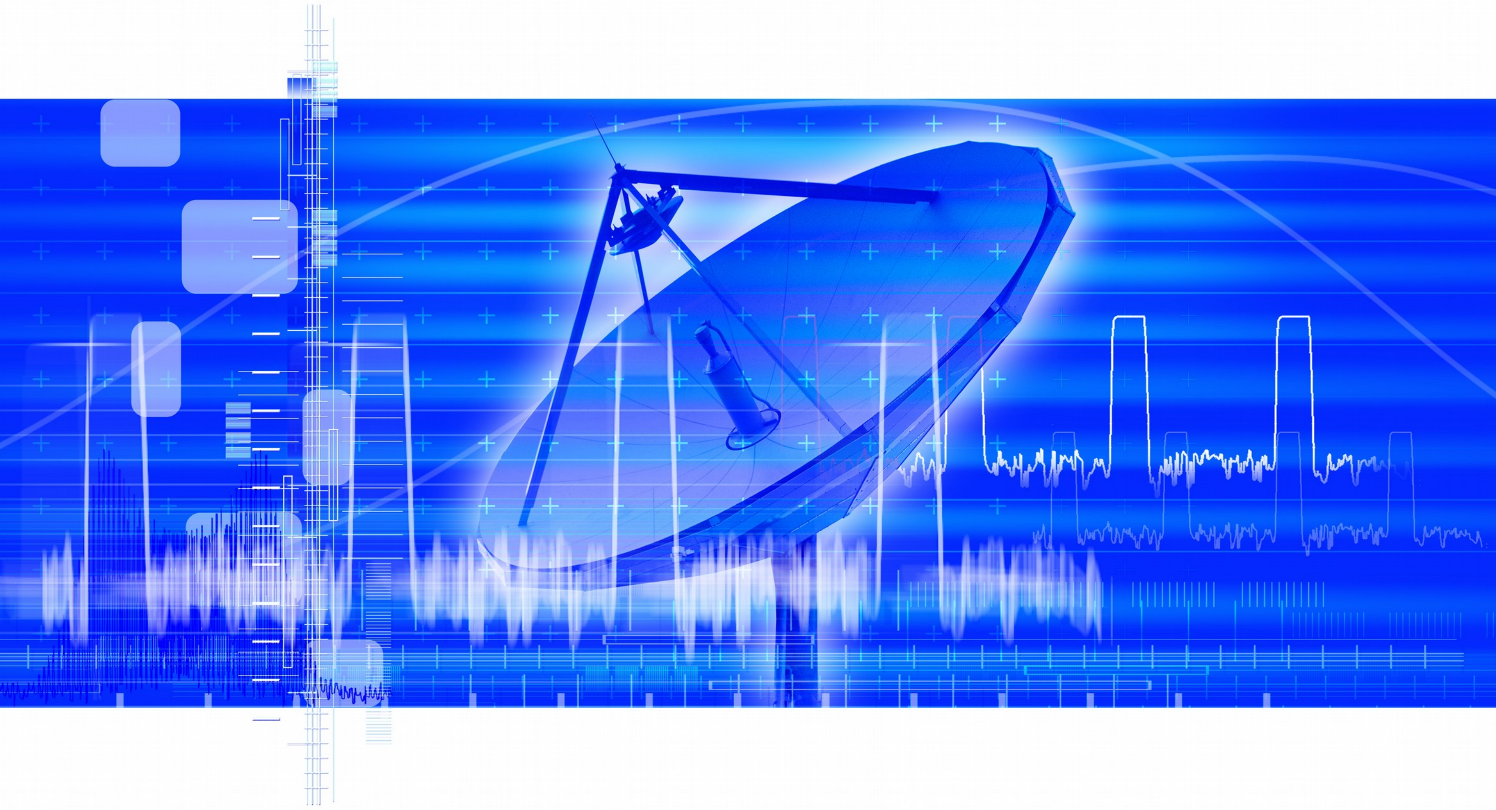
Software Manual



Pulse Sequencer Software

V 4.1

R&S® SMU-K6	**1408.7662.02**
R&S® SMJ-K6	**1409.2558.02**
R&S® SMATE-K6	**1404.8006.02**
R&S® AFQ-K6	**1401.5606.00**
R&S® AMU-K6	**1402.9805.02**
R&S® SMBV-K6	**1415.8390.02**

ROHDE&SCHWARZ

Dear Customer,

R&S® is a registered trademark of Rohde & Schwarz GmbH & Co. KG. Throughout this manual, the R&S® SMU-K6, R&S® SMJ-K6, R&S® SMATE-K6, R&S® AFQ-K6, R&S® AMU-K6 and R&S® SMBV-K6 is abbreviated as R&S Pulse Sequencer.

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1 Abbreviations

AM	Amplitude Modulation
ARB	Arbitrary (Arbitrary Waveform Generator)
ASK	Amplitude Shift Keying
AWGN	Additive White Gaussian Noise
CW	Continuous Wave
GPIB	General Purpose Instrument (Instrumentation) Bus
FFT	Fast Fourier Transformation
FM	Frequency Modulation
FSK	Frequency Shift Keying
LAN	Local Area Network
PRBS	Pseudo Random Bit Sequence
PRF	Pulse Repetition Time
PRT	Pulse Repetition Time
PRI	Pulse Repetition Interval
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
USB	Universal Serial Bus
VISA	Virtual Instrument Software Architecture
VSB	Vestigial Side Band
XML	Extensible Markup Language

2 Introduction

The R&S Pulse Sequencer software allows the flexible generation of complex pulses and pulse patterns. It is intended for use with the Rohde & Schwarz vector signal generators R&S SMU200A, R&S SMJ100A, R&S SMATE200A, R&S AMU200A, R&S AFQ100A,B and R&S SMBV100A.
This software provides an easy to use interface to build custom pulse envelopes, apply modulation or jitter as well as markers. It is also possible to build sophisticated test patterns for radar receiver tests. In addition, proprietary modulation schemes or envelopes can be applied by using the Pulse Sequencers plug-in mechanism.

Features:

- Easily generate complex pulse shapes and pulse patterns
- Create and manage a library of pulses as source for building pulse sequences
- Apply analog or digital intra pulse modulation such as AM, ASK, FM, FSK, PSK, FM Chirps
- Extend built in modulation schemes with custom plug-ins
- Simulate technical systems by applying up to four jitter types to any pulse parameter and define the distribution
- Create multi segment waveforms for fast hopping between pulse patterns
- Create RF lists for fast hopping of frequencies and levels
- Organize your work in projects, pulse libraries and sequence libraries
- Create reports during pulse pattern generation as text file or by the use of plugin as Microsoft EXCEL spread sheet
- Compatible with R&S SMU200A, R&S SMJ100A, R&S SMATE200A, R&S AMU200A, R&S AFQ100A,B and R&S SMBV100A
- Automatic transfer of the generated waveforms to the signal source using VISA Interface (GPIB, LAN, USB)
- Additional instrument options can be used to apply noise (AWGN), impairments or fading profiles to any pulse sequence. Two path instruments allow the combination and synchronization of two independent signals.

3 Release Notes

Changes from Version 1.x to Version 2.1

Pulse Settings:

- AWGN added to pulse settings
- 4 independent jitters compared to three in V 1.0
- New jitter types ramp, stair case, sine
- Custom I/Q data can be imported

Modulation:

- Custom FM-chirp can be defined by polynomial
- FSK(2) added with two frequencies at definable durations
- FSK deviation changed to -Fdev...+Fdev
- FM-chirps hold the frequency during rise and fall period
- Polyphase modulation (Frank, P1...P4) added
- New data source editor with custom and built-in data

User Interface and Graphics:

- New view mode frequency versus time
- FFT view changed to peak detector mode
- Removed unmodulated / modulated separation in pulse library
- New RF Lists features
- Up to 42 RF lists possible in project

Instrument control:

- Instrument manager with LAN search
- New instrument control concept with block chart
- Improved file transfer

Changes from Version 2.x to Version 3.0

- Maximum number of modulation plugin variables increased to 255
- Modulation plugins can generate marker data
- ARB preset can be suppressed during waveform transfer
- Added MSK modulation
- Square Root ramp type
- Max. number of RF lists increased to 100
- MSW Sequencer mode added to Multi Segment Waveforms
- DFS signal generation updates
- Bug fixes

Changes from Version 3.0 to Version 3.1

- Data sources take bits and hexadecimal input
- Added plugins and project files for ADS-B, Mode-S, Polynomial Chirp
- Rebuild using CVI 2009 Runtime Libraries
- Fixed problem loading DFS EXCEL report plugin
- Application shows icon in task bar

Changes from Version 3.1 to Version 3.4

- Fonts changed in entire applications to “Arial” fixes problems on some installations
- Improved calculation of AWGN
- Improved Multi-Segment waveform editor
- Attempting to erase a used data source displays warning message
- Empty data sources could have caused a crash
- Data sources can now be sorted
- Sequences that are used in Multi-Segment waveforms cannot be deleted
- Improved waveform preview
- Closing the baseband filter dialog did close the entire application
- Added Japan and Korea DFS signals
- Added new RFID plugins and projects
- Removed some DLL dependencies

Changes from Version 3.4 to Version 3.5

- Fixed application crash for waveforms that are shorter than 1024 samples
- Fixed erroneous PRF calculation in DFS ETSI 301 893 V1.5.1, Type 5 and 6
- Added DFS ETSI 301 893 V1.6.0 Draft (= ETSI 301 893 V1.6.1)
- DME pulse timing fixed in example project
- All user files are now placed in the user's home directory instead of the application folder. This avoids the need for elevated user rights.

Changes from Version 3.5 to Version 3.7

- Removed NFC/RFID plugins and project files. These will now be provided with a separate application note.
- DFS Updates
- Fixed renaming of output file name when waveform was created

Changes from Version 3.7 to Version 3.8

- Local waveform file names were not properly resolved

Changes from Version 3.8 to Version 3.9

- Support for new instruments added

Changes from Version 3.9 to Version 4.0

- Upgrade to newer CVI runtime 2010
- SMBV100A limits changed to 200 MHz clock, 160 MHz bandwidth, 256 Msamples
- All project files modified to use a relative path as target on the instrument
- Fixed bug: The temporary path setting was not saved properly
- The value range for polynomial chirps was increased
- DFS user manual updated

Changes from Version 4.0 to Version 4.1

- Fixed bug in polyphase modulation

4 Installation

The R&S Pulse Sequencer is intended for installation on a desktop PC running a Microsoft Windows® XP Professional, Microsoft® Vista, or Microsoft® Windows 7 operating system. The following list of prerequisites should be met before installing the application.

1.1 Hardware Requirements

Minimum Requirements

- AMD or Intel CPU running at 1 GHz or faster
- 1 GB RAM
- Screen resolution of 1024x768 pixel or higher
- 20 MB free HD space[1]
- Fast IDE or S-ATA drive[2]
- 100 M Bit LAN or VISA compatible GPIB adapter for interfacing with instrument

Recommended Hardware

- AMD or Intel CPU running at 2 GHz
- 2 GB RAM
- Screen resolution of 1024x768 pixel
- 10 GB free HD space[1]
- Fast IDE or S-ATA drive[2]
- 1 G Bit LAN or VISA compatible GPIB adapter for interfacing with instrument

[1]The space is required for program installation. During waveform creation R&S Pulse Sequencer requires large temporary files. As a rule of thumb 9 Bytes per sample need to be considered for temporary file space. Example: 125 M Samples of waveform data call for about 1 G Byte of temporary HD space.

[2] The HD is not only required to install the Pulse Sequencer software but also holds temporary data. Access should be as fast as possible to speed up waveform calculation.

1.2 Minimum Instrument Configuration

The following overview lists minimum instrument requirements for the different R&S Vector Signal Generators or Modulation Generators. Please note that the configuration required for your application may need additional instrument options. This overview only points out which minimum requirements must be met.

<u>SMU200A</u>		
R&S SMU200A	1141.2005.02	Vector Signal Generator
R&S SMU-B103	1141.8603.02	100 kHz to 3 GHz
R&S SMU-B11	1159.8411.02	Baseband Generator with ARB 16 Msample and Digital Modulation
R&S SMU-B13	1141.8003.04	Baseband Main Module
R&S SMU-K6	1408.7662.02	Pulse Sequencer
<u>SMJ100A</u>		
R&S SMJ100A	1403.4507.02	Vector Signal Generator
R&S SMJ-B103	1403.8502.02	100 kHz to 3 GHz
R&S SMJ-B51	1410.5605.02	Baseband Generator with ARB 16 Msample
R&S SMJ-B13	1403.9109.02	Baseband Main Module
R&S SMJ-K6	1409.2558.02	Pulse Sequencer
<u>AFQ100A</u>		
R&S AFQ100A	1401.3003.02	I/Q Modulation Generator
R&S AFQ-B10	1401.5106.02	Waveform Memory 256 Msample
R&S AFQ-K6	1401.5606.02	Pulse Sequencer
<u>AFQ100B</u>		
R&S AFQ100B	1410.9000.02	UWB Signal and I/Q Modulation Generator
R&S AFQ-B12	1411.0007.02	Waveform Memory 512 Msample
R&S AFQ-K6	1401.5606.02	Pulse Sequencer
<u>SMBV100A</u>		
R&S SMBV100A	1407.6004.02	Vector Signal Generator
R&S SMBV-B103	1407.9603.02	9 kHz to 3.2 GHz
R&S SMBV-B51	1407.9003.02	Baseband Generator with ARB 32 Msample, 60 MHz RF bandwidth
R&S SMBV-B92	1407.9403.02	Hard Disk (removable)
R&S SMBV-K6	1415.8390.02	Pulse Sequencer
<u>SMATE200A</u>		
R&S SMATE200A	1400.7005.02	Vector Signal Generator
R&S SMATE-B103	1401.1000.02	100 kHz to 3 GHz
R&S SMATE-B11	1401.2807.02	Baseband Generator with ARB 16 Msample and Digital Modulation
R&S SMATE-B13	1401.2907.02	Baseband Main Module
R&S SMATE-K6	1404.8006.02	Pulse Sequencer

1.3 Software Requirements

- Microsoft Windows® XP Professional or Windows® Vista
- Rohde & Schwarz VISA IO Libraries for Instrument Control, Rev. M.01.01 or other VISA runtime library, such as National Instruments VISA 4.0
- Minimum instrument firmware release

SMU200A, SMATE200A, SMJ100A	02.05.222.24	
	02.10.111.116	(Sequencer)
SMBV100A	02.05.200.19	
	02.15.85.47	(Sequencer)
AFQ100A, AFQ100B	02.10.250 beta	

- Any Microsoft® Office package containing Microsoft® EXCEL for the use of the DFS reporting feature. Please see the installation chapter for details.

1.4 Installation

If you already have version 1.x of the R&S Pulse Sequencer software installed on your machine it is advisable to install version 2.x into a separate directory in order to keep your old project files and settings. A separate section in this document describes the migration path from V 1.x projects to V 2.x projects.
Before you install the Pulse Sequencer software a VISA runtime library must be installed on your system. Please refer to the documentation provided with your VISA software for installation details.
The installation of the R&S Pulse Sequencer is started by executing the self extracting installer. After completion your application directory contains the following structure.

K6 Pulse Sequencer.exe	*Application executable*
\Plugins	*Plug-ins for intra pulse modulation or reporting*
\manual	*User manual files (pdf format)*
\cvirte	*Run time environment files*

User files are placed into the user's home path under
%HOMEDRIVE%%HOMEPATH%\Rohde-Schwarz\K6

settings.ini	*Program settings file*
\Projects	*Project files*
\Waveforms	*Storage location for K6 generated waveform files*
\LogFiles	*Text report files generated by the application*
\Reports	*Microsoft EXCEL reports for DFS signal generation*
\Temp	*Temporary files*
\Source Code	*Code examples for custom plug-ins*

The R&S Pulse Sequencer software is started by executing the '*K6 Pulse Sequencer.exe*' file. If not otherwise selected the installer places an icon on your desktop that links to this executable.
When the Pulse Sequencer software starts up it scans the sub directory *Plugins* for available user extensions. All valid plug-ins are automatically loaded and listed in the main project tree.

Note: Pulse Sequencer V 2.x provides a plug-in that automatically fills in Microsoft® EXCEL reports during the generation of DFS pulse trains. A separate manual bundled with this application explains the DFS signal generation process and use in more detail.
If you do not have Microsoft EXCEL installed on your PC or do not require to generate DFS signals it is suggested to remove the associated plug-in in the *Plugins* sub directory. The plug-in name is '*Report-DFS.dll*' and if placed outside of the *Plugins* sub directory it will not be loaded during start-up.

5 Starting the Pulse Sequencer

When the Pulse Sequencer software is started the first time it automatically loads an examples project. This project demonstrates various capabilities of the Pulse Sequencer software and may be used as a starting point for own waveforms.
General program settings, such as the last project or active instruments are stored in the *settings.ini* file in the application directory. In case the Pulse Sequencer software does not start up as expected it is suggested to remove this file which would cause the software to start with default settings.

In addition, several command line options exist for debugging purpose. These options can be used in case the application does not start up correctly.

`--dstartup`	create additional debug out during start-up (stdout window)
`--no-load-project`	do not automatically load a project during start-up
`--no-check-instr`	do not verify an instrument link during start-up
`--no-screen-test`	do not test for a minimum screen resolution during start-up

6 Migrating from V 1.x to V 2.x or V 3.x

Pulse Sequencer project data is saved as .prj files in the XML file format. Due to the nature of this file format most settings from version 1.x can be imported by version 2.x. However, additional settings that were implemented in V 2.x are not present in older project files. The following steps are recommended when loading Pulse Sequencer V 1.x project files.

1. Keep your existing V 1.x installation and install V 2.x into a separate directory
2. Load the project file from V 1.x into V 2.x
3. Verify and correct all pulse modulation related settings. For modulated pulses click at least once into one field of the pulse modulation settings to let the software update its settings table.
4. If data patterns were used for intra-pulse modulation this data needs to be provided again in the data source editor (on a project base).
5. Configure jitter 4 settings of all pulses.
6. Update the jitter settings in all sequences. The names have changed between V 1.x and V 2.x.
7. Save the file under a different name using the ‘Save Project As’ menu option.

Note
If you do not need to keep any existing Pulse Sequencer V 1.x installation it is recommended to entirely remove the old installation before attempting to install V 2.x. You may use the de-installer provided with V 1.x but it is suggested to manually clean all remaining files in the program directory. This is required because the de-installer leaves plug-ins and project files untouched as they might have been changed by the user.

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7 Configuring the Pulse Sequencer

After a fresh installation the R&S Pulse Sequencer starts with a default configuration which is defined in the *settings.ini* file in the application directory.

- All plug-ins from the sub directory Plugins are loaded
- The project '*examples.prj*' is loaded
- All temporary files are located under C:\
- Program messages are written to the log panel
- Some example VISA connections are listed on the instrument panel

The first step after a fresh installation is to verify the general settings under '*Options → Preferences*' from the menu bar.

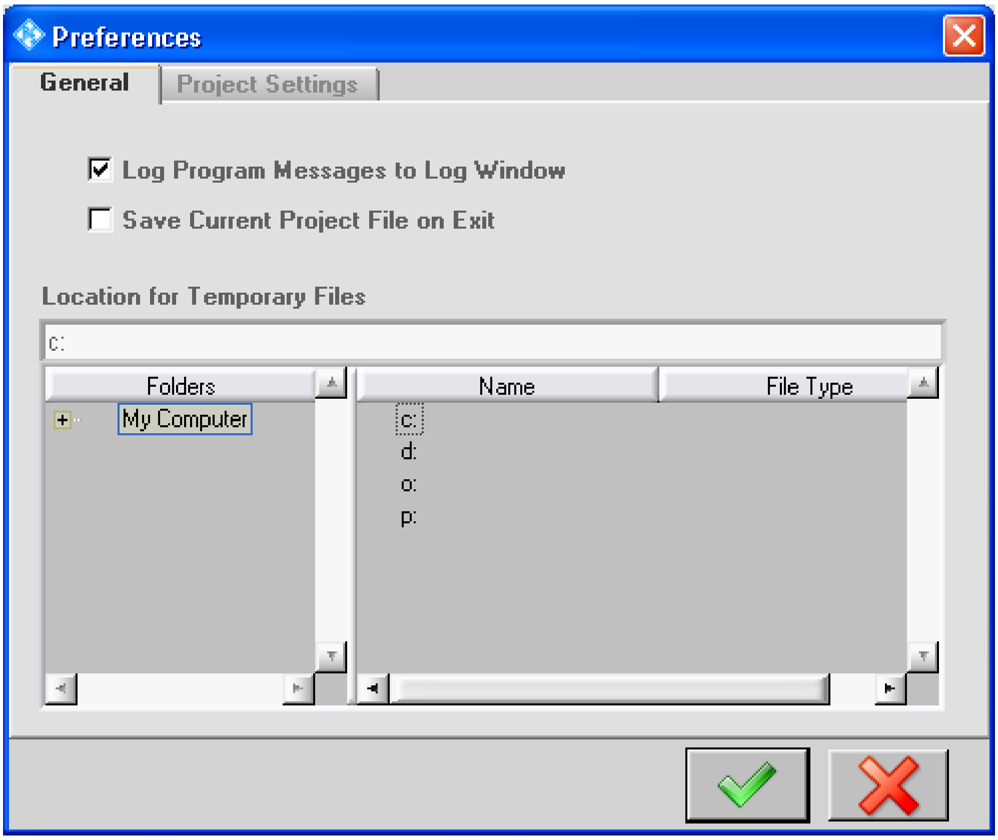


Fig. 1: General settings dialog

Log Program Messages to Log Window
Writes all program messages to the log panel. Writing these messages to the log slows down some operations but provides useful information about what tasks are performed or possible causes of errors.
Save Current Project on Exit
Always saves the current project when the R&S Pulse Sequencer software terminates.

Location for Temporary Files
The folder for temporary files specifies the location where the R&S Pulse Sequencer keeps temporary data during waveform creation. Read and write access to this drive should be fast. Therefore, it is suggested to use a local hard drive instead of network storage space. This setting is effective after the next program start since the software creates temporary files during start-up.
The required file size depends on the created waveforms. As a rule of thumb 9 bytes are required per sample during waveform calculation. For example, if a sequence generates 10 M samples of waveform output the temporary file rises to about 90 M Bytes. Using a baseband filter increases the memory consumption by a factor of two.

The '**Project Settings**' tab contains project related settings. The default configuration of this panel is shown below.

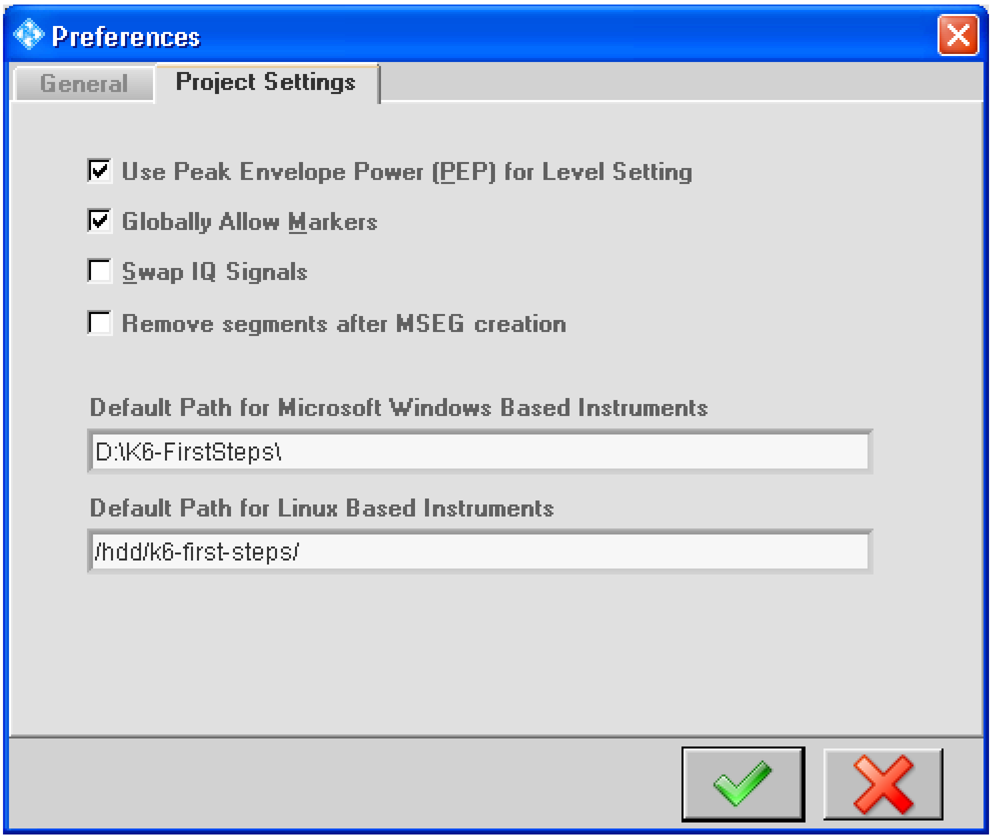


Fig. 2: Project settings dialog

Use Peak Envelope Power for Level Setting (PEP) [default: on]
Pulsed waveform typically exhibit high peak to average power ratios. This is because the pulse time is often short compared to idle times and therefore the average signal power is relatively low. Signal generators typically level their output power according to the average power which is in most cases not desirable for pulsed signals. The option forces the instrument to regard the signal as a zero peak-to-average ratio waveform and directly set the pulse peak power rather than the average signal power.

Globally Allow Markers [default: on]
If a waveform contains marker data the instrument needs to reserve additional memory. The memory allocation happens regardless of the amount of marker use. This option allows to remove any marker data from the generated waveform file and thus use more memory for waveform data.
If markers are enabled additional 4 bits are required per waveform sample (16 bits). One sample does then require 20 bits of waveform memory. The instrument option specifies the maximum waveform memory in samples without the use of markers.

Waveform Memory w/o Marker Use	Waveform Memory with Marker Use
16 M samples	16 · 16 / 20 = 12.8 M samples
32 M samples	32 · 16 / 20 = 25.6 M samples
256 M samples	256 · 16 / 20 = 205.8 M samples

Swap IQ Signals [default: off]
The option swaps the data for the I and Q signal.

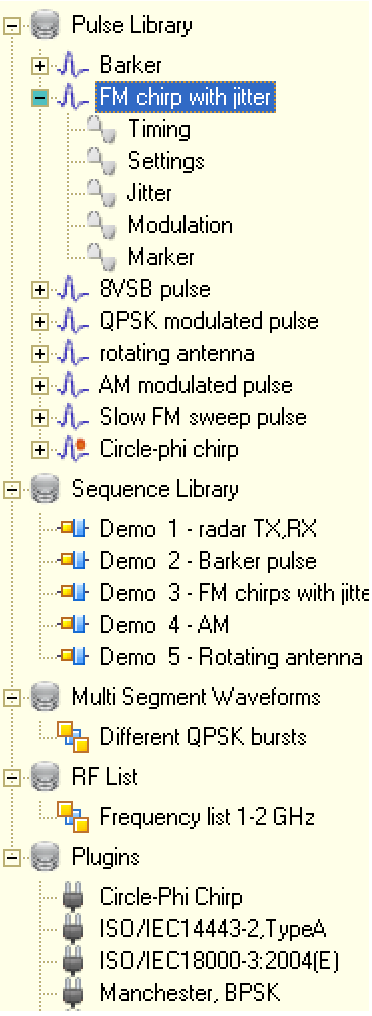
Default Path for Microsoft Windows and Linux Based Instruments
When waveforms or other data is transferred to the instrument the user often does not want to care about the specific storage location on the instrument. This option sets the default location for data transfer to the instrument.
It is important to mention that Linux and Windows based operating systems use different path formats. The Pulse Sequencer keeps default paths for both operating systems. Depending on the instrument selection the correct path is used.
Linux based systems use different locations for storing user data. Instruments without any optional hard drive generally use a sub folder under /var (e.g. /var/user or /var/smbv for the R&S SMBV100A) whereas the hard drive option adds the /hdd path.

Note
The /hdd path always exists on Linux based instruments regardless of the installed hard drive option. In the case where the hard drive is not available data cannot be stored using this path.

All changes are accepted by pressing the **OK** button and saved during the next program shut-down. It is therefore suggested to exit and restart the Pulse Sequencer software if changes were made on the general settings tab.

8 The Project Tree

All data, such as pulses, pulse sequences, Multi-Segment waveforms and RF Lists are organized in projects. The visual representation of the project contents is the project tree which shows all items organized in different libraries.
Empty Pulse Sequencer projects contain no data at all. Thus, starting a new project always requires to define pulses first, and then sequences which can be turned into waveforms.
The following section describes the project tree content in more detail.



The **Pulse Library** contains all pulses defined within the project. Pulses are the fundamental building blocks of any signal and therefore need to be created first. Each pulse entry can be further expanded to unveil detailed settings, such as timing, modulation, jitter and marker data. Pulses that use custom plug-ins are indicated with a small red dot next to the pulse icon. Selecting a pulse entry or one of its sub items shows the associated editor window on the right side.
Please note that pulses cannot be turned into a waveform. Instead the pulse entry only contains a mathematical description of pulse parameters. The sequence combines pulses and is the basis for waveform generation.

The **Sequence Library** contains all pulse sequences defined within the project. A sequence defines how pulses are arranged to form a waveform. It also adds parameters such as the sample rate or baseband filter settings. The sequence can be compiled into a waveform and transferred to the Vector Signal Generator.

The **Multi Segment Waveform Library** contains all Multi-Segment waveform definitions defined within the project. A Multi-Segment waveform is a concatenation of sequences that can be turned into waveforms using a batch processing functionality. This simplifies the generation of many waveforms and it also permits arbitrary jumps between such waveforms.

The **RF List Library** contains all RF Lists defined within the project. An RF List contains frequency and level pairs which may be combined with any baseband signal. The RF List affects only the RF section of the instrument and allows for hops across a wide frequency or level range.

The **Plug-in** tree branch contains all plug-in modules that were loaded during program start. Plug-ins are Dynamic Link Libraries (DLLs) that contain the maths used for intra pulse modulation. The Pulse Sequencer software comes with example Plug-ins that can be used as a starting point for custom implementations.

Items can be hidden from the project tree. This is useful if sequences or Multi-Segment waveforms contain pulses that do not need to be altered by this user. Use '*Project → Hide Tree Entries*' from the menu bar to toggle the view of hidden entries.

9 First Steps

The following steps demonstrate a typical work flow for the generation of a waveform.

- **Create a new project** (*File → New Project*)
- **Create a new pulse entry** (*Create → New Pulse)* and assign it a name
    - Select the timing tab:
      Specify the pulse timing, e.g. rise time, on time, fall time and the edge shapes
    - Optionally select the settings tab:
      Set levels, frequency offset, AWGN
    - Optionally select the modulation tab:
      Set intra-pulse modulation and define the data sources
    - Optionally select the marker tab:
      Modify the default marker settings
- **Create a new sequence** (*Create → New Sequence*) and assign it a name
    - Set-up the first pulse entry or add additional pulse entries by clicking the '*Add new Sequence Entry*' button just above the sequence table
    - Set the number of repetitions and click into the marker fields M1 through M4 to set the marker masking for multiple repetitions
    - Change the desired ARB sample if the default value is not sufficient
    - Specify the local waveform file name, e.g. waveforms\MyPulse.wv
- Press the **'Build Waveform'** button to create the waveform from the sequence
- Optionally select the '*Sequence View*' tab to inspect the result
- **Select the '*Transfer*' panel**
    - Activate the instrument manager panel and set-up your instrument link
      (this step is only required once)
    - Configure the remote file name and the RF section
    - Hit the '*Transfer*' button to send your waveform data to the instrument

10 Setting up the Instrument Link

The Pulse Sequencer software interfaces with your instrument in order to upload and run your waveforms, Multi-Segment waveforms or RF Lists. The software keeps a list of all known instruments and memorizes the last active instrument (default instrument). When the Pulse Sequencer software starts it checks for the availability of this default instrument and in case it cannot be accessed disables the instrument link.
One of the first steps after a fresh installation is to set-up your instruments using the '*Instrument Manager*' panel. This panel can be accessed either from the transfer panel or directly from the menu bar '*Instrument → Manager*'.
The instrument manager lists all known instruments in a tree view on the left side. This tree is divided into two branches. The first branch lists devices that were discovered during a scan whereas the second branch lists all manually added devices.

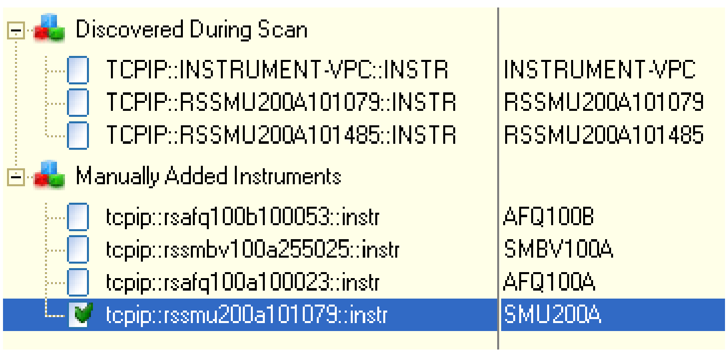


Fig. 3: Instrument selection

The Pulse Sequencer software uses VISA to interface with instruments. Instruments are therefore identified by their VISA resource string. The following list gives examples for the various physical interfaces, such as GPIB, LAN or USB. Please verify with your instrument manual which interface is supported by your hardware.

VISA Resource String	Example
GPIB<board no>::<address>::INSTR	GPIB0::28::INSTR
TCPIP::<network name>::INSTR	TCPIP::rssmu200a100123::INSTR
TCPIP::<ip address>::INSTR	TCPIP::192.168.0.123::INSTR
USB::<vendor id>::<product id>::<serial>::INSTR	USB::0xAAD::0x4B::100123::INSTR

USB connections require the vendor ID, the product ID as well as the instrument serial number. The vendor ID for all Rohde & Schwarz instruments is 0x0AAD. The following table lists product ID numbers for instruments supporting USB remote control.

AFQ100A	0x4B
AMU200A	0x55
SMATE200A	0x46
SMBV100A	0x5F

Double clicking the checkbox of an an instrument tree item opens or closes the connection. If the connection set-up was successful a green check mark indicates that this link is currently active. If the connection set-up fails a red icon shows the failure state.


Available device


Open connection


Unavailable device

The Pulse Sequencer software supports one instrument link at a time. If an active link exists and another instrument should be connected, it is required to close the active link first.

The **delete** button removes a selected entry from the instrument list. Make sure to close the instrument link before attempting to delete the device from the list.

New instruments can be added at any time by using the controls shown below. The first input field depends on the selected hardware interface. The second line is used for an optional comment. The comment has no function but it is displayed in the second column of the instrument tree.

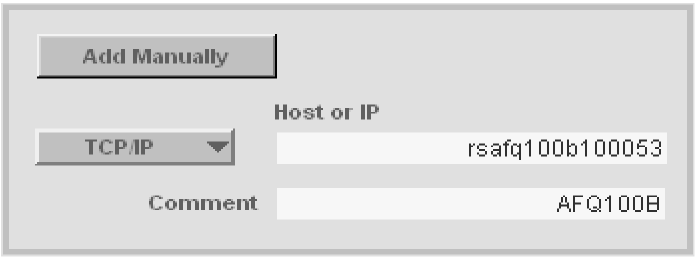


Fig. 4: Adding instruments manually

Clicking the **'Add Manually'** button adds the new instrument to the instrument tree.

The Pulse Sequencer also provides two scanning functions that can be used to discover instruments. An instrument scan can be performed on GPIB hardware or in a local area network (LAN).
Use the button '**Scan GPIB**' to add all supported devices that are connected to a local GPIB controller.

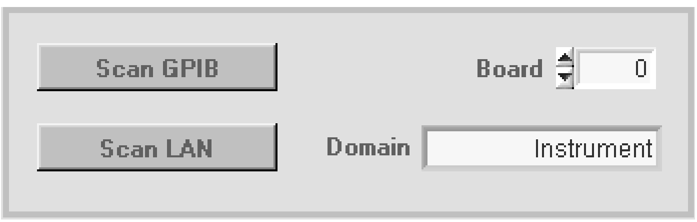
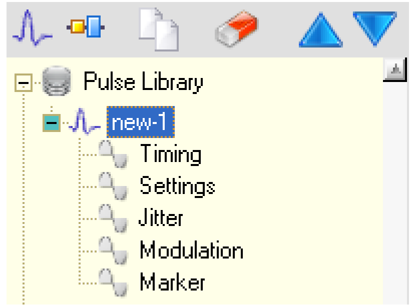


Fig. 5: Scanning for instruments

The board number is zero for the first board installed in the PC.

The '**Scan LAN**' button performs a search for instruments in a LAN. In order to narrow down the search in larger LANs a domain name should be provided for the search. By default Rohde & Schwarz instruments are configured to use the '*Instrument'* domain.

11 Creating New Pulses



Pulses are the fundamental building blocks of any sequence and therefore need to be created as a very first step in any new project. New pulses are created by either selecting '*Create → New Pulse'* from the menu bar or by clicking on the very left icon on top of the project tree.
In both cases a new pulse with default settings is created and automatically added to the project tree. New pulse entries are named ‘new-<n>’ where n is a number starting at one.
Next, the pulse parameters can be edited by selecting one of the items belonging to the new pulse entry. Clicking on one of these items shows the associated dialog panel on the right side of the project tree.

- **Timing**
  This panel defines all timing related parameters, such as delay-, rise-, on-, fall- and off-time. In addition, the pulse repetition frequency (PRF) or pulse repetition interval (PRI) may be set.
  The panel also controls the shape of the rising and falling edge, e.g. linear, cosine or raised cosine. In the case where a custom shape or I/Q data is required this panel also provides all the controls to import data from an external source.

- **Settings**
  The settings panel controls various parameters. This is the pulse power, phase and frequency settings, as well as Additional White Gaussian Noise (AWGN).

- **Jitter**
  Jitter is a mechanism that varies pulse parameters in cases where multiple repetitions of a pulse are used. This is a powerful feature for the simulation of real world scenarios or imperfections in a technical system. Pulse Sequencer provides four independent jitters that can be applied to various pulse parameters and follow different mathematical rules.

- **Modulation**
  The modulation panel defines the intra pulse modulation. The Pulse Sequencer software provides a wide range of commonly used modulation schemes, such as AM, FM, PSK or Chirps. In addition plug-ins may be utilized to add custom pulse content. This dialog also defines the data sources that are used with a modulation scheme.

- **Marker**
  Markers signals are additional digital instrument outputs that can be controlled synchronously with the waveform playback. A common use, for example, is triggering a device under test or a Spectrum Analyzer at the beginning of a pulse. The marker panel assigns marker signals to pulse sections, such as the delay-, rise-, on-, fall-, or off-time. In case of multiple pulse repetitions the sequence editor allows to further mask marker signal output to only the first, last, or all pulses.

Please see the next paragraph for a detailed discussion of the panels described above.

1.5 Timing Parameters

Timing parameters affect the pulse shape and are usually the first and most important parameters to define. The timing panel controls all phases of the pulse. This is the delay-, rise-, on-, fall-, and off-time. Time values can be set in nanoseconds (ns), microseconds (µs), milliseconds (ms) or seconds (s). The total duration is automatically calculated and shown as sum below all settings. This value cannot be edited. An alternative to setting the off time is to define a pulse repetition interval or frequency. In this case the required off time is automatically computed.

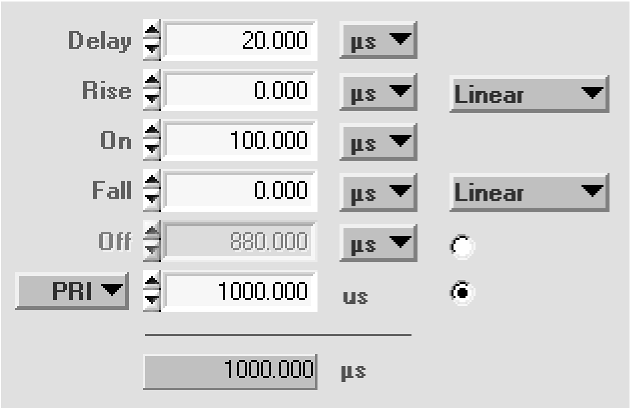


Fig. 6: Pulse timing parameters

1.5.1 Delay Time

This is the time before the rising edge of the pulse. During this time the RF power is attenuated or totally suppressed. There is no modulation or data content present during this phase of the pulse. This setting may be used to shift the pulse location in time within the PRI (pulse repetition interval) time.

1.5.2 Rise Time

This parameter sets the total time of the rising pulse edge (zero to 100 percent). The RF level changes within this interval from the off-level to the on-level. Typically the off-level uses a high attenuation, such as 100 dB whereas the on-level only uses little or no attenuation. This produces a rising RF power slope.
Modulation is already present during this phase of the pulse. Guard bits must be added to avoid truncation of data during the rising edge period.
The shape of the rising edge can be selected between linear, cosine and raised cosine. Other shapes are possible using plug-ins or arbitrary envelope data.

1.5.3 On Time

The on time defines the period of time where the pulse power is held at a constant level defined by the on-level attenuation. Typically the on-level attenuation is zero and therefore the RF power set to the maximum. The on time is the total time from the very end of the rising edge to the very beginning of the falling edge (100 % level).

1.5.4 Fall Time

For the fall time the same applies as for the rising edge section. In contrast to the rising edge power changes from the on-level to the off-level.

1.5.5 Off Time

The off time follows the falling edge of the pulse. During this time the RF power is suppressed to the off-level and no modulation is applied.
The sum of all the above times form the PRT (pulse repetition time) or PRI (pulse repetition interval).

1.5.6 PRI / PRF

PRI and PRF values define the overall time of a pulse cycle. This value can be used alternatively to the pulse off time. In this case the software uses PRF or PRI to define the overall pulse cycle time and determines the off time automatically by adding the times for delay, rising edge, on period and falling edge. The remainder to the PRI is used as the off time.
PRF or PRI settings are very useful if the pulse timing changes (e.g. by jitter) but the total duration of the pulse cycle must remain constant.

1.6 Arbitrary Pulse Envelope

Instead of defining a pulse by its rise-, on- and fall-time it is also possible to use arbitrary envelope data.
Arbitrary envelope data affects the level values versus time and therefore can be used with any kind of intra pulse modulation. The basic functionality behind arbitrary envelope data is that this data is multiplied with the existing pulse shape created from the timing parameters. Time wise the arbitrary envelope is mapped to the pulse phase consisting of rise-, on-, and fall-time. In an ideal case the rise- and fall-time is set to zero and the on-time defines the length of the arbitrary pulse shape.
Since arbitrary amplitude data is multiplied with the existing pulse shape it is suggested to use a values ranging from 0 to 1.0 to obtain correct levels.
The Pulse Sequencer software uses linear interpolation between data points to compute the resulting pulse envelope based on the given timing and ARB sample rate.

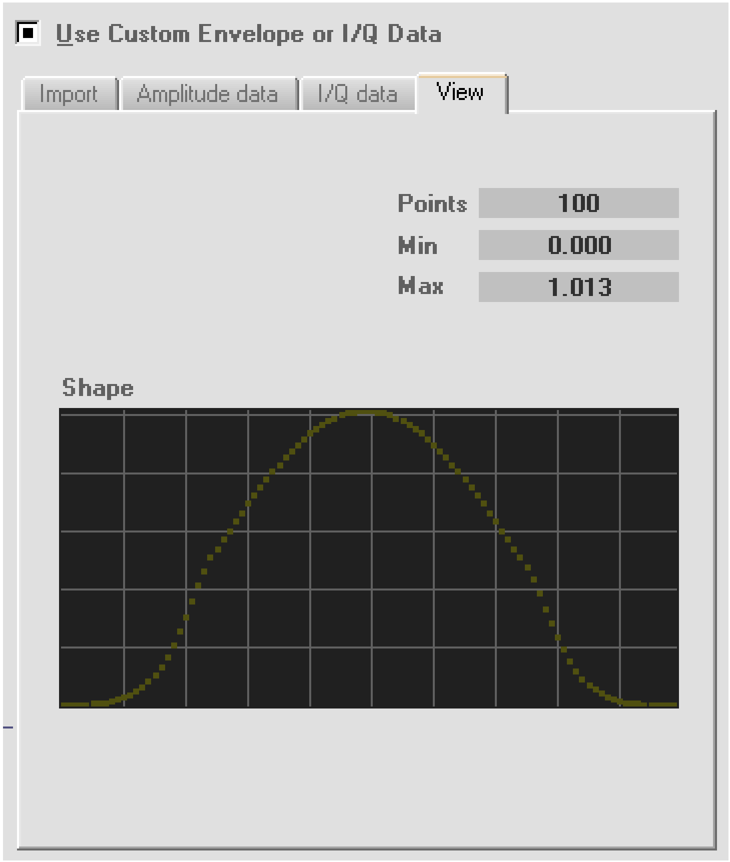


Fig. 7: Custom envelope data dialog

1.7 I/Q Data

The R&S Pulse Sequencer software can also make use of custom I/Q data for the intra-pulse modulation or envelope. Arbitrary I/Q data is applied during the rise-, on-, and fall-time of a pulse. If no rise-time and fall-time is set the I/Q data completely controls the pulse shape and the intra-pulse modulation.

1.8 Importing Data

The import tab loads arbitrary envelope or I/Q data into the Pulse Sequencer project. Once data is loaded it becomes part of the pulse definition and is saved in the project file. Copying the pulse creates a new pulse with a full copy of the imported data.

The '**Import Mode**' control selects the mode between '*Level'* (envelope data only) and '*I and Q'* for full I/Q data import. Set the mode before attempting to load any data into the Pulse Sequencer project.

The two **column controls** define the columns in an ASCII file from which the envelope or I/Q data is imported. The Pulse Sequencer software accepts floating point ASCII text files with data organized in columns.

The '**Import Data From File**' button selects the source file and imports data as defined into the project.

The '**Clear All Data**' button removes all data from the project file.

Note about arbitrary data:

Once arbitrary data is imported it becomes a permanent part of the project file. Importing a large number of data points may therefore grow the project file to a very large size. Arbitrary data remains present even if the 'Use Custom Envelope or I/Q Data' button is disabled. This allows the user to flexibly switch between both modes without the need to clear and reload any data. If arbitrary envelope data is not required any more it is suggested to clear it from the project file by using the 'Clear All Data' button. Copying a pulse also copies all arbitrary data.

1.9 General Pulse Settings

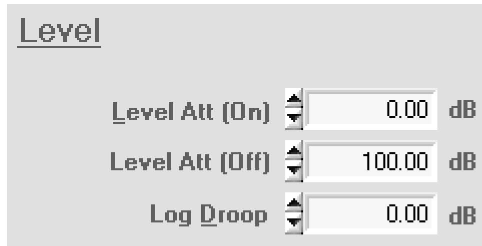


Fig. 8: Level settings

Level settings control the RF output power level during all phases of the pulse. The Pulse Sequencer uses two main settings to do so. One is the attenuation during the on-time whereas the other is the attenuation during the off-time. Usually the attenuation during the off-time is much larger than during the on-time which causes an RF pulse with a rising and falling edge. If the attenuation was set to a high value for *On* and a low value for *Off* the result would be an inverse pulse. This setting could, for example, be useful for RFID devices that may require constant RF power. Attenuation values must always be positive numbers between zero and up to about 100 dB. The value of 100 dB is usually sufficient when using a 16 bit ARB because the signal is fully suppressed beyond 96 dB of attenuation.

Log Droop specifies a logarithmic change (linear in dB scale) of the RF power during the on-time of a pulse. A positive number decreases the RF power by the set amount whereas a negative number increases power.

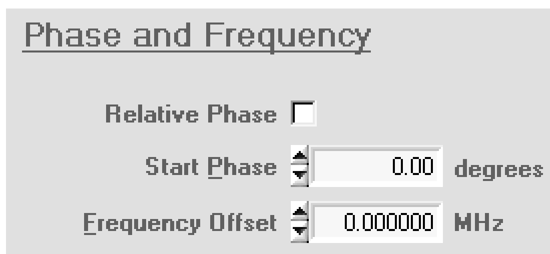


Fig. 9: Phase and frequency settings

The **Start Phase** parameter sets the phase shift of the resulting RF wave. The permissible number range is -360.0 degrees to +360.0 degrees. The phase setting refers to the starting point of the pulse and modulation may change this phase during the pulse.

Activating the **Relative Phase** check box keeps the signal phase from the end of the previous pulse and adds the start phase to this value. This enables the user to continue with a phase modulated signal from one pulse to the next.

The **Frequency Offset** shifts the pulse in frequency away from the RF carrier. It is important that large enough ARB sample rates are set in the final sequence to allow for the desired frequency shift. A minimum of double the ARB sample rate is required for a given frequency offset.

The check box **Hide Entry In Tree** is used to hide this pulse entry in the project tree. This is useful if a large number of pulses exist and the user only needs to generate sequences or Multi-Segment waveforms without seeing or altering the underlying pulse definitions.

The **AWGN** check box activates the generation of Additive White Gaussian Noise. The noise is superimposed during all phases of the pulse at a set level and bandwidth.

The **Level Att** control sets the attenuation of the AWGN signal from full scale.

The **Bandwidth** values sets the bandwidth in which the AWGN signal is created. In order to use this bandwidth it is required to chose a sufficiently high ARB sample rate in the final sequence.

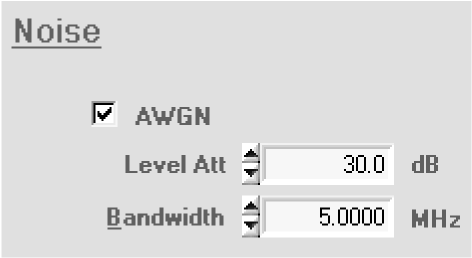


Fig. 10: AWGN settings

The example below shows the resulting pulse amplitude in logarithmic scale with AWGN at 40 dB attenuation. The pulse amplitude is attenuated by 20 dB from full scale. It can be seen that the AWGN is superimposed during all phases of the pulse.

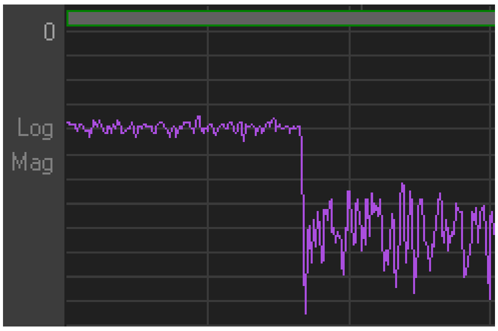


Fig. 11: Signal affected by AWGN

Jitter Settings

Fig. 12: Jitter settings

Applying jitter is one of the Pulse Sequencers most powerful functions. This paragraph discusses jitter settings in detail and highlights possible areas of use.
In general, a jitter is understood as the change of a pulse parameter in either a random or ordered way. This parameter alteration enables the simulation of real world scenarios or technical imperfections. Possible areas of use are the random variation of a rising or falling edge position for the simulation of a technically imperfect trigger signal. Parameters such as the pulse repetition frequency may also be altered by using a staircase type jitter which is required for the generation of some radar signals.

The following parameters can be affected by jitter.

- Delay Time [μs]
- Rise Time [μs]
- On Time [μs]
- Fall Time [μs]
- Off Time [μs]
- PRF, PRI [Hz, μs]
- Level Attenuation (On) [dB]
- Level Attenuation (Off) [dB]
- Frequency Offset [MHz]
- Phase [degrees]
- FM Deviation [MHz]
- Skip Entry [1,0]

The last item (Skip Entry) is not a pulse parameter. It is used to skip repetitions if a pulse is used multiple times within a sequence. A value of 1 skips the repetition whereas a value of 0 computes the pulse. The final number of pulses that result from a set of repetitions may vary if random data is used for the skip entry jitter.

The Pulse Sequencer software can assign up to four different jitters individually and simultaneously. Each jitter affects one particular pulse parameter from the list above and can use one of the following profiles.

- Uniform Distribution
- Normal Distribution (Gauss)
- Linear Ramp
- Sine Wave
- Staircase
- Value List (uniform distributed or ordered)
- Interpolated Shape
- Rules List

These profiles are discussed in the following chapters in detail.

1.9.1 Uniform Distribution

The uniform distribution is characterized by the values *Min*, *Max* and *Step*. Values occur with the same probability in the range between the minimum and maximum level. The granularity is the *Step* value.

1.9.2 Normal Distribution

The Gauss or normal distribution is characterized by the parameters *location*, *standard deviation* and *Min/Max*. The following figure illustrates the probability at which values would occur related to the standard deviation if no Min/Max limit was set.

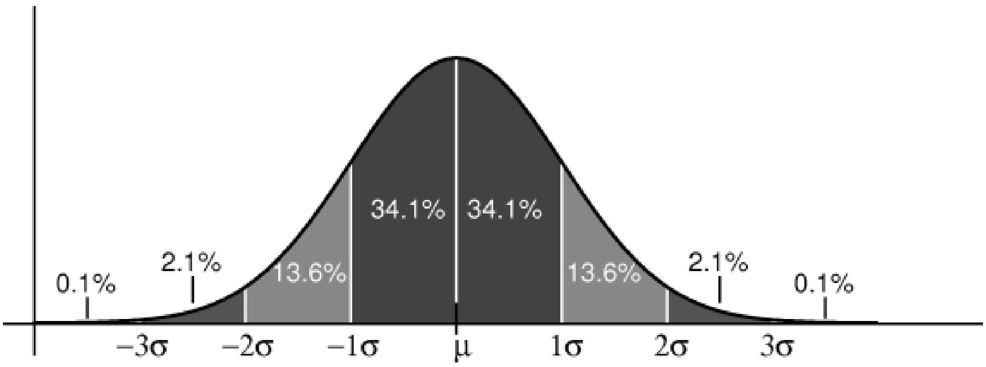


Fig. 13: Normal Distribution

The figure shows that 68.2 % of the resulting values are located in the range *Location* ± *1 σ* and 99.6 % are located within ± 3 *σ* .
At very low probabilities any value may occur. If this is not desired the Pulse Sequencer software provides a Min/Max limit that is used to cut off the distribution at both ends. All values beyond this point are set to either the minimum or maximum limit. This violates the normal distribution but is required to avoid invalid parameters such as negative times or frequencies.

1.9.3 Linear Ramp

The linear ramp changes a parameter from a minimum value to a maximum value.
The following screen shot shows a series of 10 Gauss shaped pulses with the frequency changing from -20 MHz to +20 MHz following a linear ramp. The upper curve represents power versus time in logarithmic scale whereas the lower curve shows the frequency versus time.

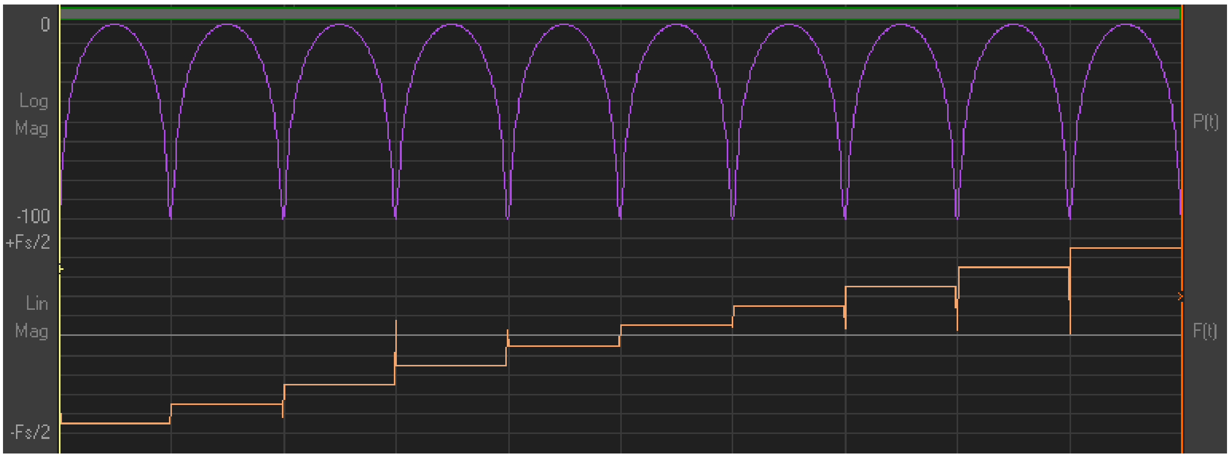


Fig. 14: Example for pulse frequency affected by linear ramp jitter

1.9.4 Sine

The sine profile creates values that follow one period of a sine wave. The amplitude parameter sets the peak amplitude of the sine wave whereas the offset parameter sets a constant offset to the entire sine wave.
The screen shot below shows a series of 100 pulses where the phase is varied from -180 degrees to +180 degrees following a sine wave shape.

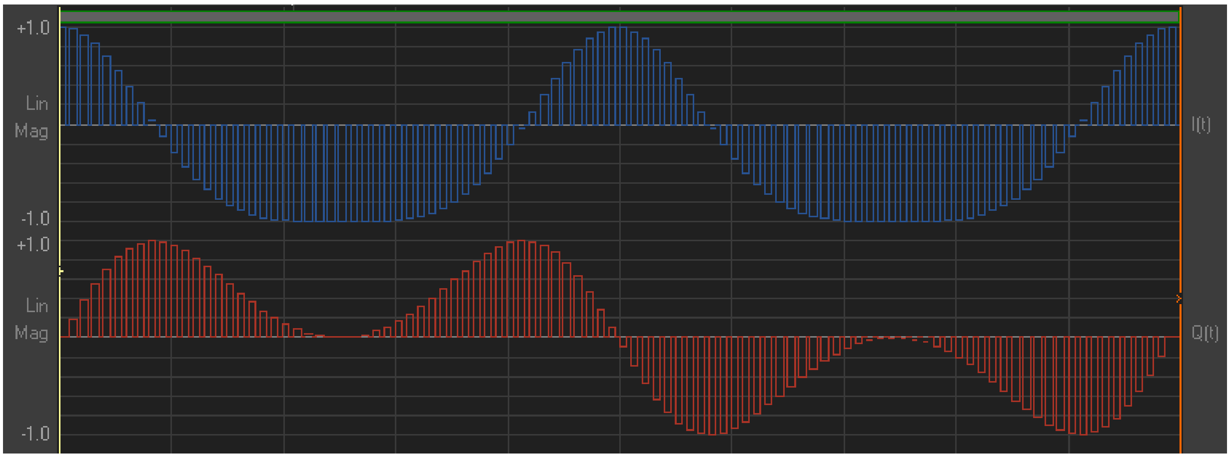


Fig. 15: Example for pulse phase affected by sine wave jitter

1.9.5 Staircase

The staircase profile creates a sequence of identical values before it moves on the the next one. The parameter count defines how many identical values are created whereas the step value defines the value change.
The screen shot below shows 100 pulses with the phase being varied from zero to 180 degrees. The count was set to 10 which creates bursts of 10 identical pulses. The step is 18 degrees which ensures that the whole 180 degrees are covered after 10 bursts.

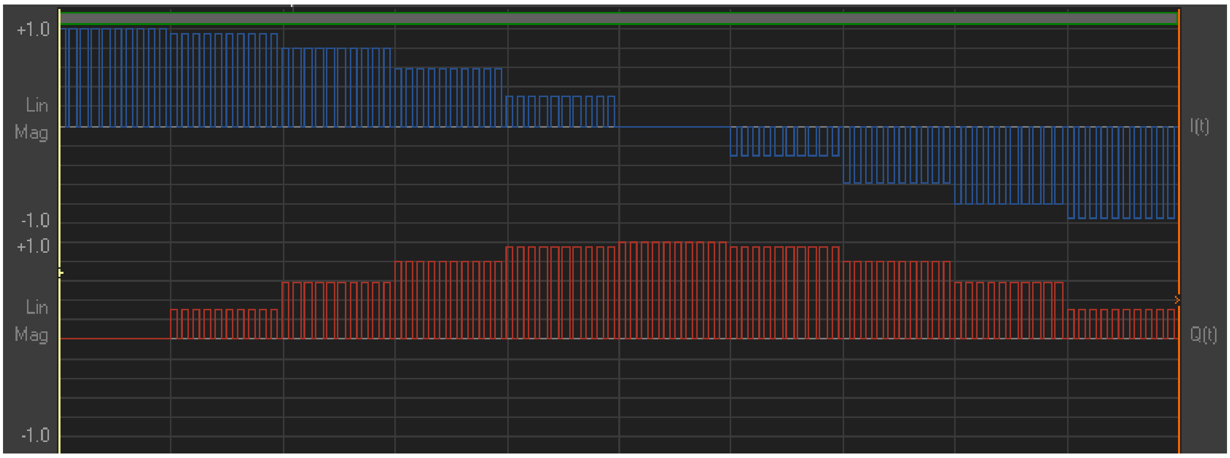


Fig. 16: Series of pulses with level controlled by staircase modulation

1.9.6 Value List (Uniform)

This profile draws random numbers from a list of values (table). The list data can either be entered manually or imported from an ASCII text file.

1.9.7 Value List (Ordered)

The ordered value list draws numbers starting from the very first list item. Subsequent pulses receive the following list entries. This mechanism continues until the end of the list is reached. A further pulse causes the list to wrap around and start over at the very beginning of the list.
List entries can either be entered manually or imported from an ASCII test file.

1.9.8 Shape (Interpolated)

The table data defines a shape which means that list entries are mapped to the number of repetitions. Linear interpolation is used if the number of repetitions is not equal to the number of list entries.

1.9.9 Rules List

The rules list is used to define complex jitter scenarios by adding mathematical rules to a list. Each list entry contains three sections that are separated by a colon.

```
<number of values> : <value> : <number of repetitions>
```

The **number of values** defines how many jitter values are created by this rule. After all values have been created the next list item is processed. The **value** section defines the numbers to be generated. The last section defines how many times each number is repeated before a new value is generated. The first and last section can be a fixed numeric value or a random expression. In case of the random function the value is created when this line item is processed the first time. This means that the number of values and the repetition count is set before values can be drawn from this rule.
The middle section can be a fixed number or an expression. In the latter case the expression is evaluated for each number that is created by this rule. The expression can be one of the following:

```
random ( <min> , <max> , <step> )
stagger ( <min> , <max> , <step> )
```

random()
The random expression creates a random number between the minimum and maximum value incuding bounds. The step size is the granularity.

stagger()
Numbers start with the minimum value and increase by the step size until the maximum is reached. It is permissible to use random expressions or fixed numbers for the <min>, <max> and <step> parameter.

The following examples demonstrate the use of the rules.

`5 : rand(5,15,1) : 1`	Creates 5 random numbers between 5 and 15. The numbers are integer values.
`100 : rand(0,100,0.01) : 5`	Creates 20 random numbers between 0 and 100 with a step size of 0.01. Each value is repeated 5 times.
`rand(1,10,1) : 3 : 1`	Creates the value 3 between 1 and 10 times (random).
`20 : rand(100,500,20) : rand(1,5,1)`	Creates 20 values, each randomly distributed between 100 and 500 and with a spacing of 20. The values are repeated between one and five times.
`10 : stagger(0,7,2) : 1`	Creates 10 values starting at 0 and increasing by by 2 until the value seven has been reached: 0, 2, 4, 6, 7, 7, 7, 7, 7, 7
`10 : stagger(0,7,random(0,5,1)) : 1`	Creates 10 values starting at 0. The step size varies between 0 and 5. The maximum value is 7.

1.10 Using Tables as Source for Jitter Values

Tables can be used as source for discrete jitter values. Depending on the selected jitter profile values are taken randomly or in an ordered way from the table. The list data is stored as part of the pulse definition in the project file. The maximum number of list entries is not limited but for speed and memory reasons large lists should be avoided.

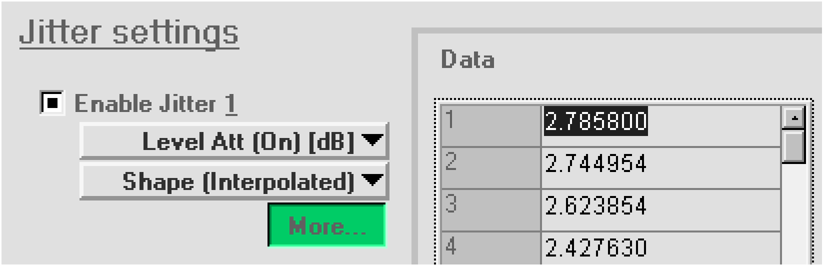


Fig. 17: Jitter values follow custom shape

The jitter details section is used to manage list entries as well as to import and visualize list data. The '*More...*' buttons are used to switch the jitter details view to one of the jitter profiles.

Editing List Entries
List entries can be altered by double clicking the item and then changing its value. If a list entry shall be removed the field must be left blank and gets automatically removed as soon as the Enter key is pressed. Appending data to the list is possible by filling in the last blank field at the end of the list. Pulse Sequencer automatically keeps adding a new blank field at the very end of the list.

Importing Data
The import filter can process ASCII text files as data source. Data needs to be organized in columns that are separated by at least one space. The column from which data is read can be set starting at 1 for the first column.
Once data is imported it is possible to **rescale** all values to fit the desired jitter range. Rescaling is done by first applying a gain factor and then adding an offset. This step can be executed repeatedly until the desired result is reached.
Use a gain of 1.0 if no gain shall be applied whereas a zero offset must be entered to only apply gain.

The '**Clear**' button removes all values from the list and frees all associated memory.
Imported data becomes a permanent part of the pulse definition. If a pulse is copied Pulse Sequencer also creates a full copy of all jitter values. Turning the jitter profile off does not free any associated memory nor does it remove jitter data from the project file. List data can only be removed by using the '*Clear*' button for the selected profile.

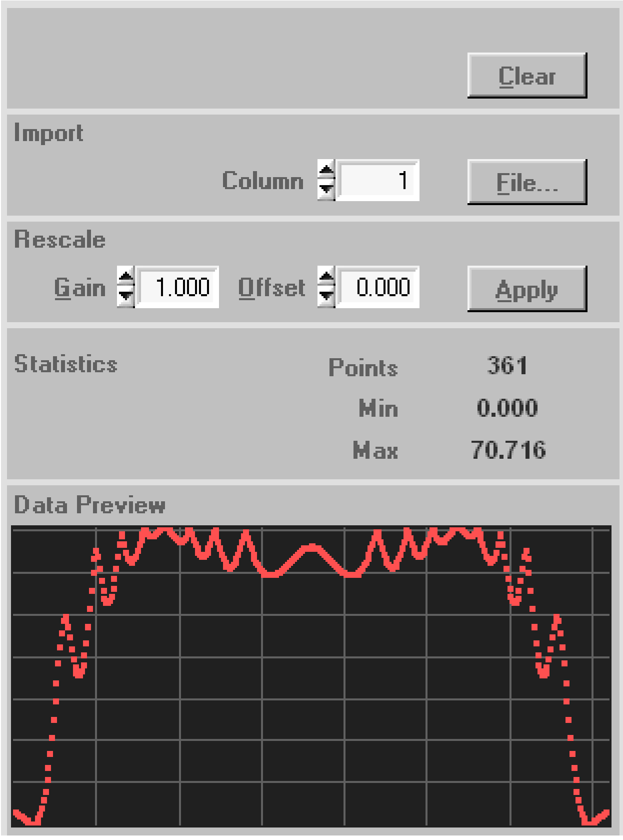


Fig. 18: Viewing jitter data

1.11 Combining Multiple Jitter Profiles

If more complex jitter scenarios are required the Pulse Sequencer software is able to apply multiple jitter profiles to the same parameter. The example below shows a series of 100 pulses with three different jitter profiles applied to the pulse power. The first jitter profile is a linear ramp that decreases the power by 40 dB across all 100 repetitions. The second jitter profile follows a sine wave. The amplitude of this sine wave is 10 dB. The third jitter applies uniform distributed noise with a maximum level of 5 dB.

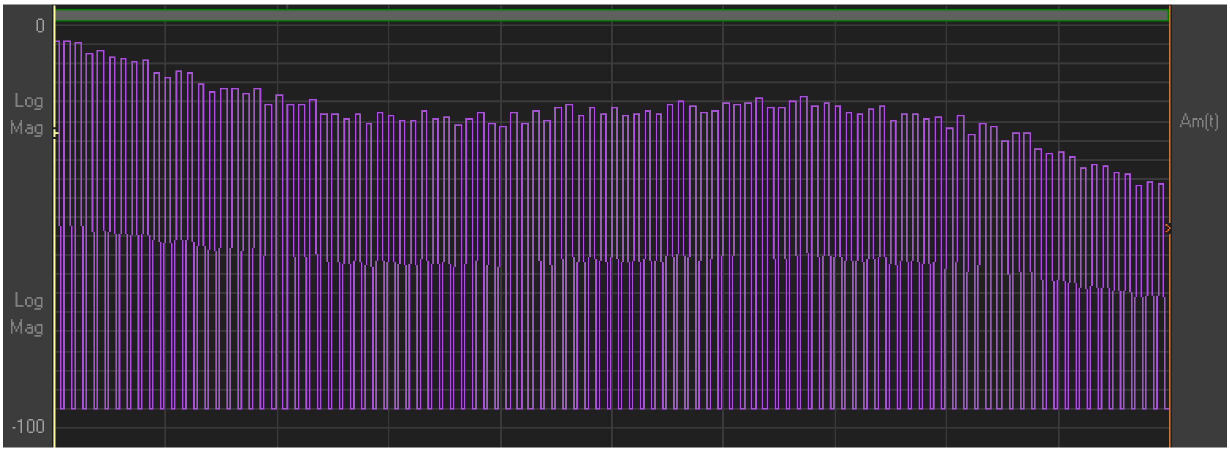


Fig. 19: Multiple jitters applied to the pulse power

1.12 Modulation Settings

The Pulse Sequencer software provides a wide range of predefined modulation schemes that can be applied as intra-pulse modulation. Intra-pulse modulation refers to the pulse rise-, on-, and fall-time. If the built in modulation schemes are not sufficient custom plug-ins may be used to extend the Pulse Sequencers capabilities.

The **modulation** tree selects the intra-pulse modulation type. 'OFF' disables the modulation and generates a pure CW signal. All other modulation types are arranged in groups, such as AM, FM, PSK, etc. An extra tree branch contains plug-in modules that were discovered during program start. These plug-ins may be used in the same way as internal modulation schemes.

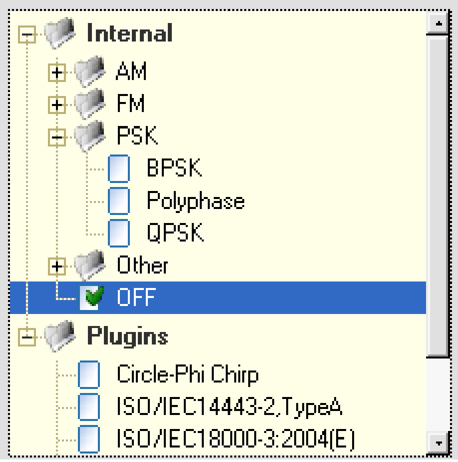


Fig. 20: Modulation selection tree

On the right side of the modulation type tree a table contains all parameters that are relevant to the selected modulation type. The table contents changes with the modulation selection. Plug-ins may also register up to 64 parameters that are available to the user. When a new modulation is selected the table gets pre-set to default values for this modulation. Modified entries are stored in the Pulse Sequencers project file.

The '**Reset**' button sets all configuration parameters back to the modulation or plug-in default settings. Out of range items are marked in **yellow**. The limits for each entry are either determined by the built in modulation or in case of a plug-in are requested from the plug-in at program start. The configuration parameters are very useful when working with plug-ins as they permit the reuse of the same plug-in code with many different configurations.

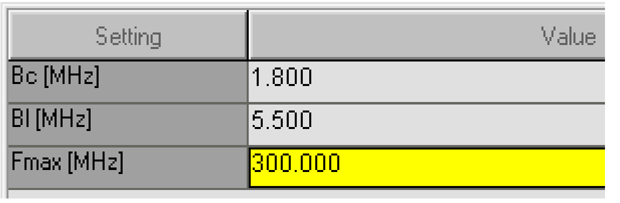


Fig. 21: Modulation parameters

Some modulation types require data which can be provided in a table below the modulation selection tree. The table is only active for modulation types that require data. The Pulse Sequencer software provides a wide range of internally defined data sources, such as patterns or PRBS generators.
Data bits are drawn starting from the first list entry. Once all bits from this entry are used up the following one provides the data bits. This mechanism continues until the end of the list is reached. Further data requirements cause the list to wrap around and start over at its beginning. The example above delivers two bits that are set to zero, then 13 bits from a Barker sequence and finally two more zero bits.

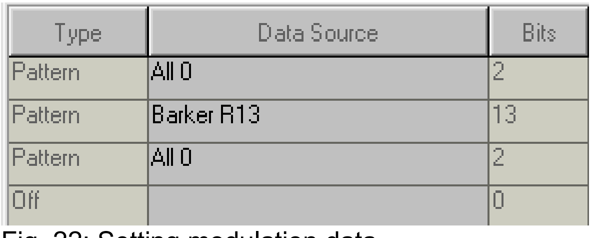


Fig. 22: Setting modulation data

Pulse Sequencer offers different types of data sources. *Random* and *Pattern* draw bits from internal generators whereas the *User* setting draws bits from data that is provided by the user.
The 'Sources' button next to the data source list is used to display the user data editor. This editor is described in the next chapter in detail.

<u>Patterns</u>

All 0	Only zero bits are generated
All 1	Only one bits are generated
1010	Alternating ones and zeros are generated

Barker Codes:

Length	**Code**	
3	1 1 0	
4 a,b	1 0 1 1	1 0 0 0
5	1 1 1 0 1	
7	1 1 1 0 0 1 0	
11	1 1 1 0 0 0 1 0 0 1 0	
13	1 1 1 1 1 0 0 1 1 0 1 0 1	

Barker codes of length 11 and 13 are mainly used in pulse compression radar systems because of their good autocorrelation properties.

1.13 The Data Source Editor

The Data Source Editor can be invoked from the menu bar '*Project → Data Sources*' or by the '*Sources*' button on the pulse modulation panel.
The tree on the left side lists all available data sources. Clicking on one of the items activates the editing fields on the right side.

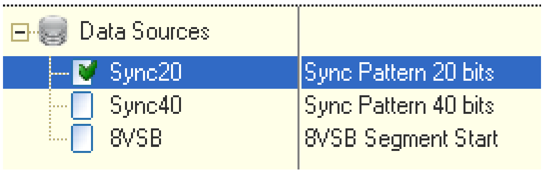


Fig. 23: Data sources tree

New data sources can be added with the '**New**' button that is located above the data sources tree. Selected entries can be removed using the '**Delete**' button.
Once a new data source is created its content can be set-up using the data bits entry field.
The number of valid bits are shown on the right side above the entry field.
The entry field evaluates zeros ('0') and ones ('1') as well as numbers in hexadecimal format.
Comments can be enclosed in slashes ('/'). The following overview explains how data is interpreted.

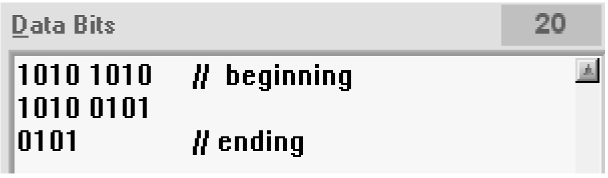


Fig. 24: Data bits editor

- All blank characters are ignored
- A slash turns the comment field on or off
- The sequence #x starts hexadecimal input for the remainder of the line
- A new line turns hexadecimal and comment mode off
- Ones and zeros are evaluated as single bits

Input Examples:

1100 0100	/ comment /	1111 0000	/ comment until end of line …
1111 0011	/ 101 is not evaluated here /		
#xABF0	/ 16 bits from hexadecimal numbers /		
#x f0 a3 7d 1e	/ 32 bits		

Data sources are available globally within the project. Once a data source is set-up its data is available in all pulses. However, each pulse draws data individually from the data source and there is no possibility to resume data that has not been used up in a previous pulse.

6.1 Built-In Modulation Types

AM

AM stands for Amplitude Modulation with a single tone.

Parameters:

AM Type	Standard LSB USB LSB+USB	Regular AM AM with only lower side band AM with only upper side band AM without carrier
Mod Freq [kHz]	0….100.0 MHz	Modulation frequency
Depth [%]	0…100	Modulation depth

ASK

ASK stands for Amplitude Shift Keying. The amplitude of the RF carrier is attenuated for a bit value of zero and remains at full level for bit values of one. The level of attenuation is specified as depth in percent.

Parameters:

Depth [%]	0….100	Modulation depth
Invert	yes | no	Invert bits
Coding	normal position	Regular ASK, set amplitude level by bit Each bit is divided into two halfs: 1 = first half active, second half blanked 0 = first half blanked, second half active

FM

FM stands for Frequency Modulation with a single tone.

Parameters:

Mod Freq [kHz]	0….25.0 MHz	Modulation frequency
Deviation [kHz]	0….300.0 MHz	Total deviation

The figure below shows power and frequency versus time. The pulse is set to a modulation frequency of 2 kHz and deviation of 4 MHz. The ARB sample rate is 10 MHz and the total pulse time is 1 ms.

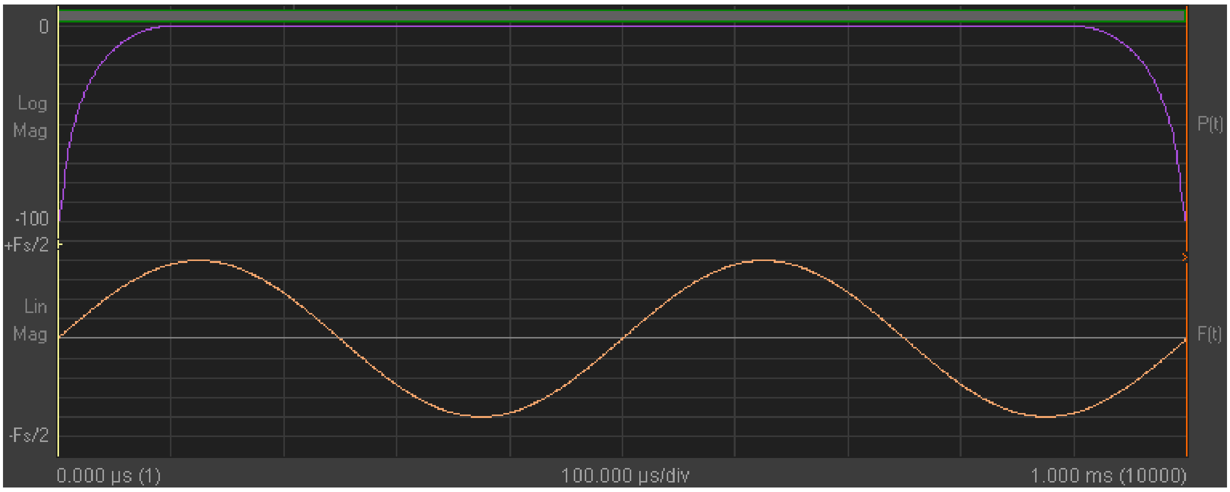


Fig. 25: FM Modulated Signal

It can be seen that the frequency changes between -Deviation and +Deviation (positive and negative full scale is half the sample rate).

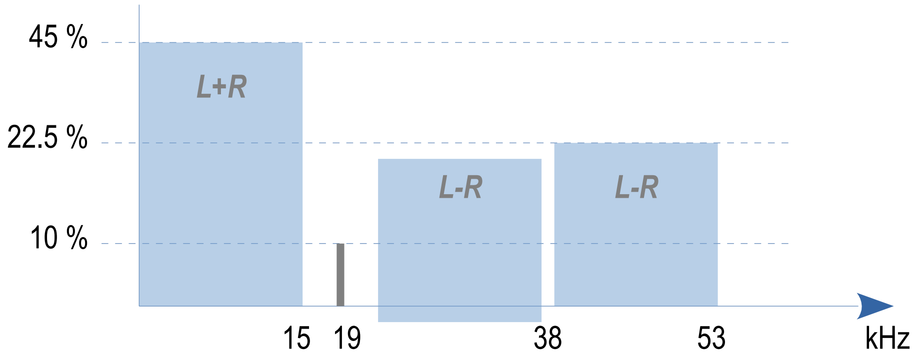
FM Stereo

The FM Stereo modulation type creates an analog FM stereo signal according to the ITU-R BS.450-3, chapter 2.2 recommendation (Transmission standards for FM sound broadcasting at VHF).

Parameters:

Deviation [kHz]	10 … 100.0 kHz	FM Deviation (default: 75 kHz)
Right Tone [kHz]	0.001 … 15.0 kHz	Audio tone for right channel
Right Audio Level	-1.000 … +1.000	Level multiplier for right audio channel (default: 1.0)
Left Tone [kHz]	0.001 … 15.0 kHz	Audio tone for left channel
Left Audio Level	-1.000 … +1.000	Level multiplier for left audio channel (default: 1.0)
MUX Pilot Level [%]	0.1 … 20.0	Level of pilot in stereophonic multiplex signal (default: 8-10%)
MUX Audio Level [%]	0.1 … 100.0	Level of audio signals in stereophonic multiplex signal (default: 80%)

The RF signal is created from a carrier that is frequency modulated by a baseband signal, called the 'stereophonic multiplex signal'. The figure below shows the contents of this signal.



The stereophonic multiplex signal contains the sum of the left and right audio channel, a pilot tone of 19 kHz and a 38 kHz carrier that is analog modulated with the audio difference signal.

FSK

FSK stands for Frequency Shift Keying. High bits set the frequency to +Deviation whereas low bits set the frequency to –Deviation.

Parameters:

Deviation [MHz]	1 HZ….300.0 MHz	The deviation from the carrier used for low or high bits

FSK(2)

FSK stands for Frequency Shift Keying. High bits set the frequency to f1 for a duration of T1 whereas low bits set the frequency to f1 for a duration of T2.

Parameters:

f1 [MHz]	0 HZ….300.0 MHz	Frequency deviation used for low bits
f2 [MHz]	0 HZ….300.0 MHz	Frequency deviation used for high bits
T1 [us]	0....100 ms	Time used for low bits
T2 [us]	0....100 ms	Time used for high bits

The figure below shows a 1 ms pulse that is modulated by the bit sequence 1100110011. f2 (high bits) is set to 2 MHz andT2 is set to 50 us. F1 (low bits) is set to 4 MHz and T1 is set to 150 us.

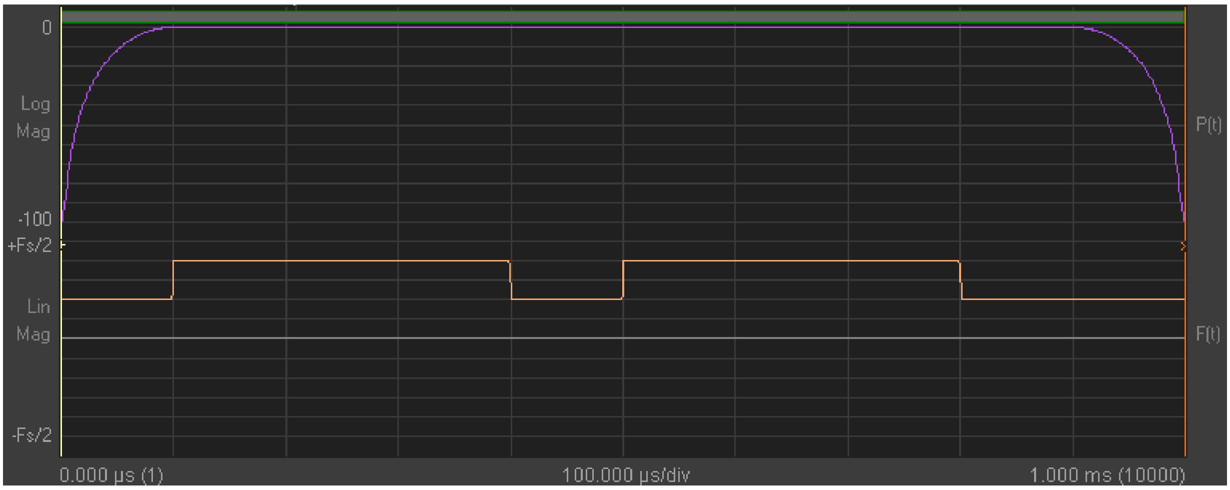


Fig. 26: FSK modulated signal

This type of FSK is useful if the bit time needs to be adjusted according to the frequency deviation, e.g. to ensure a full period count.

Multi Carrier

The multi carrier modulation creates multiple CW carriers that are equally spaced using a given spacing. In order to reduce the signal peak-to-average ratio is is possible to use random phase offsets when generating the carriers.

Parameters:

Spacing [kHz]	1 HZ….100.0 MHz	Spacing between carriers
Carriers	2....100000	Number of carriers
Random phase	yes no	User random phase to reduce pk-to-av ratio Use start phase zero

Multi Tone

The multi tone modulation creates a signal with up to five custom CW frequencies.

Parameters:

f1 [MHz]	-100 MHz....+100MHz	1st carrier frequency
f2 [MHz]	-100 MHz....+100MHz	2nd carrier frequency
f3 [MHz]	-100 MHz....+100MHz	3rd carrier frequency
f4 [MHz]	-100 MHz....+100MHz	4th carrier frequency
f5 [MHz]	-100 MHz....+100MHz	5th carrier frequency

Unused frequencies: value must be set to zero.

FM Chirp

The FM chirp sweeps the RF signal across a set frequency range.

Parameters:

RF Bandwidth [MHz]	1 HZ….600.0 MHz	The frequency is swept from -BW/2 to +BW/2
Shape	ramp up ramp down sine exp exp 10 triangular inv trian	The frequency is ascending linear The frequency is descending linear The frequency follows a full sine wave The frequency is ascending exponentially according to 2.718281828 ^ x The frequency is ascending exponentially according to 10.0 ^ x The frequency ascends and then descends The frequency descends and then ascends

Polynomial FM

This modulation creates an FM chirp that is generated using a polynomial. The equation below is used to calculate the instantaneous frequency versus time.

$$f(t) = s(a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5)$$

Parameters:

Multiplier	-10^6....$+10^6$	s
Term 0	-10^6....$+10^6$	a_0 (constant offset)
Term 1	-10^6....$+10^6$	a_1 (linear term)
Term 2	-10^6....$+10^6$	a_2
Term 3	-10^6....$+10^6$	a_3
Term 4	-10^6....$+10^6$	a_4
Term 5	-10^6....$+10^6$	a_5
Term 6	-10^6....$+10^6$	a_6

BPSK

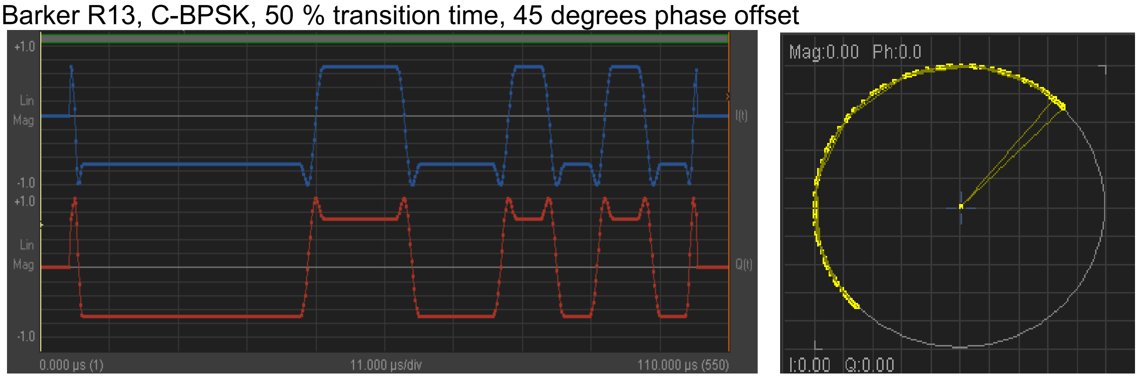
BPSK stands for Binary Phase Shift Keying. A bit value of one sets the phase to a definable value whereas zero bits leave the phase at zero. An additional phase offset may be used under the general pulse settings to rotate the constellation points.
C-BPSK stands for Constant Envelope BPSK.

Parameters:

Type	BPSK C-BPSK	Regular BPSK Constant Envelope BPSK
Phase [deg]	0.01....180.0	Phase change between 0 and 1
Transition [%]	0....100.0	Time used for transition between phases (*C-BPSK only*)
Trans Shape	cos	Transition shape (*C-BPSK only*)
Coding	normal differential	no coding use differential coding

Barker R13, BPSK, 0 % transition time, 45 degees phase offset

Barker R13, C-BPSK, 50 % transition time, 45 degrees phase offset



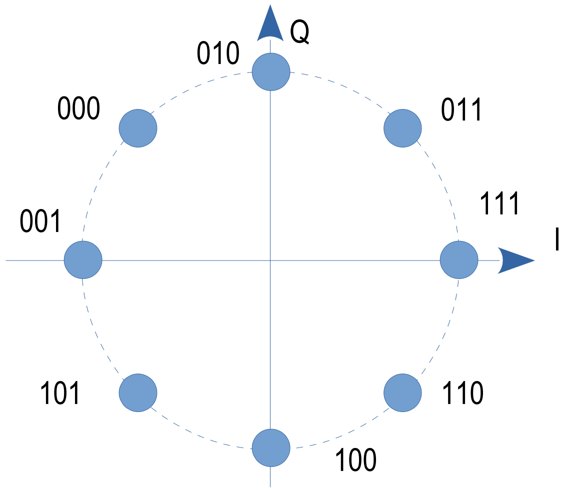
The transition settings are only required for the C-BPSK modulation type.

8PSK

8PSK stands for 8 Phase Shift Keying. A bit value of one sets the phase to a definable value whereas zero bits leave the phase at zero. An additional phase offset may be used under the general pulse settings to rotate the constellation points.

Parameters:

Type	8PSK	Regular 8PSK
Rotation [deg]	0.01....360.0	Rotation of constellation from symbol to symbol. Set to 67.5 for EDGE
Gain I	0.01...1.0	Gain for I axis. Use 1.0 for full scale.
Gain Q	0.01...1.0	Gain for Q axis. Use 1.0 for full scale.
Phase Ofs [deg]	-180.0...+180.0	Constant phase offsets that rotates the entire constellation.



Polyphase

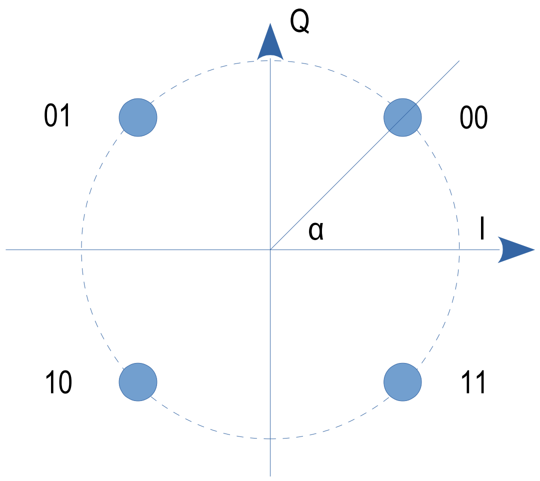
Polyphase modulation is mainly used in Low Probability of Intercept (LPI) radars.

Parameters:

Type	Frank P1 Code P2 Code P3 Code P4 Code	Frank Code P Code
Length	1....200	Code Length

QPSK

QPSK stands for Quadrature Phase Shift Keying.



α Angle [deg]

Each sample requires two bits which are mapped using the following constellation.

Bits	Based on angle (α)	For α = 45 degrees
00	α/360 * 2 π	+ ¼ π
01	pi - α/360 * 2 π	+ ¾ π
10	-pi + α/360 * 2 π	- ¾ π
11	-α/360 * 2 π	- ¼ π

Parameters:

Type	QPSK O-QPSK C-QPSK D-QPSK	Regular QPSK Offset QPSK Constant Envelope QPSK Differential QPSK
Rotation [deg]	0.0....360.0	Rotation of constellation from symbol to symbol. Set to 45 for π/4 QPSK
Gain I	0.01....1.0	Gain for I axis. Use 1.0 for full scale.
Gain Q	0.01....1.0	Gain for Q axis. Use 1.0 for full scale.
Phase Ofs [deg]	-180.0....+180.0	Constant phase offsets that rotates the entire constellation.
Angle [deg]	-180.0....+180.0	The angle between the QPSK constellation points and the I axis for an offset = 0.

C-QPSK

This type of modulation is similar to QPSK but transitions from one constellation point to the other happen at constant amplitude, thus, only phase changes occur. The following list shows how data bits are translated into phase changes.

00	- ½ π
01	- ¼ π
10	+ ¼ π
11	+ ½ π

VSB8

VSB8 stands for Vestigial Side Band and is a special type of phase modulation with eight constellation points in a straight line. Three bits are required to form one symbol. Data bits are mapped according to the following table.

	Phase	*Amplitude*
000	+ ¼ π	1.000
001	+ ¼ π	0.714
010	+ ¼ π	0.429
011	+ ¼ π	0.143
100	- ¾ π	0.143
101	- ¾ π	0.429
110	- ¾ π	0.714
111	- ¾ π	1.000

VSB16

VSB16 stands for Vestigial Side Band and is a special type of phase modulation with 16 constellation points in a straight line. Three bits are required to form one symbol. Data bits are mapped according to the following table.

	Phase	*Amplitude*
0000	+ ¼ π	1.0000
0001	+ ¼ π	0.8667
0010	+ ¼ π	0.7332
0011	+ ¼ π	0.5999
0100	+ ¼ π	0.4667
0101	+ ¼ π	0.3333
0110	+ ¼ π	0.2000
0111	+ ¼ π	0.0667
1000	- ¾ π	0.0667
1001	- ¾ π	0.2000
1010	- ¾ π	0.3333
1011	- ¾ π	0.4667
1100	- ¾ π	0.5999
1101	- ¾ π	0.7332
1110	- ¾ π	0.8667
1111	- ¾ π	1.0000

Plug-ins

The modulation is defined by an external plug-in. Plug-ins are DLL modules that are loaded during program start. They contain the maths that is required for the envelope shaping and the intra-pulse modulation. Examples are bundled with the R&S Pulse Sequencer software.
Plug-ins can register up to 64 parameters which become available to the user in the modulation parameters table. This allows the use of the same plug-in in many different configurations.
When a pulse is calculated the plug-in is provided with the general waveform settings, such as ARB sample rate as well as the registered variable values. Subsequently the plug-ins maths function is called once for each sample and required to return data in polar coordinates.

6.2 Marker Settings

The markers 1 through 4 can be freely assigned to any section of a pulse by using the check box matrix. Marker information is directly added to the resulting waveform and the marker signal output is therefore synchronous with the waveform playback.
A set marker becomes active for the entire number of samples used up for the selected period of time. For example, activating a marker during the rising edge generates an output from the very beginning of the edge until the very end of it (0 % to 100 % level).
The same marker can be assigned to multiple sections of a pulse such as rise-time, on-time and fall-time.
The example shows that marker 1 is assigned to the rising edge, the on period and the falling edge of a pulse.

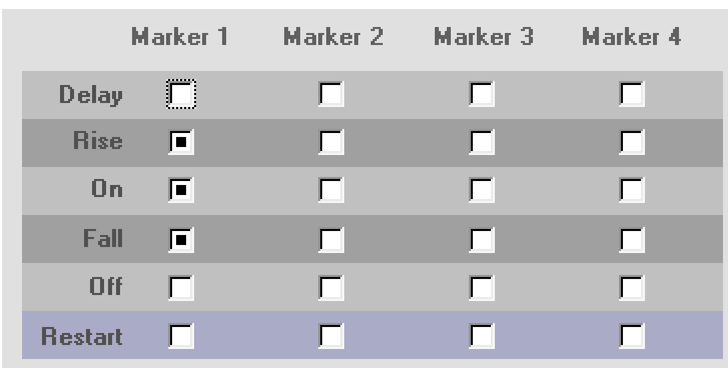
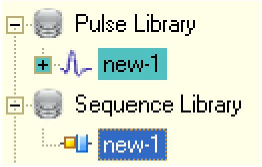


Fig. 27: Marker settings

Restart activates the marker for the first 10 % of the entire pulse repetition interval.

The marker flag definitions from this matrix are the fundamental marker definitions. When pulses are used in sequences it is possible to further restrict marker signal generation in the sequence editor. However, if a marker is not tied to any pulse section in this dialog it cannot be used in a sequence.
In addition, the preferences panel allows to inhibit markers globally. This frees memory that can be used for waveform data instead.

12 Creating Sequences



A sequence combines a series of pulses with additional information, such as the ARB sample rate, baseband filters, jitters as well as marker information. It is therefore required create pulse definitions first and then build the sequences.
A new sequence is created by either selecting '*Create → New Sequence*' from the menu bar or clicking the sequence creation button on top of the project tree (second button from left). In both cases a new sequence is created and its name set to new-<n>.
Clicking on a sequence entry in the project tree opens the sequence editor.
The sequence editor panel mainly consists of a table that is populated with the pulse entries used in the sequence. When a new sequence is created the last pulse from the pulse data base is automatically added as the very first item.

Item	Mode	Tstart [us]	Tstop [us]	Samples	Pulse Object	Rep.	Jitter 1	Jitter 2	Jitter 3	Jitter 4	M 1	M 2	M 3	M 4
1	---	0.00	600.00	6000	new-1	1	OFF	OFF	OFF	OFF	1ST	OFF	OFF	OFF

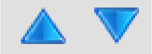
Fig. 28: One entry in the sequence editor table

A detailed description of the sequence editor follows in the next chapter.

New entries can be added to the list with the '*create new sequence entry'* button. This button has multiple functions depending on how it is used.

1. If no entries exist in the table the button adds a new sequence entry.
2. If entries exist but none of them is selected the button appends a new entry at the end of the list. The new entry is a copy of the last list entry.
3. If an existing entry is selected the button creates a copy of this entry and inserts it in the row below.

This button removes a selected list entry from the table.



The buttons move the selected entry one line up or down.

Hide the sequence in the project tree if 'Hide Tree Entries' is selected.

13 The Sequence Editor

The sequence editors main control is a table that contains the pulse entries in the order they get processed during the waveform generation. Each line represents one single pulse definition as well as additional information, such as the repetition count, jitter settings and marker mask information.

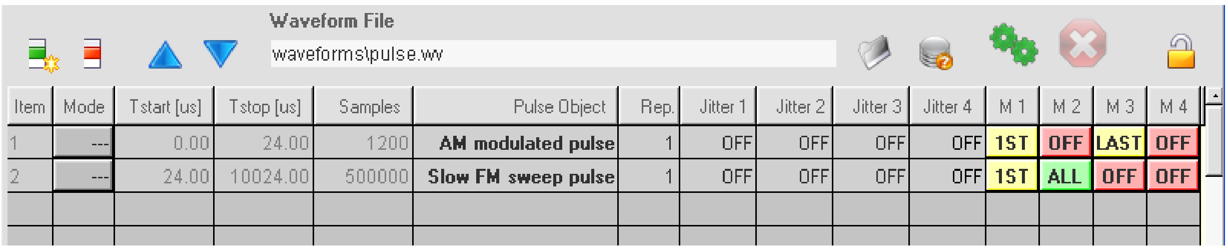


Fig. 29: Sequence editor table

Item
The very first field indicates the entry number. All pulse entries are numbered starting at index one. This column is only for reference and cannot be edited.

Mode
This field can be toggled between different states that describe how the pulse entry is added to the final waveform. The following options are available.

'---'	The entry is appended at the end of the waveform
'ADD'	The entry is added to the existing waveform starting at the beginning of the previous entry (→ overlay mode)
'MULT'	The entry is multiplied with the existing waveform starting at the beginning of the previous entry (→ overlay mode)

Tstart [µs]
Indicates the estimated starting time of the pulse entry in microseconds. This number does not take into account any alterations due to jitter. The final value may be different if jitter is applied and is available after the waveform has been created.

Tstop [µs]
Indicates the estimated stop time of this entry. The number is read only for regular pulse entries. In case of blank or CW fillers this entry sets the desired point in time.

Samples
This field contains the required number of samples as an estimation based on the pulse timing and given ARB sample rate. In case the timing is altered by jitter the final number maybe different. Therefore, the final numbers are available after a waveform creation.

Pulse Object
This field selects the pulse definition from the pulse library. Clicking this entry opens a drop down box with all available pulse definitions. In addition, two special entries exist at the top of the list which are called 'fillers'. These entries are no true pulses but act as fillers on the time scale. They either add a blanking period or a CW signal up to a certain point in time and may be used as a synchronization point. Filler entries are highlighted in blue and do not provide any jitter, repetition count or marker options.

Rep
This number sets the repetition count for the pulse entry. The default value is one and adds the pulse once to the sequence. Numbers greater than one repeat the pulse multiple times before the next line item gets processed.

Jitter 1,2,3,4
These settings define how jitter values are applied. A prerequisite for using these settings is that jitter profiles are defined in the underlying pulse definition.

OFF	No jitter is applied
Same	A jitter value is created and this value is used for all repetitions
Individual	Jitter values are calculated individually for each of the repetitions
Next	This entry only makes sense with jitter data provided by an ordered list of values. It reuses the same number for all repetitions but continues reading numbers from the list having been used by the previous line item.
Reuse	This entry only makes sense if the previous line item uses the same pulse definition. In this case all jitter values from the previous line item are reused.
Mseg	This entry only makes sense with jitter data provided by an ordered list of values and when working with Multi-Segment waveforms. It uses the Multi-Segment waveform index for taking values from the list.

M1, M2, M3, M4
These fields can be cycled through the states '*OFF*' → '*1ST*' → '*LAST*' → '*ALL*' and are used to mask marker information depending on the pulse repetition. A prerequisite for using these settings is that marker flags are assigned to pulse phases in the underlying pulse definition.

OFF	No marker information is added
1ST	Maker information is generated for the first pulse out of all repetitions only
LAST	Marker information is generated for the last pulse out of all repetitions only
ALL	The marker information is generated for all repetitions

6.3 General Sequence Settings

A sequence contains not only the order of pulses that are to be used but also general information that is required for the waveform generation. Most of these settings are located at the top of the sequence editor dialog.

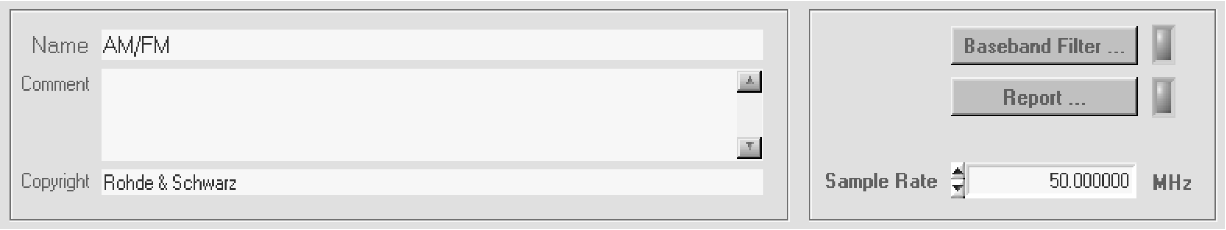


Fig. 30: General sequence settings

Name
This field sets the name of the sequence. This name is used in the project tree and identifies the sequence. The sequence names should therefore be unique within a project.

Comment
The comment is optional and added to the final waveform file. This field can be left blank if no comment is required.

Copyright
The copyright information is optional and added to the final waveform file. This field can be left blank if no copyright information is required.

Sample Rate
Sets the desired ARB sample rate. See the section →*Sample Rate Considerations* for more details. After changing the clock rate it is required to create the waveform again because the number of samples varies with the sample rate.
If the file size is not critical it is suggested to use the maximum possible clock rate for best performance. Please see your instrument manual for details about the maximum possible sample rate of your instrument.

Baseband Filter
The R&S Pulse Sequencer software provides a selection of baseband filters that can be applied to the final waveform. This allows the user to limit the bandwidth of the final waveform output.
This function can also be used to simulate the output signal of the instrument by using a low pass filter that is set to the maximum ARB bandwidth of the instrument.

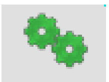
Report
The button opens the report generation dialog. The report output documents all parameters that were used during the waveform creation and is particular useful if random jitter is applied to parameters.

Fig. 31: Sequence status line and build options

Waveform File
Sets the local file name of the output waveform. The Pulse Sequencer software accepts absolute or relative paths.

File Browser
The file browser can be used to select a file from the local file system.

Info
Reads information from the local waveform file, such as sample count, peak-to-average ratio, play time, comment and copyright.



Build Waveform
This button starts the waveform creation process and is greyed out if no local waveform file is specified.

Status Line
The status line is populated after the waveform creation process has finished and contains information, such as the number of samples, the used sample rate, the overall sequence time and the signal peak-to-average ratio (CRF).

14 The Baseband Filter Dialog

The Pulse Sequencer software can run its waveform output through a baseband filter. Each sequence can use an individual baseband filter configuration but all pulses within a sequence are processed using the same filter. Use the baseband filter button from the sequence editor to open the baseband filter dialog. A green LED next to the baseband filter button indicates that the filter is active.
The baseband filter dialog is divided into three sections. The tree on the left side lists all predefined filter types. The middle section defines filter parameters that are required for the selected filter type. The right side of the dialog is used to import custom filter data if the filter type is set to 'User Data'.

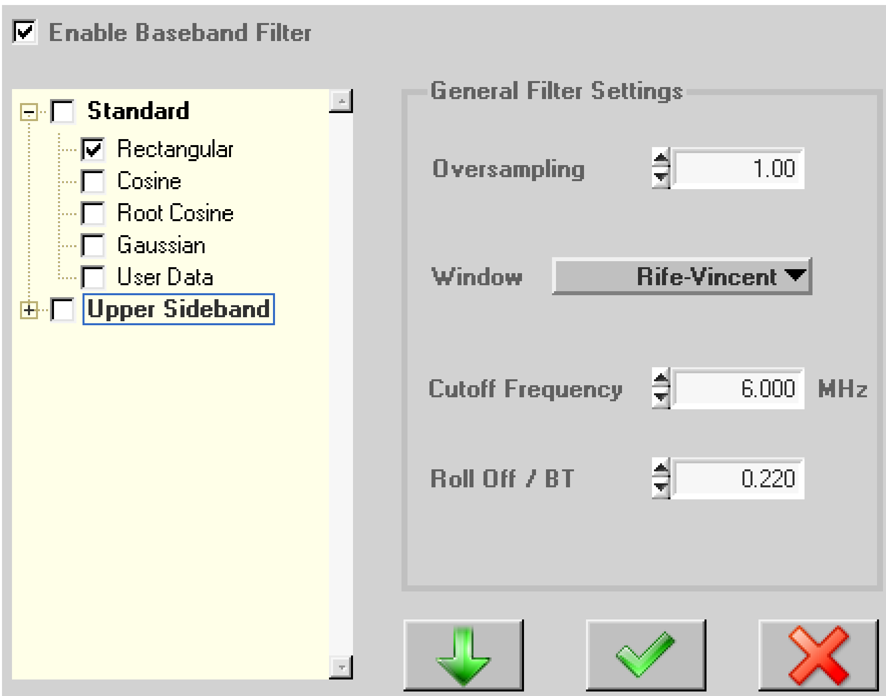


Fig. 32: Baseband filter dialog

Enable Baseband Filter
The check box enables or disables the baseband filter.

Window
The window function is multiplied with the filter function and therefore influences the resulting output spectrum.

Cutoff Frequency
Sets the filters cut-off frequency. For example, a cut-off frequency of 2 MHz results in a total RF bandwidth of 4 MHz.

Roll Off / BT
Some filters such as cosine or root cosine require an additional roll-off factor to determine the excess bandwidth. Gauss filters require the parameter B•T instead of roll-off.

B = filter 3 dB bandwidth
T = symbol period

B•T is related to the ARB sample rate before any oversampling is performed. The Pulse Sequencer software estimates the filter bandwidth by the equation *f = B • T • sample rate* assuming that one symbol corresponds to one single sample.

Oversampling
The Pulse Sequencer allows the user to set an over-sampling factor that permits rescaling the waveform to a target sample count.
Marker flags are generally tied to samples and therefore change from one sample to the next. But when fractional over-sampling factors are used additional samples need to be inserted which causes the marker flag changes to fall in between samples.

Tree
The type of filter used as the baseband filter.

Filter	Roll off / B*T	Impulse response
Rectangular		$h(t)=\mathrm{sinc}\left(\frac{t}{T}\right)=\begin{cases}\sin(t/T) & t/T\neq 0\\ 1 & t/T=0\end{cases}$
Root Cosine	Roll Off 0.001 – 1.000	$h(t)=\frac{4\alpha}{\pi\sqrt{T}}\frac{\cos\left(\frac{(1+\alpha)\pi t}{T}\right)+\frac{T}{4\alpha t}\sin\left(\frac{(1-\alpha)\pi t}{T}\right)}{1-\left(\frac{4\alpha t}{T}\right)^2}$
Cosine	Roll Off 0.001 – 1.000	$h(t)=\frac{\mathrm{sinc}\left(\frac{t}{T}\right)\cos\left(\frac{\pi\alpha t}{T}\right)}{1-4\left(\frac{\alpha t}{T}\right)^2}$
Gaussian	B*T 0.001 – 1.000	$h(t)=\frac{\exp\left(\frac{-t^2}{2\delta^2}\right)}{\sqrt{2\pi}\cdot\delta}\qquad \delta=\frac{\sqrt{\ln(2)}}{2\pi BT}$

15 Report Generation

Pulse Sequencer can generate report data during the waveform creation process. This is particularly useful if jitter modifies waveform parameters randomly. By default all report data is appended to a text file in form of columns that are separated by spaces. A header is added on top of each table that explains the content of each column.
The report button in the sequence editor opens the report generation dialog. Report settings are individually set for each sequence. A green LED next to the report button indicates that the report is active for this sequence.
Data reporting slows down the waveform creation if many pulses are to be generated because one line of text is added to the report for each pulse.

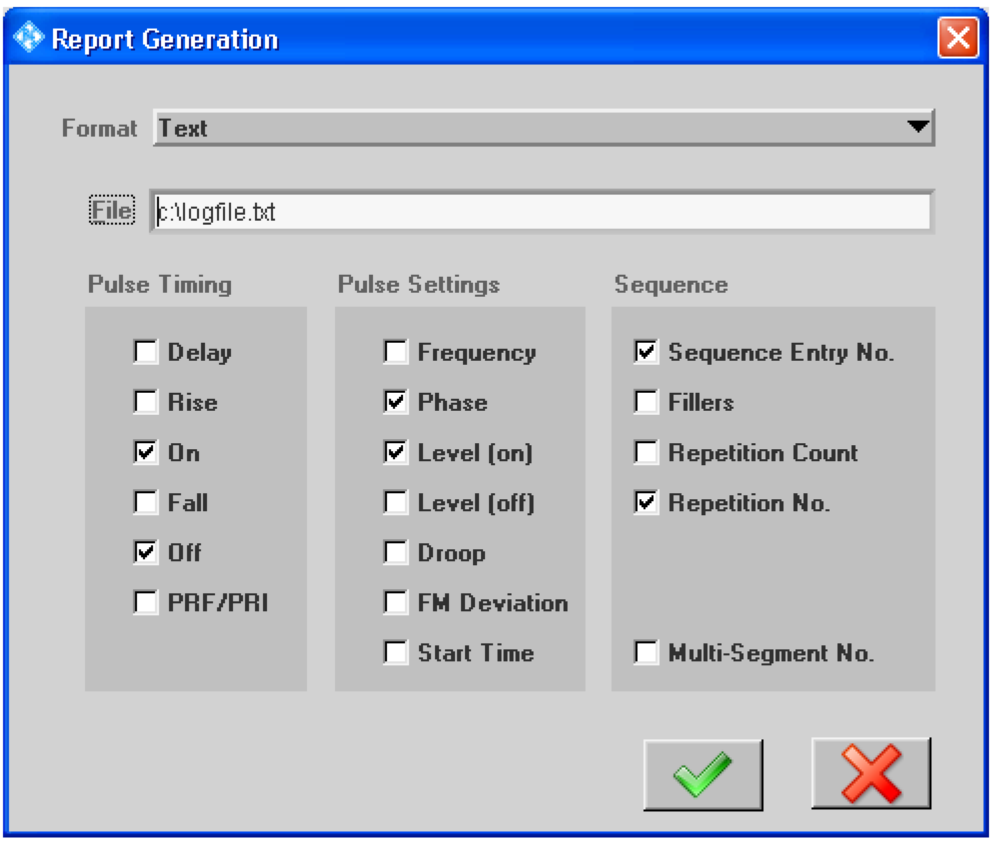


Fig. 33: Report generation dialog

Format
Sets the format of the report data.

OFF	No report data is generated
Text	Data is appended to an ASCII text file
<Plug-in>	A plug-in is used to process report data

File
Sets the file name for the report data output. New data is always appended at the end of the file. Each sequence can use its own report file.

Pulse Timing parameters
The check boxes in the pulse timing section enable reporting all values that concern the pulse timing. The reported values are the final figures including jitter. The values do not reflect any rounding errors that are caused by a baseband filter re-sampling process because baseband filtering is performed as the final step and using the complete waveform.

Frequency
The frequency offset from the carrier frequency set for the pulse including any jitter alterations.

Phase
The pulse start phase including any jitter alterations.

Level (On/Off)
The level attenuation set for the pulse including any jitter alterations.

Droop
The level decay during the pulse-on time including any jitter alterations.

FM Deviation
The FM deviation used for the pulse, e.g. for FM chirps.

Start Time
This figure is the absolute starting point of a pulse rising edge within a waveform.

Sequence Entry No.
The line item number in the sequence editor table starting at one for the first item.

Fillers
The amount of time that was added by either a CW or blank filler.

Repetition Count
The number of repetitions set for a line item in the sequence editor table.

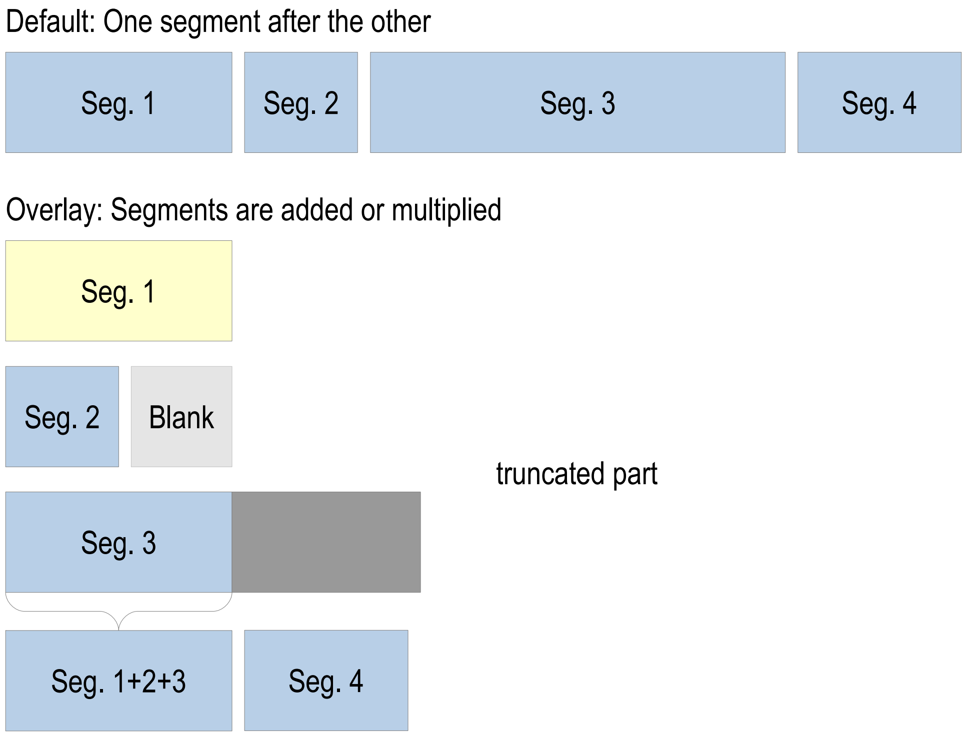
Repetition Number
In case multiple repetitions are used for a line item a separate entry is generated for each one of the repetitions. The repetition number starts with one and is increased up to the set number of repetitions.

Multi-Segment No.
If a sequence is used as part of a Multi-Segment waveform this entry reports the segment number where the sequence is used. Counting starts at one for the first segment.

16 Overlaying Pulse Entries

By default all pulse entries from the sequence editor are processed sequentially and appended to the final waveform. However, under certain conditions it may be desirable to add multiple pulses on a common time scale. The process of adding waveforms is referred to as overlay mode in the Pulse Sequencer software.

Each pulse entry within a sequence can be compared to segments on a time line. By default, segments are appended one after the other to this time line. In the overlay mode multiple segments are stacked on top of each other which allows the addition or multiplication of pulse entries. The following figure demonstrates the difference between the default sequential mode and the overlay mode.



Multiple line items of a sequence can be combined to an overlay group. The first item of this group is shown in yellow and defines the length of the entire overlay period (Seg. 1). All subsequent segments are added to the existing data starting at the beginning of the first segment. If the new segment is shorter than the length of the overlay group the remainder is left blank. Longer segments are truncated. The Pulse Sequencer software allows using blank or CW fillers as the first segment of an overlay group and therefore allows to set a defined end point for the entire group. Besides adding waveforms to each other it is also possible to multiply waveforms. This is useful for blanking signals, e.g. when simulating radar waveforms.

The screen shot below shows an example of an overlay of three pulse entries.

Item	Mode	Tstart [us]	Tstop [us]	Samples	Pulse Object	Rep.	Jitter 1	Jitter 2	Jitter 3	Jitter 4	M 1	M 2	M 3	M 4
1	---	0.00	3000.00	150000	T -->| (blank filler)	0	---	---	---	---	OFF	OFF	OFF	OFF
2	ADD	0.00	2222.22	111111	radar TX	1	OFF	OFF	OFF	OFF	1ST	ALL	OFF	OFF
3	ADD	0.00	2222.22	111111	radar RX (echoes)	1	next	next	OFF	OFF	OFF	OFF	OFF	OFF
4	ADD	0.00	2222.22	111111	radar RX (echoes)	1	next	next	OFF	OFF	OFF	OFF	OFF	OFF

Fig. 34: Sequence with overlay entries

Line item 1 sets the entire time of the overlay group to 3 ms by creating a blank filler signal. The following items (2,3,4) are added to this blank signal starting at t = 0. Jitter is used to shift the items 2 and 3 slightly in time. The result is a series of 3 pulses.

6.4 Overlay Application Examples

6.4.1 Radar Antenna TX, RX Simulation

For radar receiver testing it might be desirable to generate signals that contain the transmit pulse as well as multiple receive pulses. In this case one sequence entry could be used to generate multiple repetitions of the TX pulse as they would be transmitted during one turn of a radar antenna. The following line items are set to overlay and add the receive pulse with a time delay, frequency offset or phase shift caused by jitter profiles. This allows generating complex pulse return patterns as they might be caused by multiple reflections or antenna side lobes.

6.4.2 Sector Blanking

Many radar systems blank their signals in certain sectors to avoid interference with other equipment. In order to simulate blanking one line item of the sequence could be set up to generate multiple repetitions of a pulse as it would result from one antenna turn without blanking. The next line item is set to overlay and multiplies a single on-off pulse that generates the blanking sector.

17 The Sequence View

After an ARB waveform is created from a sequence the resulting I/Q data can be viewed using the sequence view panel. This panel displays the final I/Q output as contained in the output waveform. The sequence view tab is only available if a waveform was created successfully. Selecting different entries from the project tree invalidates data and the sequence viewer becomes unavailable again. The sequence viewer is divided into multiple areas. The large upper area shows various signals, such as I and Q, amplitude, phase or frequency versus time. The lower left side is the I/Q constellation or density plot, depending on the number of samples that are analysed. The lower right area shows an FFT spectrum of the entire waveform or the currently viewed section (view port).

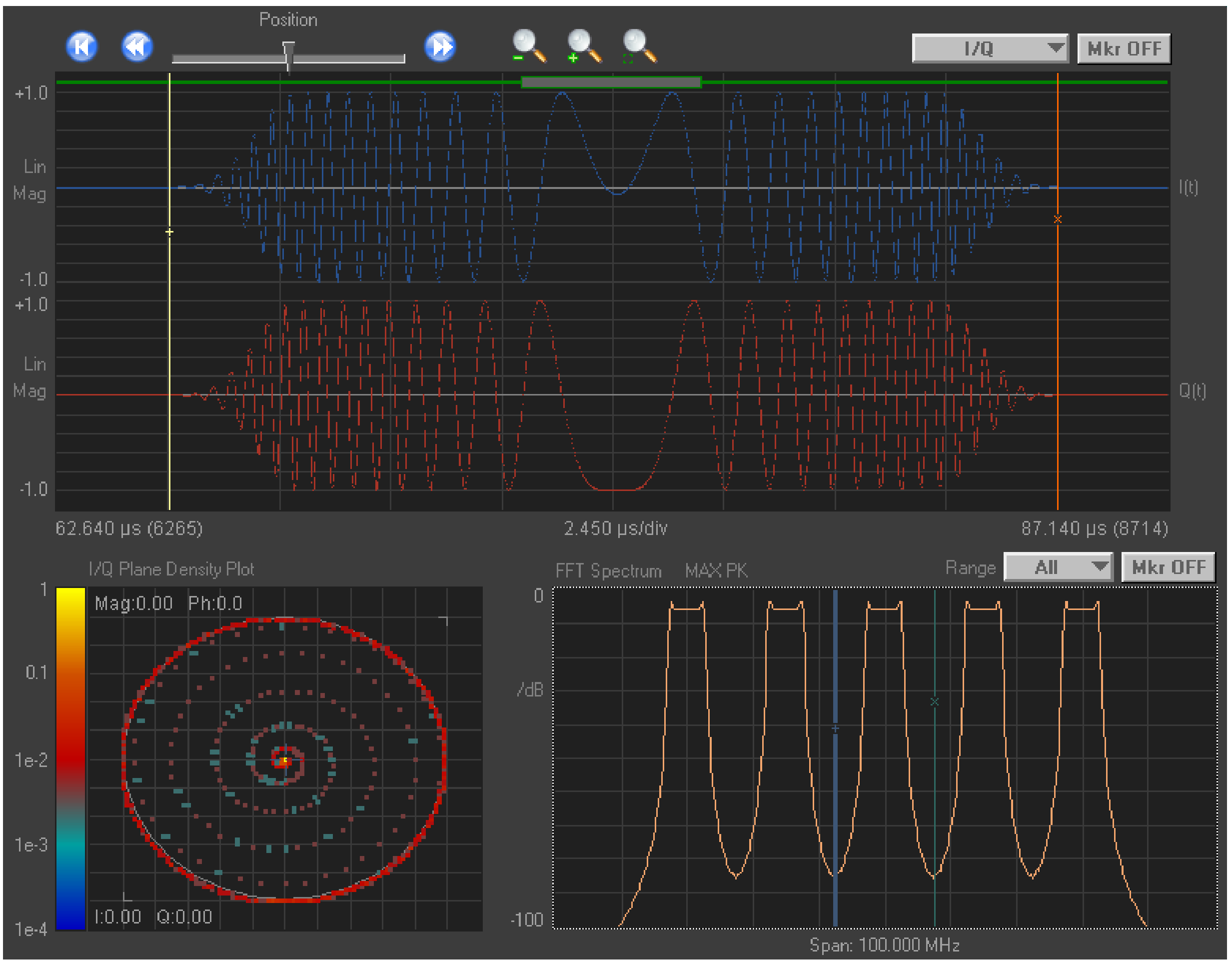


Fig. 35: Sequence view panel

6.5 Time Domain Display

The upper area is the time domain display and shows a signal versus time. This area is also referred to as the view port because it defines the section of the data looked at.
The way data is presented in the view port changes depending on the number of samples looked at. If the number of samples is greater than the number of screen points the view mode shows straight lines between the minimum and maximum value that falls within one screen point. This ensures that the full envelope is always visible. If the number of samples is lower than the number of screen points the Pulse Sequencer software shows individual sample points and connecting lines in between. The two pictures below demonstrate the difference when looking at a sine wave.

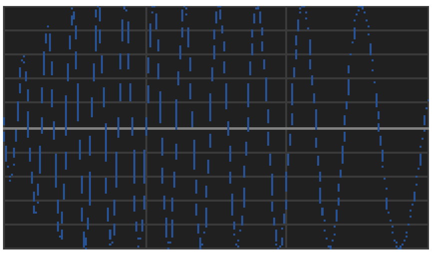


Fig. 36: Zoomed out

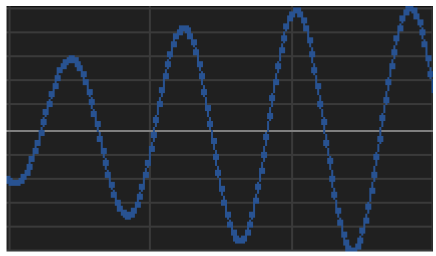
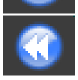
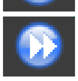


Fig. 37: Zoomed in

A set of navigation buttons are placed above the view port area. These buttons provide general navigation functions, such as moving to waveform locations, zooming in and out as well as zooming to a marked area.

 Move to the very beginning of the waveform.

 Move left by half the display length

 Move right by half the display length

Slider Reposition within the trace

 Zoom out by a factor of two

 Zoom in by a factor of two around the centre of the view port

 Zoom to the boundaries set by the two cursor lines

Two controls on the right side above the view port select the way data is represented and toggle the marker reading display. The different data representations are discussed below.

- **I/Q View**
  Sets the view port to display the I and Q signal versus time. Both signals use a linear scale in the range between -1.0 to +1.0.

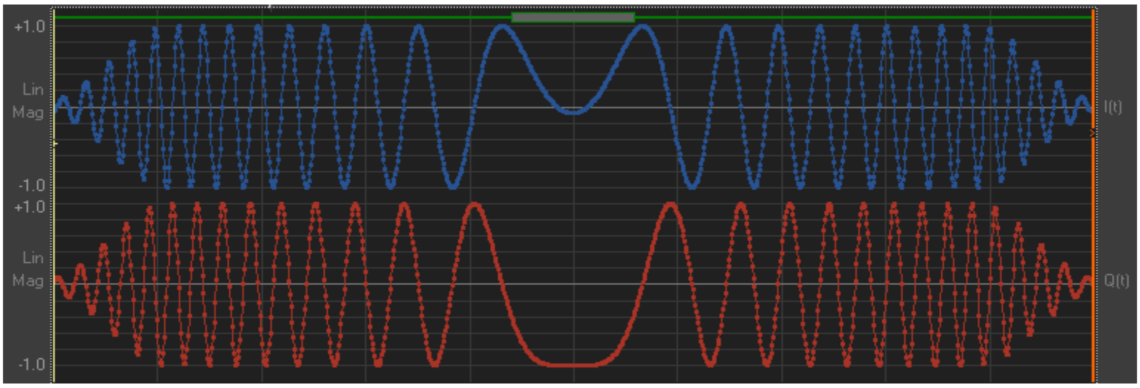


Fig. 38: I/Q waveform view of a chirped signal

This view shows the baseband output of the instrument as it would be accessible through the I and Q output connectors.

- **Polar View**
  The polar view displays the magnitude and phase angle of the signal versus time. The upper magnitude curve is scaled linear in the range from 0 to 1. The lower curve shows the phase in the range from -π to +π . A phase change is equivalent to a rotation at constant radius in the constellation diagram. The phase graph wraps around at the positive or negative borders

Fig. 39: Polar view of a BPSK modulated signal

- **Log Mag View**
  This view shows the pulse envelope in the logarithmic scale (20 log[sqrt(I^2+Q^2)]). The scale ranges from 0 dB down to -100 dB and covers the full 16 bit dynamic range of the vector signal generators internal ARB. This view mode can be utilized to see very low signal levels that would not be visible in the linear scale. The graphical representation of the envelope in the logarithmic scale can be compared to a scale typically used in Spectrum Analyzers in zero span mode (logarithmic scale).

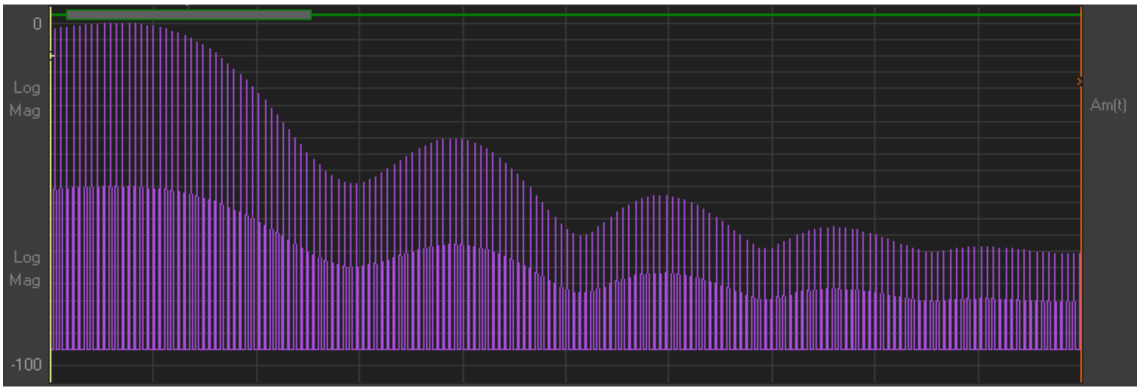


Fig. 40: Logarithmic view of pulse magnitudes

- **F(t), Am(t) View**
  This view shows the pulse envelope in logarithmic scale as well as the instantaneous signal frequency versus time. The frequency scale ranges from $-F_s/2$ to $+F_s/2$ with F_s being the ARB sampling rate.

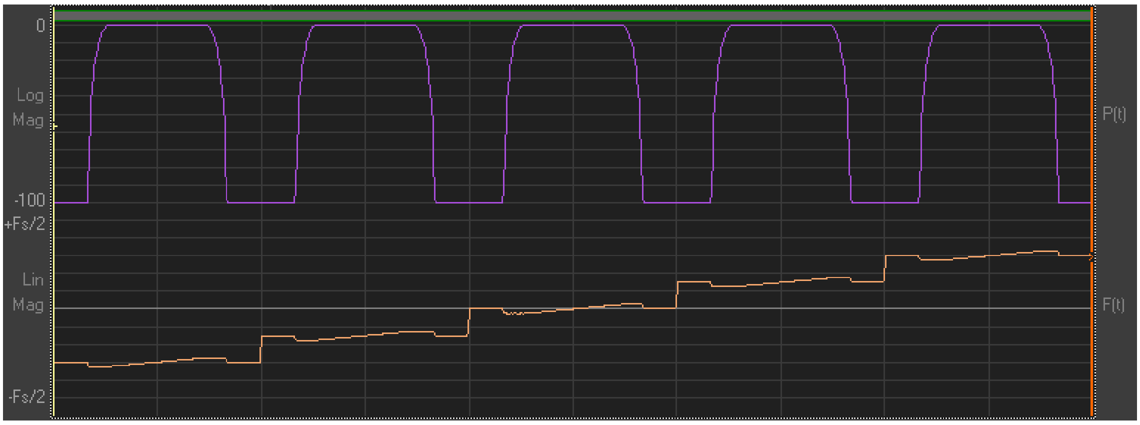


Fig. 41: Magnitude and frequency view of a series of chirped pulses

6.6 Marker (Cursor) Functions

The view port provides two vertical cursor lines that may be used for marker measurements or for defining the zoom range. Each cursor line provides its absolute position in time and the sample number that it is positioned on. In addition, the distance between the two lines is calculated and shown as time difference and frequency.
The marker readings can be enabled using the '**Mkr ON**' button.

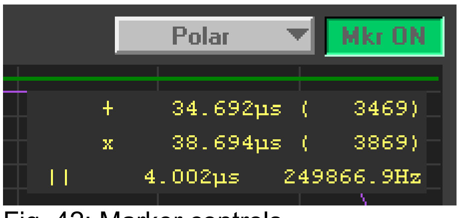


Fig. 42: Marker controls

6.7 I/Q Plane

The Pulse Sequencer software provides an I/Q plane display in the lower left area of the sequence view panel. The amount of data analysed and displayed in the I/Q plane is the signal part visible in the view port (time domain view). The representation of I/Q plane data depends on the amount of samples analysed. For a large number of samples a density plot is used with a colour scale from blue to yellow that indicates how often a sample is located at a certain I/Q constellation point. If the number of samples is relatively small the constellation points are displayed with interconnecting lines in between. In both view modes a small cursor is available and can be moved using the mouse. The cursor shows the current I and Q value as well as magnitude and phase.

- **I/Q Plane Vector Diagram**
  The vector diagram shows individual I/Q data points with connecting lines in between. This view is only available for a smaller amount of data because a large number of data points would create too many points and hide signal details. In the I/Q plane each sample must be displayed individually because averaging or min-max detection would create false data points. The grey circle marks the envelope level of 1.0. Clipping occurs if this limit is exceeded and therefore the circle indicates the maximum safe signal range.

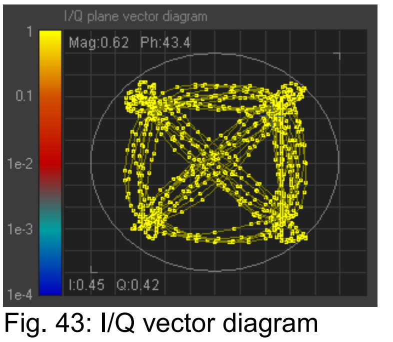


Fig. 43: I/Q vector diagram

- **I/Q Plane Density Plot**
  If a larger number of samples is analysed the Pulse Sequencer software automatically switches to a density plot. The density plot shows the probability at which I/Q points occur in the waveform. The display is relative to the point with the maximum probability (set to 1.0). In pulsed signals with long idle times this is often the origin of the coordinate system. The colour scale is logarithmic and ranges from 1.0 (bright yellow) down to a probability of 10^{-4} (dark blue). The scale on the left side is used as legend and explains the relationship between colours and probability.

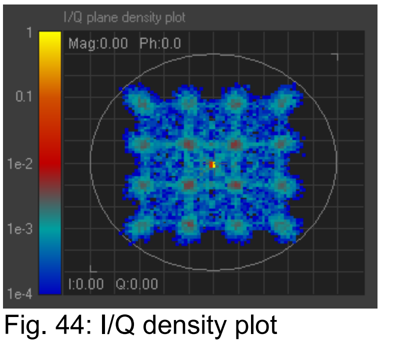


Fig. 44: I/Q density plot

6.8 FFT Spectrum

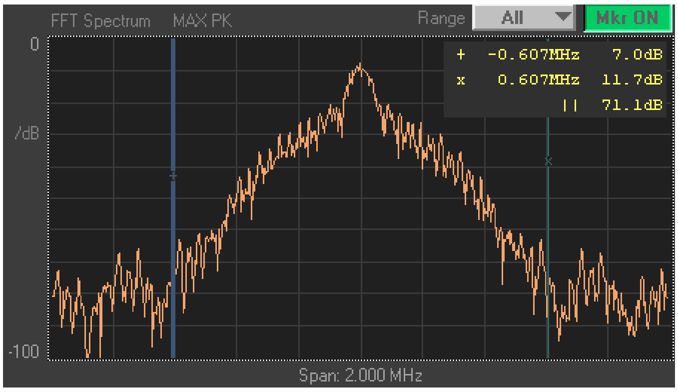


Fig. 45: FFT spectrum display

The Pulse Sequencer software displays the FFT spectrum of either the entire or a fraction of the signal in the lower right area of the sequence view. The FFT uses a logarithmic scale scale between 0 dB and -100 dB. The level scale is relative and automatically set based on the maximum signal amplitude. The frequency scale covers the ARB sample rate set for the sequence and ranges from $-F_s/2$ to $+F_s/2$. The amount of data analysed can be selected between the entire waveform and the view port content only. The amount of data that can be analysed in the FFT display is limited. For very large waveforms it might therefore be required to restrict the FFT display to the view port section only. The FFT view remains blank if the amount of data exceeds the FFT length limit.

18 The Transfer Panel

Once an ARB waveform is created from a sequence it can be transferred to the instrument. The transfer panel is used to perform this task. It also provides basic instrument control features that are required for waveform playback and signal routing.
The panel is divided into three major sections that slightly differ in colour. The top section displays the local waveform file name (source file) as well as information about the target instrument.
The middle section sets the target ARB and defines signal routing as well as basic RF parameters.
The lower section contains buttons that reset the instrument and start the waveform transfer.

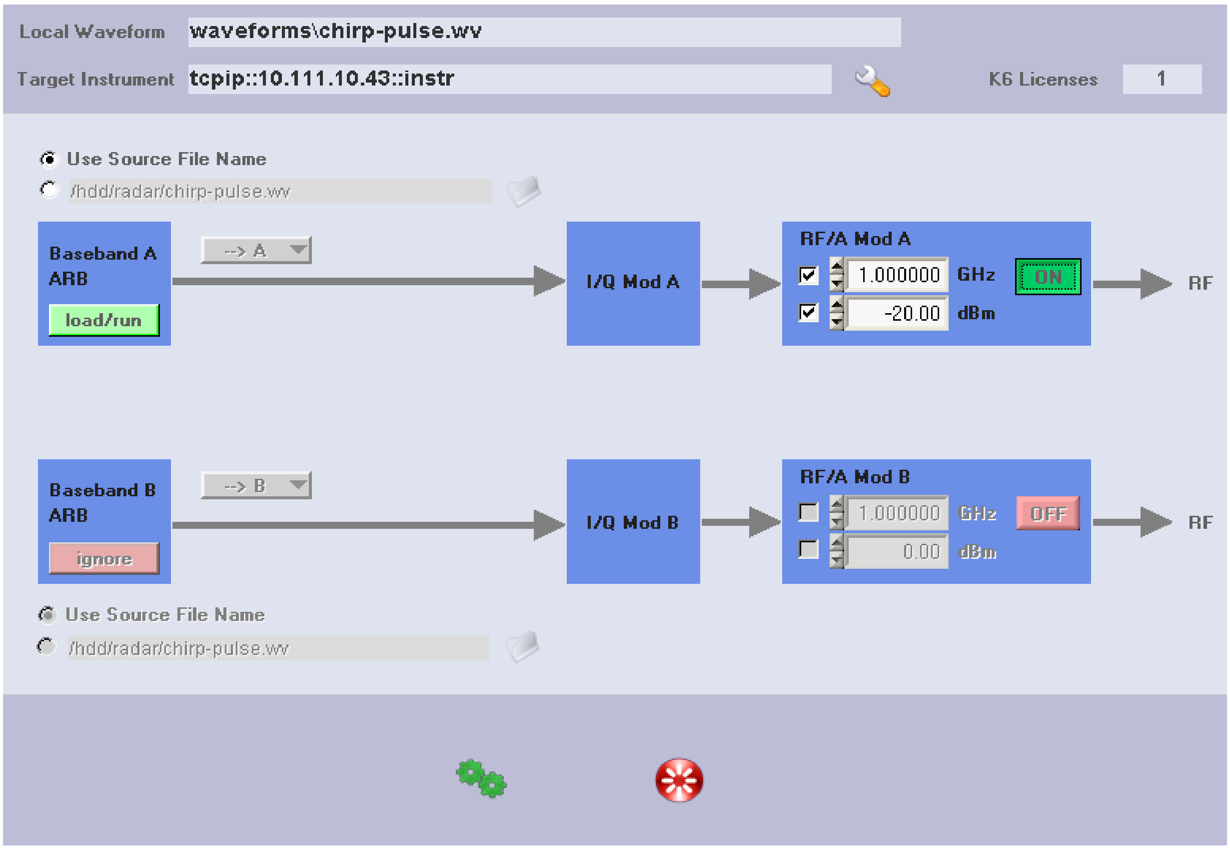


Fig. 46: Transfer panel

Local Waveform
This field contains the local waveform file name. The name is automatically filled in during the process of building a waveform from a sequence. This field cannot be edited and is blanked once a different entry from the project tree is selected.

Target Instrument
The field contains the target instruments VISA resource string. This field is automatically filled in when an instrument is selected on the Instrument Manager panel. The name of the target instrument is cleared if the instrument becomes unavailable.

Instrument Manager Button
This button opens the Instrument Manager panel which is used to select the target instrument.

K6 Licenses
Once an instrument link is set-up the K6 license count is determined by evaluating the instruments option string. Your instrument requires at least one K6 license for playing back an ARB waveform that is generated by the Pulse Sequencer software.
Two-path instruments may be equipped with a single or two K6 licenses. In case of only one license the waveform can either be played in path A or B. Two K6 licenses allow the playback of two waveforms simultaneously in path A and B.
The R&S WinIQSIM2™ software can be used to combine multiple Pulse Sequencer waveforms to a multi carrier or Multi-Segment waveform. In this case the license requirements mentioned above apply to the WinIQSIM2™ output file.

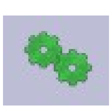
Use source file name
The Pulse Sequencer software automatically uses the waveform file name as set in the sequence editor and shown in the upper panel section. It combines this file name with the target directory set under '*Options → Preferences → Waveform Creation*' to an absolute file name used as target on the instrument. The Pulse Sequencer software uses the Linux or Windows path based on the selected target instrument. This is the simplest and recommended setting for transferring the waveform to the instrument.

Manual entry
The target file name for the waveform transfer can be specified by the user. This allows using the same file name for all generated waveforms, e.g. for testing purpose. In addition, an instrument file browser button allows the simple selection of an instrument target directory.
When using the manual entry field it is recommended to provide an absolute path, e.g. 'D:\MyFiles' for a Windows based instrument.
On Linux based instruments the path depends on hardware options. A valid standard path is /var/<instrtype>, e.g. /var/smbv for an R&S SMBV100A. If the hard disk option is available the standard path is /hdd regardless of the instrument.

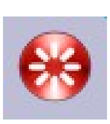
Baseband A,B
The baseband button changes its state between '*ignore*', '*load*' and '*load/run*' with each mouse click. Use this button to define the action that is to be performed when the '*Transfer and Configure*' button in the lower panel section is pressed.

Routing
This selection can be used on two-path instruments to define the routing of the baseband signals. A single path instrument only provides path A and uses a fixed routing.

RF Controls
The RF controls set the RF frequency, the output level and the output state of path A or B. The check boxes define if the frequency or level value is applied or be left unchanged. If neither frequency nor level is activated the entire RF section remains unchanged. The state of the RF output signal is set by the ON/OFF button.



Transfer and Configure
The button sends the selected waveform file(s) to the instrument and configures both paths as required.



Reset
Resets the instrument to a default state.

19 Multi-Segment Waveforms

The Pulse Sequencers project tree lists all Multi-Segment waveforms that belong to the current project. Clicking on a Multi-Segment waveform entry opens the editor panel.
New MSWs are created by selecting '*Create → New Multi Segment*' from the menu bar. This adds a new MSW description to the project tree and opens the MSW editor panel.
Multi-Segment waveforms contain a set of regular ARB waveforms with additional control information that permits arbitrary jumps between these segments.
Assembling Multi-Segment waveforms is an automated process and consists of the following steps.

- Create one a waveform from a sequence description
- Transfer the resulting waveform file to instrument
- Delete the local waveform file
- Append the waveform to the MSW description
- Repeat the above steps for all waveform segments
- Build the Multi-Segment waveform on the instrument
- Optionally build a sequencer list for the Multi-Segment waveform
- Configure the instrument for the MSW playback

All the above steps can be executed automatically by the Pulse Sequencer software.

6.9 General MSW Settings

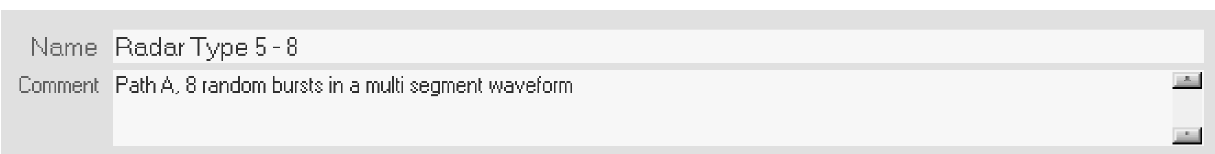


Fig. 47: General MSW settings

Name
Sets the name of the Multi-Segment waveform. This name is used for reference in the project tree and does not affect the waveform itself. Use unique names to identify the MSW in the project tree.

Comment
An optional comment field may be used to add explaining text to the MSW definition.

6.10 MSW Editor

The Multi-Segment waveform editor mainly consists of a table that defines the sequences which are contained in the Multi-Segment waveform file. Additional controls are provided to create or delete entries as well as for changing their order.

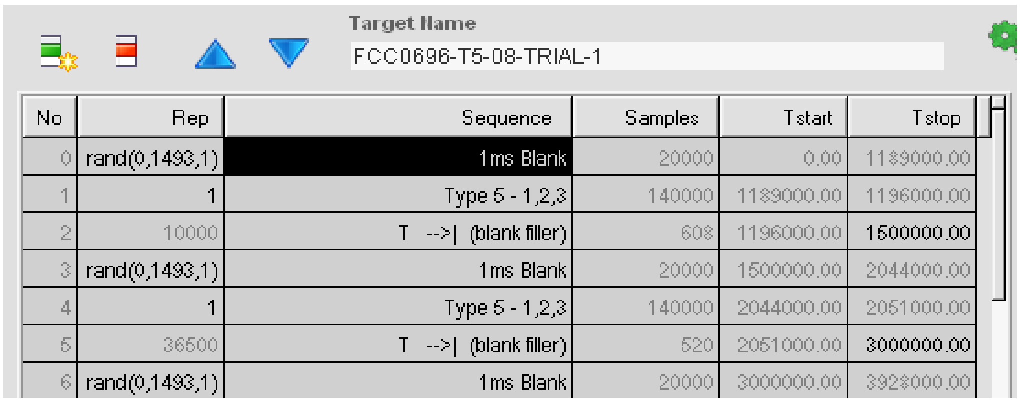
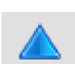


Fig. 48: MSW editor

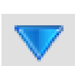
Target Name
The target name defines the name of the Multi-Segment waveform file on the instrument. When the MSW is created on the instrument the Pulse Sequencer uses the path set in the project preferences dialog (Menu '*Options → Preferences → Project Settings*').

New Entry
Creates a new line item in the MSW editor. Each line item references a sequence from the project tree. All line items are processed and appended to the MSW in the order they are listed. If a line item is selected the button creates a copy of the selection and inserts it after the selected line. If no line item is selected a new entry is appended at the end of the list.

Delete Entry
The button deletes a selected line item from the list. Deleting a line item does only affect the MSW and not the sequence that is removed.



Move Entry Up
This button moves a selected line item up by one position. The first line item cannot be moved further up and remains at its position.



Move Entry Down
This button moves a selected line item down by one position. The last item cannot be moved further down and remains at its position.

No
This column contains the zero based index number of the waveform segment. The index number is read only and only provided for reference.

Rep
The repetition count can be set if the Multi-Segment waveform is operated in sequencer mode. In this case a segment can be repeated multiple times. The entry can either be a numeric value in the range between 1 and 65536 or a random value. For random values the following expression must be used:

```
rand(<min value>,<max value>,<step size>)
```

Sequence
This column selects the sequence that is used for this Multi-Segment waveform entry. All sequences that are part of the project are available. Additionally, a blank filler waveform can be selected and adds blank signal until a definable point of time.

Samples
The sample column is read only and contains the final sample count of the sequence once it has been created. The sample count can only be determined during calculation because jitter may change the waveform length.

T_{start}
This column is read only and contains the final start time of the entry if sequencing is enabled.

T_{stop}
This column is read only for regular sequences and contains the stop time of the entry if sequencing is enabled. For blank filler segments this entry can be edited and contains the desired stop time in µs.

6.11 Building Multi-Segment Waveforms

The right side of the MSW editor contains two sections. The upper section provides settings that are required for the MSW generation process. Since MSWs are generated directly on the instrument it is required to set-up the instrument link before attempting to build the MSW.

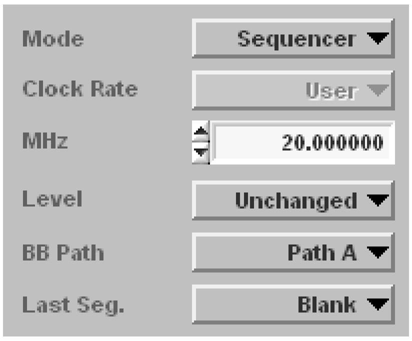


Fig. 49: MSW build settings

Mode
The build mode can be selected between '*Sequencer*' and '*Regular*'. In the sequencer mode an additional sequencer list is created and the entire Multi-Segment waveform is played automatically. This mode is useful if waveforms with long blank times need to be created. In this case blank fillers may be used and the Pulse Sequencer Software automatically determines an optimum waveform length and repetition count for the blanks segment. The regular mode adds the waveform segments but the user must switch the segments either via the user interface or via remote control.

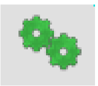
Clock Rate
The Clock Rate setting sets the target sample rate when the MSW is created on the instrument. If '*unchanged*' is selected the instrument leaves the sample rates of the individual segments unchanged. When the MSW is played back the sample rate will therefore change from segment to segment. If '*highest*' is selected the instrument re-samples all segments to the highest sample rate used in the MSW. The '*user*' setting sets a target sample rate to a fixed value. All segments are re-sampled to this target sample rate during the MSW creation process. Building a MSW takes more time when re-sampling is required.
In sequencer mode this setting is forced to '*user*' and a target clock rate must be provided.

Level
During the MSW creation the instrument can also adjust the level of MSW sections. The '*unchanged*' option does not change the level and adds segments unchanged to the final MSW. The '*equal RMS*' option rescales the segment to ensure that all segments use the same RMS signal level.

BB Path
This entry selects into which path the final MSW is loaded.

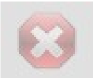
Last Seg.

In sequencer mode this option selects what happens after the last segment has been played. 'Back 1st' restarts the waveform playback at the beginning. 'Endless' repeats the last segment continuously. 'Blank' generates blank signal continuously.



Batch Build

The button starts the build process of the MSW. The process may take some time depending on the segment lengths and the number of segments but it fully automates the creation of all segments, transfer to the instrument and MSW assembly. The button is only available if an active instrument connection exists, the instrument is able to generate MSWs, and the MSW name is set.



Interrupt Build Process

The build process can be interrupted using this button. If building the Multi Segment Waveform is stopped prematurely no waveform is generated and the process nedds to be started again.

Note:

The firmware of the AFQ100A and AFQ100B does not support assembling Multi-Segment waveforms. This task is usually done using WinIQSIM2 when operating this instrument.

6.12 Operating Multi-Segment Waveforms

The lower right section of the MSW editor panel contains controls that are used to remote control the instrument when playing back Multi-Segment waveforms. An active instrument link is required in order to operate these controls.

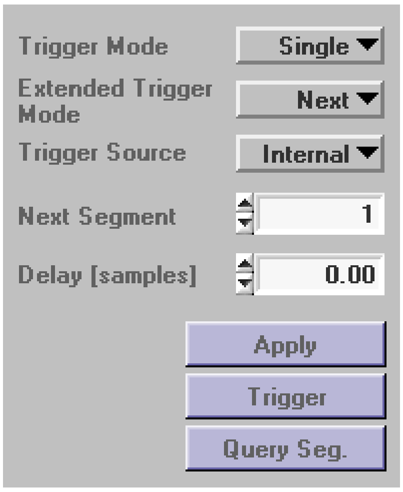


Fig. 50: MSW operation controls

Trigger Mode
The trigger mode defines the basic trigger operation mode. If '*Auto*' is selected the instrument automatically plays back a section or multiple sections of a Multi-Segment waveform. In the '*Single*' mode the waveform or segment is only played once. The Extended Trigger Mode defines if only a section or the entire MSW is affected by the trigger setting.

Extended Trigger Mode
This entry selects if only a segment or the entire MSW is affected by the trigger signal. '*Same*' sets the instrument to replay the selected segment based on the selected trigger mode. '*Next*' advances to the next MSW entry with each trigger event. '*Seamless*' is only available if all segments use the same sample rate and plays one segment after the other without any interruption.

Trigger Source
Selects the trigger source for the MSW playback. Valid choices are '*Internal*', '*Exxt1*', '*Ext2*' and '*Path2*'.

Next Segment
Selects the segment that gets selected when the 'Apply' button is pressed.

Delay [samples]
Sets a trigger delay in samples between a trigger event and the start of the MSW playback.

Apply
This button sends all of the above settings to the instrument. It also selects the current waveform segment. During the apply process the RF output of the instrument is turned off. This eliminates the accidental output of an RF signal.

Trigger
This button becomes active if an instrument connection is set up and the trigger source is set to '*Internal*'. If the trigger mode is set to '*Single*' and '*Next'* this button is used to manually start the playback of the next segment.

20 RF Lists

RF Lists only affect the RF section of the instrument. These lists can be used independently of any type of modulation and provide a hopping functionality across the entire instrument frequency and level range. The benefit of using RF Lists over remote control is mainly speed since RF Lists use precomputed instrument settings that allow for fast setting changes.
Typical switching times are in the range of 400 µs. Please see the instrument manual for further information about operating RF Lists.
The Pulse Sequencer software contains RF Lists as part of a project and simplifies the creation process.
New RF Lists are created by calling '*Create → New RF List'* from the menu bar. This adds a new RF List entry to the project tree and opens the RF List editor.

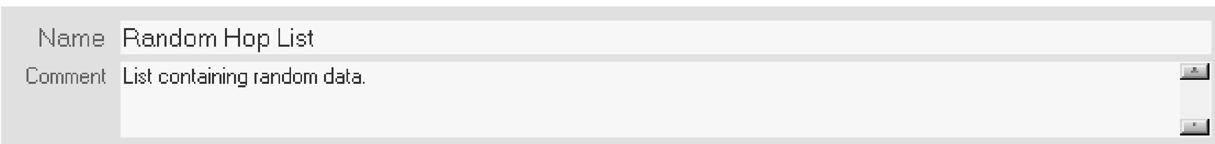


Fig. 51: General RF List settings

Name
Sets the name of the RF List. This name is used for reference in the project tree and does not affect the list itself. Use unique names to identify the RF List in the project tree.

Comment
An optional comment field may be used to add explaining text to the RF List definition.

New RF Lists have zero length and contain no items. As a very first step it is therefore required to define the list length which creates the necessary blank entries in the list editor table.

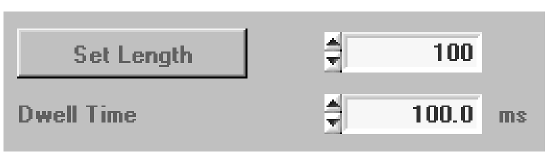


Fig. 52: RF List settings

Set Length
Sets the RF List length to the given number of list items. New items are automatically set to 1 GHz and -30 dBm. Please consult your instrument manual for the maximum RF List length of your instrument.

Dwell Time
Sets the dwell time for the RF List playback. The dwell time sets the duration of each frequency and level pair when the list is played back.

The RF List editor provides a table that contains the frequency and level pairs of the RF List. An entry can be edited by double clicking into the field. In addition, limits can be set to mask items that fall within the limit range. These items are marked green in the list.

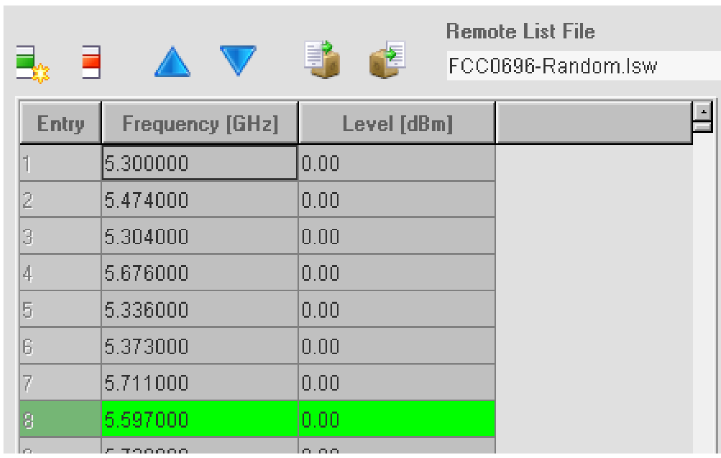
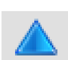


Fig. 53: RF List editor

Delete
The button deletes a selected line item from the RF List.

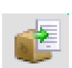
Add
Insert a new entry into the RF List.



Move Entry Up
This button moves a selected line item up by one position. The first line item cannot be moved further up and remains at its position.

Move Entry Down
This button moves a selected line item down by one position. The last item cannot be moved further down and remains at its position.

Import
The import button reads list entries from an ASCII text file. The frequency and level pairs must be separated in columns.



Export
The export button writes the RF List data to a text file. The file contains a header as well as the frequency and level pairs. The last column compares the frequency and level values against the set limits and marks the line items with pass (P) or fail (F) indicators.

```
Project : FCC 15.407 / FCC-060-96A
Author  : Rohde & Schwarz
Date    : Nov 11, 2008
Version : 2.0.0

RF List : Random Hop List

Lev min : 0.00
Lev max : 0.00
F   min : 5.592500
```

```
F   max : 5.607500

Entry    Frequency [MHz]        Level [dBm]      Limit
=====================================================
    1           5.300000               0.00          F
    2           5.474000               0.00          F
    3           5.304000               0.00          F
    4           5.676000               0.00          F
    5           5.336000               0.00          F
    6           5.373000               0.00          F
    7           5.711000               0.00          F
    8           5.597000               0.00         P
    9           5.720000               0.00          F
```

The Pulse Sequencer software provides a dialog that is used to populate the RF Lists with default values. Frequency and level can be controlled separately.

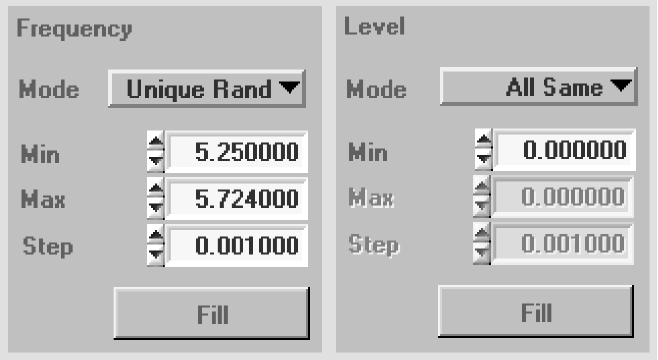


Fig. 54: Filling an RF List

Mode
The mode selection defines how the Pulse Sequencer software populates the RF List. The option '*All same*' uses the set value for all list entries. '*Uniform*' fills the list with random data. The minimum and maximum value as well as a step size can be defined. The option '*Unique Random*' populates the list with random values but it is ensured that each random value only appears once.

Fill
The button fills in the frequency or level values.

Once the RF List is populated its contents can be compared against two sets of limits. Values that are within the limit range are marked green. The limits do not affect the RF List playback.

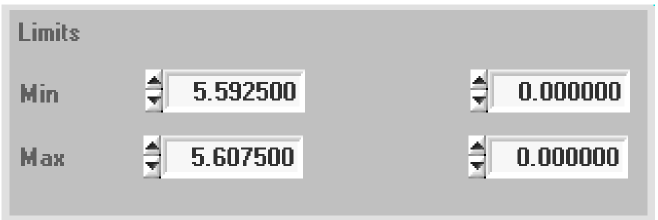


Fig. 55: RF List limit settings

Min / Max
The values define the minimum and maximum limit range for level or frequency. Any change is effective immediately and matching items are marked in green.

The Pulse Sequencer software keeps RF List data as part of the project. However, this data is not the final RF List because these lists can only be created directly on the instrument. The process of creating the RF List therefore requires an instrument connection and an instrument that supports RF Lists.

The panel at the bottom of the RF List editor provides all controls that are required to transfer the data to the instrument and build the list.

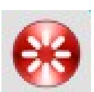
Fig. 56: RF List transfer controls

Remote List File
Set the file name of the RF List (.lsw) on the instrument. If no pathname is provided the Pulse Sequencer software uses the default path that are defined in the project settings dialog . This dialog is available from the menu bar under '*Options → Preferences → Project Settings*'.

Remote File Selection
The button opens a remote file browser which allows to select a pathname or file on the instruments file system. This dialog can also be used to copy files from the instrument to the local file system.

Path
Selects the target path for the RF List in case a two-path instrument is connected.

Start Transfer
The button transfers the list data and builds the RF List on the instrument.



Reset
This button resets the instrument to the default state.

Please Note
Once all RF List data is copied to the instrument and the '*Activate*' option is enabled the instrument starts a learning process. This learning mechanism involves a baseband pre-set to a sine wave test signal. RF Lists should therefore be transferred to the instrument before the baseband is configured.

21 The Log Panel

The log panel records status messages that the Pulse Sequencers software generates. The log panel is always available as the right most tab in the main application window. All log messages are read only but data can be marked and copied to the clipboard using Ctrl-C. The log panel output is useful to determine the cause for an error or unexpected program behaviour. It also displays all SCPI communication between the Pulse Sequencer software and the instrument.

22 Plug-in Modules

Plug-ins can be used to extend the Pulse Sequencers built in modulation capabilities. Some example plug-ins are provided with the software as binary and source code and may serve as a starting point for own applications. The following sections discuss the plug-in mechanism in more detail and provide information on the programming interface.

6.13 The Plug-in Mechanism

Plug-ins are Microsoft Windows DLLs and need to be located in the sub directory *Plugins* under the installation directory of the Pulse Sequencer software. This sub directory is searched during program start and useful plug-ins are loaded into memory for later use.
Every plug-in needs to provide a certain range of functions to identify itself and perform the calculations required for the intra-pulse modulation. These functions are described further in the programming API section of this manual. In addition, plug-ins may register a set of configuration parameters with the Pulse Sequencer software. These parameters become part of a pulse definition and may be used as variables inside the plug-in. This allows to reuse plug-ins with different configurations.
Plugins can also be used for report generation during the waveform creation process. This mechanism allows the user to create custom report data, e.g. to fill in EXCEL spread sheets with the pulse parameters that were used.

6.14 The Programming API

The following paragraph lists all functions that need to be provided by the plug-in. It explains the interface as well as the functionality that needs to be provided by each function.

6.14.1 Get Type

void __declspec(dllexport) __cdecl mod_type (char szModType[1024]);
This function is mandatory. It provides a string that is used to determine the purpose of the plug-in.

Parameters:

szModType	out	"modulation" the plug-in is used for intra pulse modulation "report" the plug-in is used for report generation

6.14.2 Get Version

void __declspec(dllexport) __cdecl mod_ver (char szModVer[1024]);
This function is mandatory. It shall return the version string of the plug-in.

Parameters:

szModVer	out	Format: X.Y.Z where X,Y and Z are numeric values, e.g. 2.34.01

6.14.3 Set Name

void __declspec(dllexport) __cdecl mod_name (char szModName[1024]);

This function is mandatory. It provides the Pulse Sequencer software with the name of the plug-in. The name serves multiple purposes. It is used to reference the plug-in from a pulse descriptions and it is used in the project tree to identify the plug-in. Particularly, the first statement requires that plug-in names are unique and do not change at a later time. If the plug-in name changes the pulse definition becomes invalid and the pulse cannot be calculated any more.

Parameters:

szModName	out	Plug-in Name. Must not be an empty string. Name must be unique.

6.14.4 Get Comment / Explanation

void __declspec(dllexport) __cdecl mod_comment (char szModComment[4096]);

This function is mandatory. It is used to return explaining text regarding the plug-in functionality.

Parameters:

szModComment	out	String with explaining text. Multiple lines are possible. May be an empty string.

6.14.5 Get Author

void __declspec(dllexport) __cdecl mod_author (char szModAuthor[1024]);

This function is mandatory. It is used to return information about the author of a plug-in.

Parameters:

szModAuthor	out	String with author information. May be an empty string.

6.14.6 Get Error

void __declspec(dllexport) __cdecl mod_error (char szModError[1024]);

This function is mandatory. It is called from Pulse Sequencer whenever another function returns *false* and may return additional error information.

Parameter:

szModError	out	Explaining error text. It is suggested to clear any internal error text after is it queried through this function.

6.14.7 Initialization

int __declspec(dllexport) __cdecl mod_init (void);

This function is used to initialize the plug-in. It is called once after the plug-in is loaded into memory and may set-up internal variables.

Return:

	true	The initialization completed successfully
	false	Error during the initialization. The plug-in is removed from memory.

6.14.8 Shutdown

void __declspec(dllexport) __cdecl mod_shutdown (void);

This optional function is called when the main application terminates and may be used to clean up previously allocated memory. Errors are not evaluated any more since the plug-in shutdown happens at a relatively late stage during the Pulse Sequencer termination.

6.14.9 Setup Parameters

*void __declspec(dllexport) __cdecl mod_setparam (const char *szType,*
*void *pData);*

This function is mandatory. It is called multiple times just before a pulse calculation starts and provides the plug-in with all required information.

szType	**pData Type**	**Bytes**	**Purpose**
trise	integer	4	Sample count for rising edge
ton	integer	4	Sample count for on-time
tfall	integer	4	Sample count for falling edge
srate	double	8	ARB sampling rate [Hz]
levon	double	8	Level during on-time, range 0 … 1.0
levoff	double	8	Level during off-time, range 0 … 1.0
levdroop	double	8	Level droop during on-time, range 0…1.0
mbits	char	10001	Bits used for modulation, string, max. 10000 ASCII ‚1’ or ‚0’
done	NULL		Last data was sent. Configuration is complete
filename	string	255	File name of report file
en_pdelay	integer	4	Enable pulse delay time for report
en_prise	integer	4	Enable pulse rise time for report
en_pon	integer	4	Enable pulse on time for report
en_poff	integer	4	Enable pulse off time for report
en_pprfpri	integer	4	Enable pulse PRF or PRI for report
en_fofs	integer	4	Enable frequency offset for report
en_phofs	integer	4	Enable phase offset for report
en_levon	integer	4	Enable level attenuation 'On' for report
en_levoff	integer	4	Enable level attenuation 'Off' for report
en_levdroop	integer	4	Enable level droop for report
en_fmdev	integer	4	Enable FM deviation for report
en_startt	integer	4	Enable pulse start time for report
en_seqno	integer	4	Enable sequence entry number for report
en_filler	integer	4	Enable filler time for report
en_repcnt	integer	4	Enable repetition count for report
en_repno	integer	4	Enable number of repetitions for report
en_msegno	integer	4	Enable multi segment number for report

It is not required to take any action inside this function nor is a return value required. It is up the author of the plug-in what to do with the provided information.
If information needs to be evaluated the function should compare the strings provided in szType against the names listed above. In case of a match the pointer pData needs to be type cast into the appropriate data type and the value read.

6.14.10 Set Values

*void __declspec(dllexport) __cdecl mod_setvalue (const char *szType, void *pValue);*

This function receives report data during the waveform creation process. It must be used to collect this data and write all relevant report data when the 'finishentry' option is called.

szType	**pData Type**	**Bytes**	**Purpose**
initreport	NULL		Start a new report, open files etc.
initentry	NULL		Start of a new entry, initialize etc.
set_seqname	string	1024	Set the sequence name
set_comment	string	4096	Set the sequence comment
set_filename	string	1024	Set the sequence file name
set_clock	double	8	Set the sequence ARB sampling rate
set_pdelay	double	8	Set pulse delay time for report
set_prise	double	8	Set pulse rise time for report
set_pon	double	8	Set pulse on time for report
set_poff	double	8	Set pulse off time for report
set_pprfpri	double	8	Set pulse PRF or PRI for report
set_fofs	double	8	Set frequency offset for report
set_phofs	double	8	Set phase offset for report
set_levon	double	8	Set level attenuation 'On' for report
set_levoff	double	8	Set level attenuation 'Off' for report
set_levdroop	double	8	Set level droop for report
set_fmdev	double	8	Set FM deviation for report
set_startt	double	8	Set pulse start time for report
set_seqno	double	8	Set sequence entry number for report
set_filler	double	8	Set filler time for report
set_repcnt	double	8	Set repetition count for report
set_repno	double	8	Set number of repetitions for report
set_msegno	double	8	Set multi segment number for report
finishentry	NULL		End of current entry, write data to report
closereport	NULL		End of report generation, close files etc.
endreport	NULL		As above but do not quit

6.14.11 Plug-in Modulation Engine

*int __declspec(dllexport) __cdecl mod_engine (double *dAM, double *dPhase, int iActSample);*

This function is mandatory. It is the core function of the plug-in and transforms samples into I/Q data.
Parameters:

dAM	out	Amplitude, range 0 ... 1.0
dPhase	out	Phase, range –Pi ... +Pi
iActSample	in	Sample number. The number always starts at zero with the very first sample of the rising edge.

Return:

TRUE	Calculation was successful
FALSE	Error during calculation. Pulse Sequencer subsequently calls the error string function and terminates any further calculation.

It is required that this function returns useful numbers for amplitude and phase.

6.14.12 Plug-in Modulation Engine 2

```
int __declspec(dllexport) __cdecl mod_engine _2(char *pcMkr,
                                               double *dAM,
                                               double *dPhase,
                                               int iActSample);
```

This function is optional and can be used instead of the classing modulation engine. It is the core function of the plug-in and transforms samples into I/Q data.

Parameters:

pcMkr	out	Marker data
dAM	out	Amplitude, range 0 ... 1.0
dPhase	out	Phase, range –Pi ... +Pi
iActSample	in	Sample number. The number always starts at zero with the very first sample of the rising edge.

Return:

TRUE	Calculation was successful
FALSE	Error during calculation. Pulse Sequencer subsequently calls the error string function and terminates any further calculation.

It is required that this function returns useful numbers for amplitude and phase.

6.14.13 Query Plug-in Configuration Parameters

```
int __declspec(dllexport) __cdecl mod_getconf (int iIndex,
                                                char szType[256],
                                                char szName[256],
                                                void *pDefaultVal,
                                                void *pMin,
                                                void *pMax);
```

This function is optional. It may be used to register configuration parameters with the Pulse Sequencer software.

Parameter:

	iIndex	in	Index number of parameter, starting at zero
	szType	out	parameter data type identifier
	szName	out	name string associated with parameter
	pDefaultVal	out	pointer to default value
	pMin	out	pointer to minimum value
	pMax	out	pointer to maximum value

For the default, minimum and maximum value settings the Pulse Sequencer software provides the function with a pointer that could hold up to 1024 bytes. The functions needs to type cast this pointer to the required data type.

Available Data Types:

szType	Data Type	Bytes	Precision	Purpose
DBL	double	8	3	double precision value
DBL6	double	8	6	double precision value
INT	integer	4	0	integer value
BOOL	integer	4	0	boolean value (yes, no)
STR	string	255	0	zero terminated string

6.14.14 Setting Plug-in Configuration Parameters

int __declspec(dllexport) __cdecl mod_setconf (int iIndex,
*void *pDat);*

The function is optional but needs to exist if plug-in parameters were registered with the Pulse Sequencer software. It is used to set configuration parameters before a pulse calculation is started. All configuration values are referenced to by the index that was used when requesting parameters from the plug-in.

Parameters:

iIndex	in	Index of configuration parameter, starting at zero
pDat	in	Data from Pulse Sequencer. The pointer needs to type casted into the correct data type.

Return:

true	Parameter was set successfully.
false	An error occurred setting the parameter. Pulse Sequencer does subsequently query the plug-in error string and stop all further processing.

23 Sample Rate Considerations

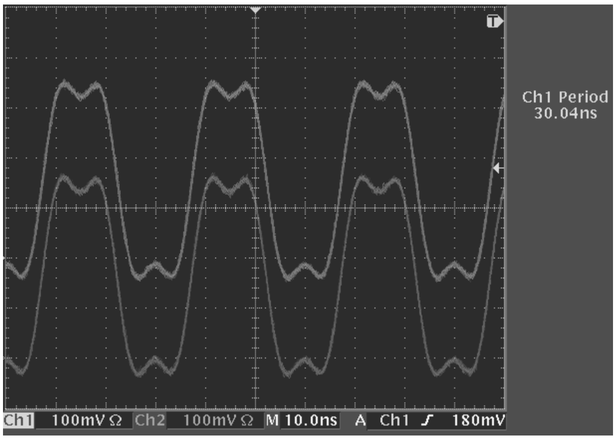
This paragraph discusses issues that may arise from false sample rate settings. It gives advice for correct settings and points out limitations for pulse timing and other parameters.
The R&S Pulse Sequencer is not directly dependant on the actual instrument when rendering waveform data. It therefore allows to use parameters within wide ranges event if the actual instrument is not capable of playing back the waveform file correctly. This behaviour is implemented intentionally to allow room for future hardware and provide means for experimentation with settings. However, special care must be taken and basic understanding of the ARB operation is required to determine optimum settings.

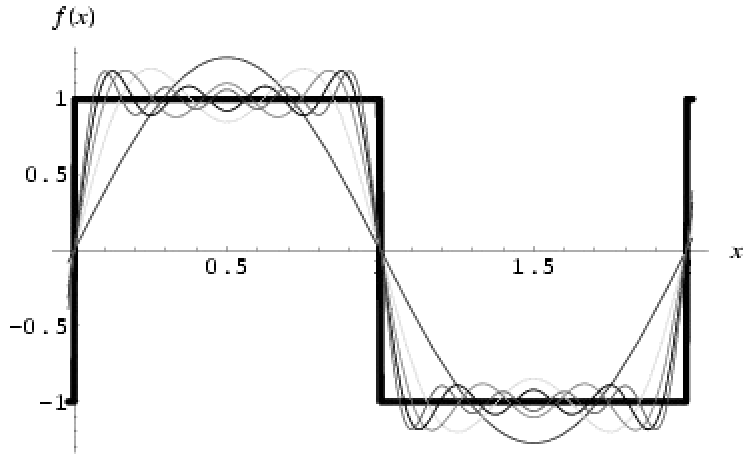
6.15 Minimum Pulse Width

The minimum pulse width is determined by the bandwidth of the instrument I/Q modulator. An AFQ100A for example is rated at 100 MHz of maximum I/Q bandwidth. This bandwidth translates into 1 / 100 MHz = 10 ns period time. This number must be regarded as the shortest possible time at which a waveform of alternating zeros and ones playing back at 200 MHz generates a perfect sine wave.

In most cases pulses require defined shapes for their rising and falling edge, e.g. trapezoid or cosine. In this case a series of harmonics are required to achieve the desired shape. The quality of the shape increases with the number of harmonics that are available and thus the useful bandwidth decreases by the same amount.

The example below shows the I and Q output (into 50 Ohm load) of an AFQ100A playing back a waveform at 200 MHz ARB sample rate. The waveform consists of three alternating ones and zeros which generates a period time of 30 ns. Since the maximum bandwidth of the instrument is 100 MHz (10 ns) we can make use of frequencies up to the third harmonic.





The figure shows a Fourier series of a square wave and can be described by the following equation:

$$f(x)=\frac{4}{\pi}\sum_{n=1,3,5,\ldots}^{\infty}\frac{1}{n}\sin\left(\frac{\pi nx}{L}\right)$$

It can be seen that even providing the 7th harmonic does not generate a very good square wave. This basic maths should be taken into consideration when designing very short pulses or considering fast rise or fall times.

6.16 Timing Error

Timing is a discrete number when dealing with ARBs where the clock rate defines the granularity on the time axis. An AFQ100A for example is specified at a maximum ARB sample rate of 300 MHz. This maximum sample rate results in a timing granularity of 1 / 300 MHz = 3.333 ns. R&S Pulse Sequencer computes the number of samples from the timing figures as well as the clock rate setting.

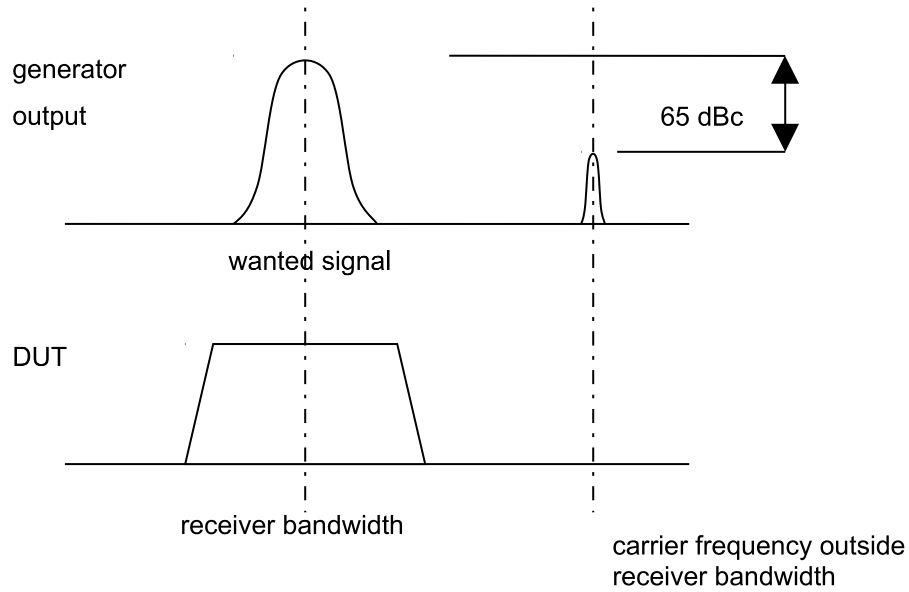
Example:
The rising time is set to 25 ns and the ARB sample rate is set to 300 MHz. The number of samples is calculated as 25 ns / 3.333 ns = 7.50075. The R&S Pulse Sequencer uses seven samples leaving an error of 25 ns – 7 * 3.333 ns = 1.669 ns. If a sample rate of 200 MHz was used the granularity would be 5 ns and the timing error therefore zero.

6.17 Dynamic Range

The full dynamic range of the R&S Vector Signal Generators ARBs provide a total of 16 bits for both, the I and the Q signal. However, the effective number of bits is less due too multiple reasons. The following example explains the effect of the carrier leakage through the I/Q modulator and points out possible solutions on how to achieve higher dynamic ranges.

The instrument specification of the R&S SMU200A lists a typical carrier leakage value of -65 dBc for the I/Q modulator. This means that even if there is no ARB signal applied to the I/Q modulator and the output level is set to 0 dBm we still see a carrier at -65 dBm at the generator output. In some applications higher dynamic ranges may be required and additional effort is required to achieve this dynamic range.

Adding a frequency offset:
If the receiver bandwidth is narrow it is possible to add a frequency offset to the pulse definitions used in the R&S Pulse Sequencer software. The device under test would then see a carrier leakage of typical -65 dBc outside of its receiver bandwidth.



Using pulse modulation in parallel:
The R&S Pulse Sequencer software allows the flexible generation of marker signals. It is possible to tie a marker signal to the active part of the pulse and route this signal to the pulse modulator input of the vector signal generator. The pulse modulator in the R&S SMU200A offers an on/off ratio of greater than 70 dBc.

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