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

1179232502
Version 06

ROHDE&SCHWARZ
Make ideas real

This document describes the following software options:

- R&S®SMM-K548 Crest Factor Reduction (1441.1130.xx)

This manual describes firmware version FW 5.30.175.80 and later of the R&S®SMM100A.

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Throughout this document, R&S® is indicated as R&S.

Contents

1 Welcome to the R&S SMM-K548 option

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

R&S SMM-K548 key features

- Reduces crest factors of baseband signals by clipping the high signal peaks and filtering the waveform afterwards.
- Reduces crest factors of waveform files played at the arbitrary waveform generator.
- Uses an iterative process to reach a desired crest factor delta.
- Provides simple and enhanced filtering:
  - Simple filtering allows you to configure channel spacing and signal bandwidth.
  - Enhanced filtering allows you to configure lowpass filter parameters stopband frequency, passband frequency and maximum filter order.

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 SMM100A user manual. The latest version is available at:

www.rohde-schwarz.com/manual/SMM100A

Installation

You can find detailed installation instructions in the delivery of the option or in the R&S SMM100A service manual.

1.1 Accessing Crest Factor Reduction settings

1. In the block diagram of the R&S SMM100A, select the "Baseband" > "ARB".

   The "ARB" dialog box opens and provides general "ARB" settings.

2. Select "Crest Factor Reduction".

   The signal generation is not started immediately. To reduce crest factors with the default settings, see "Enabling crest factor reduction" on page 11.

1.2 What's new

This manual describes firmware version FW 5.30.175.80 and later of the R&S®SMM100A.

Compared to the previous version, it provides the new features listed below:

- New design of the instrument and the GUI

- Editorial changes

1.3 Documentation overview

This section provides an overview of the R&S SMM100A user documentation. Unless specified otherwise, you find the documents at:

www.rohde-schwarz.com/manual/smm100a

1.3.1 Getting started manual

Introduces the R&S SMM100A 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.

1.3.2 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 SMM100A is not included.

The contents of the user manuals are available as help in the R&S SMM100A. 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.

1.3.3 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

1.3.4 Instrument security procedures

Deals with security issues when working with the R&S SMM100A in secure areas. It is available for download on the internet.

1.3.5 Printed safety instructions

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

1.3.6 Specifications and product brochures

The specifications document, also known as the data sheet, contains the technical specifications of the R&S SMM100A. It also lists the firmware applications 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/smm100a

1.3.7 Calibration certificate

The document is available on https://gloris.rohde-schwarz.com/calcert. You need the device ID of your instrument, which you can find on a label on the rear panel.

1.3.8 Release notes and open source acknowledgment

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

The software uses several valuable open source software packages. An open source acknowledgment document provides verbatim license texts of the used open source software.

www.rohde-schwarz.com/firmware/smm100a

1.3.9 Application notes, application cards, white papers, etc.

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

For some application sheets, see also:

www.rohde-schwarz.com/application/smm100a

1.3.10 Videos

Find various videos on Rohde & Schwarz products and test and measurement topics on YouTube: https://www.youtube.com/@RohdeundSchwarz

On the menu bar, search for your product to find related videos.

Figure 1-1: Product search on YouTube

1.4 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 SMM100A user manual.

1.5 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.

About crest factors

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 example, for a multi carrier signal that has carriers with an identical start phase. 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 digital to analog (D/A) converter is relative to the maximum value, the average value is converted with a relatively low resolution. This low resolution leads to a high quantization noise.

Both effects increase the adjacent-channel power.

Clipping and filtering algorithm

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.
- Filtering is applied after clipping. The used filters are specially designed so that they filter out the distortion.

Peak cancellation algorithm

The peak cancellation algorithm uses Blackman windowed sinc pulses and subtracts them from the original baseband signal wherever the signal amplitude exceeds a defined threshold. This threshold equals maximum peak of the baseband signal minus a user-definable crest factor difference ("Desired Crest Factor Delta").

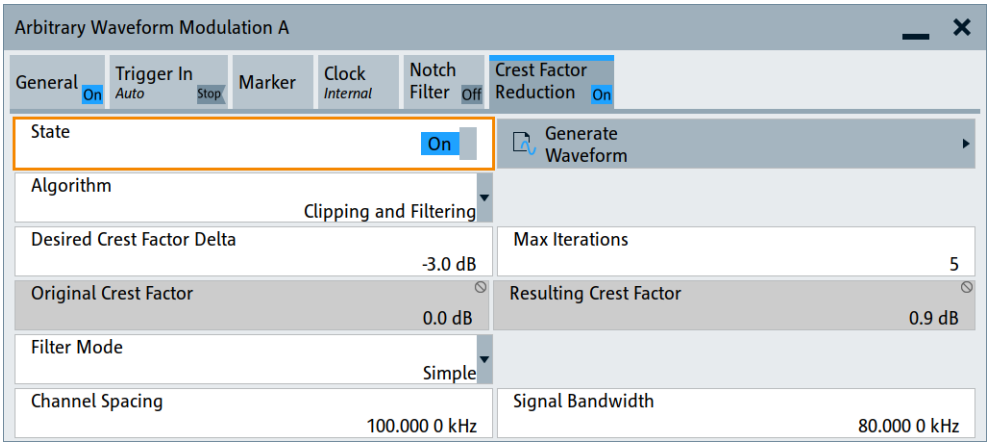
This algorithm often provides better EVM results of the output signal versus out of band noise introduced by the pulses, compared to the clipping and filtering method.

The cancellation pulse bandwidth is configurable and the cancellation pulse transition bandwidth. The achieved resulting crest factor can be higher than expected, because of filters in the signal processing chain increasing the crest factor again after a previous crest factor reduction.

3 Crest factor reduction settings

Access:

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



The dialog provides settings to configure and enable crest factor reduction.

Enabling crest factor reduction

Crest factor reduction requires an enabled "ARB" state and a valid waveform file loaded to the ARB application.

1. Load a waveform file.
   a) Select "ARB" > "General" > "Load Waveform".
   b) In the file-select dialog, select the waveform file from the directory.

   See also chapter "Loading and playing waveform files" in the R&S SMM100A user manual.
2. Select "General" > "State" > "On".
3. Select "Crest Factor Reduction" > "State" > "On".

Settings:

State
Requires an active "ARB" state, see "Enabling crest factor reduction" on page 11.

Activates 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 18

Generate Waveform
With enabled signal generation, triggers the instrument to save the current settings of an arbitrary waveform signal in a waveform file with predefined extension `*.wv`. You can define the filename and the directory, in that you want to save the file.

Using the ARB modulation source, you can play back waveform files and/or process the file to generate multi-carrier or multi-segment signals.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:WAVeform:CREate` on page 23

Algorithm
Defines the algorithm for crest factor reduction.

"Clipping and Filtering"
: This algorithm performs a hard clipping. It is followed by a lowpass 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.

"Peak Cancelation"
: This algorithm subtracts Blackman windowed sinc pulses from the signal wherever the amplitude is above a defined threshold.

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

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 19

Max Iterations
Requires "Algorithm" > "Clipping and Filtering".

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 20

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 can be present in TDD waveforms.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:OCFactor?` on page 20

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 can be present in TDD waveforms.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:RCFactor?` on page 21

Filter Mode
Requires "Algorithm" > "Clipping and Filtering".

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.

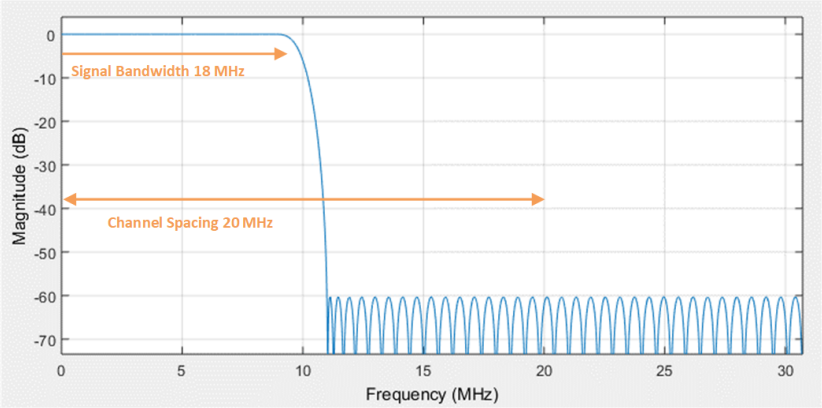


Figure 3-1: Simple filter mode

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

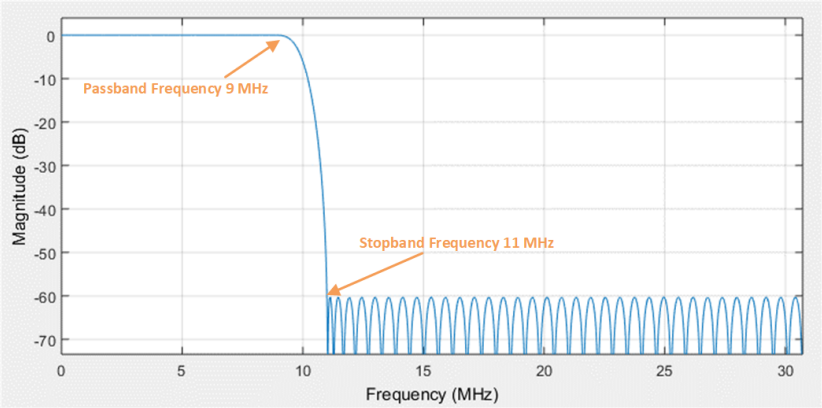


Figure 3-2: Enhanced filter mode

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

Channel Spacing
Requires "Algorithm" > "Clipping and Filtering" and "Filter Mode" > "Simple".

Sets the channel spacing.

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

Signal Bandwidth
Requires "Algorithm" > "Clipping and Filtering" and "Filter Mode" > "Simple".

Sets the signal bandwidth. Set a value that is lower than the value of the "Channel Spacing".

Remote command:
[:SOURce<hw>]:BB:ARBitrary:CFR:SBANdwidth on page 22

Stopband Frequency
Requires "Algorithm" > "Clipping and Filtering" and "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 22

Passband Frequency
Requires "Algorithm" > "Clipping and Filtering" and "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 21

Maximum Filter Order
Requires "Algorithm" > "Clipping and Filtering" and "Filter Mode" > "Enhanced".

Sets the maximum filter order.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:FORDer` on page 20

Cancellation Pulse Bandwidth
Requires "Algorithm" > "Peak Cancellation".

Sets the bandwidth of the cancellation pulse.

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

Transition Bandwidth
Requires "Algorithm" > "Peak Cancellation".

Sets the transition bandwidth of the cancellation pulse.

Remote command:
`[:SOURce<hw>]:BB:ARBitrary:CFR:TBANdwidth` on page 22

4 Remote control commands

The following commands are required to perform signal generation in a remote environment. We assume that the R&S SMM100A has already been set up for remote operation in a network as described in the R&S SMM100A 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 SMM100A user manual.

Common suffixes

The following common suffixes are used in remote commands:

Suffix	Value range	Description
SOURce<hw>	1	Available baseband signals

Programming examples

This section provides simple programming examples. The purpose of the examples is to present all commands for a given task. In real applications, you typically use an appropriate subset of these commands.

For verification and testing purposes, a software tool executed these programming examples. To keep the example as simple as possible, the examples report clean SCPI syntax elements. Non-executable command lines, for example comments, start with two characters `//`.

Before executing a SCPI sequence, most remote control programs reset or preset the instrument 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.

Example: Preparing for CFR

```
// Load an ARB waveform file, e.g., the file "test.wv".
SOURce1:BB:ARBitrary:LOAD "test"
// Activate ARB.
SOURce1:BB:ARBitrary:STATe 1
```

Example: Applying clipping and filtering algorithm

```
// Set for filter and clipping CFR algorithm.
SOURce1:BB:ARBitrary:CFR:ALGorithm CLFiltering
SOURce1:BB:ARBitrary:CFR:DCFDelta -3
SOURce1:BB:ARBitrary:CFR:ITERations 5

// Configure simple filtering.
SOURce1:BB:ARBitrary:CFR:FILTer SIMPle
```

```
SOURce1:BB:ARBitrary:CFR:CSPacing 20E6
SOURce1:BB:ARBitrary:CFR:SBANdwidth 18E6

// Configure enhanced filtering.
SOURce1:BB:ARBitrary:CFR:FILTer ENHanced
SOURce1:BB:ARBitrary:CFR:PFReq 9E6
SOURce1:BB:ARBitrary:CFR:SFReq 11E6
SOURce1:BB:ARBitrary:CFR:FORDer 100
```

Example: Applying peak cancellation algorithm

```
// Set for peak cancellation CFR algorithm.
SOURce1:BB:ARBitrary:CFR:ALGorithm PCANcellation
SOURce1:BB:ARBitrary:CFR:DCFDelta -3
// Set a cancellation pulse bandwidth of 800 kHz.
SOURce1:BB:ARBitrary:CFR:CPBandwidth 800000
// Set a transition bandwidth of 10 kHz.
SOURce1:BB:ARBitrary:CFR:TBANdwidth 10000
```

Example: Activating and monitoring CFR characteristics

```
SOURce1:BB:ARBitrary:CFR:STATe 1
SOURce1:BB:ARBitrary:CFR:MEASure:STATe?
// Response: "1"
// Query the original crest factor.
SOURce1:BB:ARBitrary:CFR:OCFactor?
// Response: "6"
// Query the resulting crest factor.
SOURce1:BB:ARBitrary:CFR:RCFactor?
// Response: "3"
// Create the waveform file "cfr.wv" with reduced crest factor.
SOURce1:BB:ARBitrary:CFR:CREate "cfr"
```

The commands specific to the option R&S SMM-K548 are as follows.

Commands:

:

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

Enables the crest factor reduction calculation.

Parameters:

<ArbCfrState> 1 | ON | 0 | OFF

*RST: 0

Example: See Example "Activating and monitoring CFR characteristics" on page 17.

Manual operation: See "State" on page 12

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

Defines the algorithm for crest factor reduction.

Parameters:

<ArbCfrAlgorithm> CLFiltering | PCANcellation

CLFiltering
Clipping and filtering algorithm. This algorithm performs a hard clipping of the baseband signal. 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.

PCANcellation
Peak cancelation algorithm. This algorithm subtracts Blackman windowed sinc pulses from the signal wherever the amplitude is above a defined threshold.

*RST: CLFiltering

Example: See Example "Applying clipping and filtering algorithm" on page 16.

Example: See Example "Applying peak cancellation algorithm" on page 17.

Manual operation: See "Algorithm" on page 12

[:SOURce<hw>]:BB:ARBitrary:CFR:CPBandwidth <ArbCfrCancPulBw>

Sets the cancellation pulse bandwidth for peak cancellation CFR algorithm.

Parameters:

<ArbCfrCancPulBw> float

Range: 0 to 250E6
Increment: 0.1

Example: See Example "Applying peak cancellation algorithm" on page 17.

Manual operation: See "Cancellation Pulse Bandwidth" on page 15

[: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 "Applying clipping and filtering algorithm" on page 16.

Manual operation: See "Channel Spacing" on page 14

[: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 "Applying clipping and filtering algorithm" on page 16.

Manual operation: See "Desired Crest Factor Delta" on page 12

[: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 "Applying clipping and filtering algorithm" on page 16.

Manual operation: See "Filter Mode" on page 13

[: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 "Applying clipping and filtering algorithm" on page 16.

Manual operation: See "Maximum Filter Order" on page 15

[: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 "Applying clipping and filtering algorithm" on page 16.

Manual operation: See "Max Iterations" on page 12

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

Queries the state of the crest factor reduction calculation.

Return values:

<MeasureState> 1 | ON | 0 | OFF

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

*RST: 0

Example: See Example "Activating and monitoring CFR characteristics" on page 17.

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 "Activating and monitoring CFR characteristics" on page 17.

Usage: Query only

Manual operation: See "Original Crest Factor" on page 13

[: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 "Applying clipping and filtering algorithm" on page 16.

Manual operation: See "Passband Frequency" on page 14

[: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 "Activating and monitoring CFR characteristics" on page 17.

Usage: Query only

Manual operation: See "Resulting Crest Factor" on page 13

[: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 "Applying clipping and filtering algorithm" on page 16.

Manual operation: See "Signal Bandwidth" on page 14

[: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 "Applying clipping and filtering algorithm" on page 16.

Manual operation: See "Stopband Frequency" on page 14

[:SOURce<hw>]:BB:ARBitrary:CFR:TBANdwidth <DDArbCfrTranBw>

Sets the transition bandwidth of the cancellation pulse for peak cancellation CFR algorithm.

Parameters:

<DDArbCfrTranBw> float

Range: 0 to 250E6
Increment: 0.1

Example: See Example "Applying peak cancellation algorithm" on page 17.

Manual operation: See "Transition Bandwidth" on page 15

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

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

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

Setting parameters:

<CreateWvFile> string

Example: See Example "Activating and monitoring CFR characteristics" on page 17.

Usage: Setting only

Manual operation: See "Generate Waveform" on page 12

List of commands

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