R&S®SMW-K548
Crest Factor Reduction
User Manual

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Version 02

ROHDE&SCHWARZ
Make ideas real

This document describes the following software options:

- R&S®SMW-K548 Crest Factor Reduction (1414.6641.xx)

This manual describes firmware version FW 4.80.041.xx and later of the R&S®SMW200A.

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The following abbreviations are used throughout this manual: R&S®SMW200A is abbreviated as R&S SMW; the license types 02/03/07/11/13/16/12 are abbreviated as xx.

Contents

1 Welcome to the R&S SMW-K548 Option

The R&S SMW-K548 is a software option that allows you to generate signals with reduced crest factor.

R&S SMW-K548 key features

- Reduces the crest factor of a baseband signal through clipping the high signal peaks and filtering the waveform afterwards.
- Can be applied to any waveform file loaded in the arbitrary waveform generator.
- It uses an iterative process to reach the desired crest factor delta.
- It is possible to adjust the filter characteristics. In simple mode, you can specify the channel spacing and signal bandwidth. Alternatively in the advanced filter mode you can specify the lowpass filter through passband and stopband frequencies.

This user manual contains a description of the functionality that the application provides, including remote control operation.

All functions not discussed in this manual are the same as in the base unit and are described in the R&S SMW user manual. The latest version is available at:

www.rohde-schwarz.com/manual/SMW200A

Installation

You can find detailed installation instructions in the delivery of the option or in the R&S SMW service manual.

1.1 Accessing the Required Settings

1. In the block diagram of the R&S SMW, select the "Baseband" > "ARB".

   A dialog box opens that displays the provided general settings.

2. Select "Load Waveform".
   Navigate to waveform file and load it.
3. Select "ARB > State > On".
4. Select "Crest Factor Reduction".

The signal generation is started. To apply the crest factor reduction with the default settings, select "State > On".

1.2 Documentation Overview

This section provides an overview of the R&S SMW user documentation. Unless specified otherwise, you find the documents on the R&S SMW product page at:

www.rohde-schwarz.com/manual/smw200a

1.2.1 Getting Started Manual

Introduces the R&S SMW and describes how to set up and start working with the product. Includes basic operations, typical measurement examples, and general information, e.g. safety instructions, etc. A printed version is delivered with the instrument.

1.2.2 User Manuals and Help

Separate manuals for the base unit and the software options are provided for download:

- Base unit manual
  Contains the description of all instrument modes and functions. It also provides an introduction to remote control, a complete description of the remote control commands with programming examples, and information on maintenance, instrument interfaces and error messages. Includes the contents of the getting started manual.
- Software option manual
  Contains the description of the specific functions of an option. Basic information on operating the R&S SMW is not included.

The contents of the user manuals are available as help in the R&S SMW. The help offers quick, context-sensitive access to the complete information for the base unit and the software options.

All user manuals are also available for download or for immediate display on the Internet.

1.2.3 Tutorials

The R&S SMW provides interactive examples and demonstrations on operating the instrument in form of tutorials. A set of tutorials is available directly on the instrument.

1.2.4 Service Manual

Describes the performance test for checking compliance with rated specifications, firmware update, troubleshooting, adjustments, installing options and maintenance.

The service manual is available for registered users on the global Rohde & Schwarz information system (GLORIS):

https://gloris.rohde-schwarz.com

1.2.5 Instrument Security Procedures

Deals with security issues when working with the R&S SMW in secure areas. It is available for download on the Internet.

1.2.6 Printed Safety Instructions

Provides safety information in many languages. The printed document is delivered with the product.

1.2.7 Data Sheets and Brochures

The data sheet contains the technical specifications of the R&S SMW. It also lists the options and their order numbers and optional accessories.

The brochure provides an overview of the instrument and deals with the specific characteristics.

See www.rohde-schwarz.com/brochure-datasheet/smw200a

1.2.8 Release Notes and Open Source Acknowledgment (OSA)

The release notes list new features, improvements and known issues of the current firmware version, and describe the firmware installation.

The open-source acknowledgment document provides verbatim license texts of the used open source software.

See www.rohde-schwarz.com/firmware/smw200a

1.2.9 Application Notes, Application Cards, White Papers, etc.

These documents deal with special applications or background information on particular topics.

See www.rohde-schwarz.com/application/smw200a and www.rohde-schwarz.com/manual/smw200a

1.3 Scope

Tasks (in manual or remote operation) that are also performed in the base unit in the same way are not described here.

In particular, it includes:

- Managing settings and data lists, like saving and loading settings, creating and accessing data lists, or accessing files in a particular directory.
- Information on regular trigger, marker and clock signals and filter settings, if appropriate.
- General instrument configuration, such as checking the system configuration, configuring networks and remote operation
- Using the common status registers

For a description of such tasks, see the R&S SMW user manual.

1.4 Notes on Screenshots

When describing the functions of the product, we use sample screenshots. These screenshots are meant to illustrate as many as possible of the provided functions and possible interdependencies between parameters. The shown values may not represent realistic usage scenarios.

The screenshots usually show a fully equipped product, that is: with all options installed. Thus, some functions shown in the screenshots may not be available in your particular product configuration.

2 About the Crest Factor Reduction

Communication standards utilizing higher order modulation techniques or using multiple carrier and complex signals consisting of the signals of more than one digital standard can feature a high crest factor. The signals of some digital standards can have high crest factors also particularly with many channels and long sequences.

The **crest factor** represents the ratio of the peak voltage value to the RMS voltage value, i.e. the peak to average ratio (**PAR**). The higher the crest factor and the resulting dynamics of a signal, the greater the requirement for a power amplifier fed by the signal to be linear. A high crest factor arises for instance, when in a multi carrier signal the carriers feature an identical start phase. This is based on the fact that the carriers are periodically superposed that leads to high peak voltages in relation to the RMS voltage values.

High crest factors entail two basic problems:

- The nonlinearity of the power amplifier (compression) causes intermodulation which expands the spectrum (spectral regrowth).
- Since the level of the D/A converter is relative to the maximum value, the average value is converted with a relatively low resolution. This leads to a high quantization noise.

Both effects increase the adjacent-channel power.

Applying clipping and filtering

A common and simple approach for achieving a lower PAR is the combination of clipping and filtering.

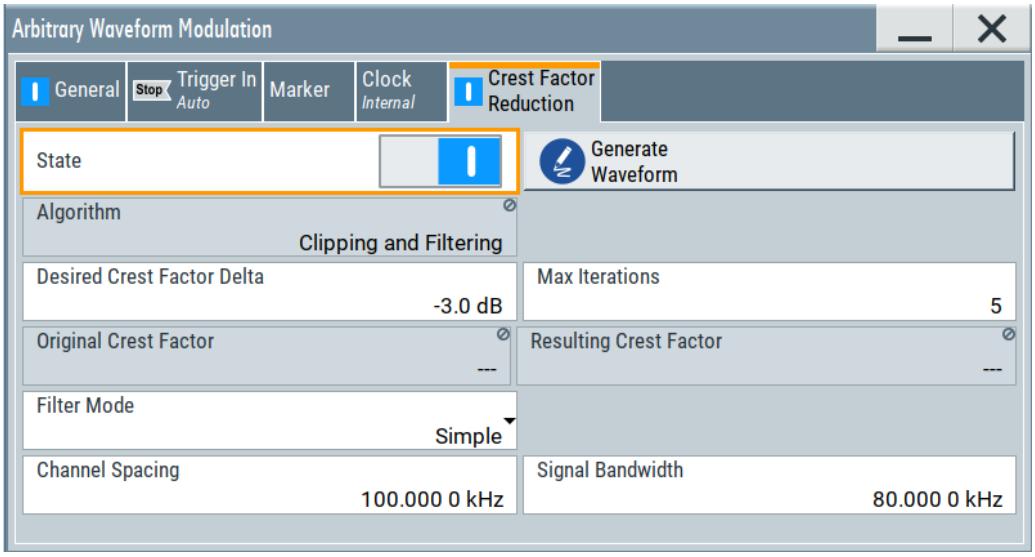
- **Clipping** is a technique that applies a wanted distortion to the signal.
  The principle includes specifying a threshold, finding out the signal peaks once the defined limits are exceeded and clipping them off. The level limit is specified as a percentage of the highest peak value. Because clipping is done before filtering, the procedure does not influence the spectrum. The error vector magnitude (EVM) however increases.
  However, signal clipping not only changes the peak value but also the average value and the effect on the crest factor is unpredictable.
- After the clipping, **filtering** is applied. The used filters are specially designed so that they filter out the distortion.

3 Crest Factor Reduction Settings

Prerequisite: An ARB file is loaded and enabled.

Access:

► Select the "Baseband > ARB > Crest Factor Reduction".



The remote commands required to define these settings are described in Chapter 4, "Remote-Control Commands", on page 14.

Settings:

State
Enables the crest factor reduction calculation.

Note: You cannot activate the crest factor reduction and the notch filter simultaneously. Enabling the notched filter automatically disables the crest factor reduction.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR[:STATe]` on page 15

Generate Waveform
With enabled signal generation, triggers the instrument to store the current settings in a waveform file. Waveform files can be further processed.

The filename and the directory it is stored in are user-definable; the predefined file extension for waveform files is `*.wv`.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:WAVeform:CREate` on page 19

Algorithm
Displays the algorithm used for the crest factor reduction. The "Clipping and filtering" algorithm performs a hard clipping. It is followed by a low pass filtering of the result in an iterative manner until the target crest factor is reached. You can define the settings of the filter that is used for the calculation.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:ALGorithm` on page 16

Desired Crest Factor Delta
Sets the value difference by which you want to change your crest factor.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:DCFDelta` on page 16

Max Iterations
Sets the number of iterations that are used for calculating the resulting crest factor. The iteration process is stopped when the desired crest factor delta is achieved by 0.1 dB.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:ITERations` on page 17

Original Crest Factor
Displays the original crest factor of the waveform after the calculation of the resulting crest factor is completed. The original crest factor is calculated as an average over the whole waveform, including any idle periods that might be present in TDD waveforms.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:OCFactor?` on page 17

Resulting Crest Factor
Displays the resulting crest factor of the waveform after the calculations are completed. The resulting crest factor is calculated as an average over the whole waveform, including any idle periods that might be present in TDD waveforms.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:RCFactor?` on page 18

Filter Mode
Selects which filter mode is used for the filtering.

"Simple" You can specify the RF bandwidth and channel spacing of the signal. The lowpass filter is designed to pass through frequency components inside the signal bandwidth and suppress components in the adjacent channel.

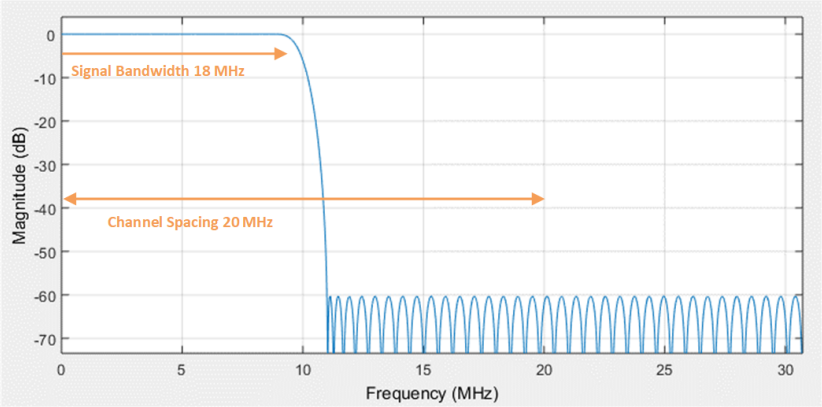


Figure 3-1: Simple filter mode

"Enhanced" In the enhanced filter mode, you can specify the passband and stopband frequencies of the lowpass filter.

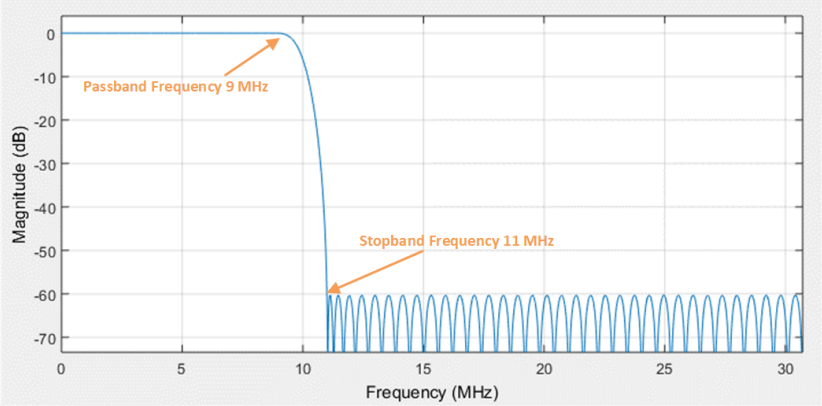


Figure 3-2: Enhanced filter mode

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:FILTer` on page 16

Channel Spacing
Available for "Filter Mode > Simple".

Sets the channel spacing.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:CSPacing` on page 16

Signal Bandwidth
Available for "Filter Mode > Simple".

Sets the signal bandwidth. The value of the "Signal Bandwidth" should not be higher than the "Channel Spacing".

Remote command:
[:SOURce<hw>]:BB:ARBitrary:CFR:SBANdwidth on page 18

Stopband Frequency
Available for "Filter Mode > Enhanced".

Sets the stopband frequency of the filter. Frequency components higher than the stopband frequency are filtered out by the lowpass filter.

Remote command:
[:SOURce<hw>]:BB:ARBitrary:CFR:SFReq on page 19

Passband Frequency
Available for "Filter Mode > Enhanced".

Sets the passband frequency. Frequency components lower than the passband frequency are passed through unfiltered.

Remote command:
[:SOURce<hw>]:BB:ARBitrary:CFR:PFReq on page 18

Maximum Filter Order
Available for "Filter Mode > Enhanced".

Sets the maximum filter order.

Remote command:
[:SOURce<hw>]:BB:ARBitrary:CFR:FORDer on page 17

4 Remote-Control Commands

The following commands are required to perform signal generation in a remote environment. We assume that the R&S SMW has already been set up for remote operation in a network as described in the R&S SMW user manual. Knowledge about the remote control operation and the SCPI command syntax is assumed.

Conventions used in SCPI command descriptions

For a description of the conventions used in the remote command descriptions, see section "Remote Control Commands" in the R&S SMW user manual.

Common suffixes

The following common suffixes are used in remote commands:

Suffix	Value range	Description
SOURce<hw>	[1] to 4	Available baseband signals

Programming examples

The corresponding sections of the same title provide simple programming examples for the R&S SMW. The purpose of the examples is to present **all** commands for a given task. In real applications, one would rather reduce the examples to an appropriate subset of commands.

The programming examples have been tested with a software tool which provides an environment for the development and execution of remote tests. To keep the examples as simple as possible, only the "clean" SCPI syntax elements are reported. Non-executable command lines (e.g. comments) start with two // characters.

At the beginning of the most remote control program, an instrument (p) reset is recommended to set the R&S SMW to a definite state. The commands `*RST` and `SYSTem:PRESet` are equivalent for this purpose. `*CLS` also resets the status registers and clears the output buffer.

In all the examples, we assume that a remote PC is connected to the instrument, the remote PC and the instrument are switched on, a connection between them is established. We also assume that the security setting "System Config > Setup > Security > SCPI over LAN" is enabled.

Example: Configuring the CFR

Prerequisite: An ARB file is loaded and enabled.

```
SOURce1:BB:ARBitrary:CFR:ALGorithm CLFiltering
SOURce1:BB:ARBitrary:CFR:DCFDelta -3
SOURce1:BB:ARBitrary:CFR:ITERations 5
SOURce1:BB:ARBitrary:CFR:FILTer SIMPle
SOURce1:BB:ARBitrary:CFR:CSPacing 20E6
SOURce1:BB:ARBitrary:CFR:SBANdwidth 18E6
SOURce1:BB:ARBitrary:CFR:STATe ON
SOURce1:BB:ARBitrary:CFR:MEASure:STATe?
//ON
SOURce1:BB:ARBitrary:CFR:OCFactor?
//6
SOURce1:BB:ARBitrary:CFR:RCFactor?
//3
SOURce1:BB:ARBitrary:CFR:CREate "cfr"
```

Example: Setting up an Enhanced Filter

```
SOURce1:BB:ARBitrary:CFR:FILTer ENHanced
SOURce1:BB:ARBitrary:CFR:PFReq 9E6
SOURce1:BB:ARBitrary:CFR:SFReq 11E6
SOURce1:BB:ARBitrary:CFR:FORDer 100
```

The following commands specific to the R&S SMW-K548 option are described here:

[:SOURce<hw>]:BB:ARBitrary:CFR[:STATe] <ArbCfrState>

Enables the crest factor reduction calculation.

Parameters:

<ArbCfrState> 0 | 1 | OFF | ON

*RST: 0

Example: See Example "Configuring the CFR" on page 15.

Manual operation: See "State" on page 10

[:SOURce<hw>]:BB:ARBitrary:CFR:ALGorithm <ArbCfrAlgorithm>

Displays the algorithm used for the crest factor reduction. The "Clipping and filtering" algorithm performs a hard clipping. It is followed by a low pass filtering of the result in an iterative manner until the target crest factor is reached. You can define the settings of the filter that is used for the calculation.

Parameters:

<ArbCfrAlgorithm> CLFiltering

*RST: CLFiltering

Example: See Example "Configuring the CFR" on page 15.

Manual operation: See "Algorithm" on page 11

[:SOURce<hw>]:BB:ARBitrary:CFR:CSPacing <ArbCfrChanSpac>

Sets the channel spacing, if `[:SOURce<hw>]:BB:ARBitrary:CFR:FILTer` is set to `SIMPle`.

Parameters:

<ArbCfrChanSpac> float

Range: 0 to depends on the sample rate of the loaded file
Increment: 0.1
*RST: 250E6

Example: See Example "Configuring the CFR" on page 15.

Manual operation: See "Channel Spacing" on page 12

[:SOURce<hw>]:BB:ARBitrary:CFR:DCFDelta <ArbCfrDCFDelta>

Sets the value difference by which you want to change your crest factor.

Parameters:

<ArbCfrDCFDelta> float

Range: -20 to 0
Increment: 0.1
*RST: -3

Example: See Example "Configuring the CFR" on page 15.

Manual operation: See "Desired Crest Factor Delta" on page 11

[:SOURce<hw>]:BB:ARBitrary:CFR:FILTer <ArbCfrFilterMod>

Selects which filter mode is used for the filtering.

Parameters:

<ArbCfrFilterMod> SIMPle | ENHanced

*RST: SIMPle

Example: See Example "Configuring the CFR" on page 15.

Manual operation: See "Filter Mode" on page 11

[:SOURce<hw>]:BB:ARBitrary:CFR:FORDer <ArbCfrMaxFilOrd>

Sets the maximum filter order, if `[:SOURce<hw>]:BB:ARBitrary:CFR:FILTer` is set to `ENHanced`.

Parameters:

<ArbCfrMaxFilOrd> integer

Range: 0 to 300
*RST: 100

Example: See Example "Configuring the CFR" on page 15.

Manual operation: See "Maximum Filter Order" on page 13

[:SOURce<hw>]:BB:ARBitrary:CFR:ITERations <ArbCfrMaxIter>

Sets the number of iterations that are used for calculating the resulting crest factor. The iteration process is stopped when the desired crest factor delta is achieved by 0.1 dB.

Parameters:

<ArbCfrMaxIter> integer

Range: 1 to 10
*RST: 5

Example: See Example "Configuring the CFR" on page 15.

Manual operation: See "Max Iterations" on page 11

[:SOURce<hw>]:BB:ARBitrary:CFR:MEASure[:STATe]?

Queries the state of the crest factor reduction calculation.

Return values:

<MeasureState> 0 | 1 | OFF | ON

`ON`: the original and resulting crest factors are already calculated.

*RST: 0

Example: See Example "Configuring the CFR" on page 15.

Usage: Query only

[:SOURce<hw>]:BB:ARBitrary:CFR:OCFactor?

Queries the original crest factor of the waveform after the calculation of the resulting crest factor is completed. The original crest factor is calculated as an average over the whole waveform, including any idle periods that might be present in TDD waveforms.

Return values:
<ArbCfrOCrestFac> float

Range: 1 to 100
Increment: 0.01
*RST: 6

Example: See Example "Configuring the CFR" on page 15.

Usage: Query only

Manual operation: See "Original Crest Factor" on page 11

[:SOURce<hw>]:BB:ARBitrary:CFR:PFReq <ArbCfrPassBFreq>

Sets the passband frequency, if `[:SOURce<hw>]:BB:ARBitrary:CFR:FILTer` is set to `ENHanced`. Frequency components lower than the passband frequency are passed through unfiltered.

Parameters:
<ArbCfrPassBFreq> float

Range: 0 to depends on the sample rate of the loaded file
Increment: 0.1
*RST: 250E6

Example: See Example "Setting up an Enhanced Filter" on page 15.

Manual operation: See "Passband Frequency" on page 13

[:SOURce<hw>]:BB:ARBitrary:CFR:RCFactor?

Queries the resulting crest factor of the waveform after the calculations are completed. The resulting crest factor is calculated as an average over the whole waveform, including any idle periods that might be present in TDD waveforms.

Return values:
<ArbCfrResCreFac> float

Range: 1 to 100
Increment: 0.1
*RST: 6

Example: See Example "Configuring the CFR" on page 15.

Usage: Query only

Manual operation: See "Resulting Crest Factor" on page 11

[:SOURce<hw>]:BB:ARBitrary:CFR:SBANdwidth <ArbCfrSignalBw>

Sets the signal bandwidth, if `[:SOURce<hw>]:BB:ARBitrary:CFR:FILTer` is set to `SIMPle`.

The value of the signal bandwidth should not be higher than the channel spacing (`[:SOURce<hw>]:BB:ARBitrary:CFR:CSPacing`).

Parameters:

<ArbCfrSignalBw> float

Range: 0 to depends on the sample rate of the loaded file
Increment: 0.1
*RST: 250E6

Example: See Example "Configuring the CFR" on page 15.

Manual operation: See "Signal Bandwidth" on page 12

[:SOURce<hw>]:BB:ARBitrary:CFR:SFReq <ArbCfrStopBFreq>

Sets the stopband frequency of the filter, if `[:SOURce<hw>]:BB:ARBitrary:CFR:FILTer` is set to `ENHanced`. Frequency components higher than the stopband frequency are filtered out by the lowpass filter.

Parameters:

<ArbCfrStopBFreq> float

Range: 0 to depends on the sample rate of the loaded file
Increment: 0.1
*RST: 250E6

Example: See Example "Setting up an Enhanced Filter" on page 15.

Manual operation: See "Stopband Frequency" on page 13

[:SOURce<hw>]:BB:ARBitrary:CFR:WAVeform:CREate <CreateWvFile>

With enabled signal generation, triggers the instrument to store the current settings in a waveform file. Waveform files can be further processed.

The filename and the directory it is stored in are user-definable; the predefined file extension for waveform files is `*.wv`.

Setting parameters:

<CreateWvFile> string

Example: See Example "Configuring the CFR" on page 15.

Usage: Setting only

Manual operation: See "Generate Waveform" on page 11

List of commands

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