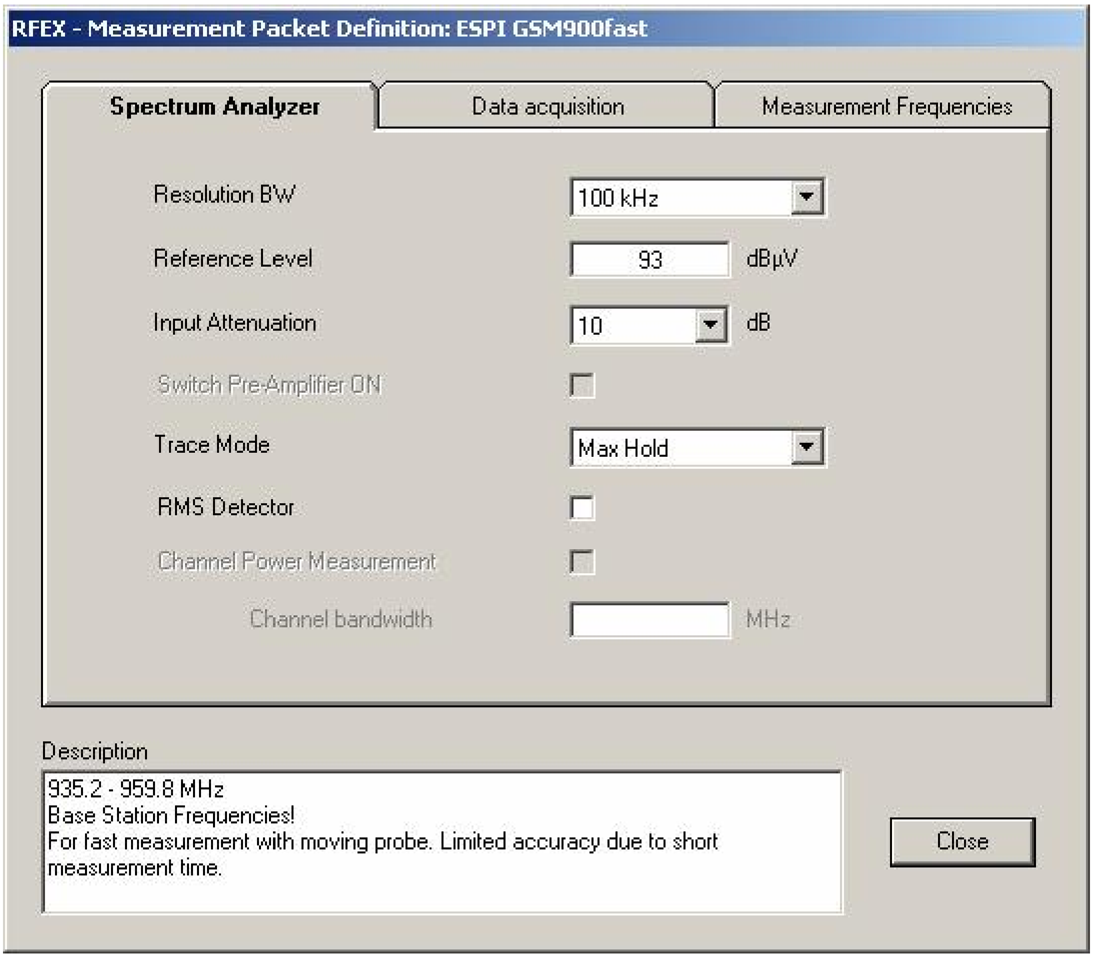
<u>Check box ***RMS Detector***</u>

If this box is selected, the RMS detector is selected at the spectrum analyzer. Otherwise the MaxPeak detector will be used. It is recommended to use the RMS detector if pulsed signals with a low duty cycle, like e.g. digital mobile phone signals, have to be measured, as these signals would be overrated by using MaxPeak detector.

*

TS-EMF

For the TS-EMF system, the Spectrum Analyzer tab looks as displayed on the next page. As mentioned in section 3.5.1, the parameters Reference Level and Input Attenuation are included here. Additionally, the parameters described on the next page are implemented only for use with the TS-EMF (analyzer model FSH3).



Check box ***Switch Pre-Amplifier ON***

If this box is checked, the 20 dB pre-amplifier will be switched on at the FSH3. This is only possible if the FSH3 has a pre-amplifier (model 23) and firmware option FSH-K1 is installed.

Check box ***Channel Power Measurement***

If this box is checked, the FSH3 will be set to do a channel power measurement instead of a normal frequency sweep. This may be useful if the bandwidth of the signal to be measured is broader than the maximum bandwidth of the FSH3 (1 MHz). This is the case, for example, for UMTS signals (3.84 MHz). As the other analyzers feature a bandwidth of 10 MHz, this setting is not necessary there.

Text field ***Channel bandwidth***

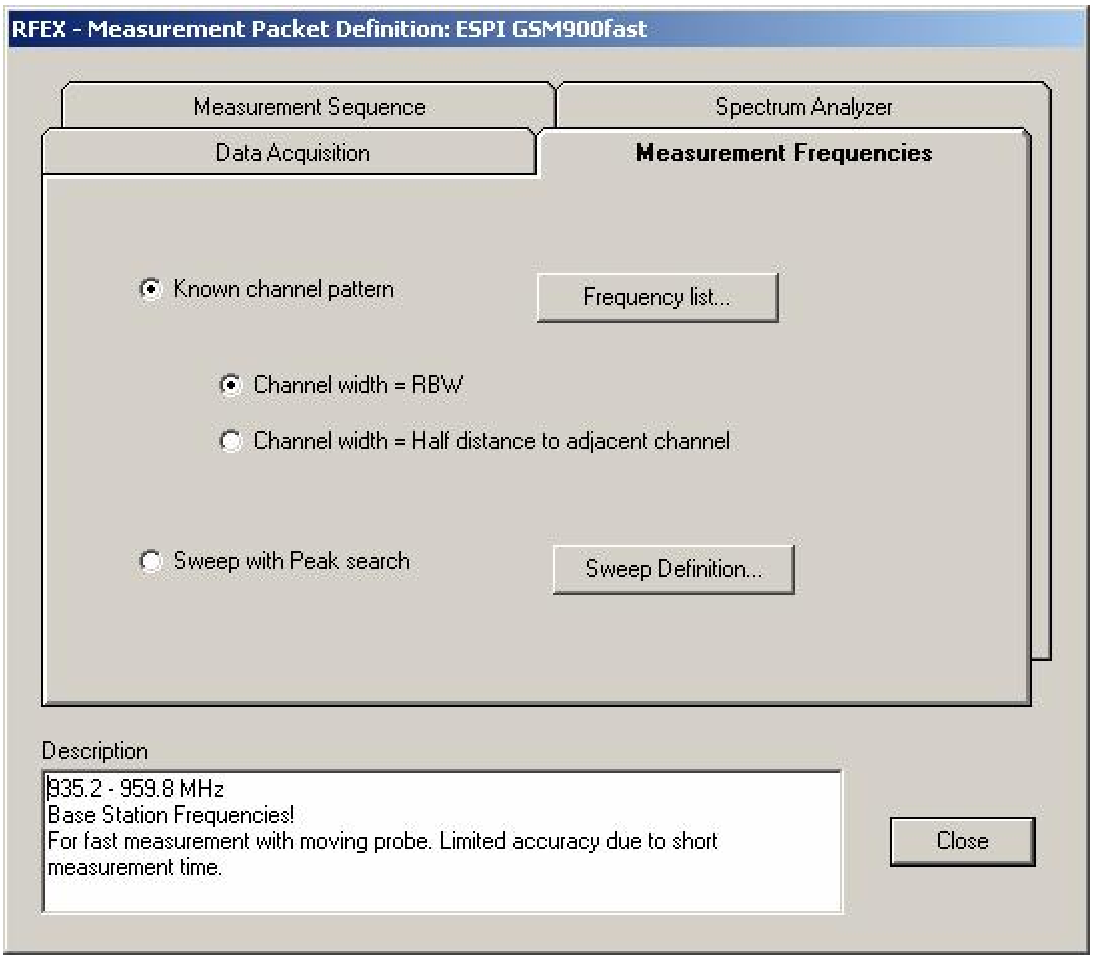
If a Channel power Measurement has been activated, the channel width to bescanned can be entered as additional parameter. It is recommended (see manual of the FSH3) to set the resolution bandwidth to maximum 10% of this channel bandwidth.

3.5.3 Measurement Frequencies Tab

One of the essential settings which are done in the measurement packet is the definition of the frequency points, where the measurements should be performed. Moreover, RFEX implemets two different modes for the measurement: a mode which is based on a channel pattern and a mode which searches the maximum levels in the measured frequency range.

Attention !

No measurement packet can be saved without defining a suitable set of measurement frequencies.



<u>Option ***Known channel pattern***</u>

If this mode is selected, the measurement frequencies are defined with equidistant spacing. A typical application is the measurement of mobile communication services (for example GSM), where the channels are defined in a known channel spacing.

The frequencies are defined in the Measurement Frequencies dialog, which is opened by clicking on the button ***Frequency list...***. See section 3.5.3.1.

In this case, the measurement is performed as follows: The complete frequency range to be measured by the spectrum analyzer is divided into stripes ("***channels***") of the same width, and the frequencies defined in the list are taken as channel centre frequencies. The maximum measurement value in each channel will be used for further processing.

Only when selecting this frequency list mode, the parameter ***Channels per sub-packet*** defined in the *Data Acquisition* tab will be taken into account; see section 3.5.4 for details.

Additionally, the width of such a signal channel can be specified more closely:

- Option ***Channel width = RBW***

  RBW stands for the resolution bandwidth set at the spectrum analyzer. Selecting this option means that only the signals immediately adjacent (covering a total of one RBW) to the channel's centre frequency will be considered when evaluating the channel's maximum signal level. If two channel frequencies are defined in a way that both channels do not intersect, there will be gaps in the overall spectrum which will not be taken into account when assigning their peak levels.

- Option ***Channel width = Half distance to adjacent channel***

  In this case the channel is calculated to cover half of the gap to the neighbouring frequency. As the adjacent channel is calculated in the same manner, all frequencies in the packet will be taken into account during level evaluation. Signals may be assigned to a channel even if they are not in the centre frequency's immediate proximity.

Option ***Sweep with Peak search***

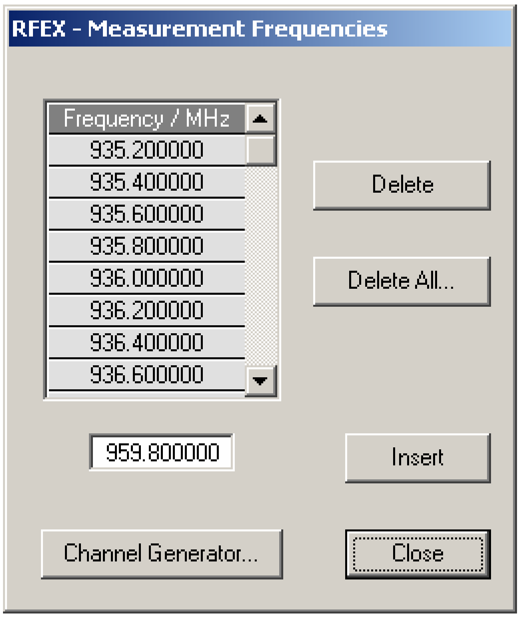
If the measurement frequencies are not expected to appear in a pattern with equidistant spacing but are expected to appear in any order, then the mode *Sweep with Peak Search* should be used. A typical application are measurements in the frequency range below 30 MHz. In this frequency range a lot of transmitters can be found with arbitrary distribution.

To define the measurement frequencies for this mode, the button ***Sweep Definition...*** is selected; see section 3.5.3.2.

In the sweep mode the measurement is done for the specified frequency range. The result data are analyzed for the maximum peaks with a number of ***n*** (***n*** can be selected). The amount of ***n*** peaks is stored for further processing.

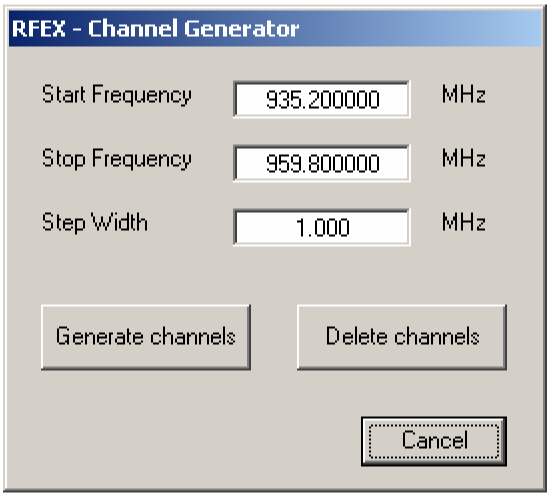
3.5.3.1 Measurement Frequencies Dialog

If the option ***Known Channel Pattern*** is been selected in the ***Measurement Frequencies*** tab, the definition of the measurement frequencies is done by a table containing the desired frequency values:



To support the generation of the table, an editor is available which is almost identical to the one in section 3.3. In this case only one row is necessary showing the frequency values.

An additional button ***Channel generator...*** is available which opens an additional dialog. This enables the user to generate or delete a list of frequencies in a fast and easy way. See next page.

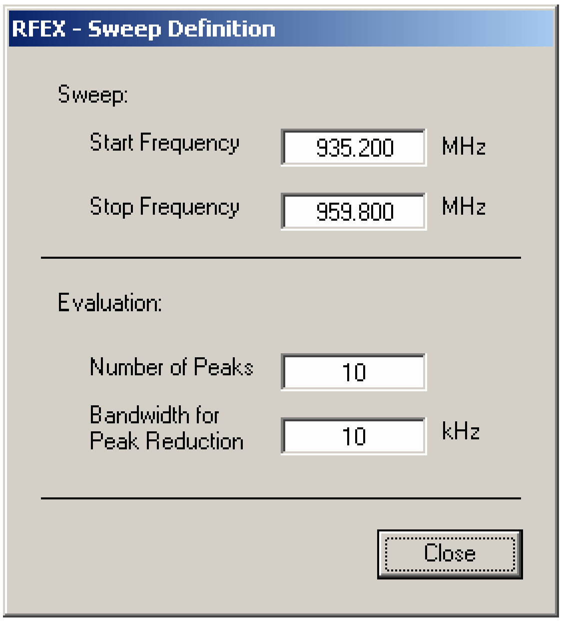


Clicking on the button ***Generate channels*** adds frequencies to the list. The list will cover the range from the start frequency up to the stop frequency with the given step width.

Clicking on the button ***Delete channels*** will delete all frequencies from start frequency to stop frequency, accordingly. Frequency values which do not match the specified frequency steps are not deleted!

3.5.3.2 Sweep Definition Dialog

If the option ***Sweep with Peak search*** is been selected in the ***Measurement Frequencies*** tab, a frequency range to sweep across has to be defined:



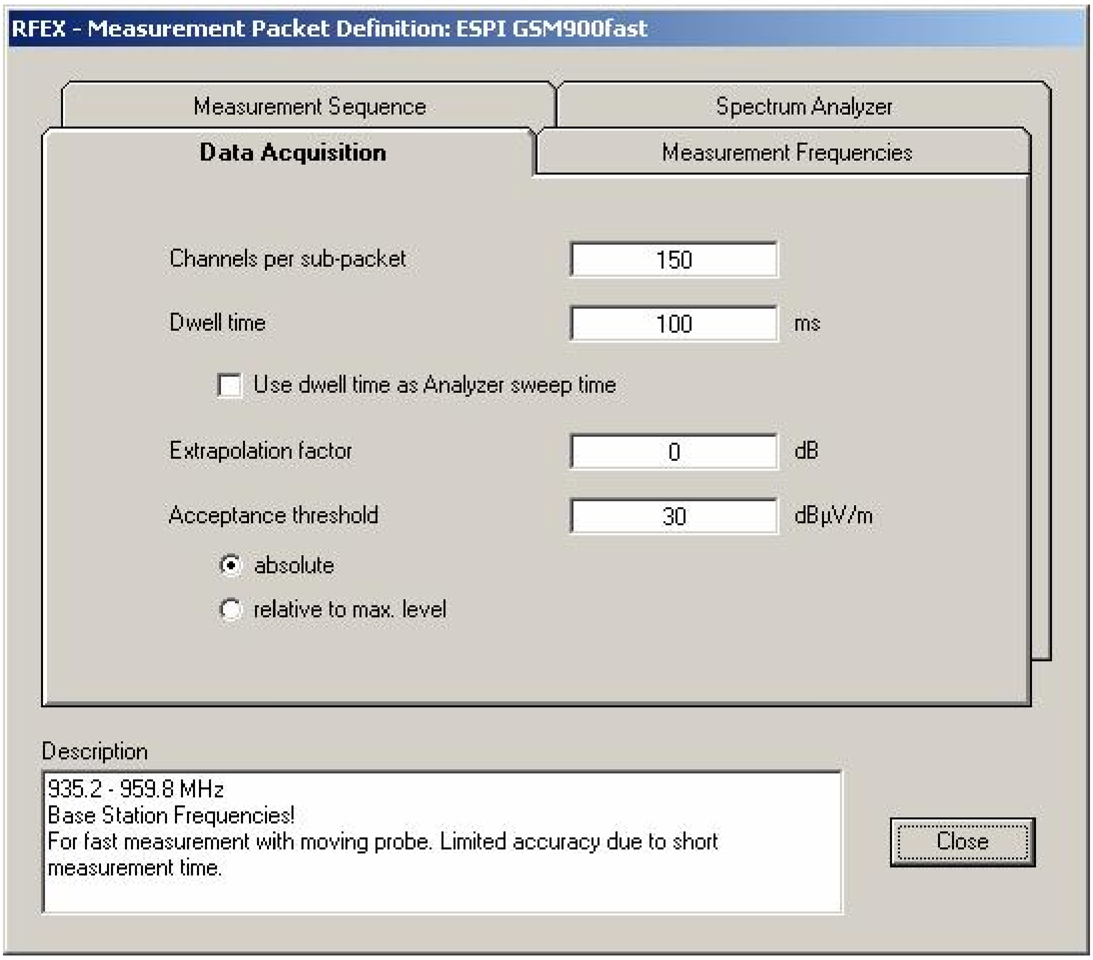
The range to sweep is defined from the ***Start** a*nd ***Stop Frequency*** text fields.

For spectrum evaluation, two additional text fields are implemented. The first one defines the ***Number of Peaks*** which shall kept from the spectrum recorded from the sweep. The number of peaks equals the amount of measurements values resulting from one sweep.

For determining what shall be considered a peak, the parameter ***Bandwidth for Peak Reduction*** is defined. This value gives the minimum distance two peaks should have to be considered as different ones. Thus, it can be avoided to keep more than one frequency value associated to one broad peak.

During the later step of measurement result compression, this parameter is also used to identify the frequencies which belong together. All peaks with a frequency not differing from each other more than this bandwidth parameter are identified to belong together. This ensures that a slight deviation of the peak frequency (e.g. caused by instability of the transmitter, atmospheric influences, or the fact that the transmitter delivers a broadband signal in comparison to the selected bandwidth of the analyzer) dos not lead to redundant measurement values.

3.5.4 Data Acquisition Tab



*

TS-EMF

*For the TS-EMF system, the parameter **Cable,** which in the general case is included in the Measurement Sequence tab, is additionally included here.*

<u>Text field ***Channels per Sub-packet***</u>

This parameter is only taken into account if the option ***Known Channel Pattern*** is selected in the ***Measurement frequencies*** tab, see section 3.5.3.

During a measurement in the ***Known Channel Pattern*** mode, the complete frequency range is not covered by one sweep. Instead the frequency range will usually be divided into smaller ranges ("sub packets") to ensure that each measurement channel is recorded with a sufficient amount of pixels (analyzer screen resolution). This text field allows to select the number of channels which should be recorded in one sub-packet. The channel width corresponds to the selected resolution bandwidth at the spectrum analyzer.

Please note the following: The less channels are defined in the sub-packet, the better the resolution of the measured spectrum will be (more pixels are available per channel). But this also increases the amount of sub-packets to be measured (requires frequent setting of the spectrum analyzer, hence increases the measurement time).

In detail, the RFEX proceeds as follows: the frequency range for a sub-packet equals to the product of the amount of channels and the resolution bandwidth. Suppose e.g. that a frequency range from 935 to 960 MHz shall be measured at a bandwidth of 100 kHz and with 20 channels per sub-packet. This results in sub-packets with 2 MHz (20 times 100 kHz) sweep range each. Therefore, the complete frequency range is divided in 13 sub-packets (the last one being somewhat smaller than 2 MHz).

During the measurement each sub-packet is extended by half the measurement bandwidth on both ends to ensure that the start frequency and the stop frequency are correctly recorded correctly (with half a bandwidth overlap).

The maximum amount of channels depends on the spectrum analyzer model: For the FSx and ESPI devices, which by default have 501 pixels trace resolution on screen, the maximum number of channels is 250; with a resolution bandwidth of 100 kHz, the sweep will cover 25.1 MHz. For the FSH3 with 301 pixels, the maximum number of channels is 150. In both cases, this results in a minimum of 2 pixels for each frequency to be measured..

Text field ***Dwell time***

This text field allows to enter the time which will be waited for to read the trace data from the spectrum analyzer after a sub-packet has been started. The time is entered in milliseconds.

By default, the sweep time is automatically set by the spectrum analyzer (coupled to the selected band width). RFEX queries the sweep time set by the analyzer and the Dwell Time set in the RFEX software will be 1.5 times this value. If the dwell time set in the RFEX software is bigger than the sweep time of the spectrum analyzer, then the analyzer will perform multiple sweeps. This setting should be selected when using the trace mode *MaxHold* for the analyzer. Generally, 100 ms is assumed to be the lowest limit for the analyzer sweep time.

Check box ***Use dwell time as Analyzer sweep time***

If this box is checked, the dwell time defined above will be used as the analyzer sweep time. Thus it is possible to force the analyzer to do slow sweeps. This can be necessary, for example, for evaluating traffic channels on TDMA mobile phone system (e.g. GSM) with sufficient measurement time.

Text field ***Extrapolation Factor***

This field is used for entering a correction factor in dB which will be added to the measured level.This can be necessary, for example, if the potential maximal emission level of a base station can only be theoretically evaluated based on a known current partial load.

Text field ***Acceptance threshold***

One of the main features of RFEX is its ability of data reduction. The amount of data ignored is mainly determined by the ***Acceptance threshold*** parameter, which because of this is one of the most critical parameters in a measurement packet. This threshold value defines a radiation level below which any measured field level will be ignored. It is very important to set this parameter in a way that it is neither too high (would lead to too low an EMF value being measured) nor too low (would lead to the analyzer's noise floor to be evaluated as radiation).

The acceptance threshold is not applied directly to the results read from the analyzer, but to the values calculated after correcting the analyzer data by the measurement antenna factor and the cable loss.

The threshold can be defined to be used in two different ways:

- Option ***absolute***

  In this case the threshold is considered to be an absolute value with unit dBµV/m. All measurement results below this threshold will be ignored from data reduction on.

- Option ***relative to max. level***

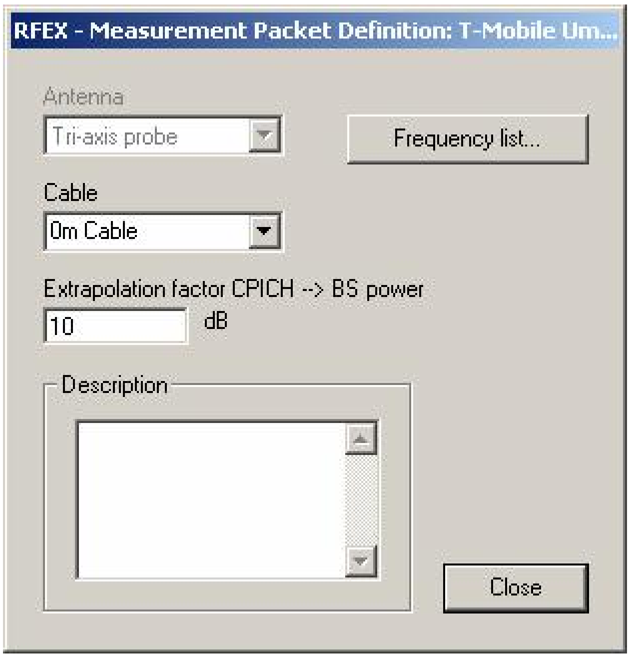
  In this case, the maximum level in the result file to be compressed is determined before the compression step. The threshold is relative to this maximum level. All measurement results with a value below the found maximum minus this relative value will be ignored from data reduction on.

  For the final result this leads to two consequences: if the measured spectrum shows a clear maximum, only this value will be kept. If the measurement does not show a maximum, but a more or less stable noise floor, all measured values will be kept and the final result will correspond to the integral of these noise signals.

As the threshold is applied for reducing the data after correcting the raw data for antenna factor and cable attenuation, it can not directly be correlated to the noise floor of the analyzer. Therefore, finding a suitable threshold level can be a relatively difficult task. In order to support the user for this task, the measurement function ***Threshold Calibration*** (see section 5.2.1) has been implemented.

3.6 Editor for UMTS Measurement Packets

If any of the options TSEMF-US1 or TSEMF-US2 enabling measurements on W-CDMA base stations with channel decoding is available, an additional entry ***Configuration à Umts Packet*** is added to the main menu of RFEX. Selecting this entry leads to a special editor for UMTS measurement packets:



As can be seen at first sight, UMTS measurements require much less parameters to be defined than standard measurements. This is because the UMTS software options configure most of the spectrum analyzer parameters automatically.

All control elements contained in the editor for UMTS measurement packets have already been described in section 3.5. please see there for a detailed reference.

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Attention !

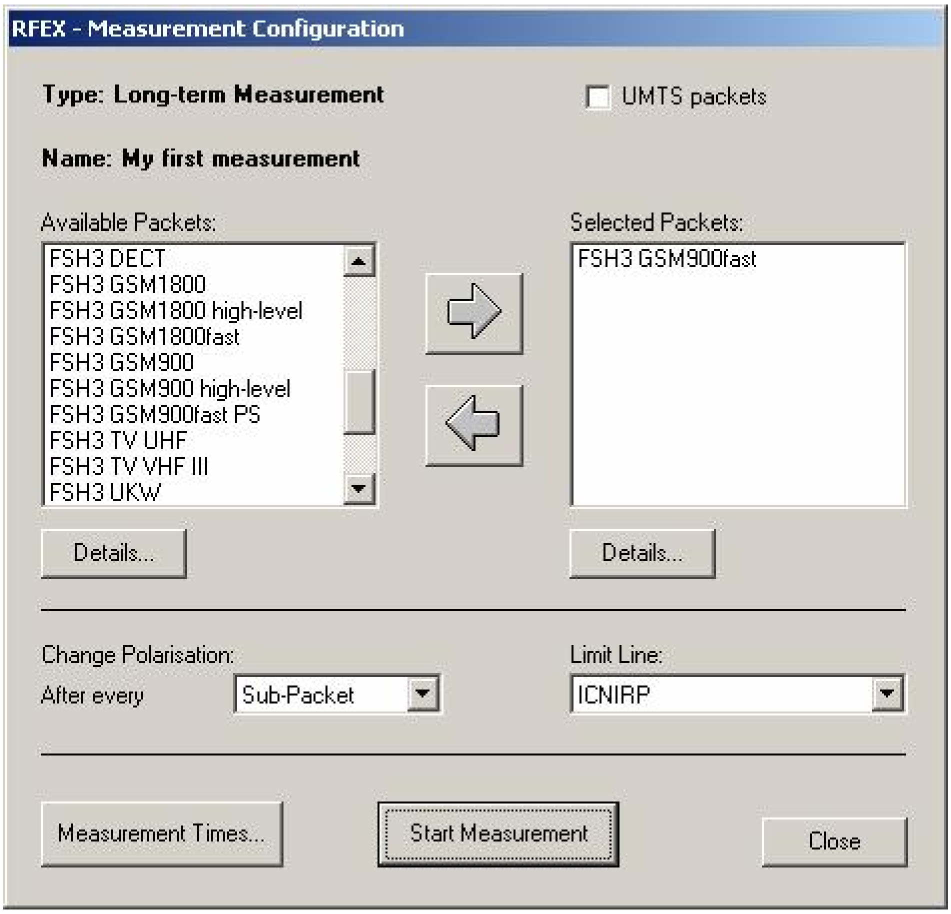
During measurements on UMTS base stations, RFEX will try to find W-CDMA signals at all of the frequencies entered in the frequency list. If no base station is found at one frequency, a timeout will not be generated and the sequence will not proceed until after some seconds. This will considerably slow down the measurement!

Please make sure to enter only frequencies on which a base station nearby is known to be active!

3.7 Measurement Configuration Editor

The task of the editor for Measurements is to combine all the measurement packets, which should be cyclically executed during a long-term measurement.

The editor is opened by the selection dialog for measurements (main menu ***Measurement***). Each time a measurement shall be performed, the editor is be opened and measurement start must explicitly be confirmed: **No measurement can be started before the measurement configuration is displayed on the screen**.



When saving a measurement configuration, not only the names of the used measurement packets are saved, but all the setup parameters (except the measurement frequencies) are saved as well. See also section 4.2.

This procedure guarantees that all setups are stored which have been used for data acquisition even if the measurement packet is going to be changed later on.

Description of the control elements

The basic feature of the editor are two lists to show the available measurement packets and the ones which should be executed. The two buttons with the arrow symbol are used to register (arrow left to right) a packet for measurement or to de-register (arrow right to left).

Each of the packets only can be selected once and therefore each packet is available in only one of both lists. During the measurement the measurement packets are performed in the same sequence as they have been selected.

Button ***Details...***

In the list, the measurement packets are only identified by name. The two buttons ***Details*** offer the possibility to view their content without leaving this editor and opening another editor for measurement packet. Selecting one of the buttons opens an additional window which shows a summary of the settings of the selected measurement packet. Before selecting one of two buttons a measurement packet must have been selected; otherwise the two buttons are not active.

Check box ***UMTS packets***

If any of the options TSEMF-US1 or TSEMF-US2 enabling measurements on W-CDMA base stations with channel decoding is available, the measurement configuration editor will additionally display this box. If it is checked, the list of available measurement packets is re-built to contain only the packets for UMTS measurements generated with the editor for UMTS packets, see section 3.6.

Selection box ***Change Polarisation***

This text field defines in which sequence the measurements are performed concerning the antennas and horizontal/vertical polarisation.

- ***After every Sub-Packet*** means that the switching of the antenna switching unit is done every time when the measurement of a sub-packet is finished. This selection is useful for systems using the same antenna for horizontal and vertical polarisation. This case no switching is done and the spectrum analyzer can keep the same settings which optimizes the measurement sequence.
- ***After every Measurement Packet*** will switch the polarisation after completion of a measurement packet. If the measurement packet only contains one configuration, no switching will be performed. This selection is used as default.
- ***After every Run*** will complete the whole measurement packet sequence before the polarisation is switched. This selection is the best solution if there is no automatic switching unit available and the switching has to be done manually.

*

TS-EMF

*For the TS-EMF system, the selection in this box is always fixed to **After every Sub-Packet**. As a consequence, the field is measured at the three axes of the isotropic field probe directly in sequence, and the measured (and corrected) values are geometrically added immediately afterwards.*

Selection Box ***Limit Line***

This selection box shows the different limit lines, which can be selected during compression of the measurement data. If a limit line is selected, measurement data can be represented as values per thousand of the limit. However, it is also possible not to select a limit line and save the measurement values in a field strength or a power flux density unit; see section 3.8 for details.

Button ***Start Measurement***

Clicking on this button saves the settings, closes the dialog and starts the measurement. Before saving, the given data are checked for consistency. At least one measurement packet must have be selected. If the measurement times have not been defined before (clicking on ***Measurement Times...***), the dialog for the definition of the measurement times will be opened, too.

Button ***Close***

Clicking on this button saves the settings and closes the dialog. Before saving, the given data are checked for consistency and an error message is generated if applicable.

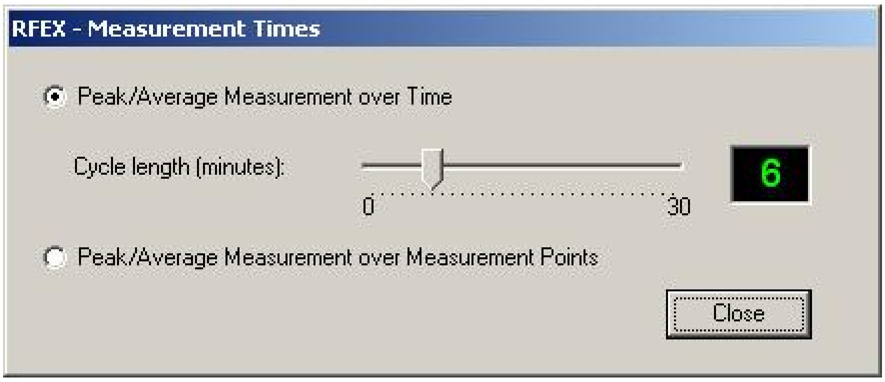
Button ***Measurement Times...***

Clicking on of this button starts the dialog for defining the measurement times. In case of a single measurement this button is not available, since the measurement packet sequence is only executed once.

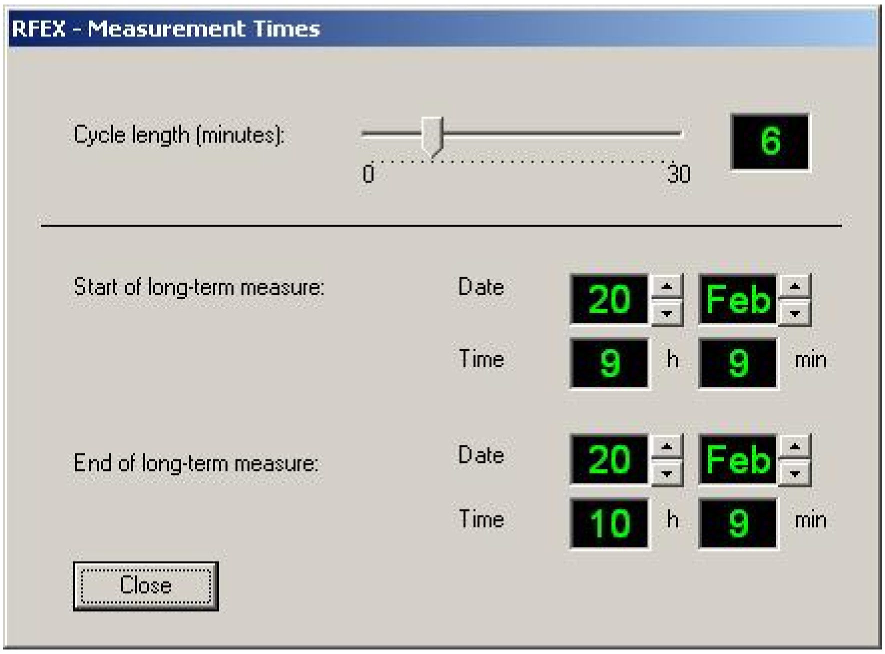
In case of a measurement in the minute range (data accumulation with Peak/Average representation) this dialog is used to define how the measurement iteration shall proceed.

Either the measurement can be defined to take place over a certain time lapse between 0 and 30 seconds, where 0 means that the selected packets are executed exactly once.

Or the measurement can be defined to take place over a range of points. In this case, after the end of each loop over all packets, the user is prompted to place the probe at the next measurement location or to finish the test.



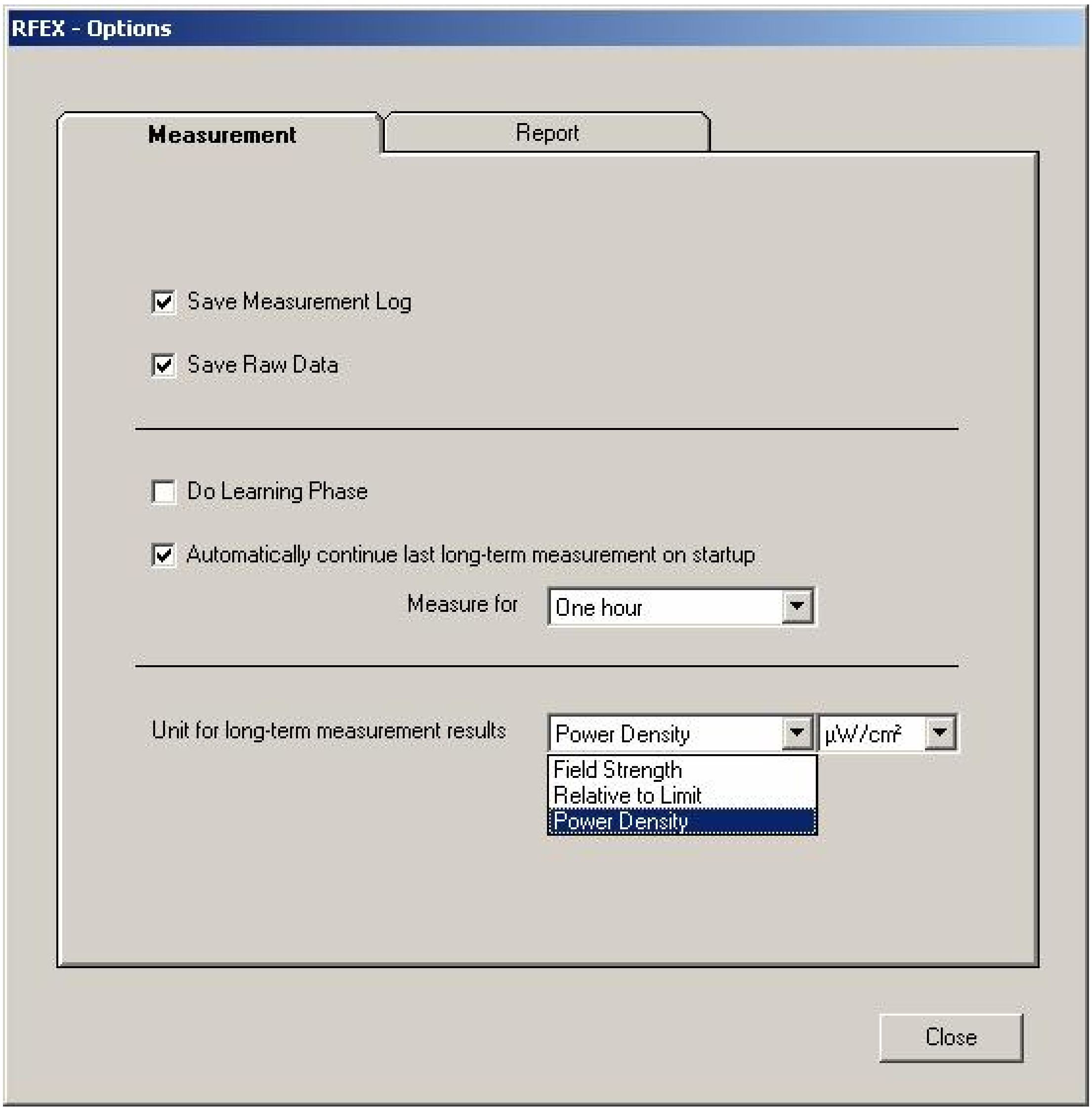
In case of a long-term measurement, which basically is not more than a sequence of peak/average measurements in the minute range, two time factors have to be defined. The first factor is the cycle length (from 0 to 30 minutes as described above). The second factor is the start and stop time for the overall measurement. To do this, several fields are foreseen to specify the time together with the date for the start and stop of the measurement. Default values are selected in a way that the measurement starts within two minutes after opening of the dialog and ends in one hour.



3.8 Options Dialog

The options dialog is opened clicking on the main menu entry ***System à Options…*** It allows the user to set a range of parameters configuring the measurement run and the extent of the reports.

3.8.1 Measurement Tab



Check box ***Save Measurement Log***

If this box is checked, the contents of the measurement log list box, which during the test run shows the current activity, will be saved to a file. See also section 4.3.4.

Check box ***Save Raw Data***

If this box is checked, the temporary data files generated during a test run will not be deleted after data compression has been completed, but will be renamed and kept. See also section 4.3.

Check box ***Do Learning Phase***

If this box is checked, the so called learning phase will be executed before starting the real measurement. The aim is to find the best setting for the spectrum analyzer's reference level and input attenuation automatically, in order to make sure there will be no overload condition at the analyzer during the test. See also section 5.1.4.

This check box is not available with the TS-EMF system as the FSH3 analyzer's input attenuation can not be set independently.

Check box ***Automatically continue last long-term measurement on startup***

If this box is checked, RFEX will automatically load and continue the last long-term measurement which had been executed before closing the application. The consistency of the measurement configuration, the availability of the selected measurement packets and the controllability of the configured instruments are checked as usual before starting the new test run, but the user does not need to click even once after starting RFEX.

The length of the test run started automatically is defined by the next parameter.

Selection box ***Measure for***

This box is enabled only if the automatic continuation of the last long-term measurement has been enabled (see previous parameter). It allows to define how long such an automatically started measurement shall last. Available selections are: *One hour, One day, One week* and *One month*.

Selection box ***Unit for long-term measurement results***

In earlier version of RFEX, long-term result files always contained three data columns giving the measured data in three different units.

This is considered to be redundant. Also, it is now possible to perform measurements and evaluate the data without referring them to a limit line, which makes it impossible to save the data in this format, as was done previously.

Hence, one single unit for saving long-term measurement data must be selected. The available units are grouped by the magnitude they represent. Possible selections are

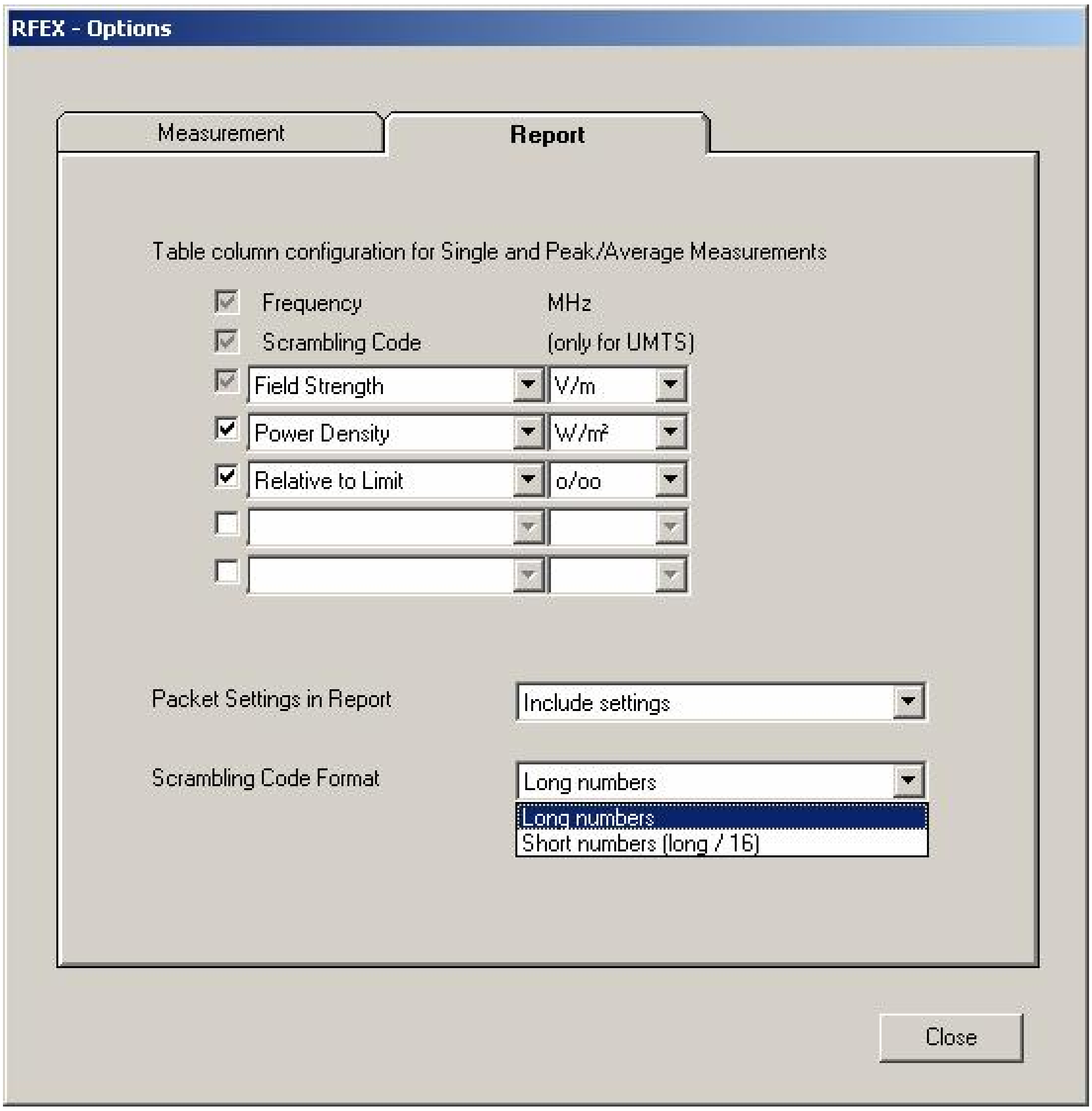
- field strength units V/m and dBµV/m,
- power density units µW/cm², W/m² and µW/m²,
- and values relative to a limit line in thousands (o/oo) or hundreds (o/o) of the limit

Power density units are always saved in a scientific format with at least three significant digits. Therefore, in this case field values different from zero will be saved even if the field is so low that the values in field strength units or relative to the limit would give a zero.

If a unit relative to the limit is selected, but the measurement is done without selecting a limit line, data will be saved in the default unit of V/m.

3.8.2 Report Tab

In this tab, the configuration of the reports generated by RFEX in Excel worksheet format can be parameterized. For detailed information about reports see section 4.4.



<u>Selection box field ***Table column configuration***</u>

The report generated by RFEX for single and peak/average measurements can be freely configured with the help of these boxes. The only fixed features of the report are:

- The first column will display the frequency in MHz.
- The second column for UMTS measurements will display the scrambling code of the identified base stations.
- At least a third column containing the measured field must be defined

The rest of the report contents, i.e. how many columns shall be generated, and which shall be the unit of each column, can be set by the user.

The field contains a column of check boxes on the leftmost side. Selecting one of these boxes will enable the rest of the row enabling the user to select a unit for displaying the measurement results.

Unit selection is done the same way as described for the long-term measurement unit in the previous section, i.e., first the applicable physical magnitude (field strength, power density or parts of the limit) is chosen, and then one of the units defined for this magnitude can be selected.

Selection box ***Packet Settings in Report***

This option is used to define the extent of the measurement packet settings to be included in a report for single and peak/average measurements. ***Do not include settings*** stands for no parameters at all to be included in the report, whereas ***Include settings*** will lead to all settings of the packet being printed to the report after the data table. ***Include frequencies as well*** will be available in a future release and will lead to the list of measurement frequencies being added to the report as well.

Selection box ***Scrambling Code Format***

This box is displayed only if any of the options TSEMF-US1 or TSEMF-US2 enabling measurements on W-CDMA base stations with channel decoding is available. As several base stations of a provider will be emitting on the same W-CDMA frequency, an additional characteristic parameter is needed to distinguish between them; this additional information is the base station's scrambling code, which will always be added to a report generated for a UMTS measurement.

This selection box allows to define if the full scrambling code number shall be added to the report, or if the short format obtained from dividing the full code number by 16 is preferred.

4 File System

This chapter describes the directory structure and the files created on the computer's hard disk by RFEX during installation and execution. Detailed information is supplied about where to find result files and reports and how they are formatted. Main intention is to enable the user to efficiently document his measurements and to define his needs for backing up all files he considers necessary.

4.1 Directory Structure

All the files generated by RFEX are kept in a fixed directory structure, which originates from the installation directory defined by the user during installation. The file structure is as follows:

Directory	Sub-Directories	Content
Installation directory		
\ Application		Executable program Rfex.ini: main initialisation file
\ Data	\ Antennas \ Limits \ Cables \ Packets	Configuration files: Correction tables and definition of measurement packets
\ Measures	\ Single \ PeakAver \ LongTerm	Measurement configurations and results
\ Reports		Excel-Files with measurement results

If not yet available, the sub-directories are created automatically during the first run of RFEX.

All files except the report files, which are generated in Excel format, are readable files in ASCII format. The format of configuration files is similar to the format of Windows initialisation files.

Tables and measurement data are stored with descriptive column headers including a unit string if applicable. The measurement results are lined up in rows with the data fields separated by tab characters. This format allows to import the files into any other application by choosing the tab character as field separation.

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Attention !

RFEX generates measurement result files and Excel sheets. These files are not managed further on, particularly there is no automatic backup feature. If a backup of the measurement data and other files is required, it must be performed from outside the RFEX application, for example by using the Windows-Explorer.

It is recommended to do regular backups and to clean up the directories containing the measurement data, especially if the option ***Save Raw Data*** (see section 3.8.1) is active.

4.2 Configuration Data

Configuration data are always saved in ASCII format. They can be opened with any editor, for example the Windows Notepad utility.

Rfex.ini

This file is used for saving, in a format similar to the format of Windows initialization files, settings defined in the Hardware Configuration dialog (see section 3.4) and the Options dialog (see section 3.8).

Data Tables

Data tables contain measurement correction factors. The following types are known to RFEX:

- Antenna Gain Factors. Stored in *Data \ Antennas*. Named **.Antenna*
- Cable Correction Factors. Stored in *Data \ Cables*. Named **.Cable*
- Limit Lines. Stored in *Data \ Limits*. Named **.Limit*

All these tables are stored as two-column tables mapping the format of the associated table editors (see section 3.3). The first column gives frequency values in MHz, the second column contains the associated level values. A header section contains column and unit descriptions as strings.

Measurement Packet Definitions

Measurement packets are edited within RFEX with the Measurement Packet editor (see section 3.5). All settings entered in this dialog will be saved to a file ending with the extension **.Packet* in the directory *Data \ Packets*. The format corresponds to a Windows initialization file.

Measurement Configurations

Measurement configuration files are generated when closing the Measurement Configuration editor (see section 3.6). At that point, the following information is stored to these files:

- Number and names of the measurement packets selected for the measurement.
- For each selected measurement packet, a separate section is generated containing a copy of the packet file itself, except the measurement frequency data.
- Settings in the Measurement Times dialog. These depend on the type of measurement being performed.
- Limit line and antenna switching scheme selected for the measurement.

During the measurement run, test execution start and stop times as well as the number of measured loops (in the case of peak/average measurement) will also be saved to this file.

Saving a copy of the measurement packets will allow to trace the measurement results to the original settings in the packets, even if the packet itself is modified later on. Only the definition for the measurement frequencies will in any case be extracted from the packet itself.

Measurement configuration files are saved to the different sub-directories in the *\Measures* directory, and are defined to have different file name extensions: **.Single* for single measurements, **.PkAv* for peak/average measurements and **.LongTerm* for long-term evaluations. The format always corresponds to a Windows initialization file.

4.3 Measurement Results

Measurement results are always saved in ASCII format. They can be opened with any editor, for example the Windows Notepad utility.

The format, the contents and the directory where to save the measurement result files, depend on the type of the measurement. In order to understand the contents of the different files, a good understanding of the measurement procedures and of how the different measurement types are related to each other is recommendable. See chapter 5 for details on the measurements.

4.3.1 Single Measurements

Single measurement result files are saved, together with their corresponding measurement configuration files in the ***Measures \ Single*** directory.

During a single measurement, RFEX drives the system in order to acquire one set of measurement data (one value for each measurement frequency) for each selected polarization for each packet. Immediately after acquisition, the value defined as extrapolation factor in the measurement packet is added to each measurement value.

These extrapolated data are saved as raw data to a file called ***<Measurement>.Raw*** where *<Measurement>* stands for the name given to this measurement when selecting it.

After the sweep has been completed for all measurement packets, these raw data are corrected for the antenna factors and the cables attenuations associated to each polarization in the measurement packet editor. The next step consists in compressing the data by comparing the values against the acceptance threshold defined in the measurement packet. Only if the value for at least one polarization exceeds the acceptance threshold, the measured data at the associated frequency will be considered from here on.

The values obtained from this compression step are saved to a file called ***<Measurement>.Result***.

Finally, the vector sum (root of the sum of square values) of the values obtained for each polarization is performed, in order to evaluate the equivalent field strength in V/m. These sums then are saved to the final result file for a single measurement, named ***<Measurement>.Compressed***.

According to the procedure described, this final result file contains one line for each frequency at which a significant field component (higher than the acceptance threshold) has been detected. Each line contains, in this order, four fields: Name of the measurement packet, time and date of data acquisition, frequency and equivalent field in V/m.

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TS-EMF

For the TS-EMF system, the above steps are performed in a little different order. Due to fact that with the tri-axis probe no explicit polarization selection is available, all three axes of the probe will sequentially be activated and the corresponding levels be evaluated.

Therefore, after adding the extrapolation factor, the measured data will first be corrected for their antenna factors (one for each axis) and then immediately added geometrically (root of sum of squares). Hence, <Measurement>.Raw will contain only one value per frequency, this value already being corrected for the antenna factors and being the vector sum of all three field components.

Correspondingly, also <Measurement>.Result, obtained after correcting the cable attenuation and compressing the data, will show only one value for each frequency. In this case, the total equivalent field values instead of each single polarization component will be taken into account when compressing the data against the acceptance threshold.

If the option ***Save Raw Data*** is selected in the Options dialog (see section 3.8), the intermediate files *<Measurement>.Raw* and *<Measurement>.Result* will not be deleted after the measurement.

4.3.2 Peak/Average Measurements

Peak/Average measurement result files are saved, together with their corresponding measurement configuration files in the ***Measures \ PeakAver*** directory.

During a peak/average measurement, the system is driven in exactly the same way as during a single measurement, with the exception that after one measurement has been performed for all selected packets, the same measurement sequence is started again, cyclically, until the measurement time defined before starting the run has been completed.

The measurement data are saved to raw data files in the same manner as during a single measurement. However, as more than one test run will be done, raw data files are saved with an additional suffix in their name extension, they will be saved as ***<Measurement>.Raw.i*** where *i* is a number starting at 0 and increasing one unit each time a measurement loop is completed.

The contents of the raw data files obviously are the same as in the case of the single measurement, being different for a standard system and for the TS-EMF system (already corrected for antenna factors and added geometrically).

After each measurement cycle, the data are accumulated. On the one hand, they are added to the sum of all previous measurements, on the other hand, the maximum value for each measurement frequency is kept in a different file.

After the measurement time is completed, the values in the first accumulated file (containing the sum of all measured data for each frequency) are divided by the total number of loops performed; this will then give the average value over all loops for each frequency. The second file will contain the peak value detected for each frequency during the whole measurement time.

These temporary files are called ***<Measurement>.Average.All*** and ***<Measurement>.Peak.All***.

The values in these files will be corrected for antenna factors and cable attenuations, just as in the case of a single measurement, then be compressed by comparing them to the acceptance threshold defined in each measurement packet, and finally added geometrically. (For the TS-EMF system, antenna factor correction and geometrical sum have already been done on the raw data).

In the end, two result files will be generated: ***<Measurement>.Average.Compressed*** and ***<Measurement>.Peak.Compressed***, containing the average and the peak values of the equivalent field strength measured during the defined time interval. The format is the same as in the case of the final result for a single measurement, only the data do not arise from one single run, but are the accumulation (peak and average values) of a number of test runs during a given measurement time.

If the option ***Save Raw Data*** is selected in the Options dialog (see section 3.8), the intermediate files *<Measurement>.Raw.i*, *<Measurement>.Average.All* and *<Measurement>.Peak.All* will not be deleted after the measurement.

4.3.3 Long-term Measurements

Long-term measurement result files are saved, together with their corresponding measurement configuration files in the ***Measures \ LongTerm*** directory. Due to the potentially large quantity of raw data, these will not be saved to the main directory, but to sub-directories having the same name as given to the measurement.

A long-term measurement consists in repeating peak/average measurement cycles during a certain time, which is defined in terms of a start and a stop time. Its total duration is arbitrary and may last for weeks or theoretically for months.

After each peak/average cycle, the same files as described in the last section have been generated. If the option ***Save Raw Data*** is selected in the Options dialog (see section 3.8), the temporary peak/average result files are renamed to ***<Measurement>.Raw.i.j***, ***<Measurement>.Average.j*** and ***<Measurement>.Peak.j***, where *j* is a number starting at 0 and increasing one unit each time a peak/average cycle is completed. These files are moved to a sub-directory *Measures \ LongTerm \ <Measurement>*.

The final result of a long-term measurement is a series of files containing one line for each measurement packet for each completed peak/average cycle. For generating this line, all result lines from the average result file of an peak/average cycle (<*Measurement*>*.Average.j*) and corresponding to a this packet, will be combined together to give one single average value. Also, all result lines from the peak result file and corresponding to the same measurement packet (<*Measurement*>*.Peak.j*) will be combined to give one single peak value. Finally, the maximum value contained in the peak result file will also be saved as the one single maximum result for the corresponding packet.

In conclusion, this final result file will contain lines made up by the packet name, a date and time stamp, an average emission value, a total peak value (average of peaks) and a single maximum emission value. If a GPS receiver is used (see section 3.4.5), an additional field containing the geographic position read out from this device at the end of the peak/average cycle will be added at the end of the line.

The above description shows how a long-term final result file is generated. However, more than one file is generated for such a measurement: It is said above that all average values will be “combined” to give one total value corresponding to a packet. This combination takes place in different ways, resulting in different values which are saved to different files:

- ***<Measurement>.Square.FinalResult*** is generated combining single values by adding the square values of the single field strength contributions. This method allows direct comparisons of the total value with the limit line defined acc. to ICNIRP (International Committee on Non-Ionizing Radiation Protection), condition 9.
- ***<Measurement>.Linear.FinalResult*** is generated taking the linear sum of the field strength values. This can directly be compared to the ICNIRP condition 7, defined for fields with a frequency up to 10 MHz. Hence, this file is created only if any measurement frequency below 10 MHz is defined in the measurement packet.
- ***<Measurement>.Rms.FinalResult*** is generated extracting the square root of the above sum of square field strength values. This Root Mean Square value is very popular among engineers doing EMF measurement.

But there is still more: If a long-term measurement lasts more than a day, one series of result files will be generated for each day during which the measurement was active. This is done by renaming the current files <*Measurement*>*.*.FinalResult* to ***<Measurement>.yyyymmdd.*.FinalResult*** where *yyyymmdd* represents the date of the just finished day.

For example, if a long-term measurement named *MyTest* is performed in the frequency range from 80 MHz to 3 GHz starting on February, 10th, 2004 and ending on February, 12th, 2004, the following files will make up the result of this test:

- *MyTest.20040210.Square.FinalResult, MyTest.20040210.Rms.FinalResult*
- *MyTest.20040211.Square.FinalResult, MyTest.20040211.Rms.FinalResult*
- *MyTest.20040212.Square.FinalResult, MyTest.20040212.Rms.FinalResult*

4.3.4 Measurement Log

If the option ***Save Measurement Log*** is selected in the Options dialog (see section 3.8.1) the content of the measurement log window which displays the measurement progress on the RFEX main screen will be saved to a file named ***<Measurement>.Log***.

4.4 Reports

As a general principle, the test reports are formatted as Excel spreadsheets and contain the final result as a table of values. Technically, an installed Excel program is driven by its software interface to generate the report files. Therefore, Excel must be installed on the PC running RFEX in order to be able to generate reports at all. If no Excel installation can be identified, report generation menu entries are disabled. In this case, still the result files can be manually imported from any other application, as they are ASCII formatted.

Additional information about the settings defined in the measurement packet(s) and graphics displaying the most significant contributions to the total field strength will be added if appropriate and configured by the user.

For single and peak/average measurements, the extent of the generated spreadsheet is mainly defined by the settings in the Options dialog (see section 3.8.2).

Single Measurement

The measurement result for a single measurement will be displayed in an Excel spreadsheet as follows:

- One worksheet will be generated for each measurement packet defined in the measurement configuration. The worksheet's name will be the same as the packet's name.
- This worksheet contains
  - A title line, giving the packet name again.
  - A value table with one row for each frequency belonging to the packet present in the single measurement's result file *<Measurement>.Compressed*.

    The number of columns and the units in which the values are displayed is defined by the user in the Options dialog (see section 3.8.2).
  - Three or four summary values at the bottom of the table. The values are: the sum of squares of all measured field strength contributions, the RMS value (root of sum of squares), and, if there is any frequency below 10 MHz in the table, the linear sum of the values measured below 10 MHz (see also the discussion of the final result files for long-term measurements in section 4.3.3). The last value is the single maximum field strength in the table.
  - If the user has selected to include the packet settings in the report (see section 3.8.2), a number of lines follows, displaying textual information about the packet settings.
  - Finally, a graphic is generated, displaying the up to 30 biggest field strength values in the table as columns over frequency.
- A summary worksheet will be generated as first of all worksheets. It contains
  - A title section identifying the measurement as a whole.
  - If a GPS receiver was available during the measurement, the geographic position queried from this device.
  - A table with the summary values of all single-packet worksheets.
  - A graphic containing all RMS summary values as columns over the packet names.

As a general principle, the summary values will be generated in units relative to the limit if a limit line is selected for report generation. If no limit is selected, the first column in the table will be used for summing up the values, and will hence define the unit of the summary values.

Peak/Average Measurement

As the result files for a peak/average measurement are basically the same as for a single measurement, the Excel spreadsheet generated for such measurements will also be very similar to the one for a single measurement. The only difference is that the contents of each worksheet will be doubled: First, a result table and a graphic for the average results will be generated, and after these, a table and a graphic for the peak values will be generated. The summary worksheet at the beginning will also contain a table and a graph for the sums of the average values for all packets, and after that, a table and a graph for the RMS sum of the peak values of each packet.

Long-Term Measurement

Although the measured data are compressed and only packet specific values are saved for long-term measurements, these may still generate huge amounts of data. Correspondingly, the Excel spreadsheets generated as reports may also be quite big.

One spreadsheet will be generated for each type of final result file saved during the measurement, where "type" refers to the result addition algorithm: square, RMS and possibly linear (see section 4.3.3). In other words, exporting long-term measurements will lead to two or three Excel files.

Each of these files contains:

- One worksheet for each final result file saved for one day. That is, if the measurement has lasted less than one day, the Excel file contains only one worksheet, if the measurement has lasted longer, there will be one worksheet for each day.
- Each worksheet will contain a table starting with a column containing the time and date stamp saved to the final result file on compressing the peak/average cycle to three single values.

  If the measurement was a UMTS base station measurement with channel decoding, a second column containing the scrambling code of each identified base station is included.

  A section follows with one column for each packet containing the average values from each line in the final result file. The section is closed by a column in which all these average values are summed up per line. Summation scheme corresponds to the scheme used for generating the single values (linear sum for square and linear files, square root of the sum for RMS files).

  The next section shows one column for each packet containing the peak values from each line, the section also being closed by a summary column.

  Finally, a third section contains the single maximum emission values.

  If GPS data are available in all or part of the result lines, a column is added at the end with the geographic position obtained from the GPS receiver when compressing the data at the end of each peak/average cycle.

Please note that it may be possible that a certain packet shows no contribution for a certain time and date stamp. In this case, the table will contain empty cells, defined by the columns associated to this packet and the rows for the given time and date. Also, some GPS position cells may be empty if, for example, the GPS receiver was not able to synchronize to the GPS system at a given moment.

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Attention !

The amount of data originating from a long-term measurement may be huge. Correspondingly, the time of generating the Excel spreadsheets displaying all these data may also be quite long. It is not uncommon that generating a long-term report may take some minutes of time.

5 Measurement Procedures

This chapter deals with the measurement procedures implemented in RFEX.

Section 5.1 describes the procedures implementing real EMF tests with which to evaluate the RF emission in the environment. Three of these procedures are available, namely Single measurement, Peak/Average measurement and Long-Term measurement. They can be thought of building a hierarchy in which each upper level makes use of the lower levels, executing them in a meaningful sequence.

Section 5.2 describes other measurement procedures for testing and adjusting the EMF system behaviour. These include Threshold Calibration, Overview Sweep and Cable Calibration.

5.1 EMF Measurement Procedures

Before any EMF measurement can be started with RFEX, the software should be fully configured. This includes:

- Data tables describing the system components like antenna factors and cable attenuation tables must be available and contain the correct data.

  For the TS-EMF system, antenna calibration data corresponding to the delivered tri-axis-probe are included on the RFEX CD-ROM, and cable calibration tables are standardised and installed automatically during software installation.

  For non-TS-EMF systems, cable attenuation factors should be calibrated with the Cable Calibration procedure (see section 5.2.3).
- The instruments making up the system must have been selected in the Hardware Configuration dialog (see section 3.4).
- Any measurement packet to be used during the measurement shall either be a standard packet delivered together with the software, or must have been generated and configured.
- We strongly recommend to do a threshold calibration run before starting a long-term measurement in order to adapt the measurement packets to the local conditions.

Any EMF measurement is started either by clicking on the corresponding buttons in the RFEX main dialog or from the ***Measure*** entry in the main menu. In any case, the Measurement Configuration dialog (see section 3.7) will be opened and must explicitly be acknowledged by the user before a measurement starts, making sure that the correct packets are selected for the measurement.

5.1.1 Single Measurement

In the context of RFEX, a *Single Measurement* is defined as the **single run** of a sequence made up of one or several measurement packets.

After clicking on the ***Start Measurement*** button in the Measurement Configuration dialog, the measurement will be according to the following steps:

1. Reset the analyser.
2. Load the first measurement packet.
3. Divide the frequency range of a measurement packet into sub-packets. This way the complete frequency range of a measurement packet is swept through by parts (partial sweeps). One partial sweep covers the frequency range calculated as the product of the measurement packet parameter *Channels per sub-packet* and the measurement bandwidth.

4. Program the analyzer with the parameters of the measurement packet and the frequency range of the first sub-packet.
5. Wait for the Dwell Time.
6. Read out the trace data from the analyzer.
7. Evaluate the trace data: store the maximum level for each measurement channel.
8. If there is at least one sub-packet left, continue with the sub-packet and step 4. Else the test for this measurement packet will have been run through: continue with step 9.
9. If there is still one measurement packet left, continue with the next measurement packet and step 3. Else all measurement packets will have been executed: continue with step 10.
10. Store the raw data and perform the correction by antenna factor and cable loss. Antenna and Cable factors are specific for each measurement packet; the values for the actual frequency points are interpolated form the tables.
11. Compress the corrected data: compare the value of the measured value with the acceptance threshold set in the measurement packet. All levels which are below this acceptance threshold are not taken into consideration any longer and are deleted out of the table.
12. Calculate the resulting field strength: if measurement data are available for both polarisations, the vector sum is formed from both results. For each frequency the resulting field strength is compared with the limit line defined for this measurement; the result is shown as the per thousand value in relation to the limit line.

The final result is a file according to the detailed description in section 4.3.1.

The above stepwise description does not include the switching between horizontal and vertical polarisation. The Measurement Configuration dialog allows to select when this switching shall take place:

- ***After every Sequence:*** the first measurement packet is started with the antenna switching set for horizontal polarisation. The whole sequence as described above is executed and for each measurement packet loaded the horizontal polarisation is set. Then the first measurement packet is loaded again but with the antenna switching set for vertical polarisation. The sequence is run again but with vertical polarisation. If there is no polarisation defined for a measurement packet then the measurement is skipped.
- ***After every Packet:*** each measurement packet is completed (until step 9 of the sequence above) with horizontal polarisation. But then the actual measurement packet is repeated again (step 3 to 9) with vertical polarisation.
- ***After every Sub-Packet:*** the above sequence is performed until step 8 with horizontal polarisation. But then not the next sub-packet is loaded but the actual sub-packet is repeated again (step 4 to 8) with vertical polarisation.

Independently of the above modes of polarisation switching, the same data are available at step 10 of the above sequence: the level values of all measurement channels for all measurement packets measured at the polarisations specified.

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TS-EMF

For the TS-EMF system, the process is executed with two little differences:

- *Instead of two measurements for independent polarisations, three measurements are taken, one for each dipole of the tri-axis field probe.*
- *There is no possibility of selecting when to switch the probe axes, they will always be switched* ***After every Sub-Packet****.*

5.1.2 Peak / Average Measurement

The Peak/Average Measurement consists of a **cyclical repetition of the single measurement** described above. The cycle time can be selected in the range 0 to 30 minutes. During this measurement the steps of the sequence as described in section 5.1.1 are performed until step 9.

Instead of correcting the raw data immediately, the raw data first are accumulated in two ways:

- On the one hand the **Average** value is evaluated. The raw data continually are added and in the end of the cycle this sum will be divided by the amount of measurements. Since the evaluation of the average value is based on the measured voltage (linear value), the raw data first are converted from dBµV (unit set at the analyzer) to mV.
- On the other hand the **Peak** value is accumulated. For each frequency the actual measured value is compared to the previous measured (and stored) value. The larger value will be stored and compared with the next value to be measured..

At the end of the defined cycle length, the average values in the average file, showing up to now the sum of all single measurements performed, are divided by the amount of all single measurements. The results are converted back to dBµV unit.

For each of both files (average values and peak values) step 10 up to step 12 of the sequence as described in section 5.1.1 are performed.

The final result are two files according to the detailed description in section 4.3.2.

5.1.3 Long-Term Measurement

The peak/average measurements described above are not suitable for a true long-term measurement. They generate too many data in order to get a compact representation of the measurement. Therefore, for true long-term measurements which may last for a theoretically **unlimited time**, it is necessary to implement further, comprehensive data compression mechanisms.

For such a long-term measurement, the data compression at the end of one peak/average measurement cycle, compresses all the information available in the average result file for each measurement packet, to one single value. The sum can be done by squares or linearly, resulting in three different long-term result files. See the discussion in section 4.3.3 for details about the result files.

Thus, for a number *n* of packets, a number *n* of resulting field strength values will be calculated and stored as the ***average emission***. The same is done for the peak value data and results in the ***maximum emission*** for each measurement packet. Furthermore for each measurement packet the largest peak value will be stored as the ***maximum single emission*** value.

This way of compressing the data does erase the relation between the measured field strength and the frequency (measurement channel). But since the test results are saved by measurement packets, the information about the origin of the RF contribution is still available (for example GSM900, TV broadcasting, etc.).

The final result of a long-term measurement is made up by three files per day included in the overall measurement time lapse. See section 4.3.3 for a detailed description

5.1.4 Learning Phase

If the option ***Do Learning Phase*** is selected in the Options dialog (see section 3.8), the so called learning phase will be executed after starting a long-term measurement and before measurement data are really acquired.

This learning phase executes a complete single test cycle with all measurement packets and polarisations defined, but no data will be stored. Instead, for each measurement packet it will be checked if the spectrum analyzer reports any overload condition (due to the signal level measured) with the currently programmed settings.

If an overload condition is detected, the input attenuation of the analyzer is increased in 10 dB steps until the overload condition disappears. If this can not be reached with a maximum of 60 dB attenuation, the measurement is aborted with a warning.

If the overload condition is removed, the IF overload condition is checked. If an IF overload condition is detected, it will be removed by increasing the reference level of the analyzer display in 10 dB steps.

If the input attenuation or the reference level have been changed during the learning phase, then the changed settings are stored to the measurement configuration file, in the section containing the copy of the measurement packet data (see section 4.2). These changed settings will then be used for the real measurement.

* *The option **Do Learning Phase** is not available with the TS-EMF system.*

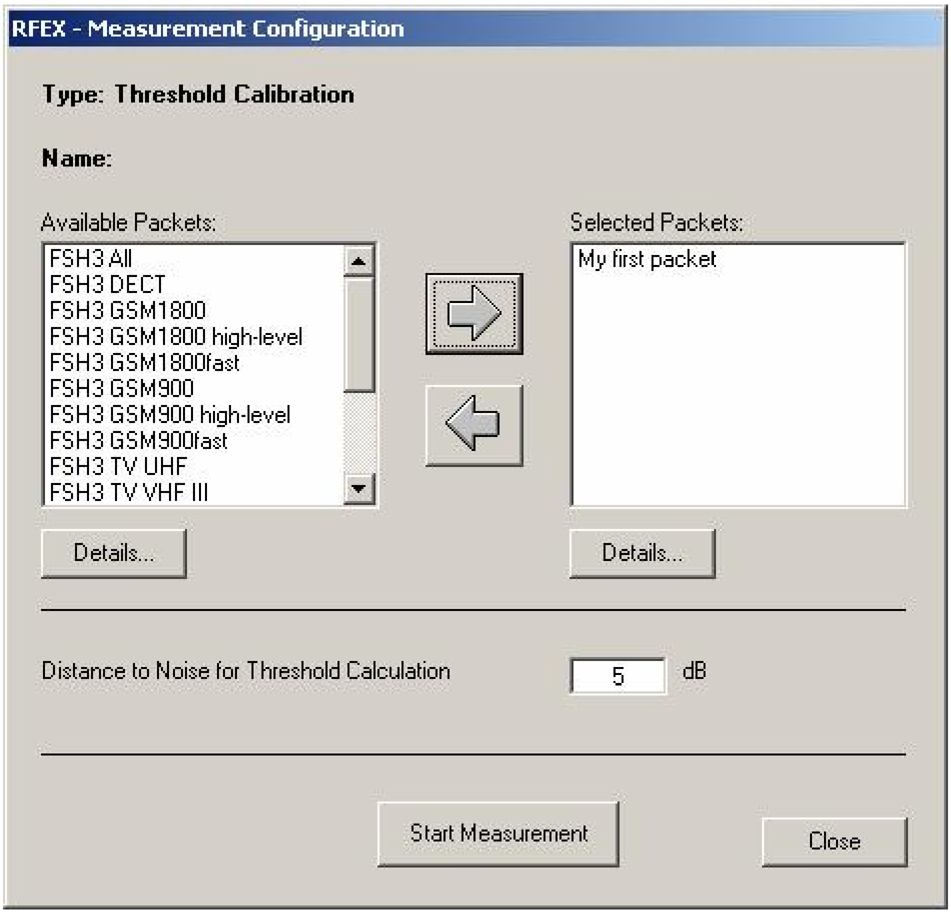
TS-EMF *For the FSH3, which is the standard analyzer for the TS-EMF system, the input attenuation is automatically set depending on the reference level. A check of a possible IF overload is not possible.*

5.2 Other Measurement Procedures

5.2.1 Threshold Calibration

As mentioned in section 3.5.4, finding a suitable value for the Acceptance Threshold parameter in the measurement packet, in a way that all noise floor signals are ignored, but all relevant peaks are kept during data compression, can be a difficult task. In order to support the user with this process, RFEX implements the so called Threshold Calibration.

This measurement is started from the main menu entry ***Measurement à Threshold Calibration*** and starts, as any other measurement, with the selection of the measurement packets to be executed:



This dialog is basically the same as the Measurement Configuration dialog as described in section 3.7. The only differences are:

- There is no need for giving a name for the measurement, as no data will be saved.
- Instead of a limit line and a polarisation change sequence, a new parameter ***Distance to Noise for Threshold Calculation*** has to be entered.

The Threshold Calibration then proceeds by executing the following steps for each selected packet:

1. Prompt the user to disconnect the RF cable from the analyzer input connector.
2. Direct the analyzer to do a sweep across the frequency range defined in the packet.
3. Query the trace data and evaluate the maximum noise level.
4. Calculate the threshold by correcting this maximum noise level for antenna factor and cable attenuation, and by adding the distance to noise value entered in the dialog.
5. Save this new threshold value to the measurement packet.

5.2.2 Overview Sweep

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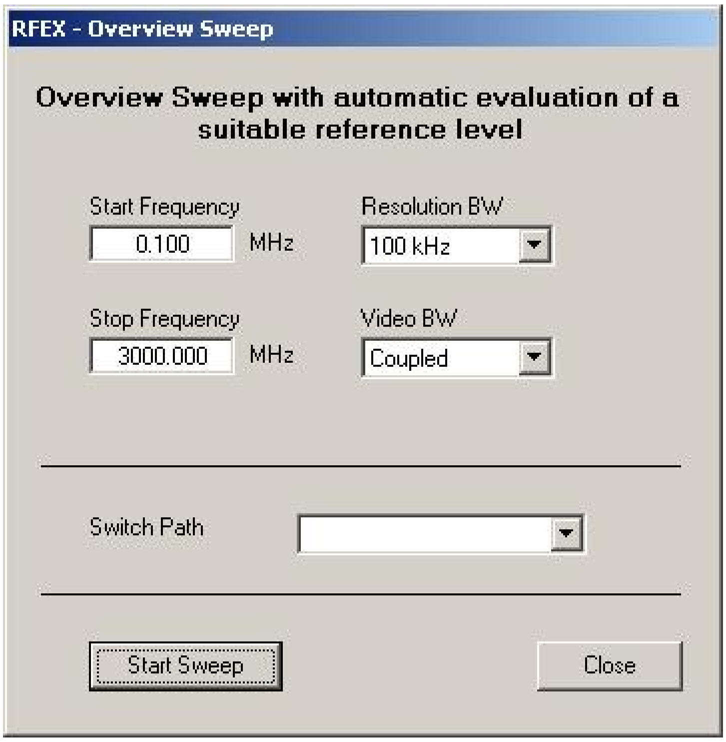
The Overview Sweep mode is not available with the TS-EMF system.

TS-EMF

The purpose of the overview sweep is to do a fast check to see if the system works correctly under remote control.

It is started by clicking on the main menu entry ***Measurement à Overview Sweep*** to open the following dialog:



Here, some basic parameters of the analyzer can be set, and one of the switch paths configured for the antenna switching unit can be selected.

Pressing the button ***Start Sweep*** transfers the settings to the analyzers and executes the sweep.

After execution of the sweep, the maximum level shown at the display will be identified. The reference level of the spectrum analyzer will be set to a value which is 20 dB above this level.

The reference level can be considered as a recommendation for setting the analyzer in the corresponding frequency range.

5.2.3 Cable Calibration

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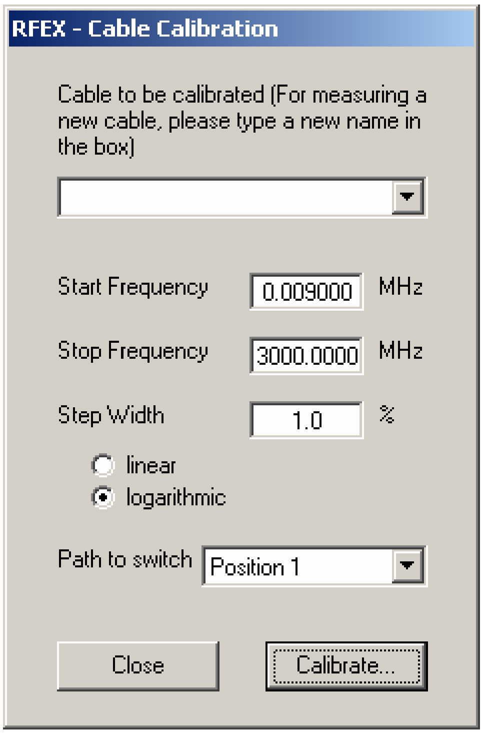
TS-EMF *For the TS-EMF system, no cable calibration is available. The cable loss of the cables used for this system has been recorded in factory and is delivered together with the system (predefined data set).*

For accurate EMF measurement, it is required to know the loss of the cables used in the system and to correct the measurement result by this cable loss (see section 3.3). The cable loss is stored as file within the RFEX software.

It is possible to enter the cable loss in table format for use within the RFEX software. But the faster and more comfortable way is an automatic measurement using the spectrum analyzer and a tracking generator. The measurement is done frequency dependant and the level difference at the two terminals of the cable is determined.

The cable calibration only can be performed if a tracking generator is available and registered in the software configuration of the RFEX (see section 3.4.3). If a generator is available, the main menu contains an entry ***Measurement à Cable Calibration...*** Clicking on it opens the following dialog:



This dialog is used to set up the parameters necessary for the cable calibration.

- ***Name of the cable***. If the calibration is successfully performed, a cable attenuation table with this name is generated. Select an existing cable from the box or enter a new name. Before starting a cable calibration, a name must be specified.
- ***Start and Stop Frequency*** are to be entered together with the step width. If the cable is used for measurement, the start and stop frequency of a later measurement packet will be limited by the frequency range of the cable calibration (see section 3.5).
- The ***Step Width*** can be defined either in linear steps (MHz) or in logarithmic steps (%).
- Finally, the ***Path to switch*** can be selected if a switch unit is available and has been configured. This allows to record the cable loss of the entire path from the antenna terminal to the input of the spectrum analyzer.

After all parameters are set, the cable calibration can be started by pressing the button ***Calibration....*** The measurement is split into two phases:

- ***Normalisation Measurement*:** The first step requires to connect the spectrum analyzer with the tracking generator by means of an additional cable (reference cable). The generator is set to a constant level of 0 dBm and the level via the reference cable is measured with the spectrum analyzer. This is done for the frequency range and the step width as specified in the setup parameters.
- ***Calibration Measurement*:** The second step asks to connect the cable (or path) to be measured **together with the reference cable used in the first step**. Another measurement is done at the same conditions and frequency points as before.
- In the end the cable loss is calculated by subtracting the normalisation level from the calibration level. The resulting level is the required cable loss with unit in dB.

Basically, the cable calibration is a relative measurement since only the difference of the normalisation measurement and the calibration measurement is of interest. This method has the advantage that the accuracy of the tracking generator is not important.

During the calibration the dialog shown above is extended in a way to represent the measurements done and to have a possibility to stop the calibration measurement.